Report of the Buzzards Bay Citizens' Water Quality Monitoring Program 1992-1995

REPORT DESIGN BY:

Eileen Gunn

Coalition Water Monitoring Program Coordinator

WRITTEN BY:

Dr. Joseph E. Costa

Dr. Brian L. Howes

Eileen Gunn

Fall 1996

JOINTLY SPONSORED BY:

the **Coalition for Buzzards Bay**

and the **Buzzards Bay Project**

With special thanks to all of the volunteers who have made this program possible.

Adelstein, Joseph
Allen, Ben
Anderson, Tanya
Appleton, Charlie
Aubut, Leslie
Austin, Barbara
Baker, Debra
Bancroft, William
Bansbach, Paul
Barao, Kevin
Barley, Dennis
Barrett, Dave
Beede, Russ
Benson, Andrea
Berger, Alice
Best, Dave
Best, Fred
Bigelow, Hawley
Blair, Wendy,
Blanchard, Tim
Bonnar, Dr. James
Bourque, Brad
Brackett, Sheila
Brogioli, Kevin
Brokaw, Tina
Buchan, Ray
Burr, Chauncey
Burr, Toby
Cafarella, Mark
Cameron, David
Canning, Peter
Canning, Galen
Cardoza, Amy
Cardoza, Michael
Clark, Eileen
Comeau, Pat
Connolly, John
Connors, Terry
Cookingham, Russell
Czyryca, Michael
Dabney, L.S.
D'Angona, Stacey
Darwin, John
Dautel, Canby
Day, Stephen
DeBaun, Clifford
Dermody, Margaret
Dexter, Owen
Doherty. Mary
Dyer, Don
Edgcomb, Bob
Edgcomb, Ginny
Eisen, Terry
Farina, Muriel
Farinon, Laurell
Fassett, Rosemary
Fassett, Stephen
Faxon, Bill
Fisher, Lorraine
Fleer, Karen
Fontaine, Molly
Ford, Isabel
Ford, John
Ford, Rodney
Fors, Steve
Frazer, Robert
Freeman, Edmund
Frohman, Sandra
Gammans, Jim
Garfield, Seth
Gauvin, Julie
Gauvin, Zack
Geagan, Barbara
Geagan, Laura
Gillespie, Gay
Giroux, Donna
Glenn, Bob
Green, Laura
Halpin, Anne
Hamel, Nicole
Hammond, David
Harvey, Lois
Hathaway, Priscilla
Hauser, John/Jessica
Henshaw, John
Herlihy, Andy
Herring, Tom
Hickey, Jim
Hickey, Katherine
Hill, John
Hiller, Joyce
Hurley, Steve
Jackson, Sarah
Jansen, Trintje
Keeler, Janet
Keene, Andrea
Kiebala, Betsy
Kilberg, Chris
Kilpatrick, Alan
Kney, Arthur
Knowlton, Richard
Koenitzer, Barbara
Koenitzer, George
Kunz, Randall
Latimer, Mary
Lisle, Kay
Lisle, Peter
Littlejohn, Thomas
Lizotte, Mike
Lodge, Dick
Longworth, William
Luttrell, Dennis
MacLean, Fran
MacLeod, Wilfred
MacNary, Julie
Manning, Dick
Mark, David
Massi, Marylyn
Maxwell, Sue
McCarter, Peg
McDonald, Peter
McGrath, Susan
McMichael, Erin
McSweeney, Bryan
Mears, Donald
Medeiros, John
Megowen, Peg
Minshew, Page
Minton, Duane
Mitchell, K.W.
Moran, Karla
Morris, Dee
Morrison, Sally
Morway, Family
Moss, Barbara
Moura, Ron
Mulvey, Brian
Mulvey, James
Munroe, Robert
Myers, Don
Myers, Penny
Myers, Walter
Neagley, Jesse
Neary, Steve
Ohnemus, William
Oliveira, Art
Peterson, Ed
Pidgeon, Cheryl
Pietraszek, Barry
Polloni, Pamela
Pratt, Ted
Prentice, Ben
Prentice, Charissa
Prince, Dick
Prince, Flo
Rapoza, Paul
Rapoza, Robert
Rasmussen, Mark
Reed, Brian
Reed, Kenneth
Richard, Raymond L.
Ripley, Carol
Rockwell, John
Rockwell, Annie
Ryder, Frank
Sands, Deb
Savery, Cindy
Schenck, MaryLou
Schenck, Jim
Schneider, Bennett
Shearer, Deborah
Simmons, James
Smart, John
Soares, Scott
Squire, Cabot
Starr, Barry
Staude, Charles
Stegeman, Sam
Steinke, Andrew
Stetson, Thomas
Suddard, Benjamin
Sylvia, Joanne
Sylvia, Tim
Szatkowski, Jim
Thomas, Dale
Thompson, Priscilla
Thompson, Ted
Turner, April
Turner, Wayne
Tyson, Alan
Veazie, Cynthia
Vogel, Jim
Warncke, Tracy
Warr, David
Warr, Skip
Wheeler, Peter
White, Norma
Wickenden, Richard
Willa, Dan
Williams, Bob
Wilson, Dorothy
Wolf, Ann
Worthington, Georgina
Zeimetz, Ester

We would also like to thank...

the Lloyd Center and the Westport River Watershed Alliance for their volunteer support; Jim Mulvey for his invaluable carpentry skills in building and maintaining our equipment; and all of the property owners that have allowed us access to the water.

Table of Contents

The Buzzards Bay Citizens' Water Quality Monitoring Program was initiated in 1992 to document and evaluate nitrogen-related water quality and long-term ecological trends in Buzzards Bay. Unlike other east coast estuaries such as Long Island Sound and Chesapeake Bay, central Buzzards Bay has fortunately not suffered from the impacts of excessive nitrogen loading. However, nitrogen inputs were identified in the Buzzards Bay Comprehensive Conservation and Management Plan (CCMP) as one of the greatest threats to the health of the Bay's more than 30 shallow, often poorly flushed, coastal embayments. Until the inception of this program, no comprehensive database existed on nutrient concentrations and the extent of eutrophication in the most sensitive areas of the Bay ecosystem.

In order to provide this critical water quality data to assist federal, state, and local environmental managers in setting priorities for management action, the Buzzards Bay Project National Estuary Program, Dr. Brian Howes of the Woods Hole Oceanographic Institution, and the Coalition for Buzzards Bay collaborated to design a citizen based monitoring program. Involving citizen volunteers was the only cost-effective way to achieve the ambitious goal of monitoring all of the Bay's important embayments from the Westport River, at the west end of the Bay, to Quissett Harbor on Cape Cod. Such a program would have the dual benefit of collecting comprehensive water quality data while educating and empowering people to get involved and make a difference in the sound management and restoration of the Bay's resources.

With funding and technical assistance from the Buzzards Bay Project, the Coalition for Buzzards Bay has recruited over eighty core volunteers throughout the Bay watershed and coordinated four seasons of data collection and analysis. This report presents the results of the first four years of water quality monitoring along with recommendations for action based on these findings and nitrogen loading evaluations conducted by the Buzzards Bay Project. The partners involved in this monitoring program are hopeful that the results presented here - as well as future data from this ongoing monitoring effort - become the foundation for both management and remedial action to protect and restore water quality in Buzzards Bay.

Continued Next Page...

The Buzzards Bay Project

The Buzzards Bay Project National estuary Program is a unit of the Massachusetts Office of Coastal Zone Management and part of the US Environmental Protection Agency's National Estuary Program. Created in 1985, the Buzzards Bay Project completed a Comprehensive Conservation and Management Plan (CCMP) for the Bay in 1991. This plan is a blueprint for the protection and restoration of water quality and living resources in the Bay and its watershed. Today, the Buzzards Bay Project provides funding and technical assistance to municipalities and citizens to implement the recommended actions contained in the CCMP. Funding for the Citizens Water Quality Monitoring Program was provided by the US EPA through the Buzzards Bay Project.

The Coalition for Buzzards Bay

The Coalition for Buzzards Bay is a non profit citizens advocacy and education organization formed in 1987. The Coalition is membership supported by approximately 2,500 individuals, businesses, and organizations. The group is most widely known for its coordination of the Citizens Water Quality Monitoring Program, educational efforts in the City of New Bedford, and an annual "Report Card" on the environmental record of Bay watershed municipalities.

What we measure and why

Oxygen is the life blood of the oceans and is vital to the proper functioning of marine plants and animals. Nutrients are also a critical and necessary part of the marine ecosystem. Unlike oxygen however, excess quantities of nutrients in marine ecosystems can adversely affect water quality and habitat, and ultimately impact a wide range of marine organisms including fish and shellfish populations. The principle sources of nitrogen inputs to coastal waters are septic systems, wastewater treatment plant discharges, fertilizers, storm water runoff, and acid rain. Similar to over fertilizing your garden, in marine ecosystems nutrient loading stimulates the growth of algae. Too much algae blocks sunlight to eelgrass, shading out this valuable nursery habitat and feeding ground. Living and dying algae consume oxygen, leading to anoxic (no oxygen) or hypoxic (little oxygen) conditions. In addition to habitat loss, this process of water quality decline, known as coastal eutrophication, can lead to bad odors and even fish kills. This relationship between oxygen and nutrients is the basis for our monitoring program.

Volunteers measure early morning oxygen (between 6 AM - 9 AM), temperature, salinity, and water clarity (secchi disk) on a set schedule once a week from May to September. These are referred to as our basic parameters. The basic parameters give us an immediate snapshot of the health of the bay and are an excellent first warning system. From these measurements volunteers can determine, on the spot, the percentage of oxygen saturation in the water and determine where additional monitoring is required. A value of oxygen below 40% is low and indicates that animals may be already stressed by low oxygen in parts of the bay.

Besides monitoring oxygen, citizens collect water samples for nutrient and chlorophyll analysis. These samples are collected from the inner to the outer

Oxygen Saturation: In our monitoring program citizen volunteers measure oxygen concentrations with water chemistry kits and record the data in parts per million (ppm). They also measure salinity and temperature. These two measurements not only help us understand patterns of circulation and freshwater inputs, but by knowing salinity and temperature, we can convert oxygen measurements into percent saturation. Percent saturation of oxygen is more meaningful than concentration, because cold water holds more oxygen than warm water and fresh water holds more oxygen than salt water. The percent saturation gives us a good understanding about how much oxygen is consumed by plants, algae and animals at night and how oxygen is produced by plants and algae in the daytime. Oxygen must be measured between 6 A.M. and 8:30 A.M. when levels are lowest from overnight plant and animal respiration.

Water Transparency: The citizen volunteers monitor the transparency of water using a simple device known as a secchi disk, which is a black and white circle lowered into the water to determine how clear the water is. The depth that the disk disappears from view is know as the secchi depth. Eutrophic waters can have poor transparency when there is a lot of phytoplankton, zooplankton, and sediments in the water. We record water transparency in meters. In the middle of Buzzards Bay, summertime water transparency can exceed 4 or 5 meters. In the less polluted embayments, water transparency can still be 2 or 3 meters. In eutrophic embayments, transparency can be less than a meter (you can't see your toes when your standing waist deep!).

Phytoplankton Pigments: Eutrophic waters have more phytoplankton (microscopic algae) in the water. Living and dead phytoplankton contain pigments known as chlorophylls and phaeophytons. The pigments make eutrophic waters look green or brown. We record the levels of phytoplankton pigments in parts per billion (ppb).

Dissolved Inorganic Nitrogen (DIN): Fertilizers, septic systems, and acid rain add inorganic nitrogen to coastal waters. The three forms of inorganic nitrogen are ammonia, nitrites, and nitrates. Citizens collect water samples which are brought to Dr. Howes' laboratory in Woods Hole for analysis. These forms of nitrogen are nutrients that are in short supply in coastal waters and are rapidly taken up by algae. Consequently they are in very low concentrations, and their levels are recorded in micromolar units. High DIN levels in an estuary means that you are either close to a human source of nitrogen or the estuary is highly eutrophic.

Particulate Organic Nitrogen (PON): Inorganic nitrogen is rapidly taken up by algae. Phytoplankton in turn are consumed by zooplankton and larger animals. Eutrophic systems have more phytoplankton and zooplankton in the water. In the laboratory, these represent most of the "particles" of nitrogen we measure.

Dissolved Organic Nitrogen (DON): The Woods Hole laboratory also measured dissolved organic nitrogen in samples filtered by citizen volunteers. DON 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 is measured in this analysis. If the volunteer does not do a good job filtering a sample, TON measurements will be overestimated. Eutrophic waters have higher DON than more pristine areas. DON is reported in ppm.

Total Organic Nitrogen (TON): We add the measurements of DON and PON together to get TON which represents the sum of all organic nitrogen in the water.

Total Nitrogen (TN): We add DIN + PON + DON to get Total Nitrogen. 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—wherever you are in an estuary-either near an inorganic nitrogen source or in an area where the inorganic nitrogen has been converted into living organisms through the food chain, total nitrogen will be higher in estuaries that are more eutrophic. One drawback with using total nitrogen as an indicator is that is some bays, a lot of nitrogen is taken up by algae on the bottom of a bay and not phytoplankton. Total nitrogen is reported as ppm. Values below 0.35 ppm are characteristic of unpolluted areas and offshore waters. Values above 0.60 ppm are typical in eutrophic areas.

portions of each embayment approximately four times between July and August. These samples, some of which are filtered in the field, are stored on ice and brought to the Woods Hole Oceanographic Institution for analysis of dissolved and particulate forms of nitrogen, phosphate, carbon/nitrogen ratios, phaeophyton, and chlorophyll a content. How this data is interpreted is explained below.

The Buzzards Bay Eutrophication Index

Inorganic nitrogen (ammonia, nitrates, and nitrites) is rapidly taken up by algae, and transformed into organic forms of nitrogen, (i.e. living organisms) and become part of the food chain. Thus a suite of nutrient indicators and forms of nitrogen must be measured at various locations within each embayment. Furthermore, the response of coastal ecosystems to nitrogen loading is complex and variable and depends upon secondary factors like bathymetry and flushing. Despite these obstacles, the Buzzards Bay Project recognized that just a few key water quality indicators can be monitored in a cost effective way to help characterize coastal eutrophication. ***The indicators we monitor are oxygen saturation, water transparency, phytoplankton pigments, and three forms of nitrogen: dissolved inorganic nitrogen (DIN), particulate organic nitrate (PON), and dissolved organic nitrogen (DON). We also keep track of total organic nitrogen (TON), and Total Nitrogen. This alphabet soup is explained in the table to the left.***

Because it is hard to interpret a single parameter, and because these observations relate to each other in how an embayment responds to nitrogen loading, the Buzzards Bay Project developed a simple Eutrophication Index integrating measurements of oxygen saturation, DIN, TON, water transparency, and chlorophyll pigments. The first step in calculating the Eutrophication Index was to calculate the summertime mean of each indicator. In the case of oxygen saturation values, we took the mean of the lowest 33% of all samples between June 1st and September 30th. We used the lowest 33% of oxygen saturation values because oxygen concentrations can be variable, and the mean of all saturation data may not be indicative of low oxygen conditions that may be stressing animal populations. By taking the mean of the lowest 33% of oxygen values, we get a better picture of worst case conditions in an embayment. Once the summertime means of the five parameters were calculated, the means were transformed into scores using a scale where good water quality values received higher scores (a maximum of 100 points possible), and poor water quality received lower scores (down to 0). The 100 point and zero point values were based on our experiences of what are good and bad water quality conditions. Intermediate values receive a score based on a formula. While these endpoints are subjective in some ways (see table below), it is meant to be a relative scale for Buzzards Bay.

Parameter	0 Point Value	100 Point Value
Oxygen saturation (lowest 1/3 of observ.)	40% sat.	90% sat.
Transparency (Secchi disk depth)	0.6 m	3 m
Phytoplankton pigments (chlorophyll+phaeopigments acid corrected)	10 ppb	3 ppb
Dissolved Inorganic Nitrogen (DIN)	10 micromolar (=0.14 ppm)	1 micromolar (=0.014 ppm)
Total Organic Nitrogen (dissolved+particulate)	0.60 ppm	0.28 ppm

The points for each of these five parameters were averaged to calculate the Eutrophication Index. Eutrophication Index scores for each embayment are depicted in the center fold map.

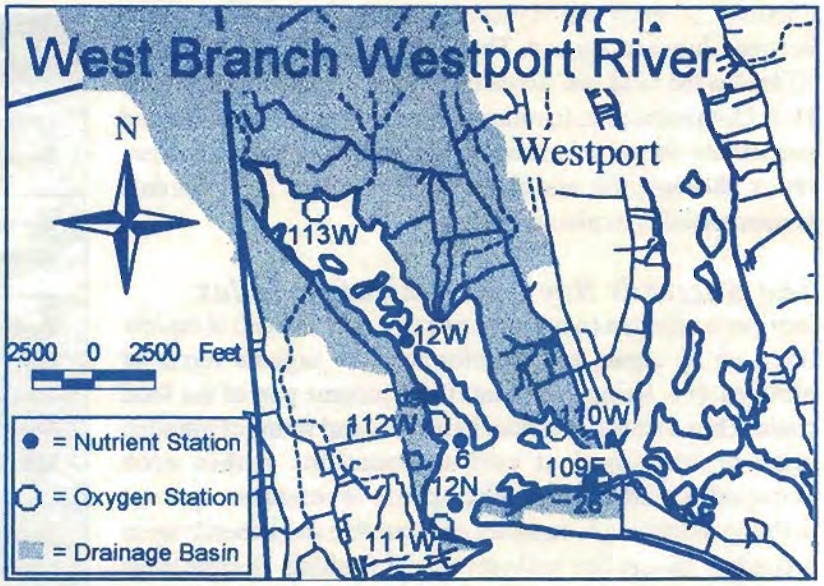
During the past four years our Eutrophication Index has evolved as we learned more about how shallow coastal embayments respond to nitrogen loading. In this report we recalculated scores for all years using the above table, which differs somewhat from previous years. Most notably, we now use only the lowest 33% of oxygen values, and as a result we changed the 100 point level to 90% saturation from the previous 100%. We also raised the low end to 40% because low oxygen conditions are occasional, even in eutrophic systems. Formerly we calculated the Eutrophication Index using only chlorophyll, we now include phaeo pigments, another important algal pigment in the water. Finally we changed the "good" and "bad" values for total organic nitrogen from previous values because we felt the new values were more reasonable for the range of organic nitrogen that we see in Buzzards Bay and to make this score more consistent with other parameters. All these changes have resulted in different scores from past reports, but the relative rankings, and the best and the worst embayments are fairly consistent.

Best sites	*Worst Sites*
• Megansett Harbor	• Eel Pond, Mattapoisett
• Quissett Harbor	• New Bedford Harbor *(Inner)*
• Clarks Cove *(Inner)*	• Slocums River
• Phinneys Harbor	• Apponagansett Bay *(Inner)*
• Mattapoisett Harbor *(Outer)*	• Westport River, East Branch *(Inner)*
• Aucoot Cove *(Outer)*	• Hammett Cove
• Red Brook Harbor	• Little River
• Onset Bay *(Outer)*	• Wareham River *(Inner)*

(Based on average available Eutophication Index Scores)

Continued on page 62

WESTPORT RIVER WEST BRANCH



Embayment and Watershed Characteristics

The West Branch of the Westport River is a broad, shallow embayment with extensive salt marsh and eelgrass beds. More acres of eelgrass have been mapped in the West Branch than any other Buzzards Bay embayment and salt marsh acreage is fourth greatest among Buzzards Bay embayments. The estuary, together with the East Branch, has some of the best shellfish resources in Buzzards Bay and historically has lead the Bay in scallop catch.

Agricultural land is the dominant land use in this watershed, and is nearly three times more extensive in area than commercial and residential lands. It is not surprising therefore that most inputs of nitrogen to the West Branch are estimated to be derived from cropland (40%). Residential and commercial land use is the second largest source (34%) followed by farm animals (13%), then other land uses. It is worth noting that farm animals (primarily dairy cows) play a more important role in fecal coliform loading and shellfish bed closures than coastal eutrophication.

Water Quality

During the past 4 years, water quality in the lower West Branch has generally been good, with Eutrophication Index scores ranging between 50 and 78. Water quality was best in 1993, the year with the most severe drought conditions, a response also seen in the East Branch. Most dramatically, total nitrogen in the water was exceptionally low that year (0.28 ppm) compared to other years (0.51-0.86 ppm). In 1992, with a summer of exceptionally heavy rains, dissolved inorganic nitrogen was highest, as might be expected from runoff of fertilizer in agricultural areas. The large increases in dissolved inorganic nitrogen in 1994 and 1995, however, are more enigmatic. Phytoplankton pigment concentrations are quite low in the West Branch, and only in 1995 did they increase, in this case by nearly 30%. This increase in phytoplankton is seen also in particulate nitrogen levels in 1994 and 1995. While increases in phytoplankton often results in increased dissolved organic nitrogen, at levels of 5 ppb, it seems unlikely that increased phytoplankton are elevating dissolved organic nitrogen in the water to the degree observed. Other possible explanations for the big increase in dissolved organic nitrogen include increase use of urea, manure, or other organic fertilizers in this watershed, or analytical error. Analytical error seems unlikely because both inner and outer West Branch showed elevated dissolved organic nitrogen in 1995, whereas the East Branch did not have the same increase in dissolved organic nitrogen.

As might be expected from the foregoing results, Eutrophication Index scores were worst in 1994 and 1995. These score reductions were driven not only by increases in dissolved organic nitrogen but by drops in dissolved oxygen as well. The drop in dissolved oxygen is illustrated by station 112W, Carey's Boat Yard. During 1992, oxygen never dropped below 70% saturation, and in 1993, oxygen concentrations were never observed below 85%. In contrast, in 1994 and 1995, dissolved oxygen dropped below 70% saturation on 4 dates and 3 dates respectively with a low value below 30% in 1995. Monitoring in 1994 and 1995 also showed big jumps in organic nitrogen in the water, also helping lower the eutrophication scores for those years. The lowering of oxygen could also affect the regeneration of nutrients from bottom sediments and could be a factor in the elevated organic nitrogen concentrations.

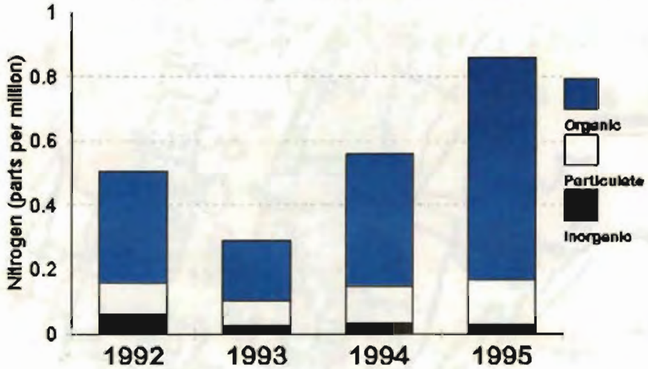
Station 12W, the northernmost regularly monitored nutrient station, exhibited worse water quality in 1992—a year of exceptionally heavy rainfall— than the more southerly stations 9 and 6. During dry years, this distinction was less apparent. These findings suggest that the runoff of nutrients may be an important factor affecting water quality in the upper West Branch.

One difficulty in evaluating the West Branch is that because of unavailable land access, the upper reaches of the estuary were not monitored in the Program. The stations more southerly of 12W reflect "dilution" with cleaner offshore waters, hence, stations 12W, 9 and 6 were classified as "outer embayment", and we have no summer data for "inner" West Branch. Thus, water quality of the estuary as a whole appears better than would be predicted by the theoretical loading

Continued on page 62

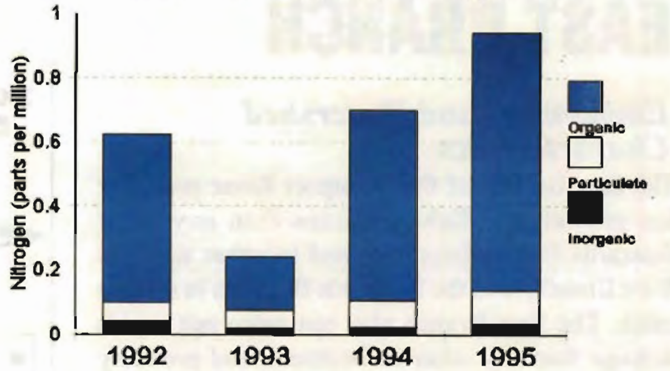
Westport River, West Branch (Outer)

Total Water Column Nitrogen



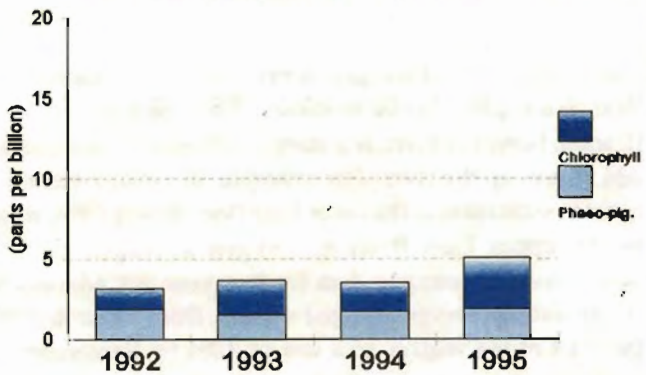
Westport River, West Branch (Mouth)

Total Water Column Nitrogen



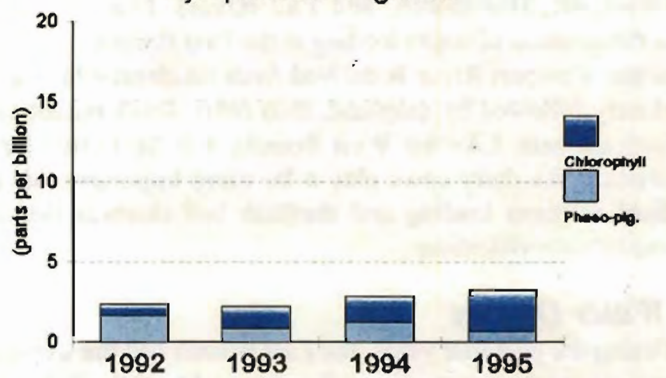
Westport River, West Branch (Outer)

Phytoplankton Pigment

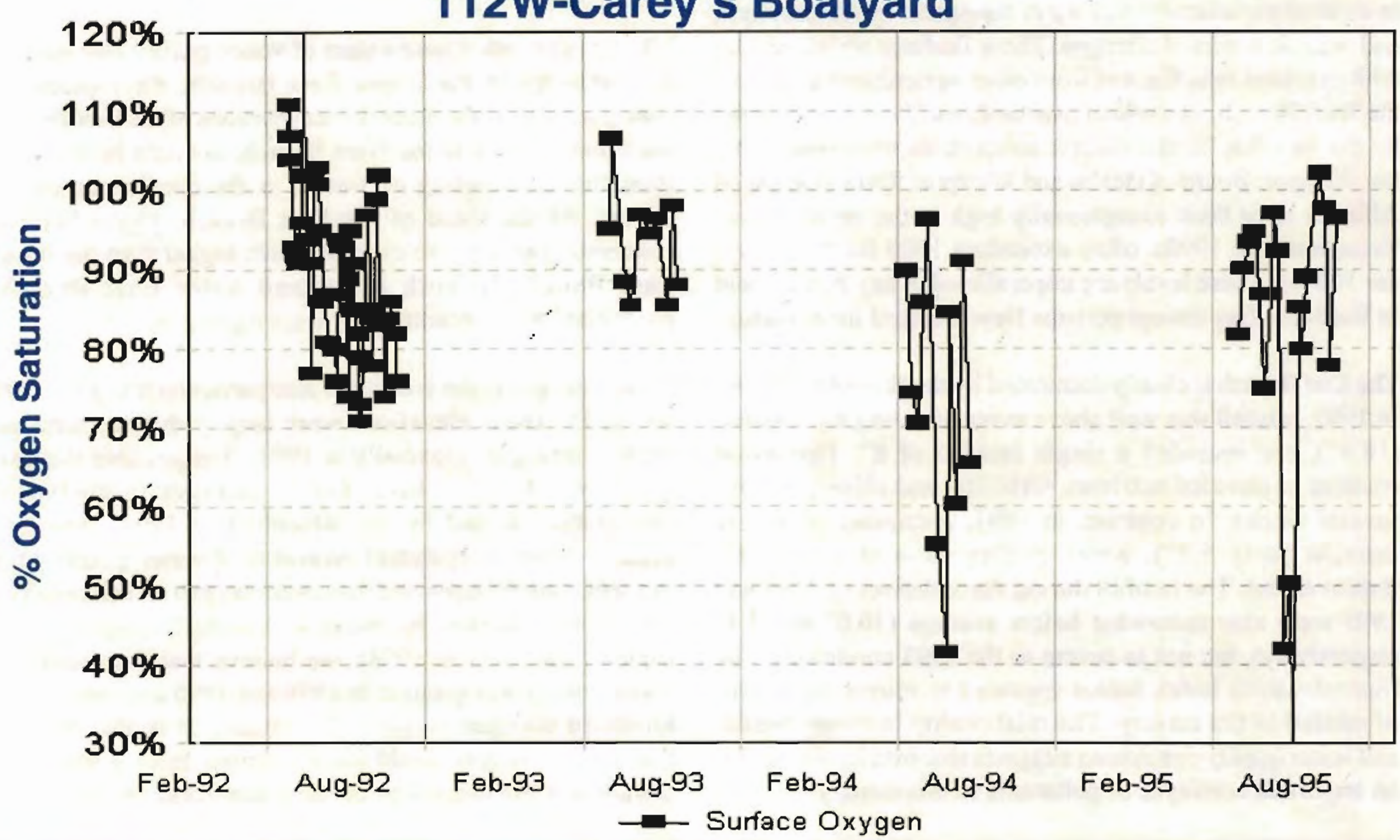


Westport River, West Branch (Mouth)

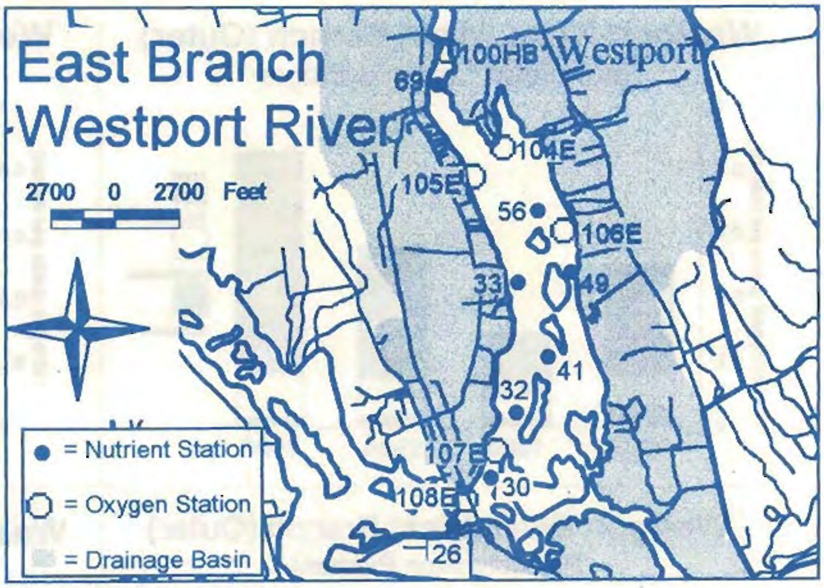
Phytoplankton Pigment



112W-Carey's Boatyard



WESTPORT RIVER EAST BRANCH



Embayment and Watershed Characteristics

The East Branch of the Westport River probably has greater shellfish resources than any other Buzzards Bay embayment, and together with the West Branch, lead the Buzzards Bay area in scallop catch. The East Branch also has more salt marsh acreage than any other embayment, and probably has among the highest eelgrass bed acreage. The watershed is the second largest in Buzzards Bay and principally lies in three municipalities (Westport, Dartmouth, and Fall River). Most anthropogenic nitrogen loading to the East Branch of the Westport River is derived from residential land use, closely followed by cropland, then other development and farm animals. Like the West Branch, it is likely that farm animals like dairy cows play a far more important role in fecal coliform loading and shellfish bed closures than in coastal eutrophication.

Water Quality

During the past four years, the East Branch had the worst or was among the worst in overall water quality of the Buzzards Bay embayments monitored. Generally the lowest scores of individual parameters were water transparency, chlorophyll, and organic forms of nitrogen. These findings are consistent with overland runoff noted from other agricultural areas like the West Branch. The role of overland runoff is also suggested by the fact that fecal coliform concentrations measured by the Westport Board of Health and Westport River Watershed Alliance have been exceptionally high in the central River throughout the 1990s, often exceeding 1000 fecal coliform per 100 ml. These levels are unparalleled in any embayment in Buzzards Bay except perhaps New Bedford inner harbor.

The East Branch is clearly dominated by the flow of the River. In 1992, rainfall was well above average during the summer (18.9"), and included a single rainfall of 8". This event resulted in elevated nutrients, turbidity, and chlorophyll for several weeks. In contrast, in 1993, a summer of severe drought (only 5.7"), water quality showed a dramatic improvement. The rainfall during the summers of 1994 and 1995 were also somewhat below average (10.0" and 8.4" respectively), but not as severe as the 1993 conditions. The Eutrophication Index scores appeared to mirror the degree of rainfall in the estuary. The relationship between rainfall and water quality conditions suggests that overland runoff is an important conveyor of pollutants to this estuary.

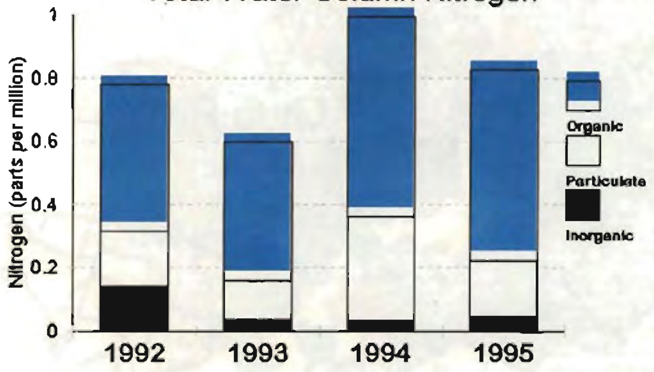
The lowest 33% of oxygen concentrations in the outer East Branch are quite similar to values observed in the outer West Branch, however there is a steep gradient in water quality as one moves up the river. For example, in 1994, mean oxygen percent saturation in the outer East Branch was 74%, whereas in the upper East Branch, oxygen averaged only 60% saturation. The oxygen data for that year at Cadmans Neck is interesting. Oxygen ranged widely, from close to 100% at the start of the season, to a low of 40% by September. This pattern was repeated at Cadmans Neck, but somewhat less dramatically in 1992.

Like oxygen, other parameters of water quality also decline dramatically in the upper East Branch. Phytoplankton concentrations in the outer (lower) portions of the East Branch were quite similar to the West Branch, as might be expected from the co-mingling of waters in the confluence of the Rivers. At the Head of the East Branch, phytoplankton concentrations are two to three times higher than the lower East Banch. In both inner and outer East Branch, phytoplankton concentrations were highest in 1994.

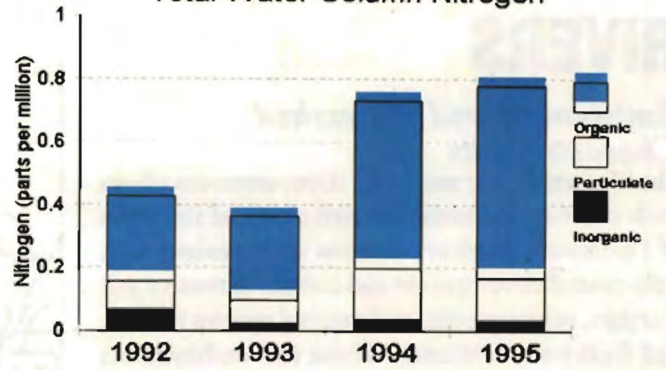
Total Nitrogen in the water was also particularly high in 1994 and 1995. These elevations were largely due to increased organic nitrogen, especially in 1994. It is possible that this increase may have been due to changes in analytical procedures adopted by our laboratory in 1994. However, because other independent measures of water quality such as particulate nitrogen and dissolved oxygen and chlorophyll also showed marked increases (chlorophyll concentrations tripled from 1993 to 1994), we believe that the decline in water quality was genuine in 1994 and 1995 and may reflect increased nitrogen inputs to the estuary. It is also possible that these changes could have resulted from a bloom of plankton in the estuary or because rainstorms more closely

Continued on page 63

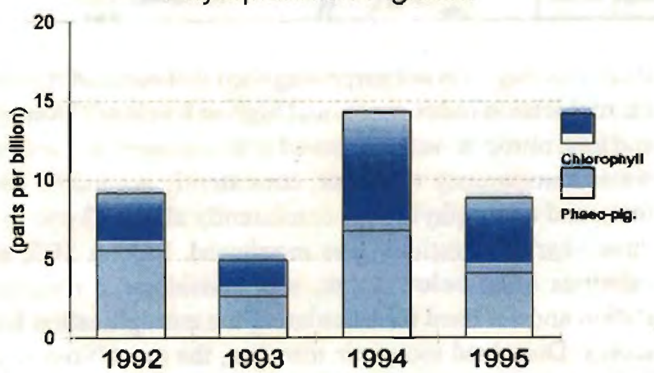
Westport River, East Branch (Inner)
Total Water Column Nitrogen



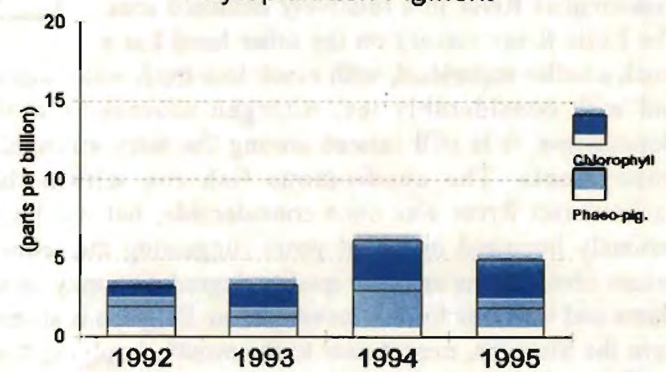
Westport River, East Branch (Outer)
Total Water Column Nitrogen



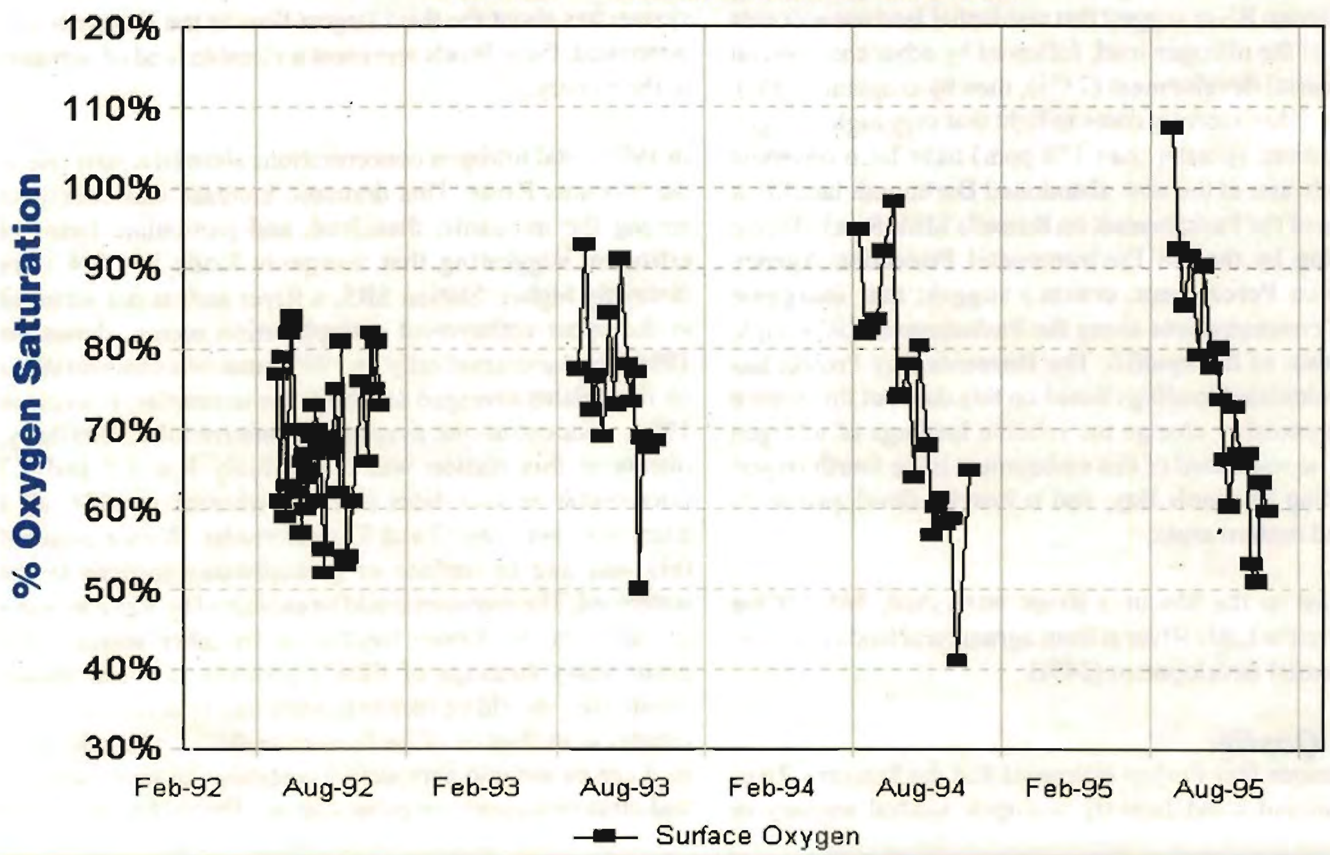
Westport River, East Branch (Inner)
Phytoplankton Pigment



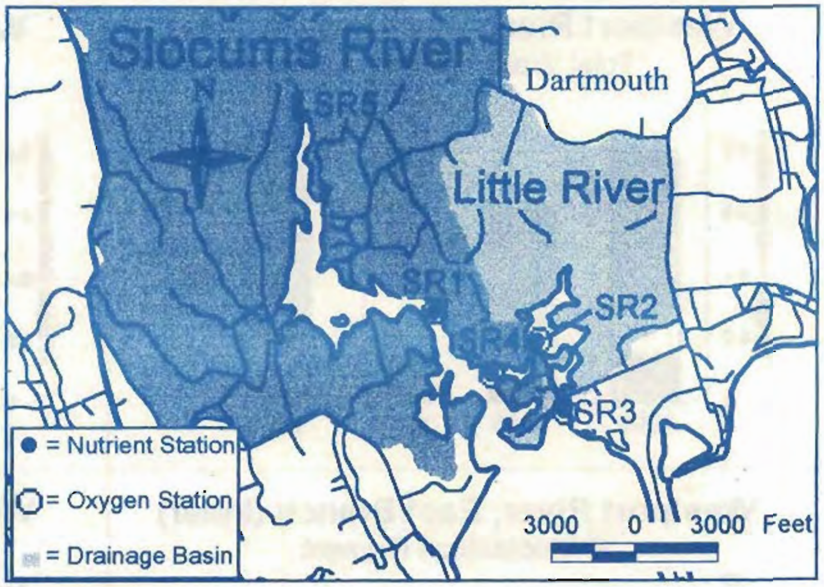
Westport River, East Branch (Outer)
Phytoplankton Pigment



104E – Cadman's Neck



SLOCUMS & LITTLE RIVERS



Embayment and Watershed Characteristics

The Slocums River and Little River estuaries adjoin each other on the southwestern shore of the town of Dartmouth. Both are shallow embayments with little coastal development and contain extensive salt marshes, eelgrass beds, endangered species habitat, and freshwater wetlands. These two embayments also have some stark differences. The Slocums River estuary has a large watershed with many sources of nitrogen, with sizeable flows from the Paskamanset River in a relatively confined area. The Little River estuary on the other hand has a much smaller watershed, with much less fresh water input, and with considerably less nitrogen sources as well. Nonetheless, it is still ranked among the most eutrophic embayments. The anadromous fish run within the Paskamanset River was once considerable, but has been seriously impaired in recent years suggesting that either stream obstructions or water quality degradation may be to blame and warrants further investigation. Eelgrass is absent from the Slocums, except near to the mouth, implying that conditions are eutrophic.

Earlier Buzzards Bay Project estimates of nitrogen loading to the Slocums River suggest that residential land use accounts for 50% of the nitrogen load, followed by other commercial and industrial development (24%), then by cropland (14%). However, it has recently come to light that very high nitrogen concentrations (greater than 140 ppm) have been observed in groundwater at the now abandoned Dartmouth landfill at the banks of the Paskamanset on Russells Mills Road. Recent monitoring by the US Environmental Protection Agency (EPA; Ken Perez, pers. comm.) suggest that inorganic nitrogen concentrations along the Paskamanset River triple downstream of the landfill. The Buzzards Bay Project has not yet calculated loadings based on this data but this source could appreciably change the relative loadings of nitrogen inputs. The watershed of this embayment is the fourth largest surrounding Buzzards Bay, and is heavily developed in its upper and eastern areas.

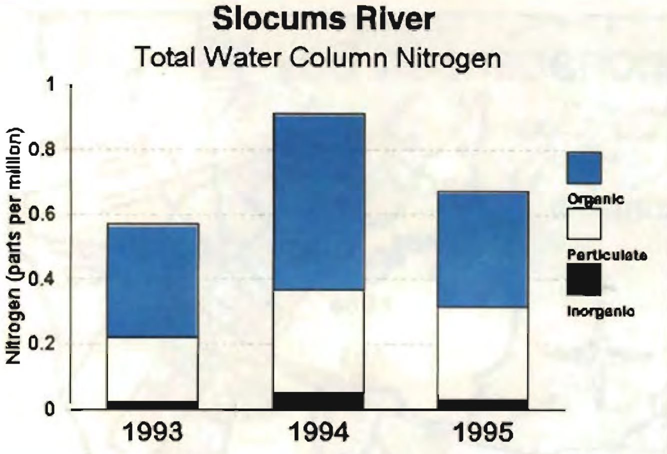
In contrast to the Slocums River watershed, 54% of the loadings to the Little River is from agricultural lands followed by residential development (24%).

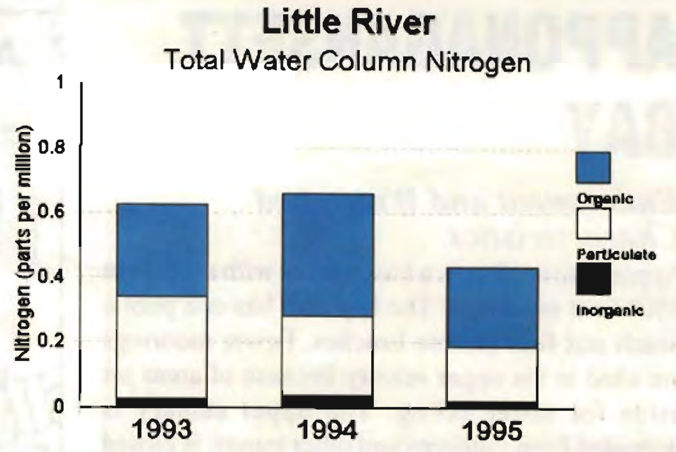
Water Quality

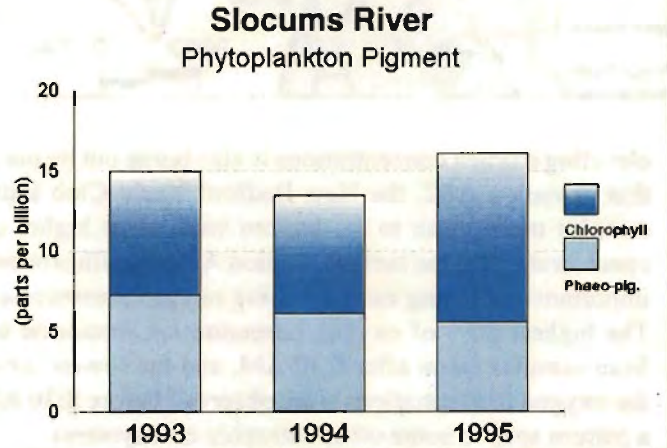
The Buzzards Bay Project estimated that the Slocums River is the second most heavily nitrogen loaded estuary in Buzzards Bay. It is not surprising then that some of the worst Eutrophication Index scores and highest levels of chlorophyll and total nitrogen were measured in this estuary. In particular, water transparency was poor, consistently around 60 cm (2 feet), and chlorophyll were consistently above 13 ppb in the three years this estuary was monitored. Station SR5, with salinities often below 5 ppt, was considered a river head station and not used for calculating the eutrophication index scores. Dissolved inorganic nitrogen, the most bioavailable form of nitrogen, was often between 15 and 40 µM (0.2-0.6 ppm) at this station, considerably higher than many Buzzards Bay streams. Because the Slocums/Paskamansett River system has about the third largest flow in the Buzzards Bay watershed, these levels represent a sizeable load of nutrients to the estuary.

