



# Water Quality Monitoring at Marsh-Billings-Rockefeller National Historical Park

## *Northeast Temperate Network 2014 Summary Report*

Natural Resource Data Series NPS/NETN/NRDS—2016/1022



**ON THE COVER**

Pogue Brook, October 2014

Photograph by: Liza McElroy

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## Executive Summary

This report on the water quality of Marsh-Billings-Rockefeller National Historical Park (MABI) includes data gathered by the Northeast Temperate Network (NETN) in the 2014 monitoring season and displays these results in graphic form, accompanied by a brief interpretation. The data address the NETN objective to detect change in the status of physical, chemical, or biological attributes of park freshwater bodies.

The NETN Freshwater Monitoring Protocol calls for one park pond and one stream to be sampled monthly from May through October at MABI. Staff measured physical and in-situ water chemistry parameters each month and periodically collected water samples for analysis at the University of Maine's Sawyer Environmental Chemistry Research Laboratory.

Monthly sampling parameters included in-situ water quality measures (pH, specific conductance, temperature, and dissolved oxygen), transparency and light attenuation (pond site only), stream turbidity, weather, stream flow (discharge), and stream and pond stage. In May (stream only), June (pond only) and August (both sites), water samples were obtained and analyzed for acid neutralizing capacity (ANC), color, nutrients, dissolved organic carbon (DOC), chloride, sulfate, and chlorophyll *a* (pond only).

Most water quality parameters for the Pogue and Pogue Brook were within state standards, and were generally within the range of EPA regional nutrient criteria, where applicable. The values were usually within the ranges of the historic NETN monitoring data. An exception is pH at the Pogue, where surface pH ranged above and below the state upper pH standard throughout the season. The Pogue and Pogue Brook are well buffered, as evidenced by the high pH and ANC measurements, and are unlikely to be adversely affected by atmospheric acid deposition. The entire historical data range (including 2014 samples) of nutrient levels for the Pogue is above the EPA criteria for both phosphorus and nitrogen; however 2014 values were at the low end of the historical range. The 2014 phosphorus and nitrogen values for Pogue Brook were all at the low end of the historical data range, and were below the EPA stream criteria.



## Introduction

This report on the water quality of Marsh-Billings-Rockefeller National Historical Park (MABI) generated by the Northeast Temperate Network (NETN) Water Quality Monitoring Program includes data gathered in the 2014 monitoring season and displays these results in graphic form, accompanied by a brief interpretation. Appendix A contains tabular data collected in 2014.

The vital signs for freshwater bodies established in the original NETN Freshwater Monitoring Protocol (Lombard et al. 2006) are water chemistry, nutrient enrichment, water quantity, and the detection of invasive plant species. These metrics were chosen to address the NPS Inventory and Monitoring Program objective to detect change in the status of physical, chemical, or biological attributes of the ecosystem.

The NETN Freshwater Monitoring Protocol calls for a total of one park pond and one stream to be sampled monthly from May through October at MABI. Two NETN Student Conservation Association (SCA) interns measured physical and in-situ water chemistry parameters each month and periodically collected water samples for analysis at the University of Maine's Sawyer Environmental Chemistry Research Laboratory. All monitoring data are incorporated into a series of comprehensive databases that ultimately feed the U.S. Environmental Protection Agency's "STORET" data system, the repository for all NPS water quality and quantity data.

## Sampling Sites

One stream sampling site was selected to represent Pogue Brook. This is the only stream within the park and it has been monitored annually since 2006. Pogue Brook can be classified as a cold water fishery, loosely defined as water that can support, on a year-round basis, wild and stocked brook trout (*Salvelinus fontinalis*) or other species requiring similar conditions. The stream monitoring site was selected as the most downstream site within the park boundary with easy access and the ability to obtain an accurate discharge measurement over a range of flows. Additionally, a pond monitoring site was established at The Pogue, a 4.5 hectare pond situated at the headwaters of Pogue Brook. Both sites are mapped in Figure 1.

## Methods

Detailed descriptions of all monitoring methods are found in the original protocol (Lombard et al. 2006) and the most recent protocol update (Gawley et al. 2014). Monthly sampling parameters included in-situ water quality measures (pH, specific conductance, temperature, and dissolved oxygen) determined with a YSI 600XL sonde, transparency and light attenuation (pond site only), stream turbidity, weather, stream flow (discharge), and stream and pond stage. In May (stream only), June (pond only) and August (both sites), water samples were obtained and analyzed for acid neutralizing capacity (ANC), color, and nutrients. Beginning in 2012, fractions of these water samples were also analyzed for dissolved organic carbon (DOC), chloride, sulfate, and chlorophyll *a*.

The pond sampling procedure entailed collecting all in-situ measurements and water samples from the deepest point of the pond (approximately 3.4 meters).

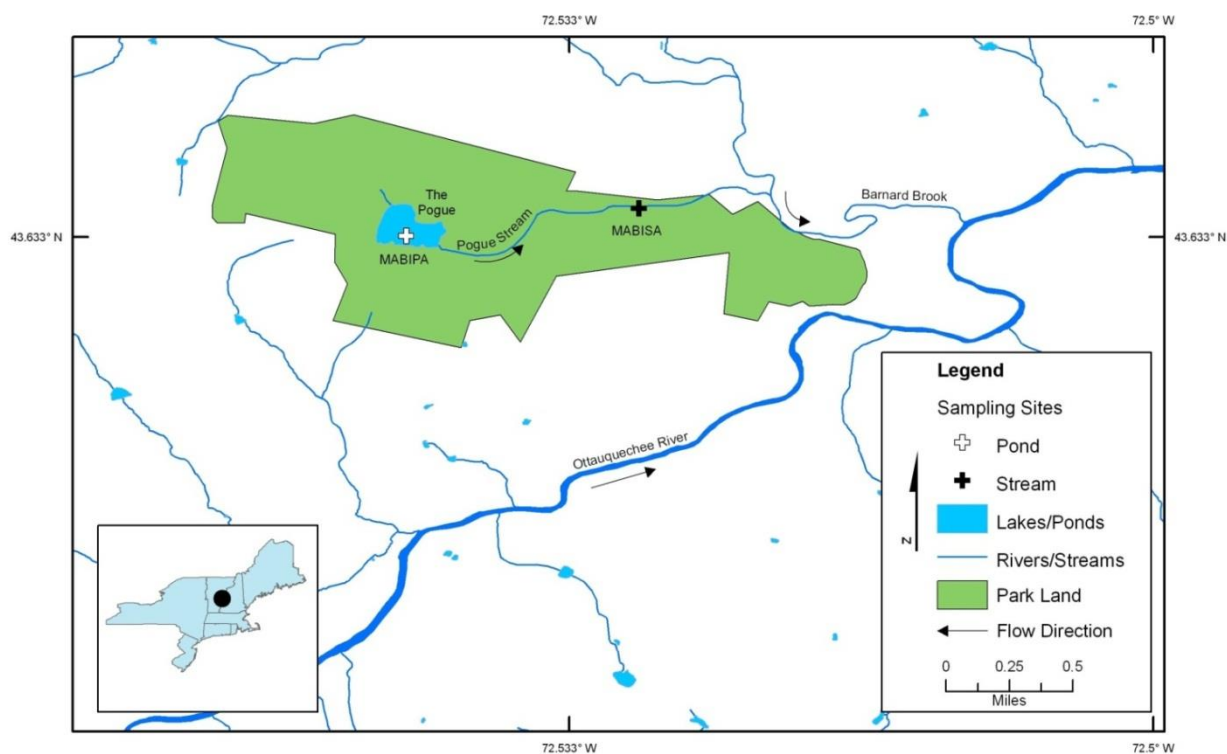


**Figure 1.** NETN water monitoring sites at Marsh-Billings-Rockefeller NHP.

Nutrient chemistry parameters were analyzed from a half-meter grab sample, obtained by submerging the sample bottle directly in the pond with a gloved hand.

Stream discharge was measured using U.S. Geological Survey protocols (Rantz et al. 1982), employing a measuring tape, wading rod, and SonTek FlowTracker current meter (a Price Pygmy current meter may be used when conditions are not suitable for a FlowTracker) to measure a particular cross-sectional area of the stream and the velocity of the water at that cross section. Pond and stream stage were measured by using a measuring tape or folding ruler to “tape down” or “tape up” from a fixed datum point to the surface of the water, or by reading the water level utilizing a staff gage. A bolt was installed to permanently mark the stream datum point in July 2012.

In-situ stream water chemical and physical measurements and water samples were collected within 5 meters of the location of the discharge measurement. Sonde measurements were taken in the main stream flow with care taken that the sonde was not resting directly on the stream bottom. Grab samples were obtained by submerging the sample bottle directly in the stream with a gloved hand.

# Water Quality Standards

The numeric Vermont water quality standards applicable to MABI monitoring sites are listed in Table 1. The standards state that total phosphorus and total nitrate loadings “shall be limited so that they will not contribute to the acceleration of eutrophication or the stimulation of the growth of aquatic biota in a manner that prevents the full support of uses” (State of Vermont Water Resources Board 2011, pages 20 and 22) and “both the change and the rate of change in pH values shall be controlled to ensure the full support of the aquatic biota, wildlife, and aquatic habitat uses” (State of Vermont Water Resources Board 2011, page 23).

**Table 1.** State of Vermont water quality standards.

| Water body type | Minimum dissolved oxygen (mg/L)                    | pH range (standard units) | Maximum total nitrogen (µg/L) | Maximum total phosphorus (µg/L) |
|-----------------|----------------------------------------------------|---------------------------|-------------------------------|---------------------------------|
| Streams         | 6-7 (cold <sup>1</sup> )<br>5 (warm <sup>2</sup> ) | 6.5-8.5                   | 2,000<br>(2 mg/L)             | --                              |
| Ponds           | --                                                 | 6.5-8.5                   | 5,000<br>(5 mg/L)             | --                              |

<sup>1</sup> Cold refers to cold water fisheries (capable of supporting brook trout and other salmonids).

<sup>2</sup> Warm refers to warm water fisheries (capable of supporting bass, pickerel, and sunfish).

EPA Ecoregion 8 water quality criteria (Table 2; U.S. Environmental Protection Agency 2000a, 2000b) are also used as a benchmark in this report. EPA water quality criteria for nutrients help translate narrative criteria within State or Tribal water quality standards by establishing values for causal variables (e.g., total nitrogen and total phosphorus) and response variables (e.g., turbidity and chlorophyll *a*). Causal variables are necessary to provide sufficient protection of designated uses before impairment occurs and to maintain downstream uses. Early response variables are necessary to provide warning signs of possible impairment and to integrate the effects of variable and potentially unmeasured nutrient loads (U.S. Environmental Protection Agency 2002).

**Table 2.** EPA Ecoregion 8 nutrient criteria.

| Nutrient Criteria    | Streams   | Lakes     |
|----------------------|-----------|-----------|
| Total Phosphorus     | 10 µg/L   | 8 µg/L    |
| Total Nitrogen       | 0.38 mg/L | 0.24 mg/L |
| Chlorophyll <i>a</i> | 0.63 µg/L | 2.43 µg/L |
| Secchi disk depth    | N/A       | 4.93 m    |

These criteria were developed specifically for Ecoregion 8 (which includes the entire states of Maine, New Hampshire, and Vermont) and are designed to represent conditions of surface waters that are

minimally impacted by human activities and thus protect against the adverse effects of nutrient over-enrichment from cultural eutrophication. The values are EPA's scientific recommendations regarding ambient concentrations of nutrients that protect aquatic resource quality. They do not have any regulatory impact or meaning.

For lakes (water bodies greater than 10 acres and with mean water residence time of 14 or more days; U.S. Environmental Protection Agency 2000a), the criteria were established based on the lower 25<sup>th</sup> percentile of lakes that EPA found data for. This percentile of all lakes is expected to approximately correspond to the 75<sup>th</sup> percentile of reference (undisturbed) lakes. In other words, 75% of lakes in the ecoregion do not meet the criteria, nor do roughly 25% of reference lakes. For streams and rivers, a parallel approach was used to establish the nutrient criteria (U.S. Environmental Protection Agency 2000b).

## Results

Monitoring results for 2014 are displayed in scatter-plot graphs showing all data for each site for a given parameter. The scatter plots of 2014 data are overlaid on box plots representing the overall range and distribution of data values collected from 2006 through 2014 for the specified parameter and site (Appendix A contains all data in tabular form). A box plot (Figure 2) is a summary plot that graphs data as a box representing statistical values. The boundary of the box closest to zero indicates the 25<sup>th</sup> percentile, a line within the box marks the median, and the boundary of the box farthest from zero indicates the 75<sup>th</sup> percentile. Whiskers (error bars) above and below the box indicate the 90<sup>th</sup> and 10<sup>th</sup> percentiles respectively. Outliers are displayed as black filled circles. At least nine data points are required to compute the 5<sup>th</sup>, 10<sup>th</sup>, 90<sup>th</sup> and 95<sup>th</sup> percentiles. If a percentile point cannot be computed, that set of points is not drawn. If EPA or other water quality criteria exist for a particular parameter they are displayed on the graphs as specification lines.

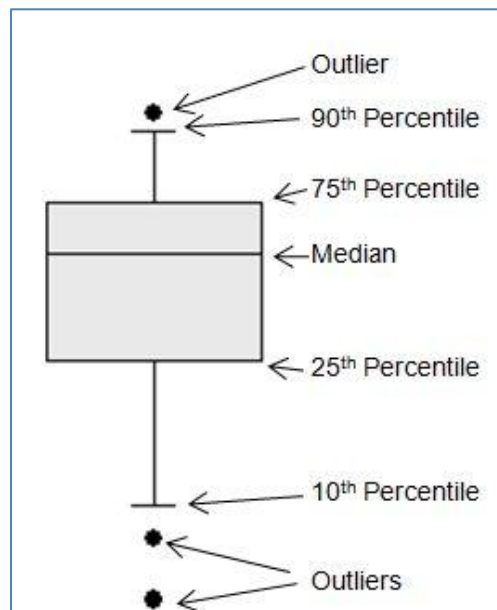


**Figure 2.** Explanation of box plot graph.

### Water Quality

Measures of water quality include specific conductance, pH, water temperature, dissolved oxygen (DO), acid neutralizing capacity (ANC), and apparent color. Assessment of water quality data aids in the interpretation of the biotic condition and ecological processes of surface water resources.

