APPENDIX C

Review of Wickford Harbor Watershed 1999 Monitoring Data

I. INTRODUCTION

Overview

This summary is based on review of Save the Bay monitoring data for Wickford Harbor and its tributaries, focusing on data collected in 1999. In support of this monitoring effort, URI provided technical assistance to Save the Bay in delineating subwatersheds, helped select tributary sample sites, provided equipment and training in measuring stream flow, analyzed tributary data, developed nutrient loading rates, and reviewed Harbor quality data to assess eutrophication status. Tributary monitoring results for March through August, 1999 are attached in Table 2. Stream Monitoring Data for the Wickford Harbor Watershed. Harbor monitoring data reviewed is included in Table 3. 1994-1999 Water Quality Data for the Wickford Harbor Watershed. Complete data, include recent monitoring results, are available through Save the Bay.

Measuring impacts to water quality

Water quality can be measured as the physical, biological and chemical health of waters. State and federal water quality standards are designed to safeguard these features by classifying waters using two parts: 1) designating standards with associated water uses such as shellfishing and swimming; and 2) establishing maximum pollutant levels, or criteria, sufficient to protect these uses. For example, salt waters classified as SA are designated for shellfishing. One of the Class SA criteria includes fecal coliform bacteria – an indicator organism associated with warm blooded animals that is harmless but signals the presence of disease-causing pathogens. For SA waters the fecal coliform count is not to exceed 14 counts / 100 ml[1].

This system works well when monitoring data is adequate. Because many of the criteria were originally established to protect public health or aquatic life from the effects of wastewater treatment plant discharges, this system also makes enforcement clear cut. Either the standard is met or it isn't. Such a clear unambiguous standard is needed to make for enforcement actions.

The problems with relying solely on established water quality criteria are that the number of criteria are limited, nutrient criteria may not exist, or they may not be sensitive enough for local conditions.[2] The Rhode Island Department of Environmental Management for example, has recently established criteria for phosphorus in freshwaters. No limit has been set for nitrogen. Because coastal waters vary in their response to nitrogen depending partly on flushing rates, RIDEM allows site-specific nitrogen limits to be set.

When designated uses are threatened by nonpoint sources, additional measures are needed to evaluate how pollutant sources affect water quality. A variety of measures, sometimes referred to as *indicators* provide an additional estimate of when water quality supports the designated uses. The most useful indicators relate directly to the water use goal. The indicator should be easy to measure. And a target value should also be established to track progress in maintaining or improving water quality. For example: *water clarity* is a standard indicator of nutrient enrichment. It can be easily measured with a secchi disc. Different target values could be set based on water use goals, for example: 1) transparency will not decrease below 4 feet for safe swimming; 2) transparency will not decrease below 6 feet for eelgrass habitat; or 3) transparency will not decrease below the average annual for a particular water body based on past monitoring to protect existing conditions.

Standard indicators recommended by EPA to track progress in maintaining or improving water quality include the following:

1. Compliance with RIDEM water quality criteria. This is the traditional yard stick for measuring whether water quality standards are being met. For drinking water supplies, shellfishing areas, and swimmable waters, the most stringent criteria is usually the fecal coliform limit (14 count/100ml for shellfishing; 50 counts/100ml for swimming). For healthy aquatic habitat, the dissolved oxygen criteria is often the limiting factor determining compliance with goals. Other ambient criteria may apply. This simply means that specific criteria may be established based on typical naturally occurring levels the water body.

2. Comparing water quality data or stream characteristics with "reference" levels typical of pristine waters in undisturbed watersheds [3]. This is typically done by comparing data collected from the impaired site with data from one or more similar sites that even if not pristine may be "least impacted". It might also include comparing current data from the impaired site to historic data from the site before the impairment. In the Wickford Cove watershed we have used the relatively unaffected Coccumcussuc Brook watershed as a reference site for other subwatersheds.

3. Biological indicators incorporate information on the number, extent, and diversity of aquatic organisms (often macroinvertebrates) as well as habitat characteristics. The EPA Rapid Bioassessment Protocol [4] is the most frequently used. The Index of Biotic Integrity (IBI)[5] and fish yields are other methods. When applied using a variety of organisms and habitat indicators, these methods show promise as a means to evaluate the whole ecosystem rather than compliance with single parameters. Results are dependent on sampling locations and skill of the evaluator in keying out macroinvertebrates. DEM currently incorporates limited use of biological indicators in their monitoring program but no data is available for Wickford Harbor.

