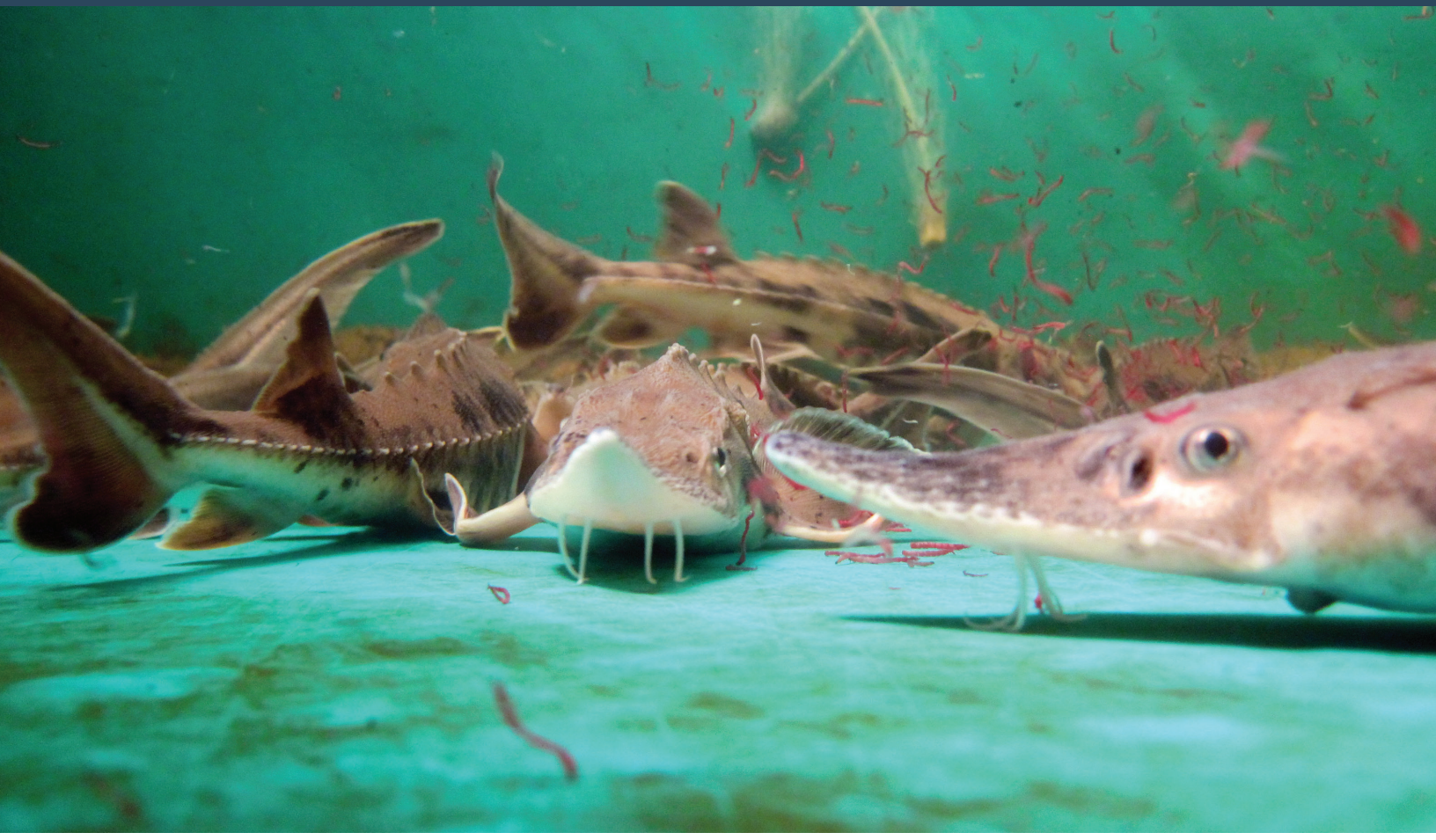
Great Lakes Sturgeon Research Priorities 2020 and Beyond

September 2021

Based on survey conducted October/November 2020 for the Great Lakes Fishery Trust
in collaboration with the Great Lakes Sturgeon Coordination Committee



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Executive Summary

Comprehensive lake sturgeon rehabilitation can be achieved only on a basin-wide scale; thus, rehabilitation requires the coordination of multiple research and management agencies with a strong emphasis on efforts that foster the development of new or existing partnerships among fishery agencies and researchers.

Collaborating with the Great Lakes Sturgeon Coordination Committee—a network of state, federal, tribal, provincial, and university researchers, with Michigan State University responsible for survey development and analysis—in late 2020, the Great Lakes Fishery Trust (GLFT) deployed a survey to 76 sturgeon researchers and managers to assess expert opinion on research needs. The results indicated support for continuing current research priorities (population, habitat, fish passage technology, and propagation techniques), with specific needs identified in each category. Additional priority research areas include climate change, forage and nutrition, invasive species and disease management, and water quality concerns.

Context of Survey Request

The GLFT has periodically engaged the research community to identify priorities for future research efforts related to lake sturgeon rehabilitation. A 2000 workshop report highlighted four research priorities for the coming years:

- Status assessment and rapid survey process: Consolidation of existing information, design of indicators and survey strategies to provide comprehensive and systemwide inventories, and coordination of periodic census efforts
- Habitat studies: Filling information gaps related to habitat utilization by various life-history stages; detailed habitat classification and inventory
- Fish passage technology for lake sturgeon: Design of safe and effective upstream and downstream passage of dams
- Propagation techniques and strategy development: Research and development to improve hatchery production and stocking success

In 2011, further needs were identified in the area of fish passage technology.

Twenty years after the initial workshop effort, the GLFT recognized the need to review research priorities to determine whether future funding priorities should remain constant or shift toward new goals.

Survey Design and Rationale

The GLFT commissioned a survey of experts on lake sturgeon to get basin-wide input on aspects related to lake sturgeon status and research needs. The Great Lakes Sturgeon Coordination Committee identified a list of 76 participants for survey distribution, representing both sides of the Great Lakes (sometimes overlapping multiple lakes) between seven U.S. states and Ontario, as well as multiple related sectors (tribal, federal, state, and provincial governments; private sector; and academia). These groups were not equally represented, but each was included to ensure input from these locations and sectors. Of the 76 invited participants, 55 provided responses to at least some questions in the anonymous survey.

The survey asked respondents to first address whether research had sufficiently addressed each of the previously identified priorities and whether each topic

should remain a research priority going forward. In addition to the four priorities noted above, participants were also asked to further consider two areas the GLFT sees as priorities: 1) whether implemented management efforts had been sufficiently evaluated and 2) consideration of social and/or economic research needs that were not explicitly identified by the 2000 workshop report. In each category, respondents were asked to identify the biggest remaining knowledge gaps, identify any new areas of research need that may have emerged since 2000, and to rank order the goals in terms of threat level and immediacy. They were also asked to identify any specific geographic locations where research is most needed over the next decade. These components represent the primary goal of the survey, which was intended to identify the state of existing research and future research needs.

In addition to these central survey components, participants were asked to identify important existing research as well as their understanding of what constitutes healthy/restored lake sturgeon populations and habitat. These questions—set aside for future analysis and not included in this report—are intended to assess the existing consensus on management goals. Finally, demographic information (sector, location, funding source, professional connection to sturgeon management, and experience) was collected to ensure that research priorities do not differ substantially by group.

Federal, state, tribal, and provincial agency staff represented 69 percent of respondents who identified their organization type, and the group could be categorized as experienced, with 79 percent having ten years or more of experience (Exhibit 1).

EXHIBIT 1. Organization Type, Primary Work Location, and Years of Experience

Organization	N
Academic	11
Federal	12
State/Provincial	17
Tribal/First Nations	4
Other	4
Total	**48**

Primary Great Lakes Work Location	N
Lake Michigan	11
Lake Superior	7
Lake Huron	2
Lake Ontario	6
Lake Erie	3
Multiple Lakes	19
Total	**48**

Years Working on Lake Sturgeon Issues	N
Less than 5 years	2
5–10 years	8
10–15 years	10
15–20 years	12
20 years or more	16
Total	**48**

Quantitative Survey Results

Existing Research

Experts were asked to consider whether each research area, as well as evaluation of management efforts, had been sufficiently assessed over the two decades since these priorities were initially stated. Using a five-point scale from "completely disagree" to "completely agree," all five priorities averaged responses in the range of 2.44 to 3.42, indicating a moderate degree of satisfaction with research coverage across each of the five areas (Exhibit 2). This result suggests progress on all of the original research priorities, but also remaining needs in each area.

EXHIBIT 2. Degree to Which Research Has Sufficiently Assessed Each Priority Area Since 2000

Research has sufficiently assessed since 2000 . . .	Average Score
The lack of cost-effective artificial propagation techniques and associated strategies to accelerate recovery of sturgeon populations	3.42
The status of sturgeon populations in the entire Great Lakes system	3.17
Habitat constraints throughout the life cycle of sturgeon populations and the role of habitat in the regulation of sturgeon population structure	2.75
Effectiveness of management plans and activities	2.62
The lack of adequate fish passage technologies for lake sturgeon in areas where dams form barriers to upstream and downstream movement and where dam removal is unlikely	2.44

Note: For scoring, the survey used a scale of one to five, with higher numbers indicating greater agreement with the statement.

Research Priorities Going Forward

Participants were asked to consider whether each of these earlier research priorities, as well as research on the impact of management plans and activities, should remain among the top sturgeon research funding priorities across the Great Lakes Basin. They were also asked about including management capacity (the resources available to address management needs) among the top priorities. Each category ranked above a three on average, indicating support for maintaining each of these priorities going forward (Exhibit 3). The strongest overall support was for research on fish passage technologies (4.04 out of five); the least support, though still overall supportive on average, with more support coming from certain groups, was expressed for research on artificial propagation techniques and associated strategies (3.08 out of five)(Exhibit 3).

EXHIBIT 3. Degree to Which Each Research Area Should Remain Atop the List of Funding Priorities

Top Sturgeon Research Funding Priorities Across the Great Lakes Basin	Average Score
Lack of adequate fish passage technologies for lake sturgeon in areas where dams form barriers to upstream and downstream movement and where dam removal is unlikely	4.04
The effectiveness of management plans and activities	3.85
Habitat constraints throughout the life cycle of sturgeon populations and the role of habitat in the regulation of sturgeon population structure	3.81
The status of sturgeon populations in the entire Great Lakes system	3.65
Management capacity to implement research recommendations [and to] increase partnership and data sharing*	3.21
Lack of cost-effective artificial propagation techniques and associated strategies to accelerate recovery of sturgeon populations	3.08

*Note: * Note a current stated priority*

Note: For scoring, the survey used a scale of one to five, with higher numbers indicating greater agreement with the statement.

Participants were then asked to rank order these priorities to consider whether certain priorities were deemed more of a threat than others in support of management efforts (Exhibit 4). This approach was particularly intended to aid decision making if funding priorities need to be narrowed. In addition to the level of threat, participants were asked to identify which areas required the most immediate attention (Exhibit 5). At this stage, participants also ranked additional research priorities they identified beyond the original six priorities. Therefore, average responses in this section indicate whether respondents believed one of these categories should be superseded by a new research area. The proposed new research category (management capacity) is ranked as the least important, with another new category (identified separately by each participant) being identified frequently as a more important threat to lake sturgeon (Exhibit 4). All six categories fall, on average, among the top six threats. Some respondents identified other threats requiring attention, including more consideration than management capacity for some. All six original priorities were ranked among the most immediate priorities for short-term funding support (Exhibit 5). Habitat constraints are listed as the greatest and most immediate priority, but the other stated categories are identified as short-term research needs as well.

The small number of participants in the study in each category makes it impossible to determine whether these differences are statistically significant. However, it does further demonstrate the need for engagement with groups such as the Great Lakes Sturgeon Coordination Committee in the process of identifying future priorities. In particular, it is crucial to identify whether any particular groups would be concerned by the removal of any specific priority, as some differences by organization were present.

