Narragansett Bay Water Quality: Status and Trends 2000

A Summary of WaterQuality Information

By

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***Much of this report is based on the RIDEM Bay WaterQuality :Status and Trends July 1998 Report to the Governor's Advisory Council on the Environment, with updates where recent data/information is available.**

Executive Summary

The water quality of Narragansett Bay is the result of many factors, both environmental and human. The Bay's watershed is remarkably vast - 1,650 square miles…over 10X the open water area of the Bay (~147 square miles). It is also one of the most densely populated in the country with an average of more than 1,100 people living in each square mile. The Industrial Revolution in America started on the banks of the Blackstone River, which flows into Narragansett Bay. From the mid-1800s into the early 1900s, sewer and industrial discharge pipes carried untreated human and industrial wastes from the cities to the nearby rivers and even directly into the Bay itself.

Current efforts to improve the Bay's water quality use environmental regulations based on state and federal environmental legislation, as well as technical outreach and education, to address the historic and ongoing pollutant sources discharging into this unique watershed. The historic combined sewer overflow problem, as well as its solution, reflect the urban character of the Bay's watershed. Future pollution control measures must also take into account current trends such as the suburbanization of the mid- and lower Bay shoreline that creates non-point pollution problems.

Twenty-five years of enforcement of Federal and State clean water laws have resulted in profound improvements in Narragansett Bay water quality. This report documents many of these. A summary of some of the major pollutant issues follows:

- In general, there is a clear North-South pollution gradient in the Bay, with highest pollutant levels in the urbanized Providence / Seekonk tidal rivers and the Fall River / Taunton River area, slightly lower levels in the urbanizing areas of Greenwich Bay and the upper Bay (between Conimicut Point and Prudence Island). Levels of pollutants in the main Bay channels decrease as one travels south towards the mouth of the Bay, with lowest levels at the East and West Passage openings to Block Island Sound. Poorly-flushes coves and harbors may also experience localized impacts from pollutants.

- The upgrading of municipal wastewater treatment facilities has reduced the biochemical oxygen demand that these facilities had placed on the Bay ecosystem. This is accomplished by the removal of solids from sewage and the biological breakdown of organic matter that occurs through secondary treatment at wastewater treatment facilities. Additional upgrading to tertiary treatment is in the design stage in Warwick, West Warwick and Cranston.

- Pretreatment requirements imposed on businesses that use metals through a variety of industrial processes has reduced the amount of metals discharged in wastewater. Technical assistance provided to these companies by environmental agencies and the development of less polluting technologies have helped to reduce the metals loadings to the Bay. The elimination of lead from gasoline has also had a significant impact on the input of this toxic metal to Narragansett Bay. Levels of metals have clearly decreased in wastewater discharges, and lowered metal concentrations are now being found in the surface sediments in the urbanized part of the estuary.

At the same time, more remains to be done to achieve the consistently high levels of water quality that Rhode Islanders desire and that Federal laws require. In spite of the fact that wastewater treatment plants have reduced the biochemical oxygen demand loadings to the Bay and have reduced the input of bacterial contaminants through chlorination, new treatment efforts must continue to deal with remaining pollutant problems. Such problems include:

- Combined Sewer Overflows (CSOs) that cause raw, untreated sewage to flow into the Bay after heavy rains due to the antiquated combined sewer lines and storm drains. The Narragansett Bay Commission is implementing a three phase construction and treatment program to deal with this issue.

- Nutrient inputs to the Bay, particularly nitrogen, are not yet dealt with. Excessive amounts of nitrogen continue to cause instances of oxygen depletion in some coves and other areas of the Bay. Nutrients are also the likely cause of lack of regrowth of critical habitat like eelgrass beds in the upper half of the Bay. Cities such as Tampa and Sarasota Bay have seen significant regrowth of submerged grass habitat once they began to remove nutrients from their wastewater treatment facilities. Habitat quality and function are likely being impaired by low oxygen levels in at least the upper third of the Bay. Present secondary treatment achieved at wastewater treatment plants does not reduce the high levels of nitrogen (up to 30 mg/L) associated with sewage. Wastewater Treatment Facilities represent a significant component of the total nitrogen load, and are the most cost-effective sources to treat, at least for initial decreases in nitrogen through optimization of present plant operations set for maximal nutrient removal capability (to ~ 7-8 mg/L). Efforts are presently underway through the RIDEM Municipal Assistance Program to provide technical assistance for operations at plants where such initial nitrogen removal may be feasible at reasonable cost. Connecticut has achieved significant decreases in nitrogen at their coastal WWTFs in this manner through a grants program to communities for cost-efficient optimization of plant operations.

- In unsewered communities, older failing septic systems can contribute significantly to bacterial and nutrient-loading. Even conventional systems that function properly do little to reduce nitrogen inputs to groundwater which can end up in the Bay, especially in sandy areas. In some areas near the Bay, newer technologies may be required that involve nitrogen reducing individual sewage disposal systems. In some areas with significant non-point sources of nitrogen, such as poor storage of manure, and poor application practices for lawn fertilizers and agricultural fertilizers, new management efforts may be needed to control these nutrient sources if the State is to achieve improvements in water quality.

- Cost-effective long-term monitoring and special surveys can be used to identify new or previously unidentified sources of pollution that impact water quality and measure the success of pollution control strategies as well as track any negative trends. It is critical that such efforts be maintained in order to provide decision-makers with accurate information that truly reflects present conditions and trends in Bay ecosystem health.

- There is inadequate data to presently judge quantifiable trends in habitat loss although there has clearly been significant losses of certain high quality habitats such as eelgrass beds in the upper Bay areas, linked to several causes, including excess nutrients.

Narragansett Bay Water Quality: Status and Trends 2000

INTRODUCTION

Narragansett Bay is quite large, covering approximately 147 square miles with an undulating shoreline that creates a string of sheltered coves where water circulation may be restricted. These characteristics, and other factors such as the location of urban areas on the Bay's shoreline and within its watershed, make it difficult to characterize the water quality of all the small coves and harbors.

In general, there is a clear north-south gradient of pollution in the main channels of the Bay, with highest pollutant levels in the urbanized Providence / Seekonk tidal rivers and the Fall River / Taunton River area, and slightly lower levels in the urbanizing areas such as Greenwich Bay and the upper Bay (between Conimicut Point and Prudence Island). Levels of pollutants in the open Bay channels continue to decrease as one travels south towards the mouth of the Bay, with lowest levels at the openings to Block Island Sound. Small harbors and coves , such as Wickford Harbor and Newport Harbor can tend to experience significant pollutant impacts due to poor flushing , which exacerbates the level and impact of local pollutant sources.

The Narragansett Bay watershed covers a land area of 1,657 square miles, more than ten times the area of the Bay itself. Only 40% of the Bay's watershed is in Rhode Island; the remaining 60% is in Massachusetts. The sheer size of the watershed and the fact that it includes 100 cities and towns in two states increases the difficulty in controlling pollutants entering the Bay, adversely impacting its water quality.

It has been more than a quarter century since the enactment in 1972 of the Clean Water Act, which created an array of regulatory programs designed to improve water quality. The Rhode Island General Assembly has also established similar laws during the past twenty-five years. In addition, major water and Bay protection and restoration efforts have been undertaken by local governments, environmental organizations, and others.

The term "pollutant" is a general term that, in the case of contaminants to the Bay, can include metals, nutrients, organic waste, and other constituents. Some of these have been more easily controlled than others. In addition to the various types of pollutants, there are also two general categories of pathways through which pollutants can enter the Bay. One of these pathways is called "point source," which means that the pollutant originates from specific and identifiable discharge pipes. The other pathway is called "non-point source," which means that the pollutants enter the Bay through more diffuse means, such as failed septic systems or runoff from land.

Due to strict federal point source discharge regulations based on Clean WaterAct requirements, greater success has been achieved in stemming point source pollutants than non-point source pollutants. The status and trends described in this report often reflect the level of regulatory control history that has occurred over the past 25 years. Specific pollutant types discussed in this report include: the amount of organic waste discharged into the Bay from municipal wastewater treatment facilities, metals flowing into the Bay, disease-causing bacteria and viruses in the water, and soluble nutrients entering the Bay from these treatment facilities.

ORGANIC WASTE

Organic waste (primarily human waste) discharged into the Bay can have dramatic environmental impacts, even if it has been partially treated. The breakdown of this waste in the water may deplete the amount of dissolved oxygen to such an extent that there is not enough oxygen remaining for fish to survive, resulting in localized fish kills. This may occur in coves or rivers where water circulation is limited and the water quickly becomes oxygen-depleted as the organic waste decomposes on the bottom. As a result of a fish kill, dead fish wash ashore, decompose, and create an odor that can be overpowering. Oxygen depletion caused by an excess of organic waste in the water can also cause other noxious smells. Malodorous decomposition of naturally occurring organic matter can result when oxygen levels fall and decomposition without oxygen (anaerobic decomposition) exists. Historical records show that during the 1800s the odors rising from the Providence River flowing through the city sometimes became so intense that people walking nearby fainted from the stench.

Over the past twenty-five years, Rhode Island has been extremely successful in removing organic waste from the effluents entering the Bay from wastewater treatment facilities. Figure 1 indicates the amount of money from federal, state, and municipal sources used to undertake major improvements to municipal wastewater treatment facilities in Rhode Island since 1973 This clearly shows a sustained level of effort on the part of Rhode Islanders to reduce the amount of human waste discharged into the Bay.

Figure 1. *Sources for all Figures in this Report are listed in Table 2 at the end.*

