



*Sustainable Ecosystems Institute*

**Independent Science Review of the Models and Linkages for  
Hydrological and Biological processes of the Missouri River**



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## **Independent Science Review of the Models and Linkages for Hydrological and Biological processes of the Missouri River**

### *Science Review Panel*

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# **Independent Science Review of the Models and Linkages for Hydrological and Biological processes of the Missouri River**

## **Executive Summary**

Sustainable Ecosystems Institute convened a workshop in October 2006 to review the hydrological model, initial progress of the habitat assessment and monitoring program (HAMP) and the biological link between Missouri River programs. HAMP participants have moved efficiently to bend-level sampling and clearly understood the intent of the BACI design framework. The panel did note several pressing issues and recommendations:

- A recurring recommendation from past reviews is to standardize the deployment of gear.
- Standardize temporal domain (specify month(s) of sampling for selected areas). This will shift across segments (upper vs. lower).
- Proceed with a power analysis after 3-5 years of data are collected.
- Sustained statistical guidance for the program.

### *Telemetry*

Although no specific information regarding the telemetry program by USGS was presented, the panel believes this could be a central activity in both research activities in support of conceptual underpinnings of the pallid sturgeon recovery and conceivably a sensitive means to monitor sturgeon recovery throughout the Missouri River. We learned that the program had not received external review and we believe high priority should be placed in integrating the telemetry program into all three elements of the pallid sturgeon recovery program which SEI has reviewed (population assessment, habitat assessment, hydrological-habitat-population linkages). We present here several opportunities to bring telemetry studies into (1) population assessment and monitoring studies, (2) habitat studies, and (3) habitat-flow integration studies. However caution is necessary as any research study should be designed explicitly for the hypothesis of interest and statistical guidance may be appropriate.

### *Conceptual Model*

The panel was encouraged by the fairly extensive draft conceptual model presented at the end of the workshop. Although it has not been examined by all participants and refinements may be needed to reflect the goals of the larger group it is an excellent starting point and appears entirely consistent with the implicit consensus conceptual framework that formed the basis of the overall HAMP bend-based BACI analysis and fish monitoring strategy. There are several types of conceptual models that can be considered based on the focus of the interest when refining the current draft.

Given the number of system components and processes on which some kinds of measurements are being taken, even a schematic diagram including all of them in a single model can become overwhelming. The panel encourages the HAMP participants to consider constructing a small family of simple but conceptually consistent and linked

process and control diagrams to caricature a demographic viewpoint (as in the current draft), a habitat-centric viewpoint, a flow/flood-centric viewpoint, and perhaps others. Breaking out some sub-models from the USGS conceptual model schema may provide a place to start.

An important component is to engage species experts and the larger community to work collaboratively to share knowledge, revise, refine, prioritize, and to ensure that the framework is consistent with conceptual models of other priority management species, and with a comprehensive, ecosystem-level adaptive management model. Other steps include: review; characterize elements of the model; construct strawman models and perform sensitivity assessments; cross-reference to field protocols; and use the conceptual model to identify core and needed ancillary studies.

### *Hydrological Model*

Although the project has made appreciable progress, it is not as far along as originally envisioned when the Panel was formed, especially in the areas of model construction and calibration, and hydro-eco linking. The Panel recognizes that in many ways this presents a new opportunity to provide suggestions about modeling early in the process, which could allow the project to better leverage the utility of the model so as to answer the overall project objectives.

The project may benefit by the following:

- Convene a forum/workshop for modelers and model consumers.
- Ensure discussions between model consumers, field technicians and modelers at all stages of the process.
- Check that the conceptual models are consistent with the data used.
- Have modelers internally release interim result in a more real-time fashion. Model consumers should inform the modelers early in the process what form of model output best suits their hypothesis testing and data sets, and recognize that such interim products may change when the model is finalized.
- Evaluating the present models with the initial SWH 1200 acre test and other model prediction post-audits.
- Models, by definition, are a simplification of reality. There are a variety of tradeoffs (and general modeler's art) inherent in deciding which, and how much, detail to include in a particular model. The project might benefit from the construction of coarsely constrained models rather than only focusing on intensively calibrated models of the 6 bends used for SWH.

### *Review and oversight*

We commend the many participants, in this and other Missouri River projects we have reviewed, for their diligence in seeking outside discussion and review. Such oversight supports the quality of the efforts carried out on these important topics. Regularizing such review should be considered a top priority.

# **Independent Science Review of the Hydrological Model and Biological Links for the Missouri River**

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## **Introduction**

Sustainable Ecosystems Institute convened a workshop in October 2006 to review the hydrological model, initial progress of the habitat assessment and monitoring program (HAMP) and the biological link between Missouri River programs. This review was a continuation of the Independent Science Review program which included reviews of the Pallid Sturgeon Assessment and Habitat Assessment and Monitoring Program (HAMP).

The review panel included:

Dr. Randall Hunt, USGS Wisconsin Water Science Center

Dr. Jim Quinn, University of California, Davis

Dr. David Secor, Chesapeake Biological Laboratory, University of Maryland

### *Program information*

The Habitat Assessment and Monitoring Program (HAMP) constitutes a major, comprehensive effort to document and assess ongoing programs of habitat creation on the Missouri River. This cooperative effort (involving federal, state and other cooperators) supports the overall program for the restoration and management of the river. Monitoring is a key component of science-based adaptive management - HAMP will be a crucial element in the overall monitoring strategy.

Other elements of monitoring include fish population and community status (initial review completed 2004) and their relationship to hydrological measurements.

### *Independent Science Review*

Independent Science Review (ISR) is an important mechanism to ensure scientific quality control, to determine whether all relevant information and opinion has been included, and to provide assurance to decision-makers that proposed management activities are well-founded in a scientific consensus. Activities by the US Army Corps of Engineers (USACE) on the Missouri River are complex, expensive, and likely to have far-reaching effects. It is therefore highly appropriate that ISR be used by the parties to assess their programs in advance of major commitments of resources.

