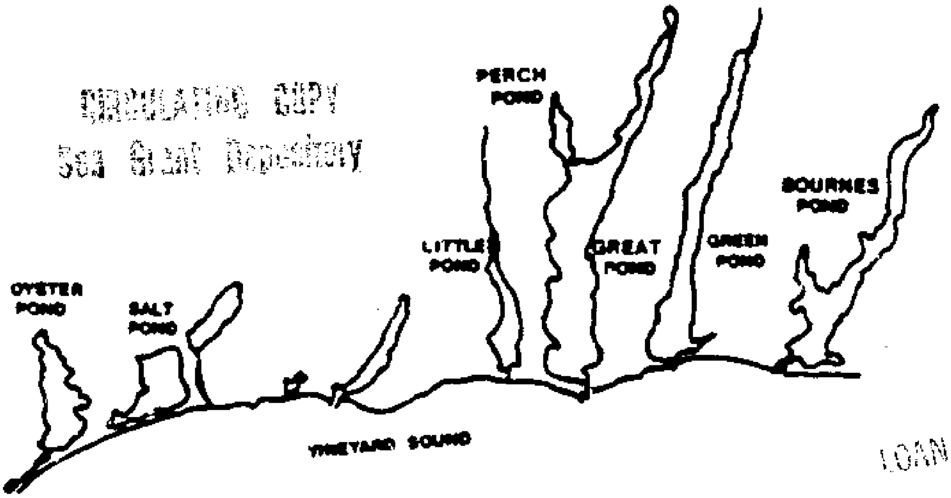
FALMOUTH POND WATCHERS

UPDATE ON 1991
CITIZEN VOLUNTEER MONITORING OF WATER QUALITY IN FALMOUTH'S COASTAL PONDS



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EXECUTIVE SUMMARY

The 1991 field season of the Citizen's Monitoring Project for Falmouth's Coastal Ponds was the most successful and productive to date, due primarily to the enthusiasm and dedication of Falmouth's Volunteer "Pond Watchers". Through their continued efforts, we now have five years of data on three of Falmouth's ecologically fragile coastal salt ponds (Oyster, Little and Green Ponds), and two summer's information on two additional ponds (Bournes and Great/Perch). This past year was a transition year in that the emphasis of the project is shifting to be more centered upon management and determining the effectiveness of management plans/projects as they are implemented. Also, 1991 was a "Special Projects" year in that in addition to the water quality sampling, fish sampling was conducted in each of the 5 main salt ponds. Another significant, although unplanned, special project was conducted as Hurricane Bob made his presence well known between our last two sampling dates.

The overall goals of the Pondwatch Project are:

1) to provide the Town of Falmouth with a data base of nutrient levels and nutrient related water quality of Falmouth's coastal ponds relative to the Coastal Overlay Bylaw;

2) to aid in evaluation of potential environmental management options for the ponds;

3) to provide a high quality independent evaluation of the impacts of both natural and man induced alterations (ex. changes to nutrient inputs or circulation) to the water quality of Falmouth's salt ponds;

4) to evaluate the effectiveness of implemented management programs aimed at protecting or improving nutrient related water quality, and;

5) to develop heightened public awareness of the cumulative impact of human activities on these ponds with the ultimate objective of fostering interactive partnerships between citizens, scientists and resource managers for maintaining the ecological health of these fragile coastal ecosystems.

This report is an interim summary of ongoing work since the 1991 Interim Report on Citizen Volunteer Monitoring of Water Quality in Falmouth's Coastal Ponds and includes review of this year's data in context with results from the project since its inception. In addition, a brief overview of a cost-effective short term remediation approach for Little Pond is included. It is becoming increasingly clear that, because of the large degree of environmental variability, the multi-year component of this effort is critical in providing accurate information on nutrient and oxygen conditions in these ponds for the development of long-term management strategies.

It is clear from the data that portions of these five Falmouth coastal salt ponds are undergoing varying degrees of nutrient related stress. In each of several years, major portions of all five ponds exhibited periodic water column stratification and periodic low oxygen and/or anoxia (hypoxia) events. The sensitivity of these systems to periodic hypoxia results from their estuarine circulation patterns and the high rates of oxygen consumption resulting from the large amount of nutrient stimulated organic matter production from phytoplankton and macrophytes. In all of the "finger" ponds (Green, Little, Bournes and Great Ponds), nutrient and oxygen conditions as well as water clarity showed a gradient of increasing quality moving from the headwaters toward Vineyard Sound. Nutrient and oxygen levels in the three salt ponds with multi-year data were not statistically different from previous years. However, it appears that nutrient levels may be increasing in some areas, Particularly Green Pond.

Oyster Pond, which had its inlet enlarged in 1990, did not appear to be significantly affected by this action. The lack of a change in Oyster Pond nutrient or salinity levels is most likely due to the partial blockage of the inlet by sedimentation soon after installation and soon after each clearing. The two "new" ponds, Bournes and Great Ponds, were most similar to Green Pond in both nutrient and oxygen levels, depth, stratification and water clarity, but had some areas of better water quality. The nutrient levels in Bournes and Great Ponds, with the possible exception of the stations directly adjacent Vineyard Sound, were in excess of 0.5 mg total nitrogen per liter and most of the area of each ponds exceeds Coastal Overlay Bylaw levels. It is also becoming clear that the areas of high nutrient concentration in all ponds generally have periodic low oxygen in bottom waters and have low species diversity of fish and invertebrates as indicated by our trapping study this past year.

The relative contribution of natural versus anthropogenic causes of this stress is being evaluated as a part of our efforts to provide information necessary for determining the potential success of a variety of remediative actions. The results from the Pond Watcher's efforts in concert with parallel scientific studies of these ponds now being conducted by WHOI-Sea Grant researchers are now beginning to provide the basis for designing data based management schemes not only for the Town of Falmouth, but for other coastal pond systems as well.

We are proud that the Falmouth Citizen's Monitoring Project has been selected for inclusion in both the 1991 and 1992 Environmental Success Index of the Renew America Program, a "unique clearinghouse of information that will be made available to policy makers, citizens' groups, private and public organizations, the media and individuals interested in finding solutions to environmental problems...being part of the ESI means that this program will be promoted as a model for others." The Pondwatchers have also just (1992) received a National Environmental Achievement Award from the National Environmental Awards Council, an honor considering the relatively short history and localized scale of this program.

INTRODUCTION

Pondwatch:

Since 1987, the Citizen Volunteer Monitoring Effort for Falmouth's Coastal Ponds (better known as the "Pond Watchers") has been providing much needed water quality data for the development of data-based management plans for now five coastal ponds in Falmouth, Massachusetts. Jointly sponsored by the Town of Falmouth and the Woods Hole Oceanographic Institution Sea Grant Program, this project represents a unique partnership between local citizens, town government and WHOI scientists whereby scientific information generated through the efforts of citizen volunteers under the guidance of WHOI scientists is applied directly (and immediately) to planning decisions for the town. The success of this project depends largely upon the efforts of a group of private citizens with wide ranging backgrounds and educational pursuits, all sharing a common interest in maintaining the health of their nearshore coastal waters. Perceived deterioration of water quality in Falmouth's nearshore coastal salt ponds, the first indicators of nutrient pollution along the coast, has led this group of "activist volunteers" to, rather than complacently observe, put their concerns into action through active participation in identifying and monitoring the nutrient related water quality of these systems (Figure 1).

Through this interactive partnership, valuable data and information is collected annually from many of Falmouth's coastal salt ponds in order to evaluate the current health of these systems as well as to develop, implement and determine the effectiveness of management strategies to improve/protect long-term water quality. With five years of monitoring we are now able to assess longer-term trends in the ecological health of these fragile coastal ecosystems, and with the 1991 data set in place have been developing science based management plans for these environments. With our existing data base and continued

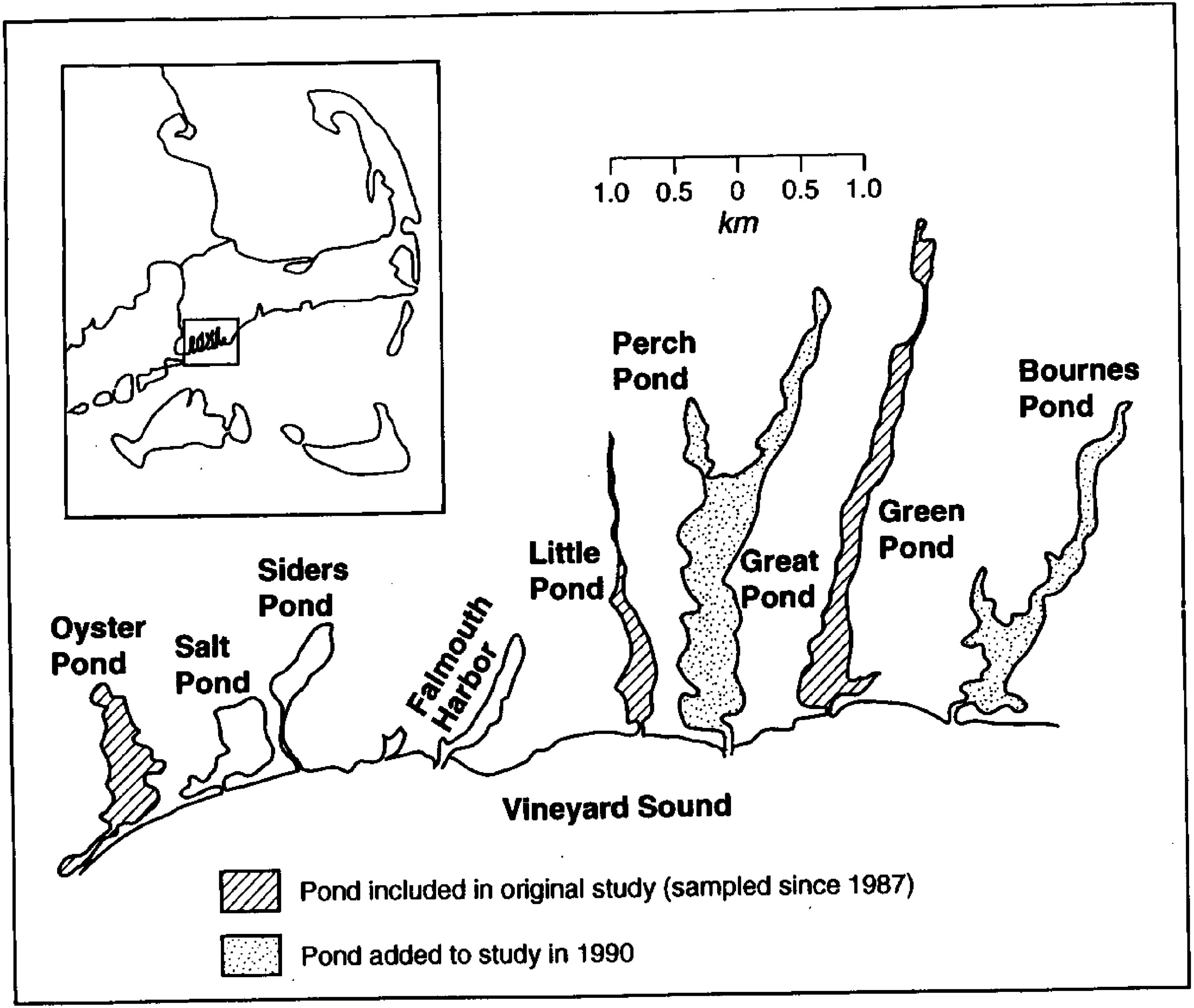


Figure 1. Relative locations of the coastal salt ponds in Falmouth, Massachusetts.

monitoring we are in a unique position both to detect continuing changes in the ecological health of these systems as a result of both long-term (chronic nutrient inputs) and short term (increased exchange with tidal waters via pond opening) alterations to the system. The value of these data bases cannot be understated in our efforts to understand and predict potential consequences of various sorts of management options for these sensitive nearshore environments. Equally significant, we are in a position to gauge the effectiveness of implemented management plans as we continue to monitor, a position nearly unique in any coastal area (Figure 2). The lack of comparable data for coastal embayments is underscored by the growing scientific interest in this project as one of the only long-term data sets available for these systems.

The goals of the project are:

1) to provide the Town of Falmouth with a data base of nutrient levels and nutrient related water quality of Falmouth's coastal ponds relative to the Coastal Overlay Bylaw;

2) to develop and evaluate various potential environmental management options for the ponds;

3) to provide a high quality independent evaluation of the impacts of both natural and man induced alterations (ex. changes to nutrient inputs or circulation) to the water quality of Falmouth's salt ponds;

4) to evaluate the effectiveness of implemented management programs aimed at protecting or improving nutrient related water quality, and;

5) to develop heightened public awareness of the cumulative impact of human activities on these ponds with the ultimate objective of fostering interactive partnerships between citizens, scientists and resource managers for maintaining the ecological health of these fragile coastal ecosystems.

APPROACH TO SCIENTIFICALLY BASED MANAGEMENT

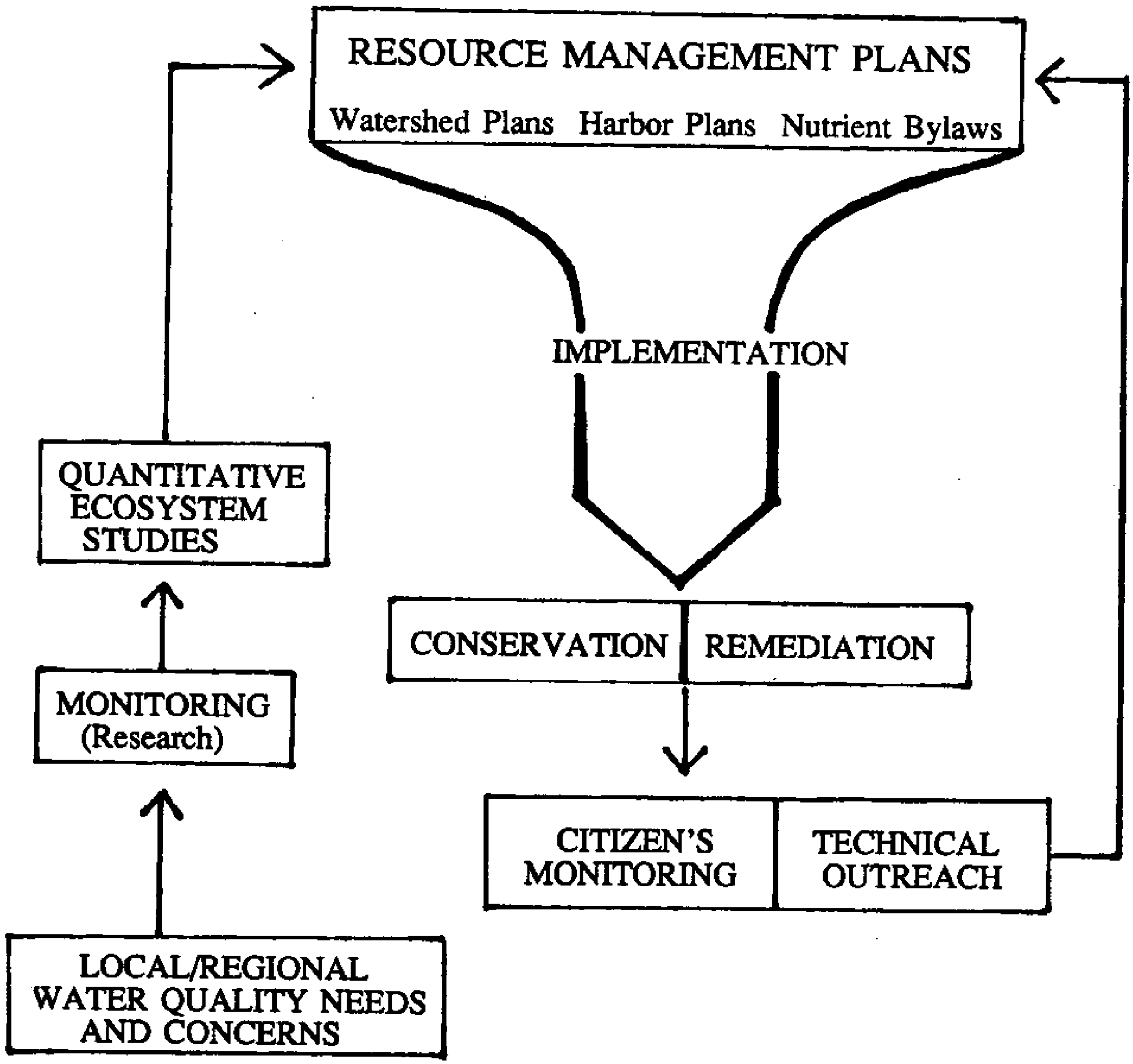


Figure 2. Schematic of scientifically based management for Falmouth's coastal ponds.

The Citizen's Monitoring Effort is unique in its partnership approach to addressing the ecological and economic consequences of coastal eutrophication. Techniques and methods used by the Pond Watchers have been specifically designed so that virtually any coastal community can undertake this type of effort efficiently but at low cost. This cooperative project has been cited by Renew America as an innovative model program, and this year received a National Environmental Achievement Award from the National Awards Council. In support of this concept, the Falmouth Pondwatch Project is being used as the model for the upcoming (1992) EPA Bays Program/Buzzards Bay Project citizen's monitoring program for the embayments of Buzzards Bay.

Steadily increasing nutrient inputs, resulting primarily from on-site septic systems, fertilizers and runoff associated with increased coastal development poses a serious long-term threat to the health of our coastal environments. Our limited understanding of the impact of nutrient overload to these systems, and of remediation measures to deal with the detrimental effects of overload, has created serious obstacles for the development of successful land management practices for these systems. Coastal salt ponds, because of their large shoreline area and generally restricted circulation and flushing, are usually the first indicators of nutrient pollution along the coast, especially for nutrients entering via groundwater such as nitrogen resulting from residential development with on-site septic disposal. These systems, by their nature, are highly productive, nutrient rich environments frequently providing suitable habitat for many species of commercially and recreationally valuable fish and shellfish. Although quite tolerant to high nutrient conditions, the delicate balance of these systems can be upset by excessive nutrient inputs resulting in the overfertilization (or "eutrophication") of these waters. Most all of Falmouth's coastal salt ponds presently show some signs of nutrient overenrichment. Portions of four in particular, Oyster, Little, Great and Green Ponds indicate signs of advanced eutrophication, with periodic dense algal blooms, malodorous conditions and occasional fish kills from low oxygen conditions resulting from nutrient related oxygen depletion in bottom waters. Although it is often difficult to separate the results of natural processes from those induced by man, increased nutrient conditions resulting from excessive loading due to human activities will certainly result in declining water quality in these sensitive coastal ecosystems.

This program has been extremely successful on several fronts. First, it has provided a data base for the Town of Falmouth that can be used to evaluate its newly enacted Coastal Pond Nutrient Overlay Bylaw, a plan which identifies nutrient threshold limits for each independent ecosystem. Information generated by the citizen volunteers has shown that some of the ponds currently exceed these threshold values, a finding needed for management decisions regarding these systems. Second, because of the large number of participants, the Pond Watchers can conduct simultaneous sampling at all sites under the same conditions of weather and tide, crucial to making site to site comparisons in these complex ecosystems. Third, the Pond Watchers provide physical data and samples for the ongoing scientific studies of coastal nutrient cycling at WHOI, an effort which would not otherwise be possible under the constraints of funding and available manpower. Equally significant, the nearly unique (multiple pond and multi-year) information generated by the program would not be generated if "experts" (researchers, State or Federal agencies) were to conduct all of the work because of the expense. The joint effort between scientists and the community has kept costs low and created a conduit for immediate transfer of environmental information to local government and an activist citizenry. The end result has been increased public awareness of the fragile nature of our coastal ecosystems not only among the Pond Watchers, but the local and regional community as well.

Management:

Increasing our understanding of these coastal salt ponds, as well as the relative success or failure of remediative measures to improve water quality in these systems, allows us to better predict the potential impacts which may result from alteration of one or more of the dominant processes which structure the system such as nutrient inputs or losses. The information resulting from this project is providing quantitative information for the development of site-specific management plans crucial to protecting the economic, aesthetic and recreational value of Falmouth's embayments and coastal salt ponds. Maintaining healthy ecological systems goes well beyond the economic benefits of harvest and recreation. The cost of remedial projects, such as those undertaken for Bournes Pond, New Bedford Harbor and Boston Harbor can be extremely expensive, ranging from multi-million to even billion dollar efforts. By better understanding these ecosystems as well as the impact of human activities on their environmental health, we may help to avert the need for expensive remediation measures before they become necessary, and if necessary we will be able to recommend appropriate cost effective remediation options.

The role of the scientists in this study is to oversee the project in terms of sample collection and analysis, and to synthesize the data within the proper ecological context. The framework for this ecological context is based upon ongoing studies in Dr. Howes' laboratory which involve coastal nutrient cycling in systems ranging from larger more open coastal systems such as New Bedford and Nantucket Harbor to permanently ice covered stratified eutrophic marine lake systems in Antarctica. These associated projects are providing valuable information with which to better understand and interpret the results from the Citizen's Monitoring Project. One of the unexpected benefits of this program has been the cooperation and communication it has generated among research scientists, citizens and local government, demonstrating the wealth of untapped energy and dedication of private citizens to environmental conservation.

