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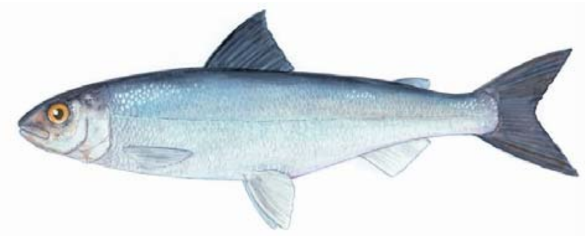
Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/045

OPTIMAL STRATEGY FOR INVASIVE SPECIES CONTROL TO ENSURE SURVIVAL AND RECOVERY OF ATLANTIC WHITEFISH IN THE PETITE RIVIÈRE LAKES



Atlantic Whitefish (Coregonus huntsmani)

(Source: DFO 2009)

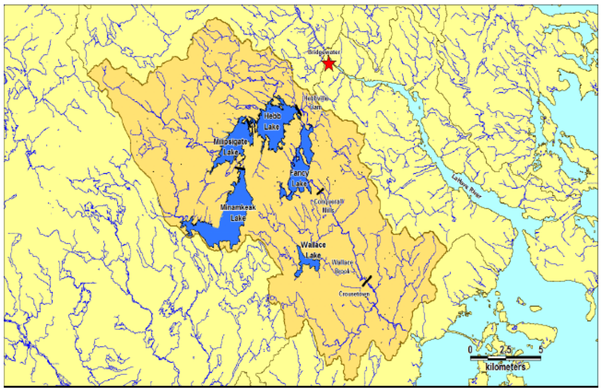


Figure 1. Map of the Petite Rivière watershed.

Context:

The Atlantic Whitefish (Coregonus huntsmani) was listed as Endangered under the Species at Risk Act *in 2003. The species is restricted to three interconnected lakes in Nova Scotia and its viability is threatened by illegal introduction of aquatic invasive fish species, in particular, Smallmouth Bass and Chain Pickerel. A proposed Recovery Strategy and Action Plan for Atlantic Whitefish were published in 2016, and subsequently finalized in 2018, which outline measures to help achieve survival and recovery of the species (DFO 2018a, 2018b).*

The Action Plan identified developing and implementing management approaches to mitigate or eliminate the threat posed by Smallmouth Bass and Chain Pickerel as a key recovery measure.

Efforts to study invasive species control methods have been underway in the Petite Rivière lakes since 2013, including testing electrofishing boat survey methods and targeted angling efforts. The purpose of this meeting will be to review the various control methods used and to provide advice on what continued invasive species control efforts are recommended to minimize the risk that invasive species present to the survival and recovery of Atlantic Whitefish in the Petite Rivière lakes.

The objective of this regional science advisory process is:

- *To document the threat posed by aquatic invasive species (i.e., Smallmouth Bass and Chain Pickerel) in the Petite Rivière lakes.*
- *To compile information on aquatic invasive species control measures that have been utilized to date in the Petite Rivière Lakes and discuss their effectiveness.*
- *To provide advice on the recommended invasive species control measures (type, level of effort, spatial and temporal extent) to minimize the risk that invasive species present to the survival and recovery of Atlantic Whitefish in each of the Petite Rivière Lakes.*

This Science Advisory Report is from the regional peer review of October 11-12, 2017 on the Optimal Strategy for Invasive Species Control to Ensure Survival and Recovery of Atlantic Whitefish in the Petite Rivière Lakes.

SUMMARY

- Over three years (2014-2016), 2,362 Smallmouth Bass and 3,129 Chain Pickerel were removed from Hebb Lake by boat electrofishing and angling methods. The proportion of the total population represented by these removals is unknown as there are no estimates of total population size for either species.
- Boat electrofishing depletion experiments demonstrated that localized populations of both Smallmouth Bass and Chain Pickerel could be dramatically reduced using a multi-pass methodology. However, depletion methods were found to be time consuming, and permitted limited shoreline coverage. Catch per unit effort (CPUE) efficiency decreased with consecutive passes. The effect of depletion removals is assumed to be temporary, as the site is likely quickly recolonized by individuals from unfished areas adjacent to the depletion site.
- Boat electrofishing linear transects were applied to increase total lake shoreline coverage. Removals in this case are primarily juveniles.
- Angling targeted at invasive species removal was applied as a supplementary control technique. Angling generally selected for larger fish than boat electrofishing.
- Eradication of invasive species is considered unlikely using boat electrofishing and angling methods, however control of the population may be achievable with ongoing effort. Other studies using boat electrofishing have been successful at controlling Smallmouth Bass abundance, albeit with much higher levels of electrofishing effort applied to smaller lakes. Once mitigation effort is removed, it is expected the population would quickly rebound.

BACKGROUND

The Atlantic Whitefish (*Coregonus huntsmani*) is classified as critically Endangered by the International Union for the Conservation of Nature (IUCN), and is at high risk for global extinction (Smith 2017). Atlantic Whitefish were first designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1984. The species' endangered status was re-examined and reconfirmed by COSEWIC in 2000 (COSEWIC 2000) and again in 2010 (COSEWIC 2010). The Atlantic Whitefish has been listed under the Canadian federal *Species at Risk Act* (SARA) since 2003 (DFO 2006). Under SARA, the responsibility to prevent the extinction of Atlantic Whitefish lies with the Department of Fisheries and Oceans Canada (DFO) (DFO 2018). Fisheries and Oceans Canada has developed an Atlantic Whitefish Recovery Strategy (DFO 2006, 2018), which continues to have the goal: "to achieve stability in the current population of Atlantic Whitefish in Nova Scotia, re-establishment of the anadromous form, and expansion beyond its current range".

The global distribution of Atlantic Whitefish has been restricted for at least the past four decades to the Petite Rivière watershed, within the approximately 16 km^2 combined area of Minamkeak, Milipsigate, and Hebb lakes (hereafter the Petite Lakes) (Edge 1984, Edge and Gilhen 2001, DFO 2009, COSEWIC 2010, Bradford et al. 2015). The Petite Lakes serve as the water supply for the Town of Bridgewater, Nova Scotia, and were not accessible from the sea for several decades, until the provision of fish passage at Hebb Lake Dam in 2012 (Themelis et al. 2014).

The Petite Lakes have been designated as Critical Habitat for Atlantic Whitefish, where critical habitat is defined as the habitat necessary for the survival or recovery of a listed wildlife species (DFO 2018). At present, survival of the species is dependent upon its continued production within the Critical Habitat of the Petite Lakes.

Several factors have likely contributed to the declines in Atlantic Whitefish abundance (DFO 2018); however, a significant and emergent threat facing survival and recovery is the establishment of introduced, invasive, piscivorous, Smallmouth Bass (*Micropterus dolomieu)* and Chain Pickerel (*Esox niger*) within the Petite Lakes. Smallmouth Bass [SMB] are not native to Nova Scotia, but are a popular game fish that has been widely distributed outside their natural range in central North America (Brown et al. 2009, Loppnow et al. 2013). This species was introduced to Nova Scotia starting in the early 1940s through legal introductions, and has subsequently been spread by natural dispersal and illegal introductions to the point where the species is now common in many watersheds throughout the province of Nova Scotia (McNeill 1995, LeBlanc 2010, Halfyard 2010). Smallmouth Bass were first reported in the Petite Rivière system (Milipsigate Lake) in 2000 (LeBlanc 2010). They now spawn successfully in all three lakes representing the critical habitat of Atlantic Whitefish.