This report is organized around the central elements of the panel's review. It begins with an element that was covered initially in the 2005 Independent Science Review (ISR) report – the HAMP Program. Then new topics that have come to the fore since the last review are addressed, including telemetry, conceptual model, and hydrological modeling issues.

## **HAMP Program and Design Issues**

The habitat assessment and monitoring program (HAMP) is a chief element of the Pallid Sturgeon Recovery Program designed to evaluate the effects of shallow water creation

and associated effects on bend-level bathymetry and flow on sturgeon habitats. Here, the more focused aim to improve shallow water habitat (SWH) is associated with the broader goal of restoring increased variability in daily and seasonal flow and bathymetry. Further, rather than an exclusive focus on pallid sturgeon, shovelnose sturgeon and other key benthic ichthyofauna are sampled at the bend level to provide more synoptic indicators of habitat changes likely to affect pallid sturgeon and to increase the statistical power available to document environmental change over time.

In May 2006, a meeting between Sustainable Ecosystems Institute (SEI) experts and HAMP program principals resulted in a shift in the experimental design underlying HAMP. Because engineering (structural) modifications were inconsistently applied across Missouri River segments and bends, the bend rather than specific structural modifications was chosen as the experimental unit. Segments were stratified into bends (approximating the 25<sup>th</sup> and 75<sup>th</sup> percentiles in bend radius) to capture the range of river geomorphologies and flow patterns likely to influence the effects of modifications on biological responses. Finally, a BACI (Before-After-Control-Impact) design was adopted to statistically contrast control bends with paired treatment (modified) bends through annual biological assessments. At the October 2006 SEI workshop, results were presented for 2005 field data (prior to the 2006 design shift, and a year when sampling effort was curtailed due to staffing and other implementation issues); monitoring efforts and design elements of the 2006 field season were also presented and discussed.

HAMP participants have moved efficiently to bend-level sampling and clearly understood the intent of the BACI design framework. For instance, data were contrasted between control and modification treatments for classes of bend radii. Further, the initial development of random un-stratified sampling within each bend type seems justified to draw bend-level inferences without clear ancillary information on factors (e.g., depth, distances from shore) upon which to stratify. The panel did note several pressing issues - the most immediate challenge for HAMP participants will be to standardize gear deployments to insure constancy of information across bends, segments, and years.

Consistency and standardization in gear deployment was recognized by the panel as the most pressing issue. Gear deployment standardization has been a recurring issue in past SEI reviews of the Pallid Sturgeon Assessment and HAMP programs. In the former, Assessment participants moved towards core gear deployment of gill nets to permit inter-annual contrasts of pallid sturgeon abundance, while ancillary gear deployments would address other research and assessment aims. The critical design element here is that a specific and consistent gear deployment permits long-term evaluation of trends, regardless of other deployed gears, which do not currently fit into the Assessment design. We recommend a similar approach for the HAMP program. The challenge is that one gear type cannot be used for all target species and life-history stages. The BACI design specifies detection of annual changes in multiple demersal species abundance (including pallid sturgeon). This leads to two design decisions: (1) Which gear type(s) give the best representation (mindful that this is not necessarily the gear with the highest catch) of multiple species at the bend level? (2) What period of sampling best represents annual changes of species abundances? Satisfying these two conditions across multiple species

and life history stages (e.g., juveniles v. adults) will necessarily entail compromises in terms of sensitivity to detect changes in particular species abundances. But standardization and gear reduction should be principal goals to effectively implement the BACI design at the bend level. Tracking species abundance based upon observations of that species in multiple gears can lead to intractable analyses and ambiguous results.

As a starting point, discussions at the October 2006 SEI workshop suggested that otter trawls and trammel nets might together serve as core gear in the HAMP design. Under this scenario, other gears such as seines and fyke nets could serve as ancillary gear deployed across segments according to objectives outside the HAMP program. Emphasis on core gear deployments need not retard refinement of sampling methods, but these should be treated initially as ancillary – then brought in through careful gear calibration studies. The recent research investigating bow-mounted trawling for instance shows promise in linking shallow water habitats to deeper habitats using similar gear types (bow v. stern mounted trawling). Careful gear comparison studies could allow bow-mounted trawling to be brought into the HAMP program in future years.

Specific months (multiple or single) should be selected for consistent sampling across bends and segments. It is expected that months will shift across segments, where effective spring sampling periods will be later in up-river segments in comparison to down-river segments. Sampling intensity and randomization procedures across bends and segments also should be standardized once gear choice and temporal sampling issues have been resolved. Gear, temporal domain, sampling intensity, and randomization procedures can be informed by over-sampling early in a monitoring program, but we urge rapid implementation of consistent application of core gear types and deployments. Once 3-5 years of data have been collected, sampling intensity and other design elements can be tested for their efficiency in detection abundance trends through power analysis, similar to the analysis undertaken in the Pallid Sturgeon Assessment.

Finally, HAMP needs sustained statistical guidance for the successful application of the BACI design. As year-to-year data accrues, the BACI design will lend itself to different statistical approaches, capable of detecting increasingly more robust rates of annual change and contrast. Initial data is likely only to support “coarse” categorical statistical analyses such as presence:absence approaches and cross-tabulation (chi-square analysis). As an example, individual gear deployments within a bend can be tallied for presence or absence of a specific species permitting hypotheses such as, modified bends have significantly more positive tows (as a proportion of total tows) than control bends. Two-way and three-way contingency table analysis can permit other factors such as % radius or gear type to be included as other factors. An example of cross tabulation for a given segment is presented below.

No. nets with...	Modification Radius 25%	Control Radius 25%	Totals
Fish present			
Fish absent			
Totals			

## **Integration of Telemetry into Pallid Sturgeon Restoration Program**

At the October 2006 SEI workshop, panelists were made aware of a multi-million dollar telemetry program already undertaken by USGS with the specific purpose of better understanding pallid sturgeon biology and habitat requirements. While no specific information was presented on this program, the panel believes that telemetry could be a central activity in both research activities in support of central conceptual underpinnings of the pallid sturgeon recovery and conceivably a sensitive means to monitor sturgeon recovery throughout the Missouri River. We learned that the program had not received external review and we believe high priority should be placed on integrating the telemetry program into all three elements of the pallid sturgeon recovery program which SEI has reviewed (population assessment, habitat assessment, hydrological-habitat-population linkages). We present here several opportunities to bring telemetry studies into (1) population assessment and monitoring studies, (2) habitat studies, and (3) habitat-flow integration studies.

