EVALUATION OF THE REMOVAL OF TREATED MUNICIPAL EFFLUENT ON WATER CHEMISTRY AND THE ABUNDANCE OF SUBMERSED VEGETATION IN KINGS BAY - CRYSTAL RIVER, FLORIDA

By

JULIA H. BISHOP

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Abstract of Thesis Presented to the Graduate School
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EVALUATION OF THE REMOVAL OF TREATED MUNICIPAL
EFFLUENT ON WATER CHEMISTRY AND THE ABUNDANCE OF SUBMERSED
VEGETATION IN KINGS BAY - CRYSTAL RIVER, FLORIDA

By

Julia H. Bishop

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Chairman: Daniel E. Canfield, Jr.
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Treated municipal wastewater effluent was removed from a 16-hectare (40-acre) cove in Kings Bay called Cedar Cove in March, 1992 in an attempt to reduce both ambient nutrient concentrations (total phosphorus and total nitrogen) and the abundance of submersed aquatic plants in Kings Bay. Elimination of the treated municipal effluent from Cedar Cove did not significantly reduce total phosphorus and total nitrogen concentrations in Kings Bay. Mean total phosphorus concentration in Kings Bay prior to the removal was 26 μg/L and after the removal was 28 μg/L. Mean total nitrogen concentrations prior to and after the removal in Kings Bay were 310 μg/L and 270 μg/L, respectively. Total phosphorus and total nitrogen concentrations, however, were significantly reduced in the immediate area of the discharge. Mean total phosphorus concentration in Cedar Cove prior to the removal was 105 μg/L and after the removal was 27 μg/L. Mean total nitrogen concentrations in Cedar Cove prior to and after the removal were 620 μg/L and 220 μg/L, respectively. A tidal storm, which had 45 to 60 km/hr (75 to 95 mph) winds and caused extensive flooding in the area, hit Kings Bay in March, 1993. The tidal storm caused elevated nutrient concentrations throughout the bay. Specific conductance one week after the "No-Name Storm" was higher than previously recorded maximum levels at fifteen of seventeen stations. Total phosphorus concentrations were higher at each station and total

nitrogen concentrations were higher at 16 of 20 stations. There were no significant changes in the abundance of tapegrass (*Vallisneria americana)* and filamentous algae (*Lyngbya* sp.) during the study in either Kings Bay or Cedar Cove. Hydrilla (*Hydrilla verticillata)* abundance was significantly reduced and the abundance of eurasian watermilfoil (*Myriophyllum spicatum*) was significantly increased in both Kings Bay and Cedar Cove between the pre- and post-removal periods. However, significant changes in the abundance of these submersed species are attributed to changes caused by the "No-Name Storm" on March 13, 1993, not the removal of the treated wastewater from Cedar Cove. Results from this study support the contention that further nutrient control is not a viable option in attempting to reduce or control the submersed aquatic vegetation in Kings Bay and that the southern and northern portion of Kings Bay seem to function as two independent water bodies. Finally, a long-term continuous monitoring program is needed, especially during tidal storm events, before the dynamics of the water chemistry and abundance of submersed vegetation in both Kings Bay and Cedar Cove can be better understood and appreciated.

INTRODUCTION

Submersed vegetation in tidally influenced, spring-fed Kings Bay represents a significant plant management problem for Citrus County and the City of Crystal River. Dense growths of submersed vegetation, especially hydrilla (*Hydrilla verticillata*) and lyngbya (*Lyngbya* sp.) restrict navigation and recreational uses in Kings Bay unless controlled. In 1960, hydrilla was introduced into Kings Bay (Gallager and Haller 1978; Joyce 1990) and has subsequently become the dominant macrophyte species. A filamentous blue-green alga, lyngbya, is also established in portions of Kings Bay and has recently (1985) replaced hydrilla in some areas of the bay.

The City of Crystal River operated a 2.84 million liters per day (0.75 million gallons per day) wastewater treatment plant which discharged treated municipal effluent into a 16-hectare (40-acre) cove of Kings Bay, called Cedar Cove (Figure 1). Total phosphorus and total nitrogen concentrations were a magnitude greater in Cedar Cove than in Kings Bay during the period of discharge (Romie 1990). Nearhoof (1989) suggested that the plant community in Cedar Cove had undergone a shift from tapegrass (*Vallisneria americana*) to hydrilla to lyngbya. It was recommended by two state agencies, the Southwest Florida Water Management District and the Florida Department of Environmental Regulation, that the treated wastewater effluent be diverted from Cedar Cove for the improvement of water quality in Kings Bay (Romie 1990) and to restore Kings Bay to its natural vegetative community (Nearhoof 1989). In March 1992, the City of Crystal River removed the treated municipal effluent from Cedar Cove by utilizing upland spray disposal.

The elimination of nutrient inputs from the municipal treatment plant has been viewed as the keystone solution for the control of the dense growths of submersed

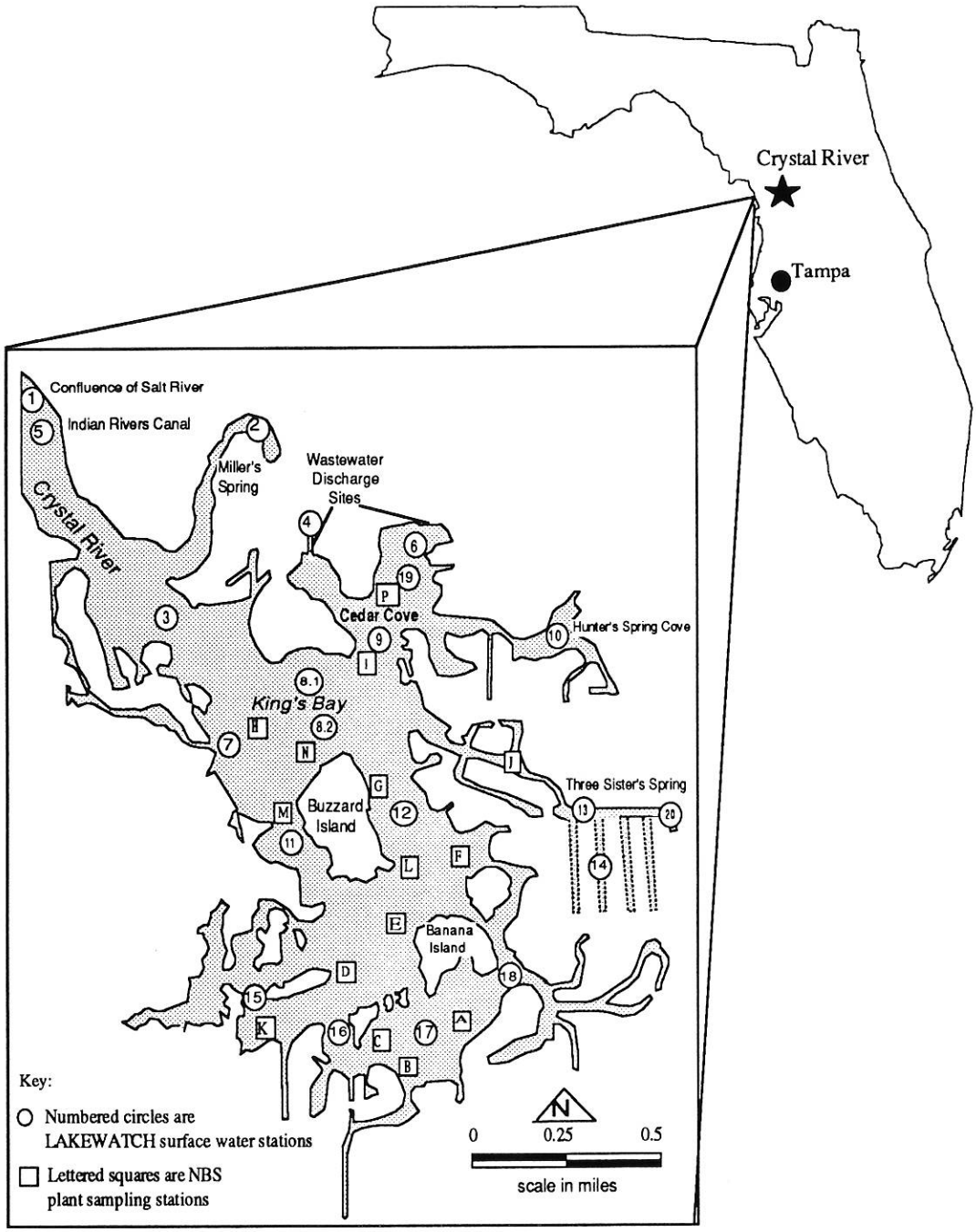

Figure 1. Location of Kings Bay, Cedar Cove, and Crystal River in the State of Florida. Location of LAKEWATCH surface water sampling stations and National Biological Service (NBS) plant sampling stations.

vegetation in Kings Bay by many who live and work in Crystal River. The management practice of reducing or eliminating a nutrient influx is commonly recommended as a method of reducing the abundance of phytoplantkon in lakes. The growths of aquatic vegetation to nuisance levels in some northern streams has been linked to the deterioration of water chemistry resulting from eutrophication (Wong and Clark 1976; Wright and McDonnell 1986a; 1986b). However, the efficiency of nutrient removal for the control of aquatic vegetation in rivers and streams is unknown. There is strong evidence that suggest other factors such as light availability rather than nutrients are the primary factor limiting aquatic vegetation in streams like Crystal River (Canfield and Hoyer 1988; Casey and Westlake 1974; Kern-Hansen and Dawson 1978; Dawson and Kern-Hansen 1978; 1979). Hence, attempts to reduce nutrient concentrations in Kings Bay may not sufficiently reduce nutrient concentrations and thus may not reduce the abundance of aquatic vegetation.

My objectives were to determine 1) whether the removal of the City of Crystal River's treated municipal effluent significantly reduced ambient nutrient concentrations (total phosphorus and total nitrogen) in Kings Bay; and 2) whether the removal has altered the abundance of submersed vegetation (exotic macrophyte species such as *Hydrilla verticillata* and *Myriophyllum spicatum*, native macrophyte species such as *Vallisneria americana* and filamentous algae such as *Lyngbya* sp.) in Kings Bay.

METHODS

Water Chemistry

Background

The Southwest Florida Water Management District (SWFWMD) conducted a study in 1990 to address citizen concerns that the discharge of treated effluent into Cedar Cove may be affecting water chemistry and causing excessive growths of submersed aquatic plants (e.g. *Hydrilla verticillata* and *Lyngbya* sp.) in Kings Bay. Based on recommendations from this study the discharge of treated municipal effluent into Cedar Cove was stopped in March 1992 to reduce nutrient loading to Kings Bay.

After the removal of the treated municipal effluent, SWFWMD had limited funds to continue a long-term water chemistry monitoring program in Kings Bay. SWFWMD and concerned citizens from Crystal River contacted the University of Florida's LAKEWATCH program and asked that a volunteer citizens' water chemistry monitoring program be established. The Coastal Rivers Basin Board of the SWFWMD subsequently provided funding to the University of Florida's LAKEWATCH program and a cooperative water chemistry monitoring program was established.

Under the auspices of the University of Florida's LAKEWATCH program, I trained fifty-seven volunteers from the local area in the summer of 1992 to collect surface water samples, to filter water for chlorophyll analysis, and to record Secchi disc readings. Two of these trained volunteers were assigned to each of the twenty-one sampling stations established throughout Kings Bay (Figure 1).

Field Procedures

Surface water samples were collected once a month on a low, out-going tide from August 1992 through May 1994. Because there were citizen concerns regarding possible differences in water chemistry concentrations between high and low tides in Kings Bay andbecause the University of Florida's LAKEWATCH program is designed to address citizen concerns, the number of stations sampled was reduced from twenty-one stations sampled on only a low tide to ten stations sampled both on a high and low tide from June 1994 through July 1994. Water samples were collected by citizen volunteers from just below the surface (0.5 m) using acid-washed, triple-rinsed, 250-ml Nalgene bottles. Samples were then placed on ice. Volunteers also collected additional surface water at each sampling location in 4-L tap-water rinsed, plastic jugs and measured water clarity at each sampling location with a 20-cm white Secchi disc.

After returning to shore, volunteers obtained a measured volume of water from the 4-L jugs and filtered the water through a Gelman Type A-E glass fiber filter to estimate the chlorophyll concentration at each sampling station. Filters were then stored over silica gel desiccant and frozen. Frozen water samples and filters were transported to the University of Florida's LAKEWATCH laboratory usually within 24 hours of sampling.

Additional Sampling

During the sampling period, a catastrophic storm event, referred to as the "No-Name Storm" by the media, caused extensive flooding in the City of Crystal River on March 13, 1993. The "No-Name Storm" coincided with the scheduled water sampling by LAKEWATCH volunteers. Because of the amount of damage caused by the storm, it was impossible for volunteers to perform their routine monthly sampling. I, therefore, sampled on March 18, 1993. After evaluation of the study site, it became clear that the "No-Name Storm" was probably going to alter many of the results for the month and possibly for many months. In fact, the effect of tidal storms on water chemistry and plant communities

in systems such as Kings Bay is largely unknown. The "No-Name Storm", thus, provided an opportunity to evaluate the effect of tidal storms on water chemistry in Kings Bay.

I collected water samples as previously described from all twenty-one sampling stations at approximately weekly intervals after the tidal surge for 13 weeks from March 18, 1993 through July 1, 1993. During this sampling time, the Florida LAKEWATCH volunteers continued their routine monthly sampling. Samples were placed on ice and transported to the University of Florida's LAKEWATCH water chemistry laboratory.

Laboratory Procedures

Water samples collected in the 250-ml bottles were analyzed for total phosphorus and total nitrogen concentrations. Total phosphorus concentrations (µg/L) were determined by using the procedures of Murphy and Riley (1962) with a persulfate digestion (Menzel and Corwin 1965). Total nitrogen concentrations (µg/L) were determined by oxidizing water samples with persulfate and determining nitrate-nitrite with second derivative spectroscopy (Crumpton et al. 1992). A total nitrogen equivalency study of nitrogen in surface waters demonstrated that this method is a suitable substitute for the standard USEPA method involving the sum of nitrate-nitrogen and Kjeldahl-nitrogen as measured with an automated analyzer (Sylvia S. Labie, Administrator, Florida Department of Environmental Regulation Quality Assurance Section, 1991). Specific conductance (µS/cm @ 25 °C) was measured from the weekly water samples collected in the 250-ml, bottles using a Yellow Springs Instrument Model 31 conductivity bridge within 24 hours of sampling. Chlorophyll concentrations (µg/L) were determined spectrophotometrically following pigment extraction with acetone (Method 10200 H; APHA 1989).

Submersed Vegetation Abundance

Background

Frequency of occurrence of submersed vegetation has been recorded bimonthly at fifteen stations in Kings Bay since April 1979 (with the exception of June 1983 to November 1985) by the National Biological Service (NBS; formally the U. S. Fish and Wildlife Service) Sirenia Project. Total biomass of submersed vegetation was recorded in Kings Bay between September 1980 and August 1981 and between April 1989 and March 1990 (Haller et al. 1983; Cowell 1990).

Field Procedures

Between April 1993 and August 1994, thirty sampling stations were sampled monthly. At each station, all species of aquatic macrophytes were recorded, a 0.25-m^2 quadrat was randomly dropped and divers removed all vegetation present within the quadrat. The sampled vegetation were then spun in nylon mesh bags to remove excess water and weighed to the nearest 0.1 kg.

Statistical Analyses

To determine if there were any changes in the water chemistry of Kings Bay as a result of the removal of the treated municipal effluent, mean values for each measured water chemistry parameter were determined for the period of record before and after the removal of the effluent. To obtain the appropriate mean values, concentration values reported for each station during a given month were averaged to provide a system-wide average monthly value. If there were multiple values for any sampling station during a given month, these values were averaged to produce a single value for that station. The system-wide monthly values prior to the removal of the treated municipal effluent were then averaged to produce a pre-removal average concentration value for each measured water chemistry parameter and the same was done for the post-removal period. Statistical

comparisons between mean values for total phosphorus and total nitrogen concentrations in each data set were done using a Student's t-test. To satisfy the assumption of normality, all data were transformed to base 10 logarithms prior to analysis. When assumptions of the Student's t-test were violated, the non-parametric Wilcoxon rank-sum test for data not normally distributed or the Welch Anova F-test for data with unequal variances were also used. All statistical analyses were performed using JMP (SAS Institute, Inc. 1994), a statistical software package for Apple Macintosh computers. Appropriate mean values were also calculated using the same methods described above for evaluation of water chemistry (specific conductance, total phosphorus and total nitrogen concentrations) in Kings Bay prior to and after the "No-Name Storm".

To determine if there were any changes in frequency of occurrence of all species (submersed vegetation regardless of species), exotic species (*Hydrilla verticillata* and *Myriophyllum spicatum*), native species (*Vallisneria americana*), and filamentous algae (*Lyngbya* sp.) in Kings Bay as a result of the removal of the treated municipal effluent, the data collected by the NBS were divided into two periods, pre-removal (data collected prior to March 1992) and post-removal periods (data collected after March 1992). Mean values for each measured plant group were determined for the period of record before the removal and after the removal of the effluent. To obtain the appropriate mean values, the same procedures discussed above were used with the exception that in order to satisfy the assumption of normality, the frequency of occurrence data were transformed using arcsin transformations. Appropriate mean values were also obtained using the same methods described above for evaluation of submersed vegetative communities in Kings Bay prior to and after the "No-Name Storm". The $p \leq 0.05$ level of significance was used in all tests of significance.

RESULTS AND DISCUSSION

Water Chemistry

Site Description

Kings Bay is located on the west coast of Florida 70 miles north of Tampa (Figure 1) and has a surface area of approximately 240 hectare (600 acres). With over thirty freshwater springs, Kings Bay discharges an estimated 25 cubic meters per second (916 cubic feet per second) down Crystal River. Crystal River flows 10 kilometers (6 miles) north-west into the Gulf of Mexico (Rosenau et al. 1977).

The U.S. Geological Service (USGS) modeled flow patterns in Kings Bay and has predicted that Kings Bay functions as two separate water bodies: a northern and southern portion (Stevens 1995). The northern portion of Kings Bay, north of Buzzard island, includes Cedar Cove and the southern portion of the bay is south of Buzzard Island. Because of the volume of spring flow and suspected tidal wedges, these two water masses do not mix in Kings Bay, but are flushed out of the Bay down Crystal River (Figure 2). Cedar Cove, a 16-hectare (40-acre) cove of Kings Bay where the City of Crystal River discharged treated municipal effluent, has limited influence on the water in the southern portion of bay.

