RESEARCH PUBLICATION 2023

Weir enumeration and capture-mark-recapture estimates of spring spawning-run size for white sucker *Catostomus commersonii* and longnose sucker *Catostomus catostomus* in the Boardman (Ottaway) River, Traverse City, Michigan, USA.

Reid G. Swanson, Daniel P. Zielinski, and Andrew M. Muir

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Great Lakes Fishery Commission
2200 Commonwealth Blvd., Suite 100 Ann
Arbor, MI 48105

Cover photographs of white sucker *Catostomus commersonii* and longnose sucker *Catostomus catostomus* in the Boardman (Ottaway) River. Left: white sucker *Catostomus commersonii* and longnose sucker *Catostomus catostomus* recently release upstream of weir traps (Andrew Muir, Great Lakes Fishery Commission). Right: white sucker *Catostomus commersonii* and longnose sucker *Catostomus catostomus* contained in the upstream facing trap (Reid Swanson, Great Lakes Fishery Commission).

Weir enumeration and capture-mark-recapture estimates of spring spawning-run size for white sucker *Catostomus commersonii* and longnose sucker *Catostomus catostomus* in the Boardman (Ottaway) River, Traverse City, Michigan, USA.

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R.G. Swanson. Great Lakes Fishery Commission, FishPass Headquarters, 310 W Front St., Suite 310 C, Traverse City, MI 49684
[1] Corresponding author (e-mail: rswanson@glfc.org)
D.P. Zielinski. Great Lakes Fishery Commission, FishPass Headquarters, 310 W Front St., Suite 310 D, Traverse City, MI 49684
A.M. Muir. Great Lakes Fishery Commission, 2200 Commonwealth Blvd., Suite 100 Ann, Arbor, MI 48105

CONTENTS

ABSTRACT

Barriers in riverine environments impede the movement of fishes between areas critical to the completion of their lifecycle, affecting both population and ecosystem viability. However, a conundrum arises when the same impediment can also prevent the upstream invasion of non-native or undesirable species. As a result, restoring connectivity can have consequences for both desirable and undesirable species, resulting in a connectivity conundrum. Fish passage solutions capable of selectively passing desirable taxa while restricting the dispersal of undesirable taxa (selective connectivity) are sought to solve this connectivity conundrum. The Selective Bi-directional Fish Passage (FishPass) project is a multi-agency initiative that will take place in the Boardman (Ottaway) River to develop and implement selective bi-directional fish guidance, sorting, and passage techniques and technologies. Relatively large migrations of both white sucker *Catostomus commersonii* and longnose sucker *Catostomus catostomus*, species native to the system and thus desirable for future passage, were identified through preliminary assessment of the Boardman River fish community. The identification and quantification of desirable species for passage is an important step in developing a selective fish passage system. In the spring of 2022, a weir normally used for harvesting salmonids during fall migrations was installed and modified to incorporate two large box style traps used to capture and enumerate the longnose and white sucker migrations into the Boardman River. Additionally, we measured fish length, weight, and used a combination of T-bar tags and fin clips to mark individuals within the run for subsequent run size estimation using mark-recapture methods. The run size estimates produced using the preferred Overton (1965) methodology were 12,170 (95% C.I 10,700-14,107) longnose sucker and 5,284 (95% C.I 3,602-8,445) white suckers although variation was observed in estimates produced by both the Schnabel (1938) and Schumacher and Eschmeyer (1943) estimators. The run size estimates reported here are the first estimates of migratory run size for any species in the Boardman River. Overall, the results of this study will be valuable for understanding capacity requirements of the FishPass system and for application to modeling the potential nutrient subsidy that could be provided to the upstream ecosystem through the restoration of this native migration to upstream waters.

INTRODUCTION

Fish migration in riverine environments is a growing area of concern as mounting anthropogenic influences, particularly fragmentation from dams and other barriers, constitute a major threat to global river species diversity. Barriers impede the movement of fishes between areas critical to the completion of their lifecycle, affecting both population and ecosystem viability. However, a conundrum arises when the same impediment can also beneficially prevent the upstream invasion of non-native or undesirable species. As a result, restoring connectivity can have consequences for both desirable and undesirable species, resulting in a connectivity conundrum. Fish passage solutions capable of selectively passing desirable taxa while restricting the dispersal of undesirable taxa (selective connectivity) are sought to solve this connectivity conundrum.

The Selective Bi-directional Fish Passage (FishPass) project is a multi-agency initiative that will take place in the Boardman (Ottaway) River (Figure 1) to develop and implement selective bi-directional fish guidance, sorting, and passage techniques and technologies (Zielinski et al. 2020). The Boardman River has been the subject of one of the most comprehensive dam removal and restoration projects in Michigan's history and one of the largest such projects in the Laurentian Great Lakes (hereafter Great Lakes) Basin (The Boardman River Ecosystem Restoration Project; https://www.theboardman.org). The Boardman River Ecosystem Restoration Project was developed to improve habitat connectivity through the removal of three dams and modification of the last remaining and lowermost dam, the Union Street Dam. Removal of the Union Street Dam was not recommended because it is the lone barrier preventing invasive sea lamprey *Petromyzon marinus* from gaining access to high quality spawning habitat in the newly connected 288 km of perennial streams. Selective fish passage at Union Street Dam is desired to maintain a barrier to invasive species while simultaneously achieving the restoration goal to re-connect the Boardman River with Lake Michigan. FishPass will replace the aging Union Street Dam with an improved dam and fish barrier with the capacity for selective fish passage, providing the infrastructure and research capacity to develop approaches to selective fish passage that can be exported around the Great Lakes basin and beyond (Zielinski et al. 2020).

The primary goal of FishPass is to develop a way to restore ecological connectivity of fish populations while maintaining the integrity of a barrier to prevent access for undesirable taxa. Upwards of 56 fish species are known to currently or historically inhabit the watershed; although the connection between the Boardman River and Lake Michigan allows for the possibility of access by any species present in Lake Michigan (Kalish et al. 2018). The composition of the Boardman River fish community has changed through time as a result of a large number of factors including dam construction, intentional fish stocking, non-native organism introduction, road construction, road/stream crossings, and oil and gas extraction (Kalish et al. 2018). The fish community is currently composed of native species, intentionally introduced (hereafter introduced; e.g., rainbow trout [steelhead] *Oncorhynchus mykiss*) and unintentionally introduced (hereafter invasive; e.g., sea lamprey). Further, stakeholders hold mixed opinions about which species should be allowed access to the upper watershed once FishPass is operational. As a result, project partners developed an agreement that only species native to the Upper Great Lakes (hereafter desirable species) are eligible for passage for the first 10 years of FishPass development. During the 10-year development and optimization period, all introduced and invasive species are considered undesirable for passage. However, sorting processes are still desired to differentiate desirable and both groups of undesirable fishes to allow for future decisions on passage to be made by fishery managers.

Regular periodic electrofishing surveys downstream of Union Street Dam (hereafter termed the Lower Boardman River - LBR) starting in 2017 indicate the presence of 25 unique fish species (Swanson et al. 2023). Relatively large numbers of both white sucker *Catostomus commersonii* and longnose sucker *Catostomus catostomus* were encountered during spring sampling efforts. Biotelemetry exploration of movement phenology of species in the river also demonstrated seasonal migration of sucker species from Lake Michigan's Grand Traverse Bay (Swanson et al., 2023) into the river presumably for spawning. Biotelemetry and fish sampling data also showed that white sucker remain a minor component of the fish community in the LBR from spring to fall. Collectively, fish community sampling and biotelemetry studies identified the longnose and white sucker as the two most abundant desirable migratory species eligible for upstream passage within the current LBR fish community. Spawning migrations of Catostomids into Great Lakes tributaries has been a growing area of study over the past decade. Recent work has shown that sucker migration can transfer lake-derived nutrients into spawning streams which contribute to the stream food web and thus the recipient ecosystem as a whole via established trophic interactions (Childress et al., 2014). Concurrent work is underway to understand the potential nutrient subsidy from fish migration upstream in the Boardman River using suckers as a model organism. Critical to this modelling is an understanding of sucker run sizes. Once run sizes have been estimated, future work can pair nutrient data to model the potential nutrient subsidy delivered upstream under different future fish passage scenarios implemented via FishPass.

Identification and quantification of desirable species for passage is an important step in developing a selective fish passage system. As described by Zielinski et al. (2020), the challenge of selective fish passage is fundamentally one of sorting an assortment of things with variable attributes. The challenges of sorting individual species from an assemblage are directly related to the number of species present and level of variance in sortable phenological, morphological, behavioral, physiological attributes, and the number of individuals eligible for passage. Consequently, an estimate of the number of individuals to be sorted for passage becomes pertinent to the potential capacity of the sorting system and ultimately productivity of the re-connected ecosystem.

Estimates of the total number of fishes in sections of streams is routinely done by fisheries researchers and management agencies throughout the world. In Michigan, two basic methods including depletion and mark-recapture estimation are most commonly done in association with electrofishing sampling methods (Lockwood and Schneider 2000). However, depletion methods are difficult to apply to deep streams and rivers because capture efficiency declines with water depth. Consequently, mark-recapture approaches are most commonly applied for rivers with similar hydraulic conditions as those found in the Boardman River. Mark-recapture estimates conducted for routine assessment, such as those described by Lockwood and Schneider (2000), typically occur over a short duration (single to a few days) and thus provide a snap shot of the population abundance. Applying these types of methods to an estimation of a migratory run size presents additional challenges due to duration at which the migration occurs. However, closed population mark-recapture using the Peterson method with some modification can overcome the challenges previously described (Geen et al. 1966; Quinn and Ross 1985; Childress et al. 2016; Harris et. al 2020).

