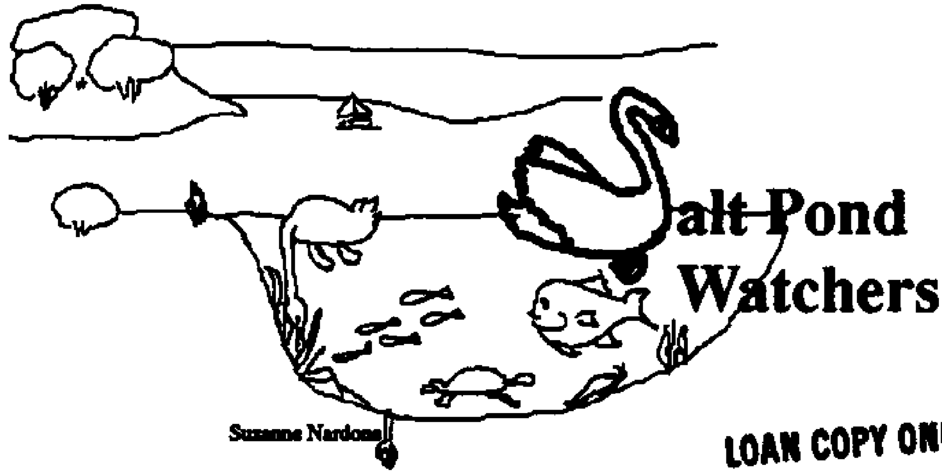

Trustom and Card's Ponds 1992

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Appalachian Mountain Club - Rhode Island Salt Pond Watchers Data Report: Water Quality in Trustom and Cards Ponds, 1992

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Contents

List of Tables

List of Figures

Introduction

Trustom Pond and the Cards Ponds are shallow lagoons which lie within the Trustom Pond National Wildlife Refuge (Figure 1). These ponds are connected to Block Island Sound by temporary breachways which are opened by storms or breached deliberately by the refuge managers. Ground water is the principal source of fresh water to these ponds; a brook flows into Cards Pond, from a mill pond above Carpenters grist mill. Figure 2 shows the flow of ground water through the watershed into the ponds. Trustom and Cards Ponds and the surrounding land are important habitats for waterfowl and other wildlife, and popular sites for hiking, birding, and scenic appreciation. While the land immediately adjacent to the ponds is protected by the refuge, there are 262 houses in the watershed of Trustom Pond and 215 in the Cards Pond watershed (based on 1988 aerial photographs, and including only the area south of Rte. 1). In 1980, 80 houses were counted in the Trustom watershed, and 202 in the Cards watershed. In 1984, it was estimated that 246 houses could be built in the Trustom watershed, and 1,095 in the Cards watershed based on zoning at that time (Olsen and Lee 1985). The potential for development has raised concerns about water quality and eutrophication. These concerns led members of the Narragansett Chapter of the Appalachian Mountain Club to organize a citizen's monitoring program in Trustom and Cards Ponds, in collaboration with the Rhode Island Salt Pond Watchers and the University of Rhode Island. This report summarizes the results of the first year of this program.

Methods

Station Location

Two stations (31 and 32) were selected for water chemistry measurements in Trustom Pond. These stations are located in the approximate deepest points of the eastern and western basins. Visual lines of sight were used to locate the stations initially, but later in the summer the stations were marked with floats. The sampling stations at Trustom Pond are reached by a canoe or rowboat kept at the pond. Before sampling, pond height is recorded from a ruled measuring stake near the boat launching site at Meadow Point. The first sample in March was taken well inshore of the present station 31 because of severe weather conditions.

The sampling location (Sta. 33) for the Cards Ponds is at the eastern end of the culvert between the East and West Ponds at the end of Moonstone Beach Road.

Field Methods

At both Trustom and Cards Ponds depth and light penetration were measured with a Secchi Disk, and water temperature was recorded with a thermometer. Three 50 milliliter water samples at each station were filtered onto glass-fiber filters for chlorophyll measurements, and the filtered water from one of these samples was saved in a polyethylene bottle for nutrient measurements. Pond watchers were instructed to make notes on water color, aquatic animals, bird sightings, or any other observations relevant to water quality.

A full account of Pond Watcher sampling methods is given in the Rhode Island Salt Pond Watcher's *Protocol Manual for Salt Pond Watchers* (Coastal Resources Center Tech. Rep. 12, 1991).

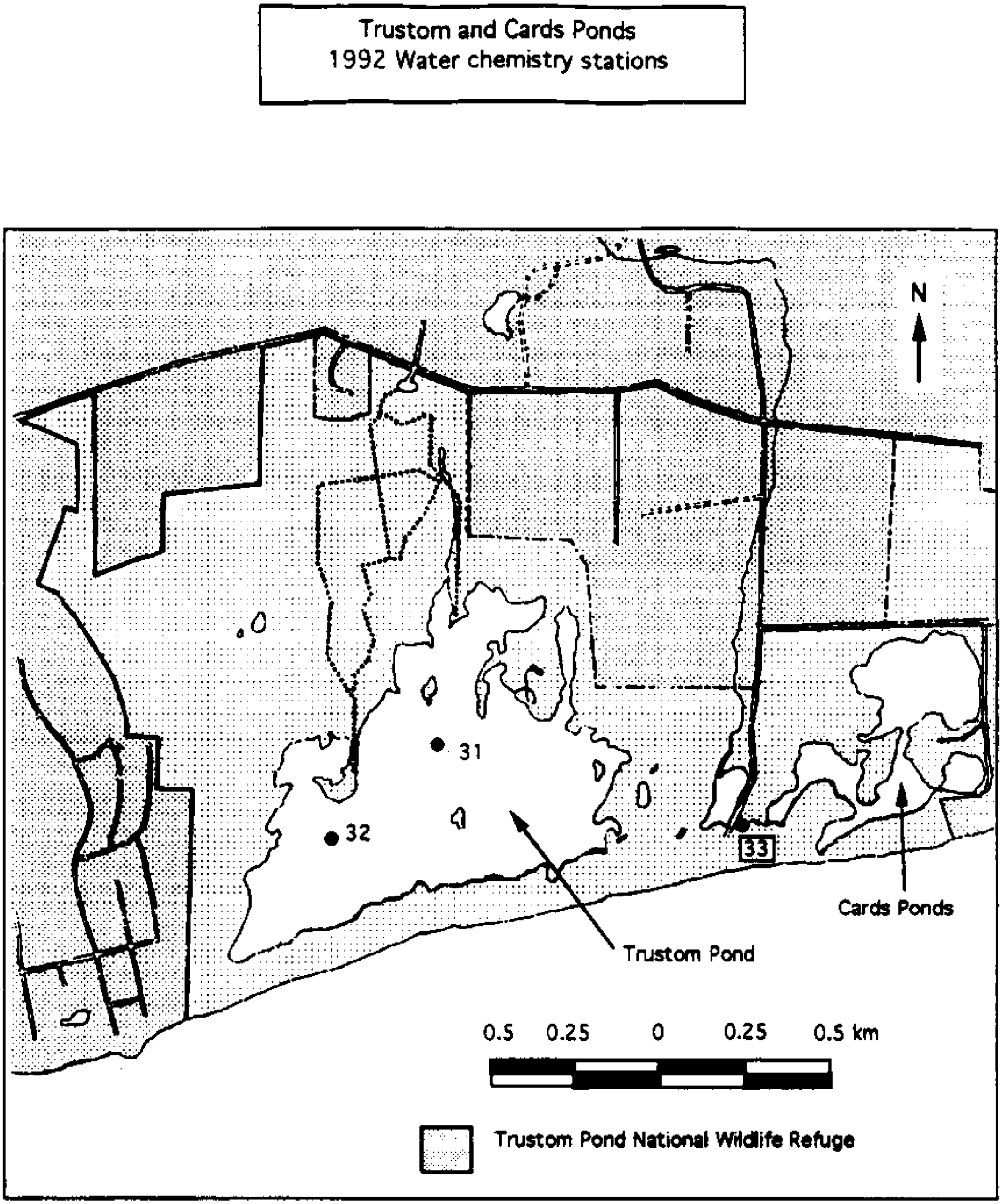


Figure 1. Map of Trustom and Card's Ponds.