From August 1992 through July 1994, the arithmetic mean total phosphorus concentration in Kings Bay was 31 μg/L (range: 19 μg/L to 68 μg/L) and the arithmetic mean total nitrogen concentration was 290 μg/L (range: 190 μg/L to 500 μg/L). The arithmetic mean chlorophyll concentration, an index of algal biomass in the water column, averaged 5.8 μg/L (range: 2.0 μg/L to 9.9 μg/L) for Kings Bay. All stations in Kings Bay had Secchi disc readings that reached the bottom and seven stations (Stations 4, 6, 9, 13,

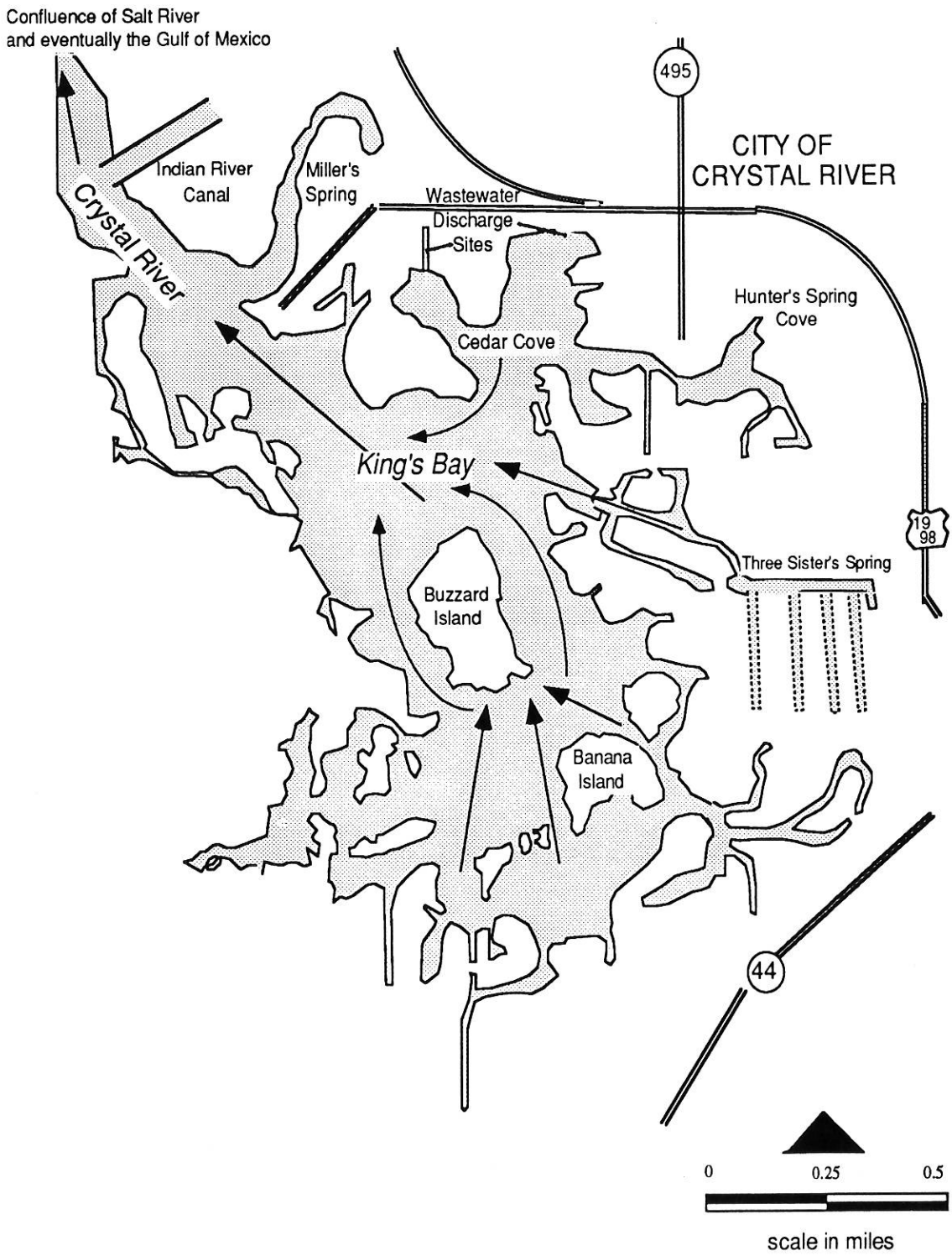

Figure 2. Arrows indicate the U. S. Geological Service's predicted flow patterns in Kings Bay.

15, 18, and 19) only reported bottom observations. The maximum recorded Secchi disc value was 28 feet, which was a bottom reading in July 1994.

Water Chemistry Changes

The first objective of this study was to determine if there was a significant reduction in surface water concentrations of total phosphorus and/or total nitrogen in Kings Bay as a result of the removal of the treated municipal effluent from Cedar Cove. Total phosphorus in the Kings Bay system averaged 35 µg/L prior to the removal of the wastewater effluent and 28 µg/L after the removal (Table 1). Total nitrogen averaged 360 µg/L prior to the removal of the wastewater effluent and 260 µg/L after the removal of the wastewater effluent. Total phosphorus concentrations were not significantly lower after the removal, but total nitrogen concentrations were significantly lower. A Welch Anova test was also performed because the assumption of equal variances for the Student's t-test was violated. The results of the Welch Anova test support the Student's t-test results. Total phosphorus concentrations were not lower, but total nitrogen concentrations were lower for the post-removal period. It seems that the removal of the treated wastewater effluent from Cedar Cove significantly reduced total nitrogen concentrations in Kings Bay.

Table 1. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), minimum and maximum arithmetic means, and number of samples (N) for Student's t-test between pre- and post-wastewater removal periods for total phosphorus and total nitrogen concentrations in Kings Bay.

Parameter		Mean (µg/L)	95% Confidence Interval (µg/L)		Min. Mean (µg/L)	Max. Mean (µg/L)	N
Total Phosphorus	Pre-removal	35	25	49	20	119	12
	Post-removal	28	25	32	18	67	24
Total Nitrogen	Pre-removal	360	250	510	170	1060	13
	Post-removal	260	230	290	200	500	24

Romie (1990) reported that total phosphorus and total nitrogen concentrations were an order of magnitude greater in Cedar Cove than in Kings Bay during the period of discharge. Pre-and post-removal mean total phosphorus and total nitrogen concentrations in Cedar Cove were therefore determined using only the data recorded for stations in Cedar Cove (Stations 4, 6, 9, and 19). Nutrient concentrations between the pre- and post-removal periods were significantly different in Cedar Cove. Mean total phosphorus concentrations in Cedar Cove prior to the removal of the wastewater effluent averaged 105 µg/L and after the removal averaged 27 µg/L (Table 2). Mean total nitrogen concentration prior to the removal averaged 620 µg/L and after the removal averaged 220 µg/L. Because the assumption of normality for the Student's t-test was violated, a non-parametric test (Wilcoxon rank sum test) was also performed. The Wilcoxon rank sum test indicates both total phosphorus and total nitrogen concentrations were significantly less after the removal of the wastewater in Cedar Cove. Clearly the removal of the treated wastewater effluent from Cedar Cove has lowered nutrient concentrations in Cedar Cove.

Table 2. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), minimum and maximum arithmetic means, and number of samples (N) for Student's t-test for pre- and post-wastewater removal periods for total phosphorus and total nitrogen concentrations in Cedar Cove.

Parameter		Mean (µg/L)	95% Confidence Interval (µg/L)		Min. Mean (µg/L)	Max. Mean (µg/L)	N
Total Phosphorus	Pre-removal	105	77	144	53	294	12
	Post-removal	27	23	31	11	72	24
Total Nitrogen	Pre-removal	620	460	830	320	1960	13
	Post-removal	220	190	260	110	560	24

The pre-removal concentrations calculated for Kings Bay included the stations in Cedar Cove. If changes in water chemistry were detected in Cedar Cove between pre- and

post-removal periods and if the water from Cedar Cove does not mix with water from Kings Bay as predicted by USGS, then the pre-removal concentrations calculated for Kings Bay would be an inappropriate representation of the actual pre-removal concentrations in the southern portion of Kings Bay. Pre-removal means for total phosphorus and total nitrogen concentrations were re-calculated for Kings Bay omitting the data collected from Cedar Cove. Mean total phosphorus concentrations in Kings Bay (with data from Cedar Cove excluded) prior to and after the removal of the wastewater effluent averaged 26 µg/L and 28 µg/L, respectively (Table 3). Mean total nitrogen concentrations averaged 310 µg/L prior to the removal and 270 µg/L after the removal of the wastewater effluent. Total phosphorus and total nitrogen concentrations for Kings Bay (excluding the data from Cedar Cove) were not significantly different between pre- and post-removal periods. Because the assumption of equal variances for the Student's t-test was violated, a Welch Anova F-test was also performed. The F-test indicates also that both total phosphorus and total nitrogen concentrations were not significantly different in Kings Bay when excluding the data in Cedar Cove. Clearly the removal of the treated wastewater effluent from Cedar Cove has not significantly altered nutrient concentrations in most of Kings Bay.

Table 3. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), minimum and maximum arithmetic means, and number of samples (N) for Student's t-test for pre- and post-wastewater removal periods for total phosphorus and total nitrogen concentrations for Kings Bay without data from stations in Cedar Cove.

Parameter		Mean (µg/L)	95% Confidence Interval (µg/L)		Min. Mean (µg/L)	Max. Mean (µg/L)	N
Total Phosphorus	Pre-removal	26	18	37	9	61	12
	Post-removal	28	25	32	18	62	24
Total Nitrogen	Pre-removal	310	210	450	100	610	13
	Post-removal	270	240	300	160	430	24

If the USGS contention that southern portion of Kings Bay and Cedar Cove act as two independent water sources both converging at the mouth of Kings Bay is correct then it is also possible for the stations downstream on Crystal River (Stations 1, 2, 3, and 5) to have been influence by the wastewater effluent. Pre- and post-removal mean total phosphorus and total nitrogen concentrations downstream on Crystal River were determined and statistically analyzed (Table 4). Mean total phosphorus concentrations prior to and after the removal of the wastewater effluent downstream on Crystal River averaged 85 µg/L and 32 µg/L, respectively. Mean total nitrogen concentration prior to the removal averaged 340 µg/L and after the removal averaged 270 µg/L. Mean total phosphorus concentration during the post-removal period was significantly lower than during the pre-removal period, but, the mean total nitrogen concentration was not significantly lower.

Table 4. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), maximum and minimum arithmetic means, and number of samples (N) for Student's t-test for pre- and post-wastewater removal periods for total phosphorus and total nitrogen concentrations for the downstream Crystal River stations.

Parameter		Mean (µg/L)	95% Confidence Interval (µg/L)		Min. Mean (µg/L)	Max. Mean (µg/L)	N
Total Phosphorus	Pre-removal	85	59	123	55	1434	12
	Post-removal	32	29	36	23	71	24
Total Nitrogen	Pre-removal	340	210	550	70	1140	13
	Post-removal	270	240	310	170	500	24

The pre- and post-removal means for Kings Bay were re-calculated and statistically re-analyzed without the inclusion of the downstream Crystal River stations. There were no significant differences for Kings Bay when omitting the Crystal River data. The removal of the treated municipal effluent from Cedar Cove, while significantly reducing nutrient concentrations in the receiving area (Cedar Cove) and its flow path (downstream Crystal

River), has not significantly lowered nutrient concentrations in the southern portion of Kings Bay. The post-removal means for both total phosphorus and total nitrogen concentrations in Cedar Cove (Table 2) and downstream Crystal River (Table 4) were not significantly different than the means calculated for Kings Bay when excluding Cedar Cove (Table 3). Given this and the fact that the water in the southern portion of Kings Bay does not mix with the water from Cedar Cove and is representative of background nutrient concentrations, nutrient concentrations in Cedar Cove and downstream Crystal River seem to have returned to background nutrient concentrations.

Because the University of Florida's LAKEWATCH volunteers were not trained to monitor specific conductance in Kings Bay, specific conductance data collected after the "No-Name Storm" were compared to maximum values recorded by SWFWMD (Romie 1990). There were no pre-storm maximum specific conductance concentrations for Stations 5, 10, and 20 because these stations were not part of the SWFWMD survey. One week after the storm, specific conductance at seventeen stations in Kings Bay ranged from 700 µS/cm @ 25° C to 4200 µS/cm @ 25° C (Figure 3). All but two of the seventeen stations (Stations 1 and 3) had conductance values that were above previously reported maximum values. Stations 1 and 3, located close to the Gulf of Mexico (Figure 1), were probably influenced by tidal cycles of water from the Gulf of Mexico more than the other stations and therefore experienced higher specific conductance than the other stations in Kings Bay.

Because total phosphorus and total nitrogen concentrations in Cedar Cove had returned to background concentrations since the removal of the wastewater effluent, total phosphorus and total nitrogen concentrations recorded after the storm were compared to maximum values documented in the University of Florida's LAKEWATCH data set. Total phosphorus concentrations at twenty stations in Kings Bay ranged from 33 µg/L to 205 µg/L one week after the storm and were higher at every station (Figure 4). Total nitrogen concentrations were higher at 16 of 20 stations and ranged from 230 µg/L to 1670 µg/L one week after the storm (Figure 5).

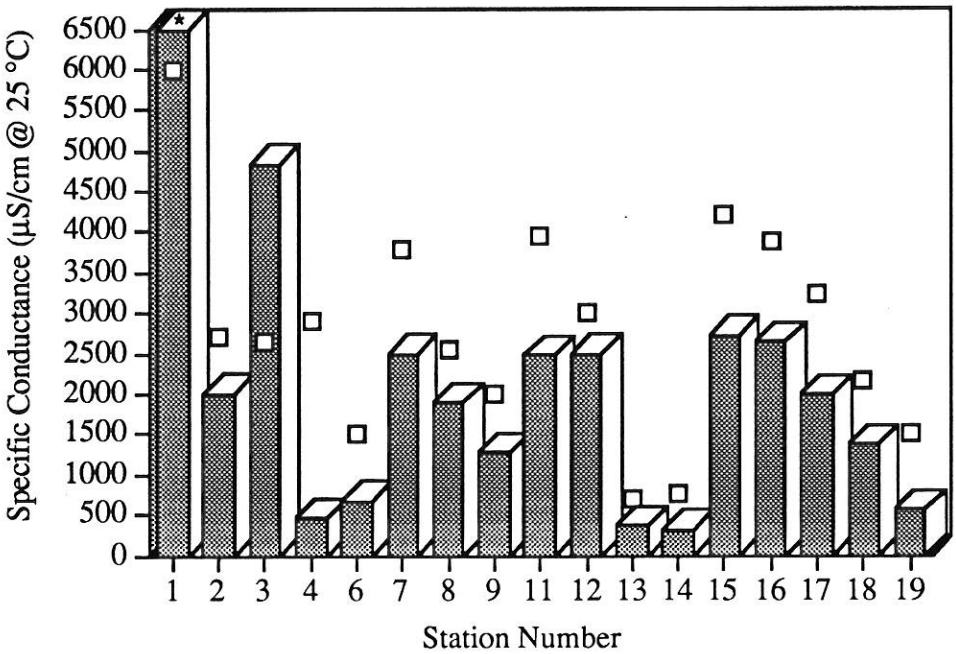

Figure 3. Specific conductance (µS/cm @ 25 °C) measured one week (March 18, 1993) after the "No-Name Storm" (open squares) compared to previously measured maximum values (shaded bars) for stations sampled in Kings Bay (Romie unpublished). * - The recorded maximum value for Station 1 was 20,700 µS/cm @ 25 °C.

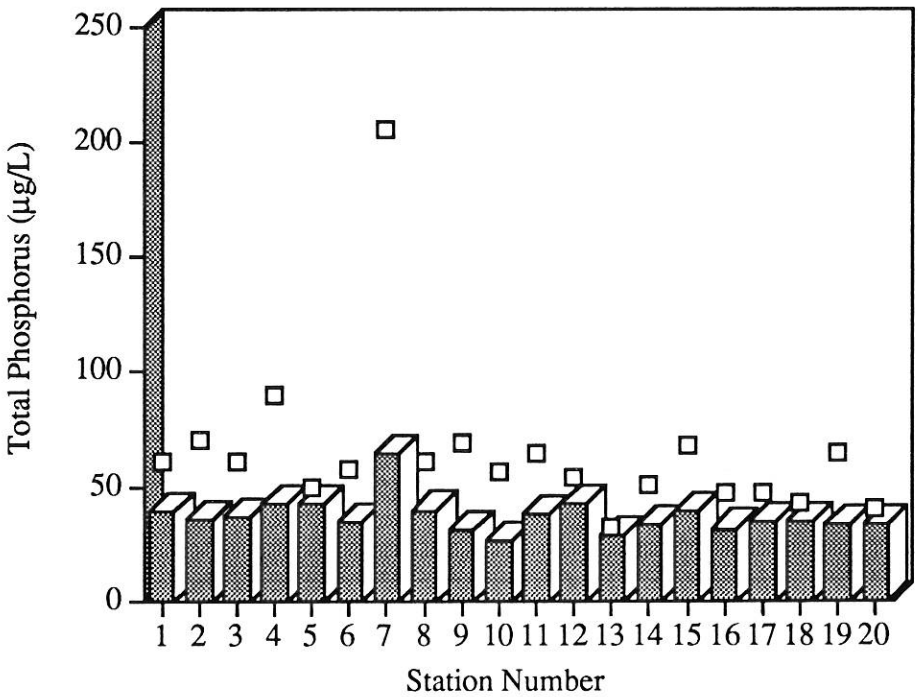

Figure 4. Total phosphorus (µg/L) concentrations measured one week (March 18, 1993) after the "No-Name Storm" (open squares) compared to previously measured maximum values (shaded bars) for all stations in Kings Bay.

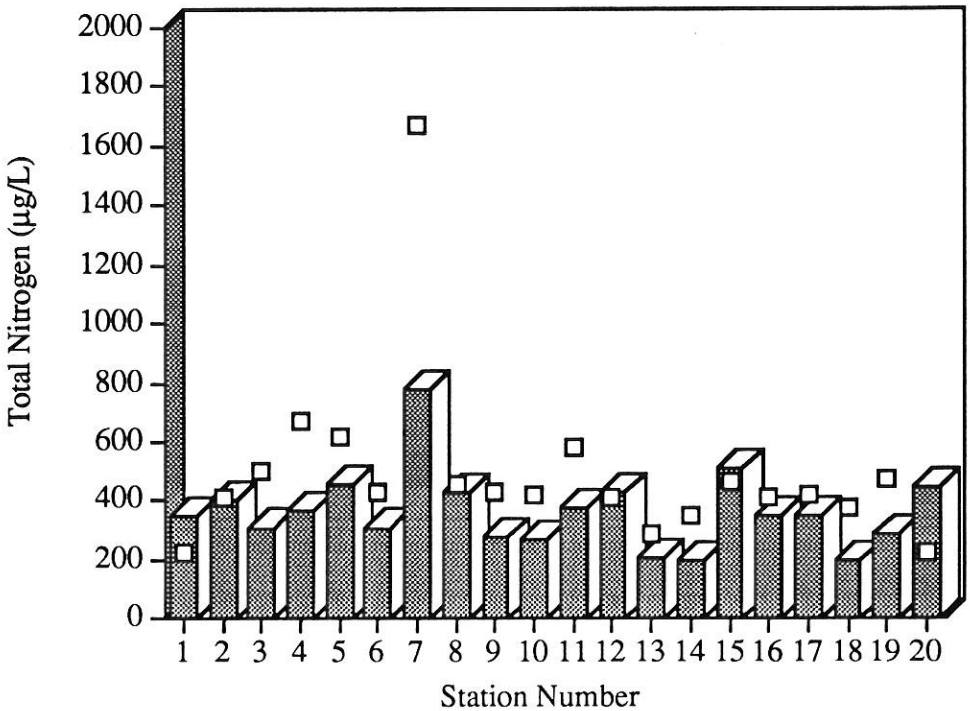

Figure 5. Total nitrogen (µg/L) concentrations measured one week (March 13, 1993) after the "No-Name Storm" (open squares) compared to previously measured maximum values (shaded bars) for all stations in Kings Bay.

