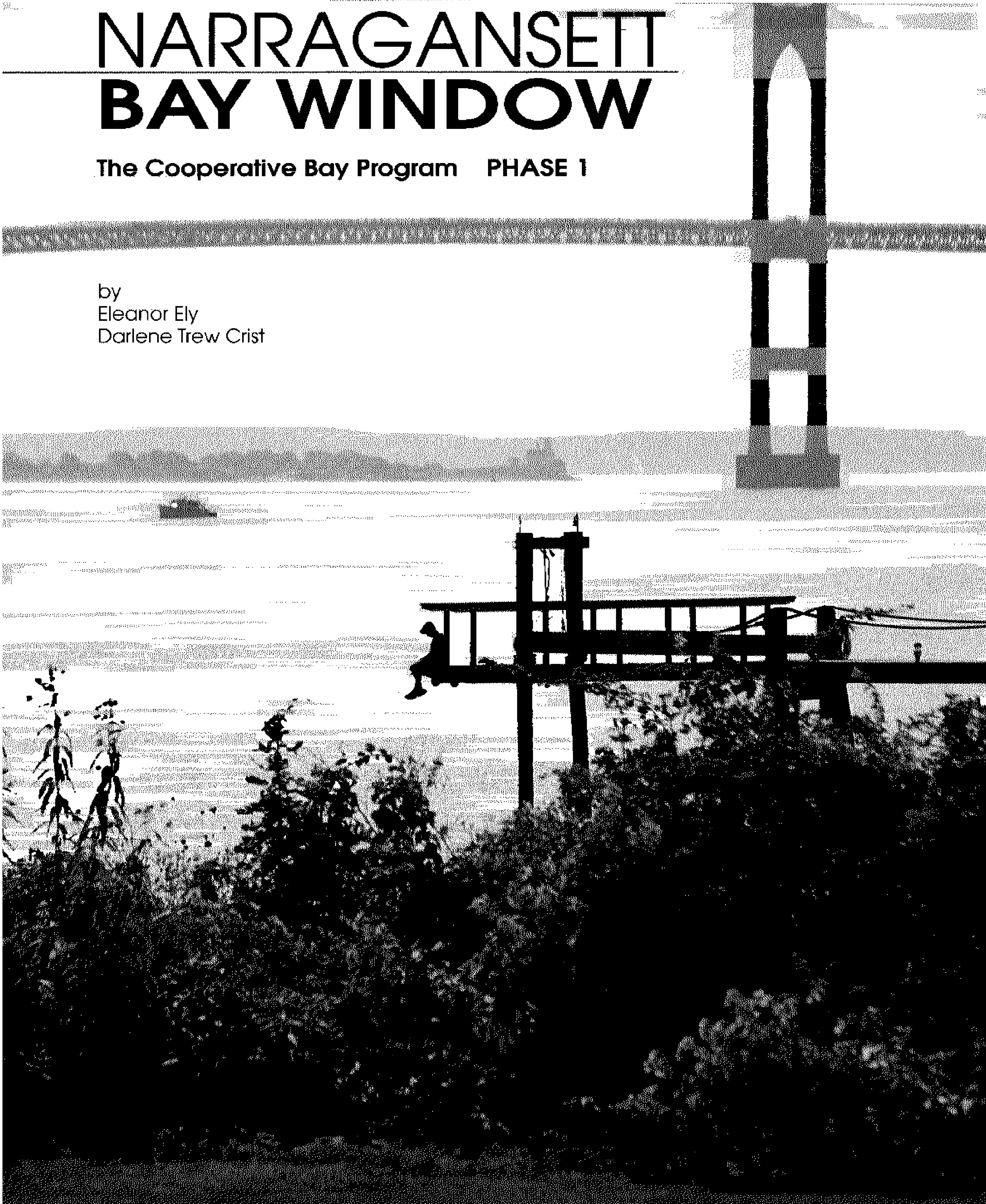
NARRAGANSETT BAY WINDOW

The Cooperative Bay Program PHASE 1

by
Eleanor Ely
Darlene Trew Crist



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Sea Grant Rhode Island

UNIVERSITY OF RHODE ISLAND

NARRAGANSETT BAY WINDOW

The Cooperative Bay Program

Phase 1

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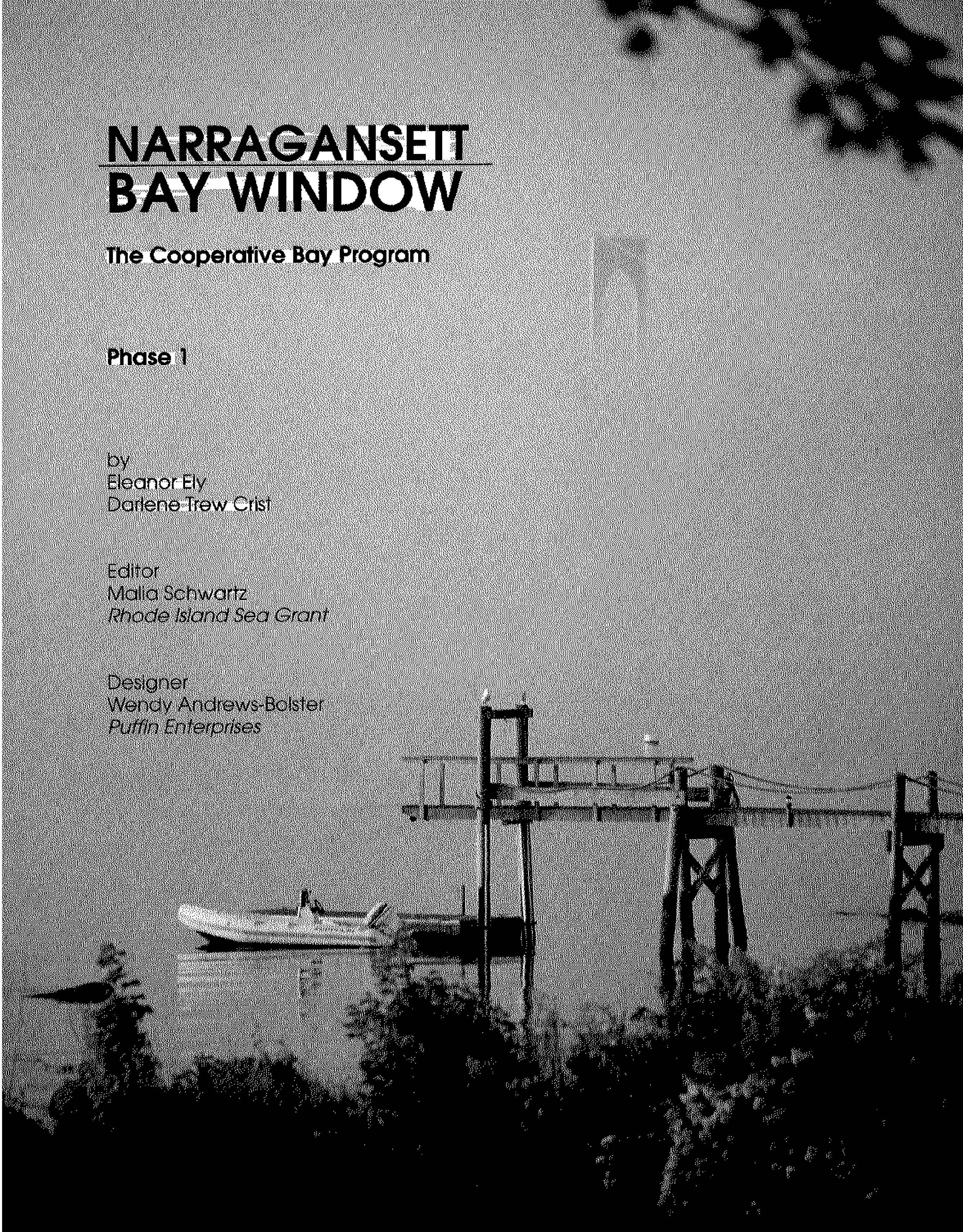
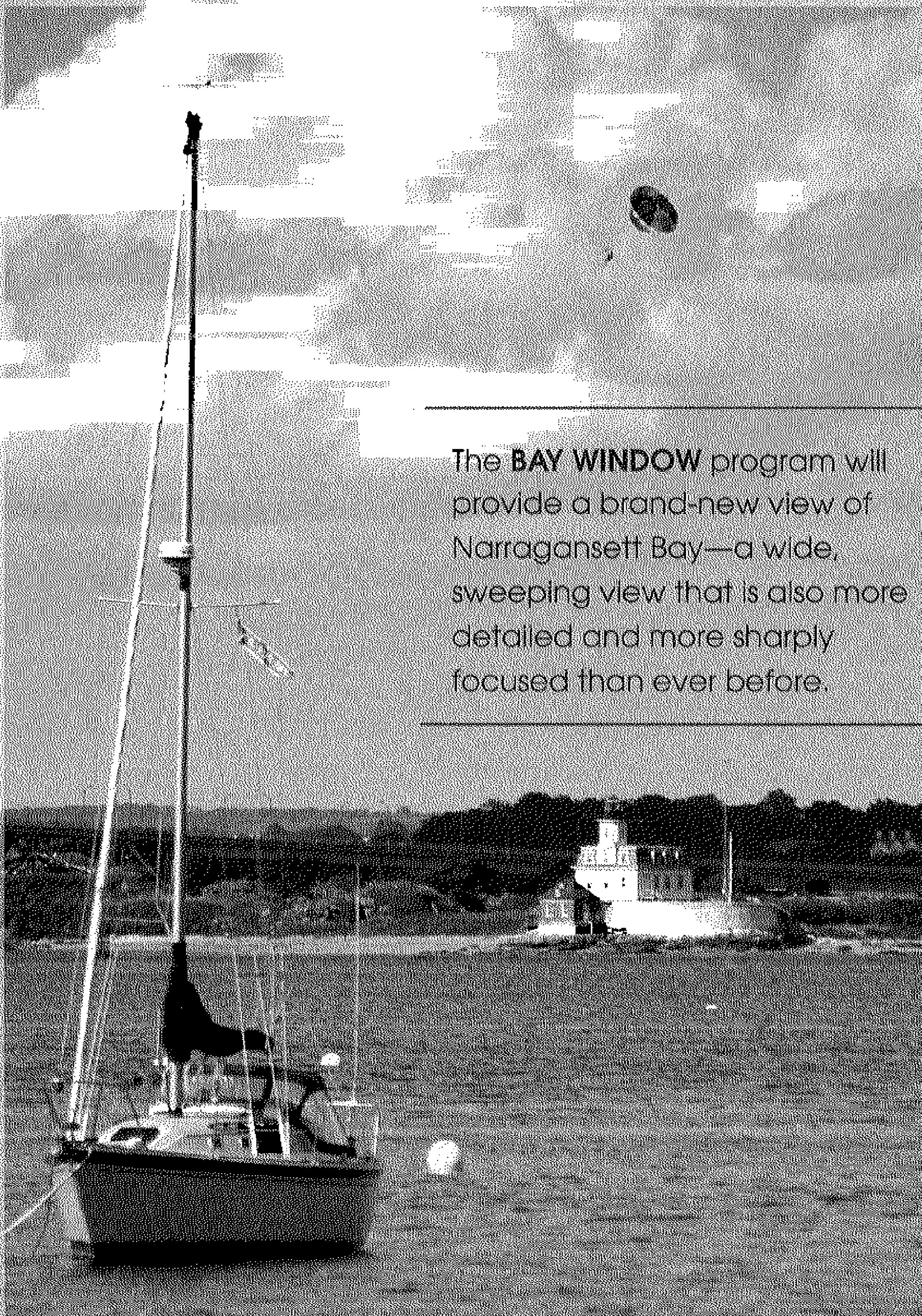
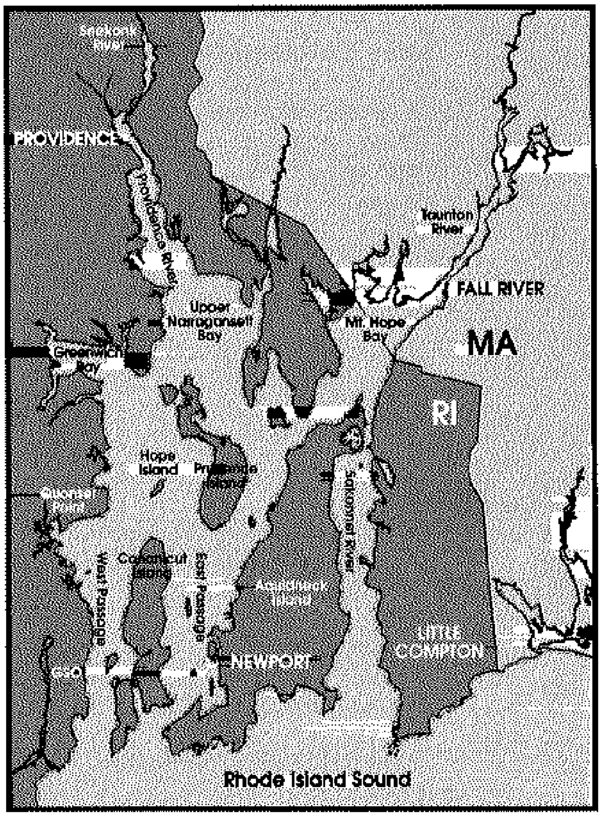