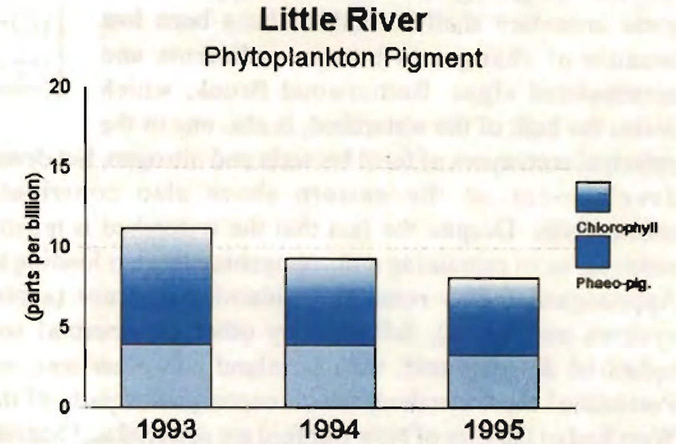
In 1994, total nitrogen concentrations showed a 30% rise in the Slocums River. This dramatic increase was consistent among the inorganic, dissolved, and particulate forms of nitrogen, suggesting that inorganic loads in 1994 were distinctly higher. Station SR5, a River station not included in the upper embayment eutrophication scores, shows the 1994 increase dramatically. In 1993, ammonia concentrations on three dates averaged around 0.8 micromolar, whereas in 1994, concentrations averaged 5 micromolar. Similarly, nitrate at this station was a relatively low 1.5 and 1.7 micromolar on two dates in 1993, whereas in 1994, all 4 dates were between 17 and 37 micromolar. We are unsure if this was due to surface or groundwater sources in the watershed. The increases could be explained by a groundwater plume from the former landfill, or by other sources. The preliminary findings of EPA's groundwater and stream monitoring should be carefully reviewed to determine if the relative contribution of the former landfill can be calculated so it can be put into perspective compared to septic systems and other non-point and point sources. Depending upon how

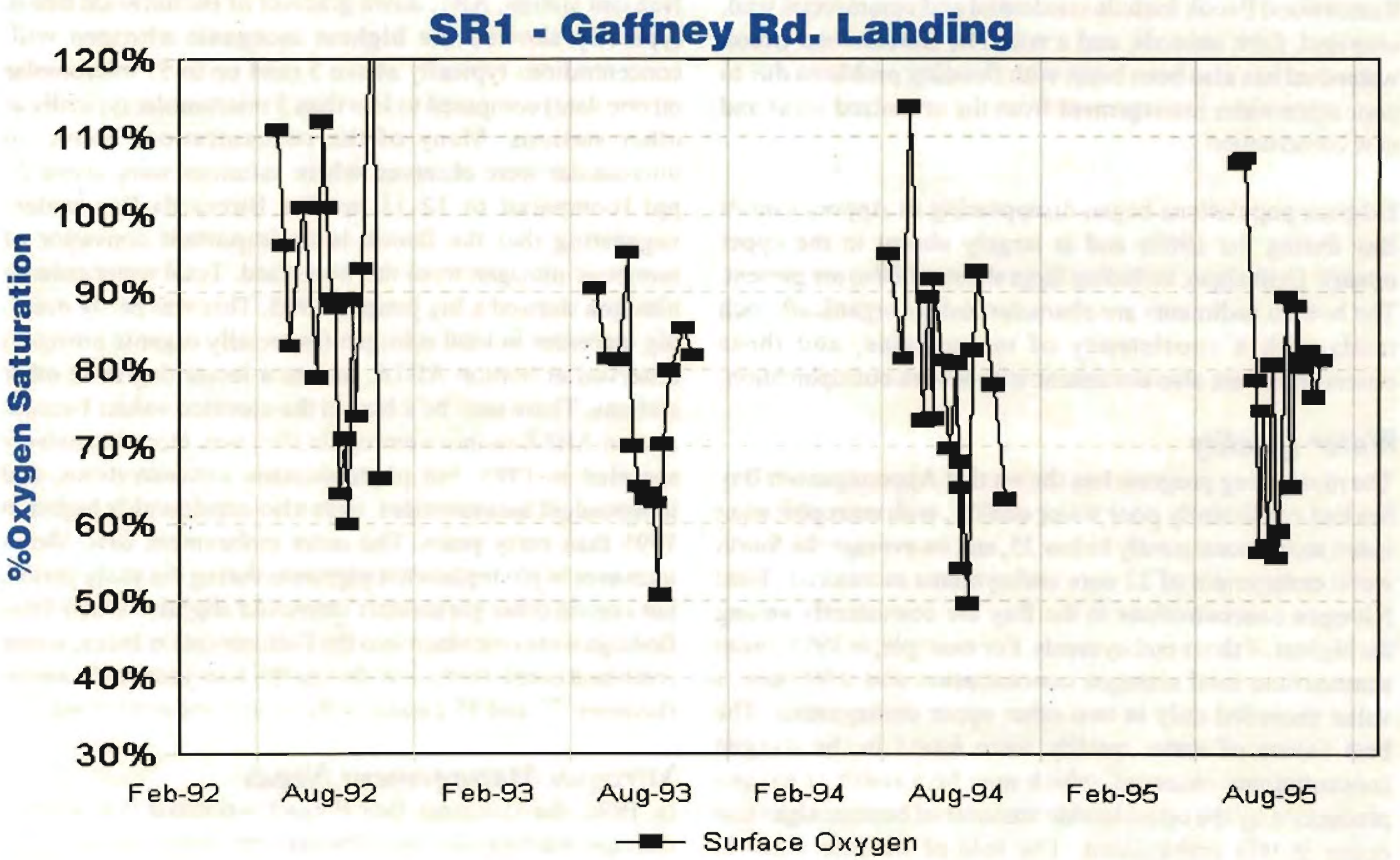
Continued on page 63


Slocums River
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1993
1994
1995
Organic
Particulate
Inorganic

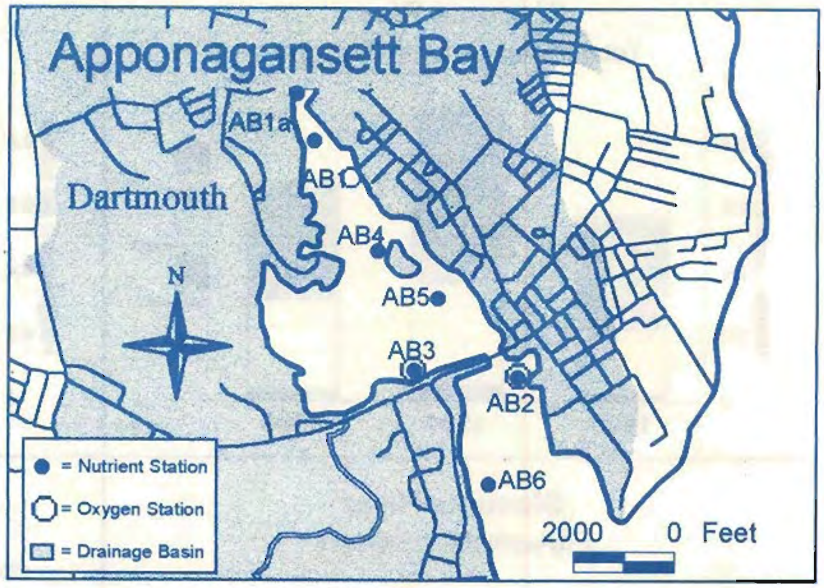

Little River
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1993
1994
1995
Organic
Particulate
Inorganic


Slocums River
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1993
1994
1995
Chlorophyll
Phaeo-pig.


Little River
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1993
1994
1995
Chlorophyll
Phaeo-pig.


SR1 - Gaffney Rd. Landing
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
Feb-92
Aug-92
Feb-93
Aug-93
Feb-94
Aug-94
Feb-95
Aug-95
Surface Oxygen

APPONAGANSETT BAY



Embayment and Watershed Characteristics

Apponagansett Bay is a busy harbor with more than 3000 boat moorings. The bay also has one public beach and four private beaches. Fewer moorings are sited in the upper estuary because of areas set aside for water skiing. The upper estuary is degraded from nutrients and other inputs, is closed to shellfishing, eelgrass beds have disappeared and some important shellfish habitat have been lost because of changes in bottom sediments and accumulated algae. Buttonwood Brook, which drains the bulk of the watershed, is also one of the principal conveyors of fecal bacteria and nitrogen, but dense development on the eastern shore also contribute substantially. Despite the fact that the watershed is mostly sewered, most remaining anthropogenic nitrogen loading to Apponagansett Bay remains residential land use (septic systems and lawns), followed by other commercial and industrial development, then farmland and other sources. Portions of the watershed, which encompasses parts of the West End of the City of New Bedford are sewered and heavily urbanized. The sources of nutrients and coliforms along Buttonwood Brook include residential and commercial land, cropland, farm animals, and a zoo. The Buttonwood Brook watershed has also been beset with flooding problems due to poor stormwater management from the urbanized areas and new construction.

Eelgrass populations began disappearing in Apponagansett Bay during the 1960s and is largely absent in the upper estuary. Drift algae, including large sheets of *Ulva* are present. The bottom sediments are characterized by organically rich muds with a consistency of mayonnaise, and these observations are also consistent with severe eutrophication.

Water Quality

The monitoring program has shown that Apponagansett Bay has had consistently poor water quality, with eutrophication index scores consistently below 35, and on average the fourth worst embayment of 27 core embayments monitored. Total Nitrogen concentrations in the Bay are consistently among the highest of those embayments. For example, in 1995, mean summertime total nitrogen concentration was 0.99 ppm, a value exceeded only in two other upper embayments. The best values of water quality were found in the oxygen concentrations observed, which may be a result of oxygen production by the considerable amounts of benthic algae that occur in this embayment. The role of benthic algae in elevating oxygen concentrations is also borne out by the fact that at station AB2, the New Bedford Yacht Club station, samples taken close to the bottom were often higher than concentrations at the surface. Station AB2 also illustrates the importance of taking early morning oxygen measurements. The highest 20% of oxygen concentration measured were from samples taken after 8:30 AM, and the lowest 20% of the oxygen concentrations were observed before 8:30 AM – a pattern seen in some other eutrophic embayments.

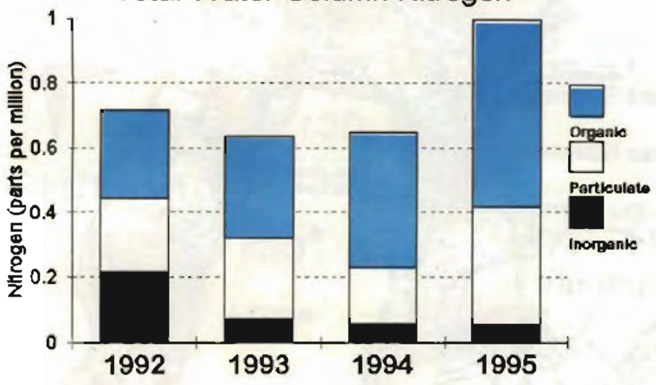
Nutrient station, AB1, down gradient of Buttonwood Brook typically showed the highest inorganic nitrogen with concentrations typically above 5 (and up to 57 micromolar on one date) compared to less than 5 micromolar typically at other stations. Many of the concentrations above 10 micromolar were observed where salinities were above 25 ppt (compared to 32-33 ppt for Buzzards Bay water) suggesting that the Brook is an important conveyor of inorganic nitrogen from the watershed. Total water column nitrogen showed a big jump in 1995. This was partly due to big increases in total nitrogen (especially organic nitrogen) observed at Station AB1A, and to a lesser degree at other stations. There may be a bias in the elevated values because station AB1A (a more eutrophic site) was more intensively sampled in 1995, but phytoplankton concentrations, and independent measurement, were also considerably higher in 1995 than early years. The outer embayment data, shows increases in phytoplankton pigments during the study period, but certain other parameters improved slightly. When these findings were combined into the Eutrophication Index, scores remained consistently low during the four year study period (between 27 and 35 points) without any apparent trend.

Nitrogen Management Needs

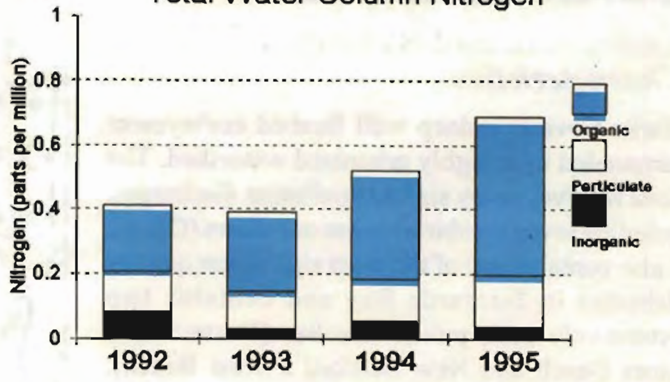
In 1994, the Buzzards Bay Project estimated that existing nitrogen loadings are only 8% over recommended nitrogen

Continued on page 64

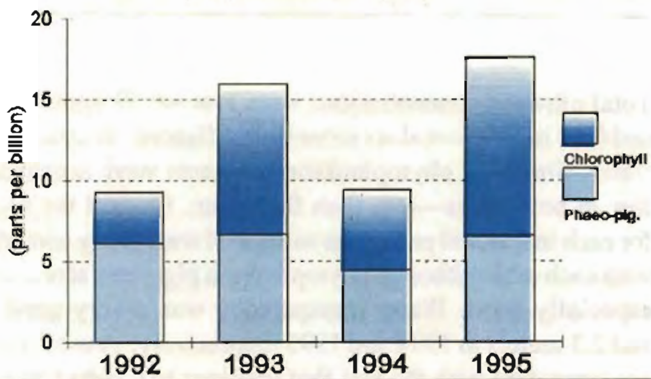
Apponagansett Bay (Inner)
Total Water Column Nitrogen



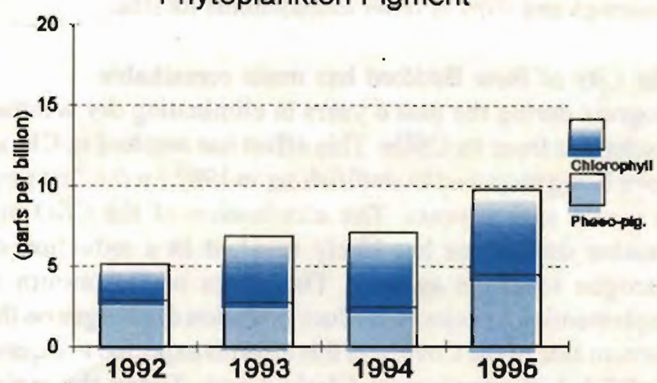
Apponagansett Bay (Outer)
Total Water Column Nitrogen



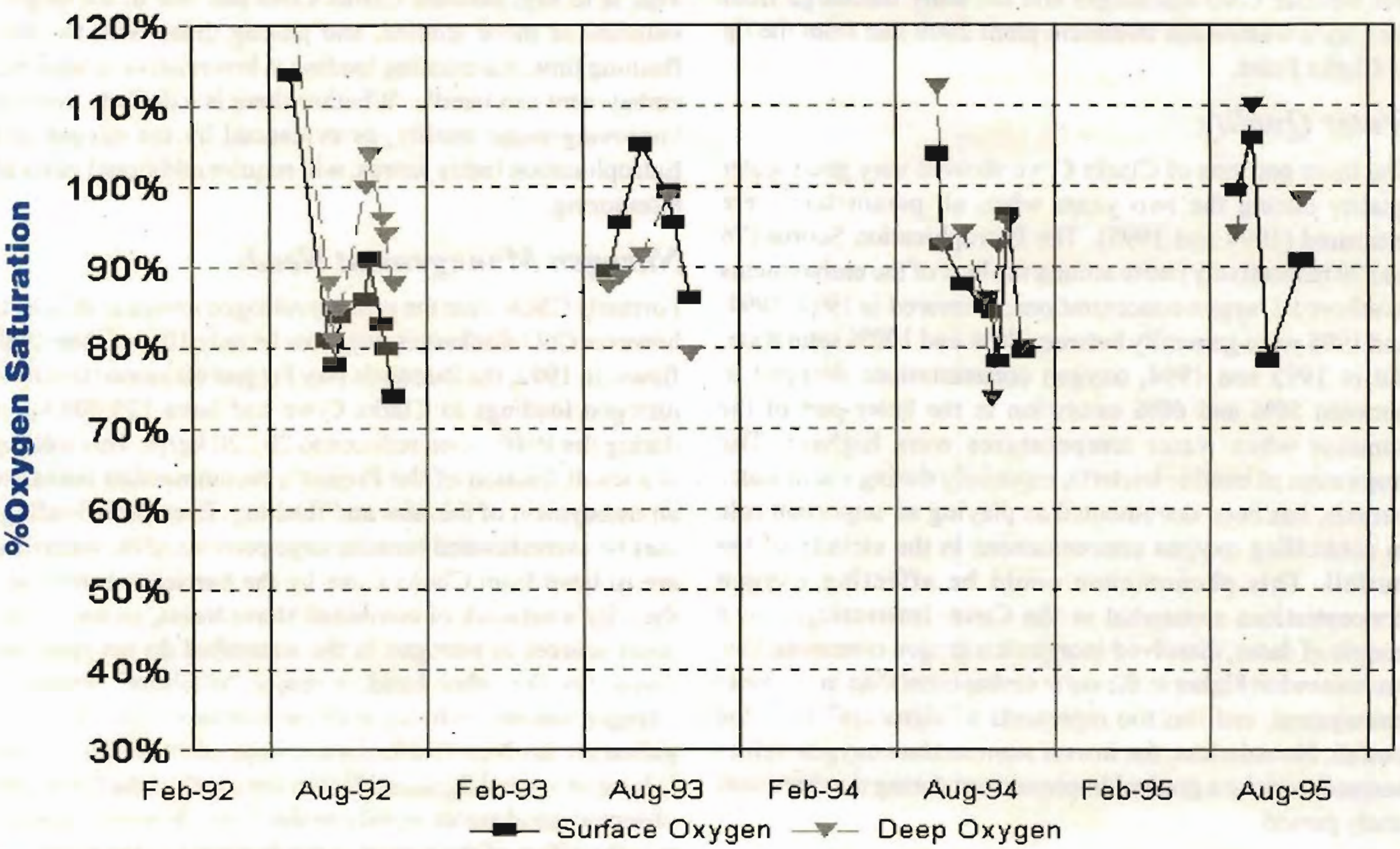
Apponagansett Bay (Inner)
Phytoplankton Pigment



Apponagansett Bay (Outer)
Phytoplankton Pigment

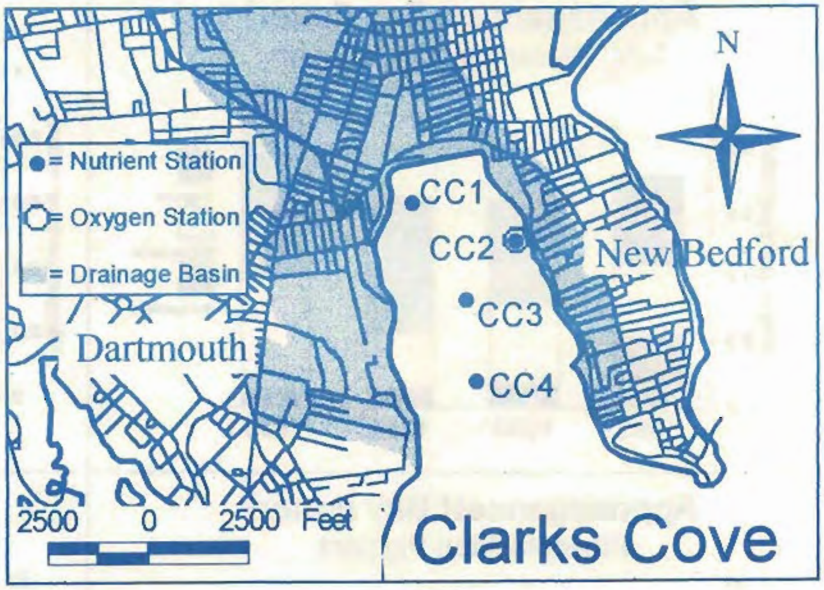


AB3 - Town Landing



CLARKS COVE

Embayment and Watershed Characteristics



Clarks Cove is a deep well flushed embayment surrounded by a highly urbanized watershed. The Cove receives many sizeable pollution discharges, including seven combined sewer overflows (CSOs). It also contains one of the most significant quahog fisheries in Buzzards Bay and contains two extensively used public beaches (Dartmouth's Jones Beach and New Bedford's West Beach). Because Clarks Cove is somewhat exposed, and part of the embayment waterfront is obstructed by the hurricane barrier, it does not contain as many moorings and slips as other embayments its size.

The City of New Bedford has made remarkable progress during the past 6 years in eliminating dry weather discharges from its CSOs. This effort has resulted in Clarks Cove being reopened to shellfishing in 1992 for the first time in nearly eighty years. The elimination of the CSO dry weather discharges has likely resulted in a reduction of nitrogen loadings as well. The Town of Dartmouth is implementing a project to reduce pollution discharges on the western side of the Cove, and this effort is expected to expand shellfish bed openings in Clarks Cove. Today the major nitrogen sources that affect water quality in the cove are the wet weather CSO discharges and the daily discharge from the City's wastewater treatment plant 2000 feet from the tip of Clarks Point.

Water Quality

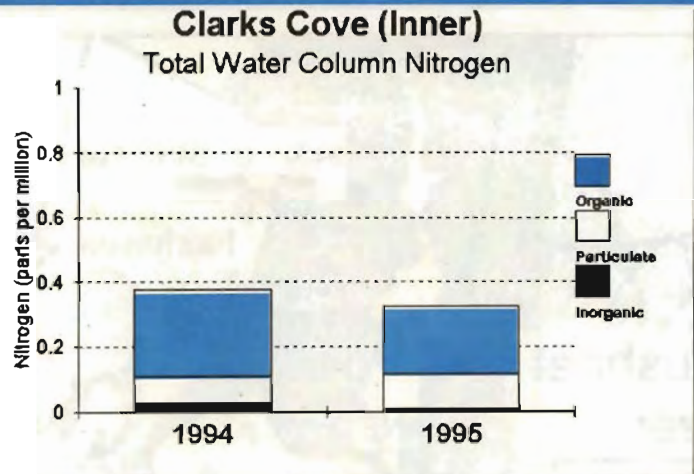
The inner portions of Clarks Cove showed very good water quality during the two years when all parameters were measured (1994 and 1995). The Eutrophication Scores (76 and 90 respectively) were among the best of the embayments monitored. Oxygen concentrations, measured in 1993, 1994, and 1995 were generally between 80% and 100% saturation, but in 1993 and 1994, oxygen concentrations dropped to between 50% and 60% saturation in the latter part of the summer when water temperatures were highest. The respiration of benthic bacteria, especially during warm water periods, has been documented as playing an important role in controlling oxygen concentrations in the vicinity of the outfall. This phenomenon could be affecting oxygen concentrations somewhat in the Cove. Interestingly on a couple of dates, dissolved inorganic nitrogen concentrations are somewhat higher in the outer embayment than in the inner embayment, and this too represents a "signature" from the outfall. Nonetheless, the lowest summertime oxygen values seemed to make a gradual improvement during the three year study period.

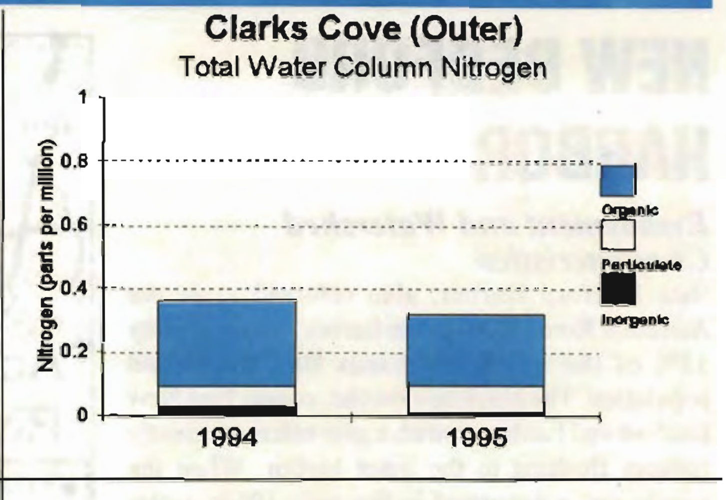
Total nitrogen concentrations were low—0.33 ppm in 1994 and 0.38 in 1995—values more like "offshore" Buzzards Bay water. Similarly phytoplankton pigments were remarkably low in both years—less than 0.38 ppm. Overall the scores for each individual parameter measured were fairly consistent with each other although phytoplankton pigments scores were especially good. Water transparency was a very good 2.2 and 2.3 meters in 1994 and 1995 respectively. These 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 low relative to what the embayment can handle. Whether there is a definite trend in improving water quality, as evidenced by the oxygen and Eutrophication Index scores, will require additional years of monitoring.

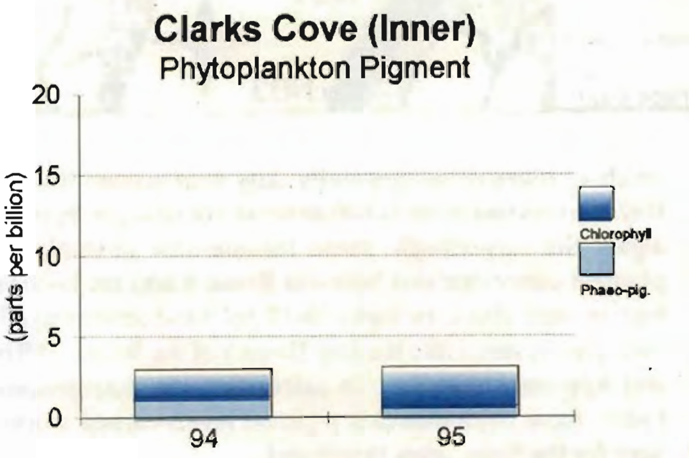
Nitrogen Management Needs

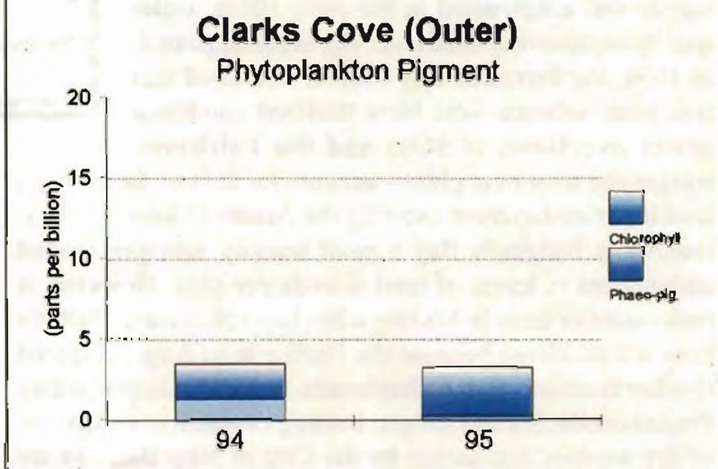
Formerly CSOs were the primary nitrogen source to the Cove, however CSO discharges may now be only 10% of their 1980 flows. In 1992, the Buzzards Bay Project estimated that total nitrogen loadings to Clarks Cove had been 125,000 kg/yr during the 1980s, then reduced to 20,720 kg/yr. This loading is a small fraction of the Project's recommended limits for an embayment of this size and flushing. Even these loadings may be overestimated because large portions of the watershed are isolated from Clarks Cove by the hurricane barrier and the City's network of combined stormdrains, so some non-point sources of nitrogen in the watershed do not reach the Cove. On the other hand, a major "offshore" source of nitrogen was not included in this assessment—the 24 million gallon per day New Bedford wastewater plant outfall—which is located several thousand feet to the south of the Cove. The observed good water quality in the Cove, however, suggest that the effect of the outfall is not focussed in the Cove.

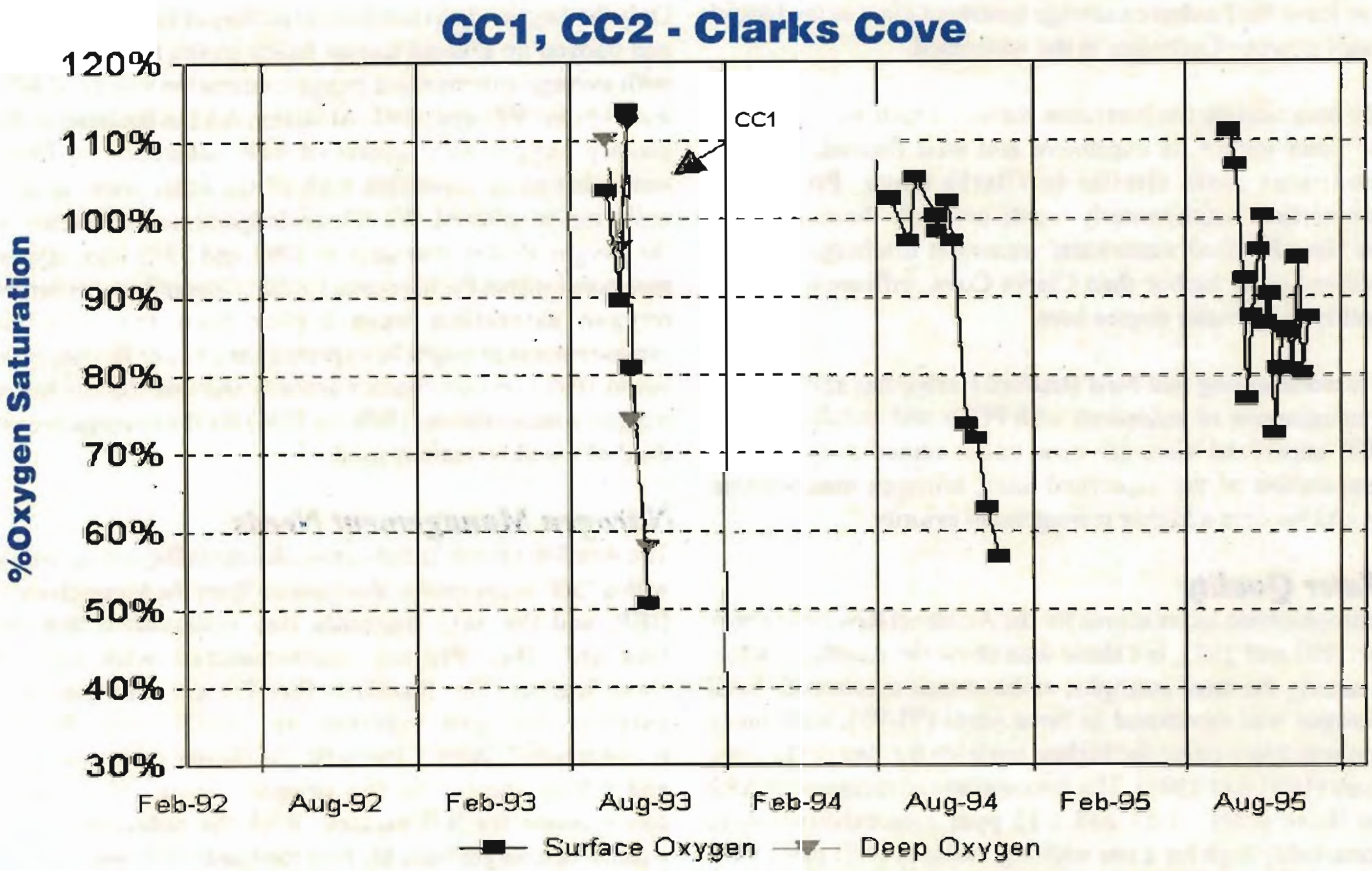
Continued on page 17


Clarks Cove (Inner)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1994
1995
Organic
Particulate
Inorganic

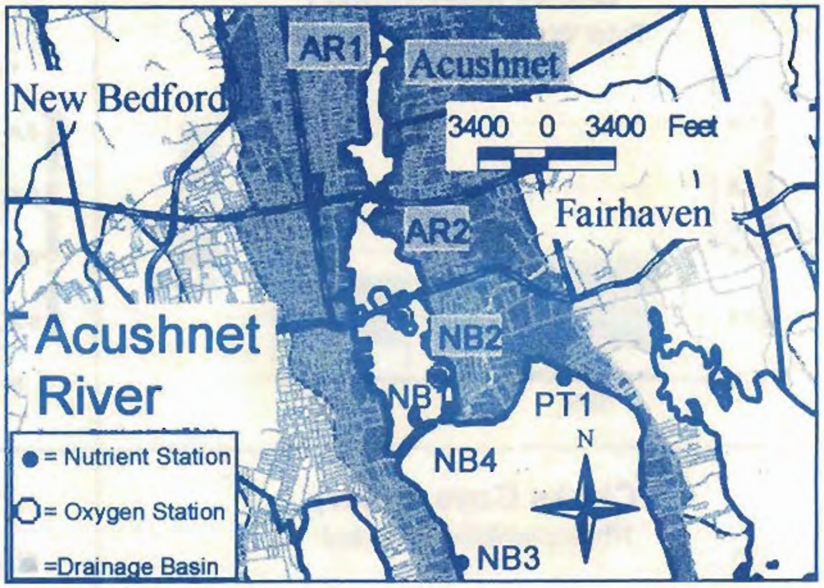

Clarks Cove (Outer)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1994
1995
Organic
Particulate
Inorganic


Clarks Cove (Inner)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
94
95
Chlorophyll
Phaeo-pig.


Clarks Cove (Outer)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
94
95
Chlorophyll
Phaeo-pig.


CC1, CC2 - Clarks Cove
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
CC1
Feb-92
Aug-92
Feb-93
Aug-93
Feb-94
Aug-94
Feb-95
Aug-95
Surface Oxygen
Deep Oxygen

NEW BEDFORD HARBOR



Embayment and Watershed Characteristics

New Bedford Harbor, also referred to as the Acushnet River, is an urban harbor surrounded by 35% of the entire Buzzards Bay watershed population. The hurricane barrier, connecting New Bedford and Fairhaven with a gate entrance, greatly reduces flushing to the inner harbor. When the barrier was constructed in the early 1960s, water quality became degraded and eelgrass disappeared. In 1994, the Buzzards Bay Project estimated that two point sources—the New Bedford combined sewer overflows (CSOs) and the Fairhaven wastewater treatment plant—account for 86% of the nitrogen load to the embayment entering the Acushnet River estuary, making it Buzzards Bay's most heavily nitrogen loaded embayment in terms of total pounds per year. However, it ranks number three in loading when bay volume and flushing time is considered because the Harbor is so deep compared to other Buzzards Bay embayments. Since the Buzzards Bay Project conducted its nitrogen loading evaluation, reductions of dry weather discharges by the City of New Bedford are resulting in lower N-loadings to the estuary and probably now leave the Fairhaven sewage treatment plant as the largest single source of nitrogen in the watershed.

The area outside the hurricane barrier, which we refer to as the outer harbor, is expansive and well flushed, and has conditions more similar to Clarks Cove. Prevailing summertime southwesterly winds probably direct more of the New Bedford wastewater treatment discharge to New Bedford outer harbor than Clarks Cove, influencing water quality to a greater degree here.

It is worth noting that New Bedford Harbor has severe toxic contamination of sediments with PCBs and metals, and the PCB superfund sites are now under remediation. After remediation of the superfund sites, nitrogen management should become a higher management priority.

Water Quality

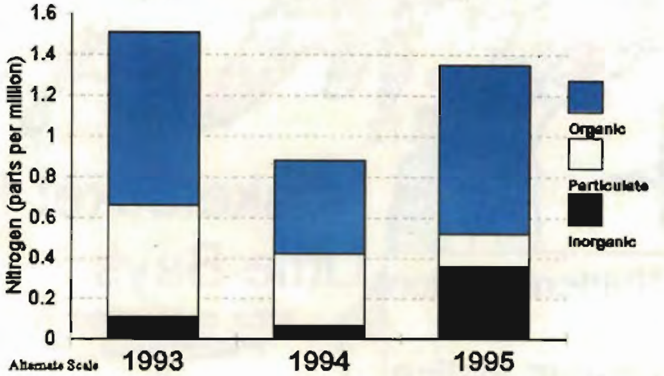
Eutrophication Index scores for the Acushnet River exist only for 1993 and 1995, but these data show the Acushnet River is among the most eutrophic embayments monitored. Total nitrogen was monitored in three years (93-95), with mean concentrations being the highest baywide for two of the three years (1993 and 1995). The concentrations recorded at AR2 for those years—1.51 and 1.35 ppm respectively—were remarkably high for a site with high salinity (>31 ppt). Such levels of nitrogen are generally only seen around Buzzards Bay in rivers and streams before uptake of nitrogen by marine algae. Not surprisingly, mean summertime phytoplankton pigment concentrations between Route 6 and the hurricane barrier were also very high (10-18 ppb) and similar to other eutrophic systems like the East Branch of the Westport River and Apponagansett Bay. In calculating the Eutrophication Index, these phytoplankton pigment levels earned scores of zero for the three years monitored.

Only the oxygen data (not shown) portrayed better conditions and buoyed up Eutrophication Index scores for the Harbor, with average summertime oxygen saturation values of 84% and 70% in 1993 and 1994. At station AR1 at the head of the estuary oxygen only averaged 44% saturation in 1992, somewhat more consistent with all the other water quality indicators monitored. We acknowledge some weaknesses in the oxygen data in that only in 1993 and 1995 was oxygen monitored within the hurricane barrier. Generally outer harbor oxygen saturation were higher than inner harbor measurements as might be expected for a better flushed area, but in 1993, the outer harbor actually showed slightly lower oxygen concentrations (84% vs 72%) for the average lowest third of the observations used.

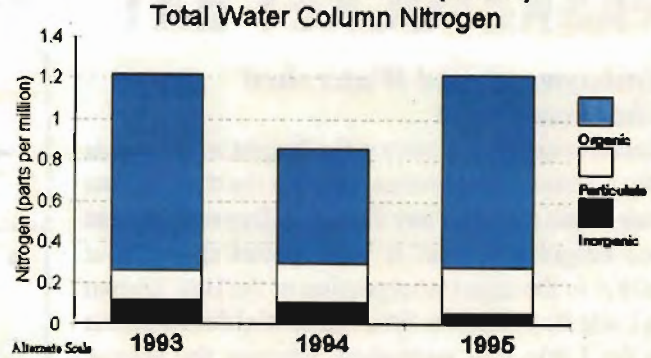
Nitrogen Management Needs

The Acushnet River is one of two Buzzards Bay embayments with a "SB" water quality designation from the Massachusetts DEP, and the only Buzzards Bay embayment that the Buzzards Bay Project recommended with the SB classification. The Buzzards Bay Project estimated that existing nitrogen loadings are 100% over Project recommended limits. Clearly the Fairhaven Treatment Plant and CSOs should be the primary focus of nitrogen management for this estuary. With the reduction of dry weather discharges from the New Bedford CSO, new nitrogen

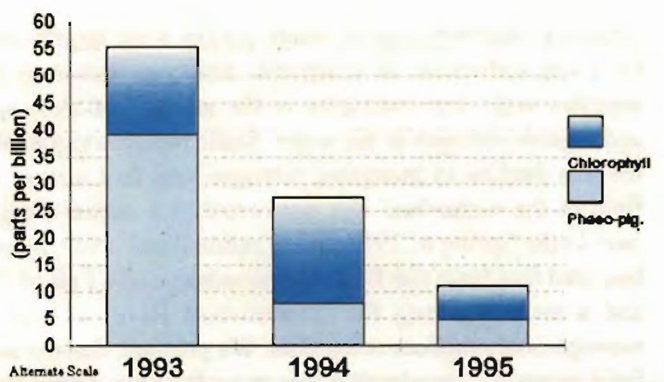
New Bedford Harbor, AR2
Total Water Column Nitrogen



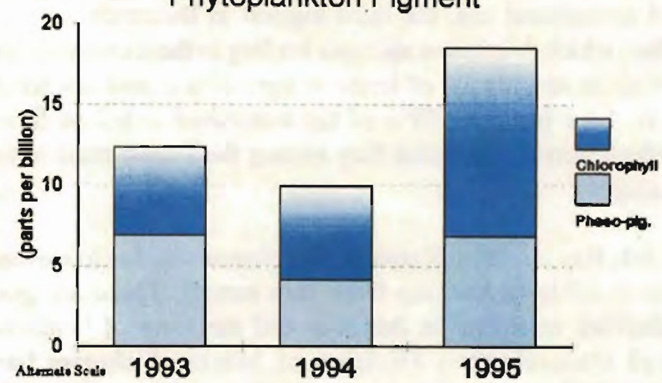
New Bedford Harbor (Inner)
Total Water Column Nitrogen



New Bedford Harbor, AR2
Phytoplankton Pigment



New Bedford Harbor (Inner)
Phytoplankton Pigment



estimates need to be developed for this source. Because the Fairhaven Treatment plant now appears to be the largest nitrogen source to the estuary, improvements in the nitrogen removal efficiency of the plant should be a priority.

◆◆◆◆◆

...Continued from page 14

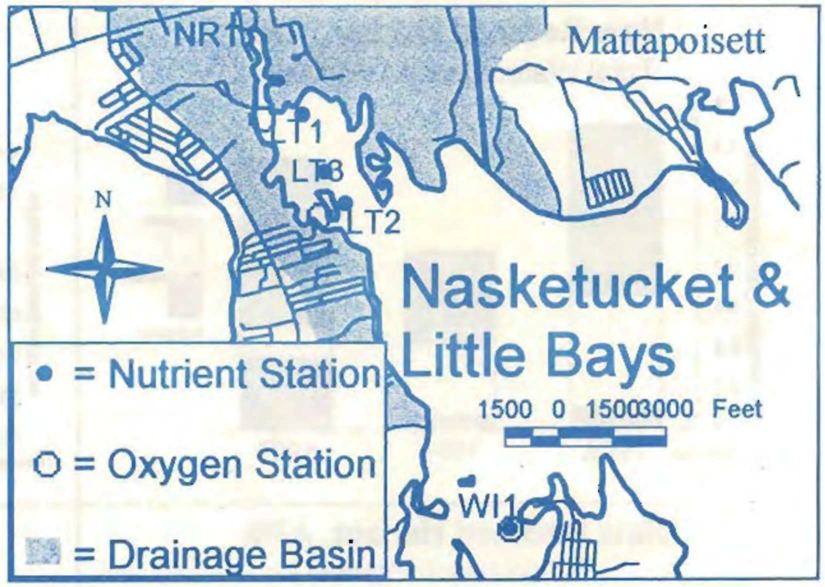
Clarks Cove

Long term fecal coliform data and anecdotal information 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 and into the outer harbor 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.

The New Bedford Sewage Treatment plant will soon upgrade to secondary treatment which will greatly reduce loadings of organic materials and solids to Buzzards Bay and modestly reduce nitrogen discharges. It appears that Clarks Cove does not require a comprehensive nitrogen management strategy. Remediation efforts should focus on further reducing CSO and stormwater pipe rainfall discharges, especially to achieve further fecal coliform reductions.

◆◆◆◆◆

LITTLE BAY & NASKETUCKET BAY



Embayment and Watershed Characteristics

Nasketucket Bay is among the largest of Buzzards Bay embayments monitored. It has the third largest area of salt marsh of any Buzzards Bay embayment and eelgrass habitat is widespread throughout except in the uppermost portion of the Bay, known as Little Bay. There is little residential development in the Little Bay watershed, whereas the greater Nasketucket Bay watershed has far more residential land use, especially along Sconticut Neck. More than a quarter of the watershed is under some type of agricultural use, the third highest in Buzzards Bay, which dominates nitrogen loading to these embayments. With an abundance of lands in agricultural and residential use, have left only 38% of the watershed is left as forest, which puts Nasketucket Bay among the lowest third in this category.

Little Bay is a rainfall conditional closure site due to elevated fecal coliform loading from rain runoff. There are good shellfish resources in this area and the town of Fairhaven and Massachusetts Division of Marine Fisheries have identified priority stormwater discharge sites and areas for septic improvements on Sconticut Neck and Little Bay for remediation.

Water Quality

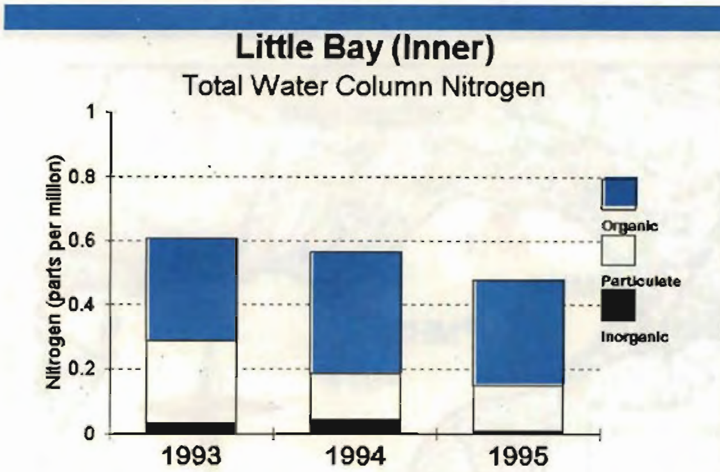
A large fraction of nitrogen loading to Nasketucket Bay arrives through Little Bay, and most of the nitrogen to Little Bay arrives via the Nasketucket River. That loading, plus the reduced flushing in Little Bay, result in poorer water quality there. River stations NR1, NR2 (Rt. 6, not shown), and NR3 (railroad bed, not shown) were monitored for nitrogen on 4 dates in 1993 (the only year that nitrogen was measured here). Station NR1 closest to the bay, had salinities ranging from 21-29 ppt, NR3, next upstream, had salinities between 4 and 12 ppt. Station NR2, most upstream, had salinities below 2 ppt. What is most interesting about the results of this survey was that there was a large spike of inorganic nitrogen midstream at station NR3, suggesting a large nitrogen source down gradient of Route 6. Concentrations of dissolved inorganic nitrogen concentrations approached a remarkably high 100 micromolar (=1.4 ppm)—a value very high for a Buzzards Bay stream.

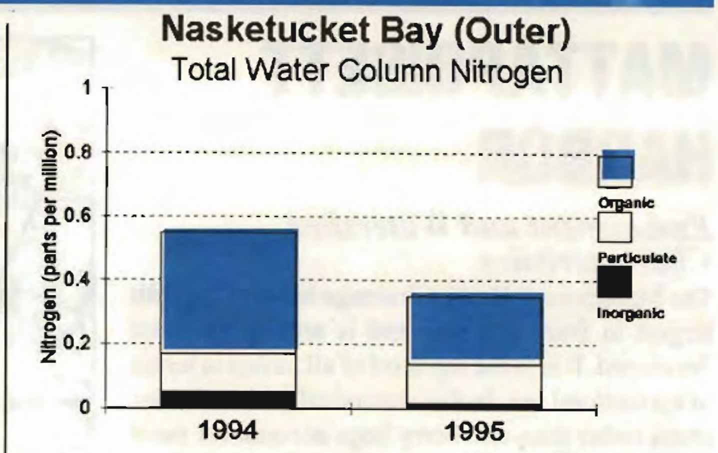
Eutrophication Index scores in Little Bay for 1993 to 1995 were 42, 43, and 59 respectively, only fair scores. The apparent improvements in water quality were largely driven by a big reduction in inorganic nitrogen levels in 1995 together with improvements in the amount of chlorophyll and organic nitrogen in the water. Some possible explanations for this decline in inorganic nitrogen was that a large corn field in the watershed was converted to a soccer field and park in the Spring of 1994, the Weeden Road area (just a few hundred feet from the Bay) was sewered in the Fall of 1993, and a nursery along the Nasketucket River changed its management practices somewhat. We presume that the soccer field received considerably less or no fertilizer applications, and that there was a sizeable dropoff in overland runoff of inorganic nitrogen from all these sources.