The elevated nutrient concentrations in Kings Bay did not remain for a prolonged period. Only specific conductance measured on March 18, 1993 (one week after the "No-Name Storm") was significantly higher than those previously measured (Table 5). Specific conductance prior to the storm averaged 1010 µS/cm @ 25 °C. Specific conductance one week after the storm averaged 1910 µS/cm @ 25 °C. All other weekly specific conductance means were within the pre-storm 95% confidence interval (940 µS/cm @ 25 °C to 1090 µS/cm @ 25 °C) and not significantly different from pre-storm specific conductance.

During the sampling period prior to the "No-Name Storm", specific conductance for the stations and springs measured in Cedar Cove were considerably lower than most of the stations and springs measured in Kings Bay. Station 4 averaged 351 µS/cm @ 25 °C, Station 6 averaged 260 µS/cm @ 25 °C, Station 9 averaged 620 µS/cm @ 25 °C, and

Table 5. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), minimum and maximum arithmetic means and N value for specific conductance in Kings Bay (including Cedar Cove) prior to the storm (Romie unpublished data, Florida LAKEWATCH). Geometric mean, 95% confidence interval, and N for specific conductance weekly in Kings Bay after the "No-Name Storm" on March 13, 1993.

PRE-STORM

Mean (µS/cm @ 25 °C)	95 % Confidence Interval (µS/cm @ 25 °C)		Min. Mean (µS/cm @ 25 °C)	Max. Mean (µS/cm @ 25 °C)	N
1010	940	1090	1020	2680	16

POST-STORM

Week Number	Date	Mean (µS/cm @ 25 °C)	95 % Confidence Interval (µS/cm @ 25 °C)		N
1	3/18/93	1910	1320	2770	18
2	3/25/93	1350	910	2010	21
3	4/1/93	1170	790	1740	21
4	4/7/93	1160	810	1670	21
5	4/18/93	1110	720	1720	18
6	4/21/93	1070	730	1580	21
7	5/4/93	1270	890	1810	21
8	5/16/93	1150	680	1920	17
9	5/27/93	1480	900	2400	21
10	6/3/93	1150	750	1770	21
11	6/17/93	1110	700	1750	21
12	6/20/93	1150	720	1830	20
13	7/1/93	1500	940	2380	21

Station 19 averaged 392 µS/cm @ 25 °C. Specific conductance at the stations located in southern Kings Bay typically averaged an order of magnitude greater (Romie 1990). The pre-storm mean specific conductance for Kings Bay may have been lowered by the inclusion of the stations in Cedar Cove. To determine whether excluding data from Cedar Cove would alter the Kings Bay results, data from Cedar Cove were analyzed separately and the Kings Bay analysis was re-run omitting the data from Cedar Cove.

Pre-storm specific conductance for Cedar Cove averaged 400 µS/cm @ 25°C (Table 6). Specific conductance in Cedar Cove was significantly higher in four of the thirteen weeks measured after the storm than previously measured values. In weeks 1 and 2 after the "No-Name storm," specific conductance averaged 1900 µS/cm @ 25°C and 1120 µS/cm @ 25°C, respectively. In weeks 5 and 9 specific conductance averaged 610 µS/cm @ 25 °C and 870 µS/cm @ 25°C, respectively. It is unclear why specific conductance is above pre-storm 95% confidence intervals in weeks 5 and 9.

Removing Cedar Cove data from the Kings Bay analysis did change the results. Pre-storm mean specific conductance in Kings Bay excluding the data from Cedar Cove was 1310 µS/cm @ 25°C (Table 7). The 95% confidence intervals for mean specific conductance after the "No-Name Storm" in Kings Bay excluding the data from Cedar Cove were never above the pre-storm 95% confidence interval. This suggests that the turn-over time of water in the southern portion of Kings Bay seems to be faster than the turn-over time in Cedar Cove. These data support the contention made by the USGS that both southern Kings Bay and Cedar Cove are two independent water bodies that converge at the mouth of Kings Bay.

Pre-storm mean total phosphorus and total nitrogen concentrations for Kings Bay (including Cedar Cove) were calculated using all data after the removal of the treated municipal effluent and prior to the storm. Pre-storm mean total phosphorus and total nitrogen concentrations in Kings Bay were 33 µg/L and 280 µg/L, respectively (Table 8 and 9). After the storm, mean total phosphorus concentrations in Kings Bay were

Table 6. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), minimum and maximum arithmetic means and N value for specific conductance in Cedar Cove prior to the storm (Romie unpublished data, Florida LAKEWATCH). Geometric mean, 95% confidence interval, and N for specific conductance weekly in Cedar Cove after the "No-Name Storm" on March 13, 1993.

PRE-STORM

Mean (µS/cm @ 25 °C)	95 % Confidence Interval (µS/cm @ 25 °C)		Min. Mean (µS/cm @ 25 °C)	Max. Mean (µS/cm @ 25 °C)	N
400	370	430	320	600	16

POST-STORM

Week Number	Date	Mean (µS/cm @ 25 °C)	95 % Confidence Interval (µS/cm @ 25 °C)		N
1	3/18/93	1900	1160	3130	4
2	3/25/93	1120	630	1990	4
3	4/1/93	620	360	1040	4
4	4/7/93	870	380	2020	4
5	4/18/93	610	600	630	3
6	4/21/93	530	340	830	4
7	5/4/93	750	400	1380	4
8	5/16/93	400	220	720	3
9	5/27/93	870	670	1140	4
10	6/3/93	520	430	640	4
11	6/17/93	460	260	790	4
12	6/20/93	400	260	610	4
13	7/1/93	1140	260	4980	4

Table 7. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), minimum and maximum arithmetic means and N value for specific conductance in Kings Bay (excluding Cedar Cove) prior to the storm (Romie unpublished data, Florida LAKEWATCH). Geometric mean, 95% confidence interval, and N for specific conductance weekly in Kings Bay without Cedar Cove after the "No-Name Storm" on March 13, 1993.

PRE-STORM

Mean (µS/cm @ 25 °C)	95 % Confidence Interval (µS/cm @ 25 °C)		Min. Mean (µS/cm @ 25 °C)	Max. Mean (µS/cm @ 25 °C)	N
1310	1220	1420	1230	3320	16

POST-STORM

Week Number	Date	Mean (µS/cm @ 25 °C)	95 % Confidence Interval (µS/cm @ 25 °C)		N
1	3/18/93	1910	1180	3110	14
2	3/25/93	1410	860	2310	17
3	4/1/93	1360	860	2150	17
4	4/7/93	1240	810	1920	17
5	4/18/93	1260	760	2080	15
6	4/21/93	1270	810	1970	17
7	5/4/93	1440	950	2170	17
8	5/16/93	1440	830	2510	14
9	5/27/93	1670	930	3020	17
10	6/3/93	1390	850	2270	17
11	6/17/93	1370	820	2280	17
12	6/20/93	1500	920	2450	16
13	7/1/93	1600	930	2740	17

Table 8. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), minimum and maximum arithmetic means and N value for total phosphorus concentration in Kings Bay (including Cedar Cove) prior to the storm (Romie unpublished data, Florida LAKEWATCH). Geometric mean, 95% confidence interval, and N for total phosphorus concentrations weekly in Kings Bay after the "No-Name Storm" on March 13, 1993.

PRE STORM

Mean (µg/L)	95 % Confidence Interval (µg/L)		Min. Mean (µg/L)	Max. Mean (µg/L)	N
33	27	42	20	147	21

POST STORM

Week Number	Date	Mean (µg/L)	95 % Confidence Interval (µg/L)		N
1	3/18/93	60	51	71	21
2	3/25/93	67	57	79	21
3	4/1/93	50	45	57	21
4	4/7/93	48	39	60	21
5	4/18/93	41	35	47	18
6	4/21/93	38	33	42	21
7	5/4/93	39	35	44	21
8	5/16/93	35	30	40	17
9	5/20/93	35	31	39	21
10	5/27/93	33	29	37	21
11	6/3/93	35	29	41	21
12	6/17/93	30	25	36	21
13	7/1/93	31	27	35	20

Table 9. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), minimum and maximum arithmetic means and N value for total nitrogen concentration in Kings Bay (including Cedar Cove) prior to the storm (Romie unpublished data, Florida LAKEWATCH). Geometric mean, 95% confidence interval, and N for total nitrogen concentrations weekly in Kings Bay after the "No-Name Storm" on March 13, 1993.

PRE STORM					
Mean (µg/L)	95 % Confidence Interval (µg/L)		Min. Mean (µg/L)	Max. Mean (µg/L)	N
280	230	350	170	1060	20

POST STORM					
Week Number	Date	Mean (µg/L)	95 % Confidence Interval (µg/L)		N
1	3/18/93	450	370	540	21
2	3/25/93	430	370	500	21
3	4/1/93	390	340	450	21
4	4/7/93	430	360	510	21
5	4/18/93	330	280	390	20
6	4/21/93	410	340	490	21
7	5/4/93	340	290	410	21
8	5/16/93	320	270	370	20
9	5/20/93	400	320	490	21
10	5/27/93	350	300	420	21
11	6/3/93	310	280	360	21
12	6/17/93	260	220	300	21
13	7/1/93	250	220	280	21

significantly elevated three weeks after the storm (March 18 and 25, and April 1, 1993) and averaged 60 μg/L, 67 μg/L, and 50 μg/L, respectively. Mean total nitrogen concentrations were elevated three of the thirteen weeks sampled after the storm. Mean total nitrogen concentrations for weeks 1 and 2 (March 18 and 25, 1993) after storm averaged 450 μg/L and 430 μg/L, respectively. The mean total nitrogen concentration on April 7, 1993 (week 4 after the storm) averaged 430 μg/L.

To determine if there was further evidence to support the notion that the southern portion of Kings Bay and Cedar Cove behaved as independent water bodies, the length of time nutrient concentrations (total phosphorus and total nitrogen) remained elevated were analyzed separately for Cedar Cove and Kings Bay (excluding the data from Cedar Cove). Pre-storm mean total phosphorus and total nitrogen concentrations in Cedar Cove prior to the storm were 28 μg/L and 200 μg/L, respectively (Table 10 and 11). For two consecutive weeks (March 18 and 25, 1993) after the storm, mean total phosphorus concentrations in Cedar Cove were significantly elevated above the pre-storm values. Mean total phosphorus concentrations for March 18 and 25, 1993 were 70 μg/L and 72 μg/L, respectively. For two consecutive weeks (March 18 and 25, 1993) after the storm, mean total nitrogen concentrations in Cedar Cove were significantly elevated above the pre-storm values. Mean total nitrogen concentrations for March 18 and 25, 1993 were 490 μg/L and 430 μg/L. Mean total phosphorus concentrations in Cedar Cove were also elevated week five (April 18, 1993) and mean total nitrogen concentrations were also elevated weeks 9 and 10 after the storm. It is unclear as to why total phosphorus and total nitrogen concentrations returned to elevated levels once they had returned to the pre-storm values.

Removing the data from Cedar Cove did change the result of the Kings Bay analysis. Pre-storm mean total phosphorus and total nitrogen concentrations in Kings Bay excluding the data from Cedar Cove were 27 μg/L and 280 μg/L, respectively (Table 12 and 13). Mean total phosphorus concentrations were elevated for roughly seven consecutive weeks after the storm from March 18, 1993 through May 4, 1993. Mean total

Table 10. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), minimum and maximum arithmetic means and N value for total phosphorus concentration in Cedar Cove with (Romie unpublished data) and without (Florida LAKEWATCH) effluent discharge prior to the storm. Geometric mean, 95% confidence interval, and N for total phosphorus concentrations weekly in Cedar Cove after the "No-Name Storm" on March 13, 1993.

PRE-STORM					
Mean (µg/L)	95 % Confidence Interval (µg/L)		Min. Mean (µg/L)	Max. Mean (µg/L)	N
28	25	31	25	33	7

POST-STORM					
Week Number	Date	Mean (µg/L)	95 % Confidence Interval (µg/L)		N
1	3/18/93	70	52	94	4
2	3/25/93	72	50	106	4
3	4/1/93	46	30	72	4
4	4/7/93	44	28	70	4
5	4/18/93	38	33	43	3
6	4/21/93	32	23	44	4
7	5/4/93	37	24	58	4
8	5/16/93	36	21	61	3
9	5/20/93	41	27	62	4
10	5/27/93	42	26	68	4
11	6/3/93	35	21	59	4
12	6/17/93	28	15	54	4
13	7/1/93	32	18	55	4

Table 11. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), minimum and maximum arithmetic means and N value for total nitrogen concentration in Cedar Cove without effluent discharge prior to the storm (Florida LAKEWATCH). Geometric mean, 95% confidence interval, and N for total nitrogen concentrations weekly in Cedar Cove after the "No-Name Storm" on March 13, 1993.

PRE-STORM

Mean (µg/L)	95 % Confidence Interval (µg/L)		Min. Mean (µg/L)	Max. Mean (µg/L)	N
200	170	240	165	270	7

POST-STORM

Week Number	Date	Mean (µg/L)	95 % Confidence Interval (µg/L)		N
1	3/18/93	490	350	690	4
2	3/25/93	430	360	520	4
3	4/1/93	310	240	400	4
4	4/7/93	320	220	490	4
5	4/18/93	290	170	490	4
6	4/21/93	350	190	660	4
7	5/4/93	280	180	420	4
8	5/16/93	300	190	460	4
9	5/20/93	440	270	720	4
10	5/27/93	390	280	540	4
11	6/3/93	280	240	330	4
12	6/17/93	230	170	300	4
13	7/1/93	240	170	340	4

Table 12. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), minimum and maximum means and N value for total phosphorus concentration in Kings Bay excluding Cedar Cove prior to the storm. Geometric mean, 95% confidence interval, and N for total phosphorus concentrations weekly in Kings Bay without Cedar Cove after the "No-Name Storm" on March 13, 1993.

PRE-STORM

Mean (µg/L)	95 % Confidence Interval (µg/L)		Min. Mean (µg/L)	Max. Mean (µg/L)	N
27	22	34	10	96	21

POST-STORM

Week Number	Date	Mean (µg/L)	95 % Confidence Interval (µg/L)		N
1	3/18/93	58	48	71	17
2	3/25/93	66	54	80	17
3	4/1/93	51	45	59	17
4	4/7/93	49	38	64	17
5	4/18/93	41	35	50	15
6	4/21/93	39	34	45	17
7	5/4/93	40	35	45	17
8	5/16/93	35	28	42	13
9	5/27/93	34	30	37	17
10	6/3/93	31	28	34	17
11	6/17/93	35	28	43	17
12	6/20/93	30	24	37	17
13	7/1/93	30	25	35	17

Table 13. Geometric mean, 95% confidence interval (geometric mean ± t value (geometric standard deviation/$(N)^{0.5}$)), minimum and maximum arithmetic means and N value for total nitrogen concentration in Kings Bay excluded Cedar Cove prior to the storm (Romie unpublished data, Florida LAKEWATCH). Geometric mean, 95% confidence interval, and N for total nitrogen concentrations weekly in Kings Bay without Cedar Cove after the "No-Name Storm" on March 13, 1993.

PRE-STORM

Mean (µg/L)	95 % Confidence Interval (µg/L)		Min. Mean (µg/L)	Max. Mean (µg/L)	N
280	220	360	130	1140	20

POST-STORM

Week Number	Date	Mean (µg/L)	95 % Confidence Interval (µg/L)		N
1	3/18/93	440	350	550	17
2	3/25/93	430	350	520	17
3	4/1/93	410	350	490	17
4	4/7/93	450	370	550	17
5	4/18/93	340	290	410	16
6	4/21/93	420	340	520	17
7	5/4/93	360	290	440	17
8	5/16/93	320	270	390	16
9	5/20/93	390	300	510	17
10	5/27/93	350	280	430	17
11	6/3/93	320	280	380	17
12	6/17/93	260	220	310	17
13	7/1/93	250	220	300	17

nitrogen concentrations were only elevated week 4 after the "No-Name Storm".

Obviously, the "No-Name Storm" caused a significant effect by elevating specific conductance, total phosphorus and total nitrogen concentrations at virtually every station in Kings Bay (including Cedar Cove), but the effects seem to have been of limited duration. The length of time that water chemistry concentrations were above pre-storm concentrations in the southern portion of Kings Bay varied with parameter (specific conductance - never, total phosphorus concentrations - 7 weeks, and total nitrogen concentrations - 4 weeks), while the rate of return to previously recorded water chemistry concentrations in Cedar Cove were more uniform (specific conductance, total phosphorus and total nitrogen concentrations - 2 weeks).

Submersed Vegetation

Site Description

Between September 1980 and August 1981, Haller et al. (1983) identified 8 taxa in Kings Bay (Table 14). Nine taxa were identified between April 1989 and March 1990 (Cowell 1990) and between April 1979 and September 1994 (with the exception of June 1983 to November 1985) (NBS; unpublished data) and between April 1993 and August 1994, 10 taxa in Kings Bay were identified. Haller et al. (1983) estimated that the mean total biomass of submersed vegetation in Kings Bay ranged from a minimum of 2.9 kg fresh wt/m^2 in May 1981 to a maximum of 3.6 kg fresh wt/m^2 in September 1980. Assuming approximately 90% water content, Cowell (1990) estimated that the mean total biomass ranged from a minimum of 3.5 kg fresh wt/m^2 in July 1989 to a maximum of 8.0 kg fresh wt/m^2 in August 1989. Between April 1993 and August 1994 the mean total biomass of submersed vegetation in Kings Bay ranged from a minimum of 2.6 kg fresh wt/m^2 on April 1993 and a maximum of 11.9 kg fresh wt/m^2 on October 1993.

Total biomass estimates were also done for the similar stations in Cedar Cover (Stations 4, 6, and 9). Cowell (1990) estimated between April 1989 and March 1990 the

total biomass for Station 4 was 6.23 kg fresh wt/m^2, for Station 6 was 15.11 kg fresh wt/m^2, and for Station 9 was 13.2 kg fresh wt/m^2. Between April 1993 and August 1994, the mean total biomass estimate for Station 4 was 4.1 kg fresh wt/m^2, for Station 6 was 10.1 kg fresh wt/m^2, and for Station 9 was 9.8 kg fresh wt/m^2.

