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ORIGINAL ARTICLE

Ecology of FRESHWATER FISH WILEY

The spatial extent of Walleye and Lake Sturgeon spawning migrations below a dam in the lower Black Sturgeon River, Lake Superior

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Abstract

In the Laurentian Great Lakes, the issue of barrier removal is complicated by the presence of non-native species below barriers. A fish tracking study was conducted to guide efforts for barrier remediation decisions for the restoration of fish populations with a focus on Walleye (*Scander vitreus*) and Lake Sturgeon (*Acipenser fulvescens*) in the Black Sturgeon River, a river system fragmented by a dam which blocks access of fishes to the majority of a large, otherwise barrier-free watershed. Data from 3 years of spawning migrations (2018–2020) indicated that the Walleye population in Black Bay likely consists of both river (65%) and lake spawners (27%), with the remaining individuals spawning in the bay or river in different years. Walleye and Lake Sturgeon showed consistent differences in the extent to which individuals migrated upstream in the river during the spawning season, despite expectations that both species would spawn at the base of the dam when prevented from further migration. The dam was presumably a barrier to migration for Lake Sturgeon, as nearly all Lake Sturgeon that entered the river migrated to the base of the dam. In contrast, few Walleye entering the river during the spawning season migrated to the dam annually. These findings suggest that Walleye and Lake Sturgeon may not benefit equally, at least in the short term, from barrier remediation or dam removal.

KEYWORDS
Acipenseridae, biotelemetry, dams, fish passage, Percidae, spawning migrations

1 | INTRODUCTION

Migratory freshwater fishes are disproportionally threatened globally in comparison with other vertebrates, with populations exhibiting, on average, a 76% decline in abundance since 1970 (Deinet et al., 2020). In the Laurentian Great Lakes (hereafter the Great Lakes), watersheds were systematically dammed and logged during European colonization at the same time fish populations were being relentlessly exploited; by the early 20th century the combination of habitat loss and overexploitation had devastated fish stocks across the Great Lakes (Christie, 1974; Kelso et al., 1996; Lawrie & Rahrer, 1973). In turn, a third main stressor, the invasive Sea Lamprey (*Petromyzon marinus*), invaded the lakes Erie, Huron, Michigan and Superior in the 1920s and within a couple of decades had further reduced native fish populations to the point where invasive species were able to take advantage of disrupted food webs and become firmly established (Christie, 1974; Muir et al., 2012). These changes happened later and were more muted in Lake Superior, the largest and deepest Great Lake, likely due to its remoteness and mismatches of Lake Superior's physicochemical characteristics with the physiological requirements of most aquatic invasive species (Grigorovich et al., 2003; Lawrie, 1978).

After years of sustained management efforts, fish populations in Lake Superior are generally considered healthy, except for migratory species that require access to tributary habitats during the spawning season (Ebener & Pratt, 2021; ECCC & USEPA, 2022). Specifically, Walleye (*Sander vitreus*) and Lake Sturgeon (*Acipenser fulvescens*), both of which are observed to migrate upstream to spawn, remain below recovery targets despite having had species-specific recovery plans developed 20 years ago (Auer, 2003; Hoff, 2003). Lake Superior Walleye and Lake Sturgeon populations declined from historical levels due to overexploitation, alteration of spawning habitats and pollution (Bruch et al., 2016; Harkness & Dymond, 1961; Schneider & Leach, 1977). While several Walleye populations in the Great Lakes basin, including the St. Louis River population in western Lake Superior, are self-sustaining and fully recovered (Matley et al., 2020; Olson et al., 2016), most populations in Lake Superior remain below historical levels (ECCC & USEPA, 2022). Conversely, few Great Lakes' Lake Sturgeon populations are considered recovered (Bruch et al., 2016), and only two of the 21 historic Lake Sturgeon populations in Lake Superior meet the criteria for recovery identified in the Auer (2003) lake-wide recovery plan (ECCC & USEPA, 2022). One factor potentially affecting both Walleye and Lake Sturgeon recovery is the presence of dams that can directly eliminate or change historic spawning habitats, block access to said habitat and influence flow regimes affecting egg and larval production (Haxton & Findlay, 2008; Haxton, Friday, et al., 2014; Kerr et al., 2010; Schneider & Leach, 1977).

Options to facilitate fish access above dams by providing passage, either via a fishway or through dam removal, are increasingly considered for the restoration of migratory fishes impacted by anthropogenic barriers (Kemp & O'Hanley, 2010; Thieme et al., 2023). Achieving consensus on a dam removal is rarely a simple process, especially in the Great Lakes basin, where restoring unrestricted access to native fishes in tributaries long disconnected from the Great Lakes by barriers could also result in new access and opportunities for the invasive Sea Lamprey and naturalized Pacific salmonids, resulting in a 'connectivity conundrum' (Walter et al., 2021; Zielinski et al., 2020).

Data to inform conflicts that arise due to the connectivity conundrum are generally lacking at most locations of interest within the Great Lakes. One such location, the Camp 43 Dam, is located 17 river kilometres (rkm) upstream from the mouth of the Black Sturgeon River, on Black Bay, Lake Superior (Figure 1). The dam, completed in 1960 to facilitate logging activities, was modified to restrict Sea Lamprey access in 1966, and now primarily serves as a barrier to invasive species (Bobrowicz, 2010; Horns et al., 2003). There is an additional ~80 mainstem rkm above the dam, including a number of lakes where there are small extant Walleye and Lake Sturgeon populations; genetic analyses indicate that both the upper watershed Walleye and Lake Sturgeon populations were once one contiguous population with the fish below the barrier (Garner et al., 2013; Wilson et al., 2007, 2022). Black Bay had one of the largest populations of Walleye in Lake Superior, which supported important commercial and recreational fisheries before its collapse in the late 1960s (Bobrowicz, 2010; Mclaughlin et al., 2013; Schneider & Leach, 1977; Wilson et al., 2007). While there is no consensus among stakeholders, several potential factors were implicated in the collapse, including overharvesting, habitat degradation and disruption from logging drives, age-0 predation by invasive Rainbow Smelt (*Osmerus mordax*), as well as restricted access to historical upstream spawning sites after the construction of the Camp 43 Dam. The status of the Black Bay Lake Sturgeon population has received less attention than the Walleye population, although the population is small and was estimated to have less than 100 spawners in both 2003 and 2004 below the Camp 43 Dam (Friday, 2004). The premise that the Lake Sturgeon population is small was recently corroborated by the determination of a low effective population size (N_e = 48 [38–59]; Wilson et al., 2022). The Black Bay Lake Sturgeon population is genetically distinct from the next nearest Lake Sturgeon population in the Kaministiquia River (Welsh et al., 2008; Wilson et al., 2022), meaning that recovery will likely need to come from increased production within the Black Sturgeon River system. Lake Sturgeon are believed to have been historically abundant, as commercial harvest records from Black Bay were the highest on Lake Superior (Goodier, 1982).

