Imprint

of the Past:

Ecological History of New Bedford Harbor

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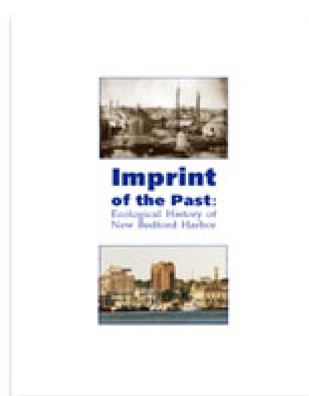
Booklet Available

A booklet entitled "Imprint of the Past: Ecological History of New Bedford Harbor" (U.S. EPA, Region 1; 2001; No. 901-R-01-003), was produced in partnership with the New Bedford Whaling Museum and EPA Region 1. This booklet includes many of the things found in this report, but it does not include the results of the sediment cores. The text in the booklet is longer and contains more details about New Bedford, more maps and figures, and more old photographs, prints, and paintings from the New Bedford Whaling Museum's collection. To request a copy of the booklet, send an email to: AEDLibrary@epa.gov.



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Introduction

New Bedford waterfront, 2001, from Johnny Cake Hill. Photo by C. Pesch

New Bedford waterfront 1867. Stephen F. Adams. Courtesy of the New Bedford Whaling Museum.

New Bedford, Massachusetts: Formerly a whaling city and producer of fine textiles; a prominent fishing port; a city with a charming historic district that was named a National Historical Park; a city with a wonderful whaling museum; a city with plans to make the waterfront more accessible. New Bedford has an interesting past and an exciting future.

Yet, like most older cities, New Bedford has environmental problems. New Bedford Harbor was named a **Superfund** site in 1982 and is currently being cleaned up. What are the environmental problems in the harbor, what led to these conditions, and what can be learned from a study of the history of development and its impact on the environment? That's the subject of this report.

New Bedford Harbor study We studied the history of development in the **watershed** surrounding New Bedford Harbor and examined how that development impacted environmental conditions in the harbor. The harbor has been subjected to a complex mix of impacts over a number of years. The sediment in New Bedford Harbor is contaminated with high concentrations of **metals** and **organic compounds**. The harbor was named a Superfund site in 1982 and scheduled to be cleaned up under that legislation. Our historical analysis shows that impacts to New Bedford Harbor occurred throughout the development period of several hundred years, not just recently. By looking at these impacts over time, we can begin to understand what happened and why.

This report contains a section on why history is important from an environmental perspective, a description of New Bedford Harbor today, the history of development in the New Bedford area and its impact on New Bedford Harbor, a "How to" section on how to start a historical analysis, information about contaminants in the environment, and a time line to put historical events in perspective.
The bibliography lists the many sources we used to put together this report. But first here's a little background information to explain the recent shift in thinking about environmental issues.

A shift in thinking about environmental issues Recently, the U.S. Environmental Protection Agency (EPA) adopted a new approach to study and manage environmental problems. Previously, the agency's emphasis was on particular chemicals and their effects on individual species in air, land, and water. But the environment is not a series of compartments, it includes a series of interconnected aquatic and terrestrial **habitats**. Human activity that affects the immediate environment may also stress areas downstream. Small stresses added over time or space may exert an additive effect. Also, an area may be impacted by multiple stresses from different sources. Implementation of environmental regulations in the past 30 years has reduced pollution from **point sources** (effluent from the end of a pipe). Today, the major pollution problems are from **non-point** sources. To address this change in emphasis, EPA has adopted a more comprehensive approach by studying problems in the natural environment, not just at the end of a pipe. The natural unit of study is the watershed, the area drained by a river system.

Community-based environmental protection This watershed approach requires new ways of thinking about protecting the environment. Each watershed has unique conditions and problems, and the people who live there should help plan the solutions. In the 1990s, EPA began a major effort in doing this with a process called "community-based environmental protection." This approach provides a consensus-building process to identify local environmental issues, evaluate community priorities, create a plan, implement solutions, and assess results. The process is open and inclusive, and is driven by local issues and local people. This type of process requires that the stakeholders (local planners, zoning officials, local business people, and citizens) understand the current problems, realize that there are long-term consequences of development, and are able to envision the possibility and extent of **remediation**. A historical analysis of the ecological consequences of development can be a valuable educational tool in this process. Citizens get interested in environmental issues when these issues are presented as part of the history of the place where they live.

Why Study History?

Historical studies are important for a number of reasons.

- Current ecological conditions in a highly degraded areas are usually a complex mix of impacts accumulated over many decades or, for older cities, over centuries. By looking at these impacts over time, we can begin to understand what happened and why.
- Historical studies enable us to see that there is a connection between land use and environmental conditions. This understanding is important to managers making land management decisions.
- Historical studies help us appreciate that some decisions and the accompanying actions can cause long-term (decades, or centuries) environmental consequences.
- Historical studies are useful in planning **remediation** projects. Environmental scientists and managers can identify which impacts are irreversible and therefore, choose to work on those that are possible to remediate.
- Historical studies have become a component of environmental litigation, especially since the passage of **Superfund** legislation. By identifying industries responsible for contaminating the environment, clean-up costs can be recovered.
- Historical studies are a good educational tool because they provide background information for environmental scientists and managers, get citizens interested in local environmental issues, build ties between the community and scientists, and can be used as topics of interdisciplinary (e.g., science, history, writing) studies in middle schools and high schools.

What can we learn from a historical study?

Historical records can:

- help identify past pollutant inputs
- determine changes in shorelines, water circulation patterns and sediment deposition
- determine modification or loss of **habitat**
- may help identify changes in **species composition** or abundance

New Bedford Today

Setting the scene The Acushnet River **watershed**, located in southeastern Massachusetts (Fig. 1), is the most urbanized area in the Buzzards Bay drainage basin; New Bedford Harbor, the **estuarine** section of the Achushnet River, is the most contaminated area in the drainage basin. The harbor is contaminated with **metals** and **organic compounds**, including **polychlorinated biphenyls** (PCBs). Because of the high concentrations of PCBs in the sediment, New Bedford Harbor was listed as a **Superfund** site in 1982. Dredging of the most contaminated sediments (the hot spot) in the upper harbor was completed in 1995 by the Army Corps of Engineers. A second phase of the project, during which an additional 170 acres of less contaminated sediment in the upper and lower harbor will be dredged, was started in 2004 and will continue annually until completed. The harbor sediments are also contaminated with high concentrations of metals: copper, chromium, cadmium, nickel, lead, and zinc.

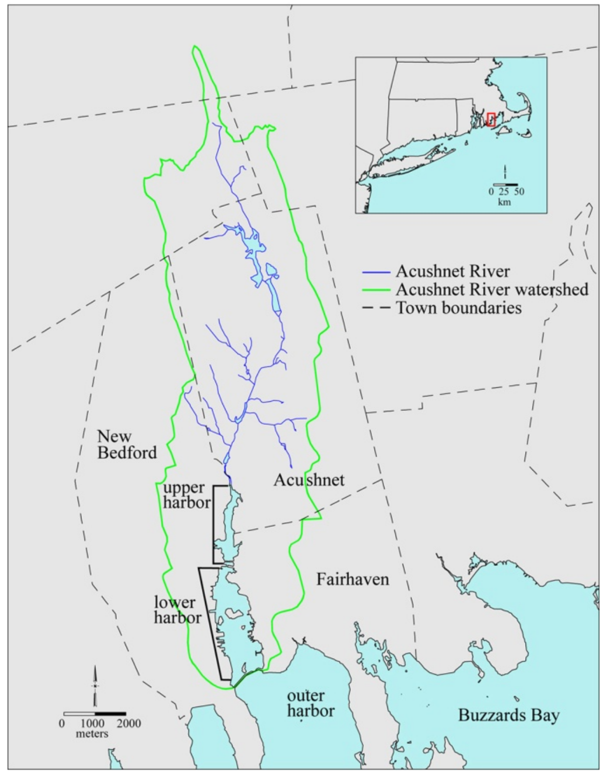


Fig. 1. New Bedford Harbor, the estuarine section of the Acushnet River, is located in southeastern Mass. The Acushnet River watershed encompasses sections of the city of New Bedford, and towns of Fairhaven and Acushnet, plus small sections of three other towns.

The city of New Bedford, on the western side of the harbor, has a population of about 100,000 and is the commercial and population center in the watershed. The city was first known as a prosperous whaling port, then as a producer of fine textiles, and most recently as a major commercial fishing port and fresh-fish processor. The New Bedford waterfront reflects current and past industries. It is lined with docks, storage and repair facilities, fish processing and packaging plants, large brick buildings that were formerly textile mills, and other commercial buildings.

New Bedford shoreline with hurricane barrier in foreground. Photo by C. Pesch

The towns on the eastern shore of the harbor are much smaller and less commercial. Fairhaven has a population of about 16,000 and Acushnet about 10,000. Marshes extend along the eastern shore of the upper harbor. Residential areas are situated on uplands behind the marshes. Residential and commercial sections, primarily marinas, marine service and repair businesses, extend along the rest of the eastern shore.


New Bedford shoreline: fishing boats (left) and former textile mills (right). Photo by C. Pesch

Marsh along Acushnet shore. Photo by C. Pesch

History of New Bedford Harbor and Acushnet River Watershed

Based on the history of the area, we divided development in the **watershed** (from the time of European settlement) into five periods: agricultural (1676-1780), whaling (1750-1900), textile (1880-1940), post-textile (1940-1980), which includes commercial fishing and a variety of industries, and environmental awareness (1970 – present). These dates are approximate and overlap but are useful to define economic development and the associated ecological effects. Finally, we included a summary of these ecological effects and their consequences.

Gosnold at Smoking Rocks, painted by William Allen Wall in 1842, depicts Bartholomew Gosnold landing at Smoking Rocks in 1602. Smoking Rocks was located on the New Bedford coast opposite Palmer Island, just north of the hurricane barrier. Courtesy of the New Bedford Whaling Museum.

Native Americans were the first inhabitants of the watershed. Bartholomew Gosnold reported that a large native population was present when he visited the area in 1602. Native Americans probably hunted in the wooded inland areas, planted crops on the flat land along the coast, and utilized the abundant marine resources found in the **estuary**: fish, shellfish, birds, and marine mammals. The coast was also the site of trade with the Europeans. Gosnold exchanged European goods for native furs.

Agricultural Period (1676 - c. 1780)

The Europeans arrived The earliest Europeans settled in the **watershed** in the mid-1600s. They were mostly Quakers who emigrated from Portsmouth, Rhode Island, and Plymouth and Taunton, Massachusetts. No exact population counts of these first settlers are available, and many of the original houses were destroyed during King Philip's War, the Anglo-Native American conflict that ended in 1676. By 1690, 11 to 13 families owned land in the area of present-day New Bedford (Fig. 2), and Joseph Russell owned a parcel of land in what was to become the center of New Bedford's waterfront district. The Russell family played an important role in the development of New Bedford.

Land was cleared These early settlers were primarily subsistence farmers. They cleared the land, planted crops, and kept livestock. They probably also fished. The effect of these early settlers on the landscape and harbor was probably minimal because the population was low. Recent studies on the effect of land-clearing in watersheds of some Chesapeake Bay tributaries found that greater than 20 percent of the watershed must be cleared before erosion increased sedimentation rates in the **estuary**. Using the number of families present in the Acushnet River watershed by 1771 and the size of the typical New England colonial farm, we estimated that about four percent of the watershed had been cleared by that time. In the later whaling and textile periods, however, more land had been cleared for commercial, industrial, and residential use, and the effects of land-clearing (change in stability and filtering capacity of soil, increased erosion, increased input of sediment and nutrients into the estuary) undoubtably occurred then.

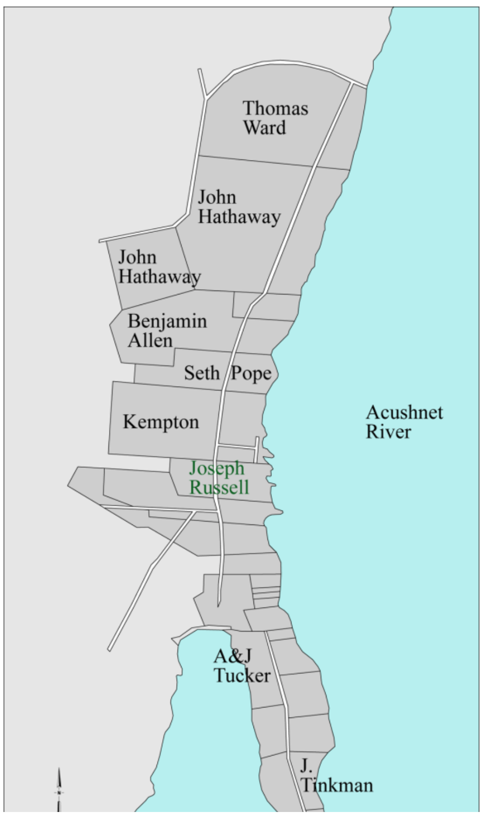


Fig. 2. Land ownership in New Bedford in 1690, taken from a map made by Henry Worth from data and survey by Benjamin Crane in c. 1711. (Old Dartmouth Historical Sketch No. 15, Story of Water Street, by Elmore P. Haskins)

This painting, Haying on the Acushnet, by William Allen Wall circa 1850, depicting an agricultural scene, is interesting because it shows the farmers utilizing the salt marsh grass along the Acushnet River. Courtesy of the New Bedford Whaling Museum.

Whaling Period (c. 1750 - c. 1900)

The first planner By the mid-1700s, the economy in the watershed began to shift to maritime-related activities: whaling, shipbuilding, and extensive import/export trading. The first locally owned whaler shipped out of New Bedford in 1755. It was owned by Joseph Russell, a descendent of the Russell family that had acquired land in New Bedford in the last quarter of the seventeenth century. Five years later, Joseph Russell sold portions of his homestead to a boat-builder, a blacksmith, a cooper, a cordwainer, and a house carpenter. All these professions supported whaling, and their presence in New Bedford stimulated the growth of the whale industry. In essence, Russell functioned as the first planner for New Bedford.

The influence of a few families

In 1765, Joseph Rotch, a senior member of an established Nantucket whaling firm, arrived in New Bedford and purchased land from Joseph Russell. Rotch brought with him money and expertise to advance the whale fishery. Within 10 years, 40 to 50 whaleships were registered in New Bedford. The families of Joseph Russell, Joseph Rotch, and Samuel Rodman, Rotch's son-in-law, dominated the economic development of New Bedford. In addition to owning whaling vessels, they were involved in outfitting whaling vessels, and in manufacturing whale oil products.

Whaleships and casks of whale oil at Central Wharf, New Bedford. Photo by Stephen F. Adams, circa 1870. Courtesy of the New Bedford Whaling Museum.

The bridge changed everything

By 1780, there were villages on both sides of the Acushnet River: Bedford village (the present-day historic district of New Bedford) on the west, and Fairhaven village and Oxford village on the east. Shipbuilding, whaling, and related businesses developed in all three villages.

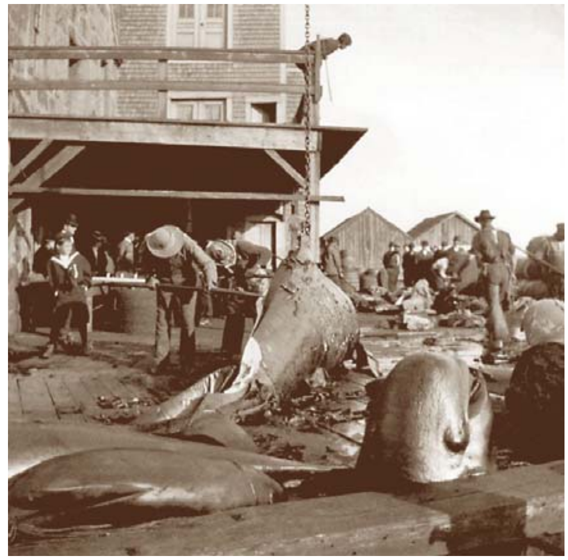
The original bridge was destroyed by the Gale of 1869 and rebuilt in 1870. The wooden bridge was replaced by steel in 1898. This photo by Joseph G. Tirrell, taken c. 1900, shows the bridge under construction. The view is east toward Fairhaven, with Fish Island in the foreground. The western section of the bridge, from New Bedford to Fish Island, had not yet been completed. Courtesy of the New Bedford Whaling Museum.

In 1798, William Rotch, a successful businessman in the whaling industry, and several other businessmen built a bridge connecting the east and west side of the river to improve commercial ties between Bedford village and Fairhaven and Oxford villages (Fig. 3). The bridge affected the pattern of development in the watershed in a major but unexpected way; it altered the river's currents and caused sediment to accumulate along the east shore north of the bridge at Oxford village. This prevented further development of Oxford as a port and shipbuilding center. Although maritime activities continued south of the bridge at Fairhaven village, physical expansion of the village was limited because the owner of the adjacent farm refused to sell until the 1830s. As a result, Bedford village (later New Bedford) on the west side of the Acushnet River, became the commercial center.

In 1858, historian Daniel Ricketson wrote of the public's opinion of the bridge: "The bridge is still thought by many to be a great public damage. It is undoubtedly a great convenience on many accounts, but it is questionable whether it accommodates the public better than might be done by the ferry boats; and, that the value of our harbor as well as the beauty of the river, is much impaired by it, few will question."

Changing shoreline The growth of the whaling industry brought changes to the shoreline of the Acushnet River, especially the western side (Fig. 4). A map of New Bedford depicting the coastline prior to 1800 showed no wharves. By 1855, numerous wharves had been constructed in the area just north and south of Fish Island. These wharves essentially extended the land out into the harbor. Fish Island, also an area of commercial activity, had become considerably larger by 1855.

