2022-23 Review of Fisheries Activities for the Recovery of Endangered Atlantic Whitefish and Southern Uplands Atlantic Salmon in Nova Scotia

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April 2023

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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 2022, building on the activities undertaken previously. This report provides a summary of monitoring and recovery initiatives undertaken in the 2022-2023 fiscal year 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 (HSP).

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*) and released hatchery-origin Atlantic whitefish into Hebb Lake, monitoring and maintaining fish passage, aquatic invasive species control, including smallmouth bass (*Micropterus dolomieu*) with nest surveys/destruction, and the deployment of light traps to capture larval invasive fish. Lastly, outreach and education activities also took place.

A total of 983 smallmouth bass and 1,091 chain pickerel (*Esox niger*) of different age classes were removed from the Petite Rivière watershed during the 2022-23 season. Eight smallmouth bass nests containing eggs or fry were destroyed, 12 guarding males were angled from the nests, and 102 larval smallmouth bass were removed using floating light traps directly following the nest surveys. At the Hebb Dam Fish Passage Facility, the number of gaspereau intercepted in the spring was the highest recorded since it opened in the fall of 2012, with 35,299 gaspereau migrating into Hebb Lake. Through the combined spring and fall monitoring of the Hebb Dam Fish Passage Facility, 60 adult smallmouth bass and two adult chain pickerel were euthanized and removed.

A total of 33 different zooplankton species were identified across the three lakes from April through September 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 April through September. The thermocline and other parameters were similar to previous years, and the data contributed to the long-term monitoring of these lakes to inform the study of Atlantic whitefish habitat. A total of 19 sites throughout the watershed were also monitored monthly for water quality using a YSI ProDSS. Consistent with previous years, 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, fish habitat improvement efforts were carried out in multiple watercourses located in the West Branch and Main River Sub-watersheds of the LaHave. This work included the installation of three instream structures and the maintenance of 20 existing structures. As a result, a total of 530 linear meters or 4,200 m^2 of instream habitat was covered during the 2022 season. GIS maps were also created to show locations where habitat

improvement work was undertaken and where Atlantic salmon presence has been confirmed.

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 (HSP) and the development of restoration plans in 2021-22 for the LaHave River watershed, the focus of salmon-related project activities for 2022-23 was to conduct instream habitat improvement in identified salmon nursery habitat. This will contribute to salmon recovery by improving habitat suitability for both spawning adults and young salmon in their early life stages.

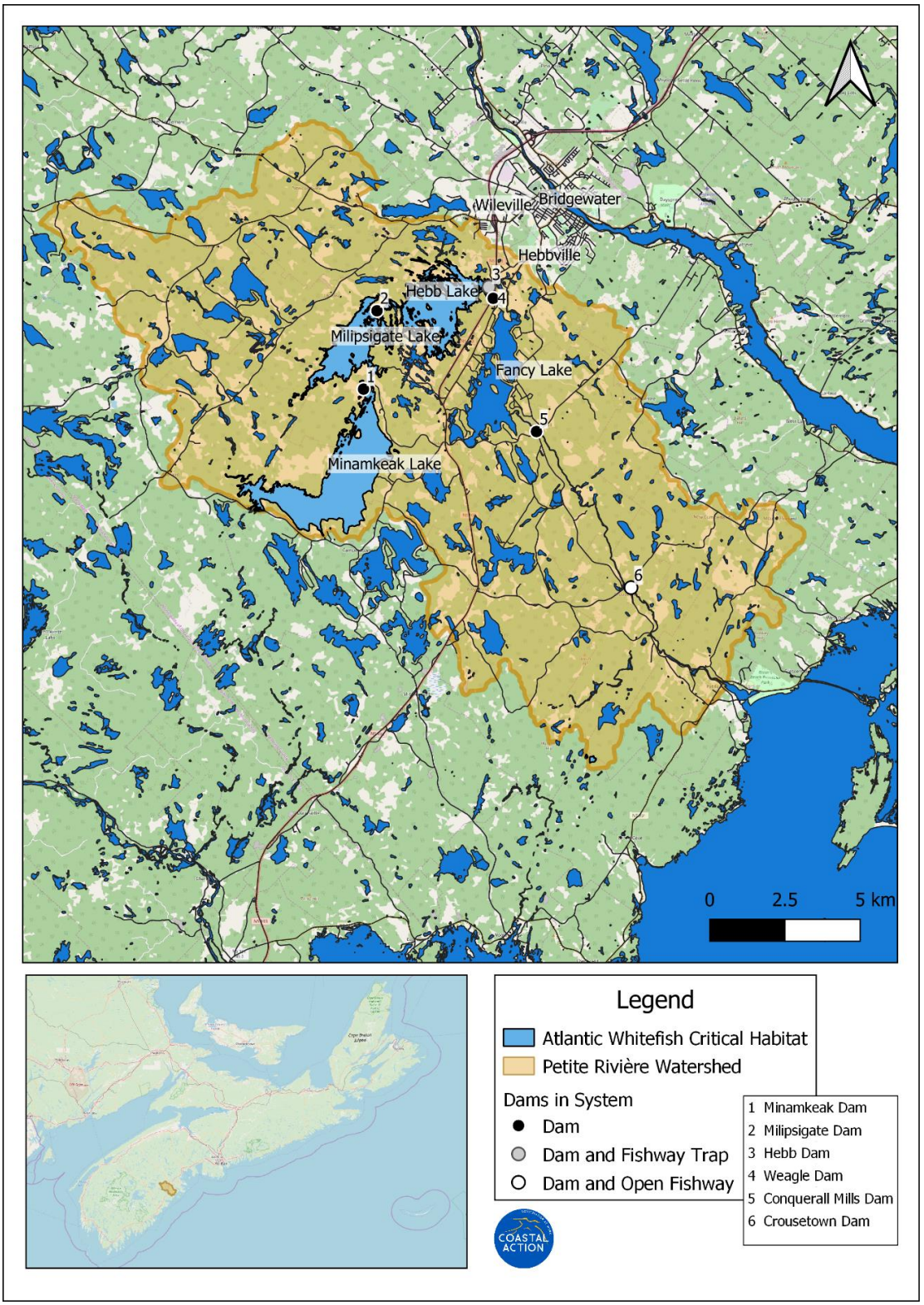

Figure 1. Map of the Petite Rivière watershed showing the three lakes (Minamkeak, Milipsigate, and Hebb) which contain the existing wild Atlantic whitefish population, as well as the dams and fishways present in the system.

1.2 Project Objectives

Coastal Action's AWRP has several goals and objectives for the 2022-23 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 three Atlantic whitefish lakes and at 19 sites throughout the Petite Rivière;
- Expand on previous zooplankton surveys on the three Atlantic whitefish lakes for a total of 12 samples collected weekly from ice-out to July and 12 samples collected monthly from July to October;
- Continue to monitor the upstream migration of gaspereau (*Alosa pseudoharengus*) into Hebb Lake in the spring; and
- Undertake fish habitat improvement and fish passage improvement at sites identified within Coastal Action's LaHave sub-watershed fish habitat restoration plans.

This report provides a detailed account of Coastal Action's activities in support of the recovery of the Atlantic whitefish and Southern Upland Atlantic salmon, as funded by the Habitat Stewardship Program for Aquatic Species at Risk. It includes fieldwork activities conducted between April 2022 and March 2023, 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. A summary of fish habitat improvement efforts within the LaHave River watershed has also been included, which describes site locations, types of work carried out, and the number of structures installed.

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. Coastal Action has also worked towards the recovery of Southern Upland Atlantic salmon by identifying and mapping key salmon habitat throughout the LaHave watershed, increasing aquatic connectivity while being mindful of the spread of invasive fish, and improving salmon nursery habitat to promote increased reproductive success and survival rates.

2.0 Methods

2.1 Spring Monitoring at Hebb Lake Dam Fish Passage Facility

The Hebb Lake Dam Fish Passage Facility trap (Figure 2) was deployed by Coastal Action staff on April 30 and was operated until June 30, 2022, to facilitate and monitor the upstream migration of gaspereau, also known as alewife. 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.

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.

In the case of the capture of an Atlantic whitefish or Atlantic salmon, the fish would be evaluated, photographed, and carefully released upstream. To facilitate visual examinations for any signs of injury (i.e., fin clips, fin/snout erosion, tags, and general health) the fish would be held in a clear-sided container. This would also allow for photos to be taken and fork length to be measured or estimated while avoiding handling. Under the direction of the DFO Project Authority, scale samples and fin clips may be obtained for aging DNA analysis.

The relative water level (inches) of Hebb Lake was also recorded daily using a gauge attached to the fishway (Figure 2) along with the water temperature of the fishway (°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 at Hebb Lake Dam Fish Passage Facility

The Hebb Lake Dam Fish Passage Facility trap was deployed again in the fall on October 27 and was operated and monitored until December 15, 2022. Under the direction of DFO-Science staff, this activity replaced fall monitoring of the rotary screw trap at Milipsigate Dam to monitor the potential upstream migration of juvenile Atlantic whitefish. These fish were hatched and raised at the Aquatron Lab at Dalhousie in the winter and spring of 2022 and released by DFO-Science into various locations in the Petite Rivière watershed, including the estuary, in the summer of 2022. As these fish look to move upstream into lake habitat for overwintering, the first opportunity to monitor for these fish would be at the Hebb Dam fishway. Any detection of these fish to confirm their survival and upstream movement through the Petite Rivière system would be of great value to the recovery efforts for the species. Notice of approval of this change in activity was sent by the HSP Program Officer via email on October 11, 2022.