EXHIBIT 4. Ranking of Threats to Lake Sturgeon Populations

Ranking of Threats	Average Rank
Lack of sufficient understanding of habitat constraints throughout the life cycle of sturgeon populations and the role of habitat in the regulation of sturgeon population structure	3.00
Lack of adequate knowledge of the status of sturgeon populations in the entire Great Lakes	3.92
Lack of adequate fish passage technologies for lake sturgeon in areas where dams form barriers to upstream and downstream movement and where dam removal is unlikely	4.22
Gaps in knowledge about implemented management plans or activities	5.53
Lack of cost-effective artificial propagation techniques and associated strategies to accelerate recovery of sturgeon population	5.86
Gaps in knowledge about management capacity to implement research recommendations [and to] increase partnership and data sharing related to lake sturgeon rehabilitation	6.24

Note: For ranking, a higher number indicates lower threat. Numbers 6.5 and above indicate an "other" category was more important.

EXHIBIT 5. Ranking of Immediate Research Priorities

Ranking of Immediate Priorities	Average Rank
Lack of sufficient understanding of habitat constraints throughout the life cycle of sturgeon populations and the role of habitat in the regulation of sturgeon population structure	3.67
Lack of adequate knowledge of the status of sturgeon populations in the entire Great Lakes system	3.85
Lack of adequate fish passage technologies for lake sturgeon in areas where dams form barriers to upstream and downstream movement and where dam removal is unlikely	4.50
Lack of cost-effective artificial propagation techniques and associated strategies to accelerate recovery of sturgeon population	5.67
Gaps in knowledge about management capacity to implement research recommendations [and to] increase partnership and data sharing related to lake sturgeon rehabilitation	5.69
Gaps in knowledge about implemented management plans or activities	5.79

Note: For ranking, a higher number indicates lower threat. Numbers 6.5 and above indicate an "other" category was more important.

Recommendations Regarding Future Priorities in Existing Areas

The following sections summarize specific research needs identified by participants in each of the six existing priority areas. A full listing of responses in each category is included in the Appendix.

Population Status

Overall, status and population research was identified as the second most sufficiently addressed (3.17), but still a substantial research priority (3.65). Lack of knowledge in this area was still identified as the second-greatest priority and second-most immediate threat to sturgeon management success. This result was also reflected in the responses about remaining research gaps: some respondents indicated that there have been important steps forward in this realm, including stock assessments in particular locations. However, respondents identified specific locations as needing additional assessment, as well as some focus on the need for more research about spawning and recruitment, genetics and population mixing, and ongoing improvement of research techniques. These three categories were also noted multiple times in response to the open-ended question about other recent impediments and research needs. This question also elicited responses about the need to address fishing mortality (as target or bycatch) and to better understand recruitment limitations.

Requests for proposals (RFPs) should continue to prioritize research on the status of sturgeon populations as they have over the past two decades, and the location list—along with some noted in response to the status and populations question—could be used to highlight those populations most in need of research.

Habitat Constraints

Habitat constraints were viewed as an area still greatly in need of research (2.75, indicating more disagreement than agreement with the statement that the topic has been sufficiently addressed) and a continued top priority (3.81). In the rank-ordering exercise, habitat constraints were viewed as the greatest and most immediate threat to lake sturgeon. The bulk of identified knowledge gaps in this area focused on habitat for larvae and juveniles. More research on habitat at early life stages is clearly a priority. Other responses noted questions about movement/migration, dams and passage (addressed in more depth in the Fish Passage Technologies section), and water/habitat quality. Each of these topics were also raised specifically regarding larval or juvenile populations. Finally, a few specific types of habitats were identified for further research (e.g., intact estuaries, drowned river mouth lakes).

Additional responses about habitat research needs were also included in the question asking participants to list up to five additional impediments for sturgeon health and rehabilitation that have emerged since 2000. Many of these responses also focused on early life stages or changing habitat needs across life stages, as well as more research needed on the imprinting process. Broader responses also highlighted migration and movement as place-related research needs.

Fish Passage Technologies

Lack of adequate fish passage technologies was identified as the area of most insufficient research over the past two decades (2.44) and most consistently a top priority for the future (4.04). Interestingly, this topic was nonetheless ranked third in terms of seriousness and immediacy of the threat when respondents were asked to compare with other priorities. Specific identified research needs in this area included an understanding of adaptation to existing barriers, possibility of removing some barriers, and developing selective barriers that can exclude undesirable species, such as sea lamprey, while allowing sturgeon through. The open-ended question about additional impediments raised additional concerns about passage (or lack thereof) as a habitat limitation.

Cost-effective Artificial Propagation Techniques and Associated Strategies

Artificial propagation for population recovery was identified as the area with greatest research advancements since 2000 (3.42) and least need for remaining atop the priority list (3.08, indicating only moderate agreement on average). Importantly, these results varied by organization type, with some respondents suggesting research in this area remains insufficient and needs to remain a priority. Lack of knowledge in this area was ranked fifth overall in terms of threat to populations, and fourth regarding the immediacy of that threat. The biggest identified knowledge gaps in this area center around assessing the impacts of these techniques on sustainable populations. In particular, there is an identified need to compare fish emerging from streamside and traditional hatcheries, as well as comparing those groups to wild individuals. Comparison needs include survival, behavior, and imprinting. Additional knowledge gaps included how to address staffing and infrastructure/equipment needs, cost reduction, and specific propagation techniques.

The open-ended question also elicited responses about needs related to genetics, stocking strategies, and production. While this area did not score the highest overall in terms of ongoing research needs, there was a wide range of research questions for this area that respondents identified as important to answer.

Management Assessment

Responses indicated that research assessing management plans and activities has been insufficient (2.62, the second-lowest score) and remains a high priority (3.85, second-highest score). However, this gap in knowledge was only the fourth greatest, and least immediate, threat. This lack of immediacy was highlighted in responses noting that it may be too early for such assessment, particularly due to lake sturgeons' long lives. However, these responses also demonstrated the need for early baseline data to support the necessary long-term research. There was identified need for evaluation metrics in this area, and consideration of long-term health/disease impacts. Some specific management actions were identified as needing assessment, particularly stocking and streamside rearing efforts. The open-ended question about other impediments did not elicit additional needs in this area, other than understanding policy and political impacts generally.

Management Capacity

Previous GLFT priorities also included the development of management capacity to implement research recommendations [and to] increase partnership and data sharing related to lake sturgeon rehabilitation. However, this category was not identified as one of the four key impediments needing most attention. This survey asked for feedback on this topic going forward, given its earlier identification. Management capacity had the second-lowest score as an ongoing priority and was ranked as the lowest and second-least immediate threat facing lake sturgeon. Participants nonetheless noted research gaps in this area, including science communication and data-sharing strategies, economic effects and interventions, and public/stakeholder outreach and education. These topics were also raised in the open-ended question about additional impediments. As such, this topic may not be a standalone category in future requests for proposals but may be best incorporated into other topics.

Location Priorities

In addition to substantive research needs, participants were also asked to prioritize locations. Priority locations may relate to convenience, specific characteristics, or most-threatened systems. A broad range of locations was prioritized for future research needs, including all five Great Lakes. Tributaries in general, and a few in particular, were highlighted as areas either lacking knowledge or where particular contexts should be studied to determine implications for sturgeon throughout the broader Great Lakes Basin. The following locations were repeatedly identified:

- Great Lakes as a whole (or multiple lakes) (eight)
- Lake Erie (11)
- Lake Huron (six)
- Lake Michigan (nine)
- Lake Ontario (seven)
- Lake Superior (six)
- Green Bay (five)
- Tributaries and connecting channels in general (seven)

Identifying New Priorities That Could Be Added to RFPs

In addition to assessing existing research priorities and whether they should remain, this survey aimed to identify additional priorities that may have emerged over the past two decades. First, there was consistent focus on research questions that bridge multiple existing priorities. For instance, the bulk of habitat focus is on early life stages and migration. These relationships across topics may suggest a need for future RFPs to highlight linkages and/or explicitly request proposals connecting priority areas. Second, the open-ended question about research gaps presented some potential new focus areas to be considered. The most prevalent categories among these responses were climate change and adaptation; invasive species and disease management, including efforts to exclude invasive species without harming sturgeon; water quality and contaminants; and sturgeon forage and nutrition needs. In addition, several responses highlighted the need to develop and test new research techniques to address a wide range of research questions.

Conclusion

This survey demonstrates support for the ongoing research priorities, with some specific direction noted, even those that have seen major advances since 2000. Management capacity, an area that has been a GLFT priority despite not addressing a specific threat to lake sturgeon, was ranked lowest among threats but nonetheless received attention in terms of specific research needs. Emerging priority research areas include climate change, forage and nutrition, invasive species and disease management, and water quality concerns.

Appendix A: Compilation of Responses, Sorted into Categories

List up to five (5) additional impediments for sturgeon health and rehabilitation that have emerged since 2000 and describe what research is most needed to address each challenge.

(Note: Duplicate responses are not included in the section. Moreover, the total number of responses was not sufficient to make it statistically significant).

1. Climate Change and Adaptation

- Not really new, but climate change
- Climate change—understand if increases in water temps and variability in stream flows are negatively impacting sturgeon
- Climate change impacts on LAS populations of all age classes
- Adaptation to changing environments—genetic, epigenetic, behavioral

2. Habitat and Migration/Movement

a. Habitat

- We do not have a good understanding on where lake sturgeon go and what habitat are used in the Great Lakes. We could use the existing GLATOS [Great Lakes Acoustic Telemetry Observation System] system and enhance it to do so.
- Better historic knowledge of connection between wetlands at river mouth areas and lake sturgeon habitat needs. Wetlands/sloughs at river mouths or at deltas were found in many historic [Great Lakes] "sturgeon rivers." We know so little of connection.
- New technologies or methods are needed to evaluate the success of habitat restoration efforts. Given the high cost of these programs, we need to solve the "attraction vs. production" problem.
- Additional restoration and rehabilitation on more systems to help achieve population goals
- Restoring spawning habitat and how adding more habitat effects small populations with limited female participants
- Need to better identify habitat constraints should be split into river and open lake. This is suggested by specifying the whole life cycle, but the assessments required differ so much it is worth separating them.
- Larval habitat and survival
- An area of need research is understanding the seasonal habitat use by juvenile, sub-adult, and adult Lake sturgeon. This is particularly relevant for systems that undergo hypoxia in the hypolimnion during thermal stratification.
- Better understanding of historic flora and fauna found at upriver spawning sites. So little has been documented on who and what composes the mosaic of life at these locations—there are not many left untouched.
- Contemporary habitat assessments—Research is needed to quantify the amount and location of spawning and nursery habitat in tributaries to further support reintroduction efforts.
- Identify habitat types and locations that may be limiting recruitment.
- Lack of quantification of suitable historic and current spawning habitat remains an impediment to establishment of quantifiable population goals.
- Juvenile sturgeon survival estimates and habitat use
- What other (how many) tributaries are capable of supporting lake sturgeon (i.e., suitable habitat)?
- Carrying capacity on small tributaries
- Habitat assessments that review suitability for multiple life stages and potential limitations that may hinder population success

- Ascertain the role of river mouths (RM) in lake sturgeon life cycle. Specifically, are RMs simply staging areas for spawning migrations; are RMs common nursery habitats? Does RM size affect their importance (e.g., drowned RM vs. typical RM)?
- Juvenile habitat use
- New spawning habitat: Some agencies are installing new spawning habitat and funding needed to evaluate the new habitat and publish literature associated with the best habitat construction practices
- [Lake sturgeon] reintroductions/translocations into extirpated sections of rivers/lakes
- Did shoal spawning ever exist?
- We need to develop functional, process-based definitions of sturgeon habitat.
- Watershed land use practices and protection of spawning tributaries. This includes the exact spawning area but also run off and water quality as well as healthy estuary habitats for larval sturgeon.

