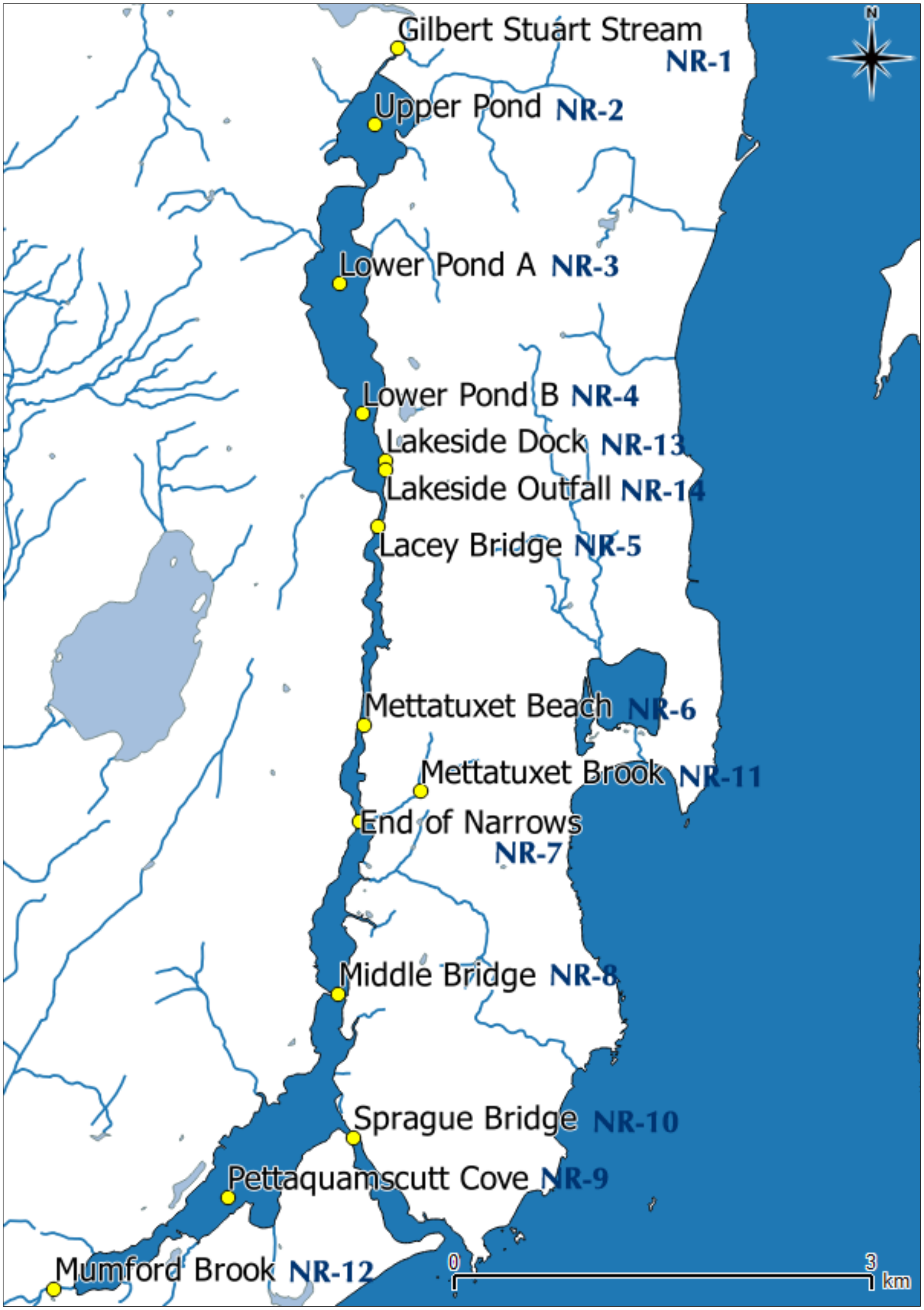
Narrow River Water Quality:
Trends and Findings Spanning a Quarter Century!

By Annette DeSilva and Veronica Berounsky

In 1992, NRPA kicked off their River Watch program and since that time volunteers have taken measurements and collected water samples to help us assess the water quality of the Narrow River. In 2016, NRPA reached the 25-year milestone of their River Watch program. To mark the event, we have compiled and plotted all of the data to examine the water quality trends and to assess the condition of our River. A presentation was made at the 2017 NRPA Annual Meeting that highlighted the trends and findings spanning the past quarter century. In this article, we will summarize many of the findings that were presented.

In the early 1990's, water quality was on the minds of many. Sewers had been installed in Middlebridge and they were starting to be installed along the Narragansett side of the River. However, stormwater from the watershed neighborhoods was still draining directly into the River. NRPA had a strong interest in starting a volunteer water monitoring program because we were aware of high bacteria levels. Also, since there were no industries along the river (obvious point sources), a watershed watch approach to studying water quality was desired.

In 1992, NRPA's "River Watch" program officially began with 10 monitoring locations. Narrow River is seven miles long and its watershed is located in North Kingstown, South Kingstown, and Narragansett. The original sites (NR 1 – 10) were picked so that they would span the length of the river from Gilbert Stuart Stream in the north to Pettaquamscutt Cove in the south. The site at Sprague Bridge is closest to the mouth of the River. Over the years we added four additional sites. In 1996, Mettatuxet Brook (in Mettatuxet) was added in response to land development demand. In 2000, Mumford Brook (near Narragansett Elementary School) was added because a Rhode Island Department of Environmental Management (RIDEM) study identified this as an area of concern [1]. Sites were added at Lakeside Rd and Lakeside Outfall (in Edgewater) in 2004 because they were near an area where a stormwater management plan would be implemented. With this data, we hope to observe pre- and post-management results.



Map Courtesy of Eric Peterson

The River Watch monitoring season runs from May to October each year. Every two weeks during the season, volunteers measure temperature and dissolved oxygen. They also collect samples for salinity and chlorophyll that are analyzed by the URI Watershed Watch Lab. Once a month, samples are also collected for bacteria, nutrient, and pH analysis. The lab analysis services are provided by URI's Watershed Watch office, which also trains all new volunteers, supplies the monitoring equipment, compiles data into the database, and creates charts and graphs.

