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Status of Selected Fishes in the Missouri River in Nebraska With Recommendations for Their Recovery

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Abstract. Population density of five species of chubs and two species of minnows in the Missouri River in Nebraska has been reduced by as much as 95% since 1971. Burbot have been nearly extirpated, sauger have been greatly reduced, and blue catfish are rare. Reasons for the decline of these species include removal of snags from the river; cessation of organic matter and sediment transport because of the construction of large dams on the mainstem and tributaries; cutoff of floodplain connection through channelization, degradation, and the cessation of flooding; alteration of the natural hydrograph to meet the need for commercial navigation; and reduction of the natural water temperature regime because of deep release of cold water from the large reservoirs. We propose remedial actions for each of these ecological changes, and we propose listing of several species as endangered in Nebraska.

In 1838, federal engineers initiated the most significant restructuring of the Missouri River since the last Pleistocene glacier retreated northward. Snags were removed, dams were constructed on the mainstem and tributaries, channels were armored with rock and piling, the natural hydrograph was replaced with a monthly metered flow, sediment and organic matter transport was short-stopped, and the floodplain was made safe for human development.

At the time of construction, nothing was done to mitigate damage to the ecosystem. The impact set in motion by these changes will never be thoroughly quantified, and a semblance of physical and biological equilibria will not happen again for decades, if ever (Petts 1984). We do know that the Missouri

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River was shortened by at least 204 km and more than 178 million ha of river channel, erosion zone, floodplain grass and timber, and tributary valley lands were either inundated or converted to crop land (Hesse 1987; Hesse and Schmulbach 1991).

At least 160 species of wildlife were resident or migrant visitors to this ecosystem, and 156 native fish species lived in the mainstem and tributaries (Hesse et al. 1988; Hesse et al. 1989). Nebraska's imperiled Missouri River wildlife include the interior least tern (*Sterna antillarum*), piping plover (*Charadrius melodus*), peregrine falcon (*Falco peregrinus*), and bald eagle (*Hatiaeetus leucocephalus*), all protected by the Endangered Species Act (ESA). The pallid sturgeon (*Scaphirhynchus albus*) was most recently (1990) listed as endangered (Federal Register 55 (173):36641). Other species have been federally listed as Category 2 (taxa for which present information indicates the possible need to list, but more information is required before listing can proceed), including: blue sucker (*Cycleptus elongatus*), sturgeon chub (*Macrhybopsis gelida*), sicklefin chub (*Macrhybopsis meeki*), and lake sturgeon (*Acipenser fluvescens*). Paddlefish (*Polyodon spathula*) is a Category 2 species and was recently proposed for listing in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; Federal Register 56 (142):33894).

This paper discusses (1) differences in density of selected fish species over time and between reaches of the Missouri River, based on changing harvest by sport and commercial fishermen and on catch per unit effort (CPUE) from biological surveys, and (2) remedial actions that will preserve and restore original features and functions of the Missouri River as an ecosystem.

Sources of Data and Methods

The Nebraska Game and Parks Commission has supported research on Missouri River fisheries since the late 1950's. Historical databases exist from seining, explosives, creel surveys, commercial fishing reports, electrofishing, gill netting, and plankton drift netting.

Many other methods were used to collect in unique situations. These methods are discussed in Mestl and Hesse (1991). Seine samples are reported as the number of fish per seine haul. One standard seine haul constituted a perpendicular extension of a 15.24- × 1.83-m bag seine, followed by an extended drag to shore while maintaining one end of the net stationary. However, standardizing a seine haul was very difficult because of varying depth and the condition of the substrate. Mesh size was always 6.13 mm. All seined fish were preserved and identified in the laboratory. Cyprinids and catfish were collected from tributary streams with an explosive (primacord). A unit of effort consisted of a 15.2-m length of explosive, containing 162.5 grains of PETN/m. Bankline and sandbar habitats were sampled. A block net was used to capture fish killed by the blast. Angler surveys have been conducted periodically in the tailwater of Gavins Point Dam and at selected locations downriver since 1956. The most recent survey was a recreational use survey conducted during 1992.

Commercial fishers were first required to purchase a license and report their catch beginning in 1944 (Nebraska) and 1945 (Missouri). Although reports were required, they were completed annually, and by fishers themselves, with little opportunity for verification. However, we believe these reports are useful to show trends in abundance of selected species based on harvest trends.

Boat-mounted electrofishing (AC and DC) has been used since the early 1960's to collect a wide range of species. We have observed different catch rates associated with the widely varying water quality conditions throughout the river. For this reason only catch per unit effort (CPUE) that differed widely is reported. Small differences cannot be justifiably assigned to changing conditions of habitat and water management. Collections were based on time spent sampling, and CPUE was the number of fish per unit of time spent electrofishing.

Experimental gillnet collections were usually limited to the unchannelized Missouri River between Fort Randall Dam and Lewis and Clark Lake (Gavins Point Dam; Figure). This is the only reach in Nebraska with extensive off-channel and sandbar pool habitat remaining. The nets were either 91 m or 61 m long, and 2.44 m deep, with six equal length panels of netting ranging from 12.7-mm to 76.2-mm mesh sizes. Nets were anchored late in the afternoon and retrieved early the next day. Data were recorded by net length, and CPUE was the number of fish caught per net-night.

