1994

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1994. *Transactions of the Nebraska Academy of Sciences*, 21: 73–87

THE STATUS OF NEBRASKA FISHES IN THE MISSOURI RIVER, 3. CHANNEL CATFISH (ICTALURIDAE: *ICTALURUS PUNCTATUS*)

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Federal Aid in Sport Fish Restoration, Dingell-Johnson Project F-75-R-11, November 1993. Publication funded by Nebraska Game and Parks Commission.

ABSTRACT

The average size of Missouri River channel catfish has declined. The percentage 10 years old or older is 4.8% compared with an unexploited population in which 32% are 10 years and older. From 1944 through 1988 commercial harvest declined as much as 64%. Total mortality was 37% at age 4 and 79% at age 5. The increased mortality occurred as they reached 13 inches and became fully recruited to the commercial fishery. Harvest statistics are not wholly reliable because reports are not verifiable and commercial fishers do not return fish tags. Harvest exceeded a reasonable limit for maximum sustained yield. Commercial minimum-size limits have been ineffective due to their design and because they are not easily enforced. Commercial catfishing was closed in action taken by the Nebraska Game and Parks Commission in November 1990 to take effect 1 January 1992. Since then the mean size has increased from 286 mm total length (TL) to 324 mm TL in 25.4-mm mesh net samples from the channelized section of the Missouri River, and the percentage of fish longer than 330 mm TL increased from 8% in 1987 to 44% in 1993.

† † †

The production of fish from a large river can be harvested by commercial and/or recreational fishers. However, not all of the fish population in the river can be caught if the stock of fish is to be maintained (Gulland, 1978). Controlling the harvest of a fish stock is one function of a management plan. Most fisheries-management plans are designed to provide enhanced benefits to people from the exploitation of a fish stock. The management of riverine fisheries has always been a sociological as well as biological endeavor. Malvestuto (1989) states that all rivers have intrinsic and socio-economic values. Large rheophilic fishes such as paddlefish, sturgeons, and the catfishes are unique and contribute to the intrinsic value of the Missouri River. These fishes are facing an uncertain future because of changes to the Missouri River ecosystem and over-exploitation.

In the Missouri River, commercial artisans have conducted fishing practices handed down through their families. For the most part, fish are processed and sold to the consumer by the fishers. Nebraska Game and Parks Commission (the Department) adopts the N.O.A.A. (1986) definition of a full-time commercial fisher as one who earns more than 50% of income from fishing. Under this definition, only eight of 148 permitted fishers in Nebraska during 1986 would be classified as full-time (Zuerlein, 1987); however, when asked what their occupation was, only six listed commercial fisher. The low number of commercial fishers is not surprising. Commercial fishing, as a practical venture, occurs in developing countries where seasonal fish harvest still provides a major portion of annual dietary protein needs, and in the oceans where extensive marine fisheries meet the large demand for a variety of fish and shellfish products (e.g., tuna, shrimp). However, the societal benefits of commercial fishing in the Missouri River have ceased for several reasons. Malvestuto (1989) observed that generally in the United States the dietary requirements of the populace are satisfied without fish. Missouri River commercial fishing is not a viable economic activity (Zuerlein, 1987); 68.8% of all commercial fishers reported earning zero dollars in 1986. Aquaculture has created a steady supply of high quality, competitively priced fish and shellfish, and recreational fishing partially fullfills the consumptive demand Americans have for fish. With very few exceptions Missouri River commercial fishers are sport fishers using nets instead of hook and line.

Effective control of the commercial harvest is essential to responsible management of the fishery but has not been a reality in Nebraska. Commercial fishers are required to purchase a permit and report their catch each year; but an average of 23.5% have failed to report since 1944. Reports are completed by the fishers at the end of each month and monthly sheets are returned at the end of the fishing year but they are not verifiable. Under-reporting of numbers and pounds harvested occurs primarily because fishing income is taxable. Morever, many commercial fishers do not return data from tagged fish, thereby impeding our ability to evaluate harvest. Based on sport-fishers creel surveys and commercial-fishers reports, which are known to be under-reported (personal communication, Jim Mason, commercial fisher, retired, Brownville, Nebraska), commercial fishers catch 93% of the channel catfish caught each year; however, Newcomb (1989) reported that only 1.4% of 278 tag returns from a 1983–1987 catfish study were from commercial fishers.

Minimum-length restrictions can be an effective management procedure when designed correctly and when they are enforceable. Prior to 1984, commercial fishers were restricted from harvesting channel catfish smaller than 330 mm TL (total length); in 1984 the restriction was changed to 381 mm TL. However, these restrictions have not effectively prevented over-harvest.

The objectives of this paper include: 1) review of the literature describeing criteria used by other resource management agencies to identify and control over-exploitation; 2) presentation of data from studies of Missouri River channel catfish that demonstrate over-exploitation; 3) description of an implemented harvest restriction; 4) review of an initial response to imposed harvest restrictions; and 5) recommendations for long-term management of Missouri River channel catfish.

Selected literature review

The acquisition of sound data from large rivers has always been a difficult task. Despite this, large river fisheries are managed with available data. The purpose of this short literature review is fourfold. First, to show that other large-river fisheries have been studied and management programs have been adopted. Second, to demonstrate that other large-river fish stocks have been over-exploited. Third, to emphasize that "overfishing" can impact the resource. Admittedly, habitat destruction has been a world-wide reality with most large rivers but this fact is not the sole reason for declining fish stocks. Finally, to learn more about the various symptoms other river managers have used to recognize over-exploitation.

North America—Commercial-fisheries harvest in the Churchill and Mackenzie basins of northern Canada are controlled by quota systems (Bodaly et al., 1989). Lake whitefish, walleye, northern pike, and lake trout are the important species. The lake sturgeon is "commercially extinct" in the Churchill basin as a result of high exploitation rates. Lake trout catches declined during the late 1950s and the decline was "ascribed to over-exploitation." Lake whitefish are more tolerant of high harvest rates; however, declining catches in Great Slave Lake were blamed on the exclusive use of large mesh gillnets which selectively eliminated older fish (Bodaly et al., 1989).

Brousseau and Goodchild (1989) reported that only a few commercial fisheries in large rivers of the Moose River Basin of Ontario are allowed to take lake whitefish or lake sturgeon. The harvest of these species is controlled closely by small quotas and maximum length limits.

A quota of 13,971 kg was established for Arctic char in the main rivers flowing into James and Hudson bays from Quebec in the early 1960s (Roy, 1989). Within 10 years fish harvest and mean size had declined sufficiently to end all commercial enterprise. During the mid-1900s commercial fisheries developed for lake sturgeon, walleye, northern pike, lake trout and lake whitefish. However, most were "forced to cease" due to declining stocks.

The Hudson River was reported to have been an incredibly rich fishery (Boyle, 1969); the river supported commercial fisheries for American shad, American eel, Atlantic tomcod, and Atlantic and shortnose sturgeon. The only stable fishery, however, was the American shad fishery. According to Limburg et al. (1989), fluctuating annual catches reflected overfishing. Overall commercial landings peaked in the 1940s and declined thereafter. The U.S. Fish and Wildlife Service (Talbot, 1954) determined that overfishing had the greatest influence upon fish abundance even though pollution, dredging, and ship traffic were evaluated as well.

The extirpation of large blue catfish, lake sturgeon, pallid sturgeon, and the decline of large paddlefish, flathead catfish, and channel catfish in the Missouri River began early in this century (Funk and Robinson, 1974) and was the result of a "fishing up process," a term used by Welcomme (1985) to describe the elimination of large fish from a multi-species fish stock. The paddlefish snag-fishery in the Missouri River is a good example of overfishing associated with deteriorating reproduction due to dam construction and channelization (Hesse and Mestl, 1993).

Europe—Over-exploitation of salmon in the River Wye of England and Wales resulted from a commercial fishery prior to the 1900s. During this period catch efficiency declined sufficiently for Welsh authorities to buy out most commercial fishers and reduce the harvest. Rapid stock recovery followed strict control; however, limited net-fishing after 1930, in concert with an expanding sport harvest, caused a decrease in the mean weight of harvested salmon. It was determined that the river phase had been overfished again (Mann, 1989).

Catches of sturgeon and salmon in the Rhine River of Germany showed a steady decline, that, in part, coincided with the alteration of the meandering, braided stream into a barge canal. However, as Lelek (1989) pointed out, the declining catch of sturgeon was a result of fishing intensity.

South American, African, and Asian rivers—Research on large tropical rivers with multi-species stocks has shown a progressive reduction in the abundance of the larger species as fishing pressure was applied (Welcomme, 1985). Increased exploitation resulted in a reduction in both the mean size of large rheophilic species and their proportion of the catch. Large species have disappeared from the Amazon River at Manaus (Welcomme, 1979), the South American Orinoco River, the west African Oueme River, and the Asian Mekong River (Welcomme, 1985).

In the Pearl River, largest in southern China, annual commercial catches fluctuated considerably. The catch between 1950 and 1980 declined by nearly 38% due to over-exploitation. Fishing intensity had increased to such a degree that older fish were eliminated from the stocks (Liao et al., 1989).

Summary: What denotes over-exploitation?

Because acquiring data from large rivers has always been difficult, river-fisheries managers have used declining commercial landings, changes in population estimates over time, disappearance of species of large fish, declining mean size, elimination of old fish from the stock, and low reproductive success as indicators of stock damage resulting from overfishing. Management techniques used to repair damaged stocks include: cessation of commercial fishing, harvest quotas, minimum and maximum size limit restrictions, rotational fishing (closed periods between open fishing periods), protected areas, and seasons.

METHODS

Hoopnet, gillnet, seine, and deepwater electrofishing methods were described in detail by Hesse (1982), Hesse and Klammer (1984), Hesse et al. (1982a), and Hesse and Newcomb (1982).

Baited hoopnets provided the greatest portion of the sample. A standard hoopnet was 0.6 m in diameter, 3 m long and constructed of either 6.35-, 25.4-, or 38.1-mm square-measure tarred nylon mesh. Nets had two throats and were baited with aged yellow cheese trimmings obtained from Dairyland Bait Company in Plymouth, Wisconsin. Hoopnets were fished in likely habitat or in known travel routes in sufficient current velocity to hold the net open when anchored with the mouth facing downstream. A unit of effort was one net fished during a 24-hr period.

