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THE STATUS OF NEBRASKA FISHES IN THE MISSOURI RIVER.

1. PADDLEFISH (POLYODONTIDAE: *POLYODON SPATHULA*)

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ABSTRACT

The mean larval paddlefish density was 60 times higher in the upper unchannelized section of the Missouri River in Nebraska compared to the lower unchannelized section, and was three times higher than the channelized section's density. Within the upper unchannelized section, 96.2% of the larvae were collected in the discharge of two tributaries, which lie in the lower one-third of the reach. Survival from larval to young-of-the-year stage (June through August) was highest during 1991 due, in part, to the recent drought. Reduced fluctuation of river stages occurred as a result of reduced runoff, which minimized the need to reduce discharge to prevent flooding in the lower basin. The mean weight of paddlefish captured during the 1991 snagging season increased from 6.89 kg in 1990 to 7.45 kg, while the mean length increased from 739 mm (eye-to-fork length) to 753 mm. The percentage of snagged paddlefish 10 years old or older decreased from 15.3% in 1990 to 9.5% in 1991. When we compared the mean length of snagged paddlefish with the mean length of gillnet-captured paddlefish from tailwater and downriver sites there was no difference as demonstrated by *t*-test. There was a significant difference ($P_t < 0.01$) between mean weights. The same relationship regarding length and weight was true when fish gillnetted downriver was compared to fish gillnetted in the tailwater ($P_t < 0.0001$). These data suggest that larger, sexually mature fish are congregated in the tailwater of Gavins Point Dam, which is a total barrier to fish migration. The quota of 1,600 fish was exceeded in 1989 and 1990 but was not reached in the 1991 or 1992 seasons, which extended the full 30 days. In the Gavins Point Dam tailwater area, total annual man-hours of fishing was up from 5,339 hours in 1990 to 8,563 hours in 1991 and 9,139 hours in 1992. Mean catch rate for 1991 was 0.1 fish per hour of snagging compared with 0.33 fish per hour in 1990; however, catch rate declined to 0.05 during 1992. A protected slot-length limit was imposed in 1992 and was considered successful because there was no indication of excessive mortality associated with catch and release.

† † †

Russell (1986) stated that "paddlefish were once abundant in the large rivers in the Mississippi River drainage. However, within the last 100 years, the peripheral range of the species has shrunk." Declining paddlefish (*Polyodon spathula* (Walbaum); Fig. 1) populations were attributed to habitat alteration and destruction, overexploitation and pollution associated with water-development projects, sport and commercial harvest for recreation and meat, and the demand for paddlefish eggs for caviar.

The history of paddlefish harvest from the Missouri River is a good example of overharvest associated with diminished recruitment. With the construction of seven large dams on the Missouri River mainstem, paddlefish

Figure 1. Paddlefish, *Polyodon spathula*.

snag fisheries developed in the tailwater of each. These isolated populations were overfished and, before biologists realized what was happening, were nearly extirpated.

Snag fishermen harvested 16,000 paddlefish during the fishing seasons in 1958, 1959, and 1960 in the tailwater of Fort Randall Dam, on the mainstem Missouri River (Unkenholz, 1982). The harvest declined abruptly in 1961 and only a very few paddlefish were harvested between 1973 and 1987, when a moratorium on paddlefishing was established jointly by Nebraska and South Dakota for the reach between Fort Randall Dam and Gavins Point Dam (the lowermost dam). The only areas of the lower Missouri River remaining open to paddlefishing lie along a 124-km portion of remnant unchannelized Missouri River from the tailwater of Gavins Point Dam to the Big Sioux River near Sioux City, Iowa, and within the boundaries of the state of Missouri (Fig. 2).

An estimated harvest of 2,831 paddlefish occurred in 1971 in the reach between Fort Randall Dam and the next dam upstream, Big Bend Dam, but by 1978 the harvest had declined to 125 fish (Unkenholz, 1982). The age of 112 paddlefish randomly selected from the Big Bend Dam tailwater catch during 1973 ranged from 11 to 20 years and nearly 88% were age 14 or older; the average weight was 28 kg. Natural reproduction was not reported after closure of Big Bend Dam in 1964 (Friberg, 1974). Approximately 8,400 paddlefish were harvested from the tailwater of Oahe Dam, the next dam upstream from Big Bend Dam, in 1960–1963, and only a few were taken thereafter (Friberg, 1974).

Paddlefish populations have prospered in Montana, according to Stewart (1987). The fishes of Fort Peck Lake (Fort Peck Dam) and Lake Sakakawea (Garrison Dam), the next dam upstream from Oahe (Fig. 2), had access to "extensive, intact spawning areas" in upper reaches of the free-flowing Missouri River and its tributaries such as the Yellowstone River. Stewart (1987) stated that the age structure of the Sakakawea population indicated a mature, healthy population; 7 percent were younger than 10 years, while 42 percent were age 20 or older. The age structure of this population was somewhat different in 1965; 41 percent were younger than 10 years, and only 2 percent were age 20 or older (Robinson, 1966). Garrison Dam was closed in 1953, isolating this population of paddlefish.

The objective of this paper is to evaluate the trend in the density of larval and late young-of-the-year (y-o-y) paddlefish, to describe population statistics based on gill- and trammel-net surveys and snag fishing harvest information, and to describe how management of paddlefish harvest in Nebraska has changed.

METHODS

Study area

The Missouri River along Nebraska's eastern border can be divided into sections based on the present morphological configuration (Fig. 2). The reach between the headwaters of Lewis and Clark Lake and the Nebraska-South Dakota border is 64 km long and remains unchannelized and unimpounded. However, after Fort Randall Dam was closed in 1952 this reach has not experienced any natural high-water events. We refer to this reach as the upper unchannelized section. Lewis and Clark Lake (42 km) is bracketed by the upper unchannelized section and the lower unchannelized section, which extends 93 km from the tailwater of Gavins Point Dam to Ponca, Nebraska. This reach has not flooded since 1952, although Gavins Point Dam was closed in 1955. This lower reach has experienced severe channel-bed degradation (deepening) due to sedimentation in Lewis and Clark Lake. There is a small (25 km) section of river that was stabilized with rock and wooden piling between Ponca, Nebraska and Sioux City, Iowa, where complete channelization starts and then extends 1,183 km to the confluence with the Mississippi River. The channelized portion along Nebraska extends for 394 km and we have separated this reach into an upper channelized section (Sioux City to Omaha, Nebraska) and a lower channelized section (Omaha to the Nebraska-Kansas border) (Fig. 2).