The direct application of data to management through close communication with the Town is especially effective in providing a data base for the Town from which to evaluate its newly enacted Coastal Pond Nutrient Overlay Bylaw. The Bylaw is a land use management plan which limits additional nutrient inputs beyond threshold levels for each embayment and a plan now being considered for implementation for many coastal communities (Bourne and Wareham). The project has stimulated interest in the local citizens for their ability to directly affect management decisions regarding the future preservation of their valuable coastal resources both through direct participation in sampling as well as public presentations to explain and present the data from the study, providing an educational medium as well as an avenue for dissemination of the results of this work. The information from this effort is reaching beyond the participants by presentations to community organizations, local and regional governments, as well as across the country through participation in national meetings on citizen's monitoring of the environment.

For a coastal community, water quality has both direct and indirect economic benefits. The health of valuable natural resources such as recreational and commercial fish and shellfish species depends on the environmental health of coastal ecosystems. Similarly, poor water quality conditions seriously affect the desirability of a coastal area for the tourist industry as well as the value of real estate properties on or near these systems, thus potentially impacting an important economic resource for many of these towns. The continuing partnership between citizens, managers, scientists and local government to monitor the health of Falmouth's salt ponds for the development, implementation and maintenance of environmental management plans is our best and most cost-effective method for maximizing the ecological and economic benefits of these important coastal resources. By better understanding these ecosystems as well as the impact of human activities on them, we may help avert the need for expensive remediation measures before they become necessary, and if necessary we will be able to recommend appropriate and effective remediation options.

STATEMENT OF THE PROBLEM

Eutrophication is the natural response of coastal aquatic systems to excessive nutrient loading. Eutrophic conditions are caused by high nutrient inputs into coastal waters which severely impact the environmental health of coastal systems, in some instances resulting in water column anoxia, fish kills, and loss of valuable eelgrass and shellfish beds. Nitrogen is generally the nutrient limiting phytoplankton and algal productivity in marine systems, and increasing the availability of nitrogen will stimulate production of these microscopic plants in these systems, much like fertilizer additions to a garden. The subsequent deterioration of coastal waters therefore is not directly the result of nutrient loading, but rather a secondary effect of the resulting overproduction of phytoplankton and submerged aquatic plants. As these plants respire at night and ultimately die and decay, oxygen is consumed and may become severely depleted in the bottom sediments and water column. It is this oxygen depletion that is ultimately responsible for the detrimental effects of excessive nutrient loading in coastal ecosystems.

Of the various forms of pollution that threaten coastal waters (nutrients, pathogens and toxics), nutrient inputs are the most insidious and difficult to control. This is especially true for nutrients originating from non-point sources, such as nitrogen transported in the groundwater from on-site septic treatment systems or lawn fertilizers. These introduce nitrogen to groundwater primarily as nitrate, which passes generally unaltered to the sediments underlying ponds and coastal waters. At the sediment/water interface at the bottom of a salt pond or harbor, the nitrate either passes up into the harbor (where it is available for plant uptake), or may be "detoxified" by a natural community of denitrifying bacteria which release the nitrogen as harmless nitrogen gas. How nitrate input is partitioned between these processes determines its effect on the biological activity and environmental health of a receiving water body. Once in the water column, the impact of a one-time input of nitrogen may be magnified many times over depending on how many times the nitrogen cycles between sediments and overlying waters column. The re-release of nitrogen after algae and phytoplankton (whose growth has been stimulated by the initial availability of nitrogen) die and decompose results in the nitrogen once again becoming available for production. Accumulated both organic and inorganic nitrogen within pond sediments may act as a "storage battery" for nutrients, continuing to provide a source of nitrogen for biological production even though the original inputs may have diminished or ceased. How many times the nitrogen cycles between sediments and the water column before being flushed out to the ocean or buried permanently in the sediments is directly related to the potential for eutrophication. Eutrophication resulting from overproduction of organic matter due to excessive nutrient loading ultimately impacts oxygen conditions. High nutrient levels are frequently associated with depletion of oxygen, potentially to the point of limiting or prohibiting survival of benthic infauna, shellfish and fish in these waters. Through the efforts of the Pond Watchers we now have several years of data on these parameters, enabling comparison of nutrient and oxygen conditions between ponds on time scales relevant to potential changes in development related inputs.

By providing a sustained data base on nutrient conditions in Falmouth's coastal salt ponds, the Citizen's Monitoring Project is enabling consolidation of several parallel investigations on nutrient cycling and water quality in these ecosystems, permitting application of new results from each effort to the range of environments found in each of the monitoring ponds and in effect multiplying the value of each project. Because the

Pondwatchers are currently monitoring a range of coastal pond systems encompassing a variety of nutrient loading conditions and flushing regimes, information gained from this effort can now be applied to a wide range of coastal pond ecosystems found in the region.

BRIEF HISTORY OF THE PROJECT

The Citizen's Monitoring Project was spawned from a cooperative effort begun in 1987 between the Town of Falmouth, The Woods Hole Oceanographic Institution (WHOI) Sea Grant Program and the research laboratory of Dr. Brian Howes in the Biology Department of WHOI. Concerned over the apparent continued degradation of water quality in its coastal salt ponds, the Town of Falmouth (through the Falmouth Planning Board) provided $5,000 as "seed money" toward initiating a water quality study of the ponds. These funds were then substantially augmented through the efforts of Dr. David Ross, coordinator of the Woods Hole Oceanographic Institution Sea Grant Program as well as a Town Meeting Member, with funding from the Sea Grant Program of NOAA, as well as with continued support from the Town.

The goals of the study were to provide the Town with information on current water quality conditions in the ponds, data critical to assessing and developing intelligent management actions to insure the protection of these fragile coastal ecosystems. In addition, the project was designed to involve local citizens directly in determining the present and future ecological health of these systems, as well as to draw community attention to the increasing human pressures on our fragile coastal resources. The value of this information became more important with the inception of a Coastal Pond Overlay Bylaw enacted by the Town in 1988, specifying annual mean threshold values for total nitrogen concentrations in Falmouth's coastal ponds. The Bylaw specified limitations of 0.32 mg total nitrogen per liter for "High Quality Areas," 0.50 mg per liter for "Stabilization Areas," and 0.75 mg per liter for "Intensive Water Activity Areas." Comprehensive data from the Citizen's Monitoring Effort would now provide crucial information far too expensive to be provided by limited Town budgets to verify the validity of these threshold values as well as provide the Planning Board with information to interpret this new Bylaw.

Parallel with the inception of the Citizen's Monitoring Project was the initiation of a more detailed scientific investigation of one of the monitoring ponds, Little Pond, by Dr. Howes' laboratory to provide in depth understanding of the processes controlling nutrient cycling and the impact of additional nutrient inputs on salt pond ecosystems. As this parallel study nears completion, we are now able to apply the information from this detailed study to management objectives for all of Falmouth's ponds. In addition, the consequences of pond management are being investigated as related to Falmouth's salt ponds in a WHOI Coastal Research Center/Sea Grant study of Sesachacha Pond, Nantucket. Sesachacha Pond is a eutrophic coastal salt pond historically opened one or two times per year to exchange with the sea, but which was left unaltered for 10 years and only recently been reopened. This pond is providing supplemental information on the efficacy of circulation management on improving salt pond environmental conditions. It has been our contention that given the great expense and limited financial resources available for remediation made necessary by excessive nutrient loading that a priori assessment of the potential efficacy of each management option is essential.

SAMPLING LOGISTICS AND EQUIPMENT

Prior to the commencement of field sampling each year, the Pond Watchers are given a refresher course on sampling procedures and information on additional "Special Projects" to be undertaken that year. Pond Captains for each pond are then responsible for distribution of sampling equipment to each of the sampling teams for the season. The individual Pond Captains are:

Oyster Pond -	John Dowling
	Julie Rankin
Little Pond -	Jack Shohayda
Upper Green Pond -	Frank Souza
Lower Green Pond -	Edmund Wessling
	Armand Ortins
Upper Bournes Pond -	Jim Begley
	Steve Molyneaux
Lower Bournes Pond -	John Soderberg
Upper Great Pond -	Herb Stern
Lower Great Pond -	Dick Erdman

Sampling equipment consists of a sampling kit with: Secchi disk fastened on a fiberglass measuring tape; color wheel for phytoplankton identification; thermometer; filters, syringes, filter forceps and in-line filter holders for field processing of nutrient samples; oxygen kit, maps, data sheets, instruction sheets, waste reagent container, pens and pencils; and other miscellaneous items of need such as clippers for opening reagent pillows, etc. Coolers for transporting and storing samples are provided as well as instruments for collection of water samples; because of the presence of deep basins in Oyster Pond, Niskin bottles were used there, pole samplers with bottles attached at fixed depths were used for the four other shallower ponds. For specific measurements such as rainfall, electronic rain gauges were purchased and installed at the homes of Bob Livingston (Oyster Pond), Robert Roy (Little Pond) and Ed Wessling (Green Pond). Rainfall amounts have been recorded on a daily basis by these conscientious Pond Watchers since August 1988 and are compiled with records maintained at a permanent weather station located at nearby Long Pond. In addition, tide gauge and water column light transmission stations were established on Little Pond at the homes of Joe Johnson and Robert Roy. The additional effort of these individuals above and beyond the routine collection of samples and physical measurements has provided ancillary data tremendously useful in interpreting the results of the monitoring effort.

Within each pond, sampling stations were located on the basis of a preliminary water quality survey, attempting to represent major ecological and physical zones within each pond. Samples are collected from each station with depth profiles made at stations deeper than 0.5 meters. These depth profiles are critical in identifying potential stratification events as well as in generating an overall understanding of the individual ecosystems. The number of stations at each pond are as follows: Oyster Pond - four; Little Pond - four; Green Pond - six; Bournes Pond - six; and Great Pond - six with an additional reference station in Vineyard Sound. On a given sampling, 27 stations must be sampled nearly simultaneously.

The selection of pre-determined sampling dates is based upon the compilation of the previous data. The sampling dates focus on periods potentially sensitive to eutrophication events. As in 1990, the 1991 sampling dates were chosen to more closely identify nutrient conditions during summer months when warmer weather results in increased biological activity and increased probability of low oxygen events. Results from previous samplings indicated that the annual variation in nutrient levels was within the range encountered during summer sampling alone and that for the 15 stations where two annual cycles were measured, the average summer total nitrogen values were the same as those in winter (with the exception of stream samples). The result is that summer sampling should give a good average view of nutrient levels and an estimate of the occurrence of low oxygen events. This is important because even periodic brief low oxygen events can significantly alter benthic animal populations so that knowing the lowest level of oxygen rather than the annual average is what is needed for environmental evaluation.

Four Pond Watcher samplings were conducted in 1991: July 14, July 28, August 11 and September 8. Cooperative weather conditions enabled sampling on the first three pre-scheduled dates, however the appearance of Hurricane Bob required (justifiably so) rescheduling of the last sampling. After early morning consultation between project coordinators and Pond Captains, the Pond Captains released their individual teams previously equipped for sampling. All teams sampled their stations nearly simultaneously (± 2 hrs) to make sure samples were collected during the same conditions of weather and tide. Simultaneous sampling of all sites is crucial to enabling site to site and pond to pond comparisons and was made feasible only through the large volunteer effort of the Pond Watchers. After sampling, coolers containing samples and data sheets were turned in to the Pond Captains for transfer to the Woods Hole laboratories for subsequent chemical and data analyses.

The following measurements and assays were conducted on each sampling (O = On Site; L = Lab):

Physical Measurements:
- (O) Total Depth
- (O) Temperature
- (O) Light Penetration (Secchi disk)
- (O) Water Color
- (O) Rainfall

Chemical Measurements:
- (L) Nitrate + Nitrite
- (L) Ammonium
- (L) Dissolved Organic Nitrogen
- (L) Particulate Organic Nitrogen
- (L) Total Dissolved Nitrogen
- (L) Phosphate
- (L) Oxygen Content
- (L) Salinity
- (L) Chloride
- (O/L) Periodic Sulfide and Chlorophyll

In addition, Pond Watchers record observations of pond state, weather and wind conditions, and any other pertinent information which may later prove useful to interpretation of the data such as algal blooms or unusual odors.

SPECIAL PROJECTS

"Special Projects" are conducted each year to gather information of a non-routine monitoring nature but which are useful either to interpret monitoring data, or assess directly habitat quality for animals and plants within the ponds. The linkage of nutrient based studies with direct habitat assessments provides a powerful tool for refining the critical nutrient levels required for maintaining the plant and animal resources. In previous years, the Pondwatchers have conducted oyster growth experiments, detailed profiling of Oyster Pond, and continue to operate in a "rapid response" mode when fish kills or other low oxygen events trigger non-routine water sampling.

In 1991, several Pondwatchers participated in a fish survey as our major "Special Project" for that year in order to gain some insight into the populations of mobile aquatic species living within each one of the ponds. Each participant was responsible for two traps, a large baited box trap and a smaller minnow trap. Surveys were conducted four times in 1991 coinciding with the water quality sampling dates. Baited traps used squid for the first three samplings and herring for the fourth sampling. Traps were set 24 hours before collection, and catch was emptied into coolers (large trap) or bags (small trap) for return to the Woods Hole labs for sorting and identification.

The "Pond Trappers" were:

Oyster Pond 1	--	Barry Norris
Oyster Pond 3	--	Stan Hart
Little Pond 1	--	Bob Rogers
Little Pond 3	--	Jack Shohayda and Jane Carter
Green Pond 2	--	Matt Adamczyk
Green Pond 5	--	Armand Ortins
Bournes Pond 2	--	David Thomas and John-David Thomas
Bournes Pond 6	--	Jon Soderberg and Alicia Soderberg
Great Pond 2	--	Herb Stern
Great Pond 6	--	Dick Erdman and Jayne Hartnett

Identification and sorting of catch was conducted by Bob Livingston with assistance from John-David Thomas, Alicia Soderberg and Jason Fink.

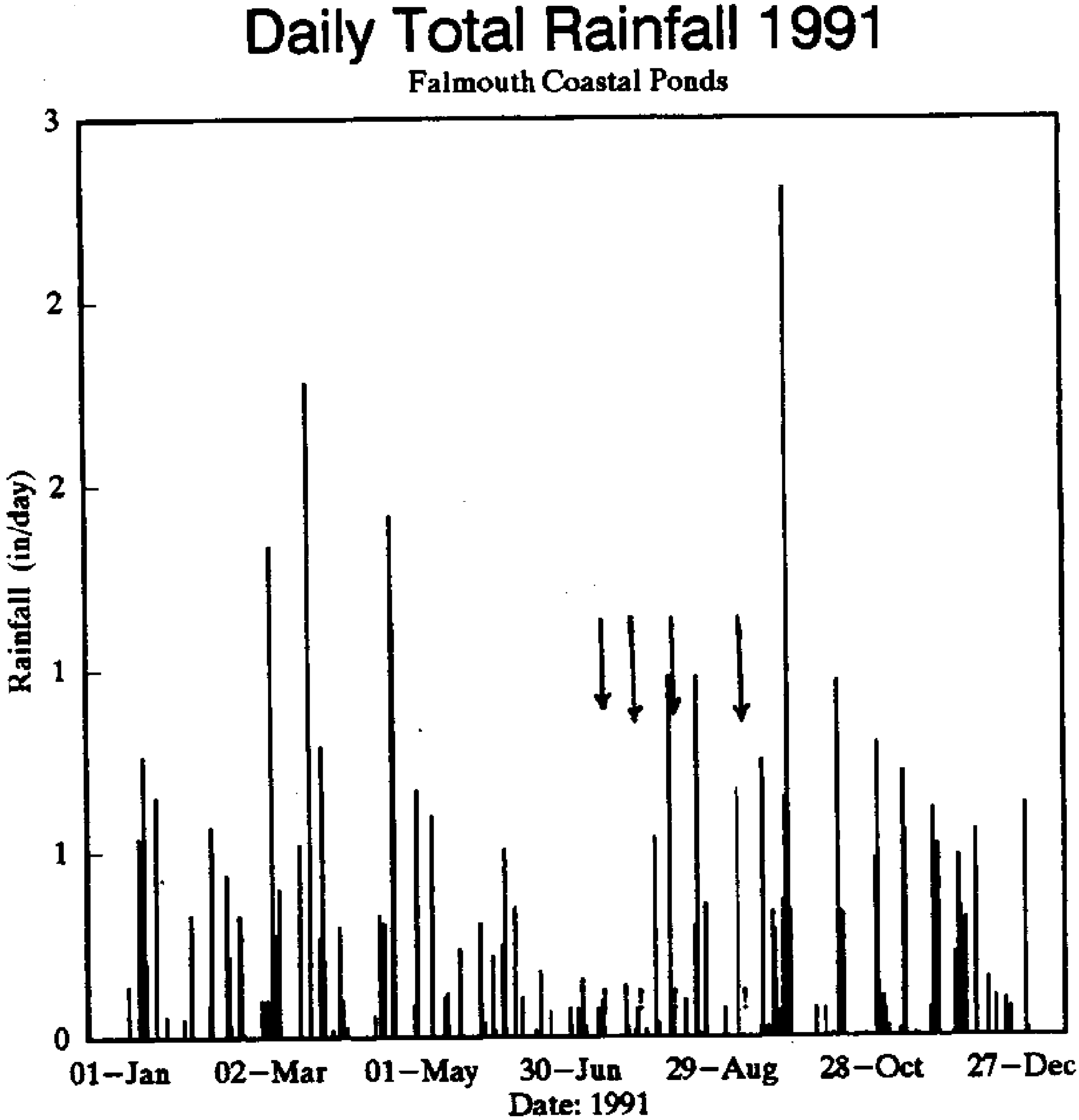
RESULTS AND DISCUSSION

The sampling program in 1991 went exceedingly well, and undaunted as always, the Pondwatchers returned to sample their stations after Hurricane Bob. Approximately 2000 chemical assays (each in duplicate) and 1000 physical measurements were conducted in the monitoring effort in 1991 alone. In addition, individual rainfall records were kept for Oyster, Little, and Green Ponds, a tide gauge was maintained on Little Pond, and a fish trapping census of the upper and lower reaches of each pond conducted.

It is becoming increasingly clear that nutrient and oxygen levels within the ponds are highly variable both spatially and temporally. Our data from all five ponds indicate that a two-fold variation between samplings is not unusual. These results stress the importance of multiple samplings and longer-term data collection for assessing nutrient related water quality in these systems.

One of the environmental factors contributing to the observed variation in nutrients and oxygen levels is rainfall. Large rain events appear to be associated frequently with low oxygen events, and relatively unflushed ponds like Oyster Pond may exhibit salinity fluctuations related in part to annual rainfall. Pond sampling was by chance conducted both after periods of high and low rainfall (Figure 3). At present the relative importance of amount of rain versus extent of low light conditions (which co-occur with rainfall) in triggering low oxygen events is not clear, however comparing our five ponds in 1990 and 1991 the major low oxygen events in both years appear to be associated with these conditions. However, not all such weather events were associated with low oxygen. As more data accumulate, we continue to work toward developing methods to predict the meteorological conditions which result in low oxygen events in the various salt pond areas.

The bathymetries of the five ponds are in keeping with their different modes of formation: Green, Little, Bournes and Great Ponds by groundwater sapping of glacial outwash versus Oyster Pond (and Perch and Salt Ponds) from kettle holes. The "finger" ponds tend to be long, narrow and shallow with generally uniform depths of 1-2 m, while kettle ponds (freshwater ones as well) tend to be more circular and deeper (eg. Oyster Pond, 6 m).

