



Water Quality Monitoring at Marsh-Billings-Rockefeller NHP

Northeast Temperate Network 2011 Summary Report

Natural Resource Data Series NPS/NETN/NRDS—2012/322



ON THE COVER

Measuring pond stage (water level) at The Pogue, September 2010
Photograph by: Beth Arsenault

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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 2011 monitoring season and displays these results in graphic form, accompanied by a brief interpretation. An appendix contains all data collected since NETN monitoring was initiated in 2006.

The vital signs for freshwater bodies included in the 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. A cooperator from the University of Vermont or a NETN hydrologic technician 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 Stream. This is the only stream within the park, and it has been monitored annually since 2006. Pogue Stream can be classified as a cold water fishery, loosely defined a 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 Stream. Both sites are mapped in Figure 1.

Methods

Detailed descriptions of all monitoring methods are found in the protocol (Lombard et al. 2006). Monthly sampling parameters included in-situ water quality measures (pH, specific conductance, temperature, and dissolved oxygen) determined with a YSI 600XL sonde, transparency (pond site only), 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. The pond sampling procedure entailed collecting all in-situ measurements and water samples from the deepest point of the pond (approximately 3 meters). Nutrient chemistry parameters were analyzed from a half-meter grab sample.

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

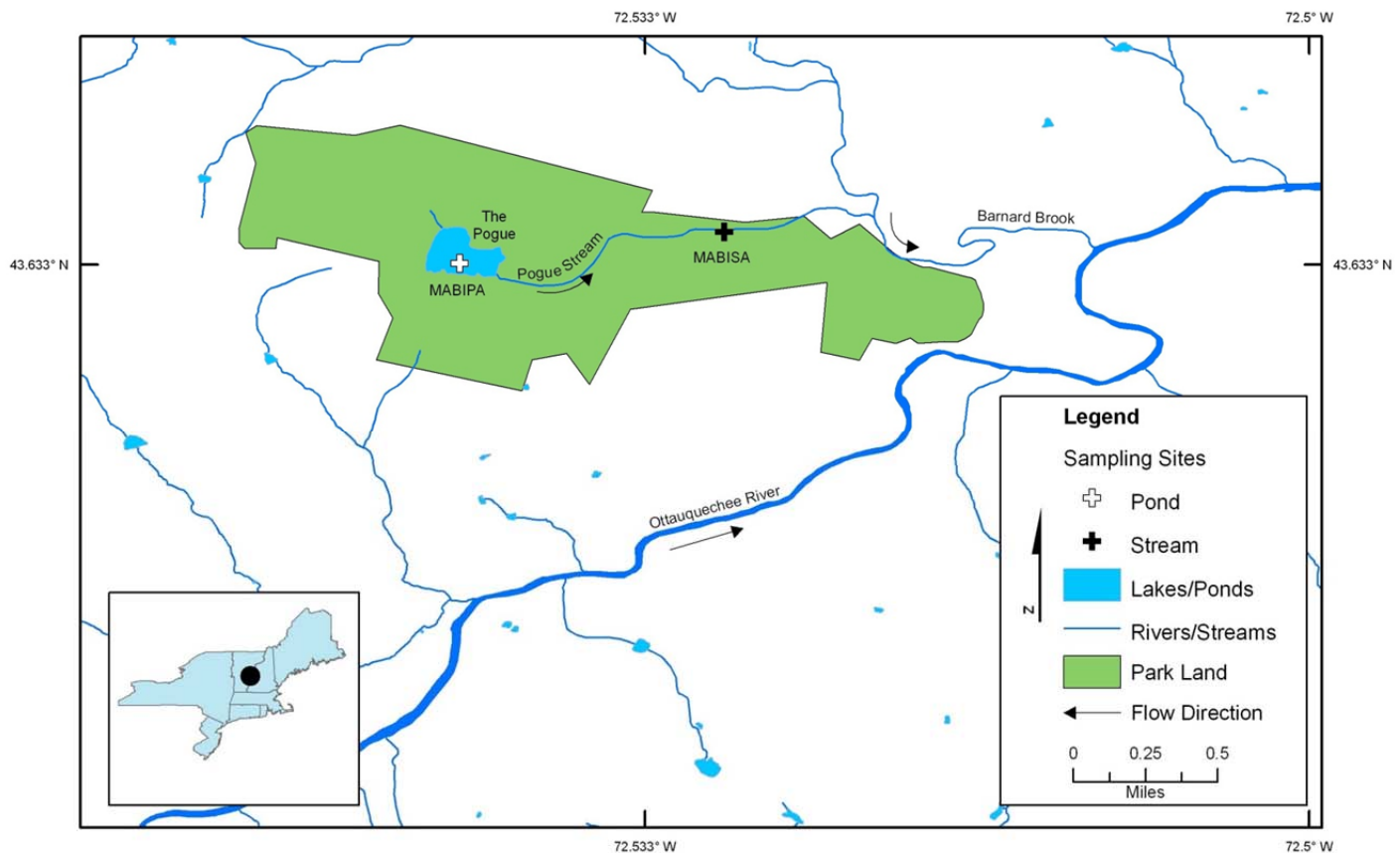


Figure 1. NETN water monitoring sites at Marsh-Billings-Rockefeller NHP.

Pygmy current meter was used in October 2011) to measure a particular cross-sectional area of the stream and the velocity of the water at that cross section.

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. A peristaltic pump and Tygon tubing were used to collect samples if water levels were too low to completely submerge a bottle.

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 ¹) 5 (warm ²)	6.5-8.5	2,000 (2 mg/L)	--
Ponds	--	6.5-8.5	5,000 (5 mg/L)	--

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

² 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.

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 (waterbodies 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 25th percentile of lakes that EPA found data for. This percentile of all lakes is expected to approximately correspond to the 75th 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 2011 are displayed in scatter-plot graphs showing all data for each site for a given parameter. The scatter plots of 2011 data are overlaid on box plots representing the overall range and distribution of data values collected from 2006 through 2011 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 25th percentile, a line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers (error bars) above and below the box indicate the 90th and 10th percentiles. Outliers are displayed as black filled circles. If EPA or other water quality criteria exist for a particular parameter they are displayed on the graphs as specification lines.

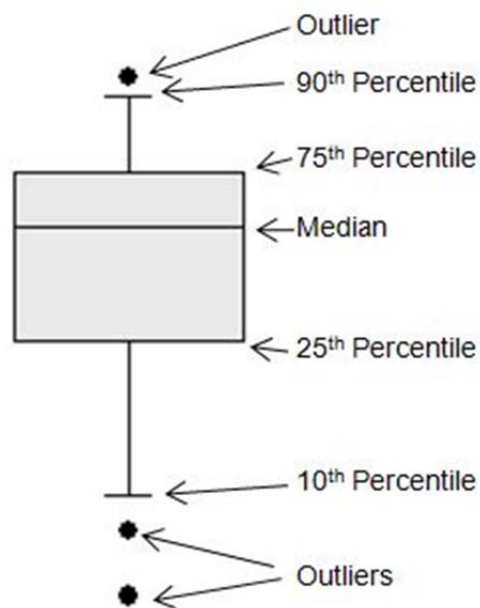


Figure 2. Explanation of box plot graph

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 can range from less than 20 to more than 1,000 microsiemens per centimeter ($\mu\text{S}/\text{cm}$). Specific conductance values from 2011 were within the appropriate range for moderate to high ionic strength waters, and were similar to the median values shown on the boxplot.