The overarching objective of this work was to quantify the run size of white and longnose suckers entering the Boardman River to inform the potential capacity requirements of a selective fish passage facility - FishPass. The secondary objectives of the work included 1) evaluating the efficiency of capturing fish to be used as test organisms in the future FishPass system by the modification and addition of trap infrastructure to the existing Traverse City Salmon Weir (TCSW) designed to harvest migrating pacific salmonids and operated by the Michigan Department of Natural Resources (MIDNR) and; 2) capturing animals for pathogen screening, isotopic analysis, and a con-current translocation experiment to understand potential future consequences of fish passage to the ecosystem.

METHODS

During spring 2022, staff from the Great Lakes Fishery Commission and partner agencies MIDNR, University of Windsor, and Cornell University installed several blocking panels at the MIDNR TCSW along with two large box style traps to capture and mark large number of longnose and white suckers to estimate how many individuals of each species migrate into the river from Lake Michigan.

STUDY SITE

Tributary to Lake Michigan's Grand Traverse Bay, the Boardman River is located in Grand Traverse County of Michigan's Lower Peninsula, USA. The river is approximately 45.4 km long, with a watershed area of approximately 743 km^2 that encompasses 288 lineal kilometers of perennial streams and 74 natural lakes. The LBR is entirely contained within the municipal boundaries of Traverse City and is characterized as an urban landscape. The Union Street Dam (44.76172° N, 85.62245° W; Figure 1) is located approximately 1.85 km upstream of where the Boardman River drains into Grand Traverse Bay (44.76499° N, 85.61272° W; Figure 1). The MIDNR TCSW (44.76449° N, -85.62695° W) is located at the approximate mid-point between the LBR confluence with Grand Traverse Bay and the Union Street Dam (Figure 1). The MIDNR TCSW was constructed ˙to block the LBR and direct migratory introduced salmonids up a pool-and-weir type fishway into a series of raceways in which they are held until maturation and then harvested for gametes to support the MIDNR hatchery system. The TCSW is typically operated from September until mid-October while the remainder of the year the grates are removed allowing passage of all species.

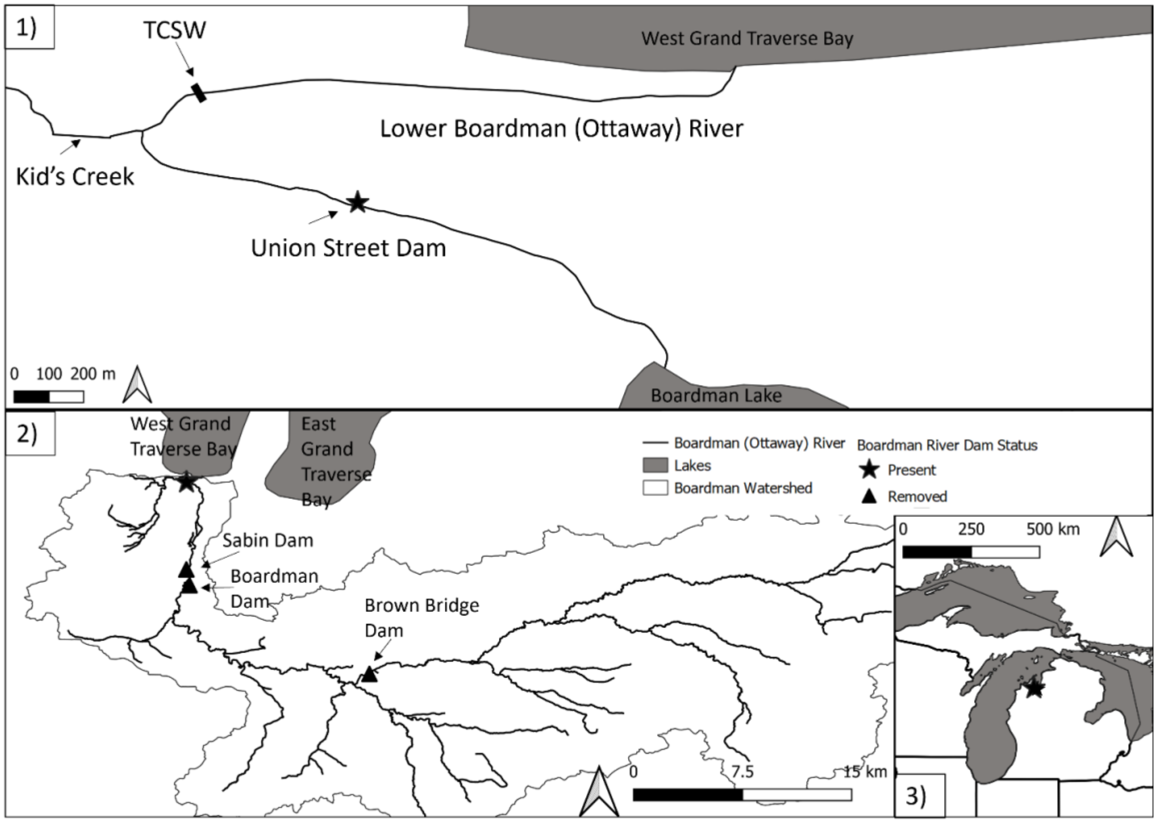

Figure 1. (1) Lower Boardman River showing the Michigan Department of Natural Resources Traverse City Salmon Weir (TCSW) and the future location of FishPass at the Union Street Dam; (2) Boardman (Ottaway) River watershed and location of the three former dams and future location of FishPass at the current Union Street Dam; and (3) Regional context of the project location.

ABIOTIC DATA

Collection of basic environmental conditions was done in association with the overarching FishPass project. Discharge in the Boardman River is continuously monitored by USGS gauges at Beitner Road (gauge # 04127200) and Brown Bridge Road (gauge # 04126970), and the Beitner Road station was used to derive continuous discharge data at Union Street Dam through direct drainage area ratio adjustment. River stage (meters relative to sea level) data were collected from three pressure sensors (Model MX-2001-04-S, Bourne, MA, USA). Sensor's locations include: 1) approximately 100 m upstream from where the Boardman River drains into Grand Traverse Bay; 2) below Union Street Bridge South (downstream of Union Street Dam) and; 3) upstream of Union Street Dam. Continuous water quality data were collected at the MIDNR TCFW using a YSI multiparameter water quality SONDE (Model 6920 V2; YSI Inc, Yellow Springs, OH, USA) installed approximately one meter upstream from the weir panels on the North bank of the river. Water quality parameters measured included water temperature, specific conductivity, conductivity, turbidity, dissolved oxygen, and dissolved oxygen saturation. Minimum and maximum air temperature was also recorded at the Cherry Capital Airport (Station ID USW00014850), approximately 4.5 km South East from the trapping site, and was obtain from the National Oceanic and Atmospheric Administration Climate Data online (Access 1/16/2023; https://www.ncei.noaa.gov/cdo-web/)

WEIR PLACEMENT AND TRAP DESIGN

The MIDNR TCSW spans the entire width of the Boardman River (Approximately 22.5 m wide) and is composed of 15 bays that can be blocked off by installing 1.5 m W x 2.4 m H panels composed of vertical bars spaced at 3 cm on center that protrude above the water surface. The box traps were custom fabricated by SLH Metals (Corunna, MI, USA) for the purposes of this project. The two individual traps installed on the existing weir were labeled downstream facing trap (DSF) and upstream facing trap (USF), in accordance with the direction that the entrance funnel was pointing relative to the flow of the LBR. The DSF caught fish migrating upstream from the downstream side of the weir and conversely the USF caught fish migrating downstream from the upstream side of the trap. The DSF consisted of a 2.3 m L x 1.5 m W x 1.5 m H extruded mesh box affixed to the upstream side of the TCSW on the north side of the LBR (Figure 2). The USF consisted of a 1.5 m L x 1.5 m W x 2.1 m H extruded aluminum mesh box affixed to the downstream side of the TCSW on the south side of the river channel. A custom weir panel was fabricated and installed in the weir panel bay upstream of the USF and connected to the entrance of the USF trap using a custom 3 m long, 0.9 m diameter hoop net (Duluth Nets by H. Christiansen Co., Duluth MN, USA). Hoop nets consisted of 19.05 mm square black treated #15 knotted nylon net, eleven 0.9 m hoops, spaced at 0.3 m intervals. Floating dock sections (1.2 m by 2.4 m; Dock Blocks of North America, North Charleston SC, USA) were installed on the north side of both box traps to facilitate staff access required to remove fish. The funnel entrance on both traps was comprised of a 0.5m long funnel with a 0.9 m diameter opening that reduced to 0.15 m diameter. The box traps and funnels were lined with 19 mm x 2 mm extruded aluminum mesh.

Trap installation required the assistance of a crane from the north bank of the river (see Figure 2) due to the weight of the traps (approximate weight 154 and 218 kg). Due to county road seasonal weight restrictions that limited when the crane could access the site, traps and associated weir infrastructure were installed on 22 April 2022, at which point the spring sucker migration had already commenced.