4. Eutrophication indicators such as Carlson's Trophic State Index (TSI) measure the level of nutrient enrichment as a way to measure and track trends in general health of a waterbody. The index is based on measurements of three characteristics: nutrients as total nitrogen or total phosphorus, water transparency based on secchi depth measurements, and chlorophyll as a measure of algal biomass. Results rate the nutrient enrichment, trophic status of the waterbody. Oligotrophic waters have low nutrients, with generally good transparency and low growth of algae. Mesotrophic waters are moderately enriched, while eutrophic waters are rich in nutrients. The index works best in lakes that respond to nutrient inputs with increased growth of algae rather than rooted aquatic plants. In addition, very well flushed waterbodies such as some river impoundments may be difficult to classify using the index. This index, used by the URI Watershed Watch program, is particularly useful in tracking long-term trends and in comparing relative differences among waterbodies. Carlson's TSI can be used for either fresh or coastal waters. We applied this index to portions of the Harbor where Save the Bay data was sufficient, resulting in a eutrophic rating for these areas.

5. Coverage and density of rooted plants or attached algae shallow water is a simple eutrophication indicator made by visual observations.[6] According to EPA guidelines, this can be quantified by estimating the percent area covered by attached algae or plants, and their type. The presence and extent of invasive, non-native aquatic plants such as milfoil can also be tracked. In Wickford Harbor, Save the Bay made visual observations of the bottom-growing algae Ulva lactuca. This algae was found to be noticably more abundant in shallow coves receiving stream flow from developed areas.

6. Presence of foam, scum, oil sheen, litter and debris, and odor. These physical indicators of impact are difficult to quantify but provide qualitative description of conditions.

7. Fish consumption advisories and contaminated sediments are other examples of quality indicators. No data are available for Wickford Harbor.

II. MONITORING RESULTS – WICKFORD HARBOR

Save the Bay's monitoring record in Wickford Harbor dates back to 1994. Save the Bay staff and volunteers sampled 20 sites throughout the Harbor with varying sampling frequency. Data are available for clarity (secchi disc depth), salinity, total nitrogen, and dissolved oxygen, with visual observations on algal blooms, extent of macroalgae coverage, and other conditions. We briefly reviewed these results to evaluate the general health of the Harbor and to identify trends. We focused on clarity and dissolved oxygen as indictors of nutrient enrichment levels. This summary is an overview of existing conditions and is not intended to be a comprehensive analysis. Wickford harbor sampling sites, key monitoring results, and comparative tributary nitrogen concentrations (dissolved inorganic nitrogen) for the spring 1999 sampling season are shown in Figure 1. Water Quality Sampling Points.

Eelgrass habitat

- Save the Bay monitoring and aerial surveys document that eelgrass – a measure of the Cove's health, is in decline. Historically extensive eelgrass beds are now limited to small areas of the Cove. The reasons for this decline are uncertain but are likely the combined result of excessive nutrients to the Harbor and restricted flushing.

Water clarity and eelgrass habitat

- Water clarity is an indicator of the "health" of a waterbody. Simple measurements of water clarity show that Wickford Cove waters are periodically clouded with excessive growth of algae, microscopic aquatic plants that thrive with overfertilization. More than a purely aesthetic matter, poor water clarity reduces the chance that established eelgrass beds and transplanted seedlings will survive.

- Eelgrass need year-round light penetration to a depth of at least 3 – 6 feet to thrive. In Wickford Harbor where the Cornelius Island eelgrass bed and a smaller eelgrass bed (STB sampling stations WH 5 and WH 50) are located, light does penetrate to the bottom, with bottom secchi measurements ranging from about 5 to 8 feet for 1998 and 1999.[7]

- Water clarity, nutrients, and chlorophyll as a measure of algal biomass are basic indicators of nutrient enrichment. The Carlson Index [8] is a standard gauge relating the level of these indicators to the nutrient enrichment status of freshwater lakes and estuaries[9]. According to this widely accepted Index, waterbodies with clarity greater than 12 feet (4 meters) are considered high quality, with low nutrients (oligotrophic). Waters with average clarity ranging from about 6-12 feet (2-4 meter) are considered moderately enriched (mesotrophic). Overfertilized (eutrophic) waters have less than six feet (2 meters) clarity.

- In Wickford Harbor, water clarity in Wickford Cove (WC7), Hussey Bridge (WC 77), and near Rabbit Island (MC 4) ranges between five to six feet, putting these waters in the over-enriched, or *eutrophic* classification. This is a cause for concern, especially since nutrients can accumulate in sediments and continue to recycle internally, making water quality improvement difficult to achieve even when nutrient inputs are reduced.

Dissolved oxygen

- Summer oxygen levels occasionally fall below the RIDEM 5 mg/l standard for healthy aquatic life in areas where flow is restricted, falling as low as 1.4 mg/l in the Loop Drive area (WC71). These low levels coincided with a severe algal bloom with water clarity at less than 2.3 feet, indicating that overabundant algae are depleting oxygen as they die off and decay.

