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Water Chemistry of an Atlantic Coastal Marsh

This paper presents the results from a water chemistry study of a small tidal marsh and its outlet stream on the southern Atlantic coast. The goal of the study was to find patterns in the water chemistry of the marsh and to identify possible causes for such patterns. Analysis also tried to identify any human influences on the marsh area. Sampling was limited, but results show definite trends for water chemistry in a tidal marsh; presumably these trends indicate general patterns which hold for most such ecosystems. This study was conducted as an educational exercise, emphasizing the practices of field research and environmental sample analysis. This study was performed as a student independent project for the course Environmental Studies 102 "Introduction to Environmental Science" at Williams College, Williamstown, Massachusetts.

Background

The tidal marsh studied is in North Myrtle Beach, South Carolina. It is an area roughly 700 meters long, northwest to southeast, by 400 meters wide, southwest to northeast, with an outlet stream that runs south and southeast through the marsh. The outflow stream flows out of the marsh and southwest, parallel to the beach before turning south by southeast across the beachfront and the beach. From the marsh to the ocean, the stream runs along 400-500 meters (See maps 1 and 2). The marsh is in a developed area, immediately surrounded by residential properties, with several large hotels on the beachfront just to the southeast. A major commercial roadway borders the marsh to the west, with many restaurants, shops, and tourist attractions. Samples were taken from the outlet stream at points from the ocean shore upstream into the marsh, as far as the indefinite source of the stream, near the northeast corner of the marsh (see map 2 for sample locations). There is a second stream which flows from the southwest and joins the major outlet stream at the edge of the beach. This tributary stream was sampled immediately above the confluence of the two streams, and at a small lagoon less than 100 meters upstream of this confluence.

The main marsh area is undeveloped, but is littered with refuse and debris, especially near the edges. Personal fishing, clamming, and crabbing are done in the marsh and around the outlet stream, although it is unclear how heavily these are practiced.

Methods and Materials

Approximately 500 mL of water was collected from each sample site on 28-29 March 1994. The surface temperature of the water was measured and recorded at each site with a portable digital conductivity meter with thermometer. Conductivity readings were also attempted at each site, but went off the scale of the meter at all but one site (the source site of the outlet stream, sample T5).

After collection, a portable pH meter, auto-calibrated with pH 7.0 and pH 4.0 buffer solutions, was used to measure pH of each sample. After return to Williamstown, filtered samples were measured for dissolved ion content using Ion Chromatography and Atomic Absorption Spectrophotometry; for these tests, dilutions of 1:10 and 1:1000 were made using distilled deionized water. These data were analyzed with attention to directional stream flow (including tidal flow changes), proximity to the ocean, and proximity to developments.

Thirteen samples were retrieved and analyzed. They are labeled, in tables and illustrations, M1 through M8 for the samples, taken on Monday, 28 March 1994, in order of collection, and T1-T5 for the samples taken the following day. With a few exceptions, the samples were collected in order from the ocean upstream into the marsh. Exceptions are the first sample, M1 taken from the edge of the marsh, and the samples taken from the tributary stream and lagoon, Samples M5 and M6; also, samples M2 and M3 of the outlet stream just before its outflow to the ocean and the ocean itself, respectively, are in opposite order of the other samples, downstream to upstream. In presentation, the samples are reordered to present the data in order from the source to the ocean (this order is: M1, T5, T4, T3, T2, T1, M8, M7, M6, M5, M4, M2, M3).

Data

Tests of samples resulted in a body of data including, for each sample:

- Temperature (degrees Celsius)
- pH
- Cation Concentrations of Ca^{+2}, Mg^{+2}, and K^{+} (in mg/L)
- Anion Concentrations of F^{-}, NO_3^{-}, SO_4^{-2}, and PO_4^{-3} (in mg/L)

These results are presented in Table 1.

