2023-24 Review of Fisheries Activities for the Recovery of Endangered Atlantic Whitefish and Southern Uplands Atlantic Salmon in Nova Scotia

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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. Several restoration and monitoring activities were completed in 2023 to support populations of these anadromous fish, building on the activities undertaken in the previous two years. This report summarizes monitoring and recovery initiatives undertaken in the 2023-2024 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, as well as downstream in the Petite Rivière 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, and aquatic invasive species control. Removal methods for invasive chain pickerel (*Esox niger)* and smallmouth bass (*Micropterus dolomieu*) include smallmouth bass nest surveys/destruction, and the deployment of light traps to capture larval invasive fish, and bycatch in passive fish traps. Lastly, outreach and education activities also took place.

A total of 560 smallmouth bass and 225 chain pickerel of different age classes were removed from the Petite Rivière watershed during the 2023-2024 season through all methods and across all Atlantic whitefish projects. This year, 33 smallmouth bass nests containing eggs or fry were destroyed, 65 adult smallmouth bass were angled from the nests, and 12 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 49,623 gaspereau migrating into Hebb Lake. Through the combined spring and fall monitoring of the Hebb Dam Fish Passage Facility, 45 adult smallmouth bass and one adult chain pickerel were euthanized and removed.

Across the three lakes in Atlantic whitefish critical habitat, 33 different zooplankton species were identified 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 of the three lakes monthly from April through September, contributing to the long-term monitoring of these lakes to inform the study of Atlantic whitefish habitat and future translocation lakes. High water temperatures above 20°C extended into September this year; a month later compared to 2021 and 2022. However, pH values improved overall; less acidic on the lower end (5.44) and less basic on the higher end (7.48), as opposed to ranges of 4.53 to 8.75 in 2021 and 3.09 to 8.53 in 2022. Nineteen sites throughout the watershed were also monitored monthly for water quality using a YSI ProDSS. Consistent with previous years, the results in both the lake and watershed sites show elevated temperatures 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 two watercourses located in the West Branch Sub-watershed of the LaHave. This work included the installation of five instream structures and the maintenance of six existing structures. As a result, a total of 288 linear meters or 1728 m^2 of instream habitat was restored during the 2023 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 2023-24 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.

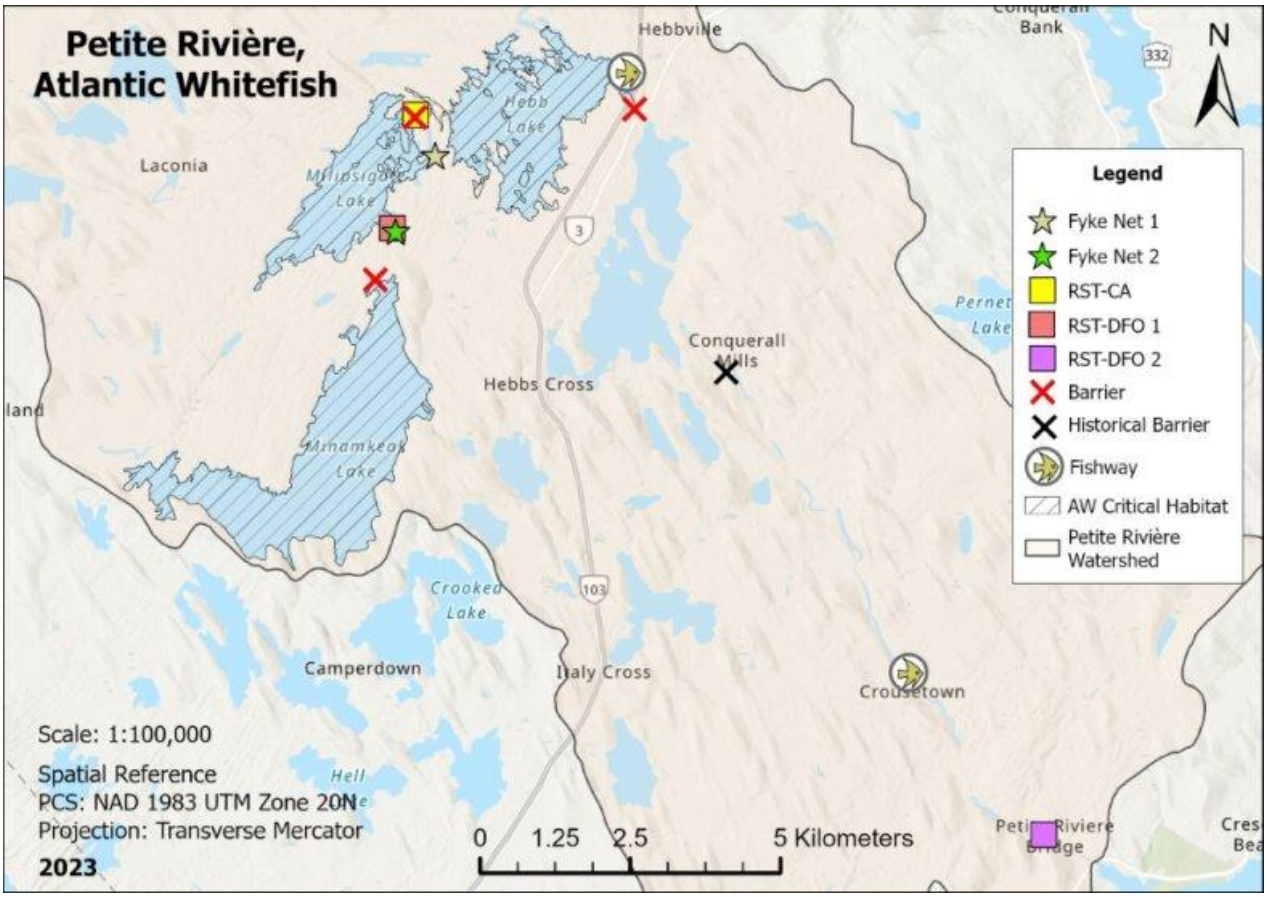


Figure 1. Map of the Petite Rivière watershed showing the three lakes (Minamkeak, Milipsigate, and Hebb) which contain the existing wild Atlantic whitefish population, as well as the dams and fishways present in the system.

1.2 Project Objectives

The broad objectives of the Atlantic Whitefish Recovery Project are to 1) contribute to the protection and recovery of critically endangered Atlantic whitefish, 2) continue working towards the re-introduction of Atlantic whitefish from the rearing program, and 3) improve habitat for Southern Uplands Atlantic salmon.

Coastal Action's AWRP had several goals and objectives for the 2023-2024 field season, and these included:

- 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;
- Continue previous zooplankton surveys on the three Atlantic whitefish lakes for a

total of 12 samples collected monthly from April through September;

- Continue to monitor the upstream migration of gaspereau (*Alosa pseudoharengus*) into Hebb Lake in the spring; and
- Undertake fish habitat restoration 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 2023 and March 2024, 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, 2023 and was operated until June 30, 2023, 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 up to five times 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. All other fish were counted and measured to fork length (cm), excluding American eels and lamprey which were measured to total length (cm). Smallmouth bass and chain pickerel were measured, euthanized, and disposed of appropriately.

In the case of the capture of an Atlantic whitefish, Atlantic salmon, or other salmonid species, 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 filled with water from the fishway. This would also allow for photos to be taken and fork length to be measured or estimated while remaining in the water and avoiding handling. Under the direction of the DFO Project Authority, scale samples and fin clips may be obtained for aging or DNA analysis.

The relative water level (measured in inches) of Hebb Lake was also recorded daily using a gauge attached to the fishway (Figure 3) along with the water temperature of the fishway (°C), which was measured using a digital thermometer. The air temperature and weather conditions were also recorded. Sometime between the fall of 2022 and the spring of 2023 Hebb fishway monitoring, the Bridgewater Public Service Commission (PSCB) changed the location and orientation of the water level gauge, so the relative water levels cannot be compared to those from previous years. The old level read low to high from the bottom of the gauge to the top, whereas the new gauge is the opposite and reads from high to low from the bottom to the top (Figure 3).

Figure 2. Left - Hebb Dam Fish Passage Trap lifted out of passage with the door open.

Figure 3. Previous (left) and new (right) water level gauges above Hebb Dam 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 September 25, 2023, and was operated and monitored until December 15, 2023. 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, PIT-tagged, and released by DFO-Science into various locations in the Petite Rivière

watershed, including the estuary, in the summer of 2023. 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 to and approved by the HSP Program Officer via email on September 6, 2023.

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 2023 to March 2024 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 a minimum of 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	Fishway	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 2023. 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 month from April 21 to September 12, 2023, 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 on the net was removed, and a rope was tied onto the metal ring of the net at three points, 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 prevented any material from entering the sample jars that would not be excluded by the mesh size of the net. 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.

Coastal Action staff continued to expand the photo identification guide of zooplankton species produced in 2022 to include the specimens found during surveys on Hebb, Milipsigate, and Minamkeak Lakes in the 2023 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 supplements the

identification keys being used and aids 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 three days between June 12 and 16, 2023. 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, 2022, and 2023, surveys were conducted by snorkelling to increase efficiency in identifying and destroying bass nests (Figure 4). Surveys were conducted with a boat operator and at least one snorkeller and angler.

Figure 4. 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 and crush the smallmouth bass eggs or fry present. The angled smallmouth bass were euthanized, measured to fork length (cm), and later disposed of appropriately. Most of the angled bass were also dissected to confirm and record the sex.

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 5). These traps were deployed from June 20 to 26, 2023, and used to target and remove larval smallmouth bass and 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 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.

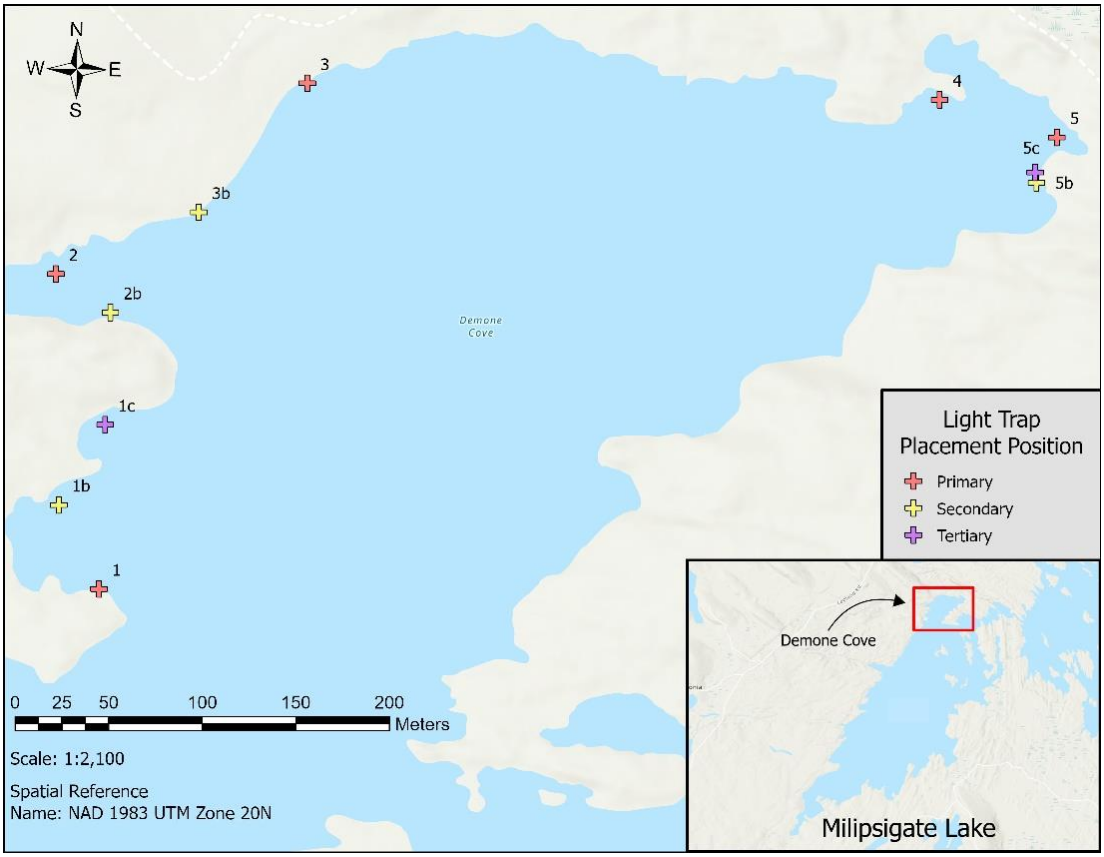


Figure 5. Map of floating light traps deployed in Demone Cove, Milipsigate Lake in the spring of 2023. Asterisks (*) indicate the second locations of light traps.

