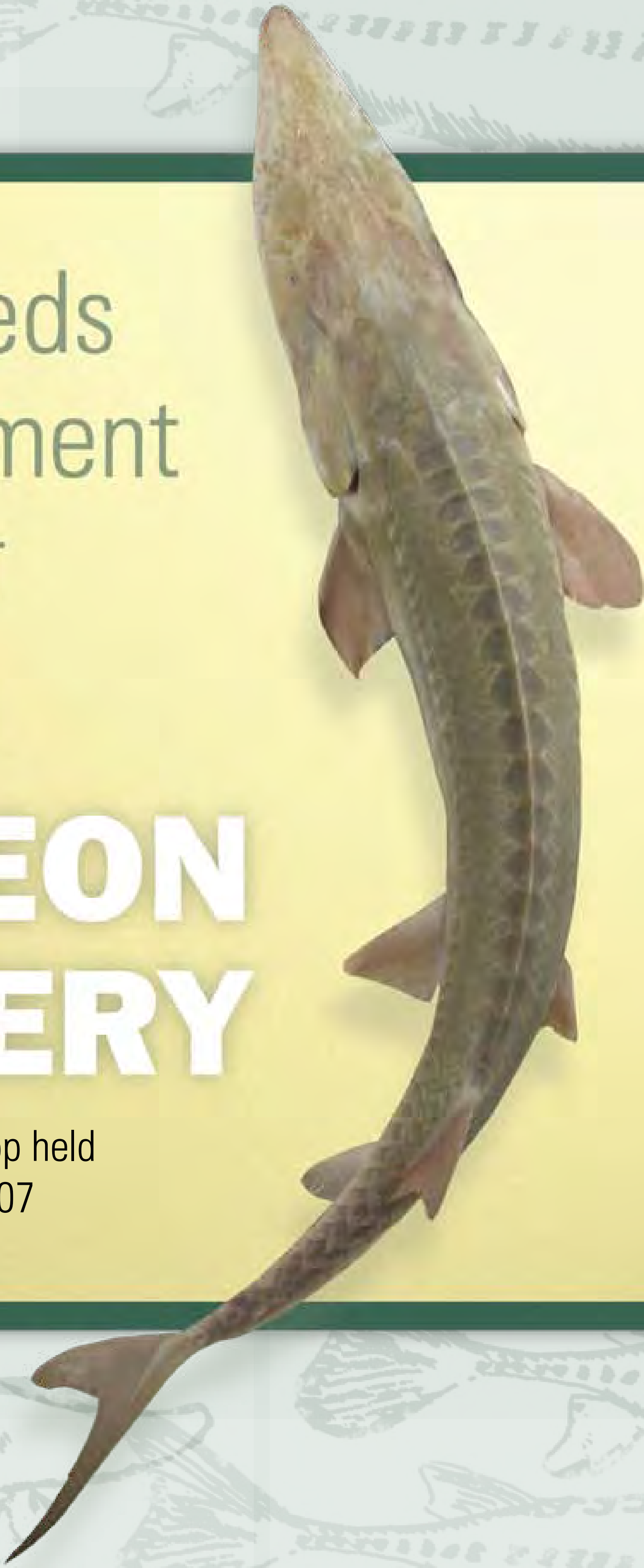
Research needs and management strategies for

PALLID STURGEON RECOVERY



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Report to the U.S. Army Corps of Engineers

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Research Needs and Management Strategies for Pallid Sturgeon Recovery

Report to the U.S. Army Corps of Engineers

Prepared by:

Harold L. Bergman, Ann M. Boelter, and Katelyn Parady
William D. Ruckelshaus Institute of Environment and Natural Resources
University of Wyoming

In cooperation with the

Research Needs and Management Strategies Workshop Steering Committee

Craig Fleming, Tom Keevin, and Doug C. Latka
U.S. Army Corps of Engineers

Carl Korschgen and David L. Galat
U.S. Geological Survey

Tracy Hill, George Jordan, Steve Krentz, Wayne Nelson-Stastny, and Mike Olson
U.S. Fish and Wildlife Service

Gerald E. Mestl
Nebraska Game and Parks Commission

Karen Rouse
Missouri Department of Natural Resources

Jim Berkley
U.S. Environmental Protection Agency

May, 2008

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Foreword

Recovery efforts for pallid sturgeon (*Scaphirhynchus albus*) under the Missouri River Biological Opinion Compliance Program ranked within the top 10 in the United States in terms of federal monetary support for endangered species recovery during 2004 (http://www.fws.gov/endangered/pubs/index.html). This observation illustrates both the nation's concern over the pallid sturgeon's imperilment and its commitment to reversing the sturgeon's historical decline in the Missouri and Mississippi rivers. The workshop reported on the following pages demonstrates that commitment, identifies and prioritizes research and management actions to contribute to recovery, and outlines some of the challenges that remain to achieve recovery.

Our intent for this second Pallid Sturgeon Workshop (the first workshop was held in 2004) was to bring together sturgeon experts from within the species' range and throughout the U.S. to capitalize on their knowledge and experience to aid recovery. We invited technical experts representing three broad areas of responsibility: managers, biologists, and scientists. These were different, but complementary, roles. Often, one of the biggest hurdles to effective resource management is the inability of these three groups to collaborate as equal partners. By including representation from all three within the Pallid Sturgeon Work Groups' geographic areas and bringing in outside subject area experts on sturgeon and habitat, we intended to capitalize on the special knowledge and experience each provides and foster an integrated and adaptive co-management approach (see Armitage et al. 2007) to prioritizing pallid sturgeon research and management needs.

The *managers'* primary role was to identify and communicate sturgeon recovery and management decisions that their respective agencies need to make. They, with advice from their superiors, biologists, and scientists, articulate recovery objectives, information needs, and research results to agency heads and the public. An essential role of managers in this workshop was to keep the breakout groups focused on prioritizing research and management to address issues relevant to their agency directives. *Biologists* provided context, familiarity with the rivers, the biology of sturgeon and other relevant fishes, and sampling techniques. Most importantly biologists served to keep the workshop grounded on what is possible to accomplish within the challenging field conditions of pallid sturgeon rivers. *Scientists* contributed research expertise, how to conduct defensible science, sampling and experimental designs, and data analysis techniques. They provided a theoretical context for sturgeons, put management needs into a hypothesis-testing framework, and were familiar with relevant literature within their areas of expertise. Scientists brought fundamental and objective knowledge to the group, ostensibly free of policy implications. These manager-biologist-scientist expert roles were not clear cut and many of the invited experts filled multiple roles (e.g., manager-biologist, or biologist-scientist).

Invitees were also selected to encompass a range of subject-matter disciplines relevant to pallid sturgeon biology and management. These included genetics/systematics, propagation, ecology (life history), physiology, population dynamics, habitat use, recovery (e.g., regulatory, legal, administrative), and other areas (e.g., commercial harvest, early life history, behavior).

Lastly, we invited representative "outside" subject–area experts. Subject areas were the same as for experts selected by the work groups, but we also targeted individuals with relevant expertise on other species of sturgeons or aspects of riverine habitat, and from outside the Missouri and lower Mississippi rivers. "Outside" experts were intended to bring in a fresh perspective, provide independent scientific review, and have little or no perception of potential conflict of interest. Their participation was essential to enhance the overall science value and credibility of the workshop.

Much has been learned about pallid sturgeon ecology, management and propagation in the three years since the first workshop in 2004 and some of these findings are summarized in the Science Updates section herein. More detailed reports can be found in the U.S. Fish and Wildlife Service's Pallid Sturgeon 5-Year Review Summary and Evaluation, and a special issue of the *Journal of Applied Ichthyology* (Volume 23, 2007). This rapid increase in knowledge on pallid sturgeon is due largely to three factors: (1) execution of the reasonable and prudent alternatives (RPAs) for recovery issued in the U.S. Fish and Wildlife Service's 2003 Amended Biological Opinion; (2) allocation of resources by Congress and the U.S. Army Corps of Engineers to implement these RPAs; and (3) the dedication of hundreds of individuals to overcome the innumerable hurdles of working on the Missouri and Mississippi rivers, on one of the rarest fishes in the U.S., and within the interjurisdictional administrative maze of state and federal agencies. Many of these managers, biologists, and scientists participated in this workshop. However, much of the credit for what we know about pallid sturgeon goes to the seldom recognized field and laboratory staffs that spend untold days managing contracts, monitoring habitat construction, collecting and tracking sturgeon, processing samples, and summarizing data.

This workshop capitalized on what worked well at the first pallid sturgeon workshop; that is, broad representation of agencies and stakeholders, transparency, and recognizing uncertainty in our knowledge and consequences of actions. Whereas the previous pallid sturgeon workshop identified a large number of research needs, we lacked the time to prioritize them. Thus a primary objective of this 2007 workshop was to update research needs and prioritize them to assist range-wide pallid sturgeon recovery. To facilitate this, the Steering Committee made several revisions for this workshop based on feedback from participants and observers of the first workshop.

The second pallid sturgeon workshop:

- Expanded treatment of the pallid sturgeon to encompass its entire 3,300-mile range from the Missouri River to the mouth of the Mississippi River;
- Canvassed the three Pallid Sturgeon Work Groups (Upper, Middle and Lower Basins) to identify and recruit sturgeon experts and used these groups to identify and prioritize research and management needs within and across the pallid sturgeon's geographic range;

- Framed discussions around a *Scaphirhynchus* sturgeon conceptual life-history model developed by the U.S. Geological Survey which provided a framework to organize, visualize, and prioritize hypotheses of how the full range of conditions and processes might affect pallid sturgeon ecology and recovery;
- Hosted a "fish bowl" discussion where our outside experts provided insights on sturgeon biology and ecology, frankly discussed among themselves research needs and priorities, and what was or was not working in the current recovery program; and
- Increased "public observer" participation by budgeting time within each working session for their comments and recommendations.

There are currently several other multi-million dollar, large-scale river/wetland restoration or recovery programs in the U.S. in addition to the Missouri River Biological Opinion Compliance Program. Most notably, these include the California Bay-Delta Program (CALFED), Colorado River (Glenn Canyon Dam Adaptive Management Program, GCDAMP), Columbia River, Everglades (Comprehensive Everglades Restoration Program, CERP), Louisiana Coastal Area, and the Upper Mississippi River (Navigation and Ecosystem Sustainability Program, NESP). It is probable these major restoration-recovery programs will soon be competing for limited federal resources. Those programs that express explicit goals and objectives, contain measurable success criteria and a targeted monitoring program to gauge performance, incorporate independent programmatic review, implement a formal Adaptive Resource Management approach, and have significant stakeholder support will likely garner a large proportion of agency resources. We anticipate that if recommendations from this workshop are implemented, pallid sturgeon recovery will be competitive with these other important efforts.

Several challenges remain to assure continued support and maximize the effectiveness of pallid sturgeon recovery, as follows.

- Integrate the various pallid sturgeon elements of population assessment, propagation and augmentation, habitat creation and restoration, monitoring, and research on flows and life history into an integrated recovery program.
- Articulate a collective multiple stakeholder-derived vision for pallid sturgeon recovery and identify system-wide goals and objectives to achieve this vision.
- Adopt a recovery approach that encompasses the full range of the pallid sturgeon's distribution within the Missouri and Mississippi rivers.
- Incorporate results of the various research, monitoring and evaluation programs into a timely and transparent mechanism to identify and implement management actions and funding priorities. "Management-critical decisions and uncertainties" need to be expressly articulated by the U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers through use of this report and the diverse technical expertise available to them.
- Move from a species-centric approach to integrating pallid sturgeon recovery into a more holistic Missouri River Ecosystem Restoration Program (MRERP).
- Implement an aggressive outreach program to educate the public on the value of healthy rivers where pallids reside and garner and maintain their continued support.

Our collective success at bringing together the participants and observers whose deliberations and recommendations follow bodes well for improving survival prospects for this iconic fish and enhancement of the rivers wherein it resides.

David L. Galat
U. S. Geological Survey
Cooperative Research Units
Department of Fisheries & Wildlife Sciences
University of Missouri, Columbia

Executive Summary

On July 31st to August 2nd, 2007, the U.S. Army Corps of Engineers (USACE) sponsored a workshop to bring together scientists, biologists and managers to discuss research and management needs for pallid sturgeon (*Scaphirhynchus albus*). At the request of the USACE, the University of Wyoming's William D. Ruckelshaus Institute of Environment and Natural Resources organized and facilitated the workshop, with the assistance of the Meridian Institute. The goal of the workshop was to develop technical guidance for resource agencies with management authority (USACE, U.S. Fish and Wildlife Service [USFWS], states, and tribes) on prioritized research and management strategies to assist range-wide pallid sturgeon recovery. Experts from inside and outside the Missouri and Mississippi River basins were invited to identify data gaps and prioritize research needs. Fifty-nine invited technical experts and 28 public observers participated in the workshop.

Presentations provided background on the current status of pallid sturgeon populations, development of a sturgeon conceptual life-history model, and science updates from the Upper, Middle, and Lower Basin Work Groups established by the Pallid Sturgeon Recovery Team. Participants used the conceptual life-history model to help frame discussions, and suggested revisions to the model. Background information and research needs identified in a similar workshop in 2004 were the basis of discussions on current data gaps.

Participants in breakout groups were asked to prioritize research and management needs relevant to each of the three sub-basins along the length of the species' range. Two areas that emerged as top research priorities for all breakout groups were a continued or increased emphasis on the uncertainties surrounding early life stages (spawning through juveniles), and increased understanding of habitat needs for all life stages. Spawning and the survival of early life stages are critical to the recovery of the species. Many data gaps still exist. Understanding habitat requirements and seasonal use for all life stages is essential. In addition, each group identified some high priorities specific to their geographic location. The Upper Basin breakout group cited lack of recruitment, and threats to fish health (e.g., iridovirus) as priority issues where research may have the greatest impact on recovery. Aside from ongoing activities, the Middle Basin breakout group identified a scientific evaluation of the stocking program, and an adequate population assessment program in the middle Mississippi River as two areas which should be considered high priority. Lower Basin breakout group members indicated that population assessment in the lower Mississippi and Atchafalaya rivers and continuing research on genetics and hybridization between pallid and shovelnose sturgeon (*Scaphirhynchus platorynchus*) are high priorities.

Funding priorities of the USACE related to Biological Opinion compliance and species recovery were discussed and it was noted that research that addresses decision-critical uncertainties would be given priority. In funding proposals, research questions to be answered need to be clearly stated, along with how the proposal relates to range-wide recovery efforts. Research proposals that extend beyond sub-basins and also leverage other resources will be viewed favorably. Proposals need to be relevant to current issues and indicate why the proposed research is important at this point in the recovery process.

In a discussion on improving the use of science in decision-making processes a suggestion was made to include members of the three basin work groups in funding decisions, or to involve the USACE more in basin work group processes. Another primary concern was the need for a range-wide approach to funding and implementing recovery efforts. Expertise needs to be brought together more often to improve communication. Several suggestions emerged for improving connections among scientists, biologists, managers, and stakeholders.

The outcomes from this workshop are important but are not the only source of input to funding agencies on how to allocate resources. Research and management needs identified herein are intended to complement other efforts aimed at pallid sturgeon recovery. Information gained from monitoring and population assessment, research, and workshops such as this can be used in an adaptive management framework to re-evaluate objectives of the USACE and the USFWS. Improved communication among all the basin areas, as well as emphasis on maintaining a range-wide view, will enhance recovery efforts at every level.

Introduction

The pallid sturgeon (*Scaphirhynchus albus*) is a large riverine fish endemic to the Missouri River and the Middle and Lower Mississippi River, and lower sections of the major tributaries to these rivers. It was listed as endangered under the Endangered Species Act (ESA) in 1990 (55 Federal Register 36641-36647) due to population declines resulting primarily from habitat modification and commercial harvest. A workshop on *Research Needs and Management Strategies for Pallid Sturgeon Recovery* was held from July 31 through August 2, 2007 in St. Louis, Missouri to develop technical guidance on prioritized research and management strategies to assist range-wide recovery of the species. The following background section covers information on federal agency planning and management aimed at recovering the species. This information was not presented at the workshop but is included here to help provide context for this report.

Background

After the pallid sturgeon was listed as endangered, a Recovery Plan was developed by the U.S. Fish and Wildlife Service (USFWS) in 1993 to address issues that led to the listing (USFWS 1993). Following consultations between the U.S. Army Corps of Engineers (USACE) and the USFWS pursuant to requirements of the ESA, a Jeopardy Biological Opinion for pallid sturgeon covering operations of the Missouri and Kansas Rivers and the Missouri River Bank Stabilization and Navigation Project was issued in 2000 and amended in 2003 (USFWS 2000a, 2003). Other Biological Opinions have been issued for the pallid sturgeon. A Jeopardy Biological Opinion was issued for the Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System (USFWS 2000b). A Non-jeopardy Biological Opinion on the Upper Mississippi River – Illinois Waterway System Navigation Feasibility Study (USFWS 2004) and a Non-jeopardy Biological Opinion for the Platte River Recovery Implementation Program (USFWS 2006) were also recently issued by the USFWS.

The goal of the Recovery Plan is to outline tasks which, if implemented, would facilitate recovering the pallid sturgeon range-wide. Biological Opinions are documents from the USFWS arising from consultation required by the ESA with any federal agency conducting or considering actions that may harm an endangered species. The Biological Opinion states the opinion of the USFWS, based upon their interpretation of the best available science, as to whether the federal action is likely to jeopardize the continued existence of a listed species, or result in incidental take, or the destruction or adverse modification of critical habitat. Biological Opinions outline required reasonable and prudent alternatives (RPAs) and suggest conservation measures that Federal agencies must or may conduct to preclude jeopardy to the species and minimize adverse impacts during the course of operation or as a result of the proposed management action. Biological Opinions are not issued for the stated purpose of recovering a species. These two efforts, recovery planning and compliance with the Biological Opinions, have different though sometimes complementary goals. Research can be specific to RPAs or conservation measures identified within Biological Opinion goals or to Recovery Plan tasks, and many such research projects will overlap. Managers and researchers should integrate efforts throughout the recovery process where possible. Scientists can help define recovery targets and information gaps, and managers can remind scientists of the practical need for research to address pressing management decisions. Research can fill data gaps and guide management actions, which in turn

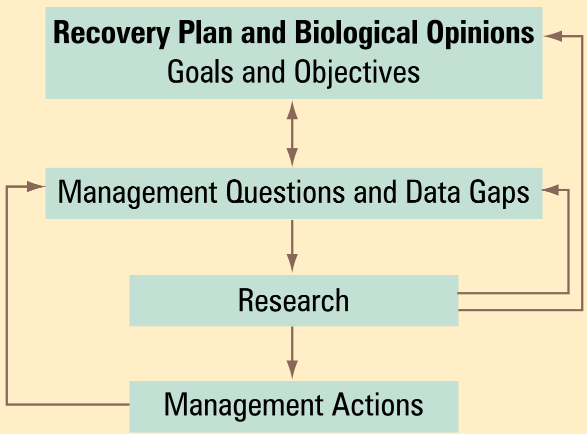


Figure 1. Relationship of research efforts to the Recovery Plan and Biological Opinions.

might raise new questions in adaptive feedback loops (Figure 1).

The 2000 Biological Opinion for the Missouri River that was amended in 2003 indicated that actions proposed by the USACE would jeopardize the pallid sturgeon. With the intent of precluding jeopardy, the USFWS provided RPAs to the USACE with elements comprising population assessment, propagation and augmentation, habitat creation and restoration, monitoring, and research on flows and life history. Goals and objectives of these elements, as outlined by Craig Fleming (Threatened and Endangered Species Section, Omaha District, USACE, personal communication, December 18, 2007) are as follows.

Pallid Sturgeon Population Assessment Program

Goal: Provide information to detect changes in pallid sturgeon and native target species populations in the Missouri River Basin.

Objectives

- Document current and long-term trends in pallid sturgeon population abundance, distribution and habitat use throughout the Missouri River system.
- Document survival, growth and habitat use of stocked pallid sturgeon in the Missouri River system.
- Document pallid sturgeon reproduction and recruitment in the Missouri River system.
- Document current and long-term trends in native Missouri River fish species abundance, distribution, and habitat usage, with emphasis on the warm water benthic fish community.

Pallid Sturgeon Propagation and Augmentation Program

Goal: Augment populations by establishing year-class structures to strengthen populations to avoid catastrophic extinction.

Objectives

- Work to develop year-class structures that are currently absent from the population due to the lack of natural reproduction and recruitment.
- Establish brood stock for future propagation efforts in case of catastrophic population decline.

Habitat Creation/Restoration/Acquisition Program

Goal: Increase the amount of shallow-water habitat available in the Lower Missouri River.

Objectives

- Alter existing habitat to increase the variability of depth and velocities.
- Increase top width of the river, creating new habitat containing a diverse mixture of depths and velocities.
- Create opportunities for re-establishing the connectivity of the floodplain to the river through creation, restoration or acquisition.

Pallid Sturgeon Habitat Assessment and Monitoring Program

Goal: Assess the physical and biological responses to habitat creation actions, which are expected to benefit pallid sturgeon and related communities.

Objectives

- Assess whether physical treatments are producing the desired habitats (types and quantity).
- Assess whether important fish variables, such as fish species composition, richness, and relative

Photo courtesy of USFWS

abundance of targeted life stages, are influenced by physical treatments.

Comprehensive Sturgeon Research Project

Goal: Assess factors affecting the reproduction, recruitment, habitat, and population dynamics of pallid sturgeon and shovelnose sturgeon in the Missouri River.

Objectives

- Document movement, habitat use and reproductive behavior of pallid and shovelnose sturgeon in the Missouri River.
- Describe the reproductive physiology of pallid and shovelnose sturgeon prior to and after successful and unsuccessful spawning.
- Determine habitat characteristics used by sturgeon for spawning, quantity of spawning habitat available, and dynamics of habitat change related to varying discharge and sediment transport.
- Assess if specific sites with coarse substrate below Gavins Point Dam are used for spawning by sturgeon.
- Evaluate the factors affecting recruitment of age-0 sturgeon.
- Develop effective forecasting models for pallid and shovelnose populations in the lower Missouri River.
- Provide database integration, geographic information science (GIS) support, and report coordination for all aspects of this project.

Water Operations

Goal: Operationally mimic a semblance of the natural hydrograph to attempt to restore environmental characteristics, cues and habitats for spawning, hatch and rearing of pallid sturgeon.

Objectives

- Gavins Point and Fort Peck Dams: provide a bimodal pulse to mimic the natural pattern of the hydrograph.
- Establish floodplain connectivity.
- Address sediment issues below Gavins Point and Fort Peck Dams.

Spring Rise Study

Goal: Assess the physical and biological response of pallid sturgeon to operational changes made at Gavins Point Dam.

Objectives

- Determine hydrologic conditions required for pallid sturgeon to successfully spawn.
- Determine hydrologic conditions for hatch, survival, and growth of larvae and young-of-year pallid sturgeon.
- Determine hydrologic conditions required for conditioning and availability of habitats associated with pallid spawning and survival to young-of-year.
- Determine the effects of hydrologic conditions on the native riverine fish fauna.

In 2003, the above elements were viewed as the best approach given the knowledge at the time. As implementation of the RPAs has proceeded, managers and scientists recognize the value of jointly discussing data gaps and research needs and refining the USACE approach in an adaptive management framework. In 2004, several federal agencies co-sponsored a collaborative workshop to help address recovery of pallid sturgeon in the Missouri River Basin. Proceedings of this workshop were published as *Research and Assessment Needs for Pallid Sturgeon Recovery in the Missouri River* (Quist et al. 2004). The workshop demonstrated the value of having open discussions with multiple stakeholders about science, management, and policy processes.

Participants at the 2004 workshop produced several lists of research needs for pallid sturgeon recovery in the Missouri River Basin. To follow-up and to expand the discussion range-wide, a 2007 workshop on *Research Needs and Management Strategies for Pallid Sturgeon Recovery* was convened. The goal of the 2007 workshop was to develop technical guidance for resource agencies with management authority on prioritized research and management strategies to assist range-wide recovery of the species. The workshop also provided a venue for collaborative information exchange among members of the scientific community and stakeholders about current research updates and new projects.

Workshop Organization

The workshop was organized by a Steering Committee and the University of Wyoming's William D. Ruckelshaus Institute of Environment and Natural Resources. Agencies represented on the Steering Committee include the USACE, USFWS, U.S. Geological Survey (USGS), U.S. Environmental Protection Agency, Nebraska Game and Parks Commission, and the Missouri Department of Natural Resources (see Appendix A). The workshop was facilitated by personnel from the Meridian Institute in Dillon, Colorado, and the Ruckelshaus Institute, who also provided meeting support. The workshop was open to the public to observe the discussions and provide input at specified times in the agenda. Fifty-nine invited technical experts from inside and outside the Missouri and Mississippi River Basins and 28 observers participated in the workshop (Appendix A).

