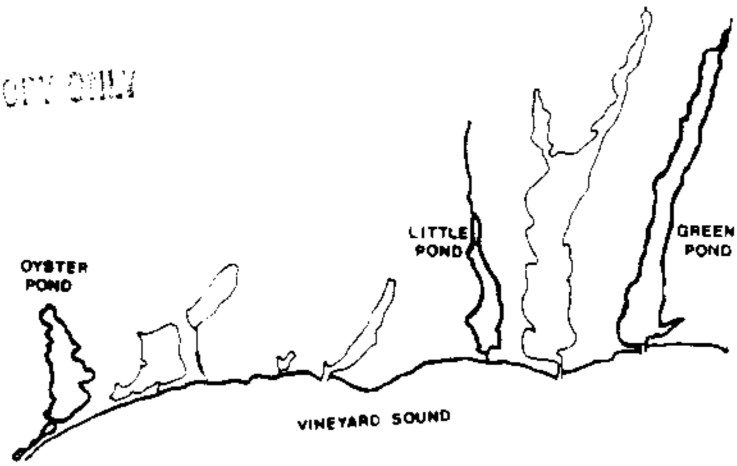
WHOI-Q-90-001 C2

FINAL REPORT ON CITIZEN VOLUNTEER MONITORING OF WATER QUALITY IN FALMOUTH'S COASTAL PONDS



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This cooperative project is conducted with funding from the Woods Hole Oceanographic Institution Sea Grant Program and the Town of Falmouth Planning Office.

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EXECUTIVE SUMMARY

In 1987 a cooperative effort was initiated between the Town of Falmouth and the WHOI Sea Grant Program to address the matter of deteriorating water quality in Falmouth's coastal ponds. This initiative led to the development and implementation of a more comprehensive project in 1988 and 1989 based on the active participation of citizen volunteers in water quality observations and sampling of Oyster, Little and Green Ponds and additional WHOI Sea Grant sponsored projects on coastal ponds being initiated.

The objectives of this "Pond Watcher Project" were 1) to provide the Town with a documentation of the water quality status of the three ponds, 2) to provide information that would assist the Town Planning Office in interpreting the newly enacted Coastal Pond Nutrient Overlay Bylaw, and 3) to generate an increased awareness among the citizenry of Falmouth of the water quality problems facing coastal ponds.

More than 60 citizens volunteered and have taken part in this project. Over the two-year period about half of these people participated in sampling trips on the ponds using their own boats, or became involved in other projects such as oyster growing and rainfall recording. About 600 person-hours were spent by volunteers in connection with this project. Sampling equipment was provided to the "Pond Watchers" by WHOI Sea Grant and training sessions were held to teach sampling techniques. Pond Watchers made measurements in the ponds and prepared samples for nutrient analyses, conducted at WHOI. Sixteen complete sampling trips were conducted between September 1987 and October 1989, ten by Pond Watchers and six by WHOI personnel. The project proceeded very smoothly, largely because of the interest and dedication of the volunteers.

This project has generated a significant body of information about Oyster, Little and Green Ponds. In general terms, the data show pronounced nutrient loading of these ponds. Existing nitrogen levels in each of the ponds already exceed the threshold guideline of 0.5 mg total nitrogen per liter specified for these ponds in the Coastal Pond Nutrient Overlay Bylaw (although the seaward end of Green Pond averages slightly less than 0.5 mg total nitrogen per liter). Moreover, all of Oyster Pond and the upper reaches of Little and Green Ponds exceed 0.75 mg total nitrogen

per liter, the guideline specified for "intensive use areas." Consistent with these nutrient concentrations was our finding of periodic low oxygen conditions during the summer months throughout Little Pond, the upper reaches of Green Pond and seasonal anoxia in the mid and upper regions of Oyster pond -- significant oxygen depletion is the ultimate negative impact of high nutrient conditions -- placing the animal and plant communities in these areas under stress. All of these findings lead to the general recommendation that management options be considered to reduce nutrient inputs (or increase nutrient outputs) to these ponds during the critical summer months.

INTRODUCTION

Like many coastal ponds in Massachusetts, salt ponds in the Town of Falmouth are showing signs of diminished water quality and ecological stress. The causes, while not always clear, appear to involve nutrient loading which may be the result of increasing human pressures on the ponds and their associated watersheds. The population of Falmouth, as well as the other towns on the Cape and Islands, is growing rapidly, bringing intense demand for the desirable properties surrounding coastal ponds. The increased multiple uses of these ponds and their drainage areas are causing nutrient enrichment of these systems. The nutrients derive from a variety of sources including septic systems, lawn fertilizers, road run-off, and other activities associated with residential and commercial developments. The significance of these development-related nutrient inputs depends in part on the relative natural loading and cycling of nutrients in the recipient pond.

Coastal salt ponds, by their nature, are highly productive, nutrient-rich environments, frequently providing areas rich in shellfish. These ecosystems are generally able to tolerate high nutrient loads but, due to their high productivity and low flushing rates, run the risk of suffering from the extremely negative impacts of over-fertilization. Three ponds in particular, Oyster, Little and Green Ponds, presently show signs of advanced eutrophication: dense algal blooms, heavy growth of bottom vegetation, unsightly algal mats, odor production, shellfish contamination and occasional fish kills. Before this present study, most of our environmental assessment of these ponds was based on visual impressions with some quantitative data on water column nutrient levels collected mainly in association with environmental impact studies for commercial and residential developments. However, the data are too few and the sampling too unstructured to provide a sufficient understanding of the nutrient status of these ponds for use in planning and management.

The Town of Falmouth, like many other towns in Massachusetts, faces the difficult questions of when and how to deal with coastal pond water quality deterioration. While it is at present unclear how much of the current nutrient loading problem in Falmouth's coastal ponds is due to development, it is certain that in most situations increased loading will accelerate the decline in water quality and the deterioration of these environments. Management options include enlarging and improving the ponds' outlets to the sea, increased sewerage, restrictions on lawn fertilization, installation of denitrification systems, rezoning, building moratoria, etc. The Town is in need of water quality data and information on these ponds in order to enact management schemes and development policies which will not compromise these outstanding natural assets.

BACKGROUND

In April, 1987, the concern over the increasing eutrophication of Oyster, Little and Green Ponds was raised at the Falmouth Town Meeting. Dr. William Kerfoot, Chairman of the Salt Pond Planning Committee for the Town of Falmouth, requested that $60,000 be appropriated to have a diagnostic study of the ponds conducted. The Town was very interested in the problems of these ponds, but was unable to provide the required funding. The Town did, however, approve $5,000 as "seed" money (under the auspices of the Town Planning Board) to help initiate a water quality study of the ponds.

Recognizing the deterioration in the water quality of these ponds, Dr. David Ross, Coordinator of the Woods Hole Oceanographic Institution Sea Grant Program as well as a Town Meeting Member, indicated that WHOI Sea Grant would try to help the Town in this regard.

During the summer of 1987, Dr. Alan White, Marine Science Advisor with WHOI Sea Grant, and Dr. Brian Howes, Assistant Scientist, and Ms. Dale Goehringer, Research Associate in the Biology Department at WHOI, developed plans for a water quality study of Oyster, Little, and Green Ponds (Fig. 1). The project consisted of two parts, a preliminary survey followed by a comprehensive two-year water quality monitoring study in 1988 and 1989 involving the participation of citizen volunteers.

The purpose of the project was to provide the Town with comprehensive documentation of present water quality conditions in the ponds. The Town requires

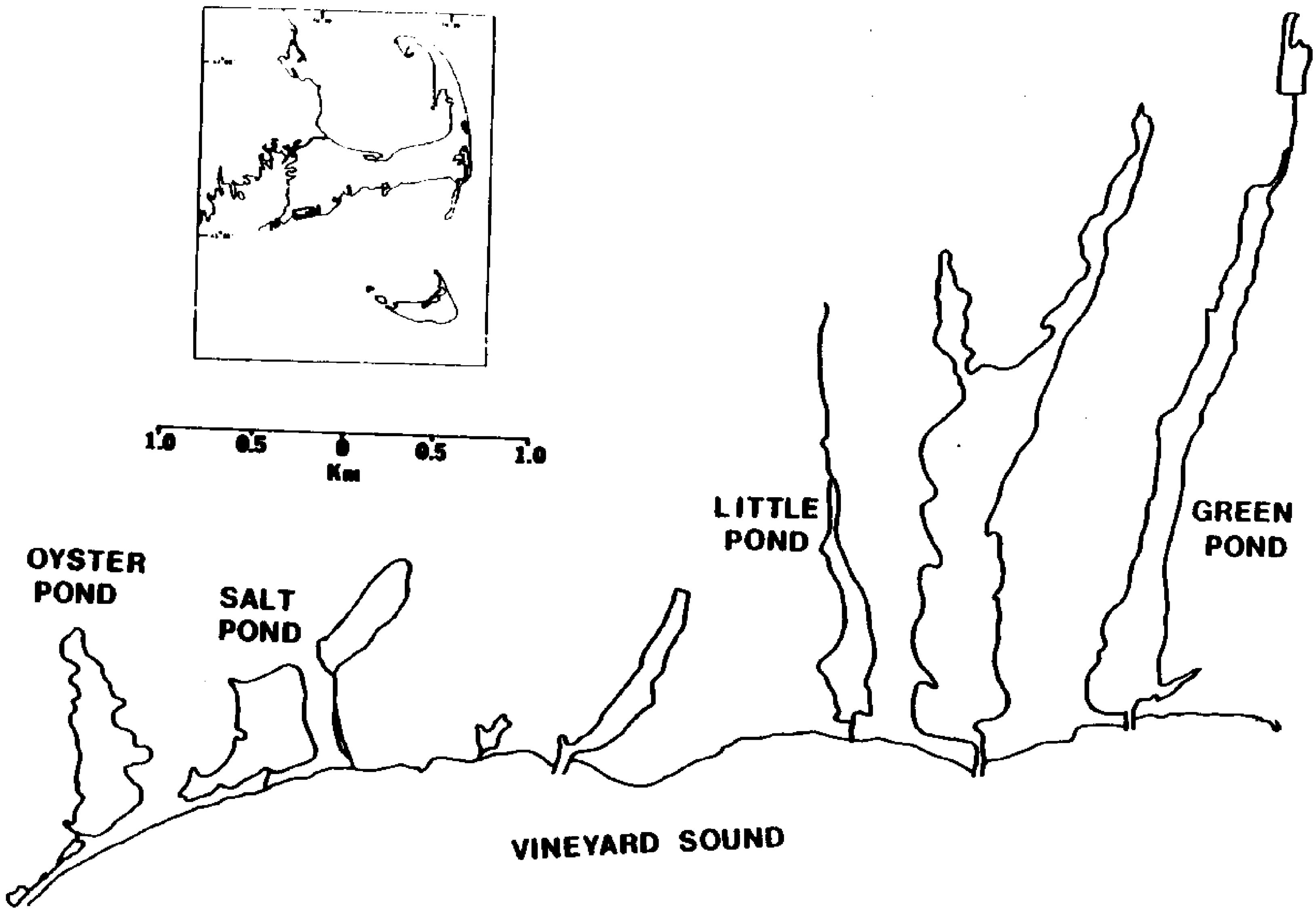


Figure 1. Relative location of the coastal salt ponds, Falmouth, MA. Little, Green and Oyster Ponds have been identified as areas of environmental concern by the Town of Falmouth.

the data for planning and for assessing the effectiveness of future management actions. Further, the project was designed to give concerned citizens an opportunity to become directly involved in the future of Falmouth's coastal ponds and to draw community attention to the increasing human pressures on these coastal resources.

At the Town Meeting in April, 1988, a Coastal Pond Overlay Bylaw was approved to preserve water quality. The Bylaw specified annual mean threshold values for total nitrogen concentrations in Falmouth's coastal ponds as follows: 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." Therefore, as this citizen-based water quality study developed, a further objective was to provide information to the Planning Board to assist it in assessing and interpreting the new Bylaw.

Funding for the preliminary survey and the first and second years of citizen monitoring has been provided jointly by the Woods Hole Oceanographic Institution Sea Grant Program and the Town of Falmouth Planning Office.

Preliminary surveys were conducted in the fall of 1987 and the spring of 1988. These surveys provided an initial data base and set the stage for the citizen volunteer component of the project in terms of developing sampling protocol (station locations, sampling depths, equipment needs, parameters to be measured, etc.). The citizens' monitoring effort began in the late spring of 1988. Through the enthusiasm, interest and selfless dedication of citizen volunteers ("Pond Watchers") we have very successfully completed the sampling program in 1988 and 1989 and have generated a substantial data set.

VOLUNTEERS

Requests for volunteers for this project were made in May and June, 1988 through newspaper articles (see Appendix 1) and radio and TV announcements. We explained that we were looking for people to perform either of two tasks. First, we needed volunteers who own, or have access to, a small boat and who would be willing to go to certain locations in the ponds once a month to make measurements and take samples -- in mid-July through mid-October, 1988 and mid-May through mid-October in 1989. Second, we needed volunteers who live close to the ponds to serve as the "eyes, ears, and noses" of the ponds and promptly report to us unusual occurrences, such as fish kills, algae mats, strange colors, bad odors, etc. It was stressed that a scientific background was not required for either task, only willingness to contribute.

The response from the community was swift and positive. Within just a few weeks, 55 people (of all ages and all walks of life) volunteered to help with the project. Since then the number of volunteers has increased to 65. A listing of these volunteers, henceforth referred to as "Pond Watchers," is given in Appendix 2.

ORGANIZATION AND TRAINING

An initial organizational meeting of the Pond Watchers was held on June 30, 1988 at Town Hall to explain the project, its overall goals, and what we expected of the volunteers. At that time, "Pond Captains" were appointed to help coordinate participation and performance for their ponds. These volunteer Pond Captains are as follows:

Oyster Pond	- John Dowling
	- Julie Rankin
Little Pond	- Jack Shohayda
Upper Green Pond	- Frank Souza
Lower Green Pond	- Edmund Wessling
	- Armand Ortins

Training sessions were held at the Woods Hole Oceanographic Institution on the evenings of July 12 and 15, 1988, in preparation for our first volunteer sampling effort on Sunday, July 17. Pond Watchers were shown the various pieces of equipment and participated in a hands-on demonstration of the techniques involved. The sampling protocol (Appendix 3) was explained step-by-step. It consisted of taking temperature, oxygen and light measurements at selected locations at the surface and at various depths and then collecting water samples, some of which were filtered for subsequent nutrient assays. A retraining session was held on May 10, 1989, in preparation for the 1989 sampling season.

EQUIPMENT

Equipment and supplies for Pond Watchers were purchased or fabricated during the spring and early summer of 1988. Eleven sets of sampling equipment and supplies were distributed among the Pond Captains. Each tool box contained a Secchi disc fastened on a fiberglass measuring tape, color wheel, thermometer, filters, filter holders, filtering syringe, forceps, oxygen kit, maps, data sheets, instruction sheets, waste reagent container, pens and pencils, etc. In addition, we provided a cooler for transporting and storing samples, and an instrument for water sampling - Niskin samplers were used for Oyster Pond, pole samplers with bottles attached at fixed locations were used for the shallower Little and Green Ponds.

Electronic (battery-operated) rain gauges were purchased and installed at Pond Watchers' homes at four locations - Oyster Pond, Bob Livingstone; Siders Pond, Alan White; Little Pond, Robert Roy; and Green Pond, Edmund Wessling. Beginning in August, 1988, rainfall amount was recorded on a daily basis by those Pond Watchers. In addition, tide gauge (Joe Johnson) and water column light transmission (Robert Roy) stations were established in Little Pond in May 1989.

SAMPLE LOCATIONS

Based on hydrographic and bathymetric data from the preliminary phase of the project, 15 sampling station locations were chosen as depicted on the maps in Appendix 4. There were four stations in Oyster Pond, four in Little Pond, six in Green Pond, and one at Buoy #2 in Vineyard Sound. Landmarks indicated on the maps enabled Pond Watchers to collect samples and take measurements at the same spot, or close to it, each month.

The depths at which samples were taken are listed in Appendix 5. Again, based on the hydrographic and bathymetric information from the preliminary study, these depths were chosen so as to provide data from the different strata (layers) of the pond.

In total, 33 sets of nutrient and particulate samples were taken and 33 sets of measurements were made by Pond Watchers per month.

SAMPLING LOGISTICS

As funding for the first year of the Pond Watcher project did not begin until July 1, 1988, the study was designed to have WHOI personnel collect samples from May through July of 1988 and Pond Watchers from July through October. Upon consensus of the Pond Watchers, the time of sampling was agreed to be Sunday mornings between 9 am and 12 noon. Prior to sampling days, Pond Captains ensured that teams of Pond Watchers (at least two per boat) were prepared to make the trip and were aware of their station designations, had adequate supplies, etc. Early in the morning on sampling days, Alan White telephoned Pond Captains to give them the "go" or "no go" for sampling, depending upon the weather and pond conditions. Fortunately, the weather was suitable for sampling on all 10 occasions in 1988 and 1989; no postponements were necessary.

Following sampling, Pond Watchers returned their samples (in coolers) and data sheets to their Pond Captains. Pond Captains kept the samples cold until Monday morning, when the samples and data sheets were collected by WHOI project personnel and returned to Brian Howes' laboratory for processing and analysis.

The dates of sampling are as follows:

September 16, 1987 (WHOI)
October 19, 1987 "
May 27, 1988 "
July 6, 1988 "
July 17, 1988 (Pond Watchers)
August 14, 1988 "
September 11, 1988 "
October 16, 1988 "
January 18, 1989 (WHOI)

March 7, 1989 "
May 21, 1989 (Pond Watchers)
June 11, 1989 "
July 16, 1989 "
August 13, 1989 "
September 10, 1989 "
October 15, 1989 "

POND WATCHER MEASUREMENTS AND ASSAYS

Following the protocol specified in Appendix 3, Pond Watchers obtained the following information for each sample location and entered it on their data forms:

total depth
temperature
light penetration (Secchi disc reading)
water color
oxygen content (using Hach kit)
comments on pond state, weather, etc.

In addition, Pond Watchers collected water samples and filtered portions of each. These water samples were kept in coolers with ice packs until they reached the laboratory where salinity and nutrient analyses were conducted as described below.

LABORATORY ASSAYS

In Brian Howes' laboratory at the Woods Hole Oceanographic Institution, a research team processed the water samples and conducted analyses to determine concentrations of the following nutrients:

nitrate plus nitrite
ammonium
dissolved organic nitrogen
particulate organic nitrogen

particulate organic carbon
dissolved organic phosphorus
phosphate
chloride

Salinity was determined by refractometer. For some samples taken during the preliminary survey phase of the project, sulfide and chlorophyll analyses were also conducted.

In total, more than 5,200 analytical determinations were made in the laboratory, coupled with more than 1,600 readings made in the field (depth, temperature, light, color, oxygen).

The results of the laboratory analyses and field measurements of oxygen and temperature are combined to produce an overall assessment of water quality conditions in the three ponds.

OYSTERS

In 1989 the Pond Watchers conducted an ancillary water quality project aimed at assessing the degree to which the ponds would support the growth of oysters.

In June oyster seed (certified disease-free) were obtained through the courtesy of Ocean Pond Corporation, Fishers Island, NY with the assistance of the Cotuit Oyster Company. On June 21 a team of volunteers weighed, measured, and numbered 600, thumbnail-size oysters. One hundred oysters were placed in each of six lantern net cages and suspended off the bottom at the six sites shown on the maps in Appendix 4 (two in Oyster Pond, one in Little Pond, two in Green Pond, and one in Vineyard Sound near the WHOI Shore Lab dock as a control).

The oysters were checked and cleaned at about weekly intervals by the following Pond Watchers:

Oyster Pond - Robert Livingstone and Barry Norris;
Little Pond - Robert Roy;
Green Pond - Stephen Molyneaux, Michael Kinney, and John Quinn;
Vineyard Sound - Alan White.

The oysters were harvested on December 10 and total weight, shell length and displacement volume were measured on December 11 to determine growth. The oysters were then frozen and two months later the weights of the oyster meats (ash-free dry weights) were determined.

COMMUNICATIONS

One of the goals of this project is to have the project serve as a vehicle for public involvement, awareness, and education concerning Falmouth's coastal ponds and the problems confronting them. The key to opening this opportunity has been the initial group of citizen volunteers who were interested and concerned enough to step forward and offer their time and assistance to help make the project succeed.

During the project we have encouraged a free flow of information between Pond Watchers and project personnel at WHOI. We maintained an "open-phone" policy with Pond Watchers, trying to be of assistance with questions and problems whenever possible. Further, through correspondence with all Pond Watchers on a regular basis we kept them informed of project progress and developments, along with summaries and explanations of certain phenomena in the ponds. On February 7, 1989 and March 23, 1990 WHOI Sea Grant sponsored "science parties" with presentations to inform Pond Watchers of the progress and results of the project as well as demonstrate our appreciation of their volunteer efforts.

We reached many other people in Falmouth, on Cape Cod, and even across the country with information about the concept of citizens' involvement in environmental monitoring and about the Pond Watcher project in Falmouth. News of the project appeared in newspaper articles (Appendix 6), on a number of radio interviews, on a taping for national television (CBN, 700 Club), at presentations given for Falmouth Garden Club's Environment Day and for Buzzards Bay Day, at national meetings on citizens monitoring of the environment held in Rhode Island and New Orleans, and in a nationally distributed directory of citizen volunteer monitoring programs resulting from those meetings.

RESULTS AND DISCUSSION

The sampling program in 1988 and 1989 went extremely well. The field, laboratory, and coordination components all proceeded better than was anticipated when the project was initially proposed. The major factor in the success of the project has been the enthusiastic and conscientious participation and cooperation of the volunteer Pond Watchers. Even the weather cooperated; all sampling trips were held as scheduled. In addition, having a large team of samplers enabled collection of data from all three ponds "simultaneously", which greatly enhances the interpond comparisons and strength of the results.

On all sampling occasions, secchi disk readings in Little Pond and Green Pond indicated that light was available at the bottom of the ponds, at 1% of surface light levels at minimum. Thus macroalgal growth on the bottom might also be a nutrient related concern for these ponds.

Physical/Chemical Processes

Falmouth's coastal salt ponds are relatively shallow, enclosed brackish water bodies that are structured ecologically by high nutrient conditions and relatively low flushing rates. Large variations in physical and chemical parameters exist both from pond to pond and from site to site within ponds. Even so, the basic relationships of nutrients, plant production, oxygen conditions and water exchange are the same as in all coastal salt ponds.

Salinity

Variations in salinity within and between ponds reflect the relative mixing of fresh (stream flow, groundwater inputs, runoff, precipitation) and salt water (specifically, exchange with Vineyard Sound) inputs. All three ponds studied, Green, Little, and Oyster Ponds, have salinities throughout the year that are significantly less than Vineyard Sound. Salinity differences between ponds appears to be directly related to the degree of exchange with Vineyard Sound (the source of salt water). All three ponds exhibit decreasing salinities with increasing distance from their inlets to Vineyard Sound (Figure 2). Green Pond exhibits a strong salinity gradient with salinity increasing from the head toward Vineyard Sound. This is not surprising

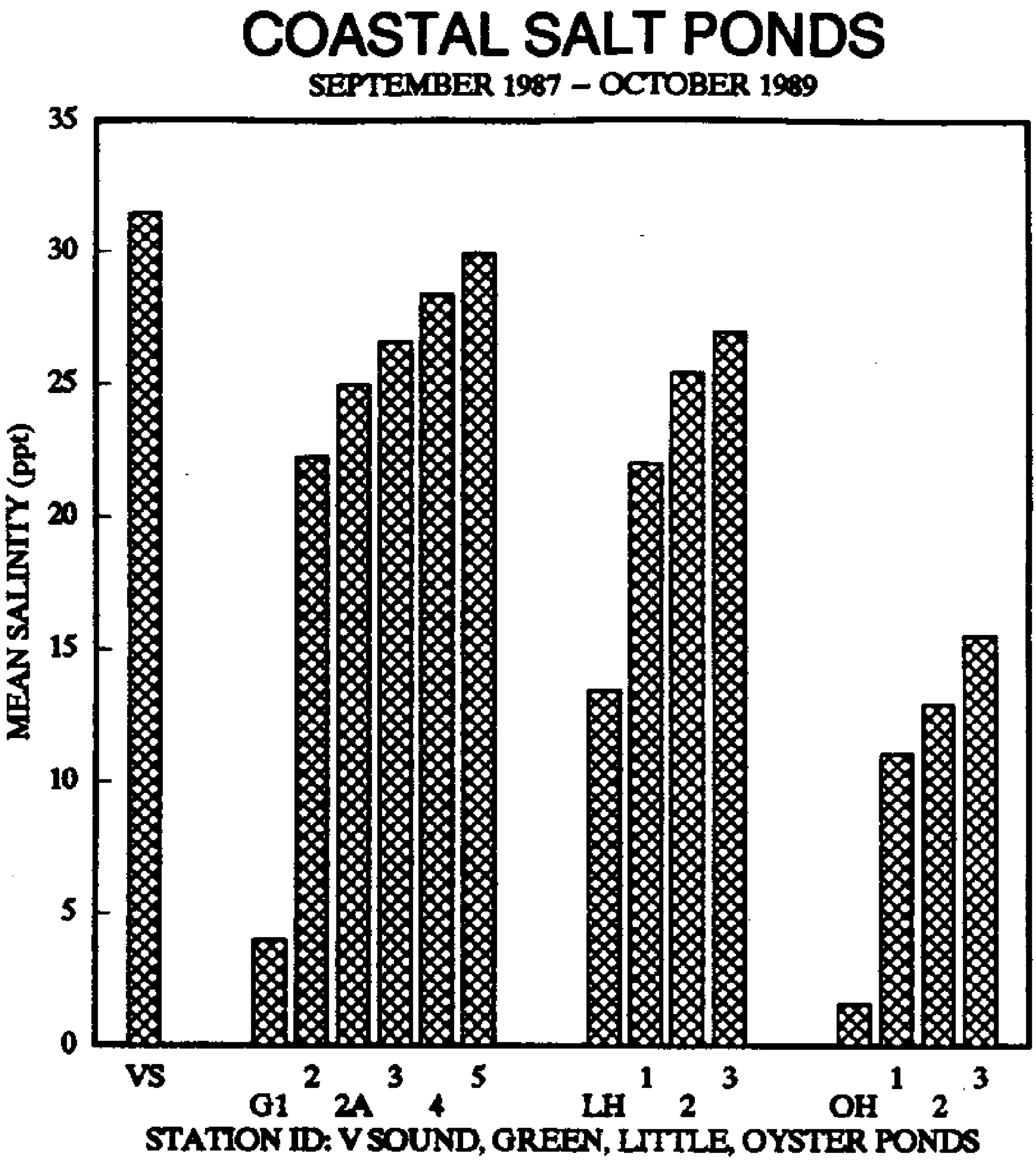


Figure 2. Average salinities for each sampling station within Green, Little and Oyster Ponds. As no strong seasonal trends in salinity were observed, the data from all 16 sampling collections has been combined.

considering the pond length and the surface, freshwater inputs at the head, groundwater discharges along its length, and increasing tidal exchange toward the mouth of the pond. The gradient for Little Pond is similar but less pronounced with the general pond salinities less than Green Pond, primarily because of its smaller size and more limited tidal exchange with Vineyard Sound. Oyster Pond is farther along the continuum and is the "freshest" of the three ponds because of its very restricted exchange with Vineyard Sound. The surface water salinities of Oyster Pond were typically around 10 ppt while water in the deep basin (Station 3) was in excess of 25 ppt. However, the interaction of the bathymetry of Oyster Pond (with its deep basins) and limited tidal exchange has resulted in an historic anoxia of its basins in summer related in part to the strong stratification caused by high salinity (dense) water settling in the basins.

Rainfall

Given the importance of direct nutrient and water inputs from rainfall and groundwater and the large variation in local rainfall which can occur in coastal areas, we are maintaining rain gauges on each of the ponds and on Siders Pond. Investigation of rainfall patterns has emphasized the importance of maintaining site-specific rain collection stations. The ponds show significant variation among them in terms of rainfall; therefore, using any single point (such as the Long Pond station) for measurement of this parameter masks the small-scale spatial variation in precipitation inputs to these ponds. Also, not unexpectedly, comparisons with data collected from Long Pond Station indicate that monthly total rainfall can be significantly different (three to four-fold) from the ten-year average frequently used in models to correlate rainfall to other environmental parameters. By keying each of our pond gauges to the Long Pond Station for several years we hope to determine a correction factor for each pond relative to Long Pond.