The Camp 43 Dam underwent emergency repairs to reduce the risk of catastrophic failure in 2020, which abruptly ended a sometimes contentious, decade long process on how to best rehabilitate native fish such as Walleye and Lake Sturgeon while maintaining control of invasive species (Mclaughlin et al., 2013). Local stakeholders remain invested in the process, and there remains interest by some stakeholders and rights holders in providing fish passage at the Camp 43 Dam to enable the recovery of these two native species. Conversely, there remains equal concern by other stakeholders in limiting Sea Lamprey and non-native salmonid access to the upper part of the watershed. Insight on spawning movements below the Camp 43 Dam of the two species of principal interest, Walleye and Lake Sturgeon, will be useful in informing any future decisions about increased connectivity in the watershed, as there remains considerable uncertainty, particularly for

FIGURE 1 (a) Map of North America (top panel) identifying the location of Lake Superior (bottom panel). The location of the Black Sturgeon River and Camp 43 Dam are noted on Lake Superior; (b) the lower Black Sturgeon River, with the Camp 43 Dam indicated by a black circle. Acoustic telemetry receiver locations are indicated by grey circles and labelled (e.g. 'REC-1'). The river mouth is at the REC-1 location and potential spawning locations are indicated by black circles and labelled (e.g. Unnamed Rapids). GIS data for each feature were provided by Statistics Canada and the United States Census Bureau (North America), NOAA (Lake Superior) and by the DFO Sea Lamprey Control Centre (Black Sturgeon River) and the MNRF (Receiver Locations). Map created in QGIS.

Walleye, about the potential benefits of barrier remediation. Walleye populations demonstrate multiple migratory life-history strategies, and can spawn in both rivers and lakes (Bozek et al., 2011). There remains uncertainty whether the historic or contemporary Black Bay Walleye population are shoal (lake) or river spawners, or are comprised of a metapopulation that demonstrates both spawning strategies (Furlong et al., 2006; Garner et al., 2013; Ryder, 1968). Conversely, Lake Sturgeon are exclusively river spawners and almost always migrate to the first insuperable barrier (Ecclestone et al., 2020). When prevented from further migration, Lake Sturgeon will spawn at the base of dams that pose an impassable barrier and prevent access to historic spawning grounds (Auer, 1996; Dumont et al., 2011; Peterson et al., 2007; Thiem et al., 2013).

An improved understanding of the movement ecology of spawning Walleye and Lake Sturgeon within the Black Sturgeon River will help address some of the uncertainties around the trade-offs with barrier remediation, and provide a basis for sound management decisions. To that end, we were specifically interested in identifying whether the Black Bay Walleye population consisted of exclusively river spawning individuals, as suggested by recent information (Bobrowicz, 2010; Furlong et al., 2006), or if the majority of the population still spawned in the bay as was originally hypothesized by Ryder (1968). We are also interested in whether Walleye showed fidelity to those spawning locations across years, and whether the location of tagging had any effect on observed migratory behaviour. Additionally, we desired to know the spatial extent of Walleye and Lake Sturgeon spawning movement up the Black Sturgeon River below the Camp 43 dam to determine potential spawning locations and, ultimately, whether the dam was a barrier to spawning movement for either species.

The broad objective of this study was to quantify spawning movements for Walleye and Lake Sturgeon in Black Bay and the lower Black Sturgeon River below the Camp 43 Dam using data from individuals implanted with acoustic transmitters over a 3 year period. Specifically, we aimed to (1) determine the proportion of the tagged Walleye population in Black Bay utilizing the Black Bay or the lower Black Sturgeon River as spawning habitat, and (2) whether those individuals demonstrated spawning site fidelity. Walleye were captured and tagged during the spawning season in both the Black Sturgeon River and Black Bay, so we also (3) determined whether their location of tagging influenced their spawning location. For those individuals that migrated into the lower Black Sturgeon River during the spawning season, we additionally (4) determined the spatial extent of Walleye and Lake Sturgeon migration in the lower Black Sturgeon River and (5) consistency of the extent of those spawning movements to infer spawning location.

2 | MATERIALS AND METHODS

2.1 | Study site

The Black Sturgeon River empties into Black Bay, a 60,000 ha embayment located in northwestern Lake Superior (Figure 1). The northern third of the bay provides a productive habitat for cool-water adapted species such as Walleye and Lake Sturgeon. Based on visual observations during their respective spawning seasons, the Camp 43 Dam location is identified as a potential spawning site for Lake Sturgeon, while the Camp 43 Dam and two sets of rapids are identified as potential spawning locations for Walleye (Figure 1). The first set of rapids is located at the Highway 17 highway bridge (Highway 17 Rapids) and the second set of rapids (Unnamed Rapids) is located closer to Black Bay.

2.2 | Walleye and Lake sturgeon acoustic tagging

A total of 139 Walleye were tagged in Black Bay ($n=79$) and the Black Sturgeon River ($n=60$) from 2016 to 2018 and were present during at least one spawning period from 2018 to 2020 (Table 1). Additional Walleye were tagged over the years as part of a broader Black Bay Walleye Acoustic Telemetry (BBWAT) project, but many of these fish were not in the telemetry array during the spawning period for the years assessed in this project and thus were not included. Adult Walleye were captured using various sampling methods (i.e. trap nets, electrofishing, short set gill nets and angling) from either the Black Sturgeon River or various other locations around Black Bay almost entirely during the spring shortly after spawning season (Appendix A). It was not possible to capture enough individuals in suitable physiological condition for tagging outside of this time period when they are concentrated in shallow, warm areas post-spawning, as the majority of the fish disperse widely into deeper parts of Black Bay for the remainder of the year (Mckee et al., 2022). All fish were measured for total length, and the second dorsal spine was clipped for age and growth analysis. In 2016, fish were anesthetized with clove oil (60 mg clove oil/L water), while in 2017 and 2018 electric fish handling gloves (32–39 V, 4–25 mA; Smith-Root, Vancouver, WA) were used for anaesthetization before surgery. Fish were placed in a padded trough, where a small incision was made on the ventral side posterior to the pelvic girdle. Acoustic transmitter tags were then surgically implanted into the coelomic cavity of the fish while onshore, near capture locations. Three tag types, including (a) 167 Vemco V16-4X tags, 2435 days projected battery life, nominal delay 120 s with random transmission intervals between 60 and 180 s; (b) 15 Vemco V16TP-4X tags, 2305 days projected battery life, nominal delay 120 s with random transmission intervals between 60 and 180 s and (c) 10 Vemco V13-1X tags, 904 days projected battery life, nominal delay 180 s with random transmission intervals between 120 and 240 s, were used in the study. The incision was closed with three sutures (polydioxanone absorbable monofilament; Ethicon, Somerville, NJ), and all fish were tagged with an external anchor tag (Floy Manufacturing) and released at their capture sites.

In May 2016, 20 Lake Sturgeon were captured in northern Black Bay by Fisheries and Oceans Canada (DFO) between Scimming Island, and the mouths of the Wolf and Black Sturgeon rivers, and tagged with acoustic transmitters. Sub-adult or adult Lake Sturgeon with total lengths greater than 1000 mm were the preferred size range for capture. Gill nets with mesh sizes of 20.3, 25.4, 30.5 and 35.6 cm (8, 10, 12 and 14 in; stretched bar measure) were set between 4 and 15 m depths for approximately 24 h. Fish were removed from the live well and placed with their ventral side up, inducing a state of tonic immobility (Cooke et al., 2013). Total length, weight, fork length and girth measurements were taken, as well as a fin segment from the left pectoral fin ray for age analysis. All individuals were tagged with an external Floy-style spaghetti tag, inserted on the left-hand side below the dorsal fin, and an 11 mm PIT tag, applied below the third dorsal scute. A subcutaneous lidocaine (2 mg/kg) injection at the site of the incision was given to numb the area. Acoustic transmitter tags (Vemco Model V16-4X; 3393 days projected battery life, nominal delay 180 s with random transmission intervals between 120 and 240 s) were surgically implanted by making an approximately 25 mm incision left of the mid-lateral line. The transmitter was inserted, and the incision was closed with 2–4 sutures. Fish were then returned to a live well for recovery and were later released near their capture location. These 20 fish were aged by drying fin rays prior to sectioning, and using a Buehler IsoMet low-speed saw to cut a 0.3 mm section. Digital imaging software was used to amplify the fin ray section to estimate the number of annuli. Age was interpreted by two experienced biologists who independently assessed both fin ray sections and decided on the most likely age.

