2021-22 Review of Fisheries Activities for the Recovery of Endangered Atlantic Whitefish and Southern Uplands Atlantic Salmon in Nova Scotia

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2021-22 Review of Fisheries Activities for the Atlantic Whitefish Recovery Project: "Recovery of Endangered Atlantic Whitefish and Southern Uplands Atlantic Salmon in Nova Scotia"

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Table of Contents

1.0 Introduction 1
1.1 Background 1
1.2 Project Objectives 3
2.0 Methods 3
2.1 Spring Monitoring at Hebb Lake Dam Fish Passage Facility 3
2.2 Fall Monitoring of Rotary Screw Trap at Milipsigate Dam 4
2.3 Water Quality Monitoring Program at 19 sites throughout the Petite Rivière watershed 4
2.4 Water Quality Monitoring on Atlantic Whitefish Lakes 5
2.5 Zooplankton Survey 6
2.6 Smallmouth Bass Nest Surveys and Light Traps 6
2.7 Sub-watershed Fish Habitat Restoration Plans 9
3.0 Results and Discussion 10
3.1 Spring Monitoring at Hebb Lake Dam Fish Passage Facility 10
3.2 Fall Monitoring of Rotary Screw Trap at Milipsigate Dam 11
3.3 Water Quality Monitoring Program at 19 sites throughout the Petite Rivière watershed 11
3.4 Water Quality Monitoring on Atlantic Whitefish Lakes 16
3.5 Zooplankton Survey 19
3.6 Smallmouth Bass Nest Surveys & Light Traps 21
3.7 Sub-Watershed Fish Habitat Restoration Plans 24
4.0 Outreach, Education, and Media Coverage 29
5.0 Recommendations 29
6.0 Acknowledgments 30
7.0 References 31

List of Tables

Table 1. Sampling details for the 19 water quality sampling sites throughout the Petite Rivière watershed 5
Table 2. Coordinates for deep-water stations in three Atlantic whitefish lakes in the Petite Riviere watershed. 6
Table 3. Smallmouth bass nest classifications and descriptions. 8
Table 4. The number of fish captured in the Hebb Dam Fish Passage Facility trap from April 30 to June 30, 2021. 11
Table 5. Number of smallmouth bass nests per class in each survey location. 22
Table 6. Number of fish captured by species in light traps in Demone Cove in Milipsigate Lake in Spring 2021. 23
Table 7. Results of culvert assessments in the West River Sub-watershed that represent barriers to fish passage and possible future aquatic connectivity improvement projects. .. 25
Table 8. Backpack electrofishing survey data from Zwicker Brook on August 25th, 2021. . 27

List of Figures

Figure 1. Map of the Petite Rivière watershed showing the three lakes (Minamkeak, Milipsigate, and Hebb) which contain the existing wild Atlantic whitefish population, as well as the dams and fishways present in the system. 2
Figure 2. Left - Hebb Dam Fish Passage Trap lifted out of passage with door open. Right - Hebb Dam water level gauge near fishway exit. 4
Figure 3. Snorkellers survey smallmouth bass survey along the rocky shoreline of Demone Cove in Milipsigate Lake in June 2021. 7
Figure 4. Map of light trap placement in Demone Cove, Milipsigate Lake in Spring 2021. Asterisks (*) indicate second locations of light traps. 9
Figure 5. Above- and below-water view of a deployed light trap. Photos were captured in 2020. 9
Figure 6. Monthly temperature measurements at 19 sites within the Petite Rivière watershed from April 2021 to March 2022. 13
Figure 7. Monthly DO measurements at 19 sites within the Petite Rivière watershed from April 2021 to March 2022. 14
Figure 8. Monthly TDS measurements at 19 sites within the Petite Rivière watershed from April 2021 to March 2022. 15
Figure 9. Monthly pH measurements at 19 sites within the Petite Rivière watershed from April 2021 to March 2022. 16
Figure 10. Monthly water quality depth profiles in Hebb Lake from June to October 2021. 17
Figure 11. Monthly water quality depth profiles in Milipsigate Lake from June to October 2021. 18
Figure 12. Monthly water quality depth profiles in Minamkeak Lake from June to October 2021. 19
Figure 13. Monthly relative abundance of dominant zooplankton species in A) Milipsigate B) Minamkeak and C) Hebb lakes from June through September 2021. 20
Figure 14. Locations of identified smallmouth bass nests in Milipsigate Outlet and Demone Cove in Milipsigate Lake between May 28 and June 8, 2021. 21
Figure 15. Left – Smallmouth bass nest with hatching eggs; right – partially hatched nest with

both eggs and fry. 23
Figure 16. Photo of double culvert: TOM002 on unnamed brook and Tompkin Road repersenting a full barrier to fish passage in both right and left culverts. 25
Figure 17. Photo of triple culvert: SHR001 on Sheridan Brook and railway repersenting a full barrier to fish passage on the left culvert, and partial barriers to fish passage on the middle and right culverts. 26
Figure 18. Photo of double culvert: SUK001, on Suker Brook and Lake Pleasant Road representing a full barrier to fish passage in both right and left culverts. 26
Figure 19. Atlantic salmon parr captured and measured in a clear fish viewer during electrofishing surveys at Zwicker Brook on August 25th, 2021. 28

Executive Summary

Atlantic whitefish (*Coregonus huntsmani*) and southern upland Atlantic salmon (*Salmo salar*) are both species at risk and face various threats preventing recovery. To support populations of these anadromous fish, several restoration and monitoring activities were completed in 2021. This report provides a summary of monitoring and recovery initiatives undertaken in 2021 in the Petite Rivière and LaHave River watersheds in Southwest Nova Scotia. These activities were funded by the Habitat Stewardship Program for Aquatic Species at Risk.

Atlantic whitefish recovery and monitoring actions were conducted within their critical habitat, the three lakes in the upper part of the Petite Rivière watershed in Lunenburg County, Nova Scotia. These included the monitoring of water quality, zooplankton surveys, monitoring the upstream migration of gaspereau (*Alosa pseudoharengus*) into Hebb Lake, aquatic invasive species control, including smallmouth bass (*Micropterus dolomieu*) with nest surveys/destruction and the deployment of light traps to capture larval invasives. Lastly, outreach and education activities also took place.

Eleven active smallmouth bass nests were destroyed, and 137 larval invasive fish were removed using light traps including chain pickerel (*Esox niger*). At the Hebb Dam Fish Passage Facility, the number of gaspereau intercepted was the highest recorded since it opened in the fall of 2012, with almost 23,000 gaspereau migrating into Hebb Lake, while 28 smallmouth bass were euthanized and removed. A total of 38 different zooplankton species were identified across the three lakes with *Daphnia catawba* being the most dominant species overall. Water quality depth profiles were taken from the deepest point of each whitefish lake monthly from June to October. The thermocline and other parameters were similar to previous years, and data collected contributed to the long-term monitoring of these lakes to inform the study of Atlantic whitefish habitat. A total of 19 sites within the watershed were also monitored for water quality monthly using a YSI ProDSS. Results show elevated temperature and low dissolved oxygen in the summer months. Aquatic species may avoid these sites during this time in search of more favourable conditions.

Additionally, a sub-watershed plan was created for the LaHave River watershed to support fish habitat, in particular Atlantic salmon, using electrofishing and culvert and stream assessments in the West River sub-watershed. Overall, we addressed knowledge gaps relating to Atlantic whitefish and Atlantic salmon, managed, and studied invasive species in critical habitat, and continued efforts to support the recovery of these fish.

1.0 Introduction

1.1 Background

The Atlantic whitefish (*Coregonus huntsmani*) is a historically anadromous fish species currently restricted to the three upper lakes (Minamkeak, Milipsigate, and Hebb) of the Petite Rivière watershed in Southwest Nova Scotia, Canada (DFO 2018; Figure 1). Under Schedule 1 of the *Species at Risk Act* (SARA), the Atlantic whitefish is "Endangered" and as such, recovery actions are required. These activities in the Petite Rivière watershed are a continuation of the ongoing Atlantic Whitefish Recovery Project (AWRP) that serves to promote the species' recovery.

Several threats are preventing the recovery of the Atlantic whitefish, several of which are historical (e.g., hydroelectric generation, dams) while the remaining population faces other contemporary threats such as inadequate fish passage, also caused by dams, and acidification (COSEWIC 2010B). Another major threat to the Atlantic whitefish is invasive fish, specifically smallmouth bass (*Micropterus dolomieu)* and chain pickerel (*Esox niger)*. These invasive species predate and compete with native Atlantic whitefish (COSEWIC 2010B). Recovery actions include monitoring and management of invasive fish, passage through dams, and habitat monitoring.

In the neighbouring LaHave River watershed, the Southern Upland population of Atlantic salmon (*Salmo salar*) has been designated by COSEWIC as "Endangered" and is currently being considered for designation under SARA (COSEWIC 2010A). Building upon work previously carried out through funding from the Habitat Stewardship Program for Aquatic Species at Risk, the focus of salmon-related project activities is to continue to develop restoration plans for the LaHave River watershed. This will contribute to their recovery through assessment of habitat quality, prioritization of salmon nursery areas, and implementation of instream restorations.