Temperature

Coastal ponds differ from adjacent coastal waters in another ecologically important, yet frequently overlooked way. The summer water temperature of the ponds can be more than 5 degrees Celcius (9 degrees Fahrenheit) warmer than

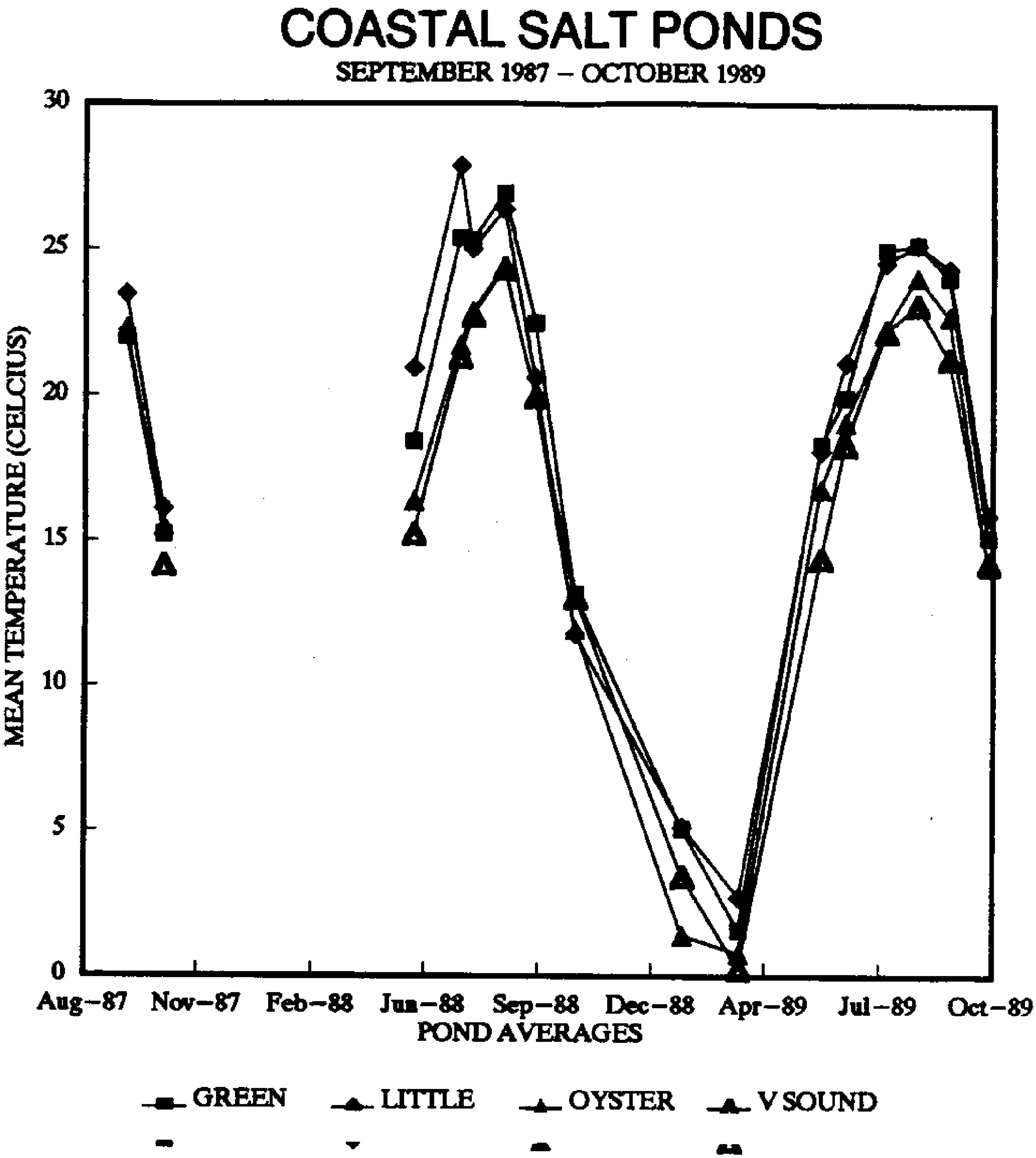


Figure 3. Average temperature of all stations within each pond for each sampling period. Oyster Pond temperatures on average are much closer to Vineyard Sound than Green and Little Ponds due to its much greater depth.

Vineyard Sound (Figure 3). This has biological significance in that increased temperature stimulates respiration, hence oxygen consumption, in these systems. The ponds generally show a gradient from higher to lower temperature from the head toward Vineyard Sound. Some of this temperature variation is due to the shallower nature of the upper regions, some due to increased mixing with cooler Vineyard Sound waters near the pond entrance. Unfortunately, these conditions place the greatest temperature "stress" on the least well flushed and highest impact areas of the ponds.

Water Column Stratification

Since each of the ponds exhibits some level of estuarine circulation, freshwater flowing toward the Sound over more dense saline water flowing in, the potential for significant water column stratification exists. Stratification has important ecological effects on nutrient rich coastal environments where production of organic matter by plants and phytoplankton is high. The high rates of organic matter production almost inevitably result in high rates of oxygen uptake at night (when photosynthesis ceases) or when the organic matter decays. In a well mixed system oxygen can be replenished from the atmosphere, but in a stratified water column bottom waters become isolated and oxygen concentrations decline.

The existence of water column stratification can be determined from profiles of temperature and salinity. Simply put, cold water is more "dense" (heavier) than warm water and more saline water is more dense than less saline water. Coupling the effects of temperature and salinity we can determine the density of water at a given depth and compare that density with other depths in the water column. If a strong vertical gradient exists, the water column is stratified. For each sampling station within each pond on each sampling time we have determined stratification based on the ratio of the density of the surface (10 cm) versus bottom waters (Figure 4a,b,c,d). Ratios above approximately 1.2 indicate strong stratification and the higher the ratio, the more likely for the situation to persist.

Using this simplified technique, the Vineyard Sound station, as expected, never showed stratification. This results from the strong tidal currents and the small

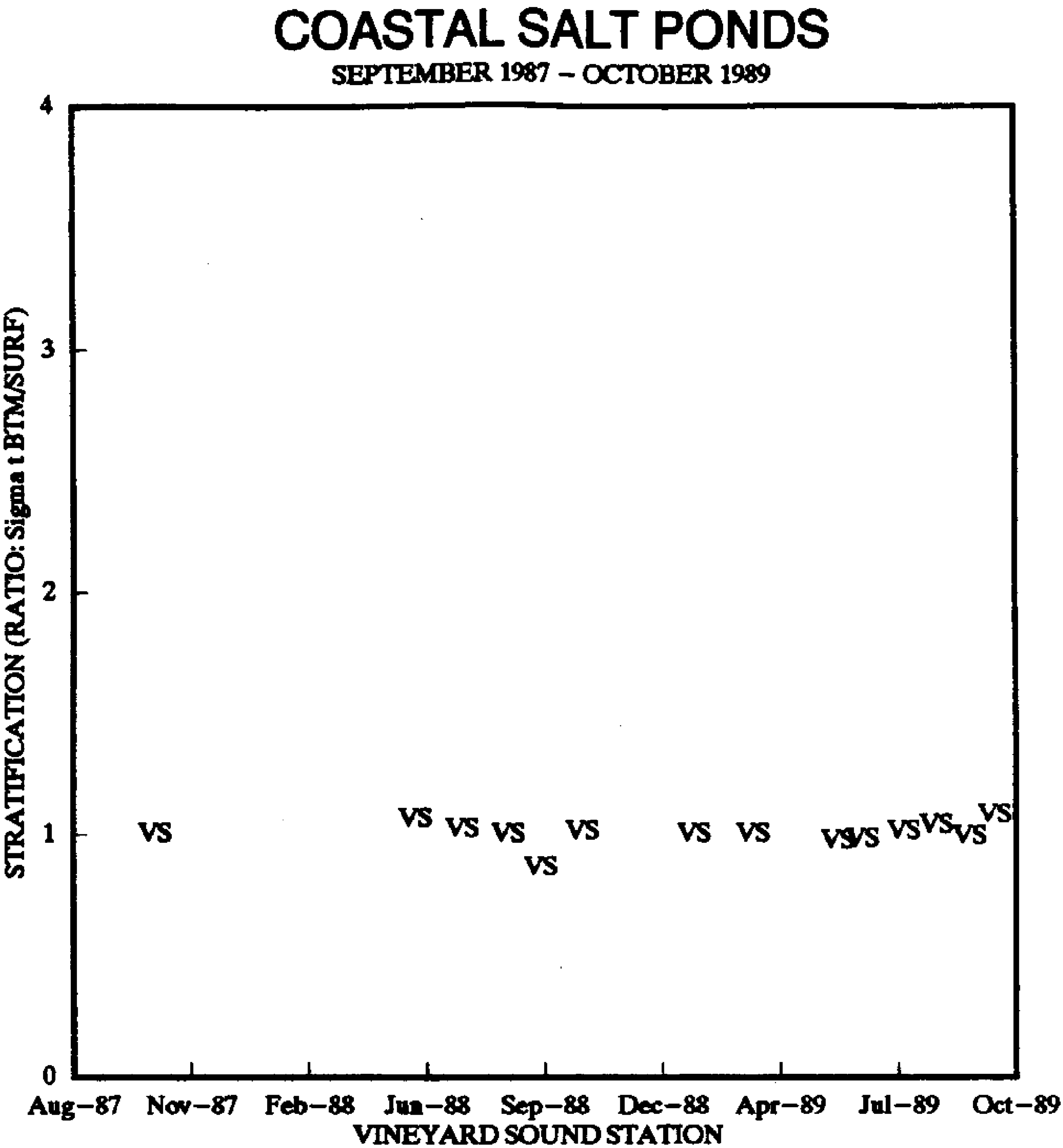
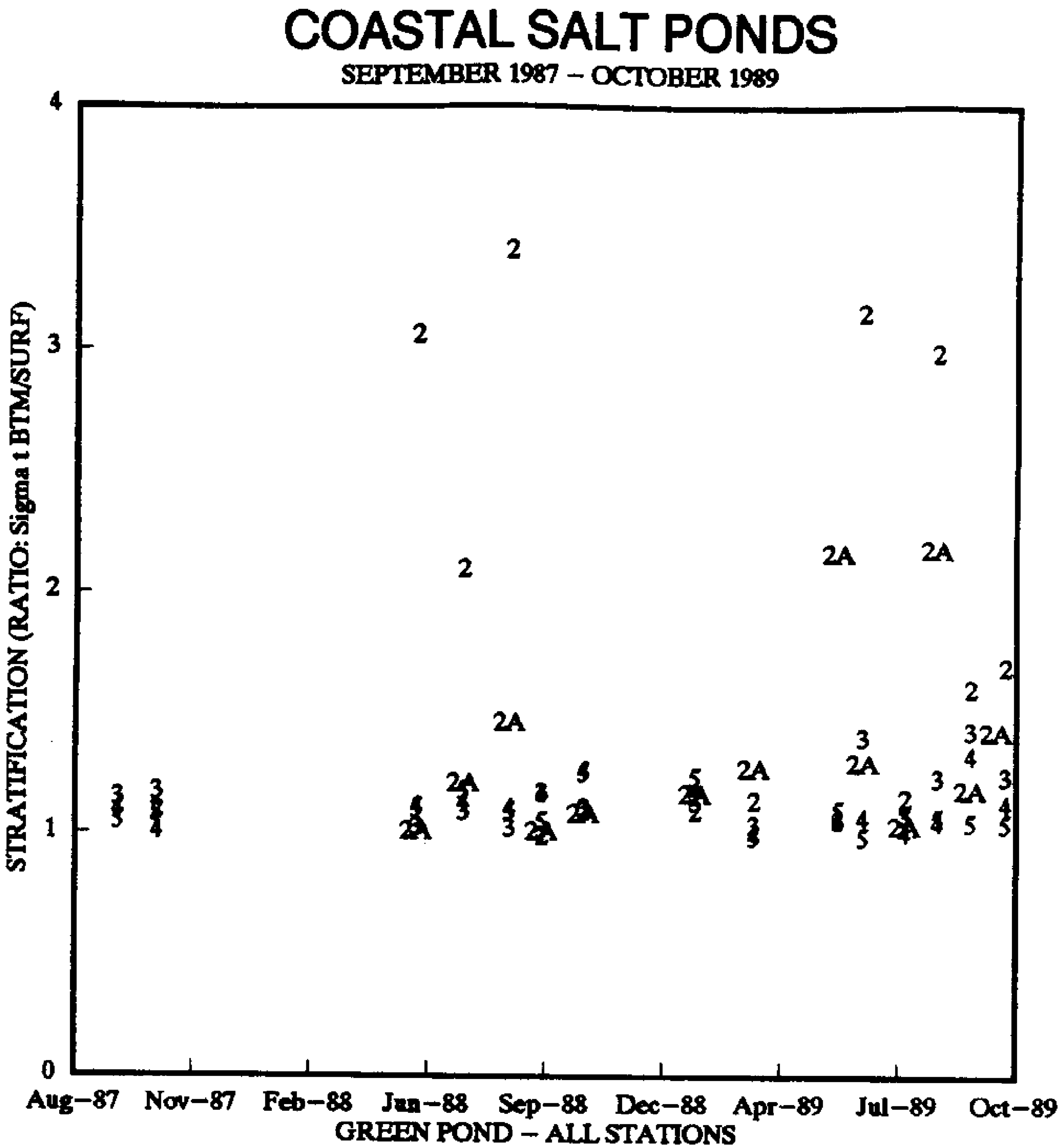


Figure 4 a,b,c,d. Ratio of Bottom to Surface water density for each sampling station and time. Symbols represent sampling station i.d.'s (See Appendix 4). Values greater than about 1.2 represent stratification.



COASTAL SALT PONDS
SEPTEMBER 1987 – OCTOBER 1989
STRATIFICATION (RATIO: Sigma t BTM/SURF)
GREEN POND – ALL STATIONS
Aug–87
Nov–87
Feb–88
Jun–88
Sep–88
Dec–88
Apr–89
Jul–89
Oct–89

Figure 4 b.

COASTAL SALT PONDS

SEPTEMBER 1987 – OCTOBER 1989

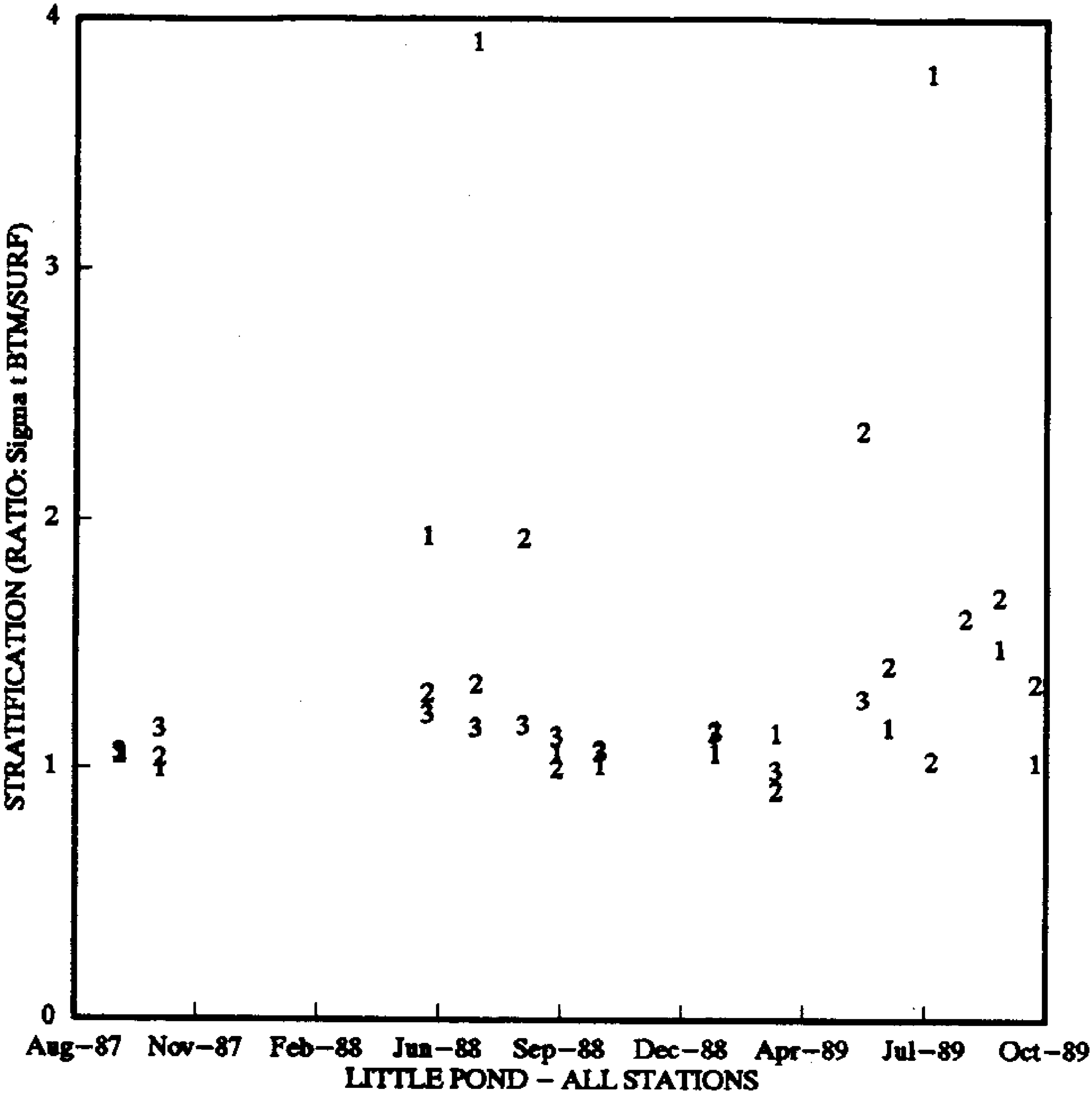


Figure 4 c.

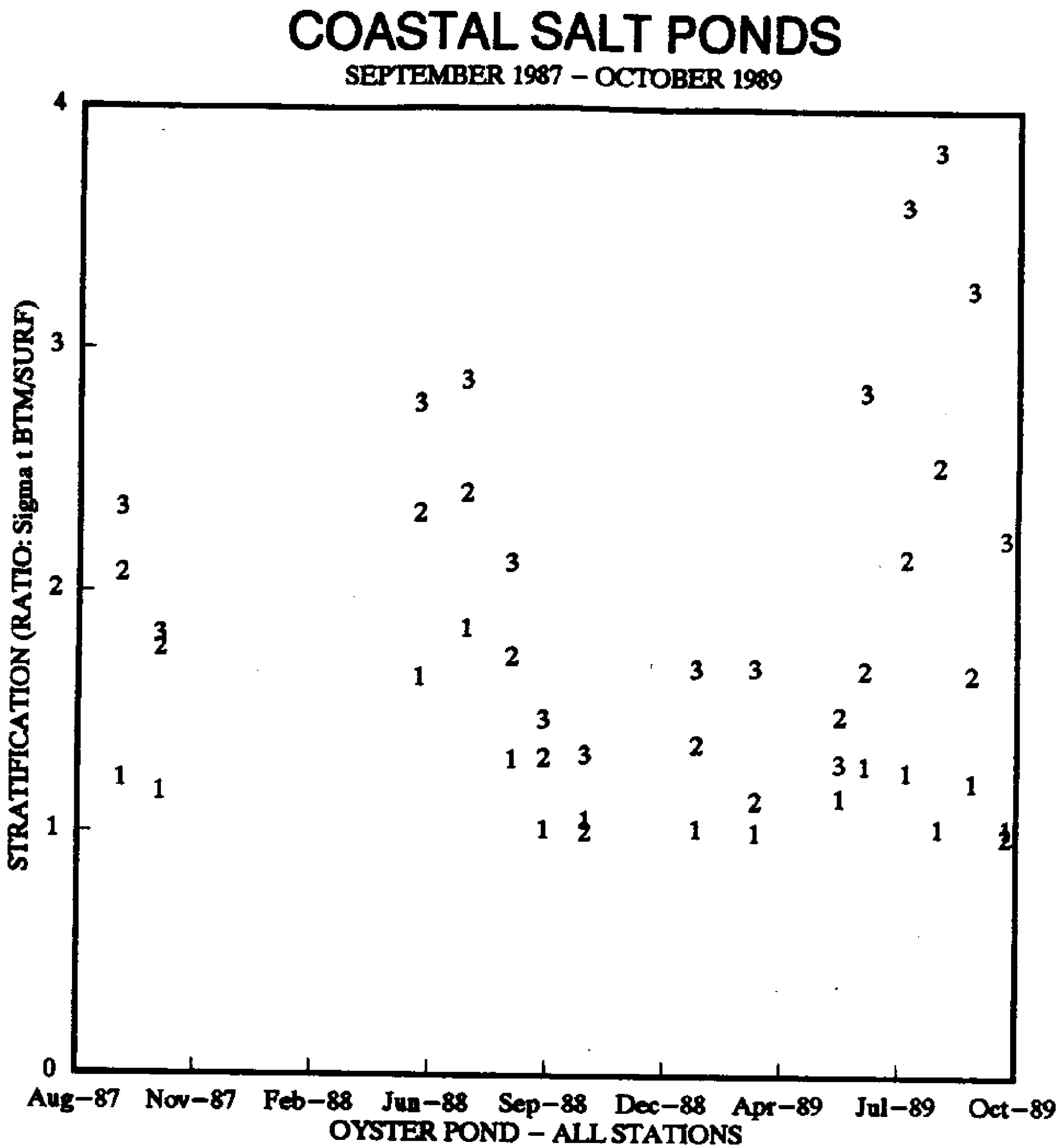

COASTAL SALT PONDS
SEPTEMBER 1987 – OCTOBER 1989
STRATIFICATION (RATIO: Sigma t BTM/SURF)
0
1
2
3
4
Aug–87
Nov–87
Feb–88
Jun–88
Sep–88
Dec–88
Apr–89
Jul–89
Oct–89
OYSTER POND – ALL STATIONS

Figure 4 d.

freshwater input relative to the volume. In contrast, parts of all of the ponds exhibited periods of strong stratification, notably Upper Green Pond (Stations 2, 2a, 3), Little Pond (Stations 1, 2, 3) and Oyster Pond (Stations 1, 2, 3). Oyster Pond Station 3 (near barrier beach) was always strongly stratified due to the 15 ppt difference in salinity between surface and bottom waters.

The most significant ecological factor after the presence of stratification itself was that stratification was a summer phenomenon and in winter (except for one station in Oyster Pond) the water column in all of the ponds was well mixed. This is most likely due to temperature effects and the velocity and direction of winter versus summer wind patterns.

Oxygen

Measurements of water column oxygen concentrations show interesting correlations among water temperature, water column stratification, and oxygen concentrations, and some background information here may be useful to the understanding of their relationships. At high temperatures, the solubility (and therefore concentration) of oxygen in water is low; when water is cooled, oxygen content increases independent of biological activity (cold water holds more dissolved gas than does warm water). This is evident in the measurements conducted in Vineyard Sound, where a decrease in oxygen concentration was found with increased temperature from spring to summer. In this case, the decrease could be accounted for solely by physical processes influencing the solubility of the gas. In the ponds, however, biological factors are much more prominent and frequently obscure the purely physical effects. When water temperatures in the ponds increase, biological activities also increase which consume oxygen. Oxygen depletion occurs when the rate of consumption exceeds the rate of delivery to the water either from the atmosphere or from photosynthesis. In waters that are vertically well mixed, oxygen exchange with the atmosphere can maintain oxygenated conditions even at high rates of consumption. However, as we have seen (Figure 4), even though the coastal ponds are shallow, they are not vertically well mixed. In summer they can become significantly stratified, potentially leading to severe oxygen depletion. Since the amount of oxygen in water changes with temperature due to physical factors, it is more relevant to gauge oxygen conditions based on percentage of saturation. In this way, samples from a variety of temperatures and salinities can be directly compared and water quality concerns directly addressed. Values of 100% of saturation represent a water column in equilibrium with the atmosphere. Although there is currently much scientific debate over acceptable oxygen values, it is certain that evidence of oxygen concentration below 80% of saturation indicate a system experiencing ecological stress. Vineyard Sound showed no significant oxygen depletion. This is expected from the well mixed nature and high water quality of Vineyard Sound waters (Figure 5a). Consistent with the summer occurence of water column stratification at Upper Green Pond (Station 2, 2a, 3; Figure 4b), Little Pond (Station 1, 2, 3; Figure 4c) and Oyster Pond (Station 1, 2, 3; Figure 4d), these stations all exhibited significant oxygen depletions in their bottom waters (Figure 5b, c, d). Oxygen depletion at these stations were frequently about 40% below atmospheric equilibrium and represent stressful conditions to both animal and plant communities. However, periods of oxygen depletion were not always correlated with stratification. This suggests that the high levels of oxygen uptake within pond sediments and water column are sufficient to deplete oxygen even under mixed conditions and indicates that periodic anoxia (absence of oxygen) may be occurring at these sites.

As large as they were, the oxygen depletions measured in this study must be regarded as minimum depletions. This is due to the fact that the measurements were made in late morning after photosynthesis had resumed, hence oxygen production by plants was underway. Our work in other coastal salt ponds and specifically in Little Pond indicates minimum oxygen conditions occur near dawn after the maximum period of darkness, with a return above 80% of saturation by late afternoon. The oxygen conditions are the best evidence that the existing nutrient conditions are in a range incompatible with the maintenance of stable animal communities. More information on the oxygen concentrations in the ponds in relation to nutrient and

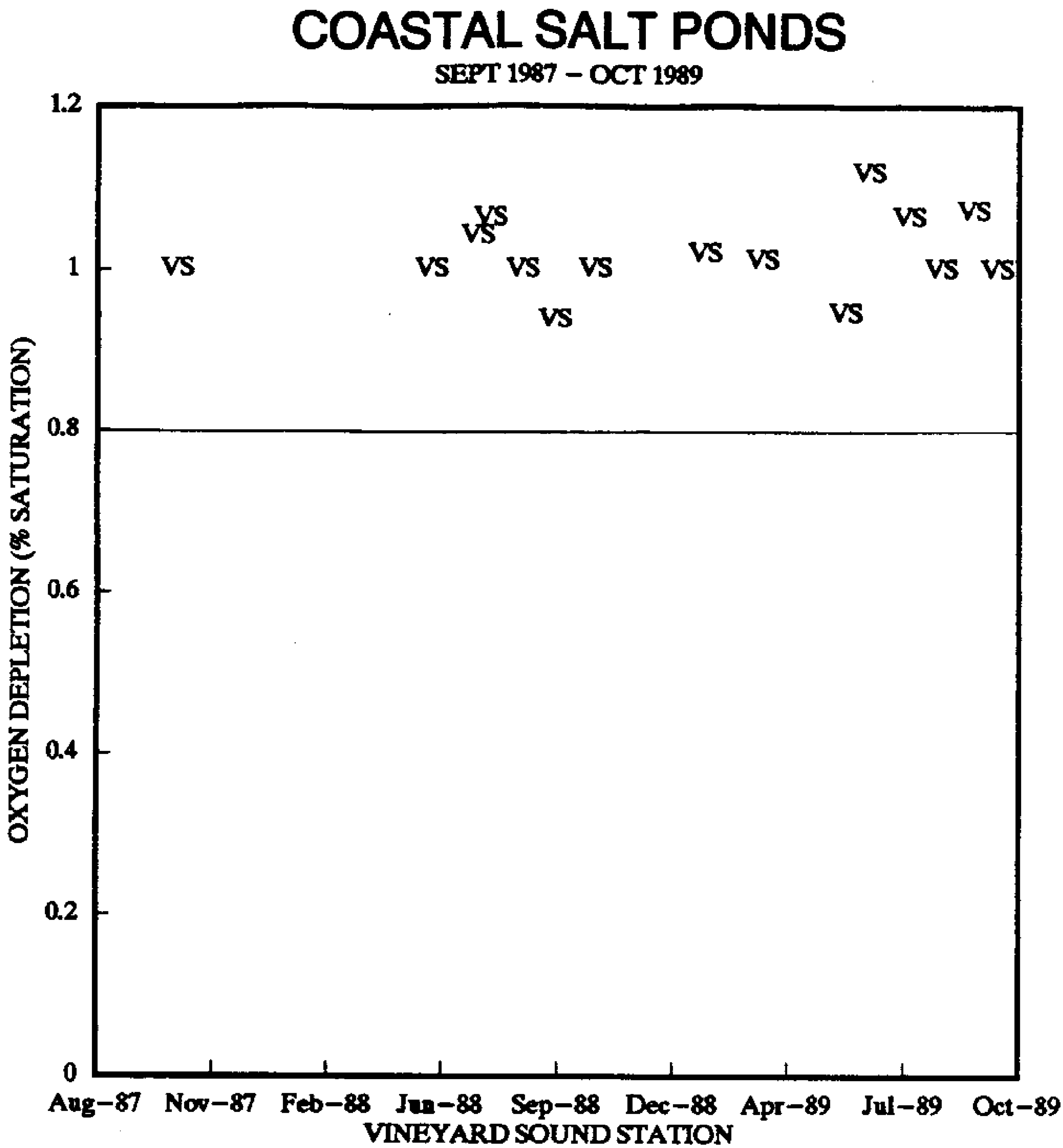


Figure 5 a,b,c,d. Oxygen concentration in bottom waters over stations and times as % of atmospheric equilibration. Values below 80% indicate potentially stressful conditions.

