TO: 2018 MRRP AM Compliance Report Authors and MRRIC

FROM: Independent Science Advisory Panel (ISAP)

RE: ISAP review of the MRRP 2018 AM Compliance Report (Draft) and associated webinars and AM Workshop

DATE: March 6, 2019

The Independent Science Advisory Panel (ISAP) has been tasked with reviewing the document *Missouri River Recovery Program 2018 Compliance Report (Draft)* (prepared largely by the MRRP Adaptive Management Technical Team, dated January 2019) and associated informational webinars and AM Workshop held during February 2019; this memo is the response to that assignment. The ISAP review addresses generally whether the Report meets its stated objectives, contextual clarity, scientific accuracy and rigor, and applicability to MRRP Adaptive Management (AM) decision making needs. The Report, its supporting materials, and associated meetings were long and extensive; time and resources for this review were short and constrained. Statements below are based on panelists' reading of the Report, participation in the webinars and AM Workshop, and limited deliberation of them as a panel. The ISAP provides this review with the expectation that it will assist in improving the current Report and also an evolving AM process that can better synthesize and focus the results of scientifically defensible investigations, modeling, and monitoring for MRRP AM decision making needs.

The review in context

The Missouri River Recovery Program appreciates that science – that is, reliable knowledge – is the template upon which one builds an adaptive resource management program for the pallid sturgeon and piping plover in and on the Missouri River. The Compliance Report (née Adaptive Management Report) confronts critical issues in the ecology of those imperiled species and draws from a common understanding of their life histories, population dynamics, and habitat use toward, among other applications,

informing quantitative models and monitoring schemes that can guide implementation of and assessment in a dynamic species management plan.

The annual report on adaptive management provides decision support to resource management planners at the interface between reliable knowledge gleaned from research, monitoring, and modeling and implementation of conservation actions prescribed in the 2018 Biological Opinion relating the operations of six dams on the Missouri River to the survival and persistence of pallid sturgeon and piping plovers. To that purpose the annual report should present just that scientific information that applies directly to the selection of management actions that are intended to benefit the species, the prioritization of those actions, their implementation, and their monitoring of them. The report needs to describe clearly how specific reliable knowledge informs the management of the two species and the habitats that support them and how uncertainties regarding the ecology of the species, their habitats, and the Missouri River ecosystem currently constrain management decisions. To that challenging endeavor the newest relevant scientific information needs to be applied and its application described.

The material comments and responses from the ISAP on the draft annual report below reflect the understanding above and the intent conveyed for the report in the Science and Adaptive Management Plan. The assessment of report elements may sound to some as generally, even overly, critical. For that reason the ISAP wishes to observe that this second reporting on adaptive management under the MRRP, describing preparations for resource management that mostly has not yet been initiated, reflects a laudable effort by a large team breaking new programmatic ground under severe time pressure. The draft report is a worthy effort that can be made better in its next iteration.

Overarching observations and concerns

The ISAP was engaged to review the 2018 Adaptive Management Report. It received a Compliance Report that largely complies with the directions in the Science and Adaptive Management Plan for an annual Adaptive Management Report. The title of the Report (as we will refer to the standing draft) needs to include the term adaptive management

(AM) and should reflect the guidance in the SAMP for adaptive management reporting in format and content, which identifies an "Annual or periodic report that documents new learning based on monitoring results, evaluates progress towards meeting species objectives, and contains recommendations for adjustments to management actions" (SAMP page xxiv), and observes "The four primary objectives of the report are (1) provide an analysis of monitoring data, especially the performance of actions relative to the targets, objectives and goals of the recovery program; (2) provide a forecast of outcomes of future management scenarios; (3) outline recommendations for managers and stakeholders; and (4) provide a review of the status of the science, including current published and unpublished research results relevant to management" (SAMP page 112). The Report achieves some of this, but the uninformed reader might not recognize the level of effort previously invested in the SAMP nor will she find more than scant addressing of the second and third objectives in the current draft report. Chapters in the SAMP that describe and discuss governance and information management and communications are not represented in the Report, nor is discussion of progress made or issues discovered to date for either of these mentioned in the Report.

The Report needs to better relate the material information presented to its specific application in adaptive resource management on the Missouri River. As presented in much of the Report, inclusion of AM within the broader investigatory agenda of continuing work in the Missouri River basin will dilute the effectiveness of adaptive management – AM should not be reported as just another add-on to ongoing *status quo* work on piping plovers and pallid sturgeon. If AM is simply equated with the scientific agenda, then there is no need to distinguish AM as a separate programmatic activity – science and AM become simply redundant. Adaptive management begins with management, not science. Science rightfully informs resource management, which might subsequently be adapted with newly considered information. But science is not management.