The workshop opened with a series of plenary session presentations to provide a review of a *Scaphirhynchus* conceptual life-history model (Wildhaber et al. 2007; see below), current information on the status of the pallid sturgeon, and updates on scientific research (see Agenda, Appendix B). Participants were assigned to breakout groups based on major components of the life-history model (Habitat, Population, or Recruitment) on the first day, and geographical segments of the species range (Upper Basin, Middle Basin, or Lower Basin) on the second day. External experts on other sturgeon species or habitat provided insight into the issues under discussion and their views on the highest priority needs for the pallid sturgeon. Funding priorities of the USACE were discussed during the final plenary session, followed by group discussion of priorities, funding, collaboration, and strategies for the future.

Goal, Objective, and Charge to Participants

The workshop brought together scientists, biologists and managers to discuss what is known and what knowledge is needed about pallid sturgeon

Workshop goal, objective, and charge

Goal – Develop technical guidance on a research and recovery strategy to assist range-wide pallid sturgeon recovery.

Objective – Involve experts in reviewing existing information, identifying data gaps, prioritizing research needs, proposing an effective science process to get answers, and identifying agencies with authority over necessary research and recovery efforts.

Charge – Refine components of the life-history model and identify and prioritize research needs.

On the first day, participants and observers were charged with refining components of the sturgeon conceptual model and identifying research and assessment needs in the context of the conceptual model, the Pallid Sturgeon 5-year Review (USFWS 2007; see below), and the science updates presented in the plenary session. On the second day, attendees worked to prioritize research needs identified in the previous day's breakout sessions and at the 2004 pallid sturgeon workshop (Quist et al. 2004). Facilitators recommended basing prioritization on whether the research subject addressed ecological bottlenecks, reflected a decision-critical uncertainty, and was scientifically and technically feasible. Time (short term *versus* long term) and geographic (Upper, Middle, or Lower Basin) considerations were also to be reflected in the prioritizations.

Report Review Process

Drafts of this report were reviewed by Steering Committee members, workshop participants and observers, and other technical experts who did not attend the workshop.

Photo courtesy of USGS

Summary of Opening Plenary Session Presentations

History, Purpose, and the Compliance-Recovery Relationship

Craig Fleming opened the workshop by emphasizing that the workshop's product will be critical for promoting range-wide pallid sturgeon recovery efforts. Participants were asked to consider existing information and current understanding while developing guidance on a research and management recovery strategy for the next five to 10 years. He also explained that the workshop was organized in the context of the conceptual life-history model to assist USACE in understanding the relationship among the sturgeon's biology, the ecological system on which the sturgeon depends, the threats and impediments to the species' recovery, and the role of USACE management practices in either hindering or promoting the recovery of life history and biological systems.

Fleming explained that USACE management activities on the Missouri River (e.g., snag removal, channelization for navigation, dams, flood control, power generation, and water control for recreation and navigation) have resulted in river habitat alteration and loss. This alteration, combined in unknown proportion with effects of contaminants and commercial fishing, led to the decline and subsequent listing of the pallid sturgeon as an endangered species in 1990.

The USACE is working to address RPA elements (see Background) and meet compliance obligations for pallid sturgeon (e.g., meeting shallow-water acreage goals and stocking shortfall, conducting flow studies, and monitoring) under the Biological Opinions. Recovery efforts go beyond compliance and the USACE is committed to understanding the riverine system, constraints, and species life history to continually promote species recovery. This includes developing stakeholder relationships and programs through an open and collaborative process, as part of an adaptive management strategy to reverse current trends until pallid sturgeon populations are stable and self-sustaining.

Pallid Sturgeon 5-Year Review

George Jordan, Pallid Sturgeon Recovery Coordinator, USFWS, presented a summary of the Pallid Sturgeon 5-year review completed by the Pallid Sturgeon Recovery Team, the team's Genetic Advisory Group, and Regions 3, 4, and 6 of the USFWS (USFWS 2007).

Six Recovery Priority Management Areas (RPMAs) were designated in the Recovery Plan (Figure 2). Recently, changes to this framework have been discussed that would consolidate some RPMAs into Management Units that correspond to the broader physiographic landscape (Figure 3). However, the 5-year review discussions at this workshop and in this report reflect the original RPMAs. In RPMA 1, 52 wild pallid sturgeon have been collected in 15 years of sampling (1990-2005), and all are believed to be adult fish. Smaller sizes of pallid sturgeon are absent, suggesting that spawning, recruitment, or both are severely limited. The population is being supplemented with hatchery-raised fish. The situation is similar in RPMA 2 where only 245 pallid sturgeon were collected from 1990-2006, smaller sizes were lacking, and hatchery fish supplemented the population. Few native wild pallid sturgeon are believed to exist in RPMA 3. The current population is predominantly hatchery-stocked fish or translocated wild adults. Pallid sturgeon captures in RPMA 4 continue to increase with fishing effort, but population levels and trends, habitat use, and movement patterns remain unknown. Of the 156 pallids collected between 1999 and 2005, 51 are believed to be wild, 82 were of hatchery

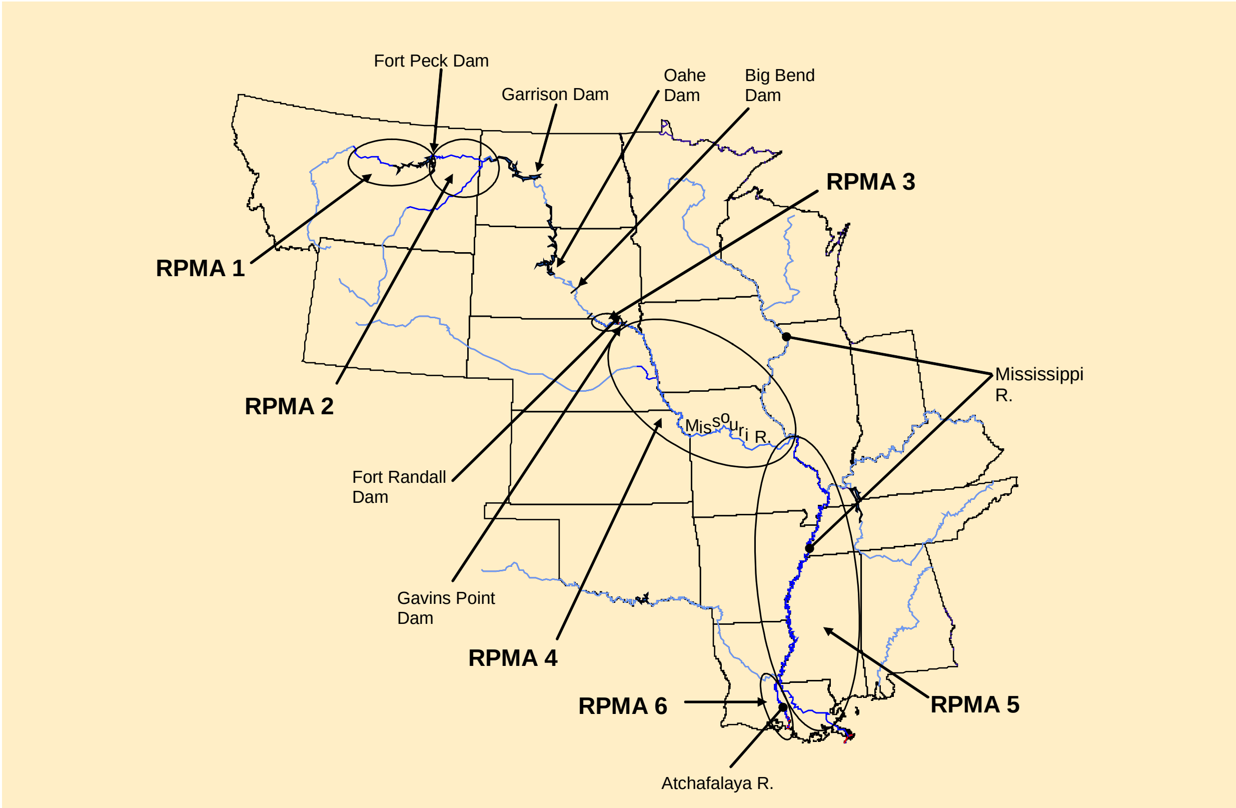


Figure 2. Recovery Priority Management Areas as defined in the Pallid Sturgeon Recovery Plan (USFWS 1993).

origin, and 24 were of unknown origin. There is limited evidence of reproduction and recruitment in RPMA 4, but it is likely occurring at levels that are insufficient to sustain the species. A similar situation exists in RPMA 5, where captures have increased with fishing effort but overall levels and trends are unknown. A conservative total of 499 pallid sturgeon were collected from the Atchafalaya River (RPMA 6) between 1991 and 2006 (using a conservative approach to species identification to separate pallid sturgeon from intermediate or "hybrid" sturgeon). Small pallid sturgeon have been collected, but further investigation is needed to document local reproduction and recruitment.

Jordan also reviewed the five reasons for listing pallid sturgeon as endangered.

Present or threatened destruction, modification or curtailment of its habitat or range.

Fifty-one percent of the range has been affected to some degree by channelization using wingdams, revetments, closing structures, and bend way weirs. Twenty-eight percent of the range is impounded with dams, and 21 percent of the range is affected by upstream impoundments, altered flow regimes, depressed turbidity and water temperatures, and continuing bank stabilization activities that limit channel meandering.

Over-utilization for commercial, recreational, scientific, or educational purposes.

At one point historical estimates of commercial harvest of all shovelnose sturgeons (most likely including pallid sturgeon) from the Mississippi and its tributaries had been reported to be as high as 700,000 pounds annually, with harvest rates between 50,000 to 100,000 pounds in the Mississippi River adjacent to the State of Illinois (Forbes and Richardson 1920). Commercial or recreational harvest of the pallid sturgeon was prohibited following listing in 1990. Five states in the Missouri River and lower Mississippi River areas currently allow commercial fishing for the morphologically similar shovelnose sturgeon, however, and pallid sturgeon remains have been discovered in commercial fish markets (Sheehan et al. 1997). Commercial fishermen have been

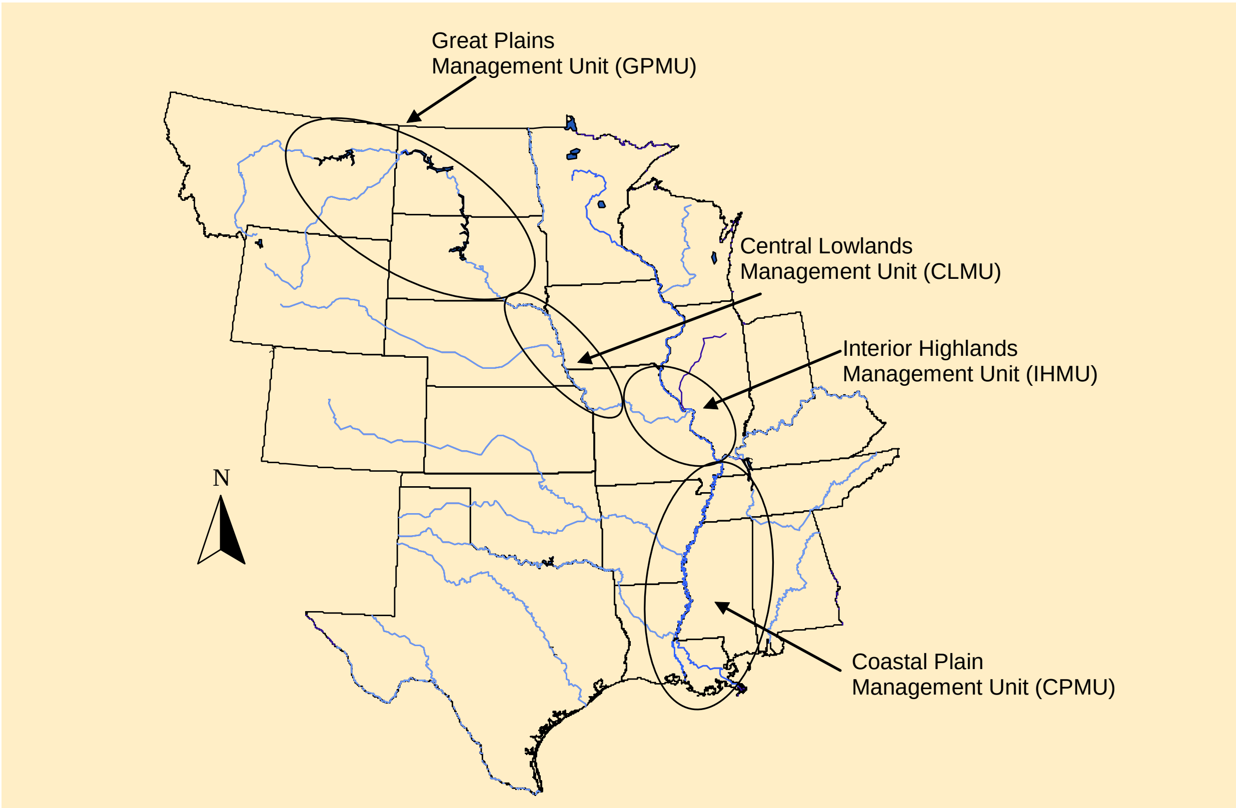


Figure 3. Outline of Management Units proposed by the Pallid Sturgeon Recovery Team in 2006.

found in possession of pallid sturgeon as recently as 2006.

Disease or predation.
An iridovirus is known to infect pallid and shovelnose sturgeon and can cause substantial mortality in hatcheries, but the effect of the virus in the wild is not well understood (Jordan 2006). Concerning predation, little has been documented about the threat in the wild but pallid sturgeon are likely eaten by predators, especially in the early life stages.

Inadequacy of existing regulatory mechanisms.
Accidental or intentional take of pallid sturgeon during commercial harvest or for scientific or educational purposes has not been fully addressed. Pallid and shovelnose sturgeon can be difficult to distinguish and this compounds the regulatory challenges.

Other natural or manmade factors affecting its continued existence.
Contaminants continue to affect pallid sturgeon, such as PCBs, cadmium, mercury, selenium, chlordane, DDE, and DDT that have been detected in three fish (Ruelle and Keenlyne 1992). Also, intersexual shovelnose sturgeon from the middle Mississippi River were found to have higher concentrations of organochlorine compounds than male shovelnose sturgeon (Koch et al. 2006). DDT metabolites, PCBs and mercury have been linked to lower condition factors, gonadal abnormalities, and hermaphrodism in white sturgeon (*Acipenser transmontanus*) (Feist et al. 2005). Finally, entrainment of pallid sturgeon occurs. In a recent study at two power generation facilities, five known hatchery-reared pallid sturgeon were entrained; three were released alive and two were found dead (Burns & McDonnell Engineering Company 2007a, 2007b).

The data indicate that without artificial supplementation, the pallid sturgeon could face local extirpation in its range above St. Louis, Missouri. Downstream from St. Louis along the Mississippi River and its tributaries, there are insufficient data on population size and recruitment trends. Thus, based on available data, the USFWS concluded that the pallid sturgeon does not meet criteria for downlisting to threatened status or for delisting in any portion of its range.

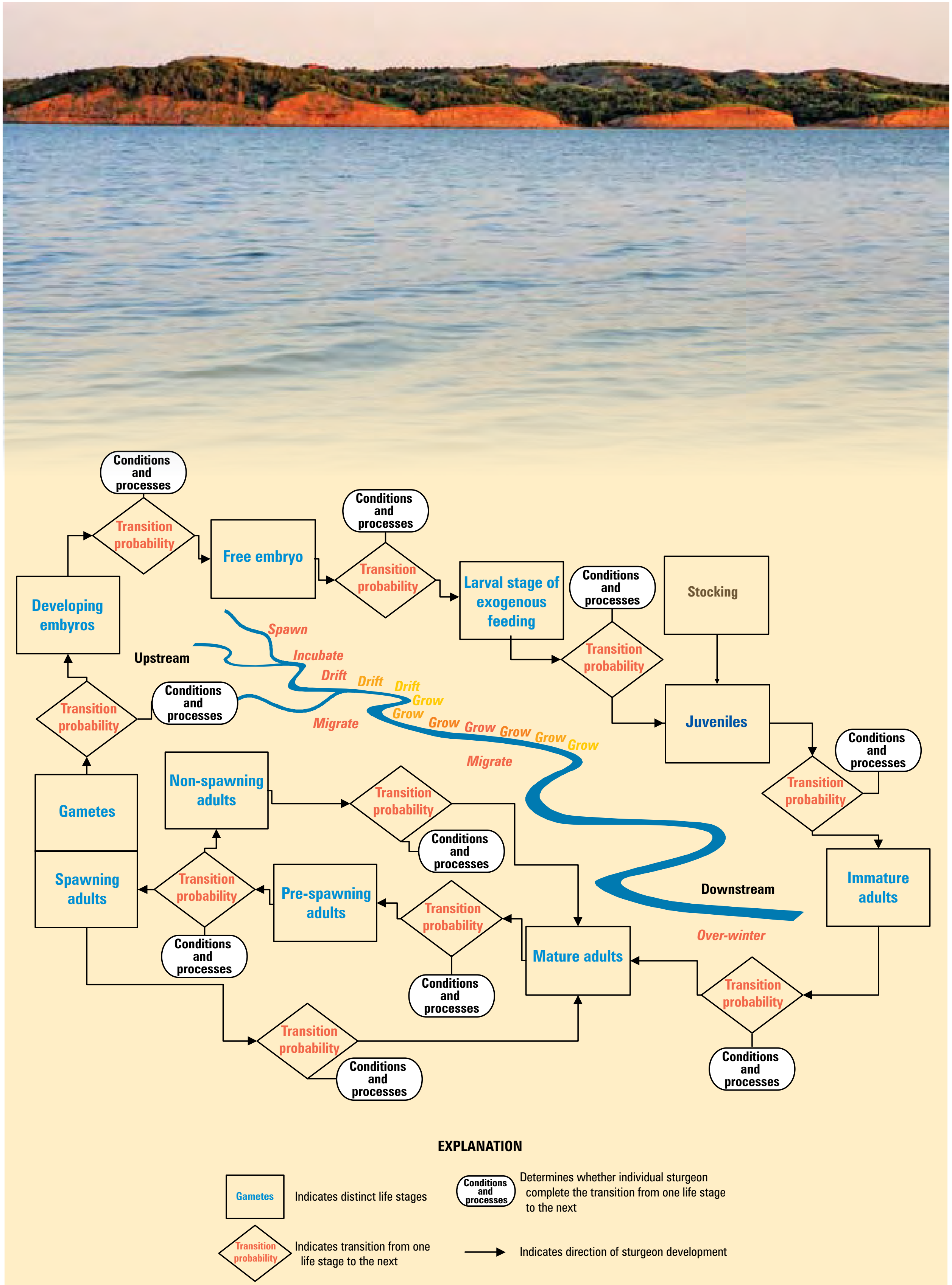


Figure 4. Overview of conceptual model of *Scaphirhynchus* sturgeon life history (from Wildhaber et al. 2007).

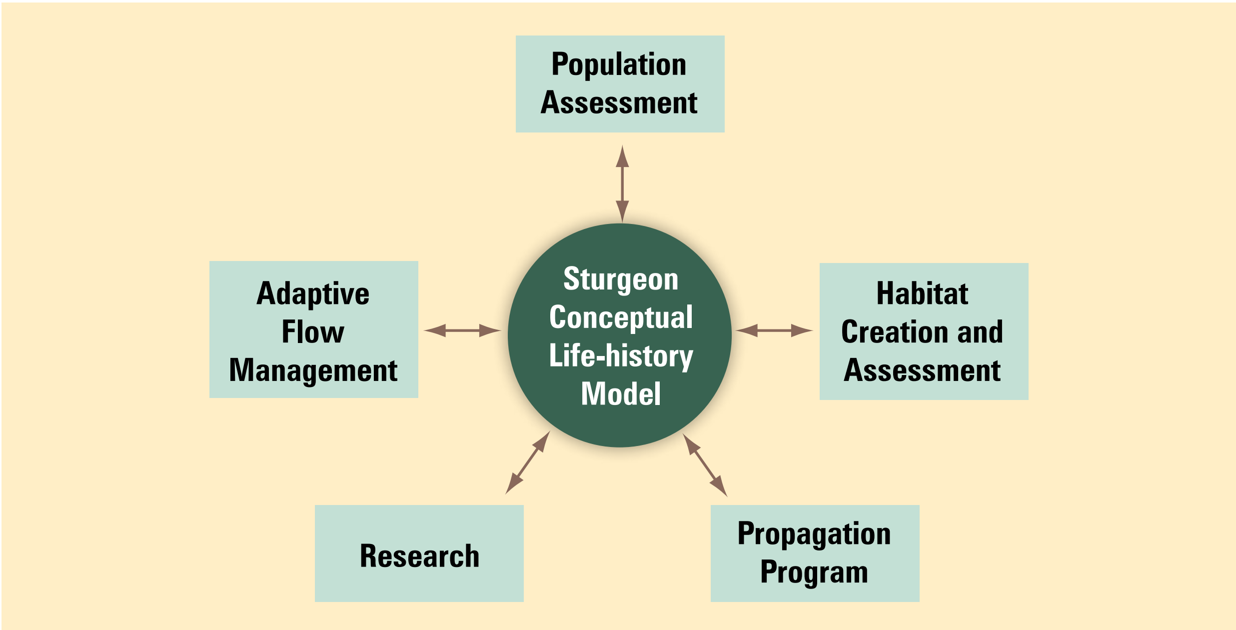


Figure 5. Relationship of the sturgeon conceptual life-history model to elements of the RPAs.

Sturgeon Conceptual Life-History Model

Aaron DeLonay, USGS Columbia Environmental Research Center (CERC) presented the sturgeon conceptual life-history model (Wildhaber et al. 2007) and a brief overview of the vision for its application. The conceptual model was created to serve as a science guide for the recovery of the species. The life history is divided into distinct life stages (boxes) and transitions from one life stage to the next (diamonds) (Figure 4). Arrows show the direction of development. Numerous conditions and processes determine whether individuals complete the transition from one life stage to the next, and submodels for each life stage further describe these conditions and processes.

As a pragmatic management tool, the model could fit within a larger ecosystem adaptive management model to benefit recovery. The life-history model is based on established knowledge about sturgeon, includes physical context at a scale appropriate to the species or population of concern, and incorporates ecological relationships. At a conceptual level, the model serves as a framework for developing a collaborative effort to organize, visualize, model, collate, communicate, prioritize, act, evaluate, adapt and re-evaluate throughout the recovery process. One important use of the model is to integrate elements of the USACE's implementation of the RPAs (Figure 5). Data gaps identified by the model can help guide research, monitoring, habitat restoration, and other efforts under the RPAs, and information gained from those efforts helps refine the model.

Photo courtesy of USGS

Science Updates

The administrative organization of the pallid sturgeon recovery program covers three distinct basin areas from northern Montana to the Gulf of Mexico. The Upper Basin covers the Missouri River Basin (including a portion of the Yellowstone River) from Montana to Gavins Point Dam in South Dakota. The Middle Basin covers the Missouri River downstream from Gavins Point Dam to the Missouri – Mississippi River confluence at St. Louis, Missouri, and also the Mississippi River from St. Louis downstream to the Mississippi – Ohio River confluence. The Lower Basin stretches from the Mississippi – Ohio River confluence downstream to the Gulf of Mexico, and includes the Atchafalya River.

To gain from the most recent information, scientists from the Upper, Middle, and Lower Basin areas were asked to present current research and new findings which are briefly summarized here (see Appendix C for more detail). These findings helped inform the workshop but are not intended to be an exhaustive compendium of current research. Some of the presented work is preliminary and is subject to change with further analysis.

Upper Basin Work Group

Pat Braaten, USGS CERC, Fort Peck, Montana presented an overview developed from input provided by the work group members.

No evidence has been found for recent spawning in the Missouri River above Fort Peck Dam. The first evidence of recent spawning below Fort Peck Dam was a 22 millimeter (mm) pallid sturgeon sampled in the Missouri River downstream from the confluence with the Yellowstone River (Braaten and Fuller 2005). In 2007, conclusive evidence of spawning was found in the Yellowstone River (RPMA 2) (contact Dave Fuller, Montana Fish Wildlife and Parks [MTFWP], Fort Peck, Montana). Spawning does occur in RPMA 2, but there is no evidence of recent recruitment. The wild adult population is estimated at 40 to 50 individuals in the Missouri River in RPMA 1 (USFWS 2007), 158 in RPMA 2 (Klungle and Baxter 2005), and low remnant numbers in RPMA 3 (USFWS 2007).