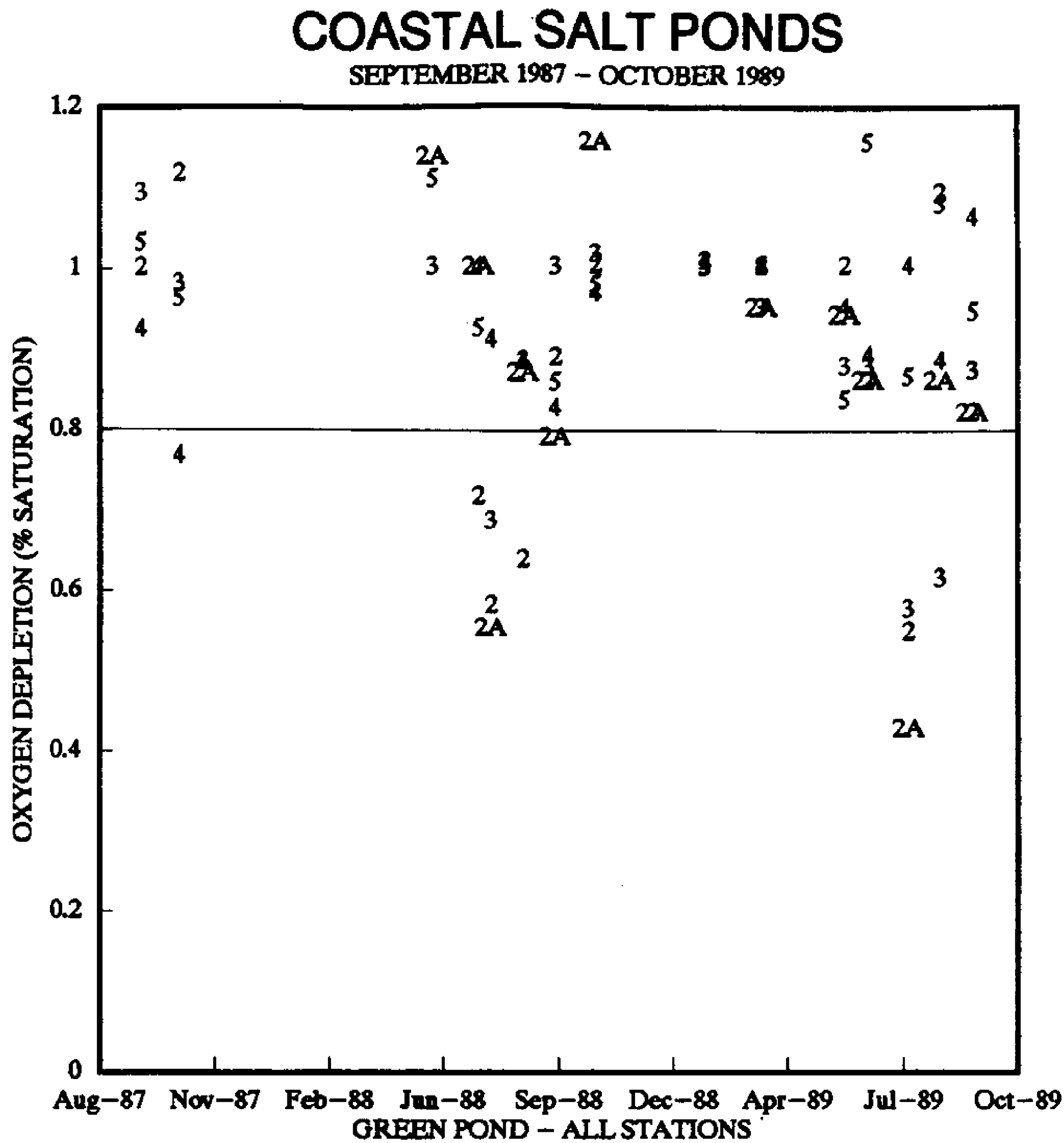
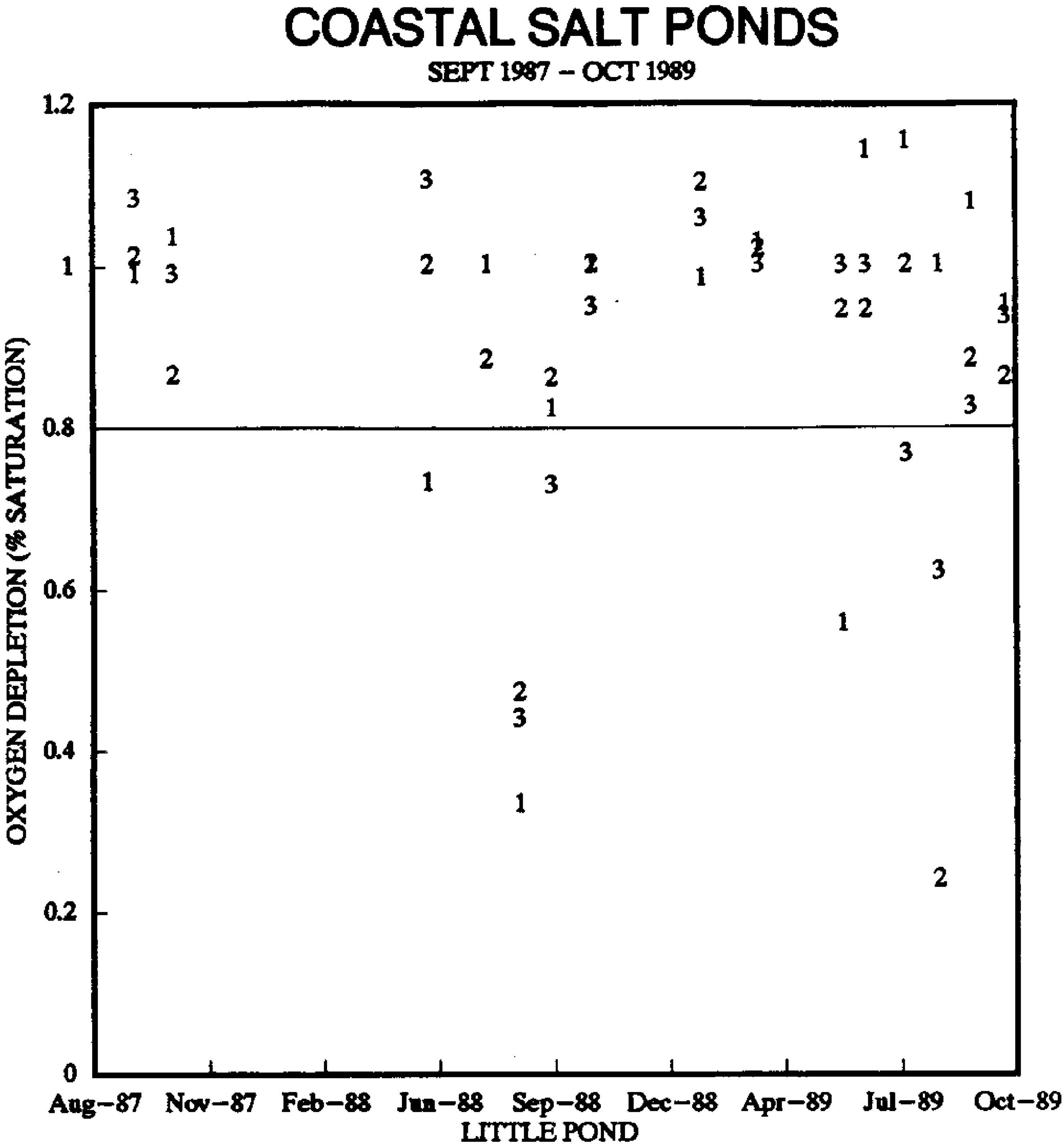

COASTAL SALT PONDS
SEPTEMBER 1987 – OCTOBER 1989
OXYGEN DEPLETION (% SATURATION)
1.2
1
0.8
0.6
0.4
0.2
0
Aug–87 Nov–87 Feb–88 Jun–88 Sep–88 Dec–88 Apr–89 Jul–89 Oct–89
GREEN POND – ALL STATIONS

Figure 5 b.



COASTAL SALT PONDS
SEPT 1987 – OCT 1989
OXYGEN DEPLETION (% SATURATION)
1.2
1
0.8
0.6
0.4
0.2
0
Aug–87
Nov–87
Feb–88
Jun–88
Sep–88
Dec–88
Apr–89
Jul–89
Oct–89
LITTLE POND

Figure 5 c.

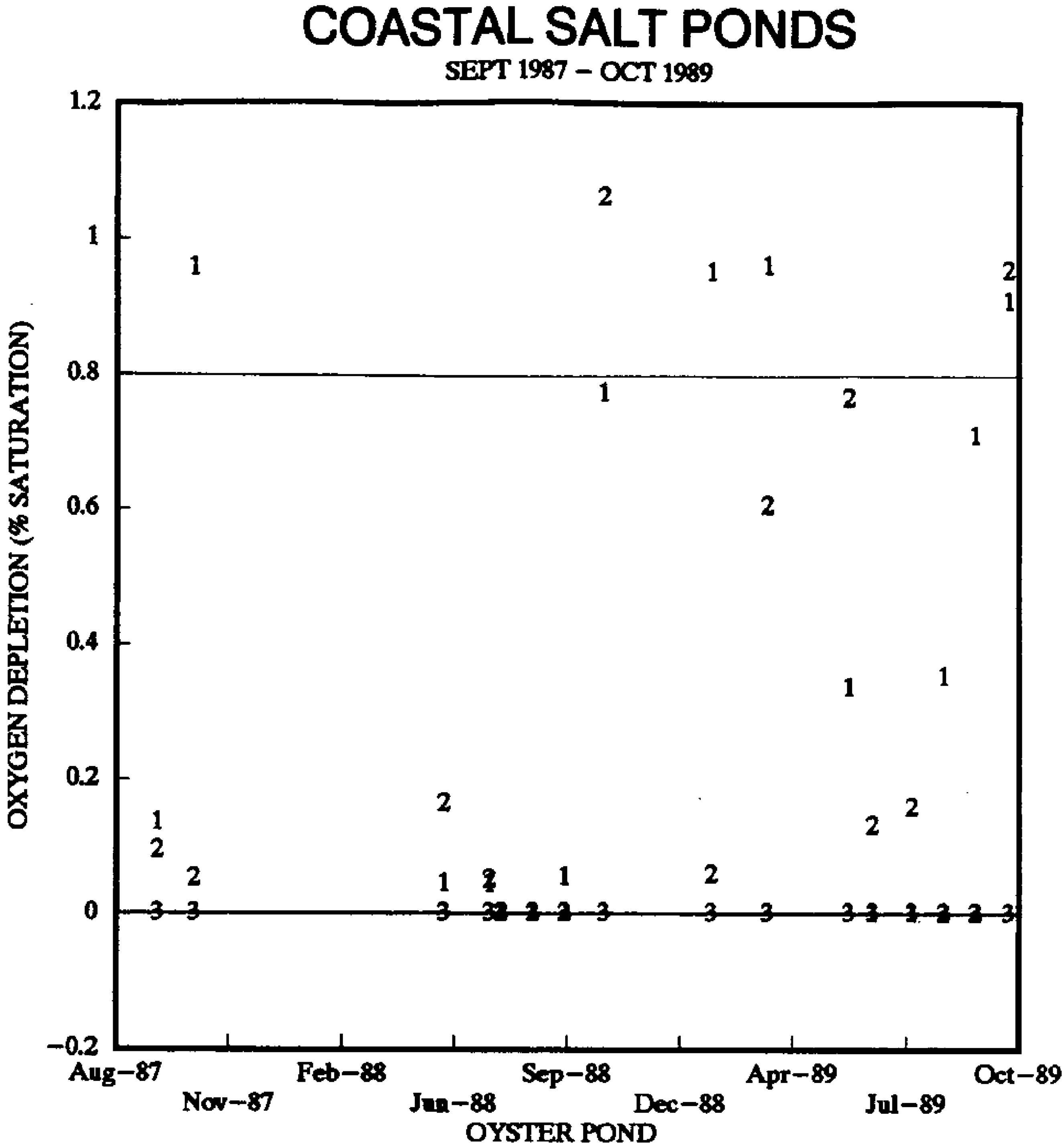

COASTAL SALT PONDS
SEPT 1987 – OCT 1989
OXYGEN DEPLETION (% SATURATION)
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
Aug−87
Nov−87
Feb−88
Jun−88
Sep−88
Dec−88
Apr−89
Jul−89
Oct−89
OYSTER POND

Figure 5 d.

physical parameters is critical to determining the overall environmental health of these systems.

Oyster Pond was the only pond to have sites of seasonal anoxia, i.e. no oxygen all summer and oxygen all winter. Both inland basins (Stations 1 and 2, Figure 5d) showed significant oxygenation during winter months. However, the summer anoxia will prevent the establishment of benthic communities at these sites. It is clear that the basins have experienced summer oxygen depletion for many years, likely a result, at least in part, of the physical configuration of the pond.

NUTRIENTS

Nutrient loading, primarily via groundwater inputs, affects each pond differently depending upon the variety of physical parameters to which each is subject. Primary factors that modify the ecological impacts of nutrient loading are flushing rates, stratification, temperature (oxygen consumption) and the form of nitrogen involved (inorganic/organic). Nitrogen is generally the limiting factor for plant growth in saltwater systems. It is for this reason that we have focussed primarily on nitrogen concentrations. In this study, total nitrogen was fractionated into inorganic (ammonium and nitrate) and organic (dissolved and particulate) pools. It is the inorganic forms which directly stimulate plant growth and lead to eutrophic conditions, but due to biological processes the form of nitrogen can cycle rapidly through all the pools. Knowing both the amount and form of nitrogen at any location helps to identify its source as well as its potential impact. A good way to evaluate how an ecosystem is responding or how it is processing nutrient inputs is to follow the changing fractionation of the total nitrogen as it moves through the system. Since the Coastal Zone Overlay uses water column integrated nutrient conditions, we have integrated our station depth profiles to depth weighted averages.

Green Pond experiences high nitrate inputs especially at the head of the pond, with a decrease in nitrate concentration moving toward Vineyard Sound (Figure 6a). The source of this nitrate entering the headwaters is probably groundwater and the nitrate is rapidly taken up by algae and phytoplankton living on the bottom and in

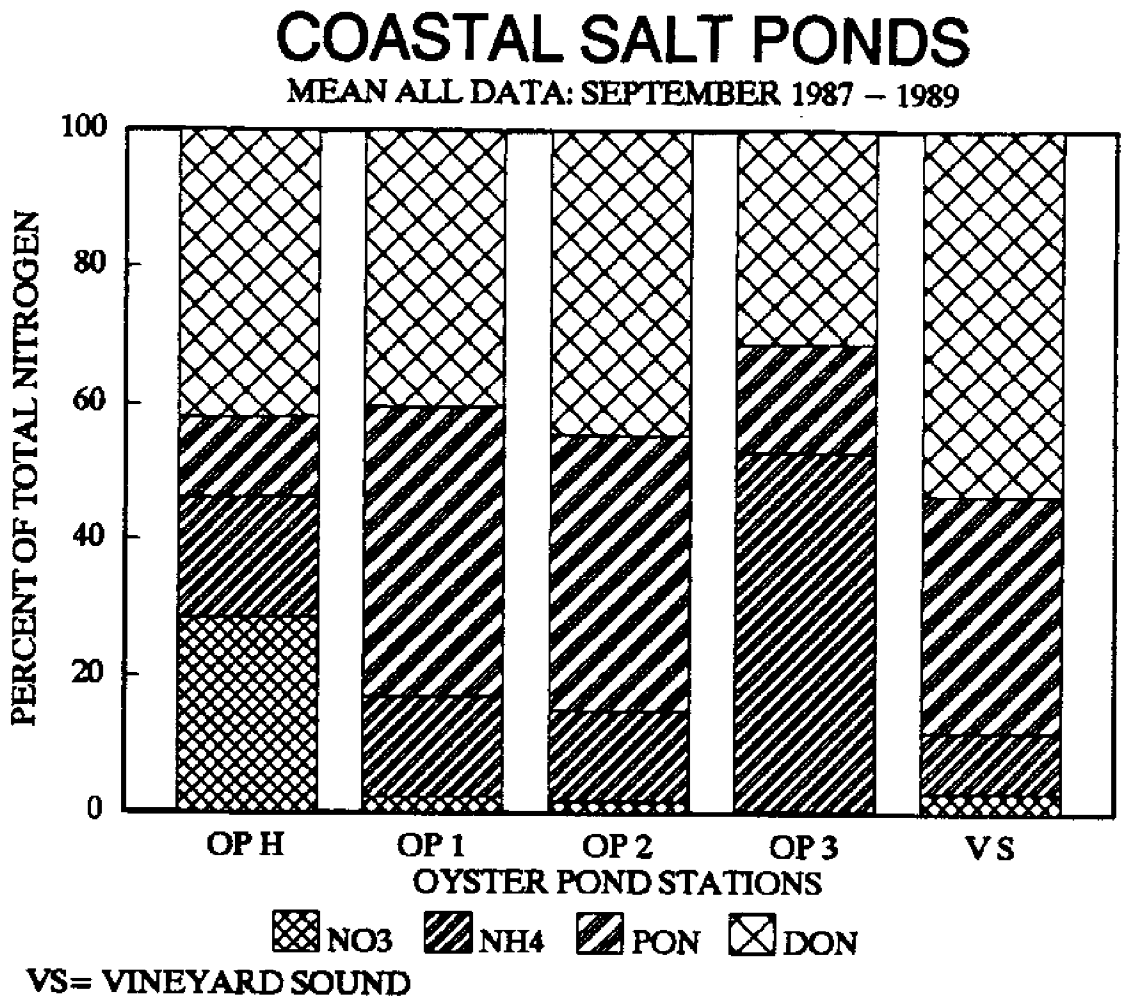


Figure 6 a,b,c. The mean percentage (n=16) of the total nitrogen at each station that consists of nitrate, ammonium, dissolved organic nitrogen (DON), or particulate oragnic nitrogen (PON). All of the ponds transform inorganic nitrogen to organic forms.

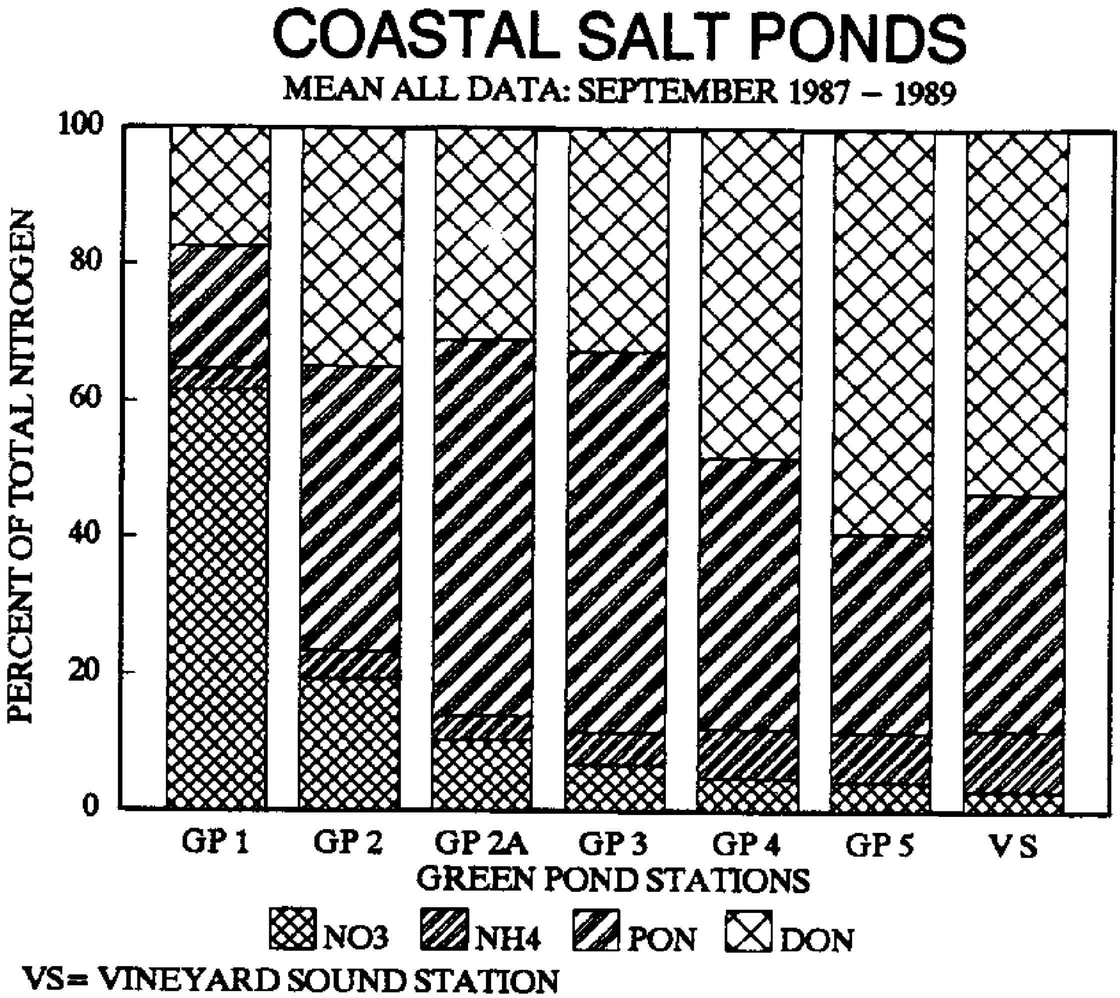

COASTAL SALT PONDS
MEAN ALL DATA: SEPTEMBER 1987 – 1989
100
80
60
40
20
0
PERCENT OF TOTAL NITROGEN
GP 1
GP 2
GP 2A
GP 3
GP 4
GP 5
V S
GREEN POND STATIONS
NO3
NH4
PON
DON
VS= VINEYARD SOUND STATION

Figure 6 b.

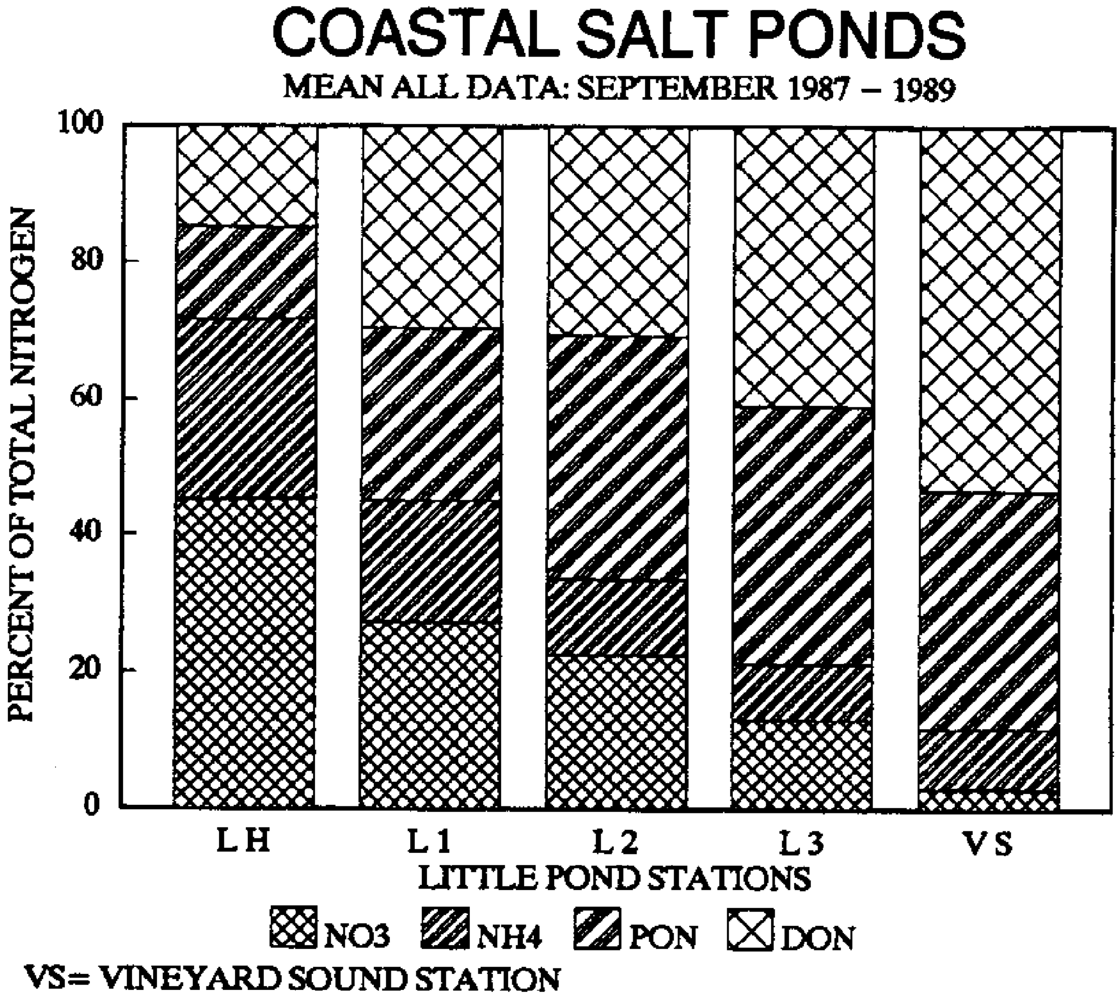

COASTAL SALT PONDS
MEAN ALL DATA: SEPTEMBER 1987 – 1989
PERCENT OF TOTAL NITROGEN
100
80
60
40
20
0
L H
L 1
L 2
L 3
V S
LITTLE POND STATIONS
NO3
NH4
PON
DON
VS= VINEYARD SOUND STATION

Figure 6 c.

the water. Moving toward the Sound we concurrently see a decrease in inorganic forms of nitrogen (nitrate and ammonium) which are directly available for plant growth, and an increase in organic forms (particulate and dissolved organic nitrogen). This is indicative of high rates of plant production, the death and decay of which consumes oxygen. It is important to note that nitrogen at this stage has not been removed from the system, merely transformed into another form. There exists, therefore, a transformation gradient of nutrient forms along the pond, with primarily inorganic nitrogen (nitrate) at the head, and most of the nitrogen at Stations 2, 2A and 3 (Appendix 4) as particulate organic nitrogen (in phytoplankton and zooplankton). It is interesting to note the lowest oxygen concentrations occur where the particulate nitrogen form predominates, and vice versa as observed in Vineyard Sound waters.

The limited flushing experienced by Little Pond results in similar nutrient conditions at all stations in the basin. Preliminary results indicate high levels of nitrate enter the inland pond stations (Figure 6b). This pond exhibits high levels of organic nitrogen (dissolved and particulate) and ecologically stressful oxygen concentrations during part of the summer season. The changing fractionation is much like in Green Pond (Figure 6a). The relative importance of nitrogen transformations within Little Pond versus "new" nitrogen entering in groundwater is the subject of a companion ongoing WHOI Sea Grant project.