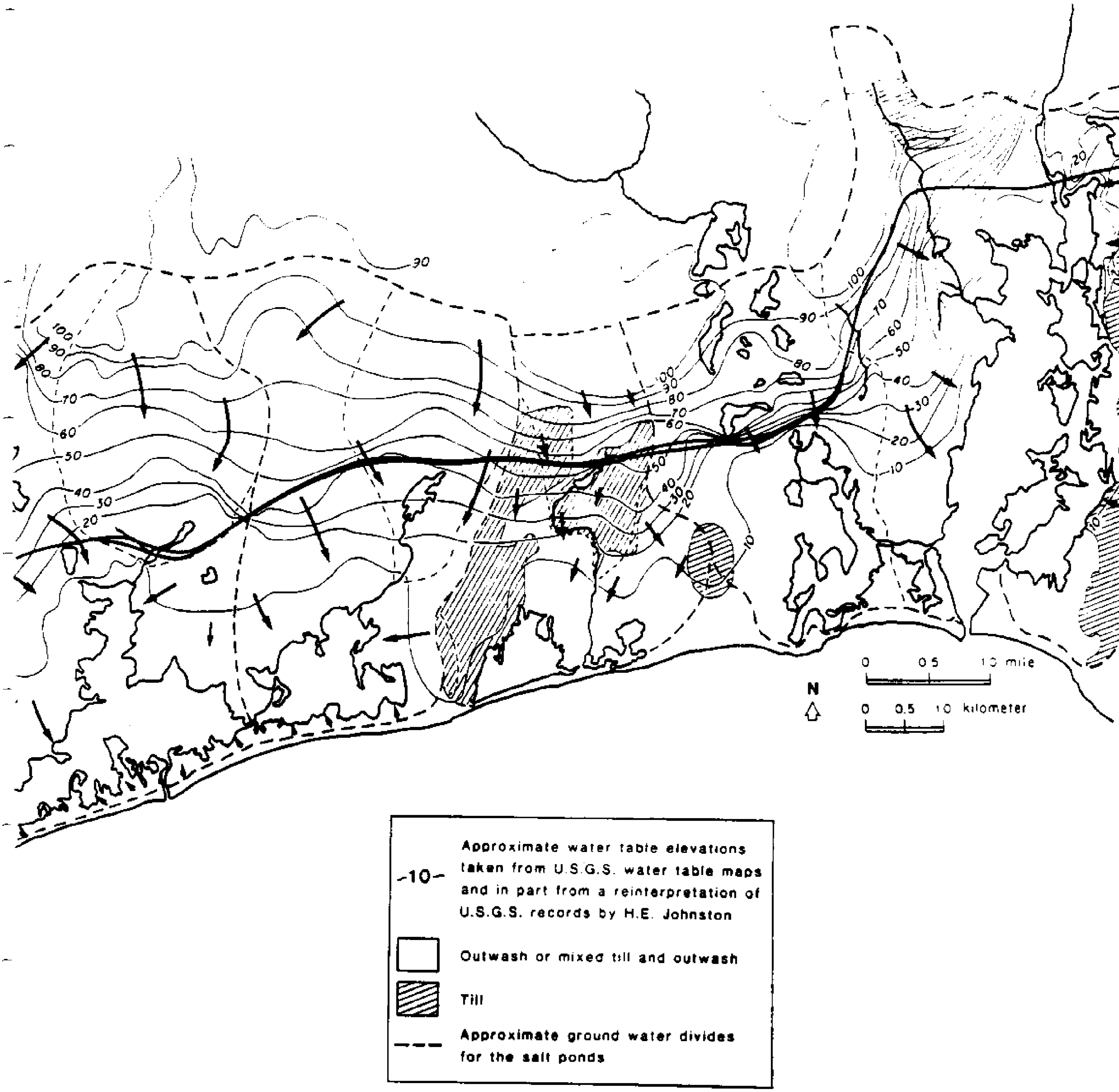


Figure 2. Map of Salt Pond Region Watershed (arrows show groundwater flow).

Laboratory Methods

Chlorophyll *a* and nutrient samples are frozen for storage, and brought to the laboratory at the Graduate School of Oceanography for analysis by a GSO graduate student. Chlorophyll filters are soaked in 5 ml of acetone for 12 hours in order to extract the chlorophyll. Fluorescence of the extracted pigment is measured using a fluorometer, and chlorophyll *a* concentrations calculated from the change in fluorescence after the addition of HCl. Salinity of nutrient samples is measured using a hand-held refractometer. Phosphate and nitrate were measured using an autoanalyzer. Laboratory methods are described in detail in *Protocol Manual for the URI Graduate Assistant* (Coastal Resources Center Tech. Rep. 13, 1991). Coliform bacteria are not sampled in Trustom or Cards Ponds.

Occasional qualitative observations on pond plankton were made by Paul Fofonoff (a GSO graduate student) using samples taken from shore or from the pond watcher's boat using either a fine - mesh (20 µm) net, or whole-water samples taken in a one - liter jar. Phytoplankton were examined at 100 X using a compound microscope, while zooplankton were observed at 40X with a dissecting microscope. Salinity of these samples was also measured using a hand-held refractometer.

Results

Trustom Pond

Fresh water flow into Trustom Pond primarily from groundwater; the pond receives only small seasonal streams. The pond was breached artificially on a regular basis, from 1975 to 1990, but this was curtailed because of the threat of disturbance to piping plovers and least terns on the barrier beach. The pond was last breached by the October 30-November 1 storm of 1991. Fish and Wildlife Service data indicate that the pond level falls well below the base of the measuring gauge after breaching. As the breach "heals", the pond level rises, taking about 3 - 4 weeks to reach the base of the gauge (0.91 m above mean sea level).

In March and April, the pond level was high, 1.8 m above sea level, (Table 1) and surface salinity was 6 ppt (parts per thousand, Figure 3). (Block Island Sound water is 30 - 33 ppt; fresh water is less than 0.5 ppt). The water temperature was low (10°C in April) and rooted aquatic plants appeared to be still dormant. Phytoplankton consisted mostly of relatively sparse nondescript flagellates. Chlorophyll *a* concentrations were low (0.6 µg/l). Nitrate concentrations were 12 - 15 µM and phosphate was 0.44 -.46 µM. The limited plant growth at this time of year accounts for the high nutrient concentrations.