During operation, the trap was lifted, and the water temperature (°C) and relative water level (inches) were recorded daily. The monitoring protocols and data collection for native and invasive fish were the same as for the spring monitoring in Section 2.1 above.

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 from April 2022 to March 2023 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	44.34448° N	64.59073° W
	Birch Brook	River/stream	44.33183° N	64.59843° W
	Minamkeak Brook	Lake	44.31993° N	64.59843° W
	Hebb Lake to Fancy Lake Outlet	River/stream	44.35044° N	64.53985° W
	Conquerall Mills Dam	River/stream	44.30833° N	64.52599° W
	Hebb Mill Brook (Publicover Lake)	River/Stream	44.29110° N	64.51426° W
	Italy Cross Intersection (Wallace Brook)	Culvert	44.26202° N	64.48882° W
	Crousetown Dam	Dam	44.26188° N	64.48510° W
	Brown Branch Brook	Culvert	44.24802° N	64.47700° W
	Wamback Mill Brook	River/stream	44.23883° N	64.45638° W
	Petite Rivière Head of Tide	River estuary	44.23420° N	64.44730° W
May 2011	Hebbville Dam	Dam	44.35199° N	64.54532° W
November 2011	Wallace Brook (Wallace Lake)	Culvert	44.27216° N	64.52512° W
	Weagle's Dam Outlet	River/stream	44.34456° N	64.54189° W
	Wildcat Brook	River/stream	44.35594° N	64.58411° W
May 2012	Fredrick's Brook	Culvert	44.31488° N	64.65692° W
	Kaulback Brook	Culvert	44.27448° N	64.45704° W
	Fire Pond	Lake	44.23794° N	64.45856° W
March 2020	Hebb Dam Fishway	Lake	44.35174° N	64.54665° W

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 from April through September 2022. 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), pressure (mmHg), 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 of deep-water stations in three Atlantic whitefish lakes in the Petite Rivière watershed.

Lake	Latitude	Longitude
Hebb	44.344842° N	64.565544° W
Milipsigate	44.335050° N	64.605120° W
Minamkeak	44.286120° N	64.600960° W

2.5 Zooplankton Survey

Vertical zooplankton hauls were conducted once per week starting after ice-out, starting April 7, through June and monthly from July through September 2022, 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 in 2021 to capture specimens at various depths on each lake for a total of 12 samples per sampling day (Table 3).

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.

This year, Coastal Action staff produced a photo identification guide of zooplankton species

found during surveys on Hebb, Milipsigate, and Minamkeak Lakes up to and including the 2022 samples. There are very few guides and keys of freshwater zooplankton found in Nova Scotia and most of those that do exist are very broad in range (i.e., North America) or are outdated. This guide will supplement the identification keys being used and aid in the efficiency and accuracy of future zooplankton identification in the Petite Rivière watershed.

Table 3. Coordinates for the zooplankton sampling sites in three Atlantic whitefish lakes in the Petite Rivière watershed.

Lake	Sample Site	Latitude	Longitude
Hebb	1	44.342578° N	64.564816° W
	2	44.343252° N	64.567531° W
	3	44.343831° N	64.569253° W
	4	44.344464° N	64.570349° W
Milipsigate	1	44.337453° N	64.603253° W
	2	44.337912° N	64.603867° W
	3	44.338336° N	64.604494° W
	4	44.338906° N	64.604948° W
Minamkeak	1	44.313014° N	64.595916° W
	2	44.311861° N	64.595296° W
	3	44.310927° N	64.594493° W
	4	44.309966° N	64.593063° W

2.6 Smallmouth Bass Nest Surveys and Light Traps

Smallmouth bass nest surveys were conducted in Demone Cove in Milipsigate Lake over four days between May 31 and June 16, 2022. The surveys built upon those conducted previously by Coastal Action and DFO Inland Fisheries from 2006 to 2021, from which Demone Cove was 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 and 2022, 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 angler.

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 4). 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 4. 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 floating larval light traps were deployed at various locations in Demone Cove on Milipsigate Lake where active smallmouth bass nests were identified during the surveys (Figure 4). These traps were deployed from June 17 to 30, 2022 and used to target and remove larval smallmouth bass and remove any incidental larval chain pickerel in the area. The traps, which float just under the surface of the water, were anchored by two small bricks and a short length of rope to prevent significant drifting (Figure 5). 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 48-72 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 quickly measured and 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 or previously successful locations to help maximize captures.

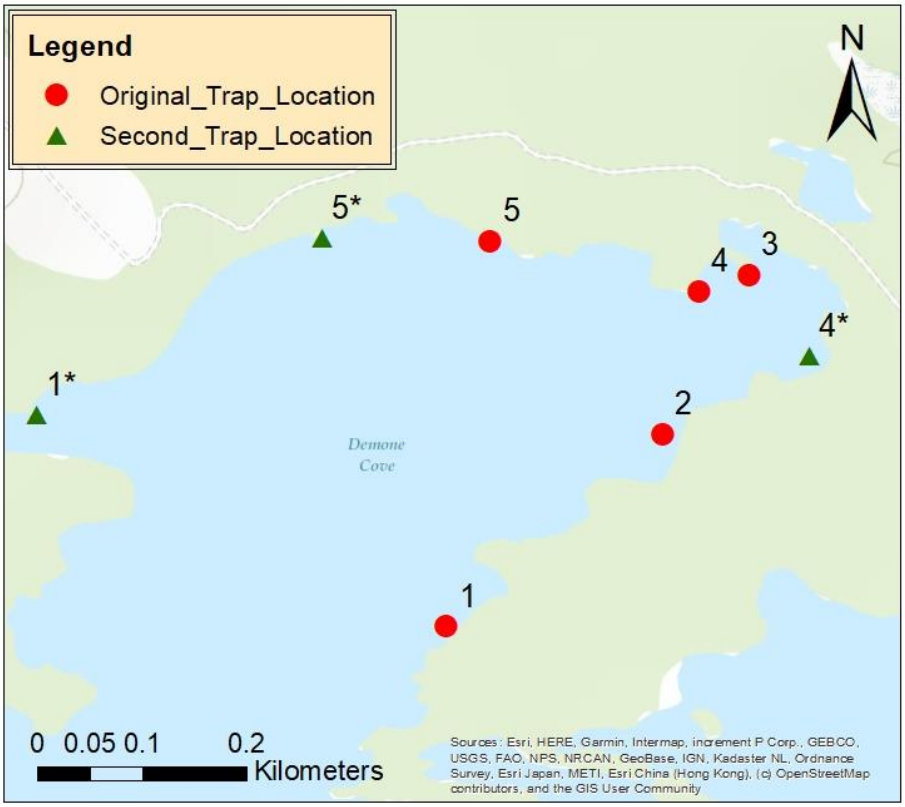

Figure 4. Map of floating light traps deployed in Demone Cove, Milipsigate Lake in the spring of 2022. Asterisks (*) indicate the second locations of light traps.

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

2.7 In-stream Fish Habitat Restoration Projects in the LaHave River watershed

Instream fish habitat improvement was completed using various methods including the installation of digger logs, deflectors, and rock sills. These methods are recommended by DFO and are highlighted in the following document: Ecological Restoration of Degraded Aquatic Habitats: A Watershed Approach. Oceans and Science Branch, Gulf Region (DFO 2006). Coastal Action has multiple staff certified and experienced in the installation of these structures for fish habitat improvement. Sites were selected for habitat improvement based on previously collected information included in Coastal Action's sub-watershed fish habitat restoration plans. Selection criteria focused on habitat suitability, level of habitat degradation, salmon distribution and abundance, and site accessibility.

Three structures, including two digger log/deflector combos and one rock sill, were installed at a site on Zwicker Brook where habitat improvement work was also completed in 2021. Each structure was designed and installed according to the protocol included within the Certification Manual for Habitat Restoration Installers (2017 version), developed by the Nova Scotia Salmon Association and Nova Scotia Environment and Climate Change. Maintenance work was also performed at two other sites where in-stream habitat improvement work had been completed in the past. This included rebuilding ramps and reforming pools of two digger logs on Wagner Brook and rebuilding 12 step pools on Silver Mill Brook. Materials required for the improvement work were mainly sourced on-site, with the exception of rebar which was used to secure the structures in place. Geographic locations for each site were added to a GIS database and are shown in Figure 6.

