POPULATION ECOLOGY OF PADDLEFISH IN THE KEYSTONE RESERVOIR SYSTEM, OKLAHOMA

By

CRAIG PATRICK PAUKERT

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Thesis Approved:

William L. Fisher
Thesis Advisor

Anthony A. Echelle

Dale Toetz

Wayne B. Powell
Dean of the Graduate College

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

Chapter II

Chapter IV

LIST OF FIGURES

Figure Page

Chapter II

Chapter III

Chapter IV

CHAPTER I.

Introduction

This thesis is composed of three manuscripts. Chapter I is an introduction to the rest of the thesis. Chapter II and III are written in the format suitable for submission to Transactions of the American Fisheries Society; Chapter IV is in a format suitable for submission to North American Journal of Fisheries Management. The manuscripts are as follows; Chapter II, "Population biology and reproductive activity of paddlefish in a prairie reservoir system", Chapter III, "Factors affecting summer distribution and movement of paddlefish in a prairie reservoir", and Chapter IV, "Evaluation of paddlefish length distributions and catch rates in three mesh sizes of gill nets with a suggested approach to standardize catch rates".

CHAPTER II.

Population Biology and Reproductive Activity of Paddlefish in a Prairie Reservoir System

Abstract.--Life history characteristics of paddlefish Polyodon spathula in the Keystone Reservoir system, Oklahoma, a prairie impoundment in southwestern edge of the paddlefish's range, were investigated from 1996-1998. The objectives of this study were to (1) determine distribution, abundance, population attributes, and exploitation of paddlefish in the system and (2) determine their spawning areas and reproductive activity. A total of 1,412 paddlefish were collected during the winter months from 1996-1998. Catch rate differences and recaptures indicated high use of the Cimarron River arm of Keystone Reservoir during late winter 1996, and high use of Salt Creek, the lower Cimarron River arm, and the Arkansas River arm of the reservoir in 1997 and 1998. Maximum age of paddlefish was 14 years; growth rates were high and similar to other Oklahoma and Louisiana populations. Condition factors (1.79-1.97) were some of the highest reported in the literature. Annual mortality estimates (27-34%) was intermediate compared with populations in northern and southern waters. However, low exploitation rates indicated mortality was primarily natural. Paddlefish spring spawning migrations were more dependent on water flows than water temperature or photoperiod. Flows from the Salt Fork River, a major tributary of the Arkansas River, appear to influence year-class strength more than the Arkansas and Cimarron rivers. Suitable spawning substrate was found in the Salt

Fork River, an area of high paddlefish use in spring. Although paddlefish migrate up the Cimarron River arm of Keystone Reservoir in spring, limited spawning habitat may prevent successful spawning in that river. Paddlefish in prairie river systems have unique challenges to their survival because these river systems are not typically conducive to successful reproduction. However, paddlefish in the Keystone Reservoir system appear to have adapted to the higher spring water temperatures and fluctuating flows enabling successful reproduction.

The paddlefish Polyodon spathula inhabits large rivers and reservoirs throughout the central United States. Significant natural populations occur in the Yellowstone River in Montana, the Missouri River, the Mississippi River, the Cumberland River system in Tennessee, the Neosho River in Oklahoma, and the Alabama River. Paddlefish have diminished in numbers during the last century due to destruction of spawning grounds, exploitation, dam construction, river channelization, dewatering of rivers, and pollution (Carlson and Bonislawsky, 1981).

Previous studies of paddlefish have focused on their distribution, movement, and habitat use in rivers of the northcentral U.S. (Gengerke 1978; Rosen et al. 1982; Southall and Hubert 1984; Moen et al. 1992). However, little is known about habitat use by paddlefish in reservoir environments (Russell 1986).

Population attributes have been documented for paddlefish in large rivers and reservoirs, mostly in the southeastern U.S. (Pasch et al. 1980; Hageman et al. 1988; Hoffnagle and Timmons 1989; Reed et al. 1989; Hoxmeier and DeVries 1997). In both rivers (Gengerke 1978; Hoxmeier and DeVries 1997) and reservoirs (Combs 1982; Hoffnagle and Timmons 1989; Reed et al. 1992; Scarnecchia et al. 1996), paddlefish growth is rapid during the first two years of life and decreases to annual increments of less than 10% after about 3-4 years (Reed et al. 1992). Paddlefish older than 15 years are common in many populations (Russell 1986), and the maximum age is 55 (Scarnecchia et al. 1996). Size and age structure of recently established paddlefish populations, however, is not well documented.

Paddlefish traditionally migrate up rivers to spawn in spring (Unkenholtz 1982; Russell 1986). Spawning occurs in flowing water over silt-free gravel (Purkett 1961) at temperatures between 10-17 C (Pitman 1991). However, gravel is sparse in prairie rivers of the southcentral and southwestern U.S., and paddlefish may be required to spawn over other substrates (Bonislawsky 1977). Also, river stage and discharge are usually highly regulated and may not exhibit the natural flow regime in spring (Unkenholtz 1986).

Over-exploitation is one of the major factors contributing to the decline in paddlefish abundance (Carlson and Bonislawsky 1981). There has been concern over recreational and commercial exploitation since Purkett (1961) concluded the Osage River, Missouri population may have been over-exploited. Combs (1982) found exploitation in Grand Lake, Oklahoma, the most popular paddlefish fishery in Oklahoma, to be 15-19%. Exploitation of paddlefish in other Oklahoma reservoir systems is unknown.

Keystone Reservoir, a prairie reservoir in northcentral Oklahoma, was created in 1964 through impoundment of the Arkansas River near the confluence of the Cimarron River. Paddlefish were present in the Arkansas and Cimarron rivers before Keystone was impounded (Linton 1961), and anecdotal reports indicate that the population has been increasing ever since (Bonislawsky 1977; Gengerke 1986; Ambler 1994). A springtime snag fishery for paddlefish has developed throughout the Keystone Reservoir system (Don Hicks, Oklahoma Department of Wildlife Conservation, personal communication). However, apart from these reports, nothing is known about the paddlefish population in this system.

The objectives of this study were to (1) determine the distribution, abundance, other population attributes, and exploitation and (2) locate spawning areas and document reproductive activity of paddlefish in the Keystone Reservoir system.

Study Site

Keystone Reservoir is a 10,600-ha impoundment on the Arkansas and Cimarron rivers in northcentral Oklahoma, 13 km west of Sand Springs (Figure 1). Maximum reservoir depth is 23.3 m, average depth is 7.7 m, and Secchi disk readings reach 1.1 m in summer (Hicks 1993). Large water-level fluctuations are common due to the large size of the watershed, power generation, and regulation of the Arkansas and Salt Fork rivers. The Cimarron River drains part of western Oklahoma that is highly mineralized, which leads to the relatively high salinity concentrations throughout the

Cimarron River arm of Keystone Reservoir (Eley 1970). The Arkansas River drains the southern plains of Kansas and has high concentrations of calcium and magnesium sulfate (Eley 1970). The Salt Fork of the Arkansas, a major tributary of the Arkansas River that enters the Arkansas River 152 km upstream from Keystone Reservoir, is heavily influenced by the natural salt flats of northwestern Oklahoma and is impounded by Great Salt Plains Dam 165 km upstream from the mouth of the Arkansas River. Conductivity readings are generally higher in the Cimarron River arm than the Arkansas River arm of the reservoir. The Cimarron River is unimpounded upstream Keystone Reservoir and exhibits highly fluctuating flows. The Arkansas River is impounded 176 km above Keystone Reservoir by Kaw Dam and has regulated flows.