Figure 6. 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

In-stream fish habitat improvement involved the use of various methods including digger logs, deflectors, and bank stabilization. These methods are recommended by DFO and are highlighted in the 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.

Five structures, including two digger log/deflector combos and three solo digger logs, were installed on Zwicker Brook and Fire Brook in 2023, both of which are located in the West Branch Sub-watershed. 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 another location on Zwicker Brook where several structures were installed over the past two seasons. This included rebuilding ramps and reforming pools to promote the proper function of the structures. Generally, these structures require maintenance in the two seasons following installation before becoming fully established within the watercourse. 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 Figures 7 and 8.

Figure 7. GIS map showing the locations where new improvement activities and maintenance work occurred on Zwicker Brook in 2023.

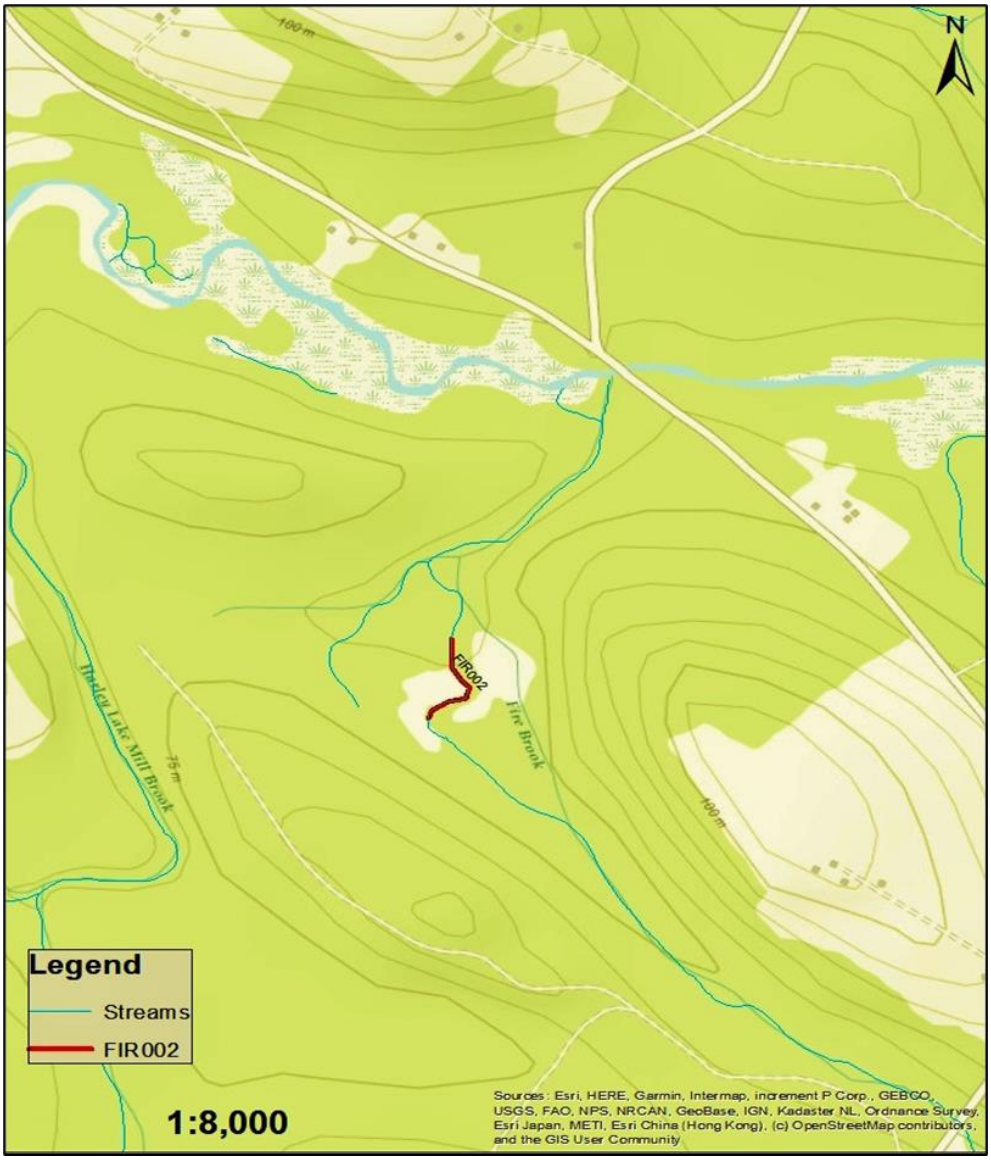


Figure 8. GIS map showing the location where habitat restoration occurred on Fire Brook in 2023.

3.0 Results and Discussion

3.1 Spring Monitoring at Hebb Lake Dam Fish Passage Facility

In May and June of 2023, a total of 52,168 fish comprised of six 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, smallmouth bass, and white sucker (*Catostomus commersonii*). The spring 2023 season had the largest recorded migration of gaspereau through the Hebb fishway at 52,075 individuals, the next highest being 35,299 in 2022 (Russell et al. 2023). Of the gaspereau counted in 2023, 101 (0.2% of the total catch) were incidental mortalities.

Since the Hebb Dam fishway opened in the fall of 2012, the number of gaspereau migrating through the fishway has increased by over 2,300% (Figure 9). The high abundance of gaspereau in Atlantic whitefish critical habitat could potentially have positive or negative implications on Atlantic whitefish in the future if the increase persists. The high abundance of gaspereau could be beneficial by providing a food source to invasive fish and other predators, thus reducing the predation of Atlantic whitefish. However, they could deplete zooplankton resources and reduce the abundance and diversity of food availability for juvenile Atlantic whitefish. Continued monitoring and further investigation of the impacts are recommended going forward.

Table 5. The number of fish captured and their life stages in the Hebb Dam Fish Passage Facility trap from Apr 30 to June 30, 2023.

Species	Life Stage	Frequency	Total Number of Each Species
American eel	Adult	33	33
Brook trout	Parr	0	2
	Adult	2	
Chain pickerel	Adult	1	1
Gaspereau	YOY	0	52,075
	Adult	52,075	
Smallmouth bass	Adult	51	51
White sucker	Adult	6	6
Total			52,168

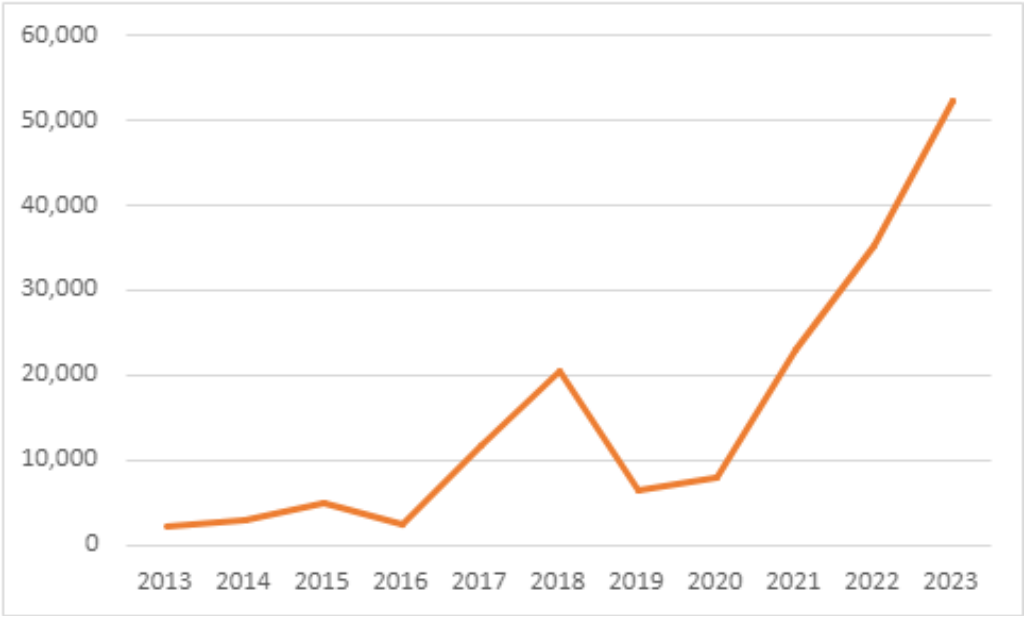


Figure 9. Abundance of gaspereau in the Hebb Dam fishway during spring monitoring from 2013 to 2023.

3.2 Fall Monitoring at Hebb Lake Dam Fish Passage Facility

During the fall monitoring of the Hebb Dam fishway trap, 20 fish comprised of four different species were captured (Table 6). These included American eel, brook trout, chain pickerel, and smallmouth bass. All fish caught were adults.

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 2023.

Table 6. The number of fish captured in the Hebb Dam Fish Passage Facility trap from September 25 to December 15, 2023. All fish were adult-stage.

Species	Total Number
American eel	11
Brook trout	1
Chain pickerel	1
Smallmouth bass	7
Total	**20**

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

There were several extreme weather events in 2023 including droughts in spring, significant rainfall exceeding 300 mm in a single event in July, and subsequent rainfall events into September. These weather events are likely to impact the total dissolved solids, dissolved oxygen, and temperature of the water.

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 -0.1°C to 27.6°C throughout 2023 (Figure 10). All sites had at least one temperature reading exceeding the 20°C threshold recommended for cold-water fish during the summer months from June to September (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.