Chain Pickerel [CP] are also not native to Nova Scotia. This species was initially introduced to three lakes in Nova Scotia in 1945 (Mitchell et al. 2010) and is now found in more than 100 lakes and several rivers (Nova Scotia Department of Fisheries and Aquaculture, unpublished). Prior to 2013 there were occasional anecdotal reports of CP in the Petite Rivière watershed, but the presence of this species was confirmed in May 2013 in both Hebb and Milipsigate Lakes (DFO 2018). There are no indications CP have yet colonized Minamkeak Lake.

Smallmouth Bass and Chain Pickerel are predatory and have potential to alter trophic and competitive regimes of habitat they invade (COSEWIC 2010). Highly piscivorous invasive species are known to fundamentally impact the ecology of water bodies through four pathways, that can operate independently or in combination (Jackson 2002). These include: direct predation, displacement of native species from their preferred habitat, alteration of the forage base, and trophic cascade wherein loss/depression of a species alters a characteristic of the lacustrine habitat (e.g., loss of minnow species results in a change in the zooplankton assemblage, which results in a change in water clarity in favour of the invasive species). Chain Pickerel have been particularly effective in reducing both abundance and species diversity and truncating fish size in Nova Scotia lakes once colonization is complete (Mitchell et al. 2010). The expansion and establishment of SMB and CP within the Petite lakes presents a threat of high concern, and acts to increase the uncertainty that ongoing survival of the Atlantic Whitefish population within the Petite Lakes can be maintained (DFO, 2018).

Similar to the Petite Rivière, illegally introduced SMB were discovered in Miraimichi Lake in 2008. Concern surrounding potential negative impacts on Atlantic Salmon in the Miramichi River watershed prompted the DFO Gulf Region to conduct an eradication and control exercise to remove SMB from Miramichi Lake between 2009-2012 (DFO 2009, Chaput and Caissie 2010). Included as part of this multi-technique program was the use of an electrofishing boat to remove SMB from the littoral zone (Shoreline Length: 8 km) (DFO 2013, Biron et al. 2014). Boat electrofishing, as applied in Miramichi Lake, appeared to have promise in controlling the population of SMB. This case study was used by DFO Maritimes Region as justification to initiate a boat electrofishing trial in 2013, and subsequently support the acquisition of an electrofishing boat and to initiate a three-year invasive species removal pilot project on the Petite Rivière watershed from 2014-2016. In addition to boat electrofishing, angling targeted at invasive species removal was applied as a supplementary control technique. This pilot project was a developed as a collaborative effort between the Department of Fisheries and Oceans (DFO), the Nova Scotia Department of Aquaculture and Fisheries and Bluenose Coastal Action Foundation.

ASSESSMENT

This invasive species control pilot project was conducted on Hebb Lake, NS (44.344618, -64.567845) because of the confirmed presence of both target aquatic invasive species (AIS) species (SMB and CP), and ease of access due to the presence of a boat launch on property owned by the Town of Bridgewater Public Service Commission. Electrofishing, using a purpose built electrofishing boat (Smith Root RF-16, Smith-Root, Eugene, OR), was conducted during the night as catch rates for SMB have been shown to be higher for nighttime versus daytime electrofishing (Paragamian 1989, Blackwell et al. 2017). The electrofishing boat was crewed with three staff; the vessel operator and two dippers stationed on port and starboard sides of the bow to collect stunned fish. Two boat electrofishing techniques, depletion and linear transect approaches, were trialed as part of the pilot project.

The depletion approach was applied in an effort to reduce as much of the AIS biomass from a sampling site as possible. Multiple transects/passes, without the use of barriers, were made perpendicularly to the shoreline, and spaced such that there was minimal overlap between the effective shocking areas from one pass to the next. Shocking only occurred, in most cases, while moving toward shore to utilize the shoreline as a barrier to fish escape. Depletion sites (Figure 2) were surveyed in September-October of 2014-2016. The number of passes per site ranged between 2-4, and shocking time was variable both between sites and passes within a site, ranging between 984-2816 seconds per pass. Total cumulative shocking time applied using the depletion approach was 15.5 hours.

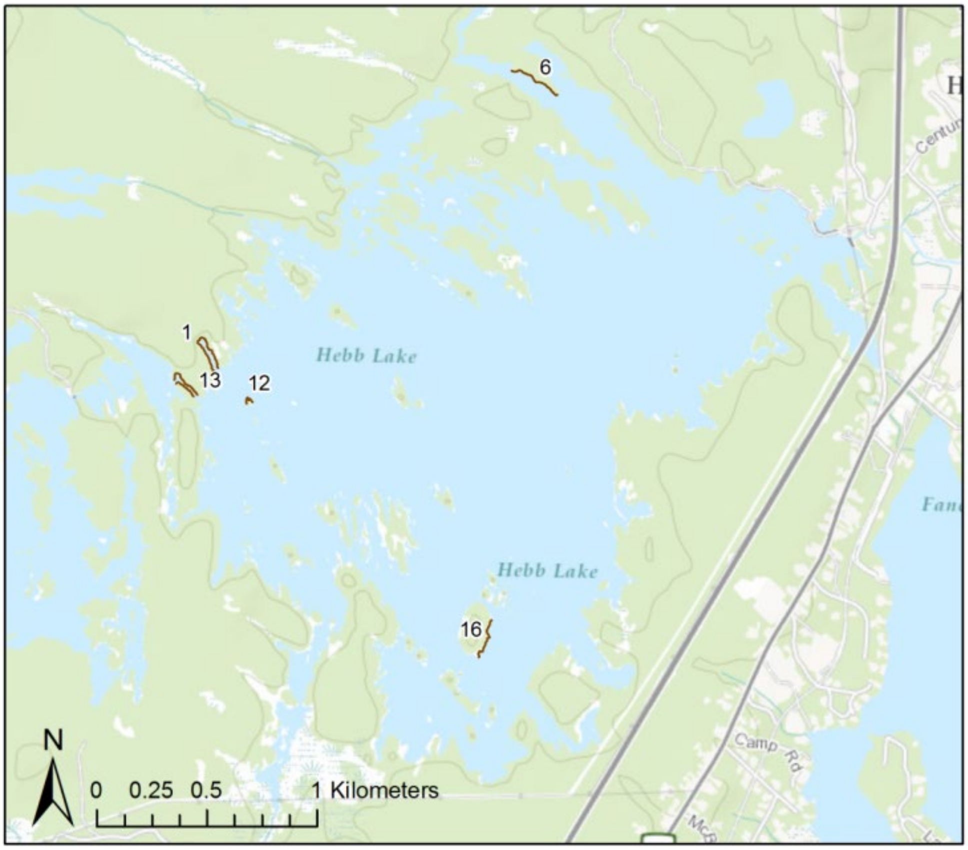


Figure 2. Map of boat electrofishing depletion experiment sites surveyed in September, 2014-2016 within Hebb Lake, Nova Scotia.

The linear transect approach was initiated in 2015 to increase total shoreline coverage. Linear passes were completed using transects parallel, instead of perpendicular, to the shoreline. Linear sites varied in length (range: 193-1220m) and were sampled over a period of several months May–October in both 2015 and 2016. Shocking time was variable within and between sites, ranging from 912-6273 seconds per transect. In 2015, 19 sites were completed over 7 nights, totaling 11.7 hours of electrofishing, and covering 12.9 km of shoreline. In 2016, coverage increased to 22 sites fished over 9 nights, totaling 16.2 hours, and covering 15.1 km of shoreline. Linear site locations are shown in Figure 3. The shoreline length of Hebb Lake, including islands, was estimated using data from the 21A07-Bridgewater Topographic Map (1:50,000) to be 67.2 km (32.3 perimeter, 34.9 island perimeter).