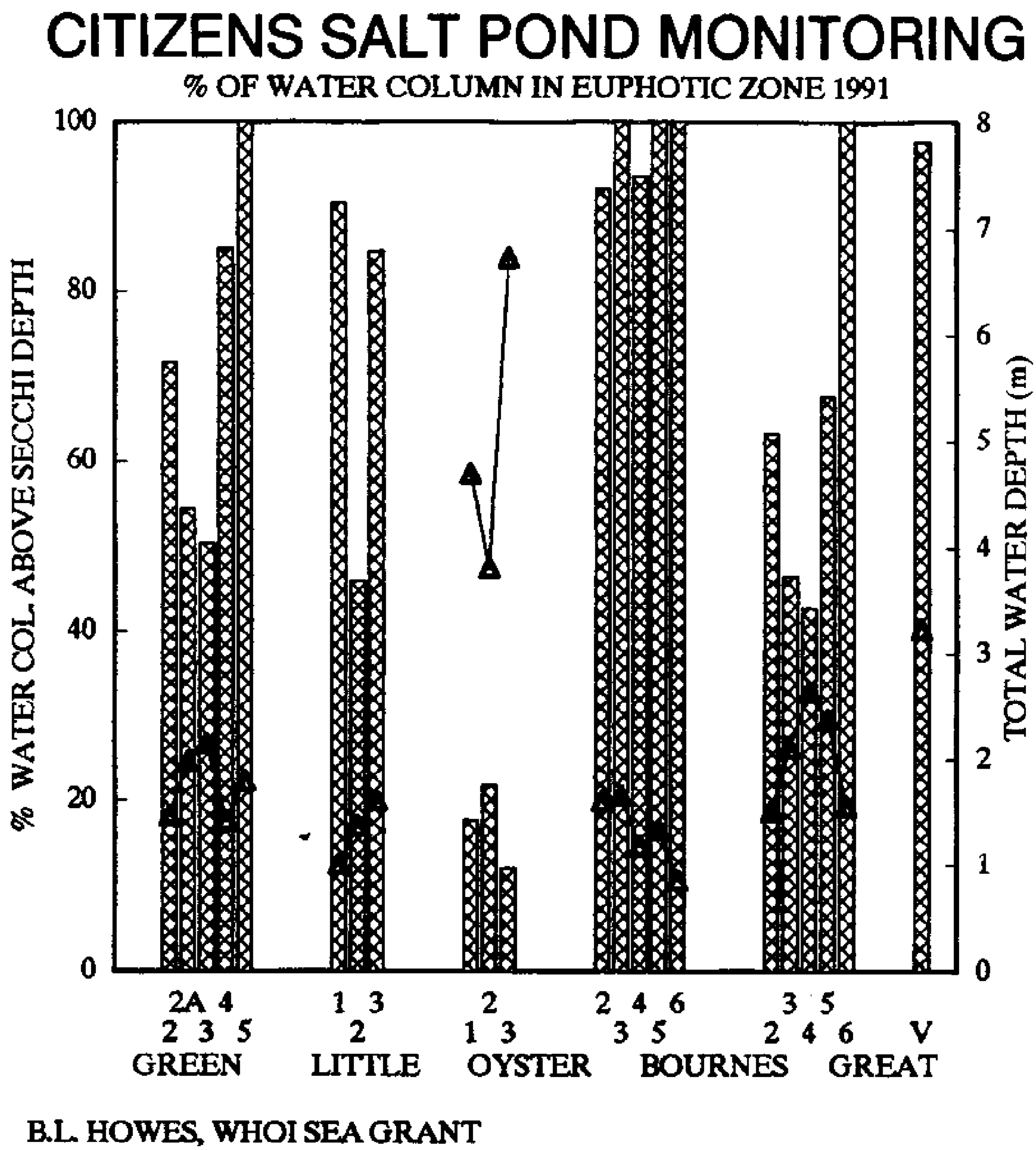


WHOI Sea Grant Pond Watchers
Arrows indicate 1991 pond samplings.

Figure 3.

An important consequence of the eutrophic state and water depth of the ponds is that light is generally attenuated before reaching the bottom where it could support benthic algae (Figure 4). Given the depth of the Oyster Pond and Perch Pond (Great Pond Station #4) stations of greater than 3 m, it may seem reasonable that they have limited light penetration. However, at a similar depth the Vineyard Sound station (3.3 m) generally has light reaching the bottom. In fact, in general most of the relatively shallow Green, Great and Little Ponds also have similarly limited light penetration. It appears that the water column at most of the stations by mid-summer are supporting large phytoplankton populations consistent with the measured high particulate organic nitrogen and carbon concentrations. It is likely that it is this high plant productivity resulting from the nutrient rich waters which is causing the measured light attenuation. It may even be that the high phytoplankiton biomass partially inhibits macroalgal production in some areas, even in these generally shallow ponds. We will be investigating the phytoplankton-light-macroalgae interactions further since macroalgal production can have deleterious ecological consequences to coastal salt pond systems.

One consistent feature of all of the ponds is the increasing salinity moving from the inland headwaters toward Vineyard Sound (Figure 5). Green, Little, Bournes and Great Pond are for the most part saline ponds with average salinities above 25 ppt. The average summer salinity gradients from head to mouth in the ponds measured this past year are slightly less than in previous years due to the effects of Hurricane Bob. It appears that the very high tides and almost no rainfall associated with Bob increased the amount of salt water contribution to the upper regions of the ponds. This can be best seen when we compare the average chloride (sodium chloride) concentrations in pond waters before versus after the Hurricane (Figure 6). The stations below the 1:1 line have higher salinities days after Bob passed through. Oyster Pond (Figure 7) due to its restricted tidal exchange hence low salinity waters was the most sensitive indicator of this effect. The bottom waters of the pond



CITIZENS SALT POND MONITORING
% OF WATER COLUMN IN EUPHOTIC ZONE 1991
% WATER COL. ABOVE SECCHI DEPTH
TOTAL WATER DEPTH (m)
0
20
40
60
80
100
0
1
2
3
4
5
6
7
8
2A 4
2 3 5
GREEN
1 3
2
LITTLE
2
1 3
OYSTER
2 4 6
3 5
BOURNES
3 5
2 4 6
V
GREAT
B.L. HOWES, WHOI SEA GRANT

Figure 4.

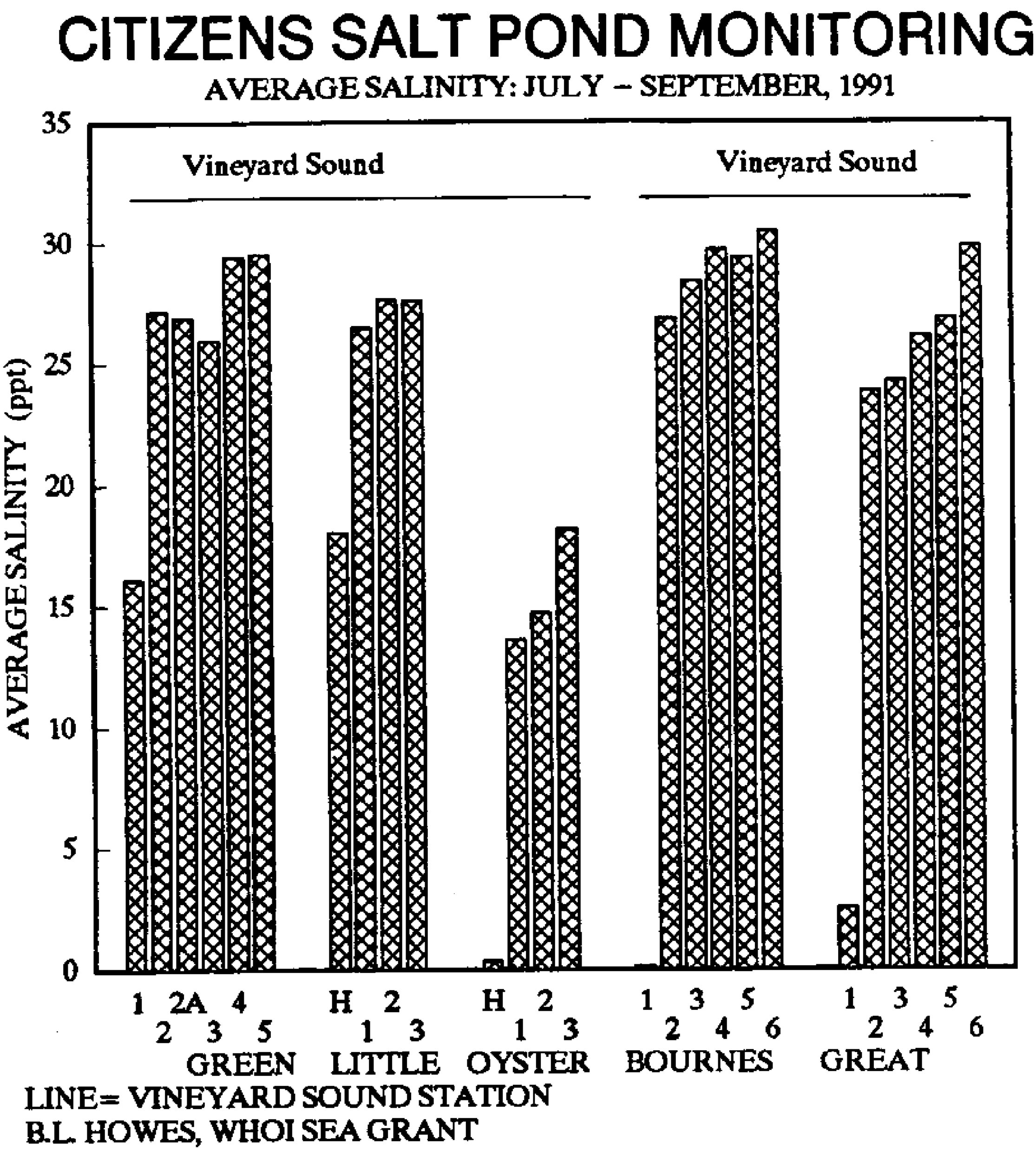
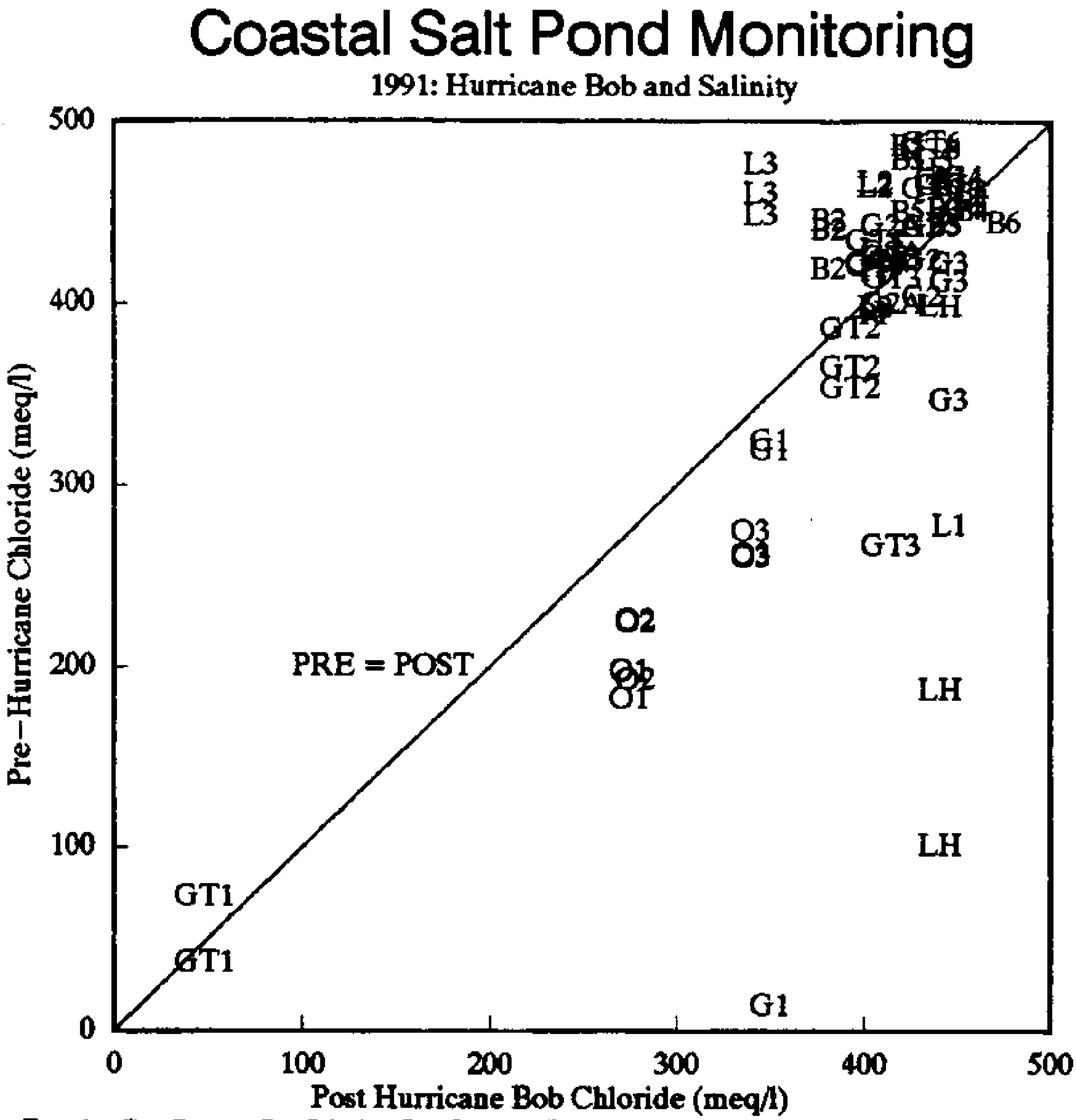

CITIZENS SALT POND MONITORING
AVERAGE SALINITY: JULY – SEPTEMBER, 1991
Vineyard Sound
Vineyard Sound
AVERAGE SALINITY (ppt)
35
30
25
20
15
10
5
0
1 2A 4
2 3 5
H 2
1 3
H 2
1 3
1 3 5
2 4 6
1 3 5
2 4 6
GREEN LITTLE OYSTER BOURNES GREAT
LINE= VINEYARD SOUND STATION
B.L. HOWES, WHOI SEA GRANT

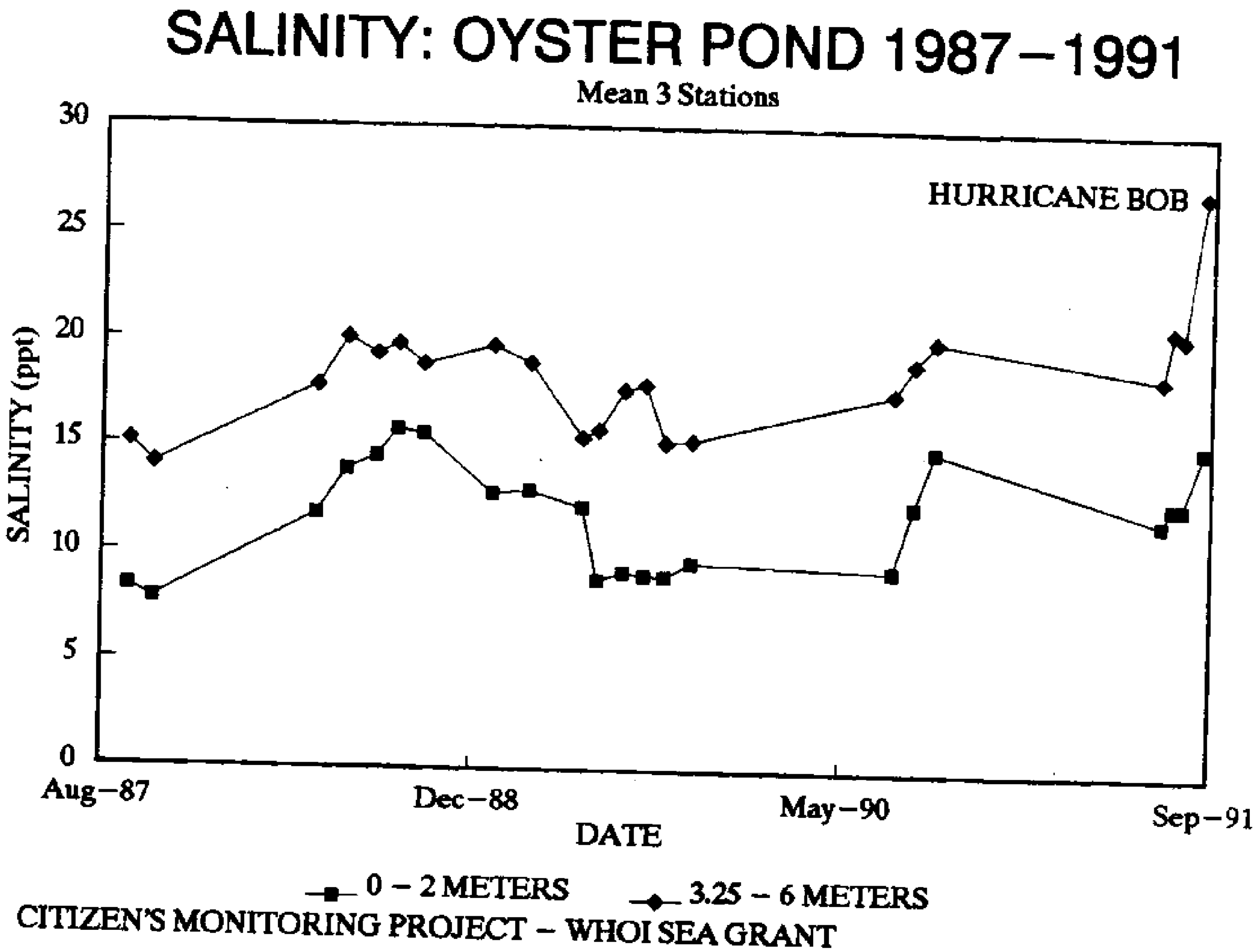
Figure 5.



Ponds: G=Green, L=Little, O=Oyster, B=Bournes, GT=Great, P=Perch, VS=

Values BELOW the 1:1 line indicate FRESHER water BEFORE Hurricane Bob.

Figure 6.



SALINITY: OYSTER POND 1987–1991
Mean 3 Stations
SALINITY (ppt)
30
25
20
15
10
5
0
HURRICANE BOB
Aug–87
Dec–88
May–90
Sep–91
DATE
0 – 2 METERS
3.25 – 6 METERS
CITIZEN'S MONITORING PROJECT – WHOI SEA GRANT

Figure 7.

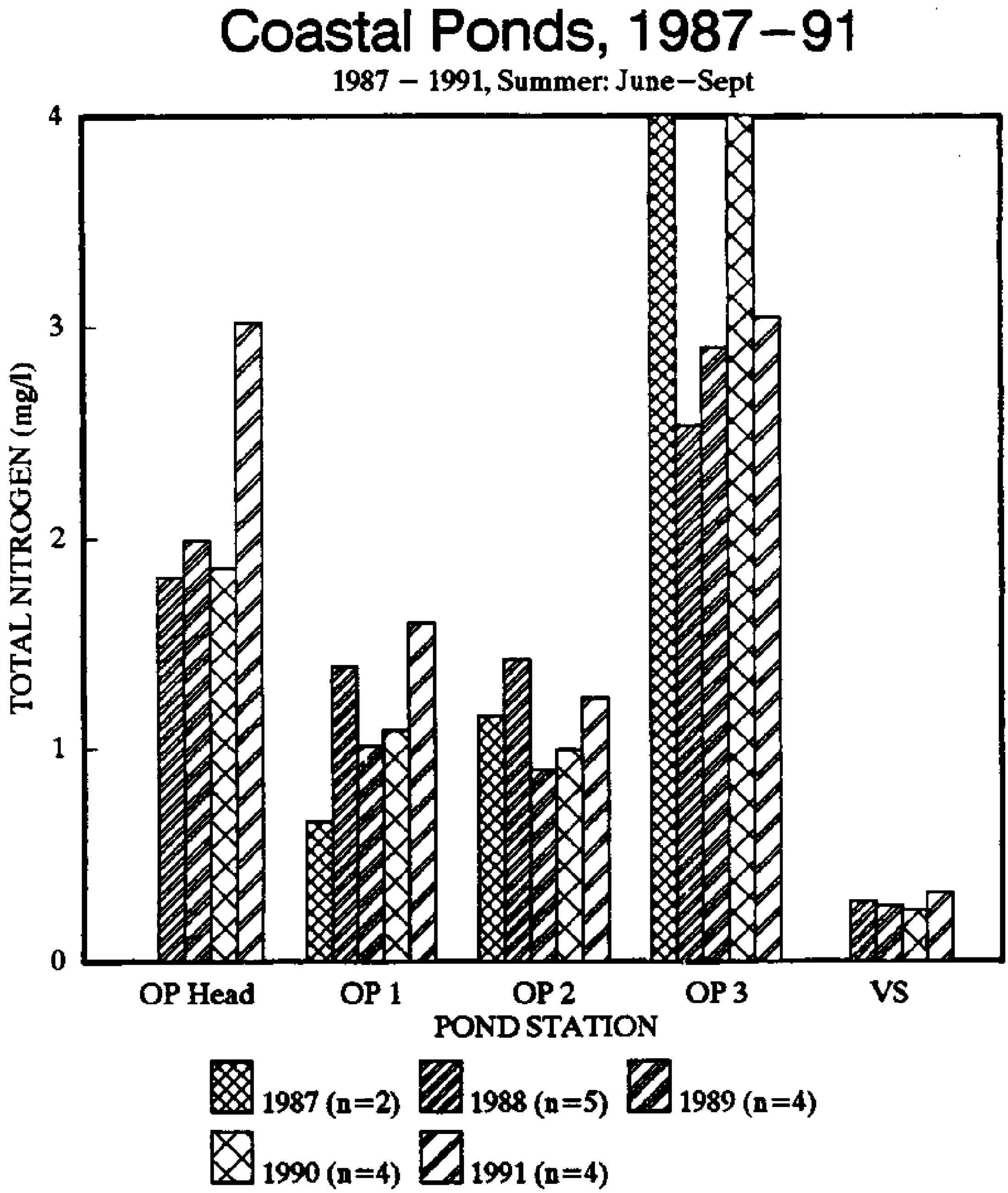
exhibited a more than 5 ppt increase with no significant increse in the surface waters, as was expected from their lower density. The pulse of high salinity/density water from Vineyard Sound moved into the pond, moving along the bottom into the deeper basins. This is consistent with an observed reduction in measured ammonium concentrations (due to dilution) in the 6 m samples of OP3. It is the strong salinity, hence density, stratification coupled with the phytoplankton production/decay in Oyster Pond found in all samples since 1987 (Figure 7) which aids in the absence of oxygen in the three main basins each summer and the "permanent" anoxia in the 6 m basin (OP3). All of the other ponds are shallower and have greater tidal velocities and therefore do not exhibit this degree of stratification found in Oyster Pond and are subject "only" to occasional brief periods of hypoxia. The physical structure (eg. bathymetry, flushing, salinity) is as important a consideration in evaluating nutrient related water quality problems as the level of nutrient loading.