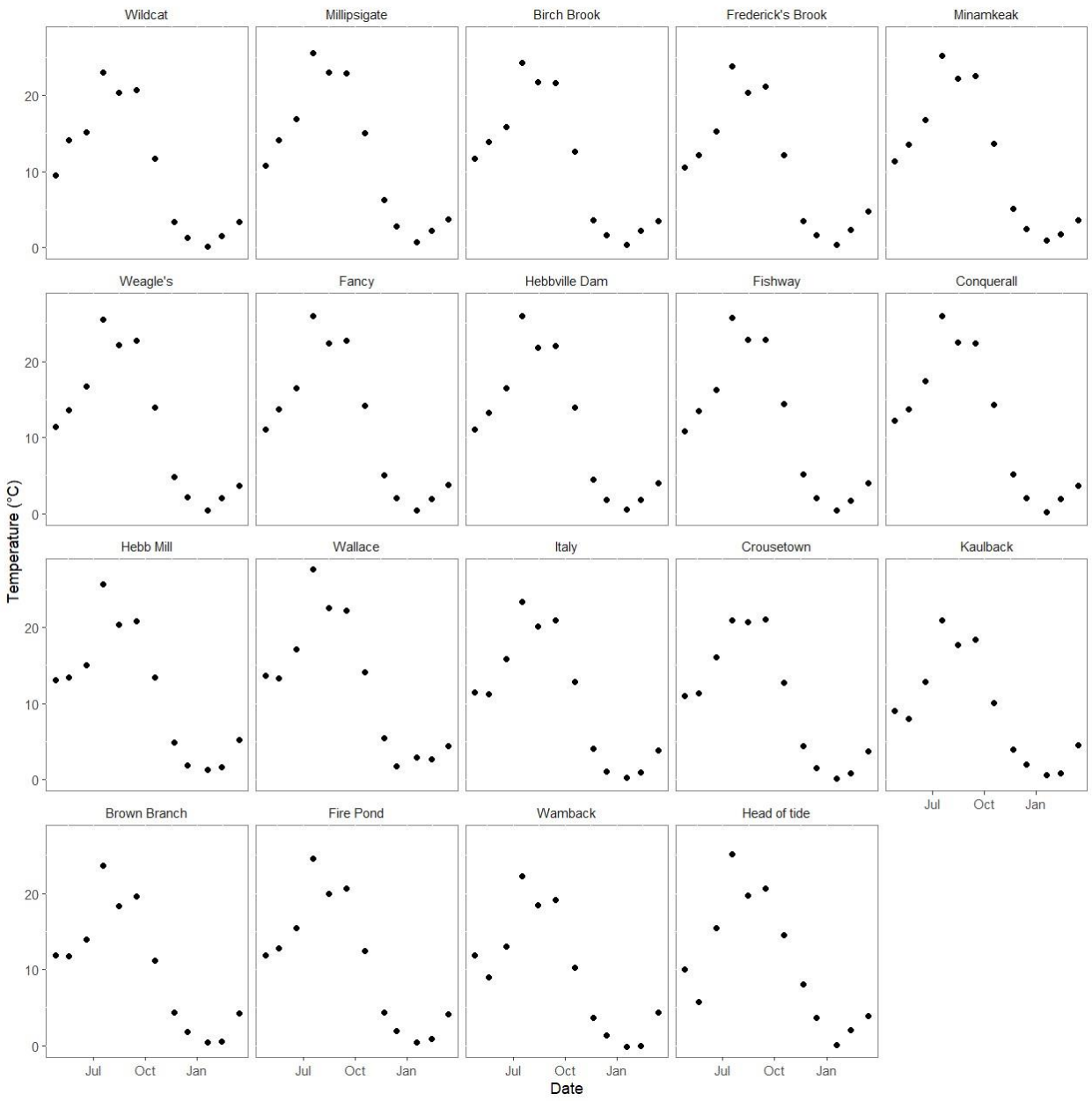


Figure 10. Monthly temperature measurements at 19 sites within the Petite Rivière watershed from April 2023 to March 2024.

Dissolved oxygen (DO) throughout the Petite Rivière watershed ranged from 4.11 mg/L to 14.41 mg/L in 2023 (Figure 11). Four sites periodically fell below the 6.5 mg/L DO threshold for cold-water aquatic life (CCME 1999). Frederick's Brook and Hebb Mill both fell below the threshold three times, Birch Brook was below the threshold twice, and Italy Cross was below the threshold once. DO was measured below this threshold most frequently in the summer months, from June to September, corresponding with elevated temperatures, as dissolved oxygen is closely related to temperature. In warmer months and during heat waves, the

combination of intense solar radiation, high air temperatures and low wind, does not allow the surface water, with higher DO, to mix into the rest of the waterbody (Shinohara et al. 2023). The minimum recorded DO was 4.11 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.

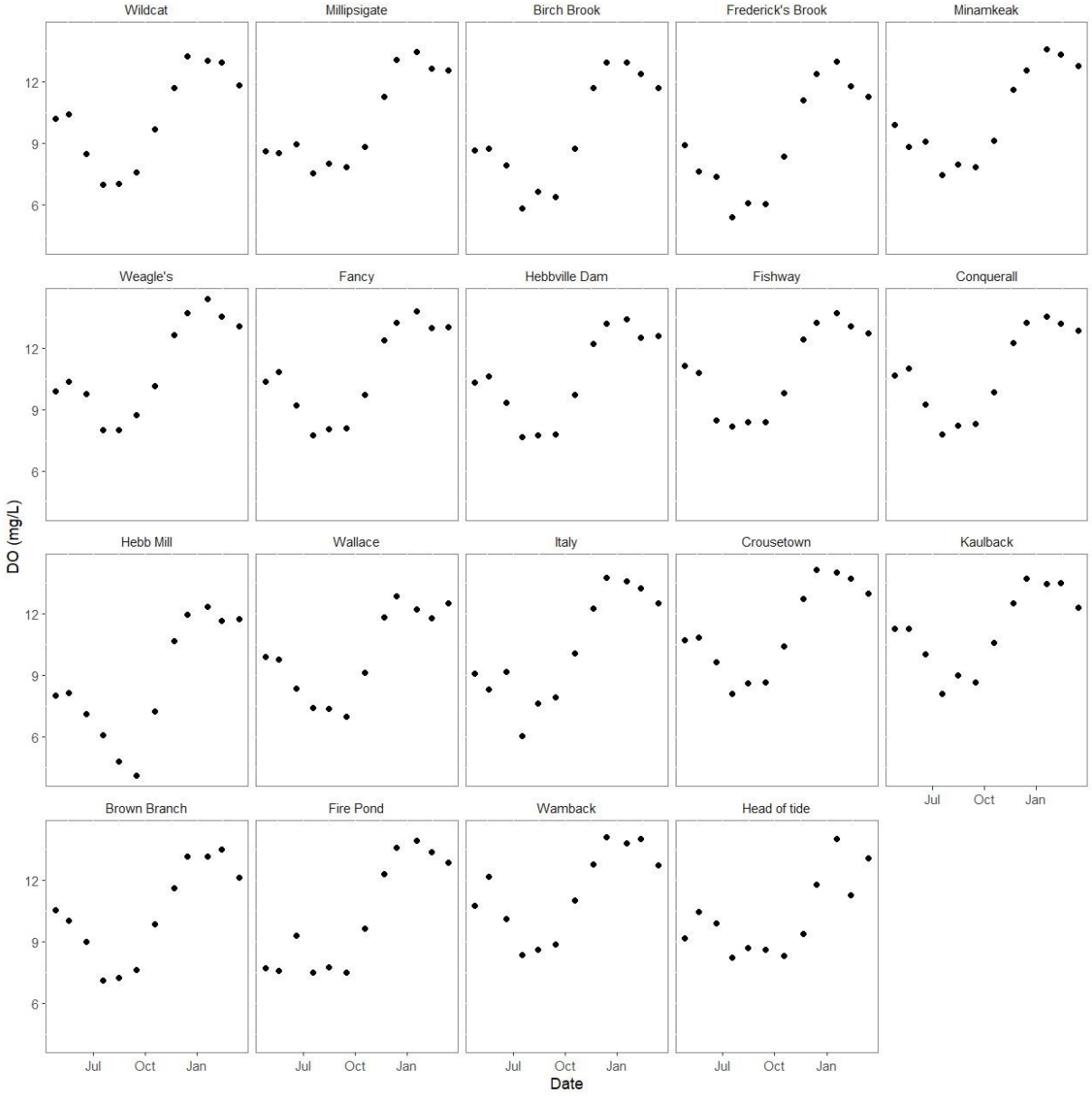


Figure 11. Monthly dissolved oxygen measurements at 19 sites within the Petite Rivière watershed from April 2023 to March 2024.

Total dissolved solids (TDS) ranged from 10 to 31.85 mg/L across the 18 freshwater sites in the Petite Rivière in 2023 (Figure 12). At the Head of Tide estuarine site, it ranged from 17 mg/L to 26481 mg/L, due to the influence of salt water (Figure 13). 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 2023, the freshwater sites do not exceed this threshold, therefore, would not pose a threat to freshwater aquatic organisms.

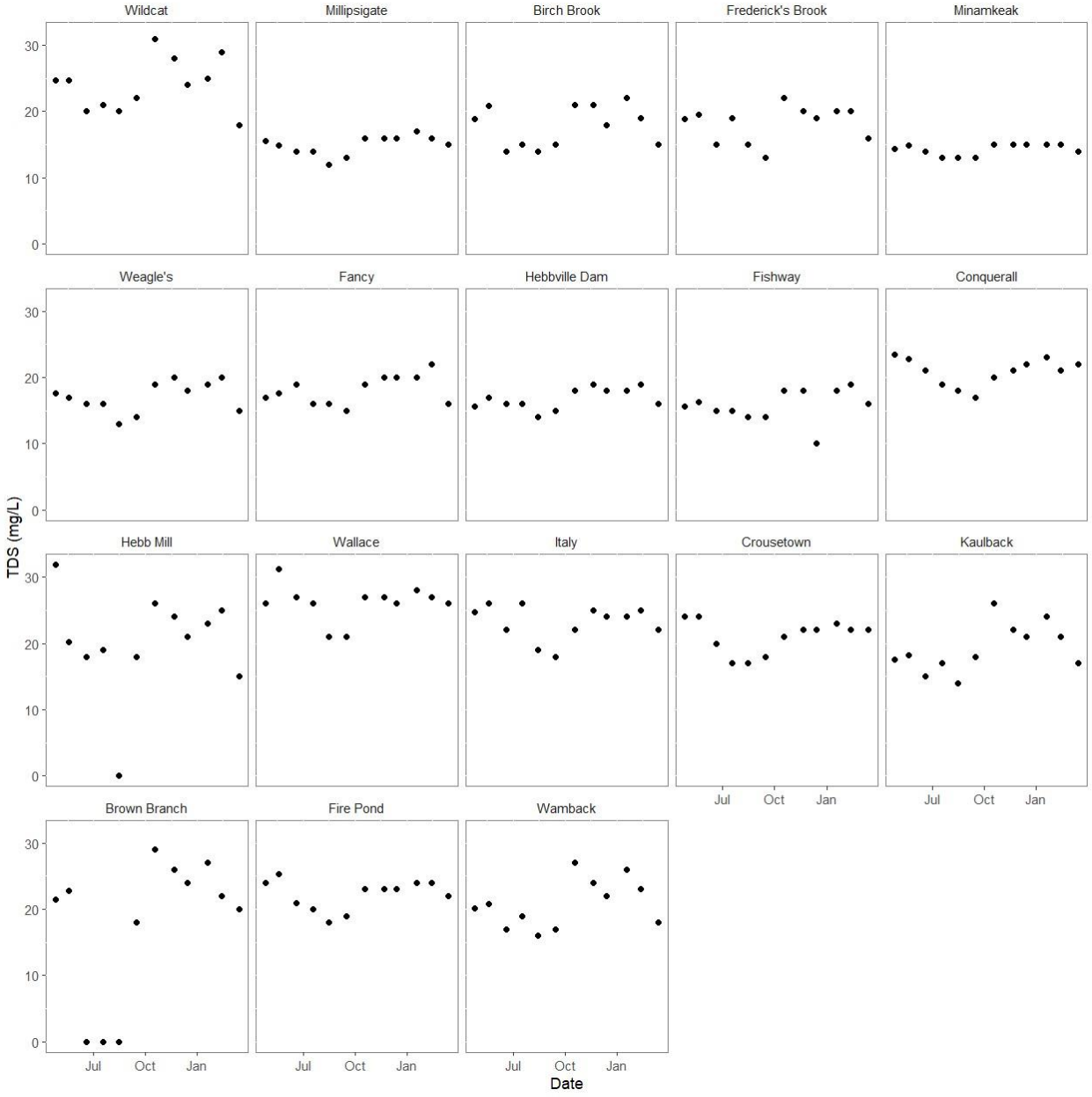


Figure 12. Monthly total dissolved solids measurements at 18 freshwater sites within the Petite Rivière watershed from April 2023 to March 2024.