While Oyster Pond also acts to transform incoming inorganic nitrogen from the watershed to organic forms, the oxygen conditions of the pond adds an additional feature to the nitrogen distribution (Figure 6c). Due to the deep salinity-stratified basins and minimal flushing, the organic matter produced which falls to the bottom and decays consumes oxygen faster than oxygen can be supplied by mixing, with the result that Station 3 is "permanently" anoxic and Stations 1 and 2 seasonally anoxic. Although there is no oxygen present, additional organic matter falling into these anoxic zones still decays except the released inorganic nitrogen remains as ammonium in the water column (Figure 6c) until it is mixed into the surface waters. Just as stratification "keeps oxygen out", it serves to "keep ammonium in". The result is the accumulation of exceedingly high levels of ammonium (18 mg N/l) especially at Station 3 which is not seasonally mixed. This condition is typical of all anoxic marine basins from Oyster Pond and Salt Pond to the Black Sea. The combination of inputs of "new" nitrogen with "old" nitrogen compounded by high (ammonium) concentrations from the anaerobic bottom waters maintains the nitrogen concentrations at the highest levels found in any of the ponds. Oyster Pond has higher nitrogen concentrations than any of the other stations in either Little or Green Pond. Although the streams entering all three ponds have fairly high levels of nitrogen as nitrate, the original source is as yet unclear and it is not possible with the available data to distinguish between natural and man-induced inputs.

Total nitrogen concentration determined as the sum of nitrate, ammonium, dissolved organic nitrogen and particulate organic nitrogen was calculated for each pond station and sampling period and for the Vineyard Sound station (Table 1). No strong seasonal trends were observed for any stations during this study (Figure 7, 8, 9, 10), although large differences were found between sampling dates due primarily to periodic algal blooms. Vineyard Sound, as expected, had the lowest observed total nitrogen and was consistently less than 0.32 mg N/l and averaged 0.267 mg N/l over the study period (Figure 7). The Upper Green Pond stations (1, 2, 2A, 3) were consistently above 0.5 mg N/l and frequently greater than 0.75 mg N/l; in fact, of these stations, only Station 3 (0.66 mg N/l) had an average total nitrogen value below 0.75 mg N/l (Figure 8 a,b,c,d). Lower Green Pond (Station 4 and 5) exhibited significantly lower total nitrogen levels due primarily to exchange with the low nitrogen Vineyard Sound water, with average values of 0.444 and 0.440 mg N/l, respectively (Figure 8 e,f).

Consistent with its reduced flushing relative to Green Pond, all stations in Little Pond exhibited total nitrogen values approaching or in excess of 0.75 mg N/l (Figure 9 a,b,c,d). In addition, an extensive macroalgal bloom occurred in June and July 1989 which impacted almost all of the pond. Oyster Pond, as discussed above, had the highest levels of total nitrogen with no single pond station having a depth averaged mean concentration of less than 1 mg N/l (Figure 10 a,b,c,d), and in the

SUMMARY DATA CITIZENS MONITORING STUDY
WOODS HOLE OCEANOGRAPHIC INSTITUTION/TOWN OF FALMOUTH
DR. A. WHITE & DR. B. HOWES

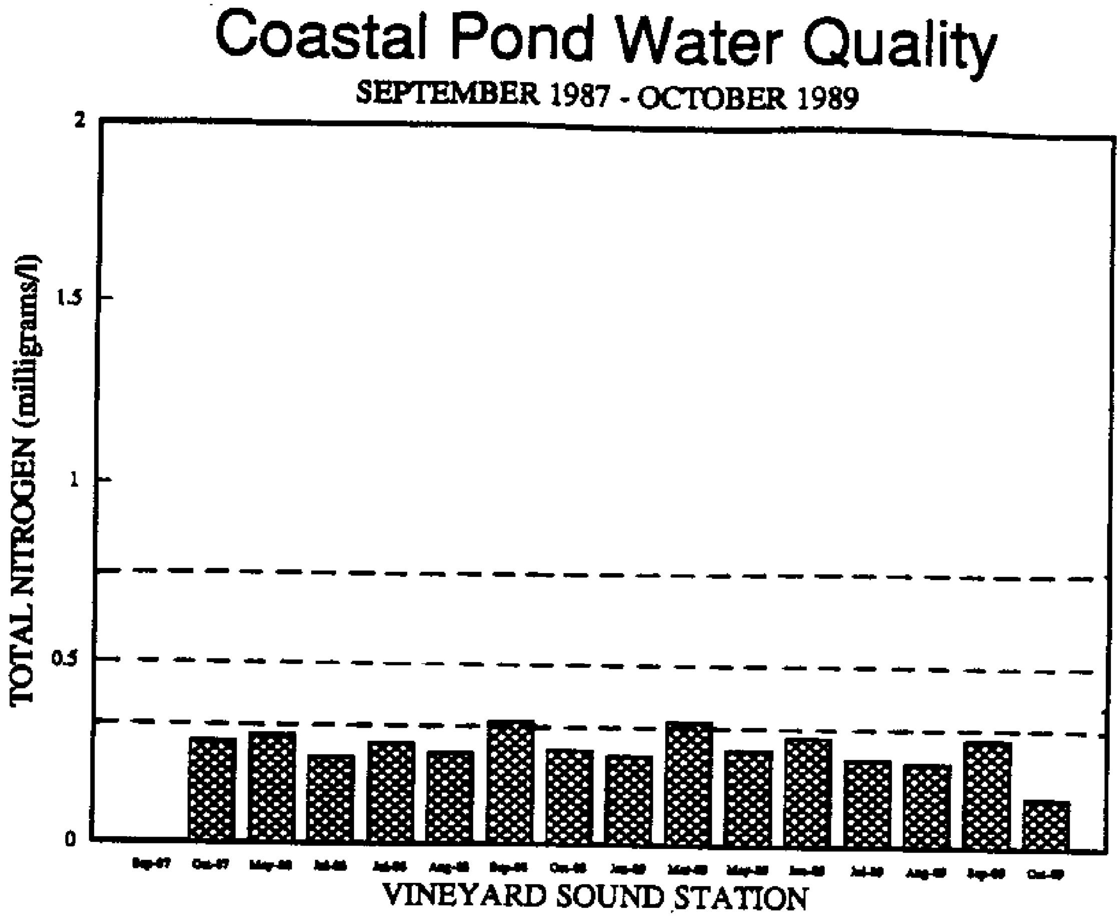
TABLE 1.

******************** TOTAL NITROGEN (MILLIGRAMS PER LITER): WATERCOLUMN AVERAGES BY STATION ********************************

Station	Sep-87	Oct-87	May-88	Jun-88	Jul-88	Aug-88	Sep-88	Oct-88	Jan-89	Mar-89	May-89	Jun-89	Jul-89	Aug-89	Sep-89	Oct-89
GREEN POND																
GP 1	0.847	1.180	1.250	1.507	0.952	1.637	1.656	0.791	1.658	0.593	0.984	1.459	1.113	1.146	1.008	0.841
GP 2	0.954	0.664	1.200	0.644	0.818	1.586	0.837	0.693	1.133	0.430	0.906	0.795	0.884	0.774	0.659	0.733
GP 2A	NA	NA	1.719	0.509	0.546	0.968	0.773	0.498	1.056	0.316	0.839	1.014	0.734	0.763	0.611	0.588
GP 3	0.421	0.786	0.931	0.480	0.451	1.703	0.596	0.824	0.598	0.295	0.614	0.974	0.373	0.525	0.500	0.513
GP 4	0.429	0.395	0.660	0.500	0.431	0.412	0.465	0.389	0.289	0.226	0.558	0.678	0.336	0.550	0.459	0.331
GP 5	0.379	0.436	0.369	0.355	0.312	0.557	0.435	0.283	0.283	0.217	0.428	0.377	0.761	0.511	0.632	0.702
LITTLE POND																
LP Head	3.729	1.154	2.399	2.162	2.351	2.167	0.761	1.047	0.412	1.222	2.651	0.995	1.939	2.976	2.593	1.381
LP 1	0.703	0.847	0.935	1.157	0.910	2.135	0.708	0.991	0.541	0.917	1.758	0.982	1.300	2.244	1.231	1.391
LP 2	0.650	0.670	0.648	0.618	0.753	1.108	0.614	0.452	0.700	0.923	1.224	0.864	0.519	0.680	0.831	0.594
LP 3	0.506	0.808	0.578	0.498	0.580	1.139	0.751	0.609	0.609	0.805	0.678	0.817	0.438	0.376	0.642	1.529
OYSTER POND																
OP Head	NA	NA	NA	NA	2.038	1.644	1.759	1.026	0.972	1.242	0.931	2.053	1.872	2.122	1.922	1.564
OP 1	1.384	1.233	2.028	2.298	2.606	2.927	4.058	2.157	2.465	2.301	1.931	3.863	1.419	1.383	1.445	2.284
OP 2	1.699	2.929	2.845	3.203	2.145	3.389	2.666	2.141	2.428	2.276	2.284	2.148	1.995	1.466	1.588	2.060
OP 3	32.737	30.409	9.512	6.773	5.707	8.402	7.633	11.680	11.118	10.509	7.427	8.503	9.858	7.570	8.942	5.223
VINEYARD SOUND																
VS	NA	0.282	0.299	0.239	0.277	0.251	0.341	0.262	0.246	0.341	0.265	0.299	0.240	0.232	0.296	0.135

************************ STATION AVERAGES (SEPTEMBER 1987 - OCTOBER 1989 ********************************

Station	NITRATE/NITRITE MEAN (uM)	NITRATE/NITRITE SE	AMMONIUM MEAN (uM)	AMMONIUM SE	PARTICULATE N MEAN (uM)	PARTICULATE N SE	DISSOLVED ORG N MEAN (uM)	DISSOLVED ORG N SE	TOTAL NITROGEN MEAN (uM)	TOTAL NITROGEN SE	TOTAL NITROGEN MEAN (milligram/l)	TOTAL NITROGEN SE (milligram/l)
GREEN POND												
GP 1	51.24	6.40	2.64	0.39	14.83	2.23	14.4	2.1	83.1	5.8	1.164	0.081
GP 2	11.80	2.02	2.46	0.42	25.57	4.68	21.4	2.2	61.2	4.7	0.857	0.065
GP 2A	5.85	1.78	1.88	0.34	30.75	6.18	17.3	1.0	55.8	5.9	0.781	0.083
GP 3	3.24	0.88	2.17	0.33	26.45	5.96	15.4	1.1	47.2	5.9	0.661	0.082
GP 4	1.54	0.39	2.27	0.34	12.60	1.62	15.3	1.2	31.7	2.2	0.444	0.030
GP 5	1.35	0.41	2.23	0.32	9.00	0.92	18.4	2.8	31.4	2.7	0.440	0.038
LITTLE POND												
LP Head	60.62	9.63	35.36	5.97	17.90	2.91	19.8	6.9	133.7	15.8	1.871	0.221
LP 1	22.77	4.52	15.01	2.85	21.34	2.86	24.6	4.0	83.7	8.6	1.172	0.120
LP 2	11.84	3.08	5.84	1.39	19.03	2.53	16.2	1.5	52.9	3.6	0.740	0.050
LP 3	6.62	1.96	4.11	0.79	19.17	3.01	20.8	3.4	50.7	4.9	0.710	0.069
OYSTER POND												
OP Head	32.42	5.12	20.29	4.05	13.48	2.82	47.8	6.2	114.0	7.6	1.595	0.106
OP 1	3.71	1.03	23.24	5.11	67.94	8.35	64.4	7.7	159.7	14.5	2.236	0.203
OP 2	2.82	0.91	21.94	5.85	67.35	6.81	74.2	6.6	166.3	9.6	2.329	0.134
OP 3	2.92	0.80	427.60	55.55	128.46	9.96	253.5	88.9	812.5	140.0	11.375	1.960
VINEYARD SOUND												
VS	0.56	0.13	1.71	0.26	6.62	0.94	10.2	1.1	19.1	0.9	0.267	0.012



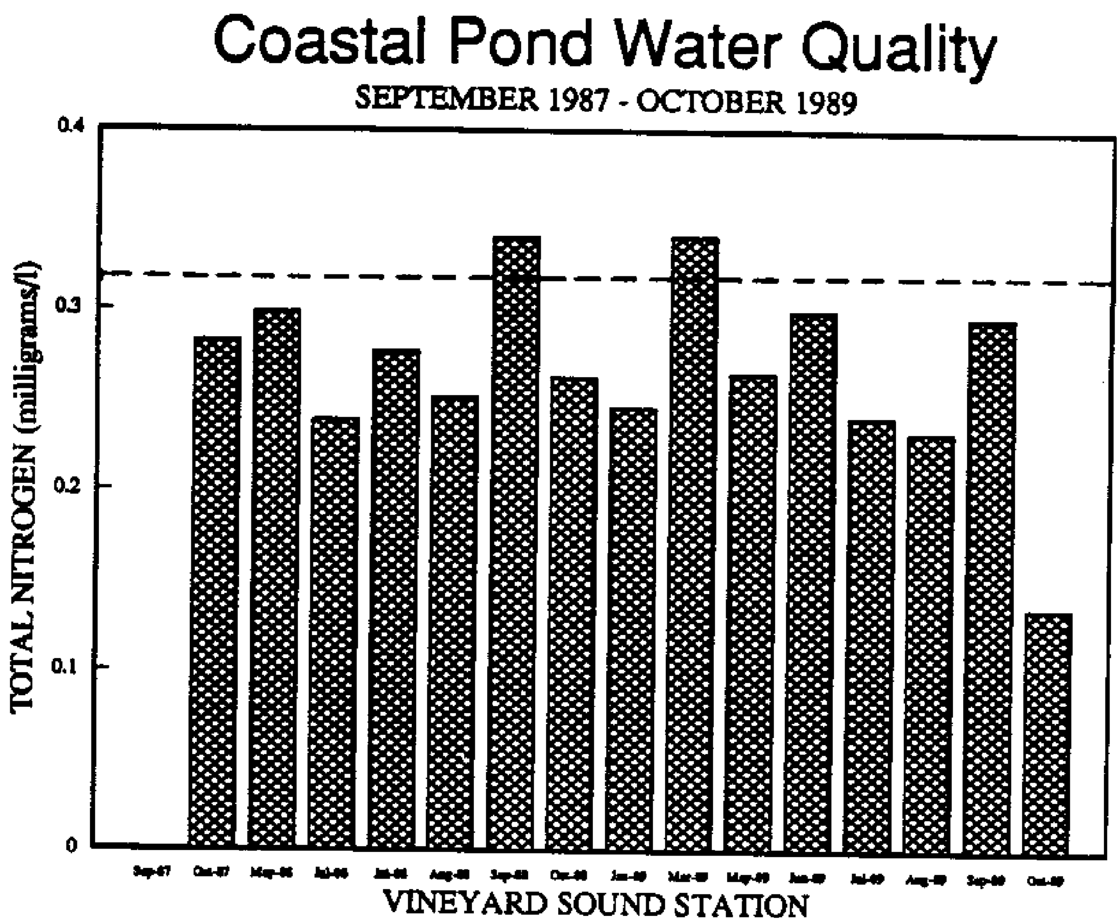


Figure 7. Total Nitrogen for Vineyard Sound Station; depth averaged values for each sampling period.

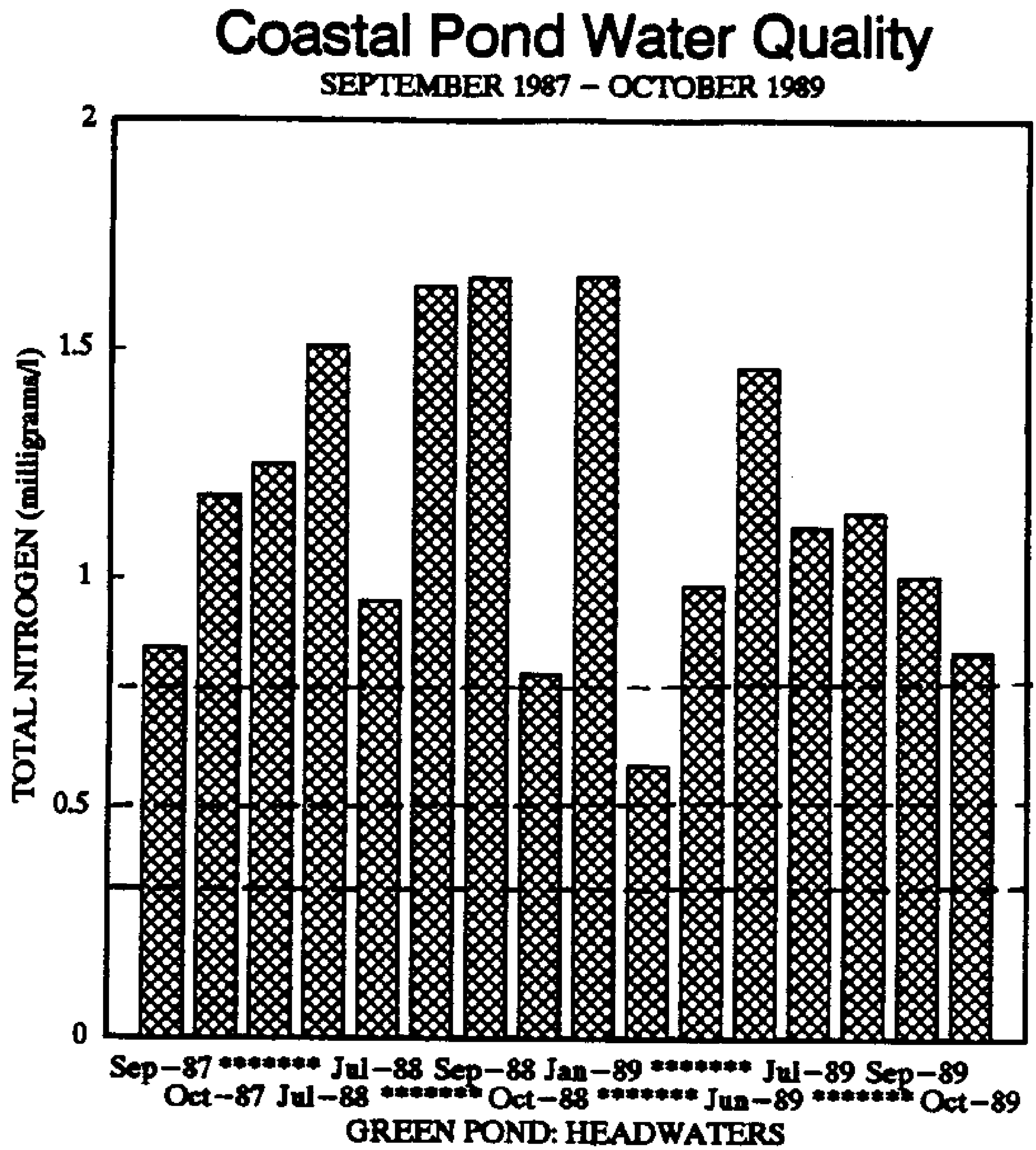


Figure 8 a,b,c,d,e,f. Total Nitrogen for Green Pond Stations; depth averaged values for each sampling period.

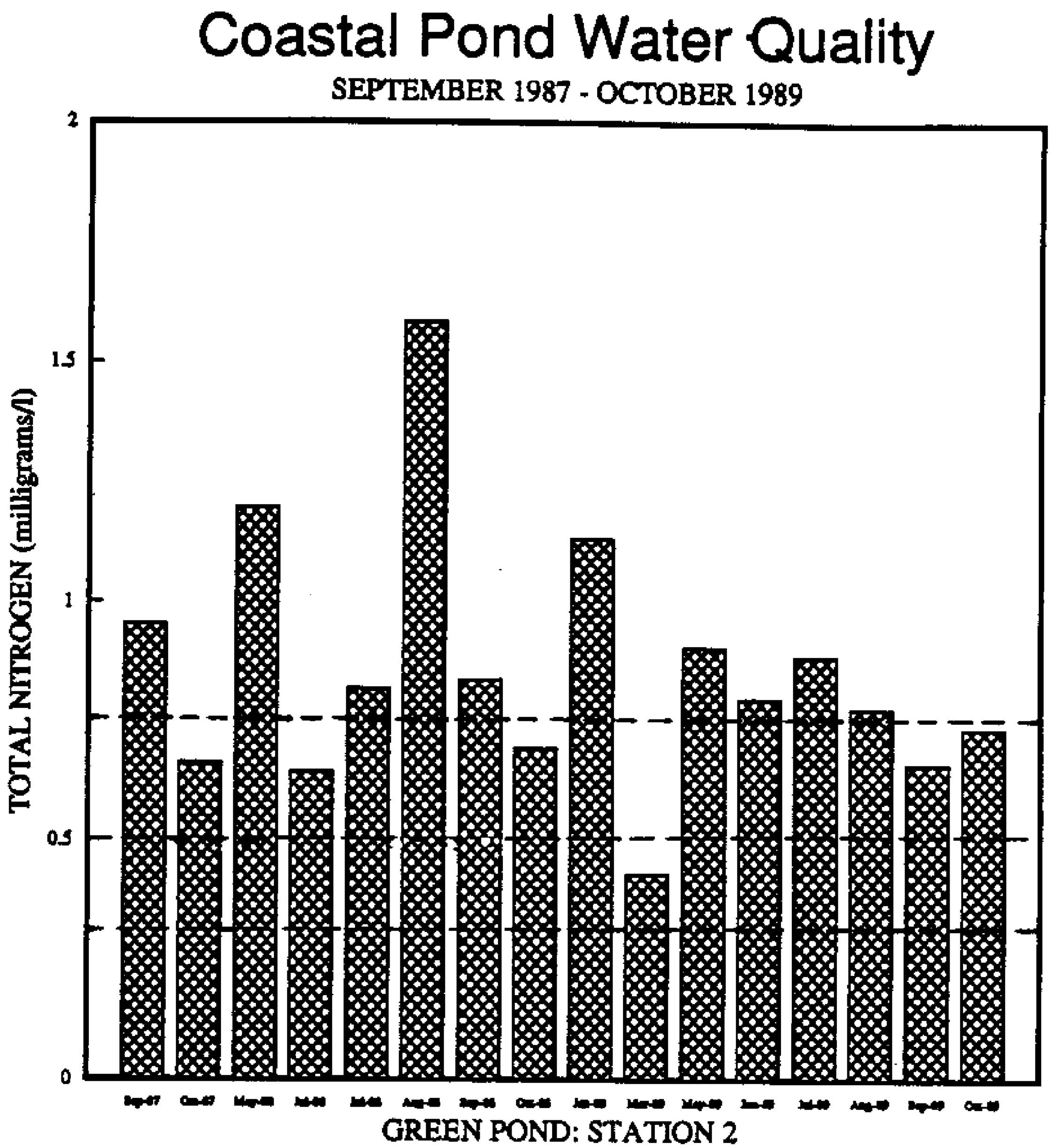

Coastal Pond Water Quality
SEPTEMBER 1987 - OCTOBER 1989
TOTAL NITROGEN (milligrams/l)
2
1.5
1
0.5
0
GREEN POND: STATION 2

Figure 8 b.

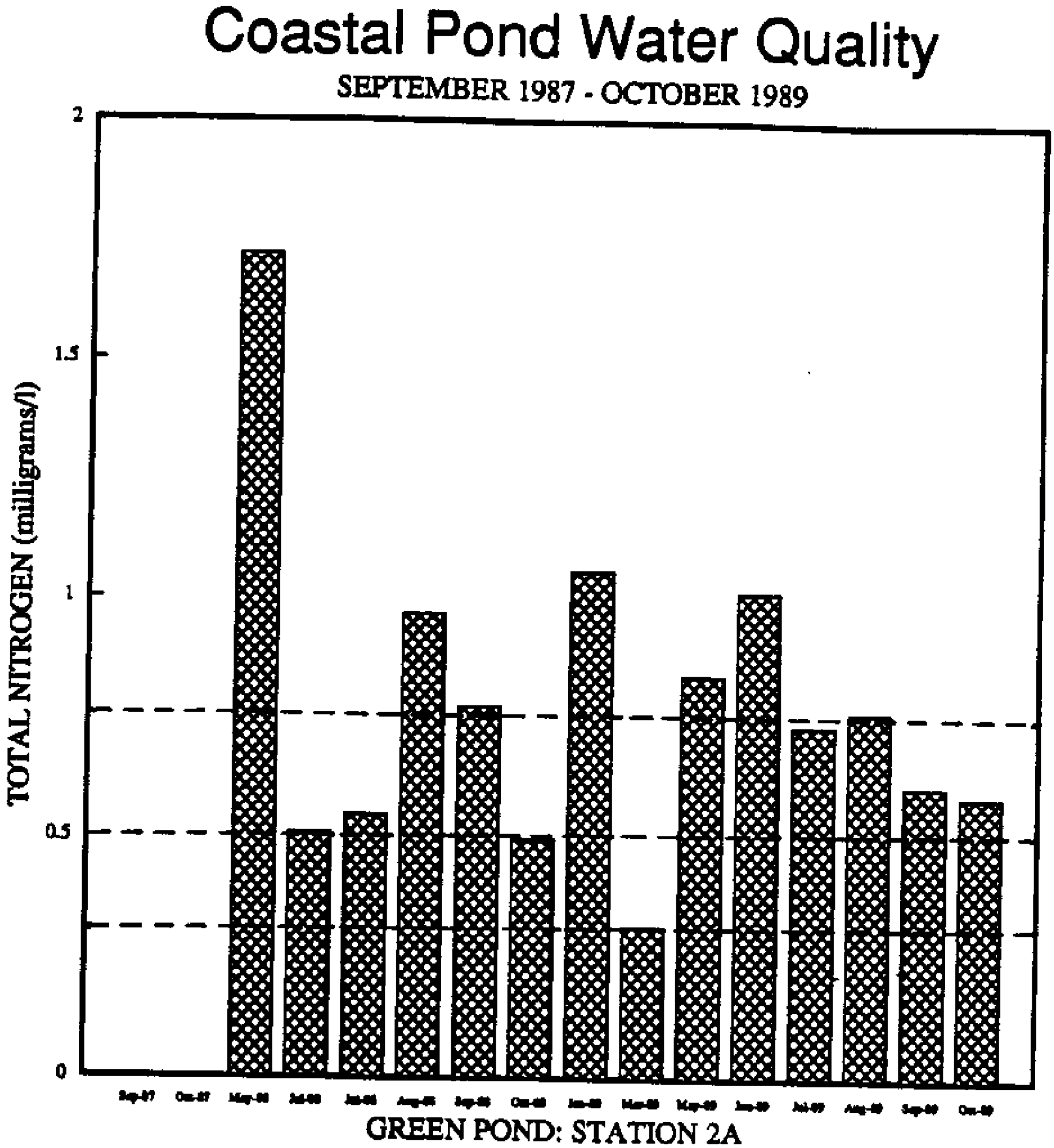
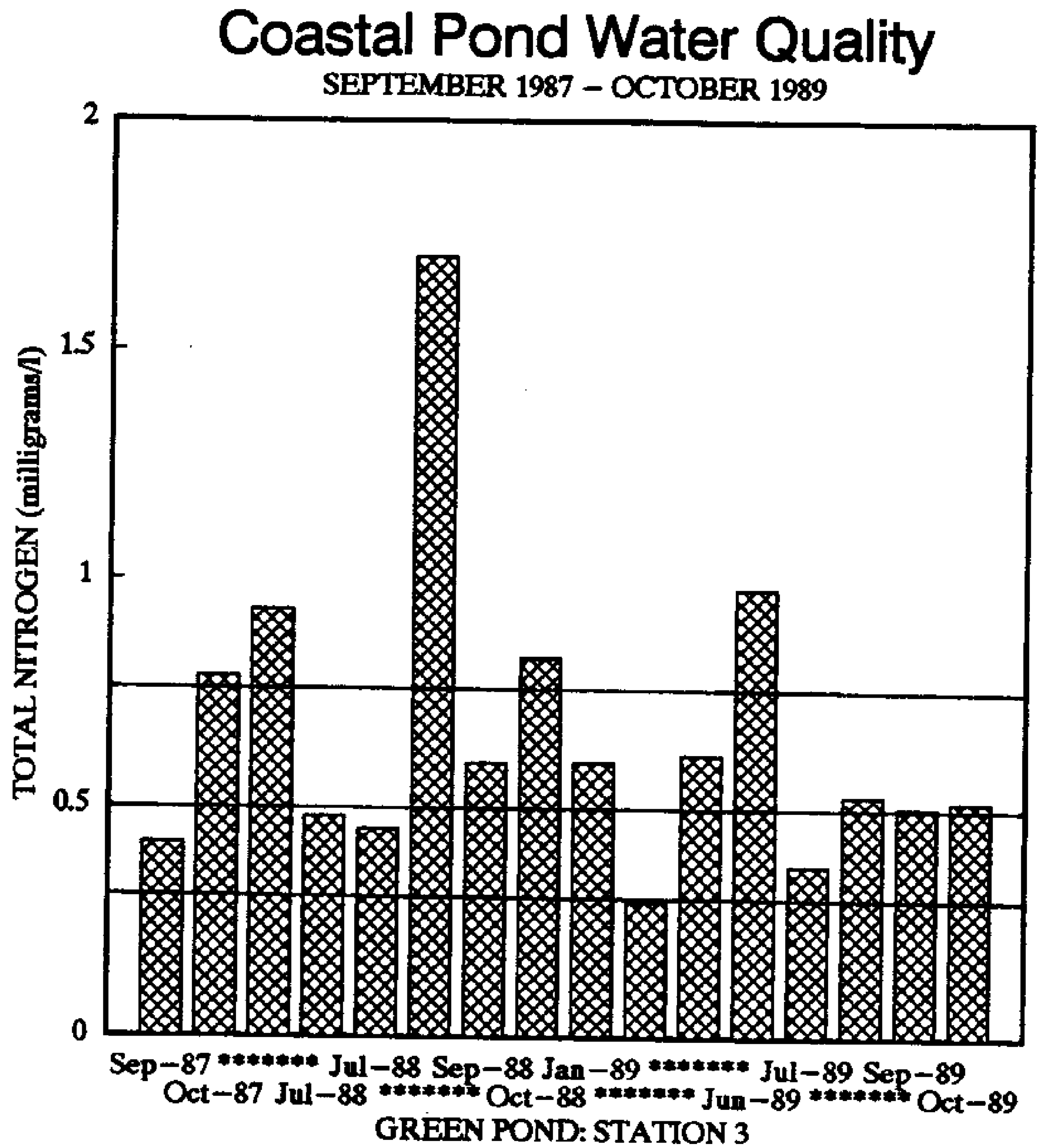

Coastal Pond Water Quality
SEPTEMBER 1987 - OCTOBER 1989
TOTAL NITROGEN (milligrams/l)
2
1.5
1
0.5
0
GREEN POND: STATION 2A

Figure 8 c.