The upper unchannelized reach has one major tributary (the Niobrara River), extensive backwater areas, and some rubble substrates; turbidity has been eliminated; water temperature has been altered due to deep-release dams; and channel degradation has occurred in the upper three-fourths of the reach. The natural hydrograph has been eliminated. Fort Randall Dam releases power-peaking discharges, which result in daily stage fluctuations downstream that exceed a meter. Since Fort Randall Dam is the last large dam on the mainstem, its reservoir is used to store high spring run-off which would otherwise contribute to high stage readings along the channelized sections. This eventuality has resulted in zero releases at Fort Randall Dam, which dewaters the upper unchannelized section. The upper channelized section has experienced extreme channel-bed degradation; old backwaters have been completely isolated from the channel. Turbidity remains somewhat higher than in the lower unchannelized section due to the inflow of material from eleven tributaries and drainage ditches.

Lewis and Clark Lake is the smallest mainstem dam and the lowermost. It can store just 9% of the water stored behind Fort Randall Dam. Gavins Point

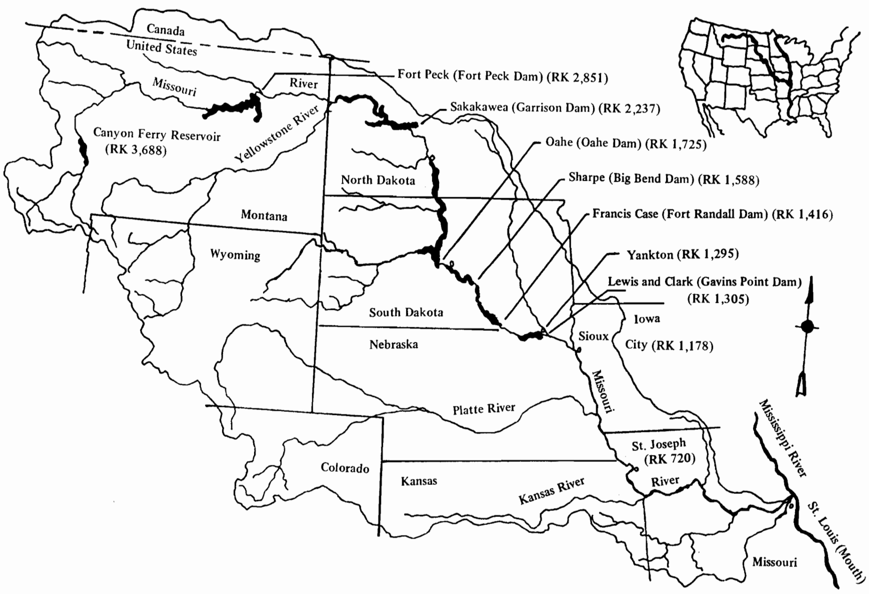

Figure 2. Map of the Missouri River basin showing the location of the main-stem dams, unchannelized reaches (between Fort Randall Dam and Lewis and Clark Lake and between Gavins Point Dam and Sioux City) and the channelized section (Sioux City downstrèam to the Mississippi River). RK = river kilometer.

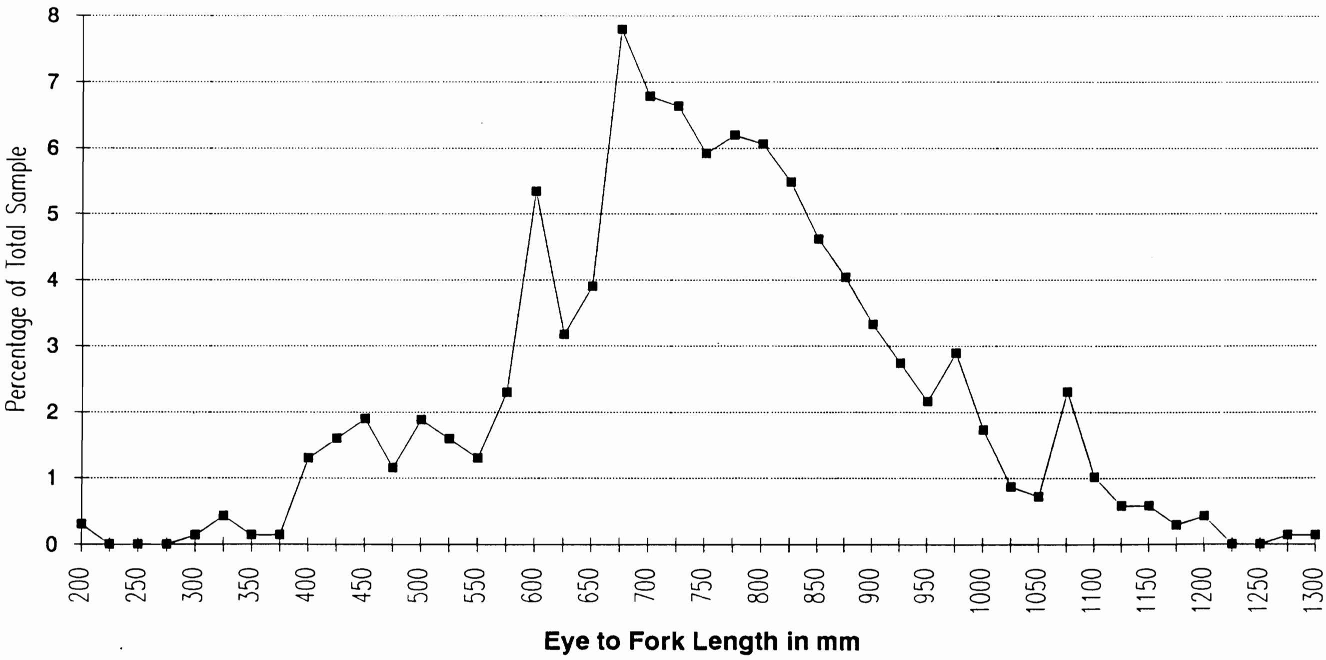

Figure 3. Length distribution of paddlefish from the lower Missouri River 1991 snag fishery.

Dam is used to re-regulate the erratic peaking discharge from upstream into an even discharge April–November to support navigation in the channelized sections.

The lower unchannelized section has several small tributaries, the James and Vermillion rivers, and a sand bed with little or no rubble substrates. Old backwaters have been eliminated due to severe channel-bed degradation; and the hydrograph has not been natural since 1954. Turbidity is higher than in upstream reaches, and water temperature is more nearly natural because Lewis and Clark Lake is shallow and completely wind-mixed. The lower channelized section is far enough from the dams that degradation no longer occurs, and in fact areas of aggradation exist. Old backwater areas have been completely cut off by rock dikes. Turbidity can become high from runoff from 20 tributary streams and drainage ditches which empty into this reach.