Prior to the 1990 field season, the Town of Falmouth (Department of Public Works) enlarged the opening for tidal exchange between Oyster Pond and Vineyard Sound (through the Trunk River). As part of the 1990 and 1991 monitoring program, we wanted to gauge the impact of this management practice on Oyster Pond. Since Oyster Pond contains fairly fresh water compared to Vineyard Sound, one method of evaluating the planned increase in tidal exchange was to measure the increase in pond salinity levels. Given that both 1990 and 1991 measurements revealed only a small increase in salinity levels, it is not possible at present to quantify an increase in the volume of tidal exchange. In fact the peak salinities in 1990 and 1991 are equal to that found in 1988 for both surface and bottom waters. The pond salinity appears to be more sensitive to freshwater inputs and evaporation than to salt water exchanges. This effect has been documented previously by K.O. Emery.

Whatever the effect of the improved opening, it appears to have been small. Of the potential causes, one likely reason is the rapid sedimentation of the new larger pond opening due to the small tidal prism. This results in the blocking of the channel and a rapid return to pre-opening conditions. This scenario is supported by the comparison of nutrient measurements in Oyster Pond in 1990 and 1991 versus the mean summer values from 1987-1989. Overall, levels of total nitrogen in post-improvement years were equivalent to pre-opening years (Figure 8). Consistent with the lack of detectable increase in salinity and improvement in nutrient levels, summer anoxia was present at all stations as in all previous years. These anoxic conditions in Oyster Pond prohibit colonization by benthic animals or fish in waters or sediments below about three meters. This represents about half of the bottom.

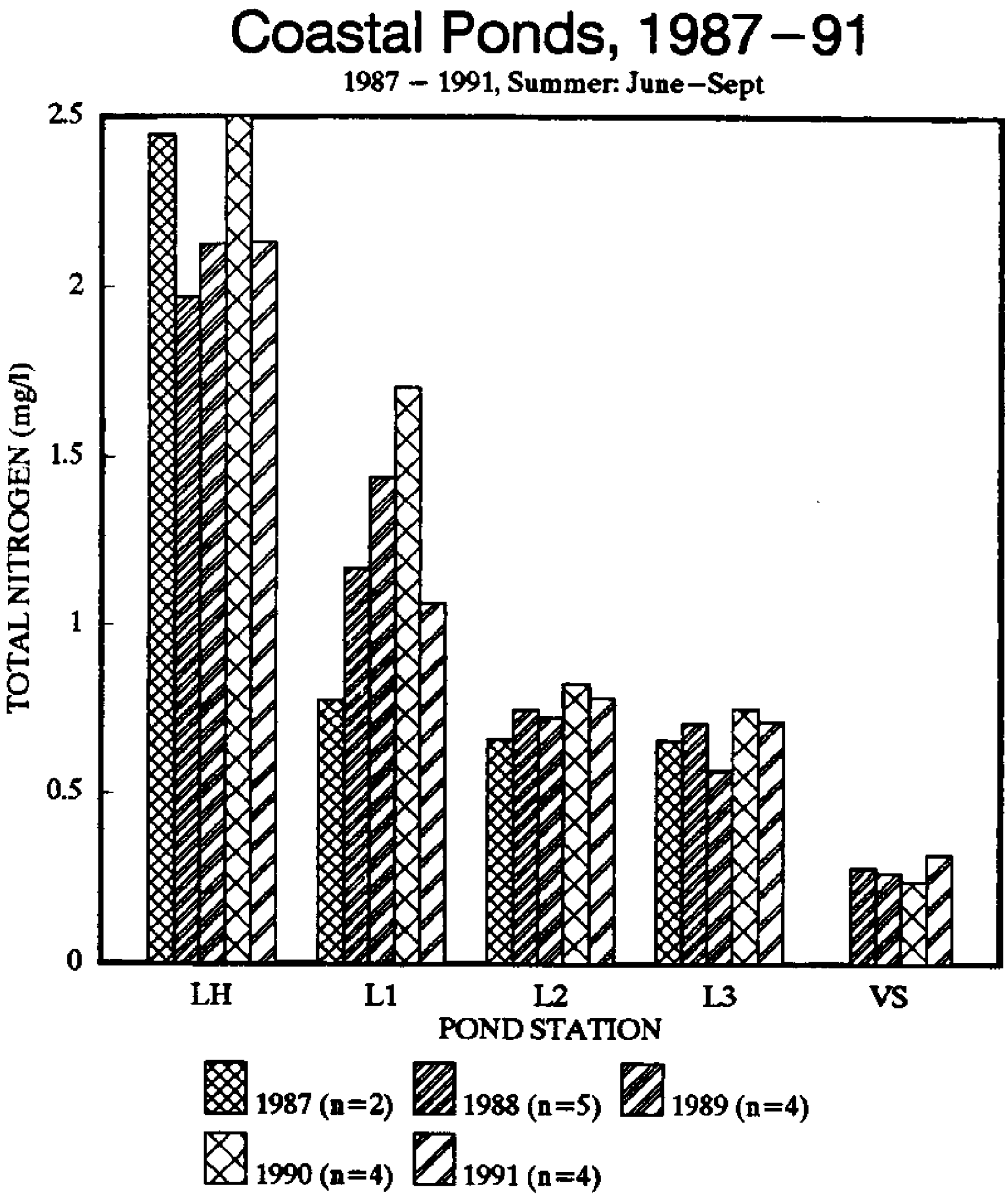
In contrast, all of the finger ponds exhibit lower nitrogen levels and better oxygen conditions than Oyster Pond, but the headwaters flowing into all five ponds were high in total nitrogen ranging from a low at Bournes (BP1) and Great Ponds (GTP1) of about 0.9 mg N/l to a high in Little Pond of over 2 mg N/l. Little Pond, much like in previous years, remains the most eutrophic of the "finger" ponds (Figure 9). However, this is deceptive as nitrogen and oxygen concentrations in the upper reaches of Green (Figure 10), Bournes (Figure 11) and Great (Figure 12) Ponds are all similar and in some cases have lower water quality than stations in Little Pond. The relatively restricted opening and more significantly the periodic sand blockages of the Little Pond Inlet serves to give Little Pond circulation and conditions like equal areas of the upper reaches of the other three ponds. In essence, since Little Pond has a relatively small surface area relative to the other ponds, it really has no greater area of low water quality than is found in each of the other three finger ponds.

Green Pond exhibited nutrient and oxygen levels on the order of previous years (1987-1989). However, there appears to be a possibility that nutrient levels are showing a variable but gradual increase in Green Pond. As in the 1990 data, the variability makes the data inconclusive at present, however the 1991 data supports an upward trend at some stations.



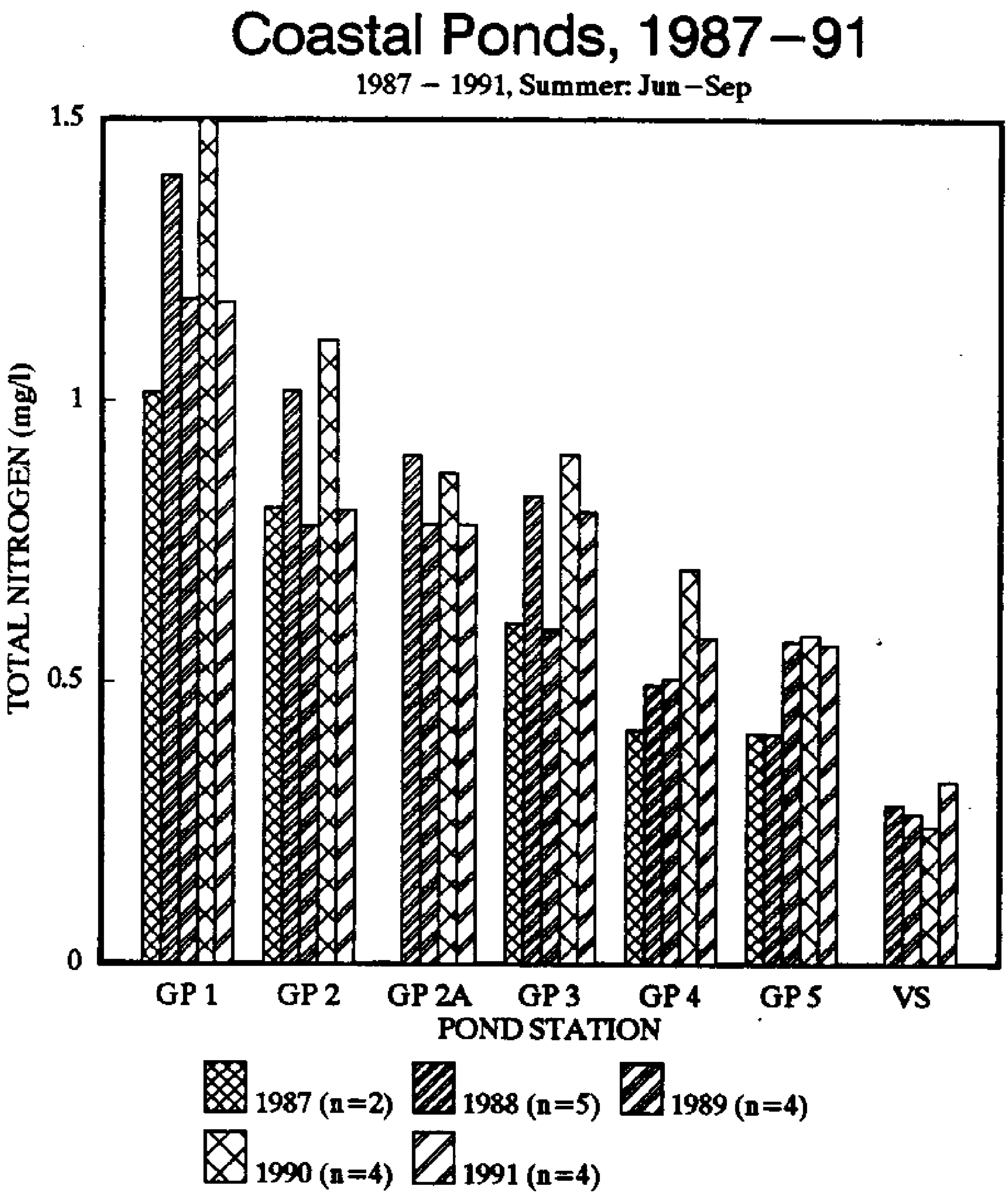
Oyster Pond Station Weighted Means
VS = Vineyard Sound Reference Station

Figure 8.



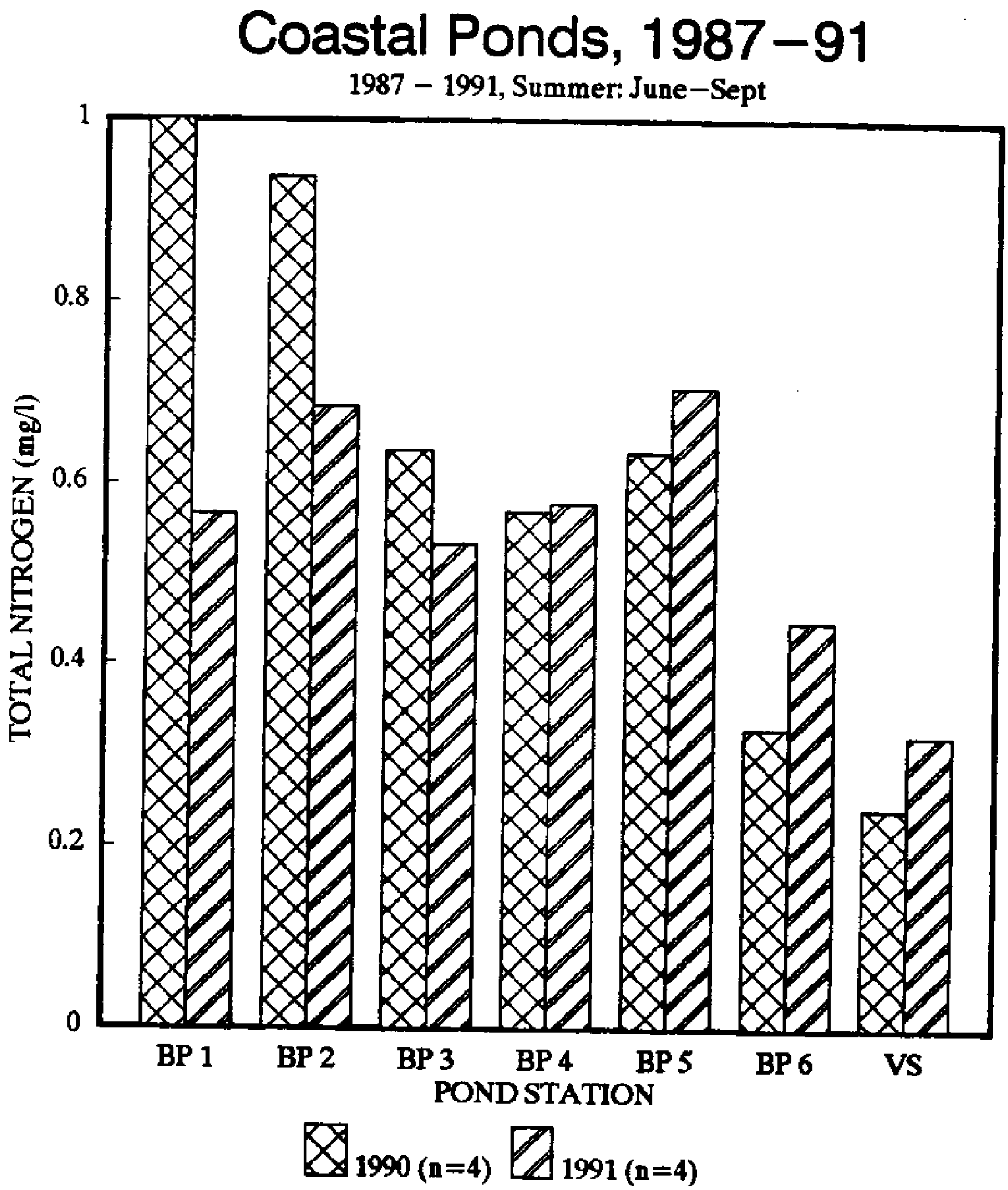
Little Pond Station Weighted Means
VS = Vineyard Sound Reference Station

Figure 9.



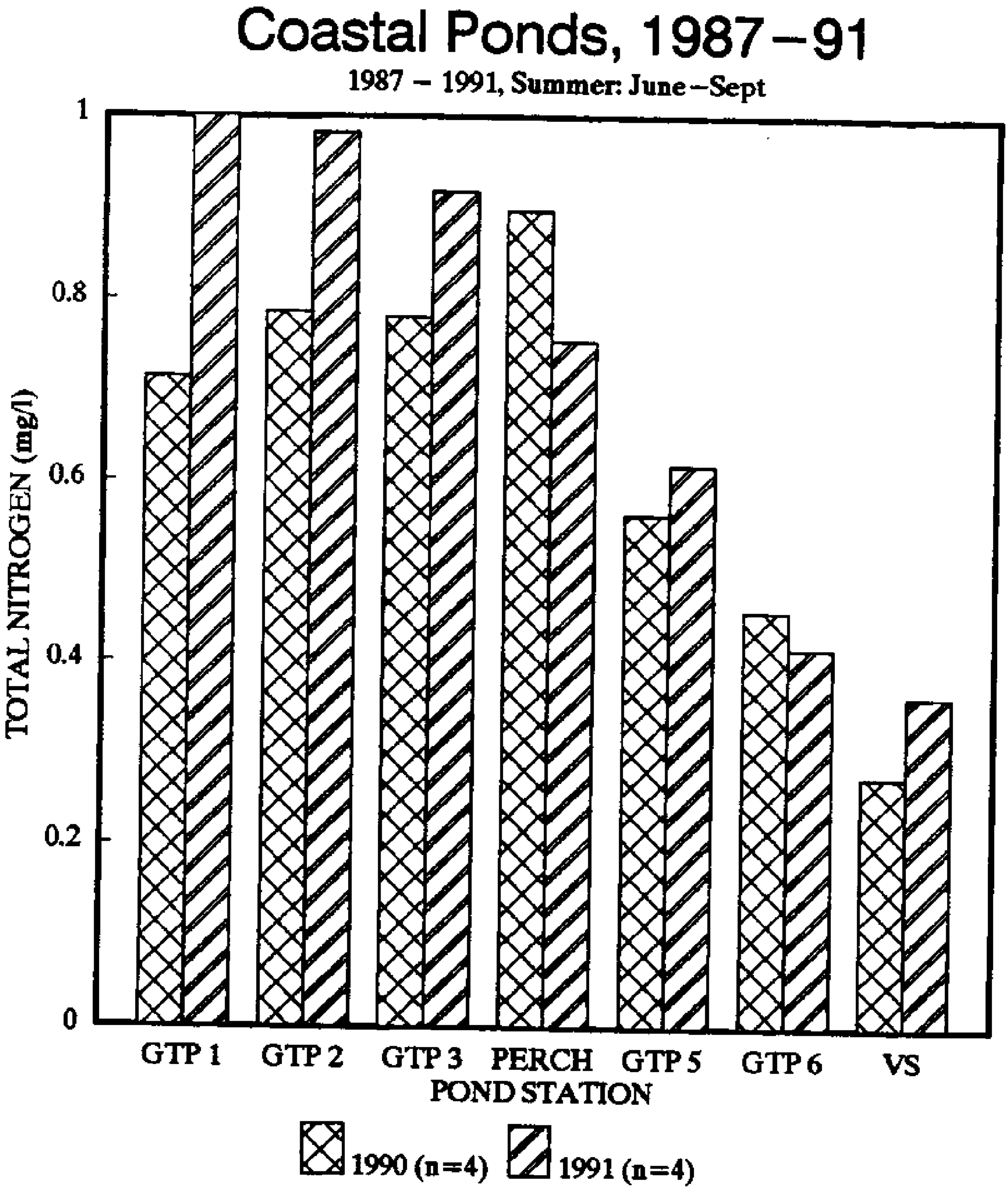
Green Pond Station Weighted Means
VS = Vineyard Sound Reference Station

Figure 10.



Bournes Pond Station Weighted Means
VS = Vineyard Sound Reference Station

Figure 11.



Great & Perch Pond Station Weighted Means
VS = Vineyard Sound Reference Station

Figure 12.

A multi-year time lag between increasing nutrient loading to a watershed and impacts on receiving pond waters is well known, and if nutrient levels are increasing in Green Pond, this is a likely contributing cause. The oxygen data from Green Pond (see below) also suggest possible declines in water quality.

As expected from their watershed nutrient loadings and physical structures, Bournes and Great Ponds showed similar nutrient and oxygen patterns to Green Pond. Nitrogen levels were high, generally over 0.5 mg/l and frequently over 0.75 mg/l, with oxygen depletions commensurate with the high nutrient levels.

Perch Pond (GTP4), a sub-basin of Great Pond, is a small deep basin with a shallow sill to Great Pond. It is highly eutrophic with average total nitrogen levels in 1990 and 1991 over 0.75 mg/l (Figure 12) and large accumulations of organic matter on the bottom. However, oxygen conditions though very poor were not exceptionally so and certainly not on the order of Oyster Pond. The rest of Great Pond was similar to Green and Bournes Pond with a continuous increase in water clarity and water quality approaching Vineyard Sound.