Coastal Pond Water Quality
SEPTEMBER 1987 – OCTOBER 1989
TOTAL NITROGEN (milligrams/l)
2
1.5
1
0.5
0
Sep–87 ******* Jul–88 Sep–88 Jan–89 ******* Jul–89 Sep–89
Oct–87 Jul–88 ******* Oct–88 ******* Jun–89 ******* Oct–89
GREEN POND: STATION 3

Figure 8 d.

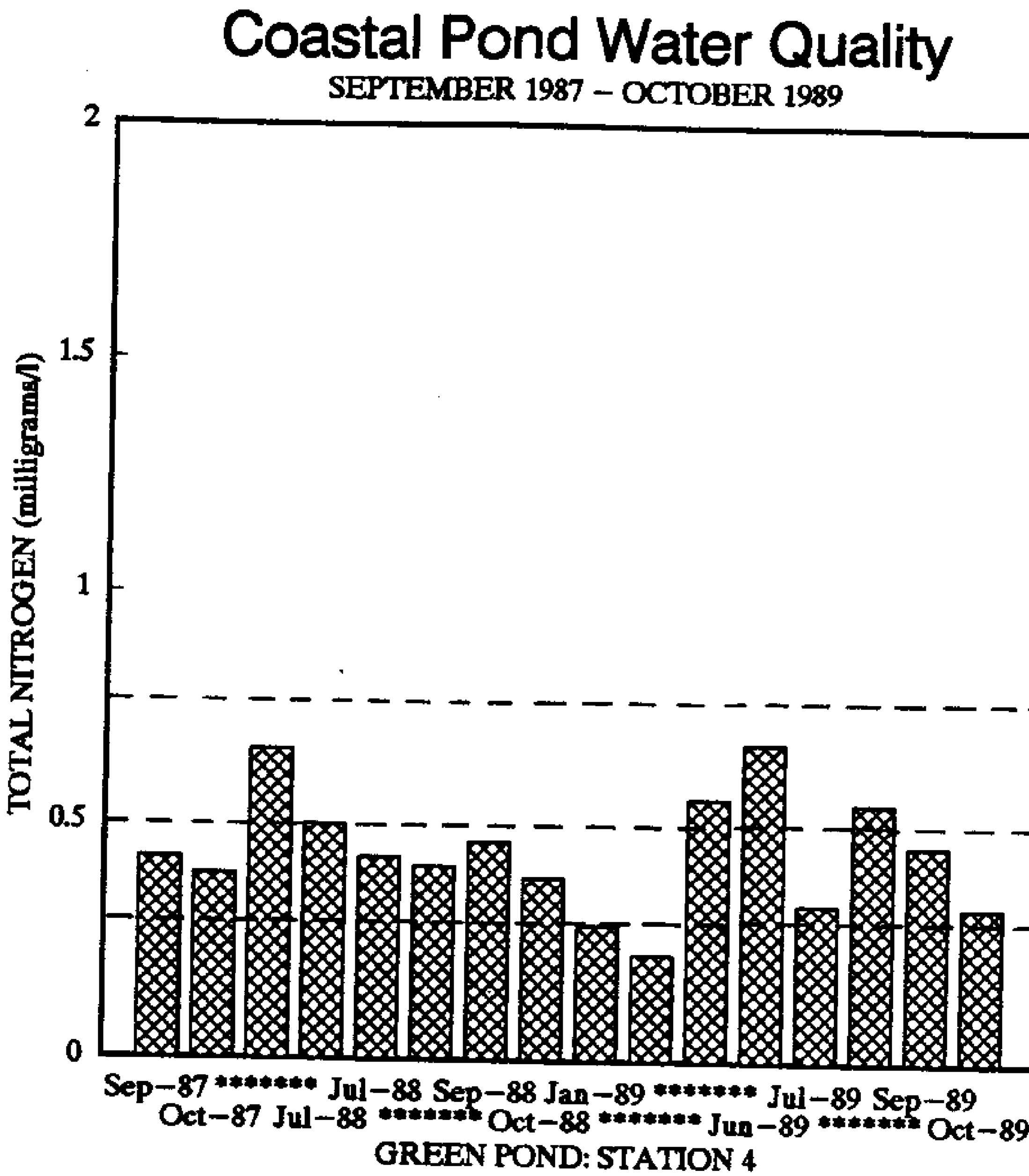

Coastal Pond Water Quality
SEPTEMBER 1987 – OCTOBER 1989
TOTAL NITROGEN (milligrams/l)
2
1.5
1
0.5
0
Sep–87 ******* Jul–88 Sep–88 Jan–89 ******* Jul–89 Sep–89
Oct–87 Jul–88 ******* Oct–88 ******* Jun–89 ******* Oct–89
GREEN POND: STATION 4

Figure 8 e.

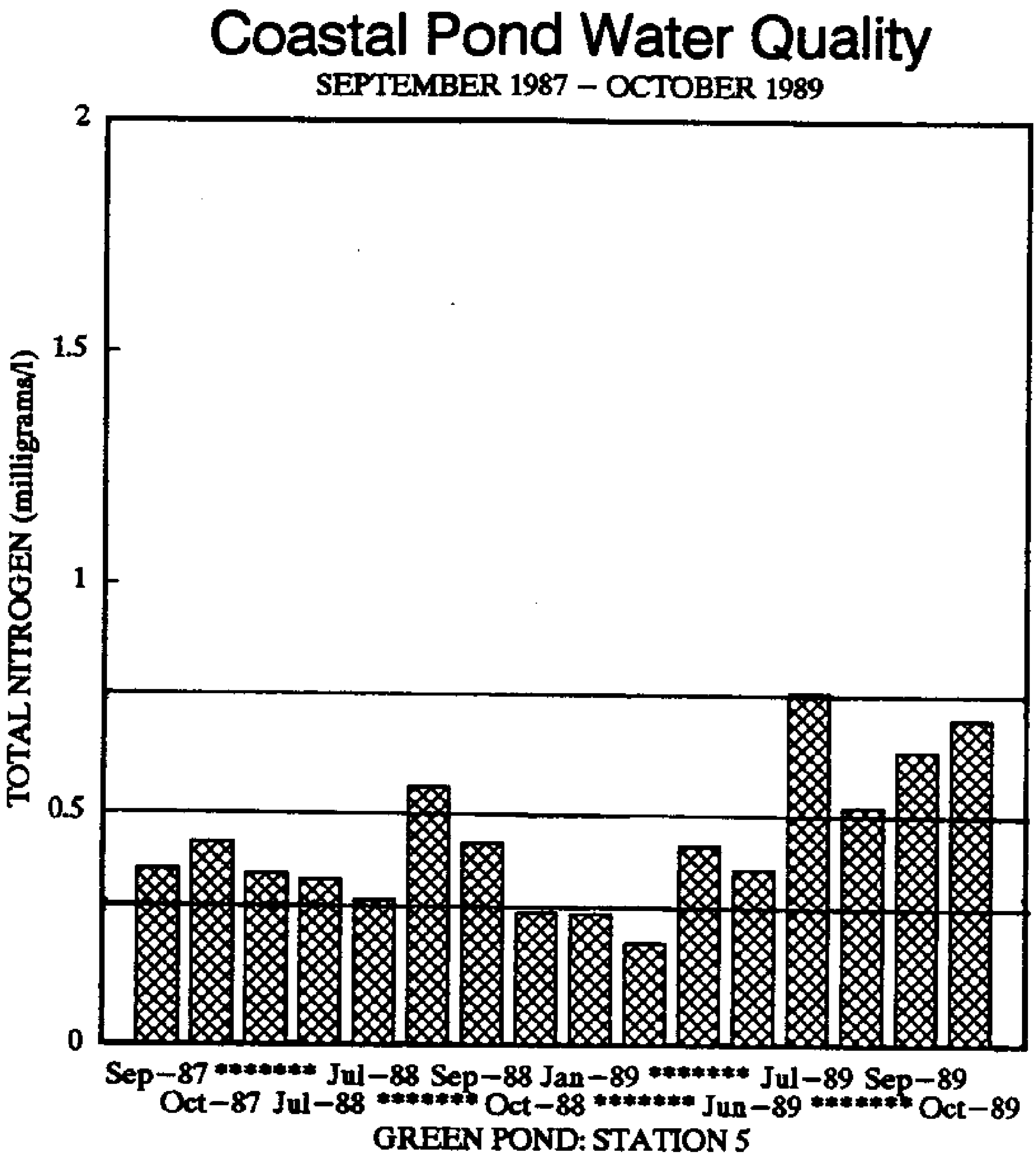

Coastal Pond Water Quality
SEPTEMBER 1987 – OCTOBER 1989
TOTAL NITROGEN (milligrams/l)
2
1.5
1
0.5
0
Sep–87 ******* Jul–88 Sep–88 Jan–89 ******* Jul–89 Sep–89
Oct–87 Jul–88 ******* Oct–88 ******* Jun–89 ******* Oct–89
GREEN POND: STATION 5

Figure 8 f.

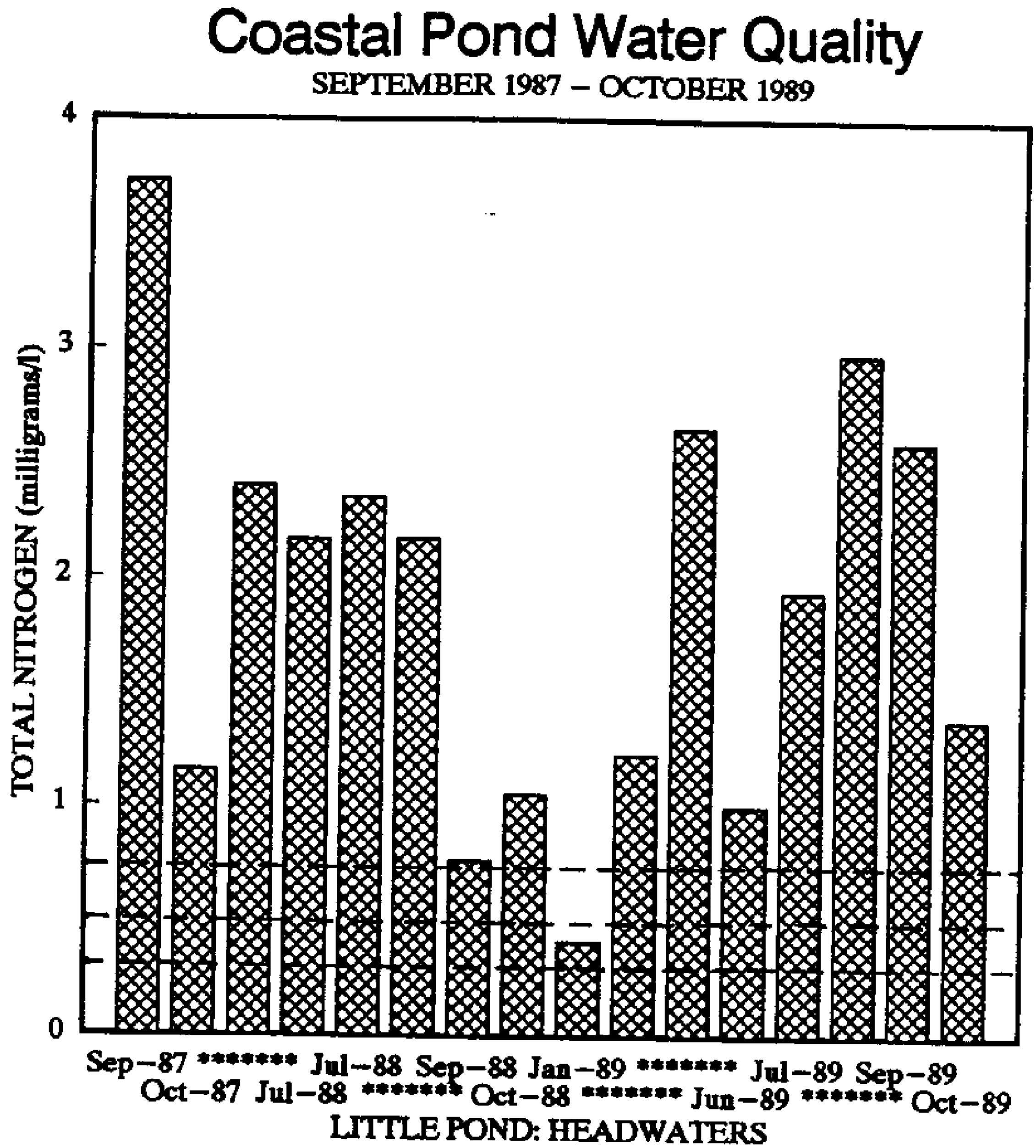


Figure 9 a,b,c,d. Total Nitrogen for Little Pond Stations; depth averaged values for each sampling period.

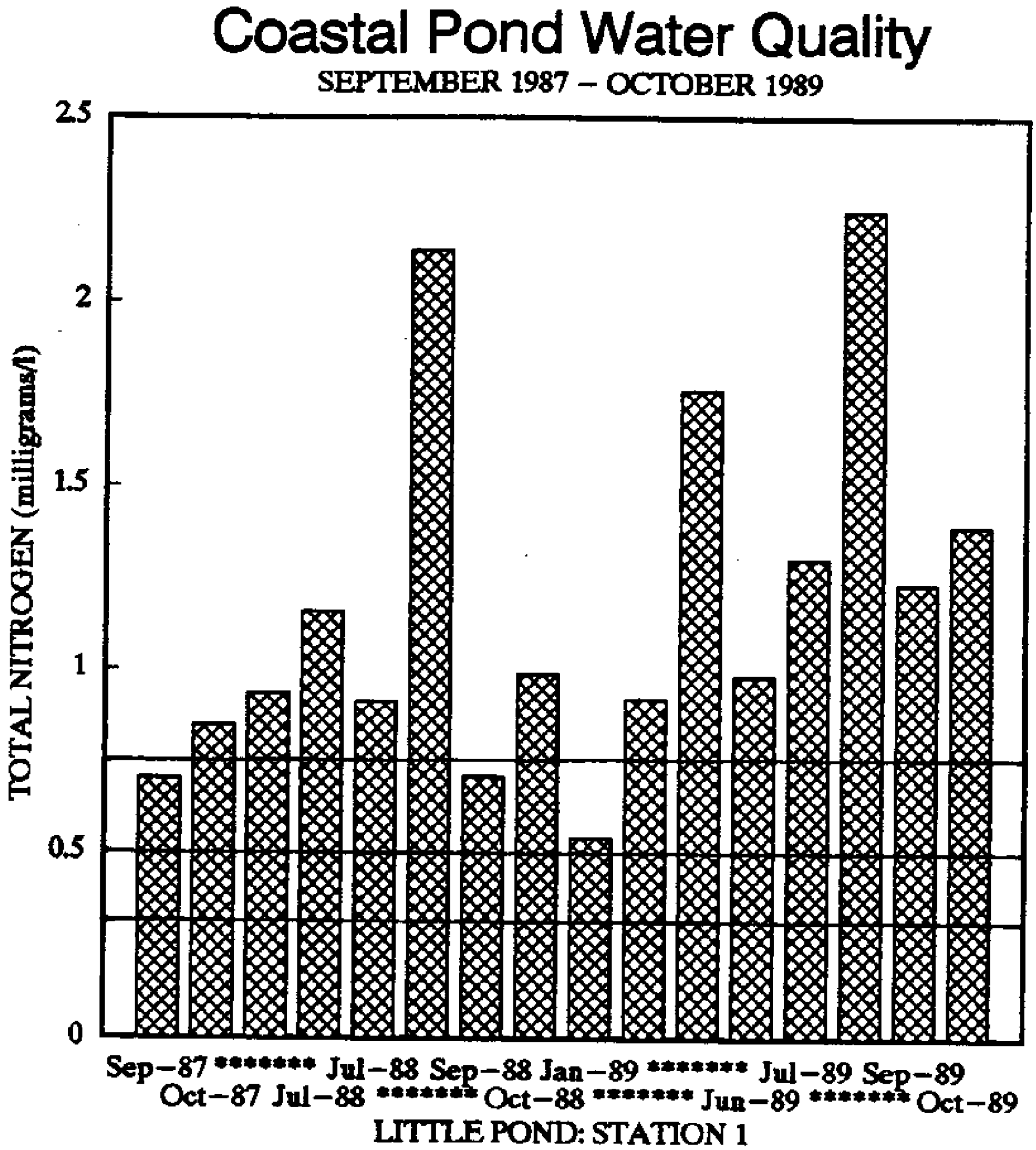

Coastal Pond Water Quality
SEPTEMBER 1987 – OCTOBER 1989
TOTAL NITROGEN (milligrams/l)
2.5
2
1.5
1
0.5
0
Sep–87 ******* Jul–88 Sep–88 Jan–89 ******* Jul–89 Sep–89
Oct–87 Jul–88 ******* Oct–88 ******* Jun–89 ******* Oct–89
LITTLE POND: STATION 1

Figure 9 b.

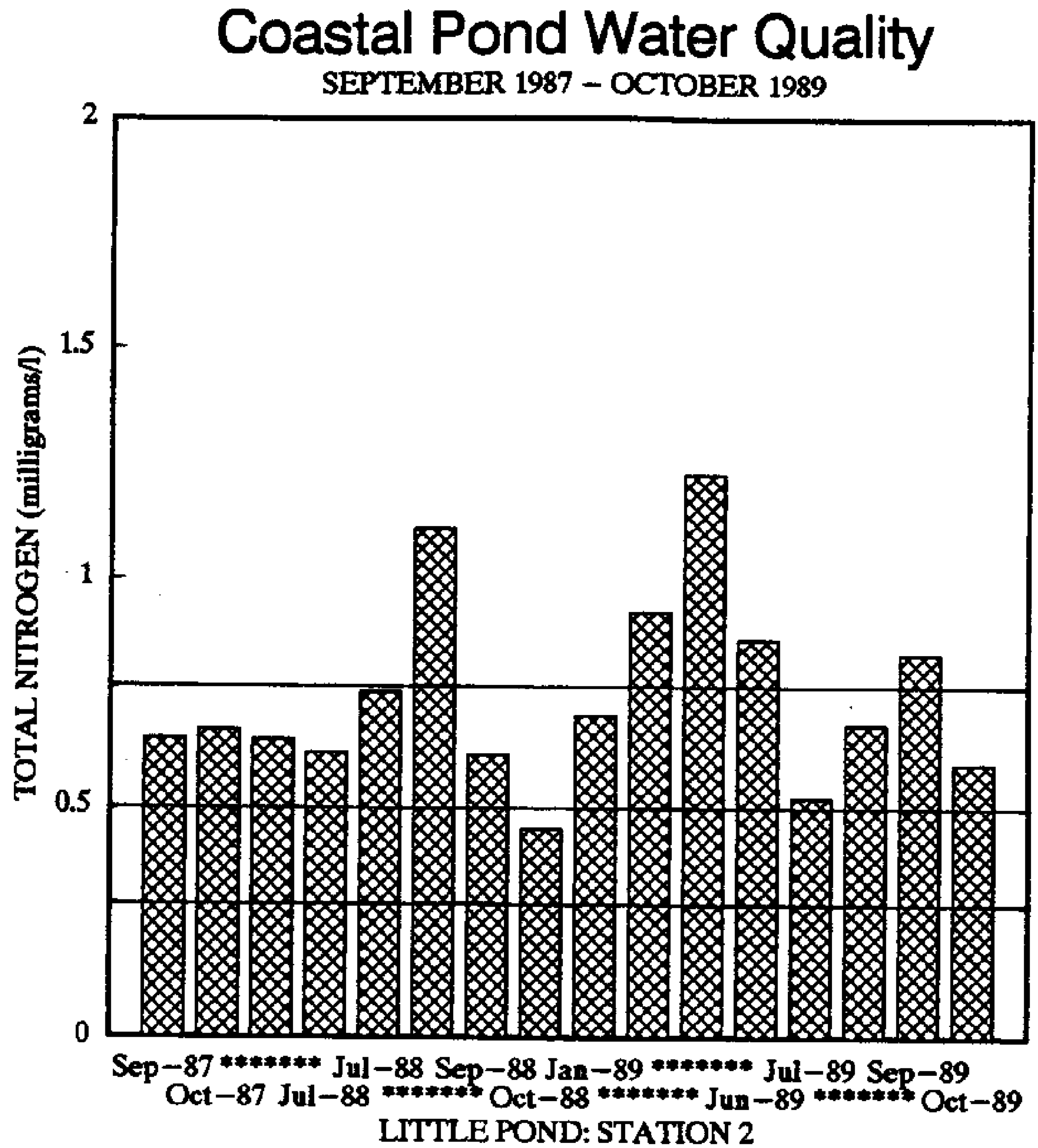
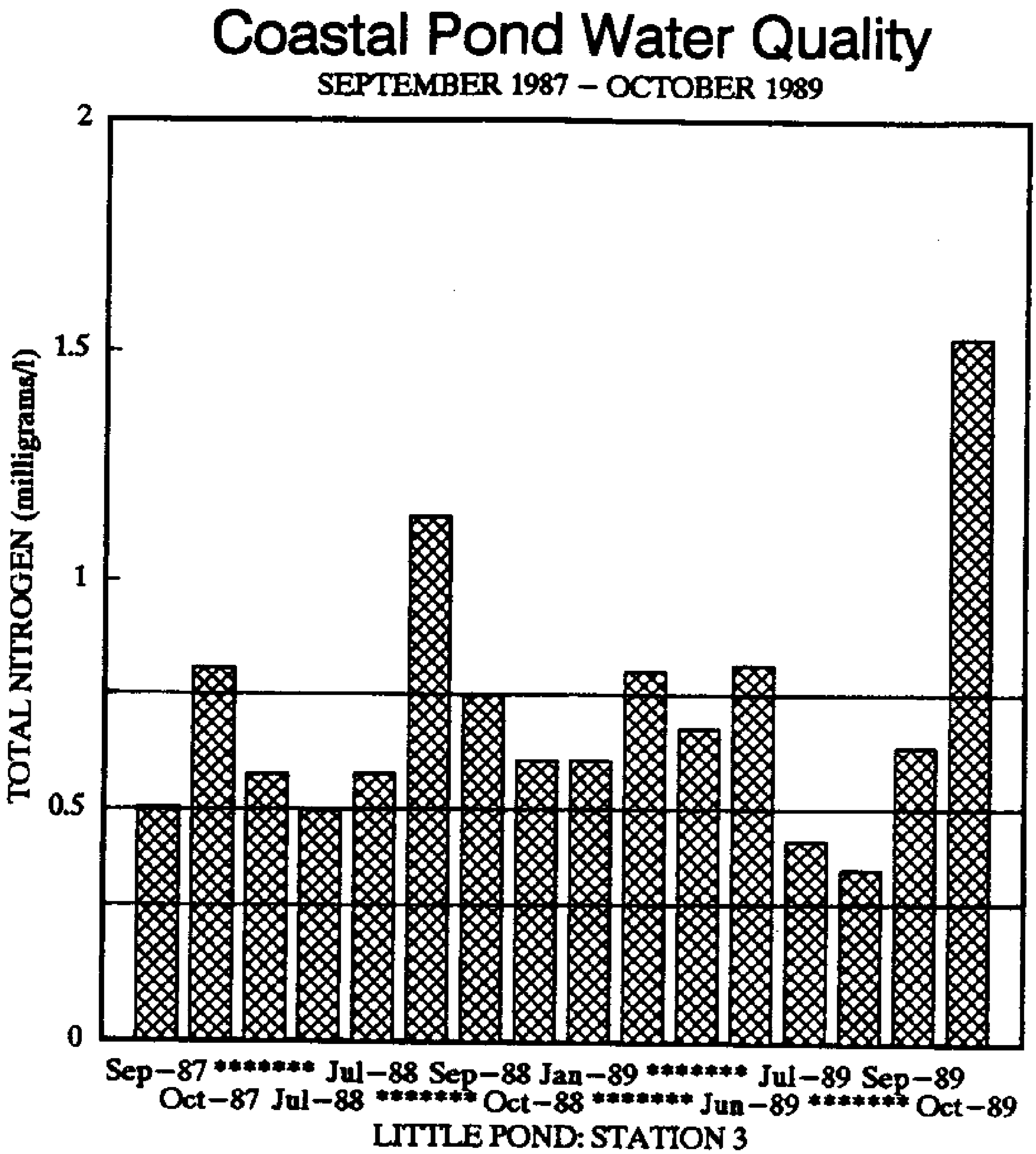

Coastal Pond Water Quality
SEPTEMBER 1987 – OCTOBER 1989
TOTAL NITROGEN (milligrams/l)
2
1.5
1
0.5
0
Sep–87 ******* Jul–88 Sep–88 Jan–89 ******* Jul–89 Sep–89
Oct–87 Jul–88 ******* Oct–88 ******* Jun–89 ******* Oct–89
LITTLE POND: STATION 2

Figure 9 c.



Coastal Pond Water Quality
SEPTEMBER 1987 – OCTOBER 1989
TOTAL NITROGEN (milligrams/l)
2
1.5
1
0.5
0
Sep–87 ******* Jul–88 Sep–88 Jan–89 ******* Jul–89 Sep–89
Oct–87 Jul–88 ******* Oct–88 ******* Jun–89 ******* Oct–89
LITTLE POND: STATION 3

Figure 9 d.