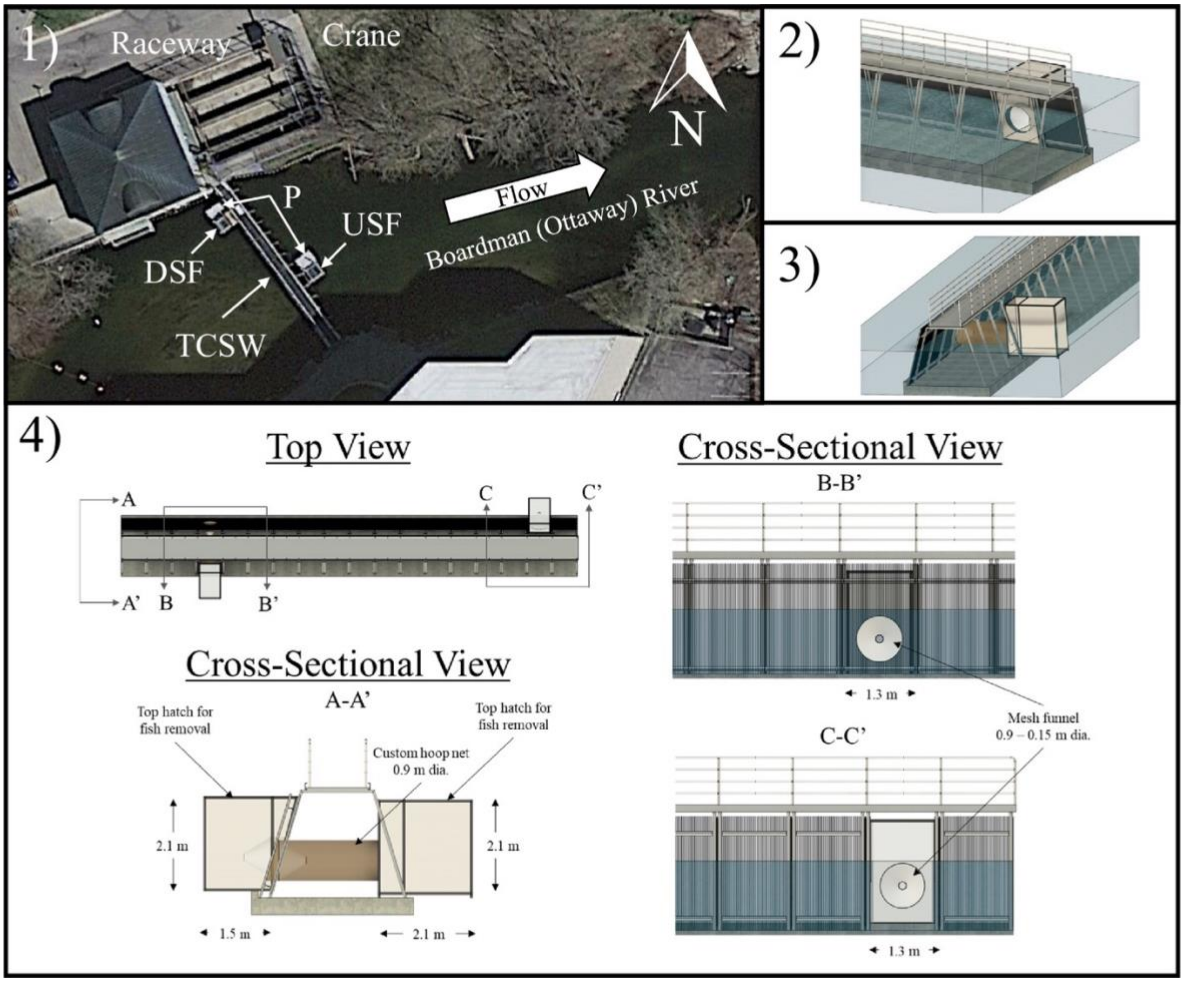

Figure 2. *Michigan Dept. of Natural Resources Traverse City Salmon Weir (TCSW) modified for the capture of migratory suckers Catostomus sp. (1) Aerial photo of the traps installed identifying the flow direction, weir structure, downstream facing trap (DSF), upstream facing trap (USF), associated work platforms (P), location of the salmon raceways, and crane pad used for weir panel and trap installation; (2) rendering of the DSF under mean water surface elevation (MWSE) conditions based on data collected from 2017-2021; (3) rendering of the USF under MWSE conditions based on data collected from 2017-2021; and (4) design schematic and dimensions of both traps.*

TRAP OPERATION, BIOLOGICAL DATA COLLECTION, AND ENUMERATION

Traps were operated from 22 April – 24 May 2022. Both traps were processed twice daily, once in the morning and once in the late afternoon. Fish captured in the traps were transferred to a large live well filled with river water, placed on the access walkway above the weir panels. Fish were removed from the traps using long handled dipnets with 41cm x 41 cm x 46 cm rectangular hoop 5 mm mesh (Midwest Lake Management INC., Polo, MO, USA). All fish were identified to species, examined for marks and tags, expressed to identify sex, measured for total length to the nearest millimeter, and where feasible, the first 10 individuals of each species processed were also weighed to the nearest gram. After 27 April, rainbow trout were not measured or weighed during processing although they were visually assessed for sex, and the presence of fin clips or other marks. This change was made to increase trap processing efficiency to reduce stress on the animals captured in the traps while still achieving project goals. The biometric information for non-sucker species is not reported here but was archived in the FishPass database.

Sex and reproductive status of fish was determined by attempting to express gametes (squeeze the abdomen from anterior to posterior end of fish and watch the vent for expression of any gametes). If gametes were expressed, the fish was noted as male (M) of female (F). Previous studies on white sucker have used the presence of tubercles on the anal fin of males to distinguish between sex (Quinn and Ross 1985); however, the presence of tubercles has been noted on females in this system and coloration differences were sometimes hard for less experienced staff to use these features to reliably distinguish sex. As a result, if no gametes were expressed but sexually dimorphic features were identified by experienced staff members (e.g., hooked jaw on male rainbow trout, coloration of male longnose sucker, tubercle presence on male white suckers) sex was also recorded with an accompanying indicator of lack of gamete expression.

Reproductive status was recorded using three categories: ripe, spent, or unknown. Ripe was defined by ready expression of gametes and the presence of extended abdomen for females. Spent is the classification for when gametes can be expressed but in very low amounts or with increased effort and it appears that the abdomen is “loose”, “empty”, etc. meaning that the fish has recently spawned. Unknown was indicated when no gametes were able to be express and sexual dimorphism and abdomen characteristics were unclear.

For the purpose of enumeration, all white and longnose sucker were implanted with a blue floy T-bar anchor tag (model FD-68BC; Floy Tag & Manufacturing Inc, Seattle, WA, USA), a small section of caudal fin was clipped, and they were released on the opposite side of the weir from which they were captured. Suckers captured in the downstream facing trap (upstream migrants) were released on the upstream side of the trap and a small clip was removed from the upper portion of the caudal fin (UCC). Suckers captured in the upstream facing trap (downstream migrants) were released on the downstream side of the trap and a small clip was removed from the lower portion of the caudal find (LCC). Caudal fin clips were selected because, to our knowledge, no other ongoing research had utilized this clipping location. All other fish species caught in the traps were released on the opposite side of the weir from where they were caught, but non-target species were not tagged or clipped for the purpose of this study. Recaptured suckers were documented through the presence of caudal fin clips. Once identified their individual floy tag was also documented to reference back to the tagging occasion. Suckers captured with caudal fin clips but lacked floy tags were used to calculate tag loss rate across the study period.

After all fish in both traps were processed, the weir panels were cleaned of debris and examined for any fish impinged after processing or expired from previous processing intervals. Recently impinged fish were placed in live-wells and re-released after an extended recovery period. In some instances, expired fish were found impinged on the upstream side of the weir panels. In these instances, the weir panels themselves were treated as a third trap and they were processed similarly to the other traps with the exception that they were indicated as expired and disposed of as permitted (MIDNR Scientific Fish Collection Permit # 12062021153859). All live-well tanks and processing equipment were emptied and thoroughly cleaned between each processing interval.

Prior to the onset of this study a variety of tags had previously been implanted in fish in the Boardman River including but not limited to floy T-bar tags, passive integrated transponders (PIT) tags, radio telemetry tags, and acoustic telemetry tags. Additionally, a variety of fin clips had been applied to various species for other research and management activities occurring within the study system. A vast majority of fin clips relate to stocking programs conducted by the MIDNR or other agencies in the Boardman River, Lake Michigan, and connected water bodies. However, some clipping was also done in association with ongoing assessment of fish movement and the associated telemetry tag implantation. As a result, all fish processed were checked for the presence of any of these marks or tags in addition to the tags and clip patterns being utilized for this study. Presence of recaptured fish from other work was noted differently than recaptures from this mark-recapture evaluation, however, if a sucker was tagged previous to this work and recaptured on multiple occasions, the first capture event was considered its marking event and the subsequent capture a recapture event. Recapture was identified through cross referencing of tag identification numbers.

To facilitate recapture efforts, two boat electrofishing surveys, one at the onset and one at the conclusion of trapping operations, were conducted following MIDNR electrofishing sampling protocols for non-wadeable rivers (Wills et al. 2011). The first electrofishing survey was conducted on 03 May 2022. During this survey all suckers were examined for fin clips. Suckers captured above the weir were given floy tags and LCCs (the same mark given post capture in the DSF) to account for individuals who migrated into the river prior to the installation of the weir. The second electrofishing survey was conducted on 18 May 2022 with the primary intention of collection one additional large re-capture event in hopes of reducing the size of the confidence interval surrounding estimates of run size.

The first 60 white and longnose suckers captured during trap operation were collected for pathogen screening and were not used for any run size estimation (See fish health section). In addition, approximately 10 males and 10 females of each species of sucker was also harvested throughout the operation for isotopic analysis. Near the conclusion of the trapping operations (10 May- 15 May) 110 of each sucker species were removed from trapping operations for con-current translocation experiment in which they were implanted with acoustic transmitters and released above the union street dam. Suckers translocated and collected for isotopic analysis were used in calculations as observed individuals but were not included in the number marked and released for run size estimation calculations (See run size estimates section). As part of the translocation operation, some fish were held in holding tanks within the weir facility to facilitate efficient tagging and translocation. During this time the facility experienced a power outage and 55 longnose and 1 white sucker perished in the holding tanks.

The DSF trap encountered some structural integrity problems on 07 May in which the welds that attached the extruded mesh broke loose allowing fish to swim through. This was remedied by constructing a PVC pipe frame insert with plastic mesh that was inserted within the existing extruded mesh and attached to the existing trap funnel. Trap operations were also suspended by removing three of the weir panels to allow fish to move freely up or downstream on the afternoon of 16 May and did not resume until the afternoon of 18 May due to a high number of mortalities impinged on the screen. The panels were reinserted following the 18 May electrofishing survey.

