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Bristol Harbor Monitoring Results 2009: A Brief Summary

January 2010

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Save Bristol Harbor's (SBH) Predictive Habitat Model Committee began the water quality data collection phase of the model development process in cooperation with the University of Rhode Island (URI) Watershed Watch program in the spring of 2009. The committee, made up of scientists from Roger Williams and Brown Universities, SBH volunteers, as well as students from Mt. Hope High School and Roger Williams University, identified eight (8) monitoring sites on the perimeter of Bristol Harbor (see Table and Figure 1 for site information). Based on docks or shorelines, these sites allowed easy and safe access for volunteers, and good distribution around the harbor. Sites on important incoming water sources were also included to in order to categorized potential inland pollution sources.

Table 1: Bristol Harbor Water Quality Monitoring Site Information

Site ID	Site Description
BH#1	Elks Club Dock
BH#2	Bristol Harbor Inn Dock
BH#3	Silver Creek Outlet
BH#4	Windmill Point Dock
BH#5	Mill Pond
BH#6	Sanroma
BH# 7	Bristol Harbor Yacht Club Dock
BH# 8	Brito Dock

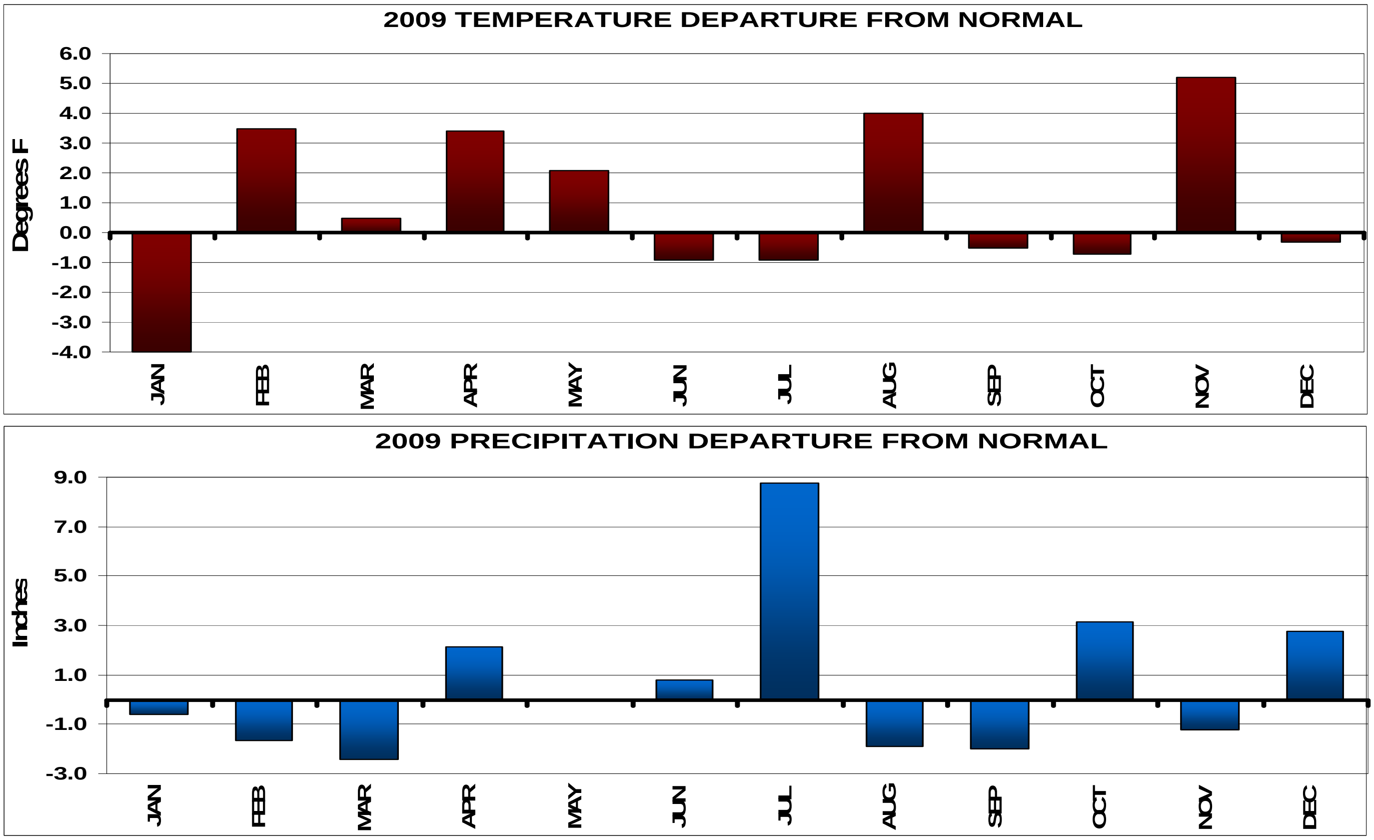
SBH volunteers were trained by URI Watershed Watch (URIWW) staff to conduct the water quality monitoring. These water quality monitors were provided with all the necessary monitoring equipment and supplies as well as a written monitoring manual that detailed all the procedures. Their regular monitoring followed a schedule developed by URIWW designed to cover the period of peak biological activity in the harbor - from mid-May through mid-October, weather permitting. The schedule consisted of biweekly on-site monitoring of water temperature, dissolved oxygen content and algae level (by chlorophyll sample collection and processing). (Please see URIWW monitoring manuals and quality assurance project plans available on the website at www.uri.edu/ce/wq/ww/Manuals.htm for more specific information.) All the on-site monitoring data was submitted on monitoring postcards.

In addition to the bi-weekly on-site monitoring, once a month the volunteers also collected a suite of water samples, which were brought to a central collection point. From there the samples were packed on ice in a cooler and brought to the URIWW laboratory in the College of the Environment and Life Sciences in Kingston. These samples were analyzed for bacteria, pH, nitrogen, phosphorus, salinity and chlorophyll according to standard URIWW laboratory procedures (see Quality Assurance Project Plan: University of Rhode Island Watershed Watch Analytical Laboratory www.uri.edu/ce/wq/wq/ww/Qapps.htm for additional information.) The sample schedule was tailored to ensure that samples were collected early in the morning in order to capture potential low dissolved oxygen events, while also making sure that the samples would reach the URIWW laboratory within acceptable hold times. Brief descriptions of the parameters monitored, the criteria used to assess conditions, data summaries, including charts and discussions of the results follow.

Figure 1. Map showing SBH Monitoring Sites

Weather summary: Weather can significantly affect water quality, and can confound the assessment of water quality findings. This summary (figure 2) is based on weather data from the URI Weather Station in Kingston, RI. Departures from normal were in relation to the average temperature and precipitation values over the past thirty (30) years. While the number of months when temperatures departed from normal were evenly distributed between being above normal and below normal (6 months each), the degree by which they departed were very different. With the exception of January, below normal temperature months were within one (1) degree Fahrenheit (F) of normal. Whereas, with the exception of March, above normal temperature months ranged from two (2) to more than five (5) degrees above normal. Warmer air temperatures can result in warmer water temperatures and changes in precipitation. Departure from normal precipitation followed a similar pattern – May was normal, six (6) months were between 0.6 and 2.4 inches below normal, and five (5) months were between 0.8 and 8.8 inches above normal precipitation. In fact the rainfall in July broke the previous record for that month. That new record was reached by having had more than fourteen (14) days of significant rainfall throughout the month, which likely contributed to the slightly lower than normal temperature for July.

Figure 2. Weather Summary Charts



Bristol Harbor on-site measurement descriptions and summaries: Volunteers measured a number of key water quality indicators using field kits at all eight sites. These field measurements were temperature, dissolved oxygen, and processing of samples for chlorophyll analysis. They were typically done on water from a depth of half a meter (0.5m) from the surface using either a sampling pole or the "one arm sampler" – the volunteer's arm that is. With the exception of temperature, duplicate samples were collected, and then duplicate measurements were made of each of the parameters, with the average or mean result reported in the following charts (Figures 3a and 3b).

Dissolved oxygen (DO) and water temperature data tells us a lot about the health of the harbor. Dissolved oxygen is critical to the survival of most of the animals and plants that live in the water and generally the more oxygen, the healthier the ecosystem. Dissolved oxygen levels below 4 milligrams of oxygen per liter of water (mg/L) can be stressful to many forms of life, particularly at the juvenile life stage. Dissolved oxygen levels below 2 mg/L, also known as hypoxic or low oxygen, is lethal for many species. When all of the DO is used up, concentrations below 0.5 mg/L, the water is called anoxic, and no plants or animals that require oxygen can survive. Oxygen enters the water through two natural processes: (1) diffusion from the atmosphere and (2) photosynthesis by aquatic plants, including algae. The mixing of surface waters by wind and waves increases the rate at which oxygen from the air can be dissolved or absorbed into the water.

