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Conservation Plan for the Interior Least Tern, Pallid Sturgeon, and Fat Pocketbook Mussel in the Lower Mississippi River

(Endangered Species Act, Section 7(a)(1))

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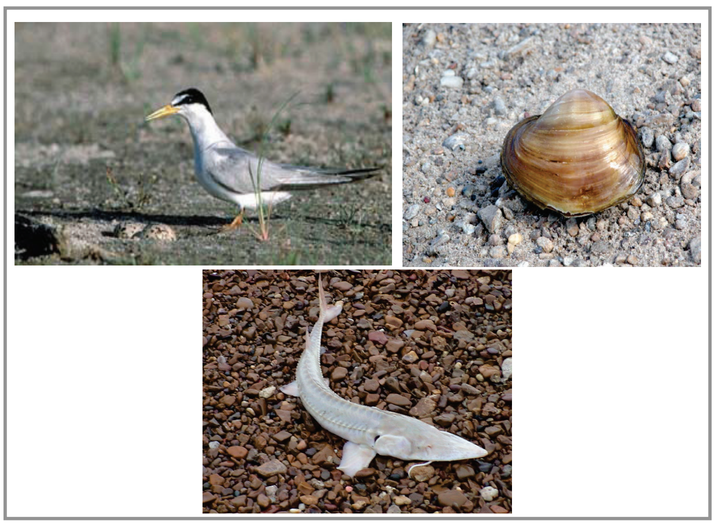

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Report prepared for the
Mississippi River Commission

MRG&P Report No. 4
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Abstract

Section 7(a)(1) of the Endangered Species Act (ESA) requires all federal agencies to use their authority as appropriate to carry out programs for the conservation (i.e., recovery) of endangered and threatened species. For more than a decade, the U.S. Army Corps of Engineers (USACE) has worked with the U.S. Fish and Wildlife Service (USFWS) and state conservation agencies to identify and resolve endangered species and ecosystem management issues that could impact USACE civil works missions in the Lower Mississippi River (LMR). It has become apparent that the very programs that have most significantly affected the river are potentially the most important and cost-effective tools to maintain and enhance its ecological functions. This is accomplished by considering and incorporating ecological engineering opportunities during the design phase of channel improvement and channel maintenance projects. The USACE has also opportunistically implemented cost-effective secondary channel restoration actions in the LMR by sharing responsibilities and resources with partner agencies. Cumulatively, both the site-specific engineering actions and the restoration opportunities have significantly benefitted the habitat baselines of endangered species associated with the LMR channel. Herein, the USACE outlines the programmatic mechanisms by which the Channel Improvement Program of the Mississippi River and Tributaries project is being utilized to implement conservation measures that maintain and improve habitat values within the LMR for recovery of endangered and other trust species inhabiting the river channel. This program has been developed under informal consultation with the USFWS, and complies with section 7(a)(1) of the ESA, USACE Environmental Operating Principles, Civil Works Ecosystem Restoration Policy (ER 1165-2-501), and supports the conservation intent of EO 13186 Responsibilities of Federal Agencies to Protect Migratory Birds.

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Preface

The research documented in this report was conducted as part of the Mississippi River Geomorphology and Potamology (MRG&P) Program. The MRG&P is part of the Mississippi River and Tributaries Program (MR&T) and is managed by the U.S. Army Corps of Engineers (USACE) Mississippi Valley Division (MVD) and Districts. The MRG&P Senior Program Manager was Freddie Pinkard and the Technical Director was Dr. Barbara Kleiss. The MVD Commander was BG Peter A. DeLuca. The MVD Director of Programs was Edward Belk.

Mississippi River engineering direction and policy advice were provided by the Mississippi River Commission. The Commission members were BG DeLuca, USACE; the Honorable Sam E. Angel; the Honorable R. D. James; the Honorable Norma Jean Mattei, Ph.D.; RDML Gerd F. Glang, National Oceanic and Atmospheric Administration; BG Margaret W. Burcham, USACE; and BG John S. Kem, USACE.

Research in support of the MRG&P was conducted by the U.S. Army Engineer Research and Development Center (ERDC) under the purview of the Environmental Laboratory (EL), Vicksburg, Mississippi. This report was prepared by Drs. Jack Killgore, Todd Slack, Rich Fischer, and Jan Hoover, and Audrey Harrison of ERDC-EL; Paul Hartfield, USFWS; Dr. David Biedenharn, Biedenharn Group; and Dr. Barb Kleiss, MVD. The report was prepared under the general supervision of Dr. Timothy Lewis, Chief, Aquatic Ecology and Invasive Species Branch, EL; Dr. Edmond J. Russo, Jr., P.E., Chief, Ecosystem Evaluation and Engineering Division, EL; Dr. Jack Davis, Deputy Director, EL; and Dr. Beth Fleming, Director, EL. COL Jeffrey R. Eckstein was Commander of ERDC. Dr. Jeffery P. Holland was the ERDC Director.

This report would not have been possible without the help of division and district personnel. In particular, thanks are extended to the following people in the Channel Improvement Program of MR&T for providing project information and reviews: Rob Davinroy (St. Louis District); Darian Chasteen, Derrick Smith, Andrew Smothers, Zachary Cook, and Carol Jones (Memphis District); Freddie Pinkard, DeAnna Prestwood, Steve Coleman, and Kent Parrish (Vicksburg District); Don Rawson and Joan

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1 Introduction

Background

The Lower Mississippi River (LMR) extends 953.5 miles from the confluence of the Ohio River to the Head of Passes, where the river subdivides into several distributaries to the Gulf of Mexico. In response to the 1927 flood, the Mississippi River and Tributaries (MR&T) project was initiated by the USACE. The project consists of levees, revetments, flood storage reservoirs, and floodways to reduce flood risk, as well as dikes, and other river training structures in the channel to facilitate low-water navigation by towboats. Construction of the MR&T project, which still continues today, has resulted in one of the most highly engineered, large river channels on the planet.

The construction of the Mississippi River levee system altered natural patterns of surface water drainage within the region and reduced the floodplain by over 80% (Baker et al. 1991). Channel engineering for navigation over the past 30 years has resulted in a gradual but significant loss of secondary channels and connectivity to adjacent floodplain habitats. In a study of a subset of LMR secondary channels, about 29 secondary channels and roughly 18,500 acres of these channels' habitat at higher water have been lost in the LMR since the 1960s (Guntren et al. in press). These changes are likely due to natural realignments and/or channel modifications — including closure dikes — conducted under the MR&T Project (Williams and Clouse 2003). Dikes constructed along the main channel have resulted in sediment accretion and loss of aquatic surface area during low water periods.

While the development of the Mississippi River for year-round navigation and flood protection has provided enormous economic benefit to the United States with a return on investment of 44:1, it has also resulted in a general decrease of channel habitat complexity in the LMR (e.g., Williams and Clouse 2003). Cumulative impacts have affected three endangered species inhabiting the LMR: Interior least tern (ILT), pallid sturgeon (PS), and fat pocketbook mussel (FPM), all of which are dependent upon in-channel and seasonally flooded habitats.

Despite river engineering activities over the past century, the LMR has not experienced any known extirpations or extinctions of channel species, such as have occurred in other large rivers of the United States. There are several reasons for this: 1) the LMR remains unimpounded, experiencing a natural flood cycle hydrograph; 2) although size and quantity of sediment input to the system has been significantly reduced through bank protection and construction of multiple impoundments of all major LMR tributaries, large quantities of stored sediment are available in the river channel that are continuously reworked during flood cycles; 3) implementation of the Clean Water Act throughout the drainage basin has significantly improved water quality in the LMR; and 4) the proactive nature of USACE, specifically Mississippi Valley Division, in carrying out its continuing responsibilities under the Endangered Species Act. These factors all contribute to maintaining the LMR channel as a highly functional and valuable fluvial ecosystem.

The current local status of the three endangered species in the LMR also reflects the ecological functionality and value of the river channel. Although considered endangered throughout their ranges, LMR populations of ILT and PS are widespread and locally common in the river channel. While there are no historical records of FPM from the LMR channel proper, it was either present in low numbers and unreported, or it has invaded the channel in recent years due to developing favorable conditions. Although the ecological requirements of the three species are not completely understood, the aquatic habitats available in the LMR, including point bars, gravel bars, eroded shorelines, functional side channels, and forested backwaters in the batture, have provided and continue to provide both direct and indirect benefits to the endangered species, and all other channel-dependent species.

The USACE, Mississippi Valley Division (USACE-MVD) is responsible for the construction and maintenance of the Mississippi River and Tributaries Project in the LMR, as well as for maintaining its ecological function. For more than a decade, the USACE-MVD LMR districts have been working with state and federal partners to maintain habitat complexity and reduce impacts to trust species by developing and applying cost-effective engineering and best management practices to routine channel maintenance and construction activities in the LMR (e.g., USFWS 2012a; DuBowy 2011).

Purpose and Scope

This Conservation Plan (Plan) is being prepared pursuant to Section 7(a)(1) of the Endangered Species Act, as amended, which requires all federal agencies to use their authority to carry out programs for the conservation (i.e., recovery) of endangered and threatened species. The purpose of the Plan is to describe how the MR&T Channel Improvement Program can be utilized to conserve ILT, PS, and FPM in the LMR. This Plan also describes results of the MVD's efforts to implement monitoring and other conservation efforts with the goal of recovering the species in the LMR. Continued implementation of these activities to maintain and enhance LMR aquatic habitat diversity is the primary goal of the Plan. Specific conservation measures are recommended to meet the purpose and goal of the Plan, but are contingent upon opportunity and annual appropriations, and other authority and budgetary constraints.

The Channel Improvement Program civil works project encompasses the LMR channel within the jurisdiction of the MVD and the Memphis, Vicksburg, and New Orleans Engineer Districts. This Plan does not address issues related to other USACE regulatory responsibilities, water diversions, or the 45 ft channel below New Orleans. The PS range encompasses all of the LMR within the scope of the Plan; ILT range includes over 600 miles of the River above Baton Rouge, LA; known range of FPM includes over 400 miles of the channel above the Old River Control Complex. The customary yearly evaluations of project construction effects at scattered sites along the river — without consideration of cumulative or system-wide effects — do not adequately address potential impacts to any of the three species. Therefore, a system-wide or landscape approach was taken in the analyses of Channel Improvement Program project effects on the PS, ILT, and FPM.

2 Environmental Setting

The Mississippi River is one of the world's largest alluvial river systems, having a drainage basin of 1,245,000 square miles, encompassing 41 percent of the contiguous United States and parts of two Canadian provinces. Worldwide, the Mississippi River ranks third in drainage area, seventh in length, and sixth in average discharge. The main stem of the river courses 2,348 miles from Lake Itasca in northern Minnesota to the Head of Passes in Louisiana. Above St. Louis, the river is impounded by 27 Locks and Dams. Between the mouths of the Missouri River at St. Louis, Missouri, and the Ohio River at Cairo, Illinois, is a 200-mile reach referred to as the Middle Mississippi River (MMR).

The Lower Mississippi River (LMR) begins at the confluence of the Mississippi and Ohio Rivers in southern Illinois and flows southward 955 miles in a meandering pattern to Head of Passes, Louisiana, where the channel subdivides into several distributaries to the Gulf of Mexico. The LMR has two distinct reaches, although Schumm et al. (1994) further subdivides the LMR into 24 reaches based on geomorphology and channel maintenance activities. From Cairo at the mouth of the Ohio River (RM 953) south to Baton Rouge, the river has well-defined point bars and forested floodplains adjacent to it (Baker et al. 1991). A minimal navigation channel is maintained at 9 feet, but is authorized for 12 feet. Below Baton Rouge, the river flows through the Deltaic Plain, 248 miles to the Gulf. The channel is deeper to accommodate ocean-going traffic (45 feet deep navigation), and meander loops, sandbars, and floodplains on both sides of the river are much reduced (Baker et al. 1991).

Geomorphology

The Lower Mississippi River Valley (LMRV) lies within the Central Gulf Coastal Plain physiographic province. A northward extending lobe, the Mississippi Embayment of this province follows the axis of the Mississippi Basin and comprises the northern part of the LMRV (Schumm et al. 1982). Virtually all LMRV landforms and deposits are the result of fluvial, Aeolian, or marine processes.

The LMRV varies in width between 40 and 110 miles and includes parts of Missouri, Illinois, Tennessee, Kentucky, Arkansas, Mississippi, and

Louisiana. According to MR&T (2012), the topography of the 53,000 square-mile LMRV is characterized by a flat to slightly undulating surface underlain by alluvial and terrace deposits. Average floodplain elevations in the LMRV decline from about 325 feet mean sea level (msl) in extreme southern Illinois to about 40 feet msl at the northern edge of the deltaic plain. The average down valley slope is only 0.6 feet/mile. Average relief in the upper part of the LMRV is about 25 feet and declines progressively southward. Uplands bordering the LMRV typically attain elevations of about 200 feet above those of the adjacent floodplain. Upland elevations also steadily decline southward.

Soils in the LMRV range up to 300 feet in depth and consist mainly of sands and silt, grading progressively to very fine sands and silts in the lower portion of the area, with extensive deposits of clay scattered through these formations. Typical of streams flowing through alluvial valleys, the LMR developed a highly sinuous course, creating numerous meander loops, bends, and oxbow lakes. The meandering characteristics of the present-day river may not have fully developed until about 5000 to 6000 years ago (Baker et al. 1991). Historically, the river shifted its channel frequently and reworked parts of its alluvial meander belt, thus contributing to the complexity of the soil structure and hydrology of the area (Saucier 1994).

The MR&T Project is a complex, comprehensive water resources project, which provides flood risk management within the alluvial valley and navigation improvement of the LMR. The primary elements of the MR&T Project include: levees, channel improvement features, such as meander cutoffs, bank stabilization, dikes, dredging, floodways, and diversion structures, and tributary basin improvements. The historical, present-day, and future morphology of the LMR reflects an integration of all these features combined with natural factors such as floods and droughts, hurricanes, tectonic activity, geologic outcrops, climatic variability, and sea level rise and other anthropogenic activities such as gravel mining. The geomorphology of present-day LMR has been significantly altered from its pre-20th century regime by dams, revetments, and levees in three primary ways: (1) channel simplification and reduced dynamism; (2) lowering of channel-bed elevation; and (3) disconnection of the river channel from the floodplain (Alexander et al. 2012). Notably, channel meandering has been eliminated by revetments, cutoffs have significantly altered the energy in the system, secondary channels have been altered by dike systems, and floodplains have been constrained by levees. For example, Winkley (1977) concludes that the LMR was a stable system between Cairo, Illinois and Natchez, Mississippi in the precutoff period, whereas stage adjustments followed the cutoffs of 16 bendways between 1933-1942. Although the morphology of the LMR has been altered significantly, it is important to recognize that the LMR, unlike the Upper Mississippi River, the Ohio River, and the Missouri River, is not heavily controlled by main channel dams and flow regulation (Biedenharn and Watson 1997; Soar et al. 2005). Therefore, the LMR is still a dynamic, open river system where morphologic adjustments are still occurring, albeit, within the constraints of a river controlled for flood risk management and navigation. Therefore, the impacts to habitat should be viewed within the context of an altered, but still dynamic river system.

Hydrology and Hydraulics

One distinct feature of the LMRV is the formation of natural levees along the banks of rivers and the associated backwater deposits dominated by dense alluvial clays that historically supported extensive wetland areas. The banks of the river can be as much as 10 to 15 feet higher than the lowlands farther back from the river. Because of these natural levees, drainage within the floodplain frequently flows away from the Mississippi River to lower elevations near the valley walls, except near tributary confluences. Bottomland drainage is provided by streams running parallel to the river and joining it through major tributaries or at points where the river meandered close to the valley wall. The clays that formed these features have low permeability and limit the ability of rainwater to infiltrate the ground surface (Kleiss et al. 2000).

In the river proper, mean top bank width is 5,450 ft, while mean width of the low-water (3 percentile flow of the discharge, Q) channel is 2,960 ft (Tuttle and Pinner 1982). Water velocities vary widely but can exceed 10 ft/sec around dike fields. The LMR hydrograph is variable, with yearly stage fluctuations of 20-40 ft (mean=22 ft). The river shows two distinct depth-distribution patterns (Miranda and Killgore 2013). Over its lower-most 248-mi segment, the river has been engineered to maintain deep water to support navigation of large container vessels, with a mean maximum depth near 66 ft and a maximum mean depth near 131 ft LWRP. The Low Water Reference Plane (LWRP) is associated with the discharge that is equaled or exceeded by 97% of the time taken from flow duration curves. This deep segment is a relatively homogeneous navigation channel, with limited variability in depths (Coefficient of Variation, CV, 40-60).

Above river mile 248, mean maximum depth at LWRP is near 26 feet and maximum depth can exceed 100 ft below LWRP. Variability in depths in this upper segment of the river is higher than in the first 250 mi (CVs about 50-70). April has the highest average monthly discharge (947,457 cfs), and October has the lowest average monthly Q (260,844 cfs) (Tuttle and Pinner 1982). At Vicksburg, Mississippi, (rm 437) mean Q is 617,000 cfs for the 1944-1994 period and mean suspended sediment load is 198 x 10^6 tons/yr (Moody and Meade 1992). Maximum discharge at Vicksburg, Mississippi during the height of the 2011 flood was 2,272,000 cfs (MR&T 2012). The timing, duration, and frequency of annual low-discharge and high-discharge events, however, vary widely among years.

Although the stability of the LMR reflects the contribution of a variety of factors such as levees, cutoffs, dikes, revetments, and dredging, the event that has had the most pronounced morphological impact on the LMR was the meander cutoff program of the 1930s and 1940s. Biedenharn and Watson (1997) documented the stage adjustments in the LMR during the precutoff (1880s–1930s), and postcutoff (1943–1994) periods and found that the entire Mississippi River, between Natchez, Mississippi, and Cairo, Illinois, is responding in a manner similar to the response of a stream to a single cutoff. Their study identified a degradational regime between Sunflower, Mississippi, and Fulton, Tennessee, and an aggradational regime between Vicksburg and Natchez, Mississippi. Upstream of Fulton and the reach between Sunflower and Vicksburg were transitioning to dynamic equilibrium. It should be recognized that these are long-term decadal trends and that short-term reversal of trends, usually in response to major flood events, may occur. Although these may be slow, long-term trends, their impact on habitat may be significant, due to changes in the hydrologic connectivity between the secondary channels and floodplain. This is particularly an issue in the degradational reaches of the river where the stage duration changes may cause the diked secondary channels to become more hydrologically isolated from the river. The evolutionary trends on the LMR occur over long time periods, and are typically measured in multiples of decades. Therefore, an opportunity exists to develop management strategies to mitigate the impacts of these long-term trends.

Habitat Classification and Distribution

There have been several aquatic habitat classifications of the LMR. The river is divided into the channel and floodplain, and within each of these two broad categories, macrohabitats have been defined based on geomorphic, hydraulic, biological, and other descriptors (Baker et al. 1991). More recently, nine macrohabitats were defined in Table 1 for the channel environment that can be easily identified and mapped (Miranda and Killgore 2011). Channel and sandbar habitats are most common in the LMR; revetted banks (Articulated Concrete Mattresses (ACM)) occur along outside bends; and natural banks occur along inside bends associated with vegetated islands, most secondary channels, and abandoned bendways. There are over 100 island complexes, which include a secondary channel island usually vegetated, and main channel border (Williams and Clouse 2003). A more recent study identified 199 chutes, which include both vegetated islands identified by Williams and Clouse (2003), and non-vegetated islands where flow in the main channel zone is bifurcated by a point bar or mid-channel bar bed forms with a crest elevation $\geq$ +5 ft. LWRP (Guntren et al. in press). Dike fields are dispersed throughout the channel border down to the lower reaches near Baton Rouge, Louisiana (rm 212 to 953.5) and average 1.0 dike/rm. Of the 774 dikes constructed since the beginning of the dike construction effort on the LMR, 225 (29%) have been notched. Overall, there are about 482,418 acres of aquatic habitat within the top banks of the river, assuming a bank-full stage (MR&T 2012).

Table 1. Type and abundance of macrohabitats in the Lower Mississippi River.

Habitat type	Description	Abundance
Steep sandbar	High sloping sandbar often associated with the downstream reach of an island or point bar where the maximum current speeds begin to cross the channel forming eddies, deep water, and depositional areas along the bank.	8,649 acres[1]
Gentle sandbar	Low sloping sandbar with moderate to high current. They constitute the primary littoral habitat in the river and occur in association with point bars, islands, middle bars, and dike systems.	70,425 acres[2]
Island complex	Usually include, from the bank outward, a secondary channel, island, and main channel. Upper reach is shallow and swift, while lower reaches become deeper and sluggish.	25,652 acres at 0 LWRP; 93->100 side channels[3]
ACM/riprap	Articulated Concrete Mattress (ACM) is placed over eroding river banks with riprap along the top portion. Buckling and variation in bottom slopes create large interstitial spaces surrounded by hard substrates. Strong currents and deep water are usually associated with this habitat.	17,915 acres[4]
Natural bank	Usually occur on the concave side of the river where consolidated silts and clays form the primary substrate. Banks are often steep and woody debris from fallen trees can accumulate.	9,266 acres [4]
Flooded shoreline	At high stages, flooded sandbars and willow trees provide temporary habitats usually occurring along the convex side of the river. Detritus and terrestrial vegetation become available in relatively shallow, low velocity refugia.	More than 360 mi at overbank flows[5]

Habitat type	Description	Abundance
Gravel bar	Coarse sand and gravel are deposited in bendways usually in the upper reaches of point bars or islands where water is shallow and swift. Gravel may extend from the shoreline to the channel border.	At least 76 bars with predominately gravel[6]
Channel	Includes the main channel and channel border. Water depth can exceed 80 ft, currents are strong, and substrate is usually sand.	321,237 acres [4]
Dike	Constructed with large rocks and extend perpendicularly from the bank to the channel border habitat. Some dikes can exceed 3000 ft in length. Large eddies can form below dikes, and depth and velocity varies greatly along its longitudinal axis.	Avg. of 1.0 dike/RM[7]

[1] Analogous to lentic sandbars from Baker et al. (1991)

[2] Analogous to lotic sandbars from Baker et al. (1991)

[3] Williams and Clouse (2003)

[4] Baker et al. (1991)

[5] Derived by dividing the river length between the Ohio River and Baton Rouge by two (720 mi/2=360) to represent a minimum value for the convex side of the river, which would always be less than the concave side but more than 360 miles.

