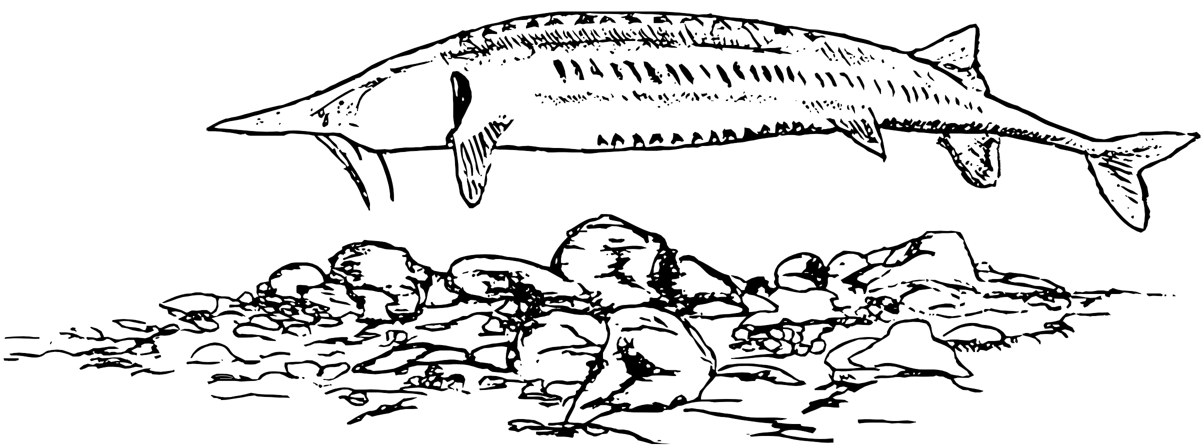
PALLID STURGEON

(*Scaphirhynchus albus*)

Range-Wide Stocking and Augmentation Plan



27 MAY 2008

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(*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
Acting

______________ Date
6/9/08

EXECUTIVE SUMMARY

The pallid sturgeon, *Scaphirhynchus albus,* was listed as endangered in 1990 by the U.S. Fish and Wildlife Service. One primary cause identified for the decline in pallid sturgeon 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 Missouri and Mississippi rivers. While there are documented occurrences of spawning success in the Missouri and Mississippi rivers, there are little to no data indicating substantial natural recruitment. Little to no recruitment and increasing threats from commercial harvest and entrainment/impingement losses in portions of the Missouri and Mississippi rivers are also believed to be important factors suppressing pallid sturgeon population abundance and size distribution in these systems. Current wild pallid sturgeon populations in the Upper Missouri River are comprised of old-aged individuals. Few presumed wild adult pallid sturgeon have been collected between Fort Randall and Gavins Point Dams during the last 10 years, but there are questions surrounding their origin (possibly translocated) and there is no evidence of recruitment success in this reach. Data from the Missouri River, downstream of Gavins Point Dam to the confluence with the Mississippi River, indicate that limited or sporadic recruitment may be occurring within this reach. An accurate assessment of the population demographic for the Lower Mississippi is lacking. The data available indicate there may be more pallid sturgeon present than initially believed. However, the sampling efforts expended 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. Take of pallid sturgeon associated with commercial harvest of shovelnose sturgeon within portions of the Missouri and Mississippi rivers is a threat that cannot be sustained long-term. The status of pallid sturgeon in the Atchafalaya River 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 indicate relatively stable length frequencies through time, suggesting that recruitment may be coming from somewhere. One theory is that larger pallid sturgeon may be attenuated into the Atchafalaya River via fish movement from the Lower Mississippi River. Limited support for this hypothesis was documented in 2006 and 2007 when hatchery-reared pallid sturgeon released in the Mississippi River were collected below the Old River Control Complex. Another hypothesis is that the Atchafalaya River group is self sustaining and that sampling practices are inadequate to detect smaller size classes. However, it is equally plausible that both entrainment from the Mississippi River and some level of recruitment is supporting the Atchafalaya River population. Adequate sampling efforts in lower Mississippi and Atchafalaya rivers have been restricted by limited funding and personnel. This lack of funding is resulting in limited information being collected to assess sturgeon population demographics. Addressing these limitations by development of funding initiatives for recovery/research work in the Mississippi and Atchafalaya rivers is essential to insure the best available data are being utilized for pallid sturgeon recovery efforts.

Recent data suggests that there is genetic population structuring within the species and caution should precede all stocking activities and brood source selection. Much of this summary was derived from data presented in the Pallid Sturgeon 5-Year Review (U.S. Fish and Wildlife Service 2007).

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

1) Supplementing management units, 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 species' historic range;
3) Mimic wild population haplotype or genotype frequencies in hatchery broodstock and progeny and,
4) Prevent the introduction of disease into the wild population.

Objectives identified in this plan do not conflict with the objectives defined in the policy regarding Controlled Propagation of Species Listed Under the Endangered Species Act (65 FR 56916-56922) and are 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 have been 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. Depending on annual hatchery spawning success, the maximum number of fish stocked each year could be limited by the number of fish propagated in the hatcheries each year. Annual stocking targets, in this plan, are based on; 1) riverine sturgeon survival rates reported in the scientific literature, 2) RPMA pallid sturgeon specific survival estimates where available, 3) the best available data in agency reports, and 4) 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 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 demographics, and habitat restoration efforts is an integral part of the recovery program. A monitoring effort, the Pallid Sturgeon Population Assessment and Monitoring Program, has been developed, independently reviewed and is currently being implemented within the Missouri River Basin (Drobish 2006). 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 co-incidentally for the Mississippi and Atchafalaya river systems to insure adequate data are collected to assess pallid sturgeon population demographics in those reaches. This plan recognizes that stocking/augmentation efforts are tools to aid 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 may help prevent local and regional extirpation, pallid sturgeon recovery is dependent upon addressing the threats affecting the species (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 can 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 will be completed by the Pallid Sturgeon Recovery Team and the Basin Workgroups. If either of these groups 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 Coordinator. The Recovery Coordinator will engage the Pallid Sturgeon Recovery Team to review the data from a range wide perspective and submit their recommendations to the Regional Director for the lead region of the U.S. Fish and Wildlife Service (Region 6, Regional Office Lakewood, CO) as well as the appropriate Basin Workgroup chair. Through this process, the stocking plan will be reviewed and updated with new or relevant information in a timely manner. In this fashion, 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 must 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 management unit or reach specific survival rates for fry through juvenile hatchery-reared pallid sturgeon to improve existing stocking calculations.

- Determine management unit or reach specific survival rates and stocking effectiveness based on size, age, stocking location/habitat, and temperature 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. Conversely, if data supports it, it may be more beneficial to stock larger individuals.

- 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. Utilize these data to refine the comprehensive tagging protocol for hatchery-reared pallid sturgeon.

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

- Determine management unit or reach specific carrying capacities for pallid sturgeon and determine the relationship and/or interaction between effective population size and river reach carrying capacities to determine more biologically sound population goals and hence more effective stocking targets.

- Determine if juvenile pallid sturgeon with fin curl problems are more 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 if juvenile pallid sturgeon with iridovirus are more physically compromised than normal hatchery-reared pallid sturgeon, how this relates to survival after being released in the wild, and how stocking iridovirus positive pallid sturgeon affects wild and previously stocked hatchery-reared pallid sturgeon

Acknowledgments

Special acknowledgments must be extended to the Upper Basin Pallid Sturgeon Workgroup Stocking Committee for providing their input and knowledge into earlier 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, the Pallid Sturgeon Recovery Team's Propagation Committee, state and federal fish health experts, and other interested parties who took the time to read and provide comments as this plan was developed.

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TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

CGL..Conservation Genetics Lab
CLMU ....Central Lowlands Management Unit
CPMU .... Coastal Plains Management Unit
CWT..Coded Wire Tag
ERDC………………………………………Engineer Research and Development Center
FWMAO…………………………………Fish and Wildlife Management Assistance Office
GPMU ....Great Plains Management Unit
HRPS.. Hatchery Reared Pallid Sturgeon
IHMU ....Interior Highlands Management Unit
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
MO ....Missouri
MT………………………………………………………………………………Montana
ND……………………………………………………………………………North Dakota
NE……………………………………………………………………………….Nebraska
NFH...National Fish Hatchery
NGPC ....Nebraska Game and Parks Commission
ORCC.. Old River Control Complex
PIT...Passive Integrated Transponder
PSIV………………………………………………………...Pallid Sturgeon Iridovirus
RM ....River Mile
RPMA ....Recovery Priority Management Area
SD…………………………………………………………………………South Dakota
SFH ....State Fish Hatchery
SIU……………………………………………………….Southern Illinois University
UBPSW..Upper Basin Pallid Sturgeon Workgroup
UC Davis………………………………………………….University of California, Davis
USACE ....United States Army Corps of Engineers
USFWS ....United States Fish and Wildlife Service
USGS ....United States Geological Survey
VHS…………………………………………………….Viral Hemorrhagic Septicemia
WA…………………………………………………………………………...Washington

INTRODUCTION

The pallid sturgeon, *Scaphirhynchus albus*, was listed by the U.S. Fish and Wildlife Service (USFWS) as Endangered throughout its range (U.S. Fish and Wildlife Service 1990). 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. Following listing, the USFWS approved a recovery plan for the species in 1993 (U. S. Fish and Wildlife Service 1993). This plan identifies many recovery tasks necessary to recover 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 regarded as an important component of recovery efforts necessary to insure persistence of the species. Where necessary, supplementation efforts likely will continue until such time 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..." (U. S. Fish and Wildlife Service 1993). When this occurs, continued supplementation should be halted.

Avoidance of extirpation over the next 50 years within the upper and middle Missouri River may depend largely on the success of the pallid sturgeon artificial propagation program. These efforts are assuming increasing importance because of the perceived lack of natural reproduction and/or documented recruitment in the Missouri River during the past 30 years. Hatchery release strategies should allow for or mimic natural evolutionary process in the absence of natural recruitment. More research is needed 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 and 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 wild fish available for hatchery propagation and subsequent stocking?" Historical information on pallid sturgeon migration patterns and mixing of fish (genetic exchange) along the river's continuum is lacking. Undoubtedly there were locally adapted populations, but likely as well there was genetic transfer among colocated populations and among the populations within the river continuum. Support for this relationship is presented in data indicating that F_{st} value differences increase with the geographic distances associated with sample collections (Heist and Schrey 2003 and 2006a and 2006b, Schrey 2007). 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 by dams in the Upper Missouri River and are exhibiting no natural recruitment. There is some evidence of spawning success and various suspected levels of recruitment in the Missouri and Mississippi rivers below Gavins Point Dam (U. S. Fish and Wildlife Service 2007). 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.

