

## **Feasibility of a Commercial Paddlefish Harvest from Norris Reservoir, Tennessee**

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*Abstract:* Mark-recapture techniques were used to estimate the abundance of harvestable size paddlefish (*Polyodon spathula*) in Norris Reservoir, Tennessee, during spring 1980. Results indicated a harvestable population of 8,772 fish with a 95% confidence interval of 4,557 to 18,467. A comparative study using gill nets of various bar mesh sizes showed that gill nets with 17.8-cm bar mesh or larger were more efficient for collecting harvestable paddlefish while having less adverse impact on sport fish species than did nets with smaller mesh sizes. Based on these results, recommendations include allowing commercial harvest on a contract basis of no more than 1,315 paddlefish (15% of the population estimate) or 395 female paddlefish which ever occurs first during the first year harvest, restricting harvest to the month of April, requiring the use of 17.8-cm bar mesh or larger gill nets, assessing the impacts on the fishery at the completion of the first year, and adjusting the harvest quotas for subsequent years if necessary.

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Reduced imports of Iranian sturgeon caviar during the late 1970's and early 1980's increased the demand for paddlefish roe. The immediate effect was increased commercial fishing pressure on paddlefish populations in the Tennessee Valley. Harvest of this species in the Tennessee Valley just prior to 1977 was primarily for flesh which was marketed as "boneless cat" in most fish markets. Roe had little market value and was often discarded. During 1977 and 1978 market value of paddlefish ranged from \$0.25 to \$2 per pound. However, by spring 1979, roe was valued at \$12-\$15 per pound. Market value of roe continued rising to \$20-\$25 per pound in 1981. By spring 1980, many commercial fishermen throughout Tennessee were fishing almost exclusively for paddlefish. This rapid increase in the value of paddle-

fish roe resulted in many fishermen changing gear types to secure a more selective catch. Small mesh 7.6- and 10.2-cm sinking gill and trammel nets were replaced by 12.7- and 15.2-cm floating and sinking nets. These larger mesh nets are more effective in harvesting paddlefish, especially larger specimens which are likely to be females bearing roe.

During the late 1970's, the Tennessee Wildlife Resources Agency (TWRA) began receiving increased pressure from commercial fishermen to open Norris Reservoir for paddlefish harvest. Paddlefish had been harvested from Norris Reservoir during a rough fish removal program conducted during 1959, 1960, and 1961 (Carroll et al. 1963). Norris Reservoir was closed to commercial fishing at the end of the 1961 season, and has remained closed to date. Current paddlefish stocks were believed to have recovered from the effects of this original exploitation. Illegal fishing violations began to escalate and commercial fishermen lobbied in the State legislature for legislative acts to open Norris Reservoir to paddlefish harvest. These acts would have forced the TWRA to open waters to commercial fishing, without any consideration for management of the resource.

Early researchers recognized that commercial over-exploitation could severely reduce paddlefish stocks (Alexander 1914, 1915, Stockard 1907) and efforts to protect paddlefish were first made in 1915 when the Louisiana Conservation Commission invoked a 6-month season (1 January to 15 July) closed to all commercial fishing (Alexander 1915). Harned (Harned, C. N., unpubl. rep., *Management recommendations for Polyodon spathula* (Walbaum) in Tennessee Waters. Tenn. Div. of Water Resour., Norris, 1979.) documented the effects of harvest on an unexploited paddlefish population in Lake Cumberland, Kentucky. In 1968 a commercial fisherman received a contract from the State of Kentucky for rough fish removal. Within 9 months of the date commercial fishing began, harvest declined to the point it was not economically feasible to continue fishing. Similar results were documented during a rough fish removal program conducted on Norris Reservoir from 1959 to 1961. During the first year, paddlefish accounted for 49% (20,256 kg) of the total harvest. Harvest declined to 32% (5,684 kg) of the total harvest in 1960, and 1,038 kg (17%) in 1961. The average weight of paddlefish taken decreased from 25.9 kg during 1959 to 16.7 kg during 1961. Barkley Lake, Kentucky, was opened to special permit gill and trammel net fishing seasons from 1 November, 1979, to 31 March, 1980 (Bowers, C. C., Jr., unpubl. rep., *Special permit gill and trammel net fishing*, Ky. Dept. Fish and Wildl., Frankfort, 1980.), and for the corresponding period in 1980-1981 (Ted Crowell pers. commun.). During the first season 7,015 paddlefish weighing 62 metric tons were harvested. Average weight per fish was 8.8 kg. During the 1980-1981 season, paddlefish harvest declined to 3,685 fish weighing 21.5 metric tons, with an average weight per fish of 5.8 kg.