In addition to the Lake Sturgeon tagged by DFO, from May 2015 to 2017, the Ontario Ministry of Natural Resources and Forestry

TABLE 1 Number and fate of Walleye fitted with acoustic transmitters from the Black Sturgeon River and Black Bay. Captures in 2016, 2017 and 2018, as well as the number of fish alive to participate in a spawning run, are shown. Note the fish captured and tagged in 2018 were not included in the analysis that year.

	2016				2017				2018		
Capture location	# tagged	# alive 2018	# alive 2019	#alive 2020	# tagged	# alive 2018	# alive 2019	# alive 2020	# tagged	# alive 2019	# alive 2020
Black Sturgeon River	38	28	24	23	22	18	13	9	16	14	10
Black Bay	56	32	27	22	39	32	31	29	21	15	13

(MNRF) tagged 11 (3 in 2015, 5 in 2016 and 3 in 2017) Lake Sturgeon in the Black Sturgeon River downstream of the Camp 43 Dam and released them at a known staging location approximately 5 rkm upstream of the barrier. These individuals ultimately migrated back down below the Camp 43 Dam after tagging and were therefore able to be included in the analysis. Gill nets with mesh sizes between 20.3 and 30.5 cm (8 to 12 in) were set overnight at depths less than 4 m as per Haxton, Whelan, et al. (2014). Total length, sex and weight (to the nearest 100 g) were recorded, and a PIT tag was inserted beneath the third dorsal scute for each fish. All individuals of sufficient size for transmitter implementation were placed in a large, covered tank and transported a short distance to an upstream landing for processing. MS-222 (tricaine methanesulphonate) was used to anesthetize the Lake Sturgeon for surgery. A small incision in the body wall proximal to the midline was made, and an acoustic transmitter tag (Vemco Model V16-4X) was implanted. The incision was closed using gut suture material (size 4–0), and individuals were placed in a tank with fresh water and an aerator for recovery. All fish tagged by the MNRF had estimated tag battery lives of 2883 days, except two fish tagged in 2017 with an expected tag life of 1549 days. Other details on these transmitters (e.g. ping rate) are not known.

2.3 | Acoustic receiver deployment and retrieval

Walleye and Lake Sturgeon in the Black Sturgeon River were detected on omnidirectional acoustic receivers (VR2W, 69 kHz; Innovasea) deployed as part of the Great Lakes Acoustic Telemetry Observation System (GLATOS) BBWAT Project. Established by the Great Lakes Fishery Commission, GLATOS uses a network of acoustic telemetry data from various researchers to aid in the understanding of fish movement ecology and to help inform management decisions (Krueger et al., 2018). Receivers were deployed between 2017 and 2020 in a gated design to determine fish movement along a potential migratory route in the river (Heupel et al., 2006). River receivers were named sequentially, with REC-1 at the river mouth and REC-7 at the Camp 43 Dam, with receivers numbered in sequence (Figure 1). Additional receivers were located in Black Bay (2016–2020) as part of a broader Walleye movement study (McKee et al., 2022); data from these receivers were used to determine whether tagged individuals were in the bay and thus available for potential migration into the river in any given year or were unavailable due to probable mortality or emigration from Black Bay.

In 2017, two receivers were deployed in the Black Sturgeon River: REC-1 at the river mouth and REC-7 downstream of the Camp 43 Dam. In 2018, three additional receivers were deployed (REC-2, REC-3 and REC-4) to further delineate migration extent in the river. In 2019, REC-6 was added, upstream of the Highway 17 Rapids. Finally, in 2020, REC-5 was deployed upstream of REC-4 (Figure 1). Receivers were deployed with an anchor and float and were suspended ~1 m from the bottom, at depths between 2 to 6 m. Receivers that were initially deployed in spring 2017 had a short gap (a couple of days to a week, but not during the spawning run for either species of interest) between recoveries and subsequent deployments as the receivers were removed, downloaded and serviced away from the field site. Since the deployments in 2018, there were consistent detections as receivers were recovered and replaced with new receivers at the same site on the same day.

2.4 | Number of fish available for annual spawning migration

It was necessary to determine the number of Walleye and Lake Sturgeon alive and available to spawn annually, as fish were tagged over multiple years and some fish likely died after surgery, were removed (i.e. via natural or human-induced mortality), or emigrated from the study area. If tagged Walleye or Lake Sturgeon were never detected after surgery on a BBWAT receiver, they were removed from the dataset and considered probable mortalities or having emigrated from the array. For each year, additional potential mortalities or emigrants were determined if a fish had their last detection on a BBWAT receiver prior to the spawning season (i.e. April of a given year for Walleye and May of a given year for Lake Sturgeon) and were not detected again.

2.5 | Data filtering

Detection range testing of receivers in the BBWAT array was conducted near Bent Island in Black Bay in 2017 and at REC-7 in 2018. Detection ranges for REC-7 in the Black Sturgeon River near the Camp 43 Dam were 97% at 150 m and 81% at 185 m respectively. The REC-1 receiver is located at the mouth of the Black Sturgeon River where conditions are likely more similar to receivers within Black Bay. At Bent Island in Black Bay, the detection range was 91% at 750 m. As such, based on the positioning of REC-1 at the mouth of the river and the detection range of receivers within the BBWAT array, some detections at REC-1 were likely on fish swimming by the mouth of the river and not entering for the purpose of spawning. Thus, fish detected at REC-2 were considered as the total number of individuals that entered the river to potentially spawn in each year. REC-2 was not deployed until 2018, and therefore analysis and interpretation of spawning for the previous year (i.e. 2017) for both Walleye and Lake Sturgeon is limited and thus was not included in this study. For this assessment, a fish was considered as likely spawning at a given location if it was not detected at the next upstream receiver during the spawning season (i.e. April to June for Walleye and May to July for Lake Sturgeon). In addition, we were uncertain about the subsequent behaviour of fish tagged during the spawning season, so the spawning movements of fish were not assessed in the year they were tagged.

Before analysis of detection data, false detections were removed from the dataset. This was done following the method of Pincock (2012), who indicated that when using Vemco (now Innovasea) acoustic transmitter tags with a nominal delay of

120 seconds (i.e. transmits randomly every 60–180 s), it is recommended that single detections (i.e. not accompanied by another detection on the same receiver) within a one-hour time interval (i.e. 30 times the nominal delay of the tag) be removed. Given the nature of the receiver array (i.e. gated in a river), false detections were manually checked to determine if fish were detected on receivers above or below the single-detection receiver to ensure a true false detection, rather than a delayed detection of a fish moving in a section of the river outside the receiver range due to the nominal tag delay. Using the criteria above 1010 (0.18%) of 560,104 detections were flagged as false; after a manual check, only three of these detections were deemed truly false and removed from the dataset. Potential mortalities or removals were identified and were removed from each year's dataset for analysis, and all remaining fish had estimated tag lives that should have spanned the entirety of the analysis.