Studies in 2004 (Braaten et al. in press) and 2007 (contact Pat Braaten, USGS CERC, Fort Peck, Montana) on drift of free embryos and larvae revealed that embryos drift for at least 11 days, during day and night, and almost exclusively in the lower 0.5 meters (m) of the water column. Total drift distance depends on water velocity and larvae may drift more than 500 kilometers (km).

Water temperature is important for developing embryos and recent laboratory research showed that lethal temperatures were 8 and 28 °C for shovelnose sturgeon embryos and 8 and 26 °C for pallid sturgeon embryos (contact Molly Webb and Kevin Kappenman, USFWS, Bozeman Fish Technology Center, Bozeman, Montana). The highest survival rates for both species were found between 12 and 20 °C.

Studies on fish health are focusing on iridoviral infections that cause a decrease in the number of sensory cells (taste buds) in the skin, with highly variable mortality rates (contact Beth MacConnell, USFWS Bozeman Fish Health Center, Bozeman, Montana). Research is proceeding on genetic tagging methods for pallid sturgeon of hatchery origin in the Upper Missouri River, with the advantage that fish can be released much earlier since there is no minimum size for tagging (contact Pat DeHaan, USFWS Abernathy Fish Technology Center, Longview, Washington).

Evaluation of the Yellowstone River above Intake Diversion for stocking juveniles indicated that this area may be suitable for pallid sturgeon restoration (contact Matt Jaeger, MTFWP, Glendive, Montana). The Upper Basin Work Group has developed a draft 10-year operational strategy for implementing pallid sturgeon recovery within their reach (Upper Basin Pallid Sturgeon Recovery Work Group 2008). This strategy will facilitate development of annual work plans, including specific recovery actions and costs. Its preparation made use of existing recovery prioritization exercises and the Pallid Sturgeon Recovery Plan to determine important components of recovery. The strategy describes these in a timeline with budgets and considers planning and compliance issues. This 10-year strategy is a working document that will be updated in an adaptive fashion.

Middle Basin Work Group

Robert Jacobson, USGS CERC, Columbia, Missouri, presented an overview developed from input provided by the work group members.

Pallid sturgeon and shovelnose sturgeon, including female shovelnose sturgeon with black eggs, were found from March through August, 2006 near coarse-substrate habitats that are located within five rivermiles downstream from Gavins Point Dam. Shovelnose sturgeon were found to aggregate near these coarse-substrate habitats during the winter period in March 2006, but significant aggregations were not documented during other flow periods (March Pulse, Interpulse, May Pulse, or Summer periods) in 2006. Based on the collections of free embryos, coupled with developmental rates and water temperatures, *Scaphirhynchus* sturgeon spawned in the Missouri River between the confluence of the James River and Ponca, Nebraska in late May and early June of 2006 when flows were 21,000-25,000 cubic feet per second (cfs) and temperatures were 19-23 ˚C. However, collection of a single free embryo in August, 2006 immediately upstream from the James River confluence suggests that *Scaphirhynchus* can spawn under variable flows (> 30,000 cfs) and water temperatures (>25 ˚C) and have an extensive spawning period (contact Darin Simpkins, USGS CERC, Columbia, Missouri).

Immature and reproductively mature wild pallid sturgeon are present in the Lower Missouri River, and adult pallid sturgeon in reproductive condition are present throughout the Lower Missouri River. Spawning has been documented by collection of exogenously-feeding larvae (> 16 mm total length; contact Wyatt Doyle, USFWS, Columbia, Missouri) and tagged, spent females.

Photo courtesy of USWFS

Shovelnose sturgeon spawning occurs in multiple places, from mid March to mid August peaking in April/May at 16-25 °C. Reproductive anomalies were regularly observed in Lower Missouri River sturgeon, including intersex gonads and teratomas (contact Aaron Delonay and Diana Papoulias, USGS CERC, Columbia, Missouri).

During spring sturgeon sampling and focused adult collection efforts in 2007, one reproductive male and one reproductive female, out of 10 adult fish, were collected in Lower RPMA 4 and the Middle Mississippi River. In Upper RPMA 4 on the Missouri River, eight reproductive males and one reproductive female were collected. This was the first year to capture and successfully spawn a gravid female as part of the propagation/population augmentation program in the Lower Missouri River (contact Wyatt Doyle, UWFWS, Columbia, Missouri).

Studies of habitat dynamics in the Lower Missouri River indicate that potential spawning substrate is abundant but distributed non-uniformly in discrete patches. Gravel-cobble substrate occurs in abundance in the Missouri River between Gavins Point Dam and Ponca, Nebraska. Preliminary analysis of telemetry locations and habitat maps indicates reproductive female shovelnose sturgeon tend to select reaches with diverse hydraulics, with both divergent and convergent flows (contact Robert Jacobson, USGS CERC, Columbia, Missouri).

Of 175,000 larval fishes collected in shallow water habitats associated with sandbars in the Lower Missouri River during a study from 2002 to 2004, eight were *Scaphirhynchus* larvae; two were verified morphometrically by the Colorado State University Larval Fish Laboratory (D. Snyder, personal communication) as large enough to be exogenously-feeding *S. albus* larvae. Of 24,500 small-bodied fishes collected in shallow waters in a 2005 study, none were *Scaphirhynchus* (contact David Galat, University of Missouri, Columbia, Missouri).

From 2002 to 2005, sturgeon sampling in the Middle Mississippi River resulted in a population estimate of 1,600 to 4,900 pallid sturgeon. Pallid sturgeon habitat was identified as adjacent to the main channel near wing dikes and islands (contact Jim Garvey, Southern Illinois University, Carbondale, Illinois; and Dave Herzog, Missouri Department of Conservation, Jackson, Missouri). Similarly, a telemetry study of pallid sturgeon habitat preference revealed that wing dike habitat was selected more than expected (contact Jim Garvey, Southern Illinois University, Carbondale, Illinois).

Lower Basin Work Group

Jan Hoover, USACE, Vicksburg, Mississippi, presented an overview developed from input provided by the work group members.

Hybridization between pallid and shovelnose sturgeon is an important issue. Genetic analyses of field-collected fish revealed that pallid sturgeon, shovelnose sturgeon, and "intermediate" forms from the Lower Mississippi River are distinct. Twenty-five percent of morphologically "intermediate" fish exhibited unique alleles. Morphological "intermediates" are not genetic "intermediates" and are not necessarily "hybrids" (Ray et al. 2007). Morphologically, pallid and shovelnose sturgeon from the Lower Mississippi River were distinct, and pallids from the Lower Mississippi River were more similar to shovelnose sturgeon than were pallids from the Upper Missouri River. Morphological variance within pallids increased moving upstream from the Lower to the Middle Mississippi River (Murphy et al. 2007a). Approximately 5 percent of sturgeon captured had morphological anomalies such as no tails, or anomalies caused by physical injury. The fish still seem to thrive and grow. The frequency of anomaly types differed between the Lower Mississippi River and Middle Mississippi River, and taillessness occurred more in the Middle Mississippi River (Murphy et al. 2007b).

A diet study of pallid and shovelnose sturgeon revealed that only pallids were piscivorous, while shovelnose sturgeon consumed invertebrates. Both pallid sturgeon and shovelnose sturgeon in the Lower Mississippi River showed greater feeding on Trichoptera (caddisflies) and Ephemeroptera (mayflies) in the winter than in the spring, but in the Middle Mississippi River fish showed reduced feeding on those same taxa. Both species in the Lower Mississippi River fed on a greater diversity of prey in the winter than in the spring. For pallid sturgeon, fish were the volumetrically dominant component of the diet (>52 percent) in both populations and during both seasons (Hoover et al. 2007). Many of the fish were unidentifiable to family or genus, but identifiable prey included Cyprinidae (minnows), many of which were *Macrhybopsis spp*. (chubs), Sciaenidae (freshwater drum), and Clupeidae (shad). Cyprinidae comprised 6 to 32 percent of total food volume, Sciaenidae less than 9 percent, and Clupeidae less than 6 percent.

A five-year telemetry study on habitat use and movement in the Atchafalaya and Mississippi rivers is underway. So far, 25 mature pallid sturgeon have been implanted with sonic tags in the Atchafalaya River, and four mature pallids were implanted in the Mississippi River (contact Paul Hartfield, USFWS, Jackson, Mississippi).

Pallid sturgeon abundance in the Mississippi River was evaluated by Killgore et al. (2007a). The researchers concluded that specimen size and relative abundance follow a latitudinal trend. Pallids are most abundant in the extremes of the range (lower part of the Lower Mississippi River and upper part of the Middle Mississippi River). The population size of pallid sturgeon below the Low Sill of the Old River Control Complex in the Atchafalaya River was estimated at about 260 adult or subadult fish in the winter and early spring of 2007.

Commercial harvest of shovelnose sturgeon is a big concern because it is difficult to distinguish shovelnose sturgeon and pallid sturgeon, and pallids are known to be taken either accidentally or on purpose (USFWS 2007). In May, 2007, the USACE wrote a letter to the USFWS requesting that commercial harvest of shovelnose sturgeon be closed in the five states bordering the pallid sturgeon range, to protect the pallid sturgeon.

Photo courtesy of USGS

Sturgeon Conceptual Life-History Model

Workshop participants were assigned to Habitat, Recruitment, or Population breakout groups on the basis of expertise to discuss refinements to the life-history model. The facilitation team asked participants to refine the model and to view research and assessment needs identified in the 2004 pallid sturgeon workshop in the context of the model, the Pallid Sturgeon Recovery Plan 5-year review, and the science updates. Definitions of habitat, recruitment, and population were contributed to the report after the workshop to help clarify the use of these terms (see Boxes 1-3).

Refinements to the Life-History Model

The model helps researchers understand the assumptions and decisions involved in pallid sturgeon management. Modifications will improve its use as part of the recovery effort, especially at the regional level where sub-models will be useful to highlight differences in limiting factors across the pallid sturgeon's range. Spatially explicit relationships also need to be investigated so that the model reflects the range of sturgeon movements. An important message accompanying the modifications recommended by workshop participants was to continually examine the assumptions behind the model. For example, lack of measurable recruitment may occur as the result of too few adults, an absence of spawning cues, or increased predation in modified habitats, but it could also occur due to insufficient lengths of fluvial habitat for drifting larvae to develop and settle. Suggested refinements to the model from each breakout group are as follows (see Appendix D for more detail).

Habitat Breakout Group

Participants in the habitat group recommended several alterations to the model:

- Change "channel engineering" to "channel constraints" to include natural features as well as constructed features;
- Develop the interactions between habitat and biotic factors (e.g., predation is affected by flow regime);
- Provide better definition of hydraulic habitat (e.g., incorporate depth, shear stress and velocity gradients);
- Emphasize the importance of habitat (including determining the characteristics of quality habitat) and productivity; and
- Integrate alternative water management scenarios into the model (e.g., reservoir operation and irrigation).

Box 1: Habitat Concepts Related to Pallid Sturgeon Reproduction and Survival

by Robert Jacobson, Wayne Stancill, and Scott Kenner

Habitat is frequently cited as a possible limitation on reproduction and survival of pallid sturgeon. Emerging information on sturgeon habitat use and availability indicates that our understanding of habitat may need to be substantially broadened beyond point measures of depth, velocity, and substrate.

Habitat is defined as the place or a set of places where a fish, a fish population, or a fish assemblage finds suitable environmental features to survive and reproduce (Orth and White 1999). The more restricted definition of *physical* habitat is the three-dimensional structure in which riverine organisms live; time (frequency, duration, sequence, rate of change) adds a critical fourth dimension (Gordon et al. 1992). Water depth, flow velocity, and substrate are the three main point characteristics of physical habitat (or biotopes) that are usually evaluated to assess the physical habitat template (Gorman and Karr 1978, Gordon et al. 1992, Clifford et al. 2006). Fausch and White (1981) and Hayes and Jowett (1994) provided research indicating velocity gradients are also important features of fish habitat and Crowder and Diplas (2000, 2002) developed metrics to quantify and differentiate spatial metrics. Water quality parameters like temperature, turbidity, and dissolved oxygen present additional variability to characterizing the habitat template. The interaction of flow regime, channel morphology, and water quality can create complex patterns of habitat patches (that is, volumes or areas characterized by uniform habitat characteristics) in time and space, which may need to be captured to adequately address habitat limitations.

Some of the generic components of habitat assessments are as follows.

Determination of habitat requirements and preferences of pallid sturgeon for critical life stages, including spawning, larval, juvenile, and adult stages. This may require intensive research in unaltered environments or controlled laboratory studies.

Determination of habitat use and selection. Habitat use contrasts with preference as it is a measure of habitat in the vicinity of fish locations which may be the best available to the fish, but not optimal or preferred habitat. Selection is measured as the ratio between used and available habitats. Habitat use may indicate utilizing resources produced in a habitat where the fish is not actually located (e.g., drifting invertebrates) as well as the benefits derived from the physical attributes associated with the habitat where a fish is located (e.g., inundated vegetation for nursery habitat).

Determination of temporal and spatial distributions of habitat patches for critical life stages, including assessment of ecological function of patches, trophic contributions and connections, patch dynamics, drift/retention dynamics, migration corridors, and how habitat processes are affected by modifications of flow regime and channel morphology.

Determination of hydrologic and sediment transport conditions necessary for formation and maintenance of pallid sturgeon habitats.

Evaluation of the role of mass fluxes, particularly sediment and organic materials, in maintaining ecological functions of habitats needed by pallid sturgeon.

Evaluation of the role of hydrologic connectivity of habitats through the channel network in reproduction and survival of pallid sturgeon (Benda et al. 2004).

Recruitment Breakout Group

Participants in the recruitment group identified two primary modifications to the model:

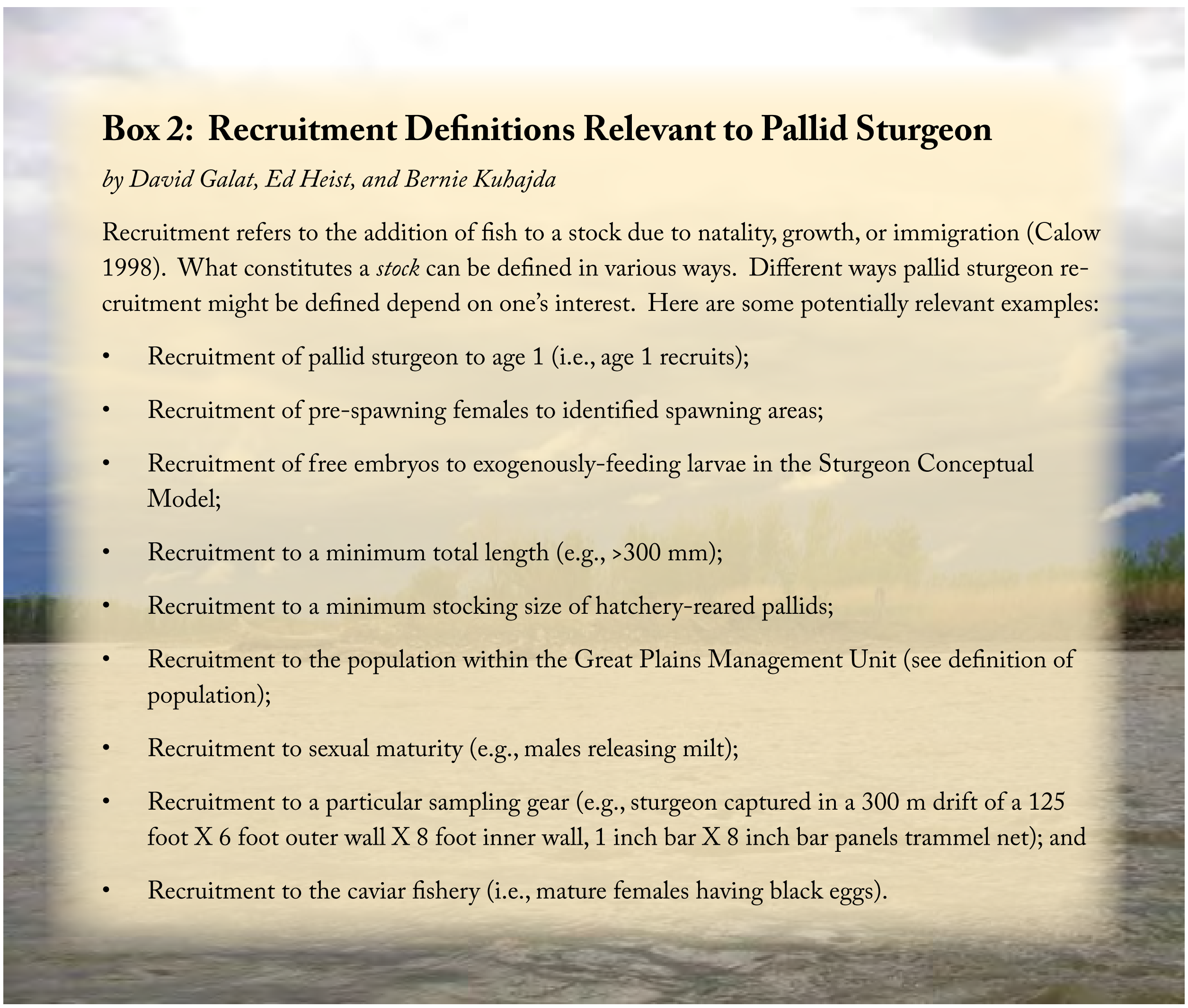
- Emphasize that larval drift is an important component of *Scaphirhynchus* life history strategy and integrate drift into the free embryo box.
- Add captive broodstock to the model. Artificial propagation was described as the "blind edge that is just falling off [the model]." The group envisioned linking a broodstock box to spawning adults to emphasize the connectivity between the two, especially relative to recovery efforts.

Population Breakout Group

The population group's recommendations for modifications to the model were extensive and detailed (Appendix D). Briefly, the recommendations included:

- Create separate model components for wild fish and hatchery fish, to acknowledge factors that selectively affect each;
- Incorporate stocking (including larvae), artificial propagation, and immigration; and
- Add reservoir operations as another factor under hydraulic habitat rather than just connected to flow.

For a more detailed summary of discussions in the first day's breakout groups, please see Appendix D.



Box 2: Recruitment Definitions Relevant to Pallid Sturgeon

by David Galat, Ed Heist, and Bernie Kuhajda

Recruitment refers to the addition of fish to a stock due to natality, growth, or immigration (Calow 1998). What constitutes a *stock* can be defined in various ways. Different ways pallid sturgeon recruitment might be defined depend on one's interest. Here are some potentially relevant examples:

- Recruitment of pallid sturgeon to age 1 (i.e., age 1 recruits);
- Recruitment of pre-spawning females to identified spawning areas;
- Recruitment of free embryos to exogenously-feeding larvae in the Sturgeon Conceptual Model;
- Recruitment to a minimum total length (e.g., >300 mm);
- Recruitment to a minimum stocking size of hatchery-reared pallids;
- Recruitment to the population within the Great Plains Management Unit (see definition of population);
- Recruitment to sexual maturity (e.g., males releasing milt);
- Recruitment to a particular sampling gear (e.g., sturgeon captured in a 300 m drift of a 125 foot X 6 foot outer wall X 8 foot inner wall, 1 inch bar X 8 inch bar panels trammel net); and
- Recruitment to the caviar fishery (i.e., mature females having black eggs).

Photo courtesy of USGS

Box 3: Population Definitions Relevant to Pallid Sturgeon

by David Galat, Ed Heist, and Bernie Kuhajda

A population is a group of individuals of the same species in a defined area at a given time. Based on this dynamic definition, if several populations of a fish species located throughout the system remain segregated for much of the year, but aggregate during spawning, they then constitute a single *spawning* population at that time. "Group" has been variously defined as individuals sharing a common gene pool or a common set of morphometric and meristic characters (Wooton 1990). Members of a population interbreed, but are unlikely to interbreed with members of other populations. The Pallid Sturgeon Recovery Team has recommended adoption of Management Units based on Geologic Provinces (Great Plains, Central Lowlands, Interior Highlands, and Coastal Plain) (Figure 3) to reflect the breaks seen between other related fish species and the change at these boundaries in the large-river fish communities (B. Kuhajda, personal communication 2007). Management units are usually defined as demographically independent populations whose population dynamics (e.g., population growth rate) depend largely on local birth and death rates rather than on immigration (Palsbøll et al. 2006). Management Units are populations of conspecific individuals among which the degree of connectivity is sufficiently low so that each population should be monitored and managed separately (Taylor and Dizon 1999).

Genetic studies using mitochondrial DNA (Campton et al. 2000) and microsatellites (Tranah et al. 2001) found that pallid sturgeon from the upper Missouri River were nearly as distinct from pallid sturgeon in the Atchafalaya River as pallid sturgeon were from shovelnose sturgeon. More recent microsatellite analyses (Schrey and Heist 2007) determined that pallid sturgeon from the middle of the range (Lower Missouri River and Middle Mississippi River) were genetically intermediate to those at the extremes of the range. In that latter study, pallid sturgeon exhibited an "isolation by distance" pattern in which geographic proximity and genetic similarity were correlated. To date there has not been sufficient sampling throughout the range of pallid sturgeon to determine whether there are significant natural breaks among pallid sturgeon "populations." Ideally such studies should focus on spawning adults and/or exogenously-feeding larvae since reproductively isolated populations may mix at times other than spawning. From a conservation genetics perspective it is considered better to err on the side of assumed genetic structure and protect "populations" from stocking of progeny from other "populations" based on Management Units.

What constitutes a pallid sturgeon population from a systematic perspective is currently problematic. First, we do not have the proper morphologic or genetic characters to build a phylogeny of *Scaphirhynchus*, so we do not yet know if the pallid sturgeon is a single lineage. Second, as mentioned above, we lack proper geographic coverage or sampling for microsatellite data to determine where, or if anywhere, significant breaks occur in the allele frequencies of *S. albus*. Consequently, at the present time distinct populations of pallid sturgeon, separate pallid sturgeon species, or clinal variation within pallid sturgeon are all potential hypotheses with much testing yet to be done.

Views from External Experts

One purpose of the workshop was to gain the views of experts from outside the Missouri River and Mississippi basins who work with different sturgeon species or bring a different perspective on habitat. These researchers each presented observations from their own work, and participated in a special "fish-bowl" facilitated discussion about research priorities among themselves (see Appendix E for more detail). Several research and management needs emerged from these presentations and discussions, including:

- Focus hypothesis testing on causation, not correlation;
- Examine contaminant effects on sturgeon;
- Conduct population assessments range-wide, but especially in the Lower Basin;
- Define spawning windows and the relative importance of photoperiod, temperature, and spring flow rise;
- Develop better parameters to quantify habitat and to address its creation and sustainability;
- Engage in more laboratory studies on habitat selection and innate habitat preferences;
- Use hydraulic models to help understand larval drift and settling;
- Increase propagation efforts to increase the number of spawning fish in the wild;
- Identify and protect the best populations in the range;
- Identify sources of local broodstock in different sub-basins; and
- Distribute the captive broodstock held at Gavins Point National Fish Hatchery among multiple facilities to reduce the risk of catastrophic loss.

Photo courtesy of USFWS

Identified and Prioritized Research and Management Needs

In the second breakout session, participants were assigned to groups based on their familiarity with a geographic location (Upper, Middle, or Lower Basin). Using a list of research and management needs identified in 2004 (see Appendix G) and the preliminary needs identified in the first breakout session (Appendix D), participants prioritized current research needs. These priority needs will be used by the USACE to develop future requests for proposals for research and science contracts.

Overview

Two common high priorities emerged from the breakout group discussions that apply to the entire pallid sturgeon range. First is the importance of early life stages (spawning through juveniles), because these stages have the biggest knowledge gaps and are ecological bottlenecks. Spawning success or failure, and survival from hatch through the transition to exogenous feeding, need to be quantified and linked to environmental conditions. Research on spawning and early life stage requirements is ongoing (as noted in the Science Updates section of this report), and remains a very high priority for all three sub-basin areas.

The second common priority is the need to understand seasonal habitat requirements and use for all life stages. Again, research is ongoing in this area but more information is needed, particularly to assist the USACE with their habitat creation and restoration program. High priority habitat needs included understanding water flow requirements, the effects of flows on the hydraulic conditions relative to various life stage requirements, the role of sediment transport and discharge, and determining the characteristics of quality spawning habitat. Habitat was also identified as a high priority by the external experts, who noted that laboratory studies can help illuminate habitat preferences.