#### ***Specific Conductance***

Specific conductance (Figure 3) is a measure of the ability of water to carry an electrical current, and is directly related to the level of dissolved ions in the water. An increase in specific conductance can be an indicator of pollutants in the water. Naturally occurring values range from less than 20 to more than 1,000 microsiemens per centimeter ( $\mu\text{S}/\text{cm}$ ). Specific conductance values from 2014 were within the appropriate range for moderate to high ionic strength waters, though one value from Pogue stream was grouped with previously identified outliers.

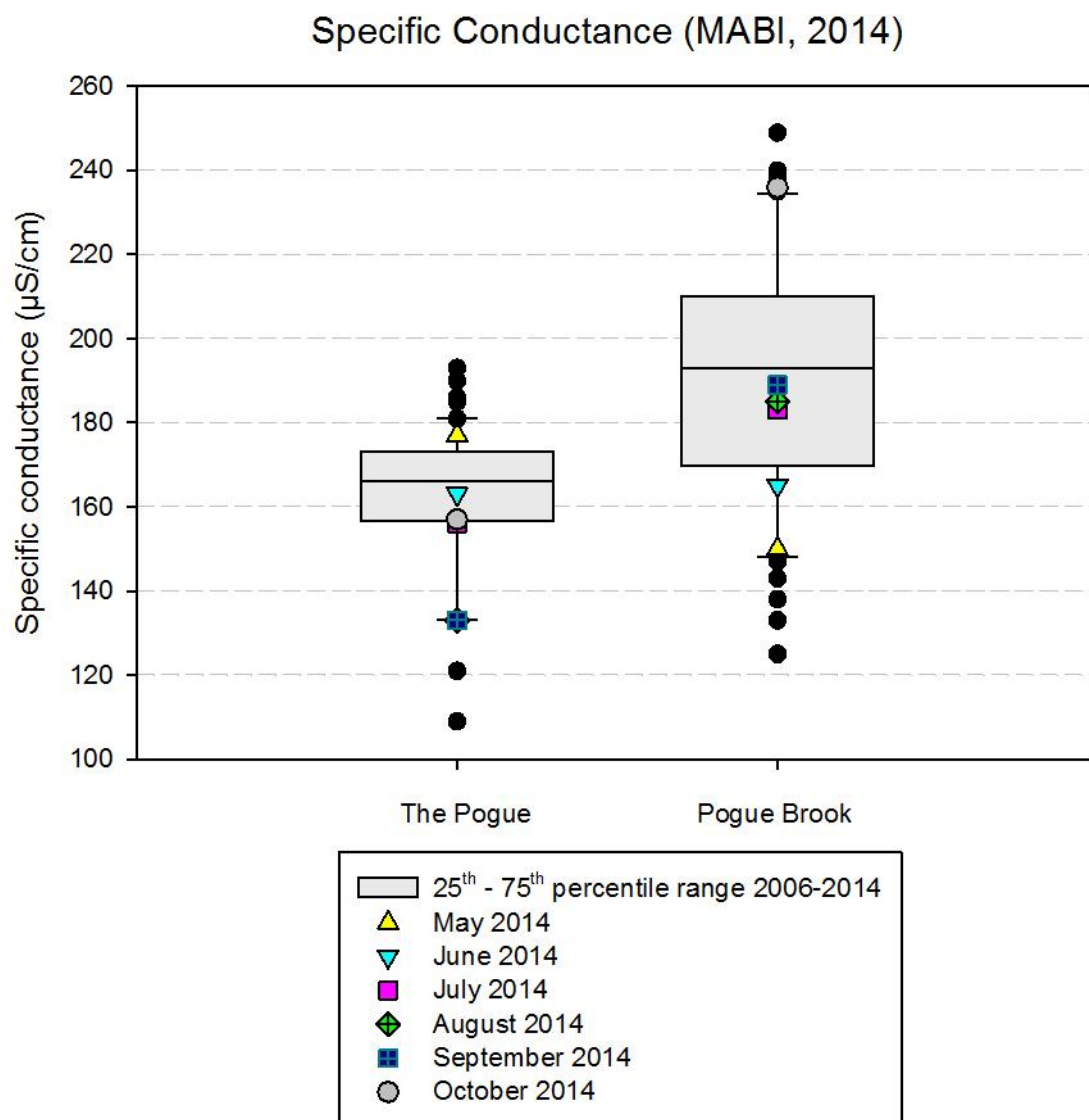


**Figure 3.** Specific conductance from 2014 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2014.

### **pH**

The pH of a water body is a measure of the hydrogen ion ( $H^+$ ) concentration and reflects how acidic or basic the water is, measured on a scale of 1 to 14, with 7 being neutral. Acid waters are below 7 (increased  $H^+$  concentration), and alkaline waters are above 7. A one unit change in pH represents a 10-fold change in  $H^+$  concentration. Vermont standards, like those of most New England states, indicate that a pH between 6.5 and 8.5 is within the acceptable range. pH values from the 2014 monitoring season (Figure 4) were moderately basic for Pogue Brook, and were within the upper and lower Vermont water quality standards. However, June and September pH values for The Pogue were above the upper Vermont water quality standard, and the September 2014 value was among some of the highest recorded at the Pogue since NETN's monitoring program began.

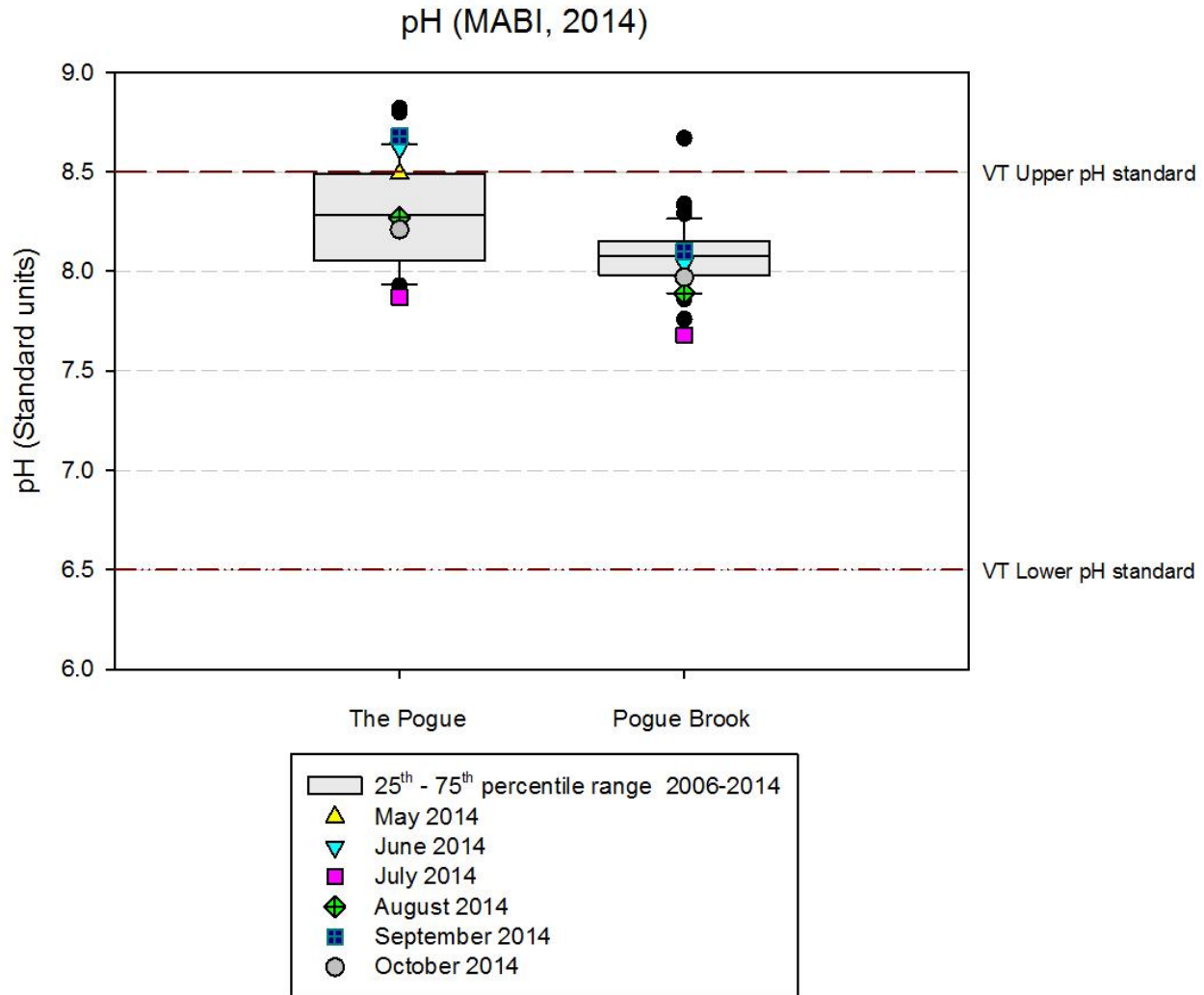


**Figure 4.** pH from 2014 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2014.

### Temperature

Temperature can affect water chemistry and biology. For example, the amount of oxygen that water can hold is directly related to the temperature of the water. The higher the temperature, the less oxygen water can hold, which can be observed in both diel (day and night) and seasonal shifts. Oxygen will naturally decline during the summer months as water temperatures rise. Temperature can also determine the kinds of plants and animals found in the lake or pond. Certain species of fish, insects, and algae will predominate during the cooler temperatures of the spring and fall, yet be less apparent during the warmer temperatures of summer. Surface water temperatures (Figure 5) were generally within the 25<sup>th</sup> to 75<sup>th</sup> percentiles in 2014, although May was below this range (potentially an outlier) while July was above.

Pogue Brook was within the 25<sup>th</sup> to 75<sup>th</sup> percentile during two months, June and October. Like the Pogue, Pogue Brook was colder than the historical range in May, in outlier territory, while July, August, and September were in the 75<sup>th</sup> to 90<sup>th</sup> percentile range.

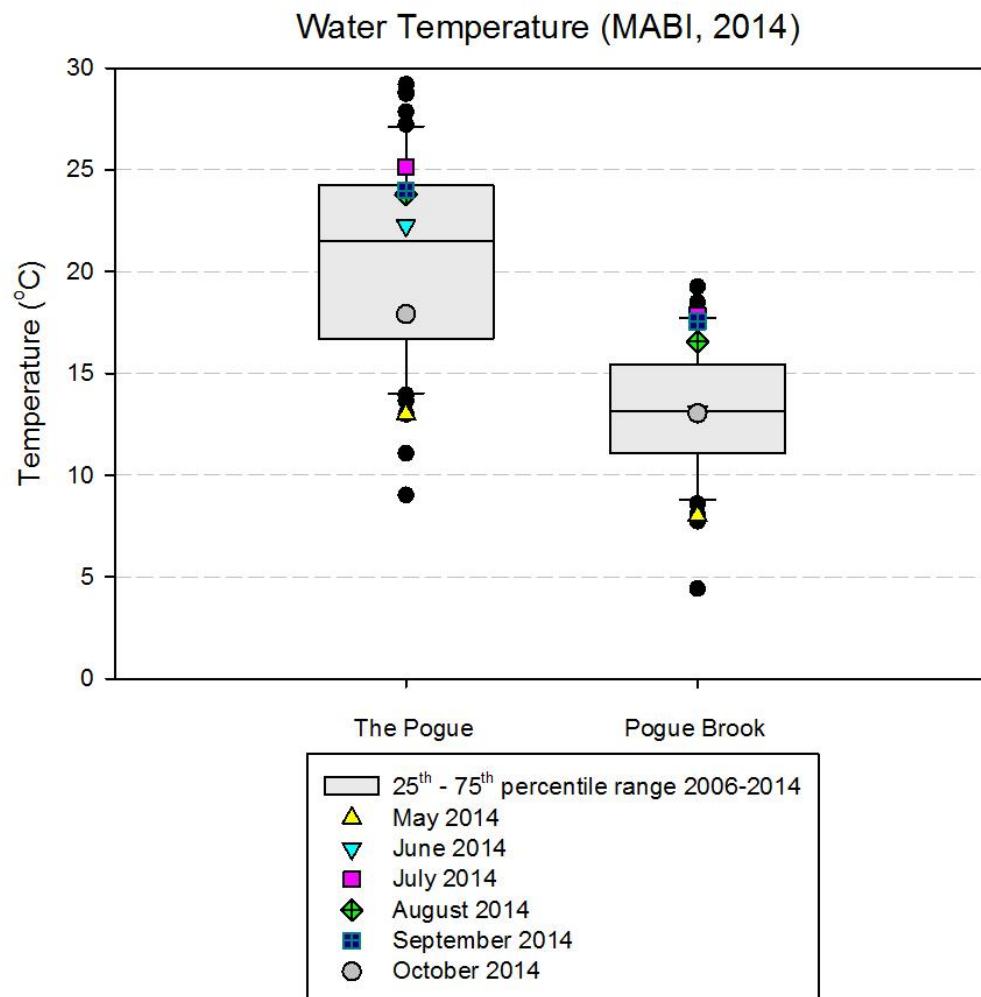


**Figure 5.** Water temperature (surface) from 2014 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2014.

### ***Dissolved Oxygen***

Dissolved oxygen (DO) is a critical indicator of water quality because aquatic life generally needs DO concentrations at or above 5 mg/L to thrive. Low oxygen can directly kill or stress organisms such that they will not be able to successfully reproduce or grow. Water with less than 1 part per million (ppm) of oxygen is considered anoxic (no oxygen present). All DO measurements at the Pogue in 2014 (Figure 6) showed the surface water was well oxygenated. With the exception of June, all measures were within the historic 25<sup>th</sup> to 75<sup>th</sup> percentile range, and well above the more stringent (7 mg/L) state DO standard. The May (obscured by the June symbol) and June readings for The Pogue are well above the 90<sup>th</sup> percentile. The June value may be suspect, possibly attributed to a damaged or poorly calibrated sensor.

