U.S. Department of the Interior
U.S. Geological Survey

Initial Biotic Survey of Lisbon Bottom, Big Muddy National Fish and Wildlife Refuge

Biological Science Report
USGS/BRD/BSR-2000-0001
December 1999

by

Dale D. Humburg
Vincent J. Burke
Editors

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Acknowledgments

Much effort goes into creating a document for publication. In addition to the authors, reviewers provided invaluable comments, which improved each chapter. Susan Rhyne provided technical edits and brought consistency to the document. Linda Goetting made changes to the document. Brian Wissel produced the layout and created many of the graphics from hand-drawn maps. Pamela Haverland supervised the production.

cover illustrations: Charles Schwartz, *Wildlife Drawings*. Conservation Commission of the State of Missouri

Suggested citation:

D.D. Humburg and Burke, V.J., editors. 1999. Initial Biotic Survey of Lisbon Bottoms, Big Muddy National Fish and Wildlife Refuge. U. S. Geological Survey, Biological Resources Division Biological Science Report USGS/BRD/BSR—2000-0001. 76 pp.

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Initial Biotic Survey of Lisbon Bottom

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Abstract. The 2,300-acre Lisbon Bottom Unit, located in central Missouri, became part of the Big Muddy National Fish and Wildlife Refuge (NFWR) after the Great Flood of 1993 devastated the Unit's farmland and network of levees. As a result, interdisciplinary studies were initiated through collaboration among various researchers, universities, and State and Federal conservation agencies to investigate the short-term effects of the flood and to expand information about the Missouri River and flood-plain systems. The studies included in these chapters investigate diverse aspects of Lisbon Bottom Unit's physical setting and biota and provide baseline information that managers can use to assess restoration efforts on Lisbon Bottom and other units of the Big Muddy NFWR.

Key words: amphibians, aquatic invertebrates, Big Muddy National Fish and Wildlife Refuge, fisheries, flood plain, geomorphology, hydrology, levee, Lisbon Bottom, mammals, Missouri River, riparian, side channel, vegetation, waterfowl, wetlands

Executive Summary

Lisbon Bottom: A Baseline of New Knowledge

by

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The Big Muddy National Fish and Wildlife Refuge (NFWR) is an integral part of the U.S. Fish and Wildlife Service's (Service's) dream of facilitating a new vision for the Missouri River.

This river, which has played such an important part in our Nation's history, is currently listed among the most endangered rivers in the United States. Once so endowed with rich and abundant natural resources, the Missouri River now serves primarily as a pathway for navigation. But the new vision for the Missouri River is one in which its rich natural resources can be reestablished and coexist with the diverse and valuable economic endeavors that depend upon the "Big Muddy."

The opportunity for implementing the vision for the Big Muddy NFWR came after the Great Flood of 1993. This very destructive event left many areas of the flood plain devastated and without future agricultural value. Willing sellers came forth, lands were purchased by the Service, and the Big Muddy NFWR began. Through acquisition and easements, the Service and other agencies, such as the U.S. Army Corps of Engineers, U.S. Department of Agriculture's Natural Resources Conservation Service, and the Missouri Department of Conservation, are jointly endeavoring to reestablish the ecological health of the Missouri River.

The vision for the Big Muddy NFWR is to acquire a total of 60,000 acres along the Kansas City to St. Louis reach of the river. Flood plain and river connections will be restored at 25 to 30 separate locations, forming habitat "beads on a string" and renewing a part of the environmentally productive and valuable Missouri River system. Regenerating bottomland forests and reestablishing wetlands and river connections collectively will add the diversity of habitat features needed to restore some of the natural functions of this valuable riverine system. The Big Muddy NFWR truly will become a "refuge" in the ecological and landscape sense of the word.

Central to the refuge is the Lisbon Bottom Unit. This 2,300-acre area was severely damaged in the Great Flood and was one of the first sites to become part of the Big Muddy NFWR. Before the flood, the area was considered prime farmland and was protected by a network of levees. All this was lost in the flood. With the destruction of the levees came the deposition of several feet of sand on this once productive farmland as well as the scouring out of land, creating deep holes filled with water. The land, having lost its agricultural value, was perfect for inclusion in the Big Muddy NFWR.

The vision for ecological recovery is paralleled by a vision of new knowledge. Lisbon Bottom was included in studies that were initiated immediately after the flood to determine both the short-term effects of the flood and also to improve our knowledge of river and flood-plain systems. These integrated studies have involved researchers from many disciplines who have investigated the condition and changes in water, soils, fish, and wildlife. Universities and State and Federal conservation agencies have cooperated to take advantage of the opportunity presented by a renewed interest in river systems.

Information collected on Lisbon Bottom already has provided the basis for management planning on the Big Muddy NFWR. In less than 5 years, vegetation has rapidly recovered, flooding recurred in 4 years, and a chute has developed through what had been farmland for much of the century. Because data collection efforts were in place, these dynamics have yielded clues to flood-plain processes rather than becoming an unknown frustration to refuge managers.

In this publication, contributions from diverse studies on Lisbon Bottom will indicate some of the initial information collected and provide a preview of what the area will become. Information presented is not intended to be a rigorous scientific analysis of flood-plain processes and events. Instead, it represents the baseline of information now in place that will be essential as future managers judge the success of restoration efforts on Lisbon Bottom and other units of the Big Muddy NFWR.

I fully expect that Lisbon Bottom will continue to be a dynamic habitat restoration in progress. Ongoing monitoring of flood-plain changes will be an integral part of our vision for restoring the Missouri River.

Chapter 1
Physical Setting

by

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Introduction

Lisbon Bottom consists of approximately 875 ha of river bottom along the Missouri River in Howard County, Missouri, from approximately river mile[1] (RM) 213 to RM 219 (Figs. 1-3). As used in this report, the Lisbon Bottom area also includes the main channel of the Missouri River adjacent to the Lisbon Bottom and portions of the adjacent flood plain in Saline County, Missouri.

Before regulation and structuring of the Missouri River, riverine[2] areas like Lisbon Bottom were shifting mosaics of dynamic habitat patches that were created and maintained by hydrologic and geomorphic processes. Flow regulation, navigation structures, and bank-stabilization projects isolated Lisbon Bottom from the river by decreasing the magnitude and frequency with which hydrologic and geomorphic processes could alter habitat characteristics.

The flood of 1993 breached agricultural levees around Lisbon Bottom, thereby reestablishing a connection to the Missouri River. Although still affected by flow regulation and the requirement to maintain navigation in the main channel, Lisbon Bottom presents the opportunity to study ecosystem processes and dynamic geomorphology in a setting that more closely mimics the natural riverine system than any other site on the navigable Lower Missouri River.

The purpose of this chapter is to describe the physical setting and processes that structure the riverine ecosystem of Lisbon Bottom and similar areas of the Lower Missouri River. The description compiles available information on temporal and spatial changes at the site, including the history of channel changes and hydrology.

Physiography of Lisbon Bottom

Lisbon Bottom is located in a valley segment[3] between the junctions of the Grand and Osage Rivers (Figs. 1, 4). This segment is on the margin of the Ozark Plateaus Physiographic Province and it is cut into relatively uniform Paleozoic cherty limestone, cherty dolomite, and minor quantities of sandstone and shale. This segment is characterized by a relatively wide valley subsegment from the Grand River junction to near Glasgow, Missouri (RM 224-250), and a narrow valley subsegment from Glasgow to the Osage River junction (RM 131-224). In the wide-valley subsegment and the segment upstream of the

[1] River miles are the long-established addressing system for distances on the Missouri River. River miles increase upstream from 0 at the junction of the Missouri and Mississippi Rivers at St. Louis. A mile is equal to 1.6 km.
[2] The term riverine is used to describe the area encompassing the channel and adjacent flood-plain areas; the flood plain is considered to extend to those areas that would potentially flood with an average frequency of at least once in 100 years in the absence of bank revetments and levees.
[3] A valley segment is a length of a river valley between substantive tributaries and having relatively uniform physiographic and geologic characteristics. For the purposes of this report, a tributary is considered to be substantive if it adds greater than approximately 5% of the cumulative drainage area and (or) drains an area of significantly different hydrologic response, sediment yield, or water-quality contribution.

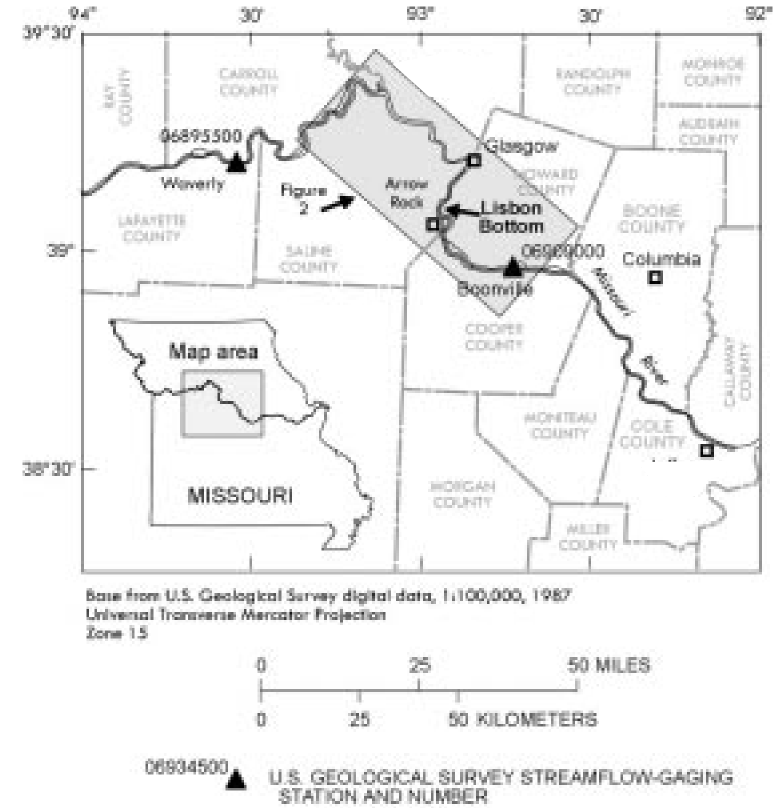


Figure 1. Location of Lisbon Bottom and nearby streamgages on the Lower Missouri River.

Grand River junction, the Missouri Valley is nearly five times wider than in the narrow-valley subsegment. Downstream of the Osage River junction, the Missouri River is increasingly affected by hydrologic characteristics and the addition of coarse sediment from the Ozark Plateaus.

Lisbon Bottom is within the narrow-valley subsegment where the valley is about 3.5 km wide; it has few alluvial terrace remnants and steep bedrock bluffs. The narrow valley and bedrock walls act to confine large floods and to promote scour and secondary currents where the channel impinges on the valley walls. A more complete description of Missouri River physiography can be found in Kelmelis (1994).

In its present-day stabilized morphology, the Missouri River is characterized by alternating reaches[4] of high and low sinuosity[5] (Fig. 4). Reaches with high sinuosity can be expected to have greater hydraulic diversity — that is, variation in depth and velocity — compared to low-sinuosity reaches because of stronger secondary currents associated with tighter bends. With a sinuosity ratio as high as 1.8 for a 6-km straight-line distance, the Lisbon Bottom reach has some of the highest sinuosity of the Grand-Osage segment.

Schmudde (1963) classified Missouri River bottoms into two broad classes: long bottoms and loop bottoms. Long bottoms are land areas enclosed by river bends that are much longer in the down-valley direction than they are in the cross-valley direction. Loop bottoms are land areas enclosed by river bends that are nearly the same size in the long-valley and cross-valley directions. Long bottoms also tend to have lower surface gradients than loop bottoms. Long bottoms correspond to low-sinuosity reaches and loop bottoms correspond to high sinuosity reaches.

Lisbon Bottom is a typical loop bottom. In the natural channels, loop bottoms tend to migrate downstream due to lateral erosion at the upstream margins and deposition of sediments on the downstream margins. Flood flows that overtop the upstream margins would tend to build up sandy natural levees, which might be separated by interposed crevasses where concentrated flows cut through the levees. Crevasses commonly occupied swales left from previous channel migration and so acted to guide flood flows from the channel, across the loop bottom, and toward the valley wall.

Because of this, there is a tendency for loop bottoms to have wetlands along the downstream one-half of the valley wall. At Lisbon Bottom small tributary basins also provide water for these low, wet areas. Because levees and splays build up the upstream margins of loop bottoms, natural loop bottoms have higher gradients than the channel, and they tend to flood from downstream to upstream as water backs up through old overflow channels.

As a result, when large floods overtopped natural levees at the upstream margin, they would typically encounter slackwater from backflooding.

The upstream margin of Lisbon Bottom has natural levees in excess of 186 m above sea level (a.s.l.); the downstream margin has elevations as low as 181 m a.s.l. Ridges and swales oriented northwest to southeast are apparent on the 1979 topographic map of the bottom but have been partly obliterated by erosion and deposition by the 1993 flood (Fig. 5).

[4]In the Missouri River, a reach is defined as a length of the river that contains one or more representations of bend and crossover macrohabitats.
[5]Sinuosity is the ratio of channel length to straight-line length between two points on the channel. It is an index of degree of channel curvature and hydraulic complexity.

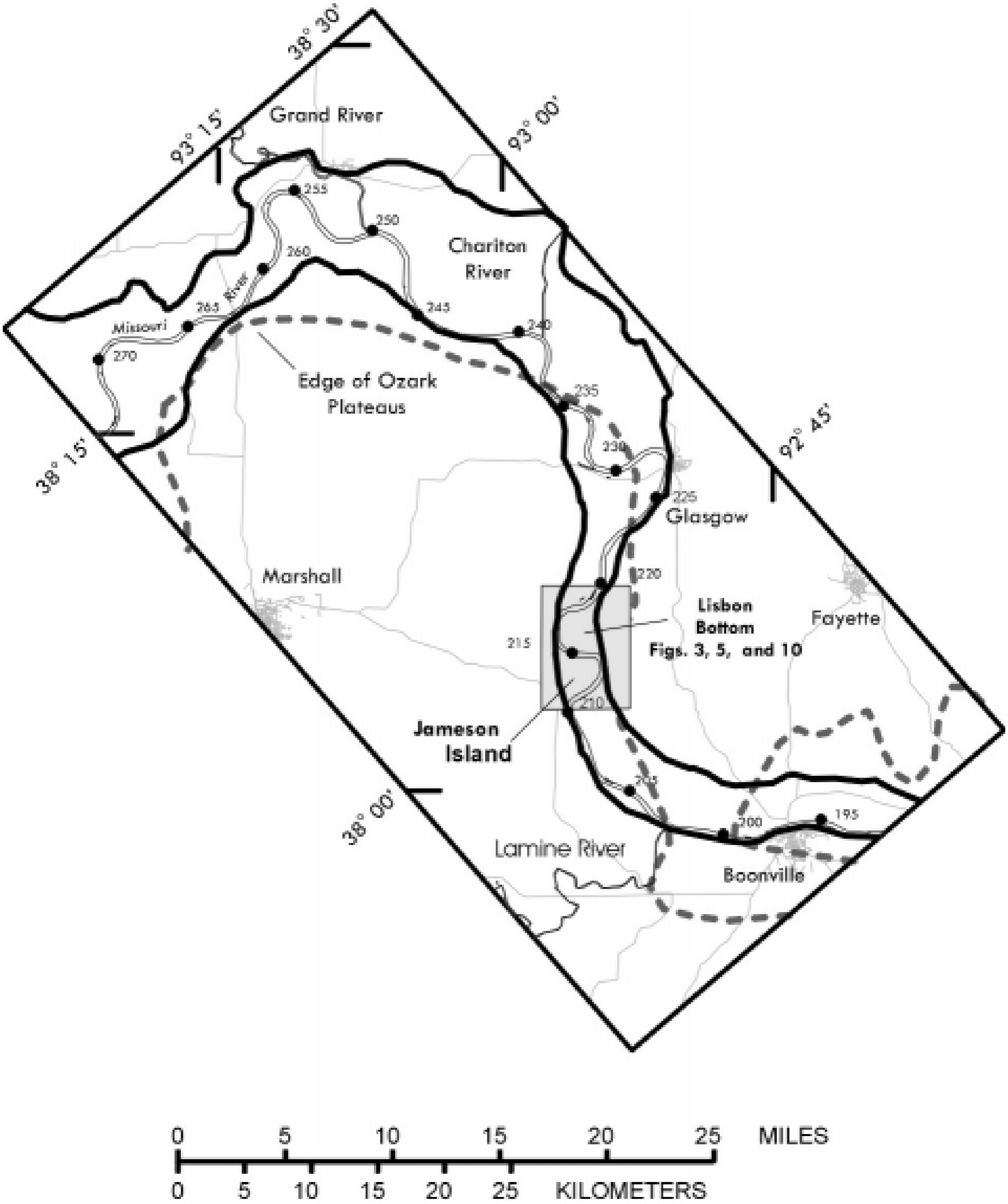


Figure 2. Location of Lisbon Bottom and Jameson Island within the Grand-Osage segment of the Missouri River.

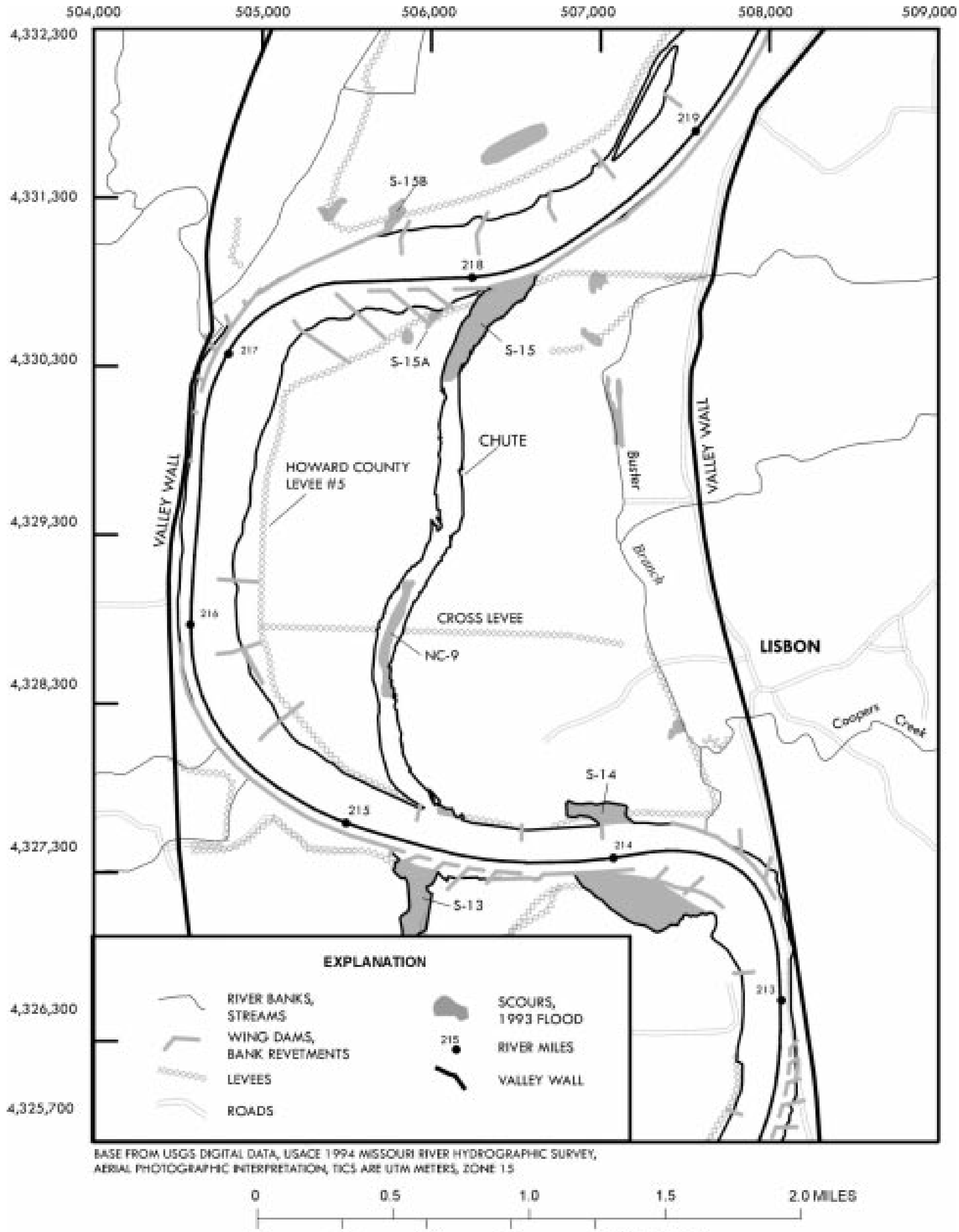


Figure 3. Map of Lisbon Bottom as it appeared in summer 1997.

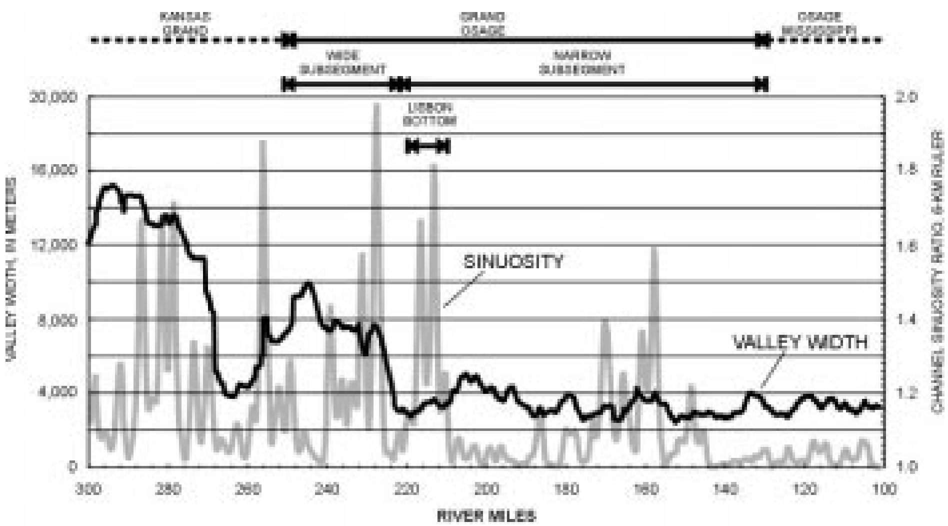


Figure 4. Graph of channel sinuosity, valley width, and segmentation of part of the Lower Missouri Valley.

The slope of the bottom is approximately 0.8 mL/km (0.0008 mL/m), compared to 0.2 mL/km (0.0002 m/m) in the channel. No surficial geology data[6] are available for Lisbon Bottom. The nature of the sediments, however, can be inferred from work at other Missouri River bottoms and from published soil maps. In general, the Missouri River valley is filled with a sequence of glacial outwash overlain by alluvial sand, gravel, and silt and clay (Kelmelis 1994). The total thickness of deposits is 18-24 m (60-80 ft). Silt- and clay-size sediment occurs in the upper 2-5 m (6 to 15 ft). In nonleveed settings, sandy sediments are dominant in natural levees toward the upstream margin of the bottom, and silt and clay are dominant in areas downstream and adjacent to the valley wall where deposition is by low-velocity water.

The soils of Howard County including the Lisbon Bottom area were mapped in the 1970's (Grogger and Landtiser 1978) and have not been remapped since. As a result of the floods of 1993-96, the surface materials of Lisbon Bottom have changed extensively in distribution; however, the description of soils from 1978 is still valid. The surface soil consists of materials ranging from well-sorted sand to silty clay and ranging from zero pedogenic[7] alteration to development of organic-rich A horizons and weak B horizons. The soils of Lisbon Bottom are classified as entisols and mollisols, indicating the predominance of weak pedogenic development and accumulation of organic matter in wetter environments.

The 1978 soil maps showed a unit classified as riverwash in lateral bars along the left bank[8] and adjacent to the channel. Sarpy sand (typic udipsamment) was mapped in natural levee positions along the upstream, left bank RM 216-218, and in a long splay extending approximately one-half of the long axis of Lisbon Bottom, adjacent to and east of the chute. This sand splay indicates historic, high-energy deposition on Lisbon Bottom similar to that which occurred in 1993 but before 1978. Hodge loamy fine sand (typic udipsamment) was mapped on low-relief ridges and also indicates deposition of bars or splays.