In addition to the above, some high priority needs were specific to sub-basin areas. The Upper Basin contains several major dams and reservoirs on the Missouri River. Lack of pallid sturgeon recruitment is a big concern with several possible causes (e.g., temperature, turbidity, habitat fragmentation due to the dams, and low population numbers). Reservoirs have artificial temperature and flow fluctuations with unknown effects. The cause of larval deaths is unknown, but could be a lack of food, predation, or related to sedimentation in reservoirs. Studies have indicated that larvae drift long distances and further understanding of larval drift is particularly important and needs to be emphasized in the conceptual life-history model. Research on the survival rates of hatchery-raised juveniles released into the Yellowstone and Missouri rivers is ongoing and remains a high priority. Understanding long-term movement patterns of adult pallid sturgeon was also ranked as high priority.

Another priority area particularly in the Upper Basin is the threat to pallid sturgeon from iridovirus, contaminants, and native and non-native predators and competitors. Studies on iridovirus are underway and need to continue, but little is known about impacts from contaminants and introduced or invasive species.

In addition to ongoing activities in the Middle Basin, implementing a scientific evaluation of the stocking program is a high priority. External experts put a high priority on maintaining broodstock in more than one location and in different basin areas, and on increasing the number of spawning adults in the wild. Artificial propagation also needs to be integrated into the sturgeon conceptual life-history model. Another high priority is population assessment in the Middle Mississippi River (Lock and Dam 26 to the mouth of the Ohio River at Cairo, Illinois).

The Lower Basin population of pallid sturgeon appears to be reproducing more successfully than other parts of the range. In the Mississippi River downstream from Cairo, Illinois, reproductive success is less of a concern. Understanding sturgeon populations in the Lower Basin is very important and population assessment in the Lower Mississippi and Atchafalaya rivers is a high priority for researchers and managers in this area. This was also noted by the outside experts who expressed that identifying and protecting the best populations in the range is a high priority. Also, research on genetics and hybridization of pallid and shovelnose sturgeon is ongoing and remains a high priority in the Lower Basin where morphological intermediates are found.

An overarching theme that came up often during the workshop is the need for more communication among managers, biologists, researchers, and stakeholders throughout the species' geographic range. Better communication would help advance research and recovery efforts in several areas. One example is the question of whether there are distinct populations of pallid sturgeon in different parts of its range. River segments in the Upper Basin are isolated due to dams, with unknown impacts on pallid sturgeon populations. Where there are few barriers to movement, as in the Lower Missouri River and in the Mississippi River, sturgeon can move long distances and coordination is needed to study the populations and potential intermixing in the Middle and Lower Basins. Another example is comparative studies of fish behavior in the Yellowstone, Missouri, and Mississippi Rivers to understand commonalities in the habitat characteristics fish are selecting. Related to the importance of range-wide communication and as indicated below in the discussion on funding priorities, research proposals that include collaboration among sub-basins will be given high priority by the USACE.

For all of the research needs, important advice was provided by the external experts to focus on causation, not correlation. Specific high priority research and management needs identified for each sub-basin are shown below. Details on medium or low priorities for each breakout group and discussion summaries are included in Appendix F.

Specific High Priority Needs for each Sub-Basin Area

Priority information needs were evaluated by each sub-basin area and were classified according to whether work was already underway to address the need (ongoing) or whether it was a short-term (one to three year) or long-term (multi-year to decade) issue.

Upper Basin

Early life stages

- Quantify survival rates and year-class density of hatchery-raised juvenile pallid sturgeon released into the Missouri and Yellowstone rivers. Ongoing.
- Quantify growth and survival rates from hatch through the transition to exogenous feeding, and from the onset of exogenous feeding through the termination of the growing season as related to environmental conditions. Short term.
- Determine if larval survival is related to drift distance and time. Long term.

Habitat

- Evaluate methods for defining flow requirements and select methods most appropriate to specific stream reaches. Ongoing.

- Evaluate fish passage management actions and flow for habitat restoration. Short term.
- Identify limiting habitats for larvae and age-0 juveniles. This is short-term research if conducted in the lab. Without a lab component, the feasibility of the study is reduced and it becomes a long-term priority.
- Describe food habits and evaluate the role of prey production. Short term.
- Determine necessary instream flow requirements. Short term.
- Identify limiting habitats for age-1+ pallid sturgeon. Ongoing.

Reproduction

- Quantify spawning success and failure in the Missouri and Yellowstone rivers and tributaries based on collections of eggs, larvae and young-of-year, and relate to environmental conditions. Short term. Participants suggested adding a laboratory component to current projects in addition to field work.

Adults

- Determine long-term movement patterns in adults. Long term.

Fish health

- Determine threats to fish health, especially iridovirus. Ongoing.

Middle Basin

Early life stages

- Describe food habits and determine ontogenetic diet shifts of larvae and age-0 juveniles. Compare transition to feeding in hatcheries and transition to exogenous feeding in the wild. Ongoing.
- Describe food habits and determine ontogenetic diet shifts for age-1+. Short term.
- Determine drift time for larval sturgeon from Middle Basin broodstock. Short term.

Habitat

- Examine habitat requirements and use by pallid sturgeon age-1+ and determine which habitats are limiting. Long term.
- Examine habitat requirements and use by larvae and age-0 juveniles and determine which habitats are limiting. Long term. Fish travel a long way and do not conduct their entire life cycle in one stretch. Time and space are factors that should be considered in these priorities.
- Re-examine assumptions about the importance of shallow water habitats (as defined in the 2000 Biological Opinion) to juvenile life stages. Juveniles may not be found in these shallow water habitats but the habitat may be important for prey production. Long term.
- Evaluate the role of sediment transport and discharge for creation and maintenance of habitat for all life history stages. Consider the different approaches from the point of view of biology and engineering. Long term.
- Determine the linkages between habitat and biotic factors for egg to free embryos stages. Long term.
- Determine the flow levels needed to move drifting larvae into critical juvenile rearing areas (e.g., shallow water habitat or vegetated habitat zones). This would address the feasibility of inundating habitat hypothesized to be important to survival of early life stages (Coutant 2004). Long term.
- Fill information gaps on the effects of reservoir operations on embryo-larval stages, such as artificial temperature fluctuations. Long term.
- Determine if dissolved oxygen levels are important to the survival of early life stages of pallid sturgeon. Long term.

Reproduction

- Determine parameters that best characterize spawning habitat and create common range-wide approaches on how to characterize that habitat. Long term. Views on spawning habitat have evolved since 2004. Spawning habitat was viewed as special and limited, but researchers now have evidence that there is more substrate heterogeneity, and spawning of shovelnose and pallid sturgeon occurs over a wide range of areas. Site fidelity and genetic issues indicate that this may be an important question for


Photo courtesy of USFWS

recovery. Also, research is needed on whether there are specific hydraulic conditions (shear stress, flow vorticity, etc.) that support spawning.

- Develop a better understanding of environmental factors that influence maturation and spawning movements, including homing. Long term. Current studies can be enhanced with iterative field work and lab work to determine causality. Other issues identified in 2004 that fall within this research area and need to be further explored include determining what food resources are necessary prior to migration to enable pallid sturgeon to complete the journey to spawning, determining the factors that elicit spawning and egg deposition, and determining which aspect of temperature triggers or prevents spawning and whether it is a constant level or a dynamic range.

- Implement a scientific evaluation of the pallid sturgeon stocking program. Short term. This priority could be integrated into a genetics plan.

Population assessment

- Collate and summarize existing data and continue development of population viability models. Ongoing.

- Expand and enhance standard protocols for sampling and modeling for all life-history stages, especially for conducting long-term monitoring and sex-specific monitoring. Long term.

- Conduct demographic sampling of the Middle Mississippi River. Three primary threat areas were identified for the Middle Basin: life stages/spawning to age 1; habitat requirements by life stage; and demographics. Demographic sampling was prioritized to include information on population structure, genetics, and the relative contribution of hatcheries. Short term.

Lower Basin

Early life stages

- Determine the causative agents affecting survival and growth in the early life stages. Long term. There is intrinsic evidence that recruitment is occurring in the Lower Basin because most fish post-date the ESA listing. However, additional data are needed to determine where and at what level reproduction and recruitment are occurring, and whether it is sufficient to maintain a sustainable population.

Habitat

- Determine habitats required for foraging, wintering, and spawning. Long term. This cross-cuts all life stages. The Lower Basin has many habitat features that are thought to be consistent with quality pallid sturgeon habitat, including long reaches of unimpeded river, a seasonally variable hydrograph, a natural temperature regime, high turbidity, and a significant amount of habitat diversity within the river channel and off-channel. Despite this perception group members felt that habitat research has not been prioritized or pursued, and further that the relative importance of habitat quantity and quality to the health of sturgeon populations in this area as compared to other factors has not been thoroughly examined. The group recommended focusing research on determining innate habitat preferences and then comparing those preferences to habitat availability. For management projects, several participants recommended focusing on habitat engineering, such as maintaining and improving habitat through USACE projects. Concerns were voiced over the lack of understanding surrounding habitat and the potential harmful consequences of habitat modification, particularly to main channel habitat. If modifications are to occur, monitoring before and after the project is necessary.

Population assessment

- Determine the population status and life history of pallid sturgeon in the Atchafalaya and Mississippi rivers. Long term. Population information from the Lower Basin and Lower Mississippi River is the largest demographic data gap in the entire range of pallid sturgeon and is important especially in relation to the connectivity of the entire river system. It is unclear if the river system has separate or mixed populations, making it difficult to define a fundamental management unit. Group members suggested using tagging and recapture along with telemetry to connect abundance assessment with pallid sturgeon movement. Another issue related to population assessment and genetics is the need for sturgeon early life-stage identification.

Genetics

- Determine the genetic structure of *Scaphirhynchus* and if intermediates are natural. Long term. Understanding genetic issues in the Lower Basin is an important part of range-wide recovery. Participants agreed that Box 6 (Highest priority research needs associated with hybridization and genetics) from the 2004 report contains several research needs that have not been met and remain relevant (see Appendix G). It was agreed, however, that "hybridization" should be replaced with "intermediates." Little is known about the underlying cause of intermediates, and group members felt it is necessary to determine if the cause is natural or related to USACE or other human activities. Laboratory research on genetics is an important part of recovery efforts. It is important to establish that the markers being used are accurate. The group also discussed genetics relative to regional differences in performance. Population differences do exist along longitudinal and latitudinal gradients, and it is unclear whether genetic or environmental factors are responsible for the differences.

Funding Priorities and Science

USACE funding

Casey Kruse, Section Chief for Endangered Species, Omaha District, USACE, discussed funding priorities and outlined key criteria for research proposals (for more detail, see Appendix D).

- Researchers should be clear about the question to be answered. Priority will be given to questions relevant to a management-critical decision or uncertainty.
- Researchers should address how the proposed work will help recover the species.
- Proposals should be expanded beyond sub-basin areas.
- Researchers should address why the proposal is important at this point in the recovery process and its relevance to current issues.
- Leveraging other resources is helpful.
- Researchers should be careful of building a kingdom and becoming isolated, or becoming competitive among areas of the pallid sturgeon range for resources and funding.

Research is part of the overall work of the USACE related to endangered species, as are management activities and monitoring, and it is a challenge to balance funding needs among these areas. Kruse agreed that collaboration among regions is needed, such as researchers from the Middle or Lower Mississippi River collaborating with Missouri River researchers. Participants asked for more transparency in the funding decision processes and to be notified of the USACE priorities annually.

Science and the decision-making process

David Galat led a discussion on moving science into the decision-making process and how proposals should be prioritized and funded. He described a three-pronged approach that includes research, monitoring and assessment, and propagation. Based on these three activities, Galat asked everyone to consider the needs of pallid sturgeon and help develop a strategy to use science to make effective management decisions (in the sense of Van Cleve et al. 2006), noting that social, economic, political and cultural issues also need to be considered in recovery efforts.

Participants noted that it is important for the USACE to have a list of the top priorities from each sub-basin. The sub-basin work groups also wish to have input into how funds are allocated specific to their needs. It was suggested that a few members of each work group should be included in funding decisions, or that the USACE should become more involved in work group processes. Also, it was suggested that sources of expertise that are not currently involved should be included, such as small colleges and private consulting firms. And it was noted that transparency in funding is a necessity and unless the forum for funding is open, the awards system will never seem fair.

Another primary concern expressed was the need to look at priorities and recovery efforts from a range-wide perspective. Participants agreed that science benefits all of society. Also, participants asserted that managers need to emphasize that the first principle of management is to "do no harm." In some situations, especially with stocking, it was suggested that a cautious approach is needed.

Participants noted that they enjoyed the workshop discussion on recovery research. Expertise at this conference needs to be brought together more often. Suggestions for improving connections among experts included:

- Create a list serve;
- Expand the Missouri River InfoLINK (http://infolink.cr.usgs.gov/index.htm);
- Develop a mechanism to get summaries from each sub-basin Work Group to the other Groups;
- Create an annual range-wide report on topics such as propagation;
- Host an annual *Scaphirhynchus* conference;
- Hold quarterly range-wide web-based conferences; and
- Create range-wide thematic work groups to foster cross-cutting collaborative communication and research efforts.

Next Steps

Sturgeon conceptual life-history model

Carl Korschgen, USGS CERC, addressed the next steps for the life-history conceptual model. Workshop participants were asked to contact any of the authors of the original model if they wish to co-author the revised model, make a hard copy with notes and give it to Carl as feedback, submit anonymous comments to the Ruckelshaus Institute, or email the Steering Committee with any comments. Upon completion, the revised model will serve as the structure for research documents, with life stages and phases serving as web hyperlinks to documented research.

Workshop outcomes

Harold Bergman, Ruckelshaus Institute, noted that a draft report from the workshop will be prepared by Ruckelshaus Institute staff and the Steering Committee. All participants and observers will have an opportunity to review the draft, as will other experts who could not attend. If new ideas come up during the review process, they will be summarized in an appendix to the report. The outcomes from this workshop will be just one source of input to agencies on allocating funding resources.

Acknowledgements

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Photo courtesy of USGS

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Appendices

A. Contact information for participants, observers, and staff

B. Workshop agenda

C. Science updates

D. Discussion summaries from breakout session I

E. Discussion summaries from plenary sessions

F. Discussion summaries from breakout session II

G. Research needs identified at 2004 pallid sturgeon workshop

H. Additional ideas contributed by reviewers

Appendix A – Contact Information for Workshop Attendees

Participants, *Steering Committee members, and ^Observers

^Mandy Annis
US Geological Survey
4200 New Haven Rd
Columbia, MO 65201
mannis@usgs.gov

^Bill Beacom
Nav-Con Services
2423 Jackson St
Sioux City, IA 51104
bbeacom@pionet.net

*Jim Berkley
US Env. Prot. Agency
1595 Wynkoop St
Denver, CO 80202
berkley.jim@epa.gov

^Dale Blevins
US Geological Survey
401 NW Capital Dr
Lee's Summit, MO 64086
dblevins@usgs.gov

^Paul Boyd
US Army Corps of Eng.
106 S. 15th St
Omaho, NE 68102
Paul.M.Boyd@
nwo02.army.mil

Pat Braaten
US Geological Survey
Box 165
Fort Peck, MT 59223
Patrick_braaten@usgs.gov

^Danny Brown
Missouri Dept. of Conservation
2360 Highway D
St. Charles, MO 63304
Danny.brown@mdc.mo.gov

Frank Chapman
University of Florida
7922 NW 71st St
Gainesville, FL 32653
fchapman@ufl.edu

Steve Chipps
South Dakota State U
Box 2140B SDSU
Brookings, SD 57007
steven_chipps@sdstate.edu

Joyce Collins
US Fish & Wildl. Serv.
8588 Route 148
Marion, IL 62959
Joyce_Collins@fws.gov

Yvette Converse
US Fish & Wildl. Serv.
4050 Bridger Canyon Rd
Bozeman, MT 59715
Yvette_Converse@fws.gov

^Glenn Covington
US Army Corps of Eng.
601 E. 12th St
Kansas City, MO 64106
William.G.Covington@
Nwk02.usace.army.mil

^Mark Czaplewski
Central Platte Nat. Res. Dist.
215 N. Kaufman Ave
Grand Island, NE 68803
mark@cpnrd.org

Aaron DeLonay
US Geological Survey
4200 E. New Haven Rd
Columbia, MO 65201
adelonay@usgs.gov

Wyatt Doyle
US Fish & Wildl. Serv.
101 Park DeVille Dr Ste. A
Columbia, MO 65203
Wyatt_doyle@fws.gob

Mark Drobish
US Army Corps of Eng.
PO Box 710
Yankton, SD 57057
mark.r.drobish@usace.army.mil

*Craig Fleming
US Army Corps of Eng.
1616 Capitol Avenue
Omaha, NE 68102
Craig.A.Fleming@
nwo02.usace.army.mil

*David Galat
U of Missouri – Columbia
Columbia, MO 65211
galatd@missouri.edu

Bill Gardner
Montana Dept Fish Wildlife & Parks
PO Box 938
Lewiston, MT 59457
fwples@tein.net

Jim Garvey
Southern Illinois University
173 Life Science II
Carbondale, IL 62901
jgarvey@siu.edu

^Joseph Gibbs
Missouri Levee & Drain District
115 Club Meadows Drive
Columbia, MO 65203
Jbg6267@aol.com

Tyler Haddix
Montana Dept Fish Wildlife & Parks
Box 165
Fort Peck, MT 59223
thaddix@mt.gov

Paul Hartfield
US Fish & Wildl. Serv.
6578 Dogwood View Prkwy.
Jackson, MS 39213
paul_hartfield@fws.gov

Gary Heidrich
Missouri Dept. of Conservation
Route 2, Box 17
Sweet Springs, MO 65351
Gary.heidrich@mdc.mo.gov

Ed Heist
Southern Illinois University
1125 Lincoln Drive
Carbondale, IL 62901
edheist@siu.edu

David Herzog
Missouri Dept. of Conservation
3815 East Jackson Blvd
Jackson, MO 63755
David.Herzog@mdc.mo.gov

*Tracy Hill
US Fish & Wildl. Serv.
101 Park DeVille Dr Ste A
Columbia, MO 65203
Tracy_Hill@fws.gov

Rob Holm
US Fish & Wildl. Serv.
Box 530
Riverdale, ND 58565
rob_holm@fws.gov

Jan Hoover
US Army Corps of Eng.
3909 Halls Ferry Road
Vicksburg, MS 39810-6199
Jan.J.Hoover@erdc.usace.army.mil

Paul Horner
Missouri Dept. of Conservation
15302 LIV 2386
Chillicothe, MO 64601
Paul.horner@mdc.mo.gov

Robert Jacobson
US Geological Survey
4200 E. New Haven Rd
Columbia, MO 65201
rjacobson@usgs.gov

Matt Jaeger
Montana Dept Fish Wildlife & Parks
2068 Highway 16
Glendive, MT 59330
Matthew_jaeger@yahoo.com

^Tom Johnson
HDR/FishPro
5201 S. Sixth Streeet
Springfield, IL 62703
Tom.Johnson@hdrinc.com

*George Jordan
US Fish & Wildl. Serv.
2900 4th Avenue N, Rm 301
Billings, MT 59101
George_Jordan@fws.gov

^Don Jorgensen
Lakota Consulting
33599 479 Avenue
Jefferson, SD 57038
donjorg@valyousat.net

*Tom Keevin
US Army Corps of Eng.
1222 Spruce St
St. Louis, MO 63103
Thomas.m.keevin@
mvs02.usace.army.mil

Scott Kenner
South Dakota School of Mines and Technology
501 E. Joseph St
Rapid City, SD 57701
Scott.Kenner@sdsmt.edu

Rob Klumb
US Fish & Wildl. Serv.
420 S. Garfield Ave Ste 400
Pierre, SD 57501
robert_klumb@fws.gov

*Carl Korschgen
US Geological Survey
4200 New Haven Rd
Columbia, MO 65201
ckorschgen@usgs.gov

^Sandy Clark Kolaks
US Geological Survey
4200 New Haven RD
Columbia, MO 65201
sjclark@usgs.gov

*Steve Krentz
US Fish & Wildl. Serv.
3425 Miriam Ave
Bismarck, ND 58501
Steven_Krentz@fws.gov

Casey Kruse
US Army Corps of Eng.
PO Box 710
Yankton, SD 57078
Casey.d.kruse@usace.army.mil

^Lauren Kruse
US Army Corps of Eng.
1616 Capitol Avenue
Omaha, NE 68102
Lauren.O.Kruse@
nwo02.usace.army.mil

Bernie Kuhajda
University of Alabama
425 Scientific Collections
Tuscaloosa, AL 35487
bkuhajda@bama.ua.edu

Boyd Kynard
US Geological Survey
PO Box 796
Turners Falls, MA 01376
boyd_kynard@usgs.gov

*Doug Latka
US Army Corps of Eng.
12565 West Center Rd
Omaha, NE 68144
Doug.C.Latka@
nwd02.usace.army.mil

^Eric Laux
US Army Corps of Eng.
106 South 15th St
Omaha, NE 68102
Eric.A.Laux@
nwo02.usace.army.mil

Jane Ledwin
US Fish & Wildl. Serv.
101 Park DeVille Dr Ste A
Columbia, MO 65203
jane_ledwin@fws.gov

^Leslie Lihou
Sierra Club
7008 Amherst Ave
St. Louis, MO 63130
leslielihou@hotmail.com

Beth MacConnell
US Fish & Wildl. Serv.
920 Technology Blvd Ste G
Bozeman, MT 59718
beth_macconnell@fws.gov

Henry Maddux
US Fish & Wildl. Serv.
PO Box 25486-DFC
Denver, CO 80225

*Gerald Mestl
Nebraska Game & Parks Commission
2200 N. 33rd St
Lincoln, NE 68503-0370
Gerald.mestl@ngpc.ne.gov

^James Mitas
Rep. Todd Akin's Staff
301 Sovereign Court Ste 201
Ballwin, MO 63011
Jim.Mitas@mail.house.gov

Gregory Moyer
US Fish & Wildl. Serv.
5308 Spring Street
Warm Springs, GA 31830
Greg_Moyer@fws.gov

Catherine Murphy
US Army Corps of Eng.
3909 Halls Ferry Rd EE-A
Vicksburg, MS 39180
Catherine.E.Murphy@
Erdc.usace.army.mil

*Wayne Nelson-Stastny
US Fish & Wildl. Serv.
PO Box 710
Yankton, SD 57078
Wayne_NelsonStastny@fws.gov

^Darby Niswonger
Missouri Dept. of Conservation
15302 LIV 2386
Chillicothe, MO 64601
Darby.caton@mdc.mo.gov

*Mike Olson
US Fish & Wildl. Serv.
3425 Miriam Ave
Bismarck, ND 58501
michael_olson@fws.gov

Diana Papoulias
US Geological Survey
4200 E. New Haven Rd
Columbia, MO 65201
dpapouliase@usgs.gov

Mike Parsely
US Geological Survey
5501A Cook-Underwood Rd
Cook, WA 98605
Michael_parsley@usgs.gov

Mark Pegg
University of Nebraska
402 Hardin Hall
Lincoln, NE 68583-0974
mpegg2@unl.edu

^Kristen Perry
Missouri Clean Water Commiss.
P.O. Box 418
Bowling Green, MO 63334
alot@onemain.com

^Meagan Perry
Sen. Kit Bond's Staff
274 Russell Senate Bldg
Washington, DC 20002
Meagan_Perry@
bond.senate.gov

Ed Peters
University of Nebraska
6270 N Country Road M
Loretta, WI 54896
epeters@unlnotes.unl.edu

^Dan Pridal
US Army Corps of Eng.
106 S 15th St
Omaha, NE 68102
daniel.b.pridal@usace.army.mil

^Joanna Reuter
US Geological Survey
4200 New Haven Rd
Columbia, MO 65201-9634
jreuter@usgs.gov

*Karen Rouse
Missouri Dept. of Natural Res.
PO Box 176
Jefferson City, MO 65102
Karen.rouse@dnr.mo.gov

Mike Ruggles
Montana Dept Fish Wildlife &
Parks
Box 165
Fort Peck, MT 59223
mikeruggles@mt.gov

Schulyer Sampson
Nebraska Game & Parks Commission
2200 N 33rd St
Lincoln, NE 68503
Schulyer.sampson@ngpc.ne.gov

George Scholten
Tennessee Wildl. Resour. Agency
PO Box 40747
Nashville, TN 37204
George.Scholten@state.tn.us

^John Shadle
Nebraska Public Power District
PO Box 499
Columbus, NE 68601
jjshadl@nppd.com

^Dirk Shulund
Western Area Power Admin.
2900 4th Avenue N
Billings, MT 59102
shulund@wapa.gov

Dane Shuman
US Fish & Wildl. Serv.
420 S Garfield Ave Ste 400
Pierre, SD 57501
Dane_shuman@fws.org

^Rob Simmonds
US Fish & Wildl. Serv.
Marion, IL 62901
rob_simmonds@fws.gov

Darin Simpkins
US Geological Survey
4200 New Haven Road
Columbia, MO 65201
dsimpkins@usgs.gov

^Jason Skold
The Nature Conservancy
1025 Leavenworth St.
Omaha, NE 68102
jskold@tnc.org

Todd Slack
Mississippi Museum of Natural Sci.
2148 Riverside Dr
Jackson, MS 39202
Todd.slack@mmns.state.ms.us

Wayne Stancill
US Fish & Wildl. Serv.
420 S Garfield Ave Ste 400
Pierre, SD 57501
wayne_stancill@fws.gov

^Scott Stuewe
HDR/FishPro
5201 S 6th St
Springfield, IL 62703
Scott.Stuewe@hdrinc.com

Sam Stukel
South Dakota Game, Fish & Parks
31247 436th Ave
Yankton, SD 57075
Sam.stukel@state.sd.us

^Emily Tracy
US Geological Survey
4200 E. New Haven Rd
Columbia, MO 65201-9634
etracy@usgs.gov

Joel Van Eenennaam
U of California, Davis
One Shields Ave
Davis, CA 95616
jpvaneenennaam@ucdavis.edu

Greg Wanner
US Fish & Wildl. Serv.
420 S Farfield Ave Ste 400
Pierre, SD 57501
greg_wanner@fws.gov

^Steve Wharton
US Env. Protection Agency
1595 Wynkoop St
Denver, CO 80202
wharton.steve@epa.gov

Mark Wildhaber
US Geological Survey
4200 E. New Haven Rd
Columbia, MO 65201-9634
mwildhaber@usgs.gov

^Rick Wilson
US Geological Survey
5231 S 19th St
Lincoln, NE 68512

Robert Wood
St. Louis University
3507 Laclede
St. Louis, MO 63104
Wood2@slu.edu

Workshop Organizers and Facilitators

Melinda Benson
Harold Bergman
Ann Boelter
Diana Hulme
Nancy Hoffer
Chad LeBeau
Katelyn Parady
Robyn Paulekas
Joe Riis

William D. Ruckelshaus Institute of Environment and Natural Resources
University of Wyoming
Dept. 3971, 1000 E. University Ave
Laramie, WY 82071
ienr@uwyo.edu

Molly Mayo
Jennifer Pratt-Miles
Meridian Institute
PO Box 1829
Dillon, CO 80435
mmayo@merid.org
jprattmiles@merid.org

Photo courtesy of USGS

Appendix B – Workshop Agenda

Research Needs and Management Strategies for Pallid Sturgeon Recovery

Tuesday, July 31 – Thursday, August 2, 2007
St. Louis, Missouri, Doubletree Westport Hotel

Tuesday, July 31, 2007

8:00 am **Welcome and Introductions—**Harold Bergman (UW Ruckelshaus Institute)

8:10 am **Welcome and Remarks—**Craig Fleming (USACE)

8:20 am **Meeting Organization/Structure/Goals/Objectives/Ground Rules —**Facilitation team

8:30 am **History, Purpose, and the Compliance-Recovery Relationship—**Craig Fleming

8:50 am **Pallid Sturgeon 5-Year Review, Summary and Evaluation**—George Jordan (USFWS)

Summary of 5-Year Review and discussion, including brief recap of key points from the May, 2004 workshop.