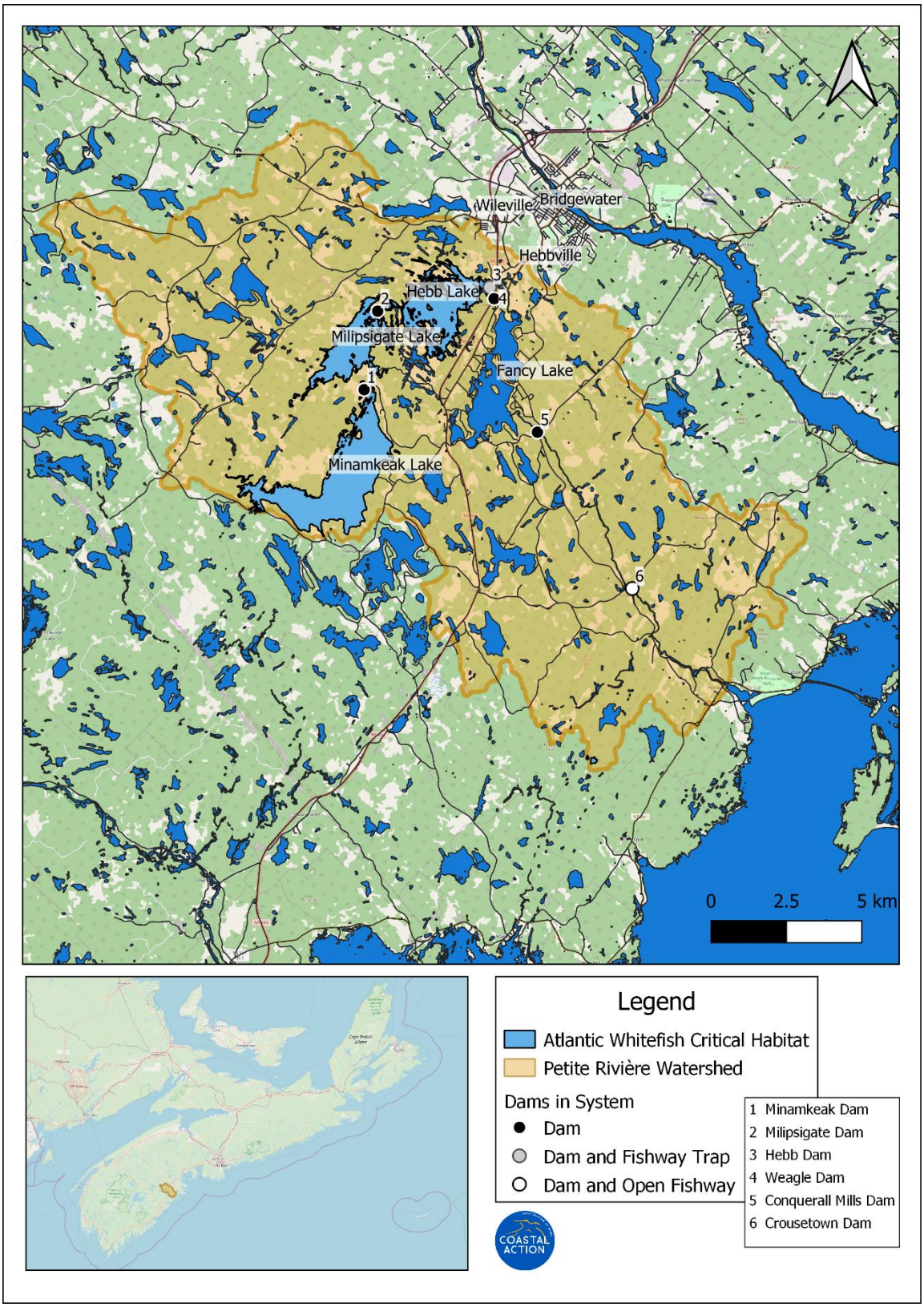

Figure 1. Map of the Petite Rivière watershed showing the three lakes (Minamkeak, Milipsigate, and Hebb) which contain the existing wild Atlantic whitefish population, as well as the dams and fishways present in the system.

1.2 Project Objectives

Coastal Action's AWRP has several goals and objectives for the 2021 field season and these include:

- Continue to remove invasive smallmouth bass and chain pickerel from the Atlantic whitefish habitat via smallmouth bass nest destruction, light traps, and the Hebb fishway trap;
- Continue to monitor water quality monthly on the Atlantic whitefish lakes and at 19 sites throughout the Petite Rivière;
- Expand on previous zooplankton surveys on the Atlantic whitefish lakes to a total of 12 samples collected monthly;
- Continue to monitor the upstream migration of gaspereau (*Alosa pseudoharengus*) into Hebb Lake in the spring;
- Update the West River LaHave Sub-watershed Fish Habitat Restoration Plan.

This report provides a detailed account of Coastal Action's activities in support of the recovery of the Atlantic whitefish, as funded by the Habitat Stewardship Program for Aquatic Species at Risk. It includes fieldwork activities conducted between April 2021 and March 2022, mainly in the three upper lakes of the Petite Rivière watershed, Hebb, Milipsigate, and Minamkeak Lakes, as well as the main branch of the Petite Rivière with some additional data collected from the nearby LaHave River watershed.

The activities outlined in this report were performed in addition to activities directly contracted to Coastal Action by Fisheries and Oceans Canada (DFO), which included the collection of juvenile Atlantic whitefish from the wild in the spring for rearing and husbandry and the removal of invasive smallmouth bass and chain pickerel through boat electrofishing. The data summaries for these activities have been submitted to DFO-Science separately.

In working towards the recovery of the species, Coastal Action removes invasive fish species from Atlantic whitefish habitat, maintains a dataset on gaspereau entering Atlantic whitefish habitat in the spring, addresses knowledge gaps relating to habitat and food sources of the Atlantic whitefish, and spreads awareness throughout the local community and beyond.

2.0 Methods

2.1 Spring Monitoring at Hebb Lake Dam Fish Passage Facility

The Hebb Lake Dam Fish Passage Trap Facility (Figure 2) was opened by Coastal Action staff on April 30, 2021, and was operated until June 30, 2021, to facilitate and monitor the upstream migration of gaspereau. The fish passage, or fishway, trap consists of a suspended 6'0" x 6'8" x 7'8" aluminum box that is deployed in the fishway to intercept any fish that are migrating upstream into Hebb Lake. Water temperature and level were recorded each day.

During operation, the trap was lifted at least once per day and twice per day when there were high numbers of gaspereau. The trap was opened using its front sliding door and each native captured fish was netted and transferred into the fishway upstream of the trap if permitted, where they would be free to continue upstream into Hebb Lake. All native fish species were permitted to pass upstream, except for sea lamprey (*Petromyzon marinus*), which were released downstream of Hebb Dam as the monitoring protocols ensured that any fish entering Hebb Lake would not pose a risk to Atlantic whitefish.

All native fish were sampled and released as per DFO protocol. Gaspereau were counted as they were transferred from the trap to the fishway upstream of the trap and all other fish were counted and measured to fork length (cm). Smallmouth bass and chain pickerel were removed and euthanized. The relative water level of Hebb Lake was also recorded (inches) daily using a gauge attached to the fishway (Figure 2) along with water temperature (°C), which was measured using a digital thermometer.

Figure 2. Left - Hebb Dam Fish Passage Trap lifted out of passage with door open. Right - Hebb Dam water level gauge near fishway exit.

2.2 Fall Monitoring of Rotary Screw Trap at Milipsigate Dam

Fall monitoring of the rotary screw trap at Milipsigate Dam was not completed during the fall 2021 season to conduct necessary maintenance and repairs on the trap.

2.3 Water Quality Monitoring Program at 19 sites throughout the Petite Rivière watershed

Coastal Action staff sampled the physical water characteristics at 19 sites throughout the watershed monthly in 2021 as part of a year-round monitoring program (Table 1). A new site was added in 2020 at the Hebb Dam Fishway to monitor the water quality going through

the fish passage structure. Physical water characteristics were measured using a ProDSS Digital Professional Series YSI sonde (model # 18A104818) temperature (°C), dissolved oxygen (% and mg/L), specific conductivity (µs/cm), total dissolved solids (mg/L), salinity (ppt), and pH. The YSI unit was calibrated monthly to ensure accuracy and the DO probe was calibrated three times in the field to prevent instrument drift.

Table 1. Sampling details for the 19 water quality sampling sites throughout the Petite Rivière watershed.

Start of sampling	Site name	Site type	Latitude	Longitude
May 2010	Milipsigate Dam	Lake	N 44.34448	W 064.59073
	Birch Brook	River/stream	N44.33183	W 064.59843
	Minamkeak Brook	Lake	N 44.31993	W 064.59843
	Hebb Lake to Fancy Lake outlet	River/stream	N 44.35044	W 064.53985
	Conquerall Mills Dam	River/stream	N 44.30833	W 064.52599
	Hebb Mill Brook (Publicover Lake)	River/Stream	N 44.29110	W 064.51426
	Italy Cross Intersection (Wallace Brook)	Culvert	N 44.26202	W 064.48882
	Crousetown Dam	Dam	N 44.26188	W 064.48510
	Brown Branch Brook	Culvert	N 44.24802	W 064.47700
	Wamback Mill Brook	River/stream	N 44.23883	W 064.45638
	Petite Rivière Head of Tide	River estuary	N 44.23420	W 064.44730
May 2011	Hebbville Dam	Dam	N 44.35199	W 064.54532
November 2011	Wallace Brook (Wallace Lake)	Culvert	N 44.27216	W 064.52512
	Weagle's Dam Outlet	River/stream	N 44.34456	W 064.54189
	Wildcat Brook	River/stream	N 44.35594	W 064.58411
May 2012	Fredrick's Brook	Culvert	N 44.31488	W 064.65692
	Kaulback Brook	Culvert	N 44.27448	W 064.45704
	Fire Pond	Lake	N 44.23794	W 064.45856
March 2020	Hebb Dam Fishway	Lake	N 44.35174	W 064.54665

2.4 Water Quality Monitoring on Atlantic Whitefish Lakes

Monthly water quality depth profiles were conducted at deep-water stations in Hebb, Milipsigate, and Minamkeak Lakes between June and October 2021. These stations were located at the deepest point of each lake (Table 2).