A harbor survey conducted by the Army Corps of Engineers in 1853 found that the wharves in New Bedford and on Fish Island, and the New Bedford-Fairhaven bridge had changed the **hydrographic** properties of the river. The bridge and wharves constricted the channel between the New Bedford coastline and Fish Island and reduced the volume of water passing through this channel during tidal exchanges. As a result, sediment accumulated along the shoreline in front of the wharves. The constriction in the channel between the shore and Fish Island caused more water to flow through the channel between Fish Island and Popes Island. This increased flow washed away mud and sand in the channel between the islands. The construction of wharves, the accumulation of sediment around the docks and in channels, and the subsequent dredging (dredging first began in 1839), affected the shellfish beds and **benthic** communities in the vicinity. In contrast, the



Small whales called blackfish, congregated off the shores of Cape Cod, Nantucket, and Martha's Vineyard. These whales were herded ashore and then sold to F. W. Nye Oil Factory, which was established on Fish Island in 1866. This photo, taken by Albert Cook Church circa 1910, shows blackfish being cut up for processing at F. W. Nye Oil Factory. The oil from blackfish was processed into a high quality lubricating oil for watches, clocks, and chronometers. The firm moved to Fairhaven by 1940, and is still in business today as Nye Lubricants, a manufacturer of lubricating oils and grease. Courtesy of the New Bedford Whaling Museum.

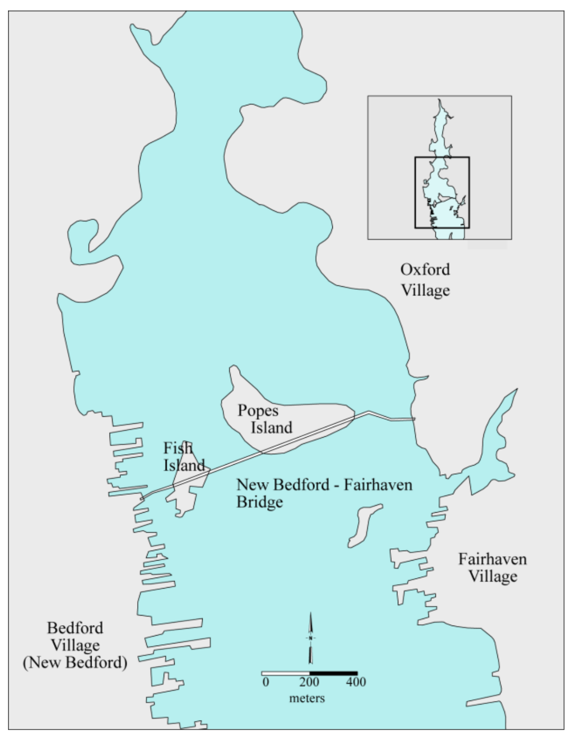


Fig. 3. The New Bedford-Fairhaven Bridge, built in 1798 to connect the villages on the east and west shore, altered currents in the harbor and as a result impacted the pattern of development in the area. The coastline shown in this figure was digitized from a map by Hatting (1855).

changes in the shoreline on the Fairhaven side were minimal because development had been limited.

Whaling wasn't the only business The growth of the whale fishery brought increases in related businesses, some of which affected the environment. Industries were concentrated in what is now the historic section of New Bedford, with most situated along the coastline (Fig. 5). During the whaling period, there were many whale oil processing firms that refined whale oil for use in lamps or as lubricating oils, or made candles and soap. These firms probably released biological wastes, lye, and caustic cleaning solutions into the environment. These substances may have caused short-term problems, but would not have persisted in the environment. These firms also may have emitted **polycyclic aromatic hydrocarbons** (PAHs) from burning wood and coal, and arsenic and mercury from burning coal.

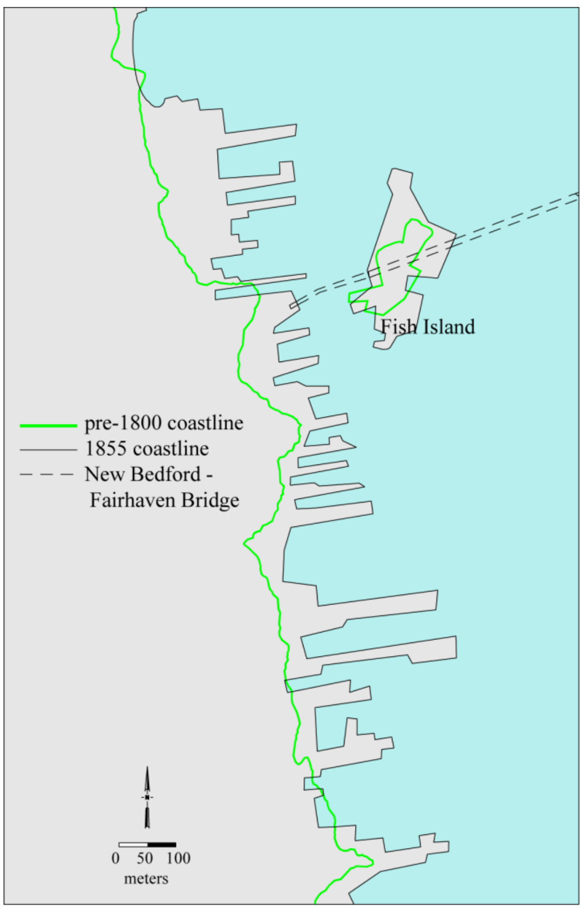


Fig. 4. The coastline in 1855 (Hatting, 1855) shows that a considerable number of wharves were built and some land gained since 1800 when no wharves were present (Map of Original Purchasers, 1753-1815, EC Leonard).

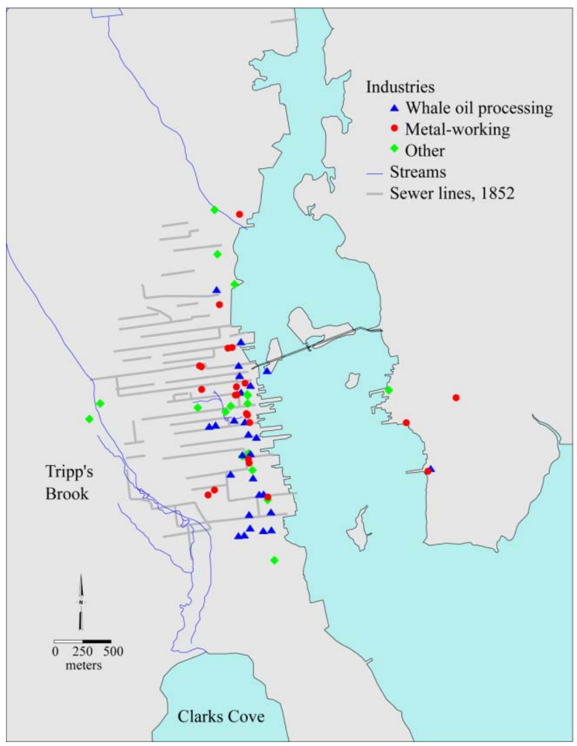


Fig. 5. During the mid-nineteenth century (c. 1830 - 1885), industries were located along the coast in what is now the historic section of New Bedford. Most industries not directly on the shore or a stream had access to the sewer system, which was installed in 1852. Sewer lines were located on east-west oriented streets and emptied directly into the harbor.

Many whaling-related industries worked with metals. Foundries, machine shops, and casting, plating and metal-working businesses provided the metal goods needed for whaling: copper sheathing for the bottoms of ships, try pots, pumps, fittings, and ship bells. Potential pollutants from these industries include **metals**, **solvents**, oils and grease, and **acids**. Although many of these metal businesses were small shops, there were a few larger ones. The largest, New Bedford Copper Company, located on the waterfront in New Bedford in 1860. The company was bought out by Revere Copper and Brass in 1928, and was in business until 2007.

Other industries that operated in New Bedford during the whaling period included tanneries, print shops, coal gas production, and manufacture of paint and varnish, glass, and chemicals. There were only a few of each of these, however. These industries probably released **acids**, **cyanide**, **petroleum hydrocarbons**, **phenols**, **metals**, **solvents**, and **biological wastes** into the environment. In contrast, there were only a few industries on the eastern shore in Fairhaven and Acushnet.

First sewers New Bedford had grown enough in the first half of the nineteenth century that the first sewer lines were installed in 1852 (Fig. 5). Since most of the early development in New Bedford occurred on the east side of the local hill, whose ridgeline extends north-south (Fig. 6), the sewer lines ran down the hill, along east-west running streets, and emptied directly into the river. Most industries not directly on the coast had access to a sewer line or were located adjacent to a stream. Liquid wastes from manufacturing were disposed of into the sewers or directly into the river or streams. In contrast, the Fairhaven side is relatively flat.

Decline of whaling Whaling reached its peak in 1857 (Fig. 7). Then a number of events during the next 20 years influenced the decline of whaling: discovery of petroleum in Pennsylvania in 1859 eliminated the need for whale oil as an illuminant; many whaleships were lost during the Civil War (1861-1865); and in 1871 and 1876 more whaleships were destroyed, crushed in the Arctic ice. By the early 1900s, the use of spring steel and other products to replace **baleen** put an end to the baleen market and an end to whaling.

For more information about whaling in New Bedford visit the web site of the New Bedford Whaling Museum

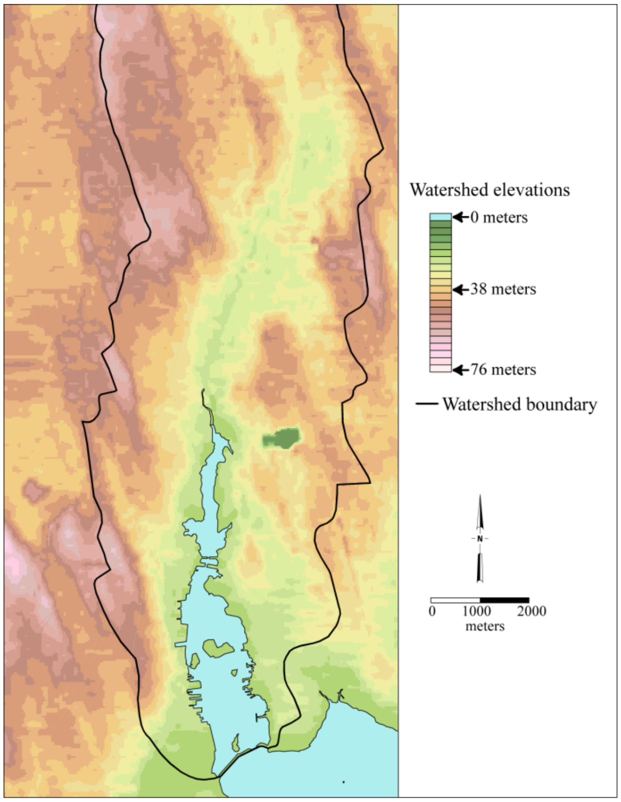


Fig. 6. This Topographic map of the watershed area shows the north-south ridgeline in New Bedford. Runoff from land east of the ridgeline flows into the Acushnet River.

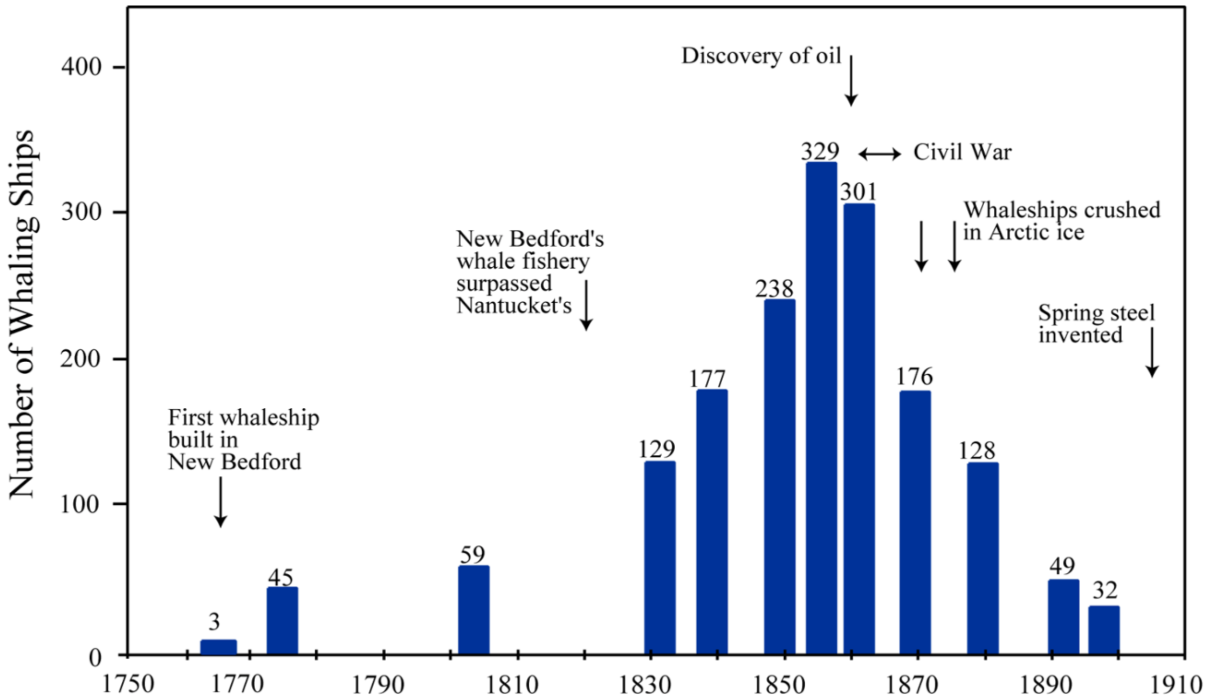


Fig. 7. Whaling reached its peak in 1857, when 329 whaling ships were registered in New Bedford. Data sources for number of whaleships: Davis, L. E., R. E. Gallman, and T.D. Hutchins. The Structure of the Capital Stock in Economic Growth and Decline, The New Bedford Whaling Fleet in the Nineteenth Century. In: Quantity & Quiddity, Essays in U.S. Economic History, Wesleyan University Press, Middletown, CT, 1987, p.344; Starbuck, A. History of the American Whale Fishery. Argosy-Antiquarian, Ltd., New York, 1964, p. 43; Tower, W.S. A History of the American Whale Fishery. Political Economy and Public Law Series, No. 20, University of Pennsylvania, Philadelphia, 1907. p. 125.

Textile Period (c. 1880 - c. 1940)

This painting of Wamsutta Mill, the first successful textile mill in New Bedford links the past, the agriculture scene in the foreground and whaleships in the distant harbor, with what was to become the future, the development of the textile industry. The Mill was painted by William Allen Wall, circa 1853. Courtesy of the New Bedford Whaling Museum.

Off to a slow start Because the whaling industry generated large amounts of capital, there was little interest in New Bedford to venture into other businesses. New Bedford's economy from the mid-1700s to the mid-1800s was dependent primarily on whaling and related businesses. By 1850, the textile industry was well established in nearby Fall River and other towns in Massachusetts, but was just beginning in New Bedford. The Wamsutta Mill, opened in 1848, was the first successful textile mill in New Bedford. But because of the continued prosperity of the whaling industry, it was another 30 years before the textile industry really started to expand in New Bedford. The Municipal Water Works, which opened in New Bedford in 1869, insured a good supply of water and made expansion of the textile industry possible.

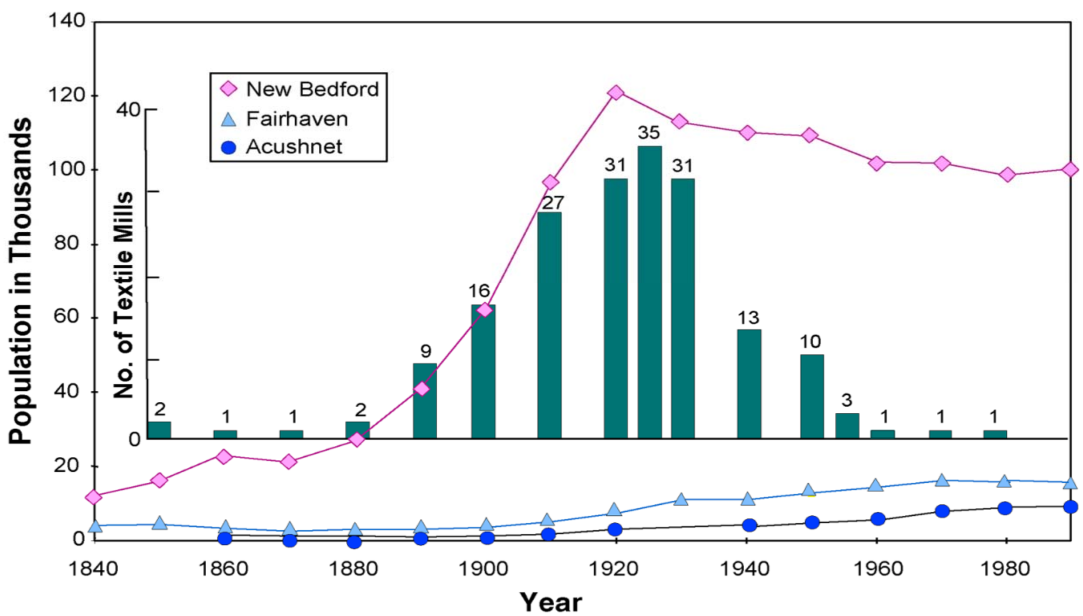


Fig. 8. From 1880 to 1920, the population in New Bedford increased more than four-fold as the textile industry expanded. In contrast, the population of Fairhaven and Acushnet was much lower.

Population boom With the decline of whaling in the 1880s, profits from the whaling industry were used to finance textile mills. As the labor-intensive textile industry expanded, New Bedford's population increased dramatically, from about 27,000 in 1880, when there were two mills, to about 121,000 in 1920 when there were 31 mills (Fig. 8). In contrast, the populations of Fairhaven and Acushnet remained much lower during this period.

Ecological impact of mills The major source of pollution from textile mills is wastewater from bleaching and dyeing processes. However, most of the mills in New Bedford did not finish or dye the cloth, they just spun yarn and wove cloth. Therefore, the primary environmental effect of the New Bedford mills was where they were built - on the relatively cheap wetlands along the west shore of the Acushnet River, north and south of the central business district, and also at the head of Clarks Cove (Fig. 9). Construction of the mills led to a loss of about 134 acres of wetlands, including almost all those along the west side of the Acushnet River. The loss of these wetlands decreased the **habitat** available for resident and migratory species, and decreased nursery areas for aquatic species. The function of these wetlands, to filter excess nutrients, pollutants, and microorganisms in runoff from the land, and to provide erosion control for the shoreline, was also lost.