The Report blurs progress in addressing ecological uncertainties with learning that is directly applicable in resource management. A certain management complacency is engendered by an all-encompassing definition of adaptive management. Keeping in

mind that Level 1 and 2 research efforts are not AM, resource management implies some anticipation of a measurable outcome directly related to management objectives as the result of an implemented management action. That is, there needs to be a quantitative relationship between the magnitude of the action and the expected response of the managed resources – that is, populations of piping plovers and pallid sturgeon and their habitats. The current bird modeling effort begins to establish these kinds of management-response functions based on habitat quality and availability for piping plovers. The pallid sturgeon population model suggests potential for developing such functions, but lags behind the development and application of the piping plover model. The management response functions should be focal points for framing up the adaptive management program and substantially informing the design, implementation, monitoring, and potential adjustment of selected management actions. An adaptive management report needs to directly convey essential reliable knowledge to resource-management decision-makers, leaving other scientific information to other reporting vehicles.

The Missouri River Restoration Program remains challenged by an inability to accurately and precisely measure the sensitive parameters that largely determine the population dynamics of piping plovers and pallid sturgeon. Analyses supporting the piping plover model identified adult survival as the key contributor to piping plover populations. Only one of the proposed piping plover monitoring approaches permits rigorous estimation of adult survival and this approach requires extensive bird banding and re-sighting, which escalates the cost of the needed monitoring program. In contrast, for pallid sturgeon, the survival of early life stages strongly influences population dynamics. But as with the piping plover, this key metric is nearly impossible to reliably estimate, as evidenced by the very few age-0 pallid sturgeon collected during the previous years of monitoring.

The Report should convey how yearly variations in hydrology contribute to assessing endpoints and guiding adaptive management, perhaps revisiting/reconsidering how yearly variations in unmanaged discharge influence AM for pallid sturgeon and piping plovers. Annual variations in Missouri River basin hydrology and corresponding river

discharges are largely uncontrollable by the management agencies, yet discharge can dramatically influence proposed management actions, including big-investment construction of ESH. It might prove useful to describe previous patterns of hydrological variability evident in the period of record that underlies so much of the physical modeling. Anticipated alterations in discharge patterns should also be described and presented in association with proposed management actions (ESH and IRC projects) as influenced by uncontrollable discharges.

The Report should "work backwards" from specific endpoints and targets to determine how to best use new data and information in evaluating and guiding adaptive management (e.g., new data on the piping plover metapopulation dynamics; new data on where age-0 pallid sturgeon are sampled). Presentations of monitoring results, management actions, or proposed studies should begin by describing the detailed functional relationship between available research and monitoring data, new model iterations, or anticipated results of management or experiments and the specific endpoints. The informative presentations should then demonstrate how proposed work – both management in an adaptive framework and data acquisition in the form of monitoring – will contribute to improving our understanding of these relationships as they influence adaptive management. Simply identifying a Big Question that is somehow addressed by the presentation is an inadequate reporting of activities in support of adaptive management.

In that same context, presentation of data in the Report should include appropriate statistics. Interpretations of trends in resource conditions, for example pallid sturgeon population declines, need to be informed by a valid underlying statistical model and analysis. In general, plots of data wherever practicable should include (identified) error bars or other summary statistics.

The report should relate HC-related planning concerns. As is evident from the discussion concerning dredging and IRCs during the AM workshop, there seems to be little flexibility among certain stakeholder interests concerning specific HC-relevant management actions (in current discussions, particularly dredging and navigation). The

resulting implicit programmatic hypothesis is that the piping plover and pallid sturgeon can be effectively managed (that is, stated goals and objectives achieved) by the agencies, while maintaining the status quo among vested economic interests in the Basin. This is likely not feasible, or at least, the feasibility of such constrained management — adaptive or otherwise — remains to be demonstrated. The danger is that substantial funds and management-years could be lost in anticipation of management successes that are simply not possible given current and future HC constraints; leaving real contributions to species conservation from the MRRP solely from hatchery augmentation of pallid sturgeon and contributions to piping plovers on the river from the unmanaged metapopulation beyond it.

A corresponding vexation is that the number (acreage) of IRCs required to achieve management objectives remains unknown. If the function of the IRCs is to locally "slow down the river" to produce a condition that better approximates the pre-impounded and channelized watercourse in order to retain age-0 and age-1 pallid sturgeon to recruit in the Missouri River, it will take many such structures. If it is so difficult to locate only 12 IRCs, are IRCs essentially off the table as viable management actions? This ought to be decided sooner than later. Similarly, if flow management remains constrained by navigation and agricultural interests to anemic and ineffective flow regimes (offering minimal or no signal to spawning sturgeon), then flow management is also a non-starter (see the 2011 ISAP report). The only recourse is population augmentation in perpetuity. While the discussion of this foundational issue in the MRRP should be undertaken elsewhere, an honest portrayal of the impediments to adaptive resource management that are being encountered should be in the Report.