Table 14. List of scientific and common names of submersed plants identified in four studies: Haller et al. (1983); Cowell (1990); NBS (unpublished data); LAKEWATCH (unpublished data) in Kings Bay.

Scientific Name	Common Name	Years of Study			
		1980-1981	1989-1990	1979-1994	1993-1994
Ruppia sp	Widgeon-grass	X	X	X	X
Hydrilla verticillata	Hydrilla	X	X	X	X
Vallisneria americana	Tapegrass	X	X	X	X
Chara sp.	Musk-grass			X	X
Myriophyllum spicatum	Eurasian watermilfoil	X	X	X	X
Najas guadalupensis	Southern naiad	X	X	X	X
Ceratophyllum demersum	Coontail	X	X	X	X
Lyngbya sp.	Lyngbya		X	X	X
Chlorophyta	Green filamentous algae		X	X	X
Caloglossa sp.	Red algae		X		X
Utricularia sp.	Bladderwort	X			
Cabomba sp.	Fanwort	X			
Potemogeton sp.	Pondweeds			X	
Total number of submersed macrophytic-type species		8	9	10	10

Because the NBS has the longest monitoring record of the frequency of occurrence of submersed plants in Kings Bay, its raw data set was used for all further analyses. Nearly all stations (n = 15) in Kings Bay had submersed vegetation between April 1979 through September 1994, except around storm events (Figure 6). The number of stations with hydrilla in Kings Bay was relatively constant, ranging from 10 of 15 stations to all 15 stations, except around storm events (Figure 7). The number of stations with eurasian watermilfoil was more variable ranging from none reported to a high of 13 stations, with

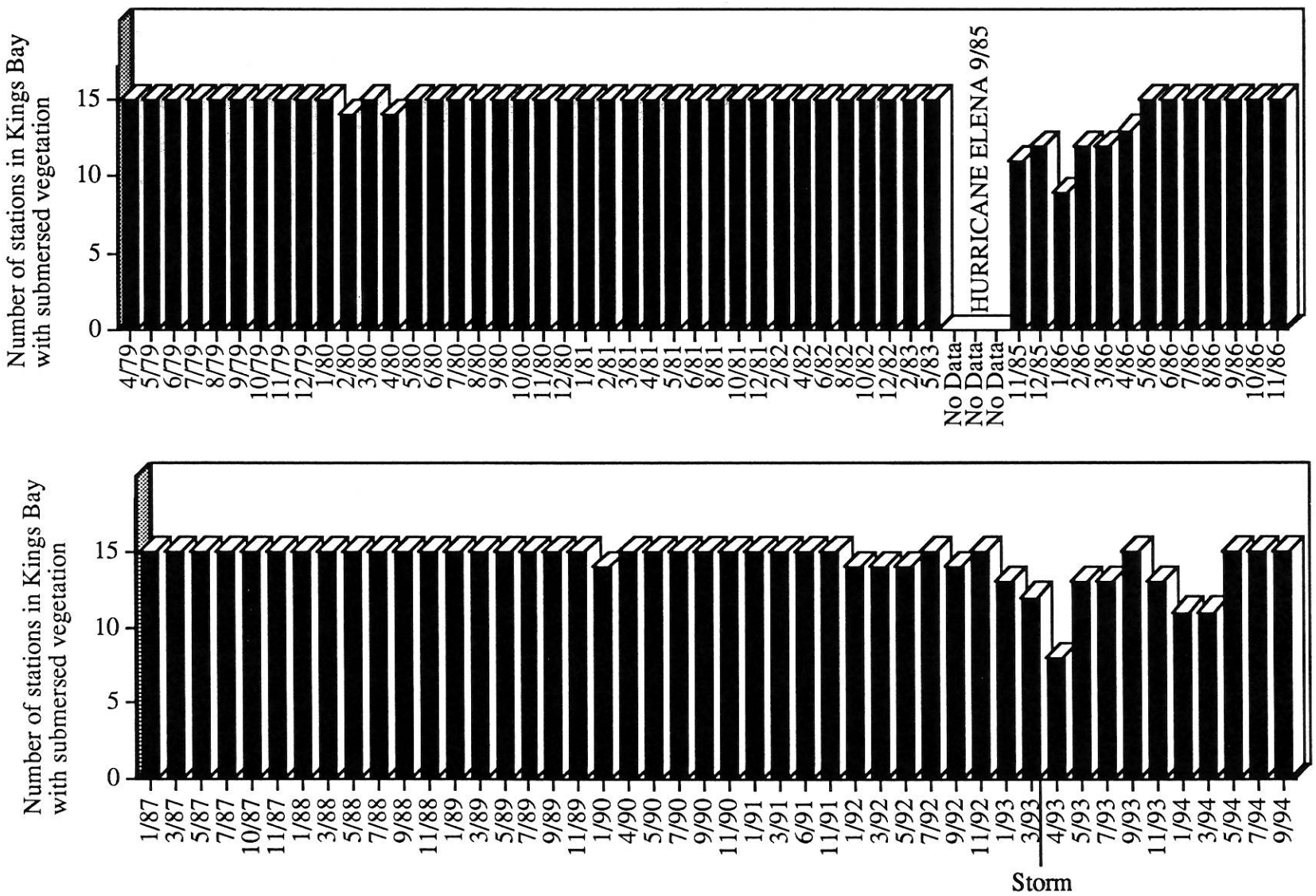

Figure 6. Number of stations (n = 15) in Kings Bay with submersed vegetation.

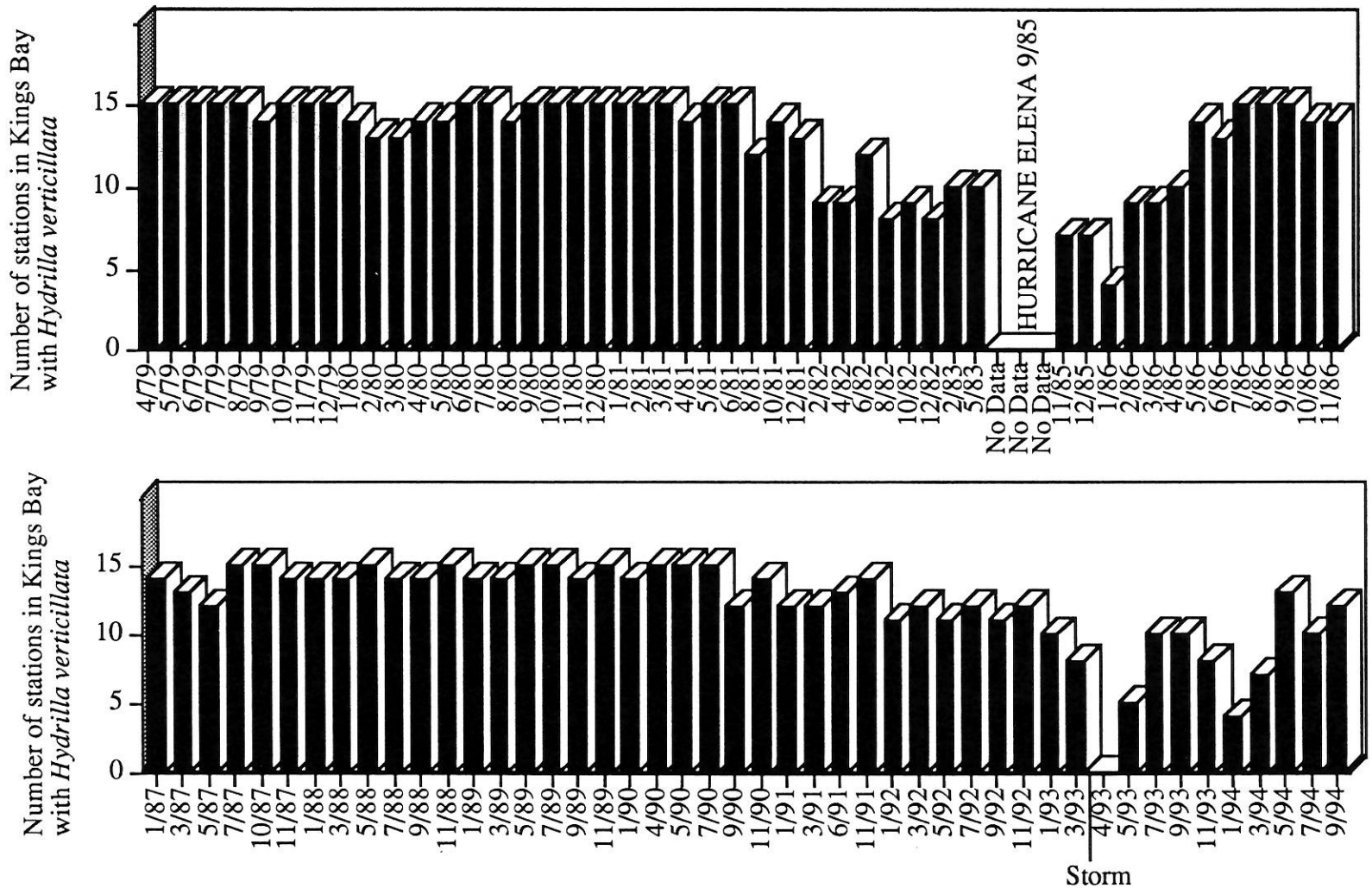

Figure 7. Number of stations (n = 15) in Kings Bay with *Hydrilla verticillata*. Missing bars are zeros.

large increases in the number of stations found having eurasian watermilfoil following storm events (Figure 8). Tapegrass was recorded from 2 stations to 7 stations in Kings Bay (Figure 9). The number of stations with filamentous algae in Kings Bay was variable ranging from none recorded to a high of 12 stations (Figure 10).

Submersed Vegetation Changes

The second objective of this study was to determine if there was a significant reduction in frequency of occurrence of all species (any submersed vegetation regardless of species), exotic species (*Hydrilla verticillata* and *Myriophyllum spicatum*), native species (*Vallisneria americana)*, and/or filamentous algae (*Lyngbya* sp.) in Kings Bay as a result of the removal of the treated municipal effluent. Because there was not a significant reduction of nutrient concentrations detected between pre- and post-removal periods in Kings Bay, it seemed more appropriate to determine if there was a significant reduction in the frequency of occurrence of submersed vegetation in Cedar Cove, since this is the area where significant reductions in the nutrient concentrations were detected.

Two of the fifteen stations monitored by NBS for submersed vegetation in Kings Bay were in Cedar Cove. Both stations in Cedar Cove during the sampling period from April 1979 through September 1994 had submersed vegetation recorded at them, with the exception of February 1980 and after the "No-Name Storm" (Figure 11). Hydrilla has always been documented at one or both of the stations in Cedar Cove except after storm events (Figure 12). Eurasian watermilfoil was usually found at only one station in Cedar Cove or not found at all, except after the "No-Name Storm" when the number of stations with eurasian watermilfoil seems to have increased (Figure 13). Tapegrass was rarely found in Cedar Cove (Figure 14) and since Hurricane Elena, filamentous algae was usually found at both stations in Cedar Cove (Figure 15).

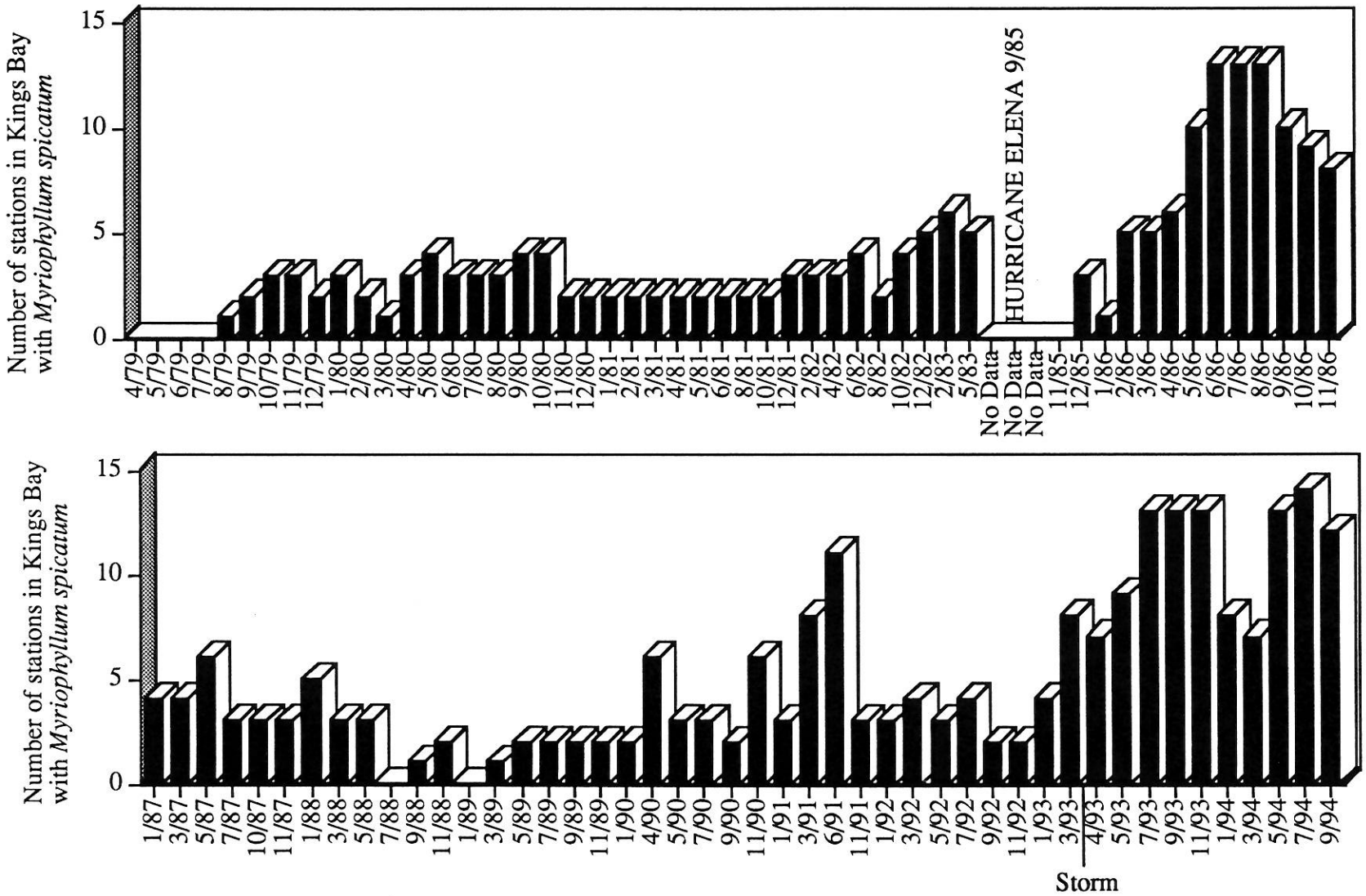

Figure 8. Number of stations (n = 15) in Kings Bay with *Myriophyllum spicatum*. Missing bars are zeros.