Pogue Brook DO was variable throughout the year, with only June and October being within the historic 25<sup>th</sup> to 75<sup>th</sup> percentile range. The May DO measure was in the outlier range, though more in keeping with the colder water temperature (similar to the May value from The Pogue), while July, August, and September were in historic low territory. It should be noted, however, that despite

having three consecutive comparatively low monthly DO measures of 9.02, 9.36, and 9.20 mg/l (July, August, and September, respectively) this is not a cause for concern because each of these measures are well above the 7 mg/l standard set by the state. Complete data from water column profiles can be found in Appendix A.

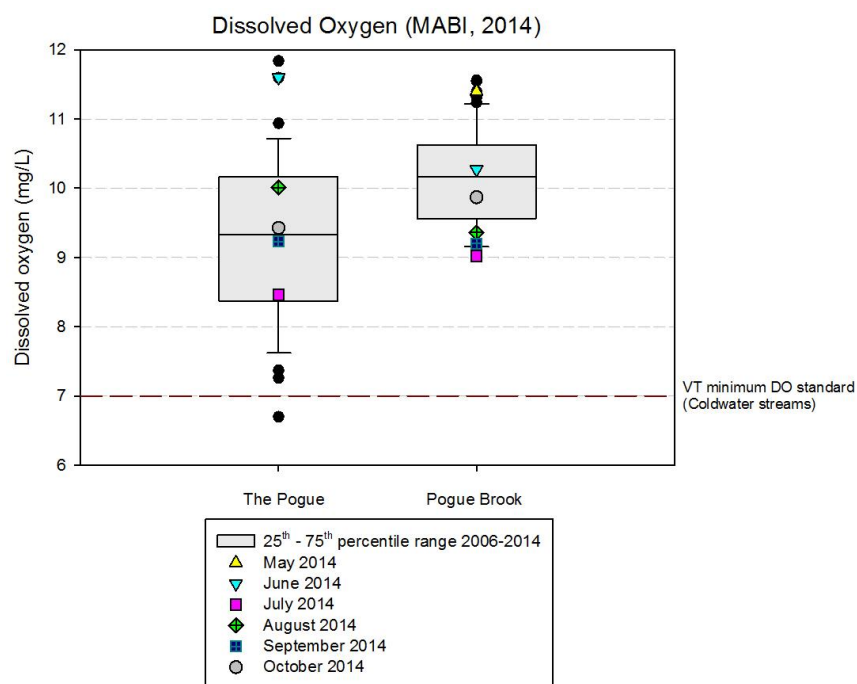


**Figure 6.** Dissolved oxygen (surface) from 2014 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2014.

### ***Acid Neutralizing Capacity***

Acid neutralizing capacity (ANC) is also known as alkalinity, or buffering capacity. It is due primarily to the presence of naturally available bicarbonate, carbonate, and hydroxide ions, with bicarbonate being the major form. Most states do not have numerical criteria for ANC in their water-quality standards. ANC values greater than 100  $\mu\text{eq/L}$  are considered well-buffered, while values less than zero typify acidic waters (Stoddard et al. 2003). Acid neutralizing capacity measured the Pogue and Pogue Brook is inversely related. In the spring ANC is high in The Pogue and low in Pogue Brook, while in the summer ANC is low in The Pogue while Pogue Brook is high. Low spring stream ANC measures are generally attributed to the influence of acidic snowmelt. All MABI ANC values are well above the 100  $\mu\text{eq/L}$  level previously mentioned, offering no cause for concern, and seasonal variation is dependent on changes in anion and cation concentrations, which vary among water bodies. Both sites were very well-buffered, likely due to the underlying geology.

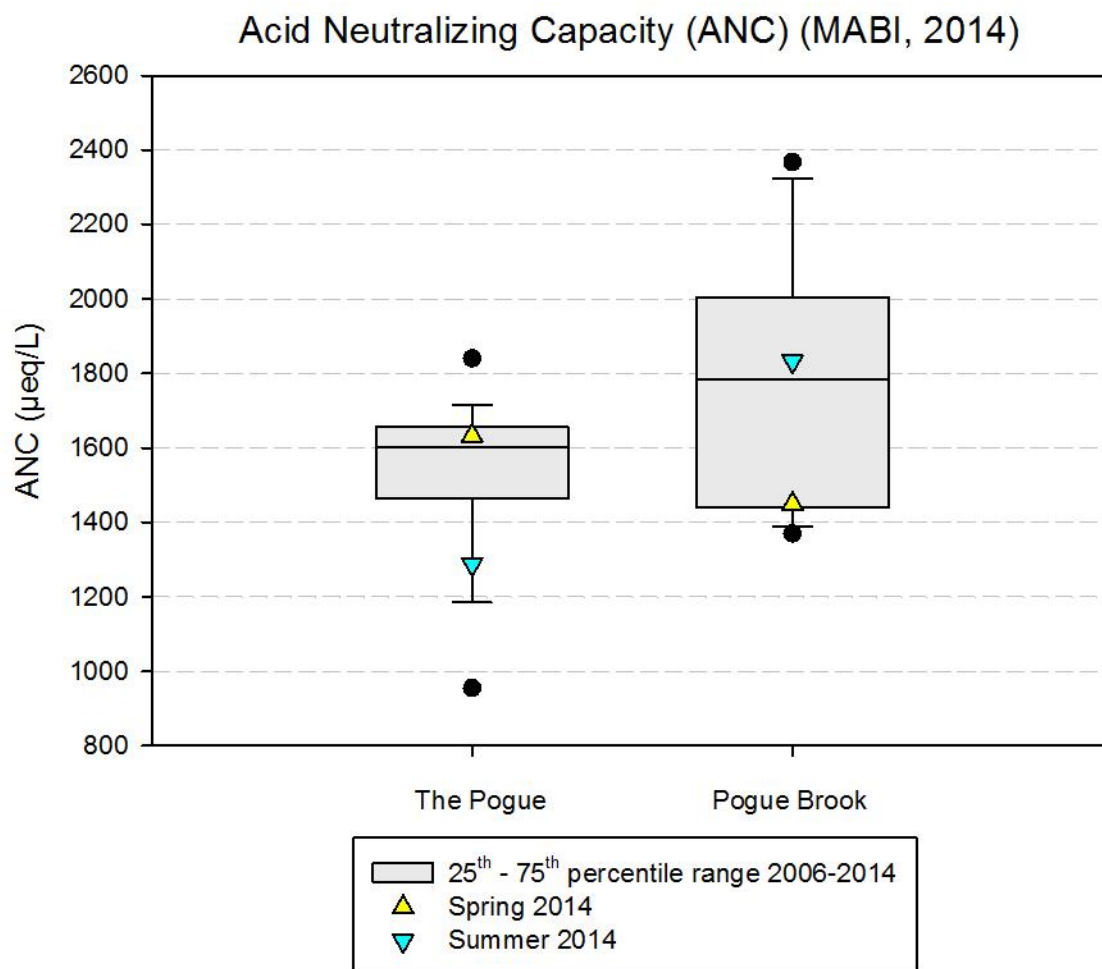


**Figure 7.** Acid neutralizing capacity from 2014 water samples overlaid on a box plot of measurements taken from 2006-2014.

### ***Apparent Color***

Color in pond and stream water is caused by natural metallic ions, humus and peat materials, plankton, weeds, and industrial wastes. Color is reported in Pt-Co units (PCU). True color is the color measurement of water from which suspended particles have been removed by filtration. Apparent color (the measurement method utilized by NETN) is determined on original samples without filtration. Color can be a rough indicator for organic acidity.

Water bodies with apparent color values of greater than 25 PCU are considered to be highly colored, and often exhibit reduced water clarity and high phosphorus concentrations. Values of color are usually not included in water quality standards, except to note that they should be “as naturally occurs”.

Color values from the 2014 samples (Figure 8) showed that both The Pogue and Pogue Stream are very close to median values.

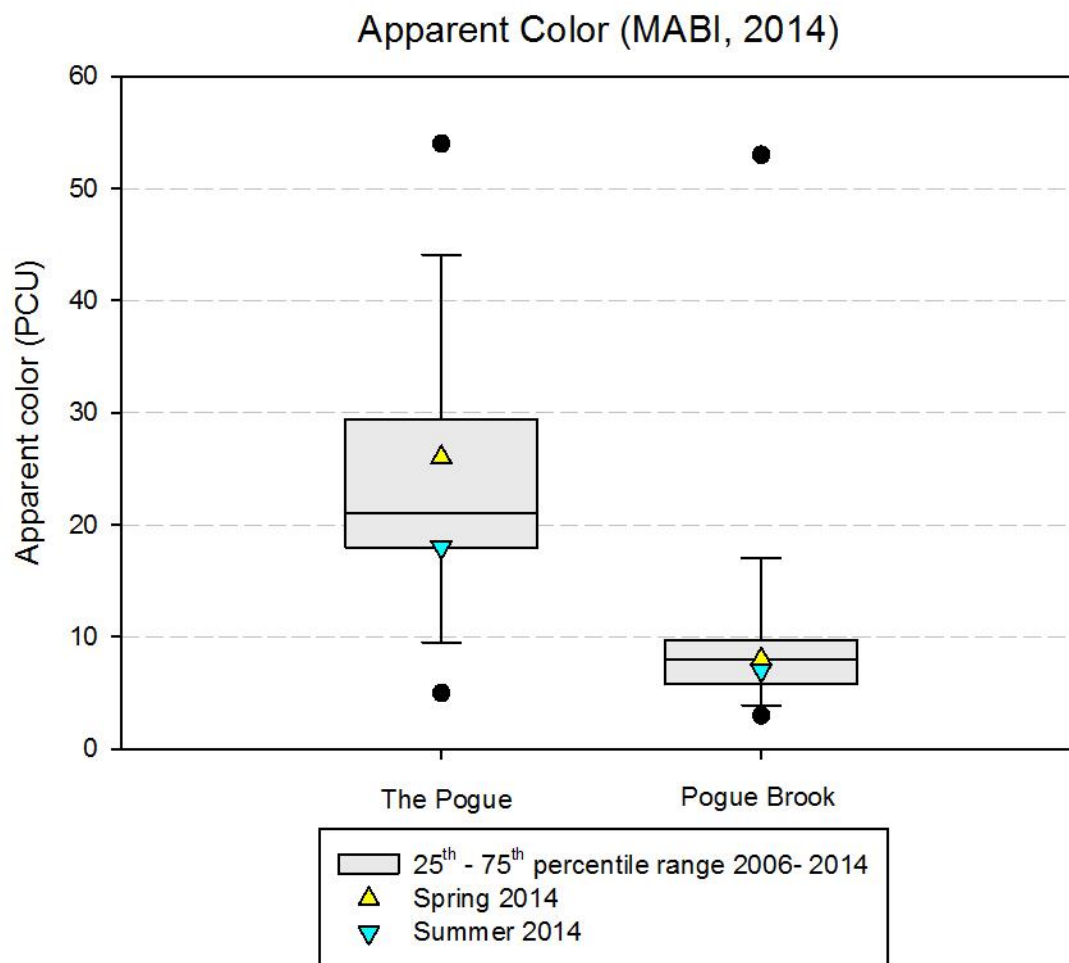


**Figure 8.** Apparent color from 2014 water samples overlaid on a box plot of measurements taken from 2006-2014.

### ***Dissolved Organic Carbon***

NETN began measuring dissolved organic carbon in 2012. Carbon is a nutrient required for biological processes. Sources of organic carbon in water include humic substances from plant and soil organic matter, wetland peat deposits, and atmospheric deposition. Certain forms of DOC can contribute to “tea” color in water, which can affect light attenuation. DOC is also an important part of the energy balance and acid-base chemistry in many freshwater systems. It also affects the transport (solubility and bioavailability) of metals, including mercury, in aquatic systems.

The DOC concentrations in most lakes and streams range from 1 mg/L to 20 mg/L, with a mean of 5.75 mg/L in streams (Meybeck 1982) and a mean of 7.58 in lakes (Sobek, et al 2007). Springtime DOC concentrations (Figure 9) in The Pogue were low compared to historical values, but within the 25<sup>th</sup> to 75<sup>th</sup> percentile range during the summer. DOC within Pogue Brook shows a tighter long term range and the 2014 values appear to be at or slightly above the 75<sup>th</sup> percentile.

