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Evaluation of lake sturgeon (*Acipenser fulvescens*) spawning success on an artificial reef constructed in the Kalamazoo River, Michigan

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The signatures of the committee members below indicate that they have read and approved the thesis of Jason Paul Lorenz in partial fulfillment of the requirements for the degree of M.S. Biology.

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Abstract

Since lake sturgeon *Acipenser fulvescens* monitoring began on the Kalamazoo river in 2009, there has been no documentation of survival past the egg stage. Spawning has occurred directly below Calkins Dam and, in 2016, an artificial spawning reef was constructed 275-m downstream to improve habitat and increase survival to the larval stage. The site was monitored with egg mats and larval drift nets to document evidence of successful natural reproduction of lake sturgeon one year prior to construction (2016) and three years post-construction of the artificial reef (2017-2019). Fertilized lake sturgeon eggs were captured all four years of the study at the Calkins Dam site (i.e., immediately below the dam but upstream of the artificial spawning reef) and eggs were only collected on the artificial reef site the last year (2019) of the study. No larval lake sturgeon were captured at the Calkins Dam site or the artificial reef site in any year of this study. Survival from egg to larvae continues to be a population bottleneck even after the construction of the artificial spawning reef, limiting recruitment of lake sturgeon in the Kalamazoo River.

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Chapter I

Introduction

The lake sturgeon (*Acipenser fulvescens*) is the only sturgeon species native to the Great Lakes. The species is characterized by long life, late maturity, intermittent spawning, high fecundity, and low adult mortality (Auer 1996; Peterson et al. 2006). Lake sturgeon history in the Great Lakes is characterized by three main periods: abundance, scarcity, and rehabilitation (Hayes and Caroffino 2012). Prior to the 1800's, lake sturgeon was plentiful in the Great Lakes. Due to the species abundance, size, and lack of value, lake sturgeon were often killed as a nuisance to commercial fisherman because the fish did damage to their fishing nets (Tody 1974). By the late 1800's, people realized that there was value in their flesh, eggs, and swim bladder, and overfishing added to the decimation of the species (Tody 1974). Other main contributors to the decline of lake sturgeon were dam construction and increases in logging, both of which primarily led to loss of accessible spawning habitat and degradation of the remaining spawning habitat.

As a result of this decline, the species was listed as threatened under the State of Michigan's Endangered Species Act (MCL 324.3605, 1994 PA 451) in the late 1900's (Hayes and

Caroffino 2012). Efforts have been gaining interest from the public to rehabilitate lake sturgeon in the Great Lakes (e.g., Holtgren et al. 2007, Roseman et al. 2011). Many different agencies have started to help conserve remnant populations, including federal, state, and tribal entities. Public outreach has fueled interest in lake sturgeon conservation through organizations, such as "Sturgeon for Tomorrow," due to the fishes prehistoric look and age. Efforts by the Gun Lake Tribe to sponsor a public release of hatchery raised lake sturgeon have resulted in crowds of 300+ individuals annually at New Richmond County park near Fennville, MI. Rehabilitation and protection efforts of a limited number of lake sturgeon stocks have been successful enough to allow recreational fisheries in Michigan like the Menominee River and Lake St. Clair. In general, the lake sturgeon conservation effort has been successful in slowing the decline (and, in limited cases, reversing the decline), educating the public to the importance of rehabilitation and protection, and identified populations in most need of human intervention to reach self-sustaining populations.

The Kalamazoo River is 1 of 11 remaining tributaries to Lake Michigan that is known to have an annual spring spawning run of lake sturgeon. Of these 11, only 5 are above the minimum viable population (MVP) level of 80 individuals set by the

Michigan Department of Natural Resources (MDNR; Smith 2010; Hayes and Caroffino 2012). Abundance estimates of lake sturgeon are very difficult to achieve due to their spawning periodicity and the difficulty of capturing individuals in the river (Pledger et al. 2013), but the most recent attempt at a population estimate for the Kalamazoo River is about 88 individuals (Hayes and Caroffino 2012; Smith 2010). The Kalamazoo River population has been deemed "Small and Declining" by MDNR, so its proximity to falling below MVP levels has given it the MDNR's highest priority for rehabilitation within the Lake Michigan Basin. A genetic analysis of Lake Michigan populations has shown that each population is genetically distinct from one another, thus making it even more critical to rehabilitate each population separately instead of transplanting individuals from other larger gene pools (Welsch et al 2010; Homola et al. 2012).

Work has been conducted by MDNR and Match-E-Be-Nash-She-Wish Band of Pottawatomi Indians (aka Gun Lake Tribe, GLT) on the Kalamazoo river since 2009 (Smith 2010). Every year there has been evidence of lake sturgeon entering the river during the spawning season based on gill net surveys at the mouth of the river near Saugatuck, Michigan. Fish are able to travel approximately 34 km upstream before reaching Calkins Dam, an impassable structure near the town of Allegan, Michigan (Figure

1). Calkins Dam was built in 1934 and is currently running as a run-of-river operation, which means that the amount of water flowing through the dam mimics the amount of flow coming downstream from above the dam. No water should be held back unnaturally in order to pass during energy demanding times. Spawning activity has been documented directly below the main turbines every year since 2009, and juvenile lake sturgeon have been protected and released back into the Kalamazoo River from naturally fertilized eggs every year since 2011. Unfortunately, larval drift surveys have not been successful in catching any larvae within the last 10 years (Smith 2010). This very concerning lack of recruitment led the MDNR and GLT to construct an artificial spawning reef downstream from Calkins Dam in an attempt to get spawning activities away from the turbines and increase survival from the egg to larval stage. Spawning on artificial reefs has been shown to be successful in other systems. In the St. Lawrence River, researchers estimated just under 500,000 lake sturgeon eggs were deposited on an artificial gravel bed for three consecutive years (Johnson et al. 2006). Another successful reef introduction for lake sturgeon spawning was documented in the Detroit River with an average deposition of 102 lake sturgeon eggs per m^2 (Roseman et al. 2011). Although lake sturgeon have been shown to deposit eggs on these artificial reefs, an overall positive effect of these reefs on the lake sturgeon populations has not yet been demonstrated (Johnson et al 2006; Bouckaert et al 2014).

