United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Biological Resources Division

Columbia Environmental Research Center
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November 15, 2007

To: Craig Fleming, U.S. Army Corps of Engineers
From: Carl Korschgen, Branch Chief for River Studies

Subject: U.S. Geological Survey FY 2008 Scope of Work

We are providing a final FY 2008 Scope of Work and a request for an additional budget allocation of $1,010,000. In total, the budget will support field work to support evaluation of the biological response of pallid sturgeon to the March spring rise and analysis, integration, and report/publication preparation for each research task funded in previous years.

The following table provides a budget overview for FY2008. In September, 2007 CERC received a MIPR from the Kansas City District for $2,000,000 of the projected $3,010,000 allocated to research (not including the funds that you provided our South Dakota and Nebraska partners for research support).

	Net	USGS Assessment	Gross
Task 1	1,156,274.33	523,725.67	1,680,000.00
Task 2	137,651.71	62,348.29	200,000.00
Task 3	334,493.65	151,506.35	486,000.00
Task 4	275,303.41	124,696.59	400,000.00
Task 6	167,935.08	76,064.92	244,000.00
TOTAL	2,071,658.17	938,341.83	3,010,000.00

We request an additional $1,010,000 as shown in the second table. Task descriptions are provided below.

	Net	USGS Assessment	Gross
Task 1	387,985.74	175,735.19	563,720.93
Task 2	46,188.78	20,920.86	67,109.63
Task 3	112,238.73	50,837.68	163,076.41
Task 4	92,377.56	41,841.71	134,219.27
Task 6	56,350.31	25,523.45	81,873.75
TOTAL	695,141.11	314,858.89	1,010,000.00

USGS appreciates the support provided by the U. S. Army Corps of Engineers and we look forward to a productive program in FY 2008.

Carl Korschgen
Branch Chief for River Studies

United States Geological Survey
Columbia Environmental Research Center
November 15, 2007

SCOPE OF WORK

Factors Affecting the Reproduction, Recruitment, Habitat, and Population Dynamics of Pallid Sturgeon and Shovelnose Sturgeon in the Missouri River

This scope of work is part of the Comprehensive Sturgeon Research Program (CSRP); a multi-year research framework developed to support pallid sturgeon recovery, and to evaluate and guide proposed management actions undertaken on the Missouri River to benefit the species. Conservation and restoration of pallid sturgeon requires knowledge of the biology of the species, and the factors limiting recovery.

The general CSRP strategy is to integrate field and laboratory studies of sturgeon reproductive ecology, habitat requirements, and physiology to produce a predictive understanding of sturgeon population dynamics (see, for example, Wildhaber and others, 2007). The tasks presented in this scope of work address the integrated study by specific disciplines. The tasks are coordinated with each other, and with other sturgeon studies being conducted on the Missouri River (population assessment and habitat monitoring), to optimize information needed for management decisions. With available resources, CSRP has focused to date on spawning as a probable bottleneck in reproduction and survival of the pallid sturgeon (Quist and others, 2004; Bajer and Wildhaber, 2007). During 2005-2007 we have emphasized:

- Development and deployment of telemetry systems to document movement and behavior of reproductive shovelnose and pallid sturgeon;
- Development of methods and understanding of how environmental cues affect reproductive physiology of sturgeon;
- Development of methods and understanding of early life history of sturgeon, including egg deposition and drift of larvae;
- Development of methods and deployment of habitat assessment systems to address physical habitat constraints on reproduction and survival;
- Integration of understanding in database development and population dynamics models.

In concept, the field portion of the CSRP study design includes a comparison between upstream and downstream reaches of the Lower Missouri River, to provide a means to isolate effects of hydrologic variability on reproductive success. This study design accommodates intentional flow releases (pulsed spring flows) downstream of Gavins Point Dam as controlled experiments, as well as using existing flow variability downstream of Kansas City to assess sturgeon responses.

The proposed 2008 CSRP effort will continue the general approach, although with decreased scope due to a lower funding level. In 2008 we will concentrate the tracking effort on reproductive pallid sturgeon (to the extent they are available) in upstream and downstream reaches, supported by habitat and physiological assessments. Major effort in 2008 will be directed at analyzing, writing, and publishing results from previous years so peer-reviewed scientific information will be available in the public domain to inform management decisions.

Task Descriptions

Task 1. Movement, habitat use and reproductive behavior of shovelnose sturgeon and pallid sturgeon in the Lower Missouri River

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- Wyatt Doyle, Branch Chief (Missouri River Operations), US Fish & Wildlife Service - Columbia FRO, Columbia, MO 65203

Background: Numerous studies have examined habitat use and movement by *Scaphirhynchus* sturgeon (Hurley and others, 1987; Latka and others, 1995; Quist and others, 1999; DeLonay and others, 2000; Bramblett and White, 2001; Snook and Peters, 2002; Hurley and others, 2004). Few of these studies have reported the reproductive status of the fish studied or followed individuals to assess whether those in reproductive condition spawned successfully. Until very recently none have specifically focused on reproductively mature fish prior to and during the spawning season. As a result, there is little information available to indicate precisely where, when and under what conditions shovelnose sturgeon and pallid sturgeon spawn. The USGS has developed and tested methodology and technology to track sturgeon during the spring spawning migration and to document changes in reproductive status and reproductive success. A pilot

study examining telemetry and remote-sensing technology, in combination with sturgeon reproductive assessment methodology was conducted in 2004. In March 2004, thirty gravid, adult female shovelnose sturgeon (*Scaphirhynchus platorynchus*) were collected from the lower Missouri River. Captured sturgeon were instrumented with ultrasonic transmitters and archival data storage devices (DST's). Instrumented sturgeon were tracked through the spawning period. Results indicate that upstream migratory movement of shovelnose sturgeon may be rapid (often > 8 km/d) and cover long distances (> 300 km). Fish recaptured following the spawning period indicated that fish implanted with transmitters and DST devices do successfully spawn. Analysis of depth data recorded by DST devices also suggests a characteristics pattern of behavior that may indicate spawning time.

