Title: Behavior of juvenile Lake Sturgeon stocked above a hydropower dam

Abstract

Hydropower dams on Great Lakes tributaries continue to restrict natural Lake Sturgeon reproduction. Providing upstream passage to allow adult Lake Sturgeon access to inaccessible spawning habitats is being pursued on some Great Lakes tributaries. However, there is a lack of data on the behavior and downstream passage of juvenile Lake Sturgeon that may be realized from upstream passage and subsequent spawning by adult Lake Sturgeon. We used acoustic telemetry and PIT tag technologies to investigate stocked juvenile Lake Sturgeon behavior, habitat use, (Cheboygan Co. MI). We tagged juvenile Lake Sturgeon (ages 0-2) in two consecutive years with PIT tags and surgically implanted acoustic transmitters (n=360) or just PIT tags (n=1874), stocked fish in two small reservoirs on the Upper Black River, and monitored habitat use, behavior, and passage survival using a combination of passive acoustic receivers, active acoustic tracking from a small boat, and PIT tag antennas installed on the dams and downstream of the dams. We also stocked larval Lake Sturgeon above both reservoirs to evaluate larval entrainment susceptibility. Larval Lake Sturgeon did not appear to be susceptible to entrainment in the small reservoirs, as no larvae were caught below Kleber Dam and only 10 were caught below Tower Dam. Although all stocking events of juvenile Lake Sturgeon resulted in some sturgeon quickly moving downstream and through the hydropower dams, a varying proportion of all ages stocked spent extended time in the reservoirs and fish used habitats immediately upstream of the dams prior to downstream passage. Analysis of fine-scale movements in front of the dams is continuing and these results may have important implications for design of downstream passage structures. The fact that sizeable proportions of juvenile lake sturgeon remained within the small reservoirs for extended periods of time has consequences for passage survival, as larger and older individuals are more susceptible to hydroelectric turbine mortality and bar-rack impingement, and also has implications for recruitment, fish passage engineering, and hydroelectric operations. The outmigration of juvenile lake sturgeon was seasonal and dependent on the interrelated factors of water temperature, spillway discharge level, and powerhouse discharge level. Based on our multi-year dataset, outmigration peaked in the spring and fall during times of seasonal water temperature changes. These outmigration peaks also corresponded with times of higher discharge through the powerhouses and spillways. Most of the outmigration movements (>90%) occurred during the nighttime hours, indicating that migratory movements are largely nocturnal. Thus, hydroelectric dam operations may be able to be modified during these outmigration time periods to increase passage survival for out-migrating juvenile lake sturgeon. Passage survival was high at both dams evaluated and varied with age. Age-0 passage survival was higher (81.8% and 86.9% at Kleber and Tower dams respectively) than passage survival for age-1 and age-2 fish (ranged from 44.9%-58.8%).

We also compared surgical techniques and incision location on juvenile Lake Sturgeon to maximize healing and minimize tag loss of surgically implanted PIT and acoustic transmitters. Our results showed surgical incisions that were lateral of the midline were preferred over midline incisions because healing, survival, and tag retention were all higher with lateral incisions. Incision closure method (Vetbond or suture) was not significantly different and both had high healing, survival, and tag retention for lateral incisions, although incisions closed with suture displayed increasing levels of inflammation over time that deteriorated the healing process. Knowledge of healing, survival, and tag retention of surgically implanted tags is an important but often overlooked component of studies that use these techniques for evaluating fish behaviors, survival, habitat use, and other variables.