Twenty-five years of data for an entire river is a large data set to evaluate. Plots have been created for every parameter for all sites for all years and these are available upon request to NRPA. For purposes of the Annual Meeting presentation, we wanted to provide a snapshot of the parameters monitored at all sites and to do this we decided to evaluate the averages of the data parameters over 25 years. The only exception was with the bacteria data, which is displayed as the geometric mean. The geometric mean of the data indicates the typical value of a set of numbers and this is consistent with RIDEM bacteria standards.

The parameter plots (temperature, salinity, dissolved oxygen, bacteria, nutrients, chlorophyll, and pH) are arranged so that each monitoring location is shown starting in the north of the River and ending in the south. There are two charts for each parameter, one for salt water and one for fresh water. The fresh water sites are streams or outfalls that flow into the river. The average values for the data are divided into two sets. One set represents the first 12 years (typically 1992 to 2003) and is shown as the blue bars on the charts. The average of the next 13 years (2004 – 2016) is shown as the green bar. This split is close to half way along the 25 years, but it also happens to coincide with the construction of the new Middle bridge in 2004, so perhaps we can see if that had any influence on the water quality. For the Freshwater sites, which started collections later, the break is after 2006, which is when the Mettatuxet Best Management Practice (BMP) was completed. For some of the nutrients, collections started only in 2006.

<u>Data Observations</u>:

Temperature - The average temperature over the past 25 years has been relatively stable; however, in more recent years the temperature is slightly higher than the initial years of monitoring at many sites. As expected, the water temperature at the sites closer to the mouth of the River is a bit cooler than those are sites at the north end of the River. The sites near the mouth are more influenced by the ocean water temperatures. Although, it isn't shown by the average data, we have observed seasonal trends annually, with cooler water in the spring and fall and warmer water in the summer.

Salinity - The Narrow River is an estuary and has flows of both freshwater and salt water. Freshwater enters through the streams and brooks and saltwater enters through the mouth of the River in the south. As expected, the sites at the south end of the River that are near the mouth have the highest average salinity, approaching the levels that you would see outside in the ocean and Bay. The Narrow River is a brackish water body, and the data shows that salinity extends all the way to the Upper Pond. At the fresh water sites, salinity measurements are not taken.

Dissolved Oxygen - Dissolved oxygen is very important to a water body. Without oxygen, the waterbody could not support life. All organisms in the River, from fish to insects to microscopic zooplankton, need oxygen for respiration. The average dissolved oxygen levels all are within ranges that can support life. However, on occasion, very low dissolved oxygen levels have been observed. It was interesting to see that in the past 13 years, the dissolved oxygen levels are on average lower than the first 12 years. This is something we will want to watch in future years.

Bacteria - The analysis of the water samples for bacteria levels screen the water for its suitability for swimming and for shellfishing, and may indicate contamination. Two groups of bacteria are commonly monitored to indicate the presence of human sewage and associated pathogens, or disease-causing organisms - fecal coliforms and enterococci. These are the ones that were evaluated by us in this study.

<u>Fecal Coliform Bacteria</u> - Beginning in 1994, the entire Narrow River was closed to shellfishing and remains closed today due to high coliform bacteria levels. Fecal coliform values are used for shellfish standards. The RI DEM standard for shellfishing is the "Geometric mean is not to exceed 14 fecal coliform per 100 mL" [2]. Figure 1 shows the geometric mean values for fecal coliform levels at all sites. The horizontal red line represents the shellfishing standard and the bars that extend above the red line exceed the safe standard for shellfishing.

At the saltwater sites, the shellfishing standard is exceeded at all sites south of Lacey Bridge (Fig 1a). For the fresh water sites, with the exception of Gilbert Stuart Stream, the fecal coliform geometric means are extremely high (Fig 1b). These sites are inputs to the river and are of concern. The data supports the rational for why the River is still closed for shellfishing and also why it is still very important to try to implement best management practices and stormwater improvements within the watershed.

Figure 1: Geometric Mean Fecal Coliform Bacteria Data

Figure 1a: Fecal Coliform Data from Saltwater Sites

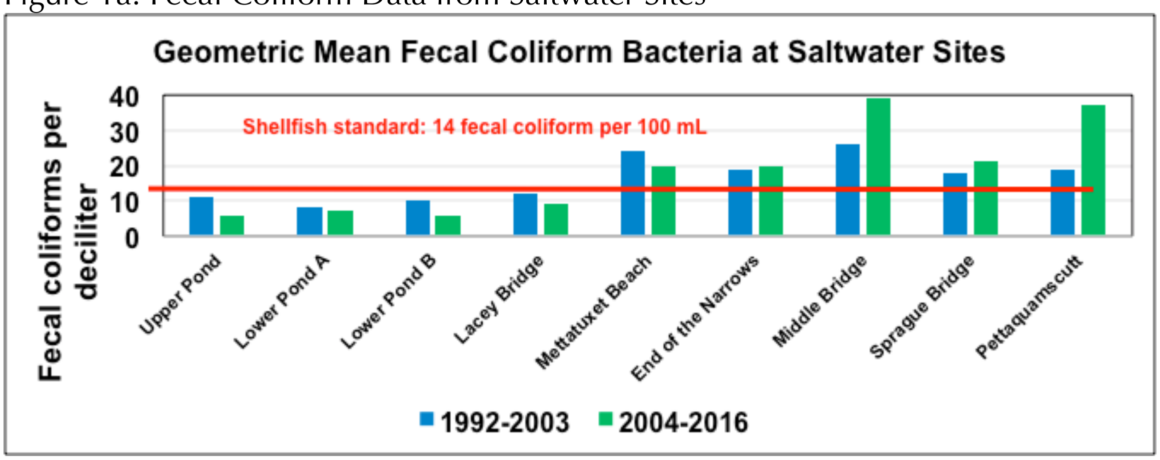
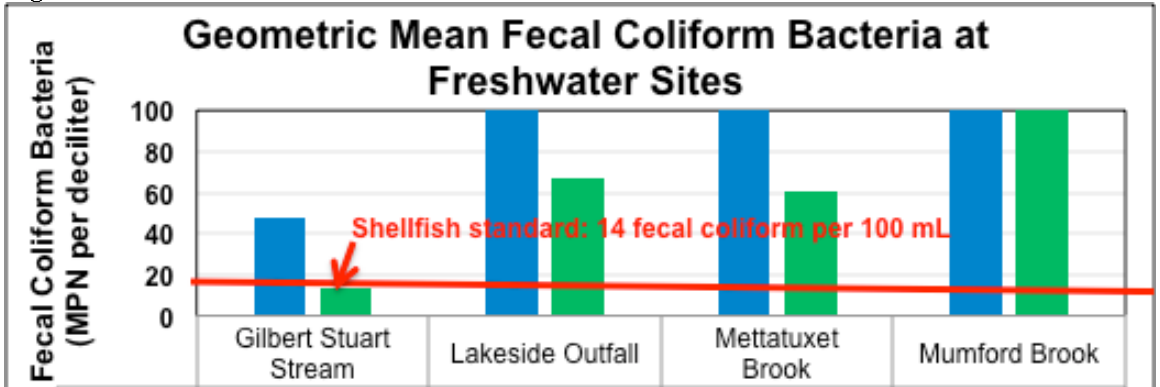