The Missouri River study area is large and manpower was limited. Hoopnet effort was restricted, in most recent surveys, to intensive collections during short periods at many locations. Monthly mean total length ($\bar{x}$TL) of sampled channel catfish was compared statistically (*t*-ratio) with annual grand mean length for collections made in 1974 and 1975 (Table 1) at Blair and Brownville, Nebraska (Fig. 1). The null hypothesis stated: there was no difference between the mean length of channel catfish collected in any month when compared to the grand mean length for that year and location. The difference between the means was found to be a real difference in only 4 of 32 months.

Gillnets were used in off-channel habitat in the unchannelized sections of the river. All nets were experimental and composed of six equal length panels of 12.7-, 25.4-, 38.1-, 50.8-, 63.5-, and 76.2-mm square-measure nylon mesh. One unit of effort was one net fished overnight. Seines were 15.2 m × 1.8 m × 6.35 mm tarred nylon mesh, constructed with a bag in the center of the net. One unit of effort was a one-quarter circle tow while one end remained stationary. Deep-water electrofishing was designed (Hesse and Newcomb, 1982) to collect channel catfish from deep, overwinter habitat in the channelized section of the river. Positive electrodes were suspended from a 15.2-m insulated copper

Table 1. Grand mean (GM) length (mm) and monthly mean length (sample size in parenthesis) of channel catfish captured in baited, one-inch mesh hoopnets during 1974 and 1975 at Brownville and Blair, Nebraska.

1974 - Brownville									
GM	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
264			179	219	275	233	235	276	279
(745)			(4)	(16)	(154)	(127)	(75)	(118)	(251)
1974 - Blair									
GM	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
263			234	202	274*	252	251	248	335
(2,926)			(72)	(76)	(1,635)	(591)	(489)	(50)	(13)
1975 - Brownville									
GM	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
271	265	252*	249	268	293	295*	269	228	290
(1,819)	(44)	(470)	(247)	(52)	(259)	(352)	(231)	(11)	(141)
1975 - Blair									
GM	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
250	268	222*	230	263	272	250	256	249	255
(2,023)	(5)	(292)	(100)	(81)	(99)	(96)	(1,091)	(204)	(55)

* P = 0.05

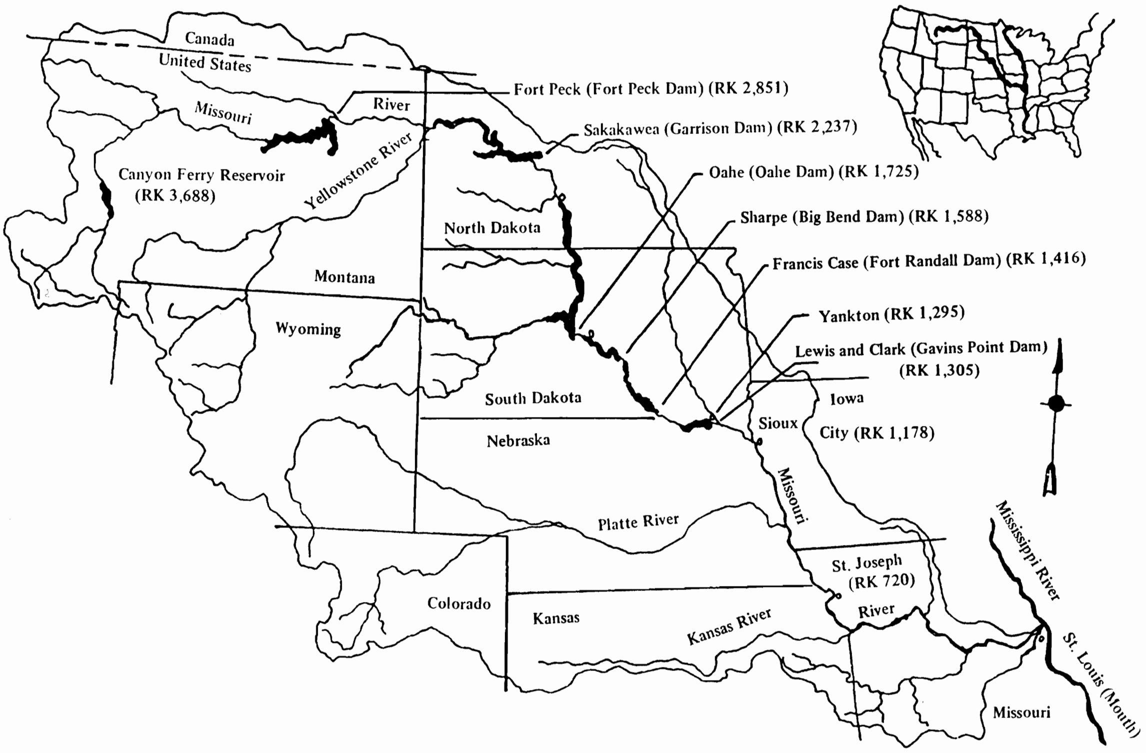

Figure 1. Map of the Missouri River basin.

cable. They were towed through likely habitat, and the most effective current was 200–240 Volts, pulsed DC, 10–15 amperes, 50% pulse width, and 90 pulses per second. The unit of effort was the number of fish captured by minute of electrofishing and the number of fish captured per wing dike.

RESULTS

Data Synthesis

Reproduction

Fish reproduction can decline as a result of overharvest, but our seine samples from the upper channelized reach of the Missouri River (upstream from Omaha, Nebraska) have shown that young-of-the-year (y-o-y) channel catfish increased from 0.7/seine haul to 2.2/seine haul (F = 5.10, p = 0.03) between 1975 and 1985. However, the difference was not significant when 1986 data were excluded from the test; 1986 upper channelized catch per unit effort (CPUE) (6.0/seine haul) was much greater than any year previous or after. However, only the channelized reach experienced the necessary conditions in 1986 for development of a strong year-class; 193 seine hauls at five sites in the unchannelized sections resulted in the capture of only six channel catfish (0.03/seine haul).

Mean discharge in the Missouri River downstream from Gavins Point Dam (measured at the Nebraska City gauge) was much higher in May and June of 1986 (1,839 m^3/s than in May and June of 1985 (1,402 m^3/s). Maximum discharge in May 1986 exceeded flood stage (went overbank) in mid to late May, at the peak spawning time for channel catfish. Maximum discharge during May each year from 1975 through 1982 remained well below flood stage, and overbank flows only occurred during two days in early May before spawning, in 1983 and 1984. The unchannelized reaches have not had significant overbank flows since the dams were completed in the mid-1950s.

Production/biomass ratio and yield.

Ricker (1978) defined fish production as the increase in biomass including all reproductive products and growth. Production from growth included the annual increase in weight of individuals that survived as well as those that grew but then died sometime during the year. Yield was that portion of production used by man. A production estimate was calculated for channelized Missouri River channel catfish. Newcomb (1989) provided a population estimate of 1,371 channel catfish/km for one section of the river. He also obtained a length distribution for a sample of 1,952 fish. However, only age-3 fish and older were fully recruited to the collecting method used. The numbers of fish by age group were transformed into natural logarithms and the following regression equation was calculated: $\log_e N = 9.8277 - 0.9769 \text{ (age)}$ (r = -0.987). The number of

Table 2. Per-km estimates of population size, mean weight, mean annual growth increment, production and biomass by age group for channel catfish from the channelized Missouri River.

Age	Number in population	Mean wt.(g)	Growth increment(g)	Production kg/km	Biomass kg/km
0	18,540*	5	5	154	58
1	6,980*	42	27	202	182
2	2,628*	105	63	152	171
3	1,184	215	110	81	158
4	430	383	168	45	102
5	101	616	233	15	39
6	51	862	246	8	27
7	13	1,108	246	2	9
8	12	1,354	246	1.8	10
9	7	1,600	246	1	7
10	3	1,846	246	0.5	3
Total	29,949			664	767

*Calculated values

age-0, 1, and 2-year old fish for this population was estimated using this equation. Table 2 presents the per-km estimate of population size, mean weight by age group, and the annual growth increment by age group (Hesse et al., 1978). An estimate of production associated with recruitment was the number of 0-age fish (18,540) multiplied by 5 g (mean weight per fish) (Hesse et al., 1979b). An estimate of the contribution of growth to production was the number of fish in an age group multiplied by an individual's growth increment during that year (Table 2). The growth of those individuals that grew throughout part of the year but died was determined by assuming growth and mortality were constant throughout the year. Half of those that died were multiplied by the total increment of growth for that age group. This applied only to un-exploited age groups (0 to 3). Since the majority of commercial channel catfish harvest occurs in the spring before growth has begun for the year, growth for those individuals that died within the heavily exploited age groups was not added in. Biomass was estimated by multiplying the number of fish in an age group by the mean weight of a fish in that age group.

The reach of river covered by these estimates was from South Sioux City, Nebraska (river mile 732), to the Nebraska border (river mile 490), a distance of 389 km. Morris et al. (1971) estimated the average width of this reach was 240.5 m. Therefore, the area is approximately 9,368 ha (24.1 ha/km).

Total channel catfish production/km from Table 2 is 664 kg or 27.7 kg/ha. Total biomass was 767 kg/km (Table 2) or 31.8 kg/ha. The production/biomass (P/B) ratio was 0.87. Portt et al. (1986) stated that the ratio of production to biomass may be used to estimate production from future biomass estimates.

Commercial fishers from Nebraska, Iowa and Missouri harvested catfish from the Missouri River. These fishers were required to report their catch at the end of each calender year. Zuerlein (1988) summarized these catch statistics for the period 1944 through 1985. Nebraska fishers-data were separated into three sections; section 1 was the unchannelized portion and sections 2 and 3 were the channelized portion of the Missouri River. Production estimates were calculated only for the channelized sections because population estimates were unavailable for the unchannelized portion.

The reported commercial harvest in 1985 was 11,240 kg from the channelized section in Nebraska; 2,180 kg from Iowa, and 5,410 kg from Missouri. Missouri's section of the Missouri River that borders Nebraska is 13% of the total length of the Missouri River in Missouri. Since Zuerlein (1988) reported only total harvest from all of Missouri for 1985, only 13% of Missouri's total reported harvest was included.

Sport fishers have been surveyed regarding their catch of catfish from the channelized reach. Groen (1973) reported that sport fishers harvested 2,005 kg of channel catfish from this reach in 1972–1973, and Hesse (1980) reported 848 kg in 1978. The mean (1,427 kg) of these two estimates was used, and it represented 7% of total catfish harvest from the channelized reach. The most recent survey of sport fishers from the channelized reach (Hesse et al., 1993) showed an estimated channel catfish harvest of 2,750 fish during May through August 1992. Groen and Schmulbach (1978) estimated that 4,621 channel catfish were harvested from the same reach during July through August 1972.