In anticipation of potential flow management actions (pulsed spring flows), this work was expanded in 2005 and 2006. In March and April, 2005 and 2006, two groups of 50 female shovelnose sturgeon from each of two hydrologically distinct segments of the Missouri River were captured and implanted with transmitters and DST devices. Each river segment was expected to exhibit distinctive differences in availability of habitat and environmental variables prior to and through out the sturgeon spawning season. The lower segment was located on the lower Missouri River between the Osage River and Grand River (river miles 130-250). The upper segment was located between the Platte River in Nebraska and the Big Sioux River in Iowa (river miles 595-734). Fish were tracked through the spawning period. Habitat use and movement data were collected. Habitats used by sturgeon during the pre-spawn, spawn, and post-spawn periods were mapped and characterized. Attempts were made to recapture sturgeon and recover implanted DST devices. A limited number of pallid sturgeon were also captured and implanted with transmitters, although none were in reproductive condition.

Comparable studies using a small number reproductive pallid sturgeon (2 females and 3 males) and a large number of shovelnose sturgeon (≤ 200) were planned for 2007 in both the upper and lower study segments. The pallid sturgeon were to be intensively tracked and the shovelnose sturgeon to be tracked less intensively over an extensive area. However due to budgetary constraints and time limitations in 2007, a shift in geographic emphasis and focus was necessary. The proposed lower segment activities were initially eliminated and the resources were transferred to an expanded upper river segment. The upper river segment was shifted upstream and was divided into two reaches or sub-segments to reflect the distinct hydrologic and physical characteristics of the roughly 180 miles below Gavins Point Dam. The dividing point between the two upper study segment reaches was the Big Sioux River (RM 734). The study reach below the Big Sioux River is physically highly modified, and narrowly channelized. The reach above the Big Sioux River contains elements of the natural physical morphology of the historic Missouri River, but has a hydrograph dominated almost completely by the releases out of Gavins Point Dam. This shift in geographic scope and increased intensity of effort was meant to result in definitive results for shovelnose sturgeon and a higher probability of meaningful results for pallid sturgeon because of the greater numbers of fish and higher resolution data. Efforts in 2007 included a total of 176 shovelnose sturgeon divided between both of the upper study sub-segments; including 100 gravid females, 25 reproductive males, and 51 non-reproductive sturgeon. The study also included 2 gravid female pallid sturgeon and 3 reproductive males all captured in the lower sub-segment. Both pallid sturgeon females were intensively tracked during the spawning season. Both were subsequently recaptured and determined to have spawned. Greater than 59% of implanted shovelnose sturgeon (n=104) were also recaptured, their reproductive success evaluated and the implanted DST tags recovered. This study was the first to record and verify spawning by tagged adult pallid sturgeon anywhere

within its range. Results suggest that pallid sturgeon spawn at multiple locations over an extended period of time. Spawning occurred without pulsed flows out of Gavins Point Dam. Results observed with pallid sturgeon are consistent with observations of shovelnose sturgeon indicating that both species may have similar reproductive strategies.

Research in 2008 will build on work conducted in 2006 and 2007 with pallid and shovelnose sturgeon. Efforts in 2008 will initially focus only adult pallid sturgeon, with an intensification of manual tracking efforts and the opportunistic addition of stationary receivers at select sites within the study reaches. Deployment of automated receivers will occur if conditions allow and if sufficient numbers of sturgeon can be captured expeditiously. In collaboration and partnership with Nebraska Game and Parks Commission comparable efforts will occur in both the upper (RM 595-734) and lower study segment (RM 130-250). Crews in both study segments will intensively track reproductive pallid sturgeon during the pre-spawn and spawning periods. Outside the spawning period, pallid sturgeon will be tracked extensively at lower frequency to determine habitat use and identify critical habitat types (e.g., over wintering habitat). In addition to intensified tracking of pallid sturgeon, attempts will be made to validate and verify observed behavioral patterns using DIDSON acoustic cameras or direct sampling. This study anticipates the need and elevated priority for significant numbers of pallid sturgeon for the propagation program. Research crews will be required to devote significant time to capture, assess reproductive status, and transfer fish to hatchery facilities to reduce potential conflict between research and spring rise evaluation needs and propagation needs expressed by the sub-basin workgroup. A high level of effort will be required to collect enough pallid sturgeon to satisfy both hatchery and research needs.

Objective: Determine movement, habitat use, and reproductive behavior of pallid sturgeon within two geographically and hydrologically distinct reaches of the Lower Missouri River. This task is a continuation of work initiated in 2005. The objectives of this work are to 1) identify pre-spawning habitat, 2) determine the direction and magnitude of spawning movements, 3) characterize patterns of habitat use during spawning migrations, 4) determine where and under what conditions sturgeon spawn, 5) verify and validate spawning behavior, 6) assess the relative success of spawning related to status, environmental conditions including natural and augmented spring flows, and 7) determine and characterize post-spawn and non-reproductive habitat. Work in 2008 will primarily focus on pallid sturgeon, based upon the successful capture of a large number of individuals in 2007. Although we were successful in capturing large numbers of pallid sturgeon in 2007, hatchery requirements and river conditions may limit the number of pallid sturgeon available for research in 2008. If reproductive pallid sturgeon are not available, our contingency plan is to use a combination of non-reproductive pallid sturgeon and reproductive shovelnose sturgeon. The work will be conducted within two geographically and hydrologically distinct reaches of the Lower Missouri River to take advantage of the longitudinal variability in the system for comparative purposes. This work will intensively evaluate the reproductive status of pallid sturgeon, instrument each with transmitters and data storage tags (DST), track their movements through spawning and attempt to recover as many as possible to evaluate their reproductive success. Pallid sturgeon not in reproductive condition will be tracked to determine movement, habitat use and the location of critical habitats.