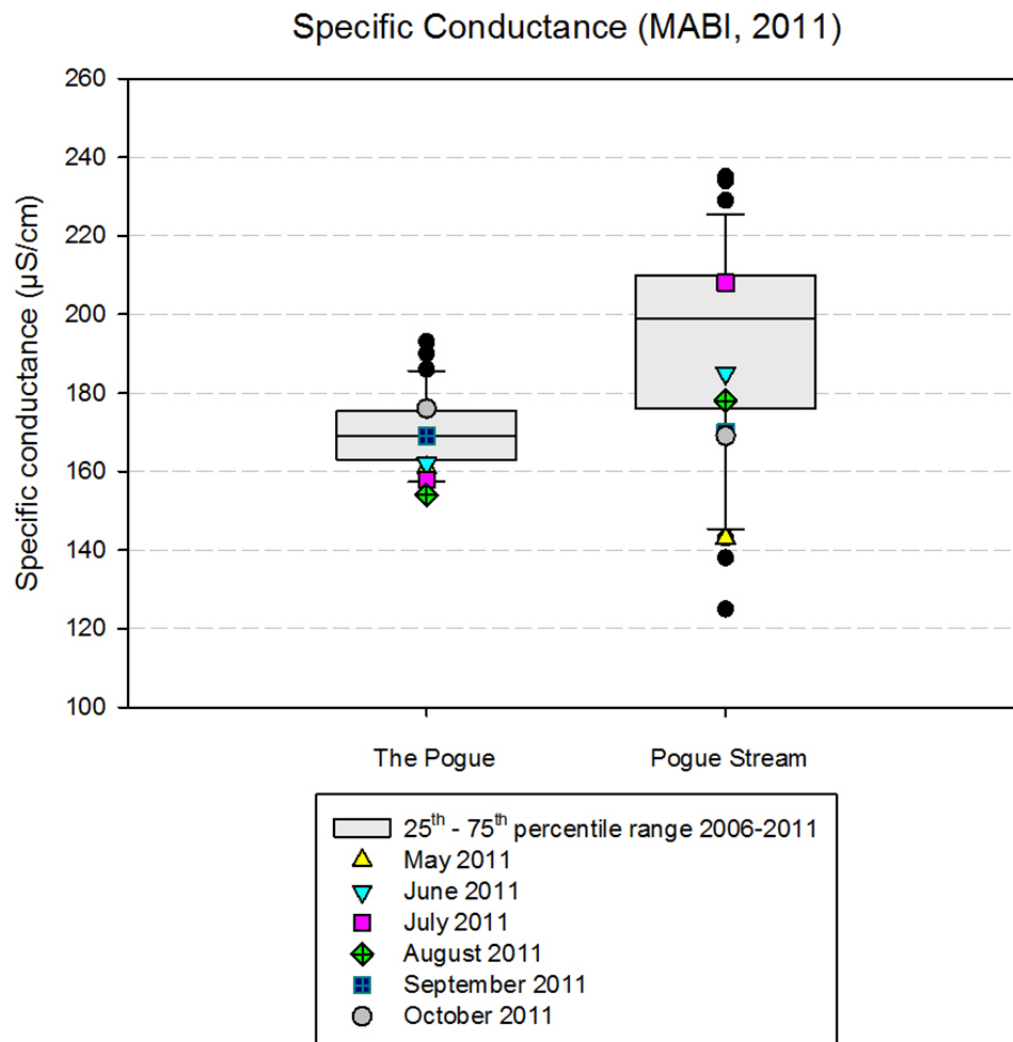


Figure 3. Specific conductance from 2011 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2011.

pH Level

The pH of a water body 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, and alkaline waters are above 7. A one unit change in pH represents a 10-fold change in acidity or alkalinity. 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 2011 monitoring season (Figure 4) were moderately basic, and (with the exception of the June value from the Pogue) were within the upper and lower Vermont water quality standards.

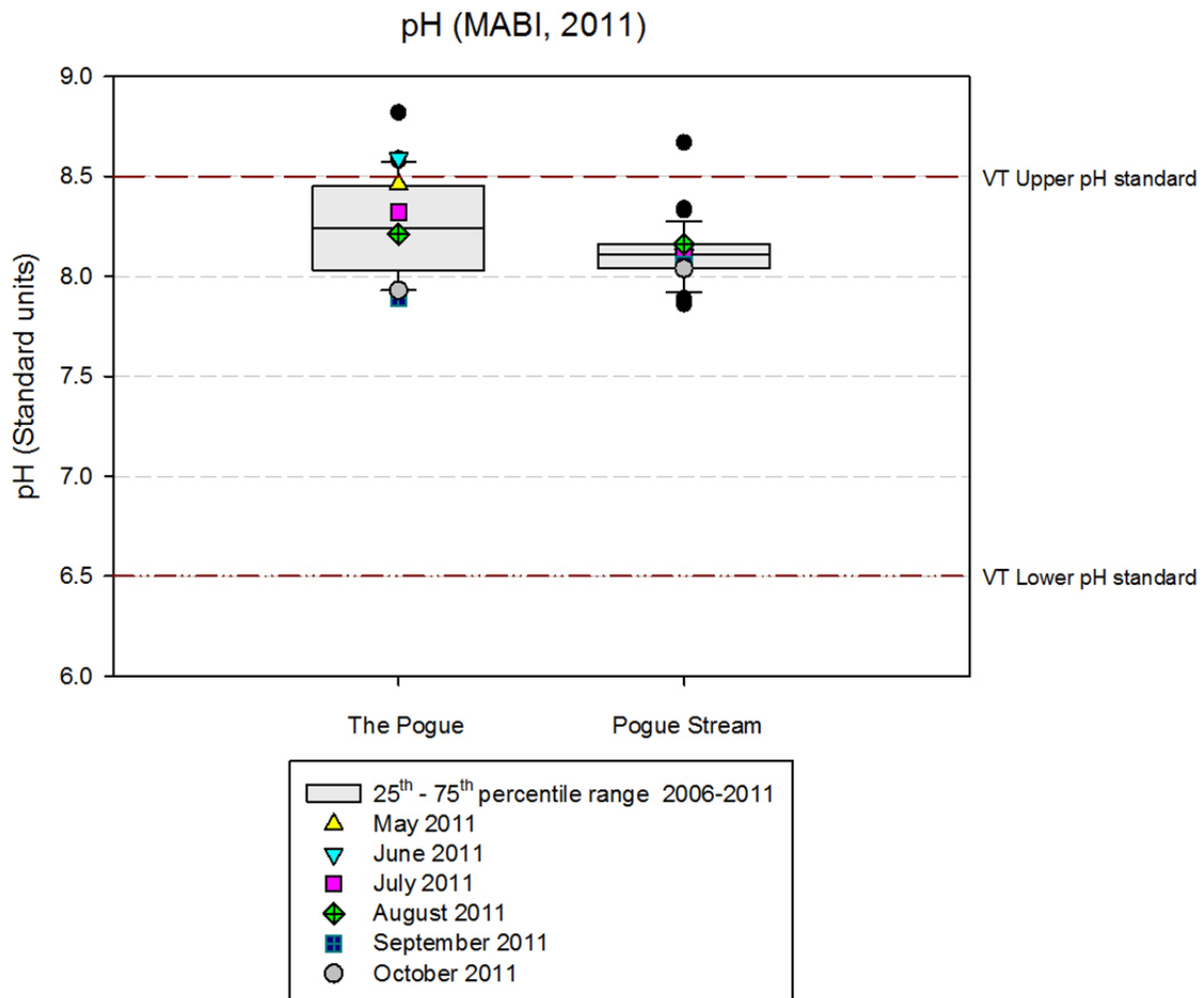


Figure 4. pH from 2011 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2011.

Water 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 the 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) appeared to be within the normal range of variability in 2011, though July values reflected the contributions of high air temperature and solar radiation.

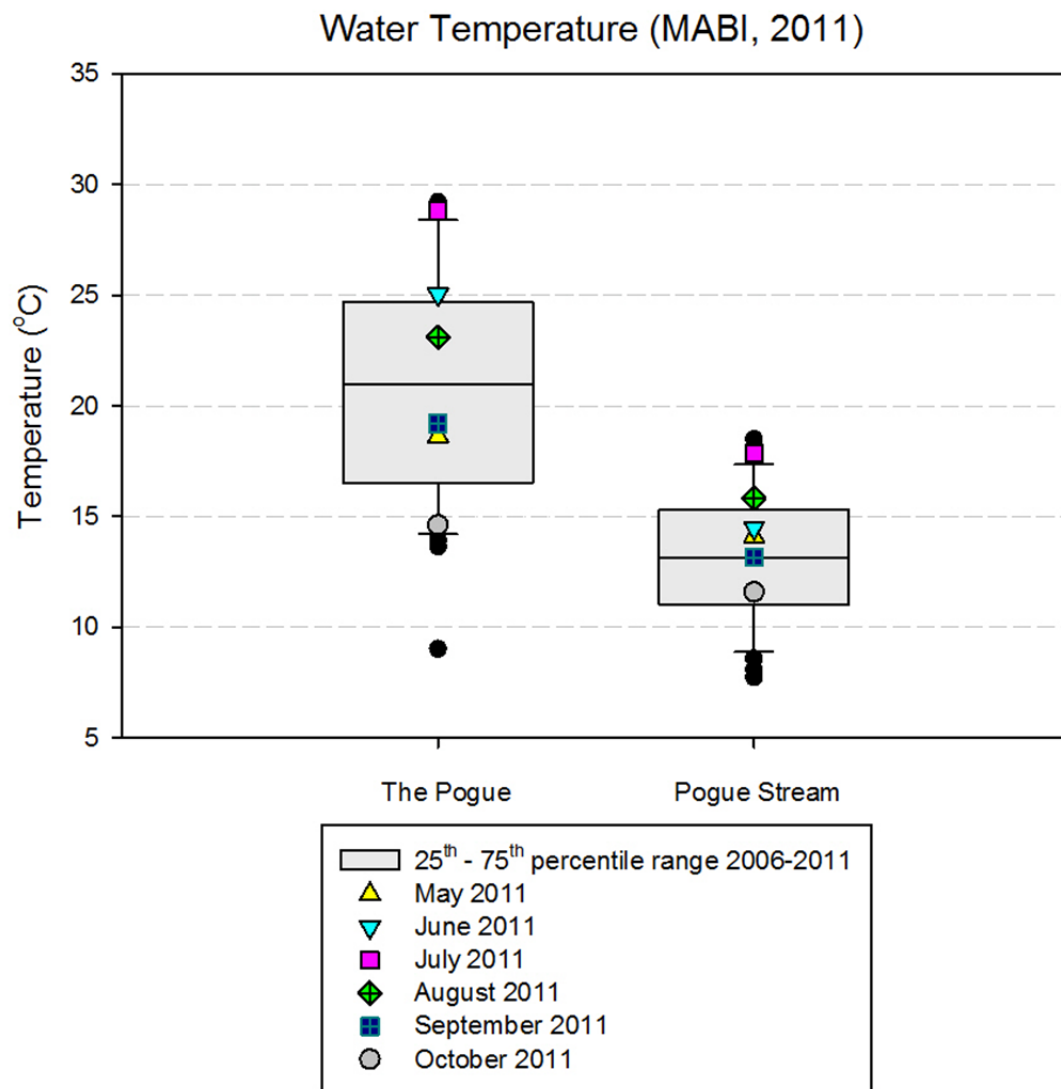


Figure 5. Water temperature (surface) from 2011 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2011.

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). Both sites were well oxygenated in 2011 (Figure 6), and were above the more stringent (7 mg/L) state DO standard.

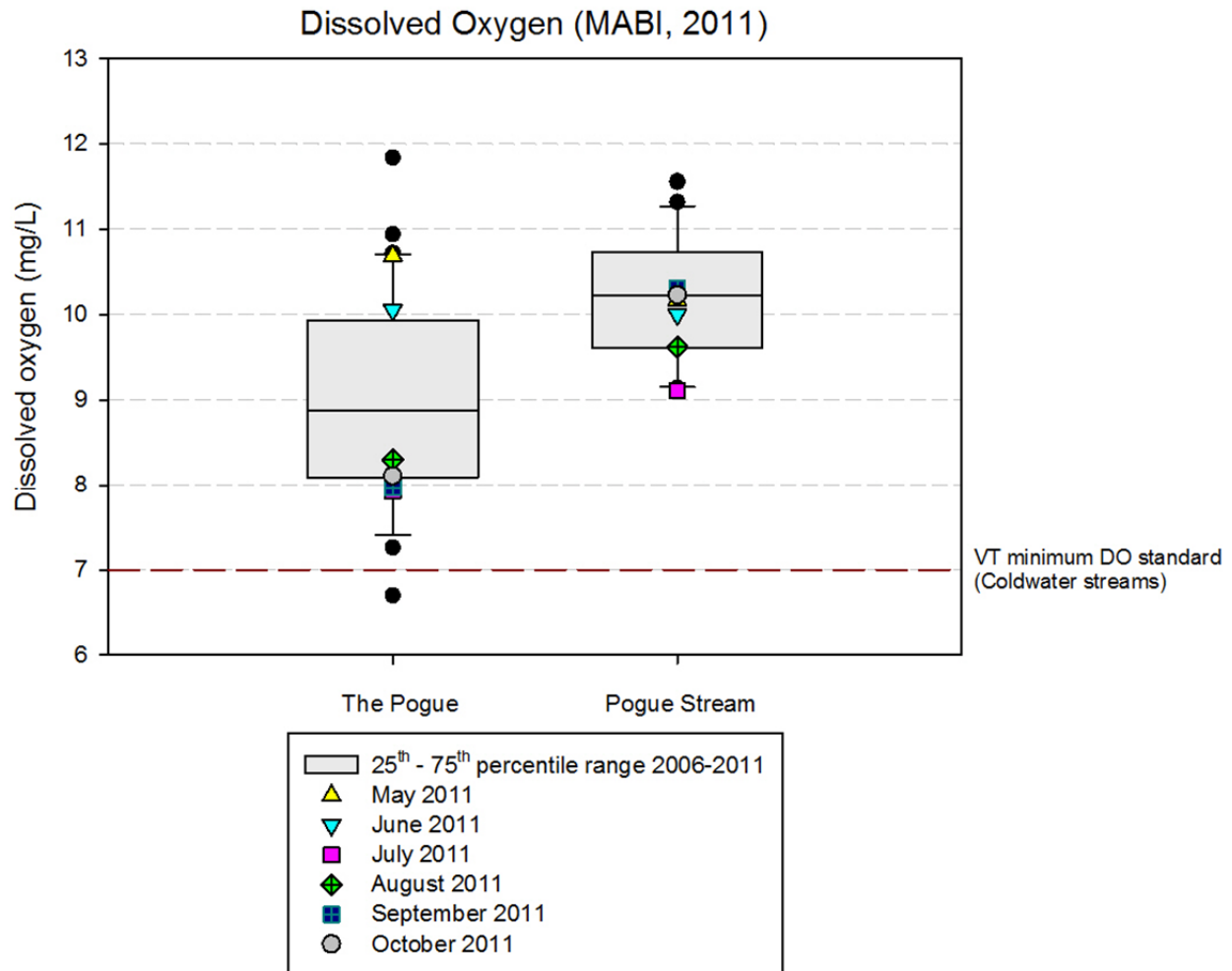


Figure 6. Dissolved oxygen (surface) from 2011 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2011.

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 in the 2011 samples (Figure 7) was lower in the spring samples from Pogue Stream, reflecting the acidic influence of snowmelt and runoff. ANC in The Pogue was more stable, showing less of a seasonal trend.

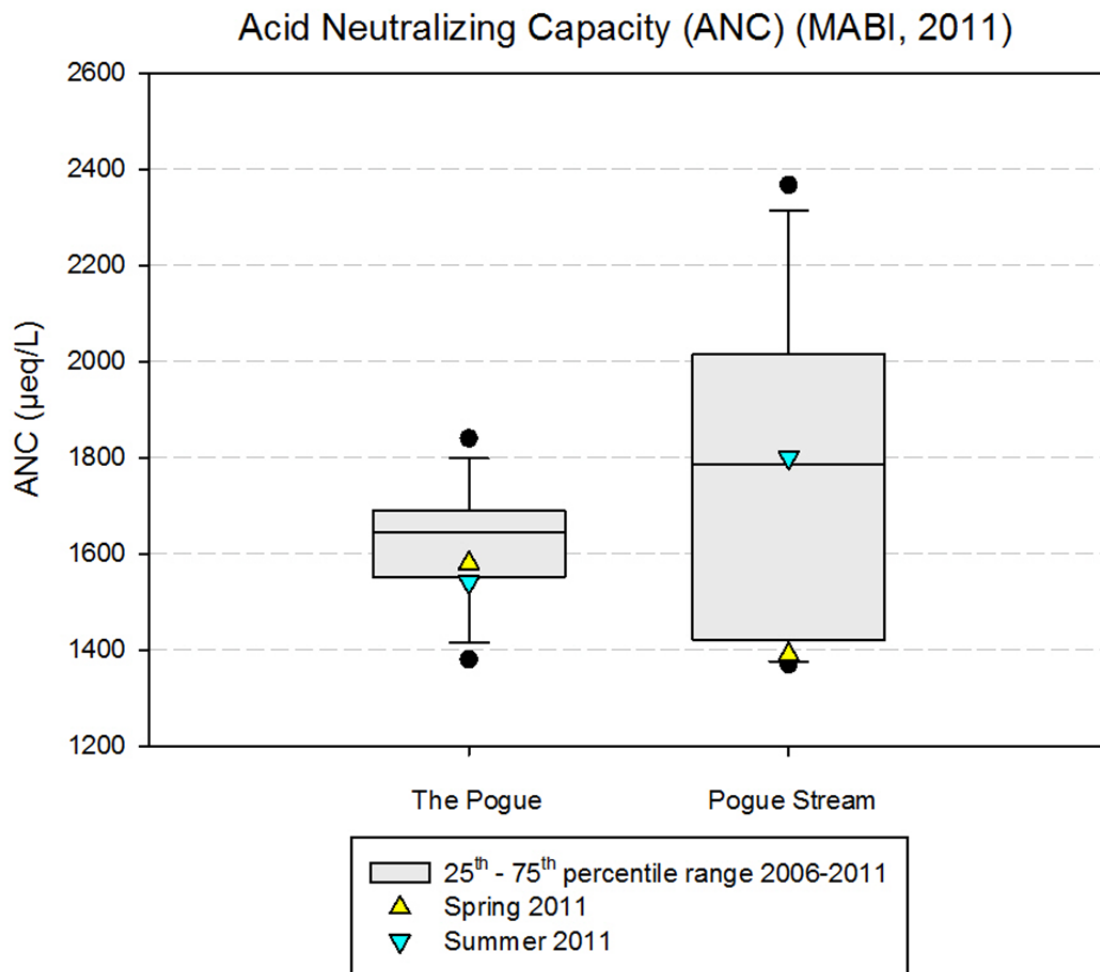


Figure 7. Acid neutralizing capacity from 2011 spring and summer water samples overlaid on a box plot of measurements taken from 2006-2011.

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 the 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.

Apparent color measurements from 2011 samples (Figure 8) showed the Pogue to be moderately colored, and both spring and summer values were very close to the overall median for this pond. Pogue Stream color values were lower than those of the Pogue.

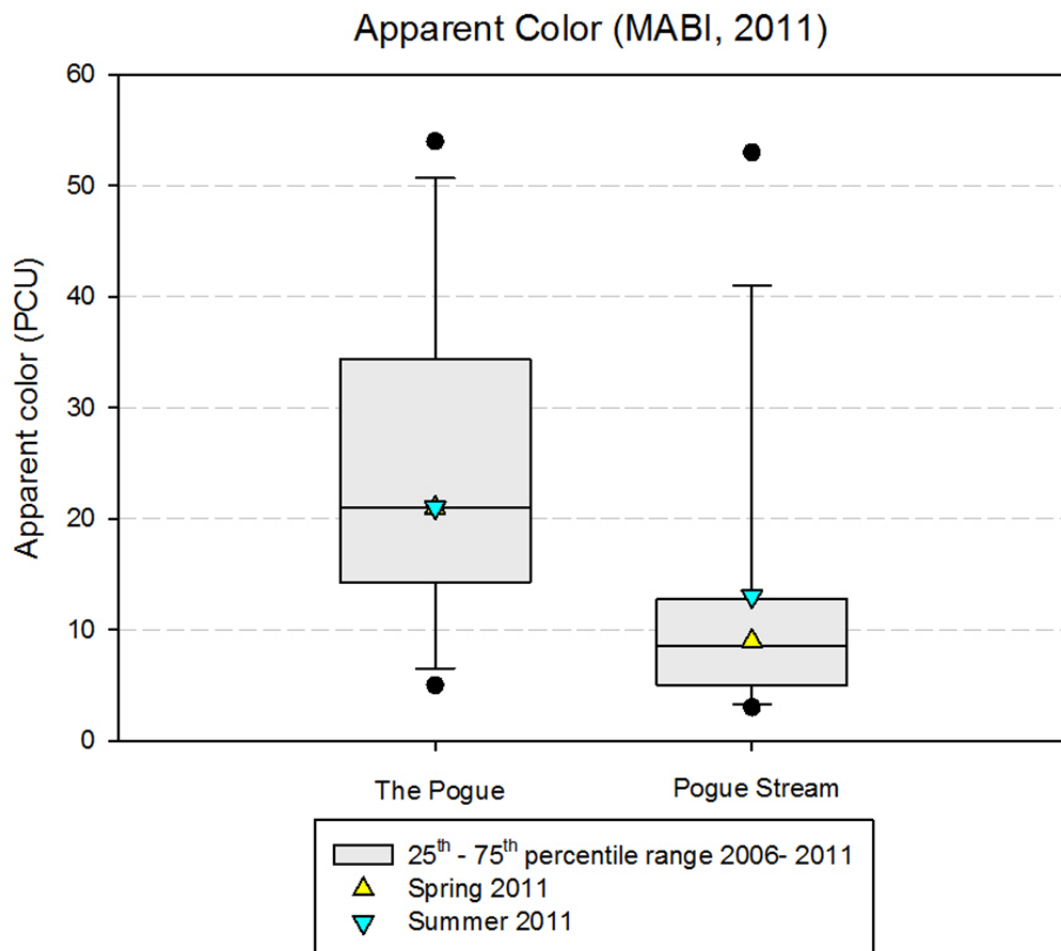


Figure 8. Apparent color from 2011 spring and summer water samples overlaid on a box plot of measurements taken from 2006-2011.

Nutrient Enrichment

Nutrient enrichment and the acceleration of eutrophication have been identified in most NETN parks as one of the stressors of greatest concern. Several forms of total and dissolved phosphorus and nitrogen, and transparency (water clarity, measured with a Secchi disk or turbidity tube), are measured to give managers information regarding the trophic status and productivity of freshwater systems.

Transparency

Transparency measurements can provide simple and affordable assessments of pond and lake productivity. Variation in precipitation is one of the major factors contributing to annual shifts in transparency. Often during drier conditions lakes and ponds will become clearer due to lower runoff of nutrient and soil inputs. In contrast, decreased transparency readings can often be attributed to the effects of high levels of spring and fall precipitation, as well as the cumulative effects of a high rainfall year.

It is difficult to obtain transparency measurements with a Secchi disk (Figure 9) in the Pogue. Due to the water clarity and shallow depth, the disk hit the pond bottom before disappearing from the observer's view in all 2011 measurements. In measurements taken with the 120 cm turbidity tube, the small target disk on the bottom of the tube was always still visible through 120 cm of pond water. Beginning in 2012, the NETN will measure light attenuation using an underwater photocell to provide additional information on the water clarity and trophic characteristics of the Pogue. Stream turbidity (of Pogue Stream) will also be measured in the field with an electronic meter.



Figure 9. Secchi disk, measuring tape, and viewing scope (left) and view of submerged Secchi disk through viewing scope (right).

Phosphorus

Phosphorus (P) is one of the major nutrients needed for plant growth. It is generally present in small amounts and limits the plant growth in streams and ponds. Several forms of phosphorus were tested individually. Total phosphorus (TP) is a measure of both inorganic and organic forms of phosphorus, and is the common water quality standard or criteria metric. Phosphorus can be present as dissolved or particulate matter, and filtered samples were analyzed for total dissolved phosphorus (TDP). Soluble reactive phosphorus (SRP, or “orthophosphate”) is a measure of the inorganic oxidized form of soluble phosphorus. This form of phosphorus is the most readily available for uptake during photosynthesis. High concentrations of SRP generally occur in conjunction with algal blooms.

In 2011, all phosphorus concentrations were relatively low, with very little seasonal (spring/summer) variation (Figure 10). Although the Pogue TP values slightly exceeded the EPA Region 8 criterion of $8\mu\text{g/L}$, they were within the expected range for a shallow, relatively productive pond. As described above (“Water Quality Standards”), the EPA criteria do not have any regulatory meaning. There are no numeric Vermont water quality standards for phosphorus.