Figure 1b: Fecal Coliform Data from Freshwater Sites



	Gilbert Stuart Stream	Lakeside Outfall	Mettatuxet Brook	Mumford Brook
1997-2006	48	287	496	4967
2007-2016	13	67	61	947

<u>Enterococci Bacteria</u> - The Rhode Island RIDEM uses a geometric mean approach for their safe swimming standards. Their standards are defined as follows [2]:

- The safe swimming Standard for salt water: not to exceed 35 enterococci per 100 mL Geometric Mean Density
- The safe swimming Standard for fresh water: not to exceed 33 enterococci per 100 mL Geometric Mean Density

In Figures 2 and 3, the horizontal red line illustrates the safe swimming standard. Any data above the standard (the red line) is considered unsafe for swimming.

The URI Watershed Watch office began enterococci analyses in 2007 (consistent with RIDEM standard) and so our enterococci data also begins in 2007.

Some observations that can be made from the enterococci plots (Fig 2) include:

- For the saltwater sites (Fig 2a), the enterococci geometric mean does not exceed the standard for safe swimming. This is a good sign.
- The deep-water sites at the north end of the river have the lowest enterococci geometric means. This area has the lowest density of homes/development and the least impacts from human sources.
- The enterococci levels increase as you go south along the river. These areas are more densely populated and the impacts from human sources are greater.
- In contrast to the saltwater sites, the enterococci levels are very high at most of the fresh water sites. To display the data, a much larger scale had to be applied. With the exception of Gilbert Stuart Stream, the safe swimming standard is greatly exceeded. This is of concern because these are in the inputs into the River. However it should be noted these streams are very shallow, so no one is swimming in these streams.
- One very interesting observation is that at the saltwater sites, the geometric means are lower in the more recent years that in the earlier year. Perhaps we are starting to see the **positive** impact of the new storm water abatement systems and sewers.

It is important to recognize that while the URIWW's Analytical Laboratories are certified by the State of Rhode Island, Watershed Watch data is intended for screening purposes only. Our data are very valuable for targeting areas of concerns and for tracking potential sources of bacterial contamination. The data should not be used to determine daily safe swimming conditions.