At each sampling site, Secchi disk depth (m) was measured and recorded, followed by a water quality depth profile using a multi-parameter YSI sonde (see Section 2.3 for additional details) taken at 1-m intervals from the surface (0.25 m depth) to the lake bottom. Temperature (°C), dissolved oxygen (% and mg/L), specific conductivity (µs/cm), total dissolved solids (mg/L), salinity (ppt), and pH were recorded during each depth profile.

Table 2. Coordinates for deep-water stations in three Atlantic whitefish lakes in the Petite Rivière watershed.

Lake	Latitude	Longitude
Hebb	44°20'49.6"N	64°33'47.1"W
Milipsigate	44°20'03.5"N	64°36'17.9"W
Minamkeak	44°17'18.5"N	64°36'06.8"W

2.5 Zooplankton Survey

Vertical zooplankton hauls were conducted once per month from June through September of 2021 in Hebb, Milipsigate, and Minamkeak Lakes to assess the relative abundance of zooplankton taxa to inform available food for juvenile Atlantic whitefish. In consultation with DFO staff, four sites were selected along a transect from one shoreline to another to capture specimens at various depths on each lake for a total of 12 samples per sampling day.

The zooplankton hauls were conducted using a Canadian Aquatic Biomonitoring Network (CABIN) kick net (mesh size 355 µm) that had been modified for use in this study. The wooden handle was removed, and a rope was tied onto the metal ring of the net at three points and then tied together to make a single line to be used for vertical hauling. Before performing the zooplankton hauls, the net was rinsed three times in the lake, without allowing lake water to spill over the top of the net. The sample jars (125 mL Mason jars) were then rinsed three times within the net while the net remained in the water with its ring above the surface. This was done to prevent any material from entering the sample jars that would not be excluded by the net's mesh size. Lake depth at each sample site was determined using a Humminbird Helix 9 SI unit. The net was lowered to 1 m off the bottom of the lake and then the net was hauled back up by hand at a constant speed of approximately 0.5 m/s. After being hauled, the net was rinsed with lake water using a squeeze bottle to ensure all net contents were flushed to the bottom of the basket. The basket was detached from the net, and the mesh filter was removed using tweezers and then rinsed off with 95% ethanol (EtOH) into a sample jar. Two hauls per site were conducted to ensure enough specimens would be present in each sample for identification.

After emptying all basket contents into the sample jar, additional ethanol was added to ensure the preservation of the sample. Samples were later analyzed using dissecting and compound microscopes. The first 50 specimens of zooplankton in each sample were identified to species level whenever possible to determine the relative abundance of species present in each lake.

2.6 Smallmouth Bass Nest Surveys and Light Traps

Smallmouth bass nest surveys were conducted in Demone Cove in Milipsigate Lake and at the Milipsigate Outlet over four days between May 28 and June 8, 2021. The surveys built upon those conducted previously by Coastal Action and DFO Inland Fisheries from 2006 to 2020, from which Demone Cove and Milipsigate Outlet were identified to contain a high number of smallmouth bass nests. The purpose of these surveys is to determine if nest destruction and removal of male smallmouth bass nest guards in previous years have

decreased the number of nests created this year.

In previous years, surveys were conducted visually from a boat along the shorelines of the coves using Rickly Hydrological Co. AquaScope II viewers. In 2021, surveys were conducted by snorkelling to increase efficiency in identifying and destroying bass nests (Figure 3). Surveys were conducted with a boat operator and at least one snorkeller and on one day, two teams were deployed.

Figure 3. Snorkellers survey smallmouth bass nests along the rocky shoreline of Demone Cove in Milipsigate Lake in June 2021.

As nests were identified by the snorkellers, the nest class and the presence of males guarding the nest were recorded along with locations using a Garmin eTrex 10 handheld GPS unit (Table 3). Once nest details were recorded, the male nest guard was angled off the nest (if present) by the boat operator, and the nest was destroyed by the snorkellers using their hands to disturb the substrate.

Table 3. Smallmouth bass nest classifications and descriptions.

Nest Classification	Description
Class A	Newly excavated
Class B	Eggs present
Class C	Fry present but not dispersed
Class D	Fry dispersed
F1	Nest abandoned after being Class A
F2	Nest abandoned after being Class B
NE	No eggs visible
N	Too late to assess

Shortly after bass nest surveys were concluded, five Watermark Quadrafoil larval light traps were installed at various locations in Demone Cove on Milipsigate Lake where hatched smallmouth bass nests were identified during the surveys (Figure 4). These traps were used to target and remove smallmouth bass and incidental chain pickerel larvae in the area. The traps were deployed for one week between June 18 – 30th, 2021 to target larval smallmouth bass and incidental larval chain pickerel in the area. The traps were anchored by two small bricks and a short piece of rope. A water-resistant LED flashlight was attached at the top of each trap and set to a low-light function (Figure 5). The traps were checked, and flashlight batteries changed, every 48 hours during deployment.

During checks, each trap was lifted into the boat and the bottom tray was removed and inspected for any fish. If a fish was found, it was identified to species level and if it was a native species, it was released with minimal handling. If the captured fish was a chain pickerel or smallmouth bass, it was euthanized and measured for total and fork length. After the fish were processed, the tray was reattached to the trap and the trap was reinstalled at the same location if successful. If traps did not effectively capture larval invasive fish, they were relocated within the cove to other known active bass nest locations to help maximize captures.

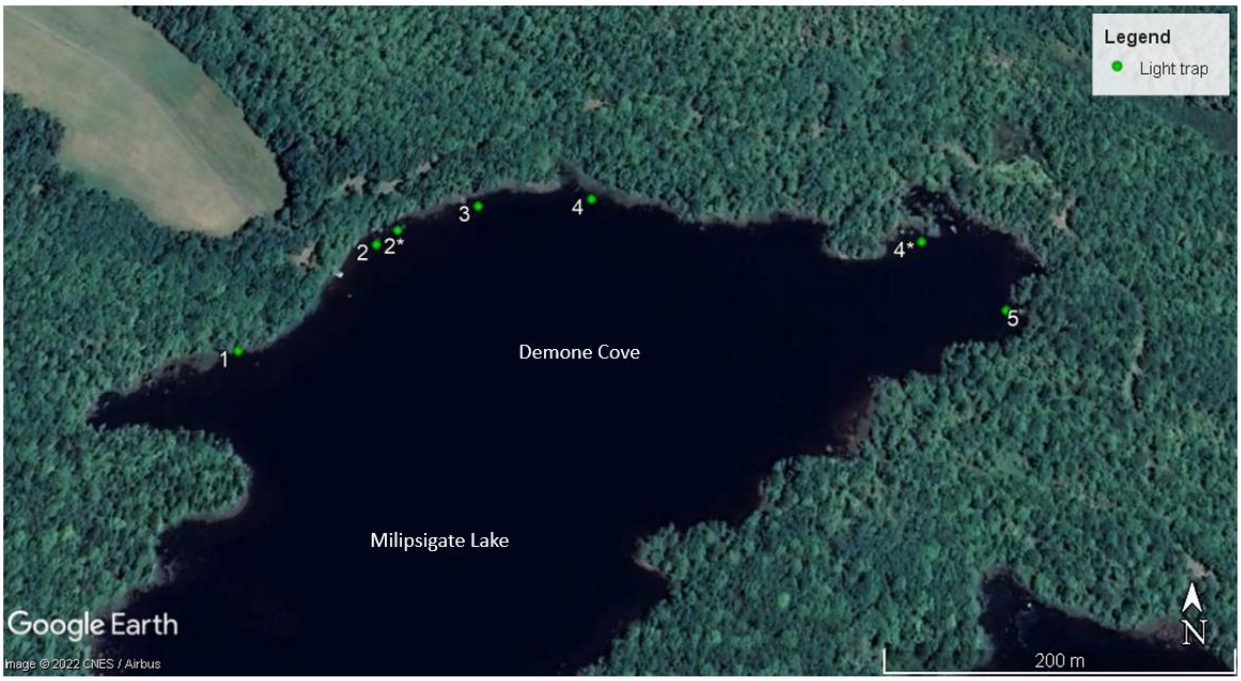

Figure 4. Map of light trap placement in Demone Cove, Milipsigate Lake in Spring 2021. Asterisks (*) indicate second locations of light traps.

Figure 5. Above- and below-water view of a deployed light trap. Photos were captured in 2020.

2.7 Sub-watershed Fish Habitat Restoration Plans

The sixth and final sub-watershed plan in the LaHave River watershed was created in 2021 by conducting culvert, aquatic connectivity, and stream assessments; as well as GIS mapping and water quality analysis to support and identify key Atlantic salmon habitat in this region. Aquatic connectivity assessments were conducted using NSSA Adopt-a-Stream protocols

(2019), which included culvert and barrier assessment information, collected by analyzing substrate, habitat, channel characteristics, tailwater cross-sections and stream elevation variation using survey equipment. Information including material, dimensions, and deterioration was collected to evaluate culverts.