Attached algae

- Visual observations show concentrated growth of the lettuce-like seaweed *Ulva lactuca* in poorly flushed areas of the cove. This is actually an algae[10] that grows along the bottom, either attached to sediments or once dislodged, moves with wind and tidal currents. Its presence is a signal of nutrient enrichment. Large amounts of this algae were found near the mouth of Richard Smith Cove stream which drains forest and highway commercial areas and may also receive groundwater inflow from a residential neighborhood. In contrast, the nearby inlet at the mouth of Cocumcussoc Brook, less than 300 feet away, which drains a largely undeveloped watershed, is free of Ulva and has abundant oysters[11].

III. MONITORING RESULTS – WATERSHED TRIBUTARIES

This review is based on tributary water quality and stream flow monitored by Save the Bay at 13 locations throughout the watershed on eight sampling dates in spring and summer 1999. URI provided assistance in subwatershed delineation, mapping, streamflow gaging, calculation of nutrient loading rates, and data analysis and display. Tributary sampling points and results are shown in Figures 1 and 2. Figure 1 compares nitrogen concentration results among sampling locations while Figure 2 includes average dissolved nitrogen concentrations.

Visual /General

- Mill Creek is a northern tributary of Mill Cove. The major western tributary, (sometimes referred to as Pine River) drains the eastern Devil's Foot Road area, adjacent high density (less than ¼ acre/housing unit) residential areas, and the Rt. 1 business district to the north. The headwaters of the major eastern tributary form in a large wetland complex East of Rt. 1, and then flow through a densely developed neighborhood (1/4 to 1 acre lot sizes) north of Newcomb Road. Mill Creek then flows through the Quonset Point/Davisville industrial park, receiving flow from a smaller tributary draining the Quonset golf course. The stream is culverted under the Quonset access road and meanders through residential areas, across Camp Avenue, and then discharges to Mill Cove. Save the Bay has monitored water quality and flow at 10 locations in Mill Creek and its tributaries.

- The Mill Creek tributary flowing from the Quonset Point golf course has occasionally had significantly higher pH than other stream monitoring locations, possibly due to lime applications to turfgrass. For the sampling period March 31- April 7, 1999 the Mill Creek tributary downstream of the golf course at the Koster Road bridge (MCT12) had a pH of 7.2. In comparison, ten other sampling locations for this time period averaged 6.5 pH. This is a significant difference given that each whole number is a 10-fold increase in acidity. Oil sheen and red sediments have been observed in this tributary. In addition, a feeder stream entering this tributary just above the sampling station was turbid and milky white on more than one occasion, possibly from upstream stone cutting operations in the industrial park.

Nitrogen

- Tributary monitoring results document that watershed streams flowing through developed portions of the watershed carry nitrogen into the Harbor at concentrations well above natural background levels typically occurring in Rhode Island. In contrast, the largely undeveloped Cocumcussoc Brook is the only stream in the watershed with very low nitrogen inputs, typical of natural areas. Visual observations show that the Cove at the mouth of Cocumcussoc Brook is in markedly good condition with a sparse growth of the macroalgea *Ulva lacutca* and a healthy oyster bed, in contrast to similar inlets with heavy algal growth that receive streamflow from developed watersheds.

- The State and federal drinking water standard for nitrogen is 10 mg/L, but North Kingstown has adopted 5 mg/L as a safety level. The naturally occurring background concentration of nitrate nitrogen in groundwater is typically about 0.2 mg/l , with over 1 mg/l considered a sign of human influence.[12] Coastal waters are considered highly sensitive to nutrient inputs even when only slightly above natural levels. As a result, regular low doses of nitrogen far below the established health standards can impair waterbody health.

- Total nitrogen concentrations in monitored tributaries ranged from 0.2 mg/l in the Cocumcussoc Brook to 2.86 mg/l at the Prospect Avenue bridge. This is based on 24 stream samples collected in spring and summer 1999 at twelve sampling locations. For the March-April sampling date, the average nitrogen concentration at the twelve sites was 1.4 mg/L. Concentrations in eight out of these twelve sites approached or exceeded this level, averaging 1.9 mg/L. Sampling sites with higher than average concentrations for this sampling date included: Callahan Bridge, Camp Ave., Nancook Road Bridge, Quidnessett School Brook, Dana Road stream, Richard Smith Cove Brook, Jenkins Pond, and Prospect Ave. Save the Bay tributary data is included in the attached Table 2. Stream Monitoring Data for the Wickford Harbor Watershed.

- For the April sampling date, nitrogen concentrations in Mill Creek and its tributaries (six of the twelve stream sampling sites) are shown in Figure 3. The only stream with very low nitrogen concentrations was Cocumcussoc (not shown) at 0.22 mg/L.