Where stocking is deemed necessary, this plan outlines a strategy for stocking pallid sturgeon with the specific goal of establishing or maintaining a population that is believed to resemble the historical population in abundance, distribution, and genetic diversity within a range-wide framework for recovery. This stocking plan is intended to cover stocking of 2008 through 2010 year class pallid sturgeon produced as part of the conservation stocking program, and was written to; 1) maximize genetic diversity in hatchery-reared pallid sturgeon based on appropriate selection of broodstock, 2) minimize consequences of immigration from potentially divergent individuals produced as part of the population augmentation program, 3) maximize the ability of stocked individuals to survive in a new environment, and 4) 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. Following is a synopsis of pertinent data and a discussion of supplementation strategies that will facilitate obtaining the following goals:

(1) Utilize current range-wide genetics and demographic data to outline management units to best conserve identified genetic variability found within the species,
(2) To identify the risks and benefits associated with stocking within each management unit,
(3) To determine if supplementation with hatchery produced pallid sturgeon is warranted within each management unit considering available population demographic data, and
(4) To consolidate and update existing supplementation strategies.

POPULATION STRUCTURE OF PALLID STURGEON

Following species listing, genetic tools have improved and subsequent data have been evaluated to help better understand the range-wide population structure of pallid sturgeon.

The presence of morphologically intermediate forms presumed to represent pallid-shovelnose sturgeon hybrids (Keenlyne *et al.* 1994, Carlson *et al.* 1985) spurred an effort to determine the genetic origins of these fish. Through these efforts, we have begun to better understand range wide genetic structuring. Tranah et al. (2001) examined genetic variation within and among three pallid sturgeon groups, two of which were located in the Upper Missouri River and one representing Atchafalaya river system. The allele frequencies at five microsatellite loci indicated the two Upper Missouri River groups, separated by Fort Peck Dam, did not differ significantly. Conversely, pallid sturgeon from the Upper Missouri River 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 North Dakota and 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 (Tranah et al. 2001).

Subsequently, Heist and Schrey (2003, 2006a, 2006b) detected genetic differences between Upper Missouri and Middle Mississippi river pallid sturgeon based on examination of eleven to sixteen microsatellite loci. Heist and Schrey (2003, 2006a, 2006b) found significant F_{st} differences between the Upper Missouri River pallid sturgeon samples when compared with samples from the Middle Mississippi River. Schrey (2007) subsequently examined samples collected from below Gavins Point Dam, SD (RM 811) downstream to Kansas City, MO (RM 367.5). Schrey (2007) suggests that pallid sturgeon in this part of the range appear genetically intermediate between the Upper and Lower Missouri River pallid sturgeon samples. However, caution should be used when looking at the Middle Missouri samples because it is not possible to rule out the idea that the intermediacy of this sample could have been influenced by upper basin origin fish stocked into the Middle Missouri River (Schrey 2007, DeHaan et al. 2008). Another confounding factor for the genetic intermediacy seen here, as well as perhaps understating the genetic structuring throughout the range of the pallid sturgeon, is the manner in which tissues are collected for genetic analyses, i.e. not collecting tissues on spawning sites. If pallid sturgeon show site fidelity to spawning grounds and have a general movement downstream after spawning, as do all other sturgeon species examined to date, then observed genetic differences between populations may be muted by having collected tissues during all months of the year when sturgeon are likely not closely associated with spawning sites.

Current data suggest that the genetic structuring within the pallid sturgeon's range may represent a one-dimensional linear stepping-stone distribution as explained in Gharrett 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 significant genetic differences among pallid sturgeon samples collected from the Upper Missouri, Atchafalaya, Middle Mississippi and Lower Missouri rivers (Heist and Schrey 2003, 2006a, 2006b, Ray et al. 2005, Schrey 2007).

DEFINING MANAGEMENT UNITS

Though pallid sturgeon are currently listed as endangered range-wide (U. S. Fish and Wildlife Service 1990), there is a need to recognize genetic and morphometric diversity within the species. A major management information gap associated with the conservation stocking program has been the need to develop a scientifically-defensible relationship, or strategy, between the geographic origins of adult fish collected for broodstock and the geographic regions within the Missouri and Mississippi rivers where their progeny are released. A more appropriate approach for recovery management likely is delineation and recognition of management units (Green 2005). Acknowledging the existence of these units should rely on two criteria; are management units distinguishable, and do these management units warrant differing degrees of conservation? Based on available data, the Pallid Sturgeon Recovery Team believes the answer to both questions is "yes" (Pallid Sturgeon Recovery Team 2006 and 2007). Following is a description of how these management units were derived.

These management units were described based on both genetic and morphological differences, but clearly delineating management units based on these items alone was difficult. It is documented that Upper Missouri River pallid sturgeon are reproductively isolated from and/or morphologically distinct from Lower Missouri/Middle Mississippi River, and Atchafalaya River pallid sturgeon (Campton et al. 2000, Kuhajda et al. 2007, Murphy et al. *2007*, Tranah et al. 2001, Heist and Schrey 2003 and 2006a, Schrey 2007). However, Middle Missouri River pallid sturgeon (Gavins Point Dam downstream to Kansas City, MO) appear to be intermediate between the Upper Missouri and Lower Missouri/Middle Mississippi group (Heist and Schrey 2006b, Schrey 2007), suggesting that, Upper Missouri River and Lower Missouri/Middle Mississippi River pallid sturgeon were not completely reproductively allopatric prior to construction of Gavins Point Dam. In conjunction with these genetic data, data relating to physiographic provinces and patterns found within other fish species (Burr and Page 1986, Cross 1967, Cross et al. 1986, Wiley and Mayden 1985) were considered in the context of pallid sturgeon stocking and augmentation efforts. The range of the pallid sturgeon extends across four physiographic provinces including the Coastal Plain, Interior Highlands, Central Lowlands, and Great Plains (described in Cross et al. 1986). Many fish species are documented to separate along these physiographic province boundaries (Wiley and Mayden 1985, Burr and Page 1989, Cross et al. 1986). The most recent genetic structure data for pallid sturgeon (Schrey 2007) shows a discernable population in the Upper Missouri River restricted to the Great Plains province, as well as some other genetic structuring roughly following the other three physiographic areas. Based on these data, the Recovery Team discussed and outlined various management unit boundaries on a map. Initial attempts to arrange existing boundaries using physiographic and biological data, with subsequent boundary refinement to align with the ability to implement management actions can be found in Pallid Sturgeon Recovery Team (2006 and 2007). Applying these management units (Figure 1) will allow for varying management or recovery schemes to best conserve the species while reducing many genetic concerns associated with artificial propagation programs.

These management units (Figure 1) described by the Recovery Team in 2006 encompass the historic range of pallid sturgeon as defined in the current recovery plan (U.S. Fish and Wildlife Service 1993) to include the Mississippi River from Keokuk, Iowa (Mississippi River RM 1317.8 to the Gulf of Mexico and the Missouri River from Fort Benton, Montana to the confluence with the Mississippi River at St. Louis, Missouri.

The Great Plains Management Unit (GPMU) is defined as the Missouri River from the Great Falls of the Missouri River, Montana to Fort Randall Dam, South Dakota. This includes important tributaries like the Yellowstone River, as well as the Marias and Milk rivers. The boundary was formed at the Great Falls as this is a natural barrier in the system above which pallid sturgeon likely could not historically migrate.

The Central Lowlands Management Unit (CLMU) is defined as the Missouri River from Fort Randall Dam, South Dakota to the Grand River confluence with the Missouri River in Missouri and includes important tributaries like the Platte River.

The Interior Highlands Management Unit (IHMU) is defined as the Missouri River from the confluence of the Missouri and Grand rivers to the confluence of the Missouri and Mississippi rivers as well as the Mississippi River from Keokuk, Iowa to the confluence of the Ohio and Mississippi rivers.

The Coastal Plain Management Unit (CPMU) is defined as the Mississippi River from the confluence of the Ohio and Mississippi rivers to the Gulf of Mexico including the Atchafalaya distributary system.

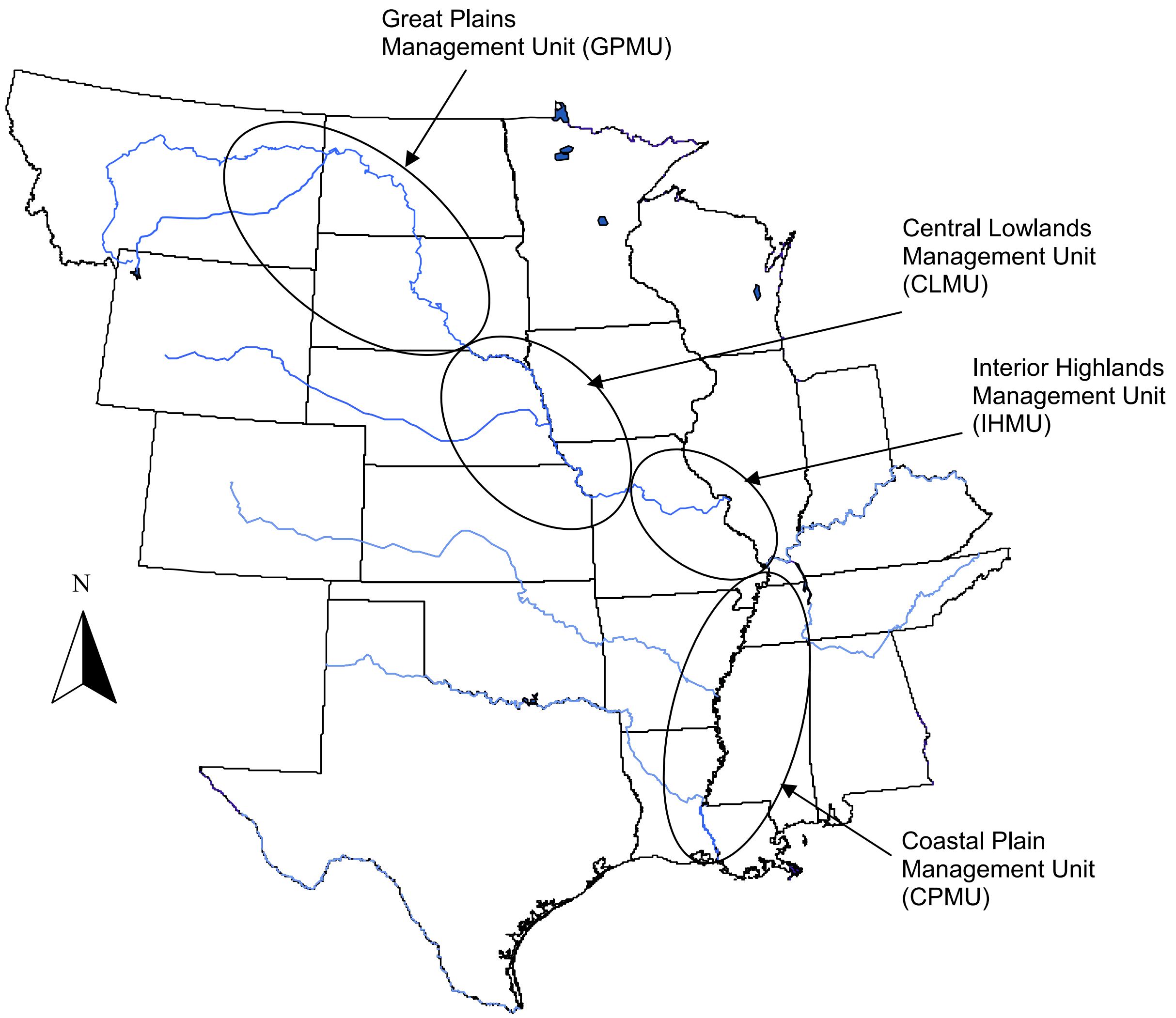

Figure 1. Outline of management units, identified by the Pallid Sturgeon Recovery Team, based on available genetic data, identified physiographic provinces, and patterns found within other fish species. Management unit definitions can be found in Defining Management Units section, this document. (For graphical representation only, map not to scale)

MAINTAINING GENETIC DIVERSITY

MINIMIZING INBREEDING DEPRESSION

Inbreeding is a genetic process that can occur when non-randomized pairing results in closely related individuals mating. This has been demonstrated to result in increased frequencies of homozygosity (Hallerman 2003a). Current practices for pallid sturgeon brood fish collections involve focused fishing efforts, generally in the fall and/or early spring, to collect wild adult fish. Every effort in this process is assumed to produce random adult brood fish collections for mating purposes. However, truly random mating may not be conducted in this fashion. In order to minimize any affects associated with potential non-random brood fish collections, annual breeding plans are developed to define male x female matings. Following is a description of this process.