Angling to remove AIS was also conducted in Hebb Lake throughout the study period. Biological study and catch per unit effort (CPUE) angling in Hebb Lake, with special focus paid to the area of the Milipsigate Lake outlet (44.344537, -64.590395), was initiated in 2013. Angling activity generally commenced in April of each year, and continued into October. Two or three anglers fished a range of habitats, including rocky drops, vegetated areas, and areas with flowing water such as at the base of Milipsigate Dam. Angling effort was applied opportunistically, and was neither randomized or standardized either spatially or temporally.

RESULTS

Depletion Experiments

Eleven depletion experiments were conducted during this pilot project; 4 in 2014, 4 in 2015, and 3 in 2016. Five unique locations were sampled during the study, sites 6, 12, and 16 were sampled in each of the three years, while sites 1 and 13 were visited a single time in 2014 and 2015, respectively (Figure 2). The target was to complete four passes at each site; however, this was not achieved in 4 cases due to weather conditions or boat mechanical issues. Selecting only those experiments with a minimum of three passes and a minimum total catch of ≥10 fish reduced the data set to 6 valid experiments for SMB and 7 for CP.

Several methods are available to analyze data from depletion experiments to estimate population size. Leslie, DeLury, and Zippen methods were evaluated using the FSA package in R (Ogle 2016a). For all methods, the experiment captured a high percentage of the estimated site specific population size (53% – 100%), well above the 2% threshold and thus removing the DeLury method from further consideration (Ogle 2016b). Results of the Zippen method were considered uncertain, as the effort between successive passes was not held constant, and a declining trend effort was observed over consecutive passes. The Leslie technique was selected as the most appropriate method based on trends in effort across sampling passes and the high proportion of the total population estimate per site being captured in each experiment (Ogle 2016b).

In most cases, the total catch in depletion experiments represented a high proportion of the total site-specific estimated population. This suggests that localized site specific depletion may have been achieved, at least temporarily. The proportion of the estimated population captured during the 1st pass was variable, but averaged 43% for SMB and 49% for CP (Table 1).

Table 1. Summary of depletion experiments conducted in Hebb Lake, showing results of the Leslie depletion method for estimating site-specific population size of Smallmouth Bass (Micopterus dolomieu) and Chain Pickerel (Esox niger), percentage of the estimated population captured on the first pass (% 1st pass), and percentage of the total catch removed from the estimated localized population (% total pop est). Note only those sites where 3 or more passes were completed, and total catch was ≥10 fish are included. SE=Standard error.

Species	Site ID	Date	Catch 1st Pass	Total Captured	Leslie pop est (SE)	% 1st pass	% total pop est
Smallmouth Bass	1	16-Sept-2014	18	37	44 (6.6)	40.9	84.1
Smallmouth Bass	12	17-Sept-2014	53	90	93 (2.2)	57.0	96.8
Smallmouth Bass	12	8 Sept 2015	26	49	54 (5.8)	48.1	53.1
Smallmouth Bass	16	24 Sept 2015	9	17	19 (1.5)	47.3	89.5
Smallmouth Bass	16	6 Sept 2016	29	56	73 (4.9)	39.7	76.7
Smallmouth Bass	12	13 Sept 2016	19	47	73 (44.2)	26.0	64.4

Species	Site ID	Date	Catch 1st Pass	Total Captured	Leslie pop est (SE)	% 1st pass	% total pop est
Chain Pickerel	6a	15 Sept 2014	57	115	129 (5.6)	44.2	96.6
Chain Pickerel	1	16 Sept 2014	73	124	128 (3.6)	57.0	96.7
Chain Pickerel	12	17 Sept 2014	8	11	11 (1.0)	72.7	100
Chain Pickerel	16	24 Sept 2015	34	72	84 (3.7)	40.5	85.7
Chain Pickerel	6a	7 Oct 2015	38	77	89 (4.6)	42.7	86.5
Chain Pickerel	16	6 Sept 2016	56	116	167 (12.3)	33.5	69.5
Chain Pickerel	6a	7 Sept 2016	29	50	57 (3.9)	50.9	87.7

Linear Transects

Linear transect experiments were initiated to expand electrofishing coverage to include a larger portion of the lake shoreline. Linear transect experiments were conducted in Hebb Lake during 2015 and 2016 (Figure 3). In this approach, only the shallow water littoral zone (≤ 2m) is sampled. In total, 41 linear transects were completed, 19 in 2015 and 22 in 2016 (Table 2).

Table 2. Summary of linear transect experiments conducted in Hebb Lake during 2015-2016. For all sites, the shocking frequency was 60 Hz and voltage range 720-1000 V. SMB = Smallmouth Bass, CP = Chain Pickerel, CPUE = catch per unit effort.

Site ID	Date	Shoreline Length (m)	Effort (s)	SMB	CPUE (SMB/hr)	CP	CPUE (CP/hr)
1	27-May-15	296.3	1067	1	3.37	15	50.61
2	27-May-15	1130.0	2748	29	37.99	45	58.95
3	28-May-15	770.1	3049	25	29.52	88	103.90
4	28-May-15	988.0	2425	5	7.42	103	152.91
5	28-May-15	705.6	1943	4	7.41	43	79.67
6	28-May-15	995.5	2324	6	9.29	56	86.75
7	28-May-15	563.0	1966	3	5.49	41	75.08
8	10-Jun-15	424.1	1966	10	18.31	24	43.95
10	7-Jul-15	1210.0	3603	40	39.97	8	7.99
11	7-Jul-15	1220.0	3736	39	37.58	20	19.27
1	9-Sep-15	296.3	1179	19	58.02	32	97.71
6	9-Sep-15	995.5	2760	11	14.35	69	90.00

Site ID	Date	Shoreline Length (m)	Effort (s)	SMB	CPUE (SMB/hr)	CP	CPUE (CP/hr)
14	9-Sep-15	756.2	2977	37	44.74	68	82.23
15	9-Sep-15	195.7	1535	35	82.08	18	42.21
17	7-Oct-15	394.5	1351	41	109.25	40	106.59
18	7-Oct-15	193.0	1718	37	77.53	42	88.01
19	26-Oct-15	509.7	1634	25	55.08	49	107.96
20	26-Oct-15	665.8	1635	9	19.82	109	240.00
21	26-Oct-15	667.1	2580	17	23.72	107	149.30
8	7-Jun-16	424.1	1778	26	52.64	42	85.04
9	7-Jun-16	1077.3	4148	158	137.13	34	29.51
14	22-Jun-16	378.0	1096	10	32.85	13	42.70
11	18-Jul-16	1220.0	6273	57	32.71	117	67.14
14	18-Jul-16	756.2	3725	15	14.50	68	65.72
5	19-Jul-16	705.6	1924	11	20.58	51	95.43
10	19-Jul-16	1210.0	4108	57	49.95	16	14.02
17	19-Jul-16	394.5	1072	19	63.81	19	63.81
18	19-Jul-16	193.0	2042	16	28.21	49	86.39
1	25-Jul-16	296.3	912	14	55.26	28	110.67
2	25-Jul-16	1130.0	2965	67	81.35	120	145.70
13	25-Jul-16	122.4	1481	26	63.20	19	46.19
21	25-Jul-16	667.1	3518	38	38.89	125	127.91
3	26-Jul-16	770.1	2575	51	71.30	75	104.85
4	26-Jul-16	988.0	3655	15	14.77	224	220.63
21	26-Jul-16	667.1	2760	12	15.65	47	61.30
5	7-Sep-16	705.6	1963	7	12.84	42	77.02
8	13-Sep-16	424.1	978	11	40.49	4	14.72
10	13-Sep-16	1210.0	4286	81	68.04	9	7.56
6	26-Sep-16	995.5	2974	17	20.58	107	129.52
7	26-Sep-16	563.0	2504	15	21.57	99	142.33
15	26-Sep-16	195.7	1705	23	48.56	5	10.56