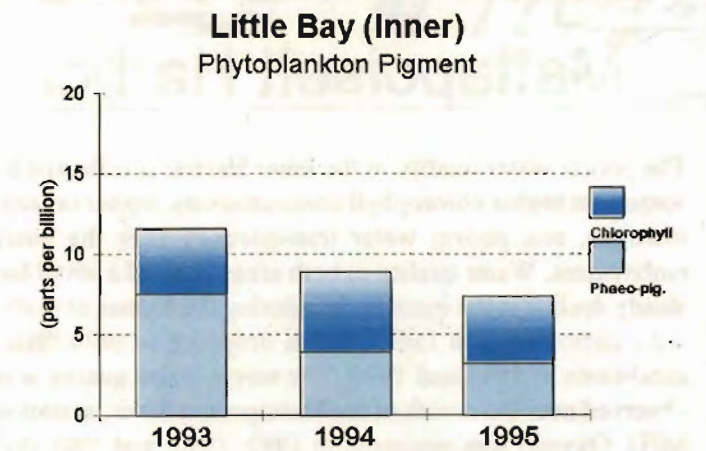
Oxygen concentrations were monitored in all four years. While both sites LT1 and LT2 were monitored in 1994 and 1995, only site LT1 was monitored in 1992, and only site LT2 was monitored in 1993. However because oxygen saturation values were very similar at both sites both in 1994 and 1995, we do not believe the use the 1992 or 1993 to be problematic. In general, oxygen concentrations were typically above 80% saturation at both sites, but in 1992, most oxygen saturation values were below 70%, with one observation at 33%. This suggests water quality in that estuary may have been worse in that year. The results from station NR1 were quite different with the average of the lowest 1/3 saturation values hovering around only 45% saturation.

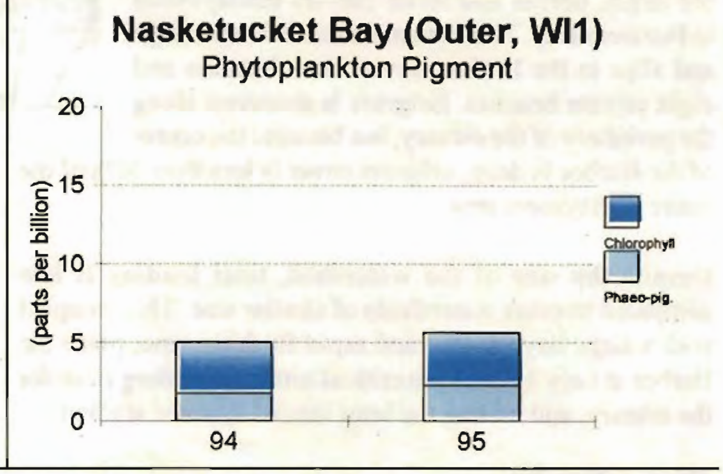
As might be expected the outer bay station at West Island (WI1) had better water quality, with very high oxygen saturation values, but in the two years of nutrient monitoring (1994 and 1995), other measures of water quality were not as good at WI1, and this station had a eutrophication Index Score of only 59 points, suggesting only fair water quality.

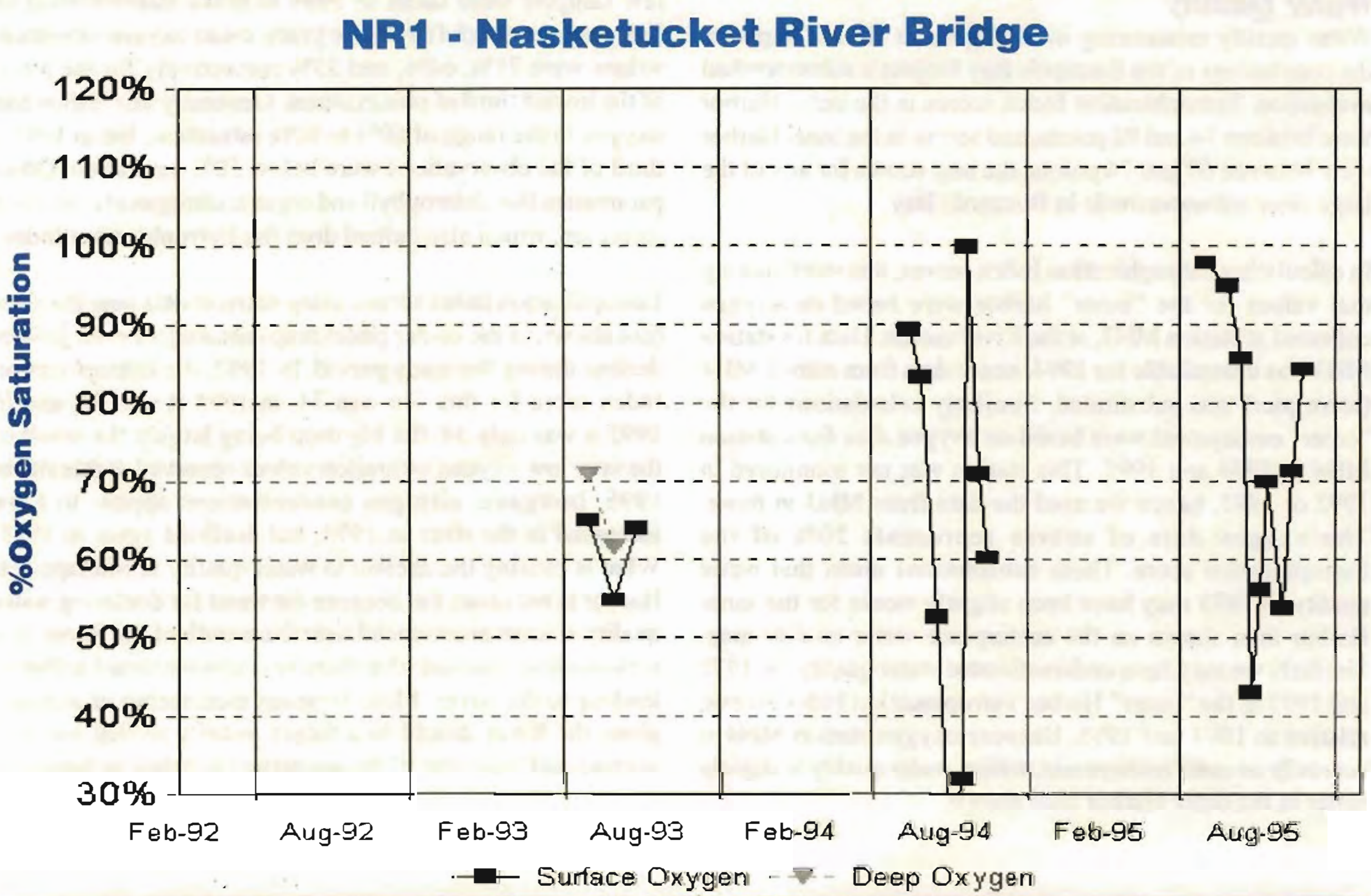
Continued on page 64


Little Bay (Inner)
Total Water Column Nitrogen
Nitrogen (parts per million)
0
0.2
0.4
0.6
0.8
1
1993
1994
1995
Organic
Particulate
Inorganic

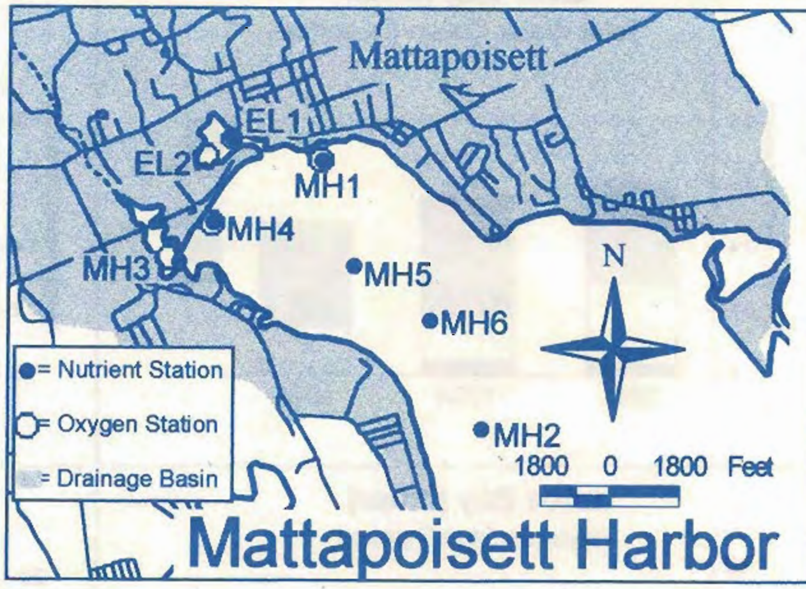

Nasketucket Bay (Outer)
Total Water Column Nitrogen
Nitrogen (parts per million)
0
0.2
0.4
0.6
0.8
1
1994
1995
Organic
Particulate
Inorganic


Little Bay (Inner)
Phytoplankton Pigment
(parts per billion)
0
5
10
15
20
1993
1994
1995
Chlorophyll
Phaeo-pig.


Nasketucket Bay (Outer, WI1)
Phytoplankton Pigment
(parts per billion)
0
5
10
15
20
94
95
Chlorophyll
Phaeo-pig.


NR1 - Nasketucket River Bridge
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
Feb-92
Aug-92
Feb-93
Aug-93
Feb-94
Aug-94
Feb-95
Aug-95
Surface Oxygen
Deep Oxygen

MATTAPOISETT HARBOR



Embayment and Watershed Characteristics

The Mattapoisett Harbor drainage basin is the fifth largest in Buzzards Bay and is among the least developed. It is in the top third of all basins in terms of agricultural use. In this watershed corn and other crops rather than cranberry bogs account for most of the agricultural activity. The Harbor is among the larger, deeper and better flushed embayments in Buzzards Bay. There are more than 650 moorings and slips in the Harbor, seven town beaches and eight private beaches. Eelgrass is abundant along the periphery of the estuary, but because the center of the Harbor is deep, eelgrass cover is less than 30% of the entire embayment area.

Despite the size of the watershed, total loading is low compared to other watersheds of similar size. This, coupled with a large bay volume and rapid flushing time, place the Harbor at only 17% of the critical nitrogen loading limit for the estuary, and among the least loaded systems studied.

Water Quality

Water quality monitoring in Mattapoisett Harbor supports the conclusions of the Buzzards Bay Project's subwatershed evaluation. Eutrophication Index scores in the outer Harbor were between 74 and 92 points, and scores in the inner Harbor were between 60 and 74 points, the best scores for any of the large river subwatersheds in Buzzards Bay.

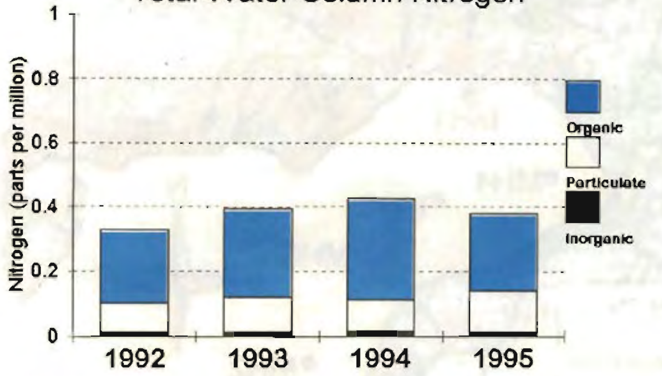
In calculating Eutrophication Index scores, it is worth noting that values for the "inner" harbor were based on oxygen collected at station MH3, at the River mouth. Data for station MH3 was unavailable for 1994, hence data from station MH4 (town pier) was substituted. Similarly calculations for the "outer" embayment were based on oxygen data from station MH4 in 1994 and 1995. This station was not monitored in 1992 or 1993, hence we used the data from MH3 in those. The oxygen data of course represents 20% of the Eutrophication score. These substitutions mean that water quality in 1993 may have been slightly worse for the inner Harbor than shown on the centerpiece water quality map. Similarly we may have underestimated water quality for 1992 and 1993 in the "outer" Harbor eutrophication Index scores, relative to 1994 and 1995. Because oxygen station MH4 is not really an outer embayment station, water quality is slightly better in the outer Harbor than shown.

The poorer water quality in the inner Harbor is reflected by somewhat higher chlorophyll concentrations, higher organic nitrogen, and poorer water transparency than the outer embayment. Water quality in both areas showed a small but steady decline in the inner Harbor during the 4 years of study, with Eutrophication Index scores dropping to only "fair" conditions in 1994 and 1995. The worse water quality was observed near the mouth of the Mattapoisett River, at station MH3. Oxygen was measured in 1992, 1993, and 1995 (too few samples were taken in 1994 to make interpretation of that year meaningful). In those years, mean oxygen saturation values were 71%, 64%, and 33% respectively for the mean of the lowest third of observations. Generally this station has oxygen in the range of 60% to 90% saturation, but in 1995 a third of the observations were below 50% saturation. Other parameters like chlorophyll and organic nitrogen also showed increases, which also helped drop the Eutrophication Index.

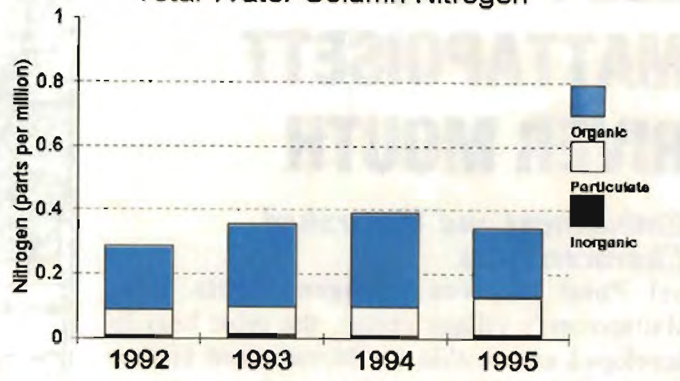
Eutrophication Index scores using nutrient data near the river (not shown in the center panel map) showed an even greater decline during the study period. In 1992, the Eutrophication Index score for this site was 74, in 1994 it was 52, and in 1995 it was only 34, the big drop being largely the result of the very low oxygen saturation values observed at this site in 1995. Inorganic nitrogen concentrations appear to have increased in the river in 1994, but declined again in 1995. What is causing the decline in water quality in Mattapoisett Harbor is not clear, but because the trend for declining water quality is most pronounced near the mouth of the River, it is reasonable to conclude that there has been increased pollutant loading to the River. More frequent monitoring of nitrogen along the River should be a future priority so that nitrogen sources and transport in the watershed is better understood.

Continued on page 64

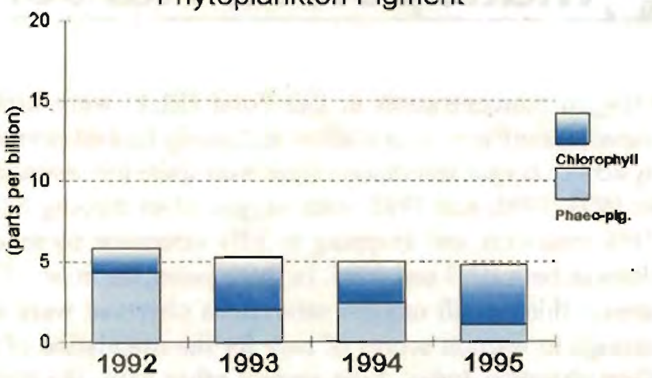
Mattapoisett Harbor (Inner)
Total Water Column Nitrogen



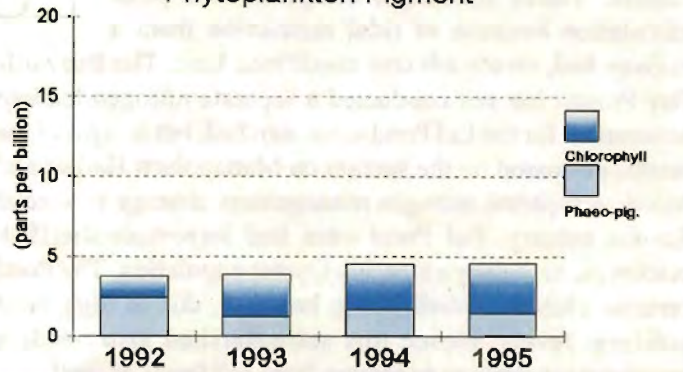
Mattapoisett Harbor (Outer)
Total Water Column Nitrogen



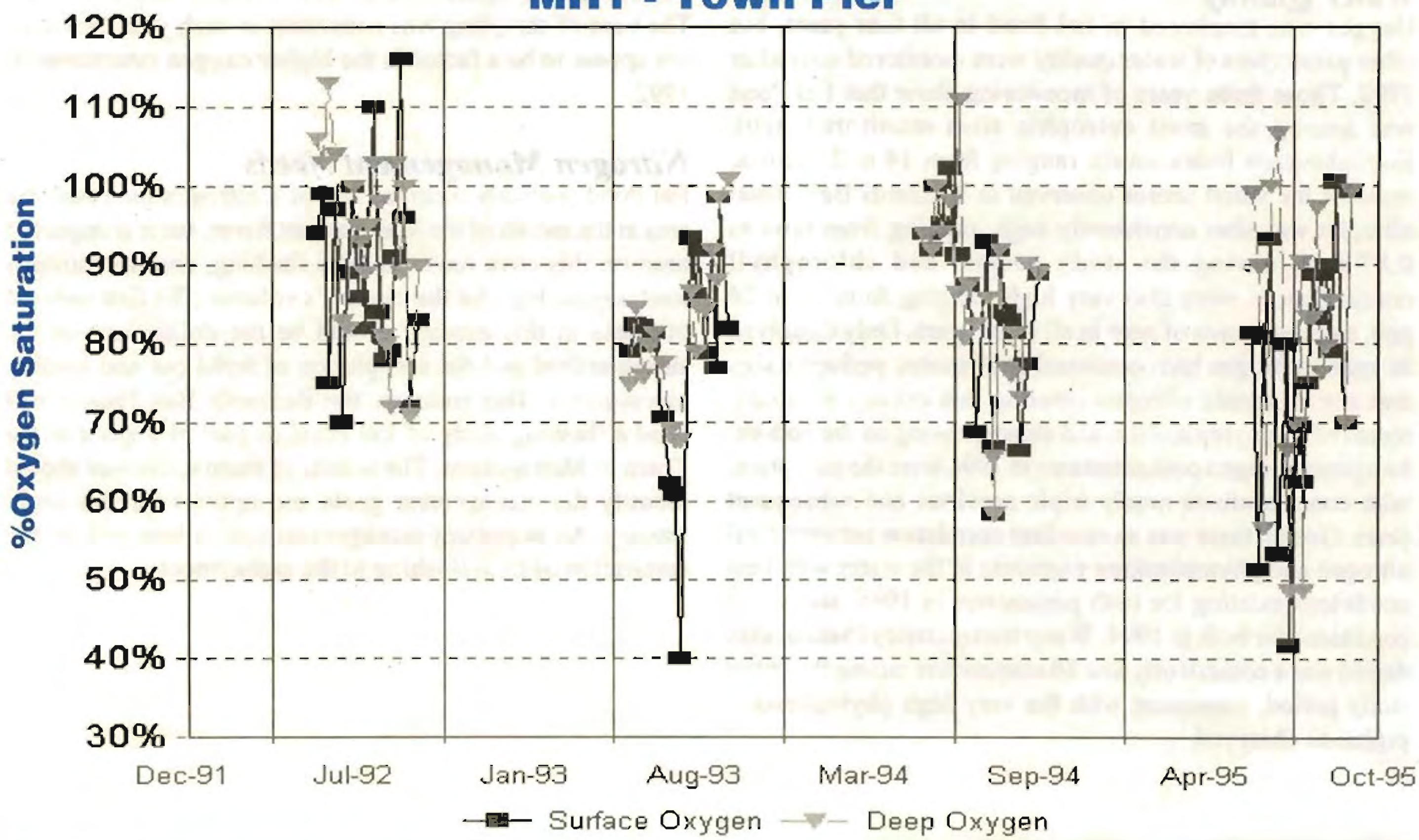
Mattapoisett Harbor (Inner)
Phytoplankton Pigment



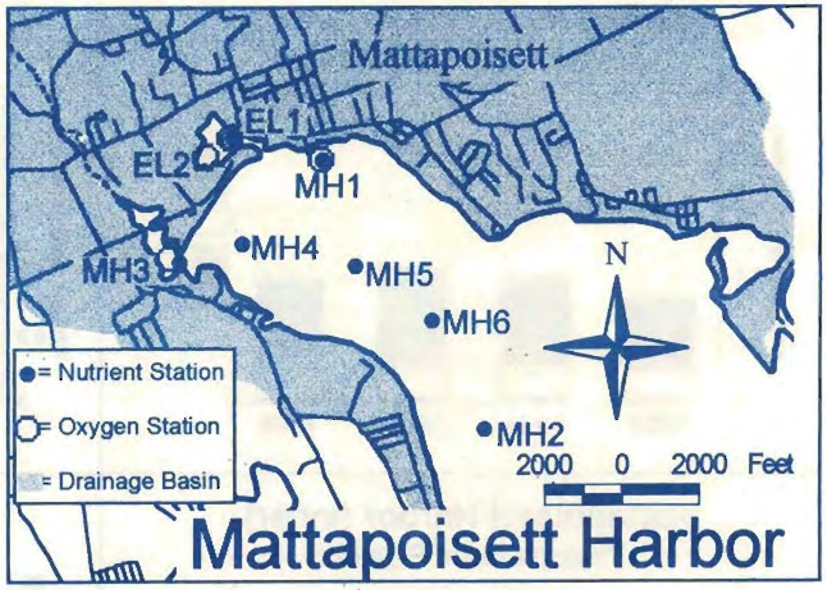
Mattapoisett Harbor (Outer)
Phytoplankton Pigment



MH1 - Town Pier



EEL POND, MATTAPOISETT RIVER MOUTH



Embayment and Watershed Characteristics

Eel Pond receives nitrogen inputs from Mattapoisett's village center, the most heavily developed area within the Mattapoisett Harbor drainage basin. However, most of the residences are sewered and dominant nitrogen sources include a golf course, residential use of lawn fertilizer, runoff. These loadings, coupled with poor circulation because of tidal restriction from a railway bed, create adverse conditions here. The Buzzards Bay Project has not conducted a separate nitrogen loading assessment for the Eel Pond subwatershed, but in light of the results discussed on the section on Mattapoisett Harbor and below, a separate nitrogen management strategy is needed for the estuary. Eel Pond once had important shellfish resources, including a sizeable Oyster population. The Pond remains closed to shellfishing however, due to high fecal coliform levels. Hence this subwatershed also needs a management strategy to reduce fecal coliforms as well.

Water Quality

Oxygen was monitored in Eel Pond in all four years, but other parameters of water quality were monitored only after 1992. Those three years of monitoring show that Eel Pond was among the most eutrophic sites monitored, with Eutrophication Index scores ranging from 14 to 23 points, some of the worst scores observed in Buzzards Bay. Total nitrogen was also consistently high, ranging from 0.64 to 0.87 ppm during the study period, and chlorophyll concentrations were also very high, ranging from 13 to 24 ppb, earning scores of zero in all three years. Only dissolved inorganic nitrogen had occasional good scores, perhaps a sign that any inorganic nitrogen entering this estuary is rapidly removed by phytoplankton and algae growing on the bottom. Inorganic nitrogen concentrations in 1994 were the exception, with concentrations nearly triple previous and subsequent years. Overall there was an excellent correlation between total nitrogen and phytoplankton pigments in the water with best conditions existing for both parameters in 1995, and worst conditions for both in 1994. Water transparency (Secchi disk depth) was a consistently low 80 centimeters during the entire study period, consistent with the very high phytoplankton pigments observed.

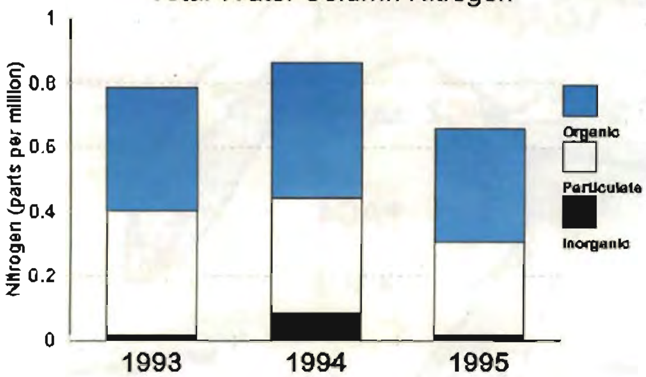
Oxygen concentration in Eel Pond (EL1) were highly variable, similar to other shallow and poorly flushed eutrophic systems. Oxygen saturation values were quite low, especially in 1993, 1994, and 1995, with oxygen often dipping below 50% saturation and dropping to 30% saturation on several dates in both 1993 and 1995. In those years, the mean of the lowest third of all oxygen saturations observed were low enough to warrant scores of zero for the calculation of the Eutrophication Index. Like several other bays, the higher oxygen concentrations in 1992 may have been a function of cooler water temperatures or other weather related factors. The time of sampling was consistent in each year, and does not appear to be a factor in the higher oxygen saturations in 1992.

Nitrogen Management Needs

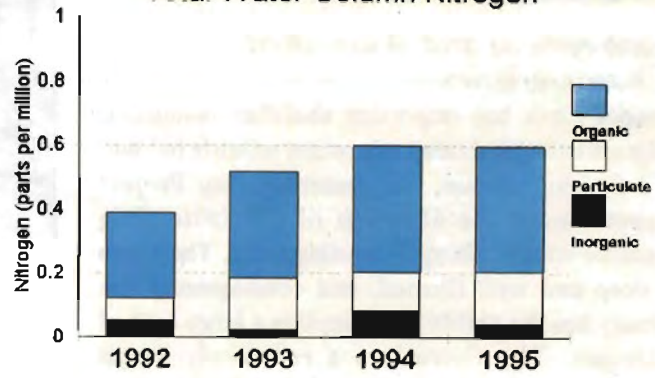
Eel Pond probably receives less of a nitrogen load than the area at the mouth of the Mattapoisett River, but it is impacted because this cove receives little flushing, and the nitrogen load is quite high for the estuary's volume. The first order of business in this estuary should be the delineation of the subwatershed and the completion of build out and loading assessments. This summer, the Buzzards Bay Project will fund a flushing study of Eel Pond as part of a grant to the Town of Mattapoisett. The results of these initiatives should identify the management goals and options for this small estuary. An important management option here will be the restoration of tidal flushing to the embayment.

◆◆◆◆◆

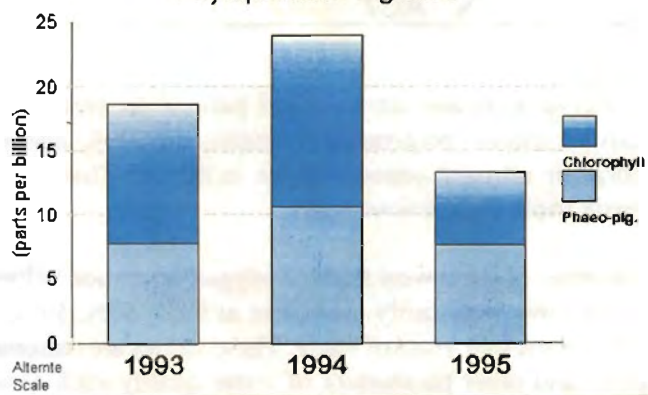
Eel Pond
Total Water Column Nitrogen



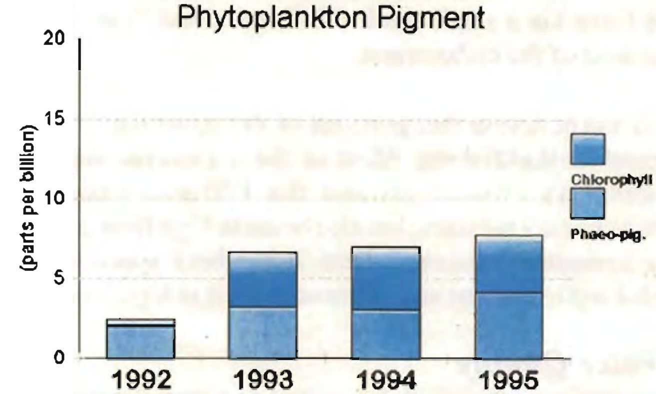
Mattapoisett Harbor (River)
Total Water Column Nitrogen



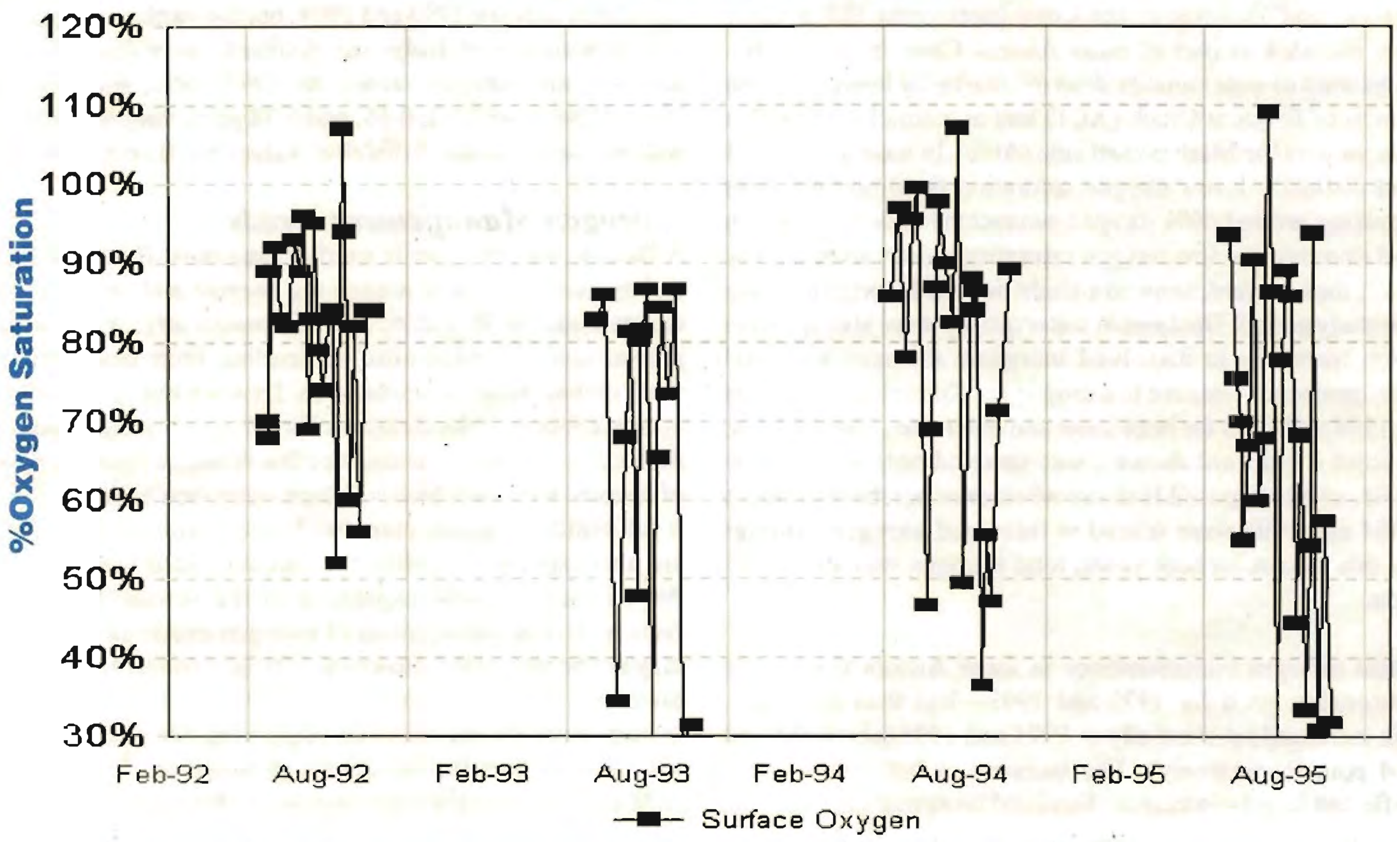
Eel Pond
Phytoplankton Pigment



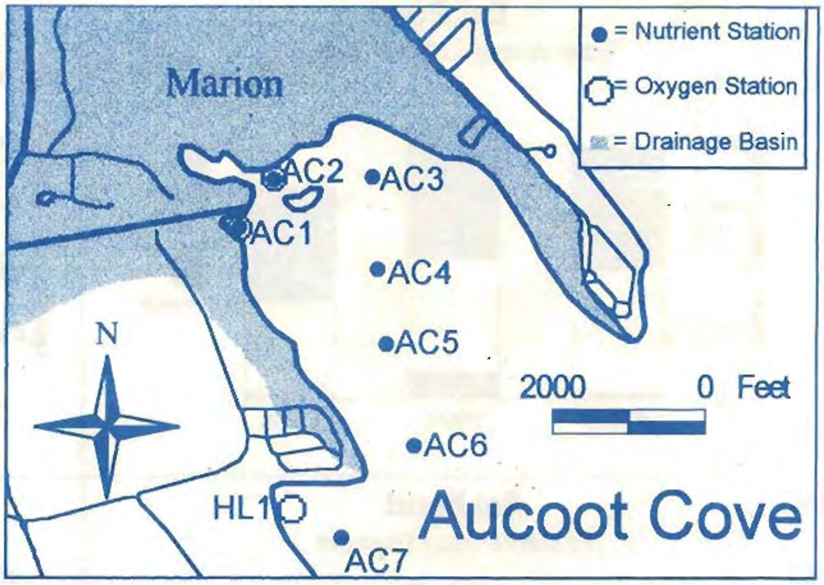
Mattapoisett Harbor (River)
Phytoplankton Pigment



EL1 - Eel Pond Railroad Bridge



AUCOOT COVE



Embayment and Watershed Characteristics

Aucoot Cove has important shellfish resources, eelgrass habit, and other important wildlife habitat, and for this reason, the Buzzards Bay Project recommended the adoption of an outstanding resource waters nitrogen loading limit. The Cove is deep and well flushed, and consequently the estuary has the ability to assimilate a large load of nitrogen. The Cove has a relatively small watershed, and the principal source of nitrogen is the Marion Sewage Treatment Facility (more than 60% of the watershed load) which discharges to the Cove via a small creek ("Effluent Creek") at the head of the embayment.

It is worth noting that portions of the upper Cove are also closed to shellfishing. Most of these closures are due to mandatory closure around the Effluent Creek as a precautionary measure, but also because high fecal coliforms are sometimes observed there. It has been speculated that failed septic systems near shore contribute to high fecal levels.

Water Quality

Aucoot Cove, especially the central and outer portions of the Cove, exhibit very good water quality, a reflection of the fact that the total nitrogen load is small compared to the volume and flushing of the Cove [note outer Hiller Cove was included as part of outer Aucoot Cove in this study]. Indicators of water quality drop off markedly however at the mouth of Effluent Creek (AC1) and at a small cove with a boatyard on the Mattapoisett side (AC2). In most years, AC1 had distinctly lower oxygen saturation (summertime lows hovering around 40% oxygen saturation) than AC2, which had summertime low oxygen saturation values around 55%. AC2, the boatyard, showed a slight decline in oxygen during the study period. Declines in water quality were also apparent from increases in dissolved inorganic nitrogen and total nitrogen which resulted in a drop in the Eutrophication Index in 1994 and 1995 for both inner and outer sites. Station AC8, Aucoot Creek (not shown), was sampled only in 1994 and 1995, so it is impossible to say whether or not the declines in 1994 and 1995 were related to increased nitrogen loadings on this stream. In both years, total nitrogen was about 0.75 ppm.

Total nitrogen concentrations in inner Aucoot Cove were reasonably good for 1992 and 1993—less than 0.35 ppm, but increased substantially in 1994 and 1995 (above 0.5 and 0.4 ppm respectively). The increase in both those years reflected largely increased dissolved inorganic nitrogen, but dissolved inorganic nitrogen and particulate nitrogen also showed similar percentage increases. In 1994, dissolved inorganic nitrogen concentrations in the outer harbor were nearly triple the previous years.

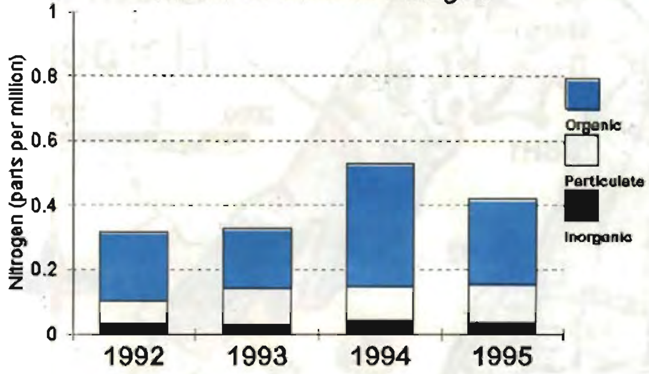
The mean of the lowest third of oxygen saturation values in Hiller Cove were fairly consistent at 69%, 60%, 59%, and 66% for the four years of study. These values are reasonably good, and other parameters of water quality such as total nitrogen and chlorophyll also indicate good water quality. The Eutrophication Index for inner Hillers Cove could be calculated only for 1993 and 1994, but the values—63 points and 74 points respectively—are similar to outer Aucoot Cove scores. Total nitrogen values, for 1993, 1994, and 1995 in Hiller Cove were 0.33, 0.36, and 0.38 ppm, very low values and similar to central "offshore" values for Buzzards Bay.

Nitrogen Management Needs

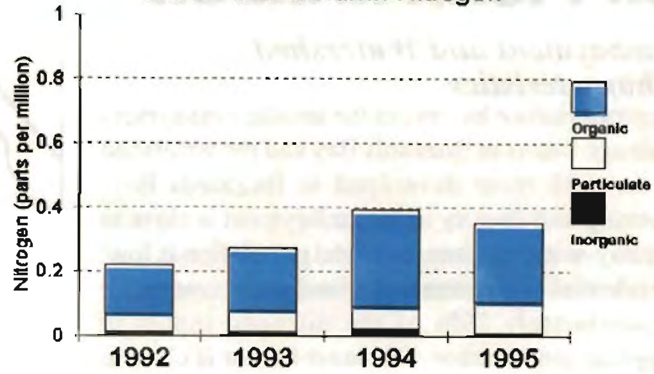
Although Aucoot Cove is smaller than most Buzzards Bay embayments, it is also among the deepest and best flushed embayments in Buzzards Bay. Consequently, it has a far greater recommended nitrogen loading limit compared to other embayments of similar area. Existing nitrogen loading is only a fourth of the Buzzards Bay Project's recommended limits. A considerable amount of this drainage basin consists of forested wetland which will limit watershed buildout. Even if full buildout occurs, potential future loadings to the Cove are also expected to below the recommended limits unless there is any sizeable expansion of the sewage treatment facility. Hence management of nitrogen inputs on that basis may not be warranted. However, nitrogen concentrations are elevated in the creek which appears degraded, and management should focus on improving the quality of the sewage treatment facility discharge to the creek. The town of Marion has planned improvements to the sewage treatment

Continued on page 65

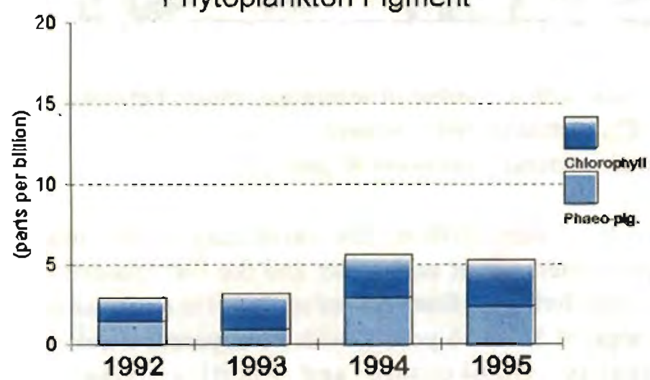
Aucoot Cove (Inner)
Total Water Column Nitrogen



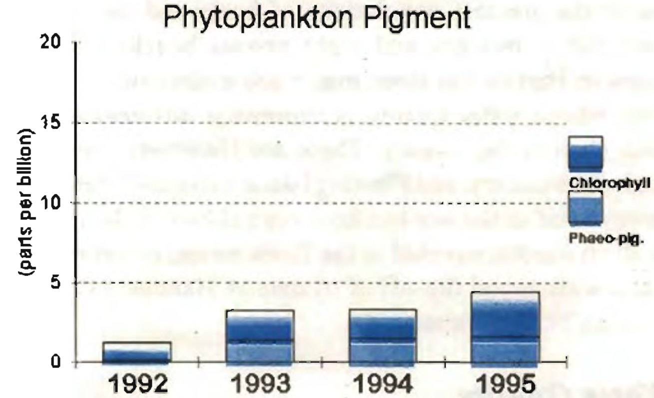
Aucoot Cove (Outer)
Total Water Column Nitrogen



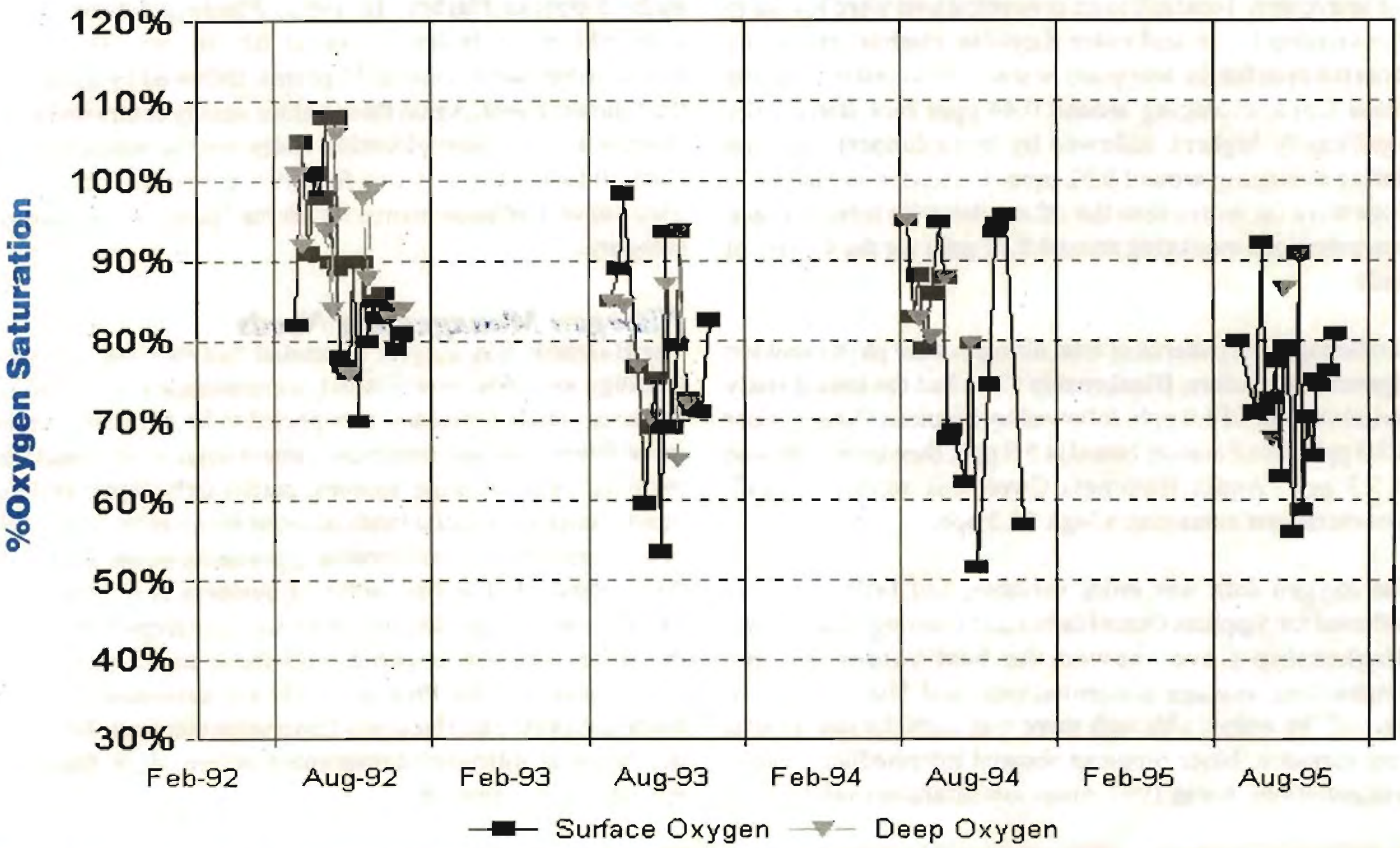
Aucoot Cove (Inner)
Phytoplankton Pigment



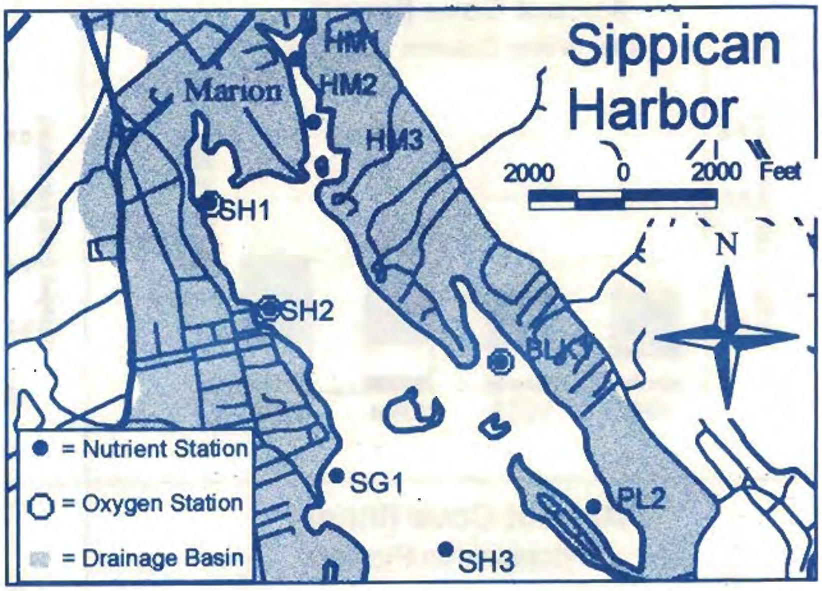
Aucoot Cove (Outer)
Phytoplankton Pigment



AC2 - Inner Cove



SIPPICAN HARBOR



Embayment and Watershed Characteristics

Sippican Harbor has one of the smaller embayment drainage basins in Buzzards Bay and the watershed is the fifth most developed in Buzzards Bay. Housing unit density in the embayment is close to the Bay-wide medium, but total population is low. Residential and commercial land use accounts for approximately 79% of the nitrogen inputs to Sippican inner harbor. The inner harbor is close to the median size and depth of Buzzards Bay embayments but the estuary's flushing time is considerably longer than most. Sippican Harbor has one of the greatest populations of boats and has three public beaches and eight private beaches. Sippican Harbor has three major sub-embayment areas whose water quality is somewhat different from the main stem of the estuary. These are Hammets Cove at the head of the estuary, and Planting Island Cove and Blankenship Cove paired in the northeastern central harbor. In 1990, the shellfish warden reported in the Town annual report that there was a widespread die-off of oysters in Hammets Cove, but this may be disease related.

Water Quality

Water Quality in inner and outer Sippican Harbor, including Planting Island Cove and Blankenship Cove were consistently fair to average. Total nitrogen concentrations were lowest in Blankenship Cove and outer Sippican Harbor, averaging about 0.4 ppm for the four years of study, followed by Planting Island Cove, averaging around 0.44 ppm (not statistically significantly higher), followed by Inner (upper) Sippican Harbor averaging around 0.52 ppm. Condition in Hammets Cove were far worse than the other sites with total nitrogen concentrations averaging around 0.72 ppm for the 4 years of study.

Paralleling these patterns of total nitrogen were phytoplankton pigments. As before, Blankenship Cove had the lowest study period average of 5.0 ppb, followed by Sippican Outer Harbor at 5.8 ppb, then Planting Island at 5.9 ppb, then inner Sippican at 7.3 ppb. Again Hammets Cove was worse off with concentrations averaging a high 15.3 ppb.

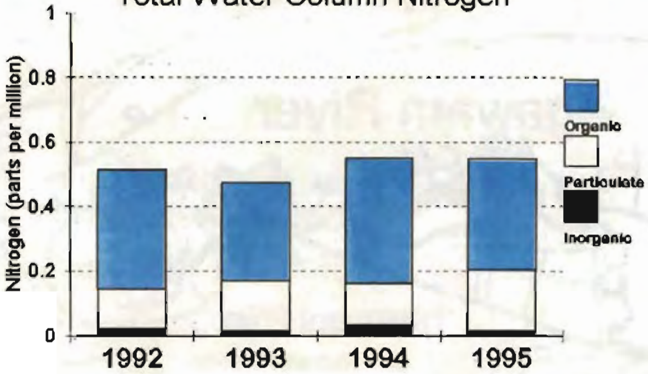
The oxygen data was more variable, and little data was collected for Sippican Outer Harbor and Planting Island Cove. Blankenship Cove showed the best values for low summertime average concentrations, and Hammets Cove showed the worse, although there was considerable year to year variation. Inner Sippican showed intermediate oxygen concentrations, but in 1992, mean low saturation values were lower with a number of saturation values between 50% and 60% at station SH1, whereas oxygen values in other years were generally between 70 and 100%.

