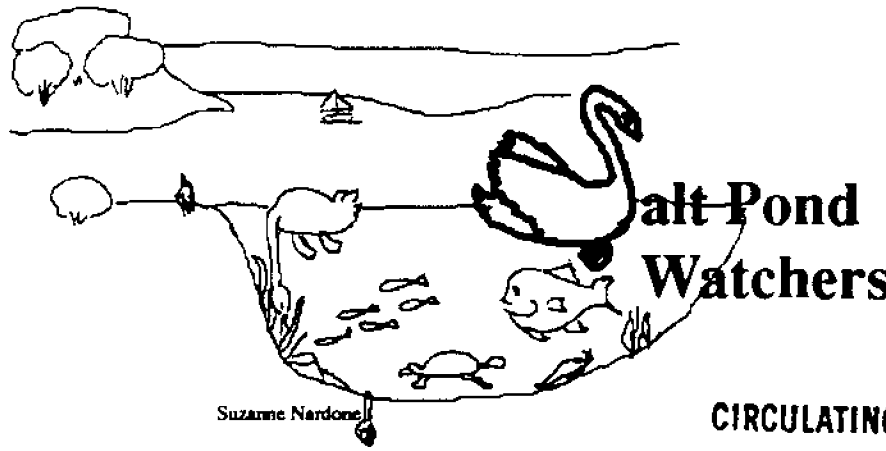


Water Quality in Rhode Island Salt Ponds, 1985-1991

A Summary Report

Coastal Resources Center
University of Rhode Island
Technical Report No. 17
November 1992

Water Quality in Rhode Island Salt Ponds, 1985-1991

A Summary Report

Virginia Lee
Paul Fofonoff
Coastal Resources Center
Graduate School of Oceanography
University of Rhode Island
Narragansett, Rhode Island

November 1992

printed on recycled paper

INTRODUCTION

Rapid development has provoked concern about water quality in the salt ponds, beautiful and productive estuaries along Rhode Island's ocean shore. This concern led to intensive study by University researchers and to the creation of a Special Area Management Plan for the Salt Pond Region (Olsen and Lee) 1985) which was adopted by the state Coastal Resources Management Council (CRMC) in 1984. In 1985, the Salt Pond Watchers, a citizens' water quality monitoring program, was initiated to monitor the impact of the Special Area Management Plan on protecting water quality in the lagoons. Since 1985, Salt Pond Watchers have measured water quality parameters that assess the two principal problems associated with residential and commercial development: eutrophication and bacterial contamination.

Seasonal Patterns

Water quality in the salt ponds varies on a seasonal basis, both because of the influence of changing light and temperature on the microbes, plants, and animals in the ponds, and because much of the population in the coastal plain is seasonal. Only a small portion of the salt pond region is sewered, the east side of Point Judith Pond and Wakefield. Most of the houses and commercial structures in the Salt Pond watersheds dispose of sewage on site by means of individual sewage disposal systems (ISDS's). Sewage inputs to the ponds from malfunctioning ISDS's can be expected to be greatest in summer when occupancy of houses in the pond watersheds is greatest.

Bacteria. Fecal coliform bacteria are sampled by Salt Pond Watchers only during the "summer" season and show different patterns from pond to pond (Figures 1 and 2). Although migratory birds can be a possible source of fecal coliforms during fall and spring, bird sightings near Salt Pond Watchers' stations are rare and do not correlate with high coliform concentrations. Contamination by coliform bacteria is a problem in at least one station in each pond. Fecal coliform concentrations are elevated within 48 hours after rains of more than 0.5 inches, indicating the importance of surface runoff in transporting bacteria into the ponds (Figure 2).

Nutrients. Seasonal cycles of nutrients are controlled by the seasonal cycles of plant growth in the ponds which in turn is governed by light availability and temperature. These cycles were fairly similar in timing between stations and ponds, but varied in amplitude according to the influence of sewage inputs and runoff. Nitrate concentrations reach a maximum in winter when phytoplankton and seaweeds and seagrasses have low rates of growth and do not remove the nutrients from the water. Then nitrate drops to low levels in summer when plant growth and uptake of nitrogen is most rapid. Phosphate concentrations at most pond stations show a nearly opposite cycle, with a minimum in late winter or early spring, and a peak in midsummer when biological activity in the sediment releases phosphates to the water column. These seasonal cycles suggest that nitrate rather than phosphate controls algal growth at most salt pond stations at present levels of nutrient loading (Figure 3).

Aquatic Plant Growth. Phytoplankton (measured as chlorophyll a) tends to grow in short pulses rather than smooth seasonal cycles and varies greatly from week to week, but overall, highest biomasses were seen in between June and September (Figure 3). This is also the time of maximum growth of seaweed and eelgrass. Warmer temperatures, long sunny days, high nutrient inputs, and high abundance of predators such as young fish, jellyfish, and ctenophores (comb-jellies) which eat phytoplankton grazing animals, all favor phytoplankton growth. At stations with greater nutrient inputs, such as upper and mid-Point Judith Pond, Fort Neck Cove in Ninigret Pond, the coves of Potter Pond (and

Rhode Island Salt Ponds and Selected Salt Pond Watcher Stations.

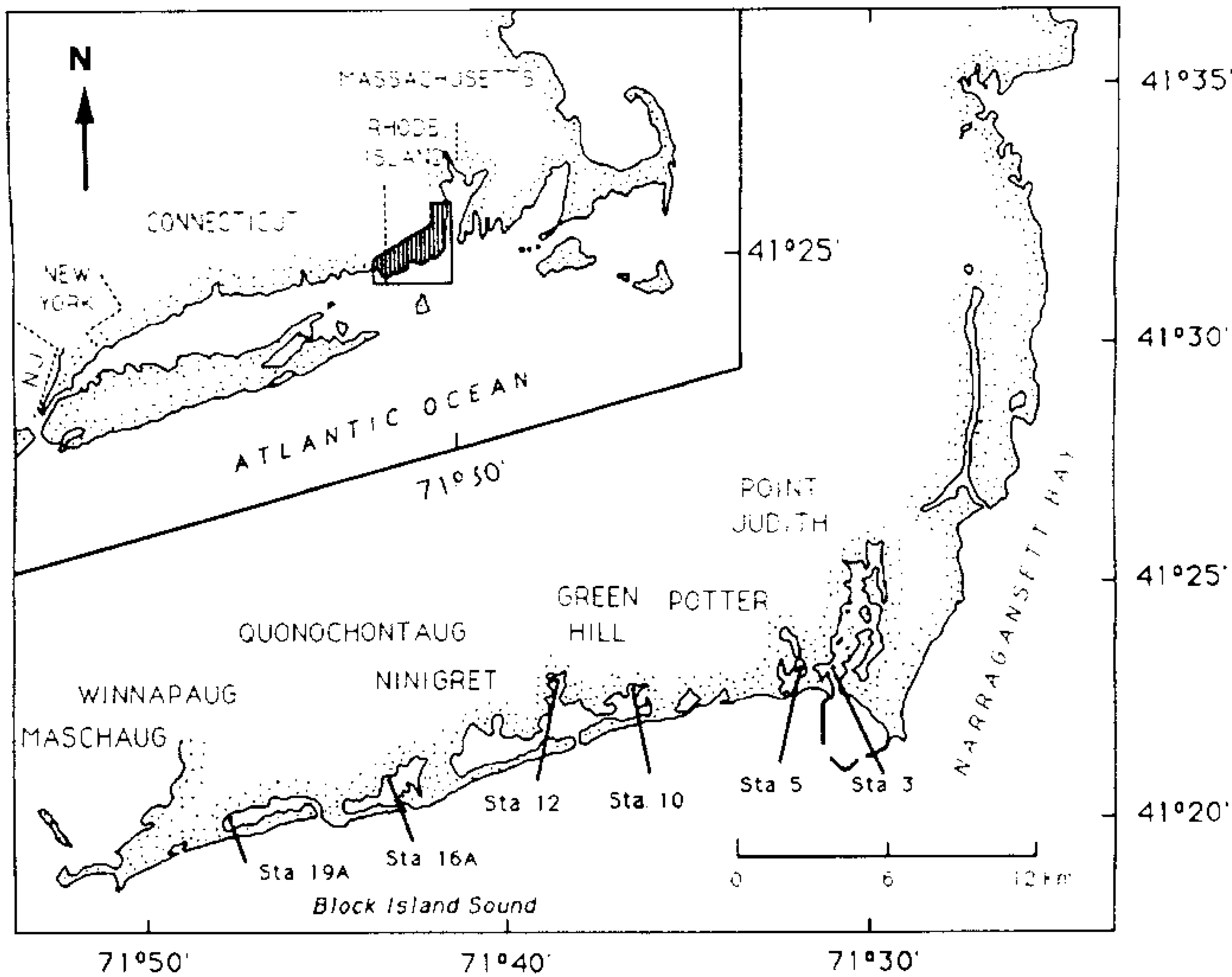


Figure 1. Monthly median fecal coliform concentrations at selected salt pond stations, 1988 - 1990 (most probable number per 100 ml)