When the first textile mills were built, residents probably thought it was good to fill in wetlands and thus, reduce disease. This idea came from the filth theory of disease transmission, which was widely accepted until the 1890s. According to that theory, diseases were caused by impure air generated by putrefied organic material, including human and animal excrement, rotting garbage, and vapors from swamps and stagnant pools. The filth theory was the basis of the nineteenth-century Sanitary Movement, which emphasized the importance of emptying cesspools and privy vaults, collecting garbage, cleaning streets, and filling in wetlands to eliminate sources of impure air. In the 1890s, bacterial research showed that the germ theory, which states that disease was caused by bacteria, was correct.

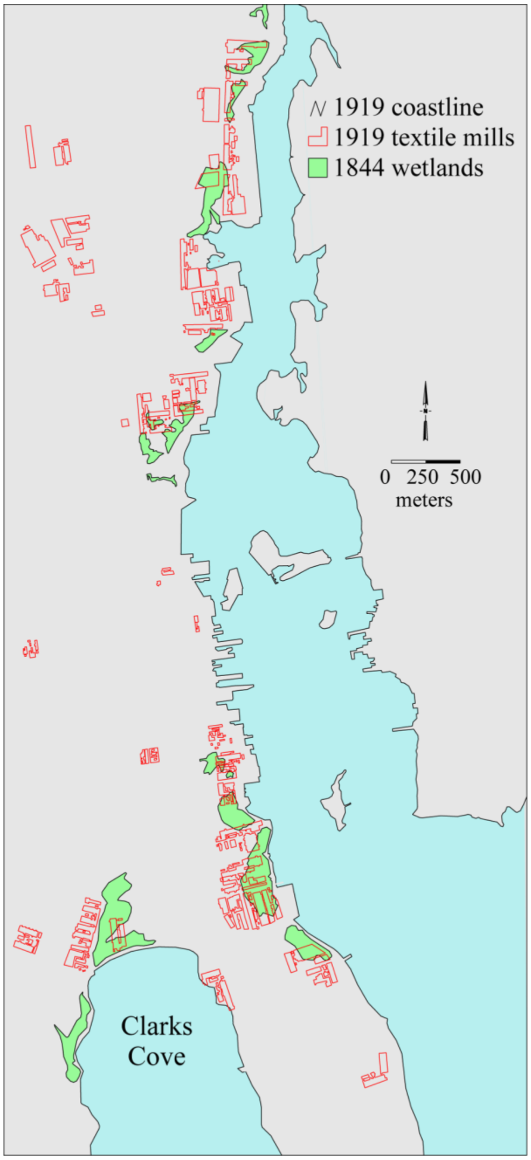


Fig.9. The New Bedford textile mills as shown on a map dated 1919 (Commission on Waterways and Public Lands of Massachusetts, 1919) were built on the wetlands, shown on an 1844 map (U.S. Coast and Geodetic Survey, 1844), to the north and south of the central business district.

It was the sewage Sewage was the biggest environmental insult of the textile period. New Bedford's dramatic increase in population, as people moved to the city to work in the mills, produced a huge increase in the amount of sewage. By 1900, the sewer system in New Bedford had been extended north, west, and south of the original system, with the pipes still emptying directly into the river. Sewage had become a **nuisance** and a public health issue. In 1870, Edward P. Haskill filed a law suit, Haskell v. New Bedford, against the city for the large amount of sewage that was accumulating at the end of his dock, causing bad odors and restricting boat access to the dock. On July 15, 1899, the local newspaper, *Morning Mercury*, reported that the board of health described the Acushnet River as "...water thick with slime and shores covered with filth from the sewers" and the evening edition (*The Evening Standard*) for that day, reported that the board said bathing in the river was dangerous to health. The sewage was also contaminating shellfish in the harbor. From 1900 through 1903, 575 people in New Bedford contracted typhoid fever (93 died) from eating contaminated shellfish. By 1904, the State Board of Health closed the Acushnet River to shell fishing (Fig. 10).

This painting, The Sewer, by Clifford W. Ashley, 1914, depicts the sewer at the foot of Union Street, New Bedford, emptying into the Acushnet River. Courtesy of the New Bedford Whaling Museum.

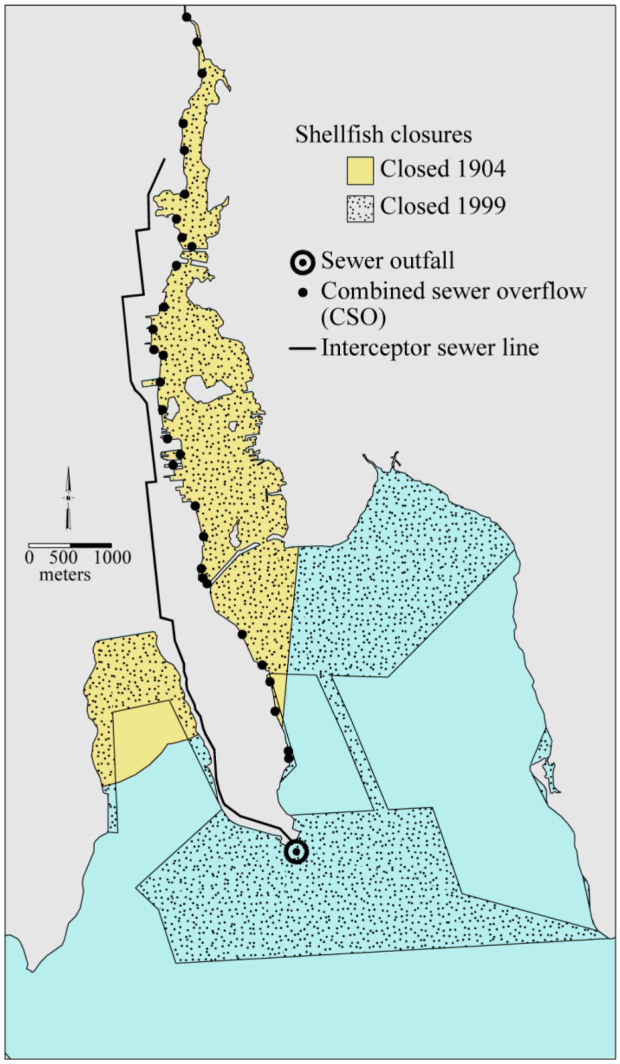


Fig. 10. The Acushnet River has remained off-limits to shellfishing since it was closed by the State Board of Health in 1904. Raw sewage still enters the harbor through combined sewer overflows (CSOs) during periods of high rainfall. Additional areas in the outer harbor were closed after the interceptor sewer line diverted wastewater to the outfall off Clarks Point. The classifications for shellfish closures in 1999 were collapsed into two groups: open (approved and conditionally approved) and closed (prohibited and restricted).

An attempt to solve the sewage problem In 1912, construction began on an interceptor sewer line to divert sewage into Buzzards Bay off the tip of Clarks Point (Fig. 10). The interceptor line and system was only partially completed, five of nine pumping districts were connected, when work on it stopped in the 1920s and did not resume until 1947. Even when the interceptor line was completed, it did not completely stop sewage from emptying into the harbor. The sewer system in New Bedford was, and still is, a combined one, which carries storm runoff in the same pipes as domestic and industrial wastes. During heavy rains, the pipes are not large enough to handle the volume, and some untreated sewage enters the harbor at various points through **combined sewer overflows**, or CSOs (Fig. 10). The outfall from the Fairhaven Water Pollution Control Facility, built in 1969, is located in the lower harbor. Fairhaven's wastewater treatment facility has had **secondary treatment** of waste from initial construction. Their sewer system is not a combined one, storm runoff does not enter the sewer pipes and treatment plant.

The Acushnet River has remained closed to shell fishing since 1904. The economic loss of having these shellfish beds closed has been estimated, in 1986 dollars, at 22 million dollars per year.

The problem with sewage Recent studies have shown that sewage effluent from outfalls causes a number of environmental problems: it increases organic carbon, reduces oxygen concentrations, reduces macrofauna, reduces species **diversity**, and increases numbers of **opportunistic species**. The presence of large amounts of sewage in New Bedford Harbor from the late 1800s on is well documented, and we can assume that during and after the textile period, sewage degraded the harbor's ecology. Contemporary data (Nelson et al., 1996) confirm that these effects remain: organic carbon is as high as 13% in sediments from the upper harbor, species diversity is low, number of dominant species is low, and opportunistic (pollutant-tolerant) species are present.

Other industries impacted the environment also During this time, other industries in the **watershed** were also likely to release pollutants (Fig. 11). As in the whaling period, metals were used by foundries, machine shops, and casting, plating and metal-working companies. A few soap-making companies were left, but most were gone by the turn of the century. The other industries depicted in this figure - oil refining, tanning, printing, production of coal gas, electricity generation, and manufacture of glass, paint and varnish, and rubber products - were possible sources of **metals**, **acids**, **petroleum hydrocarbons**, **phenols**, **cyanide**, **solvents**, and **biological wastes**. Textile mills are included in this figure, although they were not major polluters. There were a few dye houses in New Bedford, although only one was in the watershed. They released bleach and dyes that probably contained **metals** and **petroleum hydrocarbons**. In contrast to New Bedford, there were relatively few industries in Fairhaven, on the east side of the harbor.

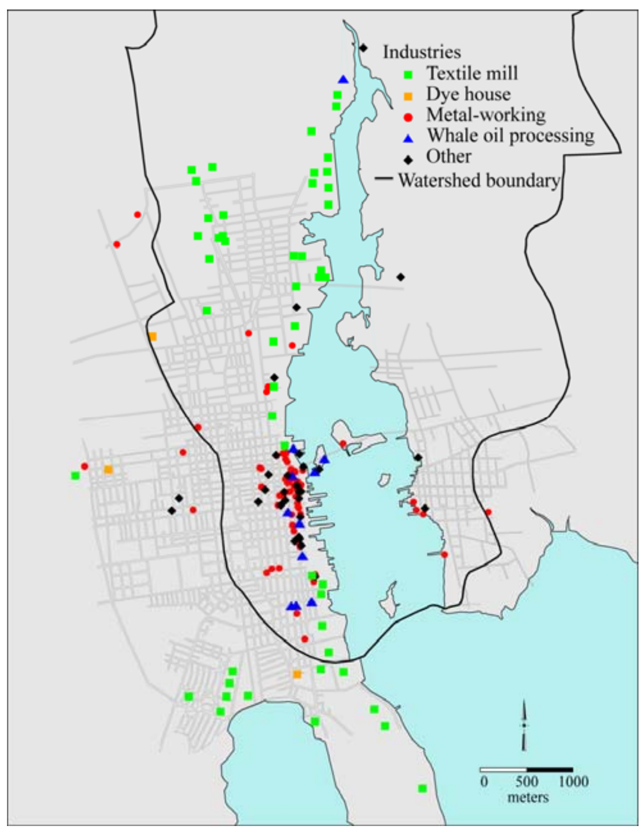


Fig. 11. Location of industries that may have released pollutants during the textile period (1880 - 1940).

Decline of textile industry A number of factors contributed to the decline in textile manufacturing in New Bedford: more favorable economic conditions for mills in the south, a prolonged mill workers strike in New Bedford in 1928, the stock market crash in 1929, and the Great Depression in the early 1930s. Mill workers were left unemployed, with few other jobs available locally. The loss of the textile mills and their tax revenues left the city in poor financial shape.

Post-Textile (c. 1940 – 1980)

Back to the sea The post-textile period was characterized by high unemployment in the first half of the period, a decline in population as workers left to find jobs elsewhere, and diversification of industry. New Bedford responded by refocusing on its connection to the sea. The commercial fishing industry expanded during this time. Although the commercial fishing fleet was active in New Bedford in the second half of the nineteenth century, those boats depended on sail and thus, could not get fresh catches back to port quickly. Several changes occurred during the beginning of the twentieth century that allowed the fishing industry to expand into a major industry in New Bedford: motors on the fishing boats, use of trucks to transport the catch, modern refrigeration, and a freezer plant built in the 1940s that added to the port's ability to process fish. The port of New Bedford became a major fresh-fish processing center on the east coast and the major scallop port on the northeast Atlantic coast. In 1984, the port of New Bedford ranked number one in the nation, based on value of landings.

Hurricane barrier The fishing fleet and other coastal businesses sustained heavy damage during the hurricanes of 1938 and 1954. In 1965, the Army Corps of Engineers finished building a barrier across the harbor entrance to protect businesses and homes from storm damage. A 150-foot gateway allows boats to pass and water to flow between the inner and outer harbors. Gates close the barrier when storms surges are predicted.

Aerial view of the hurricane barrier is courtesy of U.S. Army Corps of Engineers.

Environmental effects of hurricane barrier Although researchers have studied characteristics of the harbor after the hurricane barrier was built, only a few have addressed the possible effects of the barrier. One researcher reported that sediment is now accumulating faster in some areas of the harbor inside the barrier. Another suggested that less water is now being exchanged between the inner and outer harbors. A recent preliminary modeling study, designed specifically to evaluate the effects of the barrier, calculated that **residence time** of water inside the barrier increased up to 30 percent. The same modeling study also calculated that the pattern of water circulation near the barrier had changed, with the water forming **gyres** just north and south of the barrier during certain parts of the tidal cycle. The north gyre would mix incoming water more and thereby affect sedimentation patterns; the south gyre would recirculate water and wastes leaving the harbor, allowing part of that water to be swept back inside the barrier during the next incoming tide.

An attempt to diversify The post-textile period was not dominated by any one industry. In an attempt to offset high unemployment, a series of city and private non-profit groups, active from 1929 through the 1960s, developed strategies to encourage industries to relocate to New Bedford. They offered incentives such as moving expenses, a favorable tax strategy, and low rentals. The city, with its large empty factory spaces and large workforce with manufacturing experience and low pay scale, was attractive to manufacturers. Clothing manufacturers were a natural to occupy the empty mills and by the 1960s, they accounted for almost one-third of the manufacturing jobs in New Bedford (Fig 12).

A new environmental problem A number of other manufacturing companies moved to the city and occupied empty mill buildings. Two manufactures of electronic parts moved into empty mill buildings on the waterfront, Aerovox Corporation in 1939 and Cornell Dublier in 1941. Both of these companies used **polychlorinated biphenyls** (PCBs) in the manufacture of electronic capacitors, and discharged wastes with high concentrations of PCBs directly into adjacent waters and also through the municipal sewer system.

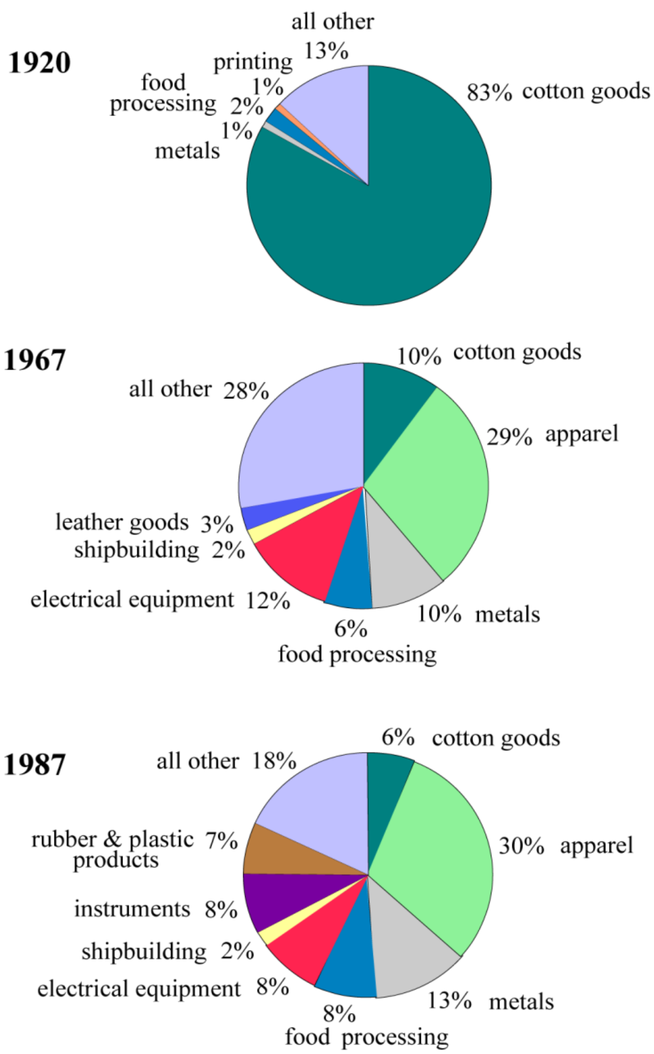


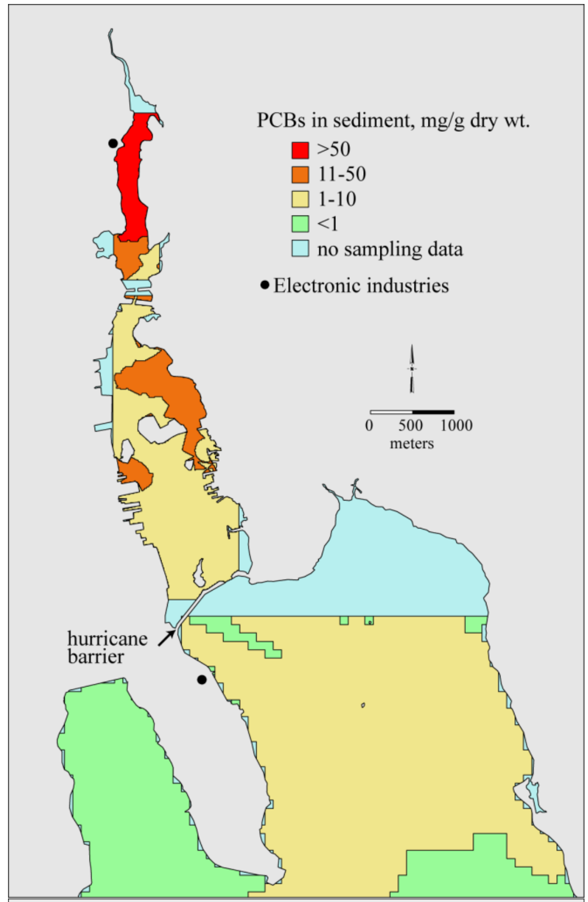
Fig. 12. The percentage of employees (calculated from Bureau of Census, Census of Manufactures data) in various manufacturing industries in New Bedford shows the diversification of manufacturing from 1920 to 1987. During this time, the actual number of employees in manufacturing jobs decreased by about 50 percent, from 43,226 in 1920 to 20,100 in 1987.

