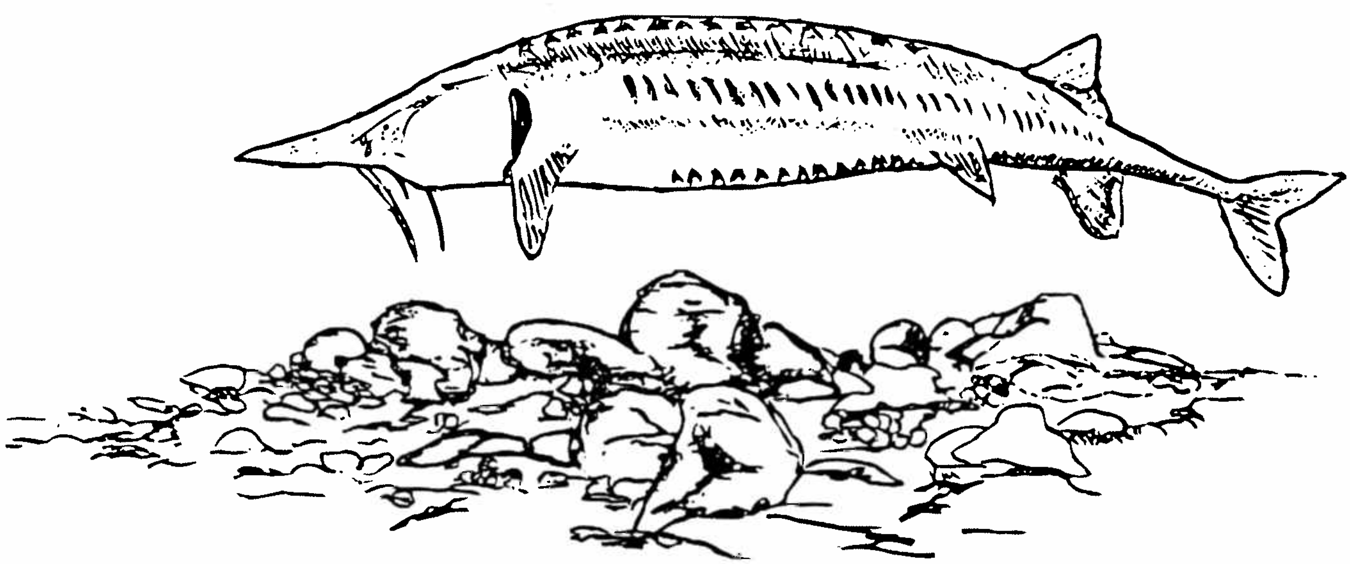
PALLID STURGEON

(*Scaphirhynchus albus*)

Range-Wide Stocking and Augmentation Plan



20 FEBRUARY 2006

PALLID STURGEON
(*Scaphirhynchus albus*)

Range-Wide Stocking and Augmentation Plan

Prepared by the Pallid Sturgeon Recovery Team

for

Region 6
U.S. Fish and Wildlife Service
Denver, CO

Approved: ____ ________________
Regional Director Date

EXECUTIVE SUMMARY{ TC \l1 "EXECUTIVE SUMMARY}

The pallid sturgeon, *Scaphirhynchus albus,* was listed as endangered in 1990 by the U.S. Fish and Wildlife Service. The primary cause identified for the decline in pallid sturgeon population abundance was habitat loss. The loss of habitat was 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. While there are documented recent occurrences of natural reproductive success in Recovery Priority Management Area (RPMA) 2, 4, and 5, there are little to no data indicating substantial natural recruitment of pallid sturgeon in RPMA 1, 2, 3, and 4. Natural mortality, little to no recruitment and increasing threats from commercial harvest in RPMA 4 and 5 are believed to be important factors suppressing pallid sturgeon population abundance and size distribution in the Missouri and Mississippi rivers. Current wild pallid sturgeon populations in RPMA 1 and 2 are comprised of old-aged individuals. No wild pallid sturgeon have been collected within RPMA 3 that were not translocated and no spawning or recruitment success has been detected. Data from RPMA 4 suggest that little to no recruitment is occurring within RPMA 4. An accurate assessment of the status within RPMA 5 is lacking. The data available indicate there may be more pallid sturgeon present than initially believed. However, the sampling efforts extended within this reach do not adequately sample all size/age classes. There are some data suggesting natural spawning success, but no data are available to accurately evaluate recruitment levels. Commercial harvest of *Scaphirhynchus spp.* within portions of RPMA 4 and 5 is a threat that sporadic recruitment can not likely sustain long term. The status of pallid sturgeon in RPMA 6 is also undeterminable at this time. There are no data available to assess spawning and natural recruitment, as the sampling methodologies are focused on one general locality coupled with manipulation of flows through the Old River Control Complex. However, the data do indicate relatively stable length frequencies, suggesting that recruitment may be coming from somewhere. One theory is that larger pallid sturgeon may be attenuated into the population within RPMA 6 via entrainment from RPMA 5. Another equally plausible theory is that the population within RPMA 6 is self sustaining and that sampling practices are inadequate to detect smaller size classes. Adequate sampling efforts in RPMA 5 and RPMA 6 have been restricted by limited funding and personnel resulting in less information available to assess sturgeon populations and movements. Addressing these limitations by development of funding initiatives for recovery/research work in RPMA 5 and 6 is essential to insure the best available data are being utilized for pallid sturgeon recovery efforts.

Post supplementation evaluations within RPMA's 1-5, are producing length frequency data that indicate stocking is proving successful in restoring a more normal distribution of size classes within the species. However, recent data also suggests that there is population structuring within the species and caution should precede future stocking activities and brood source selection.

The primary goals of augmenting pallid sturgeon numbers with hatchery produced individuals are:

1) Supplementing extant populations, where necessary, to establish multiple year classes capable of recruiting to spawning age in order to reduce the threat of local extirpation;
2) Establish or maintaining refugia populations within the specie's historic range;
3) Mimic wild population haplotype or genotype frequencies in hatchery broodstock and progeny and,
4) Minimize the introduction of disease into the wild population.

Objectives set out by this plan do not conflict with the objectives defined in the Policy Regarding Controlled Propagation of Species Listed Under the Endangered Species Act (Eddins 2000) and will be accomplished using the best available information and strategies for propagation and stocking. While much data have been published, there is a substantial amount of information contained within non-peer reviewed agency reports and unpublished literature. Information contained therein will be evaluated for applicability based on when the literature was produced if utilized techniques are generally accepted as adequate, and if the assumptions for which conclusions are drawn are valid. Initially, the maximum number of fish stocked each year may be limited by the number of fish propagated in the hatcheries each year. After attaining the target population within each RPMA, an attempt will be made to restore a more uniform contribution from each propagated family. Annual stocking targets will be based on riverine sturgeon survival rates reported in the scientific literature, RPMA pallid sturgeon specific survival estimates where available, coupled with the best available data in agency reports and expert opinion from those most familiar with pallid sturgeon demographics (i.e. Basin Workgroups). Within each RPMA, annual stocking rates will be recalculated and correspondingly reduced by any wild pallid sturgeon recruitment estimates that are calculated from sampling data. In addition, as habitat restoration continues, wild spawned sturgeon recruitment and survival rates will be reexamined to ensure they reflect any improvements resulting from those restoration efforts, and recalculated as data from monitoring efforts refine survival estimates. Annual evaluation of these data by the Basin Workgroups is imperative to insure the best data govern stocking rates.

Concurrent with stocking, management actions will be undertaken to restore river habitats and flows conducive to natural spawning and recruitment (U.S. Fish and Wildlife Service 2000). A monitoring program designed to evaluate stocking success, population status, and habitat restoration efforts is an integral part of the recovery program. A monitoring effort, the Population Assessment Program, has been developed, independently reviewed and is currently being implemented within the Missouri River Basin (Drobish 2005). A three year pallid sturgeon demographics study for the Middle Mississippi River was developed by an expert panel, reviewed by the Middle Basin Pallid Sturgeon Workgroup, and has recently been completed. Similar efforts should be developed for the rest of the Mississippi and Atchafalaya river systems to insure adequate data are collected to assess pallid sturgeon populations in those reaches. This plan recognizes that stocking/augmentation efforts are tools used in pallid sturgeon recovery, and that monitoring is a tool used to evaluate the stocking efforts and to ensure that assumptions used in this plan remain reasonable. While stocking efforts will help prevent functional extinction, natural recruitment leading to pallid sturgeon recovery is dependent upon habitat restoration efforts throughout the species' range (U. S. Fish and Wildlife Service 1993, U.S. Fish and Wildlife Service 2000) and it is only then that the goals set forth in the Pallid Sturgeon Recovery Plan will be achieved.

This plan, at the time of writing, incorporates the best available data and subsequent recommendations are based on those data. However, as new data are collected and evaluated, changes to the following stocking practices may be necessary. To insure timely updates to this stocking plan, annual review of data within the context of this plan should be completed by the Basin Workgroups. If the Basin Workgroups identify a need to modify this plan based on new or better data, they should submit the desired changes and supporting data to the Pallid Sturgeon Recovery Team coordinator. The Recovery Team will review the data from a range wide perspective and submit their recommendation to support the changes or not, to the Regional Director for the lead region of the US Fish and Wildlife Service (Region 6) as well as the appropriate basin workgroup chair. Through this process, the stocking plan will be reviewed and updated yearly and in a timely fashion, and thus supplementation practices will be modified, as necessary, to insure an adaptive evolutionary conservation approach (Fraser and Bernatchez 2001) for pallid sturgeon recovery. Basin Workgroup input will need to be submitted by December 31 of each year to the Recovery Team Coordinator to insure that updates to this plan can be completed in time to govern the following year's supplementation activities.

High Priority needs to fill information gaps that need to be addressed to insure appropriate information is contained in this plan:

- Determine survival rates for fry through age-2 hatchery reared pallid sturgeon to improve existing stocking calculations.

- Determine RPMA-specific carrying capacities and determine the relationship and/or interaction between effective population size and reach carrying capacities to determine more biologically sound population goals and hence more effective stocking targets.

- Determine survival rates and rearing and stocking effectiveness based on size, age and hatchery origin to better understand the cost-benefit of the pallid sturgeon augmentation program and how that might be improved. It may be more biologically and/or cost effective to stock pallid sturgeon at a smaller size, at different age-classes or reared in different environments.

- Determine if juvenile pallid sturgeon with fin curl problems are anymore physically compromised than normal hatchery pallid sturgeon and how this relates to survival after being released in the wild, and determine how to prevent fin curl.

- Determine tag retention for appropriate tag types and age-classes to improve population and survival rate estimates and to allow stocking to achieve the most biologically and cost effective augmentation program.

- Determine genetic similarities and evolutionary relationships among populations throughout the range of pallid sturgeon, including their evolutionary relationships to shovelnose sturgeon.

Acknowledgments

Special acknowledgments must be extended to the Upper Basin Pallid Sturgeon Workgroup Stocking Committee for providing their input and knowledge into earlier draft versions that ultimately led to development of this plan as well as all Basin Workgroup reviewers, the Pallid Sturgeon Recovery Team, the Pallid Sturgeon Recovery Team's Genetics Advisory Group, and other interested parties who took the time to read and provide comments as this plan was developed.

This document may be cited as:

Jordan, G. R. (Recovery Team Coordinator). 2006. Pallid Sturgeon (*Scaphirhynchus albus*) range-wide stocking and augmentation plan. Pallid Sturgeon Recovery Team plan submitted to U.S. Fish and Wildlife Service, Billings, Montana.

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

CGL .... Conservation Genetics Lab
CWT .... Coded Wire Tag
HRPS .... Hatchery Reared Pallid Sturgeon
LBPSW .... Lower Basin Pallid Sturgeon Workgroup
m .... meter
mm .... millimeter
MBPSW .... Middle Basin Pallid Sturgeon Workgroup
MDC .... Missouri Department of Conservation
MFWP .... Montana Fish Wildlife and Parks
NFH .... National Fish Hatchery
NGPC .... Nebraska Game and Parks Commission
ORCC .... Old River Control Complex
PIT .... Passive Integrated Transponder
RM .... River Mile
RPMA .... Recovery Priority Management Area
SFH .... State Fish Hatchery
USACE .... United States Army Corps of Engineers
UBPSW .... Upper Basin Pallid Sturgeon Workgroup
USFWS .... United States Fish and Wildlife Service
USGS .... United States Geological Survey

INTRODUCTION

The pallid sturgeon, *Scaphirhynchus albus*, was listed by the U.S. Fish and Wildlife Service (USFWS) in 1990 as "Endangered" throughout its range. It is one of the largest and most poorly understood fishes of North America. The pallid sturgeon belongs to a group of river sturgeon with flattened snouts and is one of only three members of the Genus *Scaphirhynchus*. The pallid sturgeon is a "living fossil" that is unique to the few large rivers it occupies. Like other sturgeon, it has a toothless, protrusible mouth under and far behind the nose, and four dangling barbels in front of the mouth. The USFWS approved a recovery plan for the pallid sturgeon in 1993 (U. S. Fish and Wildlife Service 1993). This recovery plan identifies many needed actions necessary to recovery pallid sturgeon through out its range. One of the tasks identified in the recovery plan was to develop a pallid sturgeon stocking plan. It should be understood that within the context of the recovery plan, supplementation efforts are not to be construed as the solution to pallid sturgeon recovery, but rather should be viewed as an important component of recovery efforts necessary to insure persistence of the species until such times that habitat restoration activities in the Missouri and Mississippi river ecosystem are sufficient enough that "...pallid sturgeon are reproducing naturally and populations are self-sustaining..." with sufficient population demographics necessary to "...maintain stability...". When this occurs, continued supplementation should be halted.

{ TC \l1 " INTRODUCTION}

This stocking plan combines and updates the separately developed Stocking/Augmentation Plans for Recovery Priority Management Area (RPMA) 1, 2, 3, 4, 5, and 6.

- RPMA 1 is the Missouri River from the headwaters of Fort Peck Reservoir upstream to the confluence of the Marias River, Montana (Figure 1).

- RPMA 2 includes 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 (Figure 1).

- RPMA 3 covers the Missouri River from 20 miles upstream of the mouth of the Niobrara River to Lewis and Clark Lake (Figure 1.). However, Jordan et al. (2005) indicate that pallid sturgeon stocked below Fort Randall Dam utilize the entire riverine reach and demonstrated seasonal movement patterns. Nebraska Game and Parks Commission (NGPC) (Gerald Mestl, personal communications) noted that their biologists have collected HRPS within the reservoir portion of this reach as well as the South Dakota Game, Fish and Parks via fall gill netting. These data suggest that the entire reach of the Missouri River between Fort Randall Dam and Lewis and Clark Lake is suitable and used by stocked hatchery reared pallid sturgeon. Emigration from RPMA 3 into 4 has also been documented by NGPC and Columbia FRO through RPMA 4 population assessment efforts.

- RPMA 4 is 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. This reach has over 800 RM available for pallid sturgeon, is not impounded, and is biologically and hydrologically connected with RPMA 5.

- RPMA5 is defined as the Mississippi River from Head of Passes, Louisiana to its confluence with the Missouri River (1153 mi (1,922 km) (Figure 1). Within this area, the river is subdivided into two segments: the Lower Mississippi, extending 953 RM from the Gulf of Mexico to Cairo, IL; and the Middle Mississippi, extending another 200 RM to just above the mouth of the Missouri River. There are no impoundments or other obstacles to flow or fish movement in RPMA 5.

- RPMA 6 is the Atchafalaya River where it leaves the Mississippi River to the Gulf of Mexico (Figure 1).

The revision and consolidation of existing stocking plans are being undertaken to:

A. Conduct a risk/benefit analysis for stocking pallid sturgeon in each RPMA,
B. develop protocols for stocking pallid sturgeon progeny at various sizes, and the genetic techniques for identifying hatchery propagated fish that allows stocking non-physically marked hatchery reared pallid sturgeon progeny during various life stages,
C. consider health concerns associated with the pallid sturgeon irridovirus,
D. incorporate new information on population genetic structuring,
E. simplify and quantify the allocation of hatchery propagated pallid sturgeon among the RPMAs covered in this plan,
F. replace outdated stocking plans, and
G. to comply with USFWS policy for propagation of endangered species (Eddins 2000).

The overarching purpose of this stocking plan is to provide a synopsis of what is currently known about pallid sturgeon demographics range wide, assess the risks and benefits associated with stocking within each RPMA, determine if supplementation with hatchery produced pallid sturgeon is warranted within each RPMA given range wide population demographics, and to centralize and update existing supplementation strategies. If stocking is deemed necessary, this plan will outline a strategy for stocking pallid sturgeon within each RPMA with the specific goal of establishing or maintaining a population that is believed to resemble the historical population in abundance and distribution within a range-wide framework for recovery.

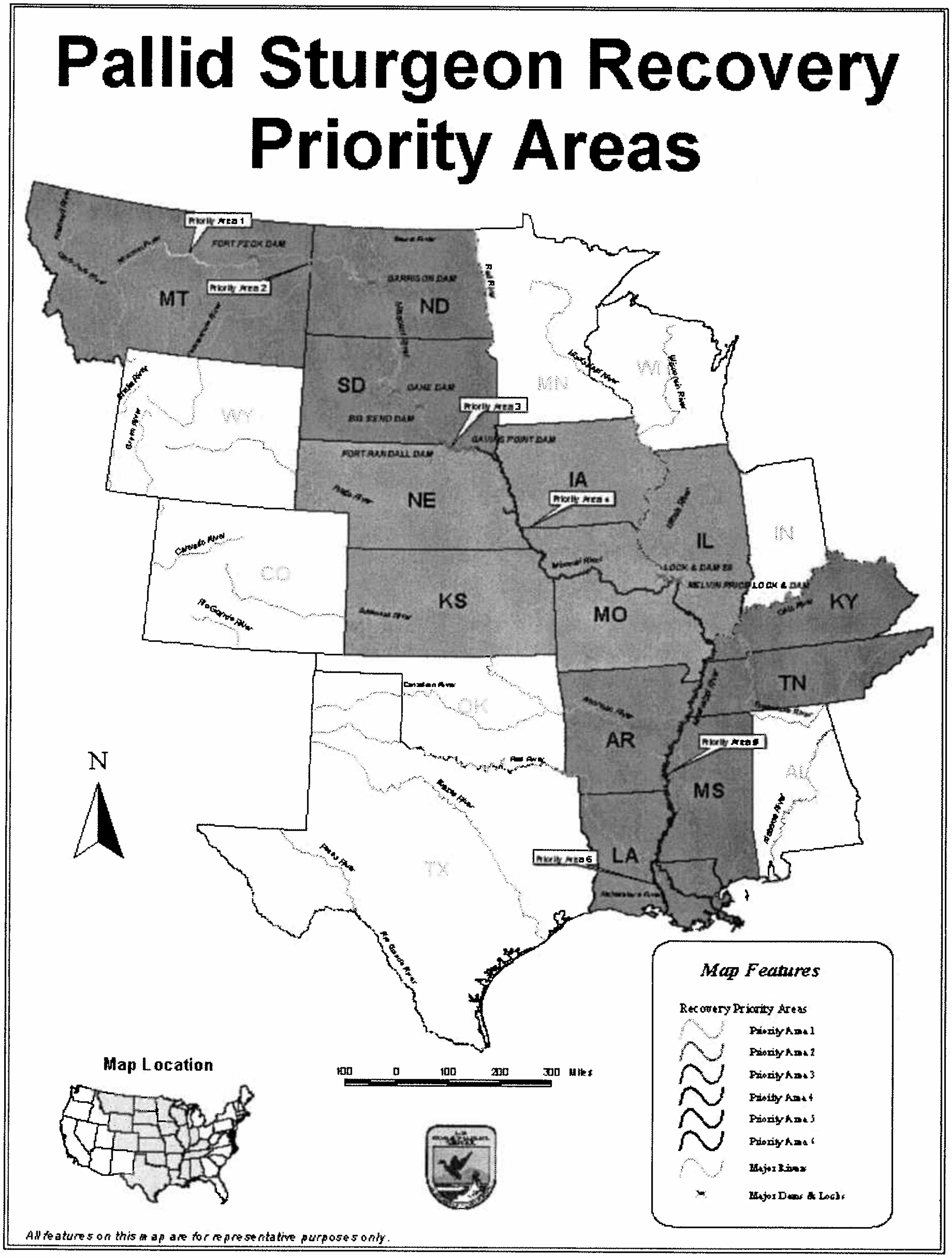


Figure 1. Pallid sturgeon Recovery Priority Management Areas 1-6. Colored States generally align with the 3 basin pallid sturgeon workgroups.

Distribution and Abundance

Pallid sturgeon were first described from nine specimens taken by commercial fishermen from 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 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," and indeed, pallid sturgeon have not been reported upstream of the mouth of the Missouri River since that observation. Because the pallid sturgeon was not recognized as a species until 1905, little is known concerning its early abundance and distribution (Pflieger 1975). Even as late as the mid-1900's, 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). They 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 first rigorous attempt to collect and quantify river sturgeon in the Mississippi and Missouri rivers was conducted during 1978-1979 (Carlson et al. 1985). Collections were made at six stations in the Mississippi River between Caruthersville and Canton, Missouri. A total of 2,549 river sturgeon were collected over 2 years, 6 of which were pallid sturgeon. Another 8 fish captured were intermediate in morphology between shovelnose and pallid, and were presumed to be hybrids (*S. albus x S. platorynchus*). A total of 1,806 river sturgeon were collected at 6 stations in the Missouri River between Brownsville and St. Louis, including 5 pallid sturgeon and 4 presumed hybrids.

A 1983 status review for the pallid sturgeon identified 250 reports or records from throughout its range (Kallemeyn 1983). The 31 records reported from the Mississippi River extended the pallid sturgeons range into Kentucky, Tennessee, Arkansas, and Mississippi, and into the Lower St. Francis River, Arkansas. Missouri River records of note included an upstream collection near Fort Benton, Montana, a 1979 record from the Platte River, and the regular occurrence of pallid sturgeon in the Yellowstone River. Kallemeyn (1983) observed that although pallid sturgeon were unquestionably rare and declining in the Upper Missouri River, at least some of the species' perceived rarity was due to inefficient sampling methods in the large rivers of the southern part of its range. A later review of pallid sturgeon status (Keenlyne 1989) recognized 28 records from the Mississippi River and extended the range into Little Bayou Pierre, St. Bernard Parish, LA, and Big Sunflower River, Sharkey Co., Mississippi.

In 1991, seven pallid sturgeon were collected from the only distributary of the Mississippi River, the Atchafalaya River, along with two fish possessing characters intermediate between pallid and shovelnose sturgeon that were assumed to be hybrids (Reed 1991). A few years later (1993-95) an additional 106 pallid sturgeon and 14 suspected hybrid captures were reported from the Atchafalaya River (Constant *et al.* 1997). Most, but not all, Atchafalaya River pallid captures have been associated with the Old River Control Complex (ORCC).

Biology and Life History{ TC \l2 "Biology and Life History}

Habitat – Reported depths of pallid sturgeon varies in the available literature and most of these data assume that the individual fish was associated with the bottom and not suspended in the water column. In the Missouri River below Fort Peck Dam and the Yellowstone River below Intake Diversion, Montana, pallid sturgeon utilized depths between 0.6 and 14.5m (Tews and Clancy 1993, Bramblett and White 2001). In this area, pallid sturgeon associated with sand and fine substrates in proportion to availability and utilized gravel and cobble substrates less than what was available (Bramblett and White 2001). In South Dakota, Pallid sturgeon tended to utilize turbid, free-flowing riverine habitat with rocky or sandy substrate and water depths of 4-5m (Erickson 1992). However, in the Platte River, Nebraska, Swigle (2003) found wild pallid sturgeon (n=2) utilizing an average depth of 1.3 m and Snook (2002) found hatchery produced pallid sturgeon in depths between 0.3 and 1.2 m. In the middle Mississippi River, Hurley (1996) found wild pallid sturgeon occupying water depths between 1.8 and 19.1 m and were most often in areas that had a maximum depth range between 6 and 12 m. This report also indicated that study fish were often associated with sandy substrate types. Carlson et al. (1985) captured pallid sturgeon in the main channel of the channelized Missouri River inside of river bends with sandbars and behind wing dikes with deeply scoured trenches. Hurley (1996) indicates that his study fish selected for; main channel borders, downstream island tips, areas between wing dams, and wing dam tips, and demonstrated negative selection for the main channel, and areas immediately above or below wing dams. Pallid sturgeon are reported to inhabit higher velocity waters than the closely-related, but smaller, shovelnose sturgeon (Forbes and Richardson 1909; Carlson et al. 1985, Bramblett 1996). Pallid sturgeon can be located in reservoir headwaters but rarely in the reservoir proper (Gardner 1996, US Fish and Wildlife Service 2003).