a) **Approach/methods.** In 2008, we will implant and track female and male pallid sturgeon meeting criteria (appropriate size and reproductive status) in each of two study segments. At least two gravid females and three ripe males should be included within each study segment. The actual numbers used will be determined based upon

the direction of the U.S. Fish and Wildlife Service, the Middle Basin Workgroup, and identified propagation needs. The river segments represent two hydrologically distinct units based on river hydrology and morphology. The first segment will be located on the Lower Missouri River between the Osage River and Grand River (rivermiles 130-250). The second segment will be located between the Platte River in Nebraska and the Big Sioux River (rivermiles 595-670). Crews will locate and track individual fish to record daily and seasonal movements. Fish will be tracked extensively during pre- and post-spawn periods. Fish in reproductive condition will be tracked intensively from April through July. Fish will be targeted for daily contact until temperatures reach 16 C at which time more frequent contact will occur. Fish not in reproductive condition will be contacted at a targeted frequency of 1 to 3 times weekly. Measurements of water conditions (e.g., temperature, conductivity, dissolved oxygen, and turbidity) and habitat characteristics (e.g., depth and substrate) will be recorded at each location to qualitatively and quantitatively describe habitat used by sturgeon during pre-spawn and spawning periods. Locations of possible spawning will be examined using DIDSON technology and may be sampled for the presence of other adult sturgeon using standard fisheries techniques. Detailed mapping of spawning habitat locations will be coordinated with task 3.

b) **Analysis.** Data on fish movement, habitat use and reproductive success will be compared among segments. Potential spawning locations will be identified for characterization, mapping and possible additional sampling for gravid adults, eggs, or larvae. Fish movement and habitat use data, along with the physical habitat data, will be analyzed using a combination of discrete-choice and utilization distribution modeling (Millspaugh and Marzluff, 2001). This approach is used to determine if the fish, through their observed behavior, are selecting one habitat type over another among the habitats available on a localized level. The localized level is defined here as the current bend of the river occupied by the fish.

c) **Reporting.** Interim progress reports will be prepared and provided to the Project Officer of the U.S. Army Corps of Engineers. Progress and results will be presented in CSRP annual reports, in the published literature, and at scientific meetings. Fish location data may be summarized in attributed GIS data layers and metadata that shows the movements of transmitter tagged fish and locations of potential spawning areas. Efforts will be made to share location and movement data as rapidly as practicable and prudent. Anticipated products of this effort by topic include:

Topic 1: Habitat use and Reproductive behavior of shovelnose and pallid sturgeon

Funded telemetry studies have resulted in the development of numerous tools for large river research and a wealth of data on location, movement and habitats used by these species. Data have also given insight to the evolved reproductive strategies employed by these species in a dynamic large river environment. The implications of this increased understanding are far reaching and may be directly applicable to management scenarios.

Published titles expected this year:

Integrating Data Collection and Management Tools to Support Multidisciplinary Research of Sturgeon on the Lower Missouri River

Multidisciplinary approach to the evaluation of the requirements of an endangered large river fish

Documentation of Spawning of Pallid Sturgeon in the Lower Missouri River

Publications to follow:

Differences in movement patterns of non-reproductive, ripe male, and gravid female shovelnose sturgeon during spawning season.

Topic 2: Resource selection and movement patterns of shovelnose and pallid sturgeon in the Lower Missouri River

Knowledge of important habitats during critical life stages for shovelnose and pallid sturgeon is needed to aid in recovery efforts. We are evaluating resource selection of gravid shovelnose sturgeon in the Lower Missouri River during the breeding season by comparing resource characteristics at sturgeon telemetry locations recorded in 2005 with the characteristics available in the river. We are examining resource selection using discrete choice models within an information theoretic framework which allows inferences from multiple sets of competing hypothesis about sturgeon resource selection. What we learn from the large set of data collected on shovelnose sturgeon will provide a start to describing pallid sturgeon behavior. The effectiveness of the model to describe pallid sturgeon behavior will be validated using data from 2007-08. Results from this analysis will aid management in identifying and conserving habitats important to sturgeon.

Products expected this year:

Selection of Physical Habitat During the Breeding Season by Female Shovelnose Sturgeon in the Lower Missouri River. This manuscript will be used to present an evaluation of habitat selection of gravid shovelnose sturgeon and the resource selection functions that describe such selection.

Publications to follow:

Validation of Resource Selection Functions (RSFs) for Shovelnose Sturgeon in the Lower Missouri River. Presented in this manuscript will be a validation of the RSFs developed from habitat selection analysis presented in the above publication.

Use of Kernels in Quantifying Large Scale River Use and Movements by Shovelnose. Presented in this manuscript will an identification of general

patterns in habitat use and movement of Lower Missouri River shovelnose sturgeon during the breeding season.

Large-scale Resource Utilization by Breeding and Non-breeding Shovelnose. In this manuscript utilization distributions from previous analysis will be used to explore shovelnose sturgeon associations with larger scale river features and morphology.

Hierarchical Bayesian Models for Estimating Shovelnose Sturgeon Migration Rates. In this manuscript we will develop hybrid statistical/physical models that take into account both tracking data and scientific knowledge (e.g., partial differential equations for the underlying migration processes) help describe shovelnose sturgeon migration rates in the Lower Missouri River

Topic 3: Predicting Spawning Success of Lower Missouri River Sturgeon using reproductive physiology and archival data storage devices (DSTs)

Spawning in sturgeon is thought to be linked to environmental patterns, rhythms, and cues. Intensive management of the Missouri River has resulted in dramatic physical changes to the river corridor and flow regime. These activities have been associated with the decline of native sturgeon species. Several significant management activities have been initiated to benefit the sturgeon. Unfortunately, little specific information is available on the biology and ecology of pallid sturgeon to guide these efforts. It is not known where, when and under what conditions these species spawn, and to what degree spawning is successful. Using measurements of biological variables associated with readiness to spawn as well as longitudinal behavioral data collected using telemetry and data storage device sensors we are attempting provide predictive models of spawning success. What we learn from the large set of data collected on shovelnose sturgeon will provide a start to predicting pallid sturgeon spawning success. The effectiveness of the model to predict pallid sturgeon spawning success will be validated using data from 2007-08. Results from this analysis will aid management in identifying and conserving habitats important to sturgeon.

Products expected this year:

Hierarchical Bayesian Markov Switching Models with Application to Predicting Spawning Success of Shovelnose Sturgeon. For this manuscript we use behavioral and physiological variables to predict spawning success. To do this, we introduce a hierarchical Bayesian model.