b. Passage as habitat limitation

- Sturgeon use of passage facilities, innovation rather than incrementalism on sturgeon passage
- Downstream passage of juvenile lake sturgeon
- Barrier Impacts-in particular nutrient loads for sturgeon survival
- We still do not have a good passive upstream fishway design at all dams or a downstream passage protection system at hydropower dams, which means the continued fragmentation of populations and the inability to colonize historic range.

c. Migration/movement

- Movement, particularly of juvenile stocked fish
- Movement of individuals between lakes
- In our mark recapture and telemetry projects we are seeing a significant amount of straying between what we thought were distinct population units. Would be useful to know what impact/genetic benefit/timing thereof etc.
- GLATOS projects in the Detroit River have shown multiple migration patterns. Is this unique to Detroit River or is this a more common strategy observed across the Great Lakes and what are the management implications?
- Open-water ecology of lake sturgeon. Many fish spend much of their life cycle in the open waters of the Great Lakes, yet we know almost nothing of their ecology and movements during this time.
- How do we get current populations to expand their range to colonize currently poorly used parts of the Great Lakes? We have some good and stable core populations, but it is unknown if they are moving into new habitats.
- We need improved understanding of how lake Sturgeon navigate rivers and lakes and the physical/biological cues they use to locate and relocate areas of past spawning/feeding. Understanding how these fish navigate would help with passage designs.
- Movements and habitat occupancy during nonspawning periods
- Large-scale movements between populations
- Acoustic telemetry array within Lake Michigan similar to Lake Huron and Detroit River systems
- Too many tracking projects looking for a question to ask. Compile knowledge and identify priorities for future (e.g., specific questions vs. where they went).
- Support for a large-scale acoustic telemetry network in eastern Lake Michigan that simultaneously tagged lake sturgeon from multiple spawning populations

d. Imprinting

- Imprinting—More research is needed about the early life period in terms of how and when imprinting occurs (Note: Three responses indicated this point.)

3. Forage and Nutrition

- Nutrient dynamics—Understanding the role that adults play in transporting nutrients upstream is important. Similarly, understanding the role that the lack of nutrients (resulting from barriers) plays in larval survival is important.
- Forage—Are changes in lower tropic levels and benthos reducing forage?
- Diet and nutrient levels and requirements of all ages

4. Contaminants/Chemicals/Water Quality

- Contaminant burdens on lake sturgeon health
- Contaminants—Using existing fin rays to look at emerging contaminant loads
- Impacts to lake sturgeon recruitment from the chemical and physical control of sea lamprey across the Great Lakes. For example, TFM is now known to cause significant mortality to age-0 sturgeon in high-alkaline rivers. Sublethal affects unknown.
- Importance of lampricide treatments on small populations
- Impact of sea lamprey treatments
- Impacts of water quality changes (improvements) since 1950s and how these improvements have helped [lake sturgeon] recovery populations
- Contaminants—Are contaminants of emerging concern and pharmaceuticals negatively impacting sturgeon reproduction or health?
- Impacts of new chemicals of concern/micro-plastics

5. Invasive Species, Predators, and Disease Threats

- Impacts of round goby and other [aquatic invasive species] on lake sturgeon reproduction
- The ecological interaction with non-native species, such as round goby and dreissenid mussels
- Lamprey impacts to growth and survival
- Compatibility of sea lamprey control and sturgeon recruitment. This includes effective barriers that don't impact sturgeon spawning migrations and effective larval treatments that don't impact sturgeon recruitment.
- Remaining risk of botulism to large lake sturgeon
- Disease
- Fish health—More research is needed with respect to understanding, preventing, and diagnosing diseases in aquaculture facilities.
- Predator-prey trophic interactions, including effects of invasive predators on natural recruitment
- Impact of invasive species and changes in the food web . . . what is the implication?
- Impacts of exotic species, e.g., round goby
- Susceptibility to existing and emerging diseases, pathogens, and viruses. We have been fortunate that sturgeon were found not susceptible to VHS. The same may not be true with future diseases or pathogens.
- Research on emerging herpes virus or any other new fish health concerns, including impacts of invasive species on sturgeon populations
- Impacts of AIS on biology and sustainability of sturgeon populations (e.g., quagga/zebra mussels)

6. Population Assessment Techniques and New Research Tools

- Developing better assessment methods for assessing population status. Working towards increased utilization of mark-recapture information that might be obtained from [passive integrated transponders (PIT)] or acoustic tags.
- Full lake population assessments: Abundance/distribution/genetics—are there populations we are missing?
- False claims of recovery based on poor [mark/recovery (m/r)] study design. Proper means to conduct m/r on sturgeon (i.e., don't mark on spawning shoal then recapture later and assume a closed population).
- When is a population deemed recovered? What density and at what life stage?
- How much research is too much? At what point [in] capturing and displacing adults during spawning (for example) is there a detrimental effect?

- Long-term monitoring—Research is needed to determine the most effective and accurate methods to determine lake sturgeon population status on a basin-wide scale.
- Increased funding and support for long-term monitoring to determine if implemented measures are working (e.g., acoustic tracking, genetic analysis, habitat assessments)
- Better measures of early life and juvenile stages
- Marking and movement studies: We need to describe long-term fish marking strategies like PIT tags that will help us to evaluate changes in populations over multiple year[s] and need to expand on acoustic movement studies to better understand movements
- Standardized population data is needed for all populations of lake sturgeon in the Great Lakes along with a good understanding of the interchange of fish between populations.
- Short-term studies—Require long-term committed funds and not rely strictly on grad students
- Reference points for population recovery and not necessarily to historical levels. Determine K for waterbodies/tributaries and current population levels
- Factors underlying low natural recruitment
- Regional estimates of larval lake sturgeon production
- Depensatory effects of low spawner abundance on natural recruitment levels
- How can we most effectively assess recruitment to determine if rehabilitation efforts are working? Assessing juveniles will give a quicker indication if rehab efforts are working than waiting for adults to mature at 20+ years old.

a. Developing targets and management techniques

- Tributary-specific targets for adult abundance. On Superior, we use 1,500 adults [as] self-sustaining, but those targets should be tributary specific based on size/discharge and historical abundance. A one-size target is not appropriate for all tributaries.
- For those populations that are doing well (HEC/lower Lake Huron)—What is working and what can be used in other areas?

b. Fishing mortality and other human impacts

- Incidental mortality from angling—especially in areas where angling is NOT permitted
- Harvest considerations within recovering populations
- Impacts to sturgeon recruitment and health from excessive human interaction or disturbance. Examples include snagging by walleye and steelhead anglers and use of high-speed boats in some rivers that transect spawning grounds, and commercial bycatch.
- Poaching—Effective monitoring, enforcement, [and] forensic capabilities
- Hooking mortality, particularly seasonal. Can we increase angling opportunities (even if catch and release) to get more stakeholder interest in lake sturgeon recovery?

7. Recruitment Limitation

- Recruitment success—In stocks where spawning is observed but recruitment is limited (i.e., Fox River, Wisconsin), assessing what aspect may be limiting recruitment—hatching success, drift, habitat, predation, etc.
- Larval and juvenile survival rates and bottlenecks
- Recruitment bottlenecks: Appear to have increased adult spawning populations over last 20 years and spawning activity, but how can we improve habitat to improve recruitment?
- Predation on stocked juveniles
- Juvenile sturgeon survival estimates and habitat use

8. Genetics

- The restrictions on the number of adult sturgeon that can be used for propagation purposes from southern Lake Huron should be increased to enable broader genetic variability for stocked fish. I believe this is a Canadian permit restriction.
- Genetic considerations
- Potential for outbreeding depression

9. Early Life History

- There still is a large gap on early life history in most systems and we do not know what happens to fry and juveniles, particularly the causes of mortality and key habitats.
- Survival of early life stages; river-specific constraints on natural recruitment
- Egg survival and hatching success
- Key determinants in early life stage survival (egg deposition through larval drift, and larval through YOY river emigration). Focus on environment and habitat quality influences but should also include parental effects.

10. Production and Stocking

- Stocking strategy—Research is needed to evaluate the survival and imprinting of streamside-reared and traditionally reared lake sturgeon. If results are similar, the most cost-effective strategy should be implemented.
- Genetic implications of stocking
- Stocking densities by life stage
- Success of conservation stocking
- Stocking site fidelity
- When to use stocking as a rehabilitation measure
- Additional support for hatchery techniques to increase sturgeon egg hatch, juvenile growth before release to wild
- Infrastructure capacity—Funding is needed to provide capacity for a "rearing focus" group to design a new streamside facility that considers new information and new technology.
- Aquaculture—More research is needed with respect to early rearing. Specifically, the transition period from exogenous feeding to 30 days post exogenous feeding.
- Hatchery products: Recruitment and fidelity associated with stocked fish as well as evaluation of survival of fingerlings versus yearlings

11. Social Science and Policy

- Potential for loss of public support for lake sturgeon rehabilitation efforts due to increasing abundance and encounters by anglers is a concern in some areas.
- Continually encourage, and possibly even mandate, communication between researchers and between research and managers. As fish people, we would inherently rather deal with fish than people, so often must be forced to do so. But it's very beneficial.
- Lack of education/outreach. Sturgeon is not a game fish in Michigan and are not in the spotlight for most recreational anglers/public.
- Political interference—An opportunity to monitor efficacy of trap and transfer at a benign dam but never funded because of perceived impacts on sea lamprey program'

12. Other

- Moving from research to on-the-ground management activities. We spend millions on research, but hesitate to spend millions on a hatchery or spawning bed improvements?
- I can't see that there are any new changes in 20 years
- Time—The populations need time to recover without additional stressors impacting the populations
- Evaluating the effectiveness of recovery efforts. How successful have long-term stocking efforts been to recovering populations. How effective have fish passage and habitat development projects been at increasing reproduction and recruitment?

- Improved remote PIT tag detection capability and/or other cost-effective remote assessment capabilities. This is admittedly a responsibility of and is actively pursued by the private sector. It just takes time and will remain a continued need.

What are the top three locations (at any scale) about which to prioritize research in the coming decade, and why?

1. Great Lakes as a Whole

- Expand on Great Lakes mixed stock analysis through movement studies and genetic research: As a species with great restoration interest, we need better knowledge of population interaction and impacts of stocking strains beyond their boundaries
- Great Lakes
- I don't understand the question. The eastern end of the Great Lakes is my location of interest and I favor there being more funding for figuring out the sturgeon limitations in the Lower Niagara River. Fortunately, there has been a study group engaged.
- Lower Great Lakes
- Southern extremes of range—potential climate impacts.
- Southern limit of range
- Major [Great Lakes tributaries], also historic sources of production and opportunities for habitat restoration and stock recovery
- The lower lakes (Erie, Ontario) as there are fewer spawning populations identified there

2. Lake Erie (11)

- Lake Erie, use to support the largest populations, we should be working aggressively to restore them
- Lake Erie
- Lake Erie tributaries. Erie historically had a very large population with only 2 of ~ 19 spawning locations currently active.
- Lake Erie
- Lake Erie as there [are] ongoing lake sturgeon reintroductions taking place and it is important to gain knowledge on the success of that program.
- Lake Erie
- Lake Erie—Monitoring a population with harvest and recreational angling is important and will provide Great Lakes managers with data relevant 30 years from now when Great Lakes populations rebound. Folks want to catch sturgeon when numbers allow.
- Lake Erie—Only two known spawning populations exist in the entire lake (Detroit/St. Clair and Niagara Rivers). To increase the sturgeon population, more tributaries need to be assessed to determine restoration potential.
- Lake Erie
- Western basin Lake Erie—Shows great promise with huge potential
- Lake Erie—Why are populations not recovering and what can be done to facilitate recovery?