FISH HEALTH

To understand and mitigate risk of disease transmission, the first 60 white and longnose suckers captured during trap operation were collected and held alive in holding tanks until the full sample size of 60 was reach. Upon which point they were transported alive to the Michigan State University Aquatic Animal Health Laboratory to be screened for a suite of potential pathogens. Specimens were sampled for Viral Hemorrhagic Septicemia Virus (VHSv), Infectious Pancreatic Necrosis Virus (HPNv), and Infectious Hematopoietic Necrosis Virus (IHNv) via culture analyses on *epithelioma papulosum cyprini* (EPC) and fathead minnow cell lines. Rapid VHSv screening was also conducted in addition to analyses via cell-culture to expedite results to allow for the aforementioned translocation experiment to be conducted within the perceived time constraints of the migration. Rapid VHSv screening was conducted on all samples (5 fish/pool, kidney tissues) using the rRT-PCR assay of Jonstrup et al. (2013). Laboratory assays were conducted in accordance with the guidelines of the Great Lakes Fishery Commission - Great Lakes Fish Health Committee (GLFC-GLFHC), the American Fisheries Society - Fish Health Section (AFS-FHS), and/or the World Organization for Animal Health (OIE).

RUN SIZE ESTIMATES USING MARK-RECAPTURE

Sucker run spawning size estimates were calculated using three closed, population mark-recapture methods developed for multiple marking and sampling periods. Multiple estimation approaches were utilized to deal with the potential and observed departures from the assumptions of a closed population and to understand the full scope of range in spawning-run sizes. The basic assumptions of a closed population model are that the population being estimated is in fact closed, or more specifically, there is no recruitment or morality and the population numbers remain stable in time. However, sucker migration into the LBR fundamentally represents a proportion of an open population inhabiting Grand Traverse Bay and connected waters moving into the river for the primary purpose of reproduction. We assert that this methodology can be applied to this scenario and the assumption of a closed population is acceptable in this case because every individual within the sampling period was subject to capture at the sampling point both when migrating upstream and downstream.

Estimates were produced from Schnabel (1938), Schumacher and Eschmeyer (1943), and Overton (1965) methods (Table 1), following Seber (1982) and Krebs (2014). These methods assume a closed population but vary in approach. Briefly, the Schnabel (1938) and Overton (1965) estimators are modifications to the Peterson method extended to a series of samples such as those that occurred in our study. Overton (1965) differs from the other two methods due to its iterative nature and specific addition of a modifier (z_i; Table 1) to deal with proportionally large numbers of known removals. The Schumacher and Eschmeyer (1943) estimator differ from the other two in that it is regression-based, and thus less sensitive to departures from the underlying assumptions. The Schnabel and Schumacher-Eschmeyer estimates were conducted using the 'fishmethods' R package (Nelson 2022) and the Overton estimate was derived independently using the equations provided in Seber (1982). Assumption testing of conformity to a close population model was conducted through visual examination by plotting the proportion of the sample marked in a sampling event compared to the number of suckers marked in the population (Appendix 1).

Table 1. *The mark recapture equations and parameters to derive the Schnabel ($\widehat{N}_{sch}$; 1983), Schumacher and Eschmeyer ($\widehat{N}_{se}$; 1943), and Overton ($\widehat{N}_o$; 1965) population estimates of white sucker Catostomus commersonii and longnose sucker Catostomus catostomus in the lower Boardman (Ottaway) River. Note that Overton (1965) estimator is an iterative solution rather than an explicit one.*

<table>
<tr><th>Method & Equations</th><th>Parameters</th></tr>
<tr><td>Schnabel (1938)
$\widehat{N}_{sch} = \frac{\sum_{i=1}^{s} n_i M_i}{\sum_{i=1}^{s} m_i + 1}$</td><td rowspan="3">$\widehat{N}$ total population size
s number of samples
n_i total number of individuals captured on the ith occasion
m_i number of marked individuals in n_i
z_i number of individuals removed on the ith sample
$u_i = n_i - m_i$ number of individuals marked for the first time and released in ith sample
$q_i = n_i - m_i - z_i$ number of marked individuals added on the ith sample
$M_i = \sum_{i=1}^{s-1} u_i$ number of marked individuals in the population prior to the ith sample
$Z_i = \sum_{j=1}^{i-1} z_j$ total number of individuals removed from the population prior to the ith sample
$Q_i = \sum_{j=1}^{i-1} q_j$ total number of marked individuals available to capture on the ith sample
$X_i = \sum_{j=1}^{i-1} m_j$ total number of recaptured marks up to and including the ith sample
$\dot{N}^{(j)}$ is determined by the previous iteration where $\dot{N}^{(j)} < \widehat{N}_o < \widehat{N}_o^{(j)}$
i, j, k summation indices</td></tr>
<tr><td>Schumacher and Eschmeyer (1943)
$\widehat{N}_{se} = \frac{\sum_{i=1}^{s} n_i M_i^2}{\sum_{i=1}^{s} m_i M_i}$</td></tr>
<tr><td>Overton (1965)
$\widehat{N}_O^{(j)} = \widehat{N}_{sch} + A^{(j)}$
$A^{(j)} = \frac{1}{X_s} \sum_{i=1}^{s} \frac{Z_i n_i Q_i}{(\dot{N}^{(j)} - Z_i)}$</td></tr>
</table>

The longnose and white suckers caught in USF and DSF traps, and fish found impinged on the weir structure itself during processing were treated as the same sampling event. The two electrofishing surveys were also considered as independent sampling events. As explained previously, suckers were removed from the mark-recapture experiment for numerous reasons including translocation, related sampling, and accidental mortality. These events were accounted for in the Schumacher-Eschmeyer and Schnabel estimates by subtracting the number removed from the experiment from the number of new marks administered. They were used as the z_i parameter in the Overton equation. However, they were used in the total number of animals captured on a sampling occasion because in all cases they were checked for marks prior to removal. A small number (n=5) of recaptures of suckers translocated above the dam were identified and distinguished from other recaptures by their FLOY tag ID and were not used in any run size estimation because they did not meet the assumption of equal probability of capture.

The use of the weir panel impingements as a source of capture data requires a similar assumption to that of a closed population in that the mortality rate on the spawning ground (i.e., above the weir) should be similar across marked or unmarked groups and thus negligible. It follows that trap results from the dead fish on the weir panels can be used if both groups (tagged and untagged) have an equal probability of mortality (i.e., impinging on the weir panels). The number of marked and unmarked white suckers impinged on the weir was approximately equal. A majority of the impinged longnose sucker were marked thus potentially introducing a directional bias to the estimate. However, disproportionately few untagged longnose suckers were observed above the weir during the electrofishing sampling conducted at the onset of the trap operation, thus supporting the assumption that mortality rates were similar across marked and unmarked groups on the weir panels for both groups of fish within both species.

RESULTS AND DISCUSSION

ABIOTIC DATA

Water temperature, air temperature, conductivity, and river stage at the mouth generally increased through the study period. Discharge, river stage at the Union Street Dam, and turbidity generally decreased through the study period. Mean water temperature during the study period was 12.2 °C (range: 6.9-17.7°C). Mean maximum air temperature was 19.4°C (range: 2.2-35.6°C) and mean minimum air temperature was 5.48°C (range: -5.5-15.0°C). Mean discharge was 9.18 m^3/s (range: 8.1-10.9 m^3/s), mean river stage was 177.19 meters above sea level (range: 177.06-177.36 meters above sea level) and 176.95 meters above sea level (range: 176.79 -176.95 meters above sea) level at the Union Street Dam and river mouth respectively.

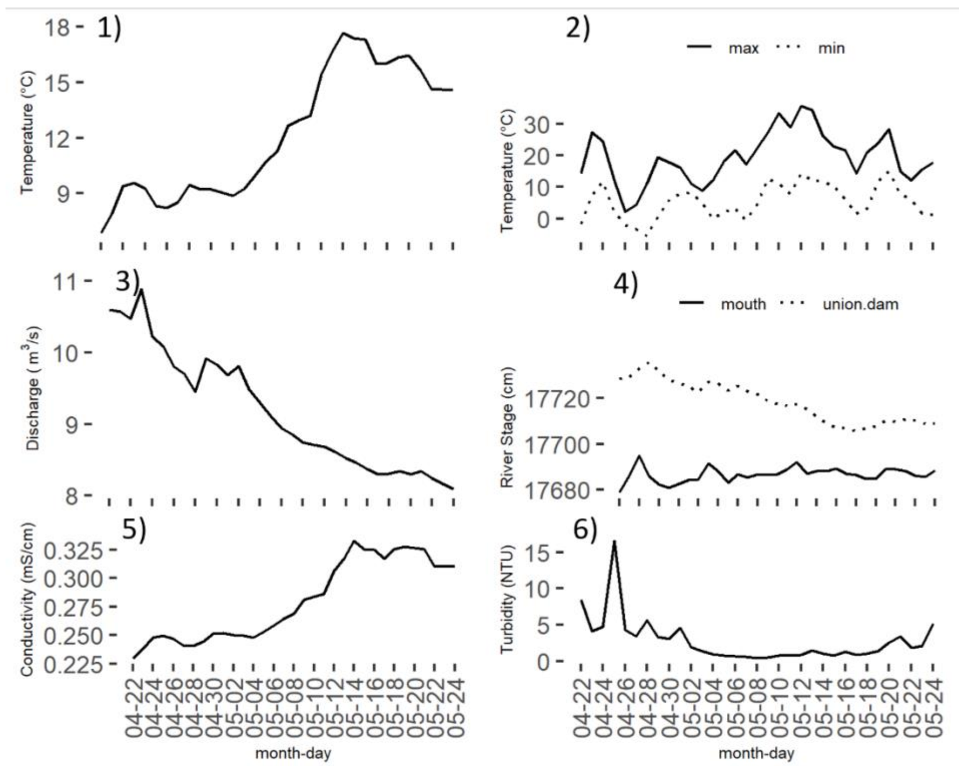

Figure 3. *(1) Abiotic data including river temperature (°C) at the Boardman River Weir; (2) minimum and maximum air temperature at the Cherry Capital Airport; (3) discharge (m^3/s) at Union Street Dam; (4) river stage at the river mouth and at the Union Street Dam (cm relative to sea level; (5) conductivity (mS/cm); and (F) turbidity (NTU) at the Traverse City Salmon Weir (TCSW) between 22 April and 24 May 2022.*