Methods

Sampling procedures.--We used a stratified random design to determine sampling sites in the four areas of the reservoir: Arkansas River arm, Cimarron River arm, main pool, and Salt Creek arm (Figure 1). The reservoir was divided into 1.6-km long sampling reaches along the channels of the Arkansas River, Cimarron River and Salt Creek, a large tributary of the Cimarron River arm. Reaches with maximum water depth less than 3.1 m were removed from the pool of potential sites because paddlefish prefer deeper waters and the gill nets we used were greater than this depth. Because the areas varied in size, samples were proportionally allocated to each area with a minimum of three sites per area (Thompson 1992).

Adult and juvenile paddlefish were collected with 127-mm, 152-mm, and 203-mm bar measure mesh gill nets, 91-m long, and 4.5-m, 6.4-m, or 9.2-m deep; the nets were set at locations in the channel during the winter months (January-March 1996; November 1996-February 1997; December 1997-March 1998). Nets were usually fished overnight (16-22 hours). Most nets were set perpendicular to the main river channel, and when possible, reached across the entire channel. Nets were occasionally set in adjacent shallow flats to capture small (<500 mm) paddlefish.

Each fish collected was measured, to the nearest millimeter, from the anterior orbit of the eye to the fork of the tail (EFL; Ruelle and Hudson 1977), weighed (nearest 0.5 kg), and tagged with a #16 individually numbered monel jaw tag. Jaw tags were labeled with the address and phone number of Oklahoma State University and a reward was given to increase tag returns by anglers. Tagged fish were released near their capture site. Because no known external characteristics can accurately distinguish between the sexes (Graham et al. 1986), sex was determined only for fish that died in the nets.

The size of the paddlefish population in Keystone

Reservoir was determined with a modified Schnabel multiple-mark-recapture estimator (Krebs 1989). Because recaptures were less than 50, 95% confidence limits were calculated from the Poisson distribution (Krebs 1989). Relative abundance, catch per unit effort (CPUE), was defined as number of fish collected/108 m^2 of gill net/24-hr set time.

Dentary bones were used to age paddlefish. These bones, which were removed from fish that died in the gill nets, were cleaned, and sectioned using a low-speed, diamond-edged sectioning saw. Several sections 22-25 μm thick were cut posterior to the lateral bend where the jaw begins to straighten. Sections were immersed in a clearing solution (glycerol) and viewed under a projector with transmitted light. Age was determined by counting annuli and associated halo bands along the mesial arm (Adams 1942). Back calculation was made by measuring the distances from the annuli to the central lumen (Reed et al. 1992). The Fraser-Lee method was used to back-calculate length at age (DeVries and Frie 1996). Fulton's condition factor (K) was estimated by

$$\underline{K} = (\underline{WT} \times 10^5)/\underline{EFL}^3,$$

where WT is weight in kg and EFL is eye-fork length in mm.

In spring 1996 and 1997, conical plankton nets were suspended for 10-20 min from bridges throughout the

Cimarron, Arkansas and Salt Fork rivers, and Salt Creek, a tributary of the Arkansas River, to collect paddlefish larvae. The nets were 0.5 m in diameter, 2.5 m in length with 0.5-mm mesh netting, and fitted with collecting buckets 10.2 cm in diameter and 30.5-cm long. The contents of the samples were preserved in 10% formalin and enumerated in the laboratory. At each sampling site, water temperature, dissolved oxygen, and conductivity were measured with a multi-parameter meter (model H20, Hydrolab Inc., Austin, TX). Water flow data were obtained from the United Sates Geological Survey (USGS) gauging stations nearest each sampling site.

In March 1997, six male paddlefish were implanted with ultrasonic transmitters (Sonotronics, Tuscon, AZ) to track them to their spawning grounds. In January-March 1998, and additional 18 fish (9 males and 9 females) were implanted with transmitters. Distribution and movement of these fish along with the previous implanted six fish were monitored in spring 1998. Transmitters were implanted using the procedures described by Paukert (1998).

Beginning in February 1998, the transmitter-tagged paddlefish were tracked with a digital receiver (Sonotronics model USR 5W) and a directional hydrophone (Sonotronics model DH-2) to determine when and where they staged in the reservoir before migrating upriver to spawn. Tracking was conducted weekly and increased as fish moved towards the presumed staging areas. Once fish left the reservoir, the Cimarron, Arkansas, and Salt Fork rivers were searched weekly. Early on, searches were conducted in all three rivers each week, beginning with the lower stretches near the reservoir. Later, tracking was conducted at known paddlefish concentrations and throughout the rivers when possible. Once a fish was located, its location coordinates were determined with a global positioning system receiver. Substrate, habitat type, and depth were recorded at sites where fish were located, and temperature, dissolved oxygen, and conductivity were recorded 1 m below the surface at these locations. Water flow data were obtained from USGS gauging stations nearest each fish location. River sections in which fish were located were searched more intensely for the remainder of the spring. Because of the vast extent of rivers in this system, our efforts were focused on areas of known paddlefish locations or where adequate spawning substrate occurred. Tracking ended when the transmitter-tagged fish were located back in the reservoir after the spring migration. Periodically throughout spring 1998, Keystone Reservoir was searched to determine if fish remained in the reservoir.

In spring 1997 and 1998, gill netting and snagging were used to collect paddlefish in the rivers to determine their distribution and reproductive status. Gill nets were also used in the reservoir in spring 1997 to determine when paddlefish returned to the reservoir from the rivers after the spawning migration. Gill nets were drifted through deep holes and bends throughout the rivers, and snagging was used when concentrations of paddlefish were located. Each paddlefish collected was weighed and measured, and sex was determined by biopsy or the presence of milt or eggs observed after squeezing the abdomen. Each fish was also inspected for a jaw tag.

The relationship between year-class strength and water flows were compared by examining the number of paddlefish collected in each age class and the magnitude of flows in the Arkansas, Cimarron and Salt Fork rivers. River flows were expressed as percent of normal flow for each month from February-May for each year, the period when paddlefish were located in the rivers during the spawning migration. Mean monthly water flow values for USGS gauging stations were taken from Blazs et al. (1997).

Statistical analysis.--Differences in catch rates among years and reservoir areas were tested with analysis of variance (ANOVA) or, when the assumptions of the ANOVA were not met, the Kruskal-Wallis procedure. Condition factors were log transformed to meet the ANOVA assumptions when more than two groups were compared. A Wilcoxon Rank Sum test was used to compare the condition of two groups when the assumptions were not met. Means comparisons were made with a Fishers Least Significant Difference or a similar non-parametric comparison (Conover 1980). Linear regression was used to determine relationships between condition and length and to estimate total instantaneous mortality (Z) of the fully recruited portion of each stock. We estimated Z as the descending limb of a plot of the natural log of the number of paddlefish collected from each age class versus age (catch curve). Simple annual mortality was estimated as $1-e^{-Z}$ (Van Den Avyle 1993). To compare condition factors for recaptured tagged fish, a paired t-test was used or, when the assumptions of the test were not met, a Wilcoxon Signed Rank test was used. All statistical analysis were preformed in SAS (Schlotzhauer and Littel 1987) with a significance level set at $\underline{P} < 0.05$.

