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# Rationale for a Harvest Slot Limit for Paddlefish in the Upper Mississippi River

DENNIS L. SCARNECCHIA

*Department of Animal Ecology, Iowa State University*
*Ames, Iowa 50011, USA*

THOMAS W. GENGERKE

*Iowa Department of Natural Resources*
*Box 7722, Spirit Lake, Iowa 51360, USA*

CLARK T. MOEN

*Department of Animal Ecology and Iowa Cooperative Fish and Wildlife Research Unit*
*Iowa State University*

*Abstract.*—In this paper, data are reviewed on the lengths, weights, and sex of paddlefish *Polyodon spathula* captured by snagging and by nets from eight pools of the upper Mississippi River in 1975–1978 and by snagging from Pool 13 in 1988. Fisheries were targeted on the largest specimens, which were typically mature females. From 1975 to 1978, only 7 of 315 male fish (2.2%) exceeded 114 cm in fork length, whereas 41 of 288 females (14.2%) exceeded that length. Only two males (0.6%) exceeded 11 years of age, whereas 22 females (7.6%) were older than age 11. Thus, among fish longer than 114 cm, there were 5.9 females harvested for every male, a highly significant difference between the sexes ($P < 0.005$). Of the 33 fish sampled in 1988 that exceeded 114 cm in fork length, 28 were females and 5 were males (5.6 females for every male). Although mature females constituted only 5.9% of the fish sampled from the population in 1975–1978, they were the primary spawners, and they are avidly sought and selected for by anglers. To protect large female spawners, rebuild the fishery, and prevent harvest of small paddlefish with substantial growth potential, a harvest slot limit of 57–86 cm for body length (front of eye to fork of tail) or 2.2–11.3 kg for weight is proposed for paddlefish in Iowa's portion of the Mississippi River. Fish larger or smaller than these limits would be protected from harvest. Management considerations include possible alternatives, public acceptance of the regulation, hooking and handling mortality, the need for evaluation and enforcement, and coordination among states.

Size limits (length or weight) are now rarely used in the management of recreational or commercial fisheries for paddlefish *Polyodon spathula*. Commercial fisheries for paddlefish in Arkansas and Mississippi have minimum-length limits of 81 cm (Combs 1986), and Missouri has a 61-cm minimum-length limit to prevent harvest of undersized fish in a put-and-grow fishery in Lake of the Ozarks (Graham 1988). The justification for minimum-size limits for paddlefish as well as for many other species has often been to protect fish until they are sexually mature and have had an opportunity to spawn at least once (Elser 1986).

Much less emphasis has been placed on protecting large, sexually mature paddlefish. In particular, large females, which can have fecundities exceeding 0.5 million eggs (Gengerke 1978), have long been sought avidly by commercial fishers, principally for their roe (Stockard 1907; Hussakof 1910; Meyer 1960; Carlson and Bonislawsky 1981). Large fish of both sexes are also preferentially sought by anglers (Purkett 1963; Combs 1982) for their food value and, additionally, they have been regarded as trophy or at least trophy-sized fish (Anderson and Ackerman 1977; Beck 1978).

In many fish populations, it is the large fish, particularly large females, that are thought to be important for reproductive success and recruitment. For this reason, in large, late-maturing species such as the sturgeons (Acipenseridae), whose largest individuals are females of high fecundity that do not spawn annually, a harvest slot regulation has often been enacted (Galbreath 1985; Atkinson 1987). White sturgeons *Acipenser transmontanus* on the Columbia River below Bonneville Dam have a harvest slot of 91–183 cm. Fish above and below these lengths are protected (King 1987). The rationale behind this regulation has been that by protecting the largest fish, most of which are females, reproduction will be enhanced, and a steady supply of harvestable fish will result within the harvest slot.

Several investigators have suggested that insufficient spawning sites and the absence of suitable spawning conditions may limit paddlefish reproduction and recruitment (Purkett 1961; Friberg 1972; Carlson and Bonislawsky 1981; Russell 1986). Most historical spawning habitat of paddlefish has been altered and lost because of dams, intentional channel modifications and sedimentation (Purkett 1961). Female paddlefish do not spawn every year and evidently spawn only every 2–3 years in Missouri (Russell 1986) and every 4–7 years in Iowa (Meyer 1960). These conclusions were based on the spacing of annuli on dentary bones, and the exact periodicity of paddlefish spawning is not known. In addition, exact timing of environmental cues (photoperiod, water temperature, and water flow) is evidently needed for successful reproduction. It may thus be several years after maturity before a given female is physiologically prepared and receives the appropriate environmental stimuli to initiate spawning. In such a situation, the protection of large females from harvest becomes particularly important so that experienced, highly fecund fish are available whenever spawning opportunities arise.