Hagni silt loam (mollic udifluvent) is stratified silt loam and fine sandy loam and was mapped on low ridges and intermediate elevations on the bottom. Leta silty clay (fluvaquentic hapludoll) is the wettest soil mapped at Lisbon Bottom and consists of fine sediments deposited in overflow channels, swales, and low areas subjected to back flooding. Nodaway silt loam (mollic udifluvent) was mapped on alluvial fans from the tributary valleys of Buster Branch, Cooper Creek, and unnamed smaller tributaries basins along the eastern valley wall. These alluvial fans were formed from reworked loess from the uplands located to the east of Lisbon Bottom; the fans provide bench areas at somewhat higher elevations immediately adjacent to the valley wall.

The dominant effect of the 1993-96 floods was to distribute a greater volume of sand over Lisbon Bottom than the 1978 soils maps indicated.

[6]Surficial geology refers to those sediments that have been recently transported and deposited near the surface of the earth. Generally, surficial geology includes descriptions of sediments, weathering, and transport processes at depths greater than those considered in the study of soils, but exclusive of bedrock. In alluvial settings like Lisbon Bottom, surficial geology includes the sequence of sediments the river, adjacent slpes, and streams deposited. Surficial geologic characteristics are critical to understanding long-term history of rivers and for understanding groundwater flow in the riverine environment.

[7]Pedogenesis refers to the integrated chemical, physical, and biological processes that form and differentiate soil horizons.

[8]Left and right bank refer to banks as seen while facing downstream.

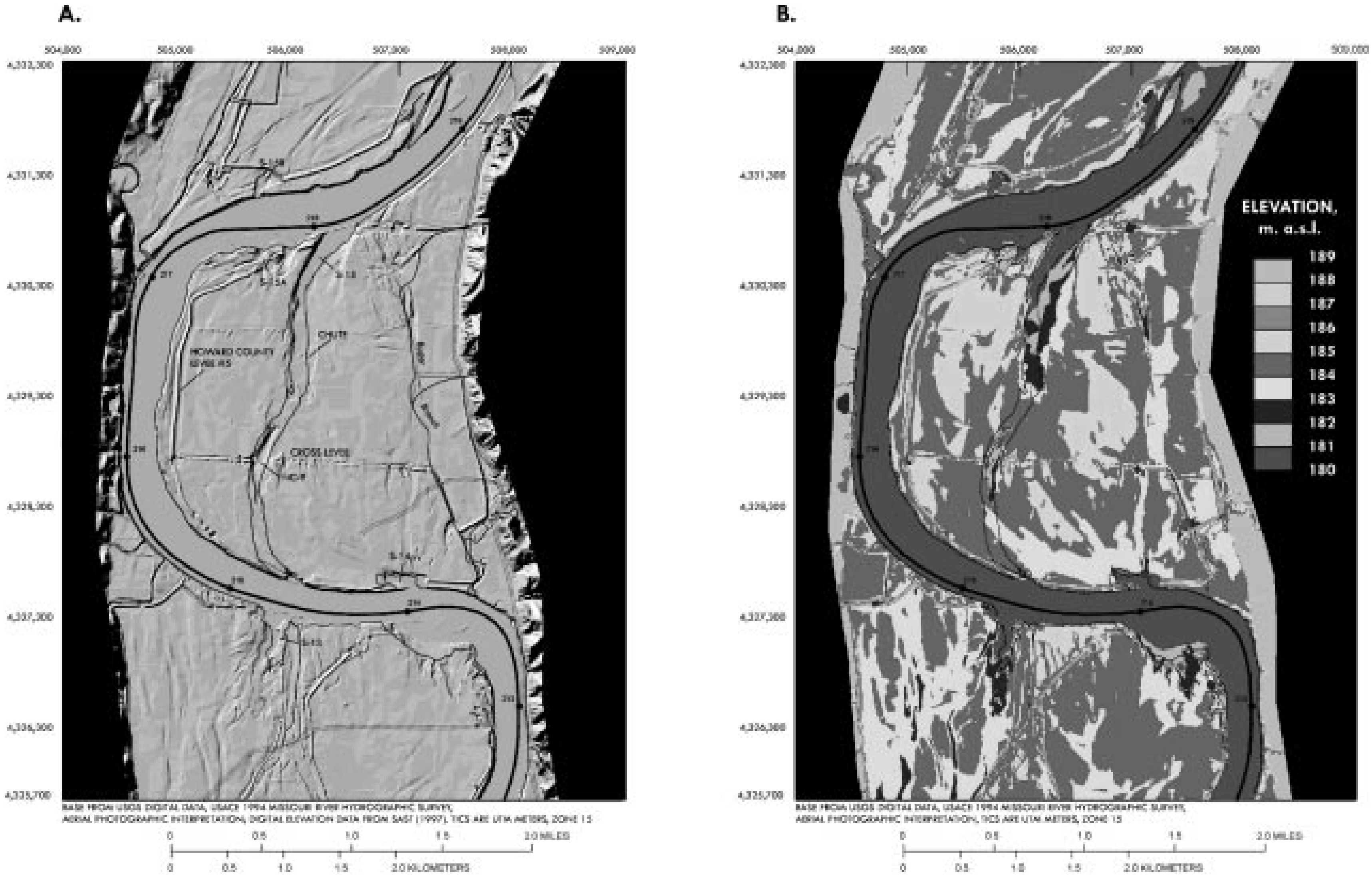


Figure 5. A. Shaded relief image of Lisbon Bottom. B. Topographic map of Lisbon Bottom with 1-m contour interval.

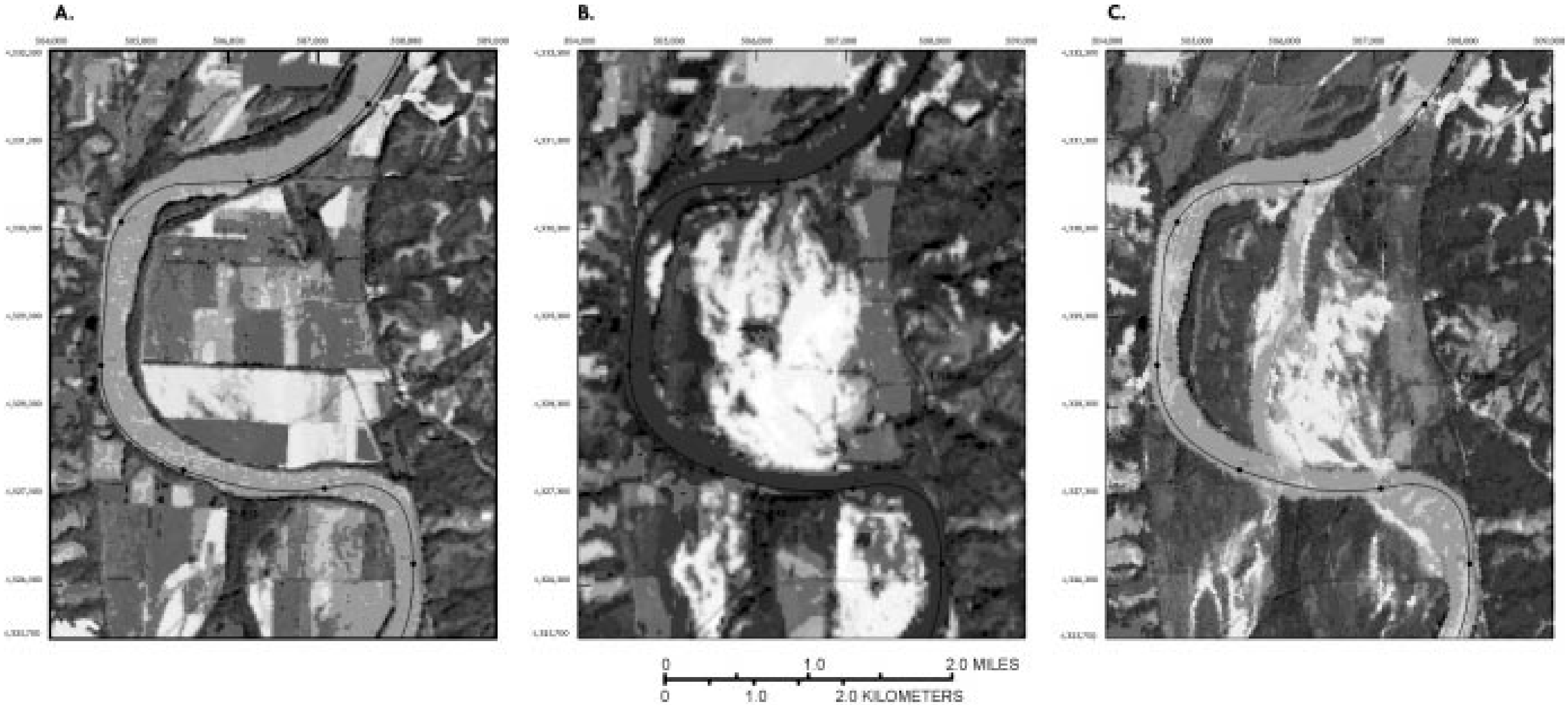


FIGURE 6. False color images of Lisbon Bottom showing extensive changes to land cover from 1992 to 1997. Red colors are indicative of vegetation cover; the more intense the color, the greater the biomass. The bright white in B. and C. represents sand deposits. From October 1994 to August 1997, much of Lisbon Bottom became more vegetated, despite the floods of May 1995 and June 1996. The difference in the color of the river between A., C. and B. is related to sediment load which is higher in A. and C. A. Pre-flood Thematic Mapper image September 24, 1992, Boonville discharge = 66,000 cfs. B. SPOT image October 11, 1994, Boonville discharge = 46,700 cfs. C. SPOT image, August 23, 1997, Boonville discharge = 91,100 cfs.

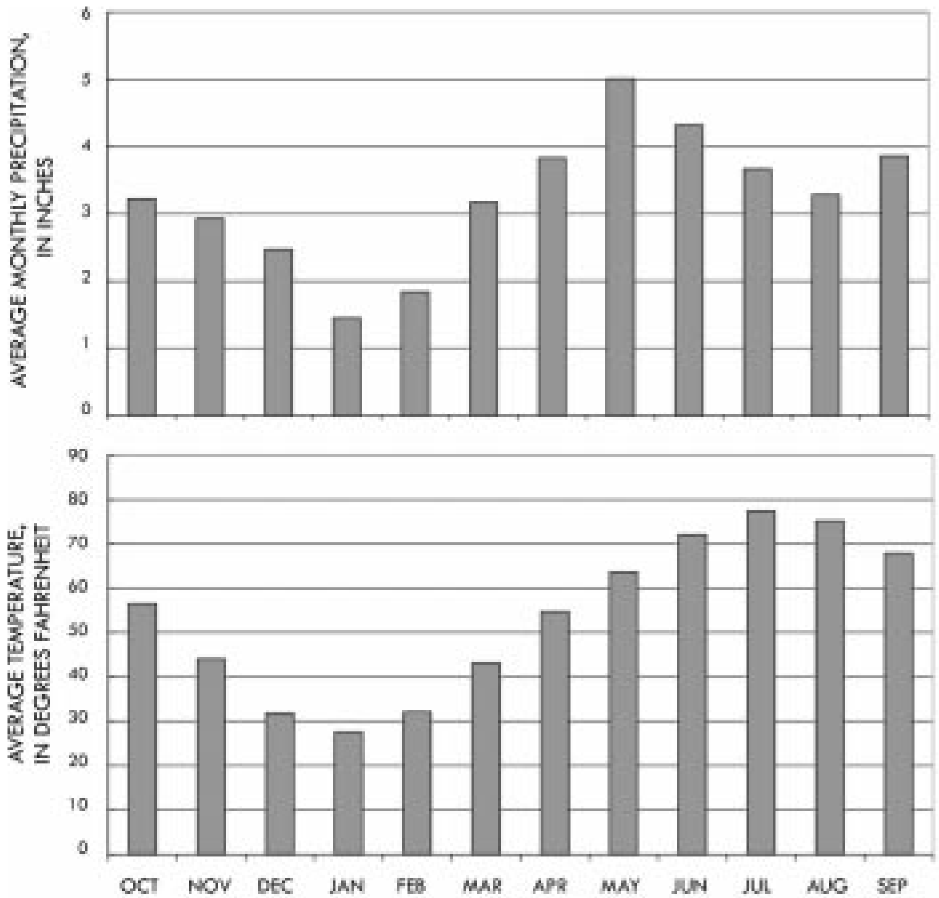


Figure 7. Normal monthly precipitation and temperature at Columbia, Missouri (N.O.A.A., 1997).

The main sand splay covered more than 70% of the area with 20 cm or more of sand and buried some areas of Hagni silt loam and Leta silty clay as it filled low-lying areas (Fig. 6). Sediments deposited by the 1993 flood have been extensively studied just downstream at Jameson Island (Fig. 2); additional information is available in Izenberg et al. (1996) and Schalk and Jacobson (1997).

Climatology, Hydrology, and Regulation History of the Grand-Osage Segment

The regional climate for Lisbon Bottom is temperate; average annual temperature is 12.2 degrees Celsius (54 degrees Fahrenheit) and average annual precipitation is 990 mm (39 in.) (NOAA 1997). Low temperatures and low precipitation tend to coincide in January, but peak precipitation tends to occur in May, 2 months ahead of the peak temperature (Fig. 7).

The closest long-term, discharge-rated streamgage is located at Boonville, Missouri. The U.S. Geological Survey (USGS) has operated this streamgage continuously since 1925. Between Lisbon Bottom and Boonville, the Missouri River gains very little discharge; the drainage area increases by only approximately 0.5%. Therefore, the Boonville streamgage can be used to evaluate hydrologic characteristics at Lisbon Bottom. However, because the valley and channel cross section and hydraulic roughness are different between Lisbon Bottom and Boonville, the relative stages and areas inundated are not expected to match, especially at flows above bankfull.

At Boonville, approximately 56% of the total drainage area of the Missouri River is regulated by mainstem dams in South Dakota, North Dakota, and Montana. In addition, discharge from the Platte and Kansas Rivers is partially regulated, so as much as 86% of the total drainage area and 73% of the median daily discharge at Boonville can be considered regulated. The remaining 14% of the drainage area arises mainly from rivers draining western Iowa and northwestern Missouri, including the Big Sioux, Grand, and Chariton Rivers.

The hydrologic record at Boonville shows the pervasive effect of flow regulation by the mainstem reservoirs (Figs. 8-10). Mainstem reservoirs were built and closed between 1937 and 1967. The period 1925-52 can be considered minimally regulated at Boonville. During 1952-67 the reservoirs filled, and after 1967 the mainstem reservoirs were managed to provide navigation flows, flood control, and recreation. A typical operating cycle for the mainstem system maintains discharges of approximately 35,000 cubic feet per second (cfs)[9] at Kansas City for the period 1 April-1 December for navigation, with alterations as necessary for flood control and other purposes (U.S. Army Corps of Engineers (USACE) 1979; 1998).

The effect of regulation for navigation flows can be seen in the trend in low flows (Fig. 8b) and in abrupt decreases in discharge around 1 December on short-term hydrographs (Fig. 10). On graphs of flow duration, the effect of regulation is most evident in loss of extremely low flows (Fig. 8d). When plotted as duration hydrographs (Fig. 9) it is clear that the net effect of regulating flows at Boonville has been to distribute the water flow more uniformly over the year. Marked increases in low flows are apparent during August-March and the two-peaked hydrograph characteristic of the unregulated river has been nearly eliminated. The post-regulation pattern of discharges shown in Fig. 9b may be altered somewhat when Missouri River Main Stem Reservoir System Master Manual (USACE 1979; 1998) is revised.

Geomorphic Dynamics and Management History of the Lisbon Bottom

The historical record of channel changes at Lisbon Bottom illustrates the natural processes of erosion and deposition and indicates the magnitude of change imposed by river management. Historical maps of channel positions in 1879 show that the Grand-Osage segment was characterized by a wide channel and numerous braided reaches characterized by bars and islands (Fig. 11). Schmudde (1963) estimated that under natural conditions the river was two to three times wider than after channel stabilization. Channel migration under natural conditions was sufficient to rework as much as one-third of the flood plain of the Missouri River in approximately 50 years (Schmudde1963).

[9]Cubic feet per second are the customary units for discharge in rivers in the United States. Multiply by 0.0283 to convert to cubic meters per second.

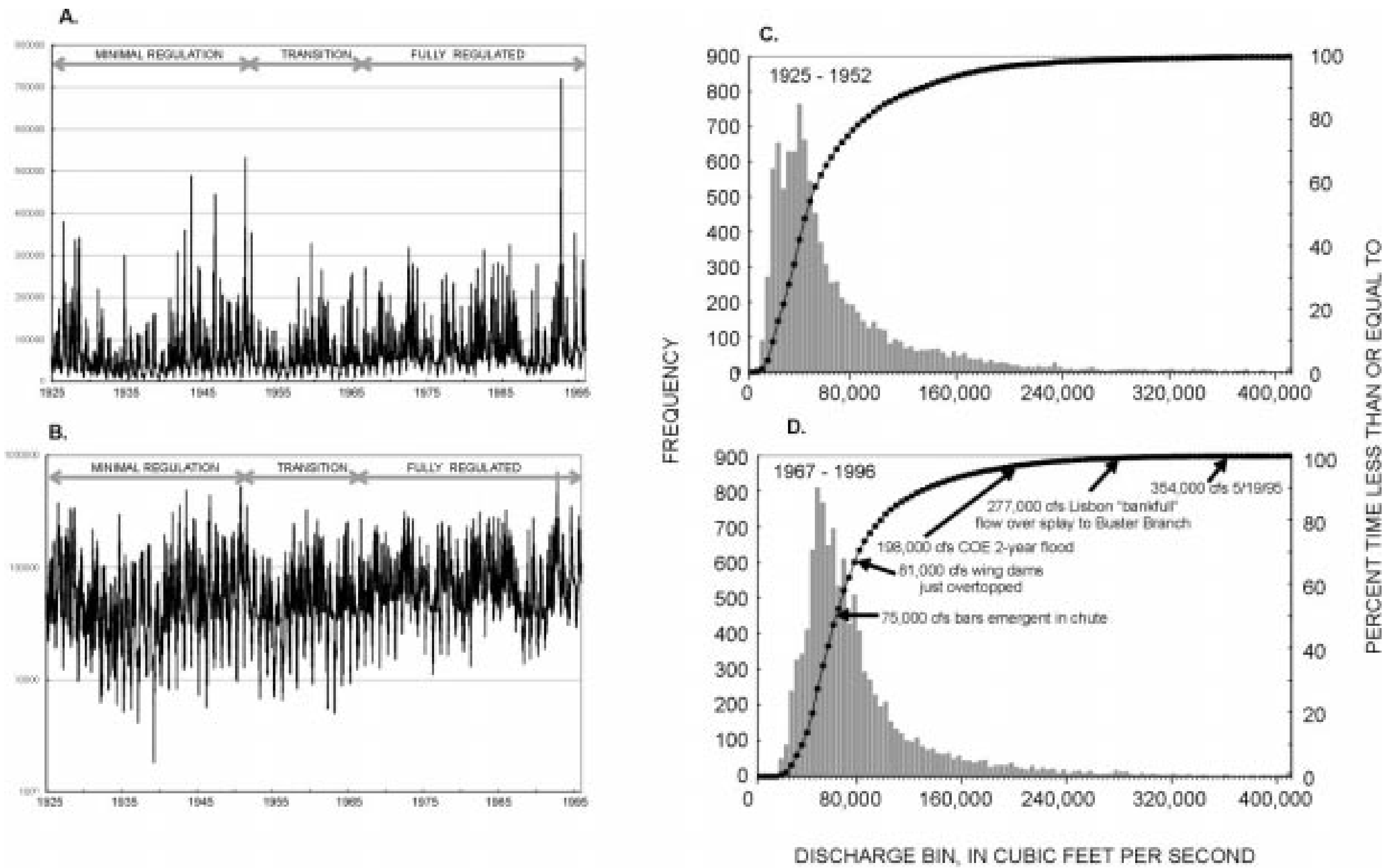


Figure 8. Graphs of discharge characteristics at Boonville, Missouri. A. Discharge plotted on arithmetic axis over time. B. Discharge plotted on logarithmic axis over time to emphasize trends in low flow. C. Histogram and cumulative frequency plots of discharge for pre-regulation period and, D. post-regulation time intervals.

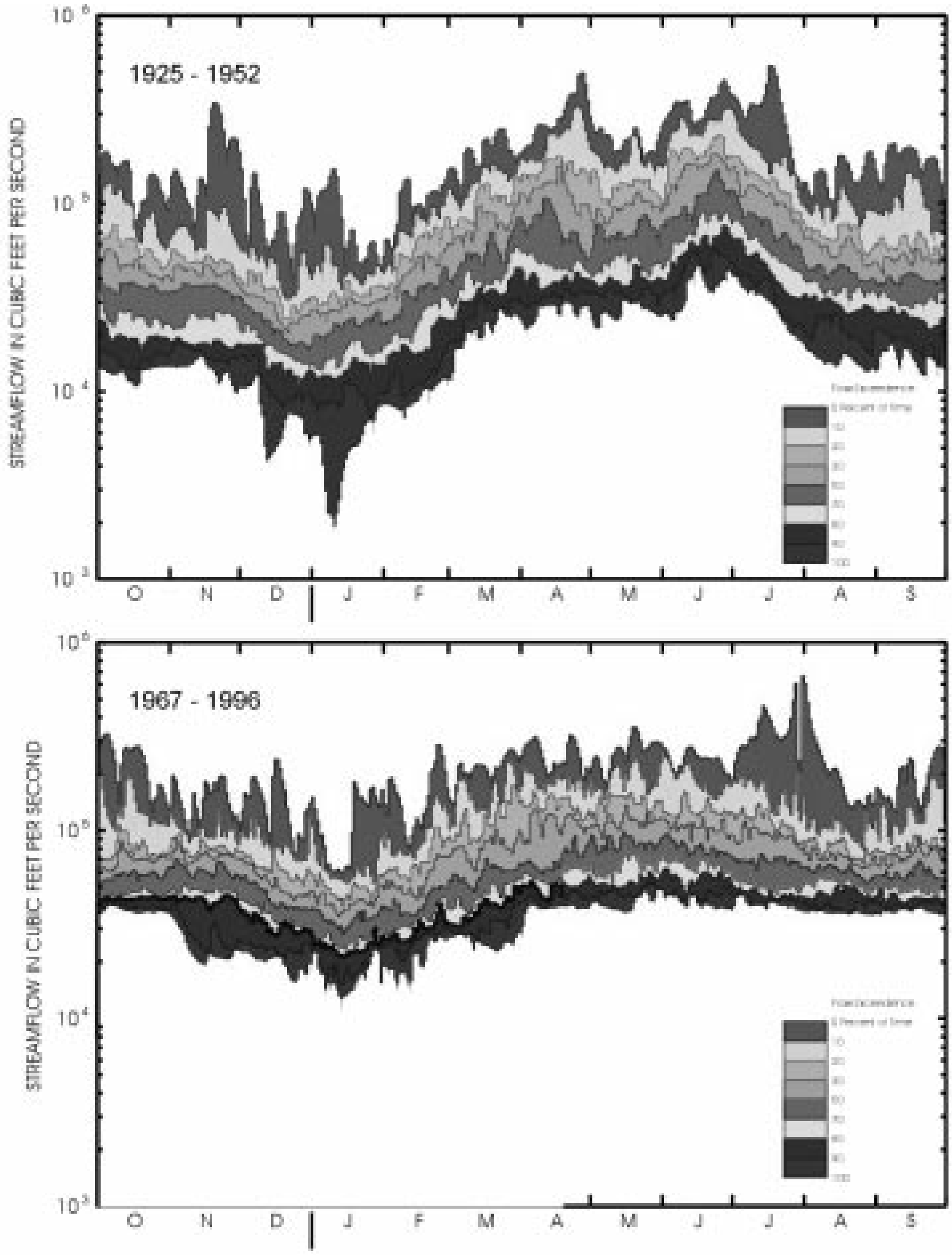


Figure 9. Duration hydrographs of Missouri River at Boonville, Missouri, showing discharges and percentages of time the discharge indicated is equaled or exceeded. Data are graphed separately for each day of the year and split into pre- and post-regulation time periods.