ENUMERATION

We captured 3,167 individual fish representing eight taxa during trap operations of which a vast majority were suckers and rainbow trout (Table 2). Longnose sucker had a considerably higher catch (n=2,427) with peak catch rates exceeding 300 individuals per day and a sizable number of white suckers were also caught (n=454) with peak catch rates exceeding 100 individuals per day (Figure 4). White suckers were caught from the onset of trap operations and were consistently present in the trap catch. Longnose suckers demonstrated a more discrete presence in the trap catch as they were not caught until the fifth day of operation, large numbers were not observed until the tenth day of operation (02 May), and the peak catch lasted ten to twelve days.

Catch rates were considerably higher in the DSF trap in comparison to the USF trap for both sucker species. This is likely due to a combination the fish's motivation and ability to detect hydraulic cues to identify the trap openings. Suckers are extremely motivated to move upstream due to an intrinsic need to reach spawning habitat to reproduce. With the weir in place, the only way to proceed upstream of the barrier was through the DSF trap entrance funnel. Conversely, the USF was affixed at the downstream side of the weir itself and connected via a hoop net. The small size of the funnel entrance when taken into consideration with the porous weir likely did not create as obvious of a hydraulic stimulus directing fish to the trap for the USF in comparison to the DSF. The observed poor performance of the DSF on 07 May is explained by the structural deficiency of the trap. Lastly, we had notable lack of recaptures for white sucker utilizing just the DSF and USF traps. The inclusion of the weir panel as a capture site and the supplemental electrofishing survey allowed us to bolster recapture numbers of white sucker to facilitate run size estimation.

Table 2. *Number of individuals (n), and recaptures from weir operation and translocation experiment (Trans; i.e., fish that moved downstream of dam after translocation above) across the total sampling effort, downstream facing trap (DSF), upstream facing trap (USF), weir panel, two electrofishing surveys conducted on 05 and 18 May 2022, and the integration of both trap operations and electrofishing used to derive run size estimates. Note: recaptures from translocation were not used in run size estimation. [CWS=white sucker Catostomus commersonii LNS=longnose sucker Catostomus catostomus, NOP=Northern pike Esox lucius, RBT=rainbow trout [steelhead] Oncorhynchus mykiss, RKB=rock bass Ambloplites rupestris, SL= sea lamprey Petromyzon marinus, SMB=smallmouth bass Micropterus dolomieu, WAE=walleye Sander vitreus].*

	Trap Only								Electrofishing		Trap + Electrofishing	
	Total		DSF		USF		Weir Panel					
Species	n	Recap (Trans)	n	Recap (Trans)	n	Recap	n	Recap	n	Recap	n	Recap
CWS	454	15 (2)	405	0 (0)	49	2 (0)	24	13 (2)	166	11 (2)	620	26 (4)
LNS	2427	237 (1)	2222	9 (0)	205	133 (0)	106	95 (1)	116	5 (0)	2543	242 (1)
NOP	5	-	5	-		-	1	-	-	-	5	-
RBT	274	-	272	-	2	-	54	-	-	-	274	-
RKB	1	-	1	-	0	-	0	-	-	-	1	-
SL	1	-	0	-	1	-	0	-	-	-	1	-
SMB	4	-	4	-	0	-	0	-	-	-	4	-
WAE	1	-	1	-	0	-	1	-	-	-	1	-
Total	3167		2910	0	257		186		282		3449	

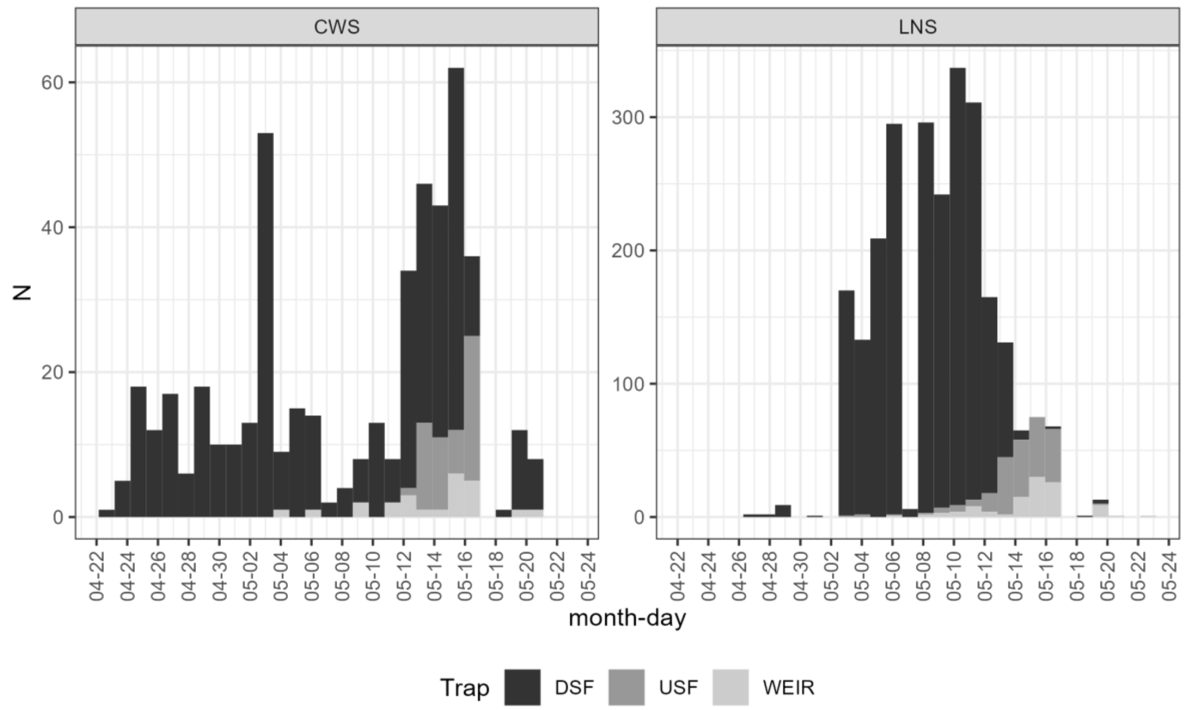

Figure 4. *White sucker Catostomus commersonii (CWS) and longnose sucker Catostomus catostomus (LNS) caught per day in downstream (DSF) and upstream facing (USF) traps and impinged on weir grates (WEIR) installed between 22 April and 24 May 2022.*

A spike in observed mortalities of suckers on the weir panels occurred between 14 May – 16 May (Figure 5) which lead to the aforementioned suspension of trap activities. The event likely occurred due to a combination of trap stress, environmental stress driven by quick increases in water temperature and the interaction between the sucker's desire to out-migrate and relatively poor trap efficiency of the USF trap. The white and longnose sucker runs are migratory spawning runs and at the conclusion of spawning, these suckers are generally motivated to return downstream to their non-spawning habitat in the Lake Michigan. The USF trap and weir impingement rates spike (Figure 4) around the time of these mortality rates spike and coincide with peak river temperatures observed (Figure 3, Figure 5), suggesting that increased catch efficiency in the USF would have helped mitigate weir impingement and mortality rates by allowing fish to exit the river as temperatures rise.

The secondary objectives of the work included evaluating the efficiency of capturing fish by adding trapping infrastructure to the TCSW. The enumeration results demonstrate that this methodology was successful for rainbow trout, and white and longnose sucker. However, lower catch rates of any other species suggest that alternative methodology be considered when attempting to capture large numbers of individuals of other species in support of future research activities at FishPass.