### ***Telemetry: Population Assessment and Monitoring***

The telemetry program has established important infra-structure by establishing remote intercept points at ~30 mile intervals throughout the Missouri River. Further, receivers linked to mobile phone technology permits real time acquisition of data from these intercept points. Thus, without placing a single boat in the water, this program has the capability of tracking fish as they undertake seasonal migrations and coarsely localize their position to specific segments. Depending upon what types of pallid sturgeon can be tagged and the duration and detection radius of tags, this scale of implementation lends itself to determination of

- spawning migrations
- segment-scale seasonal aggregations
- demographic fates of individual fish
- home range dynamics
- population structure

In many case, especially with rare species (for example, spotted owls under FEMAT), stability or recovery of a population can be more effectively detected by individual-based analysis than by regional population counts.

The premise here is that one can depend upon seasonal directed migrations to capture demographic and spatial fates of individuals. For instance, if these were non-migratory fish throughout the year, then we might never receive a signal from one of the intercept sites. Rather, because we expect pallid sturgeon to undertake seasonal migrations >30 miles each year, then absence of detection implies two fates: tag loss or death. The analysis of individual fates necessitates sophisticated likelihood approaches, which have been developed only recently (Hightower et al. 2001; Heupel and Simpfendorfer 2003). These same approaches when coupled with intensive monitoring programs can support mark-recapture estimators of population abundance. The opportunity to use telemetry to estimate vital rates and abundances also requires careful consideration of design elements such as size/stage of tagged fish, electronic tag characteristics (duration, ping and detection rate, effect on behavior, tag loss rate, etc), and where and when tagged fish are released. The availability of hatchery fish could facilitate important design elements – permitting fates of specific stages or fates within certain segments to be studied in detail.

### ***Telemetry: HAMP and Other Habitat Studies***

Mobile tracking of electronically tagged fish within segments can validate important conceptual assumptions of the Pallid Sturgeon Recovery Program and lead to novel insights on behaviors. Mobile tracking conducted at varying levels of intensity can be directed at hypotheses such as

- sturgeons utilize specific depths and flows
- sturgeons are associated with structure/sediment type/forage conditions
- sturgeons occupy narrow home ranges during winter and summer months
- sturgeons revisit home ranges each year
- home ranges increase with size and life history stage
- pallid and shovelnose sturgeons are locally allopatric
- pallid sturgeon and species X are allopatric

These are only examples of hypotheses, but emphasize the numerous questions that can be asked using mobile telemetry. We caution however that design (system of tag deployment and mobile survey coverage) should be designed explicitly for the hypotheses of interest. For instance, the determination that pallid sturgeon overlap with shovelnose in their distribution might require a coarser level of mobile tracking coverage than linking pallid sturgeon preference with a specific depth, flow, or sediment type. The past literature on fish telemetry is rife with equivocal descriptive studies using telemetry because design elements and statistics were inadequately considered. Here, as with applications directed at population assessment we urge participants to undertake quantitative studies to support monitoring aims or hypotheses tests. Analysis of telemetry data is confounded by the auto-correlated nature of relocation data. There are

now very good statistical tools to deal with this issue (repeated measures mixed model analysis) that need to be considered at the outset to insure that telemetry is sufficiently sensitive to support program aims (e.g., Secor et al. 2000; Wingate and Secor in press).

Within the HAMP program, mobile tracking can also be used to establish temporal domains and gear types that are likely effective. Because telemetry now permits deployments of hundreds of tagged fish, efficiency questions can be asked across focal species within the HAMP program.

### ***Telemetry: Linkages to Hydrology***

Telemetry represents longitudinal (continuous) data and as such lends itself well to linkages to dynamic ecosystem elements such as flow. As an example, a telemetry study on salmon smolts established prediction of migration rates due to temperature and flow regime. This permitted prediction and visualization of smolt emigration under differing environmental conditions (<http://tracking.baird.com/tracking/>). Telemetry also results in a series of specific geolocations, which can be directly linked at similar time scales to flows predicted in hydrology models. This type of research, while innovative and challenging is feasible and potentially important to the Pallid Sturgeon Recovery Program, depending upon the priority the biological conceptual model places on flow for juvenile and adult pallid sturgeons. Here again, we urge independent expert review to best take advantage of existing infrastructure and resources in investigating pallid sturgeon habitat linkages to hydrology.

## **Conceptual Models**

In the 2005 Independent Science Review (ISR) report, the panel suggested that the HAMP participants follow the process adopted in most other large ecosystem studies (e.g., the Northwest Forest Plan, the Everglades restoration, the Colorado River Project) where one or more graphical conceptual models of the critical ecosystem processes are explicitly developed. Typically, these begin as “circles and arrows” connecting ecosystem components (species, nutrients, etc.), the processes connecting them, and potential management control points in those processes. Although the panel thinks it would have been helpful to do so earlier, it is encouraged that the USGS Columbia Environmental Research Center and their collaborators have drafted a fairly extensive conceptual model as a starting point for refinement of the approach to pallid sturgeon science, and encourages further development. At the time of the review, the draft model had just been released, and had not yet been examined by many of the participants, so it is too early to judge what kinds of refinements may be needed to reflect the goals of the larger group.