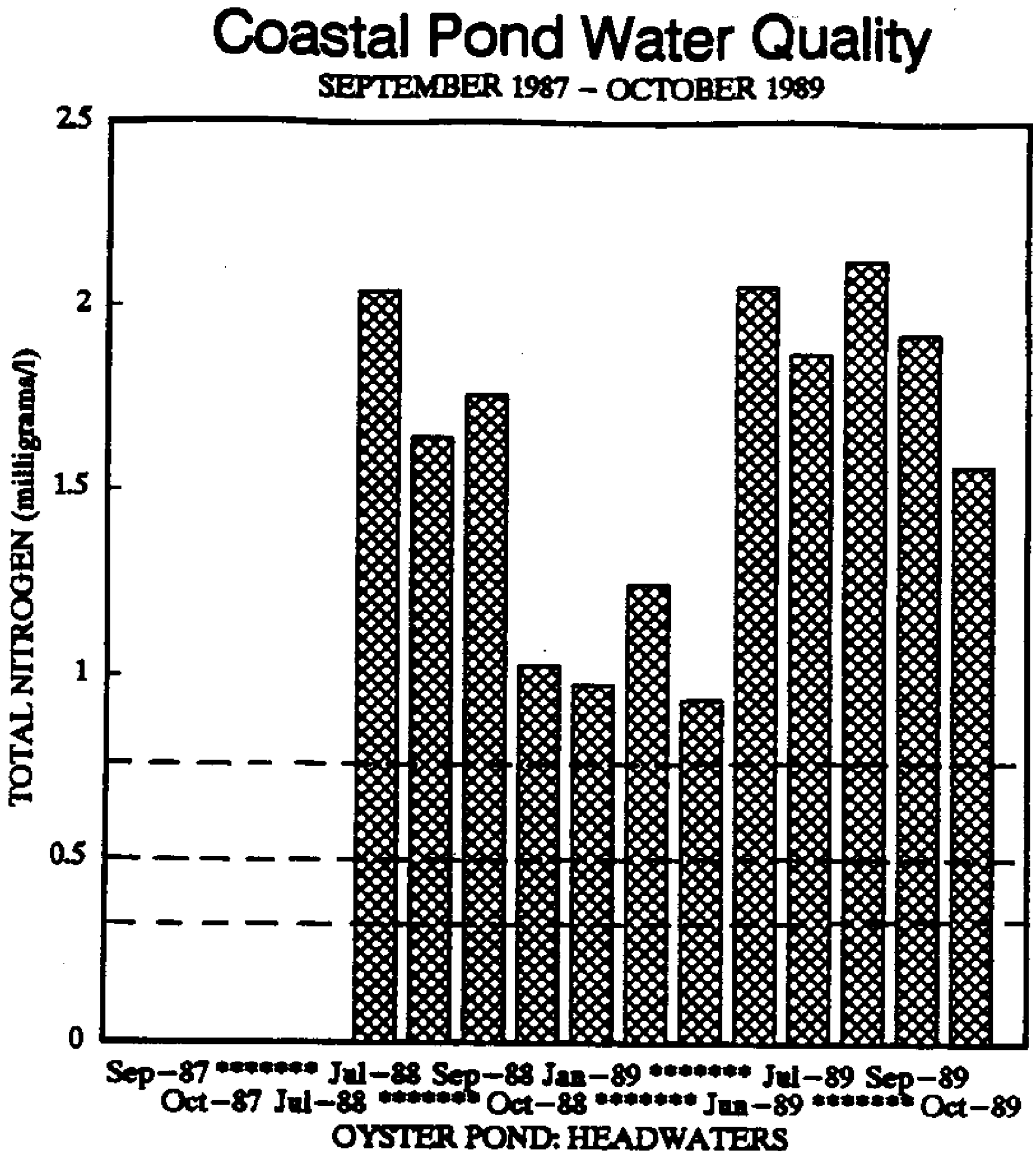


Figure 10 a,b,c,d. Total Nitrogen for Oyster Pond Stations; depth averaged values for each sampling period.

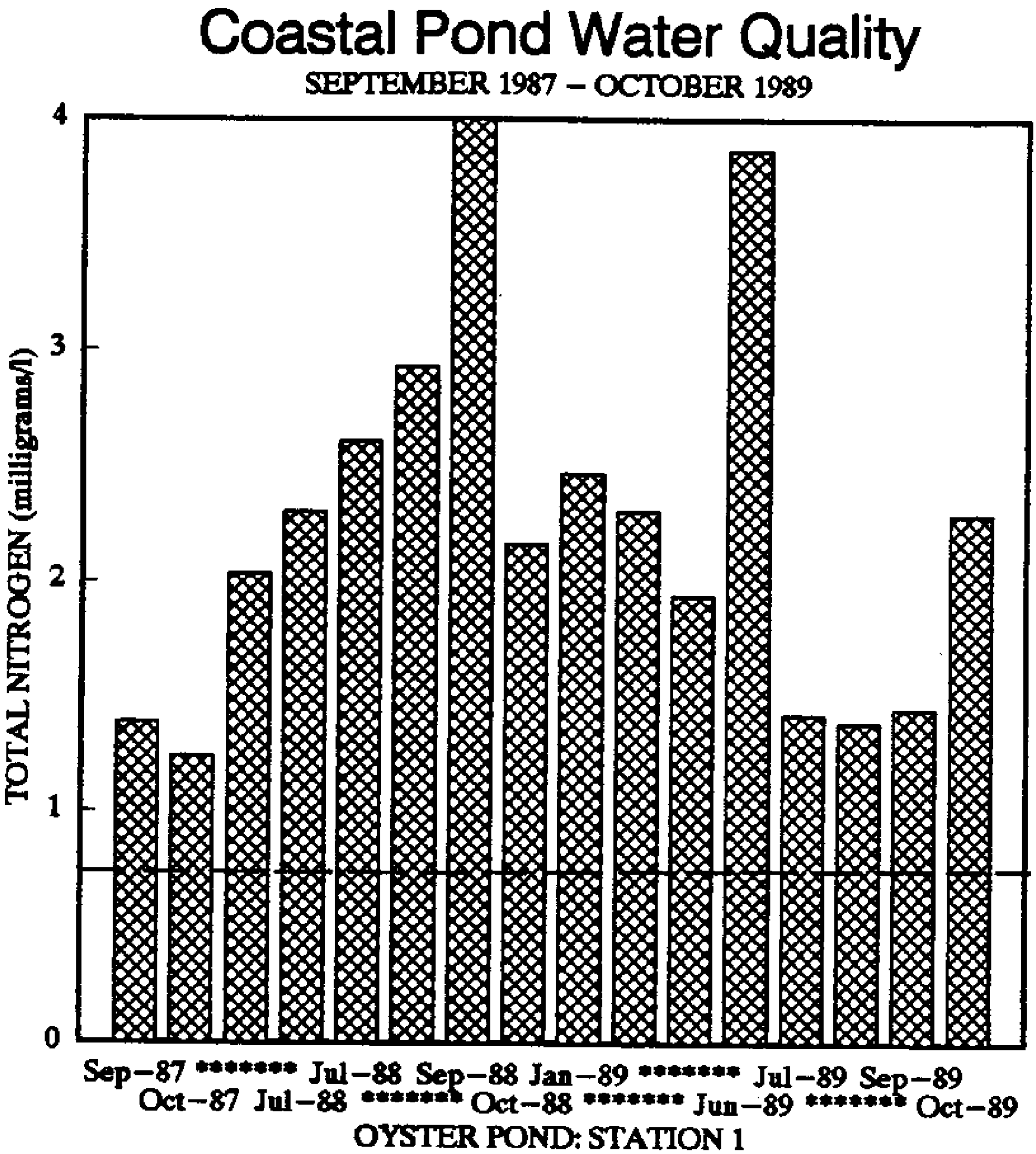

Coastal Pond Water Quality
SEPTEMBER 1987 – OCTOBER 1989
TOTAL NITROGEN (milligrams/l)
4
3
2
1
0
Sep–87 ******* Jul–88 Sep–88 Jan–89 ******* Jul–89 Sep–89
Oct–87 Jul–88 ******* Oct–88 ******* Jun–89 ******* Oct–89
OYSTER POND: STATION 1

Figure 10 b.

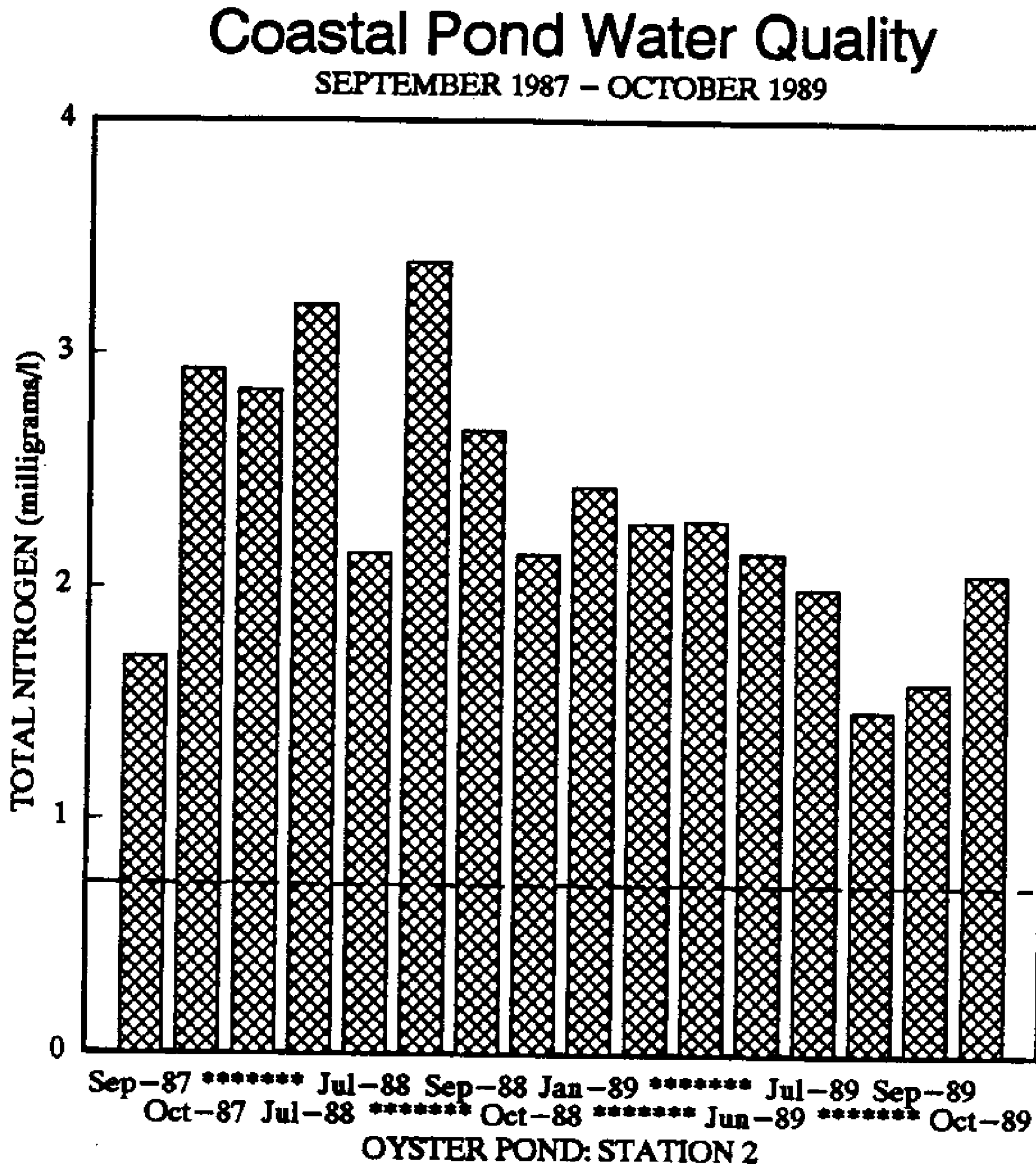
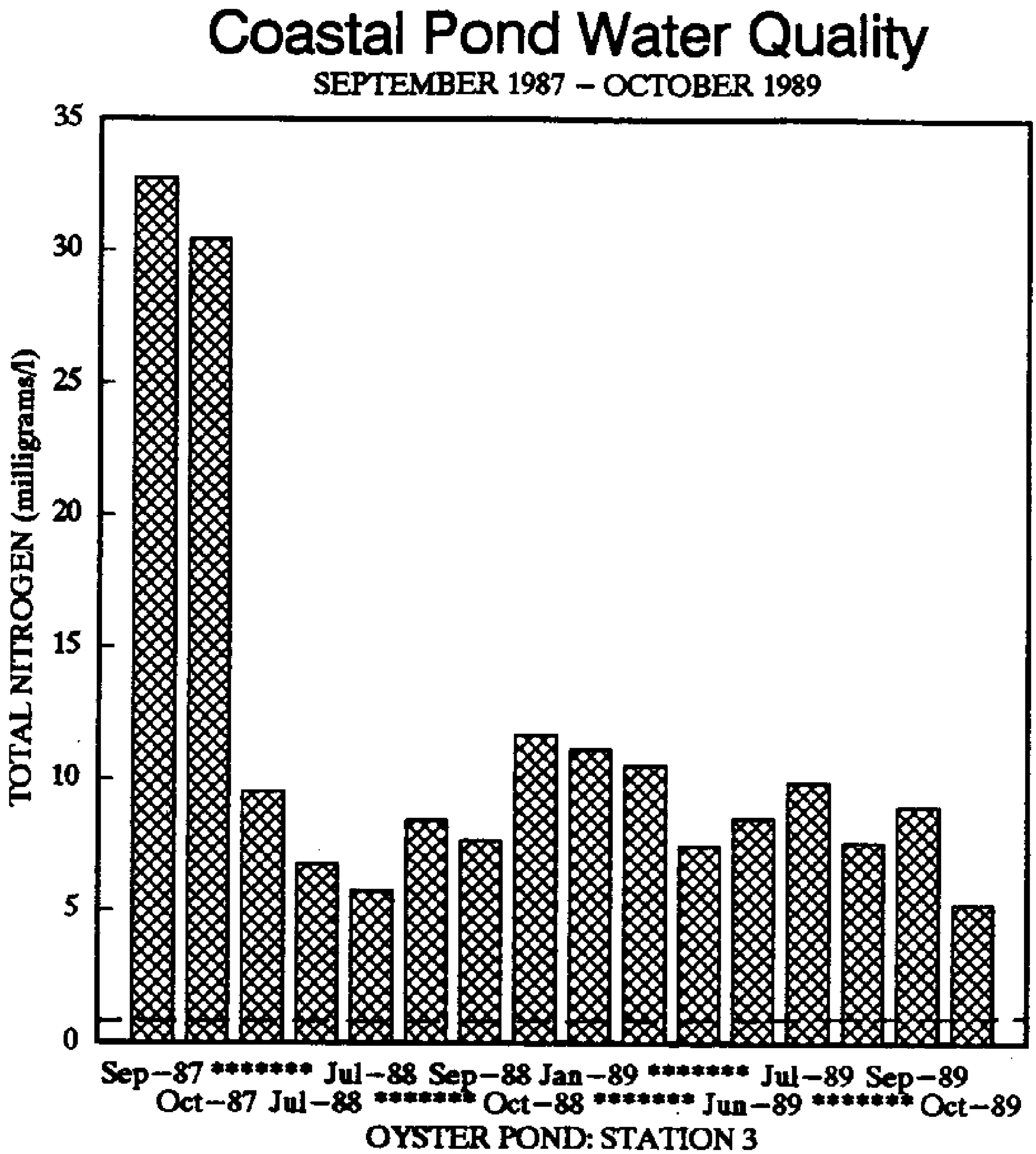

Coastal Pond Water Quality
SEPTEMBER 1987 – OCTOBER 1989
TOTAL NITROGEN (milligrams/l)
4
3
2
1
0
Sep–87 ******* Jul–88 Sep–88 Jan–89 ******* Jul–89 Sep–89
Oct–87 Jul–88 ******* Oct–88 ******* Jun–89 ******* Oct–89
OYSTER POND: STATION 2

Figure 10 c.



Coastal Pond Water Quality
SEPTEMBER 1987 - OCTOBER 1989
35
30
25
20
15
10
5
0
TOTAL NITROGEN (milligrams/l)
Sep-87 ******* Jul-88 Sep-88 Jan-89 ******* Jul-89 Sep-89
Oct-87 Jul-88 ******* Oct-88 ******* Jun-89 ******* Oct-89
OYSTER POND: STATION 3

Figure 10 d.

"permanently" anoxic Station 3 total nitrogen reached values in excess of 30 mg N/l. The large variability in the total nitrogen measured at Station 3 results primarily from the steep gradient in total nitrogen from lower values at the surface to extremely high values near the bottom. The effect of this steep gradient is that small differences in the depth of water collection results in large differences in measured nitrogen concentrations with resultant effects on the water column averages.

The total nitrogen distributions in the ponds are consistent with the areas of measured oxygen depletion. Upper Green Pond, Little Pond and Oyster Pond stations with total nitrogen values in excess of 0.75 mg N/l are the areas showing significant oxygen depletion hence diminished water quality. Only Lower Green Pond stations (Stations 4 and 5) which are well mixed, well flushed systems with lower total nitrogen concentrations, are not yet experiencing significant oxygen depletion.

Unfortunately, the oxygen and nutrient conditions measured in this study must be evaluated as a "best case", in other words the conditions are better than reality. The reason for this caveat is that as stated above, oxygen conditions were measured in late morning, while lowest oxygen concentrations occur near dawn and generally improve during the day. More importantly, in some regions of the watersheds of the ponds recent additional nutrient loading to the groundwater has not yet impacted the ponds due to the long time lag imposed by the slow rate of groundwater flow. In simple terms, the nutrient conditions in the ponds are not yet in steady state with the inputs to the watershed. In addition, particularly in Green Pond, additional loading to either the lower or upper pond will likely lower water quality throughout the whole pond given the bi-directional tidal driven flow.

OYSTERS

Oysters grew best at the site in Little Pond near Station LP3 (see map in Appendix 4) whether considered on the basis of total volume, total weight or ash-free dry weight (Figures 11 a,b,c). Oysters grew nearly as well at the seaward site in Green Pond near Station GP4 (again see map in Appendix 4). At each of these sites only one oyster died during the grow-out experiment. Oyster growth was also

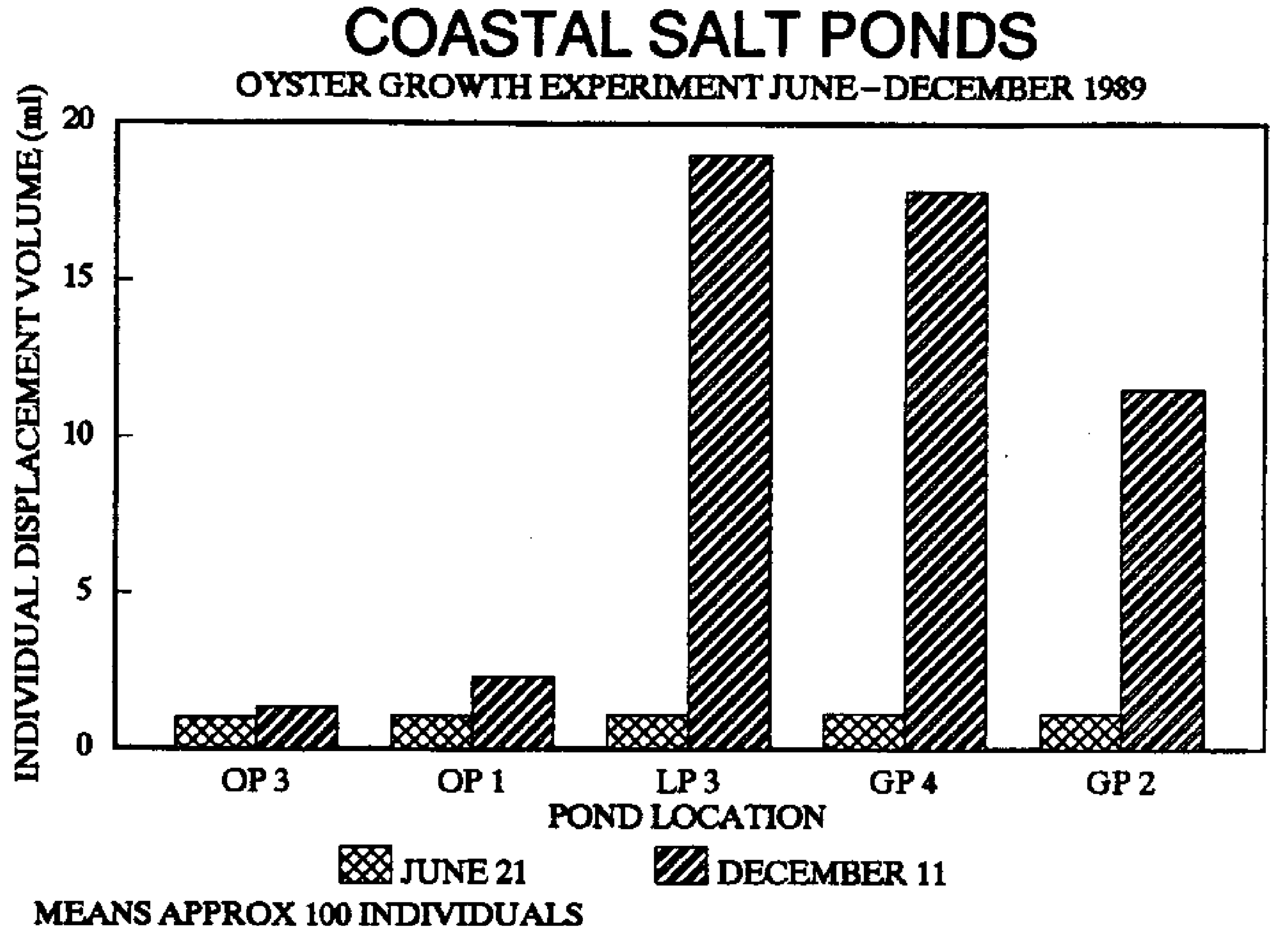


Figure 11 a. Mean displacement volume of oysters set out in Oyster, Little and Green Ponds.

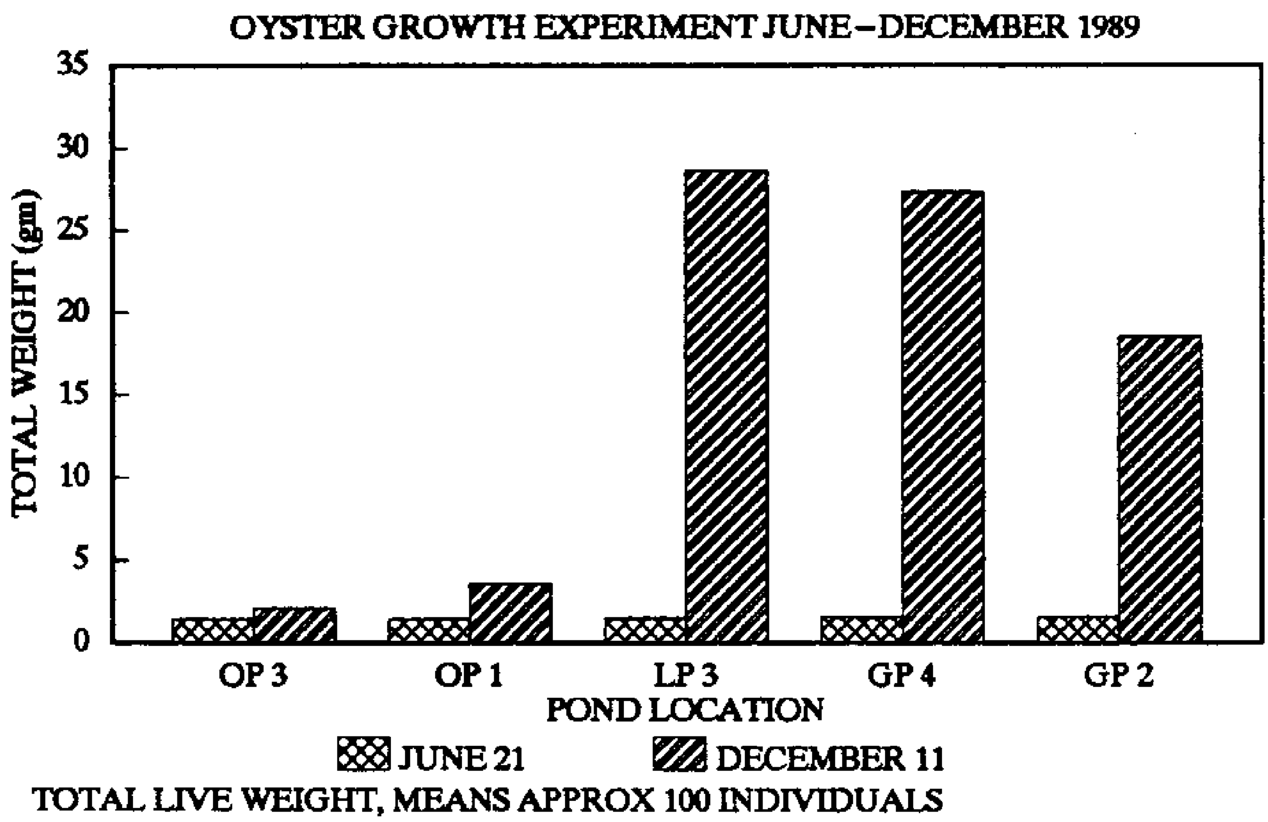


Figure 11 b. Mean individual total weight of oysters.

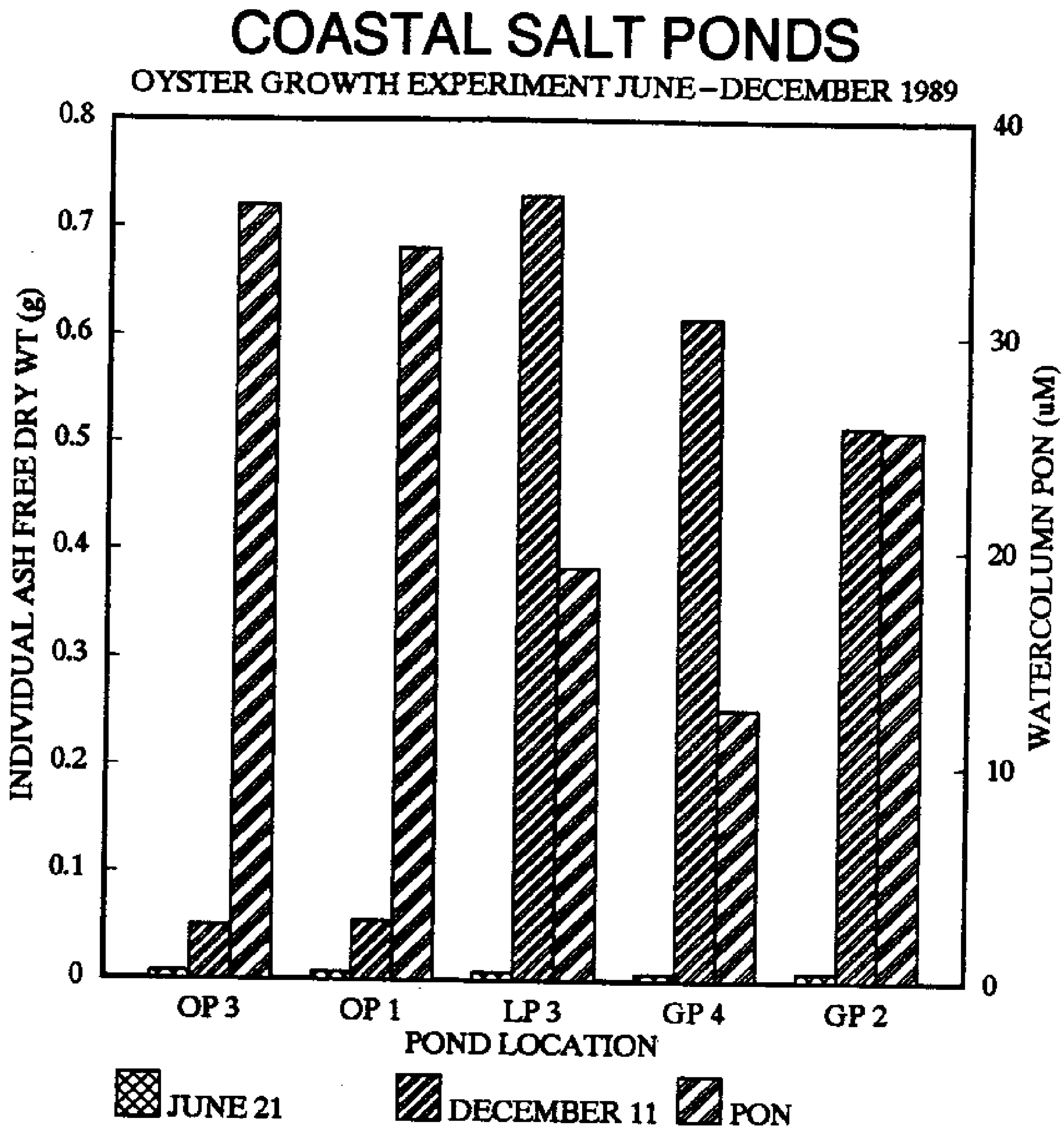


Figure 11 c. Mean ash-free dry weight of oyster tissue along with the mean concentration of particulate organic nitrogen (PON) in the water column at each site during the oyster grow-out period.

excellent at the control site in Vineyard Sound (WHOI dock near the Shore Laboratory on the bike path), but these oysters were lost during a fall storm so their growth could not be quantified. Oysters grew moderately well at the landward site in Green Pond near Station GP2 and mortality there was also minimal.

