BAYWATCHERS II

Nutrient related water quality of Buzzards Bay embayments: a synthesis of Baywatchers monitoring 1992-1998

Written by:

Dr. Brian Howes,
Tony Williams &
Mark Rasmussen

Produced by The Coalition for Buzzards Bay

The Coalition for Buzzards Bay

The Coalition for Buzzards Bay is a nonprofit, membership organization dedicated to the restoration, protection and sustainable use and enjoyment of Buzzards Bay and its watershed. Formed in 1987, the Coalition works to improve the health of the Bay for all through education, conservation, research and advocacy. Programs at The Coalition for Buzzards Bay include: Baywatchers, a bay-wide water quality monitoring program – the largest in Massachusetts – which utilizes volunteers to sample coastal water quality from Westport to Woods Hole; a Bay Lands Center supporting the conservation of important watershed open space and habitat; environmental education programs for school children and adults; and a new BayKeeper advocacy initiative to support the cleanup and protection of Buzzards Bay.

The Coalition for Buzzards Bay is membership supported by more than 2,000 individuals, families, businesses and organizations and managed by a 20 member volunteer Board of Directors. Based in New Bedford, a permanent staff of six as well as intern and part-time staff support the Coalition's work on behalf of a clean and healthy Bay.

www.savebuzzardsbay.org

The Center for Marine Science and Technology

The Center for Marine Science and Technology (CMAST) within the University of Massachusetts-Dartmouth is a new state-of-the-art marine laboratory located on Buzzards Bay. CMAST consists of 14 laboratories supporting over 25 research and teaching faculty and their technical staff and students. CMAST laboratories include expertise in coastal ecosystem level ecology, wetlands ecology, fish population biology, ornithology, phytoplankton ecology, benthic ecology, biogeochemistry, marine physiology (toxics), eelgrass ecology, data management, physical oceanography and hydrology. In addition, CMAST is an academic center which provides undergraduate and graduate research programs.

The Coastal Systems Program was established within CMAST to provide research quality information to address the growing ecological degradation of coastal ecosystems. The goal of the Program is to fill the niche between basic and applied research to provide high quality scientific support for management of coastal ecosystems (bays, harbors, wetlands and watersheds). The Coastal Systems Program is one of five research area programs within CMAST, using state-of-the-art instrumentation and methodologies to address specific coastal problems, while simultaneously producing new knowledge of the functioning of coastal systems. CMAST is a focal point for water quality monitoring throughout S.E. Massachusetts. In addition to regional studies, Coastal Systems Program personnel conduct coastal research world-wide with studies in Antarctica, the Caribbean Basin and the Black Sea.

www.cmast.umassd.edu/main.html

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THE COALITION FOR BUZZARDS BAY

Baywatchers II

Nutrient related water quality of Buzzards Bay embayments:
a synthesis of Baywatchers monitoring 1992-1998

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and

Tony Williams and Mark Rasmussen

The Coalition for Buzzards Bay

Produced by The Coalition for Buzzards Bay
December 1999

From the Authors

Those of us fortunate enough to be familiar with the open waters of Buzzards Bay enjoy one of the cleanest, highest quality estuaries on the entire eastern seaboard. Despite centuries of human use, pollution and alterations to its watershed, central Buzzards Bay water quality remains healthy.

An ecosystem-wide change, however, is occurring along the coastline. This change involves inputs of nutrients, particularly nitrogen, which is already decreasing water quality and the health of the Bay at its most vulnerable points. At greatest risk are the Bay's more than 30 harbors, coves, and river mouths which receive the initial nutrient load from the watershed. Unfortunately, these same embayments and nearshore waters are often particularly sensitive to increased nutrient loading and support the most diverse ecological habitats, productive shellfish beds, and much of the recreational use and aesthetic values of the Bay.

Since 1992, the Buzzards Bay Citizens' Water Quality Monitoring Program, known as "Baywatchers", has been monitoring and evaluating bay water quality and particularly the impacts of nitrogen loading. More than 300 dedicated citizen volunteers have contributed to the effort, sampling 180 different monitoring stations. Focused on nutrient loading and eutrophication, the degradation of water quality and loss of habitats from excessive amounts of nutrients entering the Bay's waters, the Baywatchers program is the primary source of long-term data assessing the health of the bay's embayments from Westport Rivers to Quissett Harbor on Cape Cod. As the largest citizens monitoring program in the state, Baywatchers has shown that monitoring is essential for environmental management to be based on informed, science-based decisions for the restoration and protection of Buzzards Bay.

The results of our now seven-year-old water quality monitoring effort are documented in this Report. While much of the Bay remains healthy, our data reveals that over half of all Buzzards Bay harbors and coves are showing signs of eutrophication, or nitrogen-related water quality degradation. All of the twelve major embayments on the western shore are exhibiting some signs of eutrophication - eight of these actually drop to levels where shellfish, finfish, and other aquatic life are damaged. Poor water clarity, bad odors, eelgrass loss, suffocating algae growth, stressed marine organisms and even fish kills are all symptoms of this decline.

Eel Pond in Mattapoisett - once considered one of the best oyster spots in all of Buzzards Bay, the Slocums and Little Rivers, the East Branch of the Westport, Padanaram & New Bedford Harbors, and the Weweantic and Agawam Rivers are the embayments that we are losing to nitrogen pollution.

Fortunately, all of these areas are restorable. While eutrophication impacts the entire ecology of an affected area, it is not irreversible. The return of eelgrass beds to Clarks Cove in New Bedford and Dartmouth is a prime example of the Bay's ability to rebound once there is a reduction in nitrogen loading to acceptable levels. Nevertheless, there are few easy fixes.

As a long-term ecological monitoring effort, our Citizens Monitoring Program documents trends and focuses attention to where problems exist. We have endeavored also to provide Management Recommendations for each embayment to set a course for the restoration of areas already suffering from nutrient overloading and the preservation of areas not yet harmed by human activities. There is much work to be done, but we believe that the body of data and information assembled here in this Report lays the foundation for better understanding and management of the Nitrogen Problem - the most serious and challenging threat to the health of our Bay.

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New Bedford, Massachusetts December 1999

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About the authors

Dr. Brian Howes is manager of the Coastal Systems Program and Senior Fellow at the University of Massachusetts' Center for Marine Science and Technology (CMAST). He was one of the originators of the Buzzards Bay Monitoring Program while an Associate Scientist at the Woods Hole Oceanographic Institution. The Coastal Systems Laboratory conducts the nutrient analyses for Baywatchers and other monitoring programs throughout Massachusetts. Dr. Howes has been conducting ecological research on Buzzards Bay ecosystems for over 25 years and has more than 60 scientific publications and 50 technical reports on nutrient cycling in coastal systems and nitrogen transport and inputs to coastal waters. He has directed the Falmouth PondWatchers volunteer monitoring program since 1987 and has provided the ecosystem synthesis for efforts for the restoration of six coastal embayments, to date. **Tony Williams** is the Citizens Water Quality Monitoring Coordinator for The Coalition for Buzzards Bay. Since 1996, his responsibilities include coordinating water testing, training of volunteers, data entry, database management, data analysis, and graphic production of the water quality results. Tony has worked on his family's dairy farm in Pennsylvania and was previously employed at the Florida Dept. of Natural Resources Marine Research Institute in St. Petersburg, Florida, focusing research on juvenile fish habitat in Tampa Bay. **Mark Rasmussen** is the Executive Director of The Coalition for Buzzards Bay. Mark was previously Regional Planner for the Buzzards Bay Project National Estuary Program where his work focused on land use planning and conservation. He is the Founder and past President of the Fairhaven Acushnet Land Preservation Trust and an elected member of the Fairhaven Planning Board.

Acknowledgments

We particularly want to thank the more than 300 volunteers who have participated in the Buzzards Bay Citizens Monitoring Program "Baywatchers" during the past 7 years. Their dedication, time and efforts have created the most comprehensive long-term database on the nutrient related water quality of Buzzards Bay. Water quality information collected from volunteer Baywatchers continues to be a key component in decisions being made by local, state, and federal decision makers on issues ranging from the upgrade of Bay wastewater treatment facilities, to the clean-up of roadway runoff to acquisition of coastal lands for conservation. Providing high quality data on Buzzards Bay is a result of the commitment of volunteers to the Bay that we all enjoy.

We are indebted to all of the members of the Buzzards Bay area legislative delegation who continue to recognize the importance of water quality data in making well–informed, science based decisions about the use and protection of one of our region's most important assets - Buzzards Bay. Their support has allowed this program to become a statewide model for coastal water quality monitoring.

We also wish to thank the many Marinas, Harbormasters, Shellfish Wardens, Landowners, and neighbors that have allowed use of their services, docks and other access to the water. Special thanks to Betsy White, Robin Arms and Rich Lynch, for assisting the program in training volunteers, collecting samples and entering data as water quality interns; and to Jim Mulvey, Debbie Shearer, David Warr, Tony Millham, Paul Henderson, and Dorothy Krueger, for supplies and sampling equipment. "Moo" to the Coastal Systems Team at the UMass Dartmouth Center for Marine Science and Technology Laboratory- Dale Goehringer, David Schlezinger, Kirsten Smith, Marie Evans, Robert Hamersley, Stephanie Innis, Paul Henderson, George Hampson, and their summer intern staff for all the laboratory analysis. Thanks to Dan Vasconcellos for the Baywatchers t-shirt design. Particular recognition should be given to Dr. Joseph Costa, Director of the Buzzards Bay Project, who helped to originate the Monitoring Program, produce an earlier synthesis, and for his continued support. Also to Buzzards Bay Project's Tracy Warncke and Sarah Wilkes for their assistance. Additional special recognition should be given to Pamela Truesdale, former Executive Director of CBB for program guidance and support in recent years, Cathy Roberts for all her assistance, and Eileen Gunn, former Coalition for Buzzards Bay Monitoring Coordinator, for help with initial start-up and coordination efforts.

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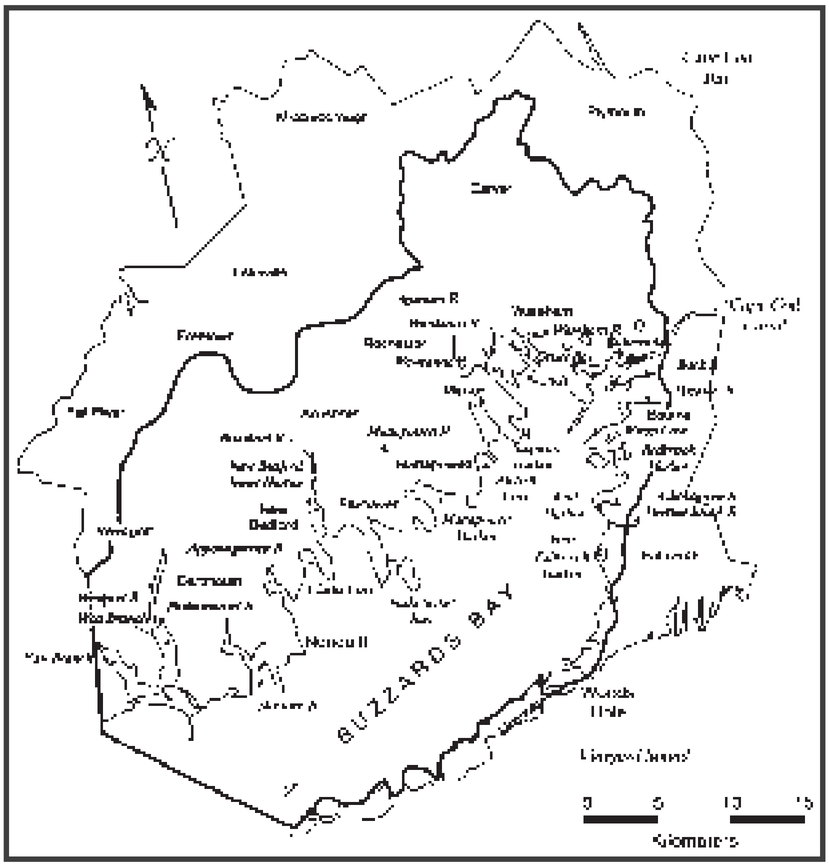
Buzzards Bay Background

Buzzards Bay, described by Gabriel Archer in an account of Bartholomew Gosnold's discovery in 1602 as "the stateliest sound I was ever in," remains one of the few relatively pristine bays in the metropolitan corridor from Washington to Boston. The bay and its surrounding marshes and uplands have provided a variety of biotic resources not only to European settlers over nearly 400 years but also to the Native Americans who relied on this estuary for thousands of years before them. Today the uplands are divided between 18 communities and although the bay is still exploited for its biotic resources, its aesthetic and recreational values add to the growing concern to preserve its environmental quality. At the same time, the health of the Buzzards Bay ecosystem, like that of almost all estuarine systems, is clearly controlled not just by processes within the bay waters themselves but also by inputs from the surrounding uplands as well. Therefore, to properly understand and manage this system, it is important to describe in detail activities and land use patterns within the watershed as well as within the tidal reach of the bay waters. This combined watershed-bay system is referred to as the "Buzzards Bay Ecosystem" and is the necessary frame of reference for understanding the biotic structure of the bay and for managing and conserving its resources.



In 1984, Buzzards Bay became one of four estuaries making up the National Estuary Program. In 1985, the Bay was designated an "Estuary of National Significance" by Congress and the Buzzards Bay Project was established to develop strategies for protecting the Bay's natural resources. A Comprehensive Conservation and Management Plan (CCMP) for Buzzards Bay was developed by the Buzzards Bay Project with support from USEPA and the Massachusetts Executive Office of Environmental Affairs which focused on three priority issues: closure of shellfish beds, contamination of fish and shellfish by toxic metals and organic compounds, and potential water quality degradation from excessive nutrient loading. The Project worked closely with regional scientists and the Coalition for Buzzards Bay in the development and continued implementation of the Plan. The Plan's focus on watershed nutrient loading helped to form a collaborative effort to assess the nutrient related health of the Bay which became the Water Quality Monitoring Program, "Baywatchers."

Buzzards Bay generally runs northeast to southwest, encompassed primarily by the Massachusetts mainland to the west, Cape Cod to the east and northeast, and the Elizabeth Islands (Cuttyhunk, Nashawena, Pasque, Penikese and Naushon) to the southeast. The bay is approximately 27 miles long and 7 miles wide and is relatively shallow with a mean depth of 11 meters. The bay was formed as a result of the last ice age and the retreat of the glaciers (about 16,000-18,000 years ago), and the geologic processes generated lasting differences in the watersheds on the western versus the eastern shores. The western shore is physically more irregular, creating more embayments than on the eastern shore. This undulating coast creates about 202 miles of waterfront, including 11 miles of public beaches.

The watershed area of Buzzards Bay is divided among 10 coastal towns located from Westport on the west to Gosnold on the east and 8 noncoastal towns, which either completely (Carver, Rochester, Acushnet) or partially (Fall River, Freetown, Lakeville, Middleborough, Plymouth) lie within the watershed boundary. The port of New Bedford, located on the southwestern shore, is the major industrial and business center within the Buzzards Bay watershed. Well known historically as a hub of the whaling industry in the early 1800's, New Bedford remains an active fishing port (coastal and offshore) for the region and represents one of the largest revenue-producing fishing ports on the east coast of the United States. The concerns over problems facing

Buzzards Bay fisheries voiced more than 100 years ago have resurfaced. In addition to the historic pollutants (urban runoff, heavy metals) and the discovery of polychlorinated biphenyl (PCB) pollution in the waters and sediments of New Bedford Harbor, degradation of the Bay's sub-embayments has refocused attention and resulted in a renewed scientific interest in the bay and its environs.

The Buzzards Bay drainage basin encompasses 426 sq. miles compared with 212 sq. miles of bay surface. Buzzards Bay is a moderate-sized estuary. Buzzards Bay differs somewhat from other major estuarine systems in that the water surface represents a large portion, almost one-third, of the total area of the bay plus watershed. This potentially decreases the role of inputs from the watershed compared with other large estuarine systems where the bay area is generally less than 10% of the total system and is a partial reason for the high water quality of the bay. Of the Bay's water area 87% is within the central Bay and with only 13% held within the 28 major embayments. However, the embayments, because of their location and physical structure, represent some of the most productive marine habitats, but also those first subject to coastal eutrophication. It is the nearshore region of the Bay which supports a variety of ecological habitats from saltmarsh to tidal wetlands, eelgrass beds, barrier beaches rocky shores and tidal rivers. These inlets with their abundance of saltmarsh and other habitats are important spawning and nursery habitats for fish, shellfish and other migratory and terrestrial species. Quite often, as in Buzzards Bay, they also serve as important recreational and aesthetic resources and also support an important tourist and fisheries industry. The high level of water quality in the Bay and its coves provides a large economic source to the local communities. It is these embayments which are the areas first subjected to coastal eutrophication because of their location and physical characteristics, often having restricted circulation and smaller volumes which limit dilution of excessive nutrients from land.

Osprey *Gil Fernandez*

Eleven small primary rivers empty into the bay; seven are found on the western shore: Agawam, Wankinco, Weweantic, Mattapoisett, Acushnet, Paskamanset, and Westport, and four on the eastern shore: Pocasset, Back, Wild Harbor, and Herring Brook. All are tidal to some extent inland from their mouths, and the eastern shore rivers are primarily groundwater fed. The river discharges on different sides of the bay reflect the very different watershed areas available for generating freshwater flows as well as the effects of their differing glacial history on surface versus groundwater flow. Inputs of freshwater discharges directly into the Bay are relatively small compared to the daily flushing of seawater, and subsequent minor dilution of salinity results in bay water salinity concentrations approximating that of nearby oceanic waters. The salinity results from the relatively small (2:1) watershed-versus-bay area and heightens the contrast between the embayments, which have more estuarine habitat, and the almost marine open Bay.

Buzzards Bay is located at a strategic transition point for habitat distribution of many marine species, being proximate to and exchanging with three very different marine systems, the Atlantic Ocean to the south, Vineyard Sound to the east, and Cape Cod Bay to the north. At its northeastern end, Buzzards Bay is connected to Cape Cod Bay by the Cape Cod Canal. The construction of this canal in 1914 allowed ships navigating along a popular trade route from northern to mid-Atlantic and southern ports to avoid the treacherous waters off of the outer coast of Cape Cod. The joining of Buzzards Bay and Cape Cod Bay via the Cape Cod Canal provides the potential for mixing of semi-tropical and arcadian species, making the bay a unique area for study of marine organisms.

The mouth of Buzzards Bay opens up to the continental shelf east of Rhode Island and Rhode Island Sound, providing access to some of the world's most productive offshore fishing grounds, notably George's Bank. Buzzards Bay itself supports varied fish populations, both resident and migratory, with over 200 recorded species and productive coastal fisheries. In fact, even the name "Buzzards Bay" indirectly reflects the fisheries resource, as it was ostensibly named after the osprey or fish-hawk (Pandion haliaetus). Feeding exclusively on fish, the osprey was known in early natural history as the buzzardet (little buzzard) and was common around the bay (in fact, even noted in Gosnolds voyage). Whether due to the buzzardet or simply the misidentification of osprey as buzzards, the name Buzzards Bay has supplanted the original "Gosnold's Hope." With the recovery of osprey populations stimulated by the banning of dichlorodiphenyltrichlo roethane (DDT) and the expansion of safe nesting platforms (most notably along the Westport River and Martha's Vineyard), Buzzards Bay may again warrant the name.

While Bartholomew Gosnold would certainly be taken aback by the alterations wrought within his "stateliest of sound's" watershed, areas of the bay itself remain much as when he sailed them almost 400 years ago. However, many activities and the increasing pressures of development are beginning to significantly alter this system. Over the past century, a regional shift in land-use from farming (and more recently from new growth forestlands) to industry, residential and tourist related development has lead to an increase in population and its associated increased nutrient loading to the Bay waters. Population growth within the Buzzards Bay watershed has increased more than 50% over the past 50 years. Some towns have grown from small rural communities to suburban communities for Boston or Providence; others have experienced continued growth in response to the demand for summer or retirement homes near the water. The land-use shifts have already resulted in local declines in water quality with potential effects on the local economy. Only management from a whole system perspective will be effective in protecting this resource that attracts so many. Identifying the resulting effects on Bay systems and the role of various land-use shifts is difficult. However, this challenge is necessary for sustaining Buzzards Bay and for implementing environmental management and future economic development in the region. Future success and protection of this ecosystem will involve monitoring, identifying physical and biological processes, providing data and synthesis, and continued public involvement. This needed management requires quantitative information on the Bay and its resources and is the basis for the founding of the Baywatchers Program.

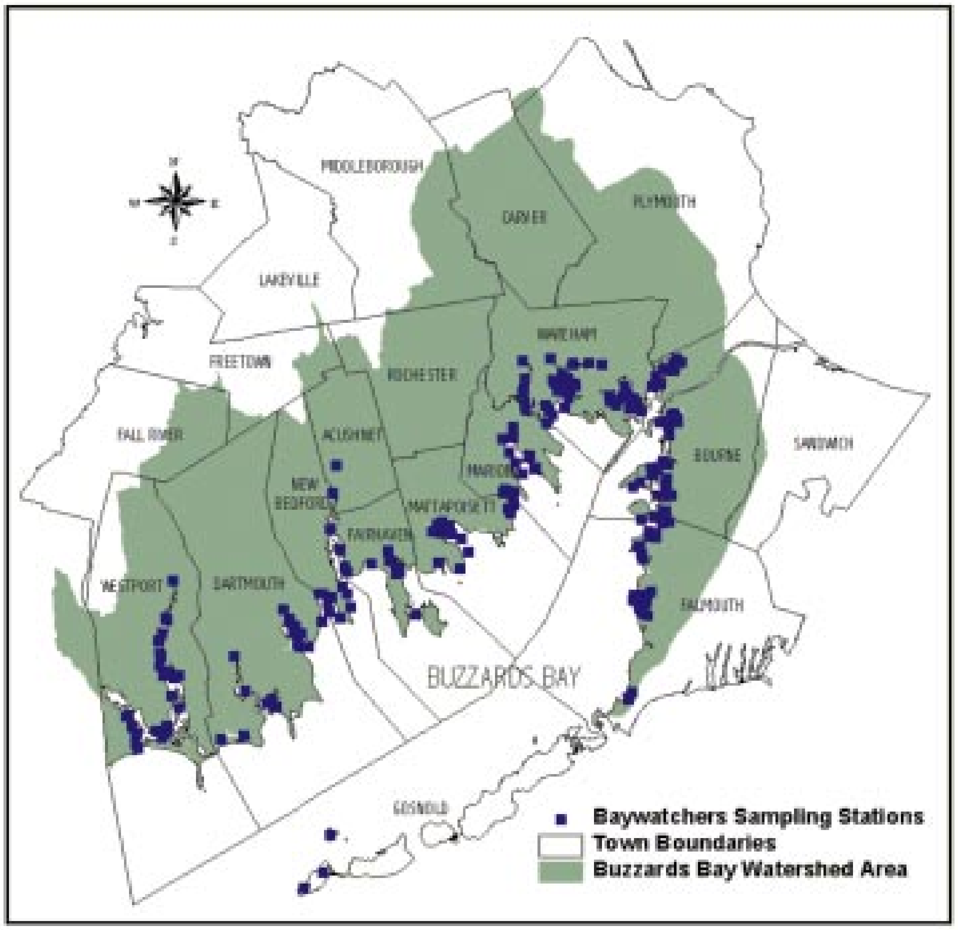
The Coalition for Buzzards Bay

Baywatchers

The Buzzards Bay Water Quality Monitoring Program

The Buzzards Bay Water Quality Monitoring Program was initiated in 1992 to assess and evaluate nitrogen-related water quality and long-term ecological trends in Buzzards Bay. The program is the primary source of long-term data on the health of the Bay's 28 major harbors and coves from the Westport Rivers on the western shore to Quissett Harbor (Falmouth) on the eastern shore. The program provides needed information to make informed, scientifically based decisions about the restoration and protection of Buzzards Bay. Until the inception of the program, no comprehensive database existed on nutrients and the extent of eutrophication in the most sensitive areas of the Bay ecosystem.

To achieve the ambitious goal of monitoring all of Buzzards Bay's major embayments and their tributaries, which cover more than a quarter of the Massachusetts coast , the Water Quality Monitoring Program needed to involve citizen volunteers. Traditional technical sampling of hundreds of water quality samples Bay-wide and nearly simultaneously (over a few hours) was simply not possible within any reasonable cost. The result has been a program which provides cost-effective comprehensive water quality data, which also educates and empowers citizens concerned with the present and future health of the Bay. It is this active citizenry which helps to foster sound management and restoration of the Bay's resources. To date 300 citizen volunteer, "Baywatchers", have contributed their time and energy in the monitoring of over 180 sampling stations.



Volunteers conduct weekly measurements from May to September of the most variable water quality parameters: dissolved oxygen, temperature, salinity, water clarity. Measurements are conducted on-site between 6 AM - 9 AM to capture the daily low oxygen period. These basic parameters give an immediate snapshot of the health of the bay and can sometimes act as an indicator for the need for additional investigation. In addition to the weekly sampling of oxygen and related parameters, more intensive nutrient sampling is conducted at 2 week intervals during July and August to capture the critical interval for evaluating nutrient related health of shallow embayments. The nutrient samplings, in addition to oxygen related parameters, determine the levels of inorganic and organic nitrogen, chlorophyll a and particulate organic carbon. These samples are collected at a minimum from the inner to the outer portions of each embayment. Three types of water samples are collected: whole water for analysis of organic carbon and nitrogen and chlorophyll on the particulates and water filtered in the field for dissolved nitrogen and phosphorus. The sample bottles are prepared by and returned (with samples) to the Coastal Systems Laboratory at the Center for Marine Science and Technology (CMAST). The Laboratory uses oceanographic techniques for determining the levels of each of the parameters of interest. Each of the water quality parameters is further described in the Water Quality Parameters section which follows.

Watershed Nitrogen and the Future of the Bay

Why do we focus on excessive nutrients, and how does this alter the aquatic ecosystem of the Bay? More than half of the United States population lives in communities within 50 miles of the coast. Southeastern Massachusetts in particular is among the fastest growing regions in the U.S. with an additional 200,000 people forecasted by 2020. As the population increases so do our use and expectations for the environment to sustain our economic and ecological needs. In the Buzzards Bay watershed, this results in increased activity within coastal ecosystems and on the Bay waters. If we continue to rely on coastal systems to provide us with a strong economy and a healthy environment, then we must also work to protect and restore a healthy Bay. The goal is to sustain fisheries and shellfisheries, clean recreational waters, our beaches, forests, open space and wetland habitats. In order to wisely protect and manage Buzzards Bay, it is necessary to first understand factors which need to be managed to prevent its degradation.

Although much of the Buzzards Bay system remains relatively healthy, there have been major changes in land use within the surrounding watershed which are resulting in significant modifications to much of the Bay's margins. This system-wide change involves inputs of nutrients, particularly nitrogen. At greatest risk are the Bay's harbors, coves, and river mouths which receive the initial nutrient load from the watershed. Unfortunately, these same embayments and nearshore waters are often particularly sensitive to increased nutrient loading and support the most diverse ecological habitats, productive shellfish beds, and much of the recreational use and aesthetic values of the Bay.

The Coalition for Buzzards Bay

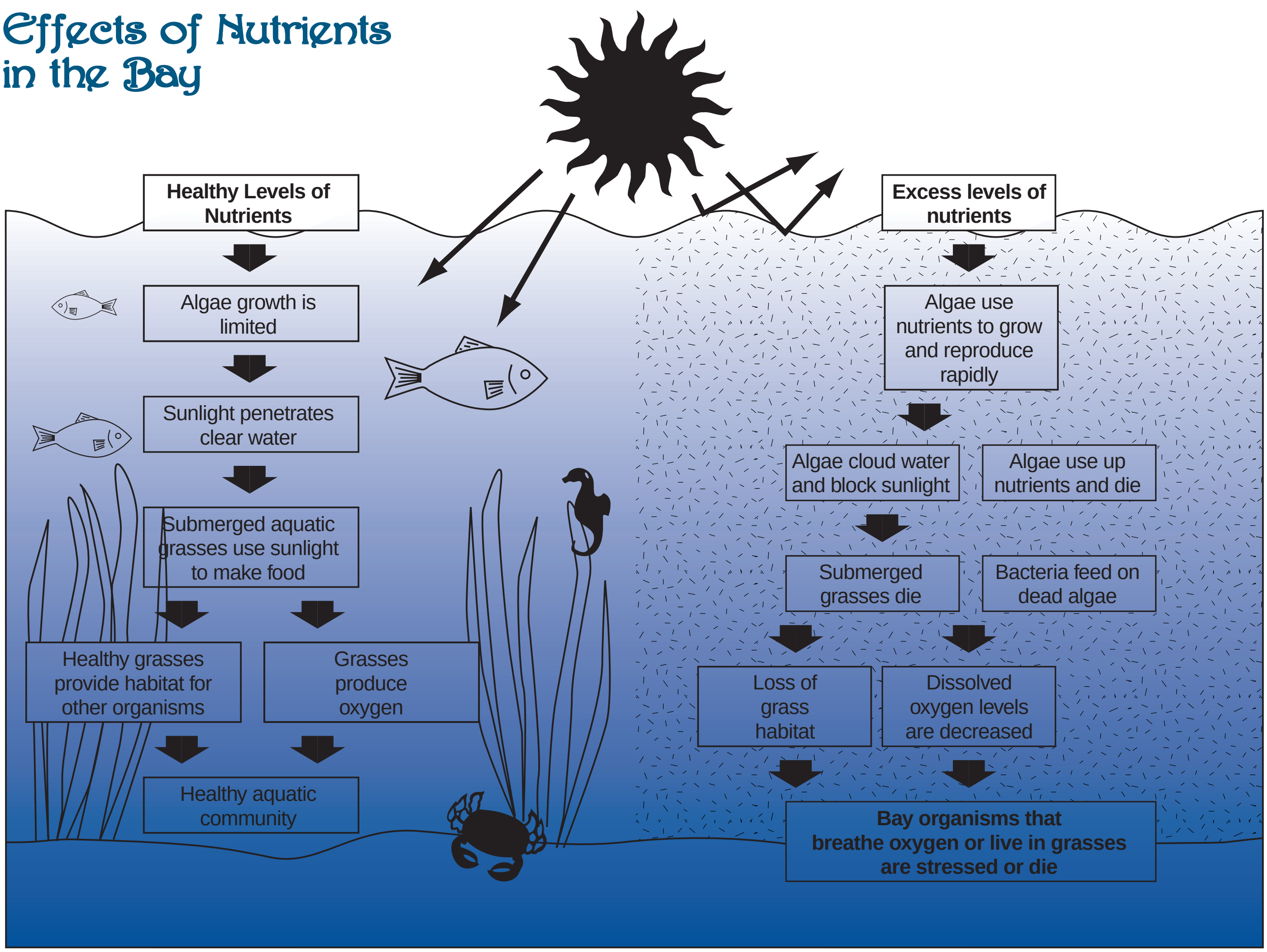
Nitrogen is a natural and essential part of all marine ecosystems. Excess quantities of nitrogen, however, adversely affect water quality and degrade habitat, ultimately impacting a wide range of marine organisms including fish and shellfish. Similar to overfertilizing your garden, nutrient overloading in marine ecosystems stimulates the growth of plants (algae and phytoplankton). Too much algae blocks sunlight to eelgrass, reducing the area of this valuable nursery habitat and feeding ground. In addition, living and dying algae consume oxygen, leading to anoxic (no oxygen) and hypoxic (low oxygen) conditions. This process of water quality decline creates a chain reaction of negative impacts known as eutrophication. Poor water clarity, bad odors, stressed marine organisms and even fish kills are all symptoms of eutrophic conditions.

Eutrophication, is the greatest long-term threat to the Buzzards Bay ecosystem. The difficulty with managing nitrogen loading stems from the widespread distribution of sources within the Bay's 432 square mile watershed. The principal sources of nitrogen input to Buzzards Bay include septic systems, wastewater treatment facilities, stormwater runoff, lawn and agricultural fertilizers, and rain. All of these sources are rooted in the watershed's growing population which has more than doubled this century alone to now include more than 375,000 people.

Nitrogen, which is a limited nutrient in coastal systems contributes to the growth of algae within Buzzards Bay waters. When water within the watershed enters into the ground or runs off the land and into streams and rivers it carries nitrogen and other watershed derived contaminants (natural and man-made) to the Bay. In the past when the Bay watershed was primarily unaltered forest and wetlands, these natural systems acted as filters to absorb and limit a relatively small amount of nitrogen from entering the Bay. Today, however, forest and vegetated watershed areas are being converted to residential development, urban areas, and nonpervious areas, which contribute to and allow more nitrogen to move freely to coastal waters. As a result, some of the embayments, particularly in the upper reaches, are becoming nutrient overloaded or eutrophic. The result has been an increased frequency of algae blooms, loss of eelgrass beds and bottom dwelling animal communities such as shellfish, worms, and crustaceans that support the food chains of the marine system.

Growing nutrient loads to coastal waters throughout the country are currently threatening many embayments, which are rapidly reaching states of nutrient overfertilization. These high nutrient loads are also believed to play a role in the increasing number of algae blooms, red tides and toxic microbes, such as *Pfiesteria piscicida*, that maybe harmful to people fish and marine mammals along the eastern coast of the country. We recognize that excessive nitrogen input to coastal waters is a form of "pollution" and that it is an issue which can occur throughout the margins of the Bay. This pollution, which can result in the loss of whole embayments as productive and economically useful marine habitats, is the basis for our monitoring program.

Effects of Nutrients in the Bay



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Water Quality Monitoring Parameters

Temperature

One of the easiest water quality tests that the volunteers perform, temperature, is also one of the most important. Temperature controls the level of dissolved oxygen which Bay waters hold when in balance with the overlying atmosphere and the rates of various biological processes. In warmer water oxygen is less soluble and respiration rate of organisms increase, hence oxygen consumption goes up. This enables one to estimate if changing oxygen conditions are the result of changes in nutrient conditions, biological production and consumption, or simply the physical component of the solubility of dissolved oxygen in water. In addition, when surface and bottom measurements are made, temperature can be used to indicate (with salinity) if the Bay waters are well mixed from top to bottom. Annual temperatures can range from about -2^{o} Celsius in winter to over 25^{o} Celsius during summer. Temperature is measured using a metal thermometer.

Water Clarity

Water clarity, or light penetration, in the embayments is affected by the amount of suspended particles, usually particles of plankton (phytoplankton and zooplankton) or silt in the water column. Eutrophic waters typically have poor light penetration or transparency. Light penetration is important for photosynthesis and growth of plants both in the water column and on the bottom. Reduced water clarity from suspended sediment can occur after heavy rains; stirring up of bottom particles by wind, waves, and boat traffic; or the rapid growth of plankton from warm temperatures and nutrients. This reduced water clarity can shade bottom dwelling plants, clog fish gills and shellfish, and hinder prey fish from finding food. Baywatchers measure water transparency using a simple device known as a Secchi Disk, a black and white circle lowered into the water. The depth that the disk disappears to the eye is known as the Secchi Depth, recorded in meters. In the middle of Buzzards Bay summertime water transparency can exceed 4 or 5 meters, in the less nutrient enriched embayments, 2 or 3 meters and in the eutrophic areas Secchi Depth can be less than 1 meter (standing waist deep, you can't see your toes!).

Salinity

Seawater contains high concentrations of dissolved salts. Salinity is the measurement of the amount of dissolved salts in a volume of water and is expressed in parts per thousand (ppt). The salinity ranges from a fairly constant 35 ppt in offshore ocean water to 0 ppt for freshwater from groundwater or stream inputs. Buzzards Bay and its sub-embayments contain a mixture of seawater and freshwater from the watershed and rainfall. Salinity varies with freshwater input and exchange with offshore waters. Stratification of the watercolumn (density stratification) can occur, where more dense, higher salinity water forms a wedge under the lighter freshwater entering from a watershed. This is very important to environmental health, since stratification can result in high productivity, high oxygen, low water clarity in surface waters and low productivity, shading and low dissolved oxygen levels near the bottom. In addition, since plants and animals generally are adapted to a specific range of salinity, salinity data can be used to delimit the range and habitat of various organisms within an embayment. Salinity is determined using a salinity table based upon measured density (by hydrometer) and temperature (by metal thermometer).

Dissolved Oxygen (D.O.)

Dissolved oxygen is the measurement of the amount of oxygen molecules dissolved in a volume of water, generally expressed as milligrams of oxygen per liter of water (mg/l) or parts per million (ppm). Oxygen is required for survival and growth of fish, shellfish, and other animals and plants. D.O. is one of the most important parameters for determining the health of a system, particularly relative to nutrient loading. D.O. levels in the water are controlled primarily by the rate of uptake in the respiration of organisms in the watercolumn and sediments and the input from photosynthesis and exchange with the overlying atmosphere. Warmer waters increase the respiration rate of animals and the consumption of oxygen. Oxygen is used by bacteria to break down the plants, algae, and animals after they die. This consumption by bacteria usually occurs at the bottom where the dead materials are deposited which creates a region of high oxygen uptake within the bottom waters of embayments. This high demand for oxygen from bottom waters can result in low oxygen levels, particularly when waters become stratified (non-vertically mixed).

D.O. solubility is the physical ability of water to hold oxygen and is dependent on water temperature and salinity. The amount of D.O. that water will hold at a specific temperature and salinity, when it is in balance with the overlying atmosphere, is termed "air saturation". Field measurements of dissolved oxygen can be compared to the "expected" level of oxygen at "air saturation" and expressed as the percentage of the expected level or more generally, the percentage of air saturation (%Air Sat). Colder water can hold more oxygen than warm water and lower salinity water more than ocean water. D.O. in milligrams of oxygen per liter of water (mg/L) is measured using Hach Dissolved Oxygen Kit and percent air saturation (%Air Sat) is calculated from D.O. using parallel measurements of temperature and salinity. Most plants and animals can function normally when the DO levels remain above 5 mg/l. However when D.O. declines to hypoxic levels (between 3 and 5 mg/l), some organisms become stressed or die. These hypoxic levels typically occur between 6 and 9 AM (before photosynthesis makes up the nighttime oxygen demand), generally during summer when waters are warm. Low D.O. waters are often associated with algae blooms from enriched nutrient conditions generally resulting from watershed inputs. Percent air saturation is used to correct oxygen levels (mg/L) for changes due to salinity and temperature and allow determination of biological effects and impacts.

Chlorophyll a

Chlorophyll a is the primary photosynthetic green plant pigment found in algae and most phytoplankton. Measuring the abundance of chlorophyll a and its immediate breakdown product, pheophytin a, indicates the amount of living (or senescent) alga or algae biomass in a body of water. These algae populations increase and decrease throughout the year with variations in temperature and light under the influence of the amount of nutrients available to support their growth. Chlorophyll a (sometimes with pheophytin a) is therefore used as an indicator of the algae population and if a bloom has occurred. High levels often indicate nutrient enriched conditions, and result in reduced water clarity, greenish coloration and the potential for low dissolved oxygen levels. Water samples for chlorophyll a and pheophytin a are collected in light-tight bottles by Baywatchers and analyzed by the Coastal Systems Laboratory at CMAST. A known volume of the sampled water is passed through a filter to collect the particles which contain the chlorophylls, which is then extracted and assayed. Concentrations of chlorophyll a and pheophytin a are recorded as micrograms of pigment per liter of water (ug/L).

Nutrients

Nitrogen and phosphorus are important plant and phytoplankton nutrients, with nitrogen generally considered the more limiting and problematic nutrient for coastal waters. Light, temperature and the availability of nutrients control the productivity of Bay waters, just as they are important for growth in a garden or lawn. Nitrogen is the primary nutrient controlling plant production within the embayments to Buzzards Bay. Some level of nitrogen input is essential for growth of phytoplankton and plants and the fish, shellfish and waterfowl which they support. However, too much nitrogen creates an overabundance of plant matter causing reduced water clarity and low oxygen conditions which has negative effects on stable plant and animal communities. For this reason, nitrogen inputs and the variety of physical parameters, which modify the level of ecological impact of nitrogen loads, are important to monitor for each embayment. These physical parameters; bathymetry (depth), stratification, temperature (for oxygen consumption), flushing rate, and the form of nitrogen involved (organic/inorganic) help to identify potential impacts to system health.

Nitrogen enters and occurs within embayments in several different chemical forms; inorganic forms (DIN - Dissolved Inorganic Nitrogen) as ammonium (NH^+_4), nitrate (NO^-_3) and nitrite (NO^-_2), which can directly stimulate plant growth, and organic forms or as dissolved (DON - Dissolved Organic Nitrogen) or particulate (PON - Particulate Organic Nitrogen) material from living and dead organisms. Organic forms of nitrogen can rapidly be changed into inorganic forms through biological processes which occur during respiration or decay. Knowing the amount and form of nitrogen at any location helps to identify its source, potential impact to an embayment and where management decisions are needed. Most of the nitrogen entering Buzzards Bay and its embayments is as inorganic nitrogen (DIN), primarily from fertilizers, septic systems, and acid rain. These forms of nitrogen are nutrients that are in short supply in coastal waters and are rapidly taken up by algae. As a result these inorganic forms are generally in very low concentrations with most of the total nitrogen pool found in organic forms. High inorganic nitrogen levels in an estuary typically indicates that the sample was collected near a source (stream, outfall etc.) or that the estuary is highly eutrophic. Organic forms of nitrogen are created when inorganic nitrogen is rapidly taken up by algae. Filtered water samples brought to the Coastal Systems Laboratory at CMAST are assayed for ammonium and nitrate+nitrite. Organic forms of nitrogen are also assayed by the Monitoring Program. Dissolved organic nitrogen is a mixture of complex organic nitrogen compounds like amino acids, urea, and other substances released by living organisms and decaying organic matter. Sometimes ultra small algae and bacteria are measured in this analysis. Since the assay by the CMAST Laboratory is conducted on samples filtered in the field, if the volunteer does not do a good job filtering a sample, both dissolved and total organic nitrogen measurements will be overestimated. Eutrophic waters typically have higher dissolved organic nitrogen concentrations than more pristine areas. Particulate organic nitrogen is inorganic nitrogen which has been used in the production of algae and phytoplankton and the zooplankton and larger animals which in turn consume them. The nitrogen may be within both plant and animal tissue, living and dead. Eutrophic systems have more organic particles within the water. Unfiltered samples collected by the Baywatchers are returned to the CMAST Laboratory for filtration and assay of the particles. Concentrations of both inorganic and organic forms of nitrogen are expressed as milligrams of nitrogen per liter (mg N/L).

Total nitrogen (TN) is merely the sum of all inorganic and organic nitrogen in the water (except for nitrogen gas). Total nitrogen is one of the most widely used indicators of eutrophication used by marine ecologists. The idea behind the use of total nitrogen is quite simple, as nitrogen is constantly being converted between various forms. Within an estuary inorganic forms can be important near nitrogen sources or in areas of high organic matter decay, whereas in other areas nitrogen has been converted into living organisms through the food chain. Total nitrogen accounts for these changes and is generally higher in estuaries that are more eutrophic. One drawback with using total nitrogen as an indicator is that, in some bays, macro-algae growing on the bottom of a bay can also take up nitrogen. To the extent that macroalgae occur, tracking total nitrogen can underestimate nutrient related health of an embayment. Total nitrogen, like other nitrogen forms is reported as “mg N/L”. Values of total nitrogen less than 0.35 mg N/L are characteristic of non-nutrient enrichment, while eutrophic areas have concentrations above 0.60-0.70 mg N/L.

Other Monitoring: Bacteria & Toxics

The Buzzards Bay **C**omprehensive **C**onservation and **M**anagement **P**lan identified three pollution problems as priority issues for monitoring;

- Health risks and closure of shellfish beds due to pathogen and fecal coliform contamination associated with the improper treatment or disposal of human wastes and other coliform and pathogen sources.
- Contamination of fish, lobster, and shellfish by toxic substances and the effects of this contamination on human health and the environment.
- Excessive nutrient inputs into the bay and their potential for causing water quality degradation and loss of habitat.

Closing of shellfish beds throughout the Bay results from pathogen contamination. *The Coalition for Buzzards Bay*

The Coalition for Buzzards Bay monitoring program was designed to fill the void of information on nutrient enrichment, primarily from human sources entering into Buzzards Bay. It does not provide information regarding either pathogen/bacteria or toxic related contamination.

Monitoring of pathogen contamination, which can result in closure of bathing beaches and shellfish beds, is monitored by local boards of health, the Massachusetts Division of Marine Fisheries (DMF), Massachusetts Department of Environmental Protection (DEP), Environmental Protection Agency (EPA), Food and Drug Administration (FDA), and a few other localized research and management projects. While some of the sources of pathogen contamination are the same as those contributing to nutrient overnrichment (ie. septic systems), management actions for each vary, often considerably. Pathogen contamination remains a critical concern in Buzzards Bay where more than 8,000 acres of shellfish beds remain closed to harvest on either a permanent or conditional/seasonal basis.

Toxic Contamination Monitoring of toxic compounds in contaminated sources, sediments, and tissues of lobsters, shellfish and fishes provide information on the fate of marine systems and potential public health effects. This information on petroleum residues, PAH's, PCB's, effluent waters, and other discharges to the Bay is monitored by a variety of local State and Federal agencies; Municipal officials, Department of Water Pollution Control (DWPC), DMF, EPA, National Oceanographic and Atmospheric Administration (NOAA) and other private contractors.

Contaminated by past discharges of toxic PCB's, New Bedford Harbor is currently undergoing cleanup. *City of New Bedford*

The Buzzards Bay Health Index

- Good to Excellent (65 - 100)
- Fair (35 - 65)
- Poor/Eutrophic Conditions (< 35)

Indices have been developed as an approach to simplifying complex and diverse data sets to focus on key issues. In the Buzzards Bay Citizen's Monitoring Program, the key issue is the level of eutrophication or nutrient related health of an embayment. The Program's primary parameters, oxygen, light penetration (Secchi Depth), chlorophyll a pigments, and nitrogen (inorganic and organic), allow for the production of a single "health index". While the index is only an approximate gauge of the health of an embayment, in application to specific embayments it does appear to agree with other health indicators, such as eelgrass distribution or organic rich sediments. The index provides a simple mechanism for the intercomparison of sites within and between embayments and allows for a "bay at a glance" picture of conditions throughout Buzzards Bay (see Water Quality Poster 1992-1998). An explanation of each key water quality parameter and the method for determining the Buzzards Bay Health Index is detailed below.

The health index is based upon independent water quality parameters which are directly related to the level of nutrient related health or level of nitrogen fertilization (eutrophication) of an embayment. The index includes the plant nutrient, nitrogen, as its availability generally limits plant production within the Bay. Total nitrogen is divided into inorganic and organic forms for the calculations. Inorganic nitrogen is the predominant form of nitrogen (nitrate, nitrite and ammonium) which enters the Bay from the watershed and stimulates the growth of phytoplankton and other plants. In the upper regions of embayments or in highly eutrophic embayments, inorganic nitrogen levels can be high. When the inorganic nitrogen is incorporated by plants it is transformed into organic nitrogen which is found within Bay waters in particulate (within cells or plant and animal matter) and dissolved (lost from plants and animals by excretion, leaching, or during decay) forms. As nitrogen loading to an embayment increases, so does the quantity of organic nitrogen found within the embayment's waters. Under eutrophic conditions high levels of inorganic nitrogen can typically be found within the headwaters of inlets with high levels of organic nitrogen throughout most of the system. Since organic nitrogen can also enter embayment waters from runoff or resuspension of bottom sediments or in dissolved forms from the watershed, we use the plant pigments chlorophyll a and pheophytin a as a gauge of the organic matter produced within the embayment waters.

	Values for Health Scores	
	0 points	**100 points**
Measured Values		
Oxygen saturation (lowest 20% of observations)	40% sat.	90% sat.
Transparency (Secchi Disk depth)	0.6 m	3 m
Phytoplankton pigments (chlorophyll+pheophytin)	10 ug/L	3 ug/L
Dissolved Inorganic Nitrogen (DIN)	10 micromolar	1 micromolar
	(=0.14 ppm)	(=0.014 ppm)
Total Organic Nitrogen (dissolved+particulate)	0.60 ppm	0.28 ppm

These pigments are found within phytoplankton and other plants within the Bay and are not typically entering the Bay from the surrounding watershed. This allows an estimate of the response of the algae within the Bay to the inorganic nitrogen entering from the watershed.

Dissolved oxygen is an important indicator of the tolerance level of an embayment to the level of nitrogen it is receiving and phytoplankton (chlorophyll) it is growing. Dissolved oxygen concentration represents the balance between inputs from photosynthesis and from the overlying atmosphere and outputs due to respiration of animal and plant communities and decaying organic matter. When Bay waters show low oxygen levels, it clearly indicates a disruption of the balance due to an overabundance of respiration and decay relative to the amount of oxygen input that the system receives. In addition, low oxygen levels are themselves directly stressful to animal and plant communities. In order to account for changes in measured oxygen levels resulting from changes in water temperature and salinity (which control the level of oxygen in water in balance with the atmosphere, with no other inputs or outputs), oxygen concentrations (mg/L) are converted to percent of air saturation. Percent saturation (%Sat) values less than 100% indicate that the waters have more oxygen consumption than supply and greater than 100% indicate excess supply, usually due to high levels of phytoplankton photosynthesis. However, since it is the degree of low oxygen conditions that control ecosystem health and since these may occur only periodically, use of the average of all oxygen measurements would tend to obscure the level of stress. For this reason, only the lowest 20% of the summer oxygen measurements are used within the index. This is a shift from 33% used previously (Baywatchers Report 1996). However, this appears to increase the sensitivity and accuracy of the index. In some embayments dissolved oxygen was measured in the surface water, rather than just above the sediment surface. In these systems the oxygen scores would represent “best case” conditions. However in the shallow estuaries monitored, we have found that surface and bottom waters generally do not show significant differences in dissolved oxygen level; when oxygen levels decline, they decline throughout the watercolumn. The final index parameter, light penetration, relates to the ability of waters to support bottom plants (eelgrass and macroalgae) but is primarily another measure of embayment response. Light penetration within the embayments to Buzzards Bay is primarily controlled by the amount of phytoplankton within the water, although localized input of other types of particles or high levels of humic acids can also affect this parameter. Typically, the higher the level of eutrophication, the less light penetrates into the watercolumn. The measure of light penetration is based upon Secchi depth.

Volunteer monitoring sampling kit *N. Garfield, 1999*

To generate the Health Index Score from the five base parameters, the summer averages were calculated. The average value for each parameter was then given a “health score” ranging from 0-100, where 100 is excellent and 0 is eutrophic (unhealthy). The excellent conditions parallel environmental conditions of healthy eelgrass beds, diverse and productive animal and plant communities, clear waters, high oxygen levels; in contrast the eutrophic conditions are where eelgrass beds have been lost, bottom animal and plant communities are depauperate, there is periodic low dissolved oxygen and occasionally even fish kills. Scores between 100-0 indicate conditions of intermediate environmental health. These values are based upon observations in Buzzards Bay and other regional embayments. Other regions may have to adjust the index to meet site specific conditions. The upper and lower levels of each parameter and the resulting index score are shown in the previous table. The value for each parameter contributing to an embayment’s health score, is calculated using a non-linear (natural logarithim) relationship of the measured parameter to the “working” range for that parameter.

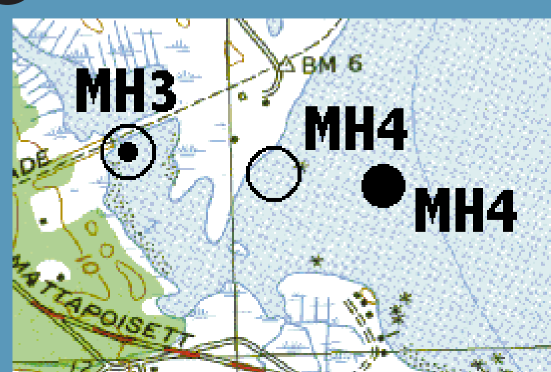
The Health Index Score is the sum of the five individual health scores for a given site. The Health Index is given with the individual parameters for each embayment site within the text and is summarized, Bay-wide, in the Water Quality Poster 1992-98. The Index should be used as a screening tool, but the individual parameters need to be referred to in order to diagnose the underlying causes of low scores.

Key to Sampling Station Maps

○ Oxygen Sampling Station

● Nutrient Sampling Station

◉ Oxygen & Nutrient Sampling Station



Nitrogen Management in Buzzards Bay Embayments

This Nitrogen Management matrix has been developed by the authors to provide an initial guide to municipalities and citizens seeking to restore nitrogen impacted areas or to develop comprehensive Nitrogen Management Plans for specific embayments. As a long-term ecological monitoring effort, the Baywatchers program documents trends and focuses attention to where problems exist. It is not, however, capable of clearly pinpointing pollution sources. The Nitrogen Management Concerns shown on the matrix have not necessarily been identified as problems in that embayment by the program, but rather are likely sources of excess nitrogen deserving of closer investigation. Also, blank boxes on this matrix are not meant to imply that a particular nitrogen management concern does not pose a potential problem for that embayment. They have not, however, been identified as a likely significant source of nitrogen loading to that area. Embayments are ordered on the Matrix from Poor (red) to Excellent (blue) nutrient related Water Quality based on 1998 sampling season results

Nitrogen Management Concerns	Apponagansett Bay	Eel Pond, Mattapoisett	Agawam River	Weweantic River	Westport River, East Branch	Acushnet River	Slocums River	Little River	Hammett Cove	New Bedford Harbor	Wareham River	Little Bay, Nasketucket	Red Brook Harbor	Aucoot Cove	Squeteague Harbor	Broad Marsh River	Nasketucket Bay
Nitrogen loading from septic systems associated with existing development	●	●	●	●	●	●	●		●	●	●	●	●		●		●
Residential development of open space & associated nitrogen loading at buildout	●	●	●	●	●	●	●		●		●	●	●	●	●		●
Nitrogen removal capacity of municipal Waste Water Treatment Facility (Sewage)			●			●				●	●			●		●	
Nitrogen loading from agricultural fertilizer applications (ie. cranberry bogs, croplands)			●	●	●		●	●			●	●	●				●
Nitrogen loading from turf fertilizer applications (ie. residential lawns, golf course)		●							●								
Runoff from animal waste	●				●							●					●
Contaminated groundwater discharge from Solid Waste Landfill plume						○	○				○		●		●		
Nitrogen imported from outside watershed			●	●		●		●		●	●			●		●	
Combined Sewer Overflow (CSO) discharges						●				●							

Nitrogen Management Concerns	Sippican Harbor	Back River	Eel Pond, Bourne	Hen Cove	Shell Point Bay	Westport River, West Branch	West Falmouth Harbor	Onset Bay	Clarks Cove	Pocasset River	Pocasset Harbor	Buttermilk Bay	Mattapoisett Harbor	Megansett Harbor	Phinney's Harbor	Quissett Harbor
Nitrogen loading from septic systems associated with existing development	●	●	●	●	●	●	●			●						
Residential development of open space & associated nitrogen loading at buildout	●			●	●	●	●	●		●		●	●	●	●	
Nitrogen removal capacity of municipal Waste Water Treatment Facility (Sewage)							●									
Nitrogen loading from agricultural fertilizer applications (ie. cranberry bogs, croplands)						●										
Nitrogen loading from turf fertilizer applications (ie. residential lawns, golf course)	●			●			●	●					●			●
Runoff from animal waste																
Contaminated groundwater discharge from Solid Waste Landfill plume							●				●			●	○	
Nitrogen imported from outside watershed							●				●					
Combined Sewer Overflow (CSO) discharges									●							

○ = Level of concern unknown.

Note: Other common pollution sources to coastal waters such as stormwater road runoff and boat wastes, while important to manage to reduce bacterial and other contamination, are typically considered minor nitrogen sources and therefore not included in this matrix.

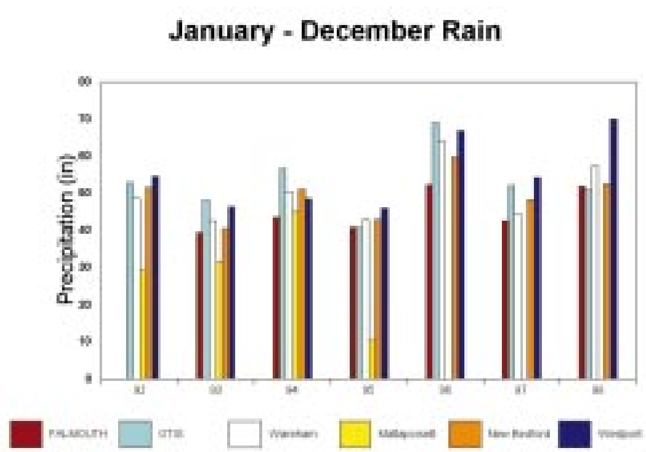
Rain Affecting Water Quality

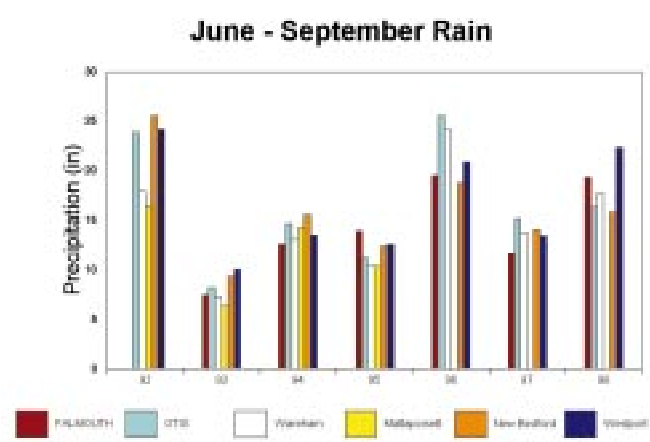
Over the seven years of monitoring, year-to-year variability in nutrient related water quality was observed in many of the embayments. While some of the shifts could be explained by changes in nitrogen inputs from the surrounding watershed, either due to increased development or implementation of remediation efforts, some variations did not appear to be related to watershed activities. In addition, some of the interannual variation did not represent a steady shift or trend. This variability is generally explainable based upon differences in tidal conditions (spring & neap) or wind driven variations in flushing or vertical mixing of the watercolumn. Sampling for nutrients is always at mid-ebb tide. However, larger scale factors like rainfall may also play a role.

Patterns of rainfall are not always consistent around the bay. Stations near the "mouth" of the Bay tend to have higher rainfall than those in the upper reaches. For example a big rainfall in 1992 dropped eight inches of rain in Westport but only 5 inches in the town of Wareham. Consequently it is important to monitor rainfall in several parts of Buzzards Bay to help interpret local conditions. For this reason also, citizens record on their data sheets how many days it has been since a rain.

7 day cycles throughout the summer and Baywatchers monitoring is a random sampling of summer weather conditions (with the exception that Monitors do not sample during a gale).

It is possible to gauge the general importance of rainfall to the monitoring results by comparing 1992 and 1996 the two highest rainfall years sampled with 1993, a regional drought year. Comparing overall nutrient water quality, no clear relationship with seasonal precipitation is seen. However within the smaller sub-embayments receiving significant freshwater inflows, nitrogen and chlorophyll a levels show a slight tendency toward lower concentrations during the high rainfall years. The lack of a "clear rainfall effect" results from the water quality values representing random samplings of weather conditions and for the Bay Health Index, the offsetting effects of higher Index values due to lower nitrogen, but lower Index values due to lower dissolved oxygen. A more complete rainfall analysis indicates that within individual embayments, effects on individual water quality parameters can be observed following specific rainfall events. However, in terms of determining long-term trends in the health of the Bay, high or low rainfall years do not appear to be biasing the data.



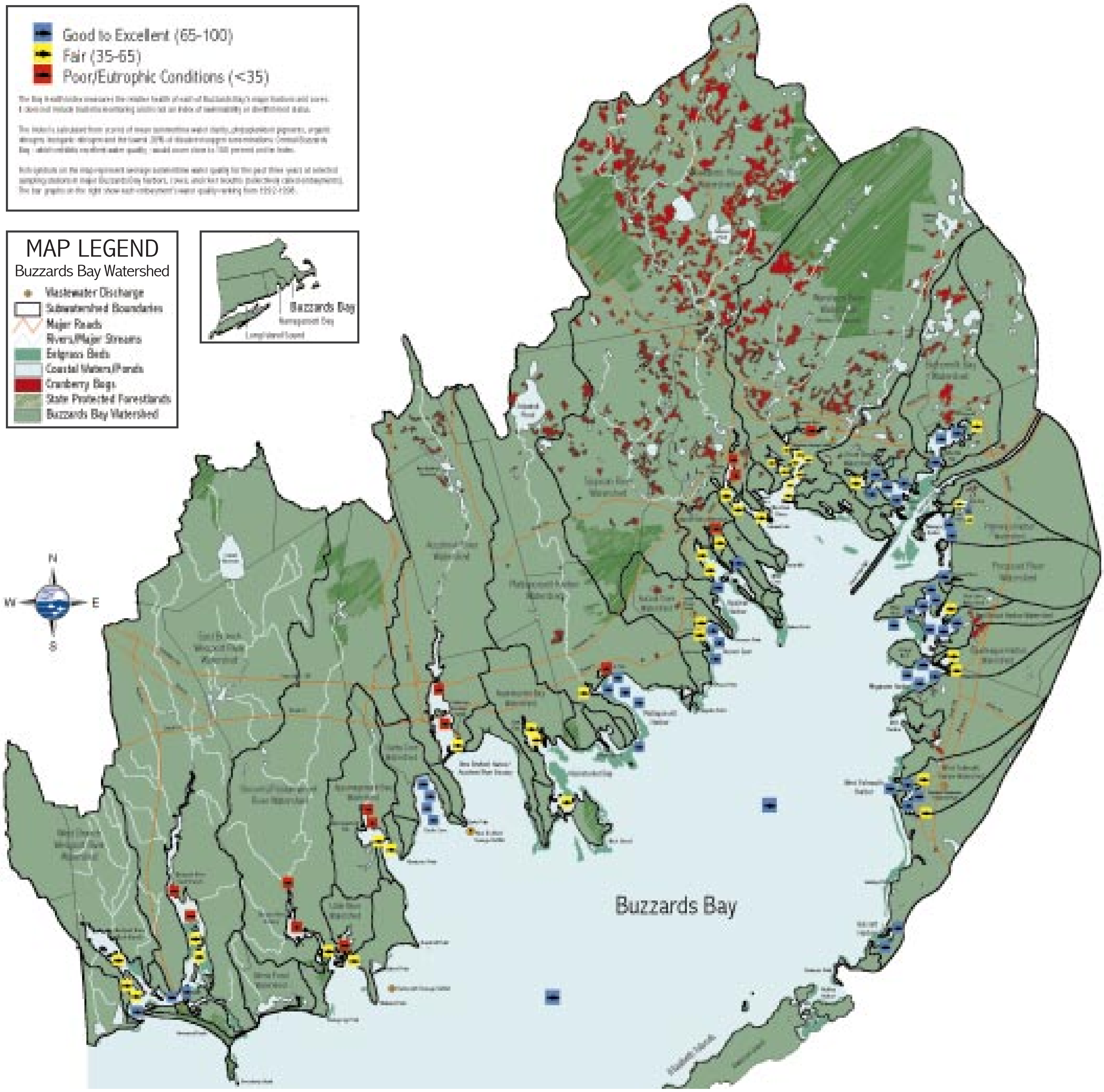


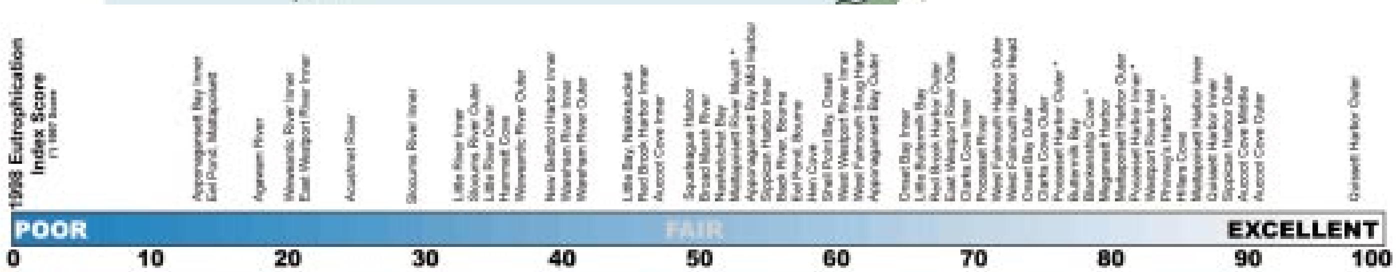
Rainfall data is collected at many locations around Buzzards Bay. We assembled data from 6 sampling locations distributed around the margin of the Bay, along the eastern shore from Falmouth and Otis AFB, at the head of the Bay from Wareham and along the western shore from Mattapoisett, New Bedford and Westport. Rainfall can affect water quality in a variety of ways including: (1) increasing inputs of nitrogen through surface water inflows, (2) increasing the probability of watercolumn stratification (unmixed watercolumn) and therefore low dissolved oxygen, (3) causing low dissolved oxygen if associated with several days of low light and (4) increasing flushing of small upper portions of estuaries. Fortunately, weather patterns within the Bay shift on 5-

Available rain fall data was provided by Dick Payne (Falmouth), Henry Forcier (Otis), Wareham Cranberry Station, Buzzards Bay Project (Wareham), Ben Schnieder (Mattapoisett), Manuel F. Camacho Jr. (New Bedford) and Dale Thomas (Westport).

While we could not present all the data collected in this program, on the following pages we show the most salient information characterizing nutrient related water quality. We hope that these findings help the public and state and local officials understand local water quality conditions and how their embayment compares to others in Buzzards Bay.

The Buzzards Bay Health Index

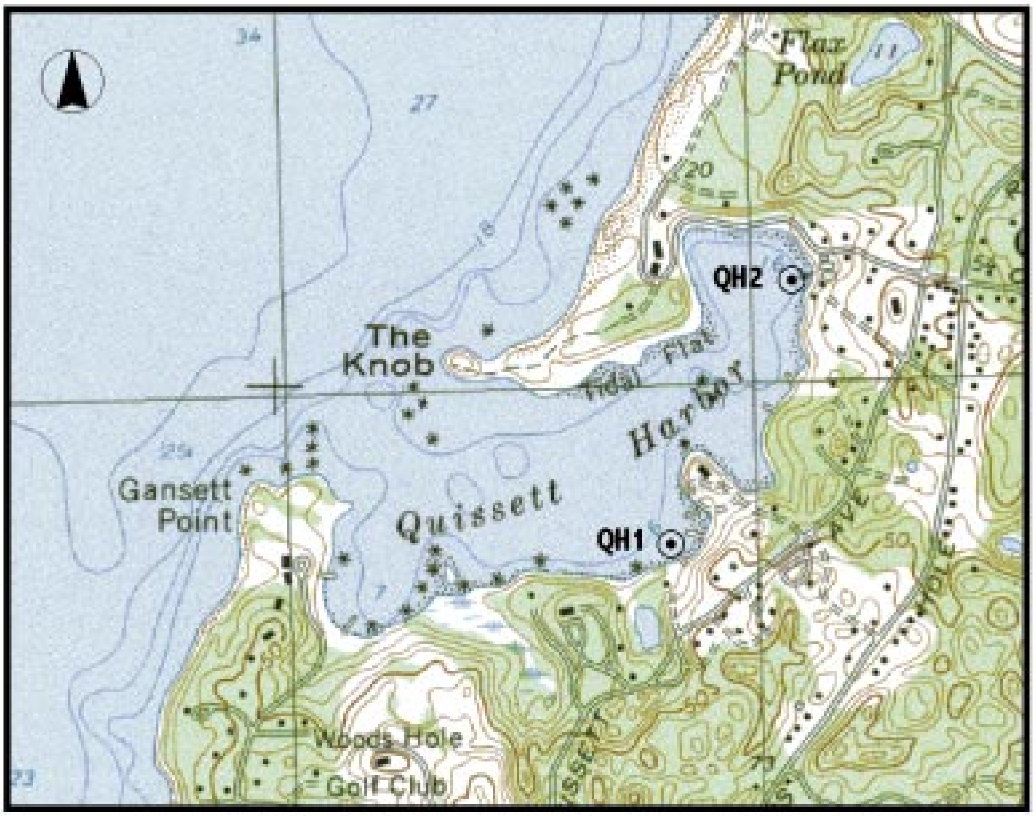




The watershed boundaries and land-use characteristics of Buzzards Bay embayments west of the Cape Cod Canal used in this report were based on the 1994 Buzzards Bay Project Reports. Land-use for watersheds to the embayments east of the Canal were based on Cape Cod Commission 1995 watershed delineations and MassGIS data. A few of the Cape Cod watersheds differ slightly from the 1996 Baywatchers Report and the 1999 Water Quality Poster due to the recent inclusion of the more up-to-date Commission information.

Quissett Harbor

Falmouth



Embayment and Watershed Characteristics

Once called Quamquisset Harbor, Quissett Harbor is one of the deeper and better flushed embayments in Buzzards Bay. The Harbor is semi-enclosed and has both an inner and outer basin. Tidal exchange with waters entering from Buzzards Bay is though a central channel. Throughout the 7 years of monitoring Quissett Harbor has ranked among the highest water quality embayments within Buzzards Bay. The Harbor watershed falls almost entirely within the Buzzards Bay glacial moraine deposits. As a result the watershed soils consist of boulders with intermixed sands and gravel. The boulders are clearly seen in the eroded shore of the Knob at the mouth of the Harbor.

With one of the smallest watersheds of all those sampled, Quissett Harbor's surrounding drainage basin consists mostly of residential land and the Woods Hole Golf Club (12% of the watershed land area). This drainage basin is also among the least forested and has a modest capacity for additional residential development. At present, the watershed has less than 150 housing units and low year-round occupancy. After residential on-site septic systems, nitrogen leaching from golf course fertilizer applications is the second largest source of loading to the Harbor.

The Harbor is used heavily by recreational boaters with approximately 240 boat moorings. The Quissett Harbor Boatyard, located within the inner Harbor has a boat pump-out available year round.

The Harbor supports healthy eelgrass beds, particularly in the outer portion. Associated with these beds is a scallop area at the mouth of the Harbor. The Town of Falmouth Shellfish Office considers the Harbor to be "113 acres of very good oyster habitat" also supporting quahogs (*Mercenaria*) and soft-shell clams (*Mya*). The habitat currently supports both recreational and commercial shellfishing. While the southern half of Quissett Harbor is classified as Approved for shellfishing, the more heavily used inner Harbor is conditionally closed to shellfishing on a seasonal basis due to the marina policy.

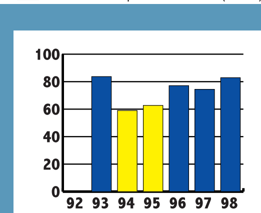
Water Quality

The high quality of Buzzards Bay source waters and the small watershed with primarily residential development contribute to the high water and habitat quality within Quissett Harbor. This is further assisted by the relatively open Harbor structure which facilitates good tidal exchange with offshore waters. In addition, the lack of a significant surface water input (river), helps to prevent pulse inputs of freshwater and nutrients which can enhance algal blooms and decrease water column mixing (salinity stratification).

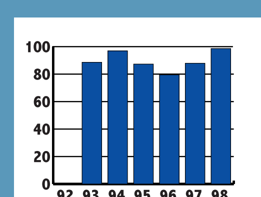
BAY HEALTH INDEX

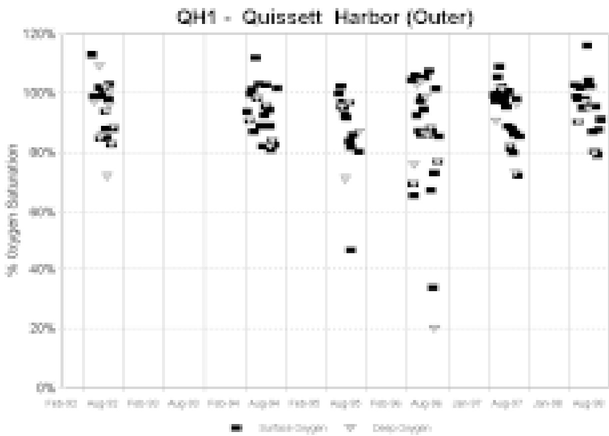
- Good to Excellent (65 - 100)
- Fair (35 - 65)
- Poor/Eutrophic Conditions (< 35)

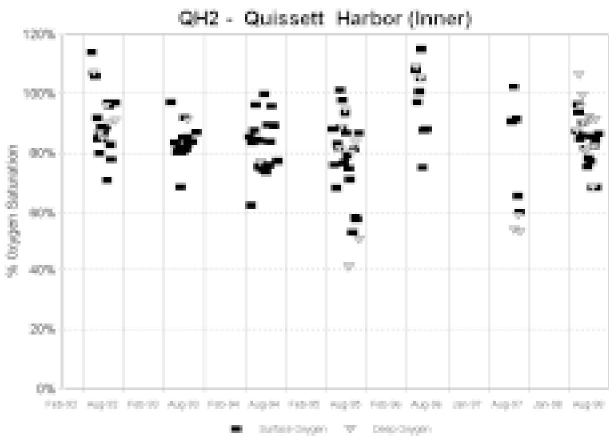
Quissett Harbor, Inner

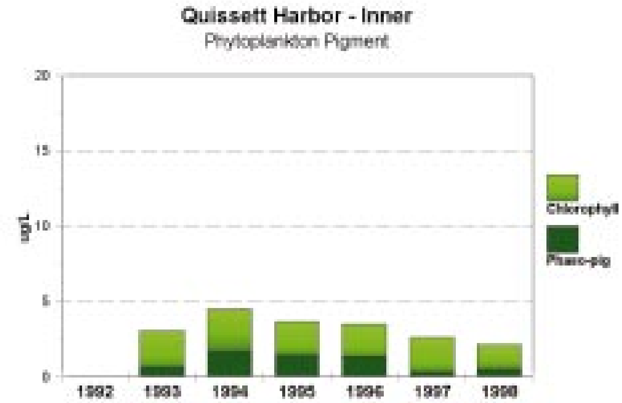


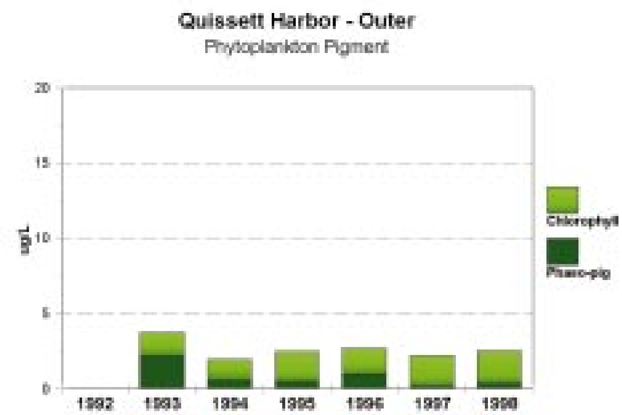
Quissett Harbor, Outer

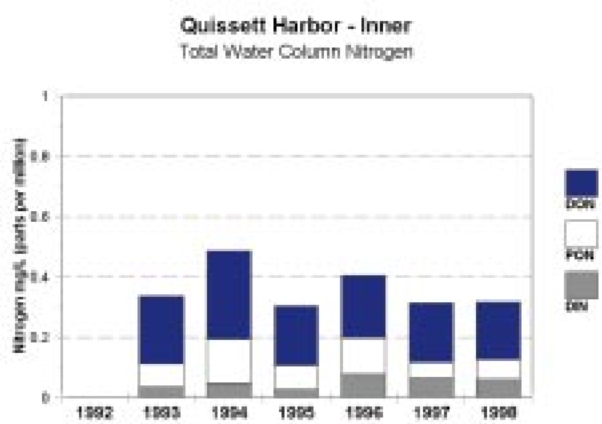


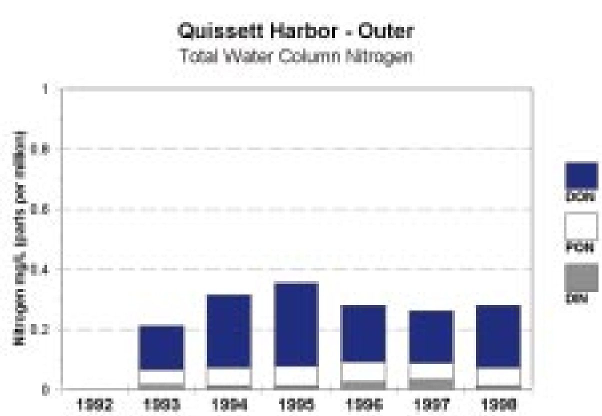












The good circulation and low terrestrial loading to the Harbor can be seen in the very small enhancement of nitrogen and chlorophyll a levels from the inner versus outer basin in each year of study. Over the long-term, average total nitrogen and chlorophyll a pigment concentrations were 30% and 32% higher in the inner Harbor compared to the outer station. The high nitrogen levels in the inner Harbor in 1994 were primarily the result of elevated dissolved organic nitrogen concentrations, the cause of which is unclear. Dissolved organic nitrogen is less involved with nutrient problems than other nitrogen forms, because in marine waters much of this material is not biologically active. Exclusive of the 1994 inner Harbor data, total nitrogen averaged only 18% higher in the inner versus outer basin with average concentrations of 0.33 and 0.28 mg/L, respectively. However, even with these increases the inner Harbor concentrations are still low, since the outer Harbor waters reflect the source waters of Buzzards Bay.