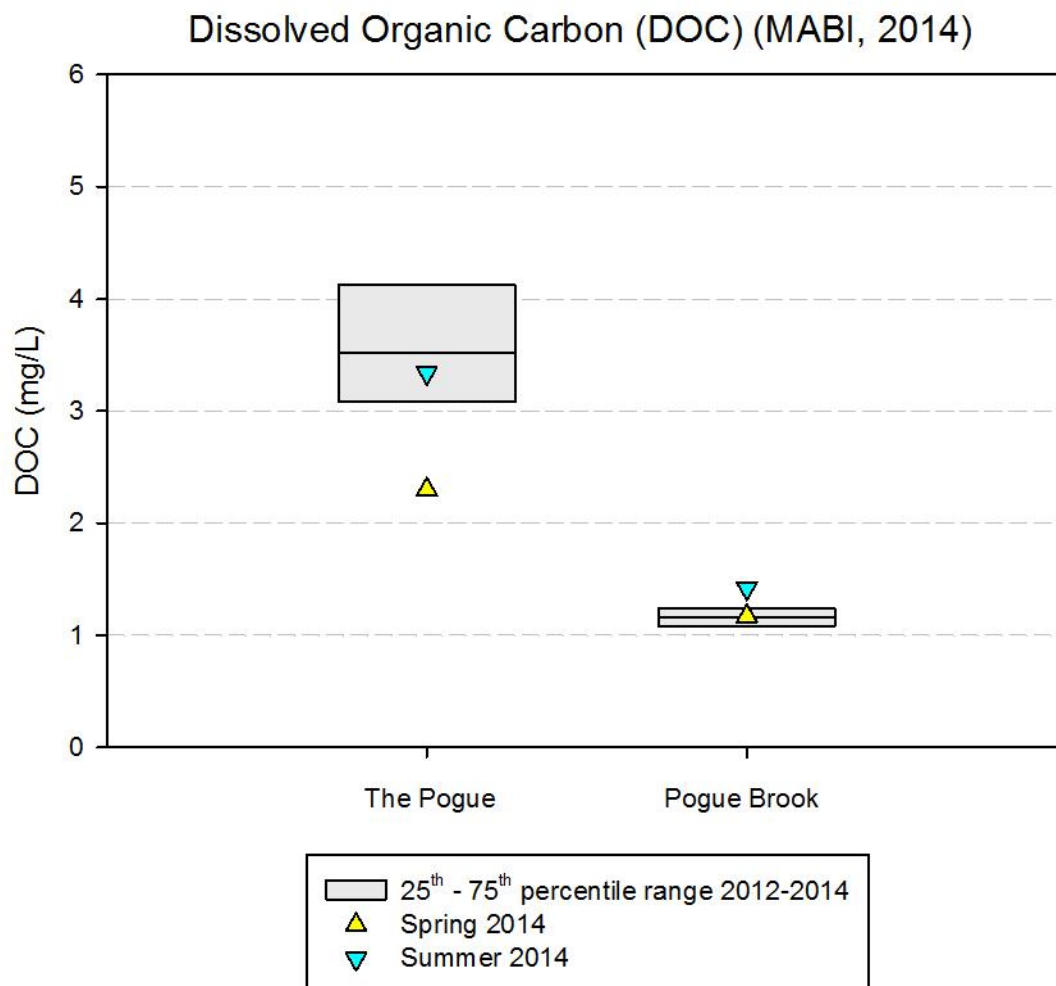


**Figure 9.** Dissolved organic carbon (DOC) from 2014 spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2012-2014.

### ***Light Penetration Profiles***

It is difficult to obtain transparency measurements with a Secchi disk in The Pogue. Due to the pond's shallow depth, the disk hit the pond bottom before disappearing from the observer's view in all NETN measurements. Beginning in 2012, NETN began measuring light attenuation in ponds with light penetration profiles. Light penetration profiles can tell us much about the conditions affecting lakes and ponds. Nearly all the energy that drives and controls lake processes is derived from solar energy, which is converted to chemical energy via photosynthesis. This chemical energy is then transported to other areas of the ecosystem as various forms of organic matter. Solar energy, absorbed by the lake and dissipated as heat, plays a large role in defining a lake's thermal structure, stratification, and circulation patterns. These factors in turn affect nutrient cycling and the distribution of dissolved gasses. By understanding the quantity and behavior of the light entering a lake system, we can learn more about how the light is utilized in the system (Wetzel and Likens 2000).

A light penetration profile is obtained using two solar radiation sensors and a datalogger to determine photosynthetically active radiation or “PAR.” One of the sensors is lowered into the water column on a weighted lowering frame, while the second sensor (“deck cell”) is left on the surface to record ambient light. The datalogger records and processes readings from both sensors, dividing the measurement of light reaching any given depth by the measurement of ambient light, to yield a percentage. The first measurement is taken from 0.1m below the surface of the water, while subsequent measurements are taken at quarter-meter increments until light penetration drops below 1% or the PAR cell reaches the pond bottom. A light attenuation coefficient can be calculated through analysis of the profile data to quantify the loss of light transmission per meter of depth. A low attenuation coefficient denotes clear water and, conversely, a higher coefficient signifies reduced water clarity. Graphs of 2014 light penetration profiles and a listing of light attenuation coefficients are found in Figure 10.

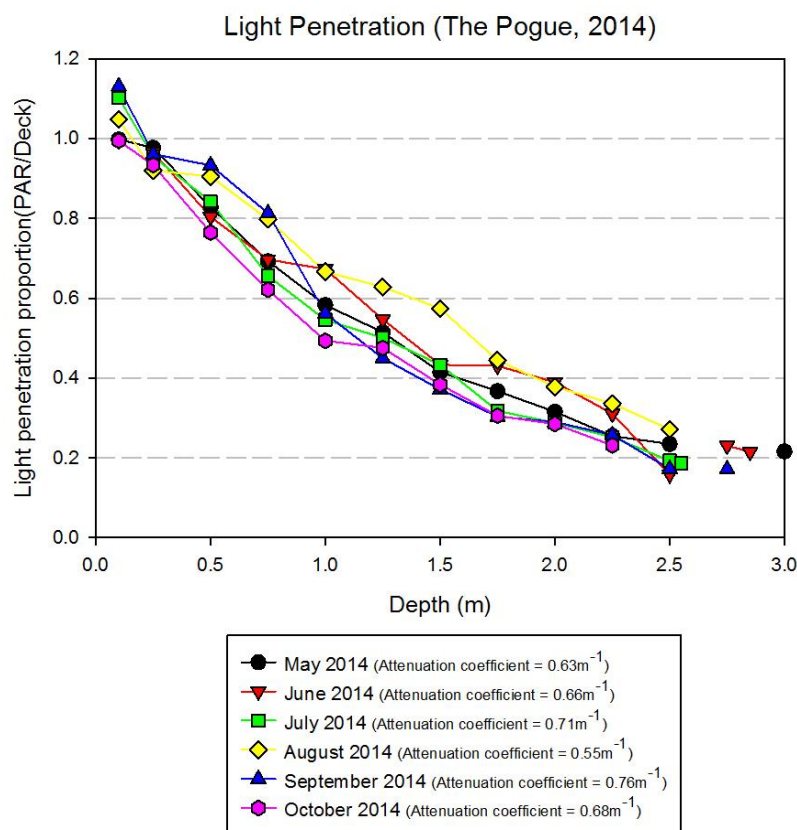


**Figure 10.** Light penetration profiles from The Pogue in 2014.

### ***Turbidity***

Turbidity is the measure of the relative clarity of a liquid. It is measured by passing light through a water sample to determine how much light is scattered, and the results are reported in nephelometric turbidity units (NTU). Turbidity is caused by suspended matter or impurities that interfere with the clarity of the water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds, and plankton and other microscopic organisms. In

natural waters, turbidity is often used as an indicator of water quality and productivity. Turbidity is measured in the field using an electronic meter.

Turbid water can create aesthetic, ecological, and health issues. Turbid water may indicate runoff from construction, roads, agriculture or other types of pollution. Suspended sediment can carry nutrients and pesticides throughout the water system. Suspended particles near the surface absorb additional heat from sunlight, raising the water temperature. High turbidity levels can reduce the amount of light reaching lower depths of lakes and streams, which can inhibit growth of submerged aquatic plants, and reduce dissolved oxygen levels. Suspended materials can clog fish gills, affecting fitness, growth, and reproduction (U.S. Environmental Protection Agency 1997). Turbidity values measured in Pogue Brook during 2014 (Figure 11) were all less than 0.7 NTU, in the low range of dry-weather turbidity of surface waters, which normally ranges from 0 to 10 NTU (U.S. Environmental Protection Agency 1999).

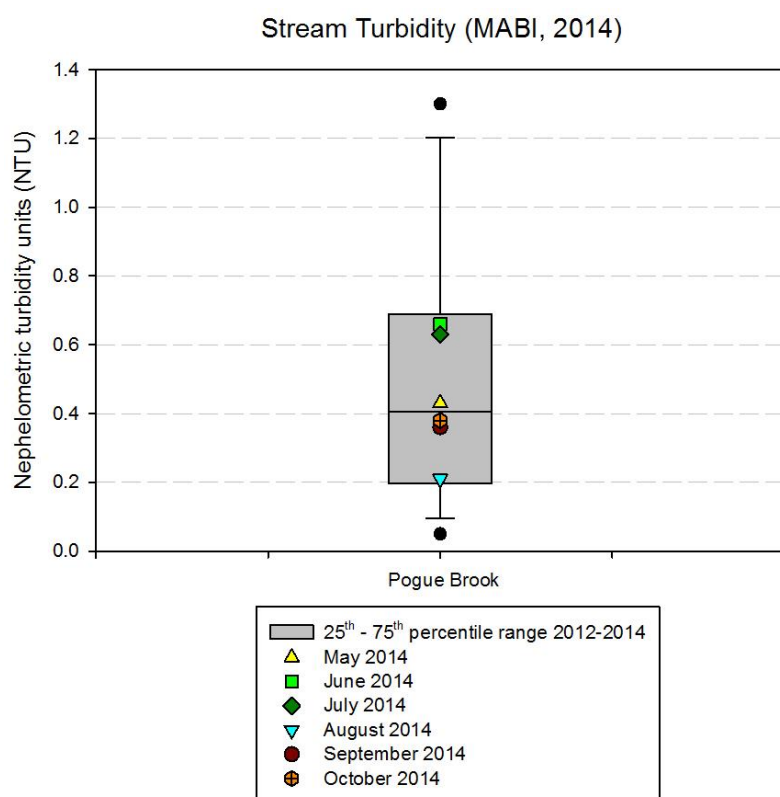


**Figure 11.** Stream turbidity from 2014 monthly measurements. The data are overlaid on a box plot of measurements taken from 2012-2014.

## Nutrient Enrichment

Nutrient enrichment and the acceleration of eutrophication have been identified in most NETN parks as one of the stressors of greatest concern. Total phosphorus and several forms of nitrogen are measured to give managers information regarding the trophic status and productivity of freshwater systems.

## Phosphorus

Phosphorus (P) is one of the major nutrients needed for plant growth. It is generally present in small amounts in natural systems and limits the plant growth in streams and ponds. Total phosphorus (TP) is a measure of both inorganic and organic forms of phosphorus, and is the common water quality standard or criteria metric. Although several forms of phosphorus were tested individually beginning in 2006, tests for total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP) were discontinued in 2012.

In 2014, total phosphorus concentrations in Pogue Brook were relatively low, with very little seasonal (spring/summer) variation (Figure 12), and below the EPA standard for streams. Although TP values from The Pogue were slightly higher and exceeded the EPA Region 8 criterion of  $8\mu\text{g/L}$ , the pond values were at the low end of the long term 25<sup>th</sup> to 75<sup>th</sup> percentile range, and also showed little seasonal variation. These higher values are not unusual for a shallow, relatively productive pond. There are no numeric Vermont water quality standards for phosphorus.

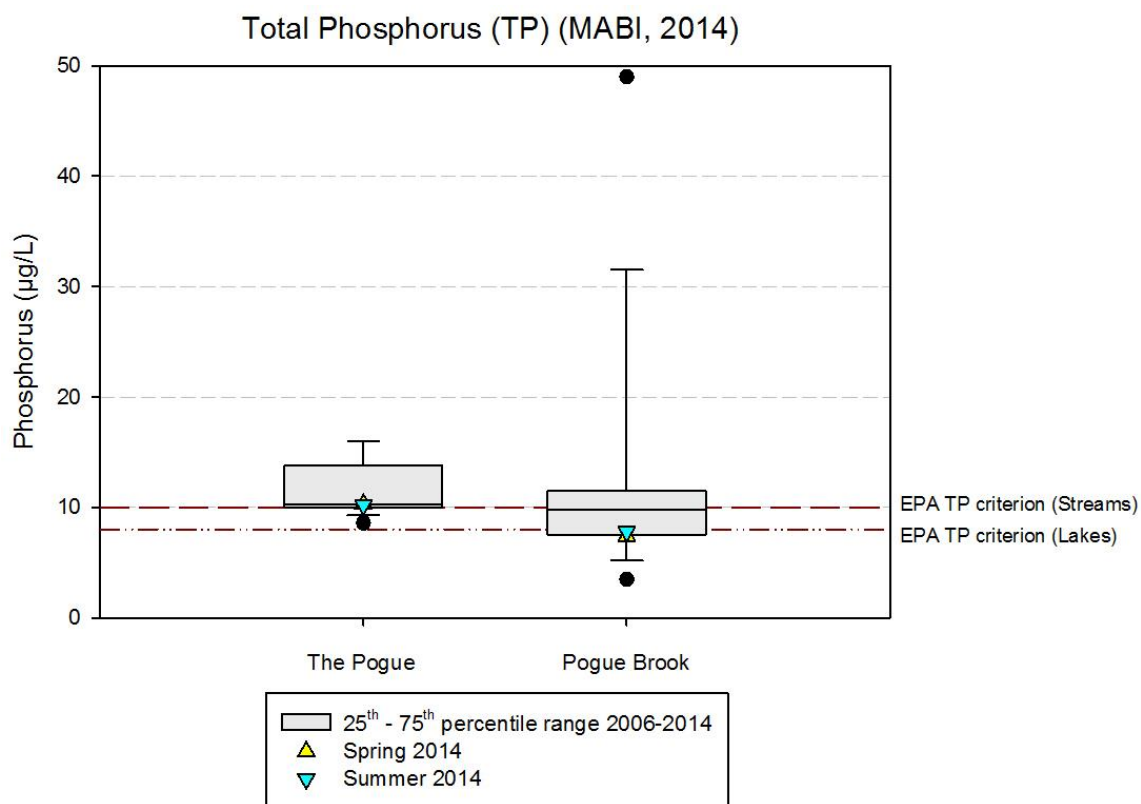


**Figure 12.** Total phosphorus (TP) from spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2006-2014.

## Nitrogen

Total nitrogen (TN) is a measure of all forms of nitrogen (organic and inorganic). Nitrogen is an essential plant element and is often the limiting nutrient in marine waters, and it can also limit some freshwater systems. The importance of nitrogen in the aquatic environment varies according to the relative amounts of the forms of nitrogen present, including nitrate, nitrite, and ammonia. Nitrate

(NO<sub>3</sub>) is the most oxidized and stable form of nitrogen in a water body, and is the primary form of nitrogen used by plants as a nutrient. Nitrite (NO<sub>2</sub>) is an unstable form of nitrogen that is either rapidly oxidized to nitrate (nitrification) or reduced to nitrogen gas (de-nitrification). This form of nitrogen can also be used as a source of nutrients for plants. Ammonia (NH<sub>3</sub>) is generated by bacteria as a decomposition product of nitrogenous organic compounds, and is also readily assimilated by plants. Results of NO<sub>3</sub>, NO<sub>2</sub>, and NH<sub>3</sub> tests are all reported as the concentrations of the N component of these compounds, expressed in mg/L.