Temperature dictates how much DO can be dissolved into the water. As the temperature increases, the amount of oxygen that can be dissolved into water decreases. For example, salt water at 5°C can contain up to 10.5 mg/L, but at 25°C it can only hold 7.0 mg/L. Higher salinity and suspended solids levels also reduce the amount of oxygen that can be dissolved into the water.

Dissolved oxygen is used by the animals in the water, as well as by plants at night when they can't use sunlight for photosynthesis. Thus DO levels are typically lowest early in the morning, which is why the SBH volunteers were scheduled to get out on the water around 6:00 am. Bacteria, fungi, and other decomposer organisms also reduce DO levels in estuaries as they consume oxygen while breaking down organic matter, such as algae. Excessive algae levels can cause DO declines when the algae die off and are decomposed.

Figure 3a. Bristol Harbor Sites Field Data Charts: BH#1 – BH#4

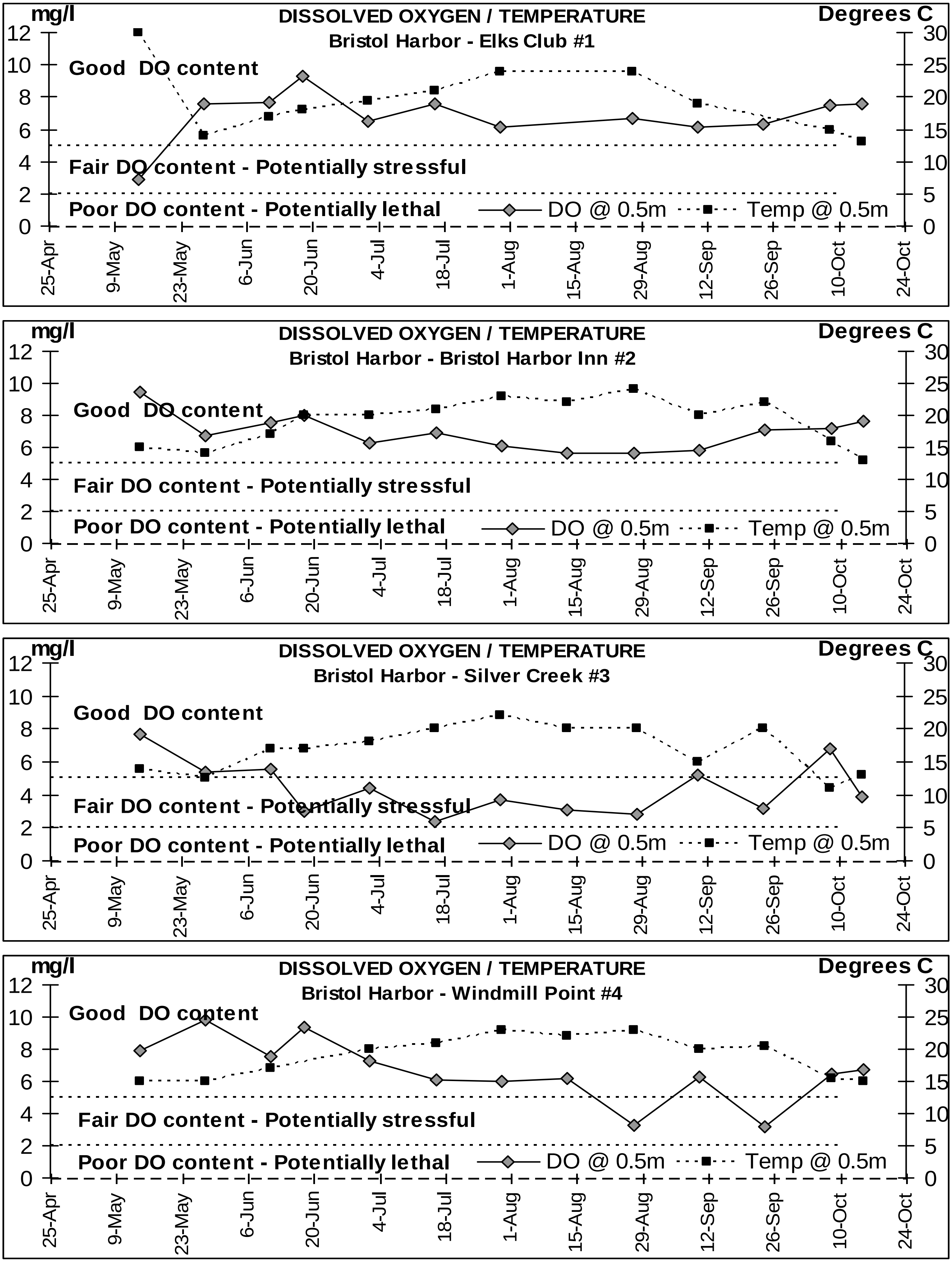
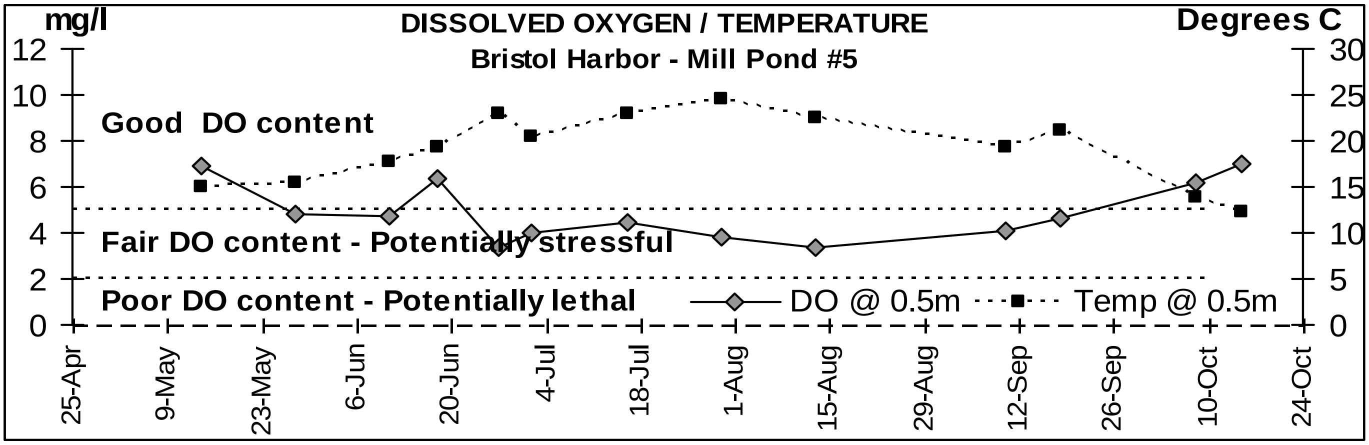
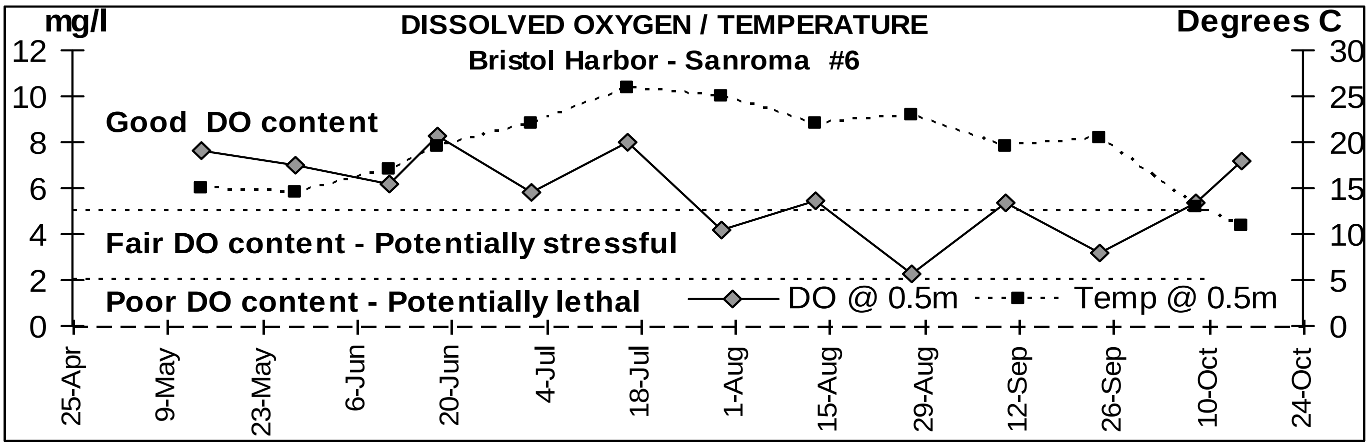
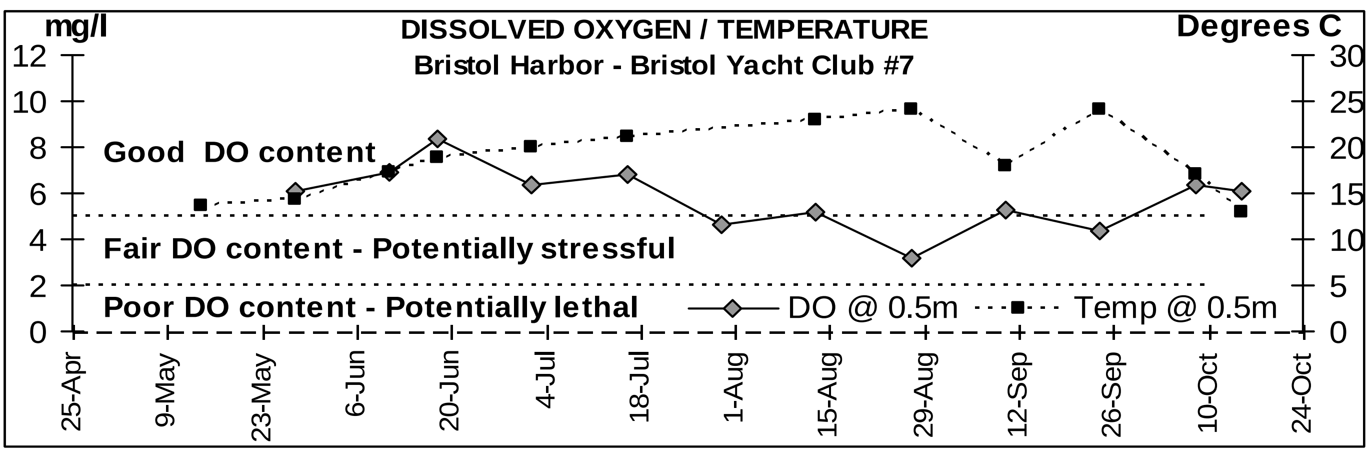