Publications to follow:

Multivariate Prediction of Spawning Success Using Markov Models. We will use behavioral and physiological variables, including temperature from DST, to predict spawning success 2007

d) **Time line.** Capture of pallid sturgeon should begin by December 1 and conclude prior to April 15 to take advantage of the start of navigation season and the potential spring pulsed flow. Fish will be allocated to research or propagation as determined by the US Fish and Wildlife Service, the Middle Basin Workgroup and the propagation program. Pallid sturgeon not in reproductive condition may be implanted at any time within the constraints of the pallid sturgeon handling protocol (U.S. Fish and Wildlife Service, 2005). Fish will be tracked from implantation through spawning (mid April – mid July) and into the post-spawning period, or until transmitter batteries fail. Recapture efforts for sturgeon designated for recapture and post-spawning assessment will commence in late July, or as behavior indicates. Pallid sturgeon will be tracked continuously. Efforts will be made to recapture pallid sturgeon and replace transmitters prior to battery failure.

e) **Budget Explanation.** Significant time will be required to capture the numbers of fish required for this study and for hatchery needs. It is extremely difficult to estimate the amount of effort required. This study has a significant amount of risk, as the numbers of pallid sturgeon in reproductive condition anticipated will exceed the numbers that have been captured to date. While the USGS, in collaboration with NGPC, has been very successful capturing pallid sturgeon, this success cannot be guaranteed. Capture efforts will include 4 USGS boats beginning December 1 and working as long as weather conditions allow through April 15. Other agencies will be asked to participate if funding is available. Six tracking boats and crews will be searching for and relocating sturgeon. Four boats will initially be assigned to the lower experimental reach. A crew consists of one crew chief and one or two additional seasonal crew members. Multiple crews may be required for each boat engaged in intensive tracking. In addition to the four USGS tracking boats in operation on the lower Missouri River, the USGS may provide up to an additional 2 boats to assist NGPC with tracking and recovery of pallid sturgeon in the upper segment. No new boats will be purchased. All boats are currently in operation and equipped to capture and track sturgeon. Each tracking boat will be outfitted with ultrasonic and radio telemetry equipment, a ruggedized field computer running ESRI ArcPad software, sub-meter GPS, water quality equipment, and depth sounder. Boats will be required to operate regardless of weather (within agency safety guidelines) and must make accommodations for the operation of sensitive electronic equipment under all conditions. The need to process telemetry data and relay results in near real time is critical for the scheduling of coordinated habitat and fisheries sampling activities. Processing and dissemination of data will require a continuous, dedicated database management effort. Boat fuel and maintenance, and supplies are based on experience of typical annual costs. Travel (vehicle costs, per diem, motel or alternate housing) is estimated based on the need for boat crews to conduct intensive tracking activities that may range over 811 miles of river. Intensive efforts to incorporate reproductively mature pallid sturgeon will require additional investment in capture effort, nets, travel, inter-agency cooperation and provisions for pallid sturgeon handling and transport. The USGS will coordinate with the U.S. Fish and Wildlife Service Columbia FRO, Nebraska Game and Parks Commission, and all participating State and Federal hatcheries. Pallid sturgeon collection efforts in the upper segment will be conducted collaboratively with Nebraska Game and Parks, and South Dakota

Game, Fish and Parks under State Programs and the Corps funded Sturgeon Population Assessment Program.

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Task 2. Reproductive Physiology to Support Assessment of the Importance of Spring Flows, Temperature, and Photoperiod to Successful Pallid Sturgeon Spawning in the Missouri River

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Background: This task provides the necessary supporting data and analyses to evaluate the biological response of pallid sturgeon to spring pulsed flows in the Missouri River. This task also continues to develop tools and acquire multi-year geographic and condition-specific data to answer questions about when, where, and what environmental cues are necessary for pallid sturgeon to spawn.

A fundamental aspect of the life-history strategy of an individual is the temporal pattern of reproduction (Ims 1990). An important contributor to fish reproductive success is synchronization of seasonal environmental conditions with the reproductive cycle. Photoperiod, temperature, and flow are the primary factors that cue the reproductive physiology of most fishes. Physiological and morphological measurements allow the scientist to evaluate the response of the sturgeon to environmental conditions. Responses may be general, such as stress, or specifically indicate how close a sturgeon is to ovulation.

Reproductive assessment prior to a telemetry study and again at recapture provides information on the reproductive readiness of the fish and subsequently whether spawning was successful or resulted in atretic oocytes. Moreover, assessment of the physiological status of captured wild sturgeon allows for an understanding of the environmental factors necessary for successful completion of the reproductive cycle. Determining physiological readiness to spawn allows us to ascertain approximately 'when' an individual sturgeon should spawn. This information can be combined with tracking and capture information (location, speed, pattern and direction of movement) to determine 'where' the sturgeon spawn. Physiological measurements on fish captured over time in a specific location can reveal whether a group of fish are synchronized and therefore likely responding to the same environmental cues, or if they are aggregating at a particular site to spawn.

A complete understanding of the relationships between environmental cues and reproductive physiology of sturgeon in the Missouri River has been hampered due to the difficulties of working in a large, inhospitable river system. For this reason, and despite iterative improvements to tracking study designs over the past four years, the question of when sturgeon spawn has been fairly well answered but only modest progress has been made in trying to answer

the question 'where and under what conditions do pallid sturgeon spawn?'. We have sound data to make predictions about pallid behaviors but limited empirical evidence of pallid spawning. Experimental manipulations of sturgeon under controlled and semi-controlled situations may provide additional insights for answering these questions.

Objectives/Approach:

Objective 1: Use physiological measurements to provide sex identification, assess reproductive readiness, assess stress of capture, and evaluate success of spawning for tracked sturgeon.