What are polychlorinated biphenyls (PCBs)? PCBs are industrial chemicals that contain carbon rings and chlorine. They were commercially manufactured and sold in the U.S. from 1929 to 1978. PCBs were used in industry for their insulating and nonflammable properties. Concern about increasing amounts of PCBs in the environment was first noted in 1968 by a Swedish scientist who measured concentrations of PCBs in fish, eagle feathers, and human hair. PCBs pose a health concern because they are **teratogenic**, **mutagenic**, and **carcinogenic**. They persist in the environment, concentrate upward in the food chain, and accumulate in fish. In 1975, some fish from the Hudson River, New York, were found to have concentrations of PCBs that exceeded the U.S. Food and Drug Administration (FDA) **action level** of 5mg/kg. For humans, the primary non-occupational source of PCBs is the ingestion of contaminated fish. The U.S. Environmental Protection Agency banned the manufacture of PCBs in 1978.

PCBs in New Bedford Harbor The presence of PCBs in New Bedford Harbor was first documented by researchers in 1976. Concentrations of PCBs in the river water exceeded the **water quality criterion** of 0.03 ug/L designed to protect marine life. Concentrations of PCBs in sediments in the upper harbor were also exceedingly high, up to 431 ug/g dry wt. (Fig. 13). New Bedford Harbor was placed on the National Priorities List for clean-up under **Superfund** legislation in 1982.

Harbor closed to all fishing To protect human health, the Massachusetts Department of Public Health closed the harbor in 1979, to the taking of all fish and shellfish because PCB residues in fish and clams found there exceeded the FDA **action level** of 5 mg/kg. Areas south of the hurricane barrier were also closed to the taking of labsters and bottom feeding finfish because particles of PCB-contaminated sediment inside the hurricane barrier are transported outside the barrier into Buzzards Bay by tides and currents (Fig. 14).

Other industries were sources of pollution As in the earlier periods, there were numerous metal-working industries in New Bedford in the post-textile period. Potential polluters included businesses that refined and stored petroleum, generated electricity, and manufactured paint, glass, rubber products, and plastics. They may have released **metals**, **acids**, **petroleum hydrocarbons**, **phenols**, **cyanide**, **solvents**, and synthetic chemicals into the environment.



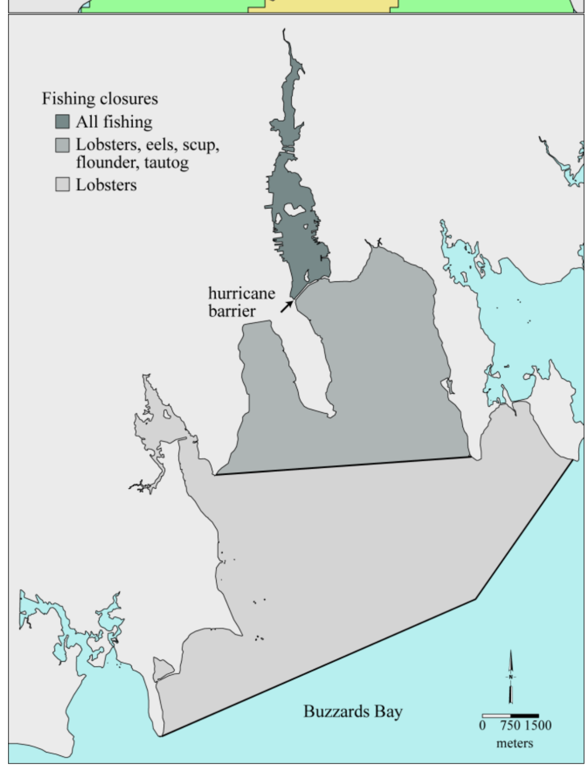


Fig. 13 (Top). Concentrations of PCBs in sediments in New Bedford Harbor were exceedingly high in the upper harbor adjacent to the electronics part manufacturing company.

Fig 14. (Bottom) In 1979, the harbor and areas south of the hurricane barrier were closed to fishing and/or shellfishing because PCB residues in fish and shellfish exceeded the FDA action level of 5 mg/kg.

Environmental Awareness (1970 – present)

The beginning of environmental awareness Although some national legislation addressing the issue of pollution was passed before 1960, Rachel Carson's book "Silent Spring" published in 1962, brought attention to the problem of pollution. On December 2, 1970, U. S. Environmental Protection Agency was created. A number of environmental laws were enacted in the 1970s (see the Public Health and Legislative section of the **timeline**).

Dredge in upper New Bedford Harbor (Oct. 6, 2004). Aerovox was located in the building in the back (center to right). Photo courtesy of EPA Region 1

The sewage problem is improving There has been some remediation of the sewage problem in New Bedford Harbor and surrounding waters. A wastewater treatment plant for New Bedford, with **primary treatment** of waste, was built in 1974. The outfall is off the end of Clarks Point. **Secondary treatment** of waste began in 1996, when a new wastewater treatment facility was brought on-line. This has improved the quality of the effluent discharged from the plant; however, untreated wastes are still discharged into the harbor from the **combined sewer overflows** (CSOs) during periods of heavy rain. A long-term plan to reduce the overflow of raw sewage into New Bedford Harbor through the CSOs was developed in 1990 (Camp, Dresser & McKee, 1990). In the 1990s, $178 million was spent to reduce the volume of waste released through the CSOs and another $200 million was committed for further improvements (personal communication, R. Labelle, New Bedford Department of Public Works, Wastewater Division, Nov. 4, 1999). Since 1990, a number of the CSOs have been eliminated; as of 2006, only 13 (of 24) CSOs remain in upper and lower New Bedford Harbor (Camp, Dresser & McKee, 2006). The Fairhaven Water Pollution Control Facility, built in 1969, empties into the harbor, but has had secondary treatment of waste since it started operation. In April, 2004, the facility started using ultraviolet light treatment, rather than chlorination, to disinfect the effluent before release.

Cleaning up PCBs In 1994 and 1995, the Army Corps of Engineers dredged about 5 acres of sediment (14,000 cubic yards) from the "hot spot," the section of the upper harbor that contained the highest concentrations of **PCBs**. The **dredge spoil** was stored in a **contained disposal facility** (CDF) until a decision was made on how to dispose of this highly contaminated sediment. In 1999-2000 the dredge spoil was dewatering and transported to an off-site landfill that was permitted for toxic waste.

The second phase of the project, dredging about 450,000 cubic yards of PCB-contaminated sediment from 170 acres in the upper and lower harbor, started in 2004 and will continue annually until the project is completed. The $15 million annual funding level allows approximately 40 days of dredging each year. The dredging is performed on a worst-first basis, generally proceeding from north to south, beginning at the former Aerovox plant (Fig. 15). The dewatered dredge spoil is sent by rail to a licensed PCB-landfill in Michigan.

For the latest information on the remedial dredging see the New Bedford Harbor website. Scientists are **monitoring** New Bedford Harbor for 30 years after the dredging to assess the effects of **remediation** (see Nelson et al., 1996).

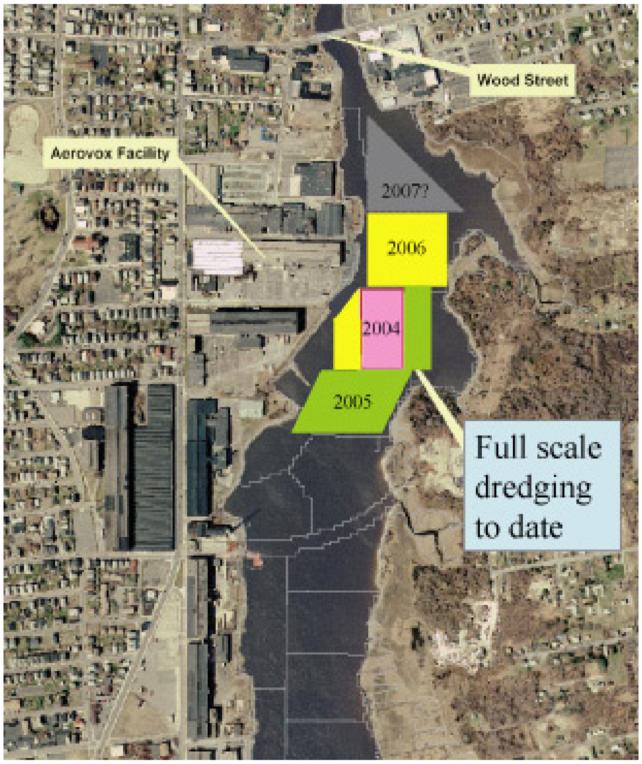


Fig. 15. Areas in upper New Bedford Harbor dredged in 2004 to 2006. Area proposed to be dredged in fall, 2007 is shown

Metal contaminated sediment Some PCB-contaminated sediment is also highly contaminated with metals, therefore, some metal-contaminated sediment is also being removed with the dredging. However, at the present time, there are no plans to deal specifically with sediments contaminated by chemicals other than PCBs. Maintenance dredging of the shipping channels, mentioned in the harbor master plan, will also remove contaminated sediment. An industrial pretreatment program, where industries remove contaminants from their wastes before releasing them into the sewer system, was instituted in 1987, so fewer contaminants are now being discharged through the outfall of the wastewater treatment plant and the CSOs.

Is there evidence that the environmental laws are being effective? Sediments record the history of contamination in estuaries. Contaminants adsorb to sediment particles, which get moved by currents and tides and settle to the bottom in areas of low flow. The contaminants in the surface sediment reflect current time and events, whereas, contaminants found deeper in the sediment correspond to past time and events. Sediment cores from estuaries can be frozen, sliced horizontally into thin slices, and the slices analyzed for various chemicals. Various methods can be used to assign approximate dates to slices down the core. When concentrations of contaminants in slices of the core are plotted by date, the resulting graph (called a sediment profile) shows the history of contamination in the estuary.

Taking a sediment core in Narragansett Bay. Winching the corer up (Top). Cutting the excess plastic off above the top of the sediment (Bottom). Photo courtesy of EPA Atlantic Ecology Division.

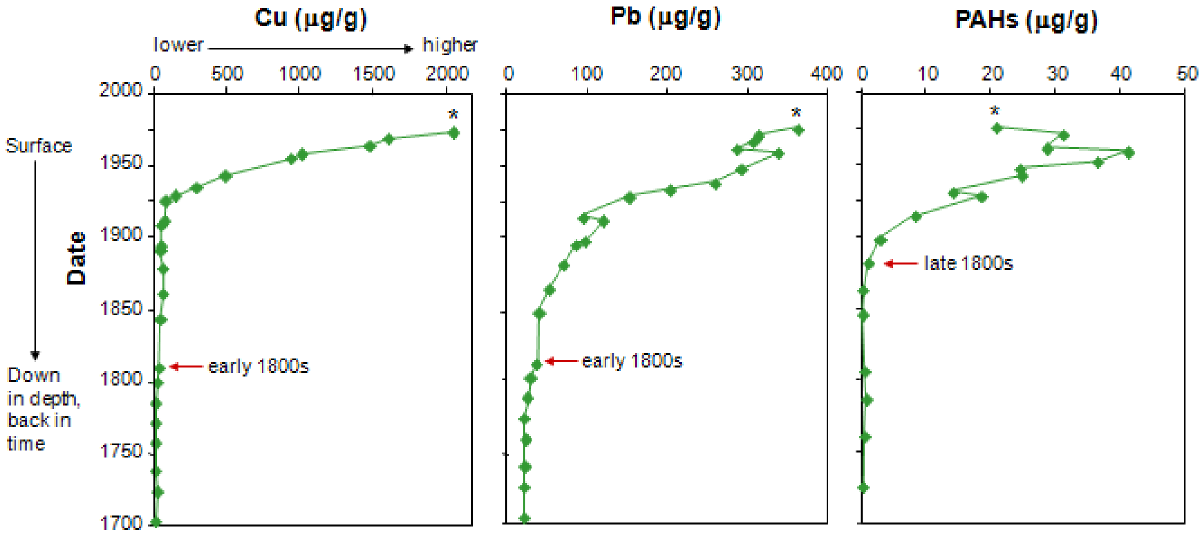


Fig. 16. One sediment core was taken in lower New Bedford Harbor. The top of the sediment core was lost (* on the graphs), probably during sampling, because the topmost horizontal slice dates to the mid-1970s; the core was taken in 1998. The arrow indicates when the concentration of the contaminant has reached a level that is statistically higher than background level (the naturally occurring concentration). Sediment concentrations of copper (Cu), lead (Pb), and polycyclic aromatic hydrocarbons (PAHs) in the core became significantly elevated over background concentration in the 1800s, the Whaling Period, although these concentrations were small compared to concentrations in later years. See Fig. 17 for the location of industries during the Whaling Period and location of the core. The metal-related businesses were the most likely sources of copper and lead. Burning of wood, charcoal, and coal, and later oil, by industries was the most likely source of PAHs.

Sediment study in New Bedford Harbor A sediment study was conducted in New Bedford Harbor to determine historical changes in the harbor over the past 350 years (Latimer, J.S. et al., 2003). Three sediment cores were taken in the harbor, two in the upper harbor (in 1996) and one in the lower harbor (in 1998), in areas that were relatively undisturbed and where sediment had accumulated. The cores were frozen, sliced horizontally and the slices analyzed for toxic organic compounds, metals, organic carbon content, carbon isotope composition, and biological indicators (dinoflagellate cysts, benthic foraminifera, and pollen). Radionuclides (^{210}Pb and ^{137}Cs) and pollen analyses were used to date the sediment slices. Plotting concentrations by date shows the history of contaminants in New Bedford Harbor sediment from the present at the surface, back in time with depth (see Fig. 16, 18, and 20). Please note, dating methods are not exact, so the dates shown on the sediment profiles are approximate, with less certainty the further back in time.

Contaminants in sediment cores correlated with development All of the contaminants measured (PAHs, PCBs, copper, lead, zinc, cadmium, silver, chromium, and nickel) increased with the urbanization of the New Bedford Harbor watershed. Statistical tests were done to establish when each contaminant increased above background level (the concentration of a chemical in the environment that occurs naturally, not the result of human activity). In the early 1800s (the whaling period), two contaminants, copper (Cu) and lead (Pb), were found at concentrations significantly above background level in the lower harbor, where development initially started (Fig 16). Although these increases were significantly above background, they were substantially lower than concentrations reached later. The shore of lower harbor was the location of foundries, machines shops, casting, plating and metal working businesses that made metal goods needed for whaling, and whale-oil processing businesses (Fig. 17). The metal-related businesses were the most likely sources of copper and lead.

PAHs There was a small, but discernable peak in **PAHs** (polycyclic aromatic hydrocarbons) in the late 1700s. This peak may reflect the burning, in 1778, of part of New Bedford by the British during the Revolutionary War (see **timeline**). Major sources of PAHs are the combustion of wood, charcoal, coal, and petroleum products. When PAHs are released to the atmosphere, many of them are attached to particles, which are deposited on land, and later washed into streams, storm drains, and nearby water bodies. PAH concentrations increased significantly above background in the late 1800s. The whale-oil processing and metal-working businesses burned wood, charcoal, and later coal. The whaling-related businesses, which increased in the second half of the 19th century, were the most likely source of PAHs in the lower harbor sediment. By the late 1950s, the concentration of PAHs had started to decrease.

Time lag in upper harbor About 100 years later, in the early 1900s, copper, lead, and PAHs were found to be significantly above background level in the upper harbor cores (Fig. 18). By this time, textile mills and other industries had been built on the shores of the upper harbor (Fig.19). These industries were the most likely source of the contaminants found in upper harbor sediments. The timing of the appearance of contaminants in the sediments followed the development along the shores of New Bedford Harbor: first appearing in the lower harbor where the initial development of wharfs and whaling-related industries occurred, and then later in the upper harbor when the textile mills and other businesses located along that shore.

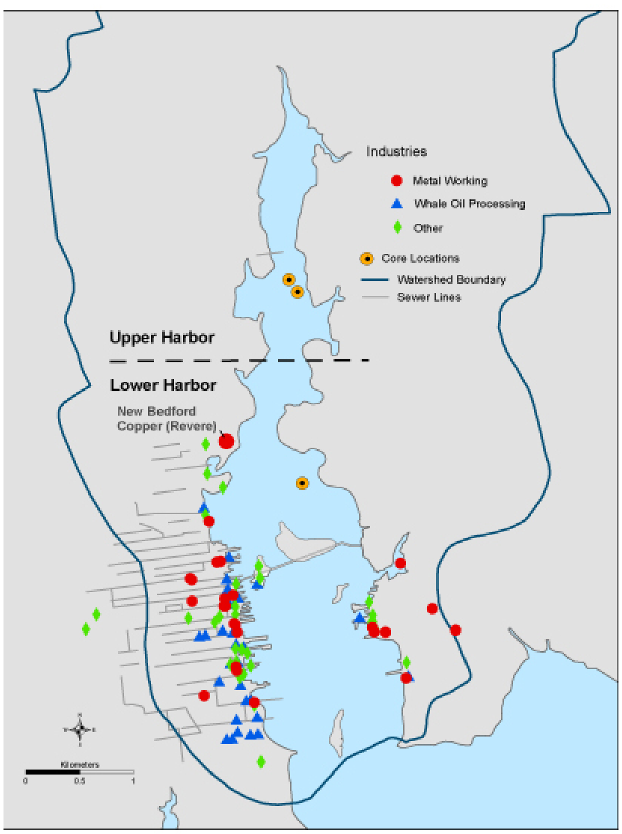


Fig. 17. Industries present from 1830 to 1887, during the Whaling Period, were clustered along the shore of the lower harbor in New Bedford, with a smaller number in Fairhaven (on east side of harbor). Not all industries are marked on this map, just those that most likely would have released pollutants, primarily metal-related businesses, whale oil processing companies, and a few others. In 1998, one sediment core was taken in the lower harbor. See Fig. 16 and 20 for the profiles of contaminants in this core. The shoreline used for this figure was taken from an 1855 map by H. F. Hatting, Map of the Town of Fairhaven, Bristol County, MA.