Results

Population Size.--We collected a total of 1,412 paddlefish in Keystone Reservoir during the winter months of 1996-1998. Of these, 1,138 were tagged with monel jaw tags. The remaining were either fish that died in our nets (mortalities; 161), recaptures (67), too small to tag (17), or not tagged (29). Fish whose survival was questionable were released without a tag. Overall mortality for the three year study was 11.4%, and mortalities increased significantly when the water temperature was above 10 C for extended periods of time. In light of this, during the last two years of the study we sampled when water temperatures were cooler, thereby reducing the number of fish that died.

We estimated the size of the paddlefish population (>500 mm EFL) in Keystone Reservoir to be 6,540 (95% CI: 3,980-12,717) fish in 1996, 8,922 (95% CI: 5,152-18,437) fish in 1997, and 10,251 (95% CI: 7,476-52,531) fish in 1998. Paddlefish density was estimated at 0.62. 0.84, and 0.97 fish/ha for the three successive years. Population estimates of paddlefish were lower in 1996 probably because the age-0 fish were too small to tag. By 1997, these fish were of tagable size (Figure 2). Our largest estimate in 1998 may have resulted from low numbers of recaptures. However, the trend for the three years suggests that the population is increasing in size.

Distribution and movement.--Distribution of paddlefish, based on catch rates, varied among reservoir areas and years (Table 1). Catch rates in the Arkansas River arm were highest in 1997 and 1998 and lowest in 1996 ($P = 0.04$). Conversely, catch rates in the Cimarron River arm were highest in 1996 and lowest in 1997 and 1998 ($P < 0.01$). Main pool catch rates were variable and showed no trend over the three-year period ($P = 0.03$). Similarly, catch rates in Salt Creek did not differ between 1997 and 1998 ($P = 0.12$), the two years this area was sampled (Table 1). In 1996, we collected the majority of paddlefish in the Cimarron River arm compared to other areas ($P < 0.01$). However, in 1997 our highest catch rates were in Salt Creek and our lowest were in the Cimarron River arm and main pool ($P < 0.01$). There was no difference in catch rates among reservoir areas in 1998 ($P = 0.16$; Table 1).

Recaptures of jaw-tagged paddlefish also indicated that there were high numbers of paddlefish in the Cimarron River arm in 1996 and these fish moved to other areas of the reservoir in 1997 and 1998. Fifty-nine percent of all recaptures at large at least one year were tagged in the Cimarron River arm in 1996 and recaptured in the Arkansas River arm or the Salt Creek arm in 1997 and 1998. It appeared that paddlefish did not return to the Cimarron arm in 1997 or 1998 in the same abundance that was there in 1996. Recaptures in 1998 and 1997 showed no trend in movement to or from any area of the reservoir.

Thirty-five percent of angler tag returns were from locations downriver from Keystone Dam. These fish were accidentally caught by anglers, intentionally snagged, or found dead.

Age and growth.--A total of 106 paddlefish dentary bones were removed for age analysis. The size range of these fish (329-1,323 mm EFL) reflected the size range of paddlefish found in the reservoir (Figure 2). Mean back-calculated length at age of paddlefish did not differ among years ($\underline{P}$ > 0.004 with Bonferroni corrections), so all years were pooled. Ages of all other fish were assigned using the back calculated mean length at age.

The oldest paddlefish, captured in 1996, was 14 years old (Table 2). Median age increased from 3 in 1996 to 4 in 1997 to 5 in 1998. Many paddlefish were between 6 and 13 years old. Instantaneous mortality for the fully recruited paddlefish population was higher in 1996 (Z = -0.414, $\underline{r}^2$ = 0.94) than in 1997 (Z = -0.315, $\underline{r}^2$ = 0.61) and 1998 (Z = -0.310, $\underline{r}^2$ = 0.83; Figure 3). Annual mortality rates were 33.9% in 1996, 29.2% in 1997, and 26.6% in 1998.

Paddlefish growth varied substantially with age. The mean length increment for age-1 fish was 233 mm (Table 2), indicating a relative annual growth rate (EFL_{t+1} - EFL_t / EFL_t) of 57.4%. Growth decreased substantially in older fish, and relative growth rates were less than 10% per year after age 4. Increases in length for recaptured fish at large one sampling season ranged from 7 to 191 mm, and for two sampling seasons ranged from 31 to 167 mm. Weight gains ranged from 0 to 7.5 kg for one sampling season and from 0.5 to 11.5 kg for two sampling seasons.

Year class strength.--Paddlefish year-class strength was evaluated using catch curve data from 1993-1997. One of the assumptions of a catch curve is constant recruitment over time (Van Den Avyle 1993). This rarely occurs in paddlefish populations and most likely did not occur in our case. However, catch curves have been used to assess year-class strength when recruitment was not constant (Hoxmeier and DeVries 1997). We also examined the relationship between year class strength and river flows. Normal water flows, based on the monthly averages for each station from 1942-1996, were 44-144 m^3/s for the Arkansas River below Kaw Dam, 15-48 m^3/s in the Salt Fork River, and from 30-145 m^3/s in the Cimarron River. Strong year classes were evident in 1993 and 1995 (Figure 3). In 1995, river flows in the Salt Fork River were high (139-221% of normal) in March and May and low (68-89% of normal) in February and April. In addition, the Cimarron River mean monthly flows for February-May 1995 were always lower than normal (53-86%). Low flows were present below Kaw Dam (21-96%) in all months except May, which had flow of 140% of normal. In 1993, all rivers were high throughout the spring (120-760% of normal), except below Kaw Dam in April (89% of normal) and the Cimarron River in February (75% of normal).

Weak year classes were evident in 1997, 1996, and 1994 (Figure 3). In 1997, flows varied among rivers and months. The Salt Fork River was near normal during all spring months in 1997 (100-105%). In contrast, flows below Kaw Dam were low to normal in March and April (62-101% of normal) and high in February and May (191-221% of normal). Cimarron

River flows were low in March and May (49-61%) and high in February and April (188-327%). In 1996, low flows occurred in all rivers from February through May (3-62% of normal). In 1994, low flows (16-92% of normal) were evident in all rivers from February-May except in the Cimarron River in April (139%) and below Kaw Dam in May (209%).

Condition.--The mean condition factor of paddlefish for the three years combined was 1.85 (SD = 0.28). Paddlefish condition was highest in 1996 and lowest in 1997 ($P < 0.01$; Table 3). To determine if this trend was because smaller fish were captured in 1996, we regressed condition factor against length. Paddlefish condition was dependent on length ($P < 0.01$), but length explained very little of the variation ($r^2 = 0.03$). Paddlefish found dead in our nets had lower condition factors ($P < 0.01$) than live fish, but the difference was small (1.86 for live fish and 1.79 for dead fish).