The proportion of the lake shoreline sampled by linear transects was compared to the estimated total shoreline length. The shoreline length of Hebb Lake, including islands, was estimated using data from the 21A07-Bridgewater Topographic Map (1:50,000) to be 67.2 km (32.3 perimeter, 34.9 island perimeter). The estimate for all linear sampling sites calculated in an identical manner was 19.8 km, or 28% of the total lake shoreline. During the course of this pilot project, sampling of linear sites were completed over 7-9 days per year, which suggest that most of the lake shoreline could be sampled within 25 - 32 days. This assumes that all areas of the lake are accessible and fishable, that the level of operational efficiency remains constant and does not improve (i.e., more sites covered per fishing night with streamlined procedures).

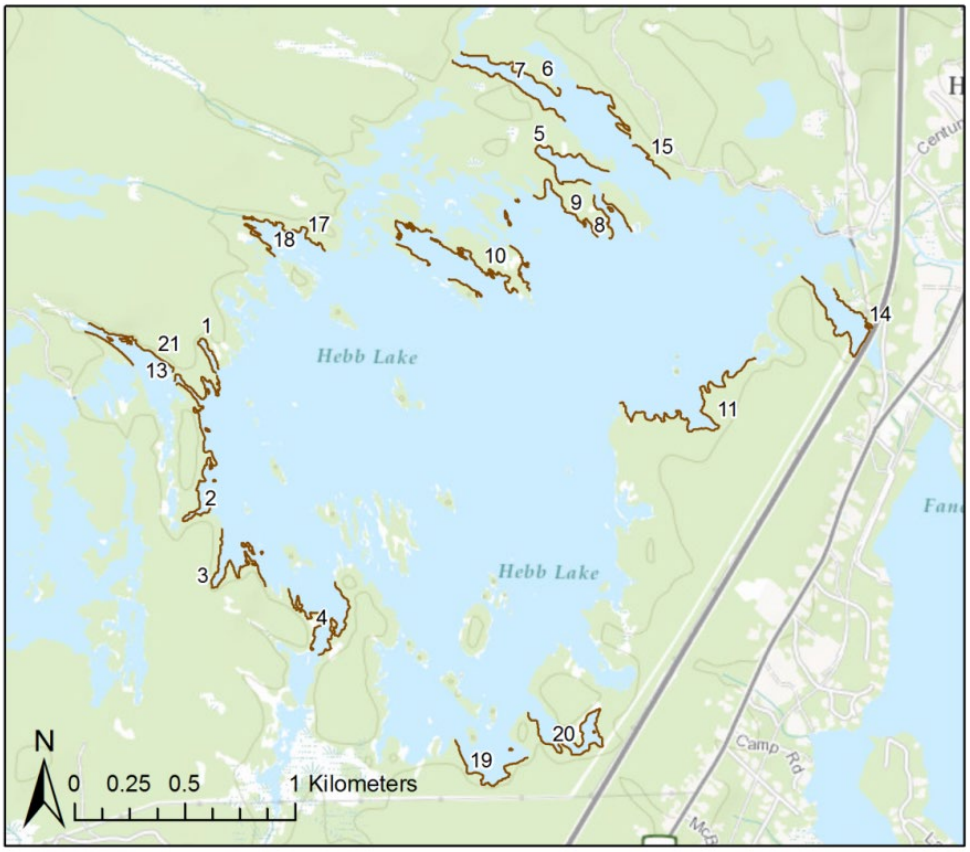


Figure 3. Location of boat electrofishing linear transects sites sampled in 2015 and 2016.

Catch per unit effort (fish/hr) was calculated for each invasive species by transect. Smallmouth bass CPUE was found to be highly variable across transects, ranging from 3 to 137 fish/hour (Table 2). Comparing sites that were fished both years, SMB CPUE increased from 33.2 to 38.3 fish/hr. Generally, the highest catch rates were observed in the western portion of the lake, particularly in 2016 (Figure 4, top panel). Site 9 was an exception, although this location was only sampled in 2016.

Catch per unit effort (fish/hr) for CP was also highly variable across linear transects, ranging from 7 to 240 fish/hr (Table 2). A comparison of CPUE between sites fished in both years showed an increase from 76 fish/hr in 2015 to 86 fish/hr in 2016. Similar to SMB, the highest catch rates for Chain Pickerel were observed in the western portion of the lake (Figure 4, bottom panel).

Catch per unit effort trends from linear transects cannot be evaluated with only two seasons of data. While 2015-2016 data are shown as a record of the sampling completed, any interpretation of these data should be considered with the utmost caution as interannual variation cannot be captured and considered with confidence. Factors such as the seasonal timing of the sampling effort, AIS population demographics, environmental conditions (i.e., water temperature, water level, weather), and electrofishing boat operator/crew efficiency can impact CPUE results.