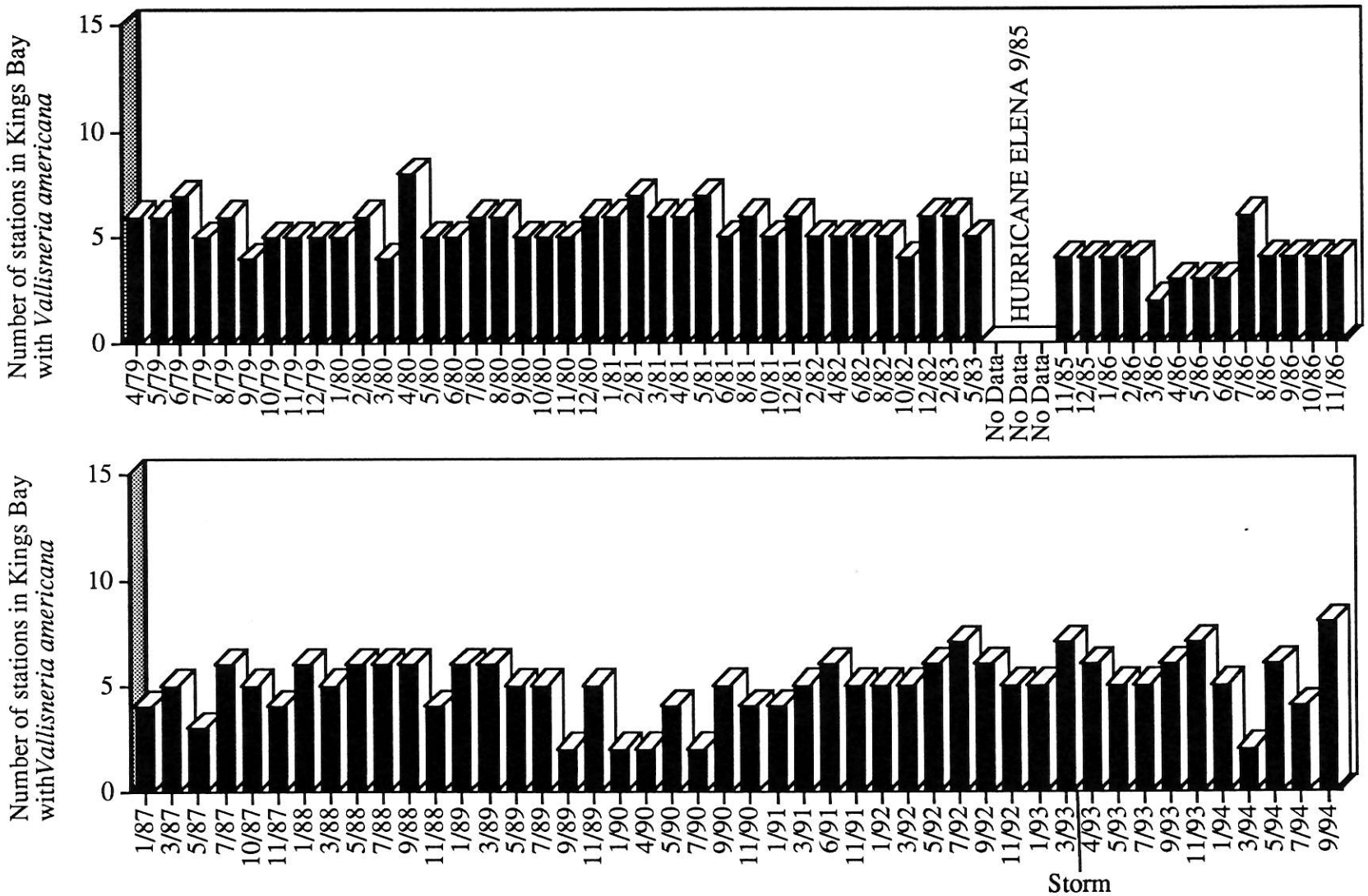

Figure 9. Number of stations (n = 15) in Kings Bay with *Vallisneria americana*

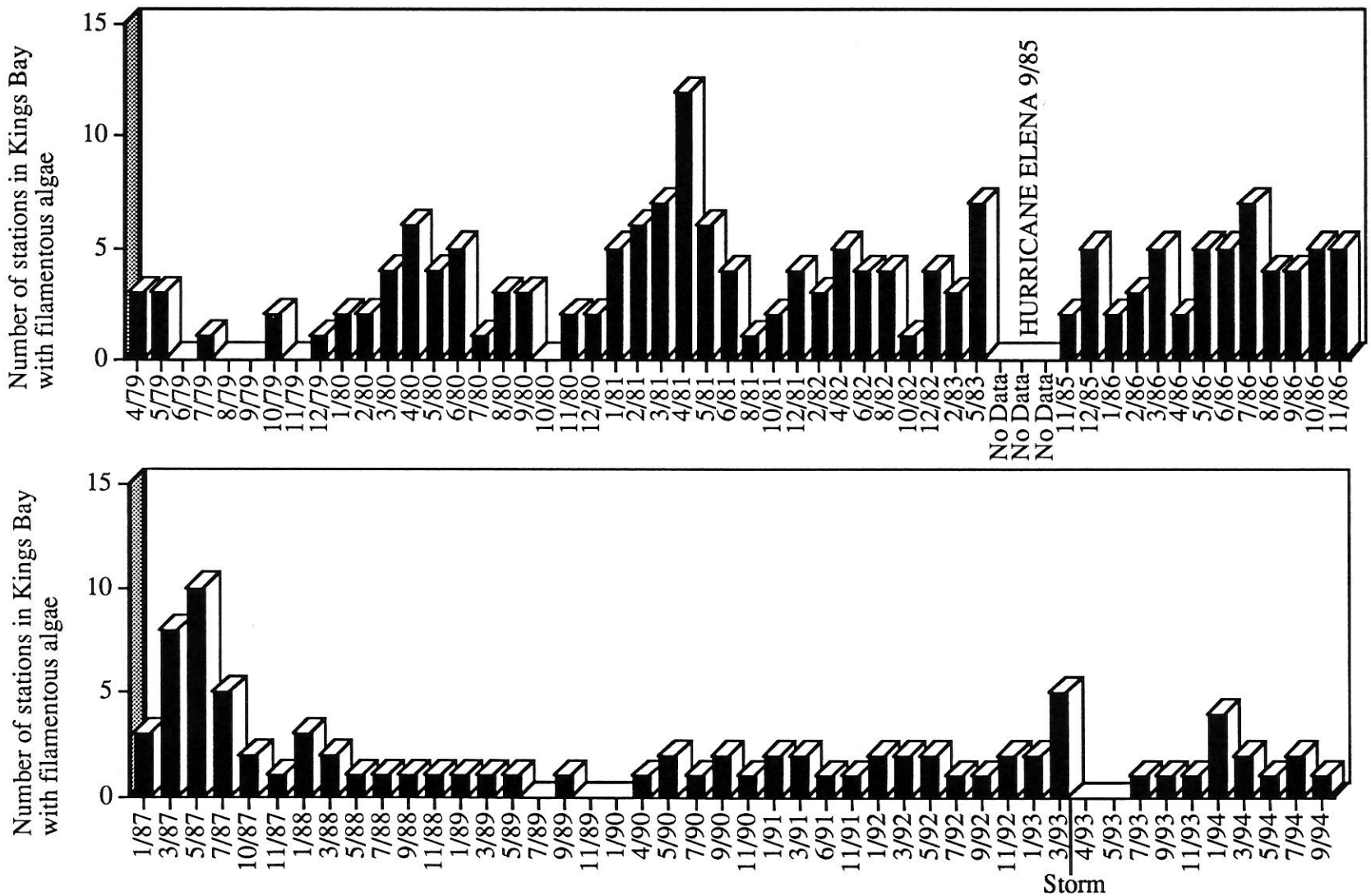

Figure 10. Number of stations (n = 15) in Kings Bay with filamentous algae. Missing bars are zeros.

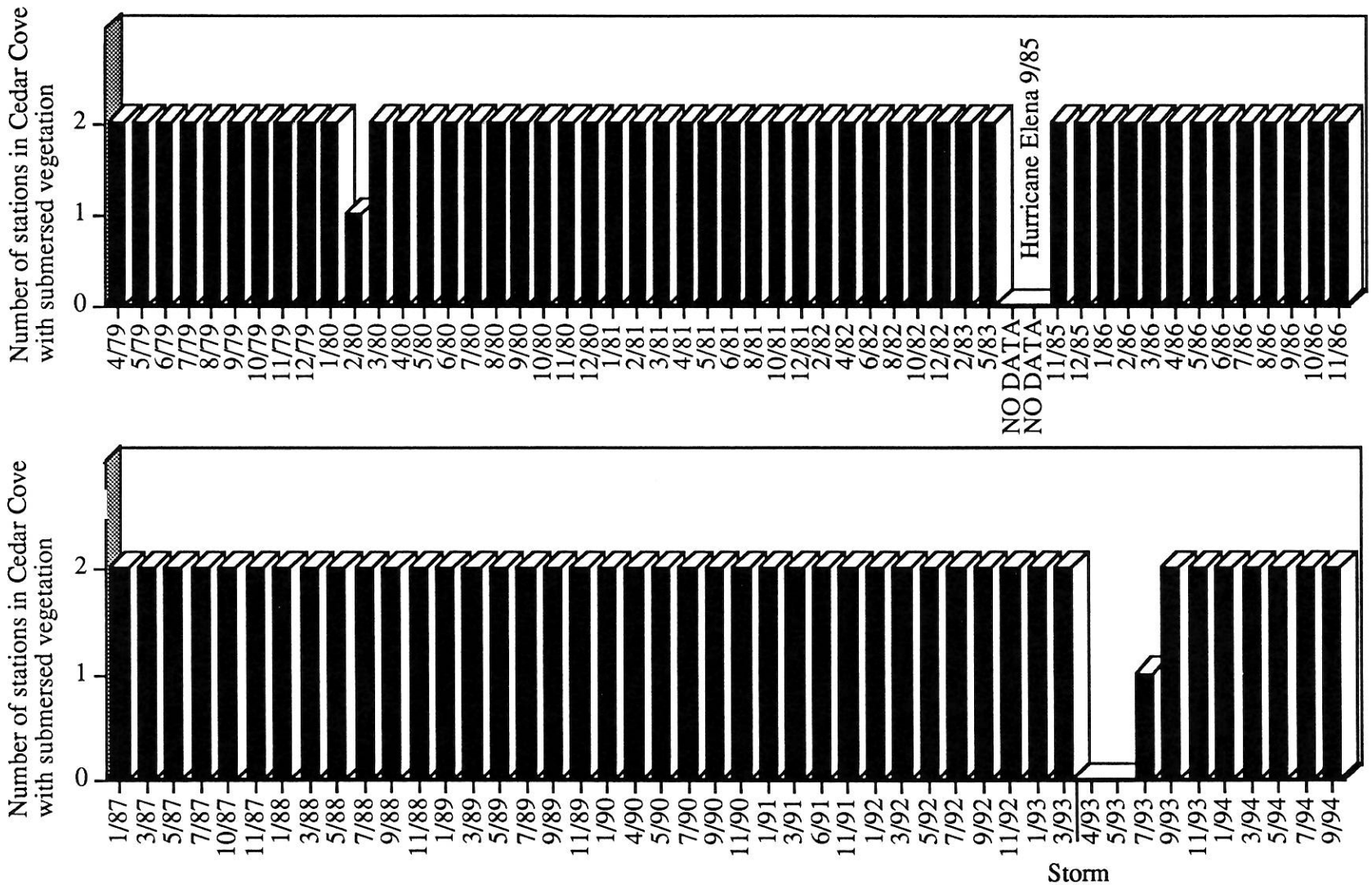

Figure 11. Number of stations (n = 2) in Cedar Cove with submersed vegetation. Missing bars are zeros.

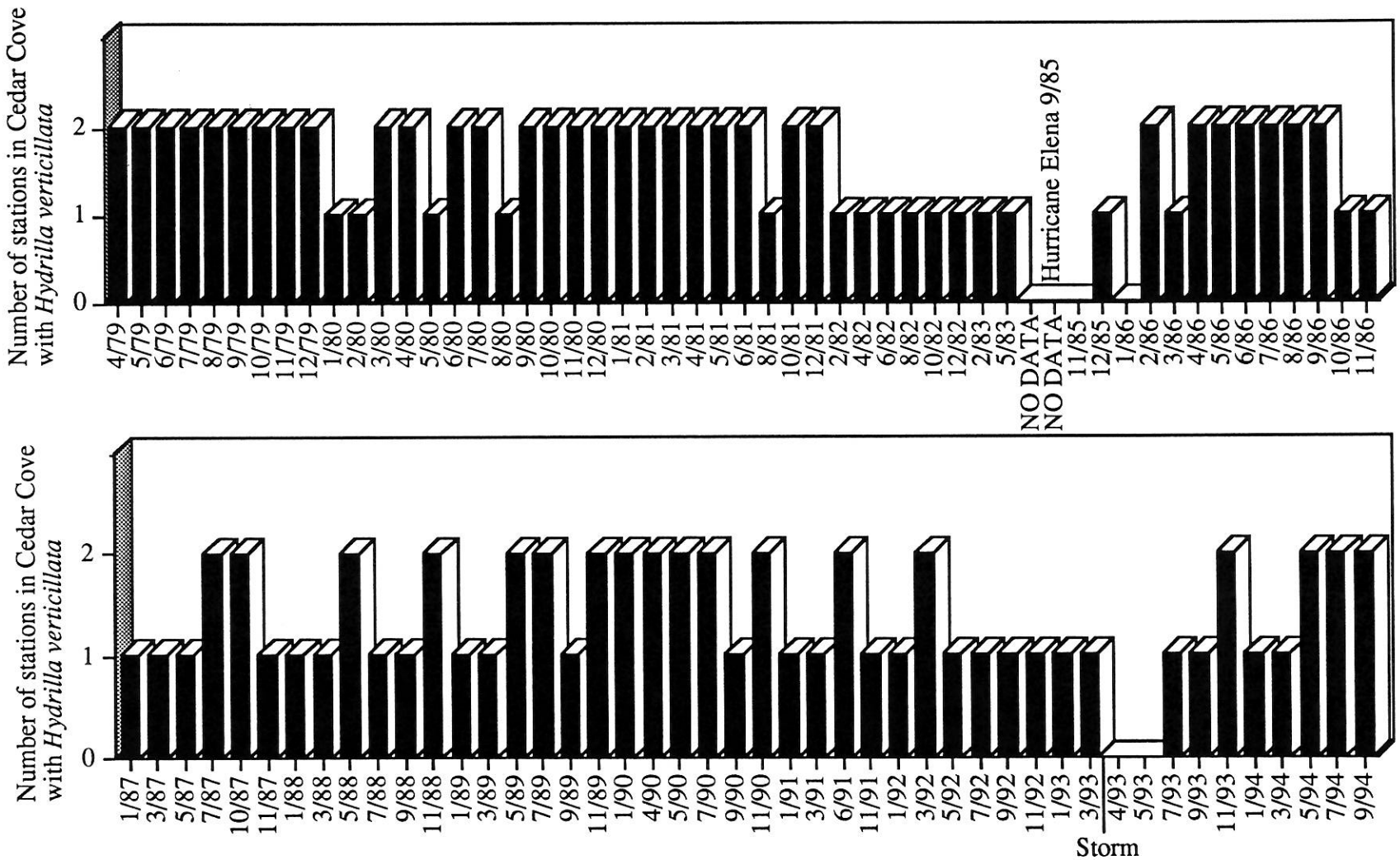

Figure 12. Number of stations (n = 2) in Cedar Cove with *Hydrilla verticillata*. Missing bars are zeros.

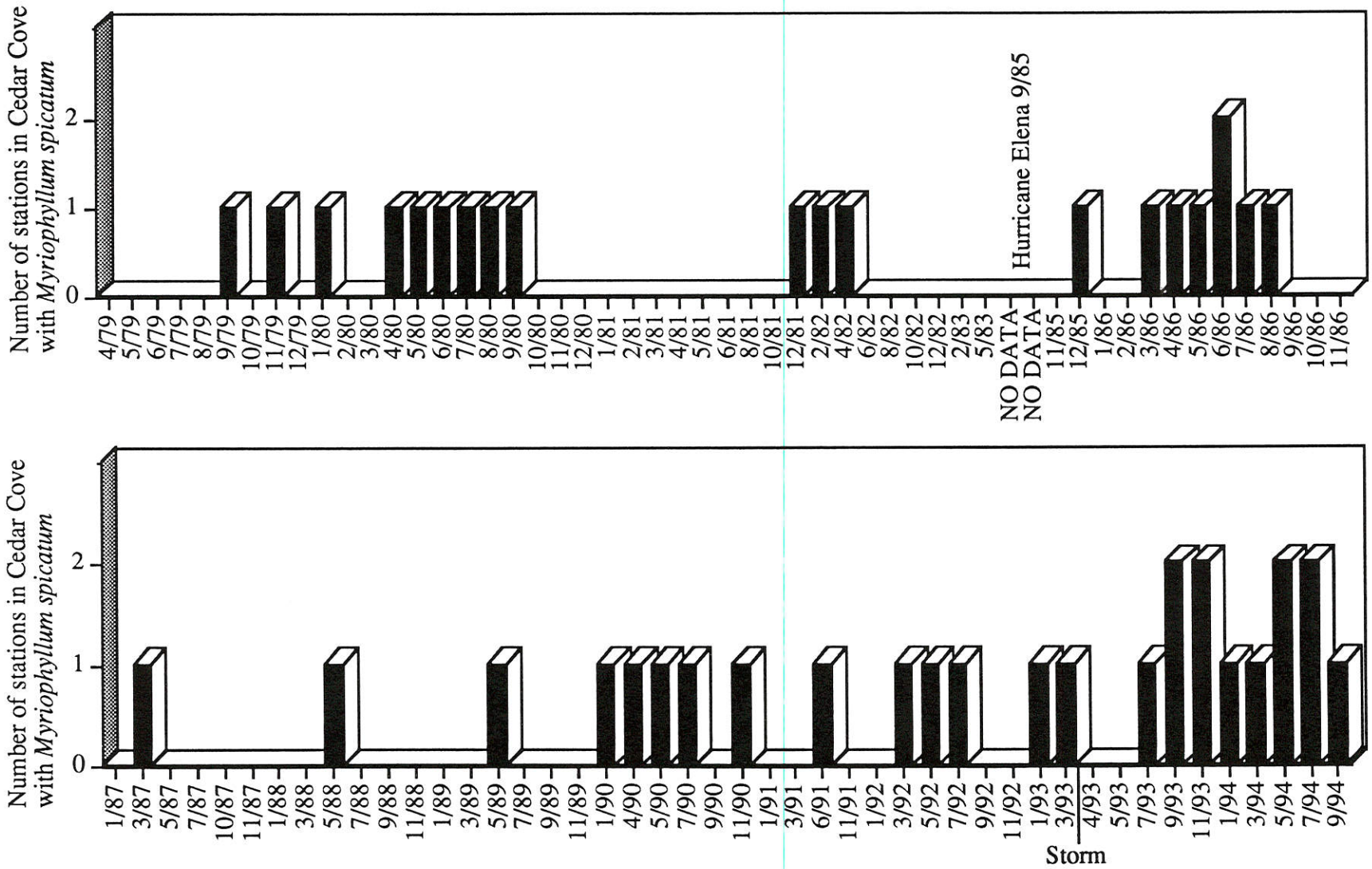

Figure 13. Number of stations (n = 2) in Cedar Cove with *Myriophyllum spicatum*. Missing bars are zeros.

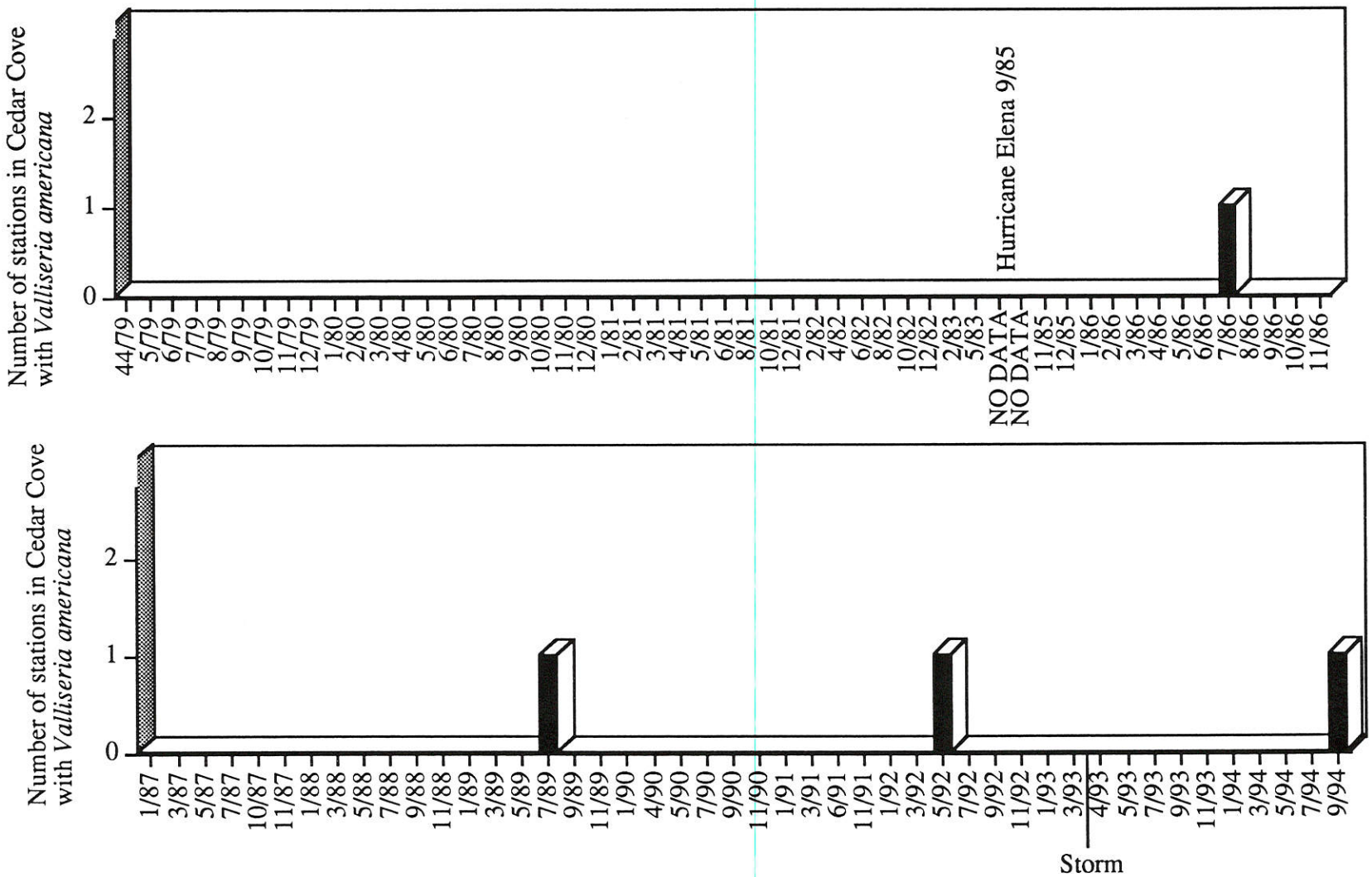

Figure 14. Number of stations (n = 2) in Cedar Cove with *Vallisneria americana*. Missing bars are zeros.