Oxygen concentrations within the Harbor were typically representative of high water quality. However, on a single date in 1995 and 1996 in the outer Harbor and 2 dates in 1995 in the inner Harbor showed significant oxygen depletions. While the outer Harbor oxygen depletion is rare and departs from the general baseline, the inner Harbor showed oxygen declines below 70% air equilibration in 6 of the 7 years. While this observation is cause for concern and the focus of additional monitoring, it should be noted that the inner sampling station is sited to gauge the Harbor's "worst case" conditions.

The Health Index for the Harbor reflects the generally high water quality of the entire system. The low scores in the inner Harbor in 1994 and 1995 result from the oxygen depletion in those years and the high dissolved organic nitrogen in 1994. While these results suggest that the inner Harbor has the "potential" for nutrient impacted water quality, these conditions are atypical and localized. The persistence of eelgrass beds and a healthy shellfishery (including bay scallops) supports the evaluation of Quissett Harbor as a high water and habitat quality embayment. Quissett Harbor (particularly the outer portion) should serve as a good long-term "benchmark" system from which to monitor changes in other systems.

Management Needs

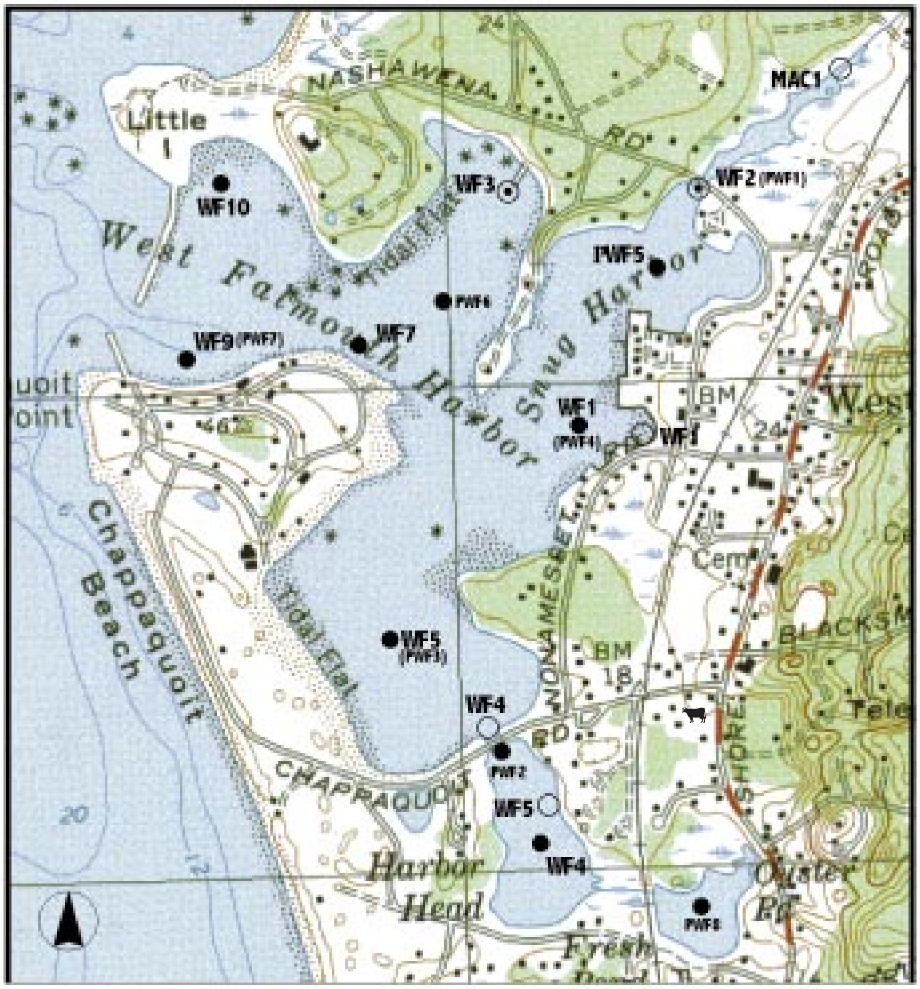
Water quality is generally excellent in Quissett Harbor and future growth projections for the watershed do not appear to threaten that status, as is the case with so many other embayments. Nitrogen sources to the Harbor are predominantly associated with residential development, however, leaching of fertilizers from the golf course represent the largest single parcel input. Opportunities to reduce fertilizer leaching may represent a simple cost-effective approach for offsetting nitrogen from future development, if an unanticipated decline in water quality is observed.

In light of the Harbor's present health, nitrogen management action is not currently anticipated for this watershed. However, determination of the cause of the infrequent occurrence of oxygen declines in the inner Harbor region is necessary for proper management of this system.

Sampling poles *J.Mulvey 1998*

West Falmouth Harbor

Falmouth



Embayment and Watershed Characteristics

West Falmouth Harbor, a coastal embayment opening into the eastern waters of Buzzards Bay, is one of the Town of Falmouth's significant marine resources. At a time when many other coastal ponds and bays in the Town have been degraded, water quality in West Falmouth Harbor has until recently remained fairly high, as pockets of eelgrass and healthy animal populations demonstrate. However, West Falmouth Harbor is a system currently undergoing changes due to nutrient overloading primarily from recent entry of nutrients discharged from the Town's Wastewater Treatment Facility (WTTF).

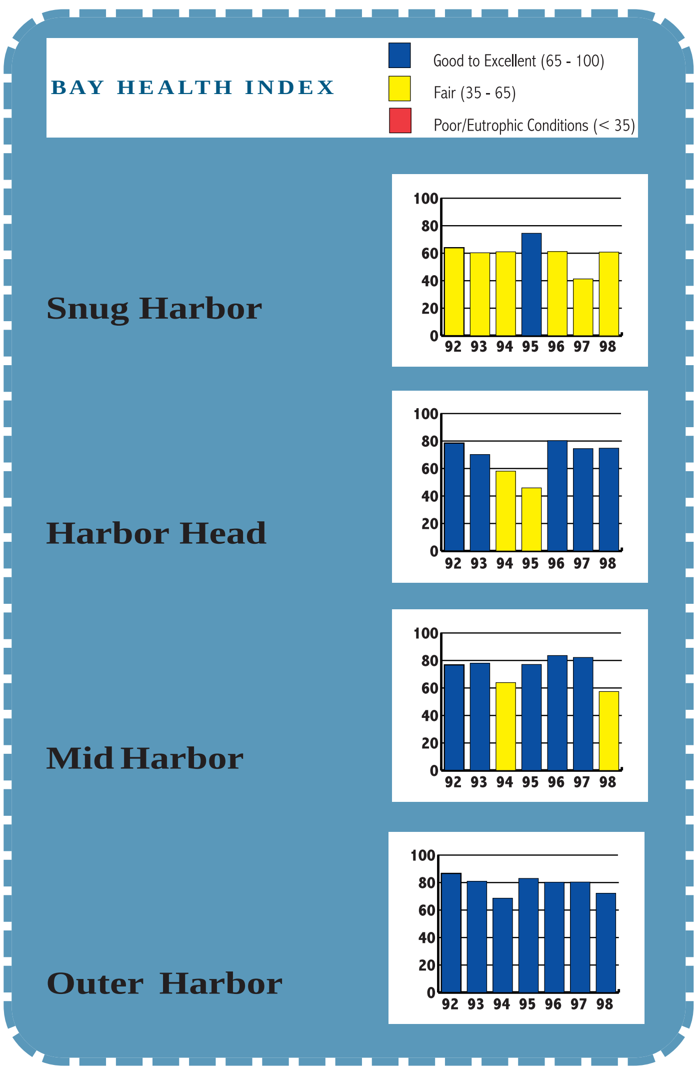
West Falmouth Harbor, historically called Chappaquoit Harbor, is an enclosed tidal system comprised of multiple basins with a mean depth at MLW of 0.6 meters. The Harbor was originally an open basin with an island, what is now Chappaquoit Point, marking the outer boundary with Buzzards Bay. Deposition of a sand spit enclosed the present Harbor as well as the Great Sippewissett and Little Sippewissett Marshes to the South. During this century, jetties were placed at the Harbor inlet, further enclosing the outer basin. The upper watershed to West Falmouth Harbor is somewhat geologically complex, being composed primarily of Falmouth Glacial Moraine. This complexity increases the difficulties of modeling the trajectories of two major groundwater plumes within the watershed, the plume from the WWTF and from the former septage lagoons at the Falmouth Landfill.

The Harbor is moderate in size, 197 acres, and composed of an outer region between the jetties and the Snug Harbor Point, the inner Harbor consisting of the Snug Harbor and Chappaquoit basins and 3 tributary systems, Mashapaquit Creek Marsh, Harbor Head and Oyster Pond. Each of these systems has its own sensitivity to nitrogen loading. Oyster Pond, a kettle pond now tidally connected to the Bay, is the deepest part of the West Falmouth Harbor marine system, more than 24 feet in depth. This 7 acre salt pond has a small channel for tidal flow and typically maintains a salinity throughout the watercolumn above 25 ppt. However, because of its depth, Oyster Pond periodically stratifies and oxygen depletion of bottom waters results. Harbor Head is a shallow basin between Oyster Pond and the primary basins of the Harbor and therefore receives nutrients from its surrounding watershed as well as nutrients from the Oyster Pond watershed which leave the Pond during ebb tidal flows. Similarly, Chappaquoit Basin receives ebb tidal waters from both Harbor Head and Oyster Pond. Snug Harbor, 37 acres, averages 1.2 m depth (at mid-tide) and is the most heavily nutrient loaded basin within the System. Snug Harbor and its upper portion, Mashapaquit Creek (14 acres) form a sub-estuary to the Harbor which began receiving nitrogen when the groundwater effluent plume from the Falmouth WWTF reached its shores in ca. 1994.

The Harbor is important for recreational boating and supports 356 moorings. The Inner Harbor has both a Town Dock and public boat ramp. The Town Dock consists of a pier with floats. Boat fueling activities at the Town Dock have been discontinued. Pump-out facilities for boat waste were not available over the period of study.

West Falmouth Harbor remains an important habitat for quahogs, soft-shell clams, and oysters and to some extent scallops. In 1993 the Harbor supplied over 8% of Falmouth's commercial and recreational catch of clams, quahogs, and scallops, some 1200 bushels valued at about $90,000 (Town of Falmouth, 1993). In addition, the inner Harbor supports an "up-weller" for shellfish propagation, maintained by the Town Shellfish Department. The Department in 1997 used the Harbor for transfer of 1158 bushels of quahogs and 100,000 of seed, while MA Division of Marine Fisheries planted seed bay scallops in 1995 (1.5 million) followed by 75,000 seed by the Town in 1997. The Harbor supports diverse areas for shellfish harvest which are Conditional/Prohibited. In November of 1998, the Harbor was reclassified as "Seasonally Approved", this allows shellfish harvest from November 1 through April 30 only. However, the region of Snug Harbor and Mashapaquit Creek is Prohibited (permanently closed). Bacterial contamination to the Harbor appears to be primarily via tidal outflows from the Mashapaquit Creek Marsh which may be in part "natural" contamination from wildlife. However, direct discharge of road runoff, particularly in the Snug Harbor region to the extent that it is occurring should be mitigated.

The Harbor supports both salt marsh and eelgrass communities. Of the 38 acres of salt marsh the largest areas are found surrounding Mashapaquit Creek and Oyster Pond. Narrow fringing marsh is found bordering much of the inner Harbor. Eelgrass beds are highly sensitive to nutrient overloading. Eelgrass beds within West Falmouth Harbor in the mid-1980's were found to cover ca. 28 acres. While a current assessment is not yet available, it appears that some loss has occurred from the inner areas. The presence of eelgrass is important to the use of West Falmouth Harbor as bay scallop habitat. It is clear from the seed/harvest programs in 1995 and 1997 that scallop production within this system is still possible, although potentially declining.



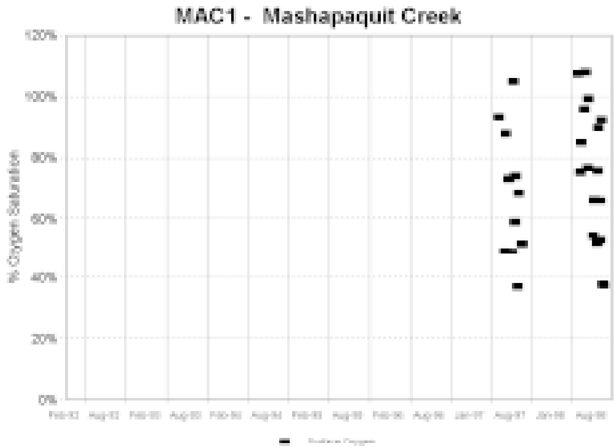
West Falmouth Harbor is notable for its diversity of nitrogen sources. The Harbor's watershed comprises a variety of nutrient sources, among them the Town's Waste Water Treatment Facility, its landfill, old septage lagoons, composting installations, runoff from roads and lawns, as well as effluent from a growing number of residential septic systems and from the Town's industrial park. The Treatment Facility was designed to reduce its nitrogen load to the Harbor through spray irrigation of vegetation, whereby nutrients would be denitrified or taken up by growing plants. However, this system has been only partially effective. The nitrogen-rich plume created by this source has entered the groundwater in the northeast section of the watershed and is currently discharging to the Snug Harbor/Mashapaquit Creek sub-estuary.

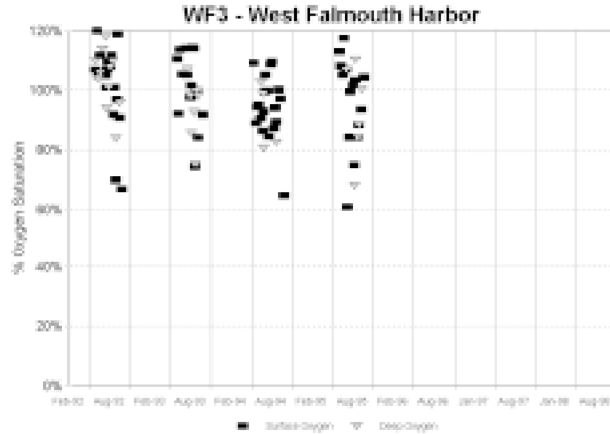
Nitrogen loading estimates from the watershed to the Harbor have been conducted by CMAST scientists, Cape Cod Commission, Buzzards Bay Project and most recently as part of wastewater facilities planning for West Falmouth Harbor. While the absolute values vary slightly, it appears that the WWTF presently contributes about 70% of the watershed nitrogen input to the Harbor. The remainder is from residential housing and light commercial areas (Falmouth Technology Park) and associated sources (roads, driveways, etc.), and the nitrogen enriched groundwater plume originating from the Falmouth Landfill and its now closed septage disposal lagoons. The WWTF has been increasing its mass of nitrogen discharged in its treated effluent since its start-up in October 1986. From 1991-92 to 1997-98 alone, effluent discharge from the WWTF has increased more than 50%. The increasing mass of N discharged results from increasing use of the Facility for septage, additional hook-ups within sewered areas and increased occupancy. This increasing rate of loading from the WWTF is much higher than from increasing development within the West Falmouth Harbor watershed. While all sources of nitrogen contribute to over-fertilization of the Harbor, the WWTF clearly presents the largest source and is increasing at the highest rate. The current facility's planning represents an opportunity to address this nitrogen source and other wastewater sources within the Harbor watershed.

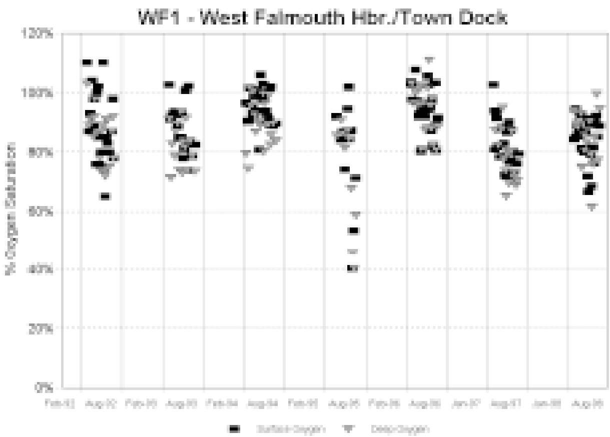
Water Quality

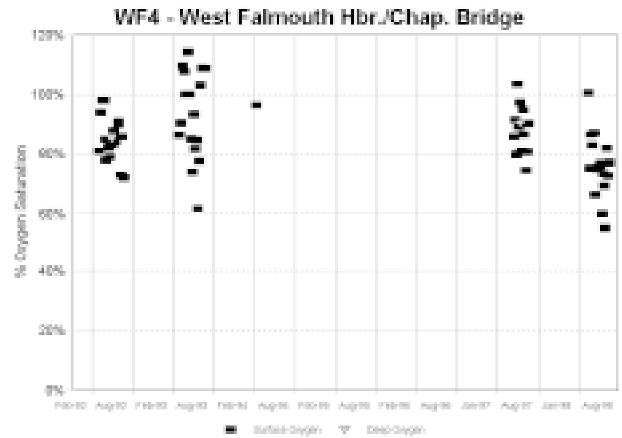
West Falmouth Harbor has been monitored by the Baywatchers and Falmouth Pond Watchers since 1992. After 1993, nutrient sampling has been by Pond Watchers and the Health Index is based upon nitrogen, oxygen and clarity parameters only. This is supported by analysis of the 1992-93 data which yielded an Index score of 66 compared to the four parameter score of 65. In 1999, chlorophyll a was added to the Pond Watchers Program.

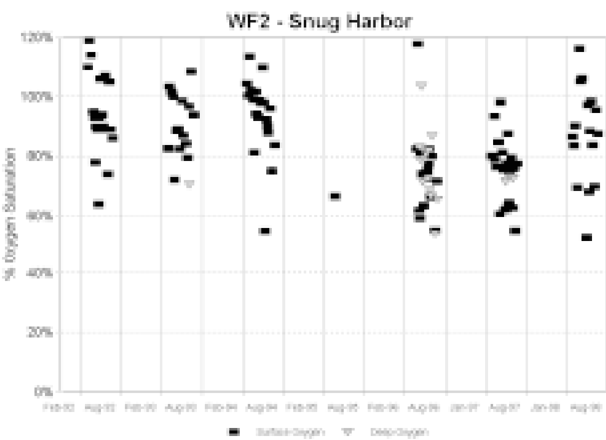
Oxygen depletion of bottom waters is observed at all Harbor stations during summer. Oxygen depletion to 80% of air saturation is common throughout the inner regions (WF1, WF2, WF4)

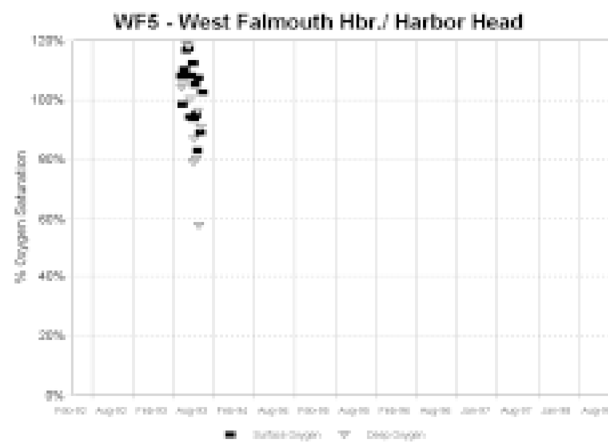












and relatively infrequent in the outer Harbor. At present, within the inner regions periodic oxygen depletion to 60% saturation is relatively common. However, only in Snug Harbor do oxygen levels routinely reach ecologically stressful levels. There appears to be a trend in the oxygen data of greater depletion in recent versus previous years in Snug Harbor and “outer Snug Harbor” (mid-region at Town Dock). The other stations although variable, do not show the same trend. Oxygen depletion to below 80% of air saturation occurred in Snug Harbor only about 15% of the time in the 1992-94 sampling compared to more than 60% in the 1995-98 sampling period with the mid-Harbor (WF1) showing a similar but smaller trend, 20% versus 32% respectively. The Falmouth WWTF nitrogen plume began discharging to the Mashapaquit Creek/Snug Harbor sub-system in the mid 1990’s (1994-95).

Nitrogen levels are consistently higher within the inner Harbor than the outer Harbor waters throughout the monitoring period. This is common to most embayments as the watershed inputs are typically highest in the inner regions and this is where flushing is lowest. However, there appears to be a trend in the nitrogen concentrations similar to that observed for oxygen and which appears to coincide with entry of the WWTF plume. The Snug Harbor total nitrogen concentrations from 1995-1998 average 23% higher than in the years 1992-93 (plume entry was 1994-95). In contrast, both the mid and outer Harbor regions showed slightly lower levels (ca. 5%) in the later versus earlier years. Therefore, it appears that the trend in nitrogen is related to events in Snug Harbor rather than being a reflection of influences from the greater system.

In addition to a decline in water quality related parameters, the Health Index suggests that changes may be resulting in a gradual decline in overall system quality. However, since this is only a screening technique, additional field measurements are required to confirm the level of decline in habitat quality associated with the observed increases in nitrogen and depletion in bottom water oxygen levels. While outer West Falmouth Harbor and Harbor Head are showing generally high water quality, above the median for the embayments to Buzzards Bay, Snug Harbor is showing only moderate to fair quality.

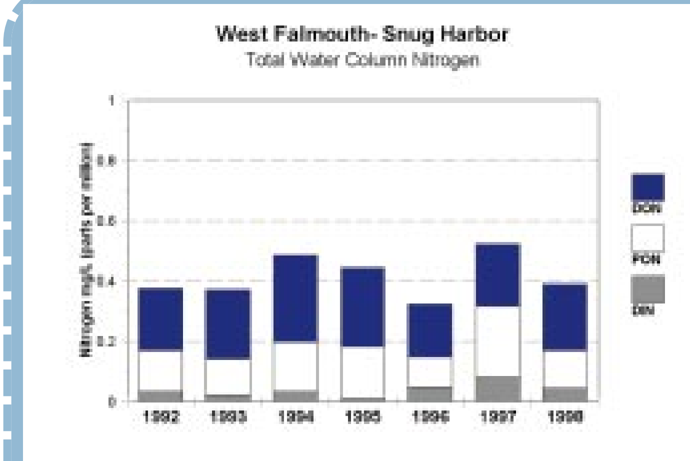
Management Needs

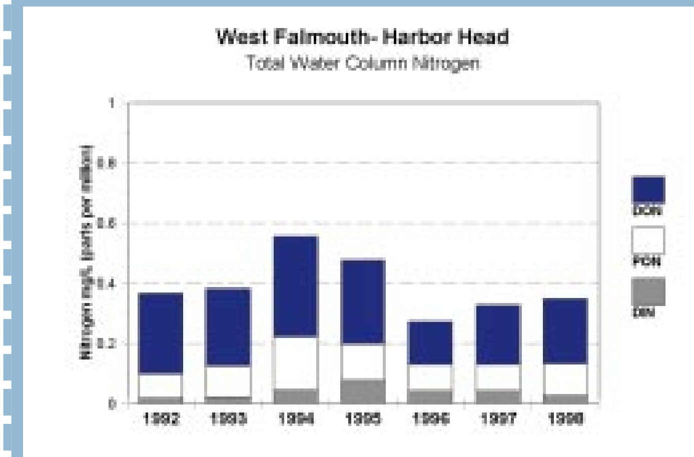
West Falmouth Harbor is showing the initial stages of nutrient overloading. While residential and commercial development within the watershed provide significant inputs of nitrogen to the Harbor, the Falmouth Wastewater Treatment Facility accounts for more than two thirds of the nitrogen loading. The Facility opened in October of 1986, while providing good treatment of organic matter, currently only removes nitrogen as sludge or when discharge is by the spray irrigation sites (as opposed to the rapid infiltration beds). Effluent discharging from the Facility averages about 20 mg N/L. A study of the facility upgrade is currently underway by the Town of Falmouth and its consultants.

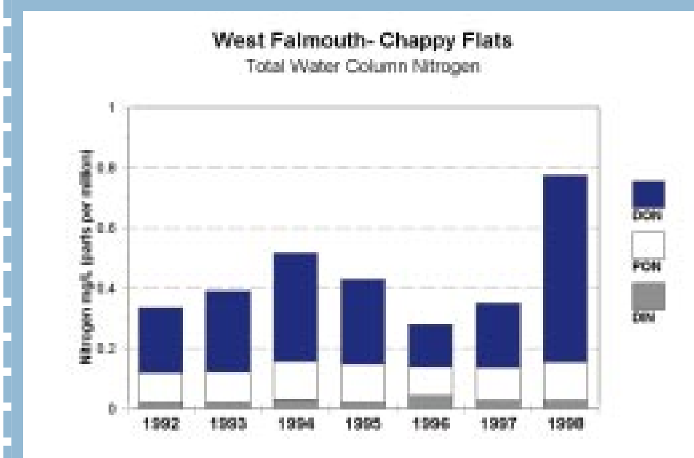
In a previous study in the early 1990's gauging the impacts of the present WWTF on West Falmouth Harbor (by B. Howes now at CMAST and J. Ramsey now at Applied Coastal Res. & Eng. Inc.) the authors concluded that small declines in the quality of the Harbor sub-systems, primarily Snug Harbor would take place. Habitat decline would result primarily from nitrogen inputs from the WWTF, continuing development within the watershed, and entry of the Landfill plume. Nitrogen management particularly for the inner Harbor was recommended as development continued. However, the authors stated that major water quality declines were not expected to result as long as there were no major additional sources of nitrogen added to the Harbor. The continually increasing nitrogen loading to the watershed from the WWTF is just such an increased load (as is the increase in potential Landfill inputs based upon new data).

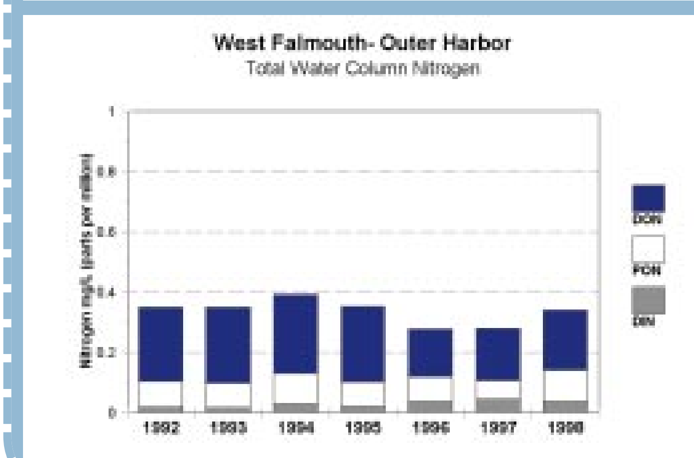
The average annual discharge of nitrogen to the spray irrigation and rapid sand infiltration beds in 1997-98 is more than 50% higher than in 1991-92. Since the WWTF represents more than two-thirds of the total watershed nitrogen loading, this translates into an increase in total nitrogen loading of more than one-third over six years. In addition, since the travel time for nitrogen from the WWTF through groundwater transport to the Harbor is about 6 years (effluent nitrogen entering the Harbor in 1998 was discharged in 1992), the Harbor will experience more than a 33% increase in total nitrogen load from present (1998) to 2004. This increase will occur even if the WWTF discharged ceased in 1998. Since Snug Harbor is currently showing the initial signs of nutrient overloading, this large input is cause for serious concern.

West Falmouth Harbor is currently in need of nitrogen management to protect its resources. Nitrogen management for this system will have to focus primarily upon reducing nitrogen inputs from wastewater due to discharge from the WWTF and from









present (and future) residential housing within the watershed. The increase in nitrogen loading from the existing groundwater plume will take place with likely negative effects on inner Harbor systems. However, nitrogen reduction should be a priority for the WWTF upgrade which will be performed over the next few years. In addition, sewering the portions of the watershed which contribute to the inner Harbor region can offset future growth and partially offset the load from the upgraded Facility.

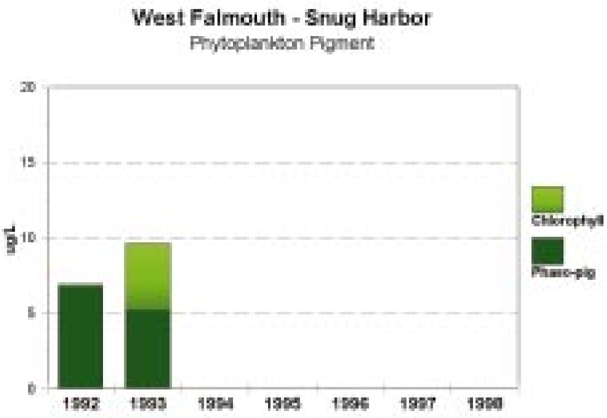
A part of the current increase in nitrogen loading is due to septage. Septage is only accepted from sites within the Town of Falmouth, but almost all is from outside of the watershed to the Harbor. Unlike the sewage entering through pipes, septage is hauled in trucks which have the option to discharge to other septage treatment facilities in the region, at only a minor increase or possibly a decrease in cost to the homeowner. Analysis of the septage volume treated by the WWTF shows a continuing increase, with averages of 21,200 gal/d, 22,900 gal/d, 26,100 gal/d and 27,900 gal/d for 1995, 1996, 1997, 1998, respectively, or a 31% increase over the past four years. While this represents only about 6% of the total WWTF volume, the nitrogen concentration in septage is generally many fold higher than for sewage. Even conservative estimates by the Town suggest that septage nitrogen may contribute more than 10% of the total WWTF nitrogen discharge. These data strongly support the contention that an immediate action to lower nitrogen loading to the Harbor is to cease accepting septage until a new nitrogen removing Facility is on-line.

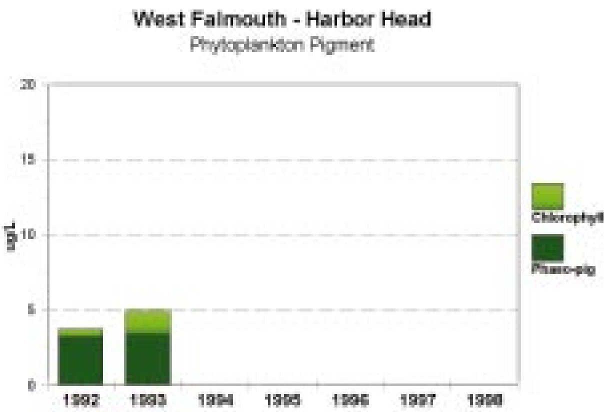
An additional short-term action may also help to reduce future nitrogen inputs to the Harbor. The salt marshes of Mashapaquit Creek at the head of Snug Harbor have been the subject of study by CMAST scientists since 1996. These marshes have been found to denitrify one-quarter to one-third of the nitrate entering in groundwater. Since these wetlands mainly receive nitrogen from the northern spray irrigation and rapid infiltration beds, maximizing use of these beds (based upon hydraulic capacity) should maximize the "natural" attenuation capabilities of the system. While there is are currently patches of macro-algae along Mashapaquit Creek and organic sediments within the Creek bottom, these do not appear to be beyond the norm for New England salt marshes. Salt marshes are naturally highly nutrient and organically rich environments, and as a result they support fish and shellfish production both within their systems and in adjacent receiving waters. Long-term nutrient additions to salt marshes have not shown negative effects even after 30 years.

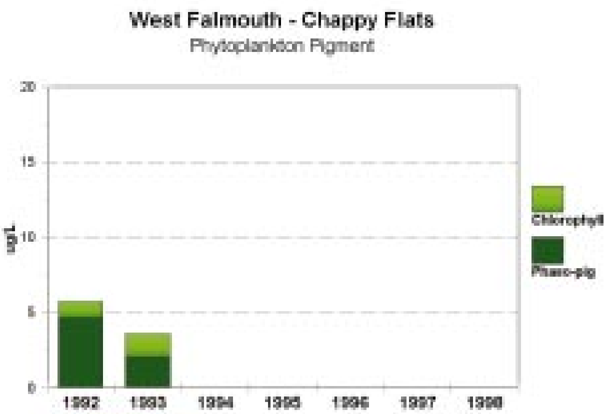
An additional management action is related to the bacterial contamination of inner Harbor waters. An evaluation of direct roadway discharges needs to be undertaken and if appropriate properly managed to prevent further contamination. The Harbor would be best served if an engineered wetland system were employed as these approaches generally provide better removals of nutrients and pathogens, rather than rapid infiltration systems which focus primarily on pathogens.

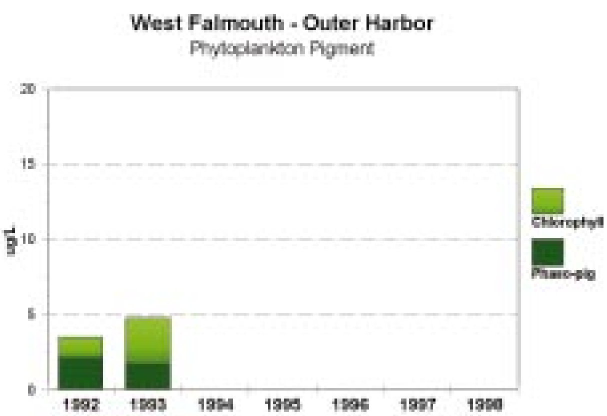
T.Williams 1998

While West Falmouth Harbor has a high tolerance for nutrient loading, it is essential that the Town manage nitrogen loading to keep within acceptable limits. The Harbor still maintains active shellfish and eelgrass resources and a modest scallop harvest. Even if interim nitrogen management actions are implemented immediately, the Harbor will see higher nitrogen loads for the next 6-8 years. These years will be critical in determining the long-term health of this system's environmental resources.





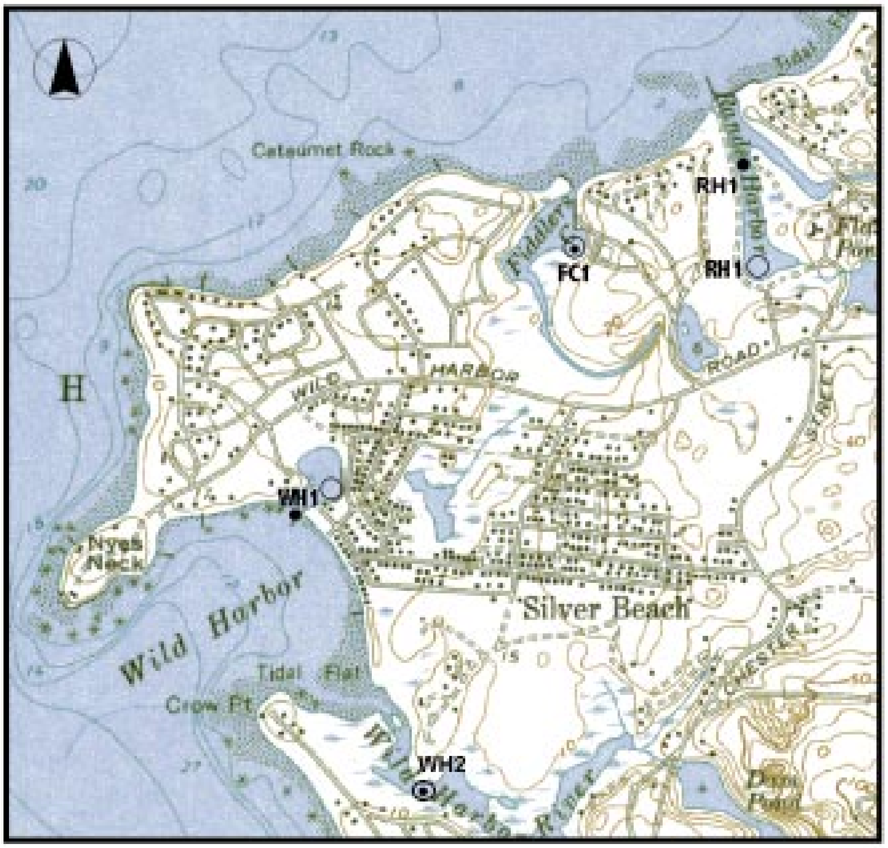




The Coalition for Buzzards Bay

Wild Harbor, Rands Harbor, Fiddlers Cove

Falmouth



Residential and commercial land covers ca. 40% of the watershed and accounts for most of the nitrogen loading to the Wild Harbor Estuary. The watershed east of Route 28 is largely undeveloped while the coastal portions are approaching full build-out. The undeveloped upper 39% of the watershed falls within the Massachusetts Military Reservation (23% of watershed) and the Crane Wildlife Management Area (16% of watershed). The lower portion of the watershed is relatively densely developed and includes the older village of North Falmouth and the Silver Beach community. The area also supports a community beach. Silver Beach has summer cottages, an increasing proportion of which are now used as year round residences. These cottages are clustered together along the shore and are showing increasing septic system failures, particularly in the New Silver Beach area. The town of Falmouth has proposed to construct a small treatment facility to handle those homes that cannot meet Title 5 septic system requirements. The general increase in watershed development coupled with increasing failure of septic systems likely contributes to bacterial contamination of the adjacent waters.

Embayment and Watershed Characteristics

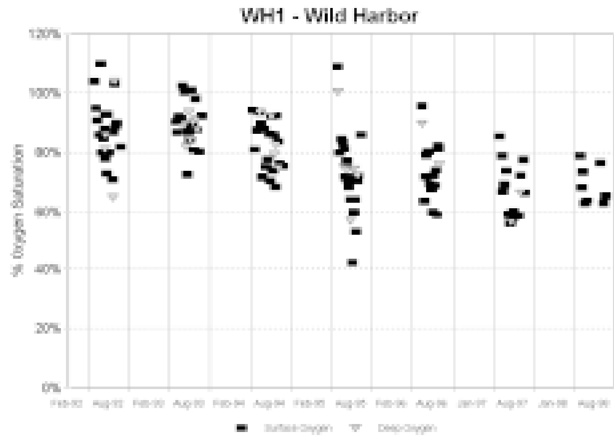
These three embayments are located in Falmouth, MA, with the two smaller systems (Rands Canal and Fiddlers Cove) on the north side of Nyes Neck connected by tidal exchanges to the high quality waters of Outer Megansett Harbor and the larger system, Wild Harbor, on the south side of Nyes Neck with direct exchanges with Buzzards Bay waters. All three systems are mainly situated in watersheds composed of glacial outwash consisting of sands and gravels. The southern and eastern portion of the Wild Harbor upland is within the Buzzards Bay Moraine.

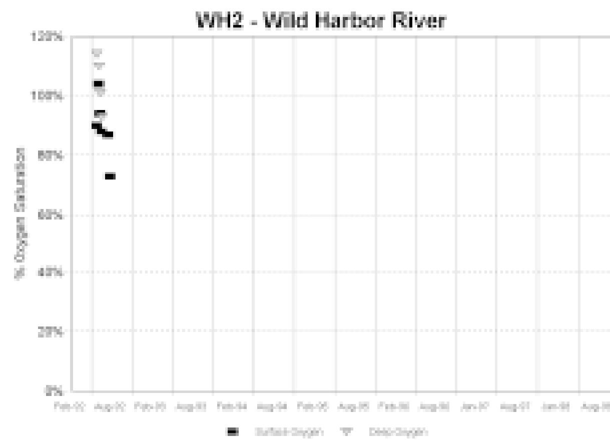
Wild Harbor is a southwest-facing embayment of 110 acres with fringing salt marsh and a predominantly sandy bottom in the outer regions. The Harbor has approximately 98 boat moorings and slips and limited boat use. Today the Harbor supports soft-shell clams, quahogs, and oysters, but is periodically closed to shellfishing and classified prohibited due to poor water quality from bacterial contamination, likely from the adjacent watershed. The outer margins of the Harbor continue to support eelgrass beds with distribution limited by the depth of the central Harbor. The marginal beds are moderately dense and showed increases from the 1970's to 1980's.

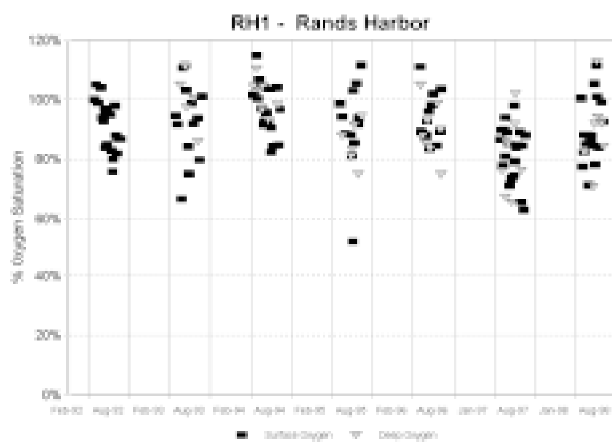
While alteration of embayment systems is occurring throughout Buzzards Bay as land-use shifts from forest and agriculture to residential development, the Wild Harbor System has had an additional stressor, oil contamination. On 16 September 1969, the barge Florida ran aground on a rocky shoal just west of Fassett's Point in West Falmouth, MA. Roughly 180,000 gallons of no. 2 fuel oil poured into Buzzards Bay and were driven by south-southwest winds into the Wild Harbor River. The oil spread over more than 1000 acres including 6.4 km of coastline. The spill caused the death of many marine and saltmarsh plants and animals. Much of the oil settled along a narrow band in the Wild Harbor Marsh and Wild Harbor boat basin, resulting in significant losses of benthic infauna and marsh grass. After four years, the spill was still evident in invertebrates, fish and birds in the heavily oiled areas. The boat basin was still heavily contaminated 5 years after the spill and its animal populations reduced in abundance and dominated by opportunistic species. Twenty years after the spill oil was still readily detectable in some of the marsh sites, to the extent that disturbance of deeper sediments produce an oily sheen. However, in the majority of the marsh areas, the oil is gone and in the subtidal sediments the spilled oil is virtually all gone. Of the marsh areas most heavily impacted by the spill, both the vegetation and animal populations appear to have fully recovered, although some oil contamination can still be detected. It appears that the longest detectable effect of the oil spill has been the closure of the area to shellfish for more than two decades.

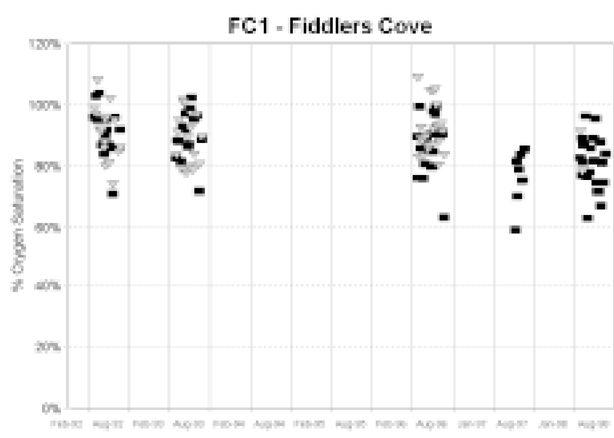
Fiddlers Cove and Rands Canal (also called Rands Harbor) just north of Wild Harbor, are actually part of the Megansett Harbor System. While these embayments have relatively small watersheds, they have been developed, primarily for single family residences. Neither of these two embayments have had quantitative nitrogen loading evaluations. However, their small volume and direct connection to the high quality tidal waters of outer Megansett Harbor are likely the primary mechanisms maintaining the present water quality within both of these highly altered estuarine systems

Both Rands Canal and Fiddlers Cove have been greatly altered over the past approximately 100 years by human activities. Fiddlers Cove and Rands Canal appear more as salt marsh creeks than embayments in 1880 and 1916 maps. In addition, the upper reaches of Fiddlers Cove still supported bordering saltmarsh in the late 1960's and 1970's. At present in much of the area, tidal wetlands have been removed or greatly reduced to increase navigable waters or by construction of hard coastal structures (e.g. riprap). Both embayments support quahogs, soft-shell clams and oysters but are only classified as Conditional for the harvest of shellfish. Eelgrass has not been noted in these systems in recent years. This contrasts with the Megansett Harbor shoreline adjacent to Rands Canal and Fiddlers Cove which currently supports extensive eelgrass beds.









Water Quality

Wild Harbor, Rands Canal and Fiddlers Cove have been monitored by the Baywatchers Program since 1992 only for dissolved oxygen levels. Based upon the oxygen monitoring results, nutrient and chlorophyll a sampling was initiated in 1999 to allow a better assessment of the health of these embayments. These systems are relatively small, with watershed loadings below the Buzzards Bay Project's impact threshold. In addition, Wild Harbor is relatively open and well flushed, and water quality concerns focus primarily on the tidal marsh region of the Wild Harbor River. The estuarine region of Rands Canal and Fiddlers Cove have been heavily altered by dredging, filling and shoreline structures. The oxygen monitoring has been conducted as a screening tool to trigger increased monitoring should periodic oxygen depletions be detected. Oxygen monitoring is not sufficient to distinguish between moderate and high water quality, however, it is a good indicator of the onset of eutrophic conditions in a coastal embayment.

Wild Harbor oxygen monitoring has focused primarily upon the northern portion of the main basin where upland development is the most extensive and dense. Overall, oxygen values indicate a moderately healthy system, despite the increased watershed nutrient loadings and oil spills of the past century. However, the oxygen saturation values do show periodic oxygen depletions below 60% of air equilibration and oxygen declines below 80%

saturation have been the typical condition from 1996-98. In addition, there appears to be a downward trend in oxygen levels from an average of ca. 90% in 1992-93 to ca. 70% in 1997-98. These data suggest first, that the inner regions of the system may be showing modest nutrient related habitat declines and second, that the system may be undergoing a gradual decline.

The oxygen data are consistent with the presence of eelgrass within the margins of the outer Harbor as the sampling location WH1 was chosen as a sentinel station to detect the onset of water quality decline. It is unlikely given the open nature of the central basin and its access to the high quality waters of Buzzards Bay, that the bulk of the Harbor is currently showing declining water quality. It should be noted also that oxygen data alone are not sufficient to determine the cause or level of environmental health within this system. However, the levels and frequency of oxygen depletion in this system and the apparent temporal trend should be cause for concern and supports the newly initiated higher level of water quality monitoring in this system.

Rands Canal appears to currently maintain relatively good water quality based upon dissolved oxygen levels. The oxygen data suggests that while some depletion is occurring, it is not severe as saturation levels below 60% of air equilibration have been observed in only a single sample over the seven years of monitoring. While the depletions are not "severe" they are greater than the 80% of air equilibration values typical of embayments with low nutrient loading and the waters of Buzzards Bay. Since the monitoring station is at the innermost portion of the Canal, the values are likely the "worst case" for this system. The data support the contention that tidal exchanges with the high quality waters of outer Megansett Harbor are currently maintaining moderate water quality within Rands Canal. However, since ca. 15% of the summer oxygen samples show saturation values of less than 80% saturation, the system appears to be susceptible to nutrient over-loading. Continued monitoring of the oxygen levels within the upper reaches of the Canal should continue with the newly initiated nutrient and chlorophyll a sampling.

Fiddlers Cove is similar to adjacent Rands Canal in size, level of alteration and watershed land-use. Therefore, it is not surprising that the Cove waters also show summertime oxygen depletion. While there are only five years of data, the oxygen levels indicate a similar water quality within the outer portion of Fiddlers Cove and inner Rands Canal. However, since the Fiddlers Cove station is in the basin near the inlet, it is likely that the upper portion of the Cove is lower in habitat health. Moderate to poor water quality within the upper Cove would be consistent with its configuration, highly altered basin, wetland loss and the changes in nitrogen load from its watershed over the past few decades. In addition, the recent oxygen data from the lower Cove suggests that conditions may be declining over the initial sampling interval of 1992-93. Given these data, a more complete analysis of water quality should be undertaken which should include both the upper and lower Cove.

Management Needs

The most pressing management concern for Wild Harbor is remediation of wastewater disposal problems primarily within the New Silver Beach community. The implementation of a community wastewater system provides a potential solution to this problem and is supported by the Falmouth Board of Health and the Buzzards Bay Project. This community wastewater project has the potential to serve as a model for many areas of the Massachusetts coast and may also have a positive effect on reducing bacterial contamination to the Harbor waters. However, this effort will only have a positive impact upon the Harbor health if the discharged nitrogen load is reduced or enters the Harbor in a better flushed region than at present. A shift in the nitrogen entry point from the central basin to a tributary should be evaluated in light of the current oxygen depletions observed at the mouth of the northern sub-basin. Community wastewater systems if properly implemented, not only provide wastewater treatment but also allow for site specific nitrogen reductions without causing a mere "shifting of the problem", since the discharge remains within the watershed of origin.

While Wild Harbor is a relatively open embayment with good flushing, the apparent oxygen depletions in the northern tributary suggest the potential for localized water quality decline. The conversion of summer cottages to year-round use is resulting in an increasing nitrogen loading to the Harbor without visible "new development". At present the watershed nitrogen loadings are being held at a "reduced" level by the large fraction of the upper watershed which is undeveloped within the Massachusetts Military Reservation and the Crane Wildlife Reserve.

Since Wild Harbor was the site of a world-famous oil spill, we take this opportunity to stress the importance of preventing discharges to the Harbor and all Buzzards Bay waters. It is important to note that oil spills continue to occur periodically throughout the Buzzards Bay system and their occurrence continues to generate significant public attention. However, about 3 times as much oil enters the Bay through small chronic discharges, storm drains and runoff than from the more dramatic spills. It is these small, but cumulatively more important oil inputs, which are controlled and prevented by citizens at the neighborhood level.

Rands Canal and Fiddlers Cove are currently showing modest oxygen depletions during summer. Fiddlers Cove oxygen levels suggest that the upper portions of the Cove may have impaired habitat quality. Given that only screening monitoring has been occurring, it is suggested that the newly initiated increased analysis be expanded to include both upper and lower Fiddlers Cove and to a lesser extent increased monitoring of Rands Canal at the present station. Maintenance of flushing of these small altered tidal systems appears to be essential.

Megansett & Squeteague Harbors

Falmouth

The Megansett and Squeteague basins are important recreational harbors supporting about 150 moorings and 75 slips. The system also supports several beaches and a public boat ramp and pier. Both systems support shellfish resources, even occasionally bay scallops. Megansett Harbor maintains 1049 acres of shellfish beds which are either Approved or Conditionally Approved for harvest. Two small sub-embayments on the southern shore of Megansett Harbor, Fiddlers Cove and Rands Harbor have significant populations of quahogs, clams and oysters. Megansett Harbor was closed to shellfishing in 1969 due to an oil spill from the barge "Florida" which caused much more long lasting impacts to adjacent Wild Harbor. Today, Megansett and Squeteague are both open to shellfishing, one of the few Buzzards Bay embayments without any pollution related bed closures.

Embayment and Watershed Characteristics

Megansett and Squeteague Harbors are actually parts of one larger embayment with two separate drainage basins. At one point the two basins were connected, but the deposition of a sandy barrier spit, due to erosion and long-shore transport, has created the two basin system seen today. In the last century this region was called Cataumet Harbor, adjacent to the village of Cataumet (then part of the Town of Sandwich). On modern charts, the larger well flushed outer basin of the embayment forms Megansett Harbor and the much smaller, shallower inner basin, Squeteague Harbor. The Harbors are connected by a narrow channel which maintains tidal flow. However, the names are not all that has changed in this system. The northern boundary of Megansett Harbor is formed by Scraggy Neck, formed of glacial moraine deposits (boulders, sand and gravel). In early maps, Scraggy Neck is not shown to be connected to the mainland, but had a sandy spit reaching towards it from the nearby shore. However, construction of a road to the Neck has created a sandy causeway which now prevents flow between the Southern portion of Red Brook Harbor (Hospital Cove) and Megansett Harbor. These systems now operate as independent hydrographic units, evidence that alterations have been made throughout Buzzards Bay to both the hydrodynamics (see also New Bedford Hurricane Barrier) as well as nutrient loads.

Both Megansett and Squeteague Harbors currently support eelgrass beds. Within Megansett Harbor, the beds are large with high density of cover. This is consistent with the observation of occasional bay scallops within this basin. However within Squeteague Harbor, the eelgrass area and density of coverage has diminished. The beds in this inner basin have retreated to the portion nearest the channel which carries high quality flood waters from the outer bay. This most likely results from the focusing of watershed inputs through groundwater flows on the inner basin. Much of the nitrogen input from the watershed to the entire system first enters the inner harbor and is then passed to the outer system in outflowing tidal waters

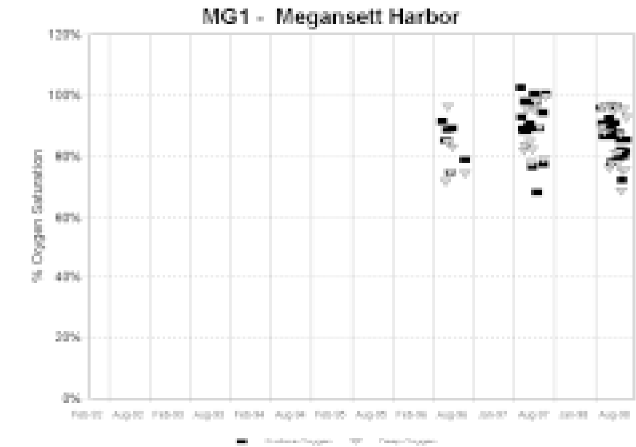
Sources of nitrogen-loading within this drainage basin are small compared to its size because more than 50% of the area is undeveloped and currently designated as protected open-space, public water supply protection areas, or part of the Massachusetts Military Reservation. Within the Megansett & Squeteague Harbor watershed 18.5% of the land or 235 acres is currently permanently protected as open space. Within this watershed a single parcel, more than one-third of watershed (467 acres), is undeveloped forest land held within the Massachusetts Military Reservation. The remaining 45% of watershed land is either developed or available for residential development with a small area in cranberry agriculture. However, as future build-out occurs within the Squeteague Harbor contributing area, further degradation of this enclosed basin is expected

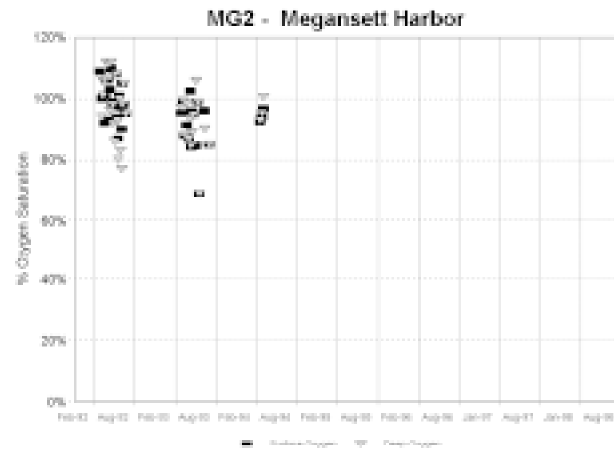
Water Quality

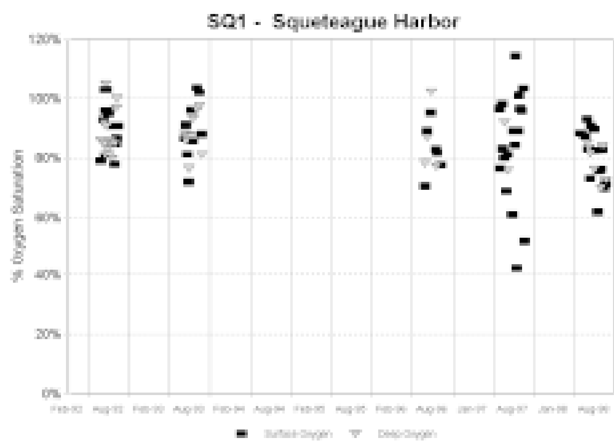
Water quality in Megansett Harbor was among the best of all of the embayments monitored in Buzzards Bay, although the inner portion, Squeteague Harbor, is showing degradation most likely related to nutrient related impacts. Within Squeteague Harbor, elevated nutrient and chlorophyll a concentrations and periodic oxygen depletion were observed, with a suggestion of recent further deterioration. Nitrogen levels were generally 1.3 to 1.5 times Buzzards Bay source waters. Similarly, chlorophyll pigments frequently averaged about 10 ug/L, significantly higher than in the main bay and 2 times that of adjacent Megansett Harbor. These results indicate that Squeteague does not have the tidal exchange necessary to flush out the land-derived nutrients and the phytoplankton which they support within this basin. These results are consistent with the thinning and loss of eelgrass beds, except those associated with the tidal channel to the outer bay. These symptoms indicate that the inner harbor is beyond its ability to assimilate additional nutrients without degrading habitat quality.

Megansett Harbor's current health is maintained both by its relatively low watershed loadings and its open deep basin with excellent exchange with the high quality waters of Buzzards Bay. The persistence of large, dense eelgrass beds throughout the Harbor is consistent with the good water clarity, low chlorophyll a levels and small elevations in total nitrogen levels observed throughout the past 7 years. Similarly, oxygen concentrations were consistently at non-stressful levels in all samples. Tidal and wind-driven mixing of the water column also helps to maintain oxygen levels by preventing stratification in this system.

The Health Index shows the contrast between the outer open basin of Megansett and the inner enclosed basin of Squeteague. The outer basin exhibited consistent high quality waters compared to the moderately degraded waters of Squeteague Harbor. In both locations, there were no definitive long-term trends in the Index and there was little inter-annual variation. The index results are consistent with the habitat parameters (eelgrass and shellfish) documented for these basins.



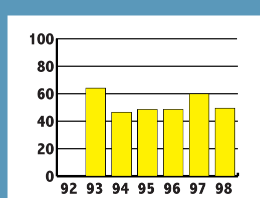




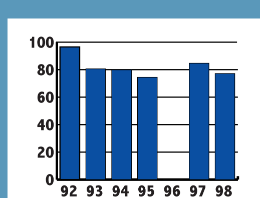
BAY HEALTH INDEX

- Good to Excellent (65 - 100)
- Fair (35 - 65)
- Poor/Eutrophic Conditions (< 35)

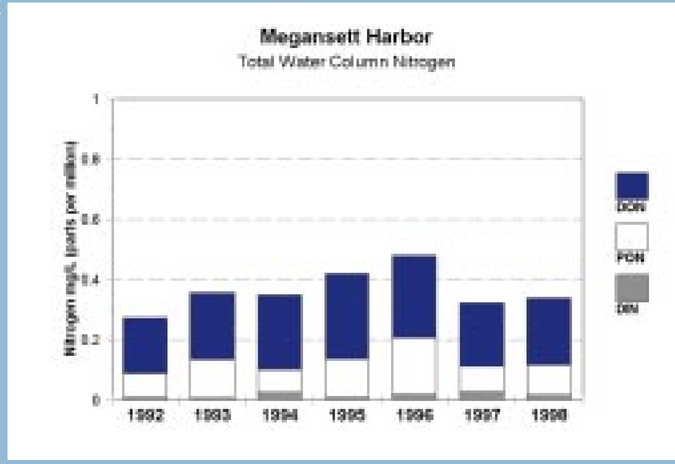
Squeteague Harbor

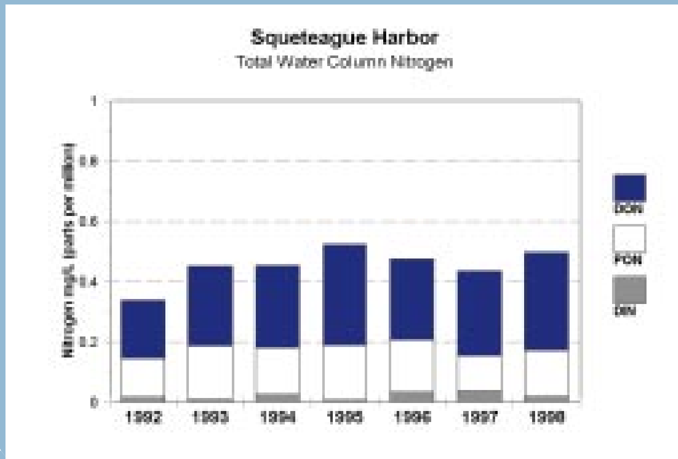


Megansett Harbor



Within the overall harbor system, Squeteague Harbor is the sentinel system for water quality decline. This inner enclosed basin has already undergone moderate degradation which likely will continue if contributing portions of the watershed continue to develop without nitrogen management. Squeteague is currently only partially degraded and nitrogen source reductions would likely produce significant and noticeable improvements in water quality. The current trend in Megansett Harbor and its contributing watershed suggests that this system will remain of high quality into the foreseeable future.





Management Needs

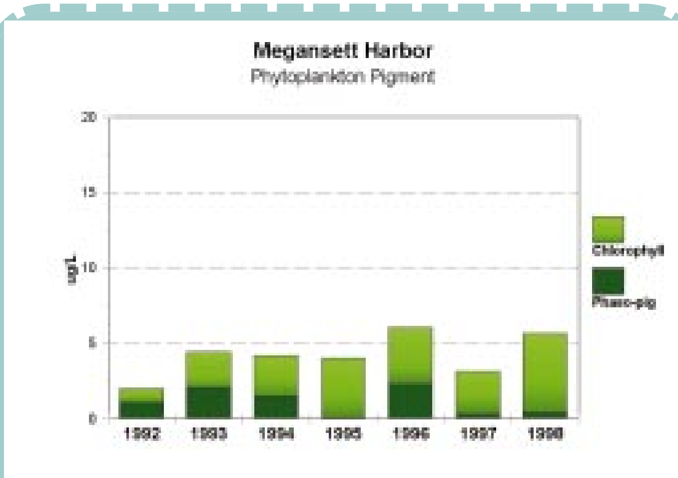
Water quality in Megansett Harbor continues to rank among the best in Buzzards Bay. In contrast, the inner basin of Squeteague Harbor, typical of coastal embayments, is enclosed and more heavily pollutant loaded with resulting water quality declines. In addition, given the configuration of the overall system, most of the nitrogen entering Megansett Harbor is discharged first to Squeteague Harbor and enters the outer basin via ebb tidal flows. Nitrogen management should focus on remediating the present decline of Squeteague Harbor, which will then also protect Megansett Harbor.

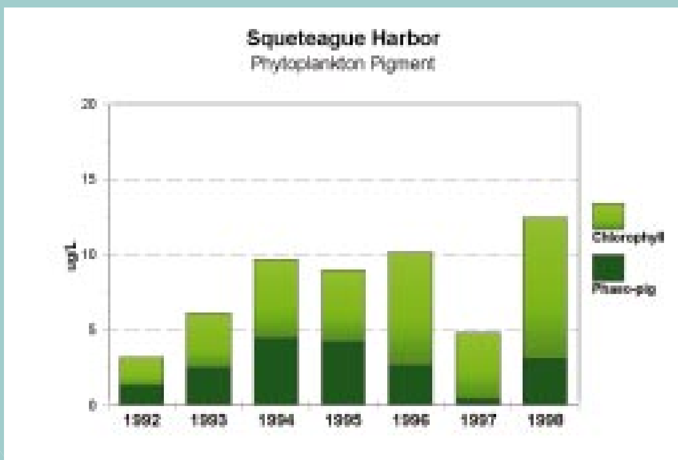
Presently, water quality within the Harbor System is significantly dependent upon the relatively low watershed nitrogen loading given the overall watershed area. Preservation of the large open-space areas, particularly forestlands is critical to preservation of the adjacent marine basins. Therefore, it is essential that future management of the large watershed area within the Massachusetts Military Reservation not result in any net increase in its nitrogen loading to groundwater which enters the Harbors.

At present, the principal sources of nitrogen to both Harbors is from residential land-use. As the entire watershed is served by on-site septic systems, wastewater is the single largest component of the watershed nitrogen load. Under present conditions, there is limited potential for additional development within the watershed given the less than 100 acres of developable land. However, nitrogen loading can still increase significantly if the primarily summer residences are converted to year-round use. Given that Squeteague Harbor is only moderately degraded, nitrogen management within its contributing area should have a significant positive effect. Similarly, increasing nitrogen loads to the inner basin should have associated water quality declines.

Squeteague Harbor, along with Red Brook Harbor to the north, is also receiving groundwater emanating from recharge within the Massachusetts Military Reservation. Part of this groundwater has been contaminated with leachate from the Base's landfill (now closed and capped). The result is a plume of contaminated groundwater, Landfill-1 Plume, which will be discharging to Squeteague Harbor. In addition to volatile organic contaminants there are also generally moderate levels of dissolved nitrogen within this plume. The concentration of nitrate in samples taken by Air Force as part of the Landfill-1 Plume cleanup plan were 2.5, 2.0, and 2.7 mg/l. These levels are above background concentrations of 0.05 mg/l and present a potential concern to the ecological health of the downgradient coastal waters. The Air Force Center for Environmental Excellence needs to evaluate the potential for this "new" nitrogen load to further degrade the marine habitats within Squeteague

T.Williams 1998





Harbor. Additional monitoring of this embayment for both organic and nitrogen contamination needs to be performed relative to effects on the marine resources. Given the ecological balance currently within the inner basin, a program to offset the contribution of nitrogen from the Massachusetts Military Reservation landfill plume may be necessary for this system. If sufficient nitrogen loading from the landfill plume is found, then the nitrogen mitigation should be modeled on the similar program developed in the Ashumet Valley Plume Response Decision, the Falmouth Nitrogen Offset Program.

Red Brook Harbor

Bourne

Red Brook Harbor supports ca. 14 acres of fringing salt marsh. However, like adjacent Hen Cove, Red Brook Harbor appears to have lost its eelgrass beds in recent years. A 1984 survey of the inner Harbor indicated that about half of the available eelgrass habitat was supporting beds (ca. 7 acres). The beds were primarily in the shallow waters at the Harbor margins due in part to the depth of the central basin. Based on data developed by the Massachusetts Wetlands Conservancy Program in 1996, eelgrass beds appear to have all but disappeared from the Harbor (and adjacent Hen Cove) with the nearest beds located outside of Bassetts Island. This decline is of concern and is consistent with a decline in water quality.

At present, the Harbor continues to support both recreational and commercial harvest of quahogs, soft-shell clams, and oysters. The inner portions of Red Brook Harbor are classified as Seasonally Approved, due to the marinas and large number of boats present during summer and the potential for pollution. Red Brook has heavy boat usage with approximately 352 boat moorings and slips, and two marinas. Each marina has a boat pump-out facility.

Red Brook represents the major surface freshwater inflow to the Harbor and to the greater Complex. Red Brook enters at the head of the Harbor and is fed primarily by groundwater and the surface waters of Red Brook Pond. The Brook also receives loading from runoff along its course. Direct discharge of groundwater is also an important source of freshwater and watershed derived nitrogen to the Harbor.

Of concern to Red Brook and the Harbor is the contribution of contamination from the landfill plume, LF-1, from the Massachusetts Military Reservation. Decades of leachate from the former landfill at Massachusetts Military Reservation has formed a groundwater plume which has begun discharging to Red Brook, and therefore the Harbor. Although the landfill is now capped and the upper portion of the plume slated for remediation, the lower portion of the plume will continue to contribute to the Harbor for many years. Fortunately the higher concentrations of organic contaminants are upgradient from the site of remediation, and removal by natural attenuation and the newly installed active treatment facility should greatly reduce their entry into the marine environment. However, it should be noted that although the levels of contamination are too high for drinking water standards, even without attenuation they are still quite low. The plume also contains nutrients which are not currently being addressed by the containment system. Since the plume is not homogeneous, but contains regions of high and low concentration, it is not possible

Embayment and Watershed Characteristics

Red Brook Harbor is the southern-most sub-embayment within the Pocasset Harbor/Hen Cove/Red Brook Harbor Complex. This greater harbor system is formed by Wings Neck to the north and Scraggy Neck to the south. Wings Neck, historically also called Wenaumet Neck, was originally an island formed as part of the Falmouth Glacial Moraine. The island was connected to the mainland by the growth of a sandy spit, which then provided a sufficiently protected environment for the development of the salt marshes at the head of Pocasset Harbor. More recently, the Complex became hydrologically distinct with the connection of Scraggy Neck, so that at present all tidal exchanges take place through the system mouth constrained by the two Necks. Red Brook Harbor, Pocasset Harbor, and Hen Cove are actually the three major coves within the greater system which are semi-separated by the centrally located trilobate Bassetts Island. One of the special concerns relating to the water quality of this complex is the entry into Red Brook Harbor of the Landfill Plume (LF-1) from the Massachusetts Military Reservation.

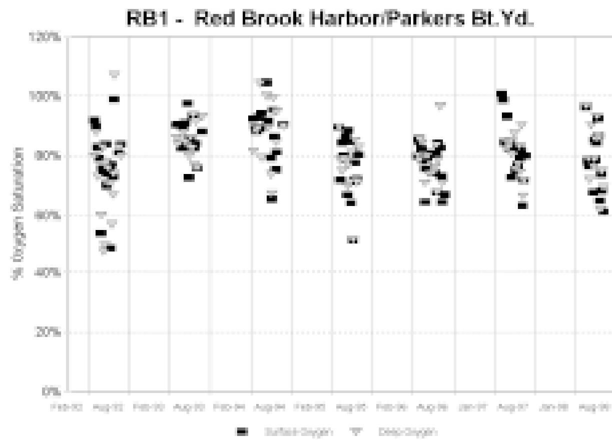
Red Brook Harbor is a moderately sized Cape Cod embayment of 151 acres and an average depth of almost 2 meters. The Harbor receives tidal exchanges with Buzzards Bay though a nearly 3 meter deep channel running between the southern end of Bassetts Island and Scraggy Neck. The inner portion of the Harbor is bounded by Handy Point and Long Point. The mouths of inner Red Brook Harbor and Hen Cove both exchange tidal waters with outer Red Brook Harbor.

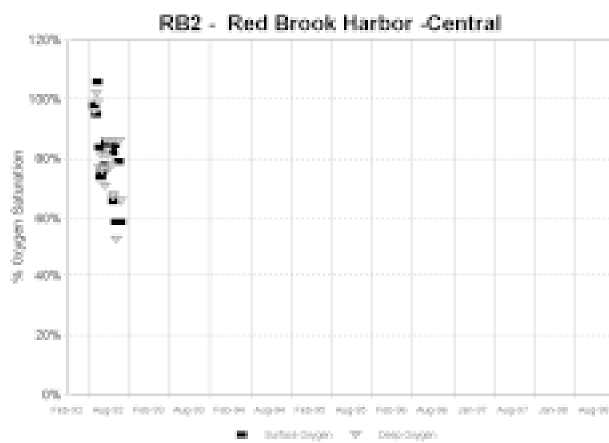
at present to gauge the magnitude of this nutrient source to the Harbor. If further studies indicate that the landfill plume is an important nitrogen source to the Harbor, then programs to offset this nitrogen load should be employed. A similar Nitrogen Offset Program was developed to remediate the effects of nitrogen entering Great and Green Ponds in Falmouth from the Ashumet Valley Sewage Plume. The Plume results from the now closed Massachusetts Military Reservation Wastewater Treatment Facility (the new facility now discharges to the Cape Cod Canal). The basis of an Offset Program is to address the nitrogen loading from a plume having a low concentration but large volume by treating nitrogen sources with high concentration and low volume (e.g. septic systems) which are more effectively managed. Treating the higher concentration and more manageable alternative sources within the watershed yields better loading reductions for the receiving waters of the Bay, because less than 100% of the plume volume (hence load) is captured by in-plume treatment systems (which are designed for organic contaminants). The plume may also discharge to the adjacent Megansett Harbor system in the future.

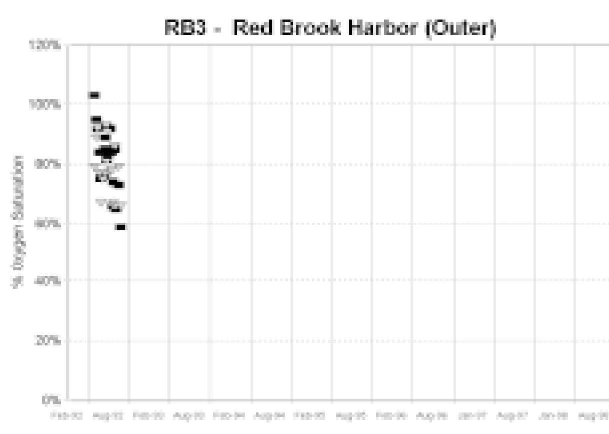
While the Red Brook Harbor watershed is of moderate size for the eastern shore of Buzzards Bay at 2,562 acres of upland, it is one of the least developed. Despite its level of development, it is almost certain that the great majority of nutrients are entering the Harbor from the usual sources associated with residential development and cranberry agriculture rather than from the LF-1 plume. The fact that 1,580 acres, or two-thirds of the watershed is forested (primarily unfragmented pine/oak forest within the Massachusetts Military Reservation), is important to water quality within the Harbor and provides a degree of "protection" against future nitrogen overloading. However, this "protection" will persist only as long as this upper region is maintained as forest lands or other non-nitrogen contributing land-uses. Although small in number when compared to western Buzzards Bay embayments, the watershed is also home to some of the few cranberry bogs (92 acres) on the eastern shore of the Bay. Given the Harbor watershed's land-use and structure, this system would be expected to support relatively good water quality. The Cape Cod Commission ranks Red Brook Harbor at the median level for Cape Cod Embayments for nitrogen sensitivity. These factors underscore the need to determine the cause of reported eelgrass loss.