Purpose

The purpose of this study was to determine whether construction of an artificial reef improved the spawning success of lake sturgeon and early-life-stage survival in the Kalamazoo River.

Scope

The goal of this study was to document increased survival of lake sturgeon eggs through enhanced spawning habitat downstream from Calkins Dam in the Kalamazoo River. The study reach was the lower 27 km of Kalamazoo River, but the main focus was within a 250-m reach below Calkins Dam where lake sturgeon spawning is known to occur. Egg deposition was monitored with egg mats and larval drift was assessed with larval drift nets downstream of both the Calkins Dam site and the artificial reef site. This study occurred for four years: one year prior to reef construction (2016) and three years post-construction (2017-2019).

Assumptions

I assumed that spawning lake sturgeon would migrate upstream to the Calkins Dam during each year of the study (2016-2019) in the lower Kalamazoo River. I also assumed that all of the lake sturgeon spawning in the Kalamazoo River occurs directly below Calkins Dam (i.e., no lake sturgeon spawned downstream of the study sites). I assumed that all migrating lake sturgeon would come into contact with the artificial reef as fish swam upstream to Calkins Dam (barrier to upstream movement) because the artificial spawning reef spans the entire width of the Kalamazoo River (and fish have to swim over it to reach Calkins Dam). Previous work by MDNR concluded that no lake sturgeon spawning activity happens in the reach downstream of the artificial reef site (there is little to no suitable spawning habitat from Calkins Dam downstream to Saugatuck).

Research Objectives

High early life mortality of lake sturgeon is amplified by anthropogenic stressors and continues to be one of the most difficult obstacles for populations to overcome, even though high mortality is natural given lake sturgeon life history strategy (Sutton et al. 2003, Caroffino et al. 2010). The exact mechanisms that limit recruitment to the adult stage is unknown and likely different in every system. Providing suitable lake sturgeon spawning habitat away from Calkins Dam (where conditions are harsh given the discharge from turbines) could potentially remove one of the factors assumed to be limiting recruitment. The objectives of this study were to evaluate whether lake sturgeon: 1) use the artificial spawning reef to spawn, and 2) spawning on the artificial reef increases survival from the egg to larval stage compared to the Calkins Dam spawning location.

Significance

The indigenous people of the Great Lakes, also known as the Anishinaabek, have held lake sturgeon (Nmé in anishinaabemowen) in high regard since their first migration to the area from "where the salt water meets fresh" (St. Lawrence Seaway). Anishinaabe people honor their relationship with the natural world through their form of government known as "dodems" or clans. Each clan is represented by an animal, and that animal's traits are what the Anishinaabek adopt as their role in society. Sturgeon clan people are known for their wisdom, and they are often philosophers and spiritualists that guide decision making and settle disputes. Just as the fish, sturgeon clan people were known to easily reach 130 years old (Punkin Shananaquet, Gun Lake Tribal Member).

Lake sturgeon was a main staple of Anishinaabek diets in the spring, and all parts of harvested fish were used. Lake sturgeon spawning runs were critical times for Anishinaabek to congregate on the river and gather food after long, cold winters. Analysis of archaeological sites have indicated that the lake sturgeon was one of the most important fish species to indigenous cultures in the early 1800's in the tributaries to Lake Michigan (Brashler et al. 1998, Martin and Brashler 2002).

The decimation and resurgence of lake sturgeon in the Great Lakes has been correlated to the decimation and resurgence of the Anishinaabek. The Anishinaabek feel deeply connected to lake sturgeon populations of the area and feel that as lake sturgeon make a comeback, their culture and people will also make a comeback.

Prior to this study, there has been little documentation of lake sturgeon recruitment in the Kalamazoo River. The only evidence has been age validation of adult lake sturgeon that are younger than the age of Calkins Dam (85 years old) and genetic evidence that the Kalamazoo River forms a unique stock (Homola et al. 2012). Without some sort of improvement to the survival of lake sturgeon in the Kalamazoo, the population is likely to be solely reliant on the streamside rearing program managed by the GLT of Pottawatomi Indians.

Chapter II

Review of Literature

Lake sturgeon populations in the Great Lakes have been reduced to an estimated 1% of their historical abundance due to severe exploitation, habitat degradation caused by siltation of logging processes, and dam construction (Auer 1996, Hay-Chmielewski and Whelan 1997). Since the mid 1900's, human overharvest has been reduced and almost eliminated, but there are lingering factors that continue to impede progress toward remnant populations being self-sustaining (Noakes et al. 1999, Crouse 1999). One of the biggest factors still hindering rehabilitation is river fragmentation and habitat degradation caused by dams (Auer 1996, Peterson et al. 2007). Dams restrict upstream migration to historical spawning grounds and also have deleterious effects on the habitat downstream that juveniles use for summer foraging and protection from predators (Auer 1996, Wilson and McKinley 2004). Other limiting factors to rehabilitation are related to lake sturgeon life history traits. The lake sturgeon is characterized by rapid juvenile growth followed by a delayed maturation, with typical spawning first occurring around age 12-15 for males and 18-27 for females (Peterson et al. 2007). Lake sturgeon has a high fecundity and is known to produce 10,000 eggs per kilogram of total body weight (Harkness and Dymond 1961, Bruch 2002). Their eggs are negatively buoyant and adhesive, sticking to the first piece of substrate with which they come into contact after being broadcast into the current. Creating many small, "inexpensive" young leads to a high natural mortality of early life stages. Sturgeon are lithophilic, broadcast spawners and provide no parental care after spawning (Harkness and Dymond 1961). The only way adult lake sturgeon can ensure their young survive is to select spawning habitat that protects eggs and larvae prior to emergence. Managers interested in the rehabilitation of lake sturgeon often focus attention on early life stage survival because that is the life stage that has the most potential to make a positive impact on population growth (Houde 1987). Adult lake sturgeon have the ability to buffer short-term reproductive failures caused by suboptimal conditions through long life and periodic spawning (every 3-5 years; Pollock 2014). However, these exact life history characteristics hinder rehabilitation when stressors like habitat degradation from dam construction limit reproduction over the long term (Pollock 2014). Emphasis must be placed on the lack of recruitment of early life stages of lake sturgeon into the spawning population. Egg deposition does not seem to be the limiting factor in most populations in the Great Lakes because there are often enough fish to produced viable eggs. For instance, lake sturgeon have been shown to spawn on accidental "spills" of rock into the water that were not intended to be placed for fish spawning activity, suggesting suitable spawning habitat was a limiting factor (Caswell et al. 2004).