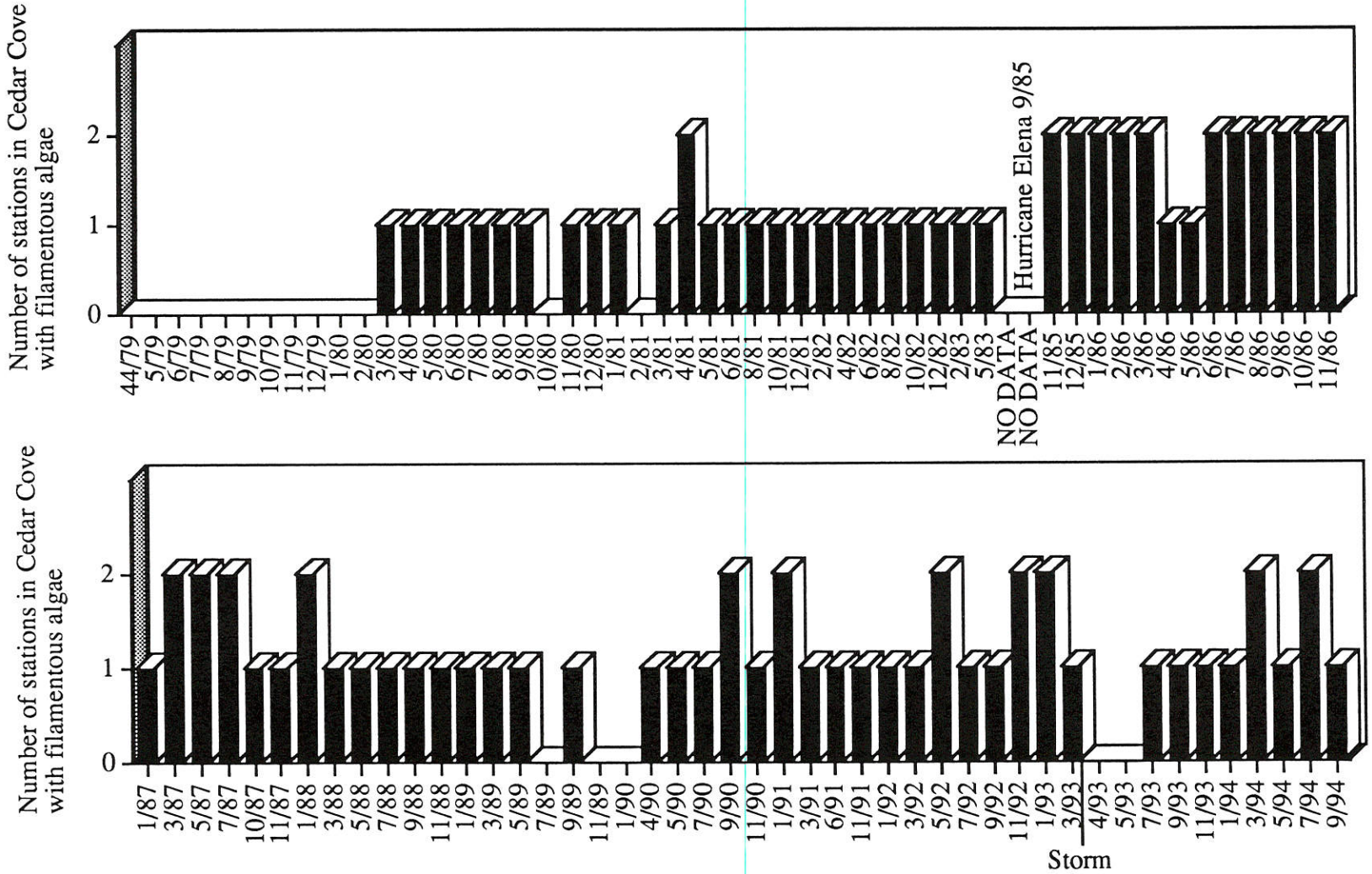

Figure 15. Number of stations (n = 2) in Cedar Cove with filamentous algae. Missing bars are zeros.

At the two stations in Cedar Cove (Stations I and P), the mean frequencies of occurrence for all species prior to and after the removal of the wastewater effluent were 81% and 73%, respectively (Table 15). Mean frequencies of occurrence for hydrilla prior to the removal was 54% and after the removal was 36%. The pre-removal mean frequency of occurrence for eurasian watermilfoil was 6% and post-removal was 24%. Mean frequencies of occurrence for tapegrass prior to and after the removal were 0% and 1%, respectively, and for filamentous algae were 34% and 40%, respectively. There were no significant differences detected between the pre- and post-removal periods for all species, tapegrass, and filamentous algae. There was a significant decrease in the mean frequency of occurrence for hydrilla, and a significant increase in mean frequency of occurrence in eurasian watermilfoil in Cedar Cove.

Table 15. Arcsin mean frequency of occurrence and 95% confidence interval ((arcsin mean ± (t value x standard deviations arcsin mean)/$N^{0.5}$)) for all species, *Hydrilla verticillata*, *Myriophyllum spicatum*, *Vallisneria americana*, and filamentous algae at two stations in Cedar Cove for pre- and post-wastewater removal. N for pre-removal = 81; N for post-removal = 16.

Species	Pre wastewater removal			Post wastewater removal		
		95% Confidence Interval			95% Confidence Interval	
	Mean (%)	Min. (%)	Max. (%)	Mean (%)	Min. (%)	Max. (%)
All species	81	78	84	73	56	90
Hydrilla verticillata	54	50	58	36	25	47
Myriophyllum spicatum	6	4	8	24	12	36
Vallisneria americana	0	0	1	1	0	4
Filamentous algae	34	29	39	40	27	53

Similar results were found for Kings Bay. The mean frequencies of occurrence for all species prior to and after the removal of the wastewater effluent were 77% and 64%, respectively (Table 16). Mean frequencies of occurrence for hydrilla prior to the removal was 60% and after the removal was 35%; mean frequencies of occurrence for eurasian watermilfoil were 10% prior to and 31% after the removal. Pre-removal mean frequency of occurrence for tapegrass was 16% and post-removal was 19%; mean frequencies of

occurrence for filamentous algae were 9% prior to and 7% after the removal. There was a significant decrease detected between pre- and post-removal periods in the mean frequency of occurrence for all species and hydrilla and a significant increase in mean frequency of occurrence in eurasian watermilfoil in Kings Bay. There were no significant differences for tapegrass and filamentous algae. To make sure that the significant differences detected in Kings Bay were not caused by the two stations in Cedar Cove, they were removed from the analysis and the Kings Bay data re-compiled. No significant differences were noted with this revised data set, and thus did not alter the conclusion.

Table 16. Arcsin mean frequency of occurrence and 95% confidence interval ((arcsin mean ± (t value x standard deviations arcsin mean)/$N^{0.5}$)) for all species, *Hydrilla verticillata*, *Myriophyllum spicatum*, *Vallisneria americana*, and filamentous algae at fifteen stations in Kings Bay, including Cedar Cove for pre- and post-wastewater removal. N for pre-removal = 81; N for post-removal = 16.

Species	Pre wastewater removal			Post wastewater removal		
		95% Confidence Interval			95% Confidence Interval	
	Mean (%)	Min. (%)	Max. (%)	Mean (%)	Min. (%)	Max. (%)
All species	77	75	80	64	55	72
Hydrilla verticillata	60	56	64	35	26	45
Myriophyllum spicatum	10	8	12	31	20	43
Vallisneria americana	16	15	17	19	16	22
Filamentous algae	9	8	11	7	4	9

The March 13, 1993, "No-Name Storm" provides a better explanation for the differences detected in the abundances of submersed vegetation between the pre- and post-removal periods than the removal of the wastewater effluent from Cedar Cove (Figures 6 through 15). The number of stations in Kings Bay documented with any submersed vegetation regardless of species one month after the storm was 8 out of 15 stations; the lowest recorded since April 1979 (Figure 6). The reduction in the number of stations documented with submersed vegetation in Kings Bay was only temporary as all fifteen stations had submersed vegetation by September 1993, two months after the tidal storm.

Hydrilla was not found at any of the 15 stations one month after the March 13, 1993 storm; a condition which had never been recorded in Kings Bay since April 1979 (Figure 7). The reduction in the number of stations with hydrilla was also only temporary. By July 1993, 12 stations had hydrilla. The number of stations with eurasian watermilfoil in Kings Bay increased after the storm (Figure 8). In July 1993, 14 of 15 stations had eurasian watermilfoil. The only other time that 13 of 15 stations had eurasian watermilfoil was after Hurricane Elena (June to August 1986).

The number of stations documented with tapegrass in Kings Bay has remained relatively constant since April 1979, even after Hurricane Elena and throughout the March 13, 1993 tidal storm (Figure 10). Two days before the storm (the March 1993 sampling date) 5 stations in Kings Bay had filamentous algae. But for two months after the storm, filamentous algae did not occur at any of the fifteen stations in Kings Bay (Figure 11). Not finding filamentous algae at any of the fifteen station in Kings Bay has not been a unique condition in Kings Bay, there were 8 other dates that filamentous algae were not found at any of the fifteen stations. Whether the storm was responsible for this reduction is uncertain, but if the storm did effect the number of stations with filamentous algae, it was only a temporary effect. Filamentous algae in July 1993 was recorded at one station in Kings Bay and by January 1994 filamentous algae was recorded at four stations in Kings Bay.

Similar vegetative patterns found in Kings Bay were recorded in Cedar Cove after the "No-Name Storm". No stations were documented with submersed vegetation for two months after the storm (Figure 11) and this was the only time since April 1979 that this had occurred. The March 13, 1993 storm had only a temporary effect on the abundance of submersed vegetation in Cedar Cove because by September 1993, both stations in Cedar Cove had submersed vegetation.

Hydrilla was not recorded at either station in Cedar Cove for two months after the March 13, 1993 tidal storm (Figure 12). The only other time this happened was after

Hurricane Elena in September 1985. But as before, this reduction in hydrilla was only temporary as by July 1993, one station, and by November 1993, both stations contained hydrilla.

It is difficult to determine if eurasian watermilfoil, tapegrass, or filamentous algae were significantly affected in Cedar Cove immediately or long term after the storm because of the variability in the number of stations where they were found (Figures 13, 14, and 15). There were many times besides those following tidal storms when eurasian watermilfoil, tapegrass, and filamentous algae were not recorded at either station in Cedar Cove.

Recovery rates of submersed vegetation in all of Kings Bay were also analyzed to further understand the influence of tidal storms on the abundance of submersed vegetation in systems such as Kings Bay. At fifteen stations in the Kings Bay system, the mean arcsin frequency of occurrence for all species and hydrilla was significantly reduced one month after the storm (Table 17). In January and March 1993, pre-storm sampling, the mean arcsin frequency of occurrence for all species in Kings Bay was 57% and 62%, respectively. In April 1993, one month after the storm, the mean arcsin frequency of occurrence of all species was 21%. During the two sampling periods prior to the "No-Name Storm" in Kings Bay, hydrilla averaged 41% and 33% and one month after the storm, hydrilla averaged 0%. Filamentous algae during the two months prior to the storm averaged 9% and 21% . For two months after the storm, filamentous algae averaged 0%.

The significant reductions on all species, hydrilla, and filamentous algae were apparently temporary because by June 1993, three months after the tidal storm, the mean frequency of occurrence for all species, hydrilla, and filamentous algae were not significantly different from pre-storm mean frequencies in Kings Bay. Eurasian watermilfoil did not change immediately after the storm, but significantly increased three months after the storm (June 1993) and was still significantly higher six and eight months after the storm (September and November 1993). Eurasian watermilfoil mean frequency of

occurrence was 8% and 19% during the two sampling periods prior to the storm, and 14% one month after the storm. Three, six and eight months after the storm, eurasian watermilfoil averaged 60%, 58%, and 56%, respectively. The mean frequency of occurrence of tapegrass was never significantly different after the "No-Name Storm".

Table 17. Mean frequency of occurrence and 95% Confidence Interval (arcsin mean ± ((t value x standard deviation arcsin mean)/$(N)^{0.5}$))) for all species, *Hydrilla verticillata*, *Myriophyllum spicatum*, *Vallisneria americana*, and filamentous algae during each sampling date in 1993 for Kings Bay (including Cedar Cove).

Month 1993	All Species Mean (95% CI) (%)	Hydrilla Mean (95% CI) (%)	Eurasian watermilfoil Mean (95% CI) (%)	Tapegrass Mean (95% CI) (%)	Filamentous algae Mean (95% CI) (%)
January	57 (38-77)	41 (21-62)	8 (0-17)	20 (3-38)	9 (0-24)
March	62 (42-81)	33 (14-52)	19 (6-32)	21 (5-37)	21 (3-39)
STORM					
April	21 (6-35)	0 (0-0)	14 (1-27)	13 (3-38)	0 (0-0)
May	48 (31-64)	16 (0-31)	29 (13-45)	16 (2-29)	0 (0-0)
June	71 (54-88)	31 (14-49)	60 (42-77)	24 (3-46)	2 (0-7)
September	71 (84-58)	30 (15-44)	58 (39-77)	24 (4-43)	6 (0-19)
November	65 (46-84)	30 (10-47)	56 (38-75)	25 (7-43)	2 (0-7)

Given the predicted USGS flow patterns and the fact that nutrient concentrations were significantly reduced in Cedar Cove but not in Kings Bay, it would not be expected that similar results in the reduction of submersed vegetation would be found in Kings Bay and Cedar Cove if the removal of the treated municipal effluent was responsible for the differences detected in the abundances of submersed vegetation. But virtually the same reductions and increases in submersed vegetation occurred in both Kings Bay and Cedar Cove. Assuming other factors remained constant, if the removal of the wastewater effluent was the cause of the significant reductions in submersed vegetation, it would also be

expected that the significant reductions would be maintained after the removal. But by September 1994, thirteen stations in Kings Bay and both stations in Cedar Cove had hydrilla (Figure 7 and 12). The significant differences detected in the abundances of submersed vegetation in Kings Bay and Cedar Cove therefore can not be attributed to the removal of the wastewater effluent, and in fact are better explained by the "No-Name Storm" on March 13, 1993.

CONCLUSION

The recommended removal of the treated municipal effluent from Cedar Cove by two state agencies has not yet achieved the desired goal of control of submersed vegetation in Kings Bay. The importance of the nutrient load of the spring discharge was virtually ignored when compared to the nutrient load from the treated municipal effluent. The treated wastewater effluent was only estimated to have contributed 15% of the total phosphorus and 3.6% of the total nitrogen entering Kings Bay (Romie 1990). Whereas, the springs were estimated to contribute 83% of the total phosphorus and 94% of the total nitrogen entering the bay. Mean total phosphorus and total nitrogen concentrations in the springs ranged from 22 µg/L to 55 µg/L and 190 µg/L to 620 µg/L, respectively (Romie 1990). Since Kings Bay is a flowing water system, nutrients are continually being replenished from spring discharge. Hence, attempts to remove external nutrient sources will not reduce ambient nutrient concentrations below spring nutrient concentrations. Nutrient concentrations discharged from the spring are found at mesotrophic and eutrophic levels, thus Kings Bay is able to support an abundance of aquatic vegetation. Research from this report supports the findings that factors other than nutrients must be the primary factors limiting aquatic vegetation in streams like Kings Bay (Canfield et al. 1985, Duarte and Kalff 1986 and 1987, Canfield and Hoyer 1988, Casey and Westlake 1974, Dawson and Kern-Hansen 1978, 1979). Both total phosphorus and total nitrogen concentrations in Cedar Cove and total phosphorus concentrations downstream of Crystal River were significantly reduced by the removal of the treated wastewater. While there were significant differences in nutrient concentrations in Cedar Cove, there has not been a significant

reduction in the frequency of occurrence between pre-removal and post-removal periods for all submersed plant species, tapegrass, and filamentous algae in either Kings Bay or Cedar Cove. Hence, further attempts to reduce nutrient concentrations in attempts to reduce the abundance of submersed vegetation in Kings Bay will not be effective.

Not only were the importance of the spring discharges ignored, but the flow patterns in Kings Bay were not adequately taken into consideration. Data from this study supports the hypothesis of the USGS that Kings Bay functions as two separate water bodies: a northern and southern portion. Removal of treated municipal effluent from Cedar Cove, the northern portion of Kings Bay, has not significantly reduced ambient nutrient concentrations in the southern portion of Kings Bay because the added nutrient in the water from Cedar Cove only mixed with the water from the southern portion of Kings Bay at the mouth of Kings Bay.

Natural changes in the environment such as the "No-Name Storm" of March 13, 1993 may significantly alter the frequency of submersed vegetation in Kings Bay. The significant reduction in hydrilla and the significant increase in eurasian watermilfoil detected in the post removal period in both Kings Bay and Cedar Cove is likely attributable to changes caused by the "No-Name Storm" on March 13, 1993. If the dynamics of the submersed plant communities in Kings Bay are going to be understood, a long-term continuous data base needs to be maintained during the course of these disturbances. Citizen volunteers are capable and eager to provide long-term continuous data bases. It is well within the scope of the volunteers from the University of Florida's LAKEWATCH program to be trained to collect samples on both the water quality and abundance of aquatic vegetation in systems like Kings Bay.

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APPENDIX

University of Florida's LAKEWATCH data collected by citizen volunteers monthly from August 1992 through July 1995. Weekly water chemistry results collected after the "No-Name Storm". Water samples collected on a low tide are designated with a 1; those with a 2 were collected on a high tide. A dot indicates data are missing.