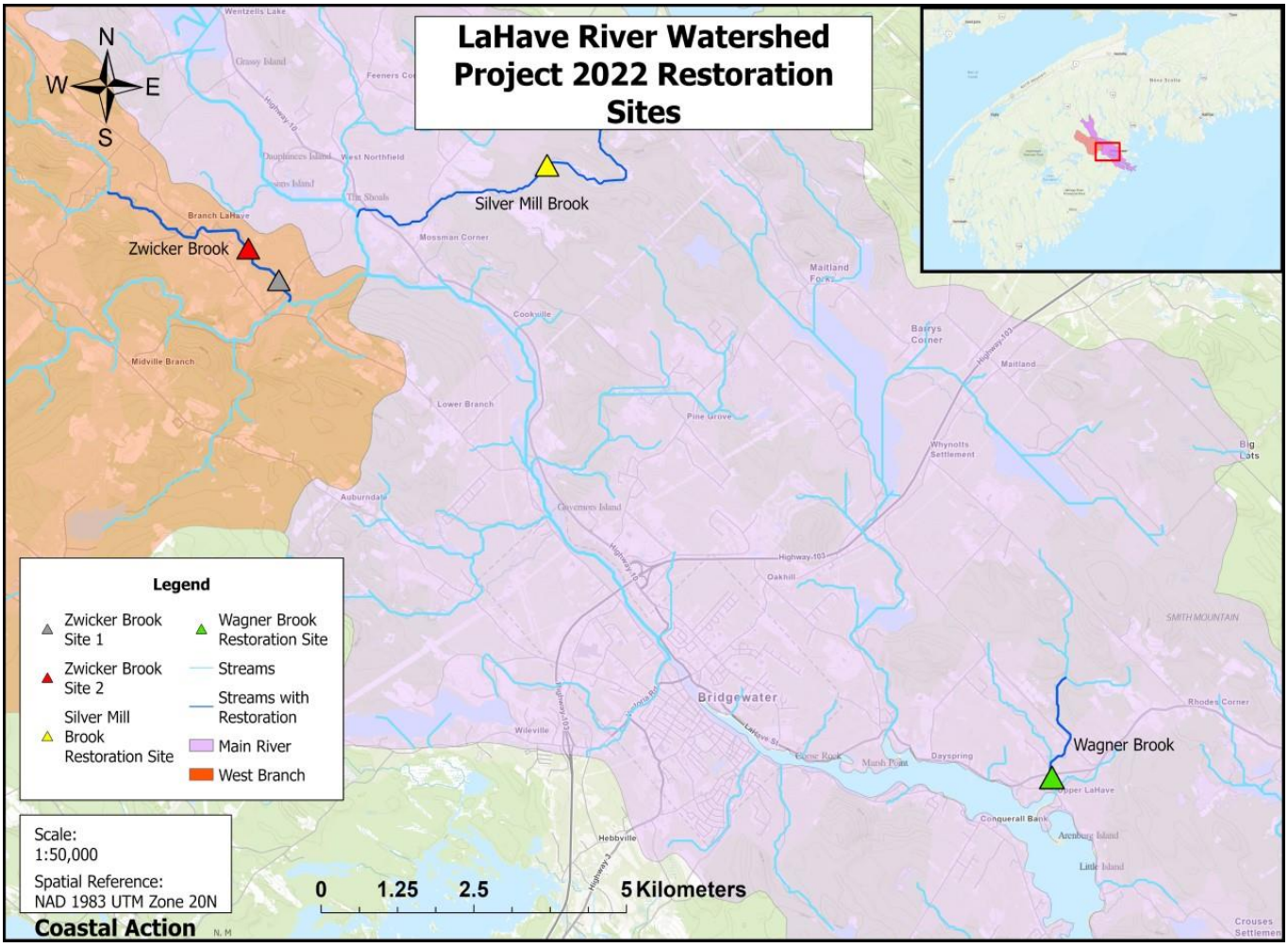

Figure 6. GIS map showing the locations where new improvement activities and maintenance work occurred in the LaHave River watershed.

2.8 Bi-weekly Monitoring of Crousetown Dam

On October 28, 2022, DFO staff observed and cleared natural debris causing a blockage to fish passage in the fishway at Crousetown Dam, likely due to beaver activity upstream of the site. The fishway is located in the lower reaches of the Petite Rivière watershed at 44.262421° N, 64.485343° W (Figure 7). As a result of the observed blockage, Coastal Action staff monitored the Crousetown Dam fishway every two weeks from November 25, 2022, to March 23, 2023. Any debris jams observed were removed to ensure adequate fish passage to the upper watershed.

Figure 7. Photos from above (left) and below (right) the fishway at Crousetown Dam after it was installed in 2018.

3.0 Results and Discussion

3.1 Spring Monitoring at Hebb Lake Dam Fish Passage Facility

In May and June of 2022, a total of 35,472 fish comprised of seven different species were captured in the fishway trap at Hebb Dam (Table 5). These included American eel (*Anguilla rostrata*), brook trout (*Salvelinus fontinalis*), chain pickerel, gaspereau, sea lamprey, smallmouth bass, and white sucker (*Catostomus commersonii*). The Spring 2022 season had the largest recorded migration of gaspereau through the Hebb fishway at 35,299 individuals, the next highest being 22,857 in 2021 (Russell et al. 2022). Of the gaspereau counted in 2022, 17 were young-of-the-year (YOY) and 91 were incidental mortalities.

Table 5. The number of fish captured and their life stages in the Hebb Dam Fish Passage Facility trap from May 1 to June 30, 2022.

Species	Life Stage	Frequency	Total Number
American eel	Adult	101	101
Brook trout	Parr	1	4
	Adult	3	
Chain pickerel	Adult	1	1
Gaspereau	YOY	17	35,299
	Adult	35,282	
Sea lamprey	Juvenile	2	2
Smallmouth bass	Adult	58	58
White sucker	Adult	7	7
Total			**35,472**

3.2 Fall Monitoring at Hebb Lake Dam Fish Passage Facility

During the fall monitoring of the Hebb Dam fishway trap, five fish comprised of four different species were captured (Table 6). These included Atlantic salmon, chain pickerel, smallmouth bass, and white sucker.

The Atlantic salmon was a notable capture since no individuals have been observed in the Petite Rivière watershed through Coastal Action's activities since one was captured in 2014 and four in 2012 during the fall Hebb Dam fishway monitoring.

The Hebb Dam fishway trap was operated and monitored in the fall from when the fishway opened in 2012 until 2018 but was not monitored from 2019 to 2021 due to low fish catches and minimal chance of capturing migrating Atlantic whitefish. That is, until the release of hatchery-raised juvenile Atlantic whitefish into the Petite Rivière estuary in the summer of 2022. However, no Atlantic whitefish were observed in the fishway in 2022.

Table 6. The number of fish captured in the Hebb Dam Fish Passage Facility trap from October 27 to December 15, 2022. All fish were adult-stage.

Species	Total Number
Atlantic salmon	1
Chain pickerel	1
Smallmouth bass	2
White sucker	1
Total	**5**

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°C to 27.7 °C throughout 2022 (Figure 8). All sites, except Kaulback Brook and Wamback Mill Brook, 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 July and August. 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.

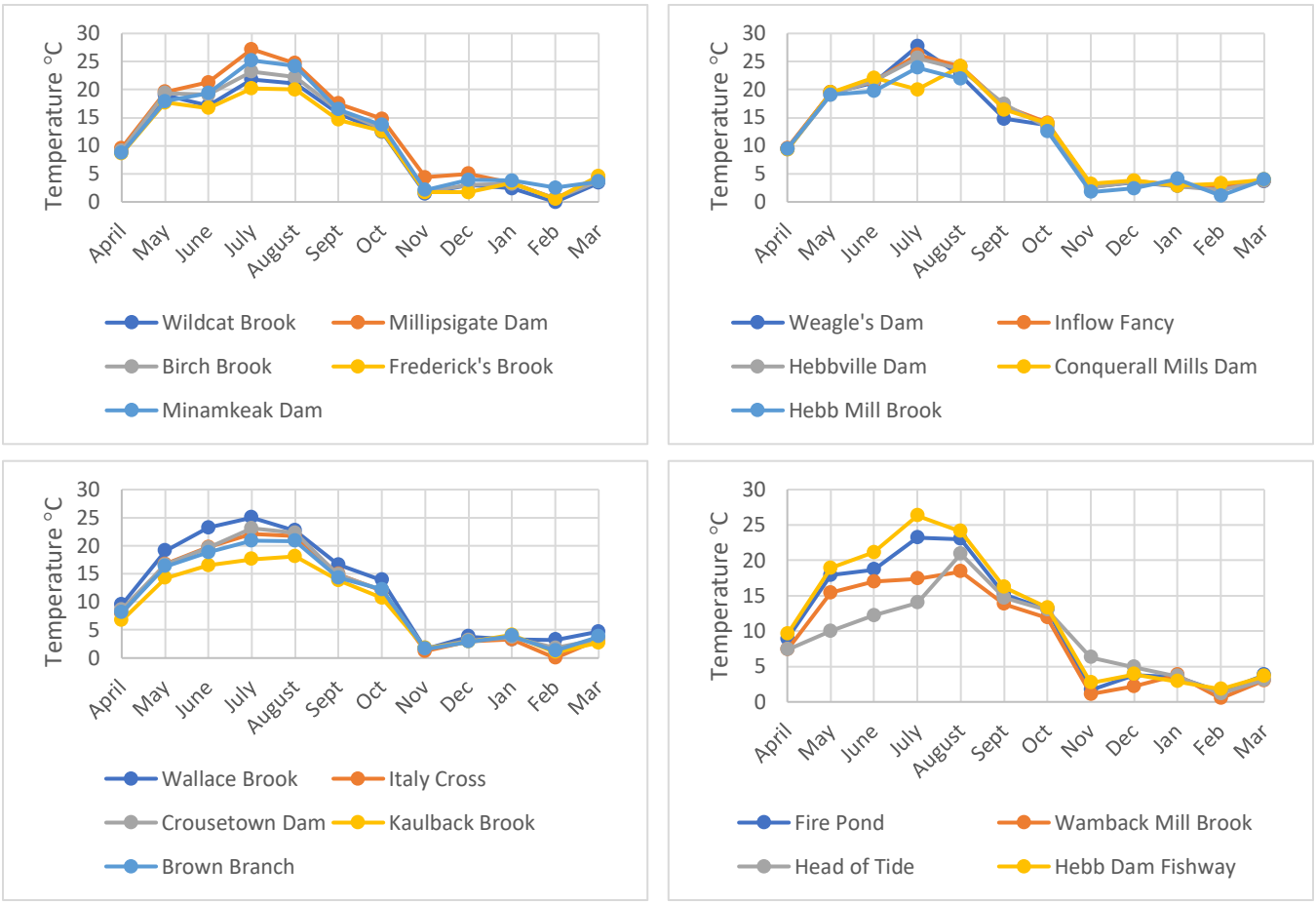

Figure 8. Monthly temperature measurements at 19 sites within the Petite Rivière watershed from April 2022 to March 2023.