Field collections

During the period 1983 through 1991 the density of drifting ichthyoplankton (including paddlefish) was measured in the upper and lower unchannelized sections. Drift-net collections were expanded during 1986 to include the channelized sections. Larval-fish samples were not acquired during 1992.

Drift-net collections were made with one-meter diameter plankton nets with 560-micron mesh netting and a flowmeter in the mouth to quantify the volume of water filtered. Two double-net tows for three to five minutes at the cutting bank, filling bank, and mid-channel constituted a typical sample at each site. Catch per unit effort (CPUE) was reported as the number of larvae per 1,000 m^3. South Dakota Game Fish and Parks reported (Unkenholz, 1982) larval-paddlefish density acquired from collection sites in the upper unchannelized sections from 1975 through 1981. These data were used with our data to provide a long-term perspective on the density of drifting paddlefish larvae.

Young-of-the-year (y-o-y) paddlefish were collected in July with a 7.9-m (headrope) semi-balloon otter trawl fished in the old river channel in Lewis and Clark Lake. CPUE was reported as the number of paddlefish captured per minute of trawling. Trawl data from 1965 through 1974 were acquired by the U.S. Fish and Wildlife Service (Kallemeyn, 1975); data from 1975 through 1981 were acquired by South Dakota Game Fish and Parks (Unkenholz, 1982), and we obtained trawl data in 1986, 1989, 1990, 1991, and 1992. Trawl data from 1987 and 1988 were collected by J. C. Schmulbach and S. Wessel of the University of South Dakota, Vermillion, with funding and equipment support from Nebraska Game and Parks Commission. All trawl data were used to provide a long-term perspective on the density of y-o-y paddlefish in Lewis and Clark Lake.

The density of paddlefish larvae and y-o-y were correlated with three hydraulic variables, including gauge index (GI) derived by subtracting the monthly minimum discharge from the monthly maximum and calculating a mean of these differences for each year between 1956 and 1991. Mean gauge (MG) was a simple mean of daily mean discharge values for the year, and flushing rate was a mean annual period (in days) that the total volume of Lewis and Clark Lake was replaced through outflow at Gavins Point Dam. GI represents a measure of annual water fluctuations, while MG accounts for water years with different total volume runoff. Flushing rate reflects the amount of water held in storage in Lewis and Clark Lake and the magnitude of discharge at Gavins Point Dam.

We used a Spearman correlation (ranked values) and a Pearson correlation to determine relationships between hydraulic variables and biological variables.

A partial creel-survey of snag fishermen was conducted in 1987; more thorough harvest surveys were completed in 1987–1991 in the Gavins Point Dam tailwater. South Dakota biologists assisted with these surveys. We acquired harvest information from snag fishermen in 1992 as part of a recreational use survey that was conducted during the entire year. All paddlefish snagged in the tailwater area were measured from the eye to the fork of the caudal fin (EF), many were weighed, and the lower jaw was removed from a subsample for age analysis. Age data were used to create a year-class index (El-Zarka, 1959), which was subsequently used to correlate with hydraulic and other biological variables.

Paddlefish have been collected since 1990 with gillnets and trammel nets, and collected fish were tagged to study exploitation rate and migrational behavior. Paddlefish were successfully captured with deadset gillnets at the surface and at the bottom in the Gavins Point tailwater area. These nets were raised every 20 minutes. Most fish collected from riverine habitat were collected by floating trammel or gillnets through likely locations. The gillnets used in 1990 were 90 m long, 2.4 m deep and wholly composed of either 51-, 64-, or 76-mm mesh. In 1991 we used gillnets that were 122 m long, 3.1 m deep, and of 76-mm mesh, anchored on the bottom and surface in the Gavins Point Dam tailwater area. Downstream from Gavins Point, in the lower unchannelized section, we floated a gillnet at the surface through likely paddlefish habitat. In 1992, we used 122-m gillnets anchored on the bottom in the tailwater area, and we floated heavy-duty (twine size 15) trammel nets with a 76-mm mesh inner panel, and

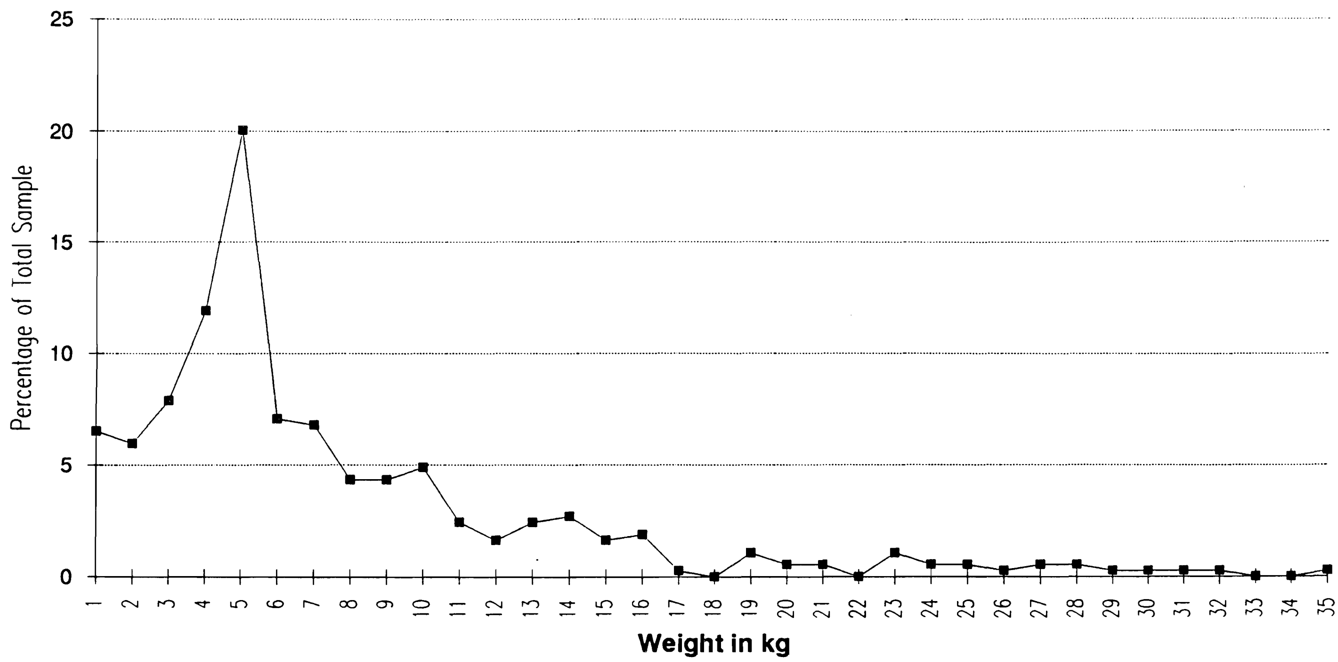

Figure 4. Weight distribution of paddlefish from the lower Missouri River 1991 snag fishery.