In this paper, we present data supporting the implementation of a harvest slot limit for paddlefish in Iowa's portion of the Mississippi River. The proposed slot limit would protect the large females, which, on the basis of available evidence, constitute the vast majority of large paddlefish in Iowa's portion of the river. The anticipated results of protecting the large females would be more successful reproduction, more small paddlefish, more fish entering the harvest slot to be caught in the fishery, and ultimately, more spawners. Alternatives to the proposed regulation are considered. We also discuss the feasibility of implementing the regulation and its biological and socioeconomic consequences.

## Sources of Data

Two sources of data were used, both from fisheries in the upper Mississippi River in Iowa. Gengerke (1978) reported length, weight, and age of 315 male and 288 female paddlefish of all sizes captured in commercial net, recreational snagging, and experimental net and snagging fisheries over the period 1975–1978 from pools 9, 11, 12, 13, 16, 17, 18, and 19. The pools extend progressively southward along the entire length of Iowa's eastern border (Figure 1). Slightly more than half (51%) of the fish were sampled from Pool 13, 18% from Pool 16, 18% from Pool 18, and the remaining 14% from pools 9, 11, 12, 17, and 19. Of the 307 fish sampled from Pool 13, 175 were obtained from the public recreational fishery below Lock and Dam 12 at Bellevue. An additional 89 fish were caught by experimental snagging in the tailwaters of Lock and Dam 12 and by drifting gill nets (30.4 × 1.8 m, with 12.7-cm bar mesh) at sites 11.3 and 12.9 km downstream from the tailwaters, near the mouth of Crooked Slough (Figure 1; Gengerke 1978).

The second data set was obtained from March 11 to 17, 1988. We sampled paddlefish by snagging in the tailwaters of Lock and Dam 12, and the lengths and weights of the fish were determined. In addition, sex was determined for all 33 fish weighing more than 6 kg. Numerous fish weighing less than 6 kg were snagged, but they were not tallied. On June 3 and July 1, 1988, three and four more fish, respectively, heavier than 6 kg were sampled in the tailwaters with 10.2-cm-bar-mesh gill nets and were also characterized according to length, weight, and sex.

Lengths were expressed as total lengths, fork lengths (tip of rostrum to fork of caudal fin), or body lengths (anterior edge of eye to fork of caudal fin: Ruelle and Hudson 1977). For fish collected in 1988, fork lengths were calculated from measured total lengths according to the relation in Gengerke (1978). For three fish in 1988 whose damaged rostrums prevented measurements of fork lengths, the fork lengths were estimated from relations between fork, total, and body lengths, as summarized in Table 1. Age determinations for fish sampled from 1975 to 1978 were based on the number of annuli on sections of dentary bones (Adams 1942). State of maturation was determined by internal examination. Fish with eggs distinguishable by eye were classified as mature. Different mature females had gonads in several different stages of development, which indicated that individual fish did not spawn annually. Eggs in different females varied in size and color from being small and whitish, to intermediate-sized and a mixture of white and black ("salt and pepper"), to large and greyish-black.

Since 1987, the commercial fishery for paddlefish has been closed in Iowa so that, at present, the state's only paddlefish fisheries on the Mississippi River are recreational snagging fisheries in tailwater areas below locks and dams. Although Gengerke (1978) found that snagging was less size-selective for paddlefish than netting, the mixed sample of fish caught by recreational, commercial, and experimental fisheries from 1975 to 1978 was

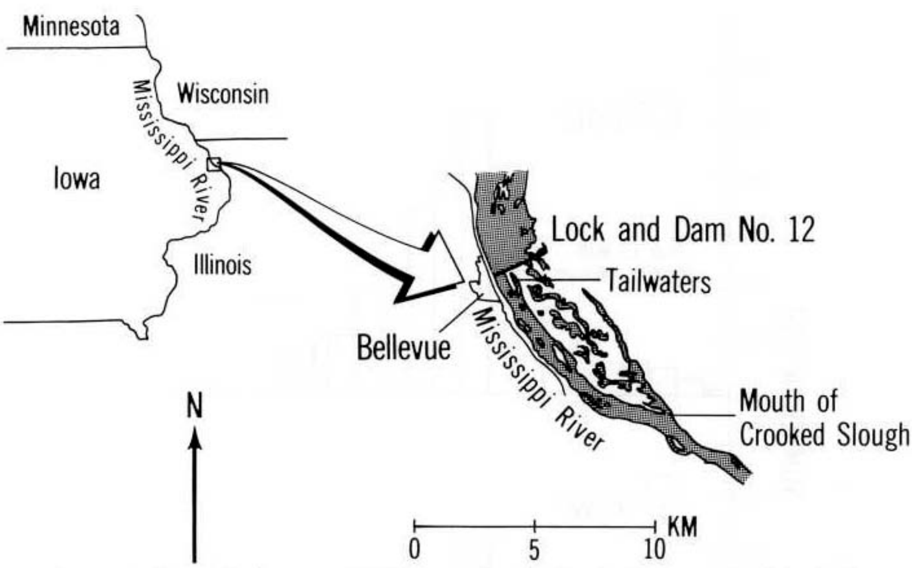


FIGURE 1.—Map of primary paddlefish sampling site, Pool 13, upper Mississippi River.

assumed to be representative of catches from Iowa's portion of the river. The fishery at Lock and Dam 12 is regarded as the the most productive site for snagging paddlefish along Iowa's border (Anderson and Ackerman 1977), and catches there were also assumed to be representative of catches from Iowa's portion of the river.