Dissolved oxygen (DO) throughout the Petite Rivière watershed ranged from 1.35 mg/L to 16.33 mg/L in 2022 (Figure 9). These readings are both lower, and higher than the results from the previous year. The probe used to collect these readings was likely giving incorrect values, mostly in December and January. The probe used was a YSI ProPlus DO probe. Following the results from January, the membrane of the probe was replaced. Following this replacement, the readings began to show concentrations more comparable to previous years, albeit at a slightly higher value. The probe has been completely replaced following the March readings.

Excluding the readings from December and January, six sites periodically 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 (excluding December and January readings) was 3.02 mg/L, above the < 2.1 mg/L DO concentration 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 can be detrimental to fish; however, the monthly sampling frequency of these monitoring activities cannot adequately reflect the range and longevity of these periods.

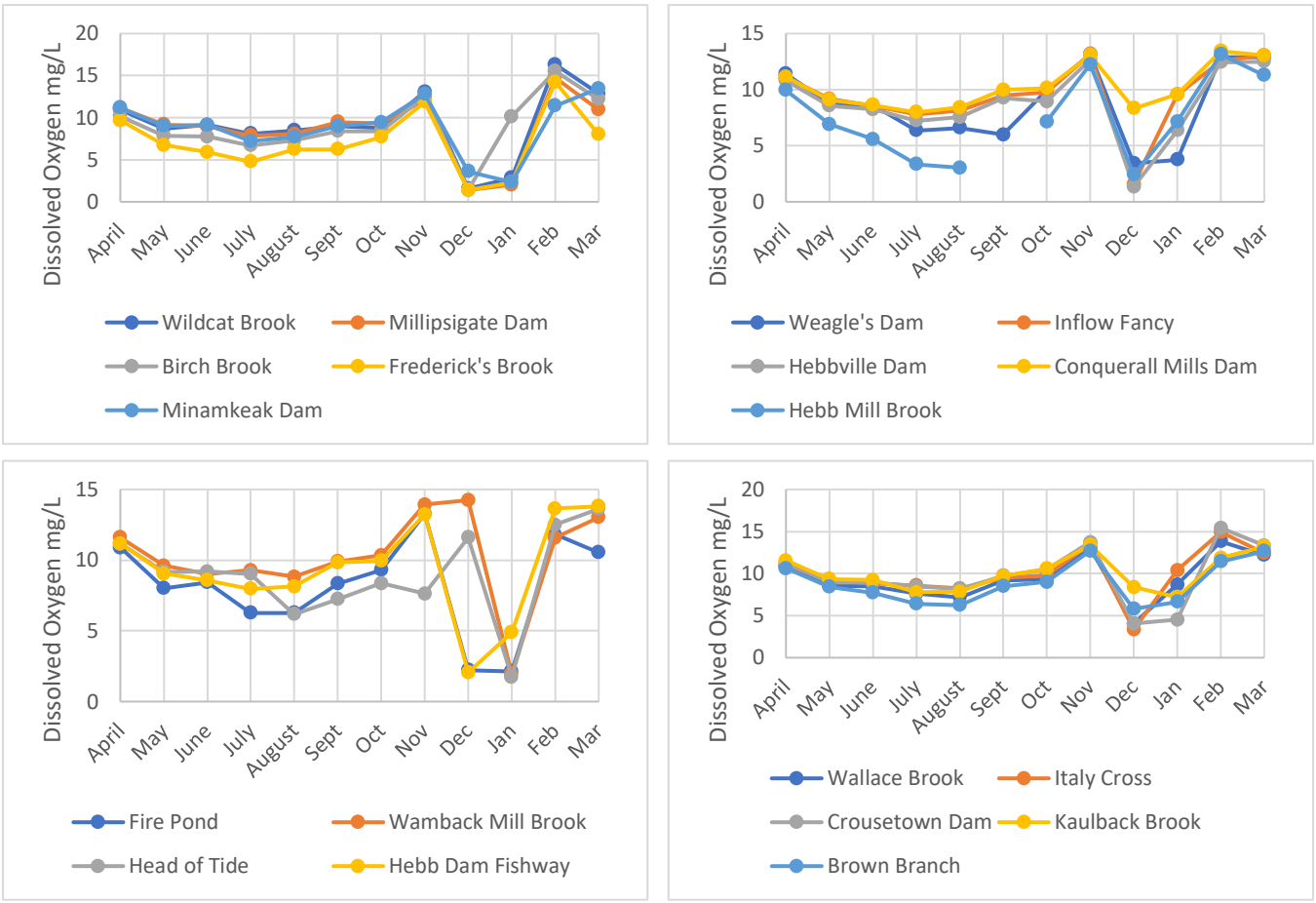

Figure 9. Monthly dissolved oxygen measurements at 19 sites within the Petite Rivière watershed from April 2022 to March 2023.

Total dissolved solids (TDS) ranged from 13.65 to 104 mg/L across the 18 freshwater sites in the Petite Rivière in 2022 (Figure 10). At the Head of Tide estuarine site, it ranged from 17 mg/L to 30,893 mg/L, due to the influence of salt water. Although the effects of TDS on fish are dependent on the life stage, juvenile and mature Salmonidae can survive in waters with TDS greater than 2,000 mg/L (Weber-Scannell and Duffy 2007). Based on the TDS measurements collected in 2022, the freshwater sites do not exceed this threshold, therefore, would not pose a threat to freshwater aquatic organisms.

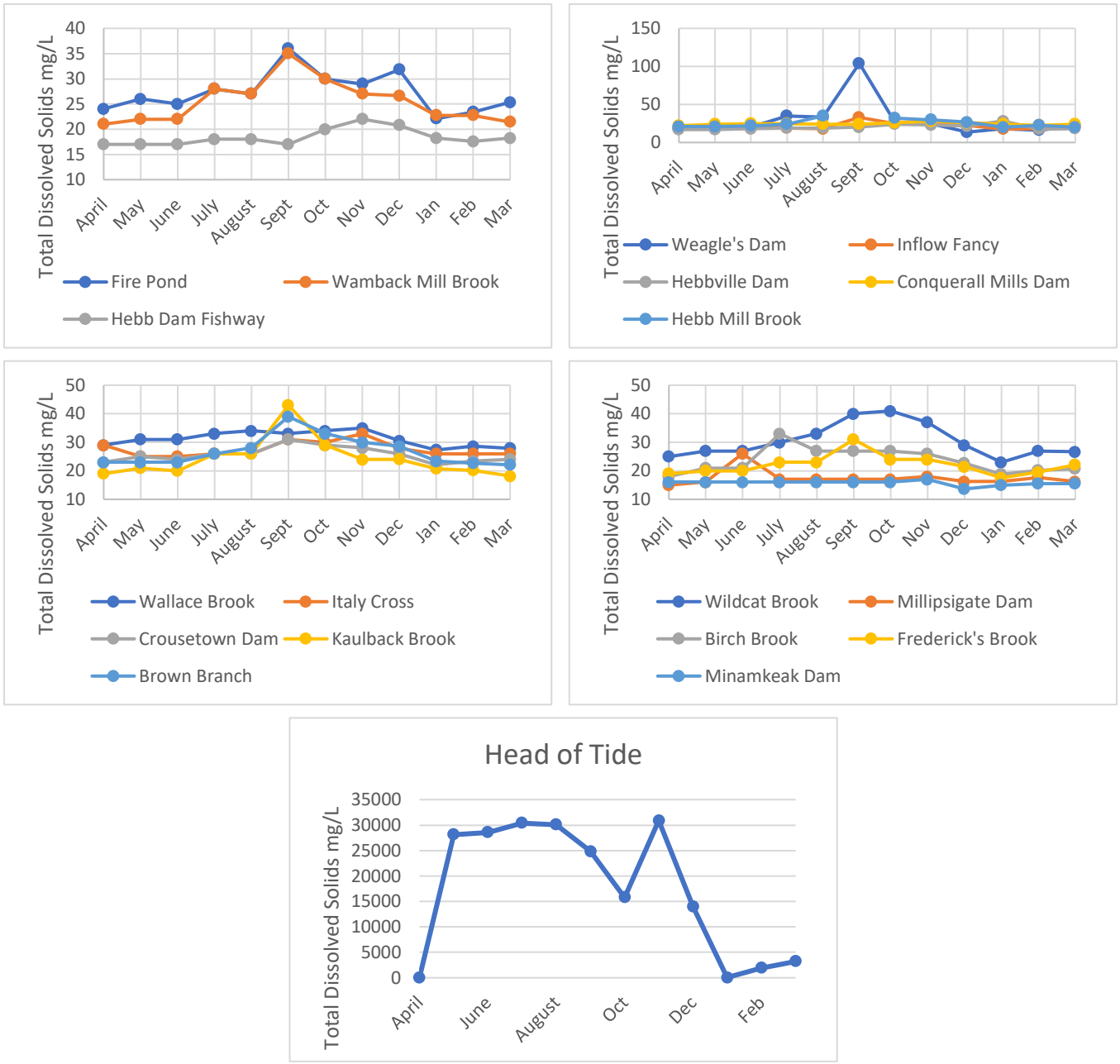

Figure 10. Monthly total dissolved solids measurements at 19 sites within the Petite Rivière watershed from April 2022 to March 2023.

The pH of the 19 Petite Rivière sites ranged from 3.14 to 8.15 with a mean of 5.92 in 2022 (Figure 11). All 19 sites, at least once, fell below the 6.5 pH threshold set by the CCME for the protection of aquatic life (CCME 2007). Therefore, the acidity of the Petite Rivière watershed does pose a threat to aquatic organisms. All sites, except Conquerall Mills Dam, 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.