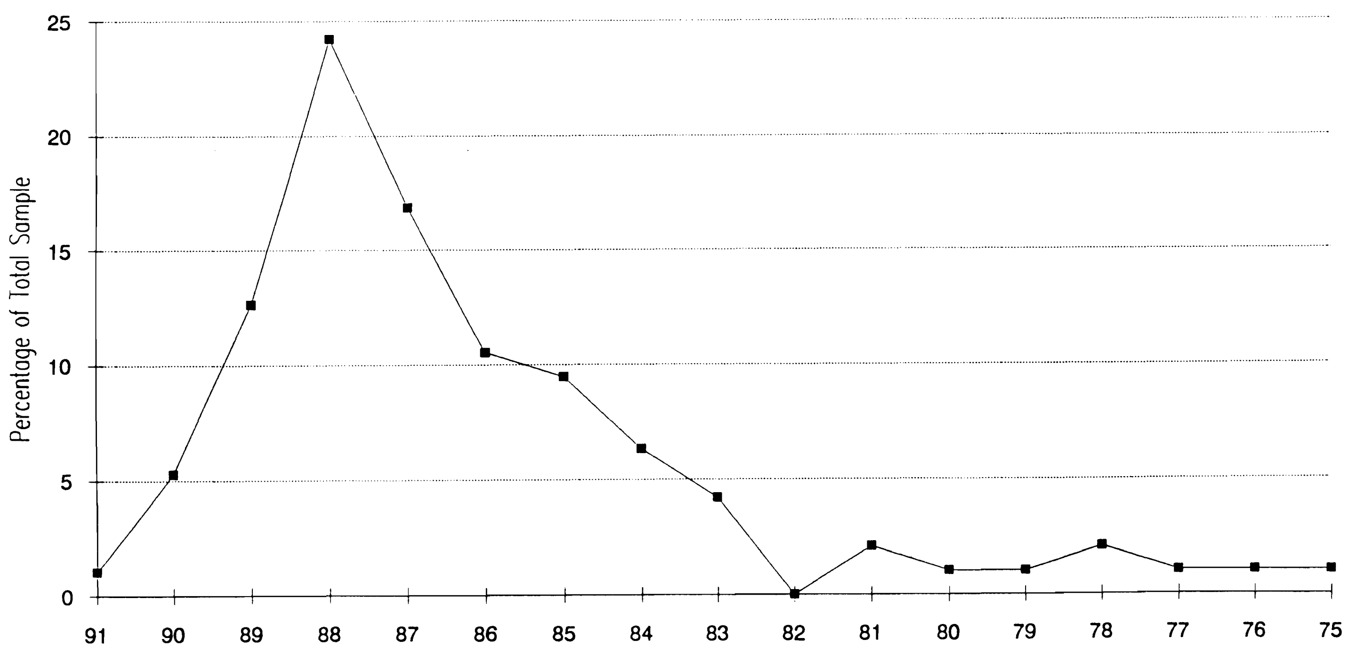

Figure 5. Age distribution of paddlefish from the lower Missouri River 1991 snag fishery.

Table I. Paddlefish larvae, volume of water filtered (×1,000m^3) and CPUE (larvae per 1,000m^3) collected from the Missouri River, Nebraska.

	Upper Unchannelized			Lower Unchannelized			Channelized		
Year	No.	(CPUE)	Volume	No.	(CPUE)	Volume	No.	(CPUE)	Volume
1983	1	(0.16)	6.41	0	(0.0)	5.94	—		—
1984	0	(0.0)	32.97	0	(0.0)	35.55	—		—
1985	3	(0.08)	38.35	1	(0.02)	46.12	—		—
1986	3	(0.43)	7.02	0	(0.0)	25.06	2	(0.15)	13.14
1987	1	(0.20)	5.02	0	(0.0)	7.72	0	(0.0)	16.70
1988	4	(0.42)	9.49	0	(0.0)	16.22	4	(0.14)	28.72
1989	8	(1.19)	6.75	0	(0.0)	9.52	0	(0.00)	15.65
1990	1	(0.03)	31.47	0	(0.0)	47.52	7	(0.19)	36.46
1991	32	(0.84)	37.98	0	(0.0)	21.02	0	(0.0)	18.55
Totals	53	(0.30)	175.46	1	(0.005)	214.67	13	(0.10)	129.22

outside panels of 457-mm mesh. The nets were 91 m long and 3.7 m deep and were tied down to 2.4 m.

RESULTS AND DISCUSSION

Larval paddlefish collections

The mean density of paddlefish larvae between 1983 and 1991 was 0.30 per 1,000 m^3 in the upper unchannelized reach. The mean density was much lower (0.005) in the lower unchannelized reach. Larval-paddlefish density averaged 0.10 per 1,000 m^3 in the channelized reach. Although the CPUE was quite variable from year to year in the upper unchannelized reach, at least one paddlefish larva was collected in all years except 1984. Only one paddlefish larva has been collected in the lower unchannelized section (1985) since 1983 and several were collected in 1986, 1988 and 1990 in the channelized section (Table I).

Drift net collections in the upper unchannelized section were made at three locations, including 16, 64 and 71 km downstream from Fort Randall Dam. The first site was just downstream from a 6-km rubble shoreline; site 2 was just downstream from the mouth of Choteau Creek, and the lowermost site was 2 km downstream from the mouth of the Niobrara River. Only 2 (3.8%) larvae were collected in the upstream site; 15 (28.3%) were collected near Choteau Creek and 36 (67.9%) were collected downstream from the Niobrara River since 1983.

All larvae from the lower two sites were collected in the turbid discharge from the two tributary streams, except one from the opposite bank from Choteau Creek. In the spring of 1991, Secchi-disk transparency averaged 1.1 m (range 0.96– 1.19 m) in all locations upstream from Choteau Creek to the tailwater of Fort Randall Dam, while in the plume of Choteau Creek and the Niobrara River, Secchi-disk transparency averaged 0.25 m (range 0.17–0.43 m). Unkenholz (1980) reported collecting 45 paddlefish larvae in 1975–1979, 93% of them downstream from the Niobrara River confluence.