Larval fish were filtered from the main channel at cutting and filling banks and at mid-channel with paired, 1-m-diameter plankton nets (560 microns). Flow meters in the net mouths were used to quantify volume of water filtered, and duration per tow was minimal to prevent net clogging. The

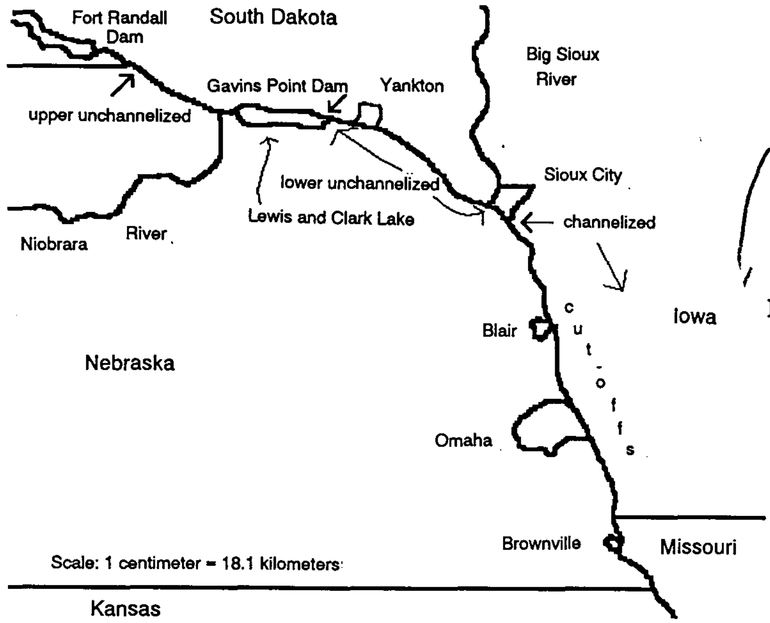

Figure. Map of the Missouri River showing the lowermost dams and unchannelized and channelized segments.

CPUE was reported as the number of larvae per 1,000 m^3 of water strained. Larval fish were identified to species, except that cyprinids and most suckers were grouped by family (Auer 1982). Larval blue sucker however, were identified to species (Hogue et al. 1981).

Status of Selected Fishes

River Chubs in the Missouri River

Five species of chubs were common in the Missouri River before it was channelized and impounded, including sturgeon chubs, *sicklefin chubs*, flathead chubs *(Platygobio gracilis)*, silver chubs (*Macrhybopsis storeriana*), and speckled chubs (*M. aestivalis*).

Sturgeon chubs were found in the Platte River at Grand Island, and in Bazile Creek near Niobrara (Everman and Cox 1896). Johnson (1942) collected them throughout the Platte, Republican, Elkhorn, and Missouri rivers. Sicklefin chubs were collected by Meek (1892) and Johnson (1942) from the Missouri River and by Morris (1960) from the Platte River. Flathead chubs were found extensively throughout most of Nebraska's rivers (Jones 1963). They were reported from all drainages except the Big Blue and Little Blue river systems (Johnson 1942). Silver chubs were distributed throughout the Missouri, Plate, Elkhorn, Loup, and Republican rivers (Everman and Cox 1896; Johnson 1942; Harlan and Speaker 1956; Morris 1960). Johnson (1942) found speckled chubs in the Platte, Elkhorn, Loup, and Republican rivers, and Meek (1894) collected them in the Big Blue River. Cross (1967) reported sturgeon chubs as widely distributed in the Missouri and Kansas rivers; sicklefin chubs were found in the Missouri and Mississippi rivers downstream from the Missouri River confluence, flathead chubs were primarily restricted to the Missouri, silver chubs were common only in the Missouri and Kansas rivers, and speckled chubs were common in the shallow side channels of the Missouri. Bailey and Allum (1962) reported sturgeon chubs from the Missouri and its largest western tributaries—the White, Cheyenne, and Grand rivers. Sicklefin chubs do not ascend the Mississippi beyond the confluence with the Missouri, and they reported its upstream limit in the Missouri River as the mouth of the Little Missouri River in North Dakota. Flathead chubs were reported to be the dominant minnow in the turbid Missouri and its larger western tributaries in South Dakota.

Silver chubs were known only in the Missouri River into southeastern South Dakota, and speckled chubs were not known to occur north of Nebraska. Pflieger (1975) considered speckled chubs common in the Missouri and lower Mississippi rivers. Sturgeon chubs, sicklefin chubs, flathead chubs, and silver chubs were considered common inhabitants of the Missouri River and the Mississippi River downstream from the Missouri confluence (Pflieger 1975). However, Pflieger and Grace (1987) reported a dramatic decline in the abundance of flathead chubs from 1940 to 1983 throughout the Missouri River in Missouri. Although they reported slight increases in the density of sturgeon chubs, sicklefin chubs, silver chubs, and speckled chubs in Missouri, these species were only numerous in the lowermost sections of the Missouri River nearest to the Mississippi River. Upper stations on the Missouri River in Missouri and adjacent to Nebraska showed low numbers of these chubs in 1978–83 collections (Pflieger and Grace 1987).

During 1971, 1974, and 1975, 16,384 small fish were seined during 3,060 seine hauls with a 15-m bag seine (6.13-mm mesh) from the channelized Missouri River in east-central and southeast Nebraska (Hesse and Wallace 1976). No sturgeon chubs or sicklefin chubs were collected; 324 (2.0% by composition) flathead chubs, 1,195 (7.3%) silver chubs, and 72 (0.4%) speckled chubs were collected (Table 1). From 1986 to 1990, 6,217 small fish were seined (234 seine hauls, 15-m bag seine, 6.13-mm mesh) from the channelized Missouri River in east-central and southeast Nebraska. One sicklefin chub and 1 sturgeon chub (0.03%), 3 (0.05%) flathead chubs, 120 (1.9%) silver chubs, and 2 (0.03%) speckled chubs were collected. Mean catches per seine haul were as follows: flathead chubs, 0.11 (1971–75) and 0.01 (1986–91); silver chubs, 0.39 (1971–75) and 0.51 (1986–91); speckled chubs, 0.02 (1971–75) and 0.009 (1986–91). Seine hauls were difficult to replicate; percent composition is a better indicator of population trend than CPUE in this instance.