Test results for nitrogen are shown in Figure 13. All TN measurements for The Pogue were above the EPA 0.24 mg/L EPA criterion for lakes though below the long-term median, while all TN measurements for Pogue stream were well below the state total nitrogen standard of 2.0 mg/L. Stream TN values were below the EPA Region 8 criterion of 0.38 mg/L. All NO<sub>3</sub> measurements from The Pogue, and NO<sub>2</sub>, and most NH<sub>3</sub> measurements from both sites were below method reporting limits. The August NH<sub>3</sub> value for The Pogue was 0.043 mg/L.

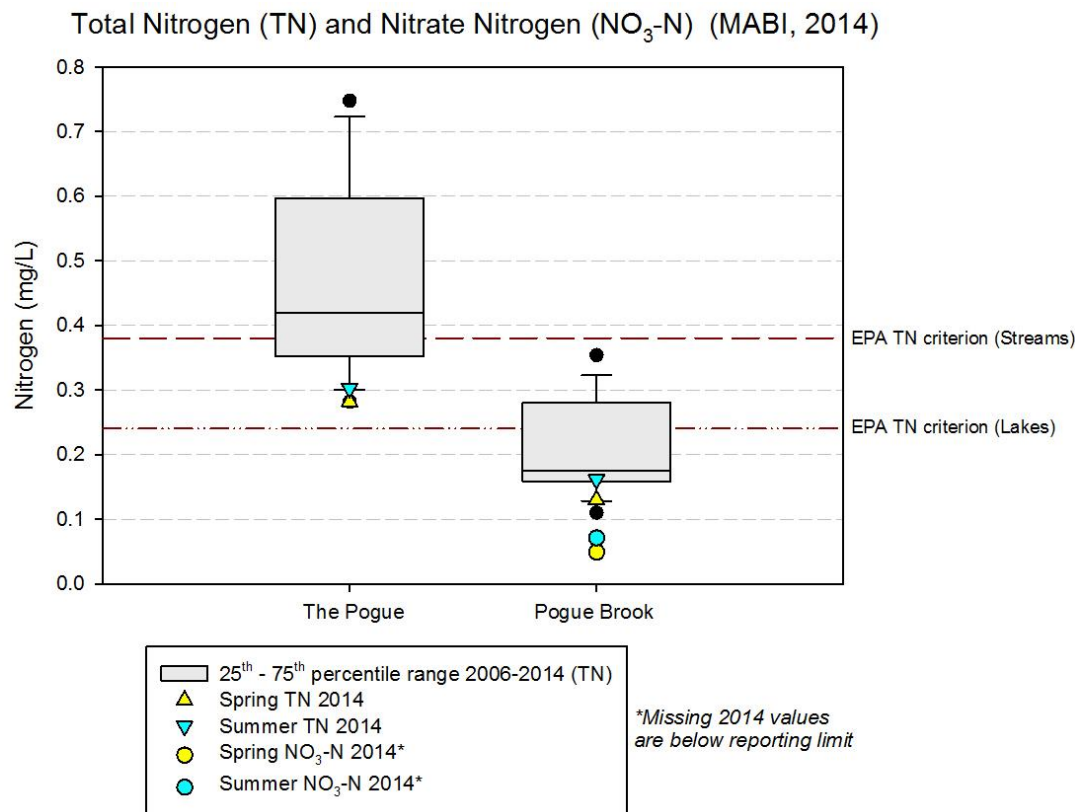


**Figure 13.** Total nitrogen (TN) and the nitrogen component of nitrate (NO<sub>3</sub>-N) from 2014 water samples. The data are overlaid on a box plot of TN measurements taken from 2006-2014.

### Chlorophyll *a*

The amount of chlorophyll *a* in a water sample is a measure of the concentration of suspended phytoplankton and can be used as an indicator of algal biomass and thus of water quality.

Chlorophyll *a* is responsible for photosynthesis and is found in various forms within the living cells

of algae, phytoplankton, and other plant matter. Like other biological response variables, chlorophyll *a* tends to integrate the stresses of various parameters over time, and thus is often an important nutrient-stress parameter to measure.

The spring 2014 measurement of chlorophyll *a* concentrations in The Pogue (Figure 14) was slightly above the long-term range but within the expected range (4 µg/L to 14 µg/L) for a moderately productive pond (New Hampshire Department of Environmental Services 1997). Conversely, the summer measurement of chlorophyll *a* was at the low end of the long-term range and below the expected range of similar ponds.

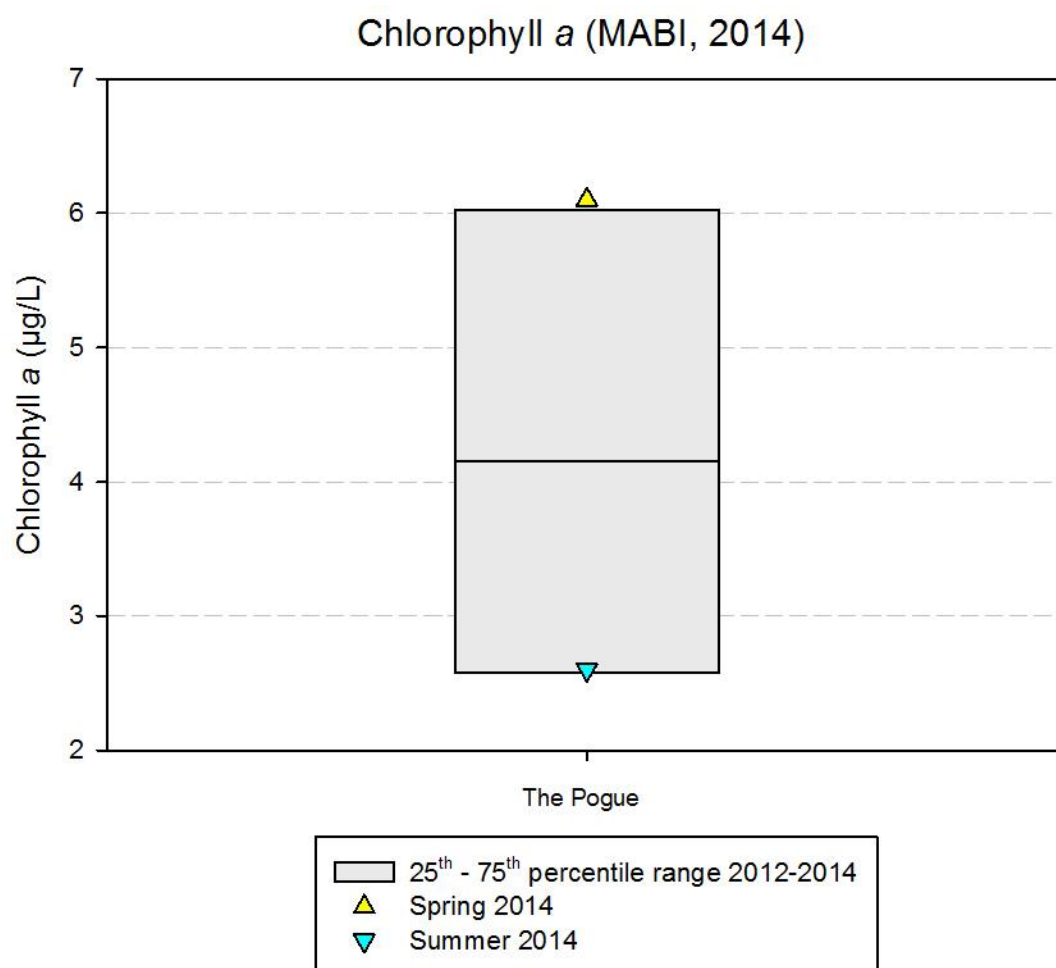


**Figure 14.** Chlorophyll *a* from 2014 spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2012-2014.

## Other Analytes

### Chloride

Chloride is one of the major negatively-charged ions in fresh water systems. The chloride content of natural surface waters will depend to a great extent on the geology of the area. Concentrations are generally greater in lakes that are in proximity to marine regions. Another source of chloride is road

run-off from de-icing materials. Chloride is important in terms of metabolic processes, as it influences osmotic salinity balance and ion exchange.

Average chloride concentration in natural fresh water is 234.1  $\mu\text{eq/L}$  (Wetzel 1983). Chloride values in MABI samples were well below this value in 2014 (Figure 15), and three of four measures were within the long-term range. However, the spring 2014 measurement from The Pogue was 17  $\mu\text{eq/L}$ , above the upper end of the long-term range for Chloride. Though the spring 2014 measurement for The Pogue is higher than might be expected given the long-term range, it is still far below the level that might be expected at a lake like The Pogue, and a single measure this far above the long-term range could be an aberration.

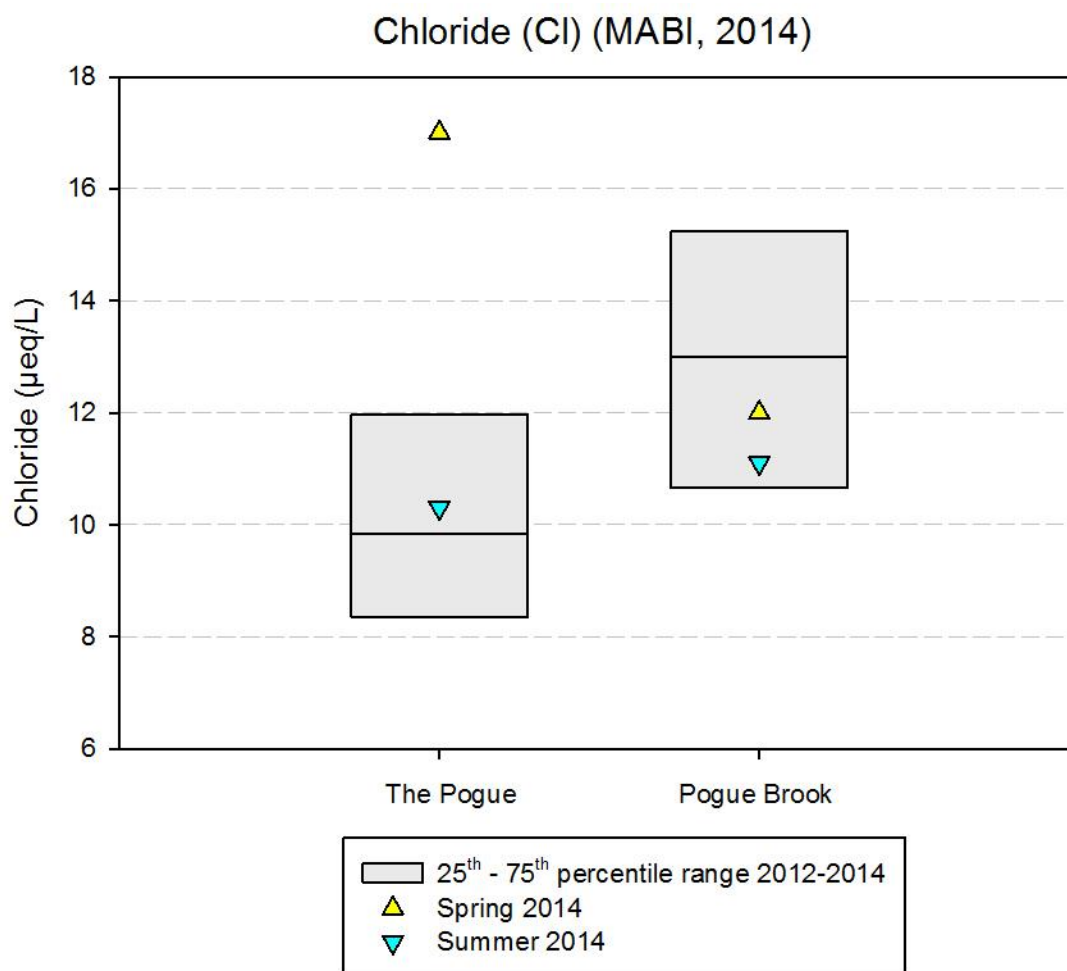


**Figure 15.** Chloride from 2014 spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2012-2014.

### **Sulfate**

Sulfate is found in most natural waters, originating from watershed geology and soils, and also from atmospheric transport and deposition (in precipitation) of by-products from the combustion of fossil fuels. Sulfate can play a major role in acidification of lakes and streams. Sulfate concentrations in

atmospheric deposition have declined significantly since 1982, in part due to the 1995 implementation of Phase I controls of the Clean Air Act Amendments and in part to other long-term pollution reduction efforts (Kahl 1999).

The usual range of sulfate concentration in natural water is 104 µeq/L to 695 µeq/L (Wetzel 1983). Sulfate concentrations at MABI were low in 2014 (Figure 16), below or near the low end of the range suggested by Wetzel (1983).