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.

Subsequently, in 2005, the USFWS Conservation Genetics Lab (CGL) at Abernathy Fish Technology Center 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 pair wise 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.

The CGL currently develops an annual breeding plan for pallid sturgeon based on which adult fish have been captured, those mated in the past, and which males have cryo-preserved milt. They have implemented methodologies 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 maintain this breeding plan and database will likely increase as fewer new natural-origin fish are collected for propagation purposes in the GPMU. 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).

MINIMIZING OUTBREEDING DEPRESSION

Outbreeding depression is a loss of species fitness associated with the disruption of locally adaptive traits or gene complexes as a result of mixing between genetically divergent populations (Hallerman 2003b). In order to minimize potential negative consequences of outbreeding depression, appropriate brood fish selection and progeny release strategies are important. Following is a description of these processes.

Past augmentation efforts have utilized GPMU, CLMU, IHMU, and CPMU parental stock with all sources producing hatchery-reared pallid sturgeon (HRPS) for supplementation efforts. By far the largest contribution of HRPS has been derived from GPMU parental stocks (see Production and History section this plan). Genetic concerns attributed to mixing of potential stocks led the Pallid Sturgeon Recovery Team to recommend utilizing local parental stocks for propagation purposes in 2005 (Pallid Sturgeon Recovery Team 2005). When efforts were made to collect 3 females and up to 9 males from the CLMU during the spring of 2005, few wild pallid sturgeon were collected, however, several hatchery-reared 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 older HRPS currently maintained as future brood fish. 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 is important.

To date, parental stocks have been collected relatively consistently from portions of the GPMU, and reliable brood collections have been difficult to obtain from other management units. Also, there will come a time when the ability to obtain wild adults from the GPMU is severely diminished as the adult population senesces. When this occurs, reliance on the brood program being developed at Gavins Point NFH may be necessary to sustain/augment populations within the GPMU.

To further define what constitutes local brood fish, the Pallid Sturgeon Recovery Team developed the following guidelines;

Brood fish collected from within the Great Plains Management Unit (GPMU) (Figure 1) are considered local brood sources for the GPMU. Brood fish collected from within the Central Lowlands Management Unit (CLMU) (Figure 1) are considered local brood sources for the CLMU. Brood fish collected from within the Interior Highlands Management Unit (IHMU) (Figure 1) are considered local brood sources for the IHMU. Brood fish collected from within the Coastal Plain Management Unit (CPMU) (Figure 1) are considered local brood sources for the CPMU. (Note: Because there are currently not enough data to support or refute stocking into the CPMU, the desired condition is not to stock until sufficient data are obtained that clearly indicate stocking should occur.)

Exceptions to these definitions of local brood stocks are as follows (Pallid Sturgeon Recovery Team 2007):

1) The portion of the CLMU that falls between Fort Randall and Gavins Point Dams has only been stocked with GPMU origin progeny and this practice should continue, but not preclude the option to supplement this reach with CLMU origin progeny.
2) Adults or gametes collected from disjunct or stranded inter-reservoir populations may be used to provide gametes for the conservation stocking program and subsequent progeny should be stocked in the management unit to which the parental group genetically

assigns. As an example, based on limited data, the genetic structure of the Lake Sharpe samples had a stronger assignment to the CLMU (Schrey and Heist 2007) though they were collected from within the GPMU. Thus, progeny derived from Lake Sharpe brood fish could be stocked into the CLMU or Lake Sharpe.

3) An additional exception to this recommendation involves stocking limited numbers, (≤ 100) necessary, to fulfill important research needs.

In essence, the careful selection of appropriate brood fishes should permit limited gene flow, from one management unit to the next, in a more appropriate longitudinal fashion than what has occurred in the past, while still allowing supplementation practices to continue, where necessary, to avoid loss of local individuals and the associated genetic diversity.

USE OF HATCHERY-ORIGIN PALLID STURGEON

PRODUCTION AND HISTORY

The first known successful pallid sturgeon spawning effort occurred at the Blind Pony State Fish Hatchery (SFH), Missouri in 1992. Pallid sturgeon produced at this facility were the product of locally collected Mississippi River (CPMU) parental stock. Approximately 7,136 hatchery reared pallid sturgeon (HRPS) from this 1992 spawning activity were coded wire and double t-bar monofilament (floy) tagged prior to release in 1994 (2,434 in the Missouri River and 4,702 in the Mississippi River). Another successful spawning effort occurred at Blind Pony SFH in 1997 from adults collected near Caruthersville, Missouri within the CPMU. Approximately 1,589 of these HRPS were released in the Lower Missouri River (IHMU) and 2,066 were released into the Mississippi River portion of the IHMU and locations within the state of Missouri's boundary with the CPMU. Natchitoches NFH successfully spawned pallid sturgeon collected from the Atchafalaya River 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 these GPMU parents have been stocked into the GPMU, CLMU, and IHMU in recent years (See Appendices 1-4). While the success of hatchery production is evident, supplementation with GPMU based progeny into the CLMU downstream of Gavins Point Dam raised concerns. 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 CPMU basin. It was therefore suggested by the LBPSW that stocking in the CPMU should be postponed, and future stocking would require a clear conservation or research objective and risk/benefit analysis.

RECORD KEEPING SYSTEM

A database will be maintained by the USFWS - Missouri River Fish and Wildlife Management Assistance Office in Bismarck 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 and average weight of fish prior to stocking, method of marking, tag numbers, and transport time. Stocking information listed in this section should be provided to RPMA managers and state hatchery chiefs in addition to the Missouri River Fish and Wildlife Management Assistance Office in Bismarck ND within 5 days of stocking. Development of a standardized form should be pursued if this would facilitate timely transfer of information.

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 area will secure all state, federal, and other necessary permits. Since the majority of GPMU supplementation efforts occur within Montana, permitting and associated responsibilities for this area will be delegated to MFWP representatives and coordinated with the North Dakota Game and Fish Department and the USFWS. Activities involving stocking in Missouri River waters bordering South Dakota and Nebraska will be coordinated through the Great Plains Fish and Wildlife Management Assistance Office, Pierre SD. The Columbia Fish and Wildlife Conservation Office, Columbia MO, will secure necessary permits from Iowa and Missouri for stocking activities in the CLMU and IHMU. Stocking within the CPMU is not deemed necessary at this time. However, any future activities involving stocking in the CPMU should be coordinated with state agency representatives and the USFWS (Natchitoches and Neosho NFH; Jackson, MS; Collinsville, IL, and Carterville, IL field offices).

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 stocking activities with the production facilities. In boundary water situations, approval will be secured from both States before stocking can occur.

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 fish biologists to identify HRPS after their release as long as DNA samples have been collected from the parental stock. These DNA methods, similar to those widely employed by law enforcement agencies in forensic investigations, will reduce the need to physically mark or tag each fish prior to release. These methods (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 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, but are only reliable if both parental genotypes are collected.

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, 2005). Jan Dean (USFWS, Personal communication, 2005) 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 retention rates in the wild has yielded moderate success with PIT tags. Matt Klungle (MFWP, personal communications, 2005) indicated a 76% tag retention rate based on sampled individuals (n=86) and Shuman et al. (2005) reported 86% retention (n=28). When PIT tags are not appropriate, such as in young-of-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). While these genetic tags have proven useful in identifying HRPS that were released and subsequently were collected with failed physical marks, or released as fry, the cost associated with reading genetic tags can be high. Given current limited resources for genetic analysis of unmarked pallid sturgeon, no non-physically marked pallid sturgeon should be released (i.e. fry stocking) downstream of Gavins Point Dam. This will reduce the confounding effects stocking may have on population assessments downstream of Gavins Point Dam.

All tagging will be conducted in accordance with basin workgroup tagging plans 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

There are numerous potential fish health issues related to artificial propagation programs. The Fish and Wildlife Service Aquatic Animal Health Policy Part (713 FW 1-5) serves as the basis for efforts to contain, control, and minimize the impacts of aquatic animal pathogens and diseases. Additionally, each state has different requirements and regulations regarding issuance of an importation permit to stock HRPS. Common factors that weigh in on these decisions include, but are not limited to the presence of; adenovirus, gill amoeba, viral hemorrhagic septicemia (VHS), pallid sturgeon iridovirus (PSIV), and the presence of recognized aquatic nuisance species.

The USFWS maintains a list of regulated pathogens of nationwide concern. These pathogens are those that have the potential to produce severe epizootics of clinical disease but are also known to exist in a carrier state. They include viral, bacterial, and parasitic agents. They generally have both a screening and confirmatory test available. Two pathogens of notable importance are viral VHS and PSIV.

VHS is a viral fish disease that has caused large scale mortalities in rainbow trout and turbot aquaculture operations in Europe and in Pacific herring and pilchard populations along the Pacific Coast of North America. The disease is caused by a rhabdovirus, Viral Hemorrhagic Septicemia Virus (VHSv). This virus has a number of identified isolates grouped in four types; three from Europe and one from North America. Each appears to have unique effects with specific pathogenicity on certain species. The isolate found in the Great Lakes Basin is most similar to the VHS strain previously isolated from the Atlantic Coast in Eastern North America.

VHS is a reportable disease that requires notification of Departments of Agriculture, United States Department of Agriculture – Animal and Plant Health Inspection Service, appropriate Canadian Agencies and International Organization for Animal Health. It is also listed as an emergency disease by the Great Lakes Fishery Commission - Great Lakes Model Fish Health Program.

Since this pathogen can clearly cause large scale mortalities of valuable adult fish and it has a wide range of potential carriers, it is critical to make every attempt to monitor pallid sturgeon for VHS.

PSIV is of special concern for USFWS Region's 3, 5, and 6. It is known to cause mortalities in HRPS and its effect on free-ranging sturgeon populations is unknown. Hatchery amplification of pathogens is a significant concern for stocking programs and recovery efforts.