The Report should convey the most contemporary reliable knowledge that is relevant to the adaptive management of the listed species. However, much of the newest information on the two species and their habitats from 2018 was given a less than thorough evaluation as a result of communication restrictions during the 2018 Fall Science Meeting (presented as time-constrained webinars). At the recent AM Workshop, applicable science was quickly summarized from the fall meeting and at least some of it appeared in the Report and was used to make decisions that support certain changes in

programmatic activities. An in-depth discussion between the technical teams, ISAP, and other experts in the field regarding the data reliability, analytical methods, and research findings was not conducted. Without an in-depth peer-to-peer exchange, it is not possible to evaluate the reliability of the technical information for making programmatic decisions. The science is the foundation of the AM program, which includes rigorous peer-review, and should be afforded the time for scientific discourse. Many of the species-specific comments and responses in this review document regards types of (scientific) issues that should in future years be addressed within the fall science forum, better allowing the adaptive management report to employ the most up-to-date, reliable knowledge of the species and their habitats relevant to river operations and conservation actions.

The Technical Teams seem to be under substantive pressure to produce deliverables according to the predetermined schedule. The deliverables appear to be hurried and, while the Report does not suffer from major science omissions, it includes substantial information not pertinent to adaptive management and much redundancy, which takes away from a clear and incisive message to resource managers. The MRRP might consider altering the timeline for a comprehensive Report to be produced every second or third year, requiring briefer reports (considerably less than 100 pages) in the interim years. The brief reports would still benefit from the peer-to-peer science exchange during the Fall Science Meeting. The brief reports would contain "score cards" (Table 68, SAMP page 403) so that the ISAP, MRRIC, and additional stakeholders are able to track the information input into management decision-making. In addition to altering the schedule, the Technical Teams could use more members and would undoubtedly benefit from including individuals outside the Missouri River basin. Additional expertise (including biometricians) could broaden the analytical methods and provide more objective decisions regarding methods, results, and conclusions.

The Report contains inconsistencies in how the Technical Team authors analyze and report results. For example, the authors suggest a decline in hatchery-origin pallid sturgeon in the lower river, but fail to comment on the consistent catch of wild fish. Understanding that the analysis for the hatchery-origin pallid sturgeon addresses the

conservation propagation program and the analysis of the wild fish would address the recruitment to the population, they both represent critical information to the MRRP and should be analyzed with similar statistical rigor.

Specific comments, points of concern, and recommendations from the Report

Summary

Focused comments
p. v – Regarding CPUE and apparent survival as endpoints on the lower river and augmented by growth rate, condition, reproductive cycling, and abundance on the upper river – note the stated need for a model to estimate apparent survival.
p. vii – Regarding statistical significance of upticks in pallid sturgeon in the upper and lower river compared to 2017 and statistical approaches to robust trend analysis. RSD demonstrates that younger fish are not naturally recruiting into the population. What are the implications for management actions other than augmentation?
p. ix – FSM results and IRCs regarding plans to update definition of IRC habitat quality criteria (e.g., depth) in relation to study results. It would seem reasonable to update IRC habitat quality criteria based on recent expansions of depths and velocities apparently acceptable to pallid sturgeon. If these habitat attributes are used to help design IRCs, then the most accurate and up-to-date values should be incorporated into the current modeling effort used in IRC evaluations.

Chapter 1

Focused comments
Throughout this chapter, and especially in tables, it would be useful to provide section references where aspects are discussed later in the report, or reference to other supporting documents.
p. 1 (bottom) and p.2 (1.2) – The "report represents…" and "also identifies…" on p. 1 does not correlate well with the two primary purposes: "documents activities…" and

"provides the foundation…" on p. 2, or with the four objectives for the report on p. 112 of the SAMP. These all need to be harmonized.
p. 7 (no. 1 under 1.4.1) – Planned IRCs were not built in 2018, nor was planned ESH. Seems these major changes should be mentioned here.
p. 13 (Table 1-3) — Productive coordination is needed among responsible entities in conserving birds and pallid sturgeon, recognizing the multiple agencies with different management objectives and responsibilities, which acting independently reduce the effectiveness of AM.
p. 15 — Regarding bird take, there is a need to include number of eggs or chicks lost, in addition to the percentages reported.
p. 17 (Table 1-6) — Progress notes: Upper and Lower River – everything is "on track" to provide relevant data – it is unclear what that means in terms of time frames relevant to AM needs.
p. 20 — "Information generated by the Technical Team is incorporated into the annual AM Report and is presented ahead of an AM Workshop" providing an opportunity for USACE and USFWS decision-makers, technical staff, contractors, and MRRIC to discuss the results of research and monitoring…" Note that this year the discussion of pertinent scientific information was limited, thus it is not an effective model for moving forward. There should be peer-evaluation of the science and scientist-to-scientist interactions to evaluate the analytical methods, results, and conclusions made by the Technical Team. Those discussions should form the foundation for logical arguments when making programmatic changes.

Chapter 2

The ISAP observes that a paradigm shift in the piping plover conservation strategy is warranted in the Report, following a fraught discussion of management planning for the species and the obligatory budgetary scoping that accompanied it during the adaptive management workshop.