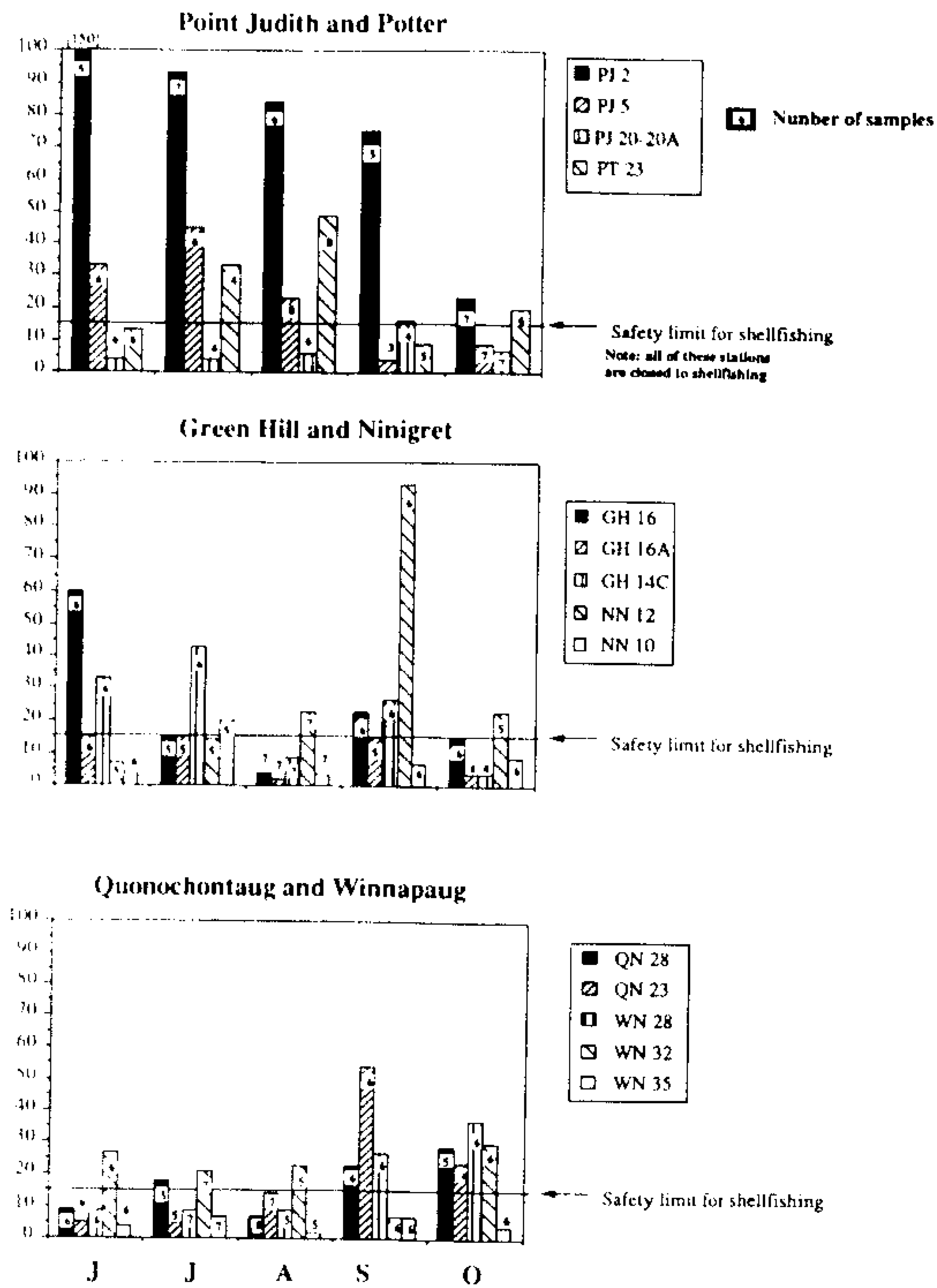
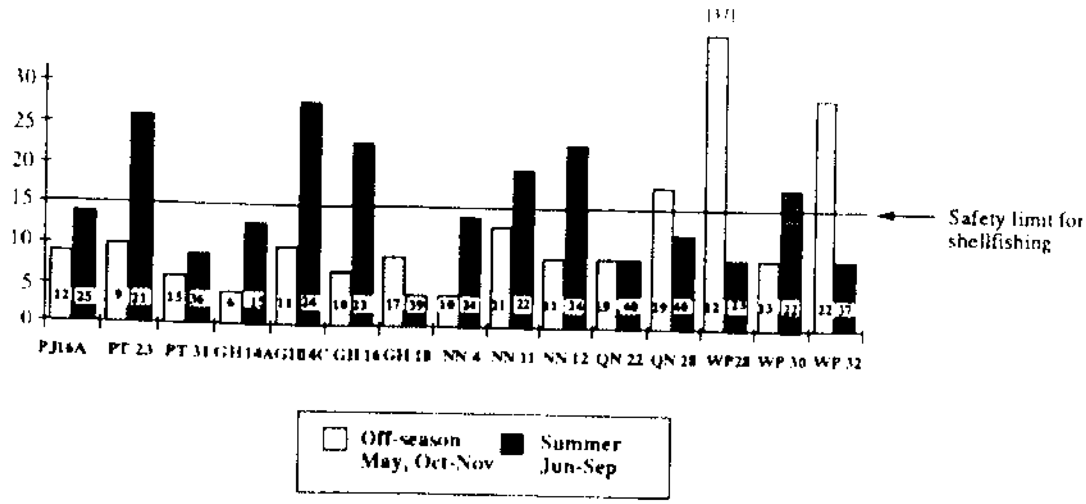


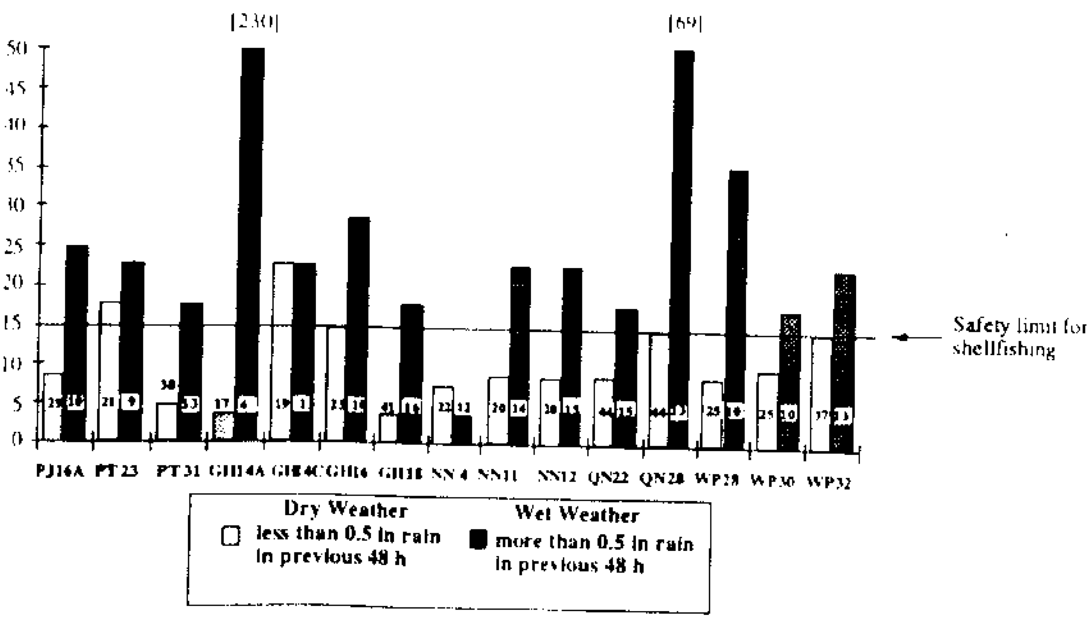
Figure 2. Effects of season and rainfall on fecal coliform concentrations at selected salt pond stations, 1985-89

