ISAP evaluation of the Pallid Sturgeon Population Assessment Program monitoring plan – revised Appendix D of the Missouri River Recovery Program Science and Adaptive Management Plan

Independent Scientific Advisory Panel

30 October 2020

This report responds to a charge[1] from the Missouri River Recovery Program (MRRP) to the Independent Scientific Advisory panel (ISAP) to review the Pallid Sturgeon Population Assessment Program (PSPAP) monitoring plan. The ISAP[2] appreciates the efforts by the Corps during this past summer to assemble in a single document a review-version of a monitoring plan that continues in development. The ISAP recognizes that work toward monitoring the status and trend of pallid sturgeon in the upper and lower Missouri River has a long and uneven history, that there is institutional desire to take advantage of past data collection in informing current and future management decisions, and that future data collection might be constrained by funding limitations. Against that background, the ISAP lauds the Corps for advances in its pallid sturgeon population modeling efforts and acknowledges the Corp's intent to bring statistical power to its monitoring deliverables. The ISAP understands that pallid sturgeon monitoring needs to service explicit information needs that are articulated in the 2018 Biological Opinion (for operation of the Missouri River main stem reservoir system et al.) and the intent of the 2018 Science and Adaptive Management Plan (SAMP, under the MRRP).

The revised PSPAP – presented as Appendix D of the SAMP provides the foundation for Missouri River pallid sturgeon monitoring and is intended to meet programmatic information needs. Specifically "The PSPAP is designed to meet many needs that include tracking progress in meeting MRRP sub-objectives, estimating metrics associated with evaluating incidental take specified in the 2018 BiOp, providing inputs for the IPSPM, developing relationships between annual flow variation and reproductive success and recruitment to age-1, and providing flexibility given uncertain future funding (e.g., potential for reduced efforts) and unpredictable environmental conditions (e.g., high flows can limit river access)" (Appendix D, page 5). The sub-objectives for the MRRP program are to increase pallid sturgeon recruitment to age-1 and maintain or increase the numbers of pallid sturgeon as an interim measure until sufficient and

[1] See Appendix A of this report.
[2] This evaluation by the ISAP was authored by Steve Bartell (chair), Steve Chipps, ad hoc panelist Barry Noon, Chris Guy, Dennis Murphy, and Melinda Daniels.

sustained natural recruitment occurs. Metrics for the program are identified in the sub-objectives: 1) catch rate of age-0 and age-1 pallid sturgeon, 2) abundance of age-0 and age-1, derived from modeling, and 3) survival of hatchery and naturally reproduced pallid sturgeon to age-1. Those metrics are to be used to determine program progress in the evaluation phase of the adaptive management process and to justify adjustments in the management of pallid sturgeon. Establishing whether the programmatic sub-objectives are being met is the fundamental responsibility of the MRRP monitoring and assessment effort, which includes project effectiveness monitoring, which is not the subject of this review.

In this report, the ISAP responds to five (compound) "questions" framed by the Corps and vetted through the Missouri River Recovery Implementation Committee's (MRRIC's) Fish Working Group. It should be understood that had the questions been posed in an interactive, in-person MRRIC forum, those queries would have initiated discussion that would range widely into issues bearing on approaches to data collection, sampling design considerations, alternative uses of gear and tools, and timing of field operations, all towards implementing effective, efficient, and accountable pallid sturgeon monitoring – in detail beyond the scope of this review. Here the ISAP answers the questions and presents observations that clarify the answers or provides relevant explanatory information. However, the responses here are not exhaustive per se; the present exchange cannot be viewed as finished product. In developing an omnibus monitoring scheme for pallid sturgeon that can inform the breadth of management decisions under the MRRP that lie ahead, there are more questions to ask and certainly more to say in response. Understood through that lens, the PSPAP monitoring plan – Appendix D from the SAMP – is not complete, nor with agency responses to review comments offered in this report will it be "finished." Rather the PSPAP document should be viewed as evergreen, subject to continuous refinement. Pallid sturgeon monitoring under the MRRP should be viewed as adaptive, just as is the management agenda targeting pallid sturgeon. Programmatic monitoring will be subject to continuous amendment and should be subject to periodic review, perhaps linked to review of the Adaptive Management and Compliance Report or less-frequent programmatic review.

The following report sections reflect the ISAP's detailed evaluation of Appendix D and supporting materials identified in the task charge (Appendix A of this report). The review was guided by charge questions provided to the ISAP by the MRRIC (in Appendix A and recounted in section headers below). The ISAP offers a number of recommendations that the Corps might consider as the PSPAP moves forward through implementation, and closes the report with a coda, setting realistic expectations for pallid sturgeon management and the ability of resource managers to detect pallid sturgeon responses to program actions.

Responses to the review questions

1. **A component of PSPAP is age-0 sturgeon monitoring as well as monitoring of recent recruits (age-1 to age-3 pallid sturgeon). The primary purpose of this component is to gain reliable estimates of pallid sturgeon reproductive success and recruitment and track changes over time which can then be related to river conditions (e.g., natural annual flow variations).**

    a. **Will the spatial extent, temporal scale, and intensity of age-0 sampling in the currently proposed sampling scheme provide sufficient and reliable data that can be used to assess reproductive success, parameterize population models, evaluate effect of natural flows events, and contribute to assessing performance of targeted management actions?**

Given the current uncertainty in the estimates of CPUE and occupancy rate, it is challenging to 1) assess reproductive success with regard to targets, 2) estimate population model parameters, 3) determine the effects of natural flows events on reproductive output, and 4) assess the performance of targeted management actions. The ISAP recognizes the difficulty in sampling age-0 and age-1 pallid sturgeon; the comments in this review are intended to help the Corps meet realistic expectations for the sampling and analyses as they relate to program objectives.

Monitoring can be viewed as the repeated sampling of a population over a span of time (Hankin et al. 2019). The span of time and frequency of sampling is dictated, in part, by the ecology and life history of the target species. For pallid sturgeon, a long-lived species with delayed age at first reproduction, the study duration is likely to exceed a decade or more in order to understand whether the population is responding positively to management actions (White 2019). At its foundation, the proposed monitoring plan for pallid sturgeon represents status and trend monitoring (Reynolds et al. 2016). Status is often defined in terms of the value of the monitoring state variable (herein population abundance) at a particular point in time, and trend is defined as a change in status over a period of time.

Drawing from the discussion in Hankin et al. (2019), the design of a monitoring program has two interrelated components: 1) the sample design used to select the sample units on each sampling occasion and 2) the temporal schedule (frequency and duration) for surveying the sample units. These are often referred to as the membership design component and the revisit design component, respectively. One way to understand membership design is to envision a list of all the primary sample units within the sample frame. For pallid sturgeon monitoring, this would be a list of the all the river bends, the primary sample units, within the range of the species in the Missouri River (the sample frame). The sample of units to survey would then be based on some probabilistic selection of *n* units from the list. The revisit design can be complex; it could involve many ways of conducting surveys in time and space. Designs refer to “panels” where a panel represents a group of survey units all sampled during the same time period (McDonald 2013). Panel designs range from *always revisit* where the same set of *n* sample units are revisited on each sampling occasion, to *never revisit* where no sample unit is ever revisited. The sturgeon monitoring plan is an *always-revisit* design where only a single panel is formed and the same set of sample units is surveyed on each occasion (each year). Many environmental sampling designs use an equal probability of selection from the membership list and an *always-revisit* survey schedule.

In general, monitoring programs require two key actions: 1) estimating the current state of the system (status) and 2), estimating how system state is changing over time (trend). Appendix D has multiple references to "status and trend monitoring," but includes minimal discussion of how the trend analyses will be conducted. These two components, status and trend, are directly tied to issues of sample design.

Design issues relevant to estimating the current state of the system focus on 1) the number of sample units required for a precise and unbiased estimate of current state; and 2) how the sample units are arranged in space. In the current design, the sample frame for monitoring is hierarchically structured according to river segments (n=11), bends within segments, and macrohabitats nested within bends. Bends are the primary sample unit. Within each sample unit, surveys are conducted to estimate the occurrence of age-0 fish using occupancy models, and the abundance of age-1 and older fish using mark-recapture methods. Decisions regarding sample sizes require an *a priori* statement of desired precision on the estimates of occupancy rate (age-0 fish) and population abundance (age-1 and greater).

Appendix D (page 34) states that "… the precision needed in the population estimates needs to be determined through discussions with the agencies." Questions about the sample size requirements cannot be completely answered until precision targets are set. Issue two requires a determination of the required spatial allocation of sample units to achieve the defined precision targets. If there is pronounced spatial heterogeneity in the value of the state variables (occupancy and abundance), then a stratified design will usually achieve precision targets with smaller sample sizes. Stratification may partially address the issue of low sample size. This question and Appendix D (page 149) make reference to the possibility of a stratified design, but this may not have been implemented to date.

Addressing the adequacy of the spatial extent and temporal scale of the survey design can be usefully informed by *a priori* estimates of the components of variance analysis. Appendix D does not include that analysis. For example, if catch rate (C) = CPUE is the state variable, then

$$C(s,t) = \mu + segment_s + time_t + \varepsilon_{s,t}$$

and information on the following variance terms is required:

$$segment_s \sim (0, \sigma^2_{segment})$$
$$time_t \sim (0, \sigma^2_{time})$$
$$\varepsilon_{s,t} \sim (0, \sigma^2_{residual})$$

Question 1a is difficult to address because the scale of the experimental unit is not clearly described. Scale is important because it influences the sample size and how data are analyzed (are pooled) to address the sub-objectives, flow events, and targeted management actions. For example, Appendix D states (lines 1121 and 1122) that "yearly changes in abundance of young sturgeon will be measured using CPUE or changes in occupancy rates." Are the yearly changes at the macrohabitat scale, segment scale, or management unit pooled to represent the upper river and lower river spatial extents? Macrohabitat appears as the scale for the experimental unit for CPUE from the data presented in Table 15. If this assumption is true and those data are representative of the variation in CPUE for age-0 pallid sturgeon (i.e., coefficient of variation = 248%), then it is doubtful that changes – assuming standard parametric statistical methods are used to describe changes – will be detected given the uncertainty of the CPUE estimates. (Uncertainty in CPUE is acknowledged in the Appendix D.) Current methods of population monitoring rely on CPUE, which is confounded by factors that affect catchability, including changes in flow. As a result, CPUE does not provide accurate data for model calibration, and in the lower Missouri River is poorly correlated with trends in stocking of hatchery fish (see section 4.4, page 391). Despite those concerns, CPUE remains an imperfect but primary performance metric for a number of important questions related to abundance of age-0 pallid sturgeon (Tables 63 and 64 in Appendix D).