Two reaches (165 km) of the Missouri River in northeast Nebraska remain unchannelized, although the uppermost reach (72 km) is isolated between Fort Randall and Gavins Point dams. During 1983–90, 32,448 small fish were seined (1,360 hauls, 15-m bag seine, 6.13-mm mesh). No sturgeon chubs, sicklefin chubs, or speckled chubs were collected; one (0.003%, 0.0007/haul) flathead chub, and seven (0.02%, 0.005/haul) silver chubs were collected.

River Minnows in the Missouri River

Plains minnows (*Hybognathus placitus*) and the western silvery minnows (*H. argyritis*) were common in the Missouri River at the turn of the century. They are similar species taxonomically and with respect to habitat preferences (Pflieger 1975). Jones (1963) reported they were widely distributed in the Platte, Republican, Loup, Elkhorn, and Niobrara rivers. The plains minnow was the most abundant minnow in the upper Missouri River in

Table 1. The relative abundance and catch per unit of effort (CPUE) of flathead chubs, silver chubs, speckled chubs, plains and silvery minnows combined, and total cyprinids seined from the Missouri River, Nebraska.

Species	Location	Period	Effort	No. sampled	Sample size	%	CPUE
Flathead chubs	channelized	1971–75	3,060	324	16,384	2.0	0.11
	channelized	1986–90	234	3	6,217	0.05	0.01
	unchannelized	1983–90	1,360	1	32,448	0.003	0.0007
Silver chubs	channelized	1971–75	3,060	1,195	16,384	7.3	0.39
	channelized	1986–90	234	120	6,217	1.9	0.51
	unchannelized	1983–90	1,360	7	32,448	0.02	0.005
Speckled chubs	channelized	1971–75	3,060	72	16,384	0.4	0.02
	channelized	1986–90	234	2	6,217	0.03	0.009
	unchannelized	1983–90	1,360	0	32,448	0.0	0.0
Plains and silvery minnows	channelized	1971–75	3,060	4,589	16,384	28.0	1.5
	channelized	1986–90	234	102	6,217	1.6	0.4
	unchannelized	1983–90	1,360	21	32,448	0.06	0.01
Total cyprinids	channelized	1971–75	3,060	6,180	16,384	37.7	2.01
	channelized	1986–90	234	229	6,217	3.7	0.9
	unchannelized	1983–90	1,360	28	32,448	0.09	0.02

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Missouri, declining as one proceeded downriver (Pflieger 1975). It occurred in schools in association with western silvery minnows, silver chubs, and flathead chubs (Pflieger 1975).

Plains minnows were abundant in the shallow, organic backwaters of the Missouri River (Cross 1967), and were abundant in the most turbid of the northern plains streams, including the Missouri River (Bailey and Allum 1962). Pflieger and Grace (1987) reported that western silvery minnows, plains minnows, and chubs composed 95.4% of all small fish in 1940–45, with plains minnows and flathead chubs by far the most numerous. They also reported a decline in the abundance of plains minnows and western silvery minnows from 1940 to 1983.

During 1971–75, 4,589 plains minnows and silvery minnows were seined from the channelized Missouri in eastern Nebraska, among 16,384 small fish (Hesse and Wallace 1976). They represented 28% of all small fish and ranked first in percent composition (Table 1). By 1986–90 only 102 (1.6%) were collected among 6,217 small fish seined in the same reach. Most plains minnows and silvery minnows, during 1971–74, were collected in southeast Nebraska stations on the Missouri River, where they represented an average of 38% of nearly 12,000 small fish collected (Hesse and Wallace 1976). During 1986-90 they were just 11.4% of all small fish captured at the same locations.

Missouri River Chubs and Minnows in Other Nebraska Streams

The Nebraska Department of Environmental Quality collected over 70,000 small fish in 350 stream sites across Nebraska (excluding the Missouri River) during 1984–88 (Bazata 1991). Flathead chubs (396 specimens) composed only 0.6% by composition and were collected in only 8.8% of the streams sampled. Johnson (1942) reported that this species was found in all drainages in Nebraska except the Big Blue and Little Blue rivers. Peters et al. (1989) collected them in only 4% of 874 electrofishing grids in the lower Platte River.

The Nebraska Department of Environmental Quality did not collect sturgeon chubs or sicklefin chubs anywhere in Nebraska streams, and Peters et al. (1989) collected one sturgeon chub and no sicklefin chubs from the lower Platte River. The Nebraska Department of Environmental Quality collected 4 (0.006% composition, 0.6% of streams) silver chubs, 12 (0.02% composition, 0.9% of streams) speckled chubs, 208 (0.3% composition, 2% of streams) plains minnows, and 182 (0.3% composition, 5.4% of streams) western silvery minnows (Bazata 1991). Peters et al. (1989) collected only 8 silver chubs (0.9% of 874 grids), 28 speckled chubs (3% of 874 grids), 473 plains minnows (9% of 874 grids), and 180 western silvery minnows (3% of 874 grids) from the lower Platte River.

The lower Niobrara River was sampled with primacord in 1976–78 (Hesse et al. 1979; Newcomb et al. 1981); 3,083 (15.3% composition) flathead chubs, 20 (0.1% composition) silver chubs, and 40 (0.2%) plains minnows were collected. This survey was repeated in 1991; 104 (12.5% composition) flathead chubs and no silver chubs or plains minnows were collected. Catch rate may be a better indicator of population density with an explosive because the explosive effort was easily duplicated, and fish response to primacord is independent of other factors (e.g., water quality). Flathead chubs were collected at the rate of 31 fish per blast in 1976–78 but only 5 fish per blast in 1991.