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Grantee Organization: Michigan Department of Natural Resources-Fisheries Division and Michigan State University

Project Team: Edward A. Baker, Research Biologist, Michigan DNR; Kim T. Scribner, Professor, Department of Fisheries and Wildlife, Michigan State University; Jonathan Hegna, Ph.D. candidate, Department of Fisheries and Wildlife, Michigan State University

Contact Person: Edward A. Baker, Michigan DNR, bakere1@Michigan.gov; Kim T. Scribner, Michigan State University, scribne3@msu.edu

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Background/Overview

Hydropower dams exist on most large Great Lakes tributaries (Holey et al. 2001) and limit Lake Sturgeon (*Acipenser fulvescens*) access to historic spawning and juvenile rearing habitats. Providing Lake Sturgeon passage (adults upstream and adults and juveniles downstream) is widely believed to be a management action that could improve Lake Sturgeon rehabilitation in Great Lakes tributaries (Auer 1996; Daugherty et al. 2009; Coscarelli et al. 2011). However, managers have limited information on the behavior of juvenile Lake Sturgeon of different ages as they proceed downstream, during times they reside in reservoir habitats above dams or their fate as they pass through hydroelectric facilities. Investigations of Lake Sturgeon behavior, habitat use, duration of reservoir occupancy, and survival in relation to passage at hydropower dams are needed to better inform managers and dam owners of the likelihood of success of passage efforts in the currency of quantifiable increases in recruitment. Fundamental biological research is also needed to inform decision makers and passage engineers about aspects of the species ecology that could be used to create downstream passage devices in ways that would be most effective for juvenile Lake Sturgeon as they migrate downstream. Research that can quantify and predict rates of downstream passage and survival would inform managers of important operational windows associated with fish age and size or seasonal or other environmentally (e.g., temperature, precipitation, vegetative cover) mediated timing of movements above and through dams. Development of passage and transport management prescriptions should be developed on pre-construction baseline data (Cowx et al. 1998).

Studies of the consequences of fish passage through dams have largely focused on species other than sturgeon (review in Ickes et al. 2001). Studies of stream salmonids suggest that adult passage around dams increases recruitment (Schmetterling 2003). However, comparable data are generally lacking for other species (Mallen-Cooper 2007) including sturgeon. Some research has been conducted on survival of juveniles above reservoirs for other sturgeon species (e.g., white sturgeon, *A. transmontanus*; Rien and North 2002). However, little is known of habitat use or survival of young Lake Sturgeon in reservoirs used as nursery areas or of the propensity of Lake Sturgeon of different ages to remain in these habitats. Downstream movements of larvae, limitations of juvenile habitat, mortality during summer episodes of poor water quality in reservoirs, and entrainment mortality of juveniles have been identified as important factors affecting white sturgeon recruitment (Jager et al. 2001) and are widely believed to significantly impact Lake Sturgeon recruitment in rivers with hydropower development (e.g., Menominee River, WI).

Previously in the Black River system we have estimated survival during the larval dispersal period (Duong et al. 2011a). In Crossman et al. (2011) we also demonstrated differences in survival in stream reaches below the dam as a function of age at release. Similar age and size specific assessments in reservoir habitats above the dams and following passage through the dams, in multiple years and though periods of different environmental conditions and dam operational levels, will provide managers with information on expected rates of passage and contributions of passed individuals to annual recruitment.

No significant changes in project objectives occurred during the study. We did change vendors for the acoustic telemetry transmitters due to the small size of the reservoirs and river and high likelihood of signal collisions that would have interfered with data collection.

Outcomes

Please characterize key outcomes of the project related to *knowledge*, *training*, *relationships*, and *practice.* Not all projects will have outcomes of all types.

See responses in italic associated with each question.

1. To what extent and how (if at all) did this research project advance scientific knowledge of the issue?

To our knowledge this study deployed more acoustic telemetry tags and more PIT tags to monitor young lake sturgeon than any previous study. This is the most comprehensive study of juvenile passage mortality and duration of reservoir occupancy ever conducted for lake sturgeon. In total 140 age-0, 110 age-1, and 110 age-2 lake sturgeon were surgically implanted with acoustic and PIT transmitters. Additionally, a total of 1,664 age-0, 167 age-1, and 37 age-2 lake sturgeon were implanted with only PIT-tags. Furthermore, approximately 40,000 lake sturgeon larvae were stocked above each reservoir. All lake sturgeon were produced and reared at the Black River Sturgeon Rearing Facility between April and September.

This is also the first study to comprehensively evaluate surgical techniques on the healing, tag retention, and survival of juvenile lake sturgeon with surgically implanted PIT and acoustic tags.