The PSIV was first detected in shovelnose at the Gavins Point National Fish Hatchery in 1999. Since 1999, iridovirus outbreaks have occurred at Gavins Point Dam National Fish Hatchery, Garrison Dam National Fish Hatchery, Neosho National Fish Hatchery, Blind Pony State Fish Hatchery, Miles City State Fish Hatchery, and Bozeman Fish Technology Center. 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 may continue to carry the virus after the initial outbreak. This virus can cause significant mortality at recommended sturgeon propagation temperatures. The iridovirus identified in the Upper Missouri River Basin can infect both shovelnose and pallid sturgeon and can be transmitted between these species. This virus is distinctly different than the white sturgeon iridovirus. The effect of this virus on wild populations is currently poorly understood. Stocking iridovirus positive fish is still subject to the approval of State and Federal Resource Management Agencies. Regulations and policies vary widely from state to state. The USFWS currently operates under the guidelines that entities responsible for border waters areas must support the stocking proposal before they are implemented.

Each hatchery involved in the production of pallid sturgeon practices fish culture methodologies intends to produce healthy fish. However, there have been instances where, despite these efforts, diseases like PSIV have resulted in the need to euthanize large numbers of fish. Recent efforts within the propagation program have focused on rearing disease free pallid sturgeon. These efforts involved implementing hatchery specific culture practices and appear to be reducing iridovirus outbreaks.

Prior to release, the health of hatchery-produced pallid sturgeon will be evaluated using the most current valid tests. Each facility will be required to undergo a pre-release health evaluation prior to each proposed stocking event. The evaluation will be based on a total of 60 randomly collected fish, sampled from cultural units representing one year class of pallid sturgeon, preferably 6 weeks prior to stocking.

VIRAL TESTING

Iridovirus**:**
Polymerase Chain Reaction protocols involve amplification of viral DNA with a measurable increase in detection sensitivity when compared to histological assays. The analytical sensitivity and specificity studies for pallid sturgeon iridovirus have been completed. The PCR assay does not react with other sturgeon viruses and has been validated with comparison to histological observations. Dose trials are in progress currently. These trials will further the development of a Quantitative PCR assay to determine the level of infection in viral positive fish.

Full development of PCR protocols are intended to provide a relatively rapid, sensitive, specific, and quantifiable viral detection method. It is designed to be included in future pre-release assessments of cultured sturgeon and monitoring efforts on free-ranging populations. It has the potential to provide fishery managers with additional tools for completing scientifically defensible risk management decisions regarding propagation and stocking.

One pectoral fin from each of 60 fish will be obtained for evaluation of presence or absence of PSIV by histology or qPCR. Iridovirus severity in histological sections 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 observation of infected cells too numerous to count in an entire section of pectoral fin. Acceptable scores for virus severity should not exceed an average of 3.0. Acceptable values for qPCR assay have yet to be determined.

Viral Hemorrhagic Septicemia Virus (VHSv): Appropriate tissue samples consisting of 1.5 gram of kidney and spleen from each fish sampled, will be obtained to assay for the presence of the causative agent of VHSv. Cell culture assays will be used on 3 cell lines including a species specific sturgeon cell line to isolate any replicating agents.

Other tests/assays will be added as needed due to emerging pathogens of concern in the Missouri River Basin.

The Service National Aquatic Animal Health Policy precludes stocking any fish undergoing a clinical outbreak of disease, but iridovirus positive non-epizootic fish may be stocked if the States receiving the PSIV positive non-epizootic pallid sturgeon are supportive of this action. Certification for stocking will also consider a lot's health history, mortality and signs of other infectious agents or non-infectious problems impacting overall health of cultured sturgeon.

All suggested stocking rates and calculations in this document assume that 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/or recruitment of wild fish in the GPMU and CLMU appear insufficient to sustain a natural population; there is a lack of data regarding levels of

reproduction and recruitment in the IHMU and CPMU (U. S. Fish and Wildlife Service 2007).

2. Any sporadic reproduction that might occur in the GPMU yields little 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 the IHMU and CPMU 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 (U. S. Fish and Wildlife Service 2007).

4. 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).

5. The current existing wild population within the GPMU will be extirpated or severely depressed before the introduced population reaches sexual maturity (U.S. Fish and Wildlife Service 2000, Kapuscinski 2002, data presented to the Pallid Sturgeon Recovery Team, Lakewood CO, 27 September 2005).

6. Genetic structuring of pallid sturgeon throughout its range (Heist and Schrey 2003, 2006a and 2006b, Schrey 2007) reflects a one dimensional linear stepping-stone distribution as explained in Gharrett 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 GPMU stocked HRPS (Table 5) were obtained from the Montana Fish Wildlife and Parks (2004) stocking plan. These estimates were modified from Kincaid (1993) in that there is a theorized level of reduced survival associated with a diet shift from a macroinvertebrate to a piscivorous diet. Also, it is hypothesized that sub-yearling pallid sturgeon will have higher mortality rates than later life stages, due 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 GPMU wild individuals available for the hatchery propagation and stocking programs dictate that stocking all available upper basin origin progeny back into the GPMU 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 the CLMU and portions of the IHMU are based on an assumption that sturgeon survival rates within these areas are similar to those documented for white sturgeon in the Kootenai River, Idaho (Ireland et al. 2002) (Table 6).

4. Iridovirus positive fish have been documented in the wild (above Fort Peck Dam, downstream of Fort Peck Dam, MT, to 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 effects on either pallid sturgeon or shovelnose sturgeon.

STOCKING RISKS/BENEFITS:

GPMU

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 the GPMU.

BENEFITS

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

Length frequency data are available that suggest that when stocking has occurred within the GPMU; those stocked fish are contributing to the population. Currently these data do not indicate natural recruitment to the adult population within the GPMU (U.S. Fish and Wildlife Service 2007). Without supplementation, the pallid sturgeon population 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 local, 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 Service 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 the GPMU, supplementation into the Missouri River, above and below Fort Peck Dam, as well as above and below Intake Dam in the Yellowstone basin would insure protection of pallid sturgeon should a stochastic event occur in any one area or at Gavins Point NFH. Gavins Point NFH currently is the only facility rearing a portion of past GPMU family lots as part of the future brood program identified in the Pallid Sturgeon Recovery Plan (U. S. Fish and Wildlife Service 1993).

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 success of the augmentation program for pallid sturgeon is demonstrated by a more normalized length frequency distribution and improved age structure within the GPMU (U.S. Fish and Wildlife Service 2007). Continued supplementation and evaluation within this management unit may prove useful in shedding some valuable insights on supplementation programs for other species.

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 mating 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 these potential risks associated with supplementation efforts. Selecting an appropriate brood source is the number one priority. While genetic studies (Campton et al. 2000, Tranah et al. 2001, Schrey 2007) indicate genetic structuring within the pallid sturgeon population range wide, they also identified that there were no detectable differences among GPMU samples collected above and below Fort Peck Dam. For these reasons, the best available brood source for artificial propagation within the GPMU should be from the GPMU. However, even within the Upper Basin, great care is being taken to reduce some of the risks of supplementation (see USE OF HATCHERY-ORIGIN PALLID STURGEON and BROOD SOURCE SELECTION FOR PRODUCTION sections 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, but incidental take associated with this activity is accounted for via 10(a)1(A) permits.

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 from the Missouri River above and below Fort Peck Dam (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 primary brood collection sites, nearly identical phenotypic characters, and comparable success of progeny stocked. 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 (*Platygobio gracilis*), 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 sturgeon 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 PSIV has been detected in pallid sturgeon propagated at several hatcheries and detected in wild sturgeon. 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. To prevent the spread of this and other diseases, disease testing will be completed on pallid sturgeon progeny prior to stocking. (see also: Fish Health section this document for specifics regarding collection of a valid sample from production facilities and subsequent histological and PCR 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 to and stocking within the GPMU.

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; 1) natural recruitment has not been documented within the GPMU, 2) data indicate that it has not occurred for many years, and 3) it may take many years to fully implement habitat restoration activities; stocking must continue to insure persistence of the pallid sturgeon within this management unit.

CLMU

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 Middle Missouri River. Following is a discussion of the benefits and risks associated with supplementation of pallid sturgeon in the CLMU.

BENEFITS

Reduction in the potential risk of extinction of local Populations

Length frequency data indicated that when stocking has occurred within the CLMU; those stocked fish are contributing to and improving population demographics. Without supplementation, the pallid sturgeon population in the Missouri River between Fort Randall and Gavins Point Dams likely will be extirpated before sufficient habitat restoration activities can be implemented to address the threats to this species. Recent work by Shuman et al. (2005) indicates that stocked GPMU hatchery-reared pallid sturgeon are surviving and growing (mean growth of age-6 and older fish was < 0.06 mm/d, mean growth for ages 2-4 was 0.238 mm/d, and the youngest year class (2004) grew 1.249 mm/d.) in this reach with all stocked year classes (1997-1999 and 2001 and 2002) being collected in their samples. For the remainder of the CLMU, the Missouri River below Gavins Point Dam to the Missouri and Grand rivers confluence, data are similar. Available length frequency data for collected pallid sturgeon indicate the majority to be adults (U.S. Fish and Wildlife Service 2007). The low numbers of naturally produced or unknown origin pallid sturgeon in smaller size classes coupled with higher relative abundances of hatchery origin pallid sturgeon and frequent captures of smaller size class shovelnose sturgeon suggests that the gears being used are effective and that natural recruitment of pallid sturgeon is sporadic or limited in portions of this management unit (Barada and Steffensen 2006, Kennedy et al. 2006, Steffensen and Barada 2006, Utrup et al. 2006). These data also indicate that hatchery stocked fish are being collected and contributing to the population.

<u>Maintenance of local population while habitat restoration efforts are implemented</u>
Miller and Kapuscinski (2003) identify addressing habitat quality and quantity as part of a comprehensive plan of which supplementation is only a part. Natural processes like sedimentation are improving habitat conditions between the Fort Randall to Gavins Point Dams reach of the CLMU. 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 Service 1993) will decline. Work in this reach indicates that it possesses necessary habitat and is suitable for pallid sturgeon supplementation efforts (Jordan et al. 2006).

In the remaining portions of the CLMU, habitat restoration efforts are also being implemented as described in the 2003 amendment to the Missouri River Biological opinion (U.S. Fish and Wildlife Service 2000). Activities include development of shallow water habitats between Sioux City and the Platte River. This was later extended upstream to Ponca State Park, Nebraska and downstream to the mouth of the Osage River, Missouri. Approximately 1,400 to 1,800 acres (566 to 728 hectares) of shallow water habitat was constructed in 2004 by notching dikes and constructing site-specific projects like dredging to connect back-water areas, and pilot channel construction (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service 2004). Chute restoration efforts appear to be providing some newly created habitats for pallid sturgeon. Adult pallid sturgeon have been collected in both Upper Hamburg Bend and Plattsmouth Chutes (K. Steffensen, NGPC, personal communication, 2005). In addition to increasing shallow water habitat in this reach, the Biological Opinion (US Fish and Wildlife Service 2000) identifies manipulation of flows from Gavins Point Dam, to stimulate a biological response from fishes as well as potentially create habitat, as an important reasonable and prudent alternative. To accomplish this, a spring rise was proposed of +17,500 cubic feet per second (total 49,500 cfs) one year out of three with an annual summer low flow of 21,000 cfs. It is believed that these releases will begin to provide the conditions that simulate the range of historic natural fluctuations of the Missouri River. Increased discharge in the spring followed by low discharge in the summer is hypothesized to provide missing cues suspected as one cause of little to no spawning/recruitment of pallid sturgeon in this reach. A minor spring rise was implemented from Gavins Point Dam in 2006. Currently, efforts are underway to develop a better understanding of important habitat features that may improve restoration project designs and substantially increase our limited database on sturgeon habitat use. Based on current and anticipated commitments for aquatic habitat restoration in the CLMU, the next several years should produce increased quantity and quality of potential sturgeon habitat.