The **BAY WINDOW** program will provide a brand-new view of Narragansett Bay—a wide, sweeping view that is also more detailed and more sharply focused than ever before.

A WINDOW ON **THE BAY**



In 1996 a barge ran aground on Green Hill Beach, spilling oil into Rhode Island waters. During the ensuing cleanup, some of those responsible for the spill challenged the Rhode Island Department of Environmental Management (RIDEM) estimates of the spill's extent. Their argument boiled down to, "How do you know the oil wasn't there before?" Although RIDEM eventually prevailed, the agency was hampered by the fact that no hard data existed to document pre-spill levels of oil in the sediments.

The late Senator John H. Chafee was disturbed to learn about this lack of data. Like most people, Chafee had assumed that researchers had a pretty complete picture of Narragansett Bay, which is considered one of the most-studied estuaries in the world. And it's true that over the years researchers have gathered a tremendous amount of valuable data on the Bay. The problem is that individual studies are usually designed to look at only one location or one issue, and since different studies use different methods, the data can't be easily combined.

In other words, we have a lot of snapshots but we don't have a panorama.

Getting a Comprehensive Picture

Senator Chafee envisioned a project that would gather broad, comprehensive data on the state of Narragansett Bay—its waters, tides, creatures, plants, and sediments, and the complex interplay among them all. Through Chafee's sponsorship, a federal grant was awarded to fund the Cooperative Bay Program, which was launched in 1998 and is being managed cooperatively by the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) and RIDEM.

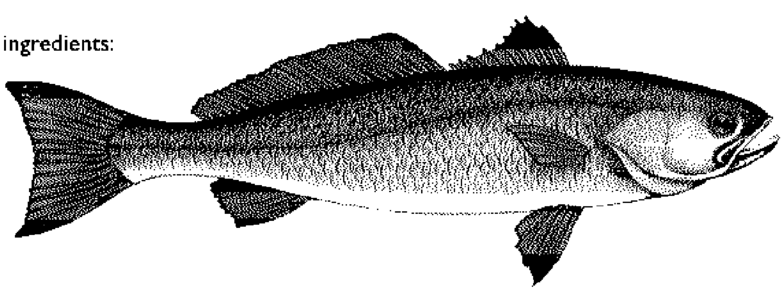
The Cooperative Bay Program has been nicknamed the "Bay Window" because it will provide a brand-new view of Narragansett Bay—a wide, sweeping view that is also more detailed and more sharply focused than ever before. The data collected by the project will help researchers look for answers to a wide variety of questions, such as:

- *How healthy is Narragansett Bay?*
- *Is pollution increasing or decreasing?*
- *Are fisheries management strategies working?*
- *Is the Bay getting warmer?*
- *Are dissolved oxygen levels adequate for Bay creatures?*

For its success, the Bay Window program relies on two key ingredients: state-of-the-art technology and scientific collaboration.

New Tools

Exciting, 21st-century technology is enabling Bay Window scientists to assess the Bay's physical, biological, and chemical properties at a higher resolution than has ever been possible before. Thanks to the program, sophisticated electronic sensors are measuring Bay conditions every 15 minutes and transmitting data directly to researchers' computers; soon the same data will be available in "real time" on the Internet. Meanwhile, other instruments are riding around the Bay on a state-of-the-art "shuttle" that carries them up and down through the water column to obtain a top-to-bottom view. And a brand-new research vessel is being built—the *R/V Chafee*, which will be specially equipped to accommodate all the latest tools.



New Collaborations

The project represents a team of federal, state, and university researchers from RIDEM, the University of Rhode Island Graduate School of Oceanography (GSO), NMFS, and Roger Williams University. This marks the first significant joint effort between NMFS and Rhode Island state agencies.

Multiple Perspectives

To obtain the broadest view of the Bay, the program is multi-pronged, bringing together the perspectives of many researchers using a variety of approaches and strategies. Data collected with newly available tools are being combined with existing datasets to detect long-term trends and patterns. The first phase initiated four major efforts, which are described in detail in the pages that follow:

1. Fish population assessment: Scientists are analyzing population trends of fish and shellfish and investigating reasons for the decline of important commercial species such as winter flounder.

2. Monthly surface-to-bottom data collection: Water conditions from the surface to the bottom are continuously measured by high-tech instruments that are towed around the Bay on the "NuShuttle."

3. Round-the-clock monitoring: Probes stationed at a variety of locations make physical, chemical, and biological measurements at 15-minute intervals day and night, year-round.

4. Sediment analysis: Sediment samples collected throughout the Bay allow researchers to compare past and present levels of contamination and identify toxic "hotspots."

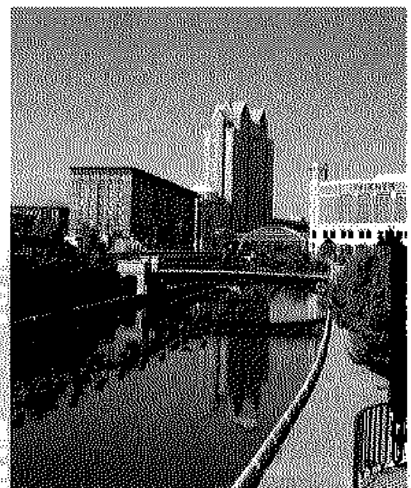
Using advanced technology that collects and analyzes data much faster, more efficiently, and less expensively than traditional methods, Bay Window researchers are building a scientific baseline for the Bay's physical, chemical, and biological properties.

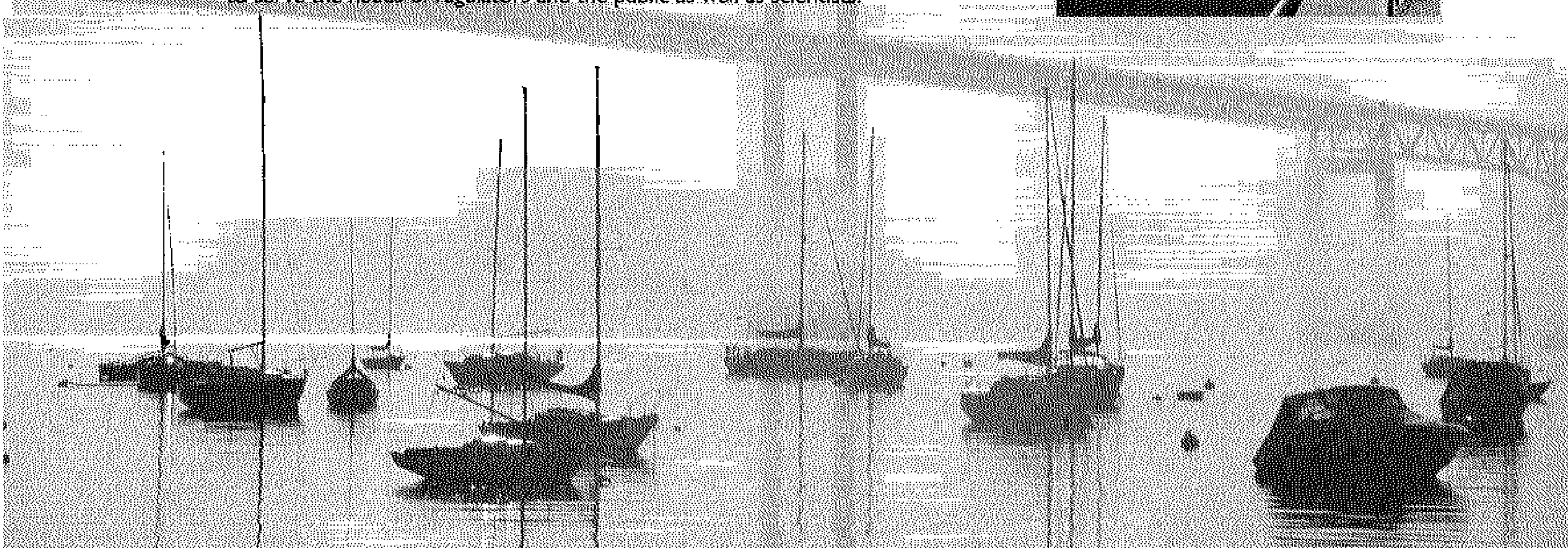
But the Bay Window was never intended to be a window through which only scientists could look. A major goal is to provide practical, useful information for those charged with protecting the Bay. Already the program is proving its value to Bay managers. Examples include the finding that critically low oxygen levels occur in more places than previously thought; the discovery that Bay waters become stratified (i.e., form layers) more often and further south than was suspected; the demonstration that toxic pollutants in Upper Bay sediments have decreased in the last decade; and the ability to quickly assess the impacts of a summer 2000 oil spill. Soon the new information being collected will be accessible via a Website designed to serve the needs of regulators and the public as well as scientists.