(most probable number per 100 ml)

Comparison of medians in summer and off-season months



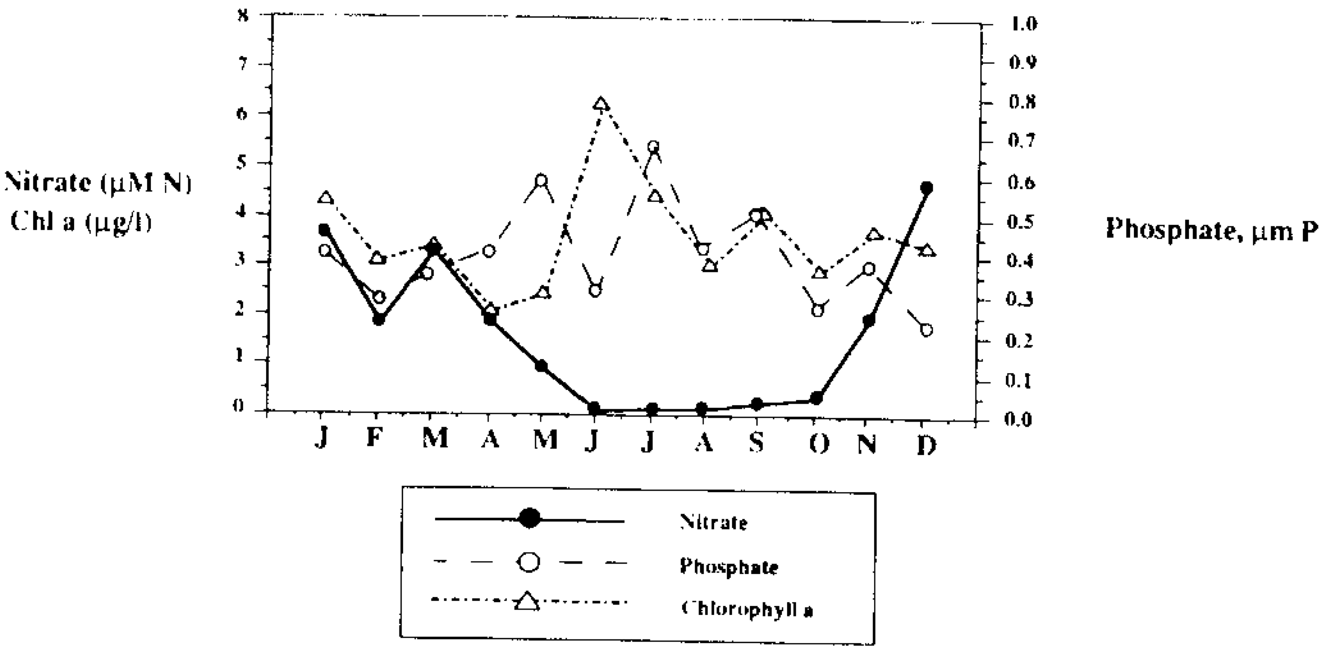
Comparison of medians in wet and dry weather



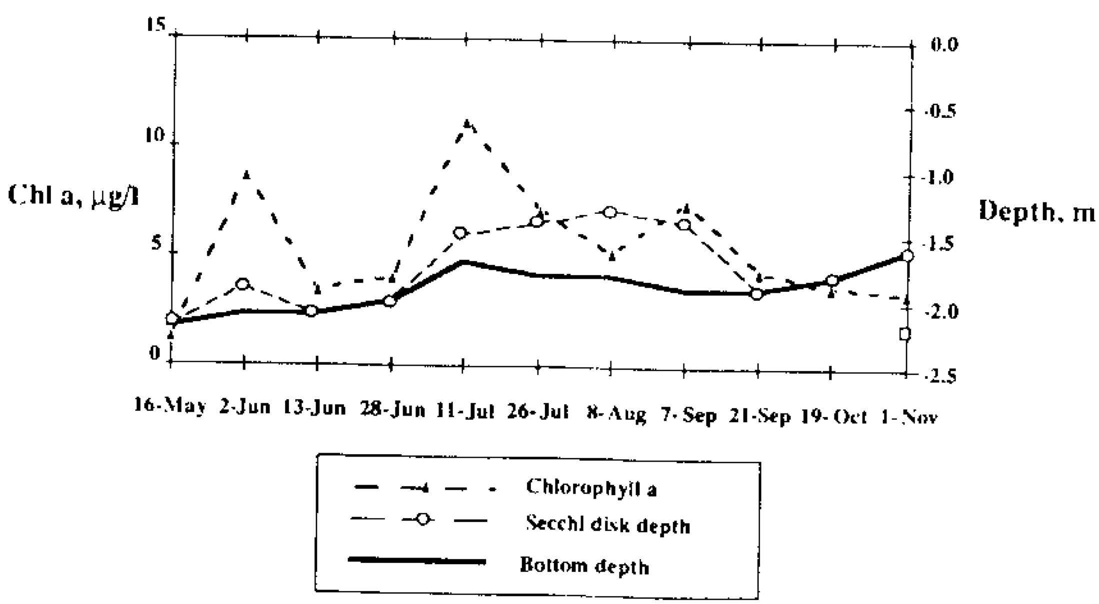
n - number of samples

Figure 3. Sta. 12, Fort Neck Cove, Ninigret Pond, 1988 - 1990

A. Annual average cycle of nitrate, phosphate, and chlorophyll a



B. Chlorophyll a concentrations and water transparency (Secchi disk depth), 1988



in some years Green Hill Pond, the abundance of phytoplankton reduces the transparency of the water during the summer so that objects on the bottom cannot be seen at a depth of one or two meters (three to six feet). This reduced transparency presents a possible threat to the survival of eelgrass, particularly in upper Point Judith Pond.

Dissolved Oxygen. Dissolved oxygen in surface waters varies seasonally, decreasing as temperature increases, but nearly always exceeds saturation levels (the amount of oxygen water of a given temperature and salinity can retain without releasing it as bubbles) even in more polluted waters such as upper Point Judith Pond (Figure 4). Supersaturation is normal in surface waters due to waves and oxygen production from phytosynthesis. Low oxygen levels did occur when ponds were covered with ice in winter, which reduces oxygen exchange between the water and air. The low levels in winter are often not a serious danger to aquatic life because organisms have low oxygen demand at temperatures near freezing.

Long-Term Changes in Water Quality in the Salt Ponds

It is encouraging that there is no evidence of long-term deterioration in the water quality parameters we've measured, with the exception of bacteria. Among the salt ponds, Ninigret and Green Hill Ponds are the two with the longest record of published research; including an annual survey in 1956-58 by Conover (1960), and an environmental impact study for the proposed Charlestown nuclear power plant (Marine Research, Inc. 1976), as well as the present Salt Pond Watcher data. Temperature, salinity, nutrient and chlorophyll data from two Salt Pond Watcher stations were compared with nearby stations from these earlier studies.

Nutrients. Analysis of summer data on temperature, salinity, nutrients, and chlorophyll, from 1985 through 1991, for six stations in Point Judith, Potter, Quonochontaug, and Winnapaug ponds does not reveal clear trends in temperature, salinity, or nitrogen. But decreases in summer average nitrate may have occurred at Point Judith (1), in the upper basin, and at Winnapaug (19A) at the west end of the pond (Figure 6). The decrease in Winnapaug Pond may have been related to the repair of a faulty septic system that was discharging to the west end of the pond. Phosphate concentrations appear to change in a surprisingly consistent way at all the salt pond stations; they reached peak levels in 1988, and have declined since. It is too soon to know if this is a significant long-term trend. Winter nitrate concentrations at Ninigret Station 12 do not appear to have changed much since 1958 (Figure 5). Winter nitrate concentrations at Green Hill (10) appear to be increasing, but there is high year-to-year variability and the periodic interruption of winter sampling by ice cover. Phosphate, however, had increased dramatically by the late 1980s then dropped in the early 1990s. Summer phytoplankton biomass, as measured by chlorophyll, was much higher in 1985-87 at Ninigret (12) and 1986-87 at Green Hill (10) than in the earlier studies or later Pond Watcher data. Chlorophyll concentrations at both stations have fallen to low levels in 1989-91, except for an isolated winter bloom at Ninigret (12) in 1991. In general, year to year variability seems to obscure long-term changes at these stations. The most significant possible change is the apparent increase in winter nitrate in Green Hill Pond in recent years, but this increase has not stimulated increased phytoplankton biomass.