Figure 3b. Bristol Harbor Sites Field Data Charts: BH#5 – BH#8







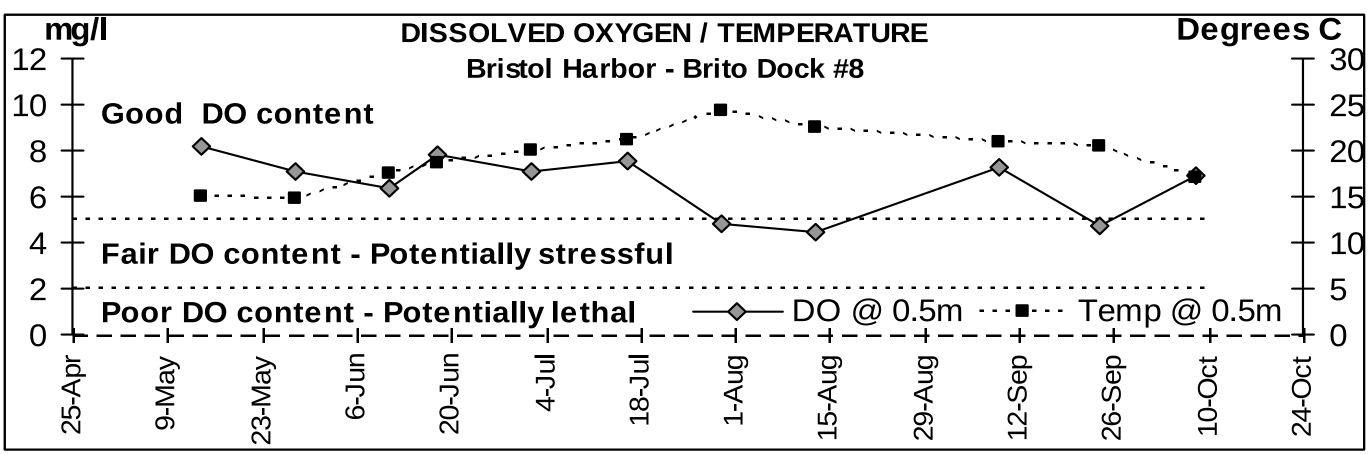
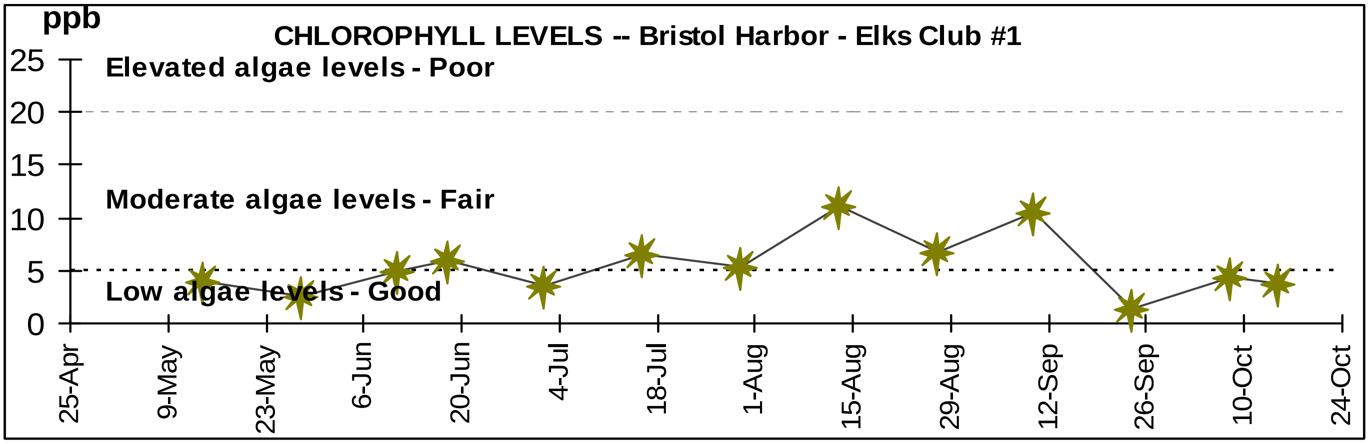
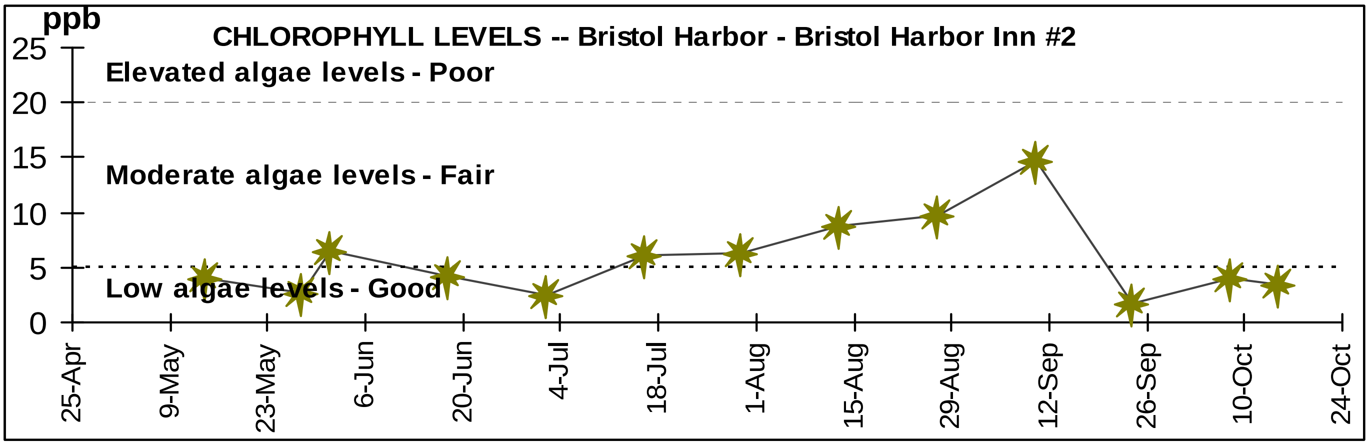
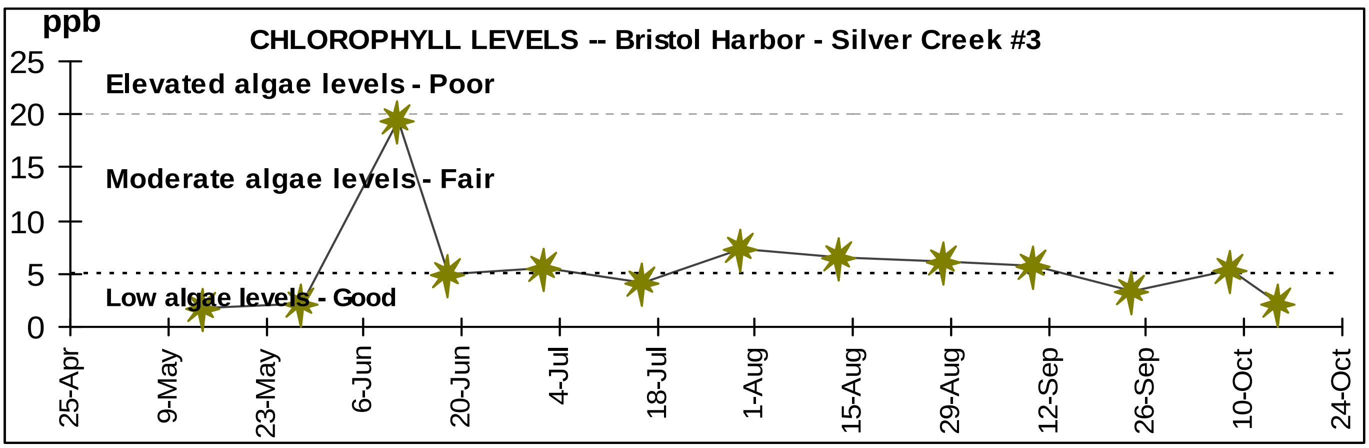


