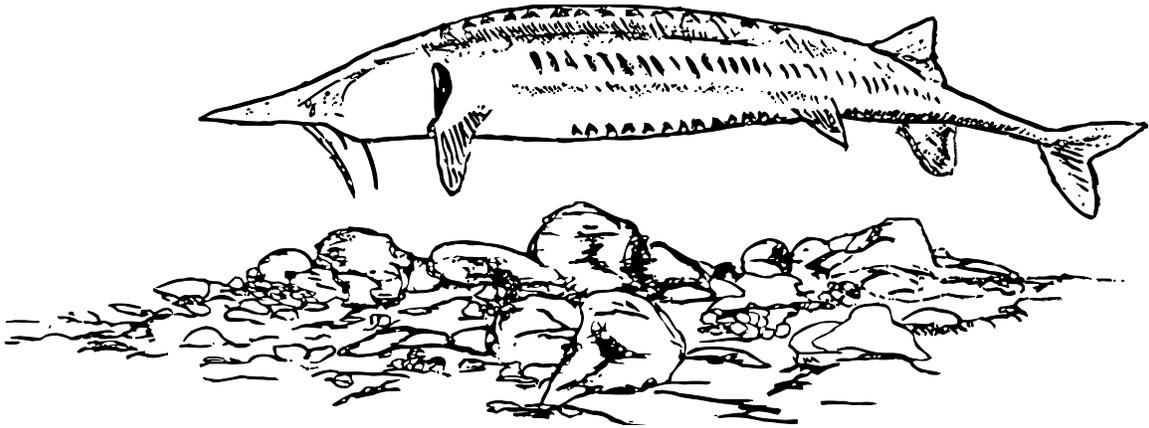


Pallid Sturgeon
(Scaphirhynchus albus)

5-Year Review
Summary and Evaluation



U.S. Fish and Wildlife Service
Pallid Sturgeon Recovery Coordinator
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5-YEAR REVIEW
Pallid sturgeon (*Scaphirhynchus albus*)

1.0 GENERAL INFORMATION

1.1 Reviewers

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1.2 Methodology Used to Complete the Review

On July 7, 2005, the U.S. Fish and Wildlife Service (USFWS) announced a 5-year review of Black-footed ferret (*Mustela nigripes*) and Pallid sturgeon (*Scaphirhynchus albus*) (70 FR 39326-39327). Through this notice, a public comment period also was initiated with a conclusion date of September 6, 2005. During this comment period, the lead office received one written comment from the Lower Brule Sioux Tribe, South Dakota, indicating that no pallid sturgeon have been reported being caught on or near the reservation during the past 5 years.

All data compilation and the drafting of this document was a group effort consisting of the Pallid Sturgeon Recovery Team, the Team's Genetic Advisory Group, and Regions 3, 4, and 6 of the USFWS. Initial data compilation for this status review was the result of a request from the Pallid Sturgeon Recovery Team Coordinator sent to biologists most familiar with pallid sturgeon demographics within all the Recovery Priority Management Areas (RPMAs) as defined in the Pallid Sturgeon Recovery Plan (USFWS 1993). This request was to summarize all demographic data from each RPMA. These demographic data as well as the most recent genetics data were summarized and presented to the Pallid Sturgeon Recovery Team and the Pallid Sturgeon Recovery Team's Genetic Advisory Group on September 28-29, 2005. The Pallid Sturgeon Recovery Team, Genetics Advisory Group, and USFWS lead and cooperating field offices compiled all available data and completed sections 2.3, 2.4, and 5.0.

The USFWS oversaw production and considered all available information to assemble this review and made all recommendations regarding appropriate status, application of the Distinct Population Segment Policy (1996), application of other relevant policies (see below), adequacy of recovery criteria, species status and classification determinations, and priority number designation. Peer review of this document was completed in accordance with the peer review plan (see Appendix A). Peer reviewer comments and responses to peer reviewers also are presented in Appendix A.

Sections 3(3), 10(a)(1)(A) and 10(j) of the Endangered Species Act (ESA) of 1973, as amended authorize the use of artificial propagation and experimental populations to further the conservation and recovery of threatened and endangered species. To clarify these roles and responsibilities, the USFWS and National Marine Fisheries Service (NMFS) jointly published a *Policy Regarding Controlled Propagation of Species Listed under the Endangered Species Act* (65 FR 56916-56912, September 20, 2000).

The NMFS has subsequently published a *Policy on the Consideration of Hatchery-Origin fish in Endangered Species Act Listing Determinations for Pacific Salmon and Steelhead* (70 FR 37204-37216, June 28, 2005). This latter policy was developed in response to the *Alesea Valley Alliance v. Evans* Federal court decision (aka "Hogan decision") which explicitly stated that hatchery-origin fish must be included with the listing of an endangered or threatened species under the ESA if those hatchery-origin fish are considered biological members of the listed entity (species, subspecies, distinct population segment, or evolutionary significant unit). This latter policy of NMFS also states, "Hatchery fish will be included in assessing an ESU's (evolutionarily significant unit) status in the context of their contributions to conserving natural self-sustaining populations."

Pallid sturgeon are currently listed as endangered under the ESA. Artificial propagation of pallid sturgeon is one component of the existing Recovery Plan and is currently ongoing. As a result, tens to hundreds of thousands of juvenile pallid sturgeon are produced and released annually via artificial propagation and captive spawning of wild-caught adults in accordance with the pallid sturgeon stocking and augmentation plan (USFWS 2006a).

The following statement is for the purpose of defining how hatchery-reared pallid sturgeon were viewed in this review, and implementing the ESA for pallid sturgeon in a manner consistent with the joint USFWS-NMFS *Policy Regarding Controlled Propagation of Species Listed under the ESA* and the *Alesea Valley Alliance v. Evans* Federal court decision. The following statement also is intended to be consistent with the NMFS' policy on the consideration of hatchery-origin fish in ESA listing determinations for Pacific salmon and steelhead.

The USFWS considers hatchery-reared pallid sturgeon, resulting from artificial propagation or captive breeding, to be members of the listed species and are, thus, protected under the provisions of the ESA, except as described in Section 10. All assessments of the status of pallid sturgeon under the ESA will consider the contributions of hatchery-origin fish to conserving natural self-sustaining populations. For the purpose of assessing the status of pallid sturgeon, the USFWS must consider the data available regarding the role of hatchery-reared pallid sturgeon in support of the conservation of naturally-spawning pallid sturgeon and the ecosystems upon which they depend, consistent with section 2(b) of the ESA (16 U.S.C. 1531(b)).

Current data indicate that hatchery-reared pallid sturgeon are essential to preventing local extirpation in portions of the range (RPMA 1 and 2) and have been used to reestablish pallid sturgeon in a small portion of the species' range (RPMA 3). However, it is too early to determine if these artificially propagated pallid sturgeon will spawn and naturally reproduce, and thus it is unclear if these hatchery-reared fish are contributing to conserving natural self-sustaining populations.

1.3 Background

1.3.1 Federal Register Notice Citation Announcing Initiation of this Review

70 FR 39326-39327, July 7, 2005

1.3.2 Listing History

Federal Register Notice: 55 FR 36641-36647

Date listed: September 6, 1990

Entity listed: Species

Classification: Endangered

1.3.3 Associated Rulemakings

NA

1.3.4 Review History

- A previous USFWS 5-year review for pallid sturgeon was noticed on November 6, 1991 (56 FR 56882). In this review, all currently listed species were simultaneously evaluated with no species-specific, in-depth assessment of the five factors, threats, etc., as they pertained to the different species' recovery. The notices summarily listed these species and stated that no

changes in the designation of these species were warranted at that time. In particular, no changes were proposed for the status of the pallid sturgeon in the review.

- Although not technically a 5-year review per our regulatory requirements, on November 7, 1993, we announced the availability of the Pallid Sturgeon Recovery Plan. This document summarized the status of the species and biological requirements of the species as best known at the time.

1.3.5 Species' Recovery Priority Number at Start of Review

2C

1.3.6 Recovery Plan or Outline

Name of plan: Pallid sturgeon (*Scaphirhynchus albus*) Recovery Plan

Date issued: November 7, 1993

Dates of previous revisions: NA

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment Policy

2.1.1 Is the species under review a vertebrate?

Yes

No

2.1.2 Is the species under review listed as a DPS?

Yes

No

2.1.3 Was the DPS listed prior to 1996?

NA

2.1.4 Is there relevant new information for this species regarding the application of the DPS policy?

Yes

No

Currently there are data that suggest some form of genetic structuring range-wide and even suggest discernable genetic groups (Heist and Schrey 2006a and b; Tranah et al. 2001). However, these data are incomplete or lacking for portions of the species' range.

Therefore, current data appear insufficient to warrant application of the DPS policy at this time. However, as new data are developed and analyzed those data will be considered and the applicability of DPS policy will be reevaluated.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?

Yes
 No

The 1993 recovery plan noted the short-term recovery objective for the pallid sturgeon is to prevent species extinction. Delisting criteria were deemed “undeterminable” in 1993. And while this recovery plan outlined “interim” downlisting criteria (see section 2.2.3 below), the criteria were vague due to our limited understanding of the species and immediate focus on preventing extinction.

2.2.2 Adequacy of Recovery Criteria

2.2.2.1 Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat?

No

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

No

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information. For threats-related recovery criteria, please note which of the 5 listing factors* are addressed by that criterion. If any of the 5 listing factors are not relevant to this species, please note that here.

Interim Downlisting Criteria: 1) a population structure with at least 10% sexually mature females occurring within each recovery-priority management area has been achieved; and 2) when sufficient population numbers are present in the wild to maintain stability.

Evaluation Of Interim Recovery Criteria: In the 14 years since the recovery plan (USFWS 1993) was approved, we have learned much about the species, its threats, and its needs. We now believe that the best scientific and commercial information available suggests these downlisting criteria are no longer relevant to a potential future downlisting as written. Each recovery priority management area

*1) Present or threatened destruction, modification or curtailment of its habitat or range;
2) Overutilization for commercial, recreational, scientific, or educational purposes;
3) Disease or predation;
4) Inadequacy of existing regulatory mechanisms;
5) Other natural or manmade factors affecting its continued existence.

(RPMA) is faced with problems beyond just total population numbers and male-to-female ratios. A self-sustaining population can not be maintained without adequately addressing identified threats. A revision of the recovery plan is suggested (see section 4.0 for a complete list of recommended future actions).

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

The pallid sturgeon is a member of the genus *Scaphirhynchus*. This species is a bottom-oriented, large rivers obligate inhabiting the Missouri and Mississippi Rivers from Montana to Louisiana (Kallemeyn 1983) and the Atchafalaya River (Reed and Ewing 1993). Within this range, pallid sturgeon tend to select main channel habitats (Sheehan et al., 1998) in the Mississippi River and main channel areas with islands or sand bars in the upper Missouri River (Bramblett 1996). Food habits of this species range from aquatic insects to fish depending on life stage (Gerrity 2005, Gerrity et al. 2006, Wanner 2006). The species can be long lived with females reaching sexual maturity later than males (Kallemeyn 1983). Spawning appears to occur between June and August, and females may not spawn each year (Kallemeyn 1983). Larval fish produced from the spawning event drift downstream from the hatching site (Kynard et al. 2002), and begin to settle from the lower portion of the water column 11 to 17 days post hatch (Braaten et al. in review).

2.3.1.1 Abundance, Population Trends, Demographic Features, or Demographic Trends

At the time the pallid sturgeon (*Scaphirhynchus albus*) was listed under the ESA on September 6, 1990 (55 FR 36641-36647), the species was known from two small populations of large, old-aged sturgeon isolated by dams surviving in the upper Missouri River, and from various rare collection records from the lower Missouri River and the Mississippi River near Grafton, Illinois, at the mouth of the Illinois River (Forbes and Richardson 1905). In their discussion, Forbes and Richardson (1905) indicate that "...about one in five hundred of the shovelnose sturgeons taken in central Mississippi [River] belongs to this new species ...” and note that catches of the new species comprised about one-fifth of total sturgeon collected near West Alton, Missouri, suggesting that pallid sturgeon were believed more abundant in the Missouri River at that time. Bailey and Cross (1954) defined the range of pallid sturgeon in the Mississippi River as extending from the mouth of the Missouri River to New Orleans, Louisiana; however, they apparently located no collection records of the species between these two points. Records of pallid sturgeon from the upper Mississippi River at Keokuk, Iowa, were discounted by Bailey and Cross (1954) as "...stragglers from downriver.” However, in 2000 the Illinois Department of Natural Resources (Atwood in litt. 2006) reported catching one pallid sturgeon in the tail waters of Melvin Price Locks and Dam. This structure is in the upper Mississippi River approximately 7 mi (11.3 km) upstream from the mouth of the Missouri River.

In 1991, the species was documented from the Atchafalaya River in central Louisiana (Reed and Ewing 1993).

Because the pallid sturgeon was not recognized as a species until 1905, few data are available concerning the species' early abundance and distribution (Pflieger 1975). Even as late as the mid-1900s, it was common for pallid sturgeon to be tallied in the commercial catch as either shovelnose, *Scaphirhynchus platorynchus*, or lake sturgeon, *Acipenser fulvescens*, (Keenlyne 1995). Correspondence and notes of researchers suggest that pallid sturgeon were still fairly common in many parts of the Mississippi and Missouri River systems as late as 1967 (Keenlyne 1989). Bailey and Cross (1954) also noted the presence of pallid sturgeon in the Missouri River from around Fort Peck Reservoir, Montana, and perhaps from Fort Benton, Montana, down to its mouth, as well as from within the Kansas River, Kansas.

The Pallid Sturgeon Recovery Plan (USFWS 1993) identified six RPMA's for implementation of recovery tasks based on most recent pallid sturgeon records of occurrence, and the potential of these areas for recovery of the species. The pallid sturgeon RPMA's (Figure 1) are defined in the Pallid Sturgeon Recovery Plan (USFWS 1993).

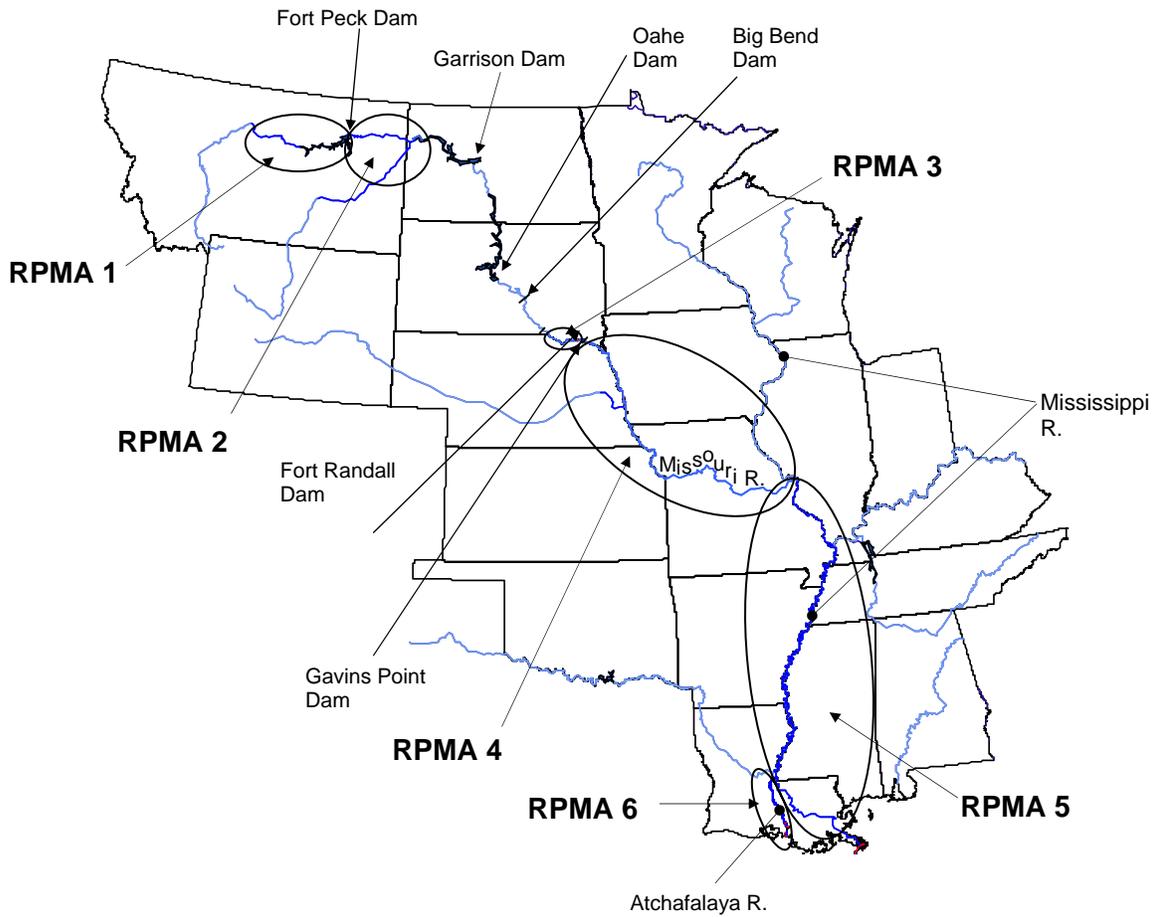


Figure 1. Map depicting Missouri and Mississippi Rivers with major dams identified. Outlined areas (ovals) correspond with approximate location of RPMAs as defined in the Pallid Sturgeon Recovery Plan (USFWS 1993). Map not to scale.

Demographic Data by Recovery Priority Management Area

Following is a summary of demographic data by RPMA. In addition to abundance information (including both wild and hatchery raised data), the following illustrates significant size differences within the species among different portions of the range (see also figures 14 and 15). This issue is discussed in further detail in section 2.3.1.6 below.

RPMA 1

RPMA 1 is defined as the Missouri River from the headwaters of Fort Peck Reservoir upstream to the confluence of the Marias River, Montana (USFWS 1993) (Figure 1). The status of wild pallid sturgeon in RPMA 1 has remained relatively unchanged since listing and continues to decline. According to data obtained from the National Pallid Sturgeon Database (USFWS 2006b), a total of 52 wild pallid sturgeon (individual fish) has been collected in RPMA 1 during 15 years of sampling (1990-2005) (Figure 2). The length frequency data suggests these are all adult fish. Current population estimates suggests that as few as 45 wild pallid sturgeon still remain in RPMA 1 (Bill Gardner, Montana Fish Wildlife and Parks (MFWP), pers. comm., 2005). There is an obvious absence of smaller sized wild pallid sturgeon despite utilization of sampling gear (gill nets, trammel nets, seines, and or trot-lines) capable of collecting smaller sized hatchery-reared pallid sturgeon (Figure 2). The size and age of surviving fish suggest that spawning, recruitment, or both, are severely limited or absent within this reach. However, the population is being supplemented with hatchery produced fish (USFWS 2006a) in efforts to prevent local extirpation. Supplementation of RPMA 1 with hatchery produced pallid sturgeon has occurred sporadically since 1997, and is required to maintain the species within this RPMA. Based on recapture data from the National Pallid Sturgeon Database (USFWS 2006b), pallid sturgeon from all stocking events have produced recaptures and are contributing to the current population structure (Figures 2 and 3).

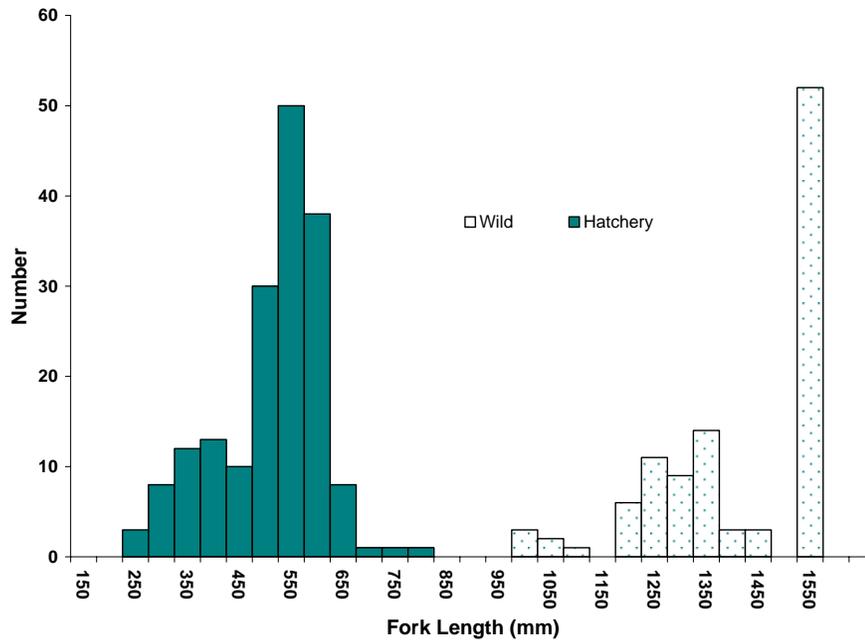


Figure 2. Upper Missouri River (RPMA 1) length frequency histogram representing each total individual wild and hatchery pallid sturgeon collected 1990-2005 for which there were length data (Wild n=52, Hatchery n=175). Data compiled from National Pallid Sturgeon Database (USFWS 2006b).

Hatchery vs. Wild Pallid Sturgeon Sampled in Upper Missouri River.

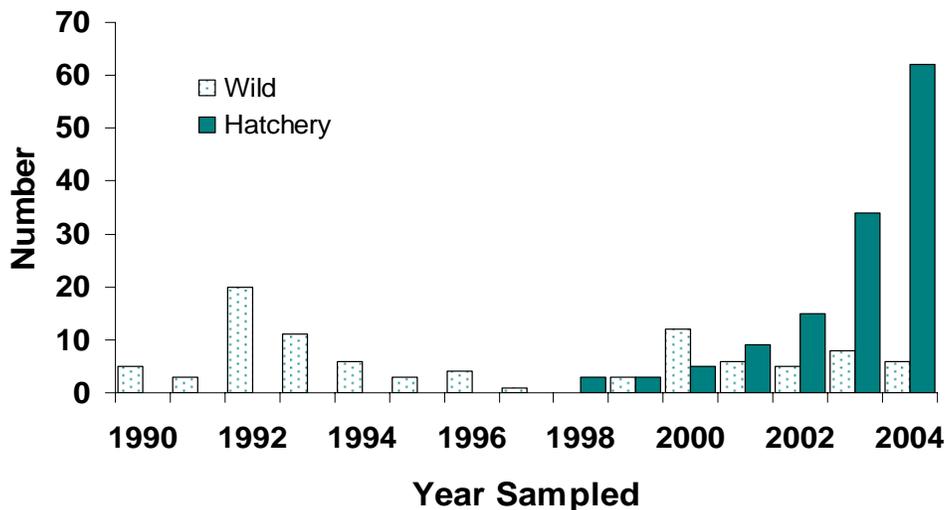


Figure 3. Upper Missouri River (RPMA 1) wild pallid sturgeon and hatchery produced pallid sturgeon collected with all gear types 1990-2004. Data compiled from National Pallid Sturgeon Database (USFWS 2006b).

RPMA 2

The Missouri River below Fort Peck Dam to the headwaters of Lake Sakakawea and the lower Yellowstone River up to the confluence of the Tongue River, Montana, is defined as RPMA 2 (Figure 1). The wild pallid sturgeon population in RPMA 2 continues to decline. According to data compiled from the National Pallid Sturgeon Database (USFWS 2006b), 527 wild pallid sturgeon captures occurred during 16 years of sampling (1990-2006). However, many of the adults were collected multiple times during those years. Removing recaptured pallid sturgeon from the query, indicates a total of 245 unique individual pallid sturgeon were collected during this timeframe. Available length frequency data indicate that these were essentially all adult fish (Figure 4). There is an obvious absence of smaller-sized wild pallid sturgeon despite utilization of sampling gear (gill nets, trammel nets, seines, and trot-lines) capable of collecting smaller sized hatchery-reared pallid sturgeon (Figure 4). The size and associated age of surviving fish suggest that spawning, recruitment, or both are severely limited within this reach. However, the population is being supplemented with hatchery-reared fish to prevent local extirpation (USFWS 2006a). Recent population estimates suggests that approximately 136 wild adult pallid sturgeon still remain in RPMA 2 (Klungle 2004). The length frequency data indicate that, up until the time supplementation began, all collected pallid sturgeon were adults except for one small fish collected in 1993 (Figures 3 and 4). This suggests that, like RPMA 1, spawning, recruitment, or both are limiting viability within this reach. Supplementation of RPMA 2 with hatchery produced pallid sturgeon has occurred sporadically since 1998 with various numbers being stocked depending on hatchery success for any given year (USFWS 2006a). To date, pallid sturgeon from all stocking events have produced recaptures and are contributing to the current population structure (Figures 4 and 5).

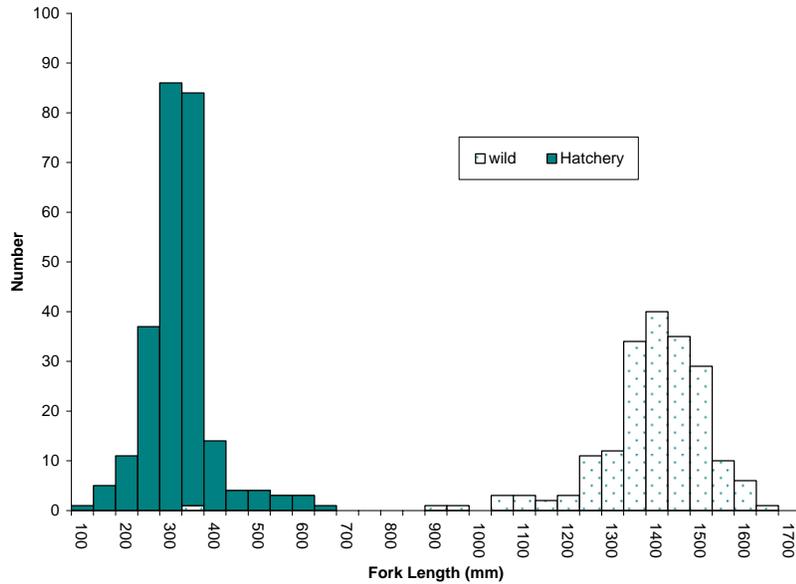


Figure 4. Upper Missouri River (RPMA 2) length frequency histogram representing each total individual wild and hatchery pallid sturgeon collected 1990-2006 for which there were length data (Wild n=192, Hatchery n=252). The 350-millimeter (mm) wild individual pallid sturgeon was collected in 1993. Data compiled from National Pallid Sturgeon Database (USFWS 2006b).

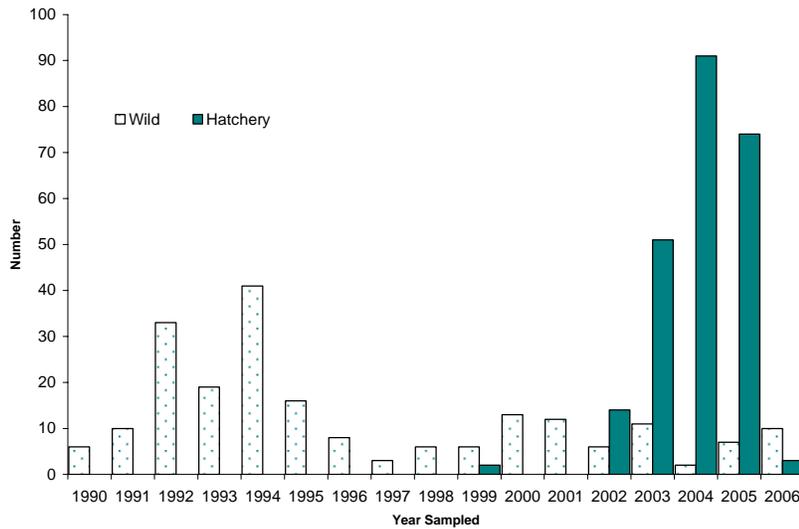


Figure 5. Upper Missouri River (RPMA 2) wild pallid sturgeon and hatchery produced pallid sturgeon collected 1990-2006. All 2006 data entries were not completed at the time this graph was made. Data compiled from National Pallid Sturgeon Database (USFWS 2006b).

RPMA 3

RPMA 3 is the Missouri River from 20 miles (mi) (32 kilometers (km)) upstream of the mouth of the Niobrara River to Lewis and Clark Lake (Figure 1). There is no native wild population of pallid sturgeon known to survive in RPMA 3 and the current population consists entirely of hatchery stocked fish. According to the National Pallid Database (USFWS 2006b), the last record of a wild species from this area, that was not translocated, was the collection of a single pallid sturgeon circa 1991. Prior to this (1952-1991), there was a small number of wild pallid sturgeon collected from this area. Figure 6 represents all wild pallid sturgeon collected in RPMA 3 including the collection of a translocated wild pallid sturgeon in 2003. Research within RPMA 3 during 1998 and 1999 (prior to stocking hatchery-reared pallid sturgeon in this reach) did not document a single pallid sturgeon, but numerous shovelnose sturgeon** were collected. A total of 102 pallid sturgeon has been collected in RPMA 3 during 2 years of sampling (2003-2005) (Figure 7). All of these were hatchery-reared with the exception of a few translocated wild pallid sturgeon. These data suggest that prior to supplementation, pallid sturgeon were extremely rare or extirpated in RPMA 3. Supplementation of RPMA 3 with hatchery-reared pallid sturgeon has occurred sporadically with various numbers being stocked depending on hatchery success for any given year. Recent work by Shuman et al. (2005) indicates that these stocked pallid sturgeon are surviving and growing (mean growth of age-6 and older fish was <0.06 mm/day (mm/d), mean growth for ages 2-4 was 0.238 mm/d, and the youngest year class (2004) grew 1.249 mm/d) in this reach with all stocked year classes (1997-1999 and 2001 and 2002) being collected in their samples (see also Figures 6 and 7).

**The shovelnose sturgeon, smallest of the ancient sturgeon species in North America, is similar in appearance to the pallid sturgeon. Like pallid sturgeon, the shovelnose has bony plates instead of scales, a ventral sucker-type mouth and large barbels or whisker-like sensors in front of its mouth. While shovelnose sturgeon have a flattened and shovel-shaped snout, the head shape of a pallid sturgeon may appear longer and skinnier. The shovelnose is generally darker in color (tan to gray or yellowish green dorsally, light ventrally) than the pallid sturgeon (greyish-white) and attains smaller maximum size. The shovelnose sturgeon rarely exceeds 15 lbs in weight, while the pallid can exceed 6 ft (2m) in length and weigh over 80 lbs (36 kg). Also, the belly of the adult shovelnose sturgeon is covered with bony plates while pallid sturgeon bellies tend to feel smooth to the touch. The barbels are positioned differently when the two species are compared. Generally, in the shovelnose all four barbels insert in a roughly even line perpendicular to the species midline, and are evenly spaced in front of the mouth. In the pallid, the outer barbels insert posterior to the inner barbels. The shovelnose sturgeon is strictly a freshwater species that was historically found throughout most of the Mississippi and Missouri River basins, from Montana south to Louisiana, and from Pennsylvania west to New Mexico. While the shovelnose has not experienced the range reduction of some of the larger Mississippi River Valley sturgeons (i.e., lake and pallid sturgeons), it is no longer found in Pennsylvania, New Mexico, and large parts of Kansas, Kentucky, Tennessee, and other States where it was once abundant. For more information see <http://www.fws.gov/Midwest/Fisheries/library/broch-shovelnose.pdf>.

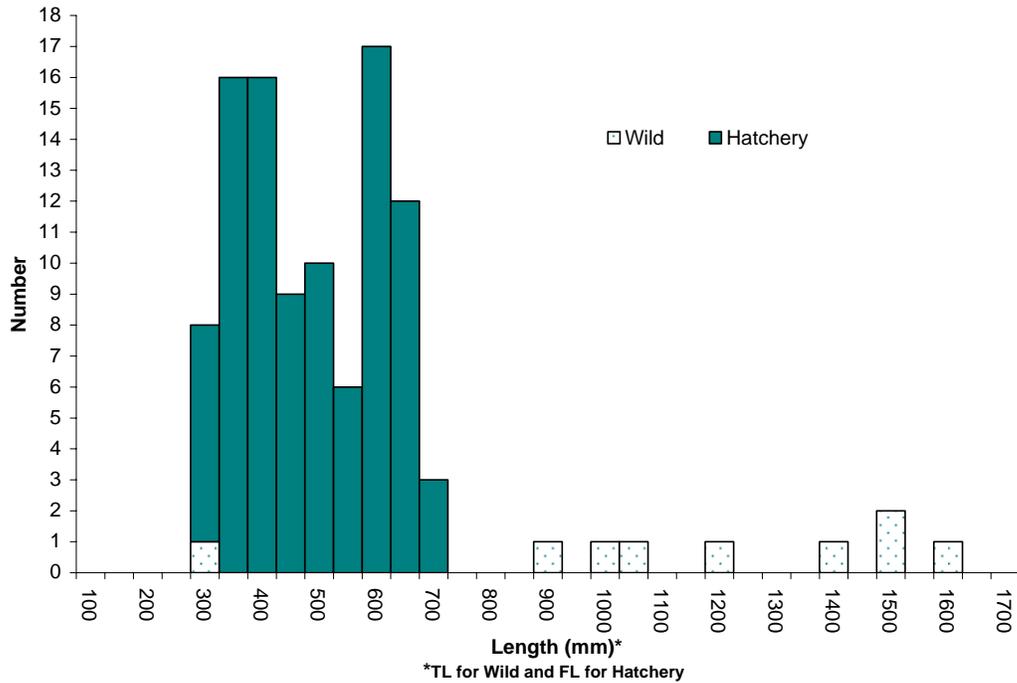


Figure 6. Upper Missouri River (RPMA 3) length frequency histogram representing each total individual wild pallid sturgeon collected 1952-2003 and hatchery pallid sturgeon collected 2001-2005 for which there were length data (Wild n=9, Hatchery n=96). The length reported is total length, not fork length for wild pallid sturgeon. The change is related to how data were reported prior to listing in 1991. The translocated 2003 fish is based on fork length (1,430 mm). The 300-mm wild pallid sturgeon was collected in 1952. Data compiled from National Pallid Sturgeon Database (USFWS 2006b).

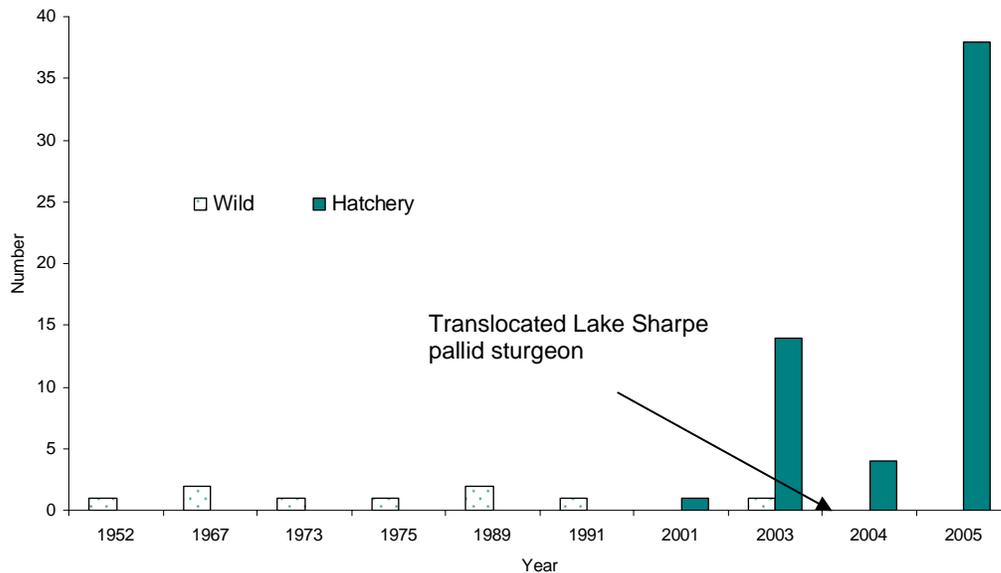


Figure 7. Upper Missouri River (RPMA 3) wild pallid sturgeon and hatchery produced pallid sturgeon collected 1952-2005. The fish collected in 2003 was a translocated pallid sturgeon from Lake Sharpe, South Dakota. Data compiled from National Pallid Sturgeon Database (USFWS 2006b).