Water Quality

Red Brook Harbor shows a slight gradient in key water quality parameters from the outer to the inner regions. Total nitrogen







BAY HEALTH INDEX

Good to Excellent (65 - 100)
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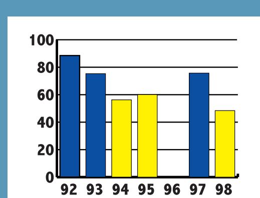
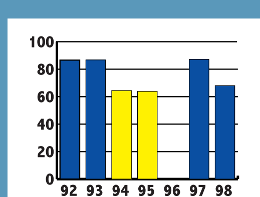
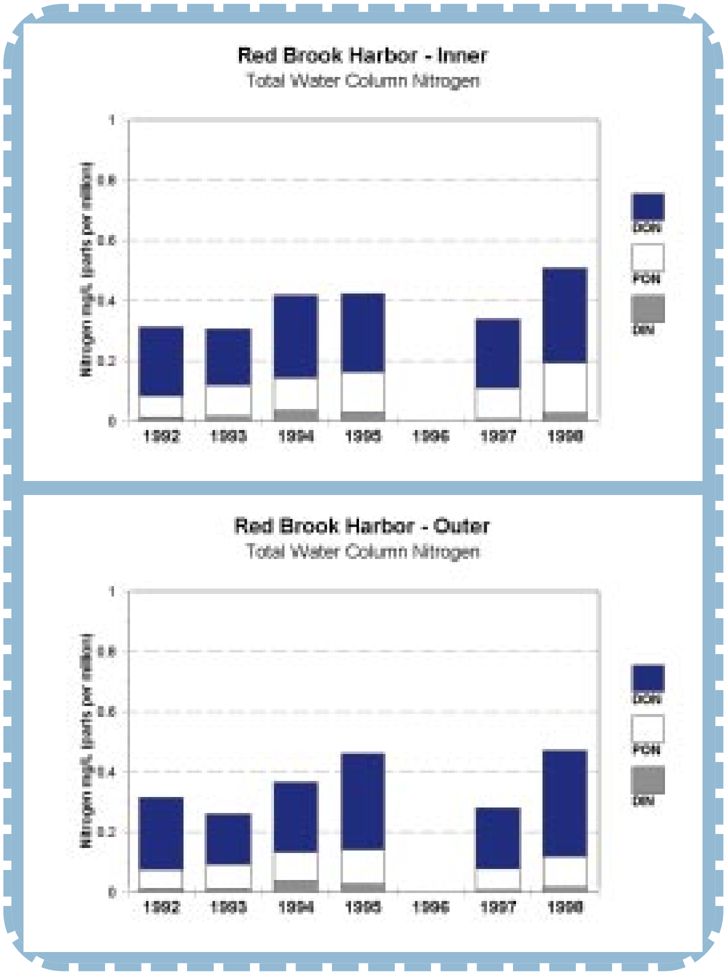
Red Brook Harbor Inner



Red Brook Harbor Outer





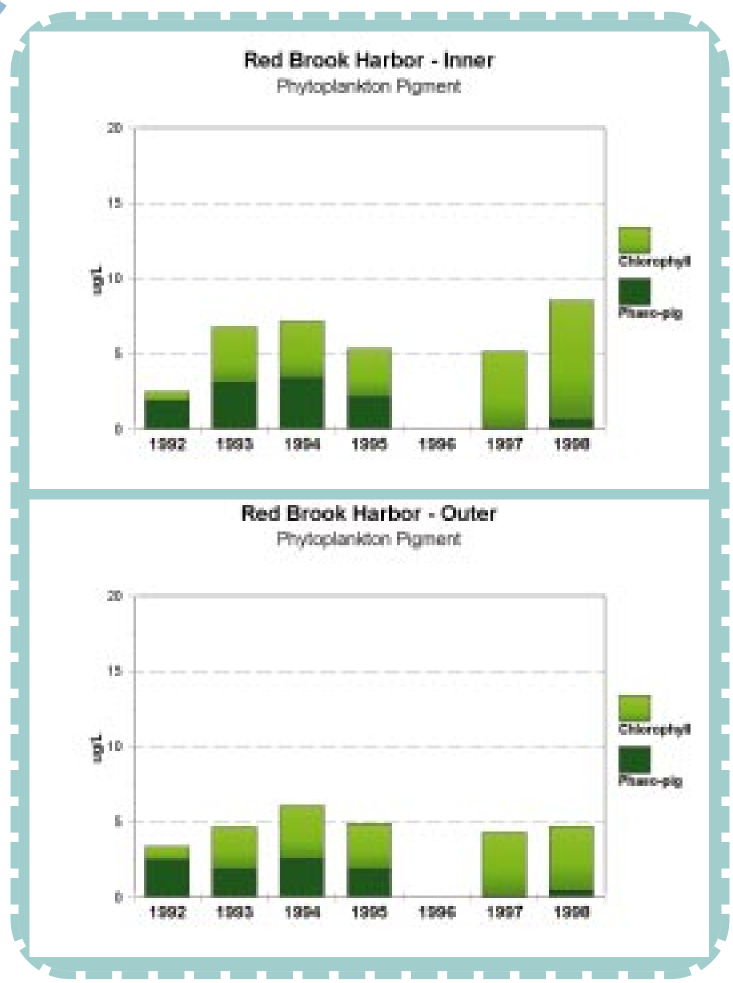
(outer 0.33 mg N/L, inner 0.38 mg N/L), chlorophyll a pigments (outer 4.9 ug/L, inner 5.4 ug/L) and particulate organic carbon (outer 0.60 mg C/L, inner 0.69 mg C/L) are all typically about 10% higher within the inner vs. outer Harbor waters. Similarly, there is a correspondingly weak salinity gradient (Outer 29.5 ppt, mid 29.4 ppt, inner 28.7 ppt) suggesting that freshwater inflows become relatively well mixed into the Harbor waters. However, the levels of these key parameters are higher than Buzzards Bay waters, but are only moderately elevated compared to other embayments. The high chlorophyll levels within the inner Harbor suggest the rapid uptake of dissolved nutrients entering from the surrounding watershed. Based upon the nutrient levels and apparent mixing, the observed dissolved oxygen depletions are slightly greater than might be expected. However, although the levels typically decline below 80% of air saturation, depletions below 60% saturation are infrequent. . The typically moderate to high oxygen values suggest only a relatively low level of stress to benthic animals from hypoxia in this harbor. However, the variability of oxygen in this estuary system indicates that it may be susceptible to weather conditions that facilitate low oxygen levels (warm temperatures, overcast, calm), and that the estuary may have difficulty in handling additional organic matter, either from plant production or input from land, without further oxygen declines.

The composite Health Index brings forward the inter-annual variations in both outer and inner Harbor water quality and the consistent pattern of slightly lower water quality within the inner versus outer region. Consistent with the levels of the individual monitoring parameters, the index classifies the inner and outer Harbor regions as having moderate to good water quality, ranking just above (outer) and below (inner) the median conditions for Buzzards Bay embayments. At present there is no clear temporal trend in water column parameters over the study period. However, the reported eelgrass decline within the Harbor is cause for concern and is consistent with the observed inter-annual declines in water quality. Evaluation of macroalgal distribution and production within this system may yield insight into the these issues.

Management Needs

At present it appears that Red Brook Harbor is incapable of assimilating additional nitrogen inputs without experiencing further water quality declines. The largest nitrogen source appears to be associated with residential development. Opportunities for additional development within the watershed are limited as most of the land is already developed or within Massachusetts Military Reservation. Any nitrogen management strategy for this estuary must take into account present and future nutrient loading from the LF-1 plume and other land-uses.

Red Brook Harbor is currently receiving nitrogen loading from the Landfill-1 contaminated groundwater plume emanating from



the Massachusetts Military Reservation. Some of the higher concentrations of nitrate in samples taken by the Air Force as part of the LF-1 cleanup plan were 2.5, 2.0, and 2.7 mg/l. These levels are well above background concentrations of 0.05 mg/l and present a concern to the ecological health of the downgradient coastal waters. However, the level of loading requires determination of the volume of nitrate enriched water within the plume. The Air Force Center for Environmental Excellence should assess the non-point source nitrogen loading to the Red Brook watershed and a long-term embayment nutrient related water quality monitoring program. It is likely that a nitrogen mitigation program similar to the Ashumet Valley Plume Response Decision (described in the Megansett section) will need to be instituted.

Boat discharges that place nutrient inputs directly into bay waters should not be occurring as the Harbor has pump-out facilities. Of the 350 slips and moorings in Red Brook Harbor, the vast majority are for summer usage and typically occupied only a few days per week. Use of existing boat pump-out facilities and compliance with proper discharge procedures should keep this source of nutrients and bacterial contaminants near zero. Boat owners should continue to be encouraged to make use of Pump-out facilities by the Town, marinas and Harbor Master.

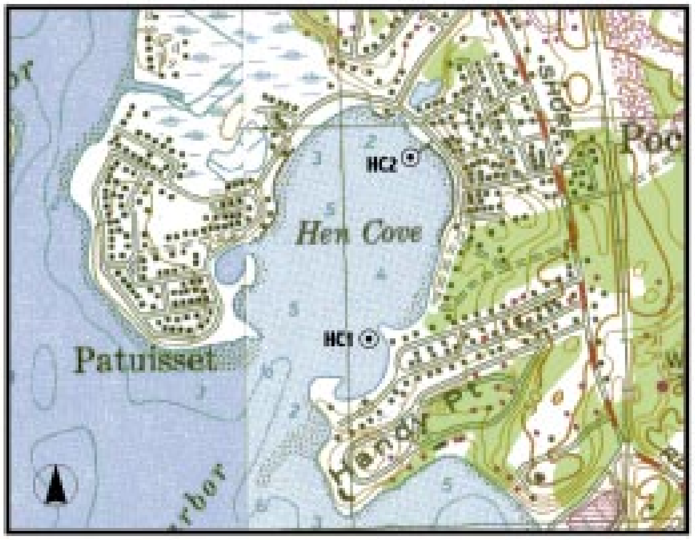
Although cranberry agriculture does not contribute more nitrogen to coastal waters than many other land uses, such as residential development on septic systems, it is important that best management practices (BMP's) be in place for minimizing nitrogen inputs to the Harbor. The Town should work with the growers to facilitate the implementation of BMP's where applicable to both protect the Harbor environment and this traditional small-scale agriculture practice. Since the Harbor is already showing incipient nutrient overloading, maintaining the upper watershed as forest, a virtually non-contributing land-use (for nitrogen), is important to the future of Red Brook Harbor.

T.Williams 1998

Red Brook, Hen Cove & Pocasset Harbor Systems

Hen Cove

Bourne



Of the three coves within the Complex, Hen Cove has the most tortuous channel for exchange with Buzzards Bay waters, due to its location directly behind Bassetts Island. As a result, Hen Cove receives tidal water which has passed and mixed with the adjacent systems, with possible increases in nitrogen levels. This mixing pattern combined with the land-use results in an annual nutrient load above recommended limits where ecological health is considered to begin to be impaired. A flushing study for the Cove was completed in 1997. The shallow bathymetry of the Cove, mean depth 0.8 m, facilitates its flushing by tidal waters.

The cove hosts a variety of marine activities with more than 100 moorings and slips, a well used public beach, private beaches and a boat launch. The Cove supports productive shellfish habitat, but shellfishing in the inner Cove is prohibited due to poor water quality from bacterial contamination. Of concern to water quality is surface water inflow to the head of the Cove from a small freshwater pond, which has had high levels of fecal coliform and nitrogen concentrations.

Hen Cove supports about 5 acres of tidal marsh, primarily at the head, but apparently has lost much of its eelgrass. Based on data developed by the Massachusetts Wetlands Conservancy Program in 1996, eelgrass was not prevalent in the Cove, the nearest beds being found outside of Bassetts Island. This is in sharp contrast to an earlier survey in 1985 which reported a 6.4 acre bed within the 14 acres of available habitat inside the Cove. This change is of concern as it may be an indicator of declining water quality.

Embayment and Watershed Characteristics

Hen Cove is the middle cove within the Pocasset Harbor/Hen Cove/Red Brook Harbor Complex. This greater harbor system is formed by Wings Neck to the north and Scraggy Neck to the south. Wings Neck, historically also called Wenaumet Neck, was originally an island formed as part of the Falmouth Glacial Moraine. The island was connected to the mainland by the growth of a sandy spit, which then provided a sufficiently protected environment for the development of the salt marshes at the head of Pocasset Harbor. More recently, the Complex became hydrologically distinct with the connection of Scraggy Neck, so that at present all tidal exchanges take place through the system mouth constrained by the two Necks. Hen Cove, Pocasset Harbor and Red Brook Harbor are actually the three major coves within the greater system which are semi-separated by the centrally located trilobate Bassetts Island. One of the special concerns relating to the water quality of this complex is the entry into Red Brook Harbor of the Landfill Plume (LF-1) from the Massachusetts Military Reservation.

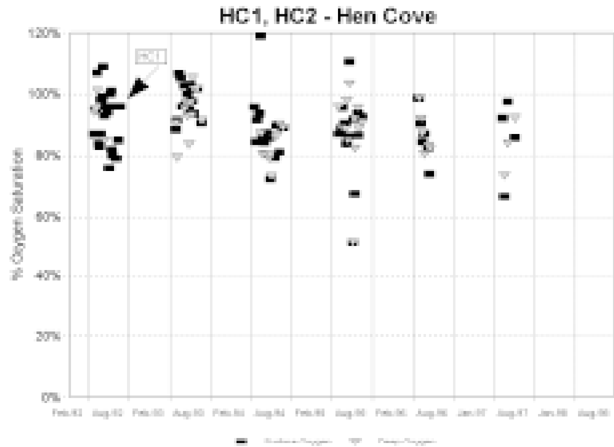
Hen Cove is one of the smallest embayments monitored, 64 acres, and is within one of the smaller watersheds, 1105 acres. However, despite its modest size, Hen Cove's watershed is relatively densely developed, particularly near the coast, with an average of 1.1 housing units per acre, among the highest for Buzzards Bay. For comparison, the adjacent Red Brook Harbor and Pocasset River Watersheds support ca. 0.2 units per acre. In addition, 94 acres of the non-residential area of the watershed is within the Pocasset Golf Club, which also contributes nitrogen to the Cove. In contrast to coastal portions of the Hen Cove watershed, the upper region supports pine/oak forest which contributes little nitrogen to the Cove. Most of this forested land (534 acres) is held within the Massachusetts Military Reservation, east of Rt. 28. Hen Cove and the greater Complex have been designated as nitrogen sensitive by the Cape Cod Commission, ranking 14 out of 52 embayments.

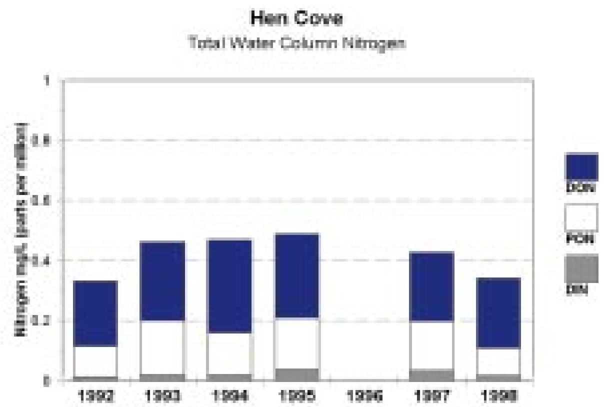
Water Quality

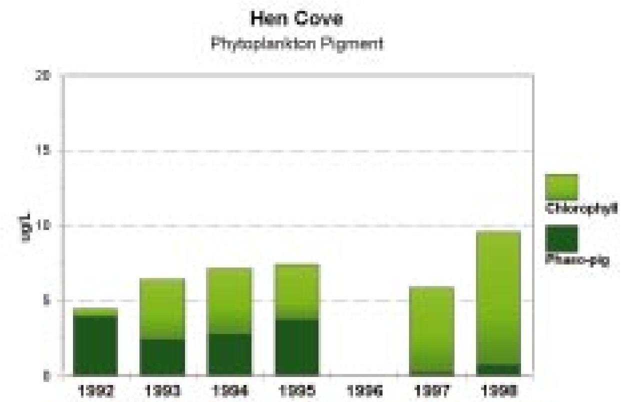
The integrated effects of watershed nitrogen loading, flushing and potential nitrogen additions to flood waters from adjacent systems are a moderate level of water quality degradation within Hen Cove. This appears to represent a relatively recent phenomenon as levels of total nitrogen and chlorophyll a pigments, and oxygen saturation showed higher water quality in 1992-93, and the presently reduced eelgrass community appears to have occurred between 1984 and 1996. Of the three coves within the Complex, Hen Cove typically shows the highest total nitrogen and phytoplankton pigment levels. In addition its shallow basin presents the potential for macroalgal accumulation which can negatively impact both shellfish and eelgrass communities.

Flushing of the Cove is not sufficient to prevent a horizontal salinity gradient of 1-2 ppt from the head to the mouth of the Cove. Since nitrogen enters the Cove from the surrounding watershed via freshwater flows, the salinity gradient is consistent with a gradient in water quality from the head to the mouth of the Cove.

However, dissolved oxygen levels do not show the same degree of depletion as the inner portions of Pocasset Harbor (prior to 1996) and Red Brook harbor. Oxygen levels are typically above 80% of air saturation, but declines to between 80% to 60%







saturation are common in 10% of samples. The higher oxygen levels in Hen Cove likely result from its much shallower basin, which is less than half the average depth, 0.8 meters, of the other two basins. The shallow basin facilitates wind-driven mixing of the watercolumn and therefore aeration of bottom waters.

Combining the monitoring parameters into the Health Index indicates that Hen Cove presently supports only fair to moderate water quality and ranks at about the median level for Buzzards Bay. All of the data are consistent with a recent decline in water quality which indicates the need for nitrogen management within this system.

Management Needs

Hen Cove is a relatively small waterbody which appears to be undergoing a water quality decline. The decline is consistent with nutrient overloading from its watershed and possibly from increased nitrogen in its flooding tidal waters. However, the principal source of nitrogen is residential development as the entire watershed is densely developed and serviced by on-site septic systems. In addition, there is the potential for additional development and for conversions of summer to year-round dwellings, which can potentially increase the wastewater nitrogen load to Hen Cove by as much as 25%. The town and local community should consider nitrogen management within this watershed both to prevent further water quality declines and for system restoration. Nitrogen management will almost certainly include approaches to decrease the wastewater nitrogen loading to the Cove. In addition, as about 8% of the watershed is Golf Course, fertilizer management (sometimes through use of organic or slow release fertilizers) and water re-use should be evaluated. Although the Pocasset Golf Club is privately owned, the Town should work with the club owner to develop programs to reduce fertilizer applications and minimize runoff of nitrogen into the Cove.

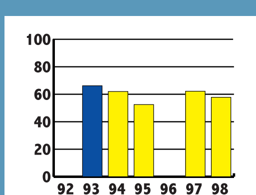
An important protection to Hen Cove is afforded by the large amount of forested land within its upper watershed within Massachusetts Military Reservation. This unfragmented forest should be maintained as a cost-effective method for water quality protection.

The sources of bacterial contamination of the Cove need to be evaluated and remediated. Proper management of direct surface water inflows can play important roles in reducing bacterial contamination and nutrient inputs. Partial remediation of stormwater inflow was completed in 1992 when rapid infiltration structures were constructed for 3 discharges to the Cove. Future remediation should consider the use of vegetated swales or other engineered wetlands to capture stormwater inflows as these technologies also provide useful tools for preventing the entry to the Cove waters of nutrients and other contaminants.

BAY HEALTH INDEX

Good to Excellent (65 - 100)
Fair (35 - 65)
Poor/Eutrophic Conditions (< 35)

Hen Cove



Pocasset Harbor

Bourne

Water Quality

Pocasset Harbor has undergone a significant improvement in water quality over the study period. In 1992-1993 the Harbor had the poorest water quality on the eastern shore of Buzzards Bay. While the more urbanized embayments on the western shore ranked lower than Pocasset Harbor, its rank was relatively low given its small watershed dominated by residential development and forest and semi-enclosed basin. The improvement is likely related to stormwater management practices implemented near Barlows landing during 1995-97.

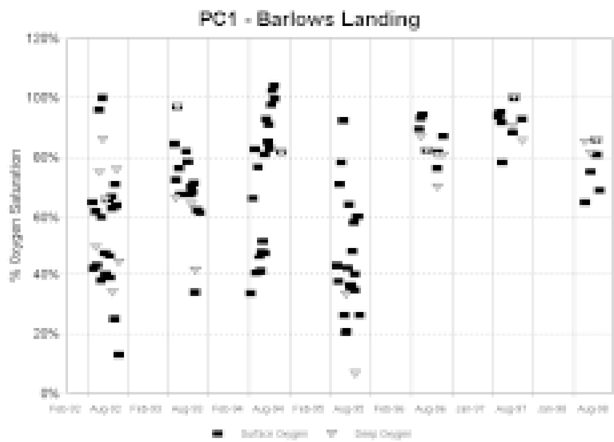
The apparent improvement in nutrient related water quality within the inner region of Pocasset Harbor is seen in some of the major watercolumn parameters. The average 20% of the lowest measured dissolved oxygen levels in the inner Harbor after 1995 have averaged 74% of air saturation compared to 39.8% from 1992-94 and the low of 18.5% in the system-wide low oxygen year of 1995. Similarly, total nitrogen and chlorophyll a pigment levels in the inner Harbor were ca. 50% higher than the outer Harbor in 1993-1995, but only 17% and 11% higher, respectively, in 1996-97 (nutrients were not assayed in 1992). Particulate organic carbon showed only about a 10% reduction over the sampling period. While there is still a gradient of improving water quality from inner to outer Harbor, the inner Harbor has improved in recent years in most of the water quality parameters.

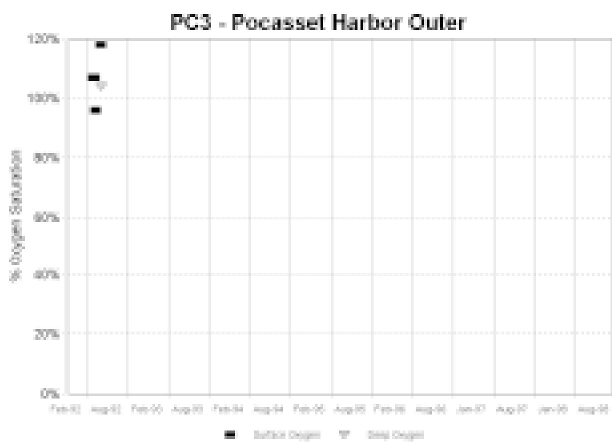
Changes in the nutrient related health of the inner Harbor is most apparent in the oxygen levels and in the Health Index. In 1994 the inner Harbor yielded an Index score of less than 25 based upon its frequent oxygen depletions below 60% saturation, nitrogen concentrations above 0.5 mg N/L and algal pigment levels averaging ca. 7 ug/L. It appears that implementation of management practices near Barlows Landing have improved conditions to the point where the Harbor presently ranks in the top quarter of Buzzards Bay embayments for nutrient related water quality. The persistence of this apparent improvement will be the focus of continued monitoring. It should be noted that this system is ranked by the Cape Cod Commission as one of the most nitrogen sensitive on Cape Cod, being fourteenth of fifty-two. Therefore there should be continued evaluation of the need for further management of this system to maintain its current water quality.

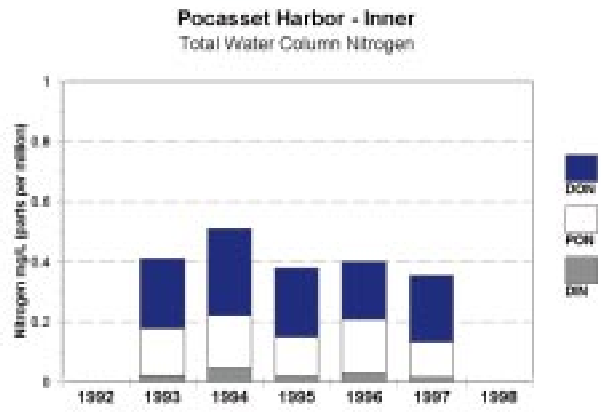
Embayment and Watershed Characteristics

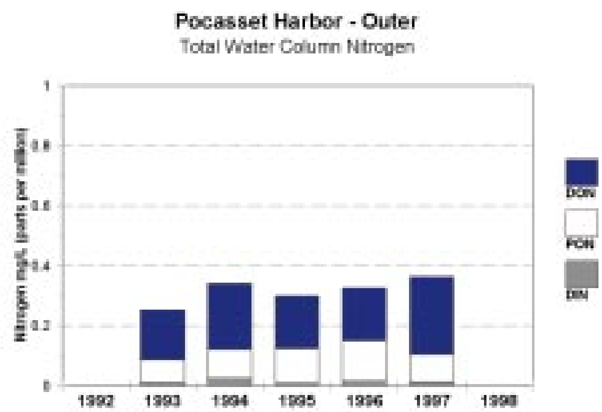
Pocasset Harbor is the northern most sub-embayment within the Pocasset Harbor/Hen Cove/Red Brook Harbor Complex. This greater harbor system is formed by Wings Neck to the north and Scraggy Neck to the south. Wings Neck, historically also called Wenaumet Neck, was originally an island formed as part of the Falmouth Glacial Moraine. The island was connected to the mainland by the growth of a sandy spit, which then provided a sufficiently protected environment for the development of the salt marshes which can be seen at the head of Pocasset Harbor. More recently, the Complex became hydrologically distinct with the connection of Scraggy Neck, so that at present all tidal exchanges take place through the system mouth constrained by the two Necks. Pocasset Harbor, Hen Cove and Red Brook Harbor are actually the three major coves within the greater system which are semi-separated by the centrally located trilobate Bassetts Island. One of the special concerns relating to the water quality of this complex is the entry into Red Brook Harbor of the Landfill Plume (LF-1) from the Massachusetts Military Reservation.

Pocasset Harbor supports significant marginal tidal wetlands both to the north and east, as well as two small marsh islands within the inner Harbor region. The Harbor is used for recreational boats and contains a beach, boat ramp and pier at Barlows Landing. The Harbor has shallow margins, particularly adjacent to the northern marshes, but maintains a 2 meter channel with depths of 7 meters in the channel between Bassetts Island and Wings Neck. Most of the eelgrass is located in the shallower inner Harbor region and bordering the main deep channel to the mouth. The beds are moderate in coverage.









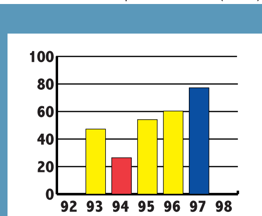
Management Needs

Pocasset Harbor appears to be a highly responsive embayment. This feature coupled with its nitrogen sensitivity ranking suggest than a nitrogen management evaluation is warranted. Similarly, all direct discharges to this Harbor should be identified and mitigated or prevented. Overall, given its small watershed, projections for maintaining a high water quality environment are good. In addition, given the existing circulation information for the Pocasset Harbor/Hen Cove/Red Brook Harbor Complex and initial analysis of the LF-1 plume constituents, it currently appears that the LF-1 plume will not be a major source of nutrients to this northern-most cove. However, nitrogen entering from the watersheds of Hen Cove and Red Brook Harbor which can then enter Pocasset Harbor in tidal exchanges is likely the major potential source of "new" nitrogen to the Harbor. The linkage of these coves by tidal exchanges illustrates the need for management to be based upon the entire Complex, not just the individual coves. The existence of eelgrass should be monitored within this system to serve as an additional indicator of water quality and system stability.

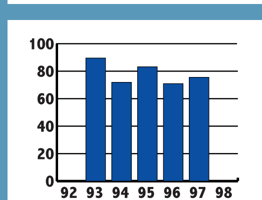
BAY HEALTH INDEX

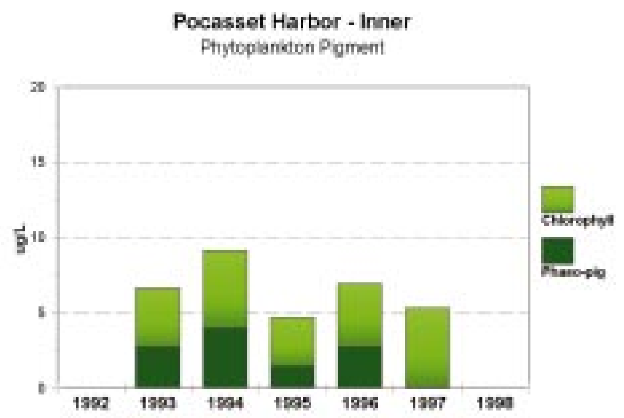
- Good to Excellent (65 - 100)
- Fair (35 - 65)
- Poor/Eutrophic Conditions (< 35)

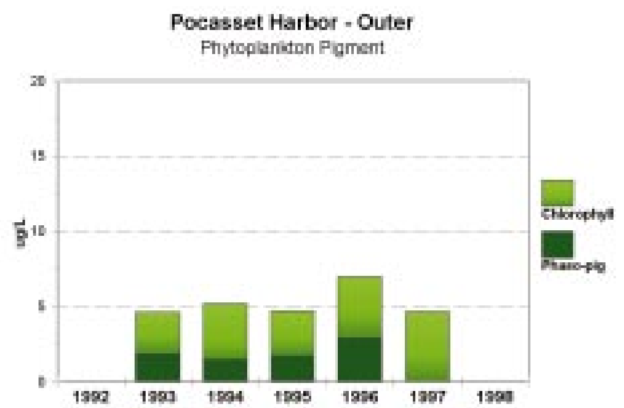
Pocasset Harbor, Inner

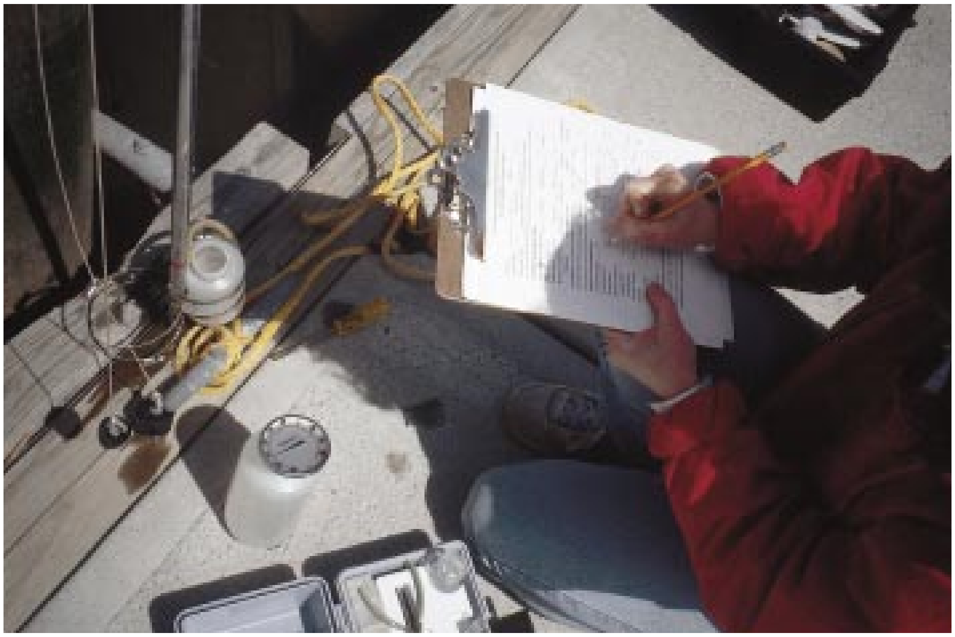


Pocasset Harbor, Outer

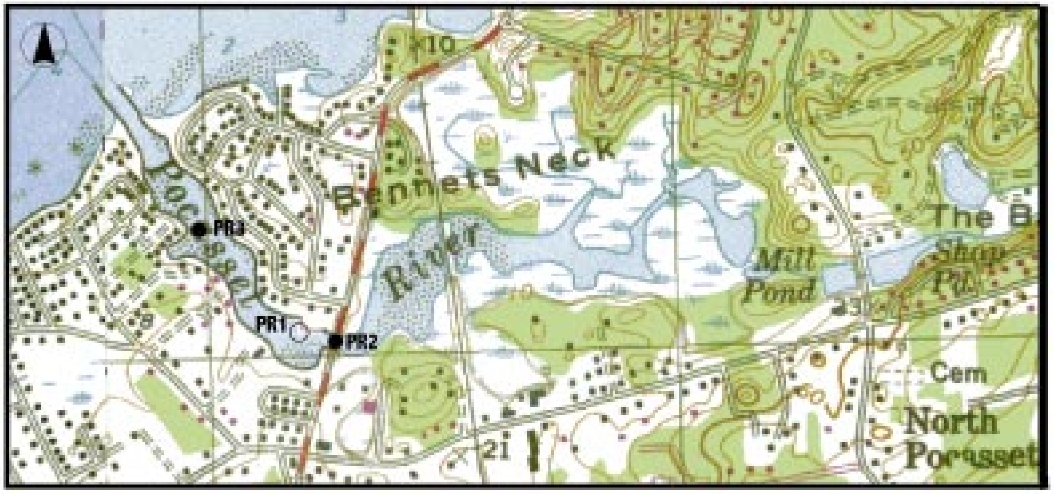








The Coalition for Buzzards Bay



Water Quality

The water quality within the Pocasset River estuary is typical of a system with significant tidal wetland and freshwater inflows and relatively low watershed nitrogen loading. It is likely that the tidal wetlands and estuarine flows are important in structuring present water quality.

Oxygen levels within the mid region of the lower estuary typically show modest oxygen depletion to between 80% and 60% of air saturation. The low dissolved oxygen levels observed in 1995 appear to be due to meteorological conditions as they were observed in a variety of embayments in that year. However, the nutrient conditions within the estuary provide the underlying cause of the 1995 depletion as they form the basis for oxygen depletion to occur. There is an apparent improvement in oxygen conditions in recent years, with the lowest 20% of oxygen readings averaging 64% of saturation from 1992-1994 and 74% of saturation from 1996-1998. While this trend is encouraging, the potential for periodic “bad oxygen years” like 1995, where oxygen routinely declines to environmentally stressful levels remains a cause for concern.

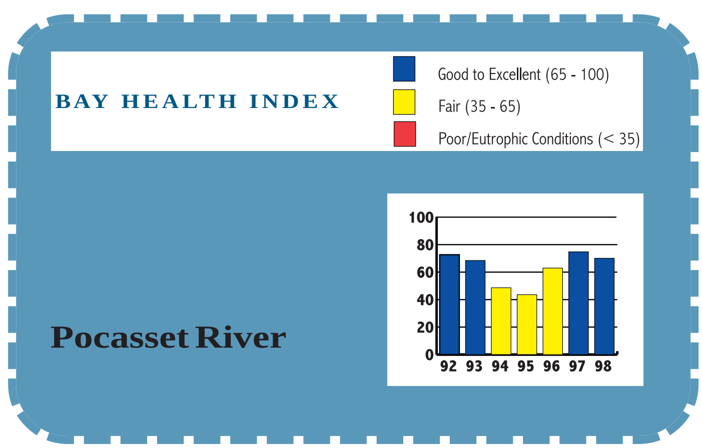
The nitrogen and chlorophyll a pigment levels are generally consistent with the observed oxygen values, and water transparency is moderate, generally about 2 meters. Overall the levels of these key parameters are relatively low and indicative of a relatively healthy lower riverine estuary. However, in the low oxygen year of 1995 the chlorophyll levels at the mid estuary were moderately elevated and the highest on record, 5.9 ug/L, but the particulate organic carbon concentrations were very high, 1.13 mg C/L, 37% higher than the next highest year. In addition, during 1995 the salinity of the estuary was about 3 ppt fresher than long-term average. The fresher conditions suggest a greater

Embayment and Watershed Characteristics

The Pocasset River Estuary is typical of small rivers on Cape Cod and is one of the smaller systems in the monitoring program. The upper fresh water portion has surface water drainage from a series of small ponds, ending in Mill Pond adjacent to County Road. Seaward of Mill Pond the lower river widens, is tidal and can be classified as a drowned river estuary. Salinities within the lower estuary, seaward of Shore Road, are indicative of a mixing zone of Buzzards Bay tidal waters and River waters. Salinity ranged from 32.0 ppt to 18.7 ppt and averaged 26.8 over the study period indicating significant freshwater discharge. The estuarine portion of the river is 198 acres and supports a proportionately large amount of wetland area, 68 acres. Much of the nearshore development is on Bennets Neck.

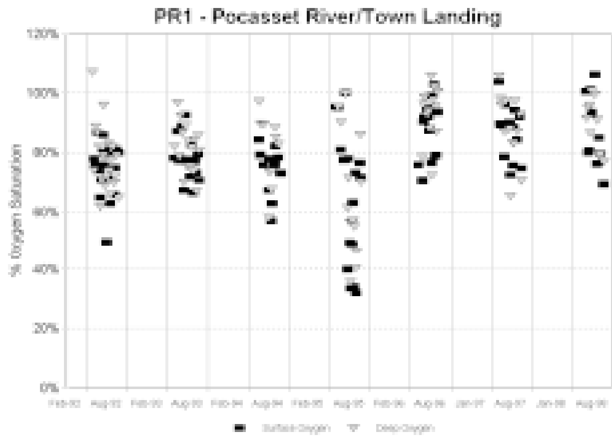
Recent land-use analysis for the Pocasset River has been conducted by the Cape Cod Commission using watershed boundaries determined from water table data. This approach allows separation of the contributing area to the River from the entire Toby’s Island basin. The combined watershed is about four-fifths in forest, but has significant development potential as the number of housing units can triple at build-out. At present, housing densities are low, 0.2 units per acre. The Pocasset River sub-watershed (2,153 acres) accounts for about half of the total combined watershed area. The upper portion of this sub-watershed (57%) falls within the Massachusetts Military Reservation and is forested, which greatly reduces nitrogen loading to the embayment.

The estuarine portion of the Pocasset River is well utilized as a mooring area with shoreline boat slips, and the inlet is fixed by stone jetties. One public beach is available, and four public access points. In the Buzzards Bay Project’s Sub-Watershed Evaluation (1994), shellfish resources were ranked as poor.



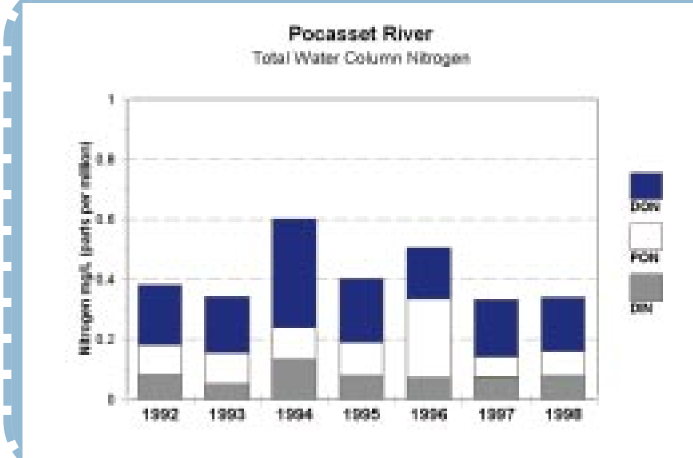
freshwater flow, but more importantly the greater potential for watercolumn stratification and oxygen declines. The data suggest an atypical input of organic matter either from a bloom or from the upstream marshes or river. All of these data are consistent with the observation of low dissolved oxygen in 1995.

The Health Index illustrates the inter-annual variations in this system and the generally good water quality within the Pocasset River estuary. The reduced water quality from 1994-96 primarily results from total carbon and oxygen levels. The periodic declines in water quality may be partially responsible for the lack of eelgrass beds within the lower river. However, the extent to which the water quality within the estuary is controlled by watershed nutrient loading versus freshwater flows and wetland interactions needs to be evaluated in any nitrogen management planning.

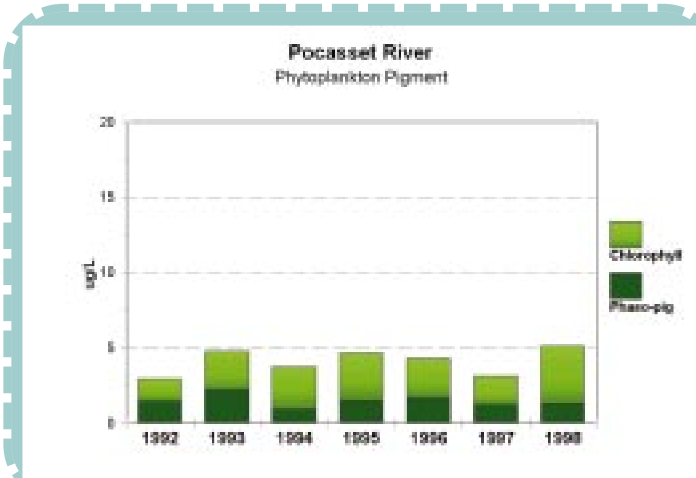


Management Needs

The Buzzards Bay Project completed an evaluation of nutrient loading to the Pocasset River in 1994 as part of the Buzzards Bay sub-watershed evaluation. Revisions to the watershed delineation and isolation of inputs to the Pocasset River have modified the earlier loading evaluation. However, it appears that current nitrogen inputs are well below levels necessary to degrade the estuary's quality, but may reach detrimental levels at full build out of the watershed. Based upon the available loading estimates and the structure and sub-habitats within the estuary, it appears that the Pocasset River is relatively healthy. Although its eutrophication score places the River near average for tributary systems to Buzzards Bay, it is probably nearer its supportable level of water quality than many other systems. This evaluation takes into consideration that the estuary has had its structure significantly altered for navigation, bridge construction and freshwater flow controls.

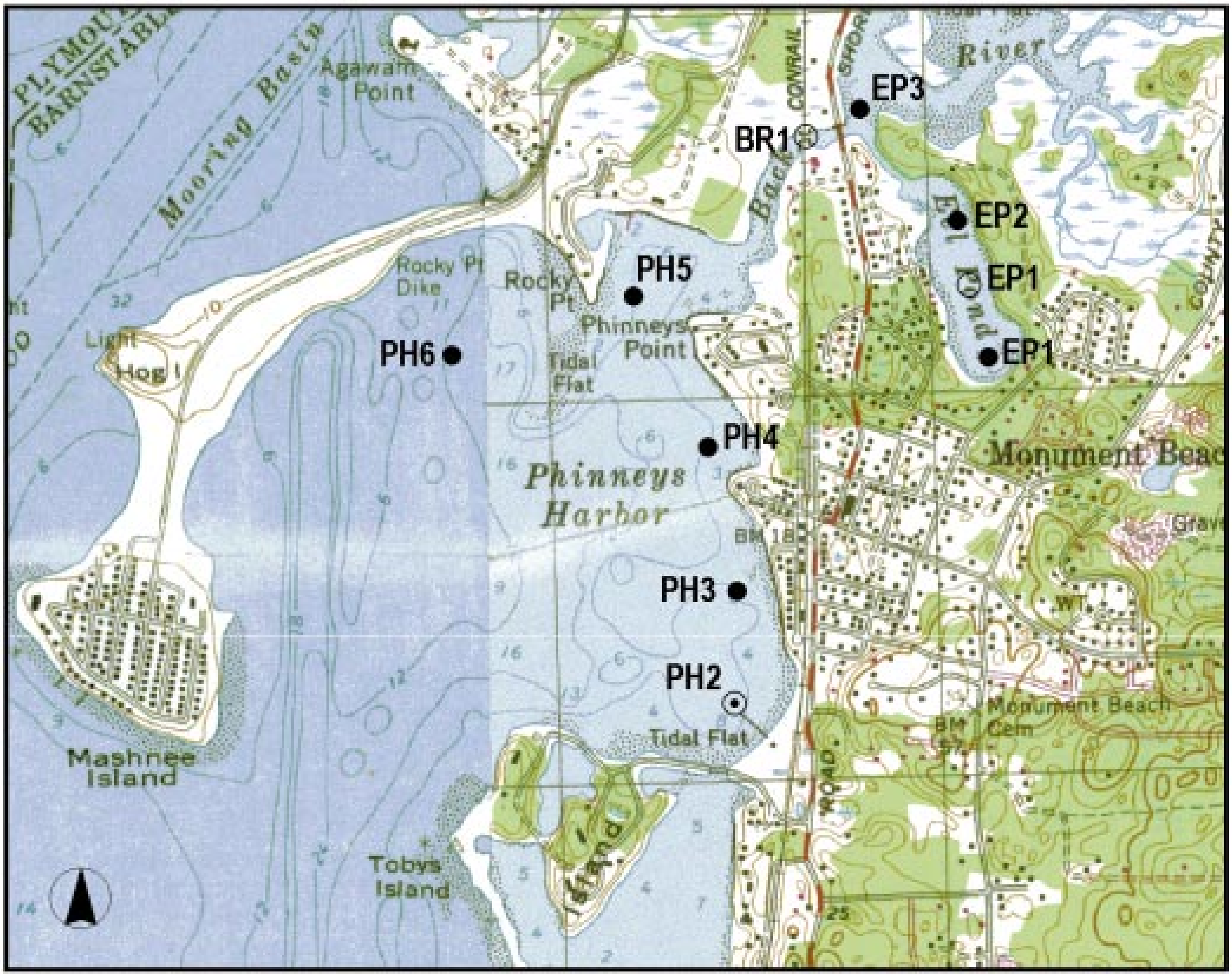


At present the moderate chlorophyll levels, yet low oxygen concentrations, suggest that potential interactions with bordering wetlands (possibly organic matter imports) may be involved in the organic matter-oxygen dynamics. Accumulated algae and organic matter in River sediments may also be accounting for these low oxygen levels. Additional work, focused upon determining the cause of the observed low oxygen conditions is needed. However, it appears that like adjacent systems, additional nutrient inputs to Pocasset River to the extent that they result in additional organic matter production, are likely to result in even more extreme oxygen depletions.



Management to maximize tidal exchanges with Buzzards Bay waters will help to maintain the quality of the Pocasset River system. It should be noted that as a tidal river with "significant" freshwater flow, the Pocasset River to its mouth at Buzzards Bay almost certainly falls under regulation by the new Massachusetts Rivers Act.

Phinney's Harbor, Back River, Eel Pond



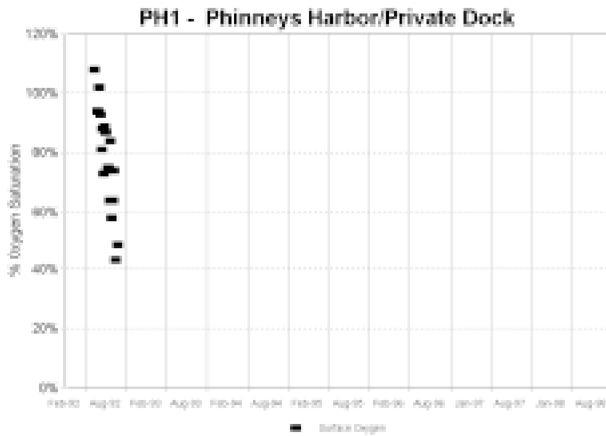
Embayment and Watershed Characteristics

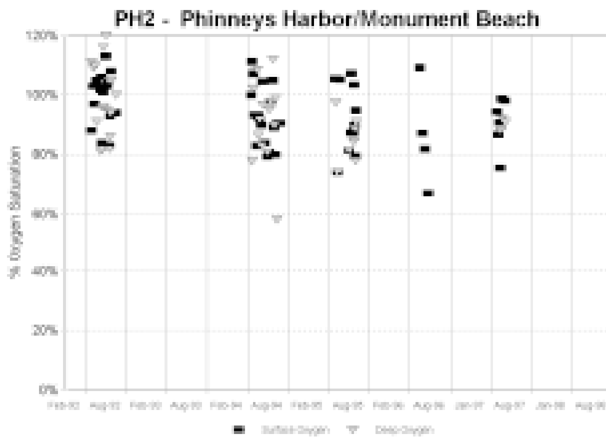
The Phinney's Harbor System consists of a relatively well-flushed semi-enclosed outer harbor region, Phinney's Harbor, and a bifurcated tributary embayment, Back River and Eel Pond. All of the tidal exchanges to the tributary enclosed embayments are via the inlet to the Back River. This makes the Back River and Eel Pond the least well flushed portions of the system. These sub-embayments receive most of the nitrogen entering from the Phinney's Harbor watershed. The moderately sized watershed (2,488 acres) to this system consists of both glacial outwash sands and gravels and Falmouth Moraine, producing a complex groundwater flow system. Freshwater enters the embayment system primarily by groundwater flow, but some small surface water flows are present particularly to Back River and Eel Pond. Records from 1880 show a surface water flow from Mill Pond to the upper Back River as the major historic stream inflow.

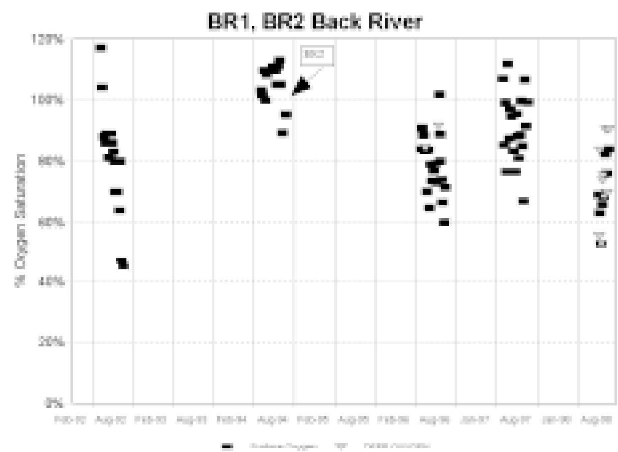
Like many of the coastal embayments to Buzzards Bay, Phinney's Harbor has been extensively modified over the past century. Charts from 1880 and 1916 indicate that what is now denoted as Phinney's Harbor, formed primarily by the northern peninsula ending at Mashnee "Island", did not exist. The peninsula is artificial, constructed to connect the mainland between Agawam and Rocky Points to Mashnee Island. This connection also connected Hog Island which was "along the way" to create the present peninsula. While this created a Harbor and may have produced additional eelgrass habitat, it also significantly altered the circulation within the region.

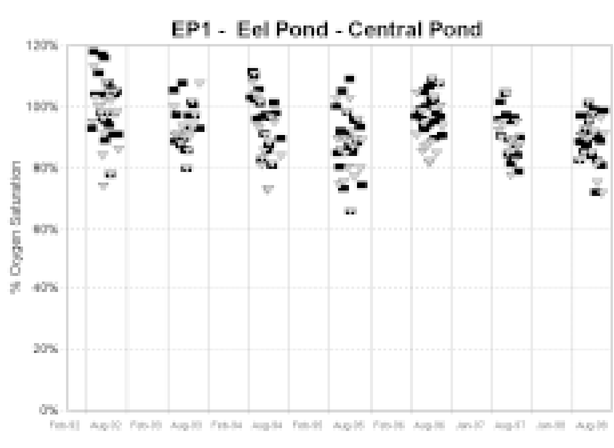
The combined estuarine area is 536 acres, similar to the size of Buttermilk Bay. The system currently supports ca. 400 moorings and slips and 1 public beach. While Phinney's Harbor has a mean depth of 2 meters and contains shallow marginal areas, the central portion of the Harbor deepens rapidly to ca. 5 meters. In contrast, Eel Pond and Back River are shallow with areas draining completely leaving tidal flats at low tide. These inner areas support almost all of the 85 acres of saltmarsh in the system, but virtually no eelgrass. Phinney's Harbor has traditionally supported abundant eelgrass beds and good shellfishing resources, although observations by the Massachusetts Division of Marine Fisheries in 1995 indicated a die-off of eelgrass within some areas of the Harbor. The region from Arthur Avenue to Toby's Island periodically has poor water quality from bacteria contamination and is seasonally closed to shellfishing, partially due to contamination from runoff from the watershed and other potential sources.

Much of the nitrogen in the watershed discharges to Phinney's Harbor through the Back River and Eel Pond. Development within the watershed is primarily in the nearshore region. Almost two-thirds of the upland is currently forested, and 39% of that forest is within the Massachusetts Military Reservation. Of the available developable lands, almost two-thirds have already been utilized. The result is a watershed approaching build-out with residential inputs accounting for almost all of the nitrogen loading to the adjacent waters. Based upon flushing, direct nitrogen loading to the outer harbor likely plays only a small role in water quality. In addition, much of the outer harbor watershed is associated with the peninsula which represents a small contributing area and nitrogen load relative to the volume of the harbor. It is the nitrogen loading to Eel Pond and Back River that is of most concern both to these systems and to the region of Phinney's Harbor adjacent to the mouth of the Back River.





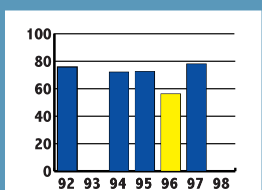




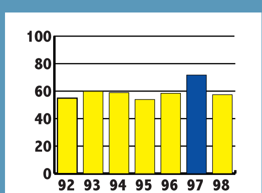
BAY HEALTH INDEX

- Good to Excellent (65 - 100)
- Fair (35 - 65)
- Poor/Eutrophic Conditions (< 35)

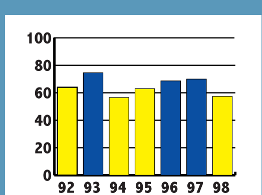
Phinney's Harbor



Back River



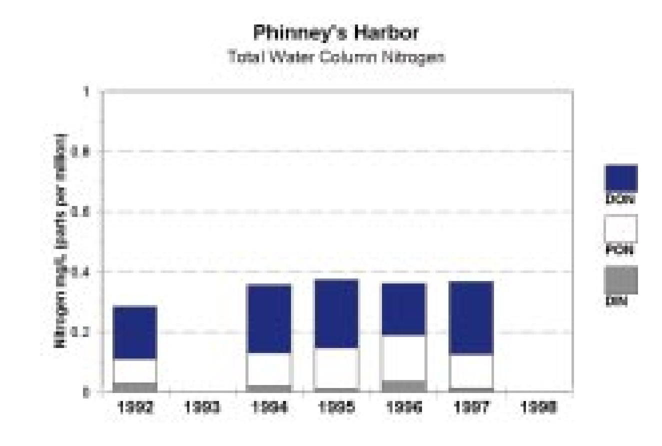
Eel Pond

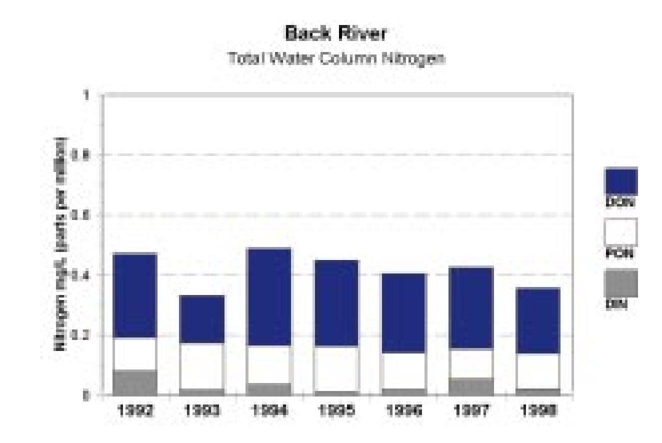


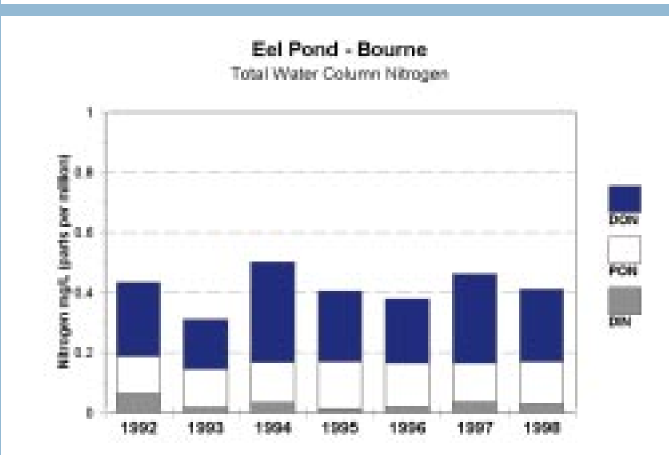
Water Quality

Phinney's Harbor has maintained relatively good nutrient related water quality throughout the monitoring period. The high chlorophyll levels in 1996 were not observed in other years. Oxygen levels within the outer Harbor are typically (90% of samples) above 80% air saturation and depletions below 70% saturation are relatively rare, (3% of samples). Similarly, key eutrophication parameters are generally good to moderate with total nitrogen, chlorophyll a pigments and particulate organic carbon averaging, respectively, 0.405 mg N/L, 7.2 ug/L and 0.81 mg C/L over the monitoring interval. However, these values do show significant enrichment over Buzzards Bay waters indicating the effects of watershed nutrient loading. The persistence of eelgrass within the Harbor is consistent with the observed levels of these water quality parameters, however, reports of some eelgrass die-off is cause for concern.

The enclosed waters of Back River and Eel Pond show only moderate water quality declines over Phinney's Harbor waters. These systems receive much of the nutrient load from the watershed that ultimately is carried to Phinney's Harbor. However, it appears that flushing of these small sub-embayments is sufficient to limit the extent of their nutrient related responses. Total nitrogen and particulate carbon levels were elevated less than 10% in Eel Pond and Back River compared to Phinney's Harbor waters. However, chlorophyll a pigments were significantly higher (14%) in Eel Pond over the incoming tidal waters and a large bloom was apparent in the summer of 1998. Oxygen levels within the sub-embayments suggests that the increase in nutrient response parameters in Eel Pond has not been sufficient to cause ecologically stressful oxygen declines. Only during 1995 were oxygen saturation values below 70% air saturation observed and values below 60% saturation have yet to be measured. In contrast, the Back River oxygen status does suggest important oxygen declines related to nutrient and organic matter loadings. During both 1992 and 1998, oxygen levels were seen to drop below 60% saturation. However, evaluating the causes of the oxygen declines in the Back River is not a simple matter. The large wetland area associated with this sub-system may also be affecting oxygen levels. It is likely that the near "emptying out" of the upper Back River during ebb tides is critical to bolstering the water quality in this system.



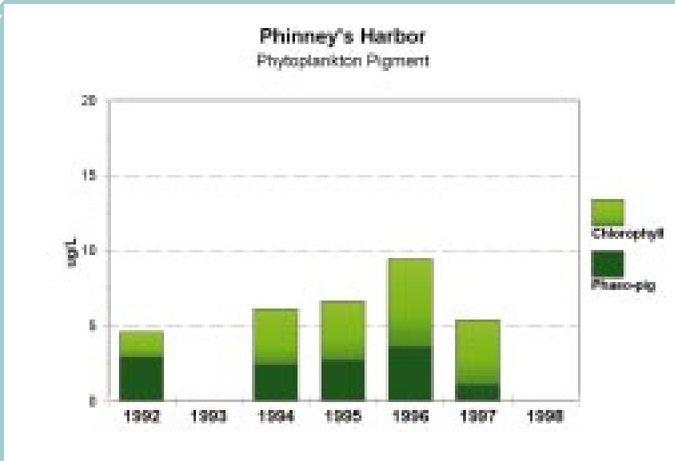


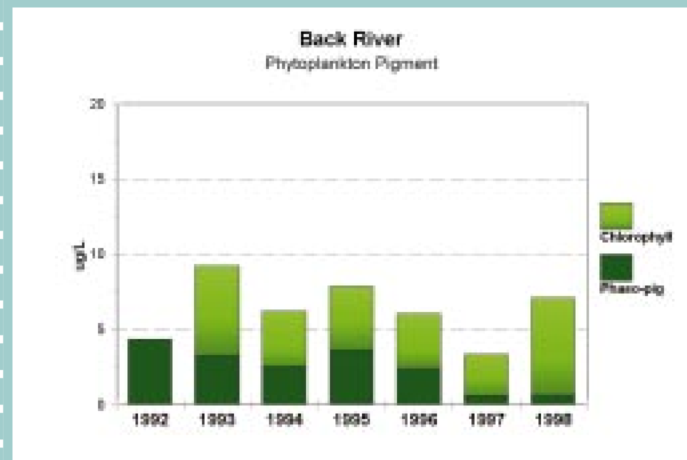


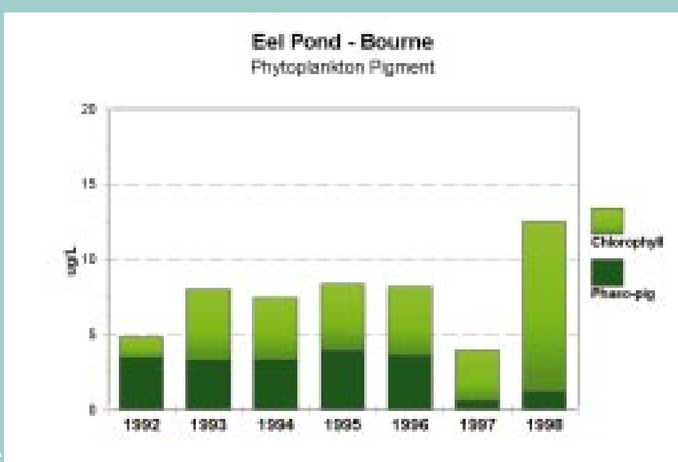
Integrating the water quality parameters into the Health Index supports the contention that Phinney's Harbor supports moderate to good water quality, that the Back River waters are in fair condition and that Eel Pond is intermediated between the two. The lack of eelgrass beds within the inner embayments is consistent with their observed water quality. However, the presence of wetlands and tidal flats within the Back River likely plays important roles in this sub-system habitat quality, and a higher level of evaluation is necessary before nutrient management of this system is undertaken. Similarly, analysis of macro-algal proliferation within the inner system, which does not show directly in the monitoring parameters, should be considered. Given the relatively open nature of Phinney's Harbor and the level of watershed build-out, this basin is projected to remain good, barring radical changes in land-use. However, periodic evaluation of the eelgrass beds within the outer Harbor is important to determine if the die-off in 1995 is part of a temporal trend.

Management Needs

Residential development accounts for nearly three-quarters of embayment loadings of nitrogen. Currently the nitrogen loading is only at ca. one-sixth of the critical nitrogen load suggested by the Buzzards Bay Project. At full buildout the nitrogen load is expected to be less than one-quarter of the critical load. What is "protecting" the Harbor from nutrient overloading is the extensive forested areas within the upper watershed. More than 60%





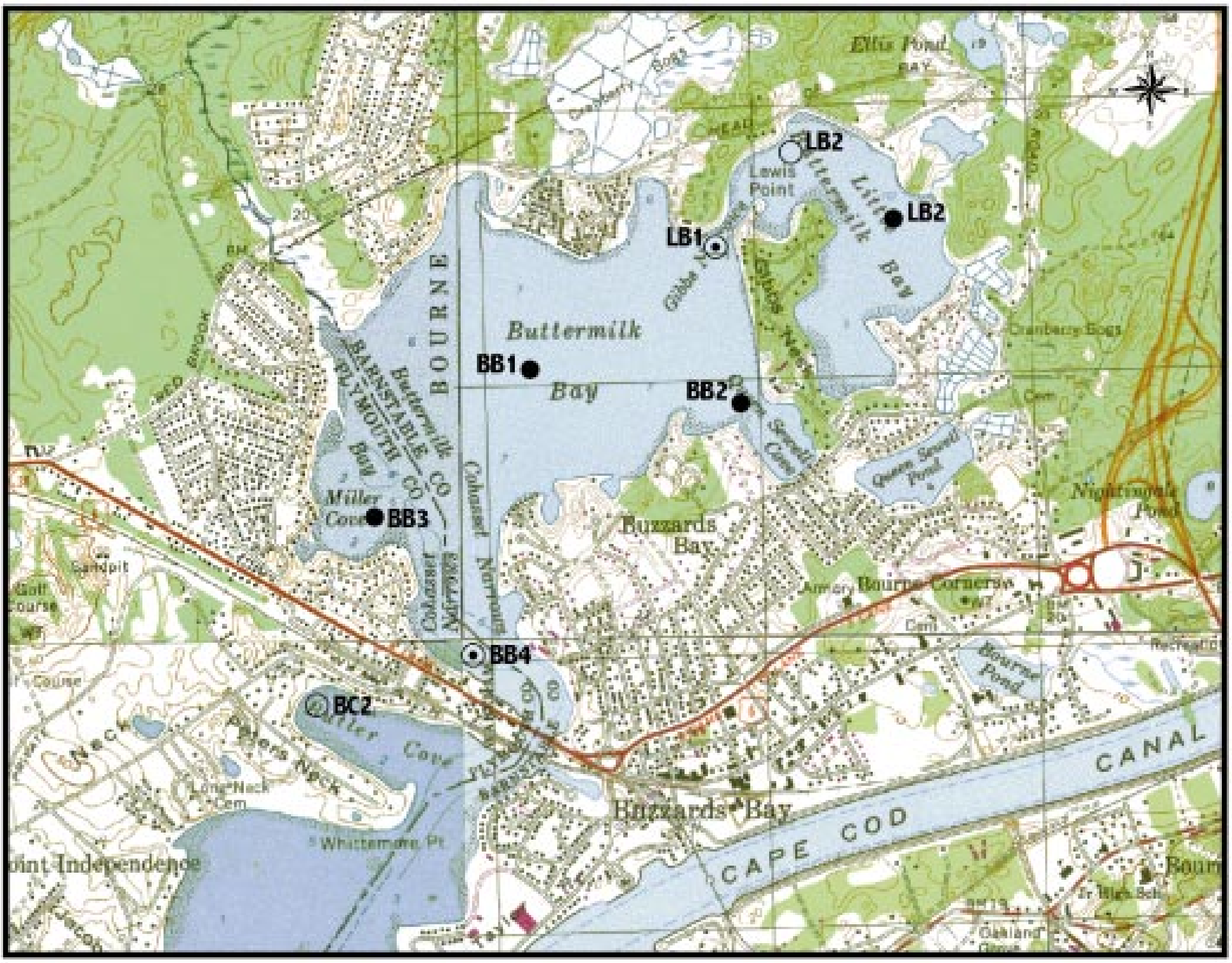


of the upland is forested and largely non-developable as most falls within the boundaries of the Massachusetts Military Reservation.

The results of the water quality monitoring program are consistent with the watershed loading assessments. However, conditions within the mouth of the Back River, the periodic plankton bloom levels in the Harbor and Eel Pond (1996 and 1998, respectively), and possible localized loss of eelgrass suggest that the Harbor System may be closer to its nutrient tolerance threshold than previously thought. At present, it appears likely that nitrogen management actions will not be required for outer Phinney's Harbor. In contrast, the inner harbor areas, Back River and Eel Pond, may require watershed nitrogen management to prevent further increased loadings. However, additional analysis will be needed to separate natural system versus watershed effects, as part of a nitrogen management plan. The Cape Cod Commission has updated the subwatershed for Phinney's Harbor, and the Buzzards Bay Project needs to update its nitrogen loading assessment for the estuary. Present efforts should focus on bacterial contamination relative to the limited seasonal shellfish bed closures and recreational beaches within the Harbor and other direct management of harbor resources.

Buttermilk Bay & Little Buttermilk Bay

Bourne, Wareham



Embayment and Watershed Characteristics

The estuarine portion of the Buttermilk Bay System is comprised primarily of a 530 acre enclosed bay, Buttermilk Bay, connected at its inland most portion through a narrow channel to Little Buttermilk Bay. Initially a freshwater kettle pond adjacent to Buttermilk Bay, Little Buttermilk Bay became connected with rising sea-level, but has restricted flushing. There are several coves within the Bays, most significantly Miller Cove and Queen Sewell Cove. Both embayments have several creeks and streams for freshwater inputs (and nitrogen), the largest being Red Brook. Nevertheless the majority of freshwater enters the Bay via groundwater. All tidal exchanges with Buzzards Bay waters are via the inlet to Buttermilk Bay at Cohasset Narrows to Butler Cove.

The watershed contributing to the Buttermilk Bays consists primarily of fine to coarse sands deposited as part of the Wareham Outwash Plain. The upland is part of the Plymouth-Carver Aquifer, one of the largest in Massachusetts. The watershed to the Bays is divided among three towns, Wareham, Bourne, and Plymouth and is the eighth largest sub-watershed to Buzzards Bay. This watershed has largely residential land-use, which is clustered, primarily in the nearshore areas, but there is also considerable new development within the upper watershed in Plymouth. Many residential areas have been and continue to be sewered since the 1990's, most notably Indian Heights adjacent to Miller Cove. Approximately 9% of the watershed is used for agriculture, mostly cranberry bogs.

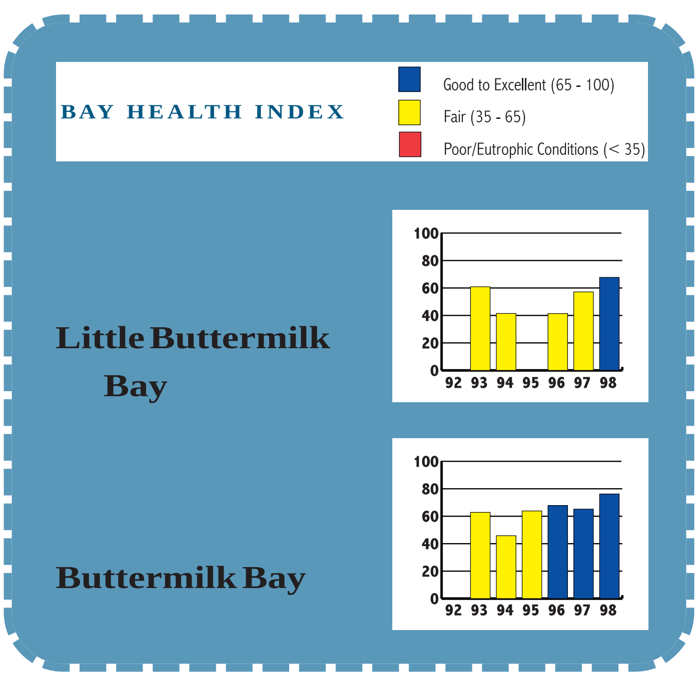
Buttermilk Bay is shallow, averaging only 1.5 meters in depth, with only a moderate dilution of salinity (25-30ppt) from freshwater inflows and is know for eelgrass beds covering nearly 40% of the embayment in the 1980's. The embayment has 3 beaches, water-skiing and other boating recreation. There are approximately 137 boat moorings and slips, and a marina providing a pump-out boat and dockside facility and a waste dump facility. Increased shoreline development has resulted in loss of salt marsh coverage with portions of this estuary's shores. Wetland loss is now primarily through small erosion events, however filling of salt marsh was a major mechanism for wetland loss only 30-40 years ago. Fortunately, many of the coves and the mouths of Red Brook and Goat Meadow Brook still support modest size marshes. Little Buttermilk Bay also supports eelgrass beds and significant shellfish populations.

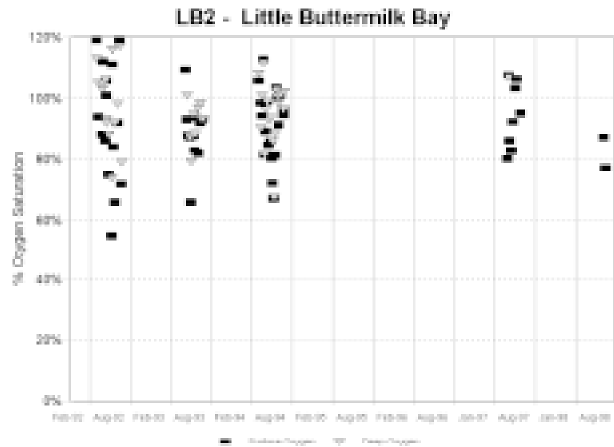
Buttermilk Bay has historically sustained an active shellfishery. However, bacterial contamination caused major restrictions to harvest in the mid-1980's. The bacterial contamination was traced primarily to stormwater runoff, particularly from roadways which has resulted in extensive surface water mitigation projects within this basin. Buttermilk Bay is the only embayment to Buzzards Bay to have remediated all (30) of its stormwater discharges.

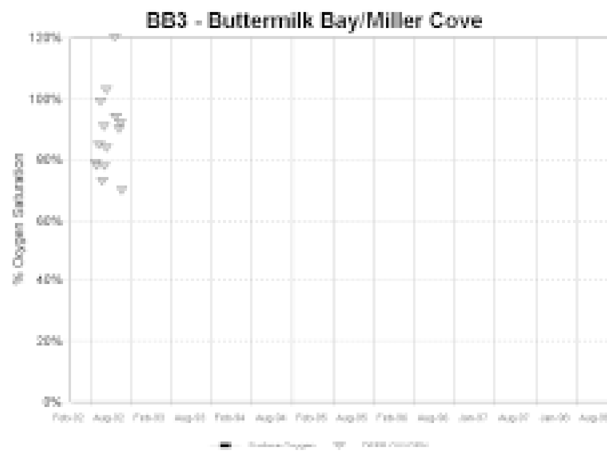
Water Quality

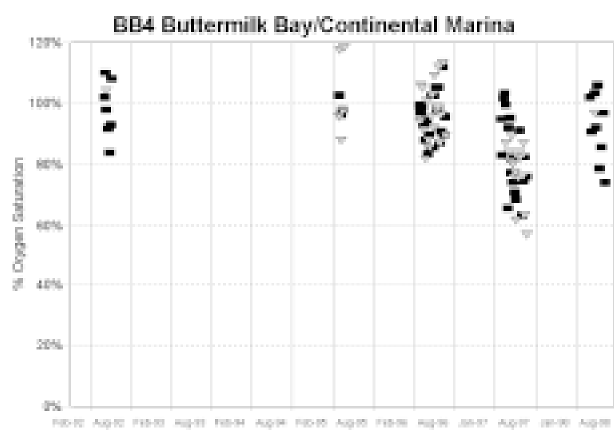
Buttermilk Bay has shown moderate to good water quality throughout the monitoring period. Oxygen levels have only shown depletions to 60% of air saturation on one occasion and generally are greater than 80% of saturation. Only in 1997 were moderate oxygen depletions, 60%-80% saturation, observed on a consistent basis. It is interesting to note that Butler Cove which is tributary to the inlet to Buttermilk Bay at Cohasset Narrows shows greater oxygen depletions than in Buttermilk Bay and is more similar to the confined waters of Little Buttermilk Bay. This is likely due to its highly developed watershed, but an accurate diagnosis is not possible from the limited data available.

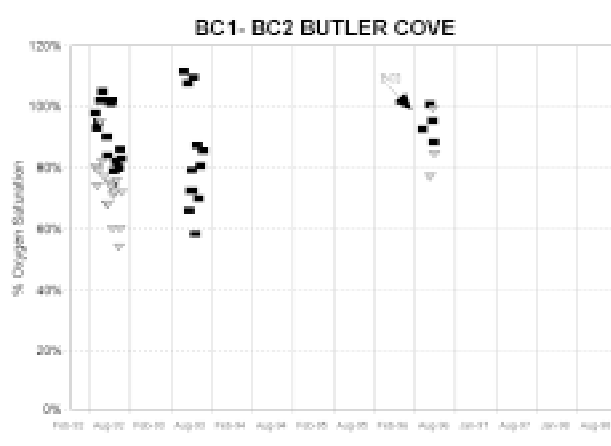
The general trend in Buttermilk Bay appears to be toward improving nutrient related water quality conditions within the Bay. Average (shown with its standard error or SE, a measure of variability) total nitrogen, particulate carbon and chlorophyll pigments all show decreasing levels when comparing 1993-95 versus 1996-98 (stations BB3, BB1, BB2); TN, 0.467 mg N/L







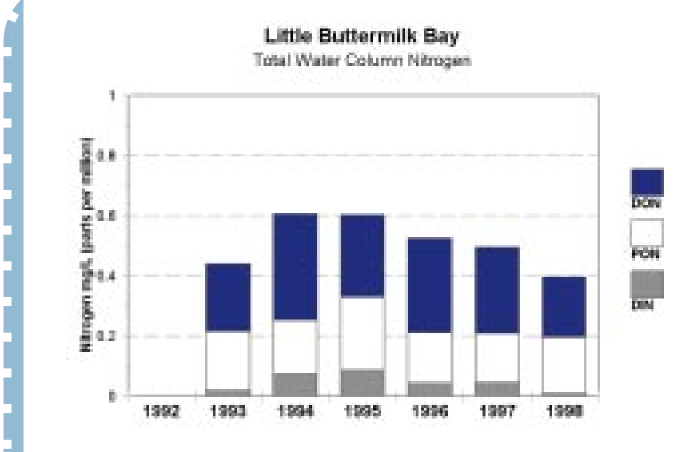


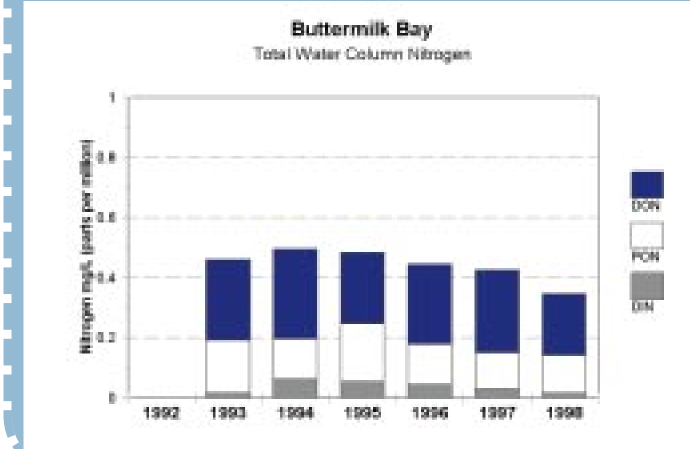


(SE=0.093) vs. 0.398 mg N/L (SE=0.064); POC, 1.13 mg C/L (SE=0.23) vs. 0.72 mg C/L (SE=0.12); Total pigment, 9.0 ug /L (SE=1.8) vs. 6.2 ug /L (SE=1.0). The levels of reduction are about one third for the phytoplankton indicators (POC and chlorophyll pigments) and half that for total nitrogen which includes a large relatively non-active pool of DON. The reductions in the key water quality parameters are reflected in the composite health index which also shows an improvement in recent years. While these data are not conclusive, it is likely that the observed reduction is related to the removal of a large percentage of the wastewater nitrogen load by sewering. Although groundwater travel times can delay the onset of nitrogen reductions to bay waters, the effects of sewering Indian Heights would be affecting Bay conditions by the late 1990's. At present, the magnitude of the expected water quality improvement is not known nor is the time interval required for full effect. However, to the extent that the observed trend is accurate it should signal the onset of improving habitat quality within Buttermilk Bay.