A popular habitat enhancement used to improve both spawning success and early life stage survival is adding artificial habitat or spawning reefs (McLean et al. 2015). Reefs can be utilized to add rocky substrate where absent or change the shape and size of rock habitat to provide suitable spawning habitat. In the Kalamazoo River, an artificial habitat was added at a location that already consisted of hard rocky substrate, but it was relatively small (J. Lorenz, personal observation). Lake sturgeon tend to spawn on large rock substrate (small, large, and boulder) due to its expansive interstitial spaces, which are used by eggs and yolk-sac larvae for protection during development (Harkness and Dymond 1961, LaHaye et al. 1992, Bruch and 2002, Manny and Kennedy 2002, Johnson et al. 2006). When searching the literature published on artificial reefs in the Great Lakes, I found that most of the reefs used by lake sturgeon in lake settings were incidental spills of rock (or placed for reasons other than fish spawning), while reefs used by lake sturgeon in tributaries and connecting channels were created for fish spawning enhancements (McLean et al. 2015).

The most notable reef constructed specifically for lake sturgeon occurred in the connecting channels of Lake St. Clair and Lake Huron, also known as the St. Clair/Detroit River system (SCDRS) (Roseman et al. 2011, Bouckaert et al. 2014, Fischer et al. 2020). In this system, like almost every lake sturgeon system, lack of spawning habitat was deemed to be the most detrimental factor in lake sturgeon recruitment. Reefs were constructed of 12 mini sections that were made of 3 different substrate types. Ultimately, the researchers could not determine whether lake sturgeon chose one substrate type over the other but were able to conclude that lake sturgeon would use a man-made reef for spawning (Roseman et al. 2011). Water velocity also was found to be an important factor associated with site selection for spawning instead of the substrate (Roseman et al 2011). Bruch and Binkowski (2002) defined lake sturgeon spawning habitat to have three main characteristics: (i) clean, rocky substrate with interstitial space for egg and larval development, (ii) water velocity over 0.5 m/s, and (iii) temperatures of 12-16 °C. The reef built in SCDRS obviously met the first criteria on all sites but failed to meet the water velocity criteria, which made it more critical for adult lake sturgeon and the driving factor behind spawning location.

Similar projects have reiterated the requirements of lake sturgeon spawning set forth by Bruch and Binkowski (2002) but placed more emphasis on the “clean” aspect of the rock substrate (Johnson et al. 2006, Dumont 2011). Algae covering the rock surface or siltation filling in interstitial spaces were shown to be detrimental to sturgeon egg and larval survival and ultimately deterring adult lake sturgeon from using the habitat for spawning in subsequent years (Johnson et al. 2006). The lake sturgeon is thought to spawn in high velocities to avoid such colonization of algae and siltation. A lot of sturgeon spawning occurs below impassable barriers with high velocities, such as dams or high gradient rapids, which should keep spawning substrate fairly clean.

Another theme that is apparent in most publications dealing with lake sturgeon spawning habitat is predation on early life stages. Nichols et al. (2003) showed an increase of survival from less than 1% to 16% of egg to larval stage by simply placing predator-exclusion chambers around freshly deposited lake sturgeon eggs in the SCDRS system. Species such as redhorse (*Maxostoma* spp.), yellow perch (*Perca flavescens*), logperch (*Percina caprodes*), crayfish (*Orconectes* spp.), mud puppies (*Necturus maculosus*), common carp (*Cyprinus carpio*), and even post-spawning lake sturgeon have been documented to feed on lake sturgeon eggs and larvae (Kempinger 1988, Nichols et al. 2003, Johnson et al. 2006, Caroffino et al. 2010). Most research in the Great Lakes agrees that egg predation by interstitial predators, like the invasive round goby (*Neogobius melanostomus*) and invasive rusty crayfish (*Orconeces rusticus*), could be the most detrimental due to their ability to access lake sturgeon eggs after they have settled into the substrate. Caroffino et al. (2010) showed a potential for a single crayfish to consume over nine lake sturgeon eggs/day and, taking into account the density of crayfish and other interstitial predators on the spawning grounds, potential predation could result in the mortality of hundreds of thousands of lake sturgeon eggs during the week-long incubation period (Kempinger 1988, LaHaye et al. 1992, Smith and King 2005).