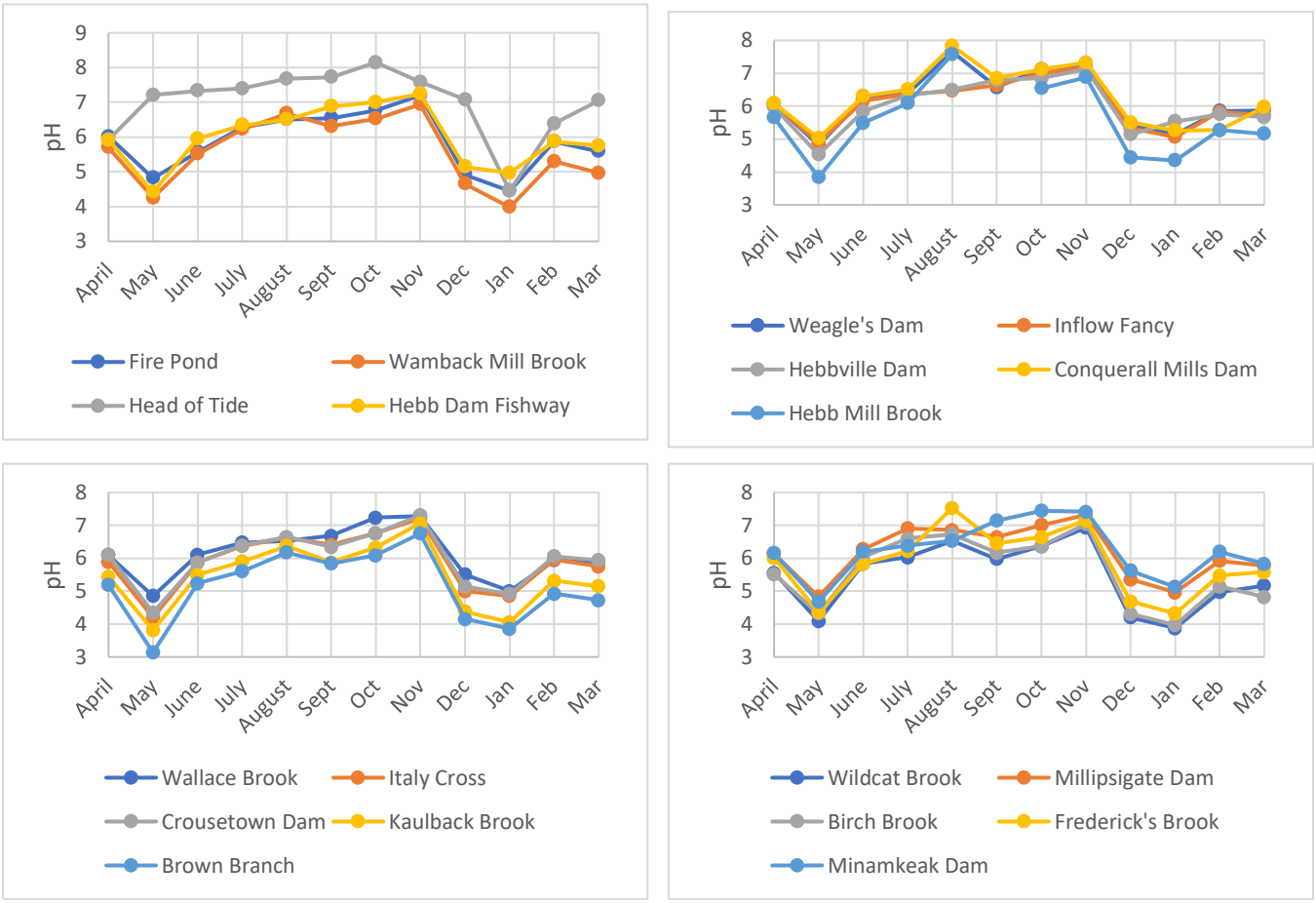

Figure 11. Monthly pH measurements at 19 sites within the Petite Rivière watershed from April 2022 to March 2023.

3.4 Water Quality Monitoring on Atlantic Whitefish Lakes

The monthly lake water quality depth profiles were done on April 21, May 19, June 16, July 18, August 15 and 16, and September 30, 2022. Due to mechanical issues, the August profile for Milipsigate Lake was completed a day later than Minamkeak and Hebb Lakes on August 16. A decrease in DO (mg/L) and an increase in TDS (mg/L) were noted around the thermocline when present in every lake.

In Hebb Lake, the thermocline was only distinguishable in the May and July samples. In May, it occurred between 7 and 8 meters (m) below the surface with a drop from 14.4 to 12.5 °C and in July, it was a more gradual shift between 4 to 10 meters from 22.9 to 17.5 °C (Figure 12).

The thermocline was observed in Milipsigate Lake in the months of May through August. In May, the temperature dropped slightly from 13.1 to 11.1 °C at 16 to 17 m below the surface (Figure 13). June through August saw larger but more gradual drops in temperature. The water temperature dropped from 18.5 to 11.8 °C between 5 to 13 m in June, 23.3 to 12 °C from 2 to 12 m in July, and 23.9 to 12.5 °C from 3 to 12 m in August. As with Hebb Lake, a thermocline was not present in the April and September depth profiles. Note that due to mechanical issues, the August profile was completed on August 16, the day after Hebb and Minamkeak Lakes were done.

May, July, and August were the only months where the thermocline was detected in Minamkeak Lake (Figure 14). In May, there was a slight decrease in water temperature from 13.1 to 11.8 °C from nine to 11 m. In July, the temperature dropped from 22.0 to 17.6 °C between 5 and 11 m. In August, there were two drops in temperature; the first being from 23.4 to 19.8 °C between 8 and 10 m and the second went from 19.6 to 17.7°C between 12 and 15 m.

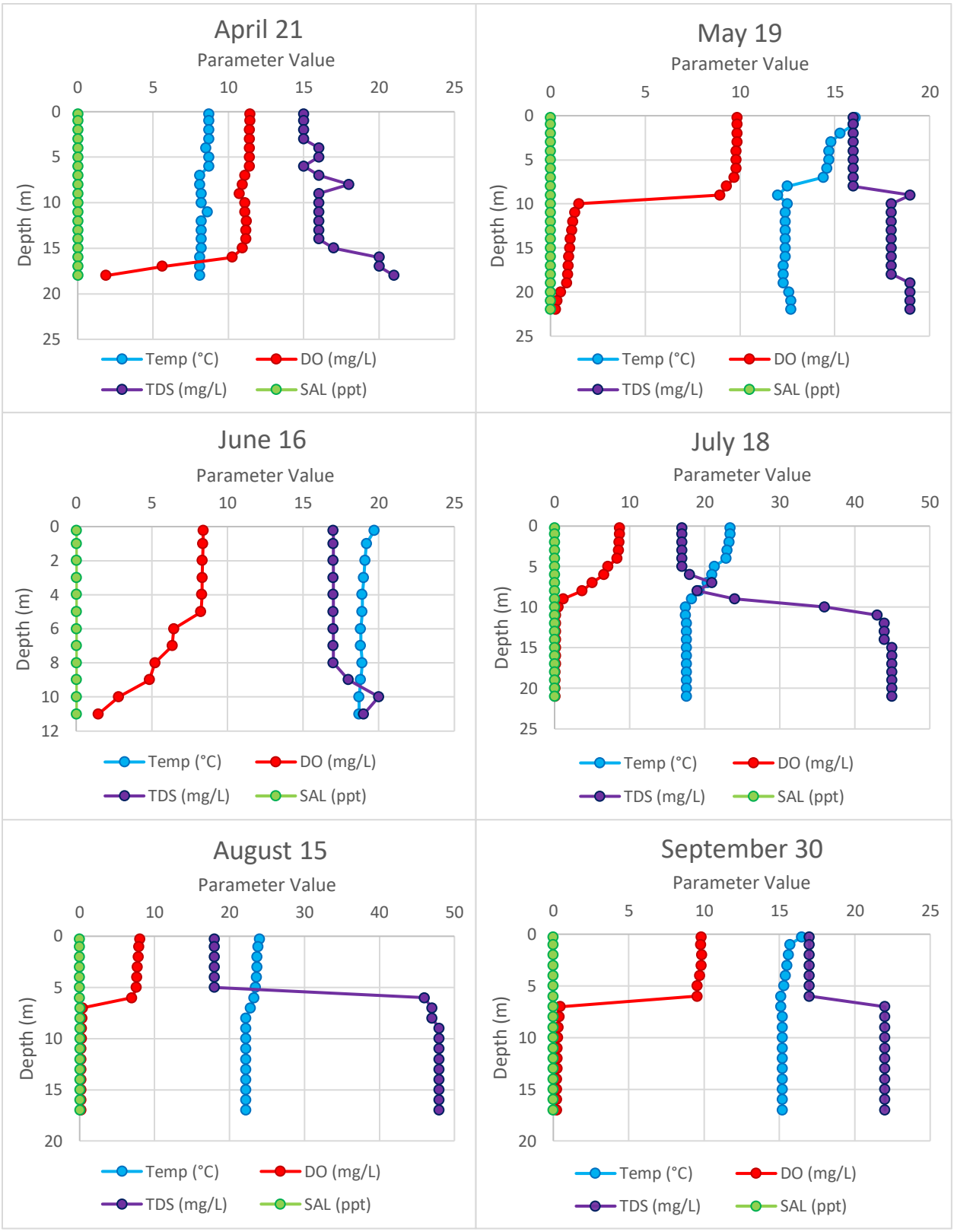

Figure 12. Monthly water quality depth profiles of Hebb Lake from April through September 2022.