On the basis of these data we recommend that sturgeon chubs, sicklefin chubs, flathead chubs, silver chubs, speckled chubs, plains minnows, and western silvery minnows be listed as endangered in Nebraska.

Burbot

Bailey and Allum (1962) reported that burbot (*Lota lota*) were found east of the Black Hills in the Cheyenne River system and were common in the Missouri River in South Dakota. Johnson (1942) collected one from the Niobrara River in Nebraska and reported them in the Platte River; however, he suggested their range was restricted to the Missouri River and lower ends of large tributaries. Burbot were rare in Missouri's portion of the Missouri River (Pflieger 1975). Cross (1967) considered burbot primarily residents of the Missouri River mainstem; however, records exist of burbot collected from the Kansas River.

Burbot were commonly harvested by sport fishers in the tailwater of Gavins Point Dam for several years after it was closed in July 1955. Orr (1958, 1962) reported 510 (5.1% composition) burbot caught there in 1956, 4,780 (2%) in 1958, 0 in 1961 (out of an estimated harvest of 539,945), and 0 in 1962 (out of 710,389; Table 2). Commercial fishers harvested 1,500 kg of burbot from Lake Sakakawea (Garrison Dam on the mainstem Missouri River in North Dakota) in 1960, none from 1961 to 1974,

Table 2. Sport fishing harvest of burbot and sauger from the Missouri River in the Gavins Point Dam tailwater, 1956–92.

Year	All harvest	Rate	Burbot No. caught	Burbot %	Sauger No. caught	Sauger %
1956	10,000	1.6	510	5.1	2,700	27.0
1958	239,000	1.6	4,780	2.0	71,700	30.0
1961	539,000	1.4	0	0.0	264,110	49.0
1962	710,000	1.4	0	0.0	284,156	40.0
1972	18,441	0.4	0	0.0	830	4.5
1978	29,294	0.1	0	0.0	3,808	13.0
1984	45,101	0.6	0	0.0	4,143	9.0
1992	51,523	0.5	0	0.0	106	0.2

11 kg in 1975, and none through 1984 (unpublished report, North Dakota Game and Fish Department, Bismarck).

Sport fishers in the area between the Gavins Point Dam tailwater and Rulo, Nebraska, were surveyed during 1972 (Groen 1973). Burbot were not harvested in the tailwater of Gavins Point Dam or from the unchannelized reach downstream. However, six burbot (1% by composition) were harvested by sport fishers downstream from Omaha. User surveys conducted in 1978, 1984, and 1992 did not report any burbot as harvested or caught and released.

Electrofishing in the channelized Missouri River in eastern Nebraska (1971–75) captured 13 burbot among 29,493 large fish (0.04%; Hesse and Wallace 1976). Since 1983, we have electrofished 2,019 large fish from these same locations and have not collected burbot. In addition, we have collected 7,024 large fish with electrofishing in the unchannelized sections in northeast Nebraska, including only 4 (0.06%) burbot.

Burbot still reproduce in northeast Nebraska portions of the Missouri River. Two larval burbot were collected in 1984 in the tailwater of Gavins Point Dam, three in 1985 (two in the tailwater and one upstream at Niobrara), and one in 1986 (16 km downstream from Gavins Point Dam). These six larvae were very rare among more than 150,000 fish larvae collected from nearly 400,000 m^3 of water. We recommend that burbot be listed as endangered in Nebraska.

Sauger

Sauger (*Stizostedion canadense*) were common in Nebraska, occurring in the Platte River west to the Nebraska–Wyoming border (Meek 1894; Everman and Cox 1896; Wyoming Game and Fish Commission 1940). Jones (1963) cited an 1896 Nebraska Fish Commission report that sauger were caught in large numbers from the Platte, Blue, Loup, Elkhorn, and Niobrara rivers; however, they were most abundant in the Missouri River. Pflieger (1975) stated that sauger are often associated with strong current and high turbidity and are somewhat restricted to large, free-flowing rivers. Sauger were common in the Missouri River in Kansas and a seasonal resident of the Kansas River (Cross 1967). Sauger were common in the Missouri River in South Dakota and in the lower ends of some larger tributaries (Bailey and Allum 1962).

Large sport fisheries for sauger developed in the tailwaters of the large mainstem dams as they were constructed (Bailey and Allum 1962). Between July 1959 and March 1960, 31,291 sauger were harvested from the tailwater of Oahe Dam (Bailey and Allum 1962). Gavins Point Dam was closed in July 1955; the sport harvest gradually increased to 239,976 fish (1.6/h) by 1958 in the tailwaters, and 30% (71,993) were sauger; Orr 1962; Table 2). The sport harvest peaked in 1962 at 710,389 fish (1.4/h), and sauger represented 40% (284,156) of the catch (Orr 1962). By 1972, harvest in the tailwater decreased to 18,441 fish, and only 830 sauger were caught (Groen 1973). In 1992, tailwater anglers harvested 51,523 fish, and only 106 sauger were caught (Hesse et al. 1992).

Few records exist of sport fishing in the riverine reaches, but those that do paint a picture of extraordinary fishing opportunities. Robinson (1958b) surveyed ice fishers using the Decatur cut-off during the winter of 1958–59; 209 fishers averaged 1.7 fish/h; 64.3% of their catch was sauger, 23.9% was crappie, and 11.7% was largemouth bass. Comments by fishers included the following: "ice fishing

Table 3. Alternating current electrofishing catch of sauger from the Missouri River, Nebraska, 1964, 1975, and 1990.