The other important data is qualitative, and comes from site descriptions, and observations made during sampling. ~~This~~ These data ~~is~~ are presented in the following list by sample site. Site descriptions include relative location description, as well as observation of general topography of the site, relative discharge and velocity of the outlet stream at that site, depth and width of the stream, and plant and animal species seen at that sampling location. Distances between sites are measured along the stream bed, not in a straight line.

Sample Sites (Identified on Map 2)

--Site M1

This sample was taken along the western edge of the marsh, at a slight clearing in the reed cover where a shallow pool of water, 3-5 cm deep, covered the deep mud. The 'clearing' was about 15m into the marsh from the edge. Reeds here were 60-90 cm high, but had a high water mark and snails clinging to the stalks 20-30 cm above the mud, suggesting a substantial water level change at high tide (sample was collected near low tide). The sample contained a great deal of suspended mud. Water Temperature: 20.7 C.

--Site M2

Sample M2 comes from the outlet stream just before it flows into the ocean (25m from the water line just before low tide). The stream cuts through the beach with relatively constant depth and width, until only 20-30m before the ocean where the stream bed flares open. The sample was taken from the flare, where the stream is about 10m wide and 15-30cm deep. There is a great deal of sand suspended in the water, which flows quite rapidly. Water Temperature: 20.0 C.

--Site M3

Sample M3 is from just offshore of the outlet. There is a rippled sandy bottom, and moderate surf. Water temperature was 18.5 C directly in front of the outflow, but 17 C 30m to the north.

--Site M4

Sample M4 was taken about 20m downstream from the confluence of the tributary stream from the southwest with the major outflow stream. The confluence is just below the small dune which divides the open beach from the beachfront area. Water temperature: 20.5 C.

--Site M5

M5 is taken from the tributary stream, just above a small rock "dam" about 40m upstream from the confluence with the major outflow stream. The tributary stream is smaller than the major outflow stream, 1.5-2m wide and less than 50cm deep. Water temperature: 20.1 C.

--Site M6

Further upstream on the tributary, there is a lagoon above the stream, roughly 30m from the rock "dam", just behind the protective dune from the open beach. The water is less than 25cm deep, but contains schools of tiny fish (2-4cm), and the tidal flats around the lagoon have thousands of tiny burrowing crabs. The living reeds here are about 8-15cm high, with many dead and dried reeds 20-40cm high. The sample was taken from the shallow water of the lagoon; water temperature: 24.6 C.

--Site M7

Site M7 is on the major outflow stream, about 200m upstream from the tributary. The sample was taken from a tiny stagnant fork adjacent to the main stream along a large tidal flat area, just beyond a small pedestrian bridge between the hotels on the beachfront and the beach. The stagnant fork had large algae and seaweed populations, and a silty bottom, 10-20cm deep. Water temperature: 24.2 C. The tide was coming in when this sample was taken, and the main stream was flowing with the tide, into the marsh. The main stream here was 5-7m wide and 0.7-1m deep.

--Site M8

The sample was taken from the main stream, just past the bridge at 48th street, roughly 250m upstream from M7.

The bottom of the streambed was much coarser here, containing many broken shells, pebbles, and gravel. This location is upstream of where the stream skirts an RV park. The stream is also larger here, 10-12m wide and up to 1m deep. The tide and stream were still flowing inshore when the sample was taken. Water temperature: 22.5 C.

--**Site T1**

Sample T1 is from the main outflow stream in the marsh margin area, about 120m upstream of sample M8 at 48th street. The tide was receding, and the stream was flowing out of the marsh rapidly when sampled. There was a heavy rain the previous night (since the collection of samples M1-8). The stream channel above 48th street widens briefly, then further inside the marsh, narrows and deepens. Water temperature: 22 C.

--**Site T2**

About 400m upstream inside the marsh, the outflow stream widens considerably over a flat sandy area, flattening to about 20cm deep. Sample T2 is from this flat. Water temperature: 22.9 C. Other than the reeds that make up the bulk of marsh vegetation, ducks, sandpipers, crabs, and some small fish were apparent. Prior to the widening of the stream, the channel was 3-4m wide and up to 1.3m deep around meanders.

