Date: 14 December 2020

To: Pallid Sturgeon Tech Team

From: a subgroup of the ISAP[1]

Re: Sample design issues underlying pallid sturgeon monitoring to serve the Missouri River Recovery Program: points of discussion from the ISAP

This memorandum is intended to initiate discussion of key underlying statistical issues that can have large impacts on the data collection design and process and an ability to link information collected from the monitoring program to adaptive management (AM) decisions as described in the Science and Adaptive Management Plan and attending documents. Below, a sub-group of the ISAP presents four overarching issues worthy of attention from the pallid sturgeon Technical Team and the ISAP and provides a few points of discussion for each. A number of the topics addressed under the issue headers below have been considered internally by the ISAP. Many of the topics are being discussed by those working toward a monitoring design and presumptively all will be considered before an initial "new" monitoring scheme is adopted. The objective here is to suggest context for exchanges among program participants and provide a basis for productive conversation with other scientists, decision makers, and stakeholders. Solutions are not provided here for the issues raised, rather the material observations below are intended to stimulate candid discussion in the remote meeting scheduled for December 17, in which possible approaches to monitoring pallid sturgeon might be vetted and to setting the stage for future meetings in which the challenges of monitoring pallid sturgeon will be explored in greater detail. The discussion has been framed in a larger context during the ISAP review of Appendix D, where the panel cautioned that any sampling design, regardless of fundamental merit, might prove challenging to implement with sufficient accuracy and precision to relate unequivocally monitored changes in population metrics to specific management actions. That caution remains.

1. Linking sample design and data collection to programmatic information needs and questions of interest

A difficult step in developing an effective monitoring program is ensuring that the sample design or road map that serves as the template for data collection will provide essential information required under the incidental take permit for Missouri River operations and insight into specific questions of interest to those charged with managing the pallid sturgeon. Overarching questions, such as "what is the abundance of juvenile and adult pallid sturgeon" are critical to the development of the sample design, because answers to these questions directly affect management decisions. From a monitoring perspective, it is imperative that clear specifications of the questions of interest be identified prior to finalizing a sample design. Similarly, it is important that questions/hypotheses to be evaluated are linked *a priori* to the specific data to be collected.

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Two questions common to all sample designs include – is the spatial extent of the sample representative of the target population? And, is the sample size large enough to produce workably precise estimates? Samples that are not representative can introduce bias, whereas samples that are not large enough can be imprecise. Several issues for discussion when considering pallid sturgeon sampling are (1) Understanding that the whole idea of the AM program is to ensure that abundance changes in pallid sturgeon over space and time are commensurate with the program objectives, do we expect pallid sturgeon abundance to differ over time and space, and if so, how will the sample design serve to capture those dynamics? (2) Will population metrics – for example CPUE, occupancy, and abundance – provide reliable information needed to inform management decisions? (3) Should samples be randomly distributed throughout the river, or focused on areas where abundance is highest, and if so, would geographically targeted data collection supply valid data for analysis and decision-making? (4) Given that the capture of pallid sturgeon are rare events in a statistical context, how should the survey design be constructed? and (5) Do mark-recapture studies on rare events provide sufficient data for AM decisions, and if so, which AM decisions can they support?

The essential foundational exercise for those designing the monitoring plan for pallid sturgeon is to list specific hypotheses/questions of interest, a task already completed. Getting agreement on questions and linking them to possible AM approaches can prove difficult. But after a list is complete, each data metric can be assigned to a question and the role of each metric within the hypothesis/question can be discussed with respect to data sufficiency, expected data precision, and usefulness within a decision-making context.

2. Linking sample design to methods of data analysis and interpretation

Prior to data collection, a detailed understanding of the ecological models, statistical approaches, and graphical analyses that will be used to analyze and interpret the resulting data should be developed. The ISAP has provided comments to the effect that methods for time-series analysis (for example, estimation of temporal trend) are not detailed in Appendix D; however, this issue is relevant for all data and analytical approaches. The robustness of a sample design is determined not only by the questions of interest, but whether the data that will result from implementing the design are sufficient for the intended analysis.

Important questions for discussion include – (1) What models will be used for abundance estimation? For example, will a binomial mixture model be used? If so, does the current (or proposed) sample design support the required data inputs? (2) What time-series models will be used, and again, does the survey design support the data requirements for these models? (3) Have the mathematics of mark-recapture models been worked out (there are many approaches), and does the survey design support the required data inputs? (4) Understanding that the closure assumption is key to both occupancy and mark-recapture models, is the survey design sufficient to minimize the effect of violating this assumption? (5) Given that mark-recapture methods are expensive and time-consuming, have alternative estimation methods that do not require marking been fully explored? and (6) Agency quality-assurance programs and project plans typically require statements about desired precision and accuracy, are these elements addressed by the survey design and how can they be determined for a very rare fish?