Condition of recaptured paddlefish at initial capture and after they had been at large for one and two years was analyzed to determine if jaw tags had any detrimental effect on condition. There was no significant difference after one year ($P = 0.42$; N = 27), but condition was lower after two years ($P = 0.03$; N = 14).

Exploitation.--Twenty-nine tags were returned by the public during the three-year study. Twelve were snagged, five were collected by trot line, five were found dead, four were accidentally caught by anglers, and circumstances were unknown for three tags. For each year, exploitation rates were calculated from tag returns from fish tagged during that year. In 1996, only 2 of 382 tags were returned by anglers for an exploitation rate of 0.5%. Both fish were taken on a trot line. In 1997, 5 of 420 tagged paddlefish were snagged for an exploitation rate of 1.2%. Two fish tagged in 1998 were caught on trot lines in 1998 for an exploitation rate of 0.6%.

Reproduction.--Sampling for early life stages of paddlefish was conducted on 10 April 1996 at four locations on the Chikaskia River, Salt Fork River, and Salt Creek. No paddlefish eggs or larvae were collected. Low flows (8-92 m^3/s) precluded sampling beyond mid-April in 1996. In 1997, we sampled for paddlefish eggs and larvae from 15-26 April at four locations on the Arkansas, Salt Fork, and Cimarron rivers. Sampling locations were determined from previous reports of spring paddlefish locations and nearby spawning substrate. Water temperatures (10-18 C) and water flow (75-269 m^3/s) were within the range suitable for paddlefish spawning. However, no paddlefish eggs or larvae were collected.

Spawning migrations.--Paddlefish spawning migrations in Keystone Reservoir were more dependent on water flow than water temperature or photoperiod. Paddlefish did not make spawning migrations in spring 1996, presumably because of low flows (8-52 m^3/s) in the rivers. However, water temperatures in February-March were 6-11 C, and paddlefish usually migrate upriver after water temperatures reach 10 C (Purkett 1961). Spawning migrations occurred in spring 1997 (based on gill net catches and tag returns in the rivers) and in spring 1998 (based on transmitter-tagged fish locations and jaw tag returns in the rivers). High water flows in 1997 (>750 m^3/s) and 1998 (>1400 m^3/s) likely prompted paddlefish to migrate up the rivers (Figure 4). Paddlefish did not appear to stage in the upper ends of the reservoir in 1997, based on little change in gill net catch rates in the upper reaches of the reservoir; however they left the reservoir during high flows, despite relatively low water temperatures (6-8 C). Paddlefish did stage in the upper ends of the reservoir in spring 1998. Of 17 fish located on 17 March, 10 were in the upper reaches of the Arkansas River arm and three were in the upper reaches if the Cimarron River arm. Paddlefish left soon afterwards, although water temperatures were again low (6-7 C). Paddlefish migrated upriver to spawn on different dates each year. In 1997, paddlefish left in late February with high flows, while in 1998 fish left during increased flows in mid-March (Figure 4). No migrations occurred in spring 1996.

In 1997 paddlefish were located in the Cimarron, Arkansas and Salt Fork rivers from 1 March-11 April (Table 4). Additionally, an angler caught a paddlefish previously tagged in the Kaw Dam tailwaters in the tailwaters on 9 June, indicating that some fish may remain in this area longer than others. Paddlefish were located in the Cimarron River near Cushing, OK (river km 95; Figure 5) where a snag fishery sometimes develops upriver to Perkins, OK (river km 138; Randall Reigh, Oklahoma Department of Wildlife Conservation Game Warden, personal communication). Paddlefish were also found in the Arkansas River in the Kaw Dam Tailwaters, 176 km upriver from Keystone Reservoir and in the Salt Fork River as far upriver as river km 15, 167 km upstream from Keystone Reservoir (Figure 5). Angler reports indicate that a snag fishery develops below Great Salt Plains Dam on the Salt Fork River 217 km upriver from Keystone Reservoir. In contrast, six male paddlefish implanted with transmitters in March 1996 remained in and made extensive movements within the reservoir during the spring spawning migrations. Length distributions from reservoir gill netting in winter compared to May gill netting in the reservoir indicated larger (>1,000 mm EFL) fish were located back in the reservoir in the same proportion as in winter beginning 16 May (chi-square goodness-of-fit test; $\underline{P} = 0.56$).

Paddlefish also migrated upriver to spawn in spring 1998 (Table 4). Seventeen transmitter-tagged fish were located in the reservoir on 17 March, and on 21 March, only two males were located in the upper reaches of Keystone Reservoir; the remainder of the fish moved upriver to spawn (Table 4). Transmitter-tagged paddlefish were located in the Cimarron and Salt Fork rivers from 2 April to 27 May. In contrast, five searches of the Kaw Dam tailwaters from 29 March to 15 May located no transmitter-tagged fish (Figure 6). In addition, no tag returns from anglers were from the Arkansas River in 1998 (Figure 5), and poor snagging success was reported in the Kaw Dam tailwaters in spring 1998. In searches of 138 km of the Cimarron River, only one transmitter-tagged fish was located (a female near Cushing, OK at river km 95; Table 4, Figure 6). Because of this, we abandoned future searches of the Cimarron River. On 16 sampling trips from 2 April to 27 May, we found eight different transmitter-tagged paddlefish in the Salt Fork River from river km 0 to river km 40 (Table 4, Figure 6). Movement of five of these eight fish was highly variable in spring 1998; however, paddlefish tended to move upriver when flows increased (Figure 7). Water temperatures in the Salt Fork River (up to 27 C) were well above optimum spawning range (10-17 C; Pitman 1991). In addition to the transmitter-tagged fish, we snagged 35 paddlefish (mostly small males; mean length 890 mm EFL, SD = 103 mm) in the Salt Fork River from 17 April to 21 May. Two of the fish were recaptures of fish jaw-tagged in the reservoir. In addition, one tag was returned by an angler from the Salt Fork River (Figure 4). One gravid female (1,256 mm EFL) was caught on 21 May, in 27 C water temperature. Searches of Keystone Reservoir on 15 April and 2 May indicated that 11 male transmitter-tagged paddlefish (890-1,132 mm EFL) did not make the spring spawning migration. Transmitter-tagged paddlefish located in the rivers during spring were first located back in the reservoir on 18 May (one female found in the Cimarron River and a 1,260 mm male last located in the Salt Fork River, Table 4). All five females located in the Salt Fork River on 20-21 May were among the 21 fish located in Keystone Reservoir on 29 May (Table 4), indicating that high flows (>300 m^3/s) in the Salt Fork River on 25-28 May triggered paddlefish to recede from the rivers to the reservoir (Figure 7).

Water flows from the tributaries of Keystone Reservoir appear to direct paddlefish migrations. In 1998, we neither located transmitter-tagged paddlefish nor received tags from anglers from the Kaw Dam tailwaters, the most popular paddlefish fishery in the system. This may have been the result of low discharge from Kaw Dam in mid-March when fish left the reservoir and moved up the Arkansas River. Concurrently, high flows occurred in the Salt Fork River, 152 km upstream from Keystone Reservoir and 24 km downstream from Kaw Dam (Figure 8). Paddlefish were first located in the Salt Fork River on 2 April and remained in the rivers until late May when high flows triggered downstream movements back to the reservoir (Table 4, Figure 7). Gill net collections and tag returns by anglers in the tailwaters of Kaw Dam indicated a significant number of fish from Keystone Reservoir moved up to the tailwaters in 1997.