Stream assessments on the West River Sub-watershed were completed using Coastal Action's protocol and included observations of the stream and bank features, as well as canopy cover, substrate and adjacent land use. Wetted, bankfull, and floodplain width, average depth, and thalweg were collected at each site. Water quality was measured using a YSI multiparameter sonde. Benthic macroinvertebrates were sampled and identified with randomized rock grabs. Finally, a riparian health assessment score was assigned to the section, calculated from scores assigned in a series of habitat evaluation questions. Coastal Action's stream assessment protocol has been adapted from the Nova Scotia Fish Habitat Assessment Protocol (NSSA Adopt-a-Stream, 2019), Nova Scotia Riparian Health Assessment Protocol, and CABIN Assessment Protocol (Environment Canada, 2012).

Backpack electrofishing surveys were also completed in 2021 to assess fish presence and abundance within the sub-watershed using a multi-pass depletion method. To capture and observe fish, the site was closed off to fish using barrier nets and two to three passes were conducted with the electrofisher. Baseline pulse frequency (Hz), duty cycle (%) and Voltz were set for general fish-catching efficiency and adjusted as needed according to fish reactions. As fish were captured, they were placed in a clean, aerated holding tank and fish were identified and measured while remaining underwater in clear viewing containers before being released back into the area in which they were captured.

3.0 Results and Discussion

3.1 Spring Monitoring at Hebb Lake Dam Fish Passage Facility

From April to June 2021, just under 23,000 fish comprised of six different species were captured in the fishway trap at Hebb Dam (Table 4). These included gaspereau, white sucker (*Catostomus commersonii*), brook trout (*Salvelinus fontinalis*), American eel (*Anguilla rostrata*), sea lamprey, and smallmouth bass. The 2021 season had the largest recorded migration of gaspereau through the Hebb fishway at 22,857 individuals, the next highest being 20,350 in 2018 (Feener et al. 2021). Of those in 2021, 45 were incidental mortalities.

Table 4. The number of fish captured in the Hebb Dam Fish Passage Facility trap from April 30 to June 30, 2021.

Species	Number
Gaspereau	22857
Smallmouth bass	28
American eel	5
Sea lamprey	18
White sucker	7
Brook trout	1
Total	**22916**

3.2 Fall Monitoring of Rotary Screw Trap at Milipsigate Dam

This activity was not completed; see section 2.2 for more information.

3.3 Water Quality Monitoring Program at 19 sites throughout the Petite Rivière watershed

Overall, most sites monitored across this watershed had similar temperature patterns across the year. Water temperatures at the 19 sites in the Petite Rivière watershed ranged from -0.04 to 26.9 °C throughout 2021 (

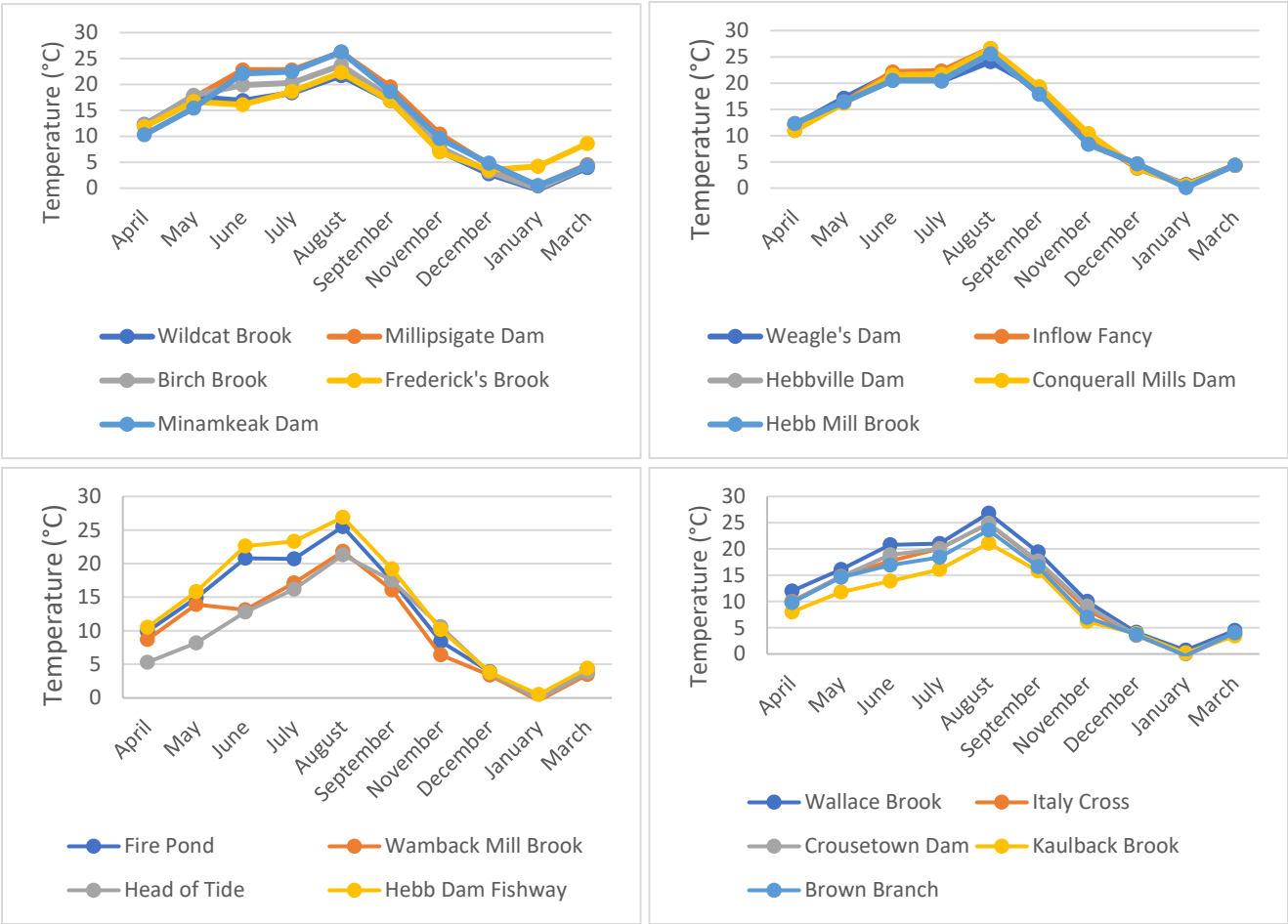

Figure 6. Monthly temperature measurements at 19 sites within the Petite Rivière watershed from April 2021 to March 2022.

). All sites had temperatures over 20 °C during the summer months from June to September, the temperature threshold recommended for cold-water fish (NSSA 2014). The highest temperatures across the monitoring period were recorded in August. In comparison to other years, water temperatures were warmer earlier in the year with several sites exceeding 20°C in June (Feener et al. 2021). Sites with larger amounts of groundwater infiltration and shaded sections of the river had lower temperatures. These areas provide important thermal refuge habitats for fish during these high temperatures.

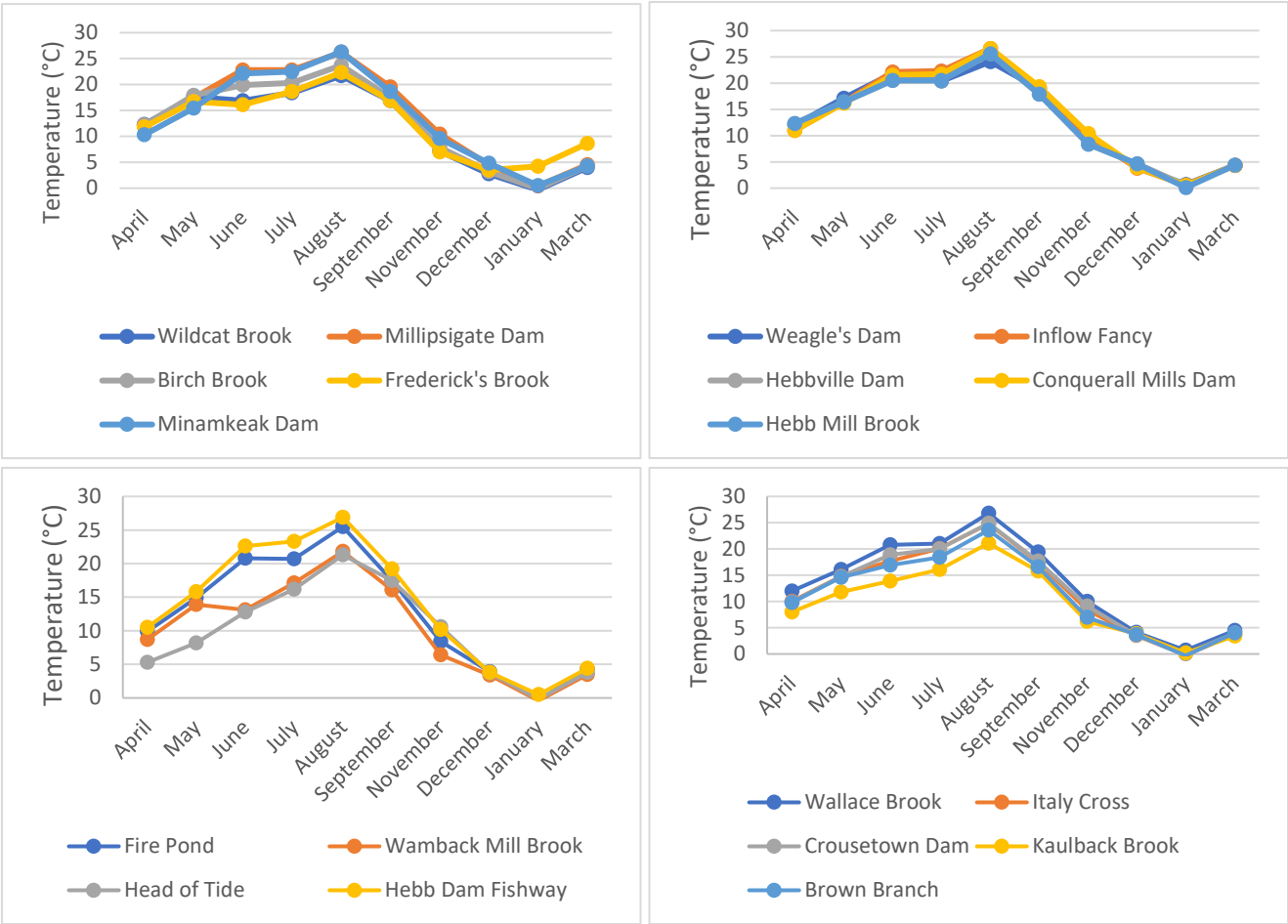

Figure 6. Monthly temperature measurements at 19 sites within the Petite Rivière watershed from April 2021 to March 2022.