--**Site T3**

Sample T3 was taken another 40m upstream from the flare in the streambed at site T2. The channel is smaller here, 2-3m wide, and 0.8-1m deep. The stream is more still above the flare, moving slowly, but still flowing to the south and east, out of the marsh. Water temperature: 23.0 C.

--**Site T4**

The stream continues to narrow further in the marsh. This sample was taken another 100-120m upstream, above two crab pots in the middle of the channel. Stream only 1-2m wide and less than 1m deep. Water temperature: 23.3 C.

--**Site T5**

The stream diverges into many small rivulets in a large open flat, and no precise single source for the stream can be found. Most of the small rivulets are 30-50cm wide and less than 15 cm deep. Attempts to move further on foot revealed very dense mud over 80cm deep, with a great deal of clay and silt sediment. The source flat is about 120m from the major road which borders the marsh to the north. Water temperature: 22 C. This was the only sample location where the conductivity meter registered for the water, the reading was 8.04 mS/cm.

Locations of all sample sites are also marked on the map of the marsh/beach area (map 2).

All of the data presented have some level of uncertainty. Observed distances were by estimate and probably have an uncertainty of 20% or more for longer distances. Recorded temperatures have uncertainty both from small variations in the water (especially for running water) and some instrument uncertainty, probably a total uncertainty for temperature of +/- 0.3 C. Instrument uncertainty and sample variation also suggest a pH variance of +/- 0.05. Ion concentration numbers also have uncertainty from variation within each sample and from instrument uncertainty, but most uncertainty can be expected due to dilution, especially for dilutions of 1:1000. Total uncertainty for ion concentrations can be expected to be as high as 25%.

Results and Interpretation

Strong upstream/downstream trends are the most apparent result of the sample analysis. These trends also correlate to changes in stream size (depth and width, or relative discharge), and velocity. Some causalities can be assumed or guessed, others are less clear. There is some evidence of influence by development, where proximity to development may correspond to a higher concentration of cations.

The data illustrates the logical trend for higher temperature in shallow and still water, and also shows a trend for warmer water further within the marsh. The trend for temperature to drop downstream can be attributed both to the increase in volume of stream discharge, and to tidal influence (Figure 1). Tidal influence is especially seen in samples M4 and M2, nearest the shore; there is also a sharp drop in temperature of all the samples collected Monday, when the tide was coming in. Samples from below the 48th street bridge all have temperatures below 21 C; the coldest of these is the tributary stream, sample M5. The confluence of this cooler stream with the main outflow stream helps explain the relatively sharp drop in temperature from sample M8 to sample M4. Samples M7 and M6 are the two shallow still-water samples, and they correspondingly have the two highest temperatures. Another factor influencing temperature data was the rainfall Monday night; the Tuesday samples show perhaps an exaggerated trend for cooler water downstream because a larger portion of the water swelling the stream was from recent rainfall, cooler than water which had been stagnant in the marsh for a longer time.