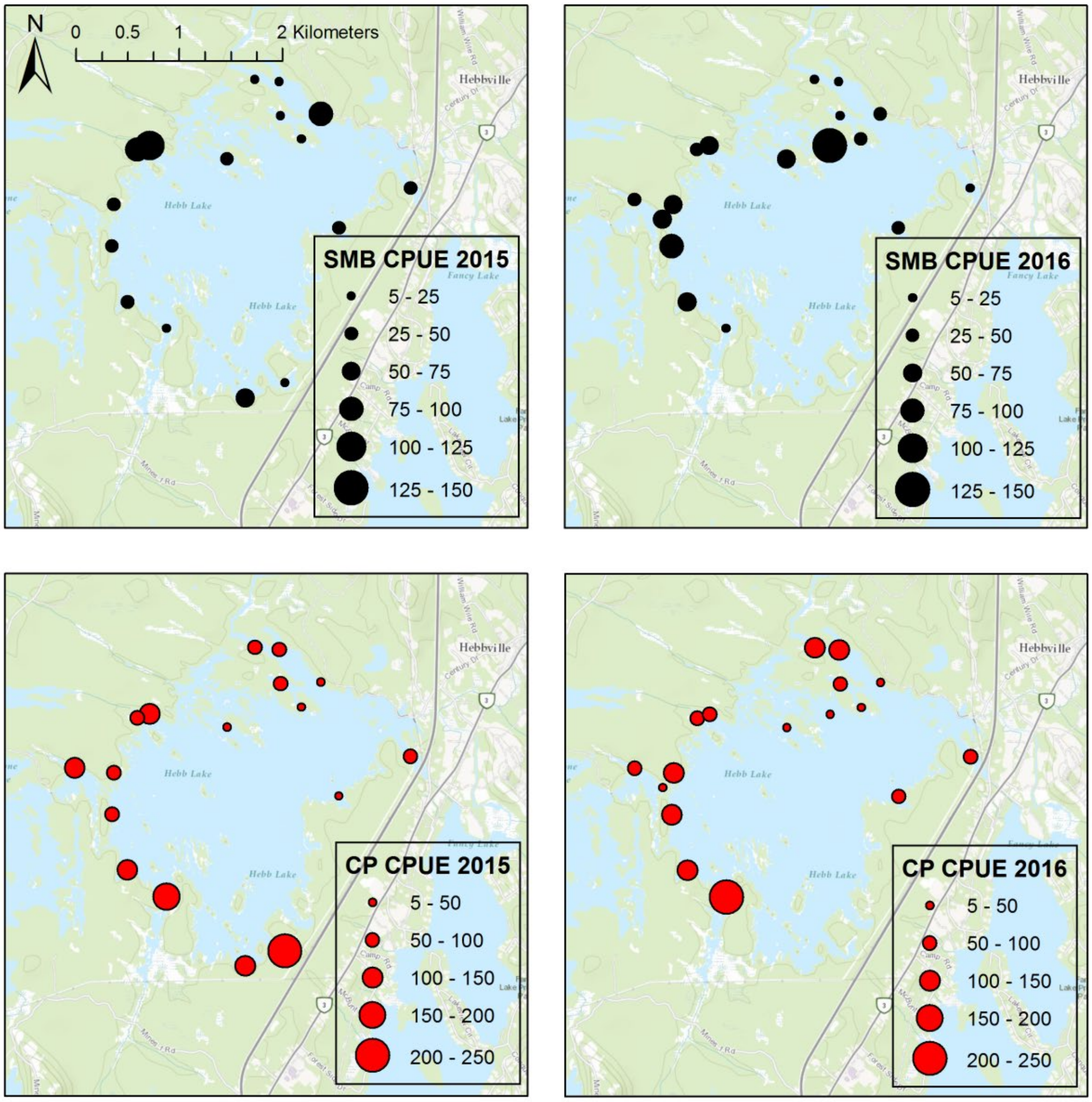


Figure 4. Catch per unit effort (fish/hr) for Smallmouth Bass (SMB; top, black) and Chain Pickerel (CP; red, bottom) from linear electrofishing sites in Hebb Lake, 2015 (left) and 2016 (right).

Length frequency data from fish collected during linear transects indicates that this method strongly selects for smaller individuals, with the majority of fish captured less than 15 cm for both SMB (Figure 5) and CP (Figure 6).

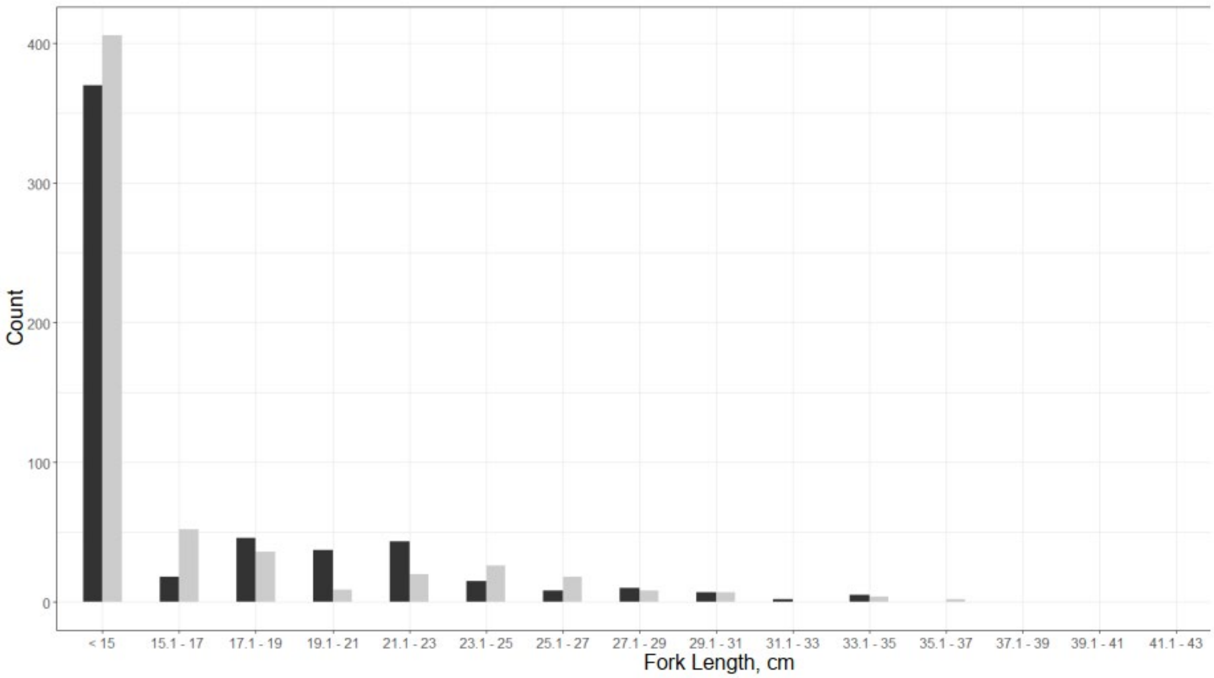


Figure 5. Length frequency distribution of Smallmouth Bass removed by boat electrofishing from linear transect stations, Hebb Lake 2015 (dark bars) & 2016 (light bars).

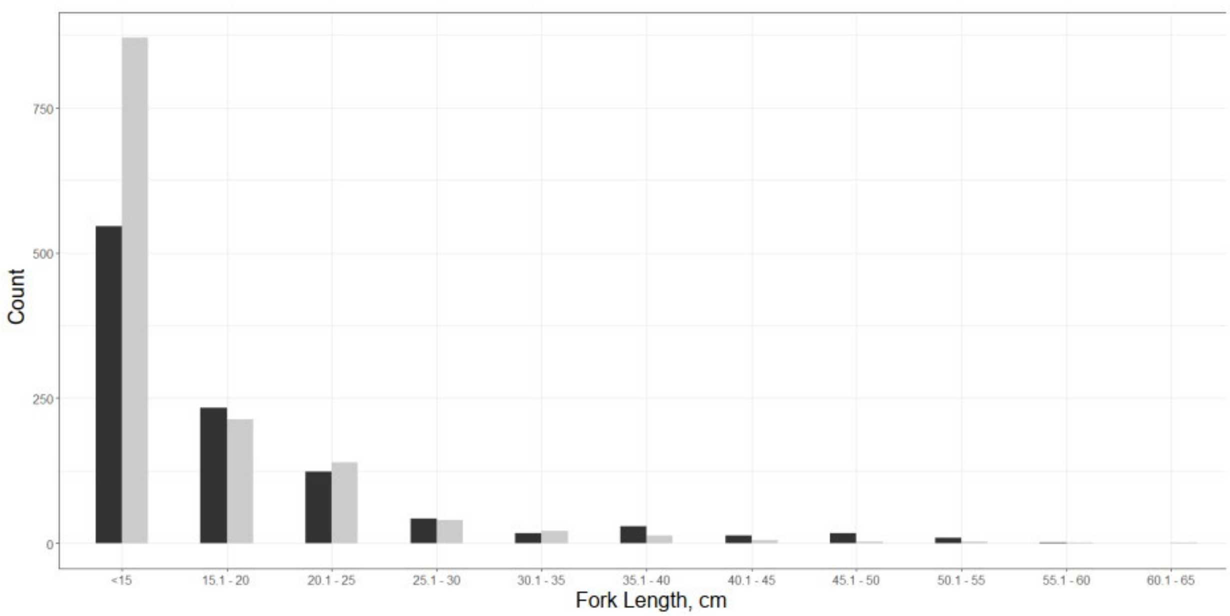


Figure 6. Length frequency distribution of Chain Pickerel removed by boat electrofishing from all linear transect stations, Hebb Lake 2015 (dark bars) & 2016 (light bars).