Conceptual models provide a variety of useful inputs to complex environmental assessment and management initiatives, many of which are listed in the USGS presentation. Most importantly, they formalize the working assumptions on which

restoration measures and monitoring designs are based, typically with an assumed chain of causality between physical, biological, and management drivers of the system and environmental outcomes. More specifically, they have often proven useful in identifying, developing consensus, and communicating:

- The major processes and links which are thought to drive the system, and those which are believed to be minor influences, secondary effects, artifacts, or epiphenomena
- The components of the system (species, nutrients, sediment, transport processes, flow regimes, etc.) that are most important and therefore subjects for research or development of management objectives (often termed “endpoints”). This inevitably involves a series of decisions on which components are to be considered explicitly, and which may be lumped into broader functional categories
- Appropriate measures and metrics to evaluate the state of the important components (i.e., indicators). These may be the endpoints (e.g., pallid sturgeon young of the year, flow duration or thresholds) but may also be easy-to-measure, if imperfect, surrogates for the actual components of management importance
- The spatial scale and boundaries of the system, particularly if the analysis requires consideration of multiple, embedded scales
- Temporal scales of the system (e.g., how is variability at the days-to-weeks scale of runoff events incorporated into a viability analysis of a long-lived fish species?)
- Potential control points – the strongly causal links that are also subject to controlled manipulation by experimenters and managers

Elements of a good conceptual model may be used to clarify strategy and information needs, a process certainly implicit in much of the development of HAMP to date. Some of the important uses include sensitivity analyses, indicator development, and monitoring design.

#### *The USGS Draft Conceptual Model*

There are a variety of perspectives for examining any complex system, and a first step is to choose one or more dominant “currencies” as the core descriptors of the important processes. The draft conceptual model uses the currency of sturgeon population cycles, tracking the numbers of fish progressing through each life history stage from eggs through mature reproductive adults, and then catalogs the important influences on the transition probabilities from each stage to the next. This is clearly an exceptionally useful, perhaps essential, way of characterizing the knowledge needed to determine whether the sturgeon population is replacing itself – i.e., is it in jeopardy? The conceptual model document then provides an expansive list of environmental influences on each transition stage (dredging, boats, entrainment, predators and competitors, sediment, temperature, contaminants, etc.), without specifying mechanistic detail on the impacts of any of them. Presumably a second phase of development will embed either

process models or measured functional relationships for the important influences for each demographic transition probability (the diamonds in Figure 2, below), and maybe in each region within the Missouri River system. (Of course, many will be difficult to measure in practice, and may require modelers to assume values and functional relationships from outside experience or other studies.) It should be noted that this conceptual modeling approach lends itself particularly well to a monitoring strategy that tracks individuals, especially with telemetry, and then uses the output of individually based models (IBMs) as metrics of the success of restoration efforts. As discussed in the initial ISR and later in this document, this approach is somewhat different from, though complementary to, assessing population changes by spatially stratified sampling, which is currently the core activity of pallid sturgeon (and other target fish species) monitoring in the Missouri River system.

*Other approaches*

Other perspectives and “currencies” are possible bases for a conceptual modeling approach. One is to use detailed habitat distributions as the principal currency, then to assess predicted shifts in locations and acreages under different management regimes, and try to optimize those with respect to their suitability for promoting survival and/or reproductive output of critical sturgeon life stages. This is implicitly the approach used in the draft documents modeling changes in the supply of shallow water habitat, under different flow regimes, created by notching dikes or creating in-channel structures. A cartoon of what a formalization of such a model might look like is given in the 2005 ISR report.

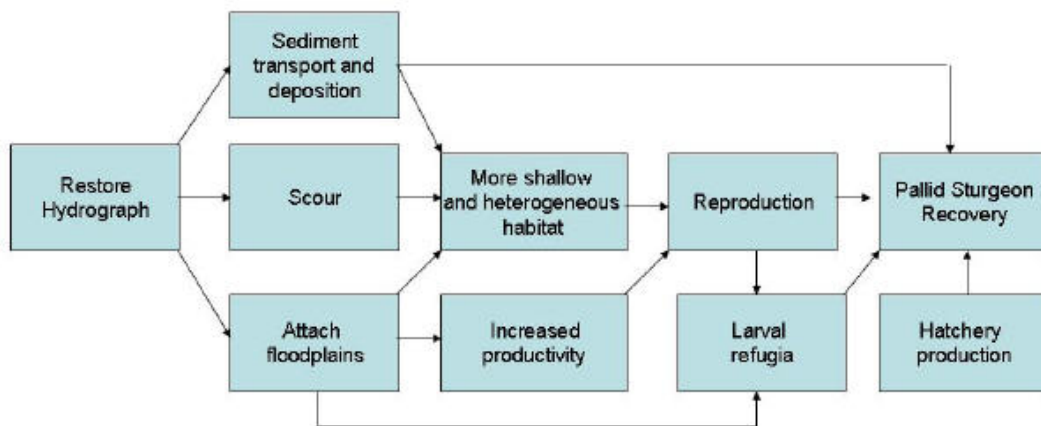


Figure 1

An advantage of using the habitat landscape rather than demography as the main “currency” is that it permits easier consideration of aggregated landscape properties, such as habitat diversity, connectivity, fragmentation, etc. and their potential effects on fish

behavior, movement, or reproductive success. If, as suggested in several documents, the apparent association between shallow water habitat and sturgeon occurrences is not because sturgeon preferentially use SWH *per se*, but rather that extensive SWH is indicative of valuable habitat complexity and diversity, then an explicitly space-based conceptual model may be particularly useful, and more detailed spatial descriptions (e.g., through imagery, GIS analyses, and perhaps automated change detection) may prove to be an important addition to HAMP protocols. To the degree that the Biological Opinion calls for more aggressive pulse flows and other innovative reservoir management for the purpose of creating habitat diversity and connectivity as an end unto itself (i.e., with benefits beyond the impacts on sturgeon, plovers, and terns), this would be a straightforward framework for assessing the success of those efforts.

Other widely used conceptual models in large ecosystem restoration initiatives have focused on community energetics, nutrient cycling, sources and fates of contaminants, feedback loops with climatic or hydrological drivers, or long term changes in such physical drivers as salinity, temperature, or water supply. It does not seem that any of these particular approaches provide especially useful perspectives for biological restoration in the Missouri River system, but they point to the possibility of structuring a conceptual model around quite different defining processes.