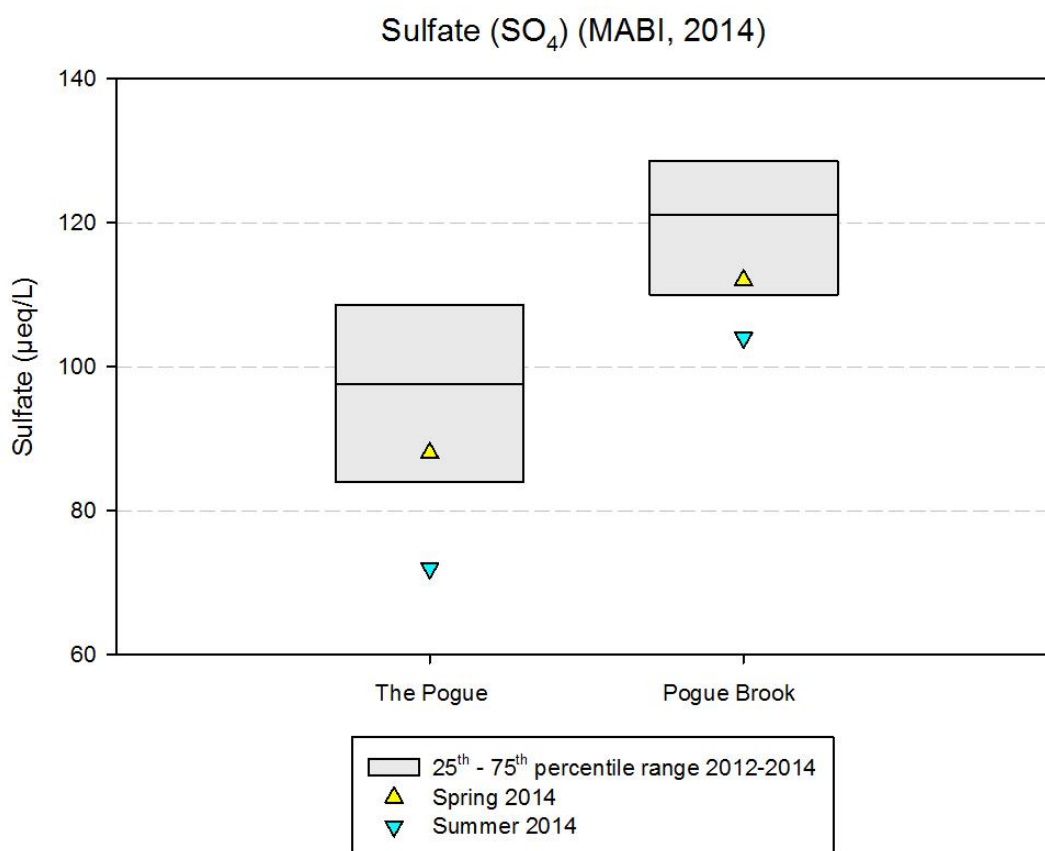


**Figure 16.** Sulfate from 2014 spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2012-2014.

## Water Quantity

Monthly stream discharge measurements, taken with a current meter and wading rod, can be used to calculate loading of nutrient chemical constituents (flow X concentration), and also provide a record of variations in stream flow. Discharge measurements from 2014 are listed in Appendix A. Stream stage (height of water) measurements can be paired with discharge values and, over time, a stage to discharge relationship can be calculated. Once this relationship is established, investigators can interpolate the stream discharge from the stage measurement alone. Numerous discharge measurements at all ranges of streamflow are required to establish and maintain an accurate stage to discharge relationship. Stream and pond stage measurements (Figure 17) were taken by measuring to the water surface from a fixed datum point. NETN staff are continuing to review discharge and stage

measurement methodology and quality assurance/quality control procedures in order to enhance the quality and utility of the water quantity data. A stage to discharge relationship graph will be produced once sufficient data are collected. Stream and pond stage measurements from 2014 are listed in tabular form in Appendix A.

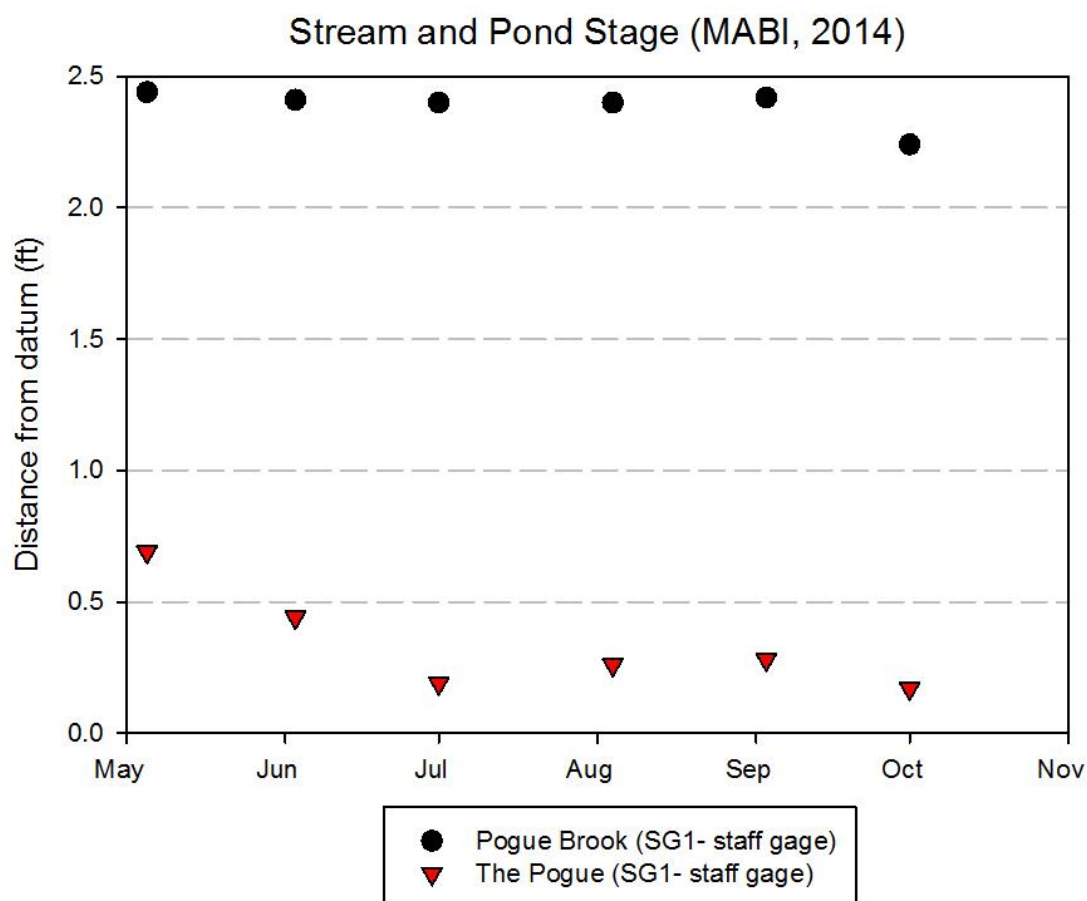


**Figure 17.** Stream and pond stage obtained in 2014 by measuring from a permanent datum point to the water surface.

### Invasive Aquatic Plants

NETN's methods for invasive aquatic plant monitoring were adapted from the Maine Center for Invasive Aquatic Plants (MCIAP), a division of the Maine Volunteer Lake Monitoring Program (VLMP). Investigators utilize a level 3 survey, which involves surveying the entire shoreline and transects covering the littoral zone. Detailed survey instructions can be found in the NETN Water Monitoring protocol (Lombard et al. 2006).

The primary targets of the invasive plant surveys were the 11 plants currently listed by the MCIAP (Table 3). Surveyors also looked for species on a secondary list (Table 4), compiled by the Vermont Agency of Natural Resources ([http://www.anr.state.vt.us/dec/waterq/lakes/docs/ans/lp\\_ans-list.pdf](http://www.anr.state.vt.us/dec/waterq/lakes/docs/ans/lp_ans-list.pdf)). For both tables, species in bold type were specifically targeted on the Vermont Water Quality

Division aquatic invasive species website  
([http://www.anr.state.vt.us/dec/waterq/lakes/htm/ans/lp\\_ans-index.htm](http://www.anr.state.vt.us/dec/waterq/lakes/htm/ans/lp_ans-index.htm)).

**Table 3.** Maine Center for Invasive Aquatic Plants species of concern.

| Common name            | Latin name                        |
|------------------------|-----------------------------------|
| European Frogbit       | <i>Hydrocharis morsus-ranae</i>   |
| Water Chestnut         | <i>Trapa natans</i>               |
| Yellow Floating Heart  | <i>Nymphoides peltata</i>         |
| Eurasian Water Milfoil | <i>Myriophyllum spicatum</i>      |
| Variable Water Milfoil | <i>Myriophyllum heterophyllum</i> |
| Parrot Feather         | <i>Myriophyllum aquaticum</i>     |
| Fanwort                | <i>Cabomba caroliniana</i>        |
| Hydrilla               | <i>Hydrilla verticillata</i>      |
| Brazilian Elodea       | <i>Egeria densa</i>               |
| European Naiad         | <i>Najas minor</i>                |
| Curly-Leaved Pondweed  | <i>Potamogeton crispus</i>        |

**Table 4.** Additional aquatic plant species of concern targeted by the Vermont Agency of Natural Resources.

| Common name          | Latin name                  | State(s) listed    |
|----------------------|-----------------------------|--------------------|
| Flowering Rush       | <i>Butomus umbellatus</i>   | NY,CT,VT           |
| Yellow Flag Iris     | <i>Iris pseudacorus</i>     | NY, NH, VT, MA, CT |
| Japanese Knotweed    | <i>Fallopia japonica</i>    |                    |
| Common Reed          | <i>Phragmites australis</i> |                    |
| Purple Loosestrife   | <i>Lythrum salicaria</i>    | NY, MA, CT, NH, VT |
| Slender-leaved Naiad | <i>Najas minor</i>          |                    |
| Great Water-cress    | <i>Rorippa amphibia</i>     | NY, CT, VT         |

Invasive aquatic plant monitoring was conducted at the Pogue during the 2014 monitoring season. Results indicated that invasive aquatic plants do not currently exist at The Pogue though the monitors were unable to conclusively determine if the species of iris observed in all locations was *Iris pseudacorus* because it was not in flower at all locations when the observations were made. Special attention should be given to identify the species of iris present.

During future visits to all NETN parks, monitors will be increasingly attentive for the presence of Didymo (*Didymosphenia geminata*), also known as “rock snot,” a highly invasive algae species that has recently invaded the northern reaches of the Connecticut River in New Hampshire and the White River and Battenkill Rivers in Vermont. This species has a great potential to alter habitats and displace native species, and is of great concern to officials in regions where infestations have been established.

Didymo can easily be spread by waders and potentially by water monitoring equipment and other gear that touches the bottoms of streams in infested areas. Just one cell breaking off and drifting downstream can spread the algae. Enhanced equipment cleaning and decontamination procedures are being included in the latest NETN monitoring protocol revision (Gawley et al. 2014).

Since non-native, invasive plants have recently been detected with increasing frequency in New England lakes and ponds, it has become crucial to closely monitor the status of park waters. The early detection of an infestation can make eradication or control more feasible, and it can lead to efforts that reduce the spread of the plant to neighboring water bodies. Designating the early detection of these plants as a NETN vital sign and the ongoing partnership with state and local monitoring and eradication efforts are highly effective prevention strategies.

## Quality Assurance and Quality Control (QA/QC)

QA/QC is important to the success of a long-term data collection and trend detection program. Quality assurance (QA) is achieved through the establishment and use of the NETN Freshwater Monitoring Protocol. Specific procedures are used to control critical components of a project such as sampling at the right place with the right equipment and using the right methods. Over the years, staff will change, equipment may be updated, and methods may evolve. Although these changes will be kept to a minimum, changes are inevitable and therefore following an established and well-documented protocol will ensure that the data remain valid.

QA requirements incorporated in the protocol include consistency and low turnover in project leaders and staff, consistency in staff training and oversight, consistency in equipment used and calibration methods, the selection of a well-established chemical laboratory with a proven track record, and a robust sample design that includes an adequate number of field and laboratory quality control (QC) samples.

QC includes the assessment of bias and variability through the use of additional samples such as blank and replicate samples. QC samples are an objective assessment of whether or not QA protocols are adequate. The protocol calls for the collection of two blank and two replicate samples (one each from lakes/ponds and streams, respectively) during both the spring and summer nutrient sampling months at Acadia NP, and the same number, distribution, and schedule at the combined eight “Lower NETN” parks. Sample collection sites are selected at random from both monitoring groups.

The latest (2014) protocol revision requires in situ measurements, including Secchi transparency, sonde water quality, and stream discharge, to be periodically replicated to ensure that field equipment and observers are performing within the required precision standards. Water quality sonde temperature, pH and specific conductance measurements are to be compared monthly in the laboratory with similar measurements made with a NIST-traceable thermometer and benchtop pH and conductivity meters. Sonde dissolved oxygen measurements will be compared in the field to measurements made using a LaMotte dissolved oxygen test kit (Winkler titration method). These additional procedures will begin network-wide in the 2015 monitoring season.

### Nutrient QC Sample Results

Analysis results of all 2014 blank samples collected from Lower NETN ponds and streams (Appendix B, Table B1) were near or below the method reporting limits, indicating little or no contamination was introduced during the sampling, handling and analysis processes. However, new instrumentation utilized at the analytical lab in June and August provided lower detection and reporting limits for several analytes ( $\text{NO}_2$ ,  $\text{NH}_3$ ,  $\text{SO}_4$ ), allowing quantification of some levels of possible contamination not detected in the past. Replicate sample analysis results (Appendix B, Table B2) showed that most Lower NETN samples were in the acceptable range of precision (relative percent difference or precision objective in units, depending on sample concentration).

## Summary

Most water quality parameters for the Pogue and Pogue Brook were within state standards, and were generally within the range of EPA criteria, where applicable. The values were usually within the ranges of the historic NETN monitoring data. The exception was the Pogue, where surface pH was at or above the State of Vermont's upper pH standard and above the historic range during three months (May, June, & September), below the historic range but within Vermont's low and high standards during one month (July), and within the range twice (August & October). Nutrient levels for The Pogue were higher than the EPA criteria for nitrogen and phosphorus, while Pogue stream was below the EPA criteria for each of these constituents. There were no indications that any significant nutrient enrichment took place during the 2014 season.

Eight years of monitoring under the NETN protocol has provided critical baseline information on the chemical and physical status of the Pogue and Pogue Brook. Several changes implemented in the 2012 monitoring season, including the addition of sulfate, chloride, chlorophyll *a*, and dissolved organic carbon (DOC) analyses to the spring and summer water chemistry testing, are helping to expand the scope and usefulness of the monitoring data. As more data are collected, the ability to detect changes outside this natural range of variability will increase, which in turn will more clearly indicate the status of the vital signs of water quality, nutrient enrichment, water quantity, and the detection of invasive plant species.

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## Appendix A. Marsh-Billings-Rockefeller National Historical Park (MABI) Water Monitoring Data, 2014.