Understanding the Bay as a System

"A lot of researchers have made measurements, but until now no one has done it with the goal of linking all the information together to understand how the whole system works," says Chris Deacutis, who is the Bay Window coordinator for RIDEM and also oversees research for the Narragansett Bay Estuary Program and Narragansett Bay National Estuarine Research Reserve (NBNERR). "This is the first time anyone has looked at the Bay at this level, at this resolution, with 21st-century technology."

We are only beginning to understand the complex and ever-changing interplay among tides, weather, pollution, algae, fish, and a host of other factors. The information being gathered by Bay Window researchers is the first step toward a holistic view of the Bay's intricate patterns.



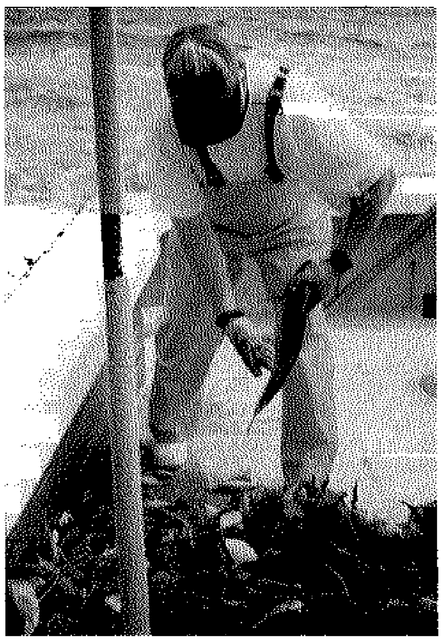


FISHERIES: WHAT'S UP, WHAT'S DOWN

Collaborators: *David Borden, Mark Gibson, Najih Lazar, Timothy Lynch, and J. Christopher Powell, RIDEM; Frank Almeida and Carol J. Meise, NMFS; Allison K. DeLong and Jeremy S. Collie, GSO*

For Bay managers, the bottom-line question is: How are the fish doing? From an economic standpoint, fish, lobster, and shellfish are the Bay's most valuable resource. And from a scientific perspective, these animals are the ultimate "barometer" for overall conditions in the Bay. From their positions in the food web, these "consumers" integrate all the other factors that affect the Bay. Any type of change, whether it be in water quality, climate, planktonic plants and animals, or human fishing pressure, ends up being reflected in fish and shellfish populations.

Darlene Trew Crist



Fish and crustaceans collected in RIDEM's regular trawl survey are sorted, counted, and weighed. All fish are measured, as are some lobster and crabs.

Fisheries Monitoring

To collect crucial data on Bay fish, RIDEM conducts monthly and seasonal bottom trawl surveys. This work may lack the glamour and cutting-edge excitement of some of the other Bay Window research, yet faithful, consistent surveying, year in and year out, is the only way to find out which species are in trouble, which are thriving, and whether management efforts such as catch restrictions are working. RIDEM's surveys have been ongoing for 22 years, but lately the effort has been hampered by an aging vessel (continuously in operation since surveys began in 1979) and uncertain funding. The Bay Window program is supporting and enhancing RIDEM's fisheries monitoring by making possible:

- Acquisition of a new vessel, the *R/V Chafee*—bigger and more seaworthy than the old one and twice as fast, featuring an expanded workspace and state-of-the-art trawling and sampling equipment.
- Addition of an "onboard observer" program. Observers ride on commercial fishing boats and note bycatch—that is, incidental capture of species of concern (such as winter flounder) that occur in the course of fishing for other species.
- Collection of data on the age of Bay fish populations. By counting "year rings" in fish scales and otoliths (a bone in the ear), researchers can determine a fish's age.
- Conversion of RIDEM's 22-year database to make it compatible with other regional datasets, including NMFS data, so that fisheries data can be shared and trends analyzed throughout all of New England.

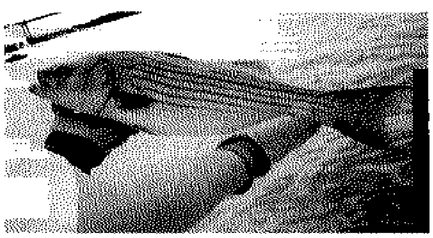
Concurrently, Bay Window is supporting a related effort by GSO scientists who are using computer modeling and 11 years of data from RIDEM juvenile winter flounder surveys to identify factors in the collapse of the Bay's winter flounder fishery. The model ruled out increased mortality of juveniles as a cause for the overall decline. It also showed that, for the juvenile stage, growth rates are better when the population density is low and survival is better when water temperatures are cooler.

What the Surveys Show

The picture revealed by the survey data is one of dramatic change. Through the early 1990s, demersal (bottom-dwelling) fish declined sharply while pelagic (off-bottom) species followed an opposite trend, as shown in the graph on page 6. Since then the numbers of pelagic fish have dropped off while demersals show some increases. "We might be seeing the beginning of another reversal, with pelagics trending down and demersals recovering—but we'll need another five to 10 years to know for sure whether this is a long-term, stable shift or just a temporary fluctuation," says Bay Window researcher Mark Gibson, RIDEM fisheries scientist.

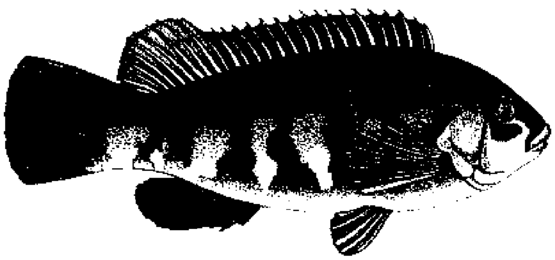
Most of the species that have increased are seasonal migrants, such as scup, butterfish, striped bass, weakfish, Atlantic herring, summer flounder, and squid, that visit Narragansett Bay in the summer. Their striking recoveries are a testament to the success of fisheries management policies both in Rhode Island and along the Atlantic coast.

Darlene Trew Crist



Fish that have not fared well are mostly residents—that is, species that spend their entire life cycle in

Narragansett Bay. These include the Bay's "signature species"—winter flounder and tautog—as well as fish without commercial or recreational importance, such as hogchoker, oyster toadfish, and sea robin. Most disturbing, these stocks have failed to recover in spite of more than a decade of severe catch restrictions (quotas and size limits) on commercially important demersal species.

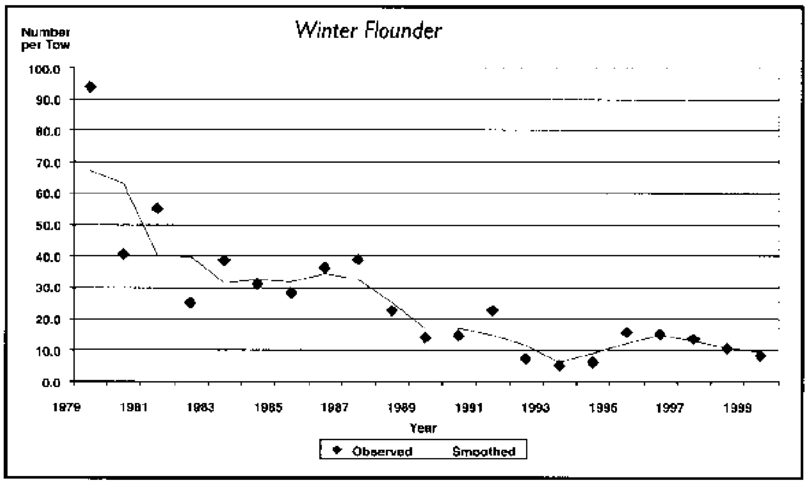


Can We Reverse the Declines?

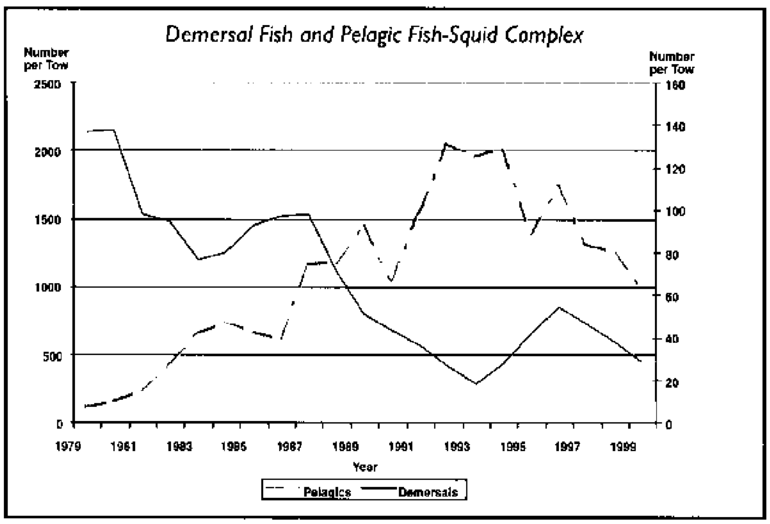
Can the Bay's winter flounder and other demersal fish be brought back? That depends on what's causing the declines. The survey data provide some clues. The affected fish are mainly Narragansett Bay residents, and they live on the bottom. Overfishing is undoubtedly a factor, but it can't be the whole story because species that are not fished have also declined. Besides, after the Atlantic States Marine Fisheries Council imposed catch restrictions in 1992, winter flounder rebounded in most other places along the Atlantic coast—but not in Narragansett Bay.

Putting it all together, Gibson concludes, "We know there's been overfishing, but in addition, something has apparently gone wrong with demersal habitat in Narragansett Bay." The question, of course, is what. Habitat includes everything from water temperature and quality to aquatic vegetation to sediment composition and contamination. New data being collected through the various Bay Window research efforts should shed light on changes and trends in Bay habitat.