Food - Adult pallid sturgeon are primarily piscivorous (Coker 1930, Carlson et al. 1985) and historically relied on large-river minnows as their primary forage. Carlson et al. (1985) determined composition of food categories by volume and frequency of occurrence in the diet of shovelnose sturgeon (n=234), pallid sturgeon (n=9), and presumed hybrids (n=9). Aquatic invertebrates (principally the immature stages of insects) composed most of the diet of shovelnose sturgeon, while larger pallid sturgeon, and presumed hybrids, consumed a greater proportion of fish (mostly cyprinids). Other researchers also reported a higher incidence of fish in the diet of pallid sturgeon than in the diet of shovelnose sturgeon (Cross 1967; Held 1969, Gerrity 2005). However, macroinvertebrates do comprise a larger proportion of juvenile pallid sturgeon diets (Great Plains FWMAO, unpublished data).

Reproduction - Pallid sturgeon exhibit delayed maturation. Males reach sexual maturity at 533 to 584 mm total length (Fogle 1961), which corresponds with an age of 5 to 7 years in the wild. Females do not become sexually mature until they reach at least 850 mm fork length which corresponds to ages of 13 to 15 years old in the wild (Keenlyne and Jenkins 1993). Pallid sturgeon have been found to have mature gametes during seasons coinciding with natural high river flows (Keenlyne and Jenkins 1993) and likely spawn as early as April in the lower portion of their range and as late as June in the northern portion. In their natural environment, male pallid sturgeon may be capable of spawning annually while it may take up to 10 years between spawning events for females, with an individual female spawning only a few times during a normal life span (Keenlyne and Jenkins 1993). Recent work presented by Dave Herzog (MDC, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, Co.) suggest that pallid sturgeon may spawn over an extended period. This could be individual fish spawning at multiple times or individual pallid sturgeon within a locality spawning at different times.

Threats

The primary threats to pallid sturgeon are degradation and alteration of habitat. Other threats that have been recognized and warrant further investigated are intercross of pallid sturgeon with the more common shovelnose sturgeon, exploitation, water depletions, contaminants, predation, and inter-species competition (US Fish and Wildlife Service 2000).

Habitat - Pallid sturgeon habitat has been dramatically altered during the past 60 years. Approximately 51 percent of the pallid sturgeon's historical range has been channelized, 28 percent impounded, and the remaining 21 percent is affected by upstream impoundments that alter flow regimes and depress both turbidity and water temperatures (Keenlyne 1989, US Fish and Wildlife Service 2000).

Missouri River

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, US Fish and Wildlife Service 2000). 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 and many theorize that this reservoir is a major impediment to larval pallid sturgeon survival. 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. At this time, shovelnose sturgeon within RPMA 1 are doing well (Bill Gardner, MFWP personal communications) while pallid sturgeon are not. Canyon Ferry, Hauser, and Holter Dams are upstream of Great Falls, MT and likely do not impose any migratory barriers as passage at the natural falls likely did not exist historically. However, these structures, like most dams, reduce sediment and nutrient transport, create an artificial hydrograph, and delay thermal cues. A reduction in sediment transport could reduce naturally occurring habitat features like sandbars. 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 spawning.

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. Many theorize that Fort Peck Reservoir and Lake Sakakawea are major 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, but they migrate for a longer time. Subsequent work was conducted by MFWP and USGS with larval pallid sturgeon released within RPMA 2 as part of a larval drift study. Their data suggest that pallid sturgeon larvae can drift up to 300 km (200 miles) at flows of 0.35 m/s, and up to 500 km (310 miles) at flows of 0.55 m/s (Braaten, 2004). This drift distance would likely transport naturally spawned pallid sturgeon larvae into the headwaters of Fort Peck Reservoir and Lake Sakakawea. However, as part of this 2004 study various ages of fry were stocked, and in 2005 four unmarked pallid sturgeon were genetically traced back to the 11-17 day old fry stocked as part of this drift study (William Ardren, USFWS, personal communication). This suggests that fry released at ages 11-17 days are able to survive to age-1 in RPMA 2 and supports the idea that older released fry are not drifting into the reservoir and also implies that larval pallid sturgeon survival within RPMA 2 may be limited during the first 11-17 days. 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 could reduce naturally occurring habitat features like sandbars. One other dam is of importance on the Yellowstone River. The Yellowstone River was likely a historically important tributary for spawning. However, in the early 1900's, the Bureau of Reclamation 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 RM upstream from the Missouri and Yellowstone river confluence. This effectively has reduced the migratory potential of pallid sturgeon within the Yellowstone River system (U.S. Bureau of Reclamation 2001). Telemetry work conducted in 2004 by Matt Jaeger (MFWP, personal communication) identified that some study fish stocked upstream of Intake Dam remained there, and he noted that a few telemetered pallid sturgeon were entrained in the irrigation ditch served by Intake Dam. 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. 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. The usual habitat threats associated with dams like an altered hydrograph and temperature profile and a reduction in sediment transport likely are limiting factors for naturally recruiting pallid sturgeon. However, other native riverine species successfully spawn within this reach.

Channelization of the Missouri River within RPMA 4 has reduced water surface area by half, doubled current velocity, and decreased sediment transport (Funk & Robinson 1974, US Fish and Wildlife Service 2000). 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 (RM 811) downstream to the mouth of the Big Sioux River (RM 734). The upper channelized portion of RPMA 4 extends from the Big Sioux River (RM 736) to the Kansas River (RM 367.5), and the lower channelized reach extends from the Kansas River confluence downstream to St. Louis, Missouri (RM 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 was forced into its current location by construction, has no natural hydrological event, and is of uniform size and construction, and 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 (Kirk Steffensen, NGPC, personal communication).

Mississippi and Atchafalaya Rivers
The Mississippi River has been significantly modified over time, and some changes resulting from that modification are likely to be detrimental to pallid sturgeon. Impoundment of major tributaries has significantly reduced sediment delivery to the main channel (Fremling et al. 1989). Construction of bendway cutoffs, to facilitate navigation, locally increased bed gradient and current velocities. Levee construction effectively increases river stage and velocities at higher discharges (Baker et al. 1991) by preventing water spillover onto the adjacent floodplains and resulting bed degradation has led to reduced river stages during periods of low discharges that have been attributed to dewatering side channels (Fremling et al. 1989). Wasklewicz (2004) found that the upper and lower reaches of the Lower Mississippi River experienced increases in peak, mean and minimum monthly stages, while the middle portion of the Lower Mississippi River experienced decreases in peak, mean, and minimum river stages. Separately, these activities produced localized changes in patterns of erosion and deposition; collectively they have resulted in a degradation trend throughout the system, leading to loss of islands, secondary channels, and shallow water habitats. Engineering activities (levees, dikes, revetments) to maintain navigation and prevent flooding have fixed the channel and further contributed to loss of in-channel habitat diversity. The Atchafalaya River may be experiencing similar trends in channel degradation. Impoundment of its two major tributaries, the Red and Black rivers, likely has reduced the sediment load and low water discharge. Construction of the ORCC was designed to stabilize the distribution of water and sediments between the Mississippi and Atchafalaya rivers, at the same proportions that occurred in 1950, to prevent the Mississippi River from changing course. Construction of the ORCC and hydropower plant may have resulted in decreased sediment being diverted into the river (Reed and Ewing 1993).

Since historical data regarding populations of pallid sturgeon is lacking or potentially incomplete, and information on spawning sites, spawning behavior, and juvenile and adult habitat needs and uses are lacking, the significance and effects of these changes on pallid sturgeon are not entirely clear. However, lower capture rates in the Lower Missouri and Middle Mississippi rivers may suggest pallid sturgeon are more seriously affected where habitat degradation is the greatest (U.S. Fish and Wildlife Service 2000).

Intercrosses (hybridization) – Intermediate offspring produced by hybridization between pallid and shovelnose sturgeon were identified as a threat to pallid sturgeon survival and conservation in the listing rule (55 FR 36646) and Recovery Plan (U. S. Fish and Wildlife Service 1993). Microsatellite studies (Tranah et al. 2004, Heist and Schrey 2004) have recently provided genetic evidence for intermediates between pallid and shovelnose sturgeon in the Missouri, Mississippi, and Atchafalaya rivers.

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. Under this evolutionary hypothesis, it has been suggested that loss of habitat diversity due to human induced environmental changes in the Missouri and Mississippi rivers may be responsible for hybridization between shovelnose and pallid sturgeon (Carlson et al. 1985, Campton et al. 1995, Simons et al. 2001). Intercrossing or hybridization in other fish species has also been attributed to limited spawning habitat, numerical dominance by one species over another, modification of spawning habitat, overlap of spawning seasons, and/or where migration to suitable spawning habitat is limited. All of these factors contribute, in some degree, to conditions currently affecting pallid and shovelnose sturgeon and their habitats range-wide. However, the processes and causes of intercrosses that have been attributed to human induced environmental changes (e.g., quantity and timing of flows, substrate changes, reduced sediment budget, decreased turbidity, etc. (Keenlyne et al. 1994, U. S. Fish and Wildlife Service 1993, Quist 2004) are most evident and profound in the Lower Missouri and Middle Mississippi rivers (U.S. Fish and Wildlife Service 2000, 2000a). In the Mississippi River basin, the Atchafalya River has been profoundly altered in the past few decades by construction of the ORCC and impoundment of the Red and Black rivers. A higher rate of reported intermediates below the ORCC may be due to habitat changes that have limited spawning areas and/or restricted movements. If this spawning, habitat quality-hybrid hypothesis is correct, human caused habitat modifications created by engineering the Missouri and Mississippi rivers may constitute a major threat to the persistence of pallid sturgeon due to the homogenization of the two species via hybridization

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 the result of natural evolutionary processes and not really a threat.

At present, there are not enough data to fully understand the evolutionary relationships between pallid and shovelnose sturgeon range-wide (*see also Intercrosses between Pallid and Shovelnose Sturgeon*). However, there are data that suggest a link between habitat alteration and declining population demographics (U.S. Fish and Wildlife Service 2000, U.S. Fish and Wildlife Service 2000a.). There are also data that demonstrate that range-wide, pallid and shovelnose sturgeon are sympatric (Tranah et al. 2001, Heist and Schrey 2003, 2004) regardless of the evolutionary processes involved. Provided that habitat alterations are interfering with natural reproductive processes, it may be less important at this time to focus on which evolutionary hypothesis is correct, and focus on improving habitats so that natural evolutionary processes can continue into the future via natural reproduction and recruitment.

<u>Over Exploitation-</u> Commercial harvest of sturgeon for roe and meat was a traditional fishery in the Missouri and Mississippi river systems. There is limited information on commercial harvest of pallid or shovelnose sturgeon in the Missouri River. However, Williamson (2003) presented data from the Missouri Department of Conservation (MDC) which showed an increase in commercial catch of shovelnose sturgeon from 5,850 pounds in 2000 to 12,370 pounds in 2001. A total of 7,472 pounds were reported in 1999. To reduce the effects of harvest on pallid

sturgeon, Montana, North Dakota, South Dakota, and Nebraska have closed commercial sturgeon fishing. While Iowa and Missouri still allow commercial harvest, Missouri has limited harvest by closing commercial sturgeon fishing in the area 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 little information on commercial harvest of sturgeon for roe and meat in the Middle and Lower Mississippi River. However, 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 pounds in 1990 to 65,462 pounds in 2001. The amount of roe taken increased from 47 pounds reported in 1999 to 8,197 pounds reported in 2001. In Kentucky, the commercial catch of shovelnose sturgeon in the Mississippi River increased from 25 pounds (flesh) in 1999 to 8,324 pounds in 2002. The harvest of roe was reported at 1,021 pounds in 2001 and 731 pounds in 2002. Commercial take of any species of sturgeon was prohibited by Mississippi and Louisiana during the early 1990's 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 allows limited shovelnose sturgeon harvest on the Missouri River for and has closed sturgeon harvest on the Big Sioux River.

There is recent evidence of incidental take of pallid sturgeon in commercial harvest of shovelnose sturgeon (Dave Herzog, MDC, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO). Pallid sturgeon remains have been discovered in fish markets and pallid sturgeon with egg biopsy scars have been documented by biologists. Preliminary age studies of pallid sturgeon spine sections have estimated maximum pallid age in the Middle Mississippi River at 15 years, with mortality rates of 37-39%. Estimates for the Lower Mississippi River indicate maximum age sampled was 21 years, with a mortality rate of 12% (James Garvey SIU, Jack Killgore, USACE, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO). The higher age and lower mortality estimates within the Lower Mississippi River, where commercial harvest of sturgeon is prohibited, suggests that incidental take of pallid sturgeon by commercial harvest is more prevalent in the Middle Mississippi River. This is a factor that must be considered in pallid sturgeon conservation. Incidental and illegal take of pallid sturgeon for commercial purposes will likely increase in the Middle Mississippi and Lower Missouri rivers as commercial pressures on shovelnose sturgeon increase due to the importation ban of beluga sturgeon (*Huso huso*) caviar into the United States and the general trend towards reduced caviar exports from the Caspian Sea sturgeon stocks (http://www.cites.org/eng/resources/quotas/sturgeon_intro.shtml).

<u>Contaminants-</u> Recent studies of shovelnose sturgeon in the Missouri and Mississippi rivers have revealed a relatively high rate of hermaphrodism (James Garvey, Southern Illinois University, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO).

Hermaphrodism in fish may be caused by exposure to certain forms of water pollution. Current data are lacking to adequately address this problem under existing environmental laws, but contaminants research should continue as part of the pallid sturgeon recovery efforts.

GENETICS

Molecular Systematics of Pallid Sturgeon

Initial genetic studies were unable to distinguish pallid from shovelnose sturgeon by examining 37 allozyme loci (Phelps and Allendorf 1983), RFLP analysis of five protein coding genes (Morizot 1994), or comparing sequence variation at the cytochrome b gene (Simons et al. 2001). Some interpreted these results as a lack of reproductive isolation between the species (e.g., pallid sturgeon could be a rare morphotype of the shovelnose sturgeon) or a low evolutionary rate within the genus *Scaphirhynchus*. Another hypothesis is 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 young species pair.

Campton et al. (2000) and Tranah et al. (2001) were able to find genetic markers that distinguish pallid from shovelnose sturgeon. They employed markers known to have greater power for describing recent population or species divergence. These two studies examined pallid and shovelnose sturgeon samples collected at each of the following locations; (1) Upper Missouri River upstream of Fort Peck Reservoir (pallid n= 8, shovelnose n= 10), (2) Upper Missouri River at the confluence of the Missouri and Yellowstone rivers (pallid n=11, shovelnose n= 10), and (3) Atchafalaya River (pallid n= 10, shovelnose n=17). Campton et al. (2000) found significant haplotype frequency differences between the two species at the mitochondrial DNA (mtDNA) control region for all three locations examined. 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. Based upon their findings, the recognition of pallid sturgeon as a species was supported.

The close evolutionary genetic relationship between pallid and shovelnose sturgeon is demonstrated by the low level of divergence at microsatellite loci and mtDNA more typically associated within populations of a species than that observed between congeneric species. Campton et al. (2000) provides some useful examples to demonstrate this point, including the finding that the average genetic distance between pallid and shovelnose sturgeon is only half the value observed between populations of white sturgeon, *Acipenser transmontanus*, in the Columbia and Frazer Rivers. They also note the relative recent divergence between pallid and shovelnose sturgeon based on mtDNA sequence data, estimating the divergence occurred during the first Wisconsin glaciation period (< 70,000 years ago). On the other hand, white and green sturgeon, *A. medirostris*, are estimated to have diverged 6 million years ago. Because white sturgeon diverged from green sturgeon millions of years ago there has been more time for the neutral or nearly neutral genetic markers to diverge (via mutation and genetic drift) providing clear genetic evidence for discrimination of the species and for substantial genetic differentiation to occur among populations within a species. This does not appear to be the case for pallid sturgeon and shovelnose sturgeon.

Intercrosses between Pallid and Shovelnose Sturgeon

The presence of morphologically intermediate forms presumed to represent pallid-shovelnose sturgeon hybrids (Keenlyne et al. 1994, Carleson et al. 1985) has 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 four 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). A plot of the hybrid index scores clearly demonstrated that the morphologically intermediate fish were also genetically intermediate between pallid and shovelnose sturgeon. These results are consistent with the hypothesis of hybridization between pallid and shovelnose sturgeon. However, others caution this study simply demonstrated that morphologically intermediate fish had genetically intermediate genotypes (Don Campton, USFWS, Personal Communication) contending the data represent a circular argument for "hybridization" because the data set on which the conclusions were based was also 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 Atchafalya 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 2004). 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 morphology, 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, neither the allopatric speciation/hybridization hypothesis nor the sympatric speciation/polyphyly hypothesis can be rejected at this time based on the available genetic information.

Results of Tranah et al. (2004) support earlier morphometric-based conclusion on the presence of intercrosses (Keenlyne et al. 1994) suggesting that intercrossing or gene flow between the two forms (pallid and shovelnose sturgeon) is more pronounced in the Mississippi and Atchafalaya rivers than elsewhere (e.g. upper Missouri River). Tranah et al. (2004) also suggest that while shovelnose and pallid sturgeon are distinct morphologically, they are undergoing intercrossing in the Lower Mississippi and Atchafalaya rivers. Morphometric data may also indicate a high rate of intercrossing in the Lower Missouri River (Grady et al. 2001, Milligan 2002, Doyle and Starostka 2003). The extent to which these intercrosses 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 as a small number of fish classified morphologically as "hybrids" were examined.

Allendorf et al. (2001) theorize 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 maybe 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 genetic intermediates between pallid and shovelnose sturgeon in the Missouri, Mississippi, and Atchafalaya Rivers (Tranah et al. 2001, Heist and Shrey 2003, 2004), these and other studies (Ray et al. 2005) have also demonstrated that shovelnose and pallid sturgeon are able to remain genetically distinct form each other in the Missouri, Mississippi, and Atchafalaya Rivers with a third group, hybrids or intermediates, being present.

More information is needed on the evolutionary dynamics of intermediates between pallid sturgeon and shovelnose sturgeon to understand if they are natural or anthropogenic. To further confound the issue, recent work (Rob Wood, Saint Louis University, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO.) identified unique microsatellite alleles in intermediate forms collected from the Mississippi River. This suggests yet another alternative hypothesis to hybridization (i.e., cryptic diversity).

Population Structure of Pallid Sturgeon

The pallid sturgeon was listed as a species (one unit) over its entire range (U. S. Fish and Wildlife Service 1993). Recent concerns have been raised regarding the genetic structuring within the species' range.

Tranah et al. (2001) examined genetic variation within and among three pallid sturgeon populations, two of which were located in the Upper Missouri River and one from the southern Mississippi / Atchafalaya river system. The allele frequencies at five microsatellite loci indicated the two Upper Missouri River populations, separated by Ft. Peck Dam, did not differ significantly. Conversely, pallid sturgeon from the two Upper Missouri populations did differ from those in the Atchafalaya River ($F_{st} = 0.13$ and 0.25; both $P < 0.01$). They concluded pallid sturgeon collected from the Missouri River in Montana (the northern fringe of their range) are reproductively isolated from those sampled from the Atchafalaya River (southern extreme of their range) and should be treated as genetically distinct populations.

Heist and Schrey (2004) also detected genetic differences between Upper Missouri and Middle Mississippi rivers pallid sturgeon based on examination of eleven microsatellite loci. Heist and Schrey (2004) found significant Fst differences between the Upper Missouri River pallid sturgeon samples when compared with samples from the Middle Mississippi River. Heist and Schrey (2006) subsequently examined samples collected from the upper portion of RPMA 4. These samples were collected below Gavins Point Dam, SD (RM 811) downstream to Kansas City, MO (RM 339). Heist and Schrey (2006) suggest that pallid sturgeon in this part of the range are genetically intermediate between the Upper and Lower Missouri River pallid sturgeon samples. These data suggest that the genetic structuring within the pallid sturgeon's range may represent a one-dimensional linear stepping-stone distribution as explained in Gharette and Zhivotovsky (2003). That is gene flow is more likely to occur between adjacent groups than among geographically distant groups and thus genetic differences would be expected to increase with geographical distance. These recent studies using microsatellite loci demonstrated genetic differences among pallid sturgeon samples collected from the Upper Missouri, Atchafalaya, Middle Mississippi and Lower Missouri rivers (Heist and Schrey 2004, Ray et al. 2005, Heist and Schrey 2006).

However, the available data do not readily support the discreteness criteria for listing multiple Distinct Population Segments (DPS) (Fay and Nammack 1996) and for the purposes of this plan, pallid sturgeon will be considered a single DPS exhibiting genetic structuring within its range.

Though pallid sturgeon range-wide are currently viewed as a single species, there is a need to recognize range-wide genetic and morphometric diversity within the species. A more appropriate approach to DPSs for recovery management likely is recognition of designatable units (DUs) as explained by Green (2005). Acknowledging the existence of DUs as suggested within Green (2005) should rely on two criteria; are DUs distinguishable, and do these DUs warrant differing degrees of conservation? Based on input from the three basin workgroups, the answer to both questions appears to be "yes".

The DUs appear distinguishable based on both genetic and morphology differences, but clearly delineating DUs based on these items alone will be difficult. It is understood that Upper Missouri River pallid sturgeon are reproductively isolated from and/or morphologically distinct from Middle Mississippi River and Atchafalaya River pallid sturgeon (Campton et al. 2000, Tranah et al. 2001, Heist and Schrey 2004). However, Middle Missouri River pallid sturgeon (upper reaches of RPMA 4) appear to be a mixture of these two groups (Heist and Schrey 2006), suggesting that at some point in time, Upper Missouri River and Lower Missouri/Middle Mississippi River pallid sturgeon were not reproductively allopatric. Limited demographic data suggest a need for differing levels of conservation status. Currently there appears to be a break occurring at the Missouri and Mississippi rivers confluence. However, this demographic break may also be confounded by a disparity in available demographic data among all RPMAs. Applying the DU concept will allow for varying management/recovery schemes to best conserve the DUs. Utilizing this approach accounts for the differing RPMA specific recommendations regarding population supplementation as identified in this plan. Figure 2 represents conceptual DUs.

Maintaining Genetic Diversity and Minimizing Inbreeding in Hatchery Broodstocks

During early propagation efforts, researchers at the University of California, Davis (UC Davis), conducted genetics work geared specifically towards analysis of the adult pallid sturgeon broodstock. Bernie May (UC Davis) provided recommendations to the propagation program as to which adult pairs are the most genetically distant. The recommendations were used to develop mating strategies that maximize the genetic diversity of the existing population.

In 2005, the USFWS Conservation Genetics Lab at Abernathy Fish Technology Center (CGL) began a genetic analysis to determine the degree of relatedness among the pallid sturgeon being used for broodstock at Miles City State Fish Hatchery (SFH), MT, Garrison Dam National Fish Hatchery (NFH), ND and Gavins Point NFH, SD. Data from 17 microsatellite loci and kinship analysis were used to provide pairwise relatedness estimates (Rxy via Goodnight and Queller 1999) allowing managers to avoid full-sib mating and minimize degree of relatedness among the families created. Programs focused on California Condors (Ralls and Ballou 2004) and St Vincent parrots (Russello and Amato 2004) are using similar genetic approaches with their captive rearing programs.

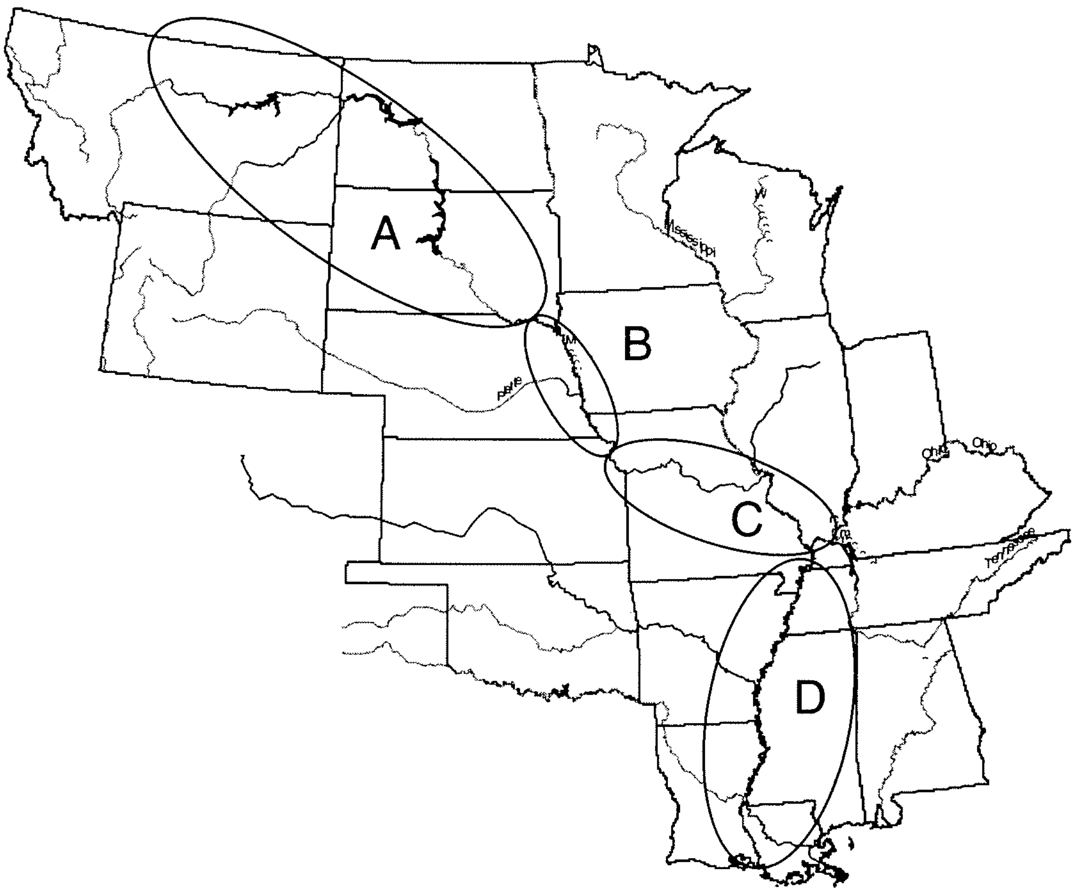


Figure 2. Conceptual outline of the DUs currently evidenced in Heist and Schrey (2004 and 2006). Oval A (RPMA 1, 2, and 3) represents the upper Missouri pallid sturgeon DU. Oval B (upper end of RPMA 4) represents the middle Missouri pallid sturgeon DU. Oval C (lower end of RPMA 4 and upper end of RPMA 5) represents the lower Missouri DU. Oval D (RPMA 5 and RPMA 6) represents the Mississippi and Atchafalaya DU (For graphical representation only, map not to scale)

The CGL is also developing a breeding plan for pallid sturgeon that will take into account which fish have been mated in the past and which males are cryo-preserved. They will implement a method currently utilized by zoos to keep track of breeding records that incorporates genetic information for new animals added to the broodstock. These programs, PM2000 (Pollak et al. 2002) and SPARKs (ISIS 1994), use pedigree and genetic information to develop mating plans that maximize genetic diversity in the population as a whole. The need to develop this breeding plan and database will increase as fewer new natural-origin fish are collected for propagation purposes. It will also allow managers a rigorous method to make choices concerning the spawning of hatchery origin, captive reared fish, or recaptured brood fish. The CGL will also review the current broodstock selection and spawning protocols to ensure they are consistent with guidelines for maximizing offspring production while maintaining genetic diversity (Fiumera et al. 2004).