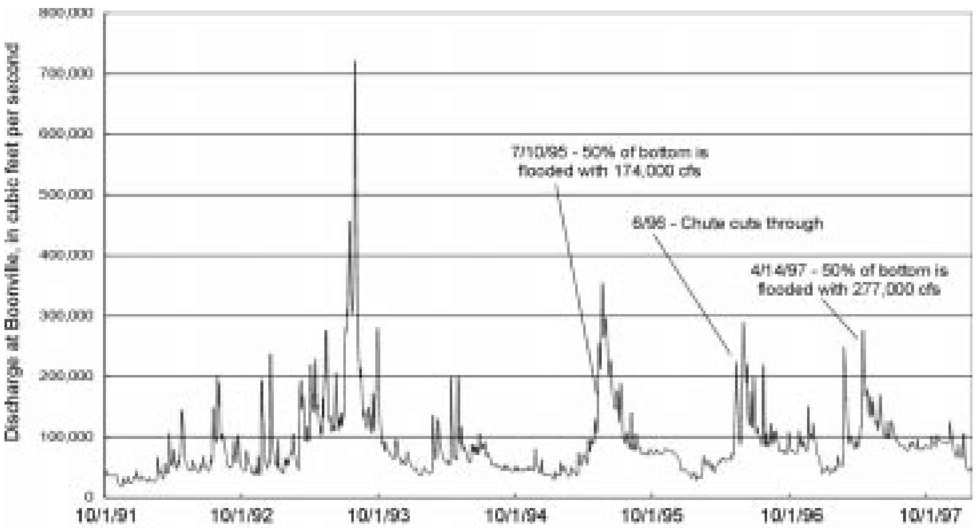
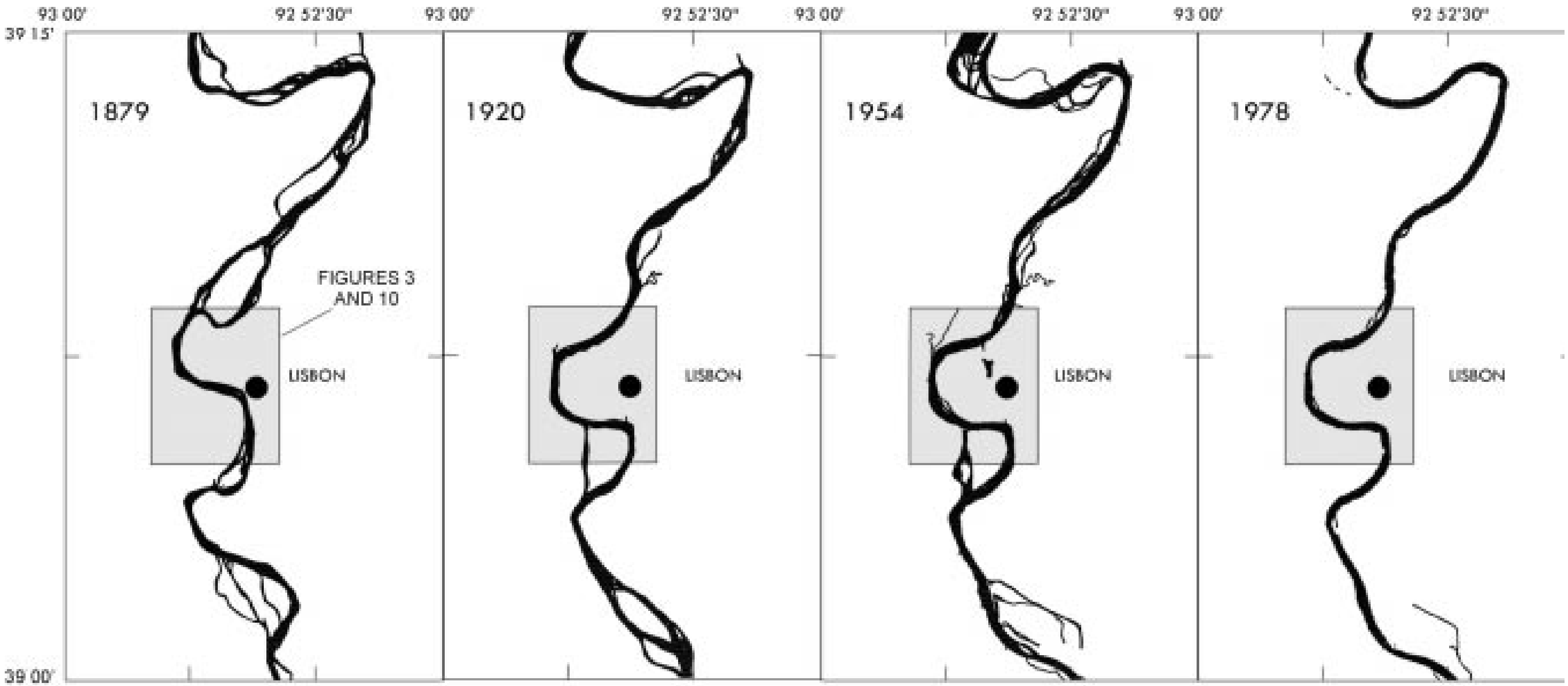


Figure 10. Hydrograph for Missouri River at Boonville, Missouri, for October 1991 to October 1997.



All maps are in UTM projection, zone 15. 1879 map was digitized from manuscript copies of 1879 hydrographic survey, Missouri River Commission (1879). The 1920 maps were digitized from the 1920 hydrographic survey (Missouri River Commission, 1920). The 1954 and 1978 maps were digitized from the hydrographic surveys of those dates (U.S. Army Corps of Engineers, 1954; 1978).

Figure 11. Historical maps of the Missouri River near Lisbon Bottom, 1879 - 1978. The maps show progressive simplification and migration of the channel. In 1879 Lisbon was a river town fronting on the river. A map in 1890 (Missouri River Commission, 1892) indicates a small amount of downstream migration of the bend, and by 1920 Lisbon has been entirely abandoned. Migration of the bend southward across Lisbon Bottom probably was natural and incremental. Since the 1940's, however, the channel has been constrained by revetments, levees, and wing dams.

Engineering alterations to improve navigability of the Missouri River began as early as the 1830's. In general, the sequence of alterations was clearing woody debris; constructing wing dikes to narrow the channel; constructing bank revetments to stabilize banks; and constructing levees to prevent inundation of urban, industrial, and agricultural lands. Interested readers are referred to comprehensive studies by Ferrel (1993; 1996) and Galat et al. (1996).

Snagging and channel clearing were the first efforts to improve navigability for keelboats and steamboats. These efforts were systematic and intensive from 1885 to 1910 (Galat et al. 1996). On 1879 project maps (Missouri River Commission 1879), Lisbon Bottom land cover is depicted as dense willows, sandbars, and a few small fields. During the interval 1879-1920, the mainstem channel of the Missouri River moved approximately 1570 m (5,150 ft) across the downstream one-third of Lisbon Bottom (Fig. 11), leaving the town of Lisbon without river access. Because 1890 maps (Missouri River Commission 1892) seem to indicate a channel position intermediate between those of 1879 and 1920, it appears that movement of the channel was incremental.

Maps from 1920 (War Department 1920) show channel revetment existed on the left bank RM 217.5-219 and three wing dikes existed on the left bank RM 217-217.5; this project was completed by 1917. Downstream from RM 216 to RM 213.5, revetment was completed on the right bank by 1915. Also in 1915, a natural chute was cut across Jameson Island (RM 214.5); this chute was closed by revetment and diking by October 1916 (War Department 1920). The entire left bank of Lisbon Bottom is noted as heavy timber and willows in 1890; however, it is unclear if the center of the bottom was heavily timbered at this time. No levees were mapped on Lisbon Bottom in 1920.

More intensive channel structuring began after authorization of the Navigation and Bank Stability Project by the Flood Control Act of 1944 (Galat et al. 1996). Navigation maps from 1954 (U.S. Army Corps of Engineers 1954) show the channel had been largely confined to its present form and position. Two more dikes were added to the left bank dike field and two short wing dikes and revetment had been added to the right bank from RM 217.5-218. In addition, two short wing dikes had been added to the right bank at RM 216, and three dikes and an additional closing revetment were added to the upstream entrance of the Jameson Island chute at RM 215. Nearly the entire right bank from RM 216.25 to 213.5 was protected by revetment in 1954. The 1954 maps depict Lisbon Bottom as a mosaic of timber, willows, scattered timber, and cultivated land.

No levees were mapped along the main channel in 1954, but short levees existed near the valley wall apparently to deal with interior drainage from Buster Branch and valley-wall tributary basins. In addition, no levees appear on USGS 7.5-minute quadrangle maps that are based on 1969 aerial photography, nor are levees apparent on the aerial photography base (1972) used for the Howard County soil survey (Grogger and Landtiser 1978). Levees did exist around the outside margin of Lisbon Bottom by 1986; however, these observations are consistent with recollections of a former landowner who stated that only low levees were constructed during the 1960's and that the main levees were not built until the mid-1980's (Bill Lay, personal communication). In 1986 the levees in the Lisbon Bottom area were incorporated as Howard County Levee District #5.

By 1993, Lisbon Bottom was completely leveed along the left bank downstream as far as Coopers Creek (Fig. 3). The levee was completed to approximately 6-11 ft above ground level, with a crown ranging 10-14 ft wide and side slopes ranging from 1:3 to 1:5 (Bob Meyer, USACE, Jefferson City, Missouri, personal communication). In April 1993 the levee was inspected and qualified for the U.S. Army Corps of Engineers maintenance program. The levee was built to a height that would protect Lisbon Bottom up to a stage of 32.0 ft on the Glasgow gage, or approximately 611 ft above sea level at RM 218. Based on extrapolation from the streamgage at Boonville[10] this is equivalent to protection from flood stages of 2-5-year recurrence interval.

Also 1993 had installed additional wing dams along the right bank RM 217.5-219. Bank revetment on the right bank extended RM 217.75-

[10]This estimate assumes (a) the construction reference plane (CRP) is a plane of equal flow duration along the river and (b) that the relation at Boonville reasonably approximates the relation between discharge and stage at Lisbon Bottom.

216.75 and RM 216-213.5. On the left bank, revetments extended from upstream of RM 219 to the wing dams at RM 218 and from RM 213.8 to 213.4.

The flood of 1993 broke the Lisbon Bottom levee in multiple places. The exact process by which the levee broke is unknown. Similar levees along the Missouri River broke by various mechanisms, including vertopping, liquefaction by seepage water, and mechanical erosion on the upstream side (Schalk and Jacobson 1996). During the 1993 flood, the peak daily flow at Boonville was 721,000 cfs on 30 July (Fig. 10). The estimated 500-year flow at Boonville is 700,000 cfs (U.S. Army Corps of Engineers, Kansas City District, written communication).

In general, once a levee is broken the potential conditions exist for extensive erosion and deposition. A large discharge of water concentrated through a narrow opening can result in high velocity, high water-surface slope, and intense turbulence. If the shear stresses produced in these situations are sufficient to erode through the cohesive top stratum composed of silt and clay, a threshold of erosion is reached because the underlying noncohesive sand can be more easily eroded.

Undermining sand promotes upstream and downstream extension of levee-break scours and maintains steep slopes on the scour margins (Jacobson and Oberg 1997). Typically, a stripped area extends along the downstream and lateral margins of a scour hole; the stripped area is characterized by erosion within the plow horizon of the surface soil and underlying cohesive sediment. Depositional areas occur downstream and lateral to the stripped area. Sand deposits — sometimes of thicknesses exceeding 15 ft (5 m) — occur in the center where flow is concentrated and silt and clay deposits occur in slow and slackwater areas within the flooded bottom.

Overflow from a flooded bottom typically creates another levee break and scour at an overflow exit. These scours can be as deep as entrance scours. Exit scours typically expand upstream with time as the steepened margin erodes. Most of the erosion apparently occurs on the declining limb of the flood hydrograph as the leveed area drains back into the main channel. Galat et al. (1997) discuss the general distribution and properties of scours the 1993 flood caused along the Lower Missouri River

The 1993 flood left one large scour at the upstream margin of Lisbon Bottom and three smaller levee breaks and scours (Figs. 3, 5). Also, the flow breached the cross-levee in numerous places, and at least five exit scours developed along the downstream margin.

Subsequently, four of these scours were identified and studied as part of the Missouri River Postflood Evaluation Project (S-15, S-15A, NC-9, and S-14; Fig. 3). Bathymetric maps of the main entrance scour (S-15, Fig. 3) and one of the exit scours (S-14, Fig. 3) document 8-9-m depths (Galat et al. 1997). None of the levee breaks were repaired after the 1993 flood, so subsequent floods of lesser magnitude were allowed to flow through the levees (Fig. 10).

Lisbon Bottom has been flooded multiple times since the peak daily flow recorded on 30 July 1993. At least nine discrete floods in excess of 200,000 cfs occurred from August 1993 to January 1998 (Fig. 10). According to a flood frequency analysis the U.S. Army Corps of Engineers performed, bankfull stage in this segment of the Missouri River is about 198,000 cfs (USACE, Kansas City District, written communication, 12 February 1997).

The largest discharge recorded at Boonville, Missouri, between August 1993 and January 1998 was 353,000 cfs in May 1995. However, the most significant discharge was the flood that peaked at approximately 290,000 cfs in late May-June 1996. The May 1995 flood inundated at least 80% of Lisbon Bottom and resulted in substantial reworking of sand deposits emplaced by the 1993 flood, but it did not change the basic architecture of the scours. However, May-June 1996 flood connected the upstream entrance scour (S-15) with the nonconnected scour at the interior levee (NC 9) and a small exit scour near RM 214.7, thereby creating the chute shown in Fig. 3.

Since formation in May-June 1996, the chute has widened, migrated laterally, and increased in complexity. When it was formed in 1996, the chute was relatively straight and had a trapezoidal cross section. A compact layer of clayey silt — probably sediment that filled the 1879 channel — created a significant "clay plug" near cross section 32 (Fig. 12); this clay plug acted as a local base level in the early evolution of the chute and slowed lateral migration.

By January 1998, the chute had developed three distinct bends and complex channel structure (Fig. 12). In the upstream portion (sections 20-28), the chute is characterized by mid-channel bars and extensive lateral flats on the left bank. The lateral flats have a discontinuous layer of sand over compacted fine sediment that predates the chute. Downstream of cross section 28, the channel has developed point bars and a meandering thalweg[11] (Fig. 12).

Aerial photographs (Missouri Department of Conservation files) taken of the chute from May 1996 to December 1997 indicate the mid-channel and lateral bars just begin to emerge when total discharge of the river is approximately 75,000 cfs. As bars emerge, it would be expected that a wide range of shallow water and bare sandbar habitats would become available for fish and birds; hence 75,000 cfs is a useful reference discharge for evaluating habitat availability.

The long-term gage record at Boonville indicates that 75,000 cfs has been equaled or exceeded approximately 50% of the time under post-regulation conditions. The discharge value at which bars become emerged is approximate because the notches in the upstream revetment have been repaired several times in this interval, thereby changing the proportion of total discharge that flows into the chute.

Discharge measurements on 2 December 1997 indicated that the chute accommodated approximately 21% of the total Missouri River discharge (26,000 cfs of 126,000 cfs). For comparison, discharges of approximately 81,000 cfs just cover most of the wing dams in the main channel.

Development of the chute has been associated with increased conveyance of floodwater through Lisbon Bottom. Aerial photographs (Missouri Department of Conservation files) during a 174,000-cfs flood on 10 July 1995 indicated that approximately 50% of Lisbon Bottom was inundated. At that time, the 174,000-cfs flow was sufficient to enter the flood plain through the upstream levee breaks and flow through low swales across the entire bottom.

On 14 April 1997 it was estimated from aerial photos that the bottom was also approximately 50% inundated by a discharge of 277,000 cfs. Thus, the same approximate degree of inundation occurred with a discharge that was 60% greater. In another comparison, the 290,000-cfs discharge in May 1996 was estimated to have inundated 90% of the bottom whereas the 274,000-cfs discharge in April 1997 was estimated at only 50% inundation. Both of these comparisons indicate less inundation of the bottom after formation of the chute. Presumably, this results from increased efficiency (conveyance) of discharge through the chute compared to nonchannelized overbank flooding.

The Future of Lisbon Bottom

The future ecological structure of Lisbon Bottom depends on how physical hydrologic and hydraulic processes are allowed to operate. These physical processes can be divided into two distinct domains: those associated with the annual hydrograph and those associated with changing geomorphology.

The first domain concerns time variation of depth and velocity of flow as determined by regulation and stochastic hydroclimatic processes. This can be referred to as the hydrologic dynamics. The second domain concerns how flow is distributed among the channel, marginal habitats, and the flood plain as determined by the geometry of the channel and flood plain. Changes in these boundary conditions — because of natural channel migration or changes in structures — can be referred to as the geomorphic dynamics.

Hydrologic dynamics are determined by a combination of reservoir release policy and stochastic climatic processes. Since significant regulation of the Missouri River began in 1952, hydrologic dynamics have produced the distribution of flows shown in Fig. 8d.

Although it is possible that future reservoir release policy will change to reflect changing societal values, it is probable that such changes will be minor because of multiple, competing uses of the Missouri River. Thus, Lisbon Bottom will likely continue to have hydrologic characteristics similar to those shown in Fig. 8d.

The floods of 1993 and 1996 were significant agents of geomorphic dynamic change. Breaching the levees upstream and downstream at Lisbon Bottom served to reconnect the flood plain to the main channel. Before the 1993 flood, discharges in excess of approximately 300,000 cfs were necessary to overtop levees and inundate any of the leveed area of Lisbon Bottom. After the 1993 flood, some parts of Lisbon Bottom were connected to the main channel at nearly all discharges.

Discharges as small as 150,000 cfs — a flow

[11] The thalweg is the line within the channel that connects the lowest elevations. The thalweg generally defines the line of greatest depth and velocity.

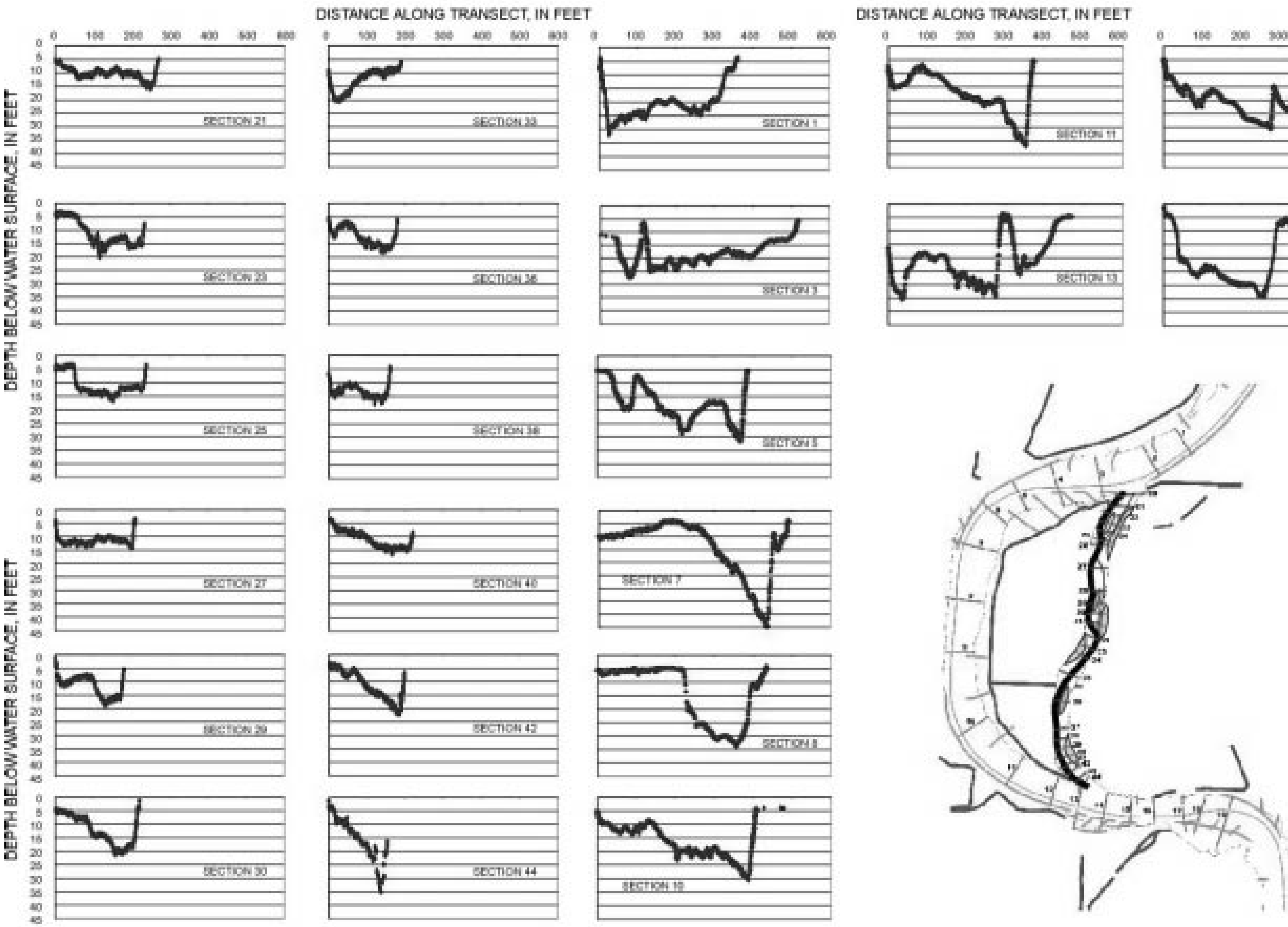


Figure 12. Selected bathymetric cross sections at Lisbon Bottom in the chute and main channel, December 2-3, 1997. Zero feet depth is the water surface on these dates.

equaled or exceeded about 8% of the time (30 days per year) on average — were able to inundate as much as 30% of Lisbon Bottom. With the formation of the chute in May-June 1996, a large area of permanently inundated, lotic habitat was added to the Missouri River at Lisbon Bottom.

Moreover, geomorphic dynamics have been allowed to continue at Lisbon Bottom. After July 1993, floods have been allowed to erode and deposit and have recreated some of the continuously shifting patches of riverine habitat that existed before engineering alteration of the Missouri River. Ongoing channel adjustment in the chute has created a pattern of mid-channel and lateral bars and a channel that is free to migrate unconstrained by bank structures. This unconstrained channel morphology has created a physical habitat that is probably very similar to what existed in secondary channels before regulation and structuring of the Missouri River.

The future of habitats in the chute depends primarily on how the entrance and exit of the chute are engineered to accommodate the needs of navigation and river stability. Navigation requirements dictate that the chute must not be allowed to pirate the main flow of the Missouri River; design changes already were being made during spring and summer 1998. If discharges sufficient to transport significant sediment are allowed to flow into the chute at least annually, channel migration and habitat maintenance can be expected to continue.

Critical questions persist regarding how much sediment and large woody debris will flow into the chute from the main channel. These factors may be key elements in determining physical habitat quantity and quality, but they are impossible to predict.

Documented channel widening, formation of mid-channel bars, and increasing sinuosity indicate that channel slope is tending to decrease along with an increase in boundary flow resistance. If margins of the channel become densely populated with willow and cottonwood, flow resistance can be expected to increase even more. These processes would be expected to slow velocities in the chute, increase hydraulic diversity, and increase sedimentation.

Formation of the chute has decreased inundation of Lisbon Bottom compared to the pre-June 1996 condition. The chute apparently has increased the efficiency of flood flow across the Bottom, thereby decreasing stages and inundation of other parts of the Bottom. By increasing advection of water in the downstream direction, the chute has decreased diffusive flow that might have otherwise contributed to adjacent wetlands along Buster Branch (Fig. 3).

This would seem to be a natural and unavoidable result of growth and evolution of an upstream entrance scour. If the management goal is extensive inundation of wetlands, it may be better to manipulate downstream revetments and levees to increase backwater flooding of the Bottom. As noted by Schmudde (1963), this is the way that flood plains naturally flooded on the Missouri River before regulation and structuring.

Similar to increased downstream advection of floodwater, the presence of the chute will act to increase downstream sediment transport. Instead of accumulating in natural levees around the upstream margin of Lisbon Bottom, sediment will tend to be transported down or through the chute. If it is not transported completely through the chute, sediment can be expected to accumulate as lateral and mid-channel bars and as flood-plain splays similar in geometry to those created in the 1993 and 1995 floods.

Eventually, the chute can be expected to form a flood plain of its own within the Lisbon Bottom if it is allowed to migrate freely. A flood plain in equilibrium with the flows allowed to flow through the chute would be expected to have diverse sandbar and wetland habitats. Moreover, as the flood plain and the margins of the chute become vegetated, it is probable that flood velocities will slow and flow directions will become more complex. With these changes, the flow of water, sediment, and organic materials through the chute will be complemented with increased lateral transport onto the flood plain and increased residence times of sediment and organic materials. Thus, the high velocities and increased flow conveyance noted in 1996 and 1997 can be interpreted as intermediary stages of a system that has been continuously evolving since 1993.

Lisbon Bottom presents a unique opportunity to increase understanding of the links between physical processes and biotic responses on the Missouri River. The near-natural physical evolution of the flood plain and chute since July 1993 provides an essential example of what can be accomplished in habitat improvement using a least-cost, passive-management strategy.