2. To what extent and how (if at all) did this project contribute to the education and advancement of graduate or undergraduate students focused on Great Lakes fishery issues?

One PhD student, Jonathan Hegna, was trained on this grant. During each of the 3 years of field work, an undergraduate hourly summer research technician was employed and trained to work with Jonathan in the field and in the laboratory. During two years of the project an additional 4 undergraduate hourly technicians were trained and assisted with surgery and biological data collection of age-0, age-1 and age-2 lake sturgeon implanted with acoustic telemetry devices and PIT tags.

3. To what extent and how (if at all) did this work help you or others on your team build new relationships with others in the research or management communities?

The logistics of our research was strongly supported by the owner/operator of the two hydroelectric dams on the upper Black River where the study field work took place. The close communications, collaboration, and data sharing were mutually beneficial to the dam owner, Michigan State University, and Michigan DNR. We also worked closely with Michigan Department of Natural Resources staff including members of the Lake Sturgeon Committee and personnel involved with habitat (including FERC) compliance. Information on passage was communicated regularly to agency colleagues.

4. To what extent and how (if at all) do the findings have action implications for fishery managers? If the research has direct management implications, do you have any knowledge of use of the findings by managers? If the research does *not* have direct management implications at this stage, to what extent did the research advance the process of identifying management responses to critical issues?

Identifying sources and levels of juvenile lake sturgeon mortality and passage survival in hydroelectric reservoir systems is vital to lake sturgeon recovery efforts. A thorough understanding of the mortality characteristics for spillways and different turbine systems that are common in the Great Lakes is necessary to evaluate the potential recruitment benefits of fish passage engineering efforts and reintroduction programs. it is important to understand the behavior of juvenile lake sturgeon when they interact with hydroelectric infrastructure because this information can guide fish passage engineering efforts and improve passage survival and efficiency.

Our research findings on efficacy of alternative surgical methods has been positively received by agency biologists and our research has been used to inform current and future study designs.

5. Considering the above or other factors not listed, what do you consider to be the most important benefits or outcomes of the project?

The estimation of levels and sources of mortality coincident with juvenile lake sturgeon passage through the two hydroelectric dams is an important outcome of this project. In addition, documentation of extended reservoir habitat use by juvenile lake sturgeon before downstream passage through the dams will be an important factor to consider when upstream passage of adult lake sturgeon is provided.

Related Efforts

1. Was this project a standalone effort, or was there a broader effort beyond the part funded by the GLFT? Have other funders been involved, either during the time of your GLFT grant or subsequently?

Although this project was a standalone effort, it did benefit from research capacity that was developed in large part by prior Great Lakes Fishery Trust funded work. The GLFT funded our projects “Assessment of Simulated Lake Sturgeon Supplementations in Michigan Drainages of the Great Lakes” and “Enhancing the success of Great Lakes lake sturgeon restoration through development of standard operating procedures for stream-side hatcheries” which made the establishment of our long-term Lake Sturgeon research effort on Black Lake possible. The infrastructure needed to execute the present project would not have been available without these prior GLFT funded projects. In a broader context, the project is part of a 20-year program that has focused on monitoring of movements and survival of juvenile lake sturgeon in the Black River system, including Black Lake, to understand impediments to recruitment during early life stages.

2. Other telemetry research in the Great Lakes has been conducted on lake sturgeon. Researchers have adapted our surgical procedures. Other active projects include adult lake sturgeon passage on the Menominee River in Wisconsin. Our groups is working closely with other agencies to communicate results.

Communication/Publication of Findings

1. List publications, presentations, websites, and other forms of formal disseminations of the project deliverables, tool, or results, including those that are planned or in process.

2. Please characterize your efforts to share the findings of this research with state, federal, Tribal, and interjurisdictional (e.g., Great Lakes Fishery Commission) agencies charged with management responsibilities for the Great Lakes fishery. If other audiences were priority for this research, please characterize your outreach efforts to those audiences as well. (Please note: You may wish to consult midterm reports in which specific audiences for the findings, and means of outreach to these audiences, were identified.)