Nitrogen concentration vs. loading

- The *concentration* of nitrogen (usually expressed as mg/L or the equivalent parts per million "ppm") is used to compare differences among sampling locations, to compare the increase from natural background levels, and to determine compliance with human health standards. Concentration information is useful in indicating pollution sources, especially contaminants washed into streams during storms or "wet weather". In summer periods without rain, most surface flow comes from groundwater feeding the streams, known as baseflow. Because stream quality during summer dry periods tends to mirror the quality of incoming groundwater, summer low-flow monitoring is often used to evaluate groundwater quality. In doing so, one must be careful to consider elevated nutrient concentrations from near-shore influences or plant decomposition.

- Concentration data can be highly variable and may not indicate the actual amount of nitrogen contributed by a stream, depending on flow. For example, low nitrogen concentrations may generate large amounts of nitrogen where stream flow is great. On the other hand, high nitrogen concentrations in a small stream with low flow may generate only small amounts of nitrogen.

- It is the total amount, or *load* of nitrogen or entering a waterbody that contributes to nutrient enrichment. Nutrient load (lbs./day) is calculated as by multiplying streamflow, usually measured in cubic feet per second (cfs) times the nutrient concentration (mg/L). Total loading naturally increases with accumulating flow from small feeder tributaries to larger streams and rivers, so loading rates normally increase with watershed size, making it difficult to compare differences among streams.

- Loading rates, calculated based on nitrogen concentrations and streamflow, for Mill Creek samping sites are shown in Figure 4. The three bars on the left, MCT 19 (Nancook Rd.), MCT 15 (Callahan Rd. Bridge), and MCT 10 (Camp Ave.) represent sites that progress from upstream to downstream locations. As expected, loading is low in the uppermost tributary at Nancook Rd. (MCT 19) and increases with accumulating flow downstream (MCT 15 an 10). In comparing nitrogen concentratons for the same dates (Figure 3.) it is interesting to note that nitrogen levels highest at Callahan Bridge in the Quonset /Davisville Park and then decrease at Camp Avenue after flowing through residential and wetland areas before the discharge at Mill Cove.

- A better way to compare inputs is to evaluate the total load of nitrogen contributed by a stream *equalized as loading per acre* based on subwatershed area. Dividing the total load by the number of acres in the watershed equalizes the difference in flow related only to watershed area. In this way per-acre nutrient loading rates can red-flag areas of disproportionately high loading. Results for two sampling sites, sampled in spring and summer are shown below.

Fig. 3: Total Dissolved Inorganic Nitrogen (NH4+no3+NO2) as N (April 1999)

Mill Creek and Tributaries

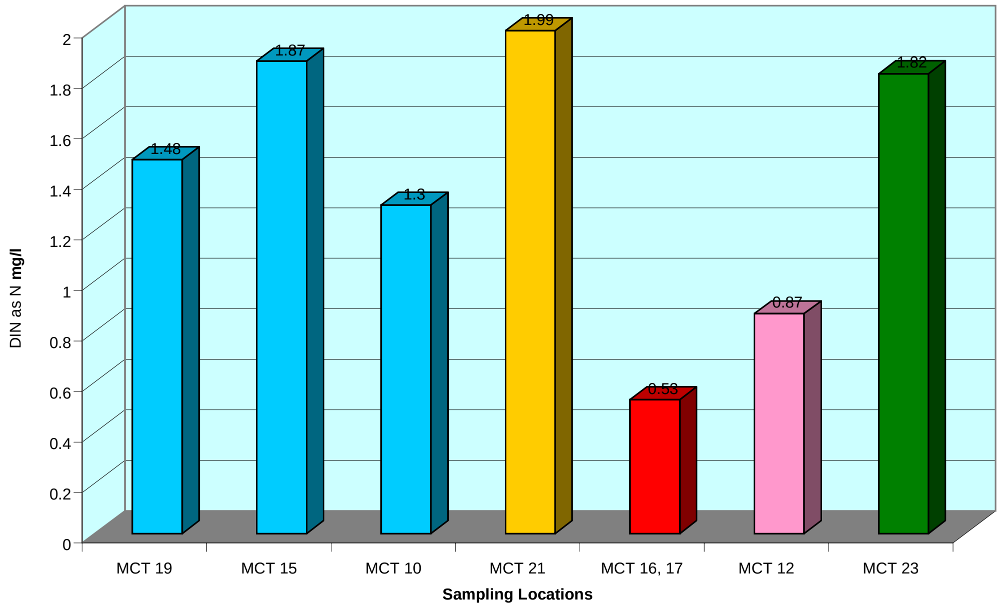
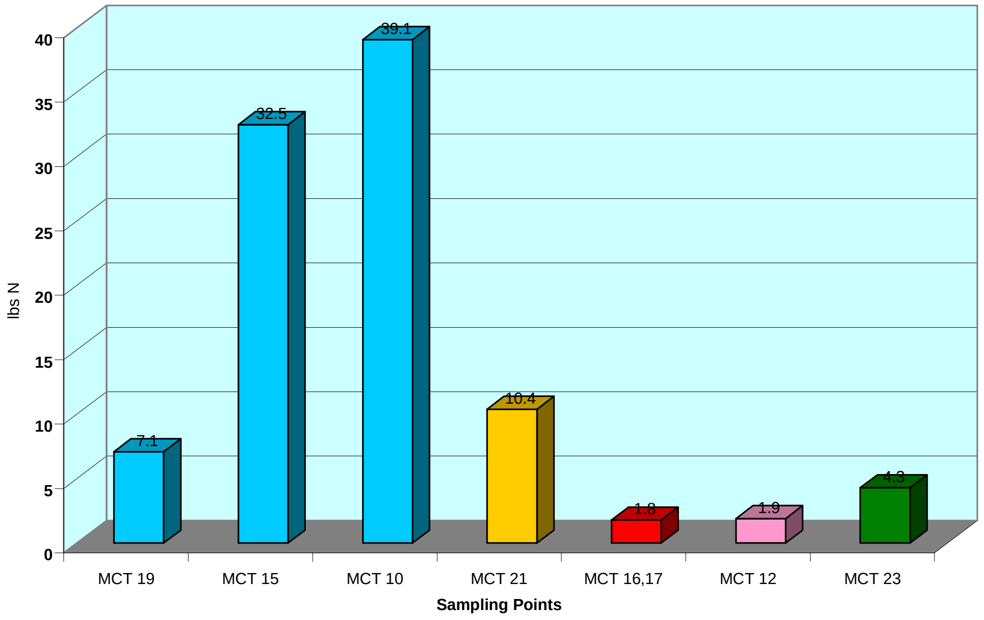