Phytoplankton. One event which did occur in all the ponds simultaneously, was an occurrence of very high phytoplankton concentrations at most stations, including landlocked Maschaug pond, from June through September of 1986 (Figures 5 and 6). This appears to have been an algal bloom on a large scale, and may have been related to the "brown tide," which occurred in Narragansett Bay in 1985, and continued from 1985 to 1987 in Peconic Bay at the tip of Long Island. Since no phytoplankton samples were

Figure 4. Average monthly dissolved oxygen concentrations at six salt pond stations, 1989 -1990

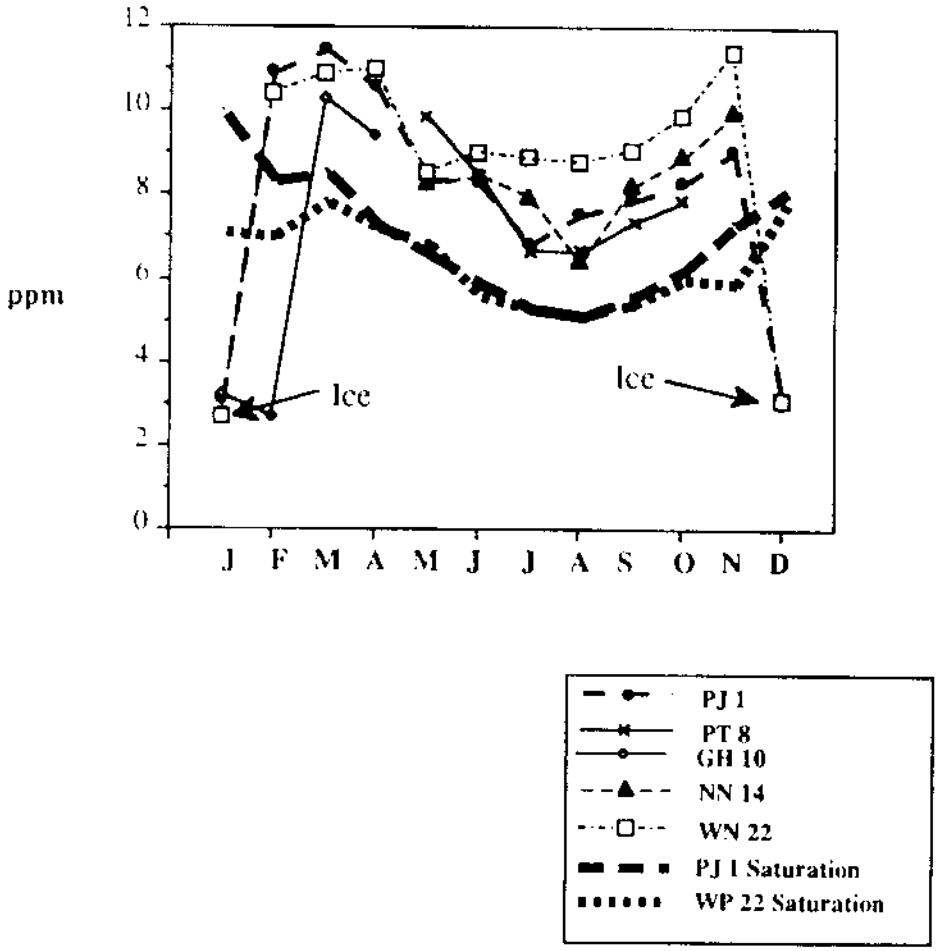


Figure 5. Ninigret Pond, Sta. 12, and Green Hill Pond, Sta. 10, summer and winter average water chemistry measurements

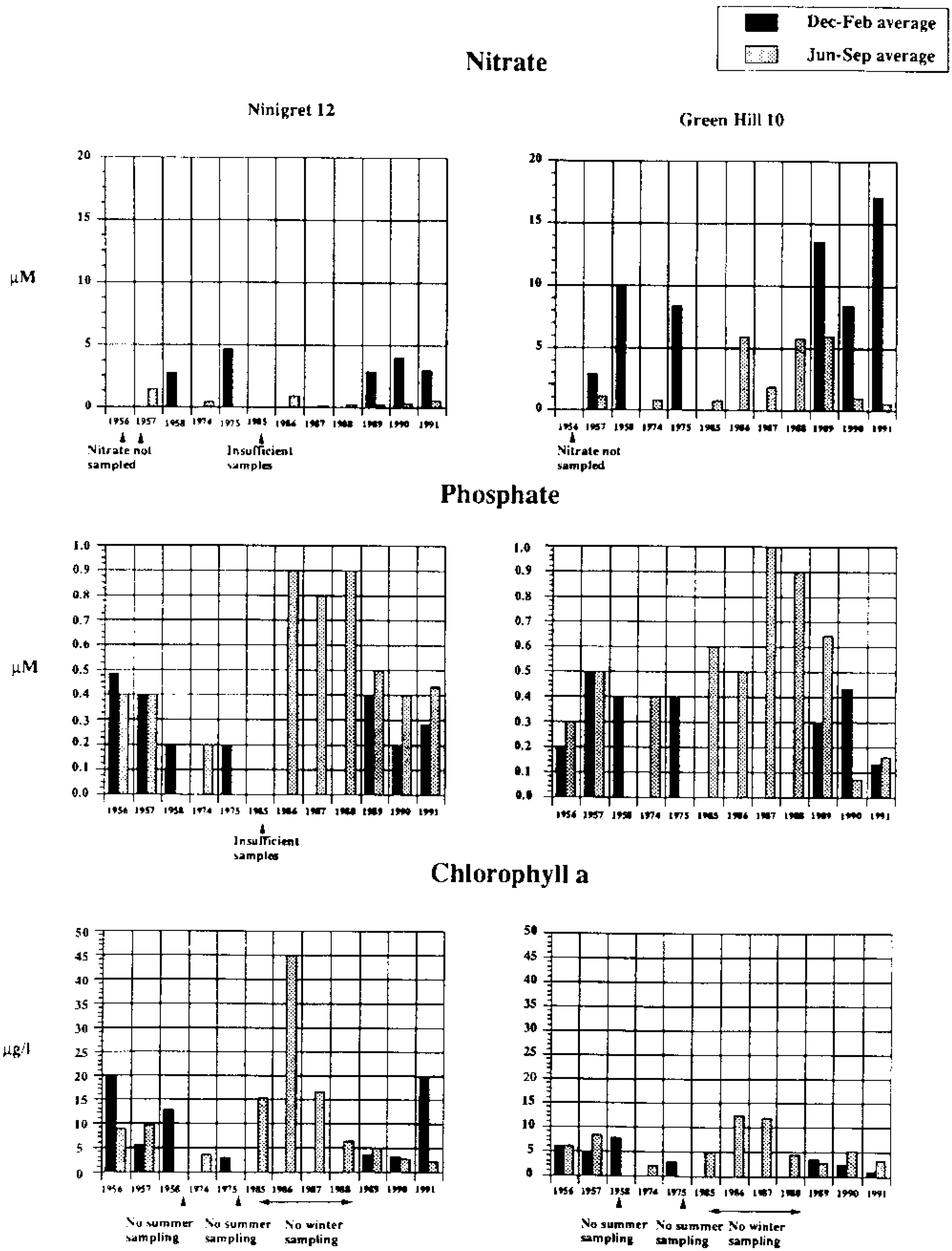


Figure 6. Summer (June - Sept.) water chemistry measurements at six salt pond stations, 1985 - 1991