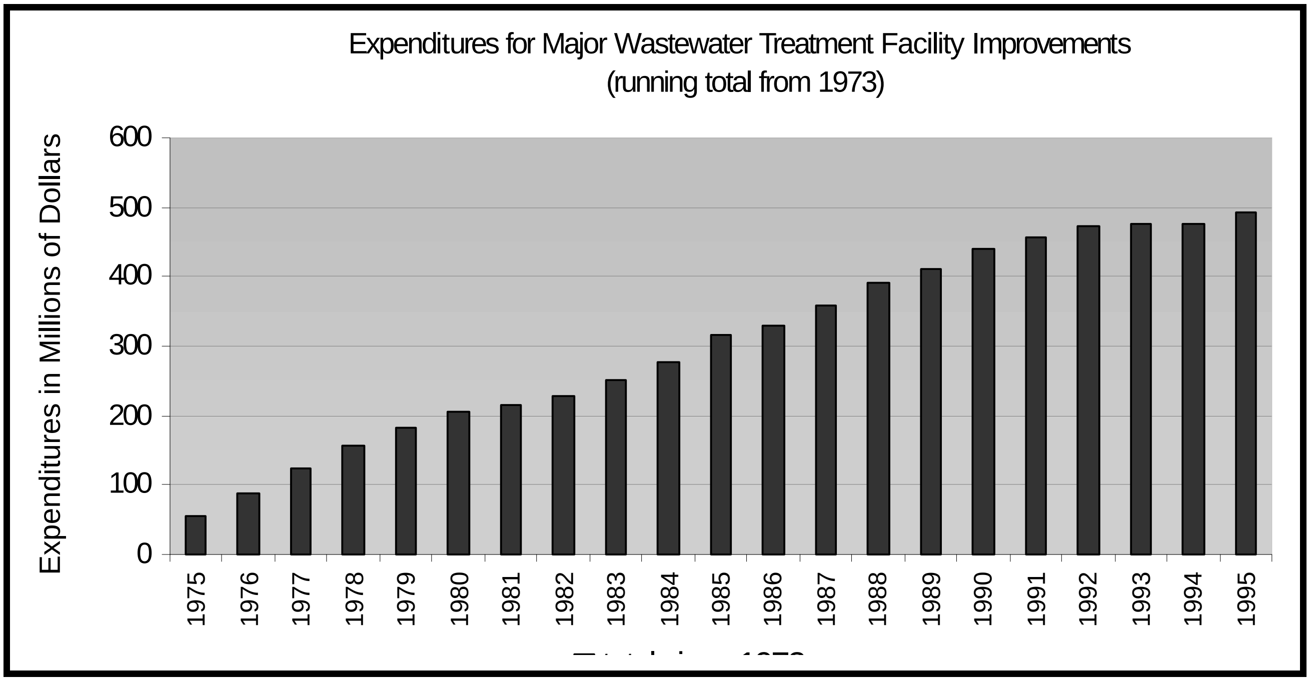
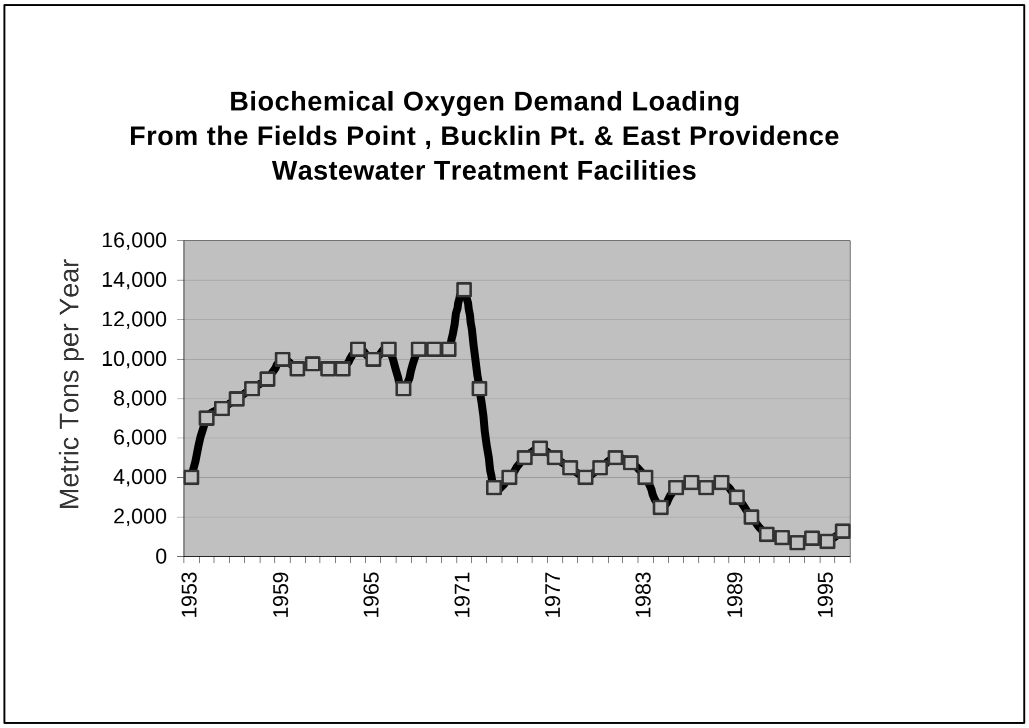


Figure 2 indicates environmental benefits resulting from reduction in the Biochemical Oxygen Demand (BOD) loading from the three upper-Bay wastewater treatment facilities. BOD is simply a measure used to determine the amount of oxygen in the water that would be required by bacteria to decompose the organic waste discharged into the water. When the BOD loading is high, more oxygen from the water would be used to decompose the waste, increasing the risk of depleting the oxygen so that fish kills result. When the BOD loading is low, less oxygen is consumed and fish kills are less likely. This dramatic reduction in loading of biochemical oxygen demand shown in Figure 2 is linked directly to the improvements made to the wastewater treatment facilities over the last three decades.

Figure 2. ***Sources for all Figures in this Report are listed in Table 2 at the end.***



The trend shows an increase in BOD loading from these facilities from 1953 to 1971. A dramatic reduction in BOD occurred in the early 1970s when the wastewater treatment facility operated by the Blackstone Valley District Commission converted to secondary treatment. The upturn in BOD loading immediately following was caused by a failure of the Fields Point wastewater treatment facility during the mid-1970s , resulting in the discharge of raw sewage into the Bay. However, the facility was taken over by the Narragansett Bay Commission which made major improvements leading to a reduction in the BOD loading. Now, wastewater treatment facilities represented in figure 2 achieve between 90% and 97% efficiency in removing the BOD loading. The overall treatment at these facilities is rated as "excellent" by the RIDEM.

However, this Bay-wide description of BOD loading does not tell the entire story. A number of coves and embayments around Narragansett Bay including the Pawtuxet, Providence, Seekonk, Kickemuit, and Palmer Rivers, as well as Greenwich Cove, Apponaug Cove, Warwick Cove, and Wickford Cove experience seasonal dissolved oxygen depletion due to decomposition of excessive plant life growing in the water column and on the bottom. Excess nutrients, often from wastewater treatment plants, result in rampant growth of plants that can die, decay, and cause fish kills. In addition, the suburbanization of land bordering the lower Bay increases the possibility of such problems in coves and embayments where flushing is restricted since septic systems, lawn fertilizers, stormwater discharges and other nutrient sources increase with development. The growth rate for the state's suburban and rural areas was projected to be 20% during the 25 year period between 1985 and 2010. The projected growth rate for the state's cities was 2.6% during the same time period. Such population trends increase the likelihood that some parts of the Bay will be impacted by non-point sources of pollution from septic systems, road run-off, and lawn fertilizers.

METALS

The waters of Narragansett Bay contain minute natural amounts of dissolved metals, called trace metals. Some of these are essential for the natural development and growth of estuarine plants and animals. However, larger concentrations in the Bay can be toxic to the plants and animals living there, and if bioaccumulated in marine organisms, can represent a health threat to the people eating them.

The input of metals into Narragansett Bay has been linked closely to the state's unique history: the development of textile mills along tributaries to the Bay beginning in the late 1700s; people moving to the cities at the upper reaches of the Bay as jobs were created in the textile industry; development of a machine tools industry to support the rapid industrialization occurring during the 1800s; the booming Civil War production of armaments in factories on the tributaries of the Bay; expansion of the jewelry and silver industries; and (more recently) state and federal laws to control the pollutants flowing into the bay.

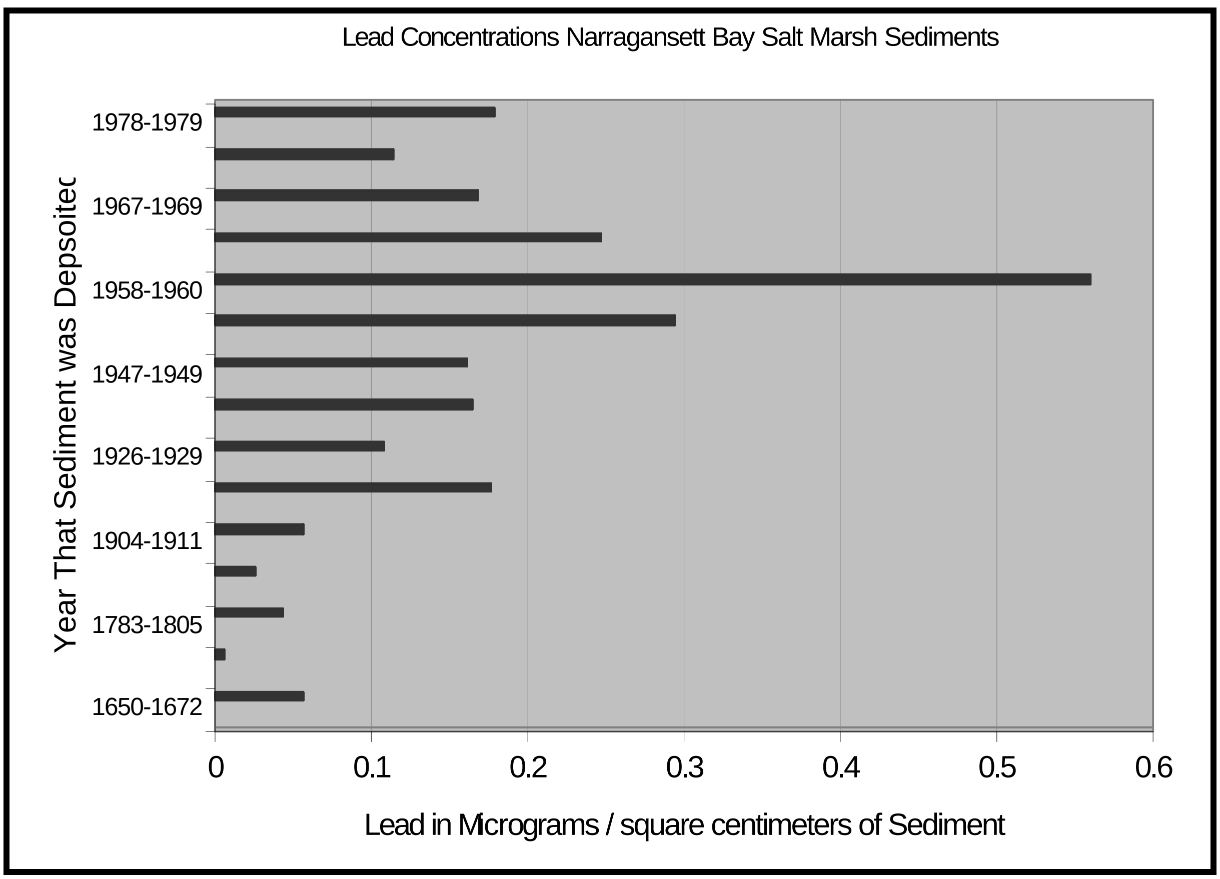
All of these phases in Rhode Island's history resulted in a change in the amounts of various metals washing down the rivers and deposited in the sediments on the floor of the Bay and the salt marshes along the shore. Many pollutants, including metals, tend to stick to small particles of silt in the water, and eventually come to be deposited on the bottom as new sediments. Each year, newer sediments are deposited upon older, creating a stratification of the Bay's pollution history.

The layer upon layer of sediments that accumulates on the floor of the Bay, in the salt marshes, and behind the dams of the rivers flowing into the Bay provide a picture of the pollution history of the Bay. Layers of sediment can be analyzed to determine the metals present, aged to determine the period when they were deposited, and then correlated with the specific aspects of Rhode Island history to reveal the types and extent of pollution that resulted from specific periods. These sediments provide a view of the state's history and are of practical significance today since these historic sediments can still impact the water quality of Narragansett Bay. The disturbance of these sediments during dredging projects , severe storms, and when dams breach, brings back old pollution problems as these historic sediments become re-suspended in the water.

A look at one particular metal, lead, in these historic sediments reveals the link between heavy metal contamination in the Bay with Rhode Island's history and urbanization. It also reveals how buried pollution problems can reappear under certain circumstances. Figure 3 shows the amount of lead contamination in different levels (and ages) of sediment in a Rhode Island salt marsh. Each sediment level reflects the human activities occurring near the Bay at the time and the extent to which those activities contributed to the amount of lead contaminating the Bay's waters and being incorporated into the layer of sediment deposited.