Total yield from sport and commercial fishers was estimated to be 20,256 kg of channel catfish (2.16 kg/ha), which represented 8.0% of total production (Y/P ratio), but must be viewed as a conservative value. Yield, as calculated, does not consider non-reporting permittees nor the probablity that reported weight may be low by as much as 75% (under-reporting). Real Y/P is likely somewhere in the range of 11% (25% under-reporting) to 31% (75% under-reporting).

Theoretically, biomass produced in excess of that needed to replace the stock can be harvested. There is a point where the maximum harvest or yield can then be maintained over time (maximum sustained yield = MSY). Allen curves have been used to predict yield from a stock of unexploited fish. From such models, Pitcher and Hart (1982) have suggested that approximately 8% of total production can be taken as MSY. The harvest of Missouri River channel catfish exceeds the theoretical limits of MSY.

Harvest statistics

Zuerlein (1988) reported the mean kg/year of channel catfish harvested by commercial fishers during four 10-year periods. Table 3 shows a regressive trend in the harvest of channel catfish when succeeding 10-year periods were compared with the period of record (1944 through 1953). A Tukey's test showed that several of these comparisons were significantly different at the 0.05 level (Table 3). Declining catch would suggest a declining standing stock, which resulted from a combination of habitat deterioration and overfishing.

In a virginal multi-species stock, fishing pressure above the limits of MSY, can alter the species composition of the stocks (Welcomme, 1979). Species composition changes, the extirpation of large specimens, and a decline in mean length pre-dates research investigations. However, the dynamic nature of harvest and stock adjustment is shown in Table 4. The percentage composition of channel catfish from commercial reports declined between 1967 and 1988. The difference in mean composition (22-year data-set separated into two 11-year periods), however, was not significant when tested in a Student-Newman-Keuls test.

The reach of Missouri River isolated between Lewis and Clark Lake and the tailwaters of Fort Randall Dam has been less intensely fished by commercial fishers in the past two decades than the reach downstream from Gavins Point Dam. Therefore, one might expect the average-sized channel catfish to be larger in this upper unchannelized section. The 1988 and 1989 mean total length channel catfish captured in 25.4-mm mesh hoopnets from the upper unchannelized (300 mm, n = 462) was compared with the $\bar{x}$TL from all locations downstream from Gavins Point Dam (272 mm, n = 808). Tukey's test proved these differences significant (p = 0.0001).

Nebraska commercial fishers were not allowed to harvest channel catfish from the upper unchannelized reach until 1979. The $\bar{x}$TL of channel catfish captured with 38.1-mm mesh hoopnets (the minimum legal net size for commercial fishers) from the upper unchannelized reach in 1982 (462 mm, n = 48) was compared with the $\bar{x}$TL in 1988 (378 mm, n = 133), and 1989 (376 mm, n = 142). Tukey's test showed that the 1982 $\bar{x}$TL was significantly larger than in 1988 and 1989 (p = 0.001).

Channelized middle-Missouri River channel catfish mean length was compared with similar data from the upper Missouri River in Montana, which has not been commercially fished, although flowing reaches are

Table 3. Comparison of mean kg per year of channel catfish commercially harvested for 10-year time periods from the Missouri River in Nebraska using Tukey's test with a significance level of 0.05. Means with the same letter are not significantly different. Percent change comes from comparison with the base period, 44–53.

Years	Mean kg/year	Tukey's	% change
1944–1953	12,101	A	
1954–1963	11,787	A	-3
1964–1973	9,004	B	-34
1974–1983	7,542	B	-61

Table 4. Percentage composition of channel catfish in the total harvest reported by commercial fisherman each year from 1967 to 1988. The mean percentage composition for the periods 1967–1988 were compared in a Student-Newman-Keuls test.

Year	% composition	Year	% composition
1967	22.9	1978	14.6
1968	21.4	1979	14.5
1969	19.9	1980	11.9
1970	19.2	1981	14.2
1971	15.5	1982	19.2
1972	14.5	1983	18.0
1973	11.2	1984	11.4
1974	12.5	1985	14.8
1975	14.5	1986	13.2
1976	14.7	1987	13.3
1977	16.2	1988	13.7
Mean	16.6		14.4

presently isolated between cold-water reservoirs. The $\bar{x}$ TL of channel catfish from this reach was 401 mm (n = 236) in 1978 (Berg, 1981). This mean was compared to the 1976-1977 mean (287 mm, n = 1,762) collected from channel catfish captured with the same gear from the channelized Missouri River in Southeast Nebraska. A Tukey's test showed these differences to be highly significant ($p < 0.0001$). Hoopnet (25.4 mm) samples revealed that the percentage of channelized Missouri River channel catfish longer than 330 mm declined from 31% in 1975 to 8% in 1987 even though the minimum length limit was raised to 381 mm in 1984.

Channel catfish growth in the channelized Missouri River compares favorably with that from other Great Plains rivers and lakes (Table 5). In fact, growth is similar to that in the Powder River and Crazy Woman Creek in Wyoming (Smith and Hubert, 1988). They have defined the catfishery in these two streams as lightly exploited. The catfisheries of the top five waters in Table 6 are lightly exploited and survival beyond 10 years old has occurred. The best of these showed that 32% of the channel catfish were 10 years old or older (Macdonald, 1990). The Missouri and Mississippi River catfisheries might be categorized as heavily exploited. Kuyon (1965) completed his studies on Des Moines River channel catfish prior to the closure of Red Rock and Saylorville dams. Prior to closure, Des Moines River catfish were potentially vulnerable to harvest by Mississippi River commercial fishers. Coralville Reservoir was constructed in 1958, however, Helms (1965) states that channel catfish were one of the two primary game fish in the lake. Though the authors do not say, it may be a fair assumption that Iowa's reservoir catfish are more heavily exploited then Wyoming's stream catfish just on the basis of demographics.

Table 6 shows the results of comparing the mean length of channel catfish from 10 different streams and lakes. An analysis-of-variance was used to test the difference between mean lengths. The Tukey option and the Waller test will group those collections that are not significantly different at the chosen level of significance (0.01). The mean total lengths of Missouri River and Mississippi River catfish (collections 8 and 9) were significantly different from the lightly exploited populations.

The total mortality rate can be used to explain the low number of old channel catfish in the Missouri River.

Table 5. Mean total length ($\bar{x}$ TL) (cm) and sample size (n) of channel catfish from rivers of the Great Plains and Midwest.

River or Reservoir		Age (years) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Red of the North	$\bar{x}$ TL	25	25	28	33	38	46	51	51	51	64	69	66	69	79	84	84	86
(Manitoba)	n	3	79	394	137	114	46	38	46	19	11	20	13	9	26	53	80	85
2. Missouri R.	$\bar{x}$ TL	18	25	31	38	43	48	51	53	53	58	58	66	71	66	69	—	71
(Montana)	n	2	7	69	87	9	15	9	7	4	3	3	3	2	7	5	0	2
3. Powder R.	$\bar{x}$ TL	—	—	25	31	36	38	43	48	53	58	58	61	64	61	66	64	66
(Wyoming)	n	—	—	29	67	66	73	38	39	34	30	30	20	23	13	4	3	3
4. Tongue R.	$\bar{x}$ TL	13	20	23	28	23	33	38	38	41	46	48	53	53	58	58	—	—
(Wyoming)	n	2	28	9	21	17	19	6	7	22	13	16	29	24	14	3	0	0
5. Lake Sharp	$\bar{x}$ TL	—	—	—	25	28	31	33	36	38	43	51	46	48	48	61	53	64
(South Dakota)	n	—	—	—	5	39	3	6	4	10	5	2	1	3	1	4	1	1
6. Coralville Res.	$\bar{x}$ TL	8	15	20	28	33	36	41	41	38	—	—	—	—	—	—	—	—
(Iowa)	n	1	30	10	6	34	16	7	1	1	0	0	0	0	0	0	0	0
7. Des Moines R.	$\bar{x}$ TL	5	13	18	23	31	36	41	51	58	—	—	—	—	—	—	—	—
(Iowa)	n	95	97	262	246	118	26	22	11	1	0	0	0	0	0	0	0	0
8. Mississippi R.	$\bar{x}$ TL	10	20	25	33	38	41	—	—	—	—	—	—	—	—	—	—	—
(Iowa)	n	20	31	42	11	3	3	0	0	0	0	0	0	0	0	0	0	0
9. Missouri R.	$\bar{x}$ TL	8	15	23	31	36	41	46	48	—	—	—	—	—	—	—	—	—
(Nebraska)	n	350	419	693	508	93	8	4	2	0	0	0	0	0	0	0	0	0

1. Macdonald, 1990; 2. Berg, 1981 (Montana); 3. Smith and Hubert, 1988; 4. Smith and Hubert, 1988; 5. Smith and Hubert, 1988; 6. Helms, 1965; 7. Kuyon, 1965; 8. Pitlo, 1979 (Pool 9); 10. Hesse and Wallace, 1976.

Table 6. Comparison of mean length (mm) of channel catfish from rivers of the Great Plains and Midwest using two different tests. The significance level chosen for these comparisons was 0.01. Means with the same letter are not significantly different.

River or lake	No.	Mean length	Tukey's test	Waller
1. Mississippi River in 1947	2,995	472	A	A
2. Red River (Manitoba)	1,173	452	B	B
3. Powder River (Wyoming)	472	442	B	B
4. Missouri River (Montana)	234	396	C D	C
5. Tongue (Wyoming)	230	391	C D E	C
6. Lake Sharpe (South Dakota)	85	345	D E	D
7. Coralville Reservoir (Iowa)	106	272	F G	E
8. Mississippi River (Iowa)	110	226	F G H	F
9. Missouri River (Nebraska)	2,077	213	G H	F G
10. Des Moines River (Iowa)	878	206	G H	G

1. Greenbank and Monson, 1947; 2. Macdonald, 1990; 3. Smith and Hubert, 1988; 4. Berg, 1981; 5. Elser et al., 1977; 6. Elrod, 1974; 7. Helms, 1965; 8. Pitlo, 1979; 9. Hesse and Wallace, 1976; 10. Kuyon, 1965.