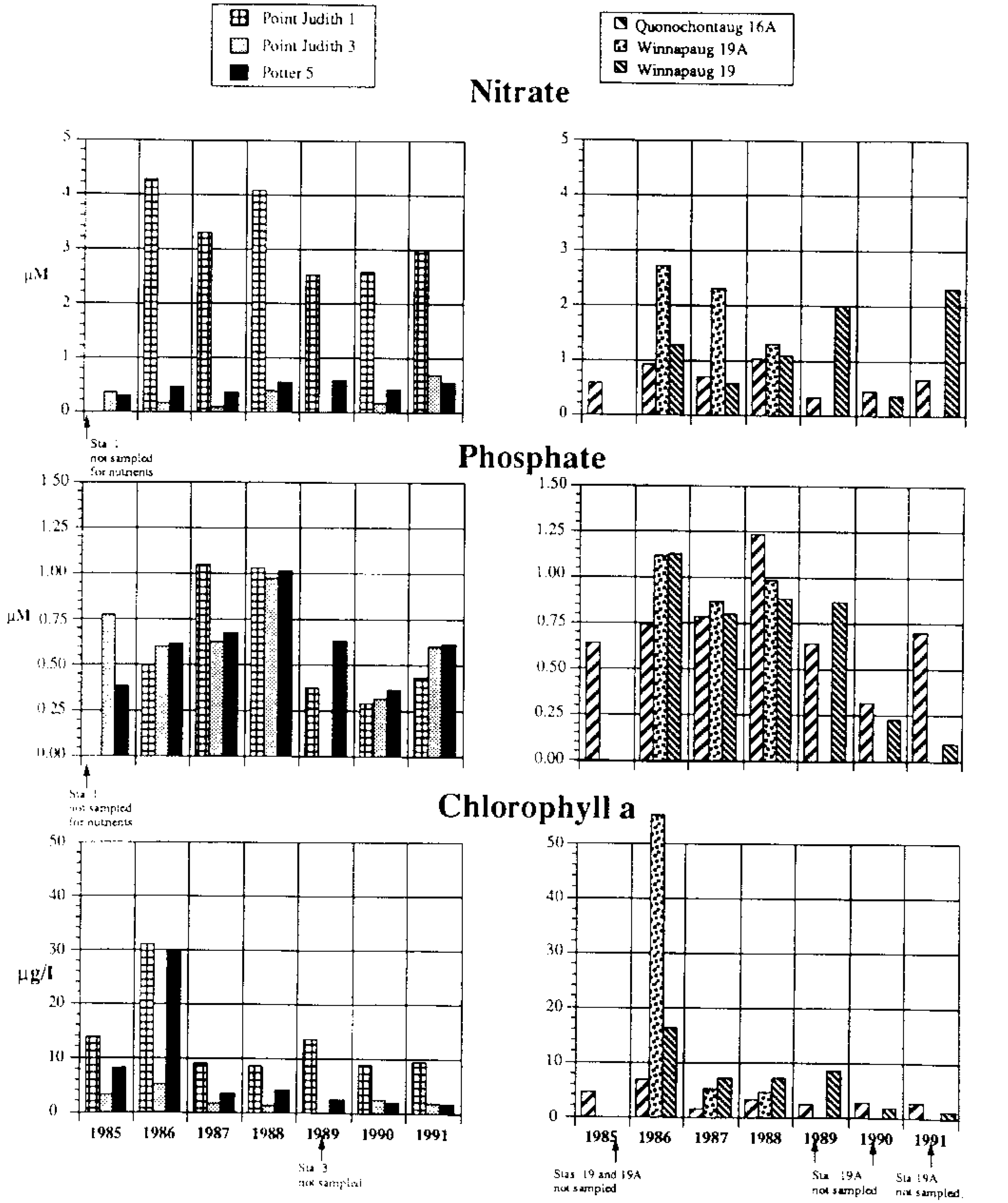
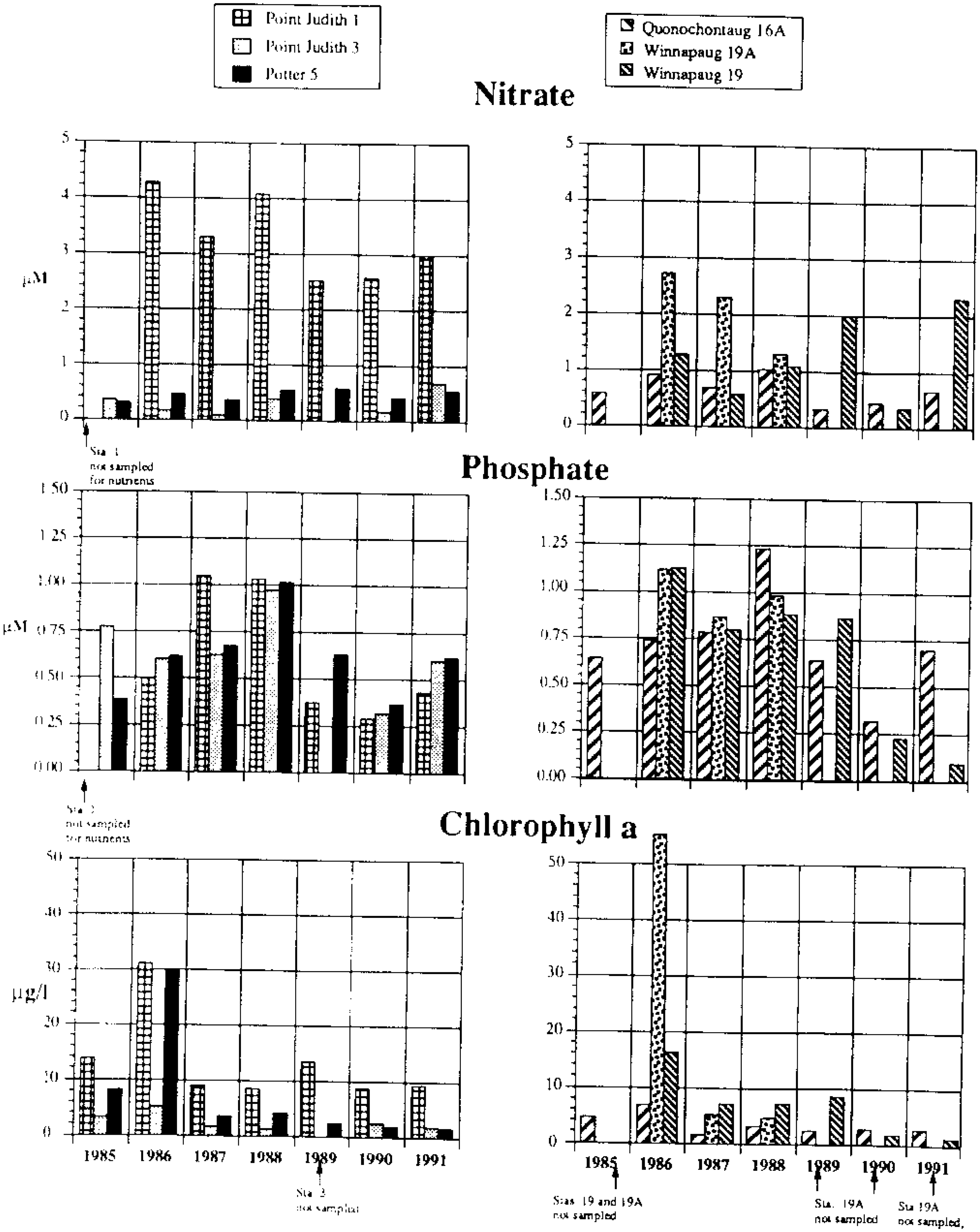


Figure 6. Summer (June - Sept.) water chemistry measurements at six salt pond stations, 1985 - 1991



examined in 1986, we do not know what organisms were responsible for the bloom in the ponds, but the "brown tide" organism was present in Point Judith and Quonochontaug Ponds in 1985. If the 1986 bloom was a "brown tide," it was part of a large-scale phenomenon. Although the causes are poorly understood, the brown tide occurs at low nutrient concentrations and is not a simple result of nutrient enrichment or sewage pollution.

Fecal Coliform Bacteria. Median fecal coliform bacteria concentrations at stations corresponding to the selected water chemistry stations are shown in Figure 7. In some areas, coliform bacteria concentrations have reached high levels and this is reflected in the closure of areas to shellfishing by DEM in Tocwotten Cove, Ninigret Pond, Green Hill Pond, Upper Point Judith Pond and the fishing port and marinas. Where clear improvements over time could be seen, they could sometimes be attributed to the repair of nearby failing septic systems as at Station 10A in Fort Neck Cove, Ninigret Pond, and Station 19A in the west end of Winnapaug Pond. Although coliform concentrations are strongly influenced by rainfall and the number of people living around the ponds, coliforms do not exhibit a uniform pattern at all stations. Rather, local sources such as failure or replacement of individual septic systems and short-lived events such as rain runoff seem to be very important.

Areas of Concern in the Salt Ponds

For detailed discussion of local problems in the salt ponds, see the full technical report. In general, each pond has several areas with high levels of coliforms, nutrients or chlorophyll (Table 1). In most cases, high levels of fecal coliforms, bacteria, nitrate, and chlorophyll occur simultaneously, but this is not always the case. For instance, the highest coliform levels in Potter Pond are in the vicinity of the point Judith-Potter breachway, although nutrient levels and chlorophyll are much higher in the North Basin and coves. Elevated coliform levels also occur on the north shore of Quonochontaug Pond, although nitrate and chlorophyll are very low. In Winnapaug Pond, nutrients and fecal coliforms are highest at the east end of the pond near the breachway, (Weekapaug) but phytoplankton biomasses are higher in Larkins Cove and the west end of the pond, perhaps because restricted flushing there permits algae to accumulate. The largest inflows of fresh water into the ponds, the Saugatucket River (Point Judith Pond) and Factory Brook (Green Hill Pond) are associated with high coliform and nutrient levels.