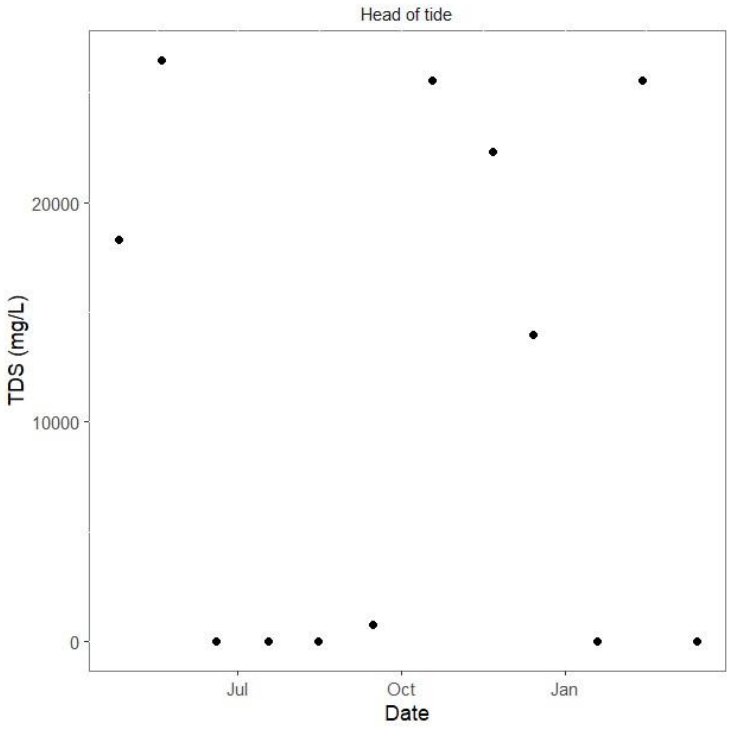


Figure 13. Monthly total dissolved solids measurements at the estuary site of the Petite Rivière watershed from April 2023 to March 2024.

The pH of the 19 Petite Rivière sites ranged from 4.75 to 8.03 with a mean of 5.80 in 2023 (Figure 14). 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. Brown Branch consistently had the lowest pH values of all sites during the 2023 sampling, with an average pH of 5.06. Birch Brook, Kaulback Brook, Brown Branch Brook, and Wamback Brook all had at least one 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.

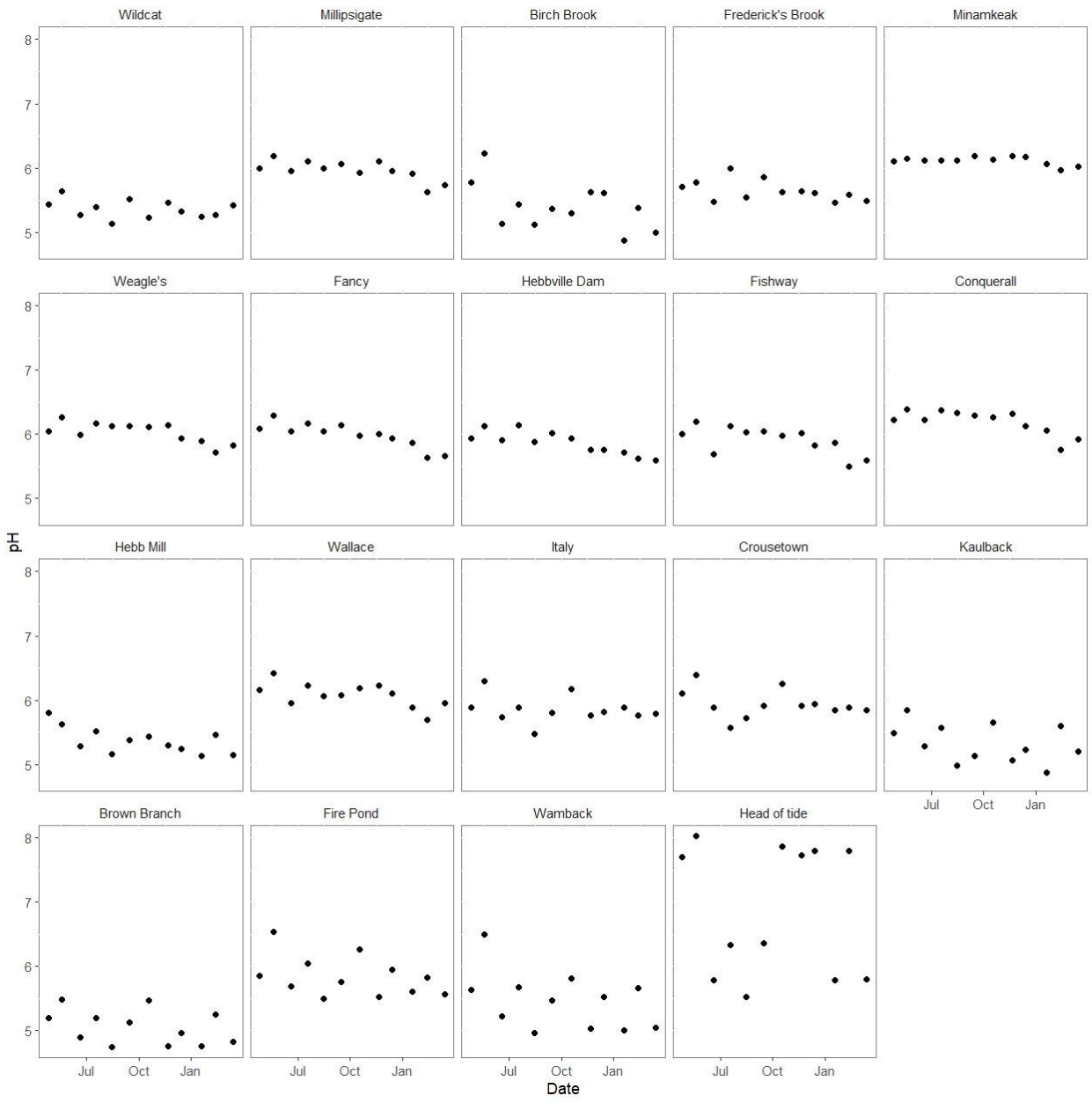


Figure 14. Monthly pH measurements at 19 sites within the Petite Rivière watershed from April 2023 to March 2024.

3.4 Water Quality Monitoring on Atlantic Whitefish Lakes

The monthly lake water quality depth profiles were done on April 21, May 23, June 21, July 20, August 24, and September 12, 2023. On the first sampling day on April 21, the pH probe was not operating correctly, so an alternate YSI probe with a short cord was used for pH. Therefore, in April, the pH was only recorded for the first two metres (Minamkeak Lake) or

three metres (Hebb and Milipsigate Lakes).

July through September reached water temperatures above 20°C for all three lakes, which is the non-early-stage cold-water fish threshold in NSSA 2014. However, in Cook et al. 2010, it was determined that the optimum and maximum growth temperatures for juvenile Atlantic whitefish were 16.5°C and 24.6°C, thus suggesting that, although it is not optimal, later-stage fish can tolerate temperatures above 20°C. The highest water temperatures occurred in July, where the surface values ranged from 24.8°C in Minamkeak Lake, 26.0 °C in Milipsigate Lake, to 26.4°C in Hebb Lake (Figures 15-17).

According to the CCME guidelines, the acceptable pH for freshwater aquatic life is 6.5 to 9.0. Cook et al. 2010 noted that "generally pHs less than 5.0 decreased survival in eggs, whereas pHs less than 4.5 decreased survival of larval and juvenile Atlantic whitefish," however the pH thresholds of adult fish were not examined. The lowest pH in 2023 was recorded in Minamkeak at 5.44, whereas the highest pH was in Hebb at 7.48. August and September were the only months in Hebb and Minamkeak when the pH met the minimum CCME guideline of 6.5 (CCME 1999). A pH level at or above 6.5 generally occurred at either the surface or below the thermocline. Milipsigate Lake did not meet the guideline in any month, at any depth, with a maximum recorded pH of 6.41. The pH ranged in Hebb Lake from 5.52 (June) to 7.48 (August), 5.54 to 6.41 in Milipsigate Lake, and 5.44 to 6.90 in Minamkeak Lake.

Dissolved oxygen is another important factor for aquatic life. The lowest acceptable DO concentration for aquatic life in cold freshwater ecosystems is 9.5 mg/L for early life stages and 6.5 mg/L for other life stages (CCME 1999). As in previous years, a decrease in dissolved oxygen (DO; mg/L) and an increase in total dissolved solids (TDS; mg/L) were noted around the thermocline, when present, in every lake.

In Hebb Lake in 2023, the most notable thermoclines appeared from June through August with the largest thermocline occurring in July (Figure 15). The surface water temperature in the July profile was 26.4°C and it quickly dropped from there and started to stabilize around 9 m deep at 14.6°C. In June, the thermal drop was small, from 16.7°C at 5 m deep to 14.0°C at 9 m. The thermocline in August dropped from 21.0 at 6 m to 17.2 at 8 m. There was a small dip in temperature in the September sample from 23.4°C to 21.0°C between 2 and 4 m deep. The dissolved oxygen fell below the CCME 6.5 mg/L threshold every month in Hebb Lake starting at 9 m below the surface in April, 17 m in May, 7 m in June, 4 m in July, 6 m in August, and 6 m in September (CCME 1999).

Thermoclines were observed in Milipsigate from June through September, with a small dip in May 2023 (Figure 16). In May, the temperature dropped slightly from 14.9°C at 4 m to 13.6 °C at 9 m below the surface. June through September saw larger but more gradual drops in temperature. In June and August, the water temperature experienced two distinct drops. In June, it occurred from 18.9 to 16.9°C from the surface to 2 m and then from 16.5 to 13.8°C from 5 to 8 m below the surface, and in August, from 23.3°C at the surface to 21.4°C at 2 m,

then a larger drop from 21.1 to 14.0°C from 4 to 12 m. The temperature declined steadily in July from the surface to 7 m from 26.0 to 14.0°C. As with Hebb Lake, the dissolved oxygen fell below the CCME 6.5 mg/L threshold every month in Milipsigate Lake starting at 13 m below the surface in April, 14 m in May, 15 m in June, 2 m in July, 6 m in August, and 6 m in September (CCME 1999).

Similarly to Hebb Lake, thermoclines were detected in Minamkeak Lake from June through August 2023 (Figure 17). On June 21, the thermocline started below 6 m, where the water temperature was 16.5 °C, and stabilized around 10 m, where it was 14.1 °C. The most dramatic thermocline occurred in July, from 24.6 °C at 2 m to 14.4 °C at 9 m. In August, the thermocline occurred between 7 and 13 m, from 21.2 °C to 14.1 °C. There was no thermocline in the September Minamkeak profile, however, the water temperature gradually declined until 14 m below the surface, at which point, it started increasing consistently by 1 °C every 1 m. This is assumed to be a temperature probe malfunction. In April, May, and September when there was no thermocline, the DO (mg/L) started to decrease, and TDS (mg/L) started to increase between 10-11 m. The dissolved oxygen fell below the CCME 6.5 mg/L threshold in every month except for April in Minamkeak Lake: starting at 12 m below the surface in May, at 13 m in June, at 6 m in July, at 8 m in August, and at 12 m in September (CCME 1999).