Establish a reserve population for use if natural population suffers catastrophic loss.
Pallid sturgeon from the GPMU have been used to establish a founder population within the CLMU between Fort Randall and Gavins Point Dams, 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 the GPMU or at Gavins Point NFH. Additionally, incorporation of locally collected brood fish into propagation activities downstream from Gavins Point Dam can result in development of a cryopreservation repository for milt to assist with genetic preservation.

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 management unit 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 gene 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 reproduce with other stocks than would occur naturally. Genetic studies (Campton et al. 2000, Tranah et al. 2001, Heist and Schrey 2003, 2006a and 2006b) indicate that genetic structuring exists within the pallid sturgeon population. The majority of fish stocked into the CLMU have been of GPMU origin. These GPMU hatchery-reared pallid sturgeon are from parental stocks that are reproductively isolated and thus genetically discernable from stocks within downstream management units (Heist and Schrey

2006 a and b, Schrey 2007). Since there are no known barriers to limit dispersal of GPMU based progeny stocked downstream of Gavins Point Dam, there is potential for future outbreeding depression resulting from released GPMU fish crossing with CPMU or IHMU pallid sturgeon.

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 pallid sturgeon stocked between Fort Randall and Gavins Point Dams. Nearly 416 pallid sturgeon (1997 year class) were stocked in 2000. 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 this reach totaling 1,855 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 the Missouri River below Gavins Point Dam 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. 2006). There have also been numerous accounts of angler caught pallid sturgeon from the 2000 stocking and sampling efforts in Fort Randall to Gavins Point reach have detected pallid sturgeon from subsequent stockings (Great Plains FWMAO unpublished data).

Heist and Schrey 2006b, suggest that Middle Missouri River (CLMU) pallid sturgeon appear to be intermediate in genetic composition between GPMU and IHMU pallid sturgeon suggesting that historical genetic exchange occurred, to some degree, between GPMU and IHMU fish. This suggests that neighboring groups occasionally strayed. Based on limited movement data and the intermediate genetic nature of some CLMU pallid sturgeon, it is probable that historically the more downstream portions of the CLMU and/up stream portion of the IHMU may have been an area where straying occurred during spawning.

For these reasons, the best available brood source for artificial supplementation within the CLMU is local parental fishes collected from within the CLMU or fish that genetically assign to the CLMU. As indicated under the Maintaining Genetic Diversity-Minimizing Outbreeding Depression section, available, physically marked hatchery-reared pallid sturgeon from the GPMU can continue to be stocked between Fort Randall and Gavins Point dams. Collection data indicates that limited numbers of these GPMU origin fish will pass through Gavins Point Dam. Given the intermediate genetic assignment of the pallid sturgeon from the Middle Missouri River (Schrey 2007), the occasional emigrant from this reach should allow future genetic exchange to occur between GPMU and CLMU/IHMU fish. Without translocating these GMPU to the Fort Randall Reach of the CLMU, this exchange likely could not continue with the existing dam infrastructure. It should also be noted that this does not preclude stocking CLMU origin fish between Fort Randal and Gavins Point Dams.

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. Recent work by Shuman et al. (2005) indicates that hatchery-reared pallid sturgeon, released into the CLMU between Fort Randall and Gavins Point Dams, are growing (mean growth of age-6 and older fish was < 0.06 mm/d, mean growth for ages 2-4 was 0.238 mm/d, and the youngest year class (2004) grew 1.249 mm/d.) Conversely, in the CLMU below Gavins Point Dam, Kirk Steffensen (NGPC, personal communications, 2006) has indicated that hatchery-reared pallid sturge 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 PSIV has been detected in pallid sturgeon propagated at several hatcheries and detected in wild sturgeon. Members of the 1998 year class of pallid sturgeon stocked previously within the Fort Randall to Gavins Point Dam reach of the CLMU were later determined to potentially have had or been exposed to the iridovirus at Gavins Point NFH. Stocking activities in the CLMU below Gavins Point Dam has also included virus positive non-epizootic hatchery-reared pallid sturgeon. The impacts of stocking iridovirus 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 (see also: Fish Health section this document). Fish health certification and approval from South Dakota Game, Fish and Parks as well as Nebraska Game and Parks Commission, and the Missouri Department of Conservation will be required prior to any stocking in CLMU.

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 between Fort Randall and Gavins Point Dams have been collected and there is no evidence of an existing self-sustaining local population within this reach that may be negatively impacted by supplementation. Given the potential intermediate genetic nature of CLMU pallid sturgeon (Heist and Schrey 2006b, Schrey 2007, DeHaan et al. 2008) many genetic concerns associated with stocking can be mitigated for. Implementation of the guidelines described in this plan will help to maintain local populations while habitat restoration efforts are incorporated to restore natural spawning and recruitment and help to maintain historical gene flow patterns currently disrupted by reservoirs and dams on the Missouri River.

IHMU

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 lower Missouri River. Following is a discussion of the benefits and risks associated with supplementation of pallid sturgeon in the Interior Highlands Management Unit.

BENEFITS

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

Currently there may not be an immanent threat of extirpation in the IHMU. Demographic data of pallid sturgeon collected in the Missouri River portion of the IHMU 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, USFWS, personal communication 2005, DeHaan et al. 2007). The best pallid sturgeon population estimates for the Mississippi River portion of the IHMU is 1,600 to 4,900 pallid sturgeon (James Garvey, SIU, personal communication, 2006). From 2002 through 2005, the US Army corps of Engineers, Missouri Department of Conservation (MDC) and Southern Illinois University (SIU) conducted a joint pallid sturgeon research project in the Mississippi River portion of the IHMU using trawling, gillnets, and trotlines as the primary sampling gears. As part of this project a little over 64,000 hours of effort (combined for all gear types) was expended to catch 11,459 shovelnose sturgeon and a total of 148 pallid sturgeon. Of the 148 pallid sturgeon collected, 12 individuals (8%) were hatchery origin fish determined by the presence of coded wire tags. This 8% likely is under representing the total number of hatchery origin fish in this sampling effort as scanning for coded wire tags was not a standard practice until 2004 (Jim Garvey, SIU, personal communication 2006). These recaptured hatchery-reared pallid sturgeon are attributed to either the 1994 or 1997 stocking efforts conducted from Missouri's Blind Pony SFH. Survival of these fish to adulthood and the fact that they comprised a minimum of 8% of adult fish sampled suggests that these early stocking have contributed to the local population demographics. If reproduction is sporadic and threats to the species are not reduced, there is the potential for extirpation to occur in the future. One of the primary threats in the IHMU is illegal take of pallid sturgeon associated with commercial fishing activities. Artificial augmentation within the IHMU would be beneficial to maintain the species until adequate regulations or protection measures are implemented to address this threat.

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 notching dikes. 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 relies predominantly on shovelnose sturgeon as surrogates for pallid sturgeon because adequate numbers of pallid sturgeon have not been obtained. Supplementation with 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 indicating that feeding habits are different (Cross 1967, Held 1969, Carlson et al. 1985, Gerrity 2005) and the two species use different habitats within the river (Forbes and Richardson 1905, Carlson et al. 1985, Bramblett 1996). Thus supplementation with HRPS will ensure adequate numbers are available to evaluate the usefulness of habitat restoration projects.

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 management unit may prove useful in shedding some valuable insights on supplementation programs for other species as well as stabilize populations where recruitment may be limited.

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, Schrey 2007) indicate genetic structuring within the pallid sturgeon population range wide. The majority of fish stocked into the Missouri portion of the IHMU have been of GPMU origin. These hatchery-reared pallid sturgeon are from parental stocks that are reproductively isolated and genetically discernable from IHMU pallid sturgeon (Schrey 2007). As no barrier to movement of these hatchery fish into the IHMU exists, there is potential for outbreeding depression resulting from GPMU pallid sturgeon crossing with IHMU and CPMU pallid sturgeon. Outbreeding depression due to mixing of genetic populations has been recognized as a factor in fish conservation for over 50 years.

Movement data for pallid sturgeon suggests that they are a mobile species. Pallid sturgeon produced at Blind Pony SFH in 1994 and 1997 were stocked at three locations in the IHMU. These fish were progeny of pallid sturgeon collected from the CPMU (Mississippi River at Caruthersville, Missouri (RM 846). In the fall of 2006, one of these HRPS was collected in the CPMU below the Old River Control Complex on the Atchafalaya River (Jan Dean, USFWS, personal communication, 2006). This single recapture documents a downstream movement from the upper portion of the CPMU into the Atchafalaya portion of the CPMU ~610 river miles.

This single instance of dispersal may be significant if the Old River Control Complex is a unidirectional barrier to movement as some theorize because a reproductive aged IHMU or CLMU fish that becomes entrained in the Atchafalaya River will have no option to migrate upstream to spawn. Subsequently, this fish likely would spawn with CPMU pallid sturgeon. Given that there were significant F_{st} values between the Mississippi River portion of the IHMU and the Atchafalaya River portion of the CPMU (Heist and Schrey 2003 and 2006a) some level of genetic exchange likely could occur that may not have occurred frequently historically. The question then becomes to what extent is this occurring. Reported data for sampling efforts in the Atchafalaya River date back to 1991 and the only recorded IHMU fish was reported in 2006. This initially suggests that the frequency of occurrence is low. On the other hand, the fish released in the IHMU in 1994 and 1997 were marked with coded wire tags as well as external double t-bar tags. Crews initially working on the Atchafalaya River did not have the necessary equipment to scan all collected fish for coded wire tags and external tags can be lost. It is reasonable to assume that more upper portion CPMU fish, than the one reported in 2006, have been collected. On the other hand, the US Army Corps of Engineers ERDC biologists have been sampling pallid sturgeon in the Mississippi River portions of the IHMU and CPMU. Similar to the Atchafalaya River sampling crews, the US Army Corps of Engineers ERDC biologists did not regularly employ coded wire tag readers until 2004. Once these tag readers became standard practice in 2004, Killgore et al. (2007) indicated that between the fall of 2004 and the spring of 2005, 47% (7 of 15) of the pallid sturgeon sampled were hatchery stocked recaptures with a coded wire tag and the authors only report finding hatchery-reared pallid sturgeon (1994 and 1997 Blind Pony SFH fish) in the Mississippi River portion of the IHMU. So if there was substantial movement from the IHMU into the CPMU by these hatchery-reared fish one would expect some being collected in the CPMU by this sampling effort.