Paddlefish spawning substrate is minimal in the Keystone Reservoir system. We did not locate adequate or even marginal spawning substrate in the Cimarron River. In contrast, the Kaw Dam tailwaters had large expanses of suitable substrate (1.3 - 3.8 cm gravel; Purkett 1961; Figure 9). Although the Salt Fork did not have large gravel bars, smaller patches of gravel as well as cobble were identified throughout the river system. Also, the Chikaskia River, which enters the Salt Fork at river km 40 has gravel shoals throughout its lower reach (Figure 9).

Discussion

Population attributes.-- Our population estimates of paddlefish in Keystone Reservoir were variable, but showed an overall increase over the three-year study. Our confidence intervals were wide because of low recapture rates, but this is not uncommon in population estimates of paddlefish. Ambler (1994) also reported high confidence intervals in Grand Lake, Oklahoma. One of the assumptions of the modified Schnabel population estimator is that the population is closed to immigration and emigration (Krebs 1989). Although we confirmed emigration of fish over Keystone Dam based on several tag returns downriver from Keystone Dam, we believe emigration was minimal during our winter sampling season (a period when paddlefish remain in reservoir; Russell 1986) because there were few high water events that would have allowed paddlefish to pass over the dam. Our density estimates of paddlefish (0.62-0.97 fish/ha) were similar to corresponding estimates in Grand Lake, Oklahoma (0.69-2.99 fish/ha; Ambler 1994) and Lake Cumberland, Kentucky (0.64 fish/ha; Hageman et al. 1988). However, our density estimates were considerably lower than those for paddlefish in an unfished sub-impoundment of Lake Barkley, Tennessee (8.80 fish/ha; Boone and Timmons 1995). Our findings suggest that the Keystone Reservoir paddlefish population is similar in size to other large reservoir populations and, based on our results and previous anecdotal reports (Gengerke 1986; Ambler 1994), is increasing in size.

Paddlefish distribution within reservoir systems is not well understood (Russell 1986). Van Eckout (1980) found concentrations of paddlefish in a large wind-swept embayment of Lake Sakakawea during the summer, whereas Hageman et al. (1988) observed a fall upstream migration in Lake

Cumberland, Kentucky. In Keystone Reservoir, catch rates of paddlefish differed among areas and years. High catch rates in the Cimarron River arm in 1996, particularly at the upper end on the Cimarron River arm indicated that paddlefish were staging in the Cimarron River arm waiting for spring flows to migrate upriver to spawn. However, we believe the distribution of paddlefish in the winters of 1997 and 1998 was more typical, with more fish in the lower Cimarron River arm, Salt Creek, and the Arkansas River arm. The morphometry of the lower Cimarron River arm and the Arkansas River arm are very similar, with a wide, poorly defined channel and deep (>10 m) water. Salt Creek, which enters the lower Cimarron River arm, may have had large numbers of paddlefish because of its close proximity to the lower Cimarron River arm. Also, sampling efficiency was probably higher in Salt Creek because of the more defined channel and constriction points. In 1996, the first indication of large numbers of fish in the Cimarron River arm of the reservoir occurred in mid-February, one-and-one-half months after our sampling began. Paddlefish typically stage in the upper ends of the reservoir when water temperatures rise to 10 C and move upriver when flows increase (Russell 1986). This may have occurred in the Cimarron River arm of the reservoir in 1996; paddlefish were already staging during that time. In 1997 and 1998 our sampling started earlier (November) and paddlefish started moving upriver from mid-February to mid-

March. Catch rates in the Arkansas River arm of the reservoir appeared highest at intermediate distances from the dam. Sampling efficiency may have been low in the lower Arkansas River arm, the widest section of the reservoir, and low catch rates in the upper Arkansas River arm indicate few paddlefish use this shallow region. Telemetry tracking results also indicated high paddlefish use of the lower and middle Arkansas River arm in summer, but fish were rarely encountered upstream of Arkansas River km 18 (Paukert 1998). The main pool of Keystone Reservoir had lower catch rates throughout the three-year study, probably because of low sampling efficiency in this wide, deep area of the reservoir. However, telemetry tracking revealed substantial use of this area by paddlefish in summer (Paukert 1998).

Winter movement of paddlefish in Keystone Reservoir varied more among years than among areas of the reservoir. Recaptures during our winter sampling indicated that fish tagged in the Cimarron River arm in 1996 moved to other areas of the reservoir in 1997 and 1998. In contrast, paddlefish tagged in 1997 showed no fidelity to any area of the reservoir after being at large for one year. Recaptures of fish tagged during the same sampling season indicated variable movement throughout the reservoir; however, most fish remained in the same area in which they were tagged.

Body condition of paddlefish in Keystone Reservoir was among the highest reported for the species (Table 3). Body condition of reservoir populations is generally higher than riverine populations because paddlefish traditionally thrive in plankton-rich reservoir waters (Russell 1986). We would expect body condition to be more similar among populations in southern U. S. reservoirs than among those in northern waters. Our paddlefish condition factors were most similar to those for populations in the Osage River, Missouri, and higher than those in Louisiana (Reed 1989) and Alabama (Hoxmeier and DeVries 1997) waters. However, the Alabama River population may be genetically different from other paddlefish populations (Epifanio et al. 1996).

Paddlefish growth in Keystone Reservoir was similar to populations in other large southern reservoirs (e.g. Grand Lake, Oklahoma and Lake Pontchartrain, Louisiana) and higher than in riverine populations (e.g. Alabama River, Alabama, the Arkansas River, Oklahoma, and the Mississippi River, Iowa; Figure 10). Growth rates were rapid in the first four years of life and decreased to less than 10% after age 4. Reed et al. (1992) noted relative growth rates of paddlefish in Louisiana decreased to less than 10% after age 3. In Kentucky, paddlefish exhibited high relative growth rates as well (Hoffnagle and Timmons 1989). Keystone Reservoir paddlefish exhibited fast growth and a relatively short lifespan, with a maximum age of 14 years. Fast growth is common in reservoirs, particularly in those with water level fluctuations that increase plankton abundance during high water periods (Houser and Bross 1959). Growth rates of paddlefish in Keystone Reservoir were higher compared to those reported for individuals collected in a pre-impoundment study of the Arkansas and Cimarron rivers (Linton 1961; Table 2, Figure 10). Linton (1961) reported a maximum paddlefish length of 511 mm and age of seven years. In contrast, paddlefish in Keystone Reservoir reached 639 mm at age 2. Paddlefish have been aged at 55 years (Scarnecchia et al. 1996), but maximum ages of 30 years are more common, with populations commonly having fish 15 years old (Russell 1986). Maximum age of paddlefish in southern waters (Combs 1982; Reed et al. 1992; Hoxmeier and DeVries 1997) is comparable to what we found for the Keystone Reservoir population.