The results of this ongoing experiment should provide invaluable information for assessing how much natural ecosystem structure and function can exist while maintaining traditional uses of the Missouri River.

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CHAPTER 2
Post-flood Vegetation Communities

by

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Introduction

The majority of Lisbon Bottom, Howard County, Missouri, was in cultivation before the 1993 flood with as much as 92% of the 814.65 ha in row crops during recent years (Table 1)(Brian McDonald, USDA). In 1993, when flood waters breeched the Lisbon Bottom levee at river kilometer 351.6, most croplands received depositions of silt and sand or were eroded. These impacts left a large portion of the land unfarmable, and in 1994 only 30% of the Bottom was cultivated.

High water levels and the erosional and depositional processes of the flood provided a unique opportunity to evaluate the natural recolonization and establishment of vegetation in previously cropped sites. Development of plant communities depends on the composition and persistence of the soil seed bank and the life span and growth requirements of species present in the seed bank. The scouring action and deposition from the flood removed residual crop material and natural vegetation, as well as altering the composition and distribution of seeds in the soil seed bank. Seeds of new species may have been deposited, viable seeds of some species may have been removed or buried, and dormant seeds may have been exposed.

The purpose of this study was to examine the composition of the soil seed bank and the post-flood vegetation community on 24 sites located in the Missouri River flood plain in order to examine the post-flood vegetation response and to provide insight into successional processes and flood-plain management (Mazourek 1998). This report focuses on the two sites on Lisbon Bottom that were investigated for the Missouri River Post-flood Evaluation (MRPE) project MRPE-S-15 and MRPE-TLIS.

Methods

During summer 1994, seed bank samples were collected from eight random locations within scoured site MRPE-S-15. Samples were brought to a University of Missouri-Columbia greenhouse where the seedling emergence method (Welling et al. 1988) was used to determine species composition of the soil seed banks. The post-flood vegetation community was evaluated during July, August, and September each year from 1994 to 1997. Percent cover, average height, and number of individuals were recorded for each species present within 12 randomly located 0.5 m-m^2 rectangular (61 cm x 82 cm) quadrats. New

Table 1. Number of acres planted in corn, soybeans, and wheat and the percentage of the total hectares on Lisbon Bottom in crop production by year (# of hectares in production/814.65 ha).

Year	Corn	Soybeans	Wheat	% Cropped
1990	105.06	396.88	251.96	92.54
1991	76.37	433.91	144.72	80.40
1992	308.66	220.28	171.76	86.00
1993	292.92	301.34	104.41	85.76
1994	0.00	202.55	36.87	29.39
1995	0.00	0.00	0.00	0.00

*Values for wheat reflect the number of hectares harvested during that calendar year.

quadrats were located each year until permanent quadrats were established in 1996. Quadrats were stratified by water depth; six were located in the shallow marsh zone (from the high water mark to the water's edge at initial sampling in July) and six were located in the deep marsh zone (from the water's edge until the water was 60 cm deep).

The post-flood vegetation community also was evaluated in temporary site MRPE-TLIS during 1996 and 1997. Percent cover, average height, and number of individuals were recorded for each species present within six randomly located 0.5-m^2 rectangular plots. Because the entire temporary site was considered shallow marsh, only six quadrats were sampled. Additional field surveys were conducted in 1996 and 1997 to document all species present in the post-flood vegetation within MRPE-S-15 and TLIS. To document species, equally spaced transects were walked periodically in each site. Then voucher specimens of each plant species encountered during these searches were collected and entered into a special collection at the Dunn-Palmer Herbarium, University of Missouri-Columbia. Nomenclature followed Steyermark (1963) and Yatskievych and Turner (1990).

Results

A total of 106 species was present in the seed bank samples, vegetation quadrats, and field surveys of MRPE-S-15 and MRPE-TLIS. Of the 106 species, 80 were present in the post-flood vegetation (surveys and quadrats combined) of MRPE-S-15 and 59 were present in the post-flood vegetation of MRPE-TLIS. However, only 16 species germinated from seed bank samples collected from MRPE-S-15 in 1994 and only 46 species were present in the sampling quadrats in all years combined.

Sorenson's coefficient of similarity (Warne 1992) was used to compare species in the seed bank to those in the vegetation community during 1994 and 1995. Similarities were greatest in 1994 (52%) and declined over time (1995:44%, 1996:39%, 1997:38%), suggesting species have been dispersed into the basin since seed bank samples were collected. Eventually, as the vegetation community becomes established, the similarity between the seed bank and vegetation should become greater (Warne 1992) due to on-site seed production by dominant species unless periodic flood events occur.

The majority of species present in the vegetation quadrats during all-sampling periods and years combined were annual wetland forbs (Table 2). However, dominant species (determined by ranking species by mean cover and by mean abundance) varied among years. For example, in 1994 cottonwood (*Populus deltoides*, facultative woody) was the dominant species followed by carpetweed (*Mollugo verticillata*, annual facultative forb), Eclipta (*Eclipta prostrata*, annual facultative forb), and sedges (*Cyperus* spp., annual and perennial wetland grasslike plants). Cottonwood was not a dominant species in the remaining years although this species was a consistent component of the vegetation community. The dominant species in 1995 were similar to 1994 with the addition of bidens (*Bidens frondosa*, annual wetland forb). Wetland annual grasses (*Panicum dichotomiflorum*, fall panic grass—1997 only—and *Eragrostris hypnoide*, lovegrass) were dominant in 1996 and 1997, followed by pigweed (*Amaranthus rudis*, annual wetland forb) and smartweeds (*Polygonum lapathifolium* and *P. persicaria* —1997 only).

Of the 59 species present in TLIS, only 24 were in the sample quadrats. The majority of these species were annual wetland forbs. The dominant species in the TLIS vegetation community varied somewhat among years as well. In 1996, pigweed, cottonwood, cocklebur (*Xanthium strumarium*, annual facultative forb), and sedges were the dominant species and in 1997, pigweed, cocklebur, prairie dogbane (*Apocynum sibiricum*, perennial facultative forb) and toothcup (*Ammannia coccinea*, annual wetland forb) were the dominants, followed by cottonwood and willow (*Salix* spp., wetland woody) as a group.

Disparities between the total number of species encountered within each study area and the number of species found in sample quadrats are due to study objectives and design. Quadrats were sampled to quantify the general response of vegetation in the flood plain after the 1993 flood. Surveys were conducted to document every species in the proximity of the study area, including species that may have occurred only once and species that occurred outside established sampling zones.

Discussion

The high number of annual wetland species colonizing MRPE-S-15 and TLIS and the persistence of cottonwood and willows in the post-flood vegetation community are consistent with the ecological characteristics of these plants. Early successional species tend to be annuals with wind- or animal-dispersed seeds that retain viability for longer time periods. Historically, the wind-dispersed cottonwood (*Populus deltoides*) and willows (*Salix* spp.) were the first to colonize newly deposited alluvium in the Missouri River flood plain (Wilson 1970, Johnson et al. 1976, Bragg and Tatschl 1977). Not present were seeds characteristic of transitional forests such as box elder (*Acer negundo*), silver maple (*Acer saccharinum*), red mulberry (*Morus rubra*), and American elm (*Ulmus americana*) or terminal forest community such as hackberry (*Celtis occidentalis*), American elm, black walnut (*Juglans nigra*), green ash (*Fraxinus pennsylvanica*), and sycamore (*Platanus occidentalis*) (Weaver 1960, Bragg and Tatschl 1977).

The current constriction of the river and water management for navigation concentrate erosion and deposition associated with major flood events on the lower terraces adjacent to the river. Consequently, future floods will likely continue to erode and deposit silt and sand at the same locations, preventing development beyond the pioneer stage. Thus, the prediction of this study is that pioneer cottonwood-willow stage will more likely persist on a scoured site like MRPE-S-15 rather than develop into a transitional forest. Although cottonwood and willow establishment has not been quantified in areas of Lisbon Bottom away the river, their growth and development have surpassed that in MRPE-S-15 and TLIS. This suggests that areas not subject to frequent flooding may develop into transitional forest over time.

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Table 2. Species present in the soil seed bank of MRPE-S-15 and species present in the post-flood vegetation of MRPE-S-15 and TLIS during 1994 through 1997. X denotes species present in quadrats and * denotes species encountered during surveys.

		Post-Flood Vegetation					
Species	**Seed Bank**	**1994 S-15**	**1995 S-15**	**1996 S-15**	**1996 TLIS**	**1997 S-15**	**1997 TLIS**
Abutilon theophrasti						*	
Acer saccharinum						X	
Amaranthus rudis		X	*	X	X	X	X
Ambrosia artemisiifolia							*
Ammannia coccinea	X				X	X	X
Apocynum sibiricum					*	*	X
Asteraceae				X			
Bidens cernua						*	
Bidens frondosa			X			X	
Bidens sp.					*		
Bidens triparta							*
Blephilia ciliata							*
Brassicaceae		X	X	X	X		
Capsella bursa-pastoris						*	
Carex hyalinolepis							*
Chenopodium album			*	X			
Cynanchum laeve			X	*	X		X
Cyperus aristatus	X		*			X	
Cyperus erythrorhizos	X		X		X	X	X
Cyperus esculentus	X		X			X	X
Cyperus odoratus	X	X	X	X	*		
Cyperus sp.	X	X	X	X	X		X
Digitaria ischaemum						X	
Echinochloa crusgalli				*		*	*
Eleusine indica			*				
Eclipta prostrata	X	X	X	X	X	X	*
Eragrostris cilianenses						*	X
Eragrostris frankii var. frankii			*				
Eragrostris hypnoides	X	X	X	X	X	X	X
Eragrostris pectinacea						X	
Erigeron annuus							*
Erigeron philadelphicus						*	
Equisetum sp.			*				
Eupatorium serotinum						X	*
Galium aparine						X	
Galium triflorum							X
Helianthus annuus						X	
Helianthus sp.			X				
Hordeum jubatum						*	

Table 2. continued

Species	Seed Bank	1994 S-15	1995 S-15	1996 S-15	1996 TLIS	1997 S-15	1997 TLIS
Ipomea lacunosa			X	*			
Ipomoea sp.					*		
Juncus interior						*	
Juncus tenuis f. tenuis						*	
Juncus torreyi						*	
Leersia oryzoides							*
Lemna minor			X				
Leucospora multifida			X				X
Lepidium virginicum						*	
Leptochloa fascicularis					*		
Leptochloa filiformis	X						*
Lindernia dubia	X	X	X	X		X	
Lobelia inflata							0
Ludwigia peploides	X					*	
Lycopus americanus			X			*	*
Lythum salicaria						*	
Mentha arvensis						*	
Mimulus ringens						*	
Mollugo verticillata	X	X	X	X		X	
Myosurus minimus							*
Oenothera laciniata						*	
Panicum dichotomiflorum			X	X	X	X	X
Panicum philadelphicum					X		
Penthorum sedoides			X	*		X	*
Phalaris arundinaceae						*	*
Phyla lanceolata	X					*	
Plantago major					*	*	
Polygonum amphibium var. coccineum				*	*		
Polygonum hydropiper							*
Polygonum lapathifolium			X	X	*	X	X
Polygonum persicaria						X	*
Polygonum sp.		X					
Populus deltoides		X	X	X	X	X	X
Potentilla norvegica				*		*	
Ranunculus sceleratus	X	X	X	*			*
Rorippa palustris						X	*
Rorippa sessiliflora	X					*	
Rorippa sinuata						*	*
Rorippa sylvestris					*	*	*
Rudbeckia hirta						*	
Rumex altissimus							*
Rumex cripus							*

Table 2. continued

Species	Seed Bank	1994	1995	1996		1997	
		S-15	S-15	S-15	TLIS	S-15	TLIS
Rumex maritimus var. fueginus						*	
Rumex obtusifolius				*		*	
Rumex sp.				*			
Sagittaria sp.					*		
Salix sp.		X					
Salix eriocephala				*	*	X	
Salix exigua				X	*		X
Salix nigra						X	
Salix sp.							X
Setaria faberi			X			*	
Setaria pumila						X	
Setaria viridis			X				
Sibara virginica							*
Sida spinosa				*			*
Solanum carolinense						*	
Sorghum halapense					X		X
Spirodela polyrhiza				X			
Sphenopolis obtusata							*
Trifolium campestre							*
Veronica anagallis-aquatica							*
Veronica peregrina	X	X	X				X
Xanthium sp.					X		
Xanthium strumarium						X	X
Unknown woody						X	

CHAPTER 3

Aquatic Macroinvertebrates

by

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Introduction

The freshwater invertebrate fauna of the United States, including insects but excluding parasitic classes, consists of approximately 11,000 described species (Pennak 1989). The fauna of the United States is not particularly well known and the total number of described species continues to increase.

Although freshwater habitats are highly fragmented and vary greatly in habitat condition, invertebrates have developed life history strategies adapted to these varying conditions (Wiggins et al. 1980) and are found in virtually every freshwater habitat type. Invertebrates play an important role in the aquatic habitats they occupy. They are a primary mechanism in the breakdown and processing of organic matter (leaves, detritus, woody debris), providing food for filter feeders and other trophic levels (Murkin 1989, Magee 1993) including fish, birds, herpetofauna, and other invertebrates.

Additionally, invertebrate communities are sensitive indicators of water and habitat quality and can provide important clues about the results of wetland management and habitat restoration. Despite their importance, the invertebrate fauna of the Lower Missouri River and its associated flood plain was poorly known before flooding in 1993.

Macroinvertebrates as defined here include freshwater invertebrates greater than 500 µm in length as measured by filtering through or sampling with a mesh size $\geq$500 µm. Aquatic insects are defined as those orders or families associated with aquatic habitats during one or all of their life stages and follows Merritt and Cummins (1996).

The levee breaks at Lisbon Bottom, river mile (RM) 213-219, created scours and inundated the entire bottomland area for several weeks during 1993 and again in 1995, 1996, and 1997. Questions arose regarding these newly created habitats and other aquatic habitats in the Missouri River flood plain after the flood and provided the impetus for the Missouri River Post-flood Evaluation (MRPE) project.

Invertebrates were studied as part of this multidisciplinary effort to evaluate the role and relative importance of flood-plain aquatic habitats to fish and wildlife. Two additional invertebrate-related studies were conducted in cooperation with the Columbia

Environmental Research Center (CERC) and the Big Muddy National Fish and Wildlife Refuge (Refuge): (1) evaluating and characterizing aquatic invertebrate communities associated with different Missouri River mainstem habitats and colonization substrates and (2) studying food habits and feeding ecology of two species of aquatic turtles present in a remnant flood-plain wetland on Lisbon Bottom (see Herpetofauna chapter, this volume). These data are being combined with the MRPE data in this report to provide a picture of the Refuge during 1994-97.

Sites

Three study sites (S-15, TLIS, BP) (Fig. 1) were sampled on Lisbon Bottom and two study sites (MR-1 and MR-2) were sampled in the Glasgow reach of the Missouri River between RM 214 (near Lisbon, Missouri) and 228 (1 mile upstream from Glasgow, Missouri). S-15, a 24-ha connected scour, was created in 1993 when the levee failed and rushing water scoured a large hole and depression downstream of the break.

Additional flooding and scouring during May and June 1996 created a chute across the Bottom. S-15 was connected to the river throughout the year and chute development continued throughout the duration of these studies. Water depths and current speed varied with river levels.

TLIS, a 7-ha temporary wetland, ranged in depth from 0-0.5 m (water within basin margins) and normally flooded when river levels rose above flood stage. Typically, this study site held water for only 4 weeks after floodwaters receded.

BP is a 0.5-ha wetland with relatively permanent water ranging in depth from 1.5 to 3 m. This site is bordered with mature trees, and like TLIS, becomes connected to the river at flood stage via a small overflow channel.

The mainstem river study sites were located on rock revetments with current velocities of 0.2-0.7 m/sec (MR-1) and in depositional muck habitats in slack water behind wing deflectors or connected scour holes (MR-2).

Methods

S-15 (1994-97) and TLIS (1996-97) were sampled using modified model "week" emergence traps (LeSage and Harrison 1979), activity traps (Murkin et al. 1983), artificial substrates, and sweep nets (Table 1). Emergence traps were set continuously and samples were collected weekly. Biweekly activity trap samples were collected by setting the trap midway in the water column for a 24-hour period. Artificial substrates were used to detect the presence or absence of snails, and sweep net samples were collected to supplement emergence trap and activity trap sampling.

Six sample stations, consisting of one emergence trap, one activity trap, and one artificial substrate each, were placed in S-15 in 1994 by randomly selecting three shallow water ($\leq$90 cm) and three deep water (90$\geq$183 cm) stations. Flooding and strong water currents prevented consistent sampling of all six stations. Lost traps and site inaccessibility greatly reduced the number of samples collected at S-15. Three shallow water sample stations were randomly placed within TLIS. Samples were collected with activity traps and artificial substrates when water levels were deep enough (15-30 cm) to allow the traps to be set. BP was sampled three times during July 1997 as part of the aquatic turtle food habits study, using a sweep net and Petite ponar grab (Holme and McIntyre 1971) (Table 1).

Sweep net samples were collected at three stations by dragging the net through the water column for a 2-m distance perpendicular to the shoreline. Ponar grab samples were collected 20 m inside the shoreline stations, and four ponar grab samples were collected at stations in the center of the pond. Water depths were measured at each station. Two study sites within the main river channel were sampled using rock basket artificial substrate samplers, a kick net, and a ponar grab in 1996 and 1997 as part of the habitat/substrate quality study (Table 1).

The MR-1 and MR-2 stations used in 1996 (RM 228) were moved to a connected scour hole (RM 214) and a revetment (RM 218) at Lisbon Bottom in 1997 (Fig. 1). The 1997 portion of the study has not been completed, and therefore only the 1996 results from this project are included in this report.

Five rock basket artificial substrate samplers were placed on the rock revetment (MR-1) for 6 weeks of colonization and retrieved in December 1996. One 100-organism field-picked invertebrate sample was taken with a kick net in October and December 1996 from MR-1 during stable or declining water levels. Five samples were taken from MR-2 with a ponar grab in December 1996 in 2-3 m of water depth.

Taxonomic level of identification varied between studies; however, for this report, insects are recorded at the family level and most other invertebrate taxa to phylum, class, or order.

Results and Conclusions

A great diversity of aquatic invertebrates apparently uses habitats in Lisbon Bottom and the Missouri River channel. In this study, 85 taxa representing five phyla (Nematoda, Annelida, Arthropoda, Gastropoda, Pelecypoda) were collected. Aquatic insects were the most common, constituting 88% of the total number of taxa. S-15 accounted for 75% of the insect taxa collected, whereas most of the other taxa were collected in TLIS (52%) and MR-1 and MR-2 (46%). Although 75% of the total number of insect taxa were collected in S-15, 16 families were unique to the MR sites; 10 were unique to S-15, and TLIS accounted for 4 unique families.

Approximately 50% of all insect orders (13) contain species that are truly aquatic for all or most of their life cycle, and representatives from each of these aquatic orders were collected. Chironomidae, Ceratopogonidae, and Corixidae were collected at all of the study sites. Chironomidae was the only family collected with each type of sampling gear. Although identification to the family level does not allow complete separation of taxa based on life history events, some separation of families among habitat types is evident.

Eight Ephemeroptera families were collected only in S-15 and MR-1. Among the Ephemeroptera families collected, Heptageniidae, Baetidae, and Caenidae were most common. Megaloptera and Plecoptera, except Perlodidae, were collected only from the MR sites; Trichoptera were collected at all sites. Hymenoptera were collected in S-15 and TLIS only. This may be due to their small size and to the sampling techniques used here but not at other sites.

Although various sampling methods were employed, some families may have been excluded. Some families of Odonata, for example, were likely underestimated or excluded in emergence trap samples because of small funnel size. Crayfish were not

Table 1. Macroinvertebrate collection methods with a reference code, brief description, and number of taxa collected by each.

Method	Code	Years Employed	Sites Employed	Description	No. of Taxa Collected
Emergence Trap	ET	1994-1997	S-15, TLIS	Floating pyramid trap basal area 0.5 m^2	49
Activity Trap	AT	1994-1997	S-15, TLIS	3.78-liter glass jar fitted with a funnel	18
Sweep Net	SN	1997	S-15, TLIS, BP	Rectangular aquatic net 800 x 900 µm mesh	11
Ponar Grab	PG	1996-97	BP, MR-2	0.023 m^2 benthic grab sampler	30
Artificial Substrate	AS	1994-1997	S-15, TLIS	Square masonite plate 450 cm^2 surface area	5
Rock Basket	RB	1996-1997	MR-1	15 cm x 15 cm x 15 cm basket w/7.62 cm limestone	27
Kick Net	KN	1996	MR-1	Rectangular aquatic net 500-µm mesh	25

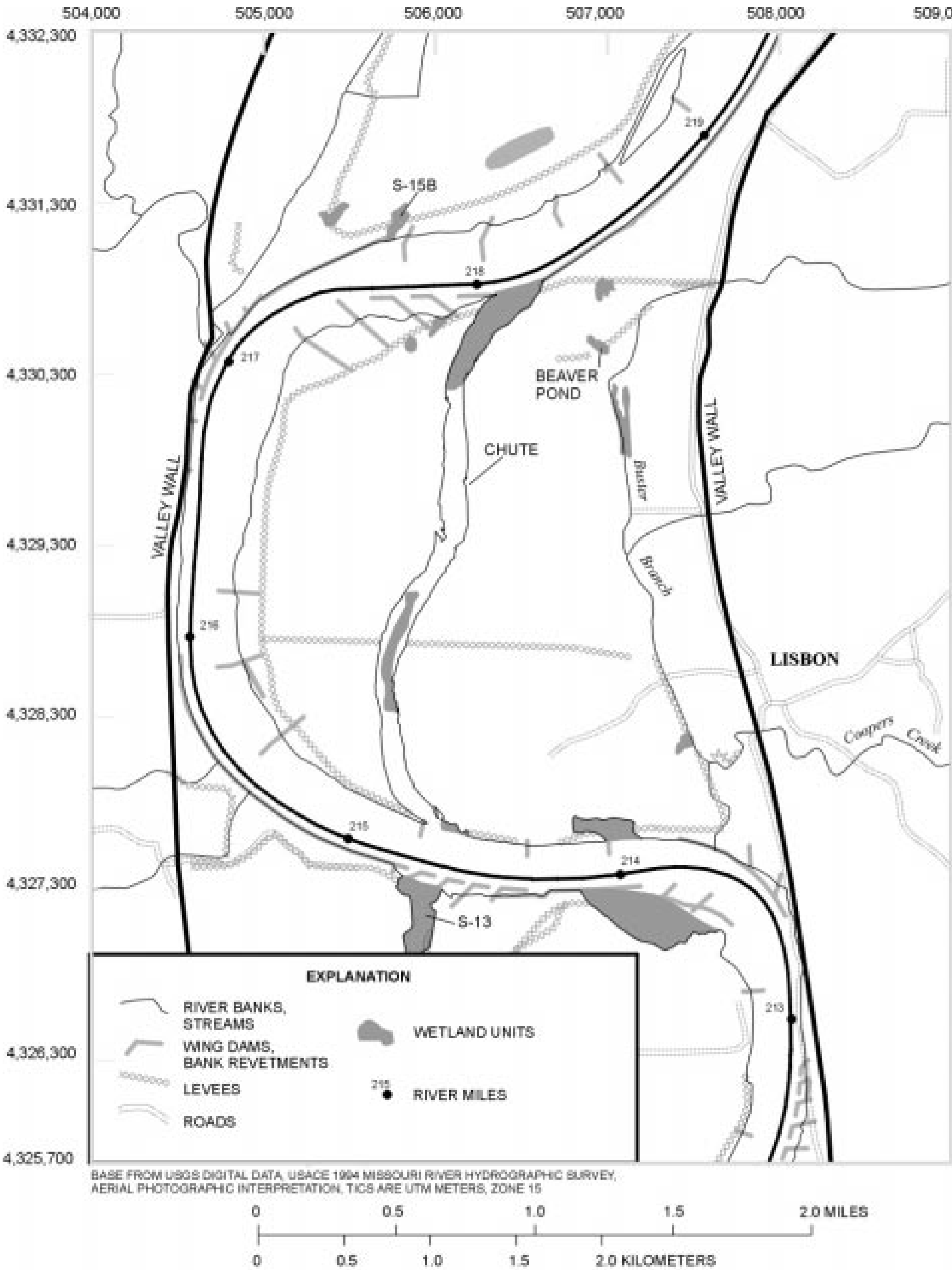

Figure 1. Sample sites on Lisbon Bottom and the Glasgow reach of the Missouri River

sampled in Lisbon Bottom during the MRPE project but were collected with a kick net at MR-1 and a sweep net in BP. Indeed, large numbers of crayfish have been collected with a cast net as part of a fish population study at BP (Duane Chapman, personal communication).