Linear Sampling – Native Species Bycatch

Counts of native species captured as bycatch during linear transects were recorded; however, these fish were not measured prior to release. Alewife (locally Gaspereau) (*Alosa* *pseudoharengus*)was the most abundant native species caught during each year of linear sampling, followed by White Sucker (*Catostomus commersonii*), Brown Bullhead (*Ameiurus nebulosus*), American Eel (*Anguilla rostrata*), White Perch (*Morone americana*), and Yellow Perch (*Perca flavescens*) (Tables 3 and 4). Gaspereau captures were dominated by the juvenile young of the year life stage. Golden Shiner (*Notemigonus crysoleucas*) and Common Shiner (*Luxilus cornutus*) were infrequently observed. Atlantic Whitefish (*Coregonus huntsman*), Brook Trout (*Salvelinus fontinalis*), and Atlantic Salmon (*Salmo salar*) were not captured during these activities.

Table 3. Numbers of native species captured during boat electrofishing linear transect sampling in 2015. Species codes are: WS=White Sucker, WP=White Perch, BB=Brown Bullhead, AE=American Eel, YP=Yellow Perch, GS=Golden Shiner, GP=Gaspereau (Alewife), CS=Common Shiner.

Date	Site	WS	WP	BB	AE	YP	GS	GP	CS
27-May	1	3	7	4	3	0	0	0	0
9-Sep	1	6	0	0	0	5	0	8	0
27-May	2	31	0	9	7	1	2	0	0
28-May	3	40	1	8	0	0	1	0	3
28-May	4	35	3	16	1	0	0	0	0
28-May	5	11	0	6	1	0	0	0	0
28-May	6	34	3	9	0	3	1	0	0
9-Sep	6	20	9	7	3	14	0	43	0
28-May	7	12	3	2	0	3	0	0	2
10-Jun	8	23	13	3	7	1	0	0	0
7-Jul	10	6	3	5	4	0	0	0	0
7-Jul	11	19	22	5	5	2	0	0	0
9-Sep	14	12	8	3	9	1	2	310	0
9-Sep	15	8	24	0	5	2	0	50	0
7-Oct	17	3	0	7	6	14	0	0	0
7-Oct	18	10	6	1	3	9	0	2	0
26-Oct	19	4	0	2	2	0	0	12	0
26-Oct	20	2	0	3	0	1	0	2	0
26-Oct	21	0	0	10	8	9	0	7	0
	Total	279	102	100	64	65	6	434	5

Table 4. Numbers of native species captured from boat electrofishing linear transect sampling in 2016. Species codes are: WS=White Sucker, WP=White Perch, BB=Brown Bullhead, AE=American Eel, YP=Yellow Perch, GS=Golden Shiner, GP=Gaspereau (Alewife), CS=Common Shiner.

Date	Site	WS	WP	BB	AE	YP	GS	GP	CS
7-Jun	8	9	2	4	3	0		0	0
7-Jun	9	23	4	5	9	2	0	2	0
22-Jun	14	5	4	2	4	1	0	0	0
18-Jul	11	10	18	2	18	0	0	63	0
18-Jul	14	6	8	1	6	0	0	21	0
19-Jul	5	10	7	0	7	4	0	14	0
19-Jul	10	9	7	2	3	0	0	1	0
19-Jul	17	3	1	3	5	4	0	15	0
19-Jul	18	7	9	7	4	3	0	30	0
25-Jul	1	1	0	5	0	0	0	0	0
25-Jul	2	3	14	5	9	0	0	16	0
25-Jul	13	1	1	1	10	0	0	6	0
25-Jul	21	2	4	14	8	3	0	9	0
26-Jul	3	9	1	8	0	10	0	10	0
26-Jul	4	7	3	21	5	3	0	10	0
26-Jul	21	1	4	9	3	5	0	12	0
7-Sep	5	7	5	0	2	4	0	11	0
13-Sep	8	4	0	0	1	0	0	6	0
13-Sep	10	20	2	0	4	0	0	23	0
26-Sep	6	12	10	3	5	8	0	5	0
26-Sep	7	12	5	2	5	0	0	5	0
26-Sep	15	11	1	0	6	12	0	7	0
	Total	172	110	94	117	59	0	266	0

Angling

Angling was conducted from April to October between 2013 to 2016, directing specifically for SMB and CP with standardized lures. The entire lake was not sampled by this method, with effort being applied most consistently over the study duration to Milipsigate outlet, situated below the Milipsigate Dam near the entrance to Hebb Lake (Figure 7).

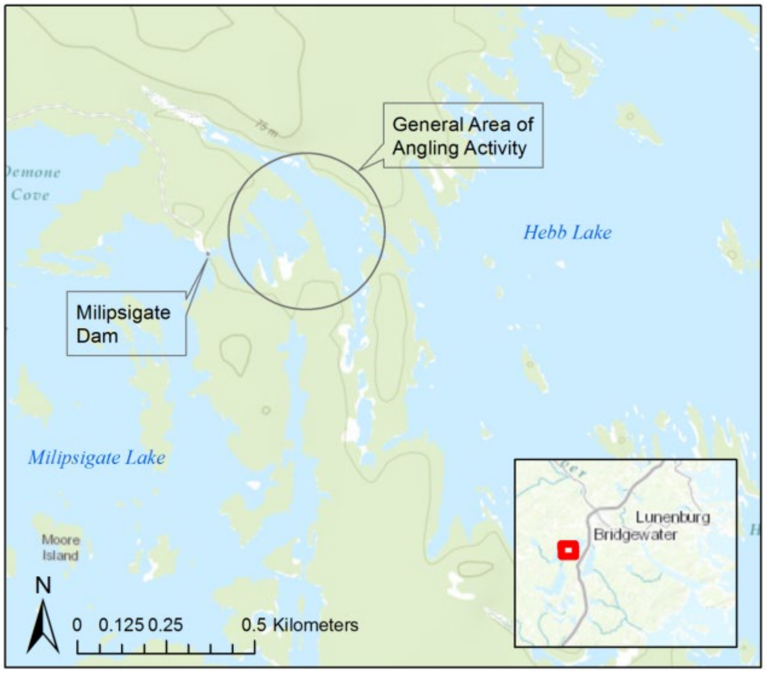


Figure 7. Location of angling effort in the Milipsigate Lake outlet, directing for Smallmouth Bass and Chain Pickerel from 2013 – 2016.

For SMB, CPUE declined over the sampling period with the 2016 CPUE value approximately half of the CPUE in the initial year of angling (Table 5). Mean length also declined over the time period, from 27 cm in 2013 to 24 cm in 2016 (Table 5).

Table 5. Effort, removals, Catch per unit effort (CPUE) , and average length of Smallmouth Bass (SMB) and Chain Pickerel (CP) captured by angling in Hebb Lake from 2013 – 2016. FL=Fork length.

Year	Hours	SMB Removals	SMB CPUE (fish/Hr)	SMB Mean FL	CP Removals	CP CPUE (fish/Hr)	CP MEAN FL
2013	56.5	342	6.1	27.0	11	0.19	33.2
2014	92.6	294	3.2	26.6	97	1.05	34.4
2015	75.2	359	4.8	25.3	63	0.84	37.0
2016	53.0	144	2.7	24.3	41	0.77	34.3

Length frequency data for Smallmouth Bass captured by angling suggest a decrease in average size as the length mode shifts to smaller fish and the abundance of larger (> 30 cm) fish declines (Figure 8).