Figure 2: Geometric Mean Enterococci Bacteria Data

Figure 2a: Enterococci Data from Saltwater Sites

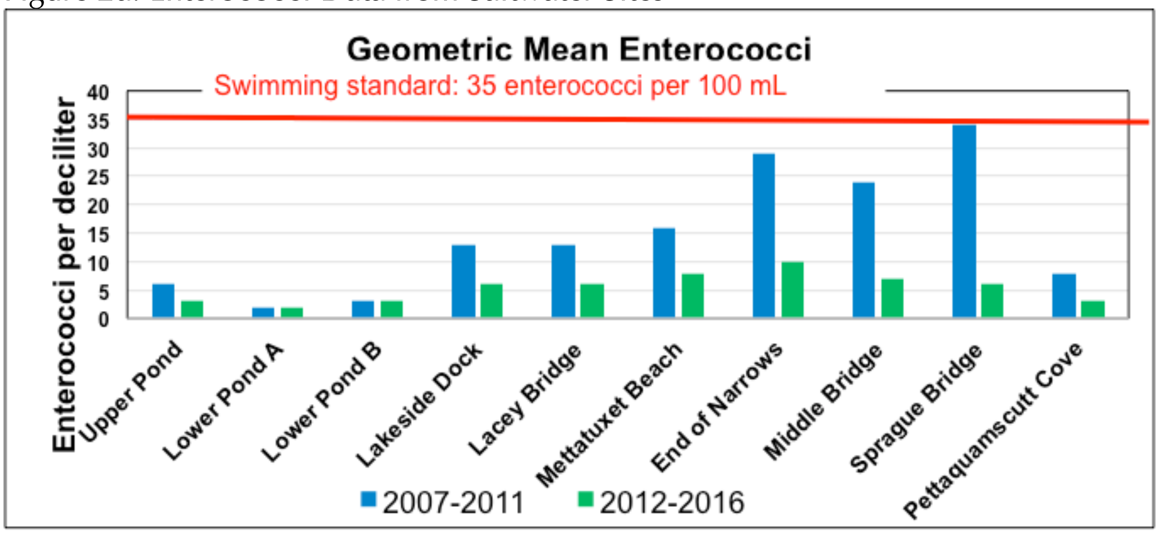
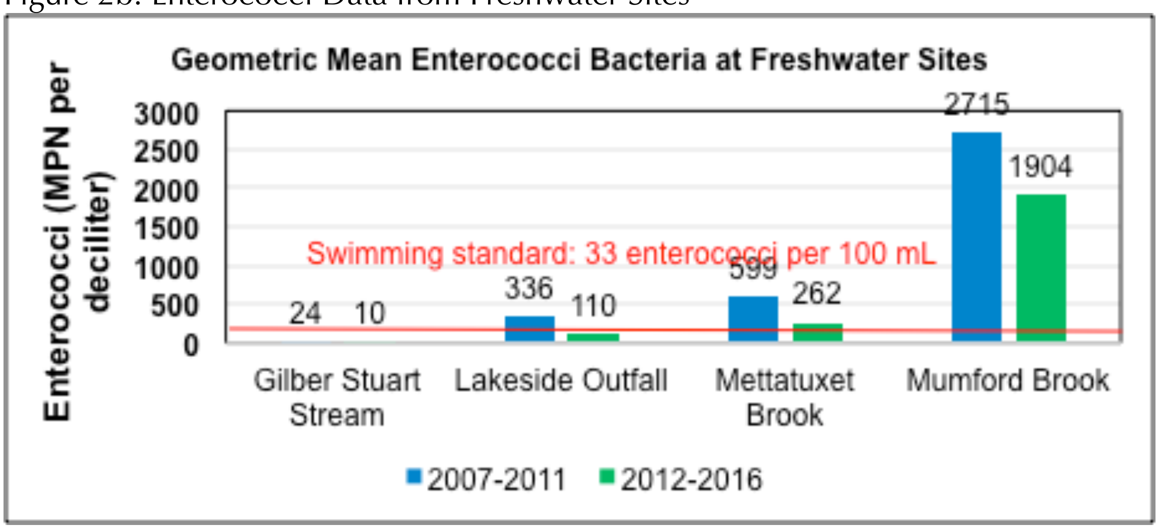
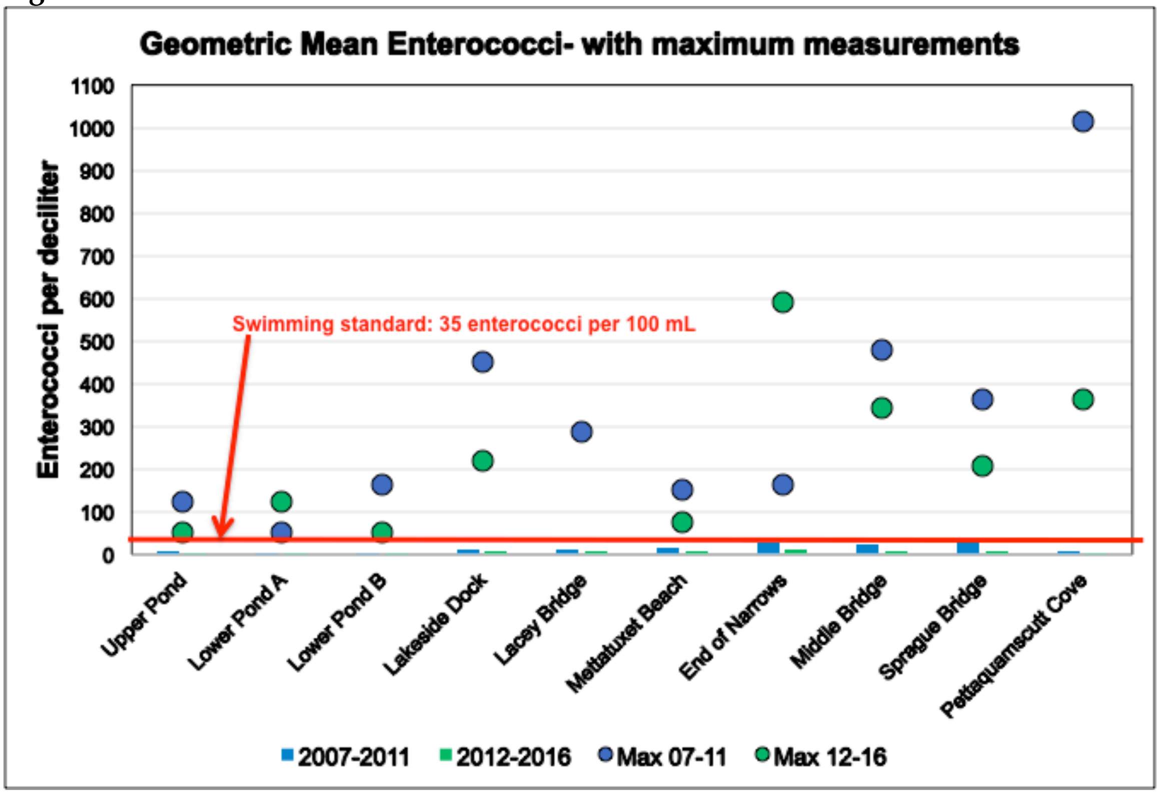


Figure 2b: Enterococci Data from Freshwater Sites



Although it is a positive sign to see that the geometric mean values for the enterococci did not exceed the safe swimming standard in saltwater, the individual enterococci data values sometimes exceed the standard significantly. In Figure 3 the maximum enterococci values (shown as blue and green dots) have been plotted above the geometric mean bars. A very large scale was required in order to show the maximum data values (the geometric mean bars are just blips at the bottom of the plot). The standard for swimming is shown as the red horizontal line. Unfortunately, the maximum enterococci values are well above the standard for safe swimming.

Figure 3: Enterococci Bacteria – Geometric Mean with Maximum Data Values



Nutrients -

Why nutrients are important: Nutrients are substances necessary for the survival and growth of plant and animals. The most important nutrients in water ecosystems are nitrogen and phosphorus. Nitrogen is more important in salt waters, phosphorus is more important in freshwaters. For the River Watch Program, Total Nitrogen and Total Phosphorus (the sum of all types of nitrogen or phosphorus) have been measured since River Watch started in 1992. Components of these: Ammonia, Nitrate, Nitrite and Dissolved Phosphorus have been measured since 2006.

How nutrients get into Narrow River: These nutrients enter the Narrow River from "nonpoint" sources such as ground water, rain, and the atmosphere (i.e. the burning of fossil fuel puts nitrogen into the atmosphere). Even without rain, excess fertilizer (which is mainly nutrients) can run off lawns into the River. During a storm, rain washes along lawns and impervious surfaces such as driveways and roads, collecting more nutrients and bacteria, and sending them towards "point sources" of streams and outfall pipes and eventually the River.

How nutrients can be a problem: Nutrients are necessary for life, but too much of a good thing is bad If nutrient levels are too high, plants floating in the water, will grow and explode in population, causing a bloom blocking sunlight from penetrating into the water, inhibiting the rooted plants, such as eelgrass from growing. Eelgrass provides an important nursery area for juvenile fish and other organisms. Also, as the bloom ages and breaks down, it uses up oxygen, taking it out of the water. Oxygen is necessary for animals, so fish, shellfish, and other animals may die.