In the Inner Harbor, the variability in the individual parameters offset each other and the Eutrophication Index scores during the four years of study fell in remarkably narrow range of 52 to 56 points, with no apparent trends in water quality. Blankenship and Planting Island Coves' Eutrophication Index scores were incomplete, but the little available data showed clearly better water quality typical of outer Sippican Harbor. In 1993, Planting Island had a Eutrophication Index Score of 63. In the same year Blankenship had a score of 71 points, followed by 65 points the following year. Again these values starkly contrasted with Hammets Cove Eutrophication Index scores which ranged from 20 to 45 points, with a four year average of 35 points. Two out of 4 of these scores fell in the "poor" water quality category.

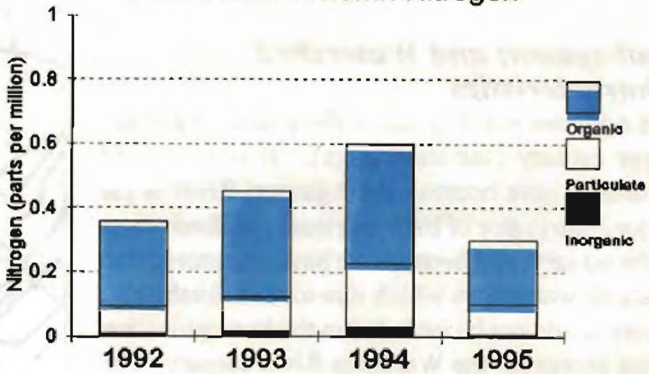
Nitrogen Management Needs

The Buzzards Bay Project estimated that existing nitrogen loadings are 16% over Project recommended outstanding resource waters limits and is expected to be 69% over limits in the future. Any nitrogen management strategy must include remediation of existing sources, particularly septic system inputs, since residential lands account for an estimated 79 % of nitrogen inputs. Considerable opportunity exists to protect this watershed. The first order of business is to conduct a parcel level nitrogen loading analysis since large portions of the watershed are sewered, and these areas were only approximated in the Project's 1994 subwatershed nitrogen loading report. The Hammets Cove subwatershed should be the focus of nitrogen management action since that area appears most degraded.

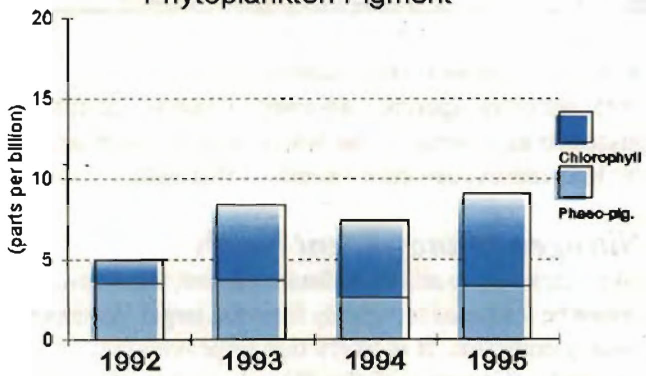
Sippican Harbor (Inner)
Total Water Column Nitrogen



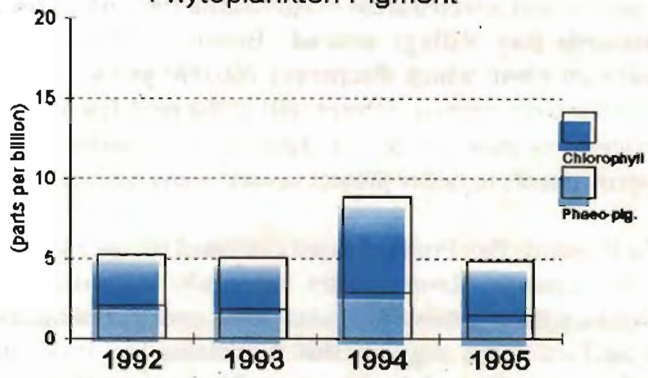
Sippican Harbor (Outer)
Total Water Column Nitrogen



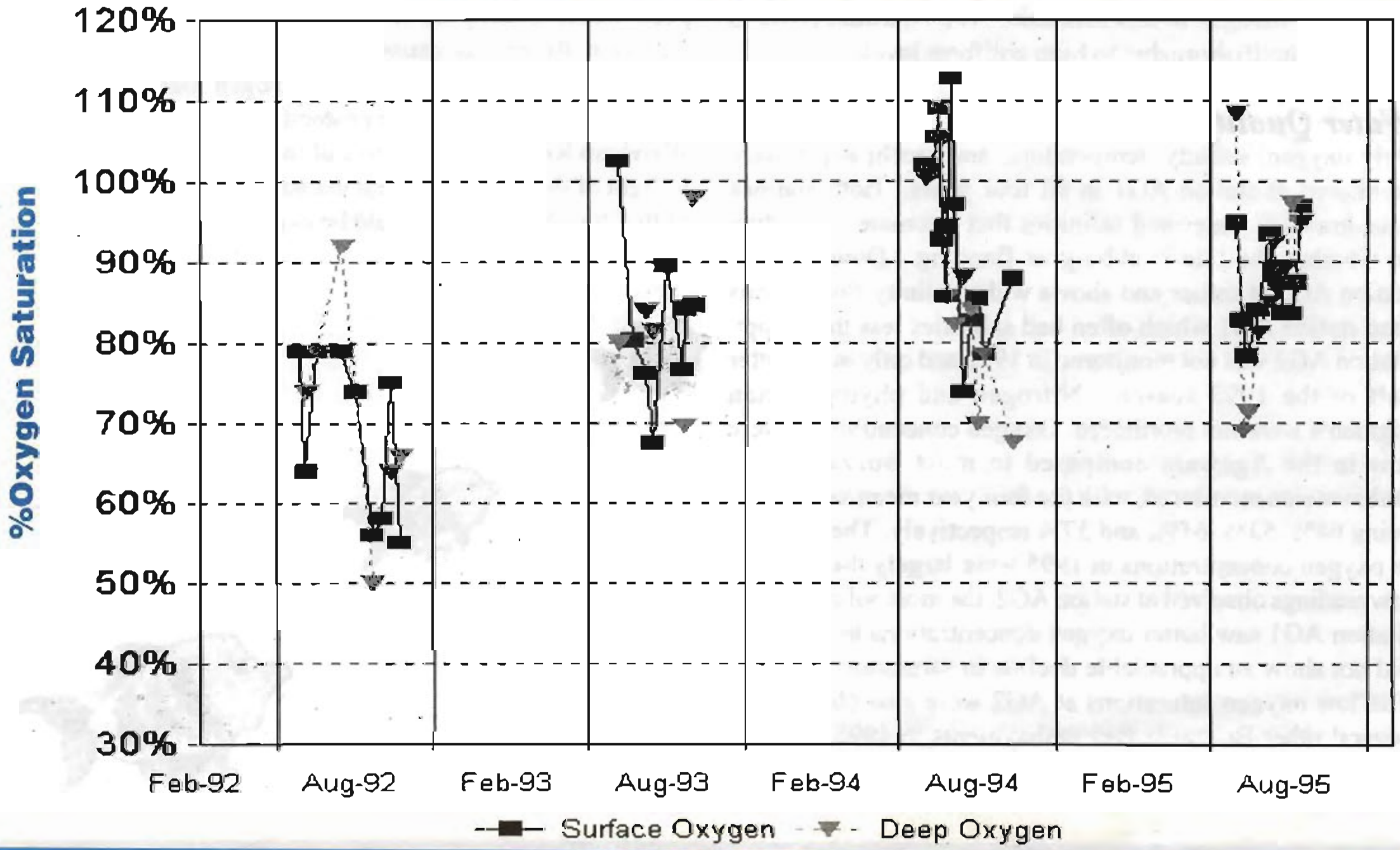
Sippican Harbor (Inner)
Phytoplankton Pigment



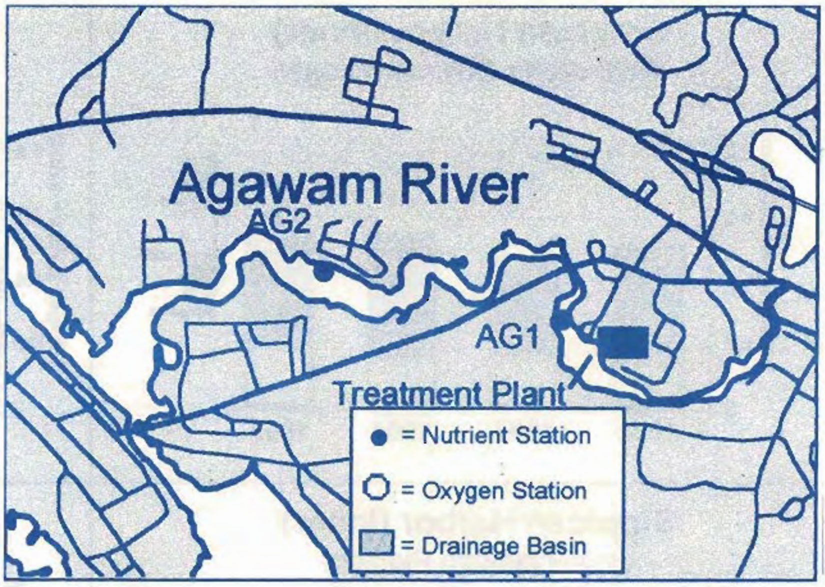
Sippican Harbor (Outer)
Phytoplankton Pigment



SH1, SH2 - Sippican Harbor



AGAWAM RIVER



Embayment and Watershed Characteristics

The Agawam River is part of the greater Wareham River estuary (see next page). It is evaluated separately here because the Agawam River is the major contributor of both nutrients and freshwater to the estuary, and because we have monitored two brackish water sites which due to their freshwater nature, could not be included in the Eutrophication Index scores for the Wareham River estuary. The Agawam River is also noteworthy because it receives discharges from the Wareham Sewage Treatment plant which serves both the town of Wareham and selected areas of Buttermilk Bay and Buzzards Bay Village around Bourne. This treatment plant, which discharges 760,000 gallons per day of secondarily treated effluent will in the next few years be reviewed by state and federal agencies for possible facility improvements to better protect coastal water quality.

The Buzzards Bay Project has not evaluated nitrogen loadings to the Agawam River estuary separately from the larger Wareham River estuary watershed, but a cursory examination of land use maps suggests that it contains less residential land than portions of the Wareham River estuary adjoining the center of Wareham Village. Clearly the sewage treatment plant, followed by upstream cranberry bogs are the largest sources of nitrogen in this subbasin. The Agawam River is closed to shellfishing due to high coliform levels.

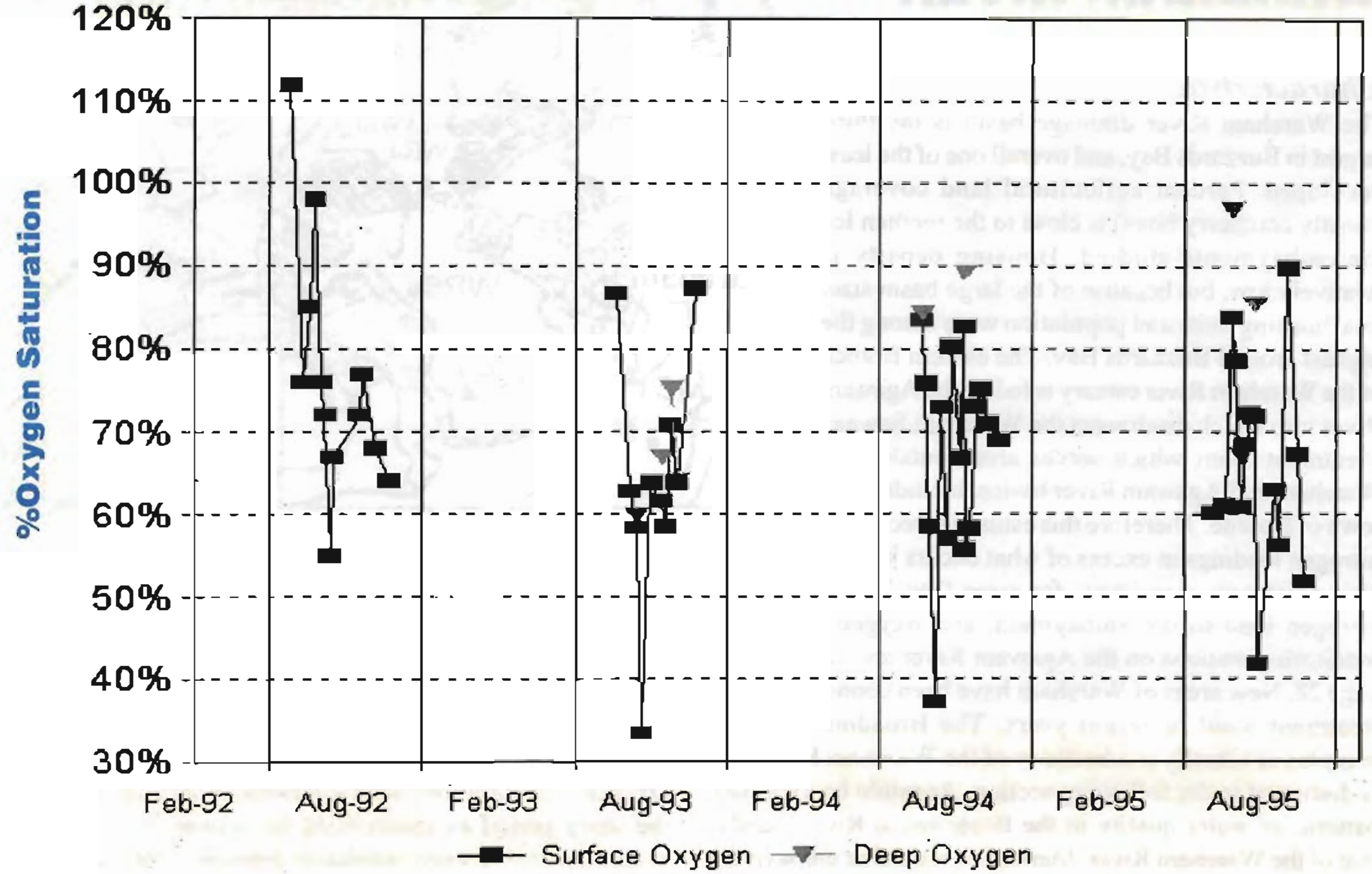
Water Quality

Only oxygen, salinity, temperature, and secchi depth were monitored at station AG1 in all four years. Both stations have brackish water and salinities that fluctuate depending on whether the tide is ebbing or flooding. Down stream station AG2 is saltier and shows wider salinity fluctuations than station AG1 which often had salinities less than 3 ppt. Station AG2 was not monitored in 1992 and only in the latter half of the 1993 season. Nitrogen and phytoplankton pigments were not monitored. Oxygen concentrations were low in the Agawam compared to most Buzzards Bay embayments monitored, with the four year mean saturations being 64%, 53%, 61%, and 37% respectively. The big drop in oxygen concentrations in 1995 were largely the result of low readings observed at station AG2, the more saline station. Station AG1 saw better oxygen concentrations in 1992 and did not show an appreciable decline in saturations in 1995. The low oxygen saturations at AG2 were also observed in several other Buzzards Bay embayments in 1995 and may be due to weather related changes in biological activity. In 1995, water transparency declined, which suggests that more phytoplankton were in the water, which could account for the lowered oxygen concentrations that year.

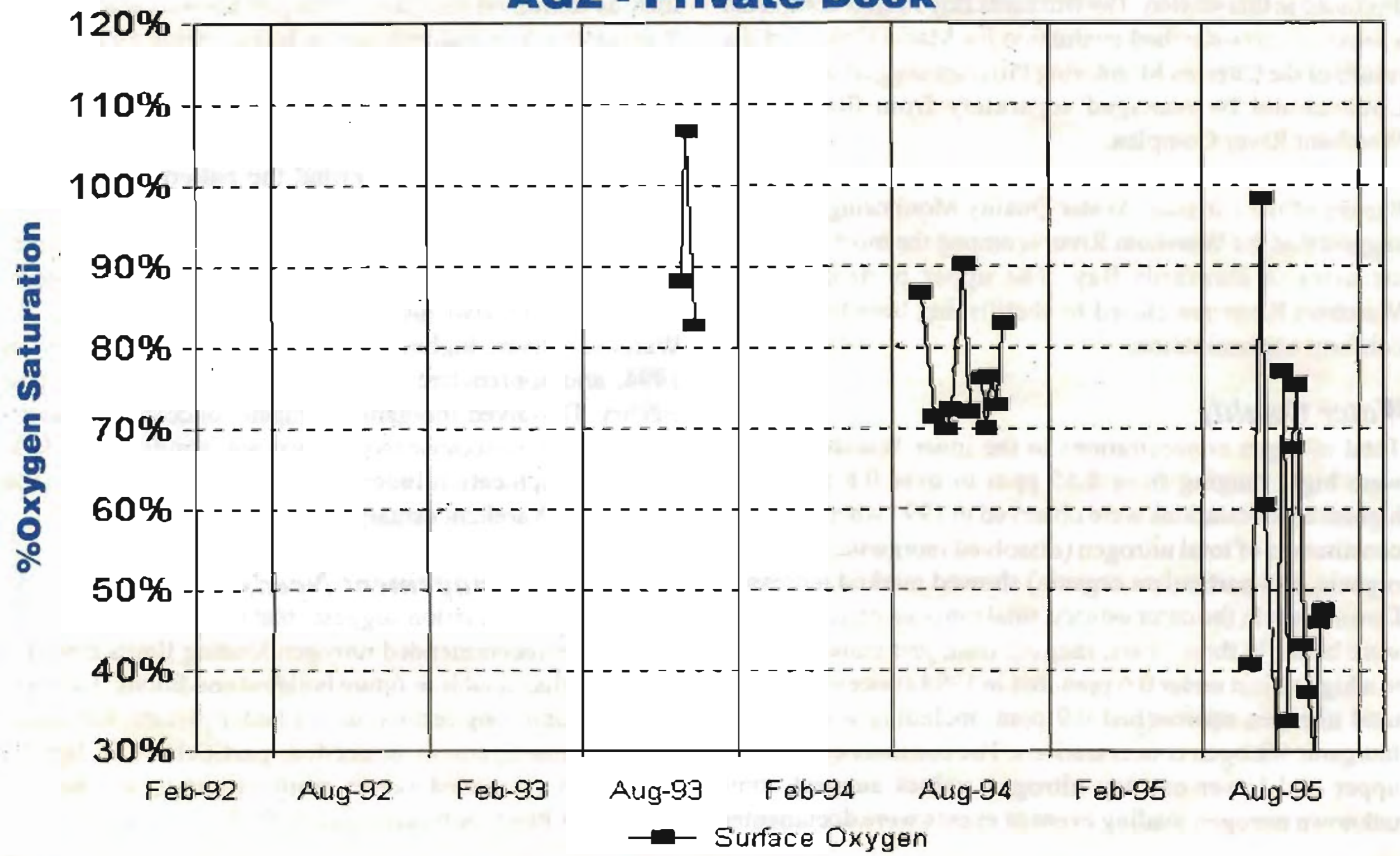
Nitrogen Management Needs

Like Marks Cove and Broadmarsh River, the Agawam River cannot be managed separately from the larger Wareham River estuary complex. It is likely that improvements in nitrogen removal efficiency of the Wareham Sewage Treatment Facility will eventually be required, particularly in light of continuing new connections to the town's sewer system and poor water quality observed in both the Wareham and Agawam Rivers. Because of low oxygen concentrations observed in the Agawam River, nitrogen loading limits for the plant should not only be protective of water quality in the Wareham River, but protective of the Agawam River as well. In light of these management decisions, nutrient monitoring of the Wareham River should be expanded into the Agawam River subestuary.

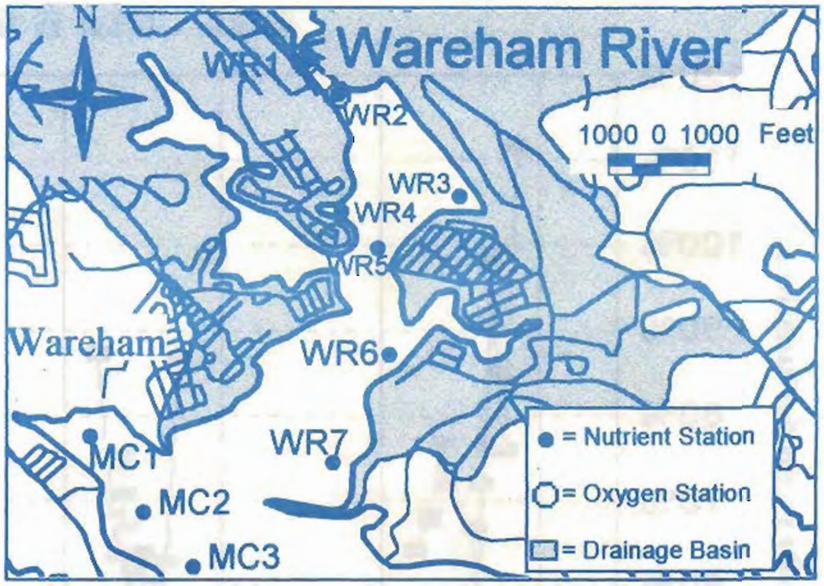
AG1 - Rte 6 Bridge



AG2 - Private Dock



WAREHAM RIVER



Embayment and Watershed Characteristics

The Wareham River drainage basin is the third largest in Buzzards Bay, and overall one of the least developed. Percent agricultural land coverage (mostly cranberry bogs) is close to the median for the embayments studied. Housing density is relatively low, but because of the large basin size, total housing units and population were among the highest around Buzzards Bay. The eastern Branch of the Wareham River estuary is fed by the Agawam River into which discharges the Wareham Sewage Treatment Plant which serves areas outside the Wareham and Agawam River basins, including the town of Bourne. Therefore this estuary is receiving nitrogen loadings in excess of what occurs in the watershed. This point source accounts for more than 25% of the total nitrogen load to the embayment, and oxygen data from monitoring stations on the Agawam River are discussed on page 28. New areas of Wareham have been connected to the treatment plant in recent years. The Broadmarsh River complex is actually a subestuary of the Wareham River, but is discussed in the following section. As might be expected, patterns of water quality in the Broadmarsh River parallel that of the Wareham River. Marks Cove, another embayment branching off near the mouth of the Wareham River is discussed in this section. The Buzzards Bay Project completed a separate subwatershed evaluation for Marks Cove, but the results of the Citizens Monitoring Program suggest that Marks Cove cannot be managed separately from the Greater Wareham River Complex.

Results of the Citizens' Water Quality Monitoring Program suggest that the Wareham River is among the most eutrophic estuaries in Buzzards Bay. The upper portions of the Wareham River are closed to shellfishing because of fecal coliform contamination.

Water Quality

Total nitrogen concentrations in the inner Wareham River were high, ranging from 0.55 ppm to over 0.8 ppm. The highest concentrations were observed in 1994 where all three constituents of total nitrogen (dissolved inorganic, dissolved organic, and particulate organic) showed marked increases. Down River in the outer estuary, total nitrogen concentrations were better in three years, ranging from just under 0.4 ppm to a high of just under 0.6 ppm, but in 1994 concentrations of total nitrogen approached 0.9 ppm, including a tripling of inorganic nitrogen concentrations. The consistency between upper and lower estuary nitrogen values suggest some unknown nitrogen loading event or events were documented in that year. This phenomenon was not limited to forms of nitrogen, but a large increase of phytoplankton was also observed in the inner harbor with a low under 5 ppb in 1992 to a high over 15 ppb in 1994. Patterns of chlorophyll in the outer river precisely mirrored year to year changes in the inner estuary, but at 20-30% lower concentrations.

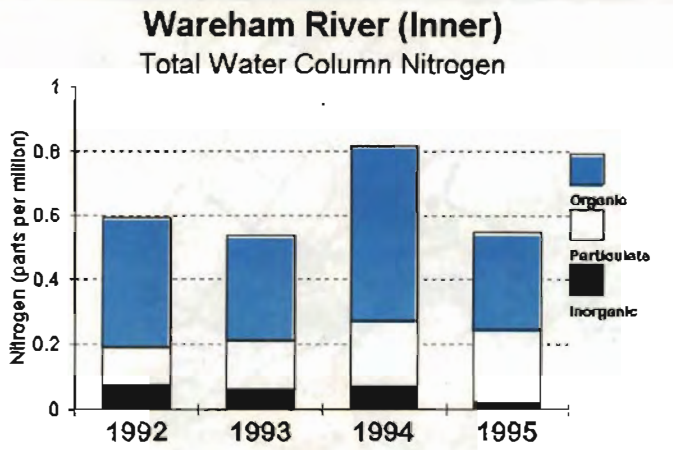
Oxygen concentrations were somewhat more consistent over the study period as exemplified by station WR1. Here % saturation levels were consistent between 1992 and 1994, but showed a marked drop in 1995. Some other parameters such as dissolved inorganic nitrogen showed some abrupt fluctuations, and Eutrophication Index scores ranged from 31 to 52 points, earning a "poor" Eutrophication Index score for one of the four years of study.

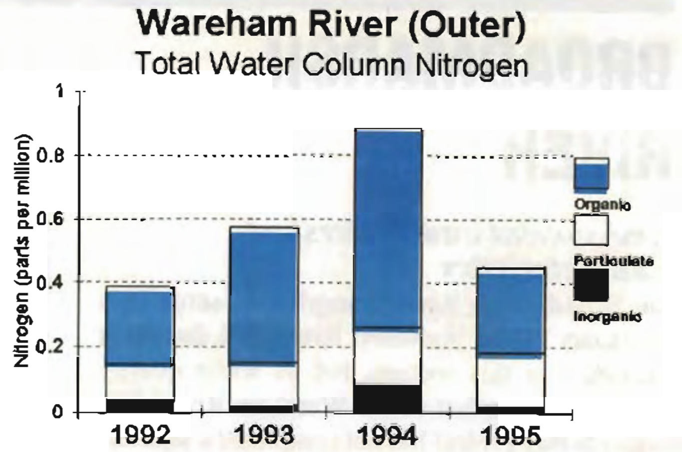
Marks Cove mirrored somewhat the pattern in the larger estuary, but apparently was also influenced more by local nitrogen inputs. During the four years of study, total nitrogen concentrations steadily rose from 0.4 to 0.8 ppm. Phytoplankton also increased dramatically, but like the Wareham River, highest concentrations were observed in 1994, and approached the 15 ppb observed in the upper estuary. Dissolved inorganic nitrogen concentration nearly tripled in 1995. Because oxygen was not monitored in Marks Cove, Eutrophication Index scores are unavailable for that part of the Wareham estuary.

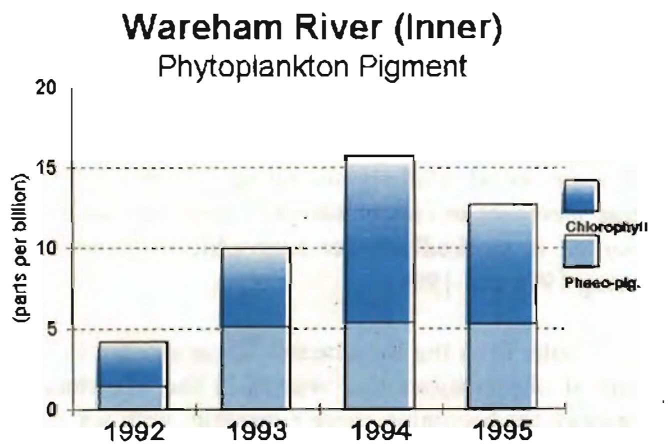
Nitrogen Management Needs

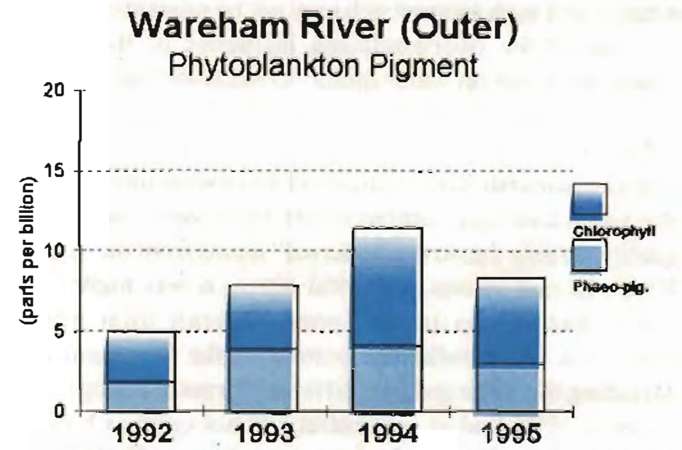
The land use evaluation suggests that the Wareham River is 100% over recommended nitrogen loading limits now, and will more than double at future buildout conditions. The water quality monitoring results paint a better picture, but clearly nitrogen management is needed, particularly in light of continued increased sewer connections to the Sewage Treatment Plant. Nitrogen loading to the Wareham River

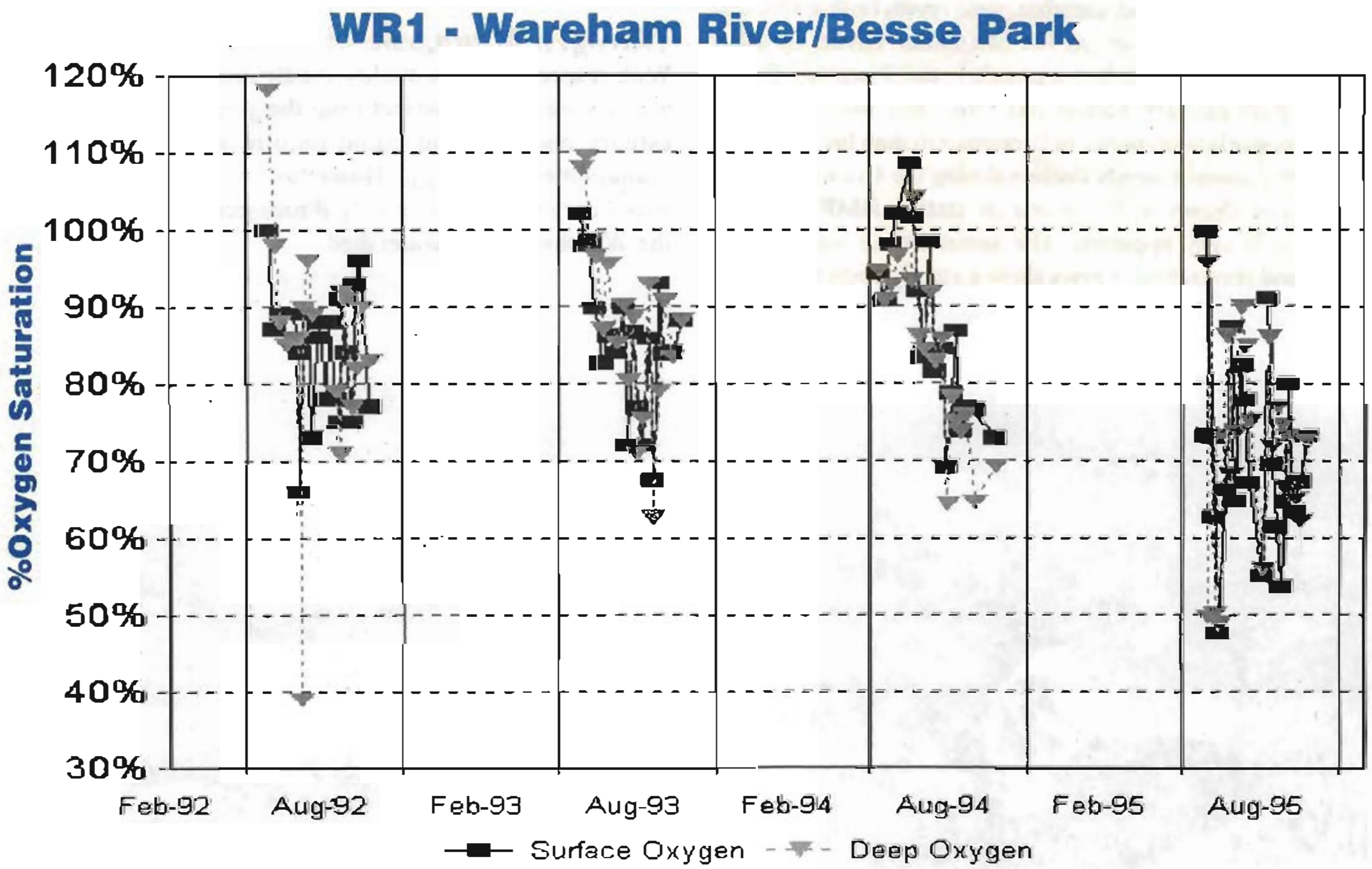
Continued on page 65


Wareham River (Inner)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1992
1993
1994
1995
Organic
Particulate
Inorganic

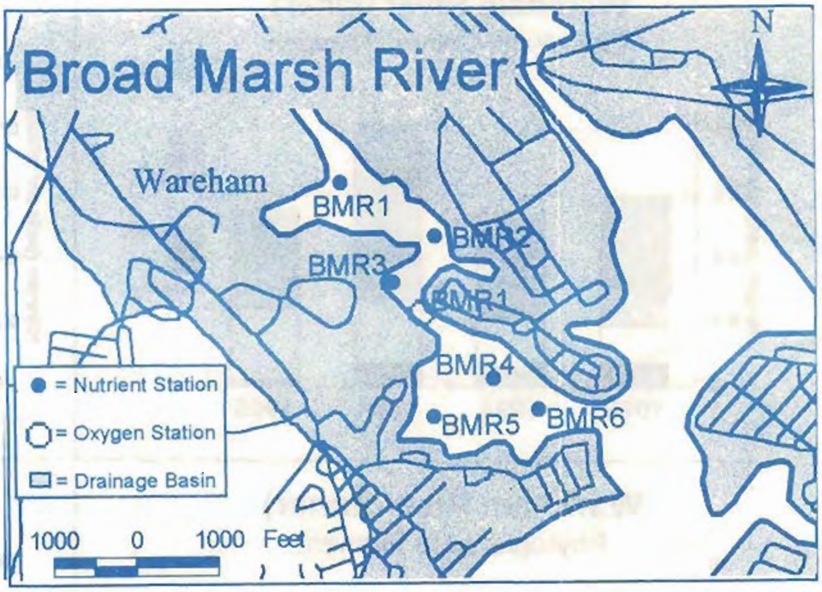

Wareham River (Outer)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1992
1993
1994
1995
Organic
Particulate
Inorganic


Wareham River (Inner)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1992
1993
1994
1995
Chlorophyll
Phaeo-pig.


Wareham River (Outer)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1992
1993
1994
1995
Chlorophyll
Phaeo-pig.


WR1 - Wareham River/Besse Park
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
Feb-92
Aug-92
Feb-93
Aug-93
Feb-94
Aug-94
Feb-95
Aug-95
Surface Oxygen
Deep Oxygen

BROADMARSH RIVER



Embayment and Watershed Characteristics

The Broadmarsh River complex is actually a subestuary of the Wareham River. We discuss it separately in this section, but its water quality closely parallels that of the Wareham River. The Buzzards Bay Project has not completed a separate subwatershed evaluation for the Broadmarsh estuary, and such an approach may not be warranted because of the overwhelming influence of the Wareham River on water quality conditions here.

Water Quality

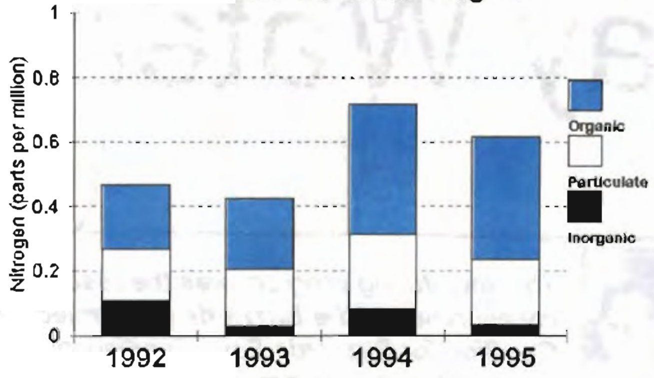
The Broadmarsh River estuary is somewhat unusual in that the inner and outer embayments have very similar water quality, largely due to the "external" inputs from the Wareham River. In fact in one year total nitrogen was higher in the outer than it was in the inner. Overall total nitrogen concentrations parallel the pattern of the Wareham River, including the large spike of different forms of nitrogen in the water in 1994 (but at concentrations not quite as high as in the central portions of the Wareham River). Phytoplankton concentrations were less variable, with levels both above and below comparable years in the Wareham River. In other words, the Broadmarsh River parallels the Wareham River, but the patterns are somewhat "damped out". Oxygen saturation levels were better in Broadmarsh than the Wareham River, but showed a steady decline during the 4 years of study. The pattern shown in the graph of station BMR1 oxygen saturation is very apparent. The summertime highs, mean values, and summertime lows show a steady decline. During the same period, total organic nitrogen in the water showed large increases in concentration. These combined changes resulted in markedly lower Eutrophication Index Scores during 1994 and 1995.

The results from the Broadmarsh River estuary support the general observations that waters in the Wareham River complex are becoming more eutrophic, with water quality being particularly poor in 1994.

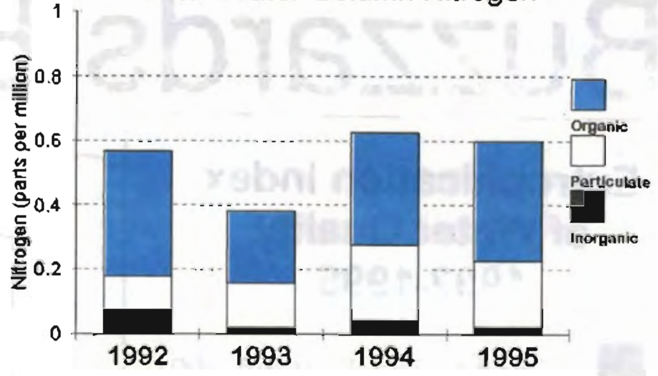
Nitrogen Management Needs

With respect to water quality the Broadmarsh River estuary appears somewhat distinct from the greater Wareham River estuary complex and could require a separate nitrogen management strategy. However, water quality in this subestuary will improve only if nitrogen is also managed in the Wareham River watershed.

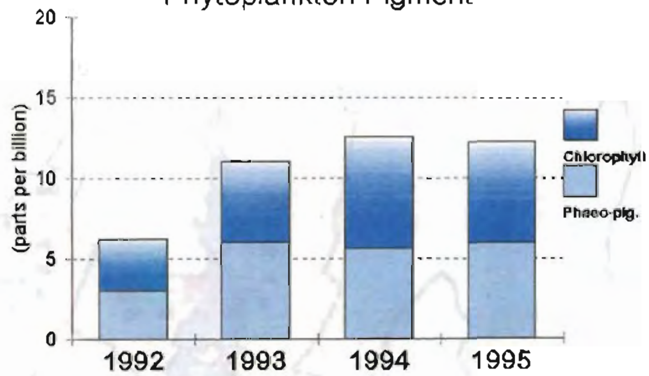
Broadmarsh River (Inner)
Total Water Column Nitrogen



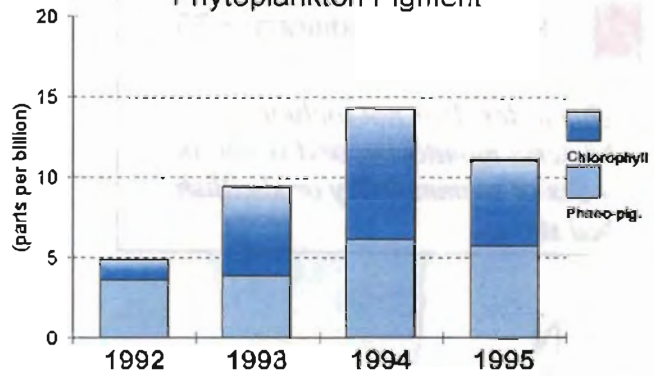
Broadmarsh River (Outer)
Total Water Column Nitrogen



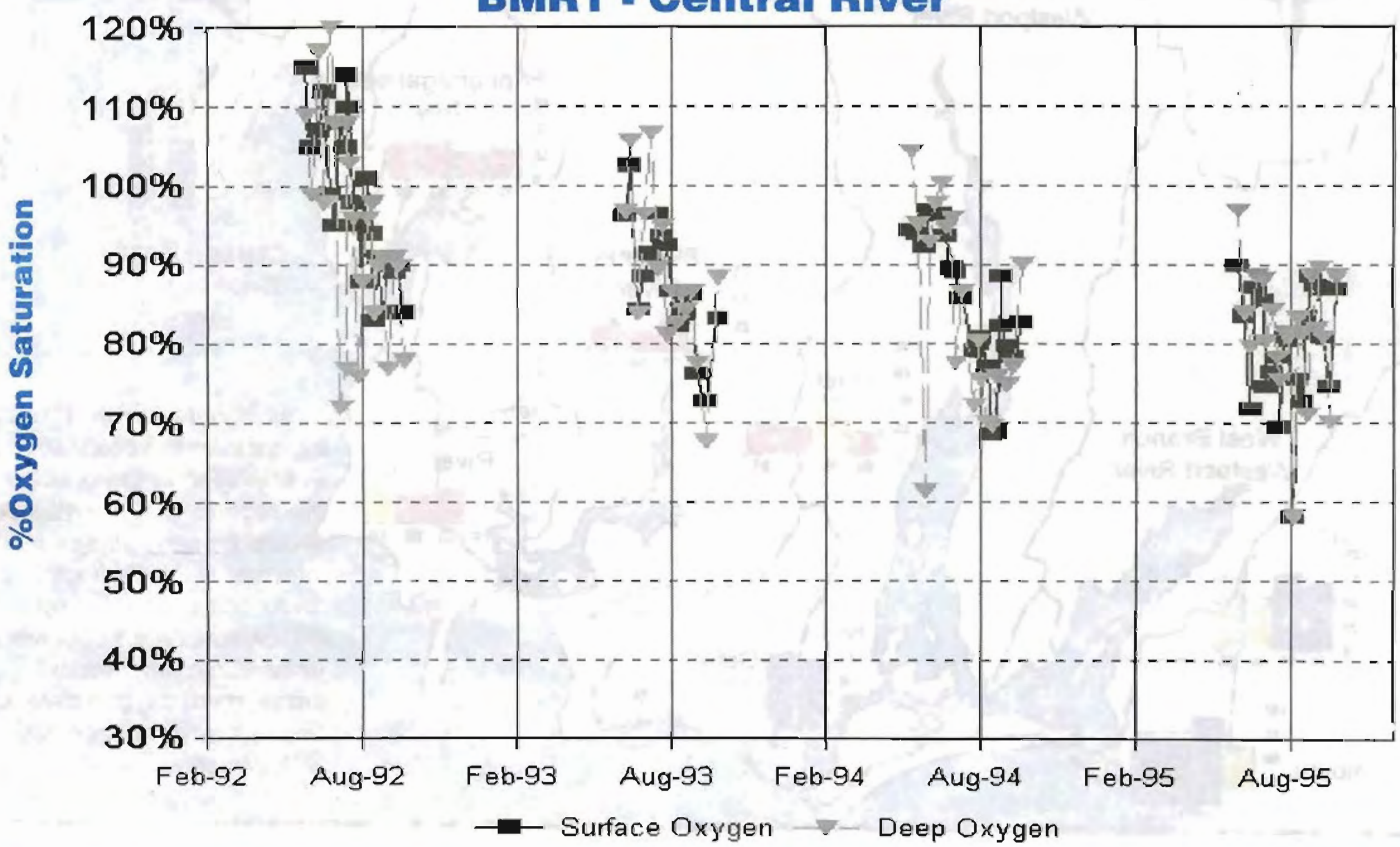
Broadmarsh River (Inner)
Phytoplankton Pigment



Broadmarsh River (Outer)
Phytoplankton Pigment



BMR1 - Central River



Buzzards Bay Water Qu

Eutrophication Index of Water Quality 1992-1995

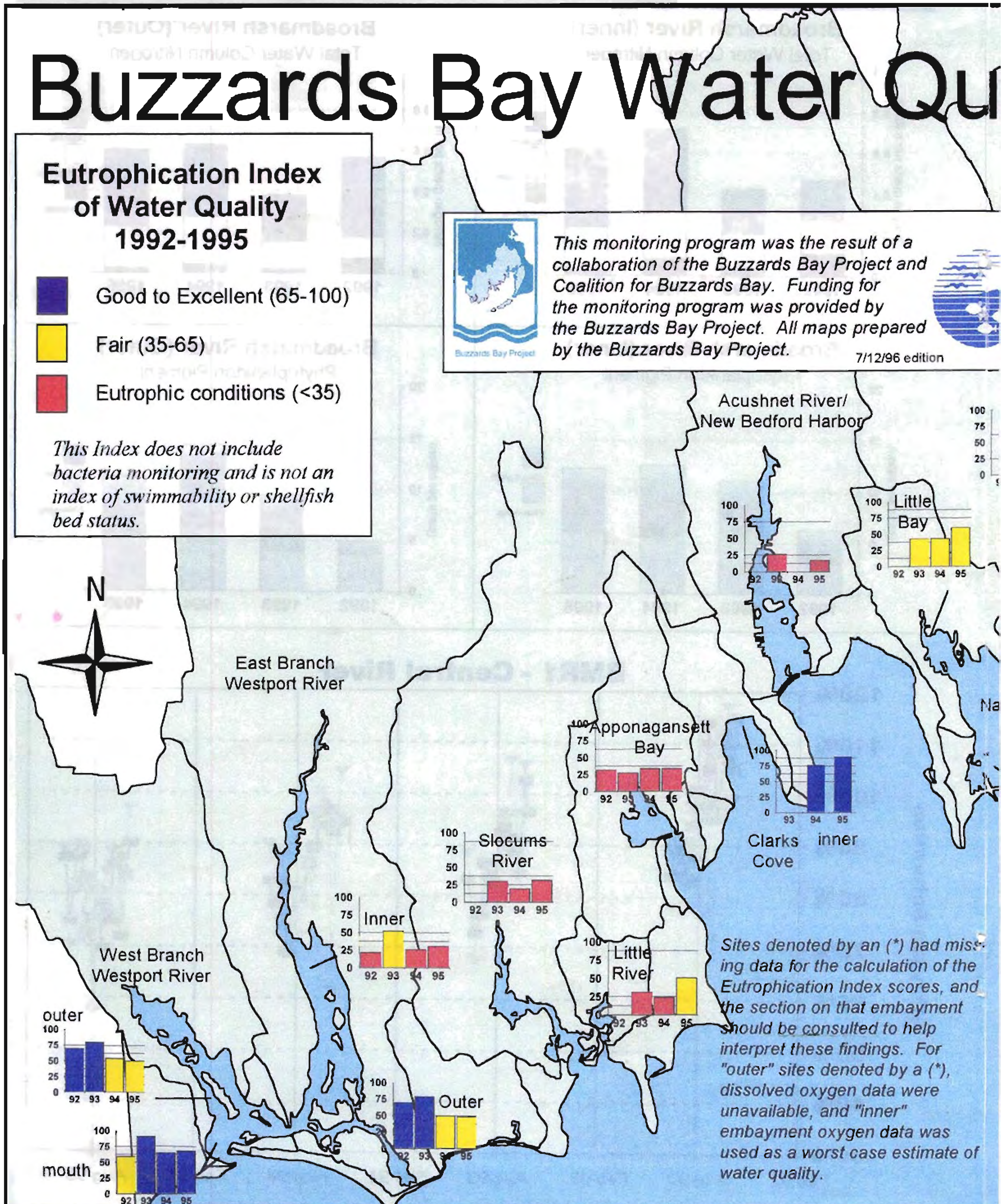
- Good to Excellent (65-100)
- Fair (35-65)
- Eutrophic conditions (<35)

This Index does not include bacteria monitoring and is not an index of swimmability or shellfish bed status.