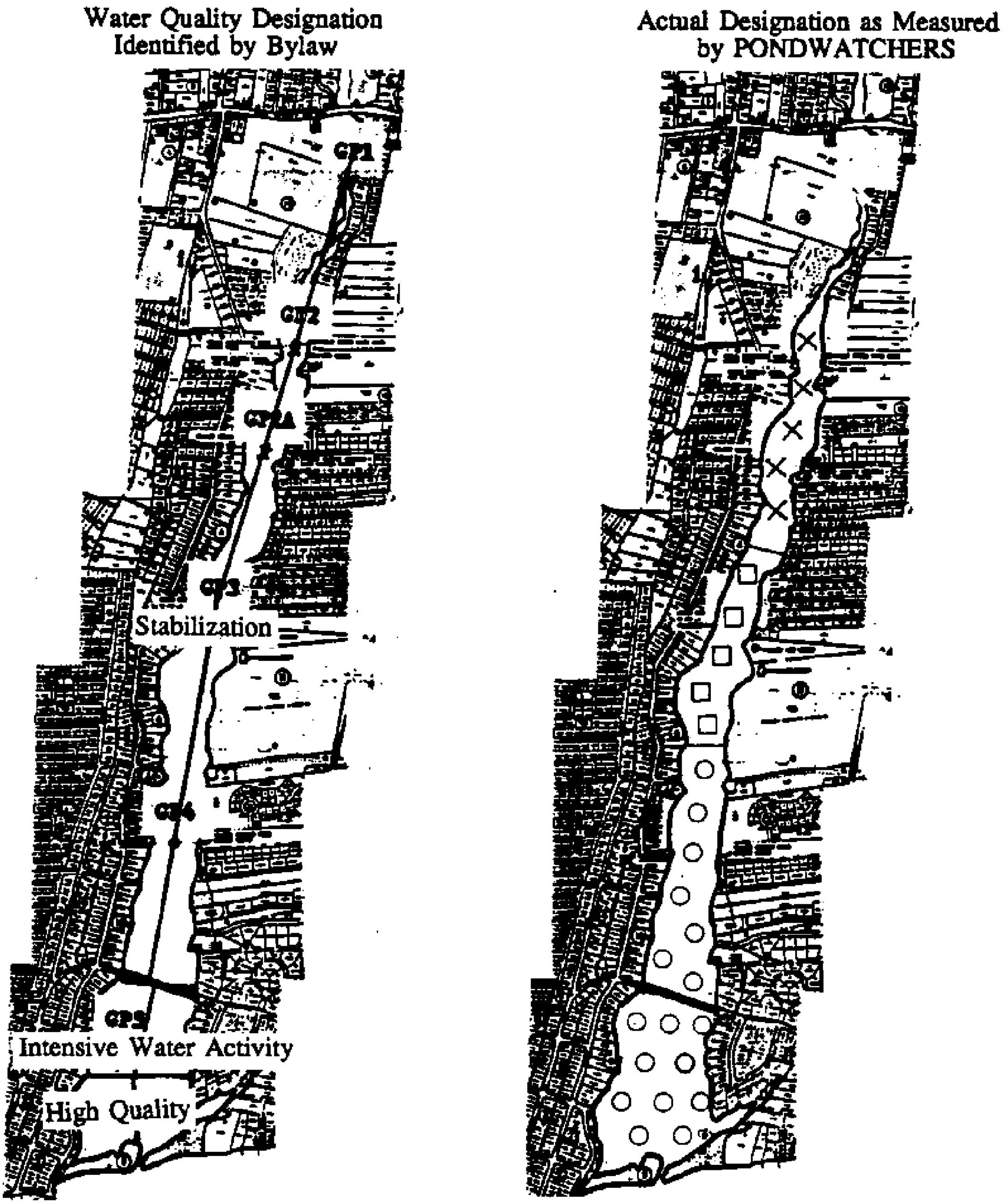
Bournes Pond, the recipient of extensive circulation alteration in the mid 1980's, had marginally better water quality than Green and Great Ponds. However, the upper reaches as in the other ponds have high nutrient levels and experience periodic low oxygen conditions. Unfortunately, it is not possible to gauge the level of "improvement" caused by remediation.

Based upon the multi-year data on the five ponds (Figures 8-12), it is possible to construct valid nutrient maps for each of the five ponds, although as conditions change they must be updated. for instance, if remediation of an area is effective, the nutrient maps used for watershed land use planning must reflect the changes. However, as no significant changes have been seen in Oyster, Little and Green Ponds over the past five years (except possibly some Green Pond stations) and our two year data set is not enough to see changes in Great and Bournes Ponds, we feel that defensible nutrient maps of existing conditions can be produced based upon our total nitrogen data base. The maps indicate that almost every area of each pond are at present above the levels allowable for total nitrogen specified in the Falmouth Coastal Pond Overlay Bylaw (Figures 13-17). In fact, many areas are above the highest level of 0.75 mg/l specified for intensive use areas. Unfortunately, many of these same areas are designated high quality or stabilization areas and would need reductions of more than 50% to reach these levels. Equally depressing is our finding that in the high nitrogen areas we indeed find low water quality as defined by low dissolved oxygen levels. In addition, areas with high nutrients also had measured low bottom water oxygen each year. This is particularly well demonstrated in the longer term data sets for Green (Figure 18), Little (Figure 19), and Oyster (Figure 20) Ponds.

While the data for Bournes and Great Ponds are not as extensive as for these ponds, both exhibit occasional low oxygen (less than 4 mg/l) at most stations (Figure 21). In all cases, the low oxygen events are periodic, probably lasting in each event several days. However, the number of low oxygen events over the summer cannot be estimated without a much more extensive sampling program and probably will occur only as site specific studies, i.e. Little Pond.

Since our concern with low dissolved oxygen is primarily due to its severe negative impacts on animals and plants living in the ponds and particularly in the bottom sediments, we can address some of the questions associated with low D.O. by measuring animal populations directly. This approach also is not perfect, but should yield good comparative data between ponds and within individual ponds. In 1991 we conducted a fish trapping cencuc in each of the five salt ponds with both an upper and lower site within each pond. Samples were collected using both "minnow" and larger commercial box traps at each station. Four 24 hour collections were made in concert with the four watercolumn samplings. The study was designed to compare areas near versus away from Vineyard Sound within each

Green Pond station locations and Water Quality Designation as identified by Coastal Pond Overlay Bylaw (adopted by Falmouth Town Meeting, April 1988) and actual designations according to the Bylaw as measured by Falmouth Pondwatchers 1987-1991.



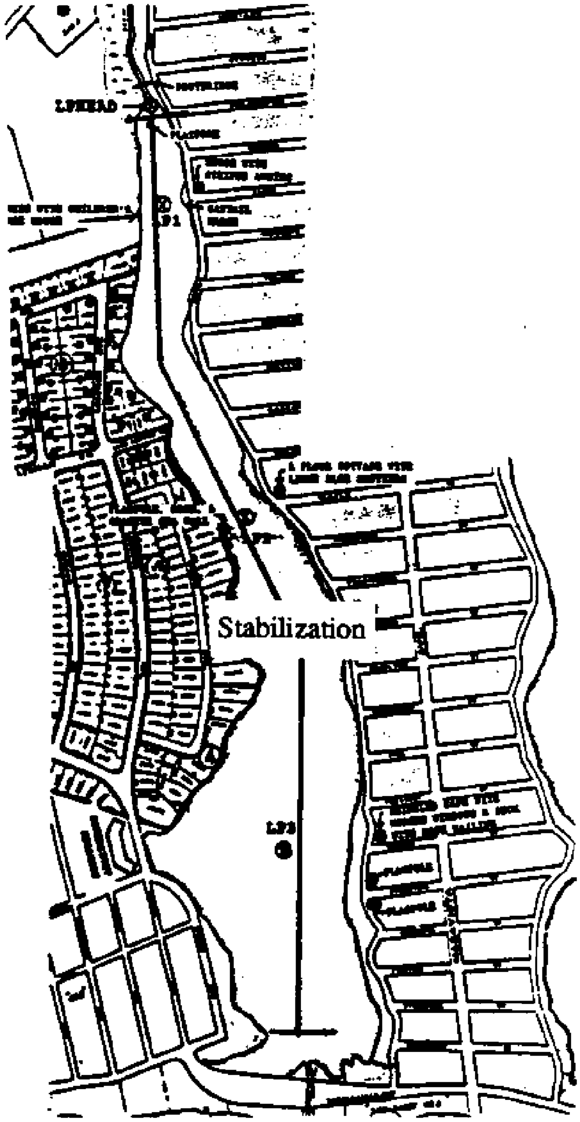
"Critical Eutrophic Levels" as designated by Coastal Pond Overlay Bylaw
(Total Nitrogen as Average Over Year)

- > 0.75 mg/l = Above Highest "Critical Eutrophic Levels" ×
- 0.5 - 0.75 mg/l = Intensive Water Activity Area □
- 0.32 - 0.5 mg/l = Stabilization Area ○
- < 0.32 mg/l = High Quality Area

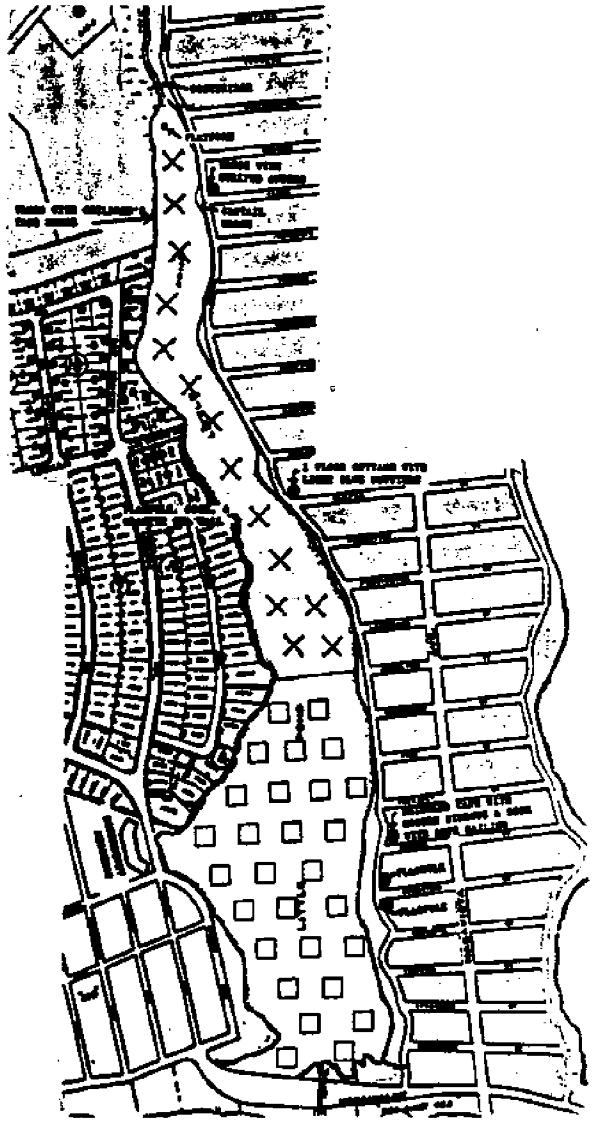
Figure 13.

Little Pond station locations and Water Quality Designation as identified by Coastal Pond Overlay Bylaw (adopted by Falmouth Town Meeting, April 1988) and actual designations according to the Bylaw as measured by Falmouth Pondwatchers 1987-1991.

Water Quality Designation Identified by Bylaw



Actual Designation as Measured by PONDWATCHERS



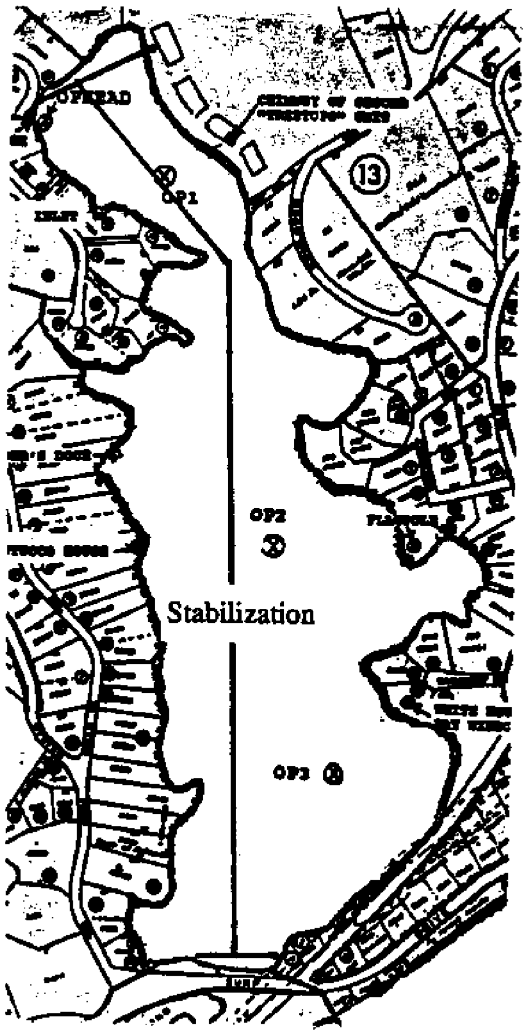
"Critical Eutrophic Levels" as designated by Coastal Pond Overlay Bylaw
(Total Nitrogen as Average Over Year)

> 0.75 mg/l	= Above Highest "Critical Eutrophic Levels"	✕
0.5 - 0.75 mg/l	= Intensive Water Activity Area	□
0.32 - 0.5 mg/l	= Stabilization Area	O
< 0.32 mg/l	= High Quality Area	

Figure 14.

Oyster Pond station locations and Water Quality Designation as identified by Coastal Pond Overlay Bylaw (adopted by Falmouth Town Meeting, April 1988) and actual designations according to the Bylaw as measured by Falmouth Pondwatchers 1987-1991.

Water Quality Designation
Identified by Bylaw



Actual Designation as Measured
by PONDWATCHERS

"Critical Eutrophic Levels" as designated by Coastal Pond Overlay Bylaw
(Total Nitrogen as Average Over Year)

> 0.75 mg/l	= Above Highest "Critical Eutrophic Levels"	X
0.5 - 0.75 mg/l	= Intensive Water Activity Area	□
0.32 - 0.5 mg/l	= Stabilization Area	○
< 0.32 mg/l	= High Quality Area	

Figure 15.

Bournes Pond station locations and Water Quality Designation as identified by Coastal Pond Overlay Bylaw (adopted by Falmouth Town Meeting, April 1988) and actual designations according to the Bylaw as measured by Falmouth Pondwatchers 1990-1991.

Water Quality Designation Identified by Bylaw

Actual Designation as Measured by PONDWATCHERS

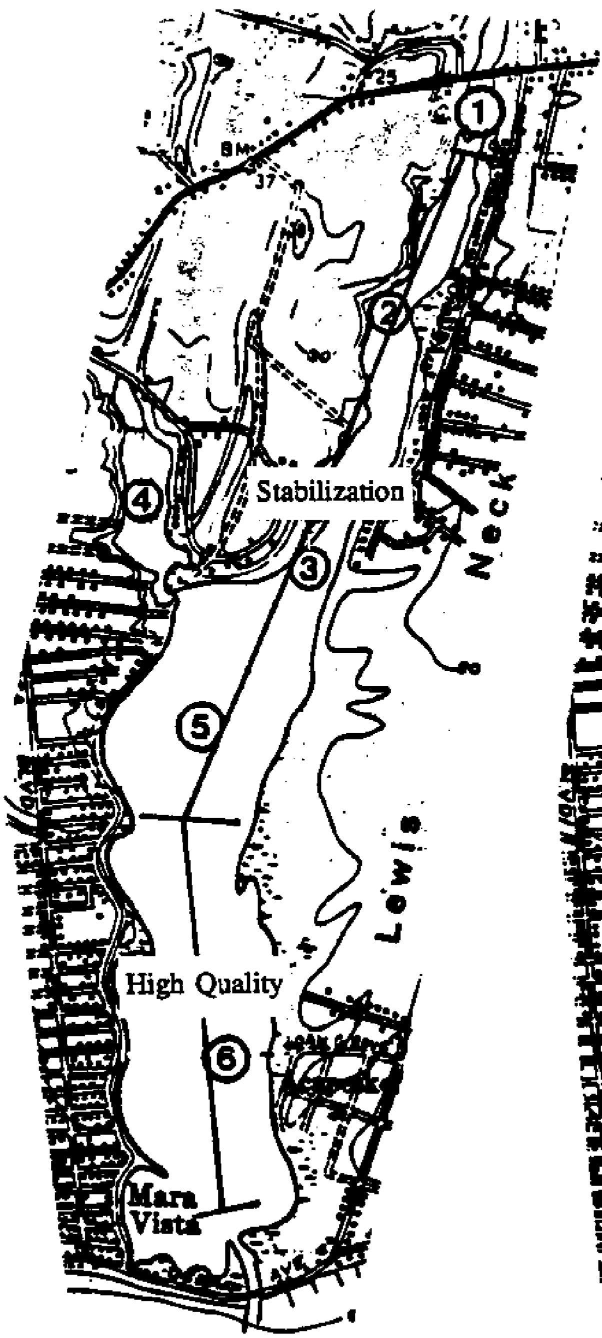
"Critical Eutrophic Levels" as designated by Coastal Pond Overlay Bylaw (Total Nitrogen as Average Over Year)

> 0.75 mg/l	= Above Highest "Critical Eutrophic Levels"	X
0.5 - 0.75 mg/l	= Intensive Water Activity Area	□
0.32 - 0.5 mg/l	= Stabilization Area	O
< 0.32 mg/l	= High Quality Area	

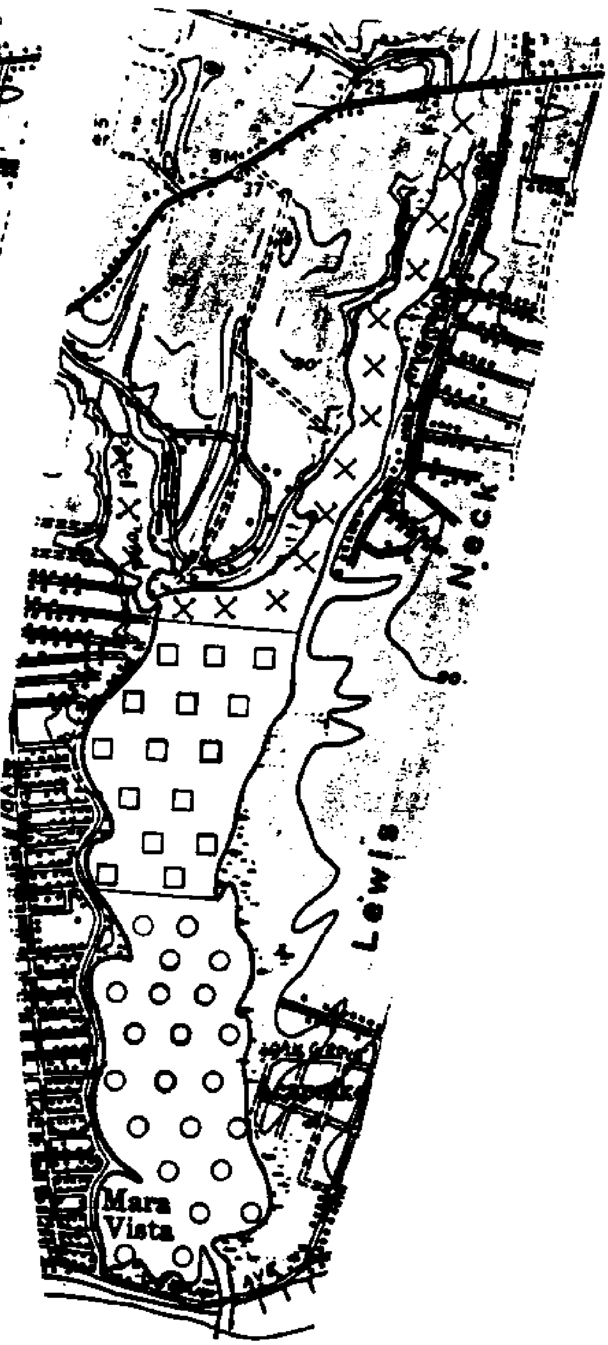
Figure 16.

Great Pond station locations and Water Quality Designation as identified by Coastal Pond Overlay Bylaw (adopted by Falmouth Town Meeting, April 1988) and actual designations according to the Bylaw as measured by Falmouth Pondwatchers 1990-1991.

Water Quality Designation
Identified by Bylaw



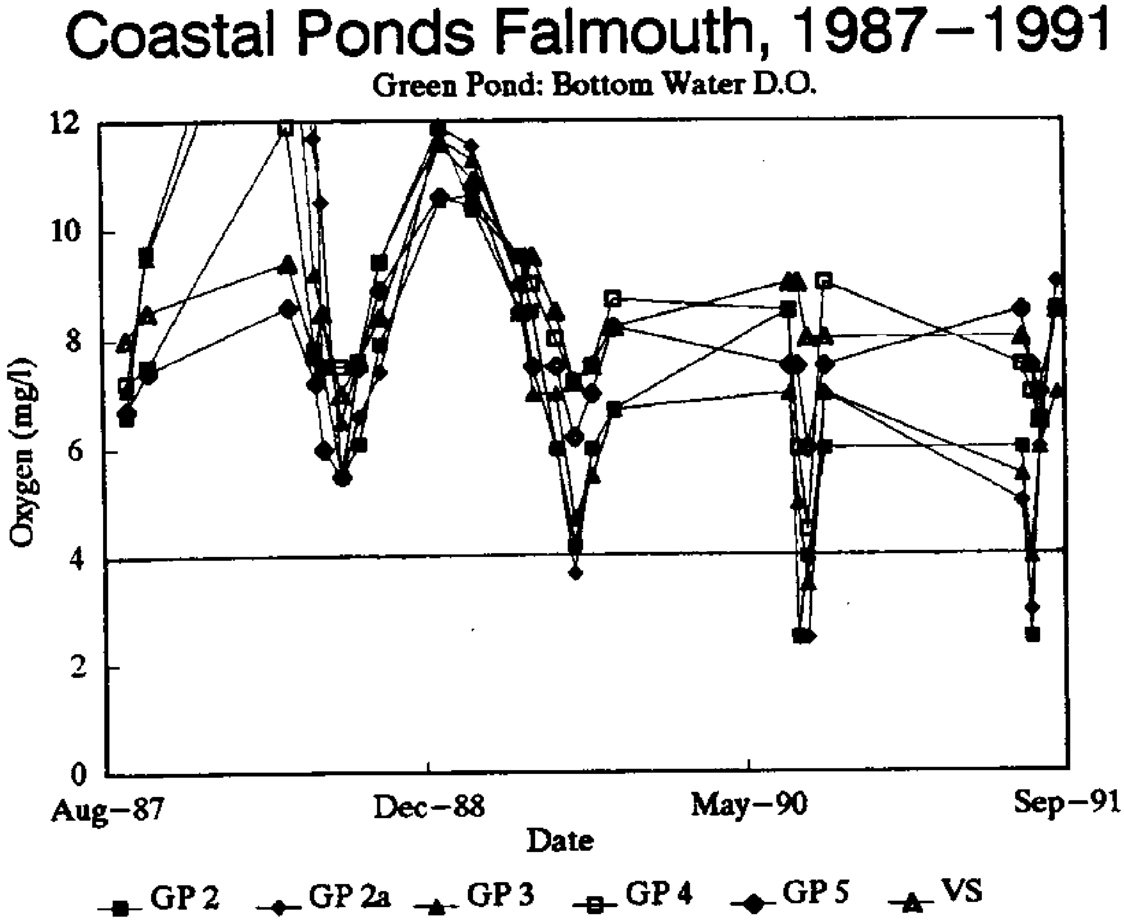
Actual Designation as Measured
by PONDWATCHERS



"Critical Eutrophic Levels" as designated by Coastal Pond Overlay Bylaw
(Total Nitrogen as Average Over Year)

> 0.75 mg/l	= Above Highest "Critical Eutrophic Levels"	×
0.5 - 0.75 mg/l	= Intensive Water Activity Area	□
0.32 - 0.5 mg/l	= Stabilization Area	○
< 0.32 mg/l	= High Quality Area	

Figure 17.