Although data collected in 1988 were from only 3 months, data collected from 1975 to 1978 were from all months, so we assumed in this paper that the above data were a reasonable representation of the actual sex ratios and sizes of fish in the stock.

## Results

### *Data from 1975 to 1978*

Of 315 male paddlefish sampled during 1975–1978, only 2 (0.6%) were older than 11 years of age (Gengerke 1978). Some males matured at age 4, most were mature by age 6, and all were mature by age 9 (Figure 2). Males 10–12 years old constituted only about 3% of the fish sampled and had fork lengths ranging from 112 to 122 cm. Only seven male paddlefish (2.2%) exceeded 114 cm in fork length (Figure 3). According to calculated length–weight relations for males age 5–10 (Table 1), a typical male with a fork length of 114 cm

TABLE 1.—Equations (from Gengerke 1978) relating total length (TL), fork length (FL), body length (BL), and weight (W) of paddlefish. Lengths are expressed in millimeters, and weights are in grams.

| Category of fish | Equation |
|---|---|
| All[a] | TL = 225 + 1.198BL |
| All[b] | TL = 120 + 0.995FL |
| Females, ages 1–4 | $\log_{10}W = -6.44 + 3.38 \log_{10}FL$ |
| Females, ages 11–18 | $\log_{10}W = -3.71 + 2.54 \log_{10}FL$ |
| Males, ages 5–10 | $\log_{10}W = -8.03 + 3.92 \log_{10}FL$ |

[a] $N = 212$; $r = 0.99$.
[b] $N = 283$; $r = 0.92$.

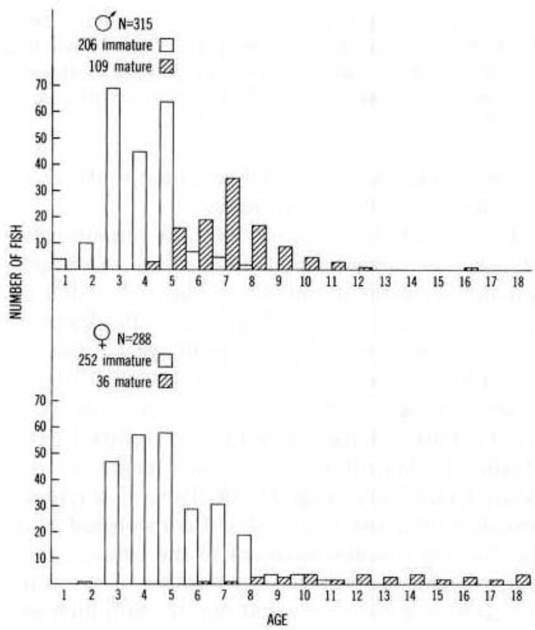


FIGURE 2.—Age and state of maturity of 315 male and 288 female paddlefish sampled from the upper Mississippi River, 1975–1978 (Gengerke 1978).

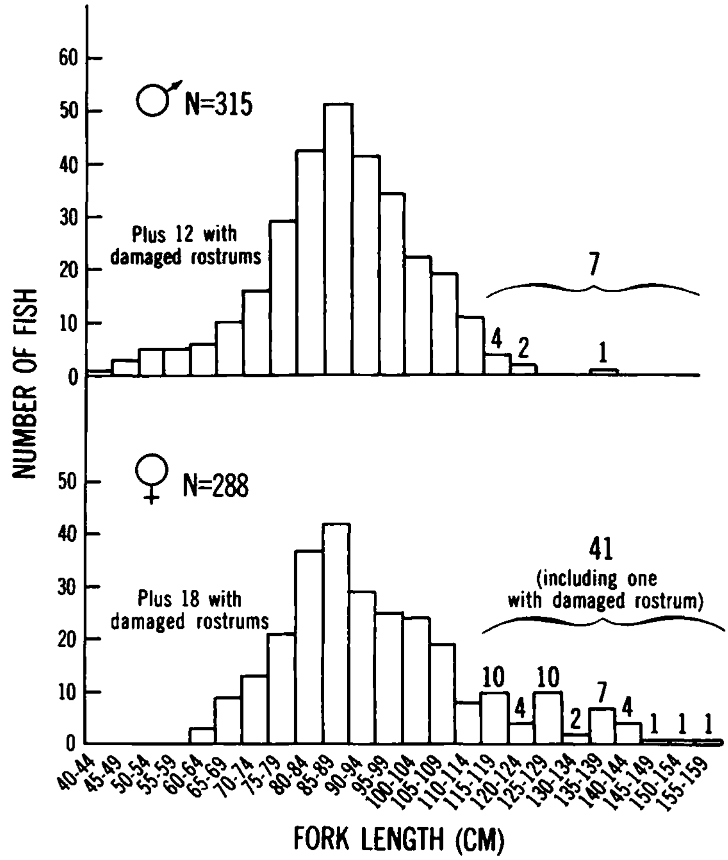


FIGURE 3.—Length frequencies for 315 male and 288 female paddlefish from the upper Mississippi River, 1975–1978. Braces indicate fish exceeding 114 cm in fork length. One male fish at age 10 with a damaged rostrum was assumed to be in the 110–114-cm-fork-length category. One female fish at age 13 with a damaged rostrum was assumed to be longer than 114 cm in fork length (Gengerke 1978).

weighed 9 kg. Among males recruited to the fishery, one out of three was mature.