Buzzards Bay Project

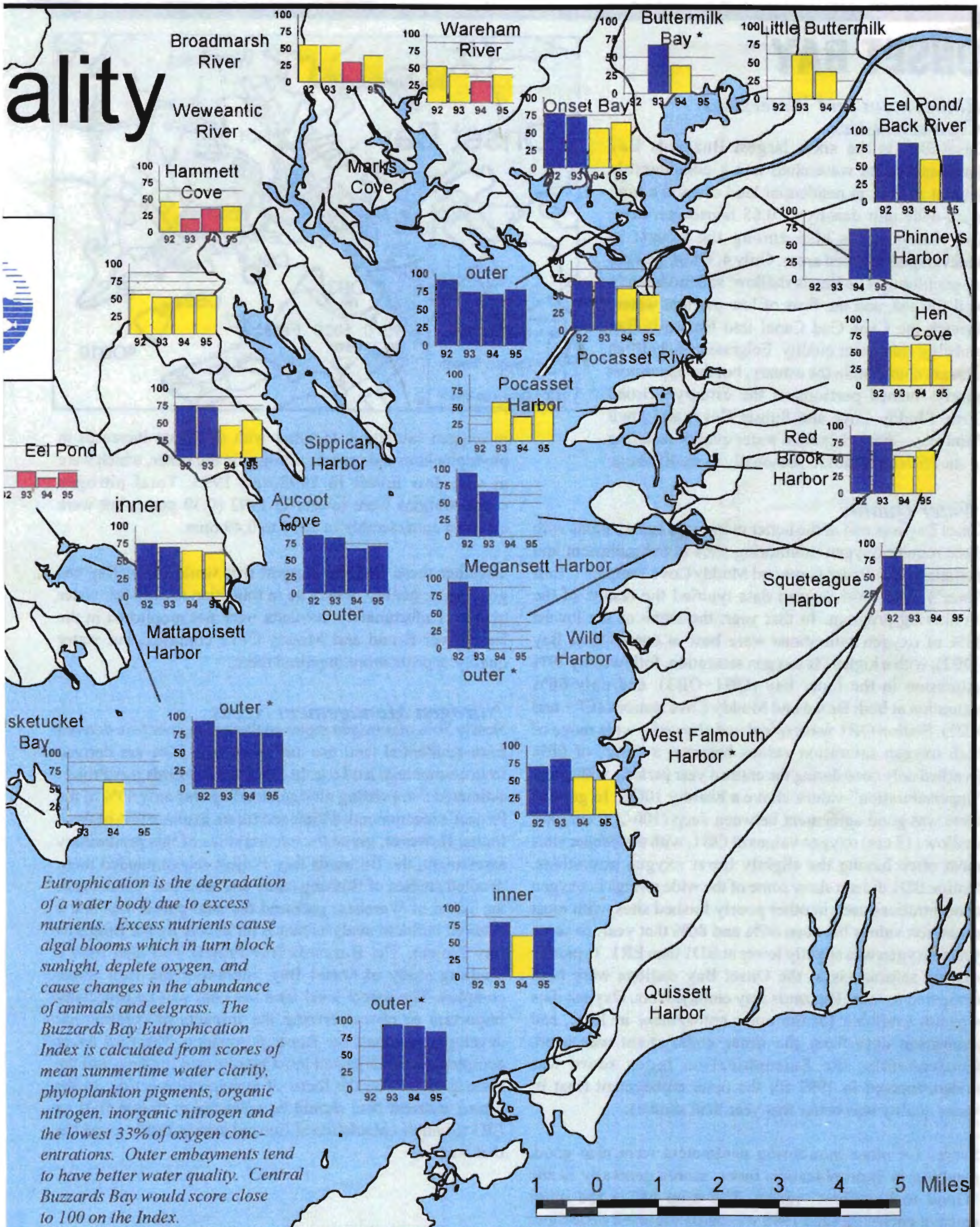
This monitoring program was the result of a collaboration of the Buzzards Bay Project and Coalition for Buzzards Bay. Funding for the monitoring program was provided by the Buzzards Bay Project. All maps prepared by the Buzzards Bay Project.

7/12/96 edition



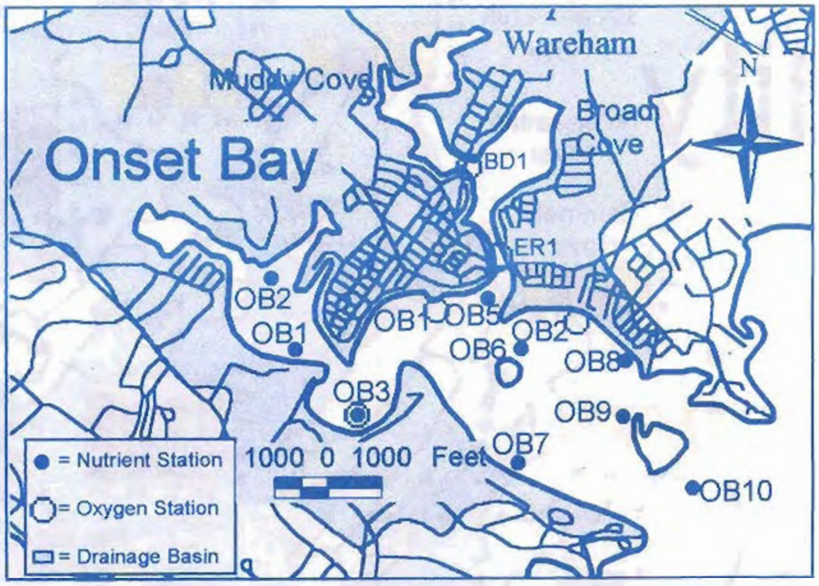
Sites denoted by an (*) had missing data for the calculation of the Eutrophication Index scores, and the section on that embayment should be consulted to help interpret these findings. For "outer" sites denoted by a (*), dissolved oxygen data were unavailable, and "inner" embayment oxygen data was used as a worst case estimate of water quality.

ality



Eutrophication is the degradation of a water body due to excess nutrients. Excess nutrients cause algal blooms which in turn block sunlight, deplete oxygen, and cause changes in the abundance of animals and eelgrass. The Buzzards Bay Eutrophication Index is calculated from scores of mean summertime water clarity, phytoplankton pigments, organic nitrogen, inorganic nitrogen and the lowest 33% of oxygen concentrations. Outer embayments tend to have better water quality. Central Buzzards Bay would score close to 100 on the Index.

ONSET BAY



Embayment and Watershed Characteristics

Onset Bay is the sixth largest Buzzards Bay embayment. Its watershed has a considerable amount of land in residential land use and a high basin-wide unit density of 0.65 houses per acre. The watershed is also among the lowest in undeveloped forested areas. Only 4.3% of the land is agricultural. The Bay is shallow, and moderately well flushed, and the flow of low nutrient waters through the Cape Cod Canal into Buzzards Bay probably aids water quality. Eelgrass and shellfish beds are abundant in the estuary, but the uppermost poorly flushed portions of the estuary—Broad Cove, Muddy Cove and Sunset Cove, and Shell Point Bay—have degraded water quality resulting in shellfish beds closed seasonally to shellfishing.

Water Quality

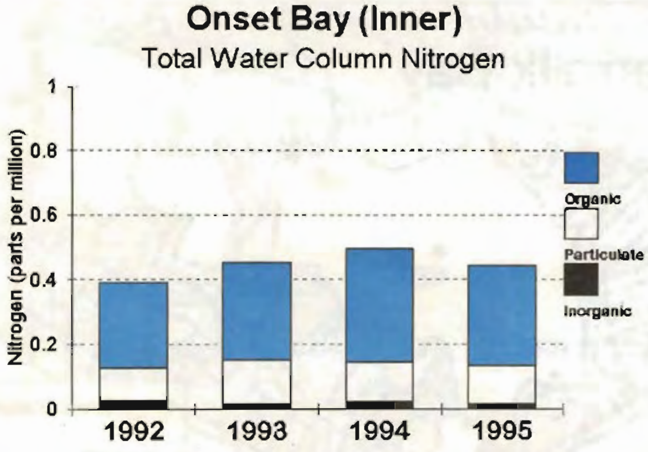
Onset Bay was one of the better monitored embayments with three regular oxygen monitoring sites in the mainstem and two sites in the Broad Cove and Muddy Cove complex ("East River"). The 1994 oxygen data typified the results of the monitoring program. In that year, the mean of the lowest 33% of oxygen saturations were best in outer Onset Bay (OB2), with a high 91% oxygen saturation, followed by 79% saturation in the inner bay (OB1+OB3), and only 66% saturation at both Broad and Muddy Cove stations (ER1 and BD1). Station OB1 was typical and showed a wide range of high oxygen saturation values between a "low" of 60% (reached only once during the entire 4 year period), with many "supersaturation" values above a healthy 100%. In general there was good agreement between deep (100-200 cm) and shallow (15 cm) oxygen values at OB1, with the deeper sites most often having the slightly lower oxygen saturations. Station BD1 did not show some of the wide swings in oxygen concentrations seen in other poorly flushed sites, with most saturation values between 66% and 86% that year. In some years, oxygen was slightly lower at BD1 than ER1. Typically oxygen saturations at the Onset Bay stations were high compared to most Buzzards Bay embayments. Oxygen data was not available for the outer embayment in 1992, and saturation data from the inner embayment was used. Consequently, the Eutrophication Index score was underestimated in 1992 for the outer embayment (that is, water quality was better that year than shown).

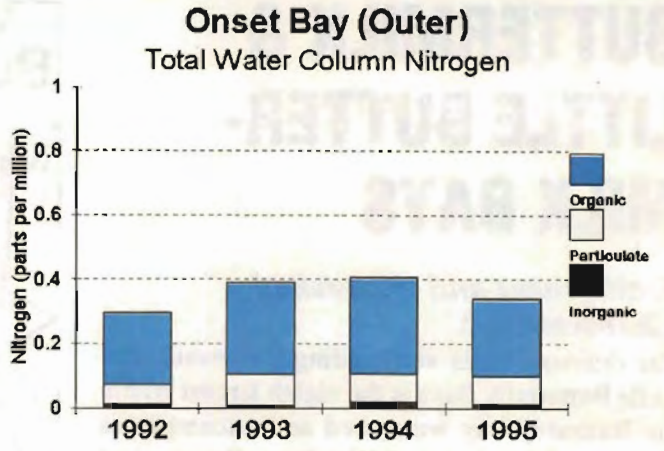
Scores for other monitoring parameters were also good, resulting in Eutrophication Index scores generally in the "Good to Excellent" range. The drop off in the inner embayment in 1994 and 1995 was partly the result of declines in oxygen saturation, together with moderate increases in phytoplankton and organic nitrogen in the water, which were at very low levels in 1992 and 1993. Total nitrogen concentrations were lowest in 1992 (0.39 ppm), but were elevated considerably in 1994 to 0.49 ppm.

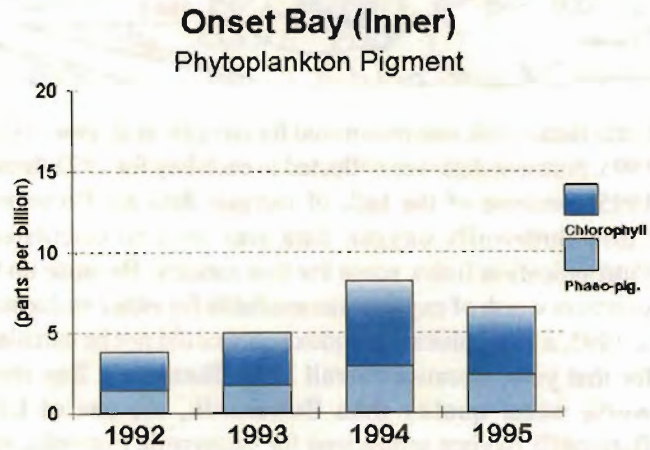
Together these findings suggest that while Onset Bay has good water quality, it may be in transition to only fair water quality. Unfortunately nutrients were not monitored in the East River-Broad and Muddy Cove complex, but water quality appears more impaired there.

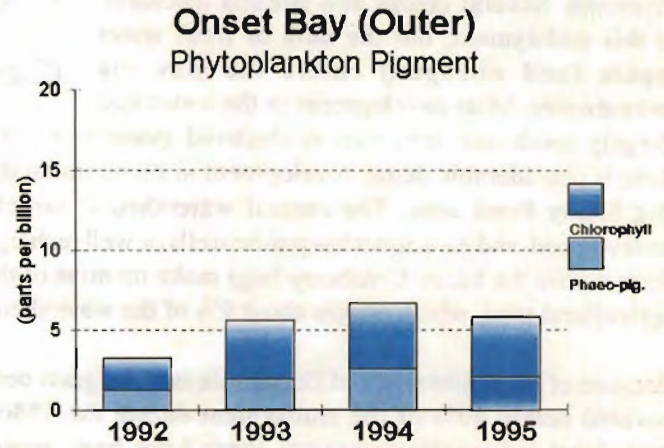
Nitrogen Management Needs

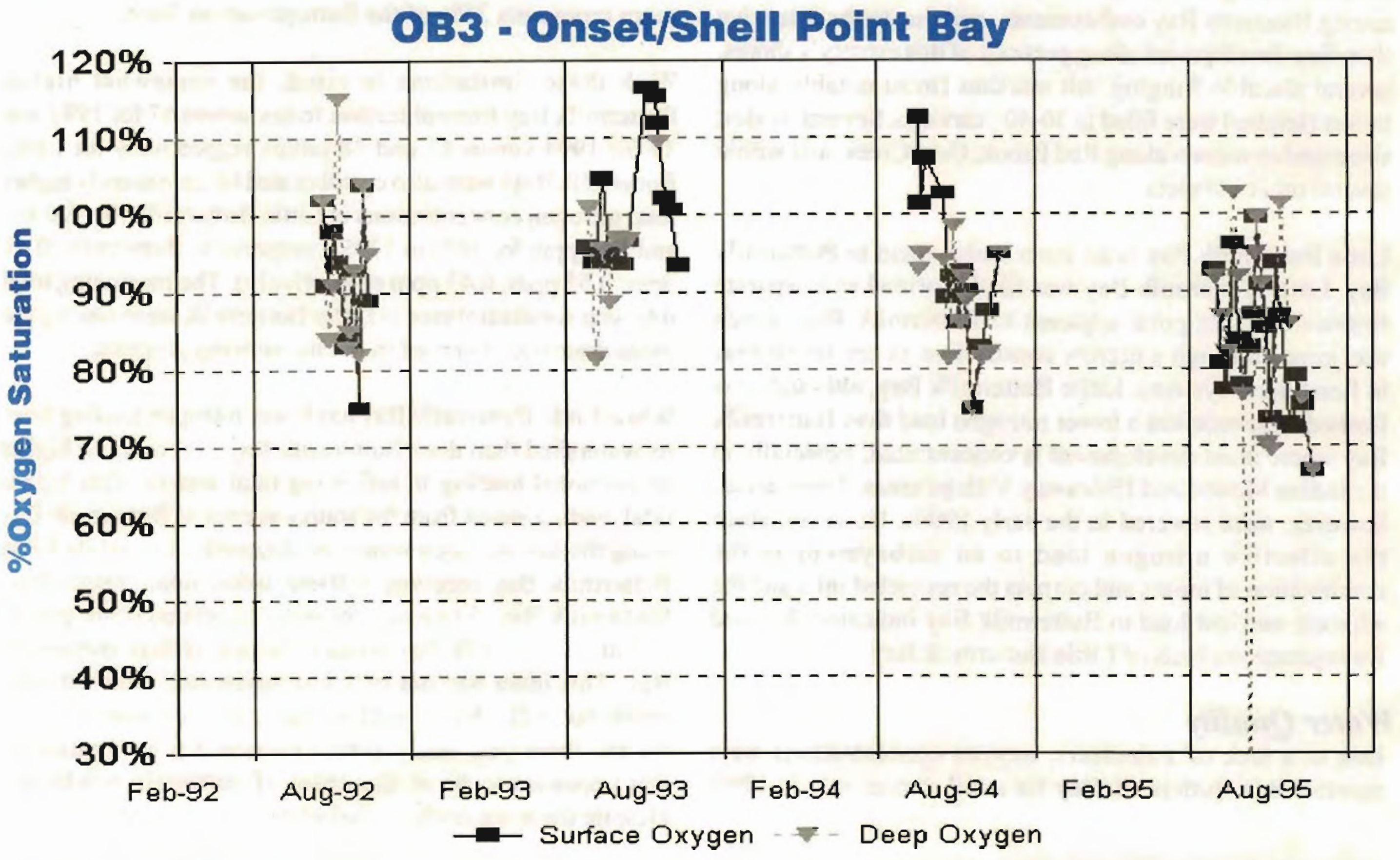
Nearly 50% of nitrogen inputs to this embayment are derived from residential land use and more than 30% are derived from commercial land use. In 1995, the Buzzards Bay Project estimated that existing nitrogen loading was only 60% of the Project's recommended limit and future loading 96% of these limits. However, given the uncertainties of this preliminary assessment, the Buzzards Bay Project recommended more detailed studies of flushing study and land use. To this end, the Town of Wareham gathered the land parcel data and a detailed buildout analysis that is underway by the Buzzards Bay Project. The Buzzards Bay Project will also fund a flushing study of Onset Bay, including the East River complex. The parcel level land use data will be especially important in characterizing the impacts of commercial development along the Route 6 corridor. The East River complex seems impacted most by nitrogen loading, and the subarea should be the focus of management action. In the future, nutrient data should be collected at station BD1 or ER1 to enable calculation of Eutrophication Index scores for that area.


Onset Bay (Inner)
Total Water Column Nitrogen
Nitrogen (parts per million)
0
0.2
0.4
0.6
0.8
1
Organic
Particulate
Inorganic
1992
1993
1994
1995

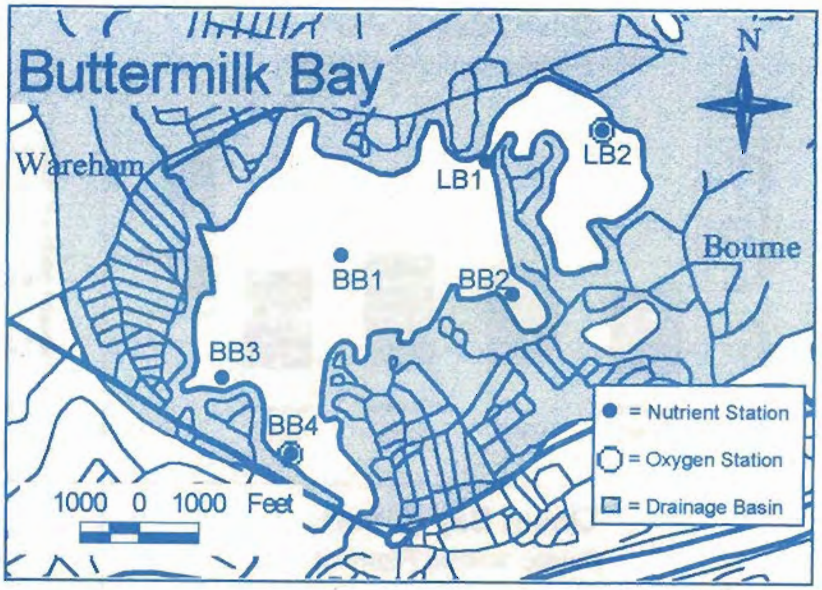

Onset Bay (Outer)
Total Water Column Nitrogen
Nitrogen (parts per million)
0
0.2
0.4
0.6
0.8
1
Organic
Particulate
Inorganic
1992
1993
1994
1995


Onset Bay (Inner)
Phytoplankton Pigment
(parts per billion)
0
5
10
15
20
Chlorophyll
Phaeo-pig.
1992
1993
1994
1995


Onset Bay (Outer)
Phytoplankton Pigment
(parts per billion)
0
5
10
15
20
Chlorophyll
Phaeo-pig.
1992
1993
1994
1995


OB3 - Onset/Shell Point Bay
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
Feb-92
Aug-92
Feb-93
Aug-93
Feb-94
Aug-94
Feb-95
Aug-95
Surface Oxygen
Deep Oxygen

BUTTERMILK & LITTLE BUTTERMILK BAYS



Embayment and Watershed Characteristic

The drainage basin surrounding Buttermilk and Little Buttermilk Bays is the eighth largest within the Buzzards Bay watershed and encompasses portions of the towns of Wareham, Bourne, and Plymouth. Several creeks and streams discharge to this embayment, but the bulk of fresh water inputs (and nitrogen) enters the Bay via groundwater. Most development in the watershed (largely residential land use) is clustered along shore, but there is considerable dense development in Plymouth in the Big Sandy Pond area. The central watershed is largely undeveloped, and each town has public wells or well recharge areas within the basin. Cranberry bogs make up most of the agricultural land, which covers about 9% of the watershed.

Because of the shallowness of Buttermilk Bay, eelgrass beds covered nearly 40% of the embayment during the 1980s. Anecdotal information suggests there have been recent declines in eelgrass cover. Total salt marsh cover ranked low among Buzzards Bay embayments, and due to the intensive shoreline development along portions of this estuary's shores, several sizeable fringing salt marshes (most notably along Indian Heights) were filled in 30-40 years ago. Several modest size marshes remain along Red Brook, Goat Creek, and within several other covelets.

Little Buttermilk Bay is an inner embayment to Buttermilk Bay. Little Buttermilk Bay was likely formed as a separate freshwater kettle pond adjacent to Buttermilk Bay, which was joined through a narrow constriction as sea-levels rose to flood these systems. Little Buttermilk Bay, although less flushed, also receives a lower nitrogen load than Buttermilk Bay where most development is concentrated, especially in the Indian Mound and Hideaway Village areas. These areas, however, were sewered in the early 1990s. However, since the effective nitrogen load to an embayment is the combination of inputs and outputs the restricted inlet and the adjacent nutrient load to Buttermilk Bay indicated the need for separate analysis of Little Buttermilk Bay.

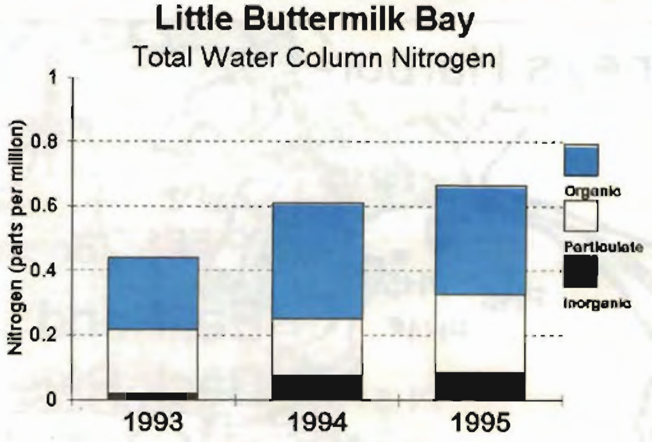
Water Quality

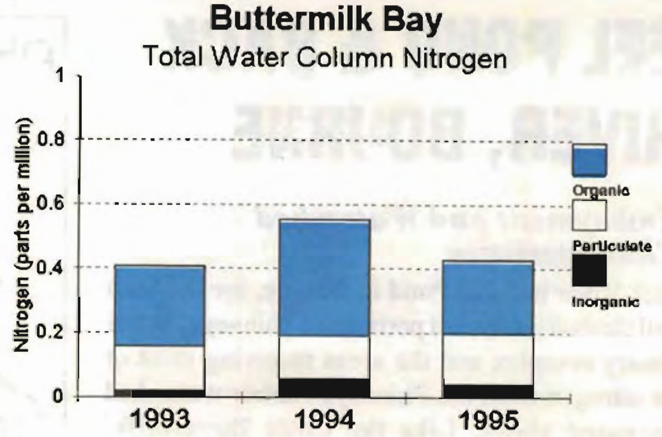
Due to a lack of volunteers, oxygen concentrations were monitored in Buttermilk Bay for a full season only in 1992. Little Buttermilk was monitored for oxygen in all years except 1995. Nutrient data was collected in each bay for 1993 through 1995. Because of the lack of oxygen data for Buttermilk, Little Buttermilk oxygen data was used to calculated a Eutrophication Index score for that estuary. Because no full summers worth of oxygen was available for either embayment in 1995, a Eutrophication Index score could not be calculated for that year. Because overall Little Buttermilk Bay shows worse water quality than Buttermilk, the use of Little Buttermilk oxygen saturations for Buttermilk Eutrophication Index scores represent a "worst case" scenario (the oxygen score represents 25% of the Eutrophication Score).

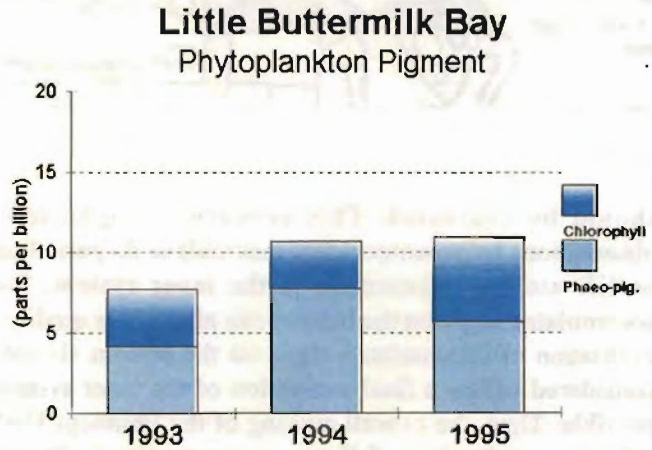
With these limitations in mind, the somewhat higher Buttermilk Bay Eutrophication Index scores 67 for 1993 and 39 for 1994 versus 61 and 38 points respectively for Little Buttermilk Bay) were also corroborated by consistently higher total nitrogen concentrations in Little Buttermilk (0.44, 0.61, and 0.69 ppm for 1993 to 1995) compared to Buttermilk (0.41 ppm, 0.55 ppm, 0.43 ppm respectively). The increasing total nitrogen concentrations in Little Buttermilk were among the more dramatic observed in the monitoring program.

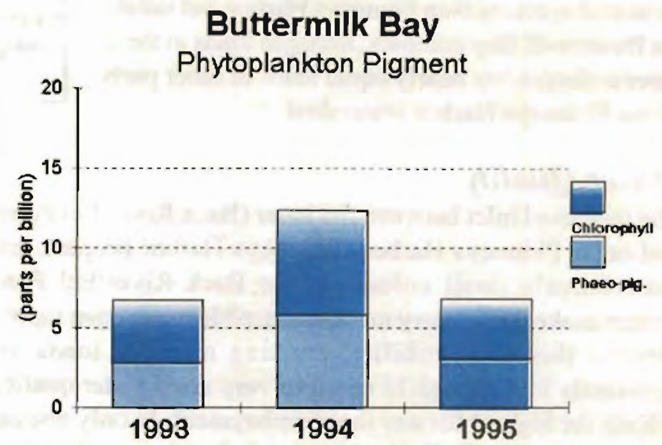
While Little Buttermilk Bay has lower nitrogen loading from its watershed than does Buttermilk Bay, it receives a higher proportional loading in inflowing tidal waters. This higher tidal loading stems from the source waters of Buttermilk Bay being the low nitrogen waters of Buzzards Bay, while Little Buttermilk Bay receives nutrient laden tidal waters from Buttermilk Bay. As a result the nutrient related water quality of Little Buttermilk Bay tends to be poorer than Buttermilk Bay. This inner bay not only has moderately high nitrogen levels but with phytoplankton pigment levels averaging 9.8 for the three year study period (versus 8.6 for Buttermilk Bay) appears to be at the onset of eutrophic conditions. Despite these somewhat pessimistic observations, oxygen

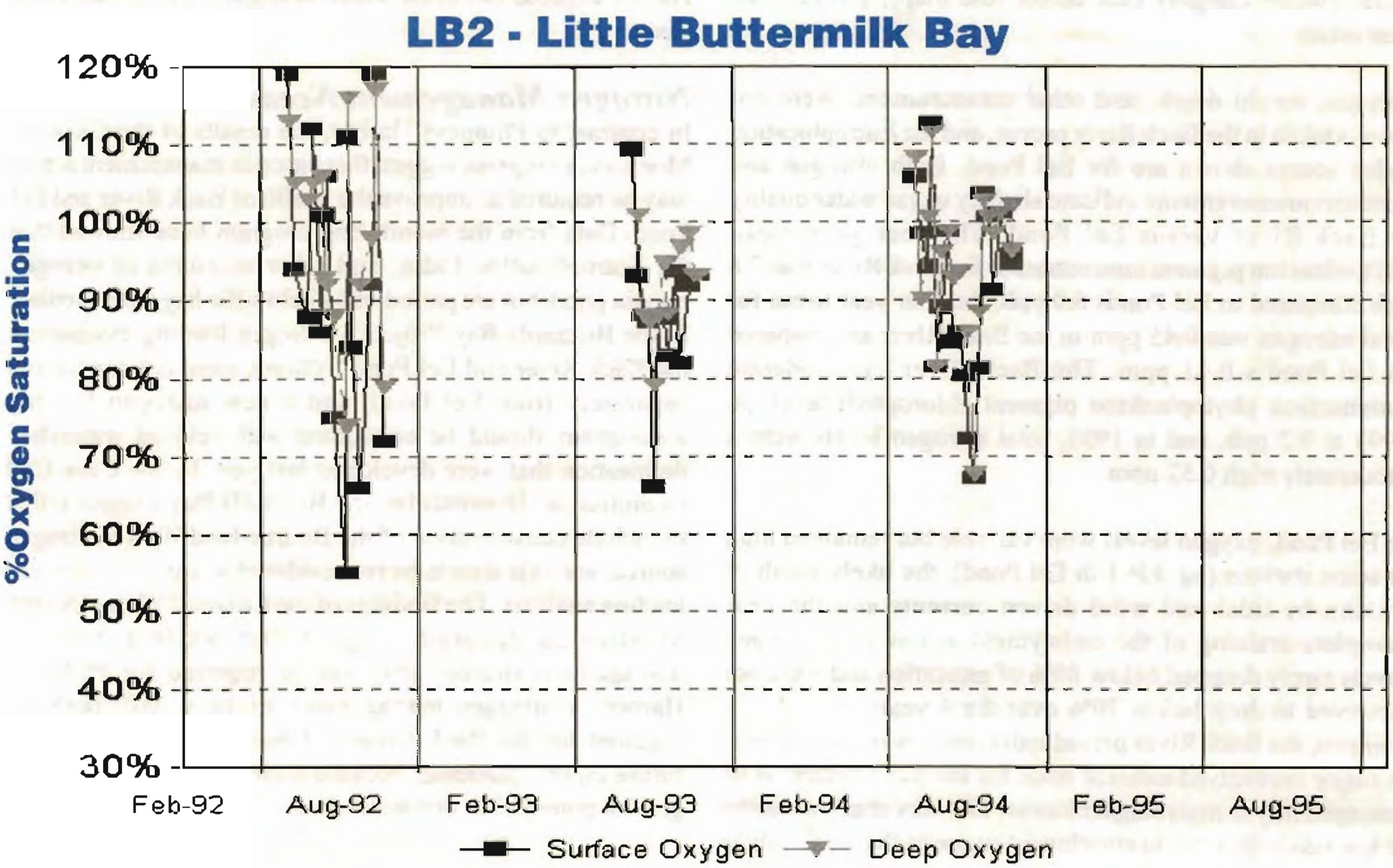
Continued on page 65


Little Buttermilk Bay
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1993
1994
1995
Organic
Particulate
Inorganic

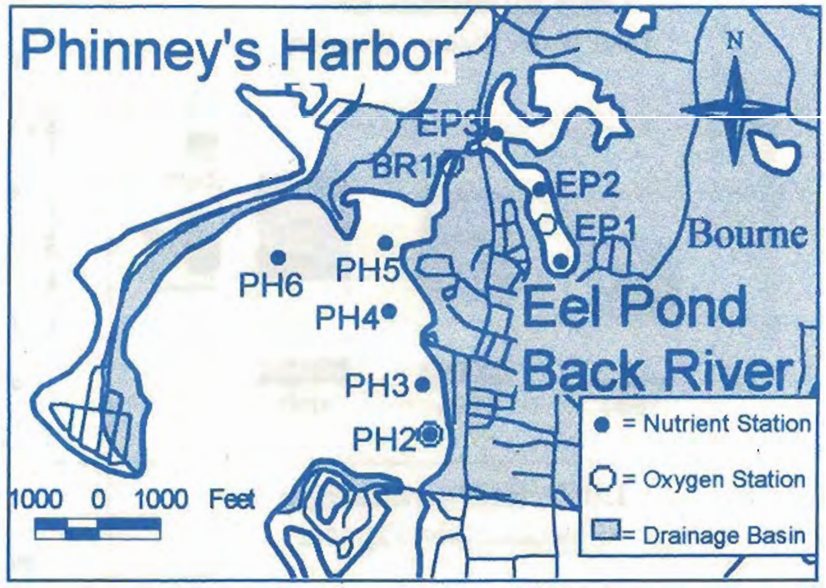

Buttermilk Bay
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1993
1994
1995
Organic
Particulate
Inorganic


Little Buttermilk Bay
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1993
1994
1995
Chlorophyll
Phaeo-pig.


Buttermilk Bay
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1993
1994
1995
Chlorophyll
Phaeo-pig.


LB2 - Little Buttermilk Bay
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
Feb-92
Aug-92
Feb-93
Aug-93
Feb-94
Aug-94
Feb-95
Aug-95
Surface Oxygen
Deep Oxygen

EEL POND & BACK RIVER, BOURNE



Embayment and Watershed Characteristics

Back River and Eel Pond in Bourne, are the least well flushed innermost portions of Phinneys Harbor estuary complex and the areas receiving most of the nitrogen from the Phinneys Harbor watershed discussed above. Like the Little Buttermilk/ Buttermilk Bay system, water quality is worse in these embayments than Phinneys Harbor, but unlike the Buttermilk Bay complex, nitrogen loads in these inner embayments nearly equal loads in other parts of the Phinneys Harbor watershed.

Water Quality

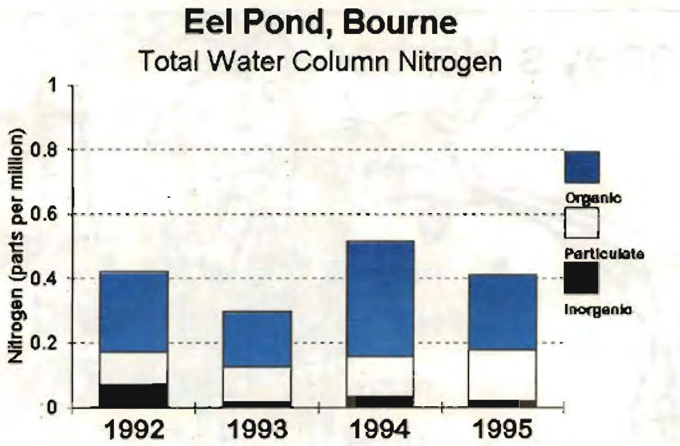
The restricted inlet between the inner (Back River/Eel Pond) and outer Phinneys Harbor (Phinneys Harbor proper), and the relatively small volume of the Back River/Eel Pond system make this estuary more susceptible to nitrogen inputs. Despite this susceptibility, existing nitrogen loads are apparently low enough to result in very good water quality, among the highest for any inner embayment. In only one out of four years did the Eutrophication Index drop in the "fair" water quality category (see center fold map), and the four year mean.

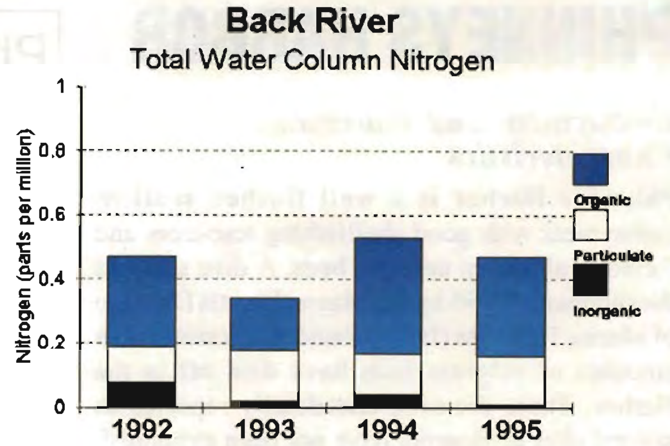
Oxygen, secchi depth, and other measurements were not always taken in the Back River proper, and the Eutrophication Index scores shown are for Eel Pond. Both nitrogen and plankton measurements indicate slightly worse water quality in Back River versus Eel Pond. The four year mean phytoplankton pigment concentration for Back River was 7.8 ppb compared to Eel Ponds 6.0 ppb, the four year mean for total nitrogen was 0.45 ppm in the Back River as compared to Eel Pond's 0.41 ppm. The Back River had moderate summertime phytoplankton pigment chlorophyll levels in 1993 at 9.2 ppb, and in 1995, total nitrogen levels were a moderately high 0.52 ppm.

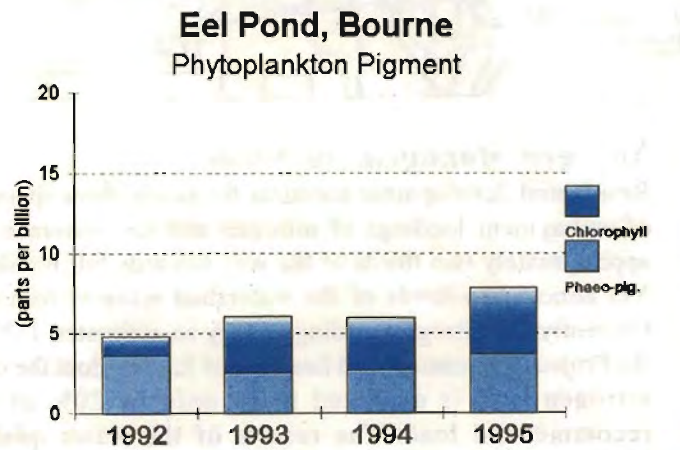
In Eel Pond, oxygen levels were variable but remained high at some stations (eg. EP-1 in Eel Pond), the likely result of mixing by tidal and wind driven currents and the near complete draining of the embayment at low tide. Oxygen levels rarely dropped below 80% of saturation and were not observed to drop below 70% over the 4 years of study. In contrast, the Back River periodically had low oxygen levels. A major unresolved nutrient issue for the inner system is its susceptibility to macroalgal blooms. The very shallow depths at low tide with nutrient enrichment suggests that macroalgae should be evaluated. This concern is supported by observations by volunteers that macroalgae do periodically proliferate and accumulate in the inner system. Since accumulated algae on the bottom can alter water quality, an evaluation of accumulated algae on the bottom should be considered before a final evaluation of the inner system is possible. Thus, the overall ranking of the Phinneys Harbor estuary complex is as follows: water quality in Phinneys Harbor exceeds Eel Pond which is slightly better than Back River.

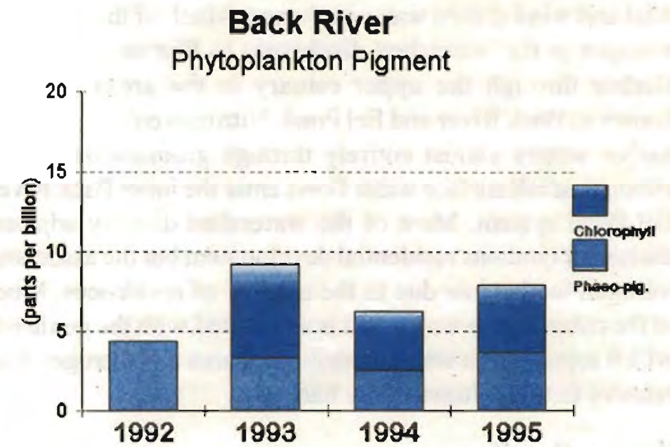
Nitrogen Management Needs

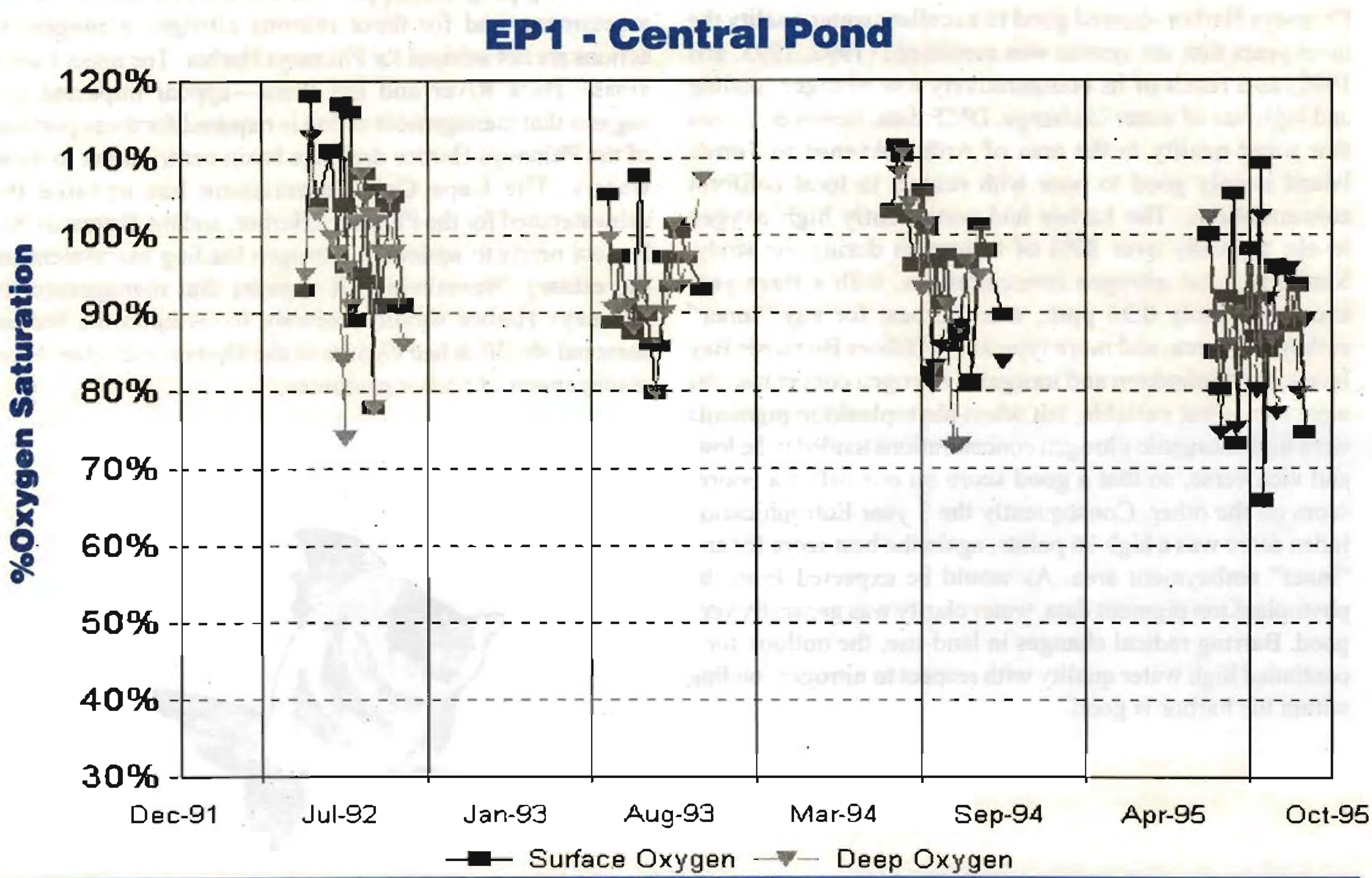
In contrast to Phinneys Harbor, the results of the Citizens' Monitoring Program suggest that nitrogen management action may be required to improve the health of Back River and Eel Pond. Data from the monitoring program have showed that the Eutrophication Index, and other measures of nitrogen remain good, but are periodically below the bay wide median. In the Buzzards Bay Project's nitrogen loading evaluation, the Back River and Eel Pond Systems were not considered separately from Eel Pond, and a new nitrogen loading assessment should be conducted with revised watershed delineation that were developed last year by the Cape Cod Commission. In particular, the Buzzards Bay Project failed to include consideration of the Bourne landfill as a nitrogen source, and this should be reconsidered in any new nitrogen loading analysis. The findings of the Citizens' Water Quality Monitoring Program suggest that while a nitrogen management strategy may not be required for Phinneys Harbor, a nitrogen management strategy will likely be required for the Back River-Eel Pond complex to mange future inputs, particular because their remains considerable growth potential in this watershed.


Eel Pond, Bourne
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1992
1993
1994
1995
Organic
Particulate
Inorganic

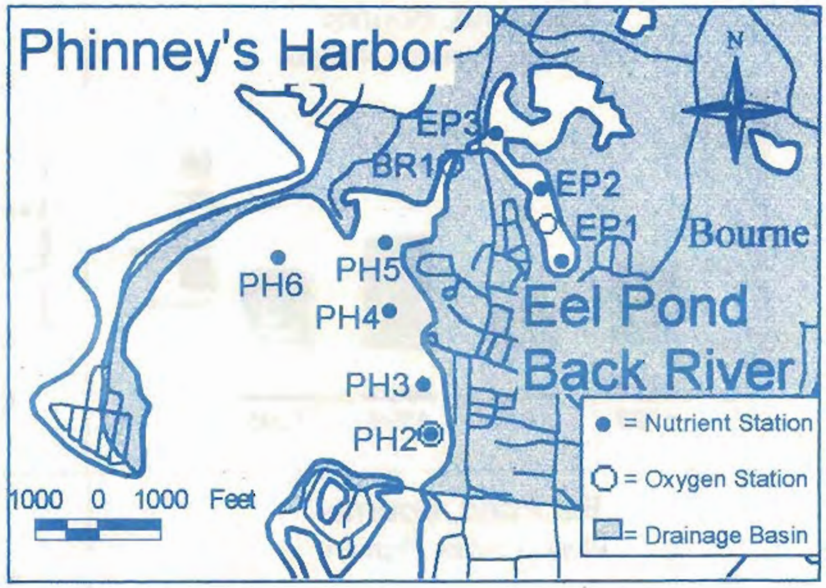

Back River
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1992
1993
1994
1995
Organic
Particulate
Inorganic


Eel Pond, Bourne
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1992
1993
1994
1995
Chlorophyll
Phaeo-pig.


Back River
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1992
1993
1994
1995
Chlorophyll
Phaeo-pig.


EP1 - Central Pond
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
Dec-91
Jul-92
Jan-93
Aug-93
Mar-94
Sep-94
Apr-95
Oct-95
Surface Oxygen
Deep Oxygen

PHINNEYS HARBOR



Embayment and Watershed Characteristics

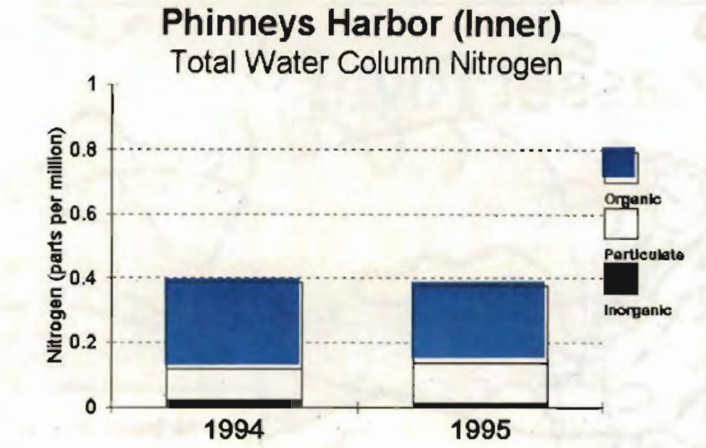
Phinneys Harbor is a well flushed shallow embayment with good shellfishing resources and formerly abundant eelgrass beds. A dive study in the summer of 1995 by the Massachusetts Division of Marine Fisheries (DMF) found that considerable amounts of eelgrass beds have died off in the Harbor. These die-offs, anecdotally reported in several sites in Bourne, have not been explained. The harbor is relatively open which enhances both tidal and wind driven water exchange. Much of the nitrogen in the watershed discharges to Phinneys Harbor through the upper estuary in the areas known as Back River and Eel Pond. Nitrogen enters harbor waters almost entirely through groundwater flows, although small surface water flows enter the inner Back River/Eel Pond system. Most of the watershed directly adjacent the harbor contains residential development but the associated nitrogen load is low due to the number of residences. 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.