Sewering is a common approach to nitrogen mitigation for restoration of coastal embayments, but caution must be taken to prevent transferring the problem to another watershed as occurred in West Falmouth Harbor in the mid-1980's (which is now in need of its own reduction in nitrogen loading). The sewering within the lower Buttermilk Bay watershed presently transfers this wastewater nitrogen loading to the Wareham Waste Water Treatment Facility (WWTF). This WWTF discharges secondarily treated effluent (limited nitrogen reduction) to the Agawam River which flows into the Wareham River Estuary. Nitrogen loading evaluations of this receiving embayment are currently underway as part of a planned upgrade of the WWTF. The goal of these evaluations is to manage nitrogen related water quality within the Wareham River Estuary as related to nitrogen loading from its watershed and the various sewered areas which currently contribute to this system. Since the WWTF will be upgraded, nitrogen removal designs can be added as required to achieve sustainable environmental quality (see Wareham River Estuary text). The Town of Wareham is supporting this effort to ensure that nitrogen removal will be at the appropriate level for the protection (or possible enhancement) of nutrient related water quality in this system.

The improving trend in Buttermilk Bay is not as readily apparent in the Little Buttermilk Bay data. This results from the limited oxygen data set and the variability in the pigment data. However, the available data does support improving nutrient related water quality within this tributary system. The improvement is likely the result of lower nitrogen and phytoplankton concentrations in the incoming flood waters from Buttermilk Bay more than decreases in nitrogen loading from its own sub-watershed. Little Buttermilk Bay has lower nitrogen loading from its watershed than does Buttermilk Bay, but all of its tidal exchange is with the waters of Buttermilk Bay after they have received their watershed nitrogen load in passage through to the inner bay. The effect is (1) that decreased nitrogen loading to Buttermilk Bay will improve conditions within Little Buttermilk Bay and (2) that Little Buttermilk Bay should show higher nitrogen and chlorophyll pigments than the outer system. Both of these effects appear to be supported by the monitoring results.

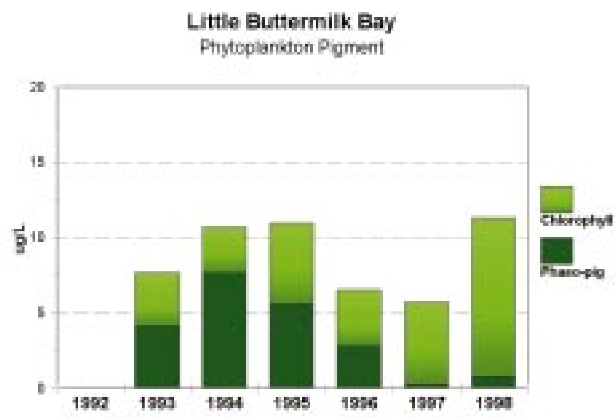


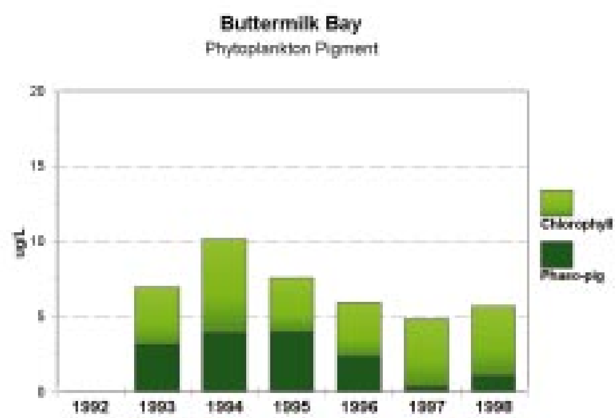


Over the monitoring period, Little Buttermilk Bay has consistently exhibited higher concentrations than Buttermilk Bay of TN (0.517 mg N/L (SE=0.023) vs. 0.426 mg N/L (SE=0.013)), particulate organic carbon (1.23 mg C/L (SE=0.10) vs. 0.88 mg C/L (SE=0.06)), and chlorophyll a pigments (8.7 ug/L (SE=1.2) vs. 7.3 ug/L (SE=0.6)). The higher TN (21%), POC (39%), and pigment (19%) levels result from the additional nitrogen loading from the Little Buttermilk Bay watershed. Higher levels of these constituents in the inner reaches is typical of embayments with restricted inlets and whose freshwater input is dominated by groundwater. These higher levels are consistent with the greater oxygen depletions and generally slightly lower eutrophication index scores for the inner versus outer basin. Since this relationship is primarily the result of embayment structure, Little Buttermilk Bay should serve as the "worst-case" or most nutrient sensitive region of the greater Buttermilk Bay System.

Management Needs

The Buttermilk Bay System is one of the few embayments to Buzzards Bay where significant management practices for protection and improvement of system health have been implemented. As a result it appears to be a system which may be



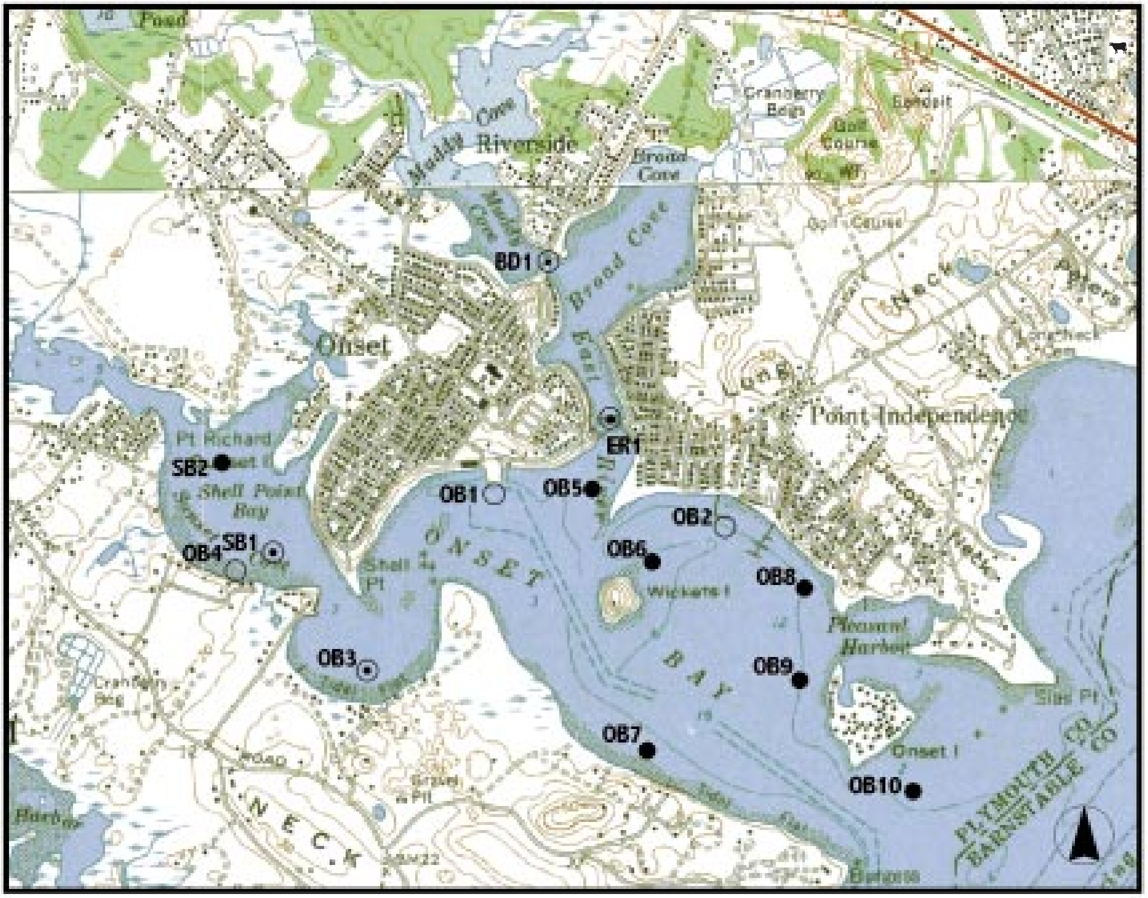


increasing in habitat quality, counter to the trend in much of the regions embayments.

Buttermilk Bay is the first embayment to Buzzards Bay where the nitrogen loading limits proposed by the Buzzards Bay Project have been adopted and where detailed mass loading evaluations have been performed. In order to protect the Bay from nutrient overloading, the towns of Wareham, Plymouth, and Bourne "reprogrammed" future growth in 1991 through zoning changes aimed at reducing the number of homes (primarily septic systems) in the watershed so that recommended nitrogen limits would not be exceeded. Further, remediation of existing nitrogen loading resulted from sewering of several densely developed nearshore areas by the Towns of Bourne and Wareham. The sewering resulted from the need to protect public health as septic systems failures were occurring in these areas. However, the collateral result was likely the current trend of improving nutrient related water quality observed in both Buttermilk and Little Buttermilk Bays. Further monitoring needs to be conducted in order to determine the extent and duration of the apparent water quality trend. If improvement continues, Buttermilk Bay should serve as a model of restoration for other embayments in South Eastern Massachusetts.

Onset Bay

Wareham



the watershed includes primarily high unit density in residential land-use with considerable commercial development along Cranberry Highway. Runoff from these areas is a significant source of pollution, causing shellfish bed closures and in some regions there are restrictions to herring migration. The single golf course within the watershed, Little Harbor Golf Course, sits on the watershed divide and partitions its nitrogen load from fertilizer usage between Onset Bay and the adjacent open Bay waters.

Embayment and Watershed Characteristics

Onset Bay is located near the head of Buzzards Bay and adjacent to the major channel to the Cape Cod Canal. This places Onset Bay within the mixing zone of two high quality waters, Buzzards Bay and southern Cape Cod Bay (via the Canal). Onset Bay is a shallow (average 2 meters) embayment but with moderate flushing, water quality is good except for the upper and inner portions of the estuary—Broad Cove, Muddy Cove and Shell Point Bay. These inner areas of the Bay are bordered by dense residential development and/or wetlands. Shellfishing within these shallow coves is on a Conditional basis, with closures after heavy rainfall. Unlike many similar embayments with more developed watersheds, eelgrass is still present in isolated beds throughout the estuary with the exception of Muddy Cove on the north end of the system and Sunset Cove at the west end.

The outer region of the embayment (central region of Onset Bay) maintains a dredged "deepwater" channel and good exchange with the low nutrient offshore waters. The Bay supports a Town Pier, almost 800 boat moorings and slips, several marinas, 4 pump-out dock facilities and 1 pump-out boat, and 6 public beaches. The shoreline also has many motels, restaurants and multifamily dwellings and is a popular tourist location. Similarly,

In 1997 the town of Wareham began construction of surface water management facilities to treat runoff from a densely developed sub-watershed and to mitigate 14 discharges from the Point Independence and Riverside areas to improve the water quality of receiving waters and reduce shellfish bed closures. The stormwater projects were paralleled in 1997 and 1998 by extension of sewer service to many densely developed neighborhoods along the Broad Cove and Muddy Cove shorelines such as the Point Independence area. These sewer projects have reduced the nitrogen load to Onset Bay, likely with long-term positive effects to the Bay system (particularly the inner regions). Sewering is a common approach to nitrogen mitigation for restoration of coastal embayments, but caution must be taken to prevent transferring the problem to another watershed as occurred in West Falmouth Harbor in the mid-1980's (which is now in need of its own reduction in nitrogen loading). The sewering within the lower Buttermilk Bay watershed and the Onset area presently transfers this wastewater nitrogen loading to the Wareham Waste Water Treatment Facility (WWTF). This WWTF discharges secondarily treated effluent (with limited nitrogen reduction) to the Agawam River which flows into the Wareham River Estuary. Nitrogen loading evaluations of this receiving embayment are currently underway as part of a planned upgrade of the WWTF. The goal of these evaluations are to manage nitrogen related water quality within the Wareham River Estuary as related to nitrogen loading from its watershed and the various sewered areas which currently contribute to this system. Since the WWTF will be upgraded, nitrogen removal designs can be added as required to achieve sustainable environmental quality (see Wareham River Estuary text).

Only about 4% of the watershed area is agricultural, mostly cranberry bogs (ca.100 acres or 75% of all agriculture). In addition, 266 acres, or 8%, of the watershed is permanently protected as open space. Much of this land is owned by the Onset Water District which maintains public drinking water wells in the area around Sand Pond between Route 495 and Cranberry Highway. However, the Onset watershed has proportionately less undeveloped forested area then most of the sub-watersheds to Buzzards Bay.

Water Quality

Onset Bay is one of the more subdivided embayments to Buzzards Bay with at least 7 sub-bays and coves. As a result a proportionately high number of monitoring stations were required to characterize this Bay. Overall, the Onset Bay System supports high water quality and nutrient related habitat health. Only the shallow innermost embayments, Shell Point Bay and Muddy Cove, show modest water quality degradation. This high overall water quality seems intuitively contradictory given the watershed's high density of development and low acreage of forested land. However, at least 4 mechanisms help to maintain the water quality of this Bay. First, while the watershed is densely developed, recent sewering is transporting a portion of the associated nitrogen, which otherwise would be impacting the bay, to another watershed. Second, although the watershed is relatively densely developed, it is proportionately small compared to most other embayments on the

BAY HEALTH INDEX

- Good to Excellent (65 - 100)
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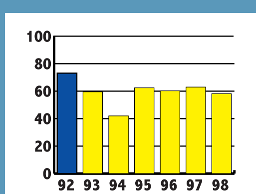
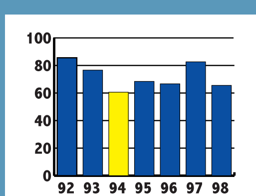
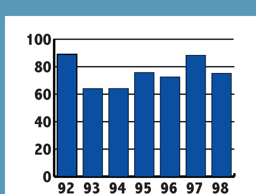
Shell Point Bay

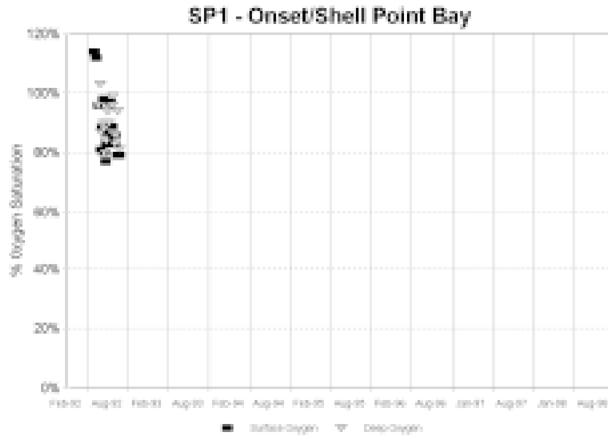


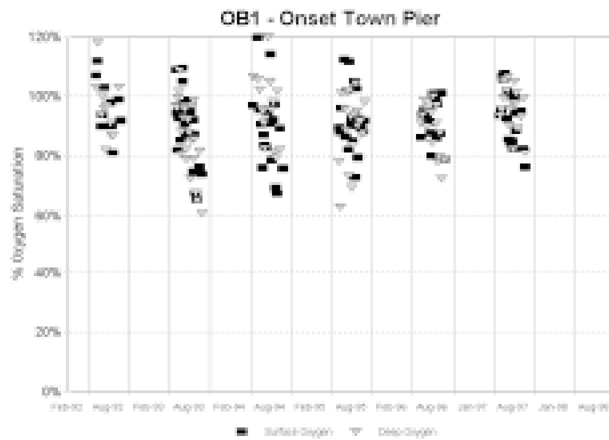
Onset Bay, Inner

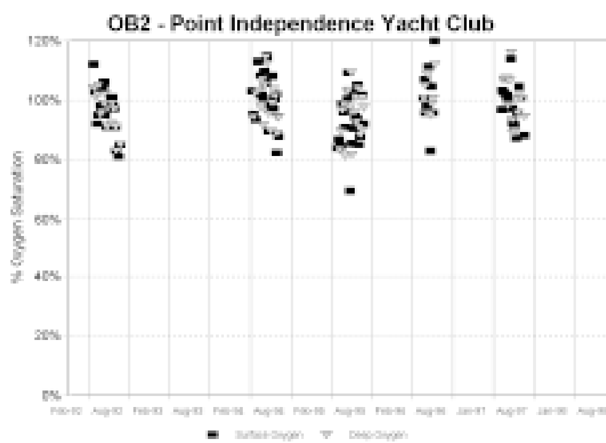


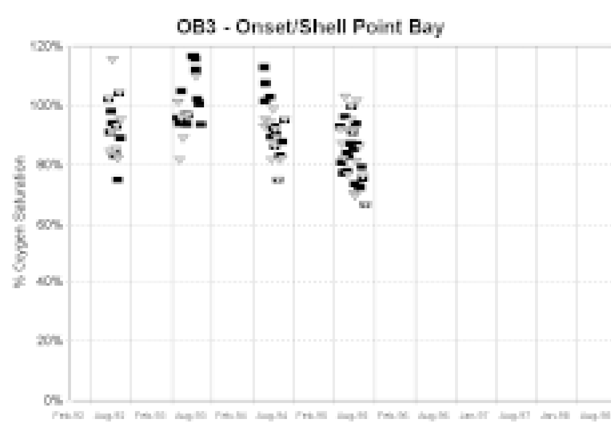
Onset Bay, Outer

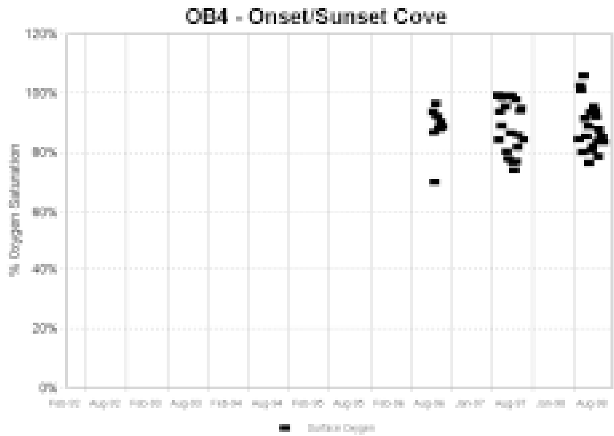


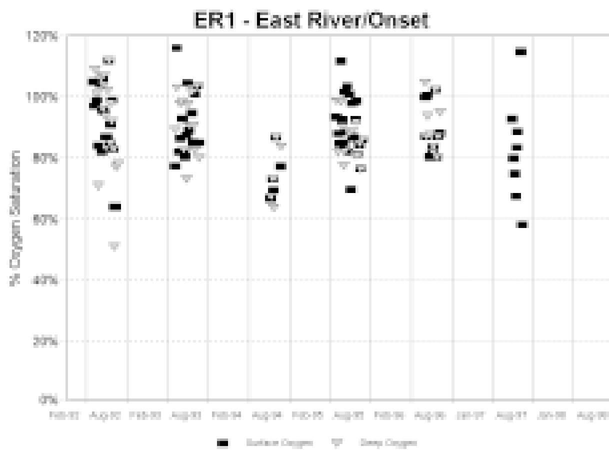


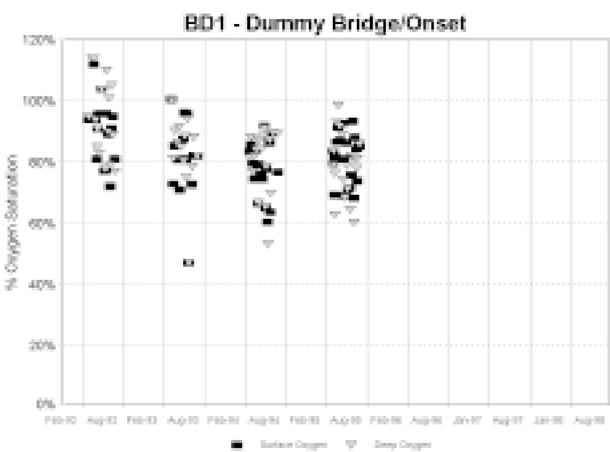


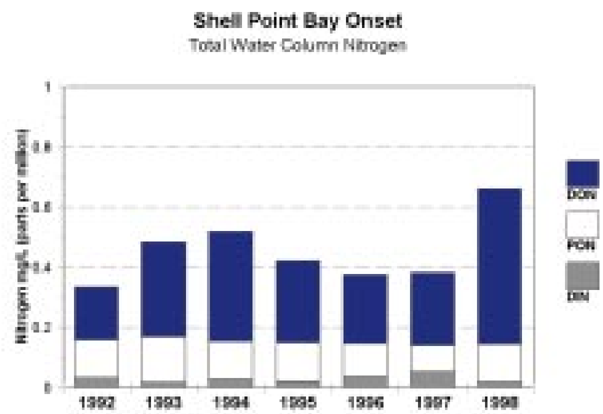


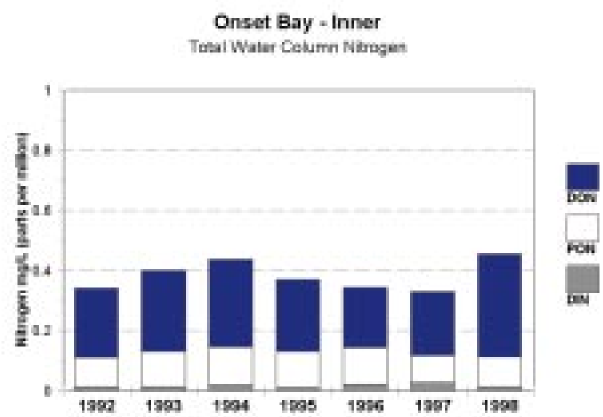


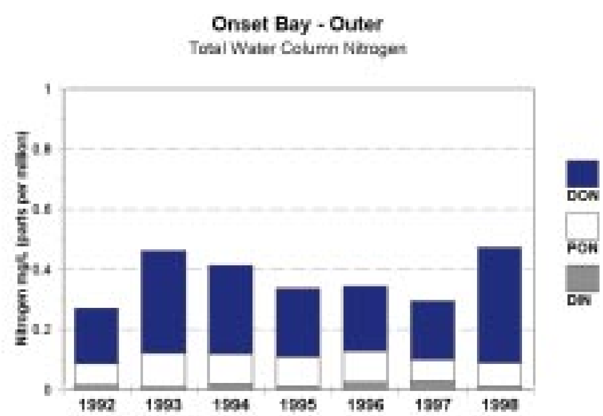






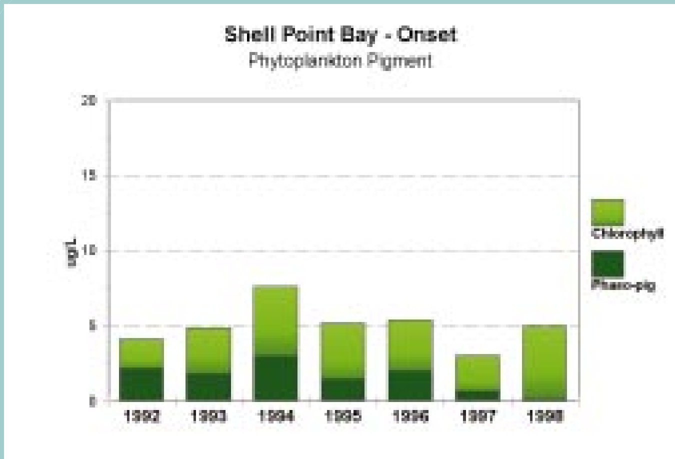


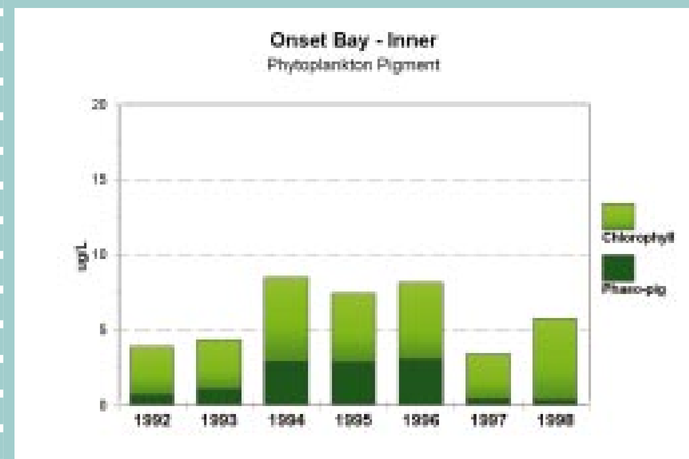


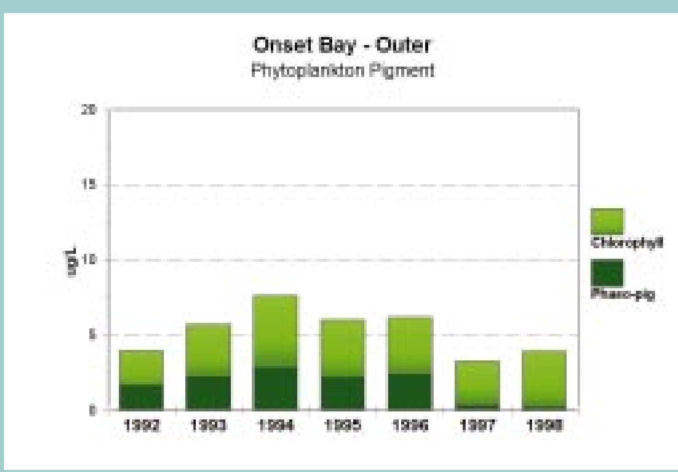


western side of Buzzards Bay. Third, Onset Bay is located at the mixing zone of the high quality waters of Buzzards Bay and Cape Cod Bay. The different tidal elevations on either side of the Canal generate high tidal current velocities which can reach 4 knots during Spring Tide. Fourth, Onset Bay has no major river discharge and therefore tends to have a more diffuse input of terrestrially derived nitrogen and is less capable of developing water column stratification which helps to maintain bottom water oxygen levels. This lack of river discharge can be seen in the absence of a strong salinity gradient from the Bay mouth to the inland shallow coves, average 30.8 ppt and 29.5 ppt respectively.

Nitrogen and chlorophyll a levels within the Inner and Outer portions of Onset Bay were similar throughout the study period reflecting the relatively well flushed conditions. Conditions within the Bay suggest only a modest elevation over the adjacent marine source waters. Only the shallow semi-enclosed waters of Shell Point Bay showed significant elevations in nitrogen, indicative of both its lower tidal exchange and it being the focus of terrestrial inputs. In addition, given the tidal wetlands bordering this sub-Bay, some level of nitrogen enhancement might be expected. However, chlorophyll a levels were not enhanced in this Cove over Onset Bay proper. The critical water quality parameter for Onset Bay was bottom water oxygen. As expected from the nutrient parameters and the flushing characteristics, Onset Bay proper (Inner and Outer) maintained relatively high oxygen levels within the bottom waters. In the more than 100 samplings no stressful oxygen conditions were observed. Even in







the inner-most portions of the Bay, Muddy Cove and Shell Point Bay, significant oxygen depletions were relatively rare and stressful levels were only observed in the Muddy Cove/Broad Cove region. Even in this portion of the Bay, only 4 dates over the sample period showed stressful oxygen depletions. All of these parameters support the persistence of eelgrass beds and the production of shellfish within this system.

The health index scores for this Bay are generally high as would be expected from the base parameters. Even in the inner regions which are showing moderate water quality degradation, the scores are approaching the "high quality" index values. While this system is showing only moderate levels of nutrient impact on its ecological health, further nitrogen loading reductions resulting as the effects of recent sewering are felt by the bay (based upon the groundwater travel times) and through additional nitrogen management would likely cause improvements within the upper portions of the system. Unlike many embayments in the western watershed of Buzzards Bay, the Onset Bay System has the potential to avoid further degradation with only modest investment. With nitrogen management the Onset System should improve and a high quality environment be sustainable well into the next century.

Management Needs

Shell Point Bay, Sunset Cove and the East River/Muddy Cove areas of the greater Onset Bay system are currently the most sensitive areas in the bay to increasing nitrogen loading and should be the focus of nitrogen management in Onset Bay. This natural characteristic of these areas makes them less capable of assimilating nitrogen loading from their surrounding watershed and more susceptible to the effects of eutrophication. Given that they appear to be only slightly degraded, nitrogen management should have discernible positive effects.

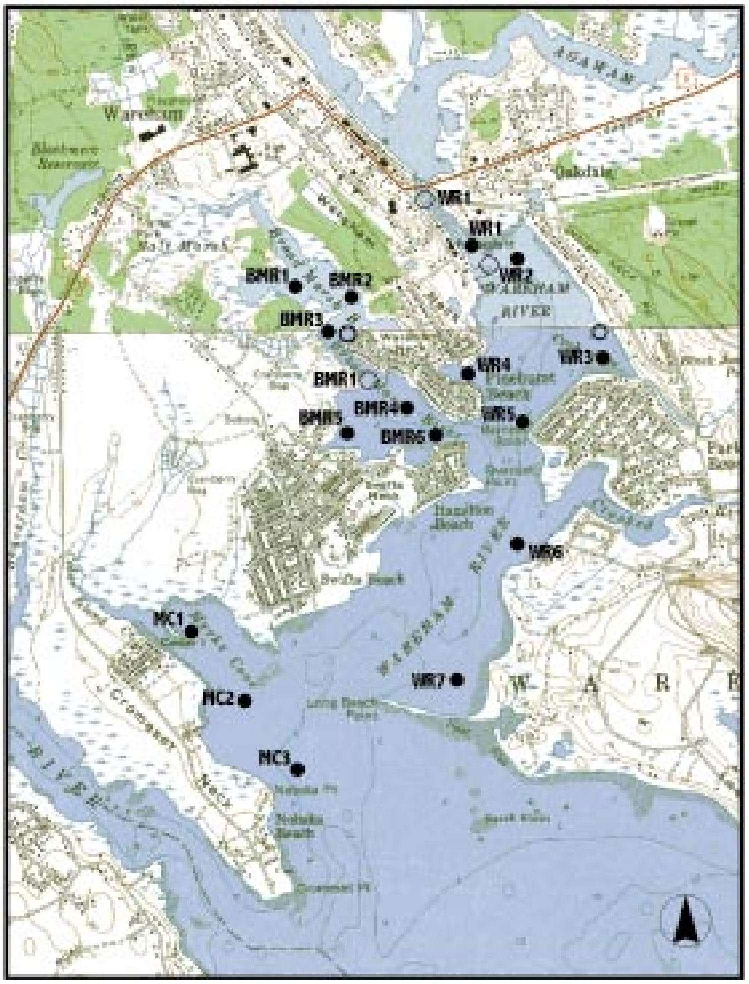
Onset Bay has the capability to control discharge of boat wastes more than most other Massachusetts bays and harbors. While boat discharges directly into bay waters typically represent a very small source of nutrients, they can be very important sources of toxic and bacterial contamination. Of the nearly 800 slips and moorings in Onset Bay, the vast majority are summer usage and generally occupied only a few days per week. The availability of the 4 pump-out dock-side facilities and pump-out boat within the harbor allows for the reduction of boat discharges to zero in this system. Boat owners should be strongly encouraged to make use of Pumpout facilities to remove entirely this source of contaminants to Bay waters.

Nitrogen management within the watershed should be conducted to preserve and improve the Bay. New development within the inner watershed should be reviewed for discharge through the Town's wastewater treatment facility, instead of use of on-site systems. The goal should be to prevent further nitrogen loading to the inner regions of the Bay. Although the Little Harbor Golf Club is privately owned, the Town should work with the club owner to develop programs to reduce fertilizer applications and minimize runoff of nitrogen into the Bay. In addition, the Town's stormwater runoff program should continue to identify and mitigate remaining discharges to the Harbor System, particularly in beach and shellfish areas. Where possible, stormwater runoff should be controlled by vegetated swales or engineered wetlands that remove nutrients as well as other contaminants. Rapid infiltration basins, though the only option in some areas, do not remove the nitrogen load from stormwater but focus on bacteria removal.

Onset Bay has one of the more densely developed watersheds and concomitantly lowest undeveloped forested areas within the Buzzards Bay watershed. For nitrogen management as well as open space benefits to the public, it is prudent to investigate protection of open space, particularly in the Point Richard area along Shell Point Bay and Sunset Cove and within the drinking water supply area adjacent to existing Onset Water District lands.

Wareham River Estuary

Wankinco, Agawam, Broadmarsh Rivers & Marks Cove



River discharges at the mouth of the Wareham River Estuary. The Weweantic River is the largest river within the Buzzards Bay watershed, contributing about 13% of the total freshwater inflow. The combined flow of the three rivers makes the Wareham River Estuary (and Weweantic Estuary) subject to the greatest surface freshwater inflows of all of the sub-embayments to Buzzards Bay. Within this relatively small region is about one-quarter of the total freshwater inflow to the Bay. The effect of this high level of freshwater discharge is reflected in the lower salinities within the Wareham River Estuary and the freshwater influence even at the system's entrance to Buzzards Bay (average salinities: Agawam River <4 ppt (upper-AG1) and 16 ppt (lower-AG2), Upper Wareham River= 23 ppt, Lower Wareham River= 25 ppt, Outer Marks Cove= 28 ppt, Weweantic at Cromeset Pt.= 23 ppt). The influence of the Weweantic River discharge would help to explain the weak salinity gradient within the mid to lower reaches of the Wareham River and the lower salinities in Marks Cove (Inner and Outer=28 ppt) compared to the mouth of adjacent Onset Bay with salinities of 31 ppt, typical of Buzzards Bay waters.

The nutrient related water quality within an embayment is the integration of the rate of nitrogen inputs from the surrounding watershed and the rate of loss through tidal exchanges. In addition, the higher the quality of the incoming tidal waters, the greater the dilution of the watershed nitrogen load and the higher the nutrient related health of the embayment. Most of Buzzards Bay's embayments are flooded with high quality, low nutrient Buzzards Bay waters, a fundamental mechanism in maintaining their generally good water quality. However, as the level of nutrients within the incoming tidal waters increases, the nutrient related health of a receiving embayment decreases, even if its watershed loading remains unchanged (see Slocums & Little Rivers). It appears likely that since waters from both the Wareham and Weweantic Rivers discharge to and are flooded from a common outer embayment, their water quality is linked by the tides. It is nearly certain that outflowing nitrogen enriched waters from these adjacent systems mix and a portion of their nitrogen load re-enters the Wareham River Estuary with the incoming flood tidewaters from the Bay. Therefore, management of nutrient related water quality within the Wareham River Complex needs to consider possible inputs from the Weweantic River as well as from its own watershed.

The Wareham River Complex's drainage basin, at 28,400 acres, is the third largest in Buzzards Bay. Land uses in the lower watershed include densely developed residential and commercial areas, while the upper watershed is lightly developed with the major developed land-use being cranberry agriculture. However, the majority of the watershed remains in undeveloped forestlands. Cranberry bog acreage in the Wareham River watershed is the second highest use, covering about 2,530 acres–containing 1,672 acres of agricultural bog surface, or 6% of the watershed land area. The adjacent

Embayment and Watershed Characteristics

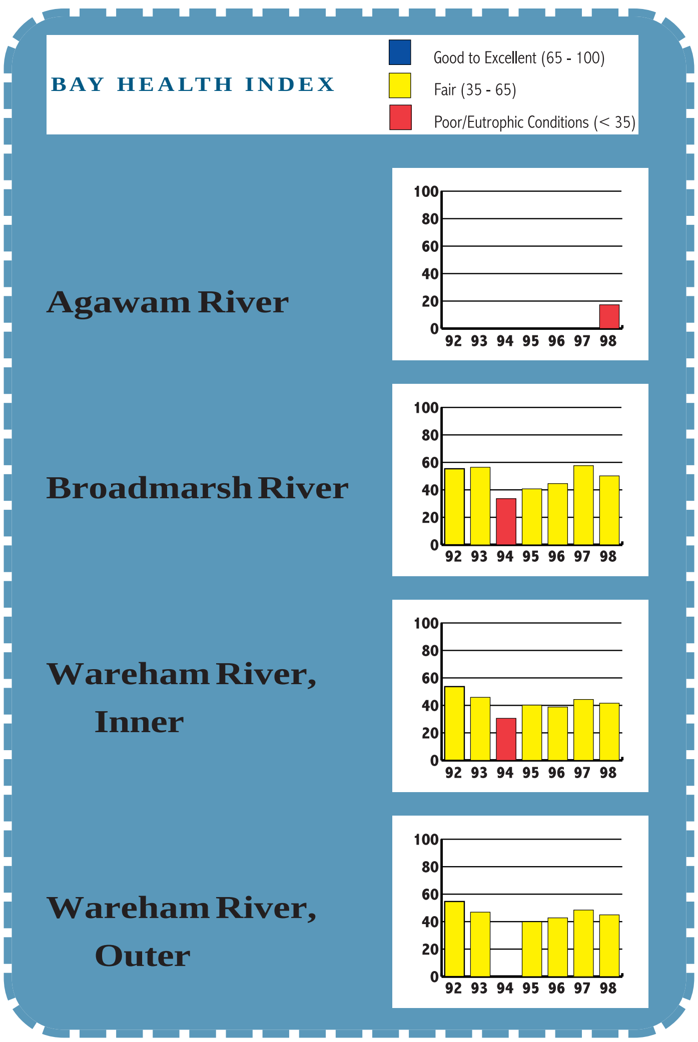
The Wareham River Complex is a drowned river estuary fed at its northern end by two major rivers, the Wankinco and Agawam, which are tidal in their lower reaches and merge to form the tidal Wareham River. The lower portion of the Wareham River Estuary includes Broad Marsh River, Crab Cove, Crooked River and Marks Cove. The mouth of the Estuary is at Long Beach Point and Cromeset Point at the tip of Cromeset Neck which separates the Wareham River Complex from the Weweantic River System. The embayment is relatively shallow (mean depth 1 meter) and of moderate size at 729 acres (Wareham River: 615 acres, Marks Cove: 114 acres).

The Wankinco and Agawam Rivers, which drain the western and eastern portions of the upper watershed respectively, are among the largest rivers discharging to Buzzards Bay, contributing almost 10% of the Bay's freshwater inflow. Both Rivers are freshwater to their control weirs at Route 28 and are tidal below. In order to manage coastal and estuarine water quality in the Wareham River system, the watersheds for both rivers must be evaluated in aggregate. In addition to the Wankinco and Agawam Rivers, the Weweantic

Weweantic River watershed has the most cranberry production of any watershed in the Buzzards Bay basin at 4,688 acres (source: Cape Cod Cranberry Growers Association).

The Wareham River watershed leads the entire Bay area in acres of permanently protected open space, 10,826 acres or 36.37% of watershed. Much of this protected land is located in the upper watershed within the Myles Standish State Forest. In fact, 65% of the 14,651 acre State Forest lies within the Wareham River watershed. These lands are an important factor in reducing potential future increases in nitrogen loading to the estuary.

Homes along the densely developed western shore of the Wareham River from Swifts Beach to Route 6, including most of Broad Marsh River, are served by municipal sewer. The remaining homes in the watershed rely on individual, on-site septic systems. The major point source of nitrogen in the watershed is the Wareham Wastewater Treatment Facility (WWTF) which discharges 1 MGD (million gal./day) of secondarily treated effluent (minimal nitrogen removal) to the Agawam River south of Route 6 and accounts for about one-third of the total watershed nitrogen load (Buzzards Bay Project 1998). This treatment facility is slated to be up-graded and additional studies are currently being conducted to ascertain its role in the water quality within the Wareham River Estuary. While some of the nitrogen load from this WWTF originates outside of the watershed to the Wareham River Complex, the removal of nitrogen loading from adjacent watersheds by sewering has been important to the nutrient related health of other embayments within the Town of Wareham (for example, Buttermilk Bay).



Results of the Citizens' Water Quality Monitoring Program indicate that this estuary is showing nutrient related water quality declines. Like many of the embayments to Buzzards Bay, the level of decline is greatest in the upper regions, where most of the land-based nutrients enter. Water quality improves farther down the estuary towards the mouth, where exchange with the high quality Buzzards Bay waters occurs. Due to the structure of the estuary, there is a clear shift in water quality from the upper (above the Sandwich Road/Route 6 Bridge) vs. lower (main basin) regions. The eastern branch of the Upper Wareham River Estuary, the tidal reach of the Agawam River, is one of the more heavily nutrient loaded estuarine regions within Buzzards Bay. The tidal reach of the Agawam River receives nutrient inputs both from the surrounding watershed and from regions outside of the watershed, imported via the Wareham Wastewater Treatment Facility. This upper region of the estuary is showing poor nutrient related habitat quality, the lowest within the Wareham River Complex.

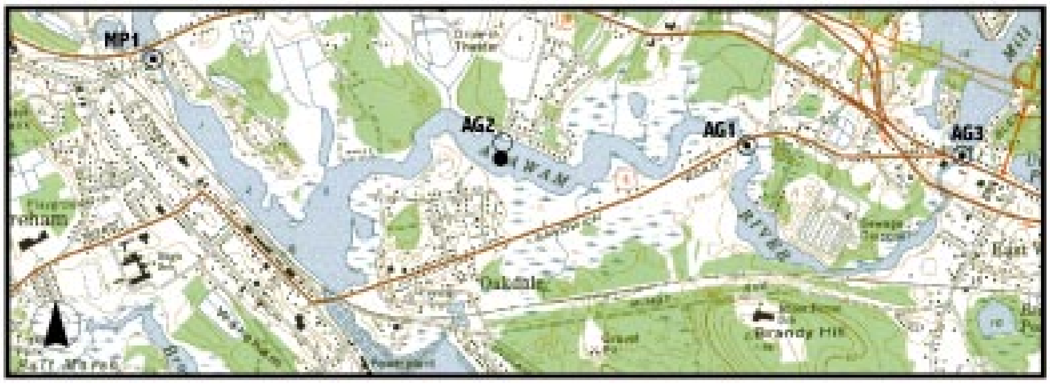
The Wareham River Complex supports approximately 291 acres of saltmarsh, most of which borders the Agawam and Broad Marsh Rivers and Marks Cove. Also of major importance to the water quality of the estuary is the large fresh surface water resources within the watershed. The large network of ponds and freshwater wetlands provides a means of nutrient retention within this watershed not present in more groundwater-dominated watersheds. Eelgrass surveys and mapping by the Massachusetts DEP Wetlands Conservancy Program in 1996 show eelgrass beds almost totally absent from the Wareham River estuary. Historically, eelgrass populations existed in dense beds outside of Long Beach Point with less dense beds within the lower estuary up to the mouth of Broad Marsh River.

The Agawam River currently supports one of the most prolific herring runs within Buzzards Bay. The herring spawn within the freshwater upper regions of the estuary (north of dam to Halfway Pond in Plymouth). Both the systems maintain fish ladders, although the Wankinco ladder appears much more difficult to transit than the stream approach at the Agawam. The Wareham River Estuary also maintains shellfish harvests. Most of the Wareham River is approved for harvest, however significant areas of the upper estuary are restricted due to bacterial contamination.

The embayment supports important recreational activities, primarily within the lower estuary. At present there are 4 public beaches and moorings and slips for 486 boats (primarily below the Sandwich Rd. Bridge). There are ample facilities for off-loading boat waste including a pump-out boat, dockside facility, and waste dump facility located at Warr's Marina.

Water Quality

The whole of the Wareham River Complex appears to be nitrogen enriched and experiencing a moderate to high level of nutrient related water quality decline. Unlike many embayments to Buzzards Bay which are dominated by nitrogen loading from their watersheds, the Wareham River Complex appears to have additional loading from "external" sources via sewering and the Wareham Wastewater Treatment Facility and through likely tidal inflows of Weweantic River waters.



Total nitrogen concentrations in the Inner (south of Sandwich Rd. Bridge) and middle (adjacent Wareham Neck) portions of the Wareham River were moderately high, 0.57 mgN/L (SE=0.02; Standard Error is a measure of variability of samples contributing to the average) and 0.54 mgN/L (SE=0.03) and showed little variation over 6 of the 7 years of study. The Outer portion of the Wareham River (Crooked River mouth to Long Beach Point) showed more variable nitrogen levels than the inner portion, but tended to be only about 10% lower than the inner areas (0.51 mgN/L, SE=0.003), due to dilution with flood tidal waters. In fact there is a notable lack of a strong nitrogen gradient within the entire system. Both upper and lower Broad Marsh River (0.53 mgN/L, SE=0.013; 0.52, SE=0.014) and upper and lower Marks Cove (0.50 mgN/L, SE=0.030; 0.45, SE=0.017) showed elevated nitrogen levels. On average, the range of total nitrogen found within the Wareham River from the Sandwich Rd Bridge to Nobska Point at the outermost portion of the estuary was only 0.57 mgN/L to 0.47 mgN/L with almost all measurements above 0.5 mgN/L. This distribution is despite the high total nitrogen levels within the Wankinco (0.64 mgN/L) and Lower Agawam (1.05 mgN/L) and low levels in central Buzzards Bay (<0.30 mg N/L).

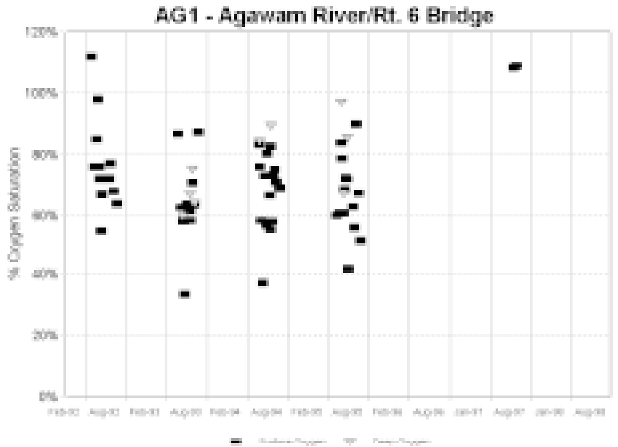
The lack of a strong horizontal gradient supports the likelihood of additional nitrogen loading from the inflowing tidal waters. If inflowing waters were unenriched Buzzards Bay waters, Outer Marks Cove concentrations would almost certainly be below what was typically observed. The average Weweantic River water near its mouth is 0.42 mgN/L (SE=0.03) which further supports this mixing hypothesis.

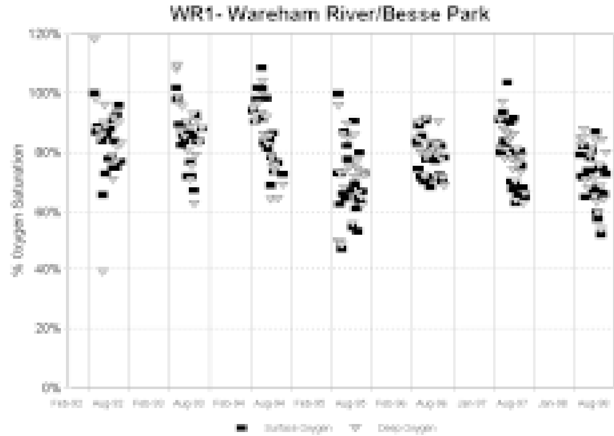
While there is more inter-annual variation in the chlorophyll a pigment concentrations, the average conditions show a nearly identical pattern to total nitrogen. The short-term variation in the pigment data reflects the periodic blooms which occur within this nutrient rich estuary. The phytoplankton pigment results indicate high levels throughout the Wareham River Estuary and similar to total nitrogen, little horizontal gradient was observed. While the levels were high, the range of chlorophyll was small; the upper to lower estuary, including Broad Marsh River and Crab Cove, averaged 10.1 ug/L (SE=0.9) to 7.8 ug/L (SE=0.1). Upper and lower Marks Cove showed similar levels to the Wareham River proper, 8.5 ug/L (SE=1.0) and 6.8 ug/L, respectively. Levels of chlorophyll a pigments within the Wankinco River were similar to the upper Wareham River, but the Agawam River had extremely high chlorophyll a concentrations associated with the WWTF. Chlorophyll concentrations were 31 ug/L (SE=0.8) and 51 ug/L in the two stations in the immediate downstream reaches of the Agawam River. These levels result from the stimulation of phytoplankton production within the Agawam by nutrient discharges from the WWTF. The large proportion of the plan pigment found as chlorophyll a (mean 82%, maximum of 100%) is consistent with the contention that the measured phytoplankton pigments were produced within the Agawam, rather than entering with the freshwater from the upper watershed. It is important to note that based upon available data (Agawam nutrient sampling is only for 1997 & 1998), the high nitrogen and chlorophyll a levels are only observed within the Agawam River between the WWTF and the confluence with the Wankinco River.

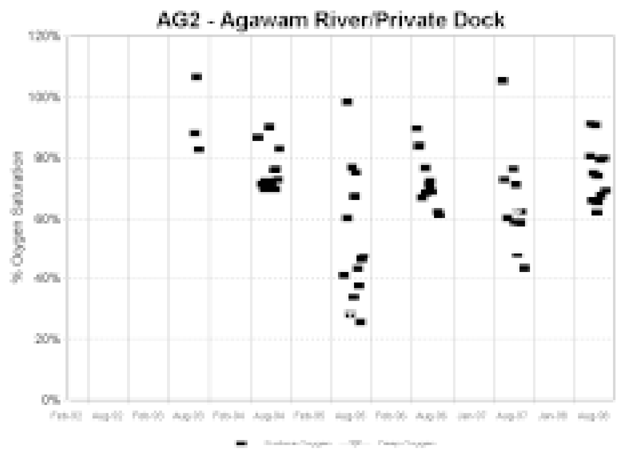
Watercolumn particulate organic carbon appears to be primarily from phytoplankton produced within the estuarine complex. This organic carbon is the source material for respiration within the watercolumn and sediments which underlies oxygen depletions. The distribution of particulate carbon concentrations follows that of the nitrogen and chlorophyll a concentrations from which it is derived. Levels within the entire Complex from the Wankinco River to Broad Marsh River and Marks Cove averaged from 1.14 mgC/L to 0.99 mgC/L with no clear gradient. Only at lower Marks Cove was the influence of tidal exchange beginning to be observable, 0.83 mgC/L (SE=0.04). The Agawam River samples were more than two fold higher than found within the rest of the estuary, 2.44-2.90 mgC/L, again demonstrating the localized high enrichment from the WWTF discharges.

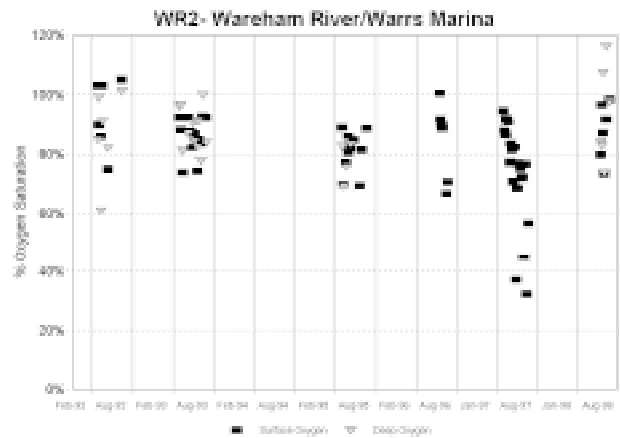
There was a consistent pattern within the inter-annual results. The three constituents of total nitrogen (dissolved inorganic, dissolved organic, and particulate organic) and chlorophyll a all reached maxima in the 1994 sampling, indicating the lowest nutrient related water quality in that year. The consistency between upper and lower estuary nitrogen and chlorophyll values suggest that a "real" event occurred, possibly related to higher effective nitrogen loading such as runoff or reduced flushing. At present the reason for this 1994 maxima is unclear. Regardless of the cause, the 1994 season may reflect the "potential worst case" water quality conditions under present land-use and flushing conditions within the Lower Wareham River Estuary. The nitrogen levels within the estuary also reflect nitrogen loading from land, with levels almost two times the ambient levels within Buzzards Bay.

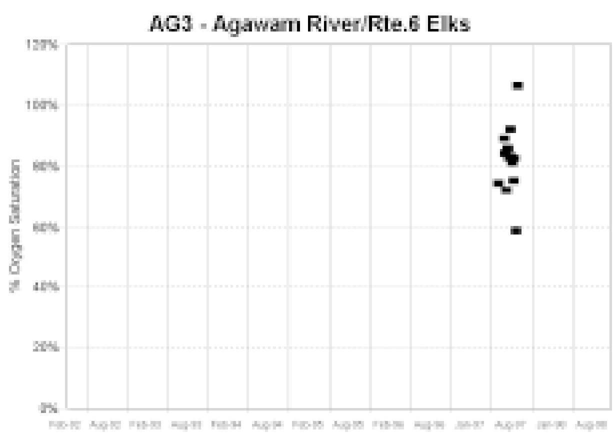
While the Agawam River portion of the Wareham River Estuary has not been monitored for nutrients until recently (1997), it is clear

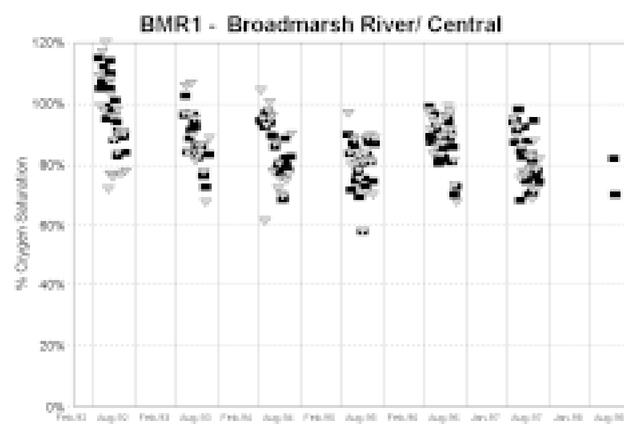












that land-based nutrient loadings (including the WWTF) are having a significant effect on both the nutrient concentrations (total nitrogen: 0.78-1.05 mgN/L) and chlorophyll levels (>30 ug/L). Both parameters reflect eutrophic conditions within this portion of the estuary. However, stressful oxygen conditions were only periodically encountered within the lower reaches of the Agawam River, with about 20% of samples below 60% of saturation, but only ca. 5% being below 40% of saturation. In contrast, moderate oxygen depletion appears to be the norm for the River stations with more than 75% of the samples showing oxygen levels below 80% of air saturation, suggesting a system with oxygen demand beyond its capability of resupply. The relationship between nutrient loading and low oxygen conditions is the major feature in determining the loading tolerance of this region of the estuary. The presence of chronic oxygen depletion and periodic declines to low oxygen levels indicates that the lower Agawam River is currently nutrient overloaded. These low oxygen levels likely result from three major sources. The largest source is related to the organic matter production stimulated by the high concentrations of available nutrients within the Agawam River. A second source of oxygen uptake in the oxidation of the high ammonium concentrations found below the WWTF in the River. Average ammonium concentrations were 0.23 and 0.15 mg N/L at the two stations in the lower reaches. The third source of oxygen uptake relates to the interactions between the River waters and the fringing salt marshes. While the marshes provide essential ecological functions to the River System (fish nursery areas, nutrient removal, erosion control, etc), they also serve as a source of organic matter. The decay of this organic input contributes to the oxygen uptake from the River waters. It is common for salt marshes to have oxygen depletion within their tidal creek waters.

Oxygen concentrations throughout the entire Wareham River (region below Sandwich Rd. Bridge) were generally only moderately depressed. Of the nearly 300 oxygen samples collected within the upper Wareham River and Broad Marsh River region of the estuary from 1992 to 1998, only 3 samples showed stressful oxygen levels (40% saturation) and only 19 showed moderately stressful levels (below 60% of saturation). However, almost half of the total samples were less than 80% of air saturation, indicating a system which is beyond its ability to assimilate additional nutrients without effecting oxygen conditions. Oxygen conditions within this region generally show lower levels than near the outlet to Buzzards Bay.

The major sub-components of the Wareham River Estuary, Broad Marsh River and Marks Cove, differ from many similar sub-embayments to Buzzards Bay, as their water quality is significantly dependent upon the quality of their adjacent tidal waters more than on their localized contributing watershed. Broad Marsh River enters into the mid region of the lower Wareham River Estuary, has a relatively small sub-watershed and extensive marsh area (per area of estuary surface), and is tidally restricted. In addition, its flooding waters are a mixture of both Wareham River (possibly Weweantic River) and Buzzards Bay waters. The result is that this small sub-embayment has nutrient, chlorophyll and oxygen levels reflective of the outer portion of the Lower Wareham River Estuary. This coupling is further demonstrated by the appearance in Broad Marsh River of the 1994 nutrient and chlorophyll maximum seen within the larger estuarine region. This indicates that the 1994 "event" was a system-wide phenomenon.

Marks Cove also mirrored the pattern of the larger estuary, but apparently was also influenced by its proximity to the outlet and likely to the Weweantic discharge as well. During the study period, total nitrogen concentrations varied within the inner Cove from 0.43 mgN/L to nearly 0.8 mgN/L. The trend of apparently increasing nitrogen levels seen in the 1992 to 1995 results is not supported by the additional sampling and underscores the need for long-term sampling to determine trends. Phytoplankton levels followed the patterns of the adjacent Wareham River Estuary. In addition, like the Wareham River, the highest average chlorophyll a pigment concentrations were observed in 1994, and approached the 15 ug/L observed in the upper estuary. Marks Cove supports the concept that nutrient enriched water is flowing into the Wareham River Complex on the flood tide. If not, the nutrient related water quality parameters measured within the mid and outer cove should better reflect the high quality Buzzards Bay waters. Instead, nitrogen and salinity levels within the Cove reflect Wareham River values.

Integrating the nutrient related parameters to derive the Health Index values indicates that the Wareham River, Broad Marsh River, Crab Cove and Crooked River have moderate nutrient related water quality. In addition, under the conditions of 1994, nutrient related water quality throughout the Wareham River Complex is poor. Because oxygen was not monitored in Marks Cove, Health Index scores are unavailable for that part of the Wareham estuary. In contrast, the limited data (1997-98) from the Agawam River indicates a poor level of nutrient related water quality within the reaches down stream from the WWTF discharge. Levels of chlorophyll within the Agawam River are typical of eutrophic (over-fertilized) coastal environments. Fortunately, the bordering saltmarshes are highly tolerant of high nitrogen flood waters.

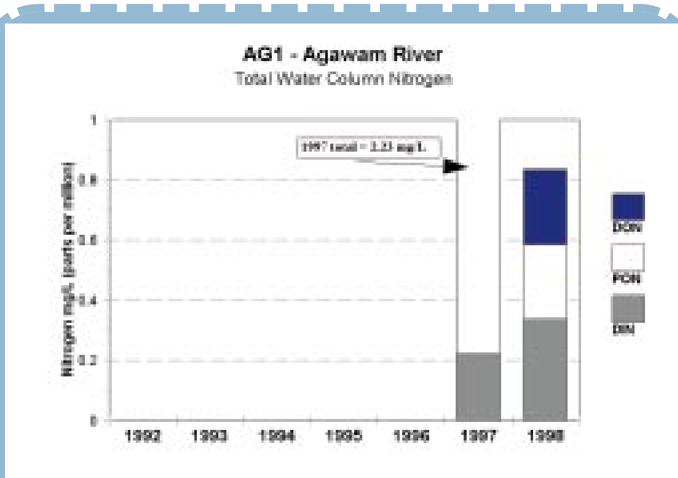
The effect of over-fertilization on animal and fish populations within this estuarine complex has not been quantified. Oxygen depletions were not always correlated with nutrient or chlorophyll a levels. This likely reflects the temporal lag between the input of nutrients to the growth of phytoplankton to their decay which causes the low oxygen levels. However, the levels of the nutrient related water quality parameters are consistent with the reduction and loss of eelgrass beds within the Agawam and Wareham River portions of the estuary. Based upon the available results it appears clear that nitrogen management of the Wareham River Complex requires an understanding of the role of the tidal source waters in addition to watershed loading in determining the level of nutrient related water quality.

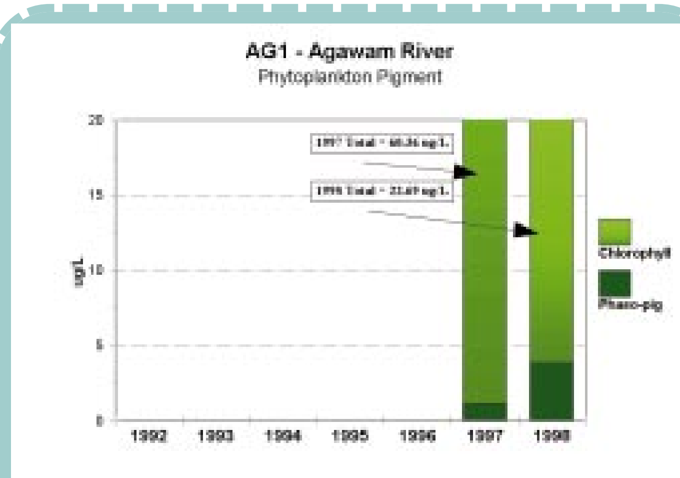
Management Needs

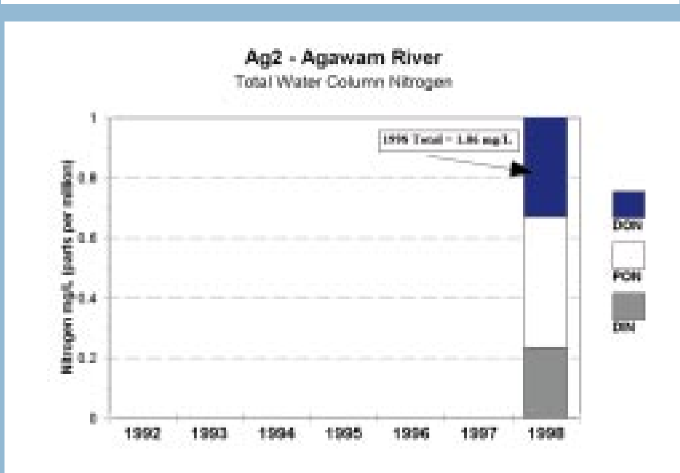
The Wareham River Estuary, relative to its large watershed, currently receives only moderate nitrogen loading. However, the estuary is currently showing moderate (lower region) to poor (Agawam River) nutrient related water quality which indicates the need for nitrogen management. Part of this management plan must include a better evaluation of this estuary's nitrogen loading tolerance and the role of watershed and tidally imported nitrogen. Nitrogen loading to the Wareham River estuary involves residential land-uses, the Wareham Wastewater Treatment Facility, and agriculture (cranberry bogs), closely followed by commercial and industrial development. In addition, it appears likely that since waters from both the Wareham and Weweantic Rivers discharge to and are flooded from a common outer embayment, their water quality is linked by the tides. It is likely that nutrient loading to the Wareham River includes some level of input from the Weweantic River. A comprehensive nitrogen management strategy must evaluate all of these sources in order to gauge the relative effectiveness of specific nitrogen remediation strategies.

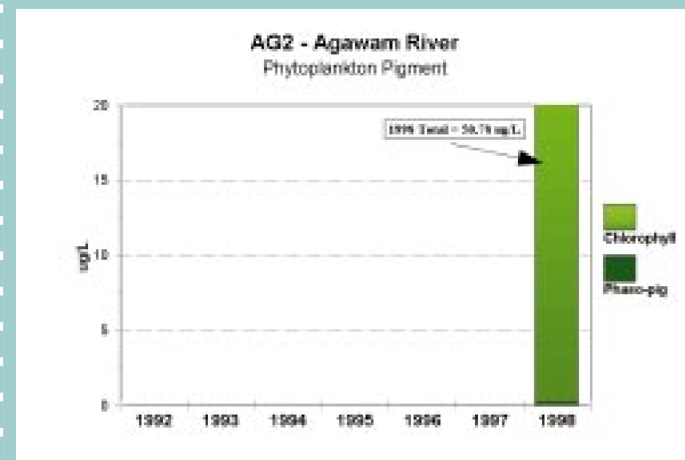
As of this writing, the Town of Wareham is in the midst of the discharge permit application process for the Town's Wastewater Treatment Facility (WWTF). The WWTF is also slated for an upgrade. Regulatory agencies responsible for issuance of the discharge permits - the US EPA and Massachusetts DEP – are evaluating new limits of nitrogen discharge as part of the plant's permit. The level to which nitrogen will be reduced at the facility and the relative proportion of future new loads originating from within versus outside of the watershed will be important factors in determining the long-term nutrient related environmental health of this estuary.

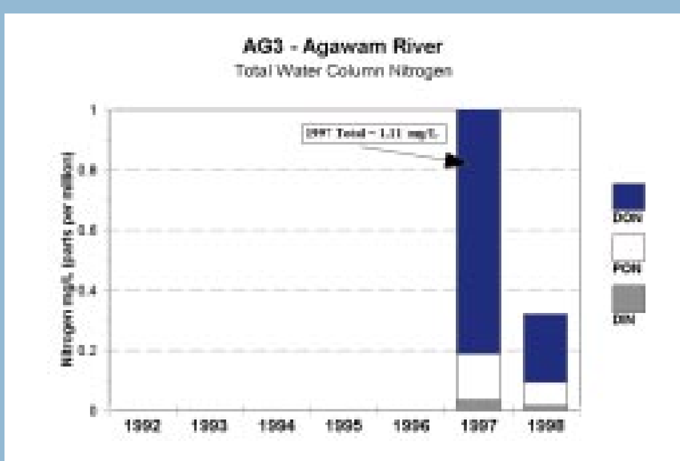
The Agawam River system periodically experiences phytoplankton blooms and moderate to low oxygen levels indicative of over-fertilization and degraded nutrient related water quality. The

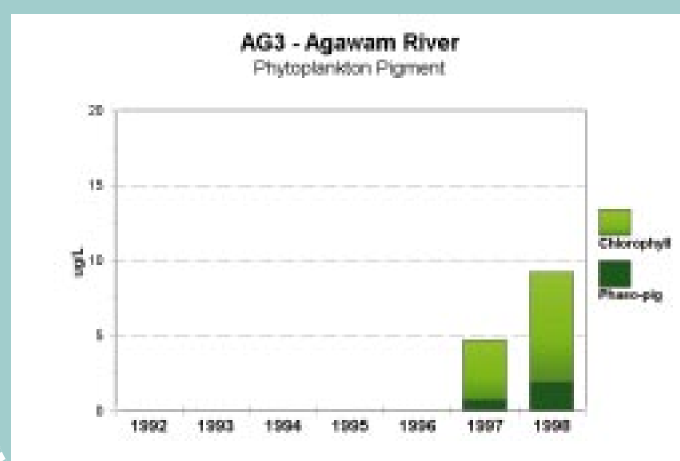




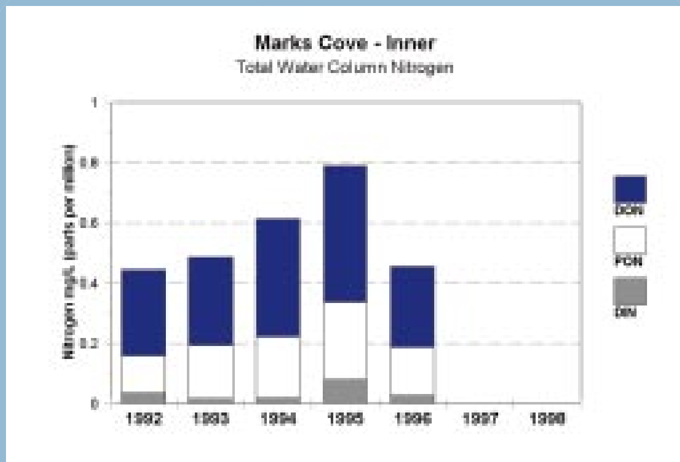


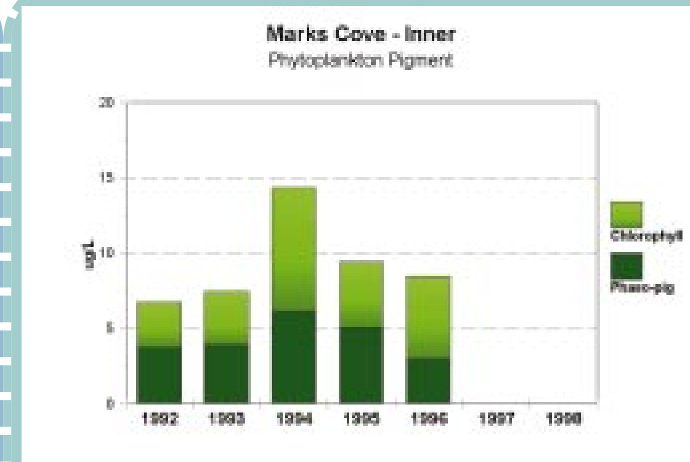


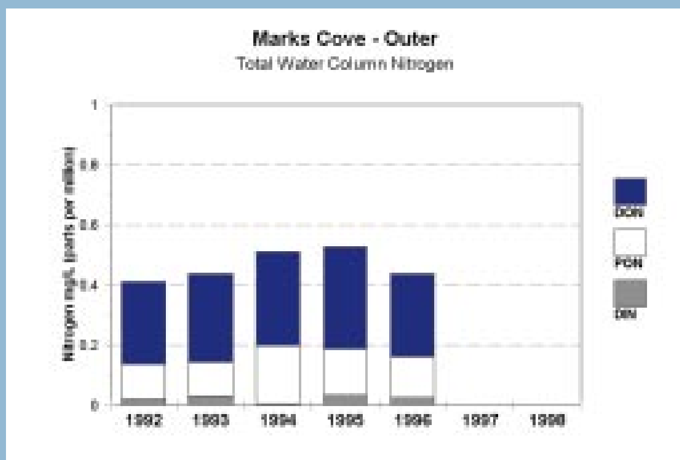


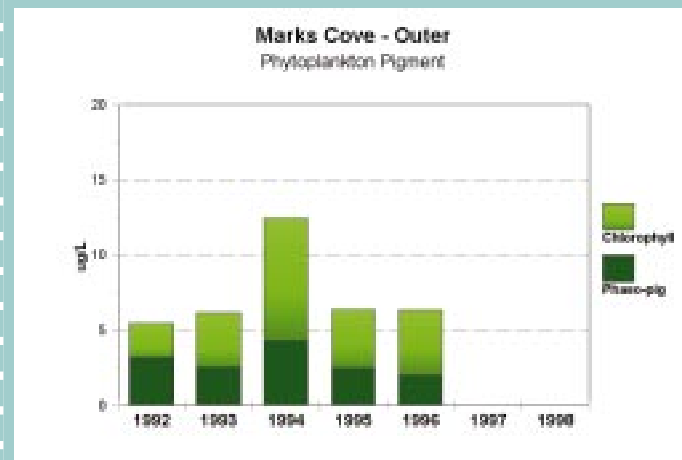


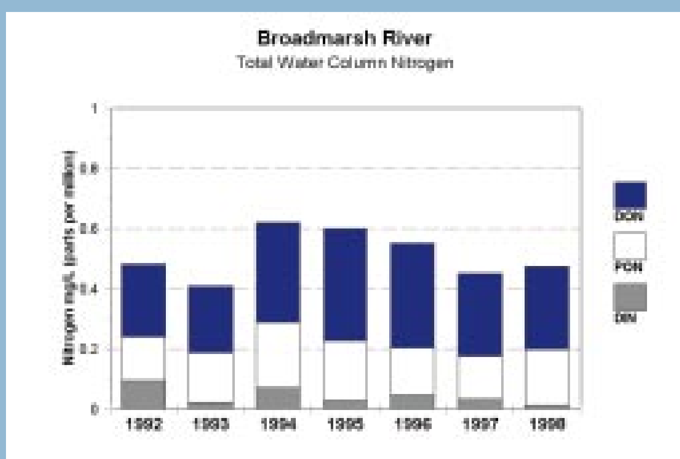
Wareham Wastewater Treatment Facility discharge is the largest point source of nitrogen loading to the Agawam River Estuary. However, estimates of nitrogen loading based on land-use, suggest that the River discharge originating in the upper watershed accounts for a similar magnitude of nitrogen load and acts as a functional point source discharge where it enters the tidal portion of the estuary. In addition to discharging nitrogen originating within the watershed to the Wareham River Complex, the WWTF also imports nitrogen from adjacent watersheds. Therefore this estuary is receiving nitrogen loading in excess of what occurs within its watershed. Currently the Facility does not treat its effluent to remove nitrogen. The upgrading of the Facility to include nitrogen removal capacity likely will be an important part of any strategy to reduce nitrogen loading to the Wareham system over the long-term. This will become an essential component as sewer service expands to import nitrogen from more areas of Town outside of the watershed. The issue addresses the central difficulty in nitrogen management. Sewering within the Weweantic River and Onset Bay watersheds to improve water quality and reopen shellfish beds merely transports the loading to a different estuary unless nitrogen reductions are instituted. If nitrogen removal processes are installed as part of the WWTF upgrade, the total loading to the estuary can be reduced if sufficient sources within the Wareham River watershed are connected to the Facility. It is even

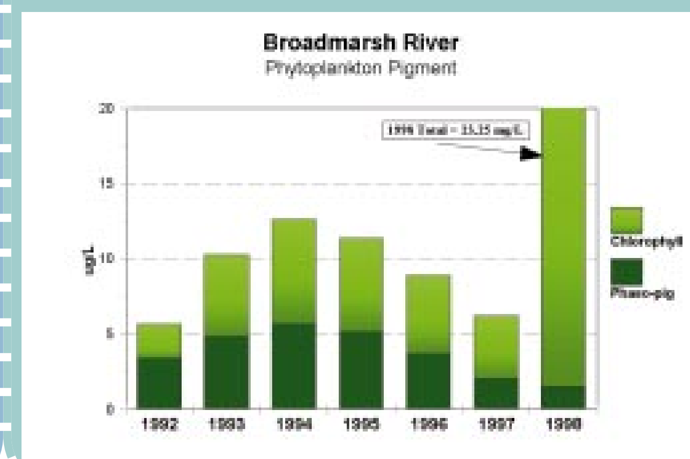






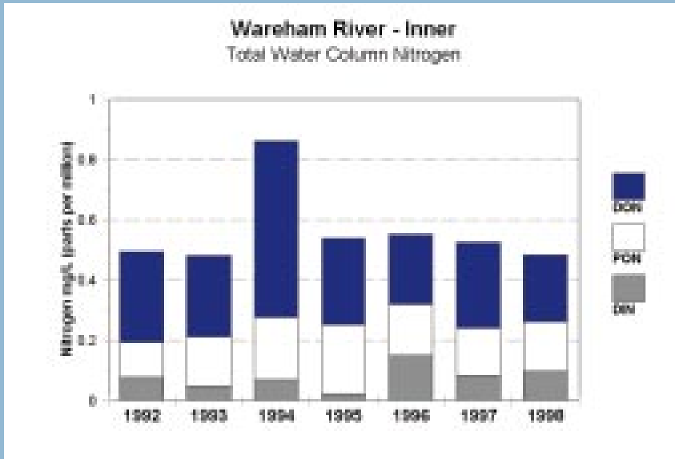


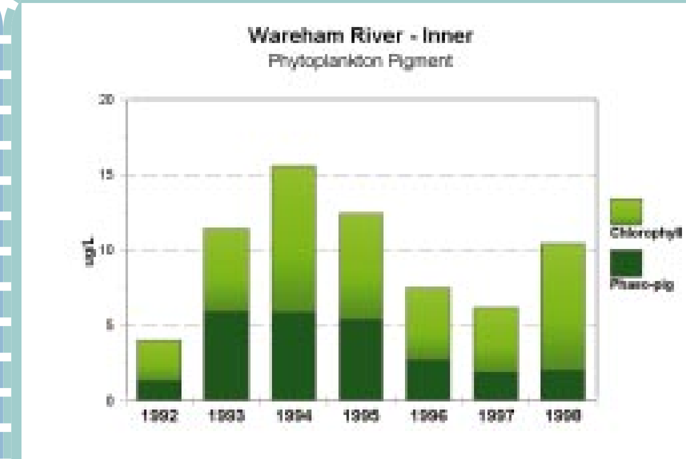


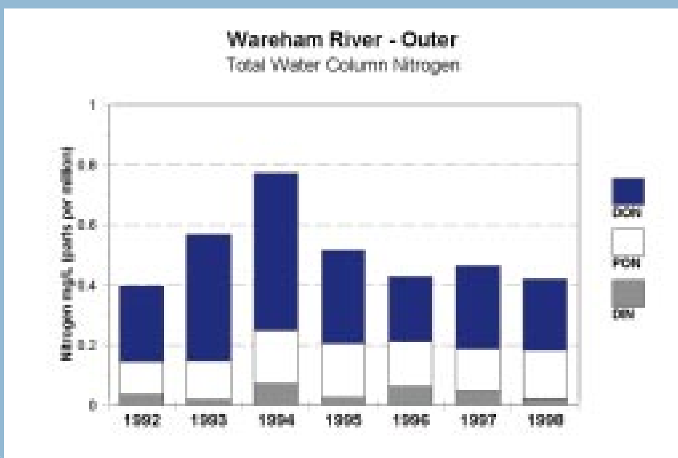


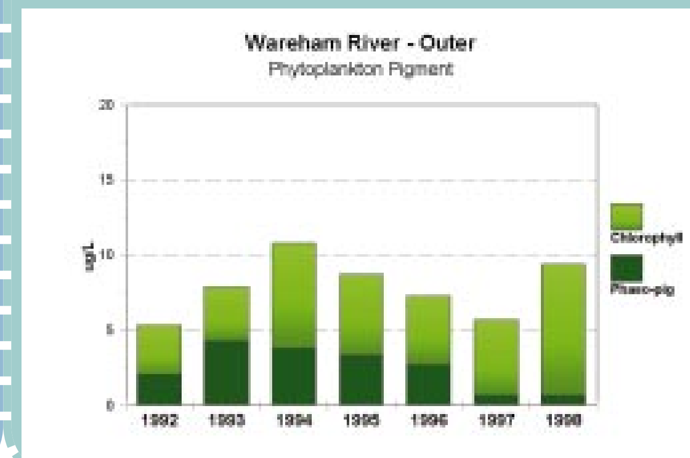
possible to off-set the imported load by additional watershed hook-ups, if the Facility has sufficient removal capacity.