Water samples from Trustom Pond in spring contained abundant (tens to hundreds of animals per liter) zooplankton consisting primarily of rotifers (small multicellular animals marked by a whorl of cilia around the mouth) and estuarine copepods (microscopic crustaceans). The rotifers found from March through July belonged to the genus *Synchaeta*, which includes freshwater and estuarine forms, The estuarine copepod *Eurytemora affinis*, particularly its larval forms, were also abundant in these months. The overall abundance of zooplankton in Trustom Pond was similar to that seen in other salt ponds, but many species which occur in the saltier ponds were missing in Trustom. Larvae of bottom-dwelling marine invertebrates, worms, clams, snails, barnacles are usually very abundant in salt pond plankton in spring and early summer, but were absent in Trustom samples (Table 2). Barnacles have been seen on rocks in the pond in some years (PF), but were not observed in 1992. The plankton community of Trustom Pond resembles that found in other intermittently breached coastal ponds

Table 1. Trustom and Cards Ponds, Water chemistry

POND	SITE*	STATION	DATE	TEMP °C	SALT PPT	N µM	P µM	CHLA µg/l	SECCHI M	DEPTH M	POND HEIGHT M	
Trustom	OFF	31	7-Mar-92	.	6	15.06	0.46	0.57	.	.	1.81	0.91
	ON	31	6-Apr-92	10	6	11.75	0.44	0.59	.	.	.	
	ON	31	4-May-92	15	6	3.94	0.10	0.77	1.9	2	1.81	
	ON	31	11-Jun-92	20	5	0.55	0.19	1.30	0.75*	2.5	.	
	ON	31	22-Jul-92	26	5	0.07	0.13	1.73	2.35*	2.35	1.50	
	ON	31	3-Aug-92	24.5	4	0.52	0.23	2.94	0.85*	2.15	1.44	
	ON	31	13-Sep-92	20	1	0.38	0.08	23.05	0.3	2.35	.	
	ON	31	24-Oct-92	12	2	0.91	0.53	31.71	.	1.25	1.54	
	ON	31	2-Nov-92	7.5	3	2.51	0.60	6.10	1.9	2.25	1.76	
	OFF	31	16-Dec-92	.	2.5	.	.	.	.	.	1.91	
Trustom	ON	32	4-May-92	15	5	3.26	0.29	0.68	.	.	1.81	
	ON	32	11-Jun-92	20	4	0.36	0.23	1.35	1.55	2.25	.	
	ON	32	22-Jul-92	26	5	0.25	0.33	3.88	1.3*	1.3	1.50	
	ON	32	3-Aug-92	25	4	0.29	0.28	2.23	0.6	1.9	1.44	
	ON	32	13-Sep-92	19	3	0.04	0.44	35.19	0.25	2.1	.	
	ON	32	2-Nov-92	7.5		1.54	0.30	7.97	1.6	1.95	1.76	
Cards	ON	33	7-Mar-92	.	0	35.32	1.64	3.31	0.5	0.5	.	
	ON	33	8-Apr-92	16	0	14.20	1.00	0.85	1.4	1.4	.	
	ON	33	1-May-92	14.5	2	11.91	0.78	1.22	1.1	1.1	.	
	ON	33	8-Jun-92	23	8	12.79	1.61	4.17	1	1	.	
	ON	33	29-Jul-92	26	10	0.55	0.48	27.48	0.8	0.8	.	
	ON (Surf)	33	22-Aug-92	20	0	8.47	1.94	17.37	1.1	1.1	.	
	ON (bottom)	33B	22-Aug-92	.	0	7.18	2.17	.	.	.	.	
	ON	33	22-Sep-92	21.5	9	0.78	0.55	20.92	0.8	0.8	.	
	ON	33	24-Oct-92	12	7	11.94	0.49	11.45	0.9	0.9	.	
	ON	33	4-Nov-92	9	6	16.10	0.87	5.81		1.41	.	

* On- At station marked on map
Off- from nearby shore location

* Secchi disk blocked by weed ^ Height from base of stake, plus elevation of base, 0.91 M above sea level

Table 2. Trustom and Cards Ponds, plankton observations

Trustom, Meadow Point (near Sta. 31)

Date	Type of sample	Salinity (ppt)	Phytoplankton: Overall abundance	Phytoplankton: Freshwater or marine forms	Phytoplankton: Distinctly marine forms	Phytoplankton: Distinctly freshwater forms	Zooplankton: Rotifers	Zooplankton: Copepods	Zooplankton: Cladocera (Freshwater)	Zooplankton: Marine invertebrate larvae	Zooplankton: Other
3/7/92	Net tow from shore	7	sparse	small flagellates pennate diatoms			*Synchaeta* and others (abundant)	*Eurytemora affinis* (abundant)			
5/2/92	1 liter from boat	4	sparse	small flagellates			*Synchaeta* (abundant)	*Eurytemora affinis* (some)			
6/16/92	1 liter from shore	4	sparse	small flagellates small centric diatoms small pennate diatoms							
7/22/92	Net tow from boat	4	sparse	small flagellates	*Chaetoceros* (diatom, rare)		*Synchaeta* and others (some)	*Eurytemora affinis* *Acartia tonsa* (abundant)			
9/19/92	1 liter from shore	0 5	very dense water yellow-green	small flagellates		large bloom of filamentou blue-green algae with heterocysts (tentatively identified as *Cylindrospermum sp.*)	*Brachionus calyciflorus* *Hexarthra sp* (distinctly freshwater forms, abundant)		Chydoridae (abundant)		
10/12/92	1 liter from shore	2	dense phototaxic cells swimming to top of jar			large brown cryptomonad very abundant *Cryptomonas ovata?* a few pennates abundant large brown ciliates, ~100 µm	unidentified rotifers *Hexarthra sp.*	*Eurytemora affinis* (some)			
11/15/92	1 liter from shore	2	sparse	small flagellates medium sized centric diatoms (*Coscinodiscus?*, *Stephanodiscus?*) pennates			unidentified rotifers	*Eurytemora affinis* abundant			
12/16/92	1 liter from shore	2 5	lots of very small cells	tiny green coccoid cells (Chlorella-like) tiny crescent-shaped cells				*Eurytemora affinis* common *Scottolana canadensis* (one seen)	Chydoridae (a few)		

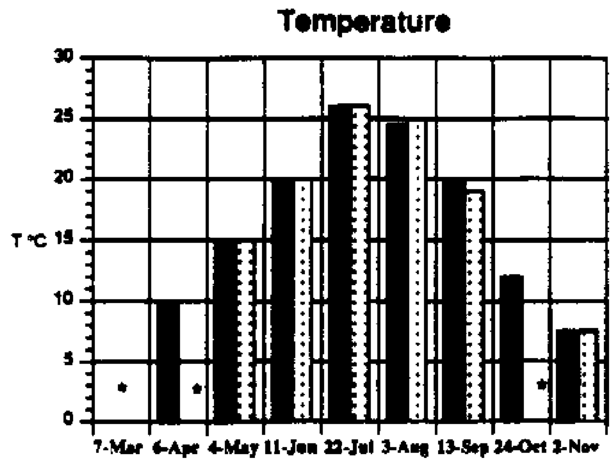
Table 2, continued. Cards, culvert between east and west ponds (Sta.33)