Findings in this report should be carefully interpreted. Three separate studies were combined to create a taxa list of invertebrates and to provide a sense of the diversity present during the early development of the Refuge. These studies were not designed to be compared with one another. The collection times and methods were similar between S-15 and TLIS but differed from BP and MR-1 and MR-2. Flooding, chute development, limited duration of flooding in TLIS, and the fact that the MR sites were only sampled during stable or declining water levels during one season (autumn and early winter) further complicate interpretation beyond the intentions of this report.

Initial sampling, however, during the first 4 years after the Great Flood of 1993 reflected a diverse invertebrate fauna on Lisbon Bottom. This work will provide baseline data and valuable information to managers and researchers in the future.

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Acknowledgments

Invertebrate work would not have been possible without the assistance of K. Klubek, J. Dowe, and many technicians who survived the challenging wet and dry conditions present in the Missouri River bottom. Support for this work was provided through the Missouri Department of Conservation, Columbia Environmental Research Center, Lincoln University, the University of Missouri-Columbia, U.S. Environmental Protection Agency, USDA Natural Resources Conservation Service, and Ducks Unlimited.

Table 2. Invertebrate taxa collected in a temporary wetland (TLIS, 45 taxa), connected scour (S-15, 60 taxa), beaver pond (BP, 11 taxa), Missouri River revetment (MR-1, 34 taxa), and Missouri River depositional muck (MR-2, 30 taxa) at Lisbon Bottom during1994-1997. Collection methods included activity trap (AT), emergence trap (ET), artificial substrate (AS), sweep net (SN), ponar grab (PG), rock basket (RB), and kick net (KN). Level of identification varied among studies.

Taxon	Collection Method	Location
Nematoda	AT, AS, PG	S-15, MR-2
Annelida	AT	S-15
Oligochaeta	AT, SN, PG	TLIS, BP
Haplotaxida		
Tubificidae	PG	MR-2
Hirudinea	PG	MR-2
Arthropoda		
Crustacea		
Cladocera	AT	S-15, TLIS
Copepoda	AT	S-15, TLIS
Decapoda		
Cambaridae	SN, KN	BP, MR-1
Palaemonidae	SN, PG	BP
Arachnoidea		
Hydracarina	AT, RB	S-15, TLIS, MR-2
Insecta		
Collembola		
Poduridae	AT	TLIS
Entomobryidae	AT, PG	S-15, TLIS, MR-2
Ephemeroptera		
Baetidae	AT, ET, PG, RB, KN	S-15, TLIS, MR-1
Isonychiidae	PG, RB, KN	MR-1
Heptageniidae	ET, SN, AS, PG, RB, KN	S-15, MR-1
Ephemerellidae	RB, KN	MR-1
Tricorythidae	SN, RB	S-15, MR-1
Caenidae	AT, RB, PG, KN	S-15, MR-1, MR-2
Leptophlebiidae	RB	MR-1
Ephemeridae	PG, KN	MR-1, MR-2
Odonata		
Anisoptera	AT	S-15
Gomphidae	PG, RB, KN	MR-1, MR-2
Corduliidae	RB, KN	MR-1
Zygoptera		
Calopterygidae	KN	MR-1
Coenagrionidae	ET, RB, KN	S-15, MR-1
Orthoptera		
Tetrigidae	ET	S-15
Tettigoniidae	ET	S-15, TLIS
Plecoptera		
Pteronarcyidae	KN	MR-1
Taeniopterygidae	RB, KN	MR-1
Capniidae	RB, KN	MR-1

Table 2. continued

Taxon	Collection Method	Location
Perlidae	RB, KN	MR-1
Perlodidae	ET, PG, RB, KN	S-15, TLIS, MR-1, MR-2
Hemiptera		
Gerridae	SN	BP
Corixidae	AT, SN, PG, KN	S-15, TLIS, BP, MR-1, MR-2
Saldidae	AT	S-15
Ochteridae	AT	S-15
Megaloptera		
Sialidae	RB, KN	MR-1
Corydalidae	RB, KN	MR-1
Neuroptera		
Sisyridae	ET	S-15
Trichoptera		
Philoptamidae	PG, RB, KN	MR-1, MR-2
Polycentropididae	ET, PG, RB, KN	S-15, MR-1, MR-2
Hydropyschidae	ET, PG, RB, KN	S-15, TLIS, MR-1, MR-2
Hydroptilidae	ET, PG	S-15, TLIS, MR-2
Leptoceridae	ET, SN, PG, RB	S-15, BP, MR-1, MR-2
Lepidoptera		
Pyralidae	ET, PG	S-15, TLIS, MR-2
Gelechiidae	ET	S-15, TLIS
Cosmopterigidae	ET	S-15
Olethreutidae	ET	S-15
Noctuidae	ET	S-15, TLIS
Coleoptera		
Gyrinidae	ET	S-15
Carabidae	ET	S-15, TLIS
Hydrophilidae	ET, SN, RB	S-15, BP, MR
Staphylinidae	ET, AT, SN	S-15, TLIS, BP
Scirtidae	ET, PG, RB	S-15, MR-2
Elmidae	PG, RB	MR-1, MR-2
Chrysomelidae	ET	S-15, TLIS
Curculionidae	ET	S-15, TLIS
Anthicidae	ET	S-15, TLIS
Heteroceridae	SN	S-15
Hymenoptera		
Scelionidae	ET	S-15
Icheumonidae	ET	S-15, TLIS
Braconidae	ET	S-15, TLIS
Mymaridae	ET	S-15, TLIS
Eulophidae	ET	S-15, TLIS
Pteromalidae	ET	S-15, TLIS
Diptera		
Ceratopogonidae	ET, SN, PG	S-15, TLIS, BP, MR-2
Chaoboridae	ET, PG, KN	S-15, TLIS, MR-1, MR-2
Chironomidae	ET, AT, SN, PG, AS, RB KN	S-15, TLIS, BP, MR-1,2
Tanypodinae	ET	S-15, TLIS, MR-1, MR-2
Orthocladinae	ET	S-15, TLIS, MR-1, MR-2

Table 2. continued

Taxon	Collection Method	Location
Chironominae	ET	S-15, TLIS, MR-1, MR-2
Culicidae	ET, AT	S-15, TLIS
Psychodidae	ET	S-15, TLIS
Simulidae	AT, RB	S-15, MR-1
Tipulidae	ET, PG	S-15, TLIS, MR-2
Dolichopodidae	ET	S-15, TLIS
Empididae	ET, PG, RB	S-15, TLIS, MR-1, MR-2
Stratiomyiidae	ET	TLIS
Tabanidae	ET	TLIS
Ephydridae	ET	S-15, TLIS
Muscidae	ET	S-15, TLIS
Anthomyiidae	ET	S-15, TLIS
Phoridae	ET	S-15, TLIS
Scathophagidae	ET	TLIS
Syrphidae	ET	S-15, TLIS
Gastropoda		
Hydrobiidae	PG	MR-2
Physidae	AS, PG	TLIS, MR-2
Pelecypoda		
Sphaeriidae	PG, AS, KN	S-15, MR-1, MR-2

Chapter 4

Fishes of Missouri River, Chute, and Flood-Plain Habitats

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Introduction

The Lisbon Bottom Unit of the Big Muddy National Fish and Wildlife Refuge (Refuge) is approximately 2,200 acres and is the first complete unit of the Refuge. Primary objectives of the Refuge are to create and restore diverse riverine aquatic habitats and reconnect the Missouri River to its flood plain where feasible. Management seeks to accomplish these objectives by encouraging natural processes of erosion, deposition, and succession to the greatest extent possible.

One of the most salient aquatic features of the Lisbon Bottom Unit is a newly created 2-mile-long free-flowing chute, or side channel (Fig. 1). This chute began forming as a levee breech scour hole during the Great Flood of 1993. The chute continued to develop during the 1995 flood and finally cut through to a flowing side channel during the 1996 flood. Extensive erosion and bank sluffing continued during 1997 due to sustained high flows that occurred throughout most of the year. The chute has progressively become wider and deeper with a developing meander pattern and channel bars have begun to form. Lisbon Bottom also contains several seasonal and permanent wetlands and is subject to periodic flooding at high Missouri River stages.

Eight studies have been completed or are ongoing to evaluate Missouri River fishes associated with various habitat components of Lisbon Bottom and adjacent Missouri River reaches (Table 1). Several are part of much larger investigations to evaluate fish use of flood-created habitat features, basinwide fish assessment, and endangered or candidate species concerns.

At the Lisbon Bottom Unit or in the Missouri River adjacent to the unit 54 fish species were collected (Table 2). Eight of these species have either a protected status under State or Federal laws or biologists consider them to potentially qualify for protected status. The status of the following fish is listed in Table 2: pallid sturgeon x shovelnose sturgeon hybrid, paddlefish, northern pike, sturgeon chub, sicklefin chub, ghost shiner, western silvery minnow, plains minnow, and blue sucker. Equally important to note are fish species that were not collected. The flathead chub, currently listed as State endangered and proposed for Federal listing, were not collected in any of the studies.

Common fish species, collected in all seven sampling studies, included gizzard shad, common carp, river carpsucker, and freshwater drum. Paddlefish, skipjack herring, silver carp, white sucker, redfin shiner, western silvery minnow, bullhead minnow, and black bullhead were each collected in only one of the seven studies.

Pflieger (1971) developed a guild system for the fishes of Missouri based on distribution patterns and centers of abundance. Fish were assigned to one of four primary faunal groups: Ozark, Big River, Lowland, and Prairie. Two secondary groups (Ozark-prairie and Ozark-lowland) were defined for species equally abundant and distributed in two of the primary areas. Two Ozark-prairie species, shorthead redhorse and white sucker, were collected on or near the Lisbon Bottom Unit.

Big River species are found primarily in the Missouri and Mississippi Rivers. The environmental factors controlling fish distribution in these rivers appear to be substrate, current velocity, and turbidity. On or near the Lisbon Bottom Unit 18 Big River species were collected (Table 2).

Lowland species are intolerant of siltation and high turbidity. They inhabit standing or slow-moving water with sand, fine gravel, and organic debris substrates. Two Lowland species, bullhead minnow and mosquitofish, were collected in connected scours on the Lisbon Bottom Unit.

Prairie species have broader ecological tolerances than the Ozark and Lowland species. They are largely absent in high gradient streams and cool, clear waters. Prairie species make up a significant proportion of Missouri and Mississippi River fishes. Seven Prairie species were collected on or near the Lisbon Bottom Unit (Table 2).

The last group, Wide-ranging, was defined as the species more widespread than the other faunal groups with broader environmental tolerances. Most Wide-ranging species occur at least occasionally in all sections of the state. Nineteen Wide-ranging species were collected on or near the Lisbon Bottom Unit (Table 2).

Kubisiak (1997) found that isolated scours in the Lower Missouri River were dominated by Wide-ranging species. Connected scours also held Wide-ranging species but they contained Prairie species and were dominated by Big River species. Faunal group diversity and species richness were compared between isolated (Study 1) and connected (Studies 4, 5, 7, and 8) scours of the Lisbon Bottom Unit. Species richness was similar with 22 species collected in isolated scours and an average of 24.8 species collected in connected scours. Isolated scour fish catches were dominated by Wide-ranging fish (59%) with 14% Big River fishes and 14% Prairie fishes. Connected scours had a larger percentage of Big River fish (32%) and fewer Wide-ranging (36%) and Prairie (13%) species than the isolated scours. In the combined studies, Wide-ranging fish dominated the connected scours.

A similar comparison was made of fish from chute habitats and the Missouri River. Chute habitats include the Lisbon Bottom Chute, the chute between the right bank and island located at river mile 219, and a shallow channel running between a large sandbar complex and the channel border adjacent to Lisbon Bottom. Species richness in the chutes (35 species) was greater than that of the adjacent river (23 species). Big River species (40%) dominated the chute samples, followed by Wide-ranging at 31% and Prairie at 14%.

The river samples contained equal numbers of Wide-ranging species (35%) and Big River species (35%) with 17% Prairie species. Differences in fish guild diversity and species richness may be due to numerous factors including sampling effort and sampling season. River samples were collected only in Study 3 in October; chute samples were collected in July, August, and October. Fish may have been using the chute in July and August to spawn, feed, or escape high river levels.

The Lisbon Bottom Chute is a truly unique feature of the Lower Missouri River. It is the first naturally created side channel to develop since the U.S. Army Corps of Engineers tamed the river. The Corps eliminated 89% of the islands in the Missouri River between 1879 and 1954 (Funk and Robinson 1974). The chutes between the islands and the shore were shallower with less current than the main channel. These areas provided diversity to the Missouri River fish habitat, serving as nursery and feeding areas. The Lisbon Bottom Unit of the Big Muddy National Fish and Wildlife Refuge will continue to be studied in an effort to understand the complex role these areas play in river systems.

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The following summaries are labeled Study 1 through 8. This format is consistent throughout the report tables. Table 1 provides a summary of principal investigators or authors, sampling dates, sampling gears, habitats sampled, types of fish data available, and physical/chemical data collected in association with fish sampling. Table 2 contains a summary of fish species collected by each study. Table 3 contains a summary of larval fish taxa collected in Studies 4 and 8. Fig. 1 provides a graphic depiction of the area with sampling locations for each study indicated by the appropriate study number.

Study #1: Fish assemblages in a permanent and temporary wetland at Lisbon Bottom.

Sites:

Two flood-plain wetlands were investigated during this study, one permanent and one seasonal. When the river is high, Missouri River water passed through the permanent wetland, Beaver Pond, to the seasonal wetland below it, Kingfisher Pond. During flooding, the ponds and surrounding inundated young willows and cottonwoods were connected. The ponds dried rapidly in July, and Kingfisher Pond dried completely in early August. Kingfisher Pond was a shallow basin with gradually sloping banks, whereas BP was a scour hole with steeper banks. Woody debris and rooted dead willows provided structure in both ponds. The water retreated below much of the littoral structure in the ponds during the study.

Large Fish Survey:

On four occasions, BP was sampled with 3.2-cm (1.25-in.) bar mesh, 1.22-m (4-ft) diameter unbaited hoop nets with attached 2.54-cm (1-in.)

mesh, 9.14-m (30-ft) long wings between early July and mid-September. White crappie constituted over half the catch and was an average size of 260 mm, quite respectable for this species. Other species captured, in order of abundance, were river carpsucker, bigmouth buffalo, bighead carp, channel catfish, black crappie, largemouth bass, common carp, bluegill, and flathead catfish. The only recaptured fish was a single largemouth bass. Gar and grass carp were observed in the pond, but none were caught in the nets.

Although Kingfisher Pond was not sampled for large fish, some potentially useful observations were made during and after the fish die off as Kingfisher Pond was drying. No large centrarchids of any kind were visible among the dead and dying fish. The vast majority of large fish in this pond when the fish kill occurred were common carp and buffalo. Grass carp and carpsucker were also abundant. This fish assemblage is quite different from that captured in BP. It is curious that only one common carp was captured in BP by using a gear normally effective for carp, yet they were prominent among dead fish at the temporary wetland.

Small Fish Cast Net Survey:

Shallow habitats in Kingfisher and BPs were each sampled on five occasions (1, 2, 7, 8, and 16 July 1997) using a small mesh (1/4-in., 3-ft radius) cast net. The net was thrown every 20 m around the edge of the ponds, with no attempt to capture fish or schools of fish which may have been seen. The area sampled by the net was estimated and fish density was estimated. Fish density in shallow areas of Kingfisher Pond was very high ($5.92 \pm 2.6/m^2$, mean $\pm$ standard deviation) and higher than in BP ($1.19 \pm 0.8/m^2$).

Fish species captured differed between the ponds. Gizzard shad were the most abundant fish in both ponds, but they began dying in Kingfisher Pond in the middle of the study. Young buffalo and carp were abundant in Kingfisher Pond (capture rates $1.19 \pm 0.78/m^2$ and $1.13 \pm 0.50/m^2$, respectively), but these species were not caught in cast nets in BP. Few centrarchids were caught in Kingfisher Pond until the last day when 26 of 101 fish caught were crappies. Crappies occupying the deeper portion of the pond may have entered the catch on that date because the entire pond was then accessible to the cast net technique due to drying. In contrast, centrarchids, mostly crappies, made up more than half of the non-shad fish caught in cast nets in BP, and the remainder primarily consisted of red shiners and bluntnose minnows.

Study #2: Population structure and habitat use of benthic fishes along the Missouri and Yellowstone Rivers.

Native fishes have been identified as the group most jeopardized by past and present management practices along the Missouri River. More than 20 species are listed as rare, threatened, or of special concern by State or Federal agencies. Eight of the nine fishes considered at risk by the U.S. Fish and Wildlife Service occupy shallow water or benthic habitats. This research compares population characteristics and habitat use of 26 benthic fish species among least-impacted, impounded, and channelized river segments found along 2,341 miles of the Missouri River and the lower 70 miles of the Yellowstone River.

Possible differences in viability of benthic fish populations among these segments offer an opportunity to elucidate causal factors for their decline and provide recommendations for their recovery. To date, two of three field seasons have been completed. Only results of the first field season have been summarized. In 1996, 25,692 fishes representing at least 78 taxa and two hybrids were collected in the Missouri and Yellowstone Rivers. All target taxa were collected except pallid sturgeon. Fifteen taxa were collected throughout the Missouri and Lower Yellowstone Rivers, six species were primarily collected in least-impacted and inter-reservoir segments, and two species were collected only in channelized segments.

Habitat use patterns of most taxa were skewed to shallow depths and slow velocities. Turbidity and water temperature patterns were variable among study segments. As part of this larger study, the Lisbon Bottom Chute and adjacent Missouri River were sampled (Fig. 1). In the Lisbon Bottom Chute and adjacent Missouri River 24 fish species were collected (Table 2).

For more information see the following reports:

Dieterman, D.J., M.P. Ruggles, M.L. Wildhaber, and D.L. Galat, editors. 1996. Population structure and habitat use of benthic fishes along the Missouri and Lower Yellowstone Rivers. 1996 Annual Report of Missouri River Benthic Fish Study PD-95-5832 to U.S. Army Corps of Engineers and U.S. Bureau of Reclamation.

Young, B.A., T.L. Welker, D. Scarnecchia, M.L. Wildhaber, and C.R. Berry, editors. 1997. Population structure and habitat use of benthic fishes along the Missouri and Lower Yellowstone Rivers. 1997 Annual Report of Missouri River Benthic Fish Study PD-95-5832 to U.S. Army Corps of Engineers and U.S. Bureau of Reclamation.

Study #3: Annual fisheries monitoring report: Lisbon Bottom Unit, Big Muddy National Fish and Wildlife Refuge.

The Columbia Fisheries Resources Office (FRO) of the U.S. Fish and Wildlife Service initiated fishery survey and monitoring work on the chute in 1997. From river mile 219 to 213, 12 sampling stations were established in the chute and adjacent Missouri River. Field surveys were conducted in July, August, and September with seine, benthic trawl, hoop net, and drifted gill net gears.

Depth, velocity, substrate, and some water quality parameters were also measured at sampling stations. Drifted gill nets were used in July but were destroyed in high water. Due to continuing high water, gill nets were not used during August and October. Paired sets of a large unbaited hoop net (first hoop 1.2-m diameter (4 ft), 4.8-m long (16 ft), #15 nylon netting, 3.7-cm bar mesh (1.5 in.)) and a small unbaited hoop net (first hoop 0.6-m diameter (2 ft), 3-m long (10 ft), #12 nylon netting, 1.8-cm bar mesh (.75 in.)) were set at Stations 1-4 every month. Nets were reset in the same location when checked daily. Six additional hoop net stations below, above, and outside the chute were sampled in October to compare the Lisbon Bottom Chute fish populations with the adjacent Missouri River. Future Lisbon Bottom sampling will include these comparative sample sites.

Benthic trawl hauls were made in the center of the Lisbon Bottom Chute. The benthic trawl was equipped with a roller rock lead line and consisted of the following dimensions: 2-m (6.4-ft) wide, 0.5-m (1.6-ft) high, 5.5-m (18-ft) long, 0.32-cm (1/8-in.) inner mesh, 3.81-cm (1.5-in.) outer chafing mesh, 16.5-cm (6.5-in.) cod-end opening. Sampling began at the head end of the chute. Progressing downstream, three to six hauls were made to the bottom of the chute. Bottom trawl samples were not collected in October due to time spent on efforts to compare the chute with the river.

Seine samples at Lisbon Bottom and Jamison Island were collected using a 7.6-m (25-ft) long, 2.4-m (8-ft) deep drag seine with 6-mm (1/4-in.) mesh. Due to high water, seining was restricted to Stations 5-7 in the chute. Lower water levels may provide more seinable habitat in the future. Jamison Island seining was conducted only in July due to the extensive time spent sampling Lisbon Bottom.

A total of 1,225 fish comprising 34 species was collected in Lisbon Bottom Chute during the 1997 surveys. Federal listing candidate species sicklefin and sturgeon chub were collected as were species of concern, plains minnow and blue sucker. A 28-in. long pallid x shovelnose sturgeon hybrid weighing 2.75 lb was also collected. Hybrid pallid sturgeon receive the same protection under the endangered species listing as pure stock relatives. Another relatively rare specimen was a nearly 3-ft long American eel. By seining the Jamison Island area, 148 fish of 10 species were collected.

The Kansas City District Corps of Engineers (Corps) will construct river control structures in the chute in 1998 to maintain the integrity of the navigation channel. Columbia FRO will continue monitoring this area to evaluate impacts of the Corps' project on habitat and fishes of the Lisbon Bottom Unit of the Big Muddy National Fish and Wildlife Refuge.

For more information see the following report:

Grady, J.M. and Milligan, J. 1998. Annual Fisheries Monitoring Report - Lisbon Bottom Unit, Big Muddy National Fish and Wildlife Refuge. Report in progress.

Study #4: The influence of connectivity on fish reproduction and larval nursery in Lower Missouri River scours.

Lower Missouri River scours created by the 1993 flood have been categorized as continuous, periodic, and isolated according to their pattern of water exchange with the river. Continuous and periodic scours represent a continuum of connectivity based on the timing and duration of their connection. The potential differences are being evaluated in adult and larval fish use of representative Lower Missouri River scours based on connectivity and developing a model to predict the availability of flood plain-habitat for reproduction and larval nursery.

Sampling occurred from April to August during 1995 and 1996. The entrance scour (S-15) on Lisbon Bottom was sampled as part of this study (Fig. 1). In the Lisbon Bottom entrance scour 15 species and five larval taxa groups were collected (Tables 2 and 3). Representing 13 families, 31 species of adult fish were captured in the study as a whole using gill nets. Goldeye, shortnose gar, gizzard shad, and common carp constituted over 75% of the adult catch among all scour categories. The 14 most abundant adult species captured were present in all three scour categories.

Larval fish were sampled with a buoyant sled net. Larval fish assemblages differed among all scour categories. Isolated scours contained nine taxa and had a more lacustrine assemblage dominated by Centrarchids. Isolated scours were devoid of goldeye, blue sucker, *Carpiodes* sp., *Stizostedion* sp., and many Cyprinidae. Periodic and continuous scours contained 18 and 19 taxa, respectively, but catch differed for Clupeids, Hiodontids, and some Cyprinids. The main factors determining larval fish assemblages in periodic scours were timing and duration of scour connectivity. Additionally, in both periodic and continuous scours, the percentage of scour area exchanging water with the river influenced catch for some taxa.

The presence of protolarvae (the earliest larval stage) is being used to determine taxa-specific appearance ranges in relation to date and temperature. Results indicate that although adult fish assemblages of scours are similar, fish reproductive and larval nursery function of scour holes is influenced by their connectivity with the river. The relationship between the presence of larval fish and the timing and duration of a scour's connectivity is predictable for many species. A model has been developed incorporating river hydrology; the connectivity factors of timing, duration, and exchange; and taxa-specific appearance times. This model will help to determine availability and suitability of larval fish nursery in flood-plain basins under consideration for restoration.

For more information see the following report:

Hooker, J.B. 1998.The influence of connectivity on fish reproduction and larval nursery in Lower Missouri River scours. M.S. thesis, University of Missouri-Columbia. Report in progress.

Study #5: Lower Missouri River flood-scoured basins as fish nursery: the influence of connectivity.

The effect of connectivity on composition, abundance, and biomass of small fishes was evaluated among 13 flood-created scours on an annual scale for four categories: isolated, periodically connected, ditch connected, and continuously connected sites. The entrance scour (S-15) on the Lisbon Bottom Unit was sampled as part of this study (Fig. 1). Daily exchange of water between scours and the river was evaluated using an index of water exchange. Comparisons of maximum depth, water clarity, and temperature paired isolated and ditch categories, whereas connected scours (i.e., site 5 on map) were more like the Missouri River channel.