- **a) Approach/methods**. Under this objective we will provide support for Task 1 of the S.O.W. as well as other agencies involved in Missouri River sturgeon research as appropriate. We will supply field crews with tissue collection materials. We will analyze blood plasma for sex hormones and cortisol at implantation of transmitters and upon recapture for readiness to spawn and stress (Papoulias et al. 2007). Readiness to spawn will also be assessed using the polarization index (Dettlaff et al., 1993). Spawning success will be evaluated based on visual and microscopic inspection of gonads and liver as available and blood reproductive hormones (Papoulias et al. 2007).
- **b) Analysis.** Not applicable
- **c) Reporting.** Progress and results will be presented in CERC quarterly and annual reports, at sturgeon/Missouri River meetings, and upon request from Missouri River researchers.
- d) **Timeline. P**reparation of collection kits will begin in February prior to the field season. Identification and assessments will be on a continuous as-needed basis throughout the year.
- e) **Budget Explanation.** The principle resources necessary to accomplish this objective are personnel time (GS-13 biologist 0.05 time, GS-9 biologist 0.3 time, a contract biologist 0.25 time) field collection supplies, and travel support.

Objective 2: Evaluate shovelnose and pallid pre-spawning and post-spawning reproductive condition coincident with local environmental conditions.

- a) **Approach/methods.** This research is intended to better define the environmental factors (including spring pulsed flows) necessary for completion of the reproductive cycle and successful spawning in the lower Missouri River. Our approach is to assess the reproductive condition of the sturgeon prior to their spawning migration, during the migration, and as soon after spawning as possible and relate the readiness to spawn and success in spawning to discharge, temperature, and day length. Data will be collected from fish used in telemetry Task 1, from fish collected by the South Dakota Game, Fish and Parks specifically for this purpose under a separate SOW with the USACOE, and others who collect sturgeon in the Missouri River or its tributaries as opportunities arise. Temperature and flow data will be obtained from river gages, deployed data loggers, and/or data collected by field crews.
- b) **Analysis.** Analysis will use data collected from multiple years under different environmental conditions. We will characterize the physiology and morphology that describes a successful spawner and an unsuccessful spawner. We will use multivariate analysis to identify those variables that are the best indicators of successful spawning. We will begin to identify the entraining environmental cycles that synchronize sturgeon spawning by ranking the hierarchical arrangement of rhythms under the assumption that the greater the synchrony with a particular cycle (event) the greater relative importance or rank with respect to timing of spawning (Morgan and Christy 1994).

c) **Reporting.** Progress and results will be presented in CERC quarterly and annual reports, sturgeon/Missouri River meetings, upon request from Missouri River researchers, in the published literature, and at scientific meetings.

d) Timeline. Tissue collection will begin in the early spring and continue until recapture of telemetered fish is suspended. Assays, tissue preparation and analysis will begin in spring and continue through fall.

e) **Budget Explanation.** Resources necessary to accomplish this objective include personnel (GS-13 biologist, 0.1 time, GS-9 biologist 0.3 time, contract biologist 0.25 time), laboratory supplies, reagents, and travel support.

Objective 3: Develop tools and assays to measure and analyze specific shovelnose and pallid reproductive hormones important in cueing migration, gamete maturation, and release. Use laboratory mesocosm studies and semi-controlled field studies to develop novel and advanced approaches to identify when, where, and under what conditions pallid sturgeon spawn.

a) A**pproach/methods. 1)** This research extends on-going work conducted at CERC to develop tools and assays to measure gonadotropin II (GtH II) and maturation-inducing steroid (MIH). Biochemical and molecular approaches are being used to develop a GtH II antibody or probe (Mañanós et al., 1997; Gen et al., 2000; Kumar et al. 2001). Chromatographic methods are being used to identify the composition of the MIH (Trant and Thomas, 1989; Webb et al., 2002). Once identified, antibodies to the compound will be made to develop an ELISA assay. **2)** A limited number of ripe male and female shovelnose sturgeon will be induced to spawn using hormonal injections similar to procedures undertaken in the hatchery to facilitate spawning. Induced fish will be carefully tracked and observed using side scan sonar, Didson and if possible listened to using hydro acoustic technology. Following indications of spawning, attempts will be made to collect the fish for analysis. **3)** Multiple ripe pair(s) of shovelnose sturgeon will be collected in the Boonville section of the Missouri River and transported to CERC. Sturgeon will be induced to spawn using hormonal injections and released to the outdoor constructed flowing 'living-stream' mesocosm. The size of sturgeon makes it difficult to maintain them under simulated riverine conditions in the laboratory. However, a recently constructed continuous looped earthen raceway (mesocosm) at CERC could allow us the opportunity to observe Scaphirynchus in the spawning act. It is anticipated that the induced fish will spawn allowing us to visualize this event using the remote sensing equipment and scuba videography. We will be able to verify if these fish do spawn because they will be easily recaptured, thus the remote sensing tools can be 'calibrated' to provide greater confidence in our ability to interpret remotely sensed data from the field. Valuable information will be obtained even if the sturgeon do not spawn because it will allow us to physiologically characterize the blood chemistry of sturgeon resorbing their gametes. This information will lead to identification of biomarkers so that we a blood sample can provide diagnostic information about the reproductive condition of the fish.

b) **Analysis.** Good laboratory practices and appropriate QA/QC will be implemented. Assays will be validated using reference materials and conditions. Archived samples from current and past years tracking studies will be analyzed once an acceptable assay is developed.

c) **Reporting.** Progress and results will be presented in CERC quarterly and annual reports, sturgeon/Missouri River meetings, upon request from Missouri River researchers, in the published literature, and at scientific meetings.
d) **Time line.** Work is in progress. We anticipate having the assays developed by fall 2008.
e) **Budget Explanation.** Accomplishing these objectives requires personnel (GS-13 0.05 time, GS-9 biologist 0.3 time, contract biologist 0.25 time), reagents, and tissues. Some tissues are already available from the CERC -80^{o}C archive; however some tissues will also need to be obtained from captive and wild-caught specimens.

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Task 3. Determine the habitat characteristics used by sturgeon for spawning, quantity of spawning habitat available, and dynamics of habitat change related to varying discharge and sediment transport.

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Background: This task addresses how sturgeon use habitat in the Lower Missouri River (LMOR), how habitat availability varies with discharge, and how habitats change over seasons to years as sediment transport alters riverbed morphology. The focus during FY 2008 will be split between analysis and synthesis of previous years' results, and enhanced assessment of pallid sturgeon spawning habitats. Enhanced assessment of spawning habitats will include assessment of habitats used by pallid sturgeon as they respond to environmental cues during the year, including potential responses to spring pulsed flows, whether such pulses are natural or due to intentional reservoir release. All aspects of this task are interdependent with other tasks within CSRP as they provide sturgeon locations, physiological understanding, and other biological data necessary to understand habitat use.

Task Objectives:

During 2008 we will continue to address the definition of spawning habitat, whether habitat spawning is limiting in the life cycle of the pallid sturgeon, and the extent to which habitat availability and quality are affected by flow regime and river engineering. This work is separated into two objectives, with the first addressing habitat use and availability and the second addressing spawning habitat dynamics.

Objective 1. Habitat Use and Availability

A central question about pallid sturgeon reproduction and survival is whether a specific limiting habitat can be identified. Because of the fundamental role of spawning in population dynamics (Quist and others, 2004; Bajer and Wildhaber, 2007; Wildhaber and others, 2007), we have emphasized definition and quantification of spawning habitat. This assessment includes hydraulic habitat mapping of areas used by sturgeon and comparison with areas available, but not used. This work is highly coordinated with Task 1.

Habitat mapping from 2006 and 2007 will be synthesized with fish location data to quantify habitat characteristics within migratory and spawning reaches. Comparison of reach-scale geomorphology and hydraulics between migratory and spawning reaches is expected to show key habitat features associated with spawning. The analysis of habitat use and availability will be published in a USGS report series.

In addition to analysis and synthesis of previous years' data, we will coordinate with Task 1 to deploy an enhanced habitat-mapping protocol. During 2008, some gravid pallid sturgeon will be tracked essentially 24-h per day to help determine exact spawning locations. We will deploy a hydroacoustic mapping boat equipped with acoustic Doppler current profiler and high-resolution multibeam echosounder to quantify habitat during spawning migration, and hopefully during spawning itself. This enhanced mapping protocol will complement previous years' data while providing habitat information around sturgeon locations at an unprecedented level of detail. The number and size of mapped patches will depend on number of tagged fish and the quality of the tracking data. We anticipate creating 6-12 maps of 1-2 hectares each around migrating and spawning sturgeon. This mapping will quantify habitats sought out by sturgeon before, during, and after potential environmental cues, whether the cues are intentional reservoir releases (spring pulsed flows) or natural.

a. **Approach/methods**. Taking care not to influence fish behavior, the site will be mapped in detail using established hydro-acoustic habitat mapping protocols. Mapping will extend over adjacent areas to allow characterization of all habitats available at that time in the vicinity as well as the patch actually used by the sturgeon. Hydroacoustic data will be used to create maps of depth, velocity, and substrate, and to extract quantitative data for statistical analyses (Elliott and others, 2004; Jacobson and others, 2004; Gaeuman and Jacobson, 2005; 2006). Selected sites will also be mapped with high-resolution side-scan sonar to provide a complementary, qualitative picture of spawning habitats. The number and locations of sites will not be known until they are identified in the telemetry phase. Increased telemetry effort in 2008 is anticipated to yield higher resolution estimates of spawning locations.
b. **Analysis**. Data will be analyzed to create maps and tabular data (Elliott and others, 2004). Data will be provided to coordinated studies to investigate statistical links between sturgeon and their physical habitat (Task 1).
c. **Reporting**. Results will be documented in an annual report of the CSRP project, a final report for this task, and may be published in other publication outlets.
d. **Time line**. Data-collection schedules depend on when probable spawning sites are identified. The probable window for data collection is April 15 – July 30. Prior to data collection, the crew will be working on upgrading instrumentation and optimizing data-collection procedures. Data will be analyzed and included in the annual report for publication in 2008.
e. **Budget Explanation.** One boat crew consisting of a captain/principal investigator and a mate/technician are assigned to this component. They will be employed full time to assure that project instrumentation is ready for deployment, to establish training and cross-validation with coordinated mapping studies, to edit, analyze and report on the data, and to provide consistent analysis and reporting of data among years. The subtask will also employ one GS-11 hydrologist fulltime for analysis and reporting. The project will use an existing

USGS habitat-assessment boat equipped with a Reson 7125 multibeam echosounding system, a sub-centimeter positioning system, a 1200 kHz acoustic Doppler current profiler, a riverbed classification system, and a 900 kHz high-resolution side-scan sonar; funds are requested for maintenance of these instruments. Supplies are based on experience of typical annual repair and maintenance of instrumentation and the boats, and travel (vehicle costs, per diem, and motel) is estimated based on the need for boat crews to be available for rapid deployment over a broad region. Funds are requested for estimated costs of producing a report in the USGS Scientific Investigation Report series.

Objective 2. Spawning Habitat Dynamics

The flow regime is considered to have a central role in determining habitat availability and geomorphic dynamics (Poff and others, 1997; Richter and others, 1997). Specific roles in reproduction and survival of Missouri River sturgeon, however, have not been identified. The objective of this subtask is to quantify sensitivity of spawning habitat to flow regime in various parts of the LMOR. The analysis includes quantification of how much spawning habitat is available at various flow exceedances, assessment of how spawning habitat is altered by sediment transport, and the sensitivity of spawning habitat quantity and quality to natural and controlled flow pulses.

Four high-probability spawning reaches were identified in 2005 based on upstream limits of sturgeon movement. These reaches were used for hydrodynamic modeling and geomorphic monitoring in 2006 and 2007. Results of modeling will be synthesized in 2008 to assess sensitivity of spawning habitats to flow regime. Part of this analysis will be to synthesize information from habitat use/availability studies (above and Task 1) to optimize hydraulic and geomorphic definitions of spawning habitat at reach, meso, and micro-habitat scales. This analysis will be published in 2008 in a USGS report series.