Year	Channelized, % of all fish	Channelized, sauger/h	Unchannelized, sauger/h
1964	10.0	10.0	11.0
1975	3.0	3.3	
1990	0.3	0.5	1.6

has been good this year but last winter was much better with a larger take of sauger."

Channelization of the river south of Omaha began in the late 1930's, but not until the late 1950's, north of Omaha. Scientific surveys were first implemented as channelization commenced in the 1950's, and Robinson (1958a) noted a "marked difference in the composition of electrofishing catches" north of Omaha, although he did not elaborate on the southern catch. However, main channel catches during 27.5 h of electrofishing (north of Omaha), included 138 (7%) sauger, 119 (6%) largemouth bass, and 148 (7.5%) crappie. Morris (1965) captured 10 sauger/h of electrofishing (10% composition) near Blair (north of Omaha; Table 3). During 1971–75, 16,418 fish were electrofished near Blair; 450 (2.7%) sauger were collected, and the catch rate had dropped to 3.3/h of electrofishing (Hesse and Wallace 1976). During 1986–90 we electrofished 8.5 h at Blair, and collected 500 fish; none was sauger. We electrofished 40 additional hours during this same period at six other sites in the channelized section and collected 2,214 fish; 13 (0.6%) were sauger (0.3/h).

In 1964, Morris (1965) averaged 11 sauger/h with a boatshocker in the unchannelized Missouri River near Yankton, South Dakota (downstream from Gavins Point Dam; Table 3). Between 1983 and 1990 we electrofished 48.7 h at St. Helena (Cedar County), which is about 8 km from Morris's collection site. We collected 1,681 fish; 80 (4.8%) were sauger, and the catch rate was 1.6/h. However, only five sauger were collected at St. Helena after 1984 (53 in 1983, 22 in 1984). Four other sites on the unchannelized reaches upstream and downstream from Gavins Point Dam and Lewis and Clark Lake were electrofished between 1983 and 1990; 221 sauger (6.4%) were among 3,455 captured fish, and the catch rate was 1.9/h.

Experimental gill nets have been used to collect fish in remnant backwaters of the Missouri River since 1983. These areas are rare and exist mostly in the unchannelized reach upstream from Lewis and Clark Lake. The sauger catch rate has declined steadily from 4.5/gillnet-night in 1983 to 0.3/gillnet-night in 1991 (Table 4). Sauger, as a percent of total fish composition, also steadily declined from 19.4% in 1983 to 4.4% in 1991. The mean CPUE for a year was compared with the following year in a *t*-test, and the annual decrease in CPUE was shown to be significantly different ($P = 0.05$).

Collection of larval fish also provided some insight into the decline of sauger in the Missouri River. We have collected more than 112,000 larval fish since 1983 (not including a large number from the Gavins Point Dam tailwater), and larval sauger density varied from 0.1 to 2.2/1,000 m^3 (mean = 0.9) in the reach upstream from Lewis and Clark Lake. Nelson (1968) reported that larval sauger density in 1965 was 10.6/1,000 m^3 in this same reach. Mean larval sauger density in the channelized section for 1986–91 was 1.1/1,000 m^3. Some or most of these may have drifted from the unchannelized section downstream from Gavins Point Dam, where mean larval sauger density was 2.3 for 1983–91. Sauger larvae composed 1.8% of all

Table 4. Experimental gillnet catch of sauger from the unchannelized Missouri River, Nebraska, during 1983–91.

Year	Total fish captured	Total CPUE	Total sauger	Sauger %	Sauger CPUE
1983	396	6.8	77	19.4	4.5
1984	393	6.7	59	15.0	3.3
1985	558	7.3	81	14.5	2.8
1986	280	7.4	20	7.1	2.0
1987	27	3.5	3	11.1	0.8
1988	501	3.8	5	1.0	0.2
1989	38	8.5	0	0.0	0.0
1990	164	5.8	0	0.0	0.0
1991	138	3.2	6	4.4	0.3

and have only begun to analyze more than 50,500 individual records. Before 1991 only one blue catfish had been collected. However, in 1991, 15 young-of-the-year blue catfish were captured in total from three locations along the Missouri River in Nebraska south of Omaha. In Missouri's section, 63,191 catfish were sampled between 1980 and 1992; 1,350 (2%) were blue catfish. However, Missouri commercial fishers reported taking 37,983 kg of blue catfish, which is 27% of all catfish harvested during 1991 from the Missouri River in Missouri. We recommend that blue catfish be listed as endangered in Nebraska.

Other Species of Special Concern

Other species of special concern in Nebraska include lake sturgeon, which has probably been extirpated from Nebraska as a wild population; pallid sturgeon, which has been listed as a nationally endangered species and is very rare in Nebraska; shovelnose sturgeon (*Scaphirhynchus platorynchus*), which is declining throughout Nebraska's portion of the Missouri River; paddlefish, which is stable to declining in Nebraska (Hesse and Mestl 1992); longnose gar (*Lepisosteus osseus*), which is declining and becoming uncommon in Nebraska; shortnose gar (*L. platostomus*), which seems stable, but whose primary habitats have been eliminated; blue sucker, which seems to be stable in Nebraska, but is reduced throughout its range nationwide and is a candidate for national listing; and flathead catfish (*Pylodictis olivaris*), which has been reduced to fewer than 1,000 individuals in the unchannelized Missouri River upstream from Lewis and Clark Lake (Hesse and Mestl 1991).

In the following discussion we outline the reasons for the decline of these native fish species, and recommend remedial actions.