The term "changes" as used in Appendix D lines 1121 and 1122 is vague and there seems to be no description of the statistical approach(es) necessary to evaluate changes (trends). Assuming "changes" is related to the targets on page 6, how will the metrics be statistically evaluated in relation to the targets? Will changes through time be evaluated using a time-series approach to detect "increasing levels of recruitment over time," as mentioned in the targets for sub-objective 1? Given that "changes" will be difficult to detect because of uncertainty in the CPUE estimates, relationships between CPUE and flow or targeted management actions will also be difficult to discern. The spatial scale for CPUE needs to be considered for the relationships with flow and targeted management actions. For example, would the relationship between CPUE and flow have a single data point for each year or each pallid sturgeon macrohabitat? In the former there would be a sample size of nine (for nine years) and in the latter it would be much higher (a sample for each macrohabitat sample by year). Furthermore, is it realistic to assume that CPUE estimates among neighboring macrohabitats are independent?

Sections D.6.3.1 and D.6.3.2 in Appendix D describe the spatial and temporal aspects of pallid sturgeon age-0 and age-1 sampling. Focusing on areas and habitats with high CPUE values for young *Scaphirhynchus* would seem to maximize the probability of capturing age-0 pallid sturgeon. The only caveat is that consideration be given to obtaining samples through at least late July (preferably August) in the UMOR. Braaten et al. (2012) reported that by the end of their first growing season, naturally growing age-0 pallid sturgeon in the UMOR vary in size from 120-140 mm. By age-1, the mean size of pallid sturgeon was 187 mm, close to the value of <200 mm reported on line 1615 "…proportion of bends occupied by age-0 sturgeon (<200 mm)… will be used to estimate basin-level occupancy," noteworthy because all fish <200 mm will be classified as 'age-0' as presented in Appendix D. Given that size of fish and date of collection will be recorded, it may be worth considering two categories of age-0 pallid sturgeon (age-0,<140 mm versus age-0, 141- ~200 mm) for occupancy modeling analyses that explore the influence of covariates on age-0 fish. These size ranges probably differ in the LMOR, but a similar differentiation should be considered (first year growing season vs first year winter survival).

Reproductive success in the PSPAP is assessed (estimated) in part through an occupancy analysis. There are a number of concerns regarding the occupancy analyses for age-0 and age-1 sturgeon. Occupancy has a relatively low information content. Occupancy is primarily used to estimate the spatial distribution of a species – it does not allow direct inference to abundance (but, see caveat below). Occupancy rate is a property of the sample unit, not directly a property of the species. All else being equal, a larger sample unit is more likely to be occupied, because it can support more individual sturgeon. In the sturgeon monitoring, inferences to occupancy rate are estimated at two spatial scales – the segment and the bend. Bends are nested within segments in the design, similar to a two-stage sample design. The primary sample unit is the bend. However, bends vary in size and presumably in sturgeon abundance within a sample unit, introducing heterogeneity in detection probabilities that cannot be directly modeled because abundance is unknown. The occupancy rate of age-0 fish, therefore, might not provide much useful information on the magnitude of recruitment. Because occupancy rate of age-0 sturgeon is not an estimate of age-0 abundance, it is not clear how estimates of this rate can be used to parameterize an age-based demographic matrix model.

Many of the occupancy rates reported in the recent progress report were very high, even though detection probabilities were low. High occupancy rates could be the result of sampling large areas, increasing the likelihood of capturing at least one individual. In addition, since the number of units where one or more fish were detected is adjusted for detection probability, small detection probabilities can result in inflated (and biased) estimates of occupancy. To help understand how low detection probabilities can lead to inflated (and imprecise) estimates of occupancy (ψ), consider the following. Let s represent the number of bends randomly sampled and s_D the number of bends where 1 or more age-0 sturgeon were detected. Then, a naive estimate of occupancy (and its variance) is

$$\hat{\psi} = \frac{s_D}{s}$$

$$\text{var}\left(\hat{\psi}\right) = \frac{\psi(1-\psi)}{s}$$

The above estimate of occupancy assumes perfect detectability (that is, no observation error). However, if we assume population closure and conduct repeated surveys (k) on at least some of the sites, an estimate of the per-visit detection probability (p) is possible. Given an estimate of p, we can correct our estimate of ψ to adjust for failure to detect age-0 fish in sample units where they were present:

$$\hat{\psi} = \frac{s_D}{sp^*}$$

$$\text{var}(\hat{\psi}) = \frac{\psi(1-\psi)}{s} + \frac{\psi(1-p^*)}{sp^*},$$

where, $p^* = 1-(1-p)^k$ (the probability of ≥ 1 detections in k surveys)

When estimating ψ, a small p^* value can greatly inflate the estimate of occupancy. In addition, the estimate of ψ is less precise because the variance of ψ now has two components: 1) the binomial variance associated with the true value of ψ, and 2) variance due to imperfect detection of age-0 sturgeon. This second component can be large if p^* is small, leading to imprecise estimates of ψ.

The occupancy values presented in Table 11 are imprecise and might not be overly informative, unless the uncertainty can be reduced. However, it may be that the described analyses are appropriate and that the presentation of the methods is simply lacking in detail. There is some discussion in Appendix D that occupancy data will be supplemented with CPUE data, which might help infer the magnitude of recruitment. As a counterpoint to the preceding concerns, a strong relationship between occupancy and abundance was demonstrated by Gaston et al. (2000). Similarly, a recent paper based on a study of a freshwater fish assemblage found a relationship between abundance and occupancy (Miranda and Kilgore 2019). Occupancy may be a better monitoring state variable than suggested in the previous discussion.

b. **Similarly, catch rates of age-1 to age-3 pallid sturgeon are used to assess recruitment and relate to annual flow variation. Will the spatial extent, temporal scale, and intensity of the proposed age-1 to age-3 sampling allow resource managers to assess recruitment, parameterize population models, relate recruitment to annual flow variations, and contribute to assessing performance of targeted management actions?**

Many of the concerns outlined in 1a above for age-0 pallid sturgeon apply to monitoring catch rate and recruitment of age-1 to age-3 pallid sturgeon. Several concerns are based on the preliminary data presented in Tables 11 and 15 for fish >200 mm that are mostly age 1 to age 3. As with age-0 monitoring results, there appears to be considerable uncertainty in CPUE and occupancy rate estimates. Correspondingly, there would need to be a large effect size to detect a statistical difference in status, trend, or relation to flow variation based on the PSPAP monitoring scheme described in Appendix D. Addressing the adequacy of the spatial extent and temporal scale of the survey design requires *a priori* estimates of the components of variance analysis, as previously noted for age-0 pallid sturgeon.

Catch of age-1 to age-3 sturgeon prove that recruitment of fish to these ages occurred, but are accompanied by many uncertainties. For example, age-3 fish represent age-0 fish that have survived 3 years, $(n_3 = s_2 s_1 s_0 n_0)$ and, thus inferences derived from older fish confound information on survival and the number of age-0 fish (n_0) actually recruited into the population 3 years prior. The proposed sampling of age-1 to age-3 pallid sturgeon, as described in Appendix D, provides data for preliminary estimates of recruitment, to estimate model parameters, to relate recruitment to variation in flow, and to evaluate performance of targeted management actions (including IRCs and spawning habitat). However, estimates of these relationships may be highly uncertain if not adjusted for size-dependent differences in catchability.

The primary challenge lies in the intensity of sampling for this rare species throughout a large, complex river system. Given the variability (lack of precision) of data available to date, it appears that the PSPAP will be challenged to provide data of sufficient accuracy and precision to usefully quantify recruitment of age-1 to age-3 pallid sturgeon. There are restrospective analyses we can use to evaluate recruitment variabiliy and factors related to recruitment variability, that incorporate CPUE values of fish that are fully recruited to the gear, by using weighted regression of loge number-at-age vs year-class (year) and evaulating residuals (Maceina and Bettoli 1998). As an example, for age-1 to age-5 sturgeon collected in a single year, catch-curve regression could be used to evaluate relative year-class strength by comparing residual values (+ or –) to environmental characteristics that were present when fish were produced (i.e. age-0).

c. **Can the proposed monitoring scheme separate the effect of flow variations on catchability and reproductive success/recruitment?**

Evaluating the effects of flow variation on reproductive success and recruitment depends on 1) monitoring age-0 production and age-1 recruitment across a range of natural flows and 2) estimating a corresponding functional relationship between flows and population metrics for incorporation into the IPSPM. Evaluation of flow events also require that one or more metrics that characterize flow be included in the analysis as covariates on occupancy rate. The flow metrics are not presented in Appendix D. Useful flow metrics would likely include measures such as minimum, maximum, and average discharge; water elevation; minimum, maximum, and average water velocity; and duration of increasing and decreasing discharge.

While question 1c uses the term "catchability," the question actually refers to catch per unit effort (CPUE) as discussed in Appendix D. Catch per unit effort – the number of individual fish caught per meter trawled – has long been used in fisheries assessments as an index of fish abundance. CPUE is related to population abundance (N) as

$$CPUE = qN$$

where q is the proportion of fish removed by one unit of sampling effort (the catchability coefficient). Because CPUE is the product of abundance and catchability, trends in CPUE over time can reflect changes in abundance, catchability, or both.

Catchability can be affected by a number of factors including fish size, environmental conditions, and gear efficiency; it is difficult to determine without reliable estimates of fish abundance (population size). For heuristic purposes, Figure 1 illustrates the potential impacts of size on catch probability based on simulations using an assumed lognormal distribution of fish sizes with a mean size of 500mm. It is important to note that CPUE, when not adjusted for catchability, can lead to uncertainty in fish-abundance estimates. However, under the unlikely scenario that catchability is similar among sample units, CPUE might provide a reliable index of fish abundance (Pierce and Tomcko 2003). Unfortunately, the relationship of CPUE to the true population size N is unknown, because catchability (q) is not estimated for pallid sturgeon < age 3 in the PSPAP. In addition, q is expected to vary with fish size (length) (see Figure 1), sampling gear, and across time and space. Given the sources of variability in "catch rate" described above, the proposed monitoring scheme will be challenged to separate the effects of flow variation from other confounding factors. Moreover, for occupancy estimates, the highest point estimate of detection probability was 0.19 for age-0 sturgeon (< 200 mm); estimated occupancy values were highly variable (Bayesian credible interval 0.008 – 0.69 in Table 13). Similar to CPUE, there

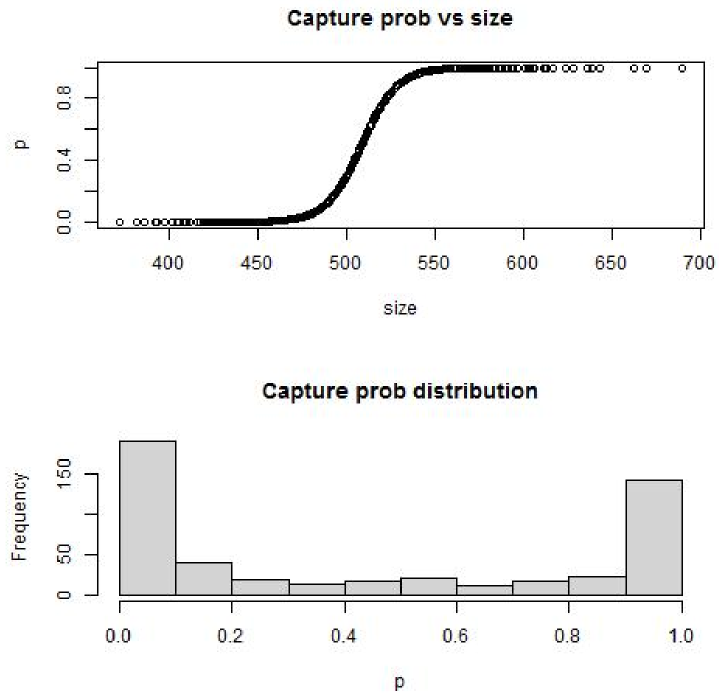

Figure 1 – *(a) simulated probability of capture (p) on the y-axis versus fish size (mm) on the x-axis; and (b) the frequency distribution of capture probabilities from the simulation based on a population size of 500 fish*

was considerable uncertainty in detection probability, implying it may be difficult to conclusively determine the effects of flow variation on detection probability.