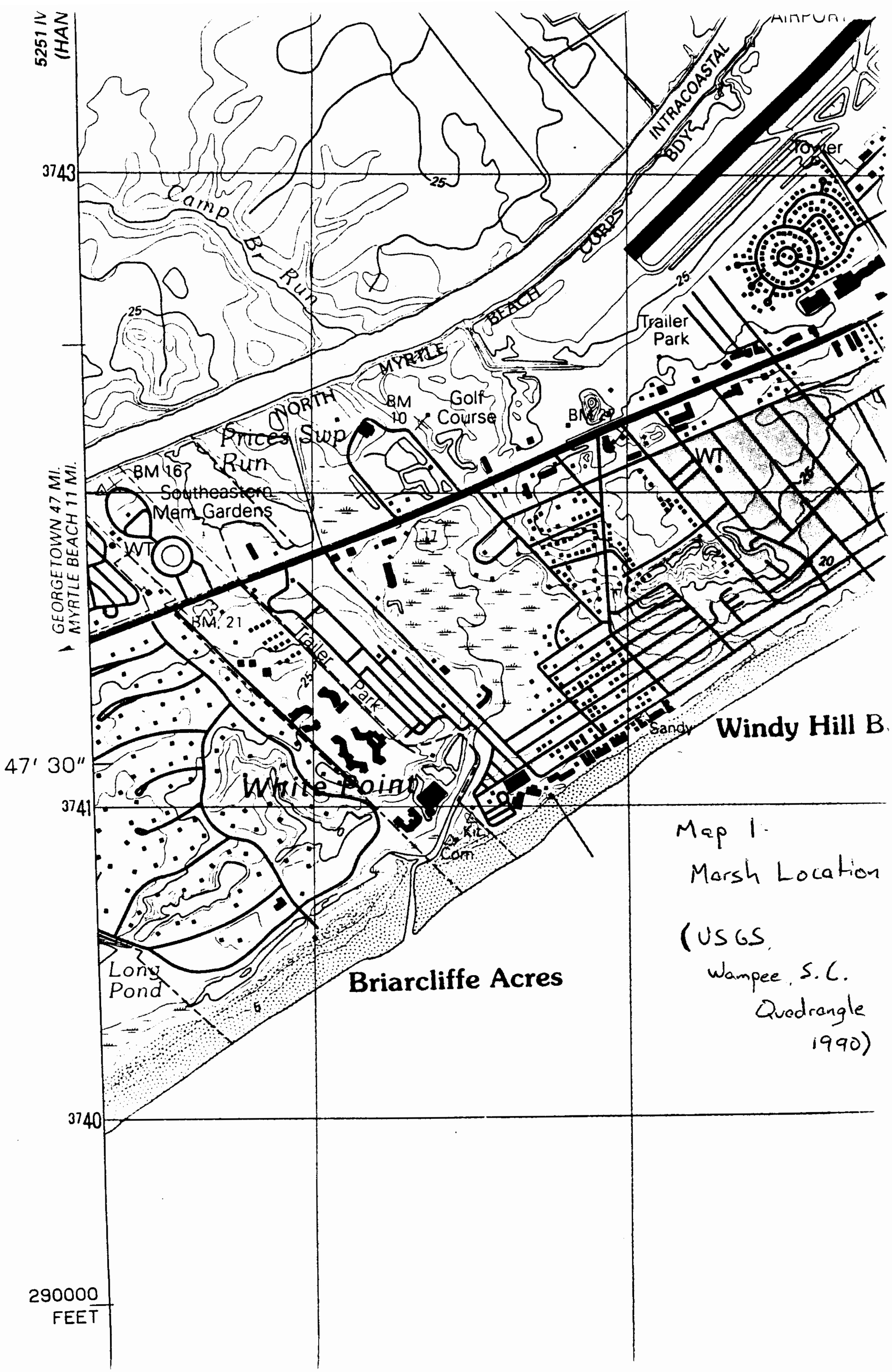
Trends in cation concentrations show both a differentiation between the two streams and a possible source of contamination along the developed northern edge of the marsh. The source sample, T5, shows relatively low concentrations of all cations, Magnesium, Calcium, and Potassium, but these concentrations increase as the stream flows past the crab pots and along the residential development on the marsh's northeastern edge, where the outflow stream is closest to the edge of the marsh, from sample sites T4 to T3. These are the samples with higher concentrations of cations. In samples T2 and T1, the concentrations decrease again, suggesting that the cations have fallen out of solution or been extracted from the water by plants (figure 2). Again at sample M8, where the stream passes under the 48th street bridge, cation concentrations rise, although tidal influences may be partially responsible for higher concentrations in the Monday samples, as with the temperature data. Concentrations in the lagoon and tributary stream are quite high, suggesting that the feeder marsh for this smaller stream may be more contaminated than the main outflow stream of the marsh analyzed by this study. Concentrations of cations rise in the main stream below the confluence of the two streams, and are highest just above the outflow to the ocean. The ocean sample itself actually has a lower concentration than the stream at outflow. The evidence of temperature diffusion around the outflow in the ocean (see sample M3) suggests that the stream itself may have significant local impact on the ocean water chemistry, so we may suppose that, in general, cation concentration in the ocean is somewhat lower than was measured. Sample M1, the stagnant water near the marsh edge, shows higher concentrations than in the cleanest samples of the main outflow stream, and much higher than the source concentrations. This could be the result of the rainfall Monday night, which would have diluted Tuesday samples, or the location's proximity to the edge of the marsh, the road, and some developments may be the cause of its higher concentrations. A third possibility is that the higher level of decaying organic matter and suspended particulate matter in the sample could deposit fairly high levels of cations in the stagnant water. All of the cation analysis is somewhat dubious however, because of the high chance for uncertainty in measurement, and the lack of any clear overarching pattern.