In all three lakes, during the months when the surface temperatures were above 20°C, there was not much vertical area, if any, that was technically suitable for fish based on the temperature and DO thresholds in NSSA 2014 and CCME 1999. Once temperatures dropped below 20°C, the DO concentration would often fall below 6.5 mg/L around the same depth or within 2 m of the 20°C mark. The amount of habitat with suitable dissolved oxygen and temperatures during the warmest months seems to be the biggest concern in terms of water quality parameters for lake-resident Atlantic whitefish. July 2023 was the most concerning month in all three of the lakes with the hottest water temperatures and the DO concentrations fell below the 6.5 mg/L threshold between 2 and 6 m below the surface.

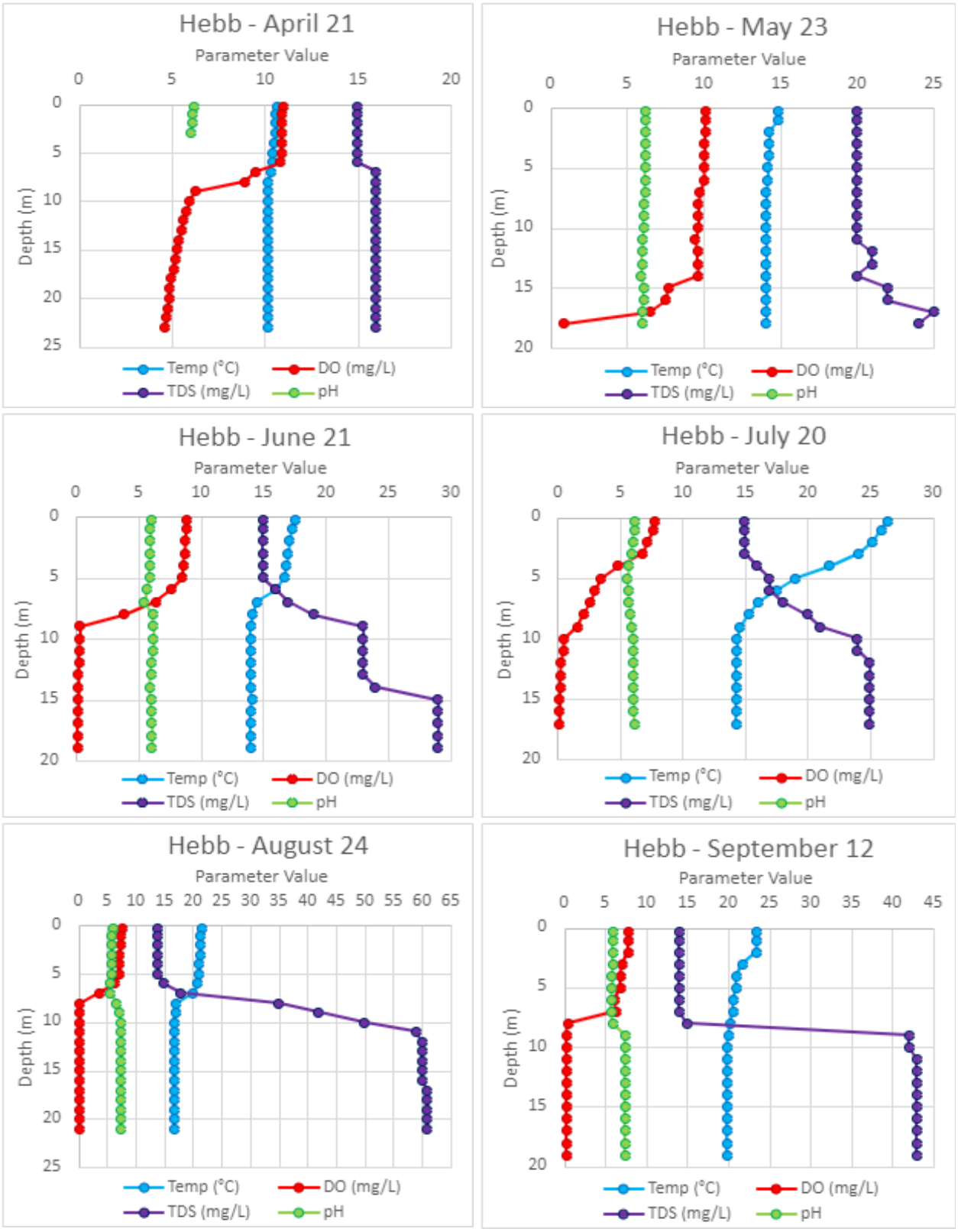


Figure 15. Monthly water quality depth profiles of Hebb Lake from April through September 2023.

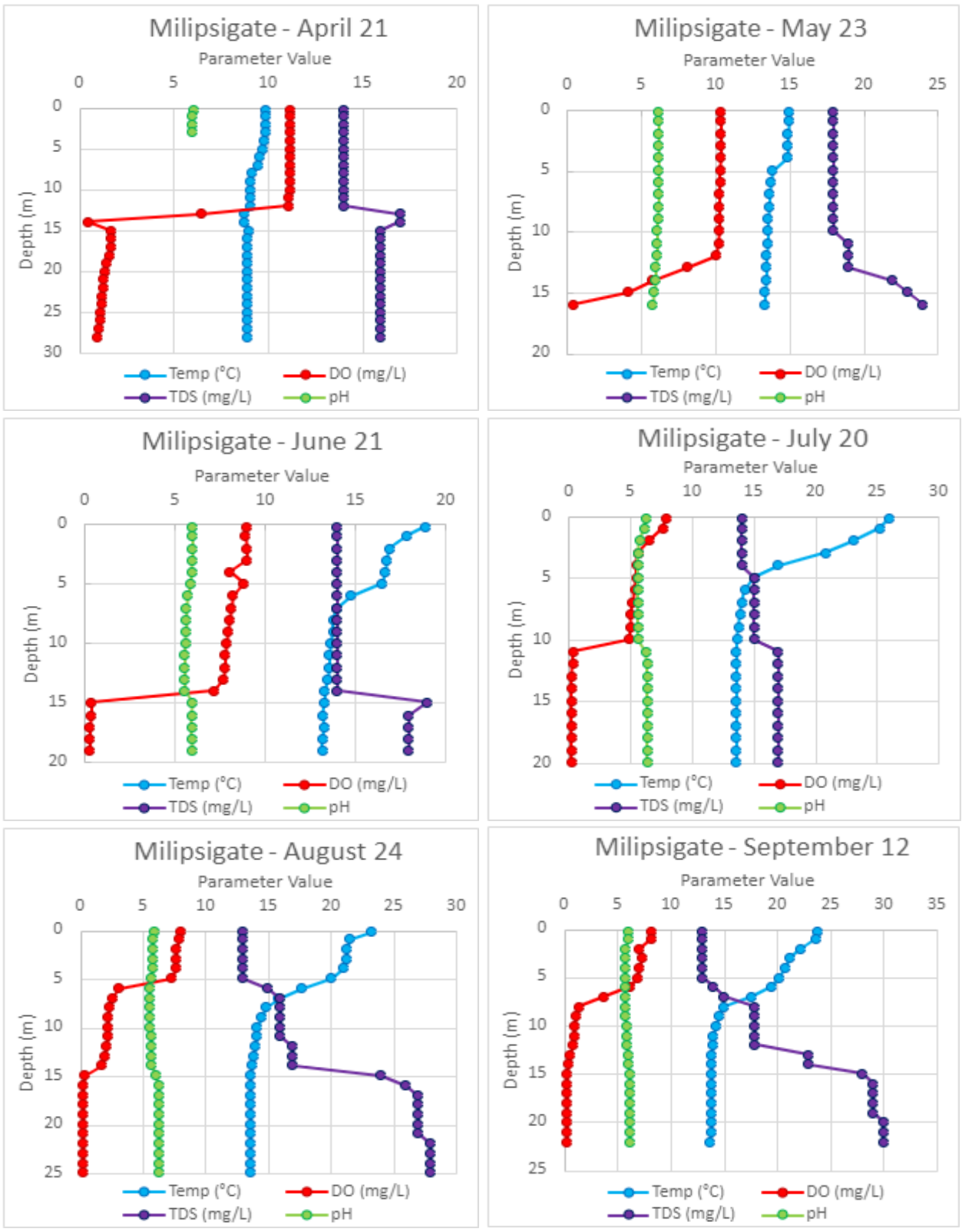


Figure 16. Monthly water quality depth profiles of Milipsigate Lake from April through September 2023.

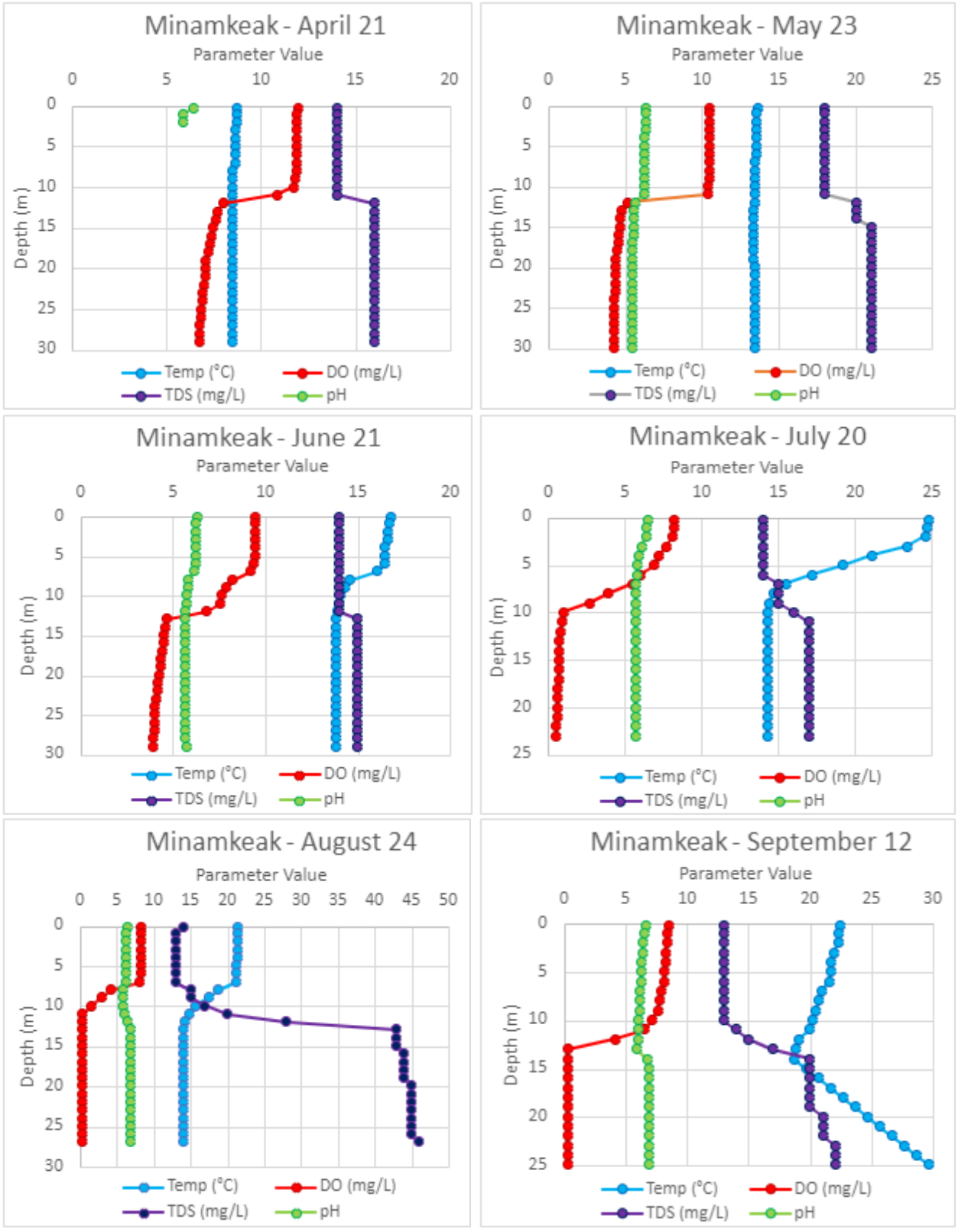


Figure 17. Monthly water quality depth profiles of Minamkeak Lake from April through September 2023.