Hesse et al. (1982b) reported that total mortality of channel catfish increased from 37% of age-4 fish (338 mm) to 79% of age-5 fish (371 mm). This represented a 42% increase in mortality and it occurred as channel catfish reached the legal commercial size-limit. Total mortality was calculated using the percentage frequency between age-classes (Ricker, 1975) for those age-classes that were fully recruited to baited hoopnets. Baited hoopnets do not collect young age-classes of channel catfish in true proportion to their actual density. The dome of a catch curve is at age 3 (Hesse et al., 1978). Therefore, total and instantaneous annual mortality, and total and instantaneous fishing mortality was calculated from tag returns from a study of Niobrara River channel catfish. Natural mortality comprised 1% of the annual total mortality rate and 2% of the instantaneous rate in winter and 13% of total and 8% of instantaneous in summer (Hesse et al., 1979b).

Newcomb (1989) used the method of Brownie et al. (1985) to estimate survival from tag returns. Total survival for all size groups of channel catfish was estimated at 24%, but only 12% of all legal sized catfish survived. The Brownie et al. (1985) method used by Newcomb (1989) to calculate survival from tag returns does not require the assumption of complete return of all tags caught. Survival of legal-sized channel catfish was found to be the highest (59%) during the initial year of an increase in the commercial size limit (330 mm TL to 381 mm TL). Moreover, survival declined to 21% by year two, and 12% by year three. The survival of sublegal fish declined from 65% to 25% to 23%. These data suggest that there has been low compliance with size limit restrictions.

Pitlo (1979) calculated a geometric mean of the total mortality rates between age groups of channel catfish in the Mississippi River as a tool to compare mortality among four navigation pools. A similar exercise was used to compare Missouri River mortality with mortality rates for catfish populations in other Great Plains and Midwest states (Table 7). Channelized Missouri River mean mortality for 1974 and 1975 was 72% (SE = 12%). The only mean mortality estimate approaching this level was the Mississippi River, Pool 9 estimate of 70% (SE = 18%) (Helms, 1975). This table also shows the percent of the sample population of channel catfish that exceeded 10 years of age. A high mean rate of exploitation was related to a low density of older fish.

Figure 2 is a plot of mortality rate by age; the data are from Table 5.6 in Hesse et al. (1982b). It shows that lower mortality rates occurred in the unchannelized Missouri River between Lewis and Clark Lake and the tailwaters of Fort Randall Dam (mean mortality = 0.42, SD = 0.21) then the remainder of the river downstream from Gavins Point Dam. This mean mortality rate was significantly different (p = 0.005) then the mean mortality rate downstream from Gavins Point Dam (mean mortality = 0.66, SD = 0.15). The unchannelized reach was more lightly exploited by commercial fishers. According to Zuerlein (1987) only 5% of all commercial fishers reported fishing this section of the river. The unchannelized reach between Yankton, South Dakota and South Sioux City, Nebraska was fished by 27% of the respondents and mean mortality was 0.63 (SD = 0.13). However, this reach is open to migration of catfish to and from the channelized section of the river, while the upper unchannelized reach is isolated by Gavins Point Dam. This may account for the much higher mean mortality rate in the lower unchannelized section.

The upper channelized section (South Sioux City to Omaha, Nebraska) was fished by 28% of respondents and mean mortality was 0.67 (SD = 0.17). The lower channelized reach from Omaha to Rulo, Nebraska, was fished by 40% of the respondents and mean mortality was 0.69 (SD = 0.14).

Figure 2 also shows the mortality rates from the Niobrara River and Little Nemaha River populations of

Table 7. Total annual mortality calculated from the percentage frequency of age-class distributions (Ricker 1975), from rivers and lakes of the Great Plains and Midwest.

River or lake	Percent mortality by age									Mean mort.	SE	% 10-yrs and older	Sample size
	2	3	4	5	6	7	8	9	10				
1. Powder R., Crazy Woman Cr., Wyoming	—	—	—	—	47	—	12	15	—	25	11	27	472
2. Des Moines R., Iowa	44	47	64	—	—	15	67	—	—	47	9	0.6	503
3. Des Moines R., Iowa	—	48	62	50	—	—	—	—	—	53	4	0	380
4. Saginaw Bay, Michigan	—	—	—	—	51	81	25	—	67	56	12	10	916
5. Grand Lake, Oklahoma	32	41	77	—	33	—	—	—	—	46	11	0	188
6. Lake Dardanelle, Arkansas	—	—	—	—	52	60	45	—	—	52	4	0	112
7. Lake Carl Blackwell, Oklahoma	—	—	—	—	36	8	69	—	—	38	18	6	255
8. Lake of the Ozarks, Missouri	—	—	—	38	21	66	—	—	—	42	13	0	434
9. Tongue, Wyoming	—	—	22	—	62	—	—	4	—	29	17	43	231
10. Tuttle Cr., Kansas	—	47	—	55	—	75	34	—	—	53	9	0.6	492
11. Lake Erie, Michigan	35	54	50	—	—	—	—	—	—	46	6	0	2,158
12. Lake Sharp, South Dakota	—	—	—	91	—	29	—	50	67	59	13	21	85
13. Kentucky Lake, Tennessee	—	—	7	62	—	—	27	—	—	32	16	11	93
14. Red River, Manitoba	—	64	18	56	25	—	50	—	—	43	9	32	1,281
15. Upper Missouri R., Montana	—	—	89	—	33	25	34	—	—	45	15	11	236
16. Coralville Reservoir, Iowa	68	34	—	53	53	—	—	—	—	52	7	0	106
17. CoralvilleTailwater, Iowa	1	27	—	78	1	—	—	—	—	27	18	0	48
18. Mississippi R., Pool-9, Iowa	—	—	—	25	52	36	43	—	—	39	6	0	144
19. Mississippi R., Pool-9, Iowa	51	88	—	—	—	—	—	—	—	70	18	0	5,709
20. Mississippi R., Pool-9, Iowa	—	—	5	41	9	—	93	—	—	37	20	0.5	213
21. Missouri R. Nebraska	—	—	37	79	95	—	75	—	—	72	12	0	4,981

1. Smith and Hubert, 1988; 2. Muncy, 1959; 3. Kuyon, 1965; 4. Lorantas, 1982; 5. Sneed, 1951; 6. Freeze and Tatum, 1977; 7. Jerald and Brown, 1971; 8. Marzolf, 1955; 9. Elser et al., 1977; 10. Klaassen and Townsend, 1973; 11. DeRoth, 1965; 12. Elrod, 1974; 13. Conder and Hoffarth, 1962; 14. Macdonald, 1990; 15. Berg, 1981; 16. Helms, 1965; 17. Helms, 1965; 18. Schoumacher and Ackerman, 1965; 19. Helms, 1975; 20. Pitlo, 1979; 21. Hesse et al., 1982b.

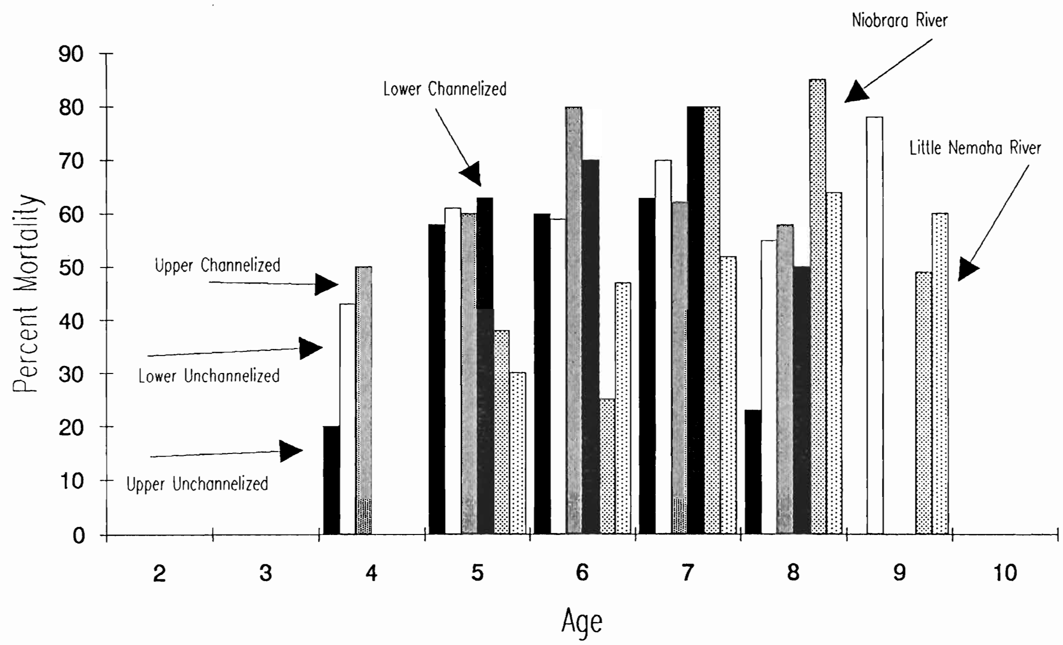

Figure 2. Total annual mortality rate for four sections of the Missouri River in Nebraska, the Niobrara River and the Little Nemaha River.

channel catfish. Lower mean mortality occurs in the tributary populations (0.42, SD = 0.21 for the Niobrara River catfish and 0.55, SD = 0.15 for the Little Nemaha). Tributaries can serve as refugia at least for 5 or 6 years. Eventually these older fish are harvested by set-line fishers in the tributary streams or as the fish move back into the main channel Missouri River and become vulnerable to nets.

Implemented harvest restrictions

The Department has maintained that where it was necessary to rebuild stressed fish stocks that it would be done through selective restrictions on fishing methods. Furthermore, it has been the Department's policy that re-allocation of selected species in the Missouri River commercial catch may be necessary to ensure equitable distribution of the resource to all users (Zuerlein and Sheets, 1988). Therefore, proposed harvest restrictions were developed based on the fact that selected fish stocks had been overharvested, and that these stocks should be rebuilt through conservative harvest practices and habitat restoration. Secondly, any surplus production which may become available should be allocated to the recreational user first. The determination regarding an available surplus will be made after a sufficient period of time has expired under reduced harvest regulations.

In order to rebuild damaged stocks, all commercial harvest of channel catfish was suspended in areas of the river jointly managed with South Dakota effective 1 January 1992. Closure of commercial harvest for Iowa, Missouri, and Kansas fishers became effective 1 July 1992. However, the decision to close these fisheries was adopted by South Dakota and Missouri Fish and Game Commissioners in July of 1990 and by Nebraska Fish and Game Commissioners in October of 1990, while Iowa and Kansas approval came early in 1991, in order to provide commercial fishers an opportunity to phase out their netting operations.