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	1	08-16-92	31	350	4.2	7.5
1	2	08-16-92	36	300	.	B(2.5)
1	3	08-16-92	27	300	3.5	B(12.0)
1	4	08-15-92	43	370	2.6	B(4.5)
1	5	08-16-92	43	350	30.0	B(4.0)
1	6	08-16-92	35	310	2.4	B(4.1)
1	7	08-15-92	37	380	7.9	P(4.0)
1	8.1	08-15-92	26	220	4.8	B(9.1)
1	8.2	08-15-92	23	360	3.7	B(7.7)
1	9	08-15-92	18	170	1.8	B(4.0)
1	10	08-15-92	22	240	2.8	P(9.0)
1	11	08-15-92	26	240	10.8	P(4.5)
1	12	08-15-92	22	150	4.4	P(7.8)
1	13	08-15-92	29	190	3.1	P(7.0)
1	14	08-15-92	29	150	3.4	P(8.0)
1	15	08-15-92	23	350	4.7	B(9.0)
1	16	08-15-92	23	330	2.1	B(6.5)
1	17	08-15-92	24	350	1.8	10.0
1	18	08-15-92	35	200	3.5	B(7.0)
1	19	08-15-92	34	240	2.6	B(5.0)
1	20	08-15-92	34	160	38.0	B(5.5)
1	1	09-13-92	30	170	4.4	5.0
1	2	.	.	.	.	.
1	3	09-12-92	23	240	5.7	B(9.0)
1	4	09-13-92	37	180	2.4	B(4.0)
1	5	09-13-92	27	130	4.8	8.0
1	6	09-13-92	24	180	1.3	B(3.3)
1	7	09-12-92	22	220	4.7	P(3.5)
1	8.1	09-12-92	20	220	4.5	B(8.4)
1	8.2	09-12-92	24	320	4.1	B(8.0)
1	9	09-12-92	16	230	2.0	B(4.0)
1	10	09-12-92	16	160	2.0	P(7.0)
1	11	09-13-92	21	220	5.0	2.5
1	12	09-12-92	18	150	23.7	6.5
1	13	09-12-92	21	190	2.1	B(9.5)
1	14	09-12-92	23	150	7.0	B(7.0)
1	15	09-12-92	20	480	8.0	B(4.5)
1	16	09-12-92	20	150	2.8	B(8.5)

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	17	09-12-92	22	120	2.6	B(10.3)
1	18	09-12-92	25	180	2.7	B(4.5)
1	19	09-12-92	22	160	1.9	B(6.0)
1	20	.	.	.	.	.
1	1	10-11-92	39	350	4.9	B(6.5)
1	2	10-10-92	34	240	1.4	B(4.0)
1	3	10-15-92	25	270	4.1	B(10.5)
1	4	10-10-92	43	250	0.4	B(4.5)
1	5	10-15-92	37	.	18.4	3.8
1	6	10-11-92	32	250	1.6	B(4.3)
1	7	10-10-92	31	370	5.2	P(4.0)
1	8.1	10-11-92	31	410	4.4	B(8.6)
1	8.2	10-11-92	33	360	4.3	B(7.8)
1	9	10-10-92	26	250	2.6	B(4.0)
1	10	10-11-92	23	240	1.5	B(8.0)
1	11	10-10-92	26	270	4.0	B(4.0)
1	12	10-10-92	30	170	3.4	P(5.0)
1	13	10-15-92	24	160	0.7	B(10.5)
1	14	10-10-92	29	200	7.4	7.0
1	15	10-10-92	28	510	4.8	B(4.3)
1	16	10-10-92	27	270	1.8	B(7.4)
1	17	10-10-92	33	300	1.4	B(10.0)
1	18	10-10-92	33	140	2.1	B(5.0)
1	19	10-10-92	27	290	1.6	B(6.0)
1	20	10-10-92	29	220	1.3	P(6.3)
1	1	11-15-92	30	300	2.5	11.0
1	2	11-14-92	34	290	3.0	B(5.5)
1	3	11-20-92	29	120	3.1	B(5.0)
1	4	11-15-92	32	150	0.7	B(4.5)
1	5	11-20-92	26	150	3.8	5.5
1	6	11-15-92	27	200	0.9	B(2.9)
1	7	11-14-92	65	780	5.2	B(1.5)
1	8.1	11-14-92	31	370	1.9	B(8.7)
1	8.2	11-14-92	40	290	3.9	6.0
1	9	11-14-92	21	200	1.1	B(3.0)
1	10	11-14-92	22	230	1.4	8.0
1	11	11-14-92	23	380	2.6	B(4.5)
1	12	11-15-92	33	230	1.5	P(2.0)
1	13	11-15-92	28	130	1.6	B(6.1)
1	14	11-20-92	34	180	5.2	B(7.8)
1	15	11-15-92	28	330	1.5	B(7.0)
1	16	11-14-92	26	340	1.3	B(7.4)
1	17	11-15-92	32	300	0.7	B(9.5)
1	18	11-15-92	25	110	1.1	B(5.0)
1	19	11-14-92	29	280	1.8	B(4.5)
1	20	11-15-92	31	350	0.7	B(1.0)
1	1	12-18-92	24	140	2.0	10.5
1	2	12-12-92	19	170	0.5	B(3.0)
1	3	12-12-92	25	160	3.4	B(2.0)
1	4	12-13-92	28	230	0.7	B(4.0)
1	5	12-12-92	24	390	3.3	B(9.0)
1	6	12-12-92	21	160	0.9	B(5.0)

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	7	12-12-92	24	280	4.2	P(2.3)
1	8.1	12-12-92	27	310	1.9	B(8.0)
1	8.2	12-12-92	24	320	2.6	B(6.9)
1	9	12-18-92	31	150	2.2	B(4.8)
1	10	12-12-92	23	270	1.9	8.0
1	11	12-12-92	23	100	3.5	P(3.0)
1	12	12-13-92	28	240	2.9	2.5
1	13	12-13-92	25	160	0.9	B(6.8)
1	14	12-12-92	26	170	.	.
1	15	12-12-92	26	280	1.6	B(9.0)
1	16	12-12-92	28	310	1.7	B(8.5)
1	17	12-12-92	31	210	1.4	B(10.0)
1	18	12-12-92	27	140	3.9	B(5.0)
1	19	12-18-92	29	120	1.1	B(4.5)
1	20	12-13-92	26	350	0.7	B(2.5)
1	1	01-24-93	33	110	7.1	6.0
1	2	01-17-93	31	320	1.9	B(3.0)
1	3	01-17-93	37	310	3.0	B(8.0)
1	4	01-18-93	33	180	2.5	B(3.5)
1	5	01-17-93	39	460	11.8	B(6.0)
1	6	01-17-93	33	180	1.6	B(3.5)
1	7	01-18-93	49	550	5.9	B(1.8)
1	8.1	01-17-93	34	320	1.4	B(7.0)
1	8.2	01-17-93	37	430	2.0	B(6.2)
1	9	01-18-93	29	230	1.7	B(6.0)
1	10	01-18-93	27	250	1.6	B(8.0)
1	11	01-17-93	38	320	4.4	B(4.3)
1	12	01-18-93	43	430	.	2.0
1	13	01-18-93	26	180	.	B(10.0)
1	14	01-24-93	24	150	4.6	B(10.7)
1	15	01-18-93	37	380	6.8	B(3.0)
1	16	01-17-93	32	350	1.0	B(8.5)
1	17	01-17-93	35	250	1.2	B(8.5)
1	18	01-18-93	31	170	1.8	B(2.8)
1	19	01-18-93	32	270	2.1	B(4.0)
1	20	01-17-93	31	450	0.6	B(2.5)
1	1	02-21-93	27	230	5.5	8.0
1	2	02-20-93	34	400	6.5	B(2.5)
1	3	02-21-93	25	300	1.8	B(9.0)
1	4	02-21-93	28	130	9.0	B(4.0)
1	5	02-21-93	23	340	1.4	6.5
1	6	02-21-93	30	150	2.9	B(3.1)
1	7	02-20-93	32	410	13.1	B(1.8)
1	8.1	02-21-93	25	300	5.6	B(7.1)
1	8.2	02-21-93	27	420	6.0	B(7.0)
1	9	02-21-93	29	280	5.8	B(5.0)
1	10	02-20-93	22	240	1.3	B(9.0)
1	11	02-21-93	23	330	3.1	B(2.9)
1	12	02-20-93	23	430	3.0	B(6.0)
1	13	02-21-93	26	210	2.5	B(9.8)
1	14	.	.	.	.	B(2.0)
1	15	02-20-93	39	340	6.0	B(5.5)
1	16	02-21-93	26	160	1.9	B(9.5)

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	17	02-21-93	32	290	2.7	B(2.8)
1	18	02-20-93	26	130	2.0	B(5.0)
1	19	02-20-93	20	120	1.6	B(5.5)
1	20	.	.	.	.	.
1	1	03-18-93	61	230	1.4	B(5.8)
1	2	03-18-93	71	410	2.9	B(1.7)
1	3	03-18-93	61	500	2.0	7.5
1	4	03-18-93	90	670	3.8	B(3.3)
1	5	03-18-93	50	620	1.5	5.0
1	6	03-18-93	58	430	4.9	B(3.3)
1	7	03-18-93	205	1670	11.7	0.7
1	8.1	03-18-93	67	490	5.9	B(5.8)
1	8.2	03-18-93	56	420	3.4	B(5.8)
1	9	03-18-93	69	430	3.5	B(5.0)
1	10	03-18-93	57	420	3.9	B(3.3)
1	11	03-18-93	65	580	3.4	B(2.5)
1	12	03-18-93	55	410	5.1	B(6.7)
1	13	03-18-93	33	290	2.4	B(4.2)
1	14	03-18-93	51	350	1.4	5.8
1	15	03-18-93	68	470	3.0	B(2.5)
1	16	03-18-93	48	410	10.0	5.0
1	17	03-18-93	47	420	3.5	B(6.7)
1	18	03-18-93	43	380	1.1	B(3.3)
1	19	03-18-93	65	480	1.7	B(3.3)
1	20	03-18-93	41	230	2.5	B(2.5)
1	1	03-25-93	50	340	.	.
1	2	03-25-93	100	240	.	.
1	3	03-25-93	119	700	.	.
1	4	03-25-93	99	460	.	.
1	5	03-25-93	55	300	.	.
1	6	03-25-93	73	440	.	.
1	7	03-25-93	111	630	.	.
1	8.1	03-25-93	79	570	.	.
1	8.2	03-25-93	81	590	.	.
1	9	03-25-93	68	470	.	.
1	10	03-25-93	37	360	.	.
1	11	03-25-93	89	620	.	.
1	12	03-25-93	60	450	.	.
1	13	03-25-93	49	290	.	.
1	14	03-25-93	63	390	.	.
1	15	03-25-93	107	870	.	.
1	16	03-25-93	37	300	.	.
1	17	03-25-93	56	550	.	.
1	18	03-25-93	53	320	.	.
1	19	03-25-93	56	370	.	.
1	20	03-25-93	48	300	.	.
1	1	04-01-93	48	620	.	.
1	2	04-01-93	70	600	.	.
1	3	04-01-93	62	460	.	.
1	4	04-01-93	69	380	.	.
1	5	04-01-93	54	620	.	.
1	6	04-01-93	43	300	.	.
1	7	04-01-93	70	460	.	.

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	8.1	04-01-93	66	470	.	.
1	8.2	04-01-93	61	340	.	.
1	9	04-01-93	43	300	.	.
1	10	04-01-93	39	350	.	.
1	11	04-01-93	70	560	.	.
1	12	04-01-93	60	510	.	.
1	13	04-01-93	32	250	.	.
1	14	04-01-93	44	300	.	.
1	15	04-01-93	61	610	.	.
1	16	04-01-93	43	330	.	.
1	17	04-01-93	36	290	.	.
1	18	04-01-93	43	260	.	.
1	19	04-01-93	36	260	.	.
1	20	04-01-93	42	310	.	.
1	1	04-07-93	42	430	.	.
1	2	04-07-93	185	1040	.	.
1	3	04-07-93	69	540	.	.
1	4	04-07-93	60	400	.	.
1	5	04-07-93	58	560	.	.
1	6	04-07-93	31	230	.	.
1	7	04-07-93	96	920	.	.
1	8.1	04-07-93	59	370	.	.
1	8.2	04-07-93	47	410	.	.
1	9	04-07-93	52	390	.	.
1	10	04-07-93	25	320	.	.
1	11	04-07-93	61	590	.	.
1	12	04-07-93	60	490	.	.
1	13	04-07-93	27	320	.	.
1	14	04-07-93	31	350	.	.
1	15	04-07-93	67	660	.	.
1	16	04-07-93	41	440	.	.
1	17	04-07-93	31	350	.	.
1	18	04-07-93	33	320	.	.
1	19	04-07-93	39	310	.	.
1	20	04-07-93	33	230	.	.
1	1	04-18-93	52	270	13.5	6.5
1	2	04-17-93	54	480	11.5	4.5
1	3	04-18-93	45	290	10.1	6.0
1	4	04-18-93	40	270	3.0	B(3.0)
1	5	04-18-93	62	300	22.1	3.0
1	6	04-18-93	36	260	4.8	B(2.6)
1	7	04-18-93	50	470	20.7	B(2.5)
1	8.1	04-17-93	48	270	10.8	5.0
1	8.2	04-17-93	57	620	18.9	4.3
1	9	04-21-93	31	210	.	.
1	10	04-17-93	28	270	12.7	5.5
1	11	04-21-93	48	690	.	3.5
1	12	.	.	.	.	.
1	13	04-21-93	27	250	5.9	B(8.8)
1	14	04-17-93	53	310	.	2.5
1	15	04-18-93	32	480	3.4	B(8.0)
1	16	04-17-93	20	220	1.3	B(6.5)
1	17	04-17-93	35	320	5.2	8.0

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	18	04-18-93	36	300	7.7	B(5.0)
1	19	04-17-93	38	460	9.0	B(5.0)
1	20	04-18-93	30	280	0.9	B(1.5)
1	1	04-21-93	40	570	.	.
1	2	04-21-93	68	260	.	.
1	3	04-21-93	36	310	.	.
1	4	04-21-93	41	420	.	.
1	5	04-21-93	44	600	.	.
1	6	04-21-93	32	530	.	.
1	7	04-21-93	45	370	.	.
1	8.1	04-21-93	38	670	.	.
1	8.2	04-21-93	49	360	.	.
1	9	04-21-93	31	210	.	.
1	10	04-21-93	24	620	.	.
1	11	04-21-93	48	690	.	.
1	12	04-21-93	56	310	.	.
1	13	04-21-93	27	250	.	.
1	14	04-21-93	36	300	.	.
1	15	04-21-93	43	680	.	.
1	16	04-21-93	34	380	.	.
1	17	04-21-93	37	570	.	.
1	18	04-21-93	36	520	.	.
1	19	04-21-93	25	330	.	.
1	20	04-21-93	27	200	.	.
1	1	05-04-93	40	390	.	.
1	2	05-04-93	44	370	.	.
1	3	05-04-93	50	650	.	.
1	4	05-04-93	50	350	.	.
1	5	05-04-93	47	230	.	.
1	6	05-04-93	33	220	.	.
1	7	05-04-93	47	420	.	.
1	8.1	05-04-93	50	510	.	.
1	8.2	05-04-93	55	550	.	.
1	9	05-04-93	44	340	.	.
1	10	05-04-93	28	210	.	.
1	11	05-04-93	49	570	.	.
1	12	05-04-93	51	570	.	.
1	13	05-04-93	25	250	.	.
1	14	05-04-93	31	300	.	.
1	15	05-04-93	43	330	.	.
1	16	05-04-93	36	200	.	.
1	17	05-04-93	34	260	.	.
1	18	05-04-93	36	490	.	.
1	19	05-04-93	27	220	.	.
1	20	05-04-93	29	240	.	.
1	1	05-16-93	42	550	6.3	4.5
1	2	05-15-93	60	410	13.9	2.8
1	3	05-16-93	37	340	7.4	5.0
1	4	05-15-93	44	240	5.1	B(3.5)
1	5	05-16-93	54	580	19.0	4.0
1	6	05-16-93	37	290	8.8	B(3.6)
1	7	05-15-93	44	420	16.0	B(3.3)
1	8.1	05-16-93	34	310	9.7	4.5

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	8.2	05-16-93	35	270	10.4	4.0
1	9	05-20-93	37	440	10.3	B(3.5)
1	10	05-16-93	21	220	5.7	.
1	11	05-20-93	42	490	.	.
1	12	.	.	.	.	.
1	13	05-20-93	26	320	.	.
1	14	05-20-93	30	440	.	.
1	15	05-16-93	25	290	5.9	B(9.0)
1	16	05-16-93	30	190	1.7	B(6.8)
1	17	05-15-93	25	250	2.5	B(9.8)
1	18	05-16-93	29	230	4.3	B(7.0)
1	19	05-15-93	29	260	.	B(5.0)
1	20	05-16-93	26	190	.	B(2.0)
1	1	05-20-93	37	280	.	.
1	2	05-20-93	43	810	.	.
1	3	05-20-93	37	140	.	.
1	4	05-20-93	61	560	.	.
1	5	05-20-93	45	130	.	.
1	6	05-20-93	36	290	.	.
1	7	05-20-93	37	440	.	.
1	8.1	05-20-93	36	320	.	.
1	8.2	05-20-93	37	500	.	.
1	9	05-20-93	37	440	.	.
1	10	05-20-93	22	490	.	.
1	11	05-20-93	42	490	.	.
1	12	05-20-93	37	810	.	.
1	13	05-20-93	26	320	.	.
1	14	05-20-93	30	440	.	.
1	15	05-20-93	40	510	.	.
1	16	05-20-93	34	580	.	.
1	17	05-20-93	30	410	.	.
1	18	05-20-93	26	390	.	.
1	19	05-20-93	36	540	.	.
1	20	05-20-93	24	310	.	.
1	1	05-27-93	32	250	.	.
1	2	05-27-93	33	330	.	.
1	3	05-27-93	41	290	.	.
1	4	05-27-93	56	350	.	.
1	5	05-27-93	35	120	.	.
1	6	05-27-93	53	310	.	.
1	7	05-27-93	36	510	.	.
1	8.1	05-27-93	31	460	.	.
1	8.2	05-27-93	37	460	.	.
1	9	05-27-93	33	410	.	.
1	10	05-27-93	21	410	.	.
1	11	05-27-93	38	660	.	.
1	12	05-27-93	32	440	.	.
1	13	05-27-93	22	200	.	.
1	14	05-27-93	30	330	.	.
1	15	05-27-93	34	340	.	.
1	16	05-27-93	24	440	.	.
1	17	05-27-93	35	430	.	.
1	18	05-27-93	29	330	.	.