Total Nitrogen: The most important point to note in Figures 4a and 4b is that the values of Total Nitrogen are in the freshwater streams and outfall are much larger than in the River itself. As a result of these inputs, the River sites near Mettatuxet Brook (Mettatuxet Beach, End of the Narrows) and Mumford Brook (Pettaquamscutt Cove) are higher than expected based on the distance down the estuary. The second point is that in general, total nitrogen decreases as sites get closer to the mouth. This is because the off shore (RI Sound) waters are low in total nitrogen. The third point is that the values of recent years are (except for Upper Pond) higher than earlier years. This suggests that the increase in houses (and lawns and driveways) in recent years (which has not happened in Upper Pond) has contributed total nitrogen despite the introduction of municipal sewers. As a guideline, the US Environmental Protection Agency suggests an upper limit of total nitrogen of 50 µmol/L (or 0.71 ppm) for rivers and streams as a measure of good water quality [3]. The sites in Narrow River and Gilbert Stuart Stream have averages below this.

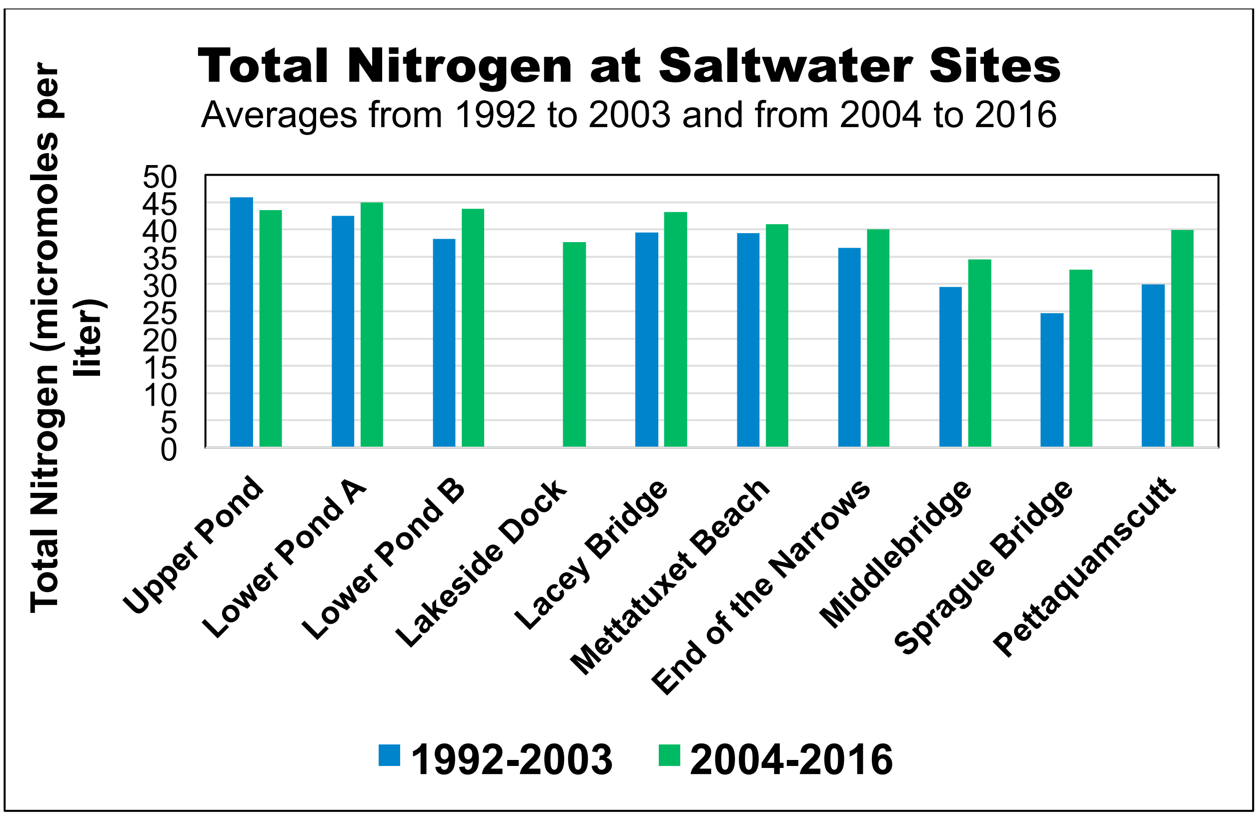


Figure 4a

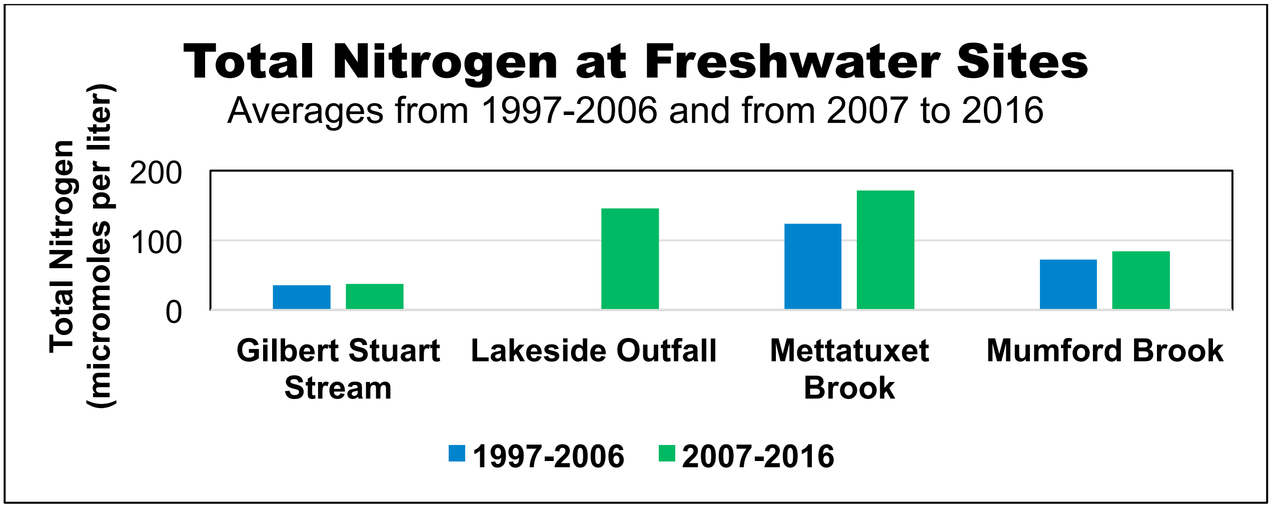


Figure 4b

***Ammonia*:** Ammonia is one of the components of total nitrogen. It is the first form of nitrogen that is released from decaying organic matter, excreted by animals (including humans) and seeps out of leaking septic systems. For the River Watch sites, it has only been measured separately since 2006 (the year the Mettatuxet BMP was completed). The values, both at the salt water sites (Figure 5a) and the freshwater sites (Figure 5b) are not particularly high, only going to 10 µmol or less, this is good news. Also the ammonia levels in recent years are always lower, in some cases about half the values, seen in earlier years. This is more good news. This all suggests that sources of ammonia have been reduced.