Dissolved oxygen (DO) throughout the Petite Rivière watershed ranged from 4.27 to 14.85 mg/L in 2021 (Figure 7). At various times during the year, 11 sites fell below the 6.5 mg/L DO threshold for cold-water aquatic life (CCME 1999). DO was measured below this threshold most frequently in the summer months, from June to September, indicating lower water quality for fish. The minimum recorded DO was 4.27 mg/L, above the < 2.1 mg/L DO concentrations known to cause detrimental effects to aquatic organisms (Moss and Scott 1961); nevertheless, low DO, coupled with increased water temperatures, can stress aquatic organisms. Low DO for extended periods of time can be detrimental to fish; however, the monthly sampling frequency of these monitoring activities cannot adequately reflect the range and longevity of these periods.

Figure 7. Monthly dissolved oxygen measurements at 19 sites within the Petite Rivière watershed from April 2021 to March 2022.

Total dissolved solids (TDS) ranged from 13.2 to 26.7 mg/L across the 18 freshwater sites in the Petite Rivière in 2021 (Figure 8). At the Head of Tide estuarine site, it ranged from 24 mg/L to 28,756 mg/L, due to the influence of saltwater. Although the effects of TDS on fish are dependent on the life stage (Weber-Scannell and Duffy 2007), juvenile and mature Salmonidae can survive in waters with TDS greater than 2,000 mg/L. Based on the TDS measurements collected in 2021, the freshwater sites do not exceed this threshold, therefore, would not pose a threat to freshwater aquatic organisms.

Figure 8. Monthly TDS measurements at 19 sites within the Petite Rivière watershed from April 2021 to March 2022.

The pH of the 19 Petite Rivière sites ranged from 3.19 to 8.28 with a mean of 5.46 in 2021 (Figure 9). All 19 sites fell below the 6.5 pH threshold set by the CCME for the protection of aquatic life (CCME 2007). Head of Tide was the only site not to fall below the 5.5 pH threshold for Southwest Nova Scotia, the regional threshold recommended by Environment and Climate Change Canada (ECCC). Therefore, the acidity of the Petite Rivière watershed does pose a threat to aquatic organisms. Most sites had a minimum pH value below 5; a value

known to decrease the survival of Atlantic whitefish eggs (Cook et al. 2010). As the sampling frequency limits data to a monthly basis, the true variability of pH within the watershed is unknown. The acidity of each site has increased as compared to previous years despite the infrequency of sampling (MacLeod 2018). Due to increasing pH, the risk to aquatic life is increasing.

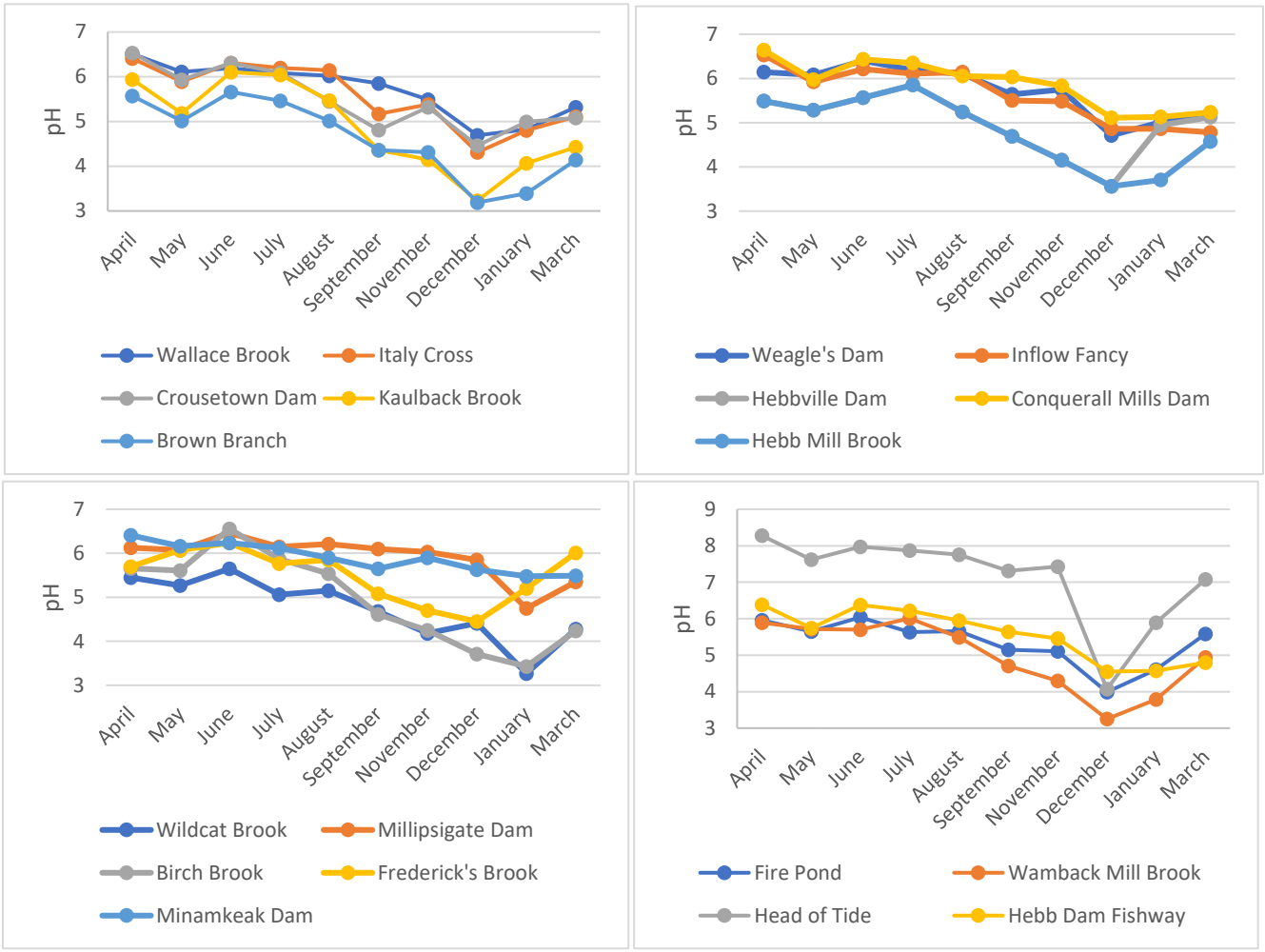

Figure 9. Monthly pH measurements at 19 sites within the Petite Rivière watershed from April 2021 to March 2022.

3.4 Water Quality Monitoring on Atlantic Whitefish Lakes

The September water quality profile was delayed to October 1, 2021, due to weather and lack of available staff.

In Hebb Lake, the thermocline was present at 12 meters below the surface and shifted to five to six meters in July (Figure 10). No thermocline was detected in the August and September depth profiles. A decrease in DO (mg/L) and an increase in TDS (mg/L) were noted around the thermocline when present.

The thermocline in Milipsigate Lake was noted at 6 m below the surface in June. It remained at the same depth in July, although the thermocline was not as drastic (Figure 11). As with Hebb Lake, a thermocline was not present in the August and September depth profiles. DO decreased and TDS increased below the thermocline when present.

Due to high winds and difficulty keeping the YSI cord vertical during June sampling on Minamkeak Lake, the thermocline was more difficult to determine but occurred between 8 and 11 m (Figure 12). The July depth profile was taken at a different site (near the zooplankton haul sites) due to mechanical issues, therefore, this profile reached a depth of 12 m, with a thermocline present at eight meters. In August, the thermocline occurred between 9 and 10 m and the thermocline was absent in September. Similar to the other two lakes, a decrease in DO and an increase in TDS were noted at or below the thermocline when present.