Hybridization

Supplementation with pallid sturgeon progeny will increase the number of pallid sturgeon in this management unit and is expected to subsequently increase the number of reproductive adults in the future. Given that there are currently relatively few adult pallid sturgeon in the Missouri River portion of the IHMU, increasing their numbers through supplementation could increase the likelihood of intercrossing with shovelnose sturgeon and thus increase the number of intercrossed or hybrid sturgeon. Artificially increasing hybrids is a threat, in that it likely would increase competition for resources between the intercrossed sturgeon and pallid sturgeon as well as contribute to genetic swamping. On the other hand, increasing the numbers of spawning adult pallid sturgeon could increase the probability that pure pallid sturgeon will find each other and mate.

Careful monitoring of pallid sturgeon, shovelnose sturgeon, and intercrosses will occur with the continued implementation of the Pallid Sturgeon Population Assessment Program (Drobish 2006) and additional genetic screening. Persistent monitoring and genetic screening within the Missouri River portion of the IHMU should quantify any increases in intercrosses relative to pallid and shovelnose sturgeon numbers. If indeed supplementation efforts are demonstrated to increase the number of intercrosses, future supplementation efforts within the Missouri River portion of the IHMU should be reevaluated.

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 the IHMU. Historical information is inadequate to determine population trends; however substantial effort has been expended during the past several years to collect pallid sturgeon in the Missouri River portion of this management unit with limited success. The gears being utilized are appropriate for sampling all size classes, yet relatively few wild or naturally produced pallid sturgeon are being found while capture of hatchery-reared 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 the Missouri River portion of the IHMU is warranted and necessary to supplement existing populations to improve population demographics and maintain some semblance of historical genetic structure until such times that habitat modifications are implemented and successful enough to allow the pallid sturgeon populations to maintain themselves. Secondary benefits include the presence of multiple size classes of pallid sturgeon to evaluate habitat improvement efforts implemented with in this RPMA. Field observations and preliminary age studies suggest that illegal commercial harvest of pallid sturgeon is occurring in the Mississippi River portion of the IHMU. 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.

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 the Lower Missouri River and the upper reaches of the Middle Mississippi River (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 within the IHMU will be considered as local parents for supplementation purposes into the Missouri River portion of the IHMU. Based on the work of Schrey (2007), the aforementioned movement data, and desires to maintain some semblance of recently identified genetic structuring, progeny from IHMU collected parents will be the first priority for supplementation. If these are not available, CPMU then CLMU progeny will be the next best options.

CPMU
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 into the CPMU (Figure 1)

BENEFITS
<u>Reduction in the potential risk of extinction of local populations</u>
Currently there may not be an immediate threat of extinction in the CPMU. Only 28 records of pallid sturgeon were recognized from the Mississippi River when the species was listed in1990 and the recovery plan was published in 1993 (U.S. Fish and Wildlife Service 1993). U. S. Army Corps of Engineers, ERDC, biologists sampled the CPMU from 2000 to 2006. During this time, 162 pallid sturgeon were collected from over 130 locations (i.e., location = specific river mile) between RM 145 to 954 (RKM 233 to 1535) (Jack Killgore, USACE, personal communication, 2005), with only three recaptures. There is also some evidence that reproduction and recruitment are occurring in the Mississippi River. Sizes of pallid sturgeon collected range between 400 and 1000 mm FL. This data set includes at least 30 "sub-adult" pallid sturgeon (i.e., < 600 mm) (Jack Killgore, USACE, personal communication, 2005) suggesting some level of recruitment in the CPMU. Additionally, a conservative total of 499 individual pallid sturgeon having been collected from the Atchafalaya River since 1991. A conservative approach to species identification was used, based upon morphometric measurements, to identify pallid versus intermediate or "hybrid" sturgeon, and thus actual number of pallid sturgeon captured from the Old River Control Complex is likely underrepresented in these data. There have been at least 37 wild adult pallid sturgeon recaptures in the ORCC area since 1991, of which 32 have been in the last three years, i.e. in FY 2004-2006 (Jan Dean, USFWS, personal communication, 2006). Without additional data and focused efforts to sample smaller sized fish, it is difficult to determine recruitment levels and artificial supplementation may not be prudent with out these additional supporting data.

<u>Maintenance of local population while habitat restoration efforts are implemented</u>
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 genetic groups (artificially elevated levels of migration) with one negative outcome being outbreeding depression. 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). 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 2003, 2006a and 2006b) 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 Gharrett 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 Missouri River portion of the IHMU have been of GPMU origin, which are genetically distinct from CPMU pallid sturgeon (Tranah et al. 2001, Heist and Schrey 2003, 2006a and 2006b, Schrey 2007). Since there is no barrier to prevent movement of GPMU origin hatchery fish into the CPMU, there is a potential for elevated genetic exchange to occur between GPMU and IHMU or CPMU groups.

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 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

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 portion of the IHMU as well as the CPMU. Historical information is inadequate to determine population trends. Current data are not collected in a fashion conducive to population trend analysis. 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 CPMU, suggesting that some recruitment likely has occurred post listing. 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.

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 CPMU. 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.

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 (2002), for a portion of the GPMU where most of the brood stock originates, wild pallid sturgeon will be available until about 2010 or 2016. At the end of this period the wild population will likely diminish to such a level that they will no longer be a reliable source for broodstock. Given this projected extirpation of wild fish, stocking practices have been tailored to maximize the contribution from wild fish while they are available. Broodstock collection efforts in the CLMU and IHMU are being implemented and this should increase the number of fish available for propagation in those management units.

Egg, fry, young-of-the-year fingerling, and yearling stockings have been considered and will be incorporated into this stocking strategy. Egg and fry stockings may be important given the potential for imprinting processes that may occur during these early life history stages. 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. However, imprinting has not yet been conclusively determined to occur in pallid sturgeon. Furthermore fry stocking has been demonstrated to produce yearling pallid sturgeon in the GPMU. 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 (Braaten 2004). During subsequent sampling efforts in 2005, 5 non-physically marked juvenile pallid sturgeon were collected. 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 potential benefits for stocking smaller fish (i.e., sub-yearlings) is to reduce hatchery habituation, artificial selection pressures, and reduce density dependent fish culture problems. On the other hand, there are data suggesting that stocking larger sized fish may also facilitate attainment of localized management objectives. There are insufficient data to determine which size classes are most effective at supporting current management objectives. Thus, where practical, it may be important to stock a variety of size classes to evaluate which ones are most effective. Stocking rates for eggs, fry, and sub-yearlings need to be evaluated and size specific survival rates must be an objective of the long term monitoring effort.

Target stocking computation methods -
Empirically derived survival rates have not been finalized for HRPS. Estimates in this plan are currently based on available data for other sturgeon stocking programs (Kincaid 1993 and Ireland et al. 2002). Efforts are being developed within the Upper and Middle basin workgroups to develop statistically valid annual survival rates for all size-classes of HRPS. Once developed, these pallid sturgeon-specific empirical data will be incorporated into this plan. In addition, stocking targets will be recalculated based on these survival rates and adjusted for any wild pallid sturgeon recruitment that is encountered during sampling.

GPMU: 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 (Ne) 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 Ne 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 estimated to be 1,000 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.

CLMU and IHMU: 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. Although, recent recaptures of hatchery propagated pallid sturgeon during targeted sampling of broodstock provide sufficient evidence for eliciting review of the existing computation. Survival rates for hatchery propagated white sturgeon have been published (Ireland et al. 2002) and were used as surrogate survival rates for pallid sturgeon estimates in the CLMU and IHMU (Appendix 6). When the middle basin pallid sturgeon workgroup convened in 2007, they recommended a target stocking rate of 40 yearling pallid sturgeon per river mile into the CLMU below Gavins point Dam. This recommendation is similar to those used to obtain lake sturgeon management targets (Wisconsin Department of Natural Resources 2000) and is more consistent with targets developed for the GPMU.

TOTAL STOCKING OBJECTIVES
An annual minimum stocking target of approximately 48,760 yearling pallid sturgeon or yearling equivalents is the objective outlined in this stocking plan for the three Missouri River management units (Figure 1) in need of supplementation (Appendix 1 – 4).

It is anticipated that there will be years when pallid sturgeon production will not meet stocking objectives for each management unit. In those years when stocking targets exceed 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. GPMU derived HRPS will be utilized for stocking back into the GPMU and the CLMU above Gavins Point Dam. CLMU or IHMU derived pallid sturgeon will be prioritized for supplementation into the CLMU and IHMU respectively. Given the past difficulty to obtain local parental stocks from the CLMU, Lake Sharpe collected brood fish should be considered local brood for the CLMU (Schrey and Heist 2007), unless new genetic data dictates otherwise.

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. This will help insure that long-term adult targets 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 brood fish are available and monitoring indicates no deleterious effects to the founder population or until natural reproduction or recruitment are sufficient for the population to maintain itself. The minimum number of fish needed annually has been estimated for each management unit (Appendixes 1 – 4), and was 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 management unit. The estimated survival rates and target numbers will be recalculated as more precise information becomes available from population assessment efforts (e.g., Drobish 2006).

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 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. The preferred stocking periods will likely occur between April and September but vary by management units 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 the risk of 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 hatchery-reared pallid sturgeon will be accounted for according to their size and time of stocking with the following ratios:

- Fry (< 1 inches fork length) will count against the total number of hatchery-reared pallid sturgeon as follows: 0.024% stocked fry for any management unit will be counted as one yearling as their estimated over-winter survival is expected to be extremely low (<1%). The value of 0.028% was determined simply by dividing the number of pallid sturgeon recaptured (n=7) and found genetically to originate from the larval drift study in 2004 (Braaten 2004, Pat Braaten, US Geological Survey, personal communication, 2007) by the number of 17-day-old pallid larvae released in that study (25,000). 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.

- Fingerlings (1 - 4 inches fork length) will count against the total number of hatchery-reared pallid sturgeon as follows: four stocked fingerlings will be counted as one yearling (4:1 ratio) based on an estimated over-winter survival rate of 25%. These are typically fingerlings stocked in June-September of the year they are spawned;

- Advanced fingerlings (> 4 inches fork length) will count against the total number of hatchery-reared pallid sturgeon as follows: two stocked fingerlings will be counted as one yearling (2:1 ratio) based on an estimated over-winter survival rate of 50%. These are typically fingerlings stocked after September but before January 1 of the year they are spawned;

- Since the age class of yearling is the class that stocking rates are calculated from, advanced fingerlings stocked as yearlings will be counted on 1:1 ratio, assuming that there is no significant mortality difference between spring-released and summer-released yearlings.

- Hatchery-reared pallid sturgeon stocked at age-2 or greater will count against a management unit'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 hatchery-reared pallid sturgeon stocked into the GPMU will be counted on a 0.7:1 ratio and age-3 hatchery-reared pallid sturgeon will be counted on a 0.8:1 ratio, and age-2 hatchery-reared pallid sturgeon stocked into CLMU or IHMU will be counted on a 0.9:1 ratio and age-3 hatchery-reared pallid sturgeon will be counted on a 0.9:1 ratio.