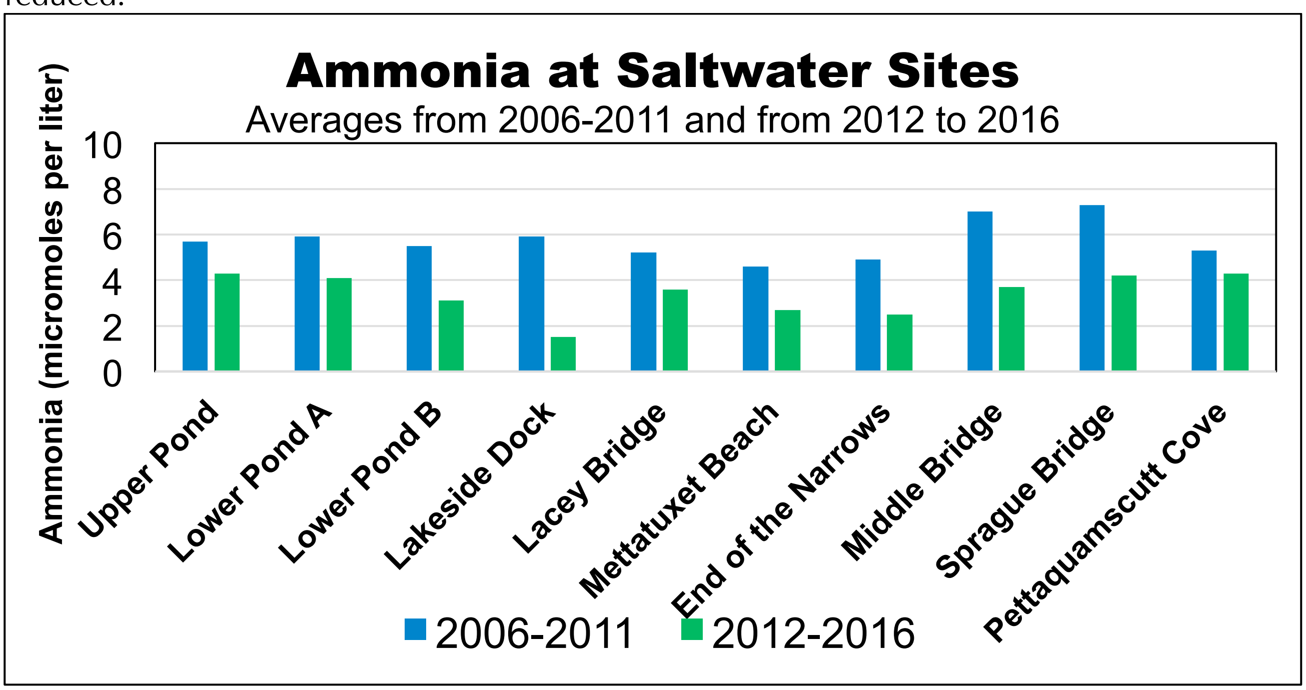


Figure 5a

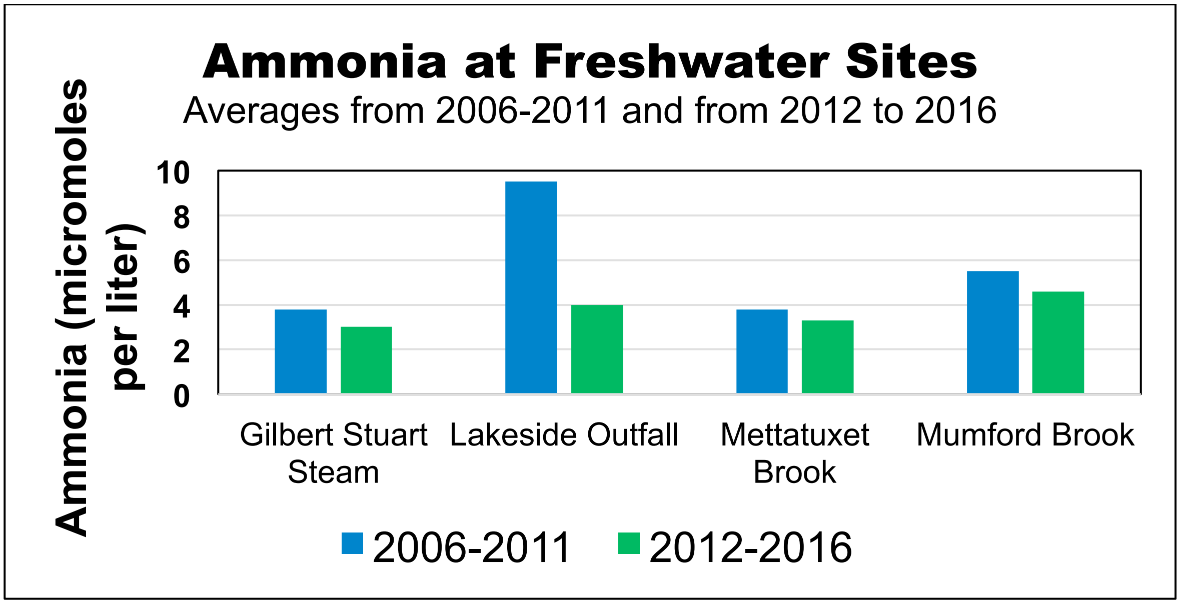


Figure 5b

Nitrate and nitrite: Nitrate and nitrite are measured together and are also components of total nitrogen. Values of nitrate and nitrite are often high is ground water, and these concentrations are the results of fertilizers, and human and animal waste. For the River Watch sites, they have only been measured separately since 2006 . The values in the River itself are low, less than 4 µmol (Figure 6a). As for ammonia, values nitrate and nitrite in recent years are much lower than in earlier years. This suggest there is less nitrate plus nitrite contamination in the River. Except for Gilbert Stuart Stream, the values are for the freshwater sites are very high, between 50 and 200 µmol (Figure 6b) and the values of recent years are higher than earlier years. This suggests the brooks and outfall are a source of nitrate plus nitrite to the River. It is interesting that the two streams flowing through undeveloped areas (Gilbert Stuart Stream and Mumford Brook) are the lowest while the outfall which drains a neighborhood and the brook that drains both a neighborhood and a wooded area are the highest, suggesting humans and households are the ultimate sources of this nitrogen and most of the total nitrogen is nitrate plus nitrite.

