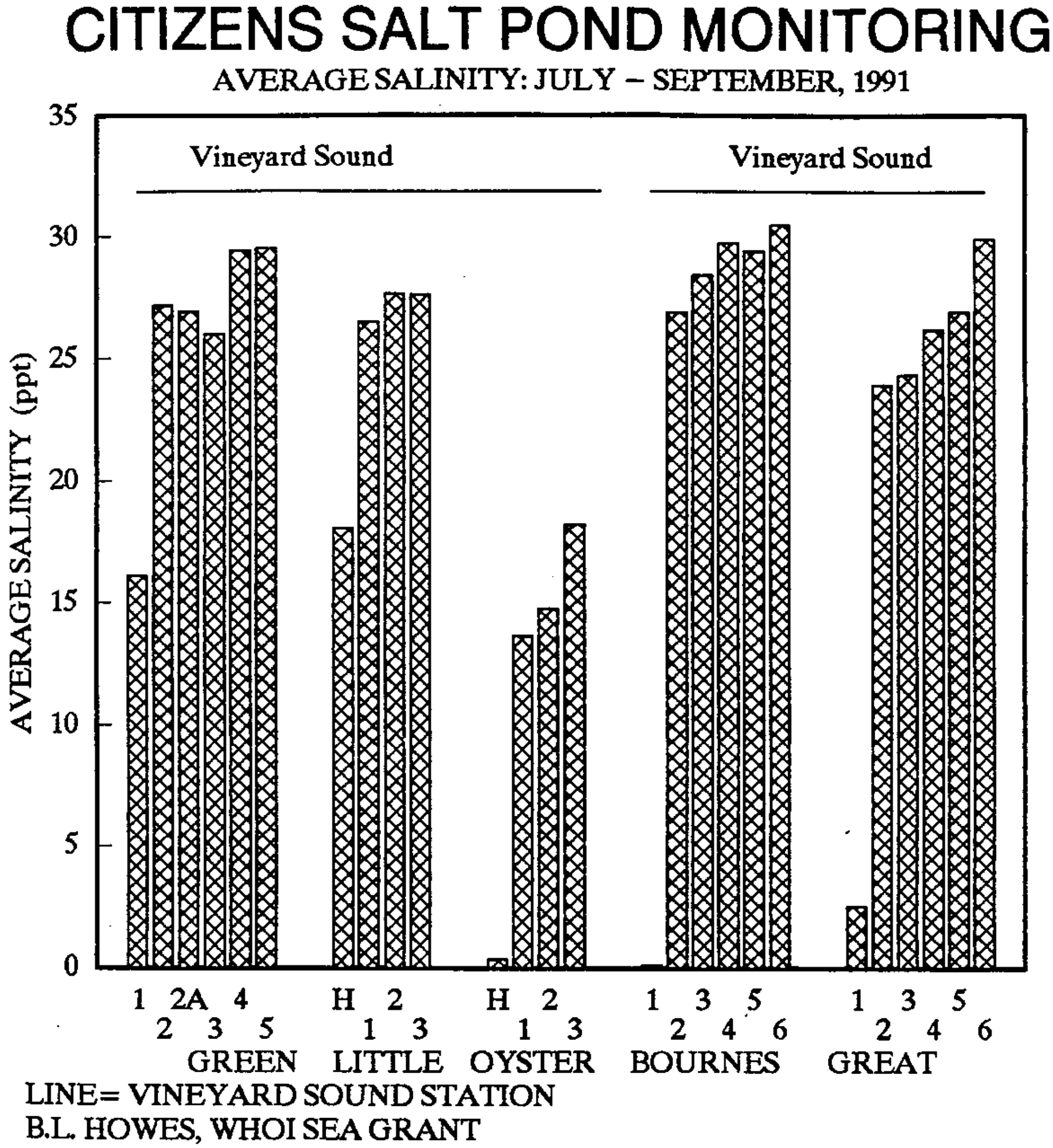
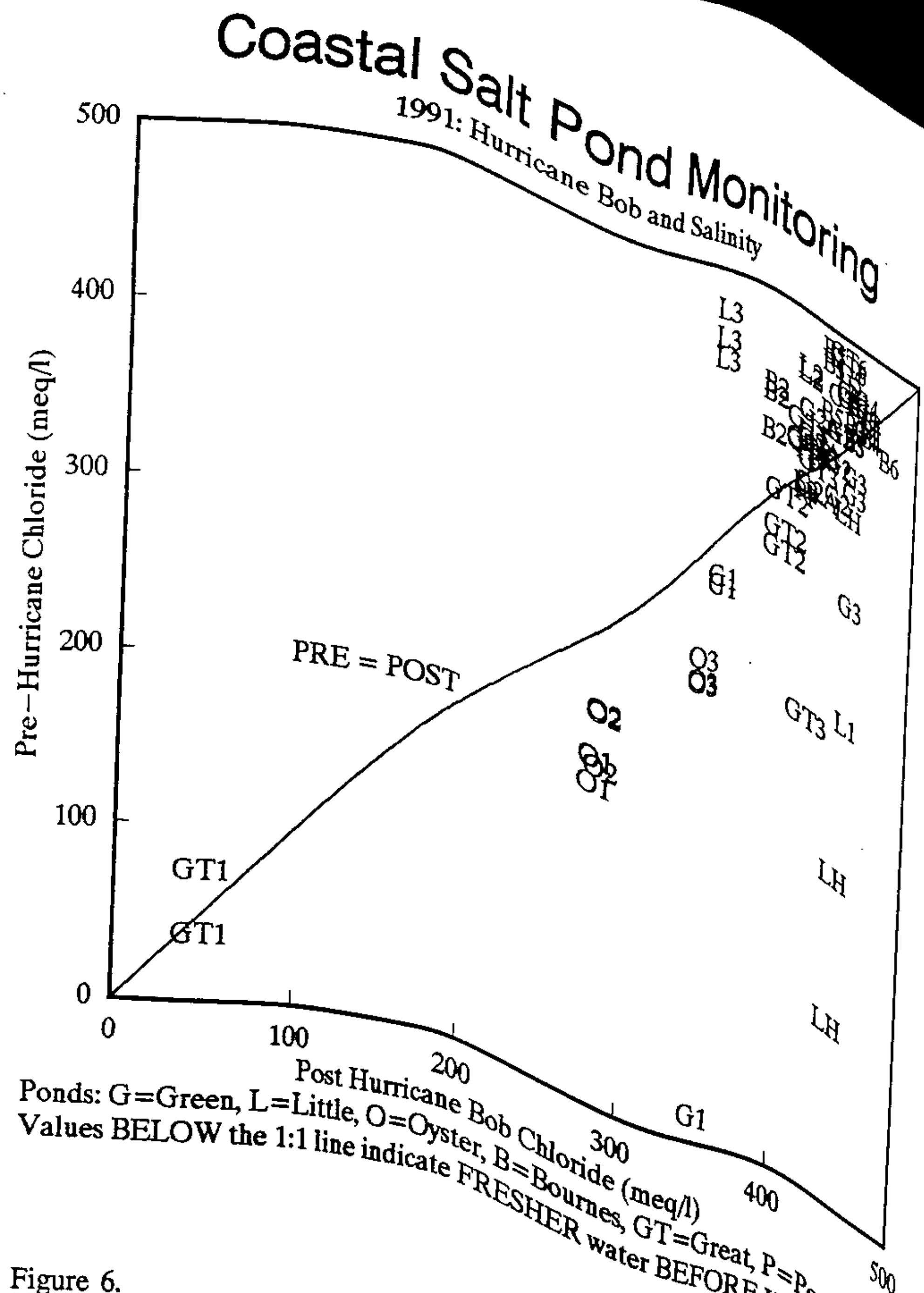