DEM's primary source of bacteria data is their own sampling program which consists of about four to six samples per year taken year-round. They make decisions for shellfishing closures based on sets of the fifteen most recent samples. Pond Watcher data is used as supplementary information by DEM in making closure decisions. Our samples are taken in May-October, when risk of exposure for recreational shellfishing is highest. It is interesting to note that several of the areas which we noted as problem areas in 1989 and 1990 were closed in 1991.

Housing Density, Nutrient Inputs and Eutrophication

We know that freshwater, both as stream flow and as groundwater, carries nutrients into the ponds so that fresher areas of the ponds are expected to be richer in nutrients. Figure 8 shows the relationship between salinity and nutrient concentrations. Nitrate behaves as we would expect. Both in winter and summer, nitrate concentration is highest in the freshest pond, Green Hill, and lowers in the saltier ponds, Point Judith and Quonochontaug. Notice that Winnapaug Pond, both in winter and summer, has higher nitrate than we would expect for its salinity, suggesting that it may be getting nitrate in less diluted form than the other ponds, as a result of more direct sewage discharges.

Areas With Possible Bacteria Contamination and Eutrophication Problems in the Rhode Island Salt Ponds, 1988 - 1990

Pond	Bacteria Station No.	Water Chemistry Station No.	Location Name	Fecal Coliforms: Median May-Nov 1988-90	Fecal Coliforms: Percent of samples exceeding 50 MPN/100 ml	Fecal Coliforms: Did station violate shellfishing standards during May-Nov 1988-90?	Fecal Coliforms: Open to shellfishing? 1992	Nitrate, µM: Jun-Sep	Nitrate, µM: May, Oct-Nov	Nitrate, µM: Dec-Feb	Chlorophyll a: June-Sept	Notes
Point Judith	2	1	Upper Pond	58	50	Area is classified SB	Closed year-round	3.00	4.40	7.98	10.00	
	6	2B		28	13	- -	- -	3.50	2.08	2.02	9.49	1
	16A	2C	Bluff Hill Cove	4	13	marginally	Open	0.38	0.39		1.06	2
	18		Great Island Bridge	16	7	no, but very close	on closure line	.				
	21A	.	Potter Pond Breachway	12	11	marginally in 88-90 higher in 91	Closed year-round	.			.	3
Potter	23	5	Potter Pond	18	26	yes	Closed year-round	0.51	0.94	3.78	2.58	4
	24		Breachway	18	14	yes	Open	.	.		.	
	26		and Narrows	9	24	yes	- -	.	.	.	.	
	30	6	Sugar Cove	5	12	marginally	Open	1.02	4.61	.	5.94	5
	27	7	North Basin	5	9	no	Open	0.84	1.20	.	6.84	
	31	8	Seaweed Cove	4	4	no	Open	0.70	3.01	.	7.13	
Green Hill	16		Factory Brook	15	18	yes	Closed seasonally	.	.	.	.	
	15A		outlet and	15	5	no	- -	.				
	.	10	nearby area	.			- -	4.49	5.42	10.35	4.11	
	14C	11	Allen Cove	23	14	yes	Closed seasonally	3.89	8.03	.	4.32	
Ninigret	4	14	Fosters Cove	9	14	marginally	Open	1.50	2.56	.	4.40	
	10A*	12	Fort Neck Cove	4	22	marginally	Open	0.18	1.03	4.32	4.56	6
	10	.		4	3	no	Open					
	11	13	Tockwotten Cove	15	29	yes	Closed year-round	1.56	2.12	.	7.78	
	12	.	East end of Pond	23	18	yes	Closed year-round	.			.	
Quonochontaug	23	17*	Shelter Harbor, Point Dock	9	27	yes	Open	0.71	2.38	1.30	1.86	7
	25	.	Cove at West end of pond	18	20	yes	Open					
	26	16A	Shelter Harbor, Haversham Cove	18	22	yes	Open	0.60	0.93	2.37	2.78	
Winnapaug	28	.	Breachway	17	38	yes	Open	.		.	.	
	29	22	East end of pond	9	19	yes	Open	4.33	7.40	9.30	3.22	
	30	.	East Cove	15	25	yes	Open					
	32	21	Larkins Cove	20	22	yes	Open	0.69	2.29	.	4.25	
		19	West end of pond					1.41	1.90	0.94	7.33	8
	35	19A		5	6	no	Open	1.29	3.46	6.54	4.71	9

Notes to Table 1. :

Samples were taken in each year of the stated time of year unless noted below
See the summaries and the raw data in Appendix B of the report "Water Quality in Rhode Island Salt Ponds" for the numbers and dates of samples taken

Entries were shaded if they exceeded the following criteria:

Median fecal coliforms:	Greater than 15 MPN/100 ml
Percentage of fecal coliforms exceeding 50 MPN/100 ml	Greater than 10%
Nitrate	
Jun-Sep	Greater than 1.00 µM
May, Oct-Nov	Greater than 3.00 µM
Dec-Feb	Greater than 5.00 µM
Chlorophyll a:	Greater than 5.00 µg/l

1 Water chemistry at Sta. 2B was sampled in May-Nov 1988, and May-Apr 1989-1990. Only two Dec-Feb samples were taken.

2 Water chemistry at Sta. 2C was sampled in May-Nov 1988 and 1989, and May-Jul 1990

3 Bacteria at Sta. 21A were sampled in 1989 and 1990. The median of six samples in 1991 was 41 with one sample (17%) over 50)

4 Only two Dec-Feb water chemistry samples were taken at Sta. 5, in 1988

5 Sta. 6 was not sampled for water chemistry in 1990.

6 Bacteria at Sta. 10A were sampled only in 1990

7 Water chemistry at Sta. 17 was sampled in 1988 through April 1989. Only three Dec-Feb samples were taken.

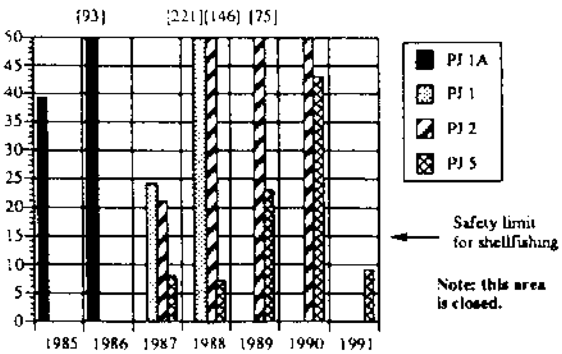
8 Water chemistry at Sta. 19A was sampled in 1988 through April 1989. Only two Dec-Feb samples were taken.

9 Water chemistry at Sta. 19 was sampled in winter only in 1990-91. only two nutrient samples and three chlorophyll samples were taken.

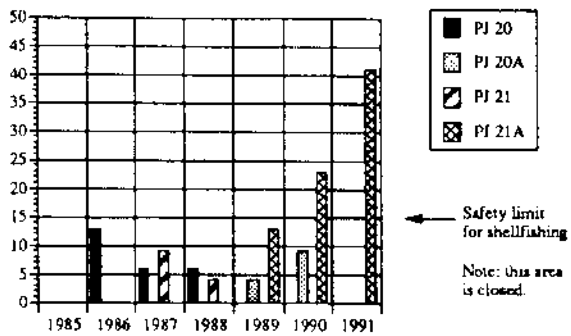
Figure 7. Annual median fecal coliform concentrations at selected salt pond locations, Most Probable number per 100 ml.

Note: Missing values indicate stations not sampled.