2.6 | Data analysis

To complete the first objective of determining the proportion of the tagged Black Bay Walleye that appear to use the river for spawning, the proportion of individual Walleye alive within the array and detected at receivers in the river during the spawning season (i.e. April to June) was assessed from 2018 through 2020. Based on the distances between each receiver and range testing, detection range overlap between receivers was deemed unlikely (Figure 1). Based on detections at each receiver, travel direction could be inferred. Objective two, assessing spawning site fidelity, was addressed by determining where individual Walleye were located (e.g. either in the Black Sturgeon River or in Black Bay) throughout the spawning season. There were concerns that the location of capture might influence future spawning migratory behaviour in Walleye, as individuals were tagged both in the Black Sturgeon River and in Black Bay. We addressed objective three by assessing whether there were differences in spawning location based on tagging location using chi-square contingency tables (Zar, 1999); we only included fish that had 3 years of spawning migration data in case there were inconsistencies across time.

The proportions of individual Walleye and Lake Sturgeon detected at each receiver in the Black Sturgeon River from 2018 through 2020 were used to investigate the fourth objective, to determine the extent of Walleye and Lake Sturgeon migration in the lower Black Sturgeon River. The annual consistency of the proportion of fish migrating upriver during the spawning season or remaining in Black Bay (objective 5) was assessed using chi-square contingency tables (Zar, 1999).

3 | RESULTS

In total, the migratory behaviour of 110 (2018), 124 (2019) and 106 (2020) Walleye representing 139 unique fish was assessed during the spawning period in Black Bay and the Black Sturgeon River (Table 1). When separated by tagging location, the number of Walleye available for spawning annually that were tagged in Black Bay was 64 (2018), 73 (2019) and 64 (2020), and the number of individuals tagged in the Black Sturgeon River was 46 (2018), 51 (2019) and 42 (2020; Table 1). Four Lake Sturgeon were identified as emigrated or potential mortalities, which meant that 27 Lake Sturgeon were available for spawning for each year. The average length of tagged Lake Sturgeon was 1184 mm (min 1010 mm, max 1405 mm), and the average length of tagged Walleye was 610 mm (min 389 mm, max 792 mm; McKee et al., 2022). No individuals of either species were observed in both Black Bay and the Black Sturgeon River during the spawning period in a given year.

3.1 | Walleye use and movement in Black Bay and the Black Sturgeon River

A majority of Walleye were found to be exclusively using the Black Sturgeon River during the spawning season, but there were Walleye that never entered the river and remained in Black Bay and a few fish that were observed in both potential spawning areas in different years. Across all years of detections, 65% of tagged Walleye (90 individuals) were detected only in the river during the spawning season, 27% (38 individuals) consistently remained in Black Bay and 8% (11 individuals) demonstrated an absence of site fidelity and were detected in both the river and bay (Table 2). Similar proportions were observed for the subset of 83 fish for which we have all 3 years of data (i.e. were tagged prior to 2018 and were alive during the three spawning seasons); 58% (48 individuals) were consistently detected in the river, 31% (26 individuals) were consistently found in Black Bay and 11% (9 individuals) were observed in both the Black Sturgeon River and Black Bay during the spawning period(s) (Table 2). There was no evidence that individuals tagged in either the river or bay preferentially spawned in their tagging location as there were no differences detected in migratory behaviour between fish tagged in the Black Sturgeon River or Black Bay when the 83 fish for which we had all 3 years of data were assessed ($\chi^2 = 2.66$, df = 2, $p = .26$).

Walleye spawning migration patterns were remarkably consistent among years. The proportion of tagged Walleye entering the river during the spawning period and detected at REC-2 (17 rkm upstream of the river mouth) ranged from 67 to 69% (Figure 2). Nearly all fish detected at REC-2 moved upstream to receiver REC-3, located just downstream of a potential spawning area (i.e. Unnamed Rapids, Figure 1), where again, 66–68% of the tagged Walleye at large in a given year were detected. The second set of rapids (i.e. the Highway 17 Rapids; Figure 1) is located downstream of REC-6, and the proportion of fish detected upstream of REC-4 (in 2018–2020) and REC-5 (in 2020) ranged from 49 to 53%. While not available in 2018–2019, the proportions of Walleye detected at both REC-4 and REC-5 in 2020 were identical indicating no loss of fish between those two receivers (Figure 2). Detections at REC-7, the most upstream receiver located downstream of the Camp 43 Dam, ranged from <1% to 6% of the tagged Walleye at large in a given year. Thus, across all years, 16–19% of all tagged Walleye were likely spawning at the Unnamed Rapids

TABLE 2 Walleye migration tracking histories (TH) is defined as a sequence of an individual's spawning activity and location observed across the three study years.

Year	TH 1	TH 2	TH 3	TH 4	TH 5	TH 6	TH7	TH 8	TH 9	TH 10	TH 11	TH 12	TH 13	TH 14	TH 15	TH 16
2018	BSR	BSR	BSR	UT	UT	BB	BB	BB	UT	BB	BSR	BSR	BSR	BB	UT	UT
2019	D/M	BSR	BSR	BSR	BSR	D/M	BB	BB	BB	BB	BB	BB	BSR	BSR	BB	BSR
2020	D/M	D/M	BSR	D/M	BSR	D/M	D/M	BB	BB	BSR	BB	BSR	BB	BSR	BSR	BB
Total	11	7	48	6	18	4	5	26	3	1	2	1	4	1	1	1
	Black Sturgeon River total = 90					Black Bay total = 38				Mixed migration strategy total = 11						

Note: Possible states include fish observed to migrate into the Black Sturgeon River (BSR), remain in Black Bay (BB) or exhibit a mixed migration strategy where some years the fish are in the river but other years in the bay. 16 unique tracking histories were observed. For example, TH1 describes individuals whose states were spawning in the BSR in 2018, D/M in 2019 and D/M in 2020. Total (or N) represents the number of tagged individuals that displayed each tracking history. D/M = Dead or out-migrated, as we do not know the true fate of those individuals; UT = the fish in question was untagged (e.g. not tagged until the following year(s)) that year.

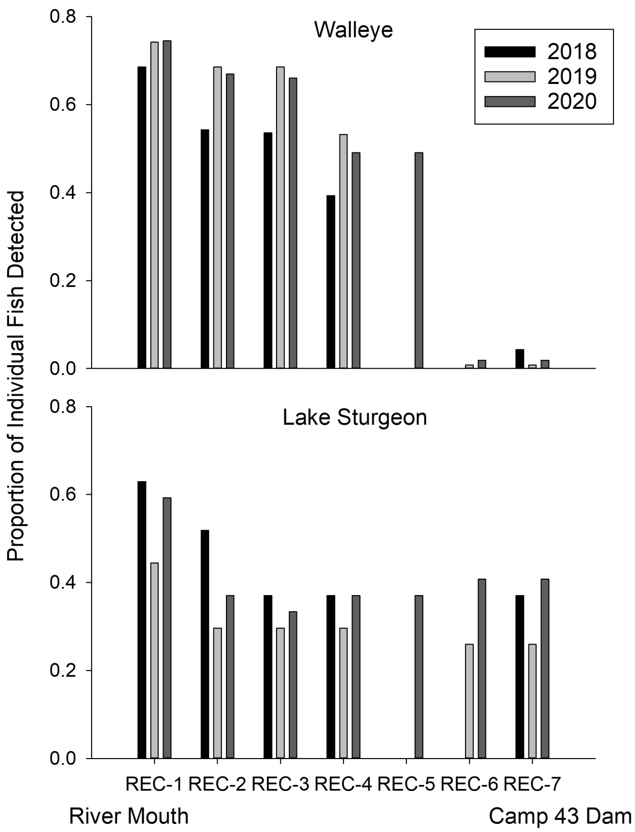

FIGURE 2 The proportion of Walleye (upper panel) and Lake Sturgeon (lower panel) alive and at large in each year detected at each receiver of the total number for that year. The bars represent the proportion of fish in a given year. Receivers are ordered by location from downstream (i.e. the river mouth) to upstream (i.e. the Camp 43 Dam). REC-5 in 2018 and 2019 and REC-6 in 2019 were not deployed within the array prior to the spawning season in that year.

location, 45–52% were likely spawning at the Highway 17 Rapids, 1–6% of Walleye were likely spawning below the Camp 43 Dam, while the remainder (31–33%) stayed in and were likely spawning in Black Bay. There was no difference in the proportions of fish detected at REC-2, REC-4 and REC-7, or remaining in Black Bay, across years (Table 3; $\chi^2 = 5.4$, df = 6, $p = .50$).