[6] See Table 2

[7] Based on 774 dikes constructed up to 2012 on the LMR between river miles 212 to 953.5.

Gravel bar habitats are of particular interest in the Conservation Plan because of their importance as spawning substrate for pallid sturgeon as well as other fish species. A recent study conducted by ERDC-GSL and the Biedenharn Group identified the general location of gravel deposits in the Lower Mississippi River using historical Red Hen imagery, photographs, field observations, and historical potamology data. The Red Hen System allows for geo-referenced HD videos to be acquired from the helicopter reconnaissance. With this technology, geo-referenced videos provide latitude and longitude in a continuous fashion along the entire flight route, thereby allowing the investigator to accurately locate all pertinent features along the stream. This results in a more efficient use of resources, and provides a broader perspective at a significantly reduced cost. This analysis divided 138 channel bars between Cairo, Illinois, and Old River into four broad categories as shown in Table 2. Although the amount of gravel generally decreased in the downstream direction, it is significant that gravel was observed throughout the study reach. This analysis represented a major first step with respect to identifying gravel locations along the river. However, these results are considered preliminary for the following reasons:

- The resolution of the Red Hen videos was often inadequate to definitively identify the presence of a gravel bar.
- Gravel deposits may have been under water at the time of the Red Hen flights. The recent 2012 Red Hen flight that was conducted at extreme

low water following the 2011 flood, has not been analyzed yet, but preliminary indications are that gravel bars may have been more prevalent than in previous flights.

- It is also likely that many gravel deposits may have been covered by sand at the time of the Red Hen flights. In fact, analysis of the historical potamology data have indicated that these are highly dynamic features, with gravel bars being alternately buried in sand and then exposed again through time.
- At some locations where gravel was observed, it is possible that these were armor layers rather than extensive gravel bars.

Table 2. Classification of channel bars between Cairo, Illinois and Old River.

Classification	Number Observed
GS – Predominately gravel	44
SG – Predominately sand but with considerable gravel	32
SPG –Mostly sand, with possible gravel, but not definitive	49
S – Predominately sand with little to no gravel	13

The LMR leveed floodplain, which includes the floodplain contained between the levees (i.e., the batture) and backwater areas, is a dynamic freshwater ecosystem, often changing markedly in response to the river's annual hydrologic regime. The 2.25 million-acre leveed floodplain is interspersed with abandoned channels (e.g., oxbow lakes), meander scars (e.g., sloughs, and large expanses of forested wetlands, and tributary mouths (Baker et al. 1991). Borrow pits, excavated in floodplains for use as fill in building or maintaining levee systems, cover 39,000 acres and function similarly as natural floodplain lakes (Miranda et al. 2013). Overall, the floodplain provides a diverse array of aquatic habitat types and is connected to the river at high water each year. Based on MR&T (2012), the LMR floodplain lying riverward of the levees is comprised of about 2.25 million acres and varies in width from 1 to 15 miles. The land cover in 1992 consisted of about 1,313,090 acres of forests, 371,569 acres of agricultural lands, and 127,408 acres of lakes, streams, and man-made water bodies (Table 3). These lands function as the main overflow system of the river and contain a diversity of terrestrial habitats and bottomland hardwood forests. Sugarberry/American elm/green ash, sycamore/sweetgum/ American elm, black willow and cottonwood/willow forest types make up 70% of the wooded bottomlands.

Table 3. Distribution of Major Habitat Types within the Lower Mississippi River Valley.[1]

Habitat Type	Area (acres) [% total]
Bottom land hardwood forests	981,887 [35 %]
Agricultural lands	478,345 [17 %]
Open water (lakes, borrow pits)	515,656 [18 %]
Backwater areas (sloughs, ponds)	680,800 [24 %]
Other	137,186 [6 %]
Total	2,793, 874

[1] Mississippi River and Tributaries 2011 Post-Flood Report, June 2012, Mississippi Valley Division

Baker et al. (1991) noted a number of distinct changes in the river ecosystem compared to the historic unaltered system. The overall floodplain was reduced by 80% due to the levee system. Many oxbow lakes are now outside of the levee system, and other waterbodies within the batture gradually fill due to sediment accretion. Turbidity, sedimentation, and expanded agricultural development impact aquatic communities associated with oxbow lakes in the Mississippi Alluvial Valley (Miranda and Lucas 2004). Main stem habitats have been altered as well. Channel cutoffs reduced the number of bendways, which shortened the river causing a major loss in channel habitat including pointbars and gravel bars. Dike fields reduce aquatic surface area due to sediment accretion between dikes, although dikes associated with outside bends often scour sediments and increase pool habitat. Closure dikes across the mouths of secondary channels increase sand deposition that reduces hydraulic connectivity to the main channel. Williams and Clouse (2003) reported a loss of 23 secondary channels with vegetated islands from the 1960s to the 1990s due to sedimentation in the channel, and Guntren et al. (in press) reported a similar trend for chutes (non-vegetated secondary channels) continuing into the 2000s. Natural steep banks have declined substantially due largely to the construction of revetments (Baker et al. 1991). However, channel habitat and transitional areas between the thalweg and shoreline (i.e., channel borders) have persisted over time and continues to provide habitat diversity in the mainstem LMR.

Effects of Climate Change on the Mississippi River System

The ability to predict the impacts of climate change on a river system as large as the Mississippi River is wrought with significant uncertainties.

Ultimately, it would be desirable to integrate climate change studies and water resource evaluations to the point where one can predict changes in river discharges and attribute those changes to either climate variability or change. However, at this point in time, efforts remain rudimentary and integration of the multitude of driving variables that influence discharge for the Mississippi have not led to conclusive predictions of change. For instance, Caldwell et al. (2012) noted that increases in impervious cover by 2060 may offset the impact of climate change during the growing season in some watersheds, while in other areas, increased water withdrawals for human consumption, industrial utilization, and irrigation could either offset or exacerbate climate change impacts. Hirsch and Ryberg (2012) concluded that there was not strong statistical evidence relating historic flood magnitudes to changes in global mean CO_2 levels. Additionally, the Mississippi River basin has had significant annual and inter-annual variability throughout the period of historical record. As a recent example, between the flood of the spring of 2011 and the drought of 2012, water levels at the gage in Memphis, Tennessee varied by 59 feet. Natural interannual and interdecadal variability make it difficult to detect potential climate changes due to anthropogenic or other sources.

Despite these constraints, climate scientists have suggested a few trends for the watershed that may be useful to consider. Bonnin et al. (2011) presented evidence that there will be an increase in heavy, flood-inducing precipitation events, particularly in the Ohio Basin, that would have a direct influence in the LMR. Raff et al. (2009) also found that for the James River in the Missouri River Basin, climate projections result in an increased simulated annual maximum flood potential through time. Also, Kunkel et al. (2013) report that although there is also large interannual variability in regional temperatures, historical tendencies for the Midwest U.S. as a whole are towards increased annual temperatures. Trends calculated from temperature data show a 0.11˚F per decade increase in annual mean temperature over the Midwest during the 1900-2010 period. Another predicted outcome is increased or prolonged periods of drought (IPCC 2007; GCRP 2009) that may affect in channel habitats utilized by pallid sturgeon and other species that are their food items.

At this time, it is difficult to say whether any of these potential climate-induced changes are likely to have any measurable impact on the three species that are the subject of this report.

3 Authorized Project Description

Channel Improvement Program

In response to the 1927 flood, the MR&T Project was authorized by the Flood Risk Management Act of 1928, which has been modified numerous times to provide the present project authority. The MR&T Project along the main stem of the Mississippi River includes an extensive, 2,216-mile levee system; three floodways to divert excess flows past critical reaches; and channel improvement and stabilization features to protect the integrity of flood reduction measures and to ensure proper alignment and depth of the navigation channel. The Channel Improvement Program of the MR&T project provides for a low-water navigation channel nine feet deep (authorized to 12 feet) and 300 feet wide from Baton Rouge, Louisiana to Cairo, Illinois and for stabilization of river banks to protect the flood risk management levees from Head of Passes, Louisiana to Cairo, Illinois and on the lower 9 miles of the Ohio River. This Conservation Plan applies to the Channel Improvement Program (CIP).

The CIP consists of the construction of river engineering structures, including stone dikes, foreshore protection dikes, articulated concrete mattresses (ACM), and trench fill revetments; and maintenance dredging to maintain the channel depth and width in the main stem of the Mississippi River. Construction dredging has also been used in a few instances. As of September 2012, there were approximately 355 miles of stone dikes, 145 miles of foreshore dikes, and 1,055 miles of operative revetment on the LMR. Stone dike work is about 91 percent physically complete, with 35 miles of dikes remaining to be constructed. The ACM revetment work is approximately 97 percent physically complete, with 36 miles to be built in the future. The CIP is scheduled to be finished in 2020. Continued maintenance beyond 2020 will be required.

River Engineering Structures

Three main types of river engineering structures are used in CIP: Revetments, dikes, and bendway weirs. In addition, hard points, round-points, and chevron dikes are used in some instances. A combination of these structures work synergistically in a river reach to achieve both flood risk management and navigation objectives. The effects of these structures on endangered species habitats are discussed in Chapter 6.

Revetments

Revetments are placed on riverbanks to arrest bank caving and protect levees and other structures, and to maintain an efficient channel alignment. Caving banks of the LMR are typically stabilized with ACM. The ACM is comprised of concrete blocks 46.5 inches long, 17.75 inches wide, 3 inches thick, spaced 1 inch apart and tied together with corrosion-resistant wire to form a continuous mattress.

In the 1980s, ACM design was modified for environmental enhancement. ACM is now constructed with longitudinal grooves over the surface of each block to reduce current velocity and increase surface area for the attachment of macroinvertebrates (Way et al. 1995). ACM is placed on the graded bank slope from just above the water surface at the time of construction and extended to a prescribed point in the channel not necessarily to the bottom. The upper bank area is graded to a typical slope of 1 vertical to 3 horizontal and paved with riprap stone; asphalt was used prior to the early 1960s. The ACM is flexible, strong, and durable and ensures complete coverage of the bank. About eight percent of the ACM surface is comprised of spaces between the individual blocks. Trench fill revetment is also occasionally used in the LMR for major channel realignment or when some continued erosion of the river bank is required to provide a desired channel alignment. A trench is excavated on the land or island along the design channel alignment and filled with quarry stone. When the river migrates laterally into the filled trench, the stone launches and stabilizes the bank.

Pokrefke (2012) described Off-Bankline revetments as an environmental enhancement alternative, providing slack water habitat compared to traditional On-Bankline revetments. According to Pokrefke (2012), the Off-Bankline revetment is a row of stone, typically “A” stone, and is placed 5 feet to 15 feet riverside of the existing bankline at an elevation of the existing bank height. Notches are typically left in the revetment to allow fish to access the slack water areas.

Between 2003 and 2012, linear feet of revetment placed annually averaged (± standard deviation) 48091.9 ± 9853.9 (Table 4). The majority of revetment laid was to repair revetment damaged by floods. Annual variability was due to funding, magnitude of flood damage and length of low stages conducive for construction activities. As of 2012, there are 1055 miles of revetment along the banks in the LMR.

Table 4. Linear feet of revetment laid over the past ten calendar years in the Lower Mississippi River.

District	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	New									
Memphis	5554	6077	1893	5829	3552	5305	2276	1392	0[1]	0
Vicksburg	6105	9159	12855	6610	9726	6669	7374	9581	0	1950
New Orleans	0	0	0	0	0	0	0	0	0	0
Maintenance										
Memphis	14983	14667	14350	12793	13952	9192	17020	13071	0[1]	34218[2]
Vicksburg	6802	9196	9984	7315	11132	10002	8502	10094	6512	27468
New Orleans[3]	10401	12057	8361	26818	11175	12370	15248	10688	7849	n/a
Total	43845	51156	47443	59365	49537	43538	50420	44826	14361	63636

[1] No ACM placed due to flood

[2] All flood-damaged ACM

[3] Combined maintenance and reinforcement

Dikes

Dikes have been used intermittently on the Mississippi River for over a hundred years; however, beginning in the 1960s, a comprehensive dike program was initiated in an effort to reduce dredging costs and establish improved navigation alignments. Stone dikes are constructed in the river channel to develop a self-maintaining (minimal maintenance dredging), low-water navigation channel with authorized project dimensions and alignment. Dike systems function, in conjunction with revetments, to modify and stabilize channel alignment, reduce discharge through secondary channels, and decrease width and increase depth of the low-water (navigation) channel through bed degradation, mainly in channel crossings (Fenwick 1969; Cobb and Magoun 1985).

The morphological response to the construction of dikes is site specific and depends upon a number of factors, such as dike type (permeable or impermeable), dike elevation, configuration (level crest, sloping crest, and stepped up or stepped down), dike angle and length, local channel sediment characteristics (size and concentration), and the hydraulic and hydrologic characteristics of the channel. However, there are some general trends associated with dikes that typically occur. First, it should be recognized that the hydraulic effects of dikes will vary with stage. The top elevation of a dike is often designed well below the top bank elevation to minimize impacts of dike construction at higher flows. Second, it must be recognized that the hydraulic and sedimentation impacts of dikes also change with time. When first constructed, the cross-sectional area of the channel will be reduced due to the presence of the dikes. However, this reduction in area is insignificant at high water stages. With time, the dikes will typically induce sediment deposition in the area between the dikes, and increase the area and depth in the main channel due to erosion.

Design of stone dike systems is variable and depends on purpose, site conditions, and economics (Pokrefke 2012). Spacing of dikes is based on experience and local factors, but is typically one to two times the length of the next upstream dike. Dikes comprising a system may be stepped-up; i.e., the dike's crown elevations increase downriver, or stepped down; i.e., the dike's elevations decrease downriver. Stepped-down dike systems tend to increase deposition between dikes during high discharges, which successively overtop each dike as stages rise, while stepped-up systems tend to promote scour between successive dikes (Franco 1967; Fenwick 1969). However, studies of dike systems on the LMR have shown that sedimentation was higher in level for stepped-up systems than in stepped-down systems. This may be due to the large channel width and wide spacing of dikes.

Transverse stone dikes, also called spur dikes, are linear structures that range in length from 1,000 to 12,000 feet (mean = 2,000 ft.) and are built of large quarry-run stone. They extend from the bank into the channel and are oriented perpendicular to flow or are angled as much as 30 degrees downstream or upstream, depending on local conditions and objectives. Stone dikes are trapezoidal in cross-section, generally with a crown width of 5-14 ft and a longitudinal profile that slopes from the riverbank towards the channel. A sloped dike profile enables the structure to affect channel alignment over a range of low to mid-bank stages. Dike length is based on total channel width and the design width or trace of the navigation channel; i.e., the required amount of channel contraction and conveyance. Crown elevations are based on the degree of channel control required, existing bed elevations, and costs. For example, a dike that traverses a deep secondary channel may have a relatively low crown elevation because construction cost increases exponentially as a function of dike height. A trail or L-head section may be constructed at a right angle and extend downstream from the channelward tip of a transverse dike to increase channel control at reduced cost or to simulate bank alignment. Rootless dikes are also used to provide habitat diversity. This type of dike has an offset typically of 100 feet or more from the river bank (Pokrefke 2012). The rootless section provides environmental diversity by altering flow and sediment transportation, and multiple dikes can be left rootless and in a line to create a secondary channel for environmental enhancement (Pokrefke 2012).

As a result of the MR&T dike program, dredging costs on the LMR have been reduced dramatically. However, the associated deposition of sediment within the dike fields reduces aquatic surface area, degrading the quality of these valuable aquatic habitat areas. In response to these concerns, a detailed data collection program was established by the Mississippi Valley Division (MVD) in order to quantify the sedimentation trends in these dike fields. Utilizing these data, Biedenharn et al. (2000) conducted a detailed study of the sedimentation trends of 28 individual dike fields on the Lower Mississippi River. For this study, the channel was divided into three distinct areas (main channel, pools, and sandbars) based on the classification scheme developed by Cobb and Magoun (1985). The pools are basically the area between the dikes as defined by the area circumscribed by the bank line and a line connecting the channelward tips of the dikes. The sandbar areas were defined as the bar area between the pool boundary and the -10 foot Low Water Reference Plane (LWRP) contour. The boundary of the main channel is the remainder of the channel up to the -10 foot LWRP contour. Although there was considerable uncertainty and variability in the individual dike-field trends, some general trends were observed. According to their report:

- The largest impacts of the dikes occur in the initial response period (first 5 to 15 years following dike construction), after which the response decreases significantly.
- The pool (area between the dikes) response is dominated by decreases in surface area, volume, and depth. However, these filling trends are affected by a number of factors. The filling trends are most pronounced in the tighter bends (Radius of Curvature/Width < 5), with the impacts being lessened as the bend radius increases. Filling is also the dominant process in the straight reaches, but the trends are less

consistent, with a number of reaches actually exhibiting enlargement. The most significant filling appears to occur in the initial 5 to 10 years following dike construction. These filling trends continue through time, but at a reduced rate.

- The main channel response was dominated by increases in surface area, volume, and depth. The most significant enlargement of the main channel occurs during the initial period immediately following dike construction.
- The sandbar area (identified as a transition area between the main channel and the pools) was highly variable, experiencing both scour and fill. The sandbars appear to represent a transition zone between the filling trends in the pools and the scouring trends in the main channels.
- The volume trends for the overall reaches (combined main channel, pools, and sandbars) indicate that the overall reaches have either enlarged or experienced no significant change, while the surface area showed no significant change or minor decreases. Thus, it appears that the dikes have either produced a larger, more efficient channel, or had no significant impact on the overall channel cross section at all.

In recognition of the potential loss of habitat resulting from sedimentation in the dike fields, the Corps began a dike notching program on the Lower Mississippi River in the late 1980s. A dike notch is a weir section in the dike that is designed to maintain flow through the dike fields at low river stages, thereby minimizing the adverse sedimentation impacts in the secondary channels. The size of the weir section depends on local site conditions, but typically the top width varies from about 100 to 300 feet, with a weir invert of about +5 feet above the LWRP. Not all dikes are subject to notching, either because of location and minimal environmental benefits, or because a notch would reduce their integrity of purpose (e.g., short dikes).

Hubbard et al. (2006) conducted a limited analysis of pre- and postnotching surveys within the Memphis and Vicksburg Districts. This was not a comprehensive assessment of dike notching; rather, it was a limited investigation based on five dike fields with a short postnotch time period ranging from 5 to 11 years. Because of the limited data, this study did not produce any conclusive trends that could be extrapolated to dike notching in general. However, the study did provide useful insight into the behavior of the five dike fields studied. Specifically, the study showed that the spatial and temporal scour and fill trends in the dike fields were extremely dynamic. The response to notching was observed to be site specific, with locations of scour and fill varying from year to year within the dike fields. These findings are important because they document that the dike fields are not static environments; rather, the dike fields are temporally and spatially highly dynamic systems.

A total of 774 dikes, averaging 1.0 dike/rm, have been constructed between river miles 212 to 953.5 since the beginning of the dike construction effort on the LMR (Table 5). Of the 774 dikes constructed, 225 (29%) have been notched to diversify bathymetry below the dike. Notching closing dikes of secondary channels may be most effective in diversifying habitat conditions by maintaining flows in secondary channels for extended periods during low river stages. To date, the combined efforts with LMRCC have cost-efficiently rehabilitated nine secondary channels with notched dikes, totaling almost 40 miles of inchannel habitat. These efforts have enhanced hundreds of acres of seasonally flooded habitats without impacting the COE's primary missions of flood damage reduction and safe, stable, commercial navigation channel creation.

Table 5. List of river training structures, excluding revetment, constructed up to 2012 or proposed for the next five years in the Lower Mississippi River.

River Training Structure	Memphis District	Vicksburg District	New Orleans District	Total
Total Dikes Constructed				
Dikes	467	293	14[1]	774
Notched dikes	147	78	0	225
Hardpoints	209	28	0	237
Chevrons	4	3	0	7
Bendway weirs	6	2	0	8
Proposed for 5-year Plan				
Dikes	28	16	0	44
Notched dikes	14	4	0	18
Hardpoints	20	0	0	20
Chevrons	0	0	0	0
Bendway weirs	10-13	4-6	0	14-19

[1] Dikes occur down to RM 212 in the New Orleans District

Bendway Weirs

Bendway weirs, originally designed by Derrick et al. (1994), are linear stone structures, similar to transverse stone dikes, except for where they are placed in the channel. These structures are placed from the concave bank across the main or navigation channel. A series of weirs are constructed in a bend to form a functional system. These structures typically have elevations 20 feet or more below the LWRP, thereby allowing passage of navigation traffic, and are variously angled upstream, depending on site conditions. Bendway weir systems are designed to increase uniformity of flow, lower velocities, and reduce shoaling in a bend. These effects are accomplished by widening the low-water channel and making it shallower, resulting in a more rectangular — as opposed to a triangular — channel cross-section. The number, length, elevation, angle, and spacing of bendway weirs are based on site conditions and physical model tests. Bendway weirs were first constructed by the St. Louis District, and are now used in the MMR and the LMR. As of 2012, Vicksburg and Memphis Districts have constructed a total of eight bendway weirs in the LMR (Table 5).

Hardpoints

Hardpoints were designed to stabilize river banks as a cost-effective alternative to revetment. Hardpoints consist of stone fills spaced along an eroding bank line, protruding only short distances into the channel. Based on a description by Lagasse et al. (2009), a root section extends landward to preclude flanking. Hardpoints are most effective along straight or relatively flat convex banks where the streamlines are parallel to the bank lines and velocities are not greater than 10 ft/sec within 50 ft of the bank line. Hardpoints may be appropriate for use in long, straight reaches where bank erosion occurs mainly from a wandering thalweg at lower flow rates. They would not be effective in halting or reversing bank erosion in a meander bend unless they were closely spaced, in which case spurs, retarder structures, or bank revetment would probably cost less. Hardpoints are most commonly placed in lieu of revetment along the concave bank in secondary channels in the LMR. Compared to revetment, hardpoints conserve natural river bank, diversify riverine habitat through deposition and scour, and provide velocity refugia for aquatic organisms. As of 2012, Vicksburg and Memphis Districts have constructed a total of 237 hardpoints in the LMR (Table 5).