Most recently, mature paddlefish have been collected in May and June in the 2-km reach between the Niobrara River and our lowermost drift-net site (personal communication, James C. Schmulbach, University of South Dakota, Vermillion). We have observed more paddlefish in this reach recently, as well, which may suggest that the harvest moratorium, started in 1987, has enhanced survival.

Young-of-the-year paddlefish collections

The highest trawl density for 1986–1992 occurred in 1991 (Table II). Moreover, 1991 proved to have the highest catch rate (1.10) since trawling began in 1965. Unkenholz (1982) reported on y-o-y paddlefish collections completed by the U. S. Fish and Wildlife Service, North Central Reservoir Investigations (1965–1974) and on similar trawl effort by South Dakota Game Fish and Parks (1975–1981). Catch rate in 1965–1974 ranged from 0.05 to 0.68 per minute of trawling; the mean was 0.22 (s = 0.18). Catch rate for 1975–1981 ranged from 0.02 to 0.33; the mean was 0.13 (s = 0.11). Most recently (1986–1991) catch rate ranged from 0.03 to 1.10; the mean was 0.34 (s = 0.36); the 1991 catch rate was the highest ever recorded. The mean for the period of 1986–1992 (excluding 1991 data) was 0.21 (s = 0.14) which more closely approximates the 1965–1974 period. The mean of annual mean daily discharges at Fort Randall Dam was 29,000 cubic feet per second (CFS) for the period 1965–1975, 31,360 CFS for the period 1975–1981, and 22,780 CFS for the period 1981–

Table II. Number of paddlefish y-o-y collected annually with a bottom trawl from Lewis and Clark Lake from 1986 through 1992. CPUE equals the number of y-o-y paddlefish per minute of trawl time.

Year	Minutes trawled	No. of y-o-y	CPUE
1986	150	35	0.23
1987*	*	*	0.07
1988*	*	*	0.38
1989	67	25	0.37
1990	104	4	0.04
1991	89	98	1.10
1992	92	15	0.16

* 1987 and 1988 data were provided by James C. Schmulbach and Scott Wessel, University of South Dakota, Vermillion. Minutes trawled and numbers collected will be reported in Wessel's thesis.

1992. Higher mean daily discharge at Fort Randall Dam shows that basin run-off was higher, which shows that fluctuating discharge was higher due to flood-control action at Fort Randall Dam. Mean GI for the periods was similar for 1965–1975 (14.02) and 1981–1991 (14.51), while the mean GI for 1975–1981 (11.95) was quite different. Lower run-off years under the controlled-release management, in place since 1954, may be beneficial for young paddlefish because there is less need to fluctuate discharge at Fort Randall Dam to reduce flood crests along the river from Omaha downstream.

Population statistics from snagged paddlefish

Harvest surveys have provided an opportunity to measure and weigh 5,075 and 3,972 paddlefish, respectively. In addition, jaws were removed from 1,714 paddlefish for aging (Table III).

Mean EF length for the period was 727 mm; mean weight was 6.63 kg and mean condition factor was 1.33. The percentage of fish 10 years of age or older (approximately the age of sexual maturity) varied; the mean for the period was 11.7%.

The survey methodolgy used in 1992 provided an opportunity to gather some limited mean-length data (snagged fish) from the upper and lower ends of the unchannelized reach open to snagging, in addition to the tailwater data. The mean length of fish snagged in the tailwater was 720 mm (s = 117 mm, N = 144 fish), and the mean length of all downriver snagged fish was 689 mm (s = 88, N = 70). The difference was significant when means were compared in a t-test (t = 1.99, p = 0.04). However, when the mean length from the upper end of the unchannelized section (nearest the tailwater area) (682 mm, s = 89 mm, N = 62) was compared with that for the lower end 84 km downstream (738 mm, s = 72, N = 8), the difference was significant (t = 1.69, p = 0.09). Larger fish have been shown to accumulate in the Gavins Point tailwater, but it is possible that they are attracted there from only a portion of the unchannelized reach downstream from the dam.

The upper Missouri River in Montana supports a large sport fishery for paddlefish. Paddlefish were isolated between Fort Peck Dam in Montana and Garrison Dam in North Dakota in 1953, a reach that includes the confluence of the Yellowstone River. Paddlefish were observed to accumulate at the Intake diversion dam (approximately 80 km upstream from the confluence) and a snag fishery developed by 1962 (Robinson, 1966). Robinson (1966) found the mean weight of snagged paddlefish (2,562) to be 9.9 kg in 1964 and 1965, and 59.2% were 10 years old or older. By 1973–1974 mean weight increased to 14.9 and 16.2 kg, respectively (Rehwinkel, 1978). Stewart (1991) reported the mean weight of 16,981 snagged paddlefish during 1981–1990 to be 21.0 kg (s = 1.1) and the mean length was 1,078.7 mm (EF, s = 10.7).

The paddlefish population downstream from Gavins Point Dam was found to include a small percentage of larger (Figs. 3 and 4) and older fish (Fig. 5). However,

Table III. Population statistics of paddlefish snagged from 1987 through 1992 in the Gavins Point Dam tailwater area.

	1987	1988	1989	1990	1991	1992	Mean
Number of fish measured	87	1,321	1,217	1,613	693	144	*5,075
Mean eye to fork length (mm)	705	749	695	739	753	720	727
Number of fish weighed	87	796	1,210	1,510	369	—	*3,972
Mean weight (kg)	4.67	7.84	6.28	6.89	7.45	—	6.63
Mean K-factor	1.17	1.49	1.41	1.29	1.28	—	1.33
Number of fish aged	368	387	578	286	95	—	*1,714
% Ten years or older	6.5	14.5	12.8	15.3	9.5	—	11.7

* Totals for the six years

recruitment to the snag fishery has continued, as demonstrated by the high percentage of fish younger than six years (78%) (Fig. 5) that have been snagged. The length and weight distributions (Figs. 3 and 4) show that small fish are recruiting into the fishery, and they contribute to a small mean length and weight. Data from 1991 were used to construct these distributions to provide the most current information; 1992 data were not used because a protected slot length limit was in effect during 1992. Therefore, 1991 was the last year to obtain length, weight and age distribution data from snag fishermen before they were allowed to select the fish they wished to keep.

We used the percentage composition between age classes to calculate total annual mortality based on 296 fish aged in 1990. The catch curve showed that age-4 and older fish were fully recruited to the snag fishery. Annual mortality was 6% for five-year-old fish but increased to 39% for six-year olds, 50% for seven-year olds and 80% for eight-year olds. Few fish survived beyond nine years and these age groups were only sporadically harvested.