In Oyster Pond, however, the oysters grew poorly at both sites, in the vicinity of Stations OP1 and OP3. The level of mortality at these sites was about 15 percent, occurring during the summer months. The inability of oysters to grow in Oyster Pond may be related to the reduced salinity of the pond, to the composition of phytoplankton available as food, or to a combination of these. Figure 11 c shows there was plenty of organic matter in the water in Oyster Pond, as indicated by the high levels of particulate organic nitrogen (PON) during the course of the experiment. Of course, this organic matter may have been in the form of phytoplankton species unpalatable to or indigestible by the oysters.

These data seem to suggest that shellfish can survive in all of the ponds. However, it is important to note that the oysters were suspended in nets above the bottom and therefore do not reflect infaunal animal survival.

NITROGEN BUDGET FOR LITTLE POND

In collaboration with the research conducted through the Pond Watcher project on Oyster, Little, and Green Ponds, a more detailed investigation of the nitrogen budget for a coastal salt pond is being conducted concurrently on Little Pond, also with WHOI Sea Grant funding. The focus of this project is to quantify nutrient inputs due to human impacts versus those from natural processes and the degree to which these interact. The study is designed to determine the processes which control the nutrient and oxygen conditions, hence the water quality of a coastal salt pond. Only by determining the controlling factors can we make rational decisions as to which environmental processes we need to target in a management program. Of major importance to the determination of current and potential impacts of this nutrient loading is understanding the extent to which the system is self sustaining as a result of nutrients incorporated into and stored within the sediments. This "battery effect" may continue to supply nutrients to overlying waters even if the original inputs are diminished. Understanding the relative importance of the sources and sinks of nutrients, primarily in the form of nitrogen, requires the construction of a nutrient budget for the entire system.

For a coastal pond ecosystem, the major nutrient inputs come from the entire watershed via groundwater, with additional but less significant input from terrestrial runoff and precipitation. The major losses occur primarily through tidal exchange with associated waters, sediment denitrification (whereby nitrate is transformed into harmless nitrogen gas), and burial into the sediments as particulate nitrogen. The most significant of these processes, which as yet remain poorly understood, are groundwater contributions and denitrification. The extent to which the input is partitioned between these fates determines the importance of each of the major inputs to potential eutrophication.

The construction of a nitrogen budget for Little Pond requires measurements of: groundwater transported nutrients, benthic regeneration of inorganic nitrogen, import and export through tidal exchange, denitrification, rainfall, streamflow and nitrogen burial in the bottom sediments. Emphasis is being placed on 1) the potential importance of benthic sediments in maintaining high levels of nutrient loading to the water column relative to alterations in the contribution of other sources, 2) the importance of groundwater transported nutrients and the loss of nitrogen to denitrification processes as it moves via groundwater flow to the pond water column, and 3) the significance of residential on-site sewage disposal and fertilizer use to the overall nutrient economy of the adjacent coastal salt pond.

The next phase of work requires delineation of the watershed contributing groundwater to the pond. The major effort of acquiring permission from land owners and installation of monitoring wells for measurement of groundwater flow and sample collection is complete and we are now in the initial stages of experimentation.

A permanent tide gauge station has been established for the monitoring of tidal range over the course of the study. A stream gauge recorder has been placed at the head of the pond to measure flow from the major stream input source. These data, when coupled with groundwater input estimates and detailed bathymetry of the pond, will give us an accurate assessment of water turnover in the pond.

Groundwater nutrient concentrations will be measured using multilevel wells to allow determination of the potential groundwater nutrient load to the pond. The extent to which these nutrients reach the pond water column will be determined from measurements of benthic nutrient exchange, sediment nutrient profiles, and groundwater seepage and denitrification measurements. Rainfall data are being collected by the Pond Watcher gauges in the area.

Finally, a census is being conducted in the watershed area to determine population, fertilizer use, age of houses, and number of bedrooms to help quantify human nutrient inputs. With this information we will be able to model the nitrogen budget for the pond and determine the relative importance of natural inputs versus human activities to pond eutrophication and the potential effects of altering the inputs to or losses from the system.

CONCLUSIONS

1) Basically, Oyster, Little and Green Ponds are more sensitive to nutrient loading than adjacent coastal waters because of similar underlying processes. Each pond displays estuarine characteristics, the waters of each pond exhibit elevated temperatures in summer, and each pond shows stratification, thus setting the stage for oxygen reduction or depletion and the ensuing ecological stress to animal and plant communities.

2) All of Little Pond, the upper reaches of Green Pond, and the mid and upper sections of Oyster Pond show periodic reduction or depletion of oxygen. The seaward basin of Oyster Pond shows persistent anoxia resulting in a high concentrations of hydrogen sulfide in the deeper waters.

3) In simple terms, the three ponds act as factories for transforming inorganic nitrogen to particulate organic nitrogen. Nitrates enter the ponds primarily at the landward sites, are taken up by the micro and macroalgal communities as they progress down the pond, and are converted into particulate nitrogen, which, as a

consequence of its decay, leads to the oxygen depletion mentioned above.

4) Although there was significant variability in nutrient levels between sampling dates, no obvious seasonal trends in nutrient levels were apparent.

5) Total nitrogen concentrations in all three ponds currently exceed 0.5 mg per liter, with the exception of the seaward region of Green Pond which averages slightly less than 0.5 mg per liter.

RECOMMENDATIONS

1) Because the nutrient data show variability through time, it is important for the purposes of assessing existing nutrient levels relative to the Coastal Pond Nutrient Overlay Bylaw that measurements be conducted on a number of occasions.

2) The lack of a strong pattern of seasonal variability in nitrogen levels allows for less intensive sample collection during the winter months meaning that more intensive sampling of nutrient conditions during warmer summer months is appropriate.

3) Because the ponds are most sensitive to oxygen depletion during the warmer months (April through November), nutrient conditions during this period are the critical values for assessing the impacts of additional nutrient loading.

4) Biologically active nitrogen pools (nitrate, ammonium and particulate organic nitrogen) may be more useful for gauging the susceptibility of ponds to nutrient loading than is total nitrogen.

5) Environmental planners should recognize that the health of coastal ponds is more directly indexed by oxygen conditions (periodic anoxia) and by the status of existing animal and plant communities than by total nitrogen conditions. In other words, low total nitrogen levels may not mean that pond water quality is satisfactory, although our results indicate that high levels of total nitrogen do seem to be related to oxygen depletion and poor water quality.

6) At present data are not available to be able to assess the relative contributions of man's activities versus natural events in the nitrogen loading of the ponds. Nevertheless, the data obtained during this study indicate that these ponds have poor water quality during the summer months. The ponds appear to be poised for more severe and widespread environmental problems if nutrient loading continues to increase above present levels. Therefore, it is recommended that management options be considered and adopted to reduce nutrient inputs (or increase nutrient outputs) to the ponds, particularly during the critical summer months.

It is intended that these recommendations be updated and expanded as more information becomes available from continuing phases of the Pond Watcher project and other WHOI Sea Grant-supported coastal salt pond projects.

PLANS FOR 1990

This Pond Watcher project was initially intended to be conducted over a two-year period, 1988 and 1989. However, the project has developed and proceeded so smoothly and productively that there are good reasons for encouraging its continuation in 1990. Now that the Pond Watcher volunteers have been trained and mobilized to be an enthusiastic and responsive group of "research assistants," it would be a shame to see a loss of the community service momentum that has been built around a common interest in the health and welfare of Falmouth's coastal ponds.

Further, a productive synergism has developed between this project and other WHOI Sea Grant-supported projects focussing on Falmouth's coastal ponds. As a result of this joint effort, substantial headway is being made in understanding the water quality status of the ponds, the detailed mechanisms involved in eutrophication of the ponds, and the links between nutrient loading and resulting ecological consequences. All of this has a significant bearing on how the Town plans and manages development around its coastal ponds. As well, these projects provide much-needed information necessary for fuller interpretation of the recently enacted Coastal Pond Nutrient Overlay Bylaw.

Accordingly, we propose to continue the Pond Watcher project in 1990, shifting emphasis toward a more intensive examination of the three ponds in mid-summer when the ponds are the most vulnerable to the effects of water quality degradation, along with a general nutrient and oxygen survey of other coastal ponds in Falmouth (such as Great Pond and Bourne's Pond) to be able to rank them relative to the ponds for which we already have information.

During the year we also intend to explore opportunities with Pond Watchers and with local, state, and federal agencies for 1) perpetuation of citizens monitoring of coastal ponds in Falmouth as a self-run effort and 2) linking such an effort with local, state, and federal funding and to the environmental regulatory infrastructure.

ACKNOWLEDGEMENTS

We wish to express our sincere thanks to all Pond Watchers for their interest in and support for this project. We are especially grateful to Pond Captains and those Pond Watchers who played a role in the sampling aspects of the project for giving freely of their time and expenses (boats, gas, ice, etc.). We thank Richard van Etten, Tony Millham, Andrea Arenovski, David Schlezinger, and David White for research support, and Lee Anne Campbell and Nanci Pacheco for their assistance with project coordination and outreach.

FALMOUTH ENTERPRISE MAY 6, 1988 Page Seven

Sea Grant Program Seeks Volunteers For Summer Coastal Pond Study

Woods Hole Oceanographic Institution's Sea Grant Program is seeking volunteers interested in participating in a study, starting this summer, of the health of three coastal ponds in Falmouth.

The purpose of the project, a cooperative venture of the Sea Grant Program and the town of Falmouth, is to monitor water quality conditions in Green, Little and Oyster ponds over a period of two years. All three ponds are showing the effects of an overabundance of nutrients accumulating in their waters, said Alan W. White, marine science adviser for the program.

The data to be collected will provide the town with information for assessing the potential effectiveness of environmental management options such as restrictions on the use of fertilizer, requiring denitrifying septic systems in coastal watersheds, a moritorium on building or opening and improving inlets from the ocean, Mr. White said.

The project originated with an article proposed by William B. Kerfoot, president of K-V Associates, Inc. of Falmouth at the annual town meeting last year. The article sought $60,000 in town funding for a study of the three ponds.

When it became evident that sufficient town funds were not available to carry out the project, institution geologist David A. Ross, coordinator of the Sea Grant Program and a town meeting member, proposed seeking Sea Grant support for the project. Town meeting members approved allocation of $5,000 last year to get the project underway.

A grant of $34,000 from Sea Grant and an additional $9,000 voted at this year's town meeting will enable organizers to proceed with the monitoring phase of the project, Mr. White said.

With the help of Brian L. Howes and Dale D. Goehringer of the institution's biology department, Mr. White collected samples from all three ponds last fall. The three plan to collect more samples this month and next to assess such environmental parameters as temperature, salinity, dissolved oxygen, light levels and the presence of various forms of nitrates and phosphates, Mr. White said.

Preliminary Report

These data will form the basis of a preliminary report on the current condition of the ponds, a baseline for the two-year monitoring project, he noted.

Mr. White hopes to attract two sorts of volunteers for the project. Boat owners willing to go out on the ponds once a month during the summer are needed to make various simple measurements and collect samples from certain locations in each pond, he said.

Also needed are pond-watchers, individuals interested in keeping an eye on the ponds year-round for unusual events, such as fish kills, extensive algal blooms and mats or bad odors, he added.

Dr. Howes and Ms. Goehringer will analyse samples collected for nutrients at their laboratory in Woods Hole. Both have been involved in nutrient studies of coastal waters for a number of years, Mr. White said.

"The involvement of citizen volunteers in environmental monitoring is taking place all over the country," he noted, pointing to a similar study of Rhode Island coastal ponds under the direction of researchers from the University of Rhode Island. "At this stage we would like to hear from people who live near these ponds and are willing to pitch in."

Volunteers will receive training, starting in early June, in the use of water samplers, thermometers, rain gauges and other instruments. Some 12 residents have already contacted the Sea Grant office to volunteer their services, Mr. White said, adding that many more are needed.

CAPE COD TIMES, TUESDAY, MAY 10, 1988

Volunteers sought to help WHOI conduct study of three ponds

By RENEE TWOMBLY
STAFF WRITER

WOODS HOLE — To find out what's going wrong with three Falmouth ponds, the Woods Hole Oceanographic Institution is seeking dozens of Falmouth residents to help keep an eye on them.

The two-year study will focus on Oyster, Little and Green ponds, which have suffered deteriorating water quality, possibly as a result of increased human activities nearby, said Alan White, of the WHOI Sea Grant program.

The institution already has the funds to get the study under way. The federal Sea Grant program awarded WHOI $34,000 to start research, and $9,000 was approved for the study at the April Falmouth town meeting.

But the effort needs help from people who live around the ponds, or people who don't, but care about water quality in Falmouth, said White.

The pond monitoring program needs two groups of residents who can gather information.

One of about 15 to 20 volunteers should be boat owners or people with access to a boat. They will go out on the ponds once a month to make simple measurements and collect samples.

This group will be active from July through September this year, and from June through September in 1989, White said. These volunteers will be trained in early June to work with water samplers, thermometers, rain gauges, and other instruments, said White, who will coordinate the program.

The other group will be pond-watchers — as many as White can sign up. They will monitor the ponds year-round, on the alert for unusual events, such as fish kills, algae blooms or bad odors. They should be residents who walk routinely around the ponds, or live by the ponds, said White.

Samples taken from the ponds will be analyzed for nutrients by Brian Howes and Dale Goehringer in WHOI's biology department. They already are working on a separate $12,000 Sea Grant project focusing on the nitrogen-cycling in Little Pond, part of a preliminary study of the ponds.

The idea to study the ponds was put before town meeting in April 1987, when Falmouth resident and environmental consultant William Kerfoot proposed an article. He said the town should pass a building moratorium around the ponds, and Falmouth should spend $60,000 to find out what to do to help the pond.

Little Pond already exceeds state limitations on such nutrients as nitrogen and phosphorus and Oyster Pond is so overrun with vegetation produced by those nutrients that its outlet is virtually blocked from the sea, said Kerfoot. Green Pond already has had a fish kill, a sign that it is suffering from those same excess nutrients, he said.

But town officials said they did not believe in a moratorium, and could not afford more than $5,000 that year. That is when David Ross, a town meeting member and WHOI scientist in charge of the Sea Grant program, said he would help raise government money to study the ponds.

At the time, he said, "Scientists in the community have shown interest in the past, and some are willing to do so again. I don't think this study can wait." The $5,000 was used to help set up the initial Little Pond study.

The project is designed to be a cooperative project between WHOI and the town of Falmouth, under the guidance of its planning office, said White.

And if successful, the joint study can lead to other projects. "The involvement of citizen volunteers in environmental monitoring is taking place in a number of locations across the country. It's a good way for people to participate in protection of their local environments and can be lots of fun," he said. "We're hoping this project will really catch on, and lead to other opportunities for citizen involvement in coastal problems."

Further information may be obtained by calling White at the WHOI Sea Grant Program, 548-1400, extension 2289.

APPENDIX 2
(updated 3/90)

POND WATCHERS
3/90
GREEN POND

Matthew and Beth Adamczyk
10 Sharon Ann Lane
East Falmouth, MA 02536
540-7334

Eleanor Baldic
Mariners Lane
Falmouth, MA 02540
548-2681

Edward L. Beattie
96 Shoreland Path
East Falmouth, MA 02536
548-6216

Charles Blumsack
59 Partridge Lane
East Falmouth, MA 02536

Jim Churchill
495 Blacksmith Shop Road
East Falmouth, MA 02536
540-0526

Jonathan Cutone
295 Edgewater Drive East
East Falmouth, MA 02536
548-8178

Ellen DeOrsay
242 East Falmouth Highway
East Falmouth, MA 02536
540-2468

Forbes Howard
65 Renee Lane
East Falmouth, MA 02536
540-8228

Mike Kinney
459 Davisville Road
East Falmouth, MA 02536
548-2028

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

Carol McKenzie
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East Falmouth, MA 02536
548-4447

Steve Molyneaux
230 Davisville Road
East Falmouth, MA 02536
540-2484
P.O. Box 595, WH 02543

Frances O'Donnell
49 Vineyard Street
East Falmouth, MA 02536
548-6033

Armand Ortins (Pond Captain)
40 Bridge Street
East Falmouth, MA 02536
548-1670

Terry Reihl
111 Portside Circle
East Falmouth, MA 02536
548-5186

Gretchen Rittershaus
P.O. Box 69
East Falmouth, MA 02536
548-0509

David Ross
53 Green Pond Road
East Falmouth, MA 02536
548-0476

Frank & Diane Souza (Pond Captain)
55 Sharon Ann Lane
East Falmouth, MA 02536
540-3246

Edmund Wessling (Pond Captain)
28 Bridge Street (Acapesket)
East Falmouth, MA 02536
548-7736

LITTLE POND

John Callahan
2 Ardmore Street
East Falmouth, MA 02536
540-3165

Jane and Richard Carter
PO Box 22, 25 Glen Avenue
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563-5383

Dick Erdman
8 Providence Street
East Falmouth, MA 02536
548-8868

Anna Gadaire
10 Amherst Ave
Falmouth, MA 02540
548-7789

Joe Johnson
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Falmouth, MA 02540
548-0592

John & Vera Justason
29 Miami Avenue
Falmouth, MA 02540
548-2459

Robert & Marie Leavens
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548-1473

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548-3650

Bobby Rogers
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East Falmouth, MA 02536
540-9372

Robert Roy
2 Massasoit Street
East Falmouth, MA 02536
548-5139

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548-0472

Gertrude Spellman
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(winter address) 61 Gary Road
Needham, MA 02192

Ted Tavares
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548-5168

Ruth (Ginny) Waight
66 Bourne Street
East Falmouth, MA 02536
548-2775

Barbara Wells
3 Ardmore Street
East Falmouth, MA 02536

OYSTER POND

Duncan Aspinwall
408 Elm Road
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540-3816

Paul Crocker
37 Fells Road
Falmouth, MA 02540
548-2106

John Dowling (Pond Captain)
Ransom Road
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Donald & Helen Light
90 Ship's Watch
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548-0277

Bob Livingstone
Fells Road
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540-8065

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102 Ransom Road
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GENERAL

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548-8537

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548-3362

Fred O'Connor
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457-1027

John Quinn
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Scott Rosewell
209 Fresh Pond Road
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563-2058

WHOI SEA GRANT
POND WATCHER PROJECT PERSONNEL

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Marine Science Advisor
WHOI Sea Grant Program
Program
548-1400 x2289, 540-9382

Brian Howes
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Biology Department
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548-1400 x2319

Lee Anne Campbell
Communicator/Staff Assistant
WHOI Sea Grant
548-1400 x2398

Dale Goehringer
Research Associate
Biology Department
WHOI
548-1400 x2744

SAMPLING PROTOCOL FOR POND STUDY
OYSTER POND

General:

The goals of the sampling program are to:
1) collect water column samples without disturbing the bottom sediments which will give artificially high nutrient and particle values;
2) process oxygen samples as quickly as possible and with the minimum chance of introducing atmospheric oxygen into the sample before the reagents are added.

The order of sampling is:

1) Collect surface samples
   a) process for oxygen,
   b) temperature
   c) nutrients

2) Collect deeper samples
   a) oxygen
   b) temperature
   c) nutrients

3) Physical measurements
   a) Secchi depth
   b) color
   c) total depth

Procedures:

Note: For simplicity we have decided to use the sampling equipment for both surface and deep water collection. If you like, you can fill the surface 1 liter nutrient bottle by hand.

1) Pre-label (with date, pond, station & depth) 1 liter nutrient bottle and .125 liter filtered H_2O bottle. Tape marking depth should just touch water surface.

2) Arm Nansen sampler - CAUTION!!! DO NOT PUT FINGERS IN SAMPLER WHERE THEY CAN BE HURT BY MISFIRE!!!

3) Lower the sampler to the appropriate depths marked on rope 0.1 meter, 2 meters, 3.25 meters, 4 or 6 meters depending upon your station (on map).

REPEAT FOR EACH DEPTH SAMPLE

3) Drop messenger.

4) Keeping the sampler vertical, bring the samples on deck. Remember to support the bottle as it will be heavier out of water.
   a) OXYGEN: Put glass O_2 bottle (with glass stopper) from Blue O_2 kit into plastic jar, lower tube from sampler to the bottom of the glass bottle from the blue oxygen kit. Open white air vent at top of sampler and open clamp on tube at bottom of sampler and let flow through the glass bottle, overflowing the glass bottle until the water rises to the black line on the plastic jar. Tap glass bottle if bubbles stick to sides. Remove tube and stop flow.
   b) Carefully insert the glass stopper (drop) so as not to trap any bubbles. (Do not pour off excess water).
   c) Now fill the 1 liter nutrient bottle and take temperature, record.

d) 1. Using the clippers in the blue oxygen kit open Reagent pillow 1;
2. remove glass stopper from glass O_2 bottle;
3. pour Reagent 1 into bottle;
4. open Reagent pillow 2 and add to bottle.
5. Replace glass stopper, careful not to trap bubbles.
6. Shake bottle vigorously holding bottle and stopper (some reagent may stick to bottom of bottle...this is O.K.).
7. Let stand 2 minutes, shake again.
8. After a total of 5 minutes, open Reagent pillow 3, remove glass stopper, add powder to bottle, replace stopper, shake vigorously until water in bottle becomes clear (no particles).
9. Remove glass stopper and fill small plastic tube to top TWICE (two volumes) pouring each time into the square glass bottle in the kit.
10. You are now ready to determine the oxygen content. Take the eyedropper and fill with solution in the brown plastic bottle in kit (do not get on hands). Now the tricky part: add 1 drop to the square bottle and swirl. Continue to add drop by drop (about 10 seconds between drops) and swirl until the yellow color goes away. Record the number of drops (1 drop = 0.5 mg O_2/liter).
11. Rinse bottles and dropper with tap water and dry.

5) **Nutrients:** (Make sure all bottles are labelled with station I.D., date & depth).

a) Take 1 liter sample bottle with sample.
b) Place filter in clear plastic filter holder, align steps in top and bottom of holder and screw on clamp to hold together.
c) Shake 1 liter bottle and fill 60cc syringe with water from bottle by removing plunger and pouring in, replace plunger.
d) Attach filter to syringe and discard first approx. 30 cc of water.
e) Push next 30cc of water into the small sample bottle provided, replace cap, shake and discard water.
f) Now refill syringe and collect all water in the now rinsed bottle until bottle is full to shoulder, cap and put on ice.
g) Cap 1 liter bottle, check label and put on ice.

6) **Physical Measurements** - Light, color & depth:

1. Lower Secchi disk into water slowly from shady side of boat until it just disappears from view. Raise and lower slightly to insure the proper depth. Read depth on tape and record.
2. Bring up to half of the disappearance depth and compare color of disk to color wheel, if available, and record.
3. Lower disk slowly until it touches bottom, record depth.

Note: sometimes the disk will hit the bottom before it disappears—record as "bottom" and the depth from the tape.

Note any unique or unusual characteristics of station — presence of algae, smell or anything that may appear unique.

On return to shore, keep samples cold and in the dark (on ice or in refrigerator, NOT freezer).

SAMPLING PROTOCOL FOR POND STUDY
GREEN AND LITTLE PONDS

General:

The goals of the sampling program are to:
1) collect water column samples without disturbing the bottom sediments which will give artificially high nutrient and particle values;
2) process oxygen samples as quickly as possible and with the minimum chance of introducing atmospheric oxygen into the sample before the reagents are added.

The order of sampling is:

1) Collect surface samples
   a) process for oxygen,
   b) temperature
   c) nutrients

2) Collect deeper samples
   a) oxygen
   b) temperature
   c) nutrients

3) Physical measurements
   a) Secchi depth
   b) color
   c) total depth

Procedures:

Note: For simplicity we have decided to use the sampling equipment for both surface and deep water collection. If you like, you can fill the surface 1 liter nutrient bottle by hand.

1) Put stopper in pre-labelled (with date, pond, station & depth) 1 liter nutrient bottle and in the 0.5 liter oxygen bottle. Make sure the side tube on the 0.5 liter bottle is placed upwards.

2) Lower the bottle to the appropriate depth 0.1 meter, 1 meter, 1.5 meter, etc. depending upon your station (on map).

REPEAT FOR EACH DEPTH SAMPLE

3) a) Pull oxygen bottle stopper (0.5 liter),
   b) then pull nutrient bottle stopper (1 liter).

4) Keeping the pole vertical, bring the samples on deck. Remember to support the bottles as they will be heavier out of water.
   a) Remove nutrient bottle, put in thermometer, record temperature, cap and set aside.
   b) **OXYGEN:** Lower tube from oxygen bottle on pole to the bottom of the glass bottle from the blue oxygen kit. Drain about 3/4 of the 0.5 liter bottle through the glass bottle, overflowing the glass bottle. Tap glass bottle if bubbles stick to sides.
   c) As volume reaches 3/4 of the 0.5 liter bottle, slowly remove the side tubing from the glass bottle and carefully insert the glass stopper (drop) so as not to trap any bubbles. (Do not pour off excess water).

d) 1. Using the clippers in the blue oxygen kit open Reagent pillow 1;
2. remove glass stopper from glass O_2 bottle;
3. pour Reagent 1 into bottle;
4. open Reagent pillow 2 and add to bottle.
5. Replace glass stopper, careful not to trap bubbles.
6. Shake bottle vigorously holding bottle and stopper (some reagent may stick to bottom of bottle...this is O.K.).
7. Let stand 2 minutes, shake again.
8. After a total of 5 minutes, open Reagent pillow 3, remove glass stopper, add powder to bottle, replace stopper, shake vigorously until water in bottle becomes clear (no particles).
9. Remove glass stopper and fill small plastic tube to top TWICE (two volumes) pouring each time into the square glass bottle in the kit.
10. You are now ready to determine the oxygen content. Take the eyedropper and fill with solution in the brown plastic bottle in kit (do not get on hands). Now the tricky part: add 1 drop to the square bottle and swirl. Continue to add drop by drop (about 10 seconds between drops) and swirl until the yellow color goes away. Record the number of drops (1 drop = 0.5 mg O_2/liter).
11. Rinse bottles and dropper with tap water and dry.