RPMA SPECIFIC PALLID STURGEON DEMOGRAPHIC DATA

RPMA 1

A total of 44 wild pallid sturgeon (individual fish) have been collected in RPMA 1 during 15 years of sampling (1990-2005) (Figure 3). The length frequency data indicate these are all adult fish. Current population estimates suggests that as few as 45 wild pallid sturgeon still remain in RPMA 1 (Bill Gardner, MFWP, personal communications). These remaining fish are all adults suggesting spawning, recruitment or both are severely limiting viability within this reach. Supplementation of RPMA 1 with hatchery produced pallid sturgeon has occurred sporadically since 1997. To date pallid sturgeon from all stocking events have produced recaptures and are contributing to the current population structure (Bill Gardner, MFWP, personal communications) (Figure 4.)

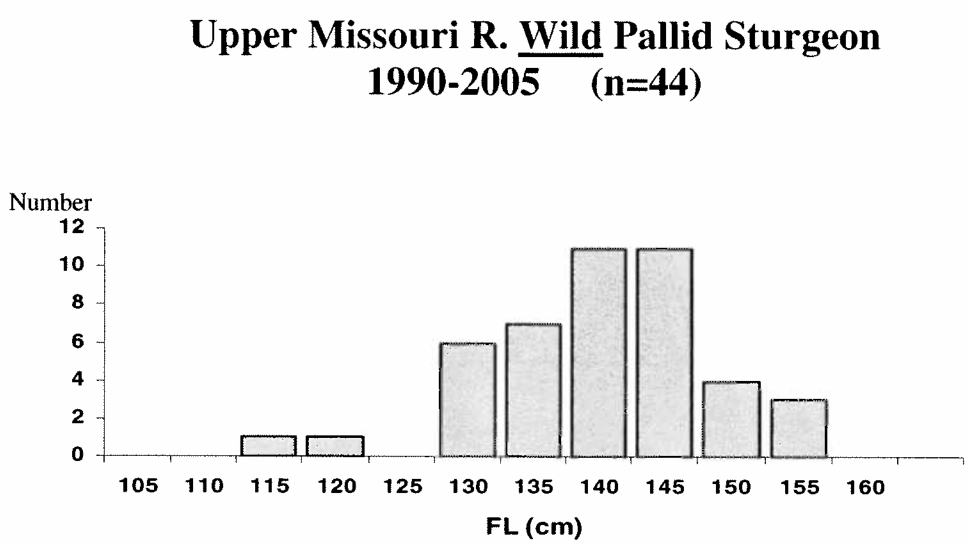


Figure 3. Upper Missouri River (RPMA 1) wild pallid sturgeon collected with all gear types 1990-2005. (Bill Gardner, MFWP, data presented to the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005)

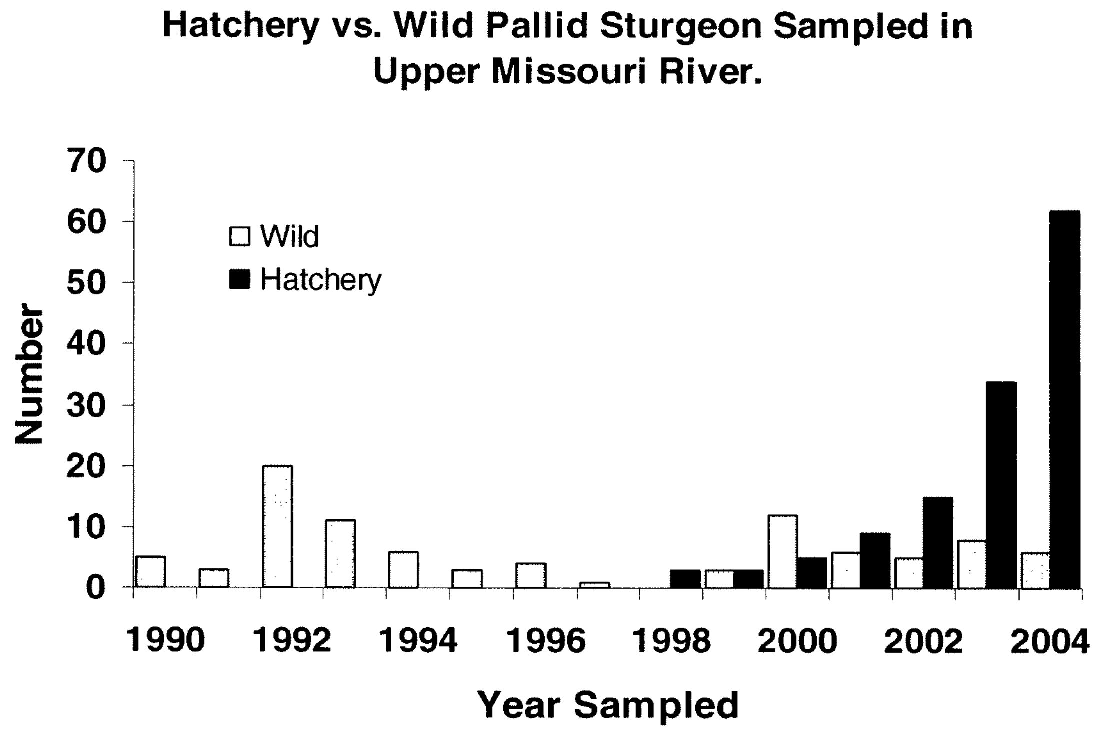


Figure 4. Upper Missouri River (RPMA 1) wild pallid sturgeon and hatchery produced pallid sturgeon collected with all gear types 1990-2005. (Bill Gardner, MFWP, data presented to the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005)

RPMA 2

A total of 510 pallid sturgeon have been collected in RPMA 2 during 16 years of sampling (1989-2005) (Figure 5). However, it should be pointed out that this is total catch with many of the adults being collected multiple times during those years. The length frequency data indicate that up until the time supplementation began, all collected pallid sturgeon were adults. This suggests that, like RPMA 1, spawning, recruitment or both are severely limiting viability of this population.

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. To date pallid sturgeon from all stocking events have produced recaptures and are contributing to the current population structure (Figure 5.)

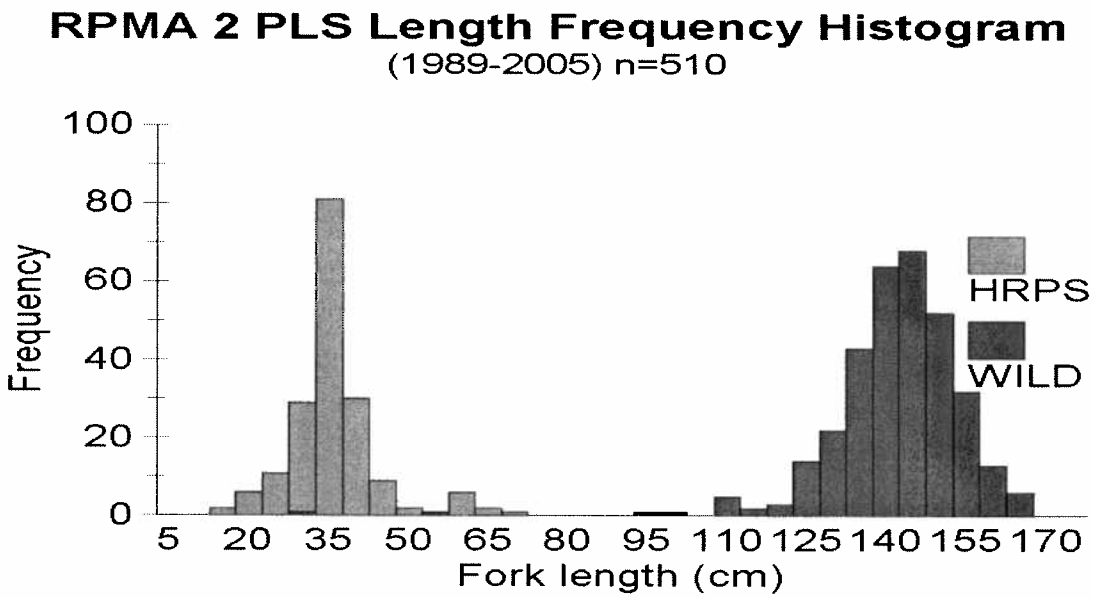


Figure 5. Upper Missouri River (RPMA 2) wild and hatchery reared (HRPS) pallid sturgeon collected with all gear types 1989-2005. (Data provided by Matt Klungle, MFWP and Steve Krentz, USFWS, data presented to the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005)

RPMA 3

Little information on pallid sturgeon abundance has been collected for RPMA 3 and habitat assessments are cursory (Duffy et al. 1996). A single wild pallid sturgeon was collected in this reach circa 1990 (Wayne Nelson-Stastney, USFWS, personal communication). To date, this is the only known non-translocated wild pallid sturgeon collected in RPMA 3. Recent work (Shuman et al. 2005) identified a pallid sturgeon to shovelnose sturgeon ratio of 1:3.25. However, their samples are based on hatchery stocked pallid sturgeon and wild shovelnose. No naturally produced pallid sturgeon were identified in that report. Furthermore, research within RPMA 3 during 1998 and 1999 (prior to stocking hatchery reared pallid sturgeon in this reach) did not collect a single pallid sturgeon, but did collect numerous shovelnose sturgeon. Recent work by Shuman et al. (2005) indicates that stocked pallid sturgeon are surviving and growing in this reach with all stocked year classes (1997-1999 and 2001 and 2002) being collected in their samples. A total of 102 pallid sturgeon have been collected in RPMA 3 during 2 years of sampling (2003-2005) (Figure 6). All of these were hatchery produced or translocated wild pallid sturgeon. Theses data suggest that prior to supplementation, pallid sturgeon were extremely rare in RPMA 3. Supplementation of RPMA 3 with hatchery produced pallid sturgeon has occurred sporadically since 2000 with various numbers being stocked depending on hatchery success for any given year. To date, pallid sturgeon from all stocking events have produced recaptures and are contributing to the current population structure (Figure 6.)

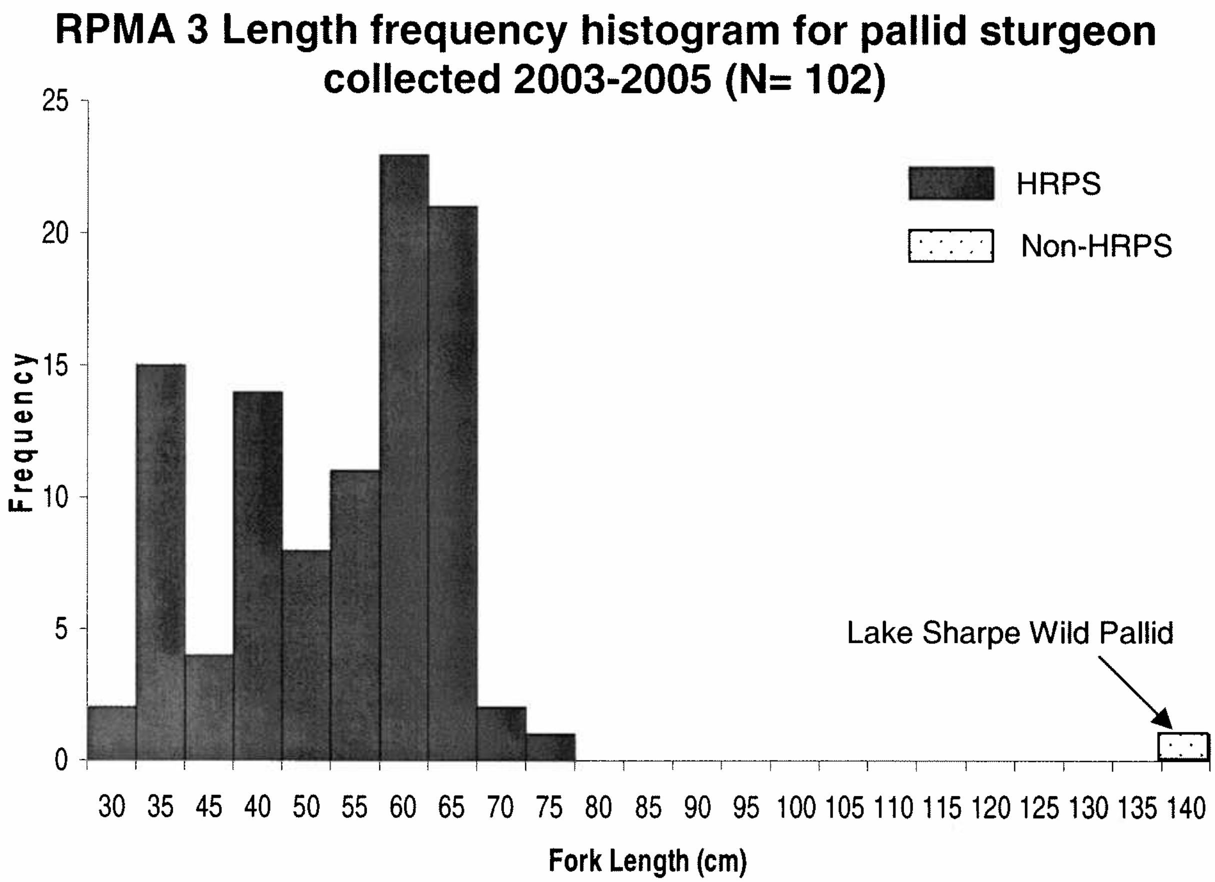


Figure 6. Upper Missouri River (RPMA 3) wild and hatchery reared (HRPS) pallid sturgeon collected with all gear types 2003-2005. (data provided by Dane Shuman, USFWS, for the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005)

RPMA 4

During the past 7 years (1999-2005) 156 pallid sturgeon have been sampled from the Lower Missouri River (Wyatt Doyle, USFWS, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO). Of those collected, 51 are believed to be wild, 82 were of hatchery origin, and 23 were unknown as to their origin (suspected to be hatchery origin fish that have shed tags) (Figure 7). Length frequency data (Figure 8) indicates that sampling gears used will collect small sturgeon. Similarly, NGPC (Kirk Steffensen and Gerald Mestl, personal communications) have indicated that following inception of the Population Assessment Program, their crews have collected young-of-the-year shovelnose sturgeon with no wild pallid sturgeon being documented.

The lack of naturally produced or unknown origin pallid sturgeon in smaller size classes coupled with high relative abundance of hatchery origin pallid sturgeon and frequent captures of smaller size class shovelnose sturgeon suggests that the gears being used are effective and that recruitment may be limiting the pallid sturgeon population in RPMA 4. These data also indicate that hatchery supplementation is successful as stocked fish are being collected and contributing to the population. To date, pallid sturgeon from every stocking event in RPMA 4 have been recaptured and are represented in the current population structure.

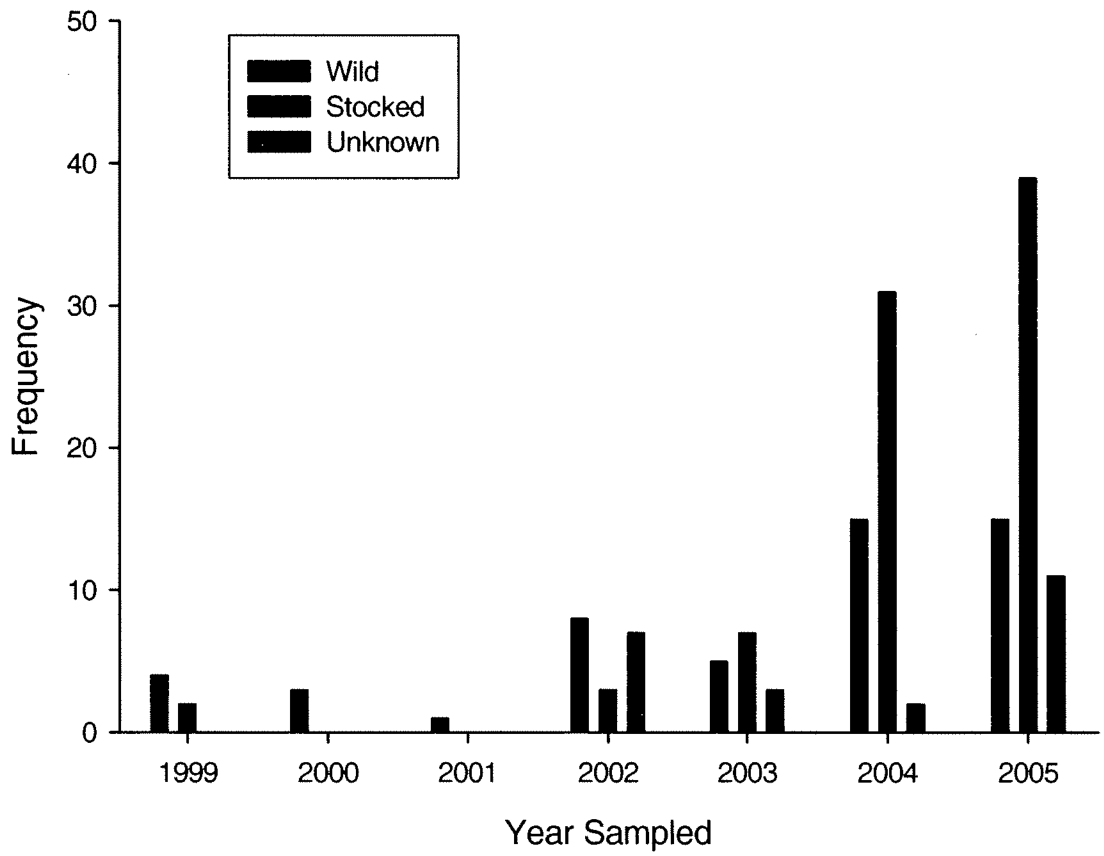


Figure 7. Missouri River (RPMA 4) wild, hatchery reared (stocked), and unknown pallid sturgeon collected with all gear types by the Columbia FRO;1999-2005. (data provided by the USFWS Columbia Fishery Resource Office, Columbia Missouri)

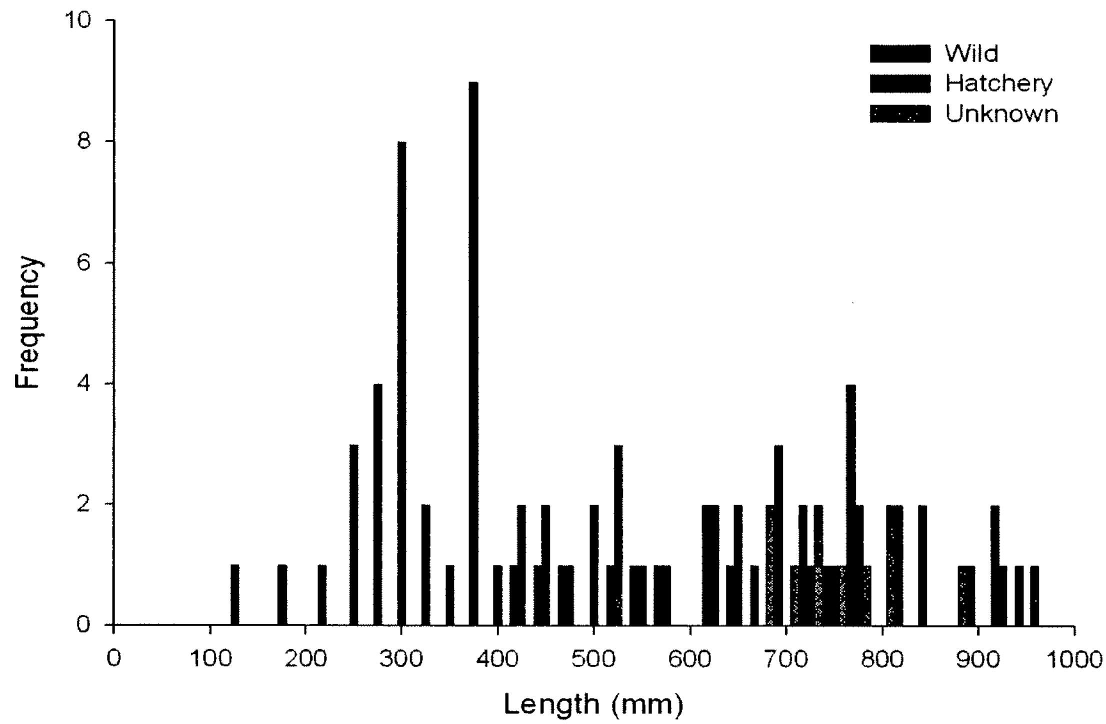


Figure 8. Missouri River (RPMA 4) wild, hatchery reared (stocked), and unknown pallid sturgeon length frequency collected with all gear types 1999-2005. (data provided by the USFWS Columbia Fishery Resource Office, Columbia Missouri)

RPMA 5

Limited information on pallid sturgeon abundance has been collected for RPMA 5. Sampling data from 1997-2004 (Jack Killgore, USACE, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO) indicate a total of 176 pallid sturgeon have been collected from the Mississippi River from RM 0 to RM 1153 while during the same time period, approximately 4900 shovelnose sturgeon were collected in the same sample area with similar gear types. Dave Herzog (MDC, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO) also presented data for the Middle Mississippi River indicating a total of 139 pallid sturgeon collected between 2002 and 2005. However, caution must be applied when looking at total catch as some of the collected pallid sturgeon reported by D. Herzog may also have been reported by J. Killgore, and it is unclear what percent of these may be hatchery origin pallid sturgeon with failed physical marks. Jack Killgore, USACE, (data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO) indicated that between the winter of 2004 and the spring of 2005, 39% (7 of 18) of the pallid sturgeon collected were hatchery stocked recaptures with a coded wire tag.

The length frequency data for the Middle Mississippi River indicate a length range from 44 to 108 cm. Pallid sturgeon in this length range are of reproductive size and in their abstract for the *Scaphirhynchus* conference (1-13 January 2005, St. Louis, Mo) Herzog et al. (2005) reported that pallid sturgeon are successfully reproducing in the Middle Mississippi River, but suggested that the lack of age 1 *Scaphirhynchus* in their samples may indicate lack of survival from the age-0 to the age-1 size class. This limited survival of early life stages, according to Herzog et al (2005), "...may be a limiting factor for long-term viability..." of *Scaphirhynchus* in the Middle Mississippi River.

RPMA 6

Sampling data from 1998-2005 (Jan Dean, USFWS, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO) indicate a total of 363 pallid sturgeon have been collected from the Atchafalaya River (Figure 9).

Length frequency data through time demonstrate that the length distribution of fish has remained relatively steady and that samples are comprised of predominantly larger fish (Figure 10). However, these data do not indicate natural recruitment per se. The length frequency data indicate that the sampling methodologies are collecting shovelnose sturgeon ranging from 40 to 75 cm FL, but the pallid sturgeon data show only larger fish ranging from 65 to 105 cm FL. The steady length frequency distribution through time may suggest recruitment of naturally produced fish into the adult population or incorporation of adult pallid sturgeon from the Mississippi River. The latter may be possible due to the control structures allowing sturgeon to pass from the Mississippi River to the Atchafalaya River with little possibility of passage from the Atchafalaya River to the Mississippi River. There are no age data on Atchafalaya pallid sturgeon; however fork length of captured fish has ranged between 65 and 110 cm.