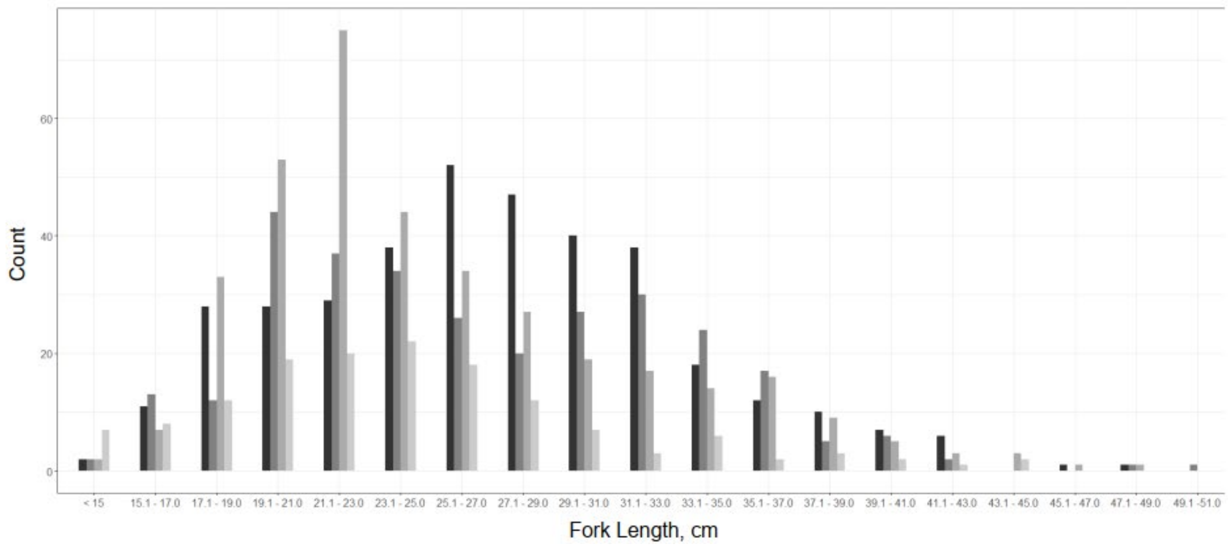


Figure 8. Length distribution of Smallmouth Bass captured by angling, 2013-2016.

Unlike SMB, length frequencies for CP do not indicate a pattern over successive years of angling effort (Figure 9). This may be caused by the ongoing establishment of CP within Hebb Lake, which was more recent (2013) than the introduction of SMB (pre-2003).

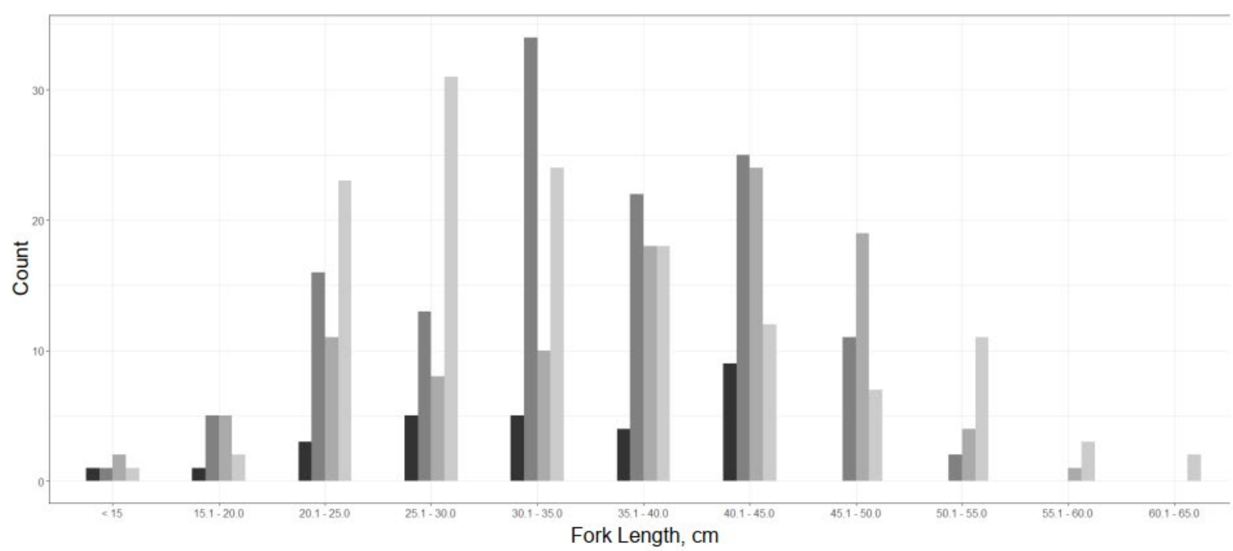


Figure 9. Length distribution (FL, cm) of Chain Pickerel captured by angling from Hebb Lake 2013-2016.

The length frequency distribution of SMB (top) and CP (bottom) differ between sampling methods (Figure 10). Length distributions of SMB and CP captured by angling differ from those captured at linear transect electrofishing stations. Angling is selective for larger fish, and was conducted across more variable habitat. Linear transect boat electrofishing was anticipated to be a non-selective capture method, but is limited to sampling from shallow littoral zone habitats (≤2m depth) where smaller fish of both species are found in higher overall abundance.