9:15 am **Discussion and exchange on first talks**

9:40 am **Explanation of Sturgeon Conceptual Life-history Model and Application—**Aaron DeLonay (USGS)

10:15 am **Questions and comments from participants and observers**

10:45 am **Science Updates** – Upper Basin – Pat Braaten and Mike Ruggles

What new science is out there to help us meet the workshop objectives? Discussion of new lessons learned, hypotheses confirmed or rejected, new questions developed from these, and emerging policy issues that may affect the science behind pallid sturgeon recovery.

11:45 am **Buffet Lunch**

12:15 pm **Continue science updates –** Middle Basin – Robb Jacobson
Lower Basin – Jan Hoover

2:15 pm **Charge and expectations to participants and observers—**Facilitation team

2:30 pm **Breakout Session I—**Refinements to the Life-history Model

Research and assessment needs identified in the May, 2004 workshop will be viewed in the context of the life-history model, the 5-year review, and research updates. Breakout groups are divided into Habitat, Recruitment, and Population. Please note that time will be set aside in breakout sessions for observer questions and comments.

5:00 pm **Reconvene in plenary session**

Brief report back from the breakouts.

5:30 pm **Workshop adjourns.**

Wednesday, August 1, 2007

8:00am **Plenary Session**

Review 3 priority items from each breakout session, and ask external experts to provide insights on their work and how it relates to issues they have heard so far.

9:45 am **Questions and comments from observers**

10:30am **Breakout Session II**

Prioritize research needs by sub-basin and by cross-cutting issues with respect to research and action. Breakout groups are divided into Upper, Middle and Lower Basin. Please note that time will be set aside in breakout sessions for observer questions and comments.

12:00pm **Lunch**

12:30 pm **Continue breakout session during lunch**

2:45 pm **Plenary Discussion**

Reports from breakout groups and discussion on priorities (if possible ending up with lists organized by short-term/long-term; high, medium, and low research and action priorities for each sub-basin).

4:30pm **Questions and comments from observers**

5:00pm **Workshop adjourns for the day. Dinner on your own.**

Thursday, August 2, 2007

8:00am Plenary Session reconvenes

8:10 am **Establishing Funding Priorities in the Real World—**Casey Kruse (USACE)

8:30 am **Discussion of results from breakout sessions**

Translate sub-basin and cross-cutting priorities into technical guidance on strategy recommendations, and discuss funding considerations.

11:15 am **Questions and comments from observers**

11:45am **Closing remarks—**Craig Fleming

12:00 noon **Workshop adjourned**

Appendix C – Science Updates

Research updates from each sub-basin area are summarized under seven categories: 1) life history; 2) bioenergetics and food habits; 3) systematics, genetics, health, physiology, and propagation; 4) habitat use, assessment, mitigation, and restoration (including water quality); 5) population assessment and restoration; 6) modeling and synthesis; and 7) policy and management. Please note that each sub-basin did not necessarily report information for each category.

These summaries are not intended to be complete reviews of all recent science, and some of the work is preliminary and subject to change. Rather, these summaries are intended to provide brief updates for some research areas since the 2004 workshop. Full citations for published information is found in the Literature Cited section of this report.

Upper Basin Work Group

Pat Braaten, USGS CERC, Fort Peck, Montana presented an overview developed from input provided by the work group members.

1. Life History

a. Spawning

- There is no evidence of recent spawning in Recovery Priority Management Area (RPMA) 1.
- 2003 - First evidence of recent spawning in RPMA 2 as a 22 mm pallid sturgeon was sampled August 12 in the Missouri River downstream from the Yellowstone River (Braaten and Fuller 2005). Species identification was based on genetics (Schrey and Heist 2004). Spawning may have occurred in either the Missouri River or Yellowstone River (some evidence for Missouri River).
- Spawning does occur in RPMA 2, but no evidence of recent recruitment.
- During 2007 we have conclusive evidence of spawning in the Yellowstone River (RPMA 2) by two females (contact Dave Fuller, Matt Jaeger, and Mike Ruggles, MTFWP; and Molly Webb, USFWS, Bozeman Fish Technology Center, Bozeman, Montana).
- Outcomes of 2007 spawn study in the Yellowstone River (contact Dave Fuller, Matt Jaeger, and Mike Ruggles, MTFWP, Fort Peck, Montana).
    - ◊ Intake Diversion Dam potentially blocked upstream migration.
    - ◊ Upstream migration apex is not necessarily the spawn location.
    - ◊ Rapid, long-distance downstream dispersal after spawning is not characteristic of female pallids in the Yellowstone River.
    - ◊ Spawning likely occurs around river km 13, and other areas.
    - ◊ Spawning occurred under average flow conditions.

    - ◊ If spawning has occurred in past years and decades similar to 2007, why is there little to no evidence of recent recruitment?

- 2007 combined with information from earlier years.

    - ◊ Based upon assessments of pallid sturgeon captured for propagation, some pallid sturgeon females exhibit a two-year spawning interval, while males can spawn annually (contact Rob Holm, USFWS Garrison Dam National Fish Hatchery, Riverdale, North Dakota; and Molly Webb and Kevin Kappenman, USFWS Bozeman Fish Technology Center, Bozeman, Montana).

b. Developing embryos

- Studies have been conducted to determine temperature thresholds, optima and developmental rates in pallid and shovelnose embryos (contact Molly Webb and Kevin Kappenman, USFWS Bozeman Fish Technology Center, Bozeman, Montana).

    - ◊ Survival rates of embryos were studied at temperatures ranging from 8 to 28 ˚C for shovelnose and 8 to 26 ˚C for pallid sturgeon.
    - ◊ Lethal temperatures were 8 and 28˚C for shovelnose embryos and 8 and 26 ˚C for pallid sturgeon embryos.
    - ◊ There were no statistically significant differences in survival from 12 to 24 ˚C, though the highest survival was seen between 12 and 20 ˚C.
    - ◊ The developmental rates of pallid and shovelnose embryos are similar to those described for white and lake sturgeon (*Acepenser fulvescens*).

c. Free embryos

- 2004 larval drift studies in a Missouri River side channel (Braaten et al. in press).

    - ◊ Embryos drift for at least 11 days.
    - ◊ Total drift distance dependent on water velocity -- some larvae may drift more than 500 km.

- 2007 larval drift studies in the mainstem Missouri River (contact Pat Braaten, USGS CERC, Fort Peck, Montana; Dave Fuller, Ryan Lott, and Mike Ruggles, MTFWP, Fort Peck, Montana).

    - ◊ 430,000 free embryos and larval pallids released to free drift in the mainstem Missouri River, ages 5, 6, 10, 12, 13 days post-hatch (dph).
    - ◊ Larvae serially sampled (4 days and 1 night) through a 185-km reach downstream from the release site at Wolf Point, Montana.
    - ◊ Drifting 5-6 dph free embryos were captured four days post-release, older ages settled from drifting to benthic habitats.
    - ◊ Free embryos drift during day and night, and drift almost exclusively in the lower 0.5-m of the water column.
    - ◊ As suggested by the 2004 studies (Braaten et al. in press), pallid sturgeon exhibit an extended drift duration during the free embryo life stage.

◊ Drift distance relative to the length of available riverine habitat may be a recruitment bottleneck if larvae drift into reservoirs (e.g., Lake Sakakawea) where survival is likely low.


Photo courtesy of USFWS

d. Larval stage of exogenous feeding

- Free embryos transition to larvae at about 19 – 20 mm (Braaten et al. in press).
- Chironomids (midges) and Ephemeroptera (mayflies) are the diet components of first-feeding and older larvae for shovelnose sturgeon (Braaten et al. 2007).
- Results suggest suitable food resources are available in RPMA 2.
- Transition to exogenous feeding has propagation implications as hatcheries experience die-offs during this time period.
- "Successful fertilization doesn't mean successful fry production – critical development occurs post-hatch and may result in larvae that do not or can not initiate feeding" (contact Rob Holm, USFWS Garrison Dam National Fish Hatchery, Riverdale, North Dakota).
- Need to determine which diet combinations enhance feeding, growth, and survival in hatchery settings.
- Feeding trials are underway at the USFWS Bozeman Fish Technology Center (contact Kevin Kappenman, USFWS, Bozeman Fish Technology Center, Bozeman, Montana).

e. Juveniles

- Studies have been conducted on shovelnose sturgeon to determine the temperature optima for growth and survival (contact Molly Webb and Kevin Kappenman, USFWS, Bozeman Fish Technology Center, Bozeman, Montana).
  - ◊ The total mortality differed significantly between treatments with no mortality seen at 14, 16, and 18 °C and the highest mortality seen at 28 and 30 °C.
  - ◊ This experiment will be repeated at the Bozeman Fish Technology Center with pallid sturgeon in fall, 2007.
  - ◊ The average batch weights at 8, 10, and 12 °C were significantly lower than the batch weights in all temperature treatments except 14 and 30 °C.
  - ◊ Shovelnose sturgeon maintained at 8 and 10 °C lost weight during the experimental period.
  - ◊ The highest batch weight was observed at 24 °C, but the highest average batch weight did not differ significantly between 16 and 28 °C.
- Bioenergetics (contact Rob Klumb, USFWS, Pierre, South Dakota; and Steve Chipps, USGS-South Dakota Cooperative Fish and Wildlife Unit, Brookings, South Dakota).
  - ◊ Metabolic rate and feeding rate increased between 10 °C and 30 °C, then sharply declined.

- ◊ Juvenile survival was high (> 80 percent) when exposed to 29 °C and 33 °C for 100 hours. Survival declined to zero when exposed to 35 °C for one hour.


Photo courtesy of USGS

- Survival (contact Bill Gardner, MTFWP, Lewistown, Montana).
  - ◊ In RPMA 1, survival of the 1997 year class of stocked juveniles after nine years was estimated at 45 percent. Theoretical survival table (Jordan 2006) predicted 9 percent survival after nine years. Thus, survival for this year class seems better than predicted.
  - ◊ However, it appears that subsequent year classes have not faired as well.
  - ◊ Information on juvenile survival rates is critically needed for all RPMAs!!
- Food habits.
  - ◊ In comparing the diet of shovelnose sturgeon and the 1997 year class of juvenile pallid sturgeon in RPMA 1, it was determined that hatchery-raised juvenile pallid sturgeon are dependent on sicklefin chubs and sturgeon chubs as a food resource (Gerrity et al. 2006).
  - ◊ Diet overlap between shovelnose sturgeon and juvenile pallid sturgeon in RPMA 3 was low; however, macroinvertebrates were still an important component seasonally (as percent dry weight) in juvenile pallid sturgeon diets (Wanner et al. 2007).

2. Systematics, genetics, health, physiology, and propagation

- Fish health (contact Beth MacConnell, USFWS Bozeman Fish Health Center, Bozeman, Montana).
  - ◊ Iridoviral infections in young-of-year pallid sturgeon persist (>6 months) and increase in severity.
  - ◊ Numbers of sensory cells (taste buds) in skin decrease as virus severity increases.
  - ◊ Mortality rates highly variable.
- Proposed research to develop management strategies for the pallid sturgeon iridovirus (PSIV).
  - ◊ Ability to detect and quantify the presence of PSIV in propagated and wild pallid sturgeon with a sensitive and validated test (quantitative Polymerase Chain Reaction) (contact Dr. Ron Hedrick, School of Veterinary Medicine, University of California, Davis, California).
  - ◊ Risk of transmission of PSIV between shovelnose and pallid sturgeon.
  - ◊ Effects of PSIV on performance (growth and sensory cell recovery) and survival of stocked pallid sturgeon in the wild.
  - ◊ Reservoirs of virus (carrier status) and ability to reactivate with stress.
  - ◊ Potential for reactivated virus from stressed fish to be transmitted to naïve fish (cohabitation).

- Development of genetic tagging methods for pallid sturgeon in the Upper Missouri River (contact Pat DeHaan, USFWS Abernathy Fish Technology Center, Longview, Washington).
  - ◊ The objective is to use genetic markers as a complementary means of tagging hatchery-origin pallid sturgeon. This method offers several advantages including the fact that all juveniles are genetically tagged once the parents have been genotyped and fish can be released much earlier since there is no minimum size for tagging fish. This method relies on genetic parentage analysis to "read" the genetic tags of the juvenile sturgeon.
  - ◊ The majority of the fish analyzed in the lab to date have been shovelnose sturgeon.
  - ◊ All unmarked *Scaphirhynchus* identified as pallid sturgeon have been of hatchery-origin.
  - ◊ Juvenile pallid sturgeon collected in 2004 and 2005 were from the 2004 larval drift study.
  - ◊ Juvenile pallid sturgeon collected in 2006 were a mix of 2004 larval drift individuals and 2005 year class.
- Pallid sturgeon broodstock management (contact Pat DeHaan, USFWS Abernathy Fish Technology Center, Longview, Washington)
  - ◊ The objective is to use genetics data to examine the relationship among broodfish to avoid crosses between closely related individuals.
  - ◊ Full parental genotyping is necessary for successful genetic marking of hatchery-origin juveniles.
  - ◊ We have developed the spawning matrices for the past three years showing, for example, the level of relatedness among all possible pairs at the hatchery and which crosses are recommended and which are to be avoided.
- Propagation progress
  - ◊ Cryopreservation (contact Rob Holm, USFWS Garrison Dam National Fish Hatchery, Riverdale, North Dakota).
  - ◊ Determination of sex and stage of maturity (contact Molly Webb and Kevin Kappenman, USFWS, Bozeman Fish Technology Center, Bozeman, Montana).
    - – Researchers at the Bozeman Fish Technology Center have been analyzing plasma sex steroid concentrations in the Upper Basin pallid sturgeon captured during broodstock collection and throughout spawning at the hatcheries since 2004. They are capable of correctly determining sex and stage of maturity in pallid sturgeon with 93 percent accuracy. They have also found that steroid concentrations in pallid sturgeon are higher than the circulating concentrations in shovelnose sturgeon.

Photo courtesy of USGS

- Determination of spawning readiness of pallid sturgeon in hatcheries (contact Molly Webb and Kevin Kappenman, USFWS, Bozeman Fish Technology Center, Bozeman Montana; Rob Holm, USFWS, Garrison Dam National Fish Hatchery, Riverdale, North Dakota; Mike Rhodes, MTFWP, Miles City State Fish Hatchery, Miles City, Montana; and Keith McGilvray, USFWS, Gavins Point Dam National Fish Hatchery, Yankton, South Dakota).
  - ◊ Researchers have applied this tool (plasma sex steroid concentration) to assess the captive future broodstock maintained at Gavins Point National Fish Hatchery to determine the sex ratio and the number of individuals that have reached first sexual maturity. Several males were successfully used in the Upper Basin stocking plan during the 2007 spawning season.

3. Habitat use, assessment, mitigation, and restoration (including water quality)

- Habitat use in the Missouri River (contact Chris Guy, Montana State University, Bozeman, Montana).
  - ◊ Water levels in the Fort Peck Reservoir highly influence the amount of suitable habitat for juvenile pallid sturgeon in RPMA 1 upstream from the reservoir.
- Suitability of Yellowstone River above Intake Diversion for juveniles/restoration (contact Matt Jaeger, MTFWP, Glendive, Montana).
  - ◊ Larval drift may preclude recruitment of fish spawned below Intake Diversion.
  - ◊ Establishing spawning populations above Intake Diversion may alleviate this bottleneck.
  - ◊ Fish stocked at warm temperatures dispersed shorter distances than fish stocked at cold temperatures.
  - ◊ Habitat at stocking locations affected post-stocking dispersal; Cartersville fish moved more than Intake fish.
  - ◊ Most fish stocked upstream of Intake Diversion at warm temperatures remained upstream of Intake Diversion.
  - ◊ The Yellowstone River above Intake Diversion is suitable for pallid sturgeon restoration.
- Comparison of pallid sturgeon high and low use areas and prey availability in RPMA 3 (contact Steve Chipps, USGS-South Dakota Cooperative Fish and Wildlife Unit, Brookings, South Dakota; and Rob Klumb, USFWS, Pierre, South Dakota, with their graduate students).

4. Population assessment

- Existing situation:
  - ◊ 40-50 wild adults in RPMA 1 (USFWS 2007).
  - ◊ 158 wild adults (95 percent Confidence Limits 129 – 193) in RPMA 2 (Klungle and Baxter 2005).
  - ◊ Remnant numbers of wild adults in RPMA 3 are low (USFWS 2007).
  - ◊ Possibly a lack of spawning, but certainly a lack of recruitment.
  - ◊ Population monitoring is in place throughout the Upper Basin (contact Mark Drobish, USACE, Yankton, South Dakota; Tyler Haddix, MTFWP, Fort Peck, Montana; Steve Krentz, USFWS, Bismarck, North Dakota; Greg Wanner and Dane Shuman, USFWS, Pierre, South Dakota).

5. **Habitat restoration initiatives**

- Physical habitat and biological response to enhanced discharge regimes in RPMA 1 - Marias River (contact Sue Camp, US Bureau of Reclamation [USBOR], Billings, Montana; and Chris Guy, Montana State University, Bozeman, Montana).
    - ◊ Spawning by shovelnose sturgeon was documented in 2006 when an experimental release of a discharge pulse occurred. There was no evidence of spawning in 2007 when experimental discharge releases did not occur.
    - ◊ Sturgeon eggs collected between 16-18 °C.
- Yellowstone River Intake diversion dam and fish screen (contact Matt Jaeger, MTFWP, Glendive, Montana; Sue Camp, USBOR, Billings, Montana; and George Jordan, USFWS, Billings, Montana).
    - ◊ Removal of Intake diversion dam and replacement is anticipated to provide fish passage, and access for pallid sturgeon to a greater upstream portion of the Yellowstone River.
    - ◊ Construction of a fish screen on the Intake diversion canal is anticipated to minimize/prevent entrainment of pallid sturgeon and other native fishes.
- Fort Peck Flow Modification Project (contact Mike Ruggles, MTFWP, Fort Peck, Montana; and Pat Braaten, USGS CERC, Fort Peck, Montana).
    - ◊ Examining options for improving habitat conditions in the Missouri River including warmwater releases and enhanced flows downstream from Fort Peck Dam.

6. **Strategic planning**

- 10-year strategy of Upper Basin Work Group: Activities leading to recovery (contact Yvette Converse, Upper Basin Chair, USFWS Bozeman Fish Technology Center, Bozeman, Montana).
    - ◊ Flow and habitat management.
        - – Restore river diversity.
        - – Instream flow.
        - – Manage human activity.
    - ◊ Life history and ecology.
        - – Research life history.
        - – Population monitoring.
    - ◊ Propagation and genetics.
        - – Implement artificial propagation.
        - – Captive broodstock.
        - – Operate conservation facilities.
        - – Research spawning and larvae.
        - – Fish health investigations.
        - – Monitor stocking program.
    - ◊ Increase public awareness and support.

Photo courtesy of USGS

- Outreach with professionals.
- Information and Education activities for the public.
- Promote publication of information.
- Produce information.
- Participate in development.
- Maintain information library.

◊ Provide program planning and support.
- Determine local actions for recovery.
- Actively participate in committees.

Middle Basin Work Group

Robert Jacobson, USGS CERC, Columbia, Missouri, presented an overview developed from input provided by the work group members.

1. Life History

a. Spawning

- Site-specific studies of flow, temperature and spawning in the Missouri River below Gavins Point Dam to determine factors affecting spawning, growth, and recruitment (contact Darin Simpkins, USGS CERC, Columbia, Missouri).

◊ Pallid and shovelnose sturgeon, including gravid shovelnose sturgeon, were found near coarse-substrate habitats in the segment located within five rivermiles downstream from Gavins Point Dam from March through August, 2006.

◊ Sturgeon appeared to aggregate in the vicinity of coarse-substrate habitats during the winter period in March, 2006.

◊ *Scaphirhynchus* sturgeon spawned in the Missouri River between the confluence with the James River and Ponca, Nebraska in late May and early June of 2006 when flows were 21,000-25,000 cfs and temperatures were 19-23 ˚C. However, collection of one larval sturgeon in August, 2006 upstream from the James River confluence suggests that *Scaphirhynchus* can spawn in the Missouri River below Gavins Point Dam under variable flows (> 30,000 cfs) and water temperatures (> 25 ˚C) and have an extensive spawning period or periods.

- Regional studies of flow, temperature and spawning to determine factors affecting spawning, growth, and recruitment (contact Aaron DeLonay and Diana Papoulias, USGS CERC, Columbia, Missouri).

◊ Immature and reproductively mature wild pallid sturgeon are present in the Lower Missouri River.

◊ Adult pallid sturgeon in reproductive condition are present throughout the Lower Missouri River. Spawning has been documented by collection of tagged, spent females and collection of exogenously-feeding larvae (identified as *Scaphirhynchus* spp).