2. Recognizing the pressing need for information on the distribution and survival of age-0 pallid sturgeon, several activities have been proposed to compensate for low capture rates, including evaluating use of shovelnose sturgeon as a surrogate species for evaluating reproduction and/or recruitment, increasing stocking of very young pallid sturgeon, improving identification and characterization of high catch areas to increase ability to stratify sampling effectively (e.g., our targeted sampling in June, 2020 in the LMOR produced about 16,000 age-0 sturgeon), and extending sampling into the middle Mississippi River.

a. Are these additions or amendments to the current sampling design(s) likely to enhance the ability to achieve the goals of the monitoring plan?

The use of shovelnose sturgeon as a surrogate species for pallid sturgeon continues to be an important topic in the MRRP and research should continue toward identifying/demonstrating similarities and differences between the species at age 0 and age 1. Surrogate systems use the response of one species to environmental disturbances or management actions to predict the response of another species to similar environmental phenomena. Use of a substitute species (shovelnose sturgeon) when the focal species (pallid sturgeon) is usually too rare to measure is defensible to the extent that similarities can be demonstrated between the life histories and ecologies of the surrogate and focal species. If a defensible argument can be made that the population-level response of these two sturgeon species to the same environmental stressors and management actions is sufficiently similar, then surrogacy can be a defensible assumption.

In general, the described additions to the sampling plan might increase the likelihood of achieving the goals of the monitoring plan. In particular, understanding recruitment failure in pallid sturgeon might prove to be a key factor in understanding recruitment success of shovelnose sturgeon or vice versa. For two closely related species living in the same environment, where one is arguably successful, while the other is not – there must be a critical, autecological difference between the species at some life-stage(s). For that reason, "… *evaluating use of shovelnose sturgeon as a surrogate species for evaluating reproduction*" requires some clarification. Although shovelnose sturgeon and pallid sturgeon are quite similar in many respects, there must be fundamental differences in their ecology. Continuing research efforts to discover those differences will be useful in answering questions about surrogacy.

One observation that is frequently mentioned in Appendix D with regard to age-0 sturgeons is the association between catches of small shovelnose and pallid sturgeon; that is, age-0 pallid sturgeon frequently are caught in combination with age-0 shovelnose sturgeon. Assuming that detection probabilities of age-0 shovelnose and pallid sturgeon are similar, there are approaches for comparing spatial patterns in the distribution of these species, including a Mantel test (Fortin and Gurevitch 1993) or a two-dimensional Kolmogorov-Smirnov test (Garvey et al. 1998). These approaches rely on arranging data into bivariate spatial coordinates (e.g., UTMs) and can be used 1) to identify whether a single distribution has arisen by random effects or 2) to compare two bivariate distributions (Garvey et al. 1998). In the example in Figure 2, the distribution of Species 1 (triangles) and Species 2 (circles) in panel A reveal no difference in their spatial distribution, whereas their spatial distributions revealed in panel B are different. Knowing whether years with high catches of age-0 shovelnose sturgeon positively correlate with

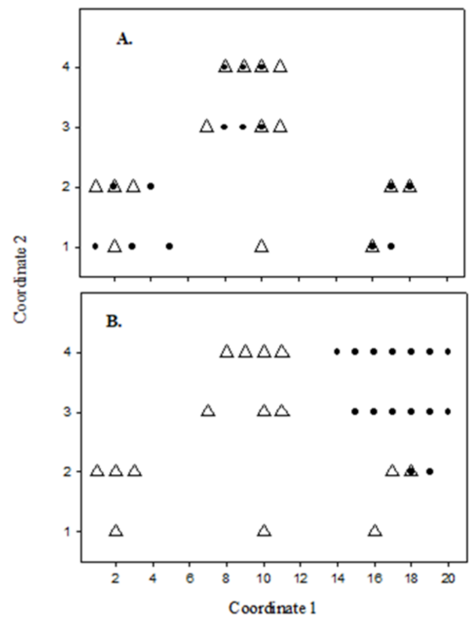

Figure 2 – *Example results from arranging spatial data into bivariate spatial coordinates on pattern detection (Chipps and Garvey 2007)*

years of high catches of pallid sturgeon age-0 could provide insight into whether mechanisms that result in strong year classes of shovelnose sturgeon also result in recruitment for pallid sturgeon – this is particularly relevant in the lower Missouri River basin and middle Mississippi River.

If the assumption of equal detection among pallid and shovel nose sturgeon is not tenable, occupancy models can be applied to estimate the probability of co-occurrence – that is, the probability that two species occur in the same sample unit (MacKenzie et al. 2018). These methods explicitly estimate detection probabilities for both species, allowing them to differ. In addition, dynamic models can be fit to multi-year survey data to estimate how co-occurrence patterns change over time.

Stocking and subsequent sampling of age-0 pallid sturgeon and shovelnose sturgeon could provide insight into sampling efficiency and how to reduce variation in CPUE and occupancy rates. This combined stocking could be used to further elucidate the similarities and differences between species with respect to catchability (detection probability) and drift dynamics, which could be used to improve the PSPAP sampling design and address questions regarding surrogacy. Stocking a known quantity of age-0 pallid sturgeon and subsequent recapture could also be used to put the number of wild age-0 pallid sturgeon in context. Stocking of age-0 sturgeon has been conducted in the upper Missouri River basin and tied to specific research questions related to drift – the studies provided information on drift dynamics that was subsequently used to propose management actions. Similar efforts could be conducted in the lower basin to facilitate a more efficient and powerful monitoring program (that is, to reduce variation with the least amount of effort) for age-0 pallid sturgeon and shovelnose sturgeon.

Targeted sampling provides an efficient approach to increase the probability of catching age-0 pallid sturgeon. In the context of the PSPAP monitoring plan and status and trend evaluation, amendments to the current sampling design should be focused on reducing variation in the metrics used to address the sub-objectives (see recommendations below). Increased catch of age-0 pallid sturgeon would provide critical information – particularly for research questions related to age, growth, diets, and genetics. However, it is also important to recognize that increased catch might not necessarily decrease variation in the metrics used to evaluate the pallid sturgeon population sub-objectives.

Targeted sampling also provides critical information to the described Bayesian state-space occupancy model applied to age-0 pallid sturgeon. However, the temporal distribution of random and targeted sampling of bends will take one of two forms (Figure 3). In panel (A), random sampling of bends is initiated and continues until the last 2 weeks of the season, when targeted sampling efforts begin. In panel (B), random sampling of bends is initiated and continues until abundance of age-0 fish increases "significantly." Then all sampling shifts to targeted bends for 2 weeks, before returning to sampling random bends to end the season. There is concern with (B) in how it might affect CPUE. In essence, the interruption of randomized sampling, because of increased catch rates of age-0 fish, could result in depressed CPUE estimates for randomly selected bends. If so, that would likely lead to hyperdepletion in CPUE estimates, where catch rates are not proportional to abundance as given by

$$CPUE = qN^{\beta}\text{, } where\ \beta > 1 \text{ (see Pierce and Tomcko 2003)}$$

It appears that targeted efforts could bias random sampling in years when age-0 pallid sturgeon numbers increase, by shifting effort away from random sampling for two weeks (Figure 3B). Conducting targeted sampling at the end of randomized sampling in years when abundance of age-0 pallid sturgeon does not increase might help to alleviate some of that bias (Figure 3A). A better, albeit less pragmatic, approach would be to randomly intersperse targeted sampling with randomized sampling; but that sampling protocol could create logistical issues and increase monitoring costs given the spatial distribution of bends in each segment. Nonetheless, it raises another question about the uncertainty in age-0 CPUE and whether gains for occupancy