Roundpoints

Multiple Roundpoint Structures (MRS) are alternating rows of rock mounds within the footprint of a typical dike. According to Pokrefke (2012), this structure is built to a two-thirds bankfull stage with the spacing of the rock mounds a function of the structure height. MRS are used like a dike to maintain the navigation channel and to create flow and bathymetric diversity within a dike field; therefore, the main benefit of these structures is to create diverse flow and scour patterns for aquatic improvement (Pokrefke 2012).

Chevrons

Chevrons were originally used by the St. Louis District in the Middle Mississippi River as a river training structure for erosion control at the upstream end of islands and as a habitat restoration tool (Davinroy 1996). Only a few chevrons have been built in the LMR. Chevrons are typically used in wider reaches of the river where a flow split is desired. A C-shape rock dike is constructed and aligned to split flow while protecting the existing shoreline. A series of chevrons are usually required to obtain the desired effect. The split flow scours the substrate along the outside trailing edges of the chevron. Scour also occurs within the interior of the chevron and can form small islands immediately downstream as sand deposits in more slackwater areas. Chevrons can simultaneously assist or aid bank protection, channel scour, and habitat diversity. As of 2012, Vicksburg and Memphis Districts have constructed a total of seven chevrons in the LMR (Table 5).

Dredging

One of the primary missions of the USACE is to maintain channel depth and width for commercial navigation. Between Cairo, Illinois and Baton Rouge, Louisiana in the LMR, the USACE maintains a 9-foot deep channel (with up to 12 feet being authorized) that is 300-feet wide and a 9-foot deep channel in the ports and harbors. Dredging occurs mostly at crossings (i.e., where the main current crosses from one bank to the other), of which there are approximately 200 between the mouth of the Ohio River and Baton Rouge, Louisiana (Baker et al. 1991). However, only a few of the 200 crossings are regularly dredged. Dredging can be substantial below Baton Rouge at low river stages to maintain the deep draft, 45-foot channel; however, this work is not done under the MT&T authority. Dredged material from the LMR is usually deposited directly in flowing water where it disperses throughout the channel or in existing dike fields. This method is referred to as within-banks or flow-lane disposal and is used above and below Baton Rouge. This type of disposal also has environmental benefits by maintaining sediment within the channel to build sandbars, reduce erosion, and provide material to build or replenish island habitats and coastal wetlands. In some cases, dredged material is pumped through a pipeline to nearby fields or other off-channel locations to build landforms, although this type of disposal has not been used in many years.

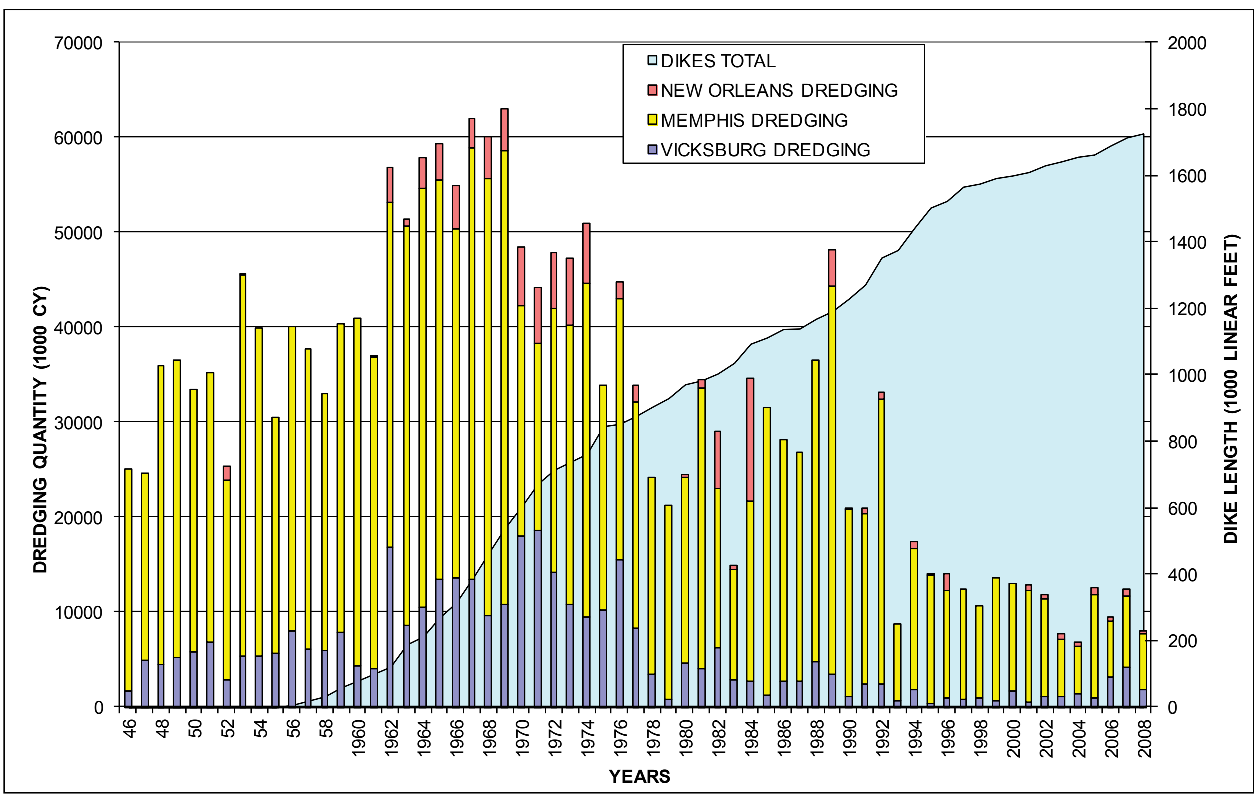
Different types of dredges (cutterhead, dustpan, and hopper) are used depending upon the area. In the LMR, large dustpan dredges (e.g., the *Jadwin, Hurley, and Potter*) are most commonly used by the USACE. The suction head, approximately the width of the dredge, is lowered to the face of the material to be removed. High velocity water jets loosen the material, which is then drawn by pump as slurry through the dredge pipe and floating pipeline where the material is deposited outside of the navigation channel. Hopper dredges (e.g., *Wheeler, Essayons, and McFarland*) are typically operated where dredged material must be moved greater distances. Hopper dredges store dredged material onboard and transport it to an approved disposal site. Hopper dredges are only used below Baton Rouge to maintain the 45-foot navigation channel. Cutterhead dredges (e.g., the *Thompson*) are equipped with a rotating cutter apparatus surrounding the intake end of the suction pipe. Cutterheads can efficiently dig and pump up to a mile of all types of alluvial materials and compacted deposits, such as clay and hardpan. Using booster pumps, cutterhead dredges have the capability of pumping dredged material longer distances, but can be cost-prohibitive and limited by available lengths of discharge pipe.

Over the past ten years, a total of almost 431,000,000 cubic yards of sediment have been dredged from the main channel of the Mississippi River, including the deep draft channel below Baton Rouge (Table 6). This represents an average of 43,000,000 ± 12,000,000 cubic yards dredged each year. Annual variation in dredging amounts is due to river stage; low water years require more dredging to maintain the navigation channel. From 1948 – 2008, the total linear feet of dikes constructed has drastically reduced the amount of annual dredging required to maintain minimum depth of the navigation channel, excluding the deep draft channel below Baton Rouge (Figure 1).

Table 6. Cubic yards of maintenance channel dredging, excluding harbors, over the past ten years in the Lower Mississippi River.

Year	Memphis District	Vicksburg District	New Orleans District				Grand Total
			Baton Rouge to Old River	New Orleans to Baton Rogue	Gulf of Mexico to New Orleans	New Orleans District Total	
2003	6,073,352	1,030,475	623,692	13,728,125	9,381,050	23,732,867	30,836,694
2004	4,953,282	1,422,200	452,464	8,656,512	13,010,523	22,119,499	28,494,981
2005	10,838,046	982,968	824,628	19,368,940	13,616,139	33,809,707	45,630,721
2006	5,883,104	3,102,696	441,035	9,953,606	7,245,234	17,639,875	26,625,675
2007	7,504,241	4,260,200	623,878	11,762,086	10,556,543	22,942,507	34,706,948
2008	5,814,028	1,851,804	325,695	28,773,375	13,406,342	42,505,412	50,171,244
2009	7,116,535	860,587	579,040	26,661,826	18,477,845	45,718,711	53,695,833
2010	7,126,552	1,318,424	366,180	22,994,560	23,055,732	46,416,472	54,861,448
2011	7,001,328	1,315,100	814,478	21,826,412	14,431,080	37,071,970	45,388,398
2012	12,706,518	3,323,993	1,926,194	24,523,153	17,626,336	44,075,683	60,106,194

Figure 1. Relationship between cumulative dike lengths and dredged quantities in the Lower Mississippi River, upstream of Baton Rouge and the deep draft channel and excluding harbors. Figure developed by Mississippi Valley Division.



4 Endangered Species Accounts

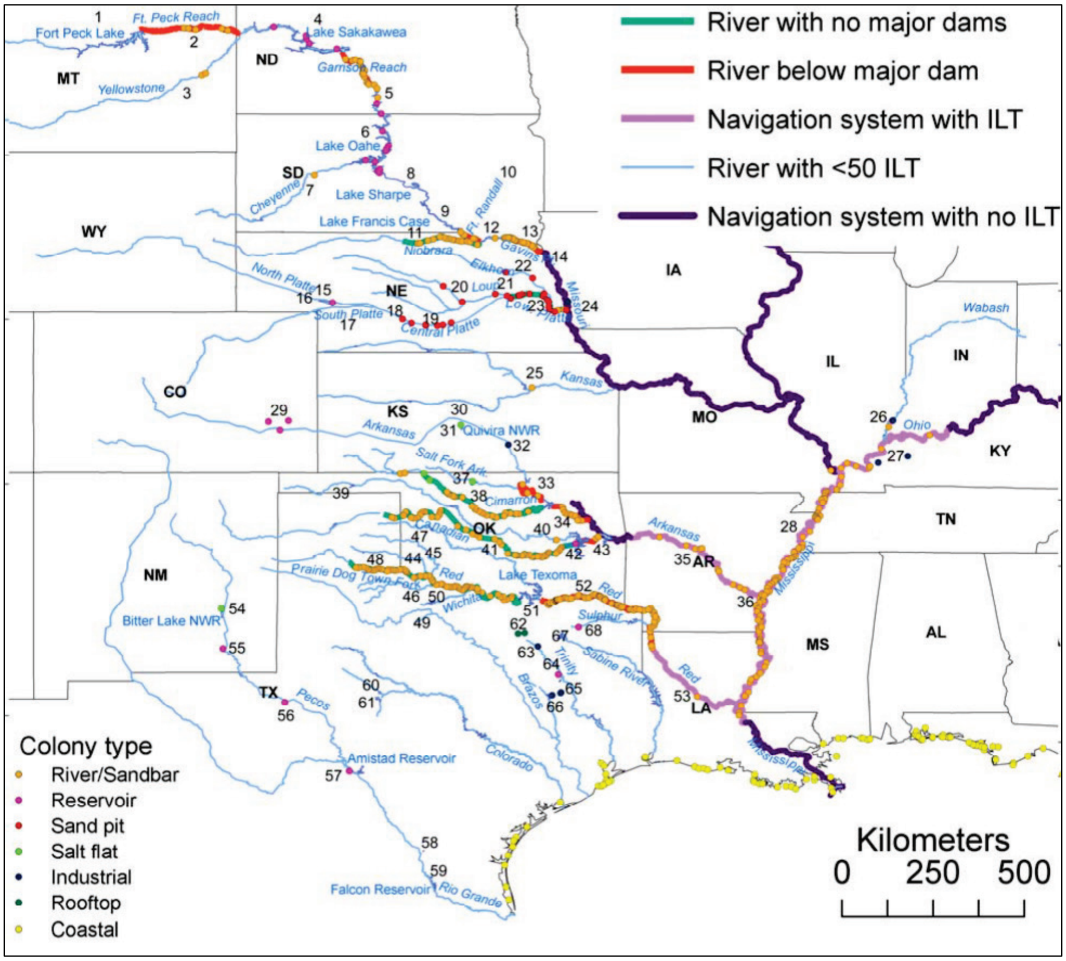
Interior Least Tern

The life history of least terns (*Sternula antillarum*) has been described in great detail many times, and in many different environments (Hardy 1957; Massey 1974; Wolk 1974; USFWS 2003; 2005a) and synthesized during the exhaustive literature review associated with the *Birds of North America* account for this species (Thompson et al. 1997) (a publication that includes, in detail, the distribution, habitat, food habits, demographics, and other life-history characteristics). Additional life-history information, as well as a detailed accounting of the Endangered Species Act, Section 7 Consultation process as it related to the USACE (Omaha District) is detailed in the 2003 USFWS Biological Opinion for the operation of the Missouri River (USFWS 2003). Management challenges for least terns also have been described in great detail (USFWS 1985; 1990a; 2003; 2005a, b; 2006). Research and monitoring needs have been articulated several times in collaborative settings (Guilfoyle et al. 2004; Lott and Pashley 2006; Martin et al. 2009; Guilfoyle and Fischer 2012). Hundreds of research papers, technical reports, master's theses, and PhD dissertations have been written on a huge variety of topics in locations and environmental contexts spanning the entire geographic range (see the bibliography link at http://leasttern.org). Also, population models have been applied in numerous contexts (Kirsch 1996; Akçakaya et al. 2003; National Research Council 2004; Lombard et al. 2010; Lott and Wiley 2012). These topics are discussed in more detail below.

Life History

Least terns are fish-eating birds that nest in open sandy areas and other bare ground areas along rivers and coasts. The population of least terns that nest on large rivers in the central United States is known as the Interior Least Tern (ILT) (Figure 2). Sandbars are the primary habitat component used for ILT nesting. When sandbars become covered in vegetation, they are no longer suitable for tern nesting. New habitat is formed when high water removes existing vegetation or deposits new sand, or when sand is deposited properly during the dredged material disposal process to create sandbars.

Figure 2. 2005 breeding distribution of the Interior Least Tern (ILT). See legends for colony types and river types. Numbers correspond to geographic segment numbers (From Lott 2006).



The ILT is found from the LMR, north to Montana along the Missouri River. The largest breeding populations occur on the LMR; along large Southern Great Plains rivers, particularly from the Arkansas, Cimarron, Canadian, and Red Rivers; southern portions of the Upper Missouri River and its tributaries – the Platte and Niobrara Rivers; and in Illinois, Kentucky and Indiana along the Wabash and Ohio Rivers.

The interior population is one of two geographically defined populations of least tern listed under the U.S. Endangered Species Act (ESA) as federally endangered (the other being the California Least Tern). The interior population was federally listed as endangered in 1985 because of suspected low numbers and concerns about breeding season habitat loss and degradation on large rivers of interior North America (USFWS 1990a). A recovery plan for ILT was published in 1990 that provided a summary of the known population size, identified suspected threats, and detailed delisting criteria (USFWS 1990a). This plan also outlined recovery strategies to increase the ILT population to approximately 7,000 adults throughout its range, and to maintain drainage-basin-specific target populations for 10 years. This number was quickly reached, possibly due to more intensive surveys, improved survey techniques, and a better understanding of tern colony locations, especially on the LMR (Kirsch and Sidle 1999). However, concern has persisted about population size goals for other drainages as set in the recovery plan, as well as the chronic threats posed to the ILT (see below). The USFWS completed its five-year review status update in 2013 for the ILT and recommended delisting due to recovery.

Distribution

Little is known about the historical distribution and abundance of ILT breeding along interior U.S. rivers. Least terns exploit early successional habitats along rivers for breeding, nesting, and brood-rearing, and then migrate long distances to winter mostly outside of the United States. The dynamic nature of rivers, which may flood during the nesting season one year, and experience drought the next, provide a highly variable set of nesting conditions for terns upon return from wintering grounds. This environmental variability necessitated that terns develop life-history strategies to cope with such stochasticity. These strategies include their relative longevity (with total lifespans as long as long as 20 years); reproductive lifespans ranging from age 2 or 3 to death (Thompson 1982, Thompson et al. 1997); their ability to renest after nest failure (which can increase recruitment following flooding and/or egg/chick predation), and a diet that can include a variety of fish species.

Today, there is much more extensive information regarding ILT distribution and abundance (Figure 2). A wide variety of federal and state agencies, universities, and non-governmental organizations have all conducted a myriad of research and monitoring activities throughout the range that provides a much clearer rangewide picture, much more so than even 10-15 years ago. In addition, tools such as the Cornell Laboratory of Ornithology eBird (www.eBird.org) portal are providing new information on least tern distribution from throughout the range that otherwise has been unavailable.

As a species, the least tern has a broad breeding distribution, with nesting records in 37 different U.S. states (Thompson et al. 1997, Pyle et al. 2001, Lott 2006, Marschalek 2010), along both coasts of Mexico and northern

Central America (Howell and Webb 1995), and many islands throughout the Caribbean (Thompson et al. 1997, Bradley and Norton 2009). Least tern breeding populations are nearly continuously distributed (with a few exceptions) from the Missouri River in Montana south through the Mississippi Valley (and its large western tributaries) along the entire Gulf of Mexico coast, west to Belize and east to Florida, up the Atlantic Coast from Florida to Maine, and throughout the Caribbean. Aside from California, coastal Least Terns are not federally listed under the ESA, although they are on several state lists of conservation concern (Thompson et al. 1997).

There are several ecological factors that likely have influenced the contemporary distribution and abundance of ILT. First, frequent flooding events, which either create habitat, or set back plant succession on sandbars (where the majority of nesting attempts take place), strongly influence ILT distribution (Sidle et al. 1992, Leslie et al. 2000). Second, ILT tend not to nest in proximity to tall vegetation (i.e., riparian forest) or other high features (USACE 2011a-Appendix B), or where channels become narrow (Jorgensen et al. 2012). Third, reduced availability of small fishes as forage throughout the breeding season may result in very low chick survival and render breeding habitat as poor quality. Fourth, changes to river systems both above and below reservoirs due to dam construction have resulted in hydrologic and sediment delivery alterations that have fragmented habitat — and subsequently — ILT drainage populations. Finally, in some locations, engineering practices have influenced distribution and abundance in a positive manner. For example, dike fields created by the USACE along the LMR designed to trap sediments and facilitate a self-regulating navigation channel have created habitat conditions (large sand accumulations behind dikes) that support the largest ILT population (by an order of magnitude) within their range (Lott 2006). Other types of nesting areas that were not historically available to ILT have also been exploited by the bird, such as reservoir shorelines, industrial sites, and dredged material deposition islands (Boylan et al. 2004; USACE 2011a, b; Fischer 2012).

The most comprehensive review of ILT distribution and population size was prepared by Mr. Casey Lott, American Bird Conservancy (ABC) under contract with USACE. Lott (2006) organized and synthesized the results of the only synchronized rangewide survey of ILT to date. Most recently, he has summarized changes in distribution knowledge during a rangewide ILT workshop in Alton, Illinois, April 2012. In brief, a 25-year data set strongly suggests ILT range expansion within and outside of areas occupied at the time of the 1985 listing; invasion and occupation of a number of types of anthropogenic habitats (i.e., reservoirs, rooftops, sand mines, industrial sites); and expansion of rangewide bird population estimates, from a low of ~2,000 at time of listing, to >17,500 in 2005 (Lott 2006). The synthesis also demonstrates that the ILT has met or exceeded rangewide numerical recovery criteria identified in the 1990 recovery plan (7,000 adult birds) for at least 18 years (1994-2012). ILT numbers essentially doubled from 1995 to the 2005 rangewide count (e.g., Lott 2006: 17,591 ILT rangewide).

Breeding and Nesting Habitat

Sandbars are the primary habitat component used for ILT nesting. Sandbars generally are not stable features of the natural river landscape, but are formed, enlarged, eroded, moved, or destroyed, depending on the dynamic forces of the river. New habitat is formed when high water removes existing vegetation or deposits new sand, or sand is deposited properly during the dredged-material disposal process to create sandbars. When sandbars become fully vegetated, birds will not select them for nesting (Thompson et al. 1997). Flooding can scour some vegetation from sandbars and convert them back to suitable nesting habitat, but at multiyear scales, if perennial woody vegetation becomes well-established and high flows can no longer remove vegetation, sandbars succeed to forest and permanently lose habitat value (Friedman et al. 1998, Johnson 2000, Wiley and Lott 2012).

Throughout much of the ILT range, the USACE is responsible for maintaining river navigation through practices such as dredging, dike construction, dredged-material disposal, and variable dam discharge actions (Fischer et al. 2004, Guilfoyle et al. 2004). These actions can have varying positive or negative effects on sandbar nesting habitat. Stabilization of major rivers for navigation, hydropower, irrigation, and flood risk management has destroyed, in large part, the dynamic nature of natural river processes (Smith and Stucky 1988). Many of the natural sandbars within the ILT range are unsuitable for nesting because of vegetation encroachment, or because they are too low and subject to frequent inundation. On the three major lock and dam navigation systems within the ILT range (McClellan-Kerr Navigation System on the Arkansas River, the Lower Ohio River Navigation System, and the J. Bennett Johnston Navigation System on the Lower Red River), ILT nesting occurs most frequently where regular dredging to maintain navigation depths results in dredged material disposal within dike-fields or confined disposal facilities (USACE 2005, 2011b) or on midchannel dredged material sites. While vegetation is often removed from dike-field disposal sites in AR due to flooding or large interannual stage differences that inundate bare sand areas for months at a time, dredged material sites with less dynamic flow regimes require regular vegetation control to persist as functioning nesting sites (USACE 2011b).

ILT also have nested on a variety of intentionally restored midriver sandbars (usually in response to regional habitat loss), such as those on the Platte, Missouri, and Canadian Rivers (Hill 1993, Plettner and Jenniges 1999, USACE 2011a- Appendix B, 2011b), and reproductive success has been highly variable on many of these sites (USACE 2011a-Appendix B, 2011b). On the Missouri River, the extremely long-duration floods of 1995-1997 created large amounts of bare sandbar nesting habitat, which quickly was degraded due to erosion and/or vegetation succession. Subsequently, sandbar construction below Gavins Point Dam began in 2004, leading to the creation of significant nesting areas for the regional ILT population. On the LMR, sand island ILT nesting habitat has been maintained by a natural flood hydrograph. While dike construction on the LMR was previously considered a potential threat to ILT (by increasing connectivity of islands to banks), higher elevations of the islands due to effects of the dikes has apparently benefitted the species. These benefits are being maintained and enhanced — where appropriate — by the USACE dike notching program.