There is certainly no requirement that the monitoring program for an ecosystem restoration initiative be constructed around a single master conceptual model, and it may be impractical, or at least undesirable, to do so. Given the number of system components and processes on which some kinds of measurements are being taken, even a schematic diagram including all of them in a single model can become overwhelming, and the fully inclusive version of the USGS draft model comes close:

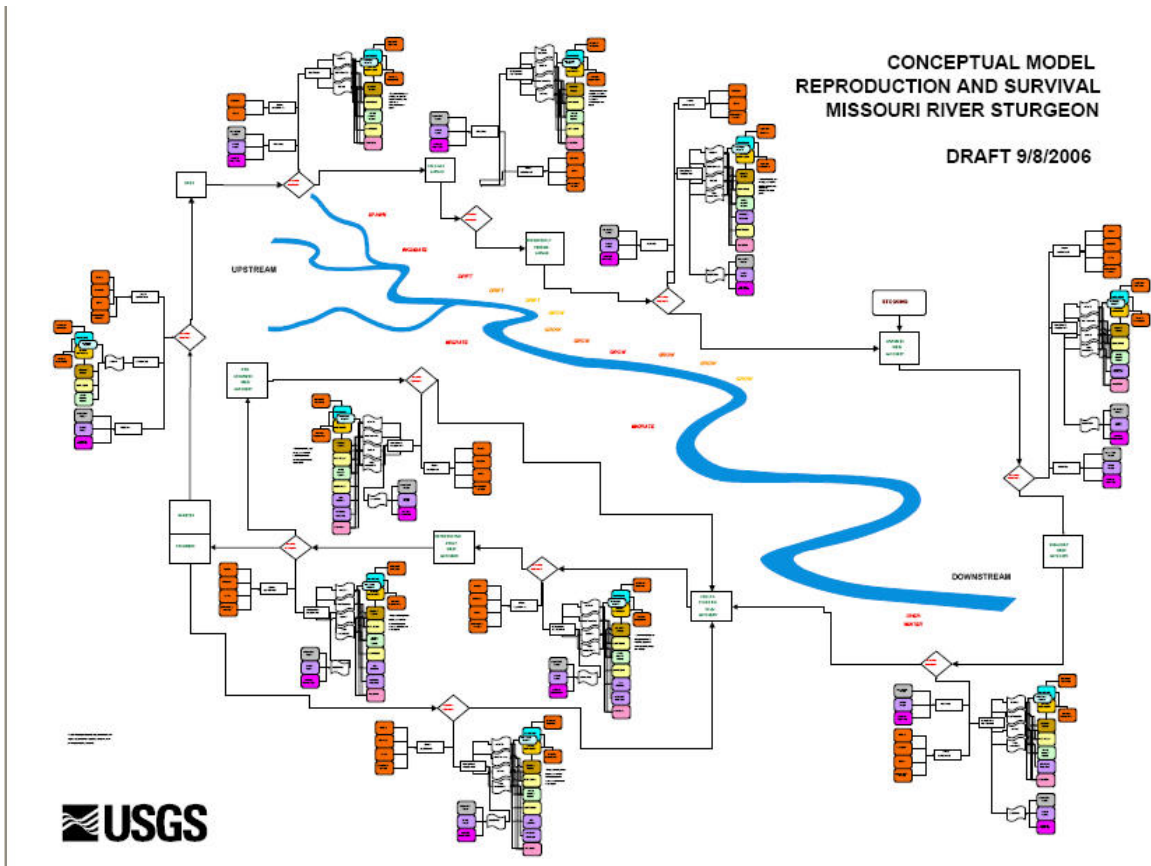


Figure 2 – USGS draft conceptual model schematic

The risk, of course, is that as the layout of entities and links becomes more comprehensive, it is more difficult to determine which ones are thought to be the system drivers, and which, among those, are candidates for management control points and/or outcome assessments. The panel encourages the HAMP participants to consider constructing a small family of simple but conceptually consistent and linked process and control diagrams to caricature a demographic viewpoint (as in the current draft), a habitat-centric viewpoint, a flow/flood-centric viewpoint, and perhaps others. Breaking out some sub-models from Figure 2 may provide a place to start.

*A transport-based conceptual model*

Another conceptual modeling framework is clearly implicit in the larger strategies developing for management of the Missouri River System, with flow regimes, hydrology, transport processes (both sediment and fish), and presumably water temperature and water quality measures as the driving “currencies”. Fish then become, in a sense “users” of the physical regime, using high flows to transport larvae and juveniles, and shifting their distributions in response both (somewhat) passive transport and habitat creation. Attributes of fish that are important to document in this class of model include behavioral responses of larvae and juveniles to flows (vertical location in the water column and use of channels vs. eddies and backwaters). The panel recognizes that these issues are well-

recognized by the fish monitoring groups and that the within-bend sampling strategy at least partially addresses the information needed for constructing habitat use and transport models. However, since an explicit conceptual model framework for flow and habitat management has not yet (as we understand it) been formulated, and the numerical models are still at an early stage of development, it is likely that the information needs to parameterize a fish transport submodel, vs. those for the current surgeon-demography conceptual model, will need to be further worked out in the future.

## ***Next steps***

The panel views the current USGS draft conceptual model as an excellent starting point, particularly for addressing recovery success in pallid sturgeon and the requirements of meeting the non-jeopardy objectives presented in the Biological Opinion. In our view, it appears to be entirely consistent with the implicit consensus conceptual framework that formed the basis of the overall HAMP bend-based BACI analysis and fish monitoring strategy (which, as discussed elsewhere, we believe is fundamentally sound, although it requires sophisticated statistical support and interpretation.) The slide presentation of the current draft model (which was the only document available to review) emphasizes that the current version is a starting point for feedback and refinement, and suggests that the HAMP group both:

Engage species experts to work collaboratively to share knowledge, revise, refine, and prioritize;

and

Engage the larger community to ensure that the framework is consistent with conceptual models of other priority management species, and with a comprehensive, ecosystem-level adaptive management model.

These are both important first steps.

Other steps could include:

*Review.* Certainly, the first requirement is to make sure that there is general agreement that the demographic processes have been well-characterized, and that the list of ecological and human influences on the transition probabilities (or vital rates) capture all of the major processes – at least those thought to both have large impacts on the success of individual sturgeon and to have reliable data either available or feasible to collect. It may also be possible to do some simplification. For example, in cases (such as “competitors”) where impacts could be large but measurements are difficult to obtain and management of the process is difficult, it may be desirable to note the process as being part of the ecological background, but omit it from the prioritized, or management-oriented, version of the conceptual model.