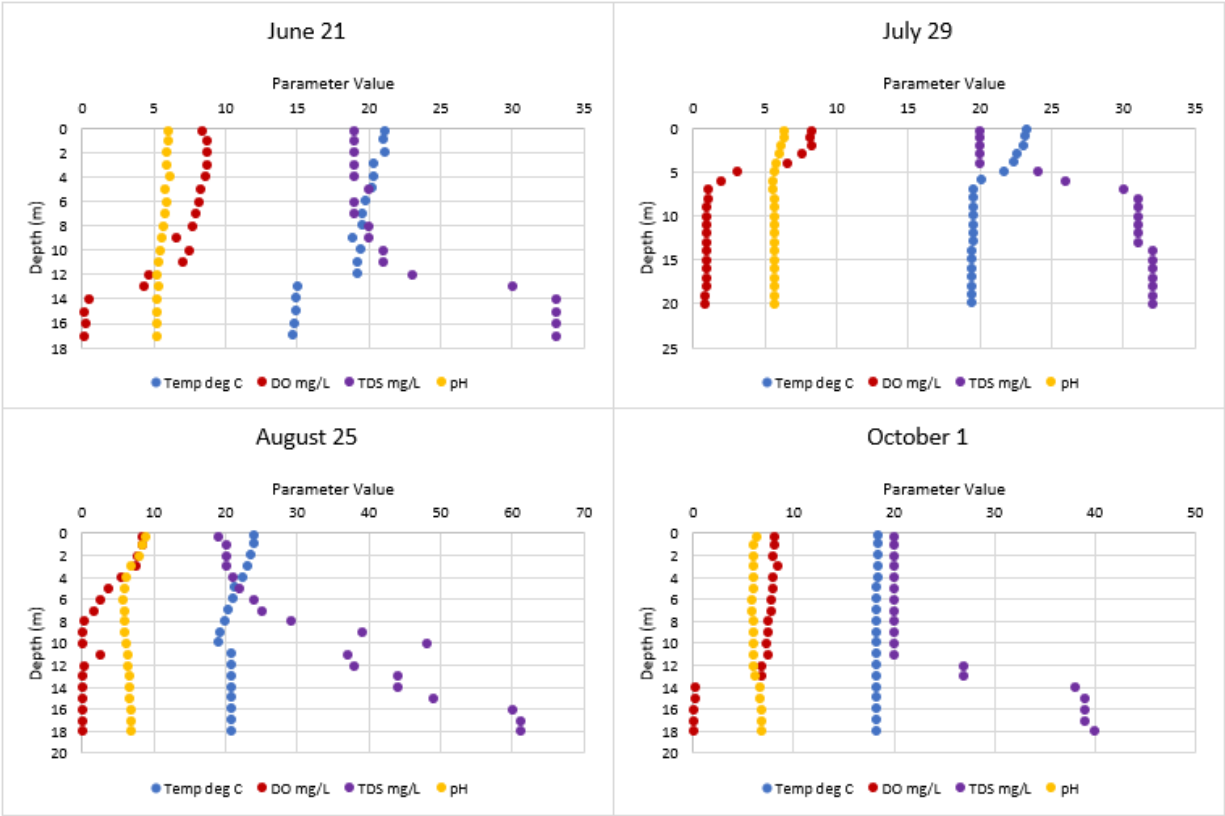

Figure 10. Monthly water quality depth profiles in Hebb Lake from June to October 2021.

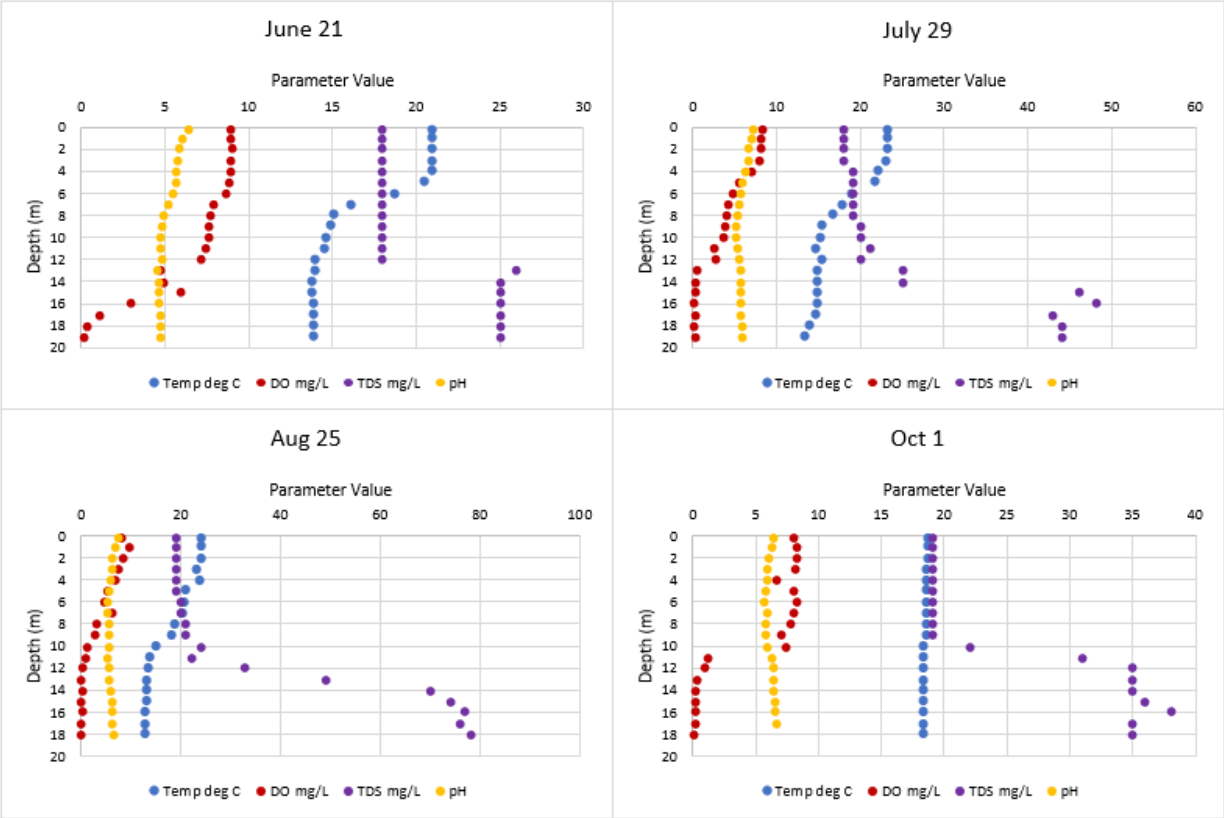

Figure 11. Monthly water quality depth profiles in Milipsigate Lake from June to October 2021.

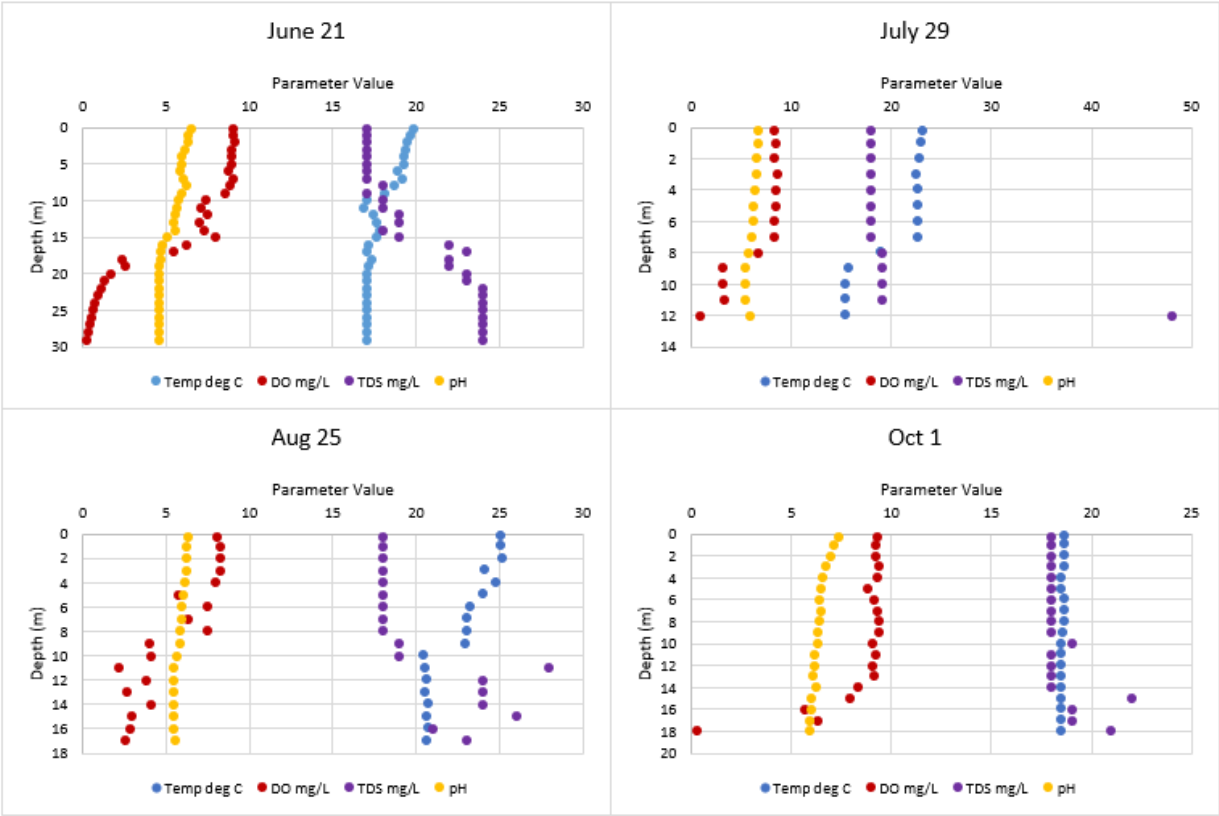

Figure 12. Monthly water quality depth profiles in Minamkeak Lake from June to October 2021.