Wintering

Though much is known about the life-history of least terns during the breeding season in North America, comparatively little is known about life-history, habitat, and threats during the non-breeding season when most individuals migrate to wintering areas outside of the United States. Least terns of unknown breeding populations are found during the winter along the Central American coast and the northern coast of South America from Venezuela to northeastern Brazil (USFWS 1990a).

Abundance

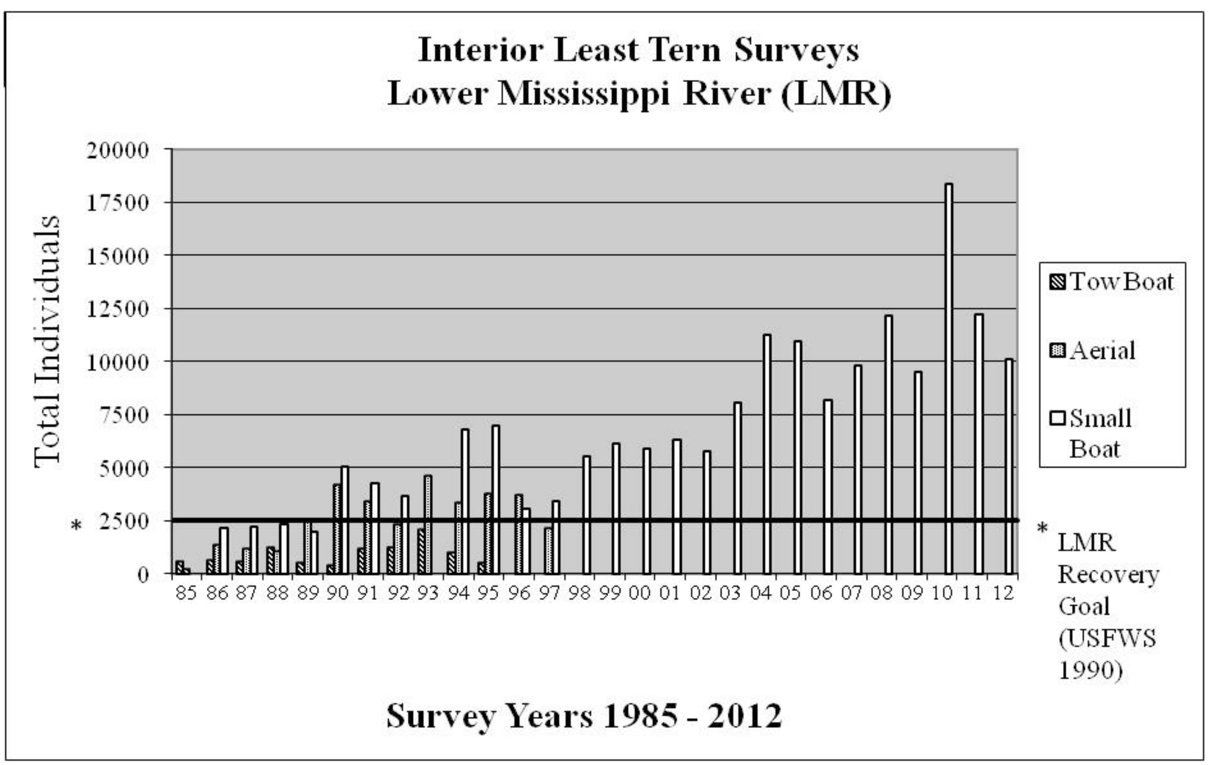
Since the initial listing of this species, knowledge, and understanding of the range and population demographics of ILT has grown considerably.

Increased monitoring efforts have revealed larger population numbers and a greater extent of overall distribution of this species than previously thought. In November 2005, ERDC-EL sponsored a regional workshop on monitoring programs for the ILT in Tulsa, Oklahoma. Discussions focused on: 1) defining goals and objectives for local, regional, and rangewide monitoring programs; 2) deciding what information to collect during monitoring programs; 3) standardizing data collection and analysis protocols among programs; 4) integrating local efforts into regional or rangewide approaches; and 5) evaluating the effects of management actions on ILT within the context of regional or rangewide recovery (Lott and Pashley 2006). Repeated efforts to standardize count protocol and data reporting since this meeting have mostly failed, although data reporting has increased in some areas. This failure has been driven, largely, by the need for individual monitoring programs to continue to supply data to local USFWS field offices in the format that was originally requested of them for Section 7 compliance. Since most ILT monitoring programs in districts and/or drainage basins have evolved independently, in the absence of communication among program participants, and without any incentive for collaboration, it has been difficult to encourage change among those involved in disparate monitoring programs, as individuals most often are compelled to stick to their unique regional protocols to be in compliance with biological opinions.

Although many ILT counts were conducted prior to 2005, regular survey coverage was incomplete across the large breeding range of ILT, limiting the ability to assess the conservation status or trends for this population. Because of the large number of programs collecting independent data on ILT (at least 29, reviewed in Lott (2006)), the ERDC-EL and ABC took the initiative to coordinate a rangewide survey during the last two weeks of June in 2005. Over 140 participants contributed to this survey, and ABC/ERDC raised additional funds, from the Tulsa District, to ensure counts were conducted in areas that are not covered by annual monitoring programs (Lott 2006). The primary objectives of this survey were 1) to provide a minimum count of the number of adult ILT occurring in North America during the breeding season; 2) to document the rangewide distribution of nesting colonies; and 3) to describe the types of habitats that are being used for nesting. Survey crews covered approximately 4,700 river miles, 22 reservoirs, 62 sand pits, 12 industrial sites, 2 rooftop colonies, and over 16,000 acres of salt flats, counting a grand total of 17,591 ILT in association with 489 different colonies. Just over 62 percent of all adult ILT were counted on the LMR (10,960 birds on 770+ river miles). Four additional river systems accounted for 33.3% of the remaining ILT, with 11.6% on the Arkansas River system (including the Canadian and Cimarron Rivers and the Salt Fork of the Arkansas River), 10.4% on the Red River system, 6.9% on the Missouri River system, and 4.4% on the Platte River system. Lesser numbers of terns were counted on the Ohio River system (1.0%), the Trinity River system in Texas (1.0%), the Rio Grande/Pecos River system in New Mexico and Texas (0.8%), the Wabash River System (0.6%), two reservoirs in East Texas (0.3%), and the Kansas River system (0.3 percent). A majority of adult terns were counted on rivers (89.9%), with much smaller numbers at sand pits (3.6%), reservoirs (2.5%), salt flats (2.3%), industrial sites (1.4%), and rooftops (0.3%).

Within the LMR, the USACE initiated annual nesting season tern counts between Cape Girardeau, Missouri, and Greenville, Mississippi, following the 1985 listing. The survey reach was extended downstream to Vicksburg, Mississippi, in 1988, and to Baton Rouge, Louisiana, in 2004. These counts have documented a persistent increase in the number of ILT known to utilize the LMR, from approximately 300 birds in 1985, to over 12,000 in 2011 (Jones 2011) (Figure 3).

Figure 3. Interior Least Tern Population Survey Results in the Lower Mississippi River, 1985-2012 (Mike Thron, USACE, Memphis).



After the 2005 rangewide survey, ABC and ERDC developed a flexible on-line data entry system for ILT surveys and encouraged partners collecting information on ILT to contribute their data. This database became the standard data entry platform for the Tulsa District's monitoring program (covering a large portion of the range of ILT), and resulted in the reporting of enough ILT counts in different areas to increase the understanding of rangewide distribution and abundance of ILT, beyond what was learned during the 2005 rangewide survey.

The ILT rangewide numerical recovery criterion (7,000 birds) (USFWS 1990a) has been met or exceeded each of the past 18 years (1994–2012). Using rangewide seasonal count data of adult ILTs from 1984 (722 terns) to 1995 (8,859 terns), Kirsch and Sidle (1999) demonstrated achievement of the numerical recovery criterion, and a positive rangewide population growth trend. They noted, however, that most of the ILT increase had occurred on the LMR. They also observed that population increases were not supported by available fledgling success estimates, and hypothesized that ILT increases were possibly due to immigration surges from a more abundant Eastern Gulf Coast least tern population.

Rangewide ILT counts doubled between 1995 and 2005 (e.g., Lott 2006: 17,591 adult ILT rangewide), and the majority of birds continue to be reported from the LMR (Lott 2006; ~62% of the 2005 rangewide count occurred in the LMR). Counts now equal or exceed population estimates for least tern along the U.S. Gulf Coast (Lott 2006). Lott (2006) noted marked declines in Gulf Coast least tern populations in recent years, and hypothesized a wider least tern metapopulation that includes Gulf Coast and ILT subpopulations, and the potential for significant immigration from the Gulf Coast inland due to high human disturbance along the coast and presence of better nesting conditions on the LMR. However, there are no data or observations directly supporting either the Kirsch and Sidle (1999) or Lott (2006) immigration hypotheses as possible factors in the 20+ year increase in ILT counts, either in the LMR or rangewide. Recent studies, however, have shown high genetic connectivity among groups of ILT inhabiting different drainage basins, as well as between interior and coastal populations (Draheim et al. 2010).

LMR Recovery Status

The 1990 delisting recovery criteria for ILT-specified protection and management of essential breeding habitats, a rangewide population of

7,000 birds, and population targets for five river drainages - Missouri, Mississippi, Arkansas, Red, and Rio Grande Rivers.

Habitat protection and management programs have been established across the ILT range over the past 20 years, primarily under section 7(a)(2) consultations. Current rangewide population estimates exceed 17,000 birds. The USFWS five-year review for the ILT in 2013 recommended delisting due to recovery.

Pallid Sturgeon

The pallid sturgeon (*Scaphirhynchus albus*) is a benthic, riverine fish that occupies the Mississippi River Basin, including the Mississippi and Missouri Rivers, and their major tributaries (i.e., Platte and Yellowstone Rivers), and the Mississippi's major distributary, the Atchafalaya River (USFWS 1990b). Pallid sturgeon (PS) belong to the family Acipenseridae (Actinopterygii: Acipenseriformes) and members of this order are often referred to as "living fossils" because of their prehistoric appearance and representation in the fossil record from the Cretaceous period of geological history (Hilton and Grande 2006). North American Acipenserids are represented in the fossil record from the pre-Pleistocene period (Hilton and Grande 2006). The PS was first described in 1905 by Forbes and Richardson as *Parascaphirhynchus albus*, but was later placed in the genus *Scaphirhynchus* (Forbes and Richardson 1905; Bailey and Cross 1954).

In 1990, the PS was listed as an endangered species under the Endangered Species Act of 1973 (USFWS 1990b). Its decline was attributed to several anthropogenic impacts, including habitat modification and commercial harvest of the fish (USFWS 1990b). More recent studies have added water contamination, entrainment, and hybridization to the list of impacts (Divers et al. 2009; USFWS 2009a; Blevins 2011; Schrey et al. 2011). A recovery plan, which listed recommendations and policy changes, was issued by the USFWS in 1993, and included a projected recovery date of 2040. The shovelnose sturgeon (*S. platorynchus*) is a sibling species to the PS and shares much of its range. The two species are morphologically similar, although the shovelnose sturgeon is more abundant than the PS (Kallemeyn 1983; Killgore et al. 2007a). To further protect the PS, the shovelnose sturgeon was listed as a threatened species under the Similarity-of-Appearance Provisions of the Endangered Species Act in 2010 (USFWS

2010b). This listing bans the commercial harvest of shovelnose sturgeon in areas where PS are known to occur (USFWS 2010b).

Habitat

Pallid sturgeon occupy the benthos of large, turbid rivers in North America, particularly the main channel (Kallemeyn 1983). Much of the natural habitat throughout the range of PS has been altered by humans, and this is thought to have had a negative impact on this species (USFWS 1993). Habitats were once very diverse, and provided a variety of substrates and flow conditions (Baker et al. 1991; USFWS 1993). Extensive modification of the Missouri and Mississippi Rivers over the last 100 years has drastically changed the form and function of the river (Baker et al. 1991; Prato 2003). Today, habitats are reduced and fragmented and much of the Mississippi River basin has been channelized to aid in navigation and flood risk management (Baker et al. 1991). The impact of habitat alteration on pallid sturgeon throughout its range is unknown, but recent studies have shown that in the unimpounded reaches, suitable habitat is available and a diverse aquatic community exists (USFWS 2007). River restoration plans in the Missouri and Mississippi rivers are currently in place, although it is unclear how much progress has been made (USFWS 2007).

Pallid Sturgeon are thought to occupy the sandy main channel in the Mississippi, Missouri, and Yellowstone Rivers most commonly, but they are also collected over gravel substrates (USFWS 1993; Bramblett and White 2001; Hurley et al. 2004; Garvey et al. 2009; Koch et al. 2012). Several studies have documented PS near islands and dikes, and these habitats are thought to provide a break in water velocity and an increased area of depositional substrates appropriate for foraging (Garvey et al. 2009; Koch et al. 2012). Increased use of side channel and main channel islands has been noted in spring, and it is hypothesized that these habitats may be used as refugia during periods of increased flow (Garvey et al. 2009; Koch et al. 2012). Recent telemetry monitoring of PS in the LMR indicates use of most channel habitats, including dikes, revetment, islands, secondary channels, etc. (Kroboth et al. 2013).

The PS occur within a variety of flow regimes (Garvey et al. 2009). In their upper range, adult PS are collected in depths that vary between 2-48 ft, with bottom water velocities ranging from 2 ft/sec and 3 ft/sec (USFWS 1993; Bramblett and White 2001; Gerrity 2005). Pallid Sturgeon in the LMR have been collected at depths greater than 65 ft, with a mean value of

33 ft, and water velocities greater than 6 ft/sec, with a mean value of 2 ft/sec (ERDC unpublished data, Kroboth et al. 2013). Turbidity is thought to be an important factor in habitat selection by PS, as they have a tendency to occupy more turbid habitats than shovelnose sturgeon (Blevins 2011). In the LMR, pallid sturgeon have been collected in turbidities of up to 340 NTUs, with a mean value of 90 NTUs (ERDC unpublished data).

Movement

The PS, like other sturgeon species, is a migratory fish species moving upstream annually to spawn (Koch et al. 2012). Movements are thought to be triggered by increased water temperature and flow in spring months (Garvey et al. 2009; Blevins 2011). Garvey et al. (2009) suggested that PS remain sedentary, or remain in one area for much of the year, and then move either upstream or downstream during spring. It is possible that because movement in large, swift rivers requires a great amount of energy, this relatively inactive period may be a means of conserving energy (Garvey et al. 2009). Most active periods of movement in the upper Missouri River (RPMA2) were between 20 March and 20 June (Bramblett and White 2001). In one study, individual fish traveled an average of 3.73 mi/day and one individual traveled over 9.94 mi/day (Garvey et al. 2009). The PS in the Missouri River have been reported as traveling up to 5.90 mi/hour and 13.30 mi/day during active periods (Bramblett and White 2001). The PS may undertake long-distance, multi-year upstream migrations or movements, based on recaptures of shovelnose sturgeon in the Missouri River that were originally tagged in the LMR. Upstream distances approaching 1245 mi have been recorded (ERDC unpublished data) and similar distances have been recorded for downstream movements (USFWS unpublished data, Kroboth et al. 2013).

Aggregations of PS have been reported in several locations in the middle Mississippi River, particularly around gravel bars, including one annual aggregation at the Chain of Rocks Dam, which is thought to be related to spawning activities (Garvey et al. 2009). Aggregations of PS in the lower 8.70 mi of the Yellowstone River are thought to be spawning areas for sturgeon from the Missouri River (Bramblett and White 2001). Pallid Sturgeon have been found to have active movement patterns during both the day and night, but move mostly during the day (Bramblett and White 2001).

Feeding

Sturgeon are benthic feeders and are well-adapted morphologically (ventral positioning of the mouth, laterally compressed body) for the benthic lifestyle (USFWS 1993; Findels 1997). Adult PS are primarily piscivorous (but still consume invertebrates), and are thought to switch from feeding primarily on invertebrates to piscivory at around age 5 or 6 (Kallemeyn 1983; Carlson et al. 1985; Hoover et al. 2007; Grohs et al. 2009). In a study of PS in the middle and lower Mississippi River, fish were a common dietary component and were represented primarily by Cyprinidae, Sciaenidae, and Clupeidae (Hoover et al. 2007). Other important dietary items for PS in the Mississippi River were larval hydropsychid caddisflies, mayflies, and true flies (Hydropsychidae (Insecta: Trichoptera), Ephemeridae (Insecta: Ephemeroptera), and Chironomidae (Insecta: Diptera)) (Hoover et al. 2007). The PS diet varies depending on season and location, and these differences probably are related to prey availability (Hoover et al. 2007). In a Mississippi River dietary study, Trichoptera and Ephemeroptera were consumed in greater quantities in winter months in the lower Mississippi River, while the opposite trend was observed in the middle Mississippi River (Hoover et al. 2007). Hoover et al. (2007) also found that in both the middle and lower Mississippi River, dietary richness is greatest in winter months.

Spawning

Freshwater sturgeon travel upstream to spawn between the spring equinox and summer solstice, and it is possible that either a second spawn or an extended spawning period may occur in the fall in southern portions of the range (i.e., Mississippi River) (USFWS 2007; Wildhaber et al. 2007). These spawning migrations are thought to be triggered by several cues, including water temperature, water velocity, photoperiod, presence of a mate, and prey availability (Keenlyne 1997; DeLonay et al. 2007; DeLonay et al. 2009; Blevins 2011). Gamete development is completed during the upstream migration and sturgeon are thought to spawn near the apex of their migration (Bemis and Kynard 1997).

It is thought that female *Scaphirhynchus* spp. do not reach sexual maturity until ages 6-17, with spawning taking place every 2-3 years. Males are thought not to reach sexual maturity until ages 4-9 (Keenlyne and Jenkins 1993; Colombo et al. 2007; Stahl 2008; Divers et al. 2009). The PS and shovelnose sturgeon at lower latitudes (e.g., lower Mississippi

River) may begin spawning at an earlier age than those in upper portions of the range (e.g., Upper and Middle Mississippi and Missouri Rivers) because they are thought to have shorter lifespans and reach smaller sizes (George et al. 2012). Also, LMR PS may be more highly fecund than those in northern portions of their range (George et al. 2012). It is thought that PS, like shovelnose sturgeon, spawn over gravel substrates, but spawning has never been observed in this species (USFWS 1993; DeLonay et al. 2007; DeLonay et al. 2009).

Early Life History

Pallid Sturgeon larval hatchlings are approximately ¼ inch in total length, and feed on yolk reserves and drift downstream with the river current for 11-17 days, until yolk reserves are depleted (Snyder 2002; Braaten et al. 2008; DeLonay et al. 2009). Length of drift and rate of yolk depletion are dependent on several factors, including water temperature, photoperiod, and water velocity (Snyder 2002; DeLonay et al. 2009). Larval drift is not completely understood and the impacts of artificial structures, as well as the role of eddies, are unknown (Kynard et al. 2007; Braaten et al. 2008). During drift, sturgeon repeat a "swim up and drift" pattern, in which they swim up in the water column from the bottom (<10 in) and then drift downstream (Kynard et al. 2002; Kynard et al. 2007). A hatchery series of shovelnose sturgeon from Louisiana (J. Dean, Natchitoches National Fish Hatchery, unpublished data) reports complete yolk sac absorption at days 8-9 posthatch, which is several days sooner than shovelnose sturgeon from Gavins Point National Fish Hatchery in South Dakota; thus, there could be a latitudinal difference in yolk absorption and larval maturation rates throughout the PS range (Snyder 2002). Exogenous feeding begins when yolk reserves are depleted and drifting has ceased, and timing can differ latitudinally (DeLonay et al. 2009). The switch from endogenous to exogenous feeding is known as the "critical period," because mortality is likely if sturgeon do not find adequate food (Kynard et al. 2002; DeLonay et al. 2009). Pallid Sturgeon begin exogenous feeding around 11-12 days posthatch in upper portions of their range, but exogenous feeding was observed in fish as small as 0.70 inches TL in the lower Mississippi River (Harrison et al. 2014), which could be as young as 6-8 days posthatch based on unpublished age and growth data from Natchitoches National Fish Hatchery (Braaten et al. 2007). The diets of young-of-year and juvenile PS and shovelnose sturgeon in upper portions of their ranges are much like those of the adult shovelnose sturgeon, and are primarily composed of aquatic insects and other benthic macroinvertebrates

(Braaten et al. 2007; Wanner et al. 2007; Grohs et al. 2009). Young-of-year and juvenile PS in the LMR feed primarily on Chironomidae over sand in channel habitats (Harrison et al. 2014)

Kynard et al. (2002) found larval PS to be photopositive with little preference for substrate color, except for a slight preference for light substrates when exogenous feeding began. It is thought that PS become increasingly photonegative starting around day 11 post-hatch (Kynard et al. 2002). In this same laboratory study, larval sturgeon swam in open habitats, seeking no cover under rocks in the swimming tube, and aggregated in small groups around days 3-5 post-hatching (Kynard et al. 2002). The black tail phenotype of young sturgeon is thought to aid in recognition and aggregation (Kynard et al. 2002). Pallid Sturgeon have been observed swimming and drifting at a wide range (2-118 in) above the bottom, depending on water velocities (although most fish are thought to say in the lower 20 in of the water column), and drift velocities are thought to range from 1-2 ft/sec (Kynard et al. 2002; Kynard et al. 2007; Braaten et al. 2008). Drift distance of larval sturgeon is thought to be between 86-329 mi (Kynard et al. 2007; Braaten et al. 2008). Juvenile PS have been found in water depths ranging an average of 8 ft in the upper Missouri River (Gerrity 2005). Maximum critical swimming speeds for juvenile PS range from 0.3 ft/sec to 0.8 ft/sec, depending on size, with larger juveniles (6-8 in TL) able to withstand higher water velocities than their smaller counterparts (5-6 in TL) (Adams et al. 1999).