The extent of exposed sandbar surface has served as a valuable proxy for available and potential piping plover habitat for the effects analysis and risk assessment in the SAMP.

ESH presumptively is reasonably well correlated with the extent and at certain times even quality of available in-river habitat for piping plovers. But referencing the islands in the Missouri River as ESH was to popularize a misnomer — the islands are not all piping plover habitat, the habitat on islands varies in quality, and habitats on individual islands evolve as they age. All else being equal, the carrying capacity of riverine islands for nesting piping plovers, that is, habitat extent and quality, is greater on bigger and newer islands. But all else is seldom, if ever, equal.

The heuristic value of island size as a proxy measure for habitat is fairly limited to modeling in support of effects analysis for the Missouri River demographic units of piping plover and does not neatly extend to pragmatic conservation planning for the species. Consider that adding 50 acres of new above-waterline substrate to a 200-acre island is unlikely to add 25% more habitat for the bird. Selective habitat enhancement activities – vegetation and predator control or nesting-gravel enhancement, for examples – have the potential of substantially increasing habitat value in certain circumstances and at a fraction of the cost of construction. The technical experts advising the MRRP on conservation of piping plovers need to consider the cycle of piping plover habitat renewal in their deliberations. Habitat renewal is initiated or reset with “natural" island formation and reconfiguration via hydrodynamic processes and continues forward with successional stages in vegetation community composition and structure and evolving impacts on resident plovers from diverse predators. Piping plovers can benefit from management interventions in certain ecological aspects of the “successional” cycle that defines habitat extent and quality. But targeted management actions, whether island construction or habitat enhancement activities, have not been shown to manifest as sustained benefits to piping plovers.

In that light, the ISAP recommends that habitat enhancement actions should be the focus of planned conservation-action agenda for 5 to 7 years following “high-water” years that are characterized by island formation and re-sculpting and resurfacing of existing islands (a high-water year is one with flow volume similar to that in 1997, 2011, and 2018). Recognizing roughly decadal return times of island-building high-water years, island construction would not be planned for eight to 12 years after the most

recent event. Initiation of construction planning would be dictated by the extent of habitat made available after the high-water year, its retention thereafter, and the success of ongoing habitat enhancement efforts. Conceivably island construction may not be required as a program-action element for the foreseeable future, depending on water years and the success of habitat enhancement efforts.

The Report should call out the need for to the current piping plover population model to incorporate metapopulation dynamics. The agencies and MRRIC should encourage the collaboration among plover-population modelers in making necessary adjustments to the current piping plover model(s). If it is shown that metapopulation dynamics should determine piping-plover management on the river and reservoirs, it might be useful to reframe the bird management objectives to simply determine whether river and reservoir habitats sources are net sources (or sinks) for these birds. Much of the information already available can be used to evaluate the source-sink dynamics of riverine habitats. Perhaps the targeted 95% chance of 50 piping plovers persisting over 50 years metric could be replaced with a simpler one (like population trends), which might be accompanied with associated reductions in monitoring demands; for example, not needing adult survival rates.

The Report might outline a formal effort to evaluate and revise the piping-plover model(s) beginning with development of a revised conceptual ecological model, as was done in the initial phase of the piping plover effects analysis. The revised conceptual model should identify at least three spatial components of the population (river, reservoir, prairie potholes) and describe interactions among them. The conceptual model should include enough detail to serve as a guide for: 1) identifying research efforts that will be required to model the population dynamics for purposes of estimating piping plover management targets on the Missouri River, 2) achieving a consensus on the priorities for completing the necessary research efforts, and 3) guiding plover monitoring needs. One reason to begin the effort sooner rather than later is the ongoing development of the bird monitoring plan. The scope of monitoring efforts must be consistent with the current understanding of piping plover population dynamics, and

the revised piping plover metapopulation model(s) that will be needed to support adaptive-management decisions using the best available science.

The Report should describe and present in an appendix the draft piping plover monitoring plan. It is the most important contribution to adaptive management of piping plovers that was generated last year. The description of bird monitoring plan options is well presented. Based on the need to reliably estimate adult piping plover survival, Option 4 may be the only choice from among the options, regardless of expense.