RPMA 4

The Missouri River downstream of Gavins Point Dam, South Dakota to the Missouri River/Mississippi River confluence, including major tributaries such as the Platte River, defines RPMA 4 (Figure 1). Although pallid sturgeon captures in RPMA 4 continue to increase with fishing effort, population levels and trends, habitat use, and movement patterns remain unknown. In the late 1990s, the USFWS Columbia Fishery Resources Office collected larval sturgeon in the Lisbon Chute on the Missouri River. Three were confirmed as larval pallid sturgeon and seven others were identified as probable pallid sturgeon (Krentz 2000) (identification by Darrel Snyder, Colorado State University Larval Fish Laboratory). Larval sturgeon (species not confirmed) also have been documented in the Missouri River below Gavins Point Dam by Nebraska Game and Parks Commission (NGPC) (Gerald Mestl, NGPC, pers. comm., 2005) and the Missouri Department of Conservation (MDC) (Herzog et al. 2005) and in the lower Platte River (Hofpar 1997, Reade 2000). Some of these smaller fish may have been pallid sturgeon, but accurately identifying these larval fish to species is difficult (Kuhajda et al. In Press). Recent studies also identify low numbers of unmarked pallid sturgeon (larger than fry) being collected from the lower Missouri River (Kennedy et al. 2006; Utrup et al. 2006). Augmentation with hatchery-reared pallid sturgeon has occurred sporadically since 1994 (USFWS 2006a), and the collection of individuals from all stocked cohorts indicates that hatchery supplementation is contributing to the population (Barada and Steffensen 2006; Kennedy et al. 2006; Steffensen and Barada 2006; Utrup et al. 2006). Of a total 156 pallid sturgeon captured between 1999 and 2005, 51 are believed to be wild, 82 were of hatchery origin, and 24 were of unknown origin. These fish were identified as wild if they did not possess a physical mark (i.e., coded wire tag or elastomere tag) indicating they were from a hatchery and were of a size class greater than what was associated with known hatchery-released fish. Fish labeled as hatchery origin had a distinguishing physical mark. Unknown individuals were consistent in length with known hatchery fish, but had no notable marks. These are considered unknown because certain marking techniques, like PIT tags, have been documented to fail. However, data within the National Pallid Sturgeon Database (USFWS 2006b), for the period 1990-2005, notes 117 unique wild pallid sturgeon for RPMA 4. Available length frequency data for these fish indicates the majority to be adults. A few have been reported that are of sub-adult sizes (<600 mm), yet these sub-adult pallid sturgeon were all collected after supplementation commenced in 1994. Retrospective testing of the unmarked fish has revealed that 23 of the 24 unmarked pallid sturgeon were of hatchery origin, and the remaining unknown origin fish remained in that category because parental genetic samples were not available for all families released downstream of Gavins Point Dam and they could have originated from one of the unsampled families (DeHaan et al. submitted). The apparent lack of naturally produced or unknown origin pallid sturgeon in smaller size classes, coupled with higher relative abundances of hatchery origin pallid sturgeon (Figures 8 and 9) and frequent captures of smaller size class shovelnose sturgeon, suggests that the sampling gear and effort being used are effective and that natural recruitment of pallid sturgeon is sporadic or limited in RPMA 4 (Barada and Steffensen 2006, Kennedy et al. 2006, Steffensen and Barada 2006, Utrup et al. 2006). These data also indicate that hatchery stocked fish are being collected and contributing to the population (Figures 8 and 9).

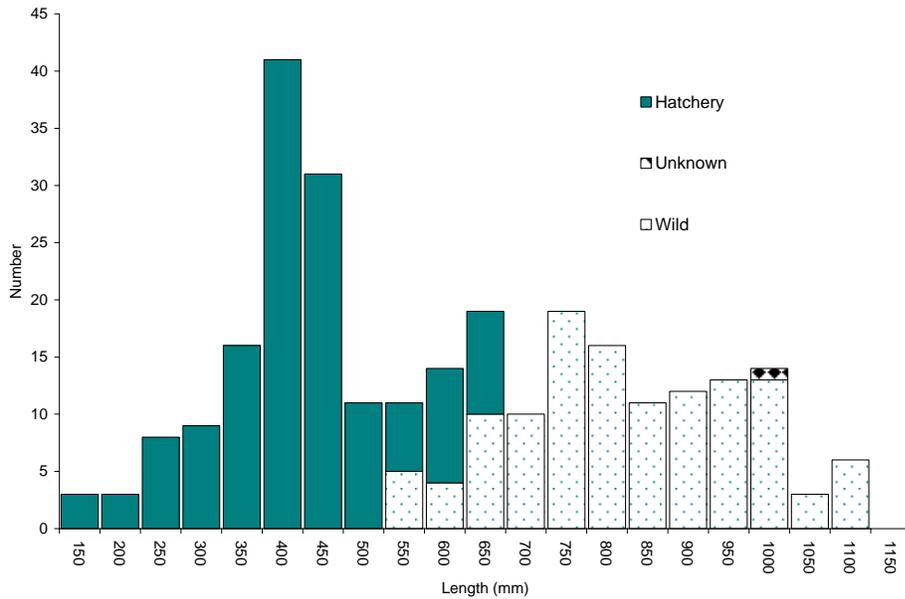


Figure 8. Middle and lower Missouri River (RPMA 4) length frequency histogram representing each total individual wild pallid sturgeon collected 1990-2005 for which there were length data. Unknown fish represented in this graph are pallid sturgeon whose origin is unknown. Their lengths are consistent with hatchery-reared pallid sturgeon yet they had no physical marks and did not match to known parents when genetically analyzed. Data compiled from National Pallid Sturgeon Database (USFWS 2006b).

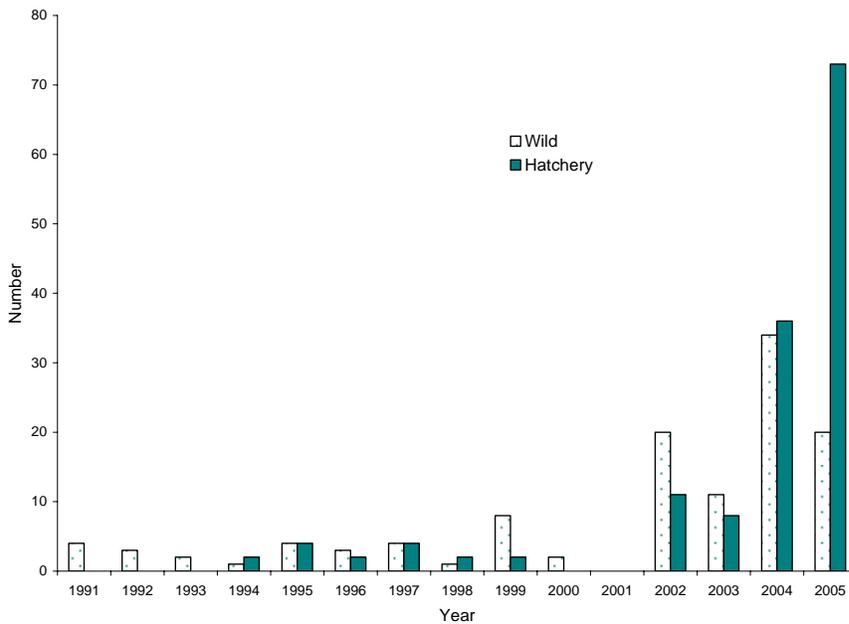


Figure 9. Middle and lower Missouri River (RPMA 4) wild pallid sturgeon and hatchery produced pallid sturgeon collected with all gear types 1991-2005. Data compiled from National Pallid Sturgeon Database (USFWS 2006b).

RPMA 5

The Mississippi River from its confluence with the Missouri River to the Gulf of Mexico defines RPMA 5 (Figure 1). While not identified in the Recovery Plan, the Mississippi River is often subdivided into two segments: 1) the lower Mississippi River, extending 953 River miles (Rmi) (1,533.7 River kilometers (Rkm)) from the Gulf of Mexico to Cairo, Illinois; and 2) the middle Mississippi River, extending 200 Rmi (321.9 Rkm) from near Cairo, Illinois, to just above the mouth of the Missouri River confluence near St. Louis, Missouri. The availability of demographic data in RPMA 5 (Figure 10) for pallid sturgeon has increased since the species was listed. Although pallid sturgeon captures in RPMA 5 continue to increase with fishing effort, population levels and trends, habitat use, and movement patterns remain unknown. Only 28 records of pallid sturgeon were recognized from the Mississippi River when the species was listed in 1990 and the recovery plan was published in 1993 (USFWS 1993). During the past 6 years, over 300 pallid sturgeon (both sub-adult and adult size classes) have been collected from the Mississippi River (Figures 10 and 11). However, caution must be applied when looking at total catch because some of the collected pallid sturgeon reported by D. Herzog, (MDC) may also have been reported by Jack Killgore (U.S. Army Corps of Engineers (USACE) during their collaborative efforts. According to the National Pallid Sturgeon Database (USFWS 2006b), 279 unique pallid sturgeon have been collected in RPMA 5 between 1990 and 2004. It is unclear what percentage of these may be hatchery origin pallid sturgeon with failed physical marks. Jack Killgore, USACE, (pers. comm., 2005) indicated that, between the winter of 2004 and the spring of 2005, 39% (7 of 18) of the pallid sturgeon sampled were hatchery stocked recaptures with a coded wire tag (CWT). Prior to 2004, pallid sturgeon were not checked for coded wire tags, a physical mark that was utilized on hatchery-reared pallid sturgeon stocked from Missouri's Blind Pony fish hatchery.

Middle Mississippi River

From 2002 through 2005, the USACE, MDC, and Southern Illinois University conducted a joint pallid sturgeon research project in the middle Mississippi River using trawling, gillnets, and trotlines as the primary sampling gears. As part of this project a little over 64,000 hours of effort (combined for all gear types) was expended to catch a total of 148 pallid sturgeon. Of the 148 pallid sturgeon collected, 12 individuals (8%) were hatchery origin fish determined by the presence of coded wire tags. This 8% is likely underrepresenting the total number of hatchery origin fish in this sampling effort because scanning for coded wire tags was not a standard practice until 2004 (Jim Garvey, Southern Illinois University, pers. comm. 2006).

Herzog et al. (2005) documented successful reproduction by the collection of larval pallid sturgeon in the middle Mississippi River, though the origin of these larval pallid sturgeon from within the middle Mississippi River is not known. Wild pallid sturgeon collected from this reach ranged between 500 and 1,000 mm fork length (FL; the length measured from the anterior most portion of the fish to the median caudal fin rays) (Figure 10). Pallid sturgeon above 600 mm FL are believed to be of reproductive size, and the capture of small adult and sub-adult pallid sturgeon around and below this size may indicate that some level of recruitment is likely occurring in the middle Mississippi River or lower Missouri River, or could be a product of

undetected marks in hatchery origin pallid sturgeon. Limited supplementation with hatchery-reared pallid sturgeon has occurred in the middle Mississippi River (USFWS 2006a).

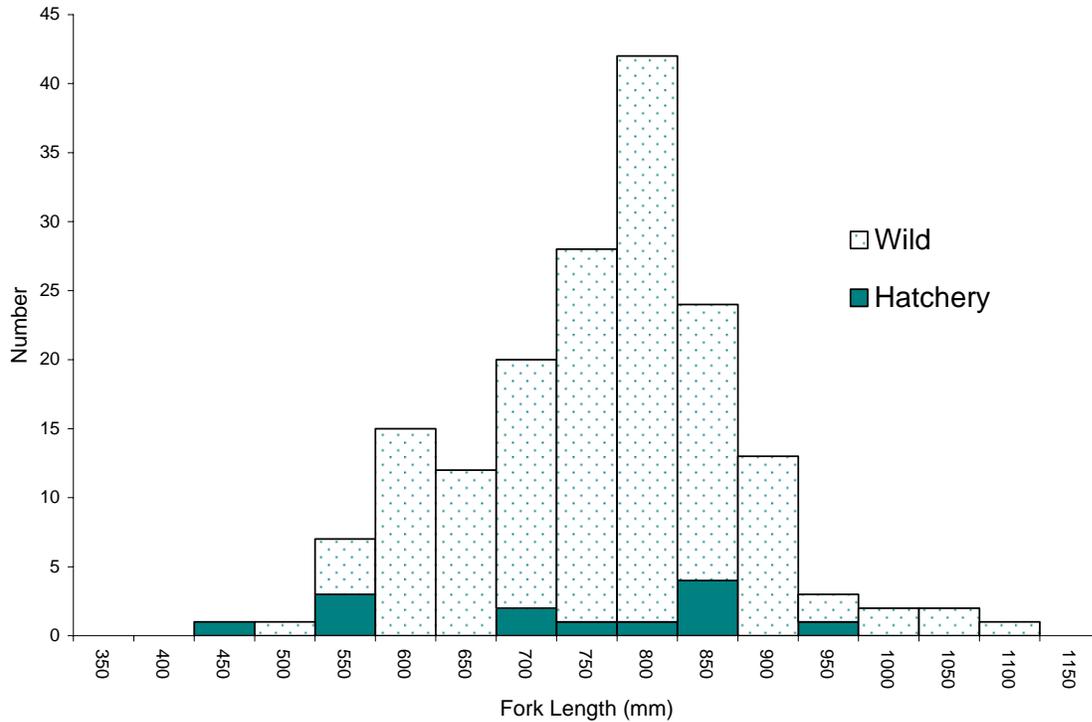


Figure 10. Middle Mississippi River (RPMA 5) length frequency histogram representing each total individual wild and known hatchery-reared pallid sturgeon collected 1991-2005 for which there were length data. The middle Mississippi River is the reach of the Mississippi River from the confluence of the Ohio River near Cairo, Illinois, to the confluence of the Missouri River, near Saint Louis, Missouri. Data compiled from National Pallid Sturgeon Database (USFWS 2006b).

Lower Mississippi River

The USACE sampled the lower Mississippi River (below the Ohio River to the mouth) from 2000 to 2006. During this time, 162 pallid sturgeon were collected from over 130 locations (i.e., specific Rmi/Rkm) between Rmi 145 to 954 (Rkm 233 to 1535) (J. Killgore, USACE, pers. comm., 2005), with 3 recaptures. Sizes of pallid sturgeon collected range between 400 and 1,000 mm FL (Figure 11). This data set includes at least 30 “sub-adult” pallid sturgeon (i.e., <600 mm FL), showing some level of recruitment in the lower Mississippi River population. It is possible that recruitment of pallid sturgeon in RPMA 5 is higher than that reflected in sampling data. Although morphologically distinct pallid sturgeon as small as 450 mm FL are occasionally captured (Figure 11), some young-of-year and sub-adult pallid sturgeon may be misidentified as shovelnose or hybrids.

One recent study found that character indices do not correctly identify small upper Missouri River hatchery-reared juvenile pallid sturgeon (<250 mm standard length; the length from the tip of the upper jaw to the posterior end of the vertebral column that is most commonly used in taxonomic studies) from shovelnose or hybrid sturgeon, or reliably separate larger pallid sturgeon (up to 600 mm standard length) from hybrid sturgeon (Kuhajda and Mayden 2001). Measurements taken from 48, 10-month old hatchery-reared juvenile pallid sturgeon (309 to 413 mm FL) spawned from Atchafalaya River stock and reared at the Natchitoches NFH, incorrectly identified all but two of these hatchery-reared pallid sturgeon as hybrids, and the two exceptions were incorrectly identified as shovelnose sturgeon (Jan Dean, USFWS, pers. comm., 2005). These juvenile fish were reared from morphologically distinct pallid sturgeon confirmed by genetic analysis.

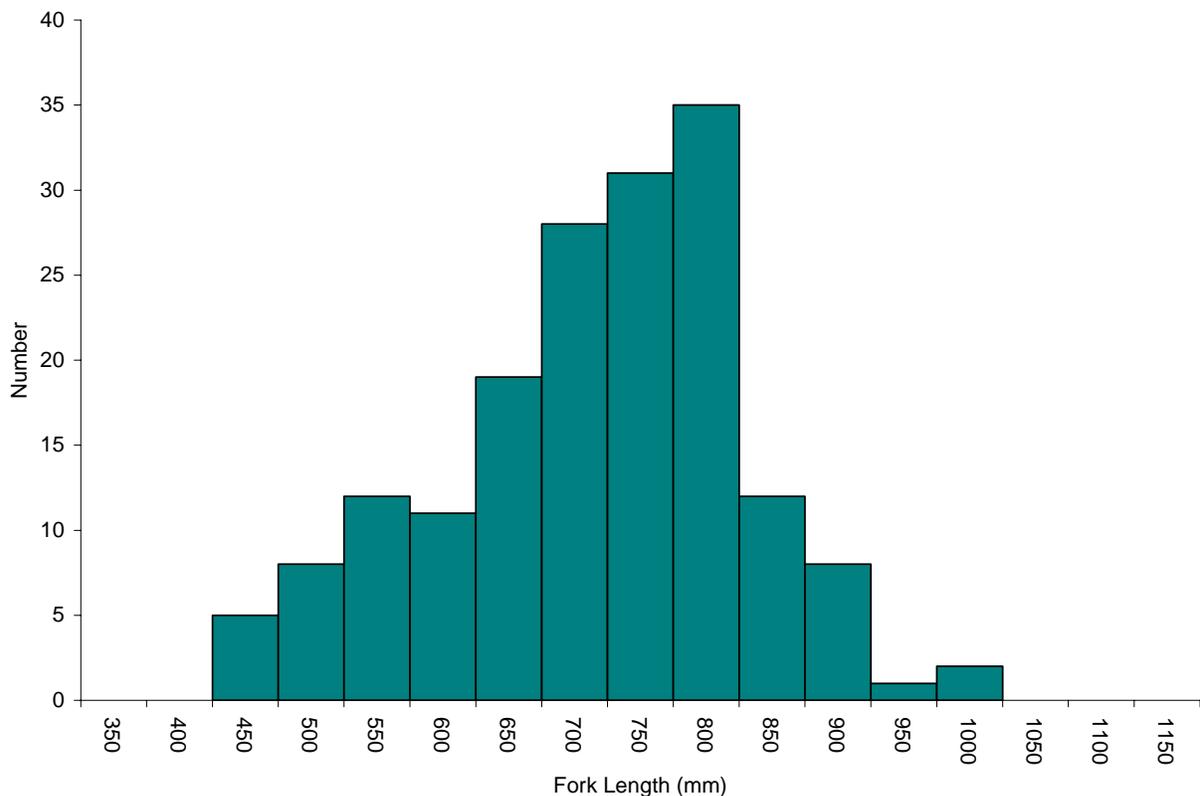


Figure 11. Lower Mississippi River (RPMA 5) length frequency histogram representing wild pallid sturgeon collected during 1991-2005 for which there were length data (n=172). The lower Mississippi River is the reach of the Mississippi River from the confluence of the Ohio River near Cairo, Illinois, to the Gulf of Mexico. Data compiled from National Pallid Sturgeon Database (USFWS 2006b).

Murphy et al. (in press) also have found greater morphological variation in specimens of pallid and shovelnose sturgeon from the Mississippi River than what is accounted for in current identification indices. These studies suggest that at least some young-of-year, sub-adult, or small

adult pallid sturgeon can be misidentified in the field as hybrid or shovelnose sturgeon. Captures of pallid sturgeon in the Mississippi River have been associated with islands, sand bars, gravel bars, and dikes, in both the main channel and in secondary channels.

RPMA 6

RPMA 6 is the Atchafalaya distributary system to the Gulf of Mexico (Figure 1). Collection data from this RPMA reflects an improvement in our understanding of the pallid sturgeon population trend. Prior to listing in 1990, pallid sturgeon had not been documented from the Atchafalaya River. In 1991, seven pallid sturgeon were collected from the Atchafalaya River near the Old River Control Complex, in Concordia Parish, Louisiana (Reed and Ewing 1993). A few years later (1993-95) an additional 106 pallid sturgeon captures were reported (Constant et al. 1997). A conservative total of 499 individual pallid sturgeon have been collected from the Atchafalaya River since 1991 (Figure 12). A conservative approach to species identification was used, based upon morphometric measurements, to identify pallid versus intermediate or “hybrid” sturgeon, and thus actual number of pallid sturgeon captured from the Old River Control Complex (ORCC) is likely underrepresented in these data. There have been at least 37 wild adult pallid sturgeon recaptures in the ORCC area since 1991, of which 32 have been during 2004-2006 (J. Dean, USFWS, pers. comm., 2006).

The length distribution of pallid sturgeon captures has remained relatively consistent over the past 7 years, although the population appears to be comprised of predominantly adult pallid sturgeon >650 mm FL (Figure 12). However, gears used to sample this area are larger mesh and may not reliably sample sturgeon smaller than 400 mm. It is currently unknown if this consistent length frequency distribution through time combined with the occasional collection of smaller pallid sturgeon, results from local reproduction and recruitment, the passage of sub-adult and/or adult pallid sturgeon from the Mississippi River through the ORCC into the Atchafalaya River, or is simply a product of gear selectivity/bias.

Gill net collections at the Old River Control Complex regularly capture shovelnose sturgeon between 400 and 750 mm FL. The pallid sturgeon are larger, measuring (with occasional exceptions) above 650 mm FL (e.g., Figure 12). It has been noted in the discussion under RPMA 5, above, that there are difficulties in separating juvenile *Scaphirhynchus* to species. This also is true in RPMA 6. For example, trawl sampling for 2 days below Old River Control Complex during June 2005, resulted in the capture of six young-of-year *Scaphirhynchus* (196 to 410 mm total length (the length measured from the anterior most portion of the fish to the tip of the caudal fin rays). Three of these fish were marked indicating they were hatchery-reared juvenile pallid sturgeon released during fall and winter of 2004, and the other three had no physical mark and were considered wild young-of-year sturgeon. A character index was used on all six fish and misidentified the three hatchery-reared pallid sturgeon as hybrids, and identified two of the unknown wild sturgeon as shovelnose and the other as a hybrid (Jan Dean, USFWS, pers. comm., 2005). Further investigation is required to determine if allometric growth is resulting in the misidentification of some juvenile or sub-adult pallid sturgeon as shovelnose or “hybrids/intermediates” (e.g., Figure 13), and to document local reproduction and recruitment in RPMA 6.

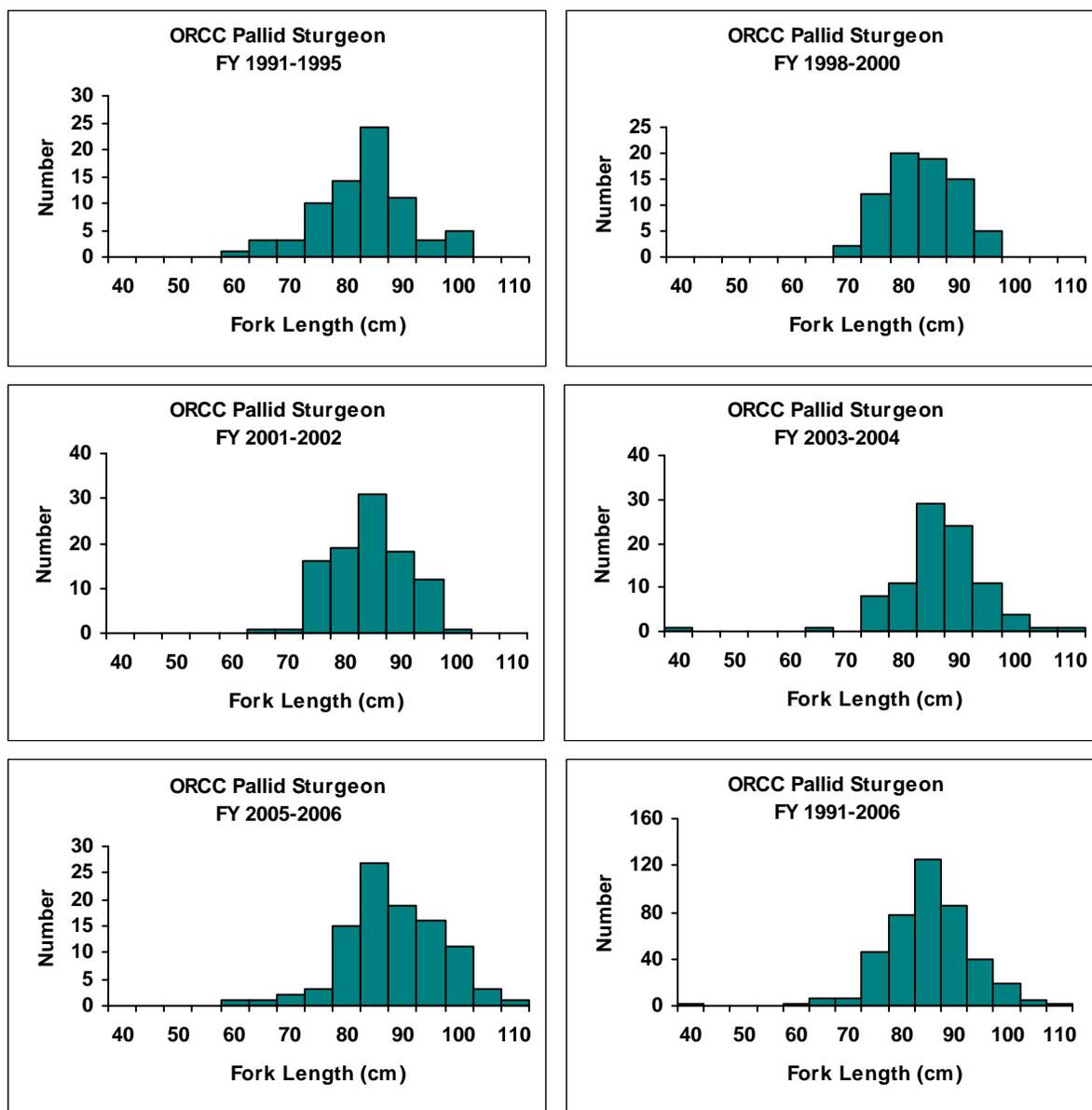


Figure 12. Conservative representation of pallid sturgeon length frequency data collected from the Atchafalaya River, 1991-2006. The actual number of pallid sturgeon captured from the Old River Control Complex area during that time likely exceeds 500 individuals. A conservative approach, based upon morphometric measurements, was used here to separate pallid sturgeon from intermediate character sturgeon. Data provided by J. Dean, USFWS and reported by Federal Fiscal Year (October-September) not calendar year (January-December).

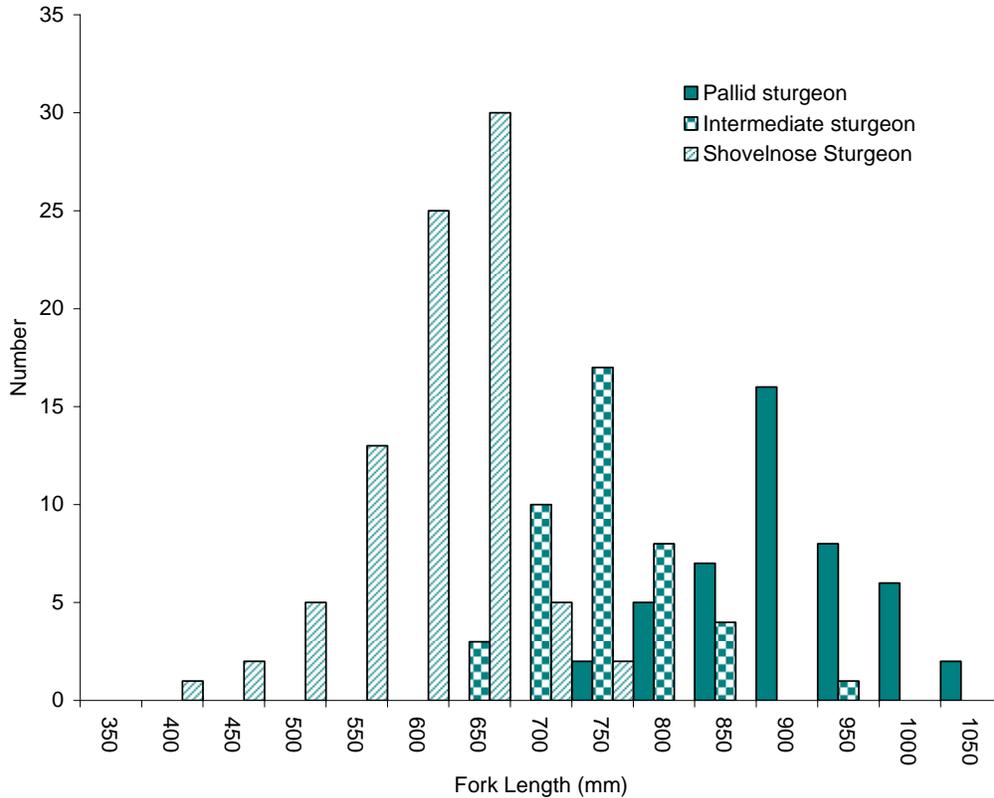


Figure 13. Length frequency histogram representing total pallid sturgeon (n=46), intermediate characteristic sturgeon (n=43) and shovelnose sturgeon (n=83) collected from the Atchafalaya River during 2005. Data provided by Jan Dean, USFWS.

2.3.1.2 Genetics, Genetic Variation, or Trends in Genetic Variation

While morphological differences among pallid and shovelnose sturgeon have been described (Bailey and Cross 1954, Keenlyne et al. 1994), genetic differentiation has been more difficult. Initial genetic studies were unable to distinguish pallid from shovelnose sturgeon by examining 37 allozyme loci (Phelps and Allendorf 1983), restriction fragment length polymorphism (RFLP) analysis of five protein coding genes (Morizot 1994), or comparing sequence variation at two mitochondrial loci (1137 bases of cytochrome b and 829 bases of the control region (D-loop) (Simons et al. 2001). These results have been variously interpreted as a lack of reproductive isolation between the species (Phelps and Allendorf 1983), a low evolutionary rate within the genus *Scaphirhynchus* (Simons et al. 2001), or that pallid and shovelnose sturgeon have recently diverged, undergone rapid morphological differentiation, and the type of genetic markers examined had not yet diverged enough to distinguish the species (e.g., Campton et al. 2000).

Campton et al. (2000) and Tranah et al. (2001) were able to find genetic markers that distinguish pallid from shovelnose sturgeon. Campton et al. (2000) found significant haplotype frequency differences, based on approximately 500 base pairs, between the 2 species at the mitochondrial DNA control region. This initial finding of genetic distinction between pallid and shovelnose sturgeon was supported by Tranah et al. (2001) who examined the same samples using five nuclear DNA microsatellite loci. The concordant conclusions from these studies using different genetic markers were the first to support the genetic distinction between pallid and shovelnose sturgeon.

Intercrosses (hybridization) Between Pallid and Shovelnose Sturgeon

The pallid sturgeon was listed as endangered over its entire range (USFWS 1990). Recent concerns have been raised regarding the genetic structuring of the species across its range. Following listing, genetic data have been evaluated to help better understand the range-wide population structure of pallid sturgeon.

The presence of sturgeon that appear to be morphologically intermediate between pallid and shovelnose sturgeon, were presumed to represent pallid-shovelnose sturgeon hybrids (Keenlyne et al. 1994, Carlson et al. 1985) and spurred an effort to determine the genetic origins of these fish. Tranah et al. (2004) combined the data from Campton et al. (2000) and Tranah et al. (2001) and added 4 additional microsatellite loci to the data set to determine the genetic origins of 10 morphologically intermediate sturgeon collected from RPMA 6. All fish were classified as pallid, shovelnose or hybrid sturgeon via the hybrid index method of Campton (1987).

Results of Tranah et al. (2004) support earlier morphometric-based conclusion on the presence of hybrids (Keenlyne et al. 1994) suggesting that intercrossing or gene flow between the two species (pallid and shovelnose sturgeon) is more pronounced in the middle Mississippi and Atchafalaya Rivers than elsewhere (e.g., upper Missouri River). Tranah et al. (2004) also suggested that while shovelnose and pallid sturgeon are distinct morphologically, they are undergoing hybridization in the lower Mississippi and Atchafalaya Rivers. Morphometric data also may indicate hybridization in the lower Missouri River (Grady et al. 2001a; Grady et al. 2001b; Doyle and Starostka 2003) based on the presence of morphologically intermediate sturgeon. The extent to which these hybrids are going beyond the first generation (introgressive hybridization) is currently unknown. Tranah et al. (2004) suggest that female pallid sturgeon are mating with shovelnose sturgeon males and the hybrids are subsequently backcrossing with the more numerous shovelnose sturgeon. This finding should be treated as preliminary because a small number of fish classified morphologically as hybrids were examined.

Allendorf et al. (2001) theorized that pallid and shovelnose sturgeon in the lower Mississippi River have not evolved reproductive isolation to the same degree as pallid and shovelnose sturgeon in the upper Missouri River and suggested there may be no pure pallid sturgeon in the lower Mississippi River because all sturgeon located in that reach comprise a hybrid swarm. Although microsatellite studies have provided evidence of hybridization between pallid and shovelnose sturgeon in the Missouri, Mississippi, and Atchafalaya Rivers (Tranah et al. 2001; Heist and Schrey 2006a and b), these and other studies (Ray et al. in press) have also demonstrated that shovelnose and pallid sturgeon remain genetically distinct from each other in the Missouri, Mississippi, and Atchafalaya Rivers, and a third group, hybrids/intermediates, are present.

These genetic comparisons of hybrids need to be considered in the context of studies with hatchery-reared pallid, shovelnose, and hybrids that show small pallids may be regularly misidentified as hybrids based on morphological characters (Kuhajda and Mayden 2001; Kuhajda et al. in press; Murphy et al. in press). More information is needed on the evolutionary dynamics of intermediate forms between pallid sturgeon and shovelnose sturgeon to understand if they are natural or if anthropogenic modification has forced an overlap of breeding areas and thus a realized threat.

Population Structure of Pallid Sturgeon

Campton et al. (2000) used approximately 500 base pairs of the mitochondrial DNA control region to examine genetic variation within and among 3 pallid sturgeon populations, 2 of which were located in the upper Missouri River (RPMA 1 and 2) and 1 from RPMA 6 river system. The pallid sturgeon from these geographically divergent areas did not share any haplotypes ($P < 0.001$), and the genetic distance between these two groups (0.14%) was nearly as great as the genetic distance between pallid and shovelnose sturgeon in the upper Missouri River (0.15%). The authors note that this may represent reproductive isolation and genetic divergence between these two populations of pallid sturgeon that is nearly as old as the isolation between pallid and shovelnose sturgeon. Another explanation offered in Campton et al. (2000) is that northern and southern pallid sturgeon arose independently from different ancestors and are not a monophyletic lineage, thereby representing two separate species.

Tranah et al. (2001) examined genetic variation within and among the same three pallid sturgeon samples. The allele frequencies at five microsatellite loci indicated the two upper Missouri River groups, separated by Ft. Peck Dam, did not differ significantly from each other. Conversely, pallid sturgeon genetic samples from the upper Missouri population did differ from samples collected from the Atchafalaya River ($F_{st} = 0.13$ and 0.25 ; both $P < 0.01$). They concluded pallid sturgeon collected from RPMA 1 and 2 (the northern

fringe of their range) are reproductively isolated from those sampled from RPMA 6 (southern extreme of their range) and should be treated as genetically distinct populations.

Heist and Schrey (2006a) found significant F_{st} differences between the upper Missouri River pallid sturgeon samples when compared with samples from the middle Mississippi River. Heist and Schrey (2006b) subsequently examined samples collected from the upper portion of RPMA 4. These samples were collected below Gavins Point Dam, South Dakota, downstream to Kansas City, Missouri. Heist and Schrey (2006b) note that pallid sturgeon in this part of the range appear to be genetically intermediate between the upper and lower Missouri River pallid sturgeon samples.

In 2006, Dr. Ed Heist and Aaron Schrey provided an overview of their research to the Pallid Sturgeon Recovery Team (Team) and the Team's Genetics Advisory Group during a conference call (see Appendix B). The results were based on output from the software package STRUCTURE. This program does not require *a priori* species identification and identifies natural groupings among samples to minimize Hardy-Weinberg deviations and linkage disequilibrium. When only putative pallid sturgeon samples were analyzed, three genetic groups of pallid sturgeon appear across the species range. The three groupings are a well differentiated upper Missouri River group and two less differentiated groups in the lower Missouri/middle Mississippi and Atchafalaya River samples.

These data (Campton et al. 2000, Tranah et al. 2001, Heist and Schrey 2006a) suggest that the genetic structuring within the pallid sturgeon's range represents two distinct groups at the extremes of the species range with a middle intermediate group representing the lower Missouri and middle Mississippi Rivers. This pattern is suggestive of a pattern of isolation by distance, with gene flow more likely to occur between adjacent groups than among geographically distant groups, and thus, genetic differences increase with geographical distance.