In contrast, 22 (7.6%) of the 288 female paddlefish were older than 11 years of age. Although females occasionally matured at ages 6, 7, and 8, it was not until age 10 that 50% of the females were mature, and it was not until age 12 that all females were mature (Figure 2). The 22 females older than age 11 were thus all mature, as were the 41 females longer than 114 cm in fork length (Figure 3). According to calculated length–weight relations for females age 11–18 (Table 1), a typical female with a fork length of 114 cm weighed 11.3 kg. Among females recruited to the fishery, only one in eight was mature. The number of ova produced by a female increased rapidly with increasing length and weight (Figures 4, 5) and approximately doubled (from 200,000 to 400,000) as the fish increased in weight from 14 to 22 kg. For fishes longer than 114 cm in fork length, there were 41 females and 7 males, or 5.9 females for every male. This difference between frequencies of large males and females was highly significant (chi-square test, $P < 0.005$).

*Data from 1988*

Of the 40 fish sampled in 1988, 33 exceeded 114 cm in fork length. Twenty-eight of these 33 fish were females and 5 were males, a ratio of 5.6 females for every male. This ratio was not statistically different from the one obtained during 1975–1978 (chi-square test, $P > 0.9$). Of the other seven fish sampled (fork lengths, 99–114 cm), three were males and four were females (Figure 6).

## Rationale for the Harvest Slot Limit

These data from the upper Mississippi River indicate that paddlefish of fork lengths greater than

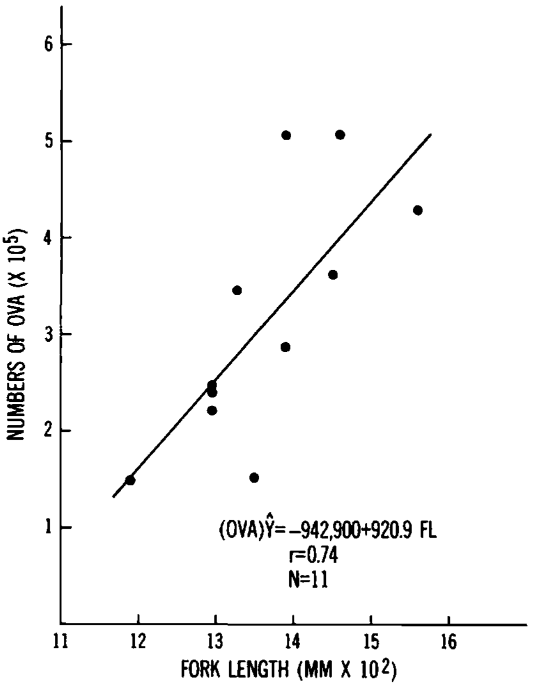


FIGURE 4.—Relation between fork length and number of ova for paddlefish from the upper Mississippi River (Gengerke 1978). Ŷ = number of ova; FL = fork length.

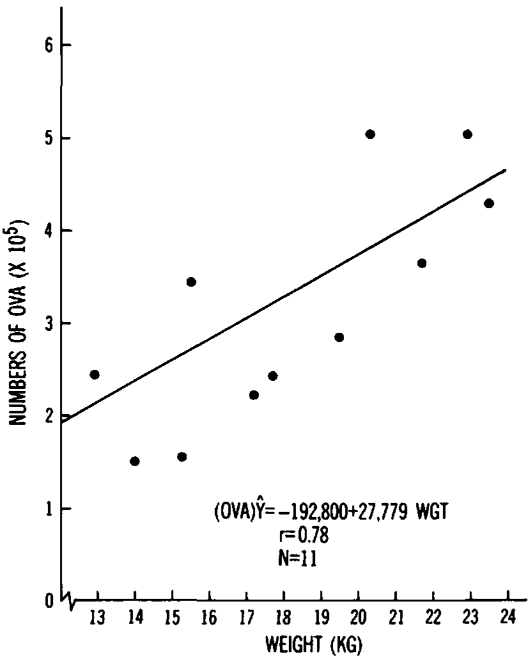


FIGURE 5.—Relation between weight and number of ova for paddlefish from the upper Mississippi River (Gengerke 1978). Ŷ = number of ova; WGT = weight.