"The question we'd like to get at," Gibson explains, "is whether these population fluctuations are due to events we can't control, like climate, or whether there are things managers can do to influence or modify these patterns." Climate might well be a factor, because the Bay's mean annual water temperature has risen by about 2 C (nearly 4 F) over the past 30 years. But there's a good chance that factors which are influenced by human activities also play a role. These include fishing pressure, low dissolved oxygen, excess nutrient concentrations, eelgrass loss, and sediment contamination. In any case, the recent success in bringing back Atlantic coast pelagic species provides grounds for optimism. "We've shown on a regional scale that fish stocks can be rebuilt," says Gibson.

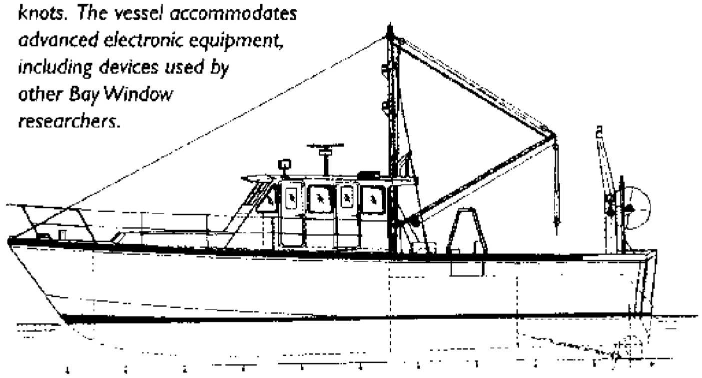


The numbers tell the story of the collapse of Narragansett Bay's winter flounder fishery. There was a modest upturn in the mid-1990s, but it has not been maintained.



From 1979 through the early 1990s, the downward plunge in numbers of bottom-dwelling fish (right axis, purple solid line) was matched by an equal upsurge in off-bottom species (left axis, pink dashed line).

The 62-foot R/V Chafee, currently being built, will be capable of speeds in excess of 20 knots. The vessel accommodates advanced electronic equipment, including devices used by other Bay Window researchers.



John W. Gilbert Assoc., Inc.

Fish that have not fared well are mostly residents—including the Bay's "signature species" such as winter flounder and tautog. Most disturbing, these stocks have failed to recover in spite of more than a decade of severe catch restrictions.

BAY WATERS: SURFACE TO BOTTOM

Collaborators: *Mark Berman and Jack Jossi, NMFS; Candace Oviatt, Edward Durbin, and Christopher Melrose, GSO*

Comprehensive data on Narragansett Bay water conditions are being collected with the help of the "NuShuttle," a sampling device so up-to-the-minute that it has only been used in a few other places in the world. The NuShuttle looks like a small yellow sleigh, but its acrobatic behavior is more suggestive of an airplane. What's new about the NuShuttle is that, as it is towed behind a research vessel, it repeatedly dives and ascends in a "flight pattern" controlled by an onboard computer. Meanwhile, the sensitive monitoring instruments in the NuShuttle's payload area continuously take a whole suite of measurements. The result is a surface-to-bottom profile of water conditions—like slicing the water to get a sideways view.

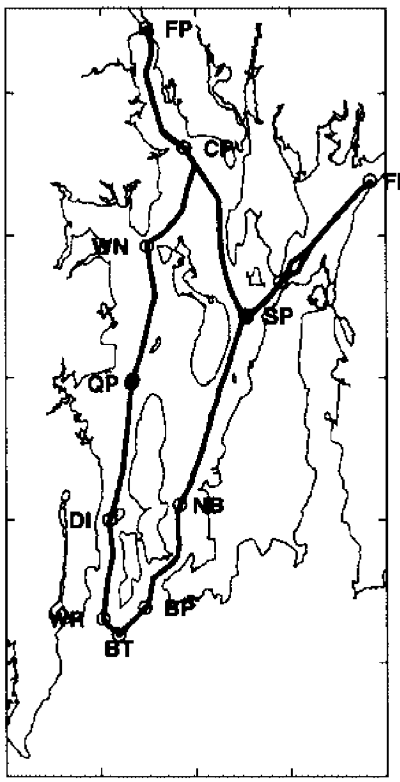
Each month, the NuShuttle makes a 10-hour, 70-mile circuit around Narragansett Bay, giving a snapshot of the Bay's water column from Newport to Providence. Its instruments measure temperature, salinity, dissolved oxygen, light levels, chlorophyll, algal growth rate, and zooplankton (minute aquatic animals).

What's new about the NuShuttle is that it repeatedly dives and ascends in a "flight pattern" controlled by an onboard computer. The result is a surface-to-bottom profile of water conditions—like slicing the water to get a sideways view.

Jerome Preziosi/NOAA

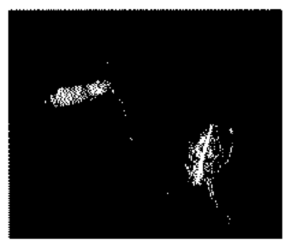
Chris Melrose, GSO graduate student, shows off the NuShuttle.

NuShuttle Cruise Track



QP = Quonset Point (start and end)
DI = Dutch Island
WR = Whale Rock
BT = Beavertail
BP = Brenton Point
NB = Newport Bridge
SP = Sandy Point
FR = Fall River
CP = Conimicut Point
FP = Field's Point
WN = Warwick Neck

The NuShuttle path starts at Quonset Point, travels south through lower West Passage, around Beavertail, north through East Passage, loops through Mount Hope Bay, up into Providence River, and back to the starting point. The resulting profile is shown on the next page.

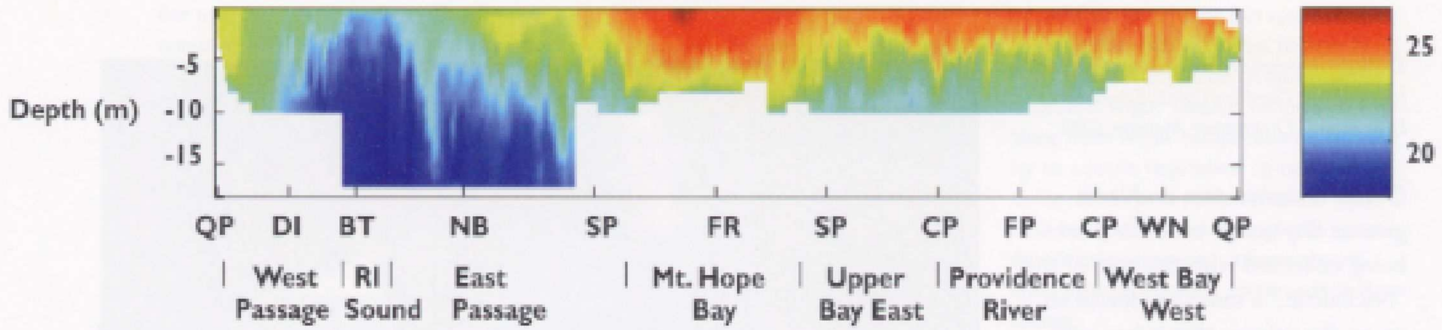


Representative zooplankton of Narragansett Bay.

Paul Hargraves/GSO

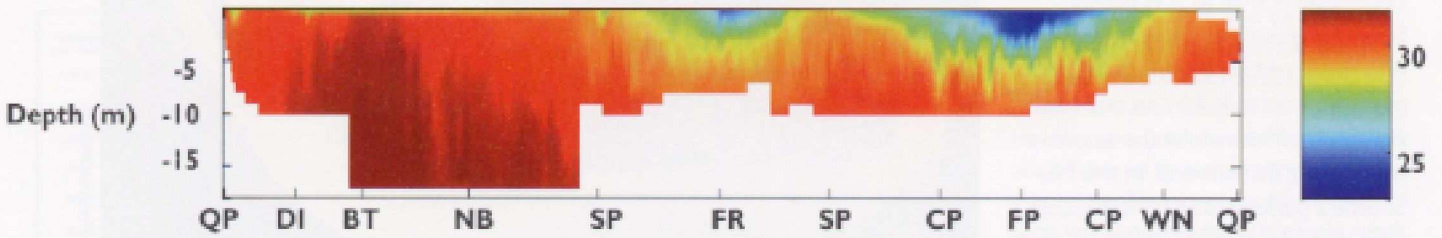
NuShuttle Profiles for August 10, 2000

TEMPERATURE (°C)



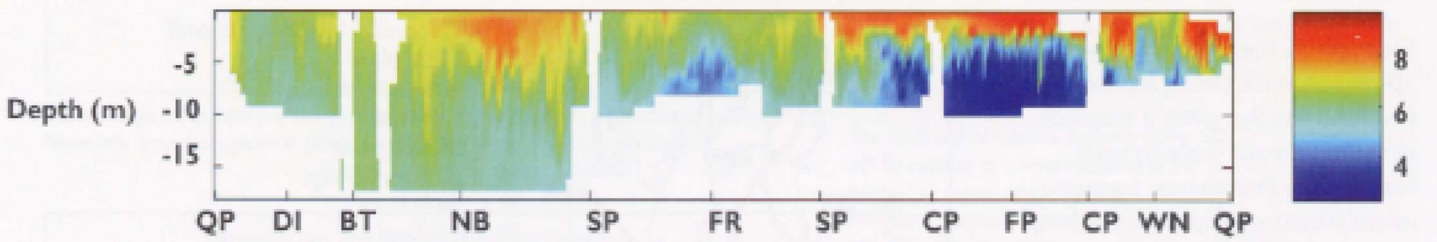
***Temperature:** The coolest water (18 C, or about 66 F) was found near the bottom of Rhode Island Sound and the lower East Passage. The surface layer in Mount Hope Bay was very warm (up to 24 C, or 75 F), possibly due to the outflow from the Brayton Point power plant. Warm water overlay cooler water in the Providence River and the eastern portion of the Upper Bay.*

SALINITY (PPT)



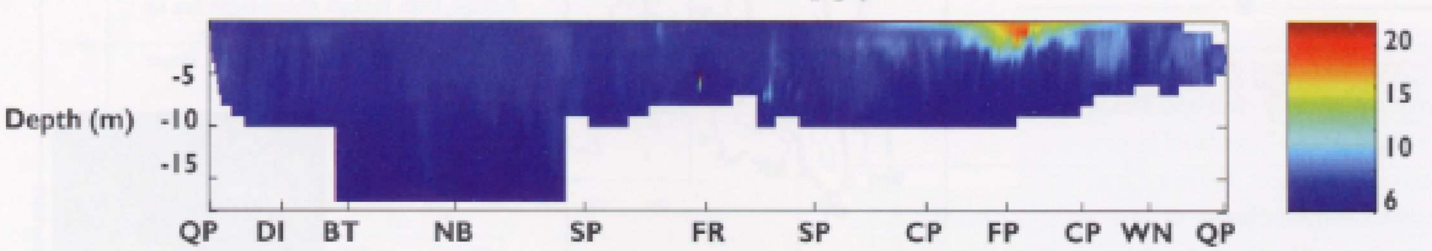
***Salinity:** There were shallow layers of fresher water at the surface of Mount Hope Bay and the Providence River, with denser, more oceanic water below.*

OXYGEN (mg/l)



***Oxygen:** A wide range of oxygen levels were found in the Bay. Concentrations tended to be high near the surface, where phytoplankton were producing oxygen through photosynthesis. However, a hypoxic area (i.e., an area with dangerously low levels of oxygen) was found below the surface in the Providence River. This corresponds to the phytoplankton bloom seen in the same location in the chlorophyll graph, below. The abundant phytoplankton cells were dying and sinking to the bottom, where bacteria were decomposing them, using up most of the available oxygen.*

CHLOROPHYLL (µg/l)



***Chlorophyll:** Chlorophyll concentration is a measure of how much phytoplankton is in the water. On this date, chlorophyll levels were low throughout most of the Bay, with one exception: a very high level in a phytoplankton bloom near the surface in the Providence River. This bloom was the result of sewage treatment plant effluents, which contain nutrients that fertilize the phytoplankton.*

21st-Century Technology

The NuShuttle features several examples of cutting-edge technology, such as the fast repetition rate fluorometer that measures the growth rate of phytoplankton (microscopic algae). Knowing the phytoplankton growth rate helps researchers predict algal blooms and die-offs.