During this project preliminary research results have been presented at several professional meetings either as poster or oral presentations. We also communicated research progress and preliminary results to state, federal, and Tribal partners through informal meetings such as the Michigan DNR internal Lake Sturgeon Committee and the Cheboygan River Watershed Sturgeon Advisory Council. The professional meetings attended and presentation titles are:

Presentations at professional conferences

Hegna, J., E. Baker and K. Scribner. An evaluation of route-specific survival estimates for juvenile LS at two hydroelectric dams. Great Lakes lake sturgeon research coordination meeting. Port Huron, MI February 21-22, 2018.

Hegna, J., K.T. Scribner, E. Baker. Lake sturgeon passage. IAGLR. Juvenile sturgeon downstream passage and survival at two hydroelectic dams. International Association for Great Lakes Research, Detroit, MI. May 22-24, 2017.

Hegna, J., K.T. Scribner, E. Baker. Juvenile sturgeon downstream passage and survival at two hydroelectic dams. . International Conference on engineering and Ecohydrology for fish passage. NOAA Fish Passage Conference. June 20, 2017, Seattle, WA.

Hegna, J., K.T. Scribner, and E. Baker. Juvenile lake sturgeon downstream passage and survival at two hydroelectric dams. North American Sturgeon and Paddlefish Society Meeting, October 2015. Oshkosh, WI.

Hegna, J., K.T. Scribner, and E. Baker. An Evaluation of Optimal Surgical Incision Placement and Closure Methods for Intracoelomic Transmitter Implantation for Age-0 Lake Sturgeon. North American Sturgeon and Paddlefish Conference, Columbia, MO, Oct. 2018.

Hegna, J., K.T. Scribner, and E. Baker. Movement and habitat use patterns of juvenile lake sturgeon in a small hydroelectric reservoir system. North American Sturgeon and Paddlefish Conference, Columbia, MO, Oct. 2018.

In addition to meeting presentations, two peer-reviewed papers have been published or accepted for publication and several more are being prepared. The published manuscripts are:

Hegna, J., K. Scribner and E. Baker. 2018. Evaluation of optimal surgical techniques for intracoelomic transmitter implantation in age-0 lake sturgeon. Fisheries Research 218:198-208.

Hegna, J., K. Scribner and E. Baker. *Accepted pending minor revision*. Movements, habitat use, and entrainment of stocked juvenile lake sturgeon in a hydroelectric reservoir system. Canadian Journal of Fisheries and Aquatic Science.

Manuscripts in preparation include:

Hegna, J., K.T. Scribner, and E. Baker. Timing, Seasonality, and Environmental and Operations Data Associated with Outmigration and Residency Characteristics of Juvenile Lake Sturgeon Stocked into a Hydroelectric Reservoir System along the Black River. In Preparation.

Hegna, J., K.T. Scribner, and E. Baker. Juvenile Lake Sturgeon Route-Specific Passage Survival and Forebay Behavior at Two Hydroelectric Dams along the Black River. In Preparation.

Peer-reviewed manuscripts are included with this final report and may be shared. The two manuscripts currently in preparation are also included with this report but we request these be kept confidential and not be shared as analysis is ongoing and results are considered preliminary at this time.

In addition to the manuscripts listed above, a Ph.D. dissertation is being prepared by Jonathan Hegna and will be provided to the GLFT upon completion.