Discussion of Cause and Effect Factors

Snag Removal

Bilby and Ward (1991) reviewed available literature on the role played by large woody debris in stream ecology. Snags were reported to alter channel morphology by influencing sediment routing, thus creating pools, gravel bars, and depositional sites. These, in turn, reduced the rate of downstream transport of particulate material. Bilby and Likens (1980) suggested that a large part of stream organic matter is associated with woody debris.

Benke et al. (1985) determined that invertebrate diversity, standing stock biomass, and production per unit of surface area were much higher on snag habitat in the Satilla River, Georgia, than in the other two main habitats (shifting sandbars of the main channel and muddy depositional areas of backwaters). They reported that snag habitat contained 60% of total invertebrate biomass per unit length of river, even though snags composed only 4% of available habitat. The Satilla was heavily snagged in the 1940's.

Steam-powered snag boats began removal of snags from the Missouri River in 1838, when 2,245 large trees were removed from the river channel and 1,700 overhanging trees were cut from the bank in the first 620 km of river upstream from St. Louis, Missouri (Chittenden 1962). Before 1885, however, snag removal was somewhat random and extended only a few hundred kilometers up the Missouri River, although the number and tonnage of snags removed were immense (Suter 1877). After 1885, snagging intensified and became systematic. In 1901, snag boats removed 17,676 snags, 69 drift piles, and 6,073 overhanging trees in 866 km of river (Funk and Robinson 1974). Today, even unchannelized sections have few remaining snags.

Leaf abscission in fall contributed a pulse of organic matter to the river system, but leaves are 90% decomposed within 1 year (Risser et al. 1981). Conversely, large woody debris provided long-term supplies of organic matter, requiring 75 years for 95% decomposition in some instances (Melillo et al. 1983).

Trees of all types and sizes were essential as aquatic insect substrate, and they provided localized zones of reduced velocity for fish. Snags reduced mean stream velocity, increased the stream top width, provided long-term organic matter supplies, and aided in fine organic matter retention (Benke et al. 1985; Hesse et al. 1988).

Snag removal from the Missouri River was completed nearly 40 years ago, but dam construction eliminated large floods, and human encroachment on the floodplain stabilized the banks even along the unchannelized remnants. Few new snags have been introduced since 1954, when Gavins Point Dam was closed. In 1963, 68.9% of secondary production in the unchannelized reach in Nebraska was from snag habitat, while mud larvae in the unchannelized reach upstream from Lewis and Clark Lake, 0.7% in the lower channelized reach, and 0.2 % in the channelized reach.

Spawning sauger were collected from a glacial till outcropping in Boyd County, Nebraska, on the Missouri River at a maximum rate of 36/h of electrofishing during 1963–65 (Nelson 1968). We have duplicated his effort (similar equipment, time of year, time of day) periodically between 1982 and 1989. Average peak catch for the period was 3.7 sauger/h. We recommend that sauger be listed as endangered in Nebraska.

Blue Catfish

Blue catfish (*Ictalurus furcatus*) were known to colonize the Missouri River north to Montana; however, Pflieger (1975) reported that they also moved seasonally in response to water temperature, returning to the most southern reaches of their range, where water remained the warmest. Large dams on the Missouri and Mississippi rivers and their tributaries prevented this migrational response to environmental stimuli and probably contributed to their demise.

Churchill and Over (1933) suggested that blue catfish were widely distributed in the Missouri, White, James, Big Sioux, and Cheyenne rivers in South Dakota. However, by the early 1960's intensive netting and creel surveys resulted in only one small specimen collected downstream from Fort Randall Dam (Bailey and Allum 1962). Jones (1963) reported that its range was probably restricted to the Missouri River in Nebraska, with an occasional large specimen occurring in the Platte River as far west as Saunders County. The blue catfish was fairly common in the Missouri River and rare in the lower Kansas and Marais des Cygnes rivers of Kansas (Cross 1967). However, he noted the incredible size of the species. He cited frequent accounts of blue catfish exceeding 50 kg. We found a news article in the *Yankton Dakotian* dated 5 August 1862 that said, "Katphish, of fabulous dimensions, are being taken from the placid waters of the Big Muddy about these times. A great many of them weigh two and three hundred pounds."

Recently blue catfish have been caught only rarely by anglers in Nebraska's portion of the Missouri River. One weighing 45 kg was caught in Lewis and Clark Lake in August 1990. Smaller specimens are commonly channel catfish mistaken for blue catfish; few contemporary sport catches have been verified to be blue catfish.

Snow (1875) considered the blue catfish "the most valuable species in the river (Kansas River), since it is quite abundant " (Cross 1967). Kingsbury (1915) reported that "the catfish was an important factor in the settlement of Dakota, and in the opinion of many of the early settlers, the food problem would have been a very serious one had it not been for the abundant supply of this best of all fishes right at the threshold of the settlements." Audubon noted in 1858 that the catfish was a very valuable article of food in the Missouri River. For scores of years the early traders subsisted almost exclusively on buffalo (bison [*Bison bison*]) and catfish (Hesse and Mestl 1989).

Funk and Robinson (1974) reported that catfish composed 30% of the commercial catch in 1894. As a group they were heavily exploited at the turn of the century, especially large blue catfish. Between 1949 and 1971 the reported commercial harvest of blue catfish in Missouri's section of the Missouri River remained somewhat stable as a percentage of total catfish catch (16%). However, their total numbers in the catch declined by nearly 80% (Funk and Robinson 1974). Reported blue catfish commercial catch in Missouri increased from 4,292 kg in 1970 to 8,610 kg in 1985, whereas no blue catfish were harvested in Nebraska's portion after 1966 (Zuerlein 1988). Commercial blue catfish harvest in Nebraska declined steadily from 5,846 kg in 1944 to 654 kg in 1966 (Zuerlein 1988; Table 5).