3.5 Zooplankton Survey

Forty-eight zooplankton samples from each lake were collected monthly from June through September of 2021. A total of 38 different species were identified. *Daphnia catawba* was the most dominant species overall, comprising 70.8% of all Milipsigate specimens, 48.5% of all Minamkeak specimens, and 25.6% of all Hebb specimens identified. Other prominent species included *Diaphanosoma sp*. and *Epischura nordenskiøldi* in all three lakes, *Latona glacialis* in Minamkeak and Hebb lakes, and *Holopedium gibberum* in Hebb Lake.

Among the June samples, *Daphnia catawba* was the dominant species in Milipsigate and Minamkeak lakes, while *Holopedium gibberum* was more abundant in Hebb samples. *Daphnia catawba* was dominant in the July samples of all three lakes, comprising 85%, 72.5%, and 67.7% of specimens identified in Milipsigate, Minamkeak, and Hebb lakes, respectively. Their relative abundance decreased in the August and September samples, while the relative abundance of *Diaphanosoma sp*. increased to be dominant in September samples, comprising 39.5% of Milipsigate and 50.5% of Minamkeak specimens (Figure 13). Alternatively, in Hebb Lake, *Latona glacialis* was the more dominant species in August, and *Epischura nordenskiøldi* was the more dominant species in September. Not all Hebb samples contained enough specimens for 50 to be identified, so relative percentages were used in all calculations. Hebb Lake samples also included the greatest diversity in zooplankton with 33 different species, resulting in lower relative abundances of its dominant species compared

to Milipsigate and Minamkeak lakes, in which 15 and 20 species were identified, respectively.

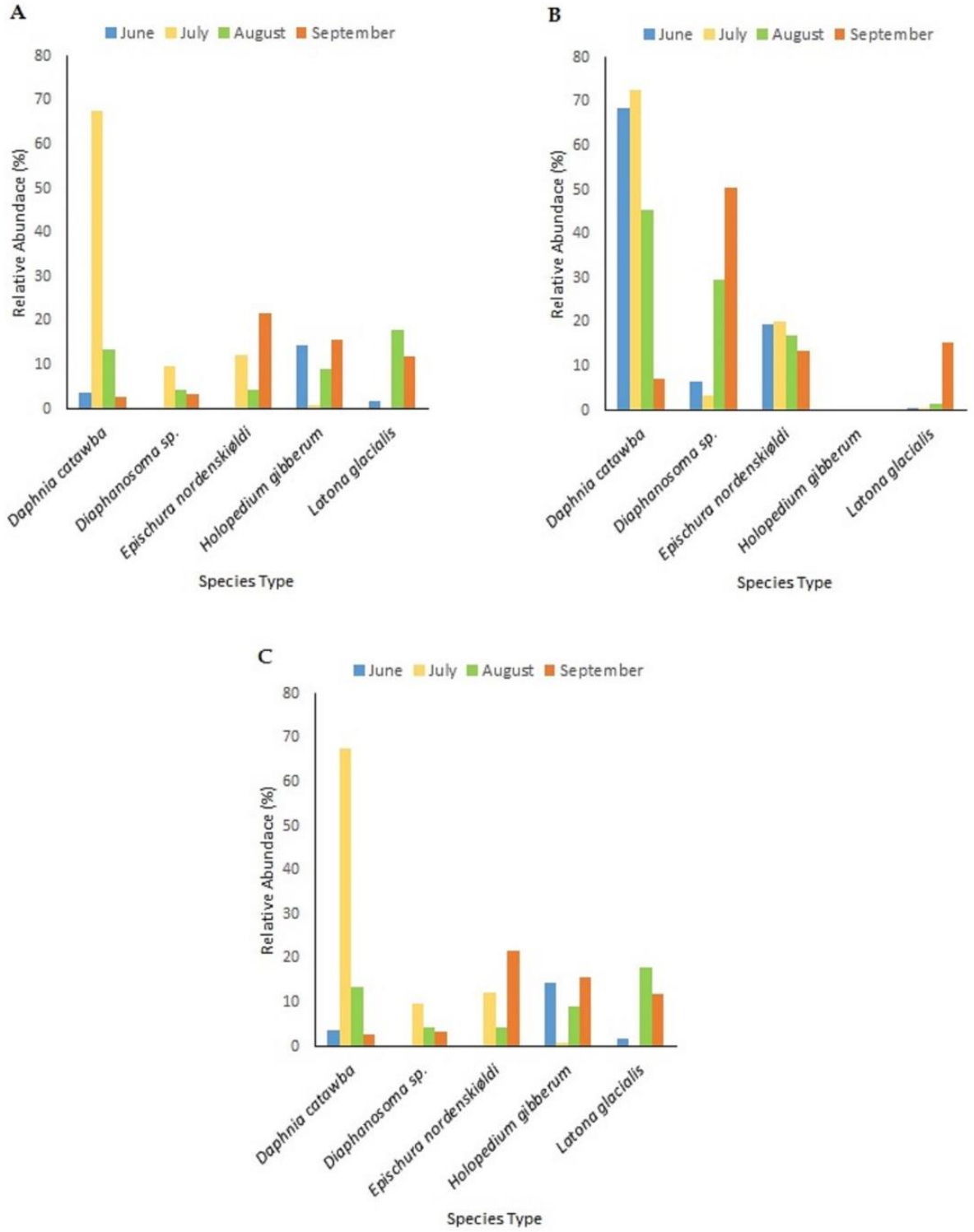

Figure 13. Monthly relative abundance of dominant zooplankton species in A) Milipsigate B) Minamkeak and C) Hebb lakes from June through September 2021.

3.6 Smallmouth Bass Nest Surveys & Light Traps

Demone Cove on Milipsigate Lake was surveyed over three days and Milipsigate Outlet over two days between May 28 and June 8, 2021 (Figure 14). During this time when the water temperature was between 17.7 and 22.8°C, 17 nests were identified in Demone Cove and 9 in Milipsigate Outlet (Figure 14). In Demone Cove, the majority of nests were classified as type A, newly excavated and without eggs, and the rest were either Class B or C. In Milipsigate Outlet the majority of nests were a tie between Classes B and C, two were a combination (partially hatched containing both eggs and fry; Figure 15), and the rest were either Class A or D. Each nest containing eggs or fry was destroyed, amounting to 11 nests, and a total of 23 males were angled from the nests. The substrate for all nests was pebble and cobble.

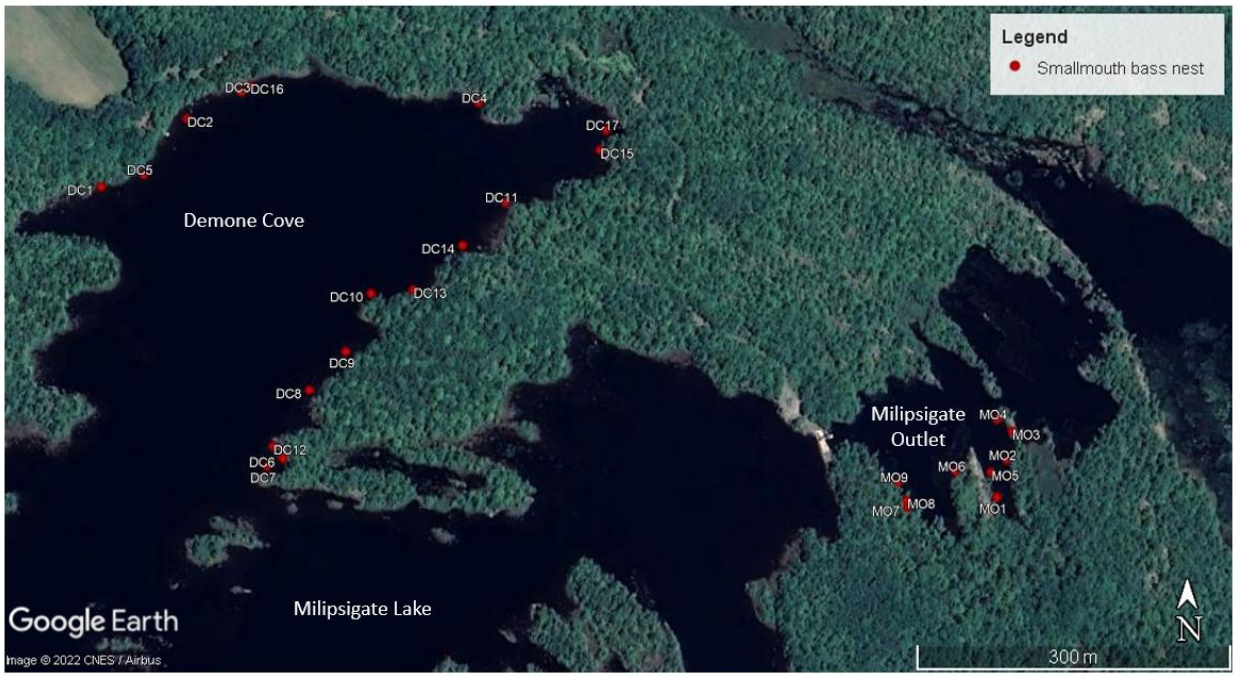

Figure 14. Locations of identified smallmouth bass nests in Milipsigate Outlet and Demone Cove in Milipsigate Lake between May 28 and June 8, 2021.

Table 5. Number of smallmouth bass nests per class in each survey location.