CITIZENS SALT POND MONITORING
AVERAGE SALINITY: JULY – SEPTEMBER, 1991
AVERAGE SALINITY (ppt)
0
5
10
15
20
25
30
35
Vineyard Sound
Vineyard Sound
1 2A 4
2 3 5
H 2
1 3
H 2
1 3
1 3 5
2 4 6
1 3 5
2 4 6
GREEN LITTLE OYSTER BOURNES GREAT
LINE= VINEYARD SOUND STATION
B.L. HOWES, WHOI SEA GRANT

Figure 5.

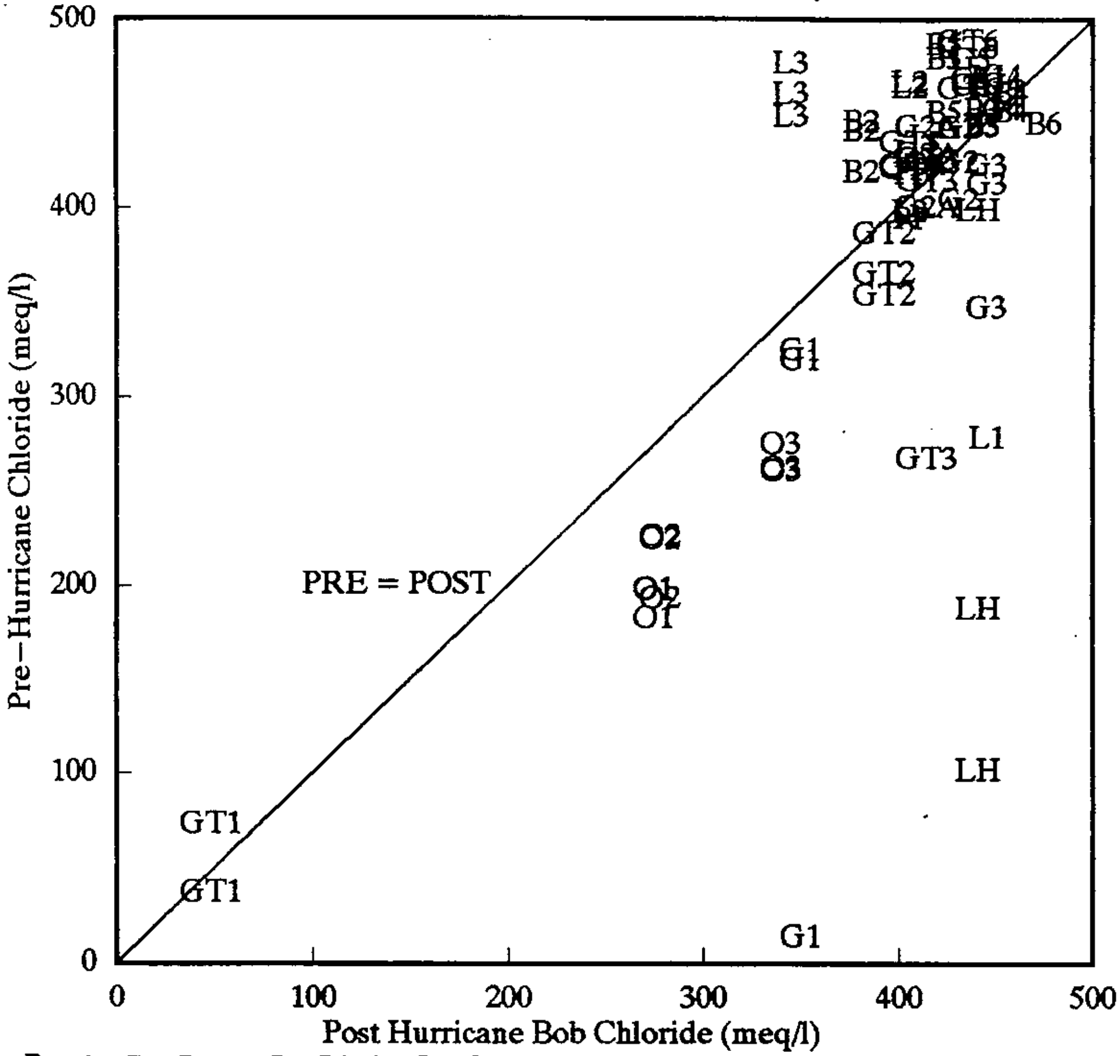


Ponds: G=Green, L=Little, O=Oyster, B=Bournes, GT=Great, P=Perch, VS=V
Values BELOW the 1:1 line indicate FRESHER water BEFORE Hurricane Bob.

Figure 6.

Coastal Salt Pond Monitoring

1991: Hurricane Bob and Salinity



Ponds: G=Green, L=Little, O=Oyster, B=Bournes, GT=Great, P=Perch, VS=V
Values BELOW the 1:1 line indicate FRESHER water BEFORE Hurricane Bob.

Figure 6.