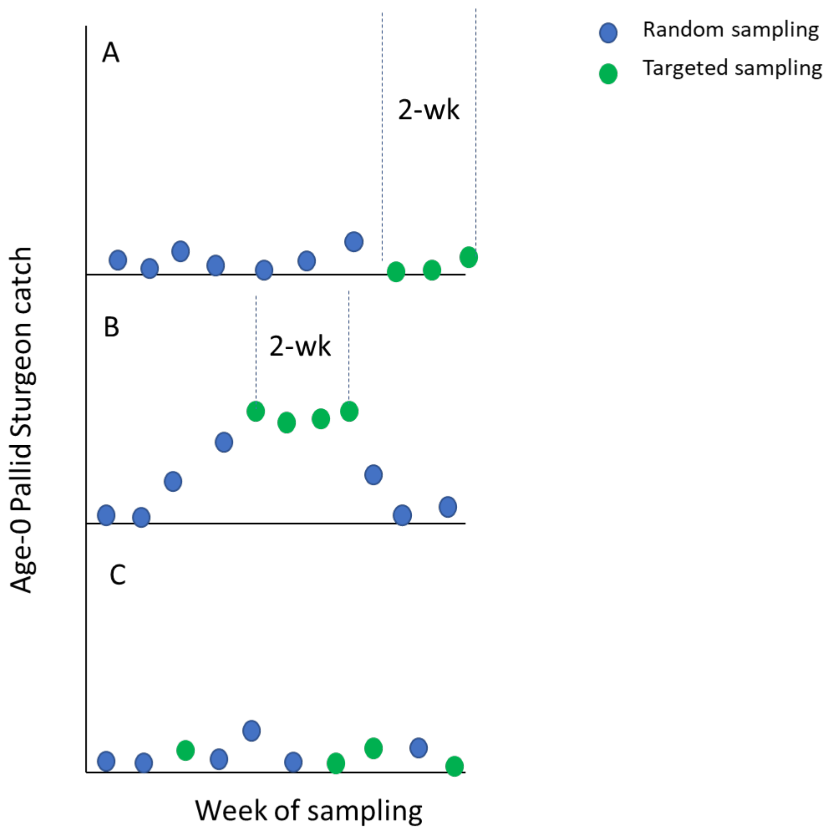

Figure 3 – *Schematic of proposed random and targeted sampling of bend sites*

modeling (targeted efforts) and increased catch of age-0 fish outweigh the costs of randomized sampling for CPUE estimates. Information on the "timing" of age-0 sturgeon sampling is described in Appendix D at line 1397 – "Age-0/1 sampling will begin in late spring/early summer throughout the geographic range of PSPAP…." and "…the timing of sampling will be determined through water temperature, preliminary trawling data, and/or spawning information gathered by telemetry." Given the importance of water temperature to spawning, embryo development, and duration of drift, it would be prudent to put the "timing of sampling" for age-0 fish into better context. Pallid sturgeon generally spawn at between 16-19 °C (Elliott et al. 2020). At these water temperatures, embryos require between 13 to 7 days to hatch (Kappenman et al. 2013); post-hatch, it takes approximately 10 to 8 days at 16-19°C (or ~183 to 156 CTUs) for larvae to settle (Mrnak et al. 2020). It is likely that the timing of spawning varies across the geographic range of pallid sturgeon (Elliot et al. 2020), but it is not clear in Appendix D how this issue is addressed and what water temperature criteria are considered to initiate sampling.

Given size-dependent mortality in young sturgeons, any "peaks" in annual abundance would likely be more pronounced during the meso-larvae life stage (22-80 mm), compared to the meta-larvae stage (> 80-150 mm). This information is important to better clarify what size range of fish are being considered 'age-0' pallid sturgeon (Figure 4). Text in Appendix D references age-0 pallid sturgeon simply as fish <200 mm (line 1615).

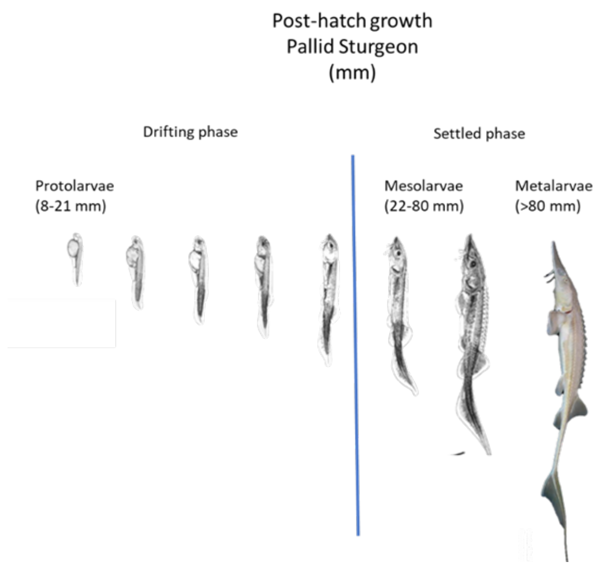

Figure 4 – *Early life-stage development in age-0 pallid sturgeon. (Photo: Matt Wagner, SDSU. Illustrations: Snyder 2002)*

b. Does the ISAP have other recommendations for handling the challenges of low sample size?

Low sample size can be overcome by increasing targeted sampling. At this point in the program, it is important that efforts to capture age-0 and age-1 sturgeon are maximized to the extent possible. However, sampling targeted sites reduces the sample frame (the spatial extent of the riverine ecosystem to which inference can be made). We caution that any sort of judgmental sampling will likely result in biased estimates that undermine statistical inference to the entire sturgeon population (see Thompson 2012). The concern expressed in this recommendation – high variability among sample units (bends) in the abundance of age-0 sturgeon and many zero counts – is valid.

To address the problem, a stratified random sample design could be adopted, where abundance strata are based on the catch data from previous years. Stratified sampling is a probability-based sampling design, where sample units (bends) are first stratified into, for example, high/medium/low abundance strata and a random sample of map-units is selected from each stratum. In addition, the number of randomly selected sample units within each stratum should be based on an optimal allocation of samples across the strata (Thompson 2012, pp 146-148). In an optimal allocation design, the number of samples within each stratum depends on 1) the size of the stratum (i.e., number of sample units within that stratum), and 2) the variability in the catch within each stratum. In this design, a stratum with high abundance of age-0 sturgeon will generally have more sample units selected than a stratum with low abundance. This generally occurs in biological studies involving counts because variability in the count increases with the mean count. A stratified design can yield unbiased, probability-based sample estimates.

To illustrate the probability-based approach, consider the conditions of three abundance strata (H, M, L), sufficient resources to sample *n* sample units (bends), and no prior information on stratum size (number of bends) or variance in the catch. In this case, one would adopt an equal allocation design

$$n_h = \frac{n}{3}$$

where, $n_h =$ the sample size in stratum *h*. However, there is information on the number of bends in each stratum, so a proportional allocation design could be developed

$$n_h = \frac{nN_h}{N}$$

where $N_h =$ the number of bends in stratum *h*, and $N =$ the total number of bends across all strata. If estimates of the standard deviation in the count (σ_h) in each stratum based on past data are available, an optimal allocation design is possible

$$n_h = \frac{nN_h\sigma_h}{\sum_{h=1}^{3} N_h\sigma_h}$$

This optimal design should result in more samples being taken in bends with a greater number of age-0 sturgeon and fewer samples in bends with few age-0 sturgeon.

As discussed previously, two primary variance components affect all monitoring programs – sampling and process variation. Only sampling variation can be reduced by increasing sampling intensity. Unfortunately, process variation is the dominant variance component in most environmental monitoring programs. Decreasing sample size will simply increase the sampling variation component when estimating trend. This is demonstrated by the following equation, which estimates the variance in the average linear trend (slope) across sites (from Urquhart 2012). A decrease in s will increase the variance estimate according to

$$\mathrm{var}(\hat{\beta}) = \frac{\sigma^2_{time} + \frac{\sigma^2_{residual}}{s}}{\sum (t - \bar{t})^2}$$

where

s = number of sample units (bends or segments)

t = time (year)

Very low catch rate, combined with uncertainty in CPUE and occupancy (detection), presents a challenge to traditional approaches for examining changes in age-0 pallid sturgeon abundance. While targeted efforts may reduce uncertainty and improve our ability to assess age-0 pallid sturgeon abundance and occupancy, the time-frame for acquiring these data is not known, and could delay attempts to explore responses of age-0 pallid sturgeon to environmental changes and management actions. Furthermore, environmental conditions that predict occupancy or abundance can differ substantially (Dibner et al. 2017), complicating decisions over which metric (CPUE or occupancy) is a better predictor of age-0 pallid sturgeon responses to environmental conditions, management actions, or both.

Exploring the relationship between pallid sturgeon abundance and occurrence can be useful for evaluating the direction and magnitude of potential environmental effects (Figure 5). In the example, each point on the graph (green triangle) represents a different year of monitoring data for a given Segment. The initiation of age-0 sampling as set forth in Appendix D sets a baseline (or starting point) for age-0 pallid sturgeon that is characterized by very few fish (low CPUE) showing up at very few sites (low occupancy) represented by the red circle. Over the following 9 years, positive changes in age-0 pallid sturgeon could follow one of three general trajectories in relation to environmental conditions, management actions, or both. Trajectory (A) shows increased occurrence of age-0 pallid sturgeon, with little change in abundance (CPUE; i.e., very few age-0 pallid sturgeon, but at more sites). Increased occurrence might be expected as a result of system-wide changes (e.g., flows) that enhance age-0 pallid sturgeon abundance (CPUE) and hence, distribution. Trajectory (B) shows an increase in the abundance (CPUE) of age-0 pallid sturgeon, but at very few sites, implying that local conditions, rather than system-wide effects may be associated with increased survival and abundance. In Trajectory (C), both abundance

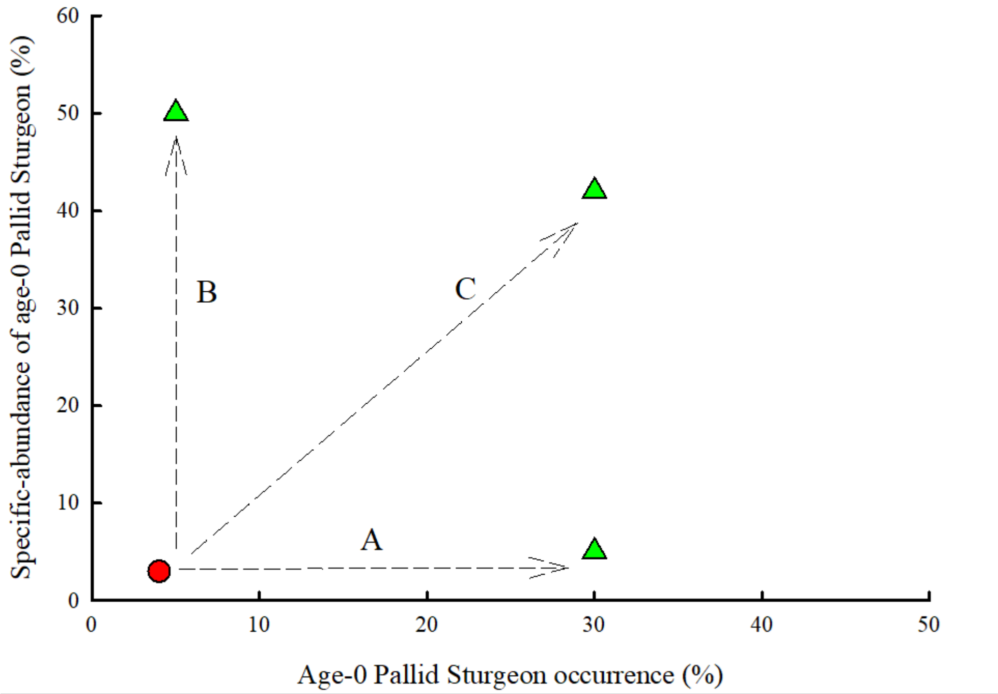

Figure 5 – *Specific-abundance versus occurrence of age-0 pallid sturgeon. Adapted from Amundsen et al (1996)*

(CPUE) and occurrence of age-0 pallid sturgeon increase compared to baseline (the management objective). Similarly, patterns in annual estimates of age-0 shovelnose abundance and occurrence could be compared to those for pallid sturgeon.