Another recently developed device is the NuShuttle's optical plankton counter (OPC), which electronically counts and measures zooplankton. "Zooplankton are not uniformly distributed in the water column, but the traditional technique—catching them in a net—doesn't show that," explains Bay Window researcher Mark Berman, NMFS oceanographer. "The OPC is showing us the distribution, both horizontally and vertically."

This investigation was designed to gain maximum knowledge with a minimum expenditure of public monies. The NuShuttle allows researchers to collect more data, more quickly, and at lower expense than traditional methods. Cost savings come from reduced ship time as well as lower costs for personnel and data handling.

Accumulating this wealth of data has both immediate and long-term payoffs. In the short term, the NuShuttle provides monthly updates on Bay conditions—timely information that proved especially valuable after an oil spill occurred in the summer of 2000. Managers at RIDEM wanted to know how much damage had been done to Bay aquatic life. The NuShuttle had collected data from the spill area just a few weeks previously. By sampling again in the same locations, researchers were able to determine that zooplankton had not been much affected—indicating that the oil had not stayed in the water column long enough to have significant long-term impacts.

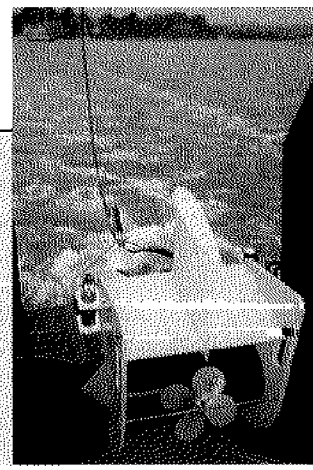
New Knowledge

The data collected to date have already provided new insight into conditions that could be affecting fish, shellfish, and other Bay creatures. For example:

Changes in algal bloom patterns: With the NuShuttle data, researchers have discovered a change in the long-term pattern of phytoplankton blooms. Normally, large blooms occur in Narragansett Bay in the late winter and early spring. These winter-spring blooms produce most of the food upon which Bay animals ultimately depend. But the scientists found that the normal winter-spring bloom did not occur in 1998 or 1999. They speculate that the change in pattern might be due to warmer-than-usual winters. Whatever the cause, the change could be affecting the abundance of Bay finfish and shellfish. Fish and shellfish larvae feed, directly or indirectly, on phytoplankton.

Low-oxygen conditions: The NuShuttle has revealed a surprising distribution of low-oxygen conditions in the Bay. Previously, scientists believed that such conditions occurred only in the deep ship channel of the Providence River and only during the summer. But the NuShuttle has provided evidence that low-oxygen conditions occur in more locations—for example, the Upper Bay and upper West Passage. These conditions are important to Bay managers since low oxygen can impair the health and growth of fish and shellfish and can be lethal to lobster, crabs, and other bottom-living creatures.

Over time, the monthly measurements made by the NuShuttle will build a reliable baseline of Bay ecological conditions that scientists can use to define normal ranges and discern cyclic patterns. With this new understanding of Bay dynamics, researchers and managers will be able to document future changes and predict how proposed uses of the Bay could affect its overall health.



Darlene Trew Crist

NuShuttle: State of the Art

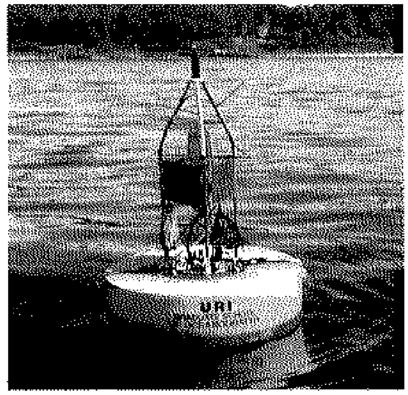
The NuShuttle, with its capability of traveling up and down through the water column, represents the very latest in monitoring technology. Instruments housed within the NuShuttle's payload area include state-of-the-art electronic equipment like the fast repetition rate fluorometer, optical plankton counter, and photosynthetic active radiation (PAR) meter, along with several more traditional monitoring devices.

- **Fast Repetition Rate Fluorometer (FRRF):** Measures the growth rate of phytoplankton electronically, in real time, without the time-consuming lab procedures required by traditional methods.
- **Optical Plankton Counter (OPC):** Measures the number and size of zooplankton by putting a curtain of light across a tunnel through which water flows. When a zooplankter interrupts that curtain, it is recorded. The animal's size is estimated from the size of the interruption.
- **Photosynthetic Active Radiation (PAR) Meter:** Measures how much light is available for photosynthesis at different depths.
- **Conductivity, Temperature, and Depth (CTD)/Fluorometer:** Measures salinity, temperature, depth, and chlorophyll.
- **Dissolved Oxygen Electrode:** Measures concentration of dissolved oxygen.
- **Continuous Plankton Recorder (CPR):** Captures zooplankton between two layers of silk mesh, making a "sandwich" that secures the creatures for later counting under a microscope.

BAY WATERS: ROUND THE CLOCK

Collaborators: *Dana Kester, GSO; Christopher F. Deacutis, RIDEM Narragansett Bay National Estuarine Research Reserve; Andrew Tate, Roger Williams University*

To an acupuncturist the human body has not just one pulse but many, each giving insight into a different aspect of a person's health. For GSO oceanographer Dana Kester, Narragansett Bay also has "a series of pulses that reflect its health and the processes that make up its 'metabolism.'" Some of the Bay's pulses follow the cycle of the seasons while others are related to changes between day and night. Kester notes that even the phases of the moon cause a pulse in the Bay, which we can see by the range of the tides and their effects on mixing of Bay waters.



Dana Kester/GSO

The floating stationary buoys consist of round foam flotation platforms about 4 feet in diameter. In the center is a watertight compartment that houses the electronics and batteries. Two sondes are connected to each buoy.

As part of the Bay Window program, Kester and other researchers are keeping a finger—in fact, several fingers—on the Bay's pulses. The "fingers" are cylindrical instruments called sondes, which are strategically deployed around the Bay. Though only about the size of a roll of paper towels, the sondes contain electronic sensors that measure temperature, salinity, dissolved oxygen, pH, and water level (tide). Some models also include a probe for measuring chlorophyll.

Watching the Bay 24/7

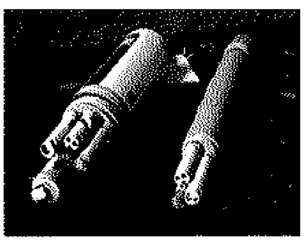
The sondes are always on the job. Every 15 minutes, day and night, year-round, they take their suite of measurements, building a detailed picture of how the Bay changes—hour to hour, day to day, season to season. This time-series dataset is revealing the Bay's cycles in greater detail than ever before, allowing scientists and managers to identify long-term patterns as well as track the effects of short-term influences like weather.

Some of the sondes are located in shallow areas, attached to permanent objects like docks; others are attached to floating buoys moored in deep holes. The buoys each have two sondes attached, one near the surface and one near the bottom.

Two sondes—one about 1.5 feet below the surface and the other 3 feet above the seafloor—are connected to the buoy by cables that provide power via solar-charged batteries.

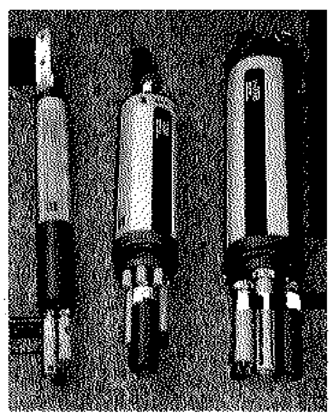
The network of sondes stationed around the Bay represents a collaborative effort: RIDEM's NBNERR maintains two stations near Prudence Island; Roger Williams University has one near the mouth of Mount Hope Bay; and GSO has one at the GSO pier and two off Prudence Island. Data from all these locations are shared to create a coordinated system for observing the Bay. In addition, the network established by Bay Window scientists has inspired other agencies to join the collaboration, thus effectively leveraging the federal Bay Window funding. For example, the Narragansett Bay Commission has deployed a buoy in the Providence River.

The data from the sondes are also being combined with the complementary NuShuttle data. The sondes provide excellent temporal resolution but have limited spatial resolution since each sonde stays at a fixed point. Meanwhile, the NuShuttle dataset has excellent spatial resolution, both horizontally and vertically, but limited temporal resolution. Together the two datasets are providing a new, panoramic view of the Bay's structure and dynamics.



Dana Kester/GSO

Slender sondes about 14 inches long contain multiple sensors packed into a small space.



Dana Kester/GSO

Every 15 minutes, day and night, year-round, the sensors take measurements, building a detailed picture of how the Bay changes—hour to hour, day to day, season to season.

The New View: A More Stratified Bay

The sondes and the NuShuttle are telling a surprising story about stratification in Narragansett Bay. Stratification refers to the separation of the water into distinct layers, with a less dense upper layer overlying a denser bottom layer. Temperature and salinity control density, with colder, saltier water being denser. In Narragansett Bay, as in any estuary, the cold, saline water coming in from the ocean tends to form a dense under-layer while the warmer freshwater from the rivers tends to stay on top. But counteracting this tendency are the effects of tides, wind, and storms, which mix the layers and break up the stratification.