Figure 4a. Bristol Harbor Sites Chlorophyll Data Charts: BH#1 – BH#4







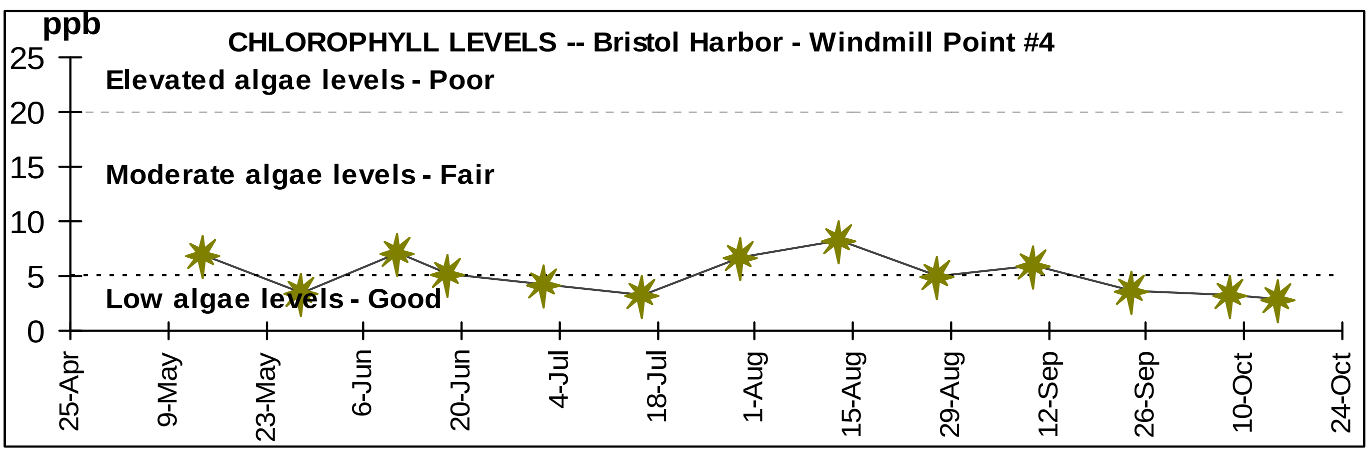
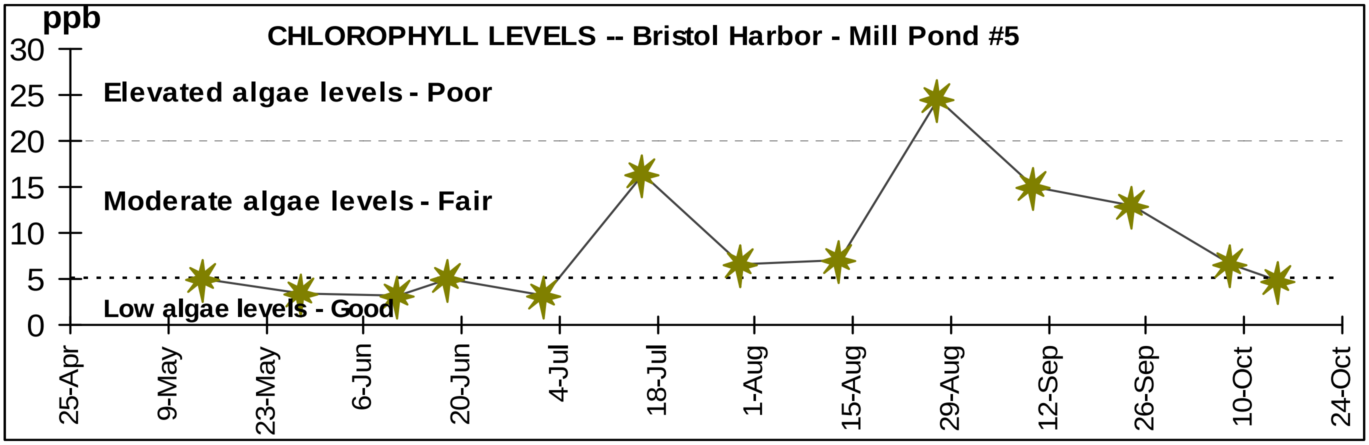
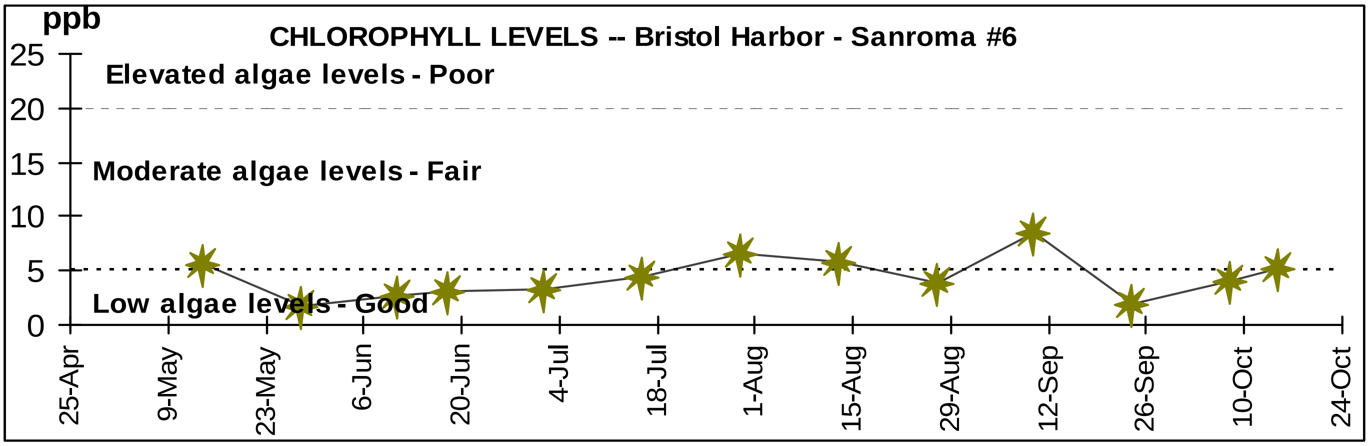
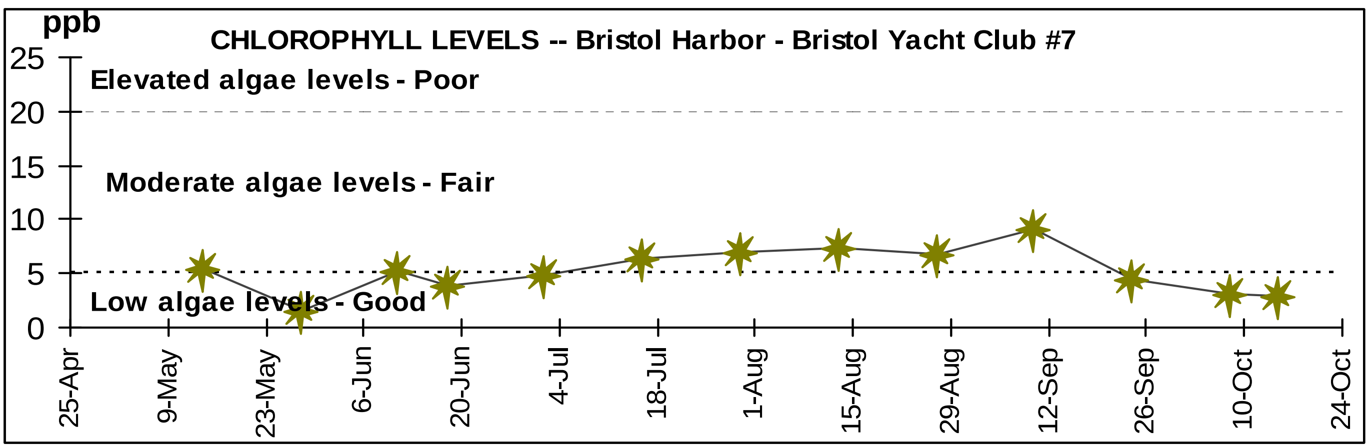
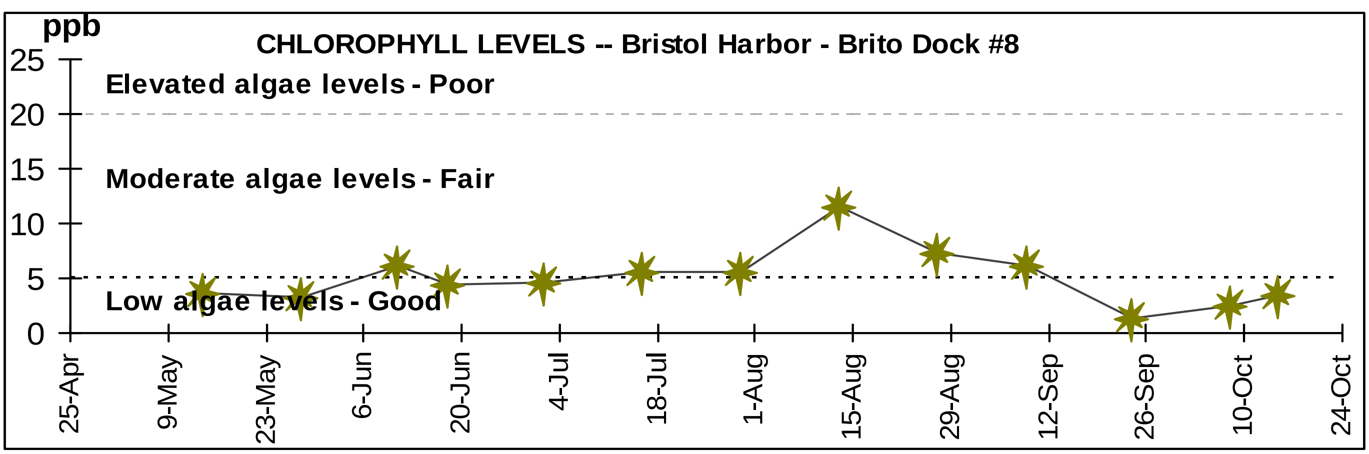