3.5 Zooplankton Survey

A total of 72 zooplankton samples comprised of 33 different species or taxonomic groups (if not identified to species level) were collected from April 21 to September 12, 2023, from Hebb, Milipsigate, and Minamkeak Lakes. This amounted to a total of 2,671 specimens identified.

Generally, the specimens that could not be identified to at least the Genus taxonomic level were left out of the total counts, except for calanoid copepods (order) and Hydracarina (family), as the identification guides that were used did not go beyond those stages. The specimens that were only identified to the genus stage included *Eurycercus*, *Gammarus*, and *Ilyocryptus*. Several samples contained less than 50 zooplankton, including Site 1 of Milipsigate and Minamkeak Lakes in April, Hebb Sites 1, 2, and 4 and all the Milipsigate sites in July, and all the Hebb and Milipsigate sites in August and September. One sample, Site 3 of Milipsigate Lake in July, did not contain any zooplankton that could be identified; there were only about a dozen exoskeletons from larval arthropods.

The number of species identified in 2023 was the same as in 2022 (33 species), however, some species were different, including two new species that have not been identified previously in these lakes: *Daphnia schødleri* and *Eubosmina hagmanni*. *D. schødleri* was found in the Hebb Lake Site 4 sample in May 2023. There was only one identified in the samples and this species is easily confused with *Daphnia Catawba*, so this could potentially demonstrate human error. Only one *E. hagmanni* was found in the Hebb Lake Site 1 sample in May. The identifier was confident, noting that the bristles were clearly on the dorsal side of the mucro.

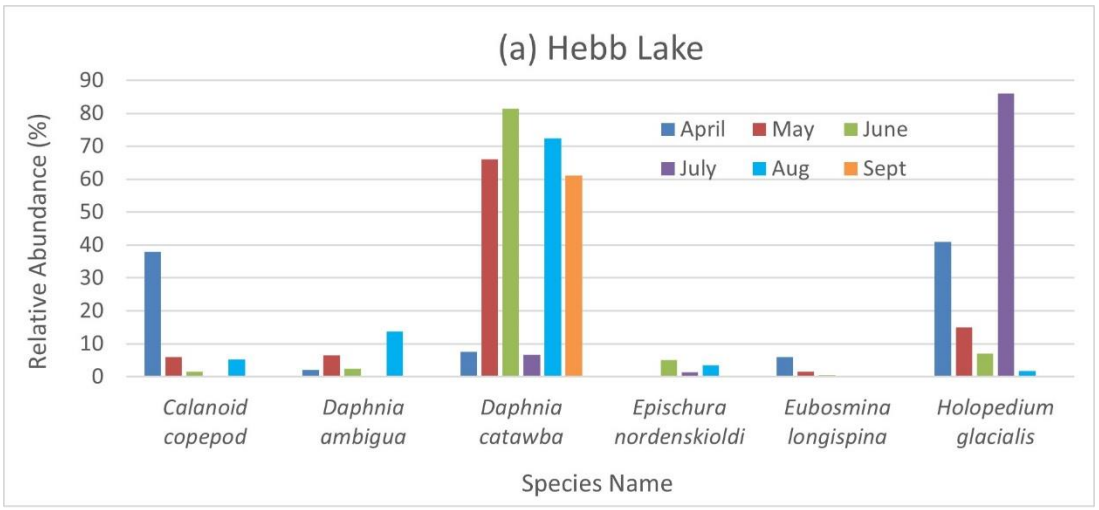
All specimens identified in 2023 belonged to the phylum Arthropoda; no Rotifera were identified. Out of the 33 species or taxa identified, 21 belonged to the superorder Cladocera, nine were in the class Copepoda, and three were classified as other arthropods. Species of *Daphnia*, which are in the cladoceran group, 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. 2023). The average relative abundances of the broader taxonomic groups across all lakes from April through September were 79.5% Cladocera, 18.8% Copepoda (class), and 1.7% other arthropods. The relative abundance of Cladocera was the lowest in April at 67.1% and peaked in June and August at 89.6% and 90.0%, respectively. In contrast, the lowest relative abundance of copepods occurred in August at 8.1% and peaked in April at 32.9%. Specifically, the *Daphnia* genus accounted for 50.0% of the overall abundance of specimens across all lakes from April through September in 2023. *Daphnia* comprised 49.9% of the Hebb Lake samples, 30.4% of Milipsigate Lake, and 63.9% of Minamkeak Lake across all months.

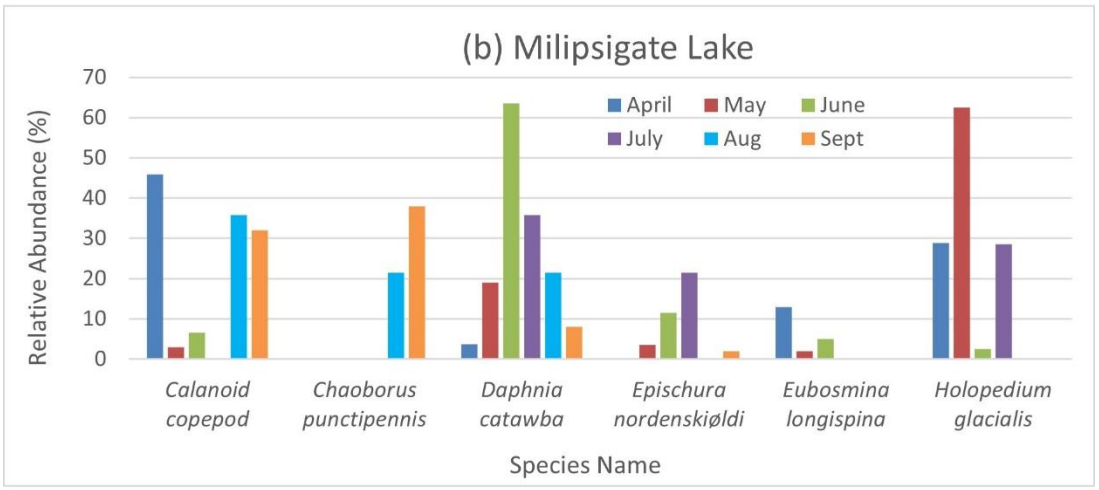
Hebb and Milipsigate Lakes had the greatest diversity of zooplankton with 24 different

species, whereas Minamkeak Lake had 17. Last year, in 2022, Minamkeak Lake had the highest diversity of 28 out of 33 total species identified followed by Hebb Lake with 27 and Milipsigate Lake with 24. The six most abundant species across the three lakes from April through September were *Daphnia Catawba* with a relative abundance of 48.0%, followed by *Holopedium glacialis* (17.1%), calanoid copepods (8.6%), *Epischura nordenskiøldi* (8.0%), *Eubosmina longispina* (5.1%), and *Diaphanosoma brachyurum* (3.3%).

The dominant species based on overall relative abundance during the sampling period in Hebb Lake were *D. Catawba* (45.2%), followed by *H. glacialis* (31.0%), and calanoid copepods (11.4%), with the next most abundant being *Daphnia ambigua* (3.6%), *E. longispina* (1.9%), and *E. nordenskiøldi* (1.7%) (Figure 18(a)). In Milipsigate Lake, the most abundant species were *H. glacialis* (28.3%), *D. Catawba* (27.4%), calanoid copepods (19.2%), *E. longispina* (5.8%), *E. nordenskiøldi* (5.1%), and *Chaoborus punctipennis* (3.3%) (Figure 18(b)). The most abundant species in Minamkeak Lake were *D. Catawba* (62.7%), *E. nordenskiøldi* (13.0%), *E. longispina* (7.1%), *Diaphanosoma brachyurum* (4.8%), *Diacyclops bicuspidatus odessanus* (4.3%), and *Leptidora kindti* (2.0%) (Figure 18(c)).

The overall seasonality of the six most dominant zooplankton species in Hebb, Milipsigate and Minamkeak Lakes are shown in Figure 19. *D. Catawba* was found every month from April through September with its highest abundances occurring in June and August. Calanoid copepods and *E. longispina* abundances peaked in April and dropped off for the remainder of the sampling months. *E. longispina* was not present in the samples from July through September. The relative abundances were typically lower than average in July, the hottest month for water temperatures, except for *H. glacialis*, which peaked in July. Calanoid copepods, *D. brachyurum*, and *E. longispina* were not found in the July samples.





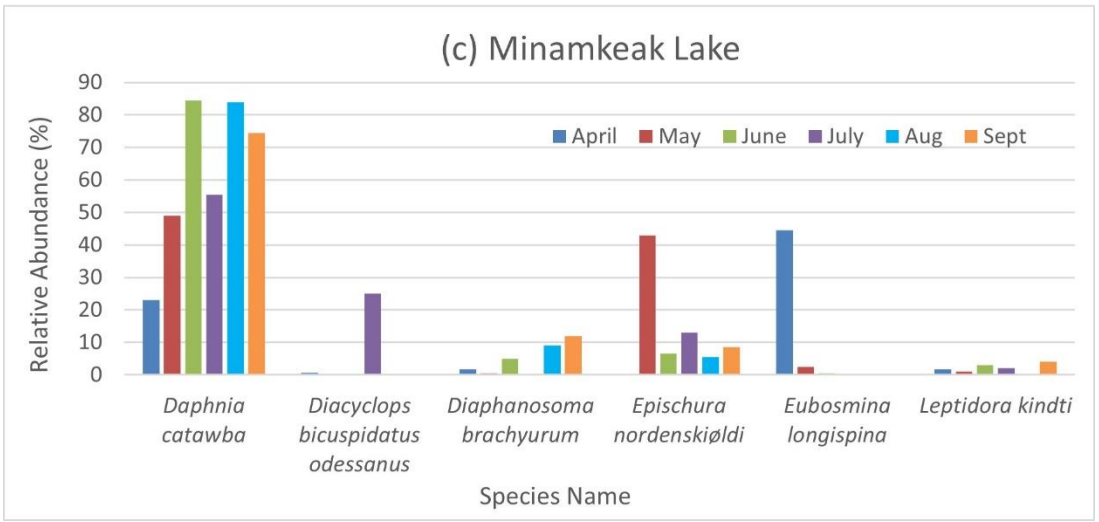


Figure 18. Relative abundance (%) of dominant zooplankton species by month in Hebb (a), Milipsigate (b), and Minamkeak (c) Lakes from April through September 2023.