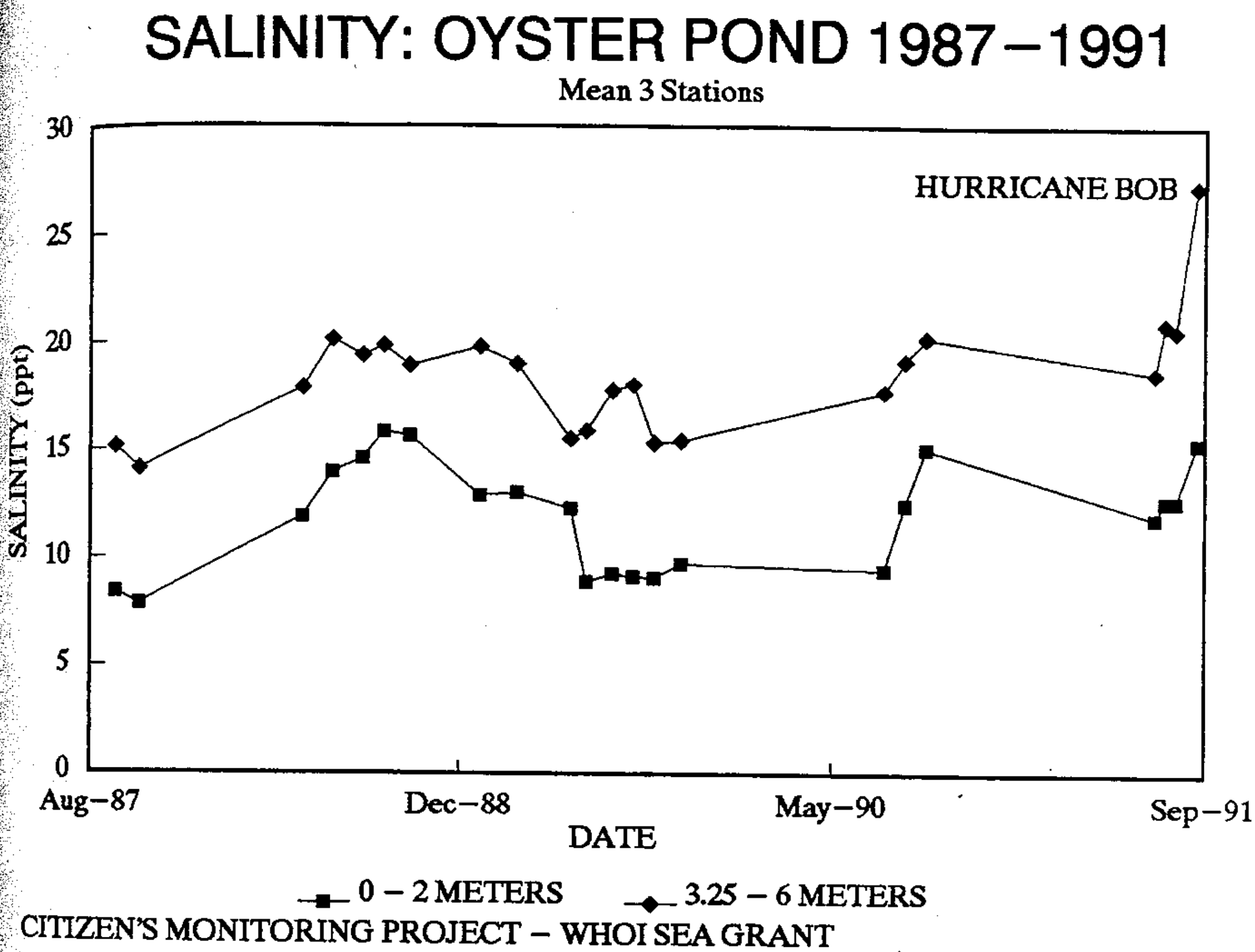

SALINITY: OYSTER POND 1987–1991
Mean 3 Stations
HURRICANE BOB
SALINITY (ppt)
30
25
20
15
10
5
0
Aug–87
Dec–88
May–90
Sep–91
DATE
0 – 2 METERS
3.25 – 6 METERS
CITIZEN'S MONITORING PROJECT – WHOI SEA GRANT

Figure 7.

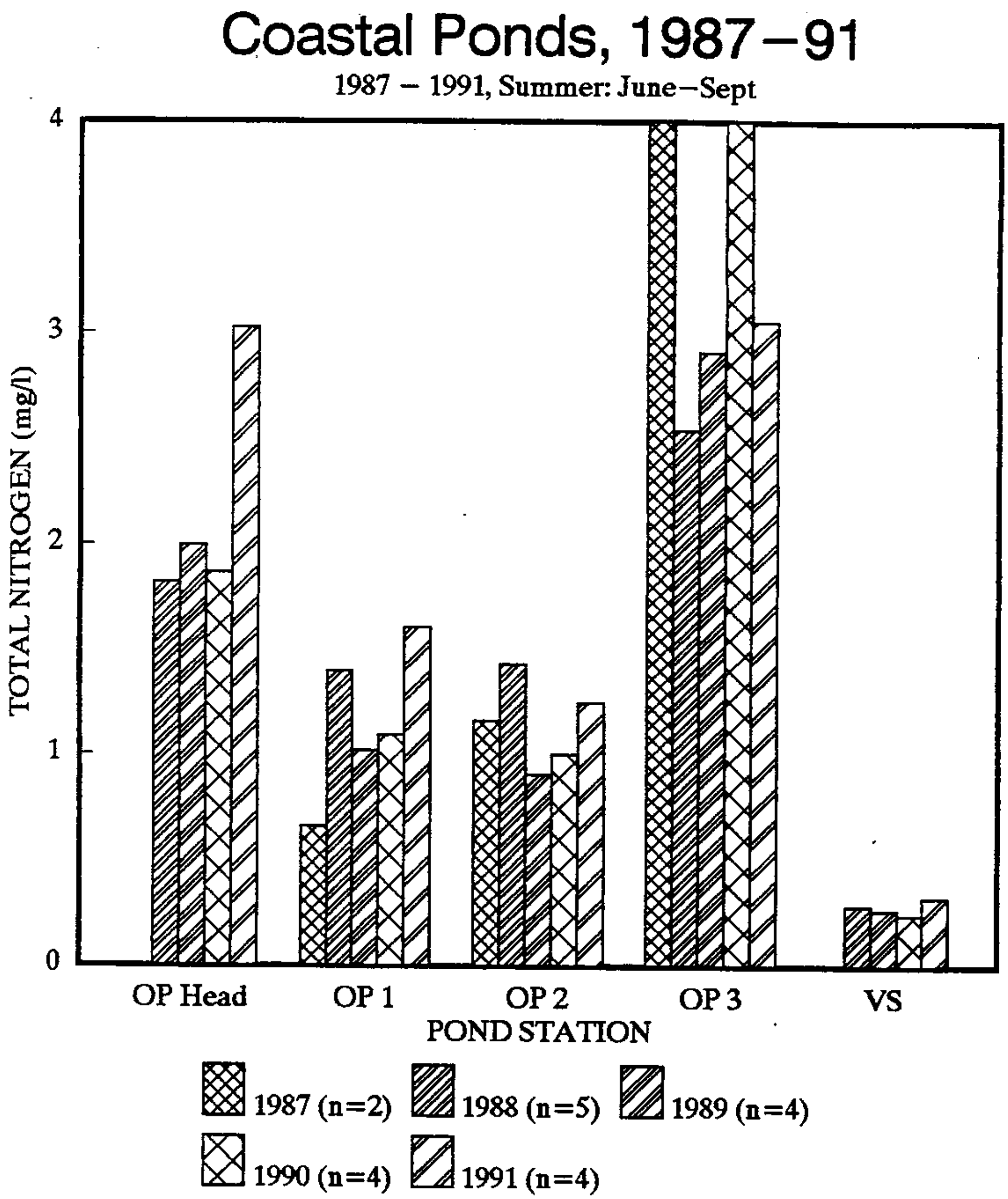
exhibited a more than 5 ppt increase with no significant increse in the surface waters, as was expected from their lower density. The pulse of high salinity/density water from Vineyard Sound moved into the pond, moving along the bottom into the deeper basins. This is consistent with an observed reduction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

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

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

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

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



Oyster Pond Station Weighted Means
VS = Vineyard Sound Reference Station

Figure 8.