TABLE 3 Frequency of observed Walleye migration strategy (spawning location) by tagging location for (i) all fish assessed over the 3-year study period, and (ii) only for fish that have data for the three spawning periods assessed.

		Tagging location		
		BSR	BB	Total
(i)				
Spawning location	BSR	44	46	90
	BB	11	27	38
	Mix	5	6	11
	Total	60	79	139
(ii)				
Spawning location	BSR	22	26	48
	BB	7	19	26
	Mix	3	6	9
	Total	32	51	83

3.2 | Lake sturgeon movement in the Black Sturgeon River

The proportion of Lake Sturgeon ($n = 27$ in 2018, 2019 and 2020) detected at each receiver was also similar among years, with no difference in the proportions of fish either remaining in Black Bay, or being detected at REC-2, REC-4 and REC-7 across years ($\chi^2 = 1.5$, df = 6, $p = .96$). The proportion of Lake Sturgeon detected entering the river during spawning season at REC-2 ranged from 37% to 52% (i.e. 10–14 individuals) annually. The remainder of the tagged Lake Sturgeon not entering the river to spawn were detected on other BBWAT receivers during the spawning period. The proportion of Lake Sturgeon at large detected at REC-7 (i.e. the receiver closest to the Camp 43 Dam), ranged from 33% to 41%. Across all years, a consistent trend was observed where Lake Sturgeon that did enter the river (i.e. detected at REC-2) migrated the full extent (i.e. to REC-7) until barred from further upstream movement by the Camp 43 Dam, with few exceptions (Figure 2). The Lake Sturgeon data show that some of the lower receivers were not 100% effective in detecting fish movement, as the proportion of fish detected at the two most upstream receivers was higher in 2020 than those further downstream (Figure 2). Ten Lake Sturgeon were detected alive in Black Bay, but not detected at REC-7 during the spawning season in any year.

4 | DISCUSSION

We identified some key differences in spawning behaviour between Walleye and Lake Sturgeon, two species which are at the centre of a barrier remediation debate in Black Bay, a large productive embayment in northwestern Lake Superior. We demonstrated the likely presence of a Black Bay Walleye metapopulation, consisting of both river and lake spawners. Approximately two-thirds of tagged Walleye consistently migrated into the Black Sturgeon River during the spawning season, while a smaller proportion (approximately one-quarter) appeared to be Black Bay spawners. The remaining individuals were present in both spawning locations across years. Walleye were primarily tagged post-spawn in either the lower Black Sturgeon River or in warmer, shallower areas in Black Bay, but tagging location did not appear to influence future spawning location. Walleye and Lake Sturgeon showed strongly consistent differences in the extent to which individuals migrated upstream in a fragmented river during the spawning season, despite our expectation that both species would migrate to and spawn at the base of the Camp 43 Dam. Of those that entered the river, only a small proportion of Walleye migrated to the dam annually, with the majority of fish appearing to find suitable spawning habitat in the lower river. In contrast, nearly all of the Lake Sturgeon that entered the river during the three spawning seasons migrated to the dam. Thus, if river connectivity was restored, either through the removal of the dam or modification to include selective fish passage, we would expect that the benefits of barrier remediation would not immediately be realized equally between the two species; Lake Sturgeon would likely more quickly demonstrate an increased spatial usage of the Black Sturgeon River based on the migration patterns observed in this study.

The identification of multiple spawning locations indicating different life-history strategies in the Black Bay Walleye population is not entirely a surprise, as Walleye in the Laurentian Great Lakes have three known life-history strategies: river resident-river spawner, lake resident-lake spawner and lake resident-river spawner (Bozek et al., 2011). Black Bay Walleye were initially believed to be comprised of almost exclusively lake spawners (Ryder, 1968), but contemporary evidence (habitat availability, genetics, spawning observations) suggested a remnant lake resident-river spawner population (Furlong et al., 2006; Garner et al., 2013). Our results indicate that both lake resident-river spawner and lake resident-lake spawner strategies are likely being utilized by Black Bay Walleye, as most but not all tagged Walleye migrated into the Black Sturgeon River at least once during the three spawning seasons encompassed by this study. Similarly, Lake Erie, has a large Walleye metapopulation that spawns both in rivers and on nearshore reef complexes representing both lake resident-river spawner and lake resident-lake spawner populations (Goodyear et al., 1982; Matley et al., 2020; Stepien et al., 2012; Strange & Stepien, 2007). It is believed that having a mix of spawning life-history strategies helps Walleye populations become resilient to environmental fluctuations during the spawning season (Bozek et al., 2011). Walleye are believed to generally demonstrate spawning site fidelity, returning to the same spawning location every spring (Olson & Scidmore, 1962). However, in the Great Lakes between 5 and 30% of individuals are believed to use alternate spawning habitats between years (Dembkowski et al., 2018; Hayden et al., 2018; Zhao et al., 2011). We observed a similar low number (8%) of Walleye using both the lake and river during the spawning season in this study. Whether the historic Black Bay Walleye population had proportions of lake resident-river spawner and lake resident-lake spawning strategies as the contemporary metapopulation remains unknown, as the historic population collapsed in the late 1960s showed no sign of recovery until the early 2000s commensurate with the stocking of various life stages from a variety of sources (Bobrowicz, 2010; Furlong et al., 2006; Garner et al., 2013), and the closure of the commercial Yellow Perch fishery.

One way to confirm the existence of both lake resident-river spawner and lake resident-lake spawner life-history strategies in Black Bay would be to determine if the two groups could be genetically discriminated. Earlier efforts using four microsatellite loci found no genetic differentiation between Walleye captured in the upper (above the Camp 43 Dam) and lower Black Sturgeon River or between historical and contemporary Black Bay samples (Wilson et al., 2007), suggesting a single lake resident-river spawner population in Black Bay. A follow-up study from the same laboratory using more (11) microsatellite loci and a larger sample size identified more complexity, detecting a significant genetic differentiation between Walleye from the upper and lower Black Sturgeon River, and an unresolved relationship between the historical Black Bay samples and the river populations (Garner et al., 2013). The identification of putative lake and river spawners based on their migration history from our telemetry results might help with the potential resolution of these two life-history strategies, as all previous sampling of fish captured in Black Bay could include fish from both populations. In addition, the recent development of a Great Lakes Walleye GTSeq panel will provide an opportunity for stock discrimination using the most advanced genomic tools, which are better at discriminating among populations than neutral genetic markers such as microsatellites (Euclide et al., 2022).