About 60% of the present homes in the Wareham River watershed are served by on-site septic systems. All of these systems, whether modern Title 5 systems or older cesspools, contribute nitrogen to the Wareham River unattenuated. It is unfeasible to extend centralized sewer service throughout the rural portions of this vast watershed. Therefore, much of future residential growth will likely continue to be served primarily by on-site septic systems. Fortunately, nitrogen from many of these areas enters the freshwater ponds before reaching the Estuary, resulting in some removal of nitrogen and lower input to the Bay. Open-space preservation provides an important method for limiting increased nitrogen loading to the upper regions of the Wareham River Complex. New initiatives should be encouraged such as protection of riparian woodlands along the Agawam and Wankinco rivers. However, the major impacts of growth will be in areas which directly increase nitrogen loading to the upper estuary, primarily the lower portion of the watershed. Watershed management, open-space planning and sewering provide the best tools for managing nitrogen loading from these areas.









A corollary to open-space preservation is to reduce the density of future development, for example by increased lot sizes. Zoning approaches are particularly applicable tools for the Towns of Wareham and Carver based upon the present distribution of developable acreage within the watershed. At present, most of the watershed is programmed for residential development on 1.5 acre lots. A move to a lesser density of development would reduce the potential new nitrogen load. For example, if the watershed to the Wareham River Complex were rezoned to a 3 acre minimum lot size - as was done by the towns of Wareham, Plymouth, and Bourne in the Buttermilk Bay watershed in 1991 - future development and its consequent nitrogen loading would be significantly reduced. However, the reduction would be less than half of that from build-out of present zoning, as there are a variety of sources of nitrogen associated with development which are less sensitive to adjustments in lot size. It should be noted that the location of future nitrogen loads is as important as their intensity. Nitrogen loads entering the headwaters of an estuary tend to have a greater impact on nutrient related water quality than those entering near the outlet. It is now possible to determine through quantitative modeling and analysis the relative impact on estuarine water quality of different nutrient sources placed at different locations within the watershed.

Cranberry growing accounts for relatively little nitrogen loading to the watershed on a per acre basis, about the same as well managed dairy farms and cattle or terrestrial croplands. While they may be locally important sources of nutrients to an associated embayment, the total input from agriculture is generally less than from residential development. Cranberry agriculture generally releases nitrogen at a rate equivalent to residential housing at a density of about 2-3 acre zoning. Within the Wareham River Estuary, cranberry agriculture occupies an area roughly equivalent to the current developed area. The large volume of cranberry operations in the Wareham River watershed make these bogs a source of nitrogen to the system that needs to be considered in a watershed nitrogen management plan. However, it is likely that nitrogen released to surface waters within the upper watershed (from bogs and other land-uses) will be partially removed in passage through the numerous ponds before discharge to the estuarine waters. Nonetheless, the cranberry industry in this area should be encouraged to continue making improvements to the efficiency of their bogs, reduce fertilizer use to the greatest extent possible and continue to implement best management practices where appropriate.

Weweantic River

Embayment and Watershed Characteristics

The Weweantic River estuary has the largest watershed in the entire Buzzards Bay basin, slightly larger than that for the Westport Rivers. The Weweantic Estuary is actually composed of two rivers, the Sippican River and Weweantic River, both discharging to a common lower tidal region. The watershed is divided one-third to the Sippican River and two-thirds to the Weweantic River and they contribute 6.6% and 13.2% of the total freshwater inflow to Buzzards Bay, respectively. The total watershed of 55,438 acres is distributed among seven towns – Wareham, Rochester, Marion, Mattapoisett, Middleboro, Carver, and Plymouth.

The Weweantic Estuary is a moderately sized embayment to Buzzards Bay at 588 acres of water surface and is relatively deep (mean depth of 5.9 m). Within the tidal reaches of the Weweantic Estuary, eelgrass beds are not present much above the mouth of Pattons Cove (Beaver Creek Marshes) which is south of the confluence of the Weweantic and Sippican Rivers (and Rt. 6). Salinity within this region averaged 18 ppt near Pattons Cove, 16 ppt within the Weweantic tributary, south of Rt. 195. and only 22.6 ppt at the tip of Cromeset Neck. These low salinities are linked to the high freshwater discharges of the rivers. It is likely that poor water quality has resulted in the loss of eelgrass from this inner region. The lower portion of the estuary currently supports less than 5 acres of eelgrass beds, in part due to the depth of the lower basin.

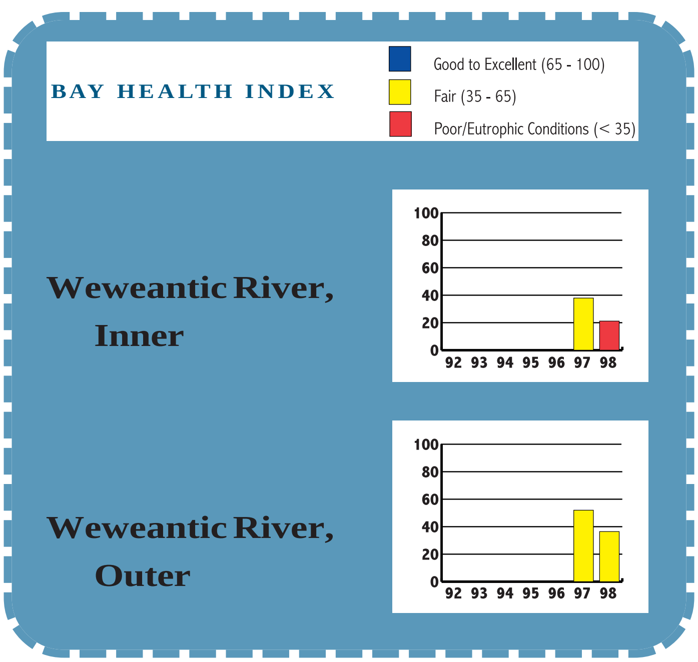
In contrast to sub-tidal eelgrass beds, emergent wetlands continue to be a dominant feature of the tidal portion of the Weweantic Estuary. Within the salt water reaches, there are 235 acres of tidal salt marsh, 0.4 acres for every acre of embayment surface. The river is also home to tidal freshwater marsh, a rare habitat type in Massachusetts. This type of habitat is created in areas where the outflow of the river is "blocked" by the high tidal waters within the lower estuary, creating a twice daily rise in the fresh waters of the lower river. In the Weweantic this region is just north of Interstate 195. Numerous state-protected rare plants and animals are associated with this unique coastal ecosystem.

Shellfish harvest is classified as Prohibited by the Massachusetts Division of Marine Fisheries in most of the Weweantic estuary including the entire Sippican River and most of the Weweantic north of Rose Point. Beaverdam Creek on the eastern shore of the estuary south of Route 6 is also Prohibited. The remainder of the estuary is on a Conditional Closure to about half way down Cromeset Point. The primary source of these closures is bacterial contamination associated with residential development and stormwater discharges along the Wareham shore.

The present condition is a long way from earlier times when Wareham on the whole was reputed to have the "choicest brand" of oysters and supports few today. How much the lack of recovery results from the continuous fishing of a depleted stock (currently at 4,000 bushels/year) and how much from habitat destruction and disease is unclear, but the day of "oisters...a foot long...so bit it must admit of a division to be got in your mouth" (Wood 1634 as quoted by Goode 1887:731) is not likely to be seen again soon on Wareham shores.

The Weweantic River historically supported a strong anadromous fish run. Today's diminished run results less from declines in environmental health than from physical impediments to herring passage which have decimated anadromous fish populations all along the coastal U.S. Efforts are currently underway to install a fishway and make improvements to the dam at Horseshoe Pond to restore the herring fishery in the river. Hopes are that the available habitat will support a run comparable to that in the nearby Agawam River.

Only 4,365 acres, or 8%, of the Weweantic watershed was developed with residential dwellings at the time of the last statewide land use survey in 1985. Although the Weweantic watershed has a low per acre housing density, it is among the fastest growing watersheds in southeastern Massachusetts. The Town of Carver which forms the headwaters of the Weweantic River showed the highest relative population growth within the Buzzards Bay watershed, with more than a four fold increase from 1960 (pop. 1,949) to 1990 (pop.10,590). If this rate of growth continues, Carver's population will reach 16,500 by the year 2020 (SRPEDD, 1997). The Buzzards Bay Project has estimated that under 1994 zoning regulations, more than 28,000 residences are possible at complete build-out of this watershed. This pattern of non-urban residential development in the Buzzards Bay watershed is the cause of much of the water quality decline presently observed in the Bay's tributary embayments. Therefore, the rapid growth of widely distributed residential development is cause for concern regarding the future health of coastal resources in the Weweantic Estuary. In contrast, most of the watershed area within the Town of Mattapoisett is held within the Haskell Swamp Wildlife Management area and therefore has lost its potential to increase future nitrogen loading to the estuary.



Most of the future development will take place in the upper watershed with its associated nitrogen load reaching the tidal portion of the Estuary in river flows. However, much of the existing development is on the lower Weweantic River estuary south of Interstate 195, which is dominated by densely developed beach communities. These communities are currently served by on-site septic systems for wastewater disposal, but many of these systems are sub-standard and the demand on them is increasing as the homes are converted to year-round use. Among these densely developed areas, sewering is planned for Weweantic Shores and Briarwood Beach. Most of these areas contribute nitrogen to the Estuary by transport of directly discharging groundwaters which form an unattenuated chronic source of nutrients to the nearshore. The nitrogen removals associated with sewering should have a positive effect on the nutrient related water quality within the adjacent estuarine waters.

The Weweantic basin has more cranberry bogs than any other coastal watershed in Massachusetts, but is fifth in proportion of land in agricultural use of the Buzzards Bay watersheds. Cranberry agriculture comprises 12% or 6,576 acres of the total Weweantic Estuary watershed area. The cumulative nitrogen loading from these bogs comprise a significant fraction of the total current loading to this estuary. Cranberry bogs release nitrogen at a level equivalent to 2-3 acre zoning of residential development and therefore require evaluation in nitrogen management for this estuary. However as many of the bogs within the upper watershed are not directly connected to the river, it is likely that their impact will be at least slightly diminished by attenuation of their nitrogen effluent by receiving surface waters (streams, lakes, ponds, wetlands).

Important to the future health of the Estuary, 8,614 acres, or 15.5% of the watershed is presently held in non-developable land including all of the Rocky Gutter Wildlife Management Area (3,410 acres) in Middleboro and most of the Haskell Swamp Wildlife Management Area in Rochester, Marion and Mattapoisett. At present, almost two-thirds of the Weweantic Estuary Watershed is available for residential development. The majority of that area is undeveloped forestlands. For an estuary already exhibiting signs of nutrient overloading, management of the estuary requires management of this watershed growth potential and is the leading management issue for the Weweantic.

Water Quality

While the Weweantic Estuary has not been monitored as intensively as many of the other embayment systems around Buzzards Bay, limited oxygen sampling was conducted in 1993-94 and full-scale monitoring began in 1997. Even with the reduced database, it is clear that the estuarine portion of the Weweantic/Sippican River System is currently supporting only fair to poor nutrient related water quality. This conclusion is supported by the lack of eelgrass within the upper estuary and possible declines near Rose Point.

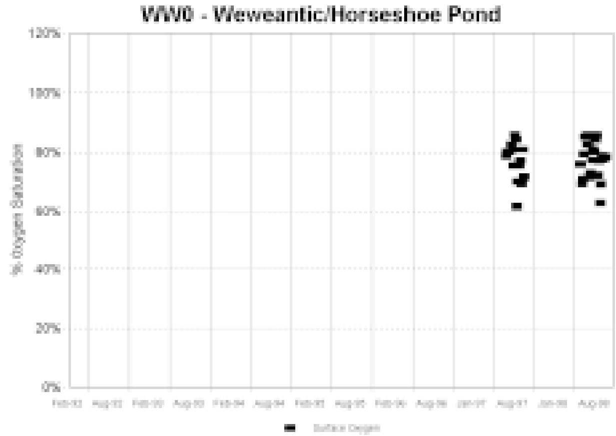
Nitrogen levels indicate a significant gradient from inner to outer regions, with total nitrogen more than 40% higher in the upper estuary, 0.694 mg N/L versus 0.484 mg N/L. This reflects the integration of the high nitrogen load transported by the River from the upper watershed and the dilution by tidal flushing with Buzzards Bay waters. The nitrogen levels are relatively high, within the range which can result in reduction in estuarine habitat quality. Similarly, the chlorophyll a pigments indicate a relatively large phytoplankton community and likely periodic blooms. As most of the pigment is in the active form, chlorophyll a, it appears that these high concentrations are resulting from phytoplankton growth within the estuary rather than transport of freshwater phytoplankton. The plankton production is almost certainly a consequence of nutrient discharge from the watershed which is focused on the upper estuary. While pigment concentrations show a gradient similar to that for total nitrogen, it is of smaller magnitude averaging only 22% over the 2 years, 11.5 ug/L versus 9.4 ug/L. These high plankton populations combined with particulate matter entering in river discharges results in the measured low water clarity. Secchi disk readings were frequently about 1 meter or less within the upper estuary. Turbidity is a major cause of declining habitat quality for eelgrass communities.

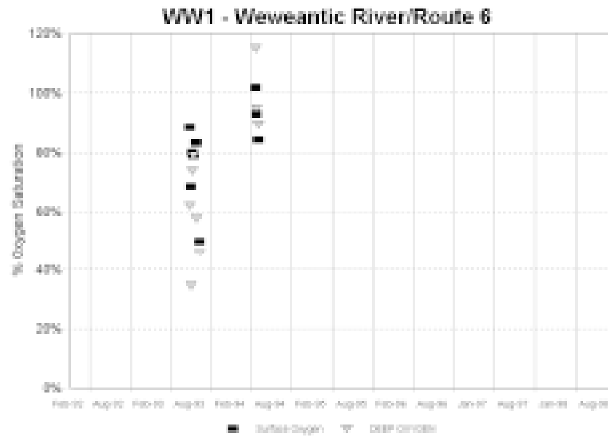
Oxygen levels showed only moderate depletion, even within the mid-estuary region. While levels rarely declined below 60% of air saturation (average lowest 20% of samples were 64% saturation), levels between 80% and 60% saturation were typical. In fact, levels at saturation were not commonly observed, in contrast to most other systems. This persistent depletion of oxygen, suggests that periodic low oxygen conditions may occur and indicates a chronically stressed system.

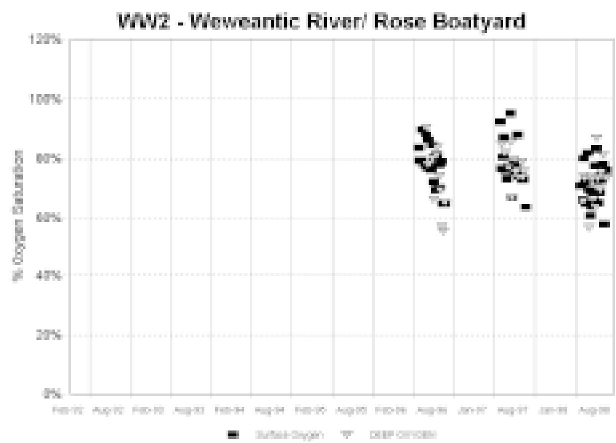
Integration of the nutrient, chlorophyll, and oxygen related parameters into the Health Index emphasizes the relatively low water quality of the Weweantic Estuary. Values place this system in the lowest quarter of the Buzzards Bay embayments studied. The lack of eelgrass supports these findings.

Management Needs

Analysis by the Buzzards Bay Project (1994) estimated that existing nitrogen loadings to the Weweantic River are more than 300% over recommended limits for healthy coastal waters. The relatively poor water quality observed in the monitoring program and limited distribution of eelgrass supports the contention of an over-fertilized estuary. The monitoring results indicate that the upper Weweantic River estuary is among the most eutrophic of Buzzards Bay embayments. The present water quality coupled with the more than two-thirds of the watershed available for increased development emphasizes the critical need for nitrogen and land use planning and growth management within this system. Since the embayment is already nitrogen enriched and beyond its healthy level of loading, increased loading will result in further declines within the upper estuary with gradual migration of poor quality conditions towards the mouth. Further decline

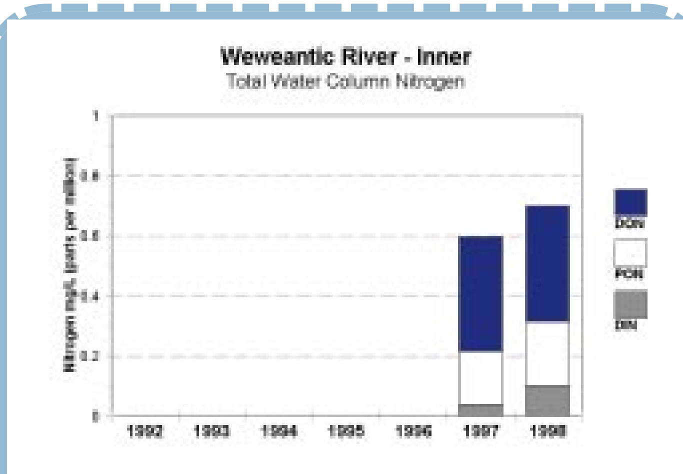


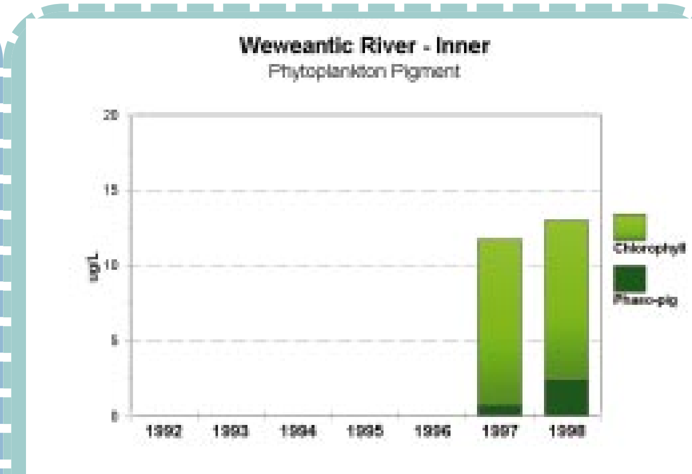


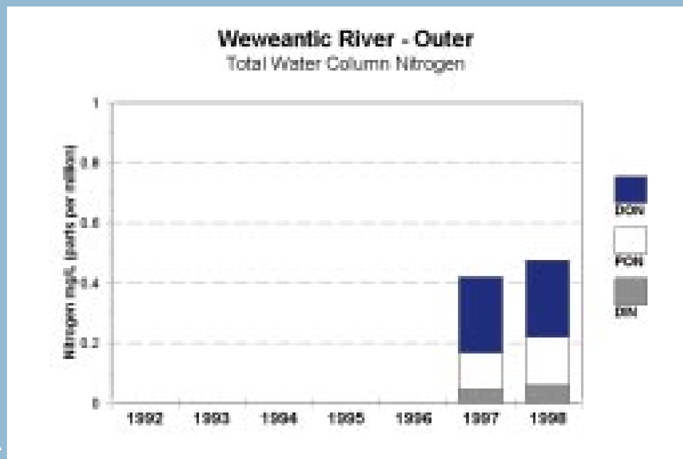


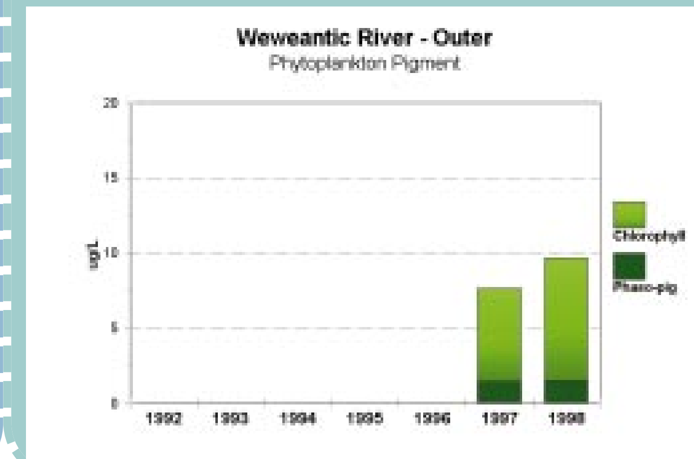
of eelgrass coverage would be expected as part of this decline. At a minimum, nitrogen management needs to occur to maintain present conditions and habitat, but a reduction in nitrogen inputs would be needed for restoration of the health of the upper estuary.

Most of the nitrogen from development comes from wastewater disposal. Almost all of the homes in the Weweantic River watershed are served by onsite septic systems. All of these systems, whether modern Title 5 systems or older cesspools, contribute the bulk of the nitrogen produced in every dwelling to the Weweantic River unattenuated through groundwater flows. However, within the upper watershed, transport through the streams, lakes and river can provide a modicum of nitrogen attenuation. Since it is unfeasible to extend centralized sewer









service to this rural, vast watershed, it is likely that residential growth will continue to be served by on site septic systems.

Nevertheless, the extension of sewers to densely developed neighborhoods, particularly along the coast, are a priority to address both public health and environmental health concerns. However, planning controls should be included in facilities planning so as not to open large areas of land to increased development. The Town of Wareham currently plans to extend sewer to Weweantic Shores within the next few years, followed by Briarwood Beach. It is unlikely that Rose Point will be reached in the near future. These actions have great potential to result in localized water quality improvements in the lower estuary – reducing both nitrogen and bacteria contamination.

In addition to direct nitrogen mitigation, growth management approaches are also available to control nitrogen related degradation of the embayment. The Weweantic watershed is capable of large increases in development over the coming decades under present zoning. Open space preservation is an important tool for managing future increases in loading by controlling both the locations and amount of land available. The current foundation of large state protected forest-lands in the watershed, and in particular the Rocky Gutter Wildlife Management Area, should be expanded and new initiatives launched to focus attention on the protection of riparian woodlands along the Weweantic mainstream.

The towns of Carver, Wareham, Middleboro, and Rochester should consider limiting the future growth potential in the Weweantic area through increased lot size requirements. At present, most of the watershed is programmed for residential development on 1.5 acre lots. A move to a lesser density of development would reduce the potential new nitrogen load. For example, if the Weweantic River watershed were rezoned to a 3 acre minimum lot size - as was done by the towns of Wareham, Plymouth, and Bourne in the Buttermilk Bay watershed in 1991 - future development and its consequent nitrogen loading would be cut in half.

Although the Weweantic watershed is ranked fifth in proportion of land under agriculture it has a large amount of cranberry agriculture distributed throughout its upper watershed. Cranberry growing accounts for relatively little nitrogen on a per acre basis, about the same as well managed dairy farms and cattle or terrestrial croplands. While they may be locally significant sources of nutrients to Buzzards Bay's embayments, the total input from agriculture is generally less than from residential development. In addition, it is likely that nitrogen released to surface waters within the upper watershed (from bogs and other land-uses) will be partially removed in passage through the numerous ponds before discharge to the estuarine waters. These figures notwithstanding, the large volume of cranberry operations in the Weweantic River watershed make these bogs an important source of nitrogen to the Weweantic system that needs to be considered in a watershed nitrogen management plan. The cranberry industry in this area should be encouraged to continue to make improvements to the efficiency of their bogs, reduce fertilizer use to the greatest extent possible, and maximize tailwater recovery systems to minimize nitrogen releases from the bog systems.

Finally it is important to note that the Weweantic River estuary may be receiving nitrogen which had previously exited the River and the Wareham Estuary on ebbing tide. The reason for this "nitrogen return" is the configuration of the mouths of these 2 major estuaries and their access to Buzzards Bay waters. This is somewhat similar to the nitrogen loading to the Little River system from the Slocums River in Dartmouth. However, given the general pattern of circulation and the lower salinity within these Estuaries, the Wareham River Estuary is likely the greater recipient of this tidal recycling of watershed nitrogen.

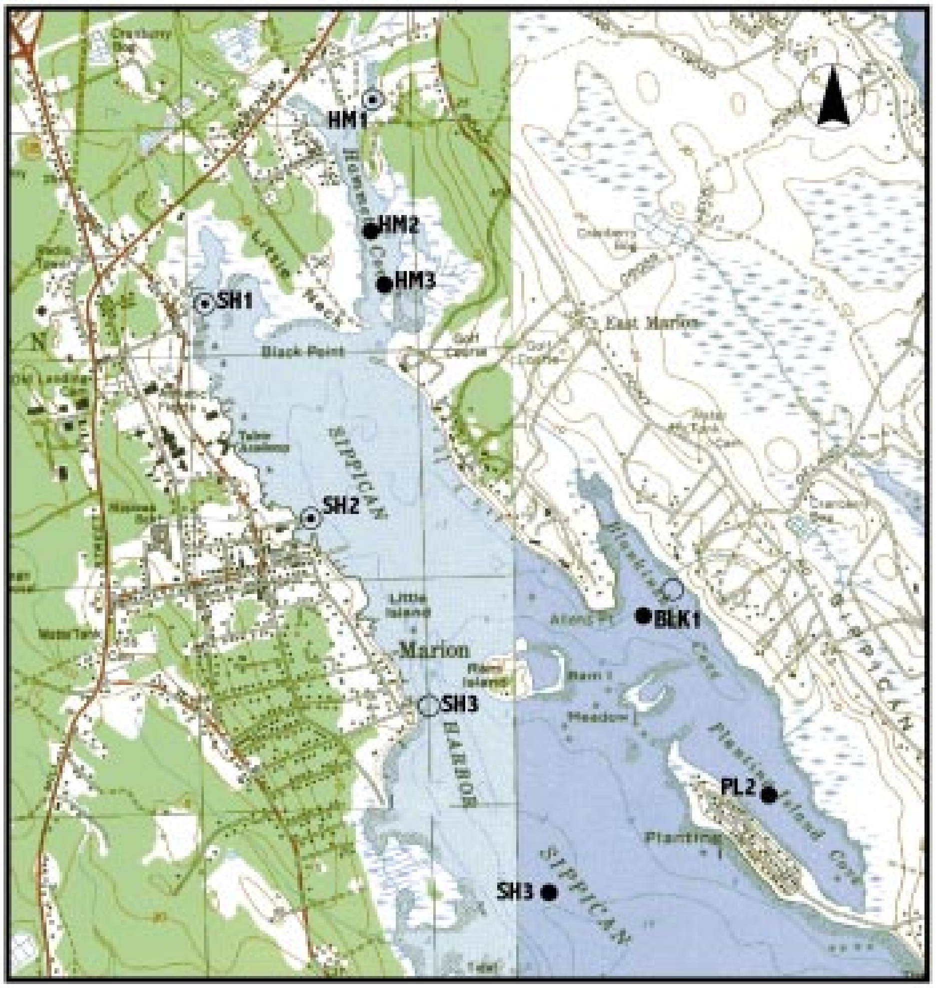
The Coalition for Buzzards Bay

The Buzzards Bay Citizens Water Quality Monitoring Program documents the impaired water quality within both the upper and lower Weweantic Estuary. Because the Weweantic watershed is so large and still has considerable growth potential, nitrogen management will be among the most challenging of all Buzzards Bay embayments studied. Nitrogen management for this estuary will likely require the use of the full spectrum of management tools such as sewer extensions, alternative septic systems, preservation of open space, and re-zoning. Specific management actions that should be considered for the Weweantic watershed are (1) the expanded sewering of dense coastal development areas to include Rose Point, (2) encouragement of continuing implementation of practices to minimize nutrient release from cranberry bogs, (3) protection of open-space, particularly in the Weweantic River corridor, and (4) increasing zoning from 1.5 acres to 3 acres. While it is clear that implementing these actions requires significant effort and time, environmental quality conditions within the Weweantic Estuary will only continue to deteriorate and expand seaward as nitrogen loading continues to increase. Additional monitoring and studies are needed to determine the degree of habitat decline anticipated under managed and unmanaged future watershed nitrogen loading.

Sippican Harbor

Hammett Cove, Blankinship Cove & Planting Island Cove

Marion



Embayment and Watershed Characteristics

Sippican Harbor is one of the larger embayments in Buzzards Bay and encompasses a variety of smaller coves and harbors. More than two-thirds of the marine region of Sippican Harbor is in the lower Harbor region, south of Ram Island, which exchanges directly with Buzzards Bay waters. The inner regions which are less well flushed consist of Inner Sippican Harbor, north of Ram Island, and Hammett Cove and tributary to the mid-Harbor, Blankinship and Planting Island Coves. Hammett Cove is the innermost portion of the Harbor Complex and is a shallow drowned river estuary which still receives most of the surface water inflow. Planting Island Cove and Blankinship Cove are located along the eastern edge of the central harbor and currently support shellfish and eelgrass habitat. The village of the Town of Marion dominates the western shore of the inner Harbor.

Given the size of the Harbor Complex, its drainage basin is relatively small. The inner Harbor watershed which dominates terrestrial nitrogen inputs to the Harbor is only 1,514 acres, smaller than that for adjacent Aucoot Cove, 2604 acres. However, the inner Harbor watershed is among the most highly developed surrounding Buzzards Bay. As a result of the level of development and relatively low flushing rate (8.6 days) for the inner Harbor and Hammett Cove, this region of the complex will be first effected by nitrogen loading and therefore would be the initial target for nitrogen management.

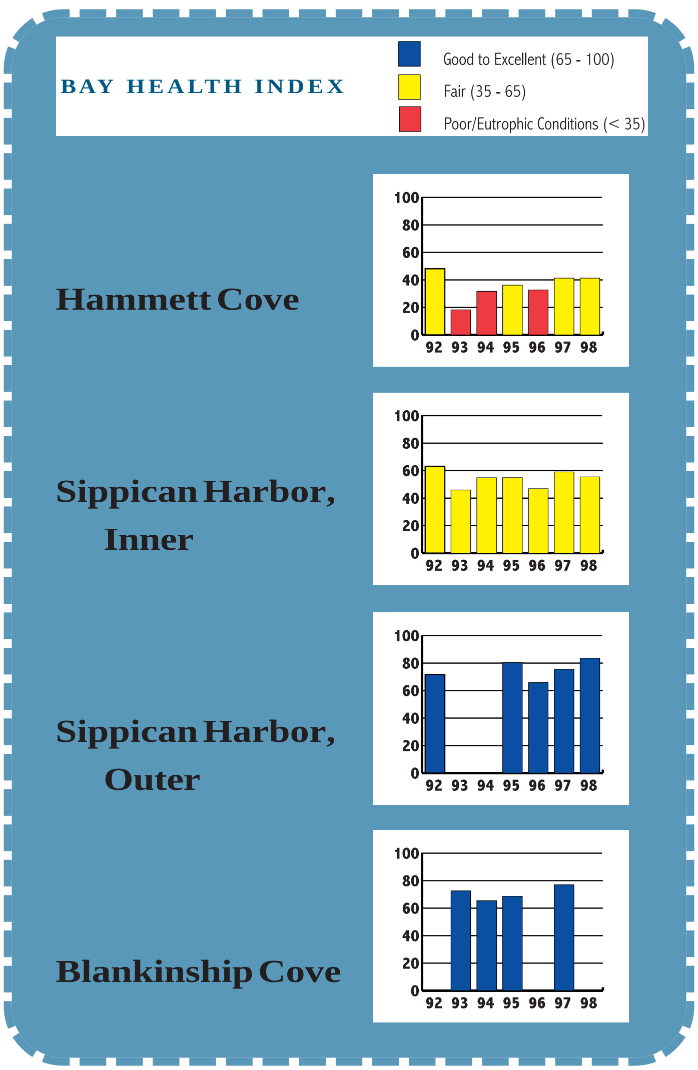
Sippican Harbor supports a high degree of recreational resources. Among Buzzards Bay's embayments, Sippican Harbor has one of the largest populations of boats with approximately 1,000 boat moorings and slips between the inner Harbor and Hammett, Blankinship and Planting Island Coves. These boats are serviced by a pump-out boat, dockside facility, and a waste dump facility. In addition, there are three public and eight private beaches along the shores of this embayment. Within Sippican Harbor oysters, quahogs, and soft-shell clams are recreationally harvested, while only quahogs and oysters continue to be commercially harvested. The inner Harbor supports only a small amount of salt marsh, 86 acres, primarily in Hammett Cove.

Eelgrass beds within the Harbor Complex are restricted to the margins and inner regions due to the depth of the central basin, average system depth is 2.2 m. However, within the inner basin: eelgrass appears to be further limited in distribution by other factors, possibly water quality. Beds within the inner Harbor extend to Little Neck, but tend to be at the margins, relatively sparse, and cover only a portion of the available habitat. Within the mid-harbor region, eelgrass beds are located primarily in the shallow, well flushed bottom between Ram Island and Planting Island. Consistent with the land-use and flushing characteristics of the Harbor, relatively healthy large eelgrass beds persist within the bulk of the nearshore region of the outer Harbor, particularly along the western shore to Converse Point. The beds along the eastern shore extend beyond Butler Point to surround Bird Island.

Bird Island is a small, ca. 1 acre, island of rock about a half mile off Butler Point. The island is notable as a roseate tern rookery, currently supporting about 1,100 nesting pairs or nearly half of the breeding pairs in the Western Hemisphere of this federally listed endangered species. Although the colony had declined to a low in the late 1980's it is currently undergoing recovery.

Approximately 153 acres, or 10%, of the land within the Sippican Harbor watershed is protected open space or under municipal ownership. Agriculture is limited to 24 acres of cranberry bogs at the upper reaches of the watershed near Interstate 195. The eastern shore of the mid-harbor is dominated by Blankinship and Planting Island Coves. The sub-watershed to these coves accounts for 29% of the watershed for the upper Harbor–446 acres– of which 80 acres, or 18%, have been permanently protected by the Sippican Lands Trust. The margins of the Coves contain saltmarsh and summer and year-round residential development.

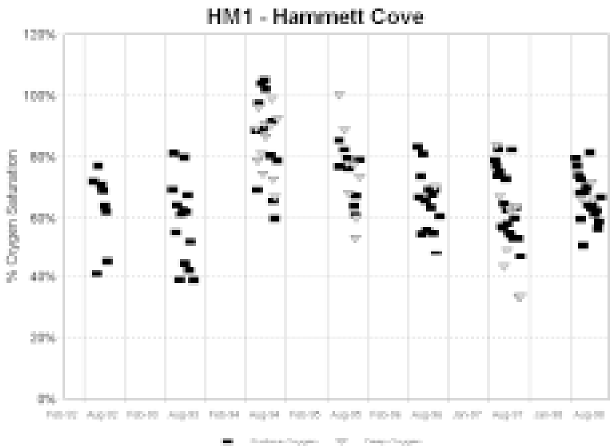
More than three-quarters of the watershed nitrogen loading to the inner portions of the Sippican Harbor Complex originates from residential and commercial land uses. However, it is important to note that much of the nitrogen generated by homes and businesses in this watershed are in sewered areas served by the Marion Wastewater Treatment Facility. The nitrogen within this wastewater is "exported" from the Sippican Harbor watershed and discharged, after secondary treatment, to Aucoot Cove. Without this municipal sewer, the nitrogen load to Sippican Harbor from densely developed Marion village would be greatly increased.

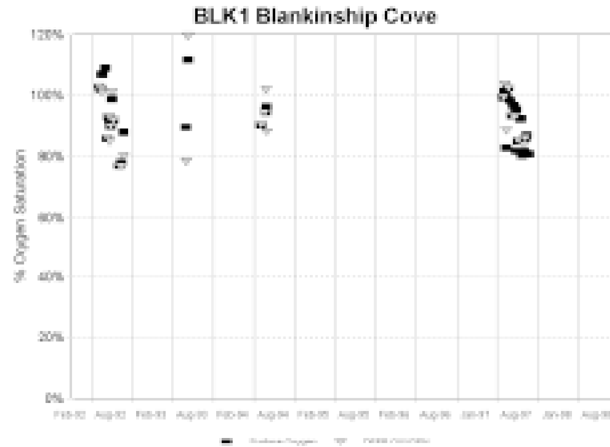


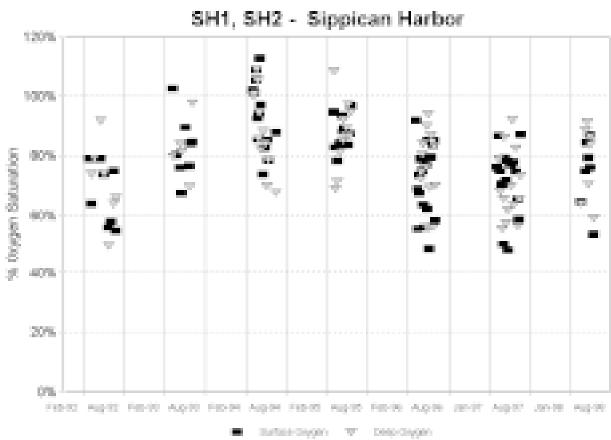
Water Quality

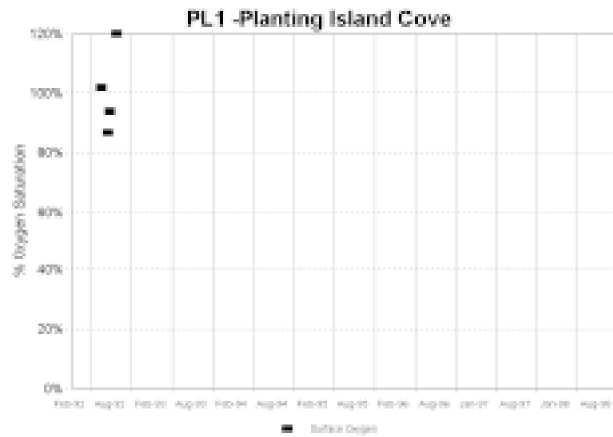
The Sippican Harbor Complex presents a wide range of nutrient related water quality, with a strong gradient of increasing quality from the inner-most reaches of Hammett Cove to the mid-Harbor Coves to the outer, lower Harbor region which flushes directly with Buzzards Bay waters. Although there was a period of higher nitrogen and phytoplankton levels at some stations in 1994-1995, conditions have been relatively stable over the last three years (1996-98) of monitoring and similar to conditions at most sites in 1992 and 1993. Hammett Cove receives watershed inputs by both groundwater and surface water inflows (including Rt. 6 runoff). This Cove, bordered by moderate residential development and saltmarsh is shallow and maintains soft organic-rich bottom sediments consistent with nutrient enrichment. Hammett Cove is currently showing poor nutrient related health. The Cove routinely has phytoplankton blooms during summer, resulting in periodic chlorophyll a levels in excess of 15-20 ug/L and a long-term summer-time average for the upper and lower regions of 12.4 (SE=2.4) ug/L and 9.1 (SE=0.9) respectively (SE= standard error, a measure of variability). These algal blooms result from the high nitrogen inputs and restricted flushing. Total nitrogen levels of 0.63 (SE=0.04) and 0.55 (SE=0.03) mg N/L for the upper and lower Cove are about twice the nitrogen levels in the Buzzards Bay floodwaters entering Sippican Harbor. The high nitrogen and high chlorophyll a concentrations are matched by high average particulate organic carbon levels (>1.39 mg C/L). These high organic carbon levels fuel the high rates of respiration within the Cove which underlie the periodic depletion of watercolumn oxygen. Oxygen levels within Hammett Cove routinely drop below 60% of air saturation in five of the seven years of monitoring. Oxygen depletion to ca. 40% of saturation were also observed. These oxygen declines commonly have negative ecological impacts in coastal embayments. The process of eutrophication (nutrient over-enrichment) has progressed to the point in Hammett Cove that this system's health is impaired and ranks in the lower tier of Buzzards Bay sub-embayments. The lack of eelgrass within this Cove is consistent with its poor water quality.

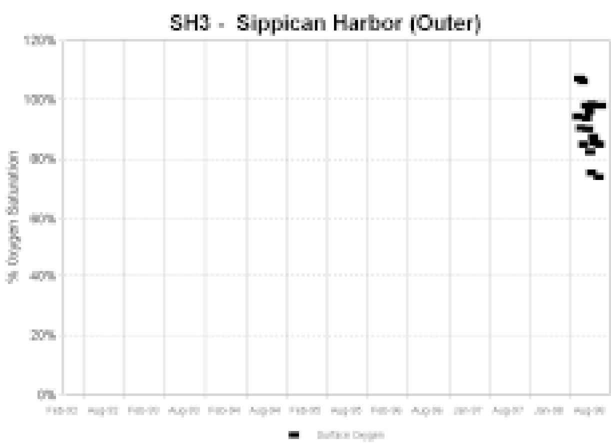
Inner Sippican Harbor (north of Ram Island) is also nutrient enriched, but not to the level of Hammett Cove. The sewering of much of the inner Harbor and its greater volume and flushing compared to upper Hammett Cove results in the inner Harbor waters having about one-third lower concentrations of chlorophyll a pigments, 39% (7.6 ug/L vs. 12.4 ug/L), particulate organic carbon, 44% (1.2 mg C/L vs. 1.829 mgC/L), and total nitrogen, 28% (0.455 mg N/L vs. .628 mg N/L) relative to the Cove. However, the observed levels of these key ecological health parameters appear to be sufficiently high to result in significant oxygen depletion within the Inner Harbor waters. While not as common as in Hammett Cove, oxygen levels periodically declined below 60% of air equilibration, although depletion below 50% was not observed over the study period. These data are consistent with the persistence of peripheral eelgrass beds within the Inner Harbor. It is clear that the Inner Harbor region is currently showing degraded water quality and is











at a level of nutrient loading where additional inputs will cause further declines.

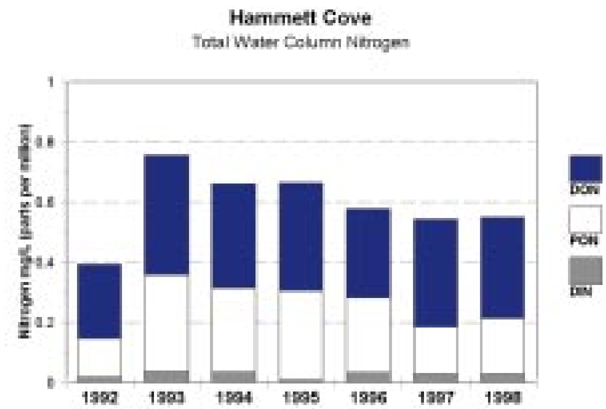
In contrast to the inner regions of Sippican Harbor, the outer Harbor and Blankinship and Planting Island Coves currently maintain low nutrient and organic matter levels with concomitantly high levels of nutrient related water quality. These systems typically show ca. 25% lower algal and organic matter levels and 12%-14% lower total nitrogen levels than the inner Harbor, and 33% to 50% of the levels in Hammett Cove. These three outer systems did not show significant differences from each other in chlorophyll a pigments or nitrogen over the study period. These relatively low levels of the key indicators of nutrient over-enrichment are consistent with the high water clarity and eelgrass beds bordering the entire outer Harbor region.

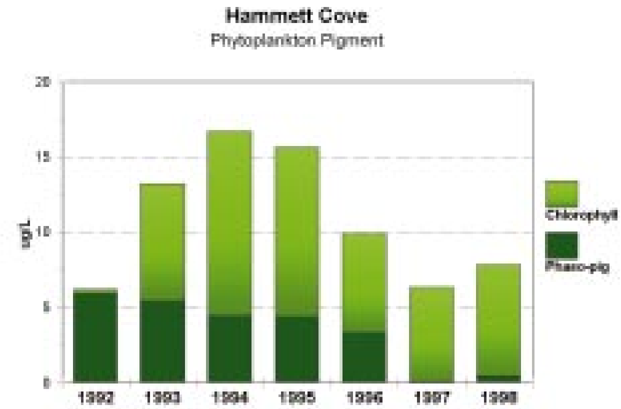
The Sippican Harbor Complex has a strong gradient in water quality parameters which mirrors its distribution of watershed inputs and tidal flushing rates. Concentrations of chlorophyll a pigments, particulate organic carbon and total nitrogen are 2.5, 2.4, and 1.6 times higher in Hammett Cove than in the outer Harbor waters. This gradient is sufficient to produce Health Index values for Hammett Cove and the Inner Harbor typically below 40 and 60, respectively, indicative of eutrophic and moderately degraded habitat quality. All of the outer Harbor sub-systems rank as high water quality areas and generally support water quality parameters within 33% of levels found in Buzzards Bay.

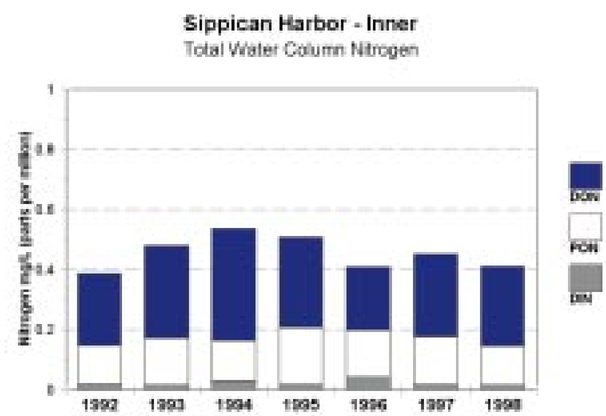
Management Needs

The outer portions of Sippican Harbor as well as Blankinship Cove exhibit high water quality, and due to their direct exchange with the open waters of Buzzards Bay, do not require nitrogen management at this time. However, the inner Harbor region, north of Ram Island, is showing low to moderate nutrient related habitat quality. This region is currently receiving nitrogen inputs in excess of its ability to process them without a decline in system health. Additional watershed nitrogen loading is likely to result in further ecological decline and loss of eelgrass communities.

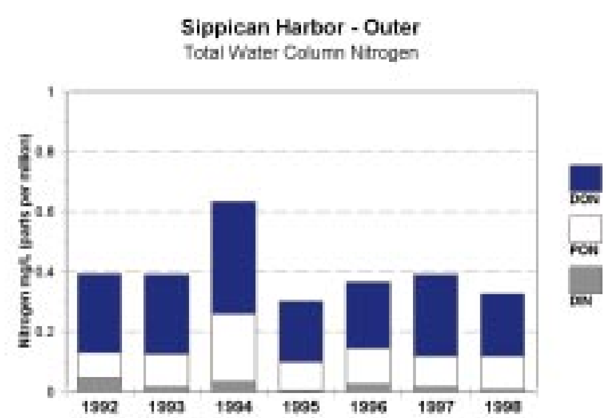
Within the Sippican Harbor Complex, Hammett Cove is the least well flushed and receives proportionately the most surface water inflows. Its water quality is well below the median for Buzzards Bay sub-embayments. However, despite its present low water quality, the relatively small sub-watershed to Hammett Cove and


Hammett Cove
Total Water Column Nitrogen
Nitrogen mg/L (parts per million)
DON
PON
DIN
1992 1993 1994 1995 1996 1997 1998

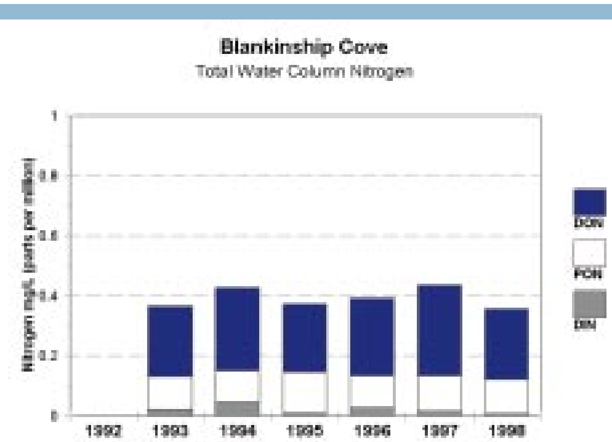

Hammett Cove
Phytoplankton Pigment
ug/L
Chlorophyll
Phaeo-pig
1992 1993 1994 1995 1996 1997 1998

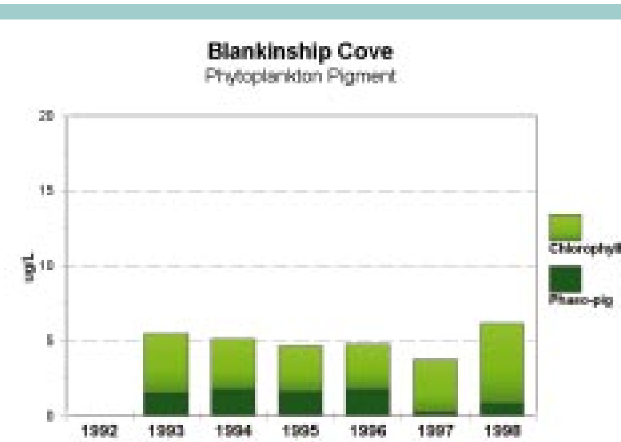

Sippican Harbor - Inner
Total Water Column Nitrogen
Nitrogen mg/L (parts per million)
DON
PON
DIN
1992 1993 1994 1995 1996 1997 1998


Sippican Harbor - Inner
Phytoplankton Pigment
ug/L
Chlorophyll
Phaeo-pig
1992 1993 1994 1995 1996 1997 1998


Sippican Harbor - Outer
Total Water Column Nitrogen
Nitrogen mg/L (parts per million)
DON
PON
DIN
1992 1993 1994 1995 1996 1997 1998


Sippican Harbor - Outer
Phytoplankton Pigment
ug/L
Chlorophyll
Phaeo-pig
1992 1993 1994 1995 1996 1997 1998


Blankinship Cove
Total Water Column Nitrogen
Nitrogen mg/L (parts per million)
DON
PON
DIN
1992 1993 1994 1995 1996 1997 1998


Blankinship Cove
Phytoplankton Pigment
ug/L
Chlorophyll
Phaeo-pig
1992 1993 1994 1995 1996 1997 1998

inner Sippican Harbor suggest that water quality might be restored through watershed nitrogen management. Both the inner Harbor and Hammett Cove sub-watershed should be evaluated for nitrogen management alternatives.

Since residential land uses account for more than three-quarters of nitrogen inputs, any nitrogen management strategy must include remediation of existing sources, particularly septic system inputs. The restoration of Hammett Cove will almost certainly require some additional sewering, likely the extension to include neighborhoods along Route 6 in the immediate watershed to the Cove. However, as much of the Sippican Harbor watershed is presently sewered, the focus on wastewater must be on the unsewered areas and new construction. With the exception of land along the abandoned rail corridor near Washburn Park, there is limited growth potential in the Sippican Harbor watershed. Focusing on Hammett Cove will also serve to enhance the inner Harbor region, since it receives the nitrogen enriched waters from the Cove on the ebbing tide.

Lawn fertilizer leaching is generally the second most important source of nitrogen to watersheds under residential development. Fertilizers also enter adjacent Sippican Harbor from the nine-hole golf course and athletic fields associated with Tabor Academy. However, the site specific role of fertilizers is generally difficult to quantify because they are applied at low concentrations over wide areas. An understanding of the role of lawn fertilizers is important for management as they present an inexpensive trade-off for controlling nitrogen inputs when compared to removing nitrogen loading from septic systems or agricultural sources. Fortunately, they are easily managed through the reductions in fertilizer application rates, the establishment of non-turf ground-covers, and in runoff areas through maintenance of vegetated buffers at the Harbor's edge.

R. Arms 1998

Hammett Cove is the immediate receptor for stormwater runoff from Route 6 and one of the more densely developed commercial areas in Marion. This stormwater runoff receives no treatment prior to discharge to the Cove. Typically, road stormwater runoff is not considered a significant nitrogen source to coastal waters and is managed primarily to control bacterial contamination and oil and heavy metals which are important to shellfisheries and eelgrass communities. Nevertheless, the amount and placement of stormwater runoff pollution in this area should be examined and remediation undertaken. If possible an added benefit to the Harbor would be attained through the use of engineered wetlands which will remove nutrients as well as the common runoff pollutants.

Sippican Harbor is one of the major boat mooring areas within Buzzards Bay. While boat discharges likely represent a very small potential source of nutrients, they also place bacteria and viral contaminants and/or organic chemicals directly into the bay. In the Harbor environment where effects of contaminants are greatest, due to low to moderate flushing and presence of shellfish and eelgrass resources, this type of discharge should be prevented. Of the 1,000 slips and moorings in Sippican Harbor, the vast majority are summer usage and typically occupied only a few days per week. Encouraging use of boat pump-out facilities and compliance with proper discharge procedures provides an easy mechanism to reduce this source of contamination to near zero.

Aucoot Cove

Marion, Mattapoisett

Embayment and Watershed Characteristics

Central Aucoot Cove and Hiller Cove form the Aucoot Cove System which is roughly defined as the marine waters inland of a line drawn between Converse Point to the north and Pease Point to the south. Hiller Cove is a small pocket in the outer southern shoreline formed by Joes Point. Aucoot Cove is an open deep embayment. The Cove's dimensions (almost as wide as it is long) result in good water exchange with the high quality waters of Buzzards Bay. The system's circulation helps to maintain its water quality even though the tidal creeks at the head of the Cove receive treated effluent from the Marion Wastewater Treatment Facility (WWTF). The location of the wastewater discharge mandates that the upper portions of the Cove are closed to shellfishing as a precautionary measure. In addition, periodic observations of high fecal coliforms within this region of the Cove suggest the possibility of bacterial contamination from wastewater (WWTF disinfection or septic system failures) and stormwater flows. It is likely that the periodic contamination is at least partially associated with wildlife/marsh processes as is commonly observed around Buzzards Bay (see for example the Buttermilk Bay Study). Without an investigation of the specific sources of bacterial contamination, management options cannot be effectively implemented. At present, there are occasional closures of shellfish beds within the Mattapoisett waters of the Cove.

The salt marsh at the head of Aucoot Cove is well developed and large relative to the size of the Cove. This marsh has been extensively altered through ditching for mosquito control. This marsh accounts for most of the 132 acres of saltmarsh within the Aucoot System, with Hiller Cove having only a small fringing marsh area.

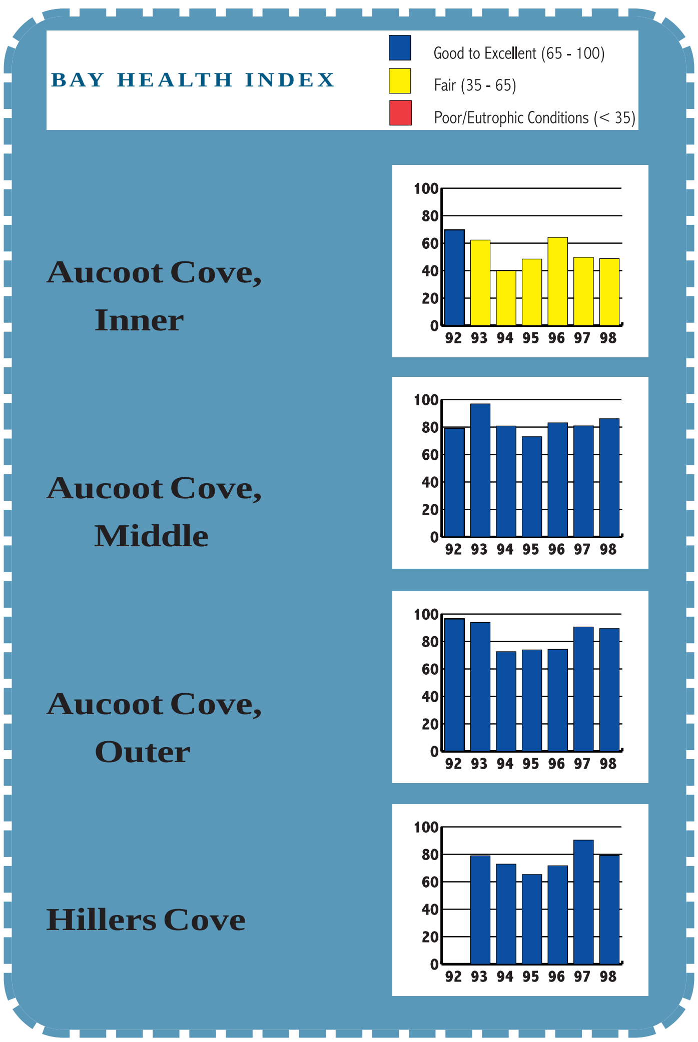
Both Aucoot and Hiller Cove support eelgrass beds primarily within the 12 foot depth contour. In addition, there are patches of attached macro-algae within the main bay area. The result of the extensive eelgrass and salt marsh habitat and the high water quality is that the Cove supports a large amount of associated shellfish habitat and other wildlife communities. The embayment has one public beach, a number of private beaches, approximately 115 boat moorings and slips, and a small boatyard at the head of the Cove on the Mattapoisett shore. Given its open structure, Aucoot Cove does not provide the same level of protection for its moorings as many of Buzzards Bay's harbors. After Hurricane Bob in 1991, the marshes at the head of the Cove were strewn to the upland edge with vessels dislodged from their moorings during the storm.

The Aucoot Cove watershed is one of the least developed coastal watersheds on the western shore of Buzzards Bay. Developed land uses in the watershed are primarily light residential and comprise approximately 300 acres or 11% of the total watershed area. Agriculture, primarily the production of cranberries, is limited to 45 acres of bogs. The remainder of land is undeveloped and is generally forested.

Given the high growth potential of the Aucoot watershed, steps are being taken to protect the resources of the watershed and bay into the future. In 1997 and 1998, the forested northern portions of the Aucoot Cove watershed, north of Interstate 195, were incorporated as part of the new Haskell Swamp Wildlife Management Area. These 485 acres are managed by the Massachusetts Division of Fisheries and Wildlife and contribute the majority of protected open space in the watershed. Cumulatively, 795 acres or 30% of the Aucoot Cove watershed are permanently protected as open space. However, the remaining open-space is sufficient to allow an increase in the area of developed land-uses of about 6 fold over present conditions.

The watershed of Aucoot Cove is not the only source of nutrients to Cove waters. Nitrogen is "imported" by the Marion WWTF which discharges to the tidal creeks at the head of the Cove. At present, the Facility discharges an average of 0.6 million gallons per day (MGD), serving 2,100 persons primarily in the Sippican Harbor watershed. At present, more than 60% of the total watershed nitrogen load to the marine environment enters through the WWTF discharge. Although the Cove itself has the ability to assimilate a large load of nitrogen, the recipient wetland creeks likely serve to "protect' the adjacent waters by intercepting nitrogen (in the form of nitrate) discharged during the period of low tide. Nitrate interception by salt marsh creeks has been demonstrated for Great Sippewissett Marsh and the Mashapaquit Creek Marsh (West Falmouth Harbor) on Buzzards Bay.

Impacts of effluent discharge to the marsh creeks is unclear. Salt marshes are capable of assimilating and/or tolerating large nitrogen loads. However, the marsh creek carrying the treated effluent to adjacent Aucoot Cove has developed a macro-algal community which periodically dislodges and covers the creek banks. Although this can be observed in a variety of marshes around the Bay, it appears that this macro-algal cover may be increasing bank erosion in the Aucoot marsh. At present, a proper evaluation has not been conducted. The Facility has moved to reduce environmental impacts from its discharge by recently improving its disinfection process to eliminate the use of chlorine. Given the large import of nitrogen to the watershed by the WWTF, the protection of open-space provides an "offset" against future nitrogen loads. It is possible that expenditures on open-space may prevent the need for a costly WWTF upgrade to tertiary treatment which might otherwise be required at full watershed development to protect Cove waters.



Water Quality

Aucoot Cove and Hiller Cove maintain a high level of water quality as a result of the open well-flushed nature of the embayments and their relatively low rate of watershed nitrogen loading. However, the typical focus of nitrogen inputs at the head of embayments is further compounded in this system by the point discharge of the Marion Wastewater Treatment Facility to the marshes at the head of the Cove. The result is a gradient in nitrogen and chlorophyll a from the inner to the outer Cove waters. Both Hiller Cove and the Outer and Middle regions of Aucoot Cove are similar in average total nitrogen, 0.30 mg/L, and chlorophyll pigment, 3.4-3.8 ug/L concentrations and show little elevation over Buzzards Bay waters. However, ebbing waters at the head of the Cove and in the marsh creeks showed increases over offshore with total nitrogen, 0.40 and 0.74, and chlorophyll pigments, 4.4 and 8.2 ug/l, respectively. Within the Cove itself the enhancement was moderate (about one third). An earlier detailed study of the Cove in 1991, showed a similar gradient in nitrogen and chlorophyll and had an average total nitrogen level within the marsh creeks of 0.58 mg/L. The large drop in nitrogen and chlorophyll levels from the marsh creek to the nearby stations in the Cove result from the rapid dilution with Cove waters and the good flushing of the Cove.

Oxygen levels within the head waters of Aucoot Cove and Hiller Cove show periodic depletions to ecologically stressful levels. However, all of the sampling sites are either within or directly adjacent to wetlands which typically discharge low oxygen waters during dark or very early morning periods. As might be expected given the intensity of the association with a wetland, Hiller Cove showed the least oxygen depletion and the inner marsh creek in Aucoot Cove (Station AC7) showed the greatest. In the 1991 study, significant oxygen depletion was not observed in Aucoot Cove except within the marshes or in the Cove directly adjacent to the marshes on the ebbing tide.

The Health Index computed for the Coves indicates high water quality except within the marshes and region adjacent to the marshes at the head of Aucoot Cove. The high water quality results from the excellent water clarity, low chlorophyll pigment and nutrient concentration. The regions of high quality waters are consistent with the distribution of eelgrass within the Coves. The Index designation of moderate water quality at the head of Aucoot Cove is driven primarily by the oxygen levels as the nutrient and chlorophyll concentrations were only moderately enhanced over Buzzards Bay levels. The extent to which the oxygen distribution within the marsh region is the result of processes related to the discharge of effluent versus natural marsh effects is at present unknown. However, it is likely that the marshes are providing additional treatment of the nutrients which are discharged to them and thus are helping to maintain the water quality within the adjacent waters.

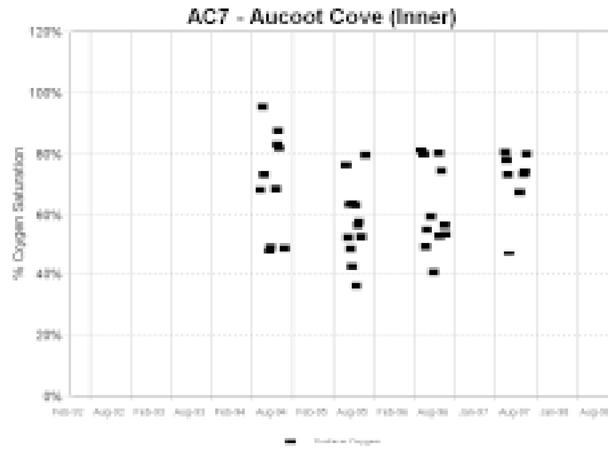
Management Needs

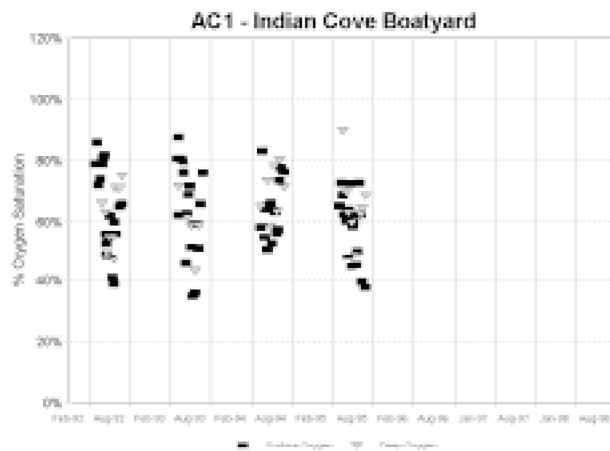
Although Aucoot Cove is smaller than most Buzzards Bay embayments, it is also among the deepest and best flushed. Consequently, it has a greater ability to assimilate nitrogen compared to other embayments of similar area. With this natural capacity, even under conditions of full build-out of its watershed, it has been suggested that future loadings to the Cove may fall within acceptable nitrogen limits unless there is any sizable expansion of the sewage treatment facility. Hence management of nitrogen inputs on a whole system basis may not be warranted.

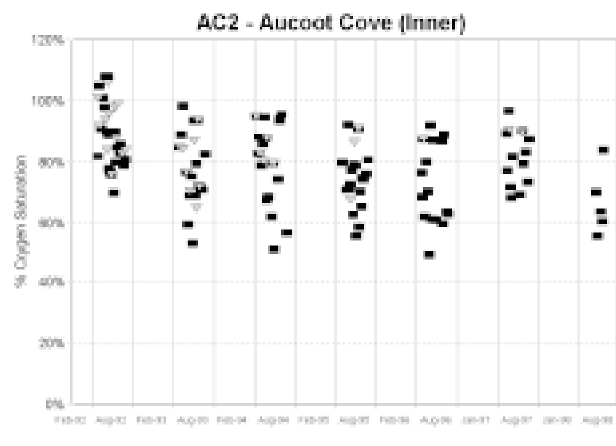
However, nitrogen concentrations are elevated in the upper Cove, particularly in the marsh creek receiving effluent. Given that this creek receives more than 60% of the total nitrogen load to the Cove, it is important to evaluate localized impact to the marsh and the waters directly adjacent to the marsh in addition to the overall Cove System. At present there are macroalgae growing in the region of the Cove adjacent to the marsh and accumulations of sea lettuce (*Ulva*) within the effluent creek. Both of these features can be diagnostic of nutrient overloading. However, it is the degree of accumulation rather than the presence or absence of macroalgae which determine the degree of degradation. At present there is concern that degradation of the marsh is occurring and therefore evaluation of the role of the WWTF is needed in order to determine what improvements to the existing facility might be warranted. The Town of Marion has planned improvements to the sewage treatment facility such as aeration of its sewage ponds and construction of an additional lagoon. Both of these improvements may help reduce nitrogen loading in effluent.

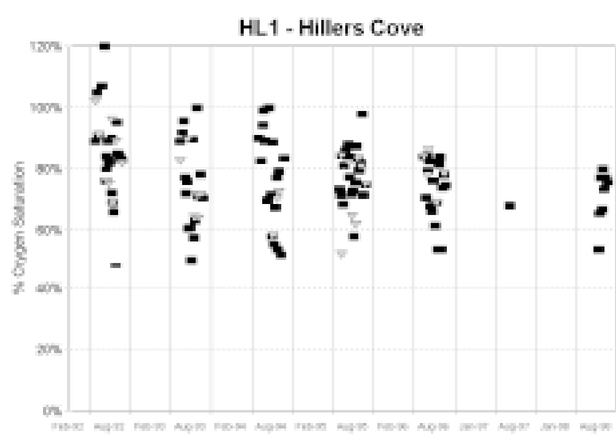
If additional import of nitrogen through the WWTF occurs, three management options need to be addressed: (1) effect of additional loading through this point source on the marsh and head of Cove resources, (2) protection of open-space within the watershed sufficient to "offset" the additional nitrogen load, (3) potential exceeding of the Cove's nitrogen capacity. At present, it appears that the nitrogen assimilative capacity of Aucoot Cove should not be exceeded under current projected development and open-space expansion. However, sufficient additional import of nitrogen from areas outside of the Aucoot Cove watershed could cause it to exceed the capacity.

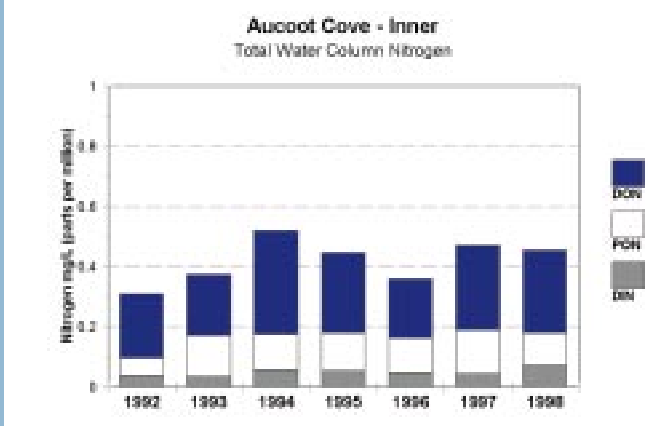
Finally, with more than half of the watershed area undeveloped and zoned for future development, management of nitrogen loading to Aucoot Cove should include careful planning of these lands to minimize forest loss. With 76% of the watershed in Marion and much of the Mattapoisett portions within the Haskell Swamp Wildlife Management Area, responsibility for watershed management falls primarily on the Town of Marion.



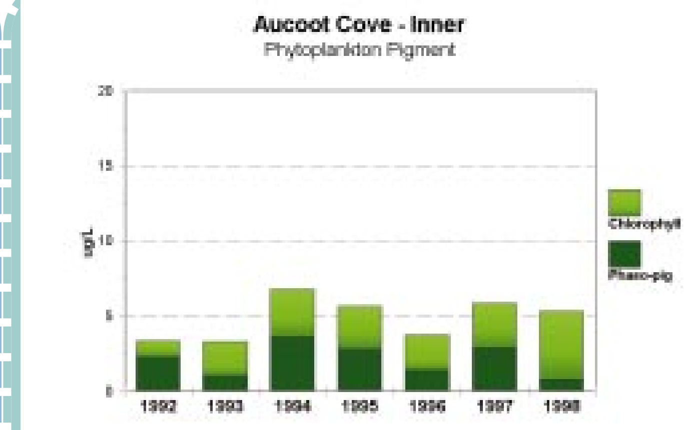




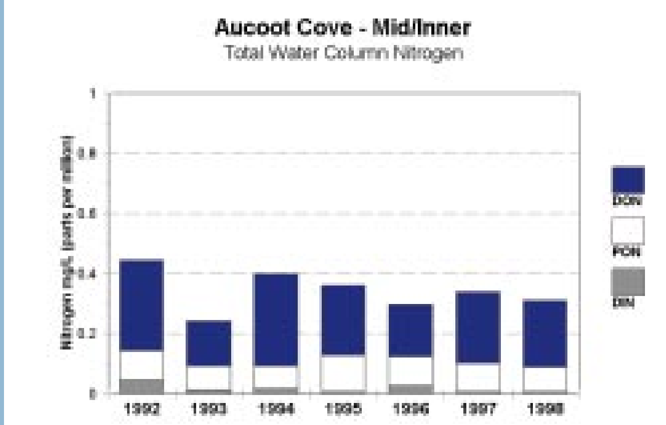




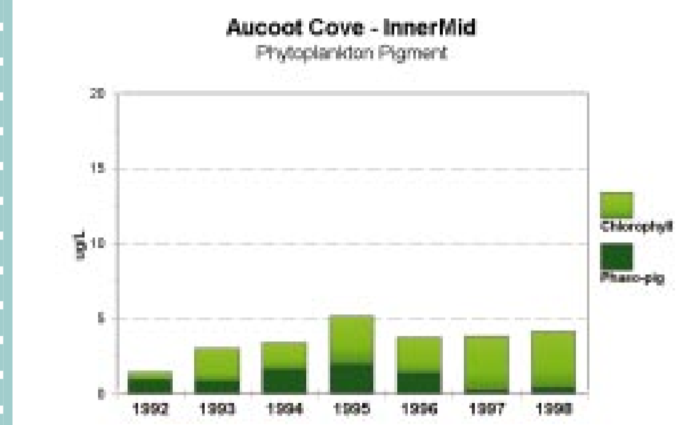
Aucoot Cove - Inner
Total Water Column Nitrogen
Nitrogen mg/L (parts per million)
DON
PON
DIN
1992
1993
1994
1995
1996
1997
1998



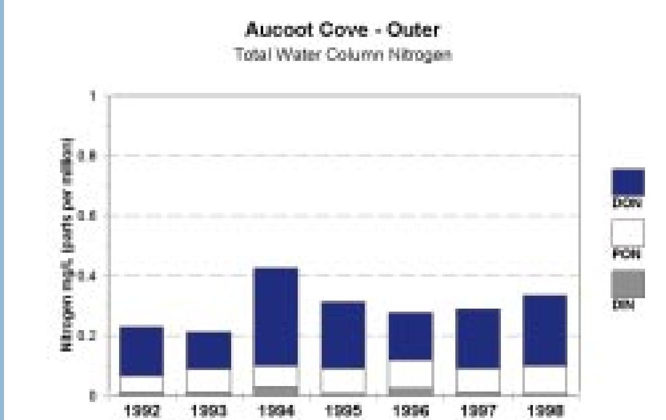
Aucoot Cove - Inner
Phytoplankton Pigment
ug/L
Chlorophyll
Phaeo-pig
1992
1993
1994
1995
1996
1997
1998



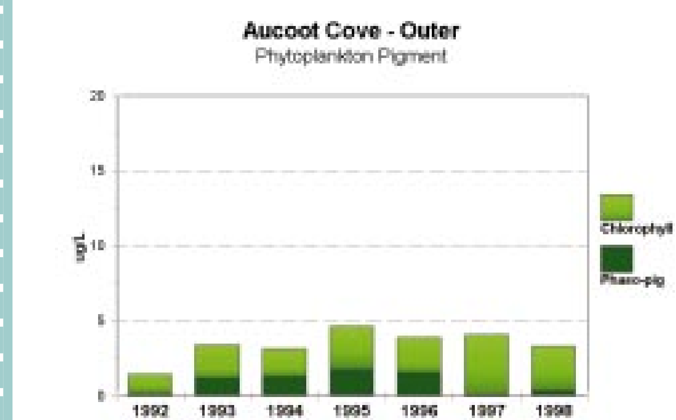
Aucoot Cove - Mid/Inner
Total Water Column Nitrogen
Nitrogen mg/L (parts per million)
DON
PON
DIN
1992
1993
1994
1995
1996
1997
1998



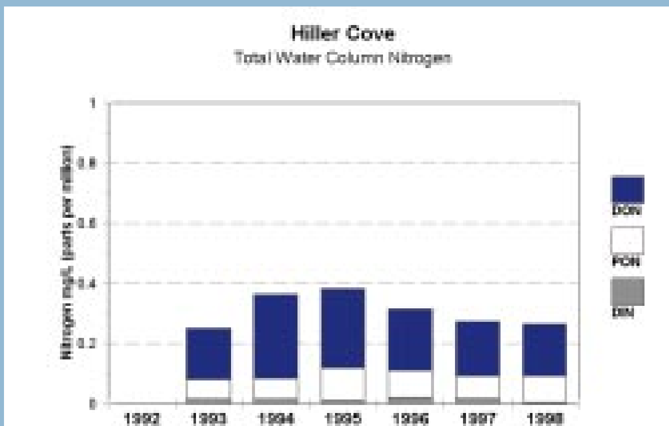
Aucoot Cove - InnerMid
Phytoplankton Pigment
ug/L
Chlorophyll
Phaeo-pig
1992
1993
1994
1995
1996
1997
1998



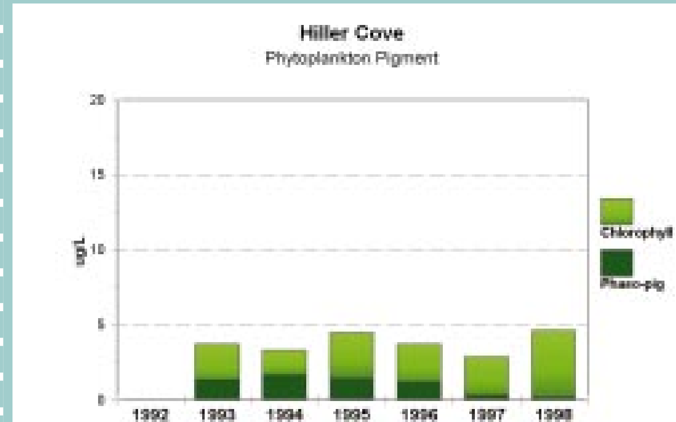
Aucoot Cove - Outer
Total Water Column Nitrogen
Nitrogen mg/L (parts per million)
DON
PON
DIN
1992
1993
1994
1995
1996
1997
1998



Aucoot Cove - Outer
Phytoplankton Pigment
ug/L
Chlorophyll
Phaeo-pig
1992
1993
1994
1995
1996
1997
1998



Hiller Cove
Total Water Column Nitrogen
Nitrogen mg/L (parts per million)
DON
PON
DIN
1992
1993
1994
1995
1996
1997
1998



Hiller Cove
Phytoplankton Pigment
ug/L
Chlorophyll
Phaeo-pig
1992
1993
1994
1995
1996
1997
1998

Mattapoisett Harbor

Embayment and Watershed Characteristics

The Mattapoisett Harbor watershed, fifth largest in Buzzards Bay, is among the least developed. The Harbor is among the larger, deeper and better flushed embayments to the Bay. In many ways the structure of the watershed and Harbor is a larger version of the adjacent Aucoot Cove System. As in most Buzzards Bay embayments, the majority of nutrients enter at the head of the Harbor due to localized development, and the discharge of nutrients from the inland watershed primarily through surface water inflows.

The Mattapoisett Harbor watershed comprises 20,690 acres and includes portions of the Towns of Mattapoisett, Rochester, Acushnet, and Fairhaven. Small streams, such as Swift Brook on the Harbor's western shore and Pine Island Stream on the east, discharge surface water to the Harbor. However, the primary source of freshwater inflow is from the Mattapoisett River. The Mattapoisett River is the fourth largest within the Buzzards Bay watershed and contributes about 6% of the total freshwater inflow to the Bay. Flowing from its source at Snipatuit Pond, the Mattapoisett River Valley serves as a regional public drinking water supply. In addition, the River is home to one of the Bay's more productive anadromous fish runs supporting both alewives and other river herring with up to 120,000 returning to spawn each year.

The watershed is dominated by forest with lesser amounts of residential and agricultural land uses. However, residential development is increasing as a large portion of the watershed remains developable. In contrast to most of the Bay's subwatersheds, agriculture is not dominated by cranberry cultivation, but by upland crops such as corn. Despite the size of the watershed, total nutrient loading is low compared to other watersheds of similar size. This relatively low nitrogen loading results primarily from the low level of development and the fact that a portion of the associated wastewater is transported to the Fairhaven WWTF and discharged into the Acushnet Estuary (New Bedford Inner Harbor). The low watershed loading, coupled with a large bay volume and rapid water exchange with the adjacent Bay, place the Harbor at only a fraction of its critical nitrogen loading limit and among the least loaded systems studied. There are no major point source discharges of pollution in the Mattapoisett Harbor watershed.

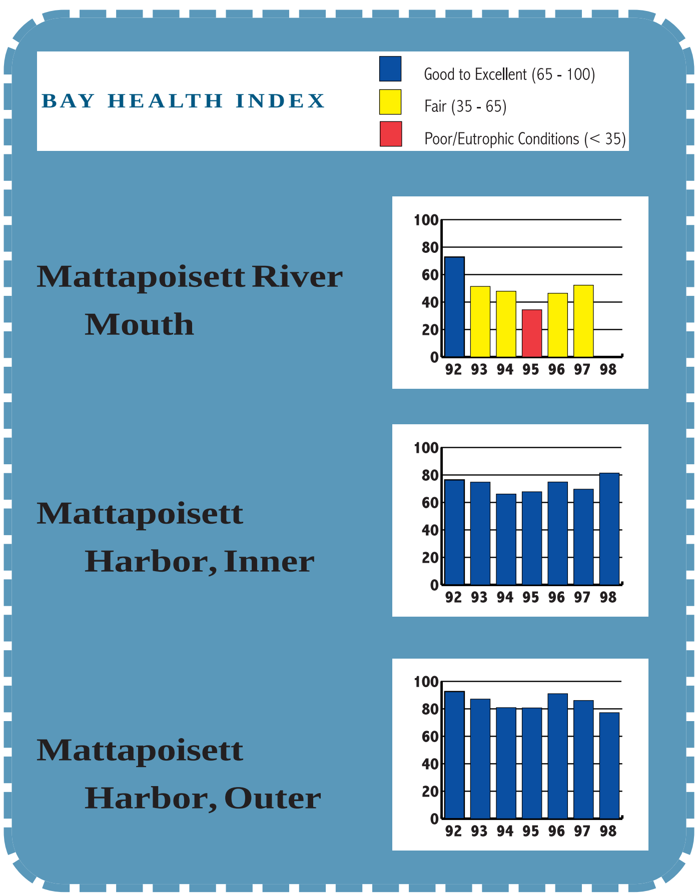
The Town historically supported shipbuilding and now the harbor maintains a large number of recreational craft. At present, there are more than 650 moorings and slips within the harbor and a town pier. Additional recreational uses of the Harbor waters are the town beach areas and numerous private beaches.

The low watershed loading and good water exchange with the Bay is consistent with the prevalence of eelgrass and shellfish beds within the Harbor. Eelgrass occurs primarily at the periphery of the embayment, because the center of the Bay is deep (>12 ft.) and has insufficient light penetration to support growth at depth. As a result, eelgrass covers only a small portion of the entire bay area. Pockets of saltmarsh are scattered throughout the embayment with the largest concentrations occurring at Pine Island Pond and south of Swift Brook on Mattapoisett Neck and smaller areas at the mouth of the Mattapoisett River and surrounding Eel Pond.

Oysters (*Crassostrea*) are most dense outside the mouth of the Mattapoisett River and near Pine Island Pond, while quahogs (*Mercenaria*) are harvested in numerous areas and varying quantities along the shoreline. Soft Shell Clams (*Mya*) are found in small quantities on the tidal flats outside the river mouth and Eel Pond, near Goat Island and along Strawberry Cove. The majority of Mattapoisett Harbor is classified as Approved for the harvest of shellfish by the MA Division of Marine Fisheries. Eel Pond, areas surrounding the Town Dock, Pine Island Pond, and the River Mouth are all subject to Conditional, Restricted, or Prohibited status due to bacterial contamination.

Water Quality

Overall, Mattapoisett Harbor currently maintains a high level of nutrient related water quality which is consistent with the observed eelgrass and shellfish beds. The high quality of the Harbor environment is a combination of low watershed loadings, a deep open basin to the Bay and a high degree of flushing with Bay waters. Nutrient and chlorophyll a pigments within the Inner and Outer Harbor basin showed a concentration gradient of less than 20% in nitrogen and 33% in chlorophyll a pigments and the Outer Harbor stations were similar to Buzzards Bay source waters. However, as is the case of many of the larger embayments to Buzzards Bay, there is some habitat degradation within enclosed inner sub-basins where watershed nitrogen loading is focused and flushing is poorest. Unfortunately, these inner semi-enclosed sub-basins are often the most ecologically productive and diverse, supporting a variety of Bay wildlife, shellfish beds, and other human uses. Within the Mattapoisett Harbor ecosystem the areas currently showing water quality declines are the Mattapoisett River Mouth and Eel Pond (see also, Eel Pond Section).



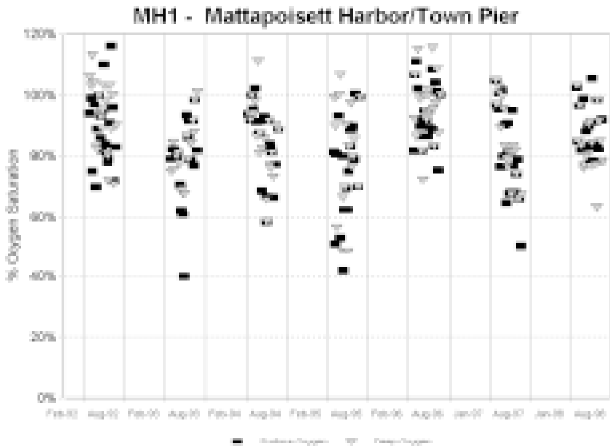
The Mattapoisett River mouth receives a large fraction of the total of watershed loading via the River. In many ways, the River acts as point source discharge from the watershed. In addition, the River mouth region serves as the estuarine mixing zone of marine and fresh waters and also supports fringing wetlands. The river mouth sampling site had annual average salinities ranging from 16 ppt to 28 ppt, compared to the 30-32 ppt within the Harbor. The River mouth is showing intermediate water quality compared to Bay and Central Harbor waters. Nitrogen and chlorophyll a pigment levels at the River mouth are consistently elevated over the Harbor, with average concentrations of total nitrogen, 0.541 mg/L versus 0.366 mg/L (Inner) and 0.308 mg/L (Outer), and chlorophyll pigments, 5.3 ug/L versus 4.7 (Inner) and 3.5 ug/L (Outer).

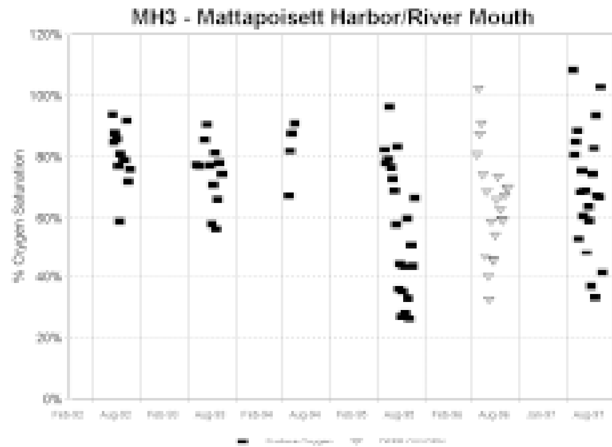
Oxygen levels within the main basin of the Harbor and at the tip of Mattapoisett Neck were consistently at or near air equilibration. In contrast, in the regions of the inner Harbor near Eel Pond and the mouth of the Mattapoisett River, periodic oxygen depletions were observed. The mouth of the River (Station MH3) showed the largest and most frequent excursions to ecologically stressful levels. The station adjacent to the River mouth in the Harbor (MH4), showed similar excursions, though less pronounced. It is likely that MH4 was influenced by water from the River during ebbing tides as suggested by the slightly fresher water than found in the central basin (MH5). To some extent periodic oxygen depletion might be expected in the region near the River, due to the input of nutrients. Diminished vertical mixing, due to estuarine circulation (freshwater flowing on top of salt water) further enhances the likelihood of oxygen depletion in this region. It is likely that the station at the Town Pier is similarly influenced by Eel Pond and even partially by the River discharge.

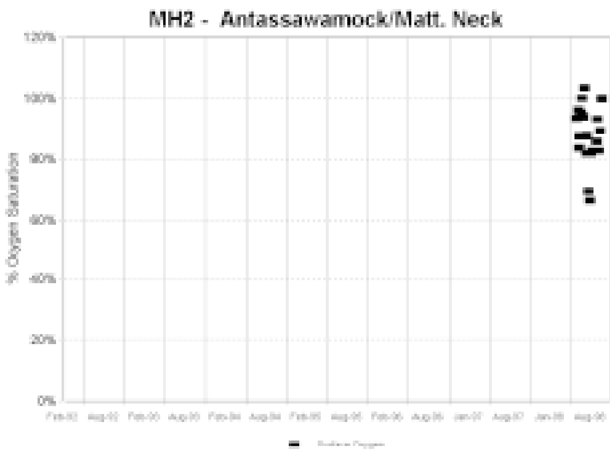
The Health Index for the regions of Mattapoisett Harbor reflects low loading and good flushing within the main Basin. Although there were interannual changes in water quality parameters, there were no clear long-term trends of declining water quality within the system. The finding of nitrogen, chlorophyll and oxygen values similar to the source waters of the Bay supported high index values. The inner versus outer Index values are similar, reflecting the relatively small spatial gradient within this system. In contrast, the mouth of the Mattapoisett River and the adjacent waters do show intermediate water quality, due in part to point source loading from the River. This part of the system, with salinities ranging from 16 ppt to 28 ppt, represents the initial mixing zone of the fresh river waters and the salt waters of the Bay. To some extent the observed conditions at the River mouth may be related to the physiography of the system (the presence of the river discharge, wetlands and estuarine circulation), and may only partially result from changes in watershed land-use.

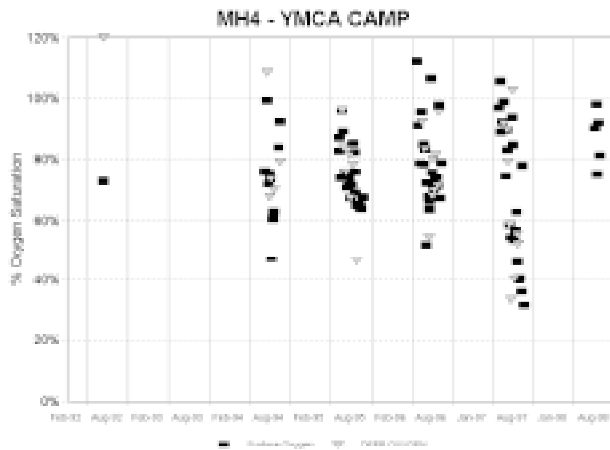
Management Needs

Water Quality in Mattapoisett Harbor continues to rank among the best on the Bay's western shore. The deep water and open

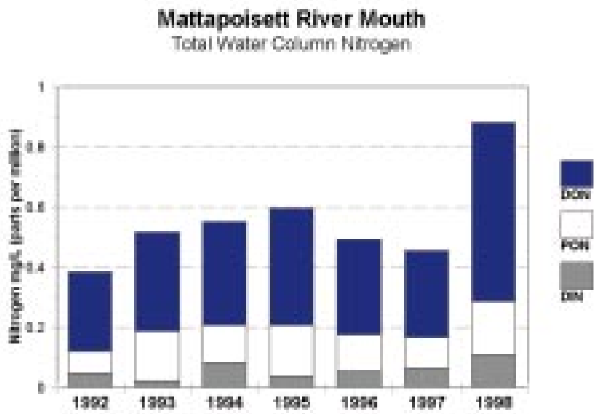


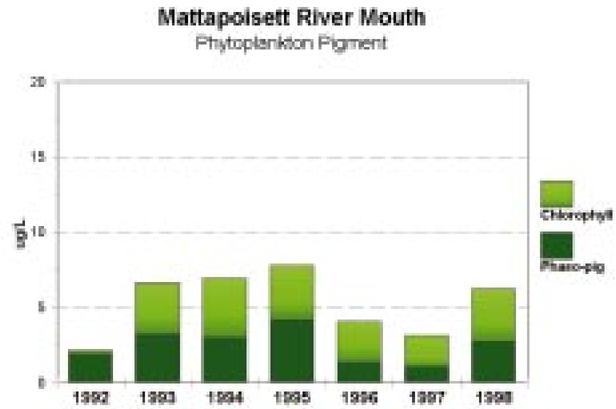




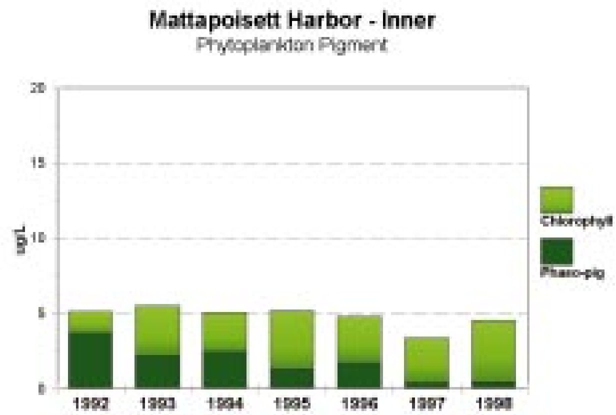


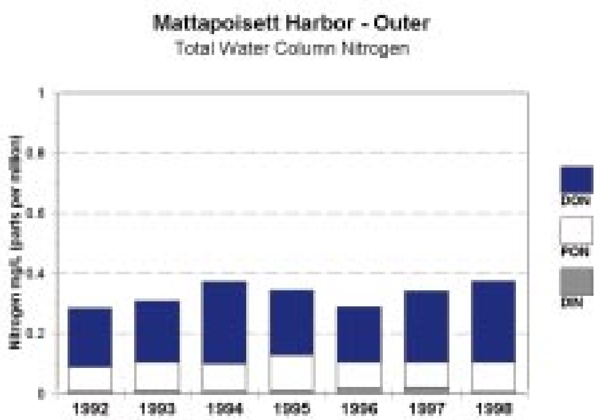
structure of this embayment support good tidal exchange (flushing) with the adjacent offshore waters of Buzzards Bay and enhance its ability to assimilate nitrogen loading from its watershed without showing declines in nutrient related health. The central basin has one of the highest capacities for assimilating nitrogen of all embayments studied. The Harbor is not expected to exceed its recommended nitrogen loading limits in the foreseeable future. Therefore, nitrogen management for the central Harbor waters does not appear to be a priority for the Town of Mattapoisett. However, sub-embayments to the Harbor are showing localized nutrient related declines. Most of the nitrogen inputs to Mattapoisett Harbor are focused in two areas: the cove at the mouth of the Mattapoisett River and Eel Pond. Both these areas are closed to shellfishing because of fecal coliform inputs and both these sub-systems show signs of degradation due to nitrogen inputs. As noted on the following pages, those portions of the watershed draining into Eel Pond and the mouth of the Mattapoisett River do require management action to restore water quality.


Mattapoisett River Mouth
Total Water Column Nitrogen
Nitrogen mg/L (parts per million)
1
0.8
0.6
0.4
0.2
0
1992
1993
1994
1995
1996
1997
1998
DON
PON
DIN


Mattapoisett River Mouth
Phytoplankton Pigment
ug/L
20
15
10
5
0
1992
1993
1994
1995
1996
1997
1998
Chlorophyll
Phaeo-pig

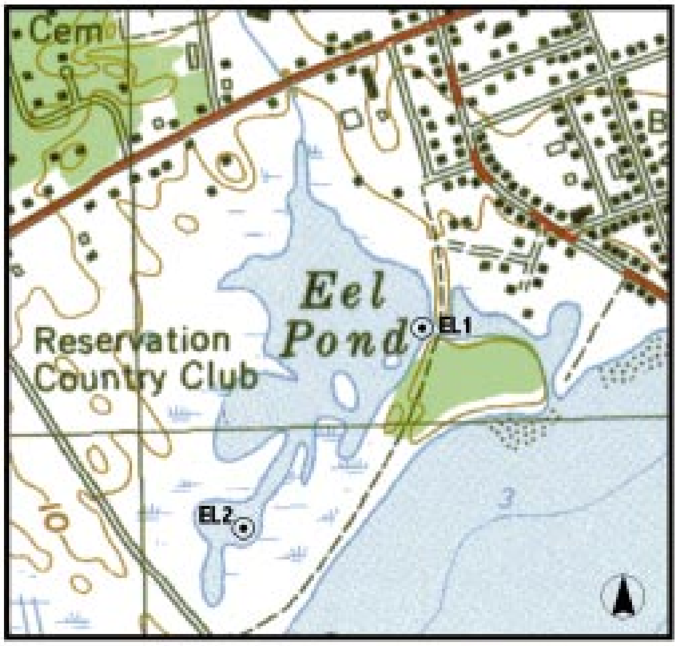

Mattapoisett Harbor - Inner
Total Water Column Nitrogen
Nitrogen mg/L (parts per million)
1
0.8
0.6
0.4
0.2
0
1992
1993
1994
1995
1996
1997
1998
DON
PON
DIN


Mattapoisett Harbor - Inner
Phytoplankton Pigment
ug/L
20
15
10
5
0
1992
1993
1994
1995
1996
1997
1998
Chlorophyll
Phaeo-pig


Mattapoisett Harbor - Outer
Total Water Column Nitrogen
Nitrogen mg/L (parts per million)
1
0.8
0.6
0.4
0.2
0
1992
1993
1994
1995
1996
1997
1998
DON
PON
DIN


Mattapoisett Harbor - Outer
Phytoplankton Pigment
ug/L
20
15
10
5
0
1992
1993
1994
1995
1996
1997
1998
Chlorophyll
Phaeo-pig

Eel Pond



Embayment and Watershed Characteristics

Eel Pond is a small coastal salt pond, 24 acres, at the head of Mattapoisett Harbor. The pond is located between the Mattapoisett village center and the mouth of the Mattapoisett River, the two most focused nitrogen sources to the Harbor. Eel Pond receives freshwater and nutrient inputs primarily by surface water inflow from Tub Mill Brook and through groundwater discharges (primarily recharged from land south of Route 6). As for many coastal salt ponds, the land area contributing to the Pond, 680 acres, is relatively large (28X) compared to the pond area.

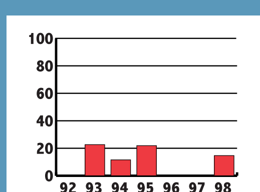
The Pond supports fringing wetlands which at one time had better access to Bay waters. Before road and railway construction the head of Mattapoisett Harbor supported a larger and more integrated wetland system than today, produced primarily by the confluence of the Mattapoisett River and Tub Mill Brook. Consistent with its salt pond-wetland structure, Eel Pond is shallow, generally about 3 feet (1 meter) deep. Although there has been no eelgrass within the Pond in recent times, it is possible that at one time that Eel Pond supported eelgrass, as does a similar system on Cape Cod (Hamblin Pond in Waquoit Bay). However, Eel Pond's shallow basin and associated wetlands do currently maintain important shellfish resources, including what was historically, a sizeable Oyster population. Unfortunately, the Pond remains closed to shellfishing, due to high fecal coliform levels. The main inlet to the Pond is restricted in 2 locations, but primarily by the construction of a railway bed. These restrictions have lowered the flushing of the Pond, thus lowering its ability to tolerate land-based nitrogen inputs and clear-out bacterial contamination, likely entering from surface water inflows and the surrounding tidal marsh. A second inlet has begun forming at the western end of the barrier beach. If this new inlet increases in size it may result in a closure of the historic inlet and possibly a major change in the flushing of the Pond.

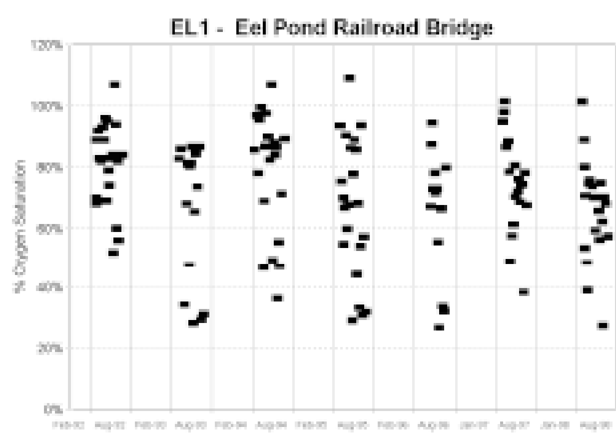
Unlike the greater watershed to Mattapoisett Harbor, the sub-watershed to Eel Pond is significantly developed and includes portions of Mattapoisett Village, Route 6 Commercial Area, and the Park Street neighborhood. Eel Pond receives nitrogen inputs from some of the most heavily developed portions of the Mattapoisett River drainage basin. At present, however, most of the residences are sewered so that nitrogen input from these areas is associated with non-wastewater sources. These non-wastewater sources generally account for about 30%-50% of the total loading from residential development. The major nitrogen sources to Eel Pond include a golf course, lawn fertilizers, runoff and stormwater discharges. At their present level, these loadings, coupled with the restricted tidal exchange, are sufficient to produce eutrophic conditions within the Pond

BAY HEALTH INDEX

- Good to Excellent (65 - 100)
- Fair (35 - 65)
- Poor/Eutrophic Conditions (< 35)

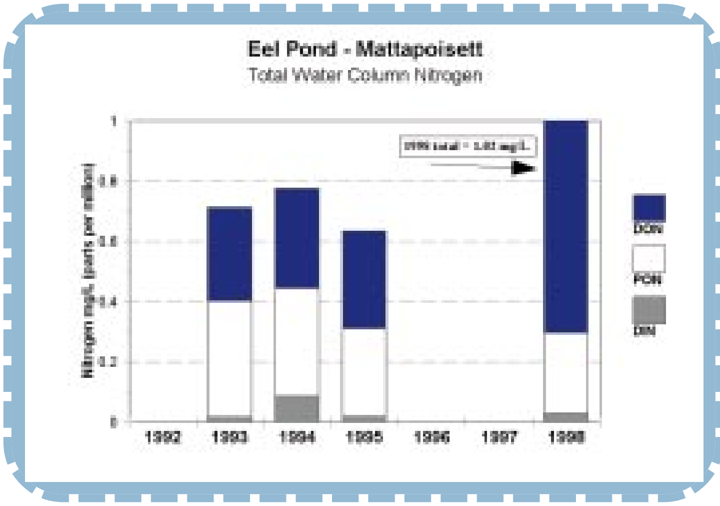
Eel Pond

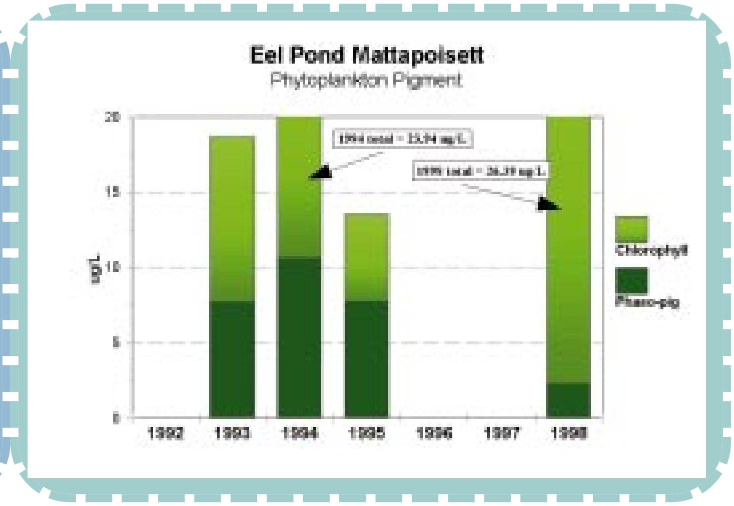




Water Quality

Eel Pond ranks among the most eutrophic embayments within the Buzzards Bay Monitoring Program. In each of the 7 years for which data is available, Eel Pond has shown evidence that it is receiving nutrient inputs sufficient to create conditions of poor water and habitat quality. While some level of nutrient enrich-





ment of Eel Pond waters over Buzzards Bay and Mattapoisett Harbor source waters can be beneficial, for instance increasing shellfish harvests, the level of enrichment in the Pond has caused degradation of its aquatic resources.

Levels of nitrogen and phytoplankton pigments within Eel Pond are consistently significantly enriched over adjacent Mattapoisett Harbor waters. The Pond versus inner Harbor is on average more than 2 fold higher for total nitrogen, 0.752 mg N/L versus 0.366 mg N/L, and 4 fold higher for chlorophyll a pigments, 19.8 ug/L versus 4.7 ug/L. In addition, throughout the study period the chlorophyll a pigments were consistently elevated, only about 15% of the measurements were less than 10 ug/L and about 50% were higher than 20 ug/L. These chlorophyll values suggest that Eel Pond serves as a phytoplankton culture system where nutrients enter from the watershed and are taken up in the Pond by algal growth and then the algae either decay within the pond, impacting dissolved oxygen levels, or are exported to the adjacent Harbor. These phytoplankton may help support some of the productive shellfish beds in the Harbor near the inlet to the Pond.

While the nutrient stimulated phytoplankton production within Eel Pond may support some associated shellfish beds, the levels are sufficient to impact fish, shellfish and potential eelgrass resources within the Pond basin. The high nutrient inputs in relation to flushing have resulted in eutrophic conditions. As clearly demonstrated by the monitoring data, during the summer months, Eel Pond is typically turbid, with secchi depths generally about 80 cm, and has frequent depletions of dissolved oxygen. Oxygen levels in Eel Pond frequently dropped to or below 50% of saturation in each year of sampling and below 30% in 4 of the 7 years. These are depletions which are stressful to animal and plant populations.

Several additional factors serve to increase the level of oxygen depletion within Eel Pond waters. The oxygen depletions are enhanced by the shallow nature of the Pond which tends to have elevated water temperatures, thus increasing oxygen uptake by biological processes. The Pond receives surface freshwater inflows which can result in a lessening of mixing of the watercolumn, hence the input of atmospheric oxygen to the oxygen depleted bottom waters. The Pond salinities occasionally are as low as 1-5 ppt and are commonly several ppt below the levels of the Harbor waters. These low salinities also suggest that tidal exchange with the adjacent marine waters of the Harbor periodically becomes greatly reduced, increasing the potential for eutrophic conditions within the Pond. In addition, the shallow nature of the Pond also increases the recycling of nitrogen from the bottom sediments which can be an important source for algae in summertime . In addition, it is likely that the Pond has always been enriched in organic matter, due to its surrounding tidal marshes. However, the current level of enrichment appears to be clearly related to watershed nutrient inputs.

Given the high levels of nitrogen and chlorophyll and observed oxygen depletions, it is not surprising that the Health Index for Eel Pond showed poor water quality conditions. In each of the 4 years for which an Index can be computed, including 1998, the index was among the lowest observed in Buzzards Bay. Based upon its consistently poor water quality, restoration of Eel Pond should be a priority within the Buzzards Bay System.

Management Needs

Eel Pond probably receives less of a nitrogen load than the area at the mouth of the Mattapoisett River, but it shows significant degradation because of its reduced flushing and small volume. In the Baywatchers Report I (1996), it was strongly recommended that the first step for the restoration of nutrient related water quality in Eel Pond was to delineate its watershed and assess present and build-out nitrogen loadings. Subsequently, during the summer 1997, the Buzzards Bay Project National Estuary Program supported a flushing study of Eel Pond as part of a grant to the Town of Mattapoisett. Following the flushing study, a report entitled, Eel Pond Water Quality Analysis and Nitrogen Loading Evaluation, was completed in April 1998. The results of these initiatives provided additional water quality monitoring data, an understanding of the flushing restrictions of the pond, and an assessment of nitrogen sources and management options for this small estuary.

During the summer of 1997, sampling indicated that watershed nitrogen entering through Tub Mill Brook was likely a major source to the pond. In addition, measurements of nitrogen concentrations in Brook waters showed lower nitrogen in the waters upstream of Route 6 versus downstream, likely due to inflow of high nitrate groundwaters downstream and possibly due to stormwater and other runoff from Route 6. Direct groundwater discharges to the Pond are also an important pathway for input of watershed nitrogen. This is seen in the 1997 Study which reported higher inorganic nitrogen levels in nearshore pond waters adjacent to the golf course, suggesting that nitrogen from fertilizers used on the Reservation Country Club are leaching into the Pond. Individual septic systems are a less dominant source than in most other watersheds around the Bay, due to sewering. However, additional hook-ups to the sewerage system still represents a mechanism for Pond nitrogen management. Fertilizer applications and road runoff comprise secondary nitrogen sources. Eel Pond is the only Buzzards Bay salt pond directly abutting an actively managed golf course, making turf management practices an important part of Eel Pond's restoration. There are no major point sources of nitrogen discharging to Eel Pond.

Eel Pond is beyond its ability to adequately assimilate nitrogen, as evidenced by the clear eutrophication already occurring in the Pond. Given its present status of nutrient overenrichment, any further loading to the Pond will cause further declines in water quality. While it has been estimated that 17 new homes on septic systems can be built in the watershed before serious impacts to Pond health and biota are experienced (H&W 1998), the point of serious health impacts appears to have already been passed prior to the 1993 monitoring season. At full buildout, the analysis completed by Horsely & Witten, Inc. further found the Eel Pond watershed to be "overprogrammed," such that approximately 352 more homes on septic systems could be built under current zoning. Any reduction therefore in future development would require major rezoning to greatly increase minimum lot size. The report is careful to note that while increasing minimum lot size would be a major benefit to nitrogen management, it is questionable whether such a major re-zoning is practical. Other land-use options might be more workable, such as additional sewer extensions, open space acquisitions, and improved turf management practices. Perhaps the most immediate option is to evaluate the degree of restoration to be achieved by the restoration of tidal flushing to the embayment either by work on the historic inlet or maintenance of the newly formed inlet.

It is important to note that, with the exception of nitrogen entering Eel Pond through atmospheric deposition, all sources of nitrogen in the watershed can be managed by the Town of Mattapoisett.

In addition to pursuing potential alterations to the circulation of the Pond which requires some additional engineering evaluations, current nitrogen source reduction efforts need to be expanded. Additional sewering of the watershed can reduce the extent of nitrogen loading impacts to the pond. If feasible, sewering the entire watershed would significantly reduce the total nitrogen load at buildout. Acquisition of open space, either in fee or restriction, provides significant protection to the pond as undeveloped land contributes virtually no nitrogen to receiving waters. In fact, forests and wetlands work to attenuate nitrogen from surface waters and atmospheric deposition, thereby serving as nitrogen sinks within the watershed. A targeted acquisition program could be extremely successful in reducing overall nitrogen loading. Although the Reservation Golf Club on the western shore of Eel Pond is privately owned, the Town should work with the club owner to develop programs to reduce fertilizer use and minimize direct runoff of nitrogen into the Pond. This can be accomplished through reduction in fertilizer applications (either application rate or area), using high nitrogen discharges within the watershed for fertilization (water recycling), and maintaining a natural buffer between managed turf areas and the pond. Eel Pond is an important aesthetic and potential shellfish resource to the Town, which can support improved water quality with the application of present technologies.

T.Williams 1998

Nasketucket Bay, Little Bay

Fairhaven

with a short channel of only ca. 2 meters depth. In contrast Nasketucket Bay has a central basin reaching 5 meters depth, although it contains extensive shallows, particularly between West Island and Sconticut Neck.

Almost all of the System's surface freshwater inflow enters through the Nasketucket River and two small streams to the headwaters of Little Bay. Since entry of bacterial contamination from coastal watersheds is almost entirely through surface water inflows, particularly from developed areas, Little Bay is a susceptible environment for this type of contamination. Most of the direct freshwater inflow to Nasketucket Bay is through groundwater discharge.

The margins of Little Bay are nearly completely colonized by saltmarshes which have been extensively ditched for mosquito control. These marshes account for most of the 294 acres of saltmarsh within the Nasketucket Bay System, the third largest saltmarsh acreage of the embayments to Buzzards Bay. In addition, the shallow margins of Nasketucket Bay currently support extensive eelgrass beds with related animal communities. The largest beds are found in the nearshore to Sconticut Neck and in the protected shallows of West Island and Long Island, although the northern shore to Brant Island also supports beds. In contrast to the utilization of available habitat by eelgrass in Nasketucket Bay, Little Bay has lost most of its eelgrass and the habitat appears now to be utilized by macroalgae. The word "Nasketucket" in Wampanoag loosely translates to "our grass river place" most likely referring to the historic abundance of saltmarsh and eelgrass within the Nasketucket Bay System.

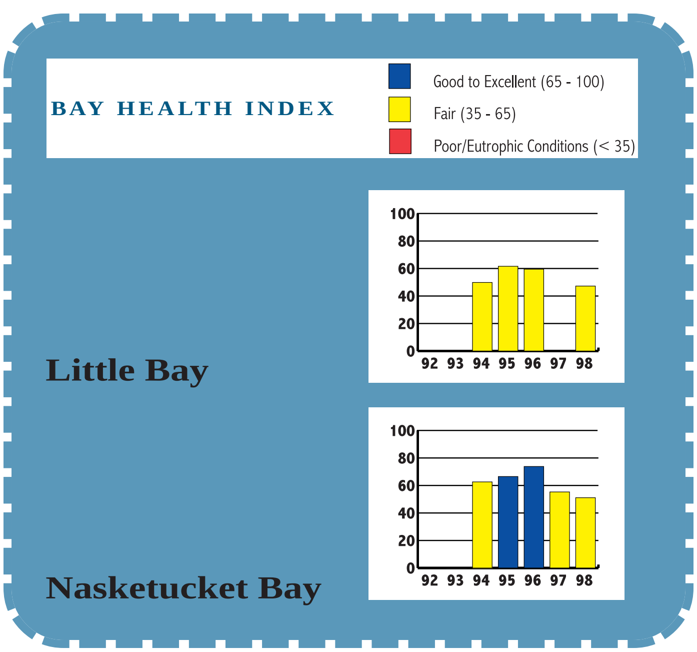
Embayment and Watershed Characteristics

The Nasketucket Bay System is among the largest of Buzzards Bay embayments within the Coalition for Buzzards Bay's Monitoring Program with 1,067 acres of water surface. The Nasketucket Bay System consists of a large outer open bay, Nasketucket Bay (859 acres), and an inner semi-enclosed bay, Little Bay (208 acres). The mouth of Nasketucket Bay is bounded to the west by Sconticut Neck and West Island and to the east by Brant Island. Historically Wilbur Point at the tip of Sconticut Neck could be considered the outer margin of this Bay, however, with the construction of the roadway joining the Neck to West Island, the functional margin has moved to Rocky Point (at the island's southern end). Little Bay or Upper Nasketucket Bay is bounded at its outer margin by a large marsh island which narrows the Bay's entrance. Little Bay is quite shallow, generally <1 meter,

Little Bay and Nasketucket Bay have historically supported good shellfish resources, primarily quahog (*Mercenaria mercenaria*) and soft-shell clam (*Mya arenaria*). The American Oyster (*Crassostrea virginica*) has been found in moderate abundance within the tidal reaches of the Nasketucket River. Bay scallop (*Argopecten irradians*), lobster (*Homarus americanus*) and conch (*Busycon canaliculatus*) are both recreationally and commercially fished. At present, Little Bay is "Conditionally Approved" by the Massachusetts Division of Marine Fisheries for the harvest of shellfish, due to elevated fecal coliform bacteria levels related to surface water inflows. Conditional approval allows harvest during dry weather, but closure during wet weather. One-quarter inch of rainfall in 24 hours closes the area to shellfish harvest for five days, subsequent rain events extend the closure period (DMF, Re-evaluation of Little Bay, Fairhaven, 1992). Removal of "Conditional Closures" will require remediation of sources of bacterial contamination and a re-evaluation of the system by DMF.

The watershed of Nasketucket Bay/Little Bay is primarily within the Town of Fairhaven with lesser areas in Mattapoisett and Acushnet. Although the Nasketucket Bay System is one of the larger embayments to Buzzards Bay, its watershed is proportionately small, 3,511 acres, with less than 3 acres of land for each acre of estuary (bay+marsh area). However, most of the watershed (3006 acres) discharges through surface and groundwater inflows initially to the semi-enclosed waters of Little Bay. Nitrogen inputs to the watershed are primarily from residential land-uses and agriculture. More than a quarter of the Nasketucket watershed supports some type of agriculture, the third highest in Buzzards Bay. Because of the distribution of watershed land-uses and inputs and its generally good flushing, Nasketucket Bay is able to maintain relatively high water quality and extensive shellfish and eelgrass resources. However, given its semi-enclosed nature and watershed area, Little Bay should be the primary focus for environmental management within this System.

Single family residential and retail commercial properties, farms, and open forestlands comprise the bulk of land uses in the sub-watershed to Little Bay. At present the Little Bay watershed contains little residential development. Most of the Nasketucket System's housing is located adjacent to Nasketucket Bay, especially along Sconticut Neck and West Island. Within Little Bay most of the immediate shoreline is undeveloped, except for a stretch along Sconticut Neck and an area at the head of the Bay known as Knollmere Beach. There are no point source discharges of pollution in the Little Bay (or Nasketucket Bay) watershed. Two large dairy farms are located approximately 1.5 miles north of the embayment along Interstate-195 which bisects the watershed west to east. Forestlands dominate the upper reaches of the watershed in the Towns of Acushnet and Fairhaven. The embayment supports recreational boating with 180 boat slips, primarily at West Island, which are used primarily during summer.



Land acquisition for wildlife and conservation has been actively pursued within the Little Bay watershed. Today, nearly 50% of the lands along the Little Bay shoreline are protected by the Fairhaven Conservation Commission, Massachusetts Division of Fisheries and Wildlife, or the private Fairhaven-Acushnet Land Preservation Trust (FALPT) as permanent open space. In addition, 136 acres of the 344 acres of the watershed in the Town of Acushnet are municipally owned and managed as forest-lands, but are not presently under permanent protection. Additional land in the outer Bay is protected and managed by the Massachusetts Audubon Society and FALPT. Maintenance of these open-spaces will help to support the water quality and marine resources within the Bay into the future.

Water Quality

Nine water quality stations have been monitored in the Nasketucket Bay System at various times by The Coalition for Buzzards Bay Citizens Water Quality Monitoring Program between 1992 and 1998. A gradient in water quality was found within the Nasketucket Bay System. Nutrient related water quality was lowest at the mouth of the Nasketucket River, moderate in Little Bay and moderate to high in Nasketucket Bay. Since a large fraction of nitrogen loading to Nasketucket Bay enters through Little Bay, and most of the nitrogen to Little Bay arrives via the Nasketucket River, most of the sampling effort has focused on the inner Bay. In addition, given the poorer flushing of Little Bay, management should first be focused there.

Nasketucket River stations, NR1 at mouth, NR2 at Rt. 6, and NR3 at railroad bed, were monitored for nitrogen levels on 4 dates in 1993. These river stations were clearly within the estuary with salinities of 21-29 ppt. at station NR1 closest to the bay, 2-12 ppt at station NR3, and below 2 ppt at the most upstream station, NR2. What is most interesting about the results of this survey was that there was an increase in inorganic nitrogen concentration at the mid-station, NR3, suggesting a large nitrogen source down gradient of Route 6. Concentrations of dissolved inorganic nitrogen were quite high averaging 1.3 mg N/L. In addition, the upper station had high concentrations of particulate organic matter flowing downstream, 2.28 mg C/L. These data support the contention that Nasketucket River is an important "point source" input of watershed loading to Little Bay.

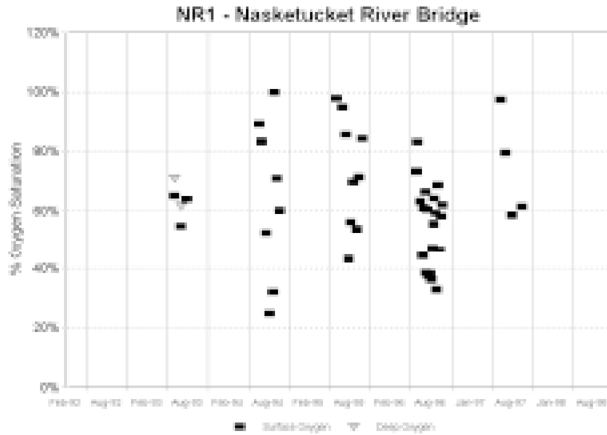
The water quality gradient within the Nasketucket Bay System is primarily within Little Bay and reflects the relatively high level of nutrient inputs compared to the Bay's flushing characteristics. Average total chlorophyll a pigments were two fold and 1.5 fold higher at the mouth of the Nasketucket River (10.4 ug/L) and inner Little Bay (7.8 ug/L) than at the mouth of Little Bay (5.2 ug/L). Particulate organic carbon (POC) and total nitrogen (TN) concentrations show a similar gradient across Little Bay from the river mouth (POC: 1.19 mg C/L, TN: 0.72 mg N/L), to inner Little Bay (POC: 1.16 mg C/L, TN: 0.49 mg N/L), to the exit to Nasketucket Bay (POC: 0.87 mg C/L, TN: 0.44 mg N/L). No consistent gradient was found between the mouth of Little Bay and the West Island station; both showed higher levels of each constituent than found in central Buzzards Bay. The cause of the elevated levels at West Island may be due to localized nutrient inputs and possibly mixed inflow of Buzzards Bay waters with the nutrient enriched outflowing waters from adjacent outer New Bedford Harbor. Waters midway between Brant and West Islands would be expected to be similar to the low nutrient waters of Buzzards Bay.

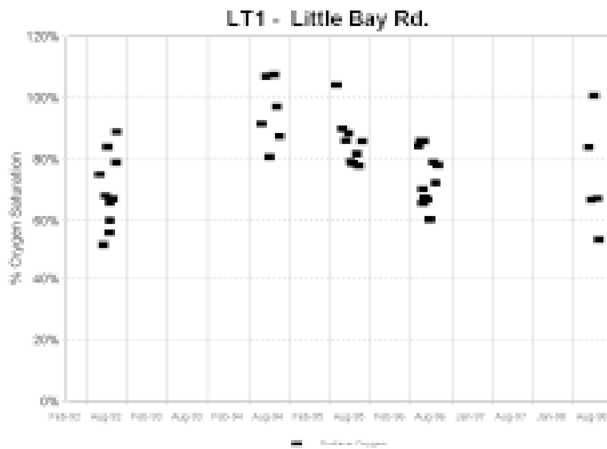
At present, Little Bay appears to have sufficient nitrogen loading to result in significant enrichment of its waters. The results are moderate levels of phytoplankton and organic matter which are more than 50% and 30% higher on average than found in the outer Bay. This causes periodic moderate oxygen declines within Little Bay, primarily in the inner region where levels below 60% of air saturation have been observed. The effect of nutrient loading (and possibly adjacent marsh effects) can be seen at the mouth of the Nasketucket River where oxygen depletions below 50% of saturation were frequently observed and depletions below 40% saturation were recorded in more than 10% of the samples. This site is susceptible to periodic isolation of bottom waters due to salinity stratification (estuarine circulation) which may contribute to the observed low oxygen levels. Oxygen conditions at the West Island station were generally above 80% of saturation, but periodic declines below 70% were observed. These values are consistent with the measured watercolumn parameters at this site.

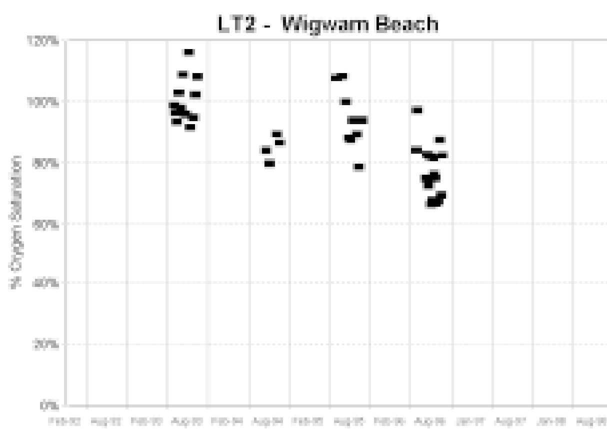
Integrating the nutrient related water quality parameters for each sub-system into the Health Index further shows the moderate level of habitat quality within Little Bay and the moderate to high level at West Island in Nasketucket Bay. These values are consistent with the present eelgrass distribution within this system. However, these values for Little Bay suggest a system which is currently receiving watershed nutrient loads at (or slightly beyond) levels sufficient to affect habitat quality. To some extent, Little Bay is a difficult system to evaluate as large wetland areas adjacent to the Bay may also contribute to some of the observed parameter levels. However, it appears that detailed nutrient and habitat evaluation of Little Bay is in order.

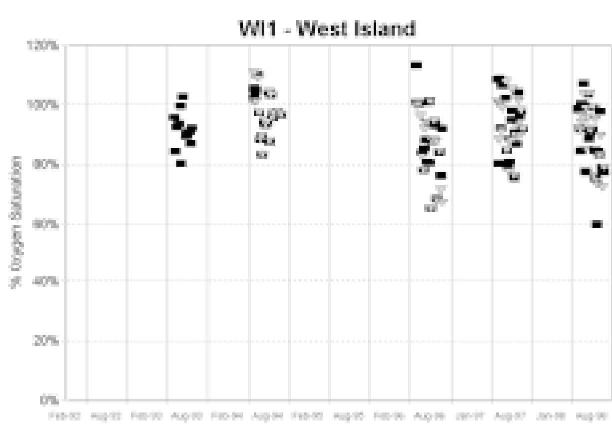
Management Needs

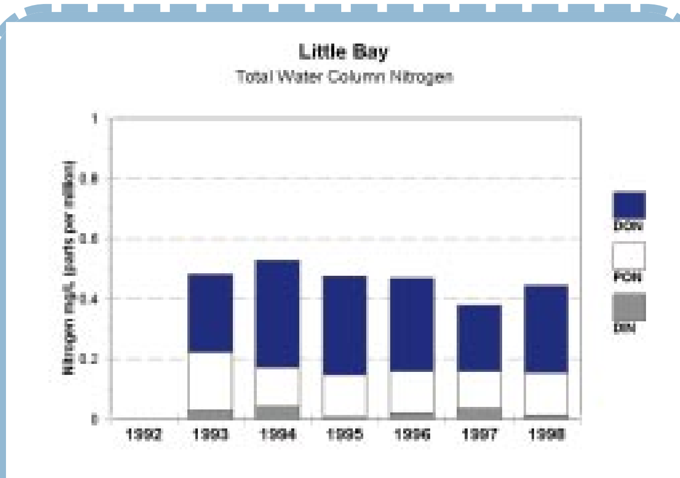
As one of Buzzards Bay's larger, better flushed embayments, central and outer Nasketucket Bay is showing only moderate to low effects from watershed pollutant loading. Managing nitrogen inputs to Little Bay and other nearshore areas of Nasketucket, however, requires a different, more detailed approach. The negative impacts of excessive nitrogen loading are usually most acute in the shallow, poorly flushed portions of an embayment. For this reason, Little Bay was recommended for more detailed investigation in the 1996 Baywatchers I Report. As a result, the Buzzards Bay Project National Estuary Program, working with the Town of

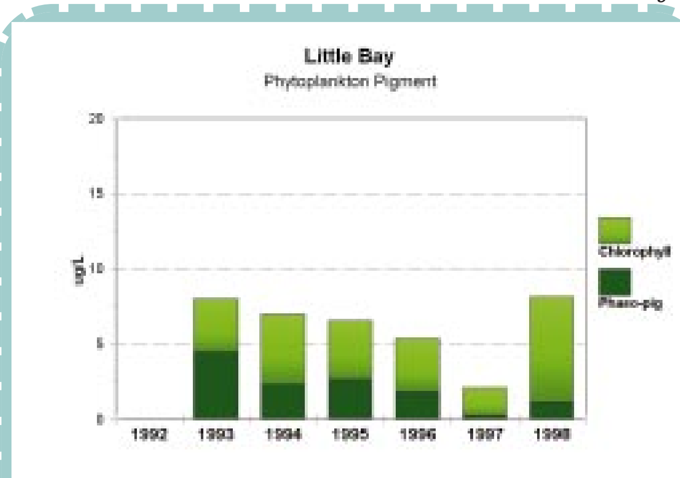


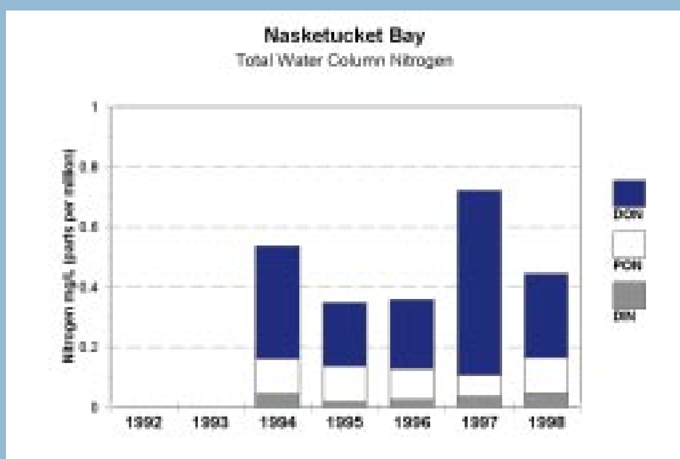


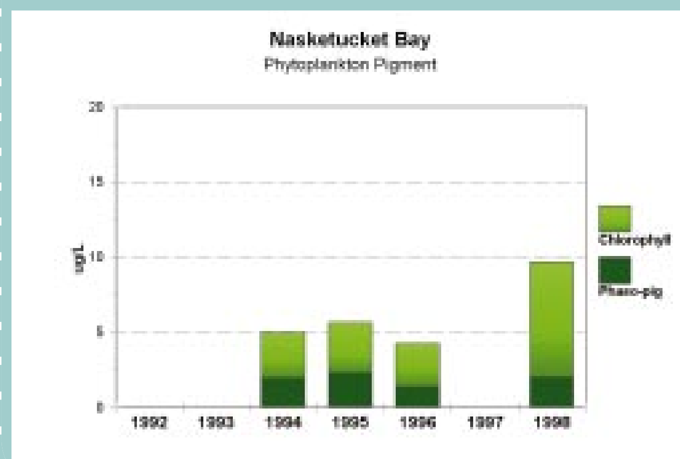












Fairhaven, completed a preliminary build-out analysis of the watershed to Little Bay in order to estimate future nitrogen loads to the bay from residential development. The land-use information was integrated with determined tidal flushing rates in Little Bay to evaluate potential effects of increasing watershed nitrogen loading to Little Bay. The results of these investigations were published in 1999 in a report entitled, "Assessment of Nitrogen Loading and Nitrogen Management Alternatives for the Little Bay Watershed".

All major watershed sources of nitrogen entering Little Bay can be controlled by the towns of Fairhaven and Acushnet. The sources of nitrogen to Nasketucket and upper Little Bay are comprised entirely of non-point sources of pollution. Although the Fairhaven Wastewater Treatment Facility lies close to the Bay on Nasketucket Creek, it discharges to Inner New Bedford Harbor and does not contribute nitrogen to Little Bay. The two largest sources of nitrogen were found to be residential dwellings and dairy farms in the watershed.

The nitrogen loading assessment for Little Bay indicated that under existing conditions, the critical load to the Bay has not been exceeded. However, the build-out analysis of the Little Bay watershed indicated that under current zoning of available land, 2,349 additional dwellings could be built. The associated additional nitrogen load, with the current loading, was determined to be in excess of the level which the Bay can tolerate without a decline in habitat quality. Zoning techniques such as increasing minimum lot size in the area to reduce build-out densities were not recommended as absolutely necessary for preventing increases in future nitrogen loads. Greater benefits are anticipated from non-regulatory actions such as selective acquisition or transfer of undeveloped lands in the watershed to permanent open space and through sewering additional portions of the watershed.

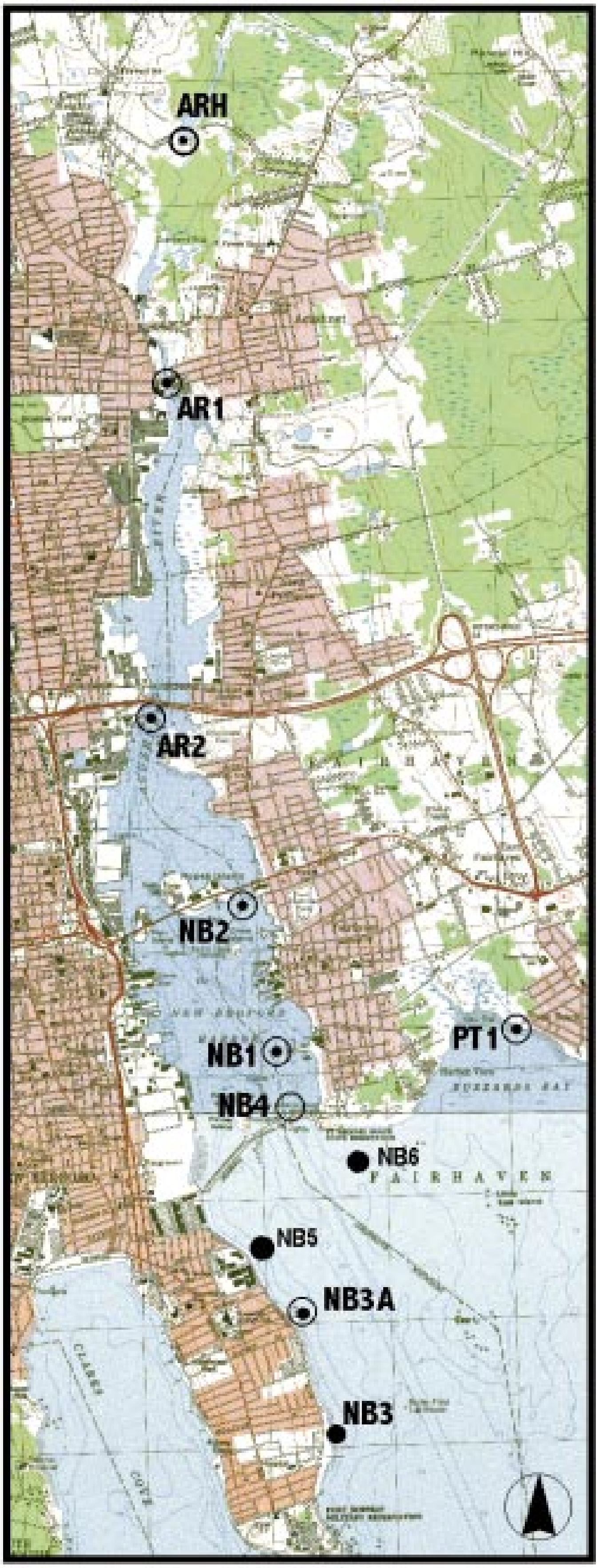
In contrast to the watershed nitrogen evaluation, monitoring of nutrient related habitat quality of these Bays by Baywatchers suggests that the nitrogen related water quality decline may have already begun within the inner reaches of Little Bay. This is based upon summertime high nitrogen and organic matter levels, moderate chlorophyll a concentrations and periodic depletion of watercolumn oxygen. In addition, macroalgal and eelgrass distributions are typical of an enriched estuary. As it is difficult to precisely determine the nitrogen loading tolerance of a bay, the site specific monitoring data brings forward a new urgency for detailed evaluation of nutrient management alternatives and their expected effectiveness for enhancing the quality of Little Bay habitats. However, as it appears that there is presently over-enrichment of Little Bay waters, a reduction in nitrogen loading rather than a reduced rate of increase is required for maintaining moderate to high water quality conditions.

Nitrogen reductions typically take the form of advanced wastewater treatment or sewering of densely developed watershed areas. The densest concentration of homes on the Little Bay shoreline is located at the bay's northern edge in an area known as Knollmere Beach. Currently 31 homes in the Knollmere area are unsewered and many of these are served by substandard septic systems. The area also has the potential to support additional dwellings on grandfathered lots. The upper eastern side of Sconticut Neck, north of Edgewater Street, should also be provided with municipal sewer as these homes, constructed on small lots, provide the second most direct avenue for nitrogen loads from residential wastewater reaching Little Bay. Not only do these areas contribute nitrogen unattenuated to the waters of Little Bay, but failing systems may be contributing to the bacterial contamination and Conditional Shellfish Closures of Little Bay. Based upon the water quality data and likely future septic system problems, the Coalition for Buzzards Bay supports sewering of these areas (as feasible) by the Town of Fairhaven. As there is significant agricultural land-use within the watershed, the Town should encourage the implementation of Best Management Practices for reducing nitrogen from this source.

In addition to reducing existing nitrogen loading, future nitrogen loading due to build-out of undeveloped areas needs to be addressed. This can be accomplished in a number of ways including increasing minimum lot sizes on unsubdivided land, sewering portions of the drainage basin as they are developed, limiting lawn sizes, purchasing either land or conservation restrictions to prevent development of open space, or by requiring the use of nitrogen reducing septic systems. Part of the solution originates with the understanding that, under present zoning rules, the Bay will undergo habitat quality declines under additional nitrogen loading.

Acquisition and preservation of existing open-space is the best mechanism (has the greatest reduction in load when compared to development on an areal basis) for reducing future nitrogen loads to the Bay. While additional acquisitions should be undertaken particularly within the Little Bay watershed, it is also important to minimize nitrogen loading from existing publicly owned open-space. In this regard, the Town of Acushnet should consider placing its 136 acres of the Little Bay watershed under conservation or similar open-space protection. This would not only serve to protect the water quality of the Bay, but maintain the land as open-space for future generations of the Town's citizens.

T.Williams 1998



Fairhaven, New Bedford

Embayment and Watershed Characteristics

New Bedford Inner Harbor, also known as the Acushnet River estuary, is the largest urbanized and industrialized Harbor on Buzzards Bay. New Bedford Harbor/Acushnet River is part of the Greater New Bedford System which also includes adjacent Clarks Cove, Apponagansett Bay and New Bedford Outer Harbor. The Harbor is one of the deepest embayments to Buzzards Bay with an average depth of 3.19 meters. It is home to a growing number of recreational boats in addition to 250 fishing vessels. New Bedford supports an active fish processing industry and remains one of the top ports for landings within the U.S. New Bedford maintains an active marine port which has traditionally supported large cargo vessels. Sedimentation within the Harbor has reduced the port's utility, and remedial dredging is planned for the near future.

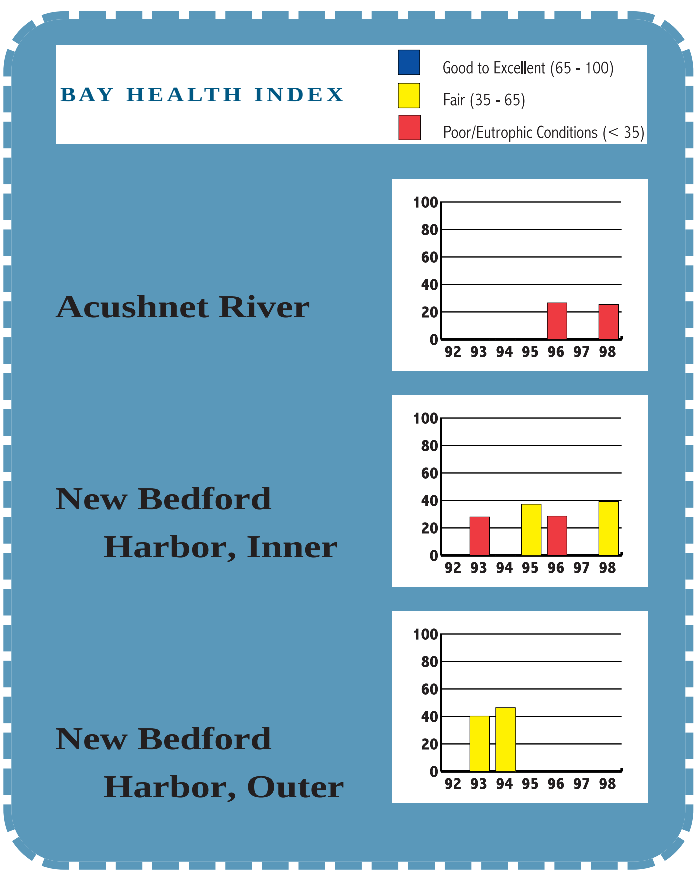
The watershed includes the eastern side of the City of New Bedford, which has the largest population in the Buzzards Bay region making up 35% of the entire Buzzards Bay watershed population. The western half of Fairhaven as well as most of Acushnet and portions of East Freetown comprise the remainder of the Harbor's large, 17,180 acre, watershed. For comparison, the watershed is nearly 10 times that for adjacent Clarks Cove. Not surprisingly, the watershed supports a relatively large flow through the Acushnet River, one of the top ten surface water discharges to Buzzards Bay. The Acushnet River supports active cranberry agriculture in the upper portion of the watershed and a large wetland complex along the river, most notably the 1100 acre floodplain swamp (south of the Reservoir) and the 350 acre Hathaway Swamp.

Principle nitrogen sources to New Bedford Harbor are the Fairhaven Wastewater Treatment Facility (WWTF) and the City of New Bedford's Combined Sewer Overflow (CSO) system. These point sources of pollution should be the primary focus of nitrogen management for this estuary. All densely developed areas in the New Bedford Harbor watershed are served by municipal sewer. On the New Bedford and Acushnet side, this residential nitrogen load is transferred out of the estuary to the Outer Harbor through the New Bedford WWTF. The upper Acushnet River watershed is more rural (over half of the area is forested) and is served by individual onsite septic systems.

As might be expected for a historic industrial port, the marine resources of the Harbor have been heavily impacted or altered. The New Bedford and Fairhaven City shorelines were completely wharved by the mid-1800's. Within this century over 200 acres of salt marsh were filled within the Harbor to support port activities. Eelgrass, which has declined throughout Buzzards Bay in recent decades, disappeared from the Harbor early in the century.

Historical use and disposal of industrial wastes have resulted in significant pollution to New Bedford Inner Harbor (inland of the Hurricane Barrier). The Harbor is classified as a federal Superfund site due to contamination of marine sediments with PCBs (polychlorinated biphenyls) and metals. PCB contamination is currently under remediation by the US Environmental Protection Agency. PCB's are long-lived and are retained within the tissues of animals, affecting both shellfish and finfish. As of this writing, PCB remediation of the upper Harbor is continuing with sediment removal and land containment. The goal is to lower PCB concentrations in Harbor sediments to less than 50 ppm (mg PCB per kg sediment). Phase I of the clean-up was completed in 1995 and consisted of removing the "Hot Spots", areas greater than 4,000 ppm. The remaining sediment removals will be completed by 2008, with disposal within Confined Disposal Facilities (CDF's) bordering the Harbor which will be capped and used as open space until new technologies arise for permanent PCB disposal. However, nutrients and pathogens from sewage have been a major problem within this estuary throughout this century and will continue to impact the Harbor ecosystems after PCB remediation is complete.

New Bedford Harbor is the region of the Acushnet Estuary enclosed by the Hurricane Barrier, which extends to the head of Clarks Cove. The Hurricane Barrier, constructed in the early 1960's has greatly reduced flushing and sediment export from the Inner Harbor to the Outer Harbor and Buzzards Bay. This barrier has a gate entrance connecting New Bedford and Fairhaven and has led to the decline in water quality and total loss of eelgrass by holding pollutants in the Harbor and reducing tidal exchange with the cleaner, open waters of Buzzards Bay. Although there have been negative consequences to the Harbor, it is the reduced flushing that has "protected" the Outer Harbor and Buzzards Bay from greater PCB contamination and has allowed for a focused clean-up. It should be noted that 1600 acres of shellfish area has been opened within the Outer Harbor since 1996. Shellfishing is prohibited the Acushnet River Estuary to the Hurricane Barrier. The Inner Harbor still supports fin fish, notably striped bass and herring.



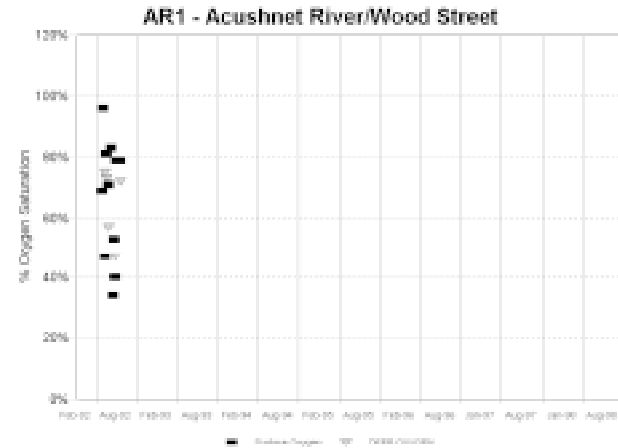
The Outer Harbor, outside the hurricane barrier, is expansive and well flushed, has 3 public beaches and is heavily developed along its western shore. The new Fort Taber Park has improved water access and provides connection between the beaches on the eastern (Outer Harbor) and western (Clarks Cove) shores of Clarks Point. Prevailing summertime southwesterly winds direct some of the New Bedford's Clarks Point Wastewater Facility's effluent to the eastern portion of the Outer Harbor slightly influencing water quality within this region. However, in general the water quality of the Greater Outer Harbor (outside of Clarks Point) appears to be relatively high and has been projected to improve as the system comes into balance with the improved effluent from the New Bedford Facility.

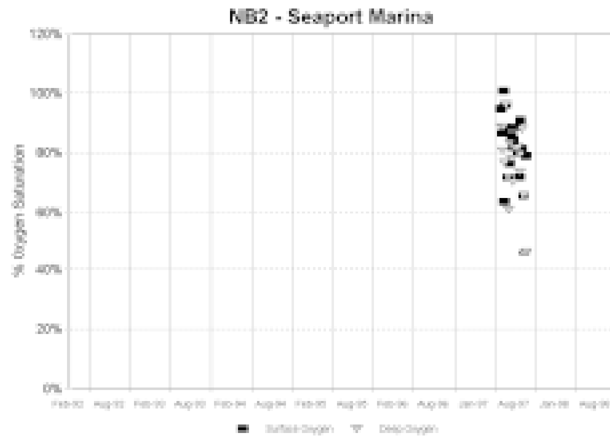
Water Quality

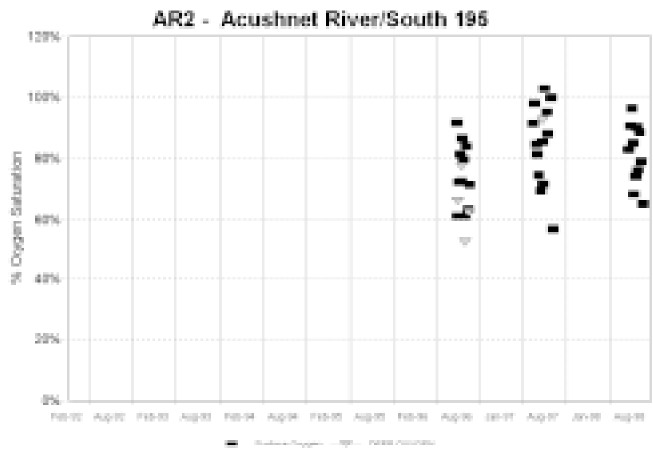
The Acushnet River Estuary has a strong gradient in water quality ranging from strongly eutrophic conditions in the upper waters, to poor conditions within the Harbor (between Coggeshall St. and the Hurricane Barrier) and moderate water quality within the Outer Harbor. The upper Acushnet River consistently had total nitrogen levels in excess of 0.6 mg/L and generally greater than 0.8 mg/L and concomitantly high chlorophyll a concentrations. Some of the highest chlorophyll a levels observed by the Monitoring Program were found in the River. Other embayments with similar chlorophyll levels include the wastewater affected region of the Agawam River Estuary and the nearby Inner portion of Apponagansett Bay.

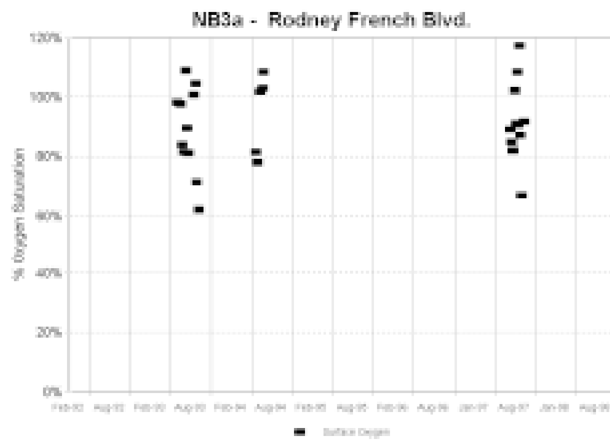
There is a consistent gradient in nitrogen and chlorophyll from the upper river to the Outer Harbor. The high nitrogen loading from the watershed and the reduced flushing resulting from the Hurricane Barrier allows the build-up of nutrients within the Harbor supporting high rates of phytoplankton production (and poor water clarity). Oxygen conditions within the Harbor showed periodic declines to "stressful" levels (40%-60% of air equilibrium), but generally showed only moderate declines. However, consistent with its very high nitrogen and chlorophyll a levels the upper Acushnet river (Station AR1), routinely experienced low oxygen conditions.