Nebraska biologists have collected catfish from the Missouri River since at least 1958. The samples taken included many age classes, including young-of-the-year. Methods of capture included seine, gill net, trammel net, hoop net, rotenone, explosives, boat electrofishing, deepwater electrofishing, telephone generator, and the newest in electronic devices, euphemistically called the skoal box. We have gathered much of these data

Table 5. Mean annual reported harvest (kg) of catfish from the Missouri River in Nebraska during four time periods (Zuerlein 1988).

Time period	Blue catfish	Channel catfish	Flathead catfish
1944–53	4,383	12,101	9,074
1954–63	2,138	11,787	6,876
1964–73	1,704	9,004	3,251
1974–83	closed	7,541	5,116

substrate, backwater insect production contributed 19.3%, and sand substrate production was 11.8%. By 1980, snag production dropped to 50.4% of total production, while backwater production contributed 14.8% and main channel sand bar 35.8% (Mestl and Hesse 1992). Based on total available habitat, snag insect production in one unchannelized reach (downstream from Gavins Point Dam) was down by 65% between 1963 and 1980 (Mestl and Hesse 1992). Recent observations in the unchannelized reach upstream from Gavins Point Dam indicate that the insect community is even less abundant than in the downstream reach. We have not quantified production differences; however, we did quantify the amount of insect biomass drifting through both unchannelized sections in 1984 (Hesse and Mestl 1985). Mean monthly invertebrate drift biomass was 83 kg in the upper unchannelized section and 376 kg in the lower unchannelized section, nearly 4.5 times greater.

The changing relative abundance of fish in the Missouri River can most likely be explained by the changing availability of insects. For instance, flathead chubs used mostly terrestrial insects, which fall into the river from woody debris protruding from the water or along the bank, while plains minnows used the film of diatoms and insects from accumulating soft sediments in quiet backwaters (Cross 1967). Overhanging trees and snag production, and off-channel backwater production have been reduced so much that midchannel sandbar production has become a larger proportion of total system production. Flathead chubs and plains minnows have been replaced by emerald shiners (*Notropis atherinoides*), which feed primarily on zooplankton in higher-current sand substrates; insects are of secondary importance in their diet (Fuchs 1967). Sauger do not compete well with sight-feeding predators such as northern pike (*Esox lucius*) and smallmouth bass (*Micropterus dolomieu*) foraging for emerald shiners in shallow, nonturbid bars and backwaters.

We propose that large woody debris, brush, leaves, and grass should be returned to the Missouri River in large quantities. Such materials are available in communities near the river, and new legislation has banned yard waste from landfills in Nebraska beginning in 1994. Communities are exploring innovative environmental options for disposal of yard waste, and placing it in the Missouri River is a better way to use it than to bury it in overflowing landfills.

Loss of Floodplain Connectivity

The Missouri River had a wide (32 km) floodplain, part of which was inundated each year. Welcomme (1985) found a direct relation between duration of floodplain inundation and standing stock of fish the next year. Karr and Schlosser (1978) suggested that standing stock may decline by as much as 98% when the lateral linkage between floodplain and channel is severed. Junk et al. (1989) proposed the flood pulse theory as a mechanism to maintain the essential linkage between river channels and the floodplain.

The Missouri River has been deprived of a floodplain. More than 178 million ha of this essential habitat has been lost (Hesse and Schmulbach 1991). This habitat represented the off-channel area, where velocity was reduced and the bottom was muddy. Morris et al. (1968) determined that, as channelization occurred, 67% of the benthic insect production was lost in direct proportion to lost off-channel habitat.

We recommend that federal mitigation projects be expanded to include the entire length of the remaining riverine sections. Project design should include the hydraulic reconnection of old cut-off sections of the erosion zone to the main river. Through acquisition in fee title or environmental easement, a publicly owned corridor should be created to provide at least a minimal floodplain.

More than $100 million has been spent to build nearly 467 km of federal levees on both sides of the Missouri River from Sioux City, Iowa, to the mouth (Missouri Basin States Association 1985; Hesse 1987). These levees were designed to protect agricultural lands on the floodplain landward of the levee. More than 10,000 ha of old erosion zone lie riverward of the levees in Nebraska. There should have been provision for the lands riverward of the levees to become part of a public corridor for the river's floodplain.

Altered Hydrograph

The precontrol Missouri River carried peak runoff during two periods, March–April and June (Hesse and Mestl 1993). Since 1954, dams on the mainstem and tributaries have eliminated the peaks and produced a flat, metered hydrograph, which has effected reproduction of native fish and aquatic insects (Hesse and Carlson 1992). Moreover, before 1954, flushing flows, known as dominant discharge, occurred every 1.5 years. After

1954, dominant discharge occurred only twice in 33 years. The result has been the stabilization of the channel's morphological configuration. Dynamic change was stopped nearly 40 years ago. Native fish and wildlife used the historical channel components (sandbars, chutes, pools, backups, dunes, islands) as essential habitat.

We recommend a return to a semblance of the natural hydrograph. Initially this change could be based on a daily percentage of the mean annual discharge during a precontrol period. This approach would allow recovery of the seasonality of flows while providing control over the magnitude; however, dominant discharge must be recovered, and development of a floodplain corridor is essential for this process to be restored in part.

Through fine tuning of the navigation channel, as much as two-thirds of the flow of the river during July–October could be stored in the mainstem reservoirs to be used to emulate the spring flood pulse in riverine reaches. We believe this can be done with only minimal effect on full service navigation (Hesse 1992), and the draft results of Master Water Control Manual modelling by the U.S. Army Corps of Engineers suggests that power generation losses will be minimal (U.S. Army Corps of Engineers 1992).