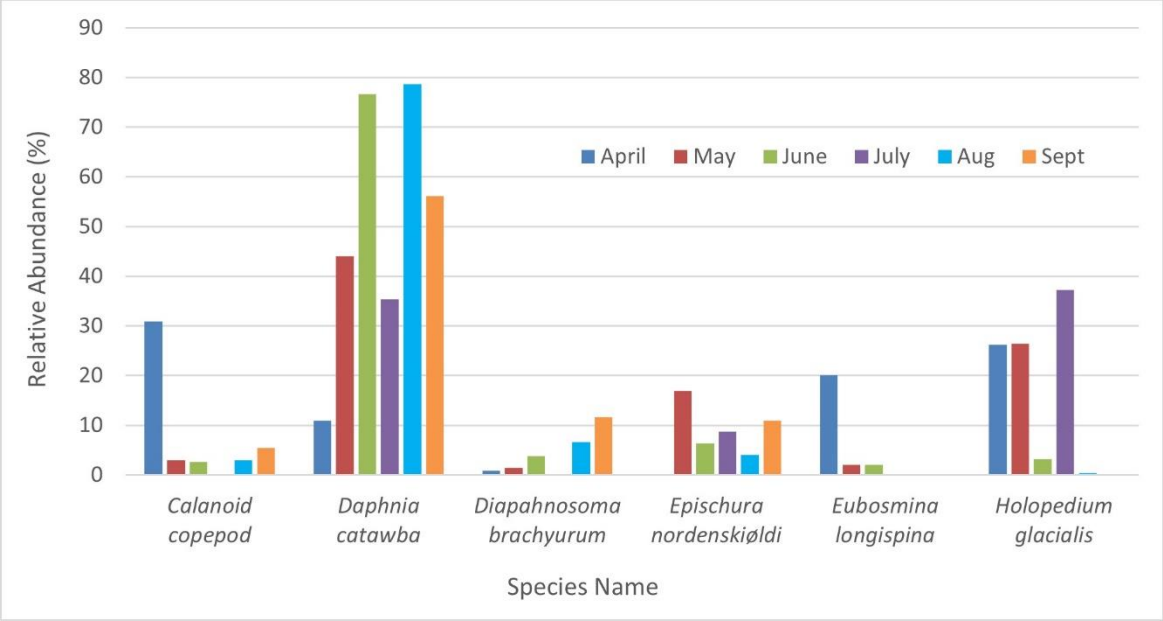


Figure 19. Overall seasonality of dominant zooplankton species in Hebb, Milipsigate, and Minamkeak Lakes based on relative abundances from April through September 2023.

3.6 Smallmouth Bass Nest Surveys & Light Traps

Demone Cove on Milipsigate Lake was surveyed over four days between June 12 and 16, 2023. During this time, when the water temperature was between 17.4 and 22.2°C, 85 nests were identified in Demone Cove (Figure 20). The majority (52) of nests were classified as type A (newly excavated and without eggs), 15 nests were classified as type B (eggs present), one nest was classified as class B/C (eggs present and non-dispersed fry), 15 nests were classified as type C (non-dispersed fry), and two nests were Class D (fry dispersed) (Table 7; Figure 21). Each nest containing eggs or fry was destroyed, amounting to 33 nests. A total of 65 adult smallmouth bass were angled throughout the surveys, at least of which 28 were guarding or staying near a nest. Of the fish caught, 42 were males and 23 were females. One adult chain pickerel was also angled during the survey. The substrate type for all nests was pebble and cobble.

In Demone Cove, 25 nests were found in 2018, 16 in 2019, 13 nests in 2020, 17 in 2021, and 44 in 2022 (Russell et al. 2023). This year had an increase of 41 nests overall from 2022. Of the nests surveyed this year, 33 had eggs or fry as compared to six the year prior. 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 2023 as in 2022, more snorkellers were surveying the cove. In 2023, four snorkellers were surveying at a time. Two of the snorkellers were experienced surveyors and the rest were newly trained in smallmouth bass nest surveys. Increased time was spent searching for nests overall and there is a chance that

some old nests were categorized as newly excavated however this does not account for the increase in active nests with eggs or fry. This year surveys totaled over ten hours of effort time, compared to approximately six hours in 2022. 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. The later timing of the surveys from June 12 to 16, 2023 as opposed to surveys from late May to early June, as occurred in 2021 and 2022, may have also been a factor in the larger number of active nests and females present.

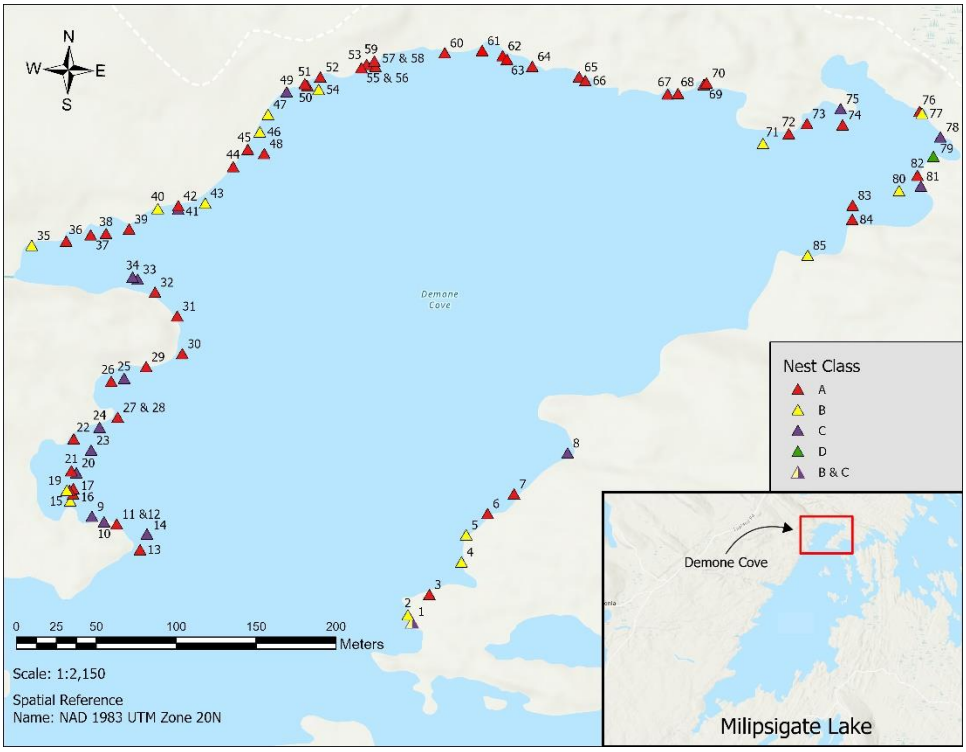


Figure 20. Locations of identified smallmouth bass nests in Demone Cove in Milipsigate Lake between June 12 and 16, 2023.

Table 7. Number of smallmouth bass nests per class in each survey location in 2023.

Location	Nest Classification	Frequency
Demone Cove	A - Newly excavated	52
	B - Eggs present	15
	B/C - Both Eggs and undispersed fry present	1
	C - Fry present but not dispersed	15
	D - Fry dispersed	2
	Total	**85**

Figure 21. Left – Smallmouth bass nest with hatching eggs; right – partially hatched nest with both eggs and fry.

The floating light traps were deployed from June 20 to June 26, 2023, in Demone Cove in Milipsigate Lake at locations where active nests were identified during the SMB nest surveys. The fishing time was an average of 142.51 hrs per trap, resulting in a total fishing time of approximately 712.53 hrs. The traps captured 12 larval smallmouth bass averaging 1.1 cm in length (Table 8). No chain pickerel were captured. Two larval yellow perch (*Perca flavescens*) were captured and released unharmed. One larval fish was not identified because escaped from the trap as it was being removed for the check.

Table 8. Number of fish captured by species in five light traps in Demone Cove in Milipsigate Lake in the from June 20 to 26, 2023.

Species	Count	Catch Per Unit Effort (# fish/hr)	Average Fork Length (cm)
Smallmouth bass	12	0.017	1.1
Yellow perch	2	0.003	1.4

This method of deploying the light traps following bass nest surveys in locations of known recently active nests has been much more effective at capturing larval smallmouth bass and less effective at capturing larval chain pickerel than the light trap trial that occurred in the

summer of 2020. Five of the six traps deployed in June and July of 2020 were installed 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 to 0.017 in 2023. However, this targeted method was still more effective at capturing larval smallmouth bass than the previous methods to target larval chain pickerel at 0.003 CPUE in 2020. More smallmouth bass nests were disturbed or destroyed, and more smallmouth bass were angled and removed in the 2023 nesting surveys than in previous years and only two of the 85 observed showed that fry had dispersed. Therefore, it is expected that the bass nest destruction and removal of breeding and guarding adults had an impact on the recruitment success, which is why so few larval bass were captured in the light traps this year. 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 used by Coastal Action in the Petite Rivière Watershed.

3.7 Instream Fish Habitat Restoration Projects

During the 2023 field season, Coastal Action successfully improved 1728 m^2 of important salmon habitat by installing instream habitat improvement structures on two watercourses in the West Branch Sub-watershed. The structures installed included two digger logs with deflectors and three solo digger logs (Figure 22). Three structures were installed on a section of Zwicker Brook where no restoration work had been previously completed. To build upon this work Coastal Action is planning to expand the site in 2024 and 2025. The remaining two structures were installed on Fire Brook in collaboration with students from the local Nova Scotia Community College. In total, the work completed on Zwicker Brook through this project has improved 4,698 m^2 of aquatic habitat. These restoration efforts have increased the availability of deep-defined pools, improved substrate composition by allowing the streams to naturally sort fines and provided increased cover.

Maintenance work was also performed on 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 2000 m^2 of salmon nursery habitat.

Figure 22. The left photo shows a digger log deflector combo installed on Zwicker Brook in 2023. The right photo shows the NSCC NRET class next to a digger log installed on Fire Brook in 2023.

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 online and in-person presentations. Social media was used to highlight AWRP fieldwork throughout the field season.