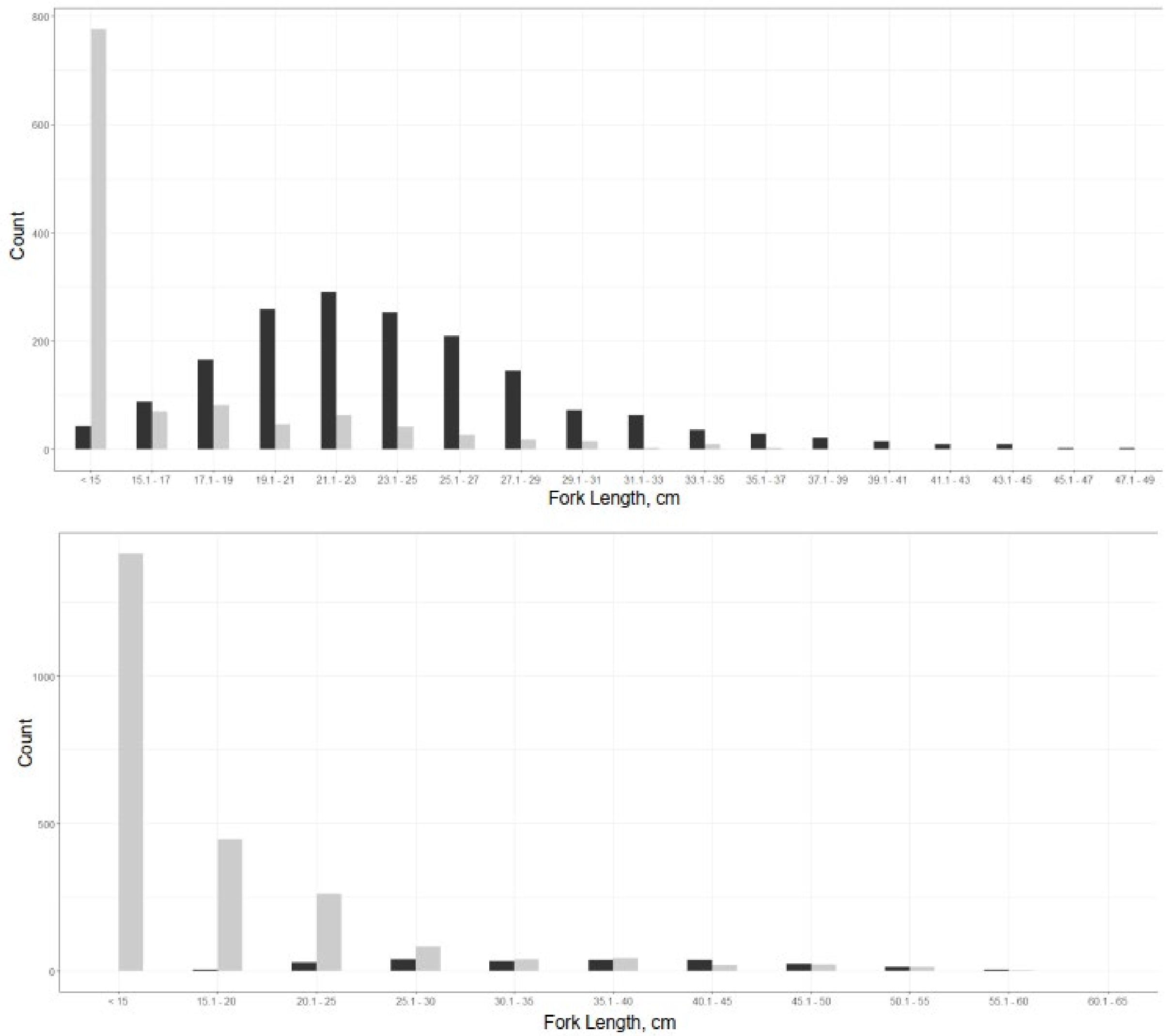


Figure 10. Comparison of length frequency distributions from linear transect boat electrofishing and angling for Smallmouth Bass (top) and Chain Pickerel (bottom) in 2015-2016. Electrofishing data is indicated by the grey bars, whereas angling data is indicated by black bars. Note that length frequency scales differ between species.

Total Removals

Over the three years of the pilot project, 2,362 Smallmouth Bass and 3,129 Chain Pickerel were removed from Hebb Lake by a combination of boat electrofishing and angling methods (Table 6). It is not possible to estimate the proportion of the total population these removals represent as estimates of lake wide population size are not available for either species. It is likely the proportion is small and the effect of these removals was minimal under the level of effort applied.

Table 6. Total removals of Smallmouth Bass (SMB) and Chain Pickerel (CP) from Hebb Lake, 2014 – 2016. Subset text indicates the removal method: dep = depletion electrofishing, lin = linear electrofishing, and ang = angling.

Year	SMB (dep)	SMB (lin)	SMB (ang)	CP (dep)	CP (lin)	CP (ang)	Yearly Total
2014	162	-	294	287	-	97	840
2015	154	393	359	176	977	63	2122
2016	110	746	144	175	1313	41	2385
Species/Method Total	426	1139	797	638	2290	201	**5347**

Sources of Uncertainty

Lake-wide population estimates, or indices of abundance, are not available for SMB and CP in Hebb Lake. It is not possible to estimate the proportion of the total population removed by AIS control measures applied in this pilot project. The spatial distribution of SMB and CP, or their preferred habitats, within Hebb Lake and its tributaries is not well understood. Boat electrofishing is only effective in the shallow (<2m) littoral zone and therefore a unknown portion of the population will not be available for capture, and is not be represented by the presented results. Potential variability in boat electrofishing data induced by seasonal, time of day, lake physical or chemical conditions, weather, and sampling efficiency (i.e., effort, settings, operator/crew experience, site familiarity) over time have not been accounted for within or between years of the pilot project. Similarly, angling effort was not applied in a systematic, or randomized way, and therefore not distributed with spatial or temporal consistency.

Differences in sampling methodology between boat electrofishing depletion experiments and linear transects prevent direct comparison of depletion first pass removals to the total removals from linear transects. Barrier nets were not applied during depletion experiments, making it possible that fish were able to enter or exit the zone of electrofishing influence during individual or between successive depletion passes.

Available literature regarding the control of invasive species using boat electrofishing focuses on SMB. Chain Pickerel have been studied less overall, have different behavior and habitats requirements; therefore, available information pertaining to the response of SMB populations to mitigation measures may not represent CP.

The effects of AIS removal may be confounded by dynamics of SMB and CP interaction, particularly time since introduction/invasion. While it is expected that SMB were fully established within Hebb Lake at the time of this pilot project, CP had been introduced more recently and may represent an early, more dynamic, state of population development.

CONCLUSION AND ADVICE

The results of boat electrofishing depletion experiments demonstrate that localized populations of both SMB and CP can be reduced considerably using a four pass methodology; however, completing each depletion site was time consuming. As the number of fish removed decreased with every pass, lower capture efficiency per unit effort occurs with successive passes. Further, the effect of depletion removals is only temporary, as the site is likely recolonized quickly by individuals from areas adjacent to the sampled habitat. Boat electrofishing linear transects enabled coverage of larger lengths of lake shoreline; however, differences in methodology prevent the results of single pass linear transects from being compared to the depletion results. The effectiveness of boat electrofishing as an AIS control measure is confined to the littoral zone (≤ 2m depth), resulting predominately in the capture of juvenile life stages. While boat electrofishing techniques have been well documented for control of SMB, there is limited information available regarding the use of boat electrofishing when applied to CP to contextualize the results obtained in this pilot project.

Angling captured a different size component of the SMB and CP populations, generally selecting for larger fish than boat electrofishing. As in the case of boat electrofishing, it is difficult to assess the impact of this mitigation approach in the absence of population estimates or abundance indices. As angling effort was neither standardized or randomized, either spatially or temporally, it is difficult to compare results between years. In general, all catch per unit effort results should be interpreted with caution. In most cases, only two data points are available and interannual variation cannot be accounted for. Minor changes in sampling (e.g., effort, timing, efficiency improvements) could impact results.

Prior studies indicate that control of AIS populations is possible; however, eradication is unlikely. While possible, control of AIS populations using mechanical removal methods require high levels of sustained effort. Resurgences are likely to occur in the absence of ongoing control measures, thus, continual effort is required. Control measures applied to date have occurred to explore means to help reduce the predation threat toward sustaining the endangered Atlantic Whitefish population until further actions can be initiated to support survival and recovery. Levels of predation on Atlantic Whitefish by AIS across life stages is unknown. Therefore it is not possible to determine preferentially which AIS life stages would be best to target for mitigation efforts to maximize reduction of potential predation pressure on Atlantic Whitefish.

Improved knowledge of the spatial distribution and habitat use of AIS species within Hebb Lake could likely increase AIS mitigation efficiency through targeted application of available effort. Mitigation efficiency improvements could likely also be realized by targeting life stages when most susceptible to capture. Specifically, with respect to control of SMB, multi-pronged approaches including targeting nesting male SMB in spring when most susceptible to removal, and where removal of nest guarding males is expected to decrease offspring survival. Removal of guarding males in spring could be followed by sampling later in the season to evaluate young of the year recruitment through removal of juvenile life stages. Future mitigation effort should be applied in a manner that permits tracking the impact on target species cohorts over time, toward the development of an index of abundance.

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SOURCES OF INFORMATION

This Science Advisory Report is from the regional peer review of October 11-12, 2017 on the Optimal Strategy for Invasive Species Control to Ensure Survival and Recovery of Atlantic Whitefish in the Petite Rivière Lakes. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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