The least questionable trend in any of the ion concentration data is in the Fluoride concentration data, which shows a steady rise further downstream (Figure 3). Possible sources for fluoride might be mineral content in the sand, silt, and clay, or biological agents. Strangely, no similar correlation appears in any of the other anion concentrations.

Overall, the clearest trend in the data is for acidification downstream through the marsh. The steady decline in pH values from samples T4 to M8 illustrates this trend convincingly. Again, we see the influence of the tributary stream, which has a higher pH than does the major outflow stream coming out of the marsh. Below the confluence of the two streams, the pH of the main outflow stream rises again; the pH of the stream at outflow point is virtually identical to the pH of the ocean, suggesting again the tidal influence in the furthest downstream sections of the outflow stream (Figure 4). Samples excluded by this downstream trend include the two warm-water stagnant samples, from the lagoon above the tributary stream and the stagnant fork of the outflow stream at the pedestrian bridge. Neither sample is directly connected to the streams, so their deviation is expected; however, the two have statistically identical pH readings. The overall trend to acidification downstream in the marsh is best attributed to plant extraction of nutrient cations from the water. The trend for plants to acidify soil in this way has been significantly documented, and it is a logical extrapolation for the wetland ecosystem that plants would also acidify water. As the stream flows past and through vegetation, and as water joining the stream has covered more distance through the marsh, pH of the stream water declines. This trend is tied to the apparent trend for the marsh to remove cations from the water, as shown in the cation surge and then decline analyzed above.

The most consistent principle of marsh chemistry seen in these data is the ability of a tidal marsh to lower the pH of water flowing out of it. This can be attributed to plant removal of nutrient cations from the water supply as it filters out of the marsh and down the outflow stream. The changes in water temperature follow logical patterns for warming by the sun in shallow sample locations. The temperature data also shows the effect of tidal flows on water in the marsh, especially in the furthest downstream areas of the outflow stream. These trends in temperature and pH give a basic portrait for the marsh chemistry as it is affected by streamflow and the tides.

Clearly & concisely written - exceptionally well-organized!



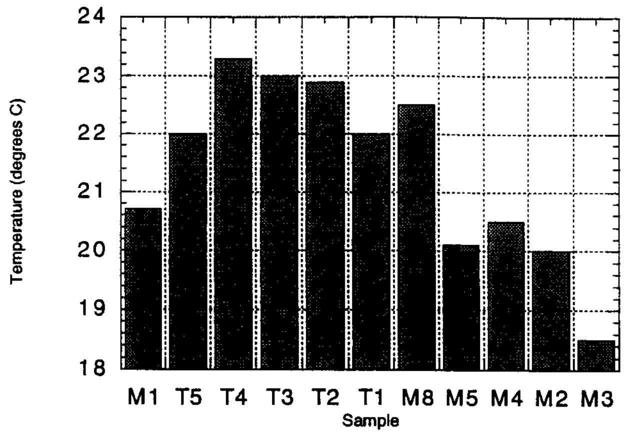
Map 1 -
Marsh Location

(USGS,
Wampee, S.C.
Quadrangle
1990)