Date	Type of sample	Salinity (ppt)	Overall abundance	Freshwater or marine forms	Distinctly marine forms	Distinctly freshwater forms	Rotifers	Copepods	Cladocera (Freshwater)	Marine invertebrate larvae	Other
3/7/92	Net tow in current	0	abundant (much silt)	pennate diatoms		*Oscillatoria* (Blue-green algae) Colonial green flagellates Large solitary green flagellates	*Synchaeta* and others (some)	*Eurytemora affinis* (a few)			flatworms (some)
4/4/92	1 liter	4	abundant	cryptomonads (red or bluish flagellates) pennate diatoms (a few)	*Skeletonema* (centric diatom, some)	Colonial green flagellates Large solitary green flagellates		*Eurytemora affinis* *Scottolana canadensis* (abundant) *Acartia tonsa* (a few)		*Polydora* Worm larvae (very abundant) Barnacle larvae	
4/12/92	Net tow in current	0	abundant (much silt)			*Oscillatoria* (Blue-green algae) Colonial green flagellates Large solitary green flagellates	*Synchaeta* and others (abundant)	*Eurytemora affinis* (a few)			flatworms (some)
5/2/92	1 liter	2	abundant	small flagellates pennate diatoms (a few)		*Oscillatoria* (Blue-green algae) (a few)	*Synchaeta* (some)	*Eurytemora affinis* (abundant)		*Polydora* Worm larvae Barnacle larvae (some)	
6/16/92	1 liter	3	abundant	medium- size flagellates large unident flagellates (abundant)	*Thalassiosira* (centric diatom, abundant)			*Eurytemora affinis* *Scottolana canadensis* (abundant) *Acartia tonsa* (a few)			
7/22/92	Net tow in current	1	abundant (much silt, water green)	pennate diatoms (abundant)		*Scenedesmus* (desmid, very abundant) *Peridinium* (dinoflagellate, rare but large)	*Synchaeta* and others (abundant)	*Scottolana canadensis* *Acartia tonsa* (abundant)		Bivalve larvae (a few)	
9/19/92	1 liter	0	abundant	pennate diatoms (common)	*Skeletonema* (rare)	Medium-size green flagellates (abundant) *Pediastrum* (colonial green algae) *Oscillatoria* (Blue-green algae) (a few)	Unidentified rotifers	*Scottolana canadensis* (a few)			
10/12/92	1 liter	0	abundant	many small and large flagellates	*Thalassiosira* (centric diatom, abundant)	Many desmids: *Actinastrum* *Pediastrum* large cryptomonad colonial green flagellates *Pandorina?*	*Synchaeta* (abundant)	*Scottolana canadensis*	unidentified (one individual)		flatworms (many)

Table 2, continued. Cards, culvert between east and west ponds

Date	Type of sample	Salinity (ppt)	Overall abundance	Freshwater or marine forms	Distinctly marine forms	Distinctly freshwater forms	Rotifers	Copepods	Cladocera (Freshwater)	Marine invertebrate larvae	Other
11/15/92	1 liter (culvert)	4	abundant	large clear gymnodinioid dinoflagellates	*Thalassiosira* (centric diatom, chain-forming abundant) *Prorocentrum* sp.		*Synchaeta* (abundant)	*Scottolana canadensis* *Eurytemora affinis* (a few of each) *Acartia tonsa* (one)			
Cards, near breachway											
11/15/92	1 liter	6	abundant		*Thalassiosira* (centric diatom, chain-forming abundant) *Katodinium rotundatum* (abundant)		*Synchaeta* (abundant)				
12/16/92	1 liter	9.5	lots of detritus vey sparse		a few flagellates 1 pennate seen			*Eurytemora affinis* (common)			

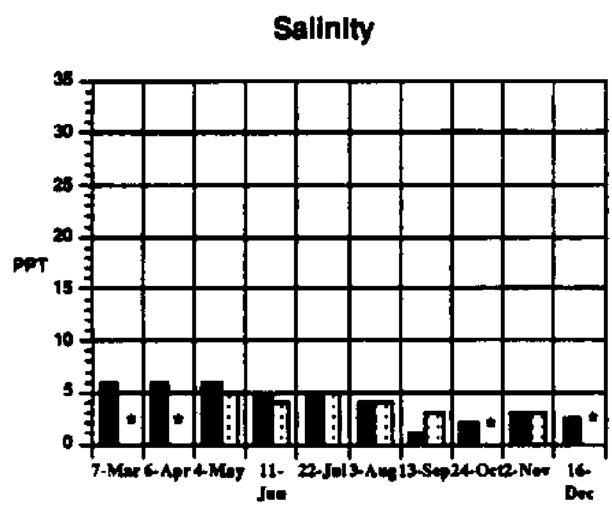
Figure 3. Trustom Pond Water Chemistry, 1992

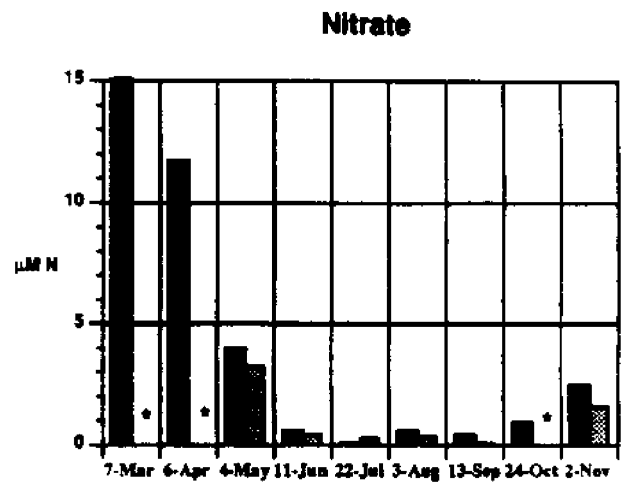


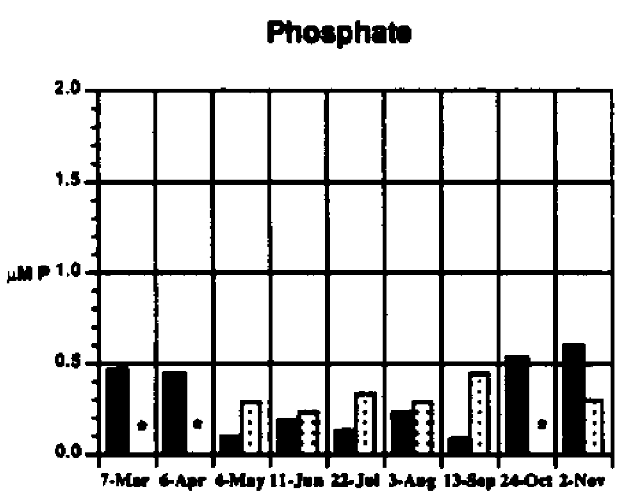
Trustom 31

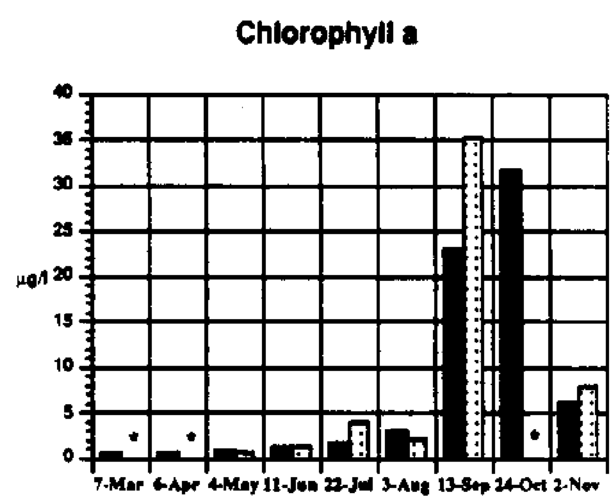
Trustom 32

* - Station not sampled









(Deevey 1948, Moss and Leah 1982) and in the upper reaches of river estuaries. Salinities in these environments are too low for the survival of most marine organisms, but usually too high for freshwater communities to develop, so. that lagoons and upper estuaries tend to be dominated by a few very adaptable species. Since estuaries and lagoons are rich in nutrients, the species which can survive here often become very abundant.