**Table A1.** YSI sonde in-situ stream and pond water quality measurements collected at MABI.

| Site      | Date     | Depth (m) | Temp (C) | DO (mg/L) | pH   | Specific Conductance (µS/cm) |
|-----------|----------|-----------|----------|-----------|------|------------------------------|
| The Pogue | 5/5/2014 | 0.00      | 12.99    | 12.10     | 8.49 | 177.00                       |
| The Pogue | 5/5/2014 | 0.48      | 12.97    | 12.17     | 8.46 | 177.00                       |
| The Pogue | 5/5/2014 | 1.01      | 12.89    | 12.22     | 8.50 | 177.00                       |
| The Pogue | 5/5/2014 | 1.50      | 12.77    | 12.27     | 8.49 | 177.00                       |
| The Pogue | 5/5/2014 | 2.01      | 12.69    | 12.69     | 8.54 | 177.00                       |
| The Pogue | 5/5/2014 | 2.52      | 12.69    | 12.73     | 8.57 | 177.00                       |
| The Pogue | 5/5/2014 | 2.64      | 12.51    | 3.69      | 6.98 | 208.00                       |
| The Pogue | 6/3/2014 | -0.01     | 22.26    | 11.60     | 8.62 | 163.00                       |
| The Pogue | 6/3/2014 | 0.50      | 21.29    | 11.95     | 8.73 | 162.00                       |
| The Pogue | 6/3/2014 | 1.00      | 20.98    | 11.80     | 8.70 | 163.00                       |
| The Pogue | 6/3/2014 | 1.50      | 20.73    | 11.45     | 8.65 | 164.00                       |
| The Pogue | 6/3/2014 | 2.00      | 20.42    | 12.88     | 8.81 | 160.00                       |
| The Pogue | 6/3/2014 | 2.50      | 20.42    | 13.10     | 8.87 | 159.00                       |
| The Pogue | 6/3/2014 | 2.76      | 19.50    | 4.70      | 7.06 | 303.00                       |
| The Pogue | 7/1/2014 | 0.01      | 25.14    | 8.46      | 7.87 | 156.00                       |
| The Pogue | 7/1/2014 | 0.50      | 24.91    | 8.27      | 7.81 | 158.00                       |
| The Pogue | 7/1/2014 | 1.00      | 24.82    | 8.28      | 7.81 | 157.00                       |
| The Pogue | 7/1/2014 | 1.50      | 24.66    | 7.38      | 7.65 | 159.00                       |
| The Pogue | 7/1/2014 | 2.00      | 24.56    | 7.69      | 7.69 | 159.00                       |
| The Pogue | 7/1/2014 | 2.50      | 24.19    | 4.52      | 7.45 | 175.00                       |
| The Pogue | 7/1/2014 | 2.73      | 23.11    | 2.94      | 6.54 | 317.00                       |
| The Pogue | 8/4/2014 | 0.00      | 23.78    | 10.01     | 8.27 | 133.00                       |
| The Pogue | 8/4/2014 | 0.49      | 23.59    | 9.96      | 8.33 | 133.00                       |
| The Pogue | 8/4/2014 | 1.03      | 23.51    | 9.80      | 8.30 | 135.00                       |
| The Pogue | 8/4/2014 | 1.51      | 23.48    | 9.81      | 8.31 | 135.00                       |
| The Pogue | 8/4/2014 | 2.03      | 23.40    | 9.78      | 8.28 | 135.00                       |

## Appendix A. Marsh-Billings-Rockefeller National Historical Park (MABI) Water Monitoring Data, 2014 (continued).

**Table A1 (continued).** YSI sonde in-situ stream and pond water quality measurements collected at MABI.

| Site        | Date      | Depth (m) | Temp (C) | DO (mg/L) | pH   | Specific Conductance (μS/cm) |
|-------------|-----------|-----------|----------|-----------|------|------------------------------|
| The Pogue   | 8/4/2014  | 2.41      | 23.40    | 7.21      | 7.75 | 141.00                       |
| The Pogue   | 9/3/2014  | 0.01      | 23.99    | 9.23      | 8.68 | 133.00                       |
| The Pogue   | 9/3/2014  | 0.50      | 23.85    | 9.39      | 8.69 | 133.00                       |
| The Pogue   | 9/3/2014  | 1.00      | 23.77    | 9.22      | 8.66 | 134.00                       |
| The Pogue   | 9/3/2014  | 1.50      | 23.68    | 8.94      | 8.58 | 134.00                       |
| The Pogue   | 9/3/2014  | 2.00      | 23.63    | 8.40      | 8.45 | 137.00                       |
| The Pogue   | 9/3/2014  | 2.28      | 23.63    | 8.07      | 8.09 | 143.00                       |
| The Pogue   | 10/1/2014 | 0.00      | 17.90    | 9.43      | 8.21 | 157.00                       |
| The Pogue   | 10/1/2014 | 0.50      | 17.90    | 9.45      | 8.25 | 157.00                       |
| The Pogue   | 10/1/2014 | 1.00      | 17.86    | 9.21      | 8.21 | 158.00                       |
| The Pogue   | 10/1/2014 | 1.50      | 17.83    | 9.16      | 8.19 | 158.00                       |
| The Pogue   | 10/1/2014 | 2.01      | 17.78    | 9.17      | 8.18 | 158.00                       |
| The Pogue   | 10/1/2014 | 2.23      | 17.78    | 7.59      | 7.95 | 164.00                       |
| Pogue Brook | 5/5/2014  | 0.09      | 8.00     | 11.40     | 8.00 | 150.00                       |
| Pogue Brook | 6/3/2014  | 0.02      | 13.10    | 10.27     | 8.04 | 165.00                       |
| Pogue Brook | 7/1/2014  | 0.06      | 17.86    | 9.02      | 7.68 | 183.00                       |
| Pogue Brook | 8/4/2014  | 0.01      | 16.55    | 9.36      | 7.89 | 185.00                       |
| Pogue Brook | 9/3/2014  | 0.03      | 17.54    | 9.20      | 8.10 | 189.00                       |
| Pogue Brook | 10/1/2014 | 0.03      | 13.03    | 9.87      | 7.97 | 236.00                       |
| The Pogue   | 5/5/2014  | 0.00      | 12.99    | 12.10     | 8.49 | 177.00                       |

## Appendix A. Marsh-Billings-Rockefeller National Historical Park (MABI) Water Monitoring Data, 2014 (continued).

**Table A2.** Laboratory nutrient chemistry data for MABI. “<MRL” indicates the result was below the method reporting limit (0.1 for TN, 1.0 for NO<sub>3</sub>, 0.005 for NO<sub>2</sub>, and 0.08 for NH<sub>3</sub>). *Missing values indicate data are unavailable.*

| Site           | Date     | ANC<br>(µeq/L) | A Color<br>(PCU) | DOC<br>(mg/L) | TP<br>(µg/L) | TN<br>(mg/L) | NO <sub>3</sub><br>(µeq/L) | NO <sub>3</sub> -N<br>(mg/L<br>Calc) | NO <sub>2</sub><br>(mg/L) | NH <sub>3</sub><br>(mg/L) | Chla<br>(µg/L) | Cl<br>(µeq/L) | SO <sub>4</sub><br>(µeq/L) |
|----------------|----------|----------------|------------------|---------------|--------------|--------------|----------------------------|--------------------------------------|---------------------------|---------------------------|----------------|---------------|----------------------------|
| The Pogue      | 6/3/2014 | 1632.64        | 26               | 2.3           | 10.3         | 0.282        | <MRL 1                     | <MRL                                 | <MRL<br>0.005             | <MRL<br>0.08              | 6.1            | 17            | 88                         |
| The Pogue      | 8/4/2014 | 1287.53        | 18               | 3.34          | 10.2         | 0.302        | <MRL 1                     | <MRL                                 | <MRL<br>.001              | 0.043                     | 2.6            | 10.3          | 72                         |
| Pogue<br>Brook | 5/5/2014 | 1450.00        | 8                | 1.17          | 7.4          | 0.13         | 3.5                        | 0.049                                | <MRL<br>0.005             | <MRL<br>0.08              |                | 12            | 112                        |
| Pogue<br>Brook | 8/4/2014 | 1832.52        | 7                | 1.42          | 7.8          | 0.161        | 5                          | 0.071                                | <MRL<br>.001              | <MRL<br>0.003             |                | 11.1          | 104                        |

## Appendix A. Marsh-Billings-Rockefeller National Historical Park (MABI) Water Monitoring Data, 2014 (continued).

**Table A3.** Stream stage and discharge data for MABI. *Missing values indicate data are unavailable.*

| Site        | Date     | Datum name          | Distance from datum (ft) | Total CS area (sqft) | Average velocity (f/s) | Discharge (cfs) |
|-------------|----------|---------------------|--------------------------|----------------------|------------------------|-----------------|
| Pogue Brook | 5/5/2014 | Staff Gage1         | 0.69                     | 2.04                 | 0.45                   | 0.92            |
| Pogue Brook | 6/3/2014 | Bolt1               | -0.76                    | 0.88                 | 0.39                   | 0.34            |
| Pogue Brook | 6/3/2014 | Staff Gage1 (10:03) | 0.44                     |                      |                        |                 |
| Pogue Brook | 6/3/2014 | Staff Gage1 (10:44) | 0.43                     |                      |                        |                 |
| Pogue Brook | 7/1/2014 | Staff Gage1         | 0.19                     | 0.84                 | 0.20                   | 0.16            |
| Pogue Brook | 7/1/2014 | Bolt1 (14:14)       | -0.84                    |                      |                        |                 |
| Pogue Brook | 7/1/2014 | Bolt1 (14:54)       | -0.83                    |                      |                        |                 |
| Pogue Brook | 8/4/2014 | Staff Gage1         | 0.26                     | 1.10                 | 0.36                   | 0.40            |
| Pogue Brook | 8/4/2014 | Bolt1               | -0.69                    |                      |                        |                 |
| Pogue Brook | 9/3/2014 | Bolt1 (14:19)       | -0.70                    | 1.42                 | 0.30                   | 0.46            |

**Table A4.** Pond stage data for MABI.

| Site      | Date      | Datum name | Distance from datum (ft) |
|-----------|-----------|------------|--------------------------|
| The Pogue | 5/5/2014  | SG1        | 2.44                     |
| The Pogue | 6/3/2014  | SG1        | 2.41                     |
| The Pogue | 7/1/2014  | SG1        | 2.4                      |
| The Pogue | 8/4/2014  | SG1        | 2.4                      |
| The Pogue | 9/3/2014  | SG1        | 2.42                     |
| The Pogue | 10/1/2014 | SG1        | 2.24                     |

## Appendix A. Marsh-Billings-Rockefeller National Historical Park (MABI) Water Monitoring Data, 2014 (continued).

**Table A5.** Light penetration profiles for MABI.

| Site      | NETN Code | Date     | Depth (m) | Deck cell ( $\mu\text{mol s}^{-1} \text{m}^{-2}$ ) | PAR cell ( $\mu\text{mol s}^{-1} \text{m}^{-2}$ ) | Proportion of penetration (PAR/Deck) |
|-----------|-----------|----------|-----------|----------------------------------------------------|---------------------------------------------------|--------------------------------------|
| The Pogue | MABIPA    | 5/5/2014 | 0.10      | 712.85                                             | 709.94                                            | 1.00                                 |
| The Pogue | MABIPA    | 5/5/2014 | 0.25      | 757.28                                             | 739.22                                            | 0.98                                 |
| The Pogue | MABIPA    | 5/5/2014 | 0.50      | 776.72                                             | 643.09                                            | 0.83                                 |
| The Pogue | MABIPA    | 5/5/2014 | 0.75      | 1084.90                                            | 751.77                                            | 0.69                                 |
| The Pogue | MABIPA    | 5/5/2014 | 1.00      | 696.01                                             | 405.97                                            | 0.58                                 |
| The Pogue | MABIPA    | 5/5/2014 | 1.25      | 693.75                                             | 356.86                                            | 0.51                                 |
| The Pogue | MABIPA    | 5/5/2014 | 1.50      | 637.51                                             | 264.42                                            | 0.41                                 |
| The Pogue | MABIPA    | 5/5/2014 | 1.75      | 525.97                                             | 193.01                                            | 0.37                                 |
| The Pogue | MABIPA    | 5/5/2014 | 2.00      | 481.21                                             | 151.76                                            | 0.32                                 |
| The Pogue | MABIPA    | 5/5/2014 | 2.25      | 479.98                                             | 122.18                                            | 0.25                                 |
| The Pogue | MABIPA    | 5/5/2014 | 2.50      | 459.95                                             | 107.99                                            | 0.23                                 |
| The Pogue | MABIPA    | 5/5/2014 | 3.00      | 450.86                                             | 97.46                                             | 0.22                                 |
| The Pogue | MABIPA    | 6/3/2014 | 0.25      | 2042.40                                            | 1972.30                                           | 0.97                                 |
| The Pogue | MABIPA    | 6/3/2014 | 0.50      | 2079.40                                            | 1634.60                                           | 0.80                                 |
| The Pogue | MABIPA    | 6/3/2014 | 0.75      | 2045.20                                            | 1425.00                                           | 0.70                                 |
| The Pogue | MABIPA    | 6/3/2014 | 1.00      | 1928.40                                            | 1298.10                                           | 0.67                                 |
| The Pogue | MABIPA    | 6/3/2014 | 1.25      | 1893.20                                            | 1034.80                                           | 0.55                                 |
| The Pogue | MABIPA    | 6/3/2014 | 1.50      | 1832.30                                            | 793.95                                            | 0.43                                 |
| The Pogue | MABIPA    | 6/3/2014 | 1.75      | 1845.90                                            | 794.60                                            | 0.43                                 |
| The Pogue | MABIPA    | 6/3/2014 | 2.00      | 2007.50                                            | 781.66                                            | 0.39                                 |
| The Pogue | MABIPA    | 6/3/2014 | 2.25      | 1427.70                                            | 451.56                                            | 0.31                                 |
| The Pogue | MABIPA    | 6/3/2014 | 2.50      | 1789.30                                            | 282.39                                            | 0.16                                 |
| The Pogue | MABIPA    | 6/3/2014 | 2.75      | 639.27                                             | 147.21                                            | 0.23                                 |
| The Pogue | MABIPA    | 6/3/2014 | 2.85      | 950.21                                             | 203.23                                            | 0.21                                 |
| The Pogue | MABIPA    | 7/1/2014 | 0.10      | 1292.30                                            | 1424.20                                           | 1.10                                 |
| The Pogue | MABIPA    | 7/1/2014 | 0.25      | 1321.30                                            | 1260.20                                           | 0.95                                 |
| The Pogue | MABIPA    | 7/1/2014 | 0.50      | 1370.10                                            | 1151.00                                           | 0.84                                 |
| The Pogue | MABIPA    | 7/1/2014 | 0.75      | 1477.00                                            | 965.73                                            | 0.66                                 |