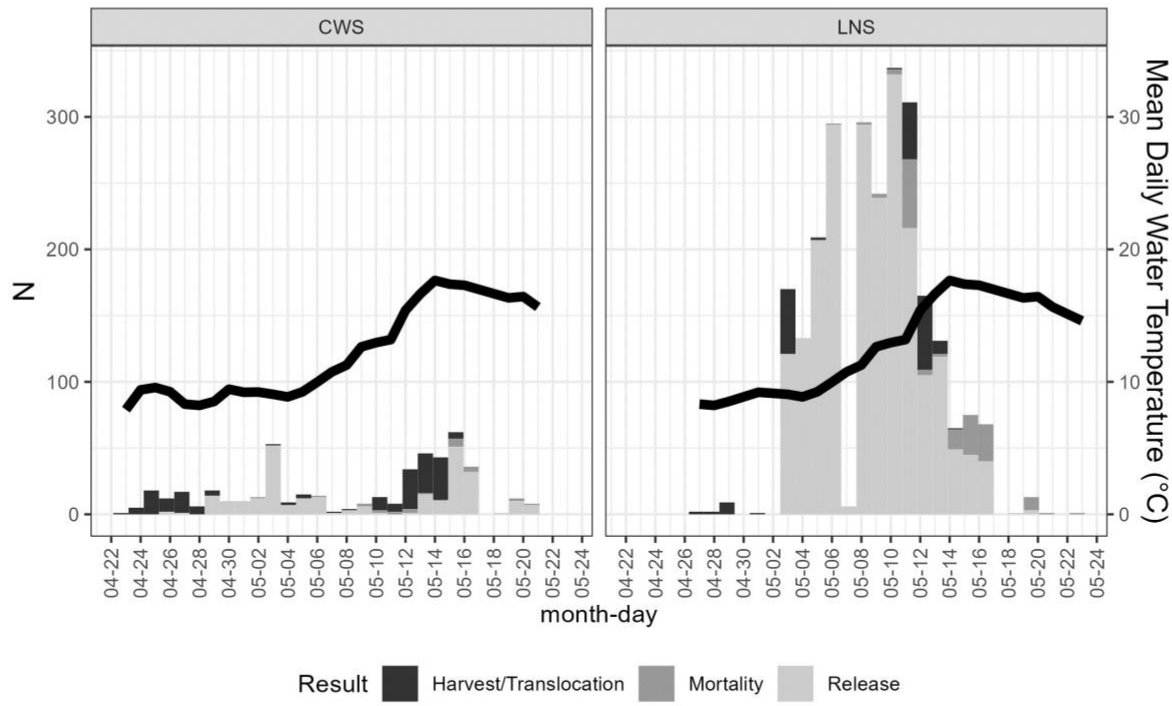

Figure 5. White sucker Catostomus commersonii (CWS) and longnose sucker Catostomus catostomus (LNS) daily trap-catch with water temperature (°C; black line) at the trap location. Note: mortality on 11 May was due to a holding tank failure not mortality associated with trap operation.

BIOLOGICAL DATA

Male longnose suckers were more abundant (51% Male, 44% female) and showed up slightly earlier than females (Figure 6). The observation of slightly more abundant male longnose sucker was also observed in an inland population of longnose suckers (Geen et al. 1966) and white suckers (Quinn and Ross, 1985) which had a documented a 1:1 sex ratio in the source lake. Quinn and Ross (1985) attributed skewed sex ratios in sucker spawning ratios to non-annual spawning behaviors in which males were three times more likely spawn in a given year and females had higher growth rates due to skipped spawning. White sucker catches had disproportionately greater females in comparison to male. However, given the protocol used in sex determination it is likely that a larger number of the individuals with undetermined sex may have been male as they did not have the distinct loose extended abdomen. It is generally thought that males of both species tend to arrive on the spawning grounds earlier than females. An examination of the 03 May electrofishing survey does show there were more males in the LBR above the weir. During trap operations, almost all suckers of both species captured in the DSF trap were identified as ripe. As expected, spent fish were almost exclusively caught in the USF trap or impinged on the weir panels during downstream post-spawn movements. However, about half of the fish in the USF trap were identified as ripe indicating that while some of the fish had completed spawning before returning downstream, some had yet to spawn. The LBR is a relatively short river reach and sucker spawning has been previously observed throughout the entire LBR reach. The interesting result that not all fish returning downstream were spent indicates that perhaps suckers move up and downstream within this reach throughout the spawning period.

The average total length of suckers captured in the trapping operation was 486 mm and 450 mm for white and longnose suckers, respectively. Females were longer and heavier on average for both species (Figure 7) a phenomenon that has also been observed in other study systems (Brown and Graham 1954; Geen et al. 1966; Childress et al. 2016).

Although the primary intention of trap operations was for sucker enumeration and run size estimation it's worth noting that the rainbow trout that were encountered demonstrated a 54.9% clipped rate (59.7% for females, 69.2% for males) suggesting that approximately half the rainbow trout present during the study are from a stocked source while the other half are naturally reproduced. Ratios of natural to stocked fish are informative to management agencies and operations in understanding the population dynamics of rainbow trout in this system.

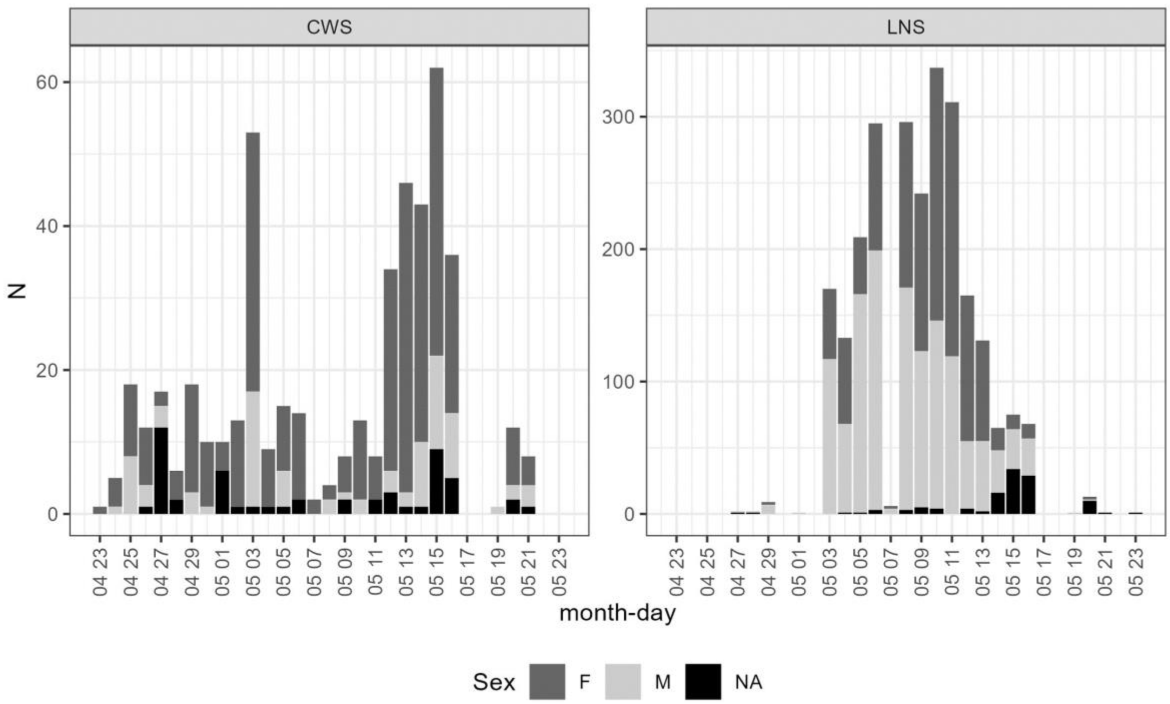

Figure 6. *White sucker Catostomus commersonii (CWS) and longnose sucker Catostomus catostomus (LNS) trap catches/day during April 22 – May 24 2022. N=number of individuals; note different scales.*

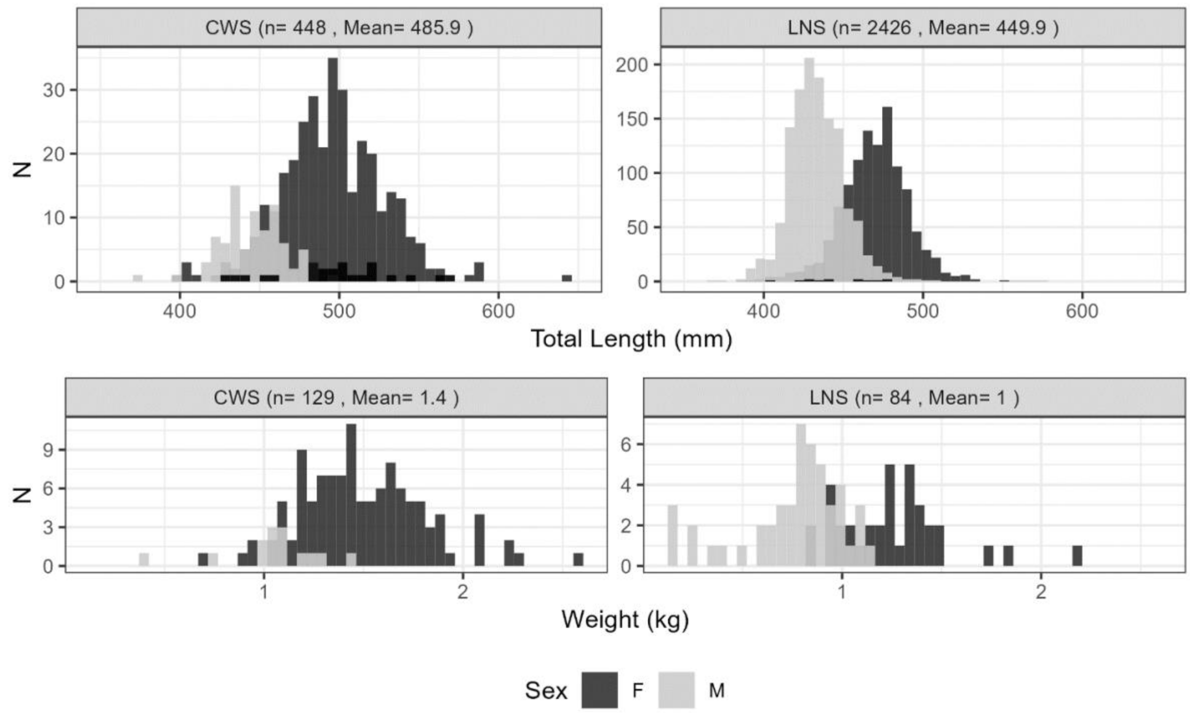

Figure 7. *Total length (top) and weight (bottom) of male (M), female (F), and unknown sex (NA) white suckers Catostomus commersonii (CWS) and longnose suckers Catostomus catostomus (LNS) trap catches/day during April 22 – May 24 2022.*

FISH HEALTH

No presence of VHSv, HPNv, or IHNv were detected via cell culture or rRT-PCR analyses.