114 cm are five to six times more likely to be females than males. These females constitute the primary mature spawners and have fecundities that can triple or quadruple as the fish grows from 114 to 150 cm in length (Figure 4). Relatively few males attain this size range. Compared to females, males mature at a younger age (Larimore 1950; Figure 2), evidently are able to spawn more frequently (Russell 1986), and, on average, do not live as long (Gengerke 1978). Thus, recreational and commercial fisheries that concentrate harvest on the largest fish are selectively harvesting mature females.

Published results from paddlefish investigations elsewhere support our conclusions. Friberg (1974) reported that, for a random sample of paddlefish captured by anglers in 1973 from the tailwaters of Big Bend Dam, South Dakota, males weighed from 9 to 30 kg (mean, 17 kg), but females were much larger—16–48 kg (mean, 30 kg). He noted a similar disparity in 1971 and 1972. His conclusion from the 1971 data, which was supported by his subsequent data, was that "Male fish obviously constituted a large portion of the fish less than 50 pounds [23 kg] and nearly all fish above 50 pounds were females" (Friberg 1972). In the Osage River, Missouri, Purkett (1961) reported that 40 males taken from the spawning population averaged 140 cm in total length and 13 kg in weight, but females tended to be longer and heavier, averaging 152 cm in total length and 19 kg in weight. According to Purkett, "Much of the greater weight of the females was due to the weight of the ovaries. These weighed 6 to 8 pounds [2.7–3.6 kg] in most ripe females." Female paddlefish were also reported to be larger and longer-lived than males in Lake Cumberland, Kentucky (Hageman et al. 1988). The size differences between male and female paddlefish are sim-

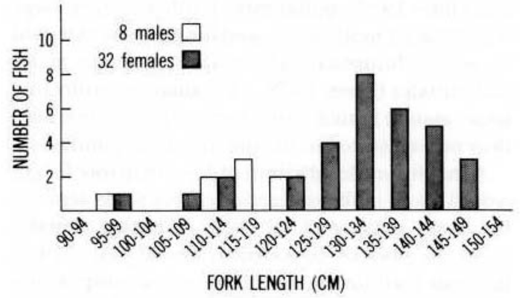


FIGURE 6.—Sex and length frequencies of 40 paddlefish sampled from the Mississippi River at Lock and Dam 12 tailwaters in 1988.

ilar to those between males and females of several species of sturgeons (Harkness and Dymond 1961; King 1987), the closest living relatives of paddlefish (Nikolskii 1961).

However, Unkenholz (1981) reported that both large males and large females occurred below Fort Randall Dam on the Missouri River, and Stockard (1907) published an early photograph of a large male taken from Lake Washington, Mississippi. In the Missouri River below Gavins Point Dam, Rosen et al. (1982) reported that the female : male ratio was 1.12:1, but that only 2 of 82 females contained mature eggs and only 16 more fish were in the advanced stages of ovarian maturation. Several other published studies (Rehwinkel 1978; Combs 1982) did not report data in a format amenable to evaluation, perhaps because there are no known reliable external characteristics for determining sex of paddlefish (Russell 1986). It would be worthwhile for investigators to reevaluate these and other existing paddlefish data for which length, weight, and age are separable by sex.

Our conclusion is that, among mature or maturing paddlefish, large males do occur but at a lower frequency than large females. In large rivers with reasonably predictable annual floods, such as the historical Mississippi River (Risotto and Turner 1985), female paddlefish would gain advantages in fecundity (Figures 4, 5) and, presumably, in fitness with larger body size. Their late maturity and intermittent spawning would be consistent with a low natural mortality of adults. For males, even small mature individuals would have abundant sperm so that, in the absence of some counterbalancing need for large males (e.g., courtship; Bell 1980), the advantages of delaying maturity for males would be less than for females. However, when mortality of large adult fish is increased as a result of harvest (Carlson and Bonislawsky 1981), fatal injuries from barges and motorboats (Rosen and Hales 1980), pollutants, or other factors, large size, delayed maturation, and long life spans would be less evolutionarily advantageous to both males and females (Horn 1978). A regulation protecting large, mature females from harvest mortality would thus be well suited to the life history of paddlefish.

A maximum-length limit of 114 cm in fork length would result in the protection of five to six females for every male, and all these protected females would be mature. In contrast, the sex ratio of fish harvested within the slot for the stock composition depicted in Figures 2 and 3 would be 1.16 males per female. For the stock composition in Figures 2 and 3, 69% of the female recruits and 73% of the male recruits would be eligible for harvest. Females at the 114-cm limit would weigh approximately 11.3 kg; males would weigh 9 kg. Similar protection of mature females could thus be obtained with either a maximum length limit of 114 cm in fork length or a maximum weight limit of 11.3 kg. If a weight limit were to be used, it would have the advantage of being a direct measure of what is to be protected (i.e., heavy females with eggs), but it is subject to measurement errors and would involve lifting and suspending fish for weighing and would perhaps result in added stress and gill damage. If a maximum-length limit were to be used, a limit based on body length would be preferable to one based on fork length. A body length limit would properly protect those large paddlefish that have damaged, malformed, or missing rostrums (Stockard 1907; Meyer 1960; Gengerke 1978; Rosen and Hales 1980). A body length limit would also discourage intentional disfigurement of rostrums. Based on the relations between total, fork, and body lengths developed by Gengerke (1978; Table 1), a 114-cm fork length would correspond to an 86-cm body length.