Figure 4a. Bristol Harbor Sites Chlorophyll Data Charts: BH#5 – BH#8









Chlorophyll is a photosynthetic pigment found in all plants, including algae. Chlorophyll-a (chl-a) is the most common form of chlorophyll, and is the form analyzed by URIWW to estimate the abundance of algae in the water - the more chl-a, the more algae. Because algae need sunlight in order to convert food energy via photosynthesis, chl-a levels tend to be higher just below the surface of the water. There algae are protected from harmful ultraviolet rays but still have access to sunlight as well as nutrients, nitrogen and phosphorus.

Algae are essential for a healthy harbor as they form the base of the aquatic food web in an estuary. It is eaten by zooplankton (microscopic animals) and small fish, which, in turn, are eaten by larger creatures. The abundance of healthy animals in an estuary often depends on the amount of algae and primary productivity taking place. However, an overabundance of phytoplankton, often called an algae bloom, can result in diminished water clarity, unpleasant odors, and lead to anoxic conditions particularly in bottom waters, sometimes resulting in fish kills. The EPA's National Coastal Assessment (NCA) program criteria for chl-a in northeastern estuaries are: <5 ppb – good; 5 – 20 ppb – fair; and > 20 ppb (EPA 2008).

Field Data Summaries: Dissolved oxygen levels at most of the Bristol Harbor sites were well within levels considered healthy (Figures 3a and 3b). Two exceptions were Silver Creek (BH#3) and Mill Pond (BH#5), which are both incoming waters or tributary sites. Low DO levels were found in the Mill Pond site from July through September, the same time period of moderate to elevated chlorophyll levels at that site (Figure 4b). Decomposition of the significant amounts of algae used up oxygen more quickly that it was replenished through mixing and photosynthesis. Silver Creek DO levels were below the chronic critical value of 5 mg/L more than sixty percent (60%) of the time monitored. With the exception of one sampling date, chlorophyll levels at that site (BH#3) were generally in the good to moderate range and consistent with other harbor sites.

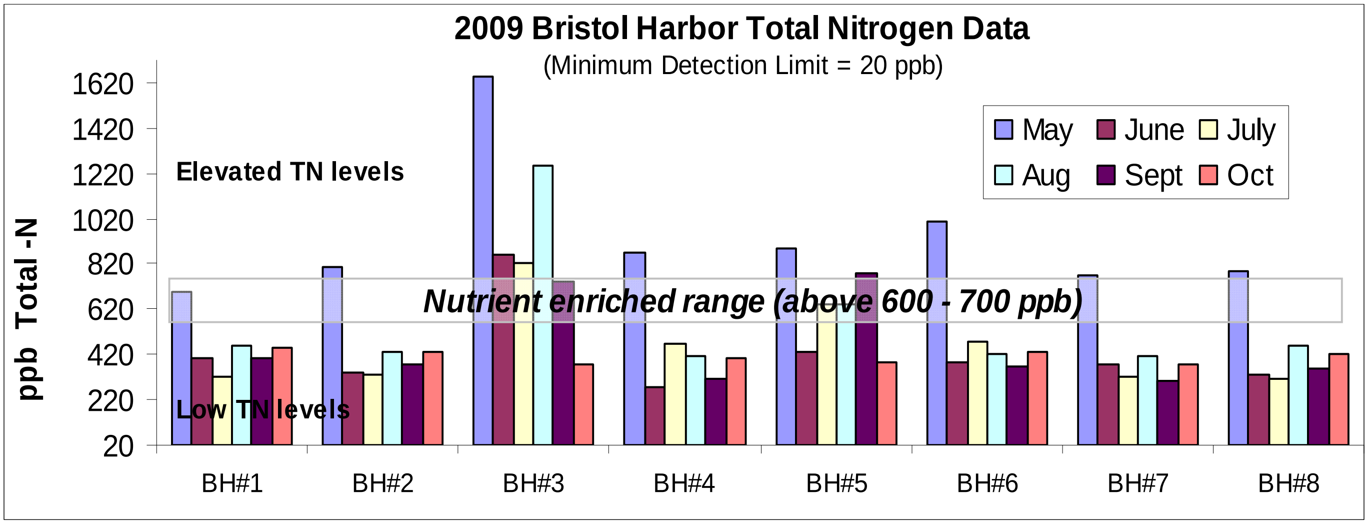
A notable feature of the field measurements is that there appears to be an overall trend of lower DO levels as the sites move from the southeast (BH#1) to the northwest (BH#7). This may reflect the circulation pattern of the harbor, with algae and other organic matter being flushed toward the north western portion of the harbor where they are decomposing. It will be very interesting to compare circulation and flow patterns in the harbor to these results.

Bristol Harbor laboratory descriptions and summaries:

Nitrogen is a natural and essential part of all marine ecosystems, as it is required for the growth of phytoplankton or algae, the primary producers that form the base of the harbor's food web (EPA 2008). It is considered the limiting nutrient in marine systems. But excess nitrogen (N) adversely affects water quality and degrades habitat, ultimately impacting a wide range marine organisms including fish and shellfish. Nutrient overloading in marine ecosystems over stimulates the growth of algae. Too much algae blocks sunlight to eelgrass, reducing the area of this valuable nursery habitat and feeding ground. In addition, living and dying algae consume oxygen, leading to anoxic (no oxygen) and hypoxic (low oxygen) conditions. This process of water quality decline creates a chain reaction of negative impacts known as eutrophication. Poor water clarity, bad odors, stressed marine organisms and even fish kills are all symptoms of eutrophic conditions marine organisms including fish and shellfish (Howes et al. 1999).