- ◊ Female pallid and shovelnose sturgeon have been documented moving upstream to spawn (as much as 400 km), reaching an apex (inferred point of spawning), then moving downstream sporadically. Downstream movement of > 900 km has been documented.
- ◊ Shovelnose sturgeon spawning occurs in multiple places, from late April to mid June, at 16-25 °C. Pallid sturgeon spawning has not been documented in tributaries; whereas shovelnose sturgeon spawning has been documented in tributaries and the mainstem. Sturgeon implanted with transmitters do not appear to aggregate.
- ◊ Non-reproductive pallid and shovelnose sturgeon generally do not migrate significant distances during the spawning season.
- ◊ Pallid and shovelnose sturgeon reproductive females can be implanted with transmitters and most (>75 percent) will spawn.
- ◊ Shovelnose sturgeon in the Ft. Randall reach (RPMA 3) attain reproductive readiness, and seemingly remain reproductively ready into late July.
- ◊ No difference was detected in reproductive readiness in shovelnose sturgeon collected randomly and at a fixed site near Gavins Point Dam. After May 1 nearly all fish collected were ready to spawn, indicating movement into the area to spawn (or limited upstream movement).
- ◊ Reproductive anomalies were regularly observed in Lower Missouri River sturgeon, including intersex gonads and teratomas.

b. Developing embryos

- Site-specific studies of flow, temperature and spawning below Gavins Point Dam to determine factors affecting spawning, growth, and recruitment (contact Darin Simpkins, USGS CERC, Columbia, Missouri).
  - ◊ Black eggs have been collected using icthyoplankton nets from the Missouri River. Given the timing of their collection in relationship to collections of larvae, they may be sturgeon.
  - ◊ Mats have successfully been used to collect eggs from lithophillic spawning fishes in the Missouri River below Gavins Point Dam, but sturgeon eggs have not yet been collected using egg mats.

c. Free embryos

- Site-specific studies of flow, temperature and spawning below Gavins Point Dam to determine factors affecting spawning, growth, and recruitment (contact Darin Simpkins, USGS CERC, Columbia, Missouri).
  - ◊ Free embryos have been sampled in the Lower Missouri River and some of its tributaries using icthyoplankton nets and trawls.
  - ◊ The collection of free embryos in the segment from Gavins Point Dam to Ponca, Nebraska and tributaries of the Missouri River suggests that conditions are suitable for at least some embryo development.
  - ◊ Free embryos also have been collected under variable flows, but relatively consistently among years within a window from mid May to mid June from Gavins Point Dam to Ponca, Nebraska when water temperatures were between 19 and 23 °C. Free embryos were collected earlier in the year in downstream reaches.

d. Larval stage of exogenous feeding

- Site-specific studies of flow, temperature, and spawning below Gavins Point Dam to determine factors affecting spawning, growth, and recruitment (contact Darin Simpkins, USGS CERC, Columbia, Missouri).

    ◊ Shovelnose sturgeon larvae grow relatively fast in the Missouri River below Gavins Point Dam (RPMA 4) in comparison to the Missouri River below Fort Peck Dam (RPMA 2).

    ◊ Shovelnose larvae can be found in areas with predictable habitat characteristics.

    ◊ The collection of shovelnose larvae of various sizes suggests that conditions are appropriate for at least some level of free embryo survival and growth.

2. Systematics, genetics, health, physiology, and propagation

- Broodstock collection and spawning study to provide hatcheries with local genetic stock for propagation, through intensive sampling with gillnets and trotlines (contact Wyatt Doyle, USFWS, Columbia, Missouri).

    ◊ Lower RPMA 4 (Missouri River downstream of Kansas City) and Middle Mississippi River: one reproductive male, one reproductive female, out of 10 adult fish.

    ◊ Upper RPMA 4 (Missouri River upstream of Kansas City to Gavins Pont Dam): eight reproductive males, one reproductive female.

    ◊ Spawning of Upper RPMA 4 fish was successful, but water quality changes due to locally heavy flooding resulted in almost total loss of 2007 progeny in the Lower RPMA 4. The successfully-spawned female was returned to the river.

    ◊ 2007 was first year to ever successfully propagate a gravid female in the Lower Missouri River.

- Determine patterns of growth and mortality in pallid sturgeon and compare with shovelnose sturgeon; determine genetic basis for hybridization (contact Ed Heist and Rob Colombo, Southern Illinois University [SIU], Carbondale, Illinois; Dave Herzog and Bob Hrabik, Missouri Department of Conservation [MODC], Jackson, Missouri; and Jack Killgore, USACE, Vicksburg, Mississippi).

    ◊ Mortality of pallid and shovelnose sturgeon is similar and suggests harvest effects.

    ◊ Age distribution of pallid sturgeon in the Middle Mississippi River truncated to a maximum of 15 years.

    ◊ Pallid and shovelnose sturgeon possess independent genetic groupings; hybrids, sharing alleles with both, do exist.

    ◊ Age distribution of shovelnose sturgeon (and likely pallid sturgeon) is shifting toward older individuals, suggesting poor recruitment.

    ◊ Fall spawning of shovelnose sturgeon has been confirmed in Middle Mississippi River.

- Detect population changes, recruitment, and propagation success of pallid sturgeon (contact Wyatt Doyle, USFWS Columbia, Missouri, and Gerald Mestl, Nebraska Game and Parks Commission [NGPC], Lincoln, Nebraska).

    ◊ 0.15 percent of all RPMA 4 and 3 percent of RPMA 3 propagated fish have been recaptured since 2002.

◊ Some biologists believe that pallid sturgeon move out of stocking area faster in upper RPMA 4 compared to lower RPMA 4 (boundary at Kansas River); larger stocked pallids move farther and faster than yearling fish.

◊ Few pallid sturgeon are captured in standard surveys when stocking has ceased.


Photo courtesy of USFWS

3. Habitat use, assessment, mitigation, and restoration (including water quality)

- Habitat assessment and monitoring program to evaluate fish response to habitat improvement actions (contact Wyatt Doyle, USFWS Columbia, Missouri; Gerald Mestl, NGPC, Lincoln, Nebraska; and Mark Drobish, USACE, Yankton, South Dakota).

  ◊ Abundance of all fish species is highly variable among months and sites.

  ◊ Few pallid sturgeon have been captured in habitat mitigation sites.

  ◊ Treatment differences among sites currently undetectable with fish data.

  ◊ Biologists believe that depth does not correlate with pallid sturgeon catch; large woody debris does.

- Habitat mitigation assessment study to evaluate chute projects, using monthly sampling (contact Wyatt Doyle, USFWS Columbia, Missouri; and Gerald Mestl, NGPC, Lincoln, Nebraska).

  ◊ Each chute is superior to some of the others for catch-per-unit-effort of some species and some life stages. This implies that each chute is unique.

  ◊ Water stage and season affect distribution, fish use, and community diversity.

  ◊ Conditioned (older) chutes are biologically and physically more diverse than those recently constructed.

- Habitat dynamics study to understand formation, availability, and function of Lower Missouri River habitats related to sturgeon reproduction and survival, using hydroacoustic mapping and hydrodynamic modeling (contact Robert Jacobson, USGS CERC, Columbia, Missouri).

  ◊ Regional reconnaissance map of coarse particulate deposits indicates potential spawning substrate is abundant but distributed non-uniformly in discrete patches. Gravel-cobble substrate occurs in abundance in the segment of the Missouri River from Gavins Point Dam to Ponca, Nebraska.

  ◊ Analysis of telemetry locations and habitat maps indicates reproductive female shovelnose sturgeon tend to select reaches with diverse hydraulics, including both divergent and convergent flows. Coarse substrate is almost always present, but not diagnostic.

  ◊ Monitoring data confirm that pulses similar in magnitude to the intentional Spring Rise flow modifications can transport sand bedload in spawning reaches, although the potential varies along the river.

Photo courtesy of USFWS

- Fish use of shallow-water habitat adjacent to sandbars in the Lower Missouri River (contact David Galat, University of Missouri, Columbia, Missouri).
  - ◊ Predictive models of sandbar morphometry indicate wing-dike sandbars provide more total area of sandbar-ATTZ (aquatic-terrestrial transition zone) habitat than point sandbars, although individual patches of wing-dike sandbars are smaller.
  - ◊ Of 175,000 larval fishes collected in shallow waters during a three-year study (2002-2004), eight were *Scaphirhynchus* larvae (two were verified morphometrically by the Colorado State University Larval Fish Laboratory [D. Snyder, personal communication] as large enough to be exogenously feeding *S. albus* larvae).
  - ◊ Of 24,500 small-bodied fishes collected in shallow waters in a 2005 study, none were *Scaphirhynchus.*
- Discharge and water quality studies using automated sensors at selected gauging stations (contact Dale Blevins, USGS, Lee's Summit, Missouri).
  - ◊ A strong diurnal cycle exists in dissolved oxygen (DO) (1-2 milligrams [mg]/Liter [L]/day) indicating substantial algae population. This effect was likely not common in the historical river, and may alter the aquatic food web.
  - ◊ There have been incidences of DO decreases substantially below the standard of 5 mg/L. DO sags are common during rises in summer and they are closely associated with turbidity increases. These water-quality fluctuations may affect larval/juvenile life stages.

◊ Water temperature excursions above 32 °C for several days in 2006 occurred at all stations downstream of St. Joseph, Missouri (stress may occur at 32 °C and fatalities at 34 °C).

◊ Temperature increases in spring often correspond with rises, both natural and artificial, making it difficult to separate the primary spawning and migration cues.

- Telemetry to determine pallid sturgeon habitat preference and spawning sites in the Middle Mississippi River (contact Jim Garvey and Ron Brooks, SIU, Carbondale, Illinois; and Bob Hrabik, MODC, Jackson, Missouri).

◊ Tracked more than 5,400 miles; 87 pallid sturgeon tagged.

◊ Wing dike habitat selected more than expected.

◊ Movements increased with spring flows.

◊ Chain of Rocks was destination for migrating pallid sturgeon during the spring.

4. Population assessment and restoration

- Detect population changes with randomized sampling through the year on entire Missouri River (contact Wyatt Doyle, USFWS, Columbia, Missouri, and Gerald Mestl, NGCP, Lincoln, Nebraska).

◊ Average annual recapture rate of stocked yearling pallid sturgeon is 0.06 percent (RPMA 4) and 1.2 percent (RPMA 3).

◊ Recapture rate is three to five times higher for age 3 versus yearlings.

◊ Recruitment in shovelnose sturgeon was detected, but no recently recruited pallid sturgeon were observed.

◊ Annual fish density change is detected in some fish community species.

◊ Densities, size, and growth are different in shovelnose and pallids between river segments.

- Sturgeon sampling in Middle Mississippi River during 2002-2005 (contact Jim Garvey, SIU, Carbondale, Illinois; Dave Herzog and Bob Hrabik, MODC, Jackson, Missouri; and Jack Killgore, USACE, Vicksburg, Mississippi).

◊ 64,000 hours effort; 11,549 shovelnose sturgeon; 143 pallid sturgeon (1:82).

◊ Population estimate: 1,600 - 4,900 pallid sturgeon exist in the Middle Mississippi River.

◊ Pallid sturgeon habitat: adjacent to main channel near wing dikes and islands.

◊ Ratio of pallid:shovelnose sturgeon at Chain of Rocks increased relative to remainder of Middle Mississippi River.

5. Modeling and synthesis

- Provide predictive understanding of shovelnose and pallid sturgeon population dynamics by developing simulation models based on parameters estimated from coordinated studies (contact Mark Wildhaber, USGS CERC, Columbia, Missouri).

◊ Population model results indicate that significant yields can be sustained for shovelnose sturgeon if minimum age of 12 years or length of 610 mm is set. This allows each fish, on average, two opportunities to reproduce during their life time.

◊ To allow pallid sturgeon two opportunities to reproduce would require a minimum age of 25 or length of 1182 mm.

Lower Basin Work Group

Jan Hoover, USACE, Vicksburg, Mississippi presented an overview developed from input provided by the work group members.

1. Life History

a. Spawning: ongoing study (contact George Scholten, Tennessee Wildlife Resources Agency, Nashville, Tennessee; and Jan Hoover, USACE, Vicksburg, Mississippi).

- Preliminary results from spawning chronology work.
  - ◊ Year 1 (2007) – spring surveys near Memphis, Tennessee.
  - ◊ Endoscopic and direct examination of gonads with classification of developmental stages (according to guidelines in Colombo et al. 2007) on shovelnose sturgeon as a surrogate for pallid sturgeon.
  - ◊ Male:Female was observed to be 1.1:1.0.
  - ◊ 23 percent females gravid in late March, but few "spent" females in early May.
- Preliminary results from spawning site study (contact Jack Killgore, USACE, Vicksburg, Mississippi).
  - ◊ Year 1 - sturgeon larvae and juveniles captured below large gravel pointbar (n=20, 22-223 mm, 5 April – 11 July).

    Five pallid sturgeon (32-70 mm) tentatively identified using morphometrics and meristics by Robert Wallus, Tennessee Valley Authority (retired), Oak Ridge, Tennessee, and Darrel Snyder, Colorado State University, Ft. Collins, Colorado.
  - ◊ Year 2 sampling at multiple locations yielded higher numbers of larvae (n=100's, early June 2007).

    Issue:
  - ◊ Should larvae be preserved in ethanol (genetics) or formalin (morphometrics/meristics)?

2. Bioenergetics and food habits (Hoover, et al. 2007, Keevin et al. 2007)

- Conclusions from diet study.
  - ◊ Samples analyzed from 45 shovelnose and 77 pallid sturgeon.
  - ◊ Only pallid sturgeon were piscivorous and fed on chubs (*Macrhybopsis*).
  - ◊ In the Lower Mississippi River both showed greater feeding on Trichoptera (caddisflies) and Ephemeroptera (mayflies) in the winter than in the spring, but in the Middle Mississippi River showed reduced feeding on those same taxa.
  - ◊ Both species in the Lower Mississippi River fed on a greater diversity of prey in the winter than in the spring. For pallid sturgeon, fish were the volumetrically dominant component of the diet (>52 percent) in both populations and during both seasons.

3. Systematics, genetics, health, physiology, and propagation

- Conclusions from genetic analyses of hatchery-reared fish: ongoing study (contact Rob Wood, Saint Louis University, St. Louis, Missouri).

◊ Hybrids from some inter-specific crosses are genetically similar to one parental species.

◊ Hybrids from other inter-specific crosses are genetically intermediate to those of both parental species.

Photo courtesy of USFWS

- Conclusions from genetic analyses of field-collected fish (Ray et al. 2007).

  ◊ Pallid, shovelnose, and "intermediate" forms from the Lower Mississippi River are distinct.

  ◊ 25 percent of morphologically "intermediate" fish exhibit unique alleles.

  ◊ Morphological "intermediates" are not genetic "intermediates," and therefore are not necessarily "hybrids."

- Conclusions from morphological analyses (Murphy, et al. 2007a).

  ◊ Pallid and shovelnose sturgeon from the Lower Mississippi River were distinct.

  ◊ Pallids from the Lower Mississippi River were morphologically more similar to shovelnose than were pallids from the Upper Missouri River.

  ◊ Variance within pallids increased moving upstream.

- Conclusions from morphological anomaly study (Murphy et al. 2007b).

  ◊ Approximately 5 percent of sturgeon captured had morphological anomalies, such as no tails or anomalies caused by physical injury. The fish still seem to thrive and grow.

  ◊ Length-weight data were compared between healthy and anomalous specimens with no significant disparities.

  ◊ Frequencies of anomaly types differed between Lower Mississippi River and Middle Mississippi River. Taillessness occurs more in Middle Mississippi River.

4. Habitat use

- Preliminary results from habitat study: Ongoing study, multi-scale approach, telemetry (contact Jack Killgore, USACE, Vicksburg, Mississippi).

  ◊ Pallid sturgeon in the Lower Mississippi River utilize a variety of habitats.

  ◊ Trotlines are most effective along steep-sloping sandbars when temperature is 10-20 °C.

- Plan for 5-year telemetry study of habitat use and movements (contact Paul Hartfield, USFWS, Jackson, Mississippi). Ongoing study.

  ◊ Implant 50+ pallid sturgeon with sonic tags and monitor location/movement.

  ◊ Atchafalaya River – Old River Control Complex (ORCC) downstream to Morgan City, Louisiana.


Photo courtesy of USFWS

- ◊ Mississippi River – Cairo, Illinois downstream to New Orleans, Louisiana.
- ◊ Results for Year 1 (2007)
  - – 25 mature pallid (15M, 10F) implanted (USFWS, Louisiana Department of Wildlife and Fisheries) in Atchafalaya River.
  - – 18 tags 5-year coded, seven tags 90-day pingers.
  - – Four mature pallid implanted (USACE) in Mississippi River.

5. Population assessment and restoration

- Conclusions from abundance study (Killgore et al. 2007a). ORCC study in progress.
  - ◊ Specimen size and relative abundance follow a latitudinal trend.
  - ◊ Pallids are most abundant in the extremes of the range (lower part of the Lower Mississippi River and upper part of the Middle Mississippi River).
  - ◊ The population size below the Low Sill of the Old River Control Complex on the Atchafalaya River was estimated at about 260 adult or subadult fish in the winter and early spring of 2007.
- Conclusions from aging study (Killgore et al. 2007b).

- ◊ Age and growth of rays (1 centimeter [cm] segment from pectoral fin ray).
- ◊ Size at age differs among populations.
- ◊ Mortality rate lower in Lower Mississippi River (13 percent) than in Middle Mississippi River (37 percent).

6. Policy and management

- Conclusions from swimming performance study (Hoover et al. 2005).
  - ◊ Model risk of dredge entrainment using empirical swimming performance data and behavioral observations.
  - ◊ Upper and Lower Basin hatchery specimens of similar size varied with respect to behavior and escape speed.
  - ◊ Fish from Atchafalaya River are faster and stronger swimmers than fish from Missouri River.
  - ◊ Risk greatest within 1.25 m of most dredge flow fields.
- Preliminary results from dredge noise study: ongoing study (contact Jan Hoover, USACE, Vicksburg, Mississippi).
  - ◊ Evaluate noise effects on risk of entrainment of pallid sturgeon.
  - ◊ Describe occupation of velocities, nearest-neighbor distances, and vertical position in the water in the absence and presence of dredge-like noise.
  - ◊ Pallid sturgeon increased free-swimming in the water column which would reduce risk of entrainment by dredges.
- Conclusions from swim training study (Varble 2006).
  - ◊ Evaluate effects of training on risk of entrainment between naïve and untrained hatchery-reared fish.
  - ◊ White sturgeon trained in flowing water (300 gallon racetrack, 11 cm/second) exhibited greater swimming endurance over a range of water velocities.
  - ◊ The fastest naïve fish were still slower than the slowest "trained" fish. This could mean hatcheries might enhance fish survival by raising them in a hydraulically challenged environment.
- Current shovelnose sturgeon harvest regulations.
  - ◊ Some states still allow commercial harvest of shovelnose sturgeon.
  - ◊ In May, 2007, the USACE wrote a letter to the USFWS asking that they close shovelnose sturgeon harvesting in the five states bordering the pallid sturgeon range, to protect the pallid sturgeon.

Appendix D – Detailed Summary of Breakout Session 1 Discussions

For the first breakout session, workshop attendees were assigned to Habitat, Recruitment, or Population breakout groups on the basis of expertise. Participants were asked to refine components of the life-history model and to identify preliminary research and management needs.

Breakout Group 1: Habitat

Participants: Pat Braaten, Joyce Collins, Aaron DeLonay, Mark Drobish, Bill Gardner, Jim Garvey, Robb Jacobson, Matt Jaeger, Scott Kenner, Jane Ledwin, Gerald Mestl, Mark Pegg, Schuler Sampson, Todd Slack, and Wayne Stancill.

Refining the life-history model

The habitat group recommended the following changes to the model.

- Change the term "channel engineering" to "channel constraints" to include natural and constructed features when identifying factors that affect survival, growth, and development.
- Develop the interactions between habitat and biotic factors. Various biotic interactions with habitat are missing from the model. For example, flow regime affects habitat productivity, which affects the transition to the free embryonic stage. Flow regime, disease, light regime, water quality, and artificial fluctuation in temperature were identified as factors that need to be part of the model.
- Extract and better define the parameters of quality hydraulic habitat. The parameters currently used need to be reconsidered and expanded to include factors such as velocity gradient, and the model needs to reflect this expansion.
- Emphasize habitat quality (including determining the characteristics of quality habitat) and productivity and the implications for pallid sturgeon survival, growth, and development, especially during drifting.
- Include larvae in stocking. The model emphasizes stocking concerns relative to juveniles, and the group felt it was important to include larvae in the stocking element of the model.
- Integrate water management (reservoir operation and irrigation) into the model.

Preliminary research questions and needs

- What parameters best characterize quality spawning habitat? Develop a consistent range-wide approach to characterizing that habitat.
- Compare fish behavior in the Missouri, Yellowstone, and Mississippi rivers to understand commonalities in habitat characteristics the fish are selecting. Habitat parameters previously identified as determining whether spawning is successful are now perceived as incomplete by some researchers. New research indicates that velocity gradients could be a parameter to which the fish respond. Other possibilities include shear stress, velocity, and depth.
- Studies completed in the Upper Basin on temperature and development relationships should be done across the entire range.
- What are the linkages between habitat and biotic factors for egg to free embryo stages? Examples of this type of connection are the influence of flow regime on predation, food quality, and food quantity; light regime on egg development; temperature regime on embryos and hatching; and habitat characteristics on disease. Identifying and researching these linkages will help to better understand transition probabilities between life stages.

- What is the effect of reservoir operations (e.g., artificial temperature fluctuations or increased velocity) on embryos? Does it prohibit hatching? Altered temperature regimes occur in many places, especially around reservoir operations. Fort Randall flow fluctuations and artificial temperature fluctuations could be affecting propagation.
- What flow levels are needed to move drifting larvae into vegetated habitat zones? Drifting involves hundreds of river kilometers and many transitions between habitats. Throughout the drifting period, vegetation zones serve as containment areas that reduce the probability of larvae becoming entrained in reservoir environments where they die.
- Re-examine assumptions about importance of shallow water habitats to juvenile life stages. Even if juveniles are not found in shallow water habitats, the habitats may be important in other ways, such as for prey production.
- When do pallid sturgeon transition from being insectivores to piscivores? How is this diet shift from invertebrates to fish important to juvenile pallid survival and growth? The transition from juveniles to immature adults may be when fish switch from mainly eating insects to mainly eating fish. However, it was noted that in the Upper Basin the transition to piscivory occurs much more quickly than in the Lower Basin. Despite this, fish that are insectivores in the Lower Basin show the same growth rates as piscivores of the same age in the Upper Basin.
- We need to better understand contaminant effects at all life stages (e.g., hormones and antibiotics in human sewage, organochlorines). Organochlorines have been preliminarily linked to intersexuality in pallid sturgeon, and other contaminants are likely also linked. Further research is needed to understand the relationship between intersexuality, hybridization, and intermediates.
- Why do pallid sturgeon use some artificial structures and not others?
- What characteristics contribute to habitat quality? How much variation in habitat can be tolerated? Complexity, patch size, spatial arrangements, areas that are source or sink of food, proximity to other habitats, and timing of habitat availability are all possible factors that contribute to habitat quality. Even if pallid sturgeon are not located in a habitat does not mean that habitat is unimportant.
- Is there a threshold depth at certain shear stress that supports spawning? Understanding the parameters of hydraulic habitat in relation to spawning cues and spawning locations is especially important.
- What aspect of temperature triggers or prevents spawning? Is it a constant level or a dynamic range? Artificial temperature regimes and fluctuations have focused attention on the relevance of temperature to spawning. It is unclear what pallid sturgeon needs are relative to temperature as a spawning cue.
- Is competition for habitat with other fish a limiting factor for mature adult pallid sturgeon? The hydraulic habitat of the Missouri and Mississippi rivers (as well as their channels) is altered continuously. As the river is constrained, habitat for most native fish species is limited and competition from invasive species is intensifying.

Breakout Group 2: Recruitment

Participants: Frank Chapman, Gary Heidrich, Ed Heist, Tracy Hill, Rob Holm, Jan Hoover, Boyd Kynard, Beth MacConnell, Henry Maddux, Catherine Murphy, Diana Papoulias, Mike Parsley, Mike Ruggles, Dane Shuman, Joel Van Eenennaam, and Robert Wood.

Defining recruitment

The group attempted to define recruitment and apply it in the context of the model. Definitions were based on a range of factors such as age, geographic location, and relation to the recovery plan. Although no single definition emerged, participants agreed that in terms of recruitment, it is important to focus efforts on egg deposition to the first few months of life. This time period is when age class strength is believed to be established.

Refining the life-history model

The group recommended several adjustments to the model.