2.3.1.3 Taxonomic Classification or Changes in Nomenclature

NA

2.3.1.4 Spatial Distribution, Trends in Spatial Distribution, or Historic Range

The historical range of pallid sturgeon is the Missouri and Mississippi River systems from near Fort Benton, Montana, to Head of Passes, Louisiana. Historically, larger tributaries like the Yellowstone, Platte, Lower St. Francis, and Big Sunflower Rivers also were utilized as well as the Atchafalaya River tributary (see also 2.3.1.1 above). Currently, pallid sturgeon habitat in the upper Missouri River is highly fragmented and reduced. RPMA 1 contains approximately 174 Rmi (280 Rkm) of flowing river conditions, RPMA 2

extends for 186 Rmi (300 Rkm), while RPMA 3 provides approximately 52 Rmi (85 Rkm) of riverine conditions between Ft. Randall Dam and Lewis and Clark Lake. Riverine conditions extend virtually uninterrupted for about 2,000 Rmi (3,200 Rkm) between Gavins Point Dam in the middle Missouri River and the Gulf of Mexico (RPMAs 4 and 5). RPMA 6 contains approximately 140 Rmi (224 Rkm) of the Atchafalaya River. The Old River Control Complex forms a potential uni-directional barrier to fish movement between the Mississippi and Atchafalaya Rivers. The structures associated with the Old River Control Complex likely could allow movement of fish from the Mississippi River into the Atchafalaya River, but could constitute a velocity type barrier to movement from the Atchafalaya River into the Mississippi River. Collection of lake sturgeon (*Acipenser fulvescens*) and one pallid sturgeon, known to have been released in the middle Mississippi River, below the Old River Control Complex, indicates passage from the Mississippi River into the Atchafalaya River does occur (B. Reed, Louisiana Department of Wildlife and Fisheries, pers. comm., 2006; Hartfield in litt, 2006). However, passage or lack of passage in the opposite direction has not been determined.

2.3.1.5 Habitat or Ecosystem Conditions

Missouri River

Anthropogenic modifications to the Missouri River restrict the life cycle requirements of pallid sturgeon by blocking movements to spawning and feeding areas, destroying spawning areas, altering conditions and flows of potential remaining spawning areas, and reducing food sources by lowering productivity (Keenlyne 1989; USFWS 2000a). The most obvious habitat changes were creation of a series of impoundments on the main stem of the upper Missouri River and channelization of the lower Missouri River for navigation. Upper Missouri River dams and their operations have--1) created physical barriers that block normal migration patterns, 2) degraded and altered physical habitat characteristics, and 3) greatly altered the natural hydrograph (Hesse et al. 1989). Moreover, these large impoundments have replaced large segments of riverine habitat with lentic conditions. Damming of the upper Missouri River has altered lotic features such as channel morphology, current velocity, seasonal flows, turbidity, temperature, nutrient supply, and paths within the food chain (Russell 1986; Unkenholz 1986; Hesse 1987).

Fort Peck Reservoir forms the lower boundary of RPMA 1 (Figure 1) and some theorize that this reservoir is a major impediment to larval pallid sturgeon survival. Currently, shovelnose sturgeon within RPMA 1 are self-sustaining (B. Gardner, MFWP, pers. comm., 2005) while pallid sturgeon are not. Recent work by Gerrity (2005) indicates that immature hatchery-reared pallid sturgeon are more likely to utilize the lower reaches of RPMA 1 than are shovelnose sturgeon. The reaches frequented by Gerrity's

study fish are attributable to the low pool levels in Fort Peck Reservoir. These lower reaches can be inundated at higher reservoir pool levels, and lose their lotic attributes. Thus it may be considered that behavioral differences occurring between the two sturgeon species results in divergent life history traits. Differences in larval drift (Kynard et al. 2002, 2005) or habitat selection in more upstream reaches (Gerrity 2005) may result in better survivorship of immature shovelnose sturgeon compared to pallid sturgeon. Similar to the observations of Gerrity (2005), Bramblett (1996) found that pallid sturgeon used 25 km of riverine habitat that would be inundated by Lake Sakakawea at full pool in RPMA 2. Canyon Ferry, Hauser, and Holter Dams are upstream of Great Falls, Montana, and likely do not impose any migratory barriers because passage at the natural falls likely did not exist historically. However, these structures, like most dams, reduce sediment and nutrient transport, maintain an artificial hydrograph, and delay thermal cues. A reduction in sediment input and transport has been shown to reduce naturally occurring habitat features like sandbars. Kellerhals and Church (1989) identify that discharge and sediment load, together with physiographic setting are primary factors controlling the morphology of large alluvial rivers. One other dam of importance in the system is Tiber Dam located on the Marias River. The Marias River may have been a historically important tributary for pallid sturgeon (B. Gardner, MFWP, pers. comm., 2005).

Fort Peck Dam was constructed in 1937 and Garrison Dam was completed in 1954. Fort Peck Dam forms the upper boundary of RPMA 2 and Lake Sakakawea forms the lower boundary (Figure 1). Fort Peck Reservoir and Lake Sakakawea may be impediments to larval pallid sturgeon survival. Support for this theory is provided in recent studies. Kynard et al. (2002) studied drift in *Scaphirhynchus* “free embryos.” They determined that post-hatch larvae begin to migrate on day 0 and that pallid sturgeon larvae may migrate at a slower rate than shovelnose sturgeon, but they migrate for a longer time. Subsequent work was conducted with larval pallid sturgeon released within RPMA 2 as part of a larval drift study. These data suggest that pallid sturgeon larvae can drift 152 to 329 mi (245 to 530 km) depending on water column velocity (Braaten et al. in review). This drift distance would likely transport naturally spawned pallid sturgeon larvae into the headwaters of Fort Peck Reservoir and Lake Sakakawea. Braaten et al. (in review) speculate that differences in larval drift rates found between shovelnose and pallid sturgeon might explain why the two species experience different recruitment levels in the upper Missouri River. As part of this 2004 study various ages (in days) of fry were stocked, and in 2005 four non-physically marked pallid sturgeon were genetically traced back to the 11- to 17-day-old fry released as part of this drift study (William Ardren, USFWS, pers. comm., 2005). This indicates that fry released at ages 11 to 17 days are able to

survive to age-1 in RPMA 2 and provides some evidence that the limitation on natural recruitment could be somewhere between the actual spawning event and the first couple of weeks after hatch.

Another limiting factor is an altered hydrograph and temperature profile attributable to water releases and reduced sediment transport from Fort Peck Dam. A reduction in sediment transport can reduce naturally occurring habitat features like sandbars (Kellerhals and Church 1989). The Yellowstone River, a major tributary to the Missouri River, was likely a historically important tributary for spawning. Bramblett (1996) documented that pallid sturgeon prefer the Yellowstone River over the Missouri River below Fort Peck, many fish move into the lower Yellowstone River during spawning season, ripe fish occur in the Yellowstone River, and aggregations of fish during spawning season strongly suggest that pallid sturgeon spawning occurs in the lower 10 to 15 Rkm of the Yellowstone River. However, in the early 1900s, the Bureau of Reclamation (BOR) completed work on the Lower Yellowstone Irrigation Project with the completion of a full channel low-head dam (Intake Dam, circa 1910) across the Yellowstone River approximately 71 Rmi (114 Rkm) upstream from the Missouri and Yellowstone River confluence. This dam has effectively reduced the migratory potential of pallid sturgeon within the Yellowstone River system (Bramblett and White 2001, Jaeger et al. 2005). Telemetry work conducted in the Yellowstone River with juvenile pallid sturgeon (Jaeger et al. 2005) identified that about half of the study fish stocked upstream of Intake Dam remained there. Telemetered pallid sturgeon also have been entrained in the irrigation ditch served by Intake Dam (Jaeger et al. 2004). Larval drift work by Braaten et al. (in review) suggests that larval drift of fish naturally produced in the Yellowstone River will likely result in the fry drifting into Lake Sakakawea, and the ongoing threat to spawning success in the Yellowstone River is likely to be downstream drift of larvae into Lake Sakakawea (Bob Bramblett, Montana State University, in litt. 2006 (see Appendix A)). Other anthropogenic modifications include bank stabilization projects and water withdrawal projects.

The primary threat to pallid sturgeon existence within RPMA 3 is historical hydrograph alterations and habitat fragmentation. Fort Randall Dam was completed in 1956 and Gavins Point Dam was completed about a year later. Fort Randall Dam forms the upper boundary of RPMA 3 and Gavins Point Dam forms the lower boundary (Figure 1). The habitat threats associated within RPMA 3 are an altered hydrograph and temperature profile, a reduction in sediment transport, and fragmentation that could preclude adequate drift distance for larval pallid sturgeon. However, other native riverine species successfully spawn within this reach.

RPMA 4 has over 800 Rmi (1,296 Rkm) available for pallid sturgeon, is not impounded, and is biologically and hydrologically connected with RPMA 5, but is not immune from anthropogenic modifications. Channelization of the Missouri River within RPMA 4 has reduced water surface area by half, doubled current velocity, decreased habitat diversity, and decreased sediment transport (Funk and Robinson 1974, USFWS 2000a). RPMA 4 can be characterized into three distinct reaches: the unchannelized, upper channelized, and lower channelized reaches. The unchannelized Missouri River reach in RPMA 4 extends approximately from Gavins Point Dam (Rmi 811/Rkm 1305) downstream to the mouth of the Big Sioux River (Rmi 736/Rkm 1184). The upper channelized portion of RPMA 4 extends from the Big Sioux River (Rmi 736/Rkm 1184) to the Kansas River (Rmi 367.5/Rkm 591), and the lower channelized reach extends from the Kansas River confluence downstream to St. Louis, Missouri (Rmi 0). The reason for the distinction of the channelized reaches is that, though they are channelized, they may provide varying degrees of habitat suitability. The upper channelized river is in its current location by construction, has no natural hydrological event, is of uniform size and construction activities, and has lost most of its sandbars, islands, and shallow water habitat. The lower reach was channelized in its natural location, has frequent high water events during the spring and summer months, and contains a wide range of dike types and sizes (USFWS 2006a).

The lower Platte River is a major Missouri River tributary in RPMA 4 and likely is/was important habitat for pallid sturgeon. The lower Platte River is defined in Snook et al. (2002) as the Platte River from the confluence with the Missouri River upstream to the Loup River. Snook (2001) documented that hatchery-reared pallid sturgeon (1992 year class produced at Blind Pony State Fish Hatchery, Missouri) released (1994) in the lower Platte River tended to remain in this reach, and speculate that habitat features like sand bars were important features for the species. In 2003, Swingle (2003) collected two presumed wild pallid sturgeon in the lower Platte River and subsequently followed their movement via telemetry. One of these was a gravid female collected early May 2001 that subsequently moved into the Missouri River on June 9, 2001, suggesting the lower Platte River may be an important tributary for spawning.

Mississippi River

RPMA 5 is unimpounded for 1,153 Rmi (1,922 Rkm) from the confluence with the Missouri River to the Gulf of Mexico (Figure 1). The Mississippi River has received a substantial amount of anthropogenic modification through time, and some changes resulting from those modifications have likely been detrimental to pallid sturgeon. These anthropogenic habitat alterations likely adversely affect pallid sturgeon by altering the natural form and functions of the Mississippi River (Simons et al. 1974; Baker et al. 1991;

Theiling 1999; Wlosinski 1999). Anthropogenic alterations to tributaries may have contributed to habitat degradation in the Mississippi River as well. Impoundment of major tributaries reduced sediment delivery to the main channel (Fremling et al. 1989) resulting in channel degradation and reduction in shallow water habitats (Simons et al. 1974; USFWS 2000b).

Middle Mississippi River

The middle Mississippi River historically had a meandering pattern and shifted its course many times over the years, leaving oxbow lakes and backwaters (Theiling 1999). The undeveloped river was shallow and characterized by a series of runs, pools and channel crossings that provided a diversity of depth along the main channel (Theiling 1999). Currently the middle Mississippi River channel is fixed as a result of channel training structures and no longer meanders across the floodplain. This has reduced channel width and surface area, and thereby reduced habitat diversity. Side channels have been cutoff from the main river channel by closing structures. Many of these have been lost over time due to sedimentation. In the middle Mississippi River, the river is no longer free to migrate and produce new side channels due to channel training structures (e.g., wingdams, revetments, closing structures). Additionally, bendway weirs inhibit the establishment of point bars on inside bends of the river channel.

Channel training structures also have altered the natural hydrograph of the middle Mississippi River by contributing to higher water surface elevations at lower discharges than in the past and to a downward trend in annual minimum stages (Simons et al. 1974; Wlosinski 1999). The downward shift of annual minimum stages can be partially attributed to the degradation of the low-water channel by wingdams (Simons et al. 1974). River stages fluctuate as much as 45 feet (ft) (15 meters (m)) annually, effectively dewatering some secondary channels during low stages (Fremling et al. 1989).

Approximately 80% of the floodplain in the middle Mississippi River has been isolated from the main channel due to levee construction. This has allowed the conversion of floodplain habitats to agriculture and other land uses. Isolated backwaters, side channels, and wetlands have been degraded or lost. Destruction and isolation of these floodplain features has reduced riverine productivity (Theiling 1999) by decreasing energy inputs (organic matter and carbon) into the main channel.

Lower Mississippi River

Anthropogenic alterations have been documented in the lower Mississippi River with identified decreases in aquatic habitats (Baker et al. 1991). Construction of bendway cutoffs to facilitate navigation in the lower Mississippi River locally increased bed gradient and current velocities. As the

river responded to the cutoffs, it first became entrenched, and then developed a semi-braided condition and a wider channel (Winkley 1977). Dikes constructed to offset this geomorphic response contributed to bed degradation. Historically, bed degradation resulted in dewatering of some side channels during periods of low discharges (Fremling et al. 1989). Levee construction effectively increased river stage and velocities at higher discharges by preventing water spillover onto the adjacent floodplains effectively isolating the floodplain (Baker et al. 1991). Wasklewicz et al. (2004) found that the upper and lower reaches of the lower Mississippi River have experienced increases in peak, mean, and minimum monthly stages, while the middle portion of the lower Mississippi River has experienced decreases in peak, mean, and minimum river stages. Separately, tributary impoundments, bendway cutoffs, and dike and levee construction changed localized patterns of channel erosion and deposition in the Mississippi River; collectively they resulted in a degradation trend throughout the system. Baker et al. (1991) documented a net loss in channel length, steep bank, sandbar, slough, oxbow lake, seasonal inundated floodplain, and floodplain pond habitat types when compared against features believed present in the lower Mississippi River prior to modification efforts. They documented an increase in low river stage pool habitat that was attributed to the extensive dike system, but noted that these artificial pools may not serve the same ecological function as lost natural slackwater habitats associated with the floodplain. Even so, 92 secondary channels remain in the lower Mississippi River between Rmi 132 and 946 (Rkm 212 and 1522), and although there has been a net loss in secondary channel habitats above +5 Low Water Reference Plane^{***} over the past 40 years, elevations around 0 Low Water Reference Plane have remained relatively consistent and there has been a net increase in acreage of -5 Low Water Reference Plane shallow water habitats (Tom Keevin, USACE, pers. comm., 2006). Effects of these changes on pallid sturgeon are unknown, because there are no historical data for comparison.

Atchafalaya River

RPMA 6, the Atchafalaya River, has been significantly affected by reductions in sediment delivery. The Old River Control Complex was designed and constructed to stabilize the distribution of water and sediments between the Mississippi and Atchafalaya Rivers at the same proportions that occurred in 1950, and to prevent the Mississippi River from changing course. However, impoundment of its two major tributaries, the Red and Black Rivers, significantly reduced the sediment load from those sources. This reduction in sediment along with the construction of a hydropower plant just above Old River Control Complex has precipitated channel and bank erosion throughout the Atchafalaya River.

^{***} Note that the Low Water Reference Plane is defined in Baker et al. (1991) as “...the river level corresponding to a discharge that is exceeded 97% of the time based on the 20-year period of record from 1954 to 1973. This elevation is assigned a value of 0 ft and river stages are referenced to this standard.”

Because historical data regarding populations of pallid sturgeon is lacking or incomplete, and information on spawning sites, spawning behavior, and juvenile and adult habitat needs and uses are lacking, the significance and effects of changes in riverine habitats on pallid sturgeon are not entirely clear. However, lower capture rates in the upper and lower Missouri and middle Mississippi Rivers suggest that pallid sturgeon are more seriously affected where habitat modification has been greatest (USFWS 2000a).

2.3.1.6 Other

The larvae of *Scaphirhynchus* are pelagic, exhibiting swim-up and drift behavior immediately after hatching. Downstream drift of larval pallid sturgeon begins day-0 at hatching and continues up to day-13, with a decline after day-8 (Kynard et al. 2002, 2005). Field studies of drift dynamics and behavior of larvae pallid sturgeon, conducted in a Missouri River side channel, suggested that they may drift 152 to 329 mi (245 to 530 km), depending on water velocity, during the first 11 days, and tend to become more benthic between days 11-17 (Braaten et al. in review), suggesting that river distance and suitable habitat available below spawning areas may be important to survival of *Scaphirhynchus* larvae, and a key factor in recruitment success of river sturgeon.

Pallid sturgeon are thought to spawn in the spring or early summer like other sturgeon species. However, the capture of *Scaphirhynchus* larvae and post-larvae in the Mississippi River during fall months, as well as spring, could be interpreted as an extended season or a second spawn in the lower latitudes of distribution (Paul Hartfield, USFWS, pers. comm., 2006).

In addition to range-wide genetic structuring identified in section 2.3.1.2., there are morphological differences documented between the upper Missouri River pallid sturgeon and pallid populations in the lower Mississippi and Atchafalaya Rivers (Kuhajda and Mayden 2001). The upper Missouri River pallid sturgeon are characterized by large sizes in excess of 60 lb, and large pointed snouts, while pallid sturgeon from the lower Missouri, Mississippi, and Atchafalaya Rivers typically have shorter and rounder snouts and fish size rarely exceeds 15 lb (Figures 14 and 15). However, pallid sturgeon exhibiting morphological traits similar to the northern sample (Figures 14 and 15) from the lower Missouri and middle Mississippi Rivers (Appendix B) have been collected. This suggests that there may be a fair amount of phenotypic plasticity in the species.

Sheared principal components analysis of 19 head measurements (e.g., snout shape, placement of barbels, size and placement of mouth) show that a size-free comparison between upper Missouri River pallid sturgeon,

shovelnose sturgeon, and known hatchery-reared hybrids are quite different from lower Mississippi and Atchafalaya Rivers pallid, shovelnose, and intermediate sturgeons (Figure 16, see also Appendix B).

These morphological data suggest different populations of pallid sturgeon in the upper Missouri and lower Mississippi/Atchafalaya Rivers. These differing groups of pallid sturgeon also appear to occur in very distinct physiographic regions. The upper Missouri River lies within the Great Plains Region of the Interior Plains Province above the Fall Line, and the lower Mississippi/Atchafalaya Rivers lie within the Mississippi Alluvial Plain of the Coastal Plain Province. There are many examples of freshwater fishes having distinct populations within a species or distinct species within a lineage across different physiographic regions (Wiley and Mayden 1985).



Figure 14. Adult pallid sturgeon: the northern specimen (largest) from the upper Missouri River (RPMA 2) and smaller southern specimen from the lower Mississippi/Atchafalaya River RPMA 5 or 6 (bottom). Both specimens represent some of the largest specimens from each region. (Photo courtesy of Dr. Bernard Kuhajda, University of Alabama.)



Figure 15. Adult pallid sturgeon: northern specimen from the upper Missouri River (right) and southern specimen from the lower Mississippi/Atchafalaya River (left). Both specimens represent some of the largest examples from each region. (Photo courtesy of Dr. Bernard Kuhajda, University of Alabama.)

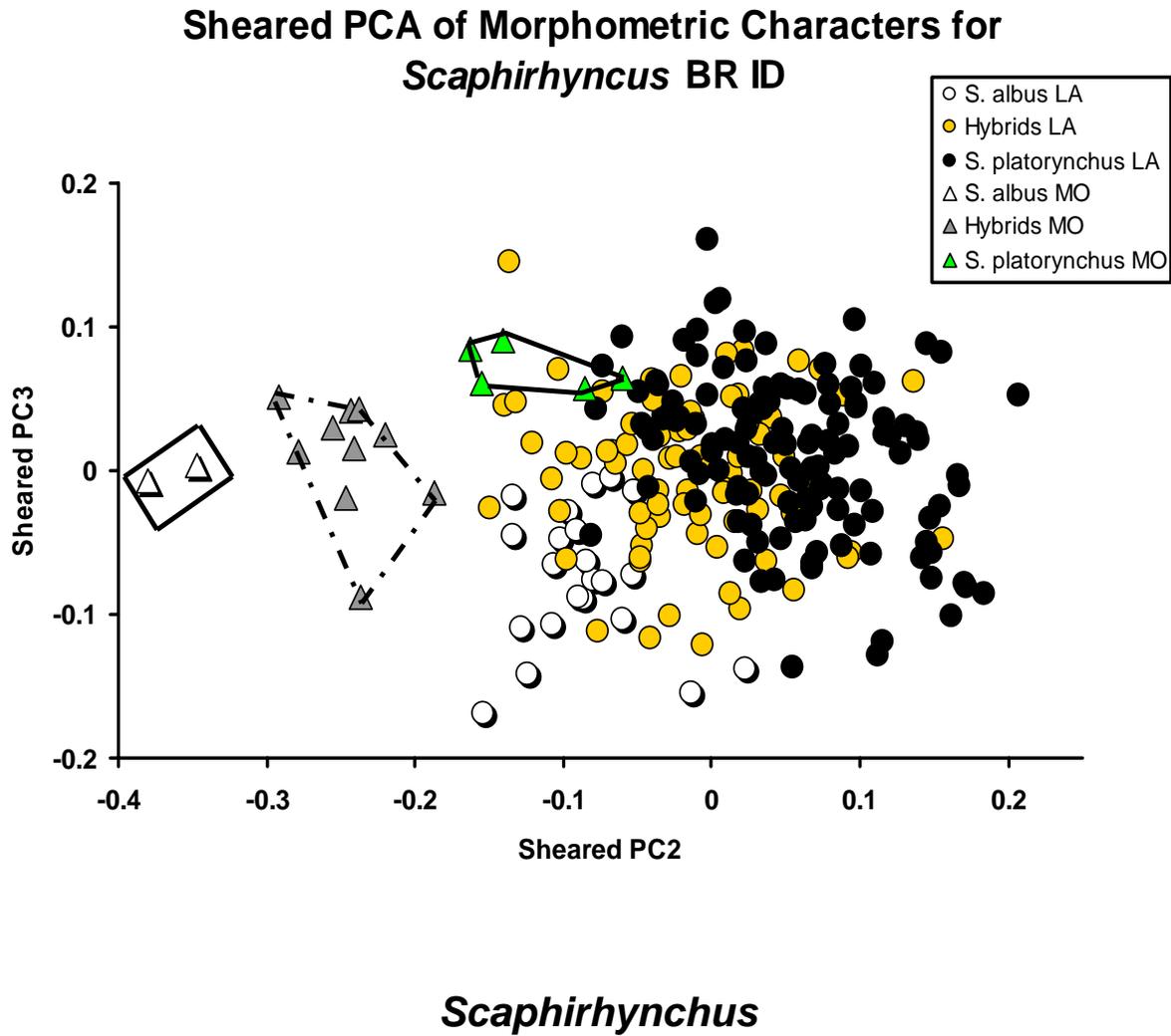


Figure 16. Sheared principal components analysis of 19 head measurements of upper Missouri River pallid sturgeon, shovelnose sturgeon, and known hatchery-reared hybrids (MO) and lower Mississippi/Atchafalaya River pallid, shovelnose, and intermediate sturgeons (LA). Each point represents measurements from an individual fish. (Courtesy of Dr. Bernard Kuhajda, University of Alabama.)

2.3.2 Five-Factor Analysis

2.3.2.1 Present or Threatened Destruction, Modification or Curtailment of its Habitat or Range

Habitat

Pallid sturgeon habitat has been dramatically altered during the past 60 years. Approximately 51% of the pallid sturgeon's historical range has been affected to some degree by channelization, 28% has been impounded, and the remaining 21% is affected by upstream impoundments that alter flow regimes, depress both turbidity and water temperatures, and have continuing bank stabilization activities that limit channel meandering (Keenlyne 1989, USFWS 2000a). Following listing in 1990, efforts have been taken to improve or restore habitats in various sections of the Missouri and Mississippi River systems, though most of these efforts have occurred during the last several years and little data are available to evaluate the success of implemented restoration projects. Below is a summary of what has been accomplished or determined since the Pallid Sturgeon Recovery Plan was completed in 1993.

Fort Benton to Fort Peck Reservoir Montana (RPMA 1)

There have been some significant changes in reservoir operations on tributaries within RPMA 1. Operations of Tiber Dam, located on the Marias River a tributary to the Missouri River, have been recently modified to occasionally accommodate a high flow discharge period in June. During 1995, 1997, and 2002 BOR provided a June peak release of 4,080, 4,500, and 5,300 cfs, respectively for downstream fisheries benefits. These releases were 1.8 to 2.3 times the average June peak discharge that has occurred since construction of Tiber Dam (1957-1994) (B. Gardner, MFWP, pers. comm., 2006). A direct response by pallid sturgeon was not observed; however, present numbers of pallid sturgeon could now be too low to detect or elicit a response. An indirect response to flow operational changes may be the recent establishment of sturgeon chub in the lower Marias River. Sturgeon chub are an important prey species of pallid sturgeon (Gerrity et al. 2006) and were documented only recently in the Marias River in 2002. The BOR is conducting a 5-year study to evaluate how operations of their four dams in the upper Missouri River system (including Tiber) affect pallid sturgeon recovery.

Recent research suggests that drought-induced lower water levels in Fort Peck Reservoir may increase available habitat for hatchery-reared juvenile pallid sturgeon as well. Gerrity (2005) noted that low water levels in Fort Peck Reservoir created an additional 34 mi (56 km) of riverine habitat upstream of the reservoir and this suggests that maintaining lower reservoir pools may be beneficial in creating additional riverine habitat for pallid sturgeon. In addition to providing juvenile pallid sturgeon habitat, the additional riverine

reach produced by low water levels in Fort Peck Reservoir also should provide some additional drift distance for larval sturgeon. However, it is yet to be determined if the additional drift distance is sufficient to promote survival of naturally produced larvae.

Fort Peck Dam, Montana to Lake Sakakawea, North Dakota (RPMA 2)

Little direct manipulation of habitat has occurred in this reach to specifically benefit pallid sturgeon. However, there are several efforts in progress that ultimately will lead to habitat connectivity or flow manipulations that may be beneficial.

The Yellowstone River is the largest tributary to the Missouri River in this reach. However, about 71 Rmi (115 Rkm) from the confluence of the Yellowstone and Missouri Rivers is a low-head dam that effectively blocks the migration of pallid sturgeon (Bramblett and White 2001). To address this barrier, a joint effort involving the Irrigation District, MFWP, USACE, BOR, USFWS, and The Nature Conservancy is underway. The primary goal of this effort is to develop suitable fish passage on the Yellowstone River at the Intake Diversion Dam and screening to prevent entrainment in the canal. Preliminary estimates suggest this project will not be completed for at least 3 to 5 years.

Another potential manipulation of existing conditions to benefit pallid sturgeon is proposed flow releases from the Fort Peck Dam spillway that could utilize warm surface water to improve temperatures and flows. The Missouri River biological opinion (USFWS 2000a) identifies these releases as important to maximizing the amount of warm water habitat available below the dam. Utilizing warm water releases to simulate natural conditions to improve spawning cues for the species have been precluded due to reservoir levels being too low to utilize the spillway. Recommendations in the Biological Opinion are based on snow pack, and identify flows ranging from 20,000 to 30,000 cfs between mid-May and the end of June. Higher flows would be recommended during higher snow pack years. To date, utilizing warm water releases to simulate natural conditions to improve spawning cues for the species have been precluded due to extended drought conditions. Like RPMA 1, the drought conditions have decreased pool levels in Lake Sakakawea resulting in more available riverine habitat. However, it is yet to be determined if this additional riverine habitat is sufficient to promote survival of naturally produced larvae.

Fort Randall Dam to Gavins Point Dam, South Dakota and Nebraska (RPMA 3)

This is the smallest RPMA identified in the Recovery Plan. Work in this reach indicates that it possesses necessary habitat and is suitable for pallid sturgeon supplementation efforts (Jordan et al. 2006). The largest tributary in this reach is the Niobrara River. Spencer Dam is a fish passage barrier on the Niobrara River and preliminary discussions, among USFWS and the State of Nebraska, to address fish passage have occurred. However, there is no real effort yet to address this concern. Development and associated bank stabilization projects still occur in this reach. These projects individually may not have a substantial impact on habitat, but cumulatively they may be reducing sediment by stopping channel meandering and the creation of new habitat. The loss of sediment inputs affects channel habitat diversity. Siltation in the upper reaches of Lewis and Clark Reservoir appears to be producing more riverine like habitat in this RPMA. However, it is yet to be determined if this additional riverine habitat is sufficient to promote survival of naturally produced larvae.

Gavins Point Dam South Dakota/Nebraska to the Mississippi River Confluence (RPMA 4)

This is the longest Missouri River RPMA identified in the Recovery Plan and has seen the most attention in terms of habitat improvement efforts. This is in part attributed to the 2003 amendment to the Missouri River Biological Opinion (USFWS 2000a). This amendment identified development of shallow water habitats between Sioux City and the Platte River. This was later extended upstream to Ponca State Park, Nebraska, and downstream to the mouth of the Osage River, Missouri. Approximately 1,400 to 1,800 acres (ac) (566 to 728 hectares (ha)) of shallow water habitat was constructed in 2004 by notching dikes and constructing site-specific projects like dredging to connect back-water areas, and pilot channel construction (USACE and USFWS 2004).

In addition to increasing shallow water habitat in this reach, the Biological Opinion (USFWS 2000a) identifies manipulation of flows from Gavins Point Dam, to stimulate a biological response from fishes as well as potentially create habitat, as an important reasonable and prudent alternative. To accomplish this, a spring rise was proposed of +17,500 cubic feet per second (cfs) (total 49,500 cfs) 1 year out of 3 with an annual summer low flow of 21,000 cfs. It is believed that these releases will begin to provide the conditions that simulate the range of historic natural fluctuations of the Missouri River. Increased discharge in the spring followed by low discharge in the summer is hypothesized to provide missing cues suspected as one cause of little to no spawning/recruitment of pallid sturgeon in this reach. A minor spring rise was implemented from Gavins Point Dam in 2006. Peak discharge of this pulse was about 25,000 cfs.

Recently there have been a variety of efforts to physically improve aquatic habitat diversity and abundance, and restore some measure of connectivity in the Missouri River and tributaries to benefit not only sturgeon but other native river species. Adult pallid sturgeon have been collected in both Upper Hamburg Bend and Plattsmouth Chutes (K. Steffensen, NGPC, pers. comm., 2005). The presence of pallid sturgeon in these created/restored habitats demonstrates their suitability for at least periodic use by multiple life stages of sturgeon. In 1998, larval pallid sturgeon were found in a naturally created chute in Missouri (Krentz 2000), suggesting that restored chutes and shallow water habitat may indeed be beneficial. Currently, efforts are underway to develop a better understanding of important habitat features that may improve restoration project designs and substantially increase our limited database on sturgeon habitat use. Based on current and anticipated commitments for aquatic habitat restoration in this RPMA, the next several years should produce increased quantity and quality of potential sturgeon habitat in RPMA 4. At present the data are incomplete or lacking to determine if these efforts are sufficient to maintain a self-sustaining population in RPMA 4.

The importance of the lower Platte River for pallid sturgeon has been documented (Snook 2002, Swigle 2003). The largest factor affecting habitat in the lower Platte River is upstream water withdrawal. A Cooperative Agreement between Nebraska, Colorado, Wyoming, and the U.S. Department of Interior (USFWS and BOR 2006) has been developed to improve and maintain habitat for species like pallid sturgeon. To date, the Platte River Recovery Implementation Program has been signed by the Department of the Interior Secretary and the Governors from Nebraska, Wyoming and Colorado. Though this program has been signed by all parties, authorizing legislation is needed to implement the thirteen year program. Planned flow improvements in the central Platte River are expected to improve conditions for pallid sturgeon in the lower Platte River. Research and monitoring will occur to assess these potential affects. Without authorizing legislation in place, agreed-upon program activities that provide ESA compliance can only be implemented to a limited extent under existing ESA authorities. For example, acquisition of program habitat lands and water projects can not occur using Federal appropriations until after the proposed legislation has become law.

Mississippi River (RPMA 5)

Middle Mississippi River

A Biological Opinion on the upper Mississippi River includes a jeopardy opinion for pallid sturgeon in the middle Mississippi River (USFWS 2000b) in part due to habitat alterations required to maintain a 9-foot navigation channel. Practices that alter habitats include--channel training structures, locks and dams, dredging and spoil disposal, and flood control projects.

Following listing of pallid sturgeon as endangered, the USACE St. Louis District issued Design Memorandum No. 24 “Avoid and Minimize Measures” in October 1992. This program was developed to minimize effects associated with maintenance of the 9-foot channel. Under this program, several projects have been completed to restore side channel connectivity and habitat diversity. Also, in recent years, as a result the jeopardy biological opinion for operation and maintenance of the 9-foot navigation channel, the USACE has initiated several “pilot” projects aimed at improving habitat diversity in the middle Mississippi River. These projects include dike modifications, construction of chevron dikes, side channel enhancement, placement of woody debris piles, and incorporation of woody debris into dikes. Specific details can be found in the Biological Opinion (USFWS 2000b).

Efforts to purchase flood prone areas have increased following flooding in 1993. By 2000, approximately 4,300 ac (1,740 ha) of former agriculture lands had been purchased from landowners who decided farming was not economically feasible in flood prone areas. Protection and restoration of these flood prone areas could provide increased flood plain access and connectivity to restore allochthonous inputs. Potential restoration of these nutrient inputs are hypothesized to be indirectly beneficial to the pallid sturgeon by increasing overall stream productivity and result in a beneficial trophic effect as well as directly beneficial by preventing further practices (e.g., rip-rap, side channel cut offs) that may be detrimental to pallid sturgeon habitats. Much of the original land purchased was incorporated into the Mark Twain National Wildlife Refuge (NWR). Also, in 2000, Mark Twain NWR was split into five separate refuges with Harlow, Wilkinson, and Meissner becoming the new Middle Mississippi River NWR.

During 2005 to 2006, through donations from the American Land Conservancy, 2,110 ac (853 ha) on Kaskaskia Island, also known as Horse Island, was conveyed to the Middle Mississippi River NWR establishing the Horse Island Division (Cail in litt. 2006). Kaskaskia Island is an approximately 16,000-ac (6,475-ha) oxbow complex created when the Mississippi River changed course during the flood of 1881 (Cail in litt. 2006). The Mississippi River carved a new channel connecting to the southern portion of the Kaskaskia River, establishing Illinois State property on the west side of the big river. Prior to conveyance to the USFWS, the American Land Conservancy enrolled 2,110 ac (853 ha) in the Wetland Reserve Program (Cail in litt. 2006). Wetland restoration and reforestation on more than 400 ac (162 ha) resulted in support from the Natural Resource Conservation Service. The Kaskaskia River is just upstream from land acquired on Horse Island, and is a tributary that joins the Mississippi River in the vicinity of where fishery biologists have reliably captured pallid sturgeon.

Also during 2005-2006, funds from the Illinois Clean Energy Community Foundation and the North American Wetlands Conservation grant program has resulted in the conveyance of 722 ac (292 ha) to the USFWS and 318 ac (128 ha) to Ducks Unlimited on Rockwood Island (Cail in litt. 2006). Rockwood Island is a 2,500-ac (1,011-ha) island and side channel complex containing both forested and agriculture lands, and an active 2.5-mi (4-km) side channel. The active side channel provides habitat for big river fishes and other wetland obligates (Cail in litt. 2006). These lands are unprotected by levees and offer the opportunity for fish and wildlife restoration activities in the future.