The number of fishers reporting commercial activity (other species remained as legal catch) declined from 131 in 1989 to 116 in 1990, 90 in 1991 and 73 in 1992. Conservation Officers reported that several of the largest and most successful catfish netters sold their equipment and ceased further netting within weeks of the decision to close catfish netting in July and October of 1990 (personal communication, William Krause, Conservation Officer, Auburn, Nebraska). The mean total harvest per year for 1986–1989 was 12,502 kg. The reported total harvest in 1990 was higher at 14,195 kg. However, the harvest increased only in lower reaches of the channelized section, and in fact dropped by 17% in the unchannelized section. The 1991 total harvest dropped dramatically to 9,805 kg (down by nearly 22% for the 1986–1989 period). The higher channelized-reach harvest in 1990 was most likely a result of fishers capitalizing on the fully recruited 1986 year-class, which, as previously noted, was very large.

First response of channel catfish to changing regulations

Only two field seasons have passed since the actual closure became effective. Weather has complicated the documentation process. Severe drought gripped the Missouri River Basin from 1987 through 1991, followed by much-above-normal precipitation in the lower basin (south of Gavins Point Dam) in 1991 through 1993. Lower basin tributaries normally become dewatered during the summer growing season due to irrigation withdrawal. Under such circumstances channel catfish remained in the main channel. Beginning in late summer 1991, tributary stream stages remained much above normal continuously through 1993. Channel catfish found more suitable habitat in these streams and for the most part have not returned to the main channel. The main-channel catch per unit effort declined from an average of 9.3 channel catfish per net-night in 1974-75 (which were average water years) to 5 per net-night in 1987 (first year of drought), 3.5 in 1989, and 1.7 in 1992. By 1993 the catch increased to 3.2 per net-night, which would suggest that some fish have begun to return to the main channel. In contrast to the main channel collections, the small number of nets set in the mouth of one tributary in 1992 resulted in a catch of 32.5 channel catfish per net-night. Sport fishers have reported low success in the main channel during the drought as well. Clearly more time must pass before the full complement of size classes of channel catfish are once again represented in the main channel. However, the samples that have been acquired since the harvest restrictions were approved suggest that channel catfish have responded to reduced exploitation (Table 8).

The 25.4-mm mesh net samples showed more significant changes in mean length than samples acquired from 38.1-mm nets. When 1987 samples were compared with 1993 samples, there was a significant increase in mean length in both type nets and in both river sections. Moreover, the $\bar{x}$ TL of channel catfish captured with 25.4-mm mesh hoopnets from the channelized section during the period of 1987–1989 was 273 mm (n = 755, SD = 72 mm), while the mean for the period of 1990-93 was 312 mm (n = 372, SD = 80 mm). The difference was significant (Prob > t = 0.0001). The mean length from 38.1-mm mesh nets was not significant. The reverse was true in the unchannelized section of the river. The mean for the first period was 378 mm (n = 184, SD = 49 mm), and 390 mm (n = 171, SD = 56) for the second period (Prob > t = 0.03) for fish captured with 38.1-mm nets. The mean length difference for fish captured with 25.4-mm nets was not significant.

Since enhanced survival will enhance recruitment, more small fish in the sample will impact the population mean length by reducing the magnitude of the increase. Change in percentage composition in selected size groups can be used to indicate population re-structure. Table 9 shows the percentage of channel catfish which exceeded 330 mm TL and 400 mm TL that were collected by both net types. The increase in numbers of larger fish from enhanced survival is readily demonstrated in 25.4-mm mesh net samples, especially in the channelized section of the river. An abrupt change occurred beginning in 1990. The percent over 330 mm increased from a mean of 14.3% for 1987–1989 to 42.8% for 1990–1993. Unchannelized section samples from the 38.1 mm nets show a similar pattern (82% for 1988-1989 to 91.3% for 1990–1993).

RECOMMENDED FUTURE MANAGEMENT OF MISSOURI RIVER CHANNEL CATFISH

It is important to maintain conservative harvest limits until it is possible to track survival for a longer period of time. Annual hoopnetting is important and more effort needs to be placed on obtaining an age distribution in addition to length and weight frequencies.

Large channel catfish are not abundant and because they are vulnerable to selective sport harvest by fishers using passive gear such as trotlines or setlines, it is important to further restrict the harvest of these older animals. This can be achieved in two ways: 1. set a maximum-length limit (protect catfish longer that a set size), 2. restrict the number of legal hooks and/or limit the passive gear fishing season. I prefer both types of restriction to assure that channel catfish will recover from nearly 150 years of over-exploitation. The maximum-length limit should be set initially at 500 mm total length. Any channel catfish caught, which measures 500 mm TL or longer, should be released. As the population ages the maximum length limit can be increased slightly. This will assure that high quality, eating sized fish can still be harvested, while increasing the density of preferred, memorable, and trophy sized catfish (Gabelhouse, 1984).

Conservation Officers complain about the liberal hook (15 per person) limits. Such "sport" harvest can be as significant on the over-harvest of catfish as the net was (Quinn, 1993). I recommend a hook limitation of four per person. These could either be fished passive (set line) or active (rod and reel) but not both.

Lastly, I would recommend that passive catfishing should not be allowed during the pre-spawning period, which runs from 1 May to 15 June in the Missouri River and its tributaries.

Table 8. Grouped year comparisons (*t*-test) of mean total length ($\bar{x}$ TL) of channel catfish captured from the Missouri River.

	n		$\bar{x}$ TL		SD		*t*-val.		*P*	
25.4 mm Mesh Hoopnets										
Year/Location	**Yr.1**	**Yr.2**	**Yr.1**	**Yr.2**	**Yr.1**	**Yr.2**	**Yr.1**	**Yr.2**	**Yr.1**	**Yr.2**
1987-1988										
Channelized	116	306	286	267	52	75	3.02	2.56	0.003	0.011
Unchannelized	120	82	285	319	32	53	-5.37	-5.86	0.001	0.001
1988-1989										
Channelized	306	333	267	274	75	75	-1.19	-1.19	0.235	0.235
Unchannelized	82	224	319	270	53	46	7.53	8.05	0.001	0.001
1989-1990										
Channelized	333	43	274	365	75	82	-6.93	-7.45	0.001	0.001
Unchannelized	224	129	270	256	46	49	2.60	2.64	0.010	0.009
1990-1991										
Channelized	43	76	365	302	82	82	4.06	4.06	0.001	0.001
Unchannelized	129	66	256	318	49	75	-6.13	-7.00	0.001	0.001
1991-1992										
Channelized	76	146	302	293	82	77	0.73	0.74	0.468	0.458
Unchannelized	66	3	319	369	75	148	-0.59	-1.10	0.613	0.275
1992-1993										
Channelized	146	107	293	324	77	73	-3.20	-3.18	0.002	0.002
Unchannelized	3	1	369	222	—	—	—	—	—	—
1987–1993										
Channelized	116	107	286	324	52	73	-4.40	-4.46	0.001	0.001
Unchannelized	120	1	284	222	—	—	—	—	—	—
38.1 mm Mesh Hoopnets										
1987-1988										
Channelized	8	3	405	401	27	28	0.22	0.22	0.837	0.828
Unchannelized	3	131	337	381	74	45	-1.02	-1.66	0.414	0.099
1988-1989										
Channelized	3	93	401	380	28	50	1.24	0.72	0.324	0.474
Unchannelized	131	50	381	375	44	59	0.62	0.70	0.537	0.484
1989-1990										
Channelized	93	26	380	389	50	33	-1.04	-0.83	0.301	0.407
Unchannelized	50	71	375	390	59	58	-1.39	-1.39	0.168	0.167
1990-1991										
Channelized	26	192	389	388	33	48	0.15	0.11	0.883	0.910
Unchannelized	71	46	390	371	58	44	2.01	1.90	0.047	0.059
1991-1992										
Channelized	192	142	388	392	48	74	-0.62	-0.66	0.535	0.510
Unchannelized	46	20	371	419	44	80	-2.53	-3.14	0.018	0.003
1992-1993										
Channelized	142	29	392	368	74	66	1.77	1.64	0.084	0.104
Unchannelized	20	34	419	400	80	44	0.96	1.11	0.346	0.273
1987–1993										
Channelized	8	29	405	368	27	66	2.40	1.55	0.023	0.129
Unchannelized	3	34	337	400	74	44	-1.46	-2.27	0.276	0.029

FINAL COMMENTS

The Missouri River channel catfish was an important resource before the turn of the century. It provided sustenance for humans traveling through and those building permanent homesteads. However, overexploitation occurred without the realization of these early residents. The channel catfish is highly prized today by contemporary anglers, but the river can no longer provide quantity and quality. The pervasive changes in form and function of the Missouri River hydrosystem has now made it difficult to recover even a limited quality fishery. It is most assuredly not going to happen unless the aggressive harvest restrictions adopted in 1990 are strengthened in future years.

The pioneer ethic is not an acceptable contemporary management philosophy. The Missouri River channel catfish is a durable species, but its worth today should not be defined by the taste of its flesh but rather

Table 9. Mean total length ($\bar{x}$ TL) of channel catfish captured in 25.4- and 38.1-mm mesh hoopnets in channelized and unchannelized sections of the Missouri River, and the percentage of the sample greater than 330 mm and 400 mm. The number in parentheses is the sample size.

Year/Location	$\bar{x}$ TL(25.4)	% > 330 mm	% > 400 mm	$\bar{x}$ TL(38.1)	% > 330mm	% > 400mm
1987						
Channelized	286(116)	8	2	405(8)	100	50
Unchannelized	284(120)	4	1	—	—	—
1988						
Channelized	265(293)	17	2	—	—	—
Unchannelized	319(82)	46	0	381(131)	82	23
1989						
Channelized	274(333)	18	3	380 (93)	82	17
Unchannelized	270(224)	5	2	375 (50)	86	16
1990						
Channelized	365(43)	62	28	389(26)	91	23
Unchannelized	256(129)	5	2	390(71)	85	27
1991						
Channelized	304 (81)	31	11	388(220)	89	26
Unchannelized	319 (66)	38	12	371(46)	88	13
1992						
Channelized	309(209)	34	10	392(144)	88	28
Unchannelized	370(3)	—	—	419(20)	95	35
1993						
Channelized	324(107)	44	10	368 (27)	67	15
Unchannelized	—	—	—	400 (34)	97	32

by the mystique of one-time behemoths that lived to reach 20 kg.