There are alternative explanations for our preferred interpretation that there are both lake resident-river spawner and lake resident-lake spawner life-history strategies present in a Black Bay metapopulation. For example, Walleye could be exhibiting prolonged periods of skipped spawning, or using alternative spawning tributaries; however, we view these alternative explanations as unlikely. Skipped spawning has been documented for many iteroparous fishes, as skipped spawning could offer a fitness advantage (Jørgensen et al., 2006; Rideout et al., 2005; Rideout & Tomkiewicz, 2011). Female Walleye have been found to skip reproduction events, likely due to inadequate lipid reserves (Henderson et al., 1996). However, there is no evidence of Walleye sequentially skipping multiple spawning years, and we identified 26 tagged fish for which we had three full years of data that never entered the Black Sturgeon River. This strongly suggests that those fish are spawning elsewhere. This is not to say that skipped spawning is not a possible strategy for some Black Bay Walleye, as we did have

11 tagged fish that were detected in either the river or bay in different spawning years. While we attribute those individuals to having a mixed-migration strategy and not exhibiting site fidelity, skipped spawning is a viable alternate explanation for those fish. A second alternative to the presence of both lake resident-river spawner and lake resident-lake spawner life-history strategies is the use of other spawning tributaries. There are smaller tributaries entering Black Bay, and the BBWAT study did place receivers in the second largest tributary, the Wolf River. While the Wolf River was infrequently visited by tagged Walleye, there was no evidence based on the timing of those incursions that they were spawning in the river. Overall, we are confident in our interpretation that a metapopulation exists comprised of both lake resident-river spawner and lake resident-lake spawners.

We observed consistent differences in the extent of Walleye and Lake Sturgeon annual spawning migrations up the Black Sturgeon River. Lake Sturgeon likely spawned at the base of the Camp 43 Dam as, unlike Walleye, most individuals migrated upstream all the way to the dam during the spawning season. Across all years, Lake Sturgeon entering the river migrated their full extent until barred from further upstream movement by the Camp 43 Dam, with few exceptions. This behaviour is supported by other studies that have demonstrated that, when prevented from further migration, Lake Sturgeon will spawn at the base of dams that pose an impassable barrier and prevent access to historic spawning grounds (Bruch et al., 2016; Peterson et al., 2007; Thiem et al., 2013). Conversely, it is not unusual to have multiple Walleye spawning locations within a single spawning tributary. There are a number of potential spawning sites in close proximity downstream of the Camp 43 Dam in the Black Sturgeon River, and our telemetry data indicate two locations were consistently accessed across years during the spawning season. While physical habitat characteristics of these potential spawning locations have not been fully studied, each location has an associated water feature associated with higher water velocities (i.e. dam and rapids). There are a number of other tributaries in the Great Lakes where multiple spawning sites are observed in close proximity, including the Maumee (Schmidt et al., 2020) and Muskegon (Rutherford et al., 2016) rivers.

A smaller proportion of Lake Sturgeon than Walleye migrated into the Black Sturgeon River annually during the spawning season, likely because female Lake Sturgeon do not reach sexually maturity until late in life (15–20 years) and exhibit spawning periodicity, spawning every 3–7 years (COSEWIC, 2017; Kerr et al., 2010). Spawning periodicity is different that skipped spawning, as it takes sturgeons multiple years to develop eggs to the point where they are viable, versus skipped spawning where eggs are usually reabsorbed due to unfavourable environmental or physiological conditions (Rideout et al., 2005). Late maturation and spawning periodicity may explain why 10 of the tagged Lake Sturgeon were never detected as part of the spawning migration over the course of our 3 year study, as they may have been too young to be sexually mature during the study period or the study duration may not be long enough to have had all females migrate to spawn if their periodicity is longer than 3 years. It is also important to note that Lake Sturgeon do have non-spawning conspecifics that migrate with the spawners (Peterson et al., 2007). Thus, some migrating Lake Sturgeon of younger ages may not be spawning and simply migrating with the spawning conspecifics. As such, individuals not migrating to the Camp 43 Dam may not have reached sexual maturation.

An additional difference to note between our handling of the two species is that the majority of the Lake Sturgeon were captured in Black Bay outside of the spawning season, whereas Walleye were captured and tagged primarily immediately post-spawn in both the lower Black Sturgeon River and shallow, warm areas in Black Bay. Ideally, Walleye from would have been tagged when the metapopulation was fully mixed in Black Bay (e.g. Beacham et al., 2019; Faust et al., 2019; Jensen et al., 2021). Unfortunately, most of these Walleye disperse into deeper, cooler water in the summer months (McKee et al., 2022) making it logistically challenging to capture and tag with a low risk of mortality. Therefore, the decision was made to try and capture Walleye post-spawn from both the lower river and embayment areas in the hopes of capturing individuals with different spawning life-history typologies. The fact that tagging location did not affect spawning location, as there were no differences detected in spawning location choice between fish tagged in the Black Sturgeon River or Black Bay, demonstrates that despite the limitations of our tagging procedure we did not overly bias the outcome of one of our main objectives, as we were able to identify both lake resident-river spawner and lake resident-lake spawner life-history strategies.

5 | MANAGEMENT IMPLICATIONS

It remains unclear how critical access to additional habitat in the Black Sturgeon River is for improving the probability of recovery for Walleye and Lake Sturgeon in Black Bay. While we identified that only a small percentage of Walleye migrated to the base of the Camp 43 Dam, genetic assessment demonstrates a historical connection between the population in the upper watershed above the dam and Black Bay (Garner et al., 2013; Wilson et al., 2007). Similarly, Lake Sturgeon genetics shows a historical connection throughout the Black Sturgeon River watershed (Wilson et al., 2022). These studies indicate that both species historically migrated up the Black Sturgeon River well past the site of the existing Camp 43 Dam. It is difficult to speculate how long it would take for a larger proportion of the Walleye that use the lower river to spawn to begin to migrate further upstream if the barrier was removed or upstream passage provided; it is also likely that these two mitigation measures would have different outcomes, as dam removal would restore natural flows and geomorphic processes, while the success of engineered fish passage solutions, especially for Lake Sturgeon, is often poor (Bobrowicz, 2010). Movement upstream could be density-dependent, with individuals looking to move upstream if the densities of spawners in other areas get too high, as has been observed for some marine fishes (Bacheler et al., 2009; Bartolino et al., 2011). Walleye populations have shown a 10-fold increase in abundance and consistent recruitment in Black Bay over the past 20 years, though recovery has plateaued for the past decade. There are high-quality spawning habitats identified above the Camp 43 Dam that are currently used by the populations of both species that are present above the barrier (Bobrowicz, 2010), and it is possible that access to these habitats would allow further growth of the population. Auer (1996) hypothesized, based on body length-migration relationships from other sturgeon species, that Lake Sturgeon need long stretches (250–300 km) of barrier-free tributary access to allow proper egg development and support self-sustaining populations. The 17 km of river available below the Camp 43 Dam is well below that recommended threshold and could be the reason why the Lake Sturgeon population in the Black Sturgeon River remains low despite the removal of known stressors such as commercial (closed in 1990) and recreational (closed in 2008) fisheries (Bobrowicz, 2010). More recent assessments have demonstrated that Lake Sturgeon can fully develop self-sustaining populations in much smaller, fragmented reaches if the proper habitats for all life stages to be successful are available (Bruch et al., 2016; McDougall et al., 2017). A better understanding of the bottleneck to Lake Sturgeon recovery in Black Bay would help determine whether allowing access to upstream habitat through barrier mitigation may help recover Lake Sturgeon without implementing mitigation measures that are less desirable to local managers and stakeholders, such as stocking, which have been necessary for Lake Sturgeon rehabilitation in other Lake Superior tributaries.