Artificial reefs can attract lake sturgeon to spawn and produce drifting larvae, even if the reef was constructed for reasons other than fish spawning (Bouckeart et al. 2014, McLean et al. 2015). The most important attributes of the reef must be clean rock with adequate interstitial spaces for incubation, high water velocities (>0.5 m/s), and have water temperatures of 12-16 °C. The first few years of a reef could be the most productive since the rock will be relatively clean and the colonization of predators will be at its lowest. Attracting spawning lake sturgeon is only the first piece of the puzzle. The survival of lake sturgeon eggs to drifting larvae is the most critical part of artificial reef function. The lake sturgeon population in the Des Prairies River (Quebec, Canada) is very large and, prior to reef construction in 1996, there was already good spawning habitat and good spawning documented. The added reef in this system was constructed to aid in lowering egg density at the spawning grounds. Lake sturgeon eggs were documented around 5,626 eggs/m prior to 1996, which is above upper limits correlated with high embryonic mortality rates for sturgeon (Khoroshko and Vlasenko 1970). The addition of 8,000 m^2 of habitat lowered the density of lake sturgeon eggs below 2,000 eggs/m from 1997 to 1999 (Dumont et al. 2011). The same effect can be detrimental to populations that have a much lower abundance of spawning adults. Dumont et al. (2011) stated that the spawning population consisted of 1,231 mature females in 1995. If the same effect of spreading adults and eggs out on small populations is considered (e.g., the Kalamazoo River is expected to have one or two spawning females each year based on genetic samples), then spreading spawning lake sturgeon across a greater area of spawning habitat could limit genetic diversity or inhibit spawning if adults are not finding each other because they are at low numbers and on different spawning reefs.

In conclusion, artificial reefs can be successful in attracting lake sturgeon to spawn, but more factors must be evaluated to ensure restoration objectives are met. Each system and population has its own unique requirements and limitations. Attracting lake sturgeon adults into spawning at a particular location is only the first step to helping the species. Habitat requirements of embryos and larvae, like protection from predators and well-oxygenated water, must be met for successful recruitment to occur.

Chapter III

Methodology

Study Site

The Kalamazoo River is a large, drowned river mouth system located in southwest Michigan. The river flows for 282 km, starting in Hillsdale County, and terminates in Saugatuck, Michigan where it flows into Kalamazoo Lake before emptying into Lake Michigan. The Kalamazoo River watershed drains approximately 5,200 km^2 of land in southwest Michigan. The Kalamazoo River was heavily impacted by the paper mill industry as well as dam construction (Wesley 2005). The paper industry is all but gone from the banks of the Kalamazoo River, and efforts are under way to remove most of the dams remaining; however, PCB's are still known to be concentrated in the sediment (Wesley 2005).

Calkins Dam, in Allegan, Michigan, is the most downstream dam on the Kalamazoo River and was constructed in 1936. At 10 m tall with no functioning fish passage, Calkins Dam is a barrier to all migratory fish movement to the upstream portions of the Kalamazoo River, which leaves about 34 km of river available for migratory fish to inhabit.

Artificial Habitat

An artificial spawning reef was installed 350 m downstream from Calkins Dam in July 2016. Consisting of 370 large boulders

(1 m x 1 m diameter) as well as 1,800 cubic yards of natural fieldstone (30 cm–60 cm diameter), the new habitat was specifically designed to mimic lake sturgeon spawning substrate while limiting sea lamprey spawning (e.g., Applegate 1950, Bruch and Binkowski 2002, Roseman et al. 2011). The new riffle spans the entire 50-m width of the river and continues for 50 m downstream, resulting in a 2,500-m^2 riffle.

Adult Lake Sturgeon Sampling

Adult lake sturgeon were sampled using 12” stretch-mesh monofilament gill nets stretching 90 m long and 2 m tall. Sampling started once ice had receded enough for access by boat. Three index sites were set nightly at the mouth of the Kalamazoo River in Saugatuck, Michigan (Figure 1) from 21:00 to 03:00 and checked every 2 hours. All lake sturgeon captured were measured for total length, fork length, commercial length, and girth. If a passive integrated transponder (PIT) tag was not detected, then a new PIT tag was inserted below the second dorsal scute posterior to the head. A subset of adults (7 individuals) also were surgically implanted with a V16-6x(69kHz) acoustic transmitter from InnovaSea as part of another study. Similarly, a small tissue sample from their dorsal fin was taken for analysis of genetic diversity and parentage for another project. Each lake sturgeon was then released back into the Kalamazoo

River near the point of capture. Sampling for adults concluded once river temperatures reached 20° C each year.

Egg Sampling

Lake sturgeon embryos were sampled directly below Calkins Dam and also on the artificial habitat site during 2016-2019 (Figure 1). Egg mat sampling consisted of steel frames (22 cm x 30 cm) wrapped in furnace filter and secured with two bungee straps (e.g., Nichols et al. 2003, Manny et al. 2007, Manny et al. 2010, Roseman et al. 2011). These mats were attached to a main cable in gangs of 10-20 along with a cinder block anchor and buoy. Approximately 50 mats were placed on the known spawning site below Calkins Dam and another 50 mats on the artificial habitat site. These mats were set once temperatures neared 10° C and were checked every day for spawning activity. Mats were checked routinely at around 20:00 because spawning has been documented to happen in the middle of the night on the Kalamazoo River in past years and hostile fishermen made checking mats during the daylight difficult (J. Lorenz, personal observation). Checking mats during nighttime hours also reduces the risk of desiccation of embryos due to direct sunlight. All eggs captured on a mat were identified and enumerated. All lake sturgeon eggs were counted and taken to the streamside rearing facility (e.g., Holtgren et al. 2007) on the Kalamazoo River for rearing throughout the summer. Egg sampling concluded once river temperatures exceeded 20° C for five consecutive days.

Larval Drift

Larval lake sturgeon sampling occurred using D-frame drift nets as described in Smith and King (2005). Nets were stacked in triplicate in an attempt to sample the entire water column. Both the dam site and the artificial reef site was sampled with four stacks of nets equally spaced across the river, resulting in 12 nets at each site. Each set of nets was fished from 21:00 to 03:00, and cod ends were pulled and emptied every hour. All larval fish and fish eggs were identified and enumerated in the field. Any lake sturgeon eggs and larvae encountered during drift sampling were measured to the nearest 1 mm and taken to the streamside rearing facility for rearing throughout the summer. Each drift net was equipped with a mechanical flow meter (General Oceanics, Inc.) to measure the amount of water sampled in nets. Flow meter readings were recorded when nets were set and pulled. The nets were first set approximately 1 week after river temperature exceeded 10° C and concluded once river temperatures reached 20° C for 1 week.