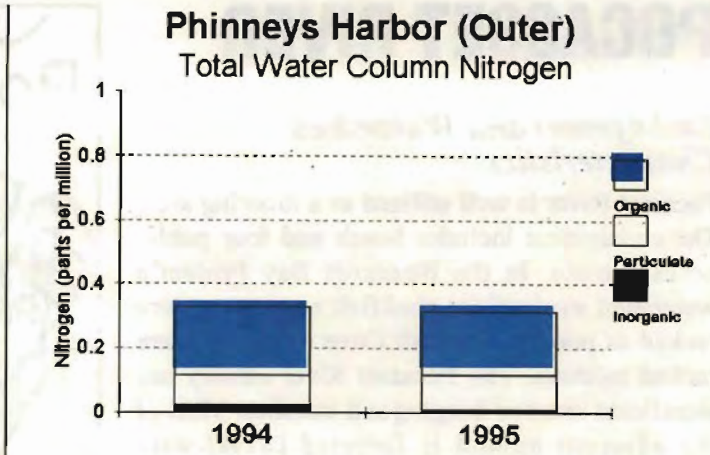
Water Quality

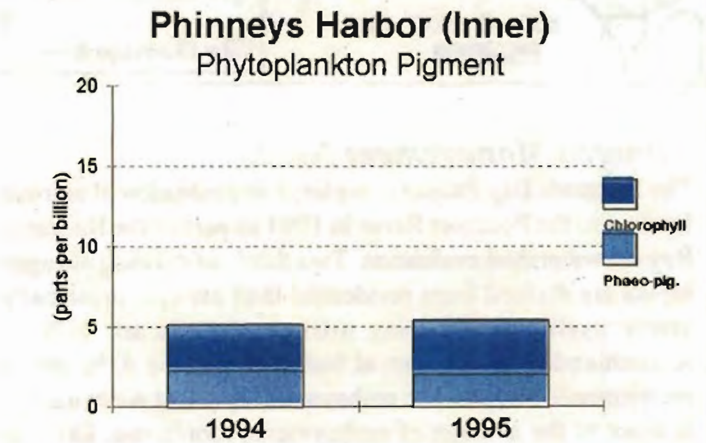
Phinneys Harbor showed good to excellent water quality the three years that the system was monitored (1992, 1993, and 1995) as a result of its comparatively low nitrogen loading and high rate of water exchange. DMF data, however, shows that water quality in the area of Arthur Avenue to Toby's Island is only good to poor with respect to fecal coliform concentrations. The harbor had consistently high oxygen levels, typically over 80% of saturation during the study. Similarly, total nitrogen concentrations, with a three year average of only 0.36 ppm, was the best for any "inner" embayment area, and more typical of offshore Buzzards Bay levels. Phytoplankton and inorganic nitrogen concentrations were somewhat variable, but when phytoplankton pigments were high inorganic nitrogen concentrations tended to be low, and vice versa, so that a good score on one offset a poorer score on the other. Consequently the 3 year Eutrophication Index score was a high 76 points, again the best score for any "inner" embayment area. As would be expected from the phytoplankton pigment data, water clarity was generally very good. Barring radical changes in land-use, the outlook for a continued high water quality with respect to nitrogen loading within the harbor is good.

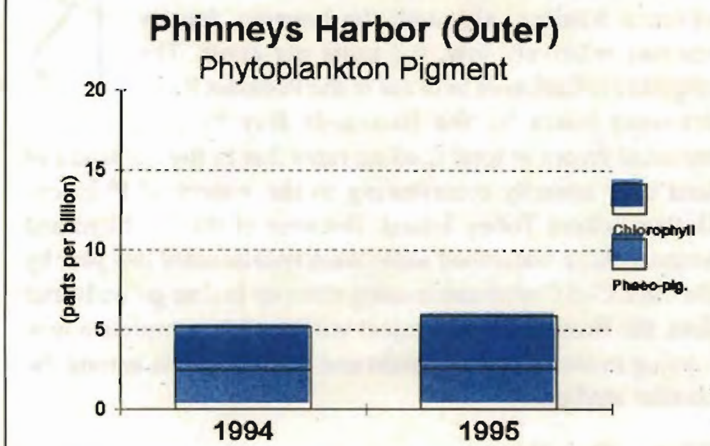
Nitrogen Management Needs

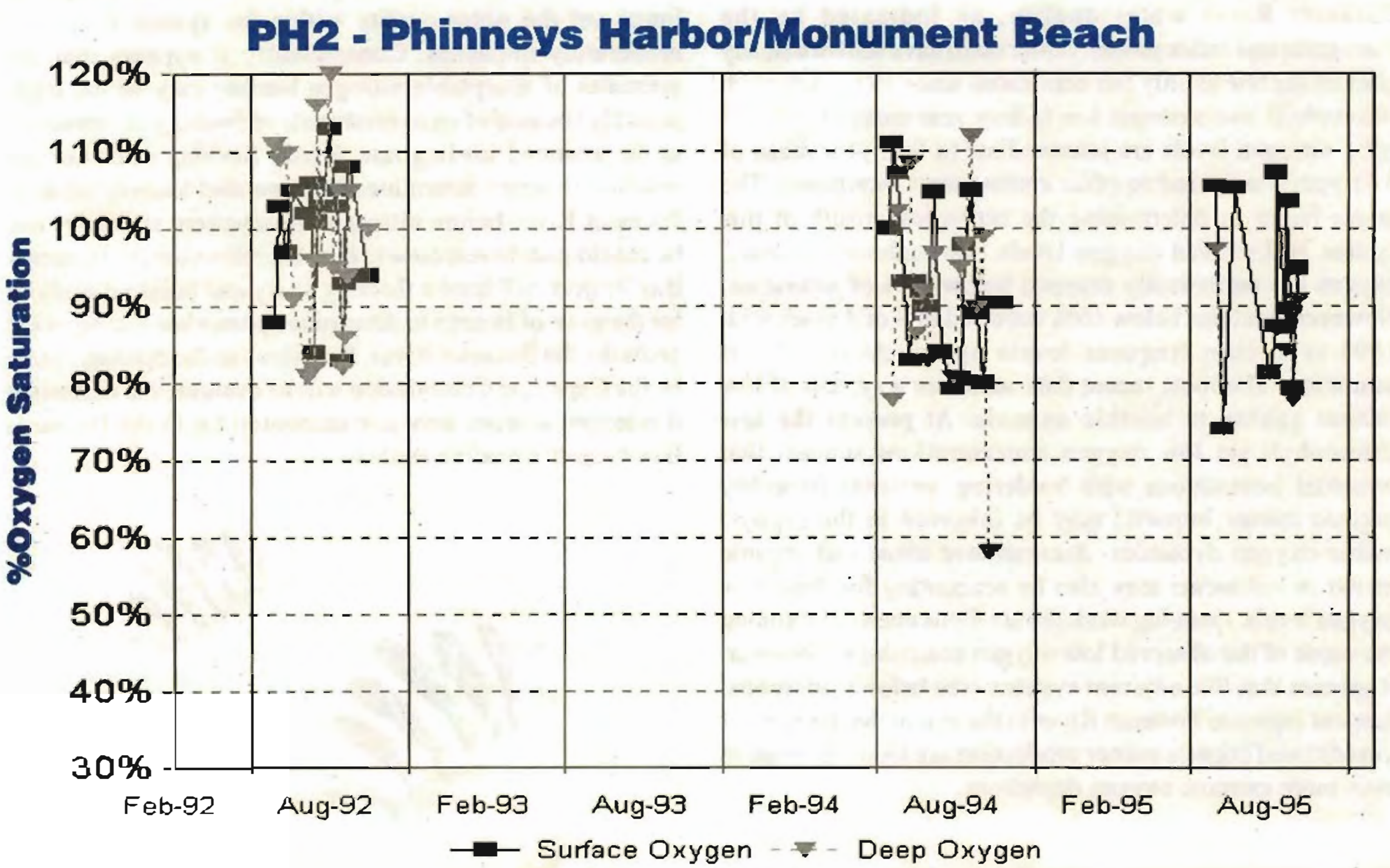
Residential development accounts for nearly three-quarters of embayment loadings of nitrogen and the watershed is approximately two thirds of the way towards full buildout. Yet almost two-thirds of the watershed remains forested. Currently the nitrogen loading is only an estimated 14% of the Project's recommended limit and at full buildout the total nitrogen load is expected to be only be 20% of the recommended load. The results of the water quality monitoring program support the current conditions loading assessment, and for these reasons nitrogen management actions are not advised for Phinneys Harbor. The upper harbor areas—Back River and Eel Pond—appear impacted and suggest that management action is required for those portions of the Phinneys Harbor drainage basin contributing to those waters. The Cape Cod Commission has updated the subwatershed for the Phinneys Harbor, and the Buzzards Bay Project needs to update its nitrogen loading assessment for the estuary. Nonetheless, it appears that management of Phinneys Harbor should probably focus upon the limited seasonal shellfish bed closure in the Harbor and other direct management of harbor resources.


Phinneys Harbor (Inner)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1994
1995
Organic
Particulate
Inorganic

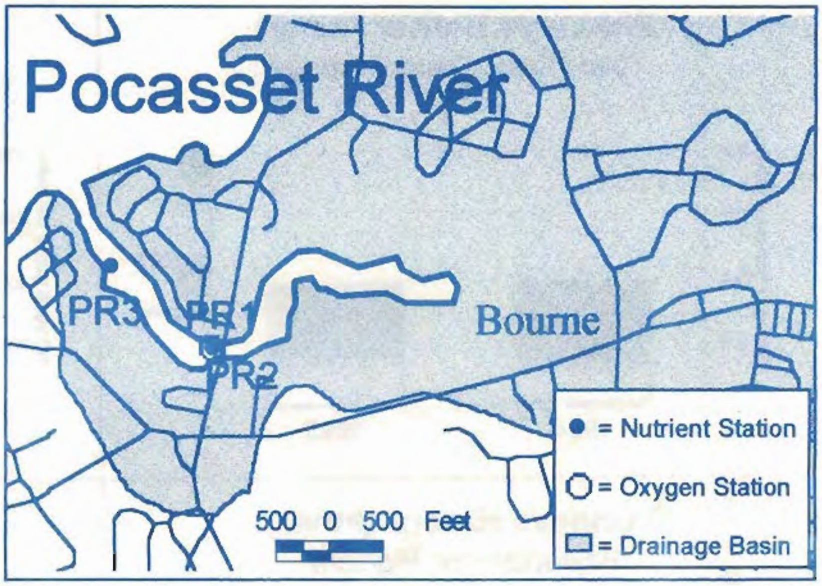

Phinneys Harbor (Outer)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1994
1995
Organic
Particulate
Inorganic


Phinneys Harbor (Inner)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1994
1995
Chlorophyll
Phaeo-pig.


Phinneys Harbor (Outer)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1994
1995
Chlorophyll
Phaeo-pig.


PH2 - Phinneys Harbor/Monument Beach
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
Feb-92
Aug-92
Feb-93
Aug-93
Feb-94
Aug-94
Feb-95
Aug-95
Surface Oxygen
Deep Oxygen

POCASSET RIVER



Embayment and Watershed Characteristics

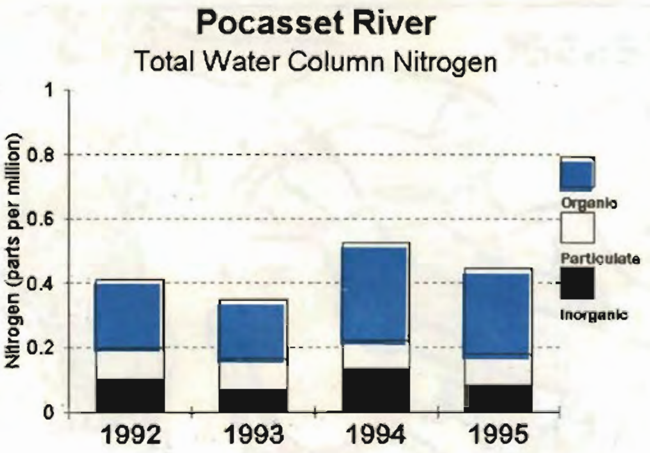
Pocasset River is well utilized as a mooring area. The embayment includes beach and four public access points. In the Buzzards Bay Project's watershed evaluation, shellfish resources were ranked as poor, but overall Cove resources were ranked medium. The Pocasset River estuary has significant areas of fringing salt marshes. Most of the adjacent upland is forested (81%) with residential development dominating the terrestrial nitrogen loading, although the housing density remains relatively low, 0.2 units per acres. The original evaluation of land use in the Pocasset River drainage basin by the Buzzards Bay Project included errors in total loading rates due to the inclusion of land area actually contributing to the waters of Phinneys Harbor behind Tobey Island. Because of this problem and because these watershed areas were redelineated last year by the Cape Cod Commission using more up to date groundwater data, the Buzzards Bay Project will need to complete a new loading evaluation. This basin and embayment is among the smaller studied.

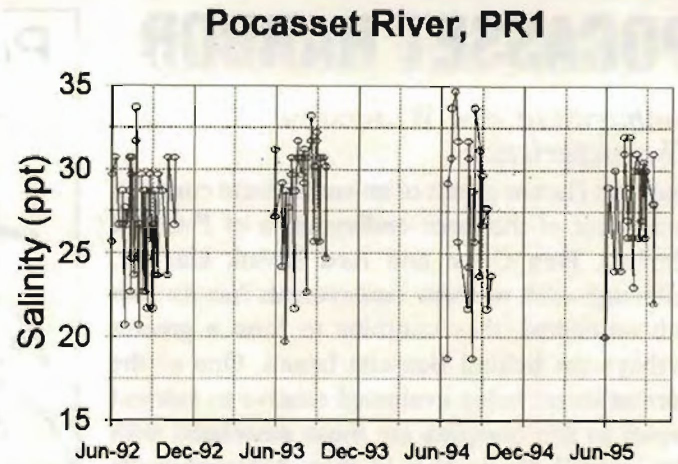
Water Quality

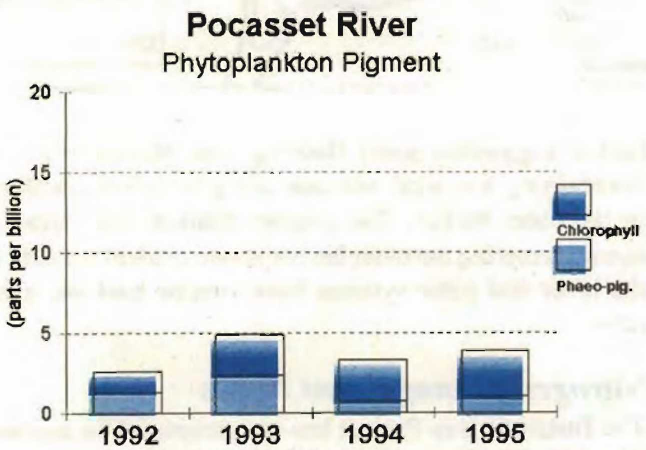
Pocasset River water quality, as indicated by the Eutrophication Index scores (center map) have shown a steady gradual decline to only fair conditions since 1992. Although chlorophyll levels remain low (a four year mean of only 3.7 ppb), nitrogen levels are intermediate (a four year mean of 0.43 ppm) compared to other embayments monitored. The major factor in determining the ecological health of this system is dissolved oxygen levels. Throughout the study, oxygen has periodically dropped below 70% of saturation. However, declines below 60% occurred in 3 of 4 years with 1995 recording frequent levels approaching 30% of saturation. The most recent data indicates a system of low habitat quality to benthic animals. At present the low chlorophyll 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 sediments may also be accounting for these low oxygen levels. Ongoing work should focus upon determining the cause of the observed low oxygen conditions. However, it appears that like adjacent systems (see below), 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.

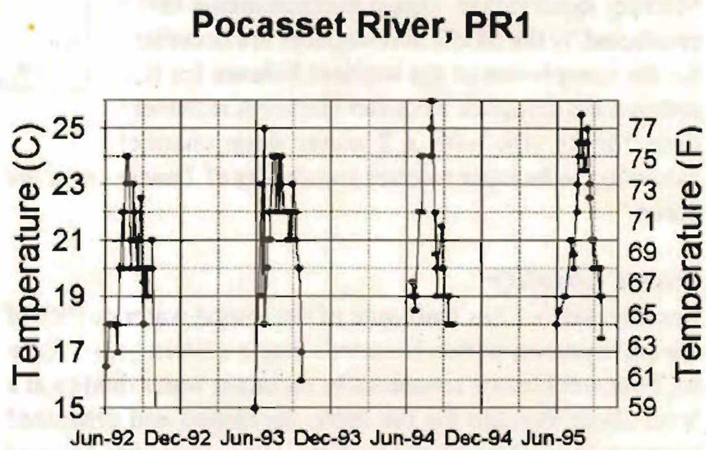
Nitrogen Management Needs

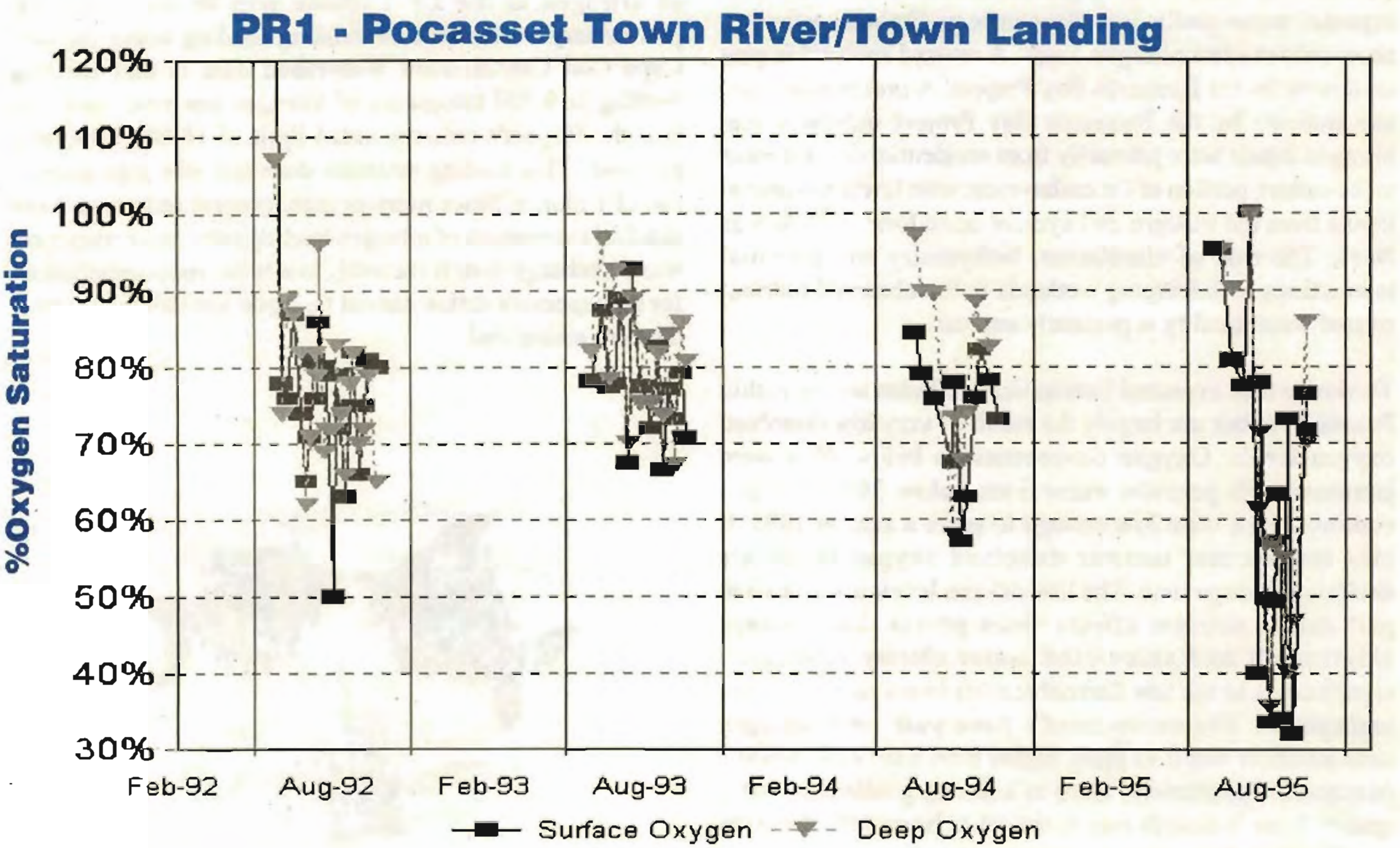
The Buzzards Bay Project completed an evaluation of nutrient loading to the Pocasset River in 1994 as part of the Buzzards Bay subwatershed evaluation. Two thirds of existing nitrogen inputs are derived from residential land use (i.e. principally septic systems). Existing nitrogen inputs are 46% of recommended limits, but at buildout will be 63% above recommended limits. The embayment's present water quality is close to the average of embayments monitored. Existing loads are much lower than the predicted assumed acceptable limits yet the water quality within the system is already moderately impacted. Consequently it appears that the estimates of acceptable nitrogen loading may be too high, possibly because of an overestimate of flushing or omissions in the assumed loading rate. Better flushing estimates are required to better determine recommended loading limits to Pocasset River before nitrogen management strategies can be considered. In response to this, later this year the Buzzards Bay Project will fund a flushing study and buildout analysis for the town of Bourne to determine appropriate management goals for the Pocasset River. Revisions to the drainage basin by the Cape Cod Commission will be examined to determine if nitrogen sources were not accounted for in the Buzzards Bay Project's loading evaluation.


Pocasset River
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
Organic
Particulate
Inorganic
1992
1993
1994
1995

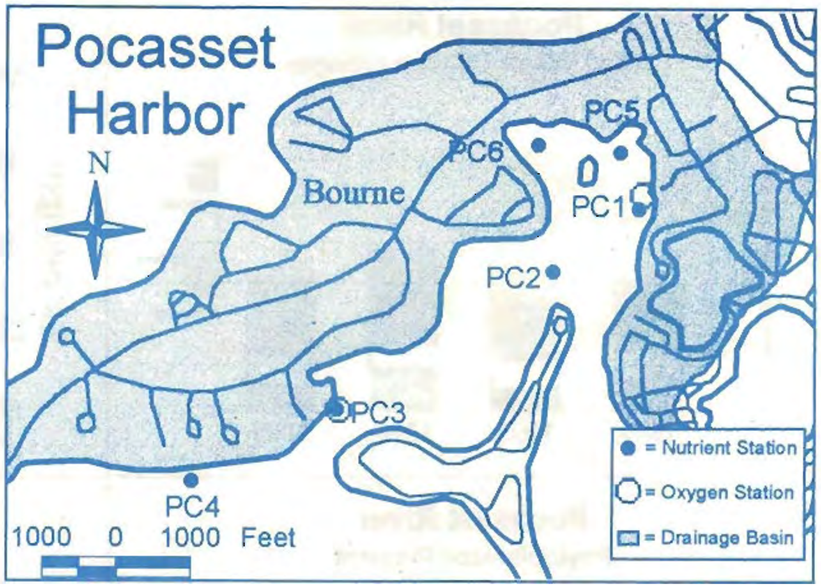

Pocasset River, PR1
Salinity (ppt)
35
30
25
20
15
Jun-92
Dec-92
Jun-93
Dec-93
Jun-94
Dec-94
Jun-95


Pocasset River
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
Chlorophyll
Phaeo-pig.
1992
1993
1994
1995


Pocasset River, PR1
Temperature (C)
25
23
21
19
17
15
Temperature (F)
77
75
73
71
69
67
65
63
61
59
Jun-92
Dec-92
Jun-93
Dec-93
Jun-94
Dec-94
Jun-95


PR1 - Pocasset Town River/Town Landing
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
Feb-92
Aug-92
Feb-93
Aug-93
Feb-94
Aug-94
Feb-95
Aug-95
Surface Oxygen
Deep Oxygen

POCASSET HARBOR



Embayment and Watershed Characteristics

Pocasset Harbor is part of an embayment complex consisting of the three embayments of Pocasset Harbor, Hen Cove and Red Brook Harbor. Although each of these embayments has its own sub-watershed, they combine to form a greater embayment behind Bassetts Island. One of the current issues being evaluated relative to nutrient inputs to this complex are those associated with the landfill plume (LF-1) from Massachusetts Military Reservation. Direct measurements being conducted by the MMR investigators are necessary for the completion of the nutrient balance for this embayment complex. Pocasset Harbor is relatively deep for its size with a 2 meter deep channel extending to its inner reaches and depths of 7 meters near the outlet.

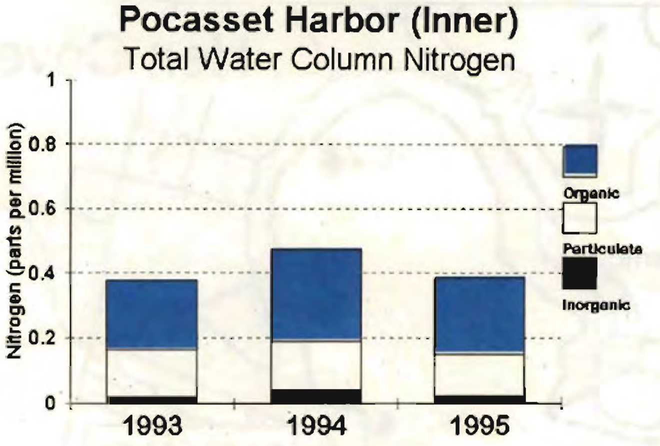
Water Quality

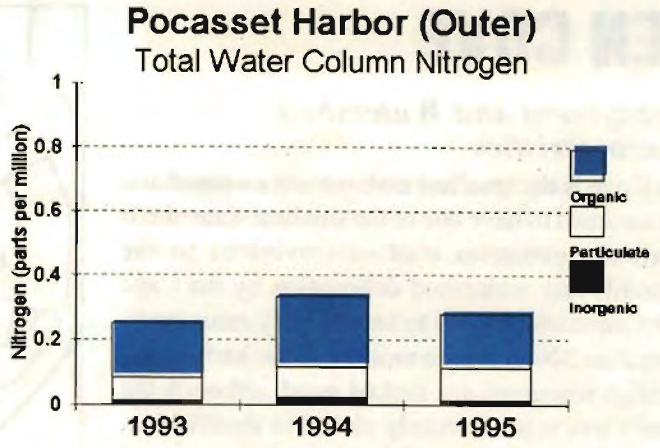
Pocasset Harbor has had some of the lowest water quality of the embayments within Buzzards Bay's eastern shore. Even so, Pocasset Harbor continues to maintain water quality at a level about average for the more developed and urbanized western shore, although the Eutrophication Index has dropped continuously since 1993. At present the cause of the less than expected water quality is unclear since preliminary estimates show only modest nitrogen loads. A revised analysis is now underway by the Buzzards Bay Project. A preliminary land use analysis by the Buzzards Bay Project indicated that nitrogen inputs were primarily from residential development in the eastern portion of the embayment with lower residential inputs from the western embayment coast formed by Wings Neck. The role of circulation, bathymetry and potential interactions with fringing wetlands in the observed nutrient related water quality is presently unclear.

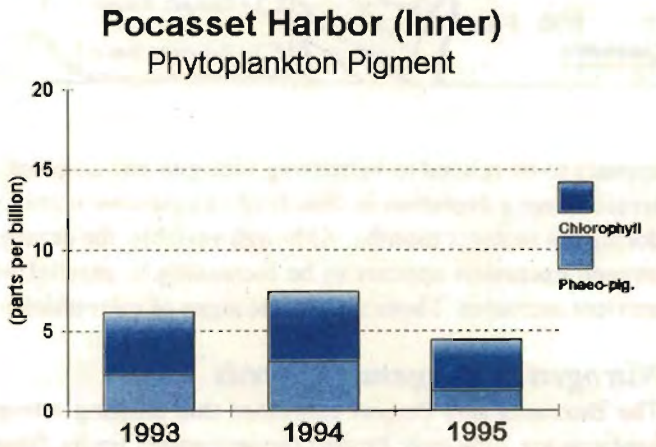
The lower than expected Eutrophication Index scores within Pocasset Harbor are largely the result of very low dissolved oxygen levels. Oxygen concentrations below 40% were common with periodic excursions below 30%. Oxygen concentrations were low enough to score a zero in 1995. It also appears that summer dissolved oxygen levels are declining through time. The low oxygen levels are at least in part due to nutrient effects since poorer than average chlorophyll and associated water clarity contribute significantly to the low Eutrophication Index scores for this embayment. The embayment's three year total nitrogen concentration was 0.41 ppm, higher than most embayments monitored. Fortunately, there is a strong gradient in water quality from Buzzards Bay to the inner basin with the outer harbor suggesting good flushing with Buzzards Bay and maintaining low total nitrogen and phytoplankton biomass in the outer harbor. The greater dilution and flushing of nutrient entering the outer harbor is also evident because both the inner and outer systems have similar land use loading rates.

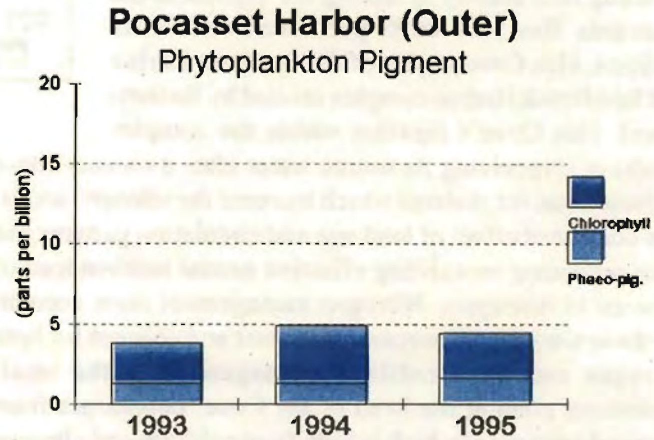
Nitrogen Management Needs

The Buzzards Bay Project has not completed an evaluation of nutrient loading to Pocasset Harbor, and a good estimate of nitrogen in the LF-1 plume will be required. Our preliminary assessment of existing loading using the new Cape Cod Commission Watershed data is that existing loading is 9,700 kilograms of nitrogen per year, only one half the Project's recommended limit of 18,000 kilograms per year. This loading estimate does not take into account the LF1 plume. Since nutrient management requires a more detailed assessment of nitrogen loading rates and embayment water exchange than is currently available, recommendations for management action cannot be made until all the relevant data are assembled.

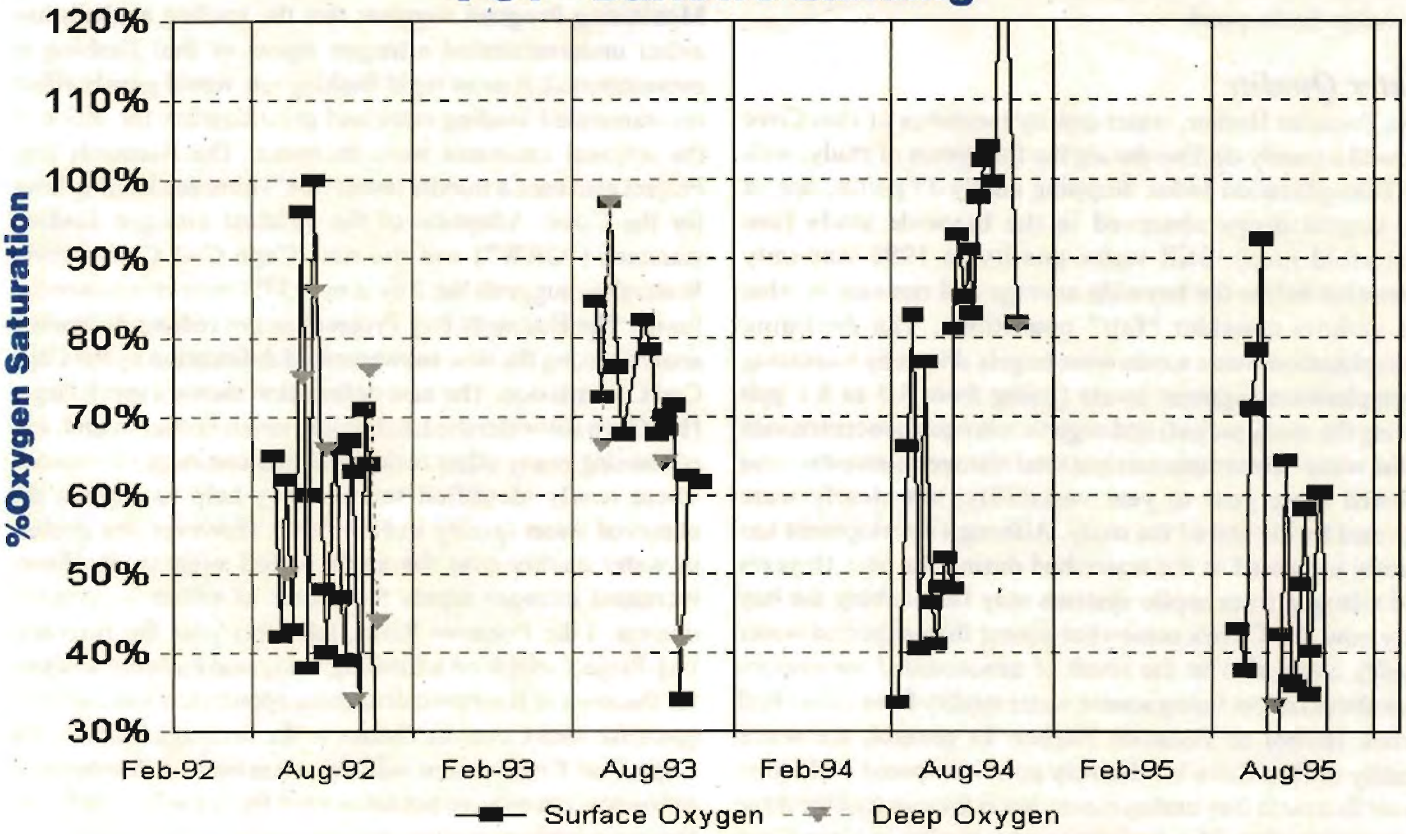




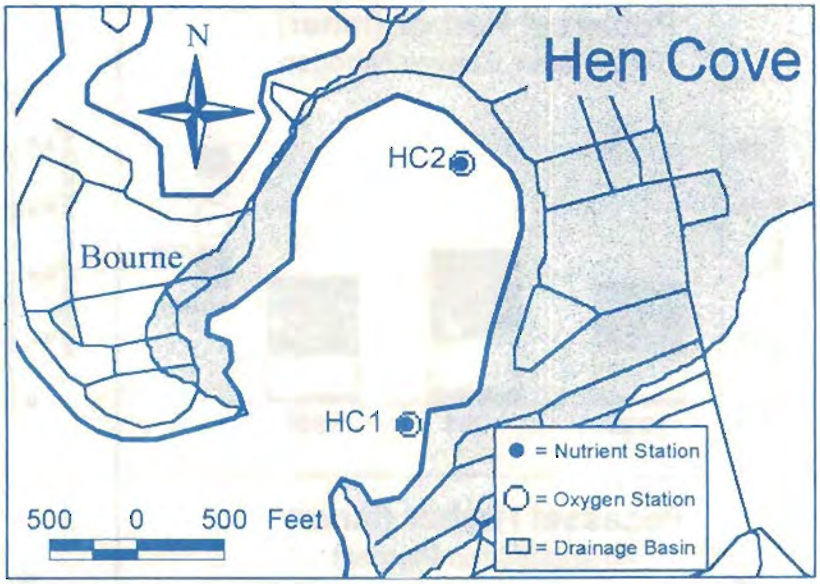




PC1 - Barlows Landing



HEN COVE



Embayment and Watershed Characteristics

Hen Cove is the smallest embayment assessed and was assumed to have one of the smallest watersheds of all the estuaries studied (revisions to the Buzzards Bay watershed delineation by the Cape Cod Commission need to be carefully examined). More than 300 boats are moored in the harbor, and shellfish resources are ranked good, although the upper Cove is permanently closed to shellfishing. The shoreline is extensively developed and dwelling unit density is among the highest in the Buzzards Bay (1.1 units per acre overall). In addition, Hen Cove is part of the Pocasset Harbor and Red Brook Harbor complex created by Bassetts Island. Hen Cove's location within the complex results in it receiving its source water after it transits either of these adjacent systems which increase the nitrogen levels. The combined effect of land-use and circulation patterns has been producing an existing effective annual nutrient load of concern to managers. Nitrogen management must account for these nitrogen resources. Of interest and concern for both nitrogen and fecal coliform management is the small freshwater pond at the head of the Cove. Discharges from the pond are typically high in both fecal coliform and nitrogen concentrations, and the Board of Health should consider a dye study to determine if any hidden cesspool overflow pipes discharge to the pond.

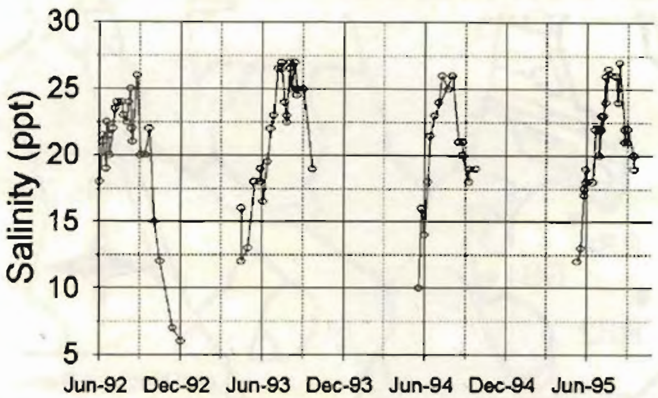
Water Quality

Like Pocasset Harbor, water quality measures of Hen Cove showed a steady decline during the four years of study, with the Eutrophication Index dropping nearly 37 points, one of the largest drops observed in the baywide study (see centerfold map). Still water quality in 1995 was only somewhat below the baywide average and remains in what the authors consider "fair" conditions. The declining Eutrophication Index scores were largely driven by increasing phytoplankton pigment levels (going from 3.3 to 8.1 ppb during the study period) and organic nitrogen concentrations in the water. Mean summertime total nitrogen concentrations showed more year to year variability, but clearly were elevated by the end of the study. Although development has greatly increased in the watershed during the past 10 years and nitrogen from septic systems may be reaching the bay only now, the Cove's somewhat poorer than expected water quality could also be the result of unaccounted for sources (see above) or declining source water quality from either Red Brook Harbor or Pocasset Harbor. In general, the water quality of Hen Cove is relatively good compared with other small Buzzards Bay embayments, but is the worst of the three estuary complex. The declining water quality in Hens Cove appears to be related to increasing nitrogen and chlorophyll levels causing depletion in dissolved oxygen concentrations during the summer months. Although variable, the degree of oxygen excursion appears to be increasing in parallel with nutrient increases. These are classic signs of eutrophication.

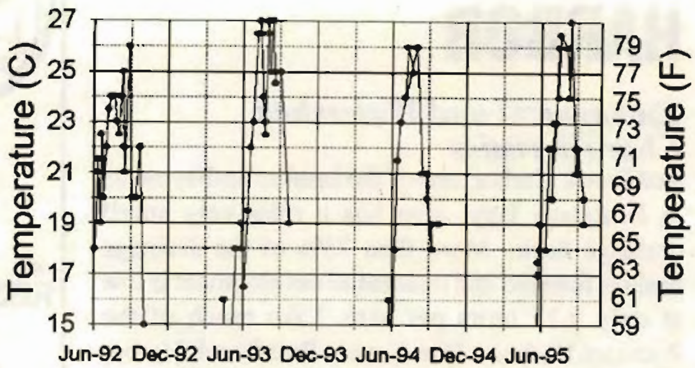
Nitrogen Management Needs

The Buzzards Bay Project estimated that existing nitrogen loadings are 23% over Project recommended limits. Nearly 70% of existing nitrogen inputs are derived from residential land use (i.e. septic systems). The Citizens' Water Quality Monitoring Program suggests that the loading analysis has either underestimated nitrogen inputs or that flushing is overestimated. A more rapid flushing rate would greatly affect recommended loading rates and prioritization for action if the original estimates were incorrect. The Buzzards Bay Project also used a middle level ("SA") nitrogen loading limit for the Cove. Adoption of the strictest nitrogen loading standard ("ORW") and the new Cape Cod Commission Watershed suggests the Bay is now 37% over recommended limits. The Buzzards Bay Project has not redone its loading analysis using the new subwatershed delineation by the Cape Cod Commission. The new delineation shows a much larger Hen Cove subwatershed, extending much farther inland, and containing many other residential and commercial sources. These newly identified sources may help to explain the observed water quality in Hen Cove. However, the decline in water quality over the study period suggest significant increased nitrogen inputs the source of which is currently unclear. Like Pocasset River, later this year the Buzzards Bay Project will fund a flushing study and buildout analysis for the town of Bourne to determine appropriate management goals for Hen Cove. Revisions to the drainage basin by the Cape Cod Commission will be examined to determine if nitrogen sources were not accounted for in the Buzzards Bay Project's loading evaluation.

Hen Cove, HC1 & HC2

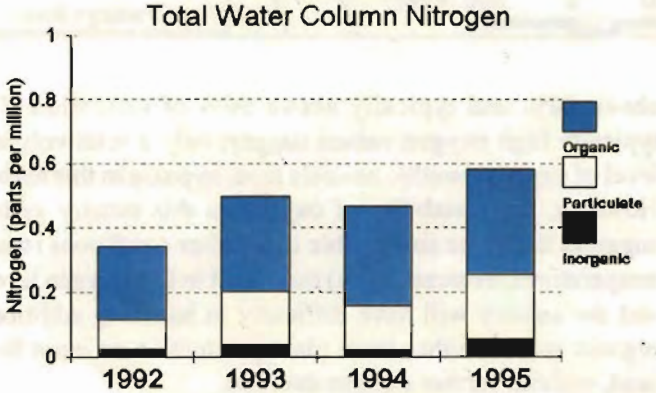


Hen Cove, HC1 & HC2



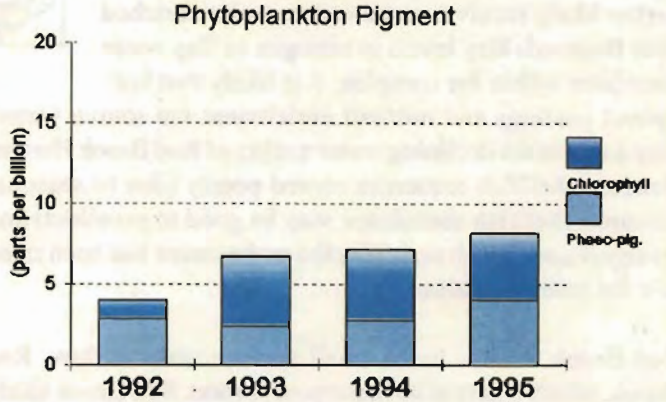
Hen Cove

Total Water Column Nitrogen

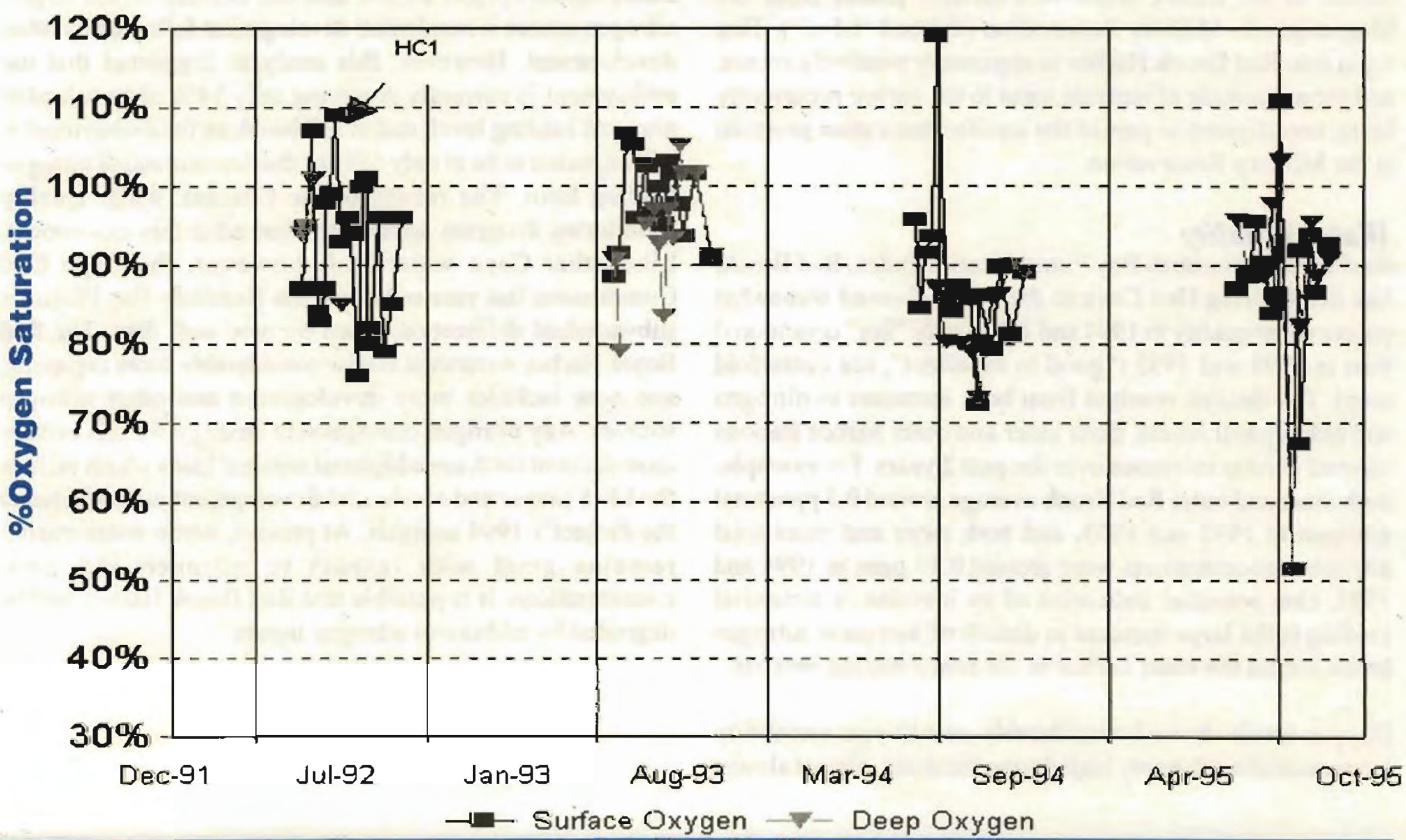


Hen Cove

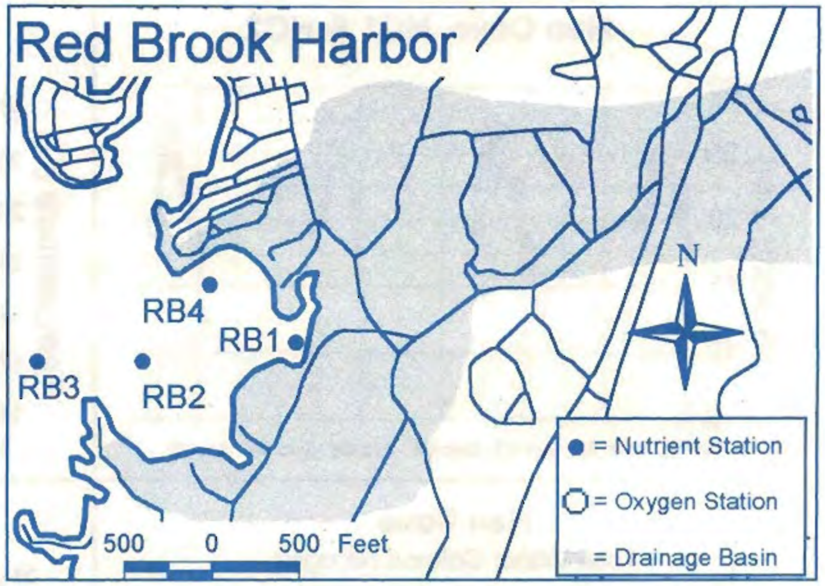
Phytoplankton Pigment



HC1, HC2 - Hen Cove



RED BROOK HARBOR



Embayment and Watershed Characteristics

Red Brook Harbor, one of the smaller embayments in Buzzards Bay, also has a relatively small drainage basin. More than 75% of the drainage basin is forested and residential development is low at only 0.15 units per acre. Like much of the Pocasset Harbor – Hen Cove – Red Brook Harbor complex, Red Brook Harbor has a depth of about 2 meters with fringing tidal flats and wetlands. The harbor likely receives some source water enriched over Buzzards Bay levels in nitrogen as Bay water circulates within the complex. It is likely that both upland loadings and nutrient enrichment via source waters play a role in the declining water quality of Red Brook Harbor. Because shellfish resources scored poorly (due to seasonal closures, shellfish abundance may be good to excellent) and no significant beach activities the embayment has been rated low for resource value.

Red Brook Harbor has a small surface water inflow, Red Brook, which enters at its innermost portion. Red Brook likely receives most of its freshwater via groundwater inflows, as well as runoff and along its course. Some of the groundwater inflow to the Brook includes a landfill plume from the Massachusetts Military Reservation (dubbed "LF-1"). This input into Red Brook Harbor is apparently relatively recent, and the magnitude of nutrient input to the harbor is currently being investigated as part of the aquifer restoration program at the Military Reservation.