Nearly 72% of the paddlefish harvested downstream from Gavins Point Dam weighed less than 6.8 kg (15 pounds); conversely, the upper Missouri River population appears to contain fewer young fish. Stewart (1991) reported just 1.6% of the snagged male paddlefish at Intake weighed less than 15 pounds and only 0.24% of the snagged females weighed less than 25 pounds.

Snag-harvest statistics

The snag-fishing season in Nebraska has become much more restrictive in the past 35 years (Stone, 1987). The entire Missouri River along Nebraska was open year-around during the 1960s and for as long as seven months (October–April) in the early 1980s. By 1987, concern for dwindling paddlefish density prompted Nebraska and South Dakota to close the upper unchannelized reach; concern for excessive incidental harvest of other species wintering in wing-dike holes in the channelized section led to closure of the river downstream from the Big Sioux River confluence at Sioux City to all snagging for paddlefish and to shortening of the season in the remaining open area to 30 days (November). These regulations remained in effect from 1987 until 1989, when a 1,600-fish harvest quota was instituted for the open area, and the daily bag limit was reduced to one. A total-user survey was implemented to count snagged fish and close the season when 60% of the quota was reached in the Gavins Point Dam tailwater area. Previous information regarding harvest suggested that approximately 60–87% of harvest occurred in the tailwater (Friberg, 1973; Hesse, 1980; Stone, 1985, 1987). A complete census of all snagged paddlefish was only possible in the tailwater area. A protected slot-length limit was imposed for the 1992 snagging season. All fish between 889 and 1143 mm EF had to be released. All other fish could be kept or released. The 1,600-fish quota remained in effect, as well, during the 1992 season.

The snagging season lasted 30 days in 1988 and the daily bag was two paddlefish per fisherman. Table IV shows the results for the first four days of the seasons for 1988 through 1991 and a season total. The harvest of paddlefish in 1988 was estimated to be 2,691 in the tailwater area at a catch rate of 0.26 per hour; 1986 harvest was estimated to have been nearly double this number (5,488) at a rate of 0.27 (Stone, 1987). All fish snagged were included in the bag by regulation during recent years. However, in 1972 snag fishermen were allowed to catch and release, and the catch rate still averaged 0.41 fish per hour (Friberg, 1973). These data suggest a decline in abundance of at least 37% between 1972 and 1988, but the actual snag catch rate in 1972 was higher if the first fish had been kept, therefore the change in density was greater.

The number of fishermen increased by 48% and man-hours increased 29% (Table IV) during 1989, the first year of the quota. The harvest quota was exceeded on the second day of the season but notification procedures prevented closure for 48 additional hours. Mean snag catch rate (0.25) was similar to 1988.

The harvest quota was exceeded on the second day of the 1990 season and the four-day season allowed time to exceed the pre-set quota by 74%. Catch rate increased (0.33) by 32% from 1989. The harvest quota for 1991 remained the same but certain areas within the tailwater were closed to snagging from a boat or the bank. These areas were locations where paddlefish, especially large females, were most vulnerable. The result of this regulation and other factors, including, abnormally warm weather early in the season and a major blizzard half way through the season, reduced the catch rate from 0.33 in 1990 to 0.10 in 1991 (Table IV). The fishing success was down and as a result the quota was not reached and the season extended a full 30 days, by which time 898 fish had been harvested. We believe the protected areas prevented some of the larger females from being harvested and contributed to the decline in mean weight experienced during 1991. Since mean length actually increased, we believe reduced harvest associated with the harvest quota has improved survival.

The protected areas included a canal that carried discharge from the powerhouse turbines. The velocity in this canal was similar to main channel velocities. If sexually mature fish were to migrate to staging areas near spawning substrates late in the fall, this canal

Table IV. Gavins Point Dam tailwater paddlefish snagging season complete census information for 1988–1992 (numbers of 1992-released fish in parentheses).

Day	No. of paddlefish	Man-hours	Catch rate	No. of fishermen	Percent successful
			1988		
1	1,150	2,684	0.43	742	—
2	257	1,125	0.23	340	—
3	113	582	0.19	211	—
4	134	784	0.17	233	—
Total	2,691	10,489	0.26	3,099	—
			1989		
1	807	3,460	0.22	1,095	74
2	199	830	0.22	363	55
3	151	630	0.23	276	55
4	207	643	0.31	315	66
Total	1,364	5,563	0.25	2,049	67
			1990		
1	877	2,814	0.31	1,055	83
2	399	1,289	0.31	590	68
3	196	459	0.43	259	76
4	271	777	0.35	428	63
Total	1,743	5,339	0.33	2,332	75
			1991		
1	303	2,993	0.10	715	42
2	114	1,628	0.07	436	26
3	50	563	0.09	202	25
4	36	371	0.10	141	26
Total	898	8,755	0.10	2,830	34
			1992		
1*	101 (39)	2,101	0.05	574	—
2*	14 (13)	1,091	0.01	352	—
3*	8 (6)	129	0.06	72	—
Total**	540 —	9,139	0.004	—	—
Total***	1,000 —	21,334	0.05	—	—

*Actual
**Estimated tailwater
***Estimated total open area

would be the most likely route selected by migrating fish. Observations during previous snagging seasons have shown the largest snagged paddlefish came from the base of the dam in this canal.

The first three days of the 1992 snagging season in the Gavins Point tailwater was monitored with a complete census as done in previous years. The remainder of the 30-day season and other portions of the open fishing area was surveyed as part of a total recreational use survey.

The number and rate of harvested paddlefish declined dramatically from previous years (Table IV), while man-hours of fishing time were about 20% higher than the previous 4-year average. The changing regulations have made it difficult to evaluate the meaning of declining catch rate. We have redoubled our effort to obtain another index for relative population density, but for now we do not know if a reduced catch rate suggests reduced density of paddlefish.

The first-year evaluation of the protected slot-length limit was successful in the sense that no mortally wounded fish were reported by any fishermen at the check stations or by patrolling conservation officers. The opportunity to release small fish was appreciated by fishermen, and the chance to fish and not harvest at all was appreciated by some as well.

Tagging and exploitation

With periodic help from South Dakota biologists, we tagged 68 paddlefish in the tailwater of Gavins Point Dam during October, 1990, but prior to the snagging season. The 1990 snag harvest was estimated to have been 1,927 fish; 16 tags were returned for an exploitation rate of 24% and a population estimate of 8,029 fish.