In February 1980 a cooperative study was initiated by the TWRA and the Tennessee Valley Authority (TVA) to determine the feasibility of a commercial paddlefish harvest from Norris Reservoir. The objectives of this study were to: 1) determine the abundance of harvestable size paddlefish in Norris Reservoir, 2) to collect basic life history information needed to develop a rational management plan for the paddlefish resource, and 3) determine if this reservoir could be opened to limited commercial fishing without significantly impacting sport fish species.

## Methods

Norris Reservoir is a storage impoundment located on the Clinch and Powell Rivers in northeast Tennessee. Norris Dam is located at Clinch River Mile (CRM) 79.5 and provides a complete barrier to upstream fish movement. At normal full pool elevation (310.9 m) the dam impounds 90 km of the Powell River and 116 km of the Clinch River. The water level is reduced 18 to 24 m each fall and winter for flood control. Minimum water level usually occurs in January; maximum in late spring or early summer. Shoreline length at full pool elevation is 1,286 km and the surface area is 13,840 ha (Moss, D. D., unpubl. ms., Handbook of Tennessee reservoirs. Tenn. Tech. Univ., Cookeville, 1967.). Norris Reservoir is a deep (maximum depth approximately 61 m), relatively clear water (usually 2.5 to 3.0 m visibility), mesotrophic impoundment characterized by steep banks and deep coves. Exposed points consist either of rocky outcroppings, gravel, clay, silt, or hard clay shale.

For the purposes of this study, Norris Reservoir was divided into 2 gill net sampling areas. Area A extended from Powell River Mile (PRM) 38 to PRM 52, and Area B extended from CRM 110 to CRM 147. These sampling areas are riverine in character with relatively constricted channels 100 to 200 m wide with depths ranging from 3 to 10 m.

Sampling for paddlefish was conducted over 2 spawning seasons and was centered in the upper reaches of the Powell and Clinch River arms of Norris Reservoir. Although paddlefish were collected on the spawning run, the 2 gill net sampling areas were not considered spawning sites as spawning was expected to occur upstream from the sampling areas. Paddlefish were tagged during the spawning run in 1980 and recaptured the following spring.

The 1980 sampling period consisted of 10 net nights beginning 29 February and ending 2 July. Fish were captured with 91.2 m x 2.4 m large mesh (10.6- and 12.7-cm bar mesh) floating and sinking gill nets. Netting was done at night to maximize catch per effort and minimize conflict with sport fishermen. To reduce netting mortality, nets were pulled and reset at intervals of <2 hours whenever possible. Captured paddlefish were placed in a hold-

ing tank in the boat until the net was pulled and reset. Weight, body length (anterior orbit of eye to fork of tail), and sex were recorded, and prior to release paddlefish were tagged with numbered Petersen disc tags. These tags were attached on the left mandible with nylon electrical wire straps. Tag numbers of recaptured paddlefish were recorded and the fish released. In addition to information on paddlefish, number of individuals of other species captured was recorded.

Male paddlefish were differentiated from female paddlefish by body conformation (males being more cylindrical and elongate with abdomen not being distended) and the presence of tubercles which give the male head a rough feeling texture. Gravid females were rotund, having noticeably distended abdomens. Females also had smooth head regions. The vents of female paddlefish were more elastic and larger in diameter, allowing entry of the smallest finger for tactile examination of the ovary. Paddlefish have relatively large eggs when fully developed; therefore, ovaries will feel bumpy when eggs are mature.

While artificially propagating paddlefish for other studies, we rarely observed flowing ripe females. Ovulation had to be induced. Most males, however, released a small amount of milt when initially captured. Thus, it was possible to distinguish between sexes based on whether or not milt was released. Although no one characteristic can be used to absolutely determine the sex of paddlefish, the several criteria used have proven reliable.

Recapture sampling was done during 9 net-nights beginning 13 April and ending 30 April, 1981. In addition to 12.7-cm mesh nets used during the 1980 sampling period, 17.8-, 20.3-, and 22.9-cm bar mesh (91.2 m x 3.7 m) gill nets were used to recover tagged paddlefish and to determine the effectiveness of various mesh size gill nets on the capture of paddlefish and sport fish species. Paddlefish were not tagged during recapture sampling, but in an effort to determine number of recaptures during the 1981 netting period, paddlefish were marked by clipping an approximate 1-inch section from the tip of the opercular flap. The right opercular flap was clipped on paddlefish collected in the Powell River arm while the left opercular flap was clipped on fish collected from the Clinch River arm. Data from all marked and tagged fish recaptured were recorded and these fish released.