Current acres/hectares for the Middle Mississippi River NWR include Meissner Island 78 ac/31 ha, Harlow Island (1,225 ac/496 ha), Beaver Island (249 ac/101 ha), Horse Island (2,110 ac/853 ha), Rockwood Island (722 ac/292 ha), and Wilkinson Island (2,532 ac/1,025 ha), which total 6,916 ac/2,799 ha (Cail in litt. 2006). In July 2004, the Mark Twain NWR Complex Comprehensive Conservation Plan and Environmental Assessment were approved, resulting in approved acquisition boundaries for the Middle Mississippi River NWR enclosing 14,758 ac/5,972 ha (Cail in litt. 2006).

The Middle Mississippi River NWR lands currently are spread along 60 mi (96 km) of the Mississippi River below St. Louis, Missouri. Protection and restoration of these areas has been attributed with improved floodplain connectivity as well as improved habitat conditions (USFWS 2000b). With the previously identified practices in place, the USFWS' Biological Opinion (USFWS 2000b) still indicates that maintaining the 9-foot navigation channel "is likely to jeopardize the continued existence of pallid sturgeon." As such, four reasonable and prudent alternatives (RPAs) were identified. These are-- 1) conduct a study of pallid sturgeon habitats on the middle Mississippi River, 2) facilitate development of a pallid sturgeon conservation and restoration plan, 3) implement the habitat restoration plan developed in item 2, and 4) implement short-term restoration measures that are believed to benefit pallid sturgeon until RPA 1-3 are completed.

Lower Mississippi River

Between 1929 and 1942, 16 bendway cutoffs were constructed by the USACE that shortened the river 152 mi (245 km) over a 503-mi (809-km) reach (Baker et al. 1991). In response to this 30% reduction in channel length, the river became entrenched in steeper gradient reaches, eroding large amounts of material from the channel banks and bed. Deposition of this material in the lower gradient reaches resulted in a semi-braided channel, and by the 1970s the river was attempting to reestablish a meandering condition (Winkley 1977). Increasing flood flows due to loss of outlets, and construction of levees in major tributaries and the Mississippi River contributed to overall channel instability. Because of these geomorphic adjustments to

anthropogenic changes, an aggressive program of bank revetment and dike construction was required to fix and maintain the navigation channel, and to protect the levee system. Although successful in its overall intent to facilitate navigation and provide flood control benefits, this program reduced secondary channel formation, floodplain connectivity, and both lentic and lotic sandbar formation in the lower Mississippi River (Baker et al. 1991).

In 1981, the USACE established the Lower Mississippi River Environmental Program, with a goal of protecting fisheries and other natural resources in the lower Mississippi River. Input from the Lower Mississippi River Environmental Program resulted in experimentations with dike placement and notches as measures to protect secondary channels and maintain shallow water and fisheries habitats. In 2001, the USACE Mississippi Valley Division, initiated informal consultation under section 7(a)(1) with the USFWS to develop and implement additional measures to conserve and manage listed species associated with the lower Mississippi River navigation channel. Under this process, the Memphis and Vicksburg Districts hold annual meetings with the USFWS and State conservation agencies to review and modify, if necessary, construction and maintenance plans and activities to minimize potential impacts to listed species, avoid further loss of secondary channel habitats, and to restore and improve secondary channel areas when possible (USACE in litt. 2004, 2005, and 2006). The USACE Mississippi Valley Division and the Districts also are working with the Lower Mississippi River Conservation Committee, State agencies, and the USFWS to identify and initiate secondary channel restoration opportunities. However, results of the Lower Mississippi River Environmental Program and section 7(a)(1) conservation actions have not been quantified and it is currently unknown if habitat degradation trends in the lower Mississippi River have been reduced, stopped, or reversed.

Atchafalaya River (RPMA 6)

The Atchafalaya River is a tributary to the Mississippi River. Water enters the Atchafalaya River from the Mississippi River through the Old River Control Complex and an adjacent hydropower plant. Construction of these structures has altered habitats by reducing sediment transport into the Atchafalaya River (Reed and Ewing 1993) and the structures likely are effective barriers for fishes trying to move from the Atchafalaya system into the Mississippi River.

Impoundment of the Red and Black Rivers, also has significantly contributed to the reduction of sediments moving into the Atchafalaya River, precipitating bank and channel erosion. Other habitat alterations in this RPMA contributing to channel habitat degradation include construction of levees and

navigation dredging. Effects of these habitat alterations on pallid sturgeon are unknown, since there is little to no information on pallid sturgeon from the Atchafalaya River prior to 1991 (USFWS 1993).

While there have been substantial anthropogenic alterations to riverine habitat throughout the range of pallid sturgeon, there have also been numerous activities design to improve current habitat conditions. Available demographic data do not indicate that these habitat improvement activities have resulted in improved pallid sturgeon populations within the Missouri River and data are insufficient to assess affects of these improvements in the Mississippi River. Thus while the threat of destruction, modification or curtailment of habitat or range may not be increasing, past activities may not have been rectified to such a point that the threat can be considered addressed.

2.3.2.2 Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Commercial or recreational harvest of pallid sturgeon is a threat to the species and is prohibited by section 9 of the ESA and by State regulations throughout the range. Collection of adults for any purpose imposes a potential reproductive loss within any given RPMA. Overutilization of pallid sturgeon for scientific or educational purposes is likely negligible. Following the species listing, possession of pallid sturgeon is governed through the ESA 10(a)1(A) permit program. Take associated with these activities is quantifiable and appears to be very small. Overexploitation for commercial or recreational purposes is harder to quantify and likely poses a bigger threat as greater numbers of reproductively capable adults can be lost in a relatively short time frame. However, incidental and illegal harvest of pallid sturgeon has been documented in the Mississippi River, and may be a significant impediment to survival and recovery of the species in some portions of its range (see 2.3.2.2., below). Other forms of overutilization are not known to currently affect the species.

Overexploitation

Commercial harvest of sturgeon for roe and meat was a traditional fishery in the Missouri and Mississippi River systems. Because pallid sturgeon and shovelnose sturgeon are very similar in appearance, increasing trends in shovelnose harvest increases the likelihood of unintentional harvest of pallid sturgeon.

Williamson (2003) presented data from the MDC that showed an increase in commercial catch of shovelnose sturgeon from 5,850 pounds (lb) (2,653 kilograms (kg)) in 2000 to 12,370 lb (5,610 kg) in 2001. A total of 7,472 lb (3,389 kg) were reported in 1999. To reduce the effects of harvest on pallid sturgeon, Montana, North Dakota, South Dakota, Nebraska, and Iowa

have closed commercial sturgeon fishing on the Missouri River. Missouri still allows commercial harvest, but has limited harvest by closing commercial sturgeon fishing on the Missouri River upstream of the Kansas River to the Iowa border. Incidental or purposeful illegal harvest of pallid sturgeon associated with commercial fishing likely is having a negative impact on the demographics of this species and should be viewed as a potential threat to pallid sturgeon in RPMA 4 where commercial harvest is still allowed.

There is a paucity of historical information on commercial harvest of sturgeon for roe and meat in the middle and lower Mississippi River. Cook (1958) provides commercial harvest information for the years 1894, 1899, 1903, 1908, 1922, and 1931. This report details total pounds harvested and from which river, but most of these data are reported as “sturgeon” with one reference to shovelnose. There appears to have been a decreasing trend in sturgeon harvest through time with a high of 8,600 lb (3,900 kg) reported in 1899 to a low of 100 lb (45 kg) reported in 1931. Williamson (2003) provided data reported by the Illinois Department of Natural Resources and the Kentucky Department of Fish and Wildlife Resources for commercial catch of shovelnose sturgeon. In Illinois, the Statewide commercial catch of shovelnose sturgeon flesh increased from 8,853 lb (4,015 kg) in 1990 to 65,462 lb (29,693 kg) in 2001. The amount of roe taken increased from 47 lb (21 kg) reported in 1999 to 8,197 lb (3,718 kg) reported in 2001. In Kentucky, the commercial catch of shovelnose sturgeon in the Mississippi River increased from 25 lb (11 kg) (flesh) in 1999 to 8,324 lb (3,775 kg) in 2002. The harvest of roe was reported at 1,021 lb (463 kg) in 2001 and 731 lb (331 kg) in 2002. Overharvest of sturgeon is a major concern in pools 12-26 of the Mississippi River. Harvest of shovelnose sturgeon roe by licensed Illinois fishermen has increased almost 10-fold since the late 1990s (Figure 17).

Several States have initiated restrictions to reduce take of pallid sturgeon. Commercial take of any species of sturgeon was prohibited by Mississippi and Louisiana during the early 1990s to avoid incidental take of endangered or threatened sturgeon species. For similar reasons, Arkansas prohibits sturgeon fishing in the Mississippi River and restricts commercial take of shovelnose sturgeon to tributaries. Tennessee, Missouri, Kentucky, and Illinois continue to allow commercial harvest of shovelnose sturgeon. Iowa currently does not allow commercial shovelnose sturgeon harvest on the Missouri River, but does allow commercial harvest on the Mississippi River.

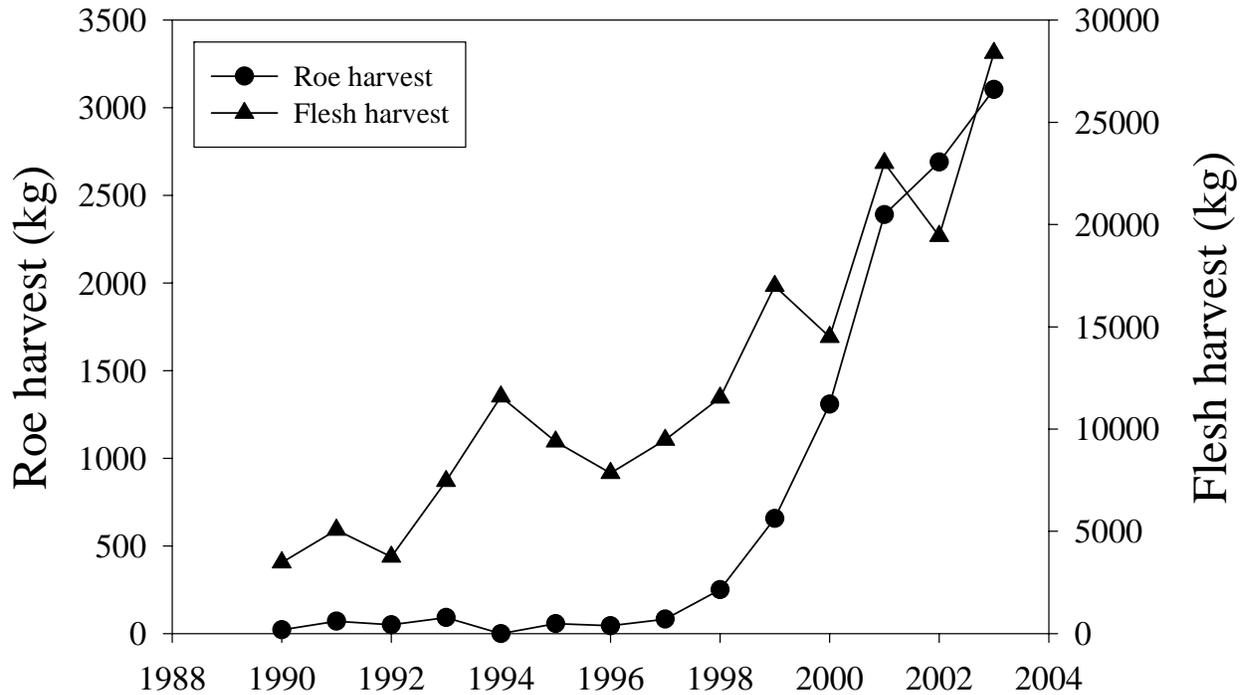


Figure 17. Reported commercial harvest (i.e., by licensed Illinois harvesters) of shovelnose sturgeon roe and flesh from Pools 12-26 of the Mississippi River.

The restrictions imposed through State fishing regulations have helped; however, there is still evidence of incidental take of pallid sturgeon associated with commercial harvest of shovelnose sturgeon. Pallid sturgeon remains have been discovered in fish markets (Sheehan et al. 1997) and pallid sturgeon with egg biopsy scars have been documented by biologists from the USFWS Columbia Fishery Resource Office, Columbia, Missouri (Wyatt Doyle, USFWS, pers. comm., 2006). In the spring of 2006, at least three adult pallid sturgeon were found in the possession of a commercial fisherman illegally fishing Arkansas waters (Keevin in litt. 2006). In that same year, there also were nearly 100 sturgeon carcasses found in a dumpster near the Chain of Rocks area in St. Louis, Missouri. Of the 100 carcasses, there was 1 suspected pallid sturgeon. Region 3 of the USFWS also has reported there are between 6 to 14 document cases of illegal or unintentional harvest of pallid sturgeon that are being investigated or part of ongoing investigations by State or USFWS law enforcement officials (Mike Oetker, USFWS, pers. comm., 2006). Preliminary age studies of pallid sturgeon spine sections in the middle Mississippi River where harvest of shovelnose sturgeon is permitted, have estimated maximum pallid sturgeon age at 15 years, with mortality rates of 37 to 39% (Colombo et al. in press). Estimates for the lower Mississippi River, where shovelnose sturgeon harvest is not permitted, place maximum age at

21 years, with a mortality rate of 12% (J. Garvey, Southern Illinois University, J. Killgore, USACE, data presented at the pallid sturgeon Recovery Team meeting September 28-29, 2005, held in Lakewood, Colorado). The higher age and lower mortality estimates for pallid sturgeon within the lower Mississippi River, where commercial harvest of shovelnose sturgeon is prohibited, suggests that incidental take of pallid sturgeon by commercial harvest is more prevalent in the middle Mississippi River. This suggests that incidental and illegal take during commercial harvest of shovelnose sturgeon is having a substantial and detrimental effect on the pallid sturgeon in the middle Mississippi River.

Overexploitation is a factor that must be considered in pallid sturgeon conservation. Unintentional and illegal take of pallid sturgeon for commercial purposes will likely increase in the middle Mississippi and lower Missouri Rivers as commercial pressures on domestic sturgeon increase due to the importation ban of beluga sturgeon (*Huso huso*) caviar into the United States and the general trend toward reduced caviar exports from the Caspian Sea sturgeon stocks (CITES 2006). This recent ban has limited supply and likely has attributed to an increase in roe prices.

The threat of overutilization for commercial, recreational, scientific, or educational purposes has diminished since listing, due in part to changes in regulations involving harvest and scientific collections. However, illegal take of pallid sturgeon still occurs and thus this threat, while reduced since listing, has not been eliminated (see also 2.3.2.4 Inadequacy of Existing Regulatory Mechanisms).

2.3.2.3 Disease or Predation

An iridovirus is known to infect pallid and shovelnose sturgeon. This disease originally surfaced during artificial propagation efforts and is known to cause substantial mortality in a hatchery rearing environment (USFWS 2006a). The iridovirus was first identified by histology from a female pallid held at Garrison Dam National Fish Hatchery (USFWS 2006). Subsequent testing has documented that this virus is found in the wild. Of 179 *Scaphirhynchus* tested from the Atchafalaya River between November 2003 and May 2004, 8 (4%) were identified as virus positive and 5 (2.8%) were considered virus suspect. Both pallid and shovelnose sturgeon tested either positive or suspect. When manifested, this disease is known to cause substantial mortality in a hatchery rearing environment, but the effect of the virus on wild populations is poorly understood (USFWS 2006). Documenting the natural background level of the virus in the wild is needed to identify an acceptable baseline percentage of virus-positive individuals in a given sample size.

Little information is available documenting piscivory as a threat limiting the recovery of the pallid sturgeon. Predation on larval fishes of all species

occurs naturally. However, habitat modifications that increase water clarity and artificially high densities of both non-native and native predatory fishes could limit a species' natural ability to sustain itself.

Pallid sturgeon larvae and fry drift freely immediately post-hatch as “free embryos” (Kynard et al. 2002, Braaten et al. in review). This drift distance would likely expose any naturally spawned pallid sturgeon to predation and transport naturally spawned pallid sturgeon larvae into the headwaters of Fort Peck Reservoir and Lake Sakakawea. In addition to these reservoirs creating a more lentic environment, they are or have been artificially supplemented with predatory species like walleye (*Sander vitreum*). Maintaining elevated populations of certain species in these reservoirs has been hypothesized as a contributing factor in poor survival of larval and juvenile pallid sturgeon. Parken and Scarnecchia (2002) reported that walleye and sauger (*S. canadense*) in Lake Sakakawea (just downstream of RPMA 2) were capable of eating wild paddlefish (*Polyodon spathula*) up to 6.6 inch (in.) (167 mm) body length (12 in./305 mm total length) and thus likely could consume naturally produced pallid sturgeon larvae and smaller hatchery produced pallid sturgeon released as part of supplementation efforts. When looking at these data for their sample location closest to the headwaters area, it appears that no age-0 paddlefish were found in walleye, but were present in sauger, a native species closely related to walleye. Braaten and Fuller (2002, 2003) examined 759 stomachs from 7 piscivores species in Montana and found no evidence of predation on sturgeon. However, in all species sampled, unidentified fish or fish fragments were present. More data are needed to adequately evaluate predation effects on pallid sturgeon recruitment success.

2.3.2.4 Inadequacy of Existing Regulatory Mechanisms

One regulatory challenge that has not been fully addressed since the Recovery Plan was finalized is accidental or intentional take of pallid sturgeon as a result of commercial harvest.

Generally, shovelnose sturgeon can be distinguished from pallid sturgeon by their smaller size as mature adults. However, this can be an inaccurate gauge at the upper size range for shovelnose sturgeon, since both species experience a wide range of size variation depending on their geographic home range (Table 1).

Table 1. Maximum and average sizes of large adult shovelnose and pallid sturgeon.

RIVER	PALLID STURGEON maximum length	SHOVELNOSE STURGEON	
		maximum length (range)	average large size
Mississippi River	1,350 mm	1,000-1,050 mm	800 mm
Lower Missouri River	1,162 mm	800-804 mm	720 mm
Upper Missouri River	1,638 mm	1,400-1,500 mm	900 mm

Currently, biologists use character indices as tools to distinguish between pallid sturgeon and shovelnose sturgeon. These tools, developed by taxonomists, use as many as 13 morphometric body measurements and meristic ray fin counts to differentiate between the two species. However, in a recent meeting of the Pallid Sturgeon Recovery Team and its Genetics Advisory Group, data were presented showing limited success using character indices when compared to genetic confirmation of species (Kuhajda et al. in press; Murphy et al. in press, see also Appendix B). Geneticists and taxonomists have shown a gradient of morphometric and genetic differences throughout these species' geographic range and suggest that recent evolutionary divergence also may complicate genetic distinction. It can be difficult for trained biologists to differentiate between shovelnose and pallid sturgeon. Pallid sturgeon are at risk in States allowing commercial harvests of shovelnose due to the difficulty in distinguishing between the two species (see also 2.3.2.2. Overutilization for commercial, recreational, scientific, or educational purposes: Overexploitation). Currently, efforts by Iowa and Missouri to restrict commercial harvest of shovelnose sturgeon to certain areas likely have reduced this threat, but may not have eliminated it. Tennessee, Missouri, Kentucky, Iowa, and Illinois continue to allow regulated commercial harvest of shovelnose sturgeon for flesh or roe. Applicable commercial harvest regulations are as follows:

- Tennessee has established a 24- to 32-in. (609- to 813-mm) FL harvestable size limit and fishing season (October 15 to May 15) for roe harvest on the Mississippi River and has closed a portion of the river to commercial harvest due to contaminants concerns (Tennessee Wildlife Resources Agency 2006).
- Missouri has established a 24- to 30-in. (609- to 762-mm) FL harvestable size limit and fishing season (November 1 through May 15) on the Missouri River. Also, there are areas closed to harvest, including Kansas City upstream to the State line and approximately 30 Rmi around the mouth of the Osage River (15 mi above and below the confluence). The restrictions for the Mississippi River are a 24- to 32-in. (609- to 813-mm) FL harvestable size limit and a fishing season (October 15 to May 15).

Commercial anglers are required to purchase a permit (MDC 2006) and harvested shovelnose sturgeon are to remain whole and intact while on waters of the State and adjacent banks. Nonresidents are not allowed to harvest shovelnose sturgeon on the Missouri River.

- Kentucky has established a 24- to 32-in. (609- to 813-mm) FL harvestable size limit, a season (October 15 through May 15), and monthly catch reporting requirements for commercial fisherman (Kentucky 2006).
- In July 2006, the Iowa Natural Resources Commission adopted changes to their commercial fishing regulations that establish a minimum shovelnose sturgeon fork length of 27 in. (686 mm). A maximum fork length of 34 in. (863 mm) also was established for the Mississippi River bordering Wisconsin. These regulation changes identify a closed season for shovelnose sturgeon harvest (May 16 through October 14) and require that shovelnose sturgeon remain intact until the fish are delivered to a processing facility (Iowa 2006).
- Illinois currently has no size limits on shovelnose sturgeon, but does require monthly reporting of roe harvest. Also, there are areas closed to commercial fishing on the Mississippi River, such as Quincy Bay, including the waterfowl management area and other USFWS NWR Waters (Illinois 2006).

While these self-imposed regulations are intended to assist with protecting *Scaphirhynchus* in the middle Mississippi River, their long-term effects have yet to be demonstrated. Recent work, by Colombo et al. (in press), indicates that the current minimum size length of 24 in. (609 mm) is not sufficient to maintain a sustainable shovelnose sturgeon fishery long term. The size range of pallid sturgeon overlaps harvestable length shovelnose sturgeon in these States and thus unintentional or illegal harvest is likely continuing because the two species can be difficult to discern from each other. This concern also is highlighted in Colombo et al. (in press). Their data suggests that in the middle Mississippi River, pallid sturgeon annual mortality rates are very similar to those calculated for the commercially harvested shovelnose sturgeon and suggest that harvest-induced mortality is negatively affecting pallid sturgeon mortality rates.

As caviar prices rise and commercial pressures on shovelnose sturgeon increase, incidental and illegal take of pallid sturgeon is expected to increase in the middle Mississippi and lower Missouri Rivers, and may become an issue in the lower Mississippi and Atchafalaya Rivers. In light of the existing regulatory, advisory, and enforcement mechanisms, the difficulties in distinguishing between pallid sturgeon and shovelnose sturgeon still exist (see also 2.3.2.2. Overutilization for commercial, recreational, scientific, or educational purposes). Accidental or intentional take of pallid sturgeon can occur and be difficult to enforce. Given the potential difficulty in enforcing regulations where the two species overlap, these regulatory mechanisms may not adequately address the illegal

harvest of pallid sturgeon. Addressing unintentional or illegal take is essential for recovery and current regulatory and enforcement mechanism may be inadequate to fully address this threat.

2.3.2.5 Other Natural or Manmade Factors Affecting its Continued Existence

Contaminants

Currently there are several fish consumption advisories for shovelnose sturgeon attributable to contaminants. Contaminant levels in pallid sturgeon also have been noted, but data are minimal. Elevated levels of polychlorinated biphenyls (PCBs), cadmium, mercury, and selenium have been detected in tissue samples from three pallid sturgeon collected from the Missouri River in North Dakota and Nebraska (Ruelle and Keenlyne 1992). Ruelle and Keenlyne (1992) also noted detectable concentrations of chlordane, DDE, DDT, and dieldrin. The effects of contaminants on pallid sturgeon reproduction also are poorly understood. However, research involving white sturgeon (*Acipenser transmontanus*) in the Columbia River found lower condition factors, gonadal abnormalities, and hermaphroditism in fishes with elevated levels of metabolites of DDT (DDE and DDD) as well as total PCBs and mercury (Feist et al. 2005). Shovelnose sturgeon collected from the lower Missouri River have a consumption advisory because of concerns relating to overelevated levels of PCB and chlordane (DHSS 2006), and also lower Missouri River shovelnose sturgeon have been noted to exhibit intersexual characteristics (Wildhaber et al. 2005). Intersexual shovelnose sturgeon from the middle Mississippi River were found to have higher concentrations of organochlorine compounds when compared against male shovelnose sturgeon (Koch et al. 2006). Current data are lacking to adequately understand and address this problem under existing environmental laws, but contaminant research suggests a link between environmental contaminants and potential reproductive problems in several sturgeon species (Feist et al. 2005; Koch et al. 2006). Research on the effects of contaminants on pallid sturgeon reproductive mechanisms should continue as part of pallid sturgeon recovery efforts.

The State of Tennessee closed commercial fishing on the Mississippi River from the State line to downstream of Meeman-Shelby State Park (Rmi 745) because of concerns over chlordane and other contaminants (Tennessee 2004). Currently, the Missouri Department of Health and Senior Services (2006) has issued a “do not eat” advisory for shovelnose sturgeon eggs because of concerns over PCB and chlordane levels. Illinois has a sturgeon consumption advisory (PCBs) on the Mississippi River between Lock and Dam 22 to Cairo, Illinois.

Entrainment

Another issue that is negatively impacting pallid sturgeon throughout its range is entrainment. The loss of pallid sturgeon associated with water intake structures has not been accurately quantified. The U.S. Environmental Protection Agency published final regulations on Cooling Water Intake Structures for Existing Facilities per requirements of Section 316(b) of the Clean Water Act. The rule making was divided into three phases. However, only Phase I and II appear applicable to inland facilities; Phase III applies to coastal and offshore cooling intake structures associated with coastal and offshore oil and gas extraction facilities. The following rule summaries are based on information found at the website <<http://www.epa.gov/waterscience/316b/>>.

Phase I rules, completed in 2001, require permit holders to develop and implement techniques that will minimize impingement mortality and entrainment. Phase II, completed in 2004, covers existing power generation facilities that are designed to withdraw 50 million gallons per day or more with 25% of that water used for cooling purposes only. This rule, implemented through National Pollutant Discharge Elimination System permits, is intended to minimize negative affects associated with water cooling structures. This rule provides permit holders with five alternatives to ensure compliance:

- 1) Demonstrate that it will reduce or has reduced its intake flow commensurate with a closed-cycle recirculating system and, therefore, is deemed to have met the impingement mortality and entrainment performance standards, or that it will reduce or has reduced the design intake velocity of its cooling water intake structure to 0.5 ft/s and, therefore, is deemed to have met the impingement mortality performance standards;
- 2) Demonstrate that its existing design and construction technologies, operational measures, and/or restoration measures meet the performance standards and/or restoration requirements;
- 3) Demonstrate that it has selected and will install and properly operate and maintain design and construction technologies, operational measures, and/or restoration measures that will, in combination with any existing design and construction technologies, operational measures, and/or restoration measures, meet the specified performance standards and/or restoration requirements;
- 4) Demonstrate that it meets the applicability criteria for a rule-specified technology or a technology that has been pre-approved by the Director and that it has installed, or will install, and will properly operate and maintain the technology; or,

- 5) Demonstrate that it is eligible for a site-specific determination of best technology available to minimize adverse environmental impacts and that it has selected, installed, and is properly operating and maintaining, or will install and properly operate and maintain, design and construction technologies, operational measures, and/or restoration measures that the Director has determined to be the best technology available to minimize adverse environmental impact for the facility.

Section 316(b) of the Clean Water Act requires the U.S. Environmental Protection Agency to insure that aquatic organisms are protected from impingement or entrainment. As part of the Phase II ruling, some power plants have begun conducting required entrainment studies.

Preliminary data on the Missouri River suggests that entrainment may be a serious threat that warrants more investigation. Initial results from work conducted by Mid-America at their Neal Smith power facilities found hatchery-reared pallid sturgeon were being entrained (Jordan in litt. 2006, Ledwin in litt. 2006, Williams in litt. 2006). Over a 5-month period, four known hatchery-reared pallid sturgeon have been entrained, of which two were released alive and two were found dead. Ongoing entrainment studies required by the Clean Water Act will provide more data on the effects of entrainment. However, addressing entrainment issues may not occur immediately and continued take of hatchery-reared or wild pallid sturgeon will limit the effectiveness of recovery efforts.

In addition to cooling intake structures for power facilities, concerns have been raised regarding entrainment associated with dredge operations and irrigation diversions. Currently little data are available regarding the effects of dredge operations. However, the USACE, St. Louis District, and the Dredging Operations and Environmental Research Program have initiated work to assess dredge entrainment of fish species and the potential effects that these operations may have on larval and juvenile *Scaphirhynchus*. Data for escape speed, station-holding ability, rheotaxis and response to noise, and dredge flow fields are being used to develop a risk assessment model for entrainment of sturgeon by dredges. If funds become available during the upcoming year (2007), field work will be expanded to include trawling of frequently dredged areas and examining dredge spoil. Entrainment has been documented in the irrigation canal supplied by Intake Dam on the Yellowstone River (Jaeger et al. 2004) (see also 2.3.1.5. Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem)). Given that entrainment has been documented to occur in the few instances it has been studied, further evaluation of entrainment at other water withdrawal points is warranted across the pallid sturgeon's range to adequately evaluate this threat.

Hybridization

The Pallid Sturgeon Recovery Plan (USFWS 1993) identifies hybridization as a threat to pallid sturgeon. This was, in part, based on work by Carlson et al. (1985) who identified sturgeon in the middle Mississippi River that were intermediate in character between shovelnose and pallid sturgeon. In addition, sturgeon with intermediate characteristics were reported in commercial catch records from the lower Missouri and middle and lower Mississippi Rivers.

The presence of morphologically intermediate forms presumed to represent pallid-shovelnose sturgeon hybrids (Keenlyne et al. 1994; Carlson et al. 1985) spurred an effort to determine the genetic origins of these fish. Recent genetic tools have been utilized to explore the concept of hybridization between pallid and shovelnose sturgeon (See also 2.3.1.2. Intercrosses between Pallid and Shovelnose Sturgeon).

Tranah et al. (2004) combined the data from Campton et al. (2000) and Tranah et al. (2001) and added 4 additional microsatellite loci to the data set to determine the genetic origins of 10 morphologically intermediate sturgeon collected from the Atchafalaya River. All fish were classified as pallid, shovelnose or hybrid sturgeon via the hybrid index method of Campton (1987). These results are consistent with the hypothesis of hybridization between pallid and shovelnose sturgeon. However, this study simply demonstrated that morphologically intermediate fish had genetically intermediate genotypes (Don Campton, USFWS, pers. comm., 2005). The data represent a circular argument for “hybridization” because the data set on which the conclusions were based also was the data set used to parameterize the “hybrid index” function. Moreover, Tranah et al. (2004) did the analyses separately for fish in the upper Missouri and Atchafalaya Rivers. As a result, genotypically-intermediate fish in one region would not necessarily have been genotypically intermediate fish in the other region, because the level of divergence between regions within species was as large as the divergence between species within regions (Campton et al. 2000, also suggested in Heist and Schrey 2006b). Based on these data, one cannot distinguish true “hybridization” (i.e., secondary contact following allopatric speciation) from sympatric speciation and assortative mating. Both mechanisms would yield a positive correlation between genotype and phenotype, which is what Tranah et al. (2004) measured. Likely, the correlation would collapse if Tranah et al. (2004) had performed their “hybrid index” analyses for all fish and both regions combined. Because pallid and shovelnose sturgeon are very closely related evolutionarily, particularly compared to other congeneric species of fishes in North America, the available data do not allow us to reject the hypothesis that pallid sturgeon (as a morphological phenotype) may have had a polyphyletic origin relative to shovelnose sturgeon.

Hence, based on the available genetic information, neither the allopatric speciation/hybridization hypothesis nor the sympatric speciation/polyphyly hypothesis can be rejected at this time.

More information is needed on the evolutionary dynamics of intermediates between pallid sturgeon and shovelnose sturgeon to understand if they are natural or a threat that has resulted from anthropogenic alterations to spawning habitat or cues.

2.4 Synthesis

The primary threats identified for pallid sturgeon in the final rule and in the Recovery Plan (USFWS 1993) were--1) curtailment of range, 2) habitat destruction and modification, 3) low population size, 4) lack of recruitment, 5) commercial harvest, 6) pollution/contaminants, and 7) hybridization. Significant new information gathered since listing is summarized below in relation to the species' status and associated threats.

Range/Habitat

The curtailment of range and habitat destruction/modification were primarily attributed to the construction and operation of dams on the upper Missouri River and modification of riverine habitat by channelization of the lower main stem Missouri and Mississippi Rivers. Dams substantially fragmented pallid sturgeon range in the upper Missouri River. However, free-flowing riverine conditions currently exist throughout the lower 2,000 mi (3,218 km) (60%) of the pallid sturgeon's historical range. Although the lower Missouri River (RPMA 4) continues to be impacted by regulated flows and modified habitats, actions have been developed and are being implemented to address habitat issues. Recent studies and data from the Mississippi River (RPMA 5) suggests that riverine habitats are less degraded than previously believed, and that they continue to support diverse and productive aquatic communities, including pallid sturgeon. Although there are ongoing programs to protect and improve habitat conditions in RPMAs 1, 2, 3, 4, and 5, positive effects from these programs on pallid sturgeon have not been demonstrated or quantified.

Population Size

Data for the Missouri River continue to indicate that wild pallid sturgeon in RPMA 1 and 2 are large, mature, and likely old individuals, and provide little to no evidence supporting a naturally self-sustaining population. There appears to be no natural wild population surviving in RPMA 3. Sampling in RPMA 4 during the past decade continues to confirm a small population of wild pallid sturgeon in the lower Missouri River. Pallid populations in RPMAs 1-3 are being augmented with hatchery produced fish in order to ensure persistence of the species until threats are adequately addressed to promote a self-sustaining population. Data collected after the Recovery Plan was developed indicate that pallid sturgeon numbers are higher in the Mississippi and Atchafalaya Rivers than initially documented in 1993 (see Demographic Data by Recovery Priority Management Area sections discussing RPMA 5 and RPMA 6). However, this increase in collections can be associated with increased sampling efforts and not quantified with catch-per-unit effort data. When listed, there were only 28 recognized records of pallid sturgeon from the Mississippi River, with no recognized records from the Atchafalaya River.

According to the National Pallid Sturgeon Database (USFWS 2006b), there have been a total of 279 individual pallid sturgeon collected from RPMA 5 and 499 collected from RPMA 6. However, the sampling effort within these RPMAs does not adequately sample all size/age classes. Population estimates are currently unavailable due to limited sampling in RPMA 5 and 6.

Recruitment

While there are documented cases of natural reproduction in RPMAs 2, 4, and 5, data on natural recruitment of pallid sturgeon continues to be limited throughout the species' range. Current wild pallid sturgeon populations in RPMA 1 and 2 are comprised of old-aged individuals, and RPMAs 1, 2, and 3 are dependent on hatchery augmentation programs for recruitment. No wild pallid sturgeon have been collected in the last 10 years within RPMA 3 that were not translocated, and no spawning or recruitment has been detected. Addressing recruitment bottlenecks in the three upper Missouri River RPMAs is critically important for the species to become self sustaining and be recovered in those reaches. A few sub-adult or young adult wild pallid sturgeon have been collected in RPMA 4, along with a few larval pallid sturgeon. Larval pallid also have been collected in the middle Mississippi River, but no data are available to accurately evaluate recruitment levels. The presence of smaller-sized cohorts of pallid (400-600 mm) in both RPMA 5 and 6, coupled with age data indicating that no pallid sturgeon were beyond 15 years old in the middle Mississippi River (Colombo et al. In Press), suggests that some level of recruitment is occurring. Additional efforts are needed to document population demography, reproduction, and recruitment in RPMAs 4, 5, and 6.

Commercial Harvest

Illegal commercial harvest of pallid sturgeon is occurring in portions of RPMAs 4 and 5. Data show lower ages and higher mortality rates of pallid sturgeon in areas where shovelnose sturgeon are commercially harvested (Colombo et al. in press). This threat is likely to increase as caviar sources are reduced world-wide and caviar prices increase.

Pollution and Contaminants

Data continue to be incomplete regarding the effects of contaminants on pallid sturgeon viability or rates of hermaphroditism. Studies of shovelnose sturgeon in the Missouri and Mississippi Rivers documents hermaphroditism (Wildhaber et al. 2005), which may be the result of exposure to certain forms of water pollution (Koch et al. 2006). Limited data also have documented elevated contaminants levels in pallid sturgeon (Ruelle and Keenlyne 1992), but there are no known documented instances of pallid sturgeon being collected exhibiting intersexual characteristics.

Hybridization

Microsatellite studies (Tranah et al. 2004; Heist and Schrey 2006a) have provided some genetic evidence for intermediates between pallid and shovelnose sturgeon in the Missouri, Mississippi, and Atchafalaya Rivers. However, it is currently unknown if all morphologically intermediate sturgeon are hybrids, if some hybridization is natural, or if hybridization is a result of habitat or other environmental changes.