3. Survey design for a very rare fish

Small, imperfect, and unknown detection probabilities may contribute substantially to the uncertainties associated with abundance and total population size estimates. This issue may reduce the ability to link monitoring data to possible management decisions. The statistical literature offers several approaches for dealing with rare events, but unfortunately, these methods typically require detailed insights about the sampled population. The degree to which sampling a rare species, like the pallid sturgeon, affects the design and implementation of a sampling framework, and subsequently identifies the approaches for data analysis, needs discussion. The current sampling unit is a river bend. An issue of concern is whether or not that sampling unit is appropriate for the scarce pallid sturgeon. Occupancy models for estimation of occurrence of age-0 sturgeon are sensitive to the concept of closure – that is, passive and active movement of the fish into or out of the sample unit during the sampling period – and the closure issue is directly linked to the low-detection probability that challenges those who are monitoring pallid sturgeon. In addition, variable abundance of sturgeon within sample units results in unmodeled heterogeneity in detection probabilities that can lead to biased estimates of occupancy.

In this context, the following issues may be useful for discussion – (1) Will employing a larger sampling unit (say, a river segment) overcome some statistical detection issues? (2) Given both rarity and low detection probability, how is a zero-sample response appropriately interpreted? (3) How will sample variance estimates be generated for rare events? (4) Would a larger sampling unit with a corresponding increase in the scale of the sampling effort and smaller sample size improve estimates over the current approach? (5) From a decision perspective, can we focus only on those areas of the river with known-to-be larger abundances for pallid sturgeon? and (6) Might abundance estimates on selective/representative portions of the river be sufficient for making AM decisions?

4. Linking survey design to potential management decisions

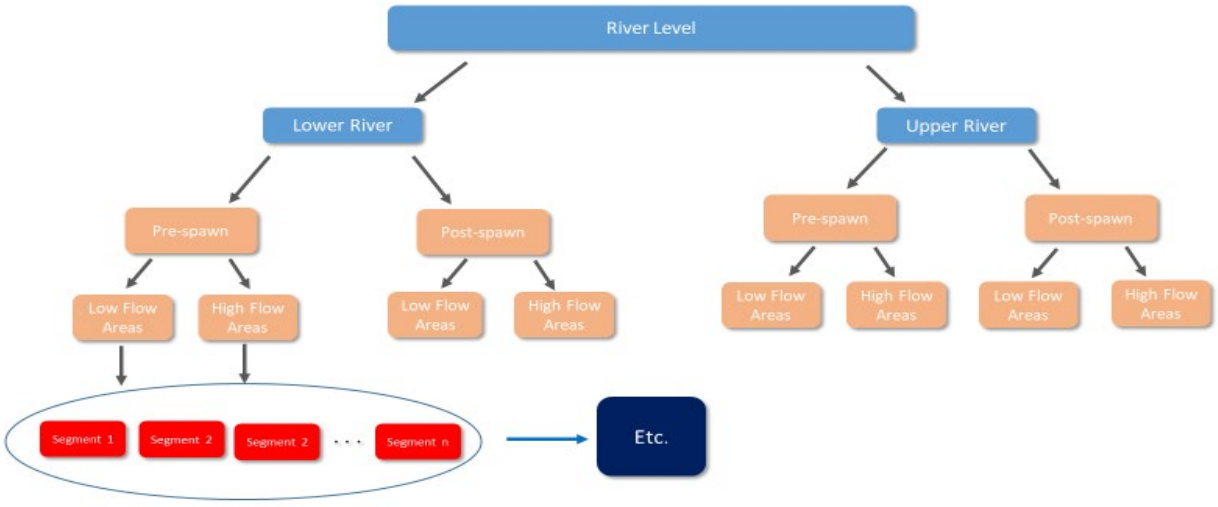
As the Science and Adaptive Management Plan and its Appendix D acknowledge, management toward recovery of endangered species in the Missouri River requires adaptable sample designs that can provide basic information on population metrics, as well as for metrics that track changes in population abundance as a function of management actions. A focus on AM may allow for non-standard sample designs in relation to management decisions. In this context, sample designs should produce data that are sufficient to track changes in ecological metrics in both space and time and, importantly, link those changes back to management actions.

Accordingly, sample-design frameworks that simply link data collection and analysis to management decisions may be more useful than complex multi-strata sampling approaches. The table below represents a very simple blocked design with randomly selected sampling units as river segments for the columns and flow as the management action as rows (and more on this below). This example is simple, but it is provided as a starter for thinking about sample design.

The two basic elements of an AM design are included in this simplistic example – randomly selected sampling units and linkage to a management action. More complex designs may or may

Flow	Randomly Selected Sampling Units (Segments)					
	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment N
Low						
Medium						
High						

not be useful. Conversation around simple versus complex designs and their linkages to AM actions could revolve around this simple approach, with discussion focusing on exactly what information is needed to conserve and recover sturgeon populations. Another approach that is common in decision-theoretic sampling is a hierarchical approach that begins by selecting random sampling units and then links the data to decision metrics in space and time. A simple conversation starter is shown in the following example.



Spatial elements of the design are shown in blue, temporal elements in orange, and random elements in red. The above design includes all the basic requirements of a statistical design focused on AM decisions. Again, comparing the hierarchical approach to current approaches could provide insights into possible changes in the current sampling design. Also, the hierarchical approach provides links to analytical models that produce results at any of the temporal or spatial levels by constructing an analytical model (or statistical model) that captures the data at specific levels for analysis.