Overall, our movement findings agree with other researchers who suggest that there could be a benefit for the passage of desirable native fishes in the Black Sturgeon watershed (e.g. Furlong et al., 2006; Garner et al., 2013; Wilson et al., 2022), as long as the passage of non-native species remains impeded (Mclaughlin et al., 2013; Rahel & Mclaughlin, 2020). There remains uncertainty about how quickly these benefits would be realized for Walleye, given how few individuals currently migrate to the Camp 43 Dam, but Lake Sturgeon would almost certainly take advantage of additional, upstream habitat access if provided. Currently, there are Great Lakes tributaries where trap and sort fishways have been implemented to address the challenge of maintaining control of invasive species while permitting passage of native fishes (Miehls et al., 2020). Trap and sort fishways are costly to operate as they require manual sorting, but they are effective at blocking further Sea Lamprey migration and could also keep undesirable Pacific salmonids out of the upper part of the watershed. However, assessments of these fishways found that the ultimate passage of desirable fish to be quite variable (7–88%, depending on species and fishway in question), and fish experienced migration delays of 5–28 days (Pratt et al., 2009). A trap and sort fishway at the Camp 43 Dam would require funding for construction and annually for staff to conduct the sorting, and there is uncertainty about whether such a facility could pass Lake Sturgeon during the spawning migration (Bobrowicz, 2010).

The Camp 43 Dam is a 'lowermost barrier', the first structure within a tributary that blocks fish passage (Zielinski et al., 2019). These lowermost barriers are a critical component of the strategy of Sea Lamprey control in the Great Lakes (Zielinski & Freiburger, 2021). The use of Sea Lamprey control barriers has created tension between stakeholders that value Sea Lamprey control versus those that value the connectivity of rivers for native fish passage (McLaughlin et al., 2013). Zielinski et al. (2019) noted that the Great Lakes Fishery Commission is leading a project on selective and bi-directional fish passage, titled FishPass, to provide up- and downstream passage of desirable, native fishes, but restrict movement of undesirable fish (i.e. invasive Sea Lamprey; http://www.glfc.org/fishpass.php). While this project is in its infancy, potential solutions such as incorporating sorting akin to recycling facilities to select for target traits of undesirable fishes to impede passage but select for passage of desirable fishes have been promising (Zielinski et al., 2020). Although the effectiveness of this system has yet to be tested in the field, findings of the FishPass project and other research underway or planned may yield potential solutions for selective fish passage at the Camp 43 Dam, where full connectivity (i.e. dam removal) would have unintended consequences (i.e. further dispersal of invasive Sea Lamprey) but selective connectivity could aid in ecosystem restoration (Zielinski et al., 2020).

AUTHOR CONTRIBUTIONS

FF, KES, MDR secured funding. KK, TCP, SJC, KES conceived study. FF, MDR, TCP conducted field work. KK, TCP analyzed data. KK, TCP wrote original draft, all authors reviewed and edited.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

These data are available through the Great Lakes Acoustic Telemetry Observation System database on request.

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APPENDIX A

Black Sturgeon River

Serial_Number	ID_Code	Common_Name_E	Weight	Sex	Capture_Location	Release_Location	Release_Date
1232059	19956	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	25-05-2018
1232064	19961	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	25-05-2018
1266077	6531	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	24-05-2018
1266078	6533	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	24-05-2018
1266080	6537	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	24-05-2018
1241410	18864	Walleye	2.65	F	Black Bay – Coldwater	Black Bay – Hurkett Cove	10-05-2017
1232014	19911	Walleye	2.465	U	Black Bay – Coldwater	Black Bay – Hurkett Cove	10-05-2017
1232016	19913	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	09-05-2017
1232017	19914	Walleye	2.22	U	Black Bay – Coldwater	Black Bay – Hurkett Cove	10-05-2017
1232019	19916	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	09-05-2017
1232020	19917	Walleye	3.4	U	Black Bay – Coldwater	Black Bay – Hurkett Cove	10-05-2017
1232022	19919	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	09-05-2017
1232023	19920	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	09-05-2017
1232024	19921	Walleye	2.94	U	Black Bay – Coldwater	Black Bay – Hurkett Cove	10-05-2017
1232025	19922	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	09-05-2017
1232027	19924	Walleye	5.6	U	Black Bay – Coldwater	Black Bay – Hurkett Cove	10-05-2017
1232028	19925	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	09-05-2017
1232029	19926	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	09-05-2017
1232030	19927	Walleye	2.93	U	Black Bay – Coldwater	Black Bay – Hurkett Cove	10-05-2017
1232052	19949	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	25-05-2018
1232055	19952	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	25-05-2018
1232056	19953	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	25-05-2018
1232057	19954	Walleye		U	Black Bay – Coldwater	Black Bay – Hurkett Cove	25-05-2018
1232063	19960	Walleye		M	Black Bay – Coldwater	Black Bay – Hurkett Cove	25-05-2018
1232065	19962	Walleye		M	Black Bay – Coldwater	Black Bay – Hurkett Cove	25-05-2018
1266084	6545	Walleye	3.21	U	Black Bay – Delaney Island	Black Bay – Delaney Island	12-05-2017
1232031	19928	Walleye	1.89	M	Black Bay – Delaney Island	Black Bay – Hurkett Cove	12-05-2017
1232032	19929	Walleye	2.645	U	Black Bay – Delaney Island	Black Bay – Hurkett Cove	12-05-2017
1232034	19931	Walleye	3.93	U	Black Bay – Delaney Island	Black Bay – Hurkett Cove	12-05-2017
1232035	19932	Walleye	2.735	U	Black Bay – Delaney Island	Black Bay – Hurkett Cove	12-05-2017
1232036	19933	Walleye	1.865	U	Black Bay – Delaney Island	Black Bay – Hurkett Cove	12-05-2017
1232037	19934	Walleye	3.68	U	Black Bay – Delaney Island	Black Bay – Hurkett Cove	12-05-2017
1232038	19935	Walleye	2.775	M	Black Bay – Delaney Island	Black Bay – Hurkett Cove	12-05-2017
1232039	19936	Walleye	1.625	U	Black Bay – Delaney Island	Black Bay – Hurkett Cove	12-05-2017
1232041	19938	Walleye	2.685	M	Black Bay – Delaney Island	Black Bay – Hurkett Cove	12-05-2017
1232044	19941	Walleye	2.535	M	Black Bay – Delaney Island	Black Bay – Hurkett Cove	12-05-2017
1232045	19942	Walleye	2.13	U	Black Bay – Delaney Island	Black Bay – Hurkett Cove	12-05-2017
1232047	19944	Walleye	2.31	M	Black Bay – Delaney Island	Black Bay – Hurkett Cove	12-05-2017
1241414	18868	Walleye		U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	11-09-2018
1241417	18871	Walleye		U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	11-09-2018
1241423	18877	Walleye		U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	11-09-2018
1266079	6535	Walleye	3.13	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	06-06-2017
1266081	6539	Walleye	1.74	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	06-06-2017
1266083	6543	Walleye	2.71	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	06-06-2017
1241390	18844	Walleye	1.795	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016