ACKNOWLEDGMENTS

Many biologists and technicians have contributed to the acquistion of these data, including: Charles Wallace, Larry Lehman, Gene Zuerlein, Roger Vancil, Leonard Koziol, Brad Newcomb, Leigh Ann Retelsdorf, Scott Wessel, Nile Kemble, Nancy Cole, Brett Kolterman, Dave Schumacher, Pat O'Brien, Joe Cassidy, Melanie Vorderstrasse, Cindy Cook, Daniel Wolff, and Paul Tornblom among others. Most noteworthy was the help provided by Gerald Mestl, who assisted with statistical processing for nearly eight years. It is important to note that William Bailey and Wes Sheets, Department Administrators, were instrumental in the organization of the protocol that lead up to the final decisions to close commercial catfishing on the Missouri River.

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THE STATUS OF NEBRASKA FISHES IN THE MISSOURI RIVER, 4. FLATHEAD CATFISH, *PYLODICTIS OLIVARIS*, AND BLUE CATFISH, *ICTALURUS FURCATUS* (ICTALURIDAE)

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Federal Aid in Fish Restoration, Dingell-Johnson Project F-75-R-1, November 1993. Publication funded by Nebraska Game and Parks Commission.

ABSTRACT

Flathead and blue catfish in the Missouri River have been over-exploited. Commercial harvest of both species ended in 1992, but commercial fishing was only part of the problem. The percentage of flathead catfish longer than 407 mm total length is very low. The density of flathead catfish in the upper unchannelized Missouri River is 6 to 10% of the density in the lower unchannelized reach, and channelized section density is six times greater than unchannelized density. Tagging studies have revealed that the population of flathead catfish in the upper unchannelized reach consists of less than 1,000 individuals. Blue catfish have been nearly extirpated and should be listed as endangered in Nebraska's portion of the Missouri River. Overharvest, reduced turbidity, and the removal of large woody debris has caused the reduced population density. Management must include restricted harvest, closed areas, protected size classes, increased turbidity, and restoration of a floodplain with seasonal flooding. In the near term, large trees from the river bottom or from communities near the river should be placed in the channel to enhance in-stream cover.

† † †

"We passed Boyer's creek on the north and stopped to dine under a shade near the high land on the south, and caught several very large white catfish and all were very fat." So stated the entry in Lewis's journal for 29 July 1804. In fact the Lewis and Clark expedition encountered numerous catfish along the Missouri River all the way to Montana. The white catfish they referenced was really the blue catfish, *Ictalurus furcatus*. Catfish were so numerous that George W. Kingsbury and G. M. Smith (1915) reported in the *History of Dakota Territory* that the catfish was an important factor in the settlement of the Dakotas, and in his opinion many of the early settlers would have had serious food problems had it not been for the abundant supply of this best of all fishes right at the threshold of the settlements.

Reports of large catfish were commonplace prior to channelization. For me the most intriguing report was published in the *Yankton Dakotian* newspaper on Tuesday, August 5, 1862: "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!." As recently as 1960 a group of five fishers using snagging gear angled more than 50 big flathead catfish from the river near Dakota City in one day of fishing. The smallest fish weighed 4 kg, while the biggest were many times heavier. In the early 1970s big blue catfish (exceeding 30 kg) were still being caught by setline and net fishers in the unchannelized reach downstream from Yankton, South Dakota. However, these were the last of the species, and only one or two old blue catfish have been captured since. These huge denizens of the turbulent and muddy Missouri have disappeared along with the spring floods.

Channel catfish (*Ictalurus punctatus*) in the Missouri River in Nebraska were over-exploited for nearly 150 years (Hesse, 1994). The flathead and blue catfish have suffered the same fate. Net-fishing was mostly responsible, as it was for channel catfish. However, set-line and/or trot-line fishing, both for commercial and sport purposes, may have contributed significantly to the total harvest of flathead and blue catfish because they were especially vulnerable to the live bait used on such lines. Quinn (1993) cites several studies which have shown a 10-fold greater harvest by trot-line fishers than by rod and reel anglers. Hesse (1980) conducted a creel survey of rod and reel sport fishers during 1978 and 1979. The mean effort expended during weekdays was 105 hours/day for the lower unchannelized reach, while the mean effort during weekdays in the channelized reach was 200 hours/day. One set-line fisher using 15 hooks will expend 1,800 hours fishing for 5 days. Many thousands of hooks are pres-

Table 1. Percent length-distributions for Missouri River flathead catfish during 1974–1993 and for the Cape Fear (North Carolina) and Flint (Georgia) rivers.

	Missouri River						Cape Fear	Flint
Size class (mm)	**1974[1]**	**1978[2]**	**1989[3]**	**1990[4]**	**1991[5]**	**1993[6]**	**1986[7]**	**1985[8]**
<305	89	63	79	72	81	72	0	46
305-407	7	27	16	23	15	23	0	17
407-457	1.4	6	2	2.7	1.6	3.4	0	10
457	0.9	2	2	1.0	1.0	1.6	10	5
483	0.7	2	0.8	0.9	1.0	0	6	5
508	0.6	0.4	0.3	0.2	0.5	0	2	0
533	0.5	0.4	0	0.2	0.2	0	12	6
559	0.3	0.4	0.3	0.3	0.4	0	4	6
584	0.2	0.2	0	0.5	0.2	0	10	0
610	0	0.2	0	0.2	0	0	7	4
635	0	0.2	0	0	0	0	13	0
660	0	0	0	0.3	0	0	7	3
686	0.5	0.2	0	0	0	0	3	2
711	0	0	0	0.2	0	0	3	0
737	0	0	0	0	0.2	0	0.5	2
762	0	0	0	0	0	0	3	1
787	0	0	0	0.2	0	0	2	0
813	0	0	0	0.2	0	0	3	0.7
838	0	0	0	0	0	0	0.5	0.7
864	0	0.2	0	0	0	0	2	0
889	0	0	0	0	0	0	3	0.5
914	0	0	0	0	0	0	1	0
940	0	0	0	0	0	0	0.5	0.2
965	0	0	0	0	0	0	3	0.2
991	0	0	0	0	0	0	1	0
1,016	0	0	0	0	0	0	4	0.2
Totals:	436	511	391	672	650	127	184	3,266

[1]Hesse and Wallace, 1976; [2]Schainost 1981; [3]Hesse and Mestl, 1990; [4]Hesse and Mestl, 1991; [5]Hesse and Mestl, 1992; [6]Hesse and Mestl, 1994; [7]Ashley and Buff, 1986; [8]Quinn, 1988.

ently fished on set-lines, trot-lines, limb-lines, and jug-lines throughout the main channel and for some distance into tributary streams. Moreover, Quinn (1993) pointed out that commercial fishers, employing trot-lines, were much more efficient at harvesting catfish than recreational trot-line fishers.

The objectives of this paper are: 1, to describe the recent past population status and harvest statistics of flathead and blue catfish in the Missouri River in Nebraska; 2, to describe some critical habitat requirements; 3, to describe an implemented harvest restriction plan; 4, to present most recent data on the status after harvest restrictions were adopted; and 5, to recommend a plan for the future management of flathead and blue catfish in the Missouri River in Nebraska.

METHODS

The earliest collecting gear for flathead catfish was the telephone generator (Morris and Novak, 1968). The earliest models, like those used by poachers, were hand cranked. Small motorcycle batteries helped drive the advanced scientific collecting model. In either form they proved to be very effective and were quite specific for flathead and blue catfish. Other catfish and nearly all scale fish were unaffected by the electrical field generated. As electrofishing technology advanced and variable pulsator units became available, settings were developed to emulate the telephone magneto (Robinson, 1975). This pulsed DC system was operated at a low duty cycle of 20% and a slow pulse rate of 40/sec. The generator used was a 5,000-watt unit operated at 230 volts. Typically the amperage output while collecting was 5–8. A single unit of effort was either the number of fish collected per wing dike sampled or the number collected per minute of electrofishing.

RESULTS

A significant amount of biometric data has been gathered for the Missouri River flathead catfish (Hesse, 1993; Hesse and Klammer, 1984; Hesse and Mestl, 1985, 1986, 1987, 1988, 1989a, 1990, 1991, 1992; Hesse and Wallace, 1976; Hesse et al., 1978; Holz, 1969; Langemeier, 1965; Morris et al., 1971; Schainost, 1979; and Schainost, 1981). However, very little information has been published regarding the blue catfish in the Missouri River in Nebraska because the fish has been reduced in density since channelization began in the 1950s, which predates most research. Zuerlein (1988) summarized commercial-catch statistics for both blue and flathead catfish.

Size distributions and relative density.

Table 1 presents a length distribution for Missouri River flathead catfish compared to the Cape Fear River population in North Carolina and the Flint River population in Georgia. Both these rivers have been characterized as under-exploited (Ashley and Buff, 1986; Quinn, 1988).

The percentage of the Missouri River flathead catfish longer than the legal commercial size limit (457 mm Total Length [TL]) was 2.6% in 1974, 4.0% in 1978, 3.0% in 1989, 2.3% in 1990, 3.4% in 1991, and 1.6% in 1993. Survival in the two under-exploited rivers is much higher; 100% of the flatheads sampled from the Cape Fear were longer than 457 mm TL, while 27% of the flatheads in the Flint River were longer. This is reflected in a table of relative stock densities (RSDS) (Gabelhouse, 1984) (Table 2), using 1989 Missouri River data from Nebraska, 1990 data from the Missouri River in Missouri (personal communication, John Robinson, fisheries biologist, Missouri Department of Conservation), and data from the Cape Fear and Flint rivers.

Table 3 presents results from electrofishing effort for Missouri River flathead catfish from the lower unchannelized reach (Fig. 1) compared with collections from the upper unchannelized and channelized reaches. The Niobrara River is the major tributary entering the upper reach, and it contributes a significant quantity of organic and inorganic sediments into the Missouri River, which is an attraction for flathead catfish. More will be said about this later. The Niobrara River plume also creates a warm water region along the bank for nearly 6 km downstream. The natural temperature regime in the Missouri River was altered by the deepwater releases from Fort Randall Dam (Hesse et al., 1993b), and the Niobrara River discharge mitigates this problem in a small area of the Missouri.

Catch-per-unit-effort (CPUE) was six times higher in lower unchannelized sections than upstream from Lewis and Clark Lake and Gavins Point Dam. No flathead catfish have been collected by electrofishing (telephone generator emulation) upstream from the Niobrara River confluence during nearly three hours of effort in recent years.