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

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

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

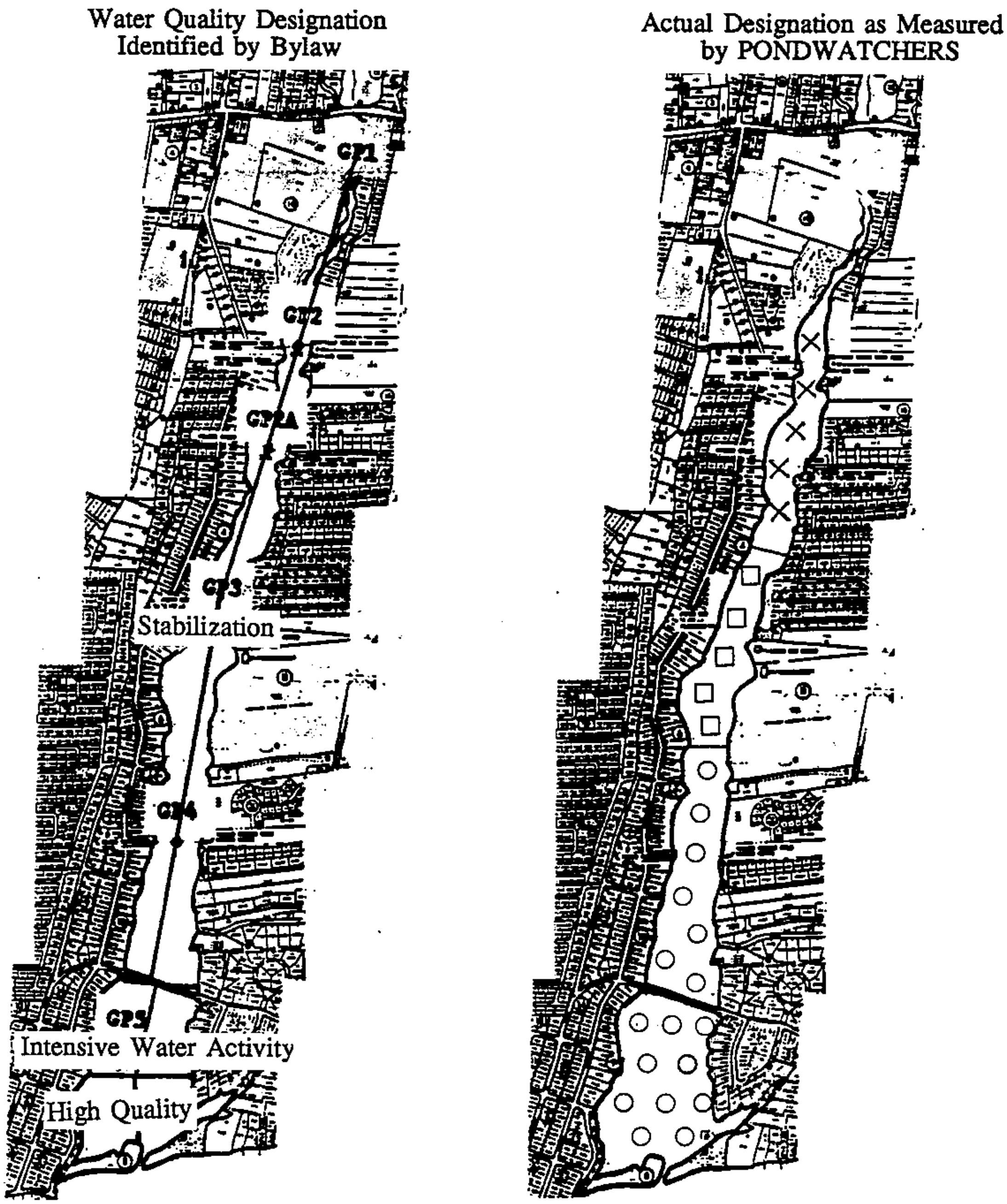
Bournes Pond, the recipient of extensive circulation alteration in the mid 1980's, had marginally better water quality than Green and Great Ponds. However, the upper reaches as in the other ponds have high nutrient levels and experience periodic low oxygen conditions. Unfortunately, it is not possible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

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

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

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

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



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

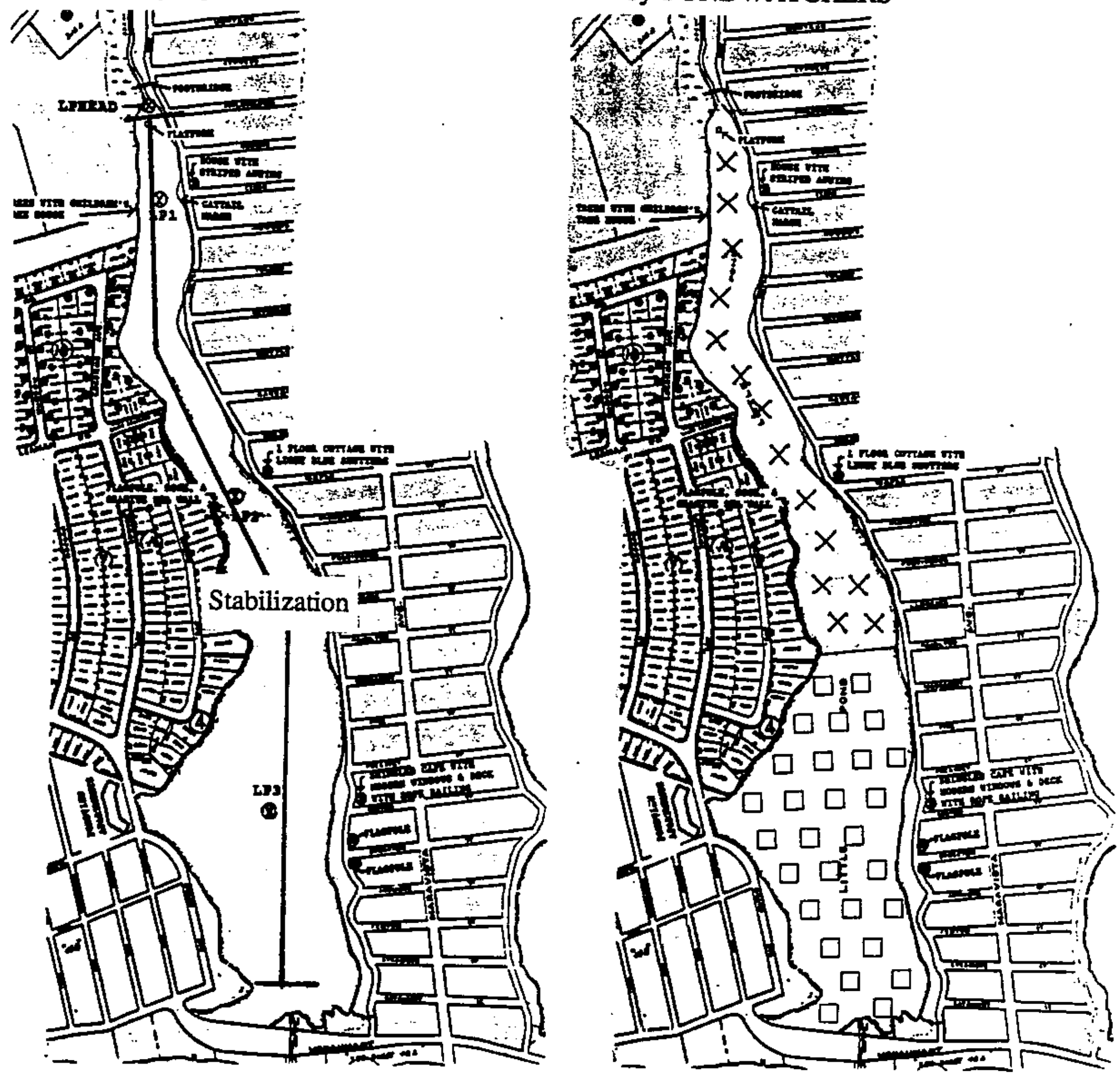
> 0.75 mg/l	= Above Highest "Critical Eutrophic Levels"	×
0.5 - 0.75 mg/l	= Intensive Water Activity Area	□
0.32 - 0.5 mg/l	= Stabilization Area	○
< 0.32 mg/l	= High Quality Area	

Figure 13.