The Atlantic Whitefish and Southern Uplands Atlantic Salmon Project was highlighted in the following events and presentations:

- Presentation for Julie Cleary's grade ten science class about freshwater ecosystem health and aquatic species, Centre scolaire de la Rive-Sud, Lunenburg County, NS (May 11, 2023);
- Invasive species angling day for Parkview Education Centre grades 11 and 12 biology classes with chain pickerel and smallmouth bass information and dissections, Wentzell's Lake, Lunenburg County, NS (June 8, 2023);
- Presentation for Wendy Page's pre-IB biology class about water quality and freshwater fish, Parkview Education Centre, Lunenburg County, NS (June 13, 2023);
- Coastal Action's Annual General Meeting, Petite Rivière Winery, Lunenburg County, NS (June 22, 2023);

- WISE Acadia guided chain pickerel dissections with girls and under-represented genders (girls+) aged 10-16 in collaboration with the Terranaut Club at Acadia University, Wolfville, NS (July 28, 2023);
- LaHave River Salmon Association (LRSA) Invasive Species Awareness Day with chain pickerel information and cooking demonstrations, Wentzell's Lake, Lunenburg County, NS (August 12, 2023);
- Terranaut Club guided chain pickerel 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 (August 20, 2023);
- Instream fish habitat restoration structure installation training with Ian Manning's second-year class in the Nova Scotia Community College's (NSCC) Natural Resources and Environmental Technology (NRET) program at Fire Brook, Bakers Settlement, NS (September 13, 2023) (Figure 22);
- Discussion panel in Emily Yeung's Oceans class for first-year students at Dalhousie University, Halifax, NS (October 13, 2023);
- South Shore Public Library (SSPL) presentation on cyanobacteria and water quality as part of the Environmental Series, Margaret Hennigar Public Library, Bridgewater, NS (October 17, 2023);
- Atlantic Whitefish Conservation and Recovery Team (AWC&RT) meeting presentation at the Mahone Bay Centre, Mahone Bay, NS (October 18, 2023);
- Presentation and workshop for Minga O'Brien's class in the NRET program about freshwater ecosystems, sampling techniques, invasive species, water quality and cyanobacteria at the NSCC, Lunenburg Campus, NS (October 24, 2023);
- Invasive species angling day for Minga O'Brien's class in the NSCC NRET program with chain pickerel and smallmouth bass information and dissections, Wentzell's Lake, Lunenburg County, NS (October 31, 2023)
- Presentation for Ian Manning's second-year class in the NRET about Coastal Action's Atlantic Whitefish Recovery Project at the Nova Scotia Community College (NSCC), Lunenburg Campus, NS (November 16, 2023);
- South Shore Public Library (SSPL) presentation on the Atlantic Whitefish Recovery Project as part of the Environmental Series, Margaret Hennigar Public Library, Bridgewater, NS (November 28, 2023);
- South Shore Public Library (SSPL) presentation on the Atlantic Salmon Recovery in the LaHave River Watershed as part of the Environmental Series, Margaret Hennigar

Public Library, Bridgewater, NS (December 5, 2023);

- Public information session on the Art for Atlantic Whitefish project presented by Dalhousie University's Climate Futures Lab group who initiated the project, Halifax Central Public Library, NS (February 25, 2024);
- Mersey Tobeatic Research Institute's (MTRI) Family Fun Day booth with species at risk crafts and Atlantic whitefish and invasive species information, MTRI Office, NS (March 9, 2024).

In addition to the events and presentations, Coastal Action published 16 social media posts related to the Atlantic Whitefish and Southern Uplands Atlantic Salmon Project, additional "stories" on Instagram, Facebook, and Twitter, and online newsletter articles through our Coastal Chronicle newsletter during the 2023-24 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 7,200 combined followers from Instagram and Facebook social media platforms with a total combined reach of 10,872 and 1047 direct interactions through likes, shares, and comments. The online newsletter Coastal Chronicle has 700 subscribers. Additionally, two articles were published about our work. Serra Hamilton from The Signal, produced by the University of King's College School of Journalism, wrote an article on the Atlantic Whitefish Recovery Project and the Art for Atlantic Whitefish campaign, published in The Signal (online) on March 12, 2024 (Hamilton 2024). Coastal Action staff Amy Russell and Taylor Wilson wrote an article on invasive chain pickerel and smallmouth bass and our HSP work for the Lunenburg Barnacle (online) published on March 14, 2024 (Coastal Action 2024).

5.0 Project Evaluation and Future Program Planning

The main goals of this project are to improve habitat conditions for at-risk aquatic fish species and assist in their recovery through species and habitat monitoring, habitat restoration, captive rearing, invasive fish removal, and public outreach. The broad objectives of this work are: 1) contribute to the protection and recovery of the critically endangered whitefish population, 2) support the whitefish rearing program and releases into the Petite Rivière to support the wild population in partnership with Dalhousie University and DFO, 3), continue work on whitefish habitat needs with a goal of re-introduction and 4) improve fish habitat for Southern Upland Atlantic salmon.

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.

Coastal Action's Atlantic whitefish work has helped inform the Atlantic Whitefish Conservation & Recovery Team (AWCRT) on the current progress of the recovery work, areas of knowledge gaps, and future work needs. Particularly, the water quality and zooplankton monitoring in the Petite Rivière watershed has helped inform the Atlantic Whitefish Range Expansion Initiative Working Group (AWREIWG) on the habitat requirements of Atlantic whitefish for lake and watershed selections for future translocation efforts.

Over the last three years from 2021-24, the Atlantic whitefish and Southern Uplands Atlantic salmon HSP work has been featured in a total of 36 events and presentations, 33 posts and additional 'stories' on various social media platforms, and four news articles were published in online and print newspapers. Community awareness and engagement are important pieces of the conservation of these species and should be continued in the future.

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 remove any debris found; integrate targeted angling of invasive chain pickerel and smallmouth bass during nesting times and where they congregate at pinch points and below barriers; monitor for signs of chain pickerel in the Petite Rivière watershed upstream of Minamkeak Brook, which is currently free of chain pickerel; investigate the second, fall spawning event for chain pickerel in Milipsigate Lake to determine how that may impact recruitment; and continue to monitor the spring migration of gaspereau at the Hebb Dam fishway. It is important to continue to monitor the water quality parameters and food availability for larval and juvenile Atlantic whitefish to monitor their existing conditions and changes over time, and to continue to build a dataset to inform future translocation sites. Increased frequency of water quality profiles in the three lakes beyond the one-day-per-month snapshot, especially during the warmest months in the summer, is recommended to gain a better understanding of the conditions for lake-resident Atlantic whitefish. Monitoring the fishways at the Crousetown and Hebb Dams is essential to ensure the free passage of Atlantic whitefish, whether lake-resident or released captive-bred fish, between the estuary and their critical habitat. In the last four years, larval and adult Atlantic whitefish have been observed in several locations within their critical habitat. Hundreds of captive-bred Atlantic whitefish have also been released throughout the watershed over the last three year as a result of the breeding program in partnership with the Dalhousie Aquatron and DFO. Monitoring gaspereau in the Hebb fishway in the spring helps inform the adequacy of fish passage between the ocean and

Atlantic whitefish critical habitat, as well as monitoring for the potential impacts that the growing gaspereau population may have on Atlantic whitefish.

In regards to the recovery of Atlantic salmon in the LaHave River Watershed, Coastal Action recommends the following activities be continued or implemented in the future: continue to identify key salmon habitat through backpack electrofishing surveys and habitat suitability index 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 by increasing the survival rate and resiliency of native fish species. Over the past three years, Coastal Action has started to focus efforts on specific tributaries aiming to address degraded habitat spread throughout each watercourse and has successfully identified several key nursery areas for salmon through electrofishing surveys and habitat suitability assessments. Moving forward, Coastal Action will continue to work towards addressing limiting factors throughout entire watercourses which is expected to have a positive cumulative effect on the habitat suitability within the watercourses selected for improvement activities. Coastal Action has already begun working with partner groups such as the Nova Scotia Salmon Association (NSSA) and the LaHave River Salmon Association (LRSA) to broaden improvement efforts on selected watercourses. The NSSA is proposing to conduct catchment liming on Fire Brook in 2024 to improve pH levels, which would further enhance the habitat where instream habitat improvement measures have already been implemented.

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7.0 References

[CCME] Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of aquatic life: Dissolved oxygen (Freshwater). In: Canadian environmental quality guidelines, 1999. Winnipeg (MB): Canadian Council of Ministers of the Environment.

[CCME] Canadian Council of Ministers of the Environment. 2007. Canadian water quality guidelines for the protection of aquatic life: Summary table. Updated September 2007. In: Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg.

Coastal Action. 2024 Mar 14. Invasive species week 2024: introducing the chain pickerel. The Lunenburg Barnacle. [accessed 2024 Apr 4]. https://www.thebarnacle.ca/invasive-species-week-2024-introducing-the-chain-pickerel/

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2010a. COSEWIC assessment and status report on the Atlantic Salmon *Salmo salar* (Nunavik population, Labrador population, Northeast Newfoundland population, South Newfoundland population, Southwest Newfoundland population, Northwest Newfoundland population, Quebec Eastern North Shore population, Quebec Western North Shore population, Anticosti Island population, Inner St. Lawrence population, Lake Ontario population, Gaspé-Southern Gulf of St. Lawrence population, Eastern Cape Breton population, Nova Scotia Southern Upland population, Inner Bay of Fundy population, Outer Bay of Fundy population) in Canada. Ottawa (ON): Committee on the Status of Endangered Wildlife in Canada. https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/atlantic-salmon.html

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2010b. COSEWIC assessment and status report on the Atlantic Whitefish *Coregonus huntsmani* in Canada. Ottawa (ON): Committee on the Status of Endangered Wildlife in Canada. https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/atlantic-whitefish-2010.html

Cook AM, Bradford RG, Hubley B, Bentzen P. 2010. Effects of pH, temperature and salinity on age-0+ Atlantic Whitefish (*Coregonus huntsmani*) with implications for recovery potential. Dartmouth (NS): Department of Fisheries and Oceans Science Branch, Maritimes Region. https://waves-vagues.dfo-mpo.gc.ca/Library/341379.pdf

[DFO] Fisheries and Oceans Canada. 2006. Ecological Restoration of Degraded Aquatic Habitats: A Watershed Approach. Oceans and Science Branch, Gulf Region. Cat. Number: Fs104-4/2006E. 180p.

[DFO] Fisheries and Oceans Canada. 2018. Action Plan for the Atlantic Whitefish (*Coregonus huntsmani*) in Canada. Species at Risk Act Action Plan Series. Ottawa (ON): Fisheries and Oceans Canada. https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/action-plans/atlantic-whitefish.html

Hamilton S. 2024 Mar 12. 'We still have a chance': Fighting for the Atlantic whitefish. [accessed 2024 Apr 4]. The Signal (University of King's College School of Journalism, Halifax, NS). https://signalhfx.ca/we-still-have-a-chance-fighting-for-the-atlantic-whitefish/

[NSSA] Nova Scotia Salmon Association NSLC Adopt-A-Stream Program. 2014. Walking the River: A Citizen's Guide to Interpreting Water Quality Data. 43 p.

Moss DD, Scott DC. 1961. Dissolved-oxygen requirements of three species of fish. Transactions of the American Fisheries Society, 90(4): 377-393.

Rowe CL, Adamowicz SJ, Hebert PDN. 2007. Three New Cryptic Species of the Freshwater Zooplankton Genus *Holopedium* (Crustacea: Branchiopoda: Ctenopoda), Revealed by Genetic Methods. Zootaxa. Auckland (NZ): Magnolia Press. 1656: 1-49.

Russell A, Feener S, MacKenzie S, Milette M, McNeely B, Reeves S, McIntyre J. 2022. 2021-22 Review of Fisheries Activities for the Recovery of Endangered Atlantic Whitefish and Southern Uplands Atlantic Salmon in Nova Scotia [Report]. Mahone Bay (NS): Coastal Action.

Russell A, Reeves S, McNeely B, Milette M. 2023. 2022-23 Review of Fisheries Activities for the Recovery of Endangered Atlantic Whitefish and Southern Uplands Atlantic Salmon in Nova Scotia [Report]. Mahone Bay (NS): Coastal Action.

Shinohara, R., Matsuzaki, S.-I. S., Watanabe, M., Nakagawa, M., Yoshida, H., & Kohzu, A. 2023. Heat waves can cause hypoxia in shallow lakes. Geophysical Research Letters, 50(8), e2023GL102967. https://doi.org/10.1029/2023GL102967

Weber-Scannell PK, Duffy LK. 2007. Effects of total dissolved solids on aquatic organism: a review of literature and recommendation for salmonid species. Am J Environ Sci. 1: 1-6.

Whitelaw J, Manríquez-Hernández J, Duston J, O'Neil SF, Bradford RJ. 2015. Atlantic Whitefish (*Coregonus huntsmani*) Culture Handbook. Can Manuscr Rep Fish Aquat Sci. 3074: vii+55 p.