*Characterize elements of the model.* Formulations vary among writers and organizations, but it is generally useful to identify which of the entities in the model represent

- Goals of management in themselves (e.g., “endpoints”)
- Indicators (which may be endpoints, but could be correlates or surrogates)
- Control points (elements, such as dam releases, under experimental or management control)
- Experimental variables – for example, the parameters stratified in the HAMP monitoring or the basis for specifying experiment-control pairings in the BACI design

The USGS schematic begins this process with a (undocumented) color scheme that labels such things as management actions (in red). It may also be useful to identify elements that are measured vs. those to be modeled vs. those allowed to vary freely.

*Construct strawman models and perform sensitivity assessments.* (See the modeling discussion later.) It is often useful to create a simple matrix representing the entities and links in the conceptual model, enter plausible values, and assess its quantitative behavior. In this case, a linearized model would be a variation on a Leslie Matrix (or stage-structured analog), which can then be used to see which parameters have the largest potential effect on its qualitative behavior (e.g., the growth rate, lambda). Highly simplified representations of conceptual models can often provide heuristic insight into which parameters could most influence behavior, even if the model is uncalibrated and unrealistic. These then become candidates for more detailed modeling and field assessment. For example, most sturgeon life-cycle models suggest that overall population growth or decline are much more sensitive to impacts on larvae than to those on adults. To some extent, this step has already been done for parts of this conceptual model.

*Cross-reference to field protocols.* Multiple causality can be investigated through experimental control (e.g., through stratification of sampling) or *post-hoc* regression-like analyses. Investigators should review the field protocols to determine whether samples are either adequately stratified with respect to the major causal processes identified in the conceptual model, and if not, whether the sampling layout allows two or more important processes to be largely co-linear (vary in parallel). Sampling stations should also have fair (relatively unbiased) representations of the possible states of each causal variable that will be evaluated statistically. In practice, avoiding bias and co-linearity in multiple, spatially auto-correlated variables can be difficult, making the systematic description in a well-constructed conceptual model useful in identifying potential problems and adjusting experimental designs and protocols accordingly.

*Use the conceptual model to identify core and needed ancillary studies* – As noted in the ISR report and above, the sturgeon monitoring and BACI studies, while well-conceived, risk losing power to discern trends because a proliferation of gear and site measures could dilute the core samples with the greatest power to detect changes in sturgeon populations and demographics. The panel urges the investigators to consider separating the core

measures, to be undertaken systematically throughout the full Missouri River system, from targeted process studies, which may use specialized gear or methods with a subset of sites or variables. Priorities for the ancillary studies are presumably the processes identified as potentially high impact by the conceptual model, but for which the core protocol yields little information.

*Visualization and communication*—The program is complex. Take advantage of the conceptual model schematics (and maybe the video game) to make it more accessible to managers, policymakers, and the interested public.

## Hydrological Model

The Panel notes that there are some circumstances that result in the comments and suggestions being less than definitive than they might be. Most easily seen is that there is a significant difference between where the Panel’s “final” review (per the initial USACE charge to the Panel) and where the project work actually is at the time of the final review. That is, while the project has made appreciable progress, it is not as far along as originally envisioned when the Panel was formed, especially in the areas of model construction and calibration, and hydro-eco linking. The Panel recognizes that in many ways this presents a new opportunity to inform and provide suggestions about modeling early in the process, which could allow the project to better leverage the utility of the model to answer the overall project objectives.

Based on our review, the panel highlights the following points on Modeling:

- 1) The conceptual model and previous work on other sturgeon all finds that water flows are likely important; because flow is a tractable goal of modeling, quantified results from a properly constructed model can inform better management of the river.**

This observation should be recognized by all work elements of the project in that the quantitative framework of a properly constructed model can connect and synthesize field efforts in ways that cannot be attained using other methods. Moreover, model results can fill in areas of the system, both in space and time, that cannot be covered with field sampling. Yet, effective models need to be structured around the specific questions being asked by model users. Specifically, the non-model project members should make sure that important spatial and temporal scales are provided to the modelers, and that the modeling development includes a number of discussions between the model and non-model team members. These discussions should be conducted during initial, intermediate, and late phases of modeling, are important for getting “buy-in” for modeling from the other project components, and are critical for ensuring that the model is as useful as the scope of the modeling effort allows.

- 2) Use of models commonly falls primarily into two overarching activities; models are used for providing: 1) a quantified framework to look at the range of**

**present river conditions (“constrain the armwaving”); and 2) Predictions of how the system responds when system drivers are outside the range of the calibrated conditions.**

The first is especially important when in a potentially controversial setting as it focus discussion on system parameters and physical processes rather than on qualitative predictions based primarily on professional judgment. The second is often the primary reason models are built. These predictions may simply be running a calibrated model to one new set of conditions; or, the model can be a heuristic mode where an ensemble of scoping simulations provides a quantified “envelope” of possible outcomes for a range of possible stresses/changes. The whole of the project should have one or more discussions on which, or both, uses will best serve the overall project needs.

**3) Models are by definition a simplification of reality. But, this simplification can include different things depending on what the objective of the model is. Thus, this objective drives the initial discussion of what to include in the conceptual model that forms the basis of model construction.**

The utility of any model is directly dependent on the conceptual model used to provide the relevant problem processes, scales, conceptualizations. In hydroecological problems such as this project, a conceptual model that encompasses all these model characteristics cannot be discerned by the modeler alone. That is, conceptual model must be developed using the best available knowledge, whether in or outside the project team. From the world of possible compartments/habitats/life stage histories/processes, the conceptual model development should include discussion on which components are most important (that is, which are the species most sensitive to). For example, biologists should convey all important “thresholds” to the extent that they are known to exist. These thresholds will direct the model emphasis so that the model is not overly complex and unwieldy, and ensures that the model is not “measuring with a micrometer and cutting with a chainsaw”.