Conventional wisdom holds that tidal energy keeps the mid-Bay and lower Bay well mixed, so that Narragansett Bay rarely becomes stratified below Conimicut Point. Now data from the sondes and the NuShuttle are proving this view inaccurate (see sidebar below). In particular, the new data are showing that during weaker or "neap" tides (tides that occur around the time of the moon's first and third quarters), especially in the summer, the Bay can stratify as far south as the Newport Bridge.

"We're finding out that we didn't know as much as we thought we did about Narragansett Bay," says Deacutis. "We've never had these pictures before. Now that we can look at the day-to-day and week-to-week changes, we're seeing that what's in the textbooks isn't always true."

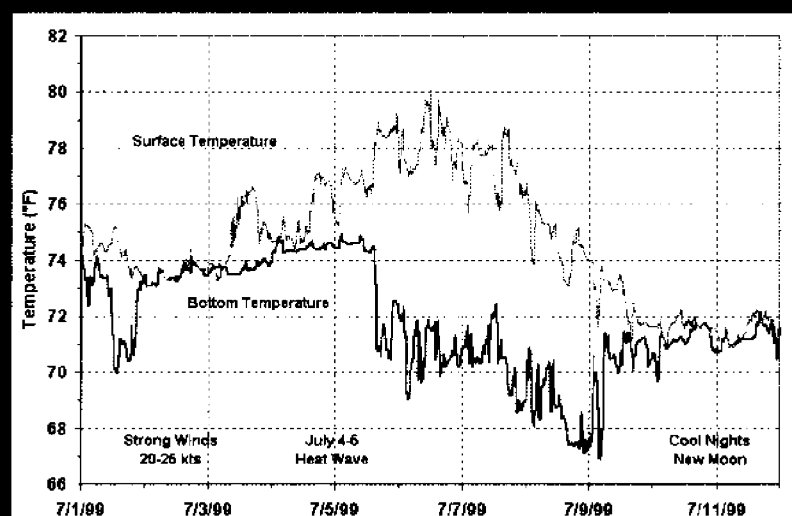
Tides, Stratification, & Bay Life

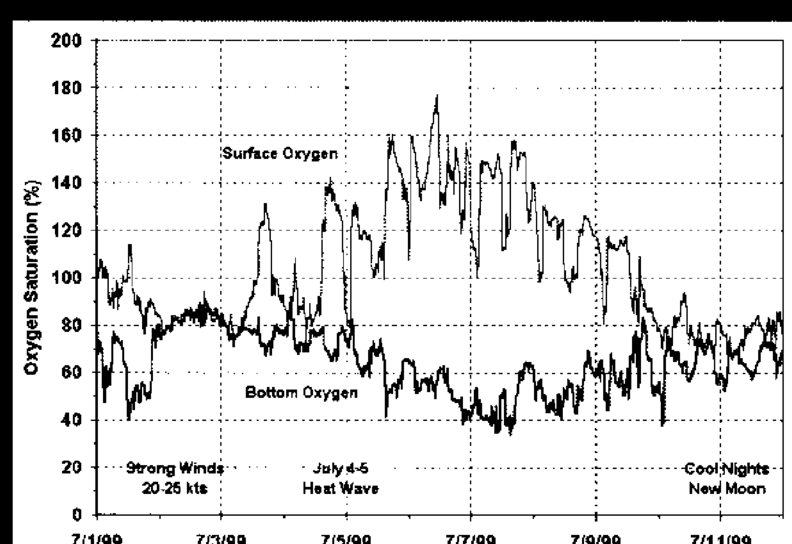
Floating stationary buoys, with their pairs of sondes making simultaneous measurements near the surface and near the bottom, are especially useful for detecting stratification. The graphs show readings taken in July 1999 from a buoy off Prudence Island. With surprising rapidity the Bay went from being mixed to being stratified to being mixed again. Several factors—storms, temperature, tides— influenced the changes.

As seen in the graphs, bottom oxygen fell when the waters became stratified. "As soon as mixing stops, dissolved oxygen begins to drop in the bottom waters, because oxygen comes from the surface," explains Deacutis.

Algal growth is also affected by stratification, and this in turn plays a role in dissolved oxygen levels. When strong mixing occurs, the algal cells get pushed down away from the sunlight and don't grow as well, but when the Bay is stratified algae are likely to bloom. Blooms can quickly lead to low levels of bottom oxygen as dead algal cells fall to the bottom and decompose, a process that consumes oxygen.

"If oxygen is going lower than we thought, that's important," says Deacutis. "Low oxygen creates problems for bottom-dwelling animals. Our next questions are, How often does this happen, how low does the oxygen get, and how long does it stay low?"

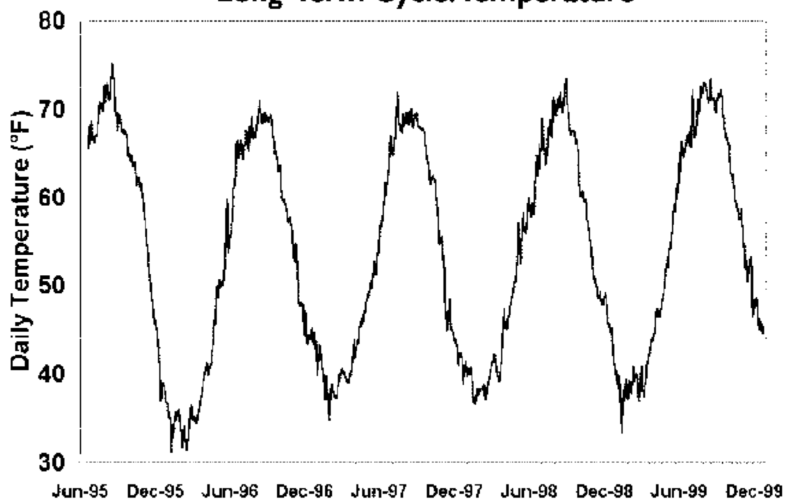




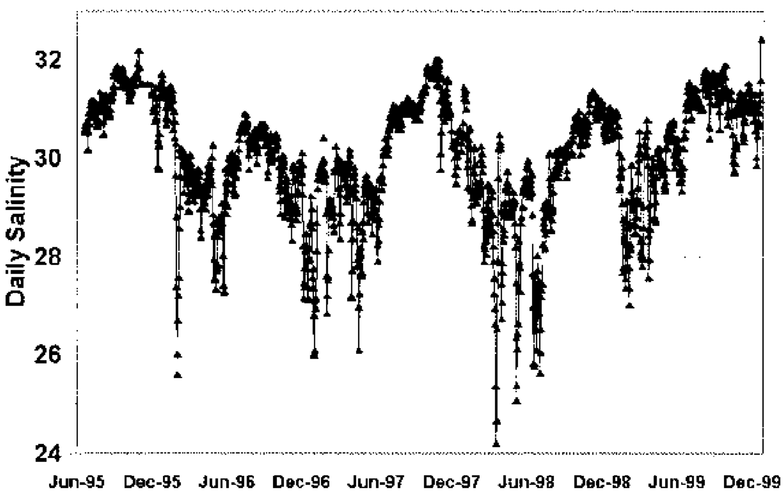
In the near future, researchers are looking forward to instantaneous transmission of data between the sondes and a centralized computer via radio links. This will provide near-real-time data on the physical condition of Narragansett Bay from the GSO pier in the south to the northern reaches of Mount Hope Bay and the Seekonk River. When fully in place, the monitoring system will be one of the highest-resolution systems in the world for tracking water quality changes on a baywide scale. The data will also be posted on a Website so that users can access near-real-time information about current Bay conditions.

"If oxygen is going lower than we thought, that's important. Low oxygen creates problems for bottom-dwelling animals. Our next questions are, How often does this happen, how low does the oxygen get, and how long does it stay low?" —Chris Deacutis, RIDEM

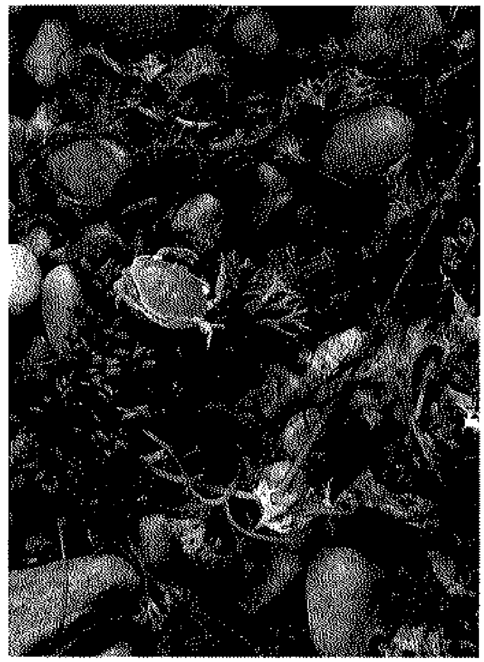
Long-Term Cycle: Temperature

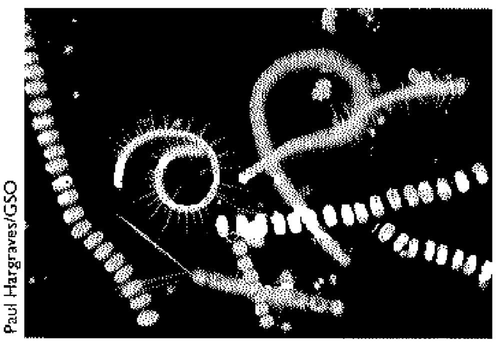


Long-Term Cycle: Salinity



By taking long-term measurements researchers can track the Bay's variability from year to year. Measurements shown were taken from surface water at GSO pier.