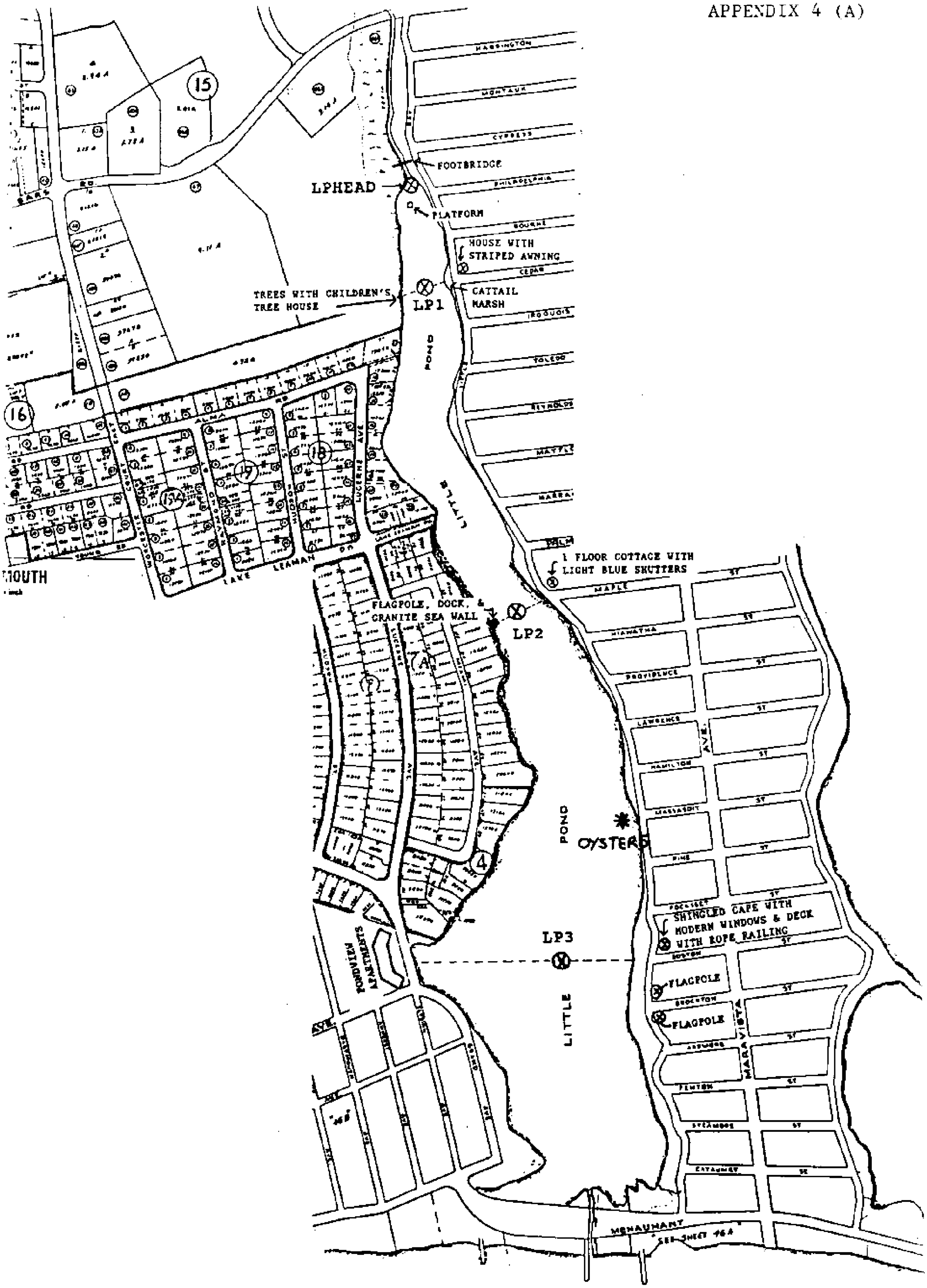
5) **Nutrients:** (Make sure all bottles are labelled with station I.D., date & depth).
a) Remove bottle from pole.
b) Place filter in clear plastic filter holder, align steps in top and bottom of holder and screw on clamp to hold together.
c) Shake 1 liter bottle and fill 60cc syringe with water from bottle by removing plunger and pouring in, replace plunger.
d) Attach filter to syringe and discard first approx. 30 cc of water.
e) Push next 30cc of water into the small sample bottle provided, replace cap, shake and discard water.
f) Now refill syringe and collect all water in the now rinsed bottle until bottle is full to shoulder, cap and put on ice.
g) Cap 1 liter bottle, check label and put on ice.

6) **Physical Measurements** - Light, color & depth:
1. Lower Secchi disk into water slowly from shady side of boat until it just disappears from view. Raise and lower slightly to insure the proper depth. Read depth on tape and record.
2. Bring up to half of the disappearance depth and compare color of disk to color wheel, if available, and record.
3. Lower disk slowly until it touches bottom, record depth.

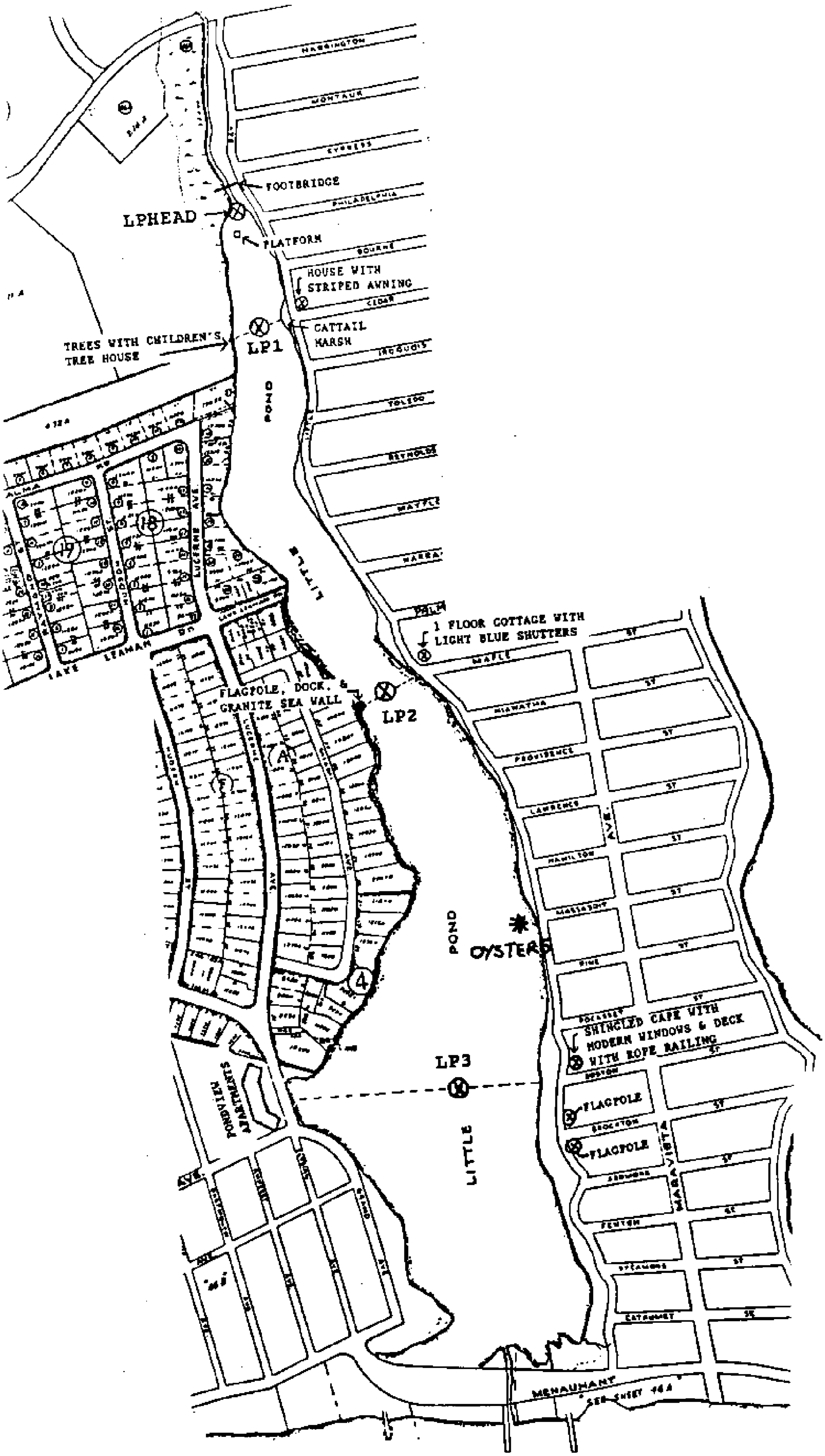
Note: sometimes the disk will hit the bottom before it disappears--record as "bottom" and the depth from the tape.

Note any unique or unusual characteristics of station -- presence of algae, smell or anything that may appear unique.

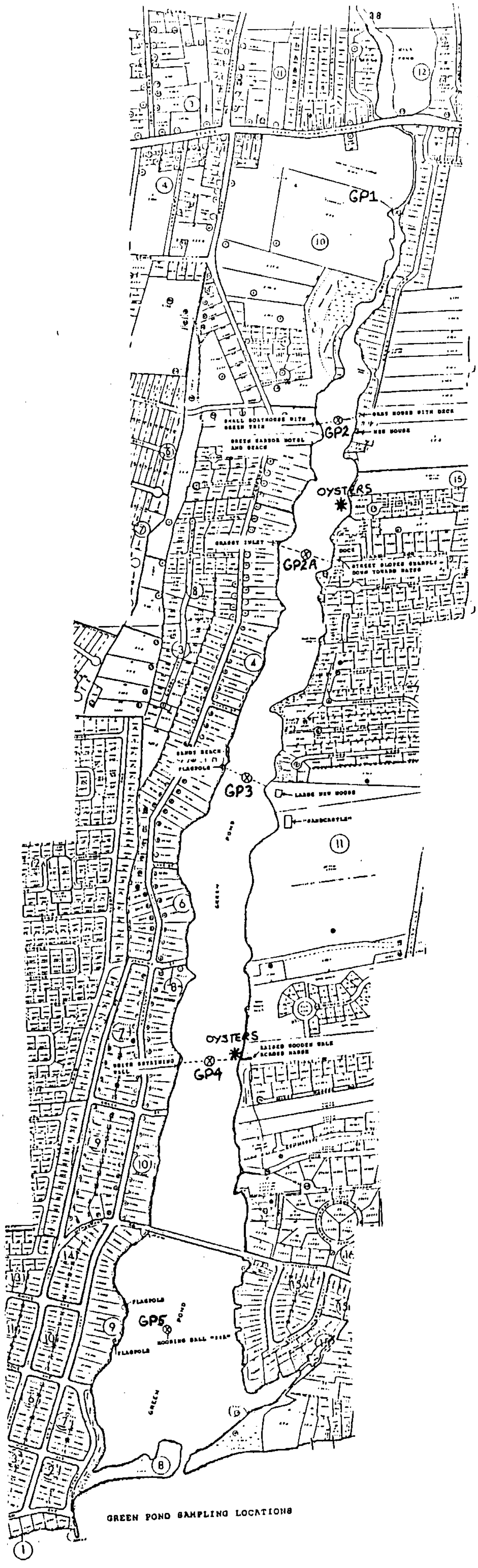
On return to shore, keep samples cold and in the dark (on ice or in refrigerator, NOT freezer).



LITTLE POND SAMPLING LOCATIONS



LITTLE POND SAMPLING LOCATIONS



GREEN POND SAMPLING LOCATIONS

Sampling Depths

Oyster Pond	
OPHead	Surface
OP1	Surface, 2 and 4 meters
OP2	Surface, 2 and 3.25 meters
OP3	Surface, 2, 4, and 6 meters
Little Pond	
LPHead	Surface
LP1	Surface and 1 meter
LP2	Surface and 1 meter
LP3	Surface and 1 meter
Green Pond	
GP1	Surface
GP2	Surface and 1 meter
GP2A	Surface and 1 meter
GP3	Surface and 1 meter
GP4	Surface and 1 meter
GP5	Surface, 1, and 1.5 meter
Vineyard Sound	
VS1	Surface, 1 and 2 meters

CAPE COD TIMES, WEDNESDAY, AUGUST 10, 1988 PAGE 3

Volunteers study Green Pond pollution

By RENEE TWOMBLY
STAFF WRITER

FALMOUTH — Armand Ortins has watched the deterioration of Green Pond from his home windows for the last two decades. Slowly, green algae took the place of a once-thriving scallop and blue-crab population.

But now Ortins thinks he can do something about it. Every month he and about 50 volunteer "pond watchers" take to the waters of Green, Little and Oyster ponds in small boats to take the pulse of the ponds. They pull out tackle boxes full of scientific equipment and spend hours measuring temperature, salinity, oxygen and nutrient levels, water clarity and other readings.

The first pond sampling was in mid-July, and the second will be Sunday morning. Results won't be tabulated until there is six months worth of data.

"I'm enjoying it," said Ortins, a "pond captain." "I wish it was done 20 years ago. But it's encouraging that the public is more aware of these problems, and that there is a desire to do something about it."

Little Pond already exceeds state limits on such nutrients as nitrogen and phosphorus and Oyster Pond is so overrun with vegetation that it is virtually blocked from the sea. Green Pond had a major fish kill in 1984, a sign it also is losing its oxygen as blooms of algae, growing on runoff lawn fertilizer and septic tank nitrogen, die and decompose.

To help keep a scientific eye on these "stressed" ponds, the Woods Hole Oceanographic Institution's Sea Grant Program in May came up with the idea of using resident volunteers to do much of the observational legwork.

And residents have shown an enormous interest in the monitoring project, said Allan White, coordinator of the program at WHOI.

White believes this novel approach of collecting water-quality data could be easily used across the Cape. "There are environmental problems galore on Cape Cod," he said yesterday. "And there are not enough state and federal mechanisms to deal with it. This has taken off with a great deal of success and it would be extremely valuable if used on a widespread basis," he said.

Ortins agrees. A former 15-year member of the Falmouth Conservation Commission who spent several years as chairman, he said it was often a losing proposition to try to instill environmental awareness in residents.

"People would be sympathetic, but they generally didn't understand things until after it happened." But now, he said, "the most encouraging thing about conservation today is the awareness."

Other pond captains are Edmond Wessling, Jack Shohayda, John Dowling, and Julie Rankin.

White said he is surprised not only at the size of the volunteer force but by its composition. Some are retired and some live on the ponds, but others come from all parts of town "because they are just plain interested in the water quality of the Cape," he said.

The pond monitoring program started on the floor of the 1987 town meeting when an $60,000 article to study the ponds was defeated because of a tight budget. But David Ross, a WHOI scientist in charge of the Sea Grant program, offered to help raise government money to study the ponds.

Since then, Sea Grant has been awarded $34,000 to start the research, and the town has contributed $9,000 to the work.

White said a similar pond-watching project started in south coastal Rhode Island three years ago has "drummed up so much interest that the data is being used for regulatory purposes by the state. The citizens are happy to be doing the work and it is extremely successful."

The Enterprise
Falmouth, Mass., Monday, August 15, 1988

Sample From Oyster Pond Resembles Pink Lemonade

by Paul D. Ott

A water sample taken from a depth of three meters in brackish Oyster Pond, Quissett, looks like pink lemonade, but you would not want to drink it.

"I was shocked by how foul the water was. I had no idea that six and twelve feet down it was so lousy," said John E. Dowling, a neurobiologist from Harvard University and trustee with the Marine Biological Laboratory in Woods Hole.

The neurobiologist said he does not know what gives the water its pinkish tinge.

Dr. Dowling is one of two pond captains for a group of 10 persons who volunteered to help with the monthly collection of water samples from Oyster Pond.

More than 50 Falmouth residents have volunteered as pond watchers for Oyster, Little and Green ponds. As pond watchers, they will take water samples from the ponds this summer and next.

The Woods Hole Oceanographic Institution Sea Grant Office and the Falmouth planning office support the project and hope to use the documented findings for planning of pond areas and to better interpret the town's coastal pond nutrient guidelines approved in April.

"Dr. Kerfoot is responsible for getting a group of us together from those of us who are concerned about these coastal ponds and the enormous amounts of nutrient loading into them," Dr. Dowling said at his summer home on Ransom Road, Quissett. William B. Kerfoot is president of K-V Associates Inc., an environmental engineering firm.

With empty, clear-plastic bottles, soon to be filled with pond water, spread out on his dining room table, Dr. Dowling sat in a chair early yesterday morning and labeled the bottles while talking about the pond.

No More White Perch

He became concerned with Oyster Pond last summer when its seemingly endless stock of white perch went dry.

"Five years ago they were incredibly plentiful in this part. They practically jumped into the boat," he said.

Dr. Dowling uses white perch for his neurobiological research at Harvard University and during the summer at the MBL.

"The perch began to disappear last summer, and I

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From Page One

'Pond Watchers' Will Continue Monitoring Water In Falmouth Ponds Next Summer

Continued

caught one perch in the pond this summer," he said.

Dr. Dowling and Julie S. Rankin, the other Oyster Pond captain for the project, spent two hours of their morning yesterday on his rowboat calculating data from water samples they took from two of the deeper areas in the southern region of the pond.

Another pair of pond watchers spent their morning at two areas in the northern region of the pond, where they measured the depth, temperature, salinity, oxygen content and collected water samples for analysis of nutrient content.

Other watchers were doing the same at Green and Little ponds.

"Everybody is going out today because we want to do it at all three ponds at about the same time and on the same day," said Mrs. Rankin, a biologist and MBL tour guide.

She conducted three tests yesterday morning on samples from Oyster Pond and found the oxygen levels beyond 3.25 meters to be at zero.

The findings corroborated the samplings taken last month.

Oxygen Level Dropped

"In some locations, virtually at two meters, the oxygen had dropped to almost nothing," Dr. Dowling said of the July samples.

The pond watchers anchored their boats at locations designated by certain landmarks. For instance, one spot where Dr. Dowling moored was directly between a flagpole on the eastern edge of the pond and a white stucco home on the western side of the pond.

To collect the samples, the pond watchers used a Niskin sampler, a long grayish-colored tube connected to weight and a line marked off by meters.

Once the sampler was lowered to the desired depth, the lower and upper hatch of the tube could be closed to trap a water sample from that depth.

After samples had been taken from the surface during the first stop in the pond at 9:30 A.M. yesterday, Dr. Dowling let the Niskin sampler drop two meters below the surface before trapping water for a sample from that depth.

"It's pretty clear at the surface; see how much that changes as we go down," he said.

Pulling the sampler aboard, he then released the water from a tube on the sampler into two plastic specimen containers. The oxygen levels at two meters were at 1.5 milligrams per liter, and the temperature of the water was 81 degrees Farenheit.

A sample at the same spot from five meters found the temperature of the water to be 67 degrees Farenheit and the oxygen levels nonexistent.

Mrs. Rankin took a whiff of the water from the specimen bottle and wrinkled her nose. "That's pretty rotten eggy," she said.

Even after the bottle had been sealed and enclosed in a cooler to prevent the breakdown of the nutrients, the odor remained on the boat for several minutes.

"You can really smell the hydrogen sulfide," Dr. Dowling said.

The pinkish color of the water from five meters also was noticeably different from that of the surface.

Other than the occasional smell brought up from the nether region of Oyster Pond by the Niskin sampler, the two hours of testing water samples aboard the boat seemed a pleasant way to spend a Sunday morning.

"This is a nice job when it's nice out here, but boy, is it a stinking job when it's lousy!" Mrs. Rankin said.

There were no complaints yesterday as an occasional breeze from the southwest drifted across the pond. The only disturbance came from an angry Canada goose whose territorial rights were lost momentarily when the pond watchers stopped to test the water.

"Okay, Canadian Goose, we're not invading your territory. We're just trying to find out what you've put in the water," Mrs. Rankin said.

Still squawking, the perturbed goose finally gave up and later flew away from the pond.

Besides getting wet occasionally, the job of a pond watcher can have one more minor disadvantage.

John E. Dowling, a neurobiologist from Harvard University, holds a sample of water from Oyster Pond that will be analyzed for its nutrient content by the Woods Hole Oceanographic Institution. (Photo by Paul Ott)

"Your clothes wind up with small holes in them from some of the reagents you spill," said Mrs. Rankin, referring to the solution used to test the oxygen level of water samples.

Both Mrs. Rankin and Dr. Dowling used care in their handling of materials and samples on the boat.

"We're very careful with all the waste we use on the dissolved oxygen, so we're not putting any contaminants in the water," Mrs. Rankin said. The utensils used for the samplings were also rinsed with distilled water brought along for the testing.

Dr. Dowling said he thinks the WHOI program is a terrific one. "It's getting people around town alert to the problems we are facing."

All the equipment and supplies used by the pond watchers are supplied by WHOI, which is also conducting the nutrient analysis of the water samples.

Alan W. White, marine science adviser with the WHOI Sea Grant Program and coordinator of the pond project, drops the supplies off at pond captains' homes prior to the testing.

Training Sessions

WHOI also provided discussion and training sessions to each of the pond watchers before the sampling began last month, Dr. Dowling said.

"The people I've met who are not part of it are very interested," he added.

Paul E. Crocker, Fells Road, is one resident on Oyster Pond who became involved because of his concern for the pond.

"When the wind and temperature is just right you get an inversion and the sulfur comes up to the surface. That's when people think the pond is polluted with sewage," said Mr. Crocker, who noted that he is "about the only one on Oyster Pond without a doctorate."

Mr. Crocker, an architect, has lived in his home beside Oyster Pond for 40 years.

"I want to make sure it's not becoming polluted," said Mr. Crocker, who is one of the residents who volunteered to be a pond watcher for the project.

Besides the disappearance of white perch from the pond, Mr. Crocker said he has noticed that the sea grass and weeds in the pond have become much thicker.

"It's very hard to fish in some of these areas now because your hook always catches in these weeds," he said.

Mr. Crocker said he uses an organic chemical-free fertilizer on his lawn, although the organic product is more expensive and cannot be bought locally.

Dr. Dowling cited the use of nutrient-laden fertilizers on lawns beside the pond as one of the possible reasons for the disappearance of the white perch.

The nonexistent oxygen levels beyond three meters in parts of the pond indicate that nothing is living at that depth, Dr. Dowling said.

"With more building, it's going to be putting an enormous nutrient load into the pond," he added.

"Falmouth is one of the first communities in the country to look at its ponds," Dr. Dowling said. "I hope when we come up with concrete recommendations that the town will take them to heart."

A pre-construction conference on the state's plans to repair the two bridges over Route 151 on Route 28 in North Falmouth will be held at 10 A.M. tomorrow in the state Department of Public Works district seven headquarters in Middleboro.

District Seven engineer Robert A. Smith announced the conference in a recent letter to selectmen. He did not say when work will start on the bridges in the north and southbound lanes of Route 28, but the state does not do any major highway work in this area in the summer, so the earliest start of the project could be expected to be next month.

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Falmouth's Pond Watchers Are Troubled By The Evidence That Pollution Is Widespread

By ANGELA FRATER

For the past two years the Falmouth Pond Watchers have monitored the water quality of Falmouth's Little, Oyster and Green Ponds with an unflagging dedication.

Sixty strong, these volunteers are a diverse group. Businessmen, architects, traffic controllers, biologists — some retired — have joined together as part of a project of the Woods Hole Oceanographic Institution Sea Grant Program. As a group they are providing more clout in solving the problem of the deteriorating ponds than they could provide as individuals.

Some of the volunteers observe the ponds year round, watching for unusual events such as fish kills, algae blooms or bad odors. Others, like Armand Ortins, Edmund Wessling and Jack Shohayda, go out on the ponds in their boats once a month to make measurements and collect water samples.

All of the pond watchers are troubled by the evidence of pollution in the town's coastal ponds: the algae, murky water and few fish and shellfish.

Mr. Ortins remembers Green Pond thirty years ago. "The water was so clear then, my kids could sit on our dock and see all kinds of marine life," he said. "Today most of that is gone. I feel sorry for people who didn't see the Cape at that time. It was still pristine then."

And Mr. Wessling, a retired businessman who also monitors Green Pond, used to get oysters, clams, quahogs and scallops there. "We still get some clams and quahogs," he said, "but the sensitive shellfish like scallops are gone." He attributes this loss to all of the building the past years on both sides of the pond. "The cesspools and lawn fertilizers are leaching into the pond," he said. "Everybody wants to live near the water; and when salt water property wasn't available, they built on the fresh water ponds."

"Still Dumping Garbage"

Jane Carter, a former WHOI technician and pond watcher on Little Pond, would like the public to be more concerned about pollution. She has lived near the ocean for many years and does a great deal of shellfishing. She has noticed the amount of shellfish has declined at an alarming rate. "People are still dumping garbage in our waters," she said.

The pond captain for Little Pond, Jack Shohayda, is opposed to plans for additional buildings on that "already over-stressed" pond. "In past summers there's been lots of foul-smelling algae on the surface," he said. "When I moved here in 1958," he continued, "Little Pond was fresh water. It had pond lillies, ducks nesting, turtles and rainbow trout as long as your arm. There's still some marine life there. But will it continue?"

This seemingly new phenomenon had been forecast repeatedly in the past. Mr. Ortins, a former chairman of Falmouth's Conservation Committee 12 years ago said "We couldn't convince people that the water would become so polluted the fish would die. The water was so clean then. We made proposals at town meetings, but nobody understood what we were talking about."

(Angela Frater is a free-lance writer from Wisconsin and part-time resident of Falmouth. A pond watcher herself, she volunteered her time in September and October to the Woods Hole Oceanographic Institution Sea Grant Program while pursuing course work in creative writing at Harvard. The National Sea Grant College Program is part of the National Oceanic and Atmospheric Administration. It provides funding for scientific research, education and advisory projects that promote the wise use and understanding of our ocean and coastal resources for the public benefit. The Woods Hole Oceanographic Institution Sea Grant Program is one of a network of 30 Sea Grant programs at universities and research institutions throughout the coastal and Great Lake states.)

Robert S. Rogers, Hamlin Avenue, Falmouth, (standing) and Robert H. Leavens, Iroquois Street, East Falmouth, prepare to shove off for a sampling trip on Little Pond.

(Photograph by Marie Leavens)

Alan White, marine science advisor for the WHOI Sea Grant Program and its Pond Watcher project, summed up this indifference. "One of the insidious things about water pollution," he said, "is that it doesn't happen overnight. It happens little by little so people can't envision the impending disaster. Your eye gets used to the fact that the water is a little green this spring, then a little greener next spring. Greener and greener until finally you can't remember how clear it was twenty years ago."

The pond watchers' work is designed to provide concrete measurements of pollution in Falmouth's coastal ponds. And the information is submitted to the town's planning commission as an aid to correcting the problem.

To garner this information, these volunteers translate their concern into action one Sunday morning each month, from May through October. From several stations on each of the three ponds — seven on Green, four on Oyster, and four on Little Pond —they measure depth, temperature, salinity and oxygen content, taking samples on the surface and at designated depths. These samples — 33 in total — are then tested for nutrients at WHOI in the laboratory of Dr. Brian Howes.

Methodical And Precise

Sampling procedures, learned in a training session held by WHOI Sea Grant, are methodical and precise. Using a printed guideline with step-by-step instructions, the volunteers determine what reagents to add to water samples, how much and when. In one test, the number of drops of reagent needed to clear the water sample measures how much oxygen is dissolved in the water.

In addition to the May-October samplings, Dr. White and Dr. Howes go out twice during the winter, in January and March. "We feel it's unfair to have volunteers out there in crummy weather," White explained. "Yet it's important for the Falmouth Planning Board to have samplings year round."

The Pond Watchers is a co-operative project funded by the WHOI Sea Grant Program and the Town of Falmouth Planning Office. It got its start at town meeting in 1987. Because of the usual tight budget situation the town was unable to fund a $60,000 article for a water quality study of the ponds. However, Dr. David Ross, coordinator of the WHOI Sea Grant Program and at that time a town meeting member, pledged Sea Grant's assistance with a study. The town then approved $5,000 toward the effort.

Two Major Points

That is when Alan White became involved. According to him, there are two major points to this project: to present to the town, in an inexpensive way, documentation of the present water quality of the three ponds, and with this documentation, give the town an accurate basis of comparison for their future actions to manage the ponds.

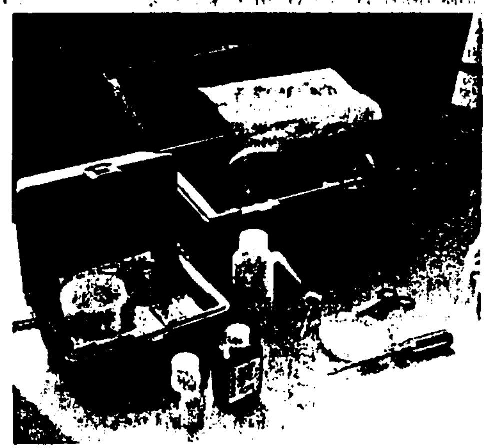
Pond Watchers is a two-year project, and funding for it terminates in June 1990. But Mr. White would like to continue it in a different form. "We don't want to see the project come to a standstill after all the enthusiasm that's been generated," he said. His goal is to shape the project into a bridge between citizens and local and state agencies, such as the state's Department of Environmental Protection. He would like this project to guide citizens in developing their own pond projects, plugged directly into local and state regulatory and policy mechanisms. "In Sea Grant, we're careful not to play an advocacy role," he said. "We present information and advice, but do not advocate. People have to make their own decisions."

Two years ago, when Mr. White canvassed the general public for pond watcher volunteers, he had 60 potential workers within three weeks. Despite this enthusiastic response, there was considerable reticence, especially among scientists, that laymen could work effectively as research assistants. That doubt was put to rest early. These volunteers have proven to be as capable as they are enthusiastic. Their professional backgrounds often involved more complex work then they use as pond watchers.

"They're willing to work beyond the call of duty," Mr. White said. "Their attitude has always been 'What else can we do?' It's magnificent working with people like that."

Armand Ortins of Ashumet Road, East Falmouth, (left) performs an oxygen test while Edmund C. Wessling, Bridge Street, East Falmouth, records the data.

(Photograph by John Porteus/WHOI)



"Pond Watchers" sampling kit for determining water quality.

(Photograph by John Porteus/WHOI)