Turbidity and nutrient concentrations were positively correlated with water exchange; chlorophyll-a was negatively correlated. Fish taxa richness and biomass were higher in continuous and periodically connected scours than in ditch connected or isolated sites. Fish catch was greater in shallow water than in deep water. Fish distribution patterns closely followed Pflieger's Missouri fishes guild pattern with Wide-ranging and Lowland common in all scours whereas Prairie and Big River fishes were restricted to periodic and continuous scours (Pflieger 1971).

In the Lisbon Bottom entrance scour 32 fish species were collected (Table 2). Connectivity with the Missouri River channel is an important factor defining the near-shore small fish assemblage in scours. Shallow, nonflowing habits in scours were heavily used. A shortage of this habitat may be a recruitment bottleneck to small fishes in the Llower Missouri River.

Cited Literature

Pflieger, W.L. 1971. A distributional study of Missouri fishes. University of Kansas Publications, Museum of Natural History 20(3):255-570.

For more information see the following report:

Kubisiak, J. 1997. Lower Missouri River flood-scoured basins as fish nursery: the influence of connectivity. M.S. thesis, University of Missouri-Columbia. 171 pp.

Study #6: Pallid sturgeon movement and habitat use in the Lower Missouri River.

The Columbia Environmental Research Center is currently in the third year of an ongoing project developing biotelemetric methods and habitat assessment capabilities to document movement and habitat use of large river fishes in the Lower Missouri River. Over the past three field seasons, 32 pallid sturgeon and 8 hybrid sturgeon have been surgically implanted with longlife ultrasonic transmitters. Sturgeon used in this study have included both translocated and native fish.

An extensive network of automated receivers is used to segment the Missouri River into 25-mile stretches, to monitor fish passage at selected locations, and to document the sturgeon's rapid long-range movement. Precise locations of sturgeon within each river stretch are determined periodically by field crews in boats and documented using GPS. Physical habitat characteristics are recorded and selected sites that sturgeon frequent are mapped using acoustic bathymetric survey equipment.

A remote monitoring site was established on the Missouri River at the lower end of the Lisbon Bottom Chute. An ultrasonic receiver was continuously in operation during 1997 and detected tagged sturgeon's passage and monitored use of the Jameson Island/Lisbon Bottom area. Tagged fish were detected and did use the area for periods of time in 1997, most notably in the spring. Sturgeon frequented river habitats with sand substrate, higher current velocities, and the downstream confluence of the chute, although no direct observations were made of sturgeon within the chute. A remote monitoring site will again be employed in the Lisbon Bottom area to monitor the remaining 20 tagged sturgeon's activity and habitat use at large in the Missouri River. Estimated transmitter life will allow monitoring of sturgeon through October 1998.

Study #7: Adult fish use of connected newly scoured holes in the Missouri River flood plain.

Four connected Missouri River scour holes created during the 1993 flood were sampled during 1995-97. This summary is for just the scour holes that are closely associated with the Lisbon Bottom area and the Big Muddy National Fish and Wildlife Refuge. These four sites are part of a larger study effort funded in part by the U.S. Environmental Protection Agency and the Missouri Department of Conservation. The dates of sampling and the locations are as follows:

River mile 214.0 L (S-14) was an exit scour that had no rock revetment in front. It was sampled 15 times from 29 June 1995 to 17 September 1996 and 735 fish were collected.

River mile 214.5 R (S-13) was an entrance scour that has a dike field in front. It was sampled 36 times between 3 July 1995 and 16 September 1997 and 1,874 fish were collected.

River mile 217.9 R (S-15b) was an exit scour with no structure in front. It was sampled five times from 27 June 1995 to 16 May 1996 and 548 fish were collected.

River mile 218.0 L (S-15) was an entrance scour with a revetment with two notches in front. It was sampled four times from 16 July 1996 to 16 September 1996 and 116 fish were collected.

Fish collections were made with 45.8-m (150-ft) by 1.8-m (6-ft) deep monofilament experimental gill nets fished for approximately 4 h at the surface in randomly selected blocks within each scour. Each 45.8-m (150-ft) net consisted of six 7.6-m (25-ft) panels of monofilament arranged in a 2.54-cm (1-in.), 5-cm (2-in.), and 7.6-cm (3-in.) mesh configuration.

A 10-min surface electrofishing run was made around each net after it had been set for at least 2 h. A 45.8-m (150-ft) long, 2.4-m (8-ft) deep multifilament gill net consisting of 15.3-m (50-ft) sections of 2.54-cm (1-in.), 5-cm (2-in.), and 7.6-cm (3-in.) mesh was fished on the bottom to sample benthic fish. Fish caught at each location were identified to species, measured to the nearest millimeter, and weighed to the nearest half ounce, later converted to grams.

At all sites sampled, water temperature, dissolved oxygen, and Secchi disk measurements were recorded. These four sites were visited 58 times and 3,205 fish representing 34 species were caught. The most numerous six species accounted for almost 85% of the fish caught: gizzard shad (43%), goldeye (14%), carp (12%), shortnose gar (9%), freshwater drum (4%), and river carpsuckers (3%). The species occurrence may vary within each scour hole. This information will be available in the final report.

For more information see the following report:

Robinson, J.W. 1998. Missouri River Post-Flood Fishery Investigation Lisbon Bottom Area. Report in progress.

Study #8: Larval, juvenile, and adult small fish use of scour basins connected to the Lower Missouri River.

Composition and abundance of larval, juvenile, and adult small fishes and physical habitat were evaluated in eight scours connected to the Missouri River. Sites were classified based on mode of formation as entrance or exit scours. One entrance scour (S-13) and one exit scour (S-14) were sampled on the Lisbon Bottom Unit (Fig. 1). There were no differences in maximum depth, near-shore depth, and water exchange between entrance and exit scours.

Morphometric data indicated that accelerated sediment deposition occurred when scours were isolated from the flood-plain via ring levees that prevented flow-through during overbank flooding. Total catch of larva, juvenile, and adult small fishes differed among scours and was related to water depth but unrelated to scour category.

Abundance and taxa richness of older larval fishes, juvenile, and adult small fishes differed among scours, were related to water depth, but were unrelated to scour category. Abundance and taxa richness of older larval fishes, juvenile, and adult small fishes were highest in scours with shallow maximum depths. In the Lisbon Bottom scour holes 18 fish species and seven larval taxa groups were collected (Tables 2 and 3). Approximate spawning times for 17 common fish taxa were estimated from the timing of peak protolarval catches and water temperature. Maintenance of the connection between the river and flood plain to retain scours and high habitat diversity is recommended. Spawning temperatures may be used to couple peaks in river stage with water temperature to maximize fish recruitment in Lower Missouri River scours.

For more information see the following report:

Tibbs, J.E. and D.L. Galat. 1997. Larval, juvenile, and adult small fish use of scour basins connected to the Lower Missouri River. Final Report to Missouri Department of Conservation. Missouri Cooperative Fish and Wildlife Research Unit, University of Missouri-Columbia. 133 pp.

Table 1. Fisheries studies conducted in the Missouri River (RM 213-219), Lisbon Bottom Chute, and other water bodies associated with the Lisbon Bottom Unit of the Big Muddy National Fish and Wildlife Refuge.

Study Number	Author or Contact	Title	Dates Sampled	Gears Used[a]	Habitats Sampled[b]	Fish Data Available[c]	Physical/Chemical Parameters[d]
1	Chapman & Ehrhardt	Fish assemblages in a permanent and a temporary wetland at Lisbon Bottom	07/97-09/97	C, F	P, W	C, G, L, T, W	C, D, N, T
2	Dieterman & Galat	Population structure and habitat use of benthic fishes along the Missouri and Lower Yellowstone Rivers	07/96 and 10/97	B, E, G, S, T	B, C, M, T	A, C, G, L, W	C, D, N, S, T, V
3	Grady & Milligan	Annual Fisheries Monitoring Report-Lisbon Bottom Unit, Big Muddy National Fish and Wildlife Refuge	07/97-10/97	B, D, H, S	B, C, L, M, O, T	C, G, L, N, W	C, D, N, R, S, T, V
4	Hooker	The influence of connectivity on fish reproduction and larval nursery in Lower Missouri River scours	04/95-08/95 04/96-08/96	G, V	S	C, L, N, V	D, N, R, T, V
5	Kubisiak	Lower Missouri River flood-scoured basins as fish nursery: the influence of connectivity	04/96-09/96	S	L, S	C, L, N, W	D, N, O, R, T, Z

[a] Gears used include (B) benthic trawl; (C) cast net; (D) drifted gill net; (E) boat-mounted electrofishing; (F) fykenet; (G) stationary gill net; (H) hoop net; (M) small-fish sled; (R^A) telemetry-automated detection; (R^B) telemetry-manual location; (S) seine; (T) drifting trammel net; (V) larval sled.

[b] Habitats sampled include (B) main-channel border; (C) main-channel bar; (L) Lisbon Bottom Chute border; (M) main river channel; (O) other side-channel border; (P) permanent wetland; (S) flood scour; (T) Lisbon Bottom Chute; (W) seasonal wetland.

[c] Fish data available include (A) age and growth; (C) catch per unit effort; (G) GPS sampling coordinates; (L) body length; (N) number of fish; (T) tag recovery; (V) larval fish data; (W) wet weight.

[d] Physical/chemical parameters include (C) conductivity; (D) depth; (N) turbidity; (O) dissolved oxygen; (R) river stage; (S) substrate; (T) temperature; (V) velocity; (Z) water chemistry parameters.

Table 1. continued

Study Number	Author or Contact	Title	Dates Sampled	Gears Used[a]	Habitats Sampled[b]	Fish Data Available[c]	Physical/Chemical Parameters[d]
6	Little & Delonay	Pallid sturgeon movement and habitat use in the Lower Missouri River	10/95-10/98	R^A, R^B	B, C, L, M, O, T	G, L, N, T, W	D, R, S, T, V
7	Robinson	Adult fish use of connected newly scoured holes in the Missouri River flood plain	6/95-9/97	E, G	B, S, T	C, N, L, W	D, O, R, S, T, Z
8	Tibbs & Galat	Larval, juvenile, and adult small fish use of scour basins connect-ed to the Lower Missouri River	04/96-09/96	M, V	S	C, N, V	D, N, O, T, Z

[a] Gears used include (B) benthic trawl; (C) cast net; (D) drifted gill net; (E) boat-mounted electrofishing; (F) fykenet; (G) stationary gill net; (H) hoop net; (M) small-fish sled; (R^A) telemetry-automated detection; (R^B) telemetry-manual location; (S) seine; (T) drifting trammel net; (V) larval sled.

[b] Habitats sampled include (B) main-channel border; (C) main-channel bar; (L) Lisbon Bottom Chute border; (M) main river channel; (O) other side-channel border; (P) permanent wetland; (S) flood scour; (T) Lisbon Bottom Chute; (W) seasonal wetland.

[c] Fish data available include (A) age and growth; (C) catch per unit effort; (G) GPS sampling coordinates; (L) body length; (N) number of fish; (T) tag recovery; (V) larval fish data; (W) wet weight.

[d] Physical/chemical parameters include (C) conductivity; (D) depth; (N) turbidity; (O) dissolved oxygen; (R) river stage; (S) substrate; (T) temperature; (V) velocity; (Z) water chemistry parameters.

Table 2. Fish species collected in the Missouri River (RM 213-219), Lisbon Bottom Chute, and other water bodies associated with the Lisbon Bottom Unit of the Big Muddy National Fish and Wildlife Refuge.

Common Name	Scientific Name	Species Status	Faunal Group (Pflieger 1971)[e]	Study Numbers 1	2	3	4	5	7	8	Number of Studies Found
Shovelnose Sturgeon	*Scaphirhynchus*		Big River			•			•		2
Pallid Sturgeon x Shovelnose Sturgeon Hybrid	*S. platorynchus x alba*	Federal Endangered	Big River			•					1
Paddlefish	*Polyodon spathula*	State Watch Lisht Federal Species of Special Concern	Big River						•		1
Longnose Gar	*Lepisosteus osseus*		Wide-ranging			•	•		•		3
Shortnose Gar	*Lepisosteus platostomus*		Big River		•	•	•	•	•		5
American Eel	*Anguilla rostrata*		Wide-ranging			•					1
Rainbow Smelt	*Osmerus mordax*	Nonindigenous Introduction			•			•			2
Skipjack Herring	*Alosa chrysochloris*		Big River						•		1
Gizzard Shad	*Dorosoma cepedi-anum*		Wide-ranging	•	•	•	•	•	•	•	7
Goldeye	*Hiodon alosoides*		Big River		•	•	•	•	•	•	6
Northern Pike	*Esox lucius*	State Rare	Unclassified						•		1
Grass Carp	*Ctenopharyngodon idella*	Exotic		•		•	•		•		4
Bighead Carp	*Hypophthalmicthys nobilis*	Exotic		•		•			•		3
Silver Carp	*Hypophthalmicthys molitrit*	Exotic							•		1
Common Carp	*Cyprinus carpio*	Exotic		•	•	•	•	•	•	•	7
Goldfish	*Carassius auratus*	Exotic	Unclassified					•			1
Speckled Chub	*Hybopsis aestivalis*		Big River		•	•		•		•	4
Sturgeon Chub	*Macrhybobpsis gelida*	State Rare Federal Species of Special Concern	Big River		•	•					2
Sicklefin Chub	*Macrhybopsis meeki*	State Rare Federal Species of Special Concern	Big River		•	•		•			3
Silver Chub	*Hybopsis storeri-ana*		Big River		•	•		•		•	4
Emerald Shiner	*Notropis atheinoides*		Big River		•	•		•	•	•	5
Redfin Shiner	*Notropis umbratilis*		Wide-ranging						•		1
River Shiner	*Notropis blennius*		Big River		•	•		•			3
Red Shiner	*Notropis lutrenis*		Prairie	•	•	•		•	•	•	6
Bigmouth Shiner	*Notropis dorsalis*		Prairie		•	•					2

Table 2. continued

Common Name	Scientific Name	Species Status	Faunal Group (Pflieger 1971)[e]	Study Numbers 1	2	3	4	5	7	8	Number of Studies Found
Sand Shiner	*Notropis dorsalis*		Prairie	•	•	•		•		•	5
Ghost Shiner	*Notropis buchanani*	State Watch List	Prairie			•		•			2
Western Silvery Minnow	*Hybognathus argyritis*	Federal Species of Special Concern	Wide-ranging					•			1
Plains Minnow	*Hybognathus placitus*	Federal Species of Special Concern	Wide-ranging			•		•		•	3
Hybognathus Minnow	*Hybognathus spp.*				•						1
Suckermouth Minnow	*Phenacobius mirabilis*		Prairie		•			•			2
Bluntnose Minnow	*Pimephales notatus*		Wide-ranging	•	•	•		•		•	5
Bullhead Minnow	*Pimephales vigilax*		Lowland					•			1
Blue Sucker	*Cycleptus elongatus*	State Watch List Federal Species of Special Concern	Big River			•	•			•	3
Bigmouth Buffalo	*Ictiobus cyprinellus*		Wide-ranging				•	•	•		3
Smallmouth Buffalo	*Ictiobus bubalus*		Wide-ranging	•		•		•	•	•	5
River Carpsucker	*Carpiodes carpio*		Prairie	•	•	•	•	•	•	•	7
Quillback	*Carpiodes cyprinus*		Prairie				•		•		2
White Sucker	*Catostomus commersoni*		Ozark-prairie			•					1
Shorthead Redhorse	*Moxostoma macrolepidotum*		Ozark-prairie			•			•		2
Black Bullhead	*Ameiurus melas*		Wide-ranging	•							1
Channel Catfish	*Ictalurus punctatus*		Wide-ranging	•	•	•	•	•	•	•	7
Blue Catfish	*Ictalurus furcatus*		Big River	•	•	•			•		4
Flathead Catfish	*Pylodictis olivaris*		Wide-ranging	•	•	•			•		4
Mosquitofish	*Gambusia affinis*		Lowland	•				•			2
Striped Bass	*Morone saxatilis*	Nonindigenous Introduction			•				•		2
White Bass	*Morone chrysops*		Big River				•	•	•	•	4
Hybrid Striped Bass	*Morone chrysops x*		Wide-ranging			•	•		•		3
Largemouth Bass	*Micropterus*		Wide-ranging	•	•	•		•	•		5
Green Sunfish	*Lepomis cynaellus*		Wide-ranging	•		•		•	•	•	5
Bluegill	*Lepomis macrochirus*		Wide-ranging	•				•	•	•	4
White Crappie	*Pomoxis annularis*		Wide-ranging	•		•		•	•		4
Black Crappie	*Pomoxis nigromaculatus*		Wide-ranging Big River	•				•	•		3
Walleye	*Stizostedion vitreum*		Big River	•					•		2

Table 2. continued

Common Name	Scientific Name	Species Status	Faunal Group (Pflieger 1971)[e]	Study Numbers							Number of Studies Found
				1	2	3	4	5	7	8	
Sauger	*Stizostedion canadense*			•		•	•	•	•		5
Freshwater Drum	*Aplodinotus grunniens*			•	•	•	•	•	•	•	7
Total Number of Fish Species Collected for Study				22	24	36	15	32	34	18	

[e] Pflieger, W.L. 1971. A distributional study of Missouri fishes. Occ. Pap. Mus. Nat. Hist. Univ. Kansas 20:225-570

Table 3. Larval fish taxa collected in the entrance (S-15) and exit (S-14) scours created by the Flood of 1993 on the Lisbon Bottom Unit of the Big Muddy National Fish and Wildlife Refuge. (Note: These fish could not be identified to species and therefore were not included in Table 2. Larval fish that could be identified to species were included in Table 2.)

Larval Fish Taxa - Not Identified to Species	**Study Numbers**	
	4	**8**
Carpiodes spp.	•	
silver-speckled chub group	•	•
sturgeon-sicklefin chub group	•	•
unidentified Cyprinidae	•	
red shiner-sand shiner group	•	•
emerald shiner group (emerald shiner, plains minnow, and Western silvery minnow)	•	•
creek chub-stoneroller goup	•	
Hypopthalmicthys sp.	•	•
Ictiobus sp.	•	
Ictiobinae sub family (Carpiodes sp. and Ictiobus sp.)	•	•
Lepomis sp.	•	
Micropterus sp.	•	
Morone sp.	•	
Pomoxis sp.	•	
Stizostedion sp.	•	•
unidentified larval fish	•	

Fig. 1. Locations of fisheries study sites in the Lisbon Bottom area. Circled numbers correspond to study numbers. Gears used include (B) benthic trawl; (C) cast net; (D) drifted gill net; (E) boat-mounted electrofishing; (F) fykenet; (G) stationary gill net; (H) hoop net; (M) small-fish sled; (R^A) telemetry-automated detection; (R^B) telemetry—manual location; (S) seine; (T) drifting trammel net; (V) larval sled. Habitats sampled include (B) main-channel border; (C) main-channel bar; (L) Lisbon Bottom Chute border; (M) main river channel; (O) other side-channel border; (P) permanent wetland; (S) flood scour; (T) Lisbon Bottom Chute; (W) seasonal wetland. Fish data available include (A) age and growth; (C) catch per unit effort; (G) GPS sampling coordinates; (L) body length; (N) number of fish; (T) tag recovery; (V) larval fish data; (W) wet weight. Physical/chemical parameters include (C) conductivity; (D) depth; (N) turbidity; (O) dissolved oxygen; (R) river stage; (S) substrate; (T) temperature; (V) velocity; (Z) water chemistry parameters.

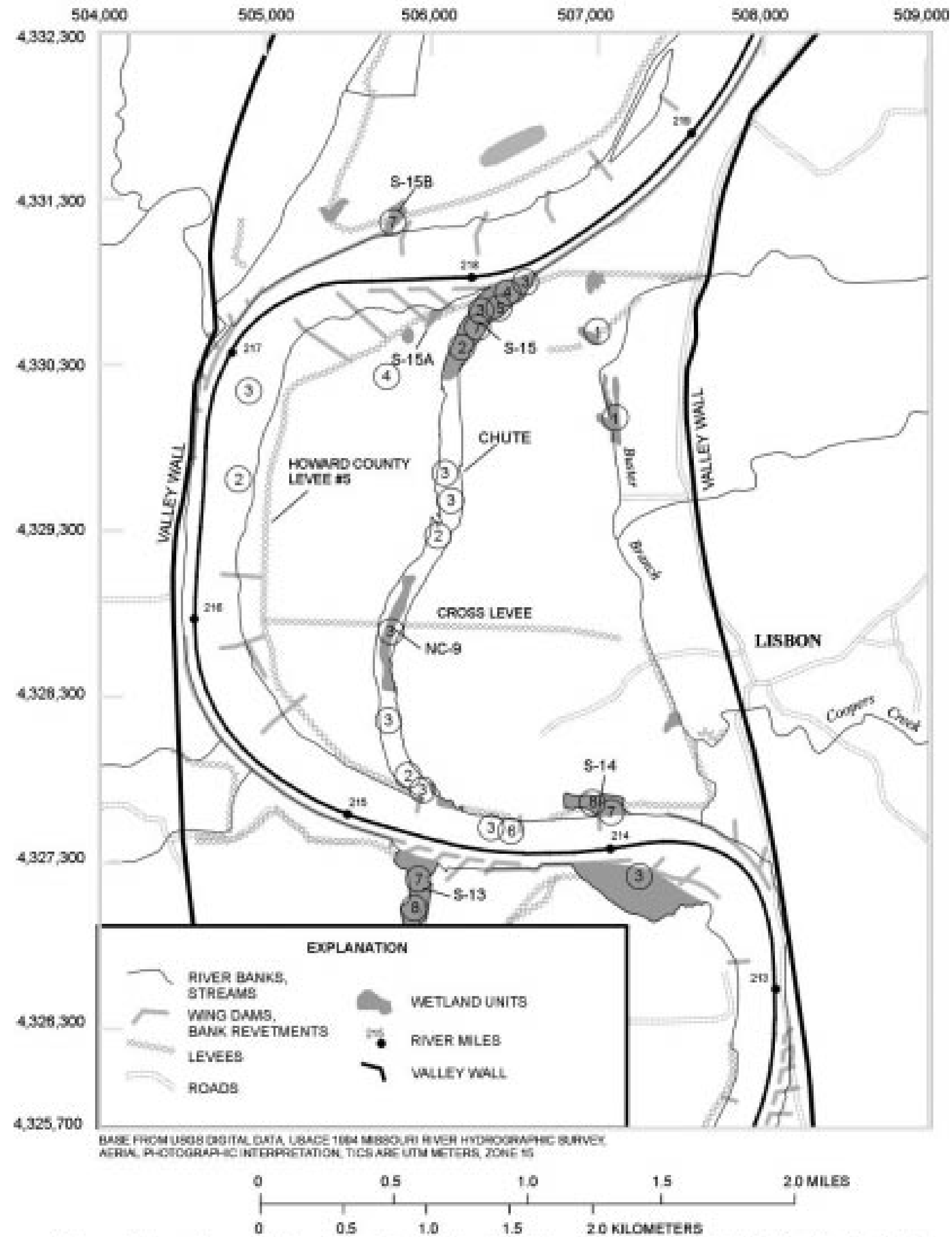

Figure 1. Locations of fisheries study sites in the Lisbon Bottom Unit of the Big Muddy National Fish and Wildlife Refuge. Circled numbers correspond to study numbers in Table 1.

CHAPTER 5

Waterbirds

by

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Introduction

Waterbirds such as waterfowl, herons, shorebirds, and seabirds depend on wetlands and deepwater habitats for foraging, breeding, and roosting. Their high mobility and selection of ephemeral habitats allow them to exploit wetlands across large areas. As a consequence, the presence and abundance of waterbirds provide information about the relative use of available wetland habitat types. Missouri lies within a migration corridor of current and historical importance to waterbirds that moves through the interior of North America (Bellrose 1980). Missouri's riparian systems, including the extensive Missouri River flood plain, are used by more than 100 species of waterbirds during spring and fall migration, as well as throughout the breeding season (Fredrickson and Reid 1986).

Severe flooding in 1993 broke levees, scoured farm fields, and deposited large volumes of sand throughout the Missouri River flood plain, including Lisbon Bottom (SCS 1993, SAST 1994). In 1994, the Missouri Department of Conservation (MDC), in partnership with State and Federal agencies and universities, initiated the Missouri River Post-flood Evaluation (MRPE) to study the recovery of wildlife habitat after the flood and to evaluate land acquisition and easement programs of highly damaged agricultural lands.

MRPE study sites include two types of areas scoured by 1993 flooding: (1) those proximate and directly connected (S), at least seasonally, to the Missouri River and (2) nonconnected sites (NC) scoured during flooding but not proximate or directly connected to the river. Temporary wetlands (T) surveyed include temporary basins in cultivated fields and those unfarmed since 1993. Finally, remnant wetlands (R) include large oxbows, wooded sloughs, and cutoff stream channels.

One of the goals of MRPE was to determine the seasonal distribution of waterbirds in the Missouri River flood plain and to determine the relative values of various wetland and aquatic habitat types for waterbirds. Flood-damaged sites on Lisbon Bottom that were subsequently included in the Big Muddy National Fish and Wildlife Refuge were among the original MRPE study areas. Four complementary projects at different scales were developed to examine waterbird use of flood-altered habitats. The objective here is to characterize species richness and abundance of waterbirds among habitat types on Lisbon Bottom during the first 4 years after a major flood disturbance. Results will provide baseline data for the nascent refuge.

Study Area

Lisbon Bottom is located in central Missouri at approximately river mile 224 of the Missouri River (Chapter 1, Fig. 1). Five MRPE study sites occur on Lisbon Bottom. They include three connected scour sites (S-14, S-15, and S-15a), one nonconnected site (NC-9), and one temporary wetland (T-LIS) (Chapter 1, Fig. 3). Repeated, prolonged flooding culminated in the development of site S-15 into a flowing side chute (CH) in June 1996, thus eliminating NC-9, which was incorporated into S-15 as the chute developed.

Methods

Waterbird species composition and abundance among different wetland types on Lisbon Bottom were determined mid-March to mid-October 1994-97 using biweekly helicopter surveys, intensive ground surveys, flush counts, and call-responses (Table 1). Helicopter surveys provide an extensive assessment of waterbird use of flood-plain habitats in which all sites can be visited within a narrow time frame. The drawback to helicopter surveys is that some bird groups, such as shorebirds, are difficult to identify to species in the brief time and from the height required by this technique.

Ground surveys, on the other hand, take longer to complete and fewer sites can be surveyed; however, birds can be identified to species and activities assessed. Some birds, such as rails and bitterns, are secretive and unlikely to be observed during a typical helicopter or ground survey. Flush counts and call-response surveys were conducted to assess wetland use by this bird group. The combined results of these complementary techniques are presented to provide baseline data on species richness for Lisbon Bottom. The total birds observed across all habitats and years are presented as only as an indication of their relative abundance during the survey periods. This study recognizes that biases associated with the different techniques limit the use of abundance and density estimates.

Helicopter Surveys

From mid-March to mid-October 1994-97, biweekly helicopter surveys were used to determine the number and distribution of birds among Missouri River flood-plain habitats. Bell Jet Ranger (206 B) helicopter surveyed four of the five MRPE sites on Lisbon Bottom that were among 140 sites between Hartsburg, Missouri, and Sioux City, Iowa (Table 1). All waterbirds using each site (excluding red-winged blackbirds) were counted by two observers from opposite sides of the helicopter at less than 30 m (100 ft) over each basin. Birds were identified to species or species group. The same pattern and coverage were consistently used on each site for all surveys.

Ground Surveys

Ground surveys of waterbirds were conducted on 20 randomly selected sites on the Missouri River flood plain, including two sites on Lisbon Bottom (Table 1) between mid-March and mid-October

1994-97. Weekly morning surveys were conducted between sunrise and 4 h after sunrise in 1994. Waterbird surveys during 1995-97 were expanded to approximately twice a week at each site during early morning (0.5 h before to 1.5 h after sunrise) and midday (1 h before to 1 h after the midpoint of sunrise and sunset). One observer conducted a complete visual survey at each site by viewing the site from several vantage points using binoculars (7X or 8X) and a spotting scope (15-30X). All waterbirds using a site (including red-winged blackbirds) were recorded. In addition, any raptors using the site or its immediate margins were recorded.

Flush Counts

Flush count surveys were conducted on 24 MRPE study sites, including 2 of the Lisbon Bottom sites, to determine chronology of use by rails, bitterns, and snipe during 1996 and 1997 (Table 1). Weekly surveys were conducted between 0600 and 1000 h from early March to late April for spring migration and from mid-August to mid-October for fall migration. Flush counts were performed by two to four observers, separated from each other by 2-3 m, walking in tandem through wetland vegetation. Study sites at Lisbon Bottom were completely surveyed during each visit and all rails, bitterns, and snipe were recorded.

Call-Response Surveys

Call-response surveys (Gibbs and Melvin 1993), used to determine densities of breeding rails, were conducted on 24 MRPE sites, including two on Lisbon Bottom. Surveys consisted of three visits per site and were conducted in early, mid, and late May between 0.5 h before sunrise and 4 h after sunrise. Recordings of three rail species (king rail, sora, and Virginia rail) were played on a portable cassette recorder located 0.075 m above the ground. Survey stations were randomly located in each basin at least 100 m apart. Maximum sound pressure 1 m from the speaker was 80 dB. Taped calls lasted approximately 50 s and consisted of 10 s of male advertisement vocalizations alternating with 10 s of silence. Responses were recorded during the periods of silence and for 30 seconds after the end of the tape.

Results and Discussion

Among all techniques on Lisbon Bottom during 1994-97, 62 species (8 orders) of waterbirds were recorded (Table 2). Total numbers of species observed were 31 in 1994 (first year post-flood), 37 in 1995, 39 in 1996, and 35 in 1997. Shorebirds (Charadriiformes) and waterfowl (Anseriformes) accounted for the greatest numbers of species (20 and 11, respectively) as well as the greatest numbers of individuals.

The most abundant species during the March through October survey period were blue-winged teal, killdeer, least sandpiper, semipalmated sandpiper, American white pelican, great blue heron, Canada goose, and pectoral sandpiper (Table 2). Large numbers of unidentified small sandpipers observed from the helicopter likely were predominated by least and semipalmated sandpipers.

More than 80 waterbird species were observed on MRPE study sites including 69 on non-connected scours, 70 on connected scours, and 45 on temporary wetlands (Galat et al. 1998). Most species (62) were also observed on Lisbon Bottom; however, differences in techniques and number of surveys (Table 1) compromise direct comparisons of species richness between basin types and years because detection rates may differ by technique and survey frequency likely would affect the number of species observed.

However, surveys were consistently conducted on S-15 during 1994-97, allowing comparison of species richness before and after chute development. During the prechute period (2½ years) 50 species of waterbirds on S-15 and 37 species were observed after the chute formed (1½ years). Of those species, 29 were observed before and after chute development. However, 21 species were observed only before the chute was created (primarily shorebirds and dabbling ducks), and 8 species were observed only after the chute was created (primarily gulls, terns, and raptors). Changes in species richness and species composition likely were due to loss of shallow water habitat within the chute and the high velocity of flow. Whereas the formation of a chute may potentially improve habitat for riverine fishes, this change may decrease habitats available for many species of waterbirds.

These baseline data reflect waterbird species present on Lisbon Bottom during the first 4 years after the 1993 flood. The development of a chute from a scour on Lisbon Bottom has provided a unique opportunity to observe changes in waterbird community composition resulting from habitat alterations during floods. In addition, changes in vegetation composition and structure within basins and in the surrounding flood plain and modification of basin morphology from future flood events may affect waterbird use of Lisbon Bottom. Waterbird data acquired by the MRPE project will be the basis for evaluating the impact of habitat succession on Lisbon Bottom.

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Table 1. Methods used to survey waterbirds in Missouri River flood-plain habitats on the Big Muddy National Fish and Wildlife Refuge, Lisbon Bottom, 1994-1997. Site name beginning with "NC" is the nonconnected scour. Site names beginning with"S" are connected scours. The site "CH" represents the chute formed in June 1996. Site name beginning with "T" is the temporary wetland. Numbers in parentheses indicate the total number of surveys conducted.

Year	**1994**		**1995**	**1996**			**1997**		
Site Type	NC	S	S	S	CH	T	S	CH	T
Survey Method									
Helicopter Surveys	NC-9	S-14 (15) S-15 (15)	S-14 (15) S-15 (15) S-15a	S-14 (15) S-15 (8) S-15a (15)	CH (7)		S-14 (15) S-15a (15)	Ch (15)	
Ground Surveys		S-15 (14)	(15) S-15 (26)	S-15 (13)	CH (28)	T-Lis (31)		CH (49)	T-Lis (43)
Flush Counts				S-15 (9)	CH (9)	T-Lis (18)		CH (22)	T-Lis (22)
Call Response Surveys				S-15 (4)		T-Lis (4)		CH (13)	T-Lis (13)

Table 2. Occurrence (+=present, •=absent) of waterbirds observed on the Big Muddy National Fish and Wildlife Refuge, Lisbon Bottom Unit, mid-March through mid-October 1994-1997. Habitats surveyed included NC= conconnected scour, S= connected scour, CH= chute created during flooding in June 1996, and T= temporary wetland. Numbers indicate individuals observed across all survey techniques, habitat types, and years.

Species		Total	94		95	96			97		
			NC	S	S	S	CH	T	S	CH	T
Podicipedformes											
Pied-billed Grebe	*Podilymbus podiceps*	5	•	•	+	•	+	•	•	•	•
Pelicaniformes											
American White Pelican	*Pelecanus erythrorhynchos*	345	•	+	+	•	•	•	•	+	•
Double-crested Cormorant	*Phalacrocorax auritus*	87	•	+	+	+	+	•	•	+	•
Ciconiiformes											
Black-crowned Night-Heron	*Nycticorax nycticorax*	1	•	•	•	•	•	•	•	•	+
Green Heron	*Butorides virescens*	2	•	+	•	•	•	•	•	•	•
Great Egret	*Ardea albus*	16	+	+	+	•	+	•	•	•	•
Great Blue Heron	*Ardea herodias*	332	+	+	+	+	+	+	+	+	•
Anseriformes											
Canada Goose	*Branta canadensis*	330	+	+	+	+	+	•	+	+	•
Mallard	*Anas platyrhynchos*	100	+	+	+	+	•	+	+	+	+
Gadwall	*Anas strepera*	99	•	•	+	+	•	•	•	+	•
Green-winged Teal	*Anas crecca*	65	•	+	+	+	+	•	•	+	+
American Pigeon	*Anas americana*	28	•	•	+	•	•	•	•	•	•
Northern Pintail	*Anas acuta*	7	•	+	+	•	•	•	•	•	•
Northern Shoveler	*Anas clypeata*	72	•	+	+	+	+	•	•	+	•
Blue-winged Teal	*Anas discors*	1869	•	+	+	+	+	+	+	+	+
Unknown Dabblers	*Anas spp.*	33	•	•	+	•	+	•	•	•	•
Wood Duck	*Aix sponsa*	20	•	+	•	•	+	+	•	•	+
Lesser Scaup	*Aythya affinis*	3	•	•	+	•	•	•	+	+	•
Scaup spp.	*Aythya spp.Mergus merganser*	31	•	•	•	•	•	•	•	•	•
Common Merganser	*Mergus merganser*	1	•	•	+	•	•	•	•	•	•
Falconiformes											
Turkey Vulture	*Cathartes aura*	19	•	•	+	•	•	•	+	+	•
Bald Eagle	*Haliaeetus leucocephalus*	2	•	+	•	+	•	•	•	•	•
Red-tailed Hawk	*Buteo jamaicensis*	4	•	•	•	•	+	•	•	•	•
Northern Harrier	*Circus cyaneus*	1	•	•	•	+	•	•	•	•	•
Osprey	*Pandion haliaetus*	1	•	•	•	•	+	•	•	•	•

Table 2. continued

Species		Total	94 NC	94 S	95 S	96 S	96 CH	96 T	97 S	97 CH	97 T
American Kestrel	*Falco sparverius*	1	•	•	•	•	+	•	•	•	•
Gruiformes											
Virginia Rail	*Rallus limicola*	1	•	•	•	•	•	•	•	•	+
Sora	*Porzana carolina*	1	•	•	•	•	•	•	•	•	+
American Coot	*Fulica americana*	116	•	•	+	+	+	+	+	+	+
Charadriiformes											
Semipalmated Plover	*Charadrius semipalmatus*	98	•	+	+	+	+	•	•	+	•
Killdeer	*Charadrius vociferus*	1293	+	+	+	+	+	+	+	+	+
Black-bellied Plover	*Pluvialis squatorola*	9	•	•	+	•	+	•	•	•	•
American Golden-plover	*Pluvialis dominica*	12	•	+	•	•	•	•	•	•	•
Marbled Godwit	*Limosa fedoa*	1	•	•	+	•	•	•	•	•	•
Greater Yellowlegs	*Tringa melanoleuca*	12	•	•	+	•	•	•	•	•	•
Lesser Yellowlegs	*Tringa flavipes*	18	•	+	+	+	•	•	•	+	+
Yellowlegs spp.	*Tringa spp.*	17	•	+	•	+	+	•	•	+	•
Solitary Sandpiper	*Tringa solitaria*	12	•	+	+	•	+	•	•	•	+
Spotted Sandpiper	*Actitis macularia*	109	•	+	+	+	+	+	+	+	+
Short-billed Dowitcher	*Limnodromus griseus*	6	•	+	•	•	•	•	•	•	•
Stilt Sandpiper	*Calidris himantopus*	10	•	+	•	•	•	•	•	+	•
Common Snipe	*Gallinago gallinago*	1	•	•	•	•	•	•	•	•	+
Sanderling	*Caldris alba*	2	•	+	•	•	•	•	•	•	•
Semipalmated Sandpiper	*Calidris pusilla*	487	•	+	+	+	+	•	•	+	•
Western Sandpiper	*Calidris mauri*	12	•	+	+	•	+	•	•	•	•
Least Sandpiper	*Calidris minutilla*	660	•	+	+	•	+	•	•	+	+
Baird's Sandpiper	*Calidris bairdii*	43	•	+	+	+	+	•	•	•	+
Pectoral Sandpiper	*Calidris melanotos*	226	•	+	+	+	•	+	•	+	+
Buff-breasted Sandpiper	*Tryngites subruficollis*	43	•	+	•	•	+	•	•	•	•
American Avocet	*Recurvirostra americana*	5	•	+	•	•	•	•	•	•	•
Unknown sm. shorebird	*Calidris spp.*	1147	+	+	+	+	+	+	+	+	•
Unknown med. shorebird		157	•	+	+	+	+	•	+	+	•
Franklin's Gull	*Larus pipixcan*	2	•	•	•	•	+	•	•	•	•
Bonaparte's Gull	*Larus philadelphia*	9	•	•	•	+	•	•	•	•	•
Ring-billed Gull	*Larus delawarensis*	14	•	•	+	+	+	•	•	+	•

Table 2. continued

Species		Total	94		95	96				97	
			NC	S	S	S	CH	T	S	CH	T
Herring Gull	*Larus argentatus*	1	•	+	•	•	•	•	•	•	•
Common Tern	*Sterna hirundo*	10	•	•	+	•	•	•	•	+	•
Least Tern	*Sterna antillarum*	5	•	•	•	•	+	•	•	+	•
Caspian Tern	*Sterna caspia*	2	•	•	•	•	•	•	•	+	•
Black Tern	*Chlidonias niger*	10	•	•	+	•	•	+	•	•	•
Unknown Tern	*Sterna spp.*	15	•	•	+	•	+	•	•	•	+
Coraciiformes											
Belted Kingfisher	*Ceryle alcyon*	5	•	•	+	•	+	•	•	•	+
Passeriformes											
Bank Swallow	*Riparia riparia*	62	•	+	•	•	+	•	•	+	•
Cliff Swallow	*Hirundo pyrrhonota*	1	•	•	•	+	•	•	•	•	•
Barn Swallow	*Hirundo rustica*	85	•	•	•	•	+	•	•	+	•
Purple Martin	*Progne subis*	1	•	•	•	•	•	•	•	+	•
Unknown Swallows		434	+	+	+	+	+	+	•	+	•
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	1	•	•	+	•	•	•	•	•	•
Red-winged Blackbird	*Agelaius phoeniceus*	21	•	•	+	•	•	+	•	•	+
Total Individuals and Species		8650	5	31	36	21	29	11	9	27	16

CHAPTER 6

Herpetofauna

by

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Introduction

Traditionally, reptiles (Subphylum Vertebrata, Class Reptilia) and amphibians (Subphylum Vertebrata, Class Amphibia) have been studied and taught collectively under the taxonomically artificial descriptor herpetofauna. Grouping the two classes and training individual scientists with dual expertise appear to extend back to the Greek origins of the word herpetofauna (herpet translated as "creepy thing"). Because sampling the two groups was often done in concert and the researchers involved had expertise with both classes, the process here will be in the traditional manner of describing both classes in a single chapter.

Modern herpetofauna in Missouri are represented by the extant reptile orders Testudines (turtles) and Squamata (lizards and snakes) and the extant amphibian orders Caudata (salamanders) and Missouri Salientia (frogs and toads). Within these orders, Missouri has substantial diversity at the familial level: 22 known families of herpetofauna contain approximately 107 species (after Collins 1990, Johnson 1987, and Zug 1993). Thus, Missouri's herpetofauna represent approximately 25% of the amphibian and reptile diversity recorded in the contiguous United States.

From a biogeographical perspective, the herpetofaunal species of Missouri and adjacent states provide potential inhabitants for Lisbon Bottom and other flood-plain habitats. However, many herpetofauna in Missouri have declined over the past several decades and their ranges may not currently intersect Lisbon Bottom. Thus, recovery of the site itself may not lead to immediate recolonization by species with reduced or fragmented ranges.

In spite of the above caveat, Lisbon Bottom has a potential to be an important site for herpetofauna because it represents one of only several sites in the Missouri River flood plain with the potential to recover many of the ecological processes of bottomland flood plains.

Sites

In general terms, during the studies there were eight "wet" and four "dry" habitat types at Lisbon Bottom that had the potential to be important to herpetofaunal life cycles. The wet areas were (1) the Missouri River main channel, (2) scours from the floods of 1993 and 1995, (3) Milligan's Chute (which began as a scour but was transformed over time into a secondary river channel), (4) the deeper pondlike areas, (5) the frequently dry (either remnant or new) channels (including their prolonged wet depressions), (6) wet depressions not associated with the channels, (7) a small creek that may be an agricultural outflow that enters the Bottom near the bluff line (labeled "Angie's Swamp") and (8) ditches, including what appears to be a borrow pit area along the road that descends from the town of Lisbon to the Bottom.

The wet habitats vary substantially with regard to their hydroperiods. The wet habitats at Lisbon Bottom can be either isolated or connected to the Missouri River, temporary, seasonal, remnant or permanent wetlands (Galat et al. 1997). Each of these habitats may provide different functions for reptile and amphibian species inhabiting the flood plain.

The main dry habitat types likely to be encountered by herpetofauna are (1) forested areas, (2) regenerating willow/cottonwood habitats, (3) sandy areas that comprise the southern half of the Bottom, and (4) the mud flats adjacent to wet areas. The dry habitats at Lisbon Bottom have been less studied with regard to herpetofauna. It should be remembered that the dry habitats are occasionally under several feet of flowing water, thus their designation is relative to other habitats and terming them dry is a misnomer during floods. Nevertheless, their general condition of being dry may provide critical habitats to herpetofauna during much of the year.

Quantitative sampling for amphibians and reptiles was conducted in four of the wet habitat types. The two sites with the greatest duration of sampling were a depressed area (a temporary wetland that the Missouri Department of Conservation identified as "Lisbon Temporary") and Milligan's Chute (including the period before it was a channel). The other areas quantitatively sampled were a deep pond (Beaver Pond), another depressed area labeled Julie's Pond, and the small creek/outflow referred to as Angie's Swamp that enter Lisbon Bottom but appear to have little or no flow and retain standing water during dry periods. Qualitative observations were made frequently over the north half of the Bottom on the portion east of Milligan's Chute (Fig. 1).

Trapping/Census Methods

To census herpetofaunal species, researchers employed a variety of methods (Table 1, Fig. 1). Terrestrial drift fences (TDF) were established adjacent to Milligan's Chute (when it was a scour site, but continued thereafter) and the temporary depression described earlier (Lisbon Temporary). These drift fences were equipped with wire-mesh funnel traps and checked every second day during the spring and summer from 1994 to 1997 at Milligan's Chute (and its precursor scour) and from 1996 to 1997 at the site termed Lisbon Temporary. Anuran calling surveys (ACS) were conducted at the same two sites during 1996 and 1997.

The creek/outflow area (Angie's Swamp) and Julie's Pond were sampled approximately every 2 weeks during the summer 1997 as part of a larger effort to determine the extent of deformed amphibian occurrence on U.S. Fish and Wildlife Service lands. These sites were seined (SEI) with a 0.5-cm mesh seine and captures of both amphibians and reptiles were recorded. Additionally, opportunistic captures by hand at the two sites were recorded.

Sampling of turtles at Beaver Pond was conducted approximately every 2 weeks during the spring and summer of 1997. Turtle species were captured either with standard turtle hoop traps (THT), a modified catfish hoop trap (CHT), or with winged fyke nets (WFN). In addition, both the Lisbon Temporary site and Milligan's Chute were sampled using THTs and WFNs.

Incidental observations during visits to Lisbon Bottom were used to supplement quantitative observations. For example, anurans often are abundant on areas such as mud flats. Herpetologists who have conducted research at Lisbon weighed these qualita-

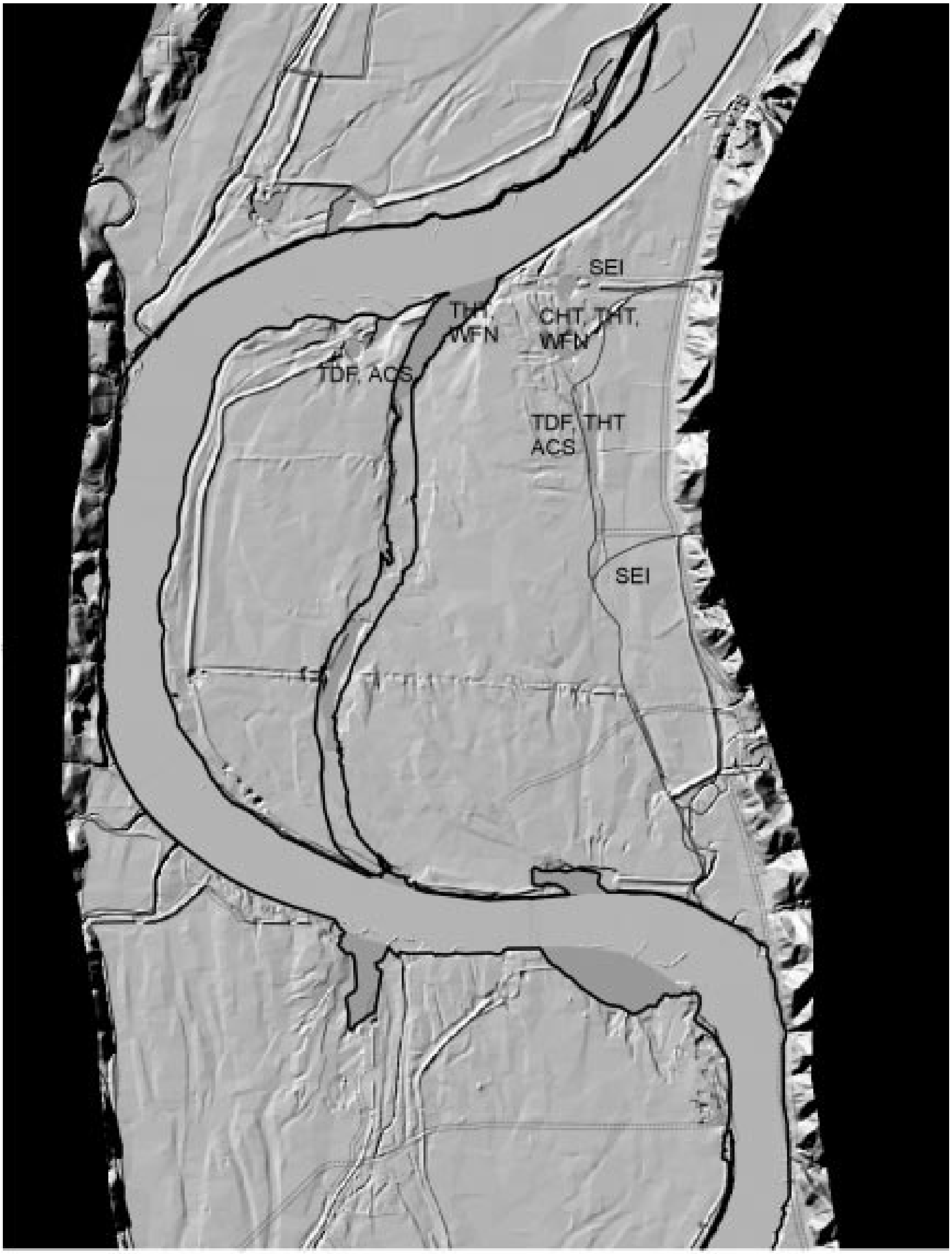

Figure 1. Trapping/census methods for herpetofaunal species.

Table 1. Herpetofaunal capture methods with reference codes, period in which each method was used, and brief descriptions.

Method	***Code***	***Years Employed***	***Description***
Anuran Call Survey	ACS	1996-97	Counts using auditory recognition of breeding frog and toad vocalizations.
Catfish Hoop Trap	CHT	1997	91-cm diameter, sardine-baited traps with a mesh size of 3.8 cm and an approximately 20-cm round opening.
Hand Capture	OCH	1994-97	Opportunistic captures by hand.
Seine	SEI	1997	9.1-m long seine with 0.5-cm mesh.
Terrestrial Drift Fence	TDF	1994-97	7.5-m long, 46-cm high aluminum valley tin drift fences equipped with wire mesh funnel traps.
Turtle Hoop Trap	THT	1994-97	60-cm and 1-m diameter sardine or dead fresh-fish baited traps with either 2.5-cm or 5-cm mesh and a 15 to 25-cm wide, thin slat opening at either one or both ends.
Winged Fyke Net	WFN	1996-97	Conventional or elongated, baited and unbaited hoop traps, sometimes with two throat openings (an initial and a secondary opening), differentiated from THT because of the use of attached nets used to guide turtles into the trap.

tive considerations when assessing how common species were in the Bottom.

Reptile Observations

Only seven reptile species were observed at Lisbon Bottom over 4 years (Table 2). These observations included two snake species and five turtle species. It is noteworthy that no lizards were observed, although six lizard species have ranges that overlap Lisbon Bottom. Several snake species and the painted turtle, *Chrysemys picta*, have ranges that overlap the Bottom, but were neither captured nor observed.

Table 2. Reptile captures, sampling methods, and qualitative estimates of abundance. Species for which more than five individuals were observed were considered to be regularly observed and species for which less than five individuals were observed were categorized as rare.

Species	***Common Name***	***Capture Method***	***Observation Frequency***
Nerodia sipedon sipedon	Northern water snake	TDF	Rare
Storeria dekayi wrightorum	Midland brown snake	TDF	Rare
Apalone mutica	Smooth softshell turtle	THT	Regular
Apalone spinifera	Spiny softshell turtle	THT	Rare
Chelydra serpentina	Common snapping turtle	SEI, THT, WHT	Regular
Graptemys pseudogeographica	False map turtle	THT, WFN	Regular
Trachemys scripta elegans	Redeared slider turtle	THT, OCH, WHT	Regular

Amphibian Observations

A total of 12 species of amphibians was encountered at Lisbon Bottom over a 4-year period (Table 3). All of the observed species were either frogs or toads. Regular sightings of anurans in the dry habitats suggest these areas are commonly used by this amphibian group.

Lisbon Bottom is within the known ranges of six species of salamanders, thus the absence of any salamander observations is noteworthy. The lack of salamander observations may be due to their absence from the area (perhaps because of years of agricultural use of the site), the timing of sampling (lack of autumn sampling), or the greater difficulty in observing these more cryptic species.

A total of 153 anurans was examined for deformities at Julie's Pond and Angie's Swamp. Of these, two showed abnormalities: one an apparent injury to a hind leg and the other (*R. catesbeiana*) a slightly crooked mouth.

Summary

Observations at Lisbon Bottom suggest that the site is inhabited by at least 19 species of herpetofauna. All of the wet areas that have been examined at Lisbon Bottom appear to be inhabited by herpetofauna and some sites appear to be particularly species rich. How the site and the species composition will change over time is uncertain, but it is hoped that efforts here to describe the site during this early period of its reversion to a wild state will provide a baseline for future examinations. Continued

Table 3. Amphibian captures, sampling methods, and qualitative estimate of abundance. Species for which more that five nonlarval individuals were observed were listed as regularly observed and species for which less that five nonlarval invididuals were observed were categorized as rare.

Species	**Common Name**	Capture Method	Observation Frequency
Acris crepitans blanchardi	Blanchard's cricket frog	TDF	Regular
Bufo americanus	American toad	TDF	Regular
Bufo cognatus	Great Plains toad	TDF	Rare
Bufo woodhousei	Woodhouse's toad	TDF, ACS	Regular
Hyla chrysoscelis	Gray treefrog	TDF, ACS	Regular
Pseudacris crucifer	Spring peeper	TDF, ACS	Regular
Pseudacris triseriata	Western chorus frog	TDF, ACS	Regular
Rana blairi	Plains leopard frog	TDF, ACS	Regular
Rana catesbeiana	Bullfrog	SEI	Rare
Rana clamitans melanota	Green frog	TDF	Rare
Rana utricularia	Southern leopard frog	TDF, ASC, SEI, OCH	Regular

monitoring of herpetofauna at this ecological site will provide new insights into minimal-management restoration in flood-plain systems.

Acknowledgments

The authors wish to express their gratitude to the large number of people and organizations who assisted with herpetofaunal studies at Lisbon Bottom, especially Duane Chapman, Phil Crockett, Matt Kowalski, Brett Matak, Tim Miller, Richard Stark, Brent Thomas, John Vogel, and the U.S. Geological Survey's Columbia Environmental Research Center.

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CHAPTER 7

Mammals

by

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Introduction

Lisbon Bottom in Howard County, Missouri, represents a recently acquired 875-ha portion of the Big Muddy National Fish and Wildlife Refuge in the Lower Missouri River flood plain (Jacobsen et al. 1998). Major flooding in 1993 deposited silt and sand that rendered much of this formerly cultivated area unfarmable (Mazourek et al. 1998). Natural revegetation of the site has been proceeding since the 1993 flood (Mazourek et al. 1998). Lisbon Bottom thus represents an unusual opportunity to study vertebrate fauna in a recently altered landscape. Here the diversity of mammal species at Lisbon Bottom is described as determined by correlating data from studies conducted for other purposes.

Mammals are integral components of most terrestrial ecosystems (Vaughn 1986) and probably serve many important functions in habitats within Lisbon Bottom as well. Small mammals influence plant species composition in regenerating flood-plain areas by seed predation and dispersal. In addition, small mammals also serve as a source of prey for larger mammals, birds, and reptiles (Vaughn 1986). Medium-sized and large mammals may contribute to ecosystem function and biodiversity by affecting vegetation structure and succession (Mcinnes et al. 1992) or regulating prey species abundance (Redford 1992). Thus, knowledge about mammal diversity at Lisbon Bottom will provide important information to managers of this refuge.

Mammal diversity at Lisbon Bottom, defined here as species richness, is likely to represent a subset of the total mammalian species richness observed in Missouri. Missouri is known to contain 66 mammal species from eight orders (i.e., Artiodactyla, Carnivora, Chiroptera, Didelphimorphia, Insectivora, Lagomorpha, Rodentia, and Xenarthra; Schwartz and Schwartz 1981). Standard sampling methods used to detect mammals vary depending on the body size of the target species (i.e., "small mammal," "medium-sized mammal," or "large mammal").

Small mammals as defined here include New World rats and mice (Cricetidae:Cricetinae), Old World rodents (Muridae), voles (Cricetidae Microtinae), shrews (Soricidae), and moles (Talpidae). Small mammals can successfully establish populations in almost any habitat and quickly colonize new habitats. Most small mammals have a short life span and a high reproductive output. Small mammals exploit a variety of food resources: rats and mice are omnivorous, voles are herbivorous, and shrews and moles are insectivorous and carnivorous.

Medium-sized mammals as defined here include squirrels (Sciuridae); weasels, minks, skunks, and otters (Mustelidae); beavers (Castoridae); rabbits (Leporidae); raccoons (Procyonidae); opossums (Didelphidae); foxes and coyotes (Canidae); and bobcats (Felidae). Large mammals are defined here as white-tailed deer (Cervidae). Medium-sized and large mammals are typically more mobile and less abundant than small mammals and thus are more difficult to accurately survey. Beavers, rabbits, and deer are entirely herbivorous. Sciurids are herbivorous or omnivorous, depending on species. Opossums are omnivorous. The remaining mammals (Mustelidae, Procyonidae, Canidae, and Felidae) belong to Order Carnivora and exploit animal prey to various degrees.

This section presents results of several surveys conducted between 1996 and 1997 that document the presence of small, medium-sized, and large mammal species at Lisbon Bottom.

Survey Sites

Small mammal species were live-trapped in three habitat types: mature forest (*Populus deltoides*, *Acer negundo*, *Acer saccharinum*), regenerating forest (sapling or shrub-sized *P. deltoides*, *Salix* spp.), and open field (unidentified herbaceous species). All small mammal trapping areas were located east of Milligan's Chute (Fig. 1). Medium-sized mammals were live-trapped in the mature forest habitat located on the northern half of Lisbon Bottom (Fig. 1). Visual observations of mammal sign were made within mature forest, regenerating forest, and field areas throughout Lisbon Bottom, as well as along the mud flats adjacent to Milligan's Chute (Fig. 1).

Survey Methods

Small mammals — Sherman live traps (3 x 3.5 x 9 in.) placed in a 30 x 30-m grid (Table 1) were used to sample small mammals within mature forest, regenerating forest, and open field habitats during fall 1996 (294 trap-nights in each habitat) and spring 1997 (294 trap-nights in each habitat). During fall 1997 (Table 1), mature forest and regenerating forest habitats were sampled using a 90 x 90-m grid of Sherman live traps (500 trap-nights in each habitat). All Sherman traps were baited with a peanut butter and oatmeal mixture. Small mammals were identified to species and tagged with uniquely numbered ear tags (National Band and Tag Company). Relative abundance of each species was ranked as "common" (10 or more captures) or "rare" (<10 captures).

Medium-sized mammals — Ten Tomahawk livetraps (32 x 10 x 12 in.) were baited with sardines, placed in mature forest habitat, and set periodically for a total of 224 trap-nights between April and August 1997. Relative abundance for all species was ranked as common or rare based on the number of captures, as for small mammals. All raccoons were released after being affixed with radio-collars (Advanced Telemetry Systems, Inc.) and uniquely numbered ear tags (National Band and Tag Co.). Raccoons were monitored via radiotelemetry for approximately 6-7 months following release to determine their fidelity to Lisbon Bottom and the flood-plain habitat. Other species captured in Tomahawk live traps were released unmarked.

Additional methods. — Between April and November 1997, visual surveys for animal sign (tracks, scat, and tunnels) were conducted opportunistically to document the presence of mammal species at Lisbon Bottom that would not be trappable in Sherman or Tomahawk live traps. Visual observations were collected along dirt paths in mature forest, regenerating forest, and field habitats east of Mulligan's Chute, as well as along the muddy eastern edge of Mulligan's Chute.

Results and Discussion

Small mammals. — Nine species of small mammals were captured at Lisbon Bottom based on 2,764 trap-nights of effort using Sherman live traps (Table 2). Three species were found to be common using Sherman live traps: white-footed mice (*Peromyscus leucopus*), deer mice (*Peromyscus maniculatus*), and house mice (*Mus musculus*). However, *Peromyscus* spp. mice were far more abundant than house mice. Six species were found to be relatively rare using this technique: prairie voles (*Microtus ochrogaster*), southern bog lemmings (*Synaptomys cooperi*), western harvest mice (*Reithrodontomys megalotis*), least shrews (*Cryptotis parva*), Elliot's short-tailed shrews (*Blarina hylophaga*), and mink (*Mustela vison*). Live trapping is not the most effective way to sample for shrew species; thus, the low numbers of individuals captured may have been a function of sampling method. Also, the capture of one mink in a Sherman live trap was an unusual event because these traps are not designed to capture animals that large.

Medium-sized mammals. — Three species of medium-sized mammals were captured at Lisbon Bottom after 224 trap-nights of effort with Tomahawk live traps during 1997 (Table 2). Two of the medium-sized mammals were found to be relatively common based on this method: raccoons

(*Procyon lotor*) and Virginia opossums (*Didelphis virginiana*). A third species, domestic dog (*Canis familiaris*), was captured on only one occasion and assigned a ranking of relatively rare. Overall, trap success rate with Tomahawk traps was 13.4% (30 mammal captures/224 trap-nights). Physical examinations revealed evidence of lactation in opossums and pregnancy in raccoons during April. Radiotelemetry monitoring of nine raccoons (4M:5F) suggested that they commonly move between Lisbon Bottom and adjacent upland habitats.

Additional observations. — Visual observations of animal sign revealed the presence of an additional seven mammal species (comprising one small mammal species, five medium-sized mammal species, and one large mammal species) at Lisbon Bottom during 1997 (Table 3): beaver (*Castor canadensis*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), eastern cottontail rabbit (*Sylvilagus floridanus*), eastern mole (*Scalopus aquaticus*), river otter (*Lontra canadensis*), and white-tailed deer (*Odocoileus virginianus*). Cottontail rabbit and white-tailed deer sign were observed in numerous locations, suggesting their distribution is ubiquitous throughout Lisbon Bottom. The presence of beaver, bobcats, coyotes, eastern moles, and river otters was documented by observing their sign in one or two locations, but the distribution and relative abundance of these species on Lisbon Bottom are unknown. The occurrence of coyotes on Lisbon Bottom appeared probable based on scat and tracks but confirmatory evidence (e.g., sightings, calls) is needed to eliminate confusion with domestic dog.

Summary

Overall, 19 species of mammals were documented at Lisbon Bottom. Nine species of small mammals were captured in Sherman live traps during 1996 and 1997. Three of these species were relatively common based on number of captures (*P. leucopus*, *P. maniculatus*, and *M. musculus*) and six small mammal species were relatively rare (*B. hylophaga*, *C. parva*, *M. ochrogaster*, *M. vison*, *R. megalotis*, and *S. cooperi*).

Two species of medium-sized mammals were common based on captures in Tomahawk live traps during 1997 (*D. virginiana* and *P. lotor*) and one medium-sized mammal (*C. familiaris*) was determined to be relatively rare. Radio-collared raccoons (*P. lotor*) were found to move between Lisbon Bottom and adjacent habitats. An additional seven mammal species were detected at Lisbon Bottom based on visual observations (*C. latrans*, *C. canadensis*, *L. rufus*, *O. virginianus, L. canadensis, S. aquaticus,* and *S. floridanus*).

Further sampling effort may result in the detection of additional mammal species at Lisbon Bottom (e.g., muskrats, *Ondatra zibethicus*; striped skunks, *Mephitis mephitis*). Alternate sampling methods such as mist nets can be used to detect the occurrence of bats (Chiroptera) at Lisbon Bottom. Ultimately, mammal species composition is likely to respond over time to major habitat changes associated with vegetation succession at Lisbon Bottom.

Acknowledgments

Mammal sampling was facilitated by C. Coyle, T. Farrand, H. McCammon, K. Smith, and D. Walton. We appreciate the logistical and financial support provided by the Missouri Department of Conservation; U.S. Geological Survey, Columbia Environmental Research Center; and University of Missouri-Columbia School of Natural Resources. This study was greatly aided by assistance from Bill Mauck, Ron Drobney, J. C. Bryant, John Smith, Doug Helmers, and Al Vogt. We thank William Lay and James Lewis for access to their property.

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Table 1. Reference codes and sampling periods for mammal survey methods used at Lisbon Bottom during 1996 and 1997.

Code	Sampling Periods	Method Description
SHR	Nov. 1996	Sherman live traps; 49 traps/grid, 5-m spacing, 6 nights
	May 1997	Sherman live traps; 49 traps/grid, 5-m spacing, 6 nights
	Sept. 1997	Sherman live traps; 100 traps/grid, 10-m spacing, 5 nights
TOM	April-Aug. 1997	Tomahawk live traps; 10 traps; periodic trapping
SCAT	April-Nov. 1997	Visual observation of scat
SIGHT	April-Nov. 1997	Visual observation of animals
TRCK	April-Nov. 1997	Visual observation of tracks
TUNN	April-Nov. 1997	Visual observation of tunnels

Table 2. Mammal species and their relative abundance documented at Lisbon Bottom during 1996 and 1997 based on captures in Sherman live traps (SHR; 2764 trap-nights) or Tomahawk live traps (TOM; 224 trap-nights). Relative abundance was assessed as follows: R = Rare (1-9 captures); and C = Common (10 or more captures).

Species	Common Name	Code	Abundance
Blarina hylophaga[a]	Elliot's short-tailed shrew	SHR	R
Canis familiaris	Domestic dog	TOM	R
Cryptotis parva	Least shrew	SHR	R
Didelphis virginiana	Virginia opossum	TOM	C
Microtus ochrogaster	Prairie vole	SHR	R
Mus musculus	House mouse	SHR	C
Mustela vison	Mink	SHR	R
Peromyscus leucopus	White-footed mouse	SHR	C
Peromyscus maniculatus	Deer mouse	SHR	C
Procyon lotor	Raccoon	TOM	C
Reithrodontomys megalotis	Western harvest mouse	SHR	R
Synaptomys cooperi	Southern bog lemming	SHR	R

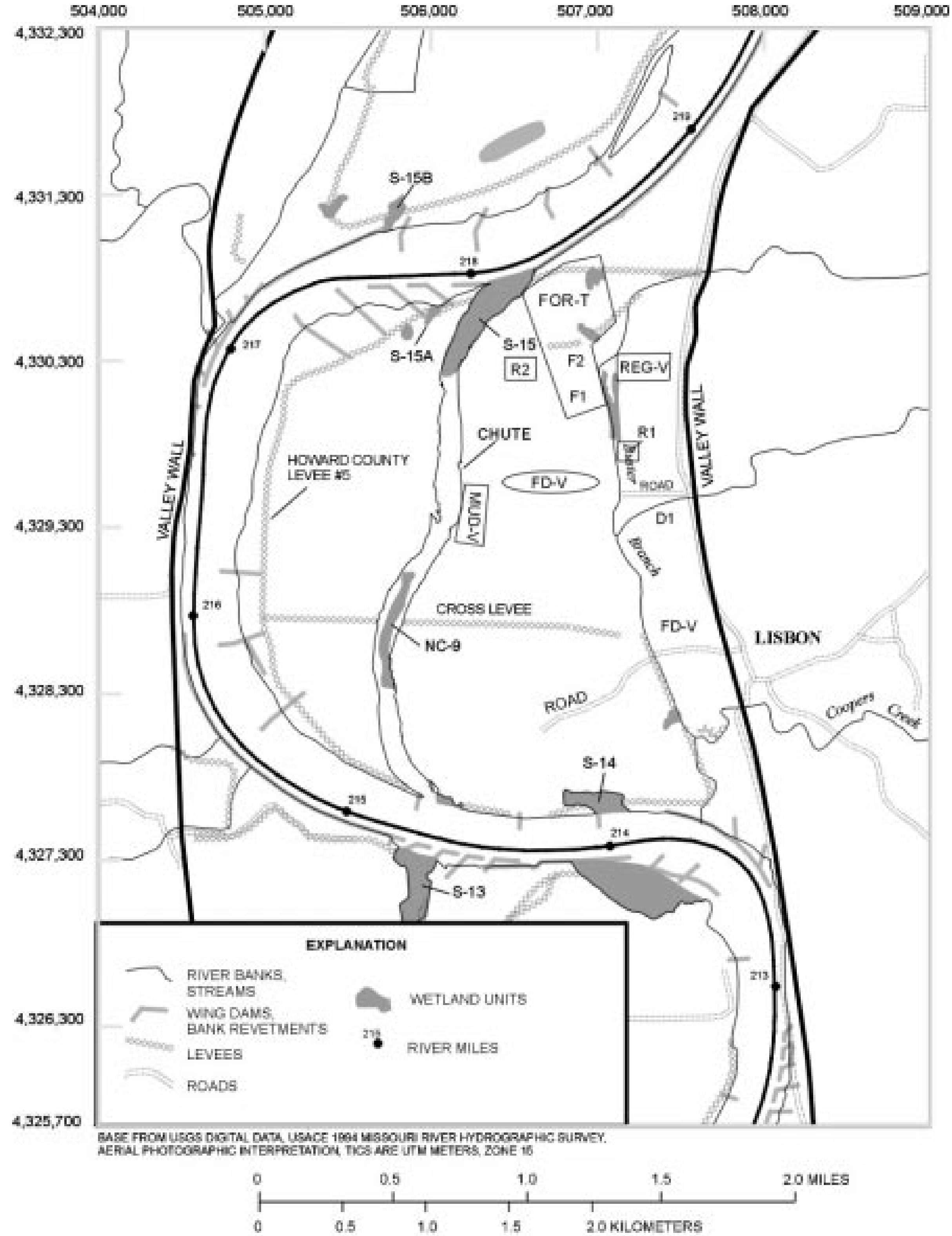
[a]Probably *B. hylophaga* rather than *B. brevicauda* based on Fritzell (*in litt.*); morphological data will be collected to confirm identification.

Table 3. Mammal species documented at Lisbon Bottom during 1997 based on visual observations of animals (SIGHT), scat (SCAT), tracks (TRCK), or tunnels (TUNN).

Species	Common Name	Code
Blarina hylophaga[a]	Elliots's short-tailed shrew	SIGHT
Canis latrans[b]	Coyote	TRCK, SCAT
Castor canadensis	Beaver	TRCK
Didelphis virginiana	Virginia opossum	TRCK
Lynx rufus	Bobcat	TRCK
Odocoileus virginianus	White-tailed deer	TRCK
Lontra canadensis	River otter	TRCK
Mustela vison	Mink	TRCK
Procyon lotor	Raccoon	TRCK
Scalopus aquaticus	Eastern mole	TUNN
Sylvilagus floridanus	Eastern cottontail rabbit	SCAT

[a]Probably *B. hylophaga* rather than *B. brevicauda* based on Fritzell (*in litt.*); morphological data will be collected to confirm identification.
[b]Additional evidence (e.g., sightings) desirable to exclude domestic dogs.

Fig. 1. Mammal sampling sites at Lisbon Bottom, Missouri, during 1996 and 1997. Small mammal trapping grids were placed in three habitats during Nov. 1996 and May 1997: mature forest (F1), regenerating forest (R1), and open field (D1). During Sept. 1997, small mammal trapping grids were set in mature forest (F2) and regenerating forest (R2). Medium-sized mammals were trapped in mature forest between April and Aug. 1997 (FOR-T). Visual surveys for mammal sign were conducted in mature forest habitat (FOR-T), regenerating forest (REG-V), field habitats (FD-V), and mud flats (MUD-V).



REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1999	Biological Science Report

4. TITLE AND SUBTITLE

Initial Biotic Survey of Lisbon Bottom, Big Muddy Fish and Wildlife Refuge

5. FUNDING NUMBERS

6.AUTHOR(S)

Dale D. Humburg and Vincent J. Burke, editors

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Department of the Interior
U.S. Geological Survey, Biological Resources Division
Columbia Environmental Research Center
Columbia, MO 65201

8. PERFORMING ORGANIZATION REPORT NUMBER

USGS/BRD/BSR-2000-0001

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Department of the Interior
U.S. Geological Survey
Biological Resources Division
Reston, VA 20192

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Release unlimited. Available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (1-800-553-6847 or 703-487-4650). Available to registered users from the Defense Technical Information Center, Attn: Help Desk, 8722 Kingman Road, Suite 0944, Fort Belvoir, VA 22060-2618 (1-800-225-3842 or 703-767-9050).

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*) The 2,300-acre Lisbon Bottom Unit, located in central Missouri, became part of the Big Muddy National Fish and Wildlife Refuge (NFWR) after the Great Flood of 1993 devastated the Unit's farmland and network of levees. As a result, interdisciplinary studies were initiated through collaboration among various researchers, universities, and State and Federal conservation agencies to investigate the short-term effects of the flood and to expand information about the Missouri River and flood-plain systems. The studies included in these chapters investigate baseline information that managers can use to assess restoration efforts on Lisbon Bottom and other units of the Big Muddy NFWR.

14. SUBJECT TERMS

amphibians, aquatic invertebrates, Big Muddy National Fish and Wildlife Refuge, fisheries, flood plain, geomorphology, hydrology, levee. Lisbon Bottom, mammals, Missouri River, riparian, side channel, vegetation, waterfowl, wetlands

15. NUMBER OF PAGES

viii + 76 pp.

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

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U.S. Geological Survey

As the Nation=s principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This responsibility includes fostering the sound use of our lands and water resource; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities.