Reducing Acidification in Endangered Atlantic Salmon Habitat

Second Year of Clam Shells

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Introduction

Despite restored access to historic Atlantic salmon (*Salmo salar*) habitat in eastern Maine, population sizes have remained low (USASAC 2020). Most Downeast rivers and streams have been identified as acidic (pH <6.5), with headwaters chronically acidic and main stems episodically acidic (Haines et al. 1990; Whiting and Otto 2008). Loss of fish populations due to acidification of surface waters has been well documented in the North Atlantic region (as reviewed by Clair and Hindar 2005; Dennis and Clair 2012). In addition, numerous studies have demonstrated that episodic exposure to low pH can have detrimental, sub-lethal impacts especially when coinciding with key salmon life stages during snow melt and spring runoff (e.g., Kroglund et al. 2008; Lacroix and Knox 2005; as reviewed by McCormick et al. 1998). Adding lime to acidic waters, through application of agricultural lime or lime slurry, has increased salmon populations in Scandinavia and Nova Scotia (as reviewed by Clair and Hindar 2005; Halfyard 2007; Hesthagen et al. 2011), and has been a recommended restoration action for Maine's acidic rivers and streams (NRC 2004). A 2009 Project SHARE pilot study investigating the efficacy of using clam shells to lime small streams suggested a trend towards improved habitat quality (Whiting 2014). For a more detailed project background, see Zimmermann (2018).

To further investigate this mitigation method, the Downeast Salmon Federation (DSF) started a multi-year liming project in the East Machias River watershed in 2019. Clam shells are being spread along the stream bottom, as well as along the banks to capture high flow events (i.e., rainfall and snowmelt, when episodic acidity is expected). The project goal is to increase juvenile salmon abundance by application of clam shells to achieve a target pH, and to evaluate changes in the macroinvertebrate community. From 2017 through summer 2019, baseline data were collected (see Zimmermann 2019). Following the initial application of shells in 2019 (see Zimmermann 2020), an additional 26 cubic meters of shells was spread along a treatment reach in Richardson Brook over two days, July 26 and August 13, 2020. This report investigates any impacts to water quality from the addition of shells.

Methods

<u>Study Location</u>

Four tributary streams to the East Machias River were monitored (Fig. 1; for physical characteristics see Appendix I Table 1 in Zimmermann 2020). These are within the homeland of the Passamaquoddy Tribe of Abenakis. The East Machias River watershed is typical of coastal eastern Maine, with extensive wetlands resulting in colored waters high in organic materials and low in pH, with high summer temperatures (Project SHARE-USFWS 2009; Zimmermann 2020). The existing salmon population in the East Machias River system is low (median large parr density 13.1 per habitat unit, $100m^2$ in 2019), with 30 redds observed in 2020 and an estimated 1289 ± 233 smolts exiting the system in 2019 (Maine Department of Marine Resources, MDMR; DSF; USASAC 2020). In 2020, redd based estimates show only 24 adults returned to the watershed (MDMR). Richardson Brook and Creamer Brook are both stocked by DSF, and the average large parr density observed during fall electrofishing is 11 parr/$100m^2$ and 16 parr/$100m^2$ respectively (Fig. 2, MDMR data). The bedrock geology in the study area is predominantly marine sandstone and slate with some volcanic rocks, especially around Creamer Brook (see Appendix I Table 2 in Zimmermann 2020; Maine Geological Survey – MGS 1985). Beaverdam Stream is stocked with 9-month old salmon parr by DSF and it has some of the most

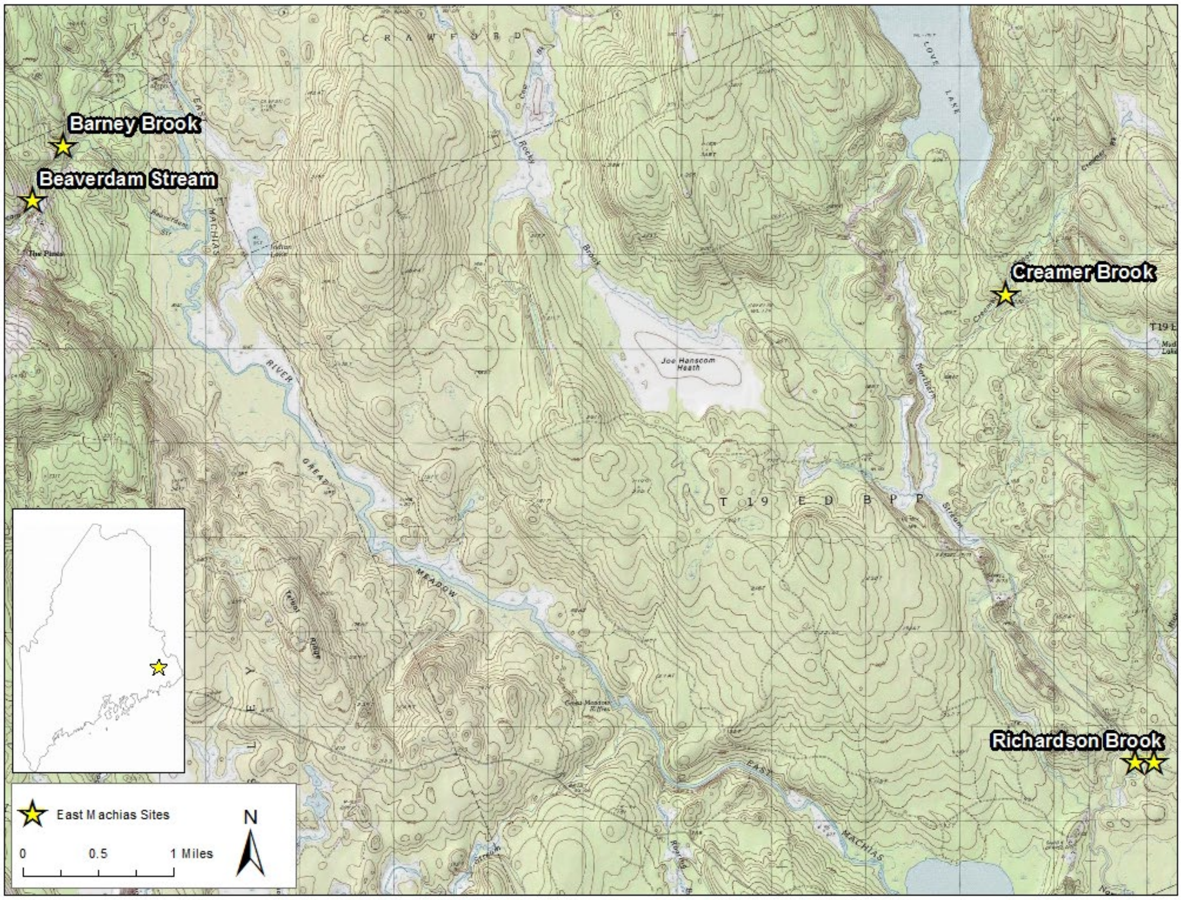

Figure 1. Map of the five study sites on four tributaries to the East Machias River. On Richardson Brook, samples were collected below the road crossing and above the shell treatment reach.

productive salmon habitat in the watershed, with an average of 14 parr/100m^2 (Fig. 2, MDMR data).

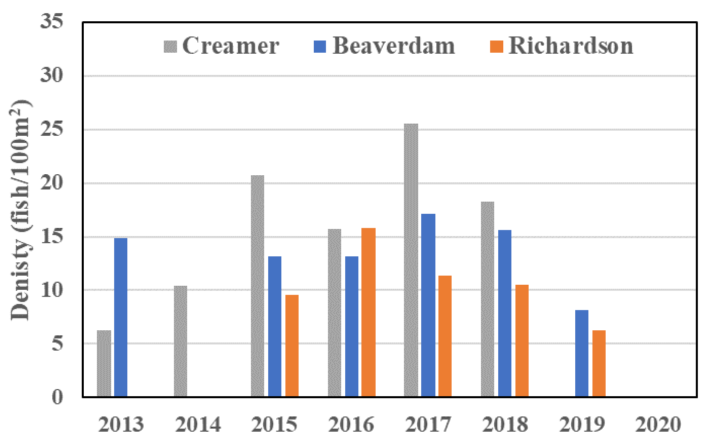

Figure 2. Salmon density in three of the study streams from 2013-2020. High flows prevented data collection in Creamer Brook in 2019. Extremely low flows prevented data collection in 2020. Data from MDMR electrofishing surveys.

<u>Water Quality</u>

Continuous monitoring devices provided water quality data every half hour from April – November 2020 (see Zimmermann 2018 for detailed methods). Grab samples for acid neutralization capacity (ANC), calcium, aluminum species, dissolved organic carbon (DOC), and base cations were collected in April, July, and November (see Zimmermann 2018 for detailed methods). Nutrient samples (nitrogen and phosphorus) were collected but results are not included in this report. With the exception of Barney Brook, macroinvertebrate samples were collected at all sites during baseflow using rock bags following the Maine Department of Environmental Protection (MDEP) Biological

Monitoring Program sampling methods (MDEP 2014). DSF staff collected additional macroinvertebrate data in October at three locations using rock bags, following the Izaac Walton League of America's stream-side identification methods (IWLA.org).

Statistical Analysis

Water quality data were analyzed using the Water Resources Database 6.1.0.71 (Wilson Engineering 2020) and R 3.5.2 (R Core Team 2018). Plots were created using *ggplot2* (Wickham 2009). All data are presented as mean ± standard deviation, unless otherwise stated. Due to the small sample sizes, non-parametric Kruskal-Wallis tests were used to compare water grab sample results between sites, seasons and years, with Dunn's multiple comparison post-hoc tests. In 2020 across all sites, 4.3% of pH data, 2.1% of specific conductance data, and 2.9% of DO data were rejected due to quality control issues. For each parameter, less than 1% of data were rejected due to equipment malfunction.

Results and Discussion

Weather

Maine experienced a mild winter followed by cold, wet weather in late spring of 2020 (NOAA 2020a). Moderate drought conditions developed during the record-breaking hot summer, becoming severe in August to September, and persisted through November (NOAA 2020b; U.S. Drought Monitor 2020; Weather Underground 2020). Rainfall amounts were most similar to 2018 (Fig. 3), however mean stream depths were the lowest observed since monitoring began, averaging 8 cm below the project mean (Zimmermann 2018, 2019, and 2020). Most rain events were of small volume (<20 mm).

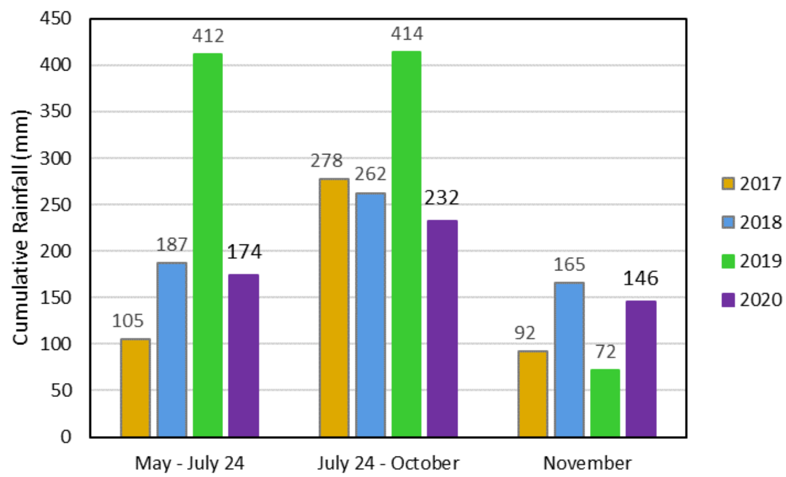

Figure 3. Cumulative annual rainfall. The three time periods represent spring pre-treatment, summer-fall shell treatment, and November post-treatment, based on shell applications in 2019-2020. Data from Weather Underground stations KMEALEXA2, KMEBAILE9 and KMEPRINC2.

pH

Salmon prefer pH values that are circumneutral (6.5-7.5), rather than acidic (<6.5). The impacts of acidity depend on 1.) duration, magnitude, and frequency of the episode, 2.) the ability of the fish to avoid adverse water quality conditions, 3.) the concentration of exchangeable aluminum (Alx), and 4.) the buffering capacity of the water (i.e., ANC and calcium; see Zimmermann 2018a for overview). pH thresholds used in this analysis are estimates of anticipated impacts to salmon populations and do not include a detailed analysis of the impact of other factors.

In the winter following the first shell application in 2019, episodic acidity events continued to occur at the downstream Richardson Brook site (Fig. 4). Winter pH remained close to the critical stress threshold of pH 5.5 (mean 5.5 ± 0.3), below which adverse impacts to salmon populations are expected, dropping below the threshold 62.7% of the time (Haines et al.

1990; Stanley and Trial 1995). Winter pH dropped below the survival threshold of pH 4.5, lethal to all salmon life stages, for 0.5% of the time, lasting on average 4.2 hours (with a maximum duration of 19 hours; Potter 1982). Acidic episodes are driven by rain events, especially those >20 mm.