In addition to netting operations, a creel survey was conducted during April 1981 when a small snag fishery for paddlefish developed on the Powell River arm of Norris Reservoir. Information collected from this survey included the number of tagged and untagged paddlefish harvested. These data were combined with netting data collected during the recovery period to estimate abundance.

Abundance of harvestable size paddlefish was estimated using Chapman's modification (in Ricker 1975) of Petersen's single census method:

$$N = \frac{(M + 1)(C + 1)}{R + 1}$$

where, N = estimated number of fish in population

M = number of fish marked

C = total catch

R = number of recaptures

The upper and lower confidence limits were calculated using values from Ricker's (1975) table for the Poisson distribution as less than 10% of the marked fish were recaptured (Lackey and Hubert 1977).

In order to eliminate potential bias due to localized sampling, sampling was conducted over 2 spawning periods to allow marked fish to randomly mix with unmarked fish. To eliminate the effect of recruitment on the population estimate, a length frequency distribution (5-mm increments) was plotted to estimate mean annual growth for fish in size classes representing potential recruits. All paddlefish captured in 1981 smaller than the smallest group of paddlefish collected in 1980 plus the mean annual growth were not considered in the population estimate.

Several researchers have reported evidence that paddlefish may not spawn annually (Meyer 1960, Elzer 1977, Carlson and Bonislawsky 1981). We have been able to confirm that some female paddlefish of sufficient size to be sexually mature are not gravid during the spawning season. We suspect not all paddlefish make annual spawning runs (Gengerke 1978; R. W. Pasch, P. A. Hackney, and J. A. Holbrook II, unpubl. rep., Ecology of the paddlefish, *Polyodon spathula* (Walbaum), in Old Hickory Reservoir, Tennessee, with emphasis on first year life history and the effects of impingement at Gallatin Steam Plant on the population, Div. Nat. Resour., TVA, Knoxville, 1978). Collection of nongravid females near spawning grounds, however, leads us to believe most adult paddlefish move to the upper portion of reservoirs (areas netted in this study) they inhabit during the spawning season. We have seen no evidence indicating males do not spawn annually. Therefore, we included all tagged paddlefish in our population estimate.

## Results and Discussion

During the 1980 sampling period 203 paddlefish were tagged and released. One hundred ninety-two were released near where they were captured in the Powell River arm of Norris Reservoir, 2 were released in the Clinch River arm, and the remaining 9 were released near Norris Dam. Dur-

**Table 1.** Number and Mean Weight of Paddlefish Collected in the Powell and Clinch River Arms of Norris Reservoir in 1980 and 1981

	Number		Mean Weight (kg)		
	Male	Female	Male	Female	Sexes Combined
<b>1980</b>					
Powell River	164	8	13.03	21.79	
Clinch River	4	5	18.98	29.33	
Total	168	13	13.17	24.70	13.98
<b>1981</b>					
Powell River	164	30	13.50	22.84	
Clinch River	36	16	17.58	27.19	
Total	200	46	14.24	24.41	16.14

ing this period there were 8 recaptures. Weights were recorded for 181 paddlefish collected in 1980 (Table 1). Average weight for all paddlefish was 13.98 kg. Males averaged 13.17 kg and females averaged 24.70 kg.

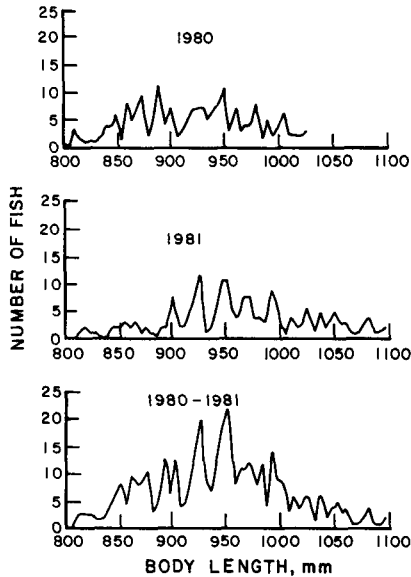
During the 1981 sampling period, 246 paddlefish were collected; 5 of these were tagged in 1980. Of the untagged fish, 216 were marked with an opercular clip prior to release. Five of these marked fish were recaptured and removed from consideration when calculating the population estimate. Average weight of the 246 paddlefish collected in 1981 was 16.14 kg (Table 1). Males averaged 14.24 kg and females averaged 24.41 kg. Catch per effort for paddlefish collected in 17.8- and 20.3-cm nets was more than double that of the 12.7-cm nets (Table 2).