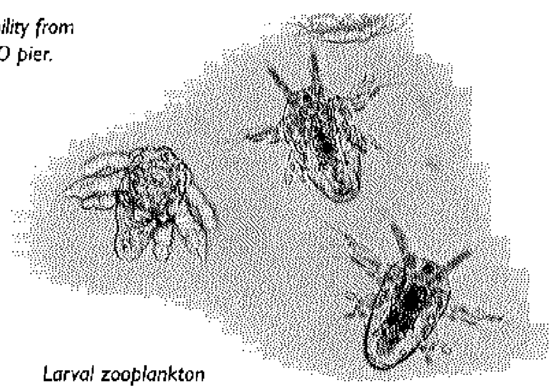




Paul Hargraves/GSO

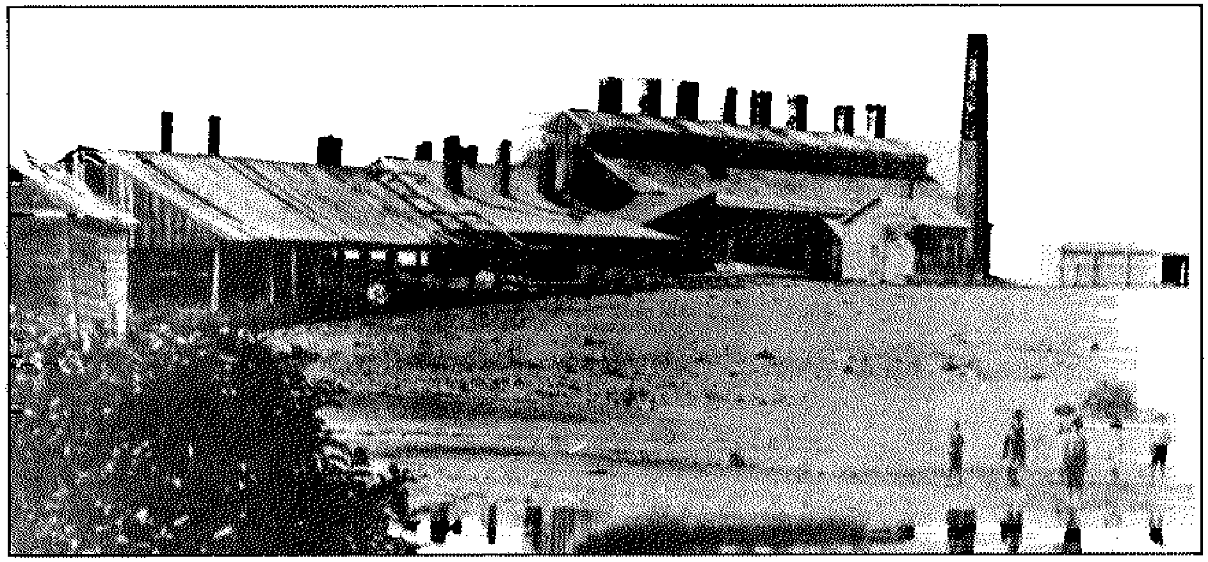
Typical phytoplankton of Narragansett Bay.

When fully in place, the monitoring system will be one of the highest-resolution systems in the world for tracking water quality changes on a baywide scale.



Larval zooplankton

BURIED HISTORY: TALES TOLD BY SEDIMENTS



Newport Historical Society

Taunton Copper Company smelter at Portsmouth, R.I., circa 1878. Reprinted from S.W. Nixon, Metal Inputs to Narragansett Bay: A History and Assessment of Recent Conditions *(1995).*

Collaborators: *John King, James Quinn, Robert Cairns, Paul Hartmann, Carol Gibson, and Elizabeth Laliberte, GSO*

The sediments at the bottom of Narragansett Bay have a story to tell, if you know how to read it. Little by little, all the time, small particles settle to the bottom of the Bay, gradually burying the previous layer. By digging into the sediments you can effectively look backward through time. A core several feet long, carefully collected to keep its structure intact, bears witness to Rhode Island's industrial and cultural history going back a century or more.

In contrast to the NuShuttle and the sondes, which record the Bay's patterns hour by hour or month by month, sediments reveal changes on a different scale entirely—a scale of decades or centuries. These are slow, cumulative changes and long-term trends that could be missed looking day to day.

Bay Window researchers studied sediments to assess toxic pollution in the Bay, past and present. Two types of sediment samples were collected. A series of shallow surface samples from locations all around the Bay gave a picture of the past decade, while three deep cores (down to about 4 feet) helped trace the history of contamination over most of the 20th century.

The sediment samples were analyzed for a variety of contaminants, including silver, copper, lead, mercury, and other metals; pesticides; and petroleum byproducts. These substances are the signatures of human activity: metals from the jewelry, textile, and other industries; pesticides from farms, gardens, and mosquito-control efforts; lead from leaded gasoline; and petroleum byproducts from the burning of fossil fuels such as coal, gasoline, and diesel.

Most of these contaminants are potentially harmful to Bay life, especially bottom-dwellers like lobster, crabs, and flounders. Copper is toxic to algae. Some of these pollutants, especially those that bioaccumulate in fish or shellfish, can cause health problems in humans or animals who eat fish or shellfish taken from contaminated waters.

John King/GSO

The powerful jaws of the Smith-McIntyre sampler scoop up chunks (about the size of large shoebox) of undisturbed sediment. Bay sediments are variable from place to place. Some consist of coarse particles like sand, shells, and gravel, while others are made up of fine silt and clay.

Background: *Balloon view of Narragansett Bay published by C.A. Pabodie & Sons*

A Cleaner Bay (Mostly)

Bay Window researchers conducted the most extensive survey ever made of shallow Bay sediments, collecting samples at 48 sites in the Bay and salt ponds (see dots on map below). They analyzed the top 2 centimeters (cm) of sediment (a little less than 1 inch), which corresponds to approximately the past five to 10 years, depending on how fast sediments accumulate in a particular location.

Twenty sites in the Bay Window survey were sites that had been previously tested in 1988. When the two sets of results are graphed side by side, one can see that the most industrialized area—the Upper Bay—has gotten cleaner over the past decade. "Clean," of course, is a relative term. In parts of the Upper Bay, contaminants still exceed levels believed to have effects on bottom-dwelling organisms. Still, the story told by these sediments is a story of dramatic success. Industries have drastically reduced toxic discharges to the Bay, and upgraded sewage treatment plants are doing a good job of removing contaminants from nonindustrial sources.

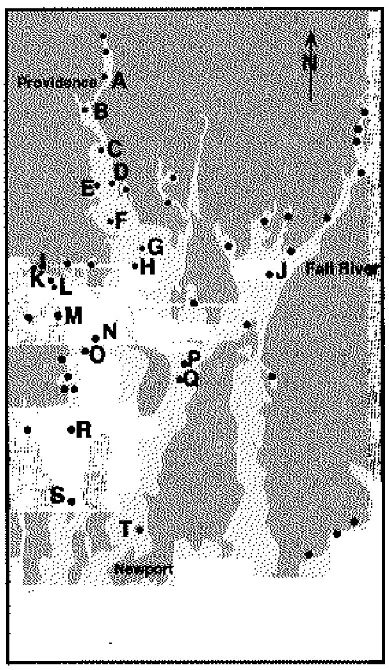
As we move further down-Bay, however, the story is not as clear. Improvements are less dramatic, and in some locations we see increases in the levels of some pollutants—even though there are few sources of contamination in these areas. Bay Window scientists hypothesize that during storms contaminated sediments from the Upper Bay become resuspended and are carried to lower, cleaner portions of the Bay. Bay Window researcher John King, GSO oceanography professor, says, "We read in the newspaper, 'The Bay is getting better'—and that is true for the most contaminated areas, but it's not necessarily true for all parts of the Bay."

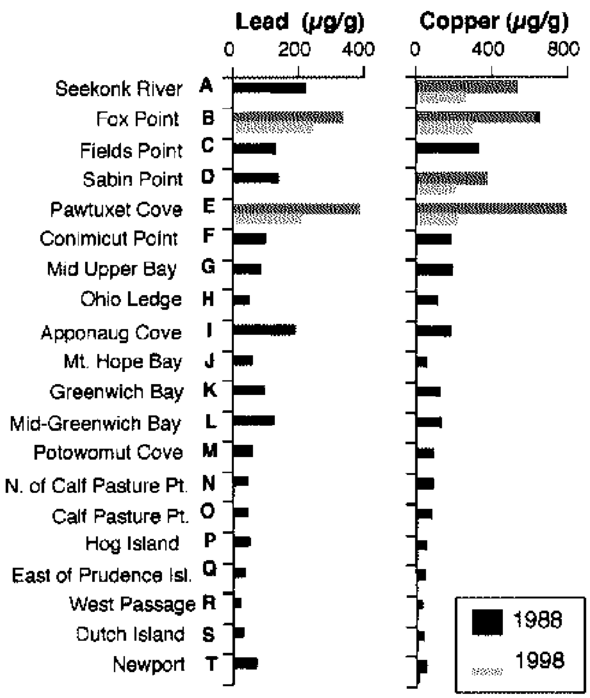
Toxic Hotspots

Because the survey was so extensive, researchers were able to identify several new "hotspots" (locations with high levels of contaminants). For example, two sites, one in the Barrington River and one in the Taunton River, had high values for the pesticide DDT, even though DDT has been banned since 1972. Both sites are near salt marshes, which may have been sprayed with DDT in the past.

A potentially serious mercury contamination problem was found in the Taunton River near Dighton, Mass. Most likely the mercury in these sediments is the legacy of a nearby chemical plant (now closed). Mercury is highly poisonous to both aquatic life and humans. GSO researchers will be conducting further studies to assess possible human health risks at this site.

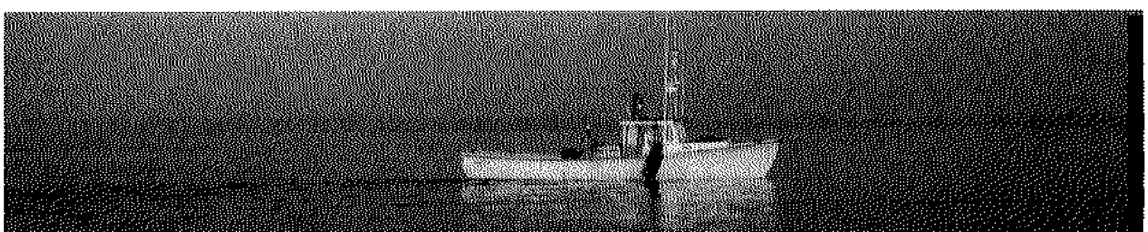
Contaminants in Shallow Bay Sediments, 1998 vs. 1988





Bay Window results (1998) are shown in blue. Levels for most metals have decreased in the Upper Bay since 1988. In the Lower Bay, differences are less dramatic and in some cases, such as lead, levels have increased slightly.