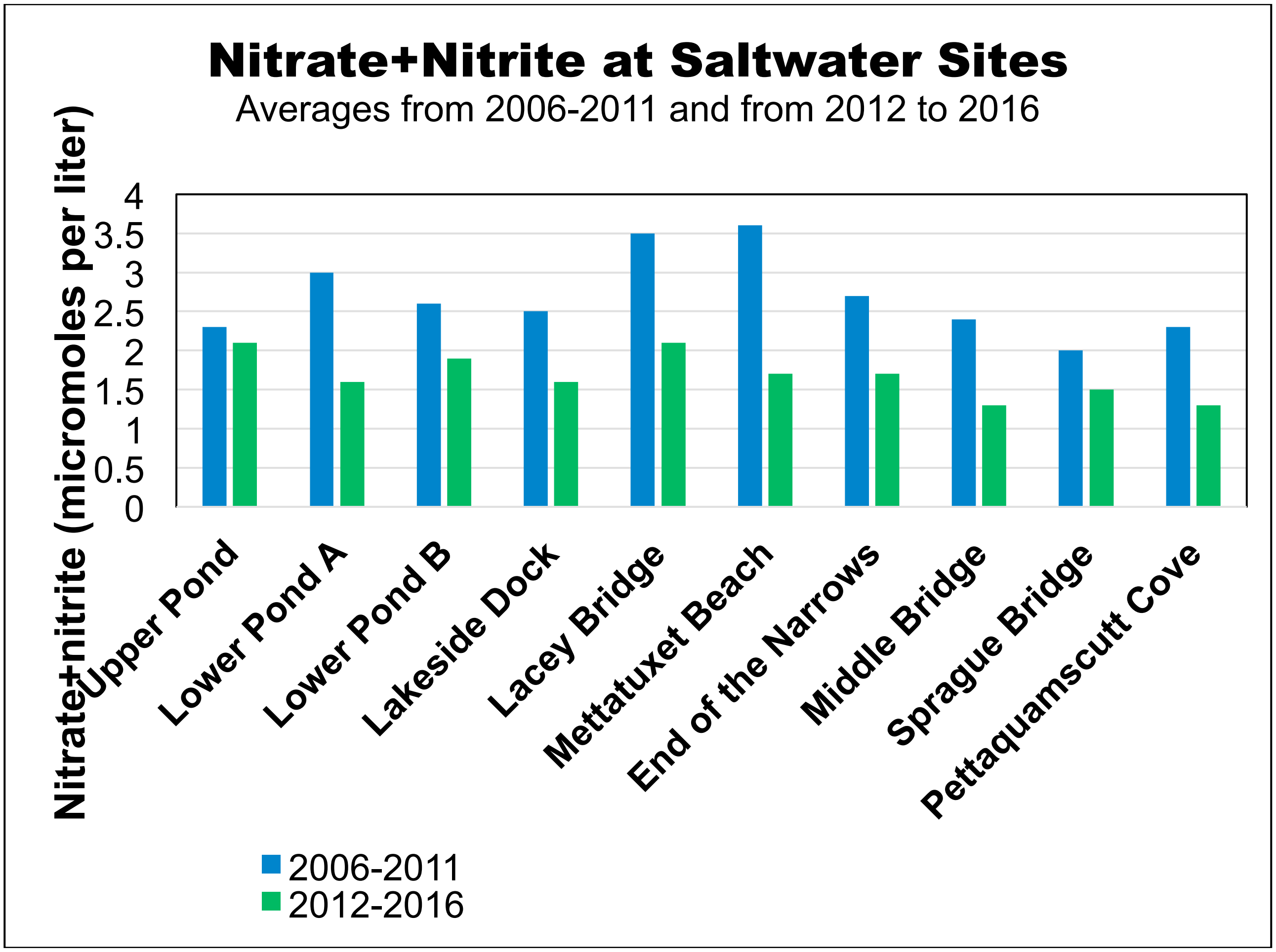


Figure 6a

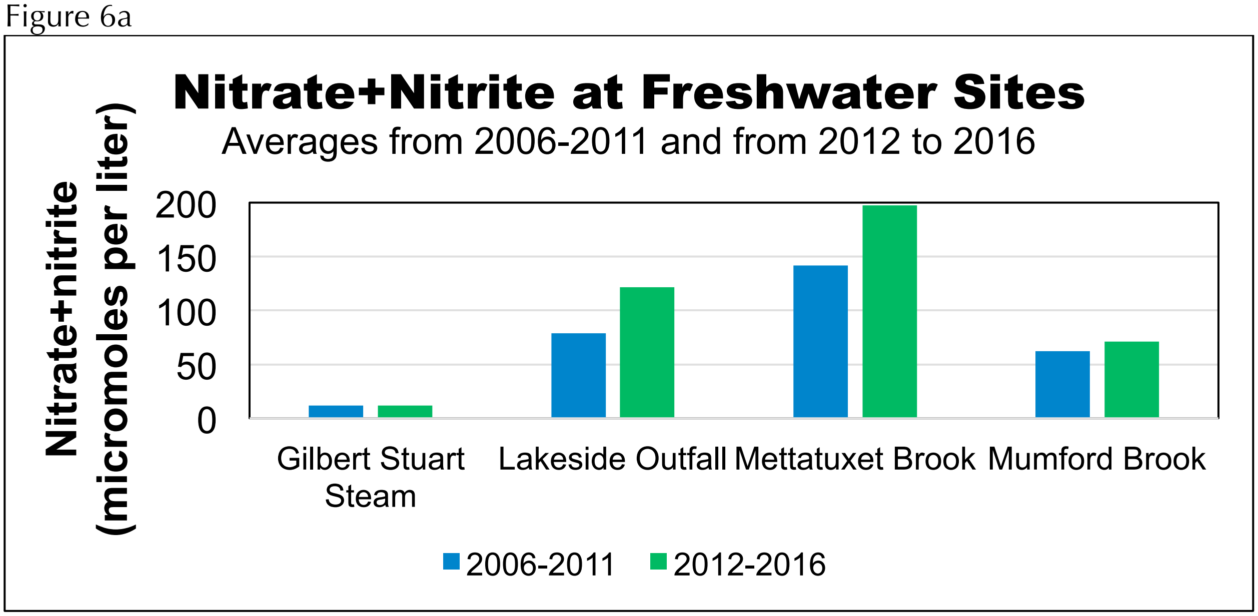


Figure 6b

Total Phosphorus: In contrast to the nitrogen, the total phosphorus levels are low, 2 µmol or less, even in the freshwater sites. There is not much difference between older years and recent years.

Dissolved Phosphorus: The inorganic component of total phosphorus, dissolved phosphorus, comes from fertilizers, organic waste, and erosion of rocks and sediments. Values
are low, 1.6 µmol or less, suggest that dissolved inorganic phosphorus is not a problem in this ecosystem. Values are lower in recent years. The highest levels are at Mumford Brook and Pettaquamscutt Cove (where Mumford Brook drains to) suggesting natural sources since Mumford drains a vegetated area, unless one of the home nearby has a leaky septic system.

Chlorophyll: Chlorophyll is a plant pigment and is a measure of how well plants are using sunlight and nutrients to grow. It is also a measure of how productive or eutrophic the ecosystem is. Chlorophyll values of between 2-11 µg/L for all the sites can be classified as oligotrophic or slightly mesotrophic, but definitely not eutrophic (43 µg/L) so not a problem. Note the values in recent years are all higher than earlier years, but still not eutrophic.

What do these water quality trends mean?

- Increasing **temperatures** are typical as indicators of global warming ☹
- Good that **dissolved oxygen** levels are high enough to support life, despite occasional low oxygen measurements ☺
- Increases in **salinity** at sites that are closer to the mouth of the River indicate sufficient inflow of RI Sound water (and with lower nutrient levels) ☺
- **Fecal coliform bacteria** levels suggest the ponds and down to Lacy Bridge and the streams and outfall are improving ☺, but the rest of the river may have some problems ☹
- **Enterococci bacteria** levels are lower in more recent years indicating improvements and swimming continues to be safe☺
- Higher **total nitrogen** values in recent years (except for Upper Pond) suggests that the increase in homes, lawns and driveways is counteracting the improvement of municipal sewers for organic nitrogen☹
- Lower recent **ammonia** levels indicate improvements ☺
- Lower recent **nitrate plus nitrite** values indicate some improvements particularly due to BMPs and municipal sewers ☺
- Low **total phosphorus** levels that are similar for all years indicates there has not been a problem with phosphorus ☺
- Lower, recent **dissolved phosphorus** levels are good ☺ but problems may exist at Pettaquamscutt Cove, Gilbert Stuart Stream, and Mettatuxet Brook ☹
- Although **chlorophyll** values have increased in recent years, they are still at a good level of production and not a problem ☺
- Not part of this study but another study shows that since 2012 eelgrass has returned to Narrow River ☺

- **Streams** (particularly Mumford Brook and Mettatuxet Brook) **and the outfall** are bringing in bacteria and nutrients and other parts of our data shows elevated levels of bacteria and nutrients after rain events so stormwater is still a source ☹