Our observations indicate that the former 2.2-kg limit for paddlefish in recreational fisheries (Iowa Conservation Commission 1956) allows the legal catch of fish about as small as are normally caught or sought by snaggers. Such a limit would protect fish with substantial growth potential. Based on formulae for females age 1–4 and relations between total, fork, and body lengths (Gengerke 1978; Table 1), such a minimum weight would correspond to a fish at a fork length of 79 cm and a body length of 57 cm. A harvest slot limit of 57–86 cm in body length or 2.2–11.3 kg in weight would be applicable to the upper Mississippi River off Iowa, but would perhaps need to be adjusted in the Missouri River and lower Mississippi River areas where paddlefish growth and maturity schedules are different (Stockard 1907; Meyer 1960; Friberg 1974). To reduce wasteful hooking mortality (Friberg 1974), no high-grading should be permitted, i.e., anglers should be required to retain any legal-sized fish, so that once a person had caught the alloted bag limit, additional snagging by that person would be prohibited. Fish outside the harvest slot would be immediately returned to the water unharmed.

## Management Considerations of the Slot Limit

### *Is It Necessary to Protect the Female Spawners?*

The critical assumption underlying the proposed harvest slot regulation is that the number and effectiveness of mature female spawners is limiting the abundance of paddlefish in the upper Mississippi River. It is assumed that, by protecting mature females and allowing them to deposit their eggs, more recruits would result. Information on the relation between stock size and recruitment of paddlefish is lacking and difficult to obtain, but it is badly needed. It is not known if paddlefish develop effective year-classes each year or if year-classes are missing because, even though data indicate that all year-classes are present (Figure 2), errors and inconsistencies are common when paddlefish are aged (Alexander et al. 1987). More information is also needed on spawning periodicity and incidence of egg reabsorption. Until the life history and population dynamics of paddlefish are better understood, it will not be possible to verify whether or not the assumption of spawning limitation is indeed accurate and the protection of mature females and their eggs is justified. However, even with high fecundity of large paddlefish (Figures 4, 5), it is reasonable to assume that spawning could be limited.

Gengerke (1978), for example, estimated from recaptures of tagged fish that Pool 13 contained 10,807 recruited paddlefish in 1976. If, as shown in Figure 2, only 5.9% of the recruits were mature females, then 645 mature females were present. If individual females spawn only every 3 years, which is conservative according to Meyer (1960), then only 215 (645/3) mature females would have spawned in the pool in that year. We are assuming that overall stock size in 1989 is as high as in 1976, even though recreational snagging effort has dropped well below that of 13 years ago because perceived abundance of fish has declined. For instance, if the stock in 1989 is only one-third that of 1976, then only 72 (215/3) mature female fish would have actively spawned in 1989. In addition, we have observational evidence from 1988 and 1989 that some mature females with large eggs do not release their eggs but hold them well past the presumed spawning season. If delayed spawning or reabsorption occurs in some years (as in the low-water year of 1988), there may have been less than 50 females actually spawning in Pool 13 in 1989.

No matter what the exact number of spawners in the upper Mississippi River and even with the admittedly speculative assumptions above, it is clear that mature, actively spawning female paddlefish typically constitute a small fraction (5% or less) of the recruits, a fraction much lower than that for most other harvested fish species. The reproductive potential of paddlefish is contained in a few large females.

If protection of large female paddlefish is desirable, several other factors should be considered in the implementation of a slot-limit regulation. These factors include possible alternatives, acceptance of the regulation by anglers, problems with hooking and handling mortality of released paddlefish, commitment to enforcing and evaluating the regulation, and coordination of the regulation with other states.

*Alternatives*

Possible alternatives to the proposed harvest slot include minimum-length limits, maximum-length limits, other harvest slots, and a protected slot. In this paper, these alternatives are evaluated according to how well they satisfy five characteristics considered to be desirable: high percentage of recruits eligible for harvest (and resultant likelihood of harvest), high percentage of eggs protected, maintenance of a trophy harvest, minimize handling and ambiguous harvest of large female fish, and increased longevity resulting in persistence of extremely large and fecund fish (larger than any fish in Figure 3). For our analyses, we assume the stock composition in Figures 2 and 3, except in our consideration of the last criterion.