Little information is provided in the Report regarding piping plover targeted management activities that were conducted in the first year of the program, what was attempted (apparently, vegetation management and predator control were conducted), what was effective and what was not, and how the activities might be modified to be more effective in the future. The Report should address what was learned regarding the role of predators in determining habitat quality during the past year and how the predator program will proceed in the coming year, including responding to the following:

1) Predator removal was conducted during the last year, but the small amount of information presented in the Report is inconsistent. In Section 2.3.1.6, the second paragraph makes a seemingly contradictory statement: “There were no apparent improvements in productivity, but predation on piping plover nests decreased slightly and predation on tern nests increased only slightly.” How could decreases in nest predation be associated with no apparent improvement in productivity?
2) The last sentence in this same paragraph could benefit from additional discussion about the lack of beneficial effects of removing 300 predators (including 249 gulls) from the site. How did the hydrological conditions and high concentration of gulls confound the results? Was it simply that there were many more gulls than the 249 that were killed?
3) During the 2018 Fall Science meeting there was a recognized need to design and conduct controlled studies to better understand the potential effectiveness of predator removal and to further investigate the conditions under which predator

removal may be effective. There is no mention in the Report of any proposals to follow up on this recognized need. Informal discussions with science staff indicate that predator removal will not occur in the 2019 nesting season. Does this imply that predator removal as a management activity will no longer be considered?

4) Apparently, caging has been used to protect nests, but virtually no information on its effectiveness is presented in the Report. During the AM workshop on 28 February 2019, it was noted by USACE staff that nest caging may lead to increased mortality of adults and fledglings. Are there data to substantiate this concern? Should this concern be the focus of a scientific study?
5) Which predator management activities will be conducted this coming nesting season, and what steps need to be taken to ensure that adaptive learning occurs?
6) The Report reports few results from vegetation management that may have been conducted last year. Can one therefore conclude that there are no substantive uncertainties concerning vegetation management and that activities to date have achieved optimal habitat results? If not, what uncertainties remain that should be the targets of investigation in vegetation management in 2019?

The statistical models introduced for evaluating piping-plover trends in the monitoring document were useful in helping to interpret the presented time-series data. The models might well be applied to analyzing trend data for pallid sturgeon and this should be explored. Particularly important is understanding the circumstances in which additional sampling effort will not likely reduce uncertainty in estimating population parameters of interest. If the accuracy and precision in parameter estimation is driven by variance associated with time or space, additional sampling effort (i.e., N) might not reduce overall variance. This sticking point was also raised in the analysis of IRC effectiveness monitoring.

Additional focused comments

At 2.2.1. — The third paragraph states "*…observed population growth rate and fledge ratio in the Northern Region have been decreasing for several years*." Given the current understanding that the northern region supports at least three nesting areas —

river, reservoir, and alkali lakes – the report should recognize and apply the term "population" only when referring to the sum of birds in all three areas and use an alternative term when referring to birds in a local habitat area. The quote above might better be worded "…observed growth rate and fledge ratio for the piping plover demographic unit nesting on the river and reservoirs have been decreasing for several years."

p. 29 – Regarding the piping plover fledge ratio, the Report, recognizing the failure to meet the plover growth-rate target of 1.14 for Northern Region since 2005, and the demographic unit in Southern Region falling below target in 2018, should address implications for AM in relation to managed ESH and predation, as well as for high flows in 2018.

p. 30 – Regarding implications of growth rates in piping plover numbers that are <1 for both regions since 2015, the Report might present projected piping plover population sizes for the next 50 years based on recent trends in growth rates for both regions. Modeled projected population sizes could be evaluated in relation to stated management targets (e.g., 50 birds over 50 years).

Page 31 – The first full sentence states "*If runoff is less in 2019, newly created sandbars and decreasing reservoir elevations will likely provide more habitat and the decline may slow or reverse*." While this may be true, it should be noted that if runoff is not less in 2019, then the opposite results might be expected. The implications for adaptive management in both cases should be considered.

p. 35 – Regarding predation on piping plovers, the Report might exercise the bird model to estimate the required intensity of predator management to meet bird targets, and address the question, do 249 removed gulls measurably reduce predation pressure?

p. 37 (Table 2-6) – The Report might encourage rapid development of an enhanced bird model to accommodate metapopulation data used in characterizing the likely outcomes of piping plover and piping plover habitat management actions on the river and at reservoirs.

p. 42-43: (projections) It is not clear that the projections are effectively entering into the decision-making and AM process.

Chapter 3

The Report provides an analysis of the monitoring data from the original PSPAP, which may not be overly useful for detecting trends in the short term (<15 years). The Report included monitoring data presented in context of the objectives of the MRRP program, particularly with respect to performance of the conservation propagation program. The Report falls short on forecasting outcomes of future management scenarios for pallid sturgeon. Conservation recommendations are mentioned in the Report as part of the 2018 BiOp; however, programmatic recommendations related to research and management actions are missing from the Report. Recommendations for additions and changes were discussed at the AM Workshop and should be presented in the Report.

The Report addresses the current status of the pallid sturgeon population using a compilation of pallid sturgeon population estimates for the upper and lower sections of the Missouri River (Table 3-1). The population estimates reported represent a variety of methods, years, and river segments, which makes interpreting the status of the pallid sturgeon population challenging. Using similar methods throughout the basin as proposed in PSPAP 2.0 would alleviate this problem. Trend data were reported for pallid sturgeon as catch-per-unit-effort data, not as abundance as stated in heading of section 3.2.1.2. Data were reported by segment and for segments pooled. Objective analytical methods for estimating trend in those data were absent and, after discussion at the AM workshop, it appears that additional sample years are needed before a significant trend might be detected. These observations are best engaged in technical exchanges at the Fall Science Meeting.