3. Lake Huron (6)

- Lake Huron—Only two known spawning populations exist in U.S. waters of the Lake Huron basin (St. Marys River and St. Clair River). In order to increase the sturgeon population, more tributaries need to be assessed to determine restoration potential
- Lake Huron—Much is known of the lower lake population, but little of the Georgian Bay/NC spawning locations, mixing with lower/Lake Michigan/eastern Superior populations. Development of a new acoustic array and tagging will help.
- Specific locations in Lake Huron include the North Channel rivers.
- Saginaw Bay tributaries (Lake Huron)—Recent efforts to stock sturgeon in several [tributaries] offers opportunities for learning more about reintroduction success especially in "short" systems (less than 50 [kilometers])

- Lake Huron as there are lake sturgeon reintroductions taking place and it is important to gain knowledge on the success of that program.
- Lake Huron. Disclaimer, I work on Lake Superior, but I consider our sturgeon populations doing relatively well compared to other lakes.

4. Lake Michigan (9)

- Lake Michigan as it has several small remnant lake sturgeon populations, but the GLATOS network is not as developed there and there is a lot to learn about the behaviors of those sturgeon populations
- Lake Michigan tributaries—Fish have been stocked from [sturgeon rearing facilities] for numerous years now and males are starting to reach maturity. We need to evaluate habitat in these subwatersheds and ensure that these mature fish will have the necessary habitat for [natural reproduction (NR)].
- Lake Michigan tributaries
- East shore of Lake Michigan systems towards reintroduction of extirpated populations
- Eastern Lake Michigan because there is a network of remnant populations that would benefit from a coordinated research focus.
- Lake Michigan: Lake Sturgeon have been stocked here and these individuals will be recruiting to adulthood soon. We need to evaluate streamside rearing. Then next 3 decades of recovery work depend on it in terms of what sources we use for stocking.
- Lake Michigan
- Lake Michigan
- Manistee and Muskegon Rivers tributary to [Lake] Michigan. Why: Because they are susceptible to regular mortality from use of TFM to control sea lamprey, spawner abundance remains low, and high human activity and dams exist in the watershed.

5. Lake Ontario (see also Niagara River section) (7)

- Lake Ontario/St. Lawrence River
- Lake Ontario—Limited current research.
- Lake Ontario and the St. Lawrence River
- Lake Ontario and tributaries—The potential is huge, many tributaries and untapped potential
- River systems, southern part of range.
- Lake Ontario
- Lake Ontario: Limited numbers in the Niagara area and the eastern end of the lake. Is there sufficient habitat for population improvements lake wide?

6. Lake Superior (6)

- Lake Superior—It has the largest number of self-sustaining populations and is the only Great Lake not yet impacted by drastic environmental changes now seen in lower 4 [Great Lakes'] food webs and to understand the link to wetlands as so many rivers in [Lake Superior] have.
- Lake Superior—Still limited knowledge for spawning populations/locations; still the most natural of the 5 lakes.
- Lake Superior. If the goal is to try and determine what is working. There are controls to use (i.e., rivers that have sustained populations), rivers that have restoration efforts ongoing, and rivers that have yet to start a rehabilitation process.
- Lake Superior
- Specific locations in Lake Superior include the Batchawana, Goulais, and Nipigon Rivers.
- Differing recoveries of [Lake Superior populations] in [Lake] Superior tributaries

7. Green Bay (5)

- Green Bay—The world's largest freshwater estuary only contains a few remnant populations. For example, the town of Nahma was named after Lake Sturgeon, and now the Sturgeon River has zero Sturgeon. It's a flagship location for species recovery.

- Green Bay. Spawning populations are in proximity. Rivers are a high priority for local restoration projects including passage. Open water tracking would be possible with expansion of telemetry grid.
- Green Bay (3 responses)

8. Black Lake

- Future research productivity is best predicted by past achievements. The Black Lake research team has demonstrated leadership and vision as a leader in lake sturgeon research in the Great Lakes and internationally.

9. St. Lawrence River (see also Lake Ontario section)

- St. Lawrence River—Has vast amount of habitat and unknown adult population size
- Upper St. Lawrence [River population] is still depressed—how to help its recovery

10. St. Clair River (see also Lake Huron section)

11. Black River (see also Theory Driven with Example Case Selection section) (1 response)

12. Detroit River/Lake St. Clair (2 responses)

13. Niagara River (see also Great Lakes as a Whole section)

- Niagara [River] /Western [Lake Ontario] populations and impacts from habitat changes

14. Menominee River (see also Lake Michigan and Theory Driven with Example Case Selection sections)(1 response)

15. St. Marys River (see also Lake Huron section)(2 responses)

16. Huron-Erie Corridor

- Huron-Erie Corridor
- Although habitat was highly damaged, historically the Huron-Erie Corridor seems to be developing into an economic opportunity for catch and release, and gathering more information on movements of Great Lake stocks.

17. Other Specific Locations

- Grand River (Lake Michigan)—Recruitment success and habitat limitations have not been well assessed.
- Central [New York]—Finger Lakes region
- St. Louis River, [Wisconsin/Minnesota]
- Northern Wisconsin lakes
- Ohio River basin
- Maumee River (Lake Erie tributary)—Monitoring stocking survival and success and assessing habitat models and habitat use by sturgeon. This project could inform further restoration efforts in Lake Erie.
- Saginaw watershed stocking effort

18. Tributaries and connecting channels in general

- Tributary scale—Knowledge of the existing habitat in tributaries is needed to determine if more tributaries can support reintroduction efforts.
- Small [Great Lakes] tributaries
- In part due to the river system size and limited agency resources, learning about adult abundance in most, if not all, Canadian tributaries is needed.
- Great Lake tributaries
- Tributaries
- Connecting channels (St. Marys, St. Clair, Detroit, Niagara, and St. Lawrence Rivers) because these areas contain robust populations that might be population sources for depleted populations in smaller tributaries
- Great Lakes connecting channels - historic important sources of production, opportunities for habitat and stock recovery

19. Theory Driven with Example Case Selection

- Tributaries where no natural recruitment is occurring but habitat upriver of dams seems conducive to providing recruits.

- We need better fry and juvenile Lake Sturgeon fate and habitat data, and this could be done at Black Lake, Menominee River, and Lake St. Clair to get the variation in systems accounted for.
- Systems with large, thriving sturgeon populations, such as the St. Clair and St. Lawrence Rivers. Understanding the factors underlying the success of these populations could aid restoration of more at-risk populations.
- Locations where populations are robust in each lake system.
- Sturgeon migration over dams/dam removals
- Wild populations of low abundance that have not shown clear and steady increases in abundance over the past 20 years (examples include lower Michigan riverine populations tributary to [Lake] Michigan and [Lake] Huron). These populations are at highest risk.
- Continued funding to expand on knowledge of existing larger populations like Detroit, Lake St Clair, and Green Bay populations: These populations represent largest populations and should serve as the basis for restoring populations in another watershed
- Any location where populations remain small, but opportunities exist for streamside rearing and release programs to be implemented.
- We need data on whether rehabilitation efforts are working, and this could be done on the Menominee, Cedar, Whitefish, Milwaukee, and Black Rivers.
- Places where indigenous peoples have cultural needs, Menominee River and/or Mid-Michigan, dam removal and/or current fish passage make these areas important potential joint managed areas, increasing understanding of success of these endeavors.
- Populations that spawn in the tributaries to Green Bay (Lake Michigan) and Georgian Bay/North Channel of Lake Huron. Existence of multiple spawning rivers within a defined region allows for comparative studies of populations and habitats.
- Priorities should be given to populations where demographic data are lacking and populations are in greatest need (e.g., lowest perceived abundance and lowest perceived natural recruitment).
- [St. Clair Detroit River System (SCDRS)]
- Northern limit of range
- Where potential management or restoration activities may have an impact.
- Keeping genetic diversity and keeping small population from extirpation
- Inland lakes/rivers—Diversity of stocks, opportunities for restoration
- Continued evaluation of recently reintroduced populations using streamside rearing (Cedar, Whitefish, Milwaukee, and Kalamazoo Rivers tributary to [Lake] Michigan and Ontonagon [River] tributary to [Lake] Superior).
- HEC
- Any population that remains small and does not appear to be increasing in size because understanding the factors limiting recovery in these populations is necessary for basin-wide recovery
- Hatchery practices: We have improved hatchery practices and now need to explore impacts on fidelity and survival of stocked products, so it's important to keep good record keeping on strains and marks applied to those products
- We need information on where Lake Sturgeon go in the Great Lakes Basin using the GLATOS system [with] an emphasis on Lakes Erie, St. Clair, Michigan, Huron, and Superior with gates throughout and on major [tributaries].
- Open-water habitats of any Great Lake
- Education and outreach to make sturgeon a focal point for public in future
- Contribution of in-lake spawning reefs

A broad range of locations is prioritized for future research needs, including all five Great Lakes. Tributaries in general, and a few in particular, are highlighted as areas either lacking knowledge or where particular contexts should be studied to determine their implications for sturgeon throughout the broader [Great Lakes] Basin.

What are the biggest remaining gaps in knowledge of status and populations throughout the system?

20. Recruitment/Reproduction/Genetics

- Whether or not streamside rearing works in terms of imprinting and successful return of adults with an appropriate level of genetic diversity.
- Recruitment around the basin and spawning population estimates
- Degree [of] sturgeon spawning success at key locations as measured by young-of-year [YOY] capture and/or egg deposition
- In-situ recruitment rates and dynamics, mixing of individual populations/spawning aggregations
- Functional genomics and gene flow. Spawning behavior and reproductive success among populations.
- Recruitment success and survival rates of young (<5 years) sturgeon
- There are likely smaller spawning aggregations/populations that we don't know about.
- Amount of straying and genetic contribution that occurs within and among populations. Can reintroduced populations use homing instincts to return to their stocked locations, and do they stray more genetically when reintroduced from other locations?
- Recruitment levels/indices of juveniles relative to adult spawners.
- Survivorship of early life stages.
- Spawning success, recruitment, critical habitat for various life stages
- Lake sturgeon movement, spawning site fidelity, open lake habitat use, and genetic structure of populations.

21. Other Life Stages

- Survival between life stages (e.g., fingerling, juvenile, sexually mature)
- Adult assessments and the size of annual spawning runs (similarly total adult population size for a spawning tributary).
- I think we still need better population estimates for the total number of adults out there, unfortunately those are difficult and labor intensive. Estimates of recruitment of young fish are also needed, but again difficult to obtain.
- Assessment of contribution of stocking programs.
- Vital rates (mortality, recruitment, etc.) for remnant populations are still largely unknown and are needed to inform management.
- Vital rates (e.g., mortality rates) are missing
- Time required to observe changes in [populations], assessment of juvenile abundance
- Where do the lake sturgeon go to feed in the lake as adults? Exact timing of when YOY fish leave river systems.

22. Specific Population Stock Assessments

- There are several historic lake sturgeon spawning tributaries throughout the Great Lakes where it is unknown whether lake sturgeon are still present, still spawn, and/or the habitat present is still suitable for lake sturgeon.
- I believe we have a sufficient understanding of the status of lake sturgeon stocks in the Great Lakes, including stock structure (or we will when recently funded genetic projects are completed). Possibly, understanding which spawning locations contribute to populations at a lake-wide scale may still be necessary.
- Eastern Lake Superior and St. Marys River
- While our knowledge has improved about Great Lakes lake sturgeon populations since 2000, many populations are still, at best, guesses. Some examples are the Lower Menominee and St. Marys River populations. We still do not have good recruitment information and know little about their lake-wide movements.
- For Michigan waters, a better idea of the status and trajectory of the St. Marys River population is needed. Also, status of natural reproduction in some of the Lower Peninsula tributaries to Lake Michigan. One of the biggest gaps yet to be adequately addressed is how to effectively assess juvenile populations.