Repeat surveys of cross-sectional transects and long profiles at the four sites also provide information for assessing the role of sediment transport in altering substrate and habitat volumes. The repeat surveys cover a range of flows during 2006-2007 that include the 2006 “Spring Rise” and the potential range of future managed flows. Analysis of substrate and habitat sensitivity to sediment-transporting events will be published in 2008 in a USGS report series.

a. **Approach/methods**. Four reaches were identified and studied in 2006 and 2007 based on fish-location data collected in 2005 that showed areas of high potential for spawning, and presence of coarse substrate. These reaches were delineated to include replicates of macrohabitats and to assure that probable spawning areas are included. Hydroacoustic mapping of the reaches used methods documented in CERC standard operating procedures, and in (Elliott and others, 2004; Jacobson and others, 2004; Gaeuman and Jacobson, 2005; 2006).
    i. **Compilation mapping.** Each reach was mapped completely, once in 2006 and once in 2007 at a relatively high discharge (although substantially less than bankfull). These datasets were used to compile base bathymetric data and high-flow calibration data. Compilation mapping used 20-40 m transect intervals with a precision depth sounder, 1200 kHz acoustic Doppler current profiler, substrate classifier, and real-

time kinematic global positioning system (RTK-GPS) using established USGS habitat-mapping protocols. At least two longitudinal transects were collected along the thalweg and opposite bank to complement transect data and to provide water-surface profile data. Terrestrial surveys were completed to reach the top of bank and to define engineering structures. LIDAR data to be released in September 2006 may be useful to supplement bathymetric surveys at our Pelican Island reach.

ii. **Calibration/validation collection**. On a subset of approximately 20 randomly selected transects, discharge, velocity, depth, substrate class, and channel-bottom elevation data were collected at five times during 2006. Additional 4-5 resurveys of these same cross sections took place during FY 2007. Each calibration/validation survey data also included a longitudinal profile (replicating profiles in i above).

iii. **Stage/discharge data**. Additional discharge and longitudinal profile data were collected at the reach as needed to compile a stage/discharge curve for modeling.

iv. **Monitoring of change**. A randomly selected subset of about 10 transects (the same set used for calibration/validation measurements) were re-surveyed using the RTK/GPS hydroacoustic mapping protocols to evaluate change in the cross section shape and area, change in substrate conditions, and change in velocity structure. Duplicate long profiles were be surveyed during each event and used to calculate bedload transport rates by bedform differencing (Simons and others, 1965), and acoustically derived bed velocities (Gaeuman and Jacobson, 2005; 2006) will be calculated along all transects.

b. **Analysis.**

i. Hydroacoustic elevation compilation data have been merged with terrestrial surveys and other available data to create a continuous surface map of the channel and flood plain elevations, extending over bank to include the nominal 10 year recurrence flood plain. Calibration/validation data will be edited and analyzed to document sensitivity of depth, velocity, and substrate class availability to changing discharge. During 2007, the compilation data were used to create a computational mesh for multidimensional hydraulic modeling (for example, (Jacobson and Galat, 2006; Johnson and others, 2006). A subset of the calibration/validation data have been used to calibrate a multi-dimensional hydrodynamic model based on USGS code (McDonald and others, 2005). During 2008, results from these models will be explored to evaluate habitat sensitivity to discharge variations and sensitivity of suspected habitat classes to modeling procedure emphasizing patch dynamics and areas of high hydraulic gradients (Bowen and others, 2003; Bovee and others, 2004; Crowder and Diplas, 2006). Additional habitat-use data collected during 2008 will be used to update and refine habitat classes and the analysis of habitat sensitivity.

ii. Change in cross-sectional shape and size, substrate, bedload transport rates, and velocity structures will be assessed over the range of monitored discharge to address sensitivity of geomorphic processes to flow manipulations. These data will also be used to assess a fundamental

assumption used in conventional hydrodynamic modeling: the extent to which the bed deforms over the modeled discharges.

c. **Reporting**. Results of data collection will be described in the annual CSRP report. Hydraulic data recorded at the reaches will be summarized to illustrate variations relating to discharge. Model results will be analyzed and published in a USGS Scientific Investigations Report.
d. **Timeline**. Analysis and reporting will take place during FY 2008. Results will be summarized in the 2008 annual report and an additional USGS report.
e. **Budget Explanation**. In addition to oversight by the principal investigator, the project is staffed with two hydrologists (0.8 and 0.2 time) and a hydraulic engineer (.08 time) who will share duties to manage the project, analyze the data, and run the hydraulic models, and write the report. Funds are requested for salaries and for estimated costs of producing a report in the USGS Scientific Investigation Report series.

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Task 4. Effects of flow and water temperature on spawning, growth, and recruitment of pallid sturgeon and shovelnose sturgeon in the Missouri River below Gavins Point Dam.

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Background/Rationale: The interactive effects of flow and water temperature on spawning of pallid sturgeon (*Scaphirhynchus albus*) and shovelnose sturgeon (*Scaphirhynchus platorynchus*) in the Missouri River are not known. Spawning is believed to occur when water temperatures approach 16-18°C in the spring. However, flows released from dams that mimic a more naturalized hydrograph with two spring pulses are thought to be a requirement for spawning (USFWS, 2000; USFWS, 2003). Consequently, studies were initiated in 2006 to determine the ecological requirements for spawning and reproduction of *Scaphirhynchus* sturgeon in the Missouri River that included evaluating sturgeon responses to flow modification below Gavins Point Dam (Fleming and others, 2006).