It would be helpful to have a section in the Report on newly available, published literature on pallid sturgeon, on similar species, on salient environmental attributes of the Missouri River or other large rivers to illustrate that the Technical Team is using the most current reliable knowledge from within and outside the Missouri River basin to inform adaptive resource management.

The Report needs to consider more fully systems connected to the main-stem Missouri River, including the Yellowstone River, other lower main-stem tributaries, including the Platt and Kansas rivers, and the Mississippi River. The Yellowstone and Mississippi rivers receive attention in the Report, but other major tributaries are rarely (if ever) mentioned. For the Mississippi River, an active surveillance system will be needed to resolve questions of pallid sturgeon exchange (drift, adult migration, etc.) that will potentially influence adaptive management of pallid sturgeon in the lower Missouri River. Even the basic question of "does the Mississippi River provide adults for the lower Missouri River?" remains unresolved, in part because of differences in tracking technology employed in the two systems. For the Yellowstone River, resolution of the Intake passage issue will provide opportunity for utilization of the river for pallid sturgeon spawning and possibly rearing. The Report should evaluate how additional main-stem tributaries factor into the pallid sturgeon adaptive management calculus, if at all.

The Report invokes the Pallid Sturgeon Integrated Population Model in section 3.2.2; however, it is difficult to evaluate the quality and utility of the model because little has been written about the model that can be subjected to independent scientific review. In that light, the Report might describe how uncertainty is estimated and incorporated in the model parameters to defend the usefulness of the model.

A clearly articulated synthesis of activities for pallid sturgeon — hypothesis evaluation, meta-analysis, weight-of-evidence assessments — is missing from the Report. The use of a MRRP scorecard, as recommended on pages 468-469 in the SAMP, would help communicate new learning in relation to management hypotheses (as per Table 68 in the SAMP). Comparative progress between years could be readily tracked by comparing scorecards.

It is unclear how the pallid-sturgeon model is being used to evaluate potential management options and the creation of consequence tables. Again, the pallid sturgeon model is something of a "black box" to reviewers of the Report, and needs to be peer-

reviewed to give assurances to the MRRP program that it will be a useful tool to assess species responses to management actions.

It has become increasingly important to determine if sampling efforts can be implemented to measure reliably survival of age-0 and age-1 pallid sturgeon, given the inherent difficulty in measuring those parameters and the potential constraints posed by variance in time and space, which may overwhelm feasible sampling efforts.

A basic bioenergetics investigation might inform the design of IRCs by bounding the likely production of pallid sturgeon prey. The computations can be extended to identify the number of early-life-stage pallid sturgeon that might correspondingly be energetically supportable within an IRC. With sufficient courage, one might even estimate the number of age-0 and/or age-1 sturgeon potentially produced by an IRC. These kinds of rough calculations might be used to estimate the number (acres) of IRCs needed to measurably affect pallid population dynamics in relation to pallid sturgeon management objectives (e.g., lambda). It is extremely important to have some idea of the number of IRCs needed to measurably influence the pallid population and determine if IRCs are realistic management tools from an energetics perspective. If further study and analysis offer strong inference of unimportance of IRCs from a pallid sturgeon food perspective, an energetics-based assessment of IRCs becomes less important.

A parallel analysis of the early life stage retention aspect of IRCs is needed to estimate the number (acres) of IRCs needed to effectively "slow down" the river and meet the management objective of a self-sustaining population within the river's management domain. Are two IRCs too many? Are two hundred IRCs insufficient? How might such an analysis inform the current staircase plan with 12 IRCs?

The structure of the Report followed the big questions and management hypotheses from the SAMP (Tables 4 and 5) under section 3.4 *Progress on Big Questions and Hypotheses* (page 74 in the Report). The same approach in future reports is recommended, with an accompanying score card to easily track progress toward big

questions and hypotheses recommended. Given only a narrative presented for certain big questions and hypotheses, and limited data for others in the Report, it is difficult to effectively evaluate the science. There needs to be a point in the AM schedule where peer-to-peer scientific discourse – including experts from outside the Missouri River basin — allows full evaluation of the available science. If time and resources are limiting, then the MRRP needs to identify the specific science products that need rigorous peer review, and then plan presentations and develop reports accordingly. The competing flow models in the upper river and redefining habitat used by age-0 pallid sturgeon in the lower river are two examples of where rigorous peer-review would have helped the MRRP make decisions.