RUN SIZE ESTIMATION

The three methods used to estimate the run size of suckers from 22 April to 24 May 2022 demonstrated variable results due to the underlying methodology. In general, a larger number of longnose suckers migrated into the LBR during the study period in comparison to white sucker (Table 3). All three methods resulted in overlapping confidence intervals which suggest that the true number of individuals within the migration lies somewhere intermediate to these results. The results from the Overton (1965) method are the most applicable to our study due to the number of mortalities we encountered during sampling and the number individuals removed from the mark-recapture experiment for additional studies. This method resulted in an estimation of 12,170 longnose and 5,284 white suckers in the run although we identify that not all the assumptions of this model were met. Assumption testing (Appendix 1; figures A1-1, A1-2) demonstrate some departure from the assumption of a closed population for both white and longnose sucker estimations. Models meeting the assumptions of a closed population should produce a linear trend in figures A1-1 and A1-2 plot while curvilinear trends indicate departures from the close population assumption (Seber 1982). The relationship for both species appears to approximate a logistic curve and the white sucker plot appears to become more sigmoidal as it levels off at high numbers of marked individuals in the population. However, the non-linear trends observed can be explained by the fact that the spring river migration portion of the population is highly motivated to move upstream, resulting in recapture events occurring on the downstream migration; sometime later in the sampling events. As a result, a perfectly linear trend would not be expected as recapture depends differentially on the timing of outmigration rather than the number of individuals tagged in the population. Taking this in account and visually examining the later portion of the graph the trend appears more linear. Overall, we identify that these models do not meet the assumptions ideally. This is not unique to our study as Seber (1982) and Overton (1965) recognize that seldom is a natural population truly closed. The potential violations of the assumptions of the Overton (1965) model suggest it is perhaps best to utilize the larger, more conservative confidence intervals provided by the Schumacher-Eschmeyer (1943) method.

Various studies have estimated the run size of longnose and white sucker migrations across a range of habitats utilizing pooled sample (i.e., methods that do not explicitly account for multiple marking and recapture periods) versions of the Peterson estimator (Geen et al. 1966; Childress et al. 2016) and regression-based Schumacher and Eschmeyer (1943) method (Quinn and Ross, 1985). Although violations of the closed population assumption may significantly bias population estimates, the estimators used here are perhaps the best option for the short duration migratory runs and duration of the trapping operation without developing a way to capture all migrating individuals; a task that is particular difficult in a river as large as the Boardman River. We suggest that while imperfect, our results are perhaps more robust than previously documented methods of using a pooled sample as we specifically account for multiple marking and recapture periods as well as known permanent removals from the population.

Table 3. *Run size estimates (N), lower (LCI) and upper (UCI) 95% confidence intervals, distribution used in confidence interval calculations (CI Distribution), and the inverse standard error (SE) from the Schnabel (1938), Schumacher and Eschmeyer (1943), and Overton (1965) methods for white sucker Catostomus commersonii (CWS) and longnose sucker Catostomus catostomus (LNS) spawning-run size estimation from the Boardman River (22 April-24 May 2022).*

Species	Method	N	LCI	UCI	Inverse SE	CI Distribution
LNS	Schnabel	11,752	10,388	13,530	5.48E-06	t
	Overton	12,170	10,700	14,107	5.29E-06	t
	Schumacher-Eschmeyer	9,338	6,123	19,663	2.75E-05	t
CWS	Schnabel	4,961	3,411	8,395	4.30E-05	Poisson
	Overton	5,284	3,602	8,445	4.04E-05	Poisson
	Schumacher-Eschmeyer	4,770	3,682	6,770	3.05E-05	t

Our resulting run size estimates are comparable to Childress et al. (2016), which reports run sizes of both sucker species into three tributaries on the Western shore of Lake Michigan. In particular the longnose sucker results from our study are similar to those of Lily Bay (n=11,352) and Hibbard Creek (n=12,305) while the resulting estimates for white sucker are similar to that of Wisely Bay Creek (n=5,376; Childress et al., 2016). To our knowledge, this is the only other study that reports mark-recapture based run size estimates for suckers in Lake Michigan tributaries. A comparison of these results should also consider the similarities and differences between study systems. While all are tributaries to Lake Michigan, the Boardman River is much larger with a discharge of 6.8 m^3/s at base flow (8.1-10.8 m^3/s observed during the study) in comparison to the smaller second-order streams evaluated on the Western shore whose discharge remain < 1.2 m^3/s during their respective study periods. This contrast suggests the Boardman River could support a large migration of suckers as larger rivers potentially have a more available habitat. However, the LBR has been isolated from the upper watershed for over a hundred years and is relatively similar in longitudinal length and potentially available spawning habitat as the tributaries evaluated by Childress et al. (2016).

Another study evaluating trap catches of seasonally operated electric sea lamprey barriers in eight tributaries to Lake Superior found catch rates ranged from fourteen to 25,737 and fifteen to 4,816 for longnose and white suckers respectively (Klinger et al., 2003). Klinger et al. (2003) were evaluating trap catches and not true mark-recapture run size estimates, however trap efficiency is never perfect, and their range of trap catch rates from a variety of tributaries confirm that the results presented here fall within a reasonable range.

It is also important to caveat that our study only provides an estimation for the time period in which it was conducted. The onset of trap operation was delayed and operations concluded earlier than planned due to an observed increase in mortalities. It is likely that this work underestimated the total annual run size of white sucker as both the trapping data presented here and related telemetry work conducted by Swanson et al. (2023) demonstrate that this species has a more protracted migration in comparison to longnose sucker. This study and the research motivating it is intended to support and restore these migrations, as such it was impossible to justify extending the duration of the study considering the observed mortality. This caveat is important as these results do not represent the total population of suckers available to migrate. White suckers have been documented to demonstrate partial migration in that not all individuals will undertake annual spawning behavior and/or migration (Quinn and Ross, 1985) further suggesting there is a potentially larger pool of available individuals that may or may not enter the river in a given year.

CONCLUSIONS AND RECOMMENDATIONS

The overarching objective of this work, to quantify the run size of white and longnose suckers entering the Boardman River, was successful. Study of the number of suckers migrating is an important step in developing a selective fish passage system. The challenges of sorting individual species from a fish community assemblage are directly related to the number of species present and level of variance in sortable phenological, morphological, behavioral, physiological attributes, and the number of individuals eligible for passage. Consequently, an understanding of the number of individuals within a group of species desired for passage is directly applicable the potential capacity of the sorting system.

Klinger et al. (2003) evaluated the proportion of annual catch that occurred at seasonally operated sea lamprey barriers which occur before the first lamprey is caught and demonstrated that greater that 78% and 80% of the longnose and white sucker migration occurred post sea lamprey arrival respectively. This reaffirms that approximately 80% of the ~15,000 sucker will need to be selectively sorted from sea lamprey, in addition to any other undesirable fish present during the spring. These numbers are applicable to sorting capacity as they likely remain fairly consistent across years due to the tendency for suckers to home for spawning. Homing has been documented in the LBR as demonstrated by the large portions (17-38%) of telemetered suckers returning to the system over multiple years (Swanson et al., 2023) and has been documented in other systems as well (Geen et al., 1966; Dence, 1948; Olson and Scidmore, 1963 as cited by Werner and Lannoo, 1994).

The secondary objectives of the work included evaluating the efficiency of capturing fish to be used as test organisms in the future FishPass system by the modification and addition of trap infrastructure to the existing TCSW. Our results suggest that this is a viable tool for accomplishing such goals for rainbow trout, and white and longnose sucker. However, this tool may only be useful for sort duration or require additional improvements/modifications in order to avoid inducing mortality such as that seen in mid-May during trap operation. Further, low catch rates of other species suggest that alternative methodology be considered when attempting to capture large numbers of individuals of other species in support of future research activities at FishPass.

If a similar operation is to be conducted in the future, several improvements and/or modifications should be considered. First, infrastructure modification or improved deployment planning to increase flexibility in when to initiate the trap operation is required. Telemetry has shown variability in the run timing of suckers and other members of the Boardman River fish community across years (Swanson et al. 2023) demonstrating the need for flexibility in deployment. Second, the traps should be modified to improve the trapping efficacy of the USF trap. An increase in the number of openings and connections could improve the probability that a fish encounters the entrance and go into the trap. Further, improvements should be considered to trap design to increase the efficiency of emptying the catch from the traps.

ACKNOWLEDGEMENTS

This manuscript is contribution 11 of FishPass. FishPass is the capstone to the 20y restoration of the Boardman (Ottaway) River, Traverse City, Michigan. The mission of FishPass is to provide up- and down-stream passage of desirable fishes while simultaneously blocking or removing undesirable fishes, thereby addressing the connectivity conundrum. We are grateful to the primary project partners: Grand Traverse Band of Ottawa and Chippewa Indians (GTB), Michigan Department of Natural Resources (MIDNR); U.S. Army Corps of Engineers; U.S. Fish and Wildlife Service, and U.S. Geological Survey. We also extend sincerest thanks to the primary partner, the City of Traverse City. Without the city's support and the vision of the city commission, FishPass would not have been possible. Funding for this contribution came from the Great Lakes Restoration Initiative and the Great Lakes Fishery Commission.