- Integrate broodstock as a component linked with spawning adults. Wild and hatchery recruitment are linked, with hatchery situations helping to identify where some of the problems with recruitment originate. Broodstock is a significant component of the pallid sturgeon's current existence, and although the life history is not being modeled for hatcheries, artificial spawning and broodstock need to be in the model.

- Add drift to the model. The lack of recruitment in the Upper Basin is likely related to a lack of drift distance, not in failure to reproduce. Drift often is overlooked; it should be a state variable or added to the free embryo box.

- The larval stage of exogenous feeding in the wild needs to be emphasized. Stocking success rates are high because this stage and its transition probability are bypassed. It is likely that the bottleneck in wild populations is within this stage.

- Upstream and downstream dispersal needs to be added within the juvenile stage.

- Spawning adults should be further emphasized. Current records of spawning adults are much lower than historical records.

Preliminary research questions and needs

- Habitat is one of the bigger unknowns in the life-history model. For example, what are the habitat needs for dispersing and post-dispersing free embryos and larvae? Stocked fish exhibit different site affinities and do not disperse as much in the Lower Missouri River as they do in upper areas. We need to better understand the habitat factors related to why some fish are staying rather than moving. Often we have only anecdotal evidence and assumptions about habitat needs (for example, the assumption that pallid sturgeon use hard rocky substrates because they have sticky eggs).

- Where is the bottleneck for recruitment in the natural life cycle? Hatchery-released fish are a tool for understanding problems with wild fish. The success of hatchery production is greatly varied, and it is unclear if the bottleneck occurs during the developing embryo stage or during the transition to feeding.

- What food resources are necessary prior to migration to enable pallid sturgeon to complete the journey to spawning? Pre-spawning migration success is a precursor to successful spawning, but biologists hypothesize that pre-spawning migration often fails due to a lack of energy.

- What components affect drift? Drift is problematic due to several factors including predators, turbidity, flow, physical structures like sandbars, and habitat diversity. The relationship between distance, drift, and all contributing factors is an area for further research.

- Are dissolved oxygen levels important to survival of early life stages of pallid sturgeon? Preliminary research suggests that during early development some thresholds of dissolved oxygen translate to higher mortality.

- How does reservoir sedimentation affect larval and juvenile survival? All RPMAs except for RPMA 4 are affected by the reservoir systems. Several questions arose about turbidity and velocity in reservoirs. What happens to free embryos and larvae when they reach a reservoir? Predators are another significant concern.

- Are contaminants a bottleneck to pallid recovery and, if so, how and where? Preliminary research indicates that early life stage shovelnose sturgeon are tolerant of contaminants that are included in human health advisories. However, further research on the exogenous feeding stage and on the emerging problem of pharmaceuticals in the environment is important.

- What is the role of larval drifting distance, retention, and predation in successful recruitment to the free swimming stage? Drift distance is not the only impediment to successful recruitment. Several components of drift may affect recruitment to the free swimming stage, including habitat diversity within the drift reach, turbidity and other aspects of flow hydrology, predators, and physical structures (such as sandbars).

- What is the role of hatcheries in species recovery? The stocking program needs to be evaluated, including testing hypotheses about time, conditions, turbidity, range of velocities, etc. Hatcheries provide an informative model for pallid sturgeon in the wild. However, many recruitment issues are only natural issues, making it important to distinguish between hatchery situations and the wild.

Breakout Group 2: Population

Participants: Steve Chipps, Yvette Converse, Wyatt Doyle, Tyler Haddix, Paul Hartfield, David Herzog, Paul Horner, George Jordan, Tom Keevin, Rob Klumb, Bernie Kuhajda, Greg Moyer, Ed Peters, George Scholten, Darin Simpkins, Sam Stukel, Greg Wanner, and Mark Wildhaber.

Refining the life-history model

General

- Most pallid sturgeon today are not moving into the later two-thirds of the life stages. Focusing on range-wide recovery is critical.
- Incorporate stocking and artificial propagation into the model. For example, taking fish for stocking could be included in "fishing." Or, a separate parallel set of boxes could be added to the matrix. Putting stocking in the same box as the non-stocking population was too limiting. The creation of separate model components for wild fish and hatchery fish acknowledges factors that selectively affect the hatchery fish.

Mature adults to pre-spawning

- Researchers identified this stage as a place in the model where stocking and immigration could be emphasized. The possibility that stocked fish are using food and habitat of wild fish was mentioned. A box should be added to the model that emphasizes competition in reference to stocked fish, and predation in reference to species such as bull sharks.
- Priorities and critical concerns for this stage included loss to entrainment, contaminants, human predation (fishing) especially in the Lower Basin, hydrology, and the contribution of abiotic factors to the transition from mature adults to spawning adults.

Spawning adults with viable gametes to developing embryos

- Add a box under human activities for stocking. Temperature, flow hydraulic habitat, channel morphology and human predation (fishing) are critical concerns.

Developing embryos to free embryos

- All abiotic components should be emphasized, especially hydraulic habitat such as sediment, temperature, water quality, and light. Contaminants and possibly non-human predation are also critical factors (although non-human predation might fit better with the next stage). Dredging and boats were declared insignificant or of very minor concern for this life stage.
- Parental care was not indicated in the model. It has been assumed that parental care does not exist but perhaps it could exist for males, and represents a small missing component of the model.

Free embryo to exogenously-feeding larvae

- Abiotic factors are again very important. Dredging, boats, and entrainment could be de-emphasized, although data are conflicting on whether larvae drift higher or lower in the water column. Remove prey availability for this stage. Competition does not exist without a limited resource, so the competition box should be removed. Mortality from research activities needs to be included within the human activities component of the model. Reservoir operations should be another factor under hydraulic habitat rather than just connected to flow, and reservoir operations could fall under human activities. Reservoir levels or habitat are connected to channel morphology. Major factors for this stage included non-native fishes and reservoir operations.

Exogenously-feeding larvae to juveniles (wild/hatchery)

- This stage and the last one are the most important stages on the basis of gaps in knowledge and influence on other life stages. The only suggestion for an addition to the model was to include a stocking component linked directly to transition probability. Critical areas to emphasize include habitat, prey availability, predation, temperature, sediment, turbidity, hydraulic habitat, and competition among non-native and native fishes (if resources are limiting, which is unknown).

Juveniles (wild/hatchery) to immature adults (wild/hatchery)

- Once more, participants expressed a need to separate wild and hatchery fish and create separate transition probabilities for each. Fish origin and genetics could fit here. Prey availability, reservoir operations, channel morphology, and human activities are critical components of this submodel.

Preliminary research questions and needs

Early life history stages

Group members agreed that embryo through juvenile phases have the most data gaps, and researchers need to:

- Determine the significance of predation, especially from non-native fishes, to developing embryos.
- Determine the environmental drivers influencing the free embryo stage.
- Determine how embryos are impacted by deltas and drifting river flows.
- Determine the non-native predators on all stages of the life cycle. The bull shark is a potential danger to adult pallid sturgeon. The influx of Asian carp into the riverine population should also be investigated.
- Identify factors associated with over-winter survival rates.
- Fill information gaps at larval stage This stage represents one of the most significant gaps in knowledge and is considered key to all life stages. Stream flow augmentation, identification of species, drift, and diet are general priority research needs. Predation and competition with broodstock pallid sturgeon and non-native fish should also be emphasized. Plankton may be diminishing with the introduction of Asian carp, and Asian fish in general represent an unknown aspect of non-native competition. Create a nutrient food web to understand the bigger ecosystem picture and food availability for pallid sturgeon.
- Fill information gaps on the impacts of reservoir operations on larval survival. The cause of larval deaths is unknown, and could be a lack of food, predation, or related to sediment. Researchers identified this as a highly significant knowledge gap. The connectivity between drift, vegetation zones, and reservoir entrainment is another research consideration.

Mature adults

- Clarify impacts from inter-regional immigration. Immigration was not included in the life-history model, but pallid sturgeon do move between basins. There is confusion surrounding the populations in each basin. Some biologists ask whether regional populations might be separate species. Others believe that we simply see geographic structuring at the extreme ends of the range and that hybridization may or may not be normal for sturgeon; however, hybridization is common in species when their environments are highly altered.
- Determine effects of stocked fish on the system in comparison to wild fish. Stocked fish are becoming a range-wide concern. Although stocking occurs on the Missouri River, hatchery fish have been identified in the Lower Basin. Studies focusing on hatchery growth, survival, and competition with wild fish should be prioritized.
- Determine if hybridization is occurring. What are the consequences? Understanding hybridization, especially in the Lower Basin, is a significant research priority.

Appendix E –Summary of Plenary Session Discussions

Day 2: External expert insights

Presentations and discussion

Bernie Kuhajda, University of Alabama, Tuscaloosa, Alabama

Kuhajda is on the Pallid Sturgeon Recovery Team, and works with Alabama sturgeon *(Scaphirhynchus suttkusi)* and *Pseudoscaphirhynchus* in Asia. He emphasized the genetic and morphological differences between communities of pallid sturgeon, and the possibility of distinct populations within the range's four geographic regions. Other species of freshwater fish in this range have different communities with different species, and it is possible that the sturgeon populations are distinct in a similar way.

Kuhajda explained that hybridization occurs in all sturgeon species throughout the northern hemisphere. The fish are polyploids with multiple sets of chromosomes. Polyploids have occurred numerous times in the evolution of sturgeon, and reticulate speciation modeling suggests that the intermediates seen today could be part of the natural evolution of sturgeon.

Initial questions for Kuhajda revolved around the significance of the reticulate speciation model in relation to conservation efforts. He noted that reticulate speciation probably does not represent a distinct ecological advantage, but does serve as a useful indicator of the sturgeon's unique genetic makeup and biology. The chromosome number of pallid sturgeon is not known and is only extrapolated from the known number of chromosomes in shovelnose sturgeon.

Another question was why hybridization occurs more in the lower part of the range than in the upper range. Kuhajda noted that during the Pleistocene the outlet for the Upper Missouri River was north in the Arctic and was completely separate from the Mississippi River. After the Pleistocene, the Upper Missouri River reconnected, creating two disparate situations of hybridization within the sturgeon's range.

A few research questions also arose during plenary discussion. For example, it was noted that most hybrids are female, which may be a product of sexual differentiation. Hatcheries have produced hybrids intentionally, and it has not been determined if the sex results of the intentional hybridization mimic those of the natural hybridization. Hypotheses such as this need to be tested to determine if these types of genetic issues are conservation priorities. Also, allele frequencies can be tested to determine if hybrids are recent or historic. Finally, a question was raised about the applicability of conservation genetics to management activities. Are pallid sturgeon recovery efforts limited by attempts to protect unique biological units at the expense of recovering the species at large? The reply was that genetics is a significant component for management. For example, moving genetically distinct populations around is generally a bad idea.

Kuhajda emphasized that the reticulate speciation model is only one model. Hybridization could occur for natural reasons, and the reticulate speciation model helps explain some of the low genetic diversity seen in both *Scaphirhynchus* and *Pseudoscaphirhynchus*.

Joel Van Eenennaam , University of California, Davis, California

Van Eenennaam noted that the insufficient population of spawning adults is a bottleneck for self-sustaining recovery and current propagation efforts need to continue and increase. Increasing the number of potential spawners ultimately increases the number of generations, and increasing overall numbers increases the odds of recruitment and recovery. Work with Atlantic sturgeon *(Acipenser oxyrhychus)* and white sturgeon shows that you need many adults to have a significant number of females actually ready to spawn each year, due to the variation in age at first maturity (spawn) and the variable number of years in between subsequent spawning (2-5 years), for individual females.

Van Eenennaam expressed concern that domestic broodstock development of pallid sturgeon is occurring at one primary location, Gavins Point National Fish Hatchery. Concentrating broodstock at one location can be disastrous if there is a major population loss at the location. He recommended other sources of broodstock be developed in each sub-basin.

Wild pallid sturgeon have always been a broodstock source for Gavins Point National Fish Hatchery and could continue to be a source if the broodstock at the hatchery were lost. Van Eenennaam noted that the adequacy of the wild population was debatable and that historically, concentrating sturgeon stock sources is risky. One participant noted that the whole basin was being discussed, but parts of the Lower Basin have a stable population and protecting spawning adults is the number one goal. In areas where population structure is unknown, other threats such as environmental problems and harvest for caviar need to be addressed. Van Eenennaam agreed that determining the population structure of the Lower Basin is also a high priority.

Mike Parsley, USGS Columbia River Research Lab, Western Fisheries Research Center, Cook, Washington
Parsley works with white sturgeon in the Columbia River Basin and noted that problems with sturgeon recovery are not unique to the Missouri and Mississippi rivers. Current perceptions of sturgeon behavior may not be what they do in a normal environment, and no one working on any river understands what "normal" is for sturgeon populations. He urged researchers to conduct more hypotheses testing that focuses on determining causation. Correlation studies can guide research, but it is causal connections that contribute the most to recovery efforts.

Parsley noted that white sturgeon are managed for harvest in the lower part of the Columbia River Basin but not in the upper. The lower three hundred miles of the basin has commercial fishing, a meat fishery, some recreational fisheries, and tribal subsistence and commercial harvest. The states of Oregon and Washington and the Columbia River Inter-Tribal Fish Commission are responsible for regulating harvest. Harvest is managed by quotas that are based on demographics, with control factors of seasons, slot length limits, and an intensive creel and catch accounting system. In the upper basin, angling for sturgeon is banned but the sturgeon population is only maintaining, not increasing. Parsley was asked about the effects of contaminants in the Columbia River. He commented that not many studies exist and some are only correlative. Fish brought into a hatchery do survive, but we do not know how contaminants affect the performance of sturgeon and this needs to be a focus area for research.

Scott Kenner, Chair, Civil and Environmental Engineering Department, South Dakota School of Mines and Technology, Rapid City, South Dakota
Kenner discussed pallid sturgeon habitat from the perspective of habitat modeling and characteristics including hydraulics, depth, and velocity. He asked researchers to elucidate the parameters of physical habitat necessary to sustain different life stages and whether or not they exist. Physical habitat research originally focused on depth and velocity but habitat is a complex, and connections between different habitats are important. Characterizing how fish move and use different habitats is critical to the operation of reservoirs and constructed habitat. Parameters that sustain the long-term life cycle need to be qualified and quantified, such as magnitude, sustainability, and duration of flows. This will help clarify how to use these environments in recovery efforts. We have less flexibility in dry periods, but when we have a lot of water we can try to recreate habitats and conditions needed to sustain populations.

Boyd Kynard, USGS Conte Laboratory, Turner Falls, Massachusetts
Kynard noted that shortnose sturgeon *(Acipenser brevirostrum)* show different adaptive characteristics from the upper to the lower areas of their range and the same might be true of pallid sturgeon. Shortnose spawning areas are in the north, with foraging and wintering areas in the south. Different populations have different numbers of foraging and wintering areas, but after spawning the fish disperse to the first foraging area. When they are 1-year-old, they will disperse throughout the population.

Ranging from north to south, differences among shortnose populations are large, including a different pre-spawning migration strategy. In the northern system, large females contribute the most to spawning success. Because of their large size, they are not well adapted to long migrations. They migrate upstream during the summer and winter preceding spawning, leaving only a short migration in the spring. Research indicates that in headwater areas, movement of pre-spawning females will occur much earlier in the summer or fall. Southern populations have access to a longer growing season and are not as energetically challenged as northern populations. In the south, all sturgeon complete the full migration in the spring.

Similar strategies might be found for northern and southern pallid sturgeon populations. Kynard suggested that pallid sturgeon researchers define spawning windows by recording spawning times and the corresponding photoperiod, temperature, and flow. He found that photoperiod sets the base for shortnose sturgeon and within that window, temperature comes into play. Flows have no correlation with spawning migrations, and the same is true for white sturgeon.

Kynard recommended laboratory work to understand innate habitat preferences. His team built an artificial spawning tunnel to clarify preferences of the shortnose sturgeon, which required fewer resources than tracking fish in the field. Long-term telemetry work is still invaluable, and tagged fish need to be recaptured to renew the tags. Kynard concluded by emphasizing that pallid sturgeon are going to need passage at the dams.

Frank Chapman, University of Florida Department of Fisheries and Aquatic Sciences, Gainesville, Florida

Chapman began by reminding the group that conferences and publications and research are all about recovery, and communication is vital. There are hundreds of projects and we could study them forever, but it is all about recovery. He also asked that group members remember the importance of socioeconomic issues and their relation to recovery success.

Chapman commended the life-history model as a communication tool, but also cautioned recovery teams to avoid becoming solely focused on the model. He emphasized that the number of pallid sturgeon in the wild is too low and propagation efforts are a high priority. Finally, he noted that while we do see natural hybridization in sturgeon, it might not always be normal for pallid sturgeon. In other parts of the world, for example, where there are habitat problems, hybridization is not necessarily normal.

Day 3 Plenary: Funding, external expert fish-bowl discussion, and facilitated open discussion

Establishing funding priorities in the real world

Casey Kruse spoke about the realities of funding including criteria, suggestions for what to include in proposals, timeliness, and leveraging of resources.

Funding is dependent on the ability to do good science and the relevance of the proposal to management decisions. Proposals that connect researchers and managers by addressing decision-critical uncertainties will be prioritized. Be clear about the research question to be answered, and address directly how the proposal relates to range-wide recovery efforts. Kruse recommended expanding research questions beyond sub-basins to acquire information that is important across the range of pallid sturgeon. Leveraging other resources is also helpful. Finally, proposals need to be relevant to current issues and address why your proposal is important at this stage in the recovery process. Kruse also discussed things to avoid when attempting to procure funding. He warned against isolation and competition between sub-basins, and to be careful of personal egos and focusing too much on money.

Discussion

Kruse was asked if researchers on the Middle or Lower Mississippi River have an opportunity to collaborate with the Missouri River researchers. He noted that collaboration among regions was needed, and although there may be internal issues concerning appropriation language, the type of collaboration suggested would be received well. The next questions were about transparency and the decision-making processes behind funding awards. Decision-making processes need to be more open and available. Researchers can inform those involved in the funding processes, and want to be able to understand why projects are funded or not funded. Participants requested a forum for vetting priorities, similar to the sub-basin work groups. Channeling funding through the sub-basin Work Groups would help alleviate concerns about transparency.

Kruse agreed that the sub-basin Work Groups are a good model of organized efforts to discuss priorities and seek funding. The prioritization list made by the Upper Basin was helpful in allocating research dollars this year. He noted, however, that the sequence of funding can change based on real-time needs and opportunities that come up quickly, and asked work group members not to get discouraged if projects that are not on their list are funded due to some immediate need.

Participants voiced concern that lists created at this workshop would be institutionalized, when priorities can change within even a year. A clear process is needed for how sub-basin Work Groups and others will feed back in and be taken seriously. It was also stated that local entities should be taken into consideration and the group recommended that the USACE actively seek input from universities during the request for proposal (RFP) process. Kruse agreed that creating collaborative synergy and seeking ideas from a wide array of entities is important. The USACE can vet research questions with local experts and objectively look at how to do what is best for the pallid sturgeon.

Finally, Kruse noted that while the USACE is developing an RFP process, they also have specific questions related to the needs of management entities and recovery partners. It is important to remember the USACE is only one of many funding agencies.

Observers asked that all data be made openly available to the public. In their experience, data are difficult to obtain and incomplete when they are available.

External experts "fish-bowl" discussion

The facilitation team designed and facilitated a special discussion in the center of the room among external experts on research and management priorities. Scott Kenner, Boyd Kynard, Bernie Kuhajda, Mike Parsley, and Ed Peters participated.

Experts were asked where they would set priorities and what is key to pallid sturgeon recovery. Scott Kenner began by stating that the model was a useful tool for understanding the biology of the species and for communication purposes. He noted that the population of adults in the Upper and Middle Basins is critical and need to be enhanced to increase spawning. Monitoring is also critical, and sample frequency and duration need to be included in a monitoring design. He identified two bottlenecks: limited spawning habitat due to reservoir operations; and the survival of drifting larvae. Kenner recommended developing better parameters to help define, create, and sustain habitat because velocity and depth do not sufficiently describe the conditions. He posed an important question: has 60 years of separation created critical pods, and should the Lower Basin be used to help sustain the Upper Basin?

Bernie Kuhajda noted that relocating pallid sturgeon outside of their natural sub-population should be a last resort. Aquatic animals tend to develop specific populations in different drainages under different conditions, and more harm than good might be caused by mixing genetics through relocation. He noted that there are real-world decisions to be made with development conflicts. Since the matter of pallid sturgeon subspecies is so complicated, recovery efforts need to focus on identifying the best populations in the range and learning how to protect them.

Mike Parsley noted that the transition probabilities stage in the Upper and Middle Basins has broken arrows in the model. The Lower Basin could be used to help the other sub-basins understand why transition probabilities are a problem.

Ed Peters, retired professor from the University of Nebraska, explained that in many places experts know how the arrows are broken. In the Upper Basin it is because the larvae do not have enough room to get to a place where they can reliably mature. When reservoir levels are down there may be deltas, but when water levels rise there is predation. In the Middle Basin, the system used to be a mile wide and has been forced down to a narrow channel. That stretch of river is no longer good pallid sturgeon habitat because it lacks larval habitat on either side of the channel. The problem is further compounded because predators have been imported into the system. He prioritized providing habitat in an attempt to recreate an ecosystem. The first step is to get enough fish to spawning size to enable researchers to determine where they spawn.

Boyd Kynard noted that shortnose sturgeon vary latitudinally in how they use habitat, and the same could be true for pallid sturgeon. Much could be learned from the Lower Basin, therefore he would put resources into population assessments and telemetry in the Mississippi River. Habitat needs cannot be explained without understanding innate habitat preferences. He would fund controlled lab studies to determine those types of preferences. He also suggested translocating fish, such as moving fish above reservoirs.

The experts were then asked if they had a stack of proposals and could only fund one, which proposal would they fund?

Kynard reiterated that population assessment in the Lower Basin is a high priority. Kenner noted the importance of identifying links to restoration and management. He would choose parameterization of habitat so that construction can be efficient and sustained in the system. Kuhajda viewed range-wide population assessment as the first priority. Peters agreed with a field assessment of populations with telemetry, and noted the need to gather data for population viability analyses for all segments. He noted that re-introducing fish above reservoirs is problematic because the segments in the middle portion between reservoirs are too short for the fish to survive. Kynard noted that this is being done in Brazil where reservoirs are being constructed quickly, and suggested putting some fish upstream and find out where they go. He explained that in Brazil they are building fishways to determine if native fishes still have an innate drive to migrate. Peters noted that a potential drawback to this is that fishways also allow predators and other problems to move upstream. Parsley said that he is not a fan of studies documenting the status quo. He emphasized understanding movements in the context of threats to survival. If they are making restricted movements, the issues are different than when they move extensively.

Regarding other recovery efforts, Kuhajda relayed that in Alabama, state politics stopped the creation of a captive breeding program. He reminded workshop attendees of the importance of overcoming regional biases and bringing in expertise from all geographic areas. He noted that this workshop worked well, but that too much time was spent on the process (i.e., two hours spent in breakout groups but only the last 10 minutes were productive in terms of prioritization). Parsley noted that process

is important and the communication in the breakout groups allowed participants to get to the last, productive, 10 minutes. Kynard, who has been on several recovery teams, commented that there is no quick or easy way to work toward recovery and it has to be done in an open forum. He commended the structure of the workshop because it allowed people at every level to be heard, and this is rare. Kenner echoed Kynard's statements, noting that in watershed management people are beginning to come together and recognize different components of the process and work to collaborate. Peters asked that the group work toward even more consistency in data recording, database maintenance, and accessibility. He felt the group worked efficiently.

During the discussion period, observers stressed the need to make data available to the public and the need to include non-federal groups in conferences and research. Small college and private consulting communities on the Missouri and Mississippi rivers are excluded from solicitations for proposals. Other comments related to the political nature of pallid sturgeon recovery efforts, and researchers were asked to collaborate and think beyond their sub–basins, and to use common sense. There are areas of the river where the fish cannot be recovered and efforts should focus on areas with existing populations. They requested that data be made accessible to the public in an understandable manner, and that research projects with no practical application be avoided. Concerns were expressed about the impacts to other parts of the ecosystem from pallid sturgeon recovery efforts, such as soil from excavation getting into the river. Finally, observers recommended focusing on genetics and invasive predators, and ensuring that policy makers are present at the next conference.

Appendix F – Detailed Summary of Breakout Session 2 Discussions

For the Day 2 breakout session, the facilitation team asked participants to focus prioritization on needs that address ecological bottlenecks, reflect decision-critical uncertainties, and are feasible in a technical and scientific sense. Feasibility was not intended to apply to funding – if a need is important enough to be prioritized, it should be funded. Time and geography were other factors to consider during prioritization.