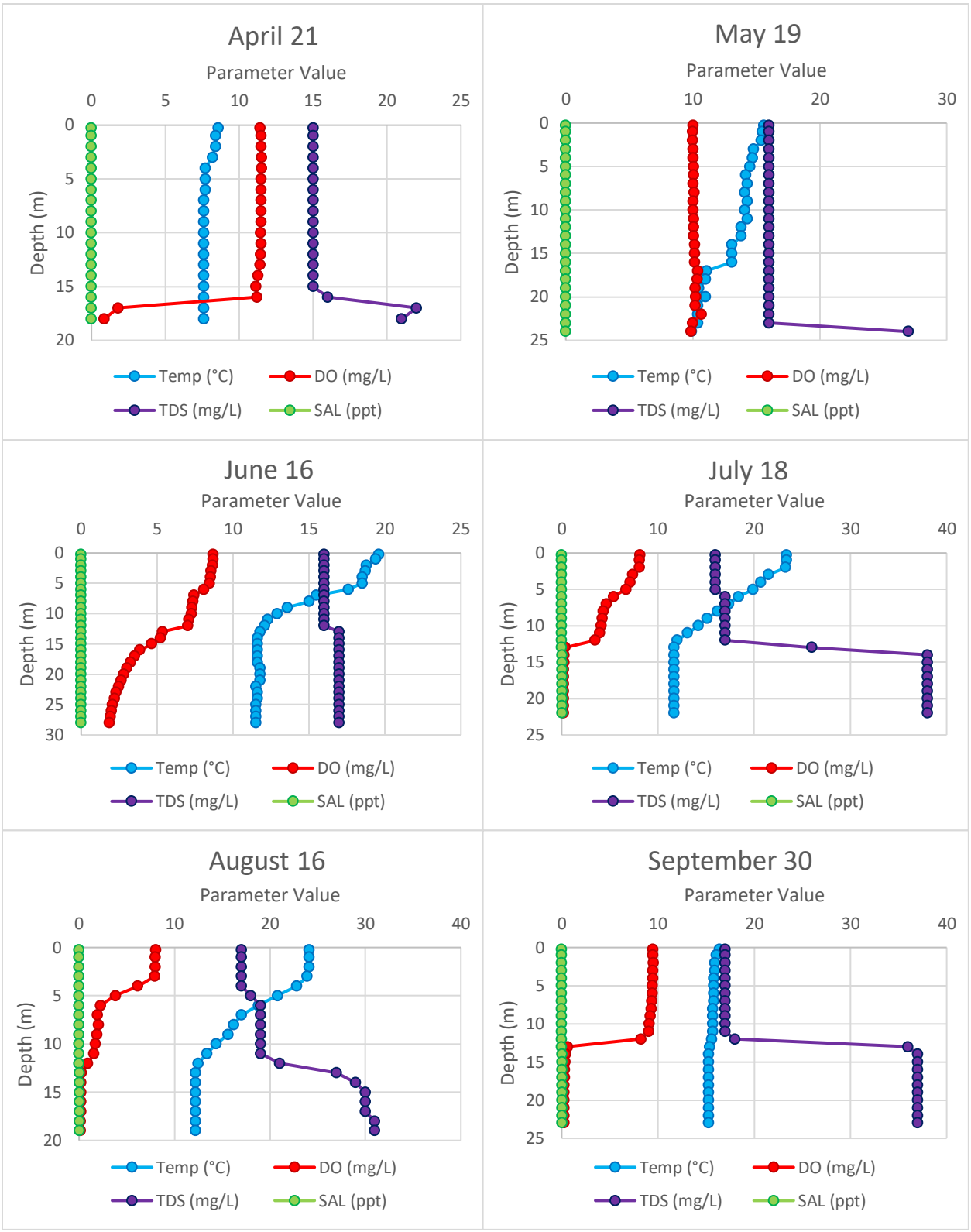

Figure 13. Monthly water quality depth profiles of Milipsigate Lake from April through September 2022.

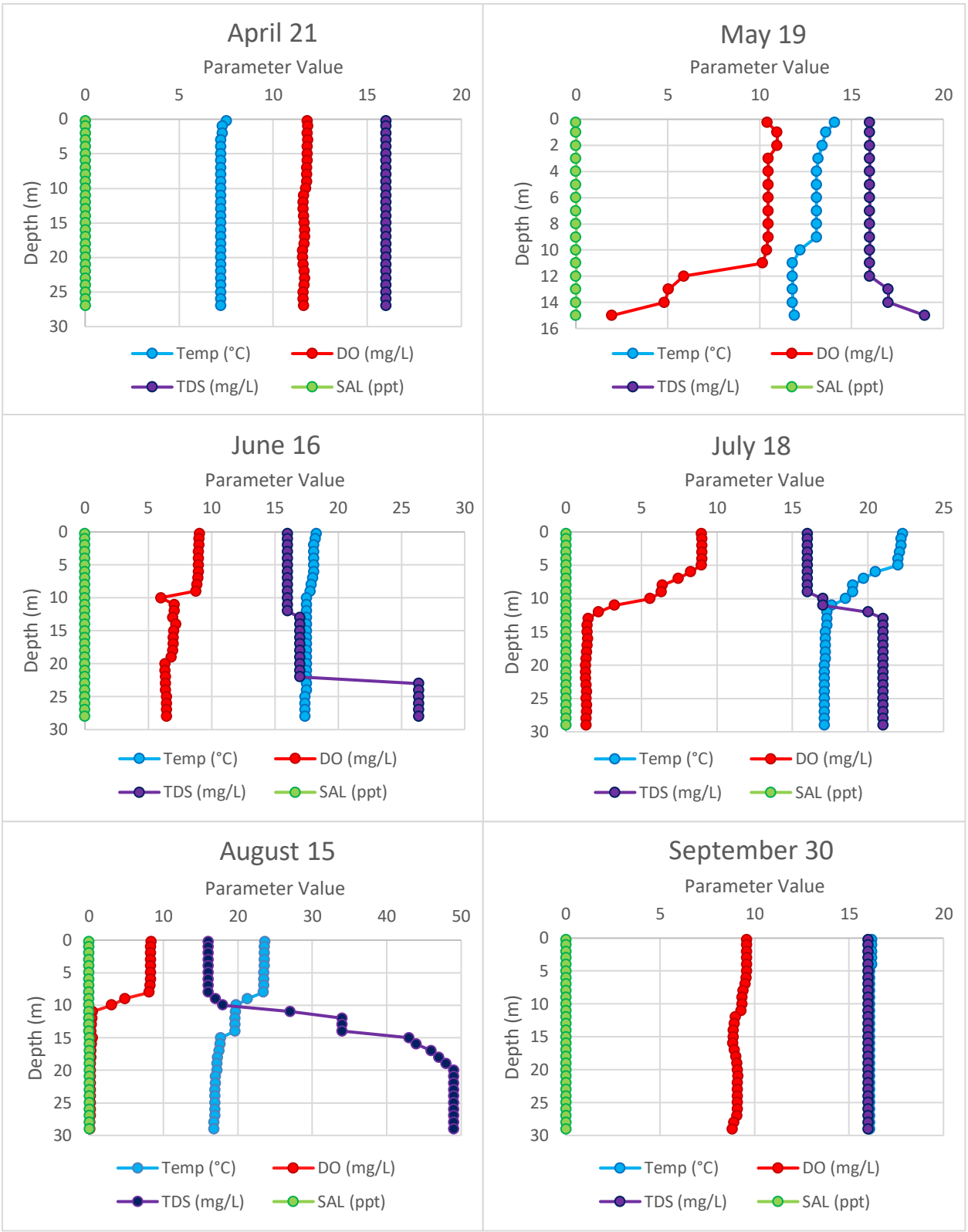

Figure 14. Monthly water quality depth profiles of Minamkeak Lake from April through September 2022.

3.5 Zooplankton Survey

A total of 192 zooplankton samples comprised of 33 different species were collected from April through September of 2022 from Hebb, Milipsigate, and Minamkeak Lakes. This amounted to a total of 9,313 specimens identified. The weekly samples were collected from April 7 to June 29, and the monthly samples were collected on July 18, August 15 and 16, and September 30, 2022. The weekly samples from April through June accounted for 156 of the total samples and 7,768 of the zooplankton specimens identified for the 2022 season. Due to mechanical issues, the August samples for Milipsigate Lake were collected on August 16, the day after Hebb and Minamkeak Lakes were sampled. Some samples contained less than 50 zooplankton, including two from Minamkeak Lake and one from Milipsigate Lake in April, as well as ten samples from Hebb Lake in July, August, and September. Minamkeak Lake had the greatest diversity of zooplankton with 28 different species, followed by Hebb Lake with 27 and Milipsigate Lake with 24 species.

Holopedium glacialis was identified as *Holopedium gibberum* in previous analyses of zooplankton in the Petite Rivière watershed. *H. glacialis* was selected as the species name during the identification and analysis process of this project due to a study by Rowe et al. (2007). The study found a genetic difference between eastern Nova Scotian *Holopedium* species which were previously all considered *H. gibberum*. A genetic test is recommended to confirm this identification; however, this species will be referred to as *H. glacialis* in this report.