Minimum-size limits would be an undesirable alternative because they would result in a low percentage of recruits eligible for harvest and, at the same time, afford little protection to large female paddlefish and their eggs. With a 129-cm minimum fork length regulation, only 6% of the recruits would be eligible for harvest, yet only 39% of the eggs would be protected (Table 2). Protection of significant numbers of eggs would be achieved only when numerical harvest was reduced to nearly zero. A trophy harvest would exist, but the handling mortality and harvest ambiguity associated with measuring large but slightly undersized females would be major drawbacks. Thus, a low minimum-size limit would fail to protect eggs and would perpetuate the selective harvest of mature females, and a high minimum-size limit would protect some eggs but essentially eliminate harvest. Neither approach would encourage longevity in individual paddlefish. Thus, minimum-size limits satisfy only the criterion for maintenance of a trophy harvest (Table 2).

In contrast, the proposed harvest slot of 57–86 cm in body length would allow 68% of the recruits to be eligible for harvest, with slightly more males eligible than females, and 96% of the eggs would

TABLE 2.—Five alternative regulations for paddlefish and how well each alternative satisfies five desirable criteria. Values were from the fork length (FL) and age distributions for females in Figures 2 and 3 and the fork length-egg number relation in Figure 4 (data from Gengerke 1978).[a]

| | Criteria examined | | | | |
|---|---|---|---|---|---|
| Regulation alternative | Percentage of recruits eligible for harvest | Percentage of eggs protected | Maintenance of trophy harvest | Minimize handling and harvest ambiguity | Longevity of individual fish encouraged |
| Minimum FL (cm) | | | | | |
| 114 | 15 | 4.4 | Yes | Problems | No |
| 119 | 11 | 8.8 | Yes | increase | No |
| 124 | 10 | 14.6 | Yes | as | No |
| 129 | 6 | 39.2 | Yes | minimum | No |
| 134 | 5 | 45.1 | Yes | length | No |
| 139 | 3 | 69.0 | Yes | requirement | No |
| 144 | 1 | 85.1 | Yes | increases | No |
| Proposed harvest slot, 57–86-cm BL[b] | 68 | 95.6 | No | Yes | Yes |
| Maximum FL, 114 cm | 85 | 95.6 | No | Yes | Yes |
| Harvest slot, 115–144 cm FL | 14 | 19.2 | Yes | No | Yes |
| Protected slot, 115–144 cm FL | 86 | 80.8 | Yes | No | No |

[a] Fishes with damaged rostrums were not included. It was assumed that any mature fish less than 115 cm FL had 134,550 eggs and that, for ages at which only some fish were mature, the largest fish of that age were the mature ones.

[b] BL (body length) = measurement from the anterior edge of the eye to the fork of the caudal fin.

be protected. Experienced anglers could quickly identify most oversized females without necessarily having to bring them into the boat. Our approach would encourage longevity of individual paddlefish. The major drawback would be the absence of a trophy harvest, the only one of our criteria not met (Table 2).

Without the minimum limit (i.e., with only a 114-cm-fork-length maximum limit), harvest of the smallest recruits would be permitted, and 85% of the recruits would be eligible for harvest with the same 96% protection of eggs. Drawbacks are lack of a trophy harvest (Table 2) and, although of secondary importance, the lack of protection for small fish.

A higher harvest slot, one for fork lengths of 115–144 cm, would protect a few of the largest females and thus 19% of the eggs, but a target fishery on large female fish would continue, and only 14% of the recruits would be eligible for harvest. Handling and ambiguous harvest of the largest females would be substantial, so the higher slot would thus satisfy only criteria for a trophy harvest and protection of the largest, most fecund fish (Table 2).

At first inspection, a plausible alternative to the proposed harvest slot would be to enact a protected slot for fork lengths of about 115–144 cm. This regulation would protect most of the mature females, but would allow the largest ones to be harvested. Overall, 86% of the recruits would be eligible for harvest, and 81% of the eggs would be protected. However, extensive handling of numerous large females would be necessary to separate out the few legal females that were present, and ambiguous harvest would be common. In addition, heavy harvest of the few trophy-sized fish would make it unlikely that large, old females would persist long once they passed the protected zone. Only three of the criteria would be satisfied (Table 2).

In summary, the proposed harvest slot satisfies four of the five criteria considered desirable and has more advantages than the two best alternatives, the maximum-length limit and the protected slot. It is also the most effective regulation for protecting the most large females and their eggs while providing a harvest of fish individually large enough to be desirable to both recreational and commercial fishers.

*Acceptance of the Regulation*

Because recreational snaggers often seek to retain the largest of the paddlefish (i.e., they practice high-grading; Kallemeyn 1975; Rosen and Hales 1980), it is not known how willingly the snaggers would accept a harvest slot regulation without a trophy harvest. Current Iowa regulations for paddlefish snagging on the upper Mississippi River are two fish per day, four in possession, with no length limits (Iowa Department of Natural Resources 1989).

Although data are lacking on the exact motivations of paddlefish snaggers, in our opinion, the two main motivations are consumption of the fish (mainly as flesh) and the status and satisfaction associated with catching a large fish. The large female fish satisfy both motivations. Other sporting values of the fish, such as fighting ability, are limited (Hussakof 1910). Large female paddlefish that are harvested are usually eaten, not mounted, and thus are not trophies in the same sense as muskellunge *Esox masquinongy* or tarpon *Megalops atlanticus*. Snaggers in Pool 13 seldom seek paddlefish for personal consumption of roe.