Location	Nest Classification	Frequency
Demone Cove	A - Newly excavated	12
	B - Eggs present	4
	C - Fry present but not dispersed	1
Milipsigate Outlet	A - Newly excavated	2
	B - Eggs present	2
	B & C - Eggs and fry present	2
	C - Fry present but not dispersed	2
	D - Fry dispersed	1
	Total	**26**

In Demone Cove, 25 nests were found in 2018, 16 in 2019, and 13 nests in 2020 (Feener et al. 2021). This year had an increase of four nests from 2020 but over half of those were newly excavated without eggs or fry and there has been an overall decrease in nests since 2018. There was higher visibility with snorkelling versus surveys from the boat, therefore some nests may have been missed in previous years. Snorkelling was also a more efficient method for surveying and is recommended, when possible, in future years.

Figure 15. Left – Smallmouth bass nest with hatching eggs; right – partially hatched nest with both eggs and fry.

One young-of-the-year (YOY) larval chain pickerel measuring 5.5 cm and 136 YOY smallmouth bass averaging 1.94 cm in length were captured between June 18 and June 30, 2021, using light traps in Milipsigate Lake. All larval white sucker and yellow perch (*Perca flavescens*) captured were released unharmed (Table 6).

Table 6. Number of fish captured by species in light traps in Demone Cove in Milipsigate Lake in Spring 2021.

Species	Count	Catch per unit effort (# fish/hr)	Average fork length (cm)
Chain pickerel	1	0.003	5.5
Smallmouth bass	136	0.471	1.9
White sucker	1	N/A	1.8
Yellow perch	3	N/A	2.6

This new method of deploying the light traps following bass nest surveys in locations of known recently active nests was much more effective at capturing larval smallmouth bass than the light trap trial in the summer of 2020 and slightly less effective at capturing larval chain pickerel. Five of the six traps deployed in June and July of 2020 were put in locations on Milipsigate Lake known to yield high numbers of juvenile chain pickerel. The catch per

unit effort (CPUE) for chain pickerel decreased from 0.019 in 2020 to 0.003 in 2021. However, the CPUE for smallmouth bass increased significantly from 0.042 to 0.471. It's expected that if the light traps are deployed even sooner following bass nest surveys, the results for catching larval smallmouth bass would improve further. Overall, boat electrofishing is still far more efficient for large-scale YOY invasive removals than the light traps.

3.7 Sub-Watershed Fish Habitat Restoration Plans

Since 2007, Coastal Action has identified key salmon habitat and conducted various assessment and monitoring activities throughout the LaHave River watershed. Sub-watershed plans have been developed for each of the six LaHave River sub-watersheds with the completion of the West River Sub-watershed Fish Habitat Restoration Plan in 2021. The plan provides a sound understanding of the environmental conditions within the West River Sub-watershed and habitat assessment data for the prioritization of restoration efforts for Atlantic salmon. Assessments of land-use practices, aquatic connectivity, fish habitat conditions, riparian health, and water quality contribute to the identification of harmful environmental impacts and are used to inform habitat restoration projects.

Culverts are significant barriers to fish and salmon passage, limiting their movement within watersheds and altering habitat (COSEWIC 2010A). Coastal Action staff conducted 22 crossing assessments; 14 of those crossings were bridges, and eight were culverts, although five of those culverts were not connected to fish habitats. Of these culverts, one was assessed as a partial barrier and two as full barriers. Table 7 presents culvert assessment results and opportunities for restoration. It is recommended that TOM 002 culvert be replaced; however, it is a low priority because there is limited upstream salmon habitat and would be complex to improve. At SHR001, a full crossing replacement is recommended, and it is of moderate priority because there is a significant amount of potential upstream habitat that would be made accessible if replaced. Lastly, SUK001 is a high priority barrier due to the significant upstream habitat and it is recommended that it be replaced or retrofitted if possible.

Table 7. Results of culvert assessments in the West River Sub-watershed that represent barriers to fish passage and possible future aquatic connectivity improvement projects.

Culvert	Outflow drop (cm)			Culvert slope (%)			Barrier status			Priority
				Right	Middle	Left	Right	Middle	Left	
TOM002	52	NA	48	2.47	NA	2.63	Full	NA	Full	Low
SHR001	4	3	-9	-1.35	-1.13	2.78	Full	Partial	Full	Moderate
SUK001	13	NA	12	1.11	NA	1.2	Full	NA	Full	High

Figure 16. Double culvert: TOM002 on unnamed brook and Tompkin Road representing a full barrier to fish passage in both right and left culverts.

Figure 17. Triple culvert: SHR001 on Sheridan Brook and railway representing a full barrier to fish passage on the left culvert, and partial barriers to fish passage on the middle and right culverts.

Figure 18. Double culvert: SUK001, on Suker Brook and Lake Pleasant Road representing a full barrier to fish passage in both right and left culverts.

Staff covered 63,280 m^2 during eleven stream assessments by ground-truthing streams on foot. Combined with previous data collected by Coastal Action, a total of 47 sites were included in the watershed plan and many sites displayed the potential for restoration opportunities. These include the possibility of installing instream structures such as digger logs (24 sites) to mimic natural digger log processes, increasing salmonid habitat and aquatic diversity, and thermal refuges for fish and gravel habitat for spawning. Twenty-one sites could benefit from bank stabilization and riparian planting which would reduce erosion, regulate stream flow, provide shade for aquatic species and maintain the stream bank. Other restoration opportunities include deflectors (1 site), fish passage improvement (1 site), garbage cleanup (1 site) and a natural blockage barrier removal (1 site). Restoration opportunities identified in this watershed offer concrete actions to improve the habitat for all fish, especially the Southern Upland Atlantic salmon.

Electrofishing was conducted on Zwicker Brook in the West Branch Sub-watershed and four different species were captured. During this survey, 11 Atlantic salmon parr were identified, indicating good quality potential nursery habitat at these sites (Table 8; Figure 19).

Table 8. Backpack electrofishing survey data from Zwicker Brook on August 25th, 2021.

Species	Frequency
Americal eel	1
Atlantic salmon	11
Banded killifish	0
Brook trout	0
Creek chub	8
Lamprey	0
White sucker	6
Total	26

Figure 19. Atlantic salmon parr captured and measured in a clear fish viewer during electrofishing surveys at Zwicker Brook on August 25th, 2021.

Electrofishing surveys proved challenging in 2021. Surveys were delayed due to an error with the scientific licencing permit date. Surveys could not be completed in the spring as anticipated, and therefore, only took place in August and September 2021. Due to high air and water temperatures (> 22°C), and large rainfall events in September there were few suitable survey days and locations. Previous electrofishing data was acquired from DFO surveys and was included in the plan; however, Coastal Action intends to conduct electrofishing in the West River Sub-watershed in 2022 to supplement current data.

These sub-watershed fish habitat restoration plans are living documents, with additions and amendments being updated as more data is collected, and restoration work is completed. The creation of this sixth and final, sub-watershed plan in the West River provides site guidelines and will allow for future fish passage improvements and in-stream restoration projects to be prioritized. Background material including the species present, development, impacts, water quality, elevation and lake and tributary information were researched and included in this plan. Along with fish passage improvement at three sites, 47 habitat improvement opportunities identified through ground-truthing field assessments are described and mapped within the West River Sub-watershed Fish Habitat Restoration Plan.

4.0 Outreach, Education, and Media Coverage

An important component of the AWRP is to provide the local community and beyond with information about the plight of the Atlantic whitefish and ongoing recovery efforts.

Throughout the year, Coastal Action presented to local community groups within Lunenburg County, Shelburne County, Halifax Regional Municipality, and beyond (through online presentations). Outreach materials were available at Coastal Action events. Social media was used to highlight AWRP fieldwork throughout the field season. Online presentations and material were used in addition to in-person outreach due to COVID-19 considerations.

The AWRP was highlighted at the following events:

- Atlantic Whitefish Community Day (October 2, 2021);
- Terranaut Club guided chain pickerel dissections as part of a summer program for girls and under-represented genders (girls+) aged 9-18 (July 11, 2021);
- LaHave River Salmon Association Pickerel Derby (July 23, 2021);
- Community guided walks in Lunenburg and Shelburne Counties (delivered through local municipalities);
- Lecture on Atlantic whitefish delivered to Aquatic Environment Class at Saint Mary's University (November 29, 2021);
- NSISC Invasive Species Forum keynote presentation on Atlantic whitefish (March 9, 2022).

Coastal Action published five AWRP-related social media posts plus additional "stories" on Instagram, Facebook, and Twitter, and online newsletter articles through our Coastal Chronicle newsletter during the 2021-22 project year. These posts showcased photos from the field and were designed to engage Coastal Action's followers with updates about project activities. These posts reach Coastal Action's 6,461 combined followers from Instagram, Facebook, and Twitter social media platforms with a total combined reach of 12,155 and 324 direct interactions. The online newsletter Coastal Chronicle reached over 500 people. Additionally, Paul Withers of CBC News wrote an article on a logging proposal adjacent to Minamkeak Lake on March 17, 2022 (Withers 2022).

5.0 Recommendations

Atlantic whitefish still face various threats and barriers to population recovery (COSEWIC 2010B; DFO 2018). The activities described in this report contribute to the ongoing recovery of the endangered Atlantic whitefish, by complementing work done by Fisheries and Oceans Canada and Coastal Action in previous years. Continued work in this watershed and direct actions to support this species at risk are required. The following recommendations would

contribute to future recovery efforts: continue to monitor water quality in Hebb, Milipsigate, and Minamkeak Lakes; investigate the second spawning event (fall spawning) for chain pickerel in Milipsigate Lake to determine how that may impact recruitment; and expand zooplankton sampling to begin earlier in the season to investigate emergence times for Hebb, Milipsigate, and Minamkeak Lakes to determine food availability for larval Atlantic whitefish as they are developing.

6.0 Acknowledgments

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