From April through September, *Daphnia catawba* and female calanoid copepods were in the top three most dominant species across all sites in the three lakes based on relative abundances (Figure 15). *H. glacialis* was in the top three in Milipsigate and Hebb Lakes, whereas in Minamkeak Lake, *Epischura nordenskioldi* was slightly more dominant (12.9%) than *H. glacialis* (11.0%). In Milipsigate and Minamkeak Lakes, *D. catawba* was the most dominant overall at 44.9% and 31.4%, respectively, whereas *H. glacialis* was the most dominant in Hebb Lake at 37.9%, followed by *D. catawba* at 30.8%. The next most prominent species included *Eubosmina longispina*, *Diaphanosoma brachyurum*, *Daphnia parvula*, and *Daphnia ambigua* (Figure 15).

Cladoceran zooplankton accounted for 19 of the 33 species identified, including those of the genus *Daphnia*. Species of *Daphnia* are believed to be a primary food source for larval Atlantic whitefish in the wild since the fish feed on *Daphnia* and *Artemia* in captivity and due to the high abundance of *Daphnia* in their habitat in previous surveys conducted by Coastal Action (Whitelaw et al. 2015; Russell et al. 2022). The total relative abundance of cladoceran zooplankton increased from 38.3% of specimens identified in April up to 90.3% of specimens identified in July and back down to 70.9% in September across the lakes. Specifically, *Daphnia* species made up 49.2% of the Milipsigate Lake samples, 33.6% of Minamkeak, Lake, and 34.4% of Hebb Lake across all months in 2022. *Daphnia* was the lowest in abundance across all sites in April and May at 15.9% and 20.6%, respectively, and reached a peak in

August at 71.5%. The abundance of this genus can be largely attributed to the presence of *D. catawba* (Figure 15).

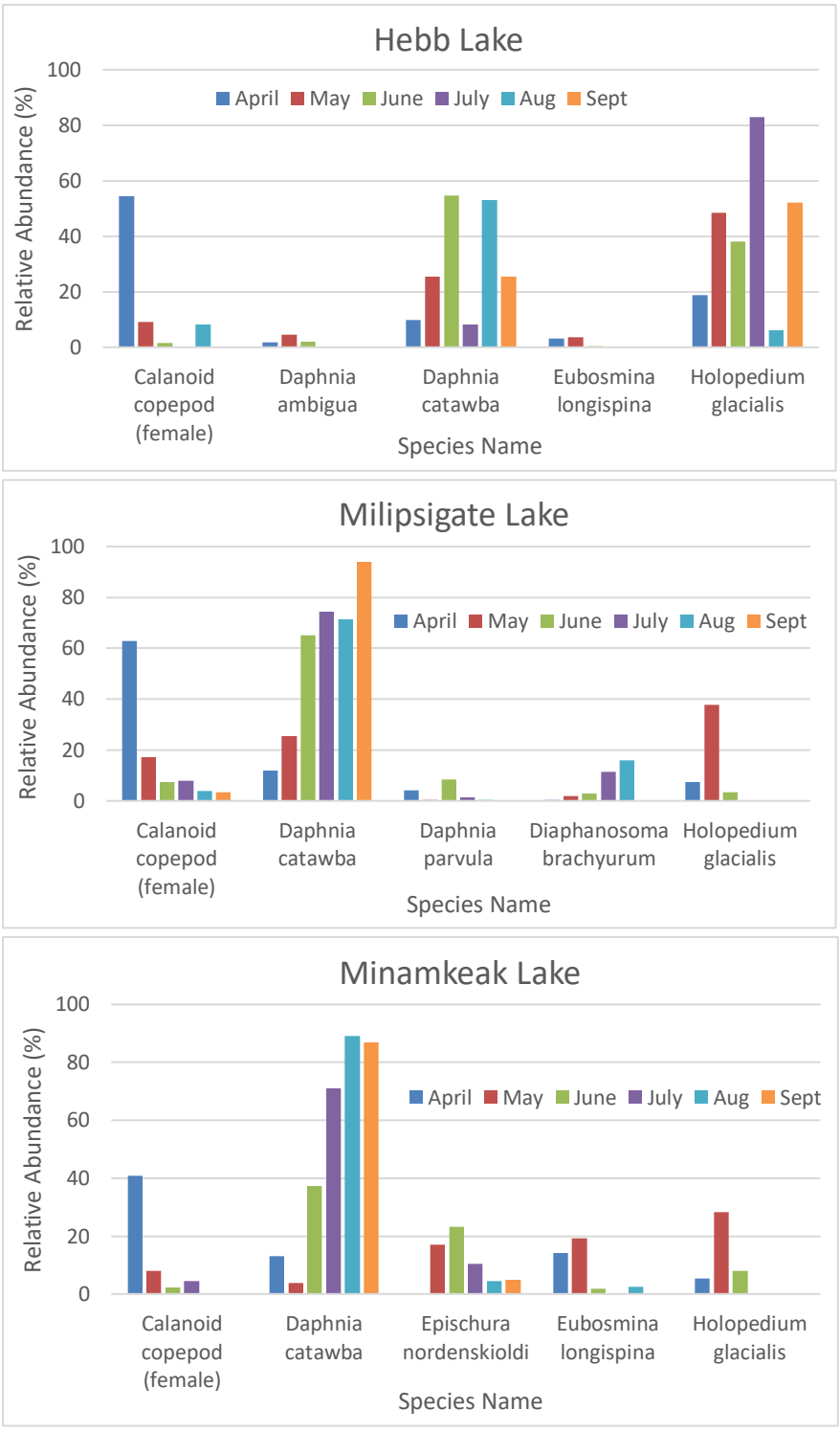

Figure 15. Relative abundance (%) of dominant zooplankton species by month in Hebb, Milipsigate, and Minamkeak Lakes from April through September 2022.

3.6 Smallmouth Bass Nest Surveys & Light Traps

Demone Cove on Milipsigate Lake was surveyed over four days between May 31 and June 16, 2022. During this time, when the water temperature was between 19.2 and 22.2°C, 44 nests were identified in Demone Cove (Figure 16). The majority of nests were classified as type A, newly excavated and without eggs, two nests were Class D, fry dispersed, and the rest were either Class B or C, containing eggs or undispersed fry (Table 7). Each nest containing eggs or fry was destroyed, amounting to eight nests, and a total of 12 guarding males were angled from the nests (Figure 17). The substrate for all nests was pebble and cobble.

In Demone Cove, 25 nests were found in 2018, 16 in 2019, 13 nests in 2020, and 17 in 2021 (Russell et al. 2022). This year had an increase of 27 nests overall from 2021 but 77% of those were newly excavated without eggs or fry. Three more nests were discovered containing eggs or fry in Demone Cove in 2022 than in 2021. Since the survey methodologies and effort amounts have changed over the years, the number of nests cannot be directly compared or used as an indication of a change in smallmouth bass nesting activity. There is higher visibility with snorkelling versus surveys from the boat, therefore some nests may have been missed in previous years. In 2022, there were also more snorkellers surveying the cove and all were newly trained in smallmouth bass nest surveys, so more time was spent searching for nests and there is a chance that some old nests were categorized as newly excavated. Snorkelling is generally a more efficient method for nest surveying than solely surveying visually from the boat and therefore is the preferred method, when possible, in future years.

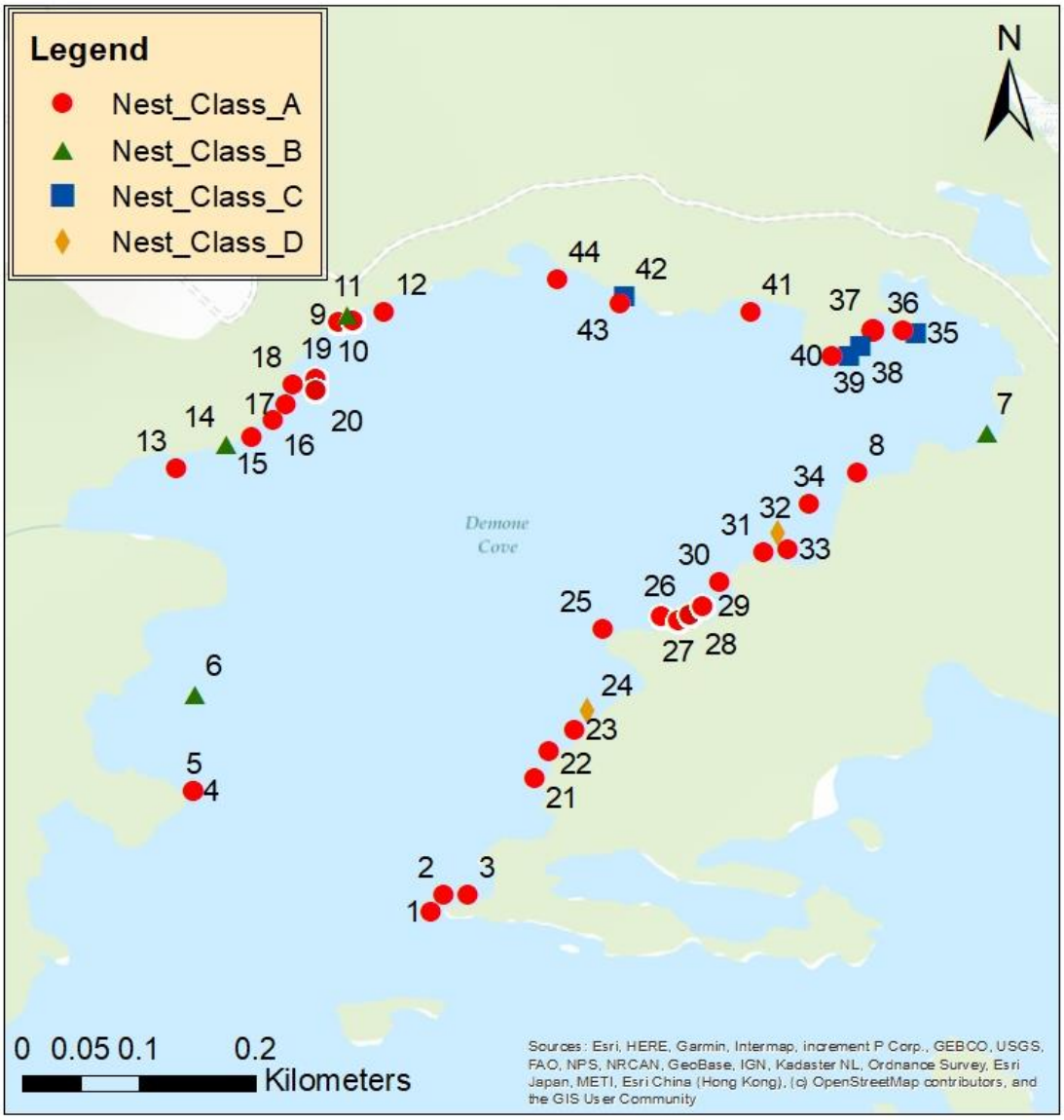

Figure 16. Locations of identified smallmouth bass nests in Demone Cove in Milipsigate Lake between May 31 and June 16, 2022.