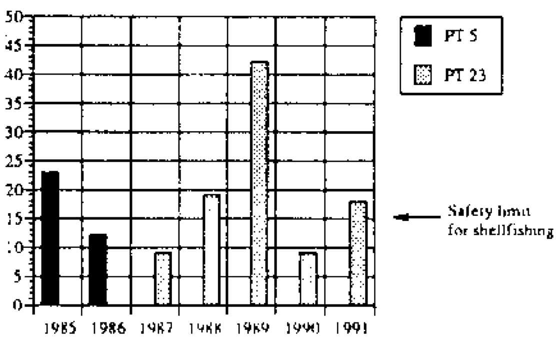
Upper Point Judith Pond



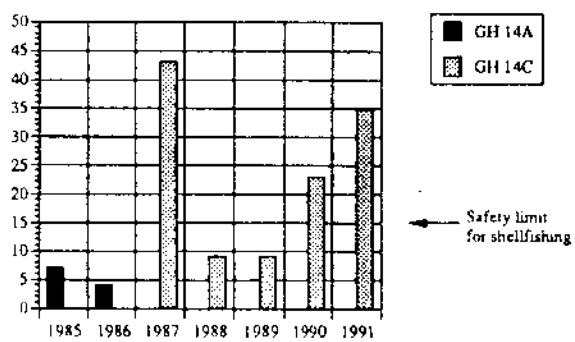
Lower Point Judith Pond



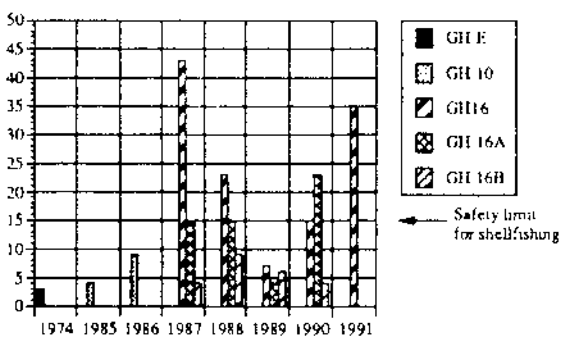
Potter Pond, Breachway Area



Green Hill Pond, Allens Cove



Green Hill Pond, Main Basin and Factory Brook area



Ninigret Pond, Fort Neck Cove

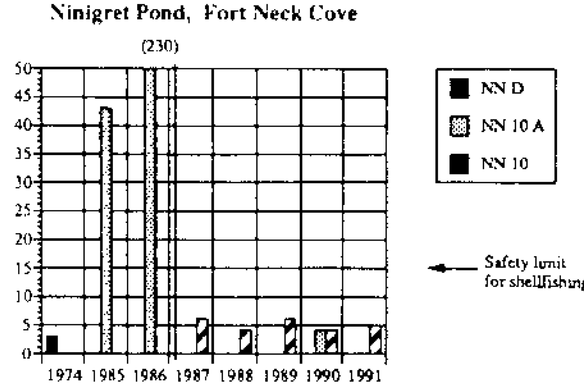


Figure 7. Annual median fecal coliform concentrations at selected salt pond locations, continued. Most Probable number per 100 ml.

Note: Missing values indicate stations not sampled.

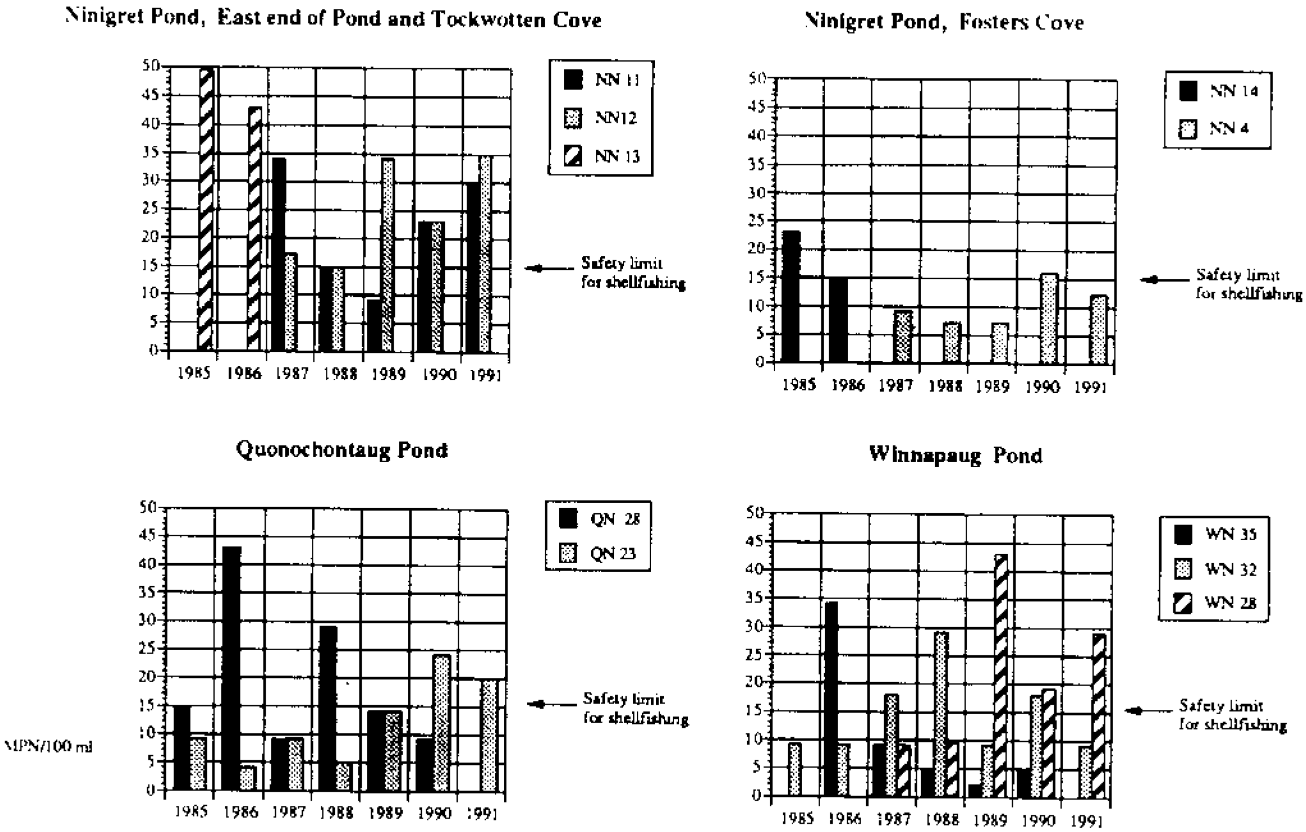
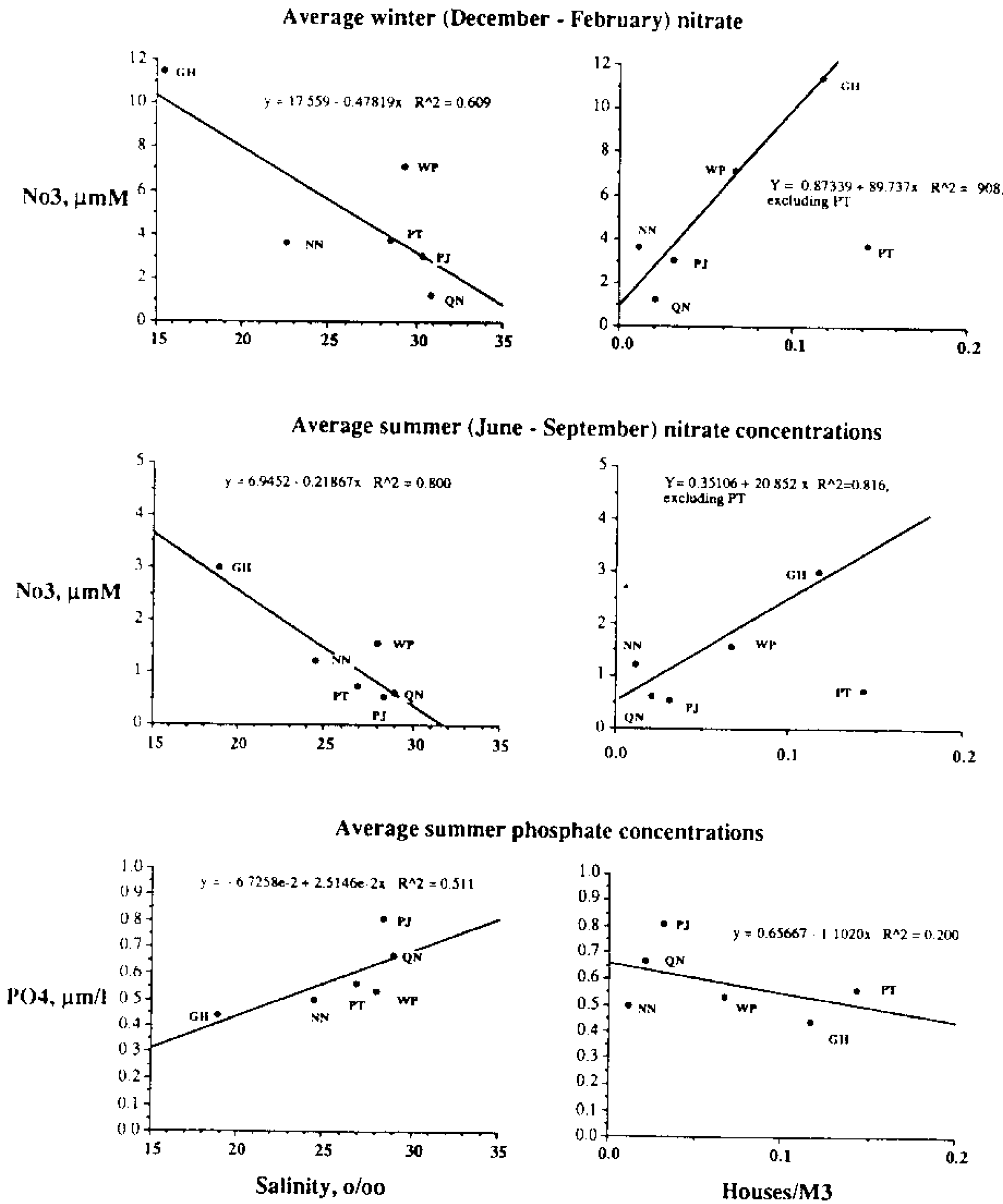