Distribution and Abundance

Pallid Sturgeon occur in parts of the Mississippi River Basin, including the Mississippi River south of the Missouri River, and the Missouri, Atchafalaya, Yellowstone, and Platte rivers, where they are adapted to the premodification habitats of these systems (Kallemeyn 1983; Killgore et al. 2007a). Recovery efforts have divided the extensive range of PS into four management units (Figure 4) (previously six recovery priority management areas (RPMAs) (Figure 5)) (USFWS 1993 and 2013). These areas were selected as areas of high importance for recovery task implementation based on population variation (i.e., morphological, genetic) and habitat differences (i.e., physiographic regions, impounded, unimpounded reaches) throughout the extensive range of the PS (USFWS 1993). The Great Plains Management Unit (GPMU) extends from Great Falls of the Missouri River, Montana, to Fort Randall Dam, South Dakota, and includes the major tributaries thereof (Yellowstone, Marias, Milk

Rivers). The Central Lowlands Management Unit (CLMU) includes the Missouri River from Fort Randall Dam, South Dakota, to the confluence of the Grand River, Missouri, and includes the major tributaries thereof (lower Platte, lower Kansas Rivers). The Interior Highlands Management Unit (IHMU) includes the Missouri River from the confluence of the Grand River, Missouri, to the confluence of the Mississippi River, Missouri, and the Mississippi River from Keokuk, Iowa, to the confluence of the Ohio River, Illinois. The Coastal Plain Management Unit (CPMU) includes the Mississippi River from the confluence of the Ohio River, Illinois, to the Gulf of Mexico, Louisiana, and includes the Atchafalaya River distributary system, Louisiana.

Figure 4. Map depicting pallid sturgeon management units.

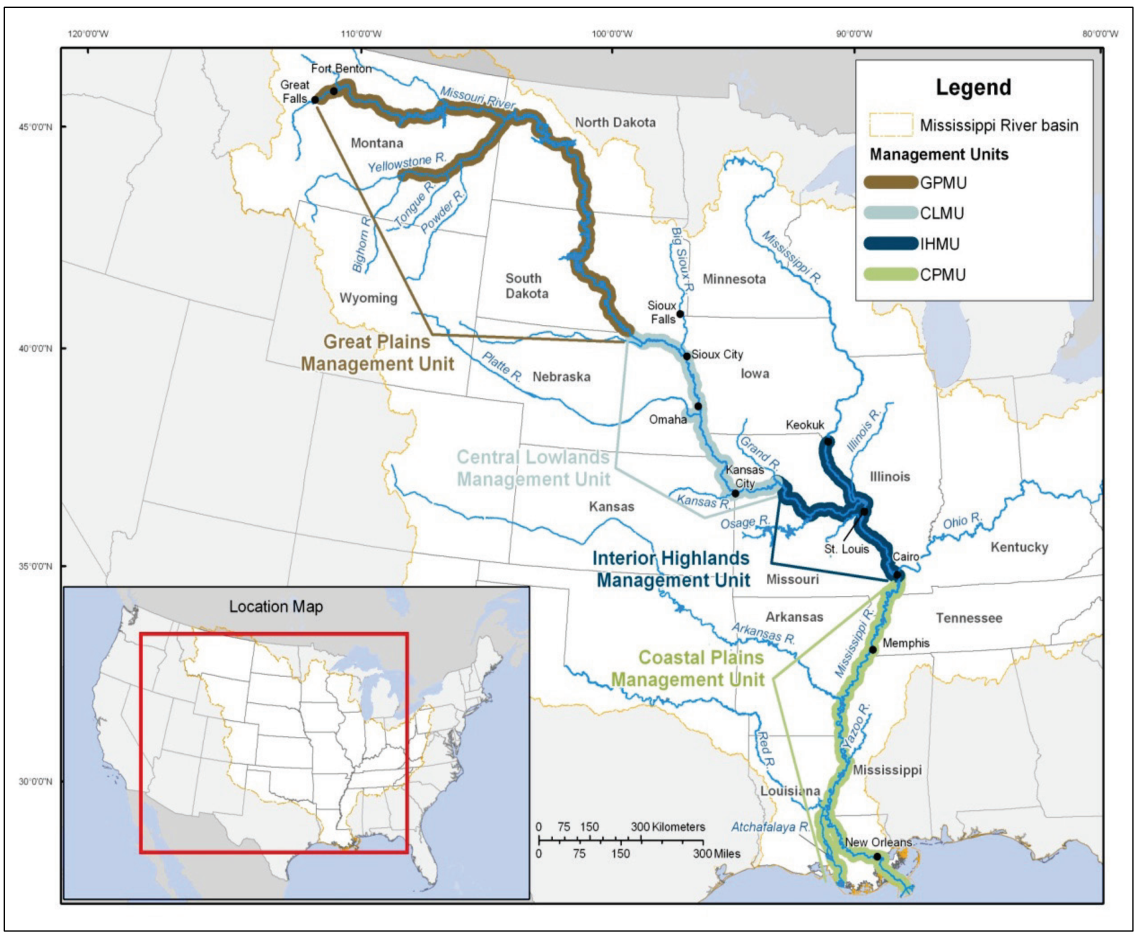
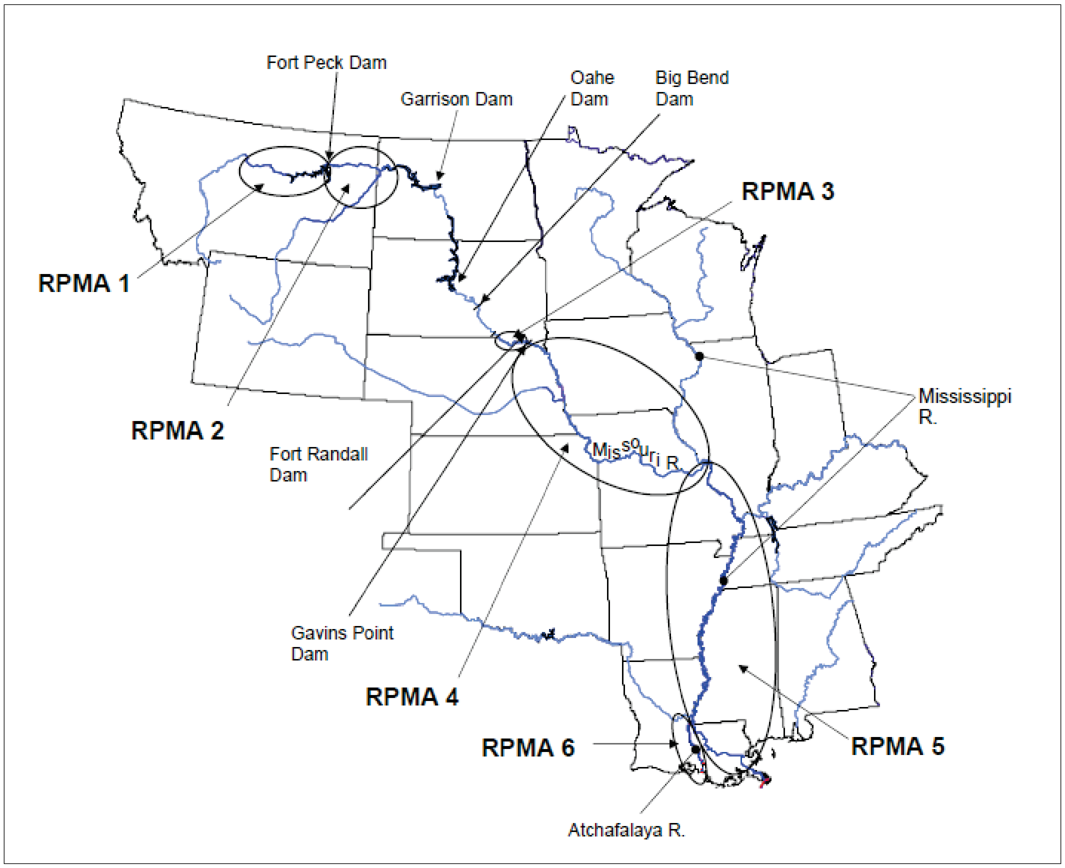


Figure 5. Map depicting PS range. Outlined areas correspond with approximate locations of RPMAs as designated in the initial PS Recovery Plan (USFWS 1993). Map not to scale. Source: Pallid Sturgeon 5-year Review (USFWS 2007).



Pallid Sturgeon differ in body size, age to sexual maturity, and population size throughout their range (Murphy et al. 2007; USFWS 2007). Pallid Sturgeon from the CPMU reach much smaller total lengths (typically <39 in TL) than PS from the GPMU; these PS are commonly reported as reaching lengths of >39 in TL (Brown 1955; Kallemeyn 1983; Keenlyne and Maxwell 1993; Bramblett and White 2001; Killgore et al. 2007b; USFWS 2007). This latitudinal difference in size has been attributed to shorter growing seasons in cooler water and the need for sturgeon in cold climates to allocate more energy (i.e., leading to larger bodies) for survival in a harsher environment (Killgore et al. 2007b). Conversely, some studies indicate that increased temperatures in the southern range of PS may shorten the growing season (Power and McKinley 1977; Conover 1990). Alternatively, it has been suggested that PS may use southern reaches of their range (i.e., middle and lower Mississippi River) for feeding habitat and as a growth period, and then migrate to more northern reaches (i.e., Missouri River and major tributaries) as adults for spawning habitat (Killgore et al. 2007b). Pallid

Sturgeon in the GPMU are also genetically distinct from PS in the CLMU and IHMU and the Atchafalaya River distributary (included in the CPMU) (Campton et al. 2000; Tranah et al. 2001). These differences highlight the importance of thorough research throughout the entire range of the PS.

Historical records of pallid sturgeon in the LMR are extremely rare, and the U.S. Fish and Wildlife Service (FWS) was able to document only 35 observations of the species from the entire Mississippi River (Keenlyne 1989); 28 of these from the LMR and none from the Atchafalaya River. Pallid sturgeon population size has not been quantitatively defined within the LMR, particularly considering the scope and scale of the available habitat to sample. However, in 2001, USACE initiated efforts to develop sampling methods for pallid sturgeon in the LMR, as well as studies on abundance, distribution, demography, and habitat use (e.g., Killgore et al. 2007a, 2007b; Hoover et al. 2007, etc.). These and other collections, as well as telemetry monitoring of sonic tagged individuals, have shown that pallid sturgeon occur throughout most of the 950 mile reach of the LMR (Bettoli et al. 2008, Killgore et al. 2007a; Kuntz and Schramm 2012), and the 200-mile reach of the Atchafalaya River (Constant et al. 1997; Herrala and Schramm 2010). Collections of pallid sturgeon in the LMR include almost 500 individuals collected between the mouth of the Ohio River and New Orleans, LA (Figure 6); no pallid or shovelnose sturgeon have been collected below RM 81 (Killgore et al. 2007a; Hartfield, in litt. 2001-2010; Kuntz and Schramm 2012) ranging in age from 0 – 21 years (50 to >800 mm fork length (Figure 7) (Killgore et al. 2007b). Over 600 pallid sturgeon ranging from 400 to >1000 mm FL have been collected from the Atchafalaya River distributary of the LMR (U.S. Fish and Wildlife Service 2007, Jan Dean, USFWS, pers. comm. 2009).

GPMU

The most recent available estimates suggest there are approximately 45 wild adult PS remaining in the most upstream portion of the GPMU (previously RPMA 1), which includes the Missouri River from the confluence of the Marias River to the headwaters of Fort Peck Reservoir, Montana. All are thought to be older adults (USFWS 2007). Natural recruitment is not thought to have occurred in this area over the last 20 years (Gerrity et al. 2008), so stocking of juveniles and larvae began in 1997 and continues today (USFWS 2007). In this region, PS are hatchery-reared from broodstock captured in the region at the Gavins Point National Fish Hatchery until age one and subsequently released (Gerrity et al. 2008).

Figure 6. Capture and telemetry locations of PLS in the LMR and Atchafalaya Rivers. Collection records were provided by ERDC and USFWS. Map developed by Mississippi Field Office, U.S. Fish and Wildlife Service.

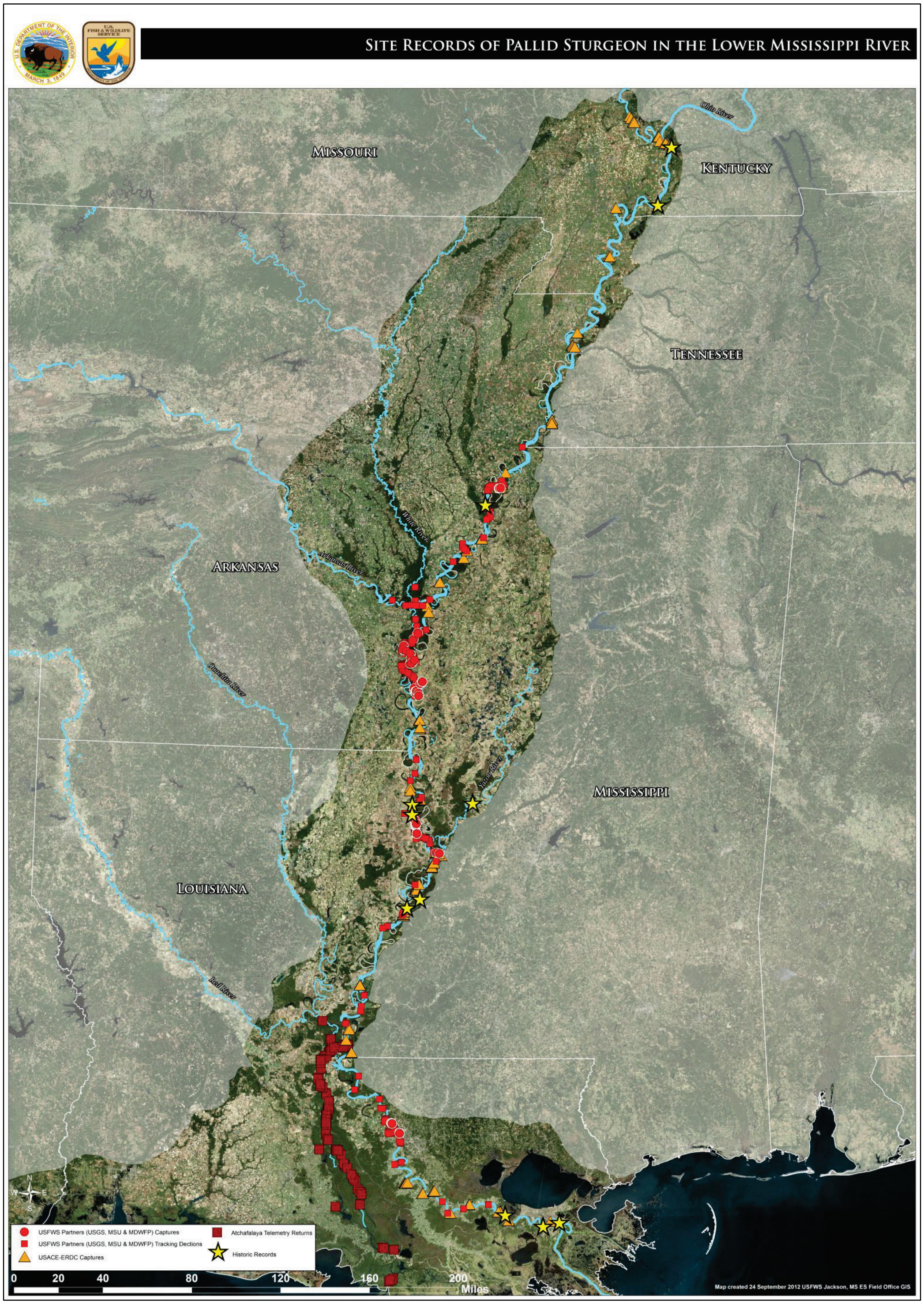
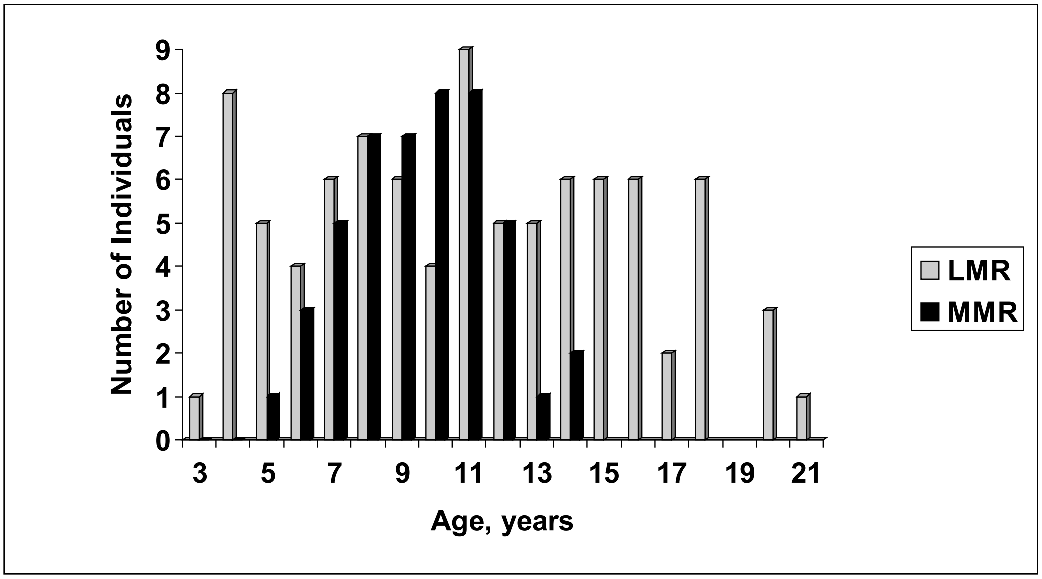


Figure 7. Age distribution of PS captured in the Lower (LMR) and Middle (MMR) Mississippi River (Killgore et al. 2007b).



Recent collection data reveal that stocking efforts are working to alleviate extirpation of the species in this section of the GPMA (USFWS 2007). Although historical population demographics from prealtered habitats are unknown, the PS population from downstream of Fort Peck Dam to the headwaters of Lake Sakakawea, North Dakota, and from the Yellowstone River below the confluence of the Tongue River, Montana (Previously RPMA 2), is thought to have declined by 40%-58% since the 1960s (Keenlyne 1989; USFWS 2007; Braaten et al. 2009). The latest estimates suggest that there are around 160 wild sturgeon remaining in this section of the GPMU, and that there is little to no natural recruitment (Klungle and Baxter 2005; USFWS 2007). Population estimates and forecasts suggest that natural populations in this section of the GPMU will be extirpated between 2016 and 2018 (Kapuscinski 2002; Klungle and Baxter 2005). However, stocking efforts are currently in place and hatchery-reared juvenile PS are being released until a population size of 1,700 individuals is reached (Braaten et al. 2009).

CLMU

There are no naturally occurring wild PS remaining in the most upstream portion of the CLMU, including the Missouri River downstream of Fort Randall Dam to Lewis and Clark Lake (formerly RPMA 3), so the entire population is made up of hatchery-reared fish and translocated wild PS (USFWS 2007). Stocking in this region began in 1997 and continues presently, and sturgeon sampling efforts have collected five out of six age classes that were stocked in this study area (Shuman et al. 2005).

A recent PS study conducted in a 50-mile reach of the lower Missouri River downstream from the confluence of the Platte River estimated a population size much higher than those in the GPMU (Steffensen et al. 2012). In this reach, 492 individuals (38 were recaptures) were collected between 2008-2010 (Steffensen et al. 2012). Of those, 93 were wild PS, and 399 were hatchery-reared PS (Steffensen et al. 2012). This count is slightly lower than the records from 1990-2005, which reported 117 unique wild PS from the Missouri River below Gavins Point Dam to the confluence of the Mississippi River (formerly RPMA 4)(USFWS 2007). It is currently unclear whether or not natural recruitment occurs in this study area (USFWS 2007).

IHMU

It is still unclear whether there is any natural recruitment in the lower Missouri River, from Gavins Point Dam to the confluence of the Mississippi River (Steffensen et al. 2010; USFWS 2007). Between 1994 and 2008, nearly 80,000 hatchery-reared PS had been released into the lower Missouri River, and as of 2008, only 1% had been recaptured (Steffensen et al. 2010). Wild PS are more frequently captured in the middle Mississippi River (MMR), which extends from the confluence of the Missouri River to the confluence of the Ohio River, than in the GPMU and CLMU. In a collaborative sampling effort between 2002 and 2005, researchers from the USACE, Missouri Department of Conservation, and Southern Illinois University, captured 148 PS, with only 12 fish of hatchery origin (USFWS 2007). In the MMR, the pallid: shovelnose sturgeon ratio ranges from 1:36 to 1:77 pallid: shovelnose (Killgore et al. 2007a). Age-0 PS have been collected in the MMR, although it is unknown where spawning occurs (Hrabik et al. 2007).

CPMU

Between 1996-2006, 162 PS were collected in the LMR, and >500 individuals have been captured to date (Killgore et al. 2007a, USFWS database 2013). Pallid: shovelnose ratios vary between 1:6 to 1:30 pallid: shovelnose (Killgore et al. 2007a). There is a relatively large population (1:6 ratio of pallid: shovelnose) of PS in the Atchafalaya River distributary than in other parts of the pallid sturgeon range, although it is still unclear whether or not natural recruitment occurs in this area (Killgore et al. 2007a; USFWS 2007). More than 600 PS have been captured and marked in the Atchafalaya to date (USFWS database 2013). Age-0 PS have been captured in the LMR, although it is unclear exactly where and when spawning occurs (ERDC, unpublished data; Hartfield et al. 2013).

LMR Recovery Status

The USFWS (1993) criteria to downlist PS from endangered to threatened include a population structure with at least 10% sexually mature females, and sufficient numbers in the wild to maintain population stability. USFWS (2007) conducted a 5-Year Review of the conservation status of the PS, including an assessment of status in each identified RPMA throughout its range. They identified a lack of adequate information on population size, recruitment, and trends in RPMAs 5 and 6 (Mississippi and Atchafalaya rivers, respectively), and the continued need for artificial supplementation efforts in RPMAs 1, 2, 3, and 4 (reaches of the Missouri River), concluding that the PS did not meet criteria for downlisting to threatened status or for delisting in any portion of its range. The 5-Year Review recommended revision of the PS Recovery Plan and criteria for recovery.