If these intermediates represent the effect of natural intercrossing between the monophyletic pallid sturgeon and shovelnose sturgeon due to anthropogenic influences, then intercrossing may indeed be perceived as a threat to the species. However, if genetically intermediate sturgeon are the result of sympatric speciation and a polyphyletic evolutionary origin of pallid sturgeon (e.g., as suggested by Campton et al. 2000 as a competing, alternative hypothesis), then these intermediate fish could be considered a natural occurrence and the previously-identified mechanisms suggested for causing hybridization may not exist and intermediate sturgeon are a component of natural evolutionary processes and may not really pose a threat.

In summary, the status of wild pallid sturgeon has not improved since listing in the Missouri River. Successful hatchery and stocking programs appear to be useful in preventing local extirpation in the Missouri River, but the notable lack of natural recruitment suggests an overall declining status. New information on habitat extent and conditions, population size, potential recruitment in the Mississippi River, and new information on population size in the Atchafalaya River has improved our understanding of the species in these areas. The immediate risk of local extirpation in RPMA 1 and 2 has been reduced by implementation of an artificial propagation program, and the species has been reintroduced in RPMA 3. Stocking also has occurred in RPMA 4, 5, and 6. However, if supplementation efforts were to cease, the species would be facing local extirpation in RPMA 1, 2, 3, and possibly 4 (the Missouri River RPMA). Numbers of wild pallid sturgeon are higher in the Mississippi and Atchafalaya Rivers than initially documented, but data regarding recruitment and spawning success, survivorship from one age class to the next, habitat needs and use, and overall abundance are still very limited. Currently it is not possible to accurately estimate the population abundance in the Mississippi and Atchafalaya Rivers and the pallid sturgeon's population status is unknown.

Genetic and morphological differences have been documented between upper Missouri River pallid sturgeon (RPMA 1 and 2) and lower Missouri and lower Mississippi/Atchafalaya River populations (RPMA 4, 5, and 6) (Campton et al. 2000, Tranah et al. 2001, Heist and Schrey 2006 a and b, Kuhajda et al.). Additional information on genetic and morphological differences is needed to clearly identify past relationships of the populations, and the significance of gene flow among them.

Although information on pallid sturgeon throughout its range has increased considerably since listing, threats to the pallid sturgeon remain essentially the same. The continued existence of the species is threatened by habitat loss and inadequate regulatory

mechanisms in all or portions of its range, and limited data suggests that contaminants may have some affect on reproduction (see 2.3.2.5 Other Natural or Manmade Factors Affecting its Continued Existence). These threats have precipitated the need for population augmentation in portions of its range. In addition to these threats, the lack of adequate information on spawning, recruitment and habitat requirements; and a lack of information on population size, recruitment, and trends in RPMA 4, 5, and 6 makes it difficult to identify positive species response to many recovery activities. The species continues to meet the definition of endangered and no change in classification is needed. However, should sufficient data become available to support Distinct Population Segments, future reclassification may consider listing Distinct Population Segments.

Significant Portion of the Range

We assessed the pallid sturgeon in each identified RPMA throughout its range. Assessing sturgeon in units smaller than RPMA is not feasible, due to data collection methods and fishing regulations that apply to streams within the range of the species. As noted above, a lack of adequate information on population size, recruitment, and trends exists in RPMA 5 and 6. In RPMA 1, 2, 3, and 4, which represent about half of the range of the pallid sturgeon, data indicate that without artificial supplementation efforts, the species could face local extirpation. Therefore, we conclude that the pallid sturgeon does not meet our criteria for downlisting to threatened status or for delisting in any portion of its range.

3.0 RESULTS

3.1 Recommended Classification:

Downlist to Threatened

Uplist to Endangered

Delist (Indicate reasons for delisting per 50 CFR 424.11):

Extinction

Recovery

Original data for classification in error

No change is needed

3.2 New Recovery Priority Number NA (Remains 2C)

3.3 If a reclassification is recommended, indicate the Listing and Reclassification Priority Number (USFWS only): NA

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

- Identify and implement measures to eliminate or significantly reduce illegal and accidental harvest of pallid sturgeon.

- Update the Recovery Plan to include the most recent information regarding genetics, distribution, life history, abundance and trends, threats, and conservation measures. The revised recovery plan shall include objective and measurable downlisting and delisting criteria that when achieved eliminate or sufficiently minimize threats to the species, per the 5 listing factors, such that it no longer rises to the level of threatened or endangered under the ESA.
- Continue further study of issues where the extent of the threat is not well understood (such as hybridization and pollution/contamination).
- Reevaluate RPMAs as they relate to conservation needs of the drainage populations. Consider identifying management units based on genetic data.
- Develop a science-based, independently reviewed program that evaluates implementation of recovery criteria as well as provides periodic reports of recovery success.
- Develop and implement standardized methodology to test for and quantify iridovirus in wild populations of *Scaphirhynchus*.
- Develop and implement methods to measure and monitor riverine habitats in the Mississippi River, and their response to engineering actions.
- Develop and implement a standardized monitoring program for the Mississippi and Atchafalaya Rivers (e.g., Missouri River Population Assessment Program) to ensure adequate demographic data are collected to assess the population structure of the pallid sturgeon in these reaches.
- Implementation of the Population Assessment Program (Drobish 2006) to monitor supplementation efforts and obtain adequate samples to thoroughly understand the demographic trends of the species.
- Implement rangewide standardized reporting requirements, i.e., catch-per-unit effort, to enable rangewide population status trend comparison.
- Identify spawning cues and habitats utilized by pallid sturgeon throughout its range.
- Conduct telemetry research to identify habitat utilization in un-impounded areas to better understand the true requirements of the species in terms of range and variety of habitats used.

Data Needed for Next 5-year Review

- Population and habitat studies in the Mississippi and Atchafalaya Rivers to establish base-line conditions for monitoring status and conservation success, and for measuring habitat trends.
- Spawning habitats and cues remain unknown; this information is essential to successful management and conservation.
- Information on migration cues, food habits, and food availability throughout the range.

- Genetic information to determine similarities and evolutionary relationships among populations throughout the range of pallid sturgeon, including their evolutionary relationships to shovelnose sturgeon.
- Experiments to assess relationships of morphology differences and causes of those differences in terms of environmental differences and genetics.
- Assessment of habitat construction projects in the Missouri and Mississippi Rivers and determination of their value for recovering pallid sturgeon and addressing the threats associated with habitat modifications.
- Evaluation of the value of spring pulses for pallid sturgeon and its habitat.
- Survival and growth of stocked juvenile pallid sturgeon and assessment of data to determine the success of supplementation efforts where it is occurring and to develop survival estimates for hatchery-reared pallid sturgeon.
- Genetic information to determine the amount and significance of hybridization between pallid and shovelnose sturgeon.
- Estimates of immigration and emigration of both wild and hatchery-produced pallid sturgeon to generate viable population assessments.
- Data to evaluate population trends, i.e., catch-per-unit effort and quantification of natural recruitment range-wide.

5.0 REFERENCES

- Allendorf, F.W., R.F. Leary, P. Spruell, and J.K. Wenburg. 2001. The problems with hybrids: setting conservation guidelines. *Trends in Ecology and Evolution* 116:11. 613-622.
- Bailey, R.M., and F.B. Cross. 1954. River sturgeons of the American genus *Scaphirhynchus*: characters, distribution, and synonymy. *Papers of the Michigan Academy of Science, Arts, and Letters* 39:169-208.
- Baker, J., J.K. Killgore, and R. Kasul. 1991. Aquatic habitats and fish communities of the Lower Mississippi River. *Aquatic Sciences* 3(4):313-356.
- Barada, A.J., and K.D. Steffensen. 2006. 2005 Annual Report, pallid sturgeon population assessment project and associated fish community monitoring for the Missouri River: Segment 8. Nebraska Game and Parks Commission, Lincoln, Nebraska.
- Braaten, P.J., and D.B. Fuller. 2002. Fort Peck flow modification biological data collection plan. Summary of 2001 Field Activities. Upper Basin Pallid Sturgeon Workgroup 2001 Annual Report.
- Braaten, P.J., and D.B. Fuller. 2003. Fort Peck flow modification biological data collection plan. Summary of 2002 Field Activities. Upper Basin Pallid Sturgeon Workgroup 2002 Annual Report.

- Braaten, P.J., D.B. Fuller, L.D. Holte, R.D. Lott, W. Viste, T.F. Brandt, and R.G. Legare. In review. Drift dynamics of larval pallid sturgeon and shovelnose sturgeon in natural habitats of the upper Missouri River. *North American Journal of Fisheries Management*.
- Bramblett, R.G. 1996. Habitats and movements of pallid and shovelnose sturgeon in the Yellowstone and Missouri Rivers, Montana and North Dakota. Doctoral dissertation. Montana State University, Bozeman.
- Bramblett, R.G., and R.G. White. 2001. Habitat use and movements of pallid and shovelnose sturgeon in the Yellowstone and Missouri Rivers in Montana and North Dakota. *Transactions of the American Fisheries Society* 130:1006-1025.
- Campton, D.E. 1987. Natural hybridization and introgression in fishes. *In* N. Ryman and F. Utter (ed), *Population Genetics and Fishery Management*. University of Washington Press. Seattle and London.
- Campton, D.E., A. Bass, F. Chapman, and B. Bowen. 2000. Genetic distinction of pallid, shovelnose, and Alabama sturgeon: emerging species and the Endangered Species Act. *Conservation Genetics* 1:17-32.
- Carlson, D.M., W.L. Pflieger, L. Trial, and P.S. Haverland. 1985. Distribution, biology and hybridization of *Scaphirhynchus albus* and *S. platyrhynchus* in the Missouri and Mississippi Rivers, Missouri. *In* S. Doroshov (ed), *Sturgeon Symposium*. Environmental Biology of Fishes 14:51-59.
- Colombo, R.E., J.E. Garvey, N.D. Jackson, B.T. Koch, R. Brooks, D.P. Herzog, R.A. Hrabik, and T.W. Spier. In Press. Harvest of Mississippi River sturgeon drives abundance and reproductive success: a harbinger of collapse? *In* *Journal of Applied Ichthyology*.
- Constant, G.C., W.E. Kelso, A.D. Rutherford, and F.C. Bryan. 1997. Habitat, movement, and reproductive status of the Pallid Sturgeon (*Scaphirhynchus albus*) in the Mississippi and Atchafalya Rivers. MIPR Number W42-HEM-3-PD-27. Louisiana State University. Prepared for U.S. Army Corps of Engineers. 78 pp.
- Convention on International Trade in Endangered Species. 2006. Export quotas for specimens of *Acipenseriformes* species included in Appendix II for 2006. 15 pp.
- Cook, F.A. 1958. Early history and trends in Mississippi freshwater fisheries with a review of game fish and bait minnow culture. Mississippi Game and Fish Commission. Jackson, Mississippi.
- DeHaan, P.W., G.R. Jordan, and W.R. Ardren. Submitted. Use of genetic tags to identify captive-bred pallid sturgeon (*Scaphirhynchus albus*) in the wild: improving abundance estimates for an endangered species. *Conservation Genetics*.

- Doyle, W., and A. Starostka. 2003. 2002 Annual Report for the Lower Missouri River Monitoring and Population Assessment Project. Report prepared for the U.S. Army Corps of Engineers, Northwest Division. U.S. Fish and Wildlife Service, Columbia, Missouri Fisheries Resources Office. January 2003. 38 pp.
- Drobish, M.R. 2006. Pallid Sturgeon Assessment Program, Volume 1.1. U.S. Army Corps of Engineers, Omaha District, Yankton, South Dakota.
- Feist, G.W., M.A.H. Webb, D.T. Gundersen, E.P. Foster, C.B. Schreck, A.G. Maule, and M.S. Fitzpatrick. 2005. Evidence of detrimental effects of environmental contaminants on growth and reproductive physiology of white sturgeon in impounded areas of the Columbia River. *Environmental Health Perspectives* 113:12.
- Forbes, S.A., and R.E. Richardson. 1905. On a new shovelnose sturgeon from the Mississippi River. *Illinois State Laboratory of Natural History* 7:37-44. In R.M. Bailey and F.B. Cross. 1954. River sturgeons of the American genus *Scaphirhynchus*: characters, distribution, and synonymy. *Papers of the Michigan Academy of Science, Arts, and Letters* 39:169-208.
- Fremling, C., J. Rasmussen, R. Sparks, S. Cobb, C. Bryan, and T. Clafin. 1989. Mississippi River fisheries: a case history, p. 309-351. In D.P. Dodge (ed) *Proceedings of the International Large River Symposium*. Canadian Special Publication of Fisheries and Aquatic Sciences 106:309-351.
- Funk, J.L., and J.W. Robinson. 1974. Changes in the channel of the lower Missouri River and effects on fish and wildlife. Missouri Department of Conservation. Aquatic Series 11. Jefferson City. 52 pp.
- Gerrity, P.C. 2005. Habitat use, diet, and growth of hatchery-reared juvenile pallid Sturgeon and indigenous shovelnose sturgeon in the Missouri River above Fort Peck Reservoir. Master's thesis. Montana State University, Bozeman.
- Gerrity, P.C., C.S. Guy, and W.M. Gardner. 2006. Juvenile pallid sturgeon are piscivores: a call for conserving native cyprinids. *Transactions of the American Fisheries Society* 135:604-609.
- Grady, J.M., L. Mauldin, B. Davison, and J. Milligan. 2001a. Missouri River pallid sturgeon survey Route 19 bridge replacement project Hermann, Missouri. Final Report prepared for the Missouri Highways and Transportation Commission. U.S. Fish and Wildlife Service, Columbia, Missouri.
- Grady, J.M., J. Milligan, C. Gemming, D. Herzog, G. Mestl, and R.J. Sheehan. 2001b. Pallid and shovelnose sturgeons in the lower Missouri and middle Mississippi Rivers. Final Report for MICRA.
- Heist, E.J., and A. Schrey. 2006a. Microsatellite tools for genetic identification of *Scaphirhynchus*. Interim Report. Southern Illinois University, Carbondale.

- Heist, E.J., and A. Schrey. 2006b. Genetic analysis of middle Missouri River pallid sturgeon. report prepared by the Fisheries Research Laboratory, Southern Illinois University at Carbondale for the U.S. Fish and Wildlife Service.
- Herzog, D.P., R. Hrabik, R. Brooks, T. Spier, D. Ostendorf, J. Ridings, J. Crites, C. Beachum, and R. Colombo. 2005. Assessment of *Scaphirhynchus* spp. spawning and rearing locations in the Middle Mississippi River: insights from collection of larval and young of the year fishes. *In* Evolution, Ecology and Management of *Scaphirhynchus*. St. Louis Missouri, January 11-13, 2005. Abstract.
- Hesse, L.W. 1987. Taming the wild Missouri River: What has it cost? *Fisheries* 12(2):2-9.
- Hesse, L.W., J.C. Schmulbach, J.M. Carr, K.D. Keenlyne, D.G. Unkenholz, J.S. Robinson, and G.E. Mestl. 1989. Missouri River resources in relation to past, present, and future stresses. Pages 352-371 *in* D.P. Dodge (ed), Proceedings International Large River Symposium. Canadian. Special Publication Fish and Aquatic Science 106.
- Hofpar, R.L. 1997. Biology of Shovelnose Sturgeon, *Scaphirhynchys platyrhynchus*, in the lower Platte River, Nebraska. Master's thesis. University of Nebraska, Lincoln.
- Illinois. 2006. Illinois commercial fishing information. PDF file available online at: <http://dnr.state.il.us/admin/systems/06/2006FishInfo.pdf>.
- Iowa. 2006. Amendments to Chapter 82 "Commercial Fishing," Iowa Administrative Code. PDF file available online at: <http://www.iowadnr.com/nrc/06may/21.pdf>.
- Jaeger, M.E., G.R. Jordan, and S. Camp. 2004. Assessment of the suitability of the Yellowstone River for pallid sturgeon restoration efforts, annual report for 2004 *in* K. McDonald (ed) Upper Basin Pallid Sturgeon Recovery Workgroup 2004 Annual Report. Helena, Montana.
- Jaeger, M., M. Nelson, G. Jordan, and S. Camp. 2005. Assessment of the Yellowstone River for pallid sturgeon restoration efforts, annual report for 2005. *In* Yvette Converse (ed) Upper Basin Pallid Sturgeon Recovery Workgroup 2005 Annual Report. Upper Basin Workgroup, Bozeman Fish Technology Center, Bozeman, Montana.
- Jordan, G.R., R.A. Klumb, G.A. Wanner, and W.J. Stancill. 2006. Post-stocking movements and habitat use of hatchery-reared juvenile pallid sturgeon in the Missouri River below Fort Randall Dam, South Dakota and Nebraska. *Transactions of the American Fisheries Society* 135:1499-1511.
- Kallemeyn, L. 1983. Status of the pallid sturgeon *Scaphirhynchus albus*. *Fisheries* 8(1):3-9.
- Keenlyne, K.D. 1989. Report on the pallid sturgeon. MRC-89-1, U.S. Fish and Wildlife Service, Pierre, South Dakota.

- Keenlyne, K.D., L.K. Graham, and B.C. Reed. 1994. Hybridization between the pallid and shovelnose sturgeons. *Proceedings of the South Dakota Academy of Sciences* 73:59-66.
- Keenlyne, K.D. 1995. Recent North American studies on pallid sturgeon, *Scaphirhynchus albus* (Forbes and Richardson). in A.D. Gerschanovich and T.I.J. Smith, (ed). *Proceedings of the International Symposium on Sturgeons*, September 6-11, 1993. VNIRO Publication., Moscow, Russia.
- Kellerhals, R., and M. Church. 1989. The morphology of large Rivers: characterization and management. *In* D.P. Dodge (ed) *Proceedings of the international large river symposium*. Canadian Special Publication of Fisheries and Aquatic Sciences 106:31-48.
- Kennedy, A.J., P.T. Horner, and V.H. Travnicek. 2006. 2005 Annual Report, Pallid sturgeon population assessment project and associated fish community monitoring for the Missouri River: Segment 10. Missouri Department of Conservation, Chillicothe, Missouri.
- Kentucky. 2006. Commercial Fishing Requirements. 301 KAR 1:155. Available online at <http://www.lrc.ky.gov/kar/301/001/155.htm>.
- Klungle, M. 2004. Field accomplishments/agency reports (RPMA 2). *In* K. McDonald (ed) Upper Basin Pallid Sturgeon Recovery Workgroup, 2004 Annual Report. Helena, Montana.
- Koch, B.T., J.E. Garvey, J. You, and M.J. Lydy. 2006. Elevated organochlorines in the brain-hypothalamic-pituitary complex of intersexual shovelnose sturgeon. *Environmental Toxicology and Chemistry* 25(7):1689-1697.
- Krentz, S. 2000. Pallid sturgeon recovery update-the latest research and management actions for recovery. Issue 11. U.S. Fish and Wildlife Service, Bismark, North Dakota.
- Kuhajda, B.R., and R.L. Mayden. 2001. Morphological comparisons of hatchery-reared specimens of *Scaphirhynchus albus*, *S. platyrhynchus*, and *S. albus* x *S. platyrhynchus* hybrids. University of Alabama, Tuscaloosa. 119 pp.
- Kuhajda, B.R., R.L. Mayden, and R.M. Wood. In Press. Morphological comparisons of hatchery-reared specimens of *Scaphirhynchus albus*, *S. Platyrhynchus*, and *S. albus* x *S. platyrhynchus* hybrids (Acipenseriformes: Acipenseridae). *Journal of Applied Ichthyology*.
- Kynard, B., E. Henyey, and M. Horgan. 2002. Ontogenetic behavior, migration, and social behavior of pallid sturgeon, *Scaphirhynchus albus*, and shovelnose sturgeon, *S. platyrhynchus*, with notes on the adaptive significance of body color. *Environmental Biology of Fishes* 63:389-403.
- Kynard, B., E. Parker, D. Pugh, and T. Parker. 2005. Experimental studies of pallid sturgeon dispersal and vertical swimming height during ontogeny. *In* *Evolution, Ecology and Management of Scaphirhynchus*. St. Louis Missouri, January 11-13, 2005. Abstract.

- Missouri Department of Conservation. 2006. A summary of Missouri fishing regulations. PDF file available online at: <http://www.mdc.mo.gov/documents/regs/fishsum.pdf>.
- Missouri Department Health and Senior Services. 2006. 2006 Fish Advisory, a guide to eating fish in Missouri.
- Morizot, D.C. 1994. Genetic studies of *Scaphirhynchus* spp. Report to the U.S. Army Corps of Engineers, Omaha District; U.S. Fish and Wildlife Service, Bismarck, North Dakota; U.S. Army Corps of Engineers, Mobile District. Genetic Analysis, Inc.
- Murphy, C.E., J.J. Hoover, S.G. George, and K.J. Killgore. In Press. Morphometric variation among *Scaphirhynchus* specimens in the lower and middle Mississippi River. *Journal of Applied Ichthyology*.
- National Marine Fisheries Service. 2005. Policy on the consideration of hatchery-origin fish in Endangered Species Act listing determinations for Pacific salmon and steelhead. *Federal Register* 70:37204-37216.
- Parken, C.K., and D.L. Scarnecchia. 2002. Predation on age-0 paddlefish by walleye and sauger in a Great Plains reservoir. *North American Journal of Fisheries Management* 22:750-759.
- Pflieger, W.L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, Missouri. 343 pp.
- Phelps, S.R., and F.W. Allendorf. 1983. Genetic identity of pallid and shovelnose sturgeon (*Scaphirhynchus albus* and *S. platyrhynchus*). *Copeia* 3:696-700.
- Ray, J.M., C.B. Dillman, R.M. Wood, R.L. Mayden, and B.R. Kuhajda. In Press. Microsatellite variation among river sturgeons of the genus *Scaphirhynchus* (Actinopterygii: Acipenseridae): A preliminary assessment of hybridization. *Journal of Applied Ichthyology*.
- Reade, C.N. 2000. Larval fish drift in the Lower Platte River, Nebraska. Master's thesis. University of Nebraska, Lincoln.
- Reed, B.C., and M.S. Ewing. 1993. Status and distribution of pallid sturgeon at the Old River Control Complex, Louisiana. Louisiana Department of Wildlife and Fisheries. Report 514-0009 Lake Charles, Louisiana.
- Ruelle, R., and K.D. Keenlyne. 1992. Contaminants in Missouri River Sturgeon. U.S. Fish and Wildlife Service Report SD-FEW-93-01. Pierre, South Dakota.
- Russell, T.R. 1986. Biology and life history of the paddlefish - a review. In J.G. Dillard, L.K. Graham, and T.R. Russell (ed). *Paddlefish: status, management and propagation*. North Central Division American Fisheries Society Special Publication 7. 159 pp.

- Sheehan, R.L., R.C. Heidinger, K.L. Hurley, P.S. Wills, and M.A. Schmidt. 1997. Middle Mississippi River pallid sturgeon habitat use project: year 2 annual progress report. Fisheries Research Laboratory and Department of Zoology, Southern Illinois University, Carbondale.
- Sheehan, R.J., R.C. Heidinger, K.L. Hurley, P.S. Wills, and M.A. Schmidt. 1998. Middle Mississippi River pallid sturgeon habitat use project. Annual progress report (year 3). Fisheries Research Laboratory and Department of Zoology, Southern Illinois University, Carbondale.
- Shuman, D.A., R.A. Klumb, and S.T. McAlpin. 2005. Pallid sturgeon population assessment and associated fish community monitoring for the Missouri River: segments 5 and 6. July 25, 2005. U.S. Fish and Wildlife Service report submitted to U.S. Army Corps of Engineers, Yankton, South Dakota.
- Simons, D.B., S.A. Schumm, and M.A. Stevens. 1974. Geomorphology of the Middle Mississippi River. Report DACW39-73-C-0026 prepared for the U.S. Army Corps of Engineers, St. Louis District, St. Louis, Missouri. 110 pp.
- Simons, A.M., R.M. Wood, L.S. Heath, B.R. Kuhajda, and R.L. Mayden. 2001. Phylogenetics of *Scaphirhynchus* based on mitochondrial DNA Sequences. Transactions of the American Fisheries Society 130:359-366.
- Snook, V.A. 2001. Movements and habitat use by hatchery-reared pallid sturgeon in the lower Platte River, Nebraska. Master's thesis. University of Nebraska, Lincoln.
- Snook, V. A., E. J. Peters, and L. J. Young. 2002. Movements and habitat use by hatchery-reared pallid sturgeon in the lower Platte River, Nebraska. American Fisheries Society Symposium 28:161-174.
- Steffensen, K.D., and A.J. Barada. 2006. 2005 Annual report, pallid sturgeon population assessment project and associated fish community monitoring for the Missouri River: segment 9. Nebraska Game and Parks Commission, Lincoln, Nebraska.
- Swingle, B.S. 2003. Movements and habitat use by shovelnose and pallid sturgeon in the lower Platte River. Master's thesis. University of Nebraska, Lincoln.
- Tennessee. 2004. Posted Streams, Rivers and Reservoirs.
- Theiling, C.H. 1999. River geomorphology and floodplain features. Pages 4-1 to 4-21 in Ecological status and trends of the Upper Mississippi River system. USGS Upper Midwest Environmental Sciences Center, LaCrosse, Wisconsin. 241 pp.
- Tranah, G., H.L. Kincaid, C.C. Krueger, D.E. Campton, and B. May. 2001. Reproductive isolation in sympatric populations of pallid and shovelnose sturgeon. North American Journal of Fisheries Management 21:367-373.

- Tranah, G., D.E. Campton, and B. May. 2004. Genetic evidence of hybridization of pallid and shovelnose sturgeon. *Journal of Heredity* 95(6):474-480.
- Tennessee Wildlife Resources Agency. 2006. Tennessee commercial fishing regulations synopsis. March 1, 2006, through February 28, 2007. PDF file available online at: http://www.state.tn.us/twra/fish/Commercial/TN_com_reg_06.pdf.
- Unkenholz, D.G. 1986. Effects of dams and other habitat alterations on paddlefish sport fisheries. In J.G. Dillard, L.K. Graham, and T.R. Russell (ed), *Paddlefish: status, management and propagation*. North Central Division of the American Fisheries Society Special Publication 7. 159 pp.
- Utrup, N., W. Doyle, C. Lee, A. Plauck, and T. Hill. 2006. 2005 Annual report, pallid sturgeon population assessment project and associated fish community monitoring for the Missouri River: segment 14. U.S. Fish and Wildlife Service, Columbia, Missouri.
- U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service. 2004. Corps and Service announce successful fish habitat construction on Missouri River, News Release June 25, 2004. Available online at <http://www.doi.gov/news/040625d>. Last accessed December 6, 2006.
- U.S. Fish and Wildlife Service. 1990. Endangered and threatened wildlife and plants; Determination of endangered status for the pallid sturgeon. *Federal Register* 55:36641-36647.
- U.S. Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants; 5-year review of listed species. *Federal Register* 56:56882-56900.
- U.S. Fish and Wildlife Service. 1993. Recovery plan for the pallid sturgeon (*Scaphirhynchus albus*). U.S. Fish and Wildlife Service, Denver, Colorado.
- U.S. Fish and Wildlife Service. 2000a. Biological opinion on the operation of the Missouri River main stem reservoir system, operation and maintenance of the Missouri River bank stabilization and navigation project, and operation of the Kansas River reservoir system. U.S. Fish and Wildlife Service, Denver, Colorado.
- U.S. Fish and Wildlife Service. 2000b. Biological opinion for the operation and maintenance of the 9-foot navigational channel on the upper Mississippi System. U.S. Fish and Wildlife Service, Region 3, Minneapolis, Minnesota.
- U.S. Fish and Wildlife Service and the National Marine Fisheries Service. 2000. Policy regarding controlled propagation of species listed under the Endangered Species Act. *Federal Register* 65:56916-56922.

- U.S. Fish and Wildlife Service. 2005. Endangered and threatened wildlife and plants; initiation of a 5-Year Review of black-footed ferret (*Mustela nigripes*) and pallid sturgeon (*Scaphirhynchus albus*). Federal Register 70:39326-39327.
- U.S. Fish and Wildlife Service. 2006a. Pallid sturgeon range-wide stocking and augmentation plan. U.S. Fish and Wildlife Service, Region 6, Denver, Colorado.
- U.S. Fish and Wildlife Service. 2006b. National pallid sturgeon database. U.S. Fish and Wildlife Service, Bismarck, North Dakota.
- U.S. Fish and Wildlife Service and the National Marine Fisheries Service. 1996. Policy regarding the recognition of distinct vertebrate population segments under the Endangered Species Act. Federal Register 61:4721-4725.
- Wanner, G.A. 2006. Sampling techniques for juvenile pallid sturgeon and the condition and food habits of sturgeon in the Missouri River below Fort Randall Dam, South Dakota. Master's thesis. South Dakota State University, Brookings.
- Wasklewicz, T.A., J. Grubaugh, S. Franklin, and S. Gruelich. 2004. 20th Century stage changes along the Mississippi River. *Physical Geography* 25(3):208-224.
- Wildhaber, M.L., D.M. Papoulias, A.J. DeLonay, D.E. Tillet, J.L. Bryan, M.L. Annis, and J.A. Allert. 2005. Gender identification of shovelnose sturgeon using ultrasonic and endoscopic imagery and the application for the method in pallid sturgeon. *Journal of Fish Biology* 67:114-132.
- Wiley, E.O., and R.L. Mayden. 1985. Species and speciation in phylogenetic systematics, with examples from the North American fish fauna. *Annals of the Missouri Botanical Garden* 72:596-635.
- Williamson, D.F. 2003. Caviar and Conservation: Status, Management and Trade of North American Sturgeon and Paddlefish. TRAFFIC North America. Washington, D.C., World Wildlife Fund.
- Winkley, B.R. 1977. Man-made cutoffs on the lower Mississippi River, conception, construction, and river response. U.S. Army Engineer District, Vicksburg, Mississippi. 209 pp.
- Wlosinski, J. 1999. Hydrology. Pages 6-1 to 6-10 in *Ecological status and trends of the Upper Mississippi River system*. USGS Upper Midwest Environmental Sciences Center, LaCrosse, Wisconsin. 241 pp.

In Litt Citations

- Atwood, B. 2006. Pallid sturgeon @ Mel Price tailwater. Email message to George Jordan.
- Cail, R.A. 2006. Re: Questions about MMR NWR. Email message to George Jordan.
- Hartfield, P. 2006. Missouri fish in Atchafalaya. Email message to multiple recipients.
- Jordan, G.R. 2006. Another dead pallid at Mid-American Neal south unit. Email message to multiple recipients.
- Keevin, T. 2006. Three More Pallid Sturgeon - Illegal Harvest. Email message to multiple recipients.
- Ledwin, J. 2006. Re: Fw: Another dead pallid at Mid-American Neal south unit. Email message to multiple recipients.
- U.S. Army Corps of Engineers. 2004. MEMORANDUM FOR RECORD Interagency Dike Meeting Memphis District. Corps of Engineers, February 24, 2004.
- U.S. Army Corps of Engineers. 2005. MEMORANDUM FOR RECORD Interagency Dike Meeting Memphis District. Corps of Engineers, February 22, 2006.
- U.S. Army Corps of Engineers. 2006. MEMORANDUM FOR RECORD Interagency Dike Meeting Memphis District. Corps of Engineers, February 23, 2006.
- Williams, B.O. 2006. March 3, 2006 Meeting Notes. Email message to multiple recipients.

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**U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW OF PALLID STURGEON (*Scaphirhynchus albus*)**

Current Classification Endangered

Recommendation resulting from the 5-Year Review

- Downlist to Threatened
- Uplist to Endangered
- Delist
- No change is needed

Appropriate Listing/Reclassification Priority Number, if applicable _____

Review Conducted by George Jordan, Pallid Sturgeon Recovery Coordinator

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve *for Henry Maddery* Date 5/4/07

REGIONAL OFFICE APPROVAL:

Lead Regional Director, Fish and Wildlife Service

Approve *George Bleck* Date 5/7/07

Cooperating Assistant Regional Director, Fish and Wildlife Service Region 3

Concur Do Not Concur

Signature *[Signature]* Date 5/29/07

for **Cooperating Assistant Regional Director, Fish and Wildlife Service Region 4**

Concur Do Not Concur

Signature *Norrea E Walsh* Date 4/13/07

APPENDIX A
Summary Of Peer Review
For The 5-Year Review Of Pallid Sturgeon (*Scaphirhynchus albus*)

A. Peer Review Method

General: On July 7, 2005, the USFWS announced the initiation of a 5-year review for Pallid Sturgeon and requested submission of any new information (70 FR 39326). In accordance with the peer review requirements of the Office of Management and Budget's Final Information Quality Bulletin for Peer Review, in fall 2006 we initiated peer review of the science relevant to the draft Pallid Sturgeon 5-year review and our use of said science.

Solicitations were sent to State agencies, professional societies, and/or universities, to nominate potential peer reviewers. We requested that these groups consider the following criteria for any potential nomination.

- Expertise: The reviewer should have knowledge, experience, and skills in one or more of the following areas: pallid sturgeon *Scaphirhynchus albus* or similar species biology; conservation biology; small and declining population dynamics and extinction risk analysis; land development and use, invasive species, and other environmental pressures within the range of these species; land planning and management; modeling; and/or evaluation of biological plausibility.
- Independence: The reviewer should not be employed by the USFWS or other agencies within the Department of Interior. Academic and consulting scientists should have sufficient independence from the USFWS or Department if the government supports their work.
- Objectivity: The reviewer should be recognized by his or her peers as being objective, open-minded, and thoughtful. In addition, the reviewer should be comfortable sharing his or her knowledge and perspectives and openly identifying his or her knowledge gaps.
- Advocacy: The reviewer should not be known or recognized for an affiliation with an advocacy position regarding the protection pallid sturgeon under the ESA.
- Conflict of Interest: The reviewer should not have any financial or other interest that conflicts or that could impair his or her objectivity or create an unfair competitive advantage.

Nominations were requested by October 6, 2006. While expertise was the primary consideration, the USFWS selected peer reviewers (considering, but not limited to, these nominations) that added to a diversity of scientific perspectives relevant to 5-year review. Under certain circumstances some conflict may be unavoidable in order to obtain the necessary expertise. If such a situation arises, promised to disclose these real or perceived conflicts in the 5-year review and the agency shall inform potential reviewers of this likely disclosure at the time they are recruited. We anticipated sending the document to the peer reviewers no later than October 20, 2006. Responses were requested by December 1, 2006.

We solicited reviews from six qualified experts. The USFWS provided each peer reviewer with information explaining his or her role and instructions for fulfilling that role, the draft 5-year review, public comments received in response to our *Federal Register* notice initiating the 5-year review (70 FR 39326, July 7, 2005), a full list of citations noting whether the source has been peer reviewed, and all citations (or for some longer documents, the relevant pages of the document) in electronic format on a CD. The purpose of seeking independent peer review was to ensure use of the best scientific and commercial information available and to ensure and to maximize the quality, objectivity, utility, and integrity of the information upon which the draft 5-year review is based, as well as to ensure that reviews by recognized experts were incorporated into the final document.

Peer reviewers provided individual, written responses to the USFWS. Peer reviewers were advised that their reviews, including their names and affiliations, would (1) be included in the official record for this review, and (2) once all reviews are completed, would be available to the public upon request.

About Public Participation

The public was provided an opportunity to comment on this planned peer review process from September 9, 2006 (when the peer review plan was posted online) through October 6, 2006. The public was invited to send comments on this peer review plan to George Jordan, Pallid Sturgeon Recovery Coordinator, 2900 4th Avenue North, Room 301, Billings, Montana 59101. Comments on this plan also may be submitted by electronic mail to >r6espeerreview@fws.gov<. The subject line should read “Pallid Sturgeon (*Scaphirhynchus albus*) 5-Year Review: Summary and Evaluation.”

The public had an opportunity to provide input on the 5-year review from July 7, 2005, through September 6, 2005 (70 FR 39326, July 7, 2005). This Notice announced our initiation of a 5-year review of the species and requested submission of any new information.

Contact

For more information, contact George Jordan, Pallid Sturgeon Recovery Coordinator 406-247-7365 or George_Jordan@fws.gov.

B. Peer Review Charge

Peer reviewers were asked not to provide advice on policy. Instead, the charge to the reviewers was to review the science relevant to the 5-year review and our use of said science, focusing their review on identifying and characterizing scientific uncertainties. Additionally, peer reviewers were asked to consider the following questions and to provide any other relevant comments, criticisms, or thoughts:

1. Is our description and analysis of the biology, habitat, population trends, historic and current distribution of the species accurate?