Concluding Remarks:

In conclusion, NRPA's River Watch program has allowed us to learn much about the water quality of Narrow River and its tributaries (and one outfall) and how it has varied over a quarter century.

These data have been very useful to the state of Rhode Island and the three towns in the Narrow River watershed by providing evidence of areas of poor water quality so that improvements could be made in the watershed such as the increased span width of the rebuilt Middle Bridge, the removal of the outhouse at Gilbert Stuart Birthplace in North Kingstown, the construction of the detention ponds and sand filters (best management practices or BMPs) in several neighborhoods in Narragansett, and the planned BMPs in South Kingstown.

Because of the retention and then slow leakage of nutrients from the soils and groundwater of the watershed, it takes years to see the effect of improvements (such as municipal sewers), but our 25 years of data are showing areas of improvement in both bacteria levels and nutrient concentrations.

Stormwater continues to be a problem and more BMPs are needed.

Levels of fecal coliform bacteria and also nitrate plus nitrite in streams and at the outfall continue to be high and the sources need to be identified.

Acknowledgements:

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Linda Green and Elizabeth Herron from the URI Watershed Watch Office have been fantastic partners. Their knowledge, experience, and dedicated assistance has been instrumental is guiding NRPA's River Watch Program through the past 25-plus years.
All the data analysis seen here, plus additional work not shown, could not have been possible without the diligent work, mapmaking, and data management carried out through many years by NRPA interns Rahat Sharif and Eric Peterson. NRPA's SCIwrite Intern Danielle Perry was a great help with the Annual Meeting PowerPoint presentation.
Finally, the River Watch program would not have been possible without the dedicated service of the volunteer monitors. Over the first 25 years of the program there have been more than 185 volunteers. They have collectively shared over 7800 hours of their time helping us to learn more about the quality of the Narrow River.

References:

[1] *Fecal Coliform TMDL for the Pettaquamscutt (Narrow) River Watershed, Rhode Island* <http://www.dem.ri.gov/programs/benviron/water/quality/rest/pdfs/narrivdr.pdf>; Rhode Island Department of Environmental Management; December 2001

[2] *Bacterial Monitoring*, URI Watershed Watch, Cooperative Extension, College of the Environment and Life Sciences (CELS), Department of Natural Resources Science (NRS) <http://cels.uri.edu/docslink/ww/water-quality-factsheets/Bacteria.pdf>; Elizabeth Herron, Kelly Addy and Linda Green, June 2015

[3] *Nitrogen and Water Quality*, URI Watershed Watch, Cooperative Extension, College of the Environment and Life Sciences (CELS), Department of Natural Resources Science (NRS) <http://seacomm.weebly.com/uploads/3/7/7/6/37768331/nitrogenfactsheet.pdf> Kelly Addy, Linda Green, and Elizabeth Herron, March 2005