Chapter IV

Results

Adult Lake Sturgeon Sampling

Adult lake sturgeon were sampled annually in Saugatuck, Michigan at two index sites (MDS, MUS) between Kalamazoo Lake and Lake Michigan and one site in Kalamazoo Lake (CG; Figure 1). Adult lake sturgeon were sampled in 2016 from 16 March to 27 April with three fish being captured, averaging 164 cm in total length (CPUE 0.025 fish/net; 121 nets). In 2017, sampling occurred from 19 February to 27 April. Three fish were also captured in 2017 with an average total length of 180 cm (CPUE 0.019 fish/net; 158 nets). Nine fish were captured in 2018 between 28 February and 29 April that averaged 161 cm in total length (CPUE 0.051 fish/net; 178 nets). Sampling occurred between 12 March and 29 April in 2019 resulting in five fish being captured, averaging 158 cm in total length (CPUE 0.035 fish/net; 142 nets) (Table 1; Appendix A). One lake sturgeon in 2019 was captured at Calkins Dam during an exploratory effort to see if any adult lake sturgeon were still around after spawning had occurred. Of the 20 fish captured from 2016-2019, five fish were recaptures that were PIT tagged prior to 2016.

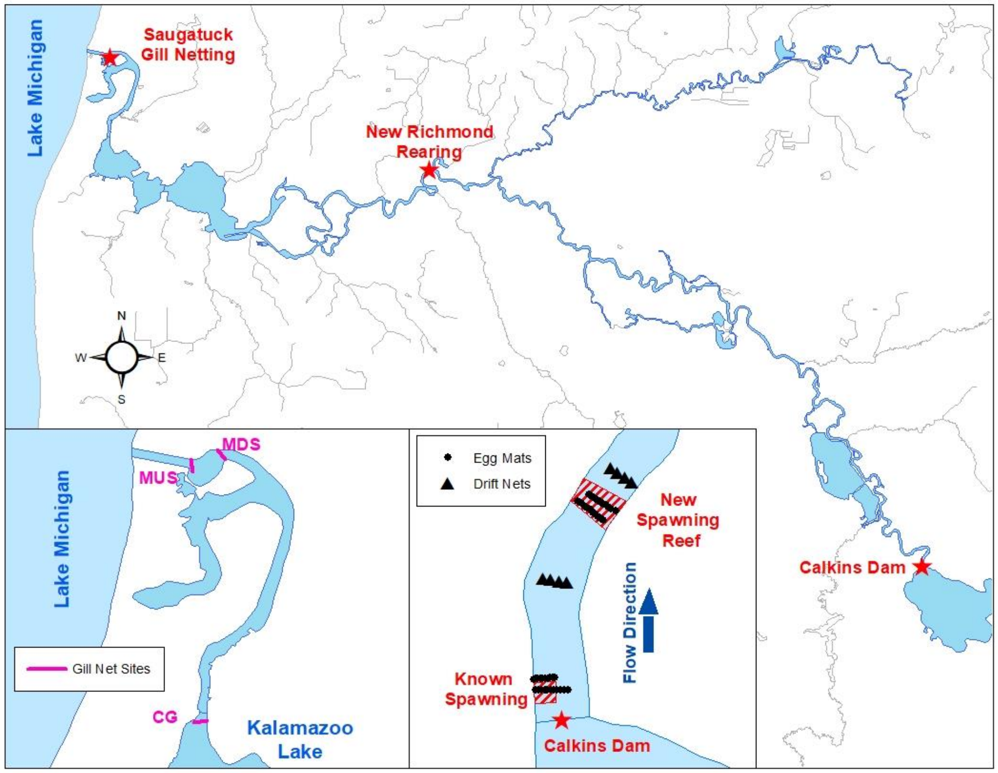

Figure 1. Map of lower Kalamazoo River depicting key sampling sites for lake sturgeon during 2016-2019. Inset maps include gill net locations at Saugatuck, MI and egg/drift sampling locations at Allegan, MI.

Table 1. Adult lake sturgeon (LAS) sampling effort during 2016-2019 in Saugatuck, MI. Adults were captured with gill nets; TL is total length.

Year	Sampling Date	Number of Nets Set	Number LAS Captured	Mean TL (cm)	TL Range (cm)
2016	3/16-4/27	121	3	164	161-170
2017	2/19-4/27	158	3	180	168-186
2018	2/28-4/29	178	9	161	144-179
2019	3/12-4/29	142	5	158	145-174