A heuristic approach that includes information on both abundance (CPUE) and occurrence might be helpful in exploring changes in age-0 pallid sturgeon. The approach is based on the relationship between specific-abundance and frequency of occurrence of age-0 fish. For a given Segment, frequency of occurrence (O) of age-0 pallid sturgeon is calculated as:

$$\mathrm{O} = \frac{N_i}{S} x\ 100$$

where N_i equals number of bends containing age-0 pallid sturgeon and S equals number of bends containing age-0 sturgeon (pallid sturgeon and/or shovelnose sturgeon).

Similarly, for a Segment, specific-abundance of age-0 pallid sturgeon (SA) is calculated as

$$\mathrm{SA} = \frac{\sum N_i}{\sum T_i} x\ 100$$

where N_i is the number of age-0 pallid sturgeon and T_i is the total number of age-0 sturgeon (shovelnose and/or pallid sturgeon) at bends with age-0 pallid sturgeon. Rather than assuming constant catchability across macrohabitats and time, it could be assumed that catchability of age-0 pallid sturgeon and shovelnose sturgeon varies similarly across space and time – a reasonable assumption given that detection probabilities are similar for both species. As an example, consider the following five bends where a total of nine age-0 pallid sturgeon were collected and a total of 514 shovelnose sturgeon were collected. Specific abundance of age-0 pallid sturgeon is then calculated as:

$$\mathrm{SA} = \frac{2+1+1+3+2}{265+59+81+3+115} = \frac{9}{523} = 0.0172 = 1.7\%$$

A biplot of SA versus O can be useful for evaluating the direction and magnitude of changes in age-0 pallid sturgeon occurrence (see Figure 5).

3. Another component of PSPAP is population estimation of juvenile and adult pallid sturgeon.

a. **Parameterizing the population model requires abundance, survival, and growth for the demographic matrix model and when employed as an individual based model additional information on spatial distribution, size distribution, growth, origin (hatchery, wild/unknown, hybrid), and movement. Is the monitoring plan set up to estimate values needed to characterize abundance, survival, spatial distribution, origin, and movement?**

The PSPAP monitoring plan is designed to estimate abundance by fish origin and covers the necessary spatial distribution. Population estimates were calculated for hatchery, hybrid, and wild (unknown) pallid sturgeon by length category and management unit. Similar to other metrics, there is considerable uncertainty in the estimates, particularly in the Central Lowlands management unit (Table 19). Survival estimation is described and has been estimated for hatchery-origin fish in the upper basin (Rotella 2017). It appears a similar approach will be used throughout the basin. Survival estimates from embryo hatch through the first growing season for age-0 pallid sturgeon will continue to be difficult to estimate with any degree of certainty.

Based on information provided in Appendix D, it appears as if the mark/recapture design will provide estimates of most of the key demographic parameters. Table 2 usefully identifies parameters in the IBM and DM that can be informed by PSPAP monitoring activities. Appendix D states that a robust mark/recapture design (following Williams et al. 2002) will be employed. This model combines open and closed capture/recapture data structures and can provide estimates of time-specific abundance, survival, capture probabilities, and temporary emigration rates. In addition, abundance estimates will be made for three surgeon size classes – <600mm, 600-800mm, and >800mm – with separate estimates for wild, hybrid and hatchery fish (see Appendix D, page 86). Individual estimates by size class seems logical; however, it is not clear why the size of captured fish is not treated as a continuous covariate. Incorporating size as an individual covariate in the robust design could be accommodated to model individual size-dependent heterogeneity in capture probability.

Under unique sampling processes, it is possible that targeted sampling may provide unbiased estimates of key population metrics. For example, Section D.6.2.1 indicates that sampling will emphasize upper Missouri River bends, where the highest catch rates have been historically encountered. Similarly, selection of sampled bends, gear types, and timing of sampling all appear identified in relation to previous success in collecting pallid sturgeon of varying age. At the same time, it should be noted that of 497 sturgeon captured, only 4 were pallid sturgeon. No age-0 pallid sturgeon were collected.

Parameterizing the population model gets at the question of verifying the model components; that is, is the model structured correctly? Given the current description and understanding of the demographic model and associated inputs, the technical team has done a good job in capturing and explaining life-stage dependent survival probabilities, reproductive events, etc. In some cases, using values estimated from the literature or related studies, and in other cases with 'first approximations' reflecting the paucity of data. Furthermore, model developers familiar with the inner workings of the model have conducted simulation modeling for parameter estimates to document model verification. These are complex models with many input parameters. A rigorous "sensitivity analysis" of the models could help reviewers better identify which parameters and supporting data need to be carefully considered as part of PSPAP data collection efforts. Understanding how response variables, such as population size, respond to sensitive input parameters (or management actions) will be important in shifting the question before planners from "Have we built the model right?" to "Have we built the right model?" For example, Section D.3.3 states that functional responses between a management action and a modeled demographic rate can be used to construct modeling scenarios to project outcomes or identify thresholds in pallid sturgeon response, but there is no mention in the PSPAP of attempts to develop functional responses for specific management actions.

The question also makes reference to an individual-based pallid sturgeon population model. The application of individual-based models (IBMs) has been successful for evaluating growth dynamics of age-0 pallid sturgeon in the Missouri River (Deslauriers et al. 2018) and should be applicable to juvenile and adult fish. Nonetheless, while IBM approaches provide platforms for testing hypotheses, it remains to be shown how application of IBMs is an essential component of the PSPAP monitoring program.

b. Is the monitoring plan capable of providing reasonable estimates of progress toward population objectives?

The PSPAP was originally developed to assess status and trends in pallid sturgeon catch rates, population structure, and habitat use in support of the 2003 Biological Opinion. As described in Appendix D, the PSPAP has been re-designed to support adaptive management of pallid sturgeon in the Missouri River. The fundamental programmatic population objective is to avoid jeopardizing the existence of pallid sturgeon from USACE actions on the Missouri River. The corresponding stated population sub-objectives are to 1) increase pallid sturgeon recruitment to age-1 and 2) maintain or increase numbers of pallid sturgeon as an interim measure until sufficient and sustained natural recruitment occurs (Appendix D, page 5-6). The monitoring plan described in Appendix D, supported by effectiveness monitoring (Appendix E), appears capable of estimating progress towards population objectives. The main issue resides in how accurate and precise the estimates might be in relation to the revised PSPAP monitoring program.

There are multiple types of overlapping and complementary monitoring programs (see Reynolds et al. 2016) including: 1) status and trend monitoring, 2) threshold monitoring, 3) effectiveness monitoring, and 4) monitoring in support of an adaptive management framework. Monitoring objectives are defined in the SAMP (page 405) as – "This program is being designed to provide population-level information for decision makers about status and trends about pallid sturgeon, serve as a validation of predictions from the Collaborative Population Model, and enhance understanding of linkages between actions and population response. It is also evaluating alternative system-wide sampling strategies which will inform the sampling strategies in this appendix."

Given those objectives, the sturgeon monitoring program appears to include all four types of monitoring programs. However, it is important to emphasize that Appendix D does not describe a complete monitoring program. Notably absent is any detailed discussion on trend estimation; that is, how the state variables described in Appendix D are changing over time and space and how measured changes might be affected by individual or combinations of directed management actions. PSPAP trend analysis could be presented in greater detail. Estimating trend from a simple linear regression of the estimated CPUE of age-0 or age-1 on time, for example, could prove inadequate. Trend estimation is not simple; describing trend as the long-term rate-of-change in a time series is not very informative (Johnson 2012). There are multiple reasons why trend estimation is difficult, but most important is that the response variable (CPUE, abundance, or occupancy rate) is subject to at least three sources of variation: 1) process variation (e.g., annual population fluctuations caused by environmental variability), 2) sampling variation (e.g., occupancy rate and abundances are estimated from a sample of the population), and 3) observation error (e.g., imperfect and size-dependent catchability). A robust trend analysis should address all three sources of variation (Humbert et al. 2009). In addition, trend estimation in fisheries and wildlife also requires an underlying model for the dynamics of the population – understanding whether population change exponential or density-dependent.

Understanding if additions or amendments to the current sample design will "enhance" the likelihood of meeting management objectives requires information not presented in Appendix D. In addition, management objectives are not clearly articulated in Appendix D in terms of measurable objectives. According to Appendix D (p. 5), the fundamental population objective for pallid sturgeon is: "Avoid jeopardizing the continued existence of the pallid sturgeon from USACE actions on the Missouri River." USFWS notes that this objective is consistent with species recovery goals focused on self-sustained populations but specific to Missouri River management actions. Understanding that the programmatic goal is 5000 pallid sturgeon based on genetic criteria, and given the current sampling design for the pallid sturgeon, it is logical to specify the target size (density or abundance) of local (segment) populations, the number of segments required to achieve population size objectives, and the spatial distribution of those populations.

In addition, for ISAP to recommend additions or amendments to the current sample design requires information on the relative contributions of space and time to system variability. An improved understanding of the three sources of variation – process variation, sampling variation, and observation error – is needed. Sampling variation can be decreased by increasing sample size (number of segments or bends sampled). However, process variation is not decreased by increasing sampling intensity. Observation error is being addressed in both the occupancy (age-0) surveys and in the mark-recapture (age-1 and greater) sampling; however, observation error is not being addressed in the CPUE data.

c. Will data generated from PSPAP and associated analyses and modeling contribute to determining progress toward meeting pallid sturgeon recovery criteria?

The recovery criteria in the Pallid Sturgeon Recovery Plan focus on achieving a self-sustaining population, defined as "… a naturally spawning population that results in sufficient recruitment of pallid sturgeon into the adult population at levels necessary to maintain a genetically diverse wild adult population in the absence of artificial population augmentation. Additionally, in this context a genetically diverse population is defined as one in which the effective population size (N_e) is sufficient to maintain adaptive genetic variability into the foreseeable future…" (Recovery Plan, page 6). Section D.2.3 describes an effective integration of the IPSPM and the PSPAP monitoring to project and correspondingly measure the potential impacts of management actions on fundamental (population) objectives. The criteria are not expressed explicitly in terms of numeric targets for population abundance (capture/recapture data) and do not directly address issues associated with geographic distribution (occupancy data). It is important to explain more fully how the current monitoring state variables (abundance and occupancy) relate to the recovery criteria. In addition, there is a strong emphasis on genetic diversity goals/objectives, but it is unclear from Appendix D whether estimating the genetic diversity of wild populations of pallid sturgeon is a priority.

The recovery criteria imply population targets in terms of effective population size (N_e). N_e is defined as the size of an ideal population, the genetic composition of which is influenced by random environmental processes in the same way as the real population (Wright 1938). In most natural populations, total population size (N) is typically greater than the idealized population at any given point in time (i.e., $N_e/N < 1$; Nunney and Elam 1994), because not all individuals will make reproductive contributions to the next generation. N_e/N is determined by the simultaneous influence of three major demographic factors: adult sex ratio, fluctuations in population size, and among individual variance in reproductive success (Lande and Barrowclough 1987). The important message here for the monitoring program is that N is likely to be substantially greater than N_e to meet recovery criteria.