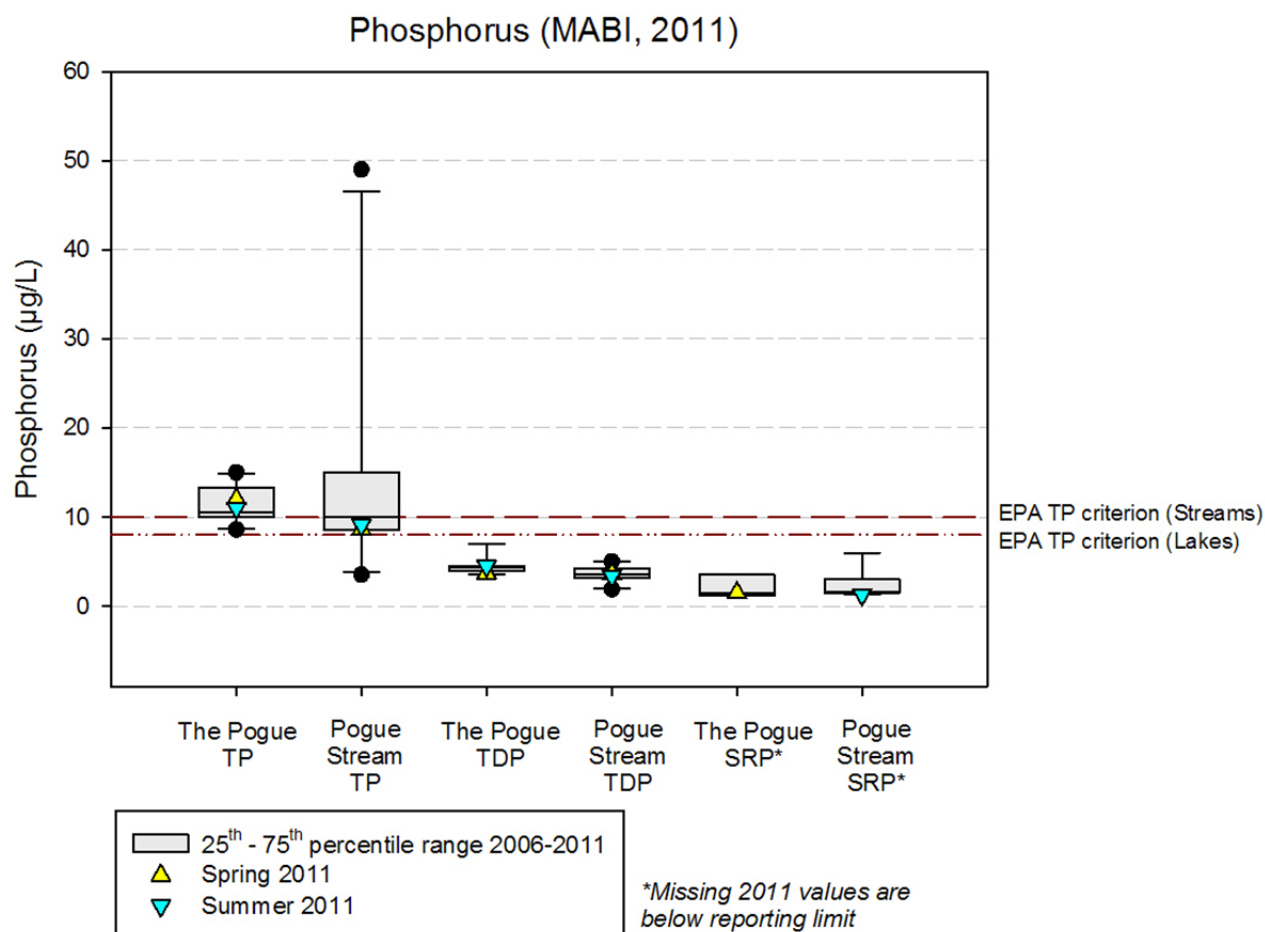


Figure 10. Total phosphorus (TP), total dissolved phosphorus (TDP), and soluble reactive phosphorus (SRP) from spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2006-2011.

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. Filtered samples were analyzed for total dissolved nitrogen (TDN). 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.

Test results for several forms of nitrogen are shown in Figure 11. Although summer TN and TDN values were the highest in the NETN data history at MABI, all stream TN measurements were below the EPA Region 8 criterion of 0.24 mg/L, and well below the state total nitrogen standard of 2.0 mg/L. Nitrate (NO_3) 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_2) is an unstable form 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. NETN water samples were analyzed with a combined test for nitrate and nitrite, as well as individual nitrite tests, and all results were very low. Several test results were below the method reporting limit of 0.005 mg/L. Ammonia (NH_3 , another inorganic, bioavailable form of concern) levels were also very low.

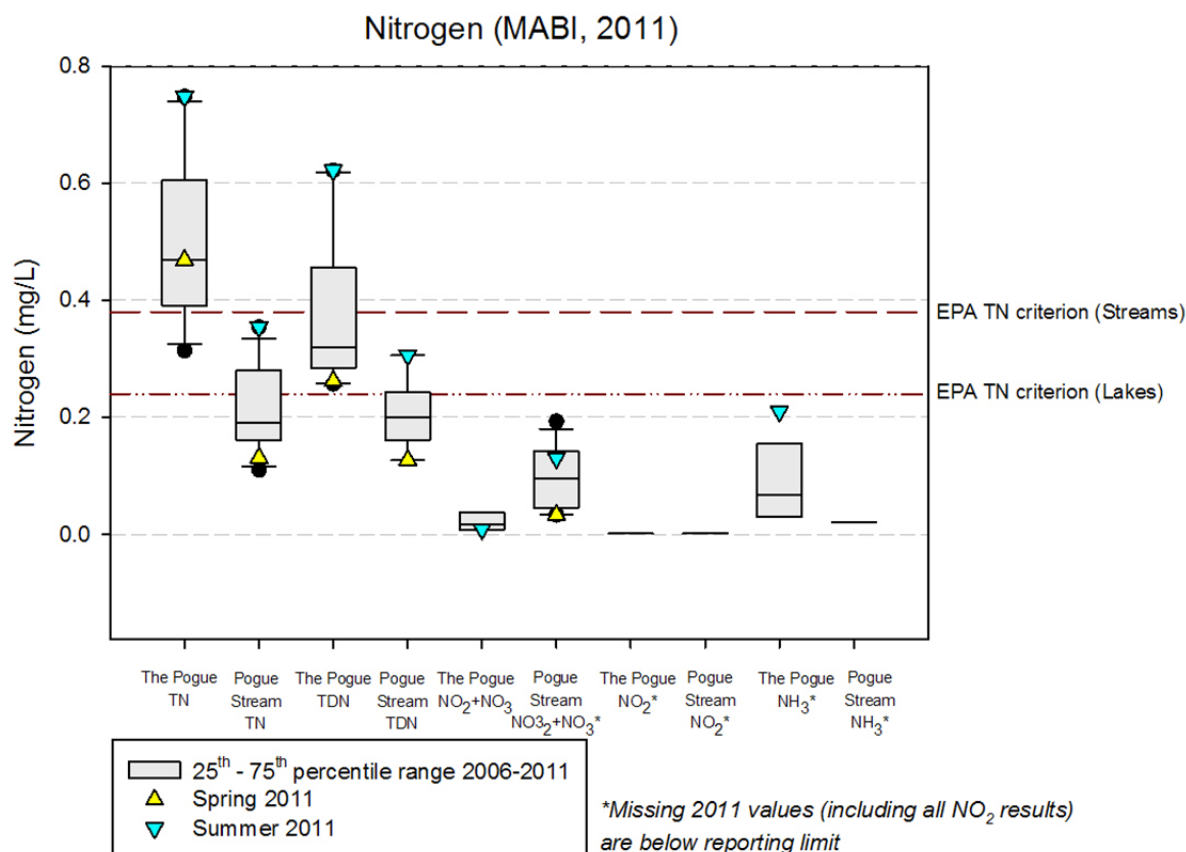


Figure 11. Total nitrogen (TN), total dissolved nitrogen (TDN), nitrite + nitrate (NO_2+NO_3), and nitrite (NO_2) from 2011 spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2006-2011. The state total nitrogen standard is 2.0 mg/L.

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 times concentration), and also provide a record of variations in stream flow. Discharge measurements from 2006 to 2011 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 12) were taken by measuring to the water surface from a fixed datum point. NETN staff are currently reviewing 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 2006 to 2011 are listed in Table A3 and A4 in Appendix A.

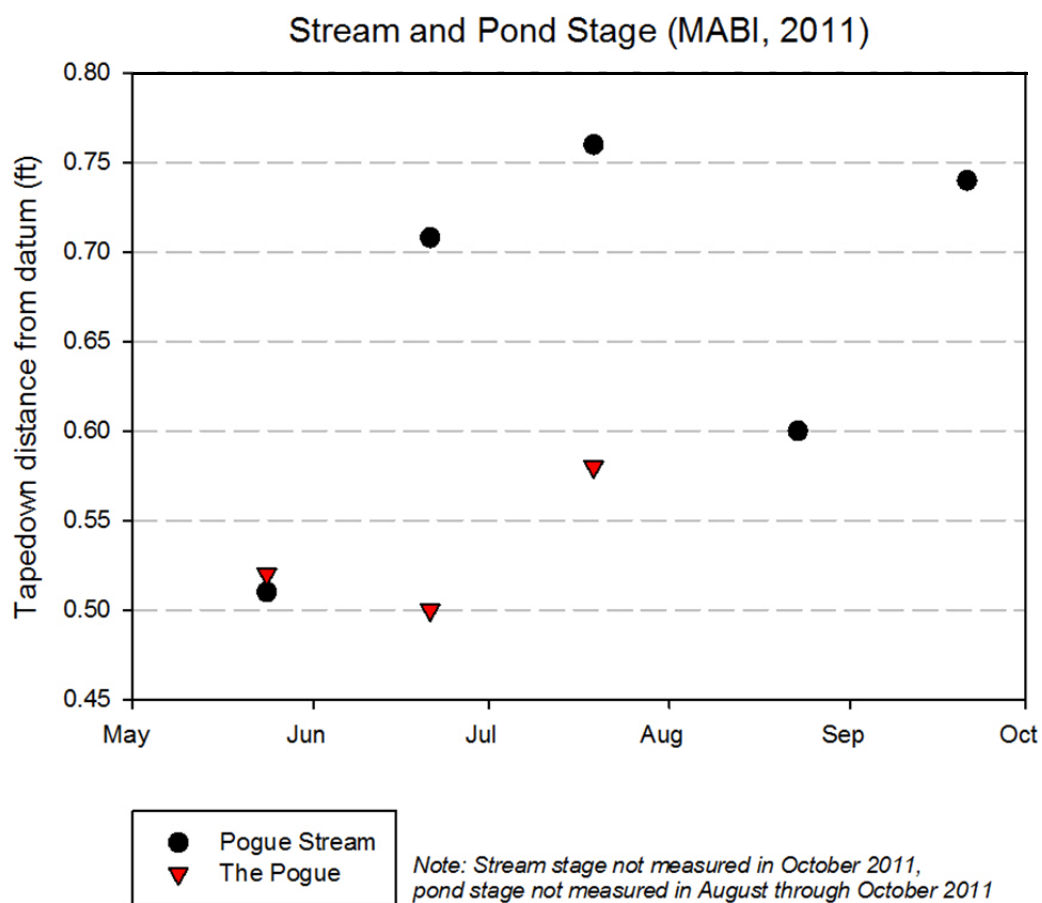


Figure 12. Stream stage obtained in 2011 by measuring from a permanent datum point down to the water surface. Note: Larger tapedown distances indicate LOWER water levels.