Paddlefish collected from the Clinch River arm of Norris Reservoir were significantly larger by weight ( $P < 0.05$ ) than those collected from the

**Table 2.** Catch Rates of Paddlefish and Striped Bass Using Various Mesh Sizes of Floating and Sinking Gill Nets in Norris Reservoir, 1981.

	12.7 cm		17.8 cm		20.3 cm		22.9 cm	
	F <sup>1</sup>	S	F	S	F	S	F	S
Net hours fished	39	62	44	2	15	0	3	2
% of total fishing effort	23.0	37.0	26.0	1.0	9.0	0.0	2.0	1.0
Striped bass per net hour	0.15	0.16	0.02	0.00	0.00		0.00	0.00
Paddlefish per net hour	1.05	0.82	2.70	1.00	2.20		0.00	0.00

<sup>1</sup> F = Floating gill net; S = Sinking gill net



**Figure 1.** Length Frequency in 5mm Groups of male Paddlefish in Norris Reservoir.

Powell River arm (Table 1). This difference held true when comparing fish of the same sex and fish collected in the same size mesh nets from both arms. These data indicate the paddlefish population in Norris Reservoir is divided into 2 distinct stocks. However, recovery of tagged fish during the 1981 sampling period does not support this interpretation. One hundred ninety-two of the 203 fish tagged during 1980 were released in the Powell River arm; 2 of the 5 subsequently recaptured during 1981 were collected in the Clinch River arm. These 2 individuals were tagged and released in the Powell River arm during 1980. This indicates substantial mixing of stocks identified in spawning runs, or at least "crossing-over" from the Powell River arm to the Clinch River arm occurred.

One hundred nine paddlefish were reported harvested by sport snagging from the upper area of the Powell River arm of Norris Reservoir on 21 and 22 April, 1981. Two of these fish were reportedly tagged. These fish were included in the calculation of the population estimate.

The length frequency distribution indicated groupings of fish into 25- to 30-mm classes (Fig. 1). This grouping was consistent for both years for fish 800 to 1,000 mm BL. Growth appeared to slow to 10 to 15 mm annually at about 1,000 mm BL. Although more than 1 age class may be represented in

each of these groups due to the growth differential in individuals, the mean annual growth for fish in this size range appears to fall between 25 and 30 mm. This was supported by the measured annual growth of tagged fish that were recaptured. The mean annual growth for the 5 recaptured fish was 32 mm with a range of 21 to 52 mm. To eliminate the effects of recruitment on the population estimate, all fish smaller than 800 mm BL (the smallest grouping of fish collected in 1980) plus 30 mm (mean annual growth) in the 1981 sample were excluded from the calculation of the population estimate. Seven fish were thereby removed from consideration. The addition of paddlefish reported during the creel survey minus the fish believed to have been recruited during the study period brought the total number of fish collected in 1981 to 343 with 7 recaptures.

The population of harvestable size paddlefish in Norris Reservoir during April and May 1980 was estimated to be 8,772 with a 95% confidence interval of 4,557 to 18,467. This is considered an estimate for the entire reservoir at the time of marking.

It was estimated that 20 to 30 fishermen harvested about 200 paddlefish by sport snagging in the Powell River arm during 1 week in April 1981. This harvest is considered unusually high. During this period, Norris Reservoir was lower than usual and the backwater had not reached Earls Hollow boat ramp. This boat ramp had been extended into the river channel during the winter 1980-1981 creating a dam approximately halfway across the river at that point. This constriction of the river channel created a chute over a shoal that increased the water velocity making it difficult for upstream migration. As spring rains increased the flow in the Powell River, paddlefish began moving upstream until reaching this blockage. There they were concentrated for a few days until the backwater inundated the shoal making upstream migration possible. Although these circumstances could repeat themselves, it is unlikely that the sport harvest of paddlefish could be developed or have any long-term impact on the paddlefish stocks in Norris Reservoir.

In addition to paddlefish, 60 fish representing 12 species were collected during the 2 sampling periods (Table 3). Striped bass (*Morone saxatilis*) was the only sport fish species collected in large enough numbers to be of any concern. A total of 27 individuals was captured over the 2 sampling periods and comprised 45% of the fish collected, other than paddlefish. During 1980 sampling, 10 striped bass were collected in 10 net nights. These fish were collected in 10.6- and 12.7-cm bar mesh gill nets. Of the 17 striped bass collected in 1981, 6 were collected in 12.7-cm floating gill nets, 10 in 12.7-cm sinking gill nets, and 1 in a 17.8-cm gill net. Catch per effort was much higher for striped bass and lower for paddlefish with relatively small mesh, 12.7-cm gill nets than with 17.8- and 20.3-cm nets (Table 2).