An effective population size of at least 50 individuals was originally viewed as the minimum number of adults needed to avoid inbreeding depression over the short term. An $N_e = 500$ individuals was subsequently proposed as necessary to retain adaptive potential in the face of environmental change over longer time periods (Lande and Barrowclough 1987). Recently, it has been suggested that the recommended 50/500 (N_e/N) criterion for effective population sizes used by in the IUCN Red List categorization system (IUCN 2013) for threatened species be revised upward to N_e over N ratios of 100/1000 individuals (Frankham et al. 2014). These are important considerations for the management of pallid sturgeon populations if the agencies are to meet delisting criteria.

The population-abundance method as outlined in the monitoring plan will be useful in determining progress toward meeting pallid sturgeon recovery criteria. However, similar to other metrics (e.g., CPUE of age-0 pallid sturgeon), the responsible agencies should work to identify causes of uncertainty in population estimates and reduce uncertainty to agreed-upon acceptable levels where possible. Linking age-0 monitoring data to recruitment and overall population dynamics is not yet complete. Observations of population states over time could inform the estimation of difficult demographic parameters, like age-0 to age-1 survival.

d. Will this approach, collaboratively integrated with the 2020 Evaluation Plan for the Conservation Propagation and Stocking Program, allow resource managers to evaluate the effectiveness of the artificial propagation program?

Evaluation of the propagation program is important and critical to addressing sub-objective 2. Monitoring of hatchery-origin pallid sturgeon survival and abundance has been successful for many years. The methods outlined in the PSPAP monitoring plan (pages 7 and 8) should be useful in evaluating the propagation program, especially if covariates are included, such as fin-curl status, hatchery origin, stocking size, family lot, and stocking location. This approach was used in the upper basin (see Rotella 2017) to improve the propagation program and could be similarly useful if incorporated in the lower basin.

Given the role of mark-recapture in the monitoring program, the PSPAP approach should continue to provide useful information on the success of the pallid sturgeon propagation program, particularly as it relates to survival variation among family lots and identifying crosses for genetic optimization. Similar concerns that were raised regarding analyses of age-0 data apply to the abundance data, that is, how will the data on abundance of hatchery-origin pallid sturgeon be analyzed relative to the objective "Maintain or increase the number of pallid sturgeon"? Again, will it be a trend analysis, if so, what approach will be used?

4. With respect to the telemetry component as described in Appendix D of the SAMP:

a. Will the telemetry component be capable of contributing to population estimates, informing movement probabilities, aid in testing population closure assumptions, and increase understanding of the population as it utilizes areas outside MRRP purview?

The proposed telemetry can be used to inform movement probabilities, assess closure assumptions, and better understand areas used by pallid sturgeon outside the MRRP purview. The telemetry network element of the monitoring plan could expand the understanding of the spatial-temporal characteristics of adult pallid movement patterns. Additionally, including telemetry data derived from partner agencies, as indicated in the monitoring plan, will expand the geographic scope of telemetry support of the MRRP. However, the methods presented in the Appendix D monitoring plan do not describe in sufficient detail how telemetry will be used to address sub-objectives for pallid sturgeon.

The main argument for using telemetry in the monitoring plan appears to be to assess the closure assumption for population-estimation models and to assess the reproductive status of individual females. Violation of the closure assumption for population-estimation models certainly needs to be considered, but this is commonly addressed without employing telemetry methods and if it must be estimated it does not need to be estimated every year as part of a monitoring plan. The monetary and logistic costs of telemetry do not appear to be commensurate with the need to test the pallid sturgeon population closure assumption. The population closure assumption might be more economically evaluated by expanding the sampling in the lower Missouri River to include the middle Mississippi River.

Similarly, spawning periodicity and fecundity are important components of the pallid sturgeon demographic population model. However, annual estimates of these components based on telemetry data might not be necessary. In anticipation of model sensitivity analysis, it seems likely to expect that uncertainty (variance) associated with spawning periodicity and fecundity parameters would have comparably lesser impacts on model results than uncertainty associated with survival estimates of age-0 pallid sturgeon as a result of the PSPAP monitoring described in Appendix D.

Appendices DA1 and DA2 describe points of entry where telemetry results can contribute to the development and implementation of the pallid sturgeon demographic and individual models. Table 1 in DA2 identifies specific parameters of the demographic and individual-based models – for example, movement, spawning, and maturation – that are to be informed by telemetry. However, specific telemetry-derived metrics to support the modeling efforts are not described in detail; neither are the potential effects of different tracking technologies described in section D.6.4.1. The reasons for using different telemetry technologies in the UMOR versus LMOR are logically presented, although potential differences in detectability between radio and acoustic tags are not discussed. Factors that affect detection distance are known to differ between acoustic and radio tags (Shroyer and Logsdon 2009), potentially reducing inference space on fish movement patterns in the upper Missouri River versus the lower river.

Development of metrics derived from telemetry data should occur early in the AM process, perhaps while the telemetry network is being installed. This timely consideration will enable efficient inclusion of telemetry results into future pallid sturgeon modeling efforts and assessments of population size and distribution. It will be important for these metrics to be identified early in the adaptive management process to delineate clear pathways for using telemetry data to help estimate model parameters to meaningfully inform the AM process. Although telemetry network data collection has not yet begun, now is a good time to identify which spatial distribution and movement metrics of significance will be used to inform the population and individual models.

b. Does the ISAP have additional thoughts on approaches to increase effectiveness and efficiency of telemetry efforts?

The positioning of telemetry receivers on major tributaries is essential to understanding movement into and out of the main-stem Missouri River in response to environmental cues. Similarly, understanding factors that affect detection distance for tagged pallid sturgeon can improve tracking efforts. For example, detection distance for acoustic transmitters tends to be less variable than that for radio transmitters (Shroyer and Logsdon 2009). Maximum detection distance (M) of radio or acoustic tags can be determined *in-situ* by deploying tags at specific locations that vary by depth, conductivity, ambient noise, water temperature, etc. That information then can be used to develop models for estimating M as a function of environmental conditions (x_n)

$$\log_e M = a + b_1x_1 + b_2x_2 + \ldots\ b_nx_n$$

In this way, limitations of telemetry technology (particularly detection distance) can be quantified relative to environmental conditions and used to adjust tracking effort. It is worth noting that recent advances in acoustic technology allow tagging of relatively small fish (<200 mm), although battery life is reduced (<50 d) due to small size of the tags.

Telemetry might be best reserved for specific research questions, such as where do pallid sturgeon spawn? Questions related to increasing the efficiency of the monitoring program can be addressed using telemetry through specific research projects, but at present are not justified as an integral part of a PSPAP long-term monitoring program. At the same time, the panel understands that telemetry involving adult females in the upper river is an essential component of effectiveness monitoring associated with the pending Fort Peck management action and does not suggest that those telemetry efforts be dropped.

5. The PSPAP is designed to be scalable so that resource constraints can be accommodated to some extent. Nonetheless, resource limitations (staffing, budget, etc.) will necessitate prioritization of PSPAP components at times if all components can't be accomplished to a sufficient degree. What are the ISAP's thoughts on relative priorities of the different monitoring components of PSPAP in serving the information needs of adaptive management?

The ISAP considers task question 5 in the light of this statement in the draft Appendix D document – "The PSPAP is designed to provide the information needed to estimate and quantify 1) abundance, 2) demographic rates, and 3) age-0 production. Management actions are hypothesized to influence pallid sturgeon demographic rates for varying stages (e.g., embryo, free embryo, exogenously feeding larvae, juvenile, adult) and the pathways for hypothesized management actions are summarized in conceptual ecological models" (D.2.2 Evaluation of management actions – page 7, lines 202-207). (The ISAP notes that age-0 production is not being addressed by the PSPAP, rather the monitoring focus is on abundance and occupancy.)

A central challenge in the early years implementing management actions identified in the SAMP and the 2019 Biological Opinion will be to identify shortcuts, efficiencies, and proxy measures that allow the MRRP's resource managers to reduce the scope and costs associated with monitoring over time. Adapting monitoring plan elements, not just targeted management actions, will be a central activity in implementing the science and adaptive management plan, especially in the near term. To that end, adaptive monitoring should be expected to move continuously toward more effective, efficient, and accountable data-collection schemes. In support of that reality, it could be valuable for the ISAP to review the evergreen and dynamic Appendix D of the SAMP every second or third year, or with future requests for input from the Corps as the monitoring schema evolve and adapt in response to on-the-ground adaptive management activities. For example, Section D.5.5. describes a simulation framework for optimization of PSPAP efforts (for example, identification of environmental covariates that maximize age-0 detection) under budgetary constraints.

The Missouri River Recovery Program planners appreciate that, at least in part, the question of prioritizing data collection, analytical exercises, and interpretive efforts in service of adaptive resource management is not wholly a "scientific" question. The need to prioritize or rank technical input to the Army Corps of Engineers' resource managers stems from constrained budgets over which the Corps has limited control and about which the ISAP has little information. Panelists have no knowledge of baseline costs for core monitoring activities addressed in the task questions above and cannot know how staffing and opportunities for efficiencies interact across effectiveness monitoring and PSPAP long-term monitoring obligations.

The ISAP could request a list of the costs associated with component and alternative monitoring activities in support of adaptive management and with that information recommend a prioritized monitoring and assessment program. However, the panel supposes that proposing a front-to-back monitoring prioritization plan would likely result in a protracted back and forth with the Corps and the technical team, with both compelled to explain why the insights from our only narrowly informed panel are not especially helpful.

The panel acknowledges that it has suggested certain activities and approaches in the responses to the task questions above, which could increase the costs of certain baseline monitoring schemes. Should certain of those suggestions be implemented, the budget for PSPAP-related monitoring could be further stressed. The panel also suggests several recommendations for ongoing or proposed PSPAP elements that might be dropped from, adapted in, or suspended or delayed under fiscal constraints to the program. These activities include

1) *Telemetry in support of PSPAP* – The ISAP appreciates the desire of fish biologists for the unique information that can be drawn from telemetry efforts targeting pallid sturgeon (see Appendix D, page 73 at line 1512). However, those studies only minimally serve the information needs obligated under the two sub-objectives at line 1563 in Appendix D. The Corps might ask itself, do planners need that information for the population models? If they think they do, is the information essential? Can population modeling work around an absence of telemetry data? The ISAP thinks that the population models may not be overly sensitive to variation in most of the metrics obtained from telemetry, and notes that telemetry is among the most expensive and labor-intensive components of a PSPAP that has more immediate information needs. Dropping

telemetry studies as they relate to PSPAP, at least over the next several years, could realize significant savings.