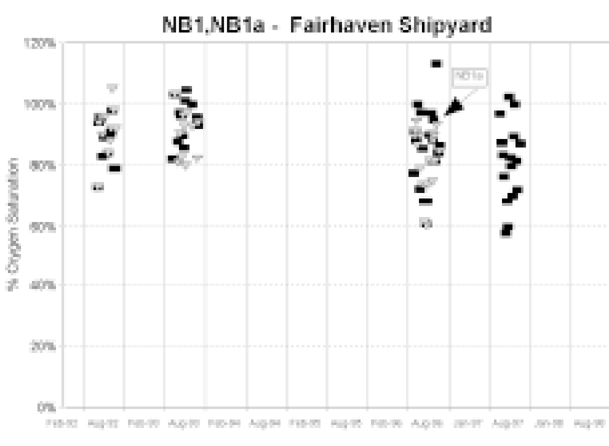
While studies during the 1980's indicated a plume of low oxygen bottom water leaving the Harbor on ebb tides, the oxygen monitoring samples tended to indicate only moderate levels of oxygen depletion. Within the mid-estuary this may result from the shallow waters and mixing causing sufficient aeration, but within the deeper waters of the lower estuary oxygen levels typically were above 60% saturation. However, it is possible that

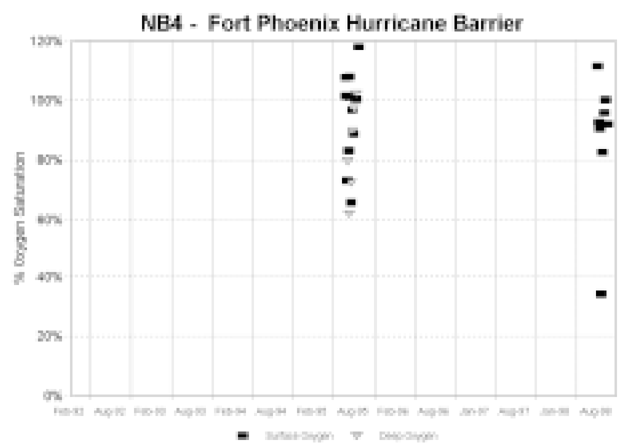








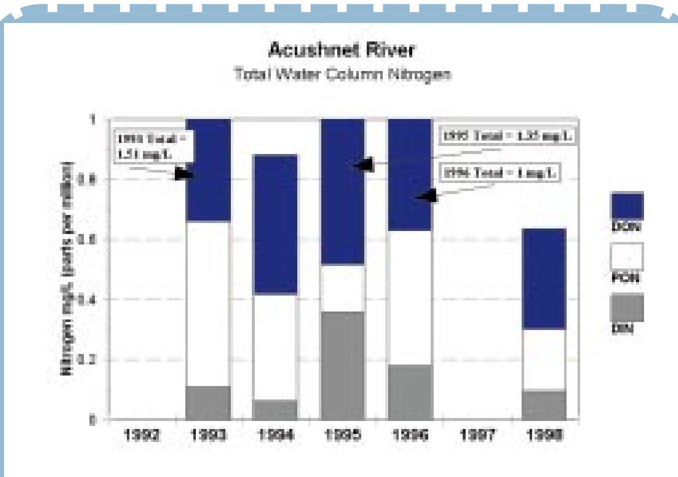


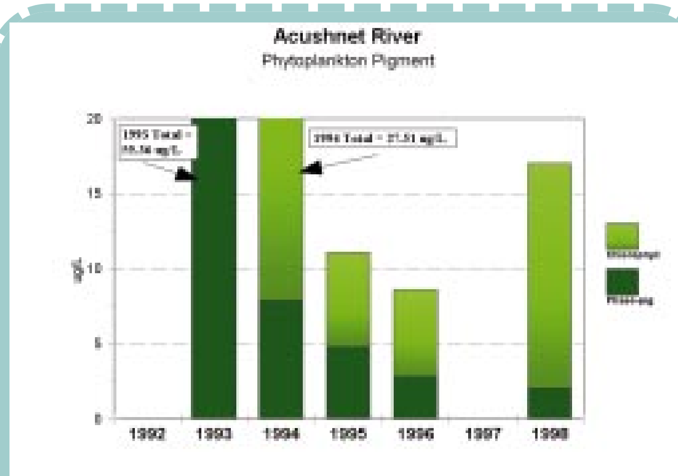


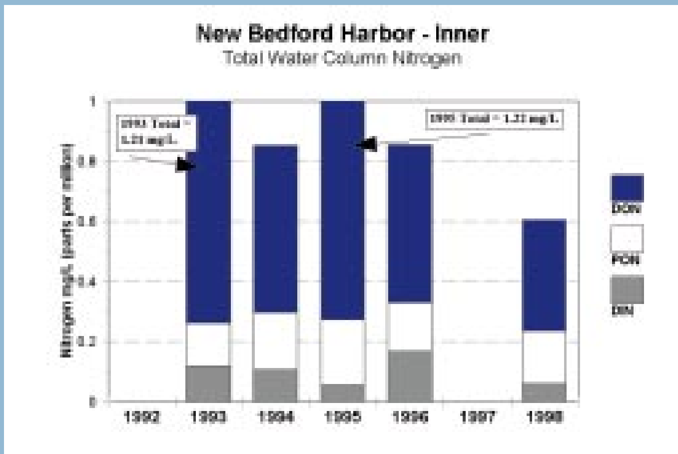
our sampling is not capturing conditions close to the bottom and there is some indication from the new sampling station at Pope's Island that significant oxygen depletions may be occurring at mid-Harbor. A more detailed evaluation of oxygen conditions is required, but the existing information clearly indicates a system well beyond its capacity to assimilate nutrient inputs without degradation. Furthermore, given the existing conditions it appears that additional nutrient inputs will cause a further decline in the level of water quality and nutrient related health of the Harbor.

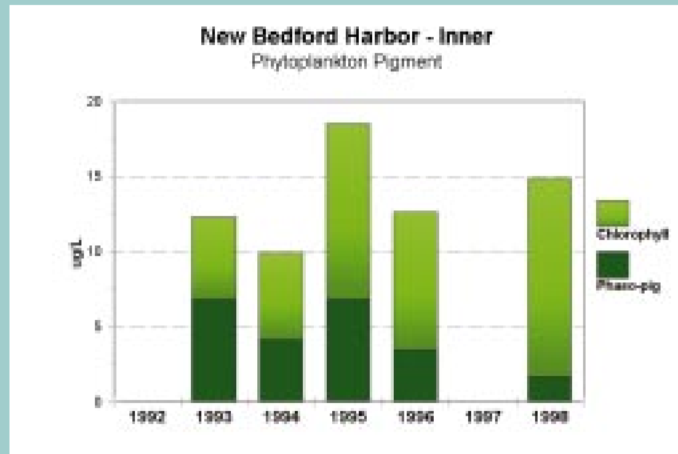
Integrating the existing information into the Health Index scores for the Acushnet River and the Harbor indicate that this estuary is among the most eutrophic embayments within Buzzards Bay.

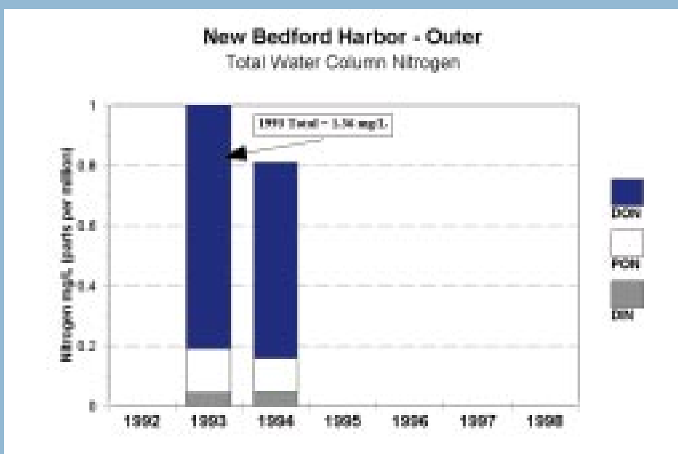
The effect of the Fairhaven WWTF discharge appears to be somewhat modified by mixing with incoming tidal waters from the Outer Harbor and Buzzards Bay. However, the incoming waters carry the nutrients up the estuary, compounding the nutrient impacts within the upper estuary. It is also likely that the soft organic rich sediments within the Harbor, in part created by the enhanced particle settling due to the Hurricane Barrier, serve as a "nutrient battery" within the Harbor. In this capacity the sediments tend to store nutrients during the winter and spring and release them to the overlying water during summer, increasing the apparent loading rate. To the extent that the slated Harbor dredging project and proposed culvert through the Hurricane

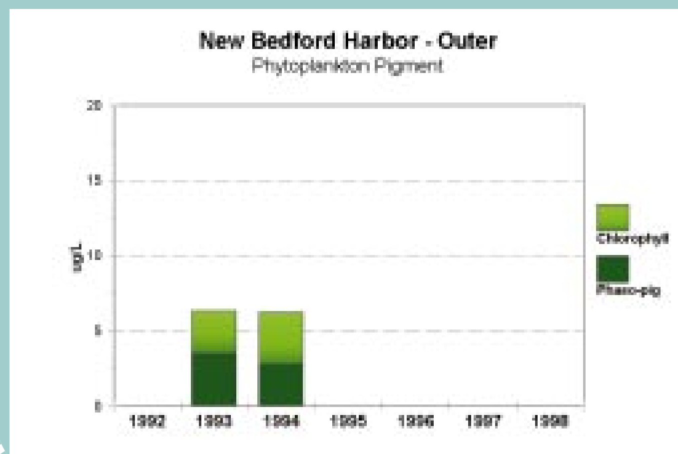










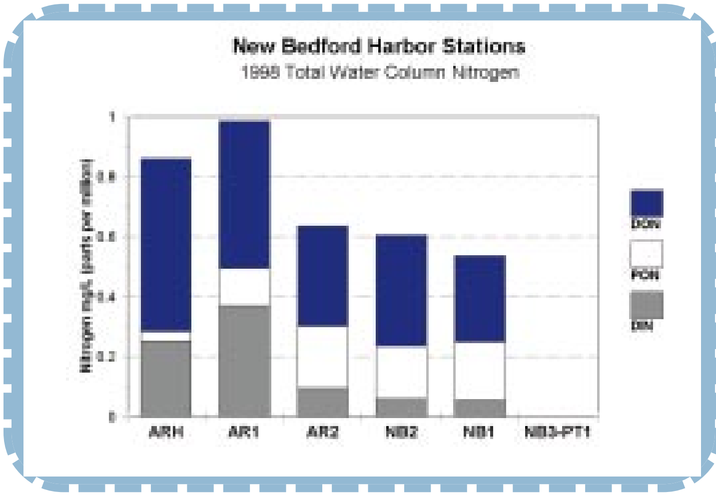


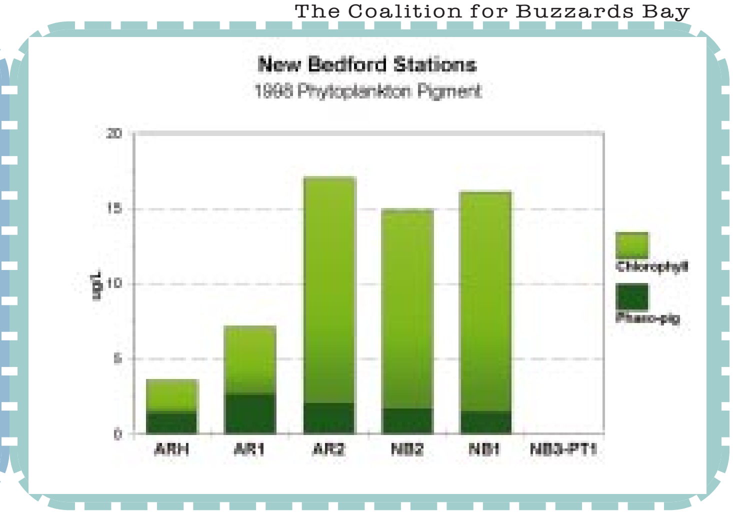
Barrier increases tidal flushing, the Harbor may receive a short-term enhancement in water quality. However, the best mechanism for improving water quality is source reduction.

The water quality monitoring suggests that while there is potential benthic animal and eelgrass habitat within the Inner Harbor region, nutrient conditions will not support these communities at present. In contrast, the Outer Harbor, while showing nutrient related stress, appears to have utilizable habitat at least for animal communities.

Management Needs

Unique among Buzzards Bay embayments which are typically dominated by a diverse array of nonpoint nitrogen sources throughout their watersheds, nitrogen management in New Bedford Harbor must include improvements to the embayment's two major point source discharges - the Fairhaven Wastewater Treatment Facility (WWTF) and the City of New Bedford's Combined Sewer Overflow (CSO) system.





As the largest single nitrogen source to the New Bedford Harbor estuary, the Fairhaven Wastewater Treatment Facility (WWTF) should be evaluated for improvements in nitrogen removal efficiency. The Fairhaven WWTF discharges an average of 2.2 million gallons per day (mgd) of secondarily treated sewage to the Inner Harbor from its location in the lower southeast corner of the estuary (off South St.). The Facility services the west side of Fairhaven as well as a growing number of homes in other parts of town. The Town of Mattapoisett also discharges wastewater to the Facility, contributing nitrogen load which would naturally flow to other embayments. The Treatment Facility coupled with Combined Sewer Overflow (CSO's) represent almost 90% of the total nitrogen entering the Inner Harbor from the watershed. Clearly, nitrogen management of this system must include the discharge from the Fairhaven Wastewater Facility.

The nitrogen discharge from the Fairhaven Facility will continue to increase as additional areas are sewered; the current discharge permit is for up to 5.0 mgd. Nitrogen removal in wastewater effluent is an established technology employed by treatment plants throughout the country. In fact, nitrogen removal continues to emerge as a requirement in WWTF discharge permits from EPA under the National Pollution Discharge Elimination System (NPDES) where the plant discharges to a sensitive coastal embayment. The permit for the Fairhaven Facility is currently up for renewal. It seems prudent to make nitrogen removal at this facility a priority, not only to improve the Acushnet Estuary, but because this facility is creating source reductions in other nearby embayments. In addition, proposals to use the Fairhaven Facility for reduction of nitrogen and bacterial contaminants in restoring or protecting adjacent embayments continue to be proposed, e.g. Priests Cove Shellfish Restoration through sewering 450 homes on Sconticut Neck (NBHTC 1997). While a centralized facility provides these opportunities for improvements in nutrient related environmental health of benefiting embayments, without nitrogen removal it is merely transferring the problem.

Recommended nitrogen loading goals for the Harbor will be most efficiently achieved through addition of some nitrogen removal capacity to the Fairhaven Wastewater Treatment Facility in concert with other non-point source reductions within the watershed. Among these source reductions is the remediation of the Combined Sewer Overflow system still discharging to the Harbor. This latter effort provides a variety of water quality benefits including nutrient reduction. At present, these CSO's represent the only discharge of untreated sewage to Buzzards Bay. The City of New Bedford has included CSO remediation as a "will be done" component in its recent Harbor planning. The City needs to make explicit in its Master Plan the need to remediate CSO's City-wide. Since the cost for CSO remediation to a system more than a century old is estimated at more than $200 million, it will undoubtedly take years to fund and implement. However, the environmental and sustainable economic benefits of undertaking this effort are clear and documented in the outcome of the improvements to Clarks Cove on the west side of New Bedford.

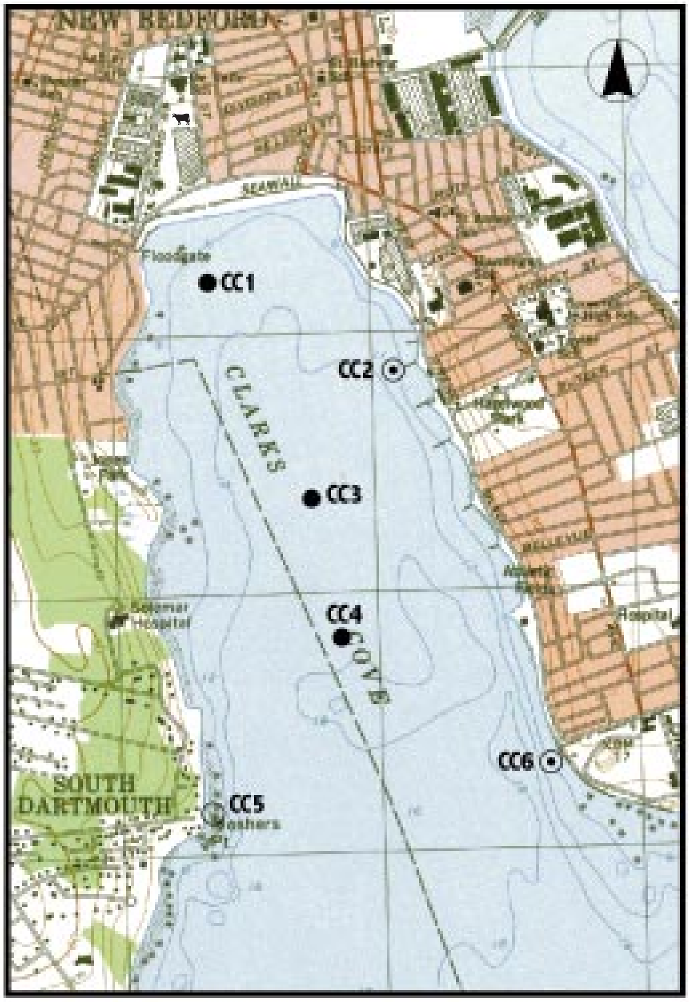
Smaller improvements, particularly to the upper reaches of the Acushnet River estuary north of Coggeshall Street, can be achieved by controlling growth in the more rural Acushnet River Valley and New Bedford Reservoir area. As new development in these areas will likely be served by individual on-site septic systems, nitrogen management needs to be considered. Recent actions by the Town of Acushnet and the private Fairhaven-Acushnet Land Preservation Trust to preserve undeveloped lands along the river should be expanded upon.

Restoration of marine resources within the Acushnet River Estuary will continue as part of the Natural Resource Restoration Plan. Given the more than 200 acres of salt marsh filled in this century alone, wetland restoration within the Harbor should be a priority. While some wetland restoration and construction is slated as part of the clean-up and is in the final restoration phase, efforts should also focus on restoring salt marsh within the lower harbor (where possible) and changing *Phragmites* (common reed) marsh back to healthy tidal wetlands throughout the system.

Without a comprehensive effort to reduce nutrient related water quality problems within the Inner Harbor, the poor water quality (which was in existence before the PCB contamination and still exists today) will continue to limit uses of the Acushnet Estuary well into the future. Harbor water quality should be viewed as an integral part of Harbor redevelopment and increased touristic and recreational uses of the Harbor as envisioned in the Harbor Master Plan and waterfront revitalization such as proposed by the New Bedford Aquarium.

Clarks Cove

New Bedford, Dartmouth



Embayment and Watershed Characteristics

Clarks Cove is located on the western shore of Buzzards Bay between the town of Dartmouth and the City of New Bedford. Clarks Cove is part of the Greater New Bedford System which also includes adjacent Apponagansett Bay, the Acushnet River Estuary and New Bedford Outer Harbor. The entrance to Clarks Cove is bordered by Apponagansett Bay to the west and the mouth of the Acushnet River Estuary to the east. The Clarks Cove watershed is comparatively small (1,866 acres) and is the most densely developed urbanized watershed in Buzzards Bay. Most of the shoreline has been modified. At the head of the Cove modifications were first for industrialization around 1900, which included the filling of about 50 acres of salt marsh, and later (1960's) for construction of the Hurricane Barrier. The eastern shore which is the high energy shoreline, has consistently supported a series of beaches (West Beach) formed by groins throughout this century. At the mouth of the Cove is the location of the new UMass Dartmouth Marine Science and Technology Center, CMAST. This center is a focus of coastal research involving restoration of wetlands and other coastal habitats. The western shore in Dartmouth also has a highly used public beach, Jones Beach. Although this is a rather large embayment, there are only 75 boat moorings and slips because the cove is open and has a long southerly fetch, and the hurricane barrier obstructs the inner portion of the waterfront.

Marine waters entering the Cove are high quality waters of the Atlantic Ocean entering through Buzzards Bay. The Cove, like Mattapoisett Harbor and Aucoot Cove, is somewhat of an anomaly on the western shore of Buzzards Bay in that it is deep and well-flushed. These characteristics enhance its ability to assimilate terrestrial nitrogen inputs without suffering serious water quality or habitat declines. Equally important to its water quality is its small watershed and lack of significant surface water inflows.

Today Clarks Cove contains one of the most significant quahog fisheries in Buzzards Bay. The construction of the new New Bedford Wastewater Treatment Facility (WWTF) stopped the discharge of primary treated sewage and addressed the periodic discharges of raw sewage from New Bedford's sewer system which had closed all of the City's shellfish beds in Clarks Cove with a major resource loss. The new facility, coupled with extensive work on the Combined Sewer Overflow (CSO) system which stopped all dry weather CSO flows to the Cove by the early 1990's, has resulted in the present conditional opening of the Cove to shellfish harvest after 91 years of closure. The total area re-opened in April of 1996 was 1600 acres, inland of Ricketson Point and Wilbur Point. Within five months of reopening, Clark's Cove alone yielded approximately $364,000 in quahogs, employing more than two dozen full time fishermen. Applying a conservative multiplier to this figure, the ripple effect on the local economy from this harvest amounts to over $1.5 million. This figure should only grow with the development of a shellfish hatchery and grow-out program targeted for the New Bedford Harbor System.

Reductions in nitrogen loading to Clarks Cove from Combined Sewer Overflows has produced a marked environmental response which is most visible through drastic improvements in overall water clarity and returning eelgrass habitats to the shallower portions of the Cove. The eelgrass bed which had been restricted to the tip of Clarks Point has been expanding into the Cove over the past decade. In addition, eelgrass restoration efforts suggest that Clarks Cove is currently capable of supporting additional eelgrass beds as seen by the water clarity, with secchi depth = 2.45 m (7 yr. mean).

Water Quality

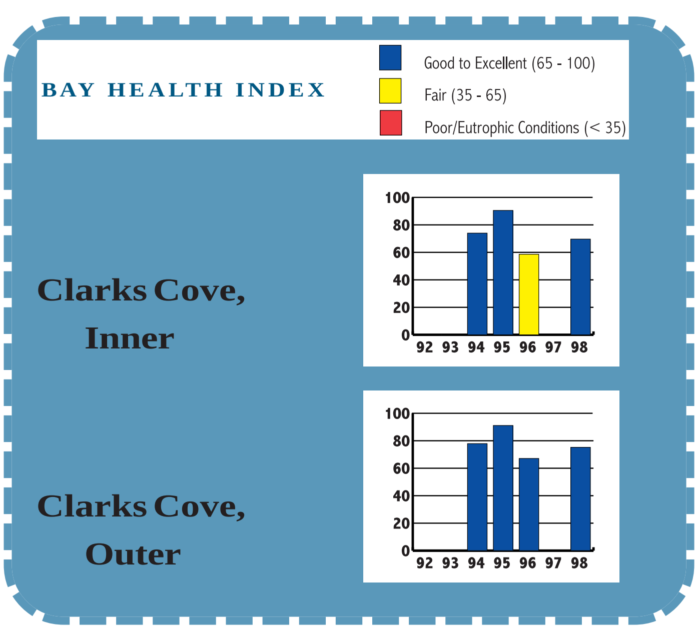
Clarks Cove, in spite of its urbanized watershed and highly altered margins, supports a high level of water quality within both its Inner and Outer portions. Health Index scores were similar throughout the basin and although variable showed no trend over the 1994-98 study interval. The role of tidal flushing in maintaining water quality can be seen in comparing the open basin of

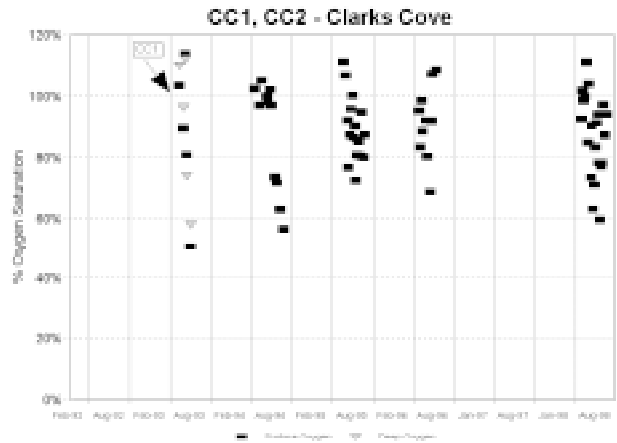
Clarks Cove with the adjacent closed basin of Apponagansett Bay which exhibits poor water quality.

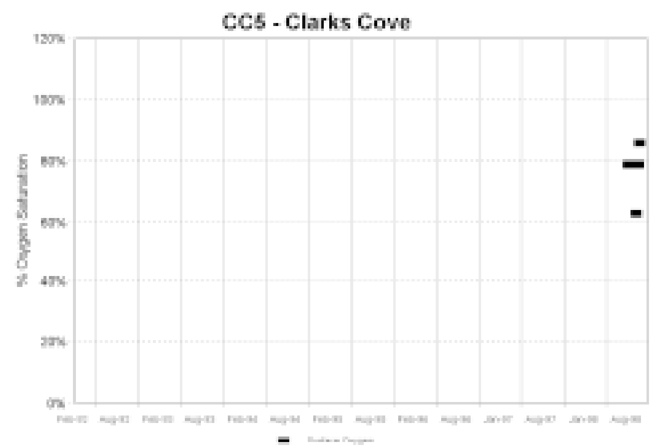
The absence of a major surface water source and the re-engineering of the CSO's around the Cove yield greatly reduced stormwater flows and their associated bacterial, hydrocarbon and nutrient loads typical of highly developed watersheds. It has been estimated by the Buzzards Bay Project that while CSO inputs were once a major pathway of nutrient entry to the Cove that they now contribute only about 10% of their 1980 level. As much of the watershed is sewered and discharges (after treatment) at Clarks Point, it appears that Clarks Cove water quality is being maintained primarily by its hydrodynamics and by the extensive source reduction program which has been implemented within the watershed.

While watershed loading to the Cove is partially controlled, the total nitrogen levels within the Cove (typically 0.33-0.4 mg/L) are enriched over the waters of Buzzards Bay. It is also clear that some of this enrichment of Cove waters results from the local watershed. However, given the placement of the Cove it is likely that nitrogen also enters from the Clarks Point outfall during periodic shifts in Outer Harbor circulation and from the tidal waters of Apponagansett Bay. It is likely that these are secondary sources, this pattern underscores the linkages between the embayments and demonstrates the statement, "communities connected by water".

The high transparency and relatively low nitrogen levels are reflected in the moderate to low chlorophyll a concentration at both sites since 1994. However, there has been the occasional phytoplankton bloom within the Inner Cove (10-16 ug/L Chlorophyll) but this has only been found in less than 10% of the summer samplings. The current chlorophyll a levels appear to be supportive of shellfish production but also allow sufficient light penetration for eelgrass beds to expand within the Cove.

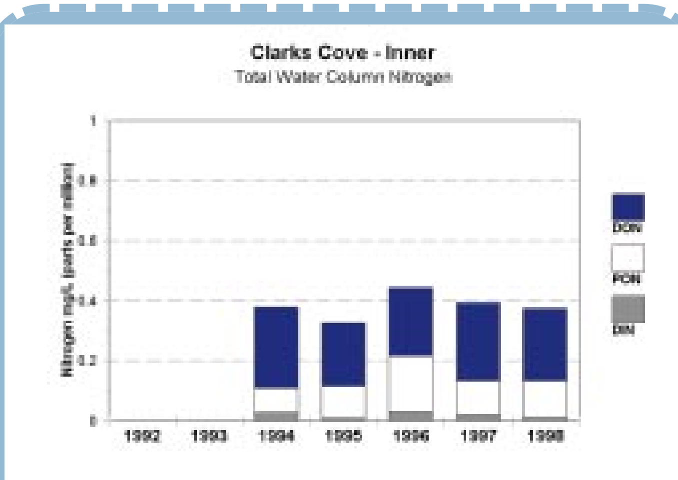


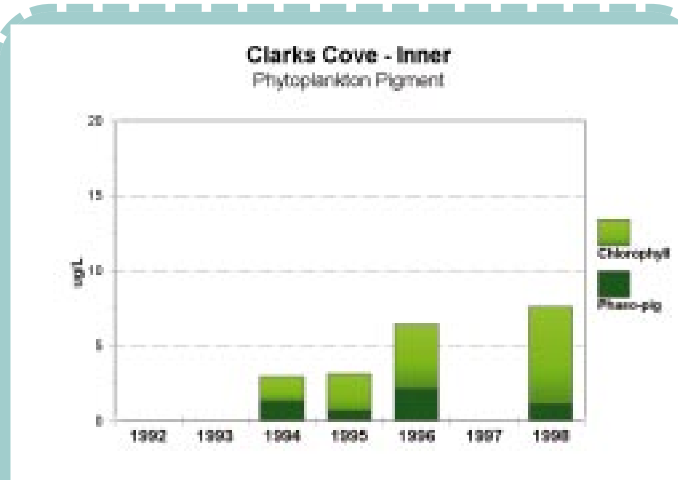


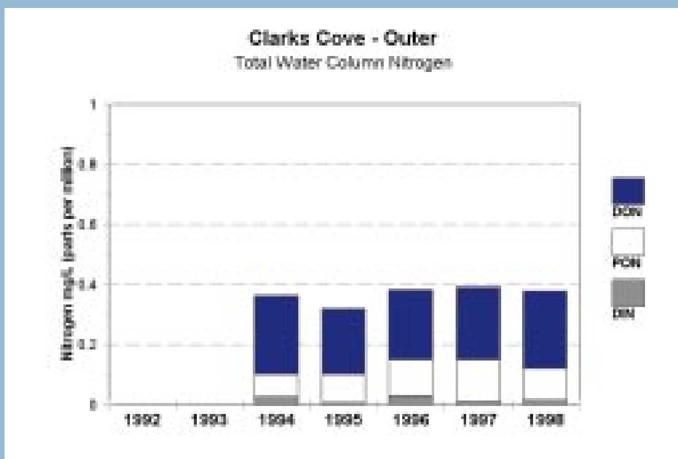


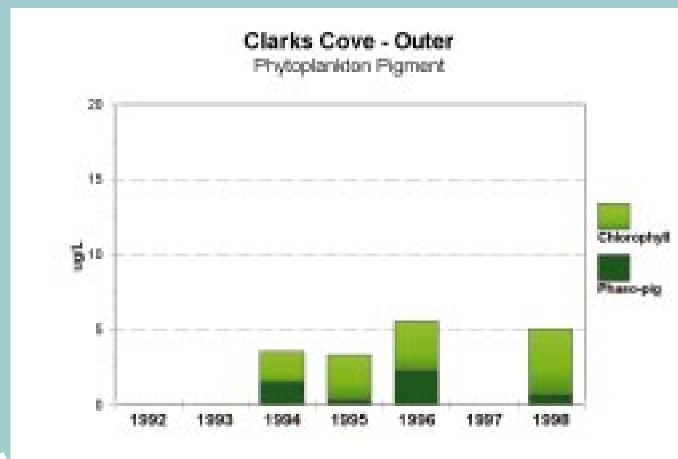
Similar to other embayments, oxygen concentrations reflect the nitrogen and chlorophyll a levels within the Cove waters. Oxygen levels generally reflect good habitat quality within the mid and outer Cove throughout the study period. Only within the Inner Cove are oxygen depletions observed, although these occurrences were relatively rare, with only 5% of the samples dropping below 60% of air equilibration. These conditions may result from the settling of periodic blooms and/or stratification of the relatively deep Cove waters. There is not sufficient data to determine if the Cove is presently in steady-state. However, the expansion of eelgrass habitat does indicate improving water quality conditions.

The overall findings are consistent with the fact that loadings to Clarks Cove are low with respect to the Cove's volume and flushing time. That is to say, because Clarks Cove has one of the largest volumes of those studied, and among those with the best flushing time, the existing loading is on the order of what the embayment can handle. Whether the Cove has reached a new equilibrium after the recent upgrading of the New Bedford WWTF to secondary treatment is currently unclear. Prediction of the level of improvement to be seen by additional watershed management practices will require additional years of monitoring.









Management Needs

The major sources of nitrogen loading in this Cove are the seven Combined Sewer Overflows (CSO's) discharges which continue to discharge raw sewage during significant rain storms and nutrient rich runoff from the watershed during all rainstorms. Within the watershed non-wastewater nitrogen continues to enter the Cove through ground and surface water pathways. In addition, nitrogen enters through flooding tidal waters which may "pick-up" nutrients from Apponagansett Bay and the New Bedford Wastewater Treatment outfall before entering the Cove. The discharge of secondarily treated wastewater is about 1000 meters from the tip of Clarks Point and is the largest point source of wastewater to Buzzards Bay discharging approximately 24 million gallons per day. While the New Bedford Wastewater Treatment Plant outfall represents a major "offshore" source of nitrogen, observed good water quality in the Cove suggest that the effect of the outfall is not focused in the Cove.

Our nutrient related water quality data, long term fecal coliform data, and anecdotal information all suggests that the reduction in CSO discharges has resulted in remarkable improvements in water quality. Besides the reduced fecal coliforms levels, eelgrass beds, formerly restricted to the clearer waters at the tip of Clarks Point on the New Bedford side and south of Ricketsons Point on the Dartmouth side are now spreading throughout the Cove apparently because of greatly improved water clarity. Unfortunately, this Buzzards Bay Monitoring Program was not in place prior to most of the reduction in CSO discharges.

It appears that Clarks Cove has benefited from the contaminant (includes nitrogen) management strategy. Remediation efforts should focus on further reducing CSO and any direct stormwater discharges, especially to achieve further fecal coliform reductions. Phytoplankton and oxygen levels within the Cove need to be monitored to determine the effect of the new wastewater facility and continuing watershed alterations. The quality of Clarks Cove waters indicates that important resources can be restored, such as shellfish and eelgrass.

Apponagansett Bay

Dartmouth

Embayment and Watershed Characteristics

Apponagansett Bay is surrounded by one of the smaller upland watersheds, 4658 acres, of the western Buzzards Bay sub-estuaries. The Bay is functionally defined with its mouth at the Padanaram Breakwater and the central bay bridge which divides the bay into its upper and lower portions. Apponagansett Bay is part of the Greater New Bedford System which also includes adjacent Clarks Cove, the Acushnet River Estuary and New Bedford Outer Harbor. In spite of its relatively small contributing area, Apponagansett is one of the most nutrient overloaded embayments of Buzzards Bay. This results from its relatively restricted passage to the upper Bay and excessive nitrogen loading from its watershed. More than one-third of the watershed is built-out, mostly with residential development, much of which is on septic systems. The remaining undeveloped land is clustered primarily in the Dike Creek area of the watershed along Bakerville Road and on the southwestern shores of the inner Harbor. Salt marshes are still apparent within the inner Bay region, although some have been significantly altered. One such marsh is being restored as part of the New Bedford Harbor Natural Resource Damage Assessment. Restoring tidal circulation to this marsh should increase some of the nitrogen assimilative capacity within the inner Bay.

The major fresh surface water inflow is via Buttonwood Brook, which drains much of the northern portion of the watershed including portions of the West End of the city of New Bedford. This is a highly urbanized area and although it is sewered, there are problems of nitrogen and bacterial loadings primarily from poor stormwater management, new construction, commercial use and the Buttonwood Park Zoo. Buttonwood Brook provides the primary surface water transport of fecal contamination to the upper Bay. Buttonwood Brook is primarily a controlled stream which has been engineered to provide needed stormwater management within the watershed. However, as runoff from its watershed has increased due to development, filtering wetlands have been removed and the stream increasingly channelized. In addition to street and other impermeable surface runoff, the Brook receives runoff from the zoo and its ponds with their high number of waterfowl. The zoo has taken some initial steps to control the runoff of wastes, but the Brook will require significant restoration to reduce its impact on the quality of the receiving waters.

Nitrogen inputs to Apponagansett Bay are also contributed by the dense residential land use on the eastern shore (septic systems and lawns), followed by other commercial development, then farmland and possible impacts from the 1,600 boat slips and moorings. The bay has a number of marinas, and two pump-out boats. The upper estuary is however degraded from the various nutrient inputs (the stream at Russell Mills Road and Buttonwood Brook) and is closed to shellfishing by the high fecal coliform levels.

The bay still is a popular embayment with one public beach and four private beaches and the upper areas set aside for water skiing. However, watershed contamination causes closures of shellfish bed within the upper bay. Consistent with its high nutrient loading, presence of wetlands on the western shore, and restrictions to sediment transport, the upper bay exhibits areas of anoxic bottom sediments consisting of fine organic-rich particles and periodic blooms of macro-algae (*Ulva* and *Gracillaria*). Eelgrass was once abundant within the upper bay before losses to wasting disease in the 1930's and showed strong recovery in the 1940's through 1960's. However, it again went into decline through the 1970's, with the last significant beds disappearing in the mid-1980's (Costa 1988). This contrasts with the lower basin and adjacent bay which supports eelgrass even today.

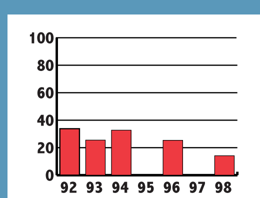
Water Quality

The monitoring program has shown that Apponagansett Bay has had consistently poor water quality over the past 7 years. This poor water quality results from the restriction of water and particle flushing of the upper basin combined with the relatively high watershed loadings. The Health Index scores consistently were below 35 for the upper and generally 40-50 for the lower basin, some of the lowest for any Buzzards Bay embayment. The poor water quality within Apponagansett Bay would even be worse, but for the high quality of its source waters within Outer New Bedford Harbor. The waters entering Buzzards Bay from the Atlantic Ocean enter the southeastern portion of the outer Harbor supplying a low nutrient and high quality source water to Apponagansett Bay and Clarks Cove. The water quality problems within Apponagansett Bay originate from the Bay's hydrodynamics and inputs from its watershed. The effect of the land inputs within the bay can be seen in the poor light penetration

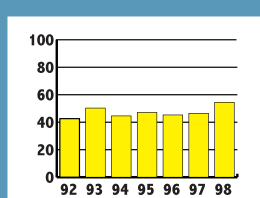
BAY HEALTH INDEX

- Good to Excellent (65 - 100)
- Fair (35 - 65)
- Poor/Eutrophic Conditions (< 35)

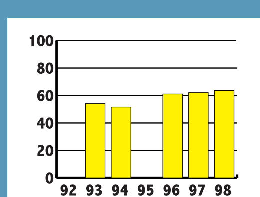
Apponagansett Bay, Inner

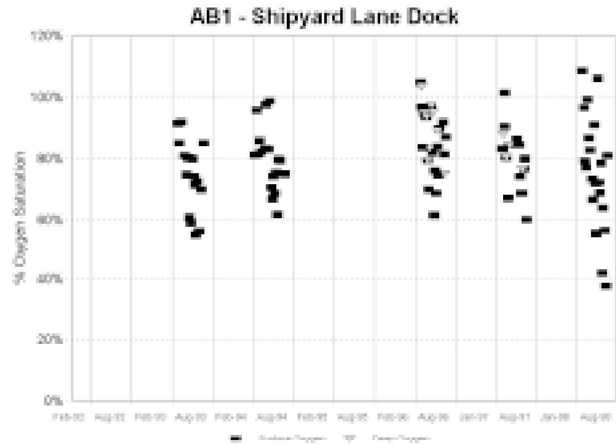


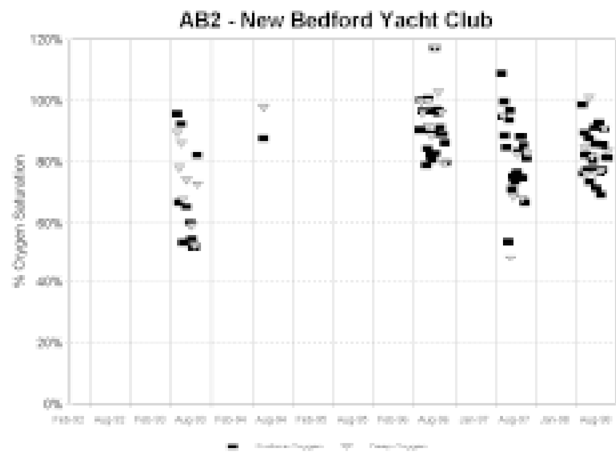
Apponagansett Bay, Middle

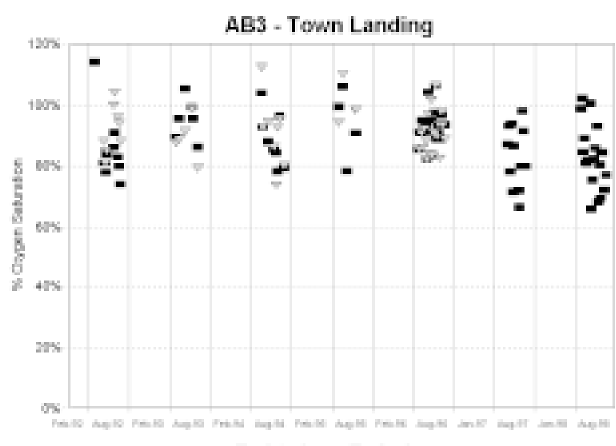


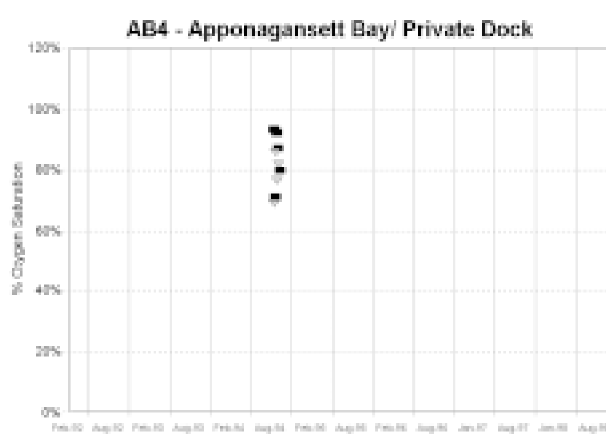
Apponagansett Bay, Outer

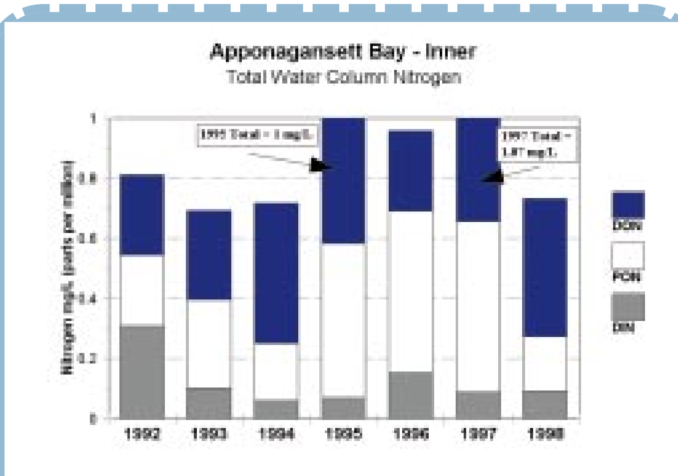


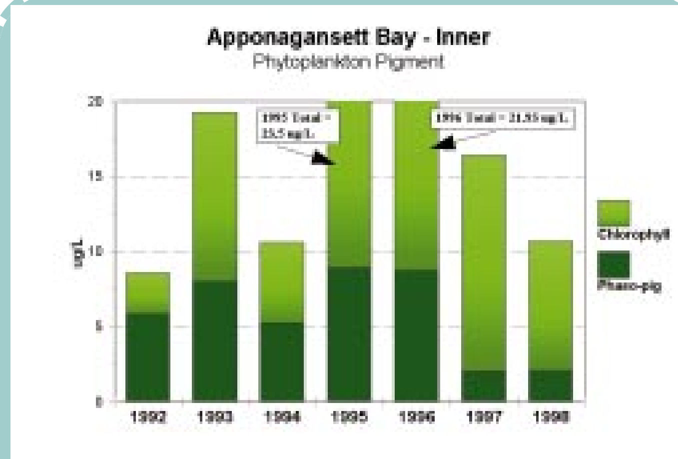


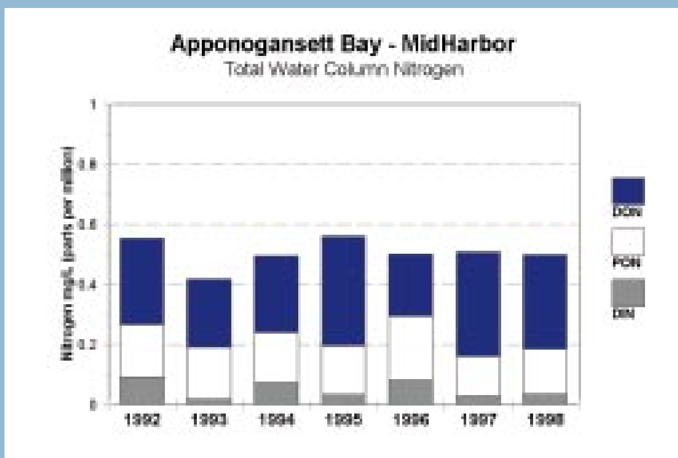


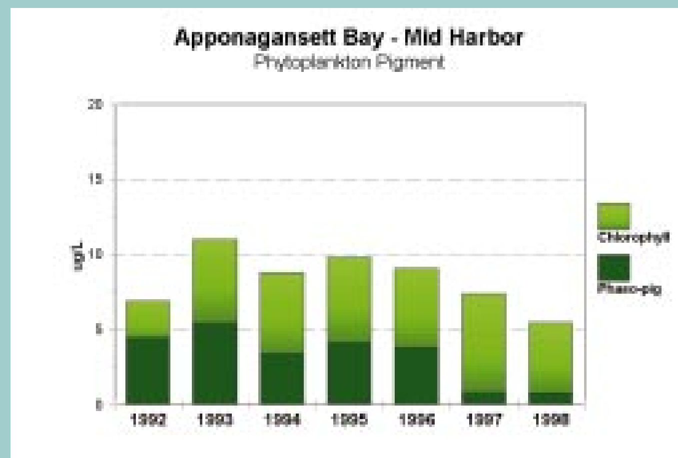


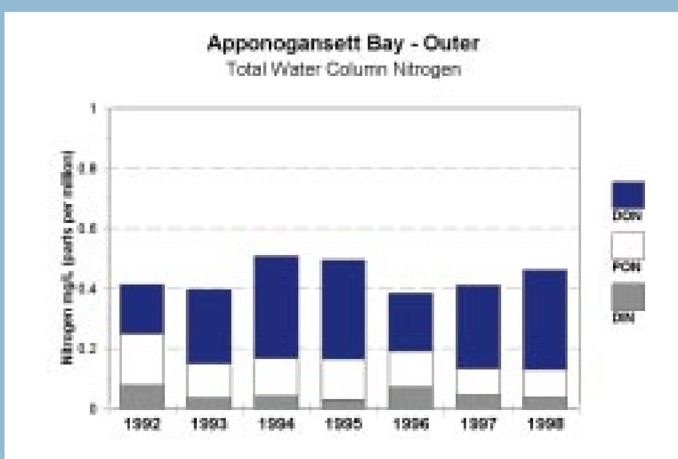


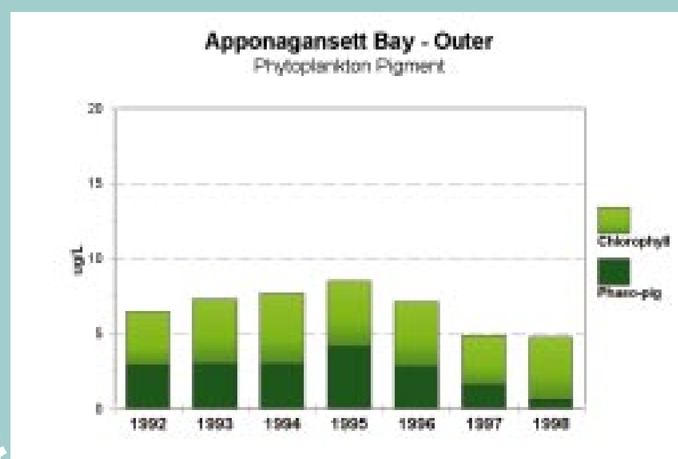












(water clarity), long-term means (July-August) of 1.27 m and 1.89 m within the upper and lower basins compared to Clarks Cove, 2.45 m.

The best indication of the effect of land-based inputs is in the primary eutrophication parameters, nitrogen and chlorophyll a (indicator of phytoplankton biomass). Total Nitrogen concentrations within the Buzzards Bay source waters to Apponagansett Bay are typically less than 0.25 mg N/L. In contrast Inner Apponagansett Bay ranged from 0.7 to 1.1 mg/L and over the past 4 years generally averaged more than 4 times the concentration of Buzzards Bay waters. While the enrichment was significantly less in the mid and outer portions of the Bay, they still showed nitrogen levels about 2 and 1.5 times incoming waters. The nitrogen enrichment results in roughly proportional elevations in measured chlorophyll a concentrations. The inner Bay shows bloom concentrations, with particularly large blooms in 3 of the past 4 years of monitoring, while the mid and outer Bay stations show only modest phytoplankton levels.

While it is clear from the limited light penetration, high nitrogen and chlorophyll a levels that the system shows a strong gradient in nutrient related health from the highly degraded inner Bay to the moderately impacted outer Bay, the sampling of oxygen concentrations showed less of a trend. However, periodic stressful oxygen levels were observed at some stations within the inner bay. In the outer Bay, oxygen levels appeared to show only modest depletions. The overall gradient in habitat quality is supported by the watercolumn measures and the observation of soft sediments and macroalgal accumulations. The history of eelgrass colonization within the Bay and its recent (mid-1980's) loss from the inner Bay is consistent with the poor water quality observed throughout the monitoring program. However, the recent loss of eelgrass may serve as a benchmark, guiding restoration of the bay should nitrogen management planning be implemented.

Overall, there does not appear to be a clear Bay-wide trend in water quality over the 7 years of monitoring. However, there is an indication that the past 4 years in the inner Bay may have been slightly worse than the initial 3 years, as the 3 highest nitrogen and the 2 highest chlorophyll a concentrations occurred in these years. This is consistent with continuing nitrogen loading to the watershed and its focused entry to the inner Bay region.

Management Needs

Apponagansett Bay is currently exhibiting nutrient related habitat degradation, particularly within the inner Bay region. The contributing watershed is more than 75% developed, and therefore nitrogen management options will tend to focus on restoration of natural systems such as Buttonwood Brook, improvements to existing wastewater and stormwater management systems discharging to the bay, and management of tidal exchange.

Wastewater treatment within the watershed relies significantly on on-site septic systems. In order to make significant reductions in overall watershed nitrogen loading, wastewater nitrogen will have to be addressed. While up-grading systems to Title V maintains public health, it does not reduce nitrogen inputs. Methods of reducing wastewater nitrogen inputs will likely need to include a combination of small denitrifying systems and exporting of nitrogen out of the watershed by expanding connections to the town's sewage treatment facility. Specific watershed areas for consideration for wastewater improvements include: Lucy & Fort street areas – northeastern corner (30 houses) and Star of the Sea.

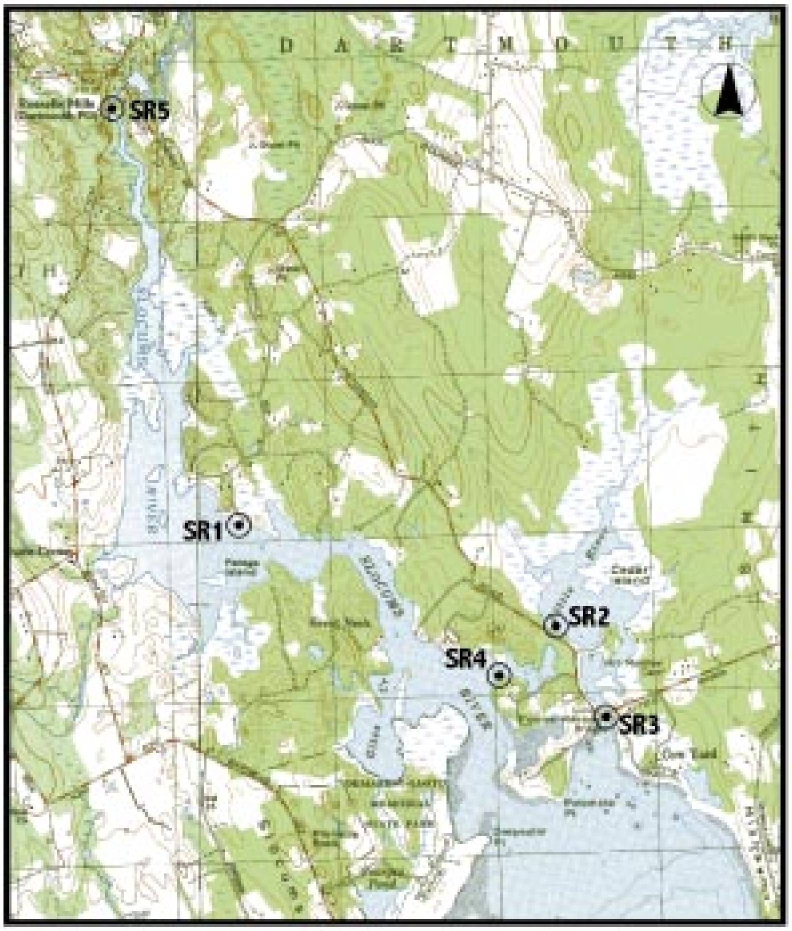
Stormwater and surface water flows are major sources of coliform and nutrients to the Bay. The major surface water source, Buttonwood Brook, has been increasingly channelized and re-engineered and its filtering wetlands removed to aid in stormwater flow. The Brook needs to be evaluated for restoration of some of its filtering wetlands to improve water quality within the Bay. In addition to street and other impermeable surface runoff, the Brook receives runoff from the zoo and its ponds with their high number of waterfowl. The zoo has taken some initial steps to control the runoff of wastes, but the Brook will require significant restoration to reduce its impact on the quality of the receiving waters.

Growth Management and Open Space Protection need to be implemented to target those areas of the watershed having the most impact on Bay water quality. Because most of the embayment basin is already developed, it has less build-out potential compared to other embayments its size. Setting aside open space and establishing per acre nitrogen loading limits on new development are important options for managing inputs from new development.

T.Williams 1998

Slocums River & Little River

Dartmouth



Both the Slocums and Little River Estuaries are shallow (0.7 meter average depth), enclosed water bodies with moderate to low flushing rates. The Slocums River system is a classic drowned river estuary, formed by the flooding of an eroded river valley by rising relative sea-level. Both estuaries receive surface water inflow at their headwaters, although direct discharge of groundwater occurs all along their shorelines. The Slocums River Estuary receives most of the surface freshwater inflow in this estuarine complex. The Slocums River Estuary is the lower end of the Paskamansett River (below the Russell Mills Dam). The Paskamansett River originates at Turners Pond in the Acushnet Cedar Swamp State Reservation and is the third largest river within the Buzzards Bay watershed, contributing 6.1% of the Bay's total freshwater inflow. Smaller streams, such as Destruction Brook, also contribute flows to the estuary. However, the Town of Dartmouth draws municipal drinking water from the Paskamansett River Valley Aquifer thereby exporting freshwater to other watersheds. In contrast, the Little River receives only small volumes of surface water inflow from small streams. The total freshwater and nutrient load entering these two estuaries is driven by their respective watershed areas and land-use.

Embayment and Watershed Characteristics

Slocums River and Little River are two moderately sized estuaries (487 acres and 124 acres, respectively) which discharge to a common bay formed between Mishaum and Barneys Joy Points. Although they have adjacent but separate watersheds they receive tidal inflows from this common Bay. Water quality monitoring has focused upon the upper portions of both estuarine systems, above Potomska Point.

During the initial monitoring by Baywatchers, water quality in the Slocums and Little River Estuaries showed signs of eutrophication and habitat loss. This estuarine complex was among those showing the greatest level of nutrient related water quality impairment in all of Buzzards Bay. The present water quality of the Slocums River Estuary is consistent with land-use analyses by the Buzzards Bay Project which suggest that this system is receiving nitrogen loads several fold higher than the threshold at which habitat decline is expected to begin. However, a similar analysis for the Little River Estuary suggests that water quality should be better than indicated by direct measurements (see below).

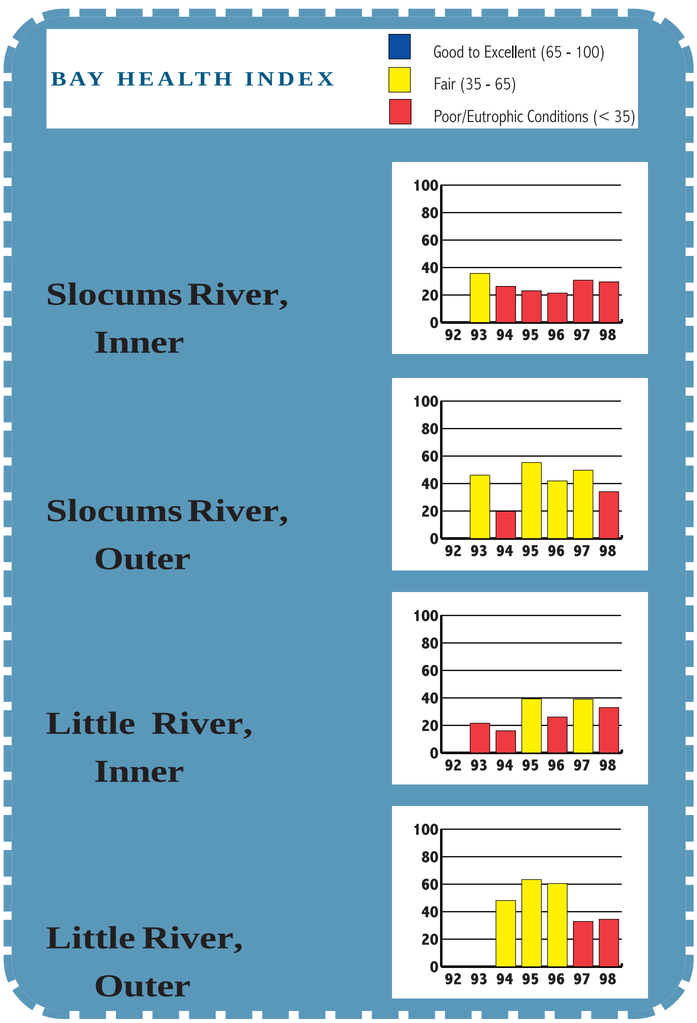
The watersheds of the Slocums and Little River Estuaries are primarily within the Town of Dartmouth, with upper parts of the Slocums watershed within New Bedford and Freetown. This upper Slocums watershed region includes the New Bedford Industrial Park, which like much of New Bedford, discharges its wastewater to the City sewer system and therefore out of the watershed (to the outfall at Clarks Point). The Slocums River watershed is the fourth largest of the embayment watersheds to Buzzards Bay encompassing 23,161 upland acres. In contrast, Little River's watershed is relatively small, only 1,125 upland acres. The differences in watershed areas helps to explain their very different volumes of surface water inflow. The differences in watershed area are also paralleled by total freshwater inputs, which can be seen in the typically lower salinities in the Slocums River (SR5-Head: 2.8-17 ppt, SR1-Mid: 25 ppt, SR4-Lower: 29 ppt) versus Little River (Upper: 29 ppt, Lower: 29 ppt) tidal regions.

The overall Slocums River watershed is presently forest-land (>60%) with much of the upper watershed discharging wastewater via municipal wastewater treatment facilities to outside of the watershed. The mid-watershed is dominated by heavy commercial development, residential development and three golf courses associated with the New Bedford, Allendale, and Hawthorne Country Clubs. The southern end of the watershed, primarily connected to the Slocums Estuary by groundwater flows, is largely undeveloped with agricultural land, light residential development, forest and wetlands comprising the primary land uses. This lower watershed region has relatively low build-out potential compared to the amount of undeveloped land, due to significant open-space preservation initiatives currently underway. To date, 4,109 acres or 17.4% of the watershed has been permanently protected, much of it along the lower estuarine portions of the Slocums River.

In contrast to the Slocums River watershed, the watershed to the Little River Estuary is relatively undeveloped, only about 7% of upland area, making it one of the least developed coastal subwatersheds to Buzzards Bay. While this suggests that nitrogen loading can increase substantially with build-out of developable land, preservation efforts are underway. At present these efforts have placed more than 478 acres under conservation restriction, preserving 42% of the upland area.

The Slocums and Little Rivers do not presently contain major beaches or boat mooring areas. This likely results from the extensive marginal saltmarshes and shallow waters. However, a major public beach does exist on the barrier beach within Demarest Lloyd Memorial State Park on the western side of the inlet to the Slocums Estuary.

As drowned river estuaries, the Slocums and Little Rivers support significant saltmarsh habitat. There is more than 0.5 acre of salt marsh (252 acres) for each acre of embayment surface in the Slocums River and more than 1.5 acres per acre of Little River waters (189 saltmarsh acres). The predominance of saltmarsh within these systems is important, as saltmarshes affect the quality of adjacent waters and tend not to be degraded by high nutrient inputs. In addition, these wetlands serve as important wildlife habitat and nursery areas for coastal fisheries.



Eelgrass beds are sparse to absent from the Slocums Estuary, except in small areas near the mouth at Potomska Point and in the Little River Estuary inland from the Little River Bridge. In contrast, the physical characteristics of these river basins are typical of areas which are supporting eelgrass in other embayments to Buzzards Bay. The absence of eelgrass within the Slocums and Little River Estuaries is most likely due to poor habitat quality due to nitrogen enrichment. It appears that eelgrass beds have been replaced by soft organic-rich sediments (the consistency of mayonnaise), a phenomenon common in eutrophic coastal waters. However, the lower nutrient, better flushed regions of the outer embayment (south of the river mouth), do support well-established eelgrass beds, particularly off of Barneys Joy Point. Eelgrass distribution may be limited more to the margins of the outer bay due to the depth of the central basin.

The present bottom sediments are generally unsuitable habitat for most marine animals, including shellfish. While within Slocums River mussels and oysters can be found in the shallows near the banks and quahogs can be observed in Little River, both estuaries, inland of Deepwater Point and the Little River Bridge, currently support marginal shellfish populations. Even if productive shellfish beds were present, shellfishing is prohibited in the upper Slocums River (above Gaffney Rd) and Little River (above the bridge) due to bacterial contamination. This contamination likely results in part from surface water inflows, but is also likely associated with the extensive tidal wetlands and highly organic sediments. In contrast, the outer bay, seaward of Deepwater Point supports productive shellfish beds with oysters, quahogs and soft-shell clams being harvested. This area is open to shellfishing except after a large rainfall (greater than 2”) which tends to flush bacterial contamination into the bay from the adjacent estuaries.

Water Quality

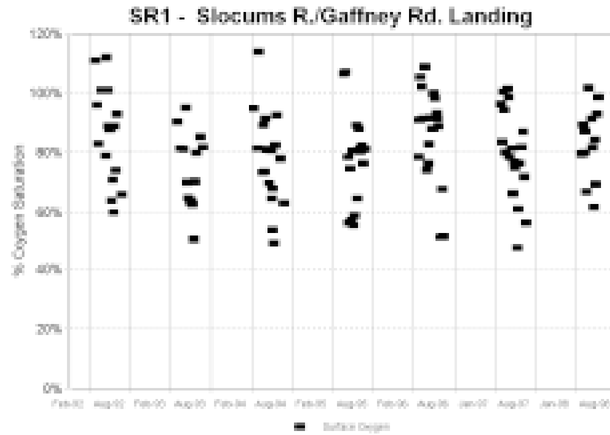
It is clear from the monitoring results that both the Slocums and Little Rivers inland of Deepwater and Potomska Points consistently support poor nutrient related water quality. The measured water quality data, absence of eelgrass bed and low shellfish populations (even without harvest) all underscore the level of poor habitat quality within Slocums and Little River Estuaries.

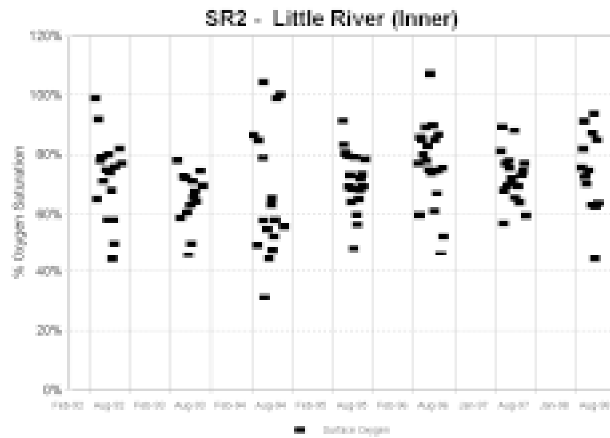
Both the Slocums and Little Rivers showed high levels of total nitrogen in both the upper and lower regions, with levels being generally 2-3 fold higher in Slocums River and more than 2 fold higher within Little River than the levels in the adjacent Buzzards Bay waters. These values clearly indicate a strong enrichment of these estuarine waters by watershed derived nitrogen. In addition, there is a strong horizontal gradient of increasing concentrations from headwaters to inlet. Within the Slocums River total nitrogen levels on average increase by 2 fold from the lower region (SR4, 0.54 (SE=0.04) mg N/L) to the uppermost station (SR5, 1.10 (SE=0.10) mg N/L) and within Little River there was a 40% increase from the inlet (SR3, 0.49 (SE=0.05) mg N/L) to the nearby mid-station (SR2, 0.68 (SE=0.05) mg N/L). Note: SE = standard error, a measure of the variability of the data used to produce the average value.

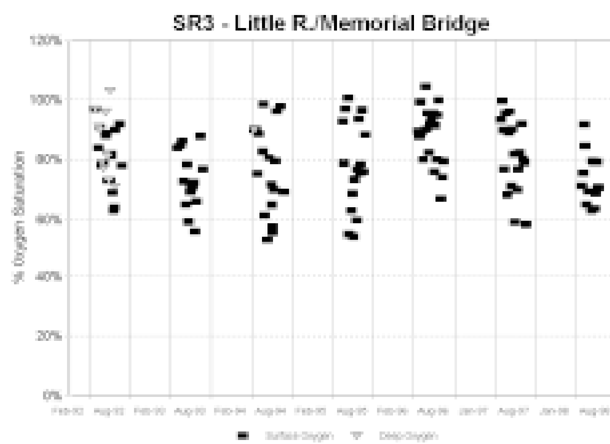
The elevated nitrogen levels within both estuaries supports high levels of phytoplankton production and organic matter accumulations. Within both estuaries chlorophyll a pigments values over 60 ug/L were recorded and levels in excess of 15 ug/L were common. In the Slocums River the effects of the nutrient gradient were clear with the percent of samples showing chlorophyll a pigments of >15 ug/L being 64% at the head, 46% at the mid-station and 18% at the inlet. Similar values for the mid and inlet station in Little River were 30% and 16%, respectively. These high chlorophyll levels were matched by high particulate organic matter concentrations. Particulate organic carbon averaged from 2 to 2.4 mg C/L in the mid and upper reaches of both estuaries and 1.2-1.3 mg C/L at the inlets. In addition there was a relatively constant ratio of carbon to chlorophyll (0.09-0.18) throughout the entire system, suggesting that most of the organic matter is derived from phytoplankton during the mid-summer sampling periods. These high concentrations of organic matter are consistent with the soft-organic rich sediments which now cover large areas of bottoms of these estuaries. In addition, these conditions result in poor water transparency throughout much of these systems, a further mechanism for eelgrass loss from these estuaries.

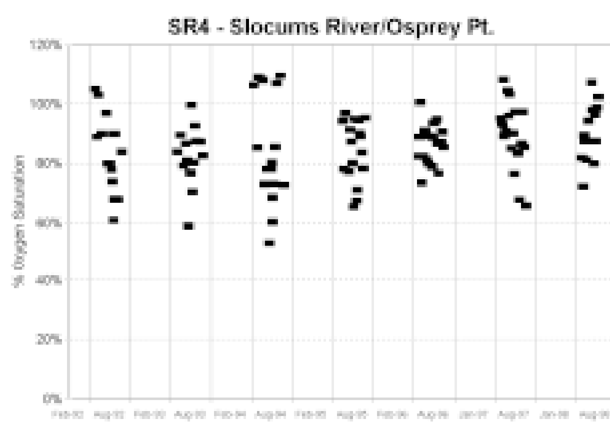
Typical of nutrient and organically enriched embayments, both the Slocums and Little Rivers show frequent depletion of dissolved oxygen. The Slocums River frequently had oxygen levels below 80% of air saturation. Watercolumn oxygen concentrations of less than 80% saturation were observed in the mid and lower estuary in 46% and 33% of samples, respectively, and periodic depletions to less than 60% of saturation in 11% of mid-station samples. The upper estuary is almost certainly experiencing even lower oxygen levels. The Little River Estuary showed even lower dissolved oxygen conditions with values less than 80% of saturation being the norm at both the mid and inlet stations, 79% and 54% of samples, respectively, and low oxygen levels (≤60% saturation) at these stations in 22% and 8% of samples. The nutrient, chlorophyll, particulate organic carbon and dissolved oxygen levels are typical of eutrophic (overfertilized) embayments.

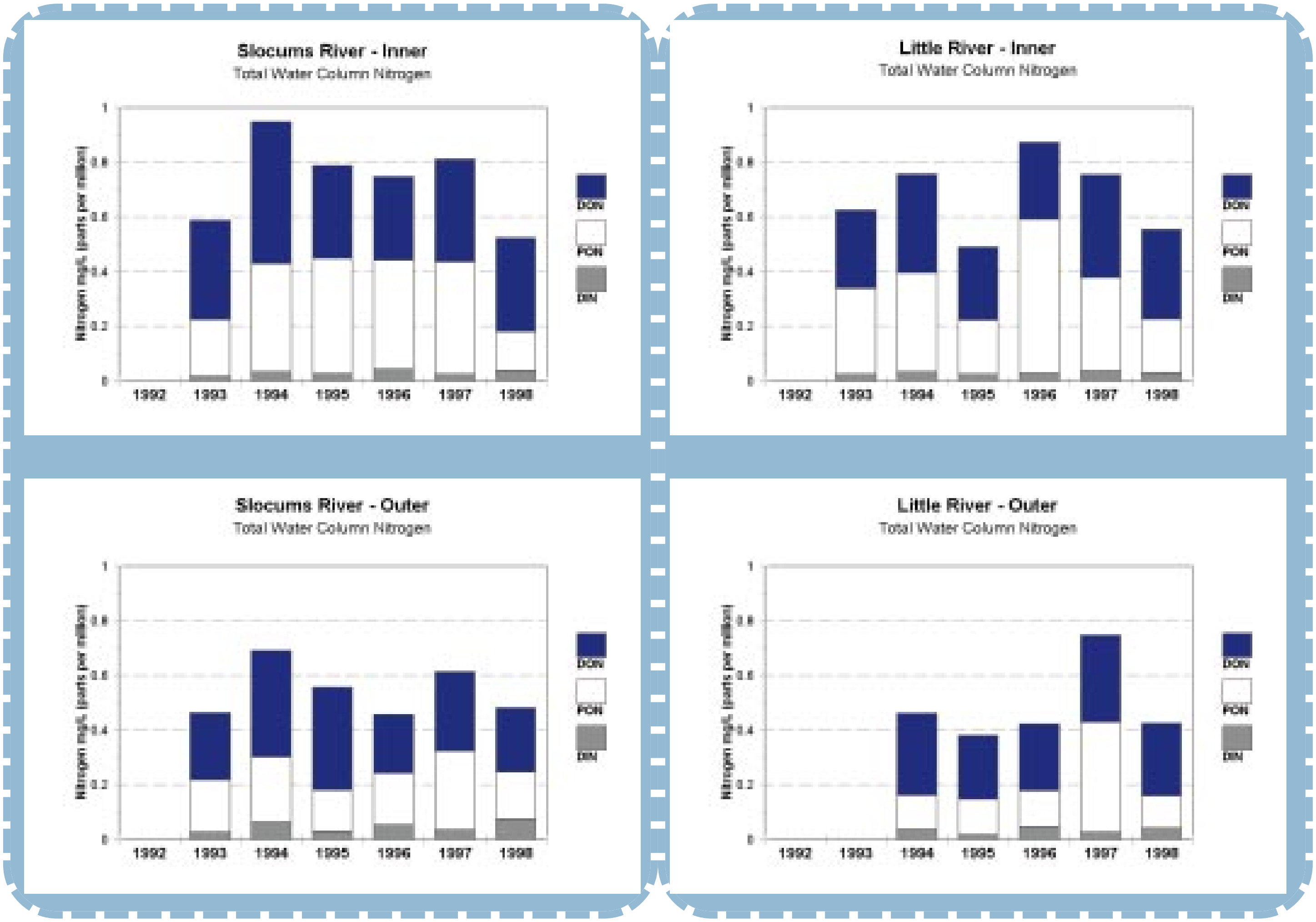
Not surprisingly, integrating the water quality parameters into the Health Index shows both the Slocums and Little River Estuaries to be experiencing eutrophication and showing poor nutrient related water quality. As in the preliminary analysis (Baywatchers I), these embayments are showing some of the lowest nutrient related habitat quality of the Buzzards Bay embayments measured. Station SR5, with salinities often below 5 ppt, was considered a brackish water station and not used for calculating the Health Index scores.







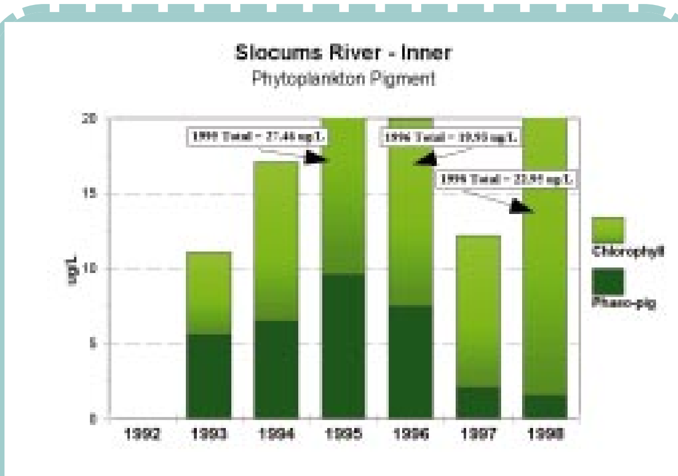


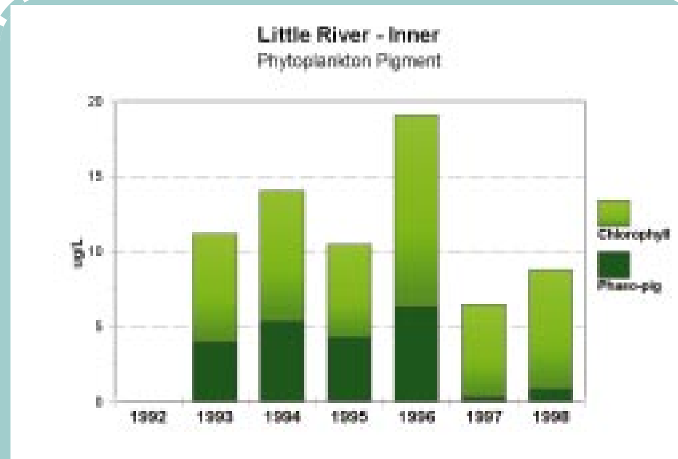


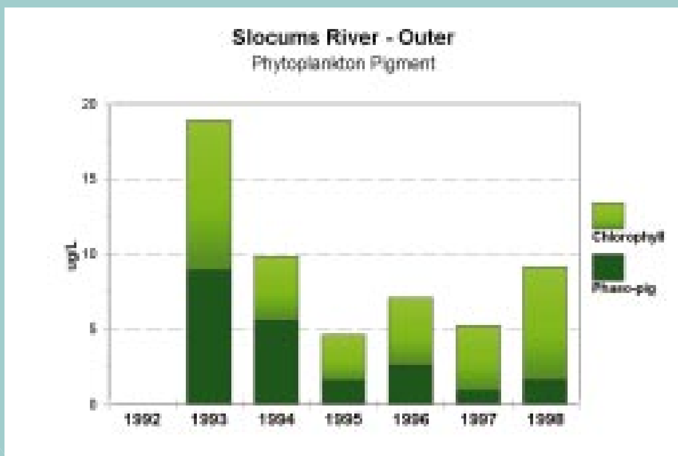
In addition to watershed inputs, there are two major factors which affect the measured nutrient related water quality within the Slocums and Little River Estuaries. First, both systems support significant amounts of saltmarsh area. Saltmarshes are typically not negatively effected by nutrient enrichment. However, saltmarshes do export organic matter from their emergent surfaces into adjacent creeks and embayments, particularly during fall. This organic matter can add to the organic enrichment observed in basin sediments adjacent to marginal saltmarsh areas, such as in the Slocums and Little Rivers. Second, while it appears clear from the analysis of nitrogen loading and land-use that the high nitrogen levels within the Slocums Estuary are associated with watershed inputs, similar analysis for the Little River would suggest much lower watercolumn nitrogen levels than observed throughout the monitoring program. Some of this apparent discrepancy between poor embayment water quality and low nitrogen loading from the watershed may be related to the fringing saltmarshes and tidal flushing, but not all. It is almost certain that the lower than projected nutrient related water quality within Little River results from nutrient enrichment of its inflowing tidal waters. The water quality of an embayment depends significantly upon the level of loading from the watershed and the quality of its incoming tidal waters. The more nutrient enriched the inflowing waters, the lower the tolerance for additional inputs from the watershed. Based on the general circulation along the western shore of Buzzards Bay and the juxtaposition of the Slocums and Little River inlets, it appears likely that during inflowing tides Little River receives tidal waters which are a mixture of low nutrient offshore waters and high nutrient waters which previously ebbed from the Slocums River. For Little River, it appears that some of the water quality results from "poor offshore waters" rather than only watershed inputs. To the extent that nutrient enrichment of inflowing waters is controlling nutrient related health of the Little River Estuary, reduction of nitrogen loading to the Slocums River should also cause improvements to the adjacent Little River system. Further evaluation of the interaction between these two estuaries should be conducted in order to support management alternatives.