Steering Committee members asked participants to keep in mind how a research priority fits into the life-history model. Currently the model is a communication tool for organizing information, but it is also intended to eventually become a predictive tool. Causal hypothesis testing is important, and feasibility means a proposal is structured to answer a question. Make sure the experimental design is solid, focus on causality, and have a spatially relevant setting. Modelers can help address some questions and spatial issues (e.g., existing contaminant dispersion models might be used to model fish early life stage dispersion). Management needs also should be considered. Prioritization should focus on research that will assist management decisions for recovery.

Several participants noted that hypothesis testing is important but so is the time scale. Thus, both short-term and long-term elements were considered in the breakout groups. Another participant noted that monitoring is a long-term element, and should be comparable among the basins so that management approaches can be compared.

An observer expressed concern with the disconnect between scientists and stakeholders, and how that disconnect could hinder the recovery process. Research ideas need to pass the common sense test, and be explained so that the average person can understand the purpose and expected results. The facilitator noted that there are many decision processes important to recovery work, and research needs to be relevant to all of those processes.

Workshop attendees were assigned to Upper, Middle, or Lower Basin breakout groups to identify and prioritize research needs for each area. As starting points, preliminary needs identified in the Day 1 breakout sessions (Appendix D) were distributed along with those from the 2004 pallid sturgeon workshop (Appendix G).

Breakout Group 1: Upper Basin

Participants: Pat Braaten, Steve Chipps, Yvette Converse, Mark Drobish, Bill Gardner, Tyler Haddix, Rob Holm, Matt Jaeger, Scott Kenner, Rob Klumb, Beth MacConnell, Henry Maddux, Mike Parsley, Mike Ruggles, Dane Shuman, Wayne Stancill, Sam Stukel, and Greg Wanner.

Prioritization

Participants began by brainstorming and then examined the existing Upper Basin management strategy document. The highest priority needs identified by the breakout group are shown in the main body of this report. In addition, the following medium to low priority needs were identified.

Medium-high priorities

- Provide general guidelines for bank stabilization projects and preferred alternatives. Evaluate projects and consider cumulative effects. Long term.
- Evaluate environmental factors related to egg survival. Long term.
- Estimate sex ratios, intervals between spawning episodes (years), and abundance of sexually mature adults. Short term.
- Identify spawning areas for pallid sturgeon. Ongoing.
- Conduct an interagency data management program to compile, manage, and maintain all research and monitoring data collected by the Recovery Program. Ongoing.

- Determine thermal optima and tolerance for juvenile pallid sturgeon growth and survival. Ongoing.
- Study cytokines and immune molecules to better understand pallid sturgeon health. Ongoing.
- Determine if sensory cells regenerate in viral-infected pallid sturgeon. Ongoing.
- Compare virus positive and virus negative pallid sturgeon to evaluate effects on growth, survivorship, etc. Ongoing.
- Use polymerase chain reaction (PCR) studies to evaluate presence of virus in the wild. Ongoing.
- Develop techniques to quantify virus rates in wild and future broodstock. Ongoing.
- After rates have been quantified, establish viral exceedence thresholds to guide stocking of virus-positive pallid sturgeon. Ongoing.
- Conduct monitoring to evaluate effectiveness of pallid sturgeon stocking. Ongoing.
- Assess the monitoring needed to evaluate the contribution to recovery of pallid sturgeon stocked over relevant reaches, life stages, and generations. Ongoing.
- Evaluate the effects of contaminants on reproduction. Short term.

Medium priorities
- Determine contaminant load and effects on pallid sturgeon embryos and larvae. Ongoing.
- Cyropreservation. Ongoing, long term. Some components are research, some are management.
- Determine which commercial diet may replace BioDiet in pallid sturgeon culture. Long term.
- Evaluate environmental and nutritional factors affecting skeletal mineralization in pallid sturgeon. Ongoing.
- Describe food habits and determine ontogenetic diet shifts of larvae and age-0 juveniles. Ongoing.
- Evaluate the role of prey production and contaminants on growth and survival of larvae and age-0 juveniles. Ongoing.
- Examine seasonal habitat requirements and use by larvae and age-0 juveniles. Ongoing.

Low priorities
- Determine age at maturity and validate ages of juvenile pallid sturgeon at large for several years in the Missouri and Yellowstone rivers. Ongoing.
- Estimate ages of adults for which fin rays are available, though there are questions whether this is feasible.
- Conduct a population viability analysis. Long term.
- Quantify egg-hatch success as related to environmental conditions (e.g., temperature, substrate, suspended solids). Long term.
- Investigate imprinting as a mechanism to stimulate homing and site fidelity. Long term.
- Document spawning, spawning habitat, and environmental conditions associated with spawning in the Missouri River and tributaries. Ongoing.
- Determine fate of stocked juveniles swimming into headwater reservoirs. Some work on this is being done in general fish surveys.

Breakout Group 2: Middle Basin

Participants: Frank Chapman, Aaron DeLonay, Wyatt Doyle, Gary Heidrich, Ed Heist, Tracy Hill, Paul Horner, Jan Hoover, Robb Jacobson, Doug Latka, Jane Ledwin, Gerald Mestl, Diana Papoulias, Mike Parsley, Mark Pegg, Ed Peters, Schuyler Sampson, Darin Simpkins, Joel VanEnennaam, and Mark Wildhaber.

Prioritization

The highest priority needs are shown in the main body of this report. In addition, the following medium to low priority needs were identified.

Medium priorities

- Determine the specific locations and microhabitat features associated with spawning.
- Identify use and availability of spawning habitat in the Missouri River and its tributaries.
- Evaluate the effects of contaminants on reproduction.
- Determine the significance of predation on developing embryos.
- Better understand the environmental drivers influencing the free embryo stage.
- Identify factors associated with over-winter survival rates of early life stages.

Low priorities

- Evaluate the role of prey production and contaminants on growth and survival of larvae and age-0 juveniles.
- Determine if imprinting occurs and if so, its significance.

Breakout Group 3: Lower Basin

Participants: Joyce Collins, Jim Garvey, Paul Hartfield, Tom Keevin, Bernie Kuhajda, Boyd Kynard, Greg Moyer, Catherine Murphy, George Scholten, Todd Slack, and Robert Wood.

Most needs discussed by the group were related to population assessment, genetics, habitat, or early life stages. The group also discussed the inadequate communication between sub-basin work groups. Significant threats to recovery identified included commercial fishing (especially with the increasing value of caviar), entrainment, contaminants, habitat, and hybridization.

Prioritization

The highest priority needs are shown in the main body of this report. In addition, the following medium to low priority needs were identified.

Medium priority

Fish passage at Chain of Rocks

- The group discussed the significance of Chain of Rocks as a barrier to fish movements. It is known that sturgeon can pass the low-head weir, but it is not known how they pass the structure or whether passage is restricted by flow conditions. Telemetry work on fish movements to evaluate the question would be long term.

Standard habitat classification

- Sub-basins lack a consistent, range-wide habitat classification system. Standardizing a classification system would ensure that everyone is referencing the same habitat type using the same terminology. The Lower Basin does have a habitat classification system for the Mississippi River and needs to coordinate with Missouri River managers and researchers with encouragement for them to use the same system.

Propagation for genetics

- With the occurrence of commercial fishing, some genetics are being removed from the Lower Basin population. Some group members expressed the consequential importance of propagation and stocking to recapture some genetics. Others, however, strongly conveyed their view that stocking would be a mistake. If stocking does happen, agencies and researchers who would be affected need to have some input.

Appendix G. Research needs identified in the 2004 pallid sturgeon workshop, *Research and Assessment Needs for Pallid Sturgeon Recovery in the Missouri River* (Quist et al. 2004)

Box 1: Highest priority research needs associated with reproduction of pallid sturgeon*

1.1 Develop a better understanding of environmental factors influencing maturation and spawning movements including homing

1.2 Determine factors that elicit spawning and egg deposition

1.3 Determine the specific locations and microhabitat features associated with spawning

1.4 Identify use and availability of spawning habitat in the Missouri River and its tributaries

1.5 Evaluate the effects of contaminants on reproduction

**These research needs are not ranked.*

Box 2: Highest priority research needs associated with early life history stages of pallid sturgeon*

2.1 Develop a better understanding of factors related to egg quality

2.2 Determine the influence of predators on egg survival

2.3 Determine environmental factors influencing egg survival

2.4 Describe food habitats and determine ontogenetic diet shifts of larvae and age-0 juveniles

2.5 Evaluate the role of prey production and contaminants on growth and survival of larvae and age-0 juveniles

2.6 Examine seasonal habitat requirements and use by larvae and age-0 juveniles

2.7 Determine which habitats are limiting for larvae and age-0 juveniles

2.8 Determine the influence of predators and competitors on larvae and juveniles

2.9 Determine if imprinting occurs, and if so, its significance

** These research needs are not ranked.*

Box 3: Highest priority research needs associated with age 1 and older pallid sturgeon*

3.1 Define upstream and downstream migration patterns of each life stage

3.2 Describe food habits and determine ontogenetic diet shifts

3.3 Evaluate the role of prey production and contaminants on growth and survival of pallid sturgeon

3.4 Examine seasonal habitat requirements and use by pallid sturgeon

3.5 Determine which habitats are limiting for pallid sturgeon

3.6 Determine the influence of predators and competitors on pallid sturgeon

** These research needs are not ranked.*

Photo courtesy of USWFS

Box 4: Highest priority research needs associated with population assessment and energy transport*

4.1 Develop standardized protocols for sampling and monitoring all life history stages of pallid sturgeon

4.2 Conduct long-term monitoring of pallid sturgeon populations to determine population status and detect trends

4.3 Examine the role of reservoirs as nutrient sinks and the subsequent effects on pallid sturgeon and other members of the fish assemblage

4.4 Examine the role of energy transport and organic debris on growth and survival of pallid sturgeon

** These research needs are not ranked.*

Box 5: Highest priority research needs associated with habitat formation and maintenance*

5.1 Evaluate the role of sediment transport for creation and maintenance of habitat for all life history stages of pallid sturgeon

5.2 Evaluate the role of discharge for creation and maintenance of habitat for all life history stages of pallid sturgeon

5.3 Determine an optimal mosaic of habitats for rehabilitating river biodiversity

5.4 Evaluate the interaction between flow manipulations and habitat improvement activities for creating habitat

5.5 Develop a framework and methodology for habitat classification

5.6 Document the occurrence and distribution of habitat relative to ecological structure and function

** These research needs are not ranked.*

Box 6: Highest priority research needs associated with hybridization and genetics*

6.1 Identify the occurrence and frequency of hybridization between pallid sturgeon and shovelnose sturgeon

6.2 Identify factors contributing to hybridization between pallid sturgeon and shovelnose sturgeon

6.3 Obtain genetic information for wild and broodstock populations of pallid sturgeon

6.4 Use genetic analysis to maximize genetic variability in fish included in propagation efforts

6.5 Adopt formal protocols for collecting tissue samples and measurements for genetic analyses and systematic studies

** These research needs are not ranked.*

Box 7: Highest priority research needs associated with propagation and fish health*

7.1 Evaluate and enhance techniques to maximize survival and health of broodstock including developing a diet that provides for healthy growth

7.2 Evaluate and stage female pallid sturgeon to determine optimal time for spawning

7.3 Improve physiological and health tools for maximizing production and survival of eggs

7.4 Develop methods to maximize the efficacy of cryopreservation

7.5 Develop diagnostic tools to evaluate iridovirus

7.6 Identify the occurrence and frequency of iridovirus in wild populations

7.7 Evaluate the effects of iridovirus on all life history stages of pallid sturgeon

7.8 Develop health baselines (e.g., blood chemistry) for all life history stages of pallid sturgeon

** These research needs are not ranked.*

Box 8: Highest priority research hypotheses related to experimental flow releases*

8.1 Changes in the flow regime enhance pallid sturgeon spawning habitats

8.2 A rise in discharge and temperature during the spring is important for maturation (post-vitellogenesis to spawning)

8.3 Changes in the flow regime enhance the availability and quality of nursery habitats

8.4 A more naturalized hydrograph (magnitude, frequency, duration, timing) will elicit spawning by pallid sturgeon

8.5 A more naturalized hydrograph (magnitude, frequency, duration, timing) will result in pallid sturgeon using previously unutilized riverine habitats

8.6 A more naturalized flow regime will enhance a dynamic channel geomorphology and associated fish habitats

8.7 Test flows downstream of Fort Peck and Gavins Point dams will affect habitat availability for pallid sturgeon, including spawning habitat

8.8 A low flow period will result in increased shallow-water habitat and will increase survival of larval and juvenile pallid sturgeon

** These research hypotheses are not ranked.*

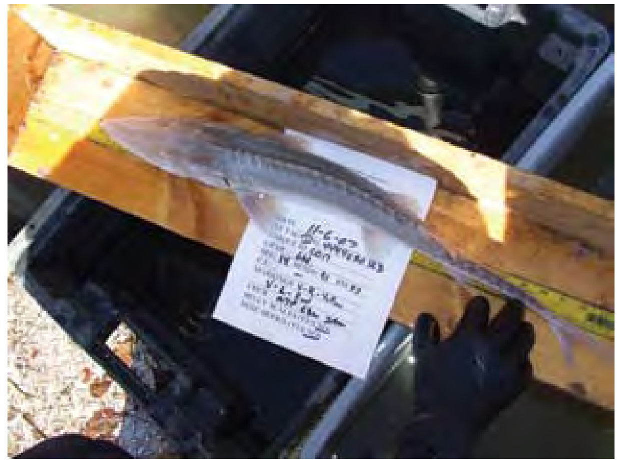

Photo courtesy of USFWS

Box 9: Highest priority research hypotheses related to construction of shallow-water habitats*

9.1 The current mosaic of habitats is available for pallid sturgeon to complete their life cycle in each segment of the Missouri River

9.2 Constructed shallow-water habitat will be used by larval and juvenile pallid sturgeon during low flow periods

9.3 Flow management and habitat construction activities will maintain riverine habitat thought to be important to pallid sturgeon and will elicit a positive biological response from pallid sturgeon and other native benthic fishes (e.g., increased abundance, growth, recruitment, and survival)

9.4 Test flows, physical habitat modification (e.g., wing dike notching or removal), and tributary inputs downstream of Gavins Point Dam will act in concert to substantially alter channel morphology and will result in a positive biological response from pallid sturgeon

9.5 Missouri River habitats can be organized into a classification system that enables quantification of the extent and temporal trends of each habitat class

** These research hypotheses are not ranked.*

Box 10: General research hypotheses related to pallid sturgeon recovery*

10.1 Key factors cueing the spawning migration of pallid sturgeon include discharge, photoperiod, water temperature, and water quality

10.2 Key factors influencing the selection of spawning sites and areas for egg deposition are substrate characteristics, depth, water velocity, turbulence, water temperature, moon phase, and discharge patterns

10.3 Survival and successful hatching of pallid sturgeon eggs are related to sediment dynamics and substrate characteristics (e.g., size, embeddedness, interstitial spaces), water temperature, water velocity, bedload movement, predation, and the amount of contaminants in the sediment

10.4 Survival and growth of larval and juvenile pallid sturgeons are related to predation and competition, discharge, water temperature, hydraulic patterns and diversity, food availability and selection, habitat availability and selection (including habitat diversity), and contaminants

10.5 Survival and growth of pallid sturgeon from age 0 to age 1 are related to predation and competition, discharge, water temperature, hydraulic patterns and diversity, food availability and selection, habitat availability and selection (including habitat diversity), and contaminants

10.6 Survival and growth of pallid sturgeon from age 1 to age-at-maturity are related to predation and competition, discharge, water temperature, hydraulic patterns and diversity, food availability and selection, habitat availability and selection (including habitat diversity), contaminants, and exploitation

10.7 Trends in presence-absence, population density, age structure, growth, mortality, and recruitment are similar among regions and do not vary through time

** These research hypotheses are not ranked.*

Appendix H – Additional Ideas Contributed by Reviewers

The following ideas, questions, research needs, or viewpoints were contributed by external reviewers of this report.

General

- The document provides a wide range of valuable information and recommendations, and summarizes the state of knowledge for many important recovery issues across the pallid sturgeon's range. This is an inherently valuable step in pallid recovery.
- One general thought that runs through the document is the USACE desire to include emphasis on collaboration among basin areas when reviewing research proposals. While this would be an ideal arrangement for recovery of the species and there are some areas where it would be truly beneficial, there are questions regarding the true ability to achieve this measure in some of the needed research topics. Most of the money the USACE has available is specifically to avoid jeopardy in Missouri River Operations. This will, in political reality, limit their ability to spend money on research that does not specifically tie into this area. Collectively, this group needs to begin to identify funding sources beyond USACE to recover this species.
- The goal of this workshop was to prioritize research and management strategies that lead to range-wide pallid sturgeon recovery. Each sub-basin breakout group came up with priorities, some of which were similar (e.g., early life history stages) while others were more basin-specific (e.g., effects of reservoirs). The workshop did achieve its goal of prioritizing research and management needs by sub-basin, but it fell short in addressing range-wide pallid sturgeon recovery. This report clearly indicate that participants, particularly the outside experts, are in favor of range-wide planning, research, and recovery. However, no specific guidance or suggestions on unifying studies to address range-wide recovery were presented.
- The Biological Opinions are directing the funding, which by their very nature, focus on specific geographic areas and not the entire range. Although there were indications that proposals will be considered if they address range-wide issues, it was not clear which topics would be acceptable. Should another workshop be convened to develop range-wide research strategies?
- The conceptual model helped guide discussions and identified data gaps. These types of models can be an effective way to plan large studies. However, the model seems too complex considering the number of additions and changes that were suggested at the workshop. The conceptual model should be simplified and maybe consider adding decision-support models to help prioritize research and guide adaptive management.
- The workshop's goal of acquiring technical guidance overlooked the technical guidance that was available prior to this workshop. The majority of the information identified within this report using the conceptual life history model, expert panels, and breakout sessions was previously available in the Recovery Plan (USFWS 1993), report from the 2004 workshop (Quist et al. 2004), and more recently in the 5-Year Review (Jordan 2007).
- The process for pallid sturgeon recovery is a long-term challenge. Funding agencies and managers need to cooperatively develop action plans that encompass strategies for five, 10, and 25 years.

Photo courtesy of USWFS

- Although referred to initially in the text, the document contains no explicit adaptive management framework or plan. This may be an envisioned future product as recovery planning progresses. If not, it would be a recommended product to translate concepts into discrete testable hypotheses that drive restoration decisions.

Habitat

- Determine tributary influences.
- Habitat classification is another example of the need for increased communication among the basins. The Missouri River researchers started with the habitat classification system utilized by the Long Term Resource Monitoring Program on the Mississippi River. They found it did not provide enough detail to classify and quantify habitat types on the Missouri River and added the more complex coding system used today.
- Habitat needs of pallid sturgeon will continue to be a major issue considering the amount of time and money that goes into habitat restoration. Participants may have discussed the challenging question of restoring habitat before we know the status of the population, but it was not obvious.

Population

- Determine existing populations of adult pallid sturgeon in all basin areas and predicted date of extirpation.
- Determine the effect of shovelnose sturgeon commercial harvest on pallid sturgeon populations in the lower Missouri and Mississippi rivers.

Genetics

- Continue to develop and refine the genetic baseline for the entire range of the pallid sturgeon.

- Regarding the assertion of unique alleles in intermediate sturgeon – this may be true, but population geneticists may not necessarily support the notion of unique alleles; this is in contrast to taxonomists who are trained to look for differences among species. Population geneticists also may think differently about "intermediates" than do taxonomists. It might be wise to independently ask them all the same questions about unique alleles and the genetics of intermediate river sturgeon.

- Stocking and genetics are major issues, but were not highlighted in this report. Discussion is needed on potential problems of stocking fish without first understanding the genetic ramifications of mixing stocks from different geographical areas. A genetic management plan may be available, but it was not obvious in this report. The lack of genetic data across the range of the species is an impediment to future stocking efforts and needs. If a genetic management plan is not available or has not been critically reviewed by outside experts, then this topic would also be important for future meetings.

Early life stages

- Regarding competition between larval pallid sturgeon and non-native fish, Dr. Duane Chapman, USGS, Columbia, Missouri, has data from Asian carp stomachs in large Midwest rivers. These data may be comparable at least anecdotally to pallid and shovelnose stomach content studies.

- In the hatchery, an early hurdle is switching to exogenous feeding at about nine days post hatch at 18-19 °C. There is a famous die-off which can occur (90 percent mortality) at about day 10. The same thing likely happens in nature at the same life stage though perhaps not at the same age, and the situation should be more dire for them in the unprotected riverine environment. The fish seem fairly fragile until they reach about 60-80 mm total length; then they seem pretty hardy. There are many large predators in the Lower Basin, so survival to about 300+ mm fork length likely is key to reaching adulthood.

Note: the following review comments were received after this report was in print and are not in the hard copy, but are included in this electronic copy.

- *New rearing techniques developed for lake sturgeon to assure or address imprinting might be adapted for pallid sturgeon. Please see: Holtgren, J.M., S.A. Ogren, A.J. Paquet, and S. Fajfer. 2007. Design of a portable streamside rearing facility for lake sturgeon. North American Journal of Aquaculture 69(4):317-323.*

- *Regarding larval survival and drift distance, there may be both drifting larvae and non-drifting larvae from one spawning event. Caution is needed in thinking there is only drift and all larvae move away from the immediate spawning area. Both the spawning site and nearby areas as well as drifting habitats may be significant.*

Upper Basin

- Gavins Point National Fish Hatchery is the only hatchery that has annually added year class and genetic representation to a future captive broodstock. It was suggested that additional locations (i.e., hatcheries) should also be holding some representation of a future captive broodstock, but this is a space-consuming endeavor. It may be feasible to utilize given river reaches to serve this purpose rather than just focusing on a hatchery environment. The Gavins Point hatchery has dealt with iridovirus issues for a decade already, so the existing future broodstock may be at risk if iridovirus is more than a common cold in sturgeon.

- Pallid sturgeon recovery must not be based upon hatchery stocking. Stocking is only a temporary stopgap measure until conditions are right for completing the life cycle naturally.

Middle Basin

- High Priority Research Needs
    - ◊ Adults – Determine existing populations of adult pallid sturgeon in the Middle Missouri River Basin.

- ◊ Genetics – Determine the genetic structure of *Scaphirhynchus* species in the Middle Missouri River Basin.

- Other
  - ◊ Regarding the report in the Middle Basin science updates summary (page C-11) that few pallid sturgeon are captured in standard surveys when stocking has ceased – this is a profound statement. We have placed so many constraints on the propagation/population augmentation effort that we are not stocking fish and as a result we catch less fish when we do not stock. Would we expect a different result given that we all know that not all of the stocked fish will survive?

Lower Basin

- Regarding the viewpoint that the Lower Basin pallid sturgeon population appears to be reproducing more successfully, biologists in the lower river were not checking pallid sturgeon for coded wire tags until a couple of years ago. Therefore, data prior to this time are questionable relative to the origin of these fish (i.e., hatchery or wild). There are no genetics in the USFWS baseline from any adults prior to about the year 2000; therefore tissue samples cannot be linked back to any parents from the spawning efforts in 1992 or 1997 which took place at the Blind Pony State Fish Hatchery in Missouri. Placing high priority on the need to incorporate population assessment in the Middle Mississippi River and Lower Mississippi River is right on track.

Next Steps

- Recommendations for research to provide missing information about innate behaviors of spawning or early life stages were simultaneously proposed with hydro operations to help spawning or early life stage survival. The urgency associated with recovery of this listed fish is clear given long-term spawning or recruitment failure and declining population abundance trajectories and how this generates the need for action. However, it seems incongruous to be targeting unknown conditions in the interest of recovery.

  A recommended approach would be to systematically identify critical uncertainties within regions or management units, propose experiments to resolve the uncertainty, and then provide in-river restoration or hatchery supported recovery targets. For example, innate behavior experiment results (in a lab setting) can provide specific hydraulic and habitat choice information by fish from the recovery areas that can then be used as empirical targets for altered hydro operations. This is difficult if not impossible to do in large altered rivers with low population numbers and no recruitment.

  It seems problematic to implement well-intentioned, large scale, or expensive actions as possible solutions when the requirements for solving the problem remain unknown. Figure 1 in the document addresses this issue conceptually, but the concept behind Figure 1 needs to be translated into specific sequential adaptive management experiments where needed throughout the pallid sturgeon's range that are focused on and directly linked to resolving limitations at relevant local or regional scales for recovery.