If telemetry is deemed necessary, under conditions of funding constraints, priority should be given to the stationary telemetry receiver network. Although not specifically related to the sub-objectives, telemetry remains one of the best means of evaluating juvenile and adult pallid sturgeon movement in response to natural or manipulated flow conditions (e.g., discharge, turbidity, temperature). Stationary telemetry stations present the most return for dollar and can function when boat crews cannot sample because of safety or labor costs. Furthermore, the stationary network of receivers will operate temporally and spatially continuously, whereas field crew sampling is necessarily focused on narrower geographies and shorter duration sampling efforts.

Age 0/1 sampling and mark-recapture sampling should be emphasized over the telemetry component of PSPAP if monitoring resources diminish. The importance of being able to detect natural reproduction and recruitment to age-1, combined with the challenges of actually collecting age-0 pallid sturgeon, suggest that these sampling efforts should be maximized at the expense of comparatively expensive fish telemetry

2) Crosswalk analyses to data generated from the previous PSPAP – In D.5.2 (page 34, lines 735-743) the use of historic PSPAP data in “potential design development” – that would be model design – is described. The appendix notes that a “large synthesis of historic PSPAP data was used in the development of a framework to evaluate alternative PSPAP designs,” including estimating “survival using multi-state capture recapture models” and taking advantage of “opportunities to estimate growth and evaluate… potential factors and covariates hypothesized to influence growth.” Surely information from the previous edition of the PSPAP was useful in bringing forward the current version that is more responsive to MRRP information needs. Moreover, the text emphasizes that “incidental benchmarks are also defined from historic PSPAP data and therefore use of those data will be necessary to optimize designs that provide benchmark data within constraints.” The panel appreciates how historic data helped inform the evolution of a contemporary PSPAP, but questions whether the historical database has future value in planning for and implementing monitoring in service of the program’s sub-objectives. The “old” PSPAP data may have mostly outlived its immediate usefulness. The historical PSPAP framework might have little use in moving forward and contemporary PSPAP data should be used to evaluate current metrics related to sub-objectives and sample size requirements for statistical analyses. Discontinue the sampling that is required for a crosswalk between the historical PSPAP and the contemporary PSPAP. The historical PSPAP provided little information for the current MRRP sub-objectives, hence the need for a revised PSPAP.

3) Emphasize a stratified-random sampling design. Judgmental sampling will result in biased estimates, undermine inference to the entire sturgeon population, and should be avoided

(Thompson 2012). The concern underlying this recommendation – high variability among sample units (bends) in the CPUE of age-0 sturgeon and many zero counts – is the reality of the PSPAP. To address this problem, a stratified random sample design could be adopted where strata are based on the CPUE from previous years. A probability-based sampling approach should be considered where sample units (bends) are first stratified into, for example, high/medium/low abundance strata and a random sample of bends is selected from each stratum. In addition, the number of randomly selected sample units within each stratum should be based on an optimal allocation of samples across the strata (Thompson 2012). In an optimal allocation design, the number of samples with each stratum depends on the size of the stratum (i.e., number of sample units with that stratum) and the variability in the catch within each stratum. In this design, a stratum with high abundance of age-0 sturgeon will generally have more sample units selected than a stratum with low abundance (see example above).

To illustrate, assume three abundance strata (H, M, L), sufficient funds to sample *n* sample units (bends), and no prior information on stratum size (number of bends) or variance in the catch. In this case, one would adopt an equal allocation design

$n_h = \frac{n}{3}$, where, $n_h =$ the sample size in stratum *h*

Given information on the number of bends in each stratum, a proportional allocation design could be developed according to

$n_h = \frac{nN_h}{N}$, where $N_h =$ the number of bends in stratum *h*, and $N =$ the total number of bends across all strata

However, if there are also estimates of the standard deviation in the count (σ_h) in each stratum based on available data, an optimal allocation design of the following is recommended as

$$n_h = \frac{nN_h\sigma_h}{\sum_{h=1}^{3} N_h\sigma_h}$$

This design should result in more samples being taken in bends with a greater number of age-0 sturgeon and fewer samples in bends with few age-0 individual sturgeon.

4) Reduce sampling on river segments below Gavins Point Dam – Mark-recapture sampling as described in Section D.6.2.2 (Page 56, lines 1098-1108) may not require the extent of segment sampling implied. D.6.3.2 indicates that "sampling for age-0 and age-1 pallid sturgeon will be restricted to lower Missouri River segments 9, 10, 13, and 14." Moreover, sampling will be extended to the Mississippi River. While the spatial coverage may be informative for tracking the movement of age-0 pallid sturgeon, the most downstream segments may be the only segments needed to address the sub-objectives with data from the PSPAP. The ISAP wonders whether future sampling might allow for further reduction in sampling, eliminating one or more segment-samples (for example, segments 9 and 10) over time based on whether segment samples from one or more provide sufficient information to assess the program's success in meeting MRRP sub-objectives.

5) Efficiency in the face of budget constraints can also be increased by employing a stratified design, but not sampling every year. The precision of the abundance and occupancy estimates in the years surveyed, and the length of the time series (i.e., number of survey years) may be more important to trend estimation than sampling every year. This can be demonstrated if the dynamics of pallid sturgeon populations can be realistically described by an exponential trend model as follows

$$N_{t+1} = \lambda N_t,$$
$$\lambda = \frac{N_{t+1}}{N_t}$$

where, $\lambda =$ growth rate (trend) between two successive surveys

In general,

$$N_t = N_0 \lambda_1 \lambda_2 \lambda_3 *** \lambda_T,$$
$$N_t = N_0 \lambda^T, \quad \text{(assuming constant } \lambda\text{)}$$

where, $N_0 =$ initial population size

Therefore, growth rate λ (trend) over T years is

$$\lambda = \left(\frac{N_T}{N_0}\right)^{1/T}$$

The overall trend (λ) in the above equation is a simple function of the first (N_0) and last (N_T) population estimates.

A simulation study to evaluate various models for trend estimation found that an exponential trend model including both process and sampling variation was able to reliably estimate true trend from a 10-year time series with five data points (Humbert et al. 2009). If surveys are not conducted each year, what is given up are annual estimates of system state (occupancy rate and population abundance), which may be necessary for state-dependent decision-making under an adaptive management paradigm.

6. Are there other comments or recommendations in addition to the answers to the above questions that you (ISAP) would make?

A strength of Appendix D is that it presents a detailed discussion of how the monitoring state variables (CPUE, occupancy rate, and abundance) are to be estimated. However, what is less well-developed is a detailed discussion of how imperfect catchability will be addressed (the observation error component). The importance of estimating the temporal and spatial components of sampling variation in order to develop an optimal sampling design to estimate trend is also not addressed in Appendix D.

In addition to the review and comment of the monitoring program, the ISAP offers some observations concerning the ongoing efforts to develop the integrated pallid sturgeon population models. As presented in Appendices DA1 and DA2, the demographic and IBM models appear to be useful approaches for estimating and forecasting population trends and modeled factors that influence age-0 pallid sturgeon recruitment. However, the modeling efforts do not appear as a critical component of the monitoring plan at this point. Many aspects of the age-0 models can be populated with input data derived from the monitoring program, thus over time these models should become more useful for forecasting and monitoring efforts. An issue regarding the modeling effort that should be considered relates to sensitivity of model results to estimated values of the many input parameters. Parameter sensitivity can vary depending on the modeling scenario. A sensitivity analysis of different scenarios that estimate age-0 survival would be instructive in evaluating the influence of parameter precision derived from monitoring and corresponding uncertainty in model results, recognizing that they potentially contribute to adaptive management and decision-making.

The models are promised as essential tools for data integration and projecting the outcomes anticipated for management actions aimed at achieving the population objectives. Realizing this promise depends importantly on translating management actions – flow manipulations, spawning habitat, IRCs – to corresponding changes in the demographic and IBM model parameter values and simulating the expected outcomes of management actions. The development of the necessary management-response functions for the two models appears to be in progress.

Appendix DA1 provides a detailed description of the demographic population model developed for pallid sturgeon. The overall model structure appears useful and conforms to the general demographic modeling approach that has been applied to other fish species and management or assessment questions. Given a credible overall model structure, there are questions concerning the estimation of parameter values that determine the model results. For example, age-0 survival (0.000075) is based on gulf sturgeon (Pine et al. 2001, cited in Appendix DA1), while Wildhaber et al. (2017) use a value of 0.00011 (0, 0.0004) based on Steffensen et al.'s (2013) population viability analysis of pallid sturgeon. The age-0 survival parameter has been shown to be highly sensitive in previous evaluations of fish demographic population models.

The mathematical structure of demographic population models results in an undesirable tendency for the population trajectories to either increase indefinitely or approach zero if the production matrix is not perfectly balanced. Modelers frequently incorporate density-dependent parameters to minimize this mathematical tendency. Are density-dependent parameters included in the model to avoid innate problems in the pallid sturgeon demographic model? If so, how were the density-dependent parameters derived?

Appendix DA2 provides a detailed description the individual-based model for pallid sturgeon. The overall approach to building the IBM for pallid sturgeon appears comparable to similar efforts developed previously for other species of fish. The apparent advantage conferred by the IBM lies in extremely detailed representation of the biology, ecology, and behavior of "individuals" of different sized (age) pallid sturgeon. Life-history measures (e.g., survival) that are estimated using a single parameter value in the demographic model can be disaggregated into component processes in the IBM. This approach provides an opportunity to match the model structure more closely to the complex life history developed in the form of the conceptual ecological models (CEMs) that were used as foundations for the pallid sturgeon effects analysis. The resulting challenge lies in the additional assumptions and large number of parameter values required to implement the highly detailed IBM compared to the demographic model.

Recommendations

Based on the preceding review of Appendix D and the supporting appendices that describe the pallid sturgeon population models, the ISAP offers the following. These recommendations are not offered as prescriptions for action, but as points of departure for continued discussion in the evolution of the PSPAP monitoring program towards maximally supporting the adaptive management of pallid sturgeon in the Missouri River.

1) The annual state of the pallid sturgeon population is characterized by two parameters – occupancy rate for age-0 fish and abundance for fish age-1 and older. These state variables are estimated annually, and management decisions are based, for the most part, on how the state of the population is changing over time (and to a lesser degree over space). This requires an estimate of trend. Substantive discussion of candidate trend models should be included in Appendix D.

2) Appendix D should discuss, in greater detail, how size-dependent heterogeneity detection and capture will be addressed so as to adjust estimates of occupancy and abundance for observation errors.

3) The appendix should clearly identify the spatial scale for the sample unit. For example, will CPUE of age-0 pallid sturgeon be analyzed per management unit, river bend/segment, or macrohabitat type to evaluate changes in space and time?