- The lake-wide populations in the five Great Lakes are probably divided into segments associated with major spawning areas and more needs to be known about the progress with, or what constraints there are on their recovery in Lake Ontario. The public support or outreach for these efforts needs to be assessed and engaged in the Lake Ontario basin.
- What is the status and population characteristics of Canadian populations? Are populations experiencing outbreeding depressions because of excessive stocking?
- I would argue that progress has been made for many (most?) populations, but there remain a few gaps. Particularly in Canadian waters, including the north shore of Lake Superior, the North Channel and Georgian Bay in Lake Huron, and in Lake Ontario.
- The quality of data available for many lake sturgeon populations is poor for many remnant populations (e.g., Muskegon or Grand River populations in Lake Michigan). Monitoring and research efforts should be able to give an idea of whether populations are increasing, decreasing, or not changing. Given the life cycle of lake sturgeon, this requires sampling effort over long timescales so that trends can be quantified.

23. Population Assessment Needs/Approaches/Techniques

- Does every population need an assessment? Sometimes I feel we spread our time and money over too large an area. Everyone wants sturgeon in their systems (even in systems which have not had them in the past). I feel research/assessment funds should be directed to historic populations which are close to self-sustaining, these are populations we don't want to lose but, in some cases, have not been adequately assessed or re-assessed for 20 years or more. I interpret this also as assessments, and I think it's critical to continue assessing these populations so we can track the success of recovery efforts.
- The general status of sturgeon populations in the Great Lakes is known in that we know the distribution of spawning populations and whether those populations are small or large. Many populations are monitored on a semiregular basis.
- I think that the status of many populations is known . . . for example, whether a functional (sufficient number of spawners) lake sturgeon population exists in a given tributary. However, the population size and growth rate of current populations still needs some work, and this is difficult to obtain due to the time investment needed to conduct surveys over many years.
- We need to continue monitoring populations and status as these improvements are made. Passive techniques, such as PIT arrays, are things that should be focused on for larger funding.
- Population abundance, spawning age/size distributions, and levels of natural recruitment remain largely unknown for the majority of Great Lakes populations.
- Listing changes are based on numerical population targets—need more data to refine those numbers
- Updates to those populations that have been receiving restoration and rehabilitation efforts.
- Population estimates within the five lakes are incomplete. Number of spawners/juveniles are unknown for most areas. Other than limited studies (e.g., HEC), many areas are only surveyed every 5 years, without any M/R work for estimates taking place. Limited knowledge of spawning locations for most LS areas. Limited knowledge of movement and genetic flow within lake populations.
- Isolation of neighboring populations, migrations, nonspawning residency areas
- In addition to dams, which are easy to identify, there are likely other barriers.
- Identifying habitats that need restoration and restoring those areas to functional status, developing measures of juvenile and [early life history]–stage abundance distribution, survival, recruitment. evaluating opportunities for angling of existing stocks
- General or broad understanding of status has improved greatly since 2000. However, details of status for certain important or at-risk populations [are] still not assessed at regular enough intervals or in enough detail to determine trends or understand causes for increasing or decreasing recruitment and abundance. Limited agency resources continue to restrict the ability of most agencies to conduct comprehensive assessments of populations necessary to sufficiently address this concern.

- Made good gains in better understanding the status of populations across the Great Lakes. Projects like GLATOS [are] important to fill the knowledge gaps, but still expect that there are still many gaps and unknowns that exist.
- Ability to adapt to environmental stressors and changing climate
- Contribution of smaller populations to the [Great Lakes]. Similarities of subpopulations (i.e., tributaries) within and among [Great Lakes]. A lot of effort has been afforded to the HEC and inferred to the rest of the [Great Lakes]. This needs to be validated.
- Many waters do not have statistically tight estimations of the current population.

What are the biggest remaining gaps in knowledge about sturgeon habitat in the Great Lakes?

1. Larval and Juvenile

- Very little is known about larval and juvenile habitat needs. More specifically, where do drifting go and what habitat are necessary to enhance natural recruitment? Additionally, what habitats are utilized by ages 1 through adulthood?
- Young-of-year lake sturgeon habitat; juvenile lake sturgeon habitat
- Again, we have gained much information, we still do not know where the fry and juveniles go in systems and have nearly no information on where they are in most of the Great Lakes.
- Habitat used by juveniles
- There has been considerable investment into lake sturgeon spawning habitat requirements; unfortunately, most studies have simply described the physical habitat characteristics of places where sturgeon spawn. This information is useful at the local scale but isn't always generalizable to other spawning rivers with contrasting ranges of physical habitat variables. What is needed is a more functional (or process-based) definition of sturgeon habitat; for example, sturgeon spawn in habitats with accelerating flows and on/near bedforms that funnel currents through interstitial spaces. This hypothetical definition can be tested across a wide range of sturgeon rivers regardless of their flows, maximum current speeds, depths, or dominant substrate.
- Age-0 and juvenile habitat use has not been adequately assessed in many systems and should remain a priority. Acoustic telemetry projects evaluating the movement patterns of all life stages will help understand habitat use and the interjurisdictional management of this species. Spawning and nursery habitat needs to be quantified in tributaries that could potentially support lake sturgeon restoration.
- Information is needed regarding larval and age-0 juvenile movements and habitat use.
- Where is habitat limiting and where is it not limiting for survival of early life stages?
- Spawning habitat, larval survival
- Juvenile habitat usage, availability of spawning habitat in seasonally abnormal years
- Larval sturgeon habitat needs
- Spawning locations
- Nursery habitat
- Habitat requirements and use by early life stages of sturgeon, particularly YOY, are still not well documented. Juvenile and adult habitat use in the open waters of Great Lakes is largely unknown.
- We don't know a lot about YOY or juvenile optimal habitat.
- Juvenile/sub-adult habitat use
- I feel that telemetry has provided great information about older juvenile and adult movement and habitat use, and there has been work on a limited number of populations to address habitat use in early life history stages. But I feel that more work on spawning, larval drift, and age-0 habitat is needed.
- Habitat use by age-0 fish and how this differs among stocks/rivers, habitat limitations on recruitment success
- First, there is much to learn about habitat use of sub-adult lake sturgeon in the Great Lakes.
- There is a gap in the understanding of the habitat needs of post-hatch larvae and small juveniles.
- Juvenile habitat use is still limited in several systems.
- Where are the nursery grounds, what is their level of degradation, and how vulnerable are they?

- How fast do larvae drift downstream, when does it occur, and what environmental or industrial/agricultural events happen when they drift, and how has river sedimentation changed over the years, are rivers carrying heavy sediment loads, does braiding occur, do larvae become stranded and die if drift occurs at periods of low flow due to water-level manipulations? We used to think the larvae needed gravel during drift, now we don't, so enhancing habitat for other than spawning areas may not be important. Flow, thalweg depth, and light may be much more important than previously thought for native populations.
- Additionally (see also Dams and Passage section), many spawning tributaries have lost valuable estuary-type areas that may be beneficial to larval development and survival. These estuaries have been lost to harbor construction and navigation but should become a focal point for habitat improvement projects.
- What role dams, substrate alteration, and invasive species play in current spawning success - is habitat a limiting factor (see also Dams and Passage and Water Quality sections)?
- Artificially created or enhanced spawning areas need to be evaluated and possibly be improved or multiplied.
- Understanding the importance of wetland and depositional habitat in river mouths as it relates to survival and recruitment of young-of-year
- The degree to which physical habitat is currently limiting early life recruitment and population growth vs. other limitations, such as spawning stock abundance, interactions with other species, or other chemical or biological features of habitat remain knowledge gaps in our understanding of habitat constraints throughout the life cycle of sturgeon populations.

2. Adults

- I haven't seen enough research on habitat understanding and constraints in relation to sturgeon. We have no idea where they go after year 6.
- Sub-adult and adult nonspawning-related habitat use

3. Dams and Passage (Also Linked to Recruitment/Juveniles)

- Determine the extent that dam passage programs might contribute new recruits to populations at the lake-wide level. This could be done without passage structures in place (e.g., trap and transfer via electrofishing).
- One gap is knowing the role dams play in altering the downstream habitat for yoy sturgeon. That is, how is the energy flow and food web different from conditions when sturgeon successfully produced enough progeny and are conditions now suitable enough to produce enough YOY if adult population becomes large enough?
- I believe the biggest threat or habitat challenge to overcome involves hydroelectric dams and other barriers. Continued work to improve connectivity in fragmented systems will benefit sturgeon.

4. Movement/Migration

- Open-lake habitat use, if past habitat restoration activities yielded positive results, movement between habitats
- Limited knowledge of movements within/between the lakes and if there is genetic flow between
- Compiling the plethora of tracking projects sturgeon have endured, meta-analytical approach

5. Water Quality

- I also consider chemical contaminates important for sturgeon, but probably a habitat issue to continue to work on for all freshwater organisms and general ecosystem health.

6. Other

[General]

- Quantity and quality of habitat needed to reach restoration goals
- As a whole, the understanding of what critical habitat is for various life stages has been addressed for lake sturgeon. Now we need to start taking actions to increase critical habitat where it is lacking.
- Think we know many of the habitat constraints, but doing something about them is more difficult
- Sort of answered this in previous question

[Specific]

- Habitat/overwintering habitat and the differences in habitat usage between juveniles and adults
- Number of habitat-based projects that use adaptive management approach to increase knowledge of habitat placement etc., GLATOS projects [are] providing increased knowledge in habitat use and development of HSI to better understand habitat availability . . . Most focus on spawning and limits on available spawning habitat. Gap might be to focus on other early life stages to better understand limiting factors to increase survivability until no longer vulnerable to predation etc.
- Second, in eastern Lake Michigan, drowned river mouth lakes appear to be important habitat for both juvenile and adult lake sturgeon. However, seasonal hypoxia in the hypolimnion seems to be the norm for lakes that become thermally stratified. There is conflicting evidence about how juvenile and adult lake sturgeon respond to these seasonal patterns (studies are from a single drowned river mouth lake). Understanding the importance of seasonal hypoxia in the hypolimnion on lake sturgeon habitat use warrants further research.
- How important are intact estuaries in the life cycle?

What are the biggest remaining gaps in knowledge about fish passage technologies in the Great Lakes?

1. Adaptation for Existing Structures

- There is only one project ongoing in the Great Lakes that is experimenting with lake sturgeon passage in a system where dam removal is unlikely. However, there are approximately 200 barriers that [the U.S. Fish and Wildlife Service] would not support funding for removal. Therefore, more studies should be conducted on the feasibility of modifying these 200 barriers to accommodate partial passage or full-time monitoring and active passage.
- How do we get good passage of these large, nonjumping, (relatively) poor swimmers upstream to spawning beds? What technologies are available that are likely to be incorporated into existing structures?
- We still do not have a good passive system for upstream passage at most dams or appropriate downstream protection for hydropower facilities.
- There have been numerous fish passage structures designed and constructed, but now it's important to thoroughly evaluate the effectiveness of these structures and use that information to guide future fish passage efforts. There also are other methods (capture and transfer for example) that may be possible in special situations to help move fish above barriers while [still] protecting against AIS.
- Locations where sturgeon passage is critically needed at this time are admittedly few. However, at the few locations where passage is currently critical to population expansion, behavior of and risks to multiple live stages (adult, juvenile and early life stages) associated with downstream and upstream navigation of barriers and also impoundments above barriers [are] not yet well understood. This "behavior understanding" need is likely to be variable depending on characteristics of particular barriers and rivers, so this work may need to be river and/or population specific. Thus, fish passage technologies may also need to be site specific. Overall, a better understanding of behavior is needed to better guide needed passage technology development.

2. Prioritization Criteria

- While there is still work to do for populations in such systems as the Menominee River, it would seem important to prioritize money for rivers and populations of fish with enough fish to work with, importance to indigenous peoples, and willingness of authorities to contribute to dam removal/passage.

3. Recruits and Early Life Stages

- Again, determining the extent to which passage will contribute new recruits to lake-wide sturgeon populations
- Studies are lacking that quantify likely levels of added larval production given passage of adults.

4. Knowledge of Passage Types

- Very limited research (or limited published) on lake surgeon uses of fishways either up or down stream around barriers/dams. Unknowns include: type of fishway that will work, attractant flow, day/night movement, approach at existing fishways (do they?), [and] transit time in a fishway.
- Fishways that are suitable for natural lake sturgeon passage remain inadequate. Hydropower operations in the U.S. and Canada remain major impediments to natural spawning cycles and successful egg and larval development. With more hydropower facilities proposed for Canadian tributaries, this remains an important topic.

5. Removal

- Design of effective partial dam removal on Great Lakes [tributaries] that will allow selective fish passage and still stop undesirable fish
- Not an expert in fish passage, other than to say that where fish passage exists, [they] tend to fail at passing fish. Therefore, emphasis being placed on barrier removal (which is timely, costly, and not always supported by the community) or restoring habitat below barrier (if feasible).

6. Barrier Types and Technology Needs

- Barriers that effectively exclude sea lamprey but allow passage of sturgeon and other desirable species. Large hydroelectric dams that have reduced the length of river accessible to spawning sturgeon and larval drift.
- Developing smart systems for selective species passage; simple systems for passing low head dams
- It's possible that technology has not moved fast enough yet to provide safe passage for lake sturgeon. Balancing habitat for native species like brook trout and lake sturgeon vs. sea lamprey production can be tricky when discussing fish passage.
- Creating successful passive fish passage (unlike the sturgeon lift that requires active efforts) to increase passage and trying to inhibit nontarget (lamprey) species
- How to pass lake sturgeon while not passing undesired fish (e.g., lamprey)

7. Other

[General]

- Some advancements have been made but still plenty of dams in the basin and further studies on fish passage needed
- Fish passage is still a major hinderance to lake sturgeon recovery
- I am not familiar [with] this aspect of their ecology and life history
- Cost effective fish passage projects need to be developed and evaluated to determine their effectiveness in allowing the upstream and downstream movement of lake sturgeon.
- I am unfamiliar with this area of research
- How can passage facilities be designed to effectively pass sturgeon?
- Pass
- Whether technical fish passage is feasible for sturgeon, also identifying where it is needed, and how successful passage needs to be for population recovery

[Specific]

- Fish passage for sturgeon is difficult and often prohibitively expensive. I don't see it happening on a broad scale. Maybe we need to accept that populations will be fragmented, and I think large enough fragments exist that we can manage sustained populations even in these larger fragments.
- Recent genetic studies on Eng/Winnipeg rivers that only [downstream movement] occurred and they were impassable barriers for [upstream]. On previously passable systems, this requires additional work; the question may not be relevant where rivers were impassable prior to the dam.
- Sturgeon need a place to go after passage. Efficacy of fish passage and fate afterwards is paramount. Don't move sturgeon for the sake of moving sturgeon (see MacLaughlin et al. 2013).

What are the biggest remaining gaps in knowledge about artificial propagation techniques and associated strategies for sturgeon population recovery in the Great Lakes?

1. Staffing, Infrastructure, and Equipment

- Despite recent research, culturists still struggle with staffing and poor survival in streamside rearing facilities. Where facilities are successful (releasing target number annually without variability in size) there are large numbers of staff or full-time staff to support early feeding demands. Instances where facilities release highly variable numbers or fish varying in size, staff and resources are limited.
- Also, "portable" streamside facilities are now aged and are breaking down and are becoming dysfunctional, with poor electrical and unreliable monitoring systems.
- The portable facilities were designed based on traditional hatchery rearing environments that don't incorporate the last two decades of research information gained with respect to lake sturgeon aquaculture. For example, every streamside facility currently in operation is designed to underfeed lake sturgeon at the larval period (those most critical period for rearing). Facility layout and staff need to change to accommodate what is known about early rearing feeding demands.
- Given the need for continued outreach and education, and the need for new rearing infrastructure, new and more permanent streamside rearing structures should be designed and staffed accordingly for the next three decades.

2. Costs (Reducing)

- An easy, cost-effective artificial propagation technique in general. This is not necessarily limited to sturgeon and further research in this field could be applied to many other species of concern
- Is it necessary to have streamside facilities on each stream scheduled to be stocked, or is there a more cost-effective way that doesn't compromise populations?
- The streamside rearing facilities seem to be pretty cost effective. I am not sure how much other research has been done in this area.
- Finding a lower-cost solution to streamside rearing trailers
- Cost varies greatly, but will likely always be high.

3. Techniques

- I agree that the propagation technologies and methods have now been well established, so the focus on this should shift to large-scale production.
- Limited knowledge of artificial propagation techniques. But could see how more research tools and techniques to ensure egg release (hormone injections) and egg/milk survivability in the field. Site fidelity and homing in hatchery raised vs. streamside rearing.
- Lack of information on hatchery or rearing selection processes
- Optimal feed rates are unknown for lake sturgeon in hatchery setting. Optimal rearing densities, effective disease treatments, are also lacking.

4. Assessing Impacts

- Survival of stocked fish; contributions of stocked fish to population growth; behavior of wild vs. stocked individuals
- Habitat use, survival, and movement patterns of lake sturgeon reared in streamside and traditional hatcheries need further assessment. Comparisons between age-0 survival and imprinting of adults between these strategies needs further evaluation.
- Survival of stocked fish
- Understanding [percentage] of sturgeon that return to spawn in natal stream
- The streamside rearing facilities seem to be working well. More follow-up on how the released fish behave in the wild—do they integrate into the main population? Are there long-term differences in growth/behavior/spawning?
- Scale of "recovery," imprinting ability when in artificial setting

- Potential for straying (spawning in a nontarget location) of stocked fish resulting in outbreeding depression of remnant stocks
- We need to refine captive breeding protocols to ensure offspring produced survive in the wild and that hatchery-based fish do not cause more harm than good.
- While the rearing and stocking aspect of this need HAS BEEN SIGNIFICANTLY advanced and largely addressed since 2000, the necessary long-term evaluation of efficacy has not yet had time to play out. Therefore, the critical need to complete evaluation as fish mature and return to stocked rivers (or stray to other rivers) has [not] yet been able to occur. This simply takes time (30 years post stocking) because of the long life and late maturity of this species and thus necessitates the long-term commitment of resource agencies to complete this evaluation, including putting forth the necessary funds to complete this long-term evaluation. As results begin to come in, there will undoubtedly continue to be need for advancement in details of the rearing and stocking aspect of artificial propagation that will continue to be needed.
- [U.S. Fish and Wildlife Service/[New York State Department of Environmental Conservation] have made great strides in spawning St. Lawrence [River] sturgeon, hatching eggs, and growing fingerlings. These efforts should be modelled by others. There is still a gap on the survival of the fingerlings that requires research.
- I am not a proponent of stocking on top of existing populations and feel that the genetic questions are more important at this point than the feasibility questions, which seem to be resolved.
- Can sturgeon be reared in traditional (nonstreamside) hatcheries and successfully imprinted in target systems?

5. Comparing Success with Traditional Hatcheries

- Evaluating the effectiveness of using streamside trailers versus traditional off-stocking site hatchery rearing practices
- What stocking and propagation techniques best lead to successful returns of spawning lake sturgeon, which will take another couple decades to answer most likely
- We have made some of the largest strides in this area and need some focus on comparing streamside and traditional hatchery fish success in stocked systems.
- Propagation has come a long way in the past 20 years, but there may be some ways to reduce rearing costs.
- Does method (hatchery vs. streamside rearing) or genetic stock matter (i.e., establishing a self-sustaining population)?
- Streamside vs. traditional hatchery survival/return

6. Other

- It seems streamside rearing and release has been successful and is cost effective for those wishing to enhance populations.
- There seems to have been much progress on this issue. Propagation has been successful in traditional hatcheries, but also in streamside rearing trailers throughout the Great Lakes region.
- No thoughts on this question
- Thank goodness for federal hatcheries being able to help state programs.
- We're starting to see results from early propagation efforts and need to learn from those to better adapt management in this area.
- I do not have sufficient knowledge to comment on this aspect of recovery.
- Research for propagation funding has never been available through this avenue/organization.

What are the biggest remaining gaps in knowledge about implemented management plans or activities?

1. Too Early for Results and/or Need for Long-term Assessments

[Note: Answers suggest it is too early to finish analyses, but not too early to start the research because baseline information is crucial.]

- It's still a bit too early, given the long-life history, to know if management plans are working. Need more time.

- Since it takes decades to fully understand the impacts of management activities, this will be a top priority for many decades to come.
- Success. This is a long-lived species which takes a decade to reach sexual maturity. Often funding or political will runs out before we can measure success. Existing benchmarks are proxies, at best.
- Evaluation of streamside-reared and traditionally reared lake sturgeon needs further assessment. It is important to realize that results (i.e., imprinting) will be difficult to obtain since they take decades to manifest. Assessing the survival of stocked fish through acoustic telemetry will also aid in achieving management objectives. For example, the number of stocked fish may need to be increased to meet management objectives if survival is low. This will likely need to be assessed on a system-by-system basis as rates will vary based on the available habitat and fish community assemblage (i.e., potentially increased predation based on certain fish communities).
- We are early in the evaluation of management plans in such a long-lived species. This needs to remain a priority.
- [New York's] plan is just being implemented in the last few years. No post plan evaluation will start until 2025.
- Assessments of stocking and management are just in initial phases.
- Limited monitoring plans for following post implemented strategies. Many funding programs are for 1–3 years of work. Given it may be 10+ years to determine if an implemented strategy or suite of programs work, we need long-term projects to follow through on this objective.
- Similar as stated in prior propagation question. The late maturity and long life of this species requires a long-term approach to evaluating management plans (30 years minimum following management action). This timeline might be compressed if comprehensive recruitment evaluation surveys are able to be conducted, but very few locations currently have adequate comprehensive evaluation surveys of recruitment (due to limited resources).
- Too early to assess right now
- It's still early days for most [management] plans and we have not assessed the success/failure of the plans yet.
- Biggest challenge is the species longevity. Need to ensure management plan targets and monitoring programs are in place over the long-term to ensure that management success [is] properly measured.
- Actual time for recovery plans to demonstrate effectiveness (think St. Louis [River] reintroduction and time for naturalization)

2. Health/Disease Impacts

- There has been minimal work done on lake sturgeon pathogens and overall health, so this is an area that is ripe for work, particularly to ensure that natural mortality rates remain a nonfactor for population rehabilitation. We have not been able to do a lot of work on the effectiveness of rehab work as most populations have been too young to see if they are successfully completing at least one of their life cycles. This is an area where much opportunity will soon come up as we have been actively managing populations for at least 20 years and benefits should start to show up.

3. Particular Management Actions in Need of Assessment

- We still need to know if proposed catch and release fisheries are harmful to lake sturgeon, especially if the season is opened immediately before and after spawning time.
- Will stocked populations be self-sustaining?
- Lots of stocking has occurred in the past couple decades but little has been invested in evaluation of the stocked fish. Evaluation of stocking (fish survival, reproduction, etc.) should be a high priority.
- We still don't know how well stocked sturgeon contribute to recovering of naturally reared offspring.
- More research in this area for better adaptive management, especially regarding the role/importance of streamside rearing.
- Given that lake sturgeon are a long-lived species, assessments are needed on the effectiveness of management practices such as streamside rearing facilities. For instance, what is the success of efforts on the Manistee and Kalamazoo Rivers in contributing to the spawning adults in the population? Additionally, research to assess at what population size is the use of streamside rearing facilities necessary? For a purely ecological point of view, it

has always struck me as odd that the Manistee River has streamside rearing, whereas the Muskegon River does not when the spawning run size of the Muskegon River is likely less than the Manistee River. Could guidelines be developed to make recommendations when streamside rearing is appropriate?

4. Impacts on Management Choices

- [In my opinion,] survival and understanding effect of genetics on reintroduction plans

5. Evaluation Techniques

- Some plans get carried away with rigid evaluation metrics when sufficient funding or staff time is not available. There should be more information on how shortcuts in evaluations can still answer the critical questions.
- There remains a lack of basic information on population abundance, sex ratios, spawning periodicity, and mortality to adequately evaluate most management plans. There remains a lack of information for managers to establish harvest management recommendations and evaluate harvest. Lake basin and population-specific age, growth, age at maturity, fecundity, and spawning periodicity remain inadequate.
- Recovery targets and how those targets are likely different for large and small tributaries due to habitat limitations
- Assessment of the effects of management actions is needed, including the development of metrics to assess the results of the actions.

6. Other

- I'm not aware of too many new management plans that have been written in the last 20 years either for watersheds or states.
- I think we need to move beyond merely assessing status and genetics of lake sturgeon and spend more time funding research that assesses the effects or potential effects of management and conservation actions.
- Ultimately, management agencies need quality management plans to help leverage funding to do important work. These plans are more of a means to an end rather than a direct strategy, but rehabilitation efforts can be very challenging to get off the ground without quality management plans.
- I'm a little confused about what exactly this question means. State management plans need to have measurable and specific goals and be able to measure progress towards achieving those goals. The state plans I'm familiar with don't do that. I believe that, in part, is because states don't have a good handle on the population status and can't commit the resources to determine if rehabilitation progress is being made.
- Impediments to natural recruitment remain unclear.
- No thoughts on this question
- I think we've done a good job of assessing the impact of activities, but must continue to do so.
- What are the best management strategies and how to implement meaningful population level activities
- This seems like a better fit for funding internally within management agencies.

What are the biggest remaining gaps in knowledge about lake sturgeon management capacity?

7. Science Communication and Sharing Data

- There is a lot to unpack from this question, so it's difficult to answer. There are folks that serve as the "go to" for PIT tag database info. There's the Lake Sturgeon Coordination meeting where data and research are routinely shared.
- Continued and more frequent [Great Lakes] sturgeon coordination meetings
- As noted above, we have little information on the effectiveness of communicating results between researchers and managers.
- Support for the Great Lakes Lake Sturgeon Coordination Meetings and Great Lakes Lake Sturgeon Tag Identification database should be continued.
- Every state/province seems to have a different strategy and staff capacity—the periodic meetings were helpful for crossing those lines and learning from each other.
- Coordination of data on tagged fish to allow identification of large-scale movement

- Additional data sharing to the sturgeon database similar to Sea Turtle Database www.seaturtledb.com
- Lake sturgeon are a binational, multijurisdictional species. Better options for data sharing and research results presentation are needed. Options for partnerships among groups for research (funding, sharing equipment, etc.) are needed.
- Establishment of a Great Lakes sturgeon recovery team, similar to recovery efforts for [threatened and endangered] species, would greatly benefit coordination of rehabilitation efforts. The function of task forces or workgroups established through the [Great Lakes Fishery Commission (GLFC)] by lake basin to coordinate and communicate aspects of lake sturgeon research, assessment, and management has worked well on a lake-basin scale.
- Coordination and outreach of successful techniques, practices is always desirable—possibly a sea grant model would be useful where they communicate information quickly and efficiently
- Lots of success with multidiscipline approach to project management. More difficult to maintain this approach over the long term. Need to consider new techniques to communicate and or data storage data sharing.
- Ensuring science gets passed onto managers
- Habitat limitations and suitability for stocked populations, status of populations around the basin—especially recruitment success

8. Economic Practices and Outcomes

- Along with no information on the economic effects of lake sturgeon rehabilitation
- Economic practices of [lake sturgeon] management and how to get more partners to share the expenses.
- Economics—why should the public care?
- By necessity, sturgeon continue to be a nongame or nonharvested species across much of their range. As such, traditional funding mechanisms to support sturgeon restoration and management (that often come from license sales) are limited. Finding ways for management agencies to institutionally maintain adequate funding for basic sturgeon monitoring and restoration, evaluation, and management continues to be a significant need.

9. Public Interest and Education

- The big thing is increasing the public and stakeholder interest in sturgeon rehabilitation. More doors will open for funding if people are more aware of our collective efforts and become allies for sturgeon recovery.
- As well as support for outreach projects such as "Sturgeon in the Classroom"
- Communication with the public

10. Other, Including Human Behavior

- Engaging limited fisheries has impacts on the populations and so do incidental encounters by anglers. There need to be answers to questions about the balance of letting anglers legally partake in some fisheries, how law enforcement can adequately have kept on top of it, and how anglers will develop self-control measures if a limited fishing option is engaged.
- Given their petition for listing under the [Endangered Species Act], it's important to understand the effects of potential listing.
- What exactly other agencies are doing/plan to do/what their results were

11. General

- From my perspective, it seems as if only projects in Lake Michigan have been supported by [the Great Lakes Fishery Trust]. There are numerous opportunities in Lake Erie and Ontario that would benefit from these funds, particularly through the GLATOS network.
- While data sharing and communication are important, I don't think its limiting sturgeon rehabilitation.
- In my opinion, data sharing between researchers and managers regarding lake sturgeon activities is quite high. There are a great deal of partnerships on many lake sturgeon projects.
- This would help, but I am not sure the funding is the limitation. I would think we probably need volunteers to organize and coordinate more than funding.

- Applicability of research results to specific management sites
- Likely not the knowledge, but lack of funding and staff capacity to implement projects
- Ego management, ownership issues, lack of education on timeline for sturgeon rehabilitation
- There are regional workgroups in place and a great data sharing effort.
- Standardizing approaches

List the three most important contributions to Great Lakes sturgeon research since 2000.

- All we know about lake sturgeon aquaculture (with the exception of 1 or 2 studies) came from research conducted in the past 10 years.
- Genetic description of Great Lakes populations with many groundbreaking published manuscripts
- The GLATOS network and acoustic telemetry
- Developing and now refining genetic stock assignment methods with genomics (not complete)
- Baseline knowledge of lake sturgeon populations has increased
- Much improved understanding of the importance of early homing to rehabilitation efforts on individual waters leading to streamside rearing options
- Funding given to increase scientific and public knowledge of lake sturgeon habitat and ecology, movements, for all life stages
- Improvements in rearing sturgeon for recovery efforts
- GLATOS network, ability to understand population dynamics, ecology, and habitat use is unprecedented
- Kessel et al. study that documented the diversity, repeatability of sturgeon movements, and that emphasized the need for conservation of phenotypic diversity in addition to genetic diversity
- Ongoing Black River marking, gamete collection, and associated [Michigan State University] research that has investigated many aspects of sturgeon-related needs
- Genetic delineations of sturgeon populations throughout the Great Lakes
- GLFC Lake Sturgeon Genetic Stocking Guidelines—provides an approach for rehabilitating lake sturgeon based on sound science and ensures the genetic integrity of existing and reintroduced populations is considered
- Great Lakes Fisheries Trust funding
- Support from Great Lakes agencies, the [GLFC], and the [Council of Lake Committees] in terms of research priorities
- Establishment of the Black Lake research facility in Michigan as a leading contributor to sturgeon research
- Spawning habitat defined, and replicated (built!), and determined successful
- Improvements in stocking/rearing strategies
- Recovery monitoring by waterbody
- Increased hatchery production
- Assessments of current population status.
- Genetic population structure of Great Lakes lake sturgeon populations
- Auer et al., (2003). A Lake Sturgeon Rehabilitation Plan for Lake Superior. GLFC: 2003-02
- Describing movement patterns and local home ranges
- Sturgeon streamside rearing for restoration and rehabilitation
- Increase in the use of acoustic telemetry in [lake sturgeon] research; we are learning where the populations live, how they move, when they move, how they mix—or don't mix. Needs to be expanded throughout the lakes; game changer for a long-lived species.
- Acoustic telemetry through GLATOS and data sharing for sturgeon migrations
- Acoustic tagging shows large movements
- Streamside rearing
- Advances and implementation of biologically sound, genetically based, and local environmental influences on rearing and stocking practices as opposed to large-scale hatchery operations

- Support of basic status assessment activities, including identification of genetic stock structure and developing genetic-related tools for helping to determine population status (i.e., parental contribution to recruitment)
- Genetics
- Artificial propagation
- Improved habitat restoration techniques
- HEC long-term work
- Improved knowledge on the distribution and abundance of populations across the basin
- Identification of genetic stocks throughout the basin
- Understanding spatial structure of lake sturgeon stocks via genetic analyses
- Reintroduction or supplementation to increase the number of waters with sturgeon, decreasing the possibility of extinction with a healthy metapopulation
- Fish pass
- Adult movement patterns
- Creating genetic guidance protocols provides a framework within which managers can use best management practices to implement rehab or re-introduction programs Great Lakes wide. Sturgeon managers did what salmonid research wish they had done.
- Movement studies mainly acoustic technology booth looking at spawning fidelity but mixing or populations and movements in nonspawning periods
- Lake sturgeon genetics work
- Evaluating lake sturgeon passage program on Menominee River (forthcoming results)
- Estimates of egg and larval mortality have been obtained
- Much improved understanding of stock genetics of Lake Sturgeon and likely genetic differences between populations
- Through regular meetings across the Great Lakes Basin fish managers, researchers and communities gathered into groups and worked together to protect and increase knowledge, importance, and awareness of this special fish.
- Identification of critical habitat for various life stages of sturgeon
- Genetic work
- Briggs et al. study that gave us the first glimpse into bathymetric habitat use by lake sturgeon— important because deep water may facilitate reproductive isolation at a regional scale
- Ongoing Lake St. Clair/Detroit River work that has filled in many of the information gaps for those populations
- Development of propagation and stocking procedures/guidelines and use of streamside rearing trailers
- Acoustic telemetry provides an understanding of the movement patterns, survival, and habitat use of lake sturgeon on a scale not achievable in the past. Data from this work can provide insight on almost all aspects of sturgeon impediments.
- Black River Research Facility
- High-priority funding from granting organizations like the Great Lakes Fishery Trust, U.S. Fish and Wildlife Service, Green Bay [Natural Resource Damage Assessment], and others
- Funding made available for lake sturgeon research through the Great Lakes Fishery Trust
- Sturgeon egg take and hatchery practice improvements
- Habitat improvement/restoration/identification
- Implications of the legacy of water quality impairments
- Telemetry and movement studies
- Refinement of culture methodologies
- GLATOS system to look at lake sturgeon movements
- Bruch and Binkowski (2002). Spawning Behavior of Lake Sturgeon (Acipenser fulvescens). J. Appl. Ichthyol. 18 (2002), 570â€“579.
- Genetics advances in recognizing distinct groups in large systems

- Increase in use of genetics and the importance of getting it correct. I.e. what populations naturally exist and do they mix? What strains to use in which areas for stocking and supporting existing populations.
- Streamside rearing for adequate imprinting to natal waters
- Constructed reefs in SCDRS attract sturgeon to spawn
- Movement toward standard assessments
- Communication, coordination, and cooperation among agencies on assessment, research, and management efforts on a lake-basin scale
- Implementation of streamside rearing and stocking technologies for reintroducing and supplementing sturgeon populations where needed across the Great Lakes basin
- Population assessments
- Habitat needs
- Improved stocking
- Use and importance of tributaries for lake sturgeon and presumably recovery
- Knowledge on basin-wide genetic structure to inform conservation stocking
- Advances in captive rearing for stocking efforts
- Understanding habitat use of lake sturgeon in the Erie-Huron corridor as part of GLATOS
- Understanding of spawning habitats and techniques to enhance degraded areas
- Coordinated lake-wide surveys in Lake Superior
- Streamside rearing and hatchery development
- GLATOS projects are providing movement data not available before. This will have enormous benefit as Great Lakes shorelines continue to be disrupted and developed.
- Development of improved hatchery practices at both traditional offsite facilities and development of streamside trailers
- Paired stocking of hatchery and streamside-reared lake sturgeon (ongoing)
- Telemetry work showing extent of connectivity and spawning site fidelity
- Genetic differentiation of populations has been resolved.
- Much better understanding of the population status of a number of Great Lakes populations, although a number of gaps remain
- Helping to establish streamside methods to assure populations could be re-established in areas where remnant stocks were found
- Assessment of sturgeon populations to evaluate status
- Improving hatchery/stocking techniques
- Sea lamprey treatment effects on YOY sturgeon
- Progress on sea lamprey control techniques that are compatible with sturgeon rehabilitation
- Population status—Knowledge regarding the distribution and population status of lake sturgeon populations
- Great Lakes Sturgeon Coordination Committee formation
- The work of the Great Lakes Sturgeon Coordination Committee has made good contributions.
- Development of interagency and academic collaboration and communication to forward lake sturgeon research and management priorities
- Genetic connections and distinctions between various lake sturgeon subpopulations
- Genetics component of stocking strategies
- Sturgeon genetics
- Increased public awareness
- Enhanced communication among workers
- Semiannual lake sturgeon coordination meeting and associated databases that came from those meetings
- Evaluating stocking programs
- Standardization of PIT tags and, where possible, other tagging techniques throughout the [Great Lakes] Basin, and the database for the tags through the GLFC. Compliance should be mandatory for groups tagging in the basin.