Flathead catfish were collected incidental to standard electrofishing effort for scaled fish. For example, 755 minutes of standard electrofishing in channelized sections of the river in 1987 and 1988 resulted in 28 flatheads (0.04/min); 1,854 minutes of electrofishing in the lower unchannelized resulted in 96 flatheads (0.05/min), but between 1977 and 1987 only 11 flatheads were collected during 2,267 minutes (0.004/min) of electrofishing in the upper unchannelized section, and all of these were captured downstream from the Niobrara River confluence, even though nearly half the effort was expended in locations upstream from the confluence. These data further suggest that flathead-catfish density in the upper unchannelized reach may be only 10% of the density downstream from Gavins Point Dam.

Table 4 shows the results of 1990 collections using flathead electrofishing gear. Reach 1 is the upper and lower unchannelized data combined, and Reach 2 is channelized data.

Table 2. Comparative relative stock density (RSD) for four populations of flathead catfish. Values are percent of the population.

	Minimum length (mm)	Cape Fear R. North Carolina	Flint R. Georgia	Missouri River: Missouri	Missouri River: Nebraska
RSD-quality	407	49	48	3	6
RSD-preferred	610	28	21	1	0
RSD-memorable	711	14	9	0	0
RSD-trophy	915	5	1	0	0

Table 3. Electrofishing collection of Missouri River flathead catfish from the unchannelized section upstream and downstream from Lewis and Clark Lake, and from the channelized section.

	Unchannelized								
	Lower unchannelized			Upper unchannelized					
	Cedar County access			Upstream from Niobrara River			Downstream from Niobrara River		
Year	Fish	Minutes	CPUE	Fish	Minutes	CPUE	Fish	Minutes	CPUE
1981	—	—	—	—	—	—	9	45	0.2
1983	32	47	0.7	—	—	—	0	42	0.0
1986	135	73	1.9	—	—	—	—	—	—
1987	—	—	—	—	—	—	0	81	0.0
1988	9	17	0.5	—	—	—	1	40	<0.1
1990	42	168	0.3	0	134	0.0	31	187	0.2
1991	3	40	<0.1	0	30	0.0	18	41	0.4
Totals:	221	345	0.6	0	164	0.0	59	570	0.1

Channelized							
Year	Fish	Minutes	CPUE	Year	Fish	Minutes	CPUE
1971[1]	435	725	0.6	1987	40	70	0.6
1974[1]	205	342	0.6	1988	59	43	1.4
1975[1]	147	294	0.5	1989	98	119	0.8
1977[2]	65	217	0.3	1990	672	452	1.5
1978[2]	70	583	0.1	1991	650	379	1.7
1980[3]	95	94	1.0	1992	183	336	0.5
1981[3]	38	36	1.1	1993	127	186	0.7
1986	57	80	0.7				
Totals:	1,112	2,371	0.5		1,829	1,585	1.2

[1]Hesse and Wallace, 1976; [2]Schainost, 1979; [3]Hesse (unpublished data)

Table 4. Flathead catfish collected from telephone generator collections in 1990 from unchannelized (Reach 1) and channelized (Reach 2) portions of the Missouri River in Nebraska.

Reach	Site	Month-Day	Flathead	Effort	CPUE
1	2	8-15	8	36	0.22222
1	2	8-17	8	58	0.13793
1	2	8-28	15	93	0.16129
1	5	8-27	14	72	0.19444
1	6	8-27	22	96	0.22917
1	15	8-28	3	17	0.17647
2	7	8-14	105	76	1.38158
2	7	9-14	23	18	1.27778
2	8	8-7	85	118	0.72034
2	11	8-21	50	28	1.78571
2	11	8-21	45	27	1.66667
2	13	8-20	112	81	1.38272
2	13	9-20	24	35	0.68571
2	13	8-20	61	37	1.64865
2	29	8-22	114	61	1.86885
2	29	8-22	53	31	1.70968

Table 5. Comparison of mean kg/yr of flathead catfish commercially harvested for 10-year periods from the Missouri River in Nebraska using Tukey's test with a significance level of 0.05. An asterisk denotes significant differences. Percent change comes from comparison with the base period 1944–1953.

Years	Mean kg/yr	Tukey's	% change
1944–1953	9,074		
1954–1963	6,876	*	-3
1964–1973	3,251	*	-26
1974–1983	5,116	*	-38

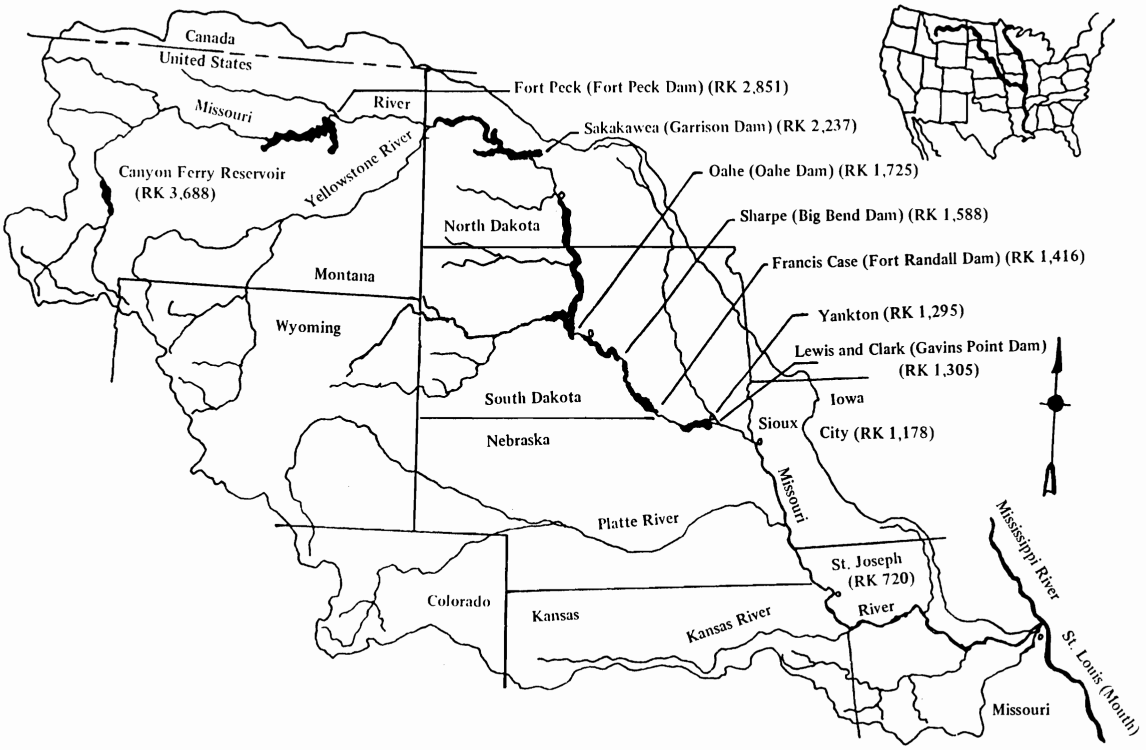

Figure 1. Map of the Missouri River basin.

The mean CPUE for Reach 1 was 0.189 and for Reach 2 was 1.301. An analysis-of-variance showed these means to be significantly different (P = 0.0001, F = 49.62, r^2 = 0.7799). The unchannelized-reach density represents just 14.5% of the channelized-reach density.

Population estimates

The relative density of flathead catfish, as measured by the catch rate with electrofishing gear, was very low. Moreover, flathead catfish were quite numerous in this reach during the 1950s and 1960s (personal communication, Medford (Toot) James, retired commercial fisher, Nebraska City, Nebraska). Mr. James recalled a single netting trip in 1956 to this upper unchannelized reach of the Missouri River that resulted in 5,400 kg of flathead catfish in one week of fishing.

During 1990, flathead catfish were collected from the upper channelized section of the Missouri River and tagged with a modified Carlin disk dangler tag (Hesse and Wallace, 1976). They (225 fish) were then transported upstream and released into the upper unchannelized reach in order to conduct a catch and release population estimate experiment. Insufficient numbers were collected from the target reach to conduct the study without importing some from outside the study area.

One week after stocking 225 tagged flathead catfish at River Marker 841, several recapture trips were made at a site several km upstream (River Marker 843), but downstream from the Niobrara River confluence; 42 minutes of electrofishing was expended, and 11 flatheads were collected (CPUE 0.26); six of these flatheads were tagged transplants. Since tagged specimens represented 55% of the sample, it was estimated that 225 tagged transplants represented 55% of the population in the reach. Several of the transplanted flatheads were reported captured by anglers during the ensuing weeks. Others were probably captured and the tags not reported, as has happened in all other tagging studies conducted on the river. Several others would have been expected to die from natural causes. One year later, 24 flathead catfish were electrofished from the study area and six were tagged transplants (25%). The population of flathead catfish living in the upper unchannelized reach (72 km) was calculated to be somewhere between 417 and 900 individuals during 1990-1991. Based on a mean from these outside limits there were nine flatheads/km in this reach. Morris et al. (1971) estimated there were 17 flatheads/km in the lower unchannelized reach in 1966, and nine flatheads/km in the upper channelized section in 1966. However, their estimates included only those fish larger than 200 mm TL, whereas, the 1990-91 estimates included all flatheads collected, including young-of-the-year. Moreover, Morris et al. (1971) studied only the wing dike habitat in the channelized section. The population of flathead catfish in wing-dike (filling-bank) habitat was estimated to be just 14% of the estimated population in revetment (cutting-bank) habitat (L.W. Hesse, unpublished data, Nebraska Game and Parks Commission, 1980). This same study found that 1,036 flatheads (669–1,974) lived in 3.4 km (305/km) of upper channelized revetment habitat during 1980 (all sizes were included). Tondreau (1988) estimated there were 249 flatheads/km (210–288) of all sizes in revetment habitat in the upper channelized section in 1988. Wing dike habitat supported 159 (140–177) flatheads/km. Estimates in 1982 and 1983 were 27% and 25% larger, respectively.

The primary difference between studies conducted by Hesse, Tondreau and Morris et al. was the gear used. Morris et al. (1971) used the telephone magneto, which could only be used to sample a single location at one time, whereas the other researchers used a boat-mounted unit that emulated the telephone magneto, and allowed the collector to move and collect continuously. I would conclude that the population estimates made by Morris et al. (1971) were very conservative, a fact they readily acknowledged in their discussion.