4) The appendix could more clearly describe the statistical approaches used to relate monitoring results to population sub-objectives. For example, annual estimates of CPUE of age-0 pallid sturgeon will be evaluated using a time-series approach to test for trends in each monitored segment.

5) Occupancy rate might be added as a metric for population sub-objective 1.

6) The monitoring plan could economize on sampling random sites and focus sampling efforts on targeted sites to reduce variation in CPUE and occupancy rate estimates. Focus effort on reducing variation in CPUE and occupancy rates at targeted sampling locations. See the example provided above, which uses a stratified design wherein strata are based on CPUE.

7) Given high variation in the historical PSPAP data combined with low catch rate of pallid sturgeon, calibrating results from historic surveys with current survey data should be a low priority effort in the monitoring plan.

8) After first stating precision targets for the occupancy and abundance state variables in the monitoring plan, it would be insightful to conduct a power analysis using the recently obtained PSPAP data. This may be particularly important if parametric statistical analysis will be used to evaluate CPUE and occupancy rates as target metrics for the population sub-objectives.

9) Ensure that data analyses and summaries of metrics in the plan readily map onto the population sub-objectives. For example, the review charge questions focus on age (as per the objectives), but the preliminary results were separated and presented by length class. Pallid sturgeon age and length are highly correlated, but matching the analytical metrics and sub-objectives can reduce confusion in interpretation.

10) The monitoring plan should continue with CPUE and occupancy rate estimators but consider ways to minimize variance in parameter estimates. Reducing variance might require substantially increasing sampling at targeted sites or substantially increasing effort in a given year to reduce variation; that might result in not sampling every year. Correspondingly, in the face of monetary and logistical constraints, the agencies might decrease efforts in maintaining the historical PSPAP, reduce the proposed spatial scale of the targeted sites in the lower basin, and cease telemetry efforts directed at evaluating capture-recapture assumptions.

11) Resource managers can use stocking of age-0 pallid sturgeon and shovelnose sturgeon in the lower basin to create a more efficient (that is, reduce variation with least amount of effort) PSPAP monitoring program for age-0 pallid sturgeon and shovelnose sturgeon.

12) Power analysis and studies using stocking of age-0 sturgeon to improve sampling efficiencies might fail to reduce the uncertainty in estimated population metrics. Under those circumstances, the sub-objectives, metrics, and analyses presented in Appendix D might require further evaluation to ensure the PSPAP monitoring program can reliably detect changes (trends) related to management actions, including flow manipulations.

13) Monitors should use sensitivity and elasticity analyses of demographic parameters to estimate the relative effects of variation in spawning periodicity and fecundity on population model outputs. Determine if annual estimates of spawning periodicity and fecundity are needed.

14) If funding is limited, resource managers should consider discontinuing telemetry in assessing the population closure assumption, reserving telemetry to address specific research questions or effectiveness monitoring for management actions.

15) The plan's authors should consider moving preliminary results of pallid sturgeon monitoring to an appendix to the PSPAP monitoring plan.

Closing Observations

In closing this review of the PSPAP monitoring plan, the ISAP offers several overarching observations. As suggested above, the ongoing effort to develop a rigorous pallid sturgeon monitoring program will not end with responses by the Corps to this review report. The process of monitoring and assessing the status of pallid sturgeon and trends in its numbers, and documenting responses by pallid sturgeon to directed management actions should be viewed as an ongoing technical engagement and an essential continuing interaction between the Corps and the ISAP. The design and implementation of pallid sturgeon population monitoring, along with the effectiveness monitoring that will accompany management actions, will need to be periodically revisited and adapted and amended as resource managers strive to meet programmatic conservation objectives for Missouri River pallid sturgeon. The effort to develop a rigorous and cost-efficient monitoring and assessment program for pallid sturgeon can be justifiably described as perhaps the most immediate and pressing "scientific" challenge facing implementation of the MRRP. A realistic characterization of quantitatively assessing the status and trends of a rare fish in a dauntingly expansive and dynamic river system is that monitoring data with low precision will remain. An effective remedy to obtain the precision necessary to meet population management objectives might well require resources in support of monitoring that are unrealistic, given current and foreseeable program funding. In its current form, function, and associated statistical power, it is unclear whether even a refined PSPAP will be able to unequivocally relate monitored changes in pallid sturgeon status or trends to management actions imposed under the MRRP. However, in combination with effectiveness monitoring and population modeling, the PSPAP monitoring might help to provide sufficiently compelling lines-of-evidence support for decision-making in relation to pallid sturgeon management in the Missouri River.

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Appendix A

ISAP REVIEW OF PALLID STURGEON POPULATION ASSESSMENT PROGRAM MONITORING PLAN
September 1, 2020

The ISAP is being tasked with answering a series of questions related to the Pallid Sturgeon Population Assessment Program (PSPAP) Monitoring Plan (revised Appendix D of the SAMP).

The primary document for review when addressing the questions below is the revised *Appendix D of the SAMP: Pallid Sturgeon Population Assessment Program Monitoring Plan*. In order to respond to the questions, the ISAP will also need to refer to*, Appendix E of the SAMP* and the *final 2019 Adaptive Management Compliance Report (AMCR).* Additional resources that are provided and may need to be accessed include: *Chapter 4 of the SAMP, the Ft. Peck AM Framework, and the 2020 Evaluation Plan for the Conservation Propagation and Stocking Program*. These documents can be accessed via Dropbox or APAN.

The questions below are intended to guide ISAP review of the PSPAP Monitoring Plan (Appendix D of the SAMP). This monitoring plan documents the purpose and objectives of PSPAP, spatial/temporal domain, monitoring variables of interest and their justification, type and magnitude of change to be detected, statistical power and design optimization efforts, monitoring design and standard operating procedures. Results of pilot implementation including progress made in developing estimators (e.g., occupancy, abundance, catch rate) and population modeling are included. The summarized estimates in the document provide a view as to expected future outputs, but will likely change and improve as additional data are added, PSPAP components come fully online (e.g., population estimates in the Yellowstone River), and the estimators are further developed. This review will need to consider, to some extent, the contribution of the Effectiveness Monitoring plans in Appendix E of the Science and Adaptive Management Plan (SAMP) as well. Effectiveness Monitoring designs depend on various components of PSPAP, and in turn provide useful information for PSPAP.

The review will include engagements with the MRRIC Fish Work Group (and MRRIC) and opportunities for questions and clarifications to allow clearer understanding of the content by the reviewers.

PANELISTS
Steve Bartell, Steve Chipps, Melinda Daniels, Chris Guy, Dennis Murphy, Barry Noon

PROPOSED PROCESS/TIMELINE

- FWG and Lead Agencies develop review questions (and MRRIC review): **May 27-June 24**
- ISAP Review: Formally initiated after charge and review materials are finalized: **September 1-October 30**
- Kick-off call with USACE and ISAP (and FWG invited to observe): **TBD week of September 7-11**
    - Presentation of plan by authors, questions from ISAP
- Report from Panel to Agency: **October 30**
- MRRIC webinar to present findings: **TBD week of November 9-13**
    - Presentation of ISAP report

- Agency response: **December 4**
- Agency/ISAP/FWG update webinar: **TBD in 2021**
    - Opportunity to share an update on steps taken regarding Fish monitoring plan and implementation efforts thus far

REVIEW PRODUCTS
ISAP will provide a final report and a set of overview slides for the MRRIC webinar.

REVIEW QUESTIONS
For each question, please explain your response in as much detail as appropriate.

1. A component of PSPAP is age-0 sturgeon monitoring as well as monitoring of recent recruits (age-1 to age-3 pallid sturgeon). The primary purpose of this component is to gain reliable estimates of pallid sturgeon reproductive success and recruitment and track changes over time which can then be related to river conditions (e.g., natural annual flow variations).
    d. Will the spatial extent, temporal scale, and intensity of age-0 sampling in the currently proposed sampling scheme provide sufficient and reliable data that can be used to assess reproductive success, parameterize population models, evaluate effect of natural flows events, and contribute to assessing performance of targeted management actions?
    e. Similarly, catch rates of age-1 to age-3 pallid sturgeon are used to assess recruitment and relate to annual flow variation. Will the spatial extent, temporal scale, and intensity of the proposed age-1 to age-3 sampling allow resource managers to assess recruitment, parameterize population models, relate recruitment to annual flow variations, and contribute to assessing performance of targeted management actions?
    f. Can the proposed monitoring scheme separate the effect of flow variations on catchability and reproductive success/recruitment?

2. Recognizing the pressing need for information on the distribution and survival of age-0 pallid sturgeon, several activities have been proposed to compensate for low capture rates, including evaluating use of shovelnose sturgeon as a surrogate species for evaluating reproduction and/or recruitment, increasing stocking of very young pallid sturgeon, improving identification and characterization of high catch areas to increase ability to stratify sampling effectively (e.g., our targeted sampling in June, 2020 in the LMOR produced about 16,000 age-0 sturgeon), and extending sampling into the middle Mississippi River.
    b. Are these additions or amendments to the current sampling design(s) likely to enhance the ability to achieve the goals of the monitoring plan?
    c. Does the ISAP have other recommendations for handling the challenges of low sample size?

3. Another component of PSPAP is population estimation of juvenile and adult pallid sturgeon.
    d. Parameterizing the population model requires abundance, survival, and growth for the demographic matrix model and when employed as an individual based model additional information on spatial distribution, size distribution, growth, origin (hatchery,

wild/unknown, hybrid), and movement. Is the monitoring plan set up to estimate values needed to characterize abundance, survival, spatial distribution, origin, and movement?

e. Is the monitoring plan capable of providing reasonable estimates of progress toward population objectives?

f. Will data generated from PSPAP and associated analyses and modeling contribute to determining progress toward meeting pallid sturgeon recovery criteria?

g. Will this approach, collaboratively integrated with the 2020 Evaluation Plan for the Conservation Propagation and Stocking Program, allow resource managers to evaluate the effectiveness of the artificial propagation program?

4. With respect to the telemetry component as described in Appendix D of the SAMP:
   a. Will the telemetry component be capable of contributing to population estimates, informing movement probabilities, aid in testing population closure assumptions, and increase understanding of the population as it utilizes areas outside MRRP purview?
   b. Does the ISAP have additional thoughts on approaches to increase effectiveness and efficiency of telemetry efforts?

5. The PSPAP is designed to be scalable so that resource constraints can be accommodated to some extent. Nonetheless, resource limitations (staffing, budget, etc.) will necessitate prioritization of PSPAP components at times if all components can't be accomplished to a sufficient degree. What are the ISAP's thoughts on relative priorities of the different monitoring components of PSPAP in serving the information needs of adaptive management?

6. Are there other comments or recommendations in addition to the answers to the above questions that you (ISAP) would make?