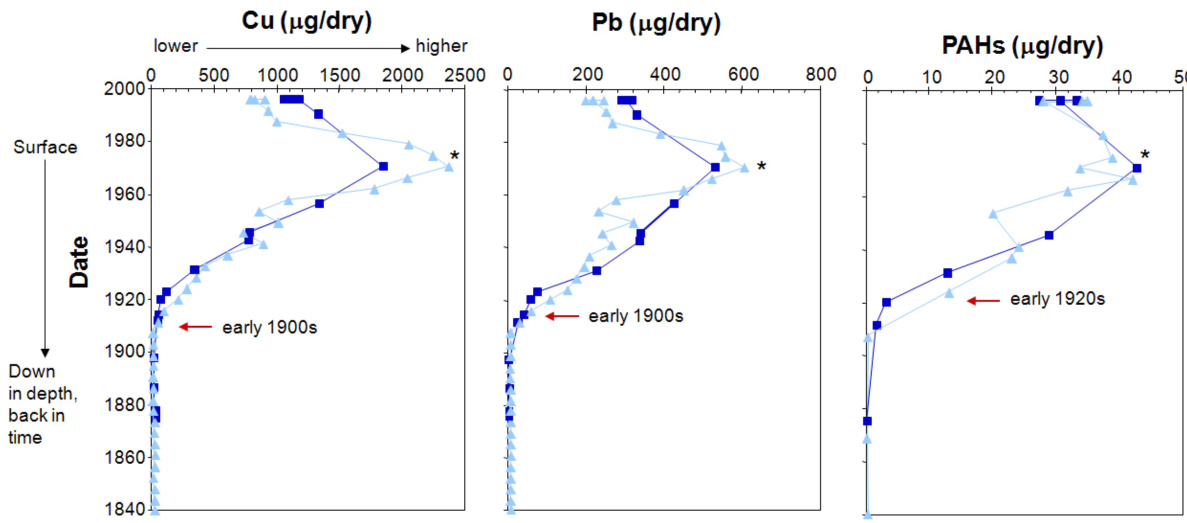


Fig. 18. In 1996, two sediment cores were taken in upper New Bedford Harbor. The two cores were located fairly close to each other (Fig 19) and were expected to have similar profiles, which they do. The arrow indicates when the concentration of contaminant has reached a level that is statistically higher than background level (the naturally occurring concentration). In the upper harbor, concentrations of copper (Cu), lead (Pb), and polycyclic aromatic hydrocarbons (PAHs) became significantly elevated over background in the early1900s. By this time, textile mills and other industries had been built on the shores of the upper harbor (Fig.19). These industries were the most likely source of the contaminants found in upper harbor sediments. In the lower harbor, concentrations of copper and lead had become significantly elevated about 100 years earlier, and PAHs significantly elevated about 40 years earlier (Fig. 17).

PCBs in cores PCBs, chemicals which were manufactured for the first time in 1929 (they don't occur naturally), showed up initially in the upper harbor (near Aerovox, the source of PCBs) in the late 1930s, and in the lower harbor in the early 1940s (Fig. 20). With the uncertainty of dating sediment cores, this difference in dates between upper and lower harbor may not be real. When PCBs enter the harbor waters they are quickly adsorbed onto sediment particles. Sediment particles can be moved by the outgoing tide, settle to the bottom, get resuspended, and then moved further down the harbor (see Fig.13 for distribution of PCBs in harbor).

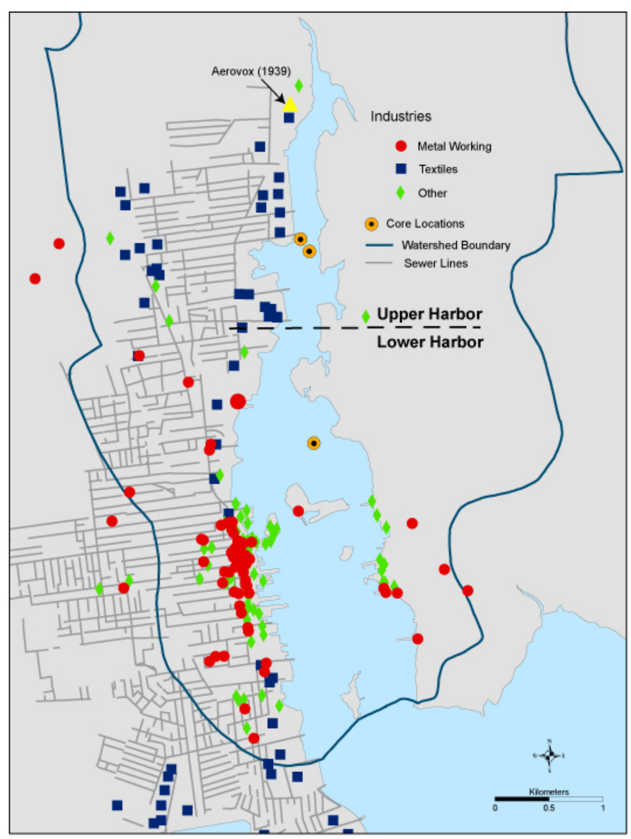


Fig. 19. By the early 1990s textile mills and other industries had been built on the shores of the upper harbor. These industries were the most likely source of the contaminants found in upper harbor sediments (see sediment core profiles, Fig 18). Aerovox Corporation (yellow triangle on map) moved into one of the empty mill buildings in 1939. See Fig. 20 for PCB concentrations in the sediment cores. The shoreline used for this figure was taken from a 1919 map (Commission on Waterways and Public Lands of Massachusetts, New Bedford Harbor).

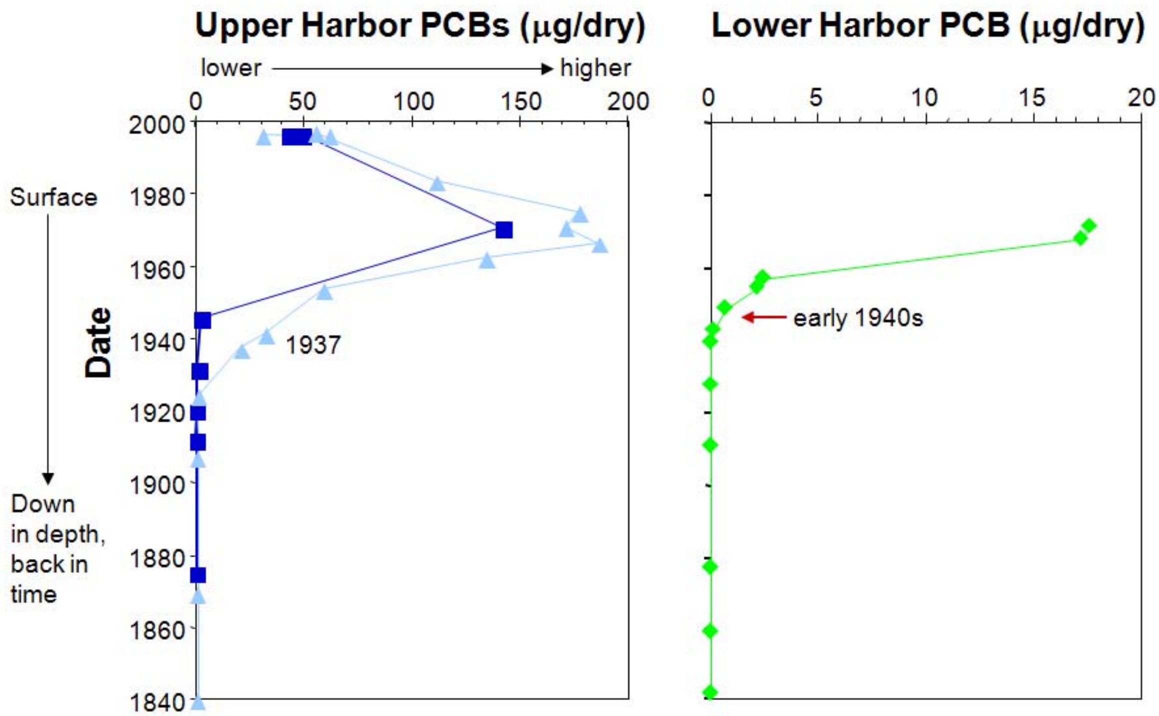


Fig. 20. PCBs showed up initially in the upper harbor in the late 1930s and in the lower harbor in the early 1940s. Dating methods give approximate dates, so this difference may not be real. Aerovox Corporation, the source of the PCBs, moved into an empty mill building on the upper harbor in 1939 (yellow triangle in Fig. 19). When PCBs enter the harbor waters they are quickly adsorbed onto sediment particles, which then can be moved by outgoing tides, settle to the bottom, get resuspended, and moved again further down the harbor (see Fig.13 for distribution of PCBs in harbor). Note the difference in scales of PCB concentration; the maximum concentration of PCBs in the upper harbor (186µg/g) is about ten times greater than that in the lower harbor (17.6µg/g).

Sediment profiles show effect of environmental regulations Concentrations of all contaminants measured in this study increased greatly after the turn of the 20th century. After environmental regulations were instituted in the 1970s, concentrations of these contaminants started to decrease, but were still substantially elevated (Fig. 18). The top of the core taken in the lower harbor was apparently lost (perhaps when coring), because the surface slice of the core dates to the middle 1970s, so a decrease is not seen in the concentrations of copper, lead, or PCBs (Fig 16). In the lower harbor, concentrations of PAHs started to decrease in the late 1950s.

The sediment profiles of contaminants in New Bedford Harbor record the history of pollution in the harbor. The increase in contaminants first appeared in the lower harbor sediments adjacent to the area of initial development. Later as development spread northward to the shores of the upper harbor, contaminants appeared in the upper harbor sediments. Contaminants increased with the urbanization of the New Bedford Harbor watershed. With the implementation of environmental legislation in the 1970s, the concentrations of contaminants started to decrease.

Summary

Reprieve - why history is important The complex environmental problems in New Bedford Harbor are easier to understand when the ecological effects are followed over time. It has become clear that the environmental problems in the harbor did not just arise in the last 50 years, but have accumulated over several hundred years. This case study has clearly demonstrated that development can have effects that are major and long-term; for example, the bridge built in 1798 affected sedimentation patterns, which in turn determined the future pattern of development in the harbor area. Hopefully, when decisions are made today we can look forward fifty to one hundred years and let that view be factored into the decision.

New Bedford shoreline just south of New Bedford-Fairhaven Bridge, foot of Middle Street: top – circa 1890, Henry P. Willis, courtesy New Bedford Whaling Museum; bottom – 2001, by Carol Pesch.

When the effects of development are examined over time (see summary chart), it is easier to determine which effects are irreversible and which may potentially be remediated. The changes made by the building of wharves, the New Bedford-Fairhaven Bridge, and the hurricane barrier, and the filling of wetlands are seemingly irreversible. But some remediation is happening. The PCB contaminated sediment in the harbor is being removed by the dredging projects conducted by the Army Corps of Engineers. Some of this sediment is also highly contaminated with metals, so metal-contaminated sediment is also being removed. In the last 20 years, a number of changes have been made to improve environmental conditions in the harbor. Improvements to the sewage system and CSOs have been and are continuing to be made, so less raw sewage is released into the harbor. Since 1987, industrial pretreatment of waste has removed contaminants from wastewater before it is released to the sewer system.

Historical studies can inform citizens about environmental issues in their communities and engage them in the process of "community-based environmental protection". Historical studies can be used in schools as topics of interdisciplinary projects that combine history and science. This historical profile has presented a realistic picture of environmental conditions in New Bedford Harbor. Although the harbor cannot be restored to pristine conditions, it can be improved and protected, especially through community-based efforts. Check the New Bedford Harbor web site for a list of public meetings and the latest updates on remedial dredging.

Ecological Effects of Development on New Bedford Harbor

Summary Chart

Development	Consequence (inferred or known*)
Agricultural Period (1676-1780)	
• Cleared land, farmed	• Minimal effect
Whaling Period (1750-1900)	
• Built wharfs • New Bedford - Fairhaven Bridge • Industries • Cleared more land for building	• Altered currents and sedimentation* [1] • Altered currents and sedimentation* [1] • Contaminated sediment in harbor • Erosion, input sediment and nutrients
Textile Period (1880-1940)	
• Built mills on wetlands • Dramatic population increase led to increased sewage input • Industries	• Loss of habitat and filtering capability • Increased organic matter, low oxygen concentration, low species diversity, closed shellfish beds* [2], Typhoid fever* [2] • Contaminated sediment in harbor
Post-Textile Period (1940 - 1980)	
• Electronics industries • Other industries • Hurricane barrier	• PCB contamination in harbor* [3,4] • Contaminated sediment in harbor* [5] • Altered circulation patterns[6]
Environmental Awareness (1970 - present)	
• Fairhaven Water Pollution Control Facility – secondary (1969) • New Bedford Wastewater Treatment Plant – primary treatment (1974) • Industrial Pretreatment (1987) • N. Bed. Wastewater Treatment Plant – secondary (1996) • Long-term plan to reduce effluent from CSOs • Dredge PCB-contaminated sediment	• Cleaner effluent • Cleaner effluent • Cleaner effluent • Cleaner effluent • Eliminate raw sewage from entering harbor • Cleaner sediment

[1] Dutton, 1853; [2] Commissioners on Fisheries and Game, 1916; [3] Summerhayes et al., 1977; [4]Weaver, 1984; [5] Pruell et al., 1990; [6] Abdelrhman, 2000

Contaminants in the Environment

There are two issues to consider about environmental contaminants: fate - what happens to the contaminant when released to the environment, and effect - what kind of damage is done.

Fate Some contaminants are short-lived in the environment and consequently affect only the immediate areas for a short time, while others persist for decades. Long-lived chemical contaminants may remain at the area of release or may be transported to other locations. For example, chemicals dumped onto the ground may adsorb to soil particles and persist there for decades. Other chemicals leach into the groundwater or adjacent streams, rivers, and lakes and are transported away from the site of disposal. The type of soil also affects fate of chemicals. Some soils, like sand, are more **permeable** and allow water to readily pass through and carry contaminants into the groundwater. Other soils, such as clay, are less permeable and allow liquids to filter through slowly enough that surface runoff will will carry most of the contaminants into nearby water bodies. Some chemicals dumped onto land will adsorb to the organic fraction of soil; some chemicals dumped into water bodies will adsorb onto the bottom sediments and persist for decades. Chemical contaminants emitted into air may be carried hundreds or thousands of miles by prevailing winds.

Effect The effect of any chemical contaminant depends on its **toxicity** and the quantity released. At high concentrations, contaminants dumped into water bodies can cause acute toxicity (death) to aquatic organisms, whereas, at lower concentrations they may cause chronic effects, such as decreased growth rate, reduced offspring, nervous system disorders, or may accumulate in the tissues. Edible species may accumulate high enough concentrations of certain chemicals that they pose a human health threat; for example, fish and shellfish from New Bedford Harbor accumulate PCBs that make them unsafe to eat. Since some species of plants and animals are more sensitive than others, pollutants may alter the **species composition** by affecting the more sensitive species, while the more tolerant ones survive.

Contaminants in the Acushnet River watershed The groups of contaminants mentioned on this web page all pose some sort of problem when released into the environment. The fate and effect of contaminants released in the Acushnet River watershed can be described in general terms (see below); the particular effect of a contaminant depends on the individual chemical or mix of chemicals, the amount released, and the physical characteristics of the disposal site.

Metals Various metals that are commonly used in industrial processes are **toxic** and insoluble. That means that they adsorb to sediments, can be accumulated by organisms, and persist in the environment. Sediments in New Bedford Harbor contain high concentrations of metals, particularly copper, chromium, zinc, and lead.

Cyanide Cyanide is highly toxic and persists in the environment. It was used by several industries in the 1800s, but is now regulated. Industries in New Bedford that may have released cyanide as a pollutant were coal-gas production and metal plating.

Petroleum hydrocarbons Petroleum hydrocarbons are comprised of hundreds of **organic compounds** derived from petroleum. Toxicity and persistence depend on the particular fraction of petroleum. Some petroleum fractions are volatile (evaporate easily) and do not persist in the environment. Although volatile compounds are toxic, they usually are not harmful to organisms because they do not stay around long enough. The less-volatile fractions are less reactive, persist longer in the environment, and are toxic. Oils and grease are general terms for some petroleum hydrocarbons.

Phenols Phenols, a particular group of organic chemicals, vary in toxicity and tend to be less persistent in the environment. Industries in New Bedford that may have used phenols were metalworking industries, petroleum refining, and coal-gas production.

Solvents Solvents are chemicals distinguished by their industrial use rather than their chemical structure. They are usually organic chemicals. Solvents vary in toxicity and persistence in the environment. They were used in many industries: dying, metalworking, printing, tanning, and manufacturng glass, electric and electronic parts, plastics, paint and varnish, and rubber products.

Acids Acids can cause acute effects in the immediate disposal area, but they do not persist in the environment because they are quickly buffered. Industries in New Bedford that likely used acids were metalworking and metal plating, printing, petroleum refining, tanning, and manufacturing rubber products.

Lye and caustic cleaning agents Lye and caustic cleaning agents are highly toxic. They can cause acute effects where they are dumped, they are very reactive and do not persist in the environment. Lye was used in tanning and soap making.

Biological wastes Biological wastes can cause acute, short-term effects when disposed in water. Biological wastes contain organic matter, which consumes dissolved oxygen (DO) as it decomposes. The amount of DO in waters can be lowered so much that resident plants and animals cannot survive. Industries in New Bedford that may have released biological wastes were tanning operations (hides and animal waste), fish processing plants (fish wastes), processing whale oil (although most of the initial processing of whale oil was done aboard the whaleships), and manufacture of rubber products.