2. Does the 5-year review provide accurate and adequate review and analysis of the factors affecting the species (habitat loss and modification, overutilization, disease, predation, existing regulatory mechanisms)?
3. Are our assumptions and definitions of suitable habitat logical and adequate?
4. Are there any significant oversights, omissions or inconsistencies in the 5-year review?
5. Are our conclusions logical and supported by the evidence we provide?
6. Did we include all necessary and pertinent literature to support our assumptions and conclusions?

C. Peer Review Comments

1. Robert G. Bramblett Review

To Whom It May Concern:

My review is structured with page numbers and quotes from the Pallid Sturgeon (*Scaphirhynchus albus*) 5-Year Review: Summary and Evaluation, U.S. Fish and Wildlife Service, followed by my comments. I added emphasis using italics and bold font in some quotes and comments.

Sincerely,

Pages 3 and 4 - “relevant new information that would lead you to consider listing this species...”

I am not an expert on DPS designation or genetics; however, it is apparent from Heist and Schrey (2006a; 2006b), that pallid sturgeon populations have a genetic structure that indicates isolation by distance. This is indicated even without a full set of data, or with data missing from parts of the species range. Tranah et al. (2001) conclude that “pallid sturgeon in the upper Missouri and Atchafalaya rivers should be managed as genetically distinct populations.”

It seems probable that pallids from the upper Missouri are markedly different from those in the lower Mississippi and Atchafalaya Rivers. Although it would be difficult to draw a line or lines that separate pallid sturgeon DPSs, it seems obvious that genetics from geographically distant populations should not be mixed. I recommend having a population geneticist evaluate considering DPS status for pallid sturgeon and if this is inconclusive, that a more complete set of genetic samples be obtained and a complete analysis be performed.

Page 8 - “wild pallid sturgeon population trend is relatively unchanged.” This statement is not supported in this report, and may not be accurate. There is just one population estimate given (without confidence intervals) thus a trend cannot be determined. The report also states that recruitment is severely limited; therefore, we have to assume that unless there is zero mortality the trend for wild pallid sturgeon is a decline in numbers.

“however, the population is being *successfully* supplemented with hatchery produced fish.” This statement is not supported in the text. There are no data presented on the growth, survival, and abundance of stocked fish. Without these data the success of supplementation cannot be assessed. Figure 3 shows that hatchery produced pallid sturgeon are being captured, but does not indicate if they are growing, surviving, or may reasonably be expected to achieve sexual maturity.

Page 9 - “wild pallid population trend has remained relatively unchanged since listing” this statement is not supported and likely not accurate. It is difficult to obtain inference on population trends and success of stocking programs from Figures 3 and 5 because it is not known whether these data represent standardized sampling or stocking efforts. Catch-per-unit effort would be more demonstrative, if sampling was standardized to season, location, and method.

A total of 245 individuals captured from 1990-2006, coupled with the most recent estimate of 136 (without confidence intervals) would suggest a strong decreasing population trend. As in RPMA 1, long-term success of hatchery augmentation is not demonstrated.

Pages 11-12 - Specific detail from the Shuman *et al.* (2005) report would help the reader assess the level of growth and survival.

“These data suggest that prior to supplementation, pallid sturgeon were extremely rare in RPMA 3.” These data suggest that pallid sturgeon were extremely rare or *extirpated* from RPMA 3.

Pages 13-14 - “These data also indicate that hatchery stocked fish are being collected and contributing to the population (Figures 8 and 9).”

Important additional information could be gleaned from these data. For example, in Figure 9, in 2004, 36 hatchery pallid sturgeon were captured and in 2005, 72 hatchery pallid sturgeon were captured. How many net-hours did it take to capture these; i.e., what was the catch-per-unit-effort (CPUE)? How many stocked cohorts were in the catch? If multiple sampling efforts were conducted, what was the recapture rate? Recapture data could be used to do multiple mark-recapture estimates that could then be used to assess recruitment to the sampling gear and the survival of stocked cohorts. By estimating some of these parameters, we could start to get at actual estimates of abundance and population trends. If we knew the survival rate of stocked fish, we could predict how many will live to attain sexual maturity thereby projecting the likelihood of success for the stocking program. I recommend that an expert population modeler be contracted to assess these types of population parameters for each RPMA using the National Pallid Sturgeon Database.

Pages 15-18 - This section reports capture of stocked fish, but no description of where, where, or how many fish were stocked.

Figure 10 - Is it correct that hatchery fish ranged as large as 900-950 mm? This is a significant finding if fish > 600 mm are considered adults. Were these hatchery fish sexually mature? Is this the only documented recruitment to adulthood of stocked pallid sturgeon?

“Although these ratios must be interpreted with caution, they demonstrate an improvement in knowledge of, and ability to collect pallid sturgeon in large river habitats.”

These ratios are difficult to interpret. For example, a 1:18 ratio could represent a total of one pallid captured to 18 shovelnose captured or 100 pallids captured to 1,800 shovelnose captured, so we do not know if overall catch went up or down. Also, the increase in pallid to shovelnose ratio is difficult to interpret if sampling was not standardized. The changing ratios could indicate many things, including sampling different habitat types, locations, times, flow conditions, capture efficiencies, increased pallid sturgeon abundance, or decreased shovelnose sturgeon abundance.

Page 19 - As mentioned previously, these recapture data could be used to calculate population estimates with confidence intervals. This would improve assessment of abundance and population trends.

“The BK character index misidentified all three hatchery-reared young-of-year as hybrids, and identified two of the wild young-of-year as shovelnose and other as a hybrid.”

Is it feasible to sample genetics on all or a subsample of all putative pallid sturgeon captured range-wide? This also would have the benefit of providing data to clarify the genetic structure of pallid sturgeon in regard to DPS status.

Page 20 - The histograms indicate that these pallid sturgeon average about 400-500 mm smaller than pallid sturgeon captured at RPMAs 1 and 2. Are these fish smaller at the same age, or younger fish? If smaller at the same age, this may have bearing on DPS status.

Page 21-24 - “The three groupings are a well differentiated upper Missouri River Group and two less differentiated groups in the lower Missouri Middle Mississippi, and Atchafalaya river samples.” Is this sufficient evidence to *consider* DPS designation (as on Pg. 3) for perhaps the upper Missouri group. If DPS listing is not appropriate, perhaps this decision needs to be supported in light of the genetic evidence presented on pages 21-24 and in the citations.

Page 25 - Similar to the observations of Gerrity (2005), Bramblett (1996) found that pallid sturgeon used 25 km of riverine habitat that would be inundated by Lake Sakakawea at full pool. Bramblett, R.G. 1996. Habitats and movements of pallid and shovelnose sturgeon in the Yellowstone and Missouri rivers, Montana and North Dakota. Doctoral dissertation. Montana State University, Bozeman.

Page 26 - “A reduction in sediment transport could reduce naturally occurring habitat features like sandbars.”

Reduction in sediment inputs does reduce naturally occurring habitat features, including sandbars. Discharge and sediment load, together with physiographic setting are primary factors controlling the morphology of large alluvial rivers (Kellerhals 1989). Kellerhals, R., and M. Church. 1989. The morphology of large rivers: characterization and management. Proceedings of the international large river symposium. Canadian Special Publication of Fisheries and Aquatic Sciences 106:31–48.

“The Yellowstone River, a major tributary to the Missouri River, was likely a historically important tributary for spawning.”

The Yellowstone River undoubtedly was and likely remains an essential spawning location. Bramblett (1996) documented the following: pallid sturgeon prefer the Yellowstone River over the Missouri River below Fort Peck, many fish move into the lower Yellowstone River during spawning season, ripe fish occur in the Yellowstone River and aggregations of fish during spawning season strongly suggest that pallid sturgeon spawning occurs in the lower 10 to 15 Rkm of the Yellowstone River. The ongoing threat to this spawning aggregation is downstream drift of larvae into Lake Sakakawea. Although Lake Sakakawea is described as a potential impediment to larval pallid sturgeon survival on page 25-26, it is not specifically addressed in the context of the Yellowstone River pallid sturgeon spawning aggregation.

Pages 30-31 - More evidence to consider a DPS?

Page 32 (and in other RPMAs with dams) - Although previously addressed, is it not appropriate to include the effect of shortened riverine reaches on larval drift as “present destruction or modification of habitat?”

Page 41 - “However, Parken and Scarnecchia (2002) reported that walleye, *Sander vitreum*, and sauger, *S. canadense*, in Lake Sakakawea (just downstream of RPMA 2) were capable of eating wild paddlefish (*Polyodon spathula*) up to 167 mm body length (305 mm total length), but Braaten and Fuller (2002, 2003) examined 759 stomachs and found no evidence of predation on sturgeon by seven piscivore species in Montana.”

This is unclear. Parken and Scarnecchia (2002) results suggest a predation threat in Lake Sakakawea, but the results of Braaten and Fuller (2002, 2003) do not lessen the suggestion of a threat because they sampled from the Missouri River, whereas Parken and Scarnecchia (2002) sampled in the reservoir. Presumably, it would be more difficult to detect predation on *Scaphirhynchus* the nearer you are to the spawning location because the larvae would be smaller and digested more rapidly, as well as probably drifting through the area for a relatively short time period. Did Parken and Scarnecchia (2002) find any *Scaphirhynchus* in the stomachs they sampled? Did they sample near the headwaters of Lake Sakakawea?

Page 46 - “Studies since listing continue to show small, **declining** old-age wild populations of pallid sturgeon in RPMA 1 and 2,” this statement conflicts with previous statements on Pages 8 and 9, e.g., “wild pallid sturgeon population trend is relatively unchanged.”

“Pallid populations in RPMA 1-3 are being **successfully** augmented with hatchery produced fish.”

It is not my intent to criticize the crucial stocking program, but I do not think it is important to acknowledge that augmentation success will only come if these fish survive to adulthood. Further challenges remain in terms of rectifying recruitment bottlenecks, otherwise stocked fish will have to be brought back to the hatchery for gamete collection, repeating the propagation/ stocking cycle. I am concerned that some readers may interpret “successful augmentation” as “problem solved.”

Page 47 - “The presence of smaller-sized cohorts of pallid (400-600 mm) in both RPMA 5 and 6 suggest some level of recruitment is occurring.” Can this be said without supporting age data given the context of overall smaller size of these southern pallid sturgeon?

2. Gene Zuerlein Review

November 28, 2006

George R. Jordan
Pallid Sturgeon Recovery Coordinator
USFWS, Jameson Federal Building
2900 4th Avenue, Room 301
Billings, MT 59101

Reference: Five-year review for pallid sturgeon per Section 4(c)(2) of the Endangered Species Act of 1973

Dear George,

The compilation of current information on pallid sturgeon by the Recovery Team, Genetics Advisory Team, and U.S. Fish and Wildlife Service has been substantial and insightful. In regard to the *draft* report entitled-Pallid Sturgeon (*Scaphirhynchus albus*), 5-Year Review: Summary and Evaluation, I have the following comments:

1. Is our description and analysis of the biology, habitat, population trends, historic and current distribution of the species accurate?

Comment - In the demographic data by RPMAs starting on pg 8, the National Pallid Sturgeon Database is often referred to, but no citation is ever used. Is this database owned by the USFWS, and if so, should it not be cited according to scientific protocols? Since it appears to be a living, working document, perhaps it should be cited as a USFWS document? Utilization of the data base to extract the number and length frequency of wild v. hatchery pallids in each RPMA is helpful in discerning approximate age of the pallids under review.

On page 13 under RPMA 4, line 9 refers to larval *Scaphirhynchus* being documented from the Platte River (G. Mestl, NGPC, pers. comm. 2005). There are a number of studies documenting larval *Scaphirhynchus* being sampled from the lower Platte River in Nebraska (Hofpar 1997, Reade 2000). The lower 100 miles of this river contains geomorphologic features conducive to habitat needs of sturgeon and prey species including shifting sand bars, braided channels, side channels, varied depths, and periodic flooding to maintain in channel characteristics conducive to sturgeon and other big river species, including blue sucker. Snook (2001) studied the movements and habitat use of hatchery-reared pallid sturgeon in the lower Platte. Likewise (Swingle 2003) studied movements and habitat use of 17 shovelnose and 2 wild caught pallids from July 2000 through October 2002. Parham et al. (2005) studied the movement of 15 pallid sturgeon in the lower Platte between 2000-2004. Of the 15 pallids caught, 6 carried either elastomere or pit tags and 9 carried no identification and were presumed to be wild fish. Additional reports and publications with Dr. Ed Peters and colleagues on the lower Platte River are currently underway. Further, a Cooperative Agreement between the States of Nebraska, Colorado, Wyoming, and the U.S. Department of the Interior is being consummated to improve and maintain habitat for four threatened and endangered species-the whooping crane, interior least tern, and piping plover in the central reach of the Platte as well as the pallid sturgeon in the lower Platte River. To date the governors of Nebraska and Colorado have signed on as well as Interior Secretary Kempthorne. The Wyoming governor is expected to sign soon. When signed, the Platte River Recovery Implementation Program (USFWS and USBR 2006) will help address pallid sturgeon needs in the lower Platte River.

On page 15 and 16 under RPMA 5, descriptors to the different reaches are delineated by Rmi and Rkm. While this is appropriate, if the Mississippi reaches also were identified with natural features such as from the Gulf of Mexico upstream to the mouth of the Ohio River, from the mouth of the Ohio upstream to the confluence with the Missouri River it might be easier for readers to identify with.

2. Does the 5-year review provide accurate and adequate review and analysis of the factors affecting the species (habitat loss and modification, overutilization, disease, predation, existing regulatory mechanisms)?

Comment - Habitat loss in each RPMA is descriptive, but you may want to briefly describe what was lost in order to bring home the immense amount of riverine habitat which was eliminated from the functioning river ecosystem. For example, on page 27 in the RPMA 4 reach about 552,000 ac of aquatic and terrestrial habitat was eliminated from the natural channel and meander belt prior to 2003 (USACE 2004). Riverine habitat loss equated in acres adds perspective, although when percentages were used they also were useful. This includes most sandbars, secondary channels, and shoal areas.

Comment - The review on Hybridization (pg 45) and Appendix B (Genetic Analysis data using the software Structure) is informative and interesting. Researchers should be applauded for this innovative genetic analysis, but acknowledgement and the statement that identification of three genetic groups of pallid sturgeon should be regarded as tentative appears to be warranted. Although the six mainstem dams and embankments were closed (Peck 1937, Garrison 1953, Oahe 1958, Big Bend 1963, Ft. Randall 1952, Gavins Point Dam 1955), given the long life span of this species, only one or two generations have potentially passed since the river has been segmented for genetic isolation. On the other hand, one tagged hatchery pallid stocked in RPMA 3 near Verdel (Rmi 851.5) on June 6, 2000, was subsequently recaptured in Omadi Bend (Rmi 721) some 130.5 miles downstream on March 3, 2006. A second tagged hatchery pallid stocked in RPMA 3 was subsequently recaptured below Gavins Point Dam (RPMA 4). Specifically, this pallid also was stocked at Rmi 851 near Verdel which is upstream of Lewis and Clark Lake on March 21, 2002. Over 2 years later it was recaptured on July 20, 2004, at Rmi 447.7 near St. Joseph, Missouri. Both of these pallids must have passed through the Gavins Point Dam power house because a drought was going on in the basin and no gates were open during this time frame. It is a known fact that paddlefish above Gavins Point Dam occasionally pass through and survive electrical generator turbines and of course occasional dam gate openings associated with high water releases. Consequently, downstream movement is possible but not upstream movement because there are no fish passageways built on any of the mainstem dams. In the future, when the USACE addresses passing trapped sediment in the system (USFWS 2003a), especially the delta built up on the upper end of Lewis and Clark Lake behind Gavins Point Dam, there is the potential that passing sediment below Gavins Point Dam also could incorporate a fish passageway within this small dam.

3. Are assumptions and definitions of suitable habitat logical and adequate?

Comment - Given the fact that pallid sturgeon were only listed in 1990 and there is descriptions of riverine habitat types lost in the systems (RPMA 1-6) it is probably the best that can be anticipated until ongoing monitoring and research study data can be analyzed. It may take a number of years to help delineate what habitat parameters within the RPMAs are being used throughout its range to include depth, velocity, etc. What riverine habitat components are used by the different life cycle stages also is important to discern, not to mention adequate food organisms needed by the different life stages of pallid sturgeon. This species cannot thrive in a vacuum, and habitat for prey fish species is important for older pallid sturgeon. Hesse (1994) stated the declining status of selected chubs and minnows in the Missouri River in Nebraska from 1971-1993 most likely contributed to the demise of sauger, catfish, burbot, and sturgeon among other species. Wanner (2006) citing (Held 1969)

refers to pallid and shovelnose sturgeon as opportunistic suctional feeders on benthic organisms using barbels, an inferior mouth, and modified fleshy lips. Wanner (2006) also cites (Coker 1930; Cross 1967; and Carlson et al. 1985) in that while adult pallids utilize aquatic insects, there is a greater proportion of fish (mostly cyprinids) in their diet compared to shovelnose sturgeon. Most likely, there are other sources of information on prey species in other RPMA's which can be resourced for the next 5-year review.

4. Are there significant oversights, omissions or inconsistencies in the 5-year review?

Comment - I do not think so. I believe the pg 46 (II.D.) Synthesis is on target and that a change in pallid sturgeon status is not currently warranted for the specified reasons. I recommend that the National Pallid Sturgeon Database be scrutinized further to determine if there are other cases of marked (elastomers etc.) pallids stocked and subsequently recaptured between RPMA 3 and RPMA 4. Results should then be shared with genetic researchers for their consideration.

5. Are our conclusions logical and supported by the evidence we provide?

Comment - Overall, authors and reviewers used the body of literature and references available to document and substantiate statements and conclusions, especially the hybridization hypotheses discussed on page 45-46.

6. Did we include all necessary and pertinent literature to support our assumptions and conclusions?

Comment - Yes. Overall, the 5-year review document is a substantial piece of work, but like many things in science, there is always new things to learn. Recently, Hay (2006) used a multi-year, multi-location data base of biological sampling to develop statistical models relating biotic responses to variables representing discharge, temperature, and turbidity in the Missouri River from Fort Randall Dam, South Dakota, to Rulo, Nebraska. Results from macroinvertebrate modeling indicated greater drift densities were related to higher flows out of Fort Randall Dam (RPMA 3) and low flows and reduced turbidity below Gavins Point Dam (RPMA 4). For larval fish modeling, water temperature was the most important predictor variable. Greater temperatures or degree days consistently increased the probability of finding larval fish and the resulting drift densities. Greater catch per unit effort of age-0 or age-1 fish were generally related to less variable discharge in the unchannelized reaches and to greater, rising discharge in the channelized reaches below Sioux City. Overall, his results suggest that a more natural discharge, temperature, and turbidity regime would benefit native fish and invertebrate species in the Missouri River.

Thanks for the opportunity to review this worthwhile document.

Gene Zuerlein
Certified Fishery Professional
Fisheries Division
Nebraska Game and Parks Commission

NEW CITATIONS

- Coker, R.E. 1930. Studies of common fishes of the Mississippi River at Keokuk. U.S. Bureau of Fisheries Bulletin 45:141-225.
- Cross, F.B. 1967. Handbook of fishes in Kansas. University of Kansas, Museum of Natural History Miscellaneous Publication 45, Lawrence.
- Hay, C.H. 2006. Fish and Invertebrate Abundance in Relation to Abiotic Factors in the Missouri River. PhD Dissertation. University of Nebraska, Lincoln. 208 p.
- Held, J.W. 1969. Some early summer foods of the shovelnose sturgeon in the Missouri River. Transactions American Fisheries Society 98:514-517.
- Hesse, L.W. 1994. The Status of Nebraska Fishes in the Missouri River, Selected Chubs and Minnows (*Cyprinidae*): sicklefin chub (*Macrhybopsis meeki*), sturgeon chub (*M. geldida*), silver chub (*M. storerians*), speckled chub (*M. aestivalis*), flathead chub (*Platygobio gracilis*), plains minnow (*Hybognathus placitus*), and western silvery minnow (*H. Argyritys*). Pages 99-108 in Transactions of the Nebraska Academy of Sciences, Vol 21., 1994.
- Hofpar, R.L. 1997. Biology of Shovelnose Sturgeon, *Scaphirhynchus platyrhynchus*, in the lower Platte River, Nebraska. Master's thesis. University of Nebraska, Lincoln. 83p.
- Parham, J.E., J.J. Olnes, C. N. Reade, and E.J. Peters. 2005. Ecology and Management of Pallid Sturgeon and Sturgeon Chub in the Lower Platte River, Nebraska. Draft Final Report to The Pallid Sturgeon, Sturgeon Chub Task Force and The Nebraska Game and Parks Commission. April 2005.
- Reade, C.N. 2000. Larval Fish Drift in the Lower Platte River, Nebraska. Master's thesis. University of Nebraska, Lincoln. 116 p.
- Snook, V.A. 2001. Movements and Habitat Use by Hatchery-Reared Pallid Sturgeon in the lower Platte River, Nebraska. Master's thesis. University of Nebraska, Lincoln. 152 p.
- Swingle, B.S. 2003. Movements and Habitat Use by Shovelnose and Pallid Sturgeon in the Lower Platte River. Master's thesis. University of Nebraska, Lincoln.
- U.S. Army Corps Engineers. 2004. Missouri River Fish and Wildlife Mitigation Project. Kansas City District, Kansas City, Missouri. <http://www.nwk.usace.army.mil/projects/mitigation/>.
- U.S. Fish and Wildlife Service and U.S. Bureau Reclamation. 2006. Platte River Recovery Implementation program. Final Environmental Impact Statement. Summary. <http://www.platteriver.org>.
- Wanner, G.A. 2006. Sampling techniques for juvenile pallid sturgeon and the condition and food habitats of sturgeon in the Missouri River below Fort Randall Dam, South Dakota. Master's thesis. South Dakota State University, Brookings. 153p.

Editorial Comments
Pallid Sturgeon (*Scaphirhynchus albus*), 5-Year Review: Summary and Evaluation
Gene Zuerlein, Nebraska Game and Parks Commission

1. Page 5. Throughout the document there are a number of names with personnel communication behind them without the year listed. See pg 5-B. Atwood, pg 18-J. Killgore, pg 32-B. Gardner, pg 34 K. Steffensen, pg 39-R. Short. Like wise, there are names listed in the text portion of the report which are not listed under Personal Communications on pg 57-58. These include K. Steffensen, NGPC pg 34; R. Short, Wisconsin pg 39; T. Keevin, USACE pg 42.
2. Page 8. figure 1 should be Figure 1. Standardize throughout the report. See pg 11 on figure 1; pg 19 on figure 1.
3. Page 17. I believe Figure 10: Middle Mississippi River (RPMA 4) should be labeled (RPMA 5). On pg 15 the RPMA 5 is defined as the Mississippi River from its confluence with the Missouri River to the Gulf of Mexico. The Middle Mississippi River is the reach between the confluence of the Ohio River near Cario, IL and the confluence of the Missouri, near Saint Louis, MO.
4. Page 18. I believe Figure 11: Lower Mississippi River (RPMA 4) should be labeled (RPMA 5). The Lower Mississippi River is the reach of the Mississippi River from the confluence of the Ohio River near Cario, IL to the Gulf of Mexico.
5. Page 49. Although a number of tributaries have been mentioned through the Missouri River Basin in relationship to the various RPMAs. It might be appropriate under the Data needed for the next 5-year review to state any tributary data generated from pallid sturgeon studies also should be reviewed. I know Dr. Ed Peters is planning on publishing his work on radio-tagged pallids in the Lower Platte River.
6. Page 51. Duffy, W.G. et al . 1996. is cited but I could not find it in the text of the report. I may have missed it, but you should check again. On page 53, Kallemeyn, L.W. 1983 also is cited but I could not find it in the report text.
7. Page 50. Braaten, P.J., and D.B. Fuller. 2004. Pg 29 has this citation as 2005.
8. Page 50-56. A number of citations are used as acronymns. It would clarify these citations if they were spelled out in parentheses after they were used. Example: pg 51, DHSS. 2006 could read MDHSS (Missouri Department Health & Senior Services). 2006. Pg 54, MDC. 2006. could read MDC (Missouri Department Conservation). 2006.
9. Page 4. Ray et al. In Press is cited but it is missing in the Literature Cited section on pg 54.
10. Page 22. Ray et al. 2005. is cited but is missing in the Literature Cited section on pg 54.
11. Page 55. TWRA. 2006 could read TWRA (Tennessee Wildlife Resources Agency). 2006.
12. Page 34. USACE 2004 is cited, but missing in the Literature Cited section.

13. Page 22. Carleson should be Carlson.

3. Vince Travnichek Review

Dr. Vince Travnichek provided comments directly on hard copy of the draft 5-Year review. His comments were primarily editorial in nature.

Critique of Draft 5-Year Pallid Sturgeon Review Document

December 6, 2006

Jim Garvey, Southern Illinois University

This report summarizes the current state of knowledge about the pallid sturgeon throughout its range in the Mississippi and Missouri River basins. I largely agree with the synthesis and conclusions. Below, I make some comments that might provide some food for thought. Of course, all of these comments are colored by my perception of the population in RPMAs 4-6.

General Thoughts

1. Should the report include a section on the potential problems associated with barge entrainment and channel dredging? Unless I missed these issues in the report, they probably need to garner some mention. Jack Killgore's group is currently involved in a St. Louis District-funded project exploring the impact of tow boats on fish communities. Although I am unsure of the source, there was some talk of sturgeon being entrained by dredging. You might want to check with Jack or Tom Keevin about this issue.
2. All the evidence points to a large population that is separated genetically by distance; however, there are no distinct boundaries among populations, with the exception of the Upper Missouri, of course. In my view, it might be instructive to have the report more forcefully state that conservation stocking must account for these geographic differences by collecting broodstock from the specific RPMAs (and perhaps even at specific locations within each RPMA) and restrict stocking to the location-specific lineages. I know there continues to be controversy about this; however, this is the risk averse approach for now until we understand more about genetics and reproductive site fidelity.
3. You mention in the report that there is marked phenotypic plasticity within the pallid sturgeon. We really need to disentangle the genetic versus environmental effects on growth and morphology. Although I realize that this report is not a SOW, we need someone to conduct some common garden experiments to determine whether the size and other physical differences among populations are due to environmental history or genes.
4. Is the eventual goal to recover pallid sturgeon without the need for hatchery supplementation? Or is stocking always going to be included? This needs to be clearly addressed in the report. It seems that the data clearly show that the dams will always reduce survival during early life. Thus, reproduction always will need to be artificially supplemented in this case.

Specific Comments

- 1) It might be useful to specifically show the major barriers on Figure 1 and how they correspond to the RPMAs.
- 2) If I correctly understand the data in Figures 3, 5, and 9, it is important to note that the presence of hatchery-reared fish does not seem to be concurrent with a continued decline of wild-produce fish. In so many instances, populations become dominated by hatchery products while the wild fish continue to decline. One of my concerns is that hatchery fish may cause some degradation of wild stocks; however, this does not appear to be the case with the limited information at hand.
- 3) There are an awful lot of references to personal communications and unpublished data (guilty as charged) and I think this is important to point out. We, as the community of researchers working with this important species, need to get the word out in the primary, peer-reviewed literature. Perhaps you can do a brief analysis of the literature to date, telling us how the information is distributed between reports and papers. I also would like to see a graph of cumulative number of publications through time.
- 4) I am unsure whether this is possible, but the report really needs to emphasize that the demarcations between the RPMAs are physical for the Upper Missouri but largely administrative for the lower Missouri and Mississippi River. I am of course biased, but I do believe (and the genetics seems to be supportive) that the southern populations are largely mixing and need to be managed in this fashion. This is implicit throughout much of the report but needs to come out strongly, in my view. Of course, the habitat issues are indeed different between the lower RPMAs but the populations might be mixing.
- 5) (p. 35) You note that pallid sturgeon have been reliably caught in the Kaskaskia River tributary. Unfortunately, there is a lock and dam directly in the mouth and we have never documented movement into that river to my knowledge. In fact, we have receivers sitting in the mouths of the major tributaries of the MMR and have never documented passage by pallids into them. We do reliably capture pallids near the Kaskaskia River tributary and the island area.
- 6) You might want to point out that we are currently at the juncture between 1 and 2 of the reasonable and prudent alternatives of the FWS Biological Opinion for the MMR (p. 36). Not sure if we are done with 1 yet, although Tom Keevin has convened a preliminary group to help draft the MMR Conservation Plan.
- 7) Colombo et al. (in press) is accepted and revised for publication in the Journal of Applied Ichthyology. It would fit nicely in the discussion starting on p. 38.
- 8) To be fair to Illinois, they are trying to implement regulations – just not there yet (p. 43). Colombo et al. (in press) evaluate some of the implemented size limits and dates and the current regulations do not appear to be sufficient for shovelnose and certainly not for pallids.
- 9) We all know (with supporting data) that the Chain of Rocks (Lowhead Dam 27, UMR) is a hot spot for sturgeon of both species. Would it be prudent to suggest closing access to all fishing at this area? We suspect that sturgeon are taken incidentally by recreational fishermen with no knowledge of the status of the species.

- 10) Another important piece of information for decisions about the potential development of DPSs (P. 48), in addition to the genetics, is the extent of movement of these fish between RPMA's. The report should be pretty stern about facilitating increased cooperation among the groups doing telemetry in the Missouri, the MMR, and now the lower Mississippi River, where telemetry efforts are planned by Hal Schramm et al.
- 11) For the lower RPMA's, we need estimates of immigration and emigration of both wild and hatchery-produced pallids to generate viable population assessments.(p. 49).
- 12) After completing our final report for the St. Louis District, it appears that we need to understand what makes successful recruitment occur in the lower RPMA's and make more of those conditions. This might help us to improve reproduction and eventually curb the need for supplemental stocking in this part of the pallid sturgeon's range (p. 49).

4. William T. Slack Review

6 December 2006

Mr. George Jordan
U.S. Fish and Wildlife Service
Pallid Sturgeon Recovery Coordinator
2900 4th Avenue North, Room 301
Billings, MT 59101

Dear Mr. Jordan:

I appreciated the opportunity to serve as a reviewer for the Pallid Sturgeon-5 Year Review and have enclosed my comments regarding the document. I have served as a reviewer for numerous peer-review scientific journals and approached this document in the same critical manner. Overall, I feel the document does well in providing the most up-to-date information on the status of pallid sturgeon as well as indicating potential threats to its recovery. As directed in your cover letter, reviewers were asked to consider the following questions during their evaluation of the document.

- 1) Is our description and analysis of the biology, habitat, population trends, historic and current distribution of the species accurate?
YES, except for spawning/nursery habitat. See Objective 3.
- 2) Does the 5-year review provide accurate and adequate review and analysis of the factors affecting the species (habitat loss and modification, over utilization, disease, predation, existing regulatory mechanisms)?
YES, except for spawning/nursery habitat. See Objective 3.
- 3) Are our assumptions and definitions of suitable habitat logical and adequate? **NO. There is no description of spawning habitat, or at least proposed spawning habitat. Identifying spawning habitat and describing the spatial and temporal use of this habitat within RPMA's by both pallid and shovelnose sturgeon should be a high priority. The Recovery Plan states little is known regarding reproduction or spawning activities of**

pallid sturgeon (in 1993). Nothing is included in the current document to indicate gains in information along that front. Habitat loss and alteration are generally listed as primary causes in the decline of pallid sturgeon throughout its range. However, it is ironic that we provide these as causes without having any substantial data on specific habitats such as spawning and/or nursery habitat. Comments are mentioned within the 5-Year Review document (i.e., page 47) indicating that documentation of recruitment within RPMAs is essential to meeting recovery objectives; however, identifying and/or quantifying habitat specific to aspects of recruitment (i.e., spawning habitat) are not listed. Spawning habitats and cues are noted as a concern within the “Data needed for the next 5-year review” section but not prioritized specifically as a “Future Action.” Shovelnose sturgeon provide the best surrogate to model potential spawning and/or nursery habitats. Efforts should be placed on targeting those habitats within RPMAs as potential pallid sturgeon spawning areas.

- 4) Are there any significant oversights, omissions or inconsistencies in the 5-year review?

See Objective 3.

- 5) Are our conclusions logical and supported by the evidence we provide? **YES**
- 6) Did we include all necessary and pertinent literature to support our assumptions and conclusions? **YES**

In addition, minor editorial and formatting suggestions are noted directly on the document. Specific points of concern are presented below:

- Do not need labels at the top of each figure. This information is often redundant with the specific figure heading. In those cases where the label is not redundant, incorporate those data/information directly into the figure heading. Also, include sample sizes ($n = \underline{\quad}$) for histograms, either on the figure or in the figure heading. Information provided in Figure 12 would make it much easier to follow the associated text in the document if sample sizes were listed for each sample period on the figure. Most figure headings are descriptive enough to stand alone from the text but others need to include additional information to better support the figure (i.e., Figure 13).
- Inconsistent use of terms throughout the document (e.g., hatchery-reared vs. hatchery reared; lower/upper vs. Lower/Upper when used to describe specific zones within an RMPA). Inconsistency with citation format in Literature Cited section, particularly with edited volumes.
- Page 14. Need to clarify text on how wild, hatchery and pallid sturgeon of unknown origin were being defined. Numbers of individuals within each category are listed but I am unsure based on the information presented within the document as to how these were determined.
- Page 19. Concerns with catch data presented for RPMA 6: Sampling effort yields absolute number and those numbers are depicted in Figure 12 and 13. Text for RPMA 6 notes “about” and “estimate” for catch effort during specified sampling periods (FY). The actual numbers that were recorded should be stated within the text. Because of the difficulties in

distinguishing between intermediates, pallid and shovelnose in RPMA 6, the workers feel that the absolute number of pallid recorded for the Area underestimates the total number that are likely there and thus use the term “conservative” for their total estimate of population size.

- Page 19, 20. Patterns depicted in Figure 12 illustrate a consistent frequency pattern that also may reflect gear selectivity. Text describes that shovelnose are regularly captured (40-75 cm FL) and that there is no obvious problem with recruitment. In addition, pallid sturgeon are consistently captured (60-100 cm FL) from the same area and the population size is considered large. It is my understanding that commercial fishermen are routinely involved in the sampling at ORCC and that similar gears are used from year to year. Isn't it just as conceivable to argue that gear selectivity is as much a reason for the pattern that is depicted (gill net mesh adequately samples sturgeon 40-100 cm FL) as is the argument that younger and older fish are migrating from the area through the ORCC? Data presented by Heise (2003) for Gulf sturgeon in the Pascagoula River notes a similar year-to-year size frequency pattern, and attributes the pattern to gear selectivity for large-sized adult Gulf sturgeon.

Heise, R.J. 2003. The migratory patterns of Gulf sturgeon, *Acipenser oxyrinchus desotoi*, within the Pascagoula River drainage and potential influences on its behavior. Ph.D. Dissertation, University of Southern Mississippi. Hattiesburg, MS

- Page 19, 20. This is the only section within the entire document that presents data within a fiscal year. Reader is not made aware of what defines the fiscal year as State and Federal resource agencies often have different fiscal years (October through September versus July through June).
- Page 22. Intercross. Is this the most appropriate term to use for this section? This section is discussing the concept of natural hybridization, backcrossing and genetic introgression between pallid and shovelnose and trying to put a single term on the concept...intercross. Wouldn't interbreed be a more all encompassing term than intercross?
- Page 23. Dugo et al. (2004) article enclosed; Data presented in this work illustrates a similar pattern in Gulf sturgeon of genetic distance associated with geographic distance. Populations from adjacent watersheds with less genetic distance than those populations from watersheds at extremes in the range.
- Page 24. Use of the term “importance”. Section II.C.1.a. notes the rarity of the animals throughout its proposed range at the time of the description of the pallid sturgeon. Its occurrence in the Yellowstone, Platte, St. Francis, Big Sunflower and Atchafalaya illustrates that its historic range was likely greater than currently recognized, but you cannot say that those river systems were “important”. You do not have the historic data to support this.
- Page 25. Discussion about Fort Peck Reservoir and its influence on survival of larval pallid sturgeon. It is unclear from the text as why immature pallid sturgeon are more likely to utilize lower reaches of RPMA 1 than shovelnose sturgeon AND how this influences survival of larval pallid sturgeon.
- Page 27. How do we know that habitat alterations within RPMA 5 have “reduced rearing habitat” when those habitats have not been adequately described and quantified throughout this reach. Comments noted in Objective 3 follow along this thread.

- Page 28. Text notes 92 secondary channels remain in lower Mississippi River. Is this based on Baker et al. (1991) data or does it reflect more current information from Keevin (2006)?
- Page 29. There is a scant amount of information for shovelnose in the Red, Black and Ouachita rivers (see Douglas 1974). Can this data be used to speculate on potential habitat and range of pallid sturgeon within those systems (particularly the Red) prior to the construction of ORCC. Shovelnose are still being captured in sufficient numbers at ORCC to suggest that habitat for spawning within those systems is still available.
- Page 29. The occurrence of larval and post-larval river sturgeon in the lower Mississippi River around Vicksburg in the fall (September, October; MS Museum of Natural Science Ichthyology Collection) suggests either fall spawning or long distance drift from upriver spawning areas. Comments in the document text propose drift of pallid sturgeon larvae from the Missouri River as a scenario for long distance drift. Data presented on page 26 and summarized on page 29 states that larval pallid sturgeon may drift 200-310 miles depending riverine current velocities but that drift declines after 8 days post-hatching. Given these parameters, 200-310 Rmi upstream of Vicksburg (USACE Rmi 440) would be between Rosedale, Mississippi (Rmi 640), and Memphis, Tennessee (Rmi 750), thus the source would not necessarily have to be the Missouri River.
- Page 32. Have sturgeon chub become reestablished in the Marias River or is this the first documentation of sturgeon chub within the river. Argument is made that occurrence of sturgeon chub is favorable for recovery of pallid sturgeon as it is an important prey species, but if the sturgeon chub had never occurred in the system it may be a mute point in arguing significance toward pallid sturgeon recovery.
- Page 33. Unsure exactly what is inferred with “bank stabilization” as it relates to development. Does this imply “bulkheading” or “armoring” of shorelines with .rip-rap and/or sheet pilings? This phenomenon has been noted to significantly affect inshore nursery habitats of coastal fisheries in Mississippi (Peterson et al. 2000). I would expect similar impacts in freshwater systems which would likely cause a cascading trophic effect.

Peterson, M.S. et al. (2000). Habitat use by early life-history stages of fishes and crustaceans along a changing estuarine landscape: differences between natural and altered shoreline sites. *Wetlands Ecology and Management* 8(2/3):209-219.
- Page 34. It is unclear from reading the text what is being “identified” in the Biological Opinion.
- Page 35. Text needs to be included to illustrate how USACE practices to maintain the navigation channel (training structures, locks and dams, dredging, etc) alter habitat. Fleeting needs to be defined.
- Page 38. Little historic data on commercial harvest in lower Mississippi River. Cook (1958) provides an excellent account of fisheries in Mississippi waters includes data for river sturgeon harvest from Mississippi River and associated tributary systems. Prudent to include those comments rather than note that there is little historic data on commercial harvest in Lower Mississippi River. A copy of the document is included in the packet of review comments.

- Page 41, section II.C.2.D. Inadequacy of existing regulatory mechanisms. The entire section is very choppy and not written very concisely. Redundant information persists throughout the section (pallid and shovelnose can be difficult to distinguish). Section needs to be reworked for better flow and to present the information in a more concise manner.
- Page 44. Entrainment. More description is needed to determine how Phase I rules differ from those implemented in Phase II. Phase I covers facilities. Phase II covers existing facilities with specifics on water withdrawal and cooling. How do facilities in Phase I differ from those in Phase II?
- Page 45, 46. Comments dealing with hybridization. Very well written and makes the points very well. Hybridization may occur between the two with a resulting intermediate morphological phenotype and intermediate genotype, and that additional research is needed to address whether hybridization in the wild is the result of natural processes or anthropogenic influences.
- Page 46. Use of “significantly”. This term is used as an opinion of the writer. Impact by regulated flows has not been quantified and thus any assessment of its impact on pallid sturgeon is qualitative. “Significantly” implies quantified comparisons evaluated with statistical analyses. Similarly, riverine habitat has been fragmented but dams do not continue to significantly fragment the habitat (implies increase in fragmentation). Habitat was fragmented by dams and will continue as such until either dams are removed (less fragmented) or added (more fragmented).
- Page 49. Recommendations for Future Actions AND Data needed for next 5-year review. Section should include focused and directed research efforts towards addressing the extent of movement by pallid and shovelnose across range. Some telemetry work has been done within the upper portions of the range where physical constraints within the system (locks and dams, defined pools) allow for a more logistic project. RPMA 4 and 5 are large areas and movement within and between these areas as well as projects addressing the extent of movement between RPMA 5 and 6 are desperately needed. Admittedly there are some pilot projects underway but dedicated funding towards projects of this scale is much needed.
- Page 49. Recommendations for Future Actions. Cease augmentation of wild stock with hatchery reared stock in RPMA 4, 5 and 6 UNTIL more information is obtained on movement within and between RPMA's. In addition, recent data obtained from research within RPMA 4, 5 and 6 suggests these populations are much larger than once perceived and stocking within these areas may not be necessary to meet recovery objectives
- Page 49. Recommendations for Future Actions. Identify spawning habitat and describing spatial and temporal use of this habitat within RPMA's by both pallid and shovelnose sturgeon to address potential mechanism for observance of hybrids/intermediates within these areas.

- Page 49. Recommendations for Future Actions. One direction note for “Future Actions” is to model the Missouri River Populations Assessment Program for RPMA 5 and 6. This is a step in the right direction but implementation of such a program is in need of dedicated funding. Many of the partnering states already have USFWS Section 6 funding in place as well as funding appropriated under the USFWS State Wildlife Grant program. However, in most cases those funds are already dedicated toward research of equal importance. A monitoring project of this scale will require teams of personnel and sufficient equipment to perform the task. What agency/entity will coordinate these efforts?

Thank you again for the opportunity and I hope my critique of the draft document and my enclosed comments will be helpful in preparing the final document for the Pallid Sturgeon 5-Year Review. Please feel free to contact me directly if you have any questions regarding my review.

Sincerely,

William T. Slack, Ph.D.
Nongame Research Biologist
Curator of Fishes

5. David L. Galat Review



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EDWARD K. LOVE FOUNDATION

December 11, 2006

George R. Jordan
U. S. Fish & Wildlife Service
Pallid Sturgeon Recovery Coordinator
Jameson Federal Building
2900 4th Avenue North, Room 301
Billings, MT 59101.

Dear George,

Thank you for the opportunity to provide a review of the U. S. Fish & wildlife Service's Pallid Sturgeon 5-Year Review. Clearly, much effort has gone into producing this report, particularly given the exponentially increasing amount of research and monitoring on Scaphirhynchus sturgeons since the USFWS Biological Opinions (BiOPs). Here are my replies to your questions with the numbers corresponding to the questions posed.

- 1. I believe that there are numerous inaccuracies in the draft description and analysis of the biology and population trends of pallid sturgeon and these concerns are detailed below with reference to specific aspects of the draft review.*
 - 2. I realize it is difficult to include an exhaustive evaluation of all available information in this review; I've noted below instances of significant omissions of information related to factors that may be affecting the species' status.*
 - 3. No comment.*
 - 4. Omissions and oversights that I've identified are detailed below.*
 - 5. I do not concur that the evidence provided herein and in the documents cited adequately support the conclusion of the pallid sturgeon's status remaining "stable" since it's listing in 1990. My concerns and requests for clarification are detailed below.*
 - 6. I've noted some omissions in the literature and urge the report preparers to analyze and incorporate results from all of the most recent pallid sturgeon population assessment and habitat-use project reports as well as pertinent literature for other sturgeon species.*
- To assist in reviewing my comments, I have assigned line numbers to the entire document (attached) and specific comments relate to these using the following format: **Pg xx, 100-103** where the number following the page number refer to specific lines in text. There also are a few editorial comments made in "Track Changes" directly on the draft.*

I commend the authors for incorporating much of the valuable information that has been acquired since the species was listed in 1990 into this review and using it to evaluate the species' current status. I hope you will find my comments and recommendations useful to your review and to furthering conservation of the species.

Sincerely,

David L. Galat
Assistant Unit Leader- Fisheries
And Associate Professor

Species status is listed as “stable” on pg. 2 I.C.2.

I am unable to locate sufficient scientific evidence within this document to justify the Report’s author’s reaching this finding. Five factors contribute to this conclusion: (1) What the ESA/FWS official policy is for the contribution of artificially propagated pallid sturgeon and their stocking is to determination of “status” is unclear. (2) Information reported and apparently used to make the conclusion of the species’ status is insufficient or incorrectly applied to make determinations about the species’ abundance or population status. (3) For a population to be stable there should be large numbers of small individuals present within a length-frequency distribution, illustrating that recruitment is replacing mortality. This is particularly important for long-lived fishes such as sturgeon where growth of old individuals is minimal. (4) The authors have not included relevant references that report a continued decline of the species. (5) The report’s Synthesis section emphasizes the highly imperiled status of this species. Text that follows addresses each of these factors.

- (1) A critical issue that I believe should be addressed in this review is to clarify for the reader the policy of ESA and FWS on the role stocking pallid sturgeon plays in the species recovery. Can it be used to “rejuvenate” critically low populations in order to increase numbers sufficiently so that natural recruitment at some point can maintain the population or increase it? Peregrine falcons and California condors are examples of where this approach has been successfully applied. I think it might be useful to the public to illustrate similar examples for endangered riverine fishes to lend additional credibility to the stocking program. An equally important question I hope can be clarified in this status review is what is the ESA/FWS’s policy relative to inclusion of stocked fish in determinations of defining the pallid sturgeon’s population status. Specifically, can a population maintained by stocking for some period of time be classified as “stable” as appears to be the case with pallid sturgeon based on this review, or is *natural* recruitment required for the population of pallid sturgeon to remain “stable”? This is an important consideration I hope can be clarified since much of the information reported on pallid catches in this review relates to stocked fish and stocked fish relative to “wild” fish.
- (2) A fundamental requirement for a wild population to be *stable* is that recruitment (presumably natural vs. artificial propagation, but see previous comment) into the population needs to balance mortality losses. A population that is *increasing* has recruitment exceeding mortality, and a *declining* population has mortality exceeding recruitment. Therefore, statements about a population’s status should be supported with evidence concerning recruitment and mortality. Can you more effectively summarize the evidence that recruitment is balancing mortality as evidence for concluding the population’s status is stable?
- (3) All length-frequency distributions in the review show comparatively few small pallid sturgeons relative to “mature” individuals. Length frequency distributions (where length is a surrogate measure of age) of a healthy population are dominated by small size classes (young

fish) (Van Den Avyle & Hayward 1999). Rarity of small size classes from most RPMAs could be a consequence of several factors acting independently or collectively: (i) sampling effort is biased towards larger size classes; (ii) sampling gears deployed are inefficient at capturing small size classes or the habitats where they may reside are ineffectively sampled (e.g., main-channel thalweg); (iii) difficulty of taxonomically separating small pallid sturgeon from small shovelnose sturgeon results in under-reporting small size classes of pallid sturgeon; or (iv) natural recruitment of pallid sturgeon to sub-mature sizes is not occurring. I recommend this review address each of these factors so that statements about population trends or condition of the pallid population can be substantiated.

Rather there is circumstantial evidence within the document that appears to support continual decline of the species throughout its range in the Missouri River. Here are some relevant quotes from the draft 5-year review for RPMAs to support this observation:

Pg. 8, 300-302; RPMA 1. “The size and age of surviving fish suggest that spawning, recruitment or both are severely limited within this reach. Supplementation of RPMA 1 with hatchery produced pallid sturgeon has occurred sporadically since 1997, and is required to maintain the population.”

Pg. 9, 352-355; RPMA 2. “The length frequency data indicate that up until the time supplementation began, all collected pallid sturgeon were adults except for one small fish collected in 1993. This suggests that, like RPMA 1, spawning, recruitment or both are limiting viability within this reach.”

Pg. 11, 378-384; RPMA 3. “There is no native wild population of pallid sturgeon known to survive in RPMA 3 (figure 1), the Missouri River from 20 miles (32.2 km) upstream of the mouth of the Niobrara River to Lewis and Clark Lake, and the current population consists entirely of hatchery stocked fish. According to the National Pallid Database, the latest wild record of the species from this area, that was not translocated, was the collection of a single pallid sturgeon circa 1991. Prior to this (1952-1991), there were a small number of pallid sturgeon collected from this area.”

Pg 14, 1-443-448; RPMA 4. “The low numbers of naturally produced or unknown origin pallid sturgeon in smaller size classes coupled with higher relative abundances of hatchery origin pallid sturgeon (Figure 9) and frequent captures of smaller size class shovelnose sturgeon suggests that the gears being used are effective and that natural recruitment of pallid sturgeon is sporadic or limited in RPMA 4 (Barada and Steffenson 2006, Kennedy et al. 2006, Steffenson and Barada, 2006, Utrup et al. 2006).”

Pg 19, 585-587; RPMA 6. “The length distribution of pallid sturgeon captures has remained relatively consistent over the past 7 years, although the population appears to be comprised of predominantly adult fish >65 cm FL (Figure 12).”

- (4) Doyle and Stroska (2003) conclude for the lower Missouri River, “Pallid sturgeon continue to decline at a rapid rate. Within the 200 river-miles sampled, the ratio of pallid to river sturgeon decreased from 1:311 in a 1996-2000 study to 1:387 in 2002.
- (5) The synthesis section summary reports catches of adult pallids remain low, recruitment of pallids is infrequently observed, pallid catches are largely composed of old-aged individuals, illegal commercial harvest appears to be increasing, inter-sex specimens of *Scaphirhynchus* are now being observed, and hybridization is now well documented – yet the overall

conclusion is: “In summary, the status of pallid sturgeon has improved since listing due to successful hatchery and stocking programs in reaches of the Missouri River; new information on habitat extent and conditions, population size, and potential recruitment in the Mississippi River; and new information on population size in the Atchafalaya River.”

For this reviewer, it seems the conclusion of a “stable” pallid population status conflicts with a substantial amount of the evidence provided herein or the references cited. Additionally, some of the information presented in this review appears misinterpreted (see previous and following comments), thus making it impossible to objectively evaluate trends in abundance or population status of pallid sturgeon throughout its range. Low numbers of pallids ≤ 350 mm TL collected, insufficient information on changes in pallid CPUE over time, lack of quantitative population estimates, increased fishing mortality, disease, contaminant levels and hybridization lead me to question the report’s conclusion that the species’ status remains stable.

Perhaps you can help your readers understand this conclusion in the final draft by clarifying what is meant by “stable”, what specific criteria were used to reach this conclusion and what other options for the species’ status exist (e.g., uncertain, declining, improving?) and what are the criteria for their designation?

What is a population? A *population* is a group of fish of the same species that are alive in a defined area at a given time (Wooten 1990). In fisheries it is generally determined by mark-recapture studies, the methods of which are described in numerous texts (e.g., Bagenal 1978, Wooten 1990, Van Den Avyle & Hayward 1999). Population is not synonymous with catch, or abundance. This status review appears to use the terms “population” or “population trend” very loosely, and in my opinion largely incorrectly. I strongly recommend including the Przemyslaw and Wildhaber (accepted) paper “Population viability analysis of lower Missouri River shovelnose sturgeon with initial application to the pallid sturgeon” in this review as it illustrates very well the type of information necessary to quantify population trends.

Reporting only catch information as is done in this status review does not contribute substantively to evaluation of a species’ abundance or its population’s status (see other comments) unless it is adjusted for effort, i.e., catch per unit of sampling effort or CPUE. For example, reporting catches as in II.C.1.a. “Abundance, population trends...” (pgs. 5-20) is misleading as does not provide the reader with accurate data about abundance or population trends. See above comment about the rigorous approach that is necessary to evaluate population trends. Statements about patterns in numbers of pallids collected over time also are misleading, unless catch data are adjusted by effort (e.g., see 2004 and 2005 Population Assessment Reports for segments 9-14 for examples of reporting CPUE). For example, pallid sturgeon sampling has likely increased markedly following RPAs in the 2000 and 2003 Biological Opinions. If effort to capture pallids has doubled from 2000 to 2005, then catches also will need to have doubled for relative abundance (not population size) to be considered “stable.” Increases in catch over time without adjustment for effort may lead to erroneous conclusions about relative abundance.

Additionally, annual catch data as presented in Figures 3, 5, 7, and 9 provides inappropriate information from which to evaluate population status (see previous comments about misuse to the term *population* throughout this report).

Conservation Measures (Pgs 32-37). A substantial amount of this review is devoted to detailing the various ongoing Missouri and Mississippi rivers mitigation, rehabilitation, or restoration programs. I think it would benefit this status review to summarize more specifically

if, or how, these programs have shown a demonstrated benefit to pallid sturgeon recovery. If there are measurable benefits, please detail. If measurable benefits are not yet able to be documented, why not? Too early, other reasons? In cases where measurable benefits have not been documented, could you detail *expected* benefits from these programs? This will provide a reference point against which future status reviews can be compared. Unless or until measurable objectives of conservation measures to benefit pallid sturgeon recovery are articulated the ability to evaluate success within an adaptive management framework will be challenging. This status review would be an ideal vehicle to provide this guidance.

Quality of evidence used to evaluate pallid sturgeon status. *There is much contention over the status of pallid sturgeon throughout its range. It is imperative given the questions being raised by basin stakeholders over the quality of science surrounding pallid sturgeon decisions (See Spring Rise Process at <http://missouririver.ecr.gov/>) that scientific evidence used to assess pallid sturgeon status be of the highest quality and subjected to independent science review. This is most effectively accomplished through publication in peer-reviewed outlets. The use of “personal communication” is discouraged and should be used with great caution as (1) validity of personal communication statements cannot be independently confirmed, and (2) it is not possible for the reader to separate opinion from scientifically supported evidence.*

I recommend considering the principles for independent review for Corps projects in the National Research Council (2002) report to assist in developing guidelines for pallid sturgeon science.

References. *The reference to Kuhajada et al. in press of larvae as “may have been pallid sturgeon” is not provided in the references on CD provided reviewers, nor is the Murphy et al. in press reference, although both are in the Report references. Please add both and any others listed in Literature Cited, but not included on CD in the final product. Status report readers need to be able to access all citations or they should be deleted as preparers of the report should not have exclusive access to any information. Other manuscripts submitted from the Scaphirhynchus Symposium and very relevant to pallid sturgeon status also should be incorporated into this review (e.g., Przemyslaw and Wildhaber accepted) and made available as soon as they are accepted for publication.*

Pg 8, 292-295. “The wild pallid sturgeon population trend has remained relatively unchanged in RPMA 1 since listing, however, the population is being successfully supplemented with hatchery produced fish (U.S. Fish and Wildlife Service 2006).”

I cannot determine what evidence was used to reach this conclusion and similar statements for other RPMAs? Do we know what the population was at listing to provide a baseline against which to compare subsequent population estimates? Reporting length frequency data (e.g. Figure 2) or yearly catch data (see previous comment) tells us nothing about **population** size or its trends. To evaluate the hypothesis that *size frequency of catches is stable over time* (note that size frequency distributions provide no evidence of population trends, but just the distribution of lengths within catches) one needs to see diagrams like Figure 2 for each year or at least for 3 to 5-year intervals (e.g., see Figure 12) and then test if the frequency distributions are statistically similar over time. If too few individuals are captured then there is insufficient data to make a conclusion – not conclude that the population is stable.

Pg 8, 298-300. “Current population estimates suggests that as few as 45 wild pallid sturgeon still remain in RPMA 1 (Bill Gardner, Montana Fish Wildlife and Parks (MFWP, personal communication, 2005).”

Formal analyses yielding population estimates would be very valuable. Can you include the results of this and methods applied along with estimates of confidence intervals so the reader can evaluate its robustness? The potential value and import to recovery of population estimates is great and thus they should be published (preferably in a peer reviewed outlet) if they are to be used to affect recovery actions. See general comments about using “personal communications”

Pg 13, 420-428. Identifying larval and juvenile pallid sturgeons is exceedingly difficult. All tentative IDs of larval pallid sturgeon must be verified by recognized experts (e.g., Darrel Snyder, Colorado State University Larval Fish Laboratory) before they are reported. I am aware that the USFWS Office 1990s larvae were confirmed by Snyder, but please include confirmation of those reported by Mestl, Herzog, and others – or acknowledge their tentative status. The following statement (Pg 17, L528-532), “One recent study found that character indices do not correctly identify small Upper Missouri River hatchery reared juvenile pallid sturgeon (<250 mm SL) from shovelnose or hybrid sturgeon, or reliably separate larger pallid sturgeon (up to 600 mm SL) from hybrid sturgeon (Kuhajda and Mayden 2001).”, implies that statements made about recruitment of pallid sturgeon or capture of small unmarked pallids should be viewed with caution when assessing population status. Until genetic techniques are available to provide a probability statement of larvae being a pallid sturgeon (Heist et al. proposal recently approved for funding through the SSP program), conclusions about pallids population status based on larvae or juveniles are suspect.

Pg 18, 552-554. *“Although these ratios must be interpreted with caution, they demonstrate an improvement in knowledge of, and ability to collect pallid sturgeon in large river habitats.”*

I agree with this statement, and in particular urge you to note that such ratios, unless adjusted for differential gears used or differential collection effort, are not helpful to evaluate the status of pallid sturgeon populations.

Pg 24, 800-802. *“A single low head dam in the middle Mississippi River near the mouth of the Missouri River between RPMA 4 and 5 is not believed to impede movement of fish.” Please include the name of this dam. If the sentence refers to Chain-of-Rocks, then I agree with the statement. However, if the sentence is referring to Melvin Price (Lock and Dam 26), then there is substantial evidence that Mississippi River locks and dams impede up-river movement of migrating fishes in general (see Wilcox et al. 2004). This is why the Upper Mississippi River Navigation and Ecosystem Sustainability Program is proposing multi-million dollar fish passage facilities on navigation dams.*

Pg 25, 835-837. *“Recent work by Gerrity (2005) suggests that immature pallid sturgeon are more likely to utilize the lower reaches of RPMA 1 than are shovelnose sturgeon.” This statement is incorrect as Gerrity examined hatchery reared juvenile pallid sturgeon (HRJPS). Please revise.*

Pg 29, 1035-1042. *“It has been considered that pallid sturgeon spawn in the spring or early summer as do other sturgeon species. However, the capture of Scaphirhynchus larvae and post-larvae in the Mississippi River during fall months as well as the spring, could be interpreted as an extended season or a second spawn in the lower latitudes of distribution (P. Hartfield,*

USFWS, personal communication, 2006). An alternative hypothesis to explain this could be later Missouri River spawning dates occurring in more northern latitudes and later downstream drift of those post-larvae pallid sturgeon being collected in the Mississippi River.”

The italicized alternative hypothesis cannot explain presence of larvae in the Mississippi River during the late summer and fall months for two reasons. First, the hypothesis that larval Scaphirhynchus drift downstream to the Mississippi River from more northern latitudes – but do not grow, as would be necessary for them to remain as larvae while drifting downriver – untenable given the high energetic demands of larval fishes and the high mortality if they do not feed once the yolk is absorbed (Fuiman and Werner 2002). Second, U.S. Fish and Wildlife Service Columbia Missouri Fishery Resources Office’s data shows that age-0 Scaphirhynchus \leq 60 mm TL were collected from the lower Missouri River from April to October 2004 (see Figure 1 attached) supporting for the Missouri River Hartfield’s hypothesis of a protracted spawning season for the Middle Mississippi. Additionally, Wildhaber et al (2006) using histological analysis of shovelnose sturgeon ovaries reported “spawning condition” females (oocyte reproductive stage V: follicles are black) in the lower Missouri River from January through August, although the greatest percentage of stage IV (pre-spawning: follicles enlarge, begin to turn black) and stage V females were collected in April and May. The evidence for a protracted spawning season for Scaphirhynchus sturgeons is quite substantial.

Pg 33, 1174-1176. “*Work in this reach indicates that it possesses necessary habitat and is suitable for pallid sturgeon recovery efforts (Jordan et al. In press).*”

This paper deals with activity patterns and habitat use of 3-year old stocked pallid sturgeon in RPMA 3. It is my understanding that recovery requires successful natural reproduction which was not evaluated in the cited paper. The study showed that resource conditions within RPMA 3 were suitable for growth of sub-adult pallids – this is not the same as “suitable for recovery”. Revise report text to more accurately reflect the studies conclusions.

Pg 34, 1206-1208. “*Increased discharge in the spring followed by low discharge in the summer may provide missing cues suspected as one cause of little to no spawning/recruitment of pallid sturgeon in this reach.*”

How does this statement relate reports of a protracted spawning for Scaphirhynchus and the observation of larval Scaphirhynchus in the lower Yellowstone and upper Missouri Rivers in years with high, low, or no spring rise (Pat Braaten, PowerPoint presentation to Spring Rise Process, 2005)? My point here is that evidence for the necessity of a spring rise as a spawning cue for Scaphirhynchus is equivocal, making the statement above a hypothesis. I suggest revising text to say, “...in the summer is hypothesized to provide missing...”

Pg 34, 1223-1226. *Suggest revising the sentence by adding italicized word “potential”:* “*Based on current and anticipated commitments for aquatic habitat restoration in this RPMA, the next several years should produce increased quantity and quality of potential sturgeon habitat in RPMA 4...*”

Finding a few pallids using a rehabilitated habitat is certainly a positive observation, but statements about their value should be made with caution until more definitive evidence is available. For example, larval and adult pallids also have been captured in the channelized lower Missouri River; does this mean we should channelized currently unchannelized reaches to further restoration efforts?

Pgs 35-36. Mississippi River (RPMA 5). *The text here summarizes a variety of acquisitions of flood-prone floodplain areas. These will certainly benefit rehabilitation of the Mississippi River floodplain ecosystem, but what evidence is there that these areas will specifically benefit pallid sturgeon that as a fluvial specialist species (Galat et al. 2005) is highly unlikely use floodplain habitats? It believe it is misleading to imply that mitigation projects for Missouri or Mississippi River navigation and bank stabilization programs that restore floodplain lands have a direct benefit on pallid sturgeon recovery. I'm aware of no evidence in this document or other literature that supports this hypothesis. These acquisitions are admirable as part of a broad ecosystem restoration program, but it currently is somewhat of a stretch to argue they specifically benefit pallid sturgeon recovery.*

Pg 40. 1479-1480. *“Little peer-reviewed information is available documenting piscivory as a threat limiting the recovery of the pallid sturgeon.”*

I find it disconcerting that here the review remarks there is little peer reviewed information supporting piscivory on pallid sturgeon, yet the majority of evidence on other aspects of pallid sturgeon biology and ecology provided in this review up until this point (genetics excluded) also has been derived from non-peer reviewed agency reports or equally non-peer reviewed personal communications. Such selective statements suggest the authors are biased against certain hypotheses of what factors are contributing to pallid sturgeon declines. Note that Quist et al. (2004) report predation as a general research hypothesis related to pallid sturgeon recovery (10.4, Pg 27). Additionally piscivory is considered a potentially important source of predation to hatchery stocked white sturgeon as Gadomski, D. M. and M. J. Parsley (2005) conclude “Our study demonstrated that predation is a likely cause of mortality of age-0 white sturgeon and may be contributing to the year-class failures that have been observed. In addition, the results from this study could be used to reduce the predation risk of artificially propagated white sturgeon released to augment declining populations since fish could be reared to sizes where their vulnerability is low.” Finally, Pflieger and Grace (1987) considered increased predation by non-native fishes coupled with increased water clarity as a result of impoundment to be a potentially significant factor affecting populations of native Missouri River fishes.

The Braaten and Fuller progress reports (also not non-peer reviewed) are cited as evidence that piscivory is not an important factor in sturgeon mortality. Their study examined food habits for only two months per year and did not evaluate post-stocking diets of potential piscivores downstream for pallid sturgeon stocking sites.

Clearly evidence for the importance of piscivory as a factor contributing to pallid sturgeon mortality is equivocal and deserves further study to support or refute the hypothesis, discounting it with anecdotal evidence will not make it go away.

Credibility of this report requires objectivity in reporting all viable hypotheses. The peer-reviewed literature indicates predation is clearly a potential factor that could be affecting mortality of pallid sturgeon and particularly hatchery reared and stocked juveniles. As such, it deserves equal consideration with other the poorly documented hypotheses for population declines treated in this review.

Pg 46. Population size section and specifically line 1742. *“Pallid sturgeon population size in the Missouri River is well documented.” This statement and much of what is in this section is unsubstantiated. The only information reporting population size in this report that this reader remembers seeing is that of Gardner for the upper Missouri River as a personal communication.*

See previous comments on the review's misuse of the term population size for catch or number sampled. Statements regarding changes in numbers of fish collected in various RPMAs cannot be used to make conclusions about population size unless they are adjusted by effort expended or used as input to quantitative population estimates (e.g., mark-and-recapture studies).

Pg 49, 1849. I recommend revising, “Develop objective and measurable recovery criteria” to add ... *and a science-based, independently reviewed program that evaluates implementation of recovery criteria and develops periodic report cards of recovery success.* Objective and measurable recovery will not be successful unless accompanied by research and monitoring that is directly tied to evaluating recovery criteria and programs are made accountable to provide quantitative products that address the measurable criteria. See Barko et al (2006) for examples of an adaptive management science process being implemented in the Upper Mississippi River and Weimer et al. (2006) for guidelines to develop protocols and information products for the application of adaptive management within DOI. Both sources can aid in developing objective and measurable recovery criteria and in their effective implementation, evaluation, and revision based on new information.

Pg 49, 1849. I very much agree with this recommendation and urge the FWS and COE to examine the Tear et al. (2005) paper: Setting measurable objectives in conservation, and follows its recommendations.

Pg 49, 1861-1879. Data needed for next 5-year review. Given the exponential increase in research and monitoring on *Scaphirhynchus* sturgeons as a result of the BiOp RPAs it will be a formidable task to thoroughly evaluate pertinent information for the next 5-year review. I strongly urge you to encourage the various research, monitoring, and evaluation programs (RM&E) to perform their own rigorous 5-year analyses related to the specific objectives of each program. Moreover, I encourage the FWS to provide each of the programs with specific questions they need answers to that will facilitate these programs providing products to the COE and FWS that are meaningful for decision making. Perhaps this will make your difficult task 5 years from now somewhat less challenging?

Improving use of science in pallid sturgeon conservation. River biologists and scientists are considered to be experts in their fields and are being asked to provide decision makers with reliable advice. The extent to which their advice is reliable depends on following principles of good science. Efforts to conserve the endangered Florida panther were severely compromised due to implementation of unreliable inferences. I recommend reviewing the Conroy et al. (2006) paper where they provide guidelines that should be equally applicable to developing reliable science for pallid sturgeon recovery.

References Cited in Review

- Barko, J.W., B.L. Johnson, and C.H. Theiling. 2006. Environmental science panel report: implementing adaptive management. NESP ENV Report 2. U. S Army Engineer District, Rock Island IL.
- Bagenal, T. 1978. Methods for the assessment of fish production in fresh waters. Blackwell Scientific Publications, Oxford.
- Conroy, M.J., and 3 coauthors. 2006. Improving the use of science in conservation: lessons from the Florida panther. *Journal of Wildlife Management* 10: 1-7.

- Fuiman, L., and R. Werner. 2002. Fishery Science--The unique contributions of early life stages. Blackwell Publishing, Ames, Iowa.
- Gadomski, D.M., and M.J. Parsley. 2005. Laboratory studies on the vulnerability of young white sturgeon to predation. *North American Journal of Fisheries Management* 25:667–674.
- Galat, D.L. and 7 coauthors. 2005. Spatiotemporal patterns and changes in Missouri River fishes. Pages 249-291 in J.N. Rinne, R.M. Hughes, and B. Calamusso (editors). Historical changes in large river fish assemblages of the Americas. American Fisheries Society, Symposium 45, Bethesda, Maryland.
- National Research Council. 2002. Review procedures for water resources project planning. Panel on Peer Review, National Academy Press, Washington.
- Pflieger, W.L., and T.B. Grace. 1987. Changes in the fish fauna of the lower Missouri River, 1940–1983. Pages 166–177 in W. L. Matthews, and D. C. Heins, editors. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman.
- Przemyslaw. G.B., and M.L. Wildhaber (accepted). Population viability analysis of Lower Missouri River shovelnose sturgeon with initial application to the pallid sturgeon. *Journal of Ichthyology*.
- Quist, M.C., and 12 coauthors 2004. Research and assessment needs for pallid sturgeon recovery in the Missouri River. Final report to the U.S. Geological Survey, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and U.S. Environmental Protection Agency. William D. Ruckelshaus Institute of Environment and Natural Resources, University of Wyoming, Laramie, WY.
- Tear, T.H., and 11 coauthors. 2005. How much is enough? The recurrent problem of setting measurable objectives in conservation. *BioScience* 55: 835-849.
- Van Den Avyle, M.J., and R.S. Hayward. 1999. Dynamics of exploited fish populations. Pages 127-166 in C. C. Kohler and W. A. Hubert. *Inland Fisheries Management in North America*. American Fisheries Society, Bethesda, MD.
- Weimer, R.T. B.K. Williams, R.C. Szaro, and C.D. Shapiro. October 2006. Adaptive management. The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group. U. S. Department of the Interior, Washington, D.C.
- Wilcox, D.B., and 7 coauthors. 2004. Improving fish passage through navigation dams on the Upper Mississippi River. ENV Report 54. U. S Army Engineer District, Rock Island IL.
- Wildhaber and 5 coauthors. 2006. Development of methods to determine the reproductive status of pallid sturgeon in the Missouri River. Final Science Support Program Report to U. S. Fish & Wildlife Service. U. S. Geological Survey, Columbia Environmental Research Center, Columbia, MO.
- Wooten, R.J. 1990. Ecology of teleost fishes. Chapman & Hall, London.

D. Response to Peer Review

RESPONSE TO REVIEWER COMMENTS (Dr. R.G. Bramblett):

Pg. 3 and 4 While data are available that indicate population structuring range-wide, listing Distinct Population Segments (DPSs) must comply with the 1996 DPS policy. Inherent in that policy is the criteria of discreteness and significance. Genetic data suggest an isolation by distance model indicating some historical level of gene flow among adjacent groups. This brings up the question of both discreteness and significance. At this time, the species is afforded full protection of the ESA and applicable regulations and laws. Listing DPSs at this time will not improve or increase protection. However, given the current data, it may be warranted to pursue DPS listing in the Upper Basin if data support a change in status (down listing or delisting) in other portions of the species' range.

As written on both page 8 and 9, the population trend at the time of listing was believed to be declining thus the statement that the wild population trend is relatively unchanged from the time of listing appears accurate. However, these sentences were reworded for clarity.

The identification of successful supplementation is somewhat open to debate and depends on one's definition of success. Because of the life history of pallid sturgeon and short duration that supplementation efforts have occurred, it is not yet possible to evaluate the long-term success of supplementation efforts, that is there are not sufficient data to adequately evaluate growth and survival. The language was modified to strike the word successfully. However, the catch data does indicate that stocked fish are surviving and as new data become available, better assessment of growth, survival, and ability to reach sexual maturity will be evaluated

Pg 11-12 Additional data from Shuman *et al* (2005) has been added. Extirpated was added to sentence.

Pg 13-14 Concerns were added to the data needs section of the 5-year review

Pg 15-18 Additional data has been added regarding capture of stocked fish.

The 1992 year class of hatchery reared pallid sturgeon released from Blind Pony in 1994 should be recruiting to adulthood, so yes, the 700-950 mm pallid sturgeon in Figure 10 are the only current known hatchery released fish that are of a size consistent with adults. Incidentally, in 2006 siblings of those fish (1992 year class from blind Pony) held at Gavins Point NFH were documented to have spawned as part of propagation efforts this year.

The use of pallid sturgeon to shovelnose sturgeon ratios is common in the literature. However, simply reporting the ratios without supplemental data does little to support what these ratios mean. These ratios can be misleading, and as presented are not good indicators of population status or trend. To avoid confusion, this section has been removed.

Pg 21-24 See comments above regarding DPS listing.

Pg 25 Comments incorporated into body of text

Pg 26 Comments incorporated into body of text

Pg 30-31 See comments above regarding DPS listing

Pg 32 Language has been added to highlight this issue

Pg 41 Reworded for clarity.

Pg 46 Language added to help address this concern.

Pg 47 Colombo *et al* (*In Press*) have age data indicating that pallid sturgeon sampled from the MMR were 15 years and younger. Reference has been added.

RESPONSE TO REVIEWER COMMENTS (Gene. Zuerlein):

Editorial comments were incorporated.

1. National Pallid Sturgeon Database has been cited as USFWS 2006b and added to literature cited section. Hofpar (1997) and Reade (2000) references have replaced G. Mestl pers. comm. Language added to highlight the importance of lower Platte River as well a Snook (2002) and Swingle (2003) references. Language discussing cooperative agreements among states to protect habitat in the Platte has been incorporated into section II.C.2. Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms) - III.C.2.a. Present or threatened destruction, modification or curtailment of its habitat or range.
2. The descriptive nature of habitat loss appears sufficient for the purpose intended. Details of documented habitat loss can be found in the Biological Opinions and thus only a general overview is provided in this document.
3. Language added relative to importance of prey species.
4. No response/changes identified.
5. No response/changes identified.
6. No response/changes identified.

RESPONSE TO REVIEWER COMMENTS (Dr. Vince Travnichek):

Editorial suggestions were incorporated.

RESPONSE TO REVIEWER COMMENTS (Dr. Jim Garvey):

General Thoughts

1. Language was added to indicate that work is being implemented to evaluate the entrainment concerns and dredge operations.
2. Implementation of appropriate supplementation activities is described in the Pallid sturgeon range-wide stocking and augmentation plan (US Fish and Wildlife Service 2006a). This plan is updated regularly to insure appropriate data are incorporated into implementing the most risk averse approaches.
3. The current data representing genetics and morphology are presented in this document. What is described here by the reviewer has been addressed in the data needed for next 5-year review section.
4. While the main-stem Missouri river dams will likely always have an effect, there are efforts underway to improve drift distance to improve early life survival. At this time, supplementation is considered a short term effort to prevent local extirpation until adequate habitat improvement measures have been implemented to restore self-sustaining populations.

Specific Comments

1. Dam locations have been incorporated into Figure 1.
2. This appears to be more of a general comment from the reviewer. Language has been added to indicate the decline of wild fish in the Missouri RPMA discussions.
3. This appears to be more of a general comment from the reviewer. The 5-year review and associated bibliography should help address the reviewer's comments. However, a graph of cumulative publications through time seems outside the scope of the 5-year review process.
4. Identification of the demarcations of the upper RPMA's being based on physical features becomes more evident with the addition of dam locations in Figure 1.
5. The reference to collection of pallid sturgeon in the Kaskaskia River has been modified to more accurately reflect that pallids are collected near this river, and not implying in the river.
6. RPA implementation of the Mississippi River Opinion (USFWS 2000b) is discussed within the document. This likely will be important data for the next 5-year review.
7. Columbo *et al.* (In Press) references has been incorporated, where appropriate.
8. Because Illinois has not implemented regulations to protect *Scaphirhynchus* (at the time of drafting) it has not been identified. If changes are implemented they will be incorporated into the next 5-year review.
9. Overexploitation associated with similarity of appearance has been documented and discussed in this document. It is outside the scope of this document to suggest closing seasons. That recommendation should be considered and reviewed by the basin workgroups and Pallid Sturgeon Recovery team.
10. While this is important, the Recovery Team and Basin Workgroups are the appropriate venue to insure coordination.
11. Added to data needed for next 5-year review section.
12. Supplementation practices are described in the Pallid sturgeon range-wide stocking and augmentation plan (USFWS 2006a). Updates of this document appear to be a more appropriate venue to address this comment.

RESPONSE TO REVIEWER COMMENTS (Dr. William T. Slack):

Editorial comments provided on hard copy were incorporated.

Response to Bullet Items

- Bullet 1** Labels have been removed from the top of figures.
- Bullet 2** Document was edit to improve consistency on term and citation formats.
- Bullet 3** Language was added to clarify Wild, Hatchery, and Unknown designations.
- Bullet 4** Reworded for clarity.
- Bullet 5** Language added to incorporate potential for gear selectivity/bias
- Bullet 6** Figure description modified to highlight the reporting by Federal fiscal year.

- Bullet 7** The term intercross is used synonymously with hybrid or intermediate. Intercross is defined in the context of the USFWS and NMFS policy on controlled propagation (Harrelson and Nammack 2000) as “Any instance of interbreeding or genetic exchange between individuals of different species, subspecies, or distinct population segments of a vertebrate species.”
- Bullet 8** Seems to be more of general comment. It does appear to reflect what is reported in Dugo et al. However, we currently are not fortunate enough to have adequate movement data nor adequate analysis or identification of regionally isolated alleles to fully comprehend fine scale genetic relationships within the pallid sturgeon population.
- Bullet 9** Correct, historical data are lacking. However, Bramblett (1996) documented the following: pallid sturgeon prefer the Yellowstone River over the Missouri River below Fort Peck, many fish move into the lower Yellowstone River during spawning season, ripe fish occur in the Yellowstone River, and aggregations of fish during spawning season strongly suggest that pallid sturgeon spawning occurs in the lower 10-15 RKM of the Yellowstone River. *In 2003*, Swingle (2003) collected two presumed wild pallid sturgeon in the lower Platte River and subsequently followed their movement via telemetry. One of these was a gravid female collected early May 2001 that subsequently moved into the Missouri River on June 9, 2001, suggesting the lower Platte River may be an important tributary for spawning. Work by these authors suggest that these two tributaries are currently important and thus likely were historically. However, this section was modified and the word important was replaced with “were also utilized.”
- Bullet 10** Gerrity (2005) did not determine why juvenile pallid sturgeon utilized the lower reaches of RPMA 1 when compared with immature shovelnose sturgeon and thus it is not reported. Language was added that may help clarify how or why selection for downstream reaches, by pallid sturgeon, could influence survival. Manly this has been attributed to conversion of lotic habitats to more lentic environments when the reservoir is at higher pool levels.
- Bullet 11** Introductory paragraph has been revised.
- Bullet 12** Tom Keevin was the source of the number of the side channels. The asterisk is there to identify where the low water reference plane definition came from. Many readers may not be familiar with the LWRP yet it seemed cumbersome to include the Baker reference with in the sentence.
- Bullet 13** This seems to be more of a question than a comment. Early in the development of the recovery plan, a cautious approach was applied regarding using range of shovelnose to describe range of pallid sturgeon. For example, there is a historical population of shovelnose sturgeon in the Bighorn River as far upstream as Wyoming. This has led some folks to consider that the Bighorn River could have been historically important for pallid sturgeon. However, this is mostly speculative and thus does not appear in literature.

- Bullet 14** Data presented on page 26 and summarized on page 29 is calculated for velocities of 0.35 and 0.55 m/s. I am not aware of average velocities on the Mississippi River so you may very well be right. Reference to late season larval and post-larval river sturgeon in the Mississippi River, possibly coming from the Missouri River, has been removed from section *II.C.1.f. Other:* where it was speculated.
- Bullet 15** There are little historical data pertaining to this species to determine if it is a new colonization event or re-colonization of previously occupied habitat. However, establishment of a species believed to utilize habitats similar to pallid sturgeon as well as documented forage for pallid sturgeon suggests there likely is some potential benefit.
- Bullet 16** Bank stabilization is used loosely to define those activities intended to fix a stream banks current location. Armoring with rip-rap or other materials, sheet pile walls, etc., is what is intended.
- Bullet 17** The modification of flows from Gavins Point Dam to stimulate a biological response from fishes as well as potentially create new habitat is an RPA and that is what is identified in the Biological Opinion. Some minor verbiage change to promote clarity.
- Bullet 18** These activities are described in the Biological Opinion.
- Bullet 19** Cook reference was added.
- Bullet 20** Section restructured to improve clarity and reduce redundancies.
- Bullet 21** More description added to section describing Phase I and Phase II rules.
- Bullet 22** No changes suggested.
- Bullet 23** Significantly has been changed to substantially and structural corrections were made.
- Bullet 24** Changes made to address.
- Bullet 25** The current stocking and augmentation plan does not provide for supplementation within RPMA 5 or 6. Available data support a need to supplement within RPMA 4. Revisions to the stocking and augmentation plan have been made by the Pallid Sturgeon Recovery Team to better insure appropriate genetic supplementation through this program.
- Bullet 26** Identification of spawning habitat added to future actions.
- Bullet 27** This comment, while quite valid, is outside the scope of the 5-year review.

RESPONSE TO REVIEWER COMMENTS (Dr. D. L. Galat):

Comment 1: Species status is listed as “stable” on pg 2 I.C.2.

This designation of “stable” was not the result of this review. Instruction to authors, (not provided to peer reviewers) requests the status (increasing, decreasing, stable, presumed extinct, only in captivity, unknown) as indicated in most recent biennial Recovery Report to Congress or annual data call (note the date of this Report or data call). This determination of “stable” is on a year to year basis and by definition in this process, Stable means: *“Species for which the information available indicates that the species status neither improved nor declined over the last year (i.e., population numbers remained constant, and threats did not affect species status during reporting period).”*

During this initial development, the status was listed as “stable.” This report factors the entire range of the species and not just the Missouri River. What also is not indicated in that section of this review is that the annual data call for 2006 indicates a declining long term trend, stating *“Again sufficient habitat improvements have not been made to ensure self sustaining populations. Continued stocking by hatcheries, while necessary, is maintaining an artificially robust population.”* Finally, final formatting changes for the 5-year review have removed this reference to species status.

- 1) Language was added to help clarify relevant policies.
- 2) There are few if any data available to determine if recruitment is balancing mortality. Thus this review relies on length frequency data and is assuming length to be indicative of age.
- 3) Language has been added, where appropriate, to discuss sampling effort bias, effectiveness of gears used on smaller size-classed sturgeon, and the apparent lack of recruitment success in the Missouri River.
- 4) Because of the potential for misinterpretation and lack of clarification, references to ratios of pallid to shovelnose sturgeon have been omitted in the final version.
- 5) Language was added for clarity to more accurately reflect and differentiate between the status in the Missouri, Mississippi, and Atchafalaya Rivers.

What is a population?

Much of the criticisms described are justifiable. Currently there do not appear to be data available for PVA type work. Also, there are currently little, if any, references to relative abundance. There are only a few instances where crude population estimates are provided (RPMA 1 and 2). Increased catch with increasing effort is to be expected and on occasions where those data are provided (RPMA 5 and 6), the determination of status remains “unknown.”

Conservation Measures (Pgs 32-37)

Much of the conservation measures described herein have not had adequate time and/or data collected to be documented. Expected benefits should be detailed in the respective biological opinions and that process. Likely a more appropriate vehicle to describe measurable objectives for pallid sturgeon recovery is the Pallid Sturgeon Recovery Plan. This review recommends the measurable and objective criteria be developed and incorporated into an updated plan.

Quality Of Evidence Used To Evaluate Pallid Sturgeon Status

At present there is not an adequate mechanism to require agency funded biologists to publish in peer-reviewed outlets and thus much of the data are contained in agency reports or other “gray literature” or is contained in the collective knowledge and experience of individual biologists/researchers. Personal communications were minimized and only utilized where absolutely necessary. The ESA requires use of “...the best scientific or commercial data available.” The best available scientific data for rare, poorly known species are often not peer-reviewed. There is an abundance of good data specific to individual projects that are not necessarily worthy of stand alone publication, or not ready to be published. If the information is relevant, and the source is credible, then the Service is required by the ESA to consider the information. This 5-year review considered available relevant data in assessing the appropriateness of the current classification of the species. It is outside the realm of this document to develop guidelines for pallid sturgeon science.

References

Every effort was made to obtain electronic copies of referenced materials for the peer reviewers. The pallid sturgeon recovery coordinator hopes to provide electronic copies of referenced material (available for download) for those interested. This will be dependant on workload and may occur until after this review is complete.

Pg 8, 292-295

The statement in question is discussing the trend in the population and not discussing the actual population demographics. For this RPMA, there was a declining trend at the time of listing and no new data are available to suggest this declining trend has changed. Language added for clarity.

Pg 8, 298-300

It is agreed that a more formal analysis of population estimates for all RPMAs is necessary. However, confidence intervals for the data in question were not available.

Pg 13, 420-428

This section identifies the larval pallid sturgeon, identified by Dr. Snyder, and subsequent sentences merely indicate the presence of larval *Scaphirhynchus* suggesting some of those could have been pallid sturgeon and noting it is difficult to accurately identify these smaller fish.

Pg 18, 552-554

Because of these concerns and the potential for misinterpretation, the pallid sturgeon to shovelnose sturgeon ratio references have been removed from the final version of the report.

Pg 24, 800-802

This section is referring specifically Middle Mississippi River and by association the Chain-of-Rocks.

Pg 24, 835-837

Change made to indicate those were hatchery-reared juveniles monitored by Gerrity.

Pg 20, 1035-1042

Changes made.

Pg 33, 1174-1176

The paper by Jordan *et al.* 2006 concludes that RPMA 3 is suitable for recovery efforts (see last line of abstract). This is not to be confused with actual recovery of the species which this paper makes no conclusions about. It basically closes with the following statement: “*However, whether conditions are present to enable a self-sustaining population, the ultimate determinate of recovery success, remains unknown.*” No revision to text is warranted.

Pg 34, 1206-1208

Changes made.

Pg 34, 1223-1226

Suggested changes incorporated.

Pg 35-36, Mississippi River (RPMA 5)

Language added to improve clarity.

Pg 40, 1479-1480

Language was added to address this concern.

Pg 46, Population size section and specifically line 1742.

Section wording changed to address this concern.

Pg 49, 1849

Noted and changed.

Pg 49, 1849

Seemed to be more of a general statement. Comments noted.

Pg 49, 1861-1879

Seemed to be more of a general statement. Comments noted.

Improving use of science in pallid sturgeon conservation.

Seemed to be more of a general statement. Comment noted.

APPENDIX B
Final Meeting Summary
Of August 24, 2006, Pallid Sturgeon Genetics Conference Call

Genetics Advisory Group/Pallid Sturgeon Recovery Team
Conference Call Summary

Participants

George Jordan*

Heather McSharry

Seth Willey

Bobby Reed*

Jan Dean*

Mike Ruggles

Doug Latka*

Robin Waples**

Kim Scribner**

Ed Heist**

Aaron Schrey

Bill Ardren**

Steve Krentz*

Bill Gardner*

Tracy Hill*

Dave Herzog*

Rob Wood**

Bernie Kuhajda*

Paul Hartfield

Gerald Mestl*

Jane Ledwin

Aaron Delonay*

Tim King**

* Pallid Sturgeon Recovery Team member

** Genetics Advisory Group Member

The purpose of the call was to revisit available genetic data to discuss adequacy and relevance to the pallid sturgeon 5-year review as well as what those data mean regarding management/recovery efforts.

The call was initiated at 0908 and concluded at 1245 MDT August 24, 2006. These minutes were finalized and released on September 7, 2006.

Following introductions, Dr. Ed Heist and his research assistant Aaron Schrey presented their research results. The data presented were microsatellite analysis of 16 loci for 539 tissue samples from *Scaphirhynchus* (approximately 60 from the upper Missouri River, approximately 60 from the middle Missouri River, close to 100 from the lower Missouri River, 150 from the middle Mississippi River, and 100 from the Atchafalaya River). The data presented indicate reproductive isolation among most sample areas. Significant F_{st} values were identified in all comparisons except the Lower Missouri River Samples when compared against the middle Mississippi and Atchafalaya River samples (Figure 1).

	Upper Missouri	Middle Missouri	Lower Missouri	Middle Mississippi	Atchafalaya
Upper Missouri	-----	0.033*	0.064*	0.065*	0.079*
Middle Missouri		-----	0.022*	0.037*	0.050*
Lower Missouri			-----	0.001	0.014
Middle Mississippi				-----	0.029*
Atchafalaya					-----

Figure 1. Pairwise F_{ST} between Samples in Pallid Sturgeon. (* = significant at $p < 0.05$). Figure and data courtesy of Dr. Ed Heist and Aaron Schrey. Dr. Heist then presented data indicating a strong patten of genetic isolation by distance (Figure 2).

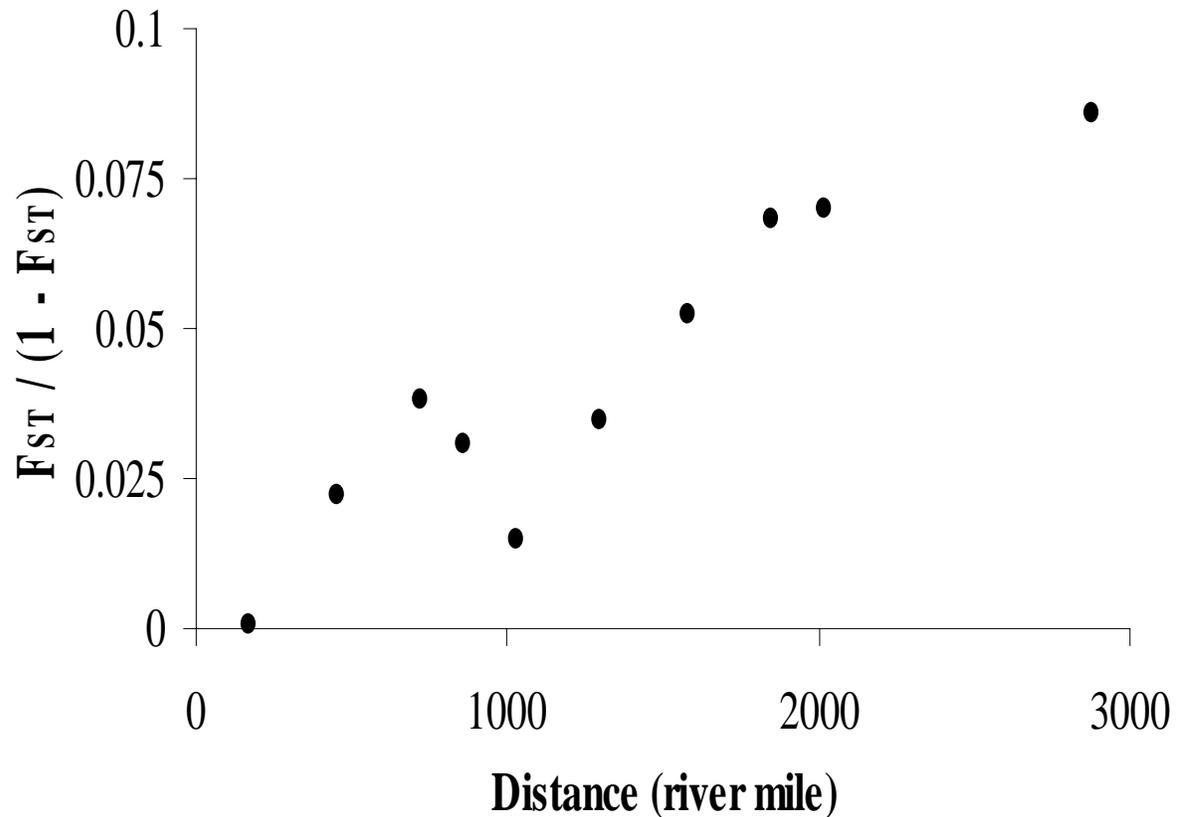


Figure 2. Graph of $F_{st}/(1-F_{st})$ over river miles to demonstrate Isolation by distance. Figure and data courtesy of Dr. Ed Heist and Aaron Schrey.

Finally, genetic grouping data were presented. The results were based on output from the software package STRUCTURE. This program does not require *a priori* species identification and identifies natural groupings among samples to minimize Hardy-Weinberg deviations and linkage disequilibrium. The results presented when all *Scaphirhynchus* samples (pallid sturgeon, shovelnose sturgeon, and hybrids) were combined from all identified geographic areas result in two groups. However, when only putative pallid sturgeon samples were analyzed, the three genetic groups of pallid sturgeon appear across the species range. The three groupings are a well differentiated upper Missouri River Group (green) and two less differentiated lower Missouri, middle Mississippi, and Atchafalaya River group (blue and yellows) (Figure 3 and 4).

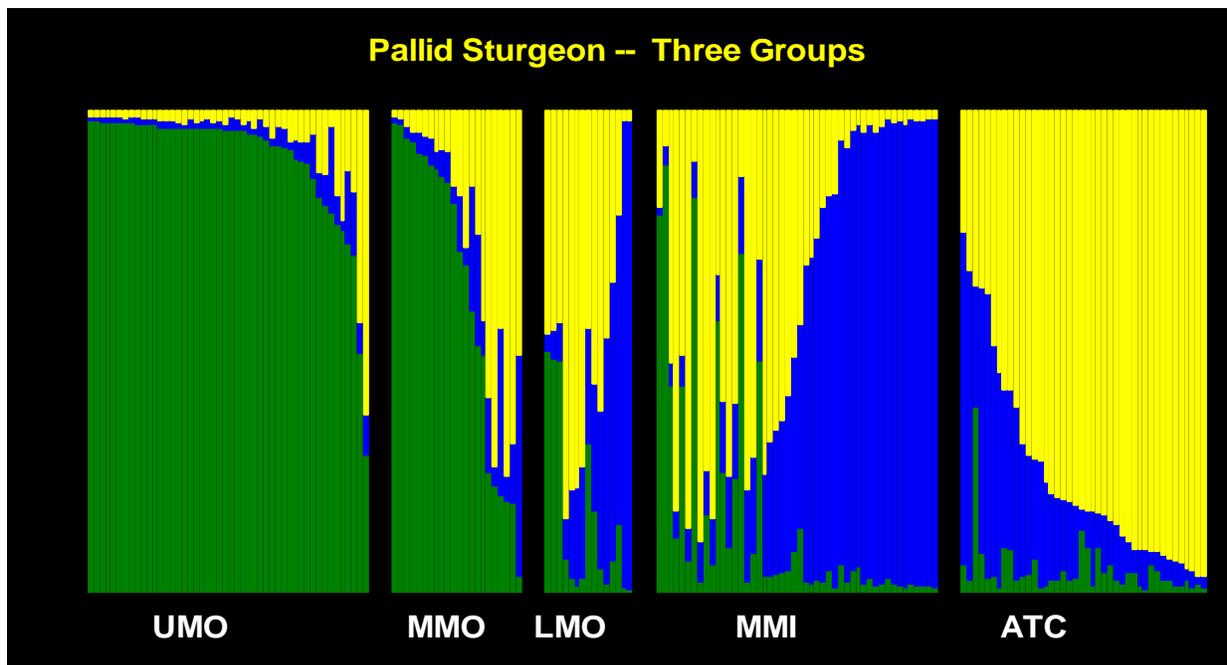


Figure 3. Genetic grouping of pallid sturgeon samples indicating one well-differentiated upper MO group (green) and two less-differentiated lower MO/Miss/ATC groups (blue and yellow). Figure and data courtesy of Dr. Ed Heist and Aaron Schrey.

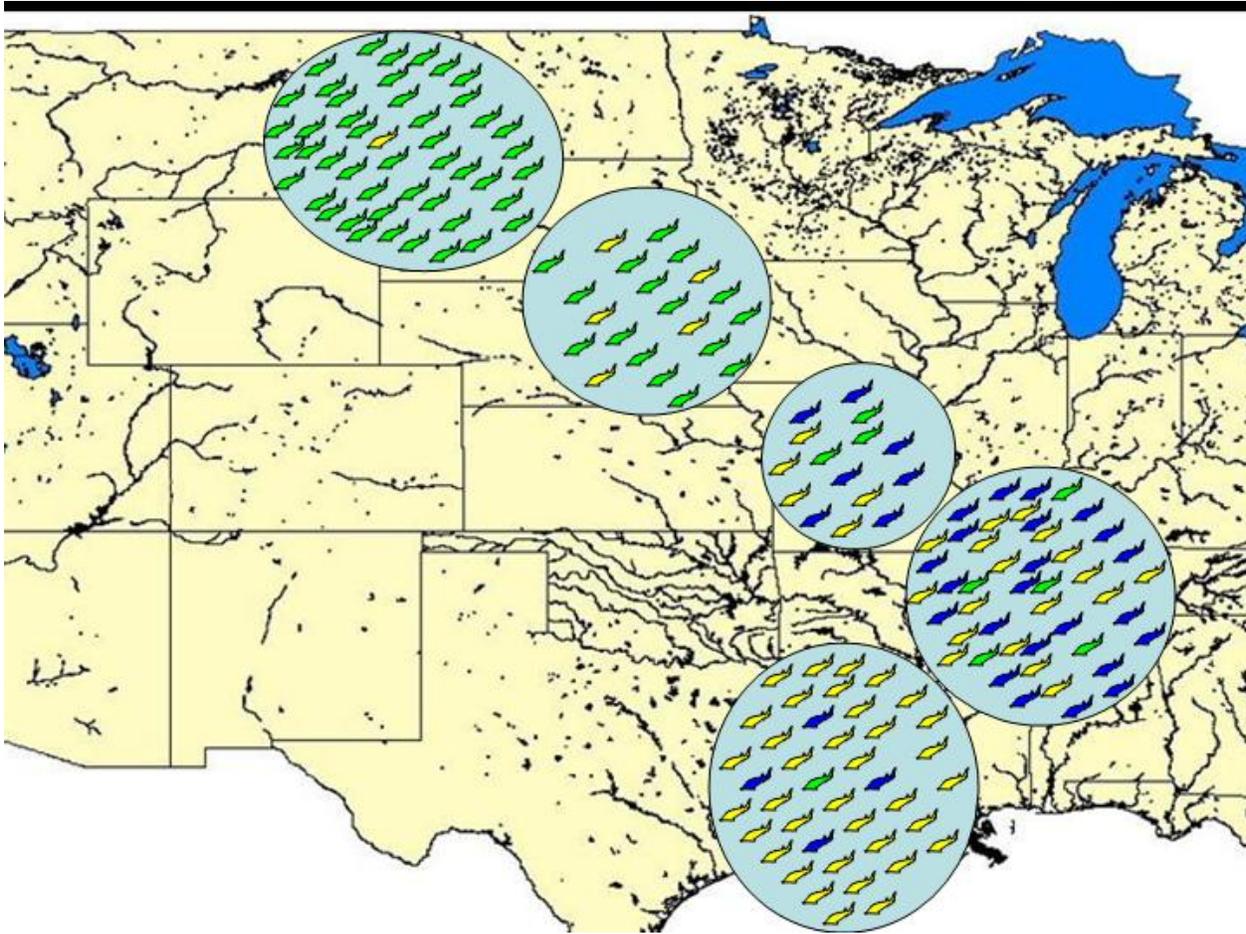


Figure 4. Genetic makeup of five geographic samples (upper Missouri, middle Missouri, lower Missouri, middle Mississippi, and Atchafalaya) of pallid sturgeon. Each fish icon represents an individual sturgeon and the color of the icon indicates which of the three apparent genetic groups to which the fish was most closely assigned. Figure and data courtesy of Dr. Ed Heist and Aaron Schrey.

The conclusions presented by Dr. Heist were:

- Pallid sturgeon exhibit significant differences in microsatellite allele frequencies among regions.
- Upper Missouri River pallid sturgeon samples are most distinct, and genetic structure among lower basin samples is less pronounced and the middle Missouri River samples appearing intermediate to upper Missouri and lower basin samples.
- Stock structure appears to exhibit an “isolation by distance effect”
- Hybridization occurs range-wide yet pallid sturgeon and shovelnose sturgeon are maintaining themselves.

Following this presentation the call was opened to participants for questions and discussions. Following is a summary of the discussions:

A question about the timing of the sample collections and the effects on the data was posed. The samples were collected from pallid sturgeon in an opportunistic fashion, not specifically during spawning periods. This would result in a less detailed picture, yet despite this, there is a surprisingly clear image of isolation by distance (Figure 2).

A brief discussion of hybridization occurred. Hybrids or genetically intermediate *Scaphirhynchus* were found in the samples. Despite the presence of genetically intermediate fish, there are very good [genetically] pallid sturgeon and shovelnose, throughout the range. The data suggests that within the upper Missouri less intermediates or no evidence of “back-crossing” middle Mississippi and Atchafalaya River data suggest a higher number of genetic intermediates in those areas.

In general, there was a pretty high level of confidence in the data analyzed. However, it was noted that the identification of 3 genetic groups of pallid sturgeon should be regarded as very tentative. Robin Waples (Genetics Advisory Group member) cautioned that the software package STRUCTURE has can have difficulty accurately distinguishing among closely related gene pools.

It also was noted that there was apparent gaps in sampling locations. For example there are no lower Mississippi River data, and a large geographical separation between the middle and lower Missouri River samples. These gaps in data could be attributable to some of the differentiation being noticed and completing the samples could provide a better understanding of genetic structuring range-wide.

Following the discussion and presentation of Dr. Heist’s genetic data, Dr. Kuhajda provided information on morphometric variation documented with pallid sturgeon.

Dr. Kuhajda presented photos of morphometric variation in pallid sturgeon collected at the extremes of the species range (Figures 5 and 6) as well as a sheared principal components analysis morphometric measurements collected from upper Missouri River pallid sturgeon, shovelnose sturgeon, and known hatchery-reared hybrids (MO) and lower Mississippi/Atchafalaya River pallid, shovelnose, and intermediate sturgeons (Figure 7).



Figure 5. Adult pallid sturgeon, representing a northern specimen from upper Missouri River (top) and southern specimen from the Lower Mississippi/Atchafalaya River (bottom). Both specimens represent some of the largest specimens from each region. Photo courtesy of Dr. Kuhajda.



Figure 6. Adult pallid sturgeon, including northern specimen from upper Missouri River (right) and southern specimen from the Lower Mississippi/Atchafalaya River (left). Both specimens represent some of the largest specimens from each region. Photo courtesy of Dr. Kuhajda.

Sheared PCA of Morphometric Characters for *Scaphirhynchus* BR ID

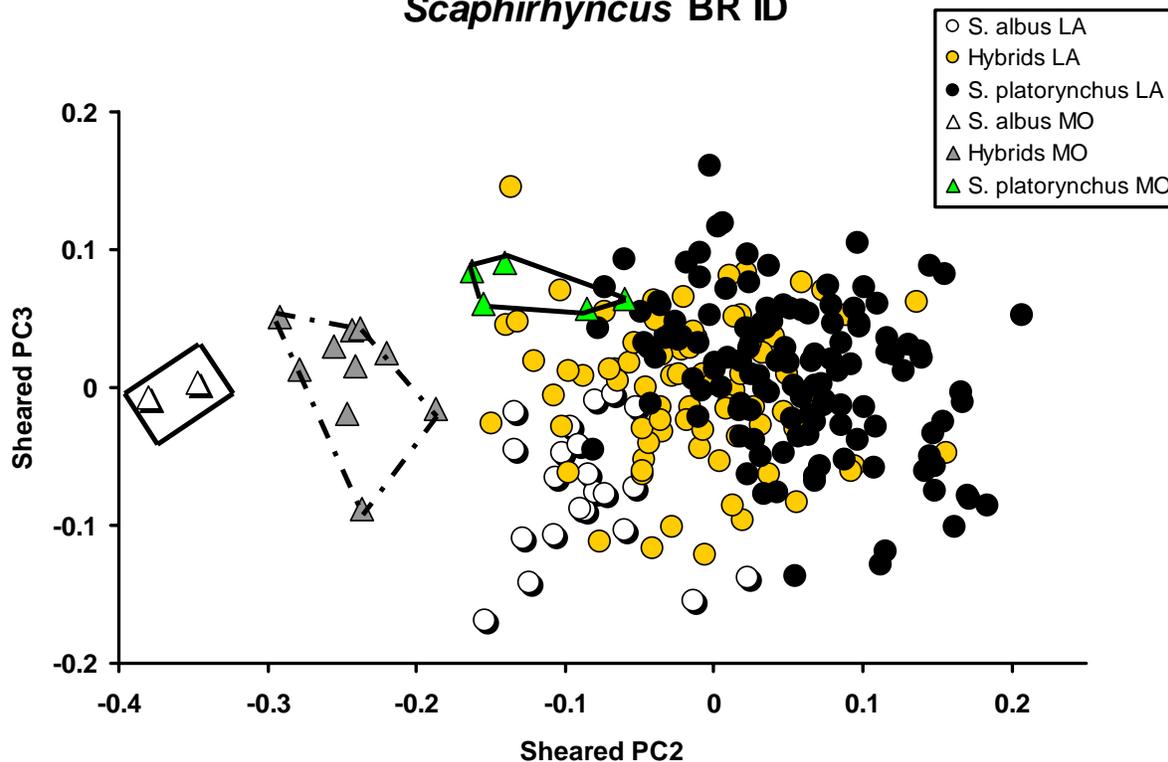


Figure 7. Sheared principal components analysis of 19 head measurements of upper Missouri River pallid sturgeon, shovelnose sturgeon, and known hatchery-reared hybrids (MO) and lower Mississippi/Atchafalaya River pallid, shovelnose, and intermediate sturgeons (LA). Each “dot” represents measurements on an individual fish. Data courtesy of Dr. Kuhajda.

There was some discussion about the photos and data presented. It was postulated that the larger fish were potentially twice as old as smaller fish. The upper basin pallid sturgeon was likely 40+ years old and current data suggest that middle Mississippi pallid sturgeon generally reach ages up to 15 years and lower Mississippi pallid sturgeon generally reach ages up to 20-25 years. Others suggested the size differences could be attributed to a shorter growing season in north latitudes. However, it was indicated that work done by Conover (1990) and others [Power and McKinley 1997] suggests that for some species the opposite is true. In lower latitudes the water temperature heats up faster and may exceed optimum growth temperatures faster than in more northern latitudes, effectively producing a shorter optimum growing season in the south. Dr. Kuhajda explained that the Principal Component Analysis removes overall body size from the equation and is not likely a factor affecting the results identifies in Figure 6.

A reference to a publication (Ruban and Sokolov 1986) also was mentioned that identified morphometric and meristic variation in Siberian Sturgeon, *Acipenser baeri*, some of which were attributed to differing (warmer) temperatures during early developmental periods and demonstrate a high plasticity in the species. Tracy Hill and Dave Herzog indicated that they

collected pallid sturgeon in the lower Missouri and middle Mississippi river with varying rostral shapes with some looking very similar to the upper basin specimen (Figures 5 and 6); suggesting some phenotypic plasticity in the species.

Following the data presentations, the general discussion moved towards the data and what does it mean for recovery actions and the existing stocking plan?

Concerns were apparent about the designatable units identified with in the current stocking and augmentation plan. The circles on the map [page 15 of the plan] appear arbitrary. The circles were adapted from Dr. Heist's data coupled with stocked juvenile pallid sturgeon collection data. May not be the best approach.

A point was made that genetics alone should not be the only data utilized to define stock structure or recoverable units. Genetic data coupled with biogeographic data and other unique traits is a more sound approach. Utilizing the data provided by Dr. Heist and biogeographical information could more accurately help define recovery areas or recovery units. For example, it was suggested that physiographic provinces may be better lines to delineate brood collection areas and stocking boundaries. One possible dividing line could be drawn between the central lowlands and great plains physiographic provinces. This fall line pretty close aligns with the data separating the green group from the yellow and blue groups in Figure 4 above. It was suggested the Platte River might be an appropriate landmark between these provinces.

Summary

- There are data supporting reproductive isolation among pallid sturgeon groups.
- There appear to be three groups of pallid sturgeon, a well differentiated group in the upper Missouri (RPMA 1, 2, and the upper reaches of RPMA 4) and two poorly differentiated groups in the lower Missouri, Mississippi, and Atchafalaya based on the current level of data.
- Genetic structure of pallid sturgeon appears to follow an isolation by distance model.
- Genetic data alone are not sufficient for delineation of population management units. Need to consider biogeography and other traits.
- Current model in stocking plan may not best fit conservation of genetic structure as it pertains to supplementation efforts for recovery.

Recommendations

- Collect genetic samples to fill in geographic sampling voids
- May want to consider recoverable units as they relate to recovery activities.
- Revisit stocking and augmentation plan to re-evaluate current supplementation practices.

Conover, D.O. 1990. The relation for capacity for growth and length of growing season: Evidence for and implications of countergradient variation. Transactions of the American Fisheries Society 119:416-430.

Power, M., and R.S. McKinley. 1997. Latitudinal variation in lake sturgeon size as related to the thermal opportunity for growth. *Transactions of the American Fisheries Society* 126:549-558.

Ruban, G.I., and L.I. Sokolov. 1986. Morphological variability of Siberian Sturgeon, *Acipenser baeri*, in the Lena River in relation with its culture in warm waters. UDC 639.3:597,442:591.49. Originally published in *Voprosy Ikhtiologii*. 3:470-475.