Blue catfish biometry

During the period of about 1958 through the present, Nebraska biologists have expended a massive amount of effort to collect more than 51,000 catfish with nets and electrofishing from the Missouri River, but only 16 blue catfish were included in this catch, and 15 of those were young-of-the-year collected downstream from Omaha in 1991. There is no information available on length, weight, or age distribution. Biologists in the state of Missouri have collected an additional 63,191 catfish, but only 2% (1,350) were blue catfish (personal communication, John Robinson, fisheries biologist, Missouri Department of Conservation, Columbia).

However, since blue catfish were quite common in the Nebraska reach before the turn of the century, according to newspaper accounts and journals of the Lewis and Clark expedition (Hesse and Mestl, 1989b) an effort was made to re-establish the species through introductions of hatchery stock obtained from brood fish in Oklahoma and Texas. More than 1.2 million fingerling (40–80 mm TL) blue catfish were stocked into the upper unchannelized section during 1980–1982. None of these were ever recovered in the Nebraska reach.

Harvest statistics

The commercial catch of flathead catfish in Nebraska's portion of the Missouri River has declined significantly since 1944 (Table 5). However, the percent composition of flatheads in the total reported commercial harvest increased significantly since 1967 (Table 6), which may reflect the very significant decline in the catch of channel catfish (Hesse, 1994).

The higher percentage of flathead catfish in the total reported commercial catch in Nebraska after 1978 was significantly different (P = 0.001) from that reported prior to 1978. Flathead catfish were more difficult to catch in the channelized section because they were not attracted to bait, as channel catfish were. They must be fished in their travel routes during short spawning periods and this typically existed on the cutting bank, which was armored with rock. Commercial gear was more readily damaged here, and it is most likely that flathead catfish would be fished less heavily while the more readily caught channel catfish was more numerous. The increased harvest most likely represented a switch to flathead catfish when insufficient numbers of channel catfish were available.

The harvest of flathead catfish since 1983 has been quite variable. It decreased from 16,581 kg in 1984 to 8,872 kg in 1986 but then increased to 13,289 kg in 1987, 15,305 kg in 1988, 18,435 kg in 1989, and 19,014 kg in 1990. Harvest dropped precipitously to 8,117 kg in 1991, which most likely resulted from the anticipated closure of commercial catfishing (which will be discussed later). Sample mean length was 208 mm TL in 1986, 160 mm in 1987, 215 mm in 1988, 236 mm in 1989 and 1990, 240 mm in 1991 and 280 mm in 1993. The difference in mean length for the period 1986–1990 (221 mm TL) compared to 1991–1993 (271 mm TL) was significant (Period 1, T = -3.261, P = 0.0023, Period 2, T = -3.489, P = 0.0005).

Table 6. Percentage composition of flathead catfish in the total harvest reported by commercial fishers each year between 1967 and 1988. The mean percentage compositions for the periods 1967–1977and 1978–1988 were compared in a Student-Newman-Keuls test.

Year	% composition	Year	% composition
1967	3.1	1978	23.3
1968	3.3	1979	15.8
1969	5.2	1980	13.2
1970	5.5	1981	18.2
1971	8.6	1982	14.6
1972	11.2	1983	14.1
1973	8.9	1984	18.1
1974	8.4	1985	14.6
1975	7.8	1986	11.1
1976	8.3	1987	14.1
1977	12.7	1988	17.2
Mean:	7.6		15.8

The commercial harvest of blue catfish in Nebraska was stopped in 1967. The harvest had steadily declined from a high of 5,846 kg in 1944 to 654 kg in 1966 (Zuerlein, 1988). The state of Missouri continued to allow the commercial harvest of blue catfish. More than 8,600 kg were reported harvested in 1985. They have represented as much as 27% of all reported catfish harvest in some years. However, since blue catfish have represented only 2% of the catfish sampled scientifically in Missouri, it is questionable whether commercial fishers have correctly distinguished the species from channel catfish, which is a common mistake. Sport fishers reported the harvest of 250 blue catfish from the Missouri River in Nebraska during 1992 (Hesse et al., 1993a). However, none of these fish were verified by any biologist in the area surveyed.

Implemented harvest restrictions

The evidence, as presented here, suggests that flathead catfish were over-harvested. Therefore, the decision was made to close commercial fishing for the flathead as was done for the channel catfish (Hesse, 1994). The decision to close was approved in October, 1990, and the closure became effective in January of 1992. In addition, the daily sport fish limit was changed from ten to ten-in-combination with channel catfish. The daily limit for blue catfish is one by sport fishers only.

The other basin states of South Dakota, Iowa, Missouri, and Kansas also adopted the closure of commercial catfishing (including blue catfish in Missouri). The evidence that the closure has altered the population structure of flathead catfish is not as apparent as it has been for channel catfish. However, there has been a significant increase in mean length, as noted earlier, and a reduction of nearly 20,000 kg of harvest since 1990 will be reflected in survival estimates obtained in the next few years.

Selected habitat

Cross (1967) suggested that flathead catfish prefer deep scour holes which form near any channel obstruction. Large tree snags created these holes along the channel and the hole itself was often strewn with smaller branches, providing excellent habitat for flatheads. Blue catfish probably used the same type of area for winter resting, but they were often found in the swiftest locations near complex habitat the rest of the year (Cross, 1967). Funk and Robinson (1974) argued that the removal of large snags from the river to expedite navigation was implicated in the decline of blue catfish. Peters et al. (1989) radiotagged seven adult flathead catfish in the Platte River, a large tributary of the Missouri River in Nebraska; 60% of 80 observations placed adult flatheads in complex cover associated with large log snags. They felt it was a very important component of flathead catfish habitat. Cross (1967) noted that the extent of survival, the rate of growth, and nesting success of channel catfish was dependent on water clarity. The muddiest impoundments provided the best in each case. The same can be said for blue and flathead catfish. Figures 2 clearly demonstrates the relationship (r = -0.9636) between decreasing water clarity (as measured by Secchi disk transparency) and increasing flathead catfish density.

Snag removal from the Missouri River was system-

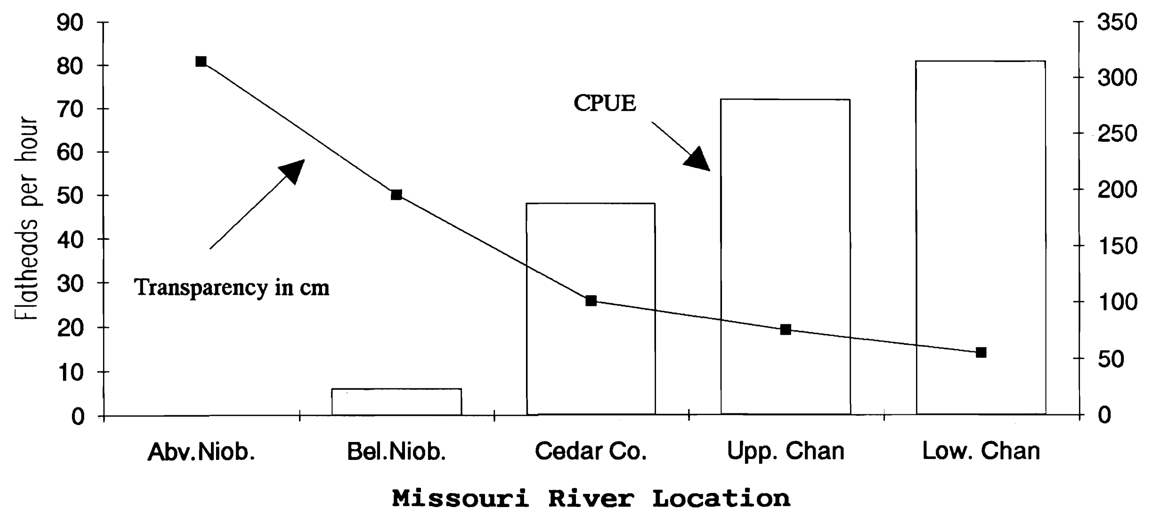

Figure 2. CPUE of flathead catfish compared to water clarity at five locations along the Missouri River in Nebraska.

atic and intense after about 1885. More than 17,000 large trees were removed from the lowermost 800 km of the river in 1901 alone (Funk and Robinson, 1974). There is strong evidence that the removal of large woody debris from the river's channels not only impacted catfish but most native Missouri River fishes (Hesse et al., 1993b).

Recommendations for future

It is most important that blue catfish should be fully protected. None caught in the Missouri River should be removed but rather released immediately. Secondly, the Missouri River blue catfish should be listed as endangered. Even though blue catfish are successfully stocked in man-made impoundments in Nebraska, they should not be stocked into the Missouri River until more information is available regarding the impact on the remaining wild genetics from hatchery fish. Hatchery blue catfish did not survive when stocked in the 40–80 mm size range. However, it is possible that blue catfish raised to a larger size before stocking would survive better. Surviving hatchery fish will most likely interbred with the very small number of remaining wild blue catfish. Since hatchery life circumvents natural selection pressures, unwanted genetic tendencies may rapidly invade the offspring of any wild/hatchery crosses (Ferguson et al., 1991). The best way to recover the blue catfish is to recover essential habitats. The re-connection of cut-off channel features such as chutes and backwaters will help. But most important is the recovery of large woody debris into the channel cross-section. This can be best achieved by re-establishment of a small floodplain adjacent to the river channel. This corridor can be inundated annually in emulation of the natural hydrograph (Hesse and Mestl, 1993; Hesse and Sheets, 1993). Trees must be allowed or helped to develop along the channels and then assisted to fall into the channels during high spring flood pulse events. In the interim, while this corridor is being developed, it is possible to use storm-damaged trees or even to cut down dead trees along the river, to replace the lost woody debris in the channels.

The recovery of large tree snags will benefit flathead catfish as well. Recovery of sediment turbidity through sediment bypass built into the mainstem dams is also essential and it is technically feasible (Hesse et al., 1993b).

The commercial harvest of flathead catfish has been stopped but heavy exploitation by setline and trotline sport fishers must be reduced as well. The reach upstream from Lewis and Clark Lake should be closed to any further harvest of flathead catfish. The small remaining stock does not have any excess production that can be harvested without contributing further to the decline of the stock. Recreational harvest in all reaches downstream from Gavins Point Dam should be controlled with a maximum size limit. Any flathead catfish longer than 500 mm TL should be released. Reduced setline or trotline fishing pressure can be achieved as was recommended for channel catfish. There should be no harvest allowed during the prespawn period, which is the month of June. The present status of flathead catfish and blue catfish in the Missouri River is insufficient to support liberal harvest regulations. Increasing catch and release requirements will provide an opportunity for these species to survive, thus highlighting their value as a sport fish.

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