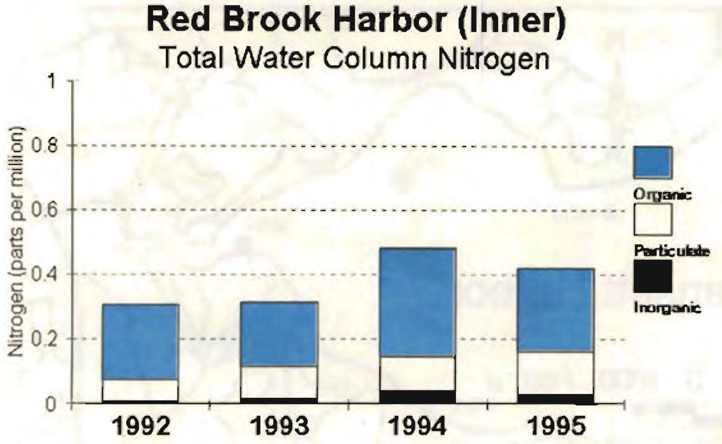
Water Quality

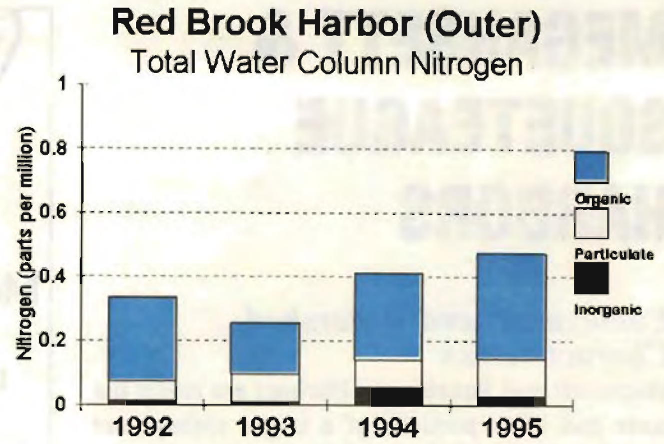
Based on the Buzzards Bay Eutrophication Index, Red Brook, like neighboring Hen Cove to the north, showed somewhat poorer water quality in 1994 and 1995 (only "fair" conditions) than in 1993 and 1992 ("good to excellent", see centerfold map). The decline resulted from both increases in nitrogen and chlorophyll levels. Both inner and outer harbor stations showed similar increases over the past 2 years. For example, both inner and outer Red Brook average around 0.3 ppm total nitrogen in 1992 and 1993, and both inner and outer total nitrogen concentrations were around 0.45 ppm in 1994 and 1995. One potential indication of an increase in terrestrial loading is the large increase in dissolved inorganic nitrogen levels within the inner harbor in the past 2 testing seasons.

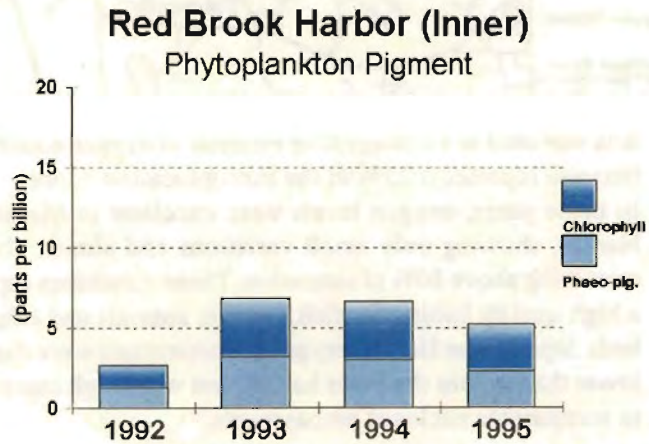
Oxygen levels showed considerable year to year variability but remained moderately high during the study, almost always above 50% and typically above 60% of saturation. The typically high oxygen values suggest only a relatively low level of stress to benthic animals from hypoxia in this harbor. However, the variability of oxygen in this estuary system suggests it may be susceptible to weather conditions (warm temperatures, overcast, calm) that result in low oxygen levels, and the estuary will have difficulty in handling additional organic matter, either from plant production or input from land, without further oxygen declines.

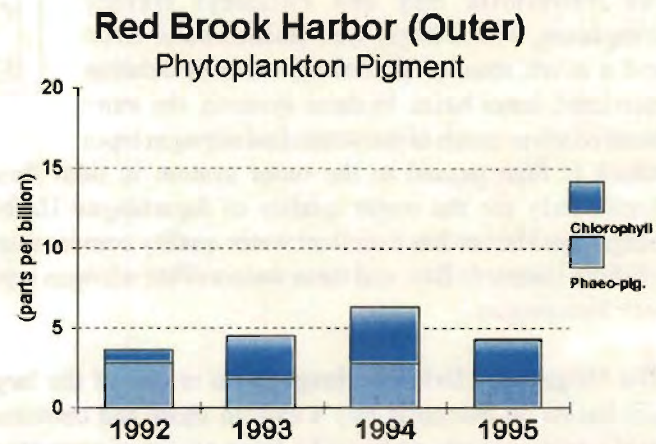
Nitrogen Management Needs

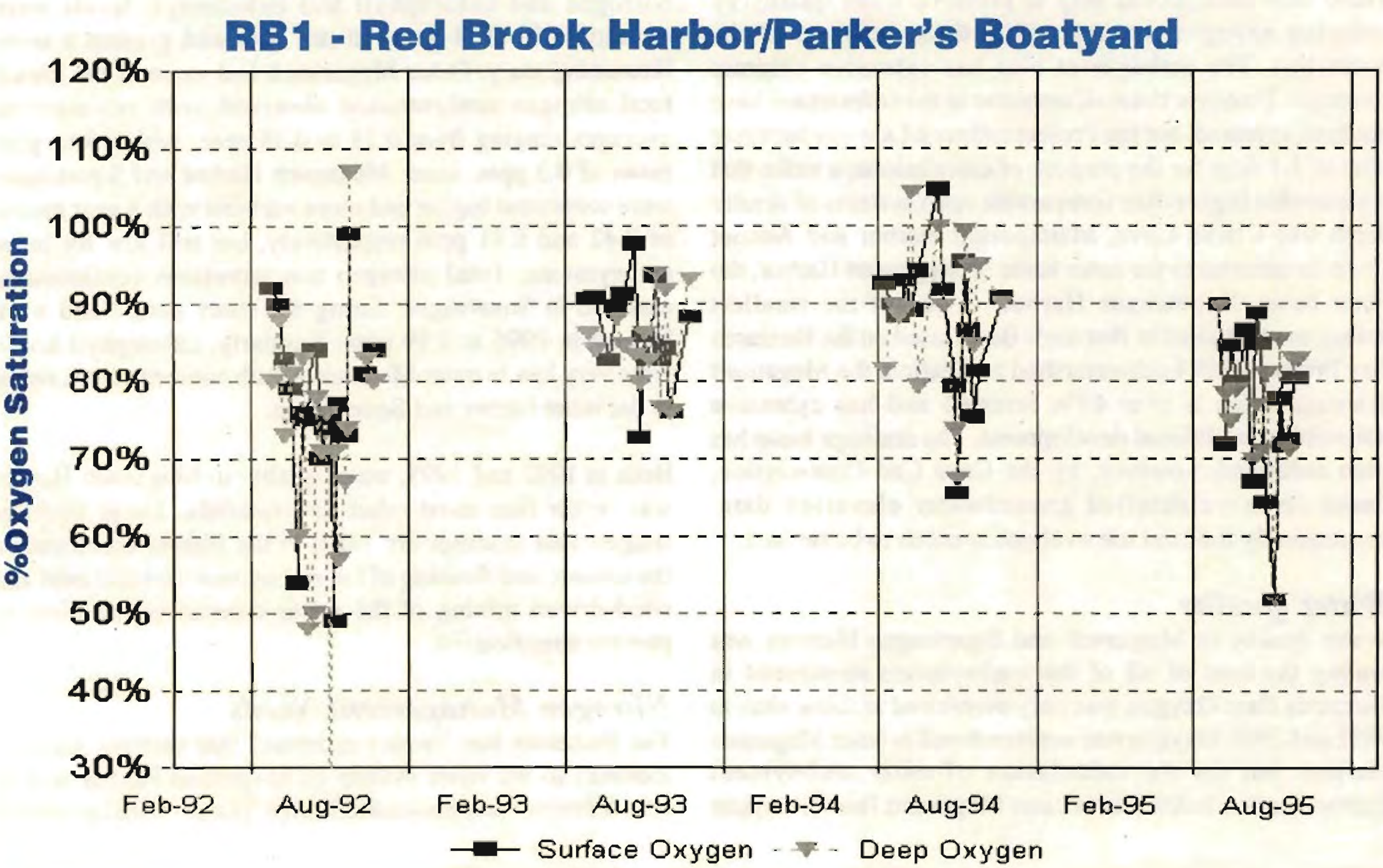
Based on the Project's 1994 land use evaluation, the largest nitrogen source is residential development followed by other development. However, this analysis suggested that the embayment is currently receiving only 14% of its tolerable nitrogen loading level, and at full buildout the embayment is still expected to be at only 55% of the recommended nitrogen loading limit. The results of the Citizens Water Quality Monitoring Program appears to contradict this assessment. Like other Cape watersheds however, the Cape Cod Commission last year redefined the Buzzards Bay Project's subwaterhed delineation based on new well data. The Red Brook Harbor watershed is now considerably more expansive and now includes more development and other nitrogen sources. Any nitrogen management strategy for this estuary must account for these additional nutrient loads which include the LF-1 plume and residential development not included in the Project's 1994 analysis. At present, while water quality remains good with respect to nitrogen and fecal concentrations, it is possible that Red Brook Harbor will be degraded by additional nitrogen inputs.


Red Brook Harbor (Inner)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
Organic
Particulate
Inorganic
1992
1993
1994
1995

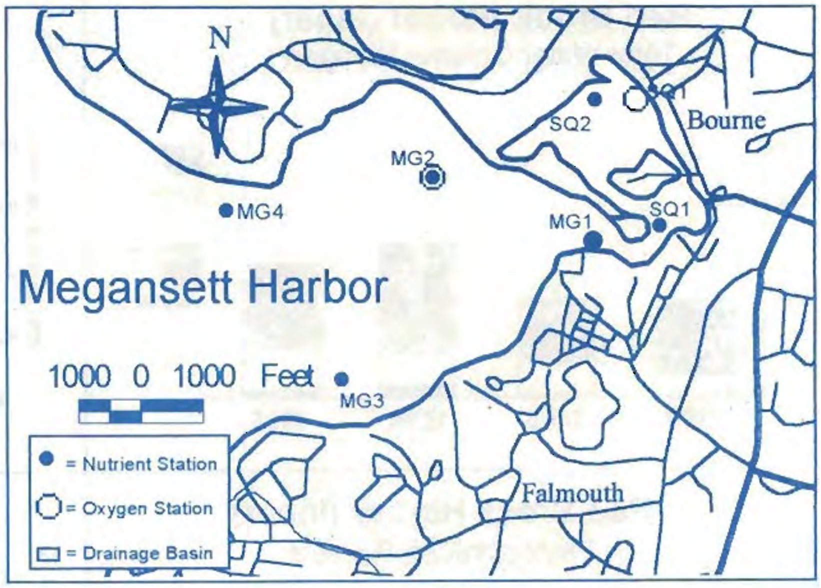

Red Brook Harbor (Outer)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
Organic
Particulate
Inorganic
1992
1993
1994
1995


Red Brook Harbor (Inner)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
Chlorophyll
Pheo-pig.
1992
1993
1994
1995


Red Brook Harbor (Outer)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
Chlorophyll
Pheo-pig.
1992
1993
1994
1995


RB1 - Red Brook Harbor/Parker's Boatyard
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
Feb-92
Aug-92
Feb-93
Aug-93
Feb-94
Aug-94
Feb-95
Aug-95
Surface Oxygen
Deep Oxygen

MEGANSETT & SQUETEAGUE HARBORS



Embayment and Watershed Characteristics

Megansett and Squeteague Harbors are really the outer and inner portions of a larger embayment complex. These Harbors are configured much like the Buttermilk Bay and Phinneys Harbor complexes, with a larger well flushed outer basin and a much smaller shallower, more circulation restricted, inner basin. In these systems, the inner basin receives much of the watershed nitrogen input which is then passed to the outer system in tidal flows. Fortunately for the water quality of Squeteague Harbor, Megansett Harbor has excellent water quality comparable to offshore Buzzards Bay, and these waters dilute nitrogen inputs into Squeteague.

The Megansett Harbor drainage basin is one of the larger sub-basins on Buzzards Bay's eastern shore and contains 2 public water supply wells and a large parcel of open space. These land-uses should help to preserve water quality by reducing nitrogen sources within those portions of the watershed. The embayment also has extensive eelgrass coverage. Turnover times of seawater in the embayment have not been assessed, but the Project estimated a water turnover time of 3.5 days for the purpose of calculations, a value that is somewhat higher than comparable open systems of similar depth like Clarks Cove, Mattapoisett Harbor and Aucoot Cove. In contrast to the outer basin of Megansett Harbor, the inner basin, Squeteague Harbor, is one of the smallest embayments studied in Buzzards Bay. Based on the Buzzards Bay Project's 1994 subwatershed evaluation, the Megansett drainage basin is over 68% forested and has extensive potential for additional development. The drainage basin has been redefined, however, by the Cape Cod Commission, based on more detailed groundwater elevation data, consequently the land use evaluation needs to be revised.

Water Quality

Water quality in Megansett and Squeteague Harbors was among the best of all of the embayments monitored in Buzzards Bay. Oxygen was only monitored at these sites in 1992 and 1993. Oxygen was not monitored in outer Megansett Harbor, but for the calculation of outer embayment Eutrophication Index scores inner Megansett Harbor oxygen data was used as a conservative estimate of oxygen conditions (oxygen represents 25% of the Eutrophication Score).
In those years, oxygen levels were excellent in Megansett Harbor, showing only small variations and almost always remaining above 80% of saturation. These conditions support a high quality habitat for fish, benthic animals and eelgrass beds. Squeteague Harbor oxygen concentrations were slightly lower than within the outer harbor, but were high compared to comparable enclosed embayments.

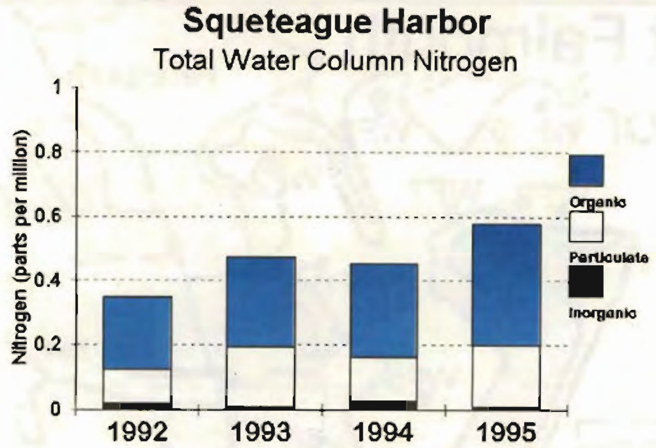
Nitrogen and chlorophyll and chlorophyll levels were monitored in all 4 years at the sites and present a more interesting story. Outer Meganssett had some of the lowest total nitrogen concentration observed, with summertime averages ranging from 0.23 to 0.38 ppm, with a four year mean of 0.3 ppm. Inner Megansett Harbor and Squeteague were somewhat higher and more variable with 4 year means of 0.42 and 0.41 ppm respectively, but still low for inner embayments. Total nitrogen concentrations continuously elevated in Squeteague during the study period and were highest in 1995 at 0.59 ppm. Similarly, chlorophyll levels were very low in outer Megansett, with concentrations rising in the inner harbor and Squeteague.

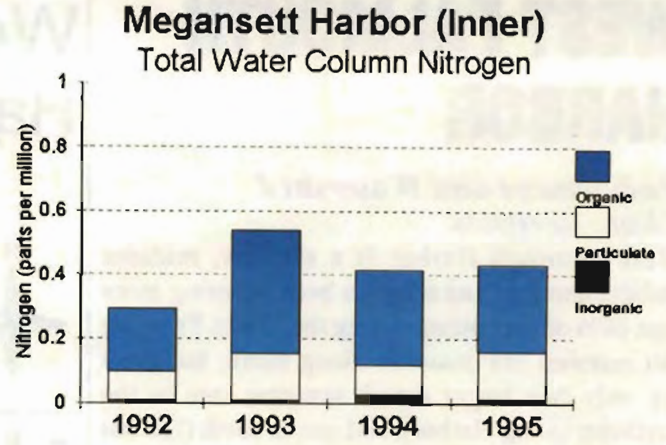
Both in 1992 and 1993, water quality in Megansett Harbor was better than most other embayments. These findings suggest that loadings are small to the Harbor compared to the volume and flushing of the embayment and that tidal and wind-driven mixing of the water column is sufficient to prevent stratification.

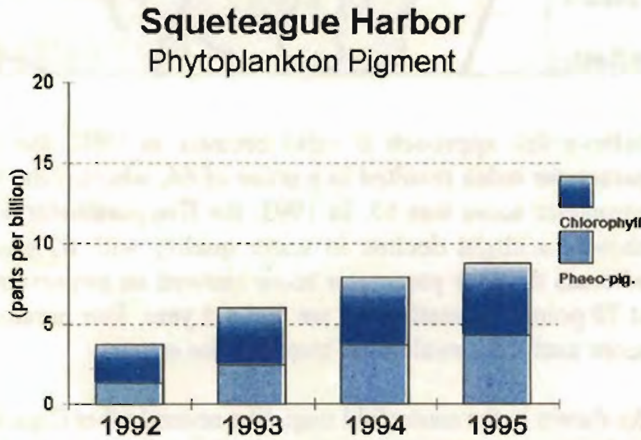
Nitrogen Management Needs

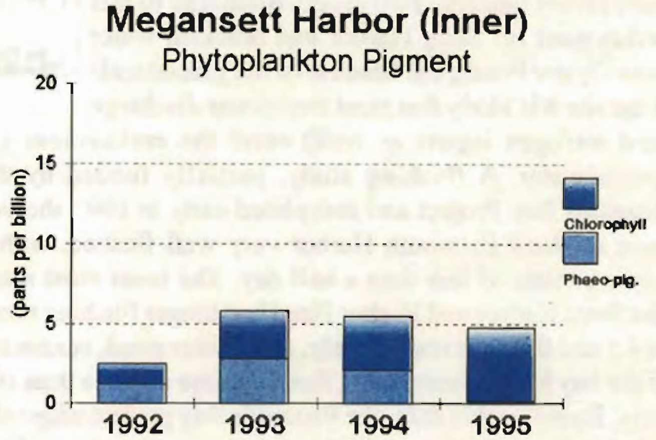
The Buzzards Bay Project estimated that existing nitrogen loadings to the outer system of Megansett Harbor is well below Project recommended limits. The principal source of

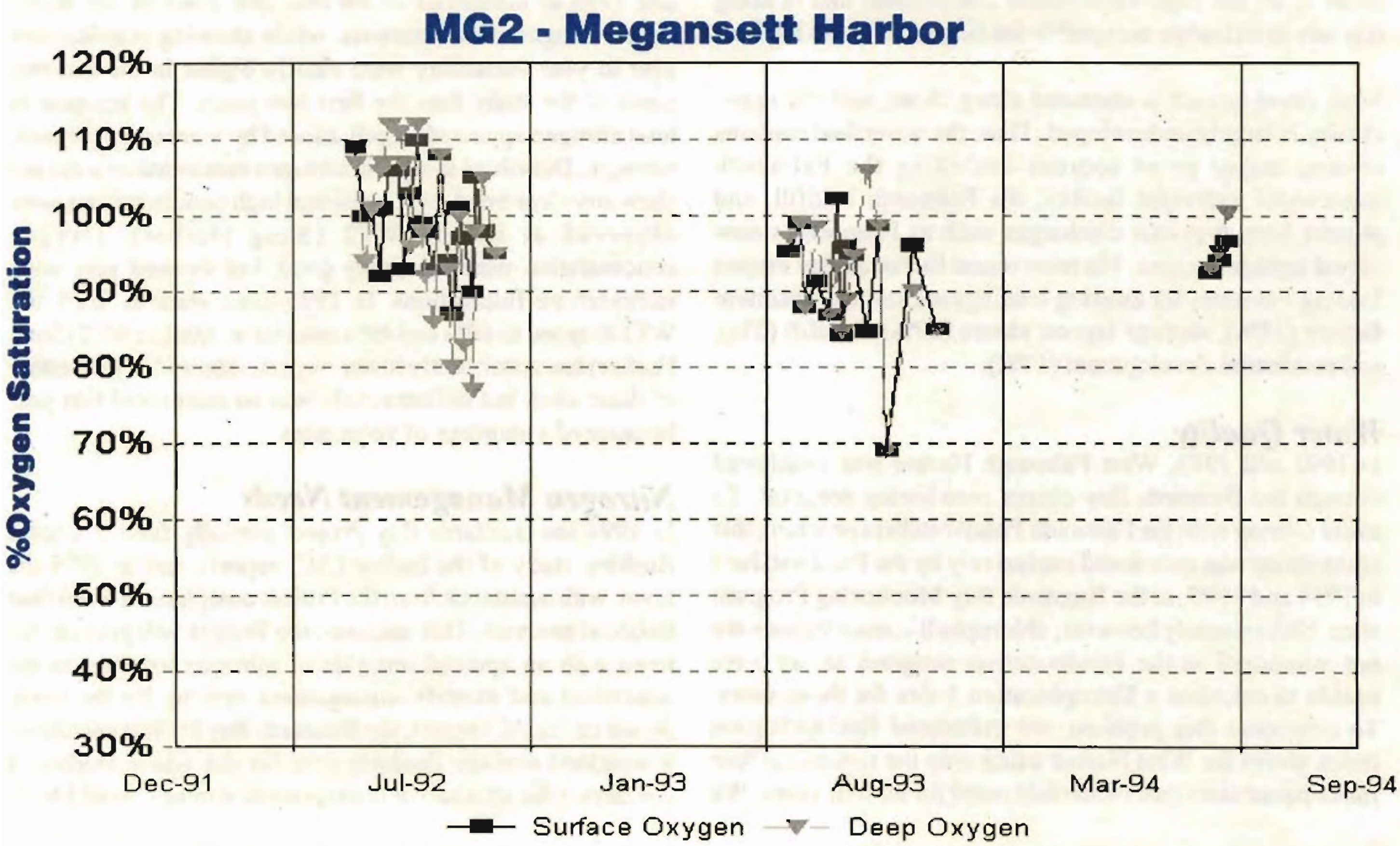
Continued on page 65


Squeteague Harbor
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1992
1993
1994
1995
Organic
Particulate
Inorganic

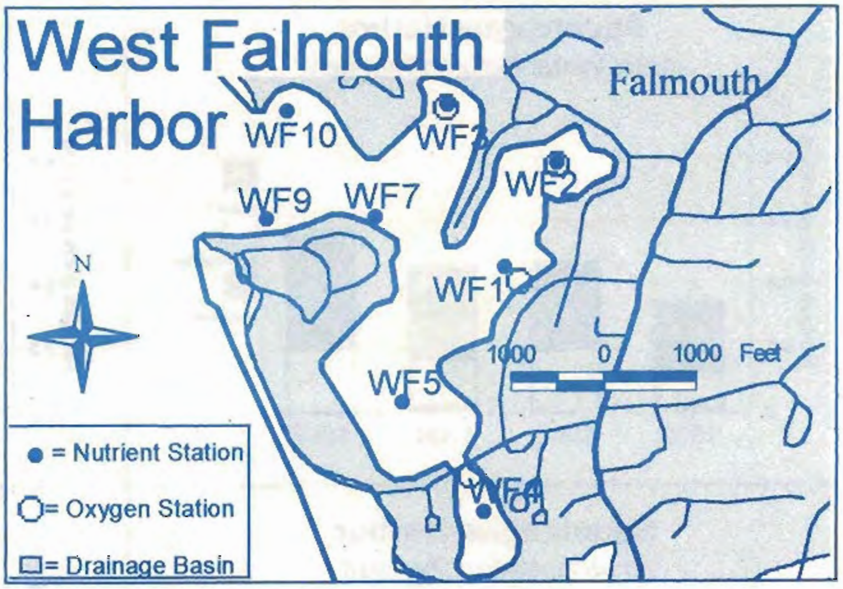

Megansett Harbor (Inner)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1992
1993
1994
1995
Organic
Particulate
Inorganic


Squeteague Harbor
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1992
1993
1994
1995
Chlorophyll
Phaeo-pig.


Megansett Harbor (Inner)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1992
1993
1994
1995
Chlorophyll
Phaeo-pig.


MG2 - Megansett Harbor
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
Dec-91
Jul-92
Jan-93
Aug-93
Mar-94
Sep-94
Surface Oxygen
Deep Oxygen

WEST FALMOUTH HARBOR



Embayment and Watershed Characteristics

West Falmouth Harbor is a shallow, midsize embayment that had eelgrass beds covering more than 80% of the bottom during the 1980s. Fringing salt marshes are common along shore, but there are only two larger marsh systems, one in the northeast (Snug Harbor), and one in south (Harbor Head). The Harbor is extensively utilized by recreational boaters. Two creeks discharge to this embayment (to Snug Harbor and brackish water from Oyster Pond), but because of the glacial soils at the site it is likely that most freshwater discharge (and nitrogen inputs as well) enter the embayment via groundwater. A flushing study, partially funded by the Buzzards Bay Project and completed early in 1995 showed most of West Falmouth Harbor very well flushed, with a turnover time of less than a half day. The inner most areas like Snug Harbor and Harbor Head had longer flushing times of 4.5 and 0.6 days respectively, and Oyster pond, connected to the bay by a culvert, had a flushing time of more than 100 days. Based on this data, the Buzzards Bay project adopted a 2.4 day turnover time calculated from a volume weighted mean of all the inner embayment components and is using this rate to calculate acceptable loading rates to the Harbor.

Most development is clustered along shore, and the upper estuary is largely undeveloped. Thus, the watershed contains several major point sources including the Falmouth wastewater treatment facility, the Falmouth landfill, and plumes from previous discharges such as Falmouth's now closed septage lagoons. The most recent Buzzards Bay Project loading estimates for existing loadings are sewage treatment facility (38%), septage lagoon plume (29%), landfill (5%), and residential development (17%).

Water Quality

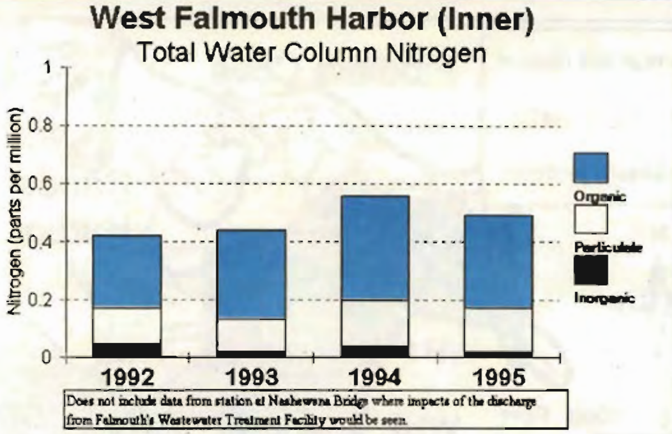
In 1992 and 1993, West Falmouth Harbor was monitored through the Buzzards Bay citizen monitoring program. To avoid overlap with the Falmouth PondWatchers program, this embayment was monitored exclusively by the Pondwatchers in 1994 and 1995, at the Buzzards Bay Monitoring Program sites. Unfortunately however, chlorophyll concentrations are not monitored in the Pondwatchers program so we were unable to calculate a Eutrophication Index for those years. To overcome this problem, we calculated Eutrophication Index scores for West Harbor using only the remaining four Index parameters (see centerfold map) for all four years. We believe this approach is valid because in 1992, the five parameter index resulted in a score of 66, whereas the four parameter score was 65. In 1993, the five parameter score showed a slight decline in water quality with 63 points, whereas the four parameter score showed an improvement at 70 points. Nonetheless, we feel a 4 year, four parameter score useful for evaluating trends in the estuary.

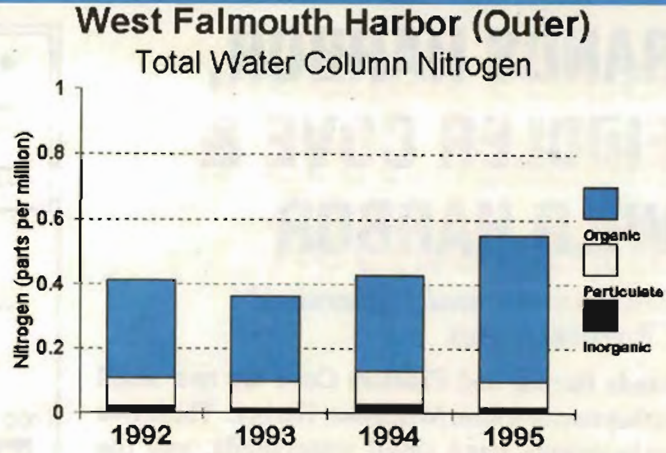
As shown in the centerfold map, like several other Cape Cod embayments, water quality was moderately worse in 1994 and 1995 as compared to the first two years of the study. Total nitrogen concentrations, while showing considerable year to year variability were clearly higher in the last two years of the study than the first two years. The increase in total nitrogen appeared largely caused by increases in organic nitrogen. Dissolved inorganic nitrogen concentrations did not show any clear trend, but occasional high concentrations were observed at station WF2 (Snug Harbor). Oxygen concentration were relatively good, but showed very wide summertime fluctuations. In 1995 inner stations WF4 and WF1 dropped to 60% and 40% saturation. Station WF2 (Snug Harbor) has consistently lower oxygen saturations than either of these sites, but unfortunately was no monitored that year because of a shortage of volunteers.

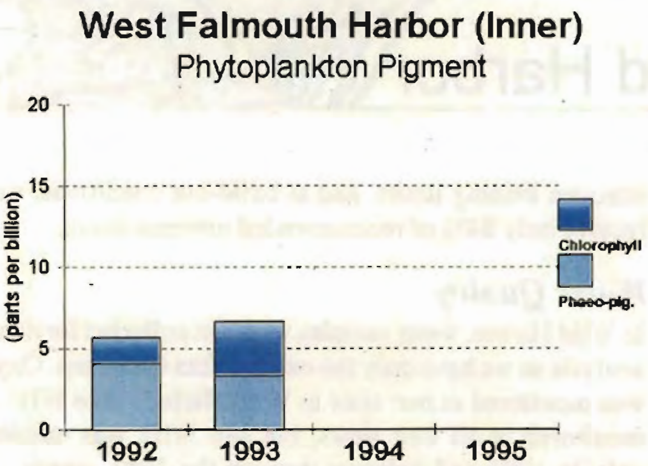
Nitrogen Management Needs

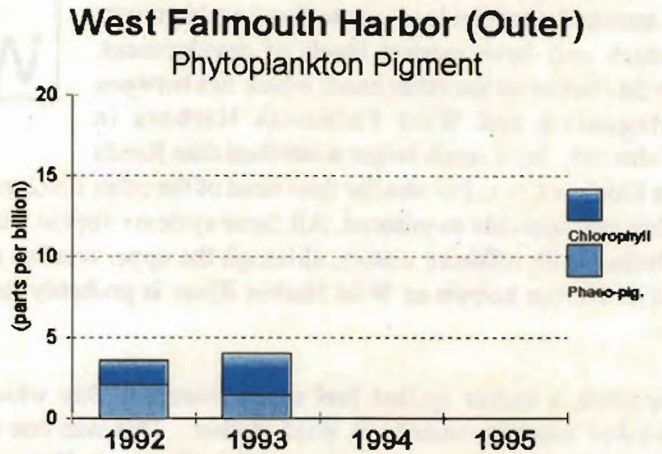
In 1994 the Buzzards Bay Project partially funded a town flushing study of the harbor (ACI report), and in 1995 the town, with assistance from the Project completed a watershed buildout analysis. This summer, the Project will provide the town with an updated analysis of nitrogen loadings in the watershed and identify management options for the town. Based on the ACI report, the Buzzards Bay Project calculated a weighted average flushing time for the whole Harbor of 2.4 days. (An alternative management strategy would be to

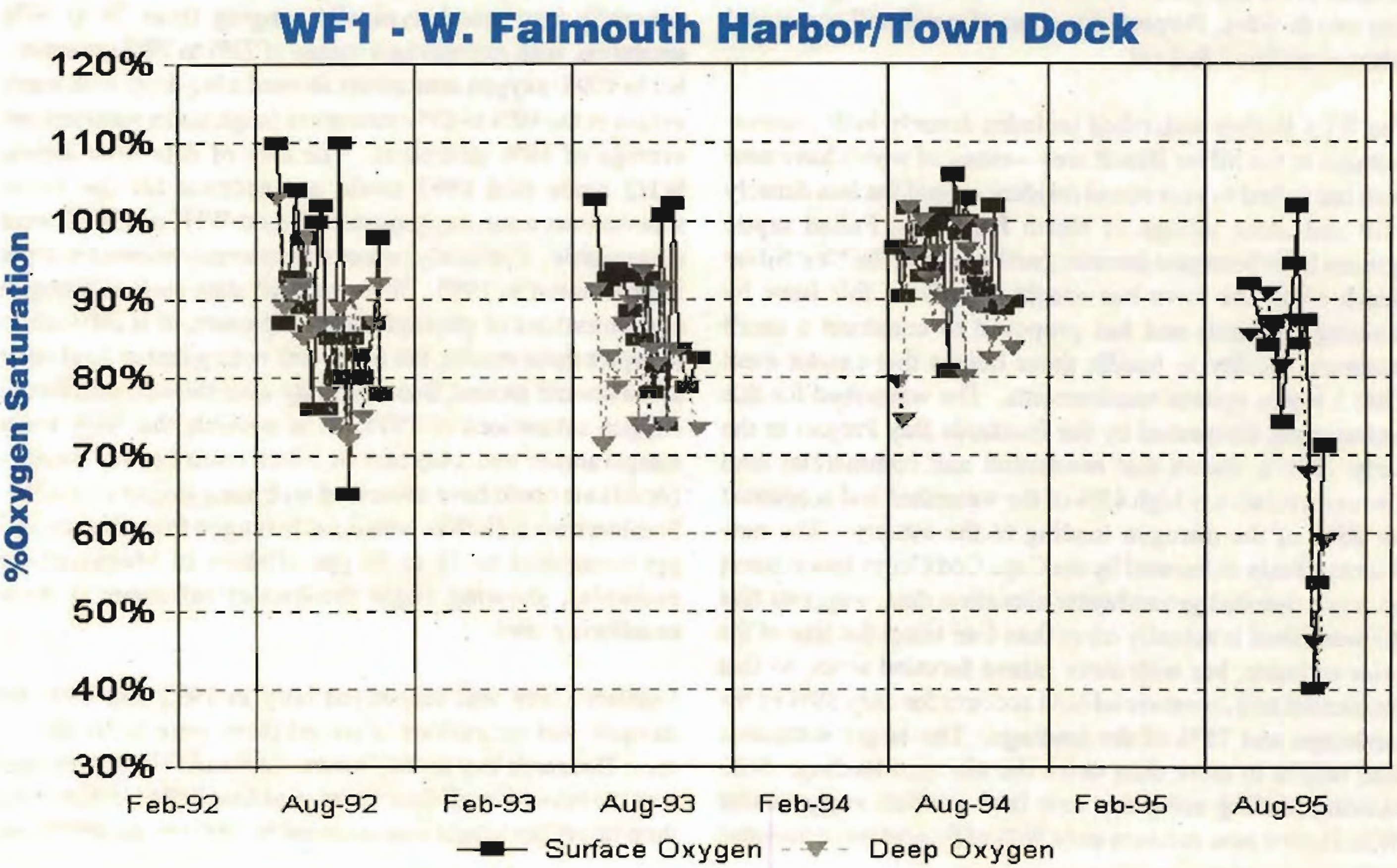
Continued on page 66


West Falmouth Harbor (Inner)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1992
1993
1994
1995
Organic
Particulate
Inorganic
Does not include data from station at Nashawena Bridge where impacts of the discharge from Falmouth's Wastewater Treatment Facility would be seen.

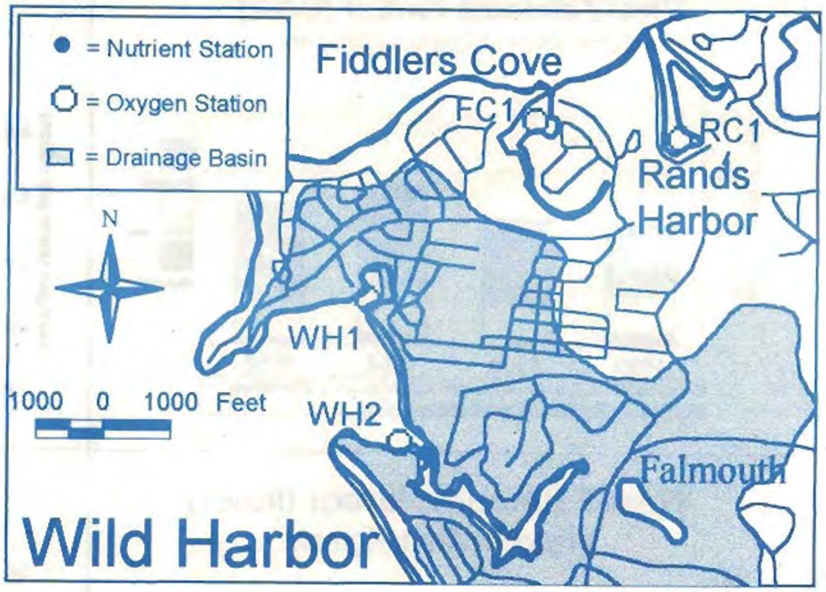

West Falmouth Harbor (Outer)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
1992
1993
1994
1995
Organic
Particulate
Inorganic


West Falmouth Harbor (Inner)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1992
1993
1994
1995
Chlorophyll
Phaeo-pig.


West Falmouth Harbor (Outer)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
1992
1993
1994
1995
Chlorophyll
Phaeo-pig.


WF1 - W. Falmouth Harbor/Town Dock
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
Feb-92
Aug-92
Feb-93
Aug-93
Feb-94
Aug-94
Feb-95
Aug-95
Surface Oxygen
Deep Oxygen

RANDS HARBOR, FIDDLER COVE & WILD HARBOR



Embayment and Watershed Characteristics

Rands Harbor and Fiddlers Cove are two small embayments within Megansett Harbor. These two embayments have small watersheds, and the Buzzards Bay Project has not evaluated separate watershed nitrogen loadings to these embayments which only have modest levels of development. Wild Harbor on the other hand, which lies between Megansett and West Falmouth Harbors in Falmouth, has a much larger watershed than Rands or Fiddlers Cove, but smaller than most of the other Buzzards Bay embayments monitored. All three systems appear well flushed with offshore waters, although the upper reaches of Wild Harbor known as Wild Harbor River is probably less so.

In 1969, a tanker spilled fuel oil in Buzzards Bay which washed ashore primarily in Wild Harbor. This was one of the larger oil spills to have occurred in Buzzards Bay and resulted in the closure of Wild Harbor to shellfishing for more than two decades. Purportedly, areas of marsh still occasional release smells of fuel oil.

The Wild Harbor watershed includes densely built summer cottages in the Silver Beach area—many of which have now been converted to year round residences, and the less densely built and older village of North Falmouth. Failed septic systems have been problematic, particularly in the New Silver Beach area. The town has sought to address this issue by draining wetlands and has proposed to construct a small treatment facility to handle those homes that cannot meet Title 5 septic system requirements. The watershed for this embayment, delineated by the Buzzards Bay Project in the early 1990's, shows that residential and commercial land covered a relatively high 45% of the watershed and accounted for 85% of the nitrogen loading to the estuary. The new drainage basin delineated by the Cape Cod Commission based on more detailed groundwater elevation data, suggests that the watershed is actually more than four times the size of the prior estimate, but with more inland forested areas, so that residential and commercial land account for only 38% of the landscape and 78% of the loadings. The larger watershed also results in more than twice the nitrogen loading. Still, existing loading using this new land use data suggests that Wild Harbor now receives only 36% of Project recommended nitrogen loading limits, and at build-out conditions, would receive only 84% of recommended nitrogen limits.

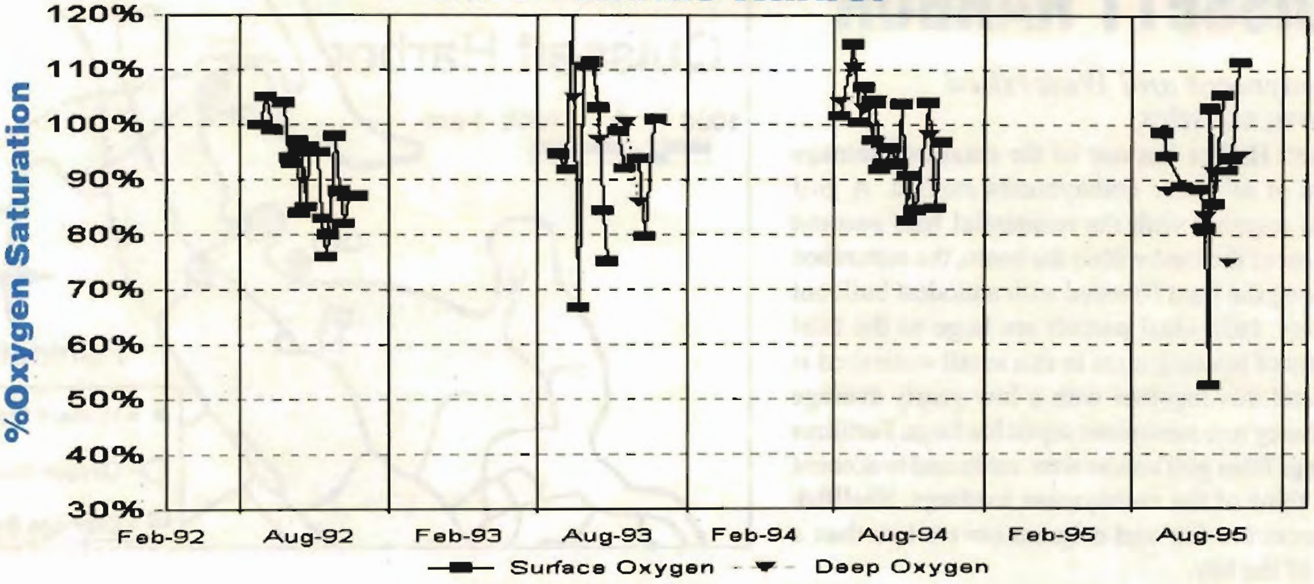
Water Quality

In Wild Harbor, water samples were not collected for nutrient analysis so we have only the oxygen data to discuss. Oxygen was monitored at two sites in Wild Harbor. Site WH1 was monitored in all four years, but site WH2 was monitored only in 1992 and halfway through the 1993 season. This monitoring showed that oxygen saturation levels were generally very good, typically ranging from 70 to 90% saturation, with summertime means of 73% to 79% saturation, but in 1995, oxygen saturations showed a big drop, with many values in the 40% to 65% saturation range, and a summertime average of 59% saturation. The lack of data from station WH2 since mid 1993 could not account for the lower summertime mean oxygen saturations at WH1 and WH2 were comparable. Curiously, water transparency showed a slight improvement in 1995. Without other data such as nitrogen concentrations or phytoplankton pigments, it is difficult to interpret these results, but it is worth noting that several other embayments around Buzzards Bay also showed declines in oxygen saturations in 1995. It is possible that high water temperatures and overcast or other contributing weather conditions could have coincided with sampling days in 1995. Summertime salinities consistently ranged from 27.5 to 28.5 ppt (compared to 30 to 31 ppt offshore in Megansett for example), showing slight freshwater influence at these monitoring sites.

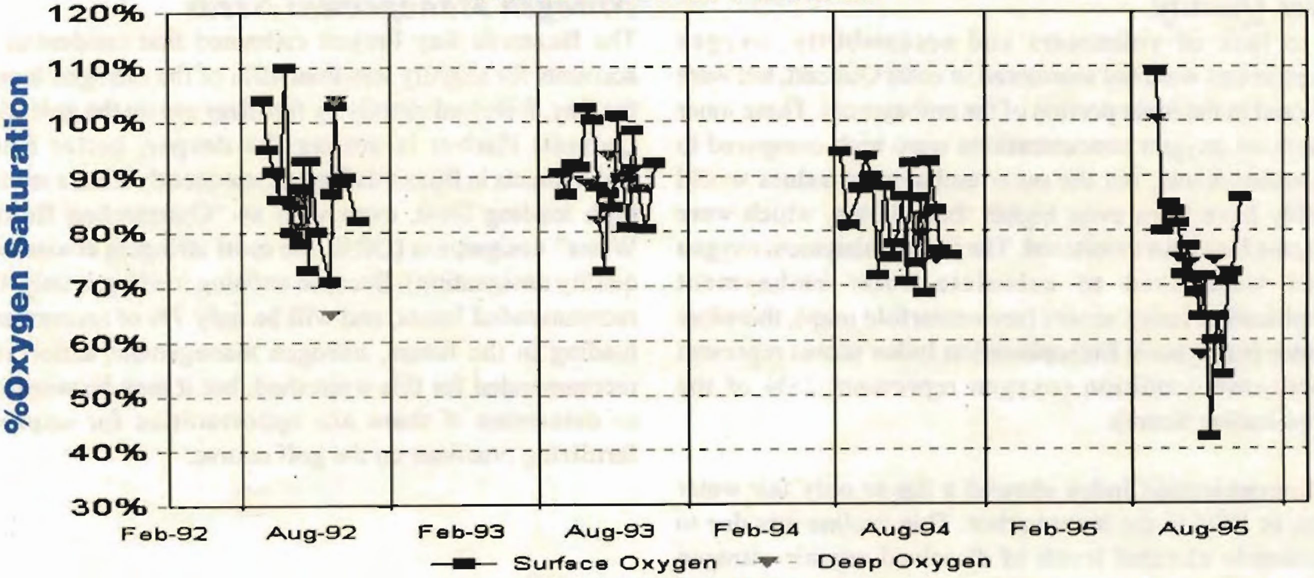
Fiddlers Cove was monitored only in 1992 and 1993 for oxygen, and saturations observed there were better than in most Buzzards bay embayments. In Rands Harbor, oxygen was monitored in all four years, and like Wild Harbor, a big drop in oxygen saturations occurred in 1995 (mean saturations

Continued on page 67

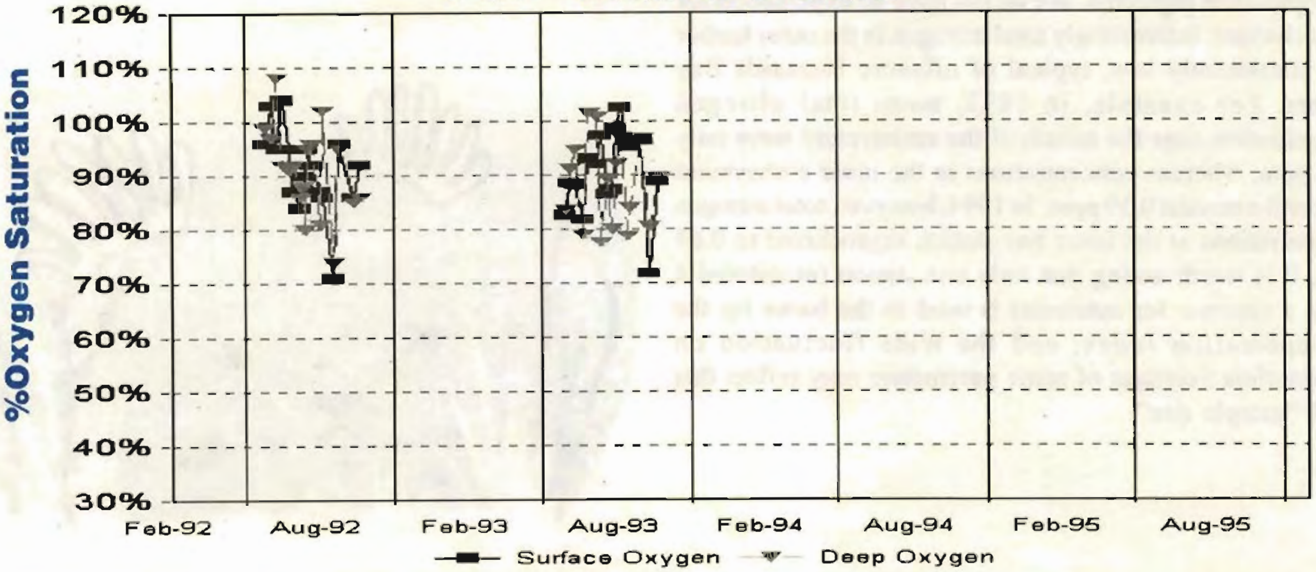
RH1 - Rands Harbor



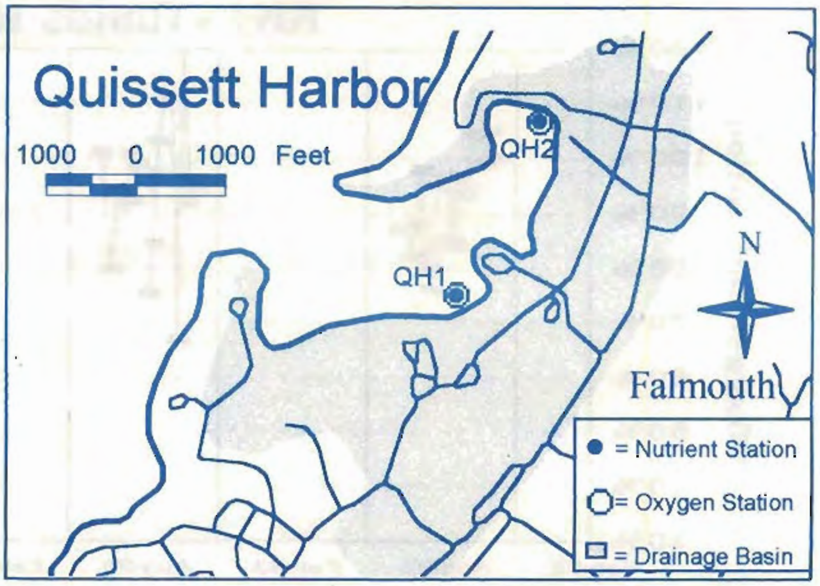
WH1 - Wild Harbor



FC1 - Fiddler's Cove



QUISSETT HARBOR



Embayment and Watershed Characteristics

Quissett Harbor has one of the smallest drainage basins of all those embayments studied. A golf course together with the residential land account for most of the land within the basin, the watershed is among the least forested with a modest buildout capacity. Individual parcels are large so the total number of housing units in this small watershed is low, and this together with a low yearly average occupancy rate minimizes septic loadings. Fertilizer loadings from golf course were estimated to account for a third of the embayment loadings. Shellfish resources are fair and eelgrass covers less than a third of the bay.