The information presented in the Report on Big Question 3 in the lower river could be problematic for evaluating the IRCs as defined in Table 68 of the SAMP. That is, if treatment sites are constructed using habitat definitions not based on the best available science on age-0 pallid sturgeon habitat use, then one would not expect a treatment effect. The original physical components of the IRC habitat were defined as: "The physical components of these habitat types are defined as follows: (1) food-producing habitat occurs where velocity is less than 0.08 m/s, (2) foraging habitat are areas with 0.5 – 0.7 m/s velocity and 1-3 m depth, and (3) interception habitat is qualitatively described as zones of the river where hydraulic conditions allow free embryos to exit the channel thalweg." (SAMP Appendices and Attachments: Attachment E.1, page 491). It is not clear what data were used to develop the original habitat definitions. If empirical data where used, why do the results differ and should that issue be elevated into rigorous peer-review? If empirical data where not used, then why would the physical components not be modified to reflect the best available science?

Available scientific evidence appears to support an alternative hypothesis — that food is not limiting pallid sturgeon performance. However, additional analyses, such as estimating the percent of empty stomachs that would occur in the age-0 catch if food is limiting, are needed. The Report could suggest that food limitation be modeled using starvation rates from laboratory studies. It seems logical that if food were limiting, then a high percentage of age-0 pallid sturgeon would have empty stomachs. (Determining if

food is a limiting factor for fishes is difficult from field data, especially for early life stages.) There may be other approaches, such as comparing historical measurements of primary and secondary production, if available, which could provide insight into whether the contemporary Missouri River is more productive than it was historically.

Uncertainty remains in how well the hydrodynamic-drift models represent "true" drift of a free embryo in the upper river. The Report should support the effort to validate hydrodynamic-drift models with free-embryo drift, that is, conduct tests similar to the free-embryo drift experiment conducted in 2016 with modifications. There is empirical evidence of a pallid sturgeon recruiting to age-1 from the 2016 drift experiment, which suggests that natural recruitment can occur in the upper river if pallid sturgeon spawn near the Milk River confluence. However, it is uncertain whether the recruitment would be enough to increase lambda, but recruitment could in theory be incorporated into the population model and evaluated.

The Report should consider whether the hydrodynamic-drift models for the upper river can be applied to the lower river. Regardless, it appears that measuring recruitment to age-1 in Missouri River pallid sturgeon currently needs to occur in the Mississippi River. A relationship between flow pulses from Gavins Point Dam and age-1 recruitment cannot be validated without directly measuring age-1 recruits in the Mississippi River.

Additional focused comments

p. 45-46 – The Report needs to describe explicitly the relevance and importance of pallid sturgeon in the Mississippi River in managing pallid sturgeon in the Missouri River. There are at least two pallid sturgeon spatial domains of interest. One domain recognizes a boundary at the confluence of the Missouri and Mississippi rivers – this is the desired management domain (i.e., a self-sustaining pallid population in the Missouri River). The second domain is defined by the post-impoundment ecology of pallid sturgeon and extends into the Mississippi River. The description of “leakage” of pallid sturgeon into the Mississippi River at the AM workshop represents a purely management perspective.

p. 48 – Regarding pallid sturgeon target numbers and carrying capacity, estimates of reach-specific carrying capacities for pallid sturgeon are needed to support the 5,000 fish per unit target in the recovery plan. Table 3-1 lists population estimates for various studies that could be analyzed and presented in terms of the 5,000 fish target.
p. 49 – Regarding statistics for age-1 pallid sturgeon recruitment, there are implications of failing to document recruitment to age-1 and possible remedies.
p. 52 – There is a need to mathematically relate the proxy measures of pallid populations to the currency of the pallid management endpoints.
p. 53 (Table 3-1) – How do the tabulated pallid populations estimates compare with the target 5,000 fish per management unit?
p. 58 – Regarding population stability, what portion of the 800+ mm fish might be expected to achieve reproductive status, especially females?
p. 60 – The Report might describe the relationship between Ne of hatchery-origin pallid sturgeon and the Ne of wild caught pallid sturgeon, particularly age-0 and age-1 individuals.
p. 61 — It is possible to specify the detailed linkages between management actions (including flows, spawning habitat, IRCs) and population model parameters. The Report might speculate on how much longer it will take to full implementation of the pallid population model in support of adaptive management.
p. 69 – The Report might answer several questions – Can monitoring and modeling be used to determine the likelihood that spawning habitat is a limiting factor? What has been the magnitude and location of spawning habitat loss since impoundment? How do opportunities for spawning habitat development compare with these historical values (and locations)?
p. 76 — Is it possible to use 1-pass multi-beam survey to assess large sections of the Missouri River to identify similar areas of gravel, cobble, and boulders, suggestive of quality spawning habitat?

The ISAP identified a number of issues that were stimulated by questions from presentations and discussion at the Adaptive Management Workshop. These might be usefully addressed with points of reference in the Report.

Key Topic 1 (for pallid sturgeon): Reproduction and Recruitment in the Lower River

Although the USACE has plans to construct spawning habitat in the lower river, essential planning information such as location and timing is scant. Does sufficient information exist to choose locations most likely to induce spawning? How will success be evaluated? How will results inform the pallid population model and ultimately lambda?