The temperature rose in May through August, reaching a maximum of 26°C. Pond height at the reference stake decreased from 1.8 m to 1.4 m. The salinity decreased from 6 to 4 ppt by August. Dense masses of sago pondweed (*Potamogeton pectinatus.*) grew in all parts of the pond; they were producing flowers and seeds in July This plant is abundant both in fresh and brackish waters. Roundleaf pondweed (*P. perfoliatus)* was found near shore. At times, the pondweed impeded rowing and obstructed the view of the Secchi disk. The water itself was relatively clear, and phytoplankton consisted mostly of relatively scarce small flagellates, although July's sample included a few marine diatoms (*Chaetoceros*). Chlorophyll concentrations remained low (0.8 - 3.9 μg/l). Zooplankton continued to be abundant, and an additional species of copepod (*Acartia tonsa)* was seen in July. With the abundant growth of rooted plants, nitrate and phosphate fell to low levels by July and August (0.07-.55 μM nitrate, 0.13 - 0.44μM phosphate).

In September, following heavy rains, the salinity fell to 1 - 3 ppt. The water was yellow-green and very turbid, with a Secchi disk depth of 0.25 - 0.30 m (about one foot) and chlorophyll a concentrations increased sharply of 23-35 μg/l) A water sample at this time contained a very dense growth of filamentous fresh water blue-green algae, tentatively identified as *Cylindrospermum* (Dr. Paul Hargraves, GSO), a species which also inhabits damp soil (Fogg et al. 1973). These algae had heterocysts, specialized cells which fix atmospheric nitrogen, and convert it to chemical forms which can be used by the algae for growth. The zooplankton was also dominated by distinctively fresh water forms, the rotifers, *Brachionus calyciforus* and *Hexarthra* sp and freshwater water-fleas (cladocerans), and the estuarine copepods *Acartia* and *Eurytemora* were not seen (Table 2), Algal blooms normally deplete nutrients to very low levels but this did not occur in a uniform fashion in Trustom Pond. Phosphate concentrations were especially low at Sta. 31 (0.08 μM) and nitrate was low (0.38μM). At station 32, nitrate was almost undetectable (0.04 μM), while phosphate was at medium levels (0.44 μM).

In the fall, temperatures in Trustom Pond fell sharply from 20°C in September to 12°C in October, and to 7.5°C in November. Salinity increased slightly to 2 - 3 ppt and pond height rose again, approaching the high levels of spring (Table 1.) The water in October was clearer than in September, but distinctly brownish, and chlorophyll concentrations continued to be very high (31.8 - 35.2 μg/l). The blue-green algae were gone, but high concentrations of large (30-40 μm) brown cryptomonad flagellates (probably a fresh water species) were seen. (Table 2). By November, water clarity had improved, with the Secchi disk visibility increasing to 1.9 m. A dieback of the pondweed was observed in November. Chlorophyll declined to 6.1-8.0 μg/l and the phytoplankton was now composed of small flagellates and centric diatoms. In October and November, *Eurytemora affinis* was found again in the zooplankton samples and fresh water rotifers were less abundant. Nitrate concentrations rose in October and November, reaching 1.5 - 2.5 μM by November. Phosphate increased to 0.60 μM by November at Sta. 31, but it remained at lower levels at Sta. 32. Increases in nutrient concentrations in fall are a normal occurrence, resulting from the declining uptake of nutrients and the decomposition of vegetation in and around the pond.

Trustom Pond was not breached during the sampling period from March through December 1992, The December 10-11 northeast storm did not breach the pond; washover and rainfall raised the pond level to 1.9 m (Table 1). Salinity was 2.5 ppt after the storm, compared to 3 ppt in November, so that the sea water added by the storm was roughly balanced by the input from the heavy rains.

Cards Ponds

Cards Ponds differ from Trustom Pond because they are strongly influenced by a stream and because the east pond is frequently breached, naturally by storms, and artificially by the Fish and Wildlife Service. The stream enters the shallow west pond and then flows under Moonstone Beach Road through a culvert (Sta. 33) into the deeper east pond where the breachway is located.

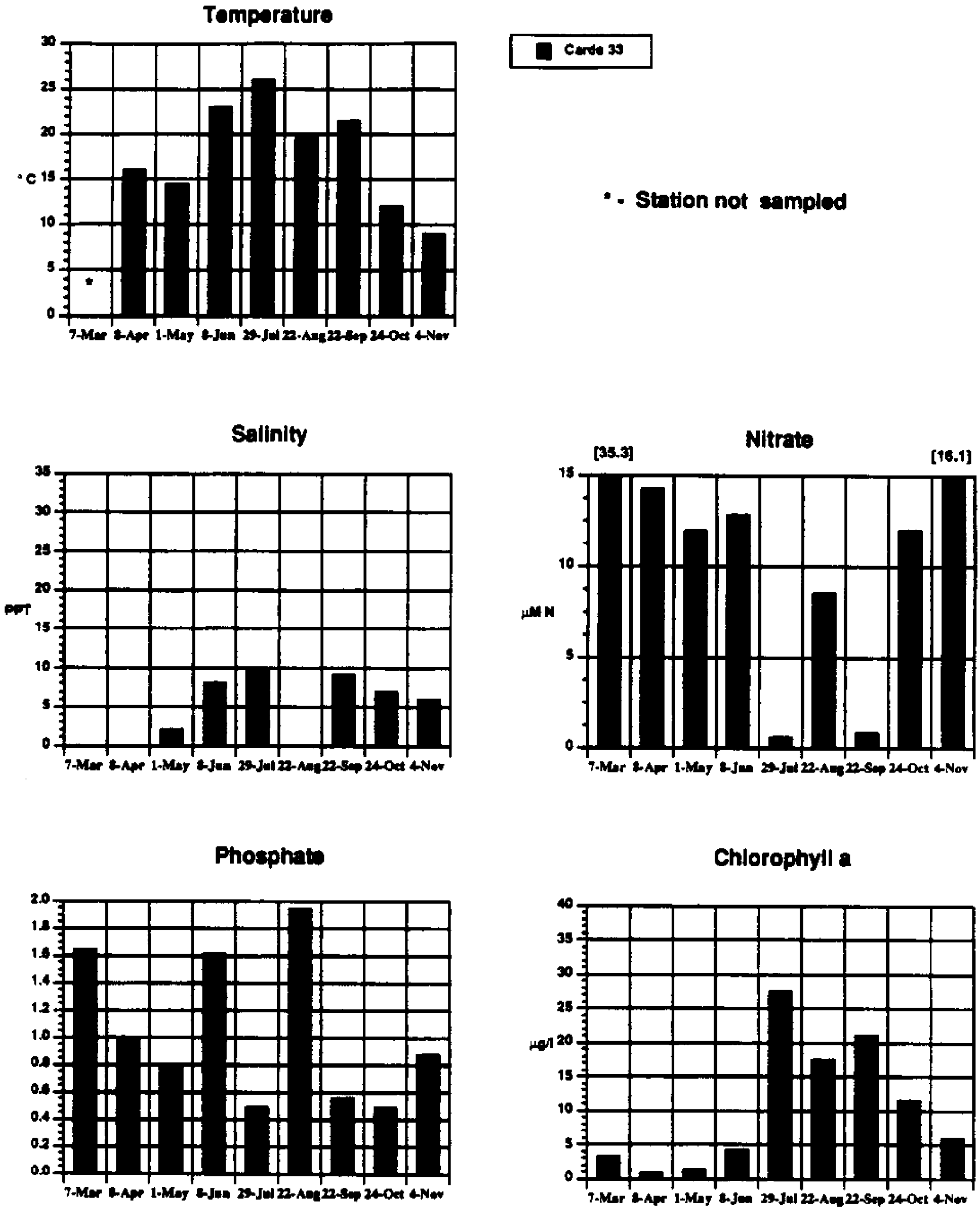
Cards Ponds had an open breachway and very low levels when it was first sampled in March. During most subsequent samplings, the breachway was closed, but the pond was breached 15 - 20 times during 1992 (David Houghton, Fish and Wildlife Service). When the breachway was open, the west pond was noticeably higher than the east pond and the stream through the culvert had a visible slope. On these occasions, the water was entirely fresh. Whether the breachway was open or closed, surface water flow through the culvert at the sampling site was always from west to east and appears to have been driven by gravity rather than tides. When the breachway was closed, water levels were higher and the water was frequently brackish. This was probably due to a compensating flow of saltier water creeping upstream from the west pond along the bottom (a "salt wedge").