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

Water Quality Designation Identified by Bylaw

Actual Designation as Measured by PONDWATCHERS



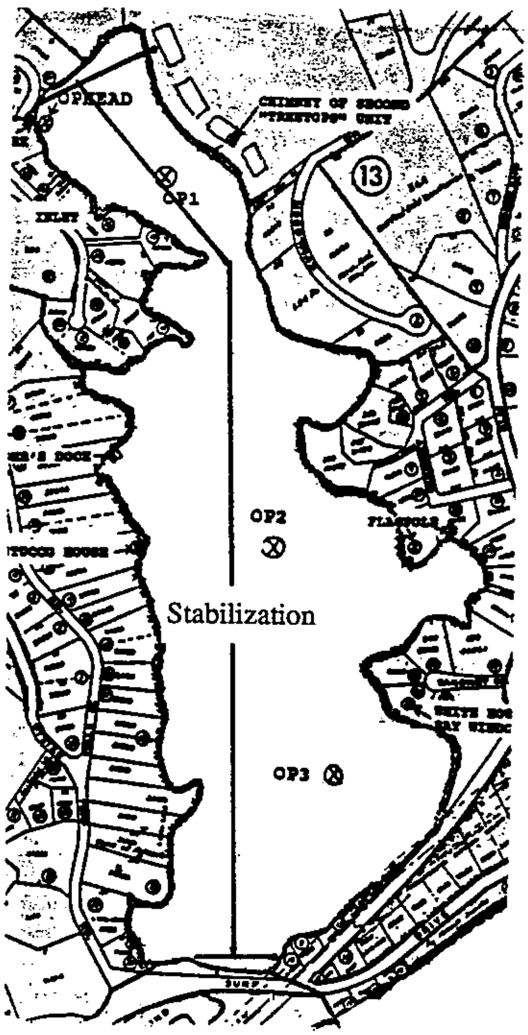
"Critical Eutrophic Levels" as designated by Coastal Pond Overlay Bylaw (Total Nitrogen as Average Over Year)

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

Figure 14.

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

Water Quality Designation
Identified by Bylaw



Actual Designation as Measured
by PONDWATCHERS

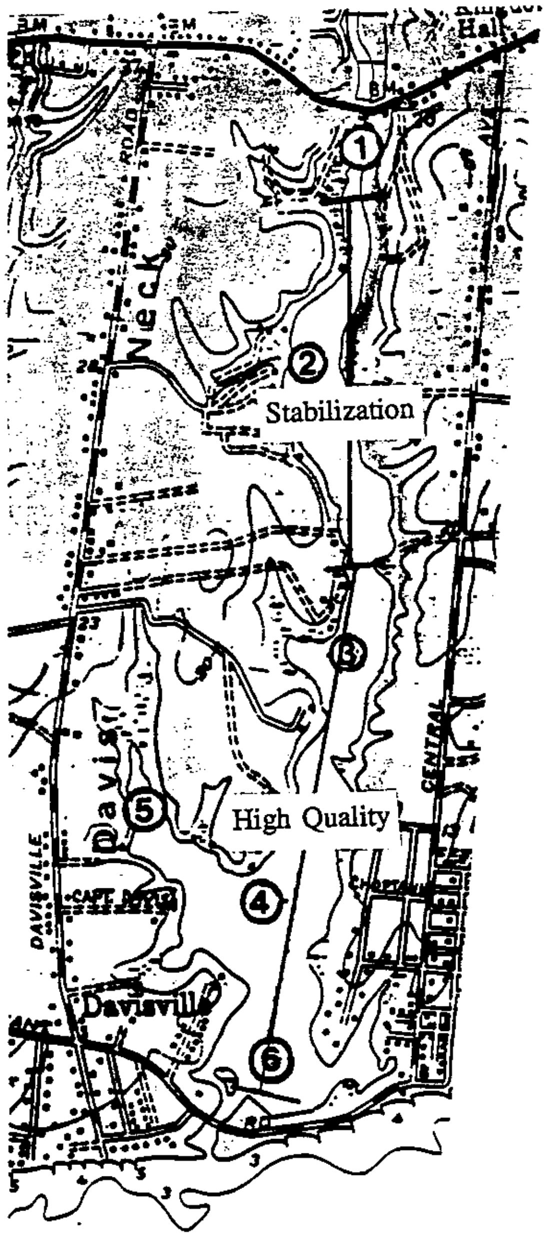
"Critical Eutrophic Levels" as designated by Coastal Pond Overlay Bylaw
(Total Nitrogen as Average Over Year)

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

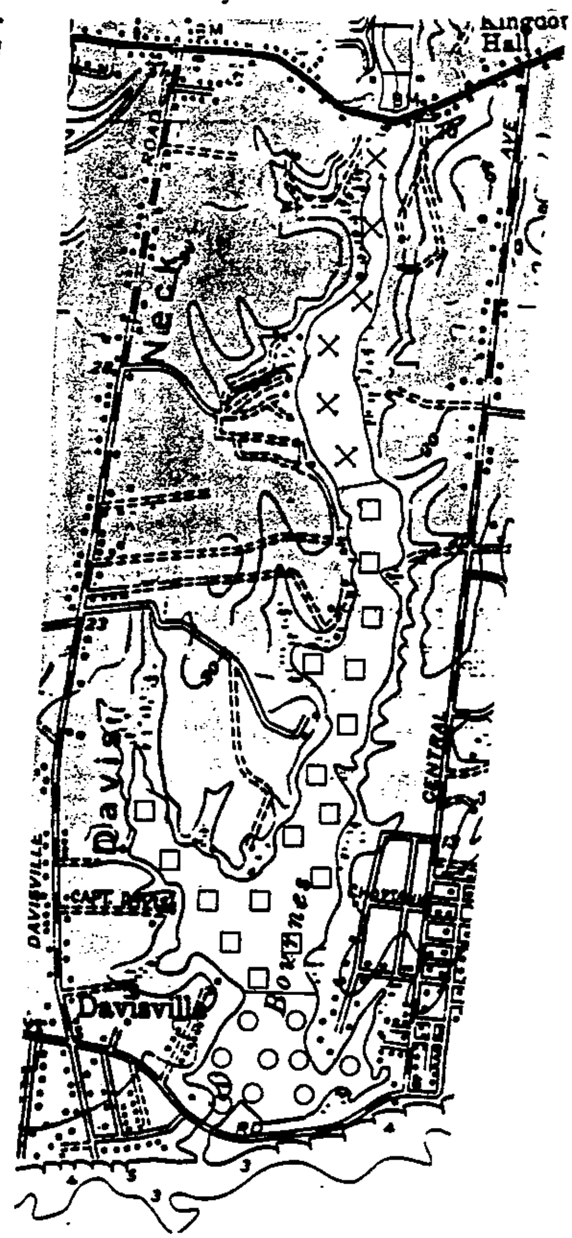
Figure 15.