<u>GPMU:</u>
<u>Upstream of Fort Peck Reservoir headwaters</u> - The estimated minimum population objective 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 (Appendix 1). The primary stocking sites 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.

<u>Downstream of Fort Peck Dam to headwaters of Lake Sakakawea and Yellowstone River</u> - The estimated minimum population objective 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). Juvenile Pallid sturgeon will be evenly divided (50:50) between the Missouri and Yellowstone rivers. Identified stocking locations include: 1) Cartersville Diversion Dam; 2) confluence of the Yellowstone and Tongue rivers; 3) Fallon Bridge; 4) Intake Diversion Dam; 5) Sidney boat ramp area; 6) the Culbertson area; 7) the Brockton area; 8) the Poplar area; 9) the Wolf Point area; and10) the Milk River/School Trust area. Yearling stocking should occur July through September. Yearling equivalents will be stocked as requested by managers.

CLMU and IHMU:

Missouri River between Fort Randall and Gavins Point Dams - The estimated population objective 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 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.

Missouri River below Gavins Point Dam - The estimated population objective is 30,000 spawning age adult (greater than or equal to 15 years of age) pallid sturgeon. Achievement of this goal will result in a density of about 36 sexually mature pallid sturgeon per RM of riverine habitat. Attainment of this goal will be met by annually stocking 33,560 yearling pallid sturgeon, or yearling equivalents, for the next 8 years (Appendix 4). The stocking locations 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).

CPMU:

Not recommended to stock at this time.

Alternatives to stocking and augmentation:

GPMU: Based on extensive sampling and knowledge of these populations, stocking and augmentation of pallid sturgeon populations are required to prevent local extirpation of pallid sturgeon from this management unit. There are no alternatives.

CLMU: Based on extensive sampling and knowledge of these populations, stocking and augmentation of pallid sturgeon populations are required to prevent local extirpation of pallid sturgeon from this management unit. There are no alternatives.

IHMU: Based on sampling and knowledge of these populations, stocking and augmentation of pallid sturgeon populations appears warranted to assist with maintaining the population while threats are being addressed.

Alternative 1: Protect pallid sturgeon within the IHMU from illegal take or take incidental to commercial harvest of shovelnose sturgeon. There is evidence that mortality of pallid sturgeon is occurring 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 the IHMU. Additional information would facilitate stocking and augmentation decisions.

CPMU: Field data are insufficient to support stocking in this management unit. However, there is evidence that mortality of pallid sturgeon is occurring due to illegal or incidental take by commercial harvest in the upper portions of the CPMU. The effects of this harvest has not been quantified in terms of reproductive success and needs further evaluation. Thus, 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 to best evaluate if stocking is necessary or not.

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Appendix 1.

Theoretical abundance table for hatchery-reared pallid sturgeon (HRPS) stocked into the GPMU above Fort Peck Dam 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 1998-2006 are presented, while the numbers of HRPS stocked during 2007-2015 are estimates. Juvenile pallid survival rates were based on a modified version of a white sturgeon stocking plan (Kincaid 1993). (Note: Where applicable all stockings have been adjusted to yearling stocking equivalents as defined in this plan. These numbers do not reflect actual numbers or size classes.)

			Year Stocked																		
Age	S	Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Adults
1-2	0.6	1998	690	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
2-3	0.7	1999	414	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3-4	0.8	2000	290	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
4-5	0.7	2001	232	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
5-6	0.6	2002	162	0	0	0	2058	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6-7	0.8	2003	97	0	0	0	1235	0	-	-	-	-	-	-	-	-	-	-	-	-	0
7-8	0.9	2004	78	0	0	0	864	0	3563	-	-	-	-	-	-	-	-	-	-	-	0
8-9	0.9	2005	70	0	0	0	691	0	2138	1556	-	-	-	-	-	-	-	-	-	-	0
9-10	0.9	2006	63	0	0	0	484	0	1496	934	3375	-	-	-	-	-	-	-	-	-	0
10-11	0.9	2007	57	0	0	0	290	0	1197	654	2025	16087	-	-	-	-	-	-	-	-	0
11-12	0.9	2008	51	0	0	0	232	0	838	523	1418	9652	5600	-	-	-	-	-	-	-	0
12-13	0.9	2009	46	0	0	0	209	0	503	366	1134	6757	3360	5600	-	-	-	-	-	-	0
13-14	0.9	2010	41	0	0	0	188	0	402	220	794	5405	2352	3360	5600	-	-	-	-	-	0
14-15	0.9	2011	37	0	0	0	169	0	362	176	476	3784	1882	2352	3360	5600	-	-	-	-	0
15-16	0.9	2012	34	0	0	0	152	0	326	158	381	2270	1317	1882	2352	3360	5600	-	-	-	34
16-17	0.9	2013	30	0	0	0	137	0	293	142	343	1816	790	1317	1882	2352	3360	5600	-	-	30
17-18	0.9	2014	27	0	0	0	123	0	264	128	309	1635	632	790	1317	1882	2352	3360	5600	-	27
18-19	0.9	2015	24	0	0	0	111	0	238	115	278	1471	569	632	790	1317	1882	2352	3360	5600	24
19-20	0.9	2016	22	0	0	0	100	0	214	104	250	1324	512	569	632	790	1317	1882	2352	3360	122
20-21	0.9	2017	20	0	0	0	90	0	192	93	225	1192	461	512	569	632	790	1317	1882	2352	110
21-22	0.9	2018	18	0	0	0	81	0	173	84	202	1072	415	461	512	569	632	790	1317	1882	272
22-23	0.9	2019	16	0	0	0	73	0	156	76	182	965	373	415	461	512	569	632	790	1317	320
23-24	0.9	2020	14	0	0	0	66	0	140	68	164	869	336	373	415	461	512	569	632	790	452
24-25	0.9	2021	13	0	0	0	59	0	126	61	148	782	302	336	373	415	461	512	569	632	1189
25-26	0.9	2022	12	0	0	0	53	0	114	55	133	704	272	302	336	373	415	461	512	569	1342
26-27	0.9	2023	11	0	0	0	48	0	102	50	120	633	245	272	302	336	373	415	461	512	1480
27-28	0.9	2024	9	0	0	0	43	0	92	45	108	570	220	245	272	302	336	373	415	461	1604
28-29	0.9	2025	9	0	0	0	39	0	83	40	97	513	198	220	245	272	302	336	373	415	1716
29-30	0.9	2026	8	0	0	0	35	0	75	36	87	462	179	198	220	245	272	302	336	373	1817
30-31	0.9	2027	7	0	0	0	31	0	67	33	78	415	161	179	198	220	245	272	302	336	1907
31-32	0.9	2028	6	0	0	0	28	0	60	29	71	374	145	161	179	198	220	245	272	302	1988
32-33	0.9	2029	6	0	0	0	25	0	54	26	64	337	130	145	161	179	198	220	245	272	2062
33-34	0.9	2030	5	0	0	0	23	0	49	24	57	303	117	130	145	161	179	198	220	245	1856
34-35	0.9	2031	5	0	0	0	21	0	44	21	51	273	105	117	130	145	161	179	198	220	1670

Appendix 2. Theoretical abundance table for hatchery-reared pallid sturgeon (HRPS) stocked into the GPMU below Fort Peck Dam 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 hatchery-reared pallid sturgeon stocked during 1998-2004 are presented, while the numbers of HRPS stocked during 2007-2015 are estimates. Juvenile pallid survival rates were based on a modified version of a white sturgeon stocking plan (Kincaid 1993). (Note: Where applicable all stockings have been adjusted to yearling stocking equivalents as defined in this plan. These numbers do not reflect actual numbers or size classes.)

			Year Stocked																			
Age	S	Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2014	2015	Adults
1-2	0.6	1998	780	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
2-3	0.7	1999	468	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3-4	0.8	2000	328	0	764	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
4-5	0.7	2001	262	0	458	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
5-6	0.6	2002	183	0	321	0	3061	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6-7	0.8	2003	110	0	257	0	1837	3986	-	-	-	-	-	-	-	-	-	-	-	-	-	0
7-8	0.9	2004	88	0	180	0	1286	2392	6700	-	-	-	-	-	-	-	-	-	-	-	-	0
8-9	0.9	2005	79	0	108	0	1028	1674	4020	3751	-	-	-	-	-	-	-	-	-	-	-	0
9-10	0.9	2006	71	0	86	0	720	1339	2814	2251	10826	-	-	-	-	-	-	-	-	-	-	0
10-11	0.9	2007	64	0	78	0	432	938	2251	1575	6496	19195	-	-	-	-	-	-	-	-	-	0
11-12	0.9	2008	58	0	70	0	346	563	1576	1260	4547	11517	9000	-	-	-	-	-	-	-	-	0
12-13	0.9	2009	52	0	63	0	311	450	946	882	3638	8062	5400	9000	-	-	-	-	-	-	-	0
13-14	0.9	2010	47	0	57	0	280	405	756	529	2546	6450	3780	5400	9000	-	-	-	-	-	-	0
14-15	0.9	2011	42	0	51	0	252	365	681	423	1528	4515	3024	3780	5400	9000	-	-	-	-	-	0
15-16	0.9	2012	38	0	46	0	227	328	613	381	1222	2709	2117	3024	3780	5400	9000	-	-	-	-	38
16-17	0.9	2013	34	0	41	0	204	295	551	343	1100	2167	1270	2117	3024	3780	5400	9000	-	-	-	34
17-18	0.9	2014	31	0	37	0	184	266	496	309	990	1950	1016	1270	2117	3024	3780	5400	9000	-	-	68
18-19	0.9	2015	28	0	33	0	165	239	447	278	891	1755	914	1016	1270	2117	3024	3780	5400	9000	-	61
19-20	0.9	2016	25	0	30	0	149	215	402	250	802	1580	823	914	1016	1270	2117	3024	3780	5400	9000	204
20-21	0.9	2017	22	0	27	0	134	194	362	225	722	1422	741	823	914	1016	1270	2117	3024	3780	5400	377
21-22	0.9	2018	20	0	24	0	120	174	326	203	650	1280	667	741	823	914	1016	1270	2117	3024	3780	665
22-23	0.9	2019	18	0	22	0	108	157	293	182	585	1152	600	667	741	823	914	1016	1270	2117	3024	781
23-24	0.9	2020	16	0	20	0	98	141	264	164	526	1036	540	600	667	741	823	914	1016	1270	2117	1229
24-25	0.9	2021	15	0	18	0	88	127	237	148	474	933	486	540	600	667	741	823	914	1016	1270	2039
25-26	0.9	2022	13	0	16	0	79	114	214	133	426	840	437	486	540	600	667	741	823	914	1016	2272
26-27	0.9	2023	12	0	14	0	71	103	192	120	384	756	394	437	486	540	600	667	741	823	914	2482
27-28	0.9	2024	11	0	13	0	64	93	173	108	345	680	354	394	437	486	540	600	667	741	823	2672
28-29	0.9	2025	10	0	12	0	58	83	156	97	311	612	319	354	394	437	486	540	600	667	741	2842
29-30	0.9	2026	9	0	10	0	52	75	140	87	280	551	287	319	354	394	437	486	540	600	667	2995
30-31	0.9	2027	8	0	9	0	47	68	126	78	252	496	258	287	319	354	394	437	486	540	600	3133
31-32	0.9	2028	7	0	8	0	42	61	114	71	226	446	232	258	287	319	354	394	437	486	540	3257
32-33	0.9	2029	6	0	8	0	38	55	102	64	204	402	209	232	258	287	319	354	394	437	486	3369
33-34	0.9	2030	6	0	7	0	34	49	92	57	183	361	188	209	232	258	287	319	354	394	437	3469
34-35	0.9	2031	5	0	6	0	31	44	83	51	165	325	169	188	209	232	258	287	319	354	394	3122
35-36	0.9	2032	5	0	6	0	28	40	74	46	149	293	153	169	188	209	232	258	287	319	354	2810

Appendix 3. Theoretical abundance table for hatchery-reared pallid sturgeon (HRPS) stocked into the Fort Randall to Gavins Point Dam reach of the CLMU 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 hatchery-reared pallid sturgeon in the population table that are ≥ 15 years old. (Note: Where applicable all stockings have been adjusted to yearling stocking equivalents as defined in this plan. These numbers do not reflect actual numbers or size classes.)