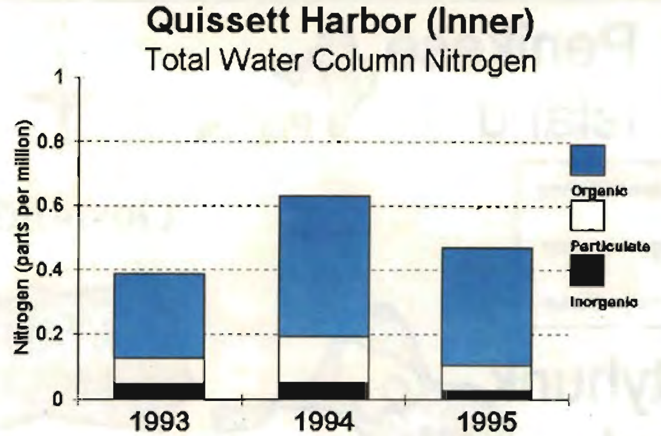
Water Quality

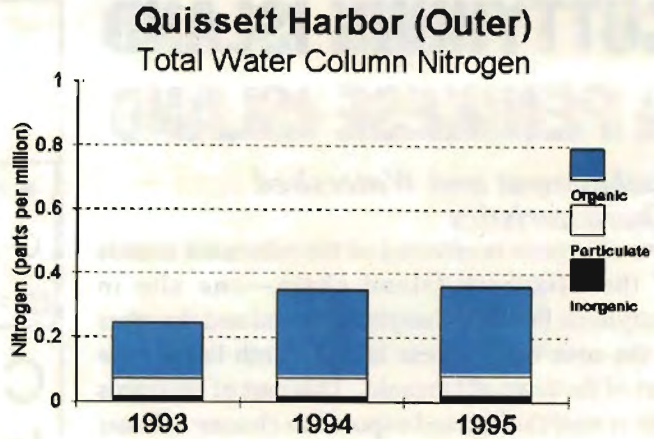
Due to lack of volunteers and accessibility, oxygen concentrations were not monitored in outer Quissett, but were monitored in the inner portion of the embayment. These inner embayment oxygen concentrations were high compared to most embayments, but the outer embayment values would probably have been even higher than shown, which were among the best sites monitored. The inner embayment oxygen values were used to calculate outer embayment Eutrophication Index scores (see centerfold map), therefore the outer embayment Eutrophication Index scores represent a worst case condition (oxygen represents 25% of the Eutrophication Score).

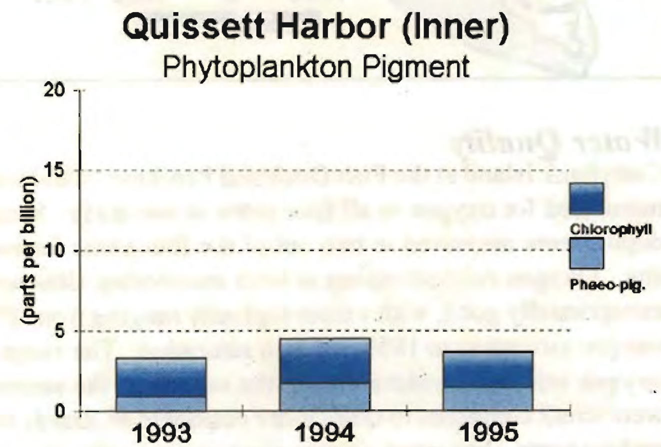
The Eutrophication Index showed a dip to only fair water quality in 1994 in the inner harbor. This decline was due to considerably elevated levels of dissolved organic nitrogen together with lesser increases in particulate nitrogen and phytoplankton pigments. We do not have an explanation for these changes. Interestingly total nitrogen in the outer harbor was consistently low, typical of offshore Buzzards Bay waters. For example, in 1993, mean total nitrogen concentration near the mouth of the embayment were only 0.21 ppm, whereas concentrations in the inner embayment were still a modest 0.39 ppm. In 1994, however, total nitrogen concentrations at the inner bay station skyrocketed to 0.63 ppm. It is worth noting that only one station (monitored 4 times a summer for nutrients) is used as the bases for the Eutrophication Index, and the wide fluctuation on summertime averages of some parameters may reflect this small "sample size".

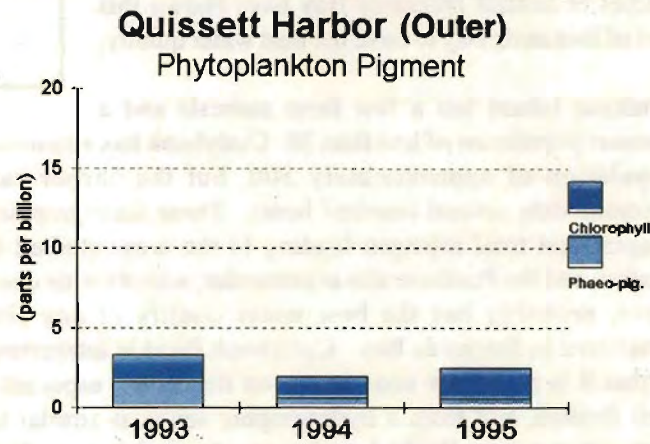
Nitrogen Management Needs

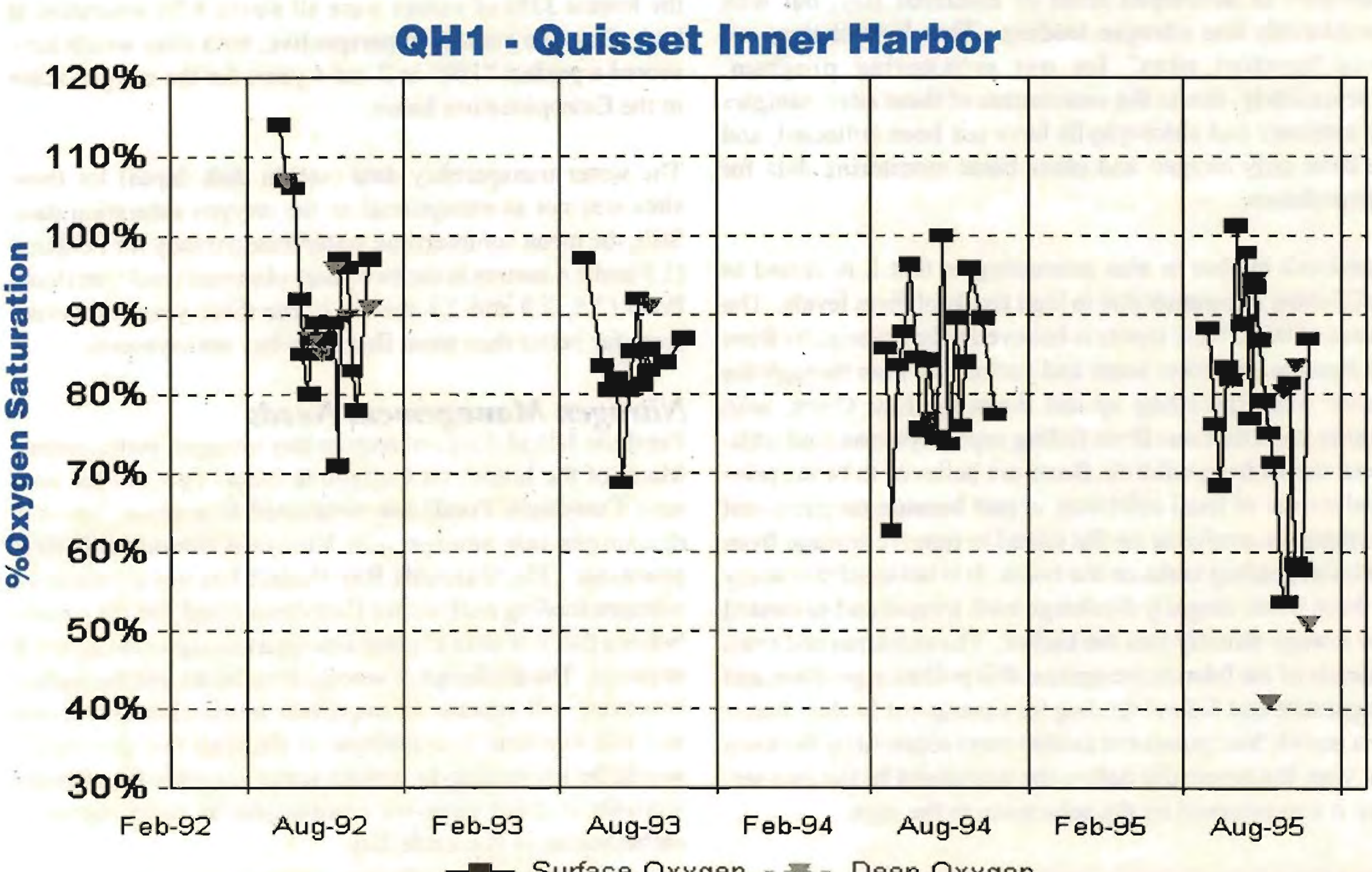
The Buzzards Bay Project estimated that residential land accounts for slightly less than 40% of the nitrogen inputs to the Bay, followed closely by fertilizer use on the golf course. Quissett Harbor is among the deeper, better flushed embayments in Buzzards Bay. Consequently it has a relatively high loading limit, even with an "Outstanding Resource Water" designation (ORW-the most stringent coastal water quality designation). Because existing loading is only 4% of recommended limits, and will be only 7% of recommended loading in the future, nitrogen management action is not recommended for this watershed, but it may be worthwhile to determine if there are opportunities for improving fertilizing practices on the golf course.


Quissett Harbor (Inner)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
Organic
Particulate
Inorganic
1993
1994
1995

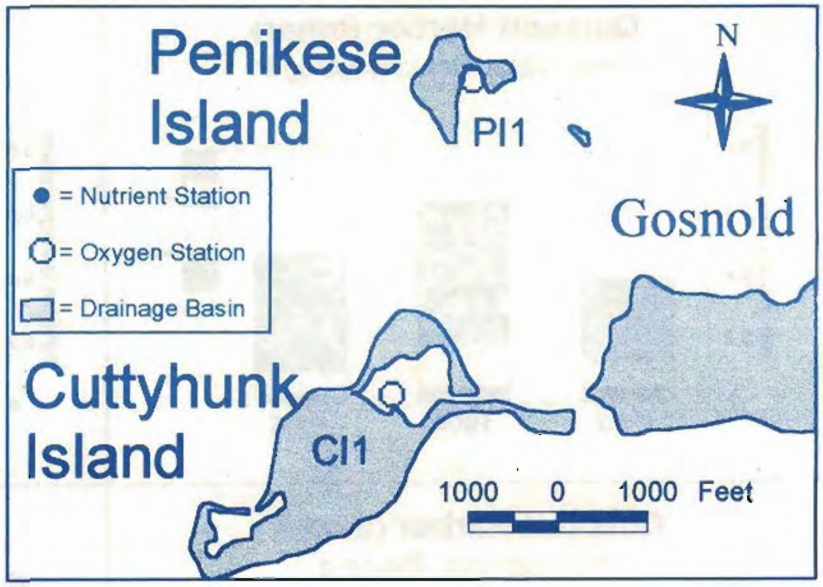

Quissett Harbor (Outer)
Total Water Column Nitrogen
Nitrogen (parts per million)
1
0.8
0.6
0.4
0.2
0
Organic
Particulate
Inorganic
1993
1994
1995


Quissett Harbor (Inner)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
Chlorophyll
Phaeo-pig.
1993
1994
1995


Quissett Harbor (Outer)
Phytoplankton Pigment
(parts per billion)
20
15
10
5
0
Chlorophyll
Phaeo-pig.
1993
1994
1995


QH1 - Quisset Inner Harbor
%Oxygen Saturation
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
Feb-92
Aug-92
Feb-93
Aug-93
Feb-94
Aug-94
Feb-95
Aug-95
Surface Oxygen
Deep Oxygen

CUTTYHUNK ISLAND & PENIKESE ISLAND



Embayment and Watershed Characteristics

Two sites were monitored on the outermost islands of the Elizabeth Island chain—one site in Cuttyhunk Pond on Cuttyhunk Island and the other in the cove on Penikese Island. Both Islands are part of the town of Gosnold. This part of Buzzards Bay is well flushed and exposed to cleaner Atlantic Ocean waters offshore. Previous oceanographic studies of central Buzzards Bay have shown this part of Buzzards Bay to have the best water quality.

Penikese Island has a few farm animals and a summer population of less than 20. Cuttyhunk has a summer population of approximately 500, but the harbor can accommodate several hundred boats. These demographics suggest that total nitrogen loading to the areas studied is modest, and the Penikese site in particular, with its wide open Cove, probably has the best water quality of any site monitored in Buzzards Bay. Cuttyhunk Pond is interesting in that it is a shallow coastal lagoon that is not especially well flushed, and from a hydrographic sense, is similar to some of the less flushed embayments we have studied elsewhere in developed areas of Buzzards Bay, but with considerably less nitrogen loading. Thus both stations are good "control sites" for our monitoring program. Unfortunately, due to the remoteness of these sites, samples for nutrients and chlorophylls have not been collected, and we have only oxygen and other basic monitoring data for interpretation.

Cuttyhunk Harbor is also interesting in that it is closed to shellfishing in summer due to high fecal coliform levels. The source of these fecal inputs is believed to be principally from the many large power boats and yachts that pass through the harbor when travelling up and down the East Coast, with smaller contributions from failing septic systems, and additional inputs from wildlife. Boats are believed to be the principal source of fecal coliforms in part because no pump-out facilities are available on the island to remove sewage from the toilet holding tanks on the boats. It is believed that many of these boats illegally discharge both treated and untreated raw sewage directly into the harbor. The residents and town officials of the Islands recognized this pollution problem and sought state and federal funding for a pump-out facility. Funds for a mobile boat pump-out facility were received by the town last year, but ironically before the boat could be put into service it was returned by the selectmen to the state.

Water Quality

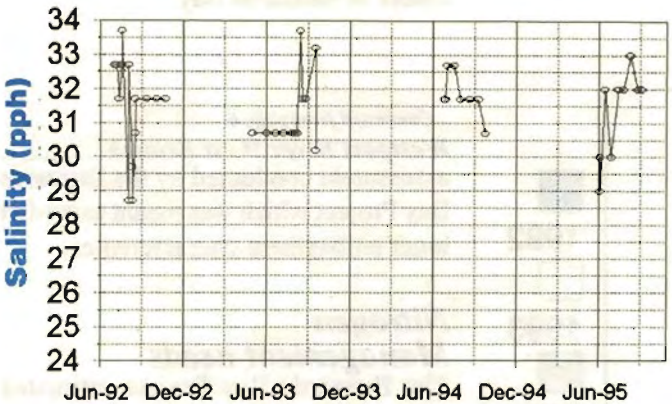
Cuttyhunk Island at the Fish Dock and Penikese Island were monitored for oxygen in all four years of our study. Secchi depths were measured in two out of the four years for each site. Oxygen concentrations at both monitoring sites were exceptionally good, with values typically ranging from 85% oxygen saturation to 105% oxygen saturation. The range of oxygen saturation values during the course of the summer were small compared to other more eutrophic Buzzards Bay embayments. The mean summertime oxygen saturations of the lowest 33% of values were all above 87% saturation at both sites. To put this in perspective, both sites would have scored a perfect "100" in 2 out 4 years for the oxygen score in the Eutrophication Index.

The water transparency data (secchi disk depth) for these sites was not as exceptional as the oxygen saturation data. Still, the mean summertime water transparency for Penikese (1.9 and 2.4 meters in the two years observed) and Cuttyhunk Pond (2.5, 2.9 and 2.1 meters in the three years observed) were far better than most Buzzards bay embayments.

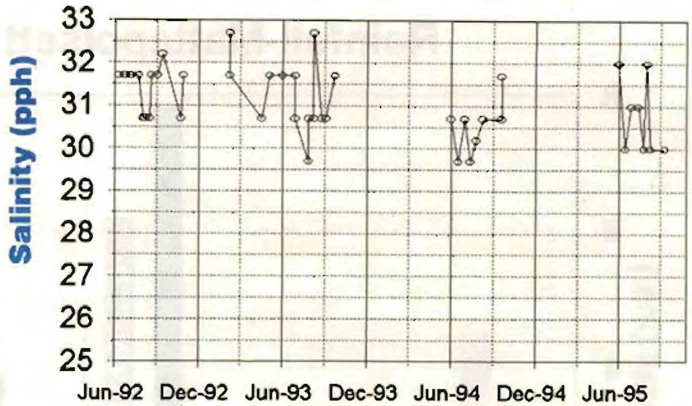
Nitrogen Management Needs

Penikese Island does not require any nitrogen management. Many of the homes on Cuttyhunk Island (but not the ones near Cuttyhunk Pond) are connected to a sewer line that discharges raw sewage into Vineyard Sound with little treatment. The Buzzards Bay Project has not conducted a nitrogen loading analysis for Cuttyhunk Pond, but the authors believe that it is unlikely that nitrogen management action is required. The discharge of sewage from boats into the harbor, however, will remain an important human health concern and will continue to contribute to shellfish bed closures. It would be interesting to collect water samples for nitrogen analysis at these sites for comparison to more eutrophic embayments in Buzzards Bay. ◆◆◆◆◆

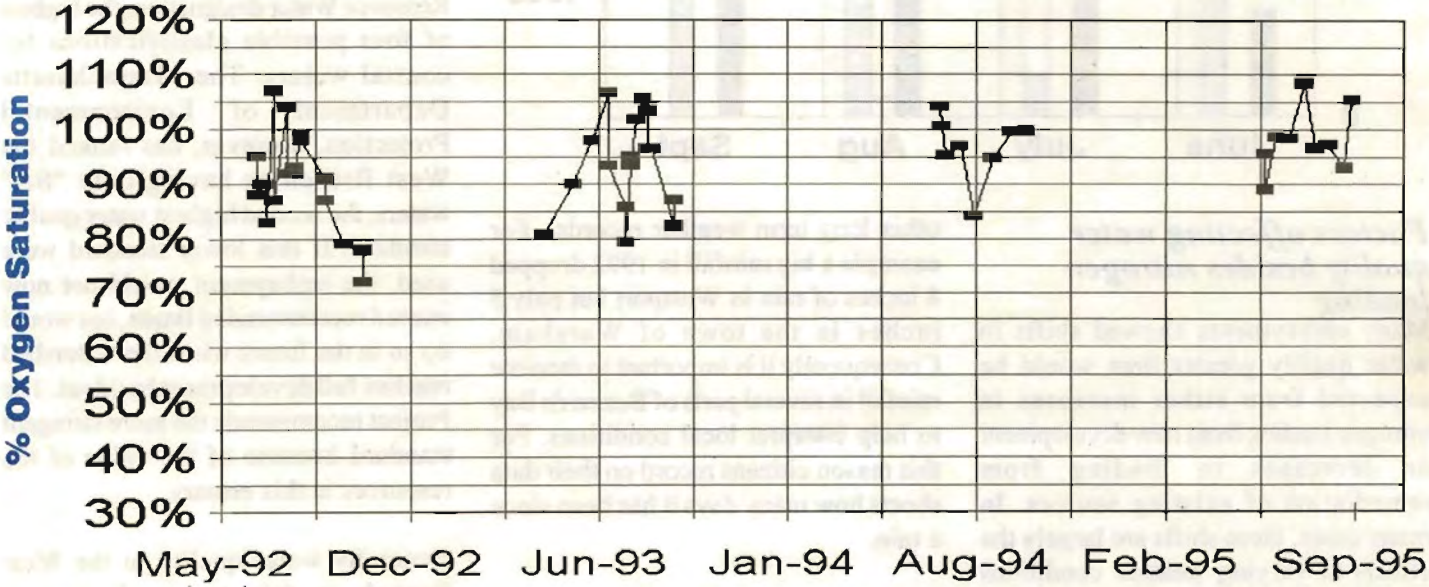
Cuttyhunk Island, CI1



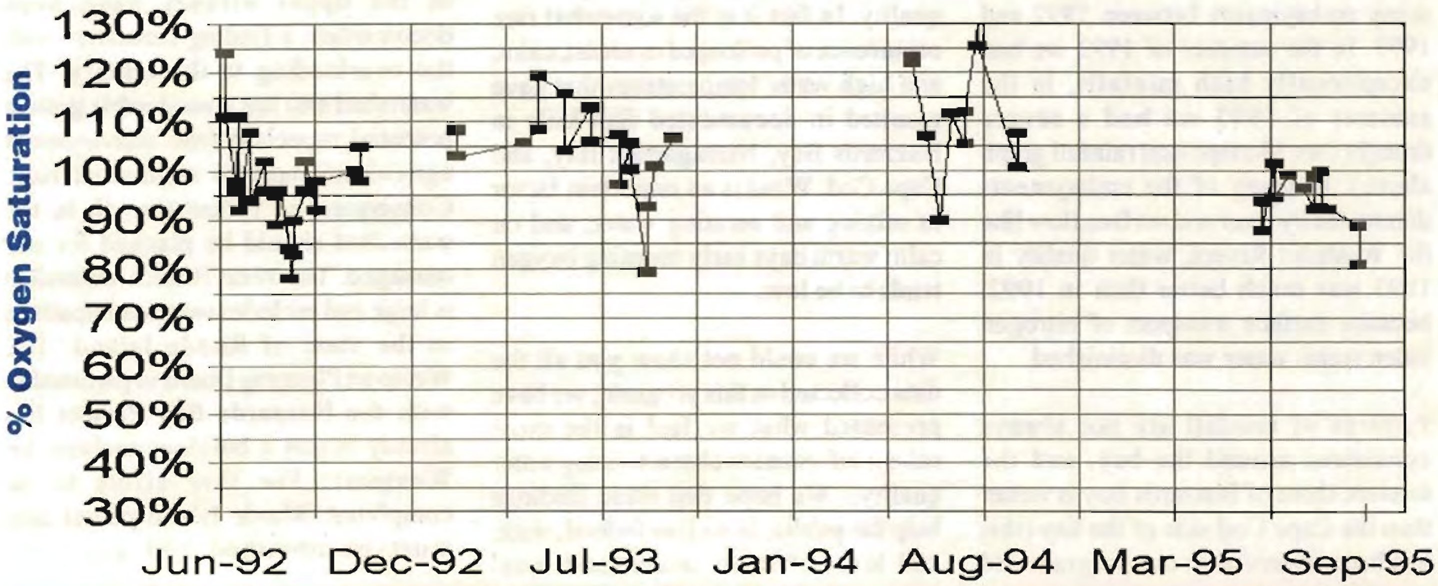
Penikese Island, PN1



Cuttyhunk Pond

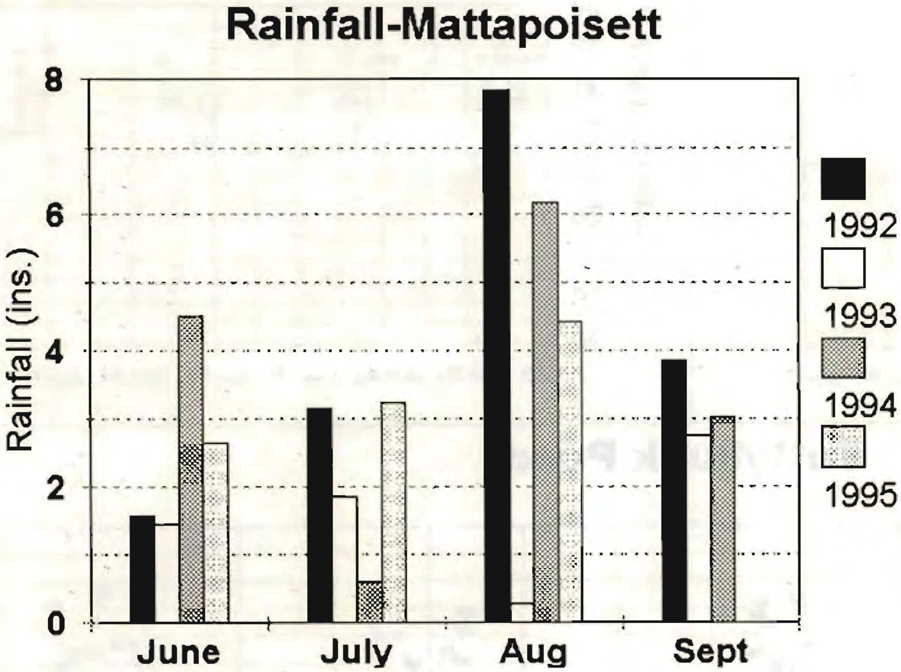


Penikese Island



...Continued from page 5

Factors Affecting Water Quality



Factors affecting water quality besides nitrogen loading

Many embayments showed shifts in water quality greater than would be expected from either increases in nitrogen loading from new development or decreases in loading from remediation of existing sources. In many cases, these shifts are largely the effects of varying weather conditions from year to year. The most important of these weather factors appears to be rainfall. A good contrast can be seen in many embayments between 1992 and 1993. In the summer of 1992 we had exceptionally high rainfalls, in the summer of 1993 we had a severe drought (see Mattapoisett rainfall graph above). In many of the embayments dominated by river and surface flow like the Westport Rivers, water quality in 1993 was much better than in 1992, because surface transport of nitrogen laden storm water was diminished.

Patterns of rainfall are not always consistent around the bay, and the western shore of Buzzards Bay is wetter than the Cape Cod side of the bay (this has been observed in our program and other long term weather records). For example a big rainfall in 1992 dropped 8 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 citizens record on their data sheets how many days it has been since a rain.

Besides rainfall, wind, water temperature and light are the main factors affecting day to day water quality. In fact it is the somewhat rare occurrence of prolonged overcast, calm, and high water temperatures that have resulted in documented fish kills in Buzzards Bay, Narragansett Bay, and Cape Cod. Wind is an important factor in mixing and aerating water, and on calm warm days early morning oxygen tends to be low.

While we could not show you all the data collected in this program, we have presented what we feel is the most salient information characterizing water quality. We hope that these findings help the public, as well as federal, state, and local officials understand local water quality conditions and how individual embayments compare to others in Buzzards Bay.

◆◆◆◆◆

...Continued from page 6

Westport River West Branch

assessment conducted by the Buzzards Bay Project which was meant to predict inner embayment characteristics.

Nitrogen Management needs

The Buzzards Bay Project estimated that existing nitrogen loadings are 22% over Project 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 appreciably 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. The Westport Planning Board in partnership with the Buzzards Bay Project has already begun a buildout analysis for Westport. For this effort to be completed, Rhode Island parcel data must be obtained and analyzed.

Nitrogen management for this estuary will require implementation of agricultural "best management practices" and controls on the number or 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.

...Continued from page 8

Westport River East Branch

coincided with sampling days. Whatever the case, both transport of nutrients and water quality in the East Branch are affected considerably by weather conditions.

Nitrogen Management needs

All indicators suggest water quality in the East Branch is impaired, and the estuary has had some of the worst Eutrophication Index Scores and total nitrogen levels around Buzzards Bay. Historical aerial photographs suggest eelgrass beds have disappeared in the upper estuary—a pattern consistent with the effects of eutrophication. 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. The Buzzards Bay Project is now working with the City of Fall River and Town of Westport to prepare Open Space Plans to meet this need.

Under so-called "outstanding resource water" designation loading limits—the strictest water quality standards—the East Branch is now overloaded with nitrogen by 200%, and future buildout loadings could further double the loading. This ORW classification may be too difficult to achieve in this estuary. In fact, currently, the Massachusetts Department of Environmental Protection has ranked the East Branch as having SB waters. The only other Buzzards Bay embayment with this low a ranking is New Bedford Harbor. For practical reasons the intermediate SA classification loading limits may be most achievable for this estuary. Using this standard, the East Branch would be classified as only being slightly over recommended limits today.

...Continued from page 10

Slocum & Little Rivers

many sites were monitored in the EPA study, additional sites along the Slocums River could be added to the Citizen's Monitoring Program to better track inputs in this complex watershed.

The results of monitoring in Little River were somewhat of a surprise, considering the low estimates of nitrogen sources in the watershed. Upon closer examination, it became apparent that water conditions and trends in the Little River often paralleled those in the Slocums River. This can be explained by the fact that the Little River and the Slocums River confluence at their mouths, with a large sandbar isolating them from offshore waters, and it is likely that some water leaving the Slocums River estuary, which has 4 times the mean tidal exchange volume of the Little River, returns on the incoming tide to the Little River. For example, in 1994, dissolved inorganic nitrogen and dissolved organic nitrogen showed dramatic increases in both the Slocums River and Little River although overall, concentrations are not as high in the Little River. Interestingly, station SR3 tends to be slightly higher in inorganic nitrogen than SR2, the more northerly station. This suggests that more nitrogen may be entering the mouth of the Little River from the Slocums than coming from the watershed.

Oxygen was monitored at station SR1, SR2, SR3, and SR4 by the Lloyd Center for Environmental Studies personnel and volunteers. All four sites show wide swings in oxygen concentrations during the summer. Such patterns are often observed in shallow bays where benthic algae and seagrasses produce high levels of oxygen on sunny days, but organic matter in the sediments and algae reduce oxygen concentrations on calm overcast days. The four sites had consistent patterns of oxygen from year to year, with the innermost stations showing lower oxygen saturations. In most years the innermost stations (SR1 and SR2) showed more extreme low and high values than outer stations SR3 and SR4. Each of these sites showed marginally better oxygen concentrations in 1992, than subsequent years, perhaps related to slightly cooler water temperatures and more rainfall, and hence river flushing in 1992. In all 4 years, mean summer oxygen saturation concentrations (lowest third of values) in the Little River were consistently lower (10% to 15% lower) than in the Slocums River. The reason for these differences are not clear.

Nitrogen Management needs

The Buzzards Bay Project estimated that existing nitrogen loadings to the Slocums River are more than 200% over Project recommended limits for SA classified waters. The relatively poor water quality documented through the water quality monitoring program, and limited distribution of eelgrass, suggest the Slocums River is among the most eutrophic of Buzzards Bay

Continued Next Page...

embayments. The Buzzards Bay Project estimated that this watershed also has considerable growth potential with 9,400 additional units possible from unbuilt or converted agricultural areas. However, the extensive wetlands in the watershed suggest this estimate of full buildout is too high. In addition, extensive wetland coverage in the watershed could help assimilate some of the nitrogen headed to the estuary.

In contrast to the Slocums River, the Buzzards Bay Project estimated that existing nitrogen loadings to Little River are well below Project recommended limits for SA waters and this conclusion appears to be supported by the water quality monitoring program. The watershed is estimated to have considerable growth potential, especially from conversion of agricultural land to residential land. Despite this, Little River is not expected to exceed recommended SA limits even at build-out conditions. The town of Dartmouth could apply outstanding resource waters nitrogen loading limits in an effort to keep this embayment as pristine as possible. Based on this loading analysis, water quality in the Little River should be better than that observed in the monitoring program. One possible explanation is that the close proximity of the mouth of the Slocums River to Little River results in the higher nitrogen loaded Slocums River flow with the incoming tide.

Because the Slocums River watershed still has considerable growth potential, nitrogen management in this watershed is expected to be challenging. Like the Westport River, nitrogen management for this estuary will require implementation of agricultural "best management practices", sewer extensions, alternative septic systems, protection of open space, and agricultural protection restrictions are important strategies in this watershed for managing future growth. Controls on the number or performance of future septic systems and upgrade of cesspools to septic systems with advanced nitrogen removal and sewering of dense areas are other management options for this estuary.

*****

...Continued from page 12

Apponagansett Bay

limits (refer to the Buzzards Bay Project's subwatershed reports). Since then, the Project revised its estimates to 22% over recommended limits. Still, this overload does not seem as bad as the degraded conditions documented by the Citizens' Water Quality Monitoring Program suggesting existing nitrogen loadings were underestimated or sources omitted from the Project's analysis. Of course the 22% overlimit was based on the so called "SA water quality" standard (second most stringent) and that the bay would be more overloaded (by more than 150%) if the more stringent "outstanding resource waters" designation limits were adopted.

Apponagansett Bay is very shallow and resuspension of sediments because of boat traffic propeller wash may also be contributing to poor water transparency and nutrient release to the water. Better controls on boat speeds in the upper estuary could be included as part of any management strategy.

Because most of the embayment basin is already developed, it has less build-out potential compared to other embayments of its size. Remediation of existing septic systems is a high priority. Possible long term strategies include upgrading cesspools to nitrogen removal systems and elimination of inputs through connections to the town's sewage treatment facility. Setting aside open space and establishing per acre nitrogen loading limits on new development are important options for managing inputs from new development.

*****

...Continued from page 18

Little & Nasketucket Bays

Nitrogen Management needs

In 1994, the Buzzards Bay Project estimated that farm animals account for 46% of the nitrogen load to the upper reaches of Nasketucket Bay (including Sconticut Neck), and other cropland and nurseries account for an additional 16%. Residential inputs account for only 20% of inputs. These estimates for farm animals were based on 1500 animal units, (which equals 1000 dairy cows). Even with these loads, the Project estimated that existing nitrogen loading to Nasketucket Bay as a whole was well below recommended limits. However, because of apparent eutrophic conditions in Little Bay, the Project recommended a separate nitrogen management strategy for the Little Bay subwatershed area (which is more dominated by agricultural inputs). Last year, the Town of Fairhaven gathered the necessary land

...Continued from page 20

Mattapoisett Harbor

Nitrogen Management needs

Residential and commercial land and roads account for 60% of the inputs to the Harbor whereas cropland accounts for 28% of the Bay's discharges. 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 ecosystems may also be degraded due to nitrogen inputs. Because of the considerable volume and degree of flushing in Mattapoisett Harbor, this embayment has one of the highest loading limits in Buzzards Bay. Using a SA water quality goal, the embayment does not now and will not in the future exceed recommended loading limits and for this reason, the nitrogen management for the Harbor as a whole was not recommended as a high priority. As noted on the following pages, however, those portions of the watershed draining into Eel Pond do require management action to restore water quality. *****

...Continued from page 24

Aucoot Cove

facility such as aeration of its sewage ponds and construction of an additional lagoon. Both these improvements will help reduce nitrogen loadings of the existing discharge volumes.

In 1990, large masses of algae accumulated on the bottom of the covelet, and large sheets of *Ulva* (sea lettuce) were observed in the Effluent Creek. Dissolved oxygen percent saturations and nitrogen and chlorophyll concentrations are elevated at both sites. For related reasons, fecal coliform levels in both of these areas are often elevated. Thus, because these two confined areas are the initial receptacles for nitrogen discharges to the Cove, they appear to be impacted even though outer portions of the Cove have good water quality and is well below recommended nitrogen loading limits.

◆◆◆◆◆

...Continued from page 30

Wareham River Estuary

estuary is nearly evenly split between residential land, the sewage treatment plant, and agriculture (cranberry bogs), closely followed by commercial and industrial development. All these sources must be included in a comprehensive management strategy. The town of Wareham is now in the early stages of planning for upgrades in the town's wastewater treatment plant and regulatory agencies like the US EPA and Massachusetts DEP are considering imposing nitrogen limits as part of the plants discharge permit scheduled for renewal in 1997. The Wareham River is now well over SA limits, and nitrogen loading could more than double at full buildout. Adoption of an SB designation for the Wareham River estuary will require a less challenging management strategy to be implemented for the estuary and may be appropriate in light of the Sewage Treatment Plant discharge.

Marks Cove has one of the smaller embayment drainage basins in Buzzards Bay, but one largely composed of residential parcels. The residential land accounts for 67% of the total nitrogen load to Marks Cove. Part of the embayment is sewered and overall Marks Cove at first glance would appear to have a relatively low nitrogen loading rate, but clearly the water quality in Marks Cove largely reflects the more degraded conditions in the Wareham and Agawam Rivers.

◆◆◆◆◆

...Continued from page 38

Buttermilk & Little Buttermilk Bays

levels remain relatively high (>60%) which may be the result of tidal mixing inhibiting stratification within this basin, or high daytime levels of oxygen production by algae. However, oxygen levels are highly variable often ranging 60% and 115% saturation during the summer, which suggests that the consumption of oxygen from organic matter decomposition is often greater than oxygen production by photosynthesis or diffusion from the atmosphere. However, as long as oxygen levels remain above 60%, habitat quality for some benthic animals (like shellfish) will be good. Unfortunately, present oxygen levels and possibly decreased light penetration due to algal blooms will likely inhibit eelgrass beds and associated scallop production.

Nitrogen Management Needs

Buttermilk Bay is the only embayment in Buzzards Bay where the Buzzards Bay Project's nitrogen loading limits have been adopted and where detailed mass loading evaluations have been performed. As a result of Project's efforts, the towns of Wareham, Plymouth, and Bourne "reprogrammed" future growth through changes in zoning to reduce the number of homes in the watershed so that recommended nitrogen limits would not be exceeded. The nitrogen loading targets were also met in part because the towns of Bourne and Wareham sewered several near shore areas, although this was done to minimize health threats associated with failing septic systems, not meet nitrogen goals. The sewering of the near shore watershed in Buttermilk Bay should result in water quality improvements over the next few years as the septic system groundwater plumes run their course to the bay. While both Buttermilk and Big Buttermilk Bay showed a big decline in the Eutrophication Index between 1993 and 1994, Buttermilk has shown too much variability from year to year to discern a clear trend. For example, although there is no Eutrophication Index score for 1995, most water quality parameters showed a moderate improvement that year in Buttermilk. On the other hand, Little Buttermilk continued a decline in 1995. In contrast, fecal coliform concentrations have remained the same during this period. Until trends become more apparent, monitoring of water quality in Buttermilk Bay should continue to determine whether additional management action is required in Little Buttermilk. Given the importance of Buttermilk Bay's water quality to Little Buttermilk Bay the nitrogen management of the larger bay may have important positive effects on the adjacent smaller system.

◆◆◆◆◆

...Continued from page 52

Megansett & Squeteague Harbors

nitrogen is residential development. The watershed has considerable growth potential, but at buildout the embayment will only be at 21% of the recommended Project limits. Consequently management action was ranked a low priority for Megansett harbor.

Similarly, the Buzzards Bay Project estimated that existing nitrogen loadings to Squeteague Harbor are only a quarter of Project recommended "SA" water quality standard limits (the second

Continued Next Page...

most stringent water quality standard). The watershed also has considerable growth potential, but will still only be 56% of the recommended limit at buildout. Should the Town of Bourne adopt the more protective Outstanding Resource Water standard, some nitrogen management controls will be required, since future loading could exceed the Projects recommended limits by 17%. This evaluation needs to be revised since the Cape Cod Commission has revised the watershed delineation originally prepared by the BBP based on new well data. However, this harbor complex represents a significant resource and nitrogen management should focus on maintenance of one of the highest quality ecological subsystems to Buzzards Bay.

◆◆◆◆◆

...Continued from page 54

West Falmouth Harbor

establish specific nitrogen loading limits for each major segment of the estuary). Using the single flushing standard approach, with an "SA" water quality standard loading limit (the second most stringent standard for coastal waters), this embayment is now 20% below recommended loading limits, but would exceed these limits at full buildout conditions. If the less stringent SA designation were applied to this embayment (somewhat analogous to the towns' "Stabilization Area" designation under its nutrient loading bylaw), a critical loading limit of 37,000 kilograms per year would be established. Nitrogen management to this level of protection would be less challenging to the town because existing loadings are now 40% of this limit and

GLOSSARY

Anoxic: A condition is which dissolved oxygen is absent. Anoxic water quality conditions often result in fish kills and shellfish mortality.

Algal bloom: A condition resulting from excessive nutrient levels or other physical and chemical conditions that enable algae to reproduce rapidly.

Anthropogenic: Human related effects. Anthropogenic impacts to water quality include wastewater from septic systems and treatment plant discharges, road and agricultural runoff, and acid rain.

Bathymetry: Measure of the depth of a water body. Important in determining the total volume of water in an embayment which is critical to nitrogen loading analysis.

Build-out Analysis: A parcel-by-parcel analysis to estimate the total number of existing and developable units, based on current zoning and other land use regulations. Such an analysis is essential for managing and limiting impacts of growth.

Combined Sewer Overflows (CSO): A pipe that, during rain storms, discharges untreated wastewater from a sewer system that carries both sewage and stormwater. The overflow occurs because a system does not have the capacity to transport and treat the increased flow caused by stormwater runoff. New Bedford is the only Buzzards Bay municipality with CSO discharges.

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 20 feet in clear waters. Eelgrass beds are an important habitat and nursery for fish, shellfish, and waterfowl.

Embayment: A small 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 pond), and river mouths.

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.

Eutrophication (coastal): The process of nutrient enrichment in aquatic ecosystems. In marine systems, 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 growth of bacteria, and can cause broad shifts in ecological communities present and contribute to 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: Bacteria that are present in the intestines and feces of warm-blooded animals and that are often used as indicators of the sanitary quality of water. Their degree of presence in water is expressed as the number of bacteria per 100 milliliters of the sample. The greater the number of fecal coliforms, the higher the risk of exposure to human pathogens. The indicator is used by the Massachusetts Division of Marine Fisheries in determining shellfish bed classification and local Boards of Health on swimming beach conditions.

Flushing Time: The mean length of time for a pollutant entering a water body to be removed by natural forces such as tides and currents; also referred to as residence time or turnover time, although there are important technical distinctions in their definitions.

Hypoxic: A condition in which dissolved oxygen is low or deficient. Hypoxic conditions stress marine plants and animals.

National Estuary Program: A state grant program within the US Environmental Protection Agency established under Section 320 of the Clean Water Act to designate estuaries of national significance and to incorporate scientific research into planning activities. Buzzards Bay was designated an Estuary of National Significance in 1985, thereby creating the Buzzards Bay Project.

Phytoplankton: Microscopic algae suspended in the water column. They contains pigments known as chlorophylls and phaeophytons which make eutrophic waters look green or brown.

Polychlorinated Biphenyls (PCB): A class of chlorinated aromatic compounds composed of two fused benzene rings and two or more chlorine atoms;used in heat exchange, insulating fluids and other applications. There are 209 different PCBs. PCBs are present in marine sediments in New Bedford Harbor where their cleanup is being coordinated by the US EPA Superfund Program. They, as well as other toxic contaminants, are not monitored as part of the Buzzards Bay Citizens Water Quality Monitoring Program.

Ulva: A green sheet-like seaweed commonly called "sea lettuce". Enteromorpha is another green algae that typically grows in long, thin green tubes. Both are found in eutrophic areas.

Watershed: The land that surrounds a body of water and contributes freshwater, either from streams, groundwater or surface water runoff, to that body of water.

would only be slightly over limit if future nitrogen inputs were not managed. The "Outstanding Resource Water" designation (ORW-the most stringent standard for coastal water quality) limit would be more difficult to achieve since the Harbor is already above the 17,000 kg per year limit under that designation, but the valuable resources and habitat of the harbor may warrant such action. Clearly this decision will be one for the town's officials and residents to decide.

...Continued from page 56

Rands Canal, Fiddler Cove & Wild Harbor

for the four years were 82%, 81%, 89%, and 76% respectively).

Nitrogen Management Needs

Because existing and future loadings to Wild Harbor appear to be well below recommended limits for Outstanding Resource Waters, nitrogen management action appears unwarranted. The declines in oxygen saturation in 1995 in Wild and Rands Harbors is intriguing and it is probably worthwhile to continue oxygen monitoring as well as to collect water samples for nutrient analysis once every several years to better put water quality conditions of these embayments in perspective.

About the authors

Dr. Joseph Costa is Executive Director of the Buzzards Bay Project National Estuary Program, which is a unit of the Massachusetts Coastal Zone Management office. Dr. Costa is an expert on the impacts of nitrogen loading to coastal waters and principal investigator on this project. Through the Buzzards Bay Project, he has developed strategies to assess and manage non-point sources of pollution to coastal watersheds. Dr. Brian Howes is an Associate Scientist at the Woods Hole Oceanographic Institution. He has authored many papers on coastal nutrient cycling and nitrogen inputs to coastal areas. He has also directed the Falmouth PondWatchers program since 1987. Eileen Gunn has been the Citizens Water Quality Monitoring Coordinator for the Coalition for Buzzards Bay since 1992. Her responsibilities have included training of volunteers, sampling coordination, data entry, database management, data analysis, graphic production, and program outreach. Ms. Gunn recently left the Coalition for Buzzards Bay and will be enrolled in Tufts University Urban and Environmental Policy Department in the fall.

Acknowledgments

The co-authors appreciate Eileen Gunn's hard work in designing and assembling this report and for her 4½ years of hard work and dedication. Her efforts ensured the success of the Monitoring Program. We particularly want to thank the more than 150 volunteers who have participated in the Buzzards Bay Citizens' Monitoring Program during the past 4 years. Special thanks to Tracy Warncke, Administrative Assistant at the Buzzards Bay Project, for all her assistance during the past four years in preparing graphics, publications, and other materials to make the citizen monitoring program a success. Thanks also to the Community Foundation of Cape Cod for providing financial assistance to print this document. Brad Hathaway helped edit this report for which we are grateful, especially on such short notice. Thanks to Mark Rasmussen for preparing the glossary and reviewing the report. Pamela Truesdale, Tony Williams and Tracy Warnke also helped review the text. This report was laid out by Karen Marshall and printed by Billard Communications of Sagamore, Massachusetts.

Buzzards Bay Project
National Estuary Program
2 Spring St., Marion, MA 02738
voice: (508) 748-3600
fax: (508) 748-3962
email: jcosta@state.ma.us

Coalition for Buzzards Bay
PO Box 268
Buzzards Bay, MA 02532
voice: (508) 759-1440
fax: (508) 759-1444

Funding for the joint Buzzards Bay Project—Coalition for Buzzards Bay Citizens' Water Quality Monitoring Program during the past five years was largely provided by the US Environmental Protection Agency through Cooperative Agreements with the Buzzards Bay Project at the Massachusetts Coastal Zone Management Office (Cooperative Agreements X001882-01, X001514-01, X991504-01, X991549-01) and the New England Interstate Water Control Commission (Cooperative Agreement X001550-01). The contents of this report does not necessarily reflect the views of either the US EPA or Commonwealth of Massachusetts.

Requests for copies of this report and inquiries regarding citizen participation should be directed to the Coalition for Buzzards Bay. Municipalities and others seeking technical guidance on water quality and habitat protection, including nitrogen management strategies, should contact the Buzzards Bay Project.