- Genetic analysis and population assessment between stocks
- They eat Dreissena.
- Genetic work to show relationships among stocks
- Ability of genetic techniques and analysis to examine population composition, harvest management practices, parentage, and contributions of spawning adults
- Fostering increased communication among sturgeon researchers/biologists/managers across the Great Lakes Basin
- Pledger, Baker, and Scribner 2013
- [Population] assessments/genetic studies
- Use of new technology (GLATOS, [geographic information systems])
- Improved knowledge on when lampricide treatments are a concern for rehabilitation (e.g., high alkalinity tributaries)
- Developing the use of streamside rearing techniques
- On-going acoustic telemetry work
- Diet

How would you briefly define a healthy/restored Great Lakes sturgeon population?

- Each [Great Lakes population] should fit this: Research suggests that in order for animal populations to exist for more than 40 generations, given constant rates of environmental catastrophe, a population should be several thousand individuals in size (adults).
- I can't quote specific numbers, but as a long-lived species with irregular intervals for spawning, enough spawning fish representing several ages should be present annually on spawning grounds with numbers associated with the size of watershed.
- Annual spawning activity, annual recruitment, presence of all life stages, genetically healthy population
- Populations with numerous sources of recruits and these sources encompass the historic range of where recruitment occurs (e.g., each Great Lake has 5–7 sources of natural recruitment that are geographically distinct)
- A population with abundant individuals in multiple age classes (healthy age structure), including early life stages
- Greater than 250 adults spawning annually. Consistent larval production that is around 1 percent of projected egg production.
- Populations should be self-sustaining, above 750 adults, and trending in an increasing fashion with enough fish available to allow for state sport and tribal fisheries.
- I would use what has been established at previous [Great Lakes Fishery Trust] and GLFC management meetings. Tough question to answer if we don't have our materials handy when answering this survey.
- Great question, one I posed earlier in the survey. This needs to be evaluated further. I think one facet though would be that a restored population needs to be self-sustaining and able to support some sort of harvest.
- Diverse age structure, routine recruitment, albeit not necessarily constant
- Self-sustaining; no human interventions required
- A naturally sustained population consisting of a healthy age and size structure that allows sturgeon to be removed from the state threatened species list
- Adult abundance meets a target that is sustainable. Consistent and measurable recruitment. Many age classes and annual spawning. A restored population should be able to support recreational and tribal harvest.
- Minimum of 750 reproducing adults at each spawning location with documented successful recruitment in 3 of 5 successive years.
- Genetically diverse, sufficient number of spawners (> 750 sexually mature adults), evidence of recruitment on a recurring basis, self-sustaining (stable or increasing population growth rate)
- A spawning population in a given river system that is naturally reproducing, and stocking is discontinued
- A healthy/restored [Great Lakes] sturgeon population is one that can reproduce on its own without supplemental stocking. Having a population with supplemental stocking is still a success but not "healthy and restored," rather reintroduced.

- Populations of sufficient spawning adult abundance and levels of natural recruitment to withstand natural and anthropogenic disturbance that would compromise long-term population persistence.
- Abundant enough that successful spawning happens [three to five] years, with no genetic drift/constraints, persistence without stocking predicted for at least 500 years
- Natural reproduction sustained by multiple year classes of adults, adults from a large range of ages, catches of juveniles in main-lake agency assessments (targeted and nontargeted)
- Fishable stocks in a variety of waterbody types in each state and province bordering Great Lakes
- Density that is relatively level/increasing (comparing to historic abundance is likely not relevant—lakes are different), age structure which shows signs of recruitment at regular intervals, growth rates which indicate adequate food supply/habitat
- Healthy age structure, consistent recruitment
- One that has an indigenous, commercial, and recreational fishery
- A population of lake sturgeon maintained by natural reproduction, like historic levels, in habitats that are of good quality, diverse age structure
- There should be a healthy age or size structure and the metrics need to be simple or easily measured.
- A self-sustaining, naturally reproducing sturgeon population, with at least 750 sturgeon capable of spawning
- Full year classes/life stages in the population (genetic?) area, sufficient spawners [male and female] to provide for annual spawning
- Population with access to suitable spawning habitat where YOY drift from, suitable nursery habitat that holds juveniles until fall, observed spawning groups of 5 males to 1 female, spawning individuals ranging from 20 to 80 years old
- Consistent year classes
- Resilient to disturbance, multiple age classes, natural recruitment
- See [A Lake Sturgeon Rehabilitation Plan for Lake Superior] for those criteria which are likely minimum criteria.
- A minimum and stable founding abundance of at least 750 mature adults, males to age 40 and females to age 70, supported by stable or increasing regular recruitment, having healthy genetic diversity lacking indications of inbreeding or outbreeding risk
- 2,000–3,000 individuals capable of breeding
- To be provided via email
- Self-sustaining, large population size, high genetic diversity/effective population size
- Structured age class, appropriate age at length/weight or condition factor, abundance of breeding adults required for sustainability
- Good recruitment, good representation over age classes, an assortment of size classes present, good genetic diversity with high Ne
- Population with 25 spawning females annually, age classes produced annually, capable of sustaining some level of mortality or supporting a catch-and-release fishery
- Spawning population > 500 adults and representing more than 12 year classes, successful recruitment (age-0 fish observed in late summer), population increases observed over 5 year averages
- A population with adults, sub-adults, and juveniles, population that achieves a predetermined abundance target
- Sturgeon numbers sufficient to spawn and produce recruitment each year.
- 1,500 adults, equal male/female, 20 year-classes, produce annual evidence of reproduction measured by viable eggs/age 0–5 young, spawn in all tributaries known to have supported LAS at one time

How would you briefly define healthy sturgeon habitat for population sustainability and/or rehabilitation?

- Barrier free with 200-foot riparian buffer from mouth to headwater
- Desire to have good spawning populations at known historic sites, evidence of successful recruitment, sufficient habitat both at spawning and recruitment sites and habitat including dietary needs for good growth and survival

- Suitable habitat for all life stages, adequate amount of suitable spawning habitat, clean water
- Access to spawning and rearing habitat within tributaries that might include passage facilities or trap and transfer operations
- Habitat that supports (i.e., provides access) all life stages, including coarse substrate for spawning, slow current areas for larvae, deeper water areas for juveniles and adults
- Spawning habitat containing cobble sized rock with deep interstitial spacing that remains watered, sandy reaches downstream
- All micro- and macrohabitats required for all life stages are available in sufficient amounts to ensure populations are self-sufficient.
- It needs to have a protected historic spawning site intact; natural, uninterrupted water flows; limited riverside developments; substantial wetlands, sloughs, and deltas at river mouths
- Healthy sturgeon habitat requires that adequate habitat is present to meet the diverse life history needs of the lake sturgeon population. A big component of this to me isn't just presence, it's also that sturgeon are using it to NR.
- Clean, rocky substrate for spawning, access to open-lake habitats
- There are many definitions of "healthy" sturgeon habitat, which is why work is needed to better define what we mean by healthy or functional habitat that supports sustainable populations and/or facilitates rehabilitation.
- Habitat in the system is available and suitable to allow for sufficient natural reproduction and is also suitable for all life stages of sturgeon.
- Unrestricted access to spawning grounds, rearing/estuary habitats available for larval sturgeon, and good water quality in spawning tributaries
- Spawning [at less than] 1 m depth, flowing water with large-sized cobble substrate; nursery—sufficient amount of river habitat for larvae to drift and settle, nursery—sand/gravel substrate for age-0 fish; nursery—benthic macroinvertebrates for growth
- In any given stream, there is adequate habitat for critical life stages of sturgeon, including spawning, egg development, and juvenile growth.
- • Any given river would have the habitat necessary to support all life stages of sturgeon, from egg to larvae, juvenile, and adult spawners.
- Large and unimpeded gravel/cobble habitats for spawning that are not restricted by barriers, diverse and unimpacted habitats that facilitate spawning of other fishes and invertebrates that constitute alternative prey for stream predator fishes
- Big, rocky, swift rivers in spring attached to nice cool, clean, mucky, organic-bottom lakes
- Adequate habitat for multiple ages and spawning to support self-sustaining population
- Habitat capable of sustaining all life stages of sturgeon in abundances comparable to those that existed prior to the period of overharvest and water quality impairment
- Habitat that allows for periodic successful reproduction and good growth rate of adults. Growth = temperature, food, activity, stress, etc.; chemical pollution below acceptable levels; low adult mortality rate (limited harvest)
- Suitable habitat for juvenile growth, suitable spawning/nursery habitat
- One that is of a size or availability to allow a healthy population that consists of all life stages
- Habitats that support all life stages needed for recruitment, reproduction, and growth; habitat that has high water quality, forage, and is of thermal preference
- Don't know
- Ensuring a natural flow regime and replacing habitat currently blocked by dams are essential components to providing an appropriate amount of habitat for all life stages. Habitat restoration may need to include fish passage around barriers.
- Sufficient habitat for spawning: Accessible, clean, sufficient water flow to provide through to hatch and drift; sufficient age-0 habitat (clean sand); followed through to juvenile and adult stage; we need to still define habitat and quantity!

- 50+ miles unimpeded river with large cobble and gravel, many deep pools, an abundance of macroinvertebrates, spawning habitat with high gradient and fast flows over 1 [meter per second]
- Clean spawning substrate, connectivity to nursery areas, appropriate abiotic conditions, sufficient food
- Accessible, meets needs for all life history stages, resilient to disturbance
- Free-flowing river system not influenced by man-made dams or hydropower facilities, with adequate large substrate materials for spawning success, adequate depositional habitat for larval and yoy development, and direct access to lake habitat
- Physical, chemical, and biological features of needed quality and quantity to support staging, spawning, and downstream juvenile rearing needs of a minimum viable founding population of 750 mature adults (see above population definition)
- Stable and free-flowing river
- To be provided via email
- Support various life stages; support large population size
- Suitable depth, flow, and substrate for spawning; suitable juvenile habitat with adequate flow/food for rapid growth
- Access to free-flowing or mimicking naturally flowing rivers, diverse habitat in rivers, including spawning habitat upstream and deep pools downstream
- Capable of supporting all life history stages, with passage or connections between spawning and rearing areas; spawning habitat that is robust enough to be useable at multiple flow levels
- Nursery habitat (sand/gravel complexes and moderate flows) present downstream spawning habitat (large, rounded rocks and higher flows) in systems that are well connected (more than 50 km of unimpeded flow); low/few contaminants; and good water quality
- Is sufficient habitat available for each life stage (i.e., spawning, nursery, sub-adult, adult)?
- Habitat within each system (tributary/estuary) that can support the above population metrics