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; Williams 2010). 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 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 from the USGS Nonindigenous Aquatic Species website (<http://nas3.er.usgs.gov/>). The database was queried to obtain species of concern for each of the states containing NETN park units. This list includes some species that have not been located in some states in which the NETN monitors (CT, NH, VT), but are of regional concern. 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).

Table 3. Maine Center for Invasive Aquatic Plants species of concern. Species in bold are targeted on the Vermont Water Quality Division aquatic invasive species website.

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. U.S. Geological Survey Nonindigenous Aquatic Species of concern. Species in bold are targeted on the Vermont Water Quality Division aquatic invasive species website.

Common name	Latin name	State(s) listed
Flowering Rush	<i>Butomus umbellatus</i>	NY, CT, VT
Pond water-starwort	<i>Callitriche stagnalis</i>	NY, CT, MA
Water Hyacinth	<i>Eichhornia crassipes</i>	NY
Yellow Iris	<i>Iris pseudacorus</i>	NY, NH, VT, MA, CT
Dotted Duckweed	<i>Landoltia salicaria</i>	MA
Water Primrose	<i>Ludwigia hexapetala</i>	NY
Purple Loosestrife	<i>Lythrum salicaria</i>	NY, MA, CT, NH, VT
European Water-clover	<i>Marsilea quadrifolia</i>	NY, CT
Water-cress	<i>Nasturtium officinale</i>	NY, CT, NH, VT, MA
Sacred Lotus	<i>Nelumba nucifera</i>	NY
Water Lettuce	<i>Pistia straitotes</i>	NY
Amphibious Yellow-cress	<i>Rorippa amphibia</i>	NY, CT, VT

Invasive aquatic plant monitoring was conducted at the Pogue during the 2011 monitoring season. Results indicated that invasive aquatic plants do not currently exist at the Pogue.

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 alga that has recently invaded the northern reaches of the Connecticut River in New Hampshire and in the White River and Battenkill River 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 is easily spread by even just one cell of the alga breaking off and drifting downstream in infested reaches. It is also very easily spread by waders and, potentially, by water monitoring equipment and other gear that touches the bottoms of streams in infested areas. Enhanced equipment cleaning and decontamination procedures are being included in the latest NETN monitoring protocol revision.

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.

Summary

All water quality parameters for the Pogue and Pogue Stream are within state standards (with the exception of the Pogue pH of 8.59 in June), and are generally within the range of EPA criteria, where applicable. The values are within the ranges of the historic NETN monitoring data, although summer total nitrogen levels were the highest reported to date. Both water bodies were well buffered, with pH values between 8.0 and 8.5, and are unlikely to be affected by atmospheric acid deposition. Nutrient levels are low (nitrogen) to low-moderate (phosphorus) but could be susceptible to increased loading from runoff. There were no indications that any significant nutrient enrichment took place during the 2011 season. The implementation of more sensitive measures of water clarity and turbidity in the 2012 season will provide additional information on the water clarity and trophic characteristics of the Pogue and Pogue Stream.

Six years of monitoring under the NETN protocol have provided critical baseline information on the chemical and physical status of the Pogue and Pogue Stream. Refinements of the monitoring protocol and enhanced quality assurance and quality control procedures have improved the data quality with each subsequent year, allowing a better understanding of the seasonal and temporal variability of individual constituents within each water body. 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, 2006-2011.

Table A1. YSI sonde in-situ water quality measurements collected at MABI.

Site	Date	Depth (m)	Temp (C)	DO (mg/L)	pH	Sp Cond (uS/cm)
The Pogue	7/20/2006	0.0	29.19	9.59	8.49	166
	7/20/2006	0.0	29.19	9.72	8.49	166
	7/20/2006	0.0	29.26	9.37	8.48	166
	7/20/2006	1.0	28.52	10.19	8.52	165
	7/20/2006	1.0	28.19	10.12	8.54	164
	7/20/2006	1.9	27.81	11.48	8.65	159
	7/20/2006	2.0	27.90	11.19	8.62	160
The Pogue	8/23/2006	0.0	22.69	8.12	8.25	166
	8/23/2006	1.0	22.66	8.19	8.16	166
	8/23/2006	2.0	22.63	8.30	8.15	165
The Pogue	9/13/2006	0.0	18.26	9.55	8.36	174
	9/13/2006	1.0	18.22	9.70	8.21	168
	9/13/2006	2.0	18.09	9.41	8.14	168
The Pogue	10/11/2006	0.0	13.94	8.67	8.01	177
	10/11/2006	1.0	13.76	8.81	7.99	177
	10/11/2006	2.0	13.76	8.85	7.97	177
The Pogue	5/8/2007	0.0	16.65	11.84	8.34	181
	5/8/2007	1.0	15.91	12.33	8.40	181
	5/8/2007	2.0	15.32	12.76	8.46	179
	5/8/2007	2.7	13.82	3.24	7.96	213
The Pogue	6/7/2007	0.0	20.62	8.96	8.30	175
	6/7/2007	1.0	20.24	9.00	8.31	174
	6/7/2007	2.0	19.60	9.99	8.43	171
	6/7/2007	2.6	19.23	5.96	7.84	230
The Pogue	7/2/2007	0.0	22.14	7.62	8.08	172
	7/2/2007	1.0	22.08	7.84	8.07	172
	7/2/2007	2.0	22.02	8.22	8.13	171
	7/2/2007	2.5	22.22	8.08	7.95	193
The Pogue	8/14/2007	0.0	25.23	8.02	8.02	167
	8/14/2007	1.0	24.50	8.02	8.04	166
	8/14/2007	2.0	23.91	9.22	8.13	162
	8/14/2007	2.4	23.65	1.19	6.94	283
The Pogue	9/10/2007	0.0	21.29	7.26	8.04	171
	9/10/2007	1.0	21.29	7.27	8.04	171
	9/10/2007	2.0	21.28	7.11	8.01	172
	9/10/2007	2.4	21.29	2.33	7.24	210
The Pogue	10/11/2007	0.0	16.41	6.70	7.93	185
	10/11/2007	1.0	16.41	6.64	7.89	185
	10/11/2007	2.0	16.40	6.62	7.86	185
	10/11/2007	2.5	16.80	1.31	7.64	199
The Pogue	5/20/2008	0.0	16.73	10.94	8.56	157
	5/20/2008	1.0	16.42	11.33	8.61	157
	5/20/2008	2.0	16.23	11.55	8.63	156
	5/20/2008	2.5	15.57	3.34	7.02	262
The Pogue	6/17/2008	0.0	23.66	8.07	8.06	161
	6/17/2008	0.0	24.32	7.68	8.15	156
	6/17/2008	1.0	23.67	8.01	8.08	162
	6/17/2008	1.0	24.23	7.77	8.17	155
	6/17/2008	2.0	24.12	7.70	8.14	155