Coastal Ponds Falmouth, 1987–1991
Green Pond: Bottom Water D.O.
Oxygen (mg/l)
12
10
8
6
4
2
0
Aug–87
Dec–88
May–90
Sep–91
Date
GP 2
GP 2a
GP 3
GP 4
GP 5
VS

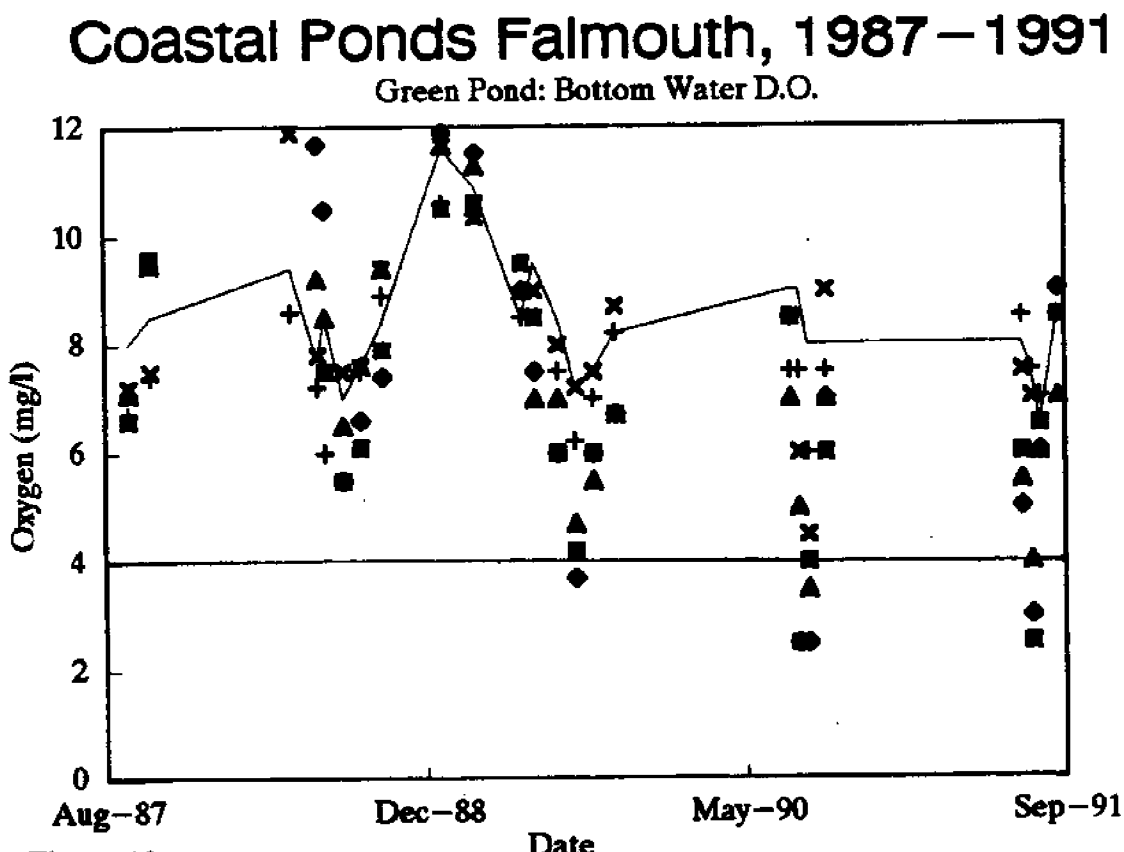
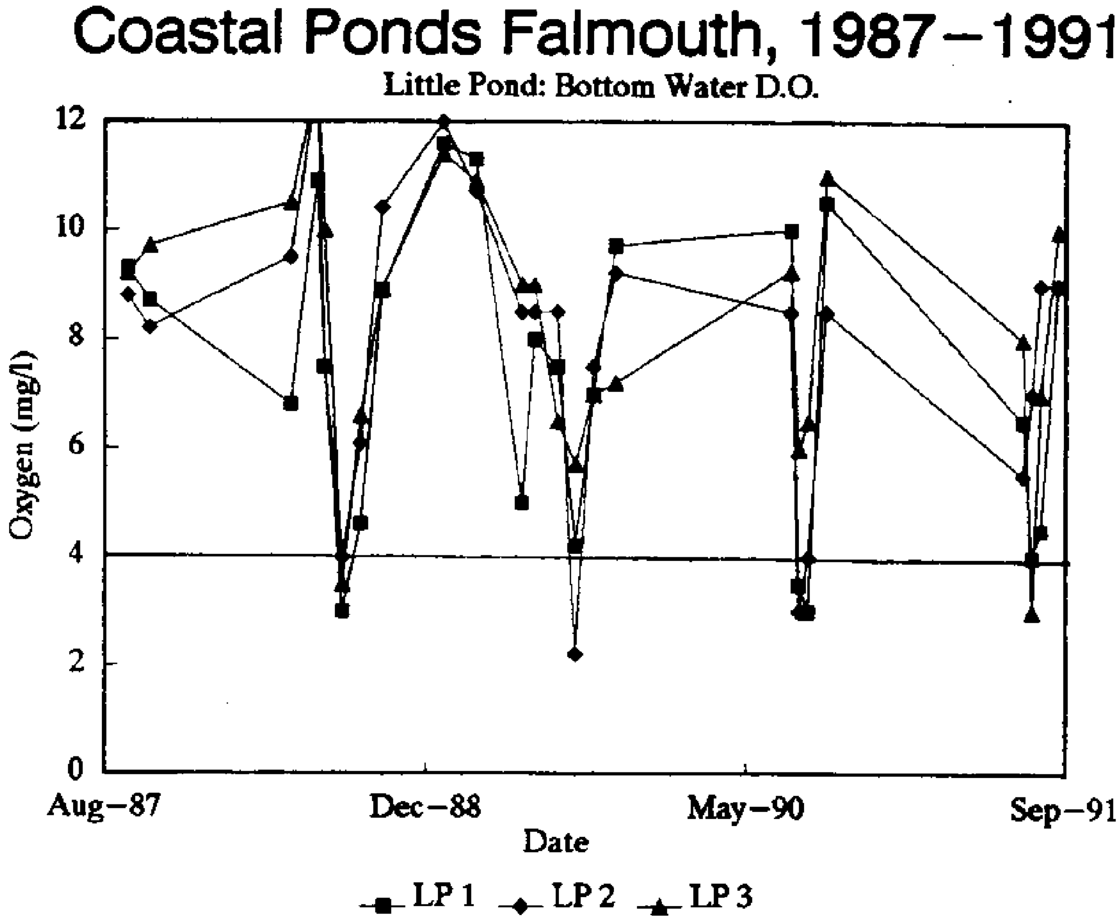
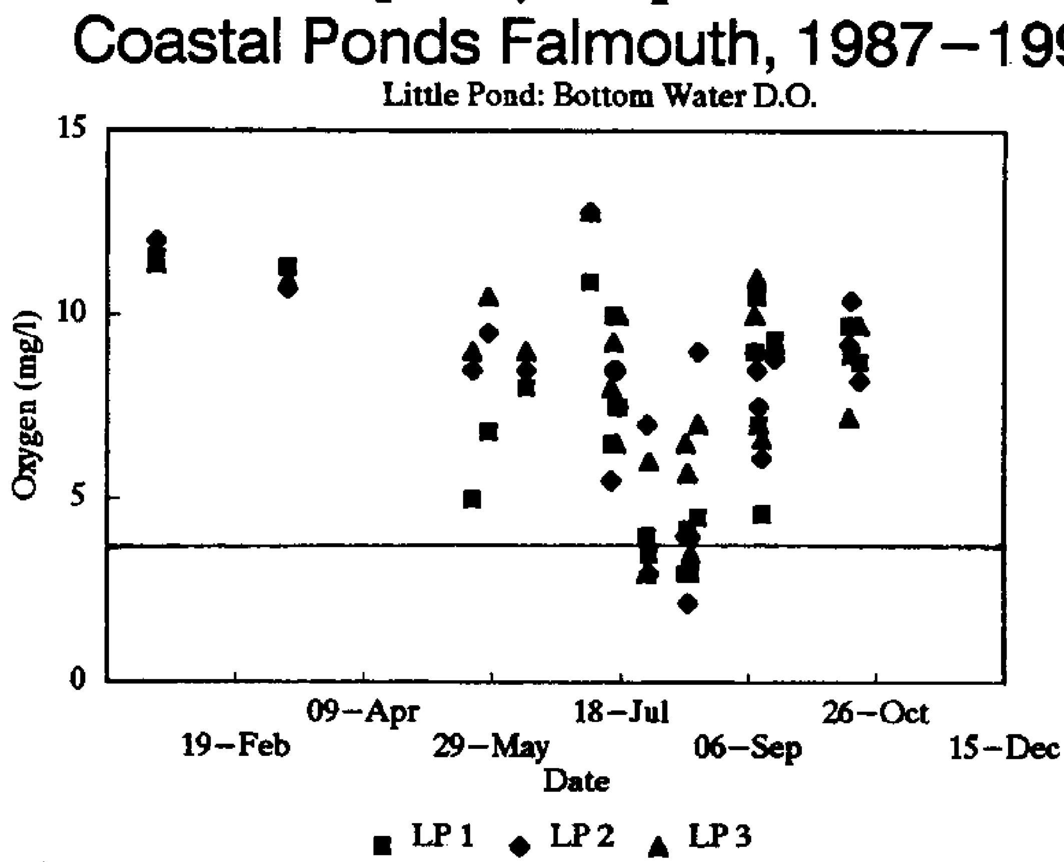

Coastal Ponds Falmouth, 1987–1991
Green Pond: Bottom Water D.O.
Oxygen (mg/l)
12
10
8
6
4
2
0
Aug–87
Dec–88
May–90
Sep–91
Date
GP 2
GP 2a
GP 3
GP 4
GP 5
VS

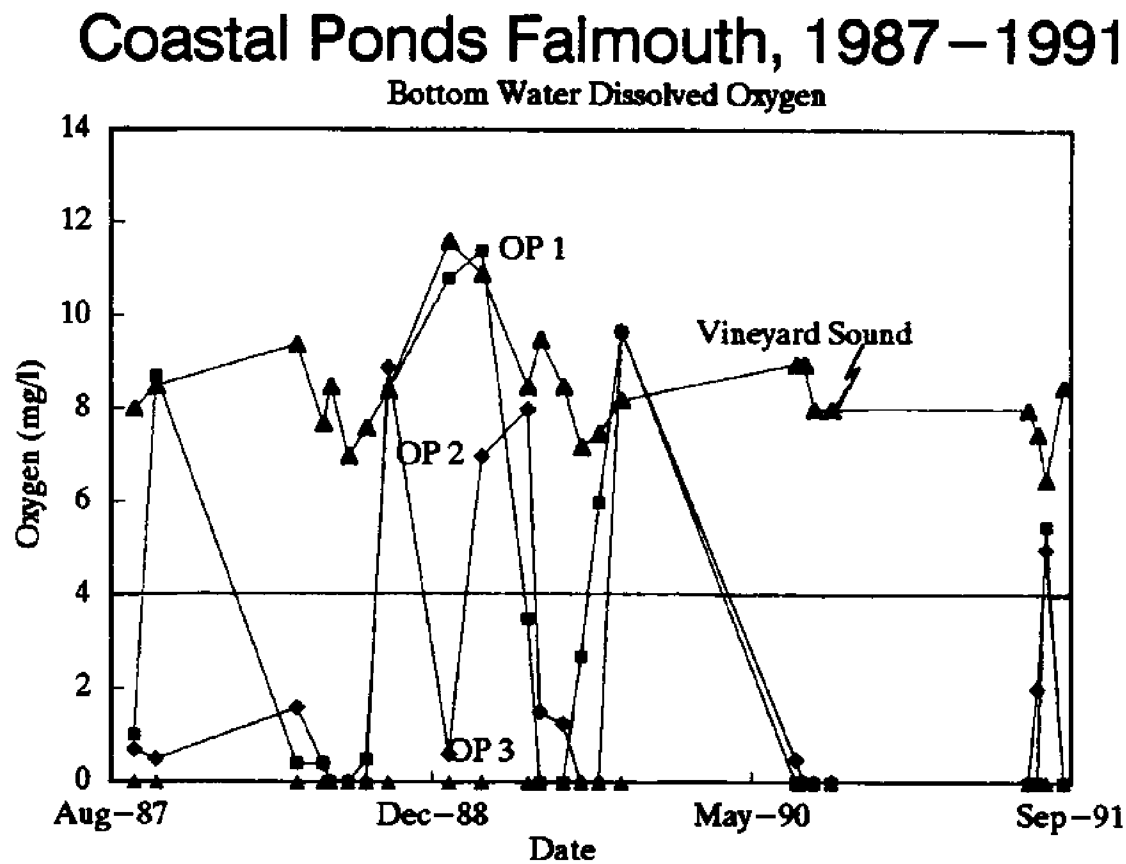
Figure 18.

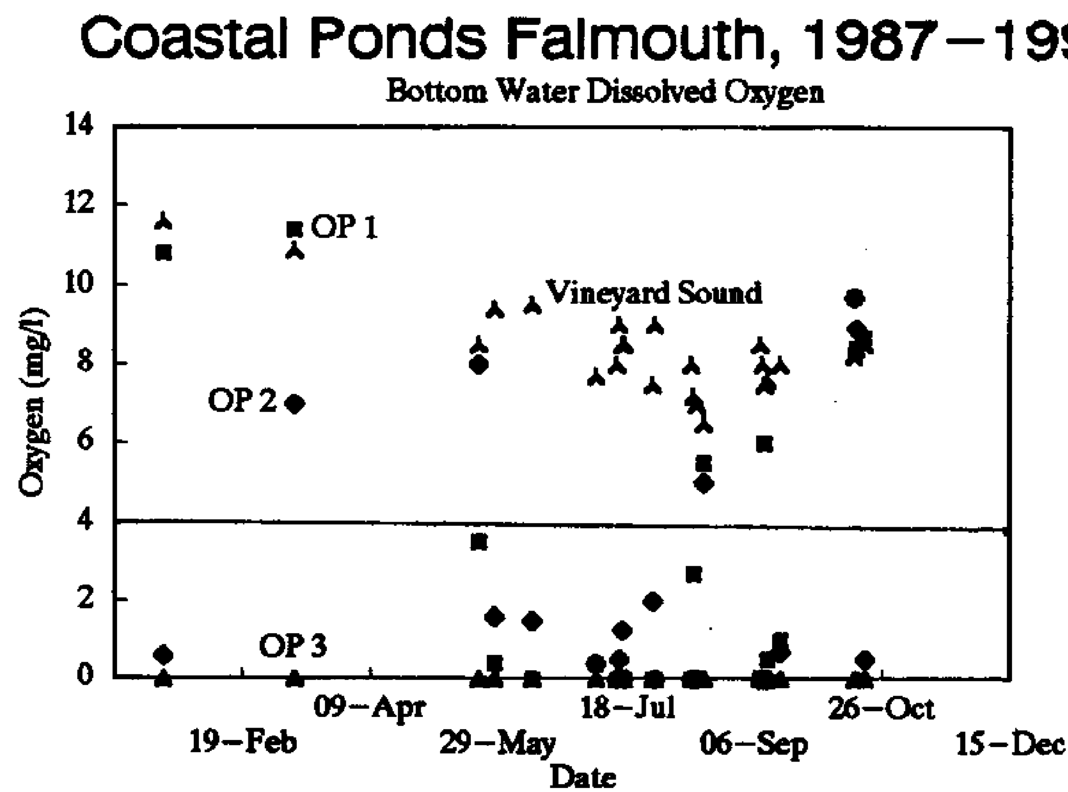




Composite Annual Cycle all years.

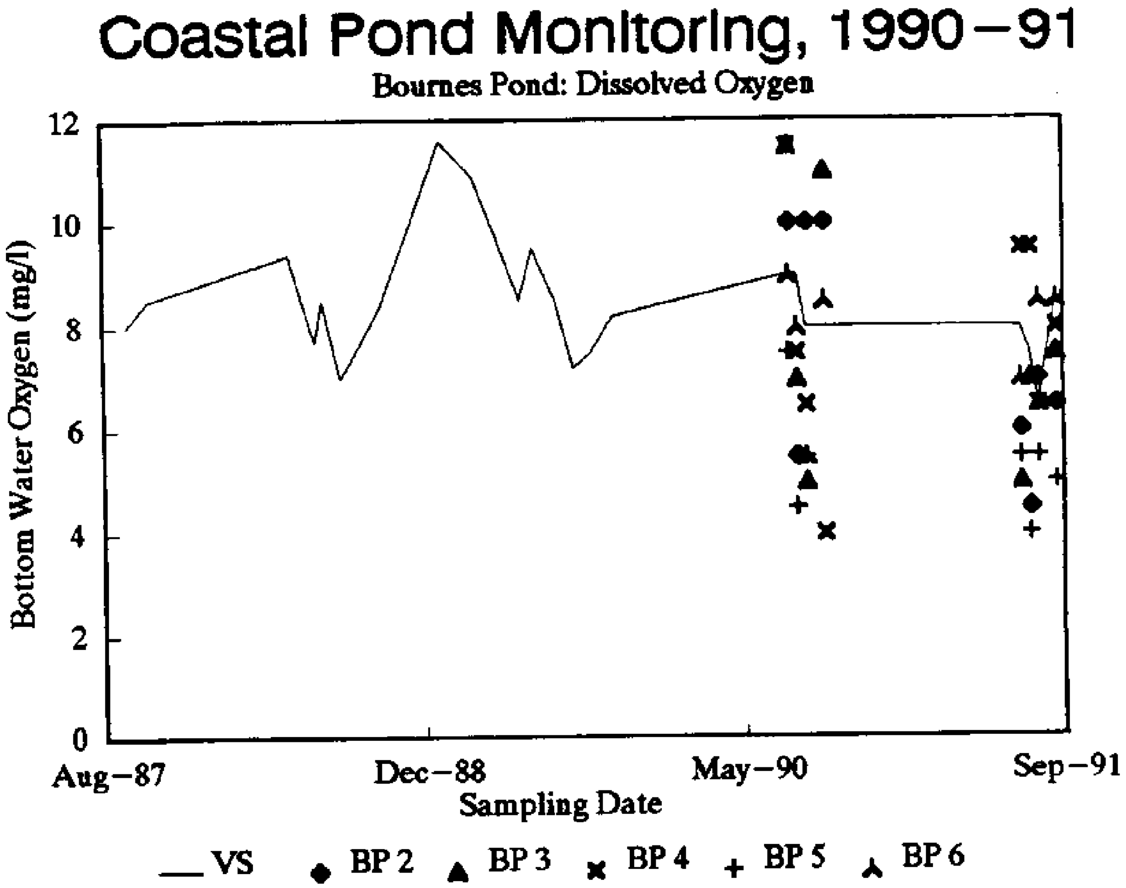
Figure 19.





Composite Annual Cycle all years.

Figure 20.