In October of 1991 we tagged 95 paddlefish in the tailwater and 9 (9% of the 1991 tags) were recovered by snag fishermen from 898 harvested fish. The relative population estimate was 9,978 fish. In addition, we tagged 177 paddlefish 19 km downriver during 1991, but only two were snagged in the tailwater. They were not included in estimates of exploitation or population. No downriver tags were returned by mail, although we know several were taken by fishermen.

We tagged 42 paddlefish during 1992 in the tailwater of Gavins Point Dam and 204 paddlefish in the riverine, unchannelized reach. All downriver fish were tagged within 8 km of the confluence of the James River. Archery fishermen returned two tags during the July archery season. Both were tagged in the riverine reach and were among 108 tagged prior to the archery season (0.9%). Four of the remaining 202 riverine-tagged fish were reported harvested during the 1992 snagging season (2.0%). One riverine tag was harvested from the riverine reach, two riverine tags were harvested from the tailwater area, and the last one was harvested by a commercial fisherman 121 km up the Kaskaskia River in Illinois. One of the 42 tailwater-tagged fish (2.0%) was harvested in the riverine portion. In addition, three 1991 tagged paddlefish were harvested during the 1992 snagging season; one was taken by a commercial fisherman from the Mississippi River at Hickman, Kentucky. Three 1990-tagged paddlefish were harvested during the 1992 season. Total exploitation based on only 1992-tagged fish reported by fishermen was about 5%. Non-reported tags would increase the rate, but most likely actual exploitation was less than 10%.

Stewart (1991) reported same-year tag returns to range from 4% to 14.1%. Combs (1982) reported that an annual exploitation rate up to 19% was not detrimental to paddlefish in Oklahoma, but Purkett (1963) and Gengerke (1978) have noted declining catch rate, mean size and age associated with exploitation rates between 7 and 22%.

The present exploitation rate (9–24%) for the fishery downstream from Gavins Point Dam was too high considering the low larval density and y-o-y survival. The harvest of 1992 resulted in an exploitation rate that is most likely appropriate for the short-term; however, additional study will be required in order to determine if this level of exploitation can be sustained for the long-term.

Gillnet survey of paddlefish downstream from Gavins Point Dam

Surveying snag fishermen to obtain length and weight data is labor-intensive, and changing management, such as closed areas or size limits can impact the data acquired. We have successfully collected paddlefish in 1991 and 1992 with gillnets and trammel nets. We believe these sampling procedures will provide long-term monitoring capability, independent of snag fishermen. Fish collected in this manner can be tagged to study exploitation.

During 1991 (spring and autumn), we captured 83 paddlefish in the Gavins Point Dam tailwater and 180 fish downstream in sandbar pools in the lower unchannelized Missouri River. Besides receiving a Monel bandet around the jaw, each fish was weighed and measured. The mean length of tailwater fish was 791 mm (EF) compared with 725 mm downriver, and mean weight was 9.0 kg vs 5.1 kg. A *t*-test showed these differences were significant ($P_t < 0.0001$). However, when mean length and weight for all paddlefish captured in 1991 in gillnets and trammel nets (tailwater and downriver) (748 mm, 6.3 kg) were compared in a *t*-test with the mean length (753 mm) and weight (7.5 kg) of fish snagged in 1991, there was no difference in mean length; although mean weight was different ($P_t = 0.007$).

During 1992, gillnet and trammel-net effort resulted in a total collection of 280 paddlefish of which 246 were tagged as reported previously. Total mean length of the netted fish was 755 mm (s = 121 mm), compared with a mean of 748 mm in 1991 (not significant). There is some evidence of the movement pattern of selected size groups of paddlefish from analyses of the mean length on a monthly basis in the tailwater area versus the upstream portion of the riverine reach. The mean length in the tailwater increases from 701 mm in March to 746 mm in April to 885 mm in August, while in the riverine reach the pattern is reversed. The mean in March was 795 mm, 764 mm in June, 746 mm in July, and 722 mm in August.

One important aspect of net surveys that remains to be worked out is an index for catch per unit effort. This remains a high priority.

Modeling

We created a matrix of biological and hydraulic variables for correlation analysis (Table V). Year-class index, GI, MG and Flush dated back to 1956. Trawl surveys dated back to 1965 and drift net surveys dated back to 1975. We used only those larval fish samples collected from the lowermost portions of the upper unchannelized section because very few larval paddlefish were collected upstream from the Niobrara River confluence. We believe this has resulted from the added impact from altered water temperature and turbidity, which might confound identification of a relationship between Fort Randall Dam discharge and larval density. For this reason, the values for larval paddlefish density are not uniform between Table II, which reported all larvae collected and all volume filtered and Table V. In addition, since fish larvae were not collected in 1992, the model does not include any 1992 data.

Table V. Biological and physical data used in correaltion modeling including adult paddlefish year class indices, y-o-y paddlefish CPUE (number per minute), larval paddlefish (only a portion of the upper unchannelized samples were included as defined in the text) CPUE (number per 1,000 m^3), GI and MG for Fort Randall Dam and flushing rate for Lewis and Clark Lake (days).

Year	Year class index	y-o-y	Larvae	GI	MG	Flush
1956	-183.20			20.80	29.60	4.3
1957	-99.87			29.50	20.45	8.3
1958	-150.37			20.80	24.85	8.1
1959	-48.33			23.15	21.70	8.4
1960	-150.77			26.05	16.35	8.9
1961	-67.44			23.95	20.90	8.5
1962	32.56			22.45	13.35	11.3
1963	122.65			25.85	23.40	7.9
1964	182.96			26.40	22.60	8.0
1965	138.92	*0.09		17.95	21.70	8.3
1966	159.00	0.13		12.70	27.30	7.5
1967	206.91	0.16		13.90	24.70	8.0
1968	143.24	0.26		12.20	30.90	6.8
1969	88.10	0.05		16.55	32.45	5.7
1970	-2.22	0.15		17.55	30.65	5.7
1971	31.24	0.13		8.90	43.45	4.8
1972	-71.39	0.33		11.75	35.85	5.1
1973	-19.72	0.68		14.00	25.15	7.3
1974	1.75	0.18		14.65	27.95	6.7
1975	-47.04	**0.17	**0.66	14.45	32.55	4.5
1976	-20.10	0.16	0.17	8.95	35.35	5.9
1977	4.42	0.17	0.38	14.70	27.80	6.9
1978	2.45	0.33		14.75	31.05	4.9
1979	7.78	0.05	0.44	12.65	35.90	6.0
1980	-2.57	0.03	0.00	6.90	27.30	6.6
1981	-15.67	0.02	0.68	11.25	29.55	7.0
1982	-36.22			24.40	22.95	7.3
1983	0.55		0.00	23.20	17.25	8.5
1984	-0.08		0.00	18.85	12.25	8.2
1985	-56.36		0.11	8.50	25.70	7.1
1986	-56.56	0.23	0.65	17.70	27.45	6.2
1987	-41.53	0.07	0.42	12.60	25.10	7.5
1988	8.79	0.38	0.70	8.20	27.15	7.0
1989	32.40	0.37	1.60	6.40	28.35	6.3
1990	11.28	0.04	0.07	12.80	21.60	7.6
1991		1.09	0.72	12.40	19.95	7.8

* Kallemeyn 1975 (1965–1975).