Our annual mortality estimates of 27-34% were intermediate between those for populations in northern and southern U. S. waters. Because exploitation is low in the Keystone Reservoir system, we believe our total annual mortality rates primarily reflect natural mortality. In Louisiana, Reed et al. (1992) reported total annual mortality (considered mainly as natural mortality) to be 26-48%. Similarly, Hoxmeier and DeVries (1997) found annual mortality estimates from 34-36% in the Alabama River. Harvest can have a significant effect on total annual mortality estimates. In South Dakota (Rosen et al. 1982) and Iowa (Gengerke 1978), about half of the 18-44% annual mortality was from exploitation. In contrast, Boone and Timmons (1995) found annual mortality of 9% in a small unfished impoundment in Tennessee. In a commercially-exploited reservoir in Tennessee, annual mortality rates were as high as 69% (Hoffnagle and Timmons 1989). In Oklahoma, commercial fishing for paddlefish was closed in 1991. However, most commercial fishing was in Grand Lake, Oklahoma and probably little commercial exploitation has occurred in Keystone Reservoir. Exploitation of paddlefish from sport fishing has been a concern since the mid 1950s (Combs 1986). Sport fisheries often develop in dam tailwaters during spring spawning migrations (Unkenholtz 1986). In the Keystone Reservoir system, the most popular sport fishery for paddlefish is the tailwaters of Kaw Dam, 176 km upstream of Keystone Reservoir on the Arkansas River. Other sport fisheries exist on the Cimarron and Salt Fork rivers, but are more limited because of poor access and limited concentration areas for paddlefish. Exploitation from sport fishing was minimal in the Keystone Reservoir system. Throughout our three-year study, exploitation ranged from 0.5-1.2%. Combs (1982) suggested that exploitation rates of 15% or lower were necessary to sustain paddlefish populations. Although non-reporting of tags is a problem when estimating exploitation (Gengerke 1978; Rosen et al. 1982), we believe that exploitation of the Keystone Reservoir population would still be minimal even if non-reporting is high (e.g. 50%).

Reproductive activity.--For paddlefish to spawn successfully, there needs to be a suitable combination of water flows, water temperature, and spawning substrate (Russell 1986). Photoperiod may also play an important role in the initiation of spring spawning migrations (Lein and DeVries 1994). Paddlefish spawning migrations in the Keystone Reservoir system seem to be more influenced by water flow than by water temperature or photoperiod. In 1996, water temperatures were suitable for the fish to move up the rivers in February and March, but low flow and apparently shallow water prevented their migration. In contrast, high flows in February 1997 were triggered movement of paddlefish up the rivers to spawn, although water temperatures remained low. In March 1998, high flows were associated with movement of paddlefish to their staging areas in the upper Cimarron and Arkansas river arms of the reservoir; the fish migrated upriver soon after, even though water temperatures were 7-8 C, which is below the optimum staging water temperature of 10 C (Purkett 1961; Pitman 1991). Tag returns in 1997 from the Kaw Dam tailwater revealed these fish moved 176 km to Kaw Dam in just a few days. In the White River, Arkansas, Filipek (1990) found paddlefish movement up to 35 km/day, and fish in Lake of the Ozarks, Missouri moved up to 45 km overnight (Russell 1972).

Paddlefish spawn at water temperatures between 10-20 C, with most activity occurring between 12-18 C (Purkett 1961; Wallus 1986; Pitman 1991). We did not document paddlefish reproduction in the Keystone Reservoir system; sampling for larvae in 1996 and 1997 proved unsuccessful. This may have been a reflection of our low and sporadic sampling effort in this large river system. In South Dakota, Unkenholtz (1982) collected only 46 larval paddlefish in 1,122 hours of netting from 1975-1981. In an eight-year study in Tennessee, Wallus (1986) collected 269 larval paddlefish. Despite our failure to collect paddlefish eggs or larvae, we are certain they spawn, or attempt to do so throughout the system when environmental conditions permit. Paddlefish moved up the rivers in the Keystone Reservoir system in 1997 and 1998 and remained there for up to two months. Water temperatures were within the suitable spawning range for paddlefish in both years. However, in 1998, paddlefish were located in the Salt Fork River beyond the maximum preferred spawning range of 18 C. Paddlefish tracked in the Salt Fork were mainly mature females and some may not have spawned. We collected a gravid female by snagging in the Salt Fork River on 21 May 1998 in 27 C water temperature. In addition, anglers reported snagging gravid females during this time. Maximum water temperature of reported paddlefish spawning in the wild is 25 C (Jerry Hamilton, Missouri Department of Conservation, personal communication). Within a few days after we collected the gravid female, increased flows of 323 m^3/s apparently initiated paddlefish movement back to the reservoir. Because of the high water temperatures and the fact that most female paddlefish return to the reservoirs immediately after spawning (Kim Graham, Missouri Department of Conservation, personal communication), we believe some individuals may not have spawned in 1998.

Increased water flows during spring apparently trigger paddlefish to spawn (Russell 1986; Wallus 1986). Wallus (1986) suggested that water flows >275 m^3/s were needed for successful reproduction in Tennessee. In Missouri, Purkett (1961) found that a 3-m rise in water levels triggered spawning. In contrast, Hoxmeier and DeVries (1997) indicated that water levels >6 m were a key to successful reproduction in Alabama. The Keystone Reservoir system is typical of other prairie river systems throughout the southwest, with highly fluctuating spring flows regulated by impoundments. However, high flows of the duration typically needed for paddlefish spawning do not occur every year. Based on our spring migration studies and year-class strength evaluations, paddlefish in the Keystone Reservoir system need sustained periods of high water and cooler water temperatures for successful reproduction. Strong year-classes in 1995 and 1993 indicate the Salt Fork River may have a pronounced influence on the reproductive success of paddlefish in the system. In years with strong year classes, the Salt Fork River always had above normal flows. In contrast, weak year-classes were associated with low flows from the Salt Fork River. The Cimarron River, which contains sparse spawning habitat, had low flows in 1995, a strong year-class for paddlefish, and had periods of high flows in 1997 and 1994, years which produced weak year-classes. Releases from Kaw Dam on the Arkansas River may also have an effect on paddlefish migration and year-class strength. In 1995, spring flows below Kaw Dam were below normal but a strong year class was still evident.

Female paddlefish may not spawn annually but may only spawn every 4-5 years (Russell 1986). Our data indicate that most female paddlefish migrate up the rivers each year during the spawning migration, but they may not successfully spawn. In spring 1997, no paddlefish >1,000 mm EFL, including females, were collected in the reservoir. In spring 1998, none of the nine transmitter-tagged females was located in the reservoir, while seven of these females were located in the rivers; all nine were located back in the reservoir in late May. Smaller male paddlefish are capable of spawning every year, but they may remain in the reservoir during the spring spawning migration. All six of the transmitter-tagged male paddlefish remained in the reservoir in 1997, and several transmitter-tagged male paddlefish remained in the reservoir in 1998. However, several smaller males were located in the rivers, indicating that there is no distinct difference in the size of males that made the spawning migration.

Conservation implications.--Creation of impoundments may diminish recruitment of paddlefish by destroying spawning grounds (Carlson and Bonislawsky 1981). In some instances, natural paddlefish populations have been extirpated by impoundments. However, paddlefish occurred in the Arkansas and Cimarron rivers before the impoundment of Keystone Reservoir (Linton 1961), and anecdotal reports, along with our data, suggest the population may be increasing. With their relatively short lifespan, we would have expected the population to have higher fecundity (Hoxmeier and DeVries 1997) or a younger at age of maturity to compensate. We did not estimate fecundity, but paddlefish in the Keystone Reservoir system appear to mature at an early age. We found enlarged testes in male paddlefish as small as 600 mm EFL (about 2 years old). The smallest mature female we collected was 960 mm EFL (about 5-6 years old). These life history adaptations seem to be sustaining the Keystone Reservoir population.

Reproduction in the system is influenced by the extreme physical conditions common in prairie rivers. Highly fluctuating and regulated flows in impoundments may alter reproductive strategies and cause paddlefish to reproduce in program of the U.S. Geological Survey, Biological Resources Division; the Oklahoma Department of Wildlife Conservation; Oklahoma State University; and the Wildlife Management Institute.

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Table 1.--Mean catch per unit effort (CPUE) of paddlefish in four areas of Keystone Reservoir, Oklahoma, 1996-1998. Salt Creek was not sampled in 1996. Means without a letter in common were significantly different (*P* < 0.05) within (a-c) and among (x-y) years.

Year	Area	CPUE	Range	N
1996				
	Arkansas arm	0.28 a,x	0.00 - 1.84	33
	Cimarron arm	1.83 b,y	0.00 - 9.11	39
	Main pool	0.12 a,x	0.00 - 0.53	21
1997				
	Arkansas arm	0.56 b,y	0.00 - 2.86	73
	Cimarron arm	0.34 a,x	0.00 - 2.22	77
	Main pool	0.23 a,xy	0.00 - 1.31	20
	Salt Creek	1.22 c,x	0.00 - 2.87	16
1998				
	Arkansas arm	0.47 a,y	0.00 - 2.42	60
	Cimarron arm	0.39 a,x	0.00 - 1.96	65
	Main pool	0.38 a,y	0.00 - 2.07	17
	Salt Creek	0.78 a,x	0.00 - 3.69	19

Table 2.--Mean length (EFL, mm) at age of paddlefish in the Keystone Reservoir system and the Arkansas River prior to impoundment. Standard errors given when available. Numbers in parenthesis are number of fish contributing to each mean length.

Age	Keystone Reservoir, OK[1]	Arkansas River, OK[2]
1	406 ± 5.2 (106)	202
2	639 ± 6.2 (103)	294
3	779 ± 7.4 (79)	361
4	877 ± 9.8 (52)	425
5	934 ± 14.2 (25)	486
6	985 ± 21.0 (17)	508
7	1012 ± 25.2 (12)	551
8	1051 ± 28.1 (11)	
9	1065 ± 32.1 (9)	
10	1094 ± 38.2 (8)	
11	1106 ± 38.3 (7)	
12	1118 ± 44.3 (6)	
13	1138 ± 45.1 (6)	
14	1055 (1)	

[1] This study

[2] Linton 1961

Table 3.--Condition (K) factors of paddlefish from selected locations in the United States.

Location	Year	K	SD	N	Reference
Keystone Reservoir, OK	1996	1.97	0.34	444	This study
	1997	1.79	0.25	544	This study
	1998	1.82	0.21	418	This study
Missouri R., SD-NE	1972-79	1.50	0.23	294	Rosen et al. 1982
Osage R., MO	1958-65	1.97[1]	*		Russell 1972
	1958-65	1.61[2]	*		Russell 1972
Lake Cumberland, KY	1984	1.55	*	612	Hageman et al. 1986
Louisiana	1986-89	1.06	*	332	Reed 1989
Alabama River, AL	1994-95	1.20-1.41[3]	*	428	Hoxmeier and DeVries 1997

[1] denotes condition for females.

[2] denotes condition for males.

[3] denotes range of condition values for all sizes and habitat types.

* not reported.

Table 4.--Locational statistics of paddlefish sampled in the Keystone Reservoir system, Oklahoma during spring 1997-1998. In 1997, numbers of recaptures tagged in Keystone Reservoir are in parenthesis. Blank cells indicate no sampling was conducted in that area.

	1997 gill net and snagging catch				1998 telemetry observations			
Week	Keystone Reservoir	Cimarron River	Arkansas River	Salt Fork River	Keystone Reservoir	Cimarron River	Arkansas River	Salt Fork River
28 Feb - 8 Mar	28(4)							
9-15 Mar	12	11(1)	10(2)		17			
16-22 Mar			0	9	2		0	
23-29 Mar		3		7		0	0	
30 Mar-5 Apr		1		2			0	5
6-12 Apr			10			1		0
13-19 Apr					8		0	8
20-26 Apr		0						5
27 Apr-3 May		0	0		9			0
4-10 May	10(1)			0				3
11-17 May	14(1)						0	3
18-24 May	2				13			5
25-31 May					21			

Figure 1. Keystone Reservoir and its major tributaries. River km distance are from Keystone Dam or, for the Salt Fork River, from the confluence of the Arkansas River.

Figure 2. Length (EFL) distributions for paddlefish collected in Keystone Reservoir during the winter months, 1996-1998.

Figure 3. Catch curve for paddlefish collected in Keystone Reservoir, 1996-1998. Mortality estimates (Z) were based on the descending limb of the catch curve. Ages indicated in legend are ages used for mortality estimates.

Figure 4. Mean daily discharge for the Cimarron and Arkansas rivers, 1996-1998, recorded at USGS gaging stations 77 km and 54 km upstream from Keystone Reservoir, respectively. Horizontal bars represent dates that paddlefish were located in both rivers in spring 1997 and 1998. Paddlefish were not found in the rivers in 1996.

Figure 5. Paddlefish locations (from gill-netting, snagging, and jaw-tag recaptures) in the Keystone Reservoir system, 1997 and 1998.

Figure 6. River sections searched and areas within those sections in which transmitter-tagged paddlefish were