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

Water Quality Designation
Identified by Bylaw



Actual Designation as Measured
by PONDWATCHERS



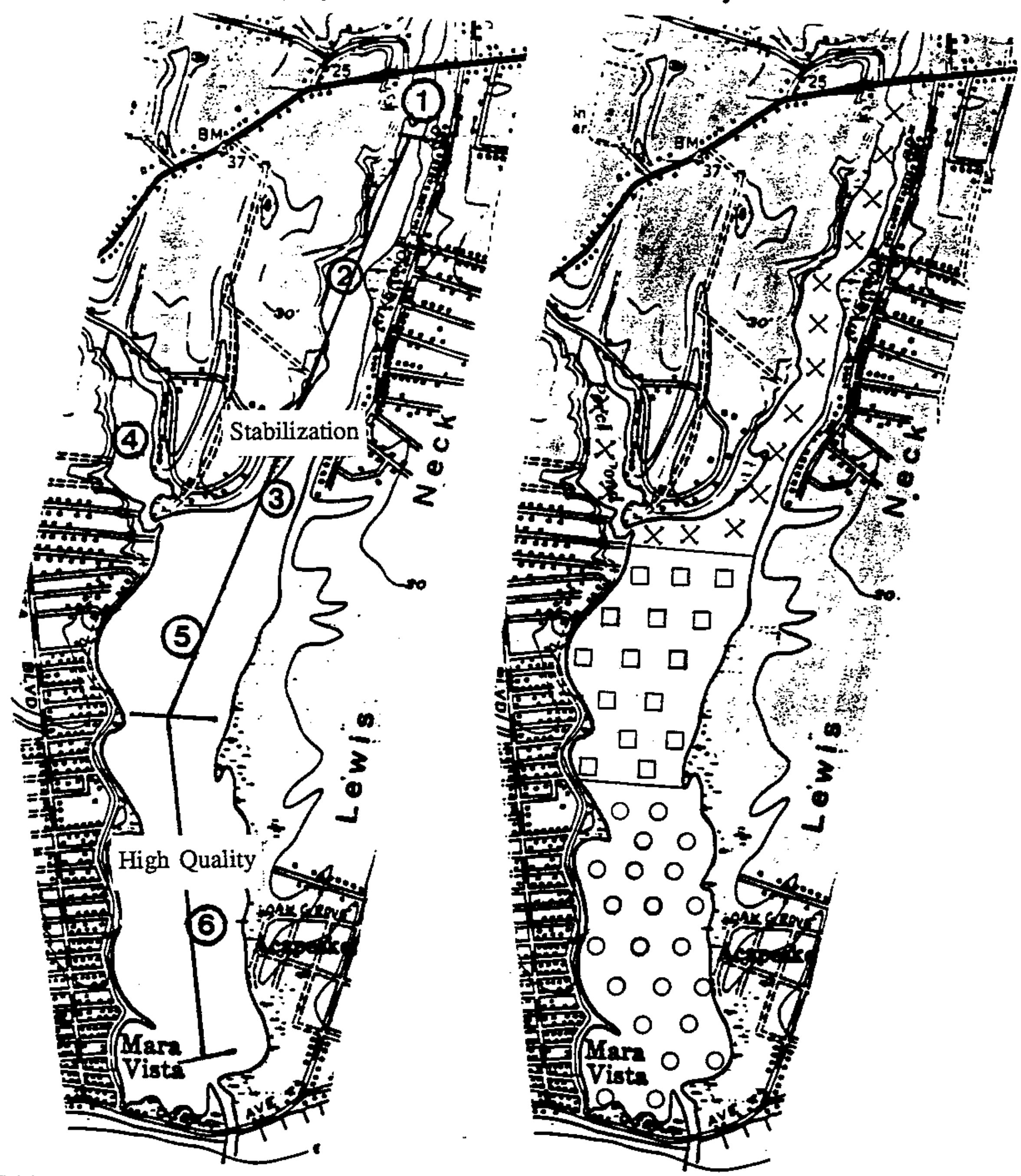
"Critical Eutrophic Levels" as designated by Coastal Pond Overlay Bylaw
(Total Nitrogen as Average Over Year)

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

Figure 16.

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

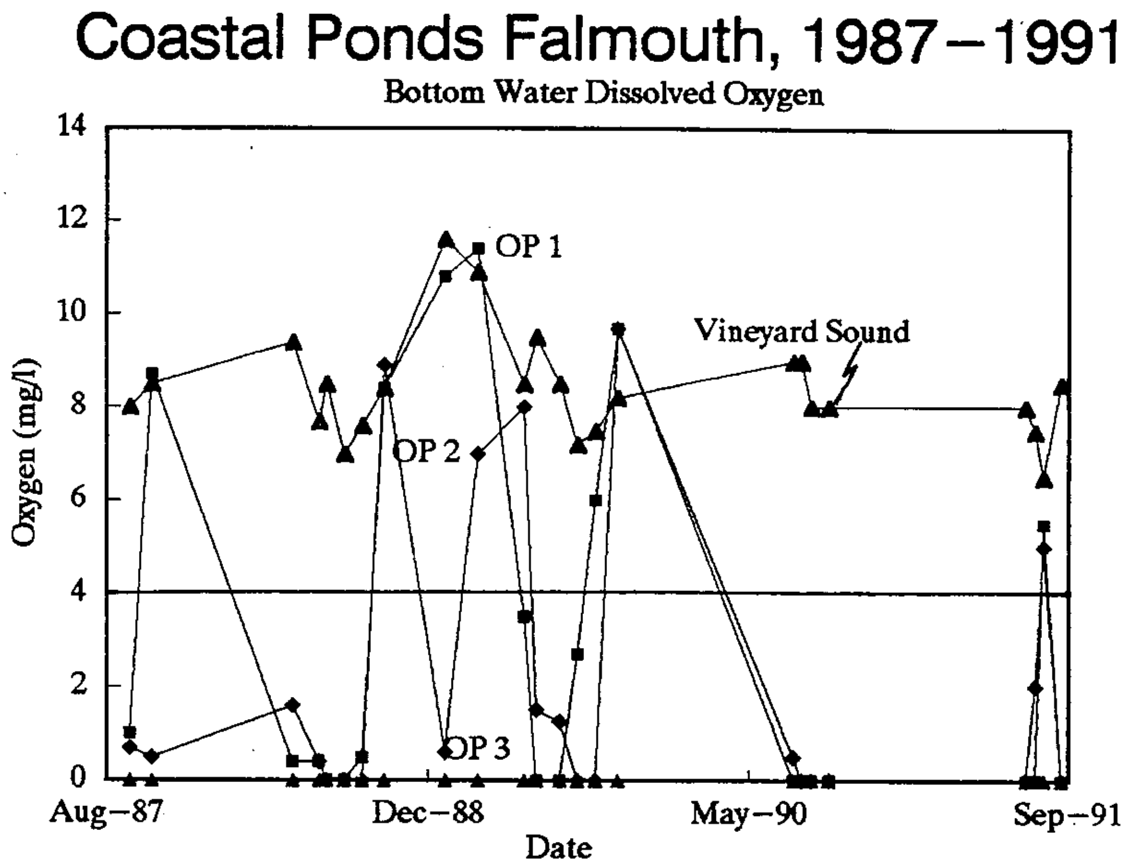
Water Quality Designation Identified by Bylaw | Actual Designation as Measured by PONDWATCHERS