In the spring, frequent breachings resulted in rapid fluctuations of water depth and salinity at the sampling site. On March 7 (breachway open) and April 8 (breachway closed), the water was fresh (Figure 4) , but a sample taken on April 4 (breachway closed) was 4 ppt (Table 2). On 12 April, the pond appeared to have been recently breached (Table 2), and the water was fresh , but in May through June the water was brackish again (2 - 8 ppt). .Temperatures were cool (14 - 16°C) in April and May and warmed to 23 °C by June. Chlorophyll concentrations were low to moderate in March - June (0.9-4.2 µg/l). The composition of the phytoplankton and zooplankton varied with the salinity of the water. Freshwater green algae were usually the most abundant forms, including several kinds of single-celled swimming flagellates and large spherical flagellate colonies (Volvocales), Especially in more brackish water, diatoms of the primarily marine and estuarine genera (*Skeletonema* and *Thalassiosira)* were also seen. Blue - green algae were present in small numbers; these consisted of non-segmented filaments without heterocysts, possibly *Oscillatoria*. Nitrate concentrations were very high in March (35 µM), and continued to be quite high through June, Phosphate also was quite high (0.8 - 1.6 µM) at this time.

Zooplankton, as at Trustom, consisted of a mixture of estuarine and freshwater forms. Rotifers were usually dominant, and consisted of many species of *Synchaeta* and some unidentified forms. Copepod larvae (nauplii) and occasional adults of *Eurytemora affinis* and *Scottolana canadensis* were found in most samples. *Eurytemora* and *Scottolana* are estuarine forms which can live and breed both in fresh water and full sea water. Another estuarine copepod, *Acartia tonsa*, was found in April, and again in June, but only in water which was detectably brackish. Larvae of a an estuarine polychaete worm, *Polydora*, were extremely abundant (thousands per liter) in a sample taken on April 4 at 4 ppt. Larvae of other bottom-dwelling invertebrates, including a barnacle (*Balanus improvisus*), and a clam (probably *Macoma balthica*) were found at salinities of 1 - 4 ppt, but not in fresh water. These animals cannot survive long or complete their life cycles at salinities much below 5 ppt (Remane and Schleiper 1974), so the adults probably inhabit deeper, saltier waters in the east pond. Dead adult barnacles were noted on the rocks around the culvert but no living barnacles were seen.

Water temperatures rose to 26°C in July, and salinity at the culvert increased to 10 ppt. Chlorophyll concentrations increased sharply to 27 µg and remained high through

Figure 4. Cards Pond Water Chemistry, 1992



October. Desmids and *Pediastrum* (non-swimming fresh water colonial algae) were the dominant phytoplankton during this period (Table 2). These forms are characteristic of a nutrient-rich freshwater phytoplankton community (Reynolds (1984). In July, nitrate and phosphate fell to low concentrations (0.6 and 0.5 μM). During heavy rains in August the salinity fell to zero, and nutrients increased (8.47 μM nitrate, 1.94 μM phosphate), probably because of high inputs from runoff. In September nitrate and phosphate fell to levels close to those in July. As water temperature declined to 9 -12 °C in October and November, and phytoplankton abundance declined, nitrate concentrations increased again.

The pond was breached quite dramatically by the December 10-11 storm. Although breaching caused the pond level to fall sharply, the stream flow in the culvert between the east and west pond was torrential and heavily laden with silt when observed on December 13.

Discussion

Trustom and Cards Ponds lack a continuous connection to Rhode Island Sound and so differ sharply from most other salt ponds on the south coast of Rhode Island in salinity, temperature, nutrients, and in their plant and animal communities. The six major salt ponds, Point Judith, Potter, Green Hill, Ninigret, Quonochontaug, and Winnapaug, have stabilized breachways and salinities ranging from 20 to 30 ppt, while Block Island Sound ranges from 31-33 ppt. The degree of exchange with the Sound and the input of nutrient-rich ground water and runoff are major factors controlling nutrient concentrations in the ponds. Green Hill Pond, with high freshwater input and restricted exchange with the Sound (through Ninigret Pond) has the lowest salinity and high nitrate concentrations, while southern Point Judith Pond and Quonochontaug Pond resemble Block Island Sound in having relatively high salinity and low nitrate levels. Figure 5 compares salinity, nitrate, phosphate, and chlorophyll levels at Trustom (Sta. 31), Cards (Sta. 33), Green Hill (Sta. 10), and Quonochontaug (Sta. 16A) in 1992. Differences in seasonal nutrient and chlorophyll patterns among the ponds will be discussed in later sections.

Plant and animal communities, both on the pond bottom (benthos) and in the water column (fish and plankton) in Trustom and Cards Ponds also differ greatly from those in the other salt ponds. Bottom plant communities in the saltier ponds are now dominated by eelgrass (*Zostera marina*) and red and green marine algae, these ponds also support quahogs, scallops, and even lobsters (in Point Judith and Quonochontaug Ponds). Plankton communities in these ponds are dominated by marine diatoms (Thomas 1970), and by the copepods *Acartia hudsonica* and *Acartia tonsa* (Jeffries 1955). Most of these organisms, with the exception of *Acartia tonsa*, cannot survive the low salinities in Trustom and Cards Ponds. To a large degree, the biological differences among the ponds result from the construction of permanent breachways in the larger ponds.

Before the stabilization of the breachways, plant communities in all of the ponds were dominated by widgeon grass (*Ruppia maritima*)(Thorne-Miller et al. 1983) The fisheries were dominated by oysters and white perch, species which are favored by low salinities (Lee 1980). Cards and Trustom Ponds have also changed. In the nineteenth century these ponds were frequently breached artificially in order to maintain optimal salinities for perch and oysters (Lee 1980). More recently, Trustom Pond was breached once a year by the Fish and Wildlife service in order to provide feeding and breeding areas for birds, but this breaching has been curtailed in recent years in order to reduce disturbance to least terns and piping plovers on the barrier beach. Less frequent breaching has resulted in lower salinities in Cards and Trustom Ponds, resulting in the disappearance of most marine species including oysters and barnacles and a decrease in abundance of white perch. Since the ponds now function primarily as a waterfowl refuge, the loss of shellfish and diverse benthic organisms is not a great concern. However, the freshening of the ponds has eliminated many invertebrate species, such as small bivalves and polychaetes which are potential foods for diving ducks and shorebirds. The decline in salinity may have caused pondweed to in crease at the expense of widgeon grass (Thorne-Miller et al. 1983). Widgeon grass is considered a more desirable food for waterfowl (D. Houghton, FWS). The reduced salinity in the ponds also permitted blooms of fresh water algae in Trustom Pond in 1992. Potentially, this could result in decreased growth of aquatic plants and a lower food supply for waterfowl. The brackish conditions of the ponds has been very favorable to the spread of the introduced reed *Phragmites australis*, which now grows in dense stands along the shore, replacing native marsh plants which are more desirable as food for wildlife (Hellings and Gallagher 1992).