A draft revision has been released by USFWS (2013); the revision notes significant genetic structure through the range, redefines management units, and identifies the potential of delisting by management area. The primary strategy for recovery of pallid sturgeon is to: 1) conserve the range of genetic and morphological diversity of the species across its historical range; 2) fully quantify population demographics and status within each management unit; 3) improve population size and viability within each management unit; 4) reduce threats having the greatest impact on the species within each management unit; and, 5) use artificial propagation to prevent local extirpation within management units where recruitment failure is occurring. Pallid sturgeon recovery will require an improved understanding of the status of the species throughout its range; developing information on life history, ecology, mortality, and habitat requirements; improving our understanding of some poorly understood threat factors potentially impacting the species; and using that information to implement management actions in areas where recovery can be achieved.

Fat Pocketbook Mussel

The fat pocketbook mussel *Potamilus capax* is a freshwater pearly mussel native to the Ohio River system and Mississippi River drainage (Watters et al. 2009). Fat pocketbook mussels (FPM) belong to the family Unionidae, which is one of two families of pearly mussels that occur in North America (Watters et al. 2009). This species was originally described as *Unio capax* Green 1832, but was later placed in the genus *Potamilus* Rafinesque (Watters et al. 2009). This species is aptly named for its valve morphology, which is highly inflated and obovate (MMNS 2001; Watters et al. 2009). This species is relatively large, with adults sometimes reaching over 5 inches in length (USFWS 1989). The FPM was listed as endangered throughout its range by the U.S. Fish and Wildlife Service in 1976, and a recovery plan was issued in 1989 (USFWS 1976; USFWS 1989). The decline of the FPM has been attributed to several anthropogenic impacts, including water contamination and loss of habitat, particularly to perturbations associated with river navigation and flood risk management (USFWS 1989). Because its shell is too thin, this species is of no commercial value (Harris and Gordon 1990). An updated 5-year review reported that the FPM species status is improving based on increases of site records throughout its range (USFWS 2012b).

Habitat

FPM occupy depositional areas of large, slow-moving rivers, and museum records suggest that this species requires flowing water and stable substrates (USFWS 1989; Watters et al. 2009). This species is typically found in sand and silt substrates, but has also been collected in mud, clay, and fine gravel substrates in depths ranging from a few inches to ten feet in depth (Baker 1928; Parmalee 1967; Harris and Gordon 1987; USFWS 1989; Harris and Gordon 1990; USFWS 2012b). The FPM, which in some populations has a very thin shell, is able to survive in deep depositional areas of silt, and it has been suggested that prior to anthropogenic habitat alteration, this species was probably common in oxbows and sloughs (Miller and Payne 2005). In the lower Mississippi River, FPM have been found in sand in secondary channels and in a mixture of sand, silt, and mud in side channels (USFWS 2012b).

Movement

Freshwater mussels generally follow two movement patterns, vertical and horizontal, and movement is thought to be seasonal and/or related to reproduction or habitat suitability (Peck 2010). FPM populations threatened by habitat modification (e.g., dredging, channel maintenance, road/bridge construction) have been relocated to more suitable habitats (Peck 2010). After relocation, this species has a tendency to move less than do nonrelocated individuals (Peck et al. 2007). FPM have an average range of approximately 21 yd, but some individuals have been noted to move >165 yd (Peck et al. 2007). A 25-month telemetry study of the movement patterns of the FPM in Arkansas demonstrated that the average home range of this species is 117.0 yd, and most movements are downstream in unimpounded reaches (Peck 2010).

Feeding

Like other freshwater mussels, the FPM feeds by circulating water through its gills, removing particulate organic matter (Miller and Payne 2005; EPA 2007). It has been demonstrated that different bivalve species filter different sized particulate matter; although the specific diet of this species is unknown (Silverman et al. 1995).

Reproduction

Gravid FPM have been found between June and December, and this species is likely bradytictic (Baker 1928; Oesch 1984; USFWS 1989; Roe et al. 1997; Watters et al. 2009). Fertilization occurs in spring after sperm are released upstream of female mussels and are siphoned into the gills (Baldridge et al. 2007; USFWS 2012b). The posterior portion of the outer gills is the marsupial region in this species (Watters et al. 2009). Glochidia are packaged in white, fragile conglutinates (Utterback 1916). Glochidia are axe-head or hatchet-shaped, with hooks along the lateral margin of the ventral flange, and measure 0.105 x 0.185 mm (Utterback 1916; Oesch 1984). The only known host species for FPM is freshwater drum *Aplodinotus grunniens* Rafinesque, but the method of glochidial attachment remains unknown (Watters et al. 2009; USFWS 2012b). It has been suggested that glochidial attachment may occur upon ingestion of the gravid adult by the molluscivorous host (Dillon 2000; Barnhart et al. 2009). Fat Pocketbook Mussels less than 5 years in age have been collected in the St. Francis system, Arkansas, and in the LMR system, indicating successful reproduction and recruitment (USFWS 2012b).

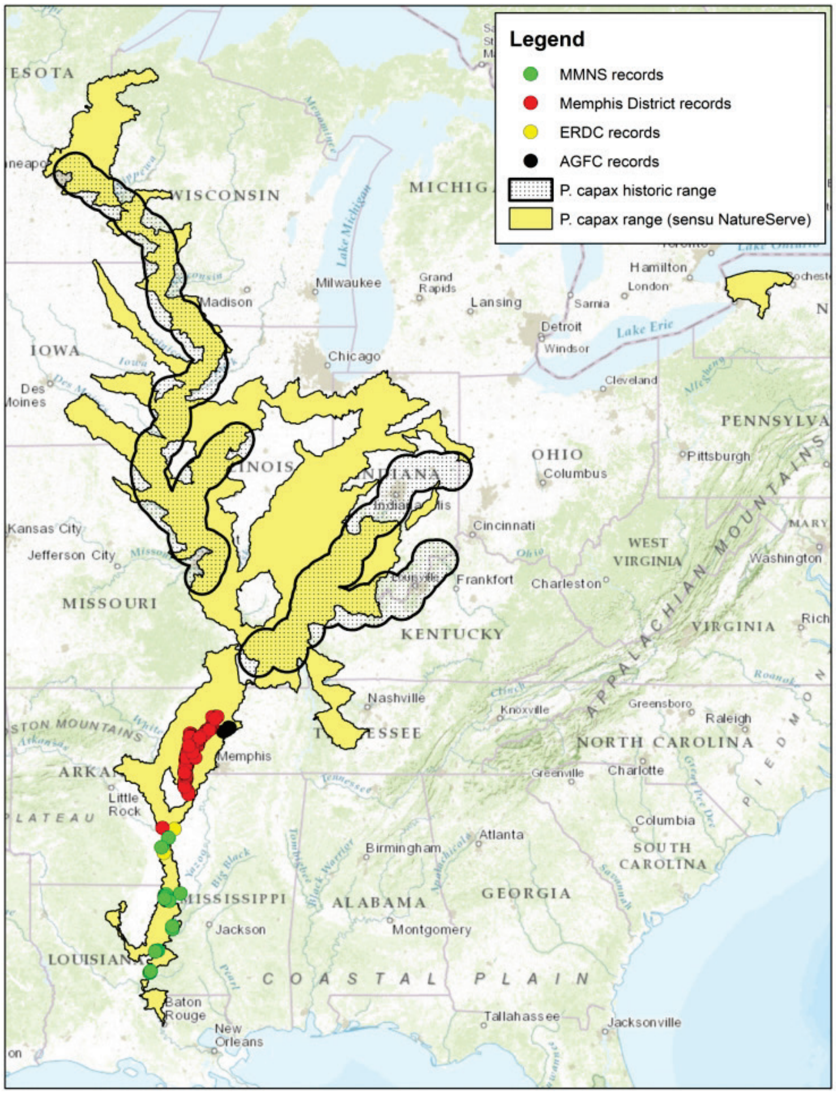
Distribution and Abundance

Historically, the FPM occurred in the upper Mississippi and Ohio rivers and the major tributaries thereof (Figure 8), but this range has declined by >70% (Harris and Gordon 1987; NatureServe 2012). There are museum records of FPM from the upper Mississippi River from the confluence of the Minnesota and St. Croix rivers to the White River, but this species has not been found there since the 1980s and is thought to have been extirpated from many of those sites (EPA 2007; NatureServe 2012; USFWS 2012b). At the time of listing, the FPM was only known from one locality, the St. Francis Floodway in Arkansas, and in 1989, an updated recovery plan was published with additional records from the St. Francis River and several small drainage ditches and tributaries (USFWS 1989, 2012b). Since 1989, additional FPM populations have been found in the St. Francis system, LMR, White, Ohio, Wabash, lower Tennessee, and Cumberland Rivers (Figure 8) (USFWS 2012b).

LMR Recovery Status

Recovery criteria require protection of the St. Francis River population of FPM, and location and protection of at least two additional viable populations in two other river systems within the historical range of the species. The Ohio River population has expanded in recent years, and a population has been discovered in the LMR. Both new populations are considered viable, based on the presence of juvenile and subadult specimens. Neither range nor population size of FPM have been defined or quantified in the Ohio and LMR; however, both populations are being considered by state and federal agencies during project planning, and are protected to some degree through formal and informal consultations.

Figure 8. Historical and present-day distribution of *Potamilus capax*. Collection records, both published and unpublished, provided by Mississippi Museum of Natural Science, Jackson, MS, USACE Memphis District, Memphis, TN, Arkansas Game and Fish Commission, Little Rock, AR, USACE-ERDC, Vicksburg, MS, and NatureServe Explorer.



5 LMR Environmental Baseline

Historical and Current Species Baselines in the LMR

Interior Least Tern

The historical distribution and abundance of ILT is poorly documented. Hardy (1957) reported the few documented ILT historical records of occurrence and nesting on the LMR, but surmised that the birds nested at many localities along the river. Downing (1980) reported 300 birds in 11 colonies during an aerial survey of the Mississippi River, and noted the greatest concentration of birds occurred between Osceola, Arkansas, and Cairo, Illinois. These primary historical sources of information were used to quantify a 1985 estimated population size of 350 to 400 adult ILT in the listing rule (50 FR 21789). The 1990 Recovery Plan utilized data from Sidle et al. (1988) and increased minimum LMR population estimate to ~2,300 adults (USFWS 1990a, b).

Nesting colonies have been monitored in the LMR for over 25 years (Figure 3) and data have shown a significant increase in ILT numbers since initiation of the Lower Mississippi River Environmental Program (LMREP) in 1982. Interior Least Tern are currently distributed along an 800-mile reach of the LMR between the confluence of the Ohio River and Baton Rouge, Louisiana. The population level has ranged from 8,000 – 18,000 birds over the past nine years, and the drainage basin recovery goal (2,500) has been exceeded for more than 20 years. Some proportion of the increase in adult ILT numbers has been attributed to improved survey efforts and efficiency (Lott 2006). Changes in survey methods utilized in the LMR and extending survey reaches correspond to some degree with higher ILT counts (Figure 3). The occurrence of large numbers of ILT within the LMR unimpounded navigation system has also been attributed, in part, to higher elevation sand and gravel bars associated with channel training dikes (Lott 2006).

USACE analyses indicate that habitat quantity has remained relatively stable and underutilized by breeding/nesting ILT for the past two decades (USACE 2008). The USACE is finalizing a habitat trend analysis of islands for the LMR (Guntren et al. in press). The LMR recovery goal (2,500 birds) has been exceeded every year since 1990. The range-wide ILT numerical recovery goal (7,000 birds) has been annually exceeded on the LMR alone since 2003 (Figure 3).

Pallid Sturgeon

The PS historical baseline in the LMR is undocumented. Prior to listing, collection records of PS in the LMR were extremely rare, and the USFWS was able to document only 35 observations of the species from the entire Mississippi River (Keenlyne 1989); 28 of these from the LMR, and none from the Atchafalaya River. Pallid Sturgeon population size has not been quantitatively defined within the LMR, particularly considering the scope and scale of the available habitat to sample. However, in 2001, USACE initiated efforts to develop sampling methods for PS in the LMR, as well as studies on abundance, distribution, demography, and habitat use (e.g., Killgore et al. 2007a, b; Hoover et al. 2007, etc.). These and other collections, as well as telemetry monitoring of sonic tagged individuals, have shown that PS occur throughout most of the 950-mile reach of the LMR (Bettoli et al. 2009, Killgore et al. 2007a, Kroboth et al. 2013, USFWS database 2013), and the 200-mile reach of the Atchafalaya River (Constant et al. 1997, Dean in litt. 2005-2009, Herrala and Schramm 2011, USFWS database 2013). Collections of PS in the LMR include almost 500 individuals collected between the mouth of the Ohio River and New Orleans, Louisiana (Figure 6)(Killgore et al. 2007a; USFWS database 2013), ranging in age from 0 – 21 years (50 to >1,000 mm fork length (FL)) (Killgore et al. 2007b, USFWS database 2013). No PS or shovelnose sturgeon have been collected below RM 81 (Killgore et al. 2007a; Hartfield, in litt. 2001-2010; Kroboth et al. 2013). Over 600 PS ranging from 400 to >1000 mm FL have been collected from the Atchafalaya River distributary of the LMR (USFWS database 2013).

Although PS population size in the LMR has not been quantified, available data suggest a substantial population when compared to fishing effort and fish species composition. Killgore et al. (2007a) found that PS comprised 2.2% of fish captured on winter set trotlines, and ranked 5th in frequency of capture out of 22 species collected. During two years of trotline sampling at Vicksburg and Tunica, Mississippi, PS comprised 2.4 and 2.5%, respectively, of fish collected at both locations, and ranked 4th in frequency of capture out of 11 species collected (Aycock et al. 2012). Recaptures of PS are also rare in the LMR. Killgore et al. (2007a) reported only five PS recaptures over seven years. In another study that conducted two years of monthly PS collection and telemetry efforts in a 30-mile reach of the Mississippi River, only a single PS recapture occurred out of >60 PS collected, tagged, and released, even though telemetry results indicate most PS remained within the sample reach (Kroboth et al. 2013).

There is also evidence that the LMR PS population can sustain removal of substantial numbers of individuals from the population. Bettoli et al. (2009) conservatively estimated that 2% of the commercially harvested sturgeon in the Tennessee reach of the LMR were PS (169 females over two seasons). Commercial harvest for sturgeon caviar has occurred annually in the Tennessee and Missouri reaches of the LMR for more than two decades. While baseline data on LMR PS is lacking, the persistence of the species following more than two decades of harvest pressure on mature PS females suggests the population is relatively robust.

Additional evidence of population size has recently been developed in association with evidence of persistent and periodic entrainment losses of LMR PS. During an emergency opening of the Bonnet Carre Spillway in 2008, the USACE and USFWS estimated up to 92 PS were injured or killed due to entrainment (USFWS 2009a). Bonnet Carre has been opened four times since the species was listed (1994, 1997, 2008, and 2011). Pallid sturgeon are freshwater fish, and once entrained, their only choice is to move into the brackish waters of Lake Pontchartrain where they likely perish or move up to the structure as the water recedes where they may be rescued as was done in 2008 and 2011. Other diversion structures that have been operating for one to five decades (Old River Control Complex, Davis Pond) are also known to entrain PS. Pallid sturgeon entrained at Old River Control Complex enter the Atchafalaya River, but it is unknown if these fish can spawn in the relatively short reach (137 river miles) between the structure and the Gulf of Mexico near Morgan City, Louisiana. It is also unlikely that pallid sturgeon can swim from the Atchafalaya River back into the Mississippi River due to head differential through the diversion structures. While episodes of commercial harvest or entrainment constitute substantial periodic or continuous localized loss of individuals to the PS population within the specific river reaches, scientific collection efforts indicate the species has persisted within the commercially harvested and diversion reaches of the LMR (e.g., Killgore et al. 2007 a, b; Kroboth et al. 2013).

LMR PS population demographics have been poorly defined but recruitment has been documented by capture of multiple age classes (Figure 7, Killgore et al. 2007a) and capture of larval PS at several locations between the confluence of the Ohio River and Vicksburg, MS. Adult PS annual mortality is low (<12%) in the LMR, compared to the Middle Mississippi River (>35%) (Killgore et al. 2007b), where commercial fishing was just recently banned (USFWS 2010b). There are latitudinal morphometric variation and length-at-age differences across the range (Murphy et al. 2007), suggesting that management goals should be reach-specific. Specific spawning and rearing habitats for PS are poorly known but are surmised to include gravel bars (for spawning) and secondary channels and flooded sand islands (for larval and juvenile recruitment). Telemetry studies in the LMR have shown larger size classes of PS use multiple channel habitats, including point bars, secondary channels, crossovers, wing dikes, island tips, natural banks, and revetted banks (Kroboth et al. 2013).

Fat Pocketbook Mussel

There are no historical records of FPM from the CIP footprint (i.e., active channel) in the LMR (Figure 8). Recent collections of FPM from the LMR indicate a widespread population (Figure 9), but intense sampling efforts are needed to assess abundance in this region. Most of the LMR collection records are from secondary and side channels along the river, particularly Gilliam Chute, in Jefferson County, Mississippi (Figure 10) (USFWS 2012b). Specimens have also been collected at St. Catherine's Creek National Wildlife Refuge. A single young individual was collected in a trawl sample below a chevron dike, Bolivar County, Mississippi. Live and fresh dead specimens have been collected from secondary channels between River Miles 410 – 800, but sampling has been insufficient to determine whether and where viable populations occur in the river.

Factors Affecting Species

Several concerns have been identified for the priority species in the LMR (USFWS 1989, 2007, 2012c). These include: habitat loss and modification for all three priority species, human disturbance to ILT nests and chicks, commercial harvest of PS, dredge entrainment of PS, sand and gravel mining entrainment and spawning habitat degradation, entrainment of PS through water control structures, effects of pollution and contaminants on all three species, and hybridization of PS with shovelnose sturgeon. Ongoing and proposed actions required to fully assess these factors are identified below.

Figure 9. Collection sites of *Potamilus capax* in the lower Mississippi River and some tributary watersheds. Collection records provided by Mississippi Museum of Natural Science, Jackson, MS, USACE Memphis District, Memphis, TN, USACE-ERDC, Vicksburg, MS, and Arkansas Game & Fish Commission, Little Rock, AR.

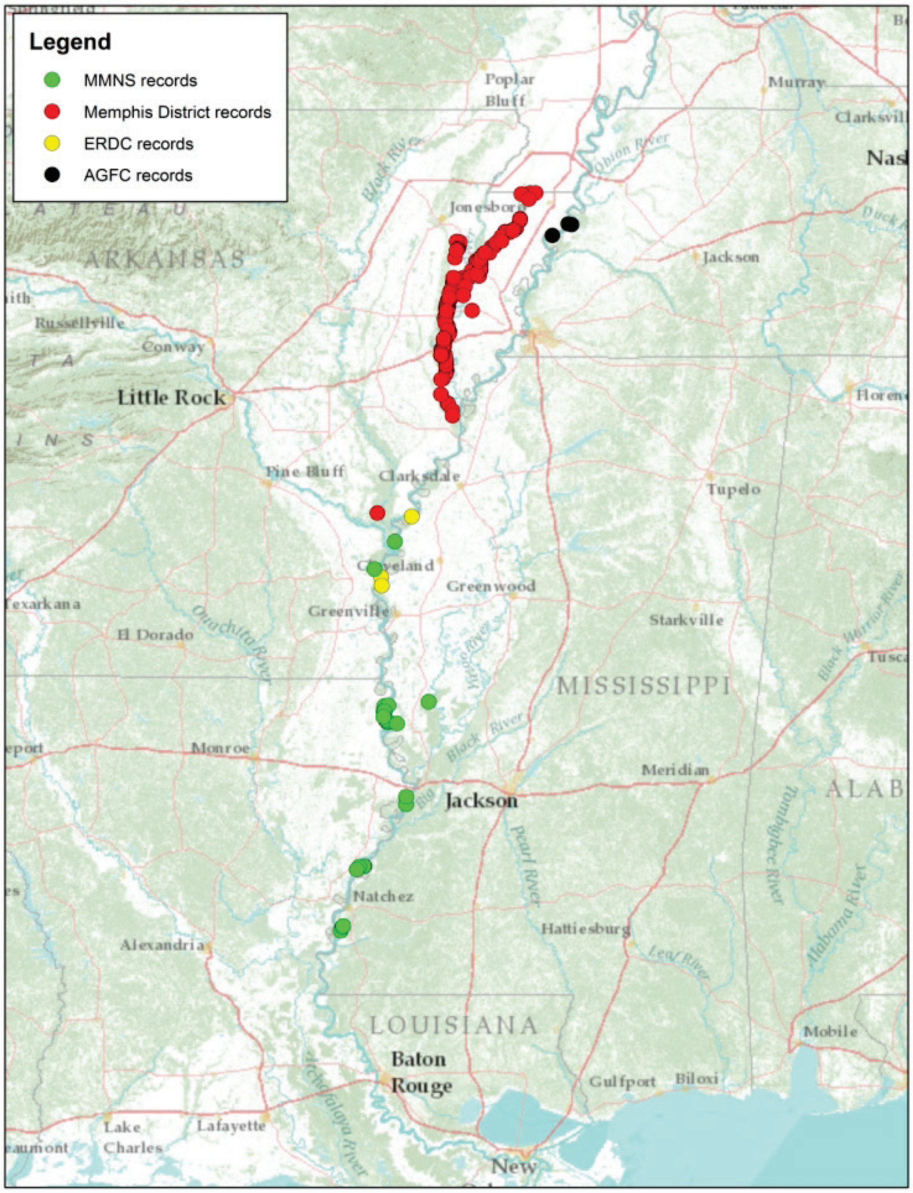
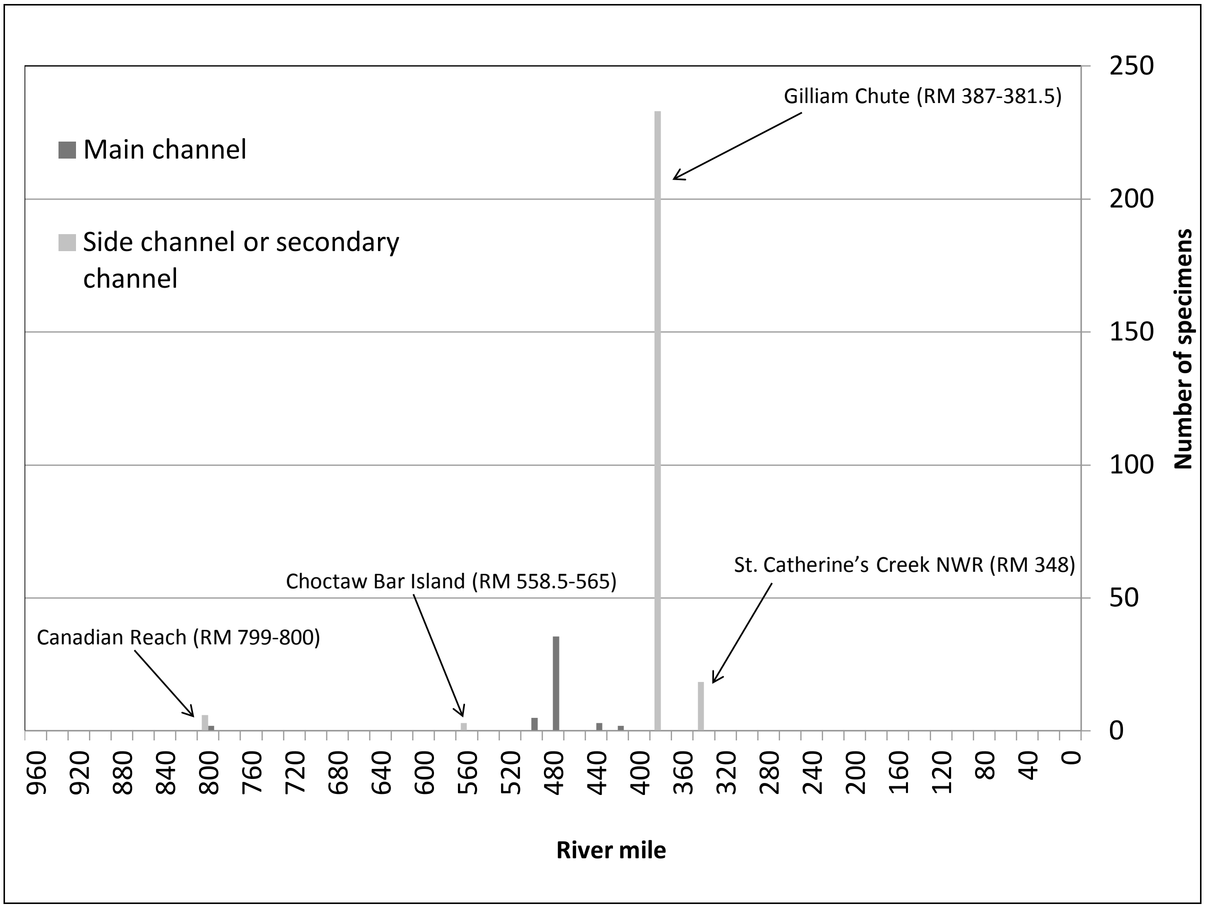


Figure 10. Collections of *Potamilus capax* in the Lower Mississippi River, including specimens collected in the Mississippi River main channel, side channels, and secondary channels. Data from ERDC.