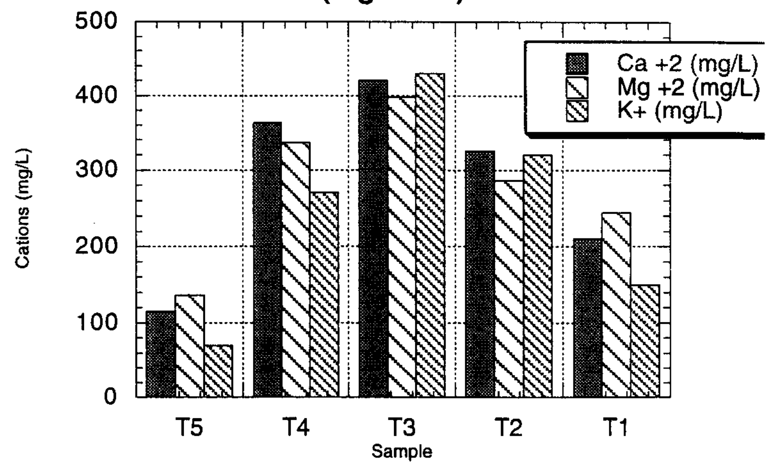
	Sample	Site Description	Temp.	pH	Ca +2 (mg/L)	Mg +2 (mg/L)	K+ (mg/L)	F- (mg/L)	NO3- (mg/L)	SO4-2 (mg/L)	PO4-3 (mg/L)
0	M1	Edge of Marsh	20.7	6.56	380	364	260	19.8		3350	5.2
1	T5	Source	22.0	7.69	115	136	70.0	4.10	0.900	610.0	90
2	T4	Crab Pots	23.3	7.94	363	336	270	10.9	0.800	1900	1.6
3	T3	Wide Flats	23.0	7.83	420	398	430	16.8	0.100	2370	3.1
4	T2	400m in Marsh	22.9	7.75	325	286	320	20.2	0.700	1960	
5	T1	Marsh Margin	22.0	7.45	210	244	150	21.7		1760	
6	M8	48th street	22.5	7.34	305	391	440	23.3	20.0	2610	4.9
7											
8	M7	Stagnant Fork	24.2	7.72	229	234	90.0	26.7	1.90	1180	1.4
9	M6	Lagoon	24.6	7.73	535	535	410			2070	10
10	M5	Rock "Dam"	20.1	7.80	612	491	390	25.0	0.800	3950	
11											
12	M4	20m below tributary	20.5	7.52	363	365	250	24.7		2800	
13	M2	Stream Mouth	20.0	7.60	593	590	47.0	21.4	98.3	2940	0.70
14	M3	Ocean	18.5	7.58	421	479	33.0	20.3	86.5	2080	

Downstream Trends

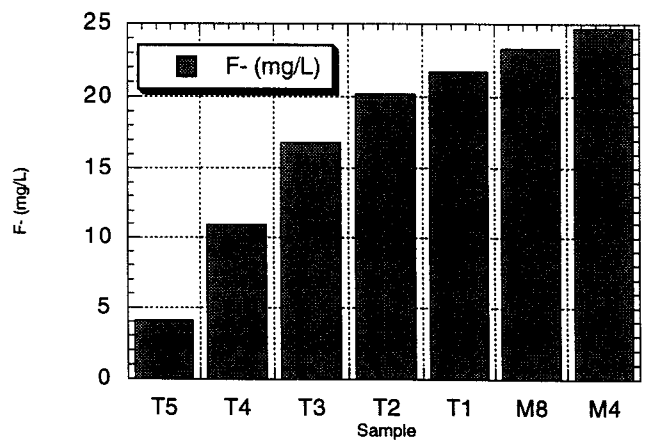
Temperature Decreases Downstream (Figure 1)



Cation Concentrations Decrease Downstream (Figure 2)



Fluoride Concentration Increases Downstream (Figure 3)



pH Decreases Downstream (Figure 4)