Fig. 4: Nitrogen Loading lbs/day (April, 1999)

Mill Creek and Tributaries



Comparing nutrient loading in Mill Creek vs. Cocumcussoc Brook

Using stream flow and nitrogen concentration data, we compared per acre nitrogen loading results for two streams draining very different watersheds, as shown in Table 1. Mill Creek flows through a watershed that is 40% dense residential, commercial and industrial development, and 36% sewered. The sampling point is at Camp Avenue (MCT 10), at the Creek's discharge to the Mill Cove inlet. We selected the Cocumcussoc Brook as a "reference" stream as it drains a largely undeveloped area and represents a natural stream with minimal human influence.

Table 1.

Comparison of Nitrogen Concentration and Total Loading in Mill Creek and Cocumcussoc Brook

A	B		C	D	E	F
Sampling Site and sub-watershed size (acres)	Sampling date		Total Nitrogen (dissolved inorganic nitrogen as N) mg/l	Stream Flow ft3/sec	Nitrogen Loading lbs./day	Total Nitrogen lbs./acre/day x 10^{-3}
Mill Brook at Camp Ave. (1,826)	Spring	4/6/99	1.3	5.62	39.1	21.4
	Summer	7/13/99	1.41	1.87	14.0	7.7
		8/6/99	1.26	1.08	7.3	4.0
		8/16/99	.85	1.85	8.4	4.6
Cocumcussoc Brook Mouth (1,026)	Spring	4/1/99	0.22	3.95	4.7	4.6
	Summer	7/13/99	1.02	0.35	1.9	1.9
		8/6/99	1.23	0.2	1.3	1.3
		8/16/99	.46	0.45	1.1	1.1

Table 1. Comparison of Nitrogen Concentration and Total Loading in Mill Creek and Cocumcussoc Brook, shows nitrogen concentrations, flow, total loading, and total loading equalized on a per acre basis for the highly developed Mill Creek watershed at Camp Avenue (MCT 10) and the undeveloped Cocumcussoc Brook watershed (MCT 43).

In spring wet weather very high stream flows combined with elevated concentrations of 1.3 mg/L in Mill Creek result in very high nitrogen loading as pollutants wash into the stream. In contrast, high flows *dilute* pollutants in the Cocumcussoc Brook to natural background concentrations of 0.22 mg/L., resulting in only moderately elevated loadings from this watershed.

In summer low flows, nitrogen concentrations range from 1.4 to .85 mg/L Mill Creek, with slightly lower concentrations in Cocumcussoc Brook, ranging from 1.23 to .46 mg/L. in Cocumcussoc Brook. The 8/16 sampling date show slightly lower concentrations in both Mill Creek and Cocumcussoc Brook, possibly due to groundwater inflow from rainfall 2 days earlier.

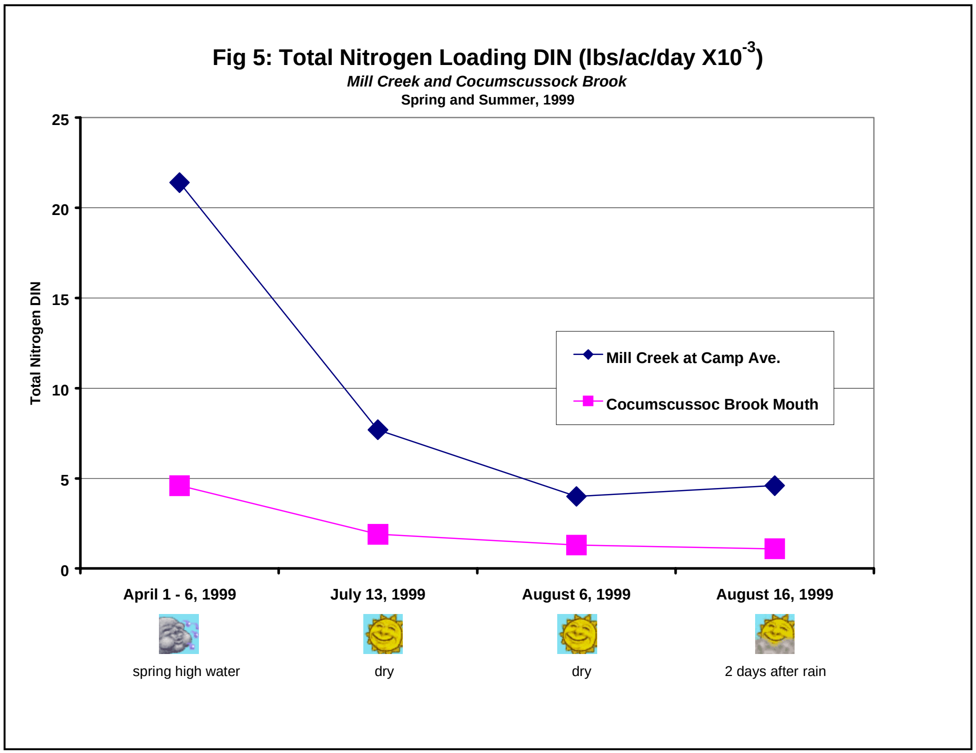


Fig 5: Total Nitrogen Loading DIN (lbs/ac/day X10^{-3})

Mill Creek and Cocumscussock Brook

Spring and Summer, 1999

Multiplying nitrogen concentration (column C) by streamflow (column D) yields the total amount, or loading of nitrogen contributed at each sampling date (column E). The loading is then divided by the subwatershed acreage for each area to equalize the contribution on a per acre basis (column F). The per acre nitrogen loading is much higher for the developed Mill Creek area than Cocumcussoc Brook, in the spring and remains slightly higher during summer dry weather. Total per acre nitrogen loadings for Mill Creek and Cocumcussoc Brook are shown in the above Figure 5.

IV. MONITORING SUMMARY

In presenting this data overview we caution that while the monitoring data is an excellent start, this is a screening-level overview using limited data. The tributary data are particularly limited, representing a brief snapshot of conditions at only four points in time over three months in one year. Long term sampling is needed to characterize water quality conditions, identify natural variations due to weather and season, distinguish between human influences and natural variability, and to establish trends.

Harbor monitoring results show that portions of the cove appear to have restricted flushing and some of these areas or showing signs of overfertilization, with heavy algal growth, poor water clarity, and occassional low dissolved oxygen. Long term monitoring is needed to determine if these conditions are stabile and limited to a few poorly flushed areas or if they are worsening over time, indicating a more urgent situation. The tributary monitoring results show that the Cocumcussoc Brook subwatershed is the only area with low nitrogen concentrations and low inputs with wet weather. All other streams flow through developed areas and are showing signs of stress.

Suggested actions focus on filling data gaps, as described below:

Harbor

- Continue Harbor monitoring of clarity, dissolved oxygen, and visual observations to monitor trends. Evaluate need for nitrogen sampling at all stations; fall and winter nitrogen levels may be most representative of ambient concentrations when algal uptake is low.
- With one bacteria sampling site in the well flushed portion of the Harbor, there is insufficient evidence to evaluate the condition of the Harbor for kayaking or canoeing.
- Expand monitoring to include fecal coliform sampling in the Harbor. In order for the data to be used in the DEM shellfish compliance program, samples must be analyzed using a procedure that estimates the Most Probable Number (MPN) of bacteria in the water. Some laboratories use the Membrane Filtration method, which provides a count of the bacteria in the sample.
- Consider recruiting volunteer monitors to participate in an expanded monitoring program. Citizen volunteers may be organized locally and trained by URI Watershed Watch or other qualified group with approved QA/QC plans. Involving volunteers expands monitoring capability, and most importantly, can enhance the visibility of the program, leading to improved public awareness of Wickford Harbor as an important habitat.
- Consider using quantitative methods to monitor macroalgae extent and abundance, also using volunteers. For example, simply mapping the location and extent of bottom algae can show changes in the type of algae and area covered more objectively than photos. Various methods are also available to measure biomass produced by collecting and weighing random samples of macroalgae.
- Consider measuring the vigor of eelgrass plants as a measure of environmental stress. Measuring how rapidly eelgrass leaves rejuvenate is an accepted indicator of health. [13]

Tributaries

- Continue stream monitoring program, measuring nutrients and streamflow simultaneously.
- Consider installing stream gages at tributary sampling points. Establish stage-discharge relationships by measuring the height of flow along a staff gage and also measuring flow using a flow meter. After a range of samples are taken under low and high flows, the height of the staff gage alone will indicate flow.
- Delineate subwatershed boundaries for each tributary sampling site and estimate subwatershed area. Using nutrient loading data developed from nitrogen concentrations sampled at known flows, develop estimates of nutrient loading equalized on a per acre basis to allow direct comparison among sampling stations. This type of data is currently available only for the 1999 Mill Creek and Cocumcussoc Brook sampling stations

Public Education

Summarize monitoring results in a user-friendly format annually and make available for wide distribution to residents, possibly through the town water department newsletter.

Table 2. Stream Monitoring Data for the Wickford Harbor Watershed

Collected by Save the Bay, April – August, 1999

Station	Description	Date	Lat. 41° N	Long. 71° W	NH_4 as N µm/l	NH_4 as N (mg/l)	NO_3 $+NO_2$ as N µm/l	NO_3 $+NO_2$ as N (mg/l)	Total DIN (NH_4+NO_3 $+NO_2$) as N mg/l	Total DIN (NH_4+NO_3 $+NO_2$) as N lbs/ft^3	Stream Flow ft^3/sec	Stream Flow liters/ sec	Nitrogen Loading (DIN) lbs/ day
FCT 64	Country Lane bridge	7-Apr-99	35.214	26.298	1.66	0.02	52.45	0.73	0.76	0.000047	0.12	3.36	0.5
FCT 64	Country Lane bridge	14-Jul-99			0.9	0.01	0.47	0.01	0.02	0.000001	0	0	0.0
MCT 10	Camp Ave. bridge	6-Apr-99	35.732	26.855	7.32	0.10	86.11	1.21	1.31	0.000081	5.62	157.36	39.1
MCT 10	Camp Ave. bridge	13-Jul-99			9.57	0.13	90.79	1.27	1.41	0.000087	1.87	52.36	14.0
MCT 10	Camp Ave. bridge	6-Aug-99			3.76	0.05	86.51	1.21	1.26	0.000078	1.08	30.24	7.3
MCT 10	Camp Ave. bridge	16-Aug-99			5.97	0.08	55.01	0.77	0.85	0.000053	1.85	51.8	8.4
MCT 12	Koster Rd bridge	6-Apr-99	35.858	26.336	11.77	0.16	50.56	0.71	0.87	0.000054	0.42	11.76	1.9
MCT 15	Callahan Rd. bridge	7-Apr-99	36.009	26.521	5.74	0.08	127.59	1.79	1.87	0.000115	3.27	91.56	32.5
MCT 16	Quonset Rd str. mouth	7-Apr-99	36.01	26.253	5.44	0.08	25.39	0.36	0.43	0.000027	0.8	22.4	1.8
MCT 17	Quonset Rd str. bridge	7-Apr-99	36.187	27.154	2.95	0.04	41.31	0.58	0.62	0.000038	0.56	15.68	1.8
MCT 19	Nancook Road bridge	7-Apr-99	36.435	27.414	1.04	0.01	104.74	1.47	1.48	0.000091	0.9	25.2	7.1
MCT 21	Quidnessett Sch. Brook	7-Apr-99			5.06	0.07	137.21	1.92	1.99	0.000123	0.98	27.44	10.4
MCT 23	Dana Rd. brk. mouth	6-Apr-99	35.45	27.118	1.58	0.02	128.11	1.79	1.82	0.000112	0.45	12.6	4.3
MCT 43	Cucomcussoc Br. mouth	1-Apr-99	34.995	27.527	0.74	0.01	15.19	0.21	0.22	0.000014	3.95	110.6	4.7
MCT 43	Cucomcussoc Br. mouth	13-Jul-99			3.9	0.05	68.9	0.96	1.02	0.000063	0.35	9.8	1.9
MCT 43	Cucomcussoc Br. mouth	6-Aug-99			1.92	0.03	85.89	1.20	1.23	0.000076	0.2	5.6	1.3
MCT 43	Cucomcussoc Br. mouth	16-Aug-99			0.95	0.01	31.95	0.45	0.46	0.000028	0.45	12.6	1.1
MCT 46	Richard Sm. Cv. Stream	1-Apr-99	35.188	27.421	26.12	0.37	95.56	1.34	1.70	0.000105	0.31	8.68	2.8
WCT 73A	Jenkins Pd. dwnstr. RR	31-Mar-99	33.768	27.792	1.63	0.02	140.19	1.96	1.99	0.000122	1.88	52.64	19.9
WCT 73A	Jenkins Pd. dwnstr. RR	13-Jul-99			7.49	0.10	126.85	1.78	1.88	0.000116	0.32	8.96	3.2
WCT 73A	Jenkins Pd. dwnstr. RR	6-Aug-99			3.58	0.05	145.71	2.04	2.09	0.000129	0.41	11.48	4.6
WCT 73A	Jenkins Pd. dwnstr. RR	16-Aug-99			4.95	0.07	135.68	1.90	1.97	0.000121	0.46	12.88	4.8
WCT 73B	Jenkins Pd. upstr. RR	13-Jul-99			8.01	0.11	123.8	1.73	1.85	0.000114	0.24	6.72	2.4
WCT 75	Prospect Ave. bridge	31-Mar-99	33.611	27.354	10.40	0.15	193.77	2.71	2.86	0.000176	0.23	6.44	3.5

Aug 6 dry; Aug 16 ~ 2 days after rain

Notes and References

---

[1] Rhode Island Department of Environmental Management. 1996. Water Quality Regulations. Providence, RI.

[2] US Environmental Protection Agency. 1996. Environmental Indicators of Water Quality in the United States. Office of Water and Wetlands website http://www.epa.gov/OWOW/indic.tblcont.html

[3] US Environmental Protection Agency. 1999b. Total Maximum Daily Load (TMDL) Program. Identification of Water Quality Indicators and Target Values. Office of Water. Washington, DC.

[4] Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. EPA/44/4-89-001. U.S. Environmental Protection Agency, Assessment and Watershed Protection Division. Washington, DC.

[5] Karr, J.R. , K.D Fausch, P.L. Anergmeier, P.R. Yant, and I.J. Scholsser. 1986. Assessing Biological Integrity in Running Waters: A method and its rationale. Illinois Natural History Survey, Special Publication #5.

[6] US Environmental Protection Agency. 1999a. Protocol for Developing Nutrient TMDLs. EPA 841-B-99-007. Office of Water. Washington, DC.

[7] NOTE on secchi measurements in Wickford Cove: Save the Bay has taken over 80 secchi readings throughout the Harbor since 1994. Forty percent of these were taken in shallow areas where the secchi disc was still visible but resting on the bottom sediments, thus these bottom readings are not true measurements of maximum clarity. The most complete secchi measurements are available for Wickford Cove (WC7). Here regular monthly monitoring spring through fall, 1994 to 1997 shows that secchi depths are fairly stable, with average monthly measurements ranging from 2.1 to 1.6 meters, and averaging 1.9 meters over four years. Single samples for June and July, 1998 and 1999, were 2 and 2.4 meters respectively but one sample is insufficient to evaluate seasonal water quality. Of the 24 measurements taken from 1994-1999, seven of the secchi depth readings (30%) were on the bottom. Excluding these measurements did not appreciably change results. Areas where depth is sufficient to reliably measure water clarity include, include Wickford Cove, the Hussey Bridge (WC 77), and Rabbit Island (MC 4), as noted above. Regular long-term monitoring is needed to determine trends and to better evaluate water quality conditions given natural seasonal variation, weather-related differences, and long-term trends.

[8] Carlson, R.E. 1997. A trophic state index for lakes. Limnology and Oceanography. 22:361-369.

[9] Personal communication, Linda Green, URI Watershed Watch. The same index is used for both freshwaters and coastal waters, according to personal communication with R.E. Carlson.

[10] Seaweeds such as Ulva are macroalgae. Microalgae is the microscopic form of algae that float free in the water column. These microalgae become visible in high concentrations, known as an algal "bloom", when they cloud the water column or clump together as tiny floating particles.

[11] Richardson, Mac. Personal communication, 1999 Save the Bay monitoring results.

[12] DeSimone, L. and L. Ostiguy. 1999. A vulnerabilty assessment of public supply wells in Rhode Island. Water Resources Investigations Report 99-4160. U.S. Geological Survey and R.I. Department of Health. Copies available from USGS Information Services, Box 25286, Building 810. Denver, CO 80225-0286

[13] Grainger, Steven. Personal communication. URI Graduate School of Oceanography, Narragansett, RI.