Habitat Loss and Modification

While it is likely that habitat modification has the potential to seriously affect all three priority species, there is little evidence of direct impacts in the LMR: i.e., knowledge and numbers of PS and ILT have increased relative to historical premodification conditions, and the occurrence of FPM was first documented from the LMR postmodification.

Appropriate habitat for PS is generally characterized as large, deep, turbid, fast, and free-flowing rivers, with spawning migration and success linked to seasonal high flow events common to a natural hydrograph. These characteristics are common in the LMR throughout nearly all of its length. The LMR appears to contain the most extensive and possibly the best quality habitat within the species' range, including complex channel habitats, numerous secondary channels and islands, and widespread gravel bars suitable for spawning. While the location and complexity of channel habitats has been modified over time by river engineering under the CIP, the potential adverse effects on PS recruitment are poorly documented or understood.

Habitat loss and modification does not appear to be a factor affecting either ILT or FPM in the LMR. As noted previously, potential LMR nesting habitat for ILT currently exceeds use by the species. The expansion of the FPM range into LMR secondary channels appears to result from recent exploitation of developing habitat conditions created within USACE dike fields; however, this is poorly documented and understood.

Maintenance Dredging

Maintenance dredging of the navigation channel is required in the LMR navigation channel, particularly within crossovers and harbors at low river stages. Dredging has been shown to take shovelnose sturgeon in the Middle Mississippi River (MMR), suggesting some level of take of PS may be occurring through dredge entrainment in the LMR. However, entrainment risk may be reduced in the LMR relative to the MMR due to the larger LMR channel and complexity. Furthermore, entrainment risk varies depending on type of dredge (cutter head, hopper, mechanical), the habitat being dredged, and size-dependent swimming capability of sturgeon (Hoover et al. 2009; Hoover et al. 2011). Dredging near nesting sandbars can disrupt ILT nesting activities. Although mussels can be subject to dredge entrainment, habitats where FPM have been found in the LMR are not subject to dredging; therefore, dredge entrainment is not considered a factor affecting FPM in the LMR.

Water Diversion Entrainment

Entrainment of PS through water control and floodway structures (i.e., Bonnet Carre floodway, Davis Pond, and the Old River Control Complex (ORCC)) is known to occur in the LMR. Water control and floodway structures are separate issues from the CIP, and are not covered under this conservation plan. The USACE has consulted with the USFWS over the 2008 spillway operation of Bonnet Carre and the proposed construction of two new diversion structures, White Ditch and Convent/Blind River. Biological Opinions have authorized take resulting from the emergency operation of Bonnet Carre, as well as possible future take of PS at the two planned structures (USFWS 2009a, 2009b, 2010a). Emergency consultations for Morganza and New Madrid floodways that were operated during the 2011 flood were also completed. The USACE and USFWS need to complete formal consultations over entrainment of this species at Davis Pond, Caernarvon, ORCC, and other proposed structures. Entrainment studies at LMR diversions, excluding ORCC but including Bonnet Carre and Davis Pond, have been completed by ERDC. The final report will document sturgeon entrained through existing diversions, document sturgeon occurring in the Mississippi River near the vicinity of existing diversions, and present population viability models for risk analysis. Results of these studies will be used to quantify entrainment of PS and shovelnose sturgeon at diversions over the project life. Localized entrainment losses will be weighed against population size and recruitment levels of PS throughout the LMR. The USACE is working to identify engineering designs to minimize entrainment losses through water control structures and has conducted rescue and recovery efforts to minimize PS population impacts due to floodway operations.

Sand and Gravel Mining

Regulatory branches of the USACE issue permits for sand and gravel mining dredging in the LMR. Regulatory issues are not directly related to the CIP and are not addressed under this conservation plan. Mississippi Valley Division sand and gravel dredging permits require avoidance of ILT nesting colony disturbance by maintaining buffers from nesting sites; permits also prohibit mining within all dike fields and secondary channels, the habitats occupied by FPM.

The USFWS has expressed concerns that permitted commercial mining dredges in the Mississippi River can entrain PS and degrade gravel bars where sturgeon spawn. The ERDC has conducted multiple studies on sturgeon susceptibility to sand and gravel dredges (ERDC-EL 2009) and provided the following information:

1. A chronology of sturgeon life history stages was compiled by sampling the temporal occurrence of larvae, juvenile, and adults using Missouri trawls. Application of these data can establish operating windows when dredges would have minimal impacts on spawning adults and young-of-year.
2. Entrainment of sturgeon was directly assessed during dredging operations by sampling dredged material and overflow, and field sampling for sturgeon in the vicinity of an active dredge. No sturgeons were collected.
3. Measurements of swimming performance by different size classes of sturgeon were conducted and compared to suction velocities created by

dredges. Data provided quantitative assessment of risk for young-of-year sturgeon of different sizes.

An initial survey of gravel bars in the LMR was conducted by ERDC (D. Biedenharn and M. Corcoran) and maps developed of their locations. Further potomological studies are necessary to fully evaluate effects of sand and gravel dredging on protected species. A Biological Opinion was recently completed by the USFWS with special conditions applied to the permits to avoid potential impacts to the species and requires permittees to submit post dredging reports to USACE and USFWS each calendar year (USFWS 2014).

Commercial Harvest of Pallid Sturgeon

Commercial harvest of sturgeon for caviar and smoked flesh has occurred to various degrees in the LMR since the 1800s. Harvest for shovelnose sturgeon has been closed for over a decade in the Arkansas, Mississippi, and Louisiana reaches of the LMR; however, harvest of shovelnose sturgeon for caviar has increased in the LMR reaches of Tennessee, Kentucky, Missouri, and Illinois where they co-occur with pallid sturgeon. Based on data that indicated significant numbers of mature female pallid sturgeon were being taken during commercial harvest of shovelnose sturgeon in the Tennessee reach of the LMR (Bettoli et al. 2009), and high mortality of PS in reaches where commercial harvesting was still legal (Killgore et al. 2007b), USFWS listed the shovelnose sturgeon within the sympatric range of PS as threatened due to similarity of appearance (USFWS 2010b). This action effectively eliminated the loss of PS to commercial caviar harvest in the LMR and MMR.

Pollution and Contaminants

Pesticides and heavy metals have been detected in the tissues of sturgeon throughout the United States and could potentially affect all three priority species to varying degrees. These contaminants cause reproductive failure and population declines, and pose potential health risks to consumers of sturgeon meat and caviar. Shovelnose sturgeon in the Mississippi and Missouri Rivers have been found with high levels of DDT and chlordane and hermaphroditic individuals have been observed (Ruelle and Keenlyne 1993), suggesting that contaminants could impact PS to some degree. However, DDT levels reported by Ruelle and Keenlyne (1993) are not likely to be present today due to the degradation of the compound. While water quality has improved in the LMR since implementation of the CWA, historical and recent water quality data for the LMR needs to be analyzed to determine the significance and trends of pollution and contaminants in the LMR. Although pollution and contaminants are not directly related to the CIP, under some conditions contaminants may be resuspended by dredging activities in contaminated sediments. The LMR is a dynamic channel constantly moving and mixing large quantities of sediment through the system. There is no indication that sediments within crossovers frequently dredged by USACE under the CIP contain contaminant levels above those considered safe by EPA.

Hydrokinetics

Applications have been made to utilize the LMR for power generation using hydrokinetic technology. Effects of hydrokinetic turbines on PS are currently undefined; however, there is potential of injury or mortality from turbine blade strikes, as well as potential behavioral effects due to electromagnetic fields and noise. USACE Mississippi River fishery data — as well as USFWS/USGS telemetry data — are being used by hydrokinetic developers to identify potential impacts to PS and other fish resources. The ILT and FPM are unlikely to be directly affected by hydrokinetic turbines; however, infrastructure sighting has the potential to affect these species or their habitats. Hydrokinetic turbines are not part of CIP, and their potential effects are the responsibility of the applicant and the Federal Energy Regulatory Commission.

Hybridization of Pallid and Shovelnose Sturgeon

Hybridization with shovelnose sturgeon has been identified as a threat to PS in the LMR. This hybridization was initially believed to be caused by a loss of species isolating mechanisms due to river engineering and habitat modifications. However, neither the mechanisms nor the essential habitat features have been identified. There is morphological and genetic evidence that some proportion of these “hybrids” are morphological variants of both species and have been misidentified due to allometric growth of PS (Murphy et al. 2007). There is also evidence that morphological and genetic variation interpreted as hybridization existed in LMR sturgeon populations prior to — and are unrelated to — engineered modification of the LMR (Hartfield and Kuhajda 2009, Schrey et al. 2011). Genetic and morphological studies are in progress to improve and standardize identification of river sturgeon in the LMR, and determine the significance and possible trends of hybridization as a threat to PS in the LMR (USFWS *in litt*. 2011).

6 Effects Analysis

Effects of the Program

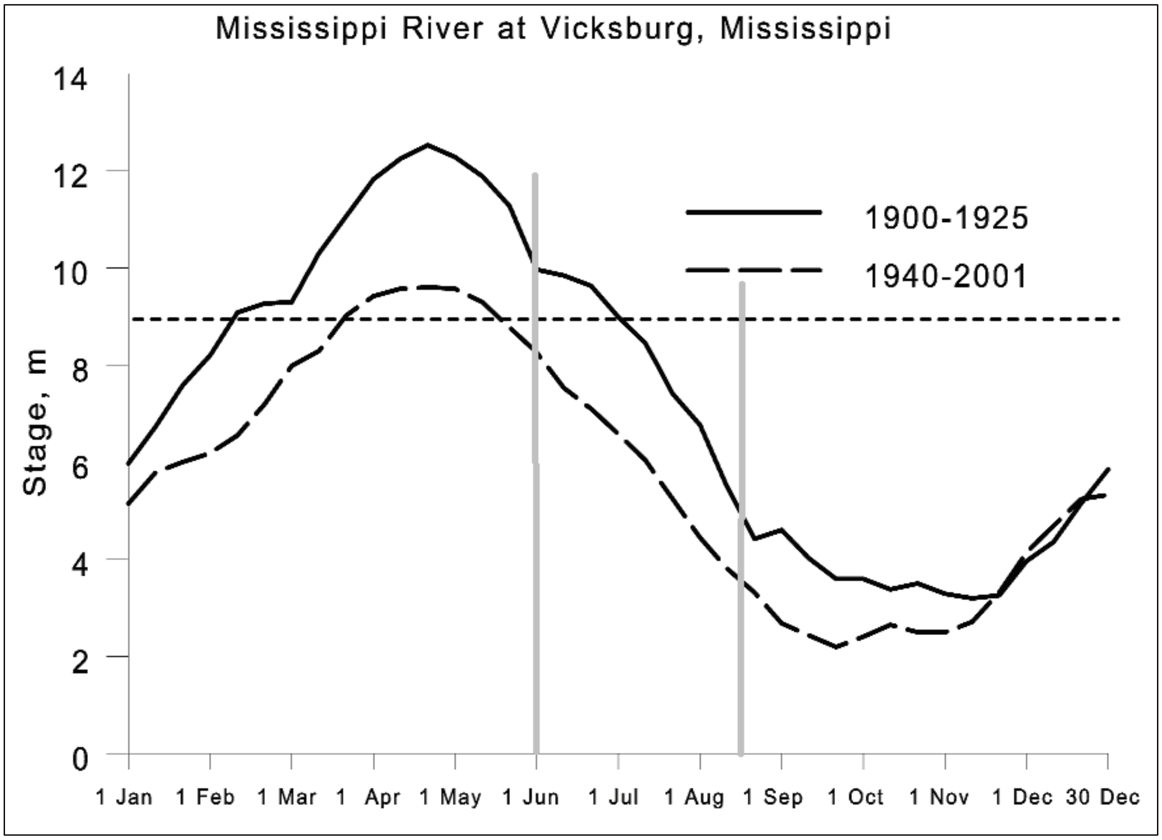
Bendway cutoffs constructed between 1929 and 1960 under the MR&T shortened the river by >150 mi (Winkley 1977). Since 1960, channel engineering conducted under the CIP has resulted in a loss of secondary channels and associated habitats (Guntren et al. in press; Williams and Clouse 2003). Therefore, the primary environmental effects of the MR&T and CIP have been the physical loss of LMR channel habitat quantity, a growing disconnect with the relict floodplain during low to moderate river stages, and a general loss of riverine habitat complexity (i.e., diversity). The responses of ILT, PS, and FPM to the effects of the CIP are evaluated below.

Interior Least Tern

There are currently no data that indicate habitat loss due to the CIP is a limiting factor for ILT in the LMR. In fact, the data suggests that overall, the ILT response to the conditions resulting from the CIP has been positive. Interior Least Tern population size has increased from a historical baseline of fewer than 500 birds, to a current baseline of ~10,000 or more breeding birds per season (see Figure 3, above). Direct causes of the population increase are not understood; however, they may be related, at least in part, to: 1) earlier and extended breeding potential due to more efficient movement of flood flows through the system (including effects of tributary impoundment and engineering) (e.g., Schramm 2004; see Figure 11); 2) higher sandbars associated with dike fields (e.g., Lott 2006); 3) dike notching and avoidance work windows implemented by the USACE under the LMREP; and/or 4) migration of coastal breeding colonies due to better nesting and forage conditions along the LMR (e.g., Lott 2006).

Human activities near nesting sandbars can disrupt ILT nesting activities. The USACE maps ILT nesting sites and maintains 1,500-ft buffers between dredging sites and nesting sandbars during CIP construction activities in the nesting season. This distance exceeds most recommendations for buffers between waterbirds and human activities (Valente and Fischer 2011).

Figure 11. Example of the reduction in average river stage (LWRP) resulting from river engineering (1940-2001), providing prolonged periods for ITL nesting due to greater availability of emergent sandbars. Dashed horizontal line represents near bankfull stage. Perpendicular line represents least tern nesting season. Based on Schramm (1994).



Terrestrialization of islands and sandbars (i.e., vegetation encroachment and accretion with the river bank) associated with dike fields has been identified as a negative factor affecting ILT. However, actions such as dike notch construction under the CIP are being increasingly utilized to sever land-based routes used by ATV recreationists and terrestrial predators to access ILT nesting colonies.

While habitat quantity and condition are not factors currently considered to be negatively affecting ILT in the LMR, USACE-MVD and districts have been actively working with partners to restore degraded secondary channels and their associated islands and bars. These activities are protecting and enhancing ILT habitat quantity and quality throughout the LMR.

Pallid Sturgeon

Consisting of only a few collection records, the historical population baseline of PS in the LMR is unknown. Attempts to determine the population status were implemented in 2001 (see account under **Historical and Current Species Baselines in the LMR**, above). Since that time, evidence of recruitment has been documented and the number of individual PS records has increased proportionately with collecting effort. The identification of the LMR PS population trend (i.e., increasing/decreasing) will require several years of continued collection efforts and monitoring. Therefore, at this time, we cannot directly determine PS response to habitat changes induced by the CIP. However, current information indicates that the PS is widely distributed throughout the LMR and suggests the species is not uncommon.

As noted under **Factors Affecting the Species**, above, there is documentation of entrainment of shovelnose sturgeon by maintenance dredging in the MMR, suggesting the PS are also vulnerable. However, risk of entrainment in the LMR during dredging may be reduced due to the larger channel size, depth, and complexity compared to the MMR.

Channel maintenance dredging locations are mapped by the USACE and are considered with regard to all locations where protected species occur and seasonal habitat use. Spawning and habitats used by sturgeon at early life history stages are protected by seasonal dredging restrictions. Telemetry monitoring of sonic-tagged PS in the LMR by USFWS/USGS has shown little use of crossovers by large-size classes of PS, particularly in relation to use of other habitats in the LMR (e.g., Kroboth et al. 2013). Pallid Sturgeon telemetry relocations are also most frequently associated with water depths greater than 18 ft (Kroboth et al. 2013), and a recent study of fish depth distribution in the LMR reported minimum depth utilized by PS was 15 ft (Miranda and Killgore 2013), well below the authorized depth of the CIP.

Fat Pocketbook Mussel

The FPM was not historically known to survive in the active channel of the LMR. Recent collections of live individuals and fresh dead shells are primarily associated with secondary channels stabilized by notched dike fields. It is likely that the dike fields created conditions appropriate for the survival of FPM. Therefore, it appears that FPM has responded positively to the effects of the CIP. Construction and maintenance activities within dike fields and secondary channels are considered annually by USACE and partner agencies for potential negative effects to the FPM and — if those effects are present — avoidance measures are identified (see below).

Avoidance and Minimization Components of the CIP

Potential effects of annual CIP channel construction and maintenance activities to PS, ILT, and FPM habitats, along with potential avoidance and minimization actions, are discussed and considered during annual partnership meetings hosted by Memphis and Vicksburg Districts (see **Management and Conservation Measures in the LMR**, below). Channel maintenance and restoration programs are currently focused on maintaining and enhancing overall channel habitat complexity through dike design and notching, restoration of secondary channels, and use of value engineering techniques, such as hard points and chevrons that simultaneously provide river stabilization and habitat benefits. Priority species and their LMR habitats will continue to be quantified and monitored by USACE and other participating agencies. These data are used to determine the extent and significance of habitat modification to the priority species. They are also used to quantify habitat benefits of creative engineering, project future habitat trends, identify habitat improvement opportunities, modify channel management programs as necessary, and monitor long-term habitat trends and responses.

7 Management and Conservation Measures in the LMR

Long-term conservation of the three priority species, as well as other components of the LMR channel ecosystem, requires a multipartner and multifaceted scientific and engineering approach that utilizes water and sediment to maintain and enhance aquatic habitat complexity, particularly the kind of complexity associated with secondary channels and seasonally flooded/exposed habitats. Under the CIP, water and sediments are manipulated through channel engineering in order to maintain flood protection and a safe and efficient 9ft deep x 300ft wide navigation channel in the LMR from Cairo, Illinois, to Baton Rouge, Louisiana. Channel engineering — including channel structure maintenance — provides opportunities to utilize flows and sediments to improve or restore in-stream habitats outside of the navigation channel at little to no extra cost, and without impacting navigation activities or flood risk management. Dike notching and other river training structures have been successfully used for more than a decade for this purpose.

Several restoration projects unrelated to navigation have been designed by the USACE, funded by state and federal partners, and constructed by private contractors. Restoration projects constructed in recent years include weirs to prevent dewatering of floodplain oxbow lakes and channels, and retrofitted dike notches to restore flow through more than 40 miles of secondary channel habitat. The USACE's collaborative approach to using CIP construction and maintenance projects as primary tools to manage and conserve the LMR ecosystem — along with a better understanding of and better mapping and avoidance of important habitat areas — has resulted in significantly improved habitat for the PS, ILT, FPM, as well as for numerous other channel-dependent species.