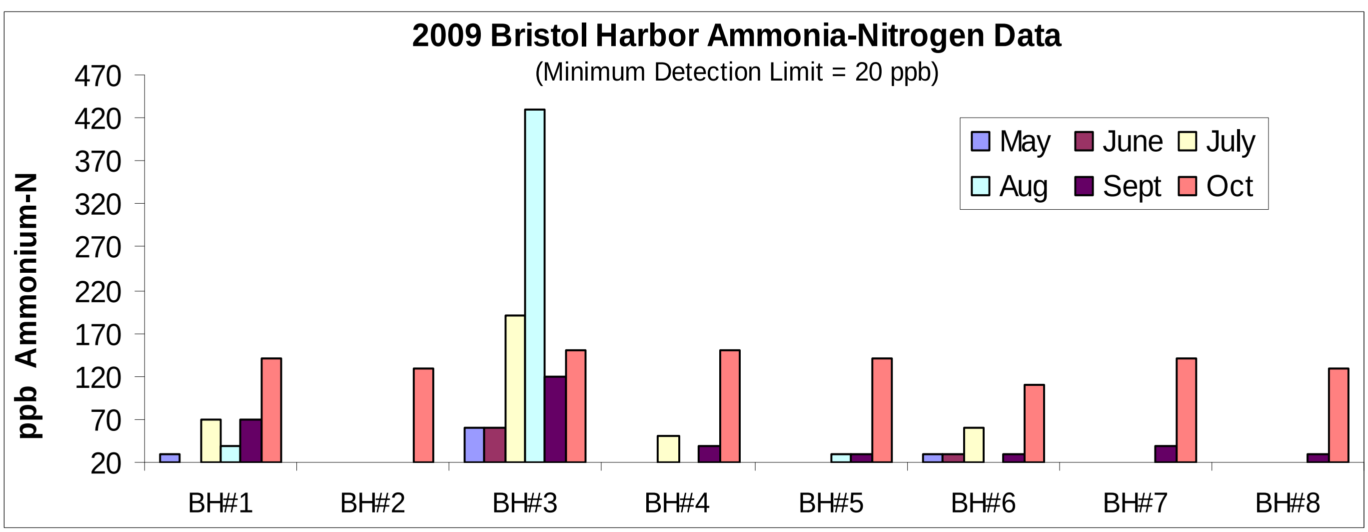
Total nitrogen, which includes both organic nitrogen (the N found in live, dead or decomposing plants and animals) as well as inorganic (the N that is dissolved into solution or bound to sediments, etc.) is widely used by scientists as an indicator of eutrophication or nutrient enrichment in marine waters. Levels below 350 parts per billion (ppb) are characteristic of low nutrient waters, while values above 600-700 ppb indicate nitrogen enrichment (Howes et al. 1999). Total nitrogen (TN) levels in most of the Bristol Harbor sites were at moderate levels throughout most of the season, with the exception of Silver Creek (BH#3) and the May samples. In May, all eight sites had TN levels considered elevated or high (figure 5). Perhaps these higher levels were due to increased turbidity typical of spring storms, caused by increased winds and rainfall. By June TN levels at all sites except BH#3 dropped to low or moderate TN, remaining at those lower concentrations for the rest of the season. While Silver Creek TN declined from May's peak, concentrations there did not reach moderate levels until October. Mill Pond (BH#5) TN were generally higher than most other BH sites, in the moderately enriched to elevated TN range for much of the season.

Figure 5. Bristol Harbor Sites – Total Nitrogen Data Chart



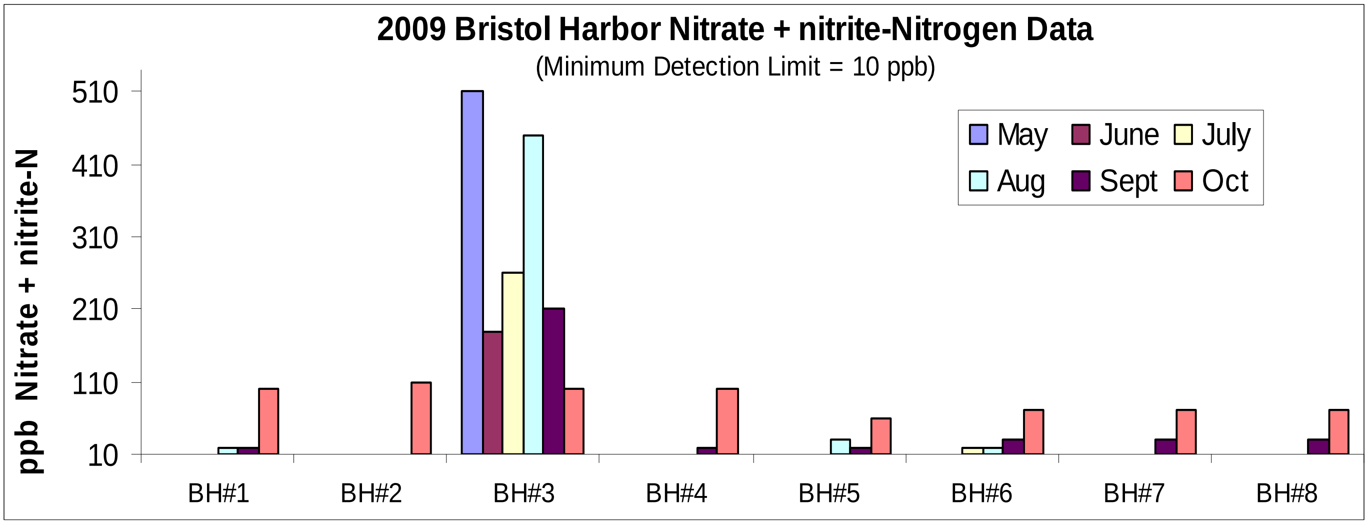
Ammonia-nitrogen is the most reactive form of N in aquatic systems. It is soluble, readily adheres to soils and sediments, and is converted to nitrate by microbes when oxygen is present through a process called nitrification. Nitrification requires a substantial amount of oxygen and carbonate, thus can reduce both DO levels and pH slightly. In excess, ammonia-nitrogen can be toxic, particularly at early life stages. The level at which it become lethal is dependent on water temperature, pH, and salinity so site specific criteria are applied (see http://www.dem.ri.gov/pubs/regs/regs/water/h20q09a.pdf for more information). In general, given the conditions in Bristol Harbor, chronic exposure critical ammonia level would be approximately >650 ppb. **Nitrate + nitrite-nitrogen** is also a soluble form of N, and is readily taken up and used by algae and submerged vegetation during the summer growing season. When oxygen is absent (anoxic conditions), bacteria convert nitrate-N to gaseous N (N_2 or N_2O) through a process called denitrification, which removes N from the soil-water environment. The National Coastal Assessment program uses dissolved inorganic nitrogen (DIN), which includes both ammonia and nitrate + nitrite-N, as a component in its coastal conditions assessment. For northeastern estuaries, DIN levels <100 ppb are considered good, 100 – 500 ppb considered fair, and > 500 ppb considered poor (EPA 2008).

Figure 6. Bristol Harbor Sites – Ammonia-Nitrogen Data Chart



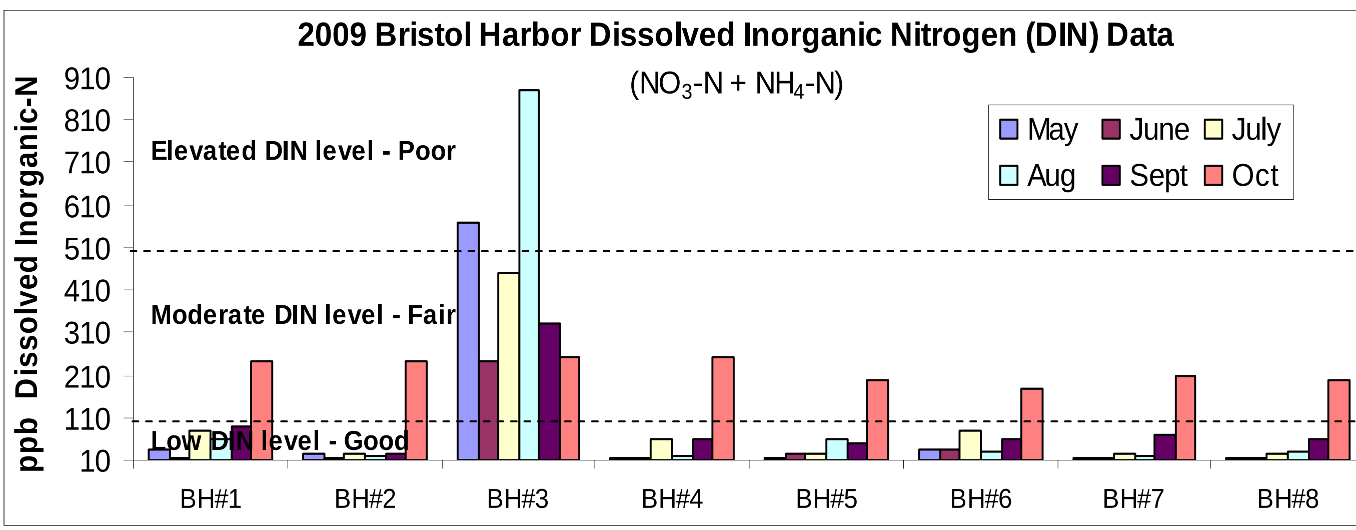
With the exception of Silver Creek (BH#3) ammonia levels were below the URIWW lab limit of detection (20 ppb) for most of the season (figure 6). Ammonia levels at all the sites reached detectable levels in the October samples, likely due to decomposition of algae and seaweed at the end of the growing season. Overall, ammonia levels were generally quite low – and never approached a critical level at any site.