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

Site	Date	Depth (m)	Temp (C)	DO (mg/L)	pH	Sp Cond (uS/cm)
The Pogue	6/17/2008	2.0	23.58	7.92	8.07	162
	6/17/2008	2.5	23.38	6.65	6.93	178
	6/17/2008	2.5	24.07	7.45	7.86	155
The Pogue	8/22/2008	0.0	24.40	9.53	8.58	154
	8/22/2008	1.0	22.28	9.68	8.57	153
	8/22/2008	2.0	21.92	10.32	8.65	152
	8/22/2008	2.3	21.91	8.23	8.40	157
The Pogue	9/24/2008	0.0	19.16	9.46	8.24	164
	9/24/2008	1.0	17.44	9.10	8.22	164
	9/24/2008	2.0	17.19	9.95	8.31	162
	9/24/2008	2.3	17.19	9.97	8.25	162
The Pogue	10/13/2008	0.0	13.65	9.87	8.09	177
	10/13/2008	1.0	13.64	9.68	8.06	177
	10/13/2008	2.0	13.57	9.48	8.02	178
	10/13/2008	2.5	13.49	9.08	7.99	179
The Pogue	5/7/2009	0.0	15.51	10.72	8.40	171
	5/7/2009	1.0	15.53	10.69	8.40	171
	5/7/2009	2.0	15.51	10.63	8.38	171
	5/7/2009	2.6	15.45	10.48	8.32	170
The Pogue	6/18/2009	0.0	20.67	8.87	8.08	167
	6/18/2009	1.0	20.66	8.88	8.09	167
	6/18/2009	2.0	20.63	8.82	8.08	167
	6/18/2009	2.6	20.61	8.73	7.99	168
The Pogue	7/21/2009	0.0	24.11	10.59	8.46	169
	7/21/2009	1.0	24.00	10.67	8.42	170
	7/21/2009	2.0	23.62	9.38	8.05	174
	7/21/2009	2.2	23.42	9.42	8.04	173
The Pogue	8/27/2009	0.0	24.99	7.26	8.01	186
	8/27/2009	1.0	23.72	7.46	8.04	185
	8/27/2009	2.0	23.22	7.59	8.02	184
	8/27/2009	2.5	23.15	7.91	7.99	183
The Pogue	10/1/2009	0.0	14.86	9.00	8.06	190
	10/1/2009	1.0	14.79	9.05	8.06	190
	10/1/2009	2.0	14.75	9.11	8.01	189
	10/1/2009	2.6	14.74	9.25	7.92	189
The Pogue	10/22/2009	0.0	9.03	10.64	8.44	193
	10/22/2009	1.0	8.45	10.64	8.43	193
	10/22/2009	2.0	8.04	10.57	8.37	194
	10/22/2009	2.2	8.03	10.24	8.33	194
The Pogue	5/25/2010	0.0	26.09	10.00	8.49	173
	5/25/2010	1.0	23.34	11.36	8.57	170
	5/25/2010	2.0	22.60	12.27	8.68	167
	5/25/2010	2.4	22.57	12.46	8.70	166
The Pogue	6/15/2010	0.0	20.99	8.68	8.36	170
	6/15/2010	1.0	19.75	8.89	8.38	169
	6/15/2010	2.0	19.28	9.69	8.49	167
	6/15/2010	2.5	19.17	1.59	7.02	233
The Pogue	7/8/2010	0.0	28.74	9.33	8.82	159
	7/8/2010	1.0	28.59	8.73	8.63	160
	7/8/2010	2.0	26.68	10.25	8.64	158
The Pogue	8/11/2010	0.0	27.85	8.64	7.93	166
	8/11/2010	1.0	25.83	9.25	7.96	165
	8/11/2010	2.0	24.98	8.94	7.80	167
The Pogue	8/11/2010	3.0	24.14	0.34	6.88	238
	9/8/2010	0.0	22.13	8.52	8.18	170

Appendix A. MABI Water Monitoring Data, 2006-2011(continued).

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

The Pogue	9/8/2010	1.0	22.05	8.57	8.15	169
	9/8/2010	2.0	22.00	7.93	8.09	169
	9/8/2010	2.4	21.97	7.45	7.92	171
The Pogue	10/5/2010	0.0	15.57	8.88	7.99	168
	10/5/2010	1.0	15.44	8.92	8.00	168
	10/5/2010	2.0	15.31	9.14	8.01	167
	10/5/2010	2.3	15.85	4.92	6.89	245
The Pogue	5/24/2011	0.0	18.63	10.69	8.46	161
	5/24/2011	1.0	18.07	11.13	8.54	160
	5/24/2011	2.0	17.06	11.68	8.56	159
	5/24/2011	2.8	15.83	0.36	6.80	214
The Pogue	6/21/2011	0.0	25.03	10.05	8.59	162
	6/21/2011	1.0	23.40	10.80	8.61	160
	6/21/2011	2.0	22.90	11.29	8.69	159
	6/21/2011	2.4	21.50	1.61	6.86	216
The Pogue	7/19/2011	0.0	28.81	7.92	8.32	158
	7/19/2011	1.0	26.50	9.28	8.51	153
	7/19/2011	2.0	25.88	8.96	8.45	154
	7/19/2011	2.6	25.49	7.69	8.12	217
The Pogue	8/23/2011	0.0	23.10	8.30	8.21	154
	8/23/2011	1.0	22.74	8.29	8.16	154
	8/23/2011	2.0	22.40	8.56	8.18	154
	8/23/2011	2.6	22.28	6.24	7.42	205
The Pogue	9/21/2011	0.0	19.19	7.97	7.89	169
	9/21/2011	1.0	17.09	8.59	7.81	166
	9/21/2011	2.1	16.85	8.71	7.87	166
	9/21/2011	2.2	16.85	8.69	7.61	166
The Pogue	10/13/2011	0.0	14.62	8.11	7.93	176
	10/13/2011	1.0	14.61	7.16	7.89	176
	10/13/2011	2.0	14.58	6.97	7.88	176
	10/13/2011	2.6	14.85	6.79	7.31	262
Pogue Stream	5/16/2006	0.3	9.09	11.32	8.04	125
Pogue Stream	6/13/2006	0.3	14.57	9.79	8.14	147
Pogue Stream	8/23/2006	0.3	15.33	9.61	8.33	199
Pogue Stream	9/13/2006	0.3	11.88	10.47	8.17	213
Pogue Stream	10/11/2006	0.3	9.92	10.87	8.07	199
Pogue Stream	4/4/2007	0.3	0.79	13.72	7.76	133
Pogue Stream	5/8/2007	0.3	11.21	10.73	8.05	150
Pogue Stream	6/7/2007	0.3	11.07	10.65	8.15	177
Pogue Stream	7/2/2007	0.3	11.20	10.57	7.98	209
Pogue Stream	8/14/2007	0.3	14.97	9.55	7.95	234
Pogue Stream	9/10/2007	0.3	14.96	9.72	7.89	210
Pogue Stream	10/11/2007	0.3	11.85	10.17	7.86	223
Pogue Stream	5/20/2008	0.3	9.18	10.90	8.11	149
Pogue Stream	6/17/2008	0.3	14.30	9.61	8.12	191
Pogue Stream	6/17/2008	0.3	14.22	9.73	8.12	191
Pogue Stream	7/21/2008	0.3	17.01	9.16	8.12	202
Pogue Stream	8/22/2008	0.3	14.68	9.89	7.99	208
Pogue Stream	9/24/2008	0.3	10.39	10.64	7.94	220
Pogue Stream	10/13/2008	0.3	8.59	11.24	8.10	229
Pogue Stream	5/7/2009	0.3	10.20	10.90	8.08	138
Pogue Stream	6/18/2009	0.3	11.62	10.59	8.13	176
Pogue Stream	7/21/2009	0.3	15.80	10.32	8.12	179
Pogue Stream	7/21/2009	0.3	15.79	10.51	8.12	176
Pogue Stream	8/27/2009	0.3	14.62	9.95	8.20	200
Pogue Stream	10/1/2009	0.3	8.09	11.56	8.12	210
Pogue Stream	10/22/2009	0.3	7.74	11.55	8.67	209

Appendix A. MABI Water Monitoring Data, 2006-2011(continued).

Table A1. YSI sonde in-situ water quality measurements collected at MABI.

Site	Date	Depth (m)	Temp (C)	DO (mg/L)	pH	Sp Cond (uS/cm)
Pogue Stream	5/25/2010	0.3	15.90	9.54	7.88	179
Pogue Stream	5/25/2010	0.3	15.88	9.82	8.22	180
Pogue Stream	6/15/2010	0.3	12.38	10.38	8.34	191
Pogue Stream	7/8/2010	0.3	18.49	9.14	8.18	212
Pogue Stream	8/11/2010	0.3	18.01	9.12	8.24	210
Pogue Stream	9/8/2010	0.3	15.53	9.17	7.97	235
Pogue Stream	10/5/2010	0.3	11.03	10.82	8.09	195
Pogue Stream	5/24/2011	0.3	14.11	10.17	8.16	143
Pogue Stream	6/21/2011	0.3	14.49	10.00	8.08	185
Pogue Stream	6/21/2011	0.3	14.55	9.62	8.13	148
Pogue Stream	7/19/2011	0.3	17.85	9.11	8.11	208
Pogue Stream	8/23/2011	0.3	15.83	9.62	8.16	178
Pogue Stream	9/21/2011	0.3	13.16	10.31	8.06	170
Pogue Stream	10/13/2011	0.3	11.60	10.23	8.04	169

Appendix A. MABI Water Monitoring Data, 2006-2011(continued).