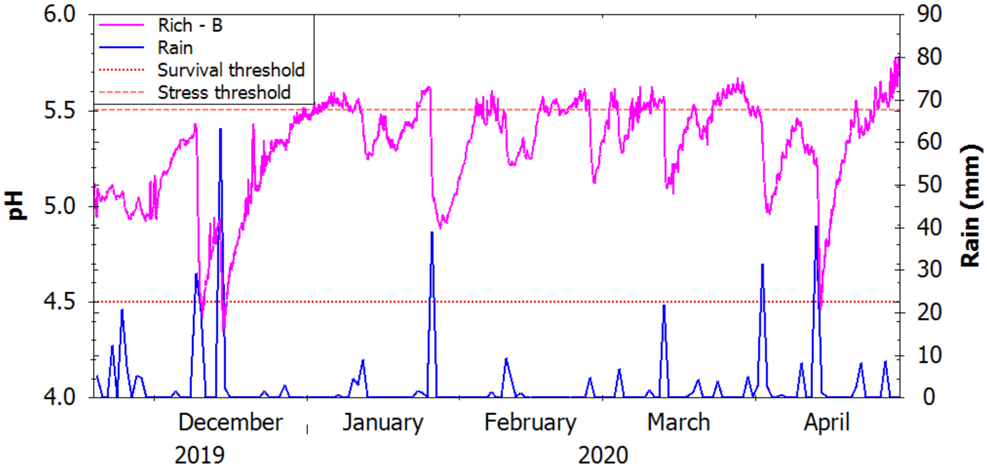

Figure 4. Winter 2019-2020 pH at the downstream Richardson Brook site, within the shell application reach. Stress threshold from Stanley and Trial 1995 and Haines et al. 1990. Survival threshold from Potter 1982. Rainfall data from Weather Underground.

From spring through fall as in the prior three years, at all sites combined, pH values remained mostly above the stress threshold of 5.5 (Fig. 5; Appendix I Tables 1 and 4; Haines et al. 1990; Stanley and Trial 1995; Zimmermann 2020). As in prior years, the only streams with pH above the threshold of 6.5, an optimal minimum pH for the protection of the most sensitive salmon life stages (alevins and smolts), were Barney and Beaverdam Brooks, for roughly half the study period (summer baseflow; Fig. 5; Appendix I

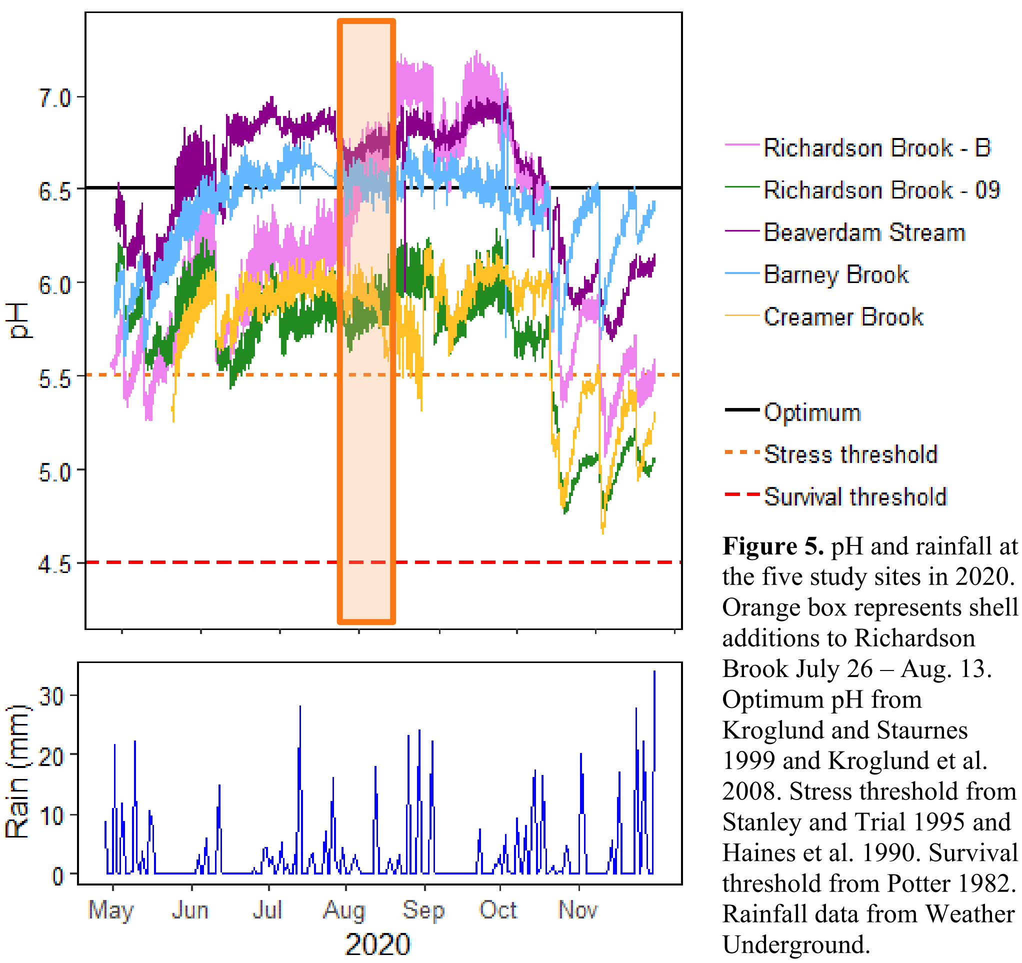

Figure 5. pH and rainfall at the five study sites in 2020. Orange box represents shell additions to Richardson Brook July 26 – Aug. 13. Optimum pH from Kroglund and Staurnes 1999 and Kroglund et al. 2008. Stress threshold from Stanley and Trial 1995 and Haines et al. 1990. Survival threshold from Potter 1982. Rainfall data from Weather Underground.

Tables 1 and 4; Kroglund and Staurnes 1999; Kroglund et al. 2008). In addition, and unlike prior years, pH at the treated Richardson Brook site (Rich-B) also exceeded 6.5, for 28% of the study period (Fig. 5; Appendix I Tables 1 and 4). Few rain events exceeded 20 mm in 2020, resulting in minimal storm-driven pH depressions until two smaller storms occurred in quick succession in mid-October, followed by further rain events in November (Fig. 5). At no site were the rain events significant enough to depress pH below the survival threshold of 4.5 (Potter 1982).

In 2020, the pH was higher than in prior years at both Rich-B (by 0.54 units) and at Beaverdam Stream (by 0.58 units). Following the addition of shells, Rich-B was 0.7 units higher in July and August compared with the baseline years 2017 and 2018, and 0.9 units higher in the following three months (Sept-Nov; Fig. 6 and Appendix I Table 6). The increase in pH at Beaverdam Stream may be due to higher relative contributions from groundwater due to extremely low stream flows. At Rich-B, if groundwater were the main contributing factor to the increase in pH, a similar increase would be expected at the untreated site approximately 0.5 mi upstream (Rich09), but no such change was observed. Unlike during baseline years, Rich-B had higher autumn pH values than the upstream site (Fig. 5). Low November rainfall was thought to explain the increase in pH in 2019 (Zimmermann 2020). However, autumn rainfall in 2020 was approximately double that of 2019 and similar to drier 2018 (Fig. 3), when the upstream site had higher pH than Rich-B (Zimmermann 2019). Therefore, rainfall cannot explain the 2020 increase in pH at the treated Richardson Brook site.

Although sub-lethal stress is still occurring at the treated site, particularly in the fall (Nov.) when 62% of the data were below pH 5.5 (Fig. 5; Baker et al. 1996; Henriksen et al. 1984; Lacroix and Knox 2005; Magee et al. 2003), this is an improvement over the three prior years of the study when values were <5.5 for all of November (Fig. 6; Zimmermann 2020). Stressful acidic events

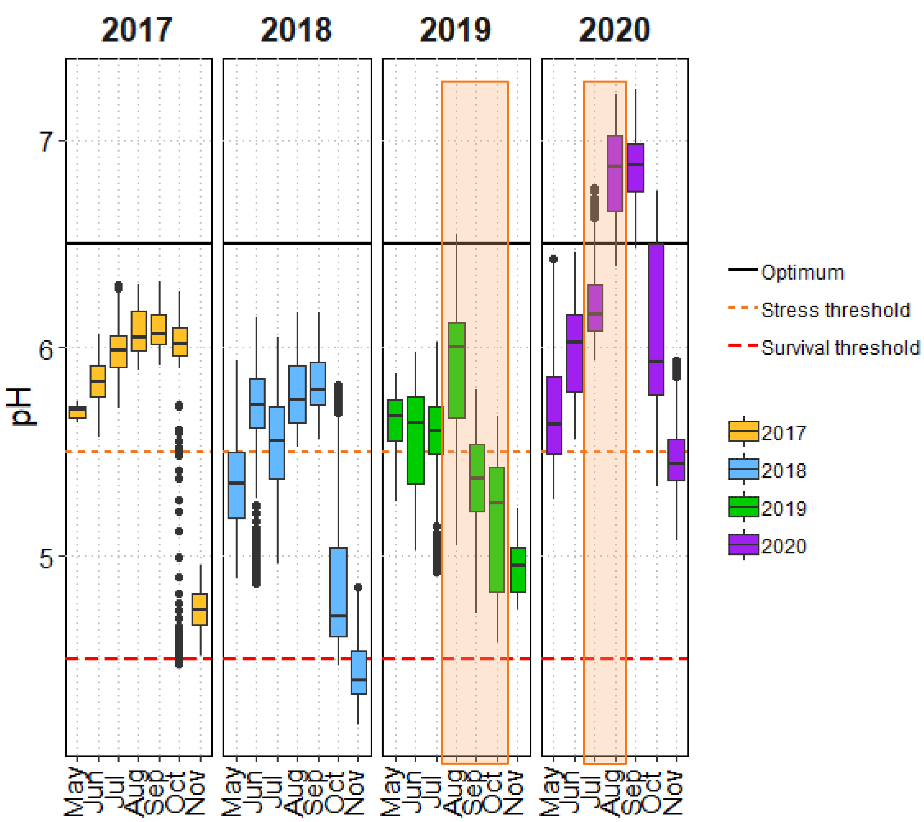

Figure 6. Monthly pH at the downstream Richardson Brook site (Rich-B). Each box represents the interquartile range, with the horizontal line representing the median, and whiskers extending to the minimum and maximum values observed, except where values are considered statistical outliers (dots). Optimum pH from Kroglund and Staurnes 1999 and Kroglund et al. 2008. Stress threshold from Stanley and Trial 1995 and Haines et al. 1990. Survival threshold from Potter 1982. Orange boxes represent shell additions in 2019 and 2020.

(<5.5) lasted for a shorter duration in 2020 (mean 12.7 hrs with a maximum duration of 19 days) as compared with a similarly dry year in 2018 (mean 52.8 hrs with a maximum duration of 56 days). The lack of change in pH in the control streams despite the dry weather suggests that the increase in pH and the decreased duration of episodic acidity events at the treated site are due to the addition of clam shells.

Stream Temperature

Salmon prefer cold waters. Stream temperatures in 2020 were similar to the prior years of the study, remaining below the threshold for optimal growth of 20°C for most of the sampling period (84%; Appendix I Table 1; Jonsson et al. 2001; USEPA 1986; Zimmermann 2020). The stress threshold of 22°C was exceeded 6.9% of the time (Cunjak et al. 2005; Elliott and Elliott 2010; Lund et al. 2002;), USEPA's short-term maxima for survival of 23°C was exceeded 4.4% of the time (USEPA 1986), and the lethal temperature for salmon survival (26-27°C for adults, 28-29°C for parr) was exceeded only 0.04% of the time (Elliott 1991 as cited in Stanley and Trial 1995; Garside 1973 as cited in Lund et al. 2002; Grande and Andersen 1991 as cited in Elliott and Elliott 2010; Shepard 1995 as cited in Frechette et al. 2018). During the hot, dry summer, Barney and Creamer Brooks remained the coldest, possibly due to the relative influence of groundwater during extreme low flows. Stressful temperatures lasted for less than 2 days at all sites, with Barney Brook never exceeding 22°C. As in prior years, sub-lethal stress may be occurring during the hottest parts of the summer.

Specific Conductance

Specific conductance is a measure of the concentration of ions in the water, or the ability of water to conduct electricity. The streams in the study area have very low specific conductance, which can increase the difficulty of accurate pH measurements and electrofishing (Zimmermann 2018). In 2020, specific conductance at the treated site in Richardson Brook attained a maximum value of 79 µS/cm, almost double the maximum observed in prior years at either the upstream or downstream sites (Fig. 7 and Appendix I Table 1; Zimmermann 2020). Extremely low flows may have concentrated the ions in the remaining stream water, however during a similarly dry summer in 2018 no such increase in specific conductance was observed (Zimmermann 2019). Specific conductance began to increase following the first shell addition (July 26, 2020), and continued to increase through Sept. 29, more than a month after the second addition of shells (Aug. 13). Rainfall events greater than 20 mm diluted stream ion concentrations, resulting in temporarily decreased specific conductance (Fig. 7). Specific conductance decreased to levels similar to the upstream control site with the autumn rains. The increase in specific conductance observed during the summer of 2020 was likely due to increased

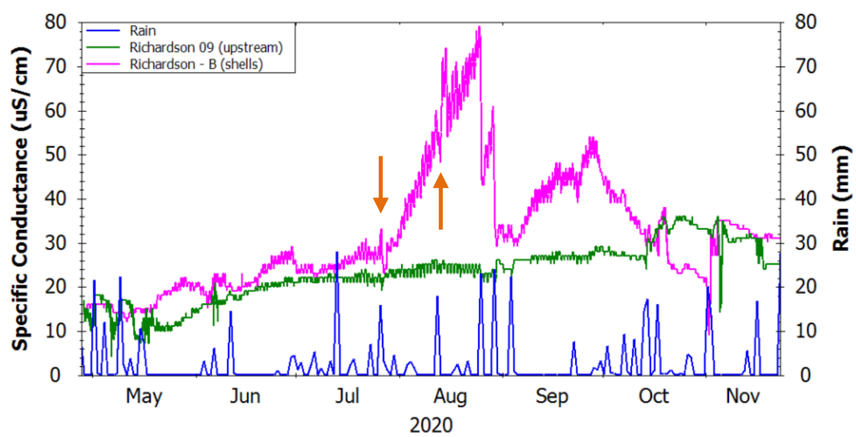

Figure 7. Specific conductance and rainfall at the two Richardson Brook sites in 2020. Orange arrows indicate days on which shells were added at the downstream site. Rainfall data from Weather Underground.

dissolution of the shells into dissolved solids such as sodium, calcium, and chloride. No negative impacts to aquatic life are expected from the increase in specific conductance, however increased ion concentrations (such as calcium) may improve the buffering capacity of the stream.

Dissolved Oxygen (DO)

Salmon prefer well oxygenated waters. As in prior years, DO levels were within a healthy range for fish and aquatic life in addition to the preferred range for salmon of >6-7 mg/L for most of the study period (>90%; Appendix I Tables 1 and 4; Stanley and Trial 1995; USEPA 1986; Zimmermann 2020). DO concentrations fell below the Maine Water Quality Standard of 7 mg/L at all sites during the hot dry summer of 2020, lasting on average 14 hours, with a maximum duration of 6.6 days at Creamer Brook (Appendix I Tables 1 and 4; 38 MRS Section 465.2.B). USEPA's threshold for acute impairment of 5 mg/L was only exceeded at two sites: at the treated Richardson Brook site for one 6-hour period and at Creamer Brook for several days in August, with durations lasting on average 9 hours, with a maximum of 27.5 hours (USEPA 1986). The hot dry summer resulted in DO minima that coincided with the warmest temperatures and lowest flows, increasing stress and possibly preventing movement of salmon to oxygen and temperature refugia, if any existed nearby. During the lowest flows at Creamer Brook, low oxygen likely reduced the survival of aquatic life that were unable to move to refugia.

Acid Neutralization Capacity (ANC)

Streams with higher ANC have a higher capacity to buffer against changes in acidity. As in prior years, summer baseflow stayed consistently above the threshold of acid sensitivity for the protection of the most sensitive aquatic species and life stages of 50 μeq/L (Fig. 8; Appendix I Table 2; Driscoll et al. 2001; Zimmermann 2020). ANC minima were higher at all sites in 2020 compared with prior years, with only one sample below the Norwegian 20-30 μeq/L critical limit for salmon (the upstream Richardson Brook site in the spring; Baker et al. 1990; Lien et al. 1996; Kroglund et al. 2002; Zimmermann 2020). ANC is likely only high enough (>100 μeq/L) for maintenance of the necessary calcium concentration (2 mg/L) during summer baseflows, and primarily only at Barney Brook and Beaverdam Stream (Brocksen et al. 1992). Although ANC at the downstream Richardson Brook site was higher than at the upstream site in 2020, it was not statistically significant. A similar difference between the two sites was observed in the first baseline year of 2017, and therefore the impact cannot be attributed solely to the addition of clamshells (Appendix I, Tables 2 and 6; Zimmermann 2018). No samples were collected during or immediately following shell additions in 2020, during the period when increases in pH and specific conductance were observed. Drought conditions in both 2017 and 2020 may have contributed to the higher values observed. In low DOC waters, ANC is an approximate surrogate for alkalinity (Garmo et al. 2014). As in prior years, no samples were above USEPA's recommended AWQC of 20 mg/L alkalinity (calculated from ANC), however this threshold doesn't apply where values are naturally lower (USEPA 1986). Relatively low ANC values indicate a deficit of buffering materials in the watershed due to thin soils (Potter 1982), allowing volatile swings in pH after rain inputs (Fig. 5) and increasing the potential for salmon mortality (MacAvoy and Bulger 1995).

Calcium

Higher calcium values enable more growth in fish. As in the prior years of the study, calcium was below the survival threshold of 2 mg/L at all sites for most (63%) of the sampling events (Fig. 8; Appendix I Tables 2 and 4; Baker et al. 1990; Baldigo and Murdoch 2007; Zimmermann 2020). Only one sample, Barney Brook during summer baseflow, was above the suggested threshold of 4 mg/L to prevent deformities and other stress (Marcus et al. 1986, as cited in Brocksen et al. 1992). Calcium values were slightly higher at the downstream Richardson Brook compared with prior years, however it was not a statistically significant difference. The absence of the anticipated increase in calcium following the addition of clam shells may be due in part because no samples were collected during or immediately following shell additions in 2020 (Appendix I Table 6), during the period when increases in pH and specific conductance were observed. As in prior years, calcium minima coincided with low pH, high aluminum, and low ANC, however some buffering of Alx is expected to occur during summer baseflow.

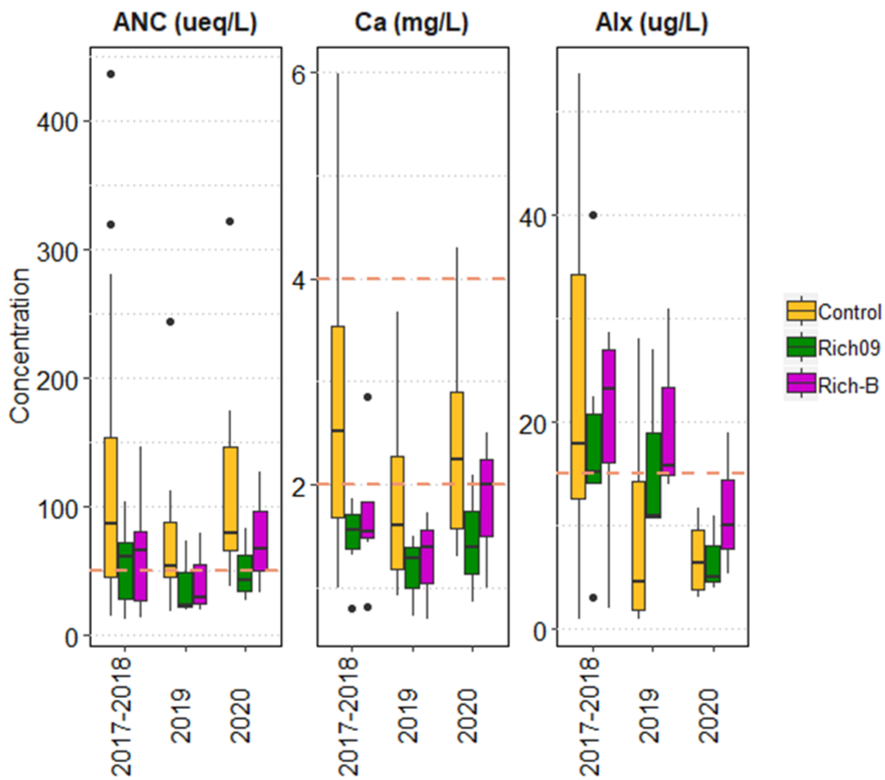

Figure 8. Acid neutralization capacity (ANC), calcium (Ca) and exchangeable aluminum (Alx). 2017-2018 represents baseline conditions. Shells were added to Rich-B in 2019 and 2020. Control includes Creamer and Barney Brooks and Beaverdam Stream. Each box represents the interquartile range, with the horizontal line representing the median, and whiskers extending to the minimum and maximum values observed, except where values are considered statistical outliers (dots). Sample size: control 2017-2018 n = 17; 2019 and 2020 n = 8; Rich09 and Rich-B 2017-2018 n = 6; 2019 and 2020 n = 3. ANC stress threshold of <50 µeq/L from Driscoll et al. 2001. Calcium stress thresholds of <4 mg/L from M. Whiting (pers. comm.) and <2 mg/L from Baker et al. 1990 and Baldigo and Murdoch 2007. Alx stress threshold of >15 µg/L from EIFAC as cited in Dennis and Clair 2012.

Aluminum

No significant changes in aluminum were observed between 2020 and prior years (Zimmermann 2020). Average total aluminum per stream ranged from 128 to 225 µg/L, well below the Maine AWQC maximum of 750 µg/L (based on a pH of 6.5-9 and dissolved organic carbon (DOC) <5 mg/L, which are significantly different from values observed in the study streams; Appendix I Tables 2 and 3; MDEP CMR Chapter 584). As expected due to the dry weather, fewer total aluminum samples exceeded USEPA's site-specific maximum criteria (CMC; ranging from 37-1,100 µg/L depending on DOC, total hardness, and pH at each sample site; USEPA 2018) in 2020 than in previous years (29% vs. 54%;). As in prior years, organic aluminum was the dominant species.

Exchangeable aluminum (Alx) can cause respiratory distress when it binds to the gills of fish. Alx values were slightly lower than in prior years at all sites (except for Beaverdam Stream, which had no change) and represented 6.9 ± 3.7% of aluminum species, however this was not a statistically significant difference. Only one Alx sample exceeded the threshold for the protection of aquatic life of 15 µg/L, at the downstream Richardson Brook site in April (Fig. 8; Appendix I Tables 3 and 4; Howells et al. 1990 as cited in Dennis and Clair 2012; Kroglund and Staurnes 1999; McCormick et al. 2009). There were no significant differences between the upstream and downstream Richardson Brook sites in 2020, indicating the addition of clam shells had no significant impact on Alx (Appendix I Table 6). However, no samples were collected during or immediately following shell additions in 2020, during the period when increases in pH and specific conductance were observed. Drought conditions may have contributed to the lower Alx observed in 2020. As in prior years, sub-lethal stress due to toxic Alx may decrease smolt tolerance to saltwater (Kroglund and Staurnes 1999; McCormick et al. 2009; Monette et al. 2008; Staurnes et al. 1995).

Dissolved Organic Carbon (DOC)

Downeast streams, including those studied here, are naturally highly colored, with relatively high organic content (and therefore high DOC) due to wetlands and coniferous forests (Haines et al. 1990). Similar to prior years, DOC ranged from 5.7 to 19 mg/L, with an average of 10.4 ± 4.5 mg/L (Appendix I Table 2; Zimmermann 2020). There were no significant differences between years across all sites, and no difference between the upstream and downstream Richardson Brook sites. It is expected that some buffering of Alx is occurring in the study streams despite low pH values, via DOC binding aluminum into inert organic complexes (Baldigo and Murdoch 2007; Kroglund et al. 2008; Tipping et al. 1991).

Base Cation Surplus

Base cation surplus (BCS) reduces the influence of natural acidity from DOC, to help distinguish the impacts of natural acidity versus anthropogenic acidification (Lawrence et al. 2007; Baldigo et al. 2009). BCS is the difference between the sum of cations (calcium, potassium, magnesium, and sodium) and anions (chloride, nitrate, sulfate, and strong organic anions as defined as 0.071*DOC-2.1; Lawrence et al. 2007). The threshold for aluminum mobilization occurs at a BCS around 0, regardless of DOC values. In 2020, BCS ranged from a minimum of -14 at Creamer Brook to 301 at Barney Brook (Appendix I Table 5). Lowest values are observed in the spring and fall, corresponds with the lowest pH values. As expected, based on calcium, ANC, and pH (Figs. 5 and 8), Beaverdam Stream and Barney Brook had the highest average BCS, and thus the highest capacity to buffer against the mobilization of toxic aluminum.

Macroinvertebrates

As in prior years, all study streams attained Maine's highest aquatic life water quality classification (Appendix II; 38 M.R.S.§§ 465; Davies et al. 2016; Zimmermann 2020). The dominant taxa were genera of mayflies and caddisflies that most often occur in areas of little current, similar to the baseline years (Appendix I, Table 7; Zimmermann 2019). A predatory caddisfly (*Oecetis*) joined the dominant taxa at two sites in 2020 (Beaverdam Stream and the upstream Richardson Brook site), likely due to its tolerance of high temperatures and low flows. Mayflies are the most sensitive group of aquatic insects to acidity (Weiderholm 1984) and represented around one third of the generic richness (ranging from 16-42% in 2020, depending on the site), suggesting a healthy macroinvertebrate assemblage requiring good water quality. Rock bags were deployed four days prior to the addition of shells in 2020 and were retrieved a week after the final shell application, however no significant differences were observed at the downstream Richardson Brook site, neither when compared to prior years nor to control sites. With the observed decrease in pH following autumn rains, low pH (<5) may have a detrimental impact on any acid-sensitive macroinvertebrates present in the study streams, although the most critical period for macroinvertebrates is likely emergence, so species that reproduce in the fall and spring would be most affected (Bradley and Ormerod 2002; Wiederholm 1984). However, as episodic acidity events have been occurring for decades, the macroinvertebrate assemblage in Downeast streams may be tolerant to low pH pulses. Salmon are thought to be opportunistic feeders, changing their diet to the most abundant prey available, so changes in macroinvertebrate abundance may have a stronger impact on salmon than changes in macroinvertebrate composition (Scott and Crossman 1973 as cited in Stanley and Trial 1995). More data are needed to determine if the addition of shells is having an impact on the macroinvertebrate community in Richardson Stream.

Conclusion

Following a second year of clam shell additions, pH in the treated section of Richardson Brook was higher than in baseline years, as well as higher than the upstream control site. At all sites, drought conditions and extremely low flows reduced the duration and severity of rain-driven acidity events, decreased dissolved oxygen, and likely increased the relative contribution of ground water to the study area. Increased specific conductance in the treated section of Richardson Brook appears to be directly related to shell applications. Acid neutralization capacity (ANC) was slightly higher in 2020, suggesting increased buffering, but this cannot be attributed to the addition of shells as the increase was observed at all sites. Similarly, exchangeable aluminum was lower in 2020 at all sites, suggesting decreased toxicity. Neither of these trends were statistically significant. The expected increase in calcium following shell additions was not observed in 2020, possibly due to the absence of samples during or immediately following shell additions, during the period when increases in pH and specific conductance were observed. Care will be taken in the following years to collect samples within a month of the addition of shells. Drought conditions likely contributed to increased stressful conditions (low DO, low flow, reduced mobility in isolated pools), however the extremely low flows also allowed more clam shells to be spread within the stream channel, rather than only along the banks. With the second year of shell additions, not only have more shells been added, but more shells will be in contact with the stream water throughout the year, which is likely to increase the impact of shells on water quality. More than half of the winter of 2019-2020 was within the stressful range of pH, with a few rainfall-driven episodic depressions that could have impacted survival of juvenile salmon. Next year, comparative over-winter pH data should be available, as loggers were deployed at both Richardson Brook sites in Nov. 2020. Sub-lethal stress due to low pH and aluminum toxicity is likely still occurring at all study streams during episodic, precipitation-driven acidity events. The low pH events often coincide with the presence of the most sensitive salmon life stages (alevins and smolts), from March through June, however the hardier life stages (parr and adults) may also be impacted during the autumn rainy season. As clam shells are added to the target area, monitoring efforts will continue until at least 2023 to determine the efficacy of using this approach to mitigate acidity.

Works Cited

Baker, J.P., Bernard, D.P., Christensen, S.W., Sale, M.J., Freda, J., Heltcher, K., Marmorek, D., Rowe, L., Scanlone, P., Suter, G., Warren-Hicks, W., and Welbourn, P. 1990. Biological effects of changes in surface water acid-base chemistry. NAPAP Report 13. In: National Acid Precipitation Assessment Program, Acidic Deposition: State of Science and Technology. Vol. II.

Baker, J.P., Van Sickle, J., Gagen, C.J., DeWalle, D.R., Sharpe, W.E., Carline, R.F., Baldigo, B.P., Murdoch, P.S., Bath, D.W., Kretser, W.A., Simonin, H.A., Wigington, P.J., Jr. 1996. Episodic acidification of small streams in the northeastern United States: effects on fish populations. Ecological Applications. 422-437.

Baldigo, B.P., and Murdoch, P.S. 2007. Effect of stream acidification and inorganic aluminum on mortality of brook trout (*Salvelinus fontinalis*) in the Catskill Mountains, New York. Canadian Journal of Fisheries and Aquatic Science. 54: 603-615.

Bradley, D.C., and Ormerod, S.J. 2002. Long-term effects of catchment liming on invertebrates in upland streams. Freshwater Biology. 47: 161-171.

Brocksen, R.W., Marcus, M.D., and Olem, H. 1992. Practical guide to managing acidic surface waters and their fisheries. Lewis Publishers, Inc. Chelsea, Michigan. 190 p.

Clair, T.A., and Hindar, A. 2005. Liming for the mitigation of acid rain effects in freshwaters: a review of recent results. Environmental Reviews. 13: 91-128.

Cunjak, R.A., Roussel, J.-M., Gray, M.A., Dietrich, J.P., Cartwright, D.F., Munkittrick, K.R., and Jardine, T.D. 2005. Using stable isotope analysis with telemetry or mark-recapture data to identify fish movement and foraging. Oecologia. 144: 1-11.

Davies. S.P., Drummond, F., Courtemanch, D.L., Tsomides, L., and Danielson, T.J. 2016. Biological water quality standards to achieve biological condition goals in Maine rivers and streams: Science and policy. Maine Agricultural and Forest Experiment Station. Technical Bulletin 208.

Dennis, I.F. and Clair, T.A. 2012. The distribution of dissolved aluminum in Atlantic salmon (*Salmo salar*) rivers in Atlantic Canada and its potential effect on aquatic populations. Canadian Journal of Fisheries and Aquatic Science. 69: 1174-1183.

Driscoll, C.T., Lawrence, G.B., Bulger, A.J. Butler, T.J., Cronan, C.S., Eagar, C., Lambert, K.F., Likens, G.E., Stoddard, J.L., and Weathers, K.C. 2001. Acidic deposition in the Northeastern United States: sources and inputs, ecosystem effects, and management strategies. BioScience. 51.3: 180-198.

Elliott, J.M., and Elliott, J.A. 2010. Temperature requirements of Atlantic salmon *Salmo salar,* brown trout *Salmo trutta* and Arctic charr *Salvelinus alpinus*: predicting the effects of climate change. Journal of Fish Biology. 77: 1793-1817.

Frechette, D.M., Dugdale, S.J., Dodson, J.J., and Bergeron, N.E. 2018. Understanding summertime thermal refuge use by adult Atlantic salmon using remote sensing, river temperature monitoring, and acoustic telemetry. Canadian Journal of Fisheries and Aquatic Sciences. 75: 1999-2010.

Garmo, Ø.A., Skjelkvåle, B.L., de Wit, H.A., Colombo L., Curtis, C., Fölster, J., Hoffmann, A., Hruška, J., Høgåsen, T., Jeffries, D.S., Keller, W.B., Krám, P., Majer, V., Monteith, D.T., Paterson, A.M., Rogora, M., Rzychon, D., Steingruber, S., Stoddard, J.L., Vuorenmaa, J., and Worsztynowicz, A. 2014. Trends in surface water chemistry in acidified areas in Europe and North America from 1990 to 2008. Water, Air, and Soil Pollution. 225: 1880.

Haines, T.A., Norton, S.A., Kahl, J.S., Fay, C.W., Pauwels, S.J., and Jagoe, C.H. 1990. Intensive studies of stream fish populations in Maine. EPA/600/3-90/043.

Halfyard, E. 2007. Initial results of an Atlantic salmon river acid mitigation program. MSc Thesis, Acadia University, 164 p.

Henriksen, A., Skogheim, O.K., and Rosseland, B.O. 1984. Episodic changes in pH and aluminum-speciation kill fish in a Norwegian salmon river. Vatten. 40: 255-260.

Hesthagen, T., Larsen, B.M., and Fiske, P. 2011. Liming restores Atlantic salmon (*Salmo salar*) populations in acidified Norwegian rivers. Canadian Journal of Fisheries and Aquatic Sciences. 68: 224-231.

Izaac Walton League of America (IWLA). Biological monitoring instructions for stream monitors. URL https://www.iwla.org/water/resources-for-monitors.

Jonsson, B., Forseth, T., Jensen, A.J., and Næsje, T.F. 2001. Thermal performance of juvenile Atlantic Salmon, *Salmo salar*. Functional Ecology. 15: 701-711.

Kroglund, F., and Staurnes, M. 1999. Water quality requirements of smolting Atlantic salmon (*Salmo salar*) in limed acid rivers. Canadian Journal of Fisheries and Aquatic Sciences. 56: 2078-2086.

Kroglund, F., Wright, R.F., and Burchart, C. 2002. Acidification and Atlantic salmon: critical limits for Norwegian rivers. Norwegian Institute for Water Research, Oslo. Report nr 111.

Kroglund, F., Rosseland, B.O., Teien, H.-C., Salbu, B., Kristensen, T., and Finstad, B. 2008. Water quality limits for Atlantic salmon (*Salmo salar*) exposed to short term reductions in pH and increased aluminum simulating episodes. Hydrology and Earth Systems Sciences. 12: 491-507.

Lacroix, G.L., and Knox, D. 2005. Acidification status of rivers in several regions of Nova Scotia and potential impacts on Atlantic salmon, Canadian Technical Report of Fisheries and Aquatic Sciences, 2573.

Lawrence, G.B., Sutherland, J.W., Boylen, C.W., Nierzwicki-Bauer, S.W., Momen, B., Baldigo, B.P., and Simonin, H.A. 2007. Acid rain effects on aluminum mobilization clarified by inclusion of strong organic acids. Environmental Science and Technology. 41 (1): 93-98.

Lien, L., Raddum, G.G., Fjellheim, A., Henriksen, A. 1996. A critical limit for acid neutralizing capacity in Norwegian surface waters, based on new analyses of fish and invertebrate responses. The Science of the Total Environment. 177: 173-193.

Lund, S.G., Caissie, D., Cunjak, R.A., Vijayan, M.M., and Tufts, B.L. 2002. The effects of environmental heat stress on heat-shock mRNA and protein expression in Miramichi Atlantic salmon (*Salmo salar*) parr. Canadian Journal of Fisheries and Aquatic Sciences. 59: 1553-1562.

MacAvoy, S.E., and Bulger, A.J. 1995. Survival of brook trout (*Salvelinus fontinalis*) embryos and fry in streams of different acid sensitivity in Shenandoah National Park, USA. Water, Air, and Soil Pollution. 85: 445-450.

Magee, J.A., Obedzinski, M., McCormick, S.D., and Kocik, J.F. 2003. Effects of episodic acidification on Atlantic salmon (*Salmo salar*) smolts. Canadian Journal of Fisheries and Aquaculture Science. 60: 214-221.

Maine Department of Environmental Protection Code of Maine Rules (MDEP CMR). Chapter 584: Surface Water Quality Criteria for Toxic Pollutants.

Maine Department of Environmental Protection. 2014. QAPP for Biological Monitoring of Maine's Rivers, Streams, and Freshwater Wetlands. Appendix Di: Methods for Biological Sampling and Analysis of Maine's Rivers and Streams. DEP-LW-0387-C2014, revised date 4/1/2014.

Maine Geological Survey (MGS). 1985. Bedrock_500K_Units. Augusta, ME, Maine Geological Survey. URL https://services1.arcgis.com/RbMX0mRVOFNTdLzd/arcgis/rest/services/MGS_Bedrock_500K_Map_Data/FeatureServer. Using: ArcGIS. Version 10.3.1. Redlands, CA: Environmental Systems Research Institute, Inc., 2010. Data accessed 2/1/2021.

Maine Revised Statutes (M.R.S.). Title 38: Waters and navigation. Chapter 3: Protection and improvement of waters. Article 4-A: Water Classification Program. Sections 464 and 465.

McCormick, S.D., Hansen, L.P., Quinn, T.P, and Saunders, R.L. 1998. Movement, migration, and smolting of Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Science. 55 (Suppl. 1): 77-92.

McCormick, S.D., Keyes, A., Nislow, K.H., and Monette, M.Y. 2009. Impacts of episodic acidification on in-stream survival and physiological impairment of Atlantic salmon (*Salmo salar*) smolts. Canadian Journal of Fisheries and Aquatic Science. 66: 394-403.

Monette, M.Y., Björnsson, B.T., and McCormick, S.D. 2008. Effects of short-term acid and aluminum exposure on the parr-smolt transformation in Atlantic salmon (*Salmo salar*): disruption of seawater tolerance and endocrine status. General and Comparative Endocrinology. 158: 122-130.

National Oceanic and Atmospheric Administration (NOAA). 2020a. Gulf of Maine region quarterly climate impacts and outlook. June 2020. URL https://www.drought.gov/drought/sites/drought.gov.drought/files/media/reports/regional_outlooks/GOM 20Spring 202020 20V2.pdf

National Oceanic and Atmospheric Administration (NOAA). 2020b. Gulf of Maine region quarterly climate impacts and outlook. Sept. 2020. URL https://gulfofmaine.org/public/wp-content/uploads/2020/11/GOM-Summer-2020.pdf.

National Research Council (NRC). 2004. Atlantic Salmon in Maine. Washington, DC: The National Academies Press. URL https://doi.org/10.17226/10892.

Potter, W. 1982. The effects of air pollution and acid rain on fish, wildlife, and their habitats – rivers and streams. U.S. Fish and Wildlife Service, Biological Services Program, Eastern Energy and Land Use Team, FWS/OBS-80/40.5. 52 pp.

Project Share and U.S. Fish and Wildlife Service (USFWS). 2009. Restoring salmonid aquatic/riparian habitat: a strategic plan for the Downeast Maine DPS rivers.

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Stanley, J.G., and Trial, J.G. 1995. Habitat suitability index models: nonmigratory freshwater life stages of Atlantic salmon. U.S. Department of the Interior. Biological Science Report 3.

Staurnes, M. Kroglund, F., and Rosseland, B.O. 1995. Water quality requirement of Atlantic salmon (*Salmo salar*) in water undergoing acidification or liming in Norway. Water, Air, and Soil Pollution. 85: 347-352.

Tipping, E., Woof, C., and Hurley, M.A. 1991. Humic substances in acid surface waters; modelling aluminum binding, contribution to ionic charge-balance, and control of pH. Water Resources. 25(4): 425–435.

United States Atlantic Salmon Assessment Committee (USASAC). 2020. Annual Report, no. 32 – 2019 activities.

United State Drought Monitor. 2020. National Drought Mitigation Center, Lincoln, NE. URL https://droughtmonitor.unl.edu/Maps/MapArchive.aspx

United States Environmental Protection Agency (USEPA). 1986. Quality Criteria for Water. EPA 440/5-86-001.

United States Environmental Protection Agency. 2018. Final Aquatic Life Ambient Water Quality Criteria for Aluminum. EPA- 822-R-18-001.

Weather Underground. 2020. Alexander Elementary School KMEBAILE9 and Heather Wood Farm KMEPRINC2. URL https://www.wunderground.com/.

Whiting, M.C. 2014. Final report for Project SHARE's Clam Shell Pilot Project. Maine Department of Environmental Protection: Bangor, Maine.

Whiting, M.C. and Otto, W. 2008. Spatial and temporal patterns in the water chemistry of the Narraguagus River: a summary of the available data from the Maine DEP Salmon Rivers Program. Maine Department of Environmental Protection: Bangor, Maine.

Wickham, H. 2009. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

Wiederholm, T. 1984. Responses of Aquatic Insects to Environmental Pollution. In: The Ecology of Aquatic Insects. Praeger Publishers, NY. 530-535.

Wilson Engineering, LLC. 2020. Water Resources Database (WRDB). St. Louis, Missouri. URL wrdb.com.

Zimmermann, E. 2018. Reducing acidification in endangered Atlantic salmon habitat: baseline data. Maine Department of Environmental Protection: Augusta, ME.

Zimmermann, E. 2019. Reducing acidification in endangered Atlantic salmon habitat: baseline data summary. Maine Department of Environmental Protection: Augusta, ME.

Zimmermann, E. 2020. Reducing acidification in endangered Atlantic salmon habitat: first year of clam shells. Maine Department of Environmental Protection: Augusta, ME.

Appendix I – Summary Data Tables

Table 1. Continuous Data Summary. Summary statistics (mean, standard deviation (SD), minimum and maximum) of measurements from YSI 600 XLM sondes, May to Nov. 2020 (n ~ 9,000), and Onset Hobo U26 dissolved oxygen loggers, June to Nov. 2020 (n ~ 8,000). Dissolved oxygen data for Barney Brook are discrete measurements from a Eureka Manta2 Sub2 sonde (n = 9).

Stream Name	pH				Temperature (°C)				Specific Conductance (µS/cm)				Dissolved Oxygen (mg/L)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Barney Brook	6.39	0.24	5.61	7.12	12.29	4.94	0.08	21.49	41	10	17	60	10.15	2.48	5.86	14.07
Beaverdam Stream	6.59	0.36	5.69	7.00	15.32	6.19	0.82	28.8	50	19	21	103	9.36	1.66	6.88	14.34
Creamer Brook	5.74	0.34	4.66	6.20	13.2	5.07	0.12	23.29	33	6	19	50	9.28	2.05	0.99	14.48
Richardson Brook - 09	5.67	0.35	4.73	6.29	14.82	5.90	1.11	26.92	23	6	4	36	8.46	1.40	5.41	12.9
Richardson Brook - B	6.19	0.54	5.07	7.24	14.68	5.92	0.95	27.8	32	13	9	79	9.28	1.91	4.77	14.3

Table 2. Discrete Data Summary. Summary statistics (mean, SD, minimum and maximum) from grab samples collected in 2017 (June 20, Aug. 1, and Oct. 11), 2018 (April 18, July 23, and Nov. 5), 2019 (April 1, July 31, and Nov. 19), and 2020 (April 28, July 22, and Nov. 23). n = 12*.

Stream Name	Calcium (mg/L)				Dissolved Organic Carbon (mg/L)				ANC (µeq/L)				pH (closed-cell)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Barney Brook	3.21	1.56	1.16	5.98	10.1	4.6	3.4	19	166.0	120.8	46.6	435.9	6.43	0.41	5.82	6.96
Beaverdam Stream	2.02	0.82	0.92	3.20	10.1	4.0	6.1	17	95.5	93.3	30.2	322.3	6.13	0.51	5.28	6.88
Creamer Brook	1.88	0.74	1.19	3.66	10.6	2.8	7.6	17	55.5	29.0	14.8	94.9	5.79	0.45	4.96	6.26
Richardson Brook - 09+	1.39	0.43	0.72	2.10	11.5	4.0	5.6	18	50.3	29.9	13.3	104	5.73	0.42	4.92	6.25
Richardson Brook - B	1.61	0.64	0.70	2.85	11.5	3.7	6.8	19	65.1	40.0	13.9	147	5.95	0.53	4.94	6.76

* Creamer Brook was not sampled in April in 2018, 2019, or 2020 (n = 9). Beaverdam Stream was not sampled in 2017 (n = 9).
+ Rich09 includes samples collected from Rich-A (a site 360m downstream) in 2017, 2018, and April 2019.

Table 3. Aluminum Species Data Summary. Summary statistics (mean, SD, minimum and maximum) from grab samples collected in 2017 (June 20, Aug. 1, and Oct. 11), 2018 (April 18, July 23, and Nov. 5), 2019 (April 1, July 31, and Nov. 19), and 2020 (April 28, July 22, and Nov. 23). n = 12*.

Stream Name	Total Aluminum (µg/L)				Dissolved Aluminum (µg/L)				Exchangeable Aluminum (µg/L)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Barney Brook	171	100	40	423	147	87	32	377	15	15	2	54
Beaverdam Stream	128	53	54	241	110	52	32	219	9	6	<1	18
Creamer Brook	225	96	94	424	204	93	92	399	33	27	9	53
Richardson Brook – 09+	181	58	101	300	167	57	75	279	15	11	3	40
Richardson Brook - B	173	60	88	293	160	58	79	278	18	9	2	31

* Creamer Brook was not sampled in April in 2018, 2019, or 2020 (n = 9). Beaverdam Stream was not sampled in 2017 (n = 9).
+ Rich09 includes samples collected from Rich-A (a site 360m downstream) in 2017, 2018, and April 2019.

Table 4. Exceedance Summary. Percentage of data observations that exceeded stress threshold values for sonde data (pH, temperature and DO) April-Nov. 2020. Grab sample data (calcium and exchangeable aluminum) combine all five years of the study 2017-2020.

Stream Name	Continuous Data					Grab Sample Data		
	pH (n ~ 9,000)		Temperature (n ~ 9,000)	Dissolved Oxygen (n ~ 8,000)^		Calcium (n = 12)*		Exchangeable Aluminum (n = 12)*
Thresholds	*<5.5*	*<6.5*	*>20.0 °C*	*<5 mg/L*	*<7 mg/L*	*<2.0 mg/L*	*<4.0 mg/L*	*>15 µg/L*
Barney Brook	0	57.1	2.3	0	11.1	25	66.7	25.0
Beaverdam Stream[a]	0	35.6	27.6	0	0.2	44.4	100	22.2
Creamer Brook	22.4	100	5.2	2.5	11.2	77.8	100	55.6
Richardson Brook – 09+	19.9	100	23.3	0	14.0	75	100	33.3
Richardson Brook – B	12.0	27.6	20.8	0.2	8.9	91.7	100	58.3

^ DO data for Barney Brook are discrete measurements from a Eureka Manta2 Sub2 sonde (n = 9).
* No grab samples were collected at Creamer Brook in April in 2018, 2019, or 2020 (n = 9)
a No grab samples were collected at Beaverdam Stream in 2017 (n = 9).
+ Rich09 includes samples collected from Rich-A (a site 360m downstream) in 2017, 2018, and April 2019.

Table 5. Base Cation Surplus (BCS). Summary statistics (mean and SD) from grab samples collected in 2019 (July 31 and Nov. 19) and 2020 (April 28, July 22 and Nov. 23). Cations include calcium, potassium, magnesium, and sodium. Anions include chloride, nitrate, sulfate, and strong organic anions (0.071*DOC-2.1, from Lawrence et al. 2007). Data converted from mg/L. n = 5*.

Stream Name	Cations (µEq/L)		Anions (µEq/L)		BCS (µEq/L)			
	Mean	SD	Mean	SD	Mean	SD	Min	Max
Barney Brook	326.03	100.85	154.22	46.43	171.81	107.28	59.88	301.3
Beaverdam Stream	321.27	82.96	249.84	70.05	71.43	38.52	28.32	131.8
Creamer Brook	223.53	28.58	193.93	50.78	29.60	38.00	-14.4	78.45
Richardson Brook - 09	199.91	43.39	154.75	43.93	45.16	32.61	2.82	85.71
Richardson Brook - B	215.32	51.30	158.55	48.65	56.77	34.04	15.53	108.3

* Creamer Brook was not sampled in April in 2019 or 2020 (n = 4).

Table 6. Treatment Summary. Mean values (± SD) pre-shell application (Apr. 28 – July 25, 2020), during shell application (July 26 – Aug. 13, 2020), and post-shell application (Aug. 14 – Nov. 23, 2020). For pH, n ~ 4,000 for pre-, 800 during, and 5,000 post-application. For grab samples (Ca, ANC, and Alx), no samples were collected during shell application due to scheduling issues. Pre-application values presented as range (n = 2, except for Creamer where n =1); post-application n = 1.

Stream Name	pH			Calcium (mg/L)		Exchangeable Aluminum (µg/L)		Acid Neutralization Capacity (µEq/L)	
	Pre	During	Post	Pre	Post	Pre	Post	Pre	Post
Barney Brook	6.3 ± 0.3	6.5 ± 0.1	6.4 ± 0.2	1.5 – 4.3	3.2	3 – 12	4	72 – 174	138
Beaverdam Stream	6.8 ± 0.1	6.7 ± 0.1	6.5 ± 0.4	1.3 – 2.7	2.8	3 – 7	6	52 – 322*	81
Creamer Brook	5.9 ± 0.1	5.9 ± 0.1	5.6 ± 0.4	1.6	1.8	9	11	79	38
Richardson Brook – 09	5.8 ± 0.2	5.8 ± 0.2	5.5 ± 0.4	0.9 – 1.4	2.5	5 – 11	4	27 – 83	68
Richardson Brook – B	5.9 ± 0.3	6.6 ± 0.2	6.3 ± 0.6	1 – 2	2.1	5 – 19	10	34 – 127	43

*ANC at Beaverdam Stream in July is flagged as suspect due to being twice as high as the field duplicate sample, and twice as high as any preceding year.

Table 7. Macroinvertebrate Summary. Samples were collected in August using rock bags following the Biological Monitoring Unit's protocol (MDEP 2014) and analyzed by a certified taxonomist to the lowest possible level (species). EPT taxa include mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera). 2017-2018 dominant taxa are presented together due to similarities between the two baseline years.

Stream Name	Station ID	Log #	Years Sampled	Total Mean Abundance	Generic Richness	EPT Generic Richness	Relative Ephemeroptera Abundance	Dominant Taxa		
								2017-2018	2019	2020
Beaverdam Stream	S-1149	2687	2018	164	39	14	14%	*Polypedilum* *Rheotanytarsus*	*Dolophilodes* *Hydropsyche*	*Polypedilum* *Oecetis* *Rheotanytarsus*
		2764	2019	396	36	18	10%			
		2833	2020	234	57	20	16%			
Creamer Brook	S-1115	2589	2017	207	40	20	28%	*Lepidostoma* Leptophlebiidae (*Paraleptophlebia*)	*Maccaffertium* *Hydropsyche*	*Paraleptophlebia* *Polycentropus* *Lepidostoma*
		2690	2018	246	37	16	77%			
		2763	2019	96	36	16	36%			
		2834	2020	194	53	21	37%			
Richardson Brook - A	S-1117	2591	2017	106	37	19	49%	*Lepidostoma* *Paraleptophlebia*		*Leucrocuta* *Maccaffertium* *Oecetis*
		2689	2018	104	31	13	42%			
		2836	2020	80	40	15	42%			
Richardson Brook - B	S-1116	2590	2017	56	31	13	31%	*Lepidostoma* Leptophlebiidae (*Paraleptophlebia*) *Promoresia*		*Maccaffertium* *Lepidostoma*
		2688	2018	89	43	21	30%			
		2835	2020	122	47	17	27%			

Appendix II – Biomonitoring Key Reports

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Classification Attainment Report

Station Information

Station Number:	**S-1149**	River Basin:	Maine Coastal
Waterbody:	Beaverdam Stream - Station 1149	HUC8 Name:	Maine Coastal
Town:	Wesley	Latitude:	44 58 54.09 N
Directions:	25M UPSTREAM FROM ROAD CROSSING.	Longitude:	67 38 24.5 W
		Stream Order:	1

Sample Information

Log Number:	**2833**	Type of Sample:	ROCK BAG	Date Deployed:	7/22/2020
Subsample Factor:	X1	Replicates:	3	Date Retrieved:	8/19/2020

Classification Attainment

Statutory Class:	**AA**	**Final Determination:**	**A**	Date:	2/17/2021
Model Result with P≥0.6:	A	**Reason for Determination:**	**Model**		
Date Last Calculated:	1/29/2021	Comments:			

Model Probabilities

First Stage Model

Class A	0.65	Class C	0.01
Class B	0.34	NA	0.00

C or Better Model

Class A, B, or C	1.00
Non-Attainment	0.00

B or Better Model

Class A or B	1.00
Class C or Non-Attainment	0.00

A Model

Class A	1.00
Class B or C or Non-Attainment	0.00

Model Variables

01	Total Mean Abundance	234.33
02	Generic Richness	57.00
03	Plecoptera Mean Abundance	5.67
04	Ephemeroptera Mean Abundance	36.67
05	Shannon-Wiener Generic Diversity	4.40
06	Hilsenhoff Biotic Index	5.02
07	Relative Abundance - Chironomidae	0.46
08	Relative Generic Richness Diptera	0.37
09	*Hydropsyche* Abundance	7.67
11	*Cheumatopsyche* Abundance	1.00
12	EPT Generic Richness/ Diptera Generic Richness	0.95
13	Relative Abundance - Oligochaeta	0.00
15	Perlidae Mean Abundance (Family Functional Group)	5.33
16	Tanypodinae Mean Abundance (Family Functional Group)	4.68
17	Chironomini Abundance (Family Functional Group)	45.48
18	Relative Abundance Ephemeroptera	0.16
19	EPT Generic Richness	20.00
21	Sum of Abundances: *Dicrotendipes, Micropsectra, Parachironomus, Helobdella*	5.68
23	Relative Generic Richness- Plecoptera	0.04
25	Sum of Abundances: *Cheumatopsyche, Cricotopus, Tanytarsus, Ablabesmyia*	4.68
26	Sum of Abundances: *Acroneuria, Maccaffertium, Stenonema*	25.29
28	EP Generic Richness/14	0.86
30	Presence of Class A Indicator Taxa/7	0.57

Five Most Dominant Taxa

Rank	Taxon Name	Percent
1	*Polypedilum*	15.55
2	*Oecetis*	13.37
3	*Rheotanytarsus*	12.99
4	*Maccaffertium*	8.52
5	*Lepidostoma*	7.25

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Classification Attainment Report

Station Number: S-1149	Town: Wesley		Date Deployed: 7/22/2020
Log Number: 2833	Waterbody: Beaverdam Stream - Station 1149		Date Retrieved: 8/19/2020

Sample Collection and Processing Information

Sampling Organization: BIOMONITORING UNIT

Taxonomist: MICHAEL COLE

Waterbody Information - Deployment			Waterbody Information - Retrieval		
Temperature:	23.57	deg C	Temperature:	19.9	deg C
Dissolved Oxygen:	7.91	mg/l	Dissolved Oxygen:	8.78	mg/l
Dissolved Oxygen Saturation:	91.7	%	Dissolved Oxygen Saturation:	96.8	%
Specific Conductance:	46.2	uS/cm	Specific Conductance:	73.4	uS/cm
Velocity:	18.3	cm/s	Velocity:	1.8	cm/s
pH:	6.67		pH:	6.71	
Wetted Width:	5.2	m	Wetted Width:	3.9	m
Bankfull Width:	6.1	m	Bankfull Width:	6.1	m
Depth:	20	cm	Depth:	17	cm

Water Chemistry

Summary of Habitat Characteristics

Landuse Name	Canopy Cover	Terrain	
Upland Conifer	Dense	Rolling	
Potential Stressor	**Location**	**Substrate**	
	Above Road Crossing	Boulder	30 %
		Rubble/Cobble	70 %

Landcover Summary - 2004 Data

Total Area (ac)	6276	High Int. Dev. %	0.1	Water %	5.4	Non-vegetated %	2.1
		Med Int. Dev. %	0.1	Wetland %	7.8	Tilled Agriculture %	0.7
		Low Int. Dev. %	1.3	Upland Woody %	82.4	Grassland %	0.0
		Development %	1.5	Natural %	86.4	Human Altered %	8.1
						Impervious %	0.7

Sample Comments

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Taxonomic Inventory Report

Station Number: S-1149 Waterbody: Beaverdam Stream - Station 1149 Town: Wesley
Log Number: 2833 Subsample Factor: X1 Replicates: 3 Calculated: 1/29/2021

Taxon	Maine Taxonomic Code	Count (Mean of Samplers) Actual	Count (Mean of Samplers) Adjusted	Hilsenhoff Biotic Index	Functional Feeding Group	Relative Abundance % Actual	Relative Abundance % Adjusted
Girardia	03010102002	0.33	0.33		--	0.1	0.1
Perlodidae	09020207	0.33	0.33		--	0.1	0.1
Acroneuria	09020209042	0.33	5.33	0	PR	0.1	2.3
Acroneuria abnormis	09020209042121	3.33		0	PR	1.4	
Acroneuria lycorias	09020209042125	1.67			--	0.7	
Boyeria	09020301004	0.67	1.00	2	PR	0.3	0.4
Boyeria vinosa	09020301004012	0.33			--	0.1	
Gomphidae	09020302	0.33	0.33		--	0.1	0.1
Hagenius	09020302008		0.33	1	PR		0.1
Hagenius brevistylus	09020302008015	0.33			PR	0.1	
Cordulegastridae	09020303	0.33	0.33		--	0.1	0.1
Corduliidae	09020305	3.33	3.33		--	1.4	1.4
Calopterygidae	09020307	3.33	3.33		--	1.4	1.4
Calopteryx	09020307043	0.67	0.67	5	PR	0.3	0.3
Baetis	09020401001		1.33	4	CG		0.6
Baetis flavistriga	09020401001004	1.33			--	0.6	
Acerpenna	09020401007	0.67	8.33	5	CG	0.3	3.6
Acerpenna macdunnoughi	09020401007001	7.67			--	3.3	
Procloeon	09020401010	0.67	0.67		CG	0.3	0.3
Heptageniidae	09020402	0.33			--	0.1	
Epeorus	09020402009	0.67	0.68	0	SC	0.3	0.3
Leucrocuta	09020402011	2.33	2.37	1	SC	1.0	1.0
Maccaffertium	09020402015	6.00	19.96	4	SC	2.6	8.5
Maccaffertium modestum	09020402015051	0.33			--	0.1	
Maccaffertium vicarium	09020402015055	13.33			--	5.7	
Leptophlebiidae	09020406	2.00	2.00		--	0.9	0.9
Habrophlebia	09020406023		0.33		--		0.1
Habrophlebia vibrans	09020406023072	0.33			--	0.1	
Eurylophella	09020410036	0.33	0.33	3	CG	0.1	0.1
Tricorythodes	09020411038	0.67	0.67	4	CG	0.3	0.3
Microvelia	09020510025	0.33	0.33		PR	0.1	0.1
Trichoptera	090206				--		
Polycentropus	09020603010	2.67	2.67	6	PR	1.1	1.1
Cheumatopsyche	09020604015	1.00	1.00	5	CF	0.4	0.4
Hydropsyche	09020604016	2.67	7.67	4	CF	1.1	3.3
Hydropsyche sparna	09020604016032	4.33			--	1.8	
Hydropsyche betteni	09020604016037	0.67			--	0.3	

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Taxonomic Inventory Report

Station Number: S-1149 Waterbody: Beaverdam Stream - Station 1149 Town: Wesley
Log Number: 2833 Subsample Factor: X1 Replicates: 3 Calculated: 1/29/2021

Taxon	Maine Taxonomic Code	Count (Mean of Samplers) Actual	Count (Mean of Samplers) Adjusted	Hilsenhoff Biotic Index	Functional Feeding Group	Relative Abundance % Actual	Relative Abundance % Adjusted
Glossosoma	09020606020	0.33	0.33	0	SC	0.1	0.1
Brachycentrus	09020609043		0.33	0	CF		0.1
Brachycentrus appalachia	09020609043096	0.33			--	0.1	
Lepidostoma	09020611064	17.00	17.00	1	SH	7.3	7.3
Molanna	09020615069	0.33	0.33	6	SC	0.1	0.1
Oecetis	09020618078	27.67	31.33	8	PR	11.8	13.4
Oecetis persimilis	09020618078157	3.67			--	1.6	
Nigronia	09020701003		0.33	0	PR		0.1
Nigronia serricornis	09020701003003	0.33			--	0.1	
Crambidae	09020905	0.33	0.33		SH	0.1	0.1
Tipula	09021001002	0.33	0.33	4	SH	0.1	0.1
Dicranota	09021001005	0.33	0.33	3	PR	0.1	0.1
Ceratopogonidae	09021010	0.33	0.33		--	0.1	0.1
Chironomidae	09021011	0.33			--	0.1	
Ablabesmyia	09021011001	0.33	0.33	8	PR	0.1	0.1
Thienemannimyia	09021011020		4.35	3	PR		1.9
Thienemannimyia group	09021011020041	4.33			--	1.8	
Pagastia	09021011025	2.00	2.01	1	--	0.9	0.9
Brillia	09021011033	0.33	0.33	5	SH	0.1	0.1
Corynoneura	09021011036	1.33	1.34	7	CG	0.6	0.6
Parametriocnemus	09021011053	5.00	5.02	5	CG	2.1	2.1
Thienemanniella	09021011062	1.67	1.67	6	CG	0.7	0.7
Tvetenia	09021011065		2.68	5	CG		1.1
Tvetenia paucunca	09021011065114	2.67			--	1.1	
Micropsectra	09021011070	5.67	5.68	7	CG	2.4	2.4
Rheotanytarsus	09021011072		30.43	6	CF		13.0
Rheotanytarsus exiguus group	09021011072127	4.33			CF	1.8	
Rheotanytarsus pellucidus	09021011072128	26.00			CF	11.1	
Stempellinella	09021011074	4.00	4.01	2	--	1.7	1.7
Tanytarsus	09021011076	3.33	3.34	6	CF	1.4	1.4
Microtendipes	09021011094		7.36	6	CF		3.1
Microtendipes pedellus group	09021011094166	0.33			--	0.1	
Microtendipes rydalensis group	09021011094168	7.00			--	3.0	
Nilothauma	09021011095	0.33	0.33	2	--	0.1	0.1
Phaenopsectra	09021011101		1.34	7	SC		0.6
Phaenopsectra obediens group	09021011101180	1.33			--	0.6	
Polypedilum	09021011102		36.45	6	SH		15.6
Polypedilum aviceps	09021011102181	34.00			--	14.5	

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Taxonomic Inventory Report

Station Number: S-1149 Waterbody: Beaverdam Stream - Station 1149 Town: Wesley

Log Number: 2833 Subsample Factor: X1 Replicates: 3 Calculated: 1/29/2021

Taxon	Maine Taxonomic Code	Count (Mean of Samplers) Actual	Count (Mean of Samplers) Adjusted	Hilsenhoff Biotic Index	Functional Feeding Group	Relative Abundance % Actual	Relative Abundance % Adjusted
Polypedilum tritum	09021011102191	1.00			--	0.4	
Polypedilum halterale group	09021011102193	1.33			--	0.6	
Simulium	09021012047			4	CF		
Hemerodromia	09021016057	2.33	2.33	3	PR	1.0	1.0
Roederiodes	09021016058	1.33	1.33	3	PR	0.6	0.6
Dubiraphia	09021113064		3.33	6	--		1.4
Dubiraphia quadrinotata	09021113064037	0.33			--	0.1	
Dubiraphia vittata	09021113064038	3.00			--	1.3	
Macronychus	09021113065		0.33	4	--		0.1
Macronychus glabratus	09021113065040	0.33			--	0.1	
Optioservus	09021113067		4.00	3	SC		1.7
Optioservus tardella	09021113067052	4.00			--	1.7	
Stenelmis	09021113070	0.67	0.67	5	SC	0.3	0.3
Acariformes	090301	0.67	0.67		--	0.3	0.3
Limnochares	09030110002	0.33	0.33		--	0.1	0.1

Maine Department of Environmental Protection
Biological Monitoring Program

Aquatic Life Classification Attainment Report

Station Information

Station Number:	**S-1115**	River Basin:	Maine Coastal
Waterbody:	Creamer Brook - Station 1115	HUC8 Name:	Maine Coastal
Town:	T19 Ed Bpp	Latitude:	44 58 16.07 N
Directions:	SITE IS DOWNSTREAM OF THE OLD BRIDGE LOCATION.	Longitude:	67 30 33.57 W
		Stream Order:	2

Sample Information

Log Number:	**2834**	Type of Sample:	ROCK BAG	Date Deployed:	7/22/2020
Subsample Factor:	X1	Replicates:	3	Date Retrieved:	8/19/2020

Classification Attainment

Statutory Class:	**AA**	**Final Determination:**	**A**	Date:	2/17/2021
Model Result with P≥0.6:	A	**Reason for Determination:**	**Model**		
Date Last Calculated:	1/29/2021	Comments:			

Model Probabilities

First Stage Model

Class A	0.89	Class C	0.00
Class B	0.11	NA	0.00

C or Better Model

Class A, B, or C	1.00
Non-Attainment	0.00

B or Better Model

Class A or B	1.00
Class C or Non-Attainment	0.00

A Model

Class A	1.00
Class B or C or Non-Attainment	0.00

Model Variables

01	Total Mean Abundance	193.67
02	Generic Richness	53.00
03	Plecoptera Mean Abundance	2.00
04	Ephemeroptera Mean Abundance	71.67
05	Shannon-Wiener Generic Diversity	4.01
06	Hilsenhoff Biotic Index	3.50
07	Relative Abundance - Chironomidae	0.22
08	Relative Generic Richness Diptera	0.40
09	*Hydropsyche* Abundance	0.67
11	*Cheumatopsyche* Abundance	0.00
12	EPT Generic Richness/ Diptera Generic Richness	1.00
13	Relative Abundance - Oligochaeta	0.00
15	Perlidae Mean Abundance (Family Functional Group)	1.33
16	Tanypodinae Mean Abundance (Family Functional Group)	3.33
17	Chironomini Abundance (Family Functional Group)	14.33
18	Relative Abundance Ephemeroptera	0.37
19	EPT Generic Richness	21.00
21	Sum of Abundances: *Dicrotendipes, Micropsectra, Parachironomus, Helobdella*	11.33
23	Relative Generic Richness- Plecoptera	0.06
25	Sum of Abundances: *Cheumatopsyche, Cricotopus, Tanytarsus, Ablabesmyia*	3.00
26	Sum of Abundances: *Acroneuria, Maccaffertium, Stenonema*	20.33
28	EP Generic Richness/14	0.71
30	Presence of Class A Indicator Taxa/7	0.43

Five Most Dominant Taxa

Rank	Taxon Name	Percent
1	*Paraleptophlebia*	21.69
2	*Polycentropus*	14.28
3	*Lepidostoma*	13.08
4	*Maccaffertium*	9.81
5	*Micropsectra*	5.85

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Classification Attainment Report

Station Number: S-1115 Town: T19 Ed Bpp Date Deployed: 7/22/2020
Log Number: 2834 Waterbody: Creamer Brook - Station 1115 Date Retrieved: 8/19/2020

Sample Collection and Processing Information

Sampling Organization: BIOMONITORING UNIT Taxonomist: MICHAEL COLE

Waterbody Information - Deployment		Waterbody Information - Retrieval	
Temperature:	17.92 deg C	Temperature:	16.1 deg C
Dissolved Oxygen:	8.87 mg/l	Dissolved Oxygen:	7.95 mg/l
Dissolved Oxygen Saturation:	92.1 %	Dissolved Oxygen Saturation:	81.3 %
Specific Conductance:	27.1 uS/cm	Specific Conductance:	43 uS/cm
Velocity:	0.1 cm/s	Velocity:	0.1 cm/s
pH:	6.05	pH:	5.96
Wetted Width:	5 m	Wetted Width:	3.9 m
Bankfull Width:	6.4 m	Bankfull Width:	6.4 m
Depth:	19 cm	Depth:	18.3 cm

Water Chemistry

Summary of Habitat Characteristics

Landuse Name	Canopy Cover	Terrain
Upland Conifer	Dense	Rolling
Potential Stressor	**Location**	**Substrate**
Logging	Above Road Crossing	

Landcover Summary - 2004 Data

Sample Comments

VISIBLE FLOW.

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Taxonomic Inventory Report

Station Number: S-1115 Waterbody: Creamer Brook - Station 1115 Town: T19 Ed Bpp

Log Number: 2834 Subsample Factor: X1 Replicates: 3 Calculated: 1/29/2021

Taxon	Maine Taxonomic Code	Count (Mean of Samplers) Actual	Count (Mean of Samplers) Adjusted	Hilsenhoff Biotic Index	Functional Feeding Group	Relative Abundance % Actual	Relative Abundance % Adjusted
Isotomidae	09020102	0.33	0.33		--	0.2	0.2
Paracapnia	09020203018	0.33	0.33	1	SH	0.2	0.2
Perlodidae	09020207	0.33	0.33		--	0.2	0.2
Acroneuria	09020209042		1.33	0	PR		0.7
Acroneuria abnormis	09020209042121	1.33		0	PR	0.7	
Boyeria	09020301004		7.67	2	PR		4.0
Boyeria vinosa	09020301004012	7.67			--	4.0	
Gomphidae	09020302	0.33	0.33		--	0.2	0.2
Cordulegastridae	09020303	0.33	0.33		--	0.2	0.2
Corduliidae	09020305	1.00	1.00		--	0.5	0.5
Calopteryx	09020307043	0.67	0.67	5	PR	0.3	0.3
Acerpenna	09020401007	1.33	1.67	5	CG	0.7	0.9
Acerpenna pygmaea	09020401007011	0.33			--	0.2	
Leucrocuta	09020402011	2.00	2.00	1	SC	1.0	1.0
Maccaffertium	09020402015	10.33	19.00	4	SC	5.3	9.8
Maccaffertium modestum	09020402015051	1.00			--	0.5	
Maccaffertium vicarium	09020402015055	7.67			--	4.0	
Habrophlebia	09020406023		4.67		--		2.4
Habrophlebia vibrans	09020406023072	4.67			--	2.4	
Paraleptophlebia	09020406026	42.00	42.00	1	CG	21.7	21.7
Ephemerellidae	09020410	0.33	0.33		--	0.2	0.2
Eurylophella	09020410036		2.00	3	CG		1.0
Eurylophella funeralis	09020410036115	2.00			SH	1.0	
Microvelia	09020510025	0.33	0.33		PR	0.2	0.2
Polycentropodidae	09020603	1.33			--	0.7	
Nyctiophylax	09020603009	0.33	0.35	5	PR	0.2	0.2
Polycentropus	09020603010	26.33	27.65	6	PR	13.6	14.3
Hydropsyche	09020604016	0.67	0.67	4	CF	0.3	0.3
Rhyacophila	09020605019		0.33	2	PR		0.2
Rhyacophila fuscula	09020605019060	0.33			PR	0.2	
Hydroptila	09020607026	2.33	2.33	6	P	1.2	1.2
Oxyethira	09020607028	0.33	0.33	3	P	0.2	0.2
Oligostomis	09020608039	0.33	0.33	2	PR	0.2	0.2
Pycnopsyche	09020610049	0.33	0.33	4	SH	0.2	0.2
Lepidostoma	09020611064	25.33	25.33	1	SH	13.1	13.1
Psilotreta	09020614068	0.67	0.67	0	SC	0.3	0.3
Oecetis	09020618078	0.67	0.67	8	PR	0.3	0.3

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Taxonomic Inventory Report

Station Number: S-1115 Waterbody: Creamer Brook - Station 1115 Town: T19 Ed Bpp

Log Number: 2834 Subsample Factor: X1 Replicates: 3 Calculated: 1/29/2021

Taxon	Maine Taxonomic Code	Count (Mean of Samplers) Actual	Count (Mean of Samplers) Adjusted	Hilsenhoff Biotic Index	Functional Feeding Group	Relative Abundance % Actual	Relative Abundance % Adjusted
Nigronia	09020701003		1.67	0	PR		0.9
Nigronia serricornis	09020701003003	1.67			--	0.9	
Tipula	09021001002	0.33	0.33	4	SH	0.2	0.2
Dicranota	09021001005	0.33	0.33	3	PR	0.2	0.2
Ceratopogonidae	09021010	1.00	1.00		--	0.5	0.5
Chironomidae	09021011				--		
Ablabesmyia	09021011001	0.33	0.33	8	PR	0.2	0.2
Labrundinia	09021011008	0.33	0.33	7	PR	0.2	0.2
Paramerina	09021011013	0.67	0.67		--	0.3	0.3
Thienemannimyia	09021011020		1.67	3	PR		0.9
Thienemannimyia group	09021011020041	1.67			--	0.9	
Zavrelimyia	09021011022	0.33	0.33	8	PR	0.2	0.2
Corynoneura	09021011036	0.33	0.33	7	CG	0.2	0.2
Cricotopus	09021011037		0.33	7	SH		0.2
Cricotopus bicinctus	09021011037057	0.33			--	0.2	
Orthocladius	09021011050		3.33	6	CG		1.7
Orthocladius annectens	09021011050092	3.33			--	1.7	
Parametriocnemus	09021011053	0.33	0.33	5	CG	0.2	0.2
Rheocricotopus	09021011057	5.00	5.33	6	CG	2.6	2.8
Rheocricotopus tuberculatus	09021011057106	0.33			--	0.2	
Synorthocladius	09021011061	0.67	0.67	2	CG	0.3	0.3
Tvetenia	09021011065		0.67	5	CG		0.3
Tvetenia paucunca	09021011065114	0.67			--	0.3	
Micropsectra	09021011070	11.33	11.33	7	CG	5.9	5.9
Tanytarsus	09021011076	2.33	2.33	6	CF	1.2	1.2
Microtendipes	09021011094		5.33	6	CF		2.8
Microtendipes rydalensis group	09021011094168	5.33			--	2.8	
Polypedilum	09021011102		9.00	6	SH		4.6
Polypedilum aviceps	09021011102181	4.00			--	2.1	
Polypedilum tritum	09021011102191	5.00			--	2.6	
Atherix	09021015055	0.33	0.33	2	PR	0.2	0.2
Empididae	09021016	0.33	0.33	6	--	0.2	0.2
Optioservus	09021113067	0.33	3.33	3	SC	0.2	1.7
Optioservus tardella	09021113067052	3.00			--	1.5	
Stenelmis	09021113070	0.33	0.33	5	SC	0.2	0.2
Acariformes	090301	0.33	0.33		--	0.2	0.2

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Classification Attainment Report

Station Information

Station Number:	**S-1116**	River Basin:	Maine Coastal
Waterbody:	Richardson Brook - Station 1116	HUC8 Name:	Maine Coastal
Town:	T19 Ed Bpp	Latitude:	44 55 34.18 N
Directions:	PARK AT WIDE SPOT IN ROAD JUST SOUTH OF THE BRIDGE TO WALK DOWNSTREAM TO THE LOWER SITE.	Longitude:	67 29 34.88 W
		Stream Order:	2

Sample Information

Log Number:	**2835**	Type of Sample:	ROCK BAG	Date Deployed:	7/22/2020
Subsample Factor:	X1	Replicates:	3	Date Retrieved:	8/19/2020

Classification Attainment

Statutory Class:	**A**	**Final Determination:**	**A**	Date:	3/29/2021
Model Result with P≥0.6:	A	**Reason for Determination:**	**Model**		
Date Last Calculated:	3/29/2021	Comments:			

Model Probabilities

First Stage Model

Class A	0.91	Class C	0.00
Class B	0.08	NA	0.00

C or Better Model

Class A, B, or C	1.00
Non-Attainment	0.00

B or Better Model

Class A or B	1.00
Class C or Non-Attainment	0.00

A Model

Class A	1.00
Class B or C or Non-Attainment	0.00

Model Variables

01	Total Mean Abundance	121.67
02	Generic Richness	47.00
03	Plecoptera Mean Abundance	3.67
04	Ephemeroptera Mean Abundance	32.67
05	Shannon-Wiener Generic Diversity	4.60
06	Hilsenhoff Biotic Index	3.55
07	Relative Abundance - Chironomidae	0.23
08	Relative Generic Richness Diptera	0.36
09	*Hydropsyche* Abundance	0.67
11	*Cheumatopsyche* Abundance	0.00
12	EPT Generic Richness/ Diptera Generic Richness	1.00
13	Relative Abundance - Oligochaeta	0.00
15	Perlidae Mean Abundance (Family Functional Group)	3.67
16	Tanypodinae Mean Abundance (Family Functional Group)	6.00
17	Chironomini Abundance (Family Functional Group)	11.00
18	Relative Abundance Ephemeroptera	0.27
19	EPT Generic Richness	17.00
21	Sum of Abundances: *Dicrotendipes, Micropsectra, Parachironomus, Helobdella*	0.33
23	Relative Generic Richness- Plecoptera	0.02
25	Sum of Abundances: *Cheumatopsyche, Cricotopus, Tanytarsus, Ablabesmyia*	4.67
26	Sum of Abundances: *Acroneuria, Maccaffertium, Stenonema*	20.00
28	EP Generic Richness/14	0.57
30	Presence of Class A Indicator Taxa/7	0.43

Five Most Dominant Taxa

Rank	Taxon Name	Percent
1	*Maccaffertium*	13.42
2	*Lepidostoma*	12.05
3	*Optioservus*	6.85
4	*Microtendipes*	6.30
5	*Oecetis*	5.75

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Classification Attainment Report

Station Number: S-1116	Town: T19 Ed Bpp		Date Deployed: 7/22/2020
Log Number: 2835	Waterbody: Richardson Brook - Station 1116		Date Retrieved: 8/19/2020

Sample Collection and Processing Information

Sampling Organization: BIOMONITORING UNIT

Taxonomist: MICHAEL COLE

Waterbody Information - Deployment		Waterbody Information - Retrieval	
Temperature:	21.12 deg C	Temperature:	18.7 deg C
Dissolved Oxygen:	9.29 mg/l	Dissolved Oxygen:	8.69 mg/l
Dissolved Oxygen Saturation:	102.8 %	Dissolved Oxygen Saturation:	93.3 %
Specific Conductance:	22.7 uS/cm	Specific Conductance:	58.8 uS/cm
Velocity:	1.8 cm/s	Velocity:	0.1 cm/s
pH:	6.53	pH:	6.97
Wetted Width:	2.1 m	Wetted Width:	1.6 m
Bankfull Width:	4.2 m	Bankfull Width:	4.2 m
Depth:	18 cm	Depth:	18 cm

Water Chemistry

Summary of Habitat Characteristics

Landuse Name	Canopy Cover	Terrain	
Upland Conifer	Partly Open	Rolling	
Potential Stressor	**Location**	**Substrate**	
Logging	Below Road Crossing	Boulder	20 %
		Gravel	20 %
		Rubble/Cobble	60 %

Landcover Summary - 2004 Data

Sample Comments

VISIBLE FLOW.

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Taxonomic Inventory Report

Station Number: S-1116 Waterbody: Richardson Brook - Station 1116 Town: T19 Ed Bpp

Log Number: 2835 Subsample Factor: X1 Replicates: 3 Calculated: 3/29/2021

Taxon	Maine Taxonomic Code	Count (Mean of Samplers) Actual	Count (Mean of Samplers) Adjusted	Hilsenhoff Biotic Index	Functional Feeding Group	Relative Abundance % Actual	Relative Abundance % Adjusted
Isotomidae	09020102	0.33	0.33		--	0.3	0.3
Acroneuria	09020209042	0.67	3.67	0	PR	0.5	3.0
Acroneuria lycorias	09020209042125	3.00			--	2.5	
Boyeria	09020301004	1.67	6.67	2	PR	1.4	5.5
Boyeria vinosa	09020301004012	5.00			--	4.1	
Corduliidae	09020305	0.33	0.33		--	0.3	0.3
Calopteryx	09020307043	1.33	1.33	5	PR	1.1	1.1
Acerpenna	09020401007	1.00	3.33	5	CG	0.8	2.7
Acerpenna macdunnoughi	09020401007001	2.33			--	1.9	
Leucrocuta	09020402011	5.00	5.00	1	SC	4.1	4.1
Stenacron	09020402014	0.33	0.33	7	SC	0.3	0.3
Maccaffertium	09020402015	5.33	16.33	4	SC	4.4	13.4
Maccaffertium vicarium	09020402015055	11.00			--	9.0	
Leptophlebiidae	09020406	1.33			--	1.1	
Habrophlebia	09020406023		0.44		--		0.4
Habrophlebia vibrans	09020406023072	0.33			--	0.3	
Paraleptophlebia	09020406026	3.67	4.89	1	CG	3.0	4.0
Eurylophella	09020410036	2.33	2.33	3	CG	1.9	1.9
Microvelia	09020510025	0.33	0.33		PR	0.3	0.3
Polycentropus	09020603010	2.33	2.33	6	PR	1.9	1.9
Hydropsyche	09020604016		0.67	4	CF		0.5
Hydropsyche morosa	09020604016030	0.33			--	0.3	
Hydropsyche sparna	09020604016032	0.33			--	0.3	
Oxyethira	09020607028	0.33	0.33	3	P	0.3	0.3
Pycnopsyche	09020610049	0.67	0.67	4	SH	0.5	0.5
Lepidostoma	09020611064	14.67	14.67	1	SH	12.1	12.1
Psilotreta	09020614068	0.67	4.33	0	SC	0.5	3.6
Psilotreta indecisa	09020614068132	3.33			--	2.7	
Psilotreta frontalis	09020614068134	0.33			--	0.3	
Helicopsyche	09020616070	0.33	0.33	3	SC	0.3	0.3
Mystacides	09020618075		0.67	4	CG		0.5
Mystacides sepulchralis	09020618075147	0.67			--	0.5	
Oecetis	09020618078	7.00	7.00	8	PR	5.8	5.8
Tipula	09021001002	0.33	0.33	4	SH	0.3	0.3
Chironomidae	09021011				--		
Paramerina	09021011013	0.67	0.67		--	0.5	0.5
Thienemannimyia	09021011020		5.33	3	PR		4.4

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Taxonomic Inventory Report

Station Number: S-1116 Waterbody: Richardson Brook - Station 1116 Town: T19 Ed Bpp

Log Number: 2835 Subsample Factor: X1 Replicates: 3 Calculated: 3/29/2021

Taxon	Maine Taxonomic Code	Count (Mean of Samplers) Actual	Adjusted	Hilsenhoff Biotic Index	Functional Feeding Group	Relative Abundance % Actual	Adjusted
Thienemannimyia group	09021011020041	5.33			--	4.4	
Corynoneura	09021011036	0.33	0.33	7	CG	0.3	0.3
Cricotopus	09021011037	1.00	1.67	7	SH	0.8	1.4
Cricotopus bicinctus	09021011037057	0.67			--	0.5	
Nanocladius	09021011049	0.67	0.67	3	CG	0.5	0.5
Orthocladius	09021011050		0.33	6	CG		0.3
Orthocladius annectens	09021011050092	0.33			--	0.3	
Parametriocnemus	09021011053	0.33	0.33	5	CG	0.3	0.3
Tvetenia	09021011065		0.33	5	CG		0.3
Tvetenia vitracies	09021011065113	0.33			--	0.3	
Micropsectra	09021011070	0.33	0.33	7	CG	0.3	0.3
Rheotanytarsus	09021011072		3.67	6	CF		3.0
Rheotanytarsus exiguus group	09021011072127	0.67			CF	0.5	
Rheotanytarsus pellucidus	09021011072128	3.00			CF	2.5	
Stempellinella	09021011074	0.67	0.67	2	--	0.5	0.5
Tanytarsus	09021011076	3.00	3.00	6	CF	2.5	2.5
Microtendipes	09021011094		7.67	6	CF		6.3
Microtendipes pedellus group	09021011094166	1.00			--	0.8	
Microtendipes rydalensis group	09021011094168	6.67			--	5.5	
Phaenopsectra	09021011101		0.33	7	SC		0.3
Phaenopsectra obediens group	09021011101180	0.33			--	0.3	
Polypedilum	09021011102	0.33	3.00	6	SH	0.3	2.5
Polypedilum aviceps	09021011102181	1.00			--	0.8	
Polypedilum illinoense group	09021011102185	1.00			--	0.8	
Polypedilum tritum	09021011102191	0.67			--	0.5	
Hemerodromia	09021016057	0.67	0.67	3	PR	0.5	0.5
Enochrus	09021105044	0.33	0.33		CG	0.3	0.3
Psephenus	09021108058		1.67	4	SC		1.4
Psephenus herricki	09021108058028	1.67			--	1.4	
Dubiraphia	09021113064	0.67	0.67	6	--	0.5	0.5
Macronychus	09021113065		2.00	4	--		1.6
Macronychus glabratus	09021113065040	2.00			--	1.6	
Optioservus	09021113067		8.33	3	SC		6.8
Optioservus tardella	09021113067052	8.33			--	6.8	
Promoresia	09021113069	1.00	1.00		--	0.8	0.8
Stenelmis	09021113070	1.67	1.67	5	SC	1.4	1.4
Physella	10010202027	0.33	0.33		SC	0.3	0.3

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Classification Attainment Report

Station Information

Station Number:	**S-1117**	River Basin:	Maine Coastal
Waterbody:	Richardson Brook - Station 1117	HUC8 Name:	Maine Coastal
Town:	T19 Ed Bpp	Latitude:	44 55 34.17 N
Directions:	DRIVE 250 FEET FURTHER SOUTH ON 19 RD THAN S-1116. PARK IN SMALL PULL OFF ON LEFT. WALK UPSTREAM THROUGH WOODS.	Longitude:	67 29 25.92 W
		Stream Order:	2

Sample Information

Log Number:	**2836**	Type of Sample:	ROCK BAG	Date Deployed:	7/22/2020
Subsample Factor:	X1	Replicates:	3	Date Retrieved:	8/19/2020

Classification Attainment

Statutory Class:	**A**	**Final Determination:**	**A**	Date:	2/17/2021
Model Result with P≥0.6:	A	**Reason for Determination:**	**Model**		
Date Last Calculated:	2/15/2021	Comments:			

Model Probabilities

First Stage Model

Class A	0.92	Class C	0.00
Class B	0.08	NA	0.00

C or Better Model

Class A, B, or C	1.00
Non-Attainment	0.00

B or Better Model

Class A or B	1.00
Class C or Non-Attainment	0.00

A Model

Class A	1.00
Class B or C or Non-Attainment	0.00

Model Variables

01	Total Mean Abundance	79.67
02	Generic Richness	40.00
03	Plecoptera Mean Abundance	5.00
04	Ephemeroptera Mean Abundance	33.67
05	Shannon-Wiener Generic Diversity	4.36
06	Hilsenhoff Biotic Index	3.62
07	Relative Abundance - Chironomidae	0.08
08	Relative Generic Richness Diptera	0.33
09	*Hydropsyche* Abundance	0.33
11	*Cheumatopsyche* Abundance	0.00
12	EPT Generic Richness/ Diptera Generic Richness	1.15
13	Relative Abundance - Oligochaeta	0.00
15	Perlidae Mean Abundance (Family Functional Group)	4.00
16	Tanypodinae Mean Abundance (Family Functional Group)	0.70
17	Chironomini Abundance (Family Functional Group)	1.06
18	Relative Abundance Ephemeroptera	0.42
19	EPT Generic Richness	15.00
21	Sum of Abundances: *Dicrotendipes, Micropsectra, Parachironomus, Helobdella*	0.00
23	Relative Generic Richness- Plecoptera	0.05
25	Sum of Abundances: *Cheumatopsyche, Cricotopus, Tanytarsus, Ablabesmyia*	1.76
26	Sum of Abundances: *Acroneuria, Maccaffertium, Stenonema*	14.33
28	EP Generic Richness/14	0.57
30	Presence of Class A Indicator Taxa/7	0.29

Five Most Dominant Taxa

Rank	Taxon Name	Percent
1	*Leucrocuta*	14.64
2	*Maccaffertium*	12.97
3	*Oecetis*	10.46
4	*Paraleptophlebia*	9.21
5	*Acroneuria*	5.02

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Classification Attainment Report

Station Number:	**S-1117**	Town:	T19 Ed Bpp	Date Deployed: 7/22/2020
Log Number:	**2836**	Waterbody:	Richardson Brook - Station 1117	Date Retrieved: 8/19/2020

Sample Collection and Processing Information

Sampling Organization: BIOMONITORING UNIT   Taxonomist: MICHAEL COLE

Waterbody Information - Deployment			Waterbody Information - Retrieval		
Temperature:	19.37	deg C	Temperature:	16.1	deg C
Dissolved Oxygen:	8.52	mg/l	Dissolved Oxygen:	8.52	mg/l
Dissolved Oxygen Saturation:	91.1	%	Dissolved Oxygen Saturation:	86.8	%
Specific Conductance:	19.9	uS/cm	Specific Conductance:	27.4	uS/cm
Velocity:	0.1	cm/s	Velocity:	0.1	cm/s
pH:	6.06		pH:	6	
Wetted Width:	2.6	m	Wetted Width:	2.6	m
Bankfull Width:	3.9	m	Bankfull Width:	3.9	m
Depth:	20.3	cm	Depth:	17	cm

Water Chemistry

Summary of Habitat Characteristics

Landuse Name	Canopy Cover	Terrain	
Upland Conifer	Dense	Rolling	
Potential Stressor	**Location**	**Substrate**	
Logging	Minimally Disturbed	Boulder	40 %
		Gravel	10 %
		Rubble/Cobble	50 %

Landcover Summary - 2004 Data

Sample Comments

VISIBLE FLOW.

Maine Department of Environmental Protection
Biological Monitoring Program
Aquatic Life Taxonomic Inventory Report

Station Number: S-1117 Waterbody: Richardson Brook - Station 1117 Town: T19 Ed Bpp

Log Number: 2836 Subsample Factor: X1 Replicates: 3 Calculated: 2/15/2021

Taxon	Maine Taxonomic Code	Count (Mean of Samplers) Actual	Count (Mean of Samplers) Adjusted	Hilsenhoff Biotic Index	Functional Feeding Group	Relative Abundance % Actual	Relative Abundance % Adjusted
Leuctra	09020204020	1.00	1.00	0	SH	1.3	1.3
Acroneuria	09020209042		4.00	0	PR		5.0
Acroneuria lycorias	09020209042125	4.00			--	5.0	
Boyeria	09020301004	1.00	1.67	2	PR	1.3	2.1
Boyeria vinosa	09020301004012	0.67			--	0.8	
Corduliidae	09020305	1.00	1.00		--	1.3	1.3
Calopterygidae	09020307	3.67	3.67		--	4.6	4.6
Calopteryx	09020307043	2.67	2.67	5	PR	3.3	3.3
Coenagrionidae	09020309	1.33	1.33		--	1.7	1.7
Argia	09020309048	2.33	2.33	7	PR	2.9	2.9
Baetis	09020401001		0.33	4	CG		0.4
Baetis pluto	09020401001009	0.33			--	0.4	
Acerpenna	09020401007		0.33	5	CG		0.4
Acerpenna pygmaea	09020401007011	0.33			--	0.4	
Leucrocuta	09020402011	11.67	11.67	1	SC	14.6	14.6
Maccaffertium	09020402015	1.67	10.33	4	SC	2.1	13.0
Maccaffertium vicarium	09020402015055	8.67			--	10.9	
Paraleptophlebia	09020406026	7.33	7.33	1	CG	9.2	9.2
Eurylophella	09020410036	3.67	3.67	3	CG	4.6	4.6
Microvelia	09020510025	0.33	0.33		PR	0.4	0.4
Polycentropus	09020603010	3.33	3.33	6	PR	4.2	4.2
Hydropsyche	09020604016		0.33	4	CF		0.4
Hydropsyche sparna	09020604016032	0.33			--	0.4	
Micrasema	09020609044	0.67	0.67	2	SH	0.8	0.8
Lepidostoma	09020611064	2.00	2.00	1	SH	2.5	2.5
Ceraclea	09020618072	0.33	0.33	3	CG	0.4	0.4
Mystacides	09020618075		2.00	4	CG		2.5
Mystacides sepulchralis	09020618075147	2.00			--	2.5	
Oecetis	09020618078	8.33	8.33	8	PR	10.5	10.5
Nigronia	09020701003		0.33	0	PR		0.4
Nigronia serricornis	09020701003003	0.33			--	0.4	
Chironomidae	09021011	0.33			--	0.4	
Labrundinia	09021011008		0.35	7	PR		0.4
Labrundinia pilosella	09021011008022	0.33			--	0.4	
Thienemannimyia	09021011020		0.35	3	PR		0.4
Thienemannimyia group	09021011020041	0.33			--	0.4	
Zavrelimyia	09021011022			8	PR		

Maine Department of Environmental Protection
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Aquatic Life Taxonomic Inventory Report

Station Number: S-1117 Waterbody: Richardson Brook - Station 1117 Town: T19 Ed Bpp

Log Number: 2836 Subsample Factor: X1 Replicates: 3 Calculated: 2/15/2021

Taxon	Maine Taxonomic Code	Count (Mean of Samplers) Actual	Count (Mean of Samplers) Adjusted	Hilsenhoff Biotic Index	Functional Feeding Group	Relative Abundance % Actual	Relative Abundance % Adjusted
Corynoneura	09021011036	0.67	0.70	7	CG	0.8	0.9
Nanocladius	09021011049	0.33	0.35	3	CG	0.4	0.4
Orthocladius	09021011050		0.70	6	CG		0.9
Orthocladius annectens	09021011050092	0.67			--	0.8	
Psectrocladius	09021011056	0.33	0.35	8	CG	0.4	0.4
Tvetenia	09021011065		0.35	5	CG		0.4
Tvetenia vitracies	09021011065113	0.33			--	0.4	
Rheotanytarsus	09021011072	0.33	0.35	6	CF	0.4	0.4
Tanytarsus	09021011076	1.67	1.76	6	CF	2.1	2.2
Lauterborniella	09021011092	0.33	0.35		CG	0.4	0.4
Microtendipes	09021011094		0.35	6	CF		0.4
Microtendipes pedellus group	09021011094166	0.33			--	0.4	
Phaenopsectra	09021011101		0.35	7	SC		0.4
Phaenopsectra punctipes group	09021011101181	0.33			--	0.4	
Simulium	09021012047	0.67	0.67	4	CF	0.8	0.8
Psephenus	09021108058		0.33	4	SC		0.4
Psephenus herricki	09021108058028	0.33			--	0.4	
Dubiraphia	09021113064		2.33	6	--		2.9
Dubiraphia quadrinotata	09021113064037	0.33			--	0.4	
Dubiraphia vittata	09021113064038	2.00			--	2.5	
Optioservus	09021113067		0.67	3	SC		0.8
Optioservus tardella	09021113067052	0.67			--	0.8	
Amnicola	10010104013	0.33	0.33		SC	0.4	0.4