Loss of Sediment Transport

Dams on the mainstem and tributaries have short-stopped the movement of sediment from upstream. The precontrol river was in a state of equilibrium; net sediment entering a reach replaced an equal amount leaving. Sand, silt, and organic matter were the raw materials for habitat development and aquatic nutrition. Precontrol average annual suspended sediment loading was 149 million metric tons at Yankton, South Dakota, and grain size averaged 20% sand, 40% silt, and 40% clay. By 1954, annual suspended sediment loading dropped 81% to 30 million metric tons. The sand fraction more than doubled, while silt and clay were halved (Slizeski et al. 1982). In addition to eliminating much of the material for habitat development, areas downstream from dams and the lower ends of tributary streams have developed severe channel bed degradation. Degradation has contributed to the loss of off-channel habitat and has furthered the severance of the floodplain–channel connection (U.S. Army Corps of Engineers 1991).

We recommend that the U.S. Army Corps of Engineers investigate sediment bypass systems for the Missouri River and its tributaries. Sediment bypass is feasible (Singh and Durgunoglu 1991), and additional benefits such as increased water storage in hydropower reservoirs; elimination of delta formations in the upper end of reservoirs, which can cause lowland flooding; and reduced degradation, which will reduce navigation channel maintenance costs, damage to water intakes and bridge abutments, and head cutting in tributary streams.

Options for study may include operating lake discharge as run-of-the-river for a year, sluice gates (below grade at the dam), sluice bypass channel, and sluice pipeline (on or in the lake bed); for a short-term solution, land adjacent to the river channel just downstream from the dam can be acquired and pushed into the river channel.

Altered Water Temperature

The largest dams on the mainstem of the Missouri River release water from depths of 42 m (Fort Randall Dam) to 59 m (Oahe Dam; U.S. Army Corps of Engineers 1985). Cold bottom strata have significantly altered downstream riverine water temperature.

Water temperature was 21° C at river km 1,112 (on the channelized reach downstream from Sioux City, Iowa) and 23° C at river km 801 on the same day in May 1987, and 26° C at river km 1,112 and 28° C at river km 801 in June 1987. This reach runs nearly straight north and south, and the effect on warming because of latitude would be greatest in this reach. Under the same circumstances, we measured water temperature at river km 1,393 (31 km downstream from Fort Randall Dam) to be 10° C in May 1987 and 16° C at river km 1,178 (216 km nearly due east). Water temperature was 17° C at river km 1,393 and 26° C at river km 1,178 on the same day in June 1987. Thermal modification of this magnitude can affect aquatic insects by altering emergence cues, egg hatching, diapause breaking, and maturation (Petts 1984). Native fish, such as sauger, sturgeon, blue sucker, and others, spawn in response to water temperature, photoperiod, and run-off cues. Today these cues send mixed signals. We recommend that selective withdrawal be incorporated into existing dam-reservoir design. Water could be discharged from near the surface, or bottom water could be mixed with surface water before release from the existing structure. Construction of a submerged weir upstream from the fixed outlets of these mainstem dams would cause cold bottom water to mix with warmer surface waters before discharge into the river downstream (Cassidy 1989). This may abate some of the effect and should be relatively less expensive than retrofitting the dam with a series of outlets at different elevations on the dam face. If the weir was constructed with quartzite rock it would also serve as an underwater reef with fisheries benefits.

Fish Bypass

Large numbers of paddlefish, blue sucker, and buffalo, as well as most other native fishes, accumulate in the tailwater of Gavins Point Dam, especially in early spring. We have successfully used these concentrations to acquire information about the size and age structure of these fish stocks; however, we have also observed breeding-sized adults, fully ripe, with no hope of finding adequate reproductive substrate in the tailwater.

Gavins Point Dam provides a good opportunity to develop a fish bypass because many fish are attracted to the strong currents in the narrow discharge canal downstream from the powerhouse. Large numbers of fish can be seen swimming along the south wall. A fish elevator could readily be installed on this wall and used in conjunction with a collection and trucking facility on the bank, which would not require alteration of the dam. Such a facility should be cost effective, and an elevator design would work effectively for most native species regardless of size. These species would subsequently be provided access to Lewis and Clark Lake and 72 km of unchannelized Missouri River. We recommend that the U.S. Army Corps of Engineers investigate construction of such a bypass.

Sport and Commercial Harvest Restrictions

Native fish stocks in the riverine portions of the river in Nebraska are only a fraction of their previous size, a result of changes in form and function of the present versus primordial Missouri River. As density declined and habitat shrank, overfishing occurred. First, the largest and oldest specimens were eliminated, and eventually the stocks were damaged (Hesse and Mestl 1990). With few exceptions (i.e., drum, redhorse, carpsucker, goldeye) most native fish stocks of the Missouri River are declining, and harvest cannot be sustained at the present level.

Sport and commercial fishing must not be allowed to overharvest remaining fish stocks. Future recovery depends on the maintenance of native genetic stocks. The harvest of sauger, largemouth bass, crappie, buffalo, blue sucker, and gar should be restricted until survey data indicate that a harvestable surplus can be sustained. Paddlefish, shovelnose sturgeon, blue catfish, and flathead catfish reproduction is not highly successful, but because they are long-lived and slow-growing, they seem more numerous than other stressed species. Harvest of these fishes should be limited and controlled. Paddlefish harvest has been closely managed in recent years, and the population in Nebraska appears to respond to careful management.

Needed Research

Future research should be focused on evaluation of implemented restoration design. The deteriorated condition of many native species indicates the need for implementation of a comprehensive management plan. Much is already known about Missouri River ecosystem function; the time has arrived to implement real restoration.

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