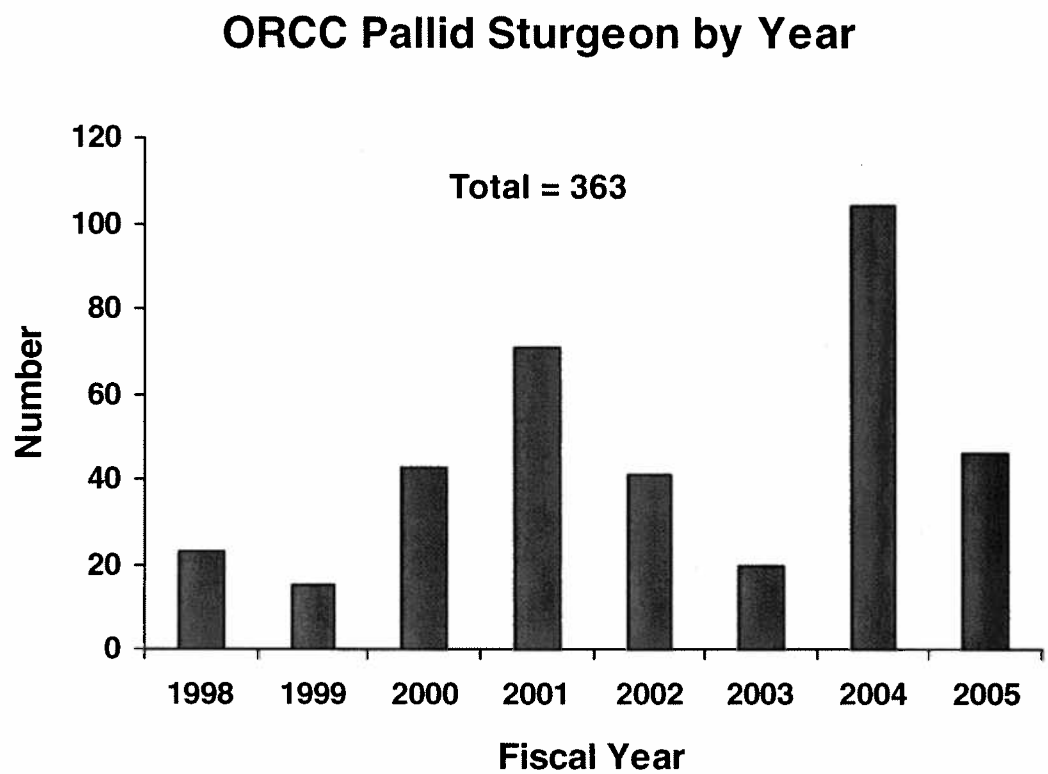


Figure 9. Atchafalaya River (RPMA 6) wild pallid sturgeon collected with all gear types 1998-2005. (data presented by Jan Dean, USFWS, at the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005)

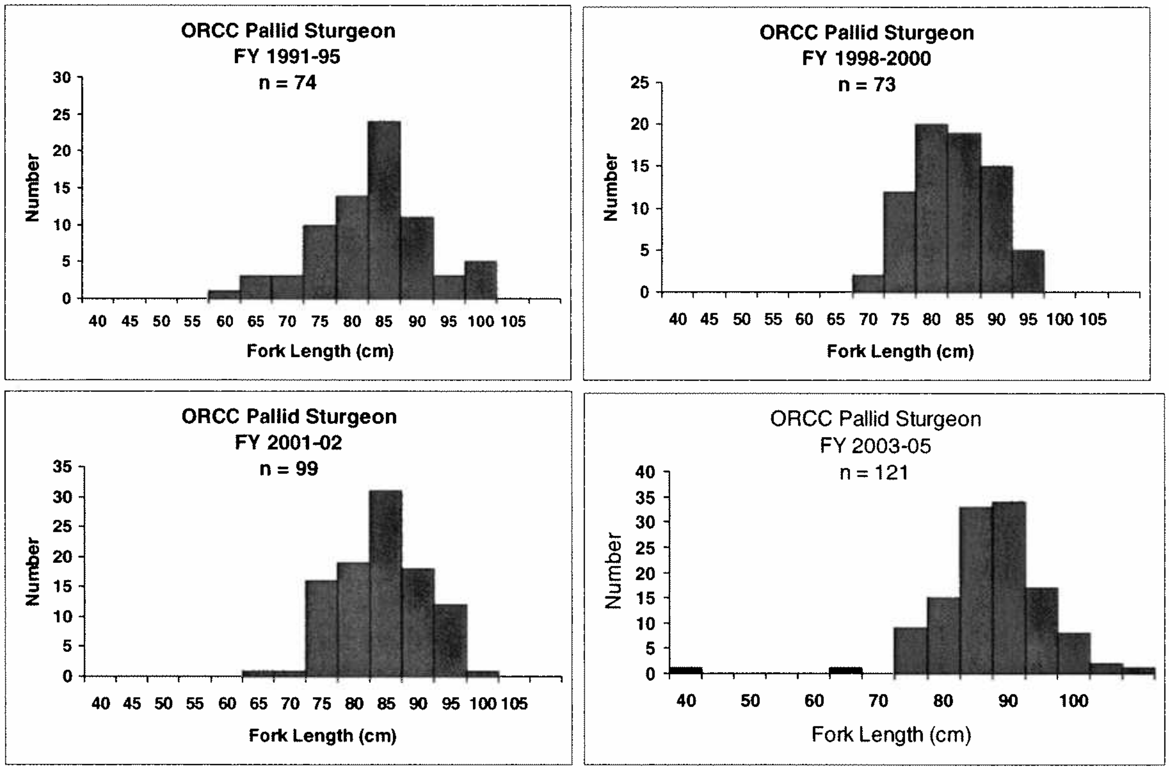


Figure 10. Atchafalaya River (RPMA 6) wild pallid sturgeon length frequency graphs collected with all gear types 1991-2005. Data presented by Jan Dean, USFWS, at the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005.

PRODUCTION AND HISTORY

The first known successful pallid sturgeon spawning effort occurred at the Blind Pony SFH, Missouri in 1992. Pallid sturgeon produced at this facility were the product of locally collected Mississippi River parental stock. Approximately 7,136 hatchery reared pallid sturgeon (HRPS) from this 1992 spawning activity were coded wire and spaghetti wire (floy) tagged prior to release in 1994 (2,434 in the Missouri River and 4,702 in the Mississippi River). Another successful spawning attempt occurred at Blind Pony SFH in 1997 from adults collected near Caruthersville, Missouri. Approximately 1,589 of these HRPS were released in the Lower Missouri River and 2,066 were released into the Mississippi River. Natchitoches NFH also successfully spawned pallid sturgeon collected from the ORCC in 1997. The resultant 35 progeny were stocked below the ORCC. Natchitoches NFH successfully propagated and stocked pallid sturgeon again in 2003-2004.

From this propagation effort, 4,755 fingerling pallid sturgeon were Passive Integrated Transponder tagged (PIT) and coded wire tagged (CWT) and released below the ORCC and 6,826 fingerling pallid sturgeon were coded wire and elastomere tagged prior to stocking at three locations in the Mississippi River. Other than these instances, the majority of HRPS have been the product of adult pallid sturgeon collected from the confluence area of the Yellowstone and Missouri rivers in North Dakota and Montana. Hatchery produced pallid sturgeon from upper basin parents have been stocked into RPMA 1-4 in recent years (See Appendices 1-4). While the success of hatchery production is evident, supplementation with upper basin HRPS in RPMA 4 began to raise concerns within the lower basin. It should be noted that hatchery success in this context is viewed as the success of hatchery produced fish to be stocked and survive in the wild. The ability of HRPS to contribute subsequent progeny is not determinable at this time due to the lack of sexual maturity of supplemented individuals and limited improvements to habitats that have occurred during the last decade. In 2004, the Lower Basin Pallid Sturgeon Workgroup (LBPSW) reviewed recent collection records from the Mississippi and Atchafalaya rivers and identified that increasing captures of wild sturgeon, as well as some evidence of reproduction and recruitment suggested a self-sustaining population in the Lower Mississippi River basin. It was therefore suggested by the LBPSW that stocking in the Lower Mississippi River should be postponed, and future stocking would require a clear conservation or research objective and risk/benefit analysis.

USE OF HATCHERY-ORIGIN PALLID STURGEON

Avoidance of extirpation over the next 50 years within the Upper Missouri River basin may depend largely on the success of the pallid sturgeon artificial propagation program. These efforts are a part of the Pallid Sturgeon Recovery Plan and are assuming increasing importance because of the general absence of natural reproduction or recruitment in the Upper Missouri River during the past 30 years. A major management information gap associated with the propagation programs is the need to develop a scientifically-defensible relationship, or strategy, between the geographic origins of adults collected for broodstock and the geographic regions within the Missouri River where their progeny are released.

Hatchery release strategies should allow for natural evolutionary units or DUs to be maintained. Research is ongoing to determine genetic similarities and evolutionary relationships throughout the range of pallid sturgeon, including their evolutionary relationships to shovelnose sturgeon. Life history information and ecological information must be incorporated into this process because the heritable variation at adaptive traits important for maintaining the evolutionary potential of the species could be evolving more rapidly than the current neutral or nearly neutral genetic markers being examined. The results of these studies are vital for the development of propagation and stocking plans that consider genetic, demographic, and environmental benefits and risks associated with these ongoing activities.

A fundamental problem with restoring severely depleted fish populations is the issue of maximizing genetic diversity while maintaining locally adapted populations (Storfer 1999, Tallmon et al. 2004). Numerous guidelines address the use of hatchery propagated fish in restoration programs including Miller and Kapuscinski (2003), but these guidelines are often unattainable when working with severely depleted populations such as pallid sturgeon. The question then becomes how best to recover the species given the limited number of fish available for hatchery propagation and subsequent stocking. Historical information on pallid sturgeon migration patterns and mixing of genetics among fish along the river's continuum is lacking. Undoubtedly there were locally adapted populations, but likely as well there was genetic transfer among collocated populations and among the populations within the river continuum. Support for this relationship was provided by Ed Heist (SIU, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO) who presented data indicating that F_{st} value differences increase with the geographic distances associated with sample collections. So historically, pallid sturgeon appeared to exhibit some form of reproductive isolation at the extremes of their range with some level of genetic exchange occurring between neighboring groups. Currently, pallid sturgeon are artificially segregated and are exhibiting no natural recruitment in the Upper Missouri River with some evidence of spawning success and various suspected levels of recruitment in the Missouri and Mississippi rivers below Gavins Point Dam. While some level of reproductive isolation existed historically, the dams on the Missouri River likely have reduced and will continue to prevent historical levels of gene flow. This stocking plan is written to maximize genetic diversity in the broodstock program as well as hatchery produced pallid sturgeon, minimize consequences of immigration from potentially divergent individuals produced as part of the population augmentation program, maximize the ability of stocked individuals to survive in a new environment, and recognize that some locally adapted populations may be influenced by reintroducing fish (Tallmon et al. 2004) now separated by Missouri River dams. As is often the case with endangered species, definitive data necessary for conservation are lacking due in part to low species numbers, limited population demographic data, and inadequate funding for sampling.

BROOD SOURCE FOR PRODUCTION

Past augmentation efforts have utilized both Missouri and Middle Mississippi river parental stock with both sources of HRPS being stocked into RPMA 4 and only Upper Missouri River origin HRPS being stocked into RPMA 1, 2 and 3. By far the largest contribution of HRPS was derived from Upper Missouri River parental stocks (see Production and History section this plan). Recent concerns about mixing of potential stocks led the Pallid Sturgeon Recovery Team to recommend utilizing local parental stocks for propagation purposes. When efforts were made to collect 3 females and up to 9 males from RPMA 4 during the spring of 2005, few naturally produced pallid sturgeon were collected, but several hatchery produced pallid sturgeon were. Those fish believed to be wild did not produce gametes when spawning attempts were made at Gavins Point NFH and it was deemed imprudent to utilize hatchery produced fish for propagation activities at that time. While it reduces genetic concerns to require collection of local parental stocks, obtaining local parents may not always be feasible and clearly defining what constitutes local parents must continue.

To date, parental stocks have been relatively easy to obtain from RPMA 2 and difficult to obtain from RPMAs 1 and 4. Also, there will come a time when the ability to obtain wild adults from the Upper Missouri River is severely diminished as the adult population senesces. When this occurs, reliance on the brood program being developed at Gavins Point NFH will be mandatory. Clearly defining local parents for RPMA 4 is a little more difficult. Local parental stocks for RPMA 1, 2, and 3 will be defined as adults collected above Gavins Point Dam. Currently, local parents for the lower reaches of RPMA 4 (Kansas City RM 339 to the Missouri River confluence RM 0) should come from within this river stretch as well as the upper portion of RPMA 5 based on recent genetic analysis (Ed Heist, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO) that demonstrated that the F_{st}

statistic differences were the smallest when making comparisons among these two areas. However, recent work by Heist and Schrey (2006) suggest that pallid sturgeon in the upper reaches of RPMA 4, defined as the area immediately downstream form Gavins Point Dam, SD (RM 811) to Kansas City, MO (RM 367.5), appear to be genetically intermediate between Upper Missouri and Lower Missouri river pallid sturgeon. Again local brood for supplementation in the upper end of RPMA 4 should come from within this 443 RM area.

In the event that brood fish can not be collected locally, it may be necessary to obtain brood from neighboring areas with the understanding that there was historical genetic exchange occurring among these neighboring DUs (Figure 2). Supplementation with HRPS from neighboring DU brood stock should minimize genetic concerns. For example, if no local parental stocks can be collected from DU B (figure2) then progeny derived from DUs A or C should be genetically acceptable, and if no parental stocks could be collected from DU C then progeny derived from DU B will be deemed appropriate. At this time there are little to no genetic data on lower Mississippi River pallid sturgeon (DU D) and their relation to pallid sturgeon collected within DU C. Yet given the connectivity of DU C and D, it should be acceptable to utilize brood form DU D to supplement DU C. Using common logic in this example and to minimize genetic concerns, should local parents not be collected from DU B, then DU C should be the first brood source priority followed by DU A. This would substantially reduce any chances of DU A pallid sturgeon interbreeding with DU C or D pallid sturgeon.

Given the genetic structuring that is present, HRPS from DUs B and C should not be stocked in DU A (Figure 2). This will require that fish produced in DU A be given first priority for meeting supplementation goals in DU A. However, coordination among all supplementation activities in the upper and middle basins is essential to insure that both basins have opportunities to meet recovery goals.

RECORD KEEPING SYSTEM{ TC \L2 "RECORD SYSTEM}

A database will be maintained by the USFWS - Missouri River Fish and Wildlife Management Assistance Office in Bismark ND on all information pertaining to stocking. These data include the broodstock source, stocking date, transport water temperatures, ambient-water temperature at the time of stocking, location of stocking, number of fish stocked, size of fish prior to stocking, method of marking, tag numbers, and transport time. It will be the responsibility of project leaders or management biologists responsible for a given RPMA to provide those data to the USFWS office identified above or per USFWS permit requirements. Standardized information collected from recaptured fish will also be forwarded and stored at the Missouri River Fish and Wildlife Management Assistance Office.

INTER-AGENCY COORDINATION

Since pallid sturgeon are recognized as an endangered species by the USFWS and most of the affected states also afford various levels of special protection to these fish; permits to handle, transport, and stock pallid sturgeon must be obtained before conducting broodstock collections and hatchery supplementation efforts. Each year project leaders or management biologists responsible for a given RPMA will secure all state, federal, and other necessary permits. Since all of RPMA 1 and the majority of RPMA 2, occurs within Montana, permitting and associated responsibilities for this area will be delegated to a MFWP representative and coordinated with North Dakota Game and Fish for activities in RPMA 2. RPMA 3 permits will be coordinated with South Dakota and Nebraska through the Great Plains Fish and Wildlife Management Assistance Office, Pierre SD. The Columbia Fishery Resource Office, Columbia MO, will secure necessary permits from Nebraska, Iowa, Kansas, and Missouri for stocking activities in RPMA 4. No responsible entities are currently identified for stocking activities in RPMA 5 or 6 as stocking is not deemed necessary in those areas at this time.

USFWS project leaders and hatchery managers will be responsible for coordinating with their respective States and basin pallid sturgeon workgroups to identify stocking sites, provide fish health results, secure fish importation and stocking permits, and coordinate fish stockings activities with the production facilities. In boundary water situations, approval will be secured from both States before stockings occur, e.g., stocking fish into RPMA 3 will require approval from both SD and NE.

FISH MARKING AND TAGGING

A fish marking/tagging system that provides positive identification of each individual and their origin will be used to monitor the success of the augmentation program. Tagging schemes are being developed or have been developed within the respective basin pallid sturgeon workgroups. Coordinated marking efforts among these workgroups are essential in areas that may allow stocked fish to out-migrate into waters of another workgroup and thus these tagging schemes should be as consistent as possible throughout the range.

The USFWS has developed DNA protocols that will allow fishery biologists to identify hatchery-produced pallid sturgeon after their release as long as DNA samples have been collected from the parental stock. These DNA methods will reduce the need to physically mark or tag each fish prior to release. These DNA methods are similar to those widely employed by law enforcement agencies in forensic investigations. These protocols (DeHaan et al. 2005) were developed by the genetics staff at the USFWS CGL at Abernathy Fish Technology Center in Longview, WA, in collaboration with researchers at the University of California, Davis, Southern Illinois University, and the University of Alabama.

For pallid sturgeon, DNA profiles (i.e. genotypes) for every hatchery-spawned adult will be determined at several microsatellite, nuclear DNA loci. Those genetic profiles will then be stored in an electronic database as identified earlier. The pedigree database will include all recorded information on each spawned adult fish including body length, capture location, capture date, spawning date, hatchery where the fish was spawned, and the identification number of the fish of the opposite sex with which each fish was mated. Multi-locus DNA genotypes will similarly be determined for unmarked, juvenile and sub-adult pallid sturgeon captured from the Missouri River and Mississippi River watersheds. The DNA profiles for these latter, unmarked fish will be compared to those of the hatchery-spawned adults in the genetic database. If an unmarked/untagged fish is of hatchery-origin, then its DNA profile will "match" with those for one (and only one) male-female pair in the database for hatchery-spawned adults. If the unmarked/untagged fish is of natural origin, then its DNA profile will not "match" with any of those for all male-female pairs in the database. These genetic identifications will occur by *exclusion.* That is, if an unmarked/untagged sturgeon possesses one or more DNA markers not possessed by either the male or female parent of a particular hatchery-spawned pair, then that pair can be excluded as potential parents of the unmarked/untagged fish. Conversely, if a particular hatchery-spawned pair is truly the parents of an unmarked/untagged fish, then 100% of the DNA markers for the unmarked/untagged fish should be shared with those parents. By using 10-15 highly variable *loci,* the probability of an incorrect match can be reduced to virtually zero (DeHaan et al. 2005). This approach thus uses DNA markers as "genetic tags" that are inherited from parents to their offspring. Released fish do not need to be "genotyped" or physically tagged; only the parents of released fish need to be genotyped, thus substantially reducing costs for "tagging" released fish. Moreover, unlike physical tags, DNA markers cannot be lost.

All stocked pallid sturgeon should be marked with at least two different methods, with the exception being those fish too small to physically mark such as fry and fingerlings < 70 mm. In these cases, genetic analysis can discern natural production from augmented fish (William Ardren, USFWS, personal communication, DeHaan et al. 2005). PIT tags will be used when possible, as they can provide a long-term identification of individual fish for future monitoring to evaluate current efforts. Pallid sturgeon that are in excess of 20 grams have been successfully PIT tagged, with a retention rate of over 95 percent after a 6-month period in captivity (Steve Krentz, USFWS, personal communication.) and Jan Dean (USFWS Personal communication) has found an overall hatchery reared juvenile pallid sturgeon PIT tag retention rate of 51% (n=96) during a 127 day study at Booker-Fowler SFH. Evaluation of transmitter retention in the wild has yielded moderate success with PIT tags. Matt Klungle (MFWP, personal communications) has indicated a 76% tag retention rate based on sampled individuals (n=86) in RPMA 2 and Shuman et al. (2005) reported 86% retention (n=28) in RPMA 3. When PIT tags are not appropriate, such as in young-of-the-year fish that are too small (<140mm), a marking system using a combination of identifiers such as CWT and sub-cutaneous latex polymer injections (elastomere) will identify fish to broodstock source and will provide family and year-class information. Elastomere color can also be used to designate stocking year and location on the rostrum. When fry stocking occurs, those fish are already marked genetically (William Ardren, USFWS, personal communication, DeHaan et al. 2005). Finally, researchers at the USFWS Bozeman Fish Technology Center are evaluating new marking techniques like scute removal. If determined to be a successful mark, this method will be incorporated into the marking schemes. All tagging will be conducted prior to transport for stocking to evaluate short-term tag loss, and allow for re-tagging if necessary, and culling of mortalities at time of stocking.

FISH HEALTH

The shovelnose sturgeon iridovirus was first detected in shovelnose sturgeon at Gavins Point NFH in 1998. Since 1998, iridovirus outbreaks have occurred at Gavins Point NFH, Garrison Dam NFH, Neosho NFH, Miles City SFH, and Blind Pony SFH. Evidence of the virus outside of the hatchery environment has also been documented. There has been one Upper Basin pallid sturgeon (adult female held at Garrison Dam) found to be virus positive by histology (Crystal Hudson, USFWS, personal communication). Between November 2003 and May 2004, 179 sturgeon pectoral fin clips were collected from the Atchafalaya River. Of these, 8 (4%) were identified as virus positive and 5 (2.8%) were considered virus suspect. These samples included both pallid and shovelnose sturgeon that tested either positive or suspect. (Bobby Reed, Lower basin Workgroup Chairperson, personal communication). In a hatchery environment, the iridovirus outbreaks can cause high initial mortality, are generally most severe for young of the year fish, and surviving pallid sturgeon appear to do well after the initial outbreak. However, virus positive non-epizootic HRPS may have reduced numbers of sensory and mucus cells that could jeopardize their survival in the wild (Crystal Hudson, USFWS, personal communication). The effect of this virus on wild populations is currently poorly understood. Stocking of iridovirus positive pallid sturgeon is a subject of much debate. The virus has been detected in samples collected from within the range of pallid sturgeon and suggests the virus could be endemic to the Missouri River Basin below Fort Peck Dam, Montana. However, an important question that has been raised is; what are the effects of stocking fish with potentially high viral titres having on fish in the receiving waters? Stocking iridovirus positive fish is still subject to the approval of State resource management agencies and policies vary widely from state to state. The USFWS currently operates under the guidelines that entities responsible for border water areas must support the stocking proposal before they are implemented. To date, iridovirus positive fish have been stocked into RPMAs 2, 3, and 4. A mechanism to score viral severity is utilized by fish health personnel. Suspect fish are analyzed histologically and iridovirus severity is ranked from 1 – 5 with 1 representing minimal infection of one or two infected cells present in the entire section of pectoral fin and five being a severe infection with too many cells to count in an entire section of pectoral fin. The USFWS agrees in principal that pallid sturgeon should not be stocked while they are experiencing an iridovirus epizootic outbreak, but iridovirus positive fish may be stocked if they are not experiencing an epizootic event and if the States receiving the virus positive non-epizootic pallid sturgeon are supportive of this action. A problem with the protocol is the lack of clear definition of when fish are experiencing an epizootic outbreak and when they are only iridovirus positive. At present, fish health experts generally rely on mortality as an indicator, when in fact, HRPS can have a high viral severity and not be experiencing significant mortalities (Crystal Hudson, USFWS, personal communication).

The condition of the liver has also been examined to evaluate the fish health. Currently the Fish Health Lab in Bozeman, Montana has developed a laboratory diagnostic liver evaluation. This technique uses fatty vacuolation of hepatocytes and samples are scored from zero to five where zero indicates no fat present and five represents hepatocytes membranes that have ruptured due to excessive fat accumulation in the cell. A score of four is considered borderline pathological, whereas a score of five is pathological. To date there is no agreed upon guidelines for rejecting or accepting fish for stocking based solely on liver condition and no fish have been rejected for stocking on this basis. However, MFWP has established criteria for deeming fish healthy (mean virus severity score ≤ 3.0 and liver condition score < 4; also in the Upper Basin Pallid Sturgeon Workroup 2005). Fish that do not meet these criteria will not be accepted for importation or stocking by MFWP's Fish Health Committee in RPMA 1 or 2. Evaluation and development of a fatty liver protocol is warranted.

All suggested stocking rates and calculations in this document assume that hatchery-reared pallid sturgeon (HRPS) are deemed healthy by a pre-release fish health assessment per regulations stipulated in Chapter 713 of the FWS Manual before stocking and that all applicable Federal and State agency permits are obtained.

SUMMARY

The Pallid Sturgeon Recovery Plan (U. S. Fish and Wildlife Service 1993) identified the development of a pallid sturgeon propagation and stocking program as a primary action to conserve pallid sturgeon. In the years since the recovery plan was developed, technology, facilities, and information have been developed to a point where this is now possible.

In the background of this document, the current best available information on pallid sturgeon has been synthesized, and is summarized as follows:

1. Reproduction and recruitment of wild fish in RPMA 1, 2, 3, and 4 are insufficient to sustain a natural population; there is a lack of solid data regarding reproduction and recruitment in RPMA 5 and 6 (based on data presented to the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005).

2. Any sporadic reproduction that might occur in RPMA 1, 2, or 3 yields no significant recruitment, likely due to poor survival of larval and/or juvenile fish and/or lack of mature adults (based on data presented to the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005).

3. An accurate assessment of the population status within RPMA 5 and 6 is lacking. The data available indicate pallid sturgeon abundance may be higher than initially believed, but sampling efforts do not adequately sample all size/age classes. There are some data suggesting natural spawning success, but no data are available to accurately evaluate recruitment levels.

4. Commercial harvest of *Scaphirhynchus spp.* within portions of RPMA 4 and 5 is a threat that sporadic recruitment can not likely sustain and likely is suppressing natural recruitment of pallid sturgeon.

5. Pallid sturgeon recovery will require some degree of augmentation and stocking within portions of its range to maintain populations until factors limiting natural spawning and recruitment are identified, mitigated, and pallid sturgeon populations are self-sustaining (U. S. Fish and Wildlife Service 1993, U.S. Fish and Wildlife Service 2000, data presented to the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005).

6. The current existing wild population within RPMA 1-3 will be extirpated or severely depressed before the introduced population reaches sexual maturity (U.S. Fish and Wildlife Service 2000, based on data presented to the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005).

7. Genetic structuring of pallid sturgeon throughout its range reflects a one dimensional linear stepping-stone distribution as explained in Gharette and Zhivotovsky (2003). That is, gene flow is more likely to occur between adjacent areas than among geographically distant areas.

Based on this information, a pallid sturgeon stocking program continues to be a primary action to conserve pallid sturgeon within portions of its range. In developing this program, the following assumptions were made:

1. Survival estimates for RPMA 1 and 2 stocked HRPS (Table 5) were obtained from the Montana Fish Wildlife and Parks stocking plan for RPMA 1 and 2. These estimates were modified from Kincaid (1993) in that they theorize some level of reduced survival associated with a diet shift from a macroinvertebrate to a piscivores diet. Also, it is hypothesized that sub-yearling pallid sturgeon will have higher mortality rates than later life stages, do in part to predation. This reasoning is the basis for the various ratios associated with stocking sub-yearling pallid sturgeon and their relation to yearling stocking equivalents.

2. The low abundance and old age of the remaining naturally recruited individuals available for the hatchery propagation and stocking programs dictate that stocking all available upper basin origin progeny in RPMA 1-3 takes precedence over the genetic composition of the founder population which can be addressed through natural selection or other techniques at a future date (Upper Basin Pallid Sturgeon Workgroup).

3. The survival estimates for RPMA 3 and 4 are based on an assumption that sturgeon survival rates within these RPMAs are similar to those documented for white sturgeon in the Kootenai River, Idaho (Ireland et al. 2002) (Table 6).

4. The target population of 6 spawning age adults per river mile is an intuitive estimate that is assumed to be sufficiently large enough to maintain population structure at adequate levels until the species is naturally recruiting.

5. Iridovirus positive fish have been documented in the wild (downstream of Fort Peck Dam, MT, Gavins Point Dam, SD, and in the Atchafalaya River). The general view is that the virus is endemic and epizootic events may be the product of high density rearing in a hatchery environment and stocking non-epizootic iridovirus positive pallid sturgeon into the wild will have no deleterious affects on either pallid sturgeon or shovelnose sturgeon.

RPMA 1
STOCKING RISKS/BENEFITS

There are inherent risks as well as potential benefits associated with most recovery actions. Such is the case with artificial augmentation of pallid sturgeon in the Upper Missouri River. Following is a discussion of the benefits and risks associated with supplementation of pallid sturgeon in RPMA 1.

BENEFITS

<u>Reduction in the extirpation risk of local populations</u>

Data are available (Bill Gardner, MFWP, data presented to the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005) that indicate when stocking has occurred within RPMA 1; those stocked fish are contributing to the population. Currently the data indicate zero natural reproductive contribution to the adult population. Without supplementation, the pallid sturgeon population in RPMA 1 will be extirpated before the threats to the species within this RPMA can be addressed.

<u>Maintenance of local population while habitat restoration efforts are implemented</u>

Implementation of restoration activities are being discussed with other state and federal agencies. Activities that have been and will be implemented are centered on habitat restoration. As various phases of habitat restoration are implemented the threat of habitat loss/degradation identified in the Pallid Sturgeon Recovery Plan (U. S. Fish and Wildlife Serivice 1993) is being reduced. Miller and Kapuscinski (2003) identify addressing habitat quality and quantity as part of a comprehensive plan of which supplementation is only a part.

<u>Establish a reserve population for use if the natural population suffers catastrophic loss.</u>

Given the genetic similarities of pallid sturgeon within RPMA 1 and RPMA 2, supplementation with in RPMA 1 would insure protection of the upper basin pallid sturgeon in the event of a catastrophic event occurring within RPMA 2 or at Gavins Point NFH. Gavins Point NFH currently is the only facility rearing a portion of past family lots as part of the future brood program outlined within the Pallid Sturgeon Recovery Plan (U. S. Fish and Wildlife Serivice 1993).

<u>Provide a means to evaluate the effects of supplementation in a recovery program.</u>

Supplementation into an existing population may or may not be beneficial (Waples and Drake 2004). The current perceived success of the augmentation program for pallid sturgeon is suggesting that a more normalized length frequency and age structure is being established within RPMA 1. Continued supplementation and evaluation within this RPMA may prove useful in shedding some valuable insights on supplementation programs for other species.

RISKS

<u>Within and among population loss of genetic diversity</u>

Miller and Kapuscinski (2003) detail many of the genetic hazards associated with supplementation programs. These authors suggest that the loss of within-population genetic diversity is mainly attributable to two causes. These are genetic drift from collecting gametes from a population of limited size and inbreeding. They also suggest that the loss of between-population genetic diversity is attributable to fish crossing from different populations (artificially elevated levels of migration) with one negative outcome being outbreeding depression. Artificial levels of gene flow can occur if parental fishes from two genetically structured stocks are inadvertently crossed in the hatchery spawning process or if the out plants from hatcheries are more likely to intermix with other stocks than would occur naturally. There are methods that when implemented can greatly reduce the risks of supplementation. Selecting an appropriate brood source is the number one priority. While genetic studies (Campton et al. 2000, Tranah et al. 2001, Heist and Schrey 2004) indicate genetic structuring within the pallid sturgeon population range wide, they also identified that there were no detectable differences among Upper Missouri River samples collected above and below Fort Peck Dam. For these reasons, the best available brood source for artificial propagation within RPMA 1 should be from RPMA 1 and/or 2. However, even within the Upper Basin, great care is being taken to reduce some of the risks of supplementation (see Maintaining Genetic Diversity and Minimizing Inbreeding in Hatchery Broodstocks section of this plan). This recommendation has some risks associated with it, like loss of wild pallid sturgeon due to handling stress associated with the artificial propagation process.

Loss of fitness due to outbreeding depression or unnaturally high rates of gene flow among genetically distinct groups of pallid sturgeon is always possible. No significant differences have been detected between pallid sturgeon sampled in the Missouri River above and below Fort Peck Dam (RPMA's 1 and 2) (Campton et al 2000, Tranah et al 2001) so it is anticipated that reduced fitness or loss of locally adaptive traits associated with outbreeding depression is not a great concern. This assumption is based on the close geographic proximity of the two groups, nearly identical phenotypic characters, and comparable success of progeny stocked from either RPMA parents into the other RPMAs. However, it should be pointed out that there has been no evaluation of life history characteristics or environmental variables to confirm or deny this hypothesis. Furthermore, the connectivity of the Upper Missouri River with the Missouri River below Gavins Point Dam and the Mississippi River is fragmented by six large impoundments thus the probability of out migration is equal to or very near to zero.

Inter and Intra-specific competition

Utilizing hatchery produced pallid sturgeon to supplement an existing population could result in increased competition with the existing population as well as with other native fishes. Adult pallid sturgeon are piscivorous and would likely forage on riverine cyprinid species such as flathead chubs, western silvery minnow (*Hybognathus argyritis*), and the less common sicklefin chubs (*Macrhybopsis meeki*) and sturgeon chubs (*Macrhybopsis gelida*). Increasing the abundance of pallid sturgeon will likely increase predation rates on riverine forage species, but the impact of increased predation is unknown. Intraspecific competition among hatchery released fish and wild fish would appear to be problematic if there was some evidence that wild pallid sturgeon were reproducing. Interspecific competition with the closely related shovelnose likely would only occur at the younger juvenile life stages as shovelnose sturgeon appear to be mostly insectivores as are pallid sturgeon juveniles (Gerrity 2005) while pallid sturgeon sub-adults (age 6+) and adults appear to be more piscivores than shovelnose adults.

Disease Transfer

The shovelnose sturgeon iridovirus has been detected in pallid sturgeon propagated at several of the production facilities and detected in wild sturgeon. However, the virus has not been documented upstream of Fort Peck Dam. The impacts of stocking iridovirus positive pallid sturgeon on populations of both shovelnose and pallid sturgeon in the receiving waters are poorly understood. The low densities of the stocked fish may mediate this threat but it must be considered. Disease testing will be completed on pallid sturgeon progeny prior to stocking. Currently, this entails collection of a statistically valid sample from production facilities and subsequent histological evaluation for evidence of the virus. Fish health certification and approval from Montana Fish Wildlife and Parks Fish Health Committee will be required prior to transportation and stocking in RPMA 1.

CONCLUSIONS

Waples and Drake (2004) discuss the potential benefits and risks associated with supplementation programs and strongly caution to evaluate the risks prior to implementation of a supplementation program. However, they also indicate that if the population faces extinction in the short-term, supplementation may be necessary in light of the potential risks. Given that natural recruitment is not occurring in RPMA 1, the data indicate that it has not occurred for many years, and that it may take many years to fully implement habitat restoration activities; stocking must continue in RPMA 1 to insure persistence of the pallid sturgeon within this reach. Based on previous genetic analysis, brood source for RPMA 1 should be collected from RPMA 1 and RPMA 2.

RPMA 2

STOCKING RISKS/BENEFITS

There are inherent risks as well as potential benefits associated with most recovery actions. Such is the case with artificial augmentation of pallid sturgeon in the Upper Missouri River. Following is a discussion of the benefits and risks associated with pallid sturgeon supplementation in RPMA 2.

BENEFITS

<u>Reduction in the potential risk of extinction of local populations</u>

Steve Krentz (data presented to the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005) indicated when stocking has occurred within RPMA 2; those stocked fish are contributing to the population demographics. Currently the data indicate limited spawning success with zero natural reproductive contribution to the adult population. Without supplementation, the pallid sturgeon population in RPMA 2 likely will be extirpated before sufficient habitat restoration activities can be implemented to address the threats to this species.

<u>Maintenance of local population while habitat restoration efforts are implemented</u>

Implementation of restoration activities are being discussed with other state and federal agencies. Activities that have been and will be implemented are centered on habitat restoration. As various phases of habitat restoration are implemented the threat of habitat loss/degradation identified in the Pallid Sturgeon Recovery Plan (U. S. Fish and Wildlife Serivice 1993) may be reduced. Miller and Kapuscinski (2003) identify addressing habitat quality and quantity as part of a comprehensive plan of which supplementation is only a part. Addressing fish passage and entrainment at Intake Dam on the Yellowstone River is paramount as this large tributary to the Missouri River is one of the few tributaries that is not impounded and still retains a relatively natural hydrograph.

Establish a reserve population for use if natural population suffers catastrophic loss.
Given the genetic similarities of pallid sturgeon within RPMA 1 and RPMA 2, supplementation within RPMA 2 will insure protection of the upper basin pallid sturgeon in the event of a catastrophic event occurring within RPMA 1 or at Gavins Point NFH by insuring the persistence of the species and the ability to retain genetically pure upper basin pallid sturgeon.

Provide a means to evaluate the effects of supplementation in a recovery program.
Supplementation into an existing population may or may not be beneficial (Waples and Drake 2004). The current perceived success of the augmentation program for pallid sturgeon is demonstrated in that a more normalized length frequency and age structure is being established within RPMA 2. Continued supplementation and evaluation within this RPMA may prove useful in shedding some valuable insights on supplementation programs for other species while insuring persistence of the species within this RPMA.

RISKS
Within and among population loss of genetic diversity
Miller and Kapuscinski (2003) detail many of the genetic hazards associated with supplementation programs. These authors suggest that the loss of within-population genetic diversity is mainly attributable to two causes. These are genetic drift from collecting gametes from a population of limited size and inbreeding. They also suggest that the loss of between-population genetic diversity is attributable to fish crossing from different populations (artificially elevated levels of migration) with one negative outcome being outbreeding depression. Artificial levels of gene flow can occur if parental fishes from two genetically structured stocks are inadvertently crossed in the hatchery spawning process or if the out plants from hatcheries are more likely to intermix with other stocks than would occur naturally. There are methods that when implemented can greatly reduce the risks of supplementation. Selecting an appropriate brood source is the number one priority. While genetic studies (Campton et al. 2000, Tranah et al. 2001, Heist and Schrey 2004) suggest genetic structuring within the pallid sturgeon population range wide, they also identified that there were no detectable differences among Upper Missouri River samples collected above and below Fort Peck Dam. For these reasons, the best available brood source for artificial propagation within RPMA 2 should be from RPMA 2 and/or 1. However, even within the genetic similarities between RPMA 1 and 2, great care is being taken to reduce most supplementation risks (see Maintaining Genetic Diversity and Minimizing Inbreeding in Hatchery Broodstocks section of this plan). This recommendation has some risks associated with it, like loss of individual wild pallid sturgeon collected as broodstock, due to handling stress.

Loss of fitness due to outbreeding depression or unnaturally high rates of gene flow among genetically distinct groups of pallid sturgeon is always possible. No significant differences have been detected between pallid sturgeon sampled in the Missouri River above and below Fort Peck Dam (RPMA's 1 and 2) (Campton et al 2000, Tranah et al 2001) so it is anticipated that reduced fitness or loss of locally adaptive traits associated with outbreeding depression is not a great concern. This assumption is based on the close geographic proximity of the two groups, nearly identical phenotypic characters, and comparable success of progeny stocked from either RPMA parents into the other RPMAs. However, it should be pointed out that there has been no evaluation of life history characteristics or environmental variables to confirm or deny this hypothesis. Furthermore, the connectivity of the Upper Missouri River with the Missouri River below Gavins Point Dam and the Mississippi River is fragmented by six large impoundments thus the probability of out migration is equal to or very near to zero.

Inter and Intra-specific competition

Utilizing hatchery produced pallid sturgeon to supplement an existing population could result in increased competition with the existing population as well as with other native fishes. Adult pallid sturgeon are piscivorous and would likely forage on riverine cyprinid species such as flathead chubs, western silvery minnow, and the less common sicklefin chubs and sturgeon chubs. Increasing the abundance of pallid sturgeon will likely increase predation rates on riverine forage species, but the impact of increased predation is unknown. Intraspecific competition among hatchery released fish and wild fish would appear to be problematic if there was some evidence that wild pallid sturgeon were reproducing. Interspecific competition with the closely related shovelnose likely would only occur at the younger juvenile life stages as shovelnose sturgeon appear to be mostly insectivores as are pallid sturgeon juveniles (Gerrity 2005) while pallid sturgeon sub-adults (age 6+) and adults appear to be more piscivores than shovelnose adults.

Disease Transfer

The shovelnose sturgeon iridovirus has been detected in pallid sturgeon propagated at several of the production facilities and detected in the wild. The impacts of stocking shovelnose sturgeon irridovirus positive pallid sturgeon on populations of both shovelnose and pallid sturgeon in the receiving waters are poorly understood. The low densities of the stocked fish may mediate this threat but it must be considered. Disease testing will be completed on pallid sturgeon progeny prior to stocking. Currently, this entails collection of a statistically valid sample from production facilities and subsequent histological evaluation for evidence of the virus. Fish health certification and approval from Montana Fish Wildlife and Parks and North Dakota Game and Fish health committees will be required prior to transportation and stocking in RPMA 2.

CONCLUSIONS

Waples and Drake (2004) discuss the potential benefits and risks associated with supplementation programs and strongly caution to evaluate the risks prior to implementation of a supplementation program. However, they also indicate that if the population faces extinction in the short-term, supplementation may be necessary in light of the potential risks. Given that natural recruitment is not occurring in RPMA 2 and the data indicate that it has not occurred for many years, and that it may take many years to fully implement habitat restoration activities like fish passage at Intake Dam or modified flow releases from Fort Peck Dam, stocking must continue in RPMA 2 to insure persistence of the pallid sturgeon within this reach. Based on previous genetic analysis, brood source for RPMA 2 should be collected from RPMA 1 and/or RPMA 2.

RPMA 3

STOCKING RISKS/BENEFITS

There are inherent risks as well as potential benefits associated with most recovery actions. Such is the case with artificial augmentation of pallid sturgeon in the Upper Missouri River. Following is a discussion of the benefits and risks associated with pallid sturgeon supplementation in RPMA 3.

BENEFITS

Reduction in the potential risk of extinction of local Populations

George Jordan (data presented to the Pallid Sturgeon Recovery Team, Lakewood Co, 27 September 2005) indicated when stocking has occurred within RPMA 3; those stocked fish are contributing to the population demographics. Without supplementation, the pallid sturgeon population in RPMA 3 likely will be extirpated before sufficient habitat restoration activities can be implemented to address the threats to this species.

Maintenance of local population while habitat restoration efforts are implemented

Natural processes like sedimentation are improving habitat conditions within this RPMA. As the upper reaches of Lewis and Clark Reservoir silts in, it is creating new riverine habitats. Unpublished data (Great Plains FWMAO) suggests that stocked HRPS are utilizing this new habitat. Also, efforts to reduce anthropogenic modifications like bank stabilization are ongoing. As the habitat naturally stabilizes and anthropogenic modifications are reduced the threat of habitat loss/degradation identified in the Pallid Sturgeon Recovery Plan (U. S. Fish and Wildlife Serivice 1993) will decline. Miller and Kapuscinski (2003) identify addressing habitat quality and quantity as part of a comprehensive plan of which supplementation is only a part. Likely, through time, natural process will improve habitat and bolster the success of the supplementation efforts.

Establish a reserve population for use if natural population suffers catastrophic loss.

Pallid sturgeon from RPMA 1 and RPMA 2 have been used to establish a founder population within RPMA 3, this established population will insure protection of the upper basin pallid sturgeon genetics and safeguard against ill effects from some unforeseen stochastic event occurring within RPMA 1 or 2 or at Gavins Point NFH.

Provide a means to evaluate the effects of supplementation in a recovery program.

Supplementation into an existing population may or may not be beneficial (Waples and Drake 2004). Continued supplementation and evaluation within this RPMA may prove useful in shedding some valuable insights on supplementation programs for other species as well as reestablishing populations where there may have been localized extinction.

RISKS

Within and among population loss of genetic diversity

Miller and Kapuscinski (2003) detail many of the genetic hazards associated with supplementation programs. These authors suggest that the loss of within-population genetic diversity is mainly attributable to two causes. These are genetic drift from collecting gametes from a population of limited size and inbreeding. They also suggest that the loss of between-population genetic diversity is attributable to fish crossing from different populations (artificially elevated levels of migration) with one negative outcome being outbreeding depression. Artificial levels of gene flow can occur if parental fishes from two genetically structured stocks are inadvertently crossed in the hatchery spawning process or if the out plants from hatcheries are more likely to intermix with other stocks than would occur naturally. There are methods that when implemented can greatly reduce the risks of supplementation. Selecting an appropriate brood source is the number one priority. While genetic studies (Campton et al. 2000, Tranah et al. 2001, Heist and Schrey 2004) suggest genetic structuring within the pallid sturgeon population range wide, they also identified that there were no detectable differences among Upper Missouri River samples collected above and below Fort Peck Dam. For these reasons, the best available brood source for artificial propagation within RPMA 3 should be from RPMA 1 and 2. This recommendation has some risks associated with it, like loss of wild pallid sturgeon due to handling stress.

Loss of genetic fitness due to outbreeding depression or unnaturally high rates of gene flow among genetically distinct groups of pallid sturgeon is always possible. However, available data do not indicate a substantial amount of out-migration of stocked pallid sturgeon from RPMA 3. Nearly 416 pallid sturgeon (1997 year class) were stocked into RPMA 3 in 2000 (Herb Bollig, personal communication). These fish were marked with a visible external dangler tag. Over the five years post stocking, two of these pallid sturgeons have been collected below Gavins Point Dam. From 2002 through 2004 there have been other stocking events in RPMA 3 totaling 1855 hatchery reared pallid sturgeon (Krentz et al. 2005), from which none have been collected below Gavins Point Dam. These data suggest that less than 1% of 3 year old stocked pallid sturgeon pass through Gavins Point Dam with no documented pass through of pallid sturgeon stocked at smaller sizes. This percentage is not far from the 3% dam pass through of white sturgeon, *Acipenser transmontanus*, on the Columbia River system documented by Kern et al. (2004). Another reason for low emigration data may be due in part to limited sampling effort. The Population Assessment Program was not fully implemented until 2005. Limited effort prior to 2005, and the magnitude of RPMA 4 likely are skewing these results. However, telemetry data indicate that stocked 3 year old pallid sturgeon remained and utilize the riverine reach of RPMA 3 (Jordan et al. 2005). There have also been numerous accounts of angler caught pallid sturgeon from the 2000 stocking and sampling efforts in that reach have detected pallid sturgeon from subsequent stockings (Great Plains FWMAO unpublished data). Finally, the genetics data (Heist and Schrey 2004) suggests that there is genetic structuring in the pallid sturgeon population with some evidence of historical levels of gene flow occurring among populations. An occasional "out-migrant" from RPMA 3 into RPMA 4 may help to maintain some low level of historical geneflow.

<u>Inter and Intra-specific competition</u>
Utilizing hatchery produced pallid sturgeon to supplement an existing population could result in increased competition with the existing population as well as with other native fishes. Adult pallid sturgeon are piscivorous and would likely forage on riverine cyprinid species such as flathead chubs, western silvery minnow, and the less common sicklefin chubs and sturgeon chubs. Increasing the abundance of pallid sturgeon will likely increase predation rates on riverine forage species, but the impact of increased predation is unknown.

Intraspecific competition among hatchery released fish and wild fish would appear to be problematic if there was some evidence that wild pallid sturgeon still persisted within RPMA 3. Interspecific competition with the closely related shovelnose likely would only occur at the younger juvenile life stages as shovelnose sturgeon appear to be mostly insectivores as are pallid sturgeon juveniles (Gerrity 2005) while pallid sturgeon sub-adults (age 6+) and adults appear to be more piscivores than shovelnose adults.

Disease Transfer

The shovelnose sturgeon iridovirus has been detected in pallid sturgeon propagated at several of the production facilities and detected in wild fish. Members of the 1998 year class of pallid sturgeon stocked previously within this reach were later determined to potentially have had or been exposed to the irridovirus at Gavins Point NFH. The impacts of stocking shovelnose sturgeon irridovirus positive pallid sturgeon on populations of both shovelnose and pallid sturgeon in the receiving waters are poorly understood, but to date, there have been no documented ill effects within this reach. The low densities of the stocked fish may mediate this threat but it must be considered. Disease testing will be completed on pallid sturgeon progeny prior to stocking. Currently, this entails collection of a statistically valid sample from production facilities and subsequent histological evaluation for evidence of the virus. Fish health certification and approval from South Dakota Game, Fish and Parks as well as Nebraska Game and Parks Commission will be required prior to transportation and stocking in RPMA 3.

CONCLUSIONS

Waples and Drake (2004) discuss the potential benefits and risks associated with supplementation programs and strongly caution to evaluate the risks prior to implementation of a supplementation program. However, they also suggest that historical habitat that may currently be void of the target species, likely should be considered as an area for reestablishment. To date, representatives from all stocking events in RPMA 3 have been collected and there is no evidence of an existing local population within this reach that may be negatively impacted by supplementation. Given that natural recruitment is not occurring in RPMA 3 and the data indicate that it has not occurred for many years, and that it may take many years to fully implement habitat restoration activities stocking should continue in RPMA 3 to insure persistence of the pallid sturgeon within this reach. Based on previous genetic analysis, brood source for RPMA 3 should be collected from RPMA 1 and RPMA 2.

RPMA 4

STOCKING RISKS/BENEFITS

There are inherent risks as well as potential benefits associated with most recovery actions. This is equally true for artificial augmentation of pallid sturgeon in the Missouri River. Following is a discussion of the benefits and risks associated with supplementation of pallid sturgeon populations in RPMA 4.

BENEFITS

Reduction in the potential risk of extinction of local populations

Currently there may not be an immediate threat of extirpation in RPMA 4 as with RPMA 1 and 2. Demographic data of pallid sturgeon collected in the lower reaches of RPMA 4 suggest that recruitment is sporadic. However, this evidence is speculative based on several unknown origin pallid sturgeon that could be naturally produced or hatchery produced fish with failed or expelled tags (Wyatt Doyle, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO). In any event, past supplementation efforts are contributing to the juvenile population, and current demographic data suggest that stocked fish have or will recruit into the adult population very soon.

Maintenance of local population while habitat restoration efforts are implemented

Miller and Kapuscinski (2003) recommend addressing habitat quality and quantity as part of a comprehensive recovery plan of which population supplementation is only a part. Implementation of conservation and restoration activities are being developed and initiated with other state and federal agencies (US Fish and Wildlife Service 2000, 2000a). Activities that have been and will be implemented are centered on habitat restoration and include actively designing and incorporating environmental features like shallow water habitat and alteration of flow releases via manipulation of dam operations to simulate a more natural spring hydrograph. Much effort and resources have been expended to design and evaluate these habitat improvement efforts thought to benefit pallid sturgeon. Evaluation of these restoration activities will rely on shovelnose sturgeon as surrogates if adequate numbers of pallid sturgeon are not obtained. Supplemented HRPS could be critical for adequate evaluation given concerns over evaluating biological responses based on surrogates (Caro et al. 2005). Further data that supports not using shovelnose as surrogates for pallid sturgeon can be found in data suggest that feeding habits are different (Cross 1967, Held 1969, Carlson et al. 1985, Gerrity 2005) and they use different habitats within the river (Forbes and Richardson 1909, Carlson et al. 1985, Bramblett 1996).

Provide a means to evaluate the effects of supplementation in a recovery program.

Supplementation into an existing population may or may not be beneficial (Waples and Drake 2004). Continued supplementation and evaluation within this RPMA may prove useful in shedding some valuable insights on supplementation programs for other species as well as reestablishing populations where there may have been localized extinction.

RISKS

Within and among population loss of genetic diversity

Miller and Kapuscinski (2003) detail many of the genetic hazards associated with supplementation programs. These authors suggest that the loss of within-population genetic diversity is mainly attributable to two causes, genetic drift associated with collecting gametes from a population of limited size and population inbreeding. They also suggest that the loss of between-population genetic diversity is attributable to fish crossing from different populations (artificially elevated levels of migration) the negative result being loss of fitness due to outbreeding depression. Artificial levels of gene flow can occur if parental fishes from two genetically structured stocks are inadvertently crossed in the hatchery spawning process or if the hatchery progeny are more likely to intermix with other stocks than would occur naturally. Genetic studies (Campton et al. 2000, Tranah et al. 2001, Heist and Schrey 2004, Schrey and Heist 2005a and 2005b) indicate genetic structuring within the pallid sturgeon population range wide. The majority of fish stocked into RPMA 4 have been of Upper Missouri River origin These HRPS are from parental stocks that are reproductively isolated and thus genetically discernable from Lower Missouri and Middle Mississippi River pallid sturgeon (Heist and Schrey 2004). As no barrier to movement of these hatchery fish into the Middle Mississippi River exists, there is potential for outbreeding depression between Upper Missouri, Lower Missouri, and Mississippi/Atchafalaya river pallid sturgeon DUs. Outbreeding depression due to mixing of genetic populations has been recognized as a factor in fish conservation for over 50 years.

While this is always a concern in non-closed systems, movement data suggests that this may not be as problematic with pallid sturgeon. Just because the two river systems are connected, does not insure that unnaturally high rates of gene flow will occur. Movement data for pallid sturgeon suggests that while they are a mobile species, individuals have not been found to roam great distances.

Within the upper portion of RPMA 4 (RM 811 to RM 498), NGPC has collected a total of 36 HRPS released into RPMA 4 (Kirk Steffensen, NGPC, personal communications). Hatchery-reared juvenile pallid sturgeon from all hatcheries involved in past stocking events except Blind Pony State Fish Hatchery are represented in these 36 recaptures. Pallid sturgeon produced at Blind Pony Hatchery in 1994 and 1997 were stocked at three locations in the lower 100 RM of RPMA 4. These fish were progeny of pallid sturgeon collected from the Mississippi River at Caruthersville, Missouri (RM 846). The lack of recaptures of these Middle Mississippi River progeny in the upper reaches of RPMA 4, suggests that Mississippi River origin pallid sturgeon stocked in the lower reaches of RPMA 4 do not readily move into the upper reaches of RPMA 4, at least as juveniles. NGPC has captured pallid sturgeon of Upper Missouri River origin that were stocked in the Missouri River at Boonville, MO (RM 195). This single recapture documents an upstream movement of 398.4 RM of an upper basin origin HRPS. NGPC has also documented a 407.3 RM downstream movement in the Missouri River from Verdel, NE (RPMA 3) to St. Joseph Bend (RM 449-443). The average documented movement of upper basin origin HRPS from stocking site to recapture location within the upper reaches of RPMA 4 was 136 RM (Kirk Steffensen, NGPC, personal communications). Additionally the Columbia Fishery Resources Office has documented an upstream 207 RM movement in RPMA 4(Boonville, Missouri to Ft. Leavenworth, Kansas) of Upper Missouri River origin HRPS. Looking at data from the lower reaches of RPMA 4 also suggests that stocked pallid sturgeon may not move long distances.

A recent query of the National Pallid Sturgeon Database indicates that of the approximately 60,000 HRPS released into RPMA 4, fourteen were subsequently captured in the Mississippi River. All these recaptured pallid sturgeon were stocked in the lower 100 miles of the Missouri River and were from the 94 or 97 stockings; these fish were produced from Mississippi River pallid sturgeon, and to date, no Upper Missouri River origin pallid sturgeon stocked within

RPMA 4 have ever been recaptured in the Middle or Lower Mississippi River. (Steve Krentz, USFWS, personal communication). This suggests that juvenile pallid sturgeon stocked from Upper Missouri River origin parents do not readily out-migrate from the Missouri River into the Mississippi River. However, there has been 3 documented instances of Middle Mississippi River collected pallid sturgeon moving up into the most downstream portion of RPMA 4 (Jim Garvey, Southern Illinois University data presented at the pallid sturgeon Recovery team meeting September 28 and 29, 2005 held in Lakewood, CO). In other studies, pallid sturgeon did not exhibit extremely large home ranges. Movement data of juvenile pallid sturgeon in Montana (RPMA 1) indicate a home range size of 1.1 to 73.9 km (Gerrity, 2005). Bramblett and White (2001) observed movements of wild adult pallid sturgeon in the Missouri River below Fort Peck Dam (RPMA 2) and noted a range of activity for adult pallid sturgeon as approximately 7 RM to 205 RM (12.4 to 331 km). Similarly, Hurley (1996) reported observed pallid sturgeon home ranges of 0.6 to 60 RM (1-97 km) with an average home range size of 21 RM (34.1 km) in the Middle Mississippi River. These data suggest that while large riverine species can and will migrate long distances, juvenile pallid sturgeon may remain in relatively localized areas.

Inter and Intra-specific competition

Utilizing hatchery produced pallid sturgeon to supplement an existing population could result in increased competition with the existing population as well as with other native fishes. Adult pallid sturgeon are piscivorous and would likely forage on riverine cyprinid species. Increasing the abundance of pallid sturgeon will likely increase competition rates that may reduce supplementation success or have a negative impact on the receiving population, but these impacts if any are unknown. Intraspecific competition among hatchery released fish and wild fish may appear to be problematic if there was some evidence that wild pallid sturgeon were reproducing in great numbers. Kirk Steffensen (NGPC, personal communications) has indicated that stocked pallid sturgeon recollected in RPMA 4 experienced a decline in their relative condition factor post stocking. However, only one pallid sturgeon from the 1999 year class was noticeably thin when collected, the remaining recaptures appeared healthy. This is a subjective observation as there are no currently accepted standard indices (i.e., relative weight) for wild pallid sturgeon and post stocking weight loss may not be a true indicator of competition, but may be a natural weight loss event that occurs when fish must transition from a hatchery environment where food is abundant to a natural environment where food must be found. Interspecific competition with the closely related shovelnose likely would only occur at the younger juvenile life stages as shovelnose sturgeon appear to be mostly insectivores as are pallid sturgeon juveniles (Gerrity 2005) while pallid sturgeon sub-adults (age 6+) and adults appear to be more piscivores than shovelnose adults.

Disease Transfer

The shovelnose sturgeon iridovirus has been detected in pallid sturgeon propagated at several of the production facilities and detected in wild. The impacts of stocking shovelnose sturgeon irridovirus positive pallid sturgeon on populations of both shovelnose and pallid sturgeon in the receiving waters are poorly understood. To date, known irridovirus positive fish have been released into RPMA 4, and there are currently no documented adverse effects on wild fish populations. The low densities of the stocked fish may mediate this threat but it must be considered. Disease testing will be completed on pallid sturgeon progeny prior to stocking. Currently, this entails collection of a statistically valid sample from production facilities and subsequent histological evaluation for evidence of the virus.

CONCLUSIONS

Waples and Drake (2004) discuss the potential benefits and risks associated with supplementation programs and strongly caution to evaluate the risks prior to implementation of a stocking program. Pallid sturgeon are distributed throughout RPMA 4. Historical information is inadequate to determine population trends; however substantial effort has been expended during the past several years to collect pallid sturgeon in this reach with limited success. We know that the gears being utilized are appropriate for sampling all size classes, yet few wild or naturally produced pallid sturgeon are being found while capture of hatchery produced pallid sturgeon and wild produced larval and young of the year shovelnose sturgeon has increased substantially following implementation of the Population Assessment Program. At this time, stocking RPMA 4 is warranted and necessary to supplement existing populations until habitat modifications are implemented and successful enough to allow the pallid sturgeon populations to maintain themselves.

Ideally local parents should be targeted to minimize genetic concerns. Ed Heist (Southern Illinois University, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO) demonstrated that the F_{st} value differences between pallid sturgeon samples analyzed from the lower 200 RM of RPMA 4 and the upper end of RPMA 5 (Missouri and Mississippi river confluence RM 1150 downstream to about RM 960) were several orders of magnitude smaller than the F_{st} differences found when comparing this group against genetic samples from the Upper Missouri Basin (RPMA 1 and 2) or Atchafalaya River (RPMA 6). Given this information, pallid sturgeon brood collected from the Middle Mississippi River (RM 1153 to RM 953 and maybe as far down as Caruthersville RM 846.5) and lower reaches of RPMA 4 (Kansas City RM 367.5 downstream to RM 0) will be considered as local parents for supplementation purposes into RPMA 4 downstream from the mouth of the Kansas River (RM 367.5). Based on the work of Heist and Schrey (2004), the aforementioned movement data, and desires to maintain some semblance of recently identified genetic structuring, it is not recommended to stock Upper Basin origin pallid sturgeon downstream of RM 367.5 in the lower reaches of RPMA 4.

There are currently little genetic data to provide guidance on what constitutes local parents in the upper portion of RPMA 4. Recent data (Heist and Schrey 2006) suggest that pallid sturgeon collected within the upper reaches of RPMA 4 are genetically intermediate between Upper and Lower Missouri River pallid sturgeon. At this time local parents will be defined as pallid sturgeon collected between Gavins Point Dam, South Dakota (RM 811) and Kansas City, MO (RM 367.5). However, as identified earlier, if local parents can not be collected in this reach of RPMA 4 the next best source is the 367.5 mile reach below Kansas City to the Missouri and Mississippi confluence. Genetic data also suggests that the upper Missouri River followed by the Middle Mississippi River are the next best sources for broodstock.

RPMA 5

STOCKING RISKS/BENEFITS

There are inherent risks as well as potential benefits associated with most recovery actions. Such is the case with artificial augmentation of pallid sturgeon in the Mississippi River. Following is a discussion of the benefits and risks associated with supplementation of pallid sturgeon in RPMA 5.

BENEFITS

Reduction in the potential risk of extinction of local populations

Currently there may not be an immediate threat of extinction in RPMA 5. There is some evidence that reproduction and recruitment are occurring in the Mississippi River. Small numbers of pallid sturgeon larvae and juveniles have been collected from the Middle Mississippi River in recent years (Reeves and Galat 2004, Herzog et al. 2005) demonstrating some measure of successful reproduction. Demographic data of pallid sturgeon in recent collections may suggest that recruitment is occurring in the Mississippi River (Jack Killgore, Dave Herzog, James Garvey, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO). In the Middle Mississippi, captured pallid sturgeon have ranged from 44 – 108 cm in Fork Length (FL), and have been aged between 5-15 years, while in the Lower Mississippi River pallid sturgeon range between 30-90 cm FL, and have been aged between 3-21 years. Female pallid sturgeon are believed to reach sexual maturity at ages of 13-15 years and over 80 cm FL, while males are believed to mature at 5-7 years at sizes over 50 cm FL.

Maintenance of local population while habitat restoration efforts are implemented

Miller and Kapuscinski (2003) identify addressing habitat quality and quantity as part of a comprehensive plan of which supplementation is only a part. Implementation of conservation and restoration activities is being discussed with other state and federal agencies. Activities that have been and will be implemented are centered on habitat restoration and may include: actively designing and incorporating environmental features into navigation operation and maintenance activities in the Mississippi River and ecosystem restoration measures that include island/side channel restoration and floodplain restoration. Features such as dike notches, hard points and round points are being used to maintain and restore the function and integrity of islands, side channels, and gravel bars, while facilitating and protecting navigation.

RISKS

Within and among population loss of genetic diversity

Miller and Kapuscinski (2003) detail many of the genetic hazards associated with supplementation programs. These authors suggest that the loss of within-population genetic diversity is mainly attributable to two causes. These are genetic drift from collecting gametes from a population of limited size and inbreeding. They also suggest that the loss of between-population genetic diversity is attributable to fish crossing from different populations (artificially elevated levels of migration) with one negative outcome being outbreeding depression. Artificial levels of gene flow can occur if parental fishes from two genetically structured stocks are inadvertently crossed in the hatchery spawning process or if the out plants from hatcheries are more likely to intermix with other stocks than would occur naturally. Genetic studies

(Campton et al. 2000, Tranah et al. 2001, Heist and Schrey 2004) indicate genetic structuring within the pallid sturgeon population range wide. This structuring may be viewed as a one dimensional linear stepping-stone distribution as explained in Gharette and Zhivotovsky (2003). That is gene flow is more likely to occur between adjacent sub-populations than among geographically distant sub-populations. The majority of fish stocked into the Lower Missouri River have been of Upper Missouri River origin, which are genetically distinct from Mississippi River pallid sturgeon (Tranah et al. 2001, Heist and Schrey 2004). Since there is no barrier to movement of these hatchery fish into the Middle Mississippi River, there is a potential of outbreeding between Upper Missouri and Mississippi river stocks. Outbreeding depression due to mixing of genetic populations has been recognized as a factor in fish conservation for over 50 years. It has been demonstrated across a variety of taxa in both natural and experimental settings. Most recently, outbreeding depression has been linked with increased disease susceptibility in bass (Goldberg et al. 2005).

Inter and Intra-specific competition

Utilizing hatchery produced pallid sturgeon to supplement an existing population could result in increased competition with the existing population as well as with other native fishes. Adult pallid sturgeon are piscivorous and would likely forage on riverine cyprinid species. Increasing the abundance of pallid sturgeon will likely increase competition rates that may reduce supplementation success or have a negative impact on the receiving population or other fishes, but the impacts of supplementation associated with inter- and intraspecific competition are unknown.

Disease Transfer

The shovelnose sturgeon iridovirus has been detected in pallid sturgeon propagated at several of the production facilities and detected in wild fish collected below Ft. Peck Dam down to the Atchafalaya River. However, the virus has not been documented in the wild above Fort Peck Dam. The impacts of stocking shovelnose sturgeon irridovirus positive pallid sturgeon on populations of both shovelnose and pallid sturgeon in the receiving waters are poorly understood. The low densities of the stocked fish may mediate this threat but it must be considered. Disease testing will be completed on pallid sturgeon progeny prior to stocking. Currently, this entails collection of a statistically valid sample from production facilities and subsequent histological evaluation for evidence of the virus

CONCLUSIONS

Waples and Drake (2004) discuss the potential benefits and risks associated with supplementation programs and strongly caution to evaluate the risks prior to implementation of a supplementation program. Pallid sturgeon are distributed throughout the Mississippi River (RPMA 5). Historical information is inadequate to determine population trends. However, there has been a positive correlation between collection effort in the Mississippi River and numbers of pallid sturgeon captured over the past decade. Mississippi River pallid populations may already meet or exceed Recovery Plan criteria, but further evaluation is necessary to support this theory. Size and age data show a young adult cohort in the Lower Mississippi River, suggesting that recruitment likely is occurring.

Although subadults are rare, they are also found throughout the system, and their rareness may result from collection methods, habitats sampled, and/or failure to distinguish from shovelnose sturgeon.

Field observations and preliminary age studies suggest that illegal commercial harvest of pallid sturgeon is occurring in the Middle Mississippi River. Although stocking to offset the effects of illegal harvest may become necessary in the future, the best alternative with the lowest risk at this time is to protect pallid sturgeon from illegal take in this area. Should the need to stock in the future exist, Natchitoches NFH and Louisiana Department of Wildlife and Fisheries have developed techniques and partnerships with local commercial fishermen and the U.S. Army Corps of Engineers to collect high numbers of pallid sturgeon (relative to other on-going or past efforts throughout the range) at the ORCC. Natchitoches NFH has developed the facilities, technology, and protocols necessary to produce hatchery fish from local sources, if needed, and has provided known parent fish for morphological and taxonomic studies.

Based on this analysis, supplementation is not presently warranted in the Mississippi River. Additional information on population demographics, habitats, and habitat use, however, is required in order to monitor status and trends of the pallid sturgeon in the Mississippi and Atchafalaya Rivers.

RPMA 6

STOCKING RISKS/BENEFITS

There are inherent risks as well as potential benefits associated with most recovery actions. Such is the case with artificial augmentation of pallid sturgeon in the Atchafalaya River. Following is a discussion of the benefits and risks associated with supplementation of pallid sturgeon in RPMA 6.

BENEFITS

Reduction in the potential risk of extinction of local populations

Currently there may not be an immediate threat of extinction in RPMA 6. There are data that suggest reproduction and recruitment are occurring in the Mississippi River. Small numbers of pallid sturgeon larvae and juveniles have been collected from the Middle Mississippi River in recent years (Reeves and Galat 2004, Herzog et al. 2005) demonstrating some measure of successful reproduction. Demographic data of pallid sturgeon in recent collections may suggest that recruitment is occurring in the Atchafalaya River also (Jan Dean, USFWS, data presented at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, CO). Sampling bias due to gear size selectivity and artificial manipulation of flows may produce data skewed for larger body sized fish. Yet through time there appears to be a consistent catch of these larger fish suggesting some recruitment either natural or from entrained pallid sturgeon from the Lower Mississippi River.

Maintenance of local population while habitat restoration efforts are implemented

Miller and Kapuscinski (2003) identify addressing habitat quality and quantity as part of a comprehensive plan of which supplementation is only a part. Implementation of conservation and restoration activities must be discussed with state and federal agencies. Without implementation of restoration activities, those forces that may be limiting natural success of pallid sturgeon within RPMA 6 likely will also limit supplementation success.

RISKS

Within and among population loss of genetic diversity

Miller and Kapuscinski (2003) detail many of the genetic hazards associated with supplementation programs. These authors suggest that the loss of within-population genetic diversity is mainly attributable to two causes. These are genetic drift from collecting gametes from a population of limited size and inbreeding. They also suggest that the loss of between-population genetic diversity is attributable to fish crossing from different populations (artificially elevated levels of migration) with one negative outcome being outbreeding depression. Artificial levels of gene flow can occur if parental fishes from two genetically structured stocks are inadvertently crossed in the hatchery spawning process or if the out plants from hatcheries are more likely to intermix with other stocks than would occur naturally. Genetic studies (Campton et al. 2000, Tranah et al. 2001, Heist and Schrey 2004) indicate genetic structuring within the pallid sturgeon population range wide. This structuring may be viewed as a one dimensional linear stepping-stone distribution as explained in Gharrette and Zhivotovsky (2003). That is gene flow is more likely to occur between adjacent sub-populations than among geographically distant sub-populations. Maintenance of gene flow from the Lower Mississippi River into the Atchafalaya likely is unidirectional and thus historically unnatural. That is pallid sturgeon from the Mississippi River likely can enter the Atchafalaya River via the ORCC, but pallid sturgeon from the Atchafalaya River likely can not move to the Mississippi River, thus limiting genetic exchange between the two rivers. If there is truly unidirectional gene flow, this will ultimately lead to genetic homogenization of the Atchafalaya River population such that they become genetically similar or identical to the source population from the Mississippi River.

Inter and Intra-specific competition

Utilizing hatchery produced pallid sturgeon to supplement an existing population could result in increased competition with the existing population as well as with other native fishes. Adult pallid sturgeon are piscivorous and would likely forage on riverine cyprinid species. Increasing the abundance of pallid sturgeon will likely increase predation rates on riverine forage species, but the impact of increased predation is unknown. Intraspecific competition among hatchery released fish and wild fish could be problematic resulting in decreased survival of the receiving population or the stocked pallid sturgeon or both. Interspecific competition with the closely related shovelnose likely would only occur at the juvenile life stages as shovelnose sturgeon appear to be mostly insectivores as are pallid sturgeon juveniles (Gerrity 2005) while pallid sturgeon adults appear to be more piscivores than shovelnose adults.

Disease Transfer

The shovelnose sturgeon iridovirus has been detected in pallid sturgeon propagated at several of the production facilities and detected in wild fish collected from the Atchafalaya River. The impacts of stocking shovelnose sturgeon irridovirus positive pallid sturgeon on populations of both shovelnose and pallid sturgeon in the receiving waters are poorly understood. The low densities of the stocked fish may mediate this threat but it must be considered. Disease testing will be completed on pallid sturgeon progeny prior to stocking. Currently, this entails collection of a statistically valid sample from production facilities and subsequent histological evaluation for evidence of the virus.

CONCLUSIONS

Waples and Drake (2004) discuss the potential benefits and risks associate with supplementation programs and strongly caution to evaluate the risks prior to implementation of a supplementation program. Pallid sturgeon are known to exist in the Atchafalaya River (RPMA 6). Historical information is inadequate to determine population trends, yet the data suggest either a self sustaining population or at the least an inflow of pallid sturgeon from a donor population in the Lower Mississippi River. Size and age data demonstrate a sustained adult cohort through time suggesting that recruitment likely is occurring by some mechanism, and further data need to be collected to better understand the population dynamics with in RPMA 6.

Based on this analysis, stocking does not appear to be warranted in the Atchafalaya River at this time. Additional information on population demographics, habitats, and habitat use, however, is required in order to monitor status and trends of the pallid sturgeon in the Atchafalaya Rivers and to evaluate if this conclusion remains accurate through time.

TARGET STOCKING NUMBER, RATIONALE, AND FREQUENCY{ TC \L2 " TARGET STOCKING NUMBER, RATIONALE, AND FREQUENCY}

The number of pallid sturgeon broodstock collected annually and the number of progeny produced each year will be limited by the existing population and the collective capability of the hatcheries to raise pallid sturgeon. Based on population estimates developed by Kapuscinski (2004) for RPMA 2, where most of the broodstock now originates, wild pallid sturgeon from RPMA 2 will be available for broodstock until about 2010 or 2012. At the end of this period the wild population will likely diminish to a level that we will no longer be able to effectively capture them for broodstock. Broodstock collection efforts in RPMA 4 are being implemented and this should increase the number of fish available for propagation purposes.

Past stocking efforts have focused almost exclusively on releasing yearling hatchery reared pallid sturgeon to avoid the assumed high predation rates associated with sub-yearling size classes. 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.

Egg, fry or young-of-the-year fingerling stockings have been considered and will be incorporated into this stocking strategy. The reason for this consideration is the potential for imprinting processes that may occur during the early life history. These processes are vitally important for migratory runs of salmon, trout and other fish species. During 1998, pallid sturgeon eggs and larvae were analyzed for thyroxine levels (Scholz et al. 2000). Thyroxine is a thyroid hormone that has been linked to the imprinting process for other species. Furthermore fry stocking has been demonstrated to produce yearling pallid sturgeon in RPMA 2. As part of a larval drift experiment in 2004, 130,000 fry ranging from 0-17 days old were released in the Missouri River below Fort Peck Dam. During sampling efforts in 2005, 5 non-physically marked juvenile pallid sturgeon were collected in RPMA 2. Utilizing genetic techniques, the CGL was able to amplify 4 of the 5 genetic samples and found that all 4 were from the 11-17 day old group of pallid sturgeon fry released in 2004. Other reasons for stocking smaller fish (i.e., sub-yearlings) is to reduce hatchery habituation, artificial selection pressures, and reduce density dependent problems. Stocking rates for eggs, fry, and sub-yearlings need to be evaluated and size specific survival rates are an objective of the long term monitoring effort.

Target stocking computation methods - There are two approaches employed within this plan to determine stocking rates. The first approach was developed by the Upper Basin Pallid Sturgeon Workgroup (UBPSW) stocking committee and governs the approach for stocking within RPMA 1 and 2 (note: computation methods below essentially were copied verbatim from Montana Fish Wildlife and Parks, 2004). The second approach governs development of stocking numbers for RPMA 3 and 4 utilizing a similar approach but with different survival rates. The two approaches are utilized due to differences in available data regarding annual survival rates within the respective RPMAs. However, stocking rates are designed to maintain target adult populations for approximately 5 years. Thus, statistically valid annual survival rates for all size-classes of hatchery propagated pallid sturgeon must be developed on a RPMA by RPMA basis.
In addition, stocking targets must be recalculated annually and adjusted for any wild sturgeon recruitment that is encountered during sampling.

RPMA 1 and 2 stocking computation methods:
Little empirical information exists to calculate minimum adult population goals for each RPMA. A minimum desired adult population for RPMA 1 was calculated taking into account estimated densities, carrying capacities, etc. Because of the similarity of habitat, a standing adult population goal for RPMA 2 was then derived using a ratio of its available river miles of habitat compared to the available habitat in RPMA 1. As the historical adult population or current carrying capacity of each RPMA is unknown, the generally-accepted conservation genetic guideline known as the "50/500 rule" was expanded to calculate the minimum required adult populations for each RPMA. The 50/500 rule states that a genetically effective population size of at least 50 individuals is necessary for the conservation of genetic diversity and the avoidance of inbreeding effects in the short term and an effective population size of at least 500 is needed to avoid deleterious effects of genetic drift over several generations (Franklin 1980). As the rates of genetic mutation and genetic drift and the periodicity of reproduction of individual pallid sturgeon are unknown, sex ratios may not be balanced, and the "50/500 rule" is, at best, a conservative recommendation, the minimum desired population goal for RPMA 1 was doubled to 1000 adult pallid sturgeon. The resulting RPMA-specific standing population objectives are:

RPMA 1 (180 RM): maintain 1,000 adult pallid
RPMA 2 (300 RM): maintain 1,700 adult pallid

These minimum standing populations will provide about 6.0 adult pallid sturgeon per river mile.

This section was taken nearly verbatim from Montana Fish Wildlife and Parks (2004).

RPMA #3 and #4 computation methods:
Hatchery propagated pallid sturgeon have been recollected in each of these Missouri River RPMAs but sufficient samples are lacking to develop highly accurate survival rates. Survival rates for hatchery propagated white sturgeon have been recently published (Ireland et al. 2002) and were used as surrogate survival rates for pallid sturgeon estimates in RPMA 3 and 4 (Appendix 6).

Total RPA stocking objectives - An annual minimum stocking target of 21,700 yearling pallid sturgeon or yearling equivelants is the objective outlined in this stocking plan for the four Missouri River RPMAs in need of supplementation (Appendix 1 – 4).

It is anticipated that there will be years when pallid sturgeon production will not meet stocking objectives. In those years when stocking targets exceed HRPS production, fish will be allocated based upon the ratio of target stocking numbers for each RPMA covered under this stocking plan. However, given the evidence of genetic structuring, genetic prioritization must also be defined. Upper Missouri River (RPMA 1 and 2) derived HRPS will be prioritized for stocking into RPMA 1-3, and RPMA 4/5 derived pallid sturgeon will be prioritized for supplementation into RPMA 4. Given the past inability to obtain local parental stocks from RPMA 4, this could result in no local parental stock for supplementation. In years when local broodstock collection and/or spawning efforts fail in the upper reaches of RPMA 4, arrangements will be made to reserve eggs from RPMA 1 and/or 2 parents for supplementation into the upper reaches of RPMA 4. During years when hatchery goals for stocking into RPMA 1, 2, 3 and 4 can not be obtained, the Pallid Sturgeon Recovery Team and representatives with appropriate jurisdiction from each RPMA will work to collectively determine RPMA specific stocking priorities based on adaptive management and available information.

In any event, all fish produced in a year may be stocked at various life stages, to safeguard against years when hatchery production is limited due to unforeseen situations such as inaccessible broodstock, hatchery failures, or disease to help insure that all RPMA stocking goals are obtained. In essence, years of good hatchery production will be used to pay down 'deficits' in stocking accrued during years of poor production. Stocking will be attempted each year in hopes of maximizing the genetic contribution from the existing wild pallid sturgeon population. Augmentation will likely continue as long as broodfish are available and monitoring indicates no deleterious effects to the founder population or until natural reproduction/recruitment are sufficient for the population to maintain itself.

The minimum number of fish needed annually for each RPMA (Appendixes 1 – 4), and detailed in the following sections, is calculated using the assumptions and data previously outlined. The primary difficulties in developing scientifically defensible annual stocking rates is the lack of information on an optimal target population and paucity of data on post-stocking survival of hatchery-reared pallid sturgeon. It is expected that normal year-to-year environmental variation in precipitation, flooding, flow rates, temperature, water quality, predator populations, and food supply will create wide variation in annual and long-term survival. Due to limited information regarding historical abundance of pallid sturgeon, it is necessary to estimate the target populations for each RPMA. The estimated survival rates and target numbers will be recalculated as more precise information becomes available from population assessment efforts (e.g., Drobish 2005).

Stocking dates will correspond to optimal habitat conditions, forage availability and condition of the progeny; this will help pallid sturgeon progeny acclimate from a hatchery environment to the wild and will facilitate conversion from a commercial diet to a natural diet. Rearing temperatures of the facility and temperatures of the stocking site need to be coordinated in advance of stocking to insure compatibility and minimize acclimation stress. Shovelnose sturgeon were found to have difficulty utilizing macro-invertebrates in higher flows (Modde and Schmulbach 1977), consequently stocking should take place prior to elevated springtime flows to allow for acclimation or after it recedes and macro-invertebrate production densities increase. Stocking juvenile pallid sturgeon during high flow events may cause the fish to move downstream into unsuitable areas. The preferred stocking periods will likely occur between April and September but vary by RPMA due to longitudinal differences in climate.

Egg, fry, and sub-yearling stockings would likely occur at a time when hatcheries exceed their capacity and the fish have to be stocked to reduce density dependent disease outbreaks. Stocking earlier life stages likely will not universally conform to the aforementioned time frame. Early life stage stocking will be accounted for based on recommendations from the Upper Basin Pallid Sturgeon Workgroup stocking committee. These ratios currently are based on an assumption of ontogenetic changes in survival that currently have no data to support or refute them, but do define a mechanism to account for stocking various size classes and are defined as follows:

Sub-yearling HRPS will be accounted for according to their size and time of stocking with the following ratios:

- Fry (< 2 inches total length) will count against the total number of HRPS as follows: 0.024% stocked fry for any RPMA will be counted as yearling as their estimated over-winter survival is expected to be extremely low (<1%). The value of 0.024% was determined simply by dividing the number of pallid young-of-year captured in 2005 (n=6) and found genetically to originate from the larval drift study in 2004 by the number of 17-day-old pallid larvae released in that study (25,000) (Pat Braaten, USGS, personal communications). Although preliminary, this value is the only empirical young of year pallid sturgeon survival data and represents a conservative minimum survival rate, and will be updated as better data are gathered and more accurate survival estimates are generated.

- Four fingerlings (2 - 4 inches fork length) counting as one yearling HRPS (4:1 ratio) stocked based on an estimated over-winter survival rate of 25%;

- Two advanced fingerlings (> 4 inches fork length) stocked during the fall will count as one yearling HRPS (2:1 ratio) based on an estimated over-winter survival rate of 50%;

- One advanced fingerling stocked during the spring will count as one yearling HRPS (1:1 ratio), assuming that there is no significant mortality difference between spring-released and summer-released fish.

- Hatchery-reared pallid sturgeon stocked at age-2 or greater will count against an RPMA's stocking rate based on their age at stocking and their estimated age-class survival rate as shown in Tables 5 and 6. For example, age-2 HRPS stocked into RPMA 1 or 2 will be counted on a 0.6:1 ratio and age-3 HRPS will be counted on a 0.7:1 ratio, and age-2 HRPS stocked into RPMA 3 or 4 will be counted on a 0.9:1 ratio and age-3 HRPS will be counted on a 0.9:1 ratio.

RPMA 1 - The minimum population objective for RPMA 1 is 1,000 spawning age adult (greater than or equal to 15 years of age) pallid sturgeon in 20 years consisting of 5 year classes and subsequent year classes following in behind them. Achievement of this goal will result in a density of about 6 sexually mature pallid sturgeon per river mile. To achieve these standing population objectives, a minimum of 5,600 yearling, or yearling equivalent, HRPS will need to be stocked in RPMA 1 (Appendix 1). The primary stocking sites for RPMA 1 will include previously identified sites and areas up to and including the lower 30 miles of the Marias River and are identified as: 1)Fred Robinson Bridge; 2) the confluence of the Missouri and Marias Rivers; 3) Coal Banks; and 4) Judith Landing. Yearling stocking should occur during April or June or between July and October in RPMA 1.

RPMA 2 - The minimum population objective for RPMA 2 is 1,700 spawning age adult (greater than or equal to 15 years of age) pallid sturgeon in 20 years consisting of 5 year classes and subsequent year classes following in behind them. Achievement of this goal will result in a density of about 6 sexually mature pallid sturgeon per river mile. Attainment of this goal will be met by stocking a minimum of 9,000 yearling pallid sturgeon, or yearling equivalents, for 20 consecutive years (Appendix 2). Stocking sites in RPMA 2 will be the previously identified sites and up to the confluence of the Yellowstone and Tongue Rivers. Previously identified sites include: 1) Intake Diversion Dam; 2) Sidney boat ramp area; 3) Big Sky Bend; 4) Fairview Bridge area; 5) the confluence of the Missouri and Yellowstone Rivers; 6) Nohly Bridge; 7) the Culbertson area; and 8) Wolf Point area. Yearling stocking should occur during April or June or between July and October in RPMA 2.

RPMA 3 - The population objective for RPMA 3 is 384 spawning age adult (greater than or equal to 15 years of age) pallid sturgeon in 20 years consisting of 5 year classes and subsequent year classes following in behind them. Achievement of this goal will result in a density of about 6 sexually mature pallid sturgeon per RM. Attainment of this goal will be met by stocking 600 yearlings, or yearling equivalent HRPS pallid sturgeon for 20 consecutive years (Appendix 3). The stocking locations for RPMA 3 are: 1) Sunshine Bottoms near Boyd County Boat Ramp; 2) the Ponca Creek confluence area near Verdel, NE; and 3) the riverine section near Running

Water, SD. Yearling stocking should occur during April or June or between July and October in RPMA 3.

RPMA 4 - The population objective for RPMA 4 is 4851 spawning age adult (greater than or equal to 15 years of age) pallid sturgeon in 20 years consisting of 5 year classes and subsequent year classes following in behind them. Achievement of this goal will result in a density of about 6 sexually mature pallid sturgeon per RM of riverine habitat. Attainment of this goal will be met by stocking 6,500 yearling pallid sturgeon, or yearling equivalents, for 20 consecutive years (Appendix 4). The stocking locations for RPMA 4 include: Mulberry Bend (RM 775.1), Sioux City (RM 732.0), Bellevue (RM 601.0), Rulo (RM 497.9), Kansas River (RM 367.5), Grand River (RM 250.0), Booneville (RM 195.1), Jeff City (RM 145.0), Mokane (RM 127.0), and Herman (RM 90.0) Yearling stockings should occur between April and June or between July and October in RPMA 4.

RPMA 5 – Not recommended to stock at this time.

RPMA 6 - Not recommended to stock at this time.

Alternatives to stocking and augmentation:

RPMA 1-3: Based on extensive sampling and knowledge of these populations, stocking and augmentation of pallid sturgeon populations are required to prevent the extirpation of the pallid sturgeon from these RPMAs. There are no alternatives.

RPMA 4:
Alternative 1: Protect pallid sturgeon in RPMA 4 from illegal take or take incidental to commercial harvest of shovelnose sturgeon. There is evidence that significant mortality of pallid sturgeon is occurring in RPMA 4 due to illegal or incidental take by commercial harvest. Recovery of an exploited sturgeon population is unlikely, even with augmentation.

Alternative 2: Develop better information on pallid sturgeon habitat, population demographics, population genetic structure, and reproduction and recruitment prior to continuing stocking efforts. There is little information on habitat requirements, natural population demographics, genetic structure or recruitment of pallid sturgeon in RPMA 4. Additional information would facilitate stocking and augmentation decisions.

RPMA 5: Recent information does not currently support stocking in RPMA 5. There is a need to develop better information on pallid sturgeon habitat, population demographics, population genetic structure, and reproduction and recruitment, and to identify trends in pallid sturgeon populations. However, there is also evidence that illegal or incidental commercial harvest of pallid sturgeon in the Middle Mississippi River needs to be controlled.

RPMA 6: Recent field data does not support stocking in RPMA 6. There is a need to develop better information on pallid sturgeon habitat, population demographics, population genetic structure, and reproduction and recruitment, and to identify trends in pallid sturgeon populations.

LITERATURE CITED

{ TC \l1 "

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.

Baker, J., K.. Killgore, and R. Kasul. 1991. Aquatic habitats and fish communities of the Lower Mississippi River. Aquatic Sciences, 3(4)313-356.

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.

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. 2004. Larval fish passage study. In McDonald, K. (ed) Upper Basin Pallid Sturgeon Recovery Workgroup, 2004 Annual Report. Helena, Montana.

Bramblett, R.G. 1996. Habitat and movements of pallid and shovelnose sturgeon in the Yellowstone and Missouri Rivers, Montana and North Dakota. Ph.D. Dissertation. Montana State University, Bozeman. 210pp.

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 Ryman, N. and F. Utter (Eds), Population Genetics and Fishery Management. University of Washington Press. Seattle and London.

Campton, D. E., A. I. Garcia, B. W. Bowen, and F. A. Chapman. 1995. Genetic evaluation of pallid, shovelnose, and Alabama sturgeon (*Scaphirhynchus albus, S. platorynchus, and S. suttkusi*) based on control region (D-Loop) sequences of Mitochondrial DNA. Final Report. Coop. Agreement (14-48-0006-94-929) between University of Florida and U.S. Fish and Wildlife. Service, Gainesville, Florida.

Campton, D. E., A. Bass, F. Chapman, and B. Bowen. 2000. Genetic distinction of pallid, shovelnose, and Alabama sturgeon: emerging species and the US 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. platorynchus* in the Missouri and Mississippi Rivers, Missouri. In S. Doroshov (ed), Sturgeon Symposium. Environmental Biology Fish. 14:51-59.

Caro, T., J. Eadie, and A. Sih. 2005. Use of substitute species in conservation biology. Conservation Biology, 1821-1826.

Coker, R. E. 1930. Studies of common fishes of the Mississippi River at Keokuk. U.S. Bureau. Fisheries. Bulletin. 45:141-225.

Constant, Glenn C., William E. Kelso, Allen D. Rutherford, and Frederick 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. 78pp.

Cross, F. B. 1967. Handbook of fishes of Kansas. University of Kansas Museum Natural History Miscellaneous Publication. 45, Lawrence, 357 pp.

DeHaan. P. W., D. E. Campton, and W. R. Ardren. 2005. Genotypic analysis and parental identification of hatchery-origin pallid sturgeon in the Upper Missouri River: Phase I Inheritance of Microsatellite, Nuclear DNA Markers. June 23rd, 2005. 35pp. USFWS Abernathy Fish Technology Center Final Report.

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. 38pp.

Drobish, M. R. (editor), 2005. Pallid Sturgeon Population Assessment Program. U.S. Army Corps of Engineers, Omaha District, Yankton, SD.

Duffy, W. G., C. R. Berry, and K. D. Keenlyne. 1996. The pallid sturgeon biology and annotated bibliography through 1994. Technical Bulletin 5. South Dakota State University, Brookings.

Eddins, W. 2000. Policy regarding controlled propagation of species listed under the Endangered Species Act. Federal Register 65:56916-56922.

Erickson, J. D. 1992. Habitat selection and movement of pallid sturgeon in Lake Sharpe, South Dakota. M.S. thesis. South Dakota St. University, Brookings.

Fay, J. J., and M. Nammack. 1996. Policy regarding the recognition of distinct vertebrate population. Federal Register 61:4721-4725.

Fisher, J. J. 1962. Some fishes of the lower Missouri River. American Midland Naturalist.

68:424-429.

Fiumera, A. C., B. A. Porter, G. Looney, M. A. Asmussen, and J. C. Avise. 2004. Maximizing offspring production while maintaining genetic diversity in supplemental breeding programs of highly fecund managed species. Conservation Biology. 18:1 pages 94-101.

Fogle, N. E. 1961. Report of the fisheries investigations during the third year of impoundment of Oahe Reservoir, South Dakota, 1960. DJ Project F-1-R-10 Report, South Dakota Dept. of Game, Fish and Parks, Pierre.

Forbes, S. A., and R. E. Richardson. 1905. On a new shovelnose sturgeon from the Mississippi River. Bulletin. Illinois State Laboraty of Natural History 7:37-44. In 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.

Forbes, S. A., and R. E. Richardson. 1909. Fishes of Illinois. Illinois Natural History Survey 3:1-357. *In* 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.

Franklin, I.R. 1980. Evolutionary change in small populations. *In, Conservation Biology, An Evolutionary-Ecological Perspective*, M.E. Soule and B.A. Wilcox, Eds., Sinauer, Sunderland, MA, pp.135-149.

Fraser, D. J. and L. Bernatchez. 2001. Adaptive evolutionary conservation: towards a Unified concept for defining conservation units. Molecular Ecology. 10 pages 2741-2752.

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. Can. Spec. Publ. Fish. Aquat. Sci. 106

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 Conservation. Aquatic Series 11. Jefferson City. 52 pp.

Gardner, W.M. 1996. Missouri River Pallid Sturgeon Inventory. Montana Fish, Wildlife and Parks. Federal Aid to Fish and Wildlife Restoration Project. F-78-R-2., Helena, Montana. 25 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 theses. Montana State University, Bozeman.

Gharrett, A. J, and L. A. Zhivotovsky. 2003. Migration. Pages 141-174 *in* J. M. Hallerman, editor. Population genetics: principles and applications for fisheries scientists. American Fisheries Society, Bethesda, Maryland.

Goldberg, T.L., E.C. Grant, K.R. Inendino, T.W. Kassler, J.E. Claussen, and D.P. Philipp. Increased infectious disease susceptibility resulting from outbreeding depression. Conservation Biology 19(2):455-462.

Goodnight, K. F. and D. C. Queller. 1999. Computer software for performing likelihood Tests of pedigree relationships using genetic markers. Molecular Ecology 8 pp 1231-1234.

Grady, J.M., J. Milligan, C. Gemming, D. Herzog, G. Mestl and R.J. Sheehan. 2001. Pallid and Shovelnose Sturgeons in the Lower Missouri and Middle Mississippi Rivers. Final Report for MICRA.

Green, D. M., 2005. Designatable units for status assessment of endangered species. Conservation Biology 19 (6) 1813-1820.

Heist, E.J., and A. Schrey 2003. Microsatellite Tools for Genetic Discrimination of Scaphirhynchus. Interim report prepared by the Fisheries Research Laboratory, Southern Illinois University at Carbondale for the U.S. Fish and Wildlife Service.

Heist, E.J., and A. Schrey. 2004. Microsatellite tools for genetic identification of *Scaphirhynchus*. Interim Report. Southern Illinois University, Carbondale, IL.

Heist, E.J., and A. Schrey. 2006. 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.

Held, J. W. 1969. Some early summer foods of the shovelnose sturgeon in the Missouri River. Transactions of American Fisheries Society 98:514-517.

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 MO, 11-13 January 2005. Abstract.

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.

Hesse, L. W. 1987. Taming the wild Missouri River: What has it cost? Fisheries.12(2):2-9.

Hurley, K. L. 1996. Habitat use, selection, and movements of Middle Mississippi River Pallid sturgeon and validity of pallid sturgeon age estimates from pectoral fin Rays. Master's thesis. Southern Illinois University, Carbondale.

Ireland, S.C., R.C.P. Beamesderfer, V.L. Paragamian, V.D. Wakkinen and J.T. Siple. 2002. Success of hatchery-reared juvenile white sturgeon (*Acipenser transmontanus*) following release in the Kootenai River, Idaho, USA. Journal of Applied Ichthyology 18: 642-650.

ISIS. 1994. SPARKS (Single Species Animal Record Keeping System). International Species Information System, Apple Valley, MN.

Jordan, G. R., R. A. Klumb, G. A. Wanner, W. J. Stancill. 2005. Post-stocking Movements of Hatchery-Reared Juvenile Pallid Sturgeon in the Missouri River Below Fort Randall Dam, South Dakota and Nebraska. Transactions of the American Fisheries Society (Submitted and in review).

Kallemeyn, L. W. 1983. Status of the Pallid Sturgeon. American Fisheries Society 8:3-9.

Kapuscinski, K. L. 2004. Abundance of wild pallid sturgeon in recovery priority Management area 2 of the Missouri and Yellowstone Rivers during 1991-2003. Montana Department of Fish, Wildlife & Parks Report, Helena.

Keenlyne, K. D. 1989. Report on the pallid sturgeon. MRC-89-1, U.S. Fish and Wildlife Service, Pierre, SD.

Keenlyne, K. D., and L. G. Jenkins. 1993. Age at sexual maturity of the pallid sturgeon. Transactions of the American Fisheries Society 122:393-396.

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). Pages 225-234 in A.D. Gerschanovich and T.I.J. Smith, eds., Proceedings of the International Symposium on Sturgeons, September 6-11, 1993. VNIRO Publ., Moscow, Russia.

Kern et al 2004 Report A *in* D.L. Ward, editor. White Sturgeon Mitigation and Restoration In The Columbia and Snake Rivers Upstream From Bonneville Dam. Annual Report (2003) to the Bonneville Power Administration, Portland, Oregon

Kincaid, H. 1993. Breeding plan to preserve the genetic variability of Kootenai River white sturgeon. U.S. Fish and Wildlife Service, Report to Bonneville Power Administration, Portland, Oregon.

Kynard, B., E. Henyey, and M. Horgan. 2002. Ontogenetic Behavior, Migration, and Social Behavior of Pallid Sturgeon, Scaphirhynchus albus, and shovelnose sturgeon, S. platorynchus, with notes on the adaptive significance of body color. Environmental Biology of Fishes 63:389-403.

Krentz, S., R. Holm, H. Bollig, J. Dean, M. Rhodes, D. Hendrix, G. Heidrich, and B. Krise. 2005. Pallid Sturgeon Spawning and Stocking Summary Report. USFWS Missouri River Managemetn Assistance Office. 40 pp. May 12, 2005. Bismark, ND.

Miller, M. M., and A. R. Kapuscinski. 2003. Genetic guidelines for hatchery supplementation programs. Pages 329-357 *in* J. M. Hallerman, editor. Population genetics: principles and applications for fisheries scientists. American Fisheries Society, Bethesda, Maryland.

Milligan, J. 2002. Hermann Bridge Replacement Study Report. Report by the U.S. Fish and Wildlife Service, Columbia Missouri Fisheries Resources Office to the Missouri River Natural Resources Committee, 16th Annual Proceedings.

Modde, T., and J. C. Schmulbach. 1977. Food and feeding behavior of the shovelnose sturgeon, *Scaphirhynchus platorynchus*, in the unchannelized Missouri River, South Dakota.

Montana Fish Wildlife and Parks. 2004. A Stocking Plan for Pallid Sturgeon in Recovery Priority Management Areas 1 and 2.

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.

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 Dept. 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. platorynchus). Copeia No.3:696-700.

Pollak, J. L., R. C. Lacy, and J. D. Ballou. 2002. PM2000: population management software. Cornell University, Ithaca, NY.

Quist, M.C. 2004. Background information. Pallid Sturgeon Research Workshop. May 18-20, 2004. Bloomington, MN. 33 pp.

Ralls, K. and J. D. Ballou. 2004. Genetic status and management of California condors. The Condor. 106:215-228.

Ray, J.M., C.B. Dillman, and R.M. Wood. 2005. Microsatellite analysis of *Scaphirhynchus* species from the southeastern United States. In: Evolution, Ecology and Management of Scaphirhynchus. St. Louis MO, 11-13 January 2005. Abstract.

Reed, B.C. 1991. Recent pallid sightings in Louisiana. Memo to Pallid Sturgeon Recovery Team. 3 pp.

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, LA.

Reeves, K. and D. Galat. 2004. Missouri Coooperative Fish and Wildlife Research Unit report to Pallid Sturgeon Update. U.S. Fish and Wildlife Service. p. 19.

Russell, T. R. 1986. Biology and life history of the paddlefish - a review. Pages 2-20 in J. G. Dillard, L. K. Graham, and T. R. Russell (eds), Paddlefish: status, management and propagation. North Central Division American Fisheries Society Special Publication 7. 159pp.

Russello, M. A. and G. Amato. 2004. *Ex situ* population management in the absence of pedigree information. Molecular ecology. 13:2829-2840.

Scholz, A.T., R.J. White, M.B. Tilson, J.L. Miller, K.N. Knuttgen. 2000. Evaluation of Thyroxine Content in Egg and Larval Pallid Sturgeon, *Scaphirhynchus albus* (Forbes and Richardson, 1905), as a potential indicator of imprint timing. Final Report submitted to USFWS. FWS Agreement No. 1448-60181-99-G435.

Schrey, A.W., and E.J. Heist. 2005a. Genetic discrimination of pallid sturgeon (*Scaphirhynchus albus*) and shovelnose sturgeon (*S. platorhynchus*) using DNA microsatellite markers. In: Evolution, Ecology and Management of Scaphirhynchus. St. Louis, MO, 11-13 January 2005. Abstract.

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. USFWS report submitted to US Army Corps of Engineers, Yankton, South Dakota.

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., E. J. Peters, and L. J. Young. 2002. Movements and habitat use by hatchery-reared pallid sturgeon in the lower Platte River, Nebraska. Pages 161-175 in Biology, management and protection of North American sturgeon. W.VanWinkle, P. J. Anders, D. H. Secor, and D. A. Dixon, editors. American Fisheries Society Symposium 28. Bethesda, Maryland.

Storfer, A. 1999.Gene flow and endangered species translocation: A topic revisited. Biological Conservation. 87:173-180.

Swigle. B. D. 2003. Movements and habitat use by shovelnose and pallid sturgeon in the Lower Platte River, Nebraska. Master's thesis. University of Nebraska. Lincoln.

Tallmon, D. A., G. Luikart, and R. S. Waples. 2004. The alluring simplicity and complex Reality of genetic rescue. Trends in Ecology and Evolution. 19:9.

Tews, A. and P. Clancy. 1993. Fort Peck Pallid Sturgeon Study. Montana Fish Wildlife and Parks final report submitted to U.S. Army Corps of Engineers. Omaha, Nebraska.

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.

Unkenholz, D. G. 1986. Effects of dams and other habitat alterations on paddlefish sport fisheries. Pages 54-61 in J. G. Dillard, L. K. Graham, and T. R. Russell (eds), Paddlefish: status, management and propagation. North Central Div. Am. Fish. Soc. Spec. Pub. 7. 159pp.

Upper Basin Pallid Sturgeon Workgroup. 2005. Pallid sturgeon propagation plan.

U.S. Bureau of Reclamation. 2001. Current operation of the Lower Yellowstone project at Intake, Montana. Draft biological assessment. Montana Area Office, Billings.

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. 1995. Stocking/augmentation plan for the pallid sturgeon (*Scaphirhynchus albus*).

U.S. Fish and Wildlife Service. 2000 (amended 2003). 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. 2000a. Final biological opinion for the operation and maintenance of the 9-foot navigation channel on the Upper Mississippi River system. U.S. Fish and Wildlife Service. Fort Snelling, MN 243 pp.

U.S. Fish and Wildlife Service. 2003. Pallid sturgeon population assessment program 2003 annual report segments 5 and 6. Great Plains Fish and Wildlife Management Assistance Office, Pierre, South Dakota.

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.

Waples, R. S., and J. Drake. 2004. Risk-benefit considerations for marine stock enhancement: a Pacific salmon perspective. pp. 260-306 in K. M. Leber, S. Kitada, H. L. Blankenship, & T. Svåsand, eds. Stock Enhancement and Sea Ranching: Developments, Pitfalls and Opportunities. Second Edition, Blackwell, Oxford.

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.

Appendix 1.

Theoretical abundance table for HRPS stocked into RPMA 1 where *Age* is the age interval of HRPS in years, *S* is the assumed survival rate for the age interval, *Year* is the year in real time, *Year Stocked* is the year in which HRPS are stocked, and *Adults* represents the sum of all HRPS ≥ 15 years old. The shaded region represents all HRPS in the population table that are ≥ 15 years old. Actual numbers of HRPS stocked during 1998-2003 are presented, while the numbers of HRPS stocked during 2004-2010 are estimates. Juvenile pallid survival rates were based on a modified version of a white sturgeon stocking plan (Kincaid 1993).

			Year Stocked													
Age	S	Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Adults
1-2	0.6	1998	732	-	-	-	-	-	-	-	-	-	-	-	-	0
2-3	0.7	1999	439	0	-	-	-	-	-	-	-	-	-	-	-	0
3-4	0.8	2000	307	0	0	-	-	-	-	-	-	-	-	-	-	0
4-5	0.7	2001	246	0	0	0	-	-	-	-	-	-	-	-	-	0
5-6	0.6	2002	172	0	0	0	2058	-	-	-	-	-	-	-	-	0
6-7	0.8	2003	103	0	0	0	1235	0	-	-	-	-	-	-	-	0
7-8	0.9	2004	83	0	0	0	864	0	3239	-	-	-	-	-	-	0
8-9	0.9	2005	74	0	0	0	691	0	1943	5600	-	-	-	-	-	0
9-10	0.9	2006	67	0	0	0	484	0	1360	3360	5600	-	-	-	-	0
10-11	0.9	2007	60	0	0	0	290	0	1088	2352	3360	5600	-	-	-	0
11-12	0.9	2008	54	0	0	0	232	0	762	1882	2352	3360	5600	-	-	0
12-13	0.9	2009	49	0	0	0	209	0	457	1317	1882	2352	3360	5600	-	0
13-14	0.9	2010	44	0	0	0	188	0	366	790	1317	1882	2352	3360	5600	0
14-15	0.9	2011	40	0	0	0	169	0	329	632	790	1317	1882	2352	3360	0
15-16	0.9	2012	36	0	0	0	152	0	296	569	632	790	1317	1882	2352	36
16-17	0.9	2013	32	0	0	0	137	0	267	512	569	632	790	1317	1882	32
17-18	0.9	2014	29	0	0	0	123	0	240	461	512	569	632	790	1317	29
18-19	0.9	2015	26	0	0	0	111	0	216	415	461	512	569	632	790	26
19-20	0.9	2016	23	0	0	0	100	0	194	373	415	461	512	569	632	123
20-21	0.9	2017	21	0	0	0	90	0	175	336	373	415	461	512	569	111
21-22	0.9	2018	19	0	0	0	81	0	157	302	336	373	415	461	512	257
22-23	0.9	2019	17	0	0	0	73	0	142	272	302	336	373	415	461	504
23-24	0.9	2020	15	0	0	0	66	0	128	245	272	302	336	373	415	726
24-25	0.9	2021	14	0	0	0	59	0	115	220	245	272	302	336	373	925
25-26	0.9	2022	12	0	0	0	53	0	103	198	220	245	272	302	336	1105
26-27	0.9	2023	11	0	0	0	48	0	93	179	198	220	245	272	302	1266
27-28	0.9	2024	10	0	0	0	43	0	84	161	179	198	220	245	272	1412
28-29	0.9	2025	9	0	0	0	39	0	75	145	161	179	198	220	245	1271
29-30	0.9	2026	8	0	0	0	35	0	68	130	145	161	179	198	220	1144
30-31	0.9	2027	7	0	0	0	31	0	61	117	130	145	161	179	198	1029
31-32	0.9	2028	7	0	0	0	28	0	55	105	117	130	145	161	179	926
32-33	0.9	2029	6	0	0	0	25	0	49	95	105	117	130	145	161	834
33-34	0.9	2030	5	0	0	0	23	0	44	85	95	105	117	130	145	750
34-35	0.9	2031	5	0	0	0	21	0	40	77	85	95	105	117	130	675
35-36	0.9	2032	4	0	0	0	19	0	36	69	77	85	95	105	117	608
36-37	0.9	2033	4	0	0	0	17	0	32	62	69	77	85	95	105	547
37-38	0.9	2034	4	0	0	0	15	0	29	56	62	69	77	85	95	492
38-39	0.9	2035	3	0	0	0	14	0	26	50	56	62	69	77	85	443
39-40	0.9	2036	3	0	0	0	12	0	24	45	50	56	62	69	77	399
40-41	0.9	2037	3	0	0	0	11	0	21	41	45	50	56	62	69	359
41-42	0.9	2038	2	0	0	0	10	0	19	37	41	45	50	56	62	323
42-43	0.9	2039	2	0	0	0	9	0	17	33	37	41	45	50	56	291

Appendix 2.

Theoretical abundance table for HRPS stocked into RPMA 2 where *Age* is the age interval of HRPS in years, *S* is the assumed survival rate for the age interval, *Year* is the year in real time, *Year Stocked* is the year in which HRPS are stocked, and *Adults* represents the sum of all HRPS ≥ 15 years old. The shaded region represents all HRPS in the population table that are ≥ 15 years old. Actual numbers of HRPS stocked during 1998-2004 are presented, while the numbers of HRPS stocked during 2005-2010 are estimates. Juvenile pallid survival rates were based on a modified version of a white sturgeon stocking plan (Kincaid 1993). (Note:2004 stockings have been adjusted for yearling stocking equivalents as defined in this plan, and some years had more than one stocking event.)

			Year Stocked															
Age	S	Year	1998	1999	2000		2001	2002	2003	2004		2005	2006	2007	2008	2009	2010	Adults
1-2	0.6	1998	780	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
2-3	0.7	1999	468	0	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3-4	0.8	2000	328	0	479	200	-	-	-	-	-	-	-	-	-	-	-	0
4-5	0.7	2001	262	0	287	140	0	-	-	-	-	-	-	-	-	-	-	0
5-6	0.6	2002	183	0	201	112	0	3061	-	-	-	-	-	-	-	-	-	0
6-7	0.8	2003	110	0	161	78	0	1837	4124	-	-	-	-	-	-	-	-	0
7-8	0.9	2004	88	0	113	47	0	1286	2474	2468	4194	-	-	-	-	-	-	0
8-9	0.9	2005	79	0	68	38	0	1028	1732	1481	2517	9000	-	-	-	-	-	0
9-10	0.9	2006	71	0	54	34	0	720	1386	1037	1762	5400	9000	-	-	-	-	0
10-11	0.9	2007	64	0	49	30	0	432	970	829	1409	3780	5400	9000	-	-	-	0
11-12	0.9	2008	58	0	44	27	0	346	582	580	986	3024	3780	5400	9000	-	-	0
12-13	0.9	2009	52	0	39	25	0	311	466	348	592	2117	3024	3780	5400	9000	-	0
13-14	0.9	2010	47	0	35	22	0	280	419	279	474	1270	2117	3024	3780	5400	9000	0
14-15	0.9	2011	42	0	32	20	0	252	377	251	426	1016	1270	2117	3024	3780	5400	0
15-16	0.9	2012	38	0	29	18	0	227	339	226	384	914	1016	1270	2117	3024	3780	38
16-17	0.9	2013	34	0	26	16	0	204	305	203	345	823	914	1016	1270	2117	3024	34
17-18	0.9	2014	31	0	23	15	0	184	275	183	311	741	823	914	1016	1270	2117	69
18-19	0.9	2015	28	0	21	13	0	165	247	165	280	667	741	823	914	1016	1270	62
19-20	0.9	2016	25	0	19	12	0	149	223	148	252	600	667	741	823	914	1016	204
20-21	0.9	2017	22	0	17	11	0	134	200	133	226	540	600	667	741	823	914	384
21-22	0.9	2018	20	0	15	10	0	120	180	120	204	486	540	600	667	741	823	670
22-23	0.9	2019	18	0	14	9	0	108	162	108	183	437	486	540	600	667	741	1040
23-24	0.9	2020	16	0	12	8	0	98	146	97	165	394	437	486	540	600	667	1373
24-25	0.9	2021	15	0	11	7	0	88	131	87	149	354	394	437	486	540	600	1673
25-26	0.9	2022	13	0	10	6	0	79	118	79	134	319	354	394	437	486	540	1943
26-27	0.9	2023	12	0	9	6	0	71	107	71	120	287	319	354	394	437	486	2187
27-28	0.9	2024	11	0	8	5	0	64	96	64	108	258	287	319	354	394	437	2405
28-29	0.9	2025	10	0	7	5	0	58	86	57	97	232	258	287	319	354	394	2165
29-30	0.9	2026	9	0	7	4	0	52	78	52	88	209	232	258	287	319	354	1948
30-31	0.9	2027	8	0	6	4	0	47	70	46	79	188	209	232	258	287	319	1753
31-32	0.9	2028	7	0	5	3	0	42	63	42	71	169	188	209	232	258	287	1578
32-33	0.9	2029	6	0	5	3	0	38	57	38	64	153	169	188	209	232	258	1420
33-34	0.9	2030	6	0	4	3	0	34	51	34	58	137	153	169	188	209	232	1278
34-35	0.9	2031	5	0	4	2	0	31	46	30	52	124	137	153	169	188	209	1150
35-36	0.9	2032	5	0	3	2	0	28	41	27	47	111	124	137	153	169	188	1035
36-37	0.9	2033	4	0	3	2	0	25	37	25	42	100	111	124	137	153	169	932
37-38	0.9	2034	4	0	3	2	0	22	33	22	38	90	100	111	124	137	153	839
38-39	0.9	2035	3	0	3	2	0	20	30	20	34	81	90	100	111	124	137	755
39-40	0.9	2036	3	0	2	1	0	18	27	18	31	73	81	90	100	111	124	679
40-41	0.9	2037	3	0	2	1	0	16	24	16	28	66	73	81	90	100	111	611
41-42	0.9	2038	2	0	2	1	0	15	22	15	25	59	66	73	81	90	100	550
42-43	0.9	2039	2	0	2	1	0	13	20	13	22	53	59	66	73	81	90	495

Appendix 3. Annual Stocking rates (Starter Value) and Target Value for RPA 3

Theoretical abundance table for HRPS stocked into RPMA 3 where *Age* is the age interval of HRPS in years, *S* is the assumed survival rate for the age interval, *Year* is the year in real time, *Year Stocked* is the year in which HRPS are stocked, and *Adults* represents the sum of all HRPS ≥ 15 years old. The shaded region represents all HRPS in the population table that are ≥ 15 years old. Actual numbers of HRPS stocked during 1998-2004 are presented, while the numbers of HRPS stocked during 2005-2010 are estimates. (Note: some years had more than one stocking event.)

			YEAR STOCKED															
AGE	S	YEAR	1998	1999	2000		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	ADULTS
1-2	0.6	1998	0	-	-	-	-	-	-	-	-	-	-	-	-	-	0
2-3	0.9	1999	0	0	-	-	-	-	-	-	-	-	-	-	-	-	0
3-4	0.9	2000	0	0	416	98	-	-	-	-	-	-	-	-	-	-	0
4-5	0.9	2001	0	0	374	88	0	-	-	-	-	-	-	-	-	-	0
5-6	0.9	2002	0	0	337	79	0	1025	-	-	-	-	-	-	-	-	0
6-7	0.9	2003	0	0	303	71	0	615	1100	-	-	-	-	-	-	-	0
7-8	0.9	2004	0	0	273	64	0	554	660	566	-	-	-	-	-	-	0
8-9	0.9	2005	0	0	246	58	0	498	594	340	600	-	-	-	-	-	0
9-10	0.9	2006	0	0	221	52	0	448	535	306	360	600	-	-	-	-	0
10-11	0.9	2007	0	0	199	47	0	404	481	275	324	360	600	-	-	-	0
11-12	0.9	2008	0	0	179	42	0	363	433	248	292	324	360	600	-	-	0
12-13	0.9	2009	0	0	161	38	0	327	390	223	262	292	324	360	600	-	0
13-14	0.9	2010	0	0	145	34	0	294	351	201	236	262	292	324	360	600	0
14-15	0.9	2011	0	0	131	31	0	265	316	180	213	236	262	292	324	360	0
15-16	0.9	2012	0	0	117	28	0	238	284	162	191	213	236	262	292	324	0
16-17	0.9	2013	0	0	106	25	0	214	256	146	172	191	213	236	262	292	0
17-18	0.9	2014	0	0	95	22	0	193	230	132	155	172	191	213	236	262	118
18-19	0.9	2015	0	0	86	20	0	174	207	118	139	155	172	191	213	236	106
19-20	0.9	2016	0	0	77	18	0	156	186	107	126	139	155	172	191	213	252
20-21	0.9	2017	0	0	69	16	0	141	168	96	113	126	139	155	172	191	394
21-22	0.9	2018	0	0	62	15	0	127	151	86	102	113	126	139	155	172	441
22-23	0.9	2019	0	0	56	13	0	114	136	78	92	102	113	126	139	155	488
23-24	0.9	2020	0	0	51	12	0	103	122	70	82	92	102	113	126	139	531
24-25	0.9	2021	0	0	46	11	0	92	110	63	74	82	92	102	113	126	570
25-26	0.9	2022	0	0	41	10	0	83	99	57	67	74	82	92	102	113	604
26-27	0.9	2023	0	0	37	9	0	75	89	51	60	67	74	82	92	102	635
27-28	0.9	2024	0	0	33	8	0	67	80	46	54	60	67	74	82	92	663
28-29	0.9	2025	0	0	30	7	0	61	72	41	49	54	60	67	74	82	597
29-30	0.9	2026	0	0	27	6	0	55	65	37	44	49	54	60	67	74	537
30-31	0.9	2027	0	0	24	6	0	49	58	33	39	44	49	54	60	67	483
31-32	0.9	2028	0	0	22	5	0	44	53	30	35	39	44	49	54	60	435
32-33	0.9	2029	0	0	20	5	0	40	47	27	32	35	39	44	49	54	392
33-34	0.9	2030	0	0	18	4	0	36	43	24	29	32	35	39	44	49	352
34-35	0.9	2031	0	0	16	4	0	32	38	22	26	29	32	35	39	44	317
35-36	0.9	2032	0	0	14	3	0	29	35	20	23	26	29	32	35	39	285
36-37	0.9	2033	0	0	13	3	0	26	31	18	21	23	26	29	32	35	257
37-38	0.9	2034	0	0	12	3	0	23	28	16	19	21	23	26	29	32	231
38-39	0.9	2035	0	0	10	2	0	21	25	14	17	19	21	23	26	29	208
39-40	0.9	2036	0	0	9	2	0	19	23	13	15	17	19	21	23	26	187
40-41	0.9	2037	0	0	8	2	0	17	20	12	14	15	17	19	21	23	169
41-42	0.9	2038	0	0	8	2	0	15	18	10	12	14	15	17	19	21	152
42-43	0.9	2039	0	0	7	2	0	14	17	9	11	12	14	15	17	19	137

Appendix 4. Annual Stocking rates (Starter Value) and Target Value for RPA 4

Theoretical abundance table for HRPS stocked into RPMA 3 where *Age* is the age interval of HRPS in years, *S* is the assumed survival rate for the age interval, *Year* is the year in real time, *Year Stocked* is the year in which HRPS are stocked, and *Adults* represents the sum of all HRPS ≥ 15 years old. The shaded region represents all HRPS in the population table that are ≥ 15 years old. Actual numbers of HRPS stocked during 1998-2004 are presented, while the numbers of HRPS stocked during 2005-2010 are estimates. (Note:2004 stockings have been adjusted for yearling stocking equivalents as defined in this plan, and some years had more than one stocking event.)

			YEAR STOCKED																
AGE	S	YEAR	1998	1999	2000		2001	2002	2003	2004		2005	2006	2007	2008	2009	2010	ADULTS
1-2	0.6	1998	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
2-3	0.9	1999	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3-4	0.9	2000	0	0	416	98	-	-	-	-	-	-	-	-	-	-	-	0
4-5	0.9	2001	0	0	374	88	0	-	-	-	-	-	-	-	-	-	-	0
5-6	0.9	2002	0	0	337	79	0	7406	-	-	-	-	-	-	-	-	-	0
6-7	0.9	2003	0	0	303	71	0	4444	9242	-	-	-	-	-	-	-	-	0
7-8	0.9	2004	0	0	273	64	0	3999	5545	4692	7657	-	-	-	-	-	-	0
8-9	0.9	2005	0	0	246	58	0	3599	4991	2815	4594	6500	-	-	-	-	-	0
9-10	0.9	2006	0	0	221	52	0	3239	4492	2534	4135	3900	6500	-	-	-	-	0
10-11	0.9	2007	0	0	199	47	0	2915	4042	2280	3721	3510	3900	6500	-	-	-	0
11-12	0.9	2008	0	0	179	42	0	2624	3638	2052	3349	3159	3510	5850	6500	-	-	0
12-13	0.9	2009	0	0	161	38	0	2362	3274	1847	3014	2843	3159	5265	3900	6500	-	0
13-14	0.9	2010	0	0	145	34	0	2125	2947	1662	2713	2559	2843	4739	3510	3900	6500	0
14-15	0.9	2011	0	0	131	31	0	1913	2652	1496	2442	2303	2559	4265	3159	3510	3900	0
15-16	0.9	2012	0	0	117	28	0	1722	2387	1347	2197	2073	2303	3838	2843	3159	3510	0
16-17	0.9	2013	0	0	106	25	0	1549	2148	1212	1978	1865	2073	3454	2559	2843	3159	0
17-18	0.9	2014	0	0	95	22	0	1394	1933	1091	1780	1679	1865	3109	2303	2559	2843	118
18-19	0.9	2015	0	0	86	20	0	1255	1740	982	1602	1511	1679	2798	2073	2303	2559	106
19-20	0.9	2016	0	0	77	18	0	1130	1566	883	1442	1360	1511	2518	1865	2073	2303	1225
20-21	0.9	2017	0	0	69	16	0	1017	1410	795	1298	1224	1360	2266	1679	1865	2073	2512
21-22	0.9	2018	0	0	62	15	0	915	1269	716	1168	1101	1224	2040	1511	1679	1865	4144
22-23	0.9	2019	0	0	56	13	0	823	1142	644	1051	991	1101	1836	1360	1511	1679	4721
23-24	0.9	2020	0	0	51	12	0	741	1028	580	946	892	991	1652	1224	1360	1511	5240
24-25	0.9	2021	0	0	46	11	0	667	925	522	851	803	892	1487	1101	1224	1360	6203
25-26	0.9	2022	0	0	41	10	0	600	832	469	766	723	803	1338	991	1101	1224	6574
26-27	0.9	2023	0	0	37	9	0	540	749	423	690	650	723	1204	892	991	1101	6908
27-28	0.9	2024	0	0	33	8	0	486	674	380	621	585	650	1084	803	892	991	7209
28-29	0.9	2025	0	0	30	7	0	438	607	342	559	527	585	976	723	803	892	6488
29-30	0.9	2026	0	0	27	6	0	394	546	308	503	474	527	878	650	723	803	5839
30-31	0.9	2027	0	0	24	6	0	354	491	277	452	427	474	790	585	650	723	5255
31-32	0.9	2028	0	0	22	5	0	319	442	250	407	384	427	711	527	585	650	4730
32-33	0.9	2029	0	0	20	5	0	287	398	225	366	346	384	640	474	527	585	4257
33-34	0.9	2030	0	0	18	4	0	258	358	202	330	311	346	576	427	474	527	3831
34-35	0.9	2031	0	0	16	4	0	233	322	182	297	280	311	518	384	427	474	3448
35-36	0.9	2032	0	0	14	3	0	209	290	164	267	252	280	467	346	384	427	3103
36-37	0.9	2033	0	0	13	3	0	188	261	147	240	227	252	420	311	346	384	2793
37-38	0.9	2034	0	0	12	3	0	170	235	133	216	204	227	378	280	311	346	2513
38-39	0.9	2035	0	0	10	2	0	153	212	119	195	184	204	340	252	280	311	2262
39-40	0.9	2036	0	0	9	2	0	137	190	107	175	165	184	306	227	252	280	2036
40-41	0.9	2037	0	0	8	2	0	124	171	97	158	149	165	276	204	227	252	1832
41-42	0.9	2038	0	0	8	2	0	111	154	87	142	134	149	248	184	204	227	1649
42-43	0.9	2039	0	0	7	2	0	100	139	78	128	121	134	223	165	184	204	1484

Table 5. Survival schedule for HRPS stocked into RPMAs 1 and 2, where *Age Interval* is the age interval of HRPS in years and *S* is the annual survival rate for the age interval. A Variable survival rate during age intervals 1-7 was suggested by the Upper Basin Pallid Sturgeon Workgroup Stocking Committee to account for the transition in feeding behavior a macroinvertebrate diet to one of piscivory. Note: Annual survival *S* after age 20 is 0.90. Juvenile pallid survival rates were based on a modified version of a white sturgeon stocking plan (Kincaid 1993).

Age Interval	S
1-2	0.6
2-3	0.7
3-4	0.8
4-5	0.7
5-6	0.6
6-7	0.8
7-8	0.9
8-9	0.9
9-10	0.9
10-11	0.9
11-12	0.9
12-13	0.9
13-14	0.9
14-15	0.9
15-16	0.9
16-17	0.9
17-18	0.9
18-19	0.9
19-20	0.9

Table 6. Survival schedule for HRPS stocked into RPMAs 3 and 4, where *Age Interval* is the age interval of HRPS in years and *S* is the annual survival rate for the age interval. Note: Annual survival *S* after age 20 is 0.90.

Age Interval	S
1-2	0.6
2-3	0.9
3-4	0.9
4-5	0.9
5-6	0.9
6-7	0.9
7-8	0.9
8-9	0.9
9-10	0.9
10-11	0.9
11-12	0.9
12-13	0.9
13-14	0.9
14-15	0.9
15-16	0.9
16-17	0.9
17-18	0.9
18-19	0.9
19-20	0.9