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APPENDIX 1 -

MARK-RECAPTURE DATA SET AND ASSUMPTION TESTING

Table A1-1. *Mark-recapture data for longnose sucker Catostomus catostomus obtained from a trap operation conducted in spring 2022 at the Michigan Dept. of Natural Resources Traverse City Salmon Weir and two associated electrofishing sampling events.*

Sample (i)	Number caught (n_i)	Number of recaptures (m_i)	Number newly marked (q_i; less removals*)	Marked at large (Q_i)
2022-04-27-AM	2	0	0	0
2022-04-28-AM	2	0	0	0
2022-04-29-AM	9	0	0	0
2022-05-01-AM	1	0	0	0
2022-05-03-AM	114	0	66	66
2022-05-03-PM	56	0	55	121
2022-05-03-efish	51	0	51	172
2022-05-04-AM	132	0	132	304
2022-05-04-PM	1	0	1	305
2022-05-05-AM	4	0	2	307
2022-05-05-PM	205	0	205	512
2022-05-06-AM	295	2	290	802
2022-05-07-AM	6	1	4	806
2022-05-08-AM	296	3	288	1094
2022-05-09-AM	240	7	223	1317
2022-05-09-PM	2	0	2	1319
2022-05-10-AM	265	4	254	1573
2022-05-10-PM	72	4	62	1635
2022-05-11-AM	311	5	206	1841
2022-05-12-AM	149	3	86	1927
2022-05-12-PM	16	12	-10	1917
2022-05-13-AM	119	23	63	1980
2022-05-13-PM	12	10	-8	1972
2022-05-14-AM	65	41	-33	1939
2022-05-15-AM	75	59	-73	1866
2022-05-16-AM	68	51	-63	1803
2022-05-18-efish	65	5	52	1855
2022-05-19-PM	1	0	1	1856
2022-05-20-AM	11	8	-14	1842
2022-05-20-PM	2	1	-1	1841
2022-05-21-AM	1	1	-2	1839
2022-05-23-AM	1	1	-2	1837
Total	**2649**	**241**	**1837**	

** removals include all deaths, harvests, and translocations*

Table A1-2. *Mark-recapture data for white sucker Catostomus commersonii obtained from a trap operation conducted in spring 2022 at the Michigan Dept. of Natural Resources Traverse City Salmon Weir and two associated electrofishing sampling events.*

Sample (i)	Number caught (n_i)	Number of recaptures (m_i)	Number newly marked (q_i; less removals*)	Marked at large (Q_i)
2022-04-23-AM	1	0	0	0
2022-04-24-PM	5	0	0	0
2022-04-25-AM	18	0	0	0
2022-04-26-AM	8	0	2	2
2022-04-26-PM	4	0	0	2
2022-04-27-AM	17	0	1	3
2022-04-28-AM	6	0	0	3
2022-04-29-AM	18	0	14	17
2022-04-30-AM	10	0	10	27
2022-05-01-AM	10	0	10	37
2022-05-02-AM	13	0	12	49
2022-05-03-AM	22	0	21	70
2022-05-03-PM	31	0	31	101
2022-05-03-efish	56	2	52	153
2022-05-04-AM	9	0	7	160
2022-05-05-PM	12	0	12	172
2022-05-05-AM	3	0	0	172
2022-05-06-AM	14	0	13	185
2022-05-07-AM	2	0	1	186
2022-05-08-AM	4	0	3	189
2022-05-09-AM	8	1	4	193
2022-05-10-AM	10	0	1	194
2022-05-10-PM	3	0	0	194
2022-05-11-AM	8	0	0	194
2022-05-12-AM	30	1	-2	192
2022-05-12-PM	4	1	-1	191
2022-05-13-AM	38	0	10	201
2022-05-13-PM	8	0	7	208
2022-05-14-AM	43	0	10	218
2022-05-15-AM	62	5	42	260
2022-05-16-AM	36	4	22	282
2022-05-18-efish	110	7	93	375
2022-05-19-PM	1	0	1	376
2022-05-20-PM	2	0	2	378
2022-05-20-AM	10	0	8	386
2022-05-21-AM	8	1	5	391
Total	**644**	**22**	**391**	

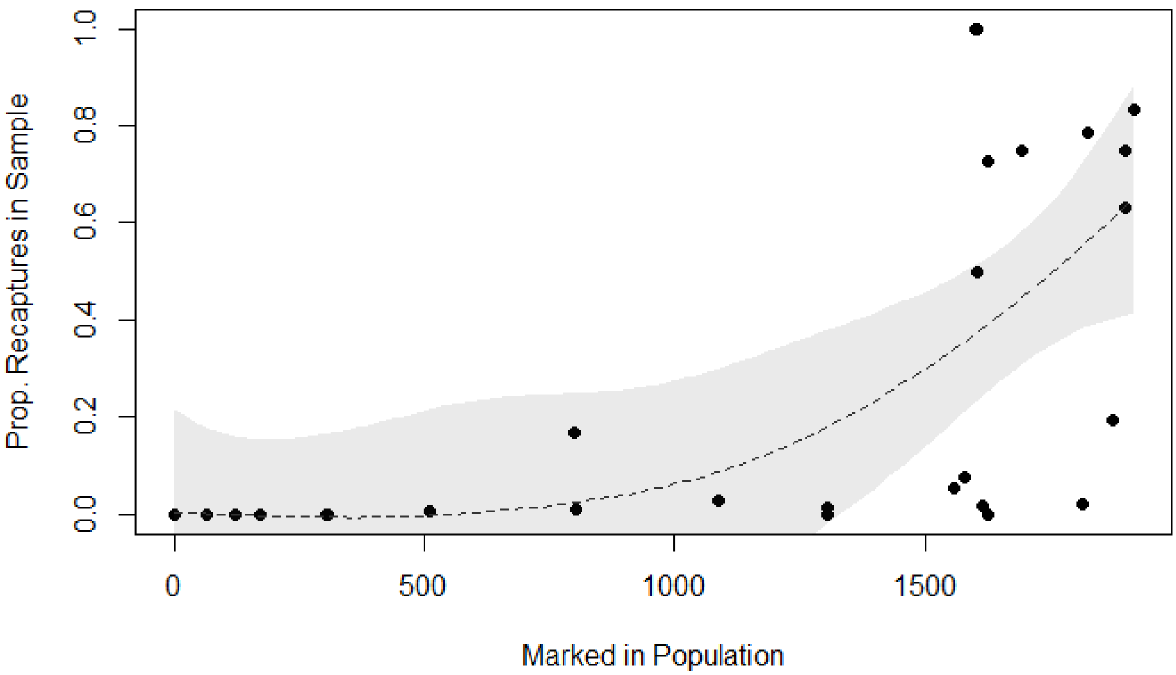

Figure A1. *Relationship between the number of longnose suckers Catostomus catostomus marked in the lower Boardman (Ottaway) River in comparison to the proportion of recaptures in the samples obtained from a trap operation conducted in spring 2022 at the Michigan Dept. of Natural Resources Traverse City Salmon Weir and two associated electrofishing sampling events.*

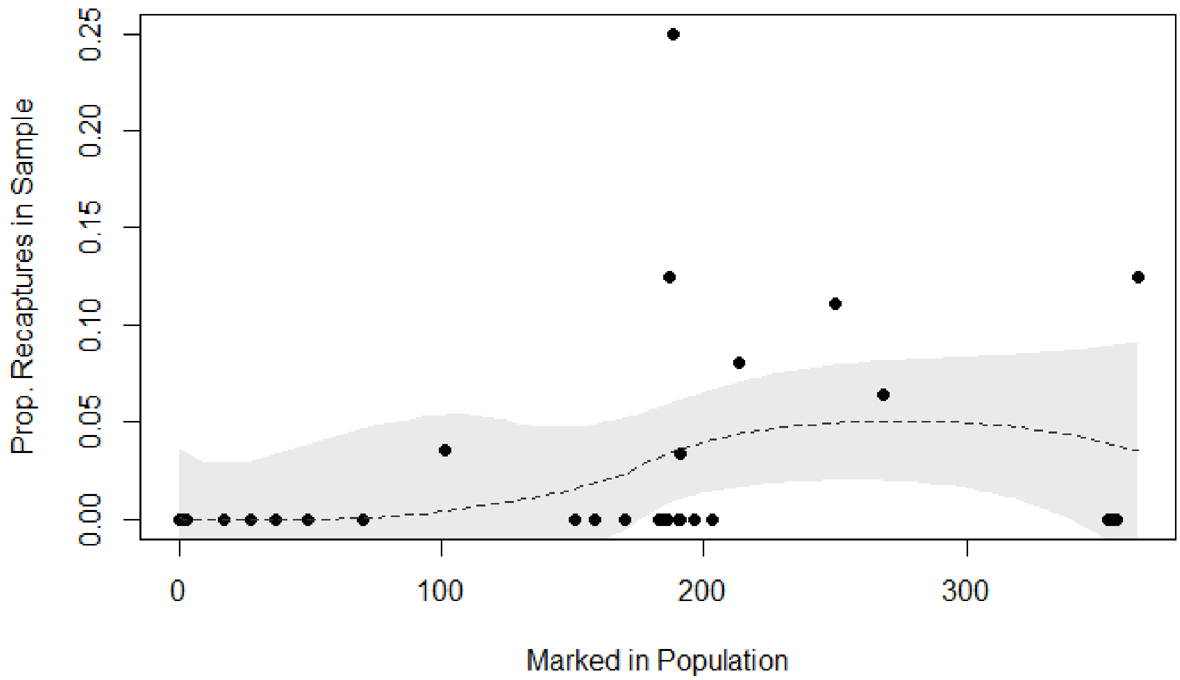

Figure A2. *Relationship between the number of white suckers Catostomus commersonii marked in the lower Boardman (Ottaway) River in comparison to the proportion of recaptures in the samples obtained from a trap operation conducted in spring 2022 at the Michigan Dept. of Natural Resources Traverse City Salmon Weir and two associated electrofishing sampling events.*

ABOUT FISHPASS

FishPass is the capstone of a ~20y restoration project on the Boardman (Ottaway) River, Traverse City, Michigan, re-connecting the river with Lake Michigan. FishPass will replace the deteriorating Union Street Dam with a new, complete barrier to all fish that will have the ability to sort and selectively pass desirable fishes while blocking harmful invaders like sea lamprey. While fully automated selective passage is the long-term goal of the project, passage of any fish during the initial 10-yrs will be coordinated with fishery management agencies, limited in number, and restricted to fishes native to the upper Great Lakes.