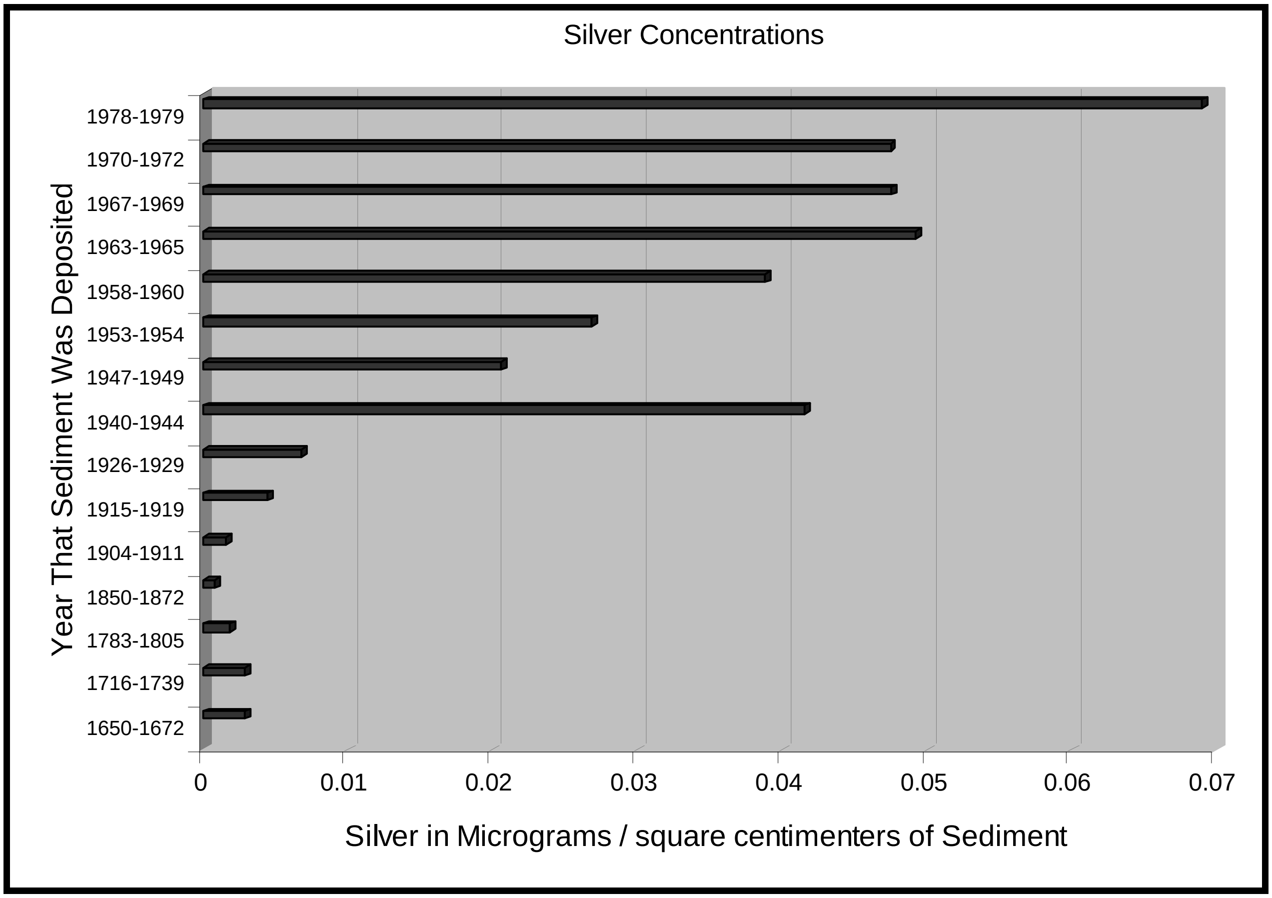
People added very little lead contamination to the Bay until the Industrial Revolution when lead was used to help fix the dyes as part of textile manufacturing. An even greater impact resulted from the manufacture of machinery, contributing still more lead to the rivers flowing to the Bay. The addition of lead to gasoline resulted in lead becoming an important contaminant from automobile tailpipes. This contaminant adhered to tiny particles that settled from the air onto surfaces and, when it rained, washed into streams and rivers that flowed to the Bay. It is estimated that in 1923, when lead was first used as a gasoline additive, Rhode Island registered vehicles emitted approximately 100 tons of lead. These emissions grew ten-fold to 1000 tons annually until 1974, when new cars were required to run on unleaded gasoline. The increase in the amount of lead detected in the salt marsh sediments (Figure 3) reflects all these land-based human activities. A large increase in the amount of lead in sediments deposited during the late 1950s probably reflects the added contamination resulting from two large hurricanes that may have washed more contaminants from the roads and re-suspended older sediments as the storm surge and hurricane waves stirred up older, more contaminated sediments. The more recent decrease in lead deposition reflects the removal of lead from gasoline, pretreatment requirements imposed on Rhode Island manufacturers, and more efficient wastewater treatment facilities including the installation of sludge presses at the Fields Point wastewater treatment facility after World War II.

Figure 3. ***Sources for all Figures in this Report are listed in Table 2 at the end.***



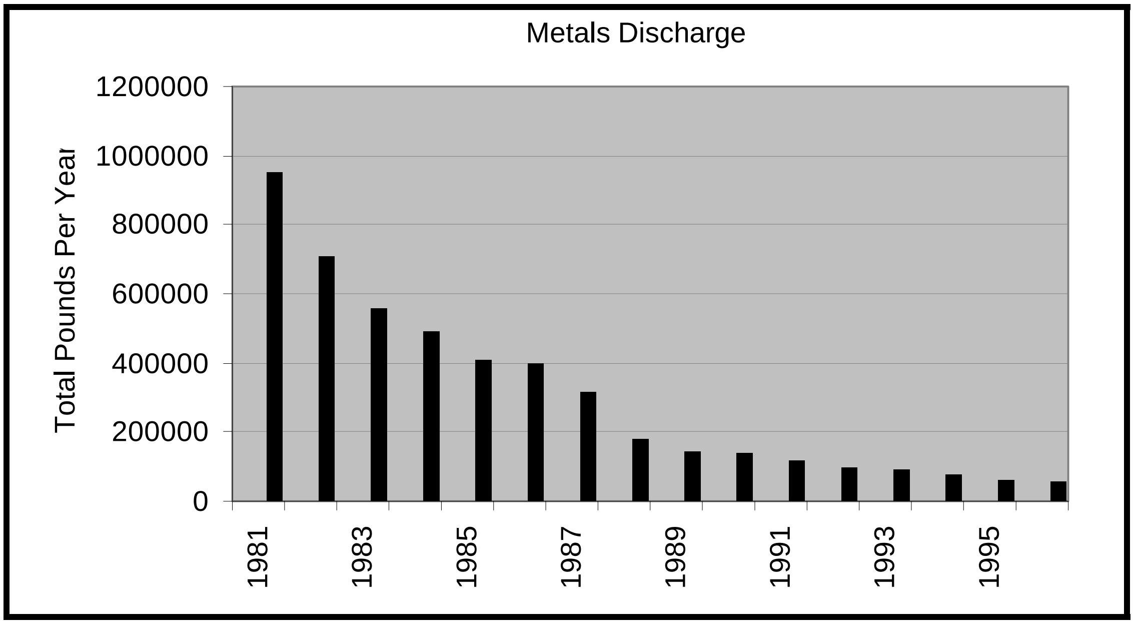
The historic record of silver in the sediments of a Narragansett Bay salt marsh mirrors the development and growth of the jewelry industry in Rhode Island. Although the jewelry industry began in the late 1700s along with the textile industry, it did not grow as rapidly, so the increase of silver in saltmarsh sediments occurred later than the increase of lead in the same sediments. This is reflected in Figure 4 which shows the amount of silver in cores taken from a Rhode Island salt marsh. The analysis of these core samples also indicates that silver deposition continued to increase even as lead deposition was decreasing. This is a result of steady growth of the jewelry industry in Rhode Island after World War II.

Figure 4. ***Sources for all Figures in this Report are listed in Table 2 at the end.***



However, Figures 3 and 4 do not show the improvements that have been achieved in the control of metals discharged into Narragansett Bay during the past fifteen years, since the analyses reflected in those figures was done in the early 1980s. During the past 15-20 years, federal and state regulatory programs have required many commercial dischargers to pretreat their processing water reducing the amount of metals and other toxic substances before releasing it to the wastewater treatment facility. Figure 5 below indicates the reductions in the metals discharges that have been achieved at the Fields Point wastewater treatment facility during the past twenty years.

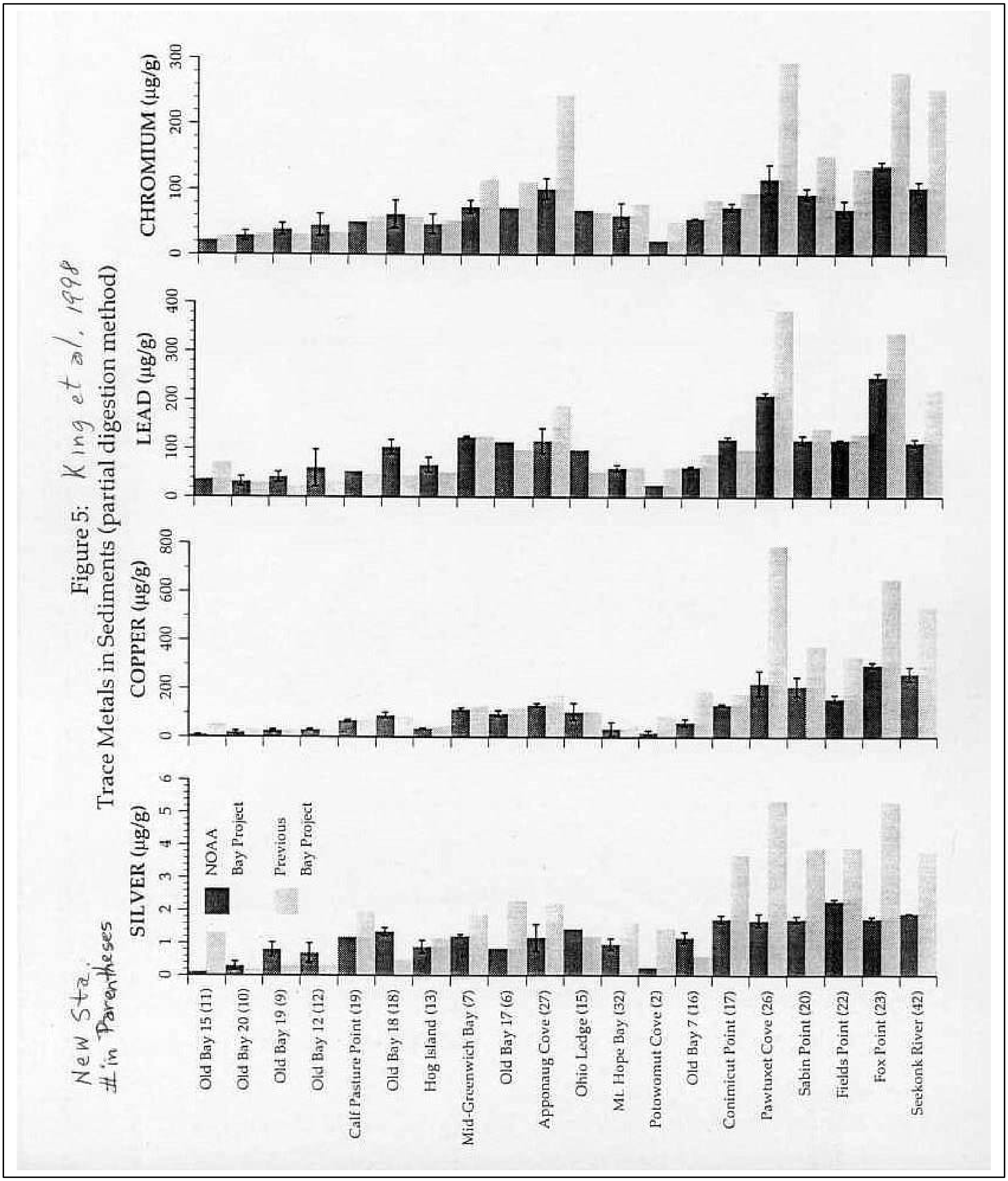
Figure 5. ***Sources for all Figures in this Report are listed in Table 2 at the end.***



More recent sediment analyses have been completed as part of a Narragansett Bay Cooperative Monitoring Study. (See Monitoring section at end of this report). Sediment data from1997-98 for 43 stations in the Bay (see Fig.6, King et al. 1998) has been obtained under this new Bay Monitoring Study, and provides an integrated picture of recently deposited sediment pollutants. In addition, comparison of data from 20 of these stations with data from sediment samples taken for the original Narragansett Bay characterization study (1988-89) by the same researchers (Drs. King and Quinn, URI/GSO), provide an indication of pollutant loading trends over the last 10 years.