Partnerships

Key partnerships and guidelines that facilitate development and implementation of this Conservation Plan have been developed over the last 10 years. In 2001, the USACE-MVD LMR districts (New Orleans, Vicksburg, and Memphis), Southeast Region USFWS, and the Lower Mississippi River Conservation Committee (LMRCC), which consists of 12 state natural resource management and environmental quality agencies, began conducting annual meetings to discuss LMR conservation issues and maintenance and construction projects. Important components of these partnership meetings include: updates on endangered species locations and habitat use in the LMR channel; the identification and consideration of using environmental engineering principles in the design and construction of river training structures; and improved communication and coordination among partners for the benefit of all trust species in the LMR.

In 2002, the USACE introduced Environmental Operating Principles (EOP) to provide direction in all aspects of USACE activity for improved stewardship of land, water, and air. EOP implementation guidelines were subsequently adopted to identify ways USACE missions can be integrated into environmental laws, values, and practices (USACE 2003). USACE-MVD has been applying EOPs into the CIP feature of the MR&T, as well as O&M activities in the LMR, with varying success. Although the CIP is almost complete, remaining components, as well as on-going and future O&M activities, provide opportunities to cost-effectively utilize EOPs to improve ecosystem responses to the programs that have affected channel habitat quantity and quality in the LMR. Annually, the USACE invites state and federal natural resource biologists familiar with river-dependent species, multiple-use management of the LMR, and commercial navigation to meet and review proposed CIP actions for the year. The USACE does this for out years as well. These natural resource biologists identify conservation actions that can be incorporated into USACE channel maintenance activities. The USACE has developed, and periodically updates, a Mississippi River Channel Improvement Master Plan, which shows constructed and proposed channel training features, environmental improvement features, and priority species locations.

The USACE has developed resources and information vital to strategic management of the LMR ecosystem. Aquatic and terrestrial habitats have been mapped within the 2.8 million-acre LMR leveed floodplain ecosystem. Aquatic habitat maps of the river's channel for 1880, 1915, and for ten-year intervals from the 1930s to the 1990s have been completed and are being used to assess historic habitat trends, conduct habitat spatial analyses, and evaluate project effects on federally endangered species, as well as on other aquatic resources. Terrestrial habitat and land cover maps prepared using 1982 and 1992 data have been used to delineate jurisdictional wetlands, plan levee construction to avoid and minimize adverse environmental impacts, and maximize beneficial conservation effects. In addition, MVD investigations under the LMREP have been conducted on fish and wildlife populations and habitat values of levee borrow pits, effects of in-channel stone dikes, and articulated concrete mattress revetments. In 2001, the MVD initiated informal consultation with the USFWS under section 7(a)(1) of the Endangered Species Act to use LMREP designs and additional measures to conserve and manage listed species associated with the LMR navigation channel.

In 2000, the LMRCC developed an Aquatic Resource Management Plan (ARMP) for the 954 river-mile long LMR reach (http://www.lmrcc.org/ARMPstrategies.pdf). The ARMP provided a 10-year operational plan to address several factors adversely affecting wetland-dependent natural resources in the LMR active floodplain and backwater areas. As mentioned previously, the partnership conducted the Mississippi River Conservation Initiative (MRCI) during 2001–2004; the MRCI consisted of a series of planning meetings in the six LMRCC-member states (Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee) that were designed to identify specific aquatic habitat restoration and public access opportunities (http://www.lmrcc.org/MRCI.htm). The MRCI was a landscape-scale effort that ultimately resulted in six state-specific lists, with 239 potential projects. In 2006, the LMRCC, under the auspices of the partnership, began compiling the MRCI projects into a landscape-scale plan – Restoring America's Greatest River (RAGR). The RAGR plan comprises the implementation phase of the partnership's five-year planning effort to rehabilitate the LMR leveed floodplain ecosystem (http://www.lmrcc.org/). Working cooperatively with the partnership, the LMRCC has developed a comprehensive Geographic Information System comprised of spatial databases covering the LMR ecosystem and the Mississippi Alluvial Valley to support the implementation of the MRCI. Data holdings include vector files of roads, hydrology, river-training features (dikes, revetments, levees, ports, etc.), public lands boundaries, satellite imagery, digital orthophotos, low water video, and raster data, including soils, land cover/land use, Digital Elevation Models, and bathymetry. These projects raise the habitat and environmental baseline of priority species, offsetting and mitigating actions which may be essential to flood risk management and the maintenance and safety of the LMR commercial navigation channel.

Since 2005, USACE has collaborated with LMRCC and other partners to: 1) conduct synoptic studies of PS population status and habitat restoration benefits; 2) obtain geo-referenced video during low water periods to evaluate status of river training structures, and to determine habitat quality in secondary channels and other areas of the LMR; 3) quantify long-term changes in depth, volume, and status of secondary channels in the LMR; 4) begin studies of gravel bars used by sturgeon and other riverine species as spawning sites; and 5) continue planning restoration projects. Information derived from these efforts is shared annually at the lower basin pallid sturgeon recovery meeting and the channel improvement meetings sponsored by the Memphis and Vicksburg Districts. Most recently, the USACE is working with partners to execute the Lower Mississippi River Resource Assessment (LMRRA).

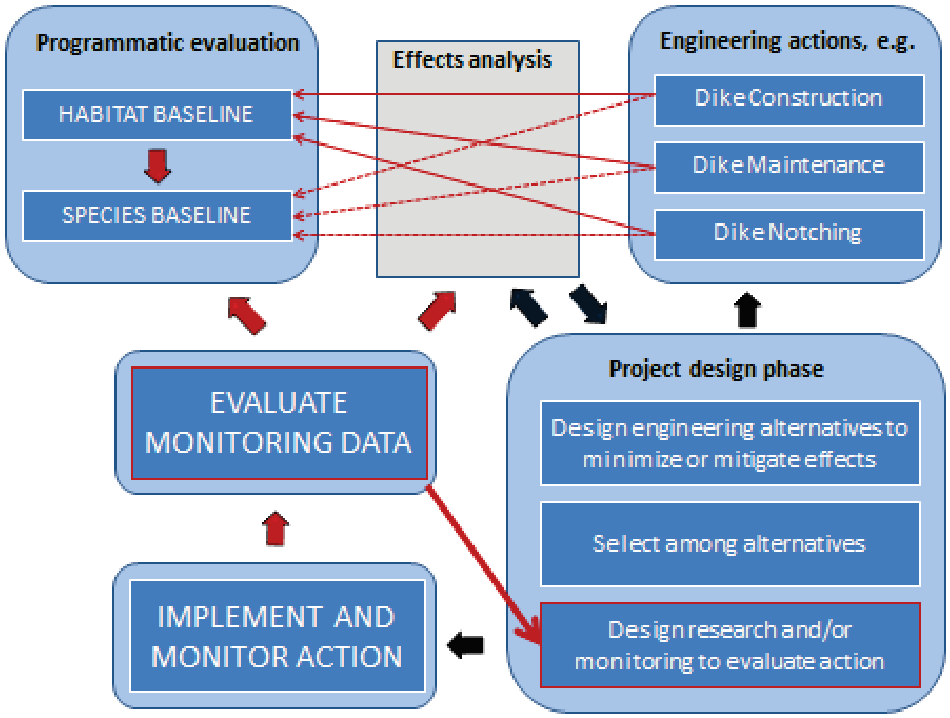
The LMRRA was authorized in WRDA 2000, Sec. 402, and funding was initiated in FY09. The reconnaissance level report was approved March 5, 2010. The purpose of the study is to develop recommendations for: 1) the collection, availability, and use of information needed for river-related management; 2) the planning, construction, and evaluation of potential restoration, protection, and enhancement measures to meet identified habitat needs; and 3) potential projects to meet identified river access and recreation needs. The Nature Conservancy (TNC), along with LMRCC and other partners, including National Audubon Society, Delta F.A.R.M., and the American Land Conservancy, have joined this effort as cost-share partners on a feasibility level watershed study with the signing of the USACE – TNC cost share on January 11, 2012.

These partnerships and actions have provided opportunities to develop, test, and implement engineering modifications that fulfill USACE missions while simultaneously protecting and enhancing channel habitat values.

Conceptual Model

The USFWS now considers the USACE partnership and engineering process outlined above as the primary strategic approach to maintain river channel habitat values in the LMR, as well as for the management and recovery of listed species associated with the channel (USFWS 2012a). This strategic approach can be modeled as follows:

Figure 12. Red boxes and arrows indicate places where input from USACE agency partners is required.



Conservation Plan Outline

The goal of this USACE-MVD conservation plan is to maintain the CIP while implementing or improving appropriate habitat conditions necessary for robust, resilient, and self-sustaining populations of ILT, PS, and FPM in the LMR. The objectives of this conservation plan are to utilize reasonable, prudent, and cost-effective channel maintenance and management practices to maintain and improve LMR channel habitat values for listed species and other native species.

The USACE-MVD and LMR districts have identified the following strategies and actions to minimize adverse effects of the CIP, and to mitigate for past and potential future loss of LMR channel habitat quantity and complexity. These strategies and actions have been implemented, and tested for more than a decade under the channel ecosystem management partnership described above. Herein, the USACE-MVD and LMR districts incorporate the following strategies and actions as Standard Operating Procedures and Best Management Practices under the CIP to conserve the endangered species associated with the LMR channel, as authorized and required under section 7(a)(1) of the Endangered Species Act . This conservation plan also complies with procedures and mandates under the

USACE Environmental Operation Principles, the Civil Works Ecosystem Restoration Policy (USACE 1999), and Executive Order 13186 under the Migratory Bird Treaty Act.

Agency conservation programs developed under section 7(a)(1) of the Endangered Species Act are intended to assist federal agencies and their potential partners in planning and implementing actions to protect and recover endangered or threatened species affected by the agencies' activities. These conservation measures are a guide for meeting the goal and objective outlined above, and do not obligate any party, including the USACE, to undertake specific actions at specific times. Implementation of the actions outlined below is contingent upon opportunity and annual appropriations and other budgetary constraints.

Strategy 1: Avoid adverse impacts directly associated with CIP engineering practices.

Actions:

1. Comply with seasonal restrictions for construction when appropriate and/or possible. Seasonal restrictions, or "windows," have been or may be established by state and federal resource agencies to minimize nesting, spawning, or juvenile disturbance during all construction and maintenance activities. Currently, construction is prohibited from 1 April to 1 August, a 5-month window, on the LMR. As new information is developed, these restrictions may be modified to reduce impacts on construction activities while protecting endangered species and their habitats. However, any changes to these seasonal restrictions could potentially impact the navigation mission of the CIP and will be carefully considered by all agencies involved.
2. Avoid closure of secondary channels. Loss of secondary channel habitat — and decline of endangered species habitat value — has occurred through the construction of secondary channel closure structures under the CIP. In recent years, alternatives such as strategic dike placement, chevrons, etc. have been successfully used in place of closure structures to maintain appropriate depth and width of the navigation channel.
3. Avoid impacts of dikes on gravel bars. Gravel bars are typically found at the upstream reach of islands and near crossings where water depth is shallow and dikes are required to maintain the navigation channel. Efforts are underway to identify established gravel bars and avoid construction activities that may result in accretion of sand over well-developed gravel

substrates. Notching existing dikes impacting gravel substrates has also been targeted.

Strategy 2: Develop and implement channel construction and maintenance operation guidelines that conserve and restore LMR habitat for all three species; guidelines should be subject to adaptive management, and should be continued if the species become fully recovered

Actions:

1. Identify and implement dike construction and maintenance designs that maximize habitat complexity. Dike notching is the primary mechanism to increase habitat complexity. Most ILT colonies on the LMR are associated with dike fields, which create higher sandbars with less exposure to flooding during the summer nesting season. Notches are created by removing rock toward the landward end during maintenance work on an existing dike or by leaving an open, low section when a new dike is built (Guntren et al. in press). Water flowing through the notch scours substrates below the dike, increasing bathymetric diversity and allowing flow to isolate nesting sandbars through most of the nesting season. Dike notching and other alternative designs of river training structures (e.g., round points, chevrons, off-bankline revetment, as described by USACE (2006) and Pokrefke (2012), that increase habitat diversity and/or reduce impacts to endangered species and other native fauna will only be considered when there is minimal effect on the purpose and intent of the authorized project (i.e., navigation/flood risk reduction).
2. Restore connectivity to the main channel whenever possible. Restoration of secondary channels by notching or removing closure dikes was identified as one of the top restoration priorities (Boysen et al. 2012) and an evaluation procedure has been developed to rank the habitat value of over 50 secondary channels for planning purposes (Killgore et al. 2012). In recent years, secondary channel restoration actions have required collaboration of multiple partners, and are expected to continue to do so.
3. Utilize chevrons instead of dikes where conditions are appropriate. Dike fields form large, homogenous sandbars that become exposed at moderate to low discharges. Chevrons will be constructed in selected areas to increase hydraulic diversity in homogenous sandbar habitat while maintaining appropriate flow conditions for navigation and bank protection.
4. Continue to create longitudinal grooves in ACM. Armoring riverbanks with ACM to protect the river channel is critical to both flood risk management

and navigation. USACE has designed deep grooves in ACM to increase surface area, reduce surface current speed, and allow greater opportunity for attachment of invertebrates. This practice increases the biomass of invertebrates consumed by PS and by prey species for PS and ILT.

5. Utilize hardpoints in lieu of revetment where conditions allow. In some erosional areas, hardpoints are an alternative to ACM. They function to prevent bank erosion with less impact to natural riverbank. Hardpoints will be considered where practical.
6. Continue to strategically place large woody debris removed from banks during revetment construction or repair into the channel. Large woody debris removed from the bank during construction and maintenance activities will be strategically placed in the channel to provide habitat for attached macroinvertebrates, as well as to provide shelter for forage fish.
7. Minimize impacts of dredging. Dredging activities will avoid or minimize impacts on gravel bars, tributary mouths, and backwater habitats. The USACE will continue to abide by recommendations provided by the USFWS, including distance buffers and timing windows. Beneficial placement of dredged material will be utilized where appropriate and authorized.

Strategy 3: Develop cost-effective monitoring programs, as funding allows, to document habitat and species response to channel operations

Actions:

1. Collaborate with USFWS and LMRCC to periodically monitor and measure habitat complexity and channel response to river training structures. Habitat complexity will be measured using existing capabilities, including bathymetric surveys, Red Hen geo-referenced video, Lidar, ground truthing, including gravel bar surveys, and aerial photography. GIS maps using River and Environmental Engineering GIS will be updated with new habitat information.
2. Utilize ILT and PS as surrogate species to monitor ecosystem response to management. Unless future information suggests otherwise, USACE will utilize these two endangered species as surrogates to document ecosystem function, quality, and response to USACE channel management, regardless of the species' future listing status under the ESA. FPM is not recommended as a surrogate species at this time due to limited data availability.
3. Conduct targeted monitoring and analysis of habitat utilization and preference of the three endangered species. Field surveys and telemetry

will be conducted to evaluate habitat use of listed species and their responses to USACE construction and maintenance activities in the LMR.

4. Collaborate with USFWS to develop and implement a more statistically rigorous monitoring program to track ILT population trends on the LMR. Over the next 1-2 years, the ERDC-EL will be coordinating with USFWS, ABC, and the USGS to develop a range-wide monitoring program for the ILT, which will serve to: (1) streamline and standardize existing monitoring techniques, and (2) provide a robust means of assessing rangewide population status into the future. Ideally, the monitoring protocol will rely upon subsampling rather than complete counts of adults throughout the range. If the ILT is delisted, monitoring on the LMR will be part of a required rangewide postdelisting monitoring plan.
5. Monitor population size and trends of PS in the LMR. Periodic monitoring of PS populations will continue using standardized collection methodologies. Key population attributes, including young-of-year survival, recruitment, adult survival, and density, will be evaluated using Population Viability Analysis models. Population size and trends will be compared among southern, middle, and upper reaches of the LMR. Information will be shared with partners at annual meetings and used to evaluate and modify conservation actions.
6. Conduct periodic surveys for presence/absence of FPM. Densities of FPM are naturally low in the LMR, and there are no historical occurrence records. Therefore, measurements of population size or trends are currently not practical. However, low-water surveys of FPM in proposed or existing construction sites in main and side channel habitats should be conducted to evaluate presence/absence as budget and authority allows.

Strategy 4: Share restoration, research, and monitoring responsibilities and costs by maintaining strong partnerships with other federal and state agencies and NGOs

Actions:

1. Continue to sponsor annual meetings with partners to discuss and implement Actions 1 and 2 as part of regular program and project efforts.
2. Continue to work with LMRCC, The Nature Conservancy, and other partners to share restoration and funding responsibilities as budget and authority allow.
3. Promote the Lower Mississippi Resource Assessment as a means to identify and implement conservation and restoration measures.

The conceptual model (Figure 12) and the objectives and actions outlined above have been developed in consultation with USFWS to comply with the ESA section 7(a)(1) statutory requirements. These requirements utilize USACE authority to establish and carry out programs for the conservation of endangered species associated with CIP river operations, and for management and restoration activities to mitigate impacts on listed species caused by river operations. They also comply with the intent and directives outlined under the USACE Environmental Operating Principles, and the Civil Works Ecosystem Restoration Policy (USACE 1999), and support the conservation intent of EO 13186 Responsibilities of Federal Agencies to Protect Migratory Birds.

Implementation

Implementation of the tasks identified above by USACE-MVD and districts will commence immediately. In fact, all of these actions have been at least partially implemented for more than a decade, and many have become standard operating procedure by USACE-MVD. For example, to date, almost 30% (230) of the dikes in the LMR (774) have been constructed or retrofitted with notches to increase channel border and seasonally flooded habitat diversity. More are in the planning process. Additionally, collaborative restoration projects between the USACE-MVD, LMRCC, and USFWS have cost-efficiently rehabilitated nine secondary channels. Combined, these projects have restored flow to almost 40 miles of in-channel habitat and enhanced hundreds of acres of seasonally flooded habitats. These projects have shown no negative effect to the USACE's primary missions of flood damage reduction and provision of a safe, stable, commercial navigation channel. Seasonal work windows are employed by USACE contractors, and are conditions in permits issued by USACE in the LMR. USACE-MVD has conducted analyses of secondary channels and completed a comprehensive secondary channel assessment (Williams and Clouse 2003; Guntren et al. in press) that will guide decisions on future restoration sites. To date, seven chevrons and 247 hard points have been constructed, resulting in preservation of several miles of natural bank habitat. Limited research (and extensive monitoring) by USACE-ERDC, USFWS, USGS, and other partners on ILT, PS, and FPM has been conducted for more than a decade, and is on-going. Research funding has been provided by USACE-MVD, USACE districts, USFWS, USGS, Arkansas Game and Fish Commission, and others. Geomorphic and species research information is shared with all partners at annual meetings conducted by and at the LMR districts.

Elements of Adaptive Management

Adaptive management is a collaborative, multidisciplinary approach that treats actions and policies as testable hypotheses from which learning derives; this approach provides the basis for changes in subsequent actions and policies (Stankey et al. 2005). Developing a *sensu stricto* adaptive management program for the three listed species relative to the CIP is not a realistic option for many reasons. These reasons include: 1) a lack of basic life history and habitat information for PS and FPM, 2) a lack of dedicated funding for research and monitoring, 3) practical constraints due to maintaining public safety and infrastructure integrity, 4) high levels of uncertainty in predicting or measuring species responses, 5) high levels of uncertainty in predicting or measuring local channel response, and 6) the duration of the management program.

The strategies and actions outlined above, however, provide for incorporating many useful elements of adaptive management into the CIP. Information gathered through channel monitoring and priority species research and monitoring has been used to modify/improve river engineering and other river regulation activities to avoid or minimize impacts to listed species and improve their habitat and population baselines in the LMR (see **Conceptual Model**, above). For example, 1) large gravel bars have been assigned a high priority for research and protection because PS larvae have been consistently collected below them and they are assumed to function as spawning substrates; 2) telemetry results are being used to provide insight into the possible effects of the timing and location of channel maintenance activities on PS habitat use; 3) ILT nesting survey data have been used in the dike maintenance program to protect and improve nesting sites; 4) identification of secondary channels occupied by FPM has been used to modify in-channel and levee construction projects and improve methods to avoid/reduce impact to the species; and 5) agencies and NGOs are collaborating in GIS documentation of species records, existing engineered structures, and engineering modifications to benefit trust species and ecosystem complexity. New information is and will continue to be considered during annual meetings between cooperating partners and agencies. At these meetings, data gaps, needs, engineering designs, and monitoring plans, and all elements of adaptive management, are collaboratively identified, prioritized, and modified if necessary.

This collaborative and adaptive approach to management and conservation of the LMR has cost-effectively and significantly improved the scientific knowledge base of the three endangered species; improved LMR habitats for them and numerous other game and nongame species; and provided substantial savings of conservation and channel maintenance funding. Continued interagency trust and cooperation are integral to continuing and fully implementing the USACE-MVD conservation plan and to ultimately achieving the conservation goals of all agencies involved in the partnership.

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14. ABSTRACT

Section 7(a)(1) of the Endangered Species Act (ESA) requires all federal agencies to use their authority as appropriate to carry out programs for the conservation (i.e., recovery) of endangered and threatened species. For more than a decade, the U.S. Army Corps of Engineers (USACE) has worked with the U.S. Fish and Wildlife Service (USFWS) and state conservation agencies to identify and resolve endangered species and ecosystem management issues that could impact USACE civil works missions in the Lower Mississippi River (LMR). It has become apparent that the very programs that have most significantly affected the river are potentially the most important and cost-effective tools to maintain and enhance its ecological functions. This is accomplished by considering and incorporating ecological engineering opportunities during the design phase of channel improvement and channel maintenance projects. The USACE has also opportunistically implemented cost-effective secondary channel restoration actions in the LMR by sharing responsibilities and resources with partner agencies. Cumulatively, both the site-specific engineering actions and the restoration opportunities have significantly benefitted the habitat baselines of endangered species associated with the LMR channel. Herein, the USACE outlines the programmatic mechanisms by which the Channel Improvement Program of the Mississippi River and Tributaries project is being utilized to implement conservation measures that maintain and improve habitat values within the LMR for recovery of endangered and other trust species inhabiting the river channel. This program has been developed under informal consultation with the USFWS, and complies with section 7(a)(1) of the ESA, USACE Environmental Operating Principles, Civil Works Ecosystem Restoration Policy (ER 1165-2-501), and supports the conservation intent of EO 13186 Responsibilities of Federal Agencies to Protect Migratory Birds.

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