How to Analyze the History of an Area

Become familiar with local history Learn about local history by using the resources at local libraries and historical societies. State historical commissions may also have reports that include the history of individual towns. Concentrate on sources that give the big picture - you can get the details later.

Look at old maps of the area Locate facilities (local library, local and state historical societies, university libraries, state library, and state archives) that have old maps of the area of interest. Compare coastlines and wetlands on old maps to current ones. Also check the Internet for web sites that have old maps.

Visit the area Drive around the area and get to know the residential, commercial, and industrial areas. Look for old buildings and learn the location of the "old section" of town.

Research former industries Reports of local boards of trade and old town and city directories list industries and businesses. Sanborn Maps (fire insurance maps) give locations of former industries and may indicate the industrial processes or types of materials stored in the buildings.

Research city and state health reports Check state libraries for state or city Department of Health reports to learn of "**nuisances**" (odor problems from sewage or other sources) or outbreaks of diseases that may be related to environmental conditions; for example, from 1900 to 1903 there was an outbreak of typhoid in New Bedford that was caused by consumption of contaminated shellfish.

Research city, state, and government engineering reports Learn about possible environmental effects by checking state libraries for engineering reports and city halls for Board of Public Works and Department of Engineering reports. For example, an Army Corps of Engineers report, dated 1853, documented the change in hydrography in New Bedford Harbor after the New Bedford-Fairhaven Bridge was built.

Check newspaper libraries Some newspapers maintain archives of articles that have appeared in their papers. These are often arranged by subject, such as sewerage or sewer system, hurricanes, or particular industries in the area. Newspaper articles can also be found on microfilm at local libraries. These articles are a good way to see what issues were important to residents.

Make a time line A time line with significant local, regional, and national events will help put local events in perspective and give an understanding of why development occurred as it did. It will also help to identify time periods associated with development and environmental effects.

Each area has its own unique history Use that unique history as a guide to indentify the environmental effects associated with development of the area.

Reference For comprehensive guidance on how to analyze the ecological history of an area consult "The Historical Ecology Handbook, A Restorationist's Guide to Reference Ecosystems" edited by Dave Egan and Evelyn A. Howell, published by Island Press, 2001.

Glossary

action level - chemical concentration in food above which consumption of that food would pose a health risk

baleen - the boney plate in the mouths of certain kinds of whales that was used to make corset stays, hoops for women's skirts, frames for hats, fans, umbrella ribs, and fishing rods

benthic - bottom-dwelling, at the surface of or in the sediment

carcinogenic - a chemical or substance that produces or incites cancer

combined sewer overflow (CSO) - a system of waste removal where storm runoff from streets empties into the same pipes as domestic and industrial wastes. In periods of high rain, the wastewater treatment plant cannot handle the increased volume and the wastewater empties through the combined sewer overflows into adjacent waterways without being treated.

contained disposal facility (CDF) - a structure built along a shoreline (or sometimes as an island) to contain solid material from dredging. The facility is lined with impervious material to contain the dredged material. The surrounding water and ground water is tested periodically to insure that toxic chemicals are not leaching from the dredged material in the CDF.

diversity - number and variety of different organisms in the environment in which they naturally occur

dredge spoil - the sediment dredged (removed) from the bottom of a harbor, river, or lake

estuarine - having to do with or found in an estuary

estuary - regions of interaction between rivers and near-shore ocean waters, where river flow and tidal action mix fresh and salt water

gyre - a circular movement

habitat - place where a population or community lives and its surroundings (both living and non-living)

hydrographic - having to do with the description and study of bodies of water (seas, lakes, rivers): as in surveying and charting; measuring flow, currents, and tides; and sounding (measuring depth)

monitoring - a study to assess the status of physical and biological conditions of a particular area at specified intervals (e.g., monthly, seasonally, yearly) over a given time period (usually years)

mutagenic - a substance that increases the frequency of mutation, the alteration in hereditary material

non-point sources - pollution that enters water from a dispersed and uncontrolled source, such as runoff from land or from the atmosphere, rather than through a pipe

nuisance - a term used in the late nineteenth century to refer to any environmental problem, for example, odor nuisance, garbage nuisance

nutrients - essential chemicals, nitrogen and phosphorous, needed by plants for growth

opportunistic species - a species that can take advantage of adverse conditions and thrive in locations where more sensitive species will not survive

organic compounds - generally all compounds that contain the element carbon, with a few exceptions, e.g., CaCO3

permeable - having openings that liquids (or gasses) can pass through

point sources - a well defined source of pollution from a single point, such as a pipe (e.g., discharges of wastewater from municipal or industrial plants)

polychlorinated biphenyls (PCBs) - a group of closely related, manufactured chemicals made up of carbon, hydrogen and chlorine (two 6-carbon rings (biphenyl - C6H5+) with two or more chlorine atoms substituted for hydrogen). Depending on the number and position of chlorine atoms attached, 209 different PCB congeners can be formed that have varying chemical and toxicological properties. PCBs were first manufactured in 1929. They were used in industry for their insulating and nonflammable properties. In 1978, manufacture of PCBs was banned after they were found to be toxic, to persist in the environment, and to concentrate upward in the food chain. For humans, the primary non-occupational source of PCBs is the ingestion of PCB-contaminated fish. The action level (concentration above which is harmful to humans) for PCBs in food, set by the U.S. Food and Drug Administration (FDA), is 5mg/kg.

polycyclic aromatic hydrocarbons (PAHs) - a group of over 100 different chemicals (composed of fused six-carbon rings) that are formed during the incomplete burning of carbon-containing fuels such as wood, coal, diesel, oil and gas, fat (e.g.,charbroiled meat), or tobacco. Also, coal tar, crude oil, creosote, and roofing tar contain PAHs. PAHs enter the air mostly as releases from volcanoes, forest fires, burning coal, and automobile exhaust. Most PAHs do not dissolve easily in water. They stick to solid particles and settle to the bottoms of lakes or rivers. Some PAHs are known or suspected carcinogens.

primary sewage treatment - a relatively uncomplicated physical process that primarily removes solids. First, the sewage passes through screens that filter out large debris such as pieces of wood, cardboard, rags, etc. It then flows to a grit chamber where sand and other heavy particles are removed. Next, the sewage enters large sedimentation tanks where suspended solids slowly settle to the bottom as sludge, and grease floats to the top and is skimmed off. In plants that provide no further level of treatment, the water is chlorinated to kill any remaining pathogens and returned to the environment at this point. Primary sewage treatment alone is no longer considered sufficient.

remediation - action to remedy or correct damage to the environment

residence time - amount of time water remains inside a specified area, e.g., harbor, bay, etc.

sewage treatment - the process of removing contaminants from sewage. Treatment includes physical, chemical and biological processes to remove physical, chemical and biological contaminants. The objective is to produce a treated effluent and a solid waste (sludge) that are suitable for discharge into the environment or for reuse. See below for various categories of sewage treatment.

secondary sewage treatment - The Federal Clean Water Act of 1972 mandated that all plants provide secondary sewage treatment. Secondary treatment begins where primary treatment leaves off. It is a biological process that uses bacteria to remove dissolved organic matter from wastewater. The microorganisms absorb organic matter from sewage as their food supply. In the final step, chlorination or ultraviolet light treatment kills pathogens before the wastewater is released to the environment.

species composition - the species found in a particular area

Superfund - a special trust fund, established by a federal law passed in 1980, modified in 1986 (Comprehensive Environmental Response, Compensation & Liability Act, CERCLA), to help finance the investigation of waste sites

teratogenic - a substance that causes developmental malformations

tertiary or advanced sewage treatment - The potential pollutants remaining after secondary sewage treatment include nutrients (nitrogen and phosphorus) and toxic chemicals. (Industries are required to pre-treat their wastewater to remove toxic chemicals before discharge into the sewer.) Advanced sewage treatment could include more than one process at a plant depending on which substances are to be removed. For example, nitrogen and phosphorus required different treatment processes for removal.

topographic - the configuration of a surface showing relief (elevations) and position of natural and man-made features

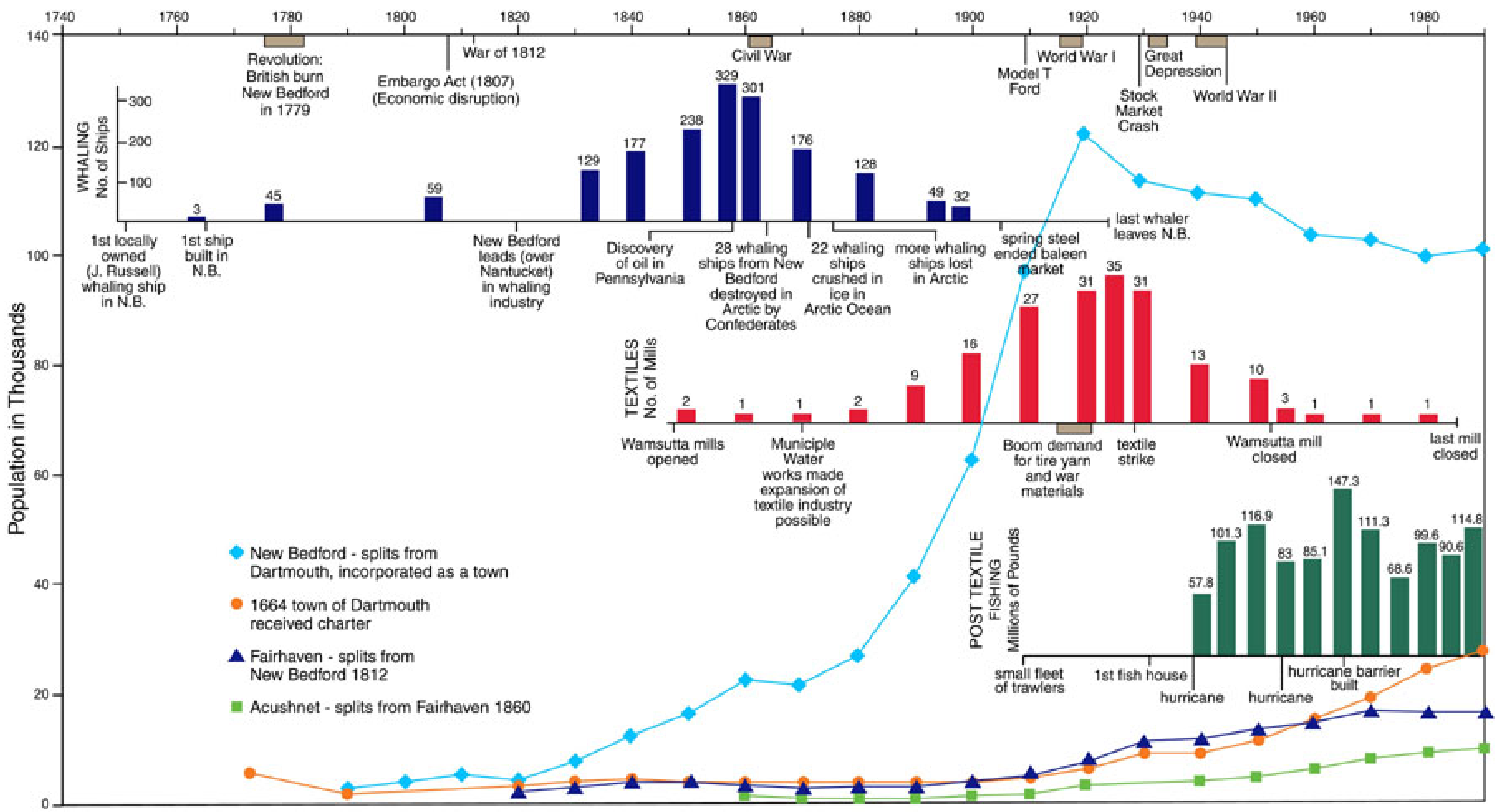
toxic - a substance that is poisonous, carcinogenic, or otherwise harmful to plants and animals

toxicity - the quality, state, or relative degree of being toxic or poisonous

watershed - the entire area of land whose runoff of water, sediments, and dissolved materials (nutrients, contaminants) drain into a lake, river, estuary, or ocean

water quality criterion - the maximum concentration of a chemical in ambient waters that would be safe for aquatic species. The criterion is determined from the results of toxicity tests using a variety of aquatic species, and consider both short-term and long-term exposures.

New Bedford Harbor Timeline



New Bedford and National Events

1602 Bartholomew Gosnold landed at Smoking Rocks (site of future New Bedford) and reported the presence of a large native population.

1652 Territory of Dartmouth deed conveyed to William Bradford and others by Massasoit and his son Wamsutta. The first settlers were mostly Quakers who emigrated from Portsmouth, Rhode Island, and Plymouth and Taunton, Massachusetts.

1664 Town of Dartmouth received charter. New Bedford, Fairhaven, and Acushnet were originally part of Dartmouth.

1675-76 King Phillip's War. During this Anglo-Native American conflict many of the original homes in Dartmouth were destroyed.

1690 Eleven to 13 families owned land in what is now New Bedford. The early settlers were subsistence farmers. They cleared land, but the amount of land cleared probably had a minimal effect on the harbor.

1755 Economy in New Bedford and Fairhaven was shifting from farming to whaling, ship-building, and import/export trade. First locally owned whaler shipped out of New Bedford.

1765 Joseph Rotch arrived from Nantucket with money and expertise to advance the whale fishery in New Bedford.

1775 40 to 50 whaleships registered in New Bedford.

1775-1783 American Revolution. The British Navy blockaded the American coast so the whale fishery was idle during much of the war.

1778 British burned part of New Bedford during the American Revolution, but the maritime economy was well enough established that the town was rebuilt.

1787 New Bedford incorporated as a town.

1798 First New Bedford-Fairhaven bridge built to improve commercial ties between Bedford village (later New Bedford) on west side of the harbor and Fairhaven and Oxford villages on the east side. The bridge changed the water circulation and sediment deposition patterns in the harbor. Sediment accumulated north of the bridge along the eastern shore at Oxford, and whaleships were no longer able to get to the docks there. Development in Fairhaven village was physically limited by the adjacent farmer's refusal to sell land for commercial development. Therefore, Bedford village (New Bedford) became the commercial center of the harbor.

1807 Embargo of 1807 halted all trade with Europe and put a damper on the whale fishery.

1812 War of 1812. The British Navy blockaded the American coast so the whale fishery was idle during much of the war.

1807 New Bedford-Fairhaven Bridge partially destroyed by wind driven tide.

1815 By 1815, twelve wharves had been built along the New Bedford shoreline. Wharves changed the water circulation and sedimentation patterns in the harbor.

1815 New Bedford-Fairhaven Bridge destroyed by hurricane.

1819 New Bedford-Fairhaven Bridge rebuilt.

1830s Discovery of huge anthracite coalfields in Pennsylvania supplied high-quality fuel for industrial use. Coal was a plentiful and inexpensive energy source for industry and railroads (Melosi, 1980). Coal combustion is a source of PAHs, mercury, and arsenic.

1839 New Bedford Harbor first dredged by U.S. Army Corps of Engineers to improve access to docks on New Bedford waterfront.

1848 Wamsutta Mill built in New Bedford. It was the first successful textile mill in the city.

1852 First sewers in New Bedford. These sewer lines were located on east-west streets and drained directly into the harbor.

1857 Peak of whaling in New Bedford. In this year, 329 whaling ships listed New Bedford as home port. Wharves built along the New Bedford shore (22 by 1851) to accommodate the whaling ships caused changes in water circulation and sedimentation patterns in the harbor. Sewage (see 1852) began to accumulate at the ends of the pipes along the New Bedford shore (see 1870).

1857 A nationwide depression caused the prices of whale oil to drop.

1859 Discovery of petroleum in Pennsylvania eliminated the need for whale oil as an illuminant and contributed to the decline of whaling.

1859 Great Richmond and Wilcox Wharf fire in New Bedford. Lumber yards, oil, and many buildings burned.

1860 New Bedford Copper located on the waterfront in New Bedford. This company supplied copper sheathing for ships hulls and other maritime uses. In 1928, it was bought out by Revere Copper and Brass. Recent studies indicate that copper concentrations in sediments taken from the harbor near the location of this company are very high (> 1000ug/g dry wt) (Nelson et al., 1996).

1861-1865 Civil War. This war disrupted the economy of the whole nation. During the war, a number of New Bedford whaling ships were lost: 24 ships were filled with rocks and sunk at the entrance to Charleston and Savannah harbors; 28 ships were stopped and burned by the Confederate raiders. This loss of whaling ships contributed to the decline of whaling.

1869 New Bedford Water Works completed. The public supply of water made expansion of the textile industry possible. The number of textile mills went from 2 in 1880, to 35 in 1925.

1869 Great gale destroys New Bedford-Fairhaven Bridge, was rebuilt by 1870.

1870 Edward P. Haskill filed a law suit against New Bedford for the large amount of sewage that had accumulated at the end of his dock, causing bad odors and restricting boat access to the dock. He won the suit.

1871 and 1876 Forty-five whaling ships from New Bedford were crushed in the Arctic Ice. This loss of ships contributed to the decline of whaling.

1875-1876 A channel was dredged between the wharves at Fairhaven and the wharves at New Bedford. From 1875 to 1952, the Army Corps of Engineers dredged numerous times to create, widen and deepen, and maintain a shipping channel approaching the harbor, and channels, turning areas, and anchorage areas within the harbor. Dredging was done in various areas of the harbor or the approach to the harbor in the following years: 1877-1891, 1893 -1894, 1896-1897, 1899-1900, 1902-1903, 1905-1913, 1916-1917, 1919, 1923, 1927, 1931-1933, 1935-1936, 1938-1940, 1944-1945, 1950, 1952.

1892 Coggeshall Street Bridge completed. This bridge serves as the dividing line between what is currently called the upper and lower harbor.

1899 New Bedford Board of Health reported that swimming in the Acushnet River was dangerous to health.

1899-1903 New Bedford-Fairhaven Bridge replaced by a steel bridge with a swivel section in middle, between Fish Island and Popes Island. The Fairhaven end of bridge was moved north to Main St.