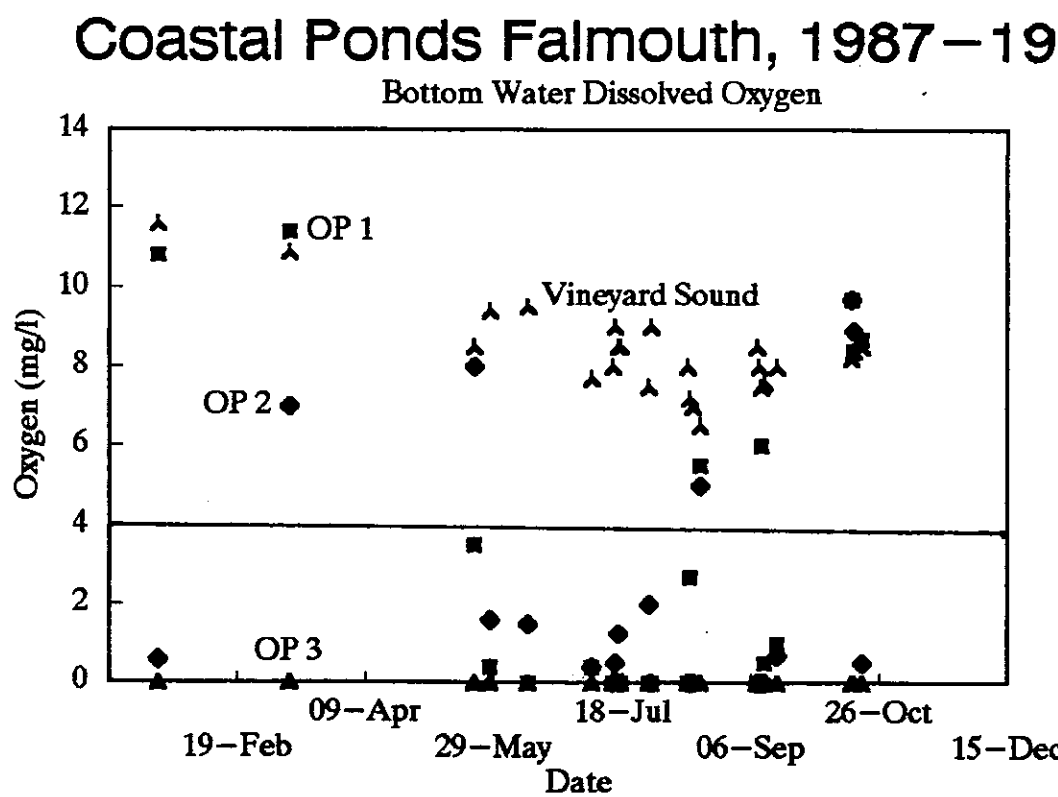


"Critical Eutrophic Levels" as designated by Coastal Pond Overlay Bylaw (Total Nitrogen as Average Over Year)

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

Figure 17.





Composite Annual Cycle all years.

Figure 20.

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

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

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

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

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

Table 1.

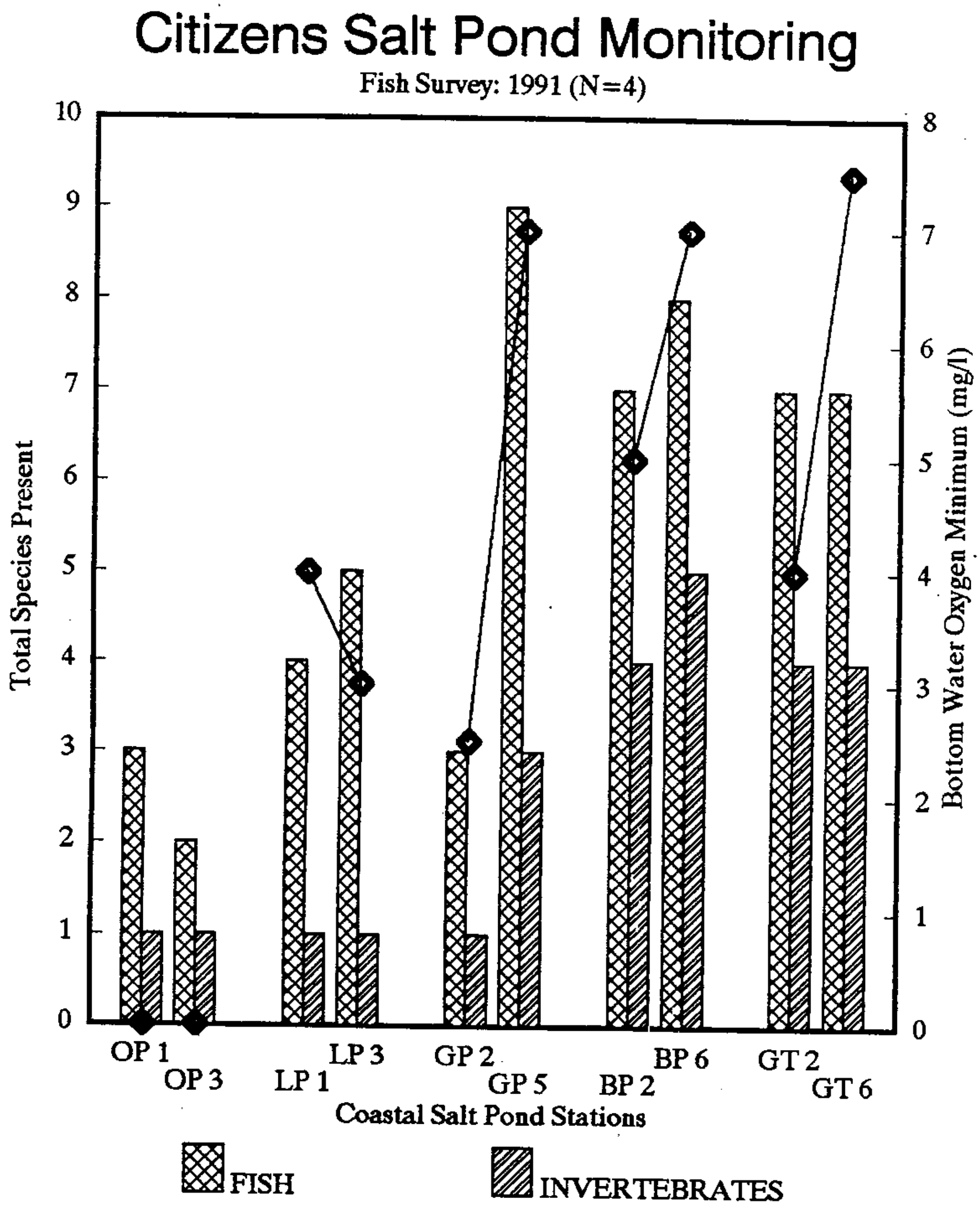

Citizens Salt Pond Monitoring
Fish Survey: 1991 (N=4)
Total Species Present
Bottom Water Oxygen Minimum (mg/l)
10
9
8
7
6
5
4
3
2
1
0
8
7
6
5
4
3
2
1
0
OP 1
OP 3
LP 1
LP 3
GP 2
GP 5
BP 2
BP 6
GT 2
GT 6
Coastal Salt Pond Stations
FISH
INVERTEBRATES

Figure 22.