**4) The conceptual model can include everything under the sun (“everything and the kitchen sink”) but is often fine tuned to create multiple models for testing specific hypotheses.**

Building a quantitative model that encompasses every possible aspect of a conceptual model is often not a useful approach. The model development time for an overly complex model is commensurately longer, the potential for construction and input errors larger, and the model runs are often longer and more unstable (Hill 2006). Moreover, such a tool is often poorly suited for the problem as its underlying parameters are more apt to be insensitive or correlated, which in turn results in problems with calibration non-uniqueness (as changes to some parameters have little effect or can be offset by changes in others). A more targeted model that is constructed to address a specific prediction of interest avoids or reduces many of these problems. However, care needs to be exercised so that such a fine tuned model is properly employed and not overextended beyond what it is suited for. Thus, there will be a suite of possible models included in testing as there are usually more than one prediction of interest and more than one hypothesis to test.

**5) Thus it follows that, because models can have multiple uses/predictions, it is important to not focus on “one model depiction of the world that gives all answers”.**

Such an all-encompassing model design often results in a modeling process that takes too long and a mediocre model that doesn't fit everything well. A superior approach is to test various hypotheses of important processes early in the modeling effort. This testing should be vetted by all pertinent members of the project team (modelers and non-modelers). With this feedback the universe of possible models can be culled to a short list of useful tools. Often, some parameters or processes can be shown to have little effect on model behavior, and can therefore be simplified out of the model formulation, even without construction or calibration of a full model.

**6) How to cull the universe of possible models? Stepwise modeling.**

In a stepwise modeling approach (Haitjema 1995), a “strawman” model is built early on with the best existing data and understanding of the system. This initial model can identify areas where field data need to be collected (both type through parameter sensitivity and prediction uncertainty and spatial/temporal location). This allows project effort/funds to be focused on the areas that give the most information for the model objective rather than spending effort for field sampling of all places at all times. Once these new data are collected the model can be tested and updated, then used again to identify weakness in our understanding and where future work can be best employed (if needed). The stepwise process also heads off a potential undesirable model outcome: initial undirected data collection and model calibration results in a model that answers the question with so much prediction uncertainty that the model does not answer the question to a useful degree.

Given the presentations and discussions with the project members, there appears to be four project objectives where models could be usefully applied:

- a. To provide SWH creation direction
- b. To help predict presence/absence of species on the river
- c. To help understand confounding factors on the BACI test
- d. To allow project members to overlay the telemetry data or other field data on a quantitative depiction of the physical system that “fills the holes” where data could not be obtained and is constrained by the underlying physics and calibration data. Such a use provides information on the conditions where fish are not present as well as the conditions measured where the fish are.

Other possible uses of model that the Panel heard include: as a visualization tool and basemap for depicting and interpreting field data, hypothesis testing using different strawman-type models, identifying depositional versus erosional environs, larval/food transport (forward and backward particle tracking), and spatial modeling with a goal of a sturgeon suitability map.

In addition, from the presentations and discussions, it appears that the project might benefit from the following actions.

**a)** Convening a forum/workshop to allow modelers and model consumers (biologists, decision makers) to discuss, and ultimately decide, what are the important model predictions, and what their priorities are. The area of hydroecology is not well developed and effective communication between modelers/non-modelers and abiotic-/biological researchers can be difficult. Therefore, such a forum/workshop will require a knowledgeable facilitator to ensure that best technologies/best science are at least considered, and expectations are in line with what the tools can be expected to do.

**b)** Ensuring that discussions between the “3 legs of the stool” (model consumers, technicians in the field, and modelers) are needed for a successful project outcome, and that communication between all three is critical at all stages of the project. This back and forth between the different project elements is especially important at the conceptual model development phase and model calibration discussions (e.g., Which river conditions? Which time of the year? Which bends?). Field crews should convey to the modelers qualitative or anecdotal information that may help the model. This can include information on which of the field data are of high quality and which might be relatively more uncertain.

**c)** Checking that the conceptual models are consistent with the data used to calibrate the model (for example, ensuring consistency between telemetry vs. HAMP field efforts). There should be an upfront recognition that a mismatch in these (“apples and orange” comparisons) will often lead to unacceptable model uncertainty.

**d)** Having modelers internally releasing interim results in a more real-time fashion even if with the qualifier “provisional results subject to revision”. The model usefulness, and the quality of the model itself, will likely not be as high quality if it is only evaluated at the end of the project. Moreover, discussion about non-final versions of the model will facilitate the identification of problem areas before the model budget is exhausted, while providing model consumers with something that can be of immediate use for their efforts. The model consumers, however, should be sure to inform the modelers early in the process what form of model output best suits their hypothesis testing and data sets. And there should be an explicit recognition that such interim products may change when the model is finalized.

**e)** Evaluating the present models with the initial SWH 1200 acre test and other model prediction post-audits. It should be recognized that calibration alone commonly may not reduce prediction uncertainty sufficiently (Moore and Doherty 2005, 2006). Assumptions that may be important for the success of field actions should be tested with field data (e.g., bedform and bed sediment is constant for range of flows).

f) Recognizing that models, being a simplification of reality by definition, can vary in amount of simplification. That is, they vary in effort, scope, and resolution needed. Thus, the project might benefit from the construction of coarsely constrained models rather than only focusing on intensively calibrated models of the 6 bends used for SWH creation. That is, quick and uncalibrated visualizations may have a place in the project activities as they can give a physically and bend boundary constrained hypothetical distribution of flow, that then can be used for synthesizing/evaluating HAMP/telemetry/other data. It may be possible to construct such uncalibrated models relatively quickly for a larger number, or perhaps all, of the study's 44 bends. If such a tool is developed there should be discussions in the forum/workshop of item a specific to these uncalibrated modeling, including what would be needed to do this effectively (flow velocity/stage/etc information at or slightly upstream/downstream of (the boundaries of the bend study unit, the measured stage, and a realization of the measured bathymetry). Other variables could be estimated or extrapolated from the nearest calibrated model and noted as an underlying assumption. Finally, such a coarse and quick modeling effort should be recognized by the project as being uncalibrated, provisional, and subject to revision, as described in item d above.