1900 By 1900, 16 textile mills in New Bedford. Many of these mills were built on wetlands. The loss of these wetlands meant decreased habitat available for resident and migratory species, and decreased nursery areas for aquatic species. The function of these wetlands, filtering excess nutrients, pollutants, and microorganisms in runoff from the land, and providing erosion control for the shoreline, was also lost.

1900-1903 There were 575 cases of typhoid fever (caused by eating contaminated shellfish) reported in New Bedford.

1904 Massachusetts State Board of Health closed the Acushnet River to shellfishing because of bacterial contamination from sewage.

1909 Model T Ford. This was the start of the automobile era. During the next 20 years, demand for yarns to make tires helped expand the textile industry in New Bedford.

1910 Acushnet Processing located in Acushnet on the shore of upper New Bedford Harbor. This plant reprocessed tires and produced organic and acid waste. In the summer of 1920, these wastes were called “objectionable” in a report on the sanitary condition of the Acushnet River (Kelley, 1921).

1912 Construction of interceptor sewer line started. This interceptor line was to connect sewer lines in New Bedford and deliver the wastes to an outfall located off the end of Clarks Point. (See 1920s below).

1920 By 1920, there were 31 textile mills in New Bedford, and the population of the city had expanded to 121,000. This growth meant a lot more sewage was being emptied into the harbor.

1920s Interceptor sewer line partially completed. Five of nine pumping districts were connected to the interceptor line. Construction was stopped until 1947. The interceptor line lessened the amount of raw sewage emptying into New Bedford Harbor but did not stop it. The sewer system is a combined one, with storm water from streets and wastewater from homes and industries emptying into the same pipes. In periods of heavy rainfall, raw sewage still empties into the harbor through combined sewage overflows (CSOs). By 2006, 11 of 24 CSOs in upper and lower New Bedford Harbor had been eliminated.

1921 Thomas Midgely of General Motors Research Laboratory found that the addition of tetraethyl lead to gasoline provided an inexpensive way to eliminate engine knock.

1923-1924 Leaded gasoline was commercially available.

1925 Textile industry in New Bedford peaked at 35 mills.

1928 Mill workers strike in New Bedford. The strike weakened the economic condition of the mills and contributed to the end of textile manufacture in New Bedford.

1929 Stock market crash. The crash affected the economy in the U.S. and contributed to the end of textile manufacture in New Bedford.

1929 PCBs (polychlorinated biphenyls) first produced. Monsanto Corporation commercially manufactured and sold PCB blends and mixtures (under the trade name Aroclor) in the U.S. from 1929 to 1977.

1930s Great Depression. The Depression affected the economy in the U.S. and contributed to the end of textile manufacture in New Bedford.

1930s Expansion of New Bedford as a commercial fishing port. This expansion continued into the 1980s.

1938 Hurricane damaged boats and waterfront businesses and houses in New Bedford, Fairhaven, and Acushnet.

1939 Aerovox Corp. moved into an empty mill building on the waterfront of upper New Bedford Harbor. Until 1978, Aerovox used PCBs in the manufacture of electronic capacitors. The plant, land around the plant, sediment in the harbor near the plant, and sewer lines were contaminated with PCBs.

1941 Cornell Dubilier moved into an empty mill building on the east side of Clarks Point. They used PCBs in the manufacture of electronic capacitors.

1954 Hurricane Carol damaged boats, waterfront businesses and houses in New Bedford, Fairhaven, and Acushnet.

1964-1965 Hurricane Barrier built. This barrier across entrance of New Bedford Harbor was built to protect the fishing fleet and waterfront businesses from storm damage. The hurricane barrier probably affected sedimentation rates and patterns, water residence times,and circulation patterns in the harbor. (Abdelrhman, 2000)

1968 Concern about PCBs in the environment first noted by a Swedish scientist (Weaver, 1984).

1969 Fairhaven water Pollution Control Facility, with secondary treatment of waste, was built. The discharge is into lower New Bedford Harbor.

1973 Beginning of phase out of leaded gasoline. Unleaded gasoline was available.

1974 Route I 195 bridge built across Acushnet River (just south of the Coggeshall St. Bridge)

1974 New Bedford Sewage treatment plant completed (primary treatment). Outfall is off the end of Clarks Point. But during periods of heavy rainfall, raw sewage still enters the harbor through the combined sewer overflows (CSOs).

1976 Presence of PCBs in New Bedford Harbor documented by researchers.

1978 U.S. EPA bans the sale of PCBs.

1979 Massachusetts Department of Public Health closed New Bedford Harbor to taking of all fish and shellfish because of residues of PCBs found in fish and clams.

1982 New Bedford Harbor placed on National Priorities List for cleanup under Superfund legislation.

1984 Port of New Bedford ranked number one in nation based on value of fish landed.

1987 Industrial pretreatment program in effect in New Bedford. Industries required to pre-treat wastes before discharging into the sewer.

1994-1995 Army Corps of Engineers dredged about 14000 cubic yards of PCB-contaminated sediment spread over about 5 acres of upper New Bedford Harbor.

1996 A new New Bedford Wastewater Treatment Facility, with secondary treatment of waste, was completed.

1996 Leaded gasoline prohibited.

2006 By 2006, 11 of 24 CSOs in upper and lower New Bedford harbor had been eliminated (see text on Environmental Awareness page).

Public Health and Legislative Events

1833 Water closet (toilet) patented in the U.S. Use of water closets in homes without sewers quickly became public health problems. The increased use of water caused privy vaults and cesspools to overflow and the surrounding soil to become saturated with foul smelling, contaminated water.

1850s -1860s "Filth theory" of disease widely accepted. Disease was thought to be caused by impure air from putrefied organic material, including human and animal excrement, rotting garbage, and vapors from swamps and stagnant pools. Emphasis was put on collecting garbage, emptying cesspools and privy vaults, cleaning streets, and filling in wetlands. The importance of wetlands, to filter pollutants, excess nutrients and harmful microorganisms, provide habit, and serve as nursery areas for aquatic species, was not recognized at this time. In cities, sewer lines were installed to carry waste away. It was common for sewer lines to empty directly into nearby waterways. (Tarr, 1985a)

1876 Massachusetts Board of Health commissioned James P. Kirkwood, a water quality specialist and civil engineer, to examine the rivers in Massachusetts. He found that the fluid refuse from some factories could be poisonous, and warned that although some wastes and sewage may not be detected in great quantities, they may make the water "not merely repulsive or suspicious, but more or less dangerous for family use." (Tarr, 1985b)

1878 First U. S. state law controlling stream pollution. This Massachusetts law gave the State Board of Health the power to control river pollution caused by manufacturing waste (Rosenkrantz, 1972).

1870s-1880s Albert Leeds, a geologist, tested the water of the Passaic River, New Jersey (the drinking water supply for Newark and Jersey City, NJ) and found that factories along the lower stretch of the river had polluted it with acids, dyes, and chemicals (Leeds, 1887).

1880 By this time, most cities with a population greater than 30,000 had a board of health, a health commission, or a health officer. Most cities had statutes restricting "noxious" manufactures to the fringes of cities.

1890s By this time, the "germ theory," which stated disease was caused by bacteria, was accepted. Acceptance of the "germ theory" put the focus on human wastes, with less concern on industrial wastes. Public health officials shifted their concern to diseases and away from environmental sanitation. Many municipalities transferred control of refuse collection and disposal from health departments to sanitation or public works departments. Removal of wastes was now considered an engineering problem, and cost and efficiency of removal became the major issues. (Tarr, 1985a, b)

1899 Refuse Act of 1899 – this is part of the Rivers and Harbors Act of 1899. The Refuse Act prohibited discharge of any refuse into navigable waters to protect navigation in rivers and coastal waters. It is administered by the Army Corps of Engineers. The Secretary of the Army would allow discharge if, in the judgement of the Chief of Engineers, anchorage and navigation was not affected, but a permit was necessary. The Rivers and Harbors Act also made it necessary to get a permit to excavate, fill, or alter the course, condition or capacity of any river, port, harbor or channel. Many of the activities covered by the Rivers and Harbor Act are now regulated by the Clean Water Act, 1977.

1906 Food and Drugs Act – first Federal law against food alteration.

1908 Started chlorination of drinking water to kill bacteria. Sand and mechanical filtration of drinking water had been used in some cities since 1897. (Tarr, 1985b)

1908 Started chlorination of drinking water to kill bacteria. Sand and mechanical filtration of drinking water had been used in some cities since 1897. (Tarr, 1985b)

1900 - 1920s Public Health: The question of pollution in waterways was raised by some individuals working for various public agencies, however, little was done. There was a reluctance to enforce the existing regulations because they might limit industrial growth. In most states, pollution problems were handled by the department of health, whose primary concern was disease. For a comprehensive discussion of these early efforts see Tarr, 1985b. However, there was some interest in contamination. In 1903, the USGS organized a Division of Hydro-economics to investigate the value of water supplies, with particular concern for turbidity, color, hardness, and various chemicals and minerals that would reduce water quality. Marshal Leighton, who headed the division, thought industrial wastes were the "great pollution problem of today". The American Public Health Association (APHA) created several committees on waste disposal: Committee on Trade Waste Disposal (1902); Committee on Sanitary Control of Waterways (1916); and Committee on Disposal of Sewage and Industrial Wastes (1927).

1913 At the request of Congress, the Public Health Service started a significant effort to investigate water-borne diseases, because the state health departments were not taking effective action. A team of sanitary engineers, chemists, biologists, bacteriologists, and medical officers worked in Cincinnati at what was to become the Public Health Service's
Center for Pollution Studies.

1900-1920s Legislative: Several industrialized states (Pennsylvania, Connecticut, Massachusetts, and Ohio) passed legislation concerning pollution of rivers. But the state boards did not insist on absolute prohibition, and exempted certain rivers. The state boards thought the solution to pollution was through cooperation with industry. The function of the state boards was to supply technical advice to industries.

1906 Massachusetts passed legislation to eliminate pollution, with the State Board of Health to advise the industry of the best way to do that.

1917 Pennsylvania passed a law which prohibited discharge of any matter harmful to fish into streams. However, in 1923, certain rivers and industries were exempted from the 1917 law. Pennsylvania Sanitary Water Board established three classes of streams: 1) relatively clean, 2) streams where pollution needed to be controlled, and 3) streams, rated "c", that were so polluted that it was not necessary to clean them up.

1925 Connecticut created a State Water Commission that had the power to eliminate pollution, but must prescribe the methods.

1922 American Water Works Association (AWWA) Committee on Industrial Wastes in Relation to Water Supply presented a report that industrial pollutants had damaged at least 248 water supplies in the US and Canada.

1924 Oil Pollution Control Act - protected commercial fisheries and resorts from oil pollution damage, and reduced fire hazards (caused by oil) in harbors. This act was enforced by the Army Corps of Engineers and applied only to coastal waters.

1927 Food, Drug, and Insecticide Administration formed - renamed the Food and Drug Administration (FDA) in 1931. In 1940, to prevent recurring conflicts between producer interests and consumer interests, FDA was transferred from the U.S. Department of Agriculture to the Federal Security Agency which, in 1953, became the Department of Health, Education, and Welfare -- now the Department of Health and Human Services.

1932 Committee on Disposal of Refinery Wastes - created by the American Petroleum Institute. This committee, along with state agencies and other groups, devised methods of controlling refinery pollution. In 1935, the methods were published in a manual, Disposal of Refinery Wastes. These methods were gradually adopted by the refinery industry on a voluntary basis. (Tarr, 1985b)

1938 Federal Food, Drug, and Cosmetic Act - regulated food, medical products, and cosmetics to ensure their safety; strengthened the Food and Drugs Act of 1906.

1948 Federal Water Pollution Control Act - authorized the Surgeon General of the Public Health Service, in cooperation with other Federal, state, and local agencies, to prepare programs to reduce or eliminate pollution of interstate waterways, and improve the sanitary conditions of surface and underground waters. Since 1948, the original legislation has been amended extensively (in 1972, 1977, 1987, and 1991) to authorize additional water quality programs and fund construction grants. In 1977 it was renamed the Clean Water Act.

1955 Air Pollution Control Act - the nation's first piece of federal legislation on this issue. The language of the bill identified air pollution as a national problem and announced that research and additional steps to improve the situation needed to be taken. It was an act to make the nation more aware of this environmental hazard.

1962 Silent Spring by Rachel Carson (Houghton Mifflin Company, Boston) - This famous book provided some of the first public evidence of how pesticides, used without proper control or knowledge, were poisoning our environment.

1962 Drug Amendments – amendments to the Federal Food, Drug, and Cosmetic Act to tighten control over prescription drugs, new drugs, and investigational drugs.

1963 Clean Air Act - dealt with reducing air pollution by setting emissions standards for stationary sources such as power plants and steel mills. It did not take into account mobile sources of air pollution, which had become the largest source of many dangerous pollutants. Congress began funding air quality research programs.

1964 Land and Water Conservation Fund Act - set up a fund for acquiring new recreation lands. However, in recent years Congress has diverted a significant percentage of the fund for purposes other than conservation and recreation.

1964 Wilderness Act - established a National Wilderness Preservation System for the permanent good of the whole people, and for other purposes.

1965 Freedom of Information Act (FOIA) - provides specifically that “any person” can make requests for government information. Citizens who make requests are not required to identify themselves or explain why they want the information they have requested.

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1965 Solid Waste Disposal Act - legislated research, demonstrations, and training for safe disposal of solid waste. The act also had provisions to share costs with states to fund the development of waste management plans. This legislation was amended in 1970 (Resource Recovery Act), 1976 (Resource Conservation and Recovery Act), 1980 (Solid Waste Disposal Act Amendments), 1984 (Hazardous and Solid Waste Amendments), and again in 1989 (Medical Waste Tracking Act).

1968 Wild and Scenic Rivers Act - the purpose of this act was to select certain rivers of the nation possessing remarkable scenic, recreational, geologic, fish and wildlife, historic,cultural, or other similar values; preserve them in a free-flowing condition; and protect their local environments.

1969 National Environmental Policy Act (NEPA) - one of the first laws written that established a broad national framework for protecting our environment. This policy established a Council on Environmental Quality (CEQ) and required all Federal agencies to complete Environmental Assessments and Environmental Impact Statements for projects.

1970 April 2 - first Earth Day.

1970 December 2 - Environmental Protection Agency created by executive order of President Nixon.

1970 Clean Air Act - regulated air emissions from area, stationary, and mobile sources. This law authorized the U.S. Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) to protect public health and the environment. The Clean Air Act was amended in 1977 (to set new deadlines for NAAQS) and again in 1990.

1970 Occupational Safety and Health Act - ensures worker and workplace safety. Employers are required to provide their workers a workplace safe from exposure to toxic chemicals, excessive noise levels, mechanical dangers, heat or cold stress, or unsanitary conditions. The act created the National Institute for Occupational Safety and Health (NIOSH) as the research institute for the Occupational Safety and Health Administration (OSHA) to establish standards for the workplace. OSHA, a division of the U.S. Department of Labor, enforces the standards.

1970 Resource Recovery Act - amendment to 1965 Solid Waste Disposal Act. The emphasis of the legislation was changed from efficiency of disposal of solid wastes to concern with reclamation of energy and materials from solid wastes. It authorized grants for new resource recovery technology and required the Environmental Protection Agency (EPA) to produce annual reports on ways to promote recycling and reduce waste. Amended in 1976 (Resource Conservation and Recovery Act, RCRA) and 1984.

1971 Lead-Based Paint Poisoning Prevention Act - prohibits the use of lead-based paint on any cooking, drinking, or eating utensil, toys or furniture, and in residential structures constructed or rehabilitated by the Federal Government.

1972 Federal Insecticide, Fungicide, and Rodenticide Act – provides federal control of the distribution, sale, and use of pesticides. The Environmental Protection Agency (EPA) was given authority to study the consequences of pesticide use and to require users (farmers, utility companies, etc) to register when purchasing pesticides. Later amendments users to take exams to certify as applicators of pesticides. All pesticides used in the U.S. must be licensed by EPA.

1972 Federal Water Pollution Control Act of 1972 - amended the original legislation in 1948 and set the basic structure for regulating discharges of pollution into the nation's waters (lakes, rivers, aquifers, and coastal areas). Congress enacted this law in response to growing public concern for water pollution. It was amended and renamed the Clean Water Act in 1977, and reauthorized in 1991.

1972 Marine Protection, Research, and Sanctuaries Act (Ocean Dumping Act) - contains permit and enforcement provisions for disposal of wastes in marine waters that are within U.S. jurisdiction. The act prohibits all ocean dumping, except that allowed by permits, and bans any dumping of radiological, chemical, and biological warfare agents, any high-level radioactive waste, and medical wastes. A number of amendments have added additional conditions: 1977 - dumping of municipal sewage sludge to cease by December, 1981; 1986 - disposal of wastes at the 12-mile site off New York/New Jersey coast be moved to a site 106 miles off shore; 1988 - amendments emphasized phasing out sewage sludge and industrial waste disposal in the ocean because it did not happen despite earlier legislation; 1992 - permit states to adopt ocean dumping standards more stringent than federal standards. Other amendments provided for ocean disposal research, monitoring coastal water quality, and establishment of marine sanctuaries. Virtually all ocean dumping that occurs today is dredged material, sediments removed from the bottom of water bodies to maintain navigation channels. The Army Corps of Engineers issues permits for ocean dumping of dredged material.

1972 Marine Mammal Protection Act (MMPA) – protects all marine mammals. The MMPA prohibits, with certain exceptions, the taking of marine mammals in U.S. waters, and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the U.S.

1973 Endangered Species Act - provides a program for the conservation of threatened and endangered species and their habitats. The U.S. Fish and Wildlife Service (Department of Interior) maintains the list of endangered and threatened species.

1973 Lead Phasedown Program - EPA imposed the first regulation on the lead content of gasoline. The phasedown of leaded gasoline continued through the 1970s, 1980s, and ended with the ban of leaded gasoline in 1996 as stipulated in the 1990 amendments to the Clean Air Act. Unleaded gasoline was available in the 1970s.

1974 Forest and Rangeland Renewable Resources Planning Act - called for the management of renewable resources on national forest lands; amended in 1976, National Forest Management Act.