Nutrient and Phytoplankton Dynamics- Some General Features

Much of the nitrate and phosphate in Trustom and Cards Ponds comes from the surrounding watershed, from septic systems, fertilizers and the feces of birds and animals. Routes of nitrogen and phosphorus transport into the ponds include ground water, streams (especially Cards), and direct runoff. Some nitrate is added directly to the ponds in the form of nitrogen oxides (smog-forming compounds) in rainfall. Ducks, geese, and swans in the ponds are potentially a major source of organic nitrogen and phosphate. Nutrient concentrations in aquatic ecosystems are controlled as much by biological cycles of growth and uptake as by inputs. The graph of nitrate concentration in Figure 5 shows that this nutrient is sharply reduced during the growing season at the different salt pond stations. At the same time, great differences among the ponds in the patterns of nutrients and chlorophyll can be seen, reflecting differences in the watershed, the degree of fresh water input and exchange with the Sound, and the biological communities in the ponds.

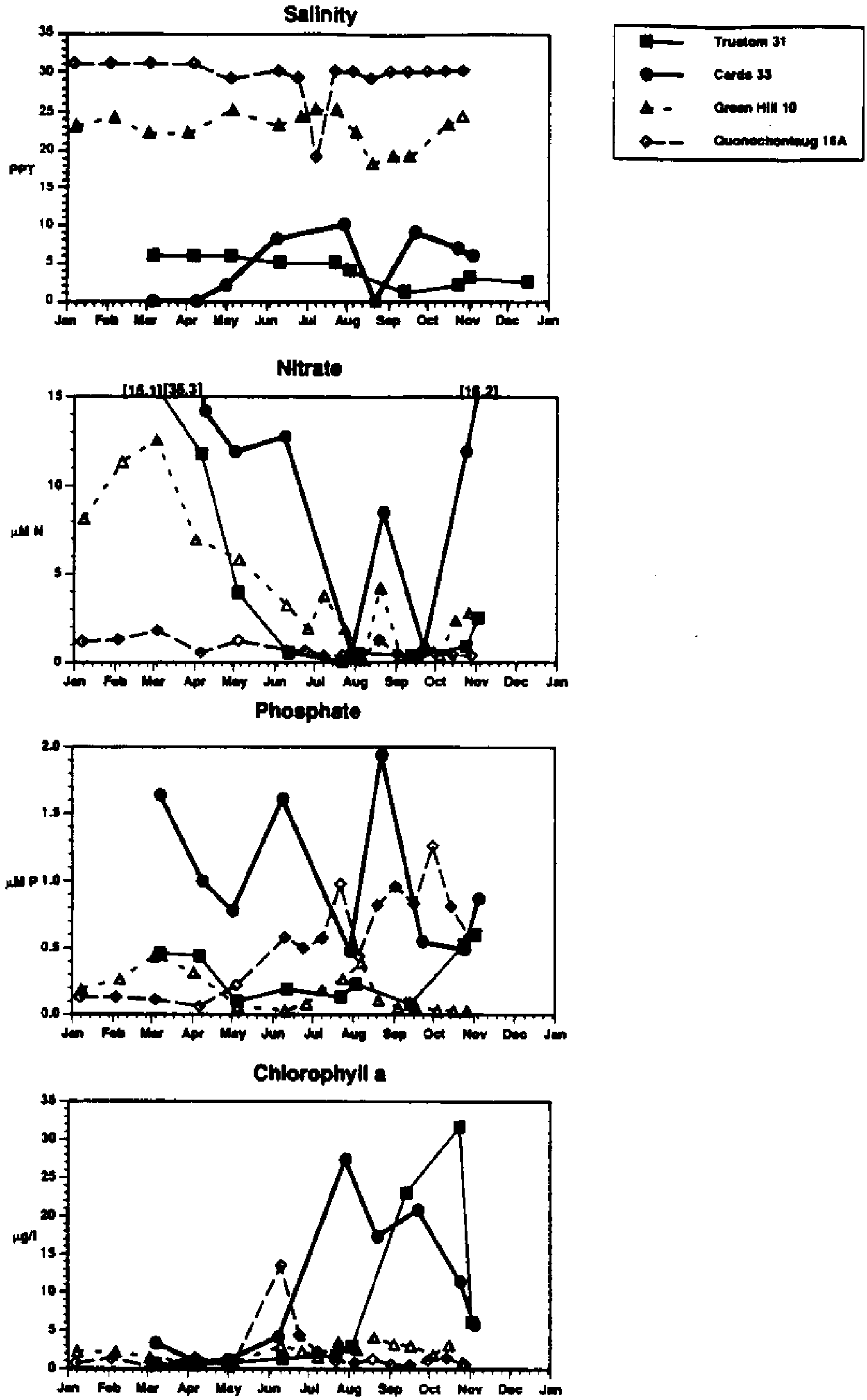
Nutrient and Phytoplankton Dynamics- Trustom Pond

Trustom Pond, as noted earlier, receives most of its fresh water from ground water. Much of the nitrogen and phosphorus entering the pond comes from this source. Nixon et al. (1982) estimated that Trustom Pond received 7,000 lbs of nitrogen per year from its watershed, (or 43 pounds per acre of pond surface), of which 90% came from ground water. About 1000 lbs or nitrogen were estimated to come from direct precipitation. 31% of the nitrogen input was estimated to come from residential sources, with 55% from agricultural fertilizers and manure. Trustom Pond had a lower loading of nitrogen (per unit area) than Point Judith, Green Hill, Potter, or Cards Pond. About 200 houses have been built in the watershed since this study, but development in the Trustom watershed remains sparse compared to that in the other ponds.

Bird droppings may be a major source of both nitrate and phosphate in Trustom Pond. Guano has been implicated as the primary cause of algae blooms in an English coastal lake which serves as the roosting site for several hundred thousand gulls (Moss and Leah 1982). Bird droppings would add organic nitrogen to the water which our present analyses would not detect directly, but some of this nitrogen is oxidized to nitrate. Counts of birds, especially swans and Canada geese would be useful in order to quantify this source of nutrients.