## **Review and oversight**

We commend the many participants, in this and other Missouri River projects SEI has reviewed, for their diligence in seeking outside discussion and review. Such oversight supports the quality of the efforts carried out on these important topics. The participants in the larger effort are drawn from multiple state and federal agencies, and there is also intense public interest in science-based management on the river. In such circumstances, independent science review will help to ensure and to demonstrate the scientific quality of work being carried out (Sullivan et al. 2006).

Peer review is a normal aspect of scientific work, and most scientists are familiar with having their activities critiqued by others. The sorts of review necessary for large ecosystem projects are best carried out by experts who have experience with similar projects elsewhere. It is also important that reviewers be familiar not just with the technical aspects of a particular project (e.g. fish capture methods) but with the practical issues involved in putting programs in place (e.g. probabilities of funding shortfalls). This combination of skills is critical to ensuring a successful and useful review. Recent directives and laws on peer review (e.g. the OMB directive on review and the Data Quality Act) mandate when reviews should occur, and provide some guidance on implementation. We strongly support such efforts, but also advise the participants in the Missouri River programs to ensure that peer review is carefully structured so as to be most useful.

One possible format, that has proven useful in other systems, is the use of a standing scientific oversight panel. The advantages of this approach are many, but foremost is the continuity it provides. Panelists need less periodic education in the issues, and are more likely to support sustained efforts than are ad hoc reviewers (who may not be as familiar

with e.g. management circumstances). Such a panel would need to be carefully managed, and to be comprised of a sufficiently broad scientific spectrum to answer most review needs. They might be available ‘on call’ for small issues, and able to carry out some tasks at distance, but they should meet periodically to review progress. Note that the Federal Advisory Committee Act sets strict guidance for how ‘advisory panels’ are selected and managed, but scientific peer review is generally exempt from such constraints. As such, it would be important to manage any standing review panel to ensure that it did not trigger FACA and NEPA requirements (basically by focusing on science and avoiding discussion of financial issues).

Regularizing peer review for the Missouri River system should be considered a top priority. SEI feels that the existing program has worked well on an ad-hoc basis - important issues have been resolved, and key decisions have been made following such reviews. However the system would be further improved if reviewers were engaged on a longer term, and interacted with project scientists on a more regular basis. This would substantially improve the depth and quality of the reviews that would be made, and would also help program scientists by providing regular and continuous advice.

## Overall Recommendations

The panel is encouraged by the strides made within the overall Missouri River program which SEI has reviewed. The following are the main recommendations for the hydrological-habitat-population linkages review above:

### *HAMP*

- A recurring recommendation from past reviews is to standardize the deployment of gear.
- Standardize temporal domain (specify month(s) of sampling for selected areas). This will shift across segments (upper vs. lower).
- Proceed with a power analysis after 3-5 years of data are collected.
- Sustained statistical guidance for the program

### *Telemetry*

- Strongly consider more aggressive telemetric tagging and tracking of individual fish
- Review and integrate the telemetry program into all three elements of the pallid sturgeon recovery program (population assessment, habitat assessment, hydrological-habitat-population linkages)
- Any research study should be designed explicitly for the hypothesis of interest and statistical guidance may be appropriate.

### *Conceptual Model*

- The panel encourages the HAMP participants to consider constructing a small family of simple but conceptually consistent and linked process and control diagrams to caricature a demographic viewpoint (as in the current draft), a

habitat-centric viewpoint, a flow/flood-centric viewpoint, and perhaps others. Breaking out some sub-models from the USGS conceptual model schema may provide a place to start.

- Engage species experts to work collaboratively to share knowledge, revise, refine, and prioritize
- Engage the larger community to ensure that the framework is consistent with conceptual models of other priority management species, and with a comprehensive, ecosystem-level adaptive management model.
- Other steps include: review; characterize elements of the model; construct strawman models and perform sensitivity assessments; cross-reference to field protocols; and use the conceptual model to identify core and needed ancillary studies.

### *Hydrological Model*

- Convene a forum/workshop for modelers and model consumers.
- Ensure discussions between model consumers, field technicians and modelers at all stages of the process.
- Check that the conceptual models are consistent with the data used
- Have modelers internally release interim result in a more real-time fashion. Model consumers should inform the modelers early in the process what form of model output best suits their hypothesis testing and data sets and recognize that such interim products may change when the model is finalized.
- Evaluating the present models with the initial SWH 1200 acre test and other model prediction post-audits.
- Models, by definition, are a simplification of reality. There are a variety of tradeoffs (and general modeler's art) inherent in deciding which, and how much, detail to include in a particular model. Fundamental choices include time steps, grid size or spacing of node points, and how to lump or disaggregate interacting model components (for example, species and size classes.) For hydroecology models of the kinds that have been prototyped to study transport of sediment and fish in the Missouri River system, strategic choices include whether to treat each locale with 1- 2- or 3 dimensional models, the spacing of nodes (e.g., highly detailed and perhaps 3-dimensional immediately downstream from chevrons and dikes, perhaps broadly spaced and perhaps even 1-dimensional in long straight reaches between bends.) Choices reflect not only the detail needed for computational stability and sufficient resolution for the questions being asked (e.g., how large might a scour hole become?), but also the nature of the input data (what are the sampling depths?). Some uses (modeling fish behavior) may need quite different time or spatial resolution than others (modeling scour), and some (deposition downstream from a chevron, regulating the occurrences of conditions exceeding a biological threshold) may be defined by regulations. Some of these choices will reflect computational limitations. However, others reflect the data provided by, and the information needs of non-modelers, and early consultation on spatial detail, timesteps, and needed parameter measurements (such as channel cross-sections) are sure to be rewarded. For example, the project might benefit

from the construction of coarsely constrained models rather than only focusing on intensively calibrated models of the 6 bends used for SWH

*Scientific review*

Peer review has proven useful in evaluating the science of the Missouri River program. Such independent review should continue. We recommend that the parties consider regularizing such review.

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