In 2006, a collaborative effort between USGS and South Dakota Game Fish and Parks resulted in capturing gravid shovelnose sturgeon at relatively high rates in late May and early June from the Missouri National Recreational River below Gavins Point Dam that were physiologically ready to spawn if appropriate stimuli were available for fish to release eggs. In addition, small larval *Scaphirhynchus* sturgeon (7-9 mm total length) were collected in late May through June downstream from gravid shovelnose sturgeon in the Recreational River Reach of the Missouri River that were radio-tagged and found near their furthermost upstream location. Several of these fish were confirmed to have spawned, including one as early as 31 May. Since *Scaphirhynchus* sturgeon hatch at approximately 7-9 mm total length (Snyder 2002) after an incubation period of approximately 3-4 days in water temperatures of 20-24°C, water temperature data from the Recreational River Reach was used to estimate when spawning occurred. Collectively, data on capture rates, physiology and movements of gravid shovelnose sturgeon, larval fish collections and water temperatures suggested that most of the spawning by *Scaphirhynchus* in the Recreational River Reach occurred between 28 May and 22 June when water temperatures were approximately 19-23°C. The timing of spawning coincided with the May pulse and summer flow periods (see Fleming and other 2006), but the collection of a few small larval sturgeon suggested a protracted spawning period. Similar work was conducted in 2007, but the study site was extended to Plattsmouth, Nebraska. Samples collected in 2007 have not yet been completely processed. Nevertheless, similar results are expected with additional insight specifically relevant to pallid sturgeon. In addition, young-of-the year shovelnose sturgeon were sampled in 2007 in this reach of the Missouri River. These data are similar to that which has been collected below Fort Peck Dam and will be useful in determining spawning timing and locations, growth rates, drift distances, and recruitment dynamics of *Scaphirhynchus* below Gavins Point Dam. To accomplish this task, additional support is requested from the Army Corps of Engineers to continue processing larval samples collected in 2007 from the

Missouri River and its major tributaries and writing agency reports and manuscripts on significant findings.

Specifically, our objectives will be to:

1) Assess the effects of flow and temperature on sturgeon aggregation and spawning and

2) Assess the spatial and temporal distributions of larval sturgeon in the Missouri River and major tributaries between Plattsmouth, Nebraska and Gavins Point Dam.

Analyses conducted for our first objective will be preliminary, and may change after additional data are collected by South Dakota Game Fish and Parks in 2008.

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Task 6. Provide database integration, GIS support, and report coordination for all aspects of this scope of work AND research support for the Fort Peck Flow Modification Biological Data Collection Plan

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- USGS Publication Hub

Background: The research activities in this scope of work will generate volumes of research data on the ecological and habitat needs, physiological endpoints, and population models of pallid and shovelnose sturgeon. This information will be useful to address management needs, if the data are properly organized, effectively displayed, carefully interpreted, and expeditiously published. Information management is often left until the end of the project, which can lead to problems in its effective use by managers and the public. To circumvent these problems, it is essential at the beginning of the project to standardize how to capture, format, archive, summarize, analyze, integrate, visualize, and distribute the information. As data layers and research reports are generated they can be efficiently provided to the other sturgeon RM&E efforts and the Missouri River Recovery Implementation Committee (MRRIC) and multiple stakeholders across the Missouri River Basin.

Objectives/Approach: There are four general activities for this task. Activities in FY 2008 will be similar to FY07. Salary support for Kim Chojnacki has been moved to Task 1 and 2.

1. **Database Management** – There are several components to database management that will be funded under this activity. The first is to support data capture for the sturgeon telemetry field work. As during the summer of 2005, a customized ArcPad® (ESRI, Redlands, California) application will be utilized to collect data on sturgeon movements and habitat use in real time. This application for mobile GIS and field mapping uses handheld or mobile computer devices to capture and display geographic information in the field. These devices eliminate 1) the need for paper field sheets, 2) the need to enter information from field sheets into database – reducing errors and time lag, and 3) are customizable to streamline specific field tasks. Customized data input screens automatically record date, time, and location variables from GPS units for "cruise log" and sturgeon location datalayers. At the end of each tracking period the data files are uploaded to a CERC computer server. Data also will be uploaded to a CERC computer server from fixed-base telemetry receiver stations. Files from all field crews and fixed-base receivers can then be integrated to produce daily maps and reports on sturgeon locations throughout the Missouri River. These products can then be served by email or as hyperlinks on a CERC website.

An integrated Microsoft Access project will be developed to link data tables with a common field but relevant to the different aspects of the total project. Data tables on individual fish metrics, tracking locations, physiology, habitat use, environmental variables, and others can be integrated in the project so that the data are readily available and searchable, and more comprehensive reports can be generated. This data structure would be readily transferable to other programs, such as SAS® for statistical analyses or ArcGIS® for spatial analyses. We will provide a legacy for the information collected by the entire project on an ongoing basis. Deliverables will be the form of updated accessible and useable databases, spatial layers, tools, and metadata from the start of the project until the end. However, ***it is expected that funding for comprehensive statistical analyses of data and development of mathematical, spatial, and hydrologic models are incorporated in previous tasks.***

Nearly all tasks of CSRP have spatial components that need to be supported through GIS expertise with ArcGIS. That support will be provided to most of the other tasks through this component. Management of the CERC Geodatabase computer server is required to ensure data management and security across the project. This is best accomplished by one person with proficient skills and sole (or near sole) administrative rights to that specific computer system.

2. Research support for the Fort Peck Flow Modification Biological Data Collection Plan

The existing 5-year funding agreement between the MTFWP and USACE directed towards implementation of the Fort Peck Data Collection Plan includes salaries, travel support, and administrative support for all MTFWP personnel. However, the existing funding agreement does not provide travel or administrative support for USGS personnel. Thus, this task specifically requests travel support, administrative support, and information dissemination support for USGS personnel involved in the Fort Peck Data Collection Plan. Deliverables for this Scope of Work will include the Fort Peck Flow Modification Biological Data Collection Plan Annual Report and research manuscripts prepared for peer-reviewed journals. The USACE will be credited as a funding agency in all reports and scientific papers published.

3. Information Dissemination and Outreach – Scientific information will be derived by analyses and synthesis of a large number of empirical and spatial datasets. This scientific information needs to be presented in several different formats to best make the findings relevant to research, management, and public audiences. With this activity we anticipate developing an outreach plan, supporting staff with expertise in environmental journalism to document the scientific process, and providing written products that best articulate science to a cross section of Missouri River stakeholders.

4. Publications/Reports – USGS publications are required to comply with extensive editorial and peer review, layout, and printing standards. Staff with expertise for the preparation of technical and non-technical products are required as well as funds for actual printing costs through USGS, the Government Printing Office, scientific journals, or other vendors.