Table A2. Laboratory nutrient chemistry data for Marsh-Billings-Rockefeller NHP. “<MRL” indicates the result was below the method reporting limit (provided after the abbreviation). *Missing values indicate data are unavailable.*

Site	Date	ANC (µeq/L)	Apparent Color (PCU)	TP (µg/L)	TDP (µg/L)	SRP (µg/L)	TN (mg/L)	TDN (mg/L)	NO ₂ +NO ₃ (mg/L)	NO ₂ (mg/L)	NH ₃ (mg/L)
The Pogue	6/13/2006	1,640	5	<MRL 20		<MRL 6	0.41		<MRL 0.060	0.001	0.006
The Pogue	8/23/2006	1,660	13	<MRL 20		4	0.50		<MRL 0.060	<MRL 0.002	0.068
The Pogue	6/7/2007	1,654	10	10	<MRL 6	3	0.43	0.32	0.041	0.001	0.053
The Pogue	8/14/2007	1,615	18	13	7	<MRL 6	0.72	0.58	<MRL 0.016	<MRL 0.002	0.099
The Pogue	6/17/2008	1,496	22	10	4	<MRL 1	0.35	0.26	0.008	<MRL 0.005	
The Pogue	8/22/2008	1,380	37	14	4	<MRL 1	0.47	0.32	<MRL 0.005	<MRL 0.005	<MRL 0.08
The Pogue	8/27/2009	1,840	54	15	4	2	0.61	0.42	0.025	<MRL 0.005	<MRL 0.08
The Pogue	6/18/2009	1,650	19	10	4	1	0.31	0.29	<MRL 0.005	<MRL 0.005	<MRL 0.08
The Pogue	6/15/2010	1,700	21	10	4	1	0.38	0.32	<MRL 0.005	<MRL 0.005	<MRL 0.08
The Pogue	8/11/2010	1,700	43	13	4	<MRL 1	0.59	0.41	<MRL 0.005	<MRL 0.005	<MRL 0.08
The Pogue	8/23/2011	1,540	27	11	5	<MRL 1	0.75	0.62	0.009	<MRL 0.005	0.210
The Pogue	6/21/2011	1,580	21	9	4	<MRL 1	0.47	0.26	<MRL 0.005	<MRL 0.005	<MRL 0.08
Pogue Stream	8/23/2006	2,000	13	<MRL 20		6	0.18		0.096	<MRL 0.002	0.024
Pogue Stream	6/13/2006	1,440	5	<MRL 20		3	0.19		0.037	<MRL 0.002	0.017
Pogue Stream	8/14/2007	2,367	3	10	5	6	0.28	0.27	0.193	<MRL 0.002	<MRL 0.02
Pogue Stream	5/8/2007	1,416	5	12	3	<MRL 6	0.27	0.20	0.150	0.002	<MRL 0.02
Pogue Stream	5/20/2008	1,435	4	4	2	2	0.11	<MRL 0.1	0.065	<MRL 0.005	
Pogue Stream	8/22/2008	1,970	8	24	4	2	0.17	0.18	0.101	<MRL 0.005	<MRL 0.08
Pogue Stream	8/27/2009	2,020	9	7	3	3	0.16	0.17	0.087	<MRL 0.005	<MRL 0.08
Pogue Stream	5/7/2009	1,370	53	49	4	2	0.29	0.15	0.039	<MRL 0.005	<MRL 0.08
Pogue Stream	8/11/2010	2,190	12	10	3	1	0.19	0.22	0.094	<MRL 0.005	<MRL 0.08
Pogue Stream	5/25/2010	1,770	8	10	5	2	0.28	0.22	0.145	<MRL 0.005	<MRL 0.08
Pogue Stream	8/23/2011	1,800	13	9	3	1	0.35	0.31	0.130	<MRL 0.005	<MRL 0.08
Pogue Stream	5/24/2011	1,390	9	12	4	2	0.13	0.13	0.033	<MRL 0.005	<MRL 0.08

Table A3. Stream stage and discharge data for Marsh-Billings-Rockefeller NHP. *Missing values indicate data are unavailable.*

Site	Date	Tapedown from datum (ft)	Total cross section area (sqft)	Average velocity (f/s)	Discharge (cfs)
Pogue Stream	5/16/2006		1.98	1.06	2.50
Pogue Stream	6/13/2006		1.21	0.65	0.95
Pogue Stream	8/23/2006		0.31	0.45	0.13
Pogue Stream	9/13/2006	1.00	0.29	0.35	0.11
Pogue Stream	10/11/2006		0.48	0.23	0.11
Pogue Stream	5/8/2007	0.60	0.96	0.57	0.56
Pogue Stream	6/7/2007	0.68	0.40	0.67	0.26
Pogue Stream	7/2/2007	0.83	0.19	0.33	0.06
Pogue Stream	8/14/2007	dry	0.14	0.16	0.02
Pogue Stream	9/10/2007	0.76	0.22	0.30	0.07
Pogue Stream	10/11/2007	0.67	0.17	0.24	0.03
Pogue Stream	5/20/2008	0.63	0.39	0.73	0.31
Pogue Stream	6/17/2008	0.78	0.23	0.35	0.10
Pogue Stream	7/21/2008	0.75	0.19	0.90	0.18
Pogue Stream	8/22/2008	0.79			
Pogue Stream	9/24/2008	0.79			
Pogue Stream	10/13/2008	0.74	0.39	0.16	0.05
Pogue Stream	5/7/2009	0.40	1.81	0.96	1.73
Pogue Stream	6/18/2009	0.71	0.60	0.40	0.24
Pogue Stream	7/21/2009	0.69	0.75	0.54	0.41
Pogue Stream	8/27/2009	0.71	0.32	0.74	0.24
Pogue Stream	10/1/2009	0.55	0.52	0.38	0.20
Pogue Stream	10/22/2009	0.54	0.59	0.30	0.18
Pogue Stream	5/25/2010	0.68	0.46	0.42	0.20
Pogue Stream	6/15/2010		0.43	0.30	0.13
Pogue Stream	7/8/2010	0.92	0.25	0.34	0.09
Pogue Stream	8/11/2010	0.79	0.23	0.29	0.67
Pogue Stream	9/8/2010	0.85	0.18	0.20	0.04
Pogue Stream	10/5/2010	0.65	0.44	0.47	0.21
Pogue Stream	5/24/2011	0.51	0.87	1.25	1.09
Pogue Stream	6/21/2011	0.71	0.32	0.40	0.13
Pogue Stream	7/19/2011	0.76	0.16	0.38	0.06
Pogue Stream	8/23/2011	0.60	0.63	0.56	0.35
Pogue Stream	9/21/2011	0.74	0.97	0.54	0.53
Pogue Stream	10/13/2011		1.66	0.56	1.03

Appendix A. MABI Water Monitoring Data, 2006-2011(continued).

Table A4. Pond stage data for Marsh-Billings-Rockefeller NHP. *Missing values indicate data are unavailable.*

Site	Date	Tapedown from datum (ft)
The Pogue	6/13/2006	
The Pogue	7/20/2006	0.42
The Pogue	8/23/2006	0.42
The Pogue	9/13/2006	
The Pogue	10/11/2006	
The Pogue	4/4/2007	
The Pogue	5/8/2007	0.42
The Pogue	6/7/2007	0.44
The Pogue	7/2/2007	0.67
The Pogue	8/14/2007	0.86
The Pogue	9/10/2007	1.09
The Pogue	10/11/2007	
The Pogue	5/20/2008	0.44
The Pogue	6/17/2008	0.54
The Pogue	7/21/2008	0.54
The Pogue	8/22/2008	
The Pogue	9/24/2008	
The Pogue	10/13/2008	0.58
The Pogue	5/7/2009	0.44
The Pogue	6/18/2009	0.54
The Pogue	7/21/2009	0.42
The Pogue	8/27/2009	0.50
The Pogue	10/1/2009	0.50
The Pogue	10/22/2009	0.50
The Pogue	5/25/2010	0.50
The Pogue	6/15/2010	
The Pogue	7/8/2010	0.54
The Pogue	8/11/2010	0.54
The Pogue	9/8/2010	0.76
The Pogue	10/5/2010	
The Pogue	5/24/2011	0.52
The Pogue	6/21/2011	0.50
The Pogue	7/19/2011	0.58
The Pogue	8/23/2011	
The Pogue	9/21/2011	
The Pogue	10/13/2011	

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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National Park Service
U.S. Department of the Interior



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