Discussion

Mitigating for the effects of hydropower dams on Great Lakes tributaries will continue to present challenges to fisheries managers and efforts to restore Lake Sturgeon to prominence in the Great Lakes fish community. Our research has demonstrated if upstream passage of adult lake sturgeon is implemented and results in successful natural reproduction then juvenile lake sturgeon ages 0-2 will be able to successfully pass downstream through small hydropower dams. While most juvenile lake sturgeon stocked above the hydroelectric dams only resided within the reservoirs for a short period of time, a significant proportion stayed within the reservoir systems for extended periods of time. It is important to note that a number of juvenile lake sturgeon are still resident within the reservoir system, as lake sturgeon are still actively out-migrating from the reservoirs and may continue to do so for some time. What is apparent is that juvenile lake sturgeon were able to make use of habitats within small reservoirs and survive within them for extended periods of time. Lake sturgeon that were stocked at a younger age (i.e., age-0) remained within the reservoirs for longer periods of time compared with lake sturgeon that were stocked at older ages (i.e., age-1 and age-2). The fact that sizeable proportions of juvenile lake sturgeon remained within small reservoirs for extended periods of time has consequences for passage survival, as larger and older individuals are more susceptible to hydroelectric turbine mortality and bar-rack impingement, which may have implications for recruitment, fish passage engineering, and hydroelectric operations. One important outcome of this research is that monitoring that relies on relatively short lived acoustic transmitters (life span usually less than 100 days) will not fully capture the life history and movement patterns of young juvenile lake sturgeon, as residency times exceed the lifespan of transmitters that are currently available for small juveniles.

The outmigration of juvenile lake sturgeon was highly seasonal and was dependent on the interrelated factors of water temperature, spillway discharge level, and powerhouse discharge level. Based on this multi-year dataset, outmigration consistently peaked in the spring and fall months during times of noted water temperature changes. These outmigration time periods also corresponded with periods of higher discharge through the powerhouses and spillways. Most

outmigration (>90%) occurred during the nighttime hours, indicating that migratory movements are largely nocturnal. Thus, hydroelectric dam operations may be able to be modified during these outmigration periods to increase passage survival for juvenile lake sturgeon.

Juvenile lake sturgeon usually made multiple separate approaches into the forebays and resided within the forebay areas for several hours during a given approach. The fact that juvenile lake sturgeon of all ages spent a considerable amount of time using habitat in front of the dam, may be promising for the design of passage systems that can engage juvenile lake sturgeon to pass through safer routes. Most of the acoustic transmitter detections in the Tower Dam forebay were located immediately adjacent to the dam, while in the Kleber Dam forebay detections were not concentrated immediately next to the dam. Forebay characteristics like topography may be key factors that may influence forebay access rates, movement characteristics, residency time, and the success of fish passage engineering efforts.

The different passage routes and turbine designs that we tested had different survival characteristics. Survival rates in the free-flowing part of the Black River below Kleber Dam were higher for age-1 and age-2 lake sturgeon (~100%) than for age-0 lake sturgeon (~88%). Older age-1 and age-2 lake sturgeon suffered from higher passage mortality rates (~55%) at the Kaplan turbine system than age-0 lake sturgeon (~30%). Delayed mortality from passage through the Kaplan turbine system accounted for 10% of the total mortality rate, regardless of age group. Similarly, older age-1 and age-2 lake sturgeon suffered from higher passage mortality rates (~40%) at the Leffel turbine system than age-0 lake sturgeon (~10-15%). Passage survival of age-0 lake sturgeon was considerably higher at the Leffel turbine system (~85-90%) compared with the Kaplan turbine system (~70%). River systems that have similar Leffel turbine systems on them would likely have higher net juvenile recruitment rates compared with river systems with similar Kaplan turbine systems and may require less fish passage engineering efforts to achieve acceptable project survival rates.

Passage survival at the Tower Dam spillway was at or near 100% for all age groups, which indicates that small spillways are able to safely pass juvenile lake sturgeon. Spillway operations may be able to be modified to take advantage of the nocturnal and seasonal outmigration patterns of juvenile lake sturgeon that we documented (see out-migration and residency research summary report) in order to increase passage numbers through the spillway and increase overall project survival.

Trash rack bar spacing was related to impingement mortality at Tower Dam and was considerable for age-1 (~13%) and age-2 (~22%) lake sturgeon, but was inconsequential for the smaller age-0 lake sturgeon (~0.4%). No impingement mortality was documented at the Kleber Dam debris bar-rack structure. The smaller bar-rack spacing at Tower Dam may have contributed to the observed mortality. Bar-rack spacing and structure design has the potential to greatly influence project mortality rates and the net recruitment of juveniles.