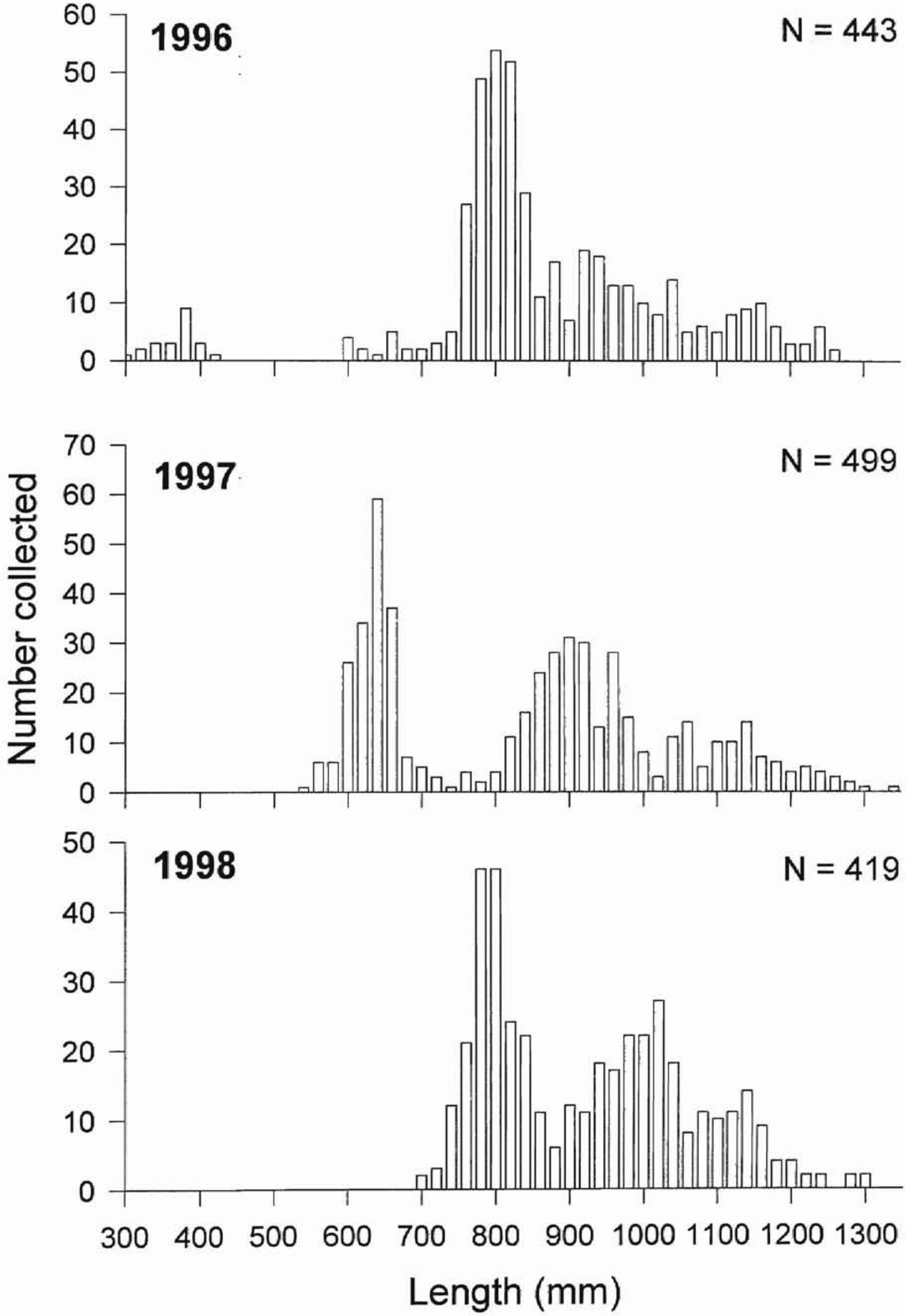
located, spring 1998.

Figure 7. Distribution and movement of 5 transmitter-tagged female paddlefish located in the Salt Fork River, Spring 1998. Kilometers are from the confluence of the Arkansas River. The heavy line is mean water flows on the Salt Fork River. Arrows indicate movement back to the reservoir. Dotted lines indicate paddlefish were not located during that period, although search efforts were conducted in that area.

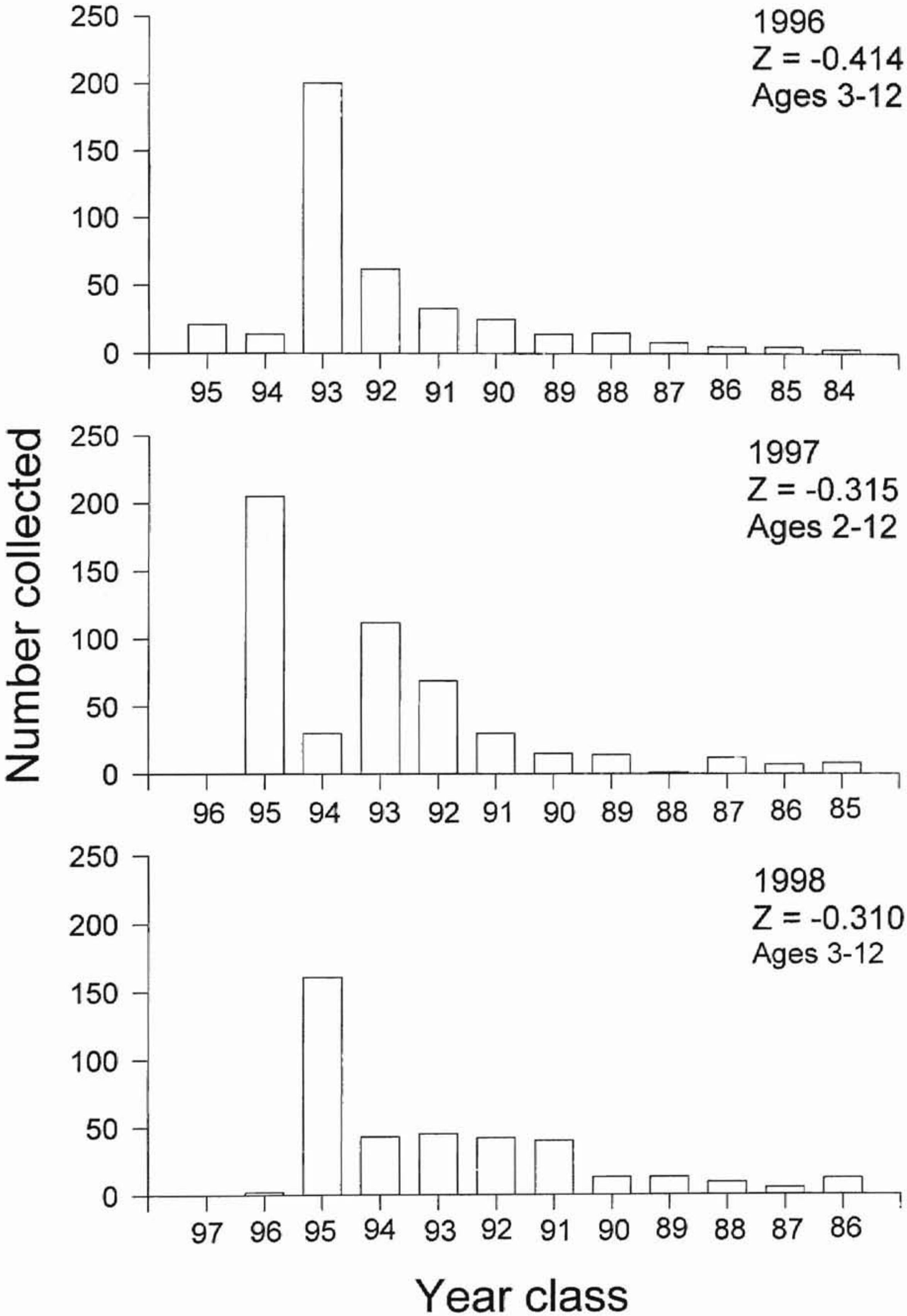
Figure 8. River flows from the Arkansas River 13 km downriver from Kaw Dam and the Salt Fork River, spring 1997 and 1998.