In general, are we collecting the appropriate information (metrics) from the river to estimate recruitment?

Key Topic 2: Food and Foraging Habitat Design Criteria (IRCs)

IRCs may be appropriate "stopover" sites for larvae drifting downstream if entrainment processes move them laterally. Do similar hydraulic forces transport larvae out of these habitats and in what time frame? How does new information (e.g., Gemeinhardt et al. 2018) inform the construction of these habitats?

Key Topic 3: Additional IRC Topics

If age-0 *Scaphirhynchus* spp. guts from individuals caught in the main channel are always full of food (primarily chironomids), then how does this inform hypotheses concerning food and foraging limitations? Are IRCs needed on the river, and how does this observation relate to AM?

Do gut contents tell us anything about feeding location? For example, are sand-dwelling chironomids found in the gut along with sand, or their sand cases (implying epibenthic

feeding) or as simply free larvae (implying water column feeding)? This information, if available, might inform the feeding mode and habitat of sturgeon.

Key Topic 4: Drift Assessment in the Upper River

Resolution of the two competing drift models (1-dimensional, 2-dimensional) appears to require additional learning. The assumption of passive drift may not be completely operable, especially during later stages of free embryo development. The tail of the advection distribution may be particularly important to larval survival, and dispersal into marginal habitats during low and high flows warrants exploration.

Would incorporating environmental DNA (eDNA) techniques add clarity to these patterns? The genetic technology for eDNA interpretation is improving at warp speed, and consideration of what such technology can add to advection-dispersion models may be useful. Currently, there appears to be little thought about eDNA.

Key Topic 5: Spring Pulse Release Below Gavins Point

The jurisdictional division between the Missouri and Mississippi rivers continues to pose challenges to adaptive management. It is clear that pallid sturgeon move between the two systems, and yet differences in staffing, agencies, and technology currently pose challenges to data integration. The inability of personnel in one river to track telemetered fish coming from the other river due to differences in telemetry technology must be resolved.

Key Topic 6: Pallid Sturgeon Trends in the Lower River

The apparent "decline" in pallid sturgeon in the lower river since 2012 is currently not supported by statistical analyses. While mean abundance of HOPS has a declining trend, the large confidence limits currently suggest no statistical difference among years. Robust statistical analysis (e.g., time series, repeated measures) is needed for these data to confirm or refute interpretations.

Perhaps more importantly, the source of the uncertainty (large error bars that often overlap zero) should be further explored. Any data interpretations will be highly limited by this uncertainty until the source is identified and hopefully reduced with a modified sampling scheme.

Regarding Fort Peck flows:

Abrupt increases or decreases in flow not typical of natural flows should be evaluated in context of possible adverse physical (e.g., erosion, sediment routing) and biological (benthic scour) effects.

Are there examples of flow implementation to improve conditions for other species of sturgeon? Possible literature to examine includes lake sturgeon (Great Lakes basin), shortnose sturgeon (US east coast), and green sturgeon (US west coast).

The (apparent) idea that it may be suitable to provide spawning and rearing habitat in either the Yellowstone River or the upper Missouri River (below Ft. Peck) is a false dichotomy. The notion that one system may be "enough" to provide habitat for pallid sturgeon, even if the other system has low function, ignores fundamental elements of biology. Specific genotypes of fish (either wild fish or HOPS produced from wild stock) may be better adapted to one system or the other in terms of reproduction and recruitment, even if some individuals wander between systems (which is normal gene flow). The goal should be to simultaneously maximize population growth potential in both systems to meet sub-objectives 1 and 2 of pallid sturgeon recovery.

Regarding interception and rearing complexes (IRCs):

The ongoing IRC project would profit from increased clarity on the power analysis and the presentation of emerging results. Given the delay in construction, the implication of continued data collection from "control" sites should be clarified, such as in terms for conversion to "treatment" sites in the future.

Statistical power can normally be increased via two mechanisms (assuming Type I Error is unchanged) by either (1) increasing sample size n or (2) increasing the difference between the control and treatment. The former is accomplished by adding replicates and the latter by modifying the treatment level or simply measuring increased response. This means that a measured response larger than that assumed in the power analysis (e.g., 80%) may result in a lower requisite sample size needed to detect a response.

Related to above point, the current portrayal of results as the mean of "controls" versus the mean of "treated" reaches (with associated error) is confusing in light of the experimental design that emphasizes paired control-treatment sites. The "staircase" design is basically a modified "BACI" design in which the differences between paired sites is the critical metric. While it will take time in the staircase design to accumulate site pairs for this metric, it would be useful to begin now to portray in graphical images the paired differences rather than the misleading raw means.

Regarding opportunistic learning from high flow events:

Learning from unpredictable flows in the lower river or purposeful flows in the upper river should be accompanied with clear goals for opportunistic measurements. What, if anything, should be measured in addition to routine monitoring? What level of learning would trigger changes in management?