In Trustom Pond, the dominant bottom plants in 1980 were sago pondweed, *Potamogeton pectinatus*. and widgeon grass (*Ruppia maritima*) Thorne-Miller et al. (1983). *Ruppia* was not seen in a casual collection of plants made in July 1992, but a more thorough survey is needed. The rapid fall in nitrate concentrations in Trustom Pond in spring , and the low chlorophyll levels through the summer suggests that until September, most of the nitrate in the ponds was being utilized by the rooted plants; little of it was going to the phytoplankton. *Potamogeton* rapidly takes up nitrate from

Figure 5. Comparison of water chemistry among selected salt pond stations, 1992



estuarine water (Caffrey and Kemp 1992). Several factors could have shifted the balance to favor blue-green algae in September. Nitrogen-fixing planktonic blue-green algae are rare in seawater, and fresh water species are inhibited by low levels of salinity (Paerl 1988). A fall in salinity due to heavy rains in August may have allowed the blue-greens to thrive. In freshwater lakes, blooms of nitrogen-fixing blue-green algae commonly occur when other plants have reduced nitrate and ammonia to low levels. Since blue-greens are capable of fixing atmospheric nitrogen, they can continue to grow and out-compete other plants. The bloom disappeared by mid-October, possibly because it ran out of phosphorus , or because of changes in the weather. Several cold fronts passed through in late September, which brought a sharp drop in temperature and strong winds which may mixed the water column. Many blue-green algae grow poorly at low temperatures and are sensitive to turbulence (Reynolds 1984, Paerl 1988)

Blue-green algae blooms in Trustom Pond are of concern for several reasons. They are considered an indicator of eutrophication in freshwater lakes (Reynolds 1984). The pea-soup color of the water during the bloom in September detracted from the aesthetic qualities of the pond. Blooms greatly reduce light penetration, and may affect growth of the pondweed, which is the major food source for waterfowl in the pond. Some species of blue-green algae are toxic and have been known to produce illness or death in animals and humans drinking water (Edler et al. 1984). A literature search found no references for such toxicity in *Cylindrospermum*. No signs of ill effects to fish or other wildlife were seen in September (D. Houghton, telephone conversation). Blue-green algae filaments are difficult for grazing animals to eat, so a dying bloom is largely consumed by bacteria, which may result in foul odors and decreased oxygen levels, sometimes leading to fish kills. The timing of the September bloom was fortunate, since the onset of cool and windy weather probably cut the bloom short and also prevented low-oxygen conditions during the decline of the bloom. A similar bloom early in the summer might have persisted for months and could have had severe effects on vegetation and fish.

Other types of algae, cryptomonads and diatoms, remained abundant in October and November. While the species that were seen may have been characteristic of fresh water, algae of these groups are found in both fresh water and marine systems, so the October blooms cannot be specifically attributed to low salinity. These species may have used nutrients released by the dying blue-green bloom, by the fall die-back of rooted vegetation, and by migrating waterfowl. Although chlorophyll concentrations during the October cryptomonad bloom equaled those of the earlier blue-green bloom, the later blooms had less effect on water color and transparency. Cryptomonads and diatoms are readily grazed by aquatic animals, so these blooms are less persistent and troublesome than those of blue-greens. (Reynolds 1984)

Breaching of Trustom Pond would have several beneficial effects, including maintaining marine invertebrate communities as food for waterfowl, and discouraging the growth of blue-green algae and other noxious fresh water phytoplankton. These benefits must be weighed against the negative effects, which include disturbance to shorebirds and the shoaling of the pond due to the washing-in of sediments. If nutrient inputs to the ponds increases, blooms of noxious marine algae may occur in spite of breaching.

Nutrient and Phytoplankton Dynamics- Cards Ponds

Cards Ponds are fed by a small but permanent stream which adds about 10% of the total 5815 lbs entering the ponds. (Nixon et al. 1982). 85% of the nitrogen entering the ponds comes from ground water, and 3% each from direct rainfall and storm runoff. In 1980, 39% of nitrogen inputs were estimated to come from residences, while 55% were agricultural (Olsen and Lee 1985). Of five salt ponds studied by Nixon et al. (1982), Cards had the highest nitrogen loading (114 lbs per acre), nearly three times that of Trustom Pond. Cards Pond also had the highest fecal coliform concentrations, well above SB safety limits for swimming and boating, indicating substantial sewage inputs .

Since our sampling station is located on a stream feeding into the main pond, our data show strong influence of stream flow. When the breachway is open, the culvert station is basically an extension of Cards Pond Brook. Even when the breachway is closed, the surface flow is fairly rapid through the culvert between the east and west pond. In early spring and late fall, high nitrate levels were high, reflecting both high stream flow and minimal plant growth. Nitrate and phosphate concentrations were lower in July and September, probably as a result of increased plant uptake at higher temperatures, heavy rains resulted in high nitrate and phosphate levels in August. The high nutrient concentrations reflected both high inputs from runoff and rapid flushing of the small west pond. (Similar but smaller nitrate spikes occurred in many other salt pond stations at this time, Figure 5.) When the volume of a body of water is small relative to its inflow and outflow, the water is replaced before its nutrients can be depleted or phytoplankton can build up (Reynolds 1984). We expect lower nutrient concentrations and higher phytoplankton abundance in the east pond compared to the sampling location at the culvert because of the slower turnover of water there.

The phytoplankton at the Cards culvert were dominated by fresh water green algae, most of which are favored by high water temperatures and high nutrient levels. (Reynolds 1984). Blue-green algae were seen in Cards Pond, but the species found there were not abundant and not known to be nitrogen-fixers. Algae in Cards Pond had an ample nitrogen supply most of the time, so nitrogen fixing species would not have had a great advantage over other species. In the saltier west pond, a greater proportion of marine species is expected, as well as greater overall abundance.

We have not had an opportunity to sample the west pond, so we have not been able to asses the effects of the breachings which occurred during the sampling season.

Recommendations for Future Monitoring

The first year of sampling by the AMC Salt Pond Watchers has produced data which will be useful for the management of Cards and Trustom Ponds. We believe that this monitoring should be continued. We offer several suggestions for future monitoring.

Trustom

1. Monthly sampling should continue through the winter (December through March, ice permitting) at one shore station (Meadow Point, near Sta. 31).

2. When algae blooms occur, a live sample should be taken to URI for identification by an algal taxonomist . A jar should be kept in the sampling kit for this purpose.

3. Since birds may be an important nutrient source in Trustom pond, the AMC group should try to organize a group of experienced birders (perhaps in conjunction with the Audubon Society) in order to make monthly bird counts at the time of .of sampling. Careful counts might be of use to the Fish and Wildlife Service for general management purposes.

4. The AMC group should contact Prof. Marilyn Harlin (URI-Botany) in order to discuss the possibility of a survey of aquatic plants in Trustom Pond, and to discuss ways of assessing the health of plants in the pond.

Cards

1. Monthly sampling should continue through the winter (December through March) at the culvert.

2. Since there are indications of stratified flow at the culvert, surface and bottom use of a bottom sampler should be considered at times when the pond is unbreached and water levels at the culvert are high. Bottom water would be flowing from the east pond and would be an indicator of conditions there. Several pond watchers have been building home-made water samplers which could be used.

3. The AMC volunteers should consider a survey of possible nutrient sources along Cards Pond Brook.

Recommendations for Management

1. Volunteer monitoring should continue for several years in order to provide data on water quality and the effect of any management changes.

2. Trustom Pond should be breached artificially at least once a year, especially if the pond has not been breached naturally by storms, in order to reduce water column nutrient concentrations , maintain salinities above tolerance limits for bloom -forming, blue-green algae, and permit growth of estuarine invertebrates as food for waterfowl and wading birds. Increased salinity may also discourage the growth and spread of the reed *Phragmites* along the shore (Hellings and Gallagher 1992) and increase the proportion of widgeon grass in the vegetation.. Timing and location of the breaching will be determined by the need to minimize disturbance to nesting birds.. Early spring (March or early April) is probably best. A second breaching in September would be beneficial both for water quality, and for feeding of migrating shorebirds. Breaching of Cards Pond should continue.

3. Encourage research related to ecosystem management in Trustom and Cards Ponds.