			Year Stocked																		
Age	S	Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Adults
1-2	0.6	1998	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
2-3	0.7	1999	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3-4	0.8	2000	0	0	571	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
4-5	0.7	2001	0	0	343	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
5-6	0.6	2002	0	0	240	0	759	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6-7	0.8	2003	0	0	192	0	455	601	-	-	-	-	-	-	-	-	-	-	-	-	0
7-8	0.9	2004	0	0	134	0	319	361	515	-	-	-	-	-	-	-	-	-	-	-	0
8-9	0.9	2005	0	0	81	0	255	252	309	868	-	-	-	-	-	-	-	-	-	-	0
9-10	0.9	2006	0	0	64	0	179	202	216	521	1005	-	-	-	-	-	-	-	-	-	0
10-11	0.9	2007	0	0	58	0	107	141	173	365	603	1200	-	-	-	-	-	-	-	-	0
11-12	0.9	2008	0	0	52	0	86	85	121	292	422	720	600	-	-	-	-	-	-	-	0
12-13	0.9	2009	0	0	47	0	77	68	73	204	338	504	360	600	-	-	-	-	-	-	0
13-14	0.9	2010	0	0	42	0	69	61	58	122	236	403	252	360	600	-	-	-	-	-	0
14-15	0.9	2011	0	0	38	0	62	55	52	98	142	282	202	252	360	600	-	-	-	-	0
15-16	0.9	2012	0	0	34	0	56	49	47	88	113	169	141	202	252	360	600	-	-	-	0
16-17	0.9	2013	0	0	31	0	51	45	42	79	102	135	85	141	202	252	360	600	-	-	0
17-18	0.9	2014	0	0	28	0	46	40	38	71	92	122	68	85	141	202	252	360	600	-	28
18-19	0.9	2015	0	0	25	0	41	36	34	64	83	110	61	68	85	141	202	252	360	600	25
19-20	0.9	2016	0	0	22	0	37	32	31	58	74	99	55	61	68	85	141	202	252	360	59
20-21	0.9	2017	0	0	20	0	33	29	28	52	67	89	49	55	61	68	85	141	202	252	83
21-22	0.9	2018	0	0	18	0	30	26	25	47	60	80	44	49	55	61	68	85	141	202	99
22-23	0.9	2019	0	0	16	0	27	24	23	42	54	72	40	44	49	55	61	68	85	141	132
23-24	0.9	2020	0	0	15	0	24	21	20	38	49	65	36	40	44	49	55	61	68	85	167
24-25	0.9	2021	0	0	13	0	22	19	18	34	44	58	32	36	40	44	49	55	61	68	209
25-26	0.9	2022	0	0	12	0	20	17	16	31	40	52	29	32	36	40	44	49	55	61	217
26-27	0.9	2023	0	0	11	0	18	16	15	28	36	47	26	29	32	36	40	44	49	55	225
27-28	0.9	2024	0	0	10	0	16	14	13	25	32	43	24	26	29	32	36	40	44	49	231
28-29	0.9	2025	0	0	9	0	14	13	12	22	29	38	21	24	26	29	32	36	40	44	237
29-30	0.9	2026	0	0	8	0	13	11	11	20	26	34	19	21	24	26	29	32	36	40	243
30-31	0.9	2027	0	0	7	0	12	10	10	18	23	31	17	19	21	24	26	29	32	36	248
31-32	0.9	2028	0	0	6	0	10	9	9	16	21	28	15	17	19	21	24	26	29	32	252
32-33	0.9	2029	0	0	6	0	9	8	8	15	19	25	14	15	17	19	21	24	26	29	256
33-34	0.9	2030	0	0	5	0	8	7	7	13	17	23	13	14	15	17	19	21	24	26	230
34-35	0.9	2031	0	0	5	0	8	7	6	12	15	20	11	13	14	15	17	19	21	24	207

Appendix 4. Theoretical abundance table for hatchery-reared pallid sturgeon stocked (HRPS) into the CLMU below Gavins Point Dam and IHMU 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. (Note: Where applicable all stockings have been adjusted to yearling stocking equivalents as defined in this plan. These numbers do not reflect actual numbers or size classes.)

			Year Stocked																						
Age	S	Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Adults
1-2	0.6	1994	2702	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
2-3	0.9	1995	1621	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3-4	0.9	1996	1459	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
4-5	0.9	1997	1313	0	0	504	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
5-6	0.9	1998	1182	0	0	302	93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6-7	0.9	1999	1064	0	0	272	56	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
7-8	0.9	2000	957	0	0	245	50	10	571	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
8-9	0.9	2001	862	0	0	220	45	9	343	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
9-10	0.9	2002	775	0	0	198	41	8	308	0	8084	-	-	-	-	-	-	-	-	-	-	-	-	-	0
10-11	0.9	2003	698	0	0	179	37	7	278	0	4850	10569	-	-	-	-	-	-	-	-	-	-	-	-	0
11-12	0.9	2004	628	0	0	161	33	7	250	0	4365	6341	12401	-	-	-	-	-	-	-	-	-	-	-	0
12-13	0.9	2005	565	0	0	145	30	6	225	0	3929	5707	7441	8534	-	-	-	-	-	-	-	-	-	-	0
13-14	0.9	2006	509	0	0	130	27	5	202	0	3536	5137	4464	5120	3671	-	-	-	-	-	-	-	-	-	0
14-15	0.9	2007	458	0	0	117	24	5	182	0	3182	4623	4018	4608	2203	3122	-	-	-	-	-	-	-	-	0
15-16	0.9	2008	412	0	0	105	22	4	164	0	2864	4161	3616	4148	1982	1873	33560	-	-	-	-	-	-	-	412
16-17	0.9	2009	371	0	0	95	19	4	147	0	2578	3745	3255	3733	1784	1686	20136	33560	-	-	-	-	-	-	371
17-18	0.9	2010	334	0	0	85	18	4	133	0	2320	3370	2929	3359	1606	1517	18122	20136	33560	-	-	-	-	-	334
18-19	0.9	2011	300	0	0	77	16	3	119	0	2088	3033	2636	3024	1445	1366	16310	18122	20136	33560	-	-	-	-	377
19-20	0.9	2012	270	0	0	69	14	3	108	0	1879	2730	2373	2721	1301	1229	14679	16310	18122	20136	33560	-	-	-	354
20-21	0.9	2013	243	0	0	62	13	3	97	0	1691	2457	2135	2449	1171	1106	13211	14679	16310	18122	20136	33560	-	-	321
21-22	0.9	2014	219	0	0	56	11	2	87	0	1522	2211	1922	2204	1053	995	11890	13211	14679	16310	18122	20136	33560	-	376
22-23	0.9	2015	197	0	0	50	10	2	78	0	1370	1990	1730	1984	948	896	10701	11890	13211	14679	16310	18122	20136	33560	338
23-24	0.9	2016	177	0	0	45	9	2	71	0	1233	1791	1557	1785	853	806	9631	10701	11890	13211	14679	16310	18122	20136	1537
24-25	0.9	2017	160	0	0	41	8	2	63	0	1110	1612	1401	1607	768	726	8668	9631	10701	11890	13211	14679	16310	18122	2996
25-26	0.9	2018	144	0	0	37	8	2	57	0	999	1451	1261	1446	691	653	7801	8668	9631	10701	11890	13211	14679	16310	3957
26-27	0.9	2019	129	0	0	33	7	1	51	0	899	1306	1135	1302	622	588	7021	7801	8668	9631	10701	11890	13211	14679	4863
27-28	0.9	2020	116	0	0	30	6	1	46	0	809	1175	1021	1171	560	529	6319	7021	7801	8668	9631	10701	11890	13211	4936
28-29	0.9	2021	105	0	0	27	5	1	42	0	728	1058	919	1054	504	476	5687	6319	7021	7801	8668	9631	10701	11890	4919
29-30	0.9	2022	94	0	0	24	5	1	37	0	655	952	827	949	453	429	5118	5687	6319	7021	7801	8668	9631	10701	9545
30-31	0.9	2023	85	0	0	22	4	1	34	0	590	857	745	854	408	386	4606	5118	5687	6319	7021	7801	8668	9631	13709
31-32	0.9	2024	76	0	0	20	4	1	30	0	531	771	670	769	367	347	4146	4606	5118	5687	6319	7021	7801	8668	17456
32-33	0.9	2025	69	0	0	18	4	1	27	0	478	694	603	692	331	312	3731	4146	4606	5118	5687	6319	7021	7801	20829
33-34	0.9	2026	62	0	0	16	3	1	25	0	430	624	543	623	298	281	3358	3731	4146	4606	5118	5687	6319	7021	23864
34-35	0.9	2027	56	0	0	14	3	1	22	0	387	562	488	560	268	253	3022	3358	3731	4146	4606	5118	5687	6319	26596
35-36	0.9	2028	50	0	0	13	3	1	20	0	348	506	440	504	241	228	2720	3022	3358	3731	4146	4606	5118	5687	29055
36-37	0.9	2029	45	0	0	12	2	0	18	0	313	455	396	454	217	205	2448	2720	3022	3358	3731	4146	4606	5118	31268
37-38	0.9	2030	41	0	0	10	2	0	16	0	282	410	356	408	195	184	2203	2448	2720	3022	3358	3731	4146	4606	28141
38-39	0.9	2031	37	0	0	9	2	0	15	0	254	369	320	368	176	166	1983	2203	2448	2720	3022	3358	3731	4146	25327

Table 5. Survival schedule for hatchery-reared pallid sturgeon (HRPS) stocked into the GPMU, 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 hatchery-reared pallid sturgeon (HRPS) stocked into CLMU and upper reaches of the IHMU, 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