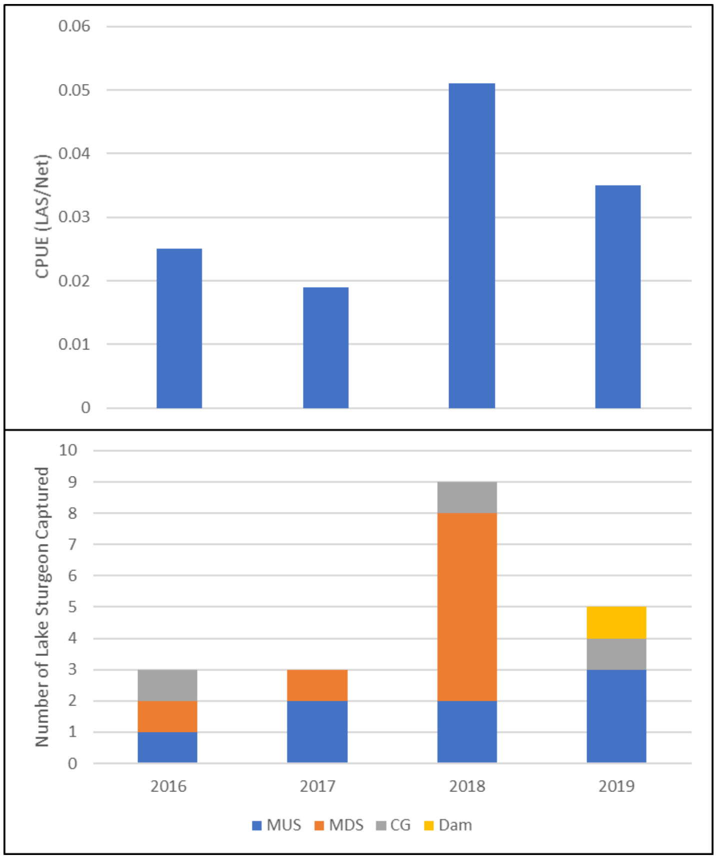

Figure 2. Lake sturgeon (LAS) adult CPUE (fish/net) for all study years 2016-2019 (top) and total LAS catch per site in 2016-2019 (bottom).

Egg Sampling

A total of 1,245 lake sturgeon eggs were captured from the known spawning location below Calkins Dam (Figure 1) during 2016-2019 (Table 2). Eggs were captured each year, and those eggs were reared at the streamside rearing facility on the Kalamazoo River in New Richmond, MI. The hatching of lake sturgeon eggs each year at the streamside rearing facility confirmed the eggs were indeed lake sturgeon and that eggs were successfully fertilized in the Kalamazoo River each year during the study. No lake sturgeon eggs were captured on the artificial spawning site (Figure 1) in 2016, 2017, or 2018 (Table 2). A total of 89 lake sturgeon eggs were captured on the artificial spawning reef in 2019 and were reared in the streamside facility, resulting in five juvenile lake sturgeon being released. Although sampling dates varied from year to year (coinciding with varying water temperatures), all lake sturgeon eggs were captured within the same week every year from 2016 to 2019 (Table 2). Eggs were collected from April 26-28 in 2016, May 1-2 in 2017, May 2 in 2018, and April 25-30 in 2019 at the Calkins Dam site. Eggs were collected off the artificial reef on April 29 in 2019.

Table 2. Lake sturgeon (LAS) egg sampling effort during 2016-2019 in Kalamazoo River near Allegan, MI.

Year	Egg Sampling Start	Egg Sampling End	Number of Egg Mats Set (mats x days)	LAS Eggs Dam	LAS Eggs Reef
2016	3/18/16	5/3/16	520	105	0
2017	4/9/17	5/7/17	720	81	0
2018	4/12/18	5/10/18	680	281	0
2019	4/19/19	5/9/19	600	778	89

Larval Drift Sampling

Each year larval drift started the first week of May and lasted about 1 month. A total of 2,346 net sets (Table 3) were completed during 2016-2019, split equally between the Calkins Dam site and the artificial reef site (Figure 1). No larval lake sturgeon were captured in the Kalamazoo River during 2016-2019 either below Calkins Dam or below the artificial reef (Table 3).

<u>Table 3.</u> Lake sturgeon (LAS) larval sampling effort during 2016-2019 in Kalamazoo River near Allegan, MI.

Year	Larval Sampling Start	Larval Sampling End	Number of Net Sets (nets x night)	Las Larvae Dam	Las Larvae Reef
2016	5/9/16	6/2/16	636	0	0
2017	5/7/17	6/1/17	631	0	0
2018	5/8/18	5/23/18	532	0	0
2019	5/5/19	5/23/19	547	0	0

Chapter V

Discussion and Conclusion

Lake sturgeon have been documented to spawn on artificial reefs throughout the Great Lakes, but the success of these reefs in bolstering adult numbers is still uncertain. Lake sturgeon research is inherently difficult to judge success since recruitment into the spawning population takes over 10 years and a lot of variables can change within that time span. The difficulty is compounded in systems like the Kalamazoo River where there is no documentation of naturally spawned juveniles in the river, leading to no information on river residency time (i.e., the amount of time juveniles spend in the river before emigrating back into Lake Michigan) of these individuals.

Calkins Dam operation is hypothesized to be one of the factors limiting survival from egg to larvae in the Kalamazoo River. No particular attributes of dam operations have been identified as problematic, although an extensive review of available data is needed. Artificial reef construction in 2016 was a result of available funding and an idea that this could be a way to improve lake sturgeon survival of egg and larval stages. Since egg collection has been consistent every year since 2009 (GLT/DNR unpublished, present study), there is evidence of spawning in the Kalamazoo River. However, no other attributes of the lake sturgeon spawning grounds were evaluated prior to reef construction. Many attributes shown to limit lake sturgeon survival in other systems (e.g., egg predation, siltation on deposited eggs) would be hard to sample in the Kalamazoo River due to the proximity of lake sturgeon spawning to the dam turbines. The closer the egg mats were deployed to the generating turbines, the more eggs get captured, but the closest that mats can feasibly be deployed near the dam is 10 m downstream. Sampling below the turbines is difficult as there seems to be a lot of debris that gear gets snagged on and lost. Multiple gangs of egg mats have been lost at the Calkins Dam site as they could not be retrieved from the substrate. The flow immediately below the dam seems very fast but cannot be safely measured without a high risk of losing equipment.

In this study, lake sturgeon spawning was documented every year directly below Calkins Dam, even after the artificial habitat was installed in 2016. The artificial reef spans the entire width of the Kalamazoo river, ensuring that the reef was passed over by every spawning lake sturgeon at the dam during 2016-2018. Successful spawning may have occurred on the artificial reef in 2019 (89 eggs collected), but the majority of lake sturgeon spawning appeared to happen at the Calkins Dam site in the same year (778 eggs collected in 2019). Genetic analysis has not been completed yet to determine whether the same sturgeon spawned at both sites or whether the spawning events were completed by different individuals. Additionally, I cannot rule out the possibility that the eggs captured on the reef site drifted down from the dam site and adhered to the mats on the reef. Eggs were deposited at the dam 25-28 April, and the eggs captured at the artificial reef were documented on 29 April.