Table 7. Number of smallmouth bass nests per class in each survey location.

Location	Nest Classification	Frequency
Demone Cove	A - Newly excavated	34
	B - Eggs present	4
	C - Fry present but not dispersed	4
	D - Fry dispersed	2
	Total	**44**

Figure 17. Left – Smallmouth bass nest with hatching eggs; right – partially hatched nest with both eggs and fry.

The floating light traps were deployed from June 17 to June 30, 2022, in Demone Cove in Milipsigate Lake at locations where active nests were identified during the SMB nest surveys. The fishing time between the five traps ranged from 310.27 to 310.43 hrs for an average of 310.34 hours, resulting in a total fishing time of approximately 1551 hrs. The traps captured 102 larval smallmouth bass averaging 1.9 cm in length (Table 8). No chain pickerel were captured. The eight yellow perch (*Perca flavescens*) captured were released unharmed.

Table 8. Number of fish captured by species in five light traps in Demone Cove in Milipsigate Lake in the spring of 2022.

Species	Count	Catch Per Unit Effort (# fish/hr)	Average Fork Length (cm)
Smallmouth bass	102	0.066	1.9
Yellow perch	8	0.005	2.3

This 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 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. Deploying five light traps in May and June of 2021 and 2022 to directly target recently hatched smallmouth bass has shown to be a superior method. The catch per unit effort (CPUE) for smallmouth bass decreased from 0.094 smallmouth bass per hour in 2021 to 0.066 in 2022. However, this targeted method was still more effective at capturing larval smallmouth bass than the previous methods to target larval chain pickerel. 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 carried out under a separate DFO contract, is still far more efficient for large-scale YOY invasive removals than any other method.

3.7 Instream Fish Habitat Restoration Projects

During the 2022 field season, Coastal Action successfully improved 900 m^2 of important salmon habitat through the installation of instream habitat improvement structures. This included two digger logs with deflectors and one rock sill, installed on a section of Zwicker Brook located in the West Branch Sub-watershed of the LaHave. One of these structures was a 14-m long digger log with a deflector included, this structure required 125 person-hours to install (**Error! Reference source not found.**). It is the largest instream structure that C oastal Action has ever installed by hand. The newly installed structures will work in conjunction with structures installed the previous year to further improve habitat at the site. In total, the work at the Zwicker Brook site in 2021 and 2022 has improved 2970 m^2 of aquatic habitat. Structures such as rock sills and digger logs increase the availability of deep high-quality pools, improve substrate composition by sorting fines, and provide increased cover (DFO 2006).

Maintenance work was also performed on the five previously installed structures at the Zwicker Brook site to ensure continued proper function. This involved redistributing

substrate that had shifted since the structures were installed in 2021. By redistributing substrate to desired locations, staff were able to increase the depth of the pools and fill gaps in the ramp section (upstream side of the log). This work resulted in improved flow over the logs and deeper, more well-defined pools below each structure. Once completed, this maintenance work covered 2070 m^2 of salmon nursery habitat. In addition to the maintenance work completed at the Zwicker Brook site, Coastal Action also performed maintenance work at two other sites located on Wagner Brook and Silver Mill Brook, both located in the Main River Sub-watershed. These opportunities were identified within Coastal Action's sub-watershed plans as sites requiring maintenance, covering an area of 1230 m^2. This work included improving the functionality of two digger logs on Wagner Brook, and one digger log and twelve step pools on Silver Mill Brook.

Figure 18. Photo showing a large digger log and deflector combination being installed on Zwicker Brook during the 2022 season.

3.8 Bi-weekly Monitoring of Crousetown Dam

The Crousetown Dam fishway was first monitored by Coastal Action staff on November 25, 2022, at which time, natural debris from beaver activity upstream was found in the fishway blocking fish passage. After that instance, the only other blockage during the monitoring period to the end of March 2023 was a partial one on February 27, 2023, due to some ice buildup at the bottom of the fishway. There was no debris in the fishway at that time and the

water was flowing well, so fish passage was possible. There was some natural debris in the form of small tree branches found in the fishway on November 30 and December 12, 2022, however, these did not cause any blockages to fish passage. Any time debris was discovered in the fishway, it was removed and cleared within the same day. Going forward, it would be beneficial for Coastal Action staff to continue to periodically monitor this fishway and clear debris as needed.

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, Halifax Regional Municipality, and beyond through both online and in-person presentations. 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 Atlantic Whitefish and Southern Uplands Atlantic Salmon Project was highlighted in the following events and presentations:

- New Germany Rural High School guided activity with grade nine students on Habitat Suitability Index Assessment on Manning Brook, located in the LaHave River Watershed in Lunenburg County, NS (May 20, 2022);
- Water Quality Education session for Mahone Bay Trinity United Church Group youth (May 24, 2022);
- Nature Nova Scotia Symposium online presentation (May 29, 2022);
- Park View Education Centre high school biology class Learn-To-Fish Day with smallmouth bass and chain pickerel angling and dissections and a presentation at Wentzell's Lake, Lunenburg County, NS (June 8, 2022);
- Terranaut Club guided smallmouth bass dissections as part of a summer program for girls and under-represented genders (girls+) aged 9-18 at the Morton Centre, Heckman's Island, NS (July 16, 2022);
- LaHave River Salmon Association (LRSA) Pickerel Tournament with chain pickerel information and cooking demonstrations, Wentzell's Lake, Lunenburg County, NS (July 23, 2022);
- New Ross Community Fair community outreach event, New Ross, NS (August 19, 2022);

- Nova Scotia Community College (NSCC) Natural Resources Environmental Technology Program instream restoration education day at Zwicker Brook, Lunenburg County, NS (September 14, 2022);
- Atlantic Whitefish Conservation and Recovery Team (AWC&RT) meeting presentation at the Mahone Bay Centre, Mahone Bay, NS (November 29, 2022);
- Aquatic Invasive Species Workshop online presentation, hosted by Mersey Tobeatic Research Institute (MTRI) in partnership with Adopt-A-Stream and the Nova Scotia Salmon Association (NSSA) (January 19, 2023);
- Nova Scotia Invasive Species Council (NSISC) Conference presentation at the Bedford Institute of Oceanography, Dartmouth, NS (February 28, 2023); and
- NSSA's W.A.T.E.R. Workshop presentation on the Atlantic Whitefish Streamside Rearing Facility at White Point Beach Resort, Hunts Point, NS (March 22, 2023).

Coastal Action published 12 social media posts related to the Atlantic Whitefish and Southern Uplands Atlantic Salmon Project plus additional "stories" on Instagram, Facebook, and Twitter, and online newsletter articles through our Coastal Chronicle newsletter during the 2022-23 project year. These posts showcased photos and videos from the field and were designed to engage Coastal Action's followers with updates about project activities. These posts reach Coastal Action's 7,104 combined followers from Instagram, Facebook, and Twitter social media platforms with a total combined reach of 12,155 and 610 direct interactions through likes, shares, and comments. The online newsletter Coastal Chronicle has 694 subscribers. Additionally, Paul Pickrem from Saltwire wrote an article on the Atlantic whitefish, published in the South Shore Breaker on March 15, 2023 (Pickrem 2023). On September 21, 2022, the Atlantic Whitefish Recovery Project staff from Coastal Action and DFO-Science were honoured to host DFO's Director General for Biodiversity, Stacy Burton, and Acting Regional Director, Mark McLean, for a site visit and to talk about the project at the Hebb Dam Fish Passage Facility.

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 and to improving the habitat of the Southern Uplands population of Atlantic salmon. These activities complement the work done by Fisheries and Oceans Canada and Coastal Action in previous years. Continued work in the Petite Rivière and LaHave River watersheds and direct actions to support these 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 as well as at the 19 sites

throughout the Petite Rivière watershed; continue zooplankton sampling in the three lakes starting in April to monitor emergence times to determine food availability for larval Atlantic whitefish as they are developing; continue monitoring the Crousetown Dam fishway for barriers to fish passage; and investigate the second spawning event (fall spawning) for chain pickerel in Milipsigate Lake to determine how that may impact recruitment. In regards to the recovery of Atlantic salmon in the LaHave River Watershed, Coastal Action recommends the following activities: continue to identify key salmon habitat through backpack electrofishing surveys and habitat suitability assessments; improve key habitat using various fish habitat improvement methods; continue educating the public on the state of the Southern Upland Atlantic salmon; and address the negative impacts of invasive species through targeted removals and limiting new introductions.

6.0 Acknowledgments

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