Serial_Number	ID_Code	Common_Name_E	Weight	Sex	Capture_Location	Release_Location	Release_Date
1241392	18846	Walleye	2.76	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241393	18847	Walleye	1.835	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241394	18848	Walleye	2.38	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241395	18849	Walleye	2.795	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241397	18851	Walleye	2.48	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241399	18853	Walleye	2.15	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241401	18855	Walleye	1.94	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241403	18857	Walleye	3.325	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241429	18883	Walleye	2.995	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241430	18884	Walleye	3.96	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241431	18885	Walleye	1.865	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241432	18886	Walleye	2.055	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241433	18887	Walleye	3.035	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241435	18889	Walleye	2.29	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241437	18891	Walleye	3.56	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241440	18894	Walleye	2.115	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241441	18895	Walleye	1.83	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241442	18896	Walleye	1.595	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241443	18897	Walleye	1.825	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241480	18934	Walleye	2.005	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241483	18937	Walleye	1.8	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241484	18938	Walleye	1.77	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241485	18939	Walleye	2.385	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241486	18940	Walleye	2.62	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1241487	18941	Walleye	2.285	U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	20-05-2016
1232048	19945	Walleye	1.655	M	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	12-05-2017
1232061	19958	Walleye		U	Black Bay – Hurkett Cove	Black Bay – Hurkett Cove	25-05-2018
1232078	19975	Walleye	1.125	U	Black Bay – Pearl Harbour	Black Bay – Pearl Harbour	19-07-2016
1232079	19976	Walleye	2.76	U	Black Bay – Pearl Harbour	Black Bay – Pearl Harbour	19-07-2016
1232068	19965	Walleye	2.14	U	Black Bay – Squaw Bay	Black Bay – Squaw Bay	27-06-2016
1232069	19966	Walleye	2.445	U	Black Bay – Squaw Bay	Black Bay – Squaw Bay	27-06-2016
1232071	19968	Walleye	2.415	U	Black Bay – Squaw Bay	Black Bay – Squaw Bay	27-06-2016
1232074	19971	Walleye	1.26	U	Black Bay – Squaw Bay	Black Bay – Squaw Bay	27-06-2016
1232080	19977	Walleye		F	Black Bay – Squaw Bay	Black Bay – Squaw Bay	23-10-2020
1241444	18898	Walleye	1.9	U	Black Sturgeon River	Black Sturgeon River	12-05-2016
1241446	18900	Walleye	1.71	M	Black Sturgeon River	Black Sturgeon River	12-05-2016
1241448	18902	Walleye	1.94	U	Black Sturgeon River	Black Sturgeon River	12-05-2016
1241449	18903	Walleye	1.7	M	Black Sturgeon River	Black Sturgeon River	12-05-2016
1241450	18904	Walleye	1.79	U	Black Sturgeon River	Black Sturgeon River	12-05-2016
1241451	18905	Walleye	1.905	M	Black Sturgeon River	Black Sturgeon River	12-05-2016
1241452	18906	Walleye	1.42	U	Black Sturgeon River	Black Sturgeon River	12-05-2016
1241453	18907	Walleye	1.185	M	Black Sturgeon River	Black Sturgeon River	12-05-2016
1241462	18916	Walleye	2.65	U	Black Sturgeon River	Black Sturgeon River	10-05-2016
1241463	18917	Walleye	3.175	F	Black Sturgeon River	Black Sturgeon River	10-05-2016
1241465	18919	Walleye	2.05	M	Black Sturgeon River	Black Sturgeon River	10-05-2016
1241466	18920	Walleye	1.975	M	Black Sturgeon River	Black Sturgeon River	10-05-2016
1241467	18921	Walleye	1.82	M	Black Sturgeon River	Black Sturgeon River	10-05-2016

Serial_Number	ID_Code	Common_Name_E	Weight	Sex	Capture_Location	Release_Location	Release_Date
1241468	18922	Walleye	2.83	F	Black Sturgeon River	Black Sturgeon River	10-05-2016
1241469	18923	Walleye	2.16	F	Black Sturgeon River	Black Sturgeon River	10-05-2016
1241472	18926	Walleye	1.45	M	Black Sturgeon River	Black Sturgeon River	10-05-2016
1241473	18927	Walleye	1.7	U	Black Sturgeon River	Black Sturgeon River	10-05-2016
1241474	18928	Walleye	1.76	M	Black Sturgeon River	Black Sturgeon River	10-05-2016
1241475	18929	Walleye	1.88	U	Black Sturgeon River	Black Sturgeon River	10-05-2016
1241476	18930	Walleye	2.51	U	Black Sturgeon River	Black Sturgeon River	10-05-2016
1241477	18931	Walleye	2.7	F	Black Sturgeon River	Black Sturgeon River	11-05-2016
1241478	18932	Walleye	2.6	F	Black Sturgeon River	Black Sturgeon River	11-05-2016
1241479	18933	Walleye	1.84	M	Black Sturgeon River	Black Sturgeon River	12-05-2016
1232050	19947	Walleye		M	Black Sturgeon River	Black Bay – Hurkett Cove	25-05-2018
1266069	6515	Walleye		U	Black Sturgeon River	Black Bay – Hurkett Cove	24-05-2018
1266070	6517	Walleye		U	Black Sturgeon River	Black Bay – Hurkett Cove	24-05-2018
1266072	6521	Walleye		U	Black Sturgeon River	Black Bay – Hurkett Cove	24-05-2018
1266073	6523	Walleye		U	Black Sturgeon River	Black Bay – Hurkett Cove	24-05-2018
1266074	6525	Walleye		U	Black Sturgeon River	Black Bay – Hurkett Cove	24-05-2018
1266075	6527	Walleye		U	Black Sturgeon River	Black Bay – Hurkett Cove	24-05-2018
1291069	7055	Walleye		M	Black Sturgeon River	Black Bay – Hurkett Cove	25-05-2018
1291071	7057	Walleye		M	Black Sturgeon River	Black Bay – Hurkett Cove	24-05-2018
1291072	7058	Walleye		U	Black Sturgeon River	Black Bay – Hurkett Cove	24-05-2018
1241409	18863	Walleye	1.435	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1241412	18866	Walleye	1.345	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1241413	18867	Walleye	3.125	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1241415	18869	Walleye	1.825	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1241416	18870	Walleye	3.085	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1241418	18872	Walleye	1.525	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1241419	18873	Walleye	2.1	M	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1241421	18875	Walleye	1.045	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1241422	18876	Walleye	1.925	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1241424	18878	Walleye	1.43	M	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1241425	18879	Walleye	2.025	M	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1241426	18880	Walleye	1.1	U	Black Sturgeon River	Black Bay – Hurkett Cove	17-05-2016
1241456	18910	Walleye	1.76	M	Black Sturgeon River	Black Bay – Hurkett Cove	13-05-2016
1241458	18912	Walleye	1.745	U	Black Sturgeon River	Black Bay – Hurkett Cove	13-05-2016
1241459	18913	Walleye	1.625	M	Black Sturgeon River	Black Bay – Hurkett Cove	13-05-2016
1241489	18943	Walleye	1.425	U	Black Sturgeon River	Black Bay – Hurkett Cove	20-05-2016
1232033	19930	Walleye	2.405	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1232040	19937	Walleye		U	Black Sturgeon River	Black Bay – Hurkett Cove	09-05-2017
1232043	19940	Walleye		U	Black Sturgeon River	Black Bay – Hurkett Cove	09-05-2017
1232051	19948	Walleye		M	Black Sturgeon River	Black Bay – Hurkett Cove	25-05-2018
1232053	19950	Walleye		M	Black Sturgeon River	Black Bay – Hurkett Cove	25-05-2018
1232054	19951	Walleye		M	Black Sturgeon River	Black Bay – Hurkett Cove	25-05-2018
1232066	19963	Walleye		M	Black Sturgeon River	Black Bay – Hurkett Cove	24-05-2018
1210991	59558	Walleye	8.3	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1210992	59559	Walleye	9.9	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1210993	59560	Walleye	9.6	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017
1210995	59562	Walleye	1.21	U	Black Sturgeon River	Black Bay – Hurkett Cove	12-05-2017