The highest CPUE for adults during this study occurred in 2018 (CPUE 0.051 fish/net; 178 nets) with the capture of nine individuals. Assuming the number of adults in the system correlates to the number of fish captured during gill net surveys, the greatest probability of the reef being used for spawning was in 2018. However, the number of lake sturgeon captured in gill net surveys can be misleading because fish cannot be accurately sexed; thus, the sex ratio of individuals migrating upstream is unknown. The greatest chance that the artificial reef is used for spawning revolves around the number of spawning females that enter the river in any given year. The number of individuals that spawn in the Kalamazoo River is estimated to be about 20 individuals (GLT/DNR unpublished data). If an average sex ratio of 6 to 1 is assumed during spawning (Bruch 2002), then only 1 or 2 females are predicted to spawn in the Kalamazoo River in any given year.

One major concern for lake sturgeon egg survival that was not addressed in the construction of the artificial reef is egg predation. The round goby is very capable of decimating a lake sturgeon cohort by egg predation when at high densities (Miano et al. 2019, Lutz et al. 2020). In the Kalamazoo River, sampling round goby on the spawning grounds below Calkins Dam is difficult because the water velocity is high, the substrate has many snags, and the human traffic (i.e., anglers) is very high. Baited traps were set at the beginning of this study to sample round goby around the artificial reef site only to have every trap stolen. Prior to 2016, when cinder blocks were used for egg mats, round gobies were commonly captured inside the cinder block holes when checking mats. Round goby eggs have been documented on almost every egg mat gang set during this study, and round goby eggs also have littered larval drift samples and the nets themselves every year (2016-2019). Lake sturgeon need clean interstitial spaces in the substrate for egg and larval incubation, which mimics ideal habitat for the round goby (Corkum et al. 1998, Johnson et al. 2005, MacInnis and Corkum 2000). Other studies have created artificial reefs to increase the volume of lake sturgeon spawning habitat and reduce the densities of egg deposition to avoid suffocation (Dumont et al. 2011). In cases of low lake sturgeon numbers, such as in the Kalamazoo River, the artificial reef may be doing more damage than good by adding more round goby habitat while the lake sturgeon numbers continue to be low. Lake sturgeon use their high fecundity to overcome predation by swamping the spawning grounds with too many eggs and larvae for predators to completely consume (Peterson et al. 2007). When adult numbers are low, so is the amount of eggs and larvae in the system, which makes it easier for a high percentage (if not all) of the lake sturgeon progeny to be consumed by predators.

Predation by other species also can affect survival of lake sturgeon eggs and larvae (Flowers et al. 2011, Heinle et al. 2019). C

Native catostomids are common in the Kalamazoo River at the same time that lake sturgeon spawn, presumably eating lake sturgeon eggs prior to spawning themselves. Lake sturgeon eggs are generally found on the inside of egg mats when pulled, assuming that water velocities tend to push them deeper into the mat material, but predation also could limit the amount found on the outer surfaces of egg mats (along with eggs on the outer surface being dislodged during retrieval). Catostomid eggs have been documented on both egg mats and larval drift samples below Calkins Dam and also on the artificial reef every year during this study. Given that lake sturgeon and native catostomids persisted for millennia prior to the recent decline in lake sturgeon numbers, egg predation by catostomids is suspect to only be an issue when lake sturgeon spawning runs are depressed.

Even though lake sturgeon eggs were collected on the artificial reef in 2019, the lack of survival from egg to larval stage in the Kalamazoo River during each year of the present study is problematic. Without survival to the larval stage, the artificial reef is falling short of its intended benefit to lake sturgeon rehabilitation. The small number of lake sturgeon eggs captured on the artificial reef compared to those captured near Calkins Dam could be a result of harassment of spawning lake sturgeon by anglers (primarily targeting steelhead) during spawning. The same day that lake sturgeon eggs were found on egg mats in 2019, there was a boat anchored on the reef fishing for steelhead (J. Lorenz, personal observation). The angler reported that he had seen lake sturgeon activity next to his boat, and he had hooked lake sturgeon four times that morning at the same spot. Angler access to the lake sturgeon spawning locations may detrimentally affect the success of lake sturgeon spawning in future years. The reef is considerably shallower (1-2 m) than the Calkins Dam site (5-6 m) and easier to access by anglers. The lack of spawning in 2017 and 2018 on the artificial reef could be associated with angler activity if the lake sturgeon were harassed at the right time during spawning. However, in 2019, the spawning fish may not have been harassed until they had already expelled gametes and 89 eggs were captured before they moved off the reef. Regardless, the effect of steelhead angling on lake sturgeon spawning success associated with the artificial reef is uncertain but seems problematic in terms of lake sturgeon rehabilitation.

Conclusion

Whether the goal of getting lake sturgeon to spawn on the artificial reef in the Kalamazoo River has been achieved is still unclear. Eggs were captured on the artificial reef, but without genetic analysis, I cannot determine if fish spawned on the reef or if the eggs were deposited upstream and drifted onto the reef. Even if spawning activity occurs at the dam and eggs drift downstream onto the reef, the effects of the artificial reef could be beneficial if the habitat provides adequate protection for survival to the larval stage; however, no larval lake strugeon were captured in drift sampling at either site during 2016-2019. Survival from egg to larvae should be the highest priority for the rehabilitation of Kalamazoo River lake sturgeon. Monitoring of this reef for lake sturgeon spawning and survival should continue; however, the factors limiting survival from egg to larvae need to be identified with appropriate management actions implemented. The most important finding of this study is that there is still little to no natural reproduction occurring at the study area (i.e., where eggs mats were deployed and larval drift sampling was conducted) in the

Kalamazoo River. The streamside rearing program carried out by the Gun Lake Tribe of Pottawatomi Indians is critical in keeping some form of recruitment in this system while survival issues are addressed below Calkins Dam. Lake sturgeon activity in the lower Kalamazoo River below the artificial reef should be assessed to confirm whether spawning occurs in other parts of the main river or any tributaries. The available age data (prior to 2016) suggests that lake sturgeon have recruited into the population after the construction of Calkins Dam, but successful reproduction appears to be occurring a low level because the population is not increasing in abundance.