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

ADDENDUM

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

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

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

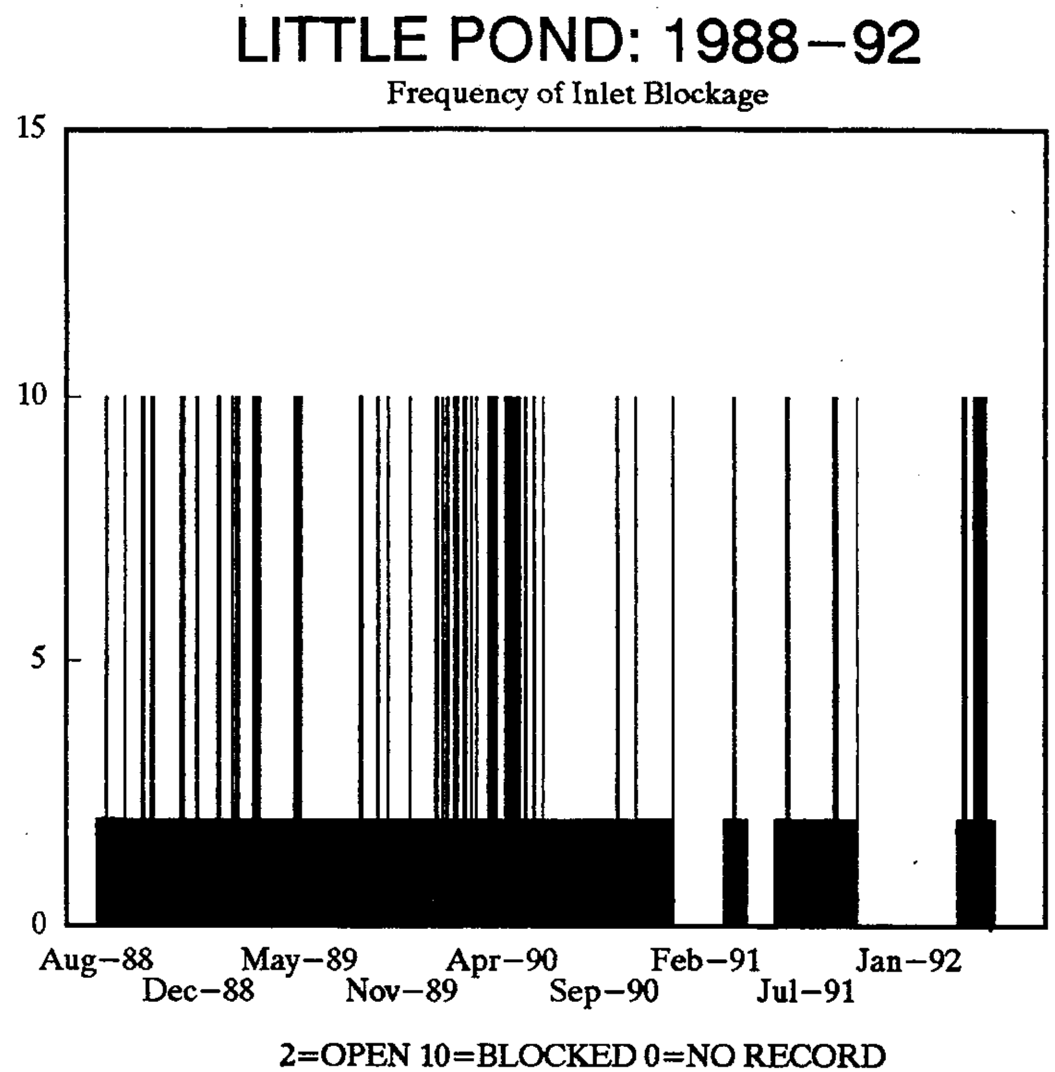
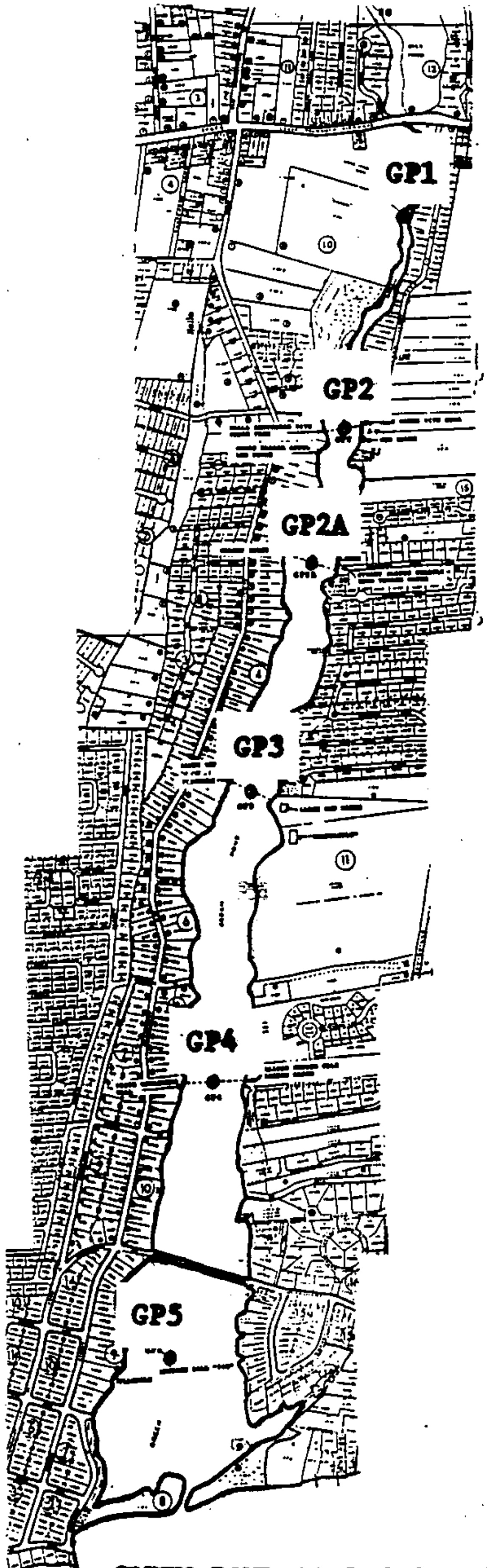

LITTLE POND: 1988–92
Frequency of Inlet Blockage
15
10
5
0
Aug–88
Dec–88
May–89
Nov–89
Apr–90
Sep–90
Feb–91
Jul–91
Jan–92
2=OPEN 10=BLOCKED 0=NO RECORD

Figure 23.



GREEN POND SAMPLING LOCATIONS