Howes, WHOI Sea Grant

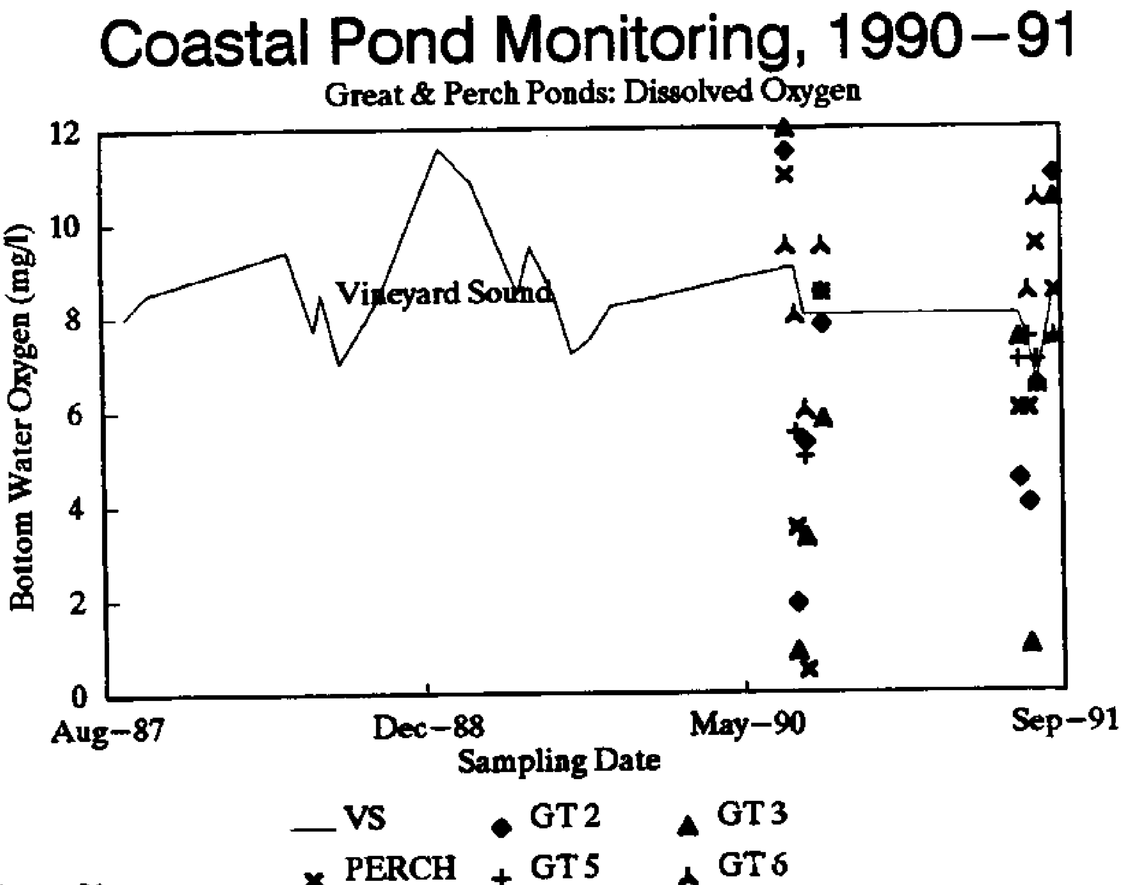


Figure 21.

pond and between the ponds themselves. Since fish collections were made in parallel with the oxygen measurements, relationships should be detected. Traps for fish are not perfect, giving qualitative results since some species don't enter traps and some eat others in the traps. However, the results of the census was consistent between all sites: areas with low bottom water oxygen had a lower number of species present than higher oxygen areas (Figure 22). This result is independent of which species (Table 1) were found and whether one considers fish or invertebrates. This finding is supported by basic ecological theory where high stress habitats generally have a lower species diversity. There was generally the lowest diversity in Oyster and Little, and Upper Green Ponds, and in the less eutrophic ponds (Bournes, Great and Green) there was a tendency for a lower diversity in the upper versus lower sites (Figure 22). These results support the contention that low oxygen and high nutrient areas are of low ecological health. Based upon these preliminary results, we hope to conduct more quantitative censusing and synthesis as part of our 1992 study. While we are continuing to use various methods to increase the accuracy of determining the quantitative relationship between nutrient levels and dissolved oxygen, it is clear that the levels specified in the Bylaw are not too low.

Although this is a progress report and will be amended as new data is added, several features are clear. First, portions of all five coastal ponds exhibit elevated nutrient levels, exceeding Falmouth Bylaw limits, and are exhibiting periodic low oxygen and diminished water quality. Second, areas of high nutrients and low oxygen appear to have diminished animal populations. Third, water quality within the ponds is an admixture of nutrient loading, natural estuarine circulation and natural physical variables (eg. temperature, salinity, stratification, depth). Fourth, initial improvement in Oyster Pond water quality from recent alterations were too small to quantify due to diminished flushing as a result of sedimentation of the tidal channel. Fifth, Green Pond may be experiencing increasing nutrient levels. This

CITIZENS SALT POND MONITORING: FISH SURVEY
WHOI Sea Grant: Howes & Livingstone

TOTAL CATCH FROM ALL SAMPLINGS: 7/14, 7/28, 8/11, 9/8/91

	OYSTER POND		LITTLE POND		GREEN POND		BOURNES POND		GREAT POND	
SPECIES	OP 1	OP 3	LP 1	LP 3	GP 2	GP 5	BP 2	BP 6	GT 2	GT 6
FISH										
American Eel	8	44	2	4	2	1	3	1		
Common Mummichog	5	65	308	161		35	339	1	178	
Sheepshead Minnow			12	2			7		10	1
Silversides			1			1	8	7		
Scup						4			1	
Black Sea Bass				2		3		7		3
Common Sea Robin							2		1	
Common Pipefish					1	2		1		1
Winter Flounder						2	1	2		5
Little Sculpin							1	2		2
Stickleback				2					6	14
Tautog								2	1	4
Cunner						1				
Toadfish						2			1	
INVERTEBRATES										
Blue Crab	9	5	9		2		2		7	4
Green Crab						2	3	5		1
Spider Crab						5	2	124	5	5
Hermit Crab										
Lady Crab								1		
Grass Shrimp				1		6	9	17	14	16
Sea Cucumber									13	
Welk								1		
FRESHWATER										
Turtle	1									
TOTAL MARINE SPECIES	3	3	5	6	3	12	11	13	11	11
FISH=	2	2	4	5	3	9	7	8	7	7
INVERTS=	1	1	1	1	1	3	4	5	4	4

Table 1.

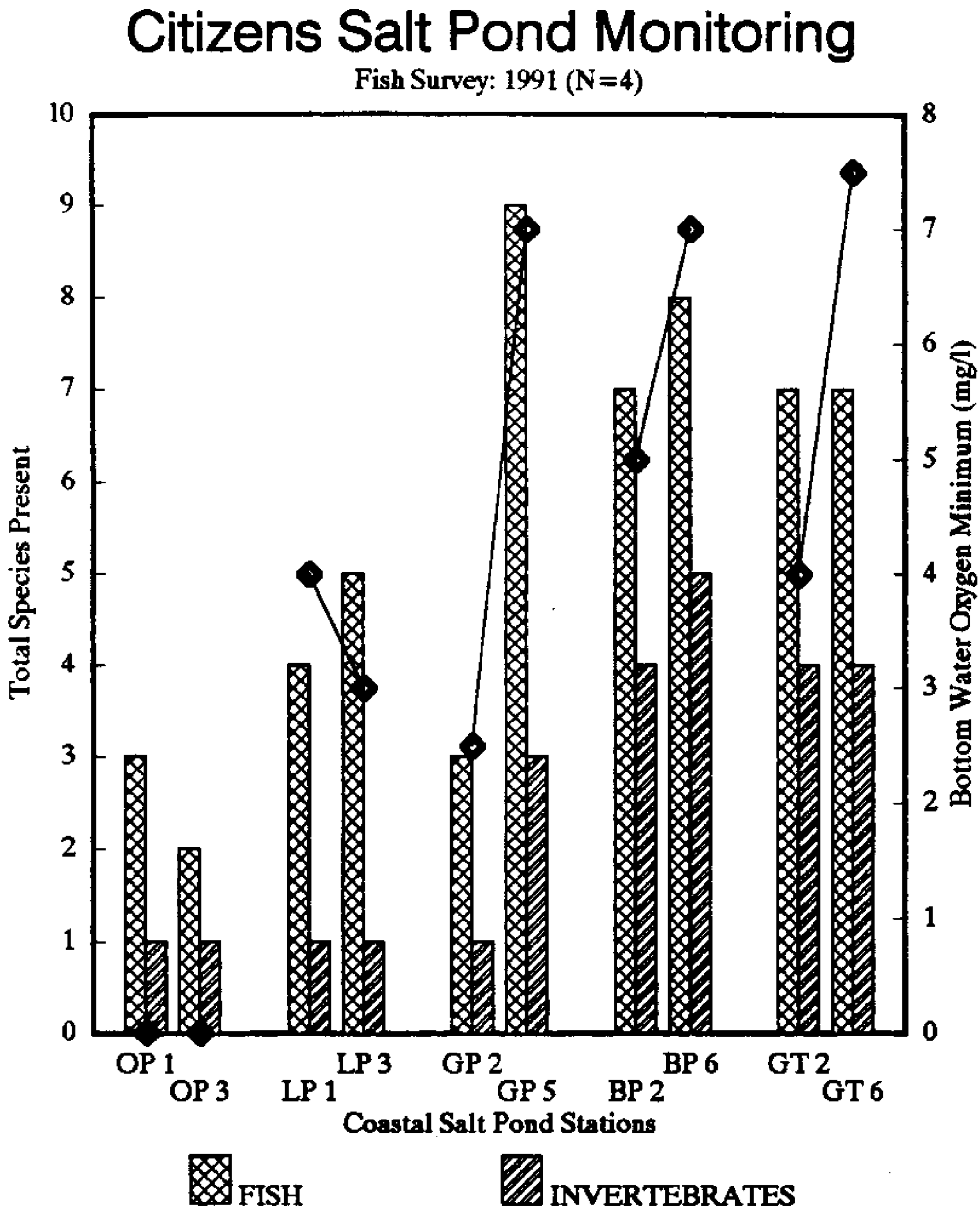

Citizens Salt Pond Monitoring
Fish Survey: 1991 (N=4)
10
9
8
7
6
5
4
3
2
1
0
Total Species Present
8
7
6
5
4
3
2
1
0
Bottom Water Oxygen Minimum (mg/l)
OP 1
OP 3
LP 1
LP 3
GP 2
GP 5
BP 2
BP 6
GT 2
GT 6
Coastal Salt Pond Stations
FISH
INVERTEBRATES

Figure 22.

emphasizes the importance of this type of monitoring in that long-term trends can be detected in their early stages, giving time for early management actions. Sixth, management of pond water quality must be conducted on not just a pond-by-pond basis but by subsections of each pond (eg. upper versus lower regions).

ADDENDUM

We are currently producing an ecological management plan for Oyster and Little Pond and hope to produce pond specific plans for each salt pond as the Pondwatch Project data base increases. However, it appears that Little Pond, the most eutrophic of the "finger" ponds, is currently in need of short-term remediation as the long-term plan is reviewed and finalized. We present here a brief overview of that short-term "fix."

While the low water quality in Little Pond results from the significant inputs of nutrients from its surrounding watershed, a mediating factor is the rate at which these nutrients are lost to Vineyard Sound through tidal exchange. As part of the Coastal Pond Project we have maintained a tide recorder in Little Pond since 1988. From our tide gauge records (and other data), we can determine the extent of the tidal exchange, and more importantly when exchange stops due to sand blocking the inlet. Our records indicate that while the Town diligently tries to dig out the inlet whenever it is blocked, that blockages are frequent and can have significant duration (Figure 23). The effect of these blockages is to magnify the impact of the nutrient loading from the watershed. In essence, decreasing output is roughly equivalent to increasing input, residential development for instance.

One of the best ecological and cost effective short-term solutions is to prevent the sand blockages at their proximate source, i.e. littoral transport from the adjacent beach (Falmouth Heights side of the Little Pond inlet). This would in the short term be performed by physical removal of the leading edge of the beach back some tens of feet. The sand can be by-passed to the beach on the opposite (downdrift) side of the inlet or used to nourish any other Town beach. At the same time, the inlet on <u>both sides</u> (pondward and seaward) of the little Pond culvert must be cleared to re-establish a good flow. While more detailed and quantitative plans will be forthcoming, this approach should, at relatively little cost, allow a good quantitative test to determine if the existing inlet, if clear to operate, is adequate (as other data appears to suggest) to flush Little Pond.

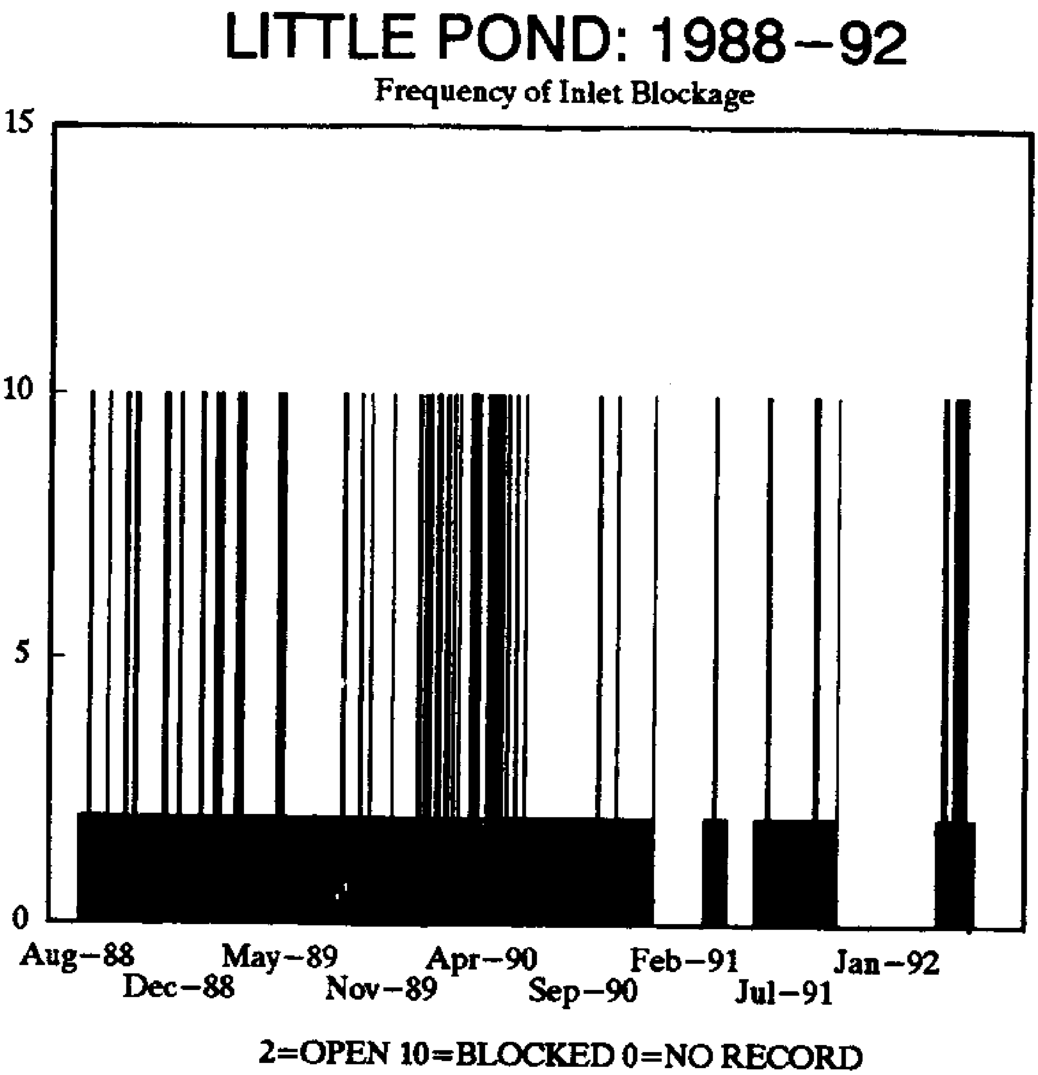
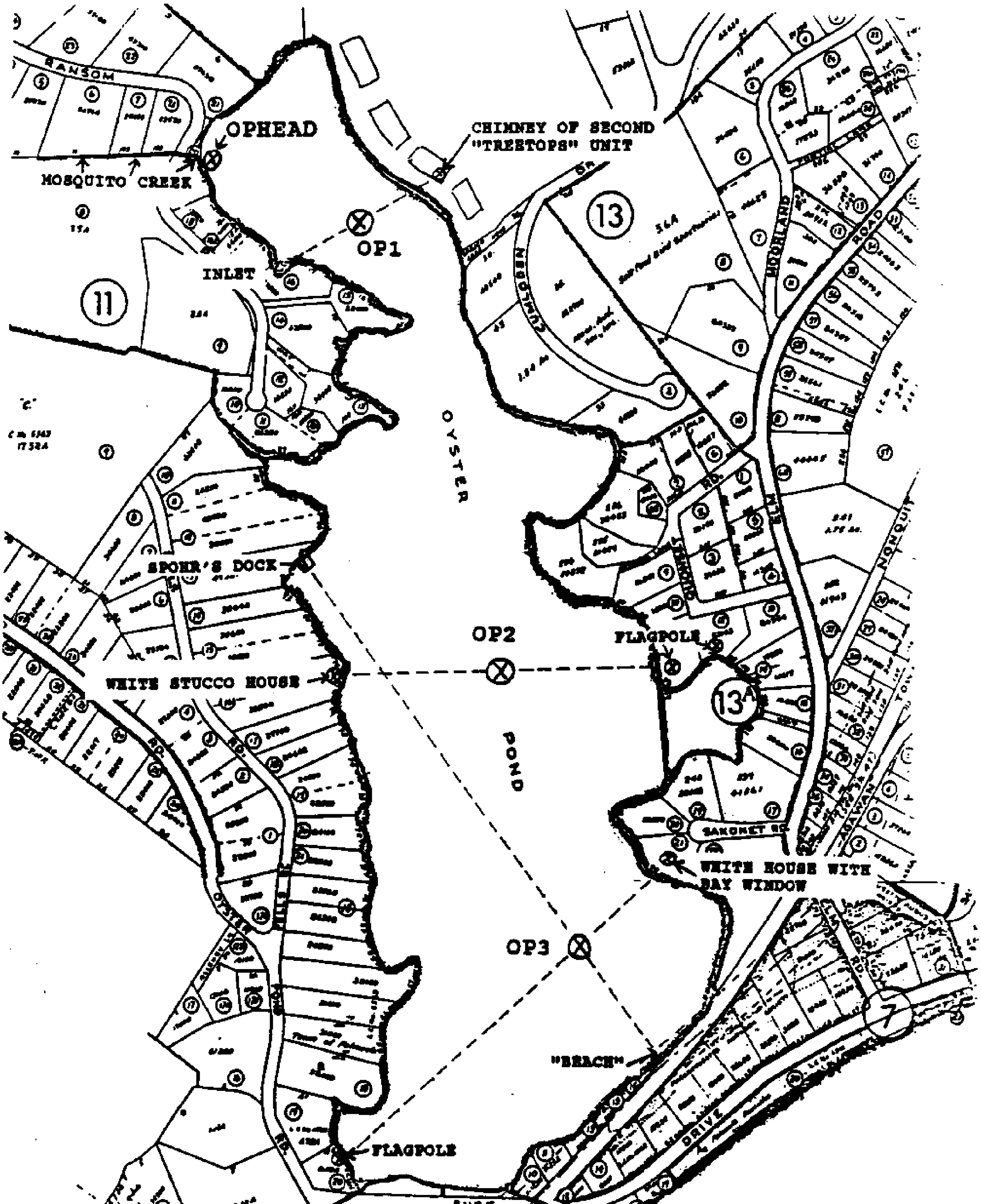

LITTLE POND: 1988-92
Frequency of Inlet Blockage
15
10
5
0
Aug-88
Dec-88
May-89
Nov-89
Apr-90
Sep-90
Feb-91
Jul-91
Jan-92
2=OPEN 10=BLOCKED 0=NO RECORD

Figure 23.

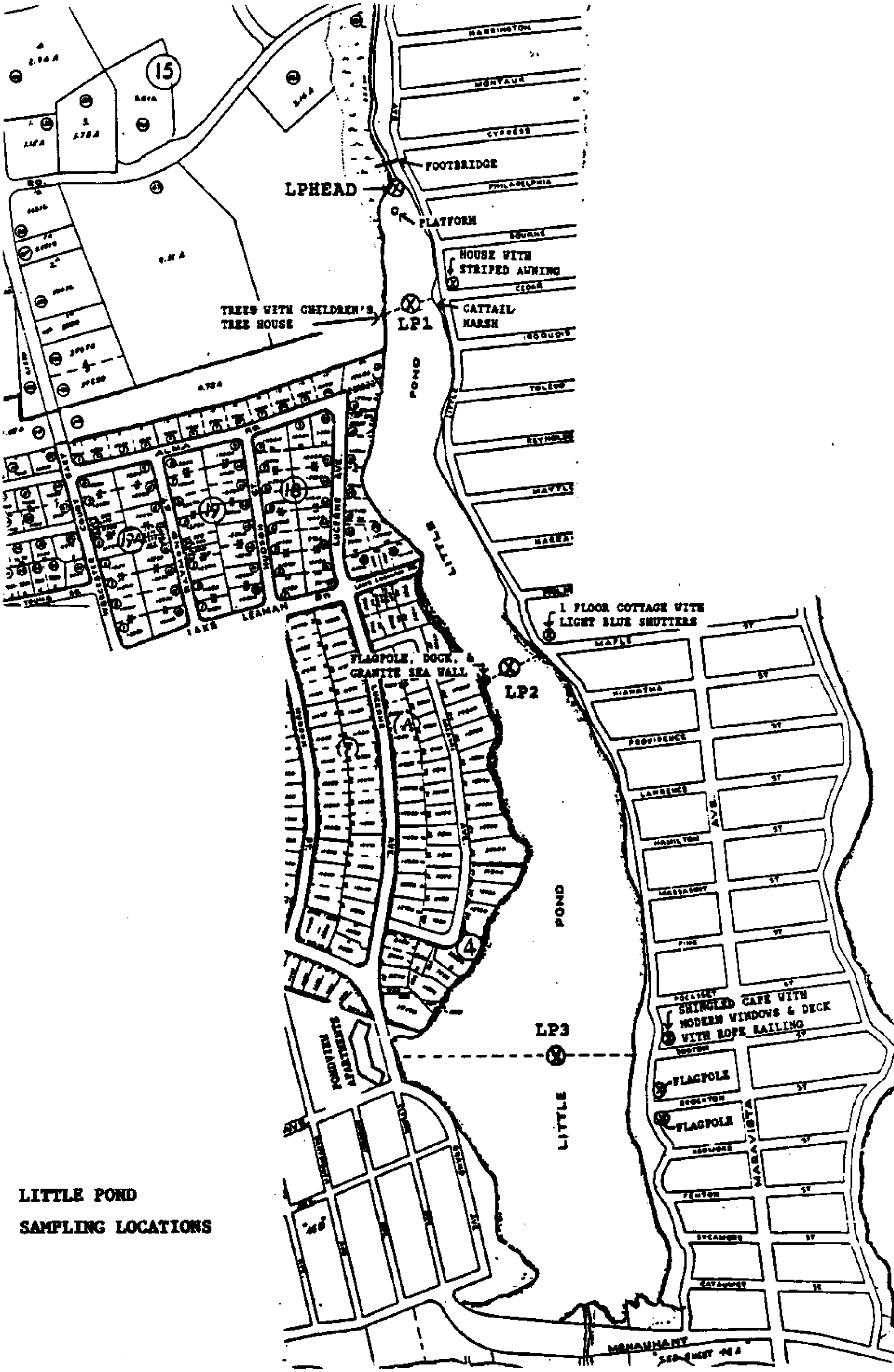
APPENDIX I.