**Table 3.** Fish Collected With Gill Nets from Norris Reservoir in 1980 and 1981 During Paddlefish Sampling

Species	1980	1981
Paddlefish, <i>Polyodon spathula</i>	203	246
Longnose gar, <i>Lepisosteus osseus</i>	1	2
Carp, <i>Cyprinus carpio</i>	1	1
River carpsucker, <i>Carpiodes carpio</i>	3	0
Quillback, <i>Carpiodes cyprinus</i>	3	1
Golden redbhorse, <i>Moxostoma erythrurum</i>	0	1
redhorse, <i>Moxostoma</i> sp.	0	1
Channel catfish, <i>Ictalurus punctatus</i>	0	1
Flathead catfish, <i>Pylodictis olivaris</i>	1	11
White bass, <i>Morone chrysops</i>	2	0
Striped bass, <i>Morone saxatilis</i>	10	17
Striped x white bass hybrid, <i>Morone saxatilis</i> x <i>chrysops</i>	1	0
Freshwater drum, <i>Aplodinotus grunniens</i>	2	1
Totals	227	282

### Management Recommendations

Norris Reservoir appears to have an adequate number of harvestable size paddlefish to allow a limited commercial harvest based on the population estimate derived from this study. The potential to over-exploit this fishery in a relatively short time was demonstrated during the rough fish removal program conducted during 1959–1961. Therefore, a conservative approach should be taken.

Management regulations typically used are restrictions on gear, seasons, open waters, size limits, and yearly harvest quotas. Opening Norris Reservoir to commercial harvest using any of these restrictions, other than a harvest quota, would leave the outcome in doubt and have the potential to adversely impact this fishery. Management plans can be developed to ensure this resource is properly maintained by evaluating effects of removing a selected number of paddlefish over a 2-year period. This evaluation would include observing changes in catch rates, size distribution, and age structure for paddlefish harvested during the first 2 years.

An experimental quota should be set for the first year's harvest. In a study similar to ours, Gengerke (1978) reported an 18% exploitation rate was not excessive. In an effort to simulate an exploitation rate near that reported by Gengerke we recommend 15% (1,315 paddlefish) of the population estimate (8,772) be harvested. This should ensure protection from over-exploitation. Harvest quotas can be adjusted after the first year if necessary.

To ensure culling of male paddlefish in favor of females does not occur, harvest of female paddlefish should be limited to 30% of the total har-

vest. Fishing should be allowed until 1,315 paddlefish or 395 female paddlefish are harvested, whichever occurs first.

Separate harvest quotas should be established for the Powell and Clinch Rivers because of disproportionate catch per effort for paddlefish in these 2 areas. Harvest on the Clinch River arm should be limited to 395 fish with no more than 118 being females. This would allow 920 paddlefish, 277 females, to be harvested from the Powell River arm.

This fishery should be opened on a contract basis to ensure adherence to the harvest quota. Contractual agreements should include special requirements needed to properly regulate the fishery and to ensure accurate information collection. For example, all fishermen should be required to check in and out at one point established on each river. Fish should be landed at these checkout points where they should be weighed, measured, sex determined, and mandible taken for aging studies. Collection of this information should allow development of future management plans.

Mesh size for gill nets should be restricted to 17.8 cm mesh and larger to ensure minimal impact on all sport fish population. Fishing of nets should be allowed Monday through Friday from sunset to sunrise to minimize conflict with sport fishermen.

To conduct a commercial fishery in this manner will require substantial manpower for regulation and data collection. Therefore, the harvest should occur when paddlefish are the most vulnerable to minimize time required to fill quotas. In addition a season from 1 April to 30 April should be imposed to minimize manpower requirements and costs.

The estimated total market value for 1,315 paddlefish is \$85,000 based on an average 8 lbs of roe per female valued at \$25 per lb and \$0.30 per lb for flesh (dressed weight is 50% of live weight). Paddlefish harvested from the Clinch River arm should be worth approximately \$25,000 while the value of paddlefish from the Powell River arm should be approximately \$59,000.

At the completion of the first season, harvest and life history data should be evaluated to establish quotas for the next year. Two consecutive fishing seasons are expected to supply sufficient data for developing long-range management plans for Norris Reservoir paddlefish stocks.

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