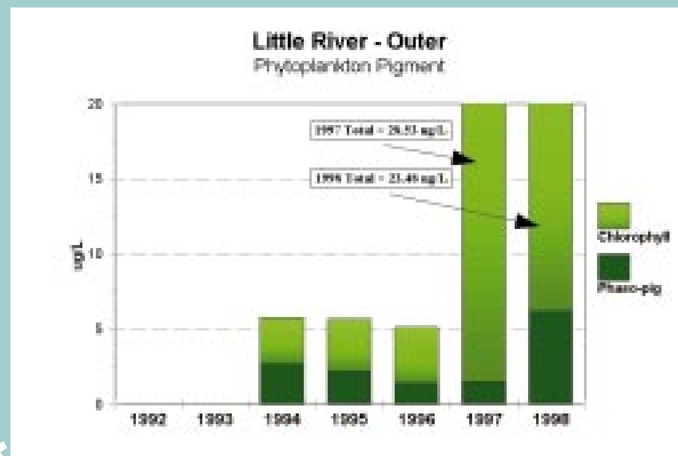
Management Needs

It is clear from the long-term monitoring results and the lack of eelgrass and shellfish beds that both the Slocums and Little River Estuaries are currently showing poor nutrient related water quality. It appears that the nutrient enrichment of the Slocums River results from nitrogen inputs from the watershed in excess of the system's capability to process them without declines in habitat quality. In contrast, nutrient loads to Little River from its surrounding watershed as projected by the Buzzards Bay Project National Estuary Program in a 1994 report should be very low relative to this system's tolerance level. The cause for this discrepancy is most likely partially due to contributions of









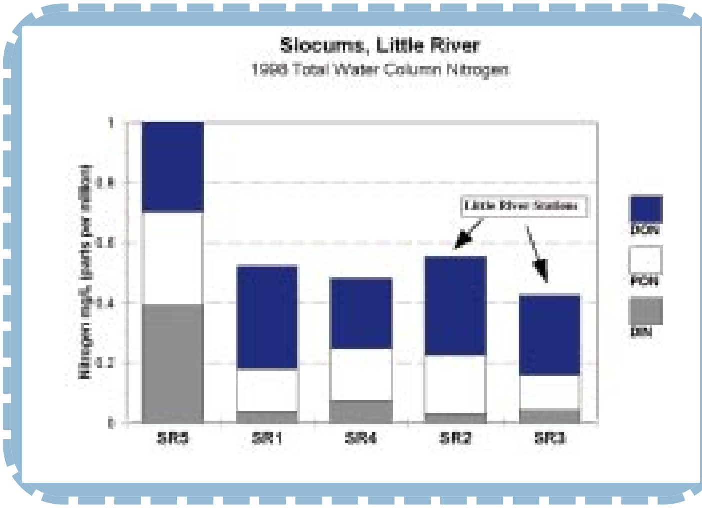
outflowing waters from Slocums River entering Little River on the subsequent flood tide. The close proximity of the inlets of the 2 estuaries within a common bay has functionally linked their watershed loads. As a result, the needed management of the Slocums River Estuary will also aid in management of the nutrient related health of the Little River Estuary.

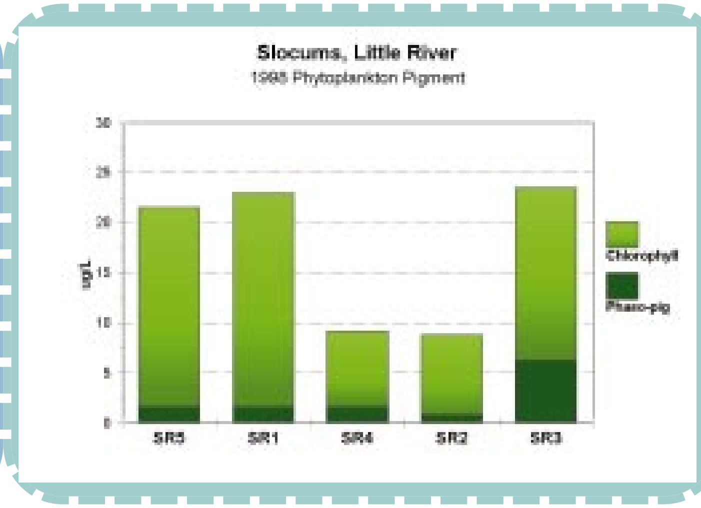
The land-use nitrogen loading analysis indicates that current loading to Slocums River is 3 fold higher than the projected tolerance level. As development of the watershed continues, the estuary has the potential to exceed its tolerance level by up to 6 fold. In other words, the Slocums is in serious decline today and future growth projections suggest that it will only get worse. In addition, the Little River watershed is estimated to have considerable growth potential, especially from conversion of agricultural land to residential land. Little River's nitrogen load is not expected to exceed recommended limits even under build-out conditions. Given the tidal linkage of these 2 systems, nitrogen management of the Slocums River should be the priority. Nitrogen management for the Slocums River Estuary will likely require the use of a whole spectrum of management tools such as sewer extensions, alternative septic systems, preservation of open space and zoning changes to manage both existing nitrogen loadings and future growth.

Open space preservation on a scale similar to the current Slocums River Conservation Project of the Dartmouth Natural Resources Trust (DNRT) and the Trustees of Reservations should continue in this watershed as it not only serves to prevent future loadings but can reduce existing loadings as well. Open space protection also serves to protect present and future drinking water wells, particularly within the Paskamansett River Valley.

Reduction of nitrogen inputs from wastewater is essential to the restoration of Slocums River. With the exception of the Route 6/ Faunce Corner Road area as well as portions of Tucker and Chase Roads, most of the Dartmouth homes in the Slocums River watershed are served by on-site septic systems. As noted earlier in this report, all of these systems, whether modern Title 5 systems or older cesspools, contribute the bulk of the nitrogen produced in every dwelling to the Slocums River unattenuated. Sewer extensions to densely developed neighborhoods need to be evaluated, but with care not to open large areas of present open-space to development. Management of nitrogen in wastewater needs to be addressed at the planning level for all new development within the watershed. New Bedford neighborhoods in the Slocums River watershed are all sewered.

Typically, road stormwater runoff is not considered a significant nitrogen contributor. More critical concerns include bacteria, sediments, and heavy metals which all comprise an important source of pollution to shellfish beds and drinking water supplies for example. Nevertheless, the scale and density of stormwater runoff pollution within the Slocums River watershed may constitute an important nitrogen source to the river and is almost





certainly linked to the bacterial contamination problems within the estuary. The upper portions of the Slocums River watershed along the Paskamansett River at Route 6, Interstate 195 and Faunce Corner Road contains one of the most heavily developed commercial areas in the entire Buzzards Bay watershed. This area discharges road runoff from more than 550 acres of impervious parking lots, commercial and light industrial buildings, and roadways. All of this stormwater runoff presently receives little or no treatment prior to discharge to the Paskamansett.

Within the watershed there is a historic point source of nitrogen at the Dartmouth Municipal Landfill on Russells Mills Road, located not much more than 1,000 feet from the banks of the Paskamansett River. From the early 1970s to 1994, the landfill received sewage sludge from the Wastewater Treatment Facility (WWTF) in addition to regular household trash and other debris. Concentrated sewage sludge is extremely high in nitrogen and high nitrogen groundwater plumes have been found associated with similar practices within the region. The Town has taken steps to eliminate this practice, since 1994 sewage sludge from the Facility is now being composted and sold as fertilizer. Furthermore the Town closed and capped the landfill in 1996 and installed a leachate collection system to capture wastes discharging through groundwater from the landfill. Collected leachate is held in "tight-tanks" and pumped as necessary to the WWTF for treatment. The leachate collection system is not designed to collect groundwater contamination. These actions were aimed at addressing pollution of the adjacent river by groundwater plumes from the landfill. It appears that time, capping and leachate collection have significantly reduced this source. However, previous contamination of the aquifer may still be discharging to the estuary for the next several years. At present, the contribution of the previous discharge that is now within the aquifer to the total nitrogen loading of the bay is unknown.

The water quality within the estuaries is dependent upon their rates of nitrogen input from the watershed and the rate of output by tidal exchange. Increasing flushing of the Slocums River will reduce the effective watershed loading. However, changes in flushing of the Slocums River need to include effects on the adjacent Little River system. Regional changes in beach and offshore sediments has been occurring for some time along the shores of Buzzards Bay between Horseneck Beach in Westport and the mouth of the Slocums River at Mishaum Point. Historical data reflect a drastic reduction in beach widths along East Beach in Westport and to a lesser extent Little Beach in Dartmouth. At the same time, shoaling and increases in beach sediments has occurred along the mouth of the Slocums off Potomska Point near Demarest Lloyd State Reservation. These changes have historically altered and restricted the tidal exchange dynamics and flushing capabilities of both the Slocums and Little River estuaries. Reduction of tidal exchanges serves to increase the level of habitat decline per unit of watershed nitrogen load, maintenance of maximal flushing rates serves to decrease the sensitivity of these estuarine systems to increased nitrogen loading.

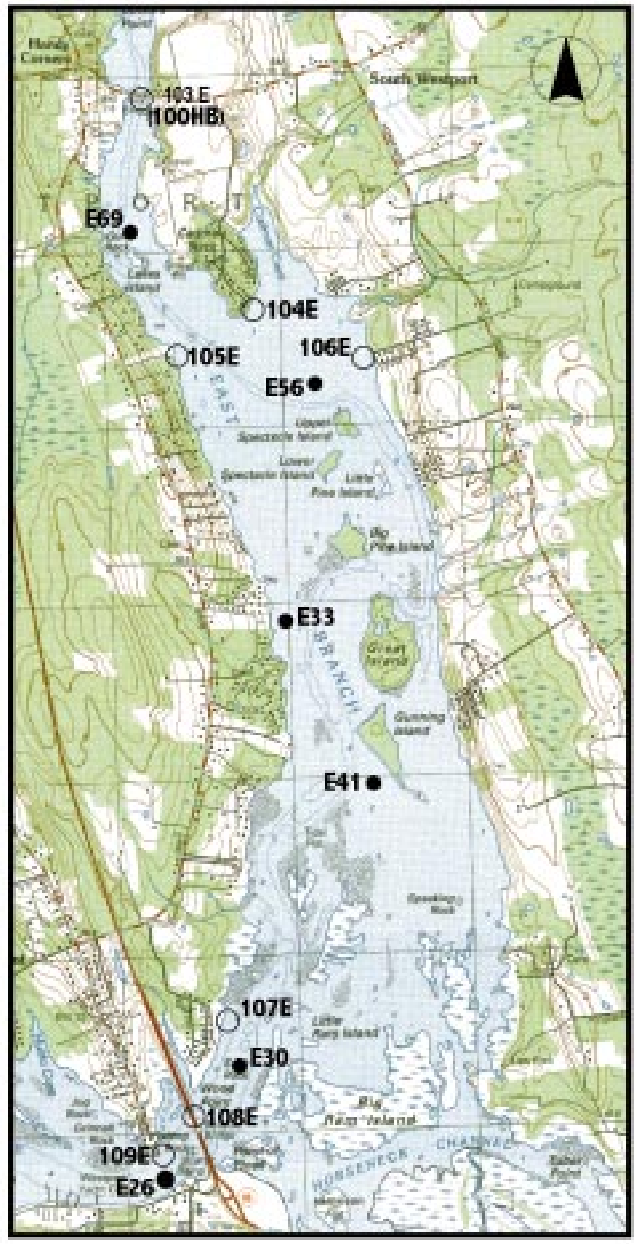
A hydrodynamic study initiated by the MA Department of Environmental Management was completed in 1999 (Woods Hole Group). This study focused on the impacts that the construction of the causeway to Gooseberry Island may have had in sand transport and movement along the coast and found no direct link between the causeway and problem. While this finding was met with a lot of skepticism in Westport, no further possible explanation or solutions have been identified.

Restoration of the Slocums and Little River Estuaries will require as a first step a quantitative assessment of the linkage between the Slocums and Little Rivers and detailed water quality and land use analysis to better identify specific sources, determine the site-specific level of reductions required, predict the level of restoration from the various available alternatives, and prioritize restoration actions. This assessment needs to include the nutrient discharges from the landfill. This effort is the basis of a watershed nitrogen management plan for the Slocums and Little River Estuaries.

East & West Branches Westport River

Embayment and Watershed Characteristics

The Westport Rivers are comprised of two major drowned river estuaries which are connected to Buzzards Bay tidal waters by a single inlet. The waters of both sub-embayments are relatively shallow, ca. 0.8 meters, as are the channels. The combined embayment surface area is large by Buzzards Bay standards, ca. 1906 acres (East: 591 acres; West: 1,315 acres). The combined upland area contributing to the embayments, 48,074 acres (East: 37,467 acres; West: 10,607 acres), forms the second largest sub-watershed to Buzzards Bay, accounting for 18% of the total watershed area. With rivers entering into the headwaters of both East and West Branches, the Westport Estuary has the greatest surface water inflow of the Buzzards Bay embayments, carrying about 20% of the total freshwater input to the Bay. Within the lower estuarine regions, groundwater inflows also discharge to embayment waters.



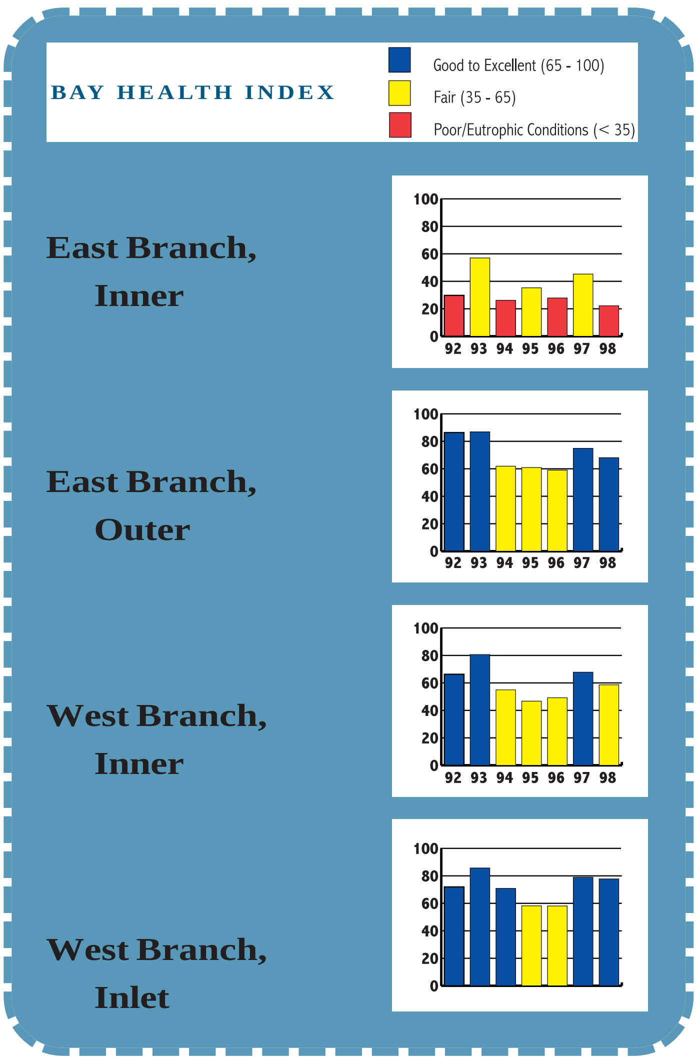
The Westport River estuary is one of the Commonwealth's greatest coastal treasures, most notably for its scenic beauty and the diversity and quality of its habitat. The Westport River Watershed falls within two states – Massachusetts and Rhode Island, and four principal municipalities – Westport, Dartmouth, Fall River, and Tiverton. However, the entire estuary is held within the Town of Westport. Included in the East Branch upper watershed is the Copicut Reservoir, operated by the City of Fall River as part of its municipal water supply.

Land-use differs between the 2 branches and is dominated in the lower regions by agriculture and light residential development and in the upper regions by forest. Agricultural activities range from dairy farms, orchards, potato and corn fields, to a growing viticulture industry. Only 19% of the Town of Westport was developed by 1985. Of the town's remaining lands, 21% is in agriculture and 60% is upland forest or wetlands. However, only 9% of the lower watershed within the Town of Westport is currently set aside as "permanent" open-space or for agriculture, such as under the MA Agricultural Preservation Restriction Program.

While the general watershed activities are similar between the branches of the Westport River (both are two-thirds forestlands), there are important differences in the dominant watershed uses which contribute high levels of nitrogen to the estuarine waters.

The West Branch of the River is rural, dominated by agricultural land, which accounts for nearly two times the area occupied by commercial and residential land-uses. Nitrogen loading from activities associated with crop and animal agriculture presently create more than half of the total watershed nitrogen load to West Branch waters. However, even with the predominance of agricultural land-uses, nitrogen loads associated with residential and commercial activities are two-thirds the load from agriculture and account for the remaining watershed nitrogen load to the estuary. In addition, while the area under agriculture is decreasing, residential development is on the rise, with its much higher associated nitrogen load per unit area. In contrast, watershed nitrogen inputs to the East Branch of the Westport River comes primarily from activities associated with residential and commercial land-uses (>55%) and to a lesser extent crop and animal agriculture (<40%). In addition, the total nitrogen loading to the East Branch is nearly 4 times higher than that to the West Branch of the River.

Although the Westport River watershed is thought of as primarily rural and agricultural, supporting most of the dairy industry around Buzzards Bay, residential development continues to increase and, with commercial activities, dominates the present nitrogen loading. The estuary has shown eutrophic conditions



and bacterial contamination in the upper reaches. However, while it is likely that farm animals like dairy cows may play an important role in fecal coliform loading, it appears that nitrogen management related to residential and commercial activities dominates nutrient related habitat quality.

In the Town of Westport which forms the shoreline and much of the lower watershed to both branches of the river, residential development is continuing. Despite years of low to moderate growth in residential land-uses in Westport, construction increased significantly in 1995 (1995 was 40 % higher than 1994) and has continued to increase (through 1998, the last full year available). Population projections by the Southeastern Regional Planning and Economic Development District (SRPEDD) suggest that under present trends, Westport's population will increase from 13,389 in 1997 to 16,500 in ten years. At present, Westport does not provide centralized water or sewer to its residents. The lack of centralized wastewater treatment makes river water quality fundamentally linked to development in the Westport River watershed. While properly designed septic systems adequately remove pathogens from wastewater, they do little to remove nitrogen which moves unattentuated through groundwater on its way to the river. Therefore, increases in the residential land-use can be expected to further impact the upper embayment waters, unless nitrogen management is undertaken for this watershed.

The Westport River supports a diversity of productive estuarine habitats, although some regions (particularly within the upper reaches) have been degraded. The Westport Rivers presently contain large quantities of saltmarsh, with more than 1,000 acres (East Branch: 783 acres, West Branch: 258 acres). The two branches of the estuary also support more eelgrass than any other enclosed embayment to Buzzards Bay, over 100 acres. However, eelgrass distribution is reduced over historic levels throughout most of the estuary. The estuary sustains the largest breeding population of Osprey (*Pandion haliaetus*) within Massachusetts. The Osprey have returned to this embayment and to Buzzards Bay in the decades since the 1960's ban on DDT, which brought them to near extinction. It is gratifying that this species for which Buzzards Bay is thought to have been named, is once again seen fishing the waters of the Bay. The Westport River estuary is also one of fifteen heron rookeries in Massachusetts with nesting black-crowned night herons, green-backed herons, and great blue herons.

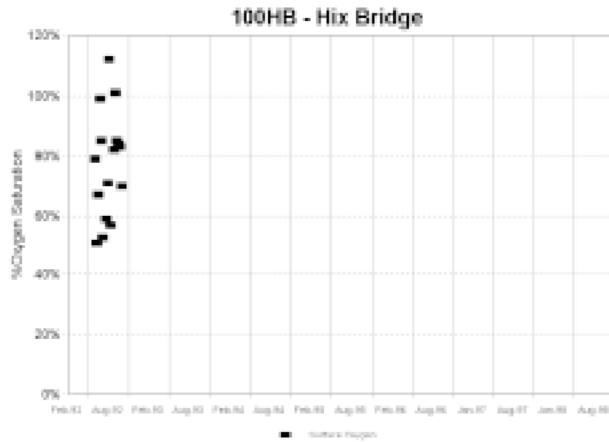
Westport River is an important recreational site within the region, with more than 600 boat moorings and slips (East Branch: >100, West Branch: >500) and recreational beaches, particularly at Horseneck Beach State Park at the mouth of the estuary. Both Branches are popular river canoeing and kayaking areas. A boat pump-out facility is located near the inlet at Westport Point, aimed at protecting the embayment's resources from additional contamination.

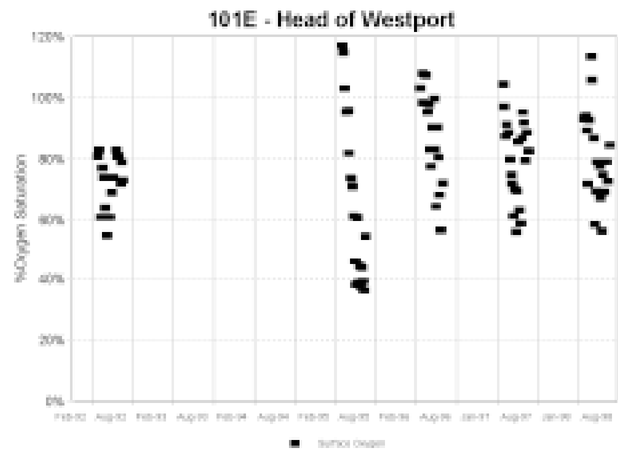
Within the tidal reaches of the River, there are approximately 2,887 acres of shellfish beds (quahogs, oysters) beds, including some of the few remaining areas for bay scallops within the region. The River yields the highest scallop catch for Buzzards Bay. However, the system suffers from a variety of watershed non-point source inputs effecting water quality. Bacterial contamination has been a problem, causing closures of shellfish beds to harvest within the Westport Rivers, primarily due to dairy farms with additional inputs from runoff from developed areas. A few of the dairy farms are run as feedlot operations with a high density of animals per acre. As a result improved management is needed to prevent significant bacterial contamination of the estuary from manure. For more than a decade there have been problems with farm runoff contaminating the upper portions of the river. During portions of the summer of 1991, all beds were closed to harvest. Large portions of the East Branch of the River are permanently closed to shellfishing as are the upper reaches of the West Branch. Currently 23% or 650 acres of the beds are Permanently Closed, due to bacterial contamination, including 1,522 acres (53% of beds) which are Conditionally or Seasonally closed. In total, 76% of the shellfish harvest potential in the Rivers is limited because of bacterial pollution. However, conditions are improving as the amount of rainfall required to trigger a conditional closure is now higher than in the early 1990's and the duration of a rainfall closure has declined from 8 days to 5 days. Compounding the bacterial closure problems, the quality of the shellfish habitat and overall river waters are suffering from the effects of excessive nitrogen loading, or eutrophication. This problem of overfertilization of embayment waters is particularly acute within the upper reaches of the East Branch, although it appears to be affecting the entire estuary. While control of bacterial contamination is important to shellfish harvest, management of the health of the beds and the estuary requires nitrogen management planning.

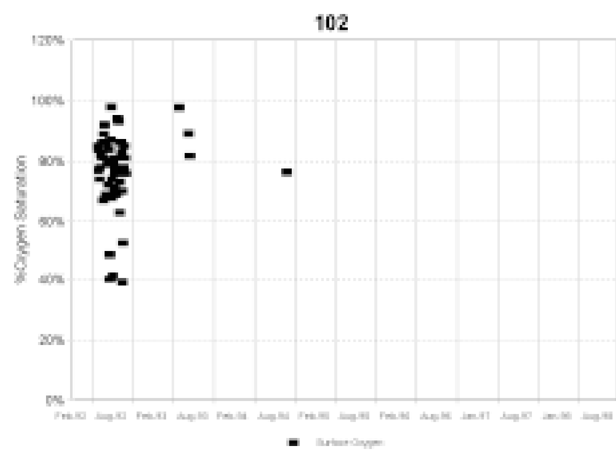
Water Quality

Habitat and water quality within the Westport River Estuary showed a consistent pattern of nutrient related degradation throughout the monitoring period, 1992-1998. However, the system is not uniform. There were significant differences between branches and gradients from the upper to lower regions within each branch. The conditions within the estuary are consistent with the watershed nitrogen loading and distribution of inputs within the watershed. That the system is currently experiencing nutrient related habitat decline is supported by analysis of historical aerial photographs which suggest eelgrass beds have disappeared in the upper estuary as a result of nutrient over-fertilization.

The East Branch estuary currently receives almost a four fold higher watershed nitrogen loading than the West Branch, consistent with its nearly four fold larger upland area. In addition, the East Branch receives inflowing tidal waters through a more convoluted channel than the West Branch which has direct access to the inlet. Comparison of similar regions (mid-estuary) of each Branch indicates that while they share similar salinity regimes, the East Branch showed a higher concentrations than the West Branch of nutrient related parameters, total nitrogen by 24%, chlorophyll a pigments by 78% and particulate organic carbon by 32%. Particulate organic carbon is the component

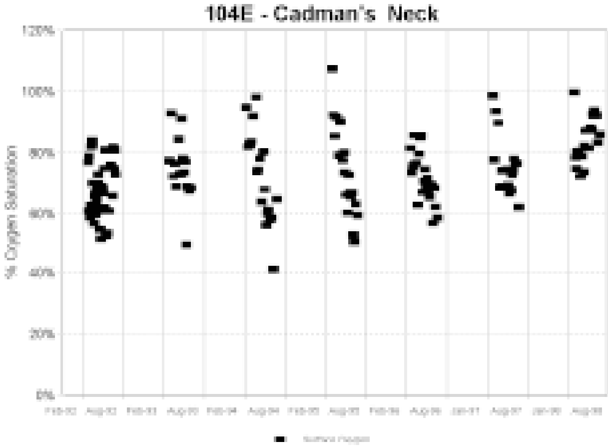


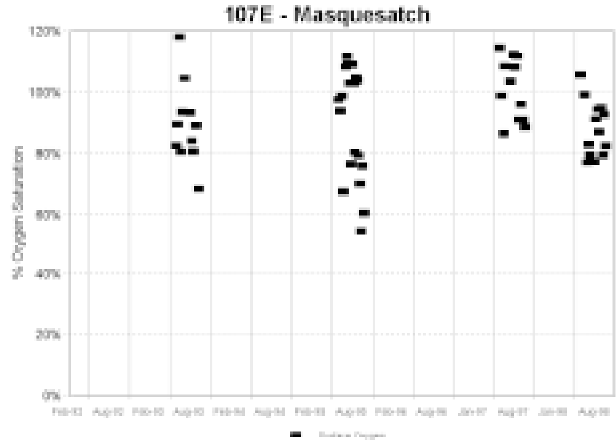


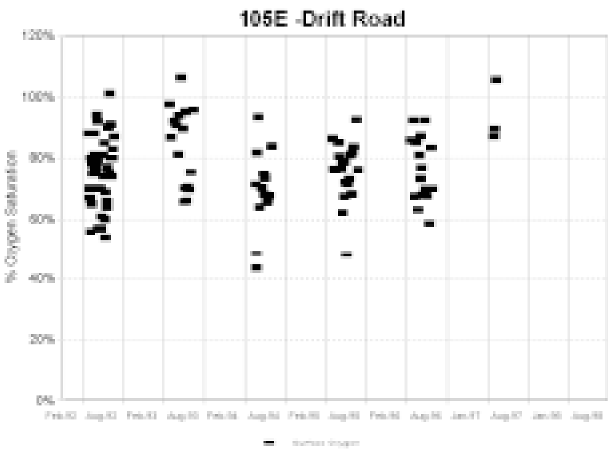


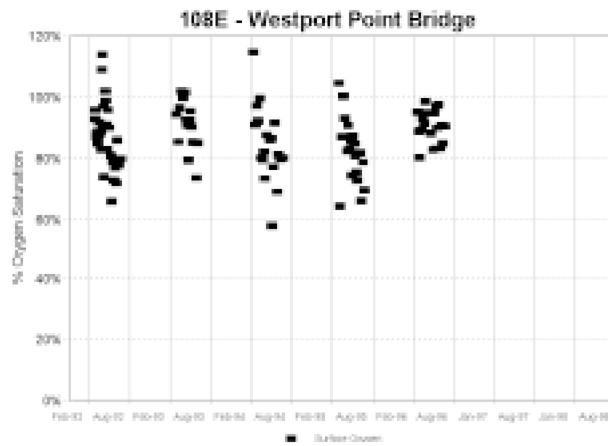
which supports oxygen respiration within the watercolumn, which if too high results in lower oxygen levels. The apparent lower habitat quality of the East Branch is consistent with the near complete loss of eelgrass beds even in the lower regions. In contrast, the West Branch supports eelgrass in the lower third to half of the tidal region.

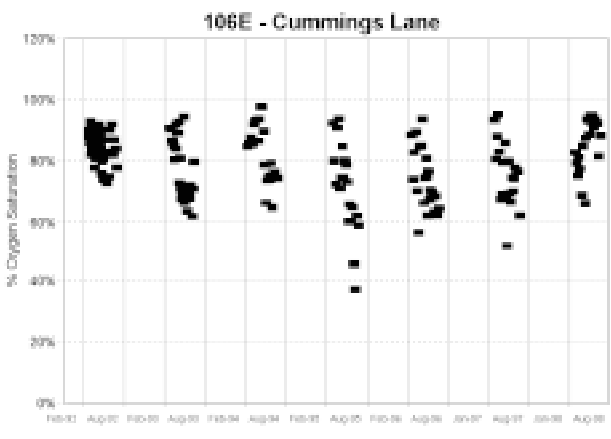
The eastern estuary shows a strong gradient in water quality from the upper regions (near Hix Bridge) to the lower portion adjacent the Rt. 88 Bridge. This gradient is not related to basin depth, but to the interplay of watershed nitrogen inputs concentrated near the headwaters and tidal exchange with the high quality waters of Buzzards Bay which increases near the inlet. Within the East

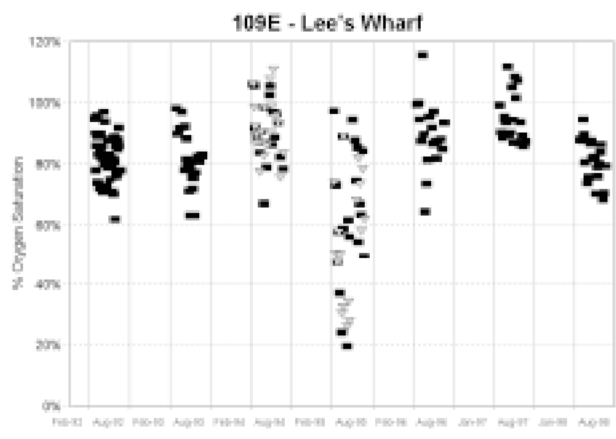




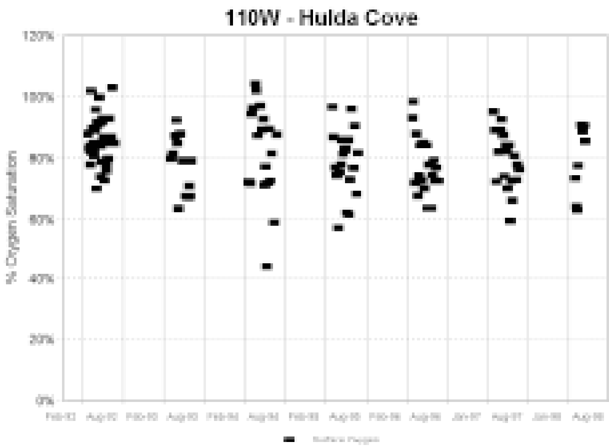


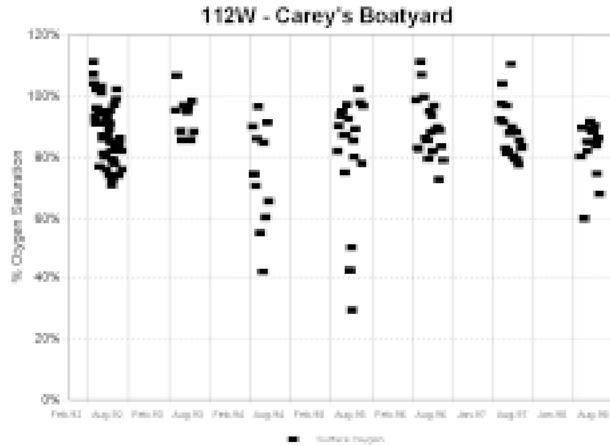


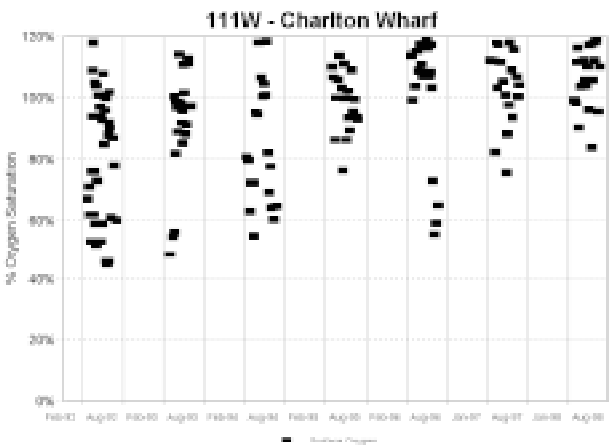


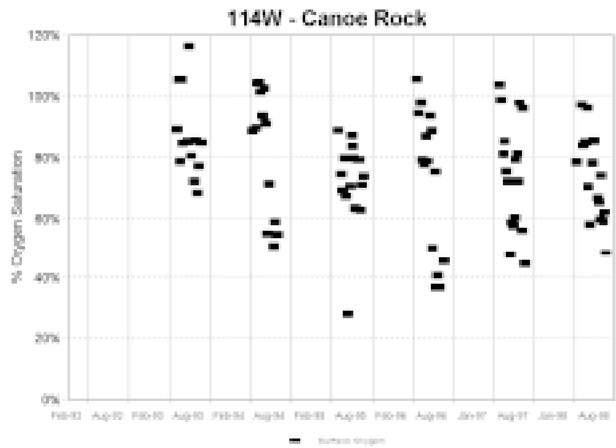


Branch there is a clear salinity gradient with averages of 21.6 ppt near Hix Bridge and 26.2 ppt and 29.9 ppt in the mid and lower regions, respectively. In this system, higher salinities are indicative of regions of higher tidal flushing. Within the East Branch the upper (just south of Hix Bridge) versus lower stations averaged almost twice the total nitrogen (1.9 times), 1.8 times the chlorophyll levels, 2.5 times as much particulate organic carbon, resulting in only 62% of the light transparency. The total nitrogen values for the upper, mid, lower and inlet regions are high and show clear over-enrichment of the upper estuary with concentrations of 0.87 (SE=0.044), 0.64 (SE=0.035), 0.46 (SE=0.034) and 0.39 (SE=0.03) mg N/L, respectively. Chlorophyll a pigments showed a similar gradient from the upper, mid, lower and inlet regions of 11.9 (SE=0.8), 7.5 (SE=0.7), 3.8 (SE=0.4) and 2.4 (SE=0.2), respectively. The chlorophyll a average values from the upper East Branch are high by Buzzards Bay standards and indicate a significant nutrient enrichment. (Note: SE is standard error a measure of variability around the average value) The enriched nitrogen levels and high phytoplankton biomass can be seen in the high particulate organic carbon levels (upper-1.33, mid-0.85, lower-0.54, inlet-0.44 mgC/L) and the correspondingly low transparencies, measured by secchi disk (upper-1.38, mid-1.66, lower-2.21 inlet-2.56 meters). Light penetrates only about half as far into the upper waters as at the inlet, greatly reducing the habitat for plants on the embayment bottom. The







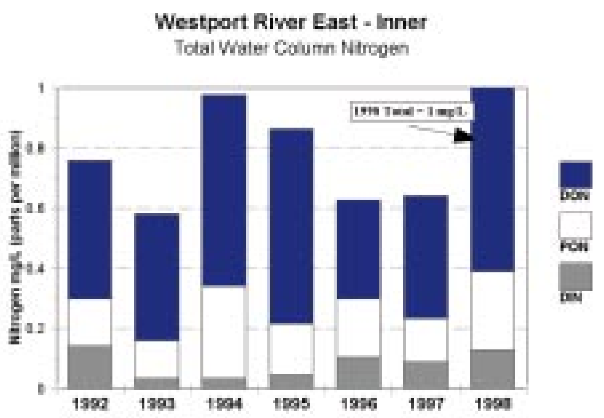


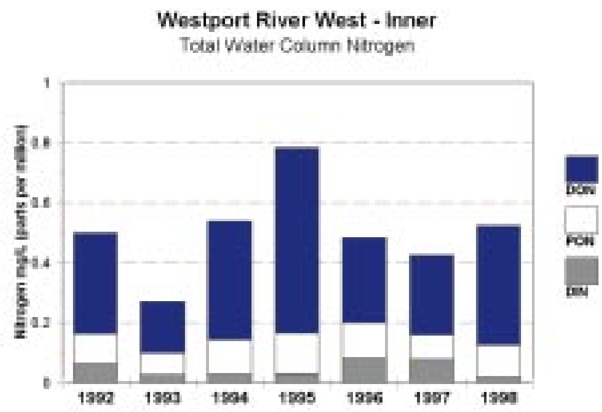
nutrient enriched conditions and reduced transparency are the likely mechanism for loss of eelgrass from these areas.

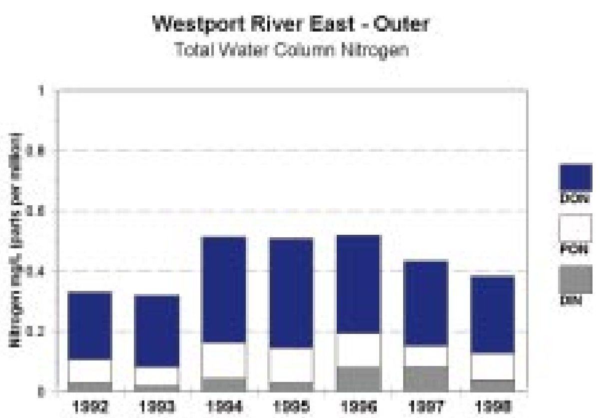
Similar to the East Branch, the West Branch showed a gradient of nutrient enrichment between the mid and lower regions and the inlet. The levels were always higher within the west basin compared to the inlet, total nitrogen was generally 40% higher (0.54 vs. 0.38 mgN/L), and transparency was 23% lower. A greater level of apparent enrichment was found in chlorophyll a pigments and particulate organic carbon which were 74% and 48% higher in the West Branch versus inlet waters, respectively. However, there was no clear gradient within the mid and lower West Branch stations. Comparison of the average mid (upper nutrient stations were collected near Toms Point) versus lower station results showed enrichments of less than 7% for total nitrogen and less than 2% for particulate organic carbon, chlorophyll a pigments and transparency. It appears that the mid and lower West Branch are relatively well mixed. This is supported by the lack of a measurable salinity gradient between these stations (mid-29.6 ppt; lower-30.0 ppt). The overall results indicate that while both River Branches are showing nutrient enrichment, the levels in the East Branch are significantly higher than the West Branch, and the horizontal gradient in water quality much better defined.

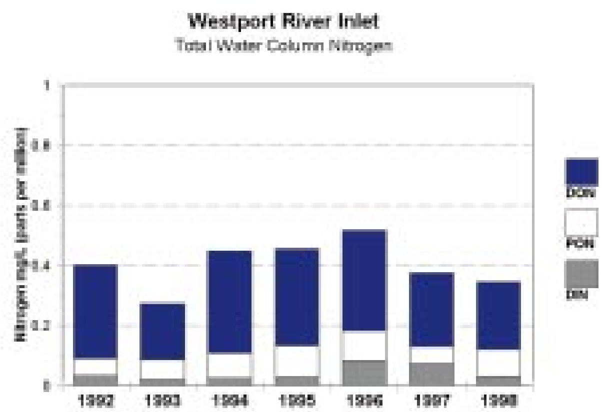
While the results are showing nutrient enrichment and eelgrass loss within the Westport Rivers, enrichment has not yet driven the system to high frequency stressful oxygen depletions. Within the East Branch oxygen levels in the uppermost reaches (Stations 101E & 104E) show relatively frequent oxygen depletion to moderately stressful levels of <60% air saturation (15% and 14% of samples respectively), but rarely shows declines below 40% saturation. Similarly, within the West Branch, oxygen declines to <60% saturation occurred in generally less than 10% of the samples at all stations, except for the station at Canoe Rock where 23% of the samples were less than 60% saturation (but only 3% below 40% saturation). Oxygen depletions below 60% saturation are clear indication of systems which are beyond their tolerance of loading for nutrients. Periodic occurrence of these conditions are typical of most of the River stations (Stations: 111W, 102W, 109E, 114W, 101E, 104E, 105E).

Integration of the water quality results into the Health Index allows a composite indicator of the River's water quality. The Index scores for the upper East Branch are quite low, indicative of a high degree of nutrient related water quality decline. This region is the most heavily nitrogen loaded and least well flushed within the Westport Estuary. The lower reach of the East Branch shows inter-annual variations between high and moderate water quality similar to levels in the West Branch. These inter-annual variations underscore the need for long-term monitoring for guiding nutrient management and restoration programs. The periodic moderate water quality Index observed at the inlet results from sampling outgoing (ebb) tidal waters which have been enriched by watershed loading during their stay within the embayment. Conditions at the inlet are actually better than the









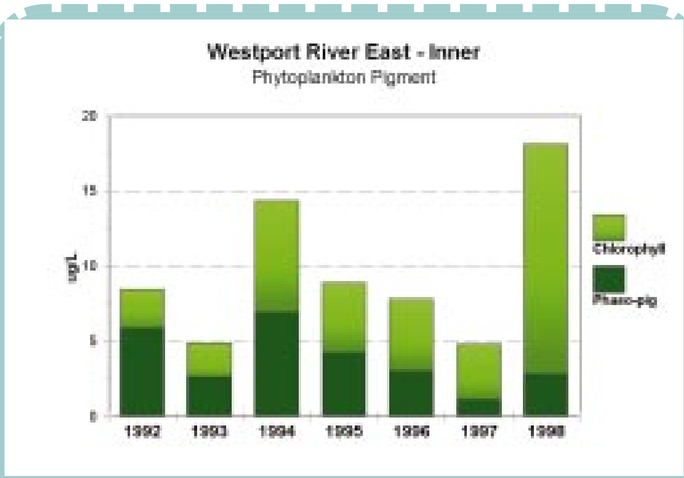
Index score suggests, since half of the time (not sampled) the inflowing high quality Buzzards Bay waters are found at this site. The result is that healthy eelgrass beds are still found near the inlet. However, for the estuarine reaches of both Branches, it is clear that nitrogen management is needed to prevent further nutrient related habitat decline which will occur as more nitrogen is loaded into the system from changing watershed land-use. Since the capacity of the system to absorb nutrients is presently overloaded and both basins are showing moderate water quality declines, reductions in the present nitrogen loading would be necessary for restoration of the water quality and habitat quality of the Westport River Estuary.

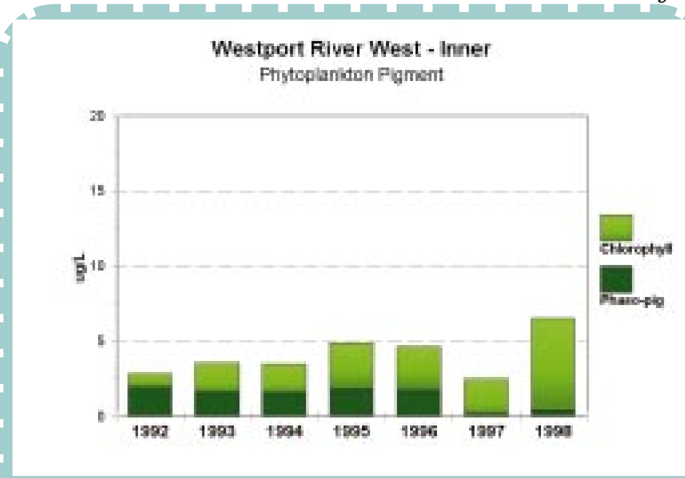
Management Needs

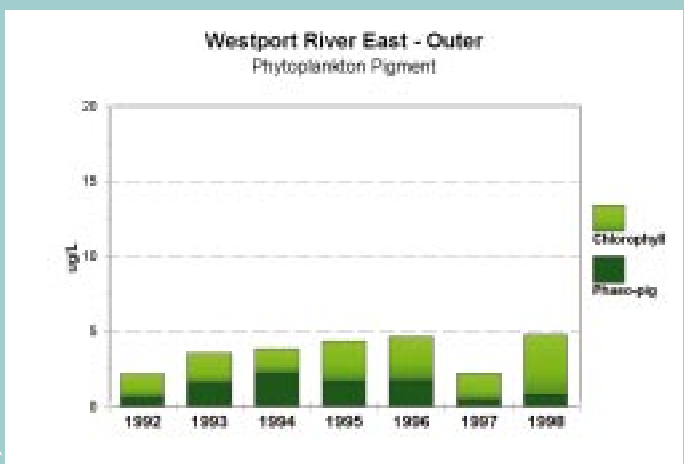
East Branch: All indicators suggest water quality in the East Branch is impaired, and the estuary has had some of the worst Health Index Scores and total nitrogen levels of the Buzzards Bay Region.

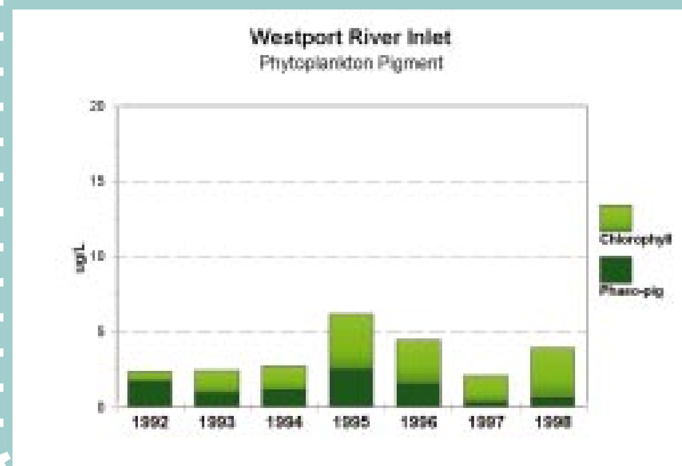
The Massachusetts Department of Environmental Protection has ranked the East Branch as having a lower designated water quality standard than other Buzzards Bay embayments. The only other Buzzards Bay embayment with a similarly low a ranking is New Bedford Harbor. Management action is required to remediate existing sources as well as to control new inputs. Like the West Branch, the watershed also has considerable growth potential, especially from conversion of agricultural land to residential land and in development of the Upper watershed lying in the City of Fall River and Town of Dartmouth. Because this upper watershed region has considerable wetland and land in forest use, a concerted effort to preserve open space can have long term benefits for protecting water quality and drinking water supplies in the Westport River.

Dairy farming remains an important land-use within the watershed of the East Branch, and additional management practices for pasture land dairies need to be followed where applicable. In this regard, implementation of Best Management Practices (BMP's) should continue to be encouraged for this agricultural practice with incentives to "clean-up" rather than remove the farm from agricultural use (i.e. "sell-out"). In 1999, the U.S. EPA required the first federal discharge permit for a New England farm – a farm within the Westport Rivers. The purpose is to minimize manure contamination of the estuary as much as possible. As this process continues, inclusion of nitrogen in addition to bacterial contamination needs to be considered. However, the habitat quality of the River requires implementation of BMP's to address bacterial and nitrogen inputs for urban and residential areas not just for farm areas. A nitrogen (and bacterial) management plan for the watershed should be considered as a mechanism to integrate the variety of BMP's being proposed for the watershed. This man-







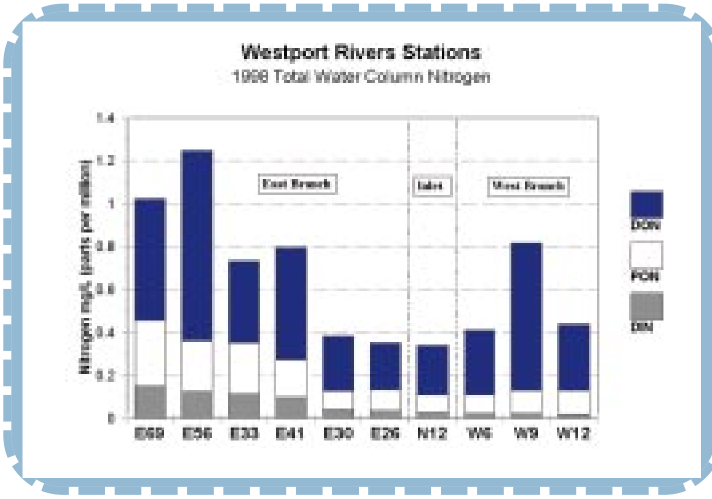


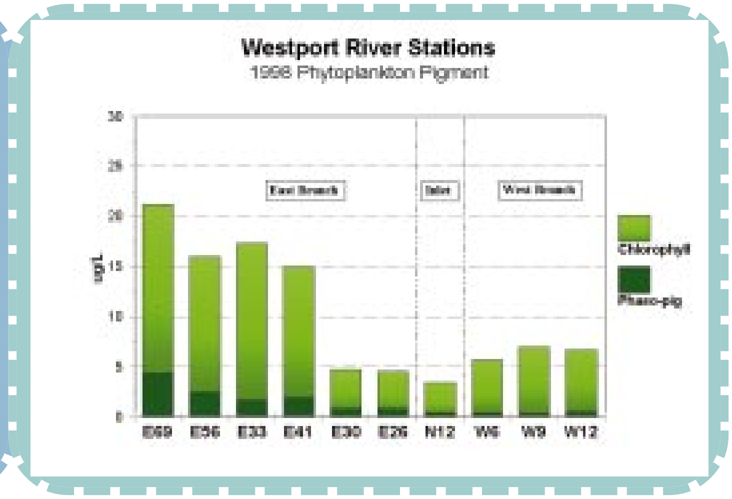
agement plan needs to be based upon a quantitative evaluation of the watershed-estuarine linkages and the tolerance of the various reaches of the River for nutrient inputs.

Protection of farm land is important both to the water quality of the estuary (if BMP's are in place) and to maintaining the heritage of the region. To this end the Massachusetts Department of Food and Agriculture, through its Agriculture Preservation Restriction (APR) Program and various conservation efforts, has had an impact most recently with the Towns of Westport and Dartmouth by bringing the Bettencourt Farm (82 acres) into the Program. At present, 1,285 acres of farmland within Westport are under preservation restriction, with 15 farms currently in the program and more slated to join in the future. These efforts should be encouraged, but need to include provisions to implement BMP's (if not already in place) so that both the farmland and the adjacent estuary are preserved for future generations.

The health of the Westport River is currently being supported by the large area of forestlands within its watershed. Forestlands contribute little nitrogen to adjacent estuaries and have positive effects on mediating surface runoff during high rainfalls. On a similar surface area basis, forestlands contribute less than 5% of the nitrogen to the Westport River than falls in rain to the estuary surface. The largest forest area within the Buzzards Bay watershed surrounds the Copicut Reservoir at the headwaters of the East Branch of the River. Nearly 5,500 acres of forest has been held from development by private owners, primarily the Acushnet Saw Mills (4,000 acres). The 1,360 acres held in smaller parcels represent an immediate threat for fragmenting the forestlands and increasing nitrogen loading to the Estuary through development. Many of these smaller parcels lie within stream corridors to the Copicut Reservoir such as the Miller Brook area. Ensuring the continuation of forest on these lands is critical to the water quality within the Westport Estuary and for present and future drinking water supplies. The City of Fall River's 1998 Open Space Plan identified preservation of forestlands in the Copicut region as its highest priority. However, protection of these large forestlands is important to all concerned with the Westport Estuary.

West Branch: The Buzzards Bay Project estimated that existing nitrogen loadings are more than 20% over their recommended limits. This analysis was based on an Outstanding Resource Water designation, the highest of four possible classifications for coastal waters. The Massachusetts Department of Environmental Protection, however, has ranked the West Branch as having only "SA" waters, the second highest water quality standard. If this lower standard were used, the embayment would not now exceed recommended limits, but would do so in the future when the watershed reaches full development buildout. The Project recommends the more stringent standard because of the value of the resources in this estuary.

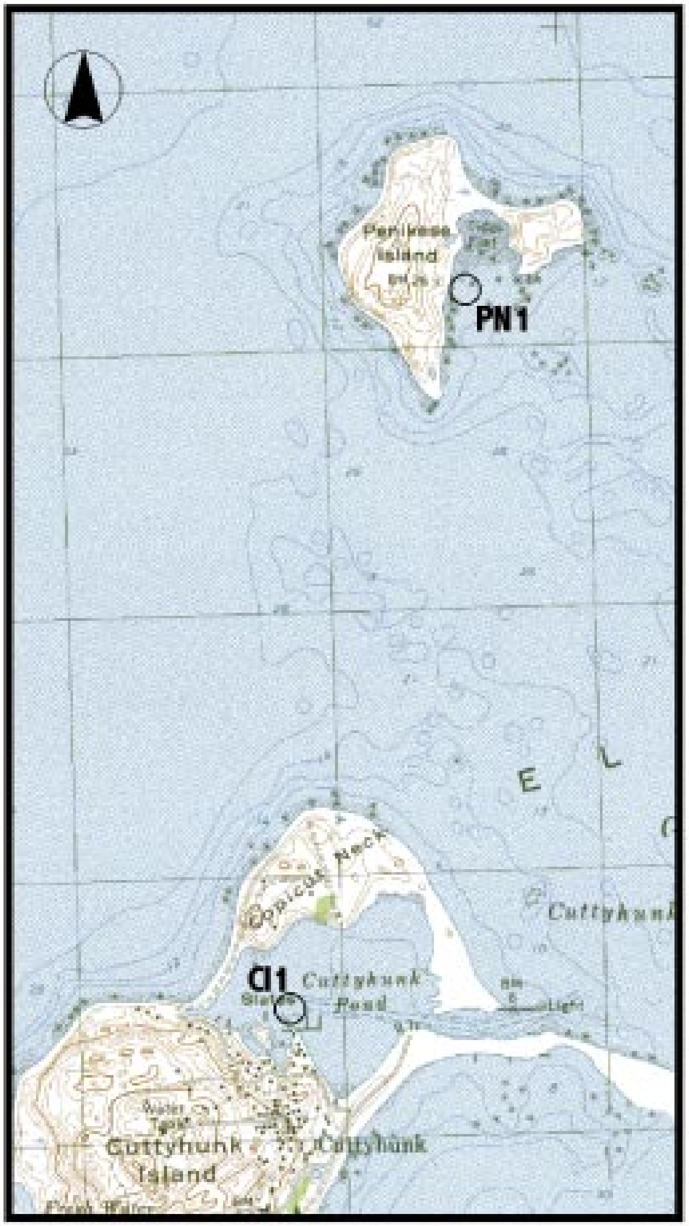




Generally water quality in the West Branch is fair to good, and is far better than conditions in the East Branch. Some loss of eelgrass beds in the upper estuary have been documented, a finding consistent with the overloading to the estuary. The watershed also has considerable growth potential, especially from conversion of agricultural land to residential land. Consequently, future growth in the watershed should be planned for and managed. The West Branch watershed is large and includes two municipalities in the state of Rhode Island. Nitrogen management for this estuary will require implementation of agricultural "best management practices" and controls on the number and performance of future septic systems. Upgrade of cesspools to septic systems with advanced nitrogen removal is another management option. Purchase of open space, agricultural protection restrictions, and conservation easements are important strategies to help manage future growth and nitrogen inputs. Given that conditions in the West Branch are not severely degraded, strategies to manage future inputs will prove worthwhile.

R. Arms 1998

Cuttyhunk Island & Penikese Island



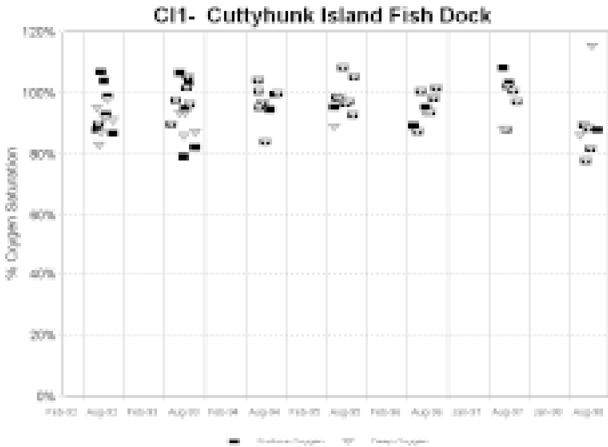
Embayment Characteristics

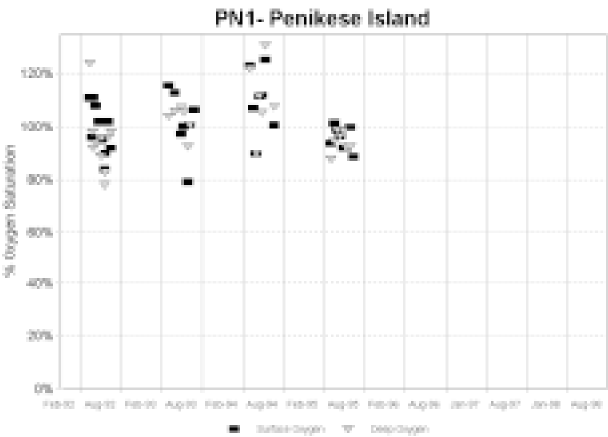
Framing the southern extent of Buzzards Bay, the Elizabeth Island chain stretches from Woods Hole in the east to Cuttyhunk Island which marks the westernmost edge of the Bay. The Islands sustain small year-round populations and Cuttyhunk is supported by both ferry and air service. They were formed by glacial moraine deposits and glacial till. Evidence of the moraine can be seen in the large boulders which form much of the coast, having been eroded by the advancing sea. These boulders provide a hard substrate for colonization by marine organisms which are not capable of living in some regions of the Bay. Cuttyhunk supports several salt ponds, the largest of which is Cuttyhunk Pond which is a shallow (generally less than 1 meter), enclosed basin with a narrow tidal inlet. Cuttyhunk Pond serves as the major safe mooring area for the Town. Cuttyhunk's smaller neighbor, Penikese Island supports no major embayments and only an open harbor on the Island's south shore. Between 1992-1998, The Water Quality Monitoring Program has maintained an oxygen sampling station in the major basin for each Island - Cuttyhunk Pond and Penikese Harbor. Given the circulation of Buzzards Bay and access to waters entering from New York Bight to the west and the Atlantic Ocean to the south and the low amount of terrestrial influence, the waters surrounding these Islands are considered to be the highest quality within Buzzards Bay.

Penikese Island is owned and managed by the Massachusetts Division of Fisheries & Wildlife and is currently largely undeveloped with the exception of the Penikese Island School. The school operates year-round residential programs for troubled youth with 12 staff and attendees and a small pen of farm animals.

In contrast, Cuttyhunk Island supports private land holdings and residences with a year-round population of about 50 residents and a summer population of up to 1,000. The focal point of the Island is the safe harbor provided by Cuttyhunk Pond. Large concentrations of boats occupy the Pond during most summer weekends. The Cuttyhunk Shellfish Constable estimates that 95% of transient boats are occupied over night. The Pond also supports a town beach, located on Barges Beach between the pond and Vineyard Sound, and two marinas, a yacht club and several private and town piers. Cuttyhunk is large enough to have local inputs of nutrients to the Pond from a variety of sources, the small sewage collection system, on site septic systems, road runoff, and boat waste.

Cuttyhunk Pond also supports productive shellfish populations. Quahogs (*Mercenaria mercenaria*) are the predominant shellfish found in Cuttyhunk Pond with soft shell clams (*Mya arenaria*), American Oysters (*Crassostrea virginica*), and blue mussels (*Mytilus edulis*) found in small patches throughout the Pond. The Pond has been classified as a Seasonally Approved/Prohibited to shellfish harvest since 1977. At present, the Pond's shellfish beds are open to harvest from October 1 through the Friday before Memorial Day, when the boats are not in the Harbor.. The closure has been related to the large number of live-aboard boats in the Pond during the summer season. A study conducted by Massachusetts Division of Marine Fisheries (DMF) during the summers of 1994 & 95 confirmed the role of boats relative to the bacterial contamination of the Pond waters. Sampling on weekdays, when boat numbers are low, yielded no discernible bacterial contamination problem with levels being below 2 FC/100mL compared to a shellfishing limit of 14 FC/100mL. In contrast, during weekends, when up to 300 boats moor in the Pond, bacterial contamination rose to "unacceptable" levels of more than 50 FC/100mL. The seasonal closure continues to be enforced based upon the indications that periodic discharges of untreated boat waste occur within the Pond. It should be noted that while this is a public health issue, the associated nutrients in the waste are not likely to represent an important nitrogen source to the Pond.





Water quality

Oxygen concentrations, water clarity, temperature, and salinity have been monitored on Cuttyhunk at the Fish Dock and on Penikese at the Stone Pier since the inception of the Baywatchers Program. More detailed nutrient monitoring has not been conducted. Oxygen concentrations on both islands are among the best in the Bay with values ranging from 85% - 105%. These values likely represent the natural variation in oxygen levels under low nutrient conditions and the level of sampling and analytical “error” of the methodology used in the monitoring program. The water clarity and oxygen values would yield full scores on the Embayment Health Index.

Management Needs

Cuttyhunk Pond–a remote, relatively unimpacted salt pond–and Penikese Harbor–an open, extremely well flushed area indicative more of open Buzzards Bay conditions–are both good “control sites” for the Baywatchers program. For this reason, we will continue to collect basic water quality information on both islands. The remoteness of the islands makes collection of time and temperature sensitive nutrient samples difficult. However, we will be able to collect periodic nutrient samples from these Island sites in the coming years. These data will represent reference sites for any larger scale changes within the Bay which are not directly linked to specific watershed shifts.

The limited data on water quality and the land-use and mooring information does not support nitrogen management recommendations at this time for either Island. However, the issue of bacterial contamination represents an area of potential concern, if summer shellfish harvest and swimming are important issues to the citizens of the Town of Gosnold. Remediation of bacterial contamination within the Pond will likely require enforcement of no-discharge regulations and pump-out facilities.

Glossary

Acid Rain: Precipitation that has a low pH (pH 5.6 is normal for natural precipitation); the precipitation becomes acidic when moisture in the air reacts with sulfur and nitrogen compounds, many of which are derived from burning of fuels. It is estimated that up to 20% of Buzzards Bay's total nitrogen load is delivered through acid rain. (Howes, 1996).

Anoxic (or anoxia): The condition that results when all of the oxygen within a volume of water is consumed, most commonly found in the water directly above the bottom sediments of a bay. Anoxic water quality conditions are common causes of fish kills and shellfish mortality.

Algal bloom: An event resulting from excessive nutrient levels or hydrologic conditions that enable algae to reproduce rapidly, often during warm weather. The level of algae which constitute a bloom is somewhat subjective, but levels of chlorophyll a above 10 ug/L approach bloom conditions.

Anadromous fish: Fish that live in the sea but enter fresh water rivers and streams to spawn (such as herring and shad).

Anthropogenic: Relating to mankind. Anthropogenic impacts to water quality are those produced by human activities, such as wastewater from septic systems and treatment plant discharges, road and agricultural runoff, and acid rain.

Aquifer: An underground geological formation that can hold, and provide, large quantities of water, often classified as confined or unconfined. Drinking water wells draw aquifer water. A sole source aquifer, like Cape Cod, derives all of its new water from rainfall (single source).

Bacteria: Microscopic one-celled organisms that are primarily responsible for the decay of organic matter and regeneration of nutrients within estuaries. Bacteria may live with oxygen (aerobic) or without oxygen (anaerobic). It is the decomposing of organic matter in water and sediment which creates much of the oxygen consumption within aquatic systems.

Bathymetry: Measure of the depth of water throughout a bay. Important in determining the total volume of water in an embayment, which is critical to N modeling and flushing analysis.

Benthic: Bottom dwelling and refers to organisms that live in, crawl upon, or attach themselves to the bottom (substrate).

Best Management Practices (BMP's): Structural, nonstructural and managerial methods that represent the most effective and practical means to control sources of pollutants. BMP's provide sustainable methods for productive use of the resource to which they are applied, both in urban and agricultural areas.

Buffer Strips: Strips of natural vegetation that separate a waterway (embayment, stream, pond) from a developed land-use area (e.g. subdivision, farm, etc.) ; also referred to as filter strips, vegetated strips, and grass buffers. The concept is to reduce the transport of contaminants from the watershed into receiving waters.

Build-out Analysis: A method for estimating future land-use, population and nutrient loads within watersheds, based upon the total number of existing and developable lots, under current zoning and other land use regulations.

CCMP: Comprehensive Conservation and Management Plan. Developed for Buzzards Bay by the Buzzards Bay Project National Estuary Program under EPA and MA Coastal Zone Management support, the Plan provides a guide for the management primarily of Buzzards Bay's embayments. The CBB Monitoring Program is providing the site specific information for specific management options.

Chlorination: The most common method of disinfecting water (either drinking or wastewater) to protect public health. When used for secondarily treated wastewater effluent, small amounts of chlorinated organic compounds can result which can affect animals within the receiving aquatic systems.

Chlorophyll a: The major photosynthetic pigment in plants and most phytoplankton which makes green plants green. The amount of chlorophyll a measured within embayment waters is related to the amount of phytoplankton (biomass). Chlorophyll a rapidly degrades to pheophytin a when phytoplankton die or are eaten.

Combined Sewer Overflows (CSO): That portion of a community's sewer system which carries both sewage and stormwaters (rain runoff from roads, parking areas etc.). Generally the sewage receives treatment before discharge. However, during high stormwater flows the capacity of the Treatment Facility can be exceeded, resulting in discharge of untreated wastewater. Separation of sewage and stormwater flows after CSO's have been installed is a very costly and difficult process. New Bedford is the only Buzzards Bay municipality with CSO discharges.

Denitrification: The conversion of nitrate, a plant available form of nitrogen, to gaseous nitrogen, the predominant atmospheric gas. The process occurs naturally by bacteria generally in soils and sediments, and is incorporated into wastewater treatment to produce Tertiary Level Effluent.

Dissolved Oxygen: The concentration of the life sustaining respiratory gas, oxygen, in water. The concentration in embayment waters is controlled by: temperature, salinity of the water, the amount of input from photosynthesis, uptake in respiration, and decay of organic matter.

Drowned River Estuary: An estuary which has been formed by the flooding of an eroded river valley by rising relative sea-level. These systems typically have rivers or streams at their headwaters. Many of the estuaries within Buzzards Bay are of this type.

Ecosystem: An group of organisms (animals and plants) that exist in the same natural community within an identifiable physical and hydrologic region. The system is spatially and functionally identifiable through the interactions between its biota and physical environment. Examples are salt marshes, forests, bays.

Eelgrass *(Zostera marina)*: A marine flowering plant that grows subtidally in sand and mud. In Buzzards Bay, eelgrass is widespread and grows to depths of up to 20 feet in clear waters. Eelgrass beds are an important habitat and nursery for fish, shellfish, and waterfowl and are particularly sensitive to increases in nitrogen loading to estuaries.

Embayment: A small bay which empties into a larger bay or any small semi-enclosed coastal water body whose opening to a larger body of water is restricted. In Buzzards Bay there are over 30 major embayments in the form of harbors, coves, coastal lagoons or salt ponds, and tidal regions of rivers.

Estuary: A semi-enclosed body of water having a free connection with the open ocean and within which seawater is measurably diluted with fresh water. The most common type regionally is associated with coastal discharges of rivers and streams. All of the embayments to Buzzards Bay are estuaries.

Eutrophication (coastal): The process of ecosystem change accompanying nutrient enrichment in aquatic systems. In Buzzards Bay, eutrophication results principally from nitrogen inputs from human activities such as sewage disposal and fertilizer use. The addition of nitrogen to coastal waters stimulates algal blooms and subsequent decay by bacteria, and can cause broad shifts in ecological communities including at higher levels anoxic events and fish kills. In freshwater systems and in parts of estuaries below 5 ppt salinity, phosphorous is likely to be the limiting nutrient and the cause of eutrophic effects.

Fecal Coliform (FC): Bacteria that are present in the intestines and feces of warm-blooded animals and that are often used as indicators of bacteria and viruses harmful to human health associated with untreated wastewater. Unfortunately, Fecal Coliform are frequently related to animal sources, rather than wastewater discharges. FC levels are expressed as the number of bacteria per 100 milliliters of the sample, higher numbers indicating the potential for greater health risks. This indicator is used by the Massachusetts Division of Marine Fisheries in determining shellfish bed classification and local Boards of Health for managing swimming at beaches.

Flushing Time: The mean length of time for a pollutant entering a water body to be carried to the adjacent Bay tides and currents; related terms are residence time and turnover time (which have important technical distinctions in their definitions).

Ground Water: Water from the water-saturated zone beneath the land surface, i.e. in the ground. The soil or other geologic material which supports the volume of groundwater is called an aquifer.

Hypoxic (or hypoxia): A condition in which the level of dissolved oxygen in water is low, generally less than 4 mg/L, but not zero (which is anoxic). Excessive nitrogen inputs to embayments can result in periodic conditions of hypoxia. Hypoxic conditions cause stress to marine plants and animals.

Leachate: Water containing dissolved substances that move downward through some specified material, such as landfill leachate, or subsurface drainage from a landfill. The term generally relates to dissolved substances which would not normally be found within the water or found at much lower concentrations, such as nutrients and man-made organic compounds.

Light penetration: The depth to which sunlight reaches within bay waters. Commonly measured using a Secchi Disk, a white and black disk lowered into the watercolumn until there is insufficient light to see it with the eye.

Loading (Nutrient Loading): The quantity or mass amount (lbs.) of a substance entering an ecosystem or environment in a defined period of time (year, month etc.). For example, nitrogen loading to a harbor.

National Estuary Program: A U.S. Environmental Protection Agency program established under Section 320 of the Clean Water Act to designate estuaries of national significance and to incorporate scientific research into planning activities through grants to states. Buzzards Bay was designated an Estuary of National Significance in 1985 and the Buzzards Bay Project, Buzzards Bay Action Committee and Coalition for Buzzards Bay were all formed around this Program.

Nitrogen: See page 15 under nutrients for explanation of – nitrate, nitrite, DIN (Dissolved Inorganic Nitrogen), DON (Dissolved Organic Nitrogen), PON (Particulate Organic Nitrogen).

Nitrogen Management Plan: A science based approach for managing the health of coastal waters. The plan is based upon a quantitative determination of the current and future nitrogen loading from the watershed to a bay, and the level of nitrogen input which the receiving bay can tolerate without significant degradation. The Plan includes actions within both watershed and receiving waters.

Nutrients: Chemical elements or substances essential for plant and animal growth. Those required in large amounts are termed "macro-nutrients" (e.g. nitrogen and phosphorus) and in small amounts, "micro-nutrients" (e.g. some metals, vitamins)

Nutrient Related Water Quality: That portion of the ecological health of a system which is controlled by the level of nutrients. The health of almost all of the embayments to Buzzards Bay is controlled primarily by the level of nitrogen input. Water quality is merely a gauge of the health of the entire complex of animal and plant communities which reside in the embayments.

Organic Matter (or organic materials): Substances that contain carbon, as well as other elements. Plants are a primary form of organic material. Secondary forms include human and animal excrement. Organic matter is broken down by bacteria which consumes watercolumn oxygen and releases nutrients for re-use by plants.

Pollutant: Any substance of such character or in such quantities that upon reaching the environment (soil, water or air) impairs the environment's usefulness or renders it offensive. Man-made contaminants such as PCB's are pollutants, as are naturally occurring compounds such as nitrate when they occur at high levels.

Phytoplankton: Microscopic algae which are suspended in the water column and transported by currents. They contain pigments for photosynthesis known as chlorophylls, which make eutrophic waters look green or brown. Phytoplankton form the basis of most marine and coastal food chains. They are consumed by zooplankton, shellfish, and various fish (e.g. herring).

Polychlorinated Biphenyls (PCB): A class of chlorinated organic compounds (two fused benzene rings and two or more chlorine atoms) used in heat exchange, insulating fluids and other applications. There are 209 different PCBs with varying levels of toxicity. New Bedford Harbor is undergoing a major PCB cleanup under the US EPA Superfund Program. PCBs and other toxic contaminants tend to be localized within the Bay and therefore are not monitored as part of the Water Quality Monitoring Program, which is bay-wide.

Sediments: The mud or sand deposits which form the bottom of Buzzards Bay and its embayments. These bottom sediments form the home for animals (benthic animals) such as shellfish. Analysis of sediments can sometimes yield insight into a system's health.

Standard Error (SE): A Measure of the variability of the data used to produce the average value.

Stratification: The layering effect that results from the waters of an embayment not being fully mixed from surface to bottom by wind or tidal action.

Ulva: A green sheet-like seaweed commonly called "sea lettuce", which can grow quite large (1 square foot sheets) and form dense accumulations in nutrient enriched areas. Enteromorpha is another green algae that typically grow in long, thin green tubes. Both are found in pristine and eutrophic areas.

Watercolumn: The waters within an embayment, generally indicating bay waters from surface to bottom.

Watershed: The land surrounding a body of water which contributes freshwater, either from streams, groundwater or surface water runoff, to that body of water. It is through these freshwater inflows that nutrients and contaminants enter Buzzards Bay.

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