Location of Sampling Stations for

Oyster, Little, Green, Great and Bournes Pond

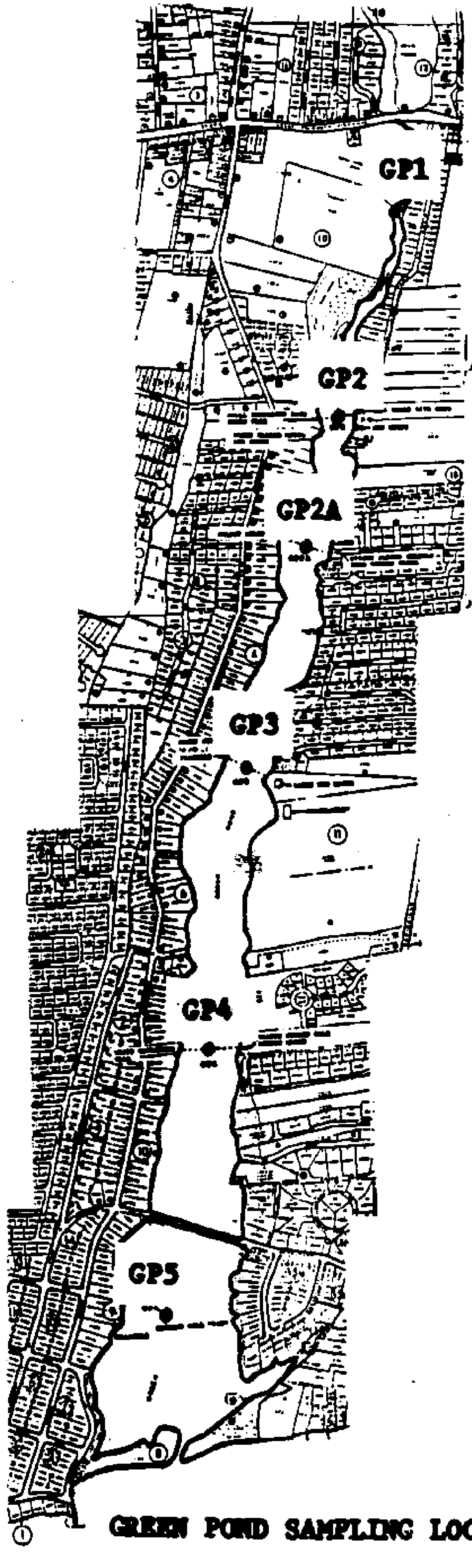


OYSTER POND SAMPLING LOCATIONS

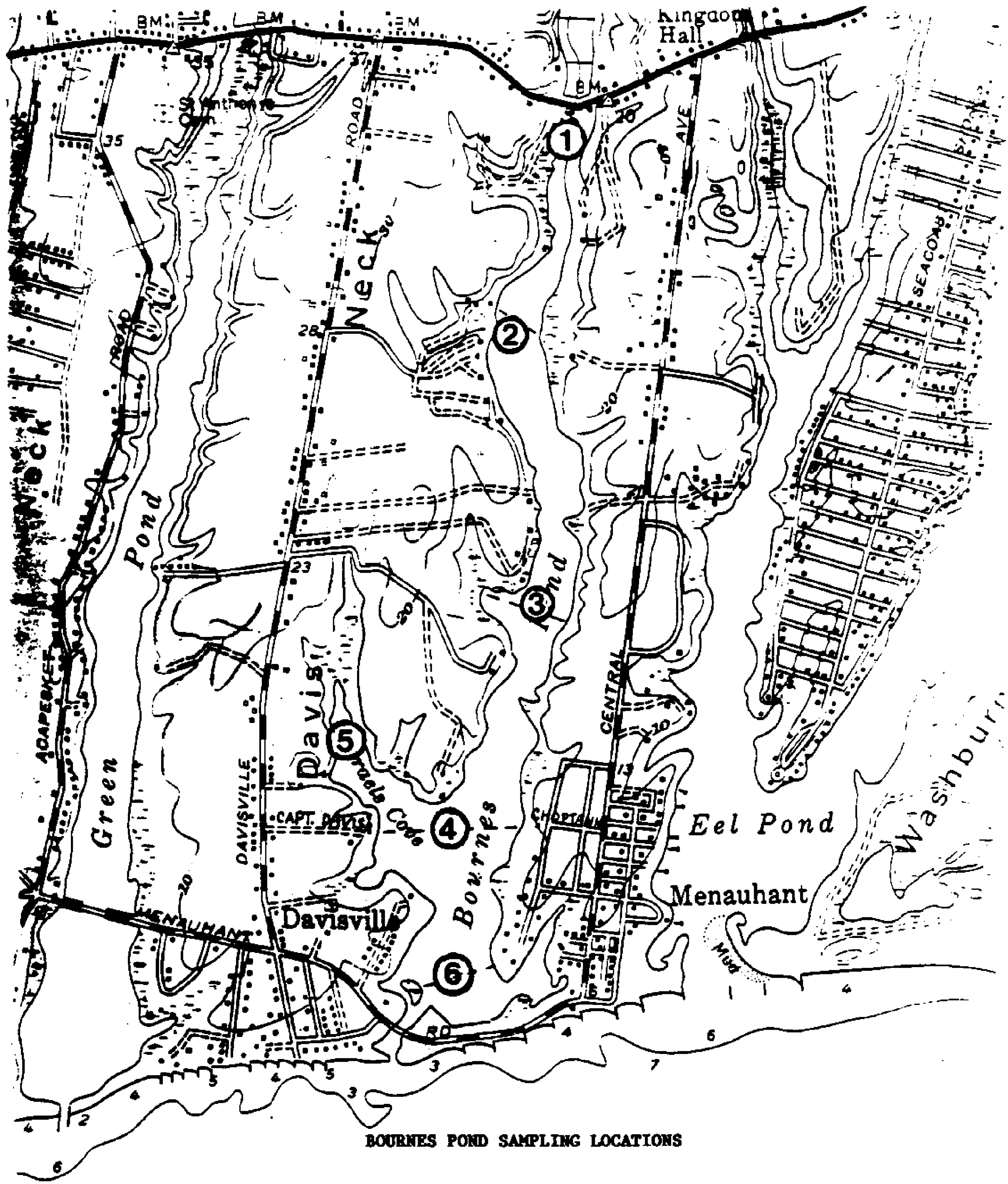


LITTLE POND

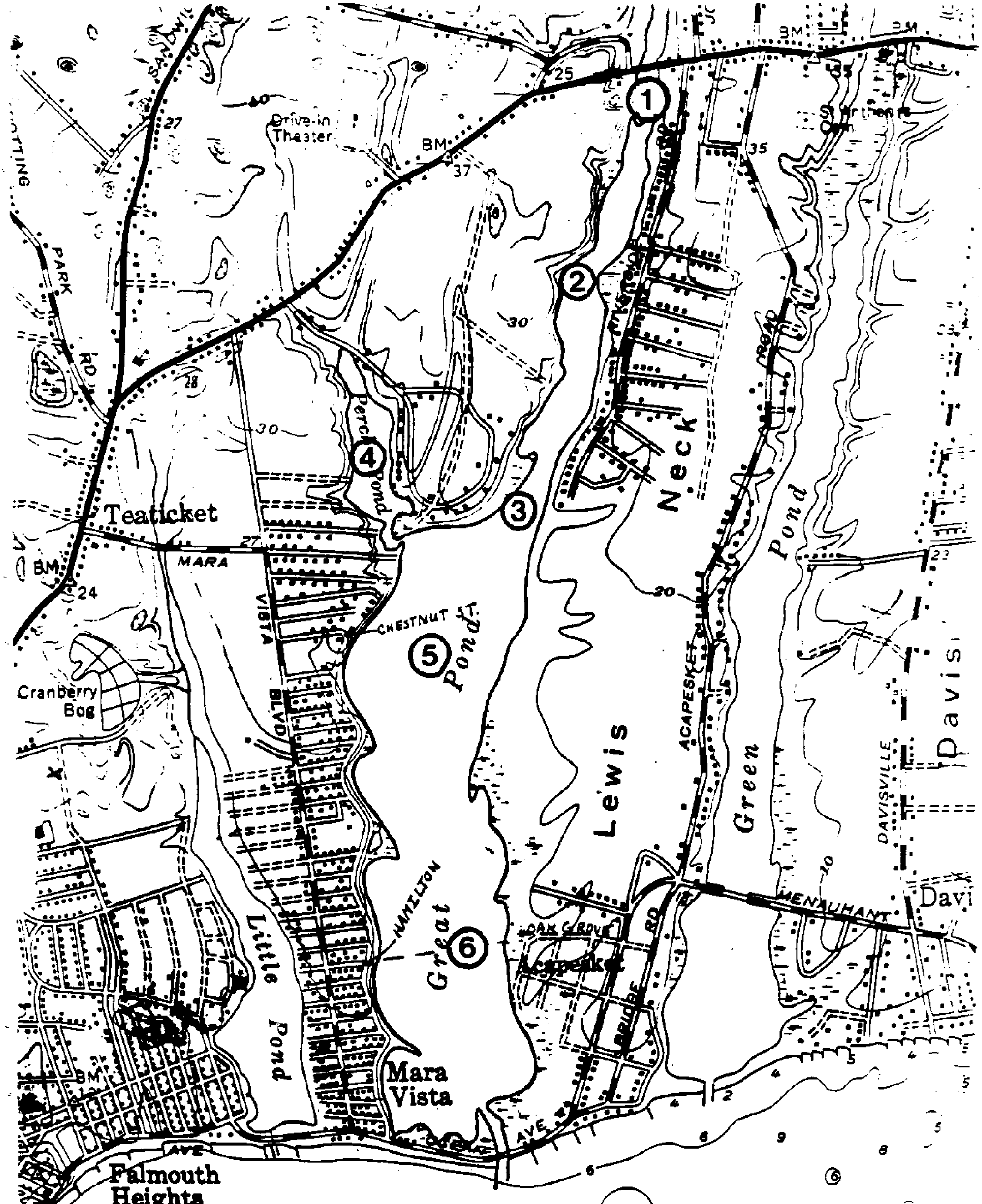
SAMPLING LOCATIONS



GREEN POND SAMPLING LOCATIONS



BOURNES POND SAMPLING LOCATIONS



GREAT POND SAMPLING LOCATIONS

Appendix II.

Alphabetical Listing of the 1991 Falmouth Pond Watchers

Pond Watchers 1991

Matthew and Beth Adamczyk
10 Sharon Ann Lane
East Falmouth MA 02536
PHONE: 540-7334
POND: Green (Pond Captain)

Andrea Arenowski
Biology Department
WHOI
Woods Hole MA 02543
PHONE: ext. 2737
POND: General

Duncan Aspinwall
408 Elm Road
Falmouth MA 02540
PHONE: 540-3816
POND: Oyster

Eleanor Baldic
Mariners Lane
Falmouth MA 02540
PHONE: 548-2681
POND: Green

Deborah Barry
6 Massasoit St.
East Falmouth MA 02536
PHONE: Little Pond
POND: 540-4150

Edward L. Beattie
96 Shoreland Path
East Falmouth MA 02536
PHONE: 548-6216
POND: Green

Jim Begley
42 Elizabeth Jean Drive
East Falmouth MA 02536
PHONE: 540-6210
POND: Bournes (Upper)

Charles Blumsack
59 Partridge Lane
East Falmouth MA 02536
PHONE: 540-0247
POND: Green

Frank Britto
355 Davisville Road
East Falmouth MA 02536
PHONE: 540-0316
POND: Green

John Callahan
2 Ardmore Street
East Falmouth MA 02536
PHONE: 540-3165
POND: Little

Lee Anne Campbell
Public Information Officer
WHOI
Woods Hole MA 02543
PHONE: Sea Grant Communicator
POND: General

Jane and Richard Carter
P.O. Box 22
North Falmouth MA 02556
PHONE: 563-5383
POND: Little

Jim Churchill
495 Blacksmith Shop Road
East Falmouth MA 02536
PHONE: 540-0526
POND: Green

Tracey Crago
WHOI Sea Grant Program
WHOI
Woods Hole MA 02543
PHONE: Sea Grant Staff Assistant
POND: General

Katherine Crew
P.O. Box 397
Falmouth MA 02540
PHONE: 548-8186
POND: General

Paul Crocker
37 Fells Road
Falmouth MA 02540
PHONE: 548-2106
POND: Oyster

Brian Currie
Town Planner
59 Town Hall Square
Falmouth MA 02540
PHONE: Town Planner
POND: Pond Watchers

Jonathan Culone
Seacoast Shores
295 Edgewater Drive East
East Falmouth MA 02536
PHONE: 548-8178
POND: Green

Ellen DeOrsay
2806 Pine St.
Galveston TX 77551
PHONE:
POND: General

John Dowling
106 Ransom Road
Falmouth MA 02540
PHONE: 548-2926
POND: Oyster (Pond Captain)

Bill Elder
41 Millfield Street
Woods Hole MA 02543
PHONE:
POND: General

Pond Watchers 1991

Dick Erdman
8 Providence Street
East Falmouth MA 02536
PHONE: 548-8868
POND: Great

Angela Frater
2403 W. Hickory Lane
Mequon WI 53092
PHONE: 548-9513
POND: General

Dale Goehringer
Biology Department
WHOI
Woods Hole MA 02543
PHONE: ext. 2744
POND: General

Kevin Griffin
45 Seatucket Road
East Falmouth MA 02536
PHONE: Green Pond
POND: 548-1082

Stan Hart
53 Quonset
Falmouth MA 02540
PHONE: 548-9005
POND: Oyster

Rick Hogan
26 Falmouth Landing Road
Falmouth MA 02540
PHONE: Green Pond
POND: 548-1389

Brian Howes
Biology Department
WHOI
Woods Hole MA 02543
PHONE: ext. 2319
POND: General

John Hulsey
Falmouth Town Hall
59 Town Hall Square
Falmouth MA 02540
PHONE: Assistant Town Planner
POND: General

Fran Jenney
53 School Street
Falmouth MA 02540
PHONE: 540-5026
POND: General

Joe Johnson
65 Miami Avenue
Falmouth MA 02540
PHONE: 548-0592
POND: Little

Clayton Jones
PO Box 181
North Falmouth MA 02556
PHONE: 540-5112
POND: Bournes (Lower)

John and Vera Justason
29 Miami Avenue
Falmouth MA 02540
PHONE: 548-2459
POND: Little

Mike Kinney
459 Davisville Road
East Falmouth MA 02536
PHONE: 548-2028
POND: Green

Robert & Marie Leavens
1 Iroquois Road
East Falmouth MA 02536
PHONE: 548-1473
POND: Little

Dick Lewis
Green Pond Fish N' Gear
366 Menauhant Road
East Falmouth MA 02536
PHONE: 548-2573
POND: Green

Donald & Helen Light
90 Ship's Watch
Falmouth MA 02540
PHONE: 548-0277
POND: Oyster

Henry Little
P.O. Box 101
West Falmouth MA 02574
PHONE: 548-8537
POND: General

Bob Livingstone
1 Fells Road
Falmouth MA 02540
PHONE: 540-8065
POND: Oyster (Rain Gauge)

Werner&Birgit Loewenstein
102 Ransom Road
Falmouth MA 02540
PHONE:
POND: Oyster

Fred Martin
P.O. Box 1054
West Falmouth MA 02574
PHONE: 548-3362
POND: General

Les Martin
PO Box 855
East Falmouth MA 02536
PHONE: 548-3362
POND: Bournes (Lower)

Pond Watchers 1991

Carol McKenzie
420 Shorewood Drive
East Falmouth MA 02536
PHONE: 548-4447
POND: Green

Arthur (Rocky) Miller
175 Lakeview Avenue
Falmouth MA 02540
PHONE:
POND: General

Tony Millham
Biology Department
WHOI
Woods Hole MA 02543
PHONE: ext. 2319
POND: General

Steve Molyneaux
P.O. Box 595
Woods Hole MA 02543
PHONE: 540-2484
POND: Bournes

Barbara & Barry Norris
52 Landfall Road
Falmouth MA 02540
PHONE: 540-7345
POND: Oyster

Frances O'Donnell
49 Vineyard Street
East Falmouth MA 02536
PHONE: 548-6033
POND: Green

Chuck Olive
69 Priscilla St.
Teaticket
East Falmouth MA 02536
PHONE: Great Pond
POND: 548-6526

Armand & Mary Ortins
40 Bridge Street
East Falmouth MA 02536
PHONE: 548-1670
POND: Green (Pond Captain)

Barbara Peri
2 Tortoise Lane
Falmouth MA 02540
PHONE: 548-2769
POND: Oyster

John Quinn
51 Weatherglass Lane
East Falmouth MA 02536
PHONE:
POND: General

Julie Rankin
PO Box 97
Ashford CT 06278
PHONE: 563-3463
POND: Oyster (Pond Captain)

Richard Rebello
60 Lucerne Avenue
East Falmouth MA 02536
PHONE: 548-3650
POND: Little

Terry Riehl
111 Portside Circle
East Falmouth MA 02536
PHONE: 548-5186
POND: Green

Gretchen Rittershaus
P.O. Box 69
East Falmouth MA 02536
PHONE: 548-0509
POND: Green

Bobby Rogers
8 Iroquois Street
East Falmouth MA 02536
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POND: Little

David Ross
WHOI Sea Grant Program
Woods Hole MA 02543
PHONE: 548-0476
POND: Green

Robert Roy
2 Massasoit Street
East Falmouth MA 02536
PHONE: 548-5139
POND: Little (rain gauge)

Adele Rustino
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Cambridge MA 02138
PHONE:
POND: General

David Schlezinger
Biology Department
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Woods Hole MA 02543
PHONE: ext. 2737
POND: General, Great

Jack Shohayda
36 Miami Avenue
Falmouth MA 02540
PHONE: 548-0472
POND: Little (Pond Captain)

Jon & Nancy Soderberg
and Alicia
PO Box 823
East Falmouth MA 02536
PHONE: 540-0186
POND: Bournes (Lower)

Pond Watchers 1991

Frank and Diane Souza
55 Sharon Ann Lane
East Falmouth MA 02536
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Raymond Tavares
Falmouth Planning Board
59 Town Hall Square
Falmouth MA 02540
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POND: Pondwatcher

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P.O. Box 869
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PHONE: Bournes Pond
POND: 540-3631

Edmund Wessling
28 Bridge Street
East Falmouth MA 02536
PHONE: 548-7736
POND: Green (Pond Captain, Rain Gauge)

Mr. & Mrs. Herb Stern
183 Bayfront Way
Falmouthport
East Falmouth MA 02536
PHONE: Great Pond
POND: 548-5488

Ted Tavares
106 Lake Leman Road
Falmouth MA 02540
PHONE: 548-5168
POND: Little

Ginny Waight
66 Bourne Street
East Falmouth MA 02536
PHONE: 548-2775
POND: Little

Alan White
National Marine Fisheries Service
Woods Hole MA 02543
PHONE:
POND: General

Charles A. Swain
Town of Falmouth Planning B
173 Main Street
Falmouth MA 02540
PHONE: Chairman
POND: Barn. County

David Thomas
P.O. Box 869
Crowell Road
East Falmouth MA 02536
PHONE: Bournes Pond
POND: 540-3631

Barbara Wells
3 Ardmore Street
East Falmouth MA 02536
PHONE:
POND: Little

Marge & Don Zinn
P.O. Box 589
Falmouth MA 02541
PHONE: 548-1559
POND: Oyster