Management Recommendations

1. A goal of 750 breeding adults has been stated as a goal for self-sustaining populations of lake sturgeon in Michigan. Given that the Kalamazoo River population is well below that number and limitations to natural recruitment are present, streamside Rearing should persist to bolster recruitment for a minimum of 25 years. Genetic analysis should be completed to ensure that there is enough genetic diversity in cohorts prior to stocking to make sure the threat of inbreeding is minimized. Guidelines outlined in Welsh et al. (2010) should be followed with respect to how

many fish to stock, when/how to stock, and genetic analysis.

2. Adult Lake Sturgeon protection is imperative. The anthropogenic activity below Calkins Dam is intense during April-May and could alter behaviors of spawning Lake Sturgeon. Lake Sturgeon are hooked every year in this area by anglers who are targeting other species. In some cases they are inadvertently snagged, and then fought for a period of time before breaking free. The water depth at the artificial reef is only 1 m. Boating activity on the artificial reef could deter lake sturgeon from spawning on the reef, and lake sturgeon could even be struck by propellers and injured. I recommend that all fishing be closed and boating be off limits upstream of the DNR boat launch (0.35 km downstream from Calkins Dam) during the months of April and May to protect lake sturgeon. Given the popularity of sportfishing in this area, at minimum boating access should be restricted within 0.35 km of Calkins Dam even if shore fishing and wading remain legal.
3. Limited survival from egg to larvae is troubling, and the cause of the mortality must be determined. Potential causes include predation, contaminants, turbidity, or substrate. The environment below the dam is hostile for both the fish and the researchers. More protection for researchers and

habitat must be completed directly below the Dam. The amount of fishing line and debris on the spawning grounds in on full display by looking at the power line going across the river. Hundreds of fishing lures and gobs of fishing line is hanging above the river waiting to fall in and contribute to the debris below the surface of the water. Also, the many anglers that frequent the river at the dam have very little sympathy for lake sturgeon and any research that inhibits their ability to catch non-native steelhead. As the DNR improves the fishing access on the East side of the river, I recommend that fishing be shut down on the west side where sturgeon spawn from April 1 to May 30. The low hanging power line should also be moved above the dam where fishing lures will not be caught and eventually littered into the river.

4. Calkins Dam should continue to operate as a Run of River facility. Altered flow regimes that maximize energy output during peak demand can be detrimental to lake sturgeon spawning as they use fast flowing water to spread their eggs over the spawning ground and also to oxygenate their eggs after being deposited. Altering flows while fish are spawning could deter spawning altogether, and alterations after spawn could cause eggs to die from low oxygen or siltation during incubation.

5. Dredging activities and other alterations of flow and bathymetry in the lower Kalamazoo should be limited during spawning migration and juvenile out-migration periods. Although it has been shown that lake sturgeon utilize the Kalamazoo River during non-spawning times, I recommend limiting anthropogenic activities to the benthos to the months of August and September. Lake sturgeon have been captured in the Kalamazoo River in February, March, April, May, June, October, November, and December (J. Lorenz, unpublished). Limiting activities to August and September in the lower river should give adults time to exit the river after spawning and juveniles should either be upstream before their out-migration or large enough to avoid such activities. More sampling is needed to know with more certainty where juveniles are located during the summer months, which would help to more accurately assess anthropogenic impacts.
6. I recommend that no additional artificial spawning reefs should be constructed in the Kalamazoo River. Although adding more spawning habitat has been suggested as a next step, we still cannot confirm whether lake sturgeon are spawning on the first constructed reef (or if the eggs we captured on mats on the reef were incidental drifting eggs). Until we can confirm that not only are sturgeon

using the first artificial reef, but also that eggs are surviving, as evidenced by drifting larvae, the value of artificial spawning reefs to the lake sturgeon population of the Kalamazoo River is unknown. Moreover, spreading out spawning lake sturgeon among multiple artificial reefs could have the opposite management effect. For instance, fewer fertilized eggs at a spawning site will not benefit from "predator swamping" with high fecundity, which may be an important evolutionary strategy for the species. Until the root cause of lake sturgeon low recruitment is identified, there should be no additional artificial spawning reefs constructed in the Kalamazoo River.

Appendices

Appendix A. Adult lake sturgeon capture 2016-2019 in Kalamazoo River. Site locations are depicted in Figure 1.

Date	Site	TL (cm)	FL (cm)	Girth (cm)	PIT Tag ID
3/31/2016	CG	162	.	82	985120015204364
4/15/2016	MUS	161	.	63	989001005374815
4/18/2016	MDS	170	.	71	989001005374813
3/26/2017	MUS	186	174	81	989001006569154
3/26/2017	MDS	185	175	83	989001006569159
4/13/2017	MUS	168	154	75	989001006569158
3/20/2018	MUS	162	154	69	989001005374798
3/20/2018	MDS	146	135	60	900118001188976
3/25/2018	MDS	176	164	90	989001006569155
4/5/2018	MDS	151	138	64	989001005374723
4/5/2018	MDS	160	148	60	989001005374769
4/5/2018	MUS	169	155	71	989001005374792
4/10/2018	MDS	159	146	64	985120015246257
4/11/2018	CG	179	167	77	989001005374804
4/16/2018	MDS	144	135	60	989001005374733
3/24/2019	MUS	154	144	67	989001005374780
4/3/2019	CG	173	158	.	989001006569066
4/8/2019	MUS	174	161	80	985120015244178
4/10/2019	MUS	145	134	66	985120015321079
4/29/2019	Dam	145	135	70	989001005374803

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