Figure 7. Bristol Harbor Sites – Nitrate + nitrite-Nitrogen Data Chart



As with ammonia, nitrate + nitrite – N levels were typically below the 10 ppb minimum detection level at all sites, except BH#3 (Figure 7). Levels at Silver Creek were particularly high in the May and August samples and surprisingly low in October. In fact the October values for BH#3 were lower than several adjacent sites. Those higher October values harbor wide resulted in DIN values reaching moderate or fair levels for that month (Figure 8). Otherwise, with the exception of Silver Creek, DIN levels were well within the low or good range. Levels at Silver Creek reached the elevated or poor DIN range in May largely as a result of quite elevated nitrate + nitrite –N values, and in August with nearly identical ammonia and nitrate + nitrite-N values.

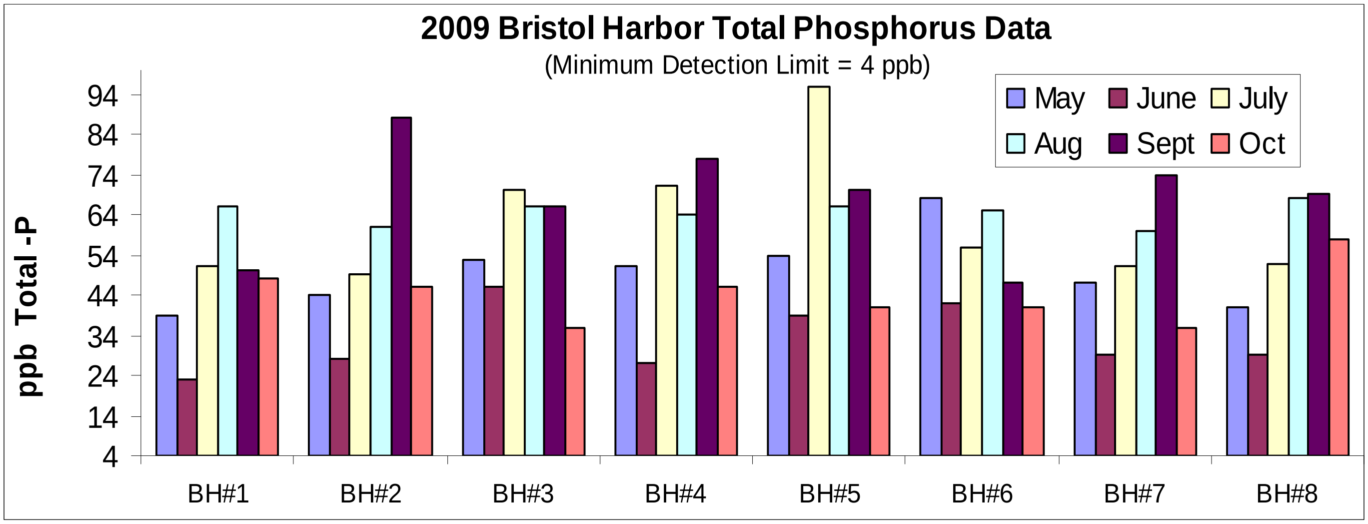
Figure 8. Bristol Harbor Sites – Dissolved Inorganic Nitrogen Data Chart



Phosphorus. In most estuaries such as the Bristol Harbor, nitrogen is the primary nutrient that controls algal and plant growth. However phosphorus is also essential for life, and in salt water environments phosphorus levels are considered in relationship to nitrogen levels. In estuaries the recommended level of total phosphorus (TP) is 10 to 100 ppb with 100 to 1000 ppb of total nitrogen (a 10:1 ratio of N to P). Under these conditions, most phosphorus-caused algal blooms may be avoided. (For more information see http://www.water.ncsu.edu/watershedss/info/phos.html.) Phosphorus was analyzed as the total form which includes P bound in particulate (organic and inorganic) matter and soluble or dissolved forms which are readily used by algae.

TP values were consistently below 100 ppb (Figure 9). For the first time, BH#3 did NOT stand out compared to the other sites – and in fact generally had lower TP values than most of the other sites. Wind Mill Pt (BH#4) and Brito Dock (BH#8), which had generally very low TN values, had comparatively high TP

Figure 9. Bristol Harbor Sites – Total Phosphorus Data Chart



levels, resulting in something closer to a 9:1 ratio for the season (table 2). All of the BH sites were strongly dominated by TN in May and most sites in June (TN was higher than 10:1 in relation to TP). With the exception of Silver Creek (BH#3), TP levels were higher in relation to TN the rest of the season for nearly all of the sites. However, largely because of the nearly 20:1 TN:TP ratio in May, all of the sites except for BH#3 were at about the 10:1 ratio for the monitoring season. Silver Creek remained dominated by TN in relation to TP throughout the season.

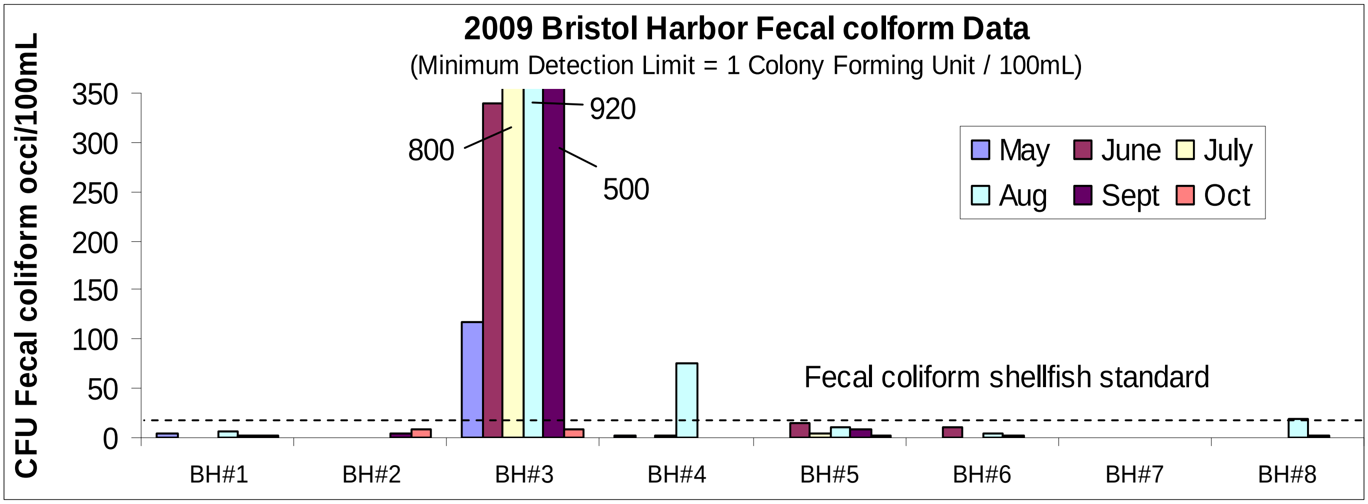
Table 2. Total Nitrogen to Total Phosphorus Ratio – Bristol Harbor Sites

	MAY	**JUNE**	**JULY**	**AUG.**	**SEPT.**	**OCT.**	**MEAN**
	Ratio of N to P (TN/TP)						
BH#1	18	17	6	7	8	9	**11**
BH#2	18	12	7	7	4	9	**10**
BH#3	31	19	12	19	11	11	**17**
BH#4	17	10	7	6	4	9	**9**
BH#5	16	11	7	10	11	10	**11**
BH#6	15	9	9	6	8	10	**10**
BH#7	16	13	6	7	4	11	**10**
BH#8	19	11	6	7	5	7	**9**

= 10 means N to P ratio is at recommended 10:1 ratio
> 10 means N more than recommended 10 times the amount of P
< 10 means P too high in relation to N

Fecal coliform bacteria monitoring: Fecal coliform bacteria are an indicator of fecal contamination and potentially disease causing organisms or pathogens. The National Shellfish Sanitation Program (NSSP) has established acceptable fecal coliform levels (14 colony forming units (cfu)/100 mL) for waters from which shellfish can be harvested. The standard was designed to prevent human illness associated with the consumption of fresh and frozen shellfish, and thus is quite conservative. Because bacteria levels can fluctuate dramatically and be impacted by short-term sources affecting quite small areas such as by seagull or duck droppings, bacteria average concentrations are typically reported as the geometric mean. This statistical method transforms a set of highly variable data in order to better represent a central tendency. Thus a single very high sample will not overwhelm routine low or below detection values as might happen with arithmetic averaging.