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	19	05-27-93	31	500	.	.
1	20	05-27-93	26	300	.	.
1	1	06-03-93	40	320	.	.
1	2	06-03-93	63	390	.	.
1	3	06-03-93	71	290	.	.
1	4	06-03-93	52	300	.	.
1	5	06-03-93	39	350	.	.
1	6	06-03-93	40	310	.	.
1	7	06-03-93	82	680	.	.
1	8.1	06-03-93	38	390	.	.
1	8.2	06-03-93	38	370	.	.
1	9	06-03-93	28	260	.	.
1	10	06-03-93	28	280	.	.
1	11	06-03-93	39	360	.	.
1	12	06-03-93	35	310	.	.
1	13	06-03-93	20	200	.	.
1	14	06-03-93	21	200	.	.
1	15	06-03-93	28	320	.	.
1	16	06-03-93	30	330	.	.
1	17	06-03-93	22	340	.	.
1	18	06-03-93	26	410	.	.
1	19	06-03-93	26	250	.	.
1	20	06-03-93	22	200	.	.
1	1	06-17-93	35	270	.	.
1	2	06-17-93	119	480	.	.
1	3	06-17-93	28	200	.	.
1	4	06-17-93	51	250	.	.
1	5	06-17-93	36	200	.	.
1	6	06-17-93	25	270	.	.
1	7	06-17-93	37	200	.	.
1	8.1	06-17-93	29	350	.	.
1	8.2	06-17-93	27	270	.	.
1	9	06-17-93	20	220	.	.
1	10	06-17-93	20	290	.	.
1	11	06-17-93	35	260	.	.
1	12	06-17-93	33	280	.	.
1	13	06-17-93	26	360	.	.
1	14	06-17-93	24	140	.	.
1	15	06-17-93	33	430	.	.
1	16	06-17-93	20	320	.	.
1	17	06-17-93	27	270	.	.
1	18	06-17-93	23	250	.	.
1	19	06-17-93	25	180	.	.
1	20	06-17-93	19	150	.	.
1	1	06-20-93	36	100	4.9	.
1	2	06-19-93	26	280	4.7	.
1	3	06-20-93	25	300	4.6	.
1	4	06-20-93	41	240	7.9	.
1	5	06-20-93	45	580	21.9	.
1	6	06-20-93	30	250	6.4	.
1	7	06-19-93	52	530	30.6	.
1	8.1	06-19-93	35	310	9.7	.
1	8.2	06-19-93	29	460	12.8	.

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	9	06-19-93	14	150	2.3	.
1	10	06-19-93	17	190	2.2	.
1	11	06-20-93	31	250	12.6	.
1	12	.	.	.	.	.
1	13	06-17-93	26	360	6.1	.
1	14	06-20-93	28	270	13.0	.
1	15	06-20-93	27	360	15.8	.
1	16	06-19-93	14	340	4.9	.
1	17	06-20-93	24	210	2.5	.
1	18	06-20-93	28	260	11.8	.
1	19	06-19-93	24	270	6.0	.
1	20	06-20-93	28	200	.	.
1	1	07-01-93	44	150	.	.
1	2	07-01-93	54	190	.	.
1	3	07-01-93	34	240	.	.
1	4	07-01-93	53	300	.	.
1	5	07-01-93	40	290	.	.
1	6	07-01-93	27	190	.	.
1	7	07-01-93	42	390	.	.
1	8.1	07-01-93	35	280	.	.
1	8.2	07-01-93	28	320	.	.
1	9	07-01-93	29	270	.	.
1	10	07-01-93	20	220	.	.
1	11	07-01-93	36	350	.	.
1	12	07-01-93	30	300	.	.
1	13	07-01-93	22	170	.	.
1	14	07-01-93	20	290	.	.
1	15	07-01-93	28	370	.	.
1	16	07-01-93	24	340	.	.
1	17	07-01-93	23	210	.	.
1	18	07-01-93	24	180	.	.
1	19	07-01-93	25	200	.	.
1	20	07-01-93	21	200	.	.
1	1	07-11-93	38	560	3.4	.
1	2	07-10-93	63	540	14.5	.
1	3	07-11-93	26	260	6.5	.
1	4	07-11-93	34	200	1.3	.
1	5	07-11-93	39	510	10.8	.
1	6	07-10-93	30	220	10.4	.
1	7	07-11-93	50	610	23.9	.
1	8.1	07-10-93	29	220	14.1	.
1	8.2	07-10-93	25	130	12.8	.
1	9	07-11-93	33	290	.	.
1	10	.	.	.	.	.
1	11	07-11-93	32	430	19.4	.
1	12	07-10-93	24	280	16.3	.
1	13	.	.	.	.	.
1	14	07-10-93	25	100	5.9	.
1	15	07-10-93	22	120	17.5	.
1	16	07-11-93	20	110	3.7	.
1	17	07-10-93	20	240	2.9	.
1	18	07-10-93	14	150	2.1	.
1	19	07-10-93	21	150	.	.

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	20	.	.	.	.	.
1	1	08-15-93	42	350	11.6	.
1	2	08-14-93	35	430	10.4	.
1	3	08-14-93	24	190	6.8	.
1	4	08-15-93	36	170	5.0	.
1	5	08-15-93	41	220	18.8	.
1	6	08-15-93	21	150	5.8	.
1	7	08-14-93	39	320	17.3	.
1	8.1	08-14-93	25	310	11.1	.
1	8.2	08-14-93	24	350	10.1	.
1	9.0	08-14-93	19	120	3.1	.
1	10	08-15-93	26	110	4.3	.
1	11	.	.	.	.	.
1	12	08-20-93	23	110	16.1	.
1	13	08-15-93	25	130	5.2	.
1	14	08-15-93	24	130	2.1	.
1	15	08-15-93	20	280	18.6	.
1	16	08-15-93	29	150	6.0	.
1	17	08-22-93	26	110	10.6	.
1	18	08-27-93	33	170	2.6	.
1	19	08-14-93	18	160	2.8	.
1	20	08-15-93	37	260	6.4	.
1	1	09-12-93	40	360	14.9	.
1	2	09-11-93	27	310	14.5	.
1	3	09-11-93	27	200	9.1	.
1	4	09-12-93	30	200	0.8	.
1	5	09-12-93	38	340	19.1	.
1	6	09-12-93	29	210	1.5	.
1	7	09-11-93	32	300	12.7	.
1	8.1	09-11-93	26	290	12.4	.
1	8.2	09-11-93	23	270	9.7	.
1	9	09-11-93	29	220	2.9	.
1	10	09-12-93	18	540	1.3	.
1	11	09-11-93	30	260	26.6	.
1	12	09-12-93	22	300	.	.
1	13	09-12-93	23	190	2.5	.
1	14	09-11-93	30	230	16.1	.
1	15	09-11-93	24	290	3.6	.
1	16	09-11-93	24	110	2.1	.
1	17	09-11-93	25	130	4.1	.
1	18	09-11-93	28	120	2.5	.
1	19	09-11-93	24	150	4.0	.
1	20	09-11-93	64	560	20.5	.
1	1	10-09-93	25	170	10.5	7.5
1	2	10-09-93	21	180	6.6	B(6.0)
1	3	10-10-93	20	160	7.2	11.0
1	4	10-08-93	24	170	.	.
1	5	10-09-93	25	180	26.1	5.0
1	6	10-10-93	29	200	1.2	B(5.0)
1	7	10-10-93	24	190	7.6	P(4.5)
1	8.1	10-09-93	19	370	8.1	9.3
1	8.2	10-09-93	23	370	6.4	8.0
1	9	10-09-93	26	250	2.4	B(5.0)

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	10	.	.	.	.	.
1	11	10-09-93	24	310	22.4	4.0
1	12	10-10-93	21	320	7.4	6.5
1	13	10-10-93	19	170	1.6	B(8.0)
1	14	10-09-93	26	130	2.5	B(7.0)
1	15	10-10-93	.	.	5.5	B(10.0)
1	16	10-08-93	20	310	2.9	B(6.5)
1	17	10-08-93	26	270	5.6	6.8
1	18	10-10-93	16	210	2.5	B(7.0)
1	19	10-09-93	23	200	2.3	B(5.0)
1	20	.	.	.	.	.
1	1	11-07-93	27	410	5.7	8.5
1	2	11-06-93	26	370	9.3	B(4.5)
1	3	11-07-93	29	360	4.9	B(14.0)
1	4	11-07-93	34	230	0.5	B(4.0)
1	5	11-07-93	37	320	4.6	4.0
1	6	11-06-93	32	240	2.2	B(4.0)
1	7	11-07-93	39	420	5.2	B(2.0)
1	8.1	11-06-93	26	280	9.5	B(10.8)
1	8.2	11-06-93	22	350	8.4	B(10.2)
1	9	11-06-93	20	270	3.6	.
1	10	11-06-93	22	270	1.2	.
1	11	11-07-93	24	330	9.4	B(3.2)
1	12	11-07-93	30	640	.	5.0
1	13	11-07-93	25	200	1.6	B(9.0)
1	14	11-06-93	29	330	8.5	6.0
1	15	11-07-93	69	1030	.	B(4.5)
1	16	11-06-93	29	320	7.1	B(6.5)
1	17	11-06-93	27	290	2.1	B(9.5)
1	18	11-07-93	30	250	1.8	B(4.0)
1	19	11-06-93	27	300	.	B(6.0)
1	20	11-07-93	30	390	29.9	B(2.5)
1	1	12-11-93	23	230	2.3	8.5
1	2	12-11-93	23	650	3.9	B(4.5)
1	3	12-11-93	19	150	3.7	10.0
1	4	12-11-93	25	580	1.7	B(3.5)
1	5	12-11-93	35	270	8.2	7.0
1	6	12-12-93	22	620	2.2	B(3.0)
1	7	12-11-93	23	770	5.0	B(4.3)
1	8.1	12-11-93	26	510	2.6	B(6.7)
1	8.2	12-11-93	23	320	3.2	B(7.1)
1	9	12-11-93	42	550	.	B(4.0)
1	10	12-12-93	24	590	2.9	P(8.0)
1	11	.	.	.	.	.
1	12	12-12-93	25	780	.	B(8.0)
1	13	12-12-93	24	240	1.3	B(9.0)
1	14	12-11-93	24	250	1.8	B(5.5)
1	15	12-11-93	47	710	3.8	B(3.0)
1	16	12-11-93	25	820	4.2	B(7.4)
1	17	12-12-93	32	310	2.3	B(10.0)
1	18	12-11-93	40	320	2.1	B(4.0)
1	19	12-11-93	26	590	.	B(5.0)
1	20	12-12-93	42	670	.	B(2.0)

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	1	01-09-94	30	430	3.3	B(2.0)
1	2	01-08-94	34	530	8.7	B(3.0)
1	3	01-08-94	32	310	3.4	11.0
1	4	01-08-94	33	260	2.1	B(2.8)
1	5	01-09-94	29	490	16.8	5.0
1	6	01-09-94	39	320	3.0	B(2.1)
1	7	01-09-94	45	670	7.0	P(2.0)
1	8.1	01-08-94	30	320	3.3	B(6.1)
1	8.2	01-08-94	31	300	.	B(6.4)
1	9	01-08-94	35	340	4.6	B(3.0)
1	10	01-08-94	30	360	4.2	B(6.0)
1	11	01-08-94	26	330	2.6	B(2.5)
1	12	01-09-94	33	480	.	B(4.5)
1	13	01-09-94	31	320	1.7	B(8.0)
1	14	.	.	.	.	.
1	15	01-08-94	38	450	4.3	B(7.0)
1	16	01-08-94	31	330	1.5	B(6.5)
1	17	01-08-94	33	440	2.7	B(9.0)
1	18	01-08-94	41	330	4.9	B(4.0)
1	19	01-08-94	31	300	1.9	B(4.0)
1	20	01-09-94	104	680	3.4	B(1.0)
1	1	02-06-94	25	300	2.9	7.0
1	2	02-05-94	32	310	7.2	B(1.5)
1	3	02-06-94	36	500	5.7	12.0
1	4	02-05-94	28	260	0.9	B(4.0)
1	5	02-06-94	26	450	5.6	5.0
1	6	02-20-94	28	240	3.5	B(4.5)
1	7	02-05-94	42	300	5.8	B(3.0)
1	8.1	02-05-94	27	290	.	B(6.4)
1	8.2	02-05-94	25	270	.	B(5.9)
1	9	02-05-94	28	260	2.2	B(2.0)
1	10	02-20-94	30	320	5.9	B(4.5)
1	11	02-20-94	39	610	18.0	B(4.0)
1	12	02-06-94	34	290	5.5	6.0
1	13	02-06-94	25	240	2.5	B(7.0)
1	14	02-06-94	29	190	2.2	B(7.0)
1	15	02-06-94	22	200	.	B(5.0)
1	16	02-05-94	27	380	1.2	B(6.5)
1	17	02-05-94	28	380	1.0	B(9.0)
1	18	02-06-94	30	280	.	B(4.0)
1	19	02-05-94	19	240	.	B(6.0)
1	20	02-20-94	23	170	3.1	B(3.0)
1	1	03-20-94	32	220	4.1	8.0
1	2	03-19-94	46	120	7.4	B(3.0)
1	3	03-20-94	34	270	6.0	10.0
1	4	03-20-94	28	170	1.4	B(4.0)
1	5	03-20-94	28	100	5.1	.
1	6	03-19-94	19	160	1.3	B(3.8)
1	7	03-19-94	42	150	15.7	B(3.0)
1	8.1	03-19-94	35	270	8.9	7.0
1	8.2	03-19-94	36	280	7.6	6.9
1	9	03-19-94	22	80	3.1	B(5.0)
1	10	03-28-94	20	150	3.3	B(5.5)

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	11	03-19-94	38	110	13.1	P(3.0)
1	12	03-19-94	36	600	7.0	6.0
1	13	03-20-94	30	230	2.3	B(7.0)
1	14	03-28-94	24	150	4.1	10.0
1	15	03-19-94	40	490	13.9	B(3.5)
1	16	03-19-94	28	150	3.2	B(7.7)
1	17	03-19-94	33	220	2.8	B(10.5)
1	18	03-19-94	23	100	2.5	B(3.5)
1	19	03-19-94	18	100	1.7	B(6.0)
1	20	03-28-94	25	110	5.4	B(6.0)
1	1	04-10-94	32	250	3.3	6.5
1	2	04-09-94	23	170	2.0	B(8.0)
1	3	04-09-94	27	190	4.6	10.0
1	4	04-10-94	28	210	1.2	B(4.0)
1	5	04-10-94	31	400	5.5	7.0
1	6	04-28-94	21	140	0.6	B(4.8)
1	7	04-09-94	29	340	5.0	P(3.0)
1	8.1	04-09-94	29	310	2.9	B(8.0)
1	8.2	04-09-94	29	320	2.1	B(7.8)
1	9	04-09-94	20	200	1.1	B(3.0)
1	10	04-28-94	15	140	1.4	B(4.5)
1	11	04-09-94	32	340	4.2	B(5.5)
1	12	04-09-94	28	380	4.5	4.0
1	13	04-10-94	23	210	3.1	B(8.0)
1	14	04-28-94	24	130	4.6	B(9.0)
1	15	04-10-94	29	230	.	B(3.0)
1	16	04-10-94	23	150	3.3	B(7.0)
1	17	04-09-94	26	210	2.7	B(11.5)
1	18	04-10-94	23	120	.	B(4.0)
1	19	04-09-94	20	170	1.2	B(4.0)
1	20	04-28-94	25	150	4.4	B(3.3)
1	1	05-26-94	25	320	2.2	.
1	2	05-26-94	25	240	.	.
1	3	05-26-94	22	230	5.4	.
1	4	05-26-94	22	180	3.0	.
1	5	05-26-94	22	170	7.9	.
1	6	05-26-94	19	220	1.5	.
1	7	05-26-94	16	320	.	.
1	8.1	05-26-94	18	330	3.0	.
1	8.2	05-26-94	12	220	4.0	.
1	9	05-26-94	13	310	2.0	.
1	10	05-26-94	15	180	1.8	.
1	11	05-26-94	13	270	2.6	.
1	12	05-26-94	12	280	4.8	.
1	13	05-26-94	20	190	4.6	.
1	14	05-26-94	19	160	2.7	.
1	15	05-26-94	12	430	4.2	.
1	16	05-26-94	17	250	4.5	.
1	17	05-26-94	24	260	7.3	.
1	18	05-26-94	19	250	4.5	.
1	19	05-26-94	19	210	3.0	.
1	20	05-26-94	24	260	6.4	.
1	1	06-26-94	22	190	4.8	B(6.0)

Tide	Station	Date	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi (Ft)
1	2	06-26-94	74	540	5.6	B(2.5)
1	3	06-28-94	27	180	2.6	B(4.0)
1	4	06-25-94	10	90	3.4	B(5.0)
1	5	06-26-94	16	220	5.7	P(7.0)
1	5.1	06-26-94	35	390	28.6	5.0
1	6	.	.	.	.	.
1	7	06-24-94	21	150	5.0	B(12.0)
1	8	06-15-94	11	140	9.3	P(4.5)
1	9	06-15-94	11	130	11.8	P(2.0)
1	10	06-09-94	14	140	0.4	B(20.0)
2	1	06-27-94	20	200	5.4	B(5.5)
2	2	06-27-94	18	200	6.5	B(4.0)
2	3	06-30-94	25	210	5.6	B(4.0)
2	4	06-11-94	11	190	5.4	B(7.5)
2	5	06-11-94	12	110	4.1	B(7.0)
2	6	06-19-94	9	280	4.1	4.8
2	7	06-19-94	18	260	2.5	B(10.4)
2	8	06-11-94	7	130	5.6	P(7.5)
2	9	06-30-94	15	100	3.6	B(8.4)
2	10	06-11-94	12	90	3.6	B(9.0)
1	1	07-31-94	23	410	4.1	8.0
1	2	07-31-94	27	260	3.8	B(2.0)
1	3	07-24-94	32	220	6.6	B(4.0)
1	4	07-22-94	16	160	2.5	B(5.0)
1	5	07-23-94	19	210	6.4	B(7.0)
1	5.1	07-31-94	45	260	35.0	3.5
1	6	.	.	.	.	.
1	7	07-31-94	23	180	0.9	B(10.0)
1	8	07-15-94	12	110	6.1	P(2.3)
1	9	07-15-94	13	380	3.7	B(8.8)
1	10	07-13-94	13	230	1.7	B(28.0)
2	1	07-30-94	15	170	4.3	9.0
2	2	07-30-94	19	160	5.2	B(3.5)
2	3	07-31-94	35	130	1.9	B(5.0)
2	4	07-16-94	18	130	8.4	B(6.5)
2	5	07-16-94	14	120	3.6	6.0
2	6	07-16-94	12	170	3.7	B(9.9)
2	7	07-16-94	17	190	0.9	B(5.3)
2	8	07-16-94	13	230	2.9	B(6.5)
2	9	07-31-94	20	150	.	8.5
2	10	07-16-94	14	110	1.0	B(13.5)

BIOLOGICAL SKETCH

Julia H. Bishop was born in Pontiac, Michigan and moved to Florida in 1984. She graduated from Niceville Senior High School, Florida, in 1987. She received a Bachelor of Science in Forest Resources and Conservation, with a major in wildlife ecology and a minor in Zoology, from the University of Florida in 1992. While working for the Florida LAKEWATCH program, Julia earned a Master of Science degree, with a major in fisheries and aquatic sciences specializing in limnology, at the University of Florida in 1995.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Daniel E. Canfield, Jr., Chairman
Professor of Fisheries and Aquatic Sciences

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Charles E. Cichra
Associate Professor of Fisheries and Aquatic Sciences

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

William T. Haller
Professor of Agronomy

This thesis was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Master of Science.

August, 1995

Dean, College of Agriculture

Dean, Graduate School