> *The fact that high levels of toxic contaminants lie buried just a few feet deep in Bay sediments gives rise to significant concern when dredging projects are proposed, particularly in highly polluted areas. Resuspending these substances could essentially bring back, at least temporarily, the conditions of the mid-20th century.*



Chris Deacutis/RIDEM

Deep Cores

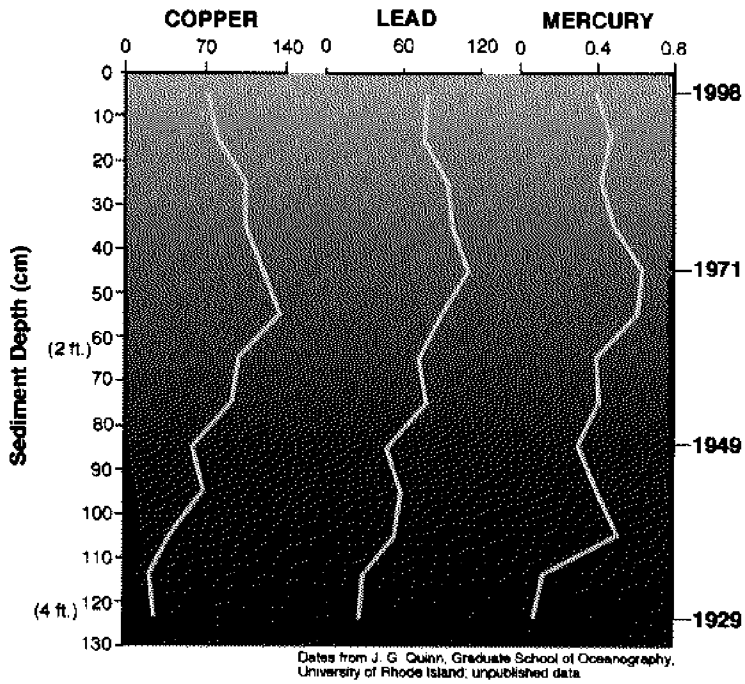
Deep core samples were taken at Apponaug Cove in Warwick, in the Seekonk River, and at a site near Quonset Point. All three cores tell essentially the same story: Most contaminants peaked in the 1950s, '60s, or '70s, then began a steady decline which continues to the present.

The sediment core from Quonset Point is especially interesting because it tracks the history of the Naval Air Station, which was built in 1940 and closed in the early '70s. Many metals and other contaminants were discharged into Narragansett Bay by the Naval Air Rework Facility, which refurbished aircraft during World War II and remained in operation until the late 1960s. The bottom of the Quonset Point core, 130 cm down (about 4.5 feet), corresponds to the late 1920s-early 1930s, before the base was built. Here the levels of contamination are low. The maximum levels for most metals occur 30 to 60 cm down (approximately the 1960s and '70s), after which there is a gradual but steady decline.

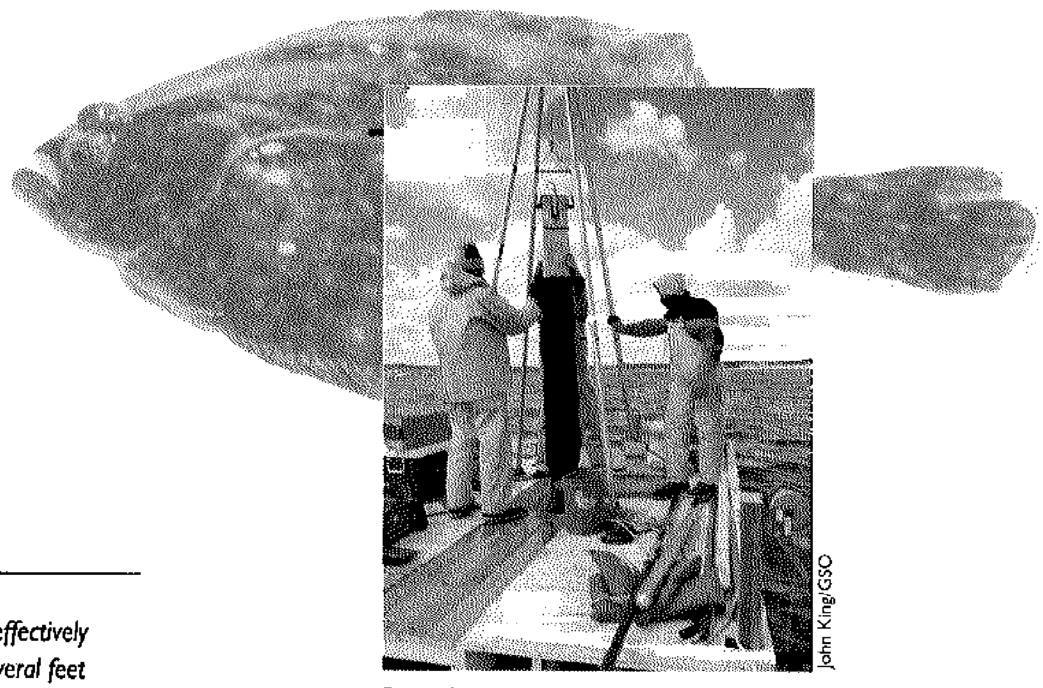
Even though far fewer pollutants are entering Narragansett Bay today than in the past, the fact that high levels of toxic contaminants lie buried just a few feet deep in Bay sediments gives rise to significant concern when dredging projects are proposed, particularly in highly polluted areas such as the Providence River. Resuspending these substances in the water column could essentially bring back, at least temporarily, the conditions of the mid-20th century, causing harm to Bay fish and shellfish, as well as to humans who eat them.

By digging into Bay sediments you can effectively look backward through time. A core several feet long bears witness to Rhode Island's industrial and cultural history going back a century or more.

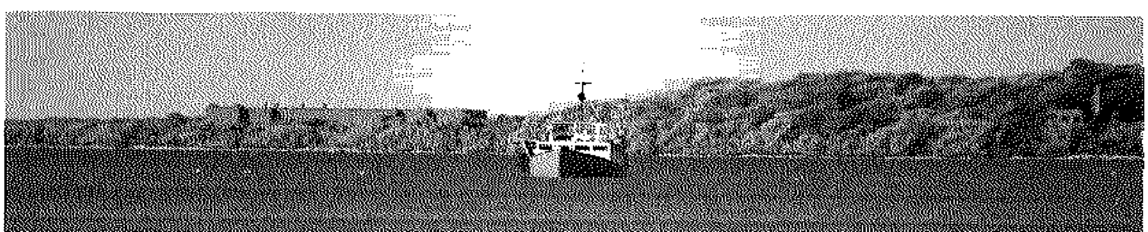
Trace Metals in Quonset Point Core Sediments
(all concentrations in µg/g)



Deep cores collected at Quonset Point reflect the site's history. Depth is indicated on the left side of the graph; approximate dates on the right. Maximum pollutant levels are found at depths corresponding to the 1960s and '70s.



Researchers collect a "freeze-core" sample by pushing a hollow metal box filled with dry ice and alcohol into the sediment. A core of sediment freezes around the outside of the box.

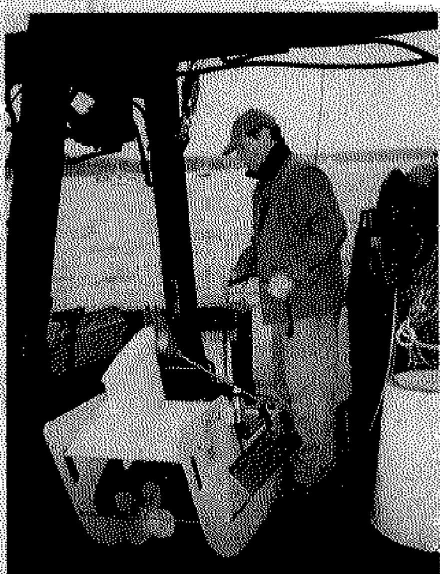


NEXT STEPS

In its first phase, the Bay Window has begun to bring Narragansett Bay into focus. By involving a diverse group of researchers and equipping them with state-of-the-art tools, the program is gathering information about the Bay at a scale and level of detail never before possible.

What's next? First and foremost, it is essential that Bay Window monitoring—by the NuShuttle, the sondes, the bottom trawls—be continued. "Our goal is very big," says Deacutis. "We're trying to understand how the whole system works."

The Bay is a highly complex ecosystem. It may be shifting due to climate changes. It is certainly affected by human activities. To answer major questions, such as why bottom fish haven't recovered, a much more complete picture of conditions is needed. It will take at least 10 years of data collection before real changes and trends are visible against the background of normal season-to-season and year-to-year variability.



Darlene Trew Crist

Pursue New Questions

The driving force behind the project is to develop a solid, comprehensive, long-term baseline, but the work is also paying dividends in short-term knowledge. We're finding that Narragansett Bay still holds plenty of surprises. New discoveries are raising new questions to be investigated, such as:

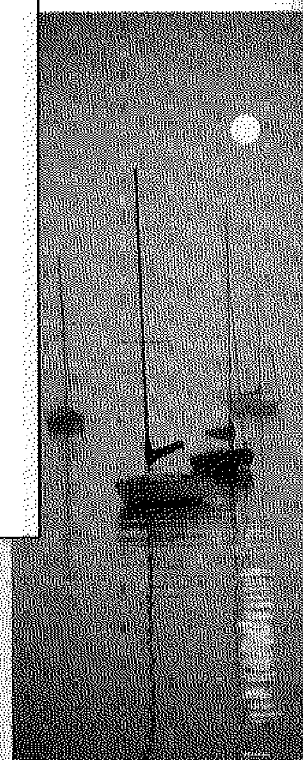
- *What factors are responsible for the recent change in annual phytoplankton bloom patterns?*
- *How much health risk is associated with toxic substances in Bay sediments?*
- *How widespread are low dissolved oxygen events and how long do they last?*
- *How often and in what locations does stratification occur, and how does this impact Bay life?*

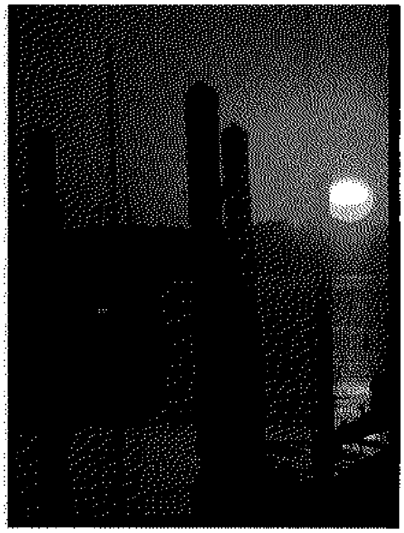
Website

An exciting next step, soon to be operational, will be the posting of Bay Window data on a Website (www.narrbay.org). Information from the sondes will be available on an almost real-time basis, much like an online weather report, allowing users to find out about everything from temperature, salinity, and dissolved oxygen to the locations of phytoplankton blooms. Current information on temperature and salinity conditions will be especially useful for fishermen. The site will also have links to other Bay-related Web pages, including maps, other data sets, surf reports, and recreational information.

Putting It All **Together**

The Bay Window program stands as a model for scientific assessment that can be replicated for other estuaries throughout the United States. Ultimately the data from all the Bay Window research will serve as the basis for a computer model that will predict the response of Bay animals and plants to changing physical and chemical conditions. "A long dataset is what will unlock the Bay's patterns," says Deacutis. Perhaps, 10 years from now, Narragansett Bay will graduate from being one of the "most-studied" estuaries to being the best-understood estuary in the world.





The Bay Window program relies on two key ingredients: state-of-the-art technology and scientific collaboration.

The Bay Window...the first time anyone has looked at the Bay at this level, at this resolution, with 21st-century technology.