Results from King et al. (1998) show major decreases since the 1988-89 samples (Fig 6) for trace metal concentrations in all metals analyzed in surface sediment samples taken from the most industrially-impacted areas of the Bay, the Providence / Seekonk tidal Rivers and the Taunton River (Mount Hope Bay). Stations from mid Bay areas showed little change or slight increases in metals for the recent sampling, and followed the overall pollution gradient found in the Bay: greatest sediment pollution concentrations are always in the most industrialized/urbanized areas (e.g., Providence/ Seekonk Rivers) of the upper Bay, and decrease rapidly as one moves downbay.

Figure 6. *Sources for all Figures in this Report are listed in Table 2 at the end.*
Dark columns are recent (1997-98) data; grey are 1988-89 values



The decrease in concentrations of metals in the most polluted stations from the recent (1997-8) sediment data has lowered the upper range seen in surface sediment concentrations for these metals, although highest levels are still nearest the major loading sources (major WWTFs and industrialized river mouths). This trend of decreasing metal concentrations likely reflects both the success of WWTF pretreatment programs and the decrease in the number of metal discharges from industries such as jewelry and electroplating due to the shift in the global manufacturing economy over the last 20 years.

In contrast, sediment nitrogen and carbon loads appear to have increased (King et al.,1998), indicating that the Bay is experiencing a continued increase in nutrients and biological productivity response to those nutrients.

These results likely reflect the improvement in secondary treatment achieved over the last decade at the major WWTFs. The dramatic reduction in metals entering the Bay is one of the successes resulting from effective state and federal water pollution laws and regulations which caused the development and implementation of innovative technologies to control such pollution.

DISEASE-CAUSING ORGANISMS

A wide range of bacterial and viral illnesses can be transmitted via human waste in surface water. Such illnesses include gastroenteritis, Salmonella, and infectious hepatitis. The pathogens causing these diseases as well as other bacterial and viral pathogens can enter Narragansett Bay from both point and non-point sources. Some of the point sources include wastewater treatment facilities (WWTFs), combined sewer overflows (CSOs), and storm drains. Non-point sources of pathogens may be individual septic systems (ISDSs), runoff, and discharges of human waste from boats.

The relative contributions of these sources change as management strategies are designed to eliminate specific sources. Although not the primary source of pathogens, the over 35,000 boats registered in RI were known localized sources of fecal discharges to the Bay from marine toilets. In late 1993, the Narragansett Bay Estuary program completed a siting plan for construction of marine pumpout facilities to address the discharge of human waste from boats in Narragansett Bay. Since 1995, the RIDEM Office of Water Resources has worked with the RI Marine Trades Association, coastal municipalities, and marinas to apply for federal grants under the US F&W Clean Vessel Act to cover 75% of the cost of constructing adequate pumpout facilities so that boaters have an environmentally responsible means of discharging human waste. By 1997, 34 pumpout facilities and one dump station were installed around the Bay. In 2000, the most recent Clean Vessel Act grant funds will bring the number of facilities (including pumpout barges) to 52 in RI marine waters, 44 being located within the Bay. A list of the present pumpout sites is available on the internet at http:// www.state.ri.us/dem/ nodscmap.jpg .

Now, all of the boats with marine toilets in Narragansett Bay can be serviced by pumpout facilities. This focused management program to create a system of pumpout facilities for boats in the Bay enabled Rhode Island to apply for federal designation of the entire Bay as a "No Discharge Area. Pumpout facilities have already been extremely successful in Block Island's Great Salt Pond, an 800-acre area with 1,000 boats during summer weekends and up to 2,000 on holiday weekends. The pumpout facilities have so improved water quality during the summer that the upper part of the Great Salt Pond can be opened for shellfishing, even at the height of the summer season. In 1998, Rhode Island successfully became the first state in the US to have all marine state waters designated by the US EPA as a "No Discharge Area" for boater sewage wastes, virtually eliminating boater waste as a non-point source of pathogens.

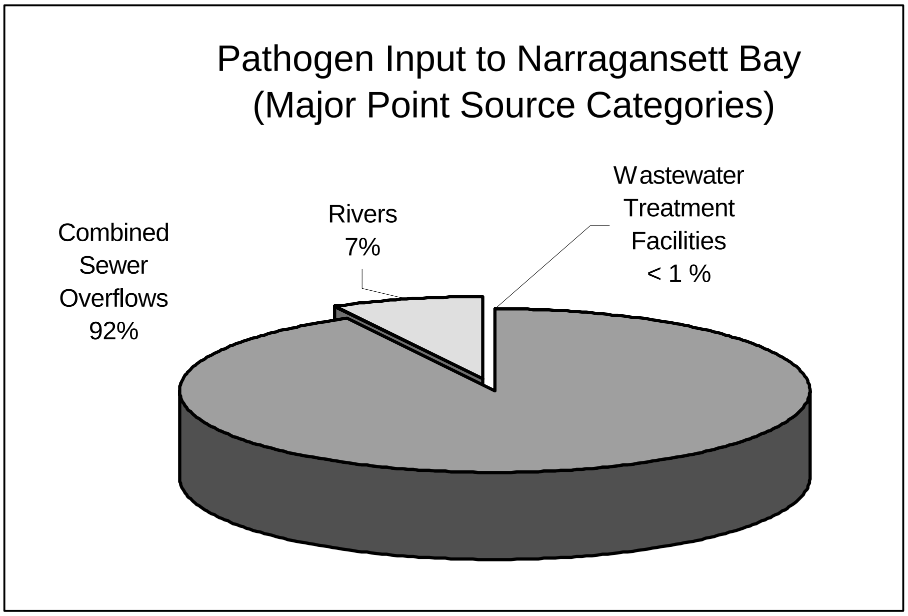
Likewise, the systematic upgrading of wastewater treatment facilities in the Narragansett Bay watershed has significantly reduced bacterial pathogens entering the Bay from point sources. (The chlorine treatment used at WWTFs for disinfection is very effective at killing bacterial pathogens but less effective at treating viral pathogens.) One of the main functions of wastewater treatment plants is to effectively treat human waste as a means of reducing the transmission of disease to people who swim or boat in water bodies receiving human effluent or who eat shellfish caught in nearby waters.

Figure 7 indicates the major point sources of pathogens into Narragansett Bay and the relative importance of those sources. This chart clearly shows that WWTFs have become a minor source of pathogens to the Bay due to their disinfection process. At the same time, it indicates the relatively large contribution of Combined Sewer Overflows (CSOs) to the loading of pathogens.

CSOs are the discharges resulting from the combined sanitary sewers and storm drains that were constructed near the turn of the twentieth century to manage both stormwater and sewage in the metropolitan Providence area. During heavy rains when the stormwater flow exceeds the capacity of the wastewater treatment facility (usually >1/2" rain /24h), all of the flow exceeding treatment facility capacity (including the untreated human waste) is discharged directly to the Bay via the combined sewer overflows.

The yearly input of pathogens to the Bay resulting from the raw sewage in CSO discharges varies, depending upon the size and frequency of rain events that result in storm flows exceeding the capacity of the wastewater treatment facilities. The Narragansett Bay Commission, which operates the Fields Point Wastewater Treatment Facility, estimates that 3.2 billion gallons of untreated waste are discharged into the Bay yearly from the 86 CSOs in its management district. (There are approximately 120 CSO inputs including those associated with other cities bordering the Bay.) The present management plan is to spend nearly $400 million in three phases to abate the metropolitan Providence CSO problem and dramatically reduce the pathogens discharged into the Bay. Addressing the Providence CSO problem could significantly improve bacterial water quality since more than 70% of the CSO inputs to the Bay are in the Narragansett Bay Commission's management area. The first phase of these improvements is now being implemented by the Narragansett Bay Commission.

Figure 7. ***Sources for all Figures in this Report are listed in Table 2 at the end.***

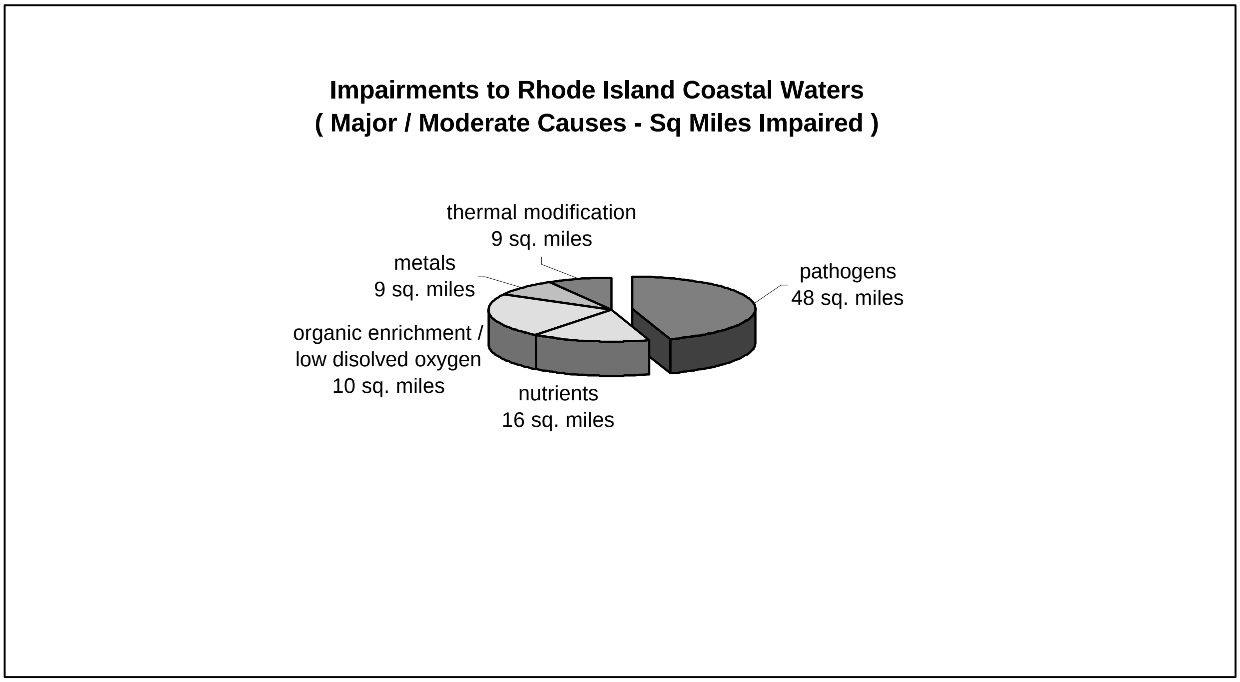


Shellfishing Beds

The opening or closing of shellfishing beds reflects the improvement or degradation, respectively, of bacterial water quality in specific areas of the Bay. Increased suburban development near the shore of the mid-Bay, lower Bay, and tidal rivers flowing to the Bay has resulted in more contamination from septic systems, runoff, and other sources, while the antiquated combined sewer overflows and urban wastewater treatment facilities servicing the urbanized upper Bay communities continue to contaminate the upper Bay. Figure 8 reveals that pollution from pathogens impairs more square miles of the state's waters than any other major contaminant, negatively impacting approximately 48 square miles of Rhode Island's estuarine waters (including other coastal waters besides Narragansett Bay).