## Appendix A. Marsh-Billings-Rockefeller National Historical Park (MABI) Water Monitoring Data, 2014 (continued).

**Table A5 (continued).** Light penetration profiles for MABI.

| Site      | NETN Code | Date     | Depth (m) | Deck cell ( $\mu\text{mol s}^{-1} \text{m}^{-2}$ ) | PAR cell ( $\mu\text{mol s}^{-1} \text{m}^{-2}$ ) | Proportion of penetration (PAR/Deck) |
|-----------|-----------|----------|-----------|----------------------------------------------------|---------------------------------------------------|--------------------------------------|
| The Pogue | MABIPA    | 7/1/2014 | 1.00      | 1493.00                                            | 814.19                                            | 0.55                                 |
| The Pogue | MABIPA    | 7/1/2014 | 1.25      | 1373.20                                            | 687.32                                            | 0.50                                 |
| The Pogue | MABIPA    | 7/1/2014 | 1.50      | 1383.60                                            | 599.34                                            | 0.43                                 |
| The Pogue | MABIPA    | 7/1/2014 | 1.75      | 1588.70                                            | 502.78                                            | 0.32                                 |
| The Pogue | MABIPA    | 7/1/2014 | 2.00      | 1530.10                                            | 440.43                                            | 0.29                                 |
| The Pogue | MABIPA    | 7/1/2014 | 2.25      | 1473.80                                            | 371.00                                            | 0.25                                 |
| The Pogue | MABIPA    | 7/1/2014 | 2.50      | 1440.60                                            | 276.96                                            | 0.19                                 |
| The Pogue | MABIPA    | 7/1/2014 | 2.55      | 1365.30                                            | 253.90                                            | 0.19                                 |
| The Pogue | MABIPA    | 8/4/2014 | 0.10      | 1843.20                                            | 1930.80                                           | 1.05                                 |
| The Pogue | MABIPA    | 8/4/2014 | 0.25      | 1697.80                                            | 1561.10                                           | 0.92                                 |
| The Pogue | MABIPA    | 8/4/2014 | 0.50      | 1136.20                                            | 1028.60                                           | 0.90                                 |
| The Pogue | MABIPA    | 8/4/2014 | 0.75      | 1542.30                                            | 1229.70                                           | 0.80                                 |
| The Pogue | MABIPA    | 8/4/2014 | 1.00      | 1665.40                                            | 1109.30                                           | 0.67                                 |
| The Pogue | MABIPA    | 8/4/2014 | 1.25      | 1453.00                                            | 859.42                                            | 0.63                                 |
| The Pogue | MABIPA    | 8/4/2014 | 1.50      | 976.99                                             | 548.57                                            | 0.57                                 |
| The Pogue | MABIPA    | 8/4/2014 | 1.75      | 774.17                                             | 343.89                                            | 0.44                                 |
| The Pogue | MABIPA    | 8/4/2014 | 2.00      | 801.09                                             | 302.82                                            | 0.38                                 |
| The Pogue | MABIPA    | 8/4/2014 | 2.25      | 670.02                                             | 219.97                                            | 0.34                                 |
| The Pogue | MABIPA    | 8/4/2014 | 2.50      | 567.68                                             | 153.97                                            | 0.27                                 |
| The Pogue | MABIPA    | 9/3/2014 | 0.10      | 1589.80                                            | 1797.60                                           | 1.13                                 |
| The Pogue | MABIPA    | 9/3/2014 | 0.25      | 478.24                                             | 469.37                                            | 0.96                                 |
| The Pogue | MABIPA    | 9/3/2014 | 0.50      | 1374.30                                            | 1276.90                                           | 0.93                                 |
| The Pogue | MABIPA    | 9/3/2014 | 0.75      | 1184.60                                            | 952.78                                            | 0.81                                 |
| The Pogue | MABIPA    | 9/3/2014 | 1.00      | 1785.80                                            | 1002.70                                           | 0.56                                 |
| The Pogue | MABIPA    | 9/3/2014 | 1.25      | 237.23                                             | 106.56                                            | 0.45                                 |
| The Pogue | MABIPA    | 9/3/2014 | 1.50      | 1615.00                                            | 600.97                                            | 0.37                                 |
| The Pogue | MABIPA    | 9/3/2014 | 1.75      | 1813.10                                            | 549.47                                            | 0.30                                 |
| The Pogue | MABIPA    | 9/3/2014 | 2.00      | 1664.60                                            | 481.69                                            | 0.29                                 |

## Appendix A. Marsh-Billings-Rockefeller National Historical Park (MABI) Water Monitoring Data, 2014 (continued).

**Table A5 (continued).** Light penetration profiles for MABI.

| Site      | NETN Code | Date      | Depth (m) | Deck cell ( $\mu\text{mol s}^{-1} \text{m}^{-2}$ ) | PAR cell ( $\mu\text{mol s}^{-1} \text{m}^{-2}$ ) | Proportion of penetration (PAR/Deck) |
|-----------|-----------|-----------|-----------|----------------------------------------------------|---------------------------------------------------|--------------------------------------|
| The Pogue | MABIPA    | 9/3/2014  | 2.25      | 1690.70                                            | 432.34                                            | 0.26                                 |
| The Pogue | MABIPA    | 9/3/2014  | 2.50      | 1818.50                                            | 310.48                                            | 0.17                                 |
| The Pogue | MABIPA    | 9/3/2014  | 2.75      | 1773.80                                            | 304.51                                            | 0.17                                 |
| The Pogue | MABIPA    | 10/1/2014 | 0.10      | 322.15                                             | 320.21                                            | 0.99                                 |
| The Pogue | MABIPA    | 10/1/2014 | 0.25      | 317.12                                             | 296.05                                            | 0.93                                 |
| The Pogue | MABIPA    | 10/1/2014 | 0.50      | 292.60                                             | 223.67                                            | 0.76                                 |
| The Pogue | MABIPA    | 10/1/2014 | 0.75      | 258.62                                             | 160.65                                            | 0.62                                 |
| The Pogue | MABIPA    | 10/1/2014 | 1.00      | 252.90                                             | 124.75                                            | 0.49                                 |
| The Pogue | MABIPA    | 10/1/2014 | 1.25      | 228.90                                             | 108.79                                            | 0.48                                 |
| The Pogue | MABIPA    | 10/1/2014 | 1.50      | 221.59                                             | 85.09                                             | 0.38                                 |
| The Pogue | MABIPA    | 10/1/2014 | 1.75      | 207.66                                             | 63.38                                             | 0.31                                 |
| The Pogue | MABIPA    | 10/1/2014 | 2.00      | 195.70                                             | 55.70                                             | 0.28                                 |
| The Pogue | MABIPA    | 10/1/2014 | 2.25      | 178.98                                             | 41.38                                             | 0.23                                 |

**Table A6.** Secchi disk profiles for MABI.

| Site      | Date      | Secchi Depth (m) | (B=disk hit bottom) |
|-----------|-----------|------------------|---------------------|
| The Pogue | 5/5/2014  | 2.95             |                     |
| The Pogue | 6/3/2014  | 2.8              |                     |
| The Pogue | 7/1/2014  | 2.7              |                     |
| The Pogue | 8/4/2014  | 2.6              |                     |
| The Pogue | 9/3/2014  | 2.57             |                     |
| The Pogue | 10/1/2014 | 2.55             |                     |

## Appendix B. Marsh-Billings-Rockefeller National Historical Park (MABI) Blank and Replicate Water Samples, 2013.

**Table B1.** 2014 Blank sample analysis results (Lower NETN).

| Site | Date      | ANC<br>(µeq/L) | A Color<br>(PCU) | DOC<br>(mg/L) | Chla<br>(µg/L) | Cl<br>(µeq/L) | SO <sub>4</sub><br>(µeq/L) | TP<br>(µg/L) | TN (mg/L) | NO <sub>2</sub> (mg/L) | NO <sub>3</sub><br>(µeq/L) | NH <sub>3</sub> (mg/L) |
|------|-----------|----------------|------------------|---------------|----------------|---------------|----------------------------|--------------|-----------|------------------------|----------------------------|------------------------|
| SARA | 5/20/2014 | -1.70          | 1                | <MRL 0.5      |                | <MRL 2        | <MRL 2                     | <MRL 1       | <MRL 0.1  | <MRL 0.005             | <MRL 1                     | <MRL 0.08              |
| WEFA | 6/11/2014 | -2.12          | 1                | <MRL 0.5      | <MRL 1         | <MRL 2        | <MRL 2                     | <MRL 1       | 0.017     | <MRL 0.005             | <MRL 1                     | <MRL 0.08              |
| MABI | 8/4/2014  | -2.95          | 1                | <MRL 0.5      |                | <MRL 2        | <MRL 2                     | <MRL 1       | 0.018     | <MRL .001              | <MRL 1                     | <MRL 0.003             |
| MABI | 8/4/2014  | -1.44          | 1                | <MRL 0.5      | 0.2            | <MRL 2        | <MRL 2                     | <MRL 1       | <MRL 0.1  | <MRL .001              | <MRL 1                     | 0.01                   |

**Table B2.** Replicate sample analysis results and measurement quality analysis (Lower NETN).

| Site   | Date      | Color<br>Reg | Color<br>Rep | Diff<br>(PCU) | % Diff | DOC<br>Reg | DOC<br>Rep | Diff<br>(mg/L) | % Diff | ANC<br>Reg | ANC<br>Rep | Diff<br>(µeq/L) | % Diff |
|--------|-----------|--------------|--------------|---------------|--------|------------|------------|----------------|--------|------------|------------|-----------------|--------|
| MIMASA | 5/22/2014 | 207          | 204          | 3.0           | 1.4%   | 8.85       | 8.62       | 0.23           | 2.60%  | 755.0      | 749.0      | 6.0             | 0.8%   |
| MABIPA | 6/3/2014  | 26           | 26           | 0.0           | 0.0%   | 2.3        | 2.39       | -0.09          | 3.91%  | 1632.6     | 1628.9     | 3.7             | 0.2%   |
| WEFAPA | 8/12/2014 | 30           | 32           | -2.0          | 6.7%   | 5          | 5          | 0.00           | 0.00%  | 379.8      | 378.4      | 1.3             | 0.4%   |
| MORRSB | 8/12/2014 | 19           | 22           | -3.0          | 15.8%  | 2          | 1.85       | 0.15           | 7.50%  | 789.7      | 791.6      | -1.9            | 0.2%   |

| Site   | Date      | Chla<br>Reg | Chla<br>Rep | Diff<br>(µg/L) | % Diff | TP<br>Reg | TP<br>Rep | Diff<br>(µg/L) | % Diff | TN<br>Reg | TN<br>Rep | Diff<br>(mg/L) | % Diff |
|--------|-----------|-------------|-------------|----------------|--------|-----------|-----------|----------------|--------|-----------|-----------|----------------|--------|
| MIMASA | 5/22/2014 |             |             |                |        | 124       | 136       | -12.0          | 9.7%   | 0.77      | 0.87      | -0.11          | 13.7%  |
| MABIPA | 6/3/2014  | 6.1         |             |                |        | 10.3      | 10.3      | 0.0            | 0.0%   | 0.28      | 0.30      | -0.02          | 7.8%   |
| WEFAPA | 8/12/2014 | 3.4         |             |                |        | 15.3      | 15        | 0.3            | 2.0%   | 0.54      | 0.45      | 0.09           | 16.5%  |
| MORRSB | 8/12/2014 |             |             |                |        | 28.4      | 30.3      | -1.9           | 6.7%   | 0.49      | 0.48      | 0.01           | 2.1%   |

**Appendix B. Marsh-Billings-Rockefeller National Historical Park (MABI) Blank and Replicate Water Samples, 2013 (continued).**

| Site   | Date      | NO <sub>3</sub><br>Reg | NO <sub>3</sub><br>Rep | Diff<br>(µeq/L) | % Diff | NO <sub>2</sub><br>Reg | NO <sub>2</sub><br>Rep | Diff<br>(mg/L) | % Diff | NH <sub>3</sub><br>Reg | NH <sub>3</sub><br>Rep | Diff<br>(mg/L) | % Diff |
|--------|-----------|------------------------|------------------------|-----------------|--------|------------------------|------------------------|----------------|--------|------------------------|------------------------|----------------|--------|
| MIMASA | 5/22/2014 | 8.9                    | 8.4                    | 0.50            | 5.6%   | 0.0072                 | 0.0073                 | 0.000          | 1.4%   | < MRL                  | < MRL                  |                |        |
| MABIPA | 6/3/2014  | < MRL                  | < MRL                  |                 |        | < MRL                  | < MRL                  |                |        | < MRL                  | < MRL                  |                |        |
| WEFAPA | 8/12/2014 | < MRL                  | < MRL                  |                 |        | < MRL                  | < MRL                  |                |        | 0.032                  | 0.03                   | 0.002          | 6.3%   |
| MORRSB | 8/12/2014 | 28                     | 28                     | 0.00            | 0.0%   | < MRL                  | < MRL                  |                |        | 0.024                  | < MRL                  |                |        |

| Site   | Date      | SO <sub>4</sub><br>Reg | SO <sub>4</sub><br>Rep | Diff<br>(µeq/L) | % Diff | Cl Reg | Cl Rep | Diff<br>(µeq/L) | % Diff |
|--------|-----------|------------------------|------------------------|-----------------|--------|--------|--------|-----------------|--------|
| MIMASA | 5/22/2014 | 213                    | 199                    | 14.0            | 6.6%   | 4330   | 3985   | 345.0           | 8.0%   |
| MABIPA | 6/3/2014  | 88                     | 88                     | 0.0             | 0.0%   | 17     | 17     | 0.0             | 0.0%   |
| WEFAPA | 8/12/2014 | 92                     | 89                     | 3.0             | 3.3%   | 932    | 932    | 0.0             | 0.0%   |
| MORRSB | 8/12/2014 | 291                    | 300                    | -9.0            | 3.1%   | 170    | 175    | -5.0            | 2.9%   |



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