1974 Safe Drinking Water Act - protects the quality of all drinking water, actual and potential, surface or underground. The act authorized the Environmental Protection Agency (EPA) to establish safe drinking water standards and requires all operators of water systems to comply with the health related standards.

1974 Shoreline Erosion Control Demonstration Act - established a national shoreline erosion control development and demonstration program. Funding was provided for planning, designing, and constructing prototype engineered and vegetative shoreline erosion control devices and methods, monitoring these prototypes, and transferring the technology to private property owners, and state and local entities.

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1975 Hazardous Materials Transportation Act (HMTA) - protects against "risks to life and property which are inherent in the transportation of hazardous materials in commerce." These regulations apply to any person who transports a hazardous material, or who manufactures, maintains, repairs, or tests containers which are used to transport hazardous materials.

1976 Amendment to Coastal Zone Management Act of 1972- established the National Estuarine Research Reserve System. The National Estuarine Research Reserve System protects and studies estuarine areas through a network of 25 reserves that represent different biogeographic regions in the United States.

1976 Federal land Policy and Management Act - established public land policy and guidelines for its administration and provides for the management, protection, development, and enhancement of the public lands.

1976 Fishery Conservation and Management Act (FCMA) – (renamed the Magnuson-Stevens Fishery Conservation and Management Act in 1996) brought federal regulatory jurisdiction to fishery resources between the U.S. territorial sea (generally three miles offshore) and 200 miles offshore in a fishery conservation zone. This area was later named the U.S. Exclusive Economic Zone or EEZ. Congress passed the law chiefly to address heavy foreign fishing in U.S. waters, promote the development of a domestic fishing fleet, and link the fishing community more directly to the fishery management process. The FCMA effectively phased out foreign fishing vessels and factory processing ships from U.S. waters and established eight regional fishery management councils that are responsible for preparing fishery management plans for commercial and recreational fishing within U.S. waters.

1976 National Forest Management Act - reorganized, expanded and otherwise amended the Forest and Rangeland Renewable Resources Planning Act of 1974, which called for the management of renewable resources on national forest lands. The National Forest Management Act required the Secretary of Agriculture to assess forest lands, develop a management program based on multiple-use, sustained-yield principles, and implement a resource management plan for each unit of the National Forest System. It is the primary statute governing the administration of national forests.

1976 Resource Conservation and Recovery Act (RCRA) - amendment to 1970 Resource Recovery Act and 1965 Solid Waste Disposal Act. This amendment made the federal government play a more active regulatory role. It gave the Environmental Protection Agency (EPA) authority to control hazardous waste from "cradle to grave." It instituted the first federal permit program for hazardous waste and prohibited open dumps. This act only concerns active or future facilities and does not address problems with abandoned or historic waste sites (see CERCLA, 1980). Amendments in 1984 and 1986 addressed other aspects of waste disposal problems.

1976 Toxic Substances Control Act (TSCA) - gives the Environmental Protection Agency (EPA) the authority to track industrial chemicals produced or imported into the United States. EPA can require reporting or testing of chemicals that may pose an environmental or human-health hazard, and can ban those that pose an unreasonable risk.

1980 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) - provided a “superfund” to clean up uncontrolled or abandoned hazardous waste sites, and accidents, spills, and other emergency releases of pollutants to the environment. The Environmental Protection Agency (EPA) was given the authority to find
the parties responsible, assure their cooperation in the cleanup, and recover cleanup costs.

1984 Hazardous and Solid Waste Amendments (to RCRA, 1976) - with this amendment, the federal government tried to prevent future problems by prohibiting disposal of untreated hazardous wastes on land, setting liner and leachate collections requirements for land disposal facilities, setting deadlines for closure of land facilities that did not meet the requirements, and establishing a corrective action program for land disposal facilities. Regulations were also established for underground storage tanks. The Environmental Protection Agency (EPA) was given more authority to enforce the regulations.

1986 Amendments to RCRA (1976) - enabled EPA to regulate underground storage tanks.

1986 Emergency Planning and Community Right-to-Know Act (Title III of SARA, see below) - legislation to help local communities protect public health, safety, and the environment from chemical hazards. Congress required each state to appoint a State Emergency Response Commission (SERC).

1986 Superfund Amendments and Reauthorization Act (SARA) – reauthorized CERCLA (see 1980) to continue to cleanup abandoned or historic hazardous wastes sites.

1987 Water Quality Act of 1987 (Reauthorization of Clean Water Act, 1977) - established a comprehensive program for controlling toxic pollutant discharges; required states to develop and implement programs to control non-point sources of pollution (rainfall runoff from farm and urban areas, construction, forestry, and mining sites); authorized grants for construction of wastewater treatment facilities; created the National Estuary Program; and revised many of the Act's regulatory, permit, and enforcement programs.

1988 Lead Contamination Control Act (LCCA) - authorized Center for Disease Control (CDC) to provide grants to states to administer a program for preventing childhood lead poisoning. With these grants, states were to screen infants and children for lead; refer cases of elevated blood lead levels to the state for treatment; provide education to communities with the highest risk for elevated blood lead (above 25 jig/dL); establish programs to test and eliminate lead in water from schools and day care centers; and provide for public notification of drinking water analyses.

1988 Ocean Dumping Ban Act of 1988 (also known as Ocean Dumping Reform Act of 1988, U.S. Public Vessel Medical Waste Anti-dumping Act of 1988, and Shore Protection Act of 1988) - amends the Marine Protection, Research, and Sanctuaries Act of 1972. Title I (Ocean Dumping of Sewage Sludge and Industrial Waste) prohibits all dumping of sewage sludge and industrial waste into the ocean after 1991. Title III (Dumping of Medical Waste) prohibits the dumping of medical wastes into the ocean or navigable waters. Title IV (Shore Protection Act) requires that vessels carrying municipal or commercial waste within U.S. waters have a permit from the Secretary of Transportation and meet certain prescribed conditions.

1989 Medical Waste Tracking Act - amended the Solid Waste Disposal Act (1965) to require the Administrator of the EPA to promulgate regulations on the management of infectious waste.

1990 Clean Air Act Amendment - amended the Clean Air Act of 1970 to include problems, such as acid rain, ground-level ozone, stratospheric ozone depletion and air toxics, that were not originally addressed. Leaded gasoline to be prohibited after January 1, 1996.

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1990 Coastal Zone Act Reauthorization Amendments - the Coastal Non-point Source Pollution Control Program (Section 6217) addresses non-point pollution problems in coastal waters. Section 6217 requires the 29 states and territories with approved Coastal Zone Management Programs to develop Coastal Non-point Pollution Control Programs.

1990 The National Environmental Education Act of 1990 - gives the U.S. Environmental Protection Agency (EPA) authority to provide national leadership to increase environmental literacy. It authorizes the EPA to develop and disseminate environmental curricula, publications, and training programs; provide grants to educational institutions, teachers, and students; and give awards recognizing outstanding contributors in the field of environmental education.

1990 Oil Pollution Act of 1990 - strengthened the Environmental Protection Agency's (EPA) ability to prevent and respond to catastrophic oil spills. EPA has published regulations for aboveground oil storage facilities and the Coast Guard has published them for tankers. Oil storage facilities and tankers must submit plans to the federal government detailing how they will respond to large spills. A trust fund, financed by a tax on oil, is available for cleanup costs if the responsible party is unable to pay.

1990 Pollution Prevention Act - mandates source reduction and waste management of all toxic and hazardous substances. Beginning in 1991, the amount of toxic substances treated, disposed, recycled, recovered, or released must be reported to the Environmental Protection Agency in this effort to reduce and prevent pollution.

1992 Energy Star Program – a program to help individuals and businesses identify energy-efficient products.

1992 Residential Lead-Based Paint Hazard Reduction Act (Title X of the Housing and Community Development Act) - redefines the federal response to lead poisoning by directing several federal agencies [Department of Housing and Urban Development (HUD), the Environmental Protection Agency (EPA), and the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor] to establish a coordinated effort to reduce lead hazards in residential and commercial buildings, interior dust, and exterior soil. Some issues the act addresses are: proper training and accreditation of workers who will remove lead-based paint; disclosure by sellers of houses that have lead hazards; and establishment of unsafe levels of lead in paint, soil or dust.

1996 Land Disposal Program Flexibility Act - amendments to 1976 Resource Conservation and Recovery Act (RCRA). This act exempts hazardous waste from RCRA regulation if the waste is treated so that it no longer is hazardous and is disposed in a facility regulated under the Clean Water Act or injected in a deep well regulated under the Safe Drinking Water Act.

1996 Food Quality Protection Act (FQPA) - amends the two major laws that governed the use of pesticides, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and Federal Food, Drug, and Cosmetic Act (FFDCA), and changes the way EPA regulates pesticides. The act requires that a new safety standard, "reasonable certainty of no harm," must be applied to all pesticides used on foods.

1996 Safe Drinking Water Act - amendment to the Safe Drinking Water Act of 1974. While the original act focused on treatment as the means of providing safe drinking water, this amendment recognized the importance of protecting drinking water at the source, and providing operator training for water systems, funding for water system improvements, and public information.

1996 Use of leaded gasoline banned (see 1990 Clean Air Act Amendment).

1997 The Food and Drug Administration Modernization Act (FDAMA) - amends the Federal Food, Drug, and Cosmetic Act of 1938, which regulates food, drugs, biological products, medical products, and cosmetics.

2000 Beaches Environmental Assessment and Coastal Health Act (BEACH) - requires all coastal states to implement a consistent and rigorous beach monitoring, closure, and public notification program based on monitoring enterococcus bacteria. EPA is to maintain a national data base of beach monitoring data.

2000 Estuaries and Clean Waters Act - establishes a national goal of restoring one million acres of estuary habitat by 2010 and authorizes a total of $275 million over the next five years for matching funds for local estuary habitat restoration projects. The Act reauthorizes the National Estuary Program, the Chesapeake Bay Program, the Long Island Sound Program, and the Clean Lakes Program. This legislation also establishes an Estuary Habitat Restoration Council that is responsible for developing a National Habitat Restoration Strategy within one year, and for reviewing and establishing funding priorities among restoration projects.

2002 Small Business Liability Relief and Brownfields Revitalization Act - to provide certain relief for small businesses from liability under the Comprehension Environmental Response, Compensation, and Liability Act of 1980, and to amend such Act to promote the cleanup and
reuse of brownfields, to provide financial assistance for brownfields revitalization, to enhance State response programs, and for other purposes.

2005 Clean Air Interstate Rule (CAIR) – reduce air pollution that moves across state boundaries, will achieve reductions of sulfur dioxide (SO2) and/or nitrogen oxide (NOx) emissions across 28 eastern states and the District of Columbia.

2005 Reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act (of 1996) - promote long-term sustainable use of U.S. marine resources, build upon the successes of the 1996 act, and evolve to meet modern needs and scientific understanding.

Scientific Studies Conducted in New Bedford Harbor

Monitoring Study: A 30-year post-dredging monitoring study is being conducted in New Bedford Harbor to assess the effects of remediation. Publications resulting from this work are listed below. For more information, contact William Nelson by e-mail at nelson.william@epa.gov.

- Nelson, W.G., B.J. Bergen, S.J. Benyi, G. Morrison, R.A. Voyer, C.J. Strobel, S. Rego, G. Thursby, and C.E. Pesch. 1996. New Bedford Harbor Long-Term Monitoring Assessment Report: Baseline Sampling. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division, Narragansett, RI. EPA/600/R-96/097.
- Nelson, W.G. and D.J. Hansen. 1991. Development and use of site-specific chemical and biological criteria for assessing New Bedford Harbor Pilot Dredging Project. Environmental Management 15(1): 105-112.
- Bergen, B.J., K. Rahn, and W.G. Nelson. 1998. Remediation at a Marine Superfund Site: Surficial Sediment PCB Congener Concentration, Composition and Redistribution. Environmental Science and Technology, 32: 3496-3501.

Sediment Cores: Paleoecological studies were conducted in New Bedford Harbor to determine historical changes in the harbor over the past 350 years. Sediment cores were analyzed for toxic organic compounds, metals, organic carbon content, carbon isotope composition, and biological measures (dinoflagellate cysts, benthic foraminifera). Vertical distribution of the contaminants in the sediment cores correlated with development in the watershed. Contaminants increased with the urbanization of the New Bedford Harbor watershed. Starting in the mid- to late-1700s (the whaling period), three contaminants (PAHs, copper, and lead) were found at concentrations significantly above background level. Concentrations of all contaminants increased greatly after the turn of the 20th century. After environmental regulations were instituted in the 1970s, concentrations of contaminants started to decrease, but were still substantially elevated. This work has been published (see below). For more information contact Jim Latimer by e-mail at latimer.jim@epa.gov.

- Latimer, J.S., W.S. Boothman, C.E. Pesch, G.L. Chmura, V. Pospepova, and S. Jayaraman. 2003. Environmental stress and recovery: the geochemical record of human disturbance in New Bedford Harbor and Apponagansett Bay, Massachusetts (USA). Science of the Total Environment, 313: 153-176.
- Chmura, G.L., A. Santos, V. Pospelova, Z. Spasojevic, R. Lam, and J. S. Latimer. 2004. Response of three paleo-primary production proxy measures to development of an urban estuary. Science of the Total Environment, 320: 225-243.
- Pospelova, V. 2003. Dinoflagellate cyst assemblages and environmental factors controlling their distribution in New England (USA) estuaries. Ph.D. McGill University, Montreal.
- Pospelova V., G.L. Chmura, W.S. Boothman, and J.S. Latimer. 2002. Dinoflagellate cyst records and human disturbance in two neighboring estuaries, New Bedford Harbor and Apponagansett Bay. Science of the Total Environment, 298: 81-102.

Hydrodynamics: The hydrodynamics, contaminant transport, and residence time in New Bedford Harbor were modeled using two-dimensional vertically averaged numerical models. The effect of the hurricane barrier was also studied. This work has been published. For more information contact Mohamed Abdelrhman by e-mail at abdelrhman.mohamed@epa.gov.

- Abdelrhman, M.A. 2002. Modeling how a hurricane barrier in New Bedford Harbor, Massachusetts, affects the hydrodynamics and residence times. Estuaries, 25 (2): 177-196

Chemical Contaminants: The concentrations of numerous chemical contaminants were measured in the sediments of New Bedford Harbor. Samples were collected along a south to north transect of the estuary. These surface sediment samples were analyzed for polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polycyclic aromatic hydrocarbons (PAHs), and several trace metals. Most of these contaminants were found in high concentrations in New Bedford Harbor sediments. This work has been published.

- Pruell, R.J., C.B. Norwood, R.D. Bowen, W.S. Boothman, P.F. Rogerson, M. Hackett, and B.C. Butterworth. 1990. Geochemical study of sediment contamination in New Bedford Harbor, Massachusetts. Marine Environmental Research, 29: 77-101.

Genetic Adaptation to Pollutants by Resident Fish: A large population of the non-migratory fish, *Fundulus heteroclitus* (mummichog) resides in the urban estuary of New Bedford, MA, USA, which is highly contaminated with polychlorinated biphenyls (PCBs), and other pollutants that are toxic to fishes and other vertebrates. New Bedford mummichogs contain tissue concentrations of PCBs that are lethal to mummichogs from uncontaminated populations. However, our toxicological studies document that New Bedford mummichogs are profoundly tolerant to some of the most toxic effects of these contaminants, and this tolerance is inherited at least through two generations of uncontaminated laboratory rearing. These results suggest that the population of mummichogs resident to New Bedford are genetically adapted to PCBs. This adaptation could have resulted from intense selection by toxic PCBs, removing sensitive individuals and leaving only tolerant individuals to re-populate the site. Furthermore, site history suggests that this chemical tolerance has evolved very rapidly (within a few decades). Collaborative studies are revealing the biochemical and genetic mechanisms associated with this evolved chemical tolerance in New Bedford mummichogs to better understand how fish (and other vertebrates) can survive toxic chemical exposures. Similarly, comparisons between New Bedford mummichogs and populations resident to other highly contaminated sites reveal that even fish populations within the same species use different mechanisms to cope with chemical contamination. Much of this work has been published (see below). For more information contact Diane Nacci by e-mail at nacci.diane@epa.gov.

- Nacci, D., Coiro, L., Kuhn, A., Champlin, D., Munns, W.R., Jr., Specker, J., and Cooper, K. 1998. A fish embryonic EROD bioassay. Environmental Toxicology and Chemistry 17(12): 2481-2486.
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- Cohen, S., 2002. Strong positive selection and habitat-specific amino acid substitution patterns in MHC from an estuarine fish under intense pollution stress. Molecular Biology and Evolution 19: 1870 -1880.

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- Roark, S.A., Nacci, D., Coiro,L., Champlin, D., and Guttman, S.I. 2005. Population genetic structure of a non-migratory marine fish *Fundulus heteroclitus* across a strong gradient of PCB contamination. Environmental Toxicology and Chemistry 24(3): 717 - 725.
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- McMillan, A.M., Bagley, M.J., Jackson, S.A., Nacci, D.E. 2006. Genetic diversity and structure of an estuarine fish (*Fundulus heteroclitus*) indigenous to sites associated with a highly contaminated urban harbor. Ecotoxicology 15: 539 – 548.
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More publications on Genetic Adaptation: For more information contact Mark Hahn by e-mail at mhahn@whoi.edu

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- Powell, W. H., Bright, R., Bello, S. M., and Hahn, M. E. 2000. Developmental and tissue-specific expression of AHR1, AHR2, and ARNT2 in dioxin-sensitive and -resistant populations of the marine fish, *Fundulus heteroclitus*. Toxicol Sci, 57: 229-239.

Liver Disease in Winter Flounder: A study was conducted to look at the patterns of liver disease in winter flounder in New England, including flounder from New Bedford Harbor. Of nine sites studied, flounder from New Bedford Harbor had the highest incidence, 26 %, of liver neoplasms (cancer). Fifty-seven percent of all flounder collected from New Bedford Harbor had some liver disease. Sediment from the study sites was analyzed for PCBs, PAHs, cadmium, copper, and lead. The fish with the highest incidence of disease came from the sites with the highest levels of sediment contamination. This study has been published:

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