The level of success in controlling pathogens has been mixed. In some coves, shellfish beds that had been closed are now conditionally open due to improvements in controlling bacterial contamination and due to the ability to better monitor the quality of the water so that the area can be closed temporarily when bacterial contamination reaches an unsafe level. However, uncontrolled bacterial contamination continues to keep approximately 25% (~32 sq. miles) of RI shellfishable waters impaired (permanently or conditionally closed). The majority (75% ;~97 sq. miles) of the Bay's shellfishable (SA & SA {b} waters are open for shellfishing.

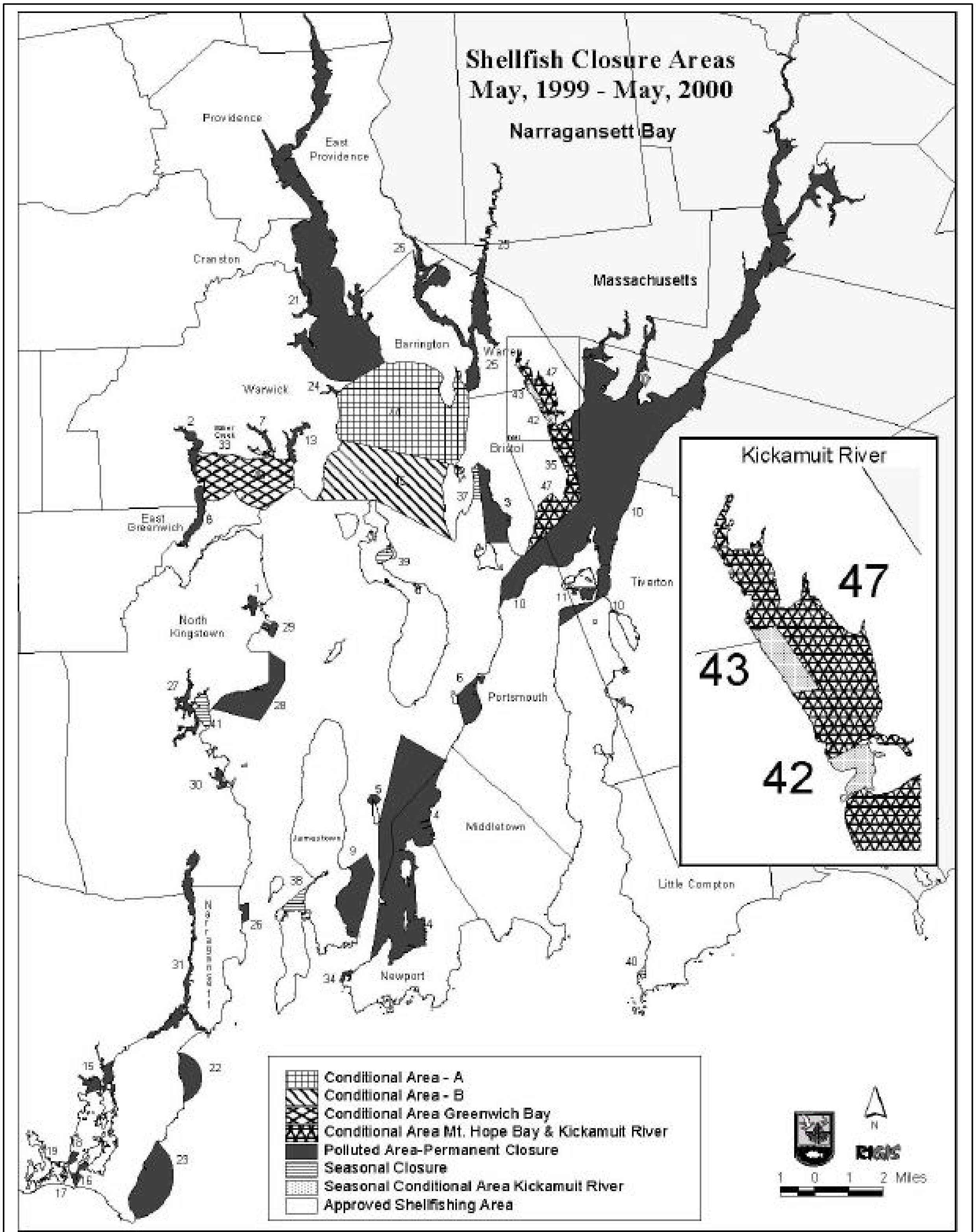
Figure 8. ***Sources for all Figures in this Report are listed in Table 2 at the end.***



The map in figure 9 shows the status and location of the Bay's shellfishing beds. It graphically reveals the relationship between urbanized/industrialized areas and impaired waters that result in the closure of shellfish beds of the Providence River, upper Narragansett Bay, and Mount Hope Bay. However, this map also reveals the smaller but growing trend of the negative impacts caused by the suburbanization of land bordering Greenwich Bay, Pettaquamscutt River, and Island Park resulting in the closure of shellfish beds nearby. Suburban communities often depend upon individual septic systems instead of municipal sewerage. The failure of septic systems can release pathogens into nearby Bay waters (or into streams flowing to the estuary), and impair the water bodies to such an extent that shellfishing beds must be closed.

Greenwich Bay (see Figure 9), is a 4.9-square mile arm of Narragansett Bay that supports one of the most productive shellfish beds on the entire East Coast. The quahog harvest from this relatively small shellfish bed is worth approximately $1 million yearly at the dock and stimulates approximately $4 million in the state's economy. Nearly 90% of all the shellfish harvested from Narragansett Bay during the winter months is taken from Greenwich Bay. Therefore, the closure of this area to shellfishing in 1992 due to high bacteria levels focused the state's attention on the sources of pollution that caused the closure A special stormwater study of fecal coliform and other pollutant sources by the University of Rhode Island and the RIDEM identified the major sources of bacterial contamination. A coalition of federal and state agencies, URI RI SeaGrant, and the City of Warwick, along with Save The Bay and volunteer citizen water quality monitors performed further studies, as well as implementation of corrective measures. These included improvements to manure holding facilities at a dairy farm bordering a brook that flows to Greenwich Bay (which turned out to be a major fecal source), enforcement of sewer tie-in to a historic mill building, and required residential tie-in to available sewer lines at Oakland Beach to eliminate the pollutants that originated from nearby failing septic systems, and partial grants and low-interest loans (by Warwick) for use of alternative septic systems where there were no sewers. Such improvements, coupled with a mechanism for closing the shellfish beds temporarily after storms, has allowed the embayment to be re-opened to shellfishing. Such focused efforts to identify and control sources of water pollution can be successful and the Greenwich Bay Project serves as a model for other local embayments that may be threatened due to landuse problems near the shore.

Figure 9. Available at http://www.state.ri.us/dem/shellnar.htm



NUTRIENTS

Nutrients, such as nitrogen and phosphorus, are essential for plants to flourish. Plants in the Bay also require nutrients and respond especially to one particular nutrient: nitrogen.

Algae, microscopic-sized plants which grow in the water column, are the most common form of plants living in the Bay. Like garden plants that are over-fertilized, algae growth can become excessive when there is too much nitrogen in the water. They grow rapidly when nitrogen is added to the water, particularly during the warmer months, and can sometimes "bloom" in such high concentrations that they color the water.

Rampant algae blooms can degrade the estuarine environment in two ways. First, most algae plants grow very quickly (days to weeks), then die and sink, decomposing on the floor of the Bay in a bacterial process that consumes oxygen. The oxygen removed from the water because of decomposition results in less oxygen available to the aquatic animals living near the bottom. This oxygen reduction may lead to the death of bottom organisms like crabs and marine worms if they cannot obtain enough oxygen from the water to survive. Occasionally, fish may become trapped in low oxygen waters by wind and tidal currents, causing a fish kill. This occurs mainly in the warm summer months when there is normally less oxygen in the water anyway. (Cold water can hold much more dissolved oxygen than warm water can.) In late summer, oxygen levels can temporarily fall so low in some areas of the Bay that essentially all bottom life dies, and the area becomes temporarily uninhabitable.

One of the first impacts that show when nutrients exceed normal levels in estuaries like Narragansett Bay is a change in the types of plant communities that occur there naturally. By analogy, low-nutrient upland soils will support specific native plants adapted to live in low-nutrient environments. When such soils are fertilized, the former plant community may be gradually replaced by other plants that can take advantage of the newly-fertilized soil. Some researchers now believe that the constant elevated flow of nutrients into the Bay has altered the ecology of this fragile ecosystem by causing a change in the estuarine plant communities and Bay-sediment animal communities. Coloration of the water and high levels of nutrients may cause clear-water bottom-living plants such as eelgrass (*Zostera marina*) to die off. These species provide critical refuge habitat for juvenile flounder, crabs, and scallops. Such a loss of high quality eelgrass habitat has clearly occurred over the last century in Narragansett Bay, especially in shallow embayments like Greenwich Bay and the Palmer River. Part of Greenwich Bay was once known as "Scalloptown" due to the large numbers of scallops found in the extensive eelgrass meadows covering much of Greenwich Bay over half a century ago.

Today, no significant eelgrass beds occur north of Jamestown, and none remains in Greenwich bay or the Palmer River (see Figs 10 & 11). Several factors including disease, hurricane damage, and decreased water clarity due to excess nutrients from the urban centers are all thought to play a role in these losses. The excess nutrients appear to be restraining the return of the beds. This does not mean that losses are inevitable : in Tampa Bay and Sarasota Bay, FLA, significant regrowth of bottom grass habitat occurred once nutrients from WWTFs were controlled.

Figure 10. Historical distribution of Eelgrass in Narragansett Bay

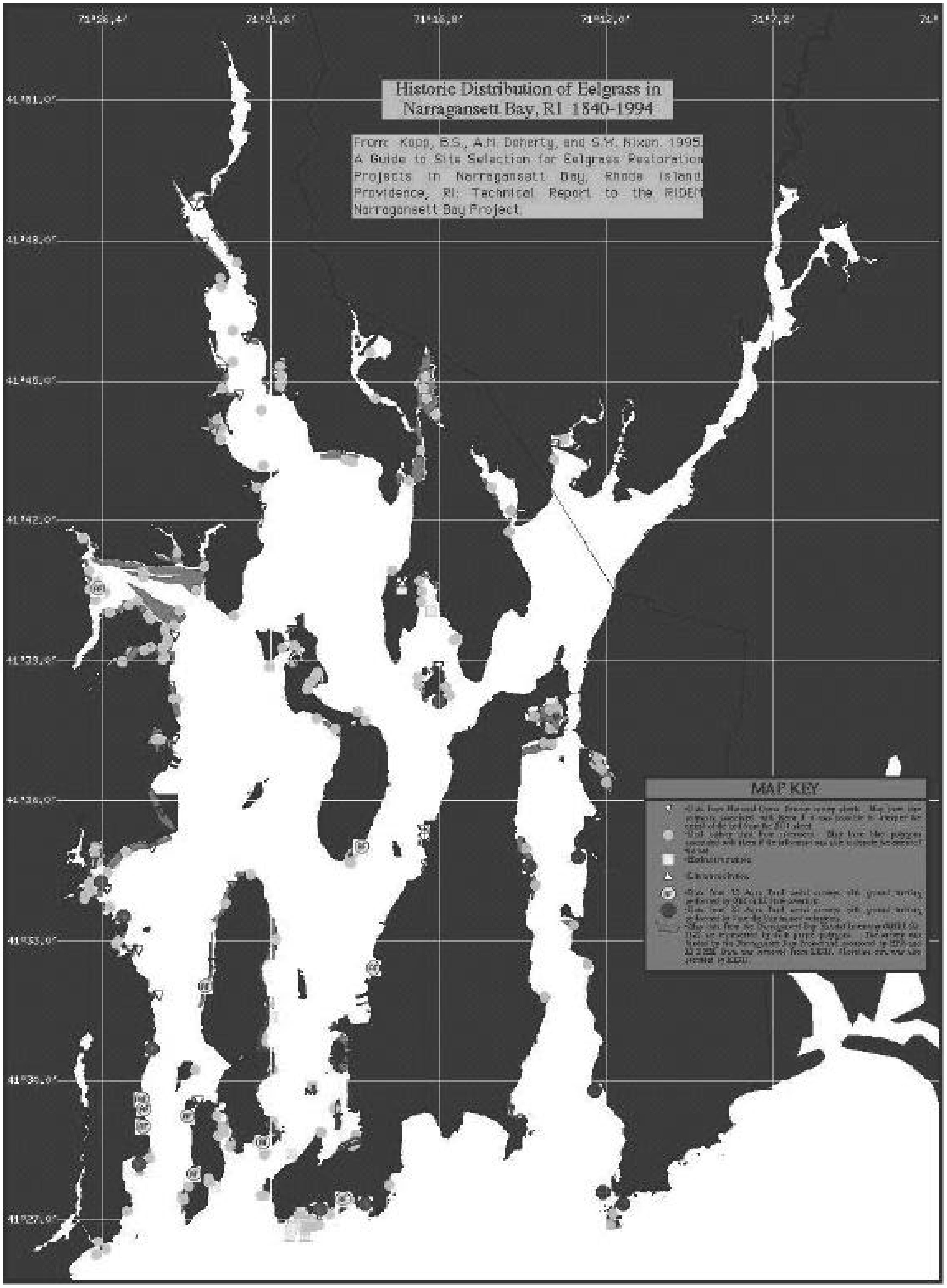
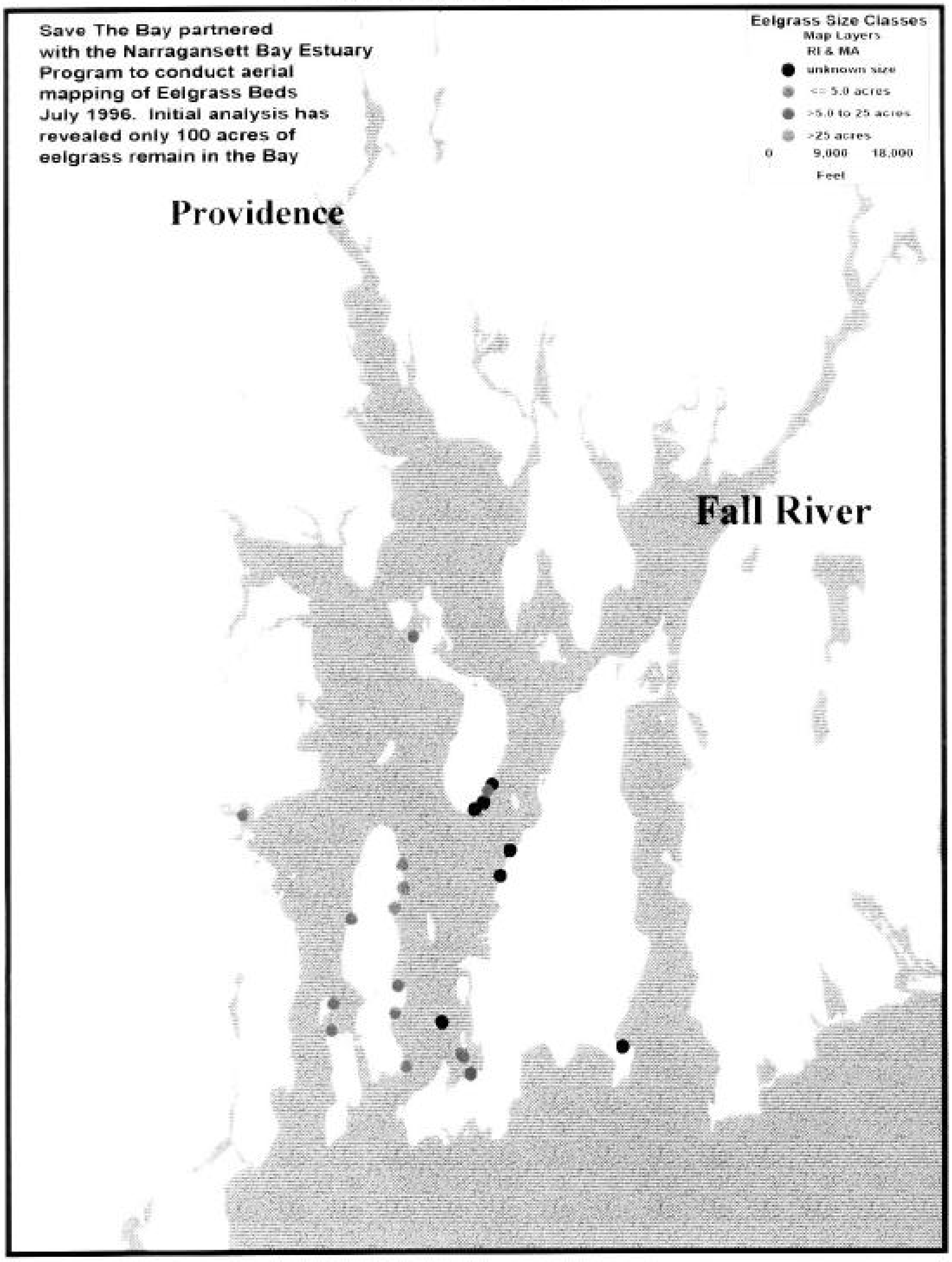


Figure 11. ***Sources for all Figures in this Report are listed in Table 2 at the end.***

Eelgrass Beds 1996



More recent work in the RI Coastal Ponds has shown that eelgrass has decreased 41% in those areas over the last 3 decades, and appears to be linked to nirogen loads from housing development (i.e., septic system density) increases (Short *et al*., 1996). Similar relationships between housing / ISDS density and eelgrass losses have been found in Waquoit Bay, MA (Short *et al*., 1996; Valiela *et al*., 1992). In such unsewered communities, even conventional septic systems that function properly do little to reduce nitrogen inputs since they are not designed to remove the dissolved nitrogen. In areas near such sensitive poorly flushed areas, newer technologies that involve nitrogen-reducing individual disposal systems, as well as best management practices for lawn fertilizers and agricultural fertilizers may be necessary to achieve improvements in water quality that allow the critical eelgrass habitat to return to normal levels.

Another change in the plant community of estuaries like Narragansett Bay due to excess nutrients can be the replacement of naturally-occurring algae with nuisance algae, some of which are toxic to Bay animals and even to people. Scientists believe that increasing the nutrients in estuaries may result in more frequent outbreaks of these nuisance and toxic species. So far, there is no evidence of increased blooms of toxic species like those producing "red tides" within Narragansett Bay. However, other plant species replacements have been seen. Sea lettuce (*Ulva*), a common large alga which resembles green cellophane when alive, often carpets the bottom in shallow coves and harbors today in areas of the Bay where nutrient levels are elevated. This can severely degrade the environment for other plants and animals that inhabit the area. Furthermore, high water temperatures result in the sudden die off of sea lettuce (which resembles toilet paper when dead), resulting in large amounts of unsightly decomposing organic matter, lowering evening dissolved oxygen to uninhabitable levels even in shallow coves, killing fish and invertebrates like crabs and sand shrimp.

Low oxygen impacts usually occur after the initial impacts of loss of eelgrass and other senistive plants. Such conditions can cause major species shifts on the bottom, with sensitive species dying off suddenly, and species least susceptible to low oxygen dominating the bottom organism types. It turns out that the quahog is a hardy species able to "clam up" and slow down its metabolism to endure at least short-term periods of low oxygen. However, such conditions slow down the growth of these shellfish, and may decrease the ability to sustain the population if fishing pressure is exerted on already-stressed populations. Work done by DEM F&W show quahogs in the Providence River exhibit a low meat to shell weight ratio, suggesting they are under considerable low oxygen stress. Recent surveys done by the RIDEM in the Providence and Seekonk Rivers clearly show very low dissolved oxygen levels through much of these two tidal rivers in the warm summer months (see Figure 12). In addition, preliminary unpublished data from a collaborative volunteer dissolved oxygen survey of the upper half of Narragansett Bay in 1999 indicates that low dissolved oxygen extends into the upper Bay , and can occur in deep areas of the upper West Passage as well as the entire Western side of Greenwich Bay and parts of the upper West Passage during summer neap tide conditions, at times crossing perhaps a third of the Bay (see Figure 13). Such conditions can effect the area available for healthy fish habitat, and may play a role in the recent RIDEM F&W fish population analysis indicating that bottom fish species are decreasing in numbers while water column species are increasing.

Figure 12. 1996 Summer Dissolved Oxygen levels (mg/l) in the Seekonk and Providence Rivers [Numbers < 3.0 indicate serious low oxygen levels].

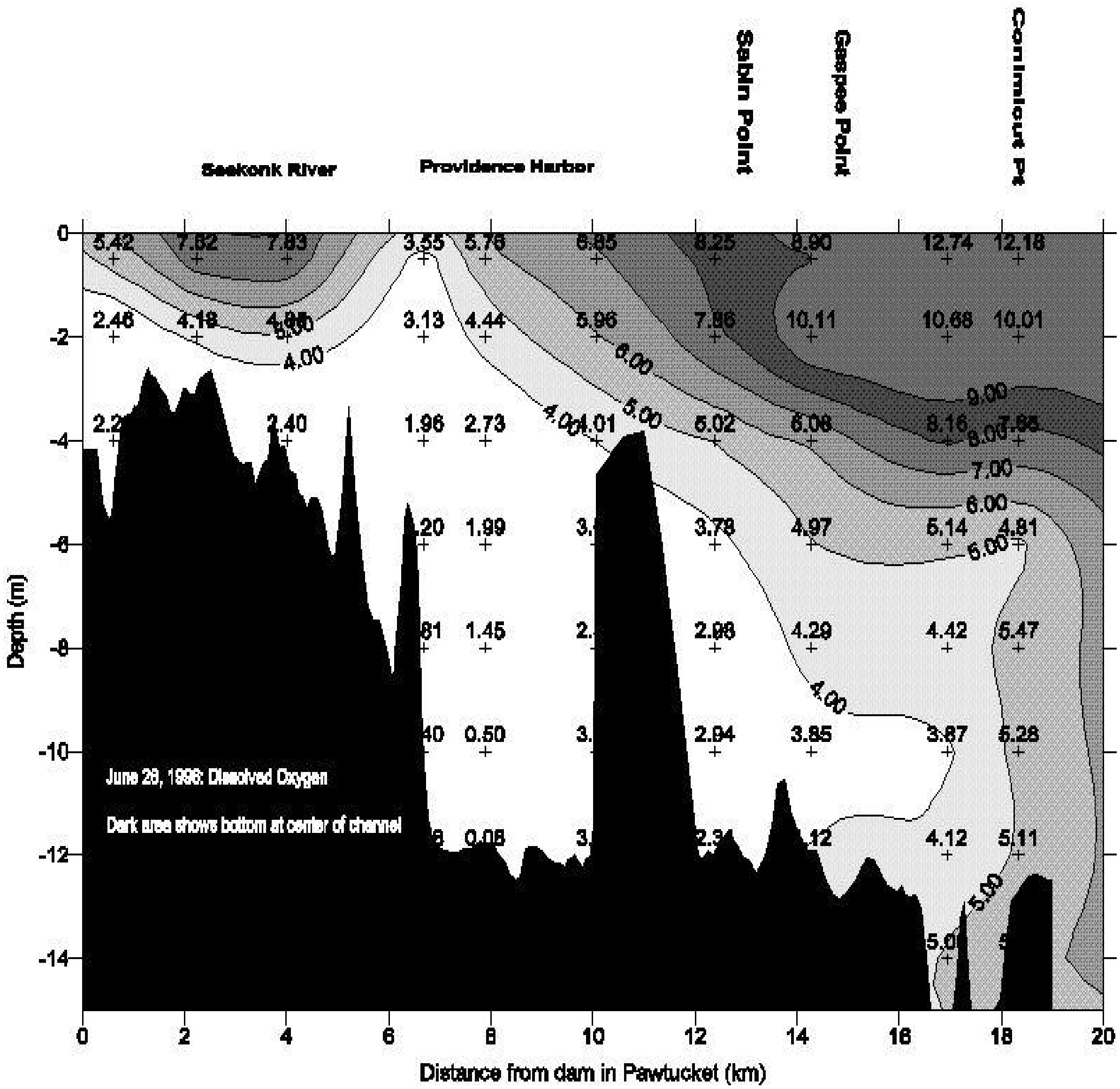
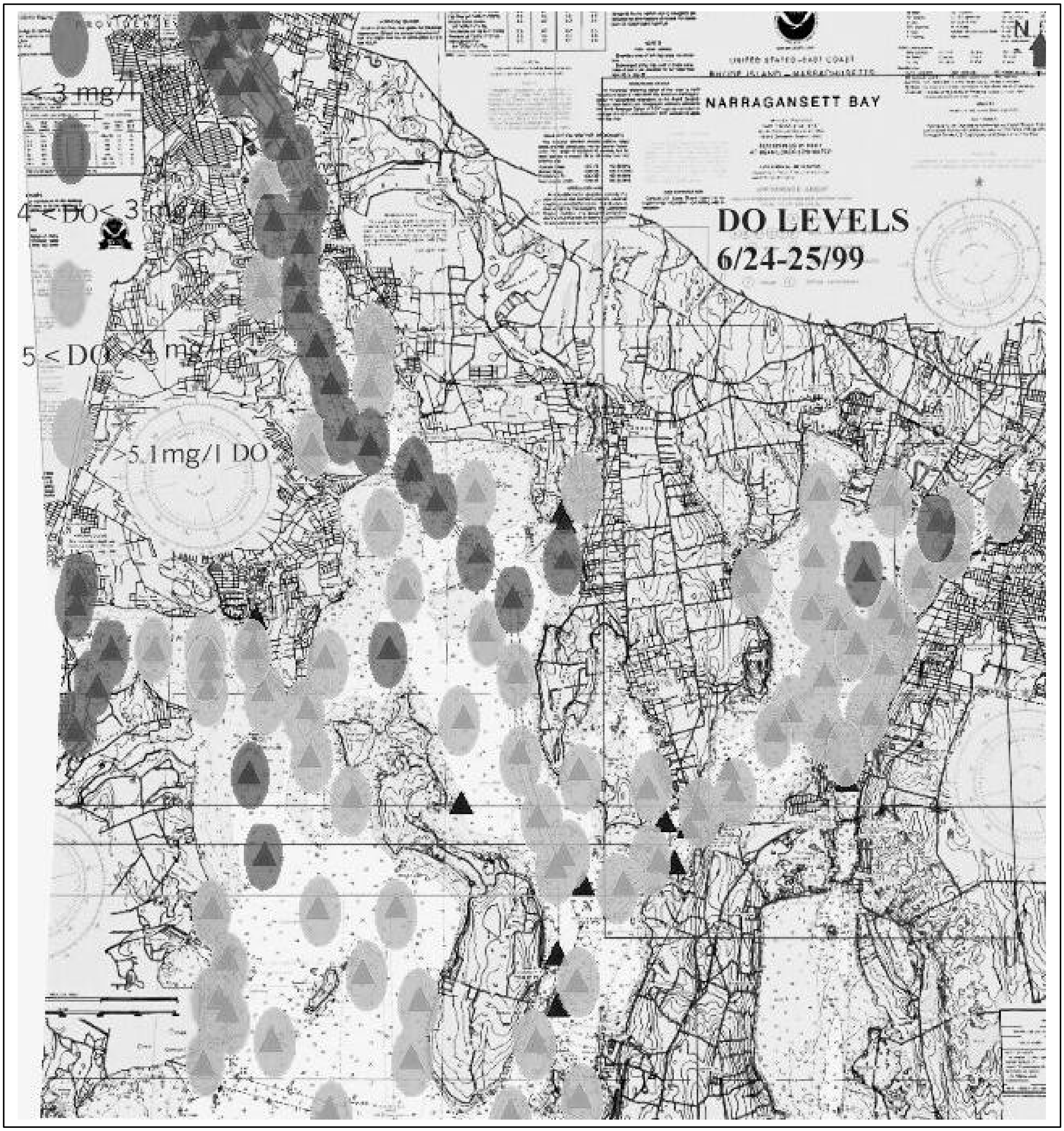
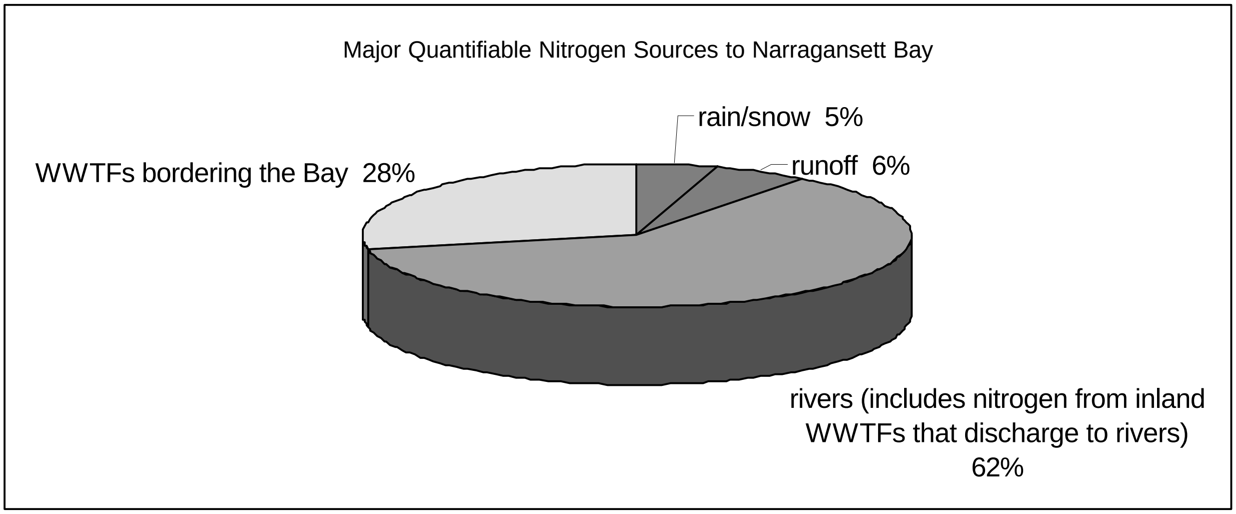


Figure 13. Preliminary unpublished dissolved oxygen values in bottom waters of Narragansett Bay June 24-25, 1999 - Volunteer DO survey results.
[Low DO <4 mg/L = darker grey ellipses]



The nutrients flowing into the Bay have increased as cities around the bay have grown and land uses changed in the towns within the Bay's watershed. Non-point sources of nutrients include: fertilized lawns and farms that leach nutrients to the groundwater or from which nutrients are washed as storm runoff to streams and rivers that flow to the Bay; air-borne nutrients that can settle on the surface of the Bay or are washed from the sky by rain and snow; and individual sewage disposal systems (ISDSs) that discharge nutrients into the groundwater and, eventually, to the bay. Conventional septic systems that function properly do little to reduce nitrogen inputs to groundwater which can end up in the Bay, especially in sandy areas. Wastewater treatment facilities are major point sources of nutrient enrichment to the Bay. Figure 14 indicates that sewage from wastewater treatment facilities represent a significant major source of nitrogen to the Bay. (The large contribution of nitrogen in river water includes the nitrogen from wastewater discharges upstream.)

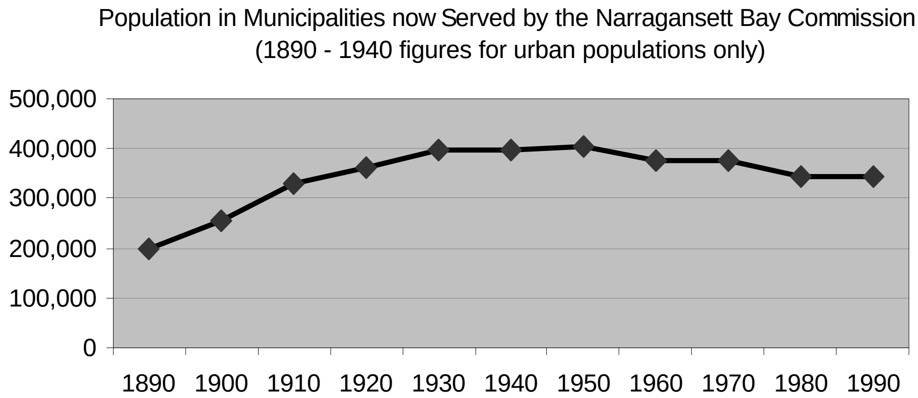
Figure 14. ***Sources for all Figures in this Report are listed in Table 2 at the end.***



The large input of nitrogen to the Bay in sewage can be traced to the creation of a municipal water system in the metropolitan Providence area during the late 1800s and the construction of a sewer system in the early 1900s, making it possible to flush human waste from homes and workplaces to the wastewater treatment plant and then out into the Bay. The amount of nitrogen flowing from this source to the Bay is directly related to the size of the population served by wastewater treatment facilities. Figure 15 shows the increase in the number of people living in the urban metropolitan area now served by the Narragansett Bay Commission's wastewater treatment facilities.

As the urban population serviced by wastewater treatment facilities around the Bay (and even in Massachusetts cities on rivers flowing to Narragansett Bay) grew, nitrogen inputs increased. But Figure 15 tells only part of the story since it reflects just the population serviced by the Narragansett Bay Commission's wastewater treatment facilities. Actually, more than one million people throughout the entire Narragansett Bay watershed are serviced by wastewater treatment facilities that discharge effluent to the Bay.

Figure 15. ***Sources for all Figures in this Report are listed in Table 2 at the end.***



It is not possible to calculate precisely the increase in nitrogen loading to Narragansett Bay since prehistoric times, but scientists' estimates help to provide some perspective regarding the extent of the "fertilization" of the Bay caused by people. A recent calculation made by Dr. Scott Nixon of URI suggests human activity has increased the nitrogen loadings to the Bay five-fold over the level that existed before colonization, at least doubling the algae production in the Bay (Nixon et al., 1997). Another article entitled "Enriching the Sea to Death" by Dr. Nixon, written for the layperson, is available at http://www.sciam.com/specialissues/0898oceans/IMG/ 0898nixon.html . This article has an excellent graphic showing the radical increase in nitrogen to Narragansett Bay over the last 200 years .
(Available at: http://www.sciam.com/1998/0898oceans/0898nixonbox3.html).

Wastewater Treatment facilities represent the most treatable part of the nutrient load going into the Bay. Typical operations at present secondary wastewater treatment plants do not remove dissolved nutrients. Although elimination of nitrogen to extremely low levels in such facilities is an expensive proposition, there are ways to cost-effectively decrease the levels now released at treatment plants by optimizing natural nitrogen-removal processes within the system, sometimes achieving a reduction of over 60% by slowing the flow and manipulating treatment to allow for further biological processes to occur within the tanks under controlled conditions. In this manner, naturally occurring bacteria within the system can remove significant amounts of nitrogen, especially in plants with the largest nutrient outputs. Some plants in RI continuously release total nitrogen at very high levels, up to 25-30 mg/L. Connecticut has shown that significant decreases in nitrogen down to 7-8 mg/L are achievable at their coastal WWTFs through these shifts in operational procedures, and has provided a grants program to communities for cost-efficient nutrient removal through alterations of plant operations.

As part of its Municipal Assistance Program, the RIDEM Office of Water Resources Operations and Maintenance section is providing plant specific nutrient optimization training to 5 Rhode Island Wastewater Facilities. The training will be at the Fields Point, East Greenwich, Cranston, Warwick and West Warwick wastewater treatment facilities. Ms. Semon-Brown, a regional expert on plant operations and nutrient removal who oversees the Stamford Conn. plant, will work with plant operations and laboratory staff to devise real-world strategies to optimize nutrient treatment and removal at these plants. There is no cost to the communities and the information they receive is not intended as a state-mandated approach which must be followed. It is expected that this program will be able to assist the plants in coming up with both short- and long-term approaches to nutrient reductions in the plant's final effluent.

Monitoring

Although it has often been stated that Narragansett Bay is one of the most studied estuaries in the world, the reality is that most of these studies have been for specific short-term research goals not designed to provide long-term comparable data that allow coastal decision makers and others to detect subtle changes to the Bay ecosystem. The original Narragansett Bay Project, funded by the US EPA, utilized marine scientists in the area to provide a "snapshot" of the Bay's ecosystem health in 1980-1981xxx??? However, not much could be stated about trends due to lack of long-term monitoring data sets.

The Narragansett Bay Comprehensive Conservation & Management Plan (CCMP), a part of the Statewide Guide Plan emphasizes the importance of development of a long-term ecosystem monitoring program on the Bay. A Long-term Monitoring Plan report to the NBP recommends the pursuit of a monitoring system which addresses the following issues:

- Detecting long-term changes in the functioning of the Bay ecosystem.
- Assessing the influence of changing anthropogenic pollutant loadings and the success of management actions.
- Establishing baseline data to detect events such as fisheries collapse and algal blooms and their interactions with ecological disturbances.
- Provide a framework to support on-going Bay Research

There are only a small handful of long-term monitoring efforts, and they are usually limited to specific subparts of the Bay ecosystem, or to only specific limited areas of the Bay. The University of Rhode Island maintains 2 small monitoring programs; one for plankton, and one for fish, but these are severely limited in area coverage to 2 sites, one at mid Bay near Fox Island, and one at the mouth of East Passage (Whale Rock). The data is very valuable due to its long-term nature (over 36 years), and these programs should be maintained due to their unique long-term history (no other data sets go back that far for these subsets of the ecosystem). The RIDEM Division of Fish & Wildlife has maintained a monthly trawl at xxx stations throughout the Bay, including Mount Hope Bay since 19xx to better track adult fish populations in our RI marine waters. In 19xx, they added a monthly spring/summer beach seine survey to track changes in juvenile fish populations throughout the Bay. Both have been critical in discerning the shift from bottom fish species to water column (pelagic) species over the last decade (discussed in the fisheries white paper).

However, until very recently, there was no such long-term monitoring program for water quality beyond bacterial surveys for fecal coliform levels in surface waters over shellfish beds. This has caused a critical data gap for water quality data, especially as it relates to emerging water quality and other ecosystem-wide issues in the Bay such as excess nutrients and their link to low dissolved oxygen, shifts in phytoplankton blooms, etc. At the URI Oceanography School dock, the URI Mesocosm Ecosystem Research Laboratory (MERL) has maintained a weekly measurement of chlorophyll a (a cost-effective proxy measurement for the amount of algae in the water), and several other physical water parameters. Dr. Candace Oviatt of URI has examined this data along with data from special surveys performed in the upper Bay, and has recently noted (Oviatt, 2000) that something is causing a loss of the normal springtime phytoplankton bloom in the Bay in recent years. Warming trends in winter water temperatures may be involved, but more study is required. This type of shift has significant ecosystem level repercussions on the bottom organisms that rely on the spring bloom to supply important food sources to the bottom. There is a strong need to continue such investigations in a manner that allows comparison of data over many years.

Until the development of recent new monitoring technologies, no on has been able to measure the extent and frequency of low dissolved oxygen events in the Bay. In 199xxx, NOAA funded the deployment of 2 new technology continuous monitoring water quality samplers at the Narragansett Bay Estuarine Research Reserve on Prudence Island: one at the "T-dock" on the south end, and one in Potters Cove on the NE side. Shortly thereafter, Dr. Dana Kester of URI began to deploy a similar continuous monitoring device at the GSO dock, and also added a surface and bottom sampler at a buoy off the NE corner of Hope Island near Quonset Point. Data from these sites began to suggest that the upper half of the Bay may be experiencing occasional summertime periods of low dissolved oxygen levels near the bottom, a situation never thought to occur in the open Bay below Conimicut Point. This was not a complete surprise since an NBP study (#NBP-90-28) discussed evidence from investigations of bottom organisms in the Bay that suggested the upper Bay and Greenwich Bay may be experiencing impacts associated with excess nutrient levels, including low oxygen events. Two voluntary unfunded surveys of dissolved oxygen levels in the upper half of the bay last summer (1999) by scientists have provided more data (see Fig.13.) to suggest that the extent of the low oxygen may cover significant portions of the upper Bay and parts of Greenwich Bay and Mount Hope Bay during summer low tide flow conditions (neap tides).

Dr. Kester's research took him and his devices to Hong Kong, and the Bay was left w/ fewer sampling sites. At this time, the late Senator John Chafee recognized the critical value of a long-term ecosystem-based water quality monitoring program, and was successful at convincing Congress to set aside funds to initiate a Narragansett Bay Cooperative Study, which was to utilize the latest technologies in order to develop a long-term monitoring network to track Bay ecosystem conditions and trends. A federal grant totaling $1.5 million for monitoring work on Narragansett Bay and other RI marine waters provided the first steps towards purchasing hardware and setting up a comprehensive continuous monitoring system.

This comprehensive monitoring network, which began in 1999, is a collaborative effort with RIDEM Div. Of Fish & Wildlife, Office of Water Resources, and the Narragansett Bay Estuary Program; NOAA National Marine Fisheries Service; the US EPA; the National Estuarine Research Reserve at Prudence Island; the University of Rhode Island; and Roger Williams University.

The in-Bay components of the monitoring system include at least 3 major efforts:

1) A monthly survey of the zooplankton (tiny floating animals critical to the food chain) in the Bay using an advanced computer-controlled shuttle towed behind a boat. The device can move up and down the water column, sampling zooplankton while simultaneously measuring depth, salinity, temperature, dissolved oxygen (D.O.), pH, and chlorophyll a as a tow boat covers set transects of the Bay. The present transect layout covers the Providence River, Upper Bay, Mount Hope Bay, and the East and West Passages.

2) Continuous water quality monitoring stations at 7 sites strategically selected around the Bay to provide a good picture of the overall health of the Bay. These stations have one or two continuous monitoring probes set at a depth just off the bottom, and for some , a second probe set just below the surface. Both measure salinity, temperature, D.O., pH, tide height, and, for surface sites, chlorophyll a is also measured to track phytoplankton blooms.

3) Surface sediment samples and analyses for heavy metals and organics at approximately 43 stations scattered around the Bay.

In addition to this water column monitoring effort, significant advances are being made through a collaborative program between NOAA NMFS Woods Hole and the RIDEM Fish & Wildlife to develop a standardized, computerized data base to record, process, and analyze fisheries management data. In addition, funds are being provided to RIDEM Division of Fish & Wildlife to replace the ailing trawler now used for fisheries population data generation.

Much of the water column monitoring for this comprehensive effort is concentrated on issues related to excess nutrients and their impacts, including low dissolved oxygen. Sediment samples were taken in 1997 and 1998, while the water column continuous monitoring probe system was active for summer 1999, and , with current funding, is expected to continue for at least one more year. Dr. Kester's buoys were slightly damaged by the January 2000 ice flows in the upper Bay, which moved them over 5 km further south. After repairs, the system should become fully activated again late Spring 2000. Monthly transect sampling of the zooplankton in the Bay by Narragansett NOAA / NMFS scientists began in February 1998, and funding is available to continue through this year (2000). Three new monitoring sites are expected to be developed this summer 2000 through a successful federal grant proposal by the Narragansett Bay Commission.

The data for this monitoring system will eventually be posted and available to the public on the World Wide Web through the data center at the URI Environmental Data Center.

This Narragansett Bay Cooperative Monitoring System, although in its infancy, will provide an excellent comprehensive picture of the present conditions of various aspects of the Narragansett Bay ecosystem. It is critical that continued funding support be located in order to obtain adequate data for decision-makers to accurately recognize trends and changes in the Bay ecosystem. This system is presently considered a national example of a multi-agency/institution collaborative state-of-the-art monitoring effort that pools the significant marine expertise concentrated in the Ocean State in a highly cost-effective manner. Without maintenance of such a system, we will continue to grope for answers to management questions

Marine Coastal Habitat

The Narragansett Bay Estuary Program collaborated with Save The Bay, URI, and UMA Amherst to obtain 1996 aerial photos of the Bay shore, and have shoreline habitats digitized into a GIS map format. The following table summarizes the results. Because of the mapping resolution (1:12,000 and 1:40,000), only features >1/4 acre or 40' width are counted for onshore habitats such as saltmarsh. Eelgrass beds can only be distinguished >1/2 acre, so that number reflects moderate sized beds visible in the photos. The NBEP is coordinating an ongoing trends analysis with USF&W and UMA Amherst to look at changes from ~1950 to present for saltmarshes in the Bay. Data is inadequate to quanitatively judge losses at this time.

Table 1. SUMMARY OF ESTUARINE AND MARINE HABITATS ACREAGES FOR NARRAGANSETT BAY (1996)

Habitat Type	**Area in Acres**
Open Water	124,259.4
High Salt Marsh	2,708.7
Beaches	1,450.5
Rocky Shores	573.3
Tidal Flats	568.6
Low Salt Marsh	443.2
Brackish Marsh	427.6
High Scrub-Shrub Marsh	159.3
Eelgrass Beds	99.5
Pannes & Pools	46.3
Dunes	43.0
Artificial Jetties & Breakwaters	23.1
Oyster Reefs	9.0
Stream Beds	3.5
TOTAL	130,815.0

Source: *Report on the Analysis of True Color Aerial Photographs to Map Submerged Aquatic Vegetation and Coastal Resource Areas in Narragansett Bay Tidal Waters and Nearshore Areas, Rhode Island and Massachusetts*. Prepared by Irene Huber, Natural Resources Assessment Group, University of Massachusetts, November 1999. Narragansett Bay Estuary Program Report No. 117.

Table 2. Sources of Charts, Tables, and Graphs in this Report.

Figure 1 --

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Figure 2 --

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Figure 5 --

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Figure 6 --

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Figure 7 --

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Figure 9 --

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Figure 10 --

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Figure 11 --

Save The Bay, GIS map of 1996 eelgrass bed locations , 1998

Figure 12 --

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Figure 13 --

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Shellfish maps -- http://www.state.ri.us/dem/shellnar.htm
Pumpout Sites - -http://www.state.ri.us/dem /pumpout/pumpmap2.htm
Other DEM Map Sites: http://www.state.ri.us/dem/nodscmap.jpg
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