Figure 8.

Nutrient concentrations in the salt ponds in relation to salinity and housing density 1988 - 1990



Phosphate, on the other hand, is highest in the saltier ponds and least in Green Hill and Ninigret, suggesting that salt water is the chief source of this nutrient. (Phosphate has varied two to fourfold in the ponds from 1988 through 1990; the correlation was strongest in 1988, weaker in 1990, and nonexistent in 1989). The ratio of nitrate to phosphate, which determines which nutrient is limiting for algal growth, is also strongly correlated with salinity. The ratio varied greatly from year to year but was usually less than the Redfield ratio for phytoplankton composition, 16N:1P, indicating that nitrate was the limiting nutrient in most ponds.

We can see that nutrients are related to freshwater influx and tidal flushing. Freshwater is a transporter of nitrate, but septic systems are the primary source,in the salt pond watersheds. Therefore, nitrate should also be related to the number of houses in a watershed. One way to look at the possible effects of development in the ponds is to compare the ponds with each other, and in order to see whether the ponds with greater or lesser development in their watersheds differ in nutrient levels or phytoplankton biomass. The number of houses in each pond's watershed south of Route 1 was determined using aerial photographs taken in 1988 and 1980, and compared with average summer (June-September) and winter (December-February) water chemistry data for 1988-90.*

Figure 8 shows that both summer and winter nitrate concentrations are strongly correlated with housing density for five of the ponds. (Potter has far lower nitrate than we would expect. Possible explanations for the lower-than-expected nitrate in Potter Pond include very limited winter sampling, and high phytoplankton biomass and removal of nitrate.)

For most ponds, housing density around the ponds is correlated with nitrate concentrations in the ponds. Can we make the next step and relate nutrient levels to phytoplankton? Figure 9 shows that there is not a linear relationship between nitrate, either in winter and summer, and summer chlorophyll. It is possible that as nitrate is added at low levels, the growth of the algae increases, but since the high nitrate environments have less phosphate, the algae may become phosphate-limited in environments such as Green Hill Pond.

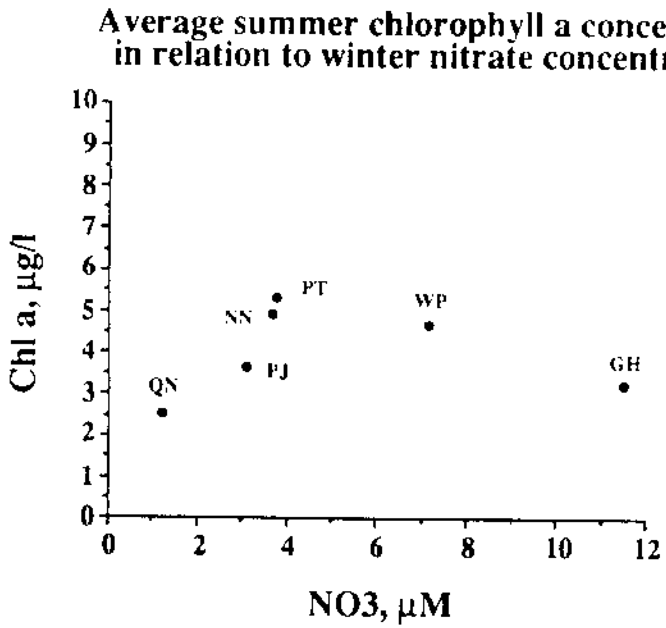
There are many reasons why nutrients may not be well correlated with chlorophyll concentrations. Phytoplankton does not always accumulate; much of the time it is eaten as fast as it grows by zooplankton and shellfish, so increased nutrients may be converted into larger biomasses of grazing animals. Phytoplankton are not the only consumers of nutrients in the ponds; much of the plant production in the ponds is in the form of seagrasses, macroalgae (seaweeds), and microscopic benthic (bottom) algae which pond watchers have not been sampling. Very high nutrient loadings in shallow lagoons tend to promote massive growth of large bottom algae and noxious phytoplankton, both of which may be inedible to grazers. It is possible that nutrient loadings to the ponds as a whole have not reached a threshold where they produce a clear response in terms of phytoplankton growth, although some stations do show elevated chlorophyll concentrations.

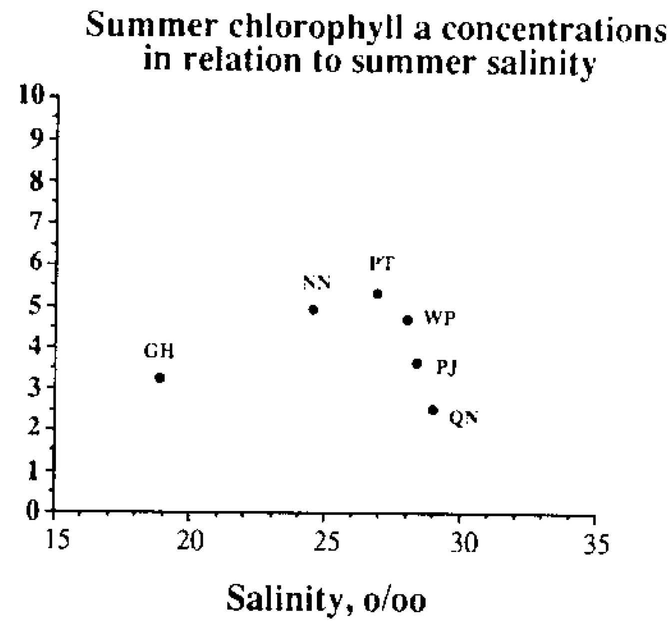
We can conclude from our comparison that there is a probable relationship between housing density and nitrate levels in the salt ponds. Continued increases in housing density in the watersheds of the salt ponds can be expected to result in an increase of this nutrient, although year-to-year variability in weather and phytoplankton cycles may make these changes difficult to detect over periods of only a few years. As inputs of nitrogen and phosphorus to the groundwater increase, so does the potential for annoying or

* These years were chosen because winter sampling was not done in earlier years.

Figure 9.

Summer (Jun-Sep) Chlorophyll a concentrations in the salt ponds in relation to nitrate and salinity 1988-1990





dangerous algal blooms. The risk of bacterial contamination also increases as the number of houses in the salt pond watershed grows. While we cannot conclude that drastic large-scale changes have occurred as a result of housing development, regions of each pond appear to show signs of eutrophication or persistent bacterial contamination.

Greatly increased development will probably result in increased algal growth, decreased water transparency, and a decline in the biological and recreational quality of the ponds. These conditions have already occurred in similar coastal lagoons that have been surrounded by dense concentrations of housing, such as Great South Bay, Long Island, Buttermilk Bay, Massachusetts, and Rehoboth Bay, Delaware. It is important to remember that in addition to increased nutrient loadings, many other factors associated with development affect the fish, shellfish, and the aesthetic quality of the ponds including hydrocarbons from roads and outboard motors, organic chemicals and metals from antifouling paints, herbicides, overfishing, disturbance and shading of the bottom by docks, and the transport of sand into the ponds through the breachways. Careful planning is required now to preserve or improve the present levels of water quality in the ponds and prevent the deterioration that has been seen in similar coastal bays elsewhere.