The slot limit would not eliminate harvest for food. Two fish within the slot limit would still provide a minimum daily catch of 4.5 kg of fish and, potentially, up to 22.7 kg. Such a yield would compare favorably by weight with yields of other recreational species. In addition, the slot limit would not eliminate a trophy fishery nor prevent status and satisfaction accruing to the snagger. Only a trophy *harvest* would be eliminated. More information is needed on how much value paddlefish snaggers place specifically on the flesh and caviar of the larger fish and on how much less desirable it might be to snag, perhaps photograph, and release a large fish than to harvest it. Snaggers should be informed that if the harvest slot limit regulation were successful, more and larger paddlefish would potentially become available in the future.

If a trophy harvest were deemed to be essential, variations on the proposed slot limit exist that would result in more protection for mature female paddlefish and their eggs than present regulations provide. A limit of one large trophy fish (above the harvest slot) per day could be allowed in addition to a limit of one fish within the proposed harvest slot. Such a regulation would maintain a trophy harvest but prevent the harvest of two large females by any one person in a day. The value of such a regulation would depend on how many trophy-sized paddlefish individual snaggers are harvesting daily.

Another more conservative alternative would be to permit harvest of a maximum of one trophy-sized paddlefish per person per year. The effectiveness of this regulation would depend on how many trophy-sized fishes are caught per person per year under present regulations. Hesse et al. (1988) reported that few snaggers fishing below Gavins Point Dam on the Missouri River caught more than four fish (of all sizes) per year, most caught fewer than three fish, and the most fish caught by any one person was 17. More information is needed on individual angler harvests of paddlefish from the upper Mississippi River before the effectiveness of either of these regulations could be estimated. However, with effective implementation of either of these two modifications (daily or annual trophy catch limits), the proposed harvest slot would satisfy all five of the criteria for an acceptable regulation.

### *Hooking and Handling Mortality*

Friberg (1974) reported that small paddlefish were snagged below Gavins Point Dam in December and held in a hatchery pond for about 4 months, during which 3 of the 21 fish died, and 8 had developed sores as a result of the snagging. Although this result was not from a controlled experiment, it argues against high-grading and indicates that more research is needed on the effect of snagging on mortality of paddlefish, particularly as it applies to large fish. Gengerke (1978) reported that of 2,012 paddlefish caught (mainly by snagging) and tagged from 1975 through 1978 in pools of the upper Mississippi River, 387 were subsequently recaptured during that period by recreational, experimental, and commercial fisheries. Evidently, substantial numbers of paddlefish can survive snagging to be caught again. Our observations from tagging paddlefish suggest that handling mortality would be greatest during the warm days of summer, but the main fishery occurs in winter and early spring before spawning time. Depending on the intensity of effort, fishery closures during the warm season may or may not be necessary.

### *Enforcement and Evaluation of the Regulation*

Because the primary areas where paddlefish are caught are well known and localized (e.g., below Lock and Dam 12, Crooked Slough area, etc.), effective enforcement is feasible. In addition, several authors have expressed the need for evaluation of paddlefish fisheries and regulations (Carlson and Bonislawsky 1981; Combs 1986; Dillard et al. 1986), and creel censuses have been conducted (e.g., Friberg 1974; Hesse et al. 1988). In the absence of information relating number of spawning adults to number of young paddlefish, monitoring the fishery for recruits may be the most practical way to evaluate the regulation. Because of the long life span of the paddlefish and the difficulty of catching small specimens, it would be several years after the regulation's enactment before any changes in stock status would be evident.

Under the proposed harvest slot limit, it would be particularly important to monitor catches within and beyond the harvest slot to make sure some females move through the slot to protected status. Under the proposed regulation, females would enter the harvest slot at age 3 and remain there until somewhere in their ninth year (age 8).

Finally, if a paddlefish harvest slot regulation were to be based on length, it would be important to set the maximum-length limit conservatively, and to enforce the regulation closely, because once female paddlefish attain a weight of about 10 kg, most of their growth is in weight and girth rather than in length. This is evident in Figures 4 and 5, which show that a nearly twofold increase in weight (from 12.8 to 23.5 kg) corresponds to a 2.7-fold increase in egg number but only a 38-cm increase in fork length.

### *Coordination with Other States*

Rosen et al. (1982) identified the need to manage paddlefish consistently within "biologically relevant regions." The regulations suggested here should be considered along the upper Mississippi River by states adjacent to Iowa, and consistency of harvest slot regulations among these states should be sought for both recreational and commercial fisheries. The proposed harvest slot limits will do little good for the highly migratory paddlefish unless Iowa and adjacent states with paddlefish fisheries agree on uniform or similar regulations. The basic biological rationale for harvest slot limits presented here is applicable to both commercial and recreational fisheries.

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