** Unkenholz 1982 (1975–1981).

There was a strong relationship between larval density and y-o-y abundance in the upper unchannelized reach (r = 0.6445, p = 0.0237). We also found fairly strong relationships between larval density and GI (r = -0.3728, p = 0.1712), and MG (r = 0.4014, p = 0.1380). We found no relationship between year-class index, which is derived from snagged fish in the lower unchannelized reach (downstream from Gavins Point Dam) and other variables, including, larvae, y-o-y, GI, or MG. However, we did find a strong relationship in a Pearson correlation between the June–August flushing rate for Lewis and Clark Lake and year-class index (r = 0.4487, p = 0.0317). The best relationship occurred when we selected only June data (r = 0.6047, p = 0.0022); (June–July r = 0.5619, p = 0.0053; July r = 0.4733, p = 0.0225; August r = 0.1762, p = 0.4212).

These results suggest that successful reproduction occurs when fluctuating discharge is minimized. It also shows that year-class development downstream from Gavins Point Dam is dependent on recruitment from upstream and occurs as a result of the discharge of young paddlefish during June and July primarily. Since we do not collect paddlefish larvae in the tailwater, we believe they exit the lake after they have matured beyond the larval stage.

RECOMMENDATIONS

Our data demonstrate that, although the spawning migration has been blocked by dams, paddlefish could find limited spawning substrates downstream from Gavins Point Dam. However, our data clearly demonstrate that successful spawning, as measured by the presence of larvae in the drift, has not occurred in the lower unchannelized section of the Missouri River. There are at least two possible reasons, including too few sexually mature females or the lack of a spawning cue (the spring rise in water elevation). We have demonstrated that harvest has eliminated many of the older fish that would be sexually mature. Purkett (1963) suggested that rising stage during the spring spawning period was essential for the onset of spawning in paddlefish. We have found a negative relationship between the density of drifting paddlefish larvae and fluctuating discharge at Fort Randall Dam. The hydrograph at Fort Randall, Gavins Point and all other mainstem dams no longer resembles the natural hydrograph (Hesse and Mestl, 1993). Unless a semblance of the natural hydrograph is recovered, we will not have an effective way to determine the impact of no spring rise.

Scarnecchia et al. (1989) discussed the relative merits of protecting female spawning-size paddlefish and concluded that, for those living in the upper Mississippi River, protection was important. They proposed a harvest slot length limit of 57-86 cm (EF).

We disagree with Scarnecchia's et al. (1989) assessment of a study by Friberg (1974) that concluded "high-grading" results in high mortality. The study was not interpreted properly, and in reality it concluded that 86% of the snagged paddlefish held in hatchery ponds during the summer survived. We have observed old snagging wounds and rostrums entirely removed by outboard motor propellers on 31% of all paddlefish in the Gavins Point Dam tailwater. Many of these wounds were healing and the fish, with very few exceptions, appeared otherwise quite healthy. Our major concern regarding hook related mortality was the possibility of a hook piercing the interior wall of the body cavity, which could create a severe infection internally. We reduced the legal hook size to one-half inch measured from point to shank in an effort to minimize this problem.

We selected a protected slot of 889–1,143 mm (35–45 inches) (EF). Our regulation, as written, allows fishermen to release even those fish shorter or longer than the slot. Based on the 1991 harvest information, we would have eliminated 17% of the fish removed in 1991, assuming all fish outside of the slot were kept. Fish in the protected slot will range from 9 to 18 kg (20 to 45 pounds). We expected harvest would be concentrated on fish in the 4- to 9-kg range because these were the prefered eating size and were most numerous. Actual harvest ranged from 0.4 to 10 kg. Maintenance of a strict harvest quota should prevent overharvest of young fish. We expect large numbers of paddlefish to accumulate in the protected range. Many of these fish will survive beyond the slot; however, the slot includes females in their earliest years of maturity, thus enhancing the number of available spawning females. At the same time we allowed snag fishermen the opportunity to harvest trophy sized paddlefish, thus enhancing the special image of this unique animal. Several additional snagging seasons with the slot limit will be required before statistics on mean length can be used to fully evaluate the impact of this regulation on paddlefish. Moreover, as some paddlefish interchange with other rivers tributary to the Mississippi, it may take more than several seasons. Continued tag studies will be essential in order to evaluate exploitation rates for paddlefish, especially on those fish larger than the slot. If exploitation of these older fish exceeds 25%, we would recommend an added restriction of one trophy sized paddlefish per fishermen per year. In addition, tagging should be implemented in other locations within the Mississippi River system in order to more fully understand the relationship of one river with another from the viewpoint of a paddlefish.

We have determined that the use survey, as conducted during 1992, did not do an effective job estimating paddlefish harvest. We are left with only one real alternative to obtain good harvest and exploitation data and that is to conduct a near total census as has been done during the previous four years. However, another possible alternative is used by the State of Wisconsin to manage lake-sturgeon harvest. Fishermen are issued one tag per year. To be kept, the fish must be immediately tagged upon its catch. Further, the fish must be reported by telephone to the central office by 1800 hours the next day. In our case, 1,600 tags (or whatever number we decide upon) could be made available at the beginning of the year. Only one tag could be obtained at a time, and it could be used either for archery or snagging. Once the tag has been filled and reported the fisherman could obtain another tag by mail if any remain. With such a management plan, archery season could open 1 July and remain open for one month. Snagging season could open 1 November and remain open one month or until 1,600 tagged fish were reported as a result of harvest during both seasons. In this manner both harvest methods are covered under one quota. At the end of the season, unused tags and an eye to fork length of harvested fish should be returned on a card supplied with each tag issued. Failure to return cards or tags could be justification for non-issuance of future tags. We propose that this approach be adopted for the 1995 season and beyond.

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