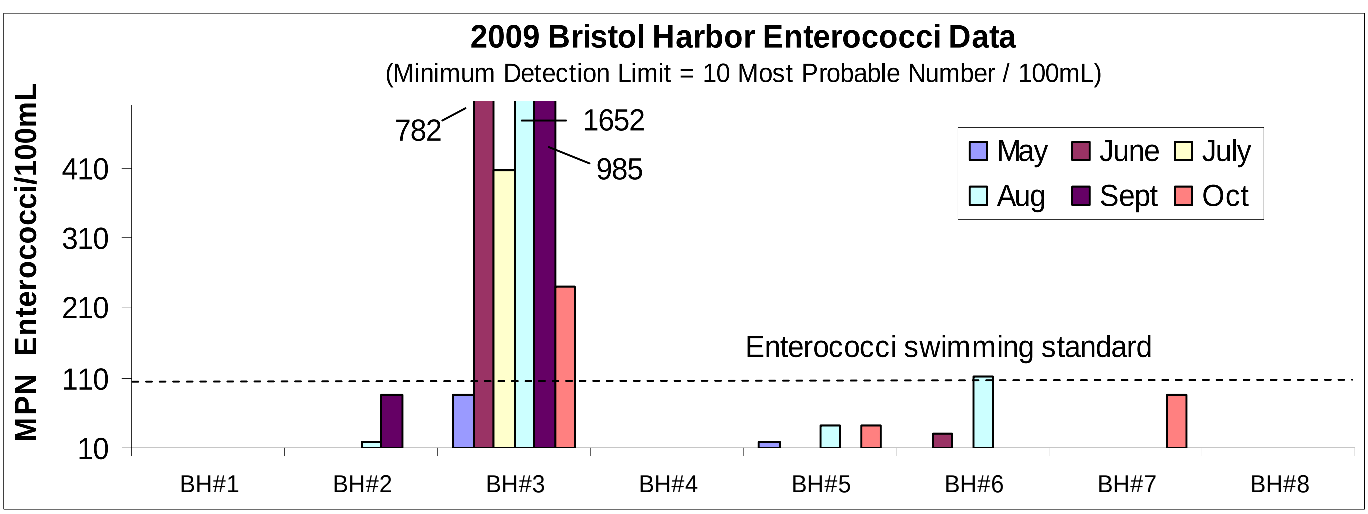
Figure 10. Bristol Harbor Sites – Fecal Coliform Bacteria Data Chart



Nearly all of Bristol Harbor had fecal coliform values considered safe for shellfishing most of the season (Figure 10). The one exception was Silver Creek (BH#3) which significantly exceeded the shellfishing criteria for each collection except in October. Nearby Wind Mill Pt (BH#4) exceeded that shellfish criteria in August, possibly due to flow from Silver Creek bringing elevating bacteria levels. But it is also not unusual for intermittent high bacteria readings due to transient sources – such as a gull or goose. Given the overall low values at BH#4, and most Bristol Harbor sites, fecal coliform is not a significant problem harbor wide.

Enterococci bacteria monitoring: In 2004, *Enterococcus spp.* took the place of fecal coliform as the new federal standard for water quality at public beaches. It is believed to provide better correlation than fecal coliform with many human pathogens often found in sewage, particularly those associated with gastrointestinal illnesses. Based on federal recommendations, the Rhode Island Department of Environmental Management (RIDEM) set the primary contact (swimming) water quality standard for salt waters at a geometric mean of 35 enterococcus/100 mL for five or more samples. To be more responsive to short term events, the Rhode Island Department of Health (RIHealth) adopted a *single sample standard* for swimming advisories at designated beaches. For salt waters, the RIHealth beach standard is 104 most probable number (mpn - a statistically based reporting method) enterococci /100 mL, and 61 mpn for fresh water.

Figure 11. Bristol Harbor Sites – Enterococci Bacteria Data Chart



Nearly all of Bristol Harbor had enterococci values considered safe for swimming most of the season (Figure 11). Again, Silver Creek (BH#3) was the exception, with enterococci values that significantly exceeded the swimming criteria for each collection except in May. Interestingly, nearby Wind Mill Pt

(BH#4) had enterococci values below the detection limit of 10 mpn for each collection date. Given the very high enterococci values at BH#3, the enterococci values imply that either there was not significant flow toward Wind Mill Pt (as previously suggested) or that the enterococci were dying off at a much faster rate than were the fecal coliform bacteria. Die-off rates vary considerably in the literature, and are dependent on environmental conditions as well as specific organism strains (RRPR 2008). So without additional information it is impossible to determine if the one high fecal event at BH#4 was due to out flow from Silver Creek or some other transient source. A similar single high event was noted at Sanroma (BH#6) for enterococci in August. But in general, the majority of Bristol Harbor would be considered safe for swimming throughout the season, based on enterococci values.

Overall Water Quality Summary: Both the on-site monitoring and laboratory analyses indicate that with the exception of the Silver Creek (BH#3) site, Bristol Harbor is in generally good condition. Nutrients are typically low, and dissolved oxygen levels usually sufficient for most aquatic species. Chlorophyll concentrations, an indicator of algal productivity, were generally in the low to moderate range, but brief algal blooms were noted at a few sites. Bacteria levels are mostly within both acceptable shellfishing and swimming criteria. The most significant finding was the identification of Silver Creek as a source of excess nitrogen (total, ammonia and nitrate + nitrite) and bacteria, and its impact on local dissolved oxygen levels. While additional monitoring is essential at all the Bristol Harbor sites in order to establish baseline conditions, clearly continued monitoring at BH#3 is critical to reduce watershed impacts. Additional sites moving upstream along Silver Creek could help to identify specific nutrient and bacteria sources, possibly allowing remediation of those sources.

References:

Howes, Brian, Tony Williams and Mark Rasmussen, 1999. *BayWatchers II Nutrient related water quality of Buzzards Bay embayments: a synthesis of Baywatchers monitoring 1992-1998* http://www.savebuzzardsbay.org/bayinfo/publications/BaywatchersII/baywaters-pages3-34.pdf.

National Oceanic and Atmospheric Administration's (NOAA) Ocean Service Education Monitoring Estuaries website http://oceanservice.noaa.gov/education/kits/estuaries/estuaries10_monitoring.html

Russian River Pathogen Project (RRPP) Working Draft Report, Updated 01/28/2008 http://rrpp.ice.ucdavis.edu/node/7

Save Bristol Harbor website http://www.savebristolharbor.com

United States Environmental Protect Agency (EPA), 2008. National Estuary Program Coastal Condition Report Introduction http://www.epa.gov/owow/oceans/nepccr/pdf/nepccr_intro.pdf

University of Rhode Island (URI) Office of Marine Programs' Discovery of Estuarine Environments website http://omp.gso.uri.edu/ompweb/doee/science/intro.htm)

University of Rhode Island Watershed Watch website (includes monitoring manual, data, fact sheets, and links to local, regional and national information) http://www.uri.edu/ce/wq/ww

Acknowledgements: Volunteer water quality monitoring would not be possible without the dedication of outstanding volunteers such as Cara Cromwell, Christy Nadalin, Janet Christopher, Jan Armor, Denise Arsenault, Bob Arsenault, Joe Arruda, Stephan Brigidi, Chip Cavallaro, Barbara Healy, Jil Mestre, Katey Amaral, Keith Maloney, Brooke Cotta, Bob Aldrich, Rob Hancock, Susan Donovan, and Alexia Oliver. These outstanding individuals got up very early each Thursday morning throughout the season, rain or shine, working in teams to gather this essential information. They were lead by indomitable local coordinators and Save Bristol Harbor founders Chip Carvallaro, Keith Maloney and Joe Arruda. Those gentlemen worked with a committee to identify monitoring sites, recruited volunteers, coordinated training sessions, ensured that the local volunteers had all the necessary equipment, supplies and any other resources they needed, and acted as couriers delivering samples on a monthly basis (even though it meant crossing two bridges on the trip to Kingston). They helped to build team unity by hosting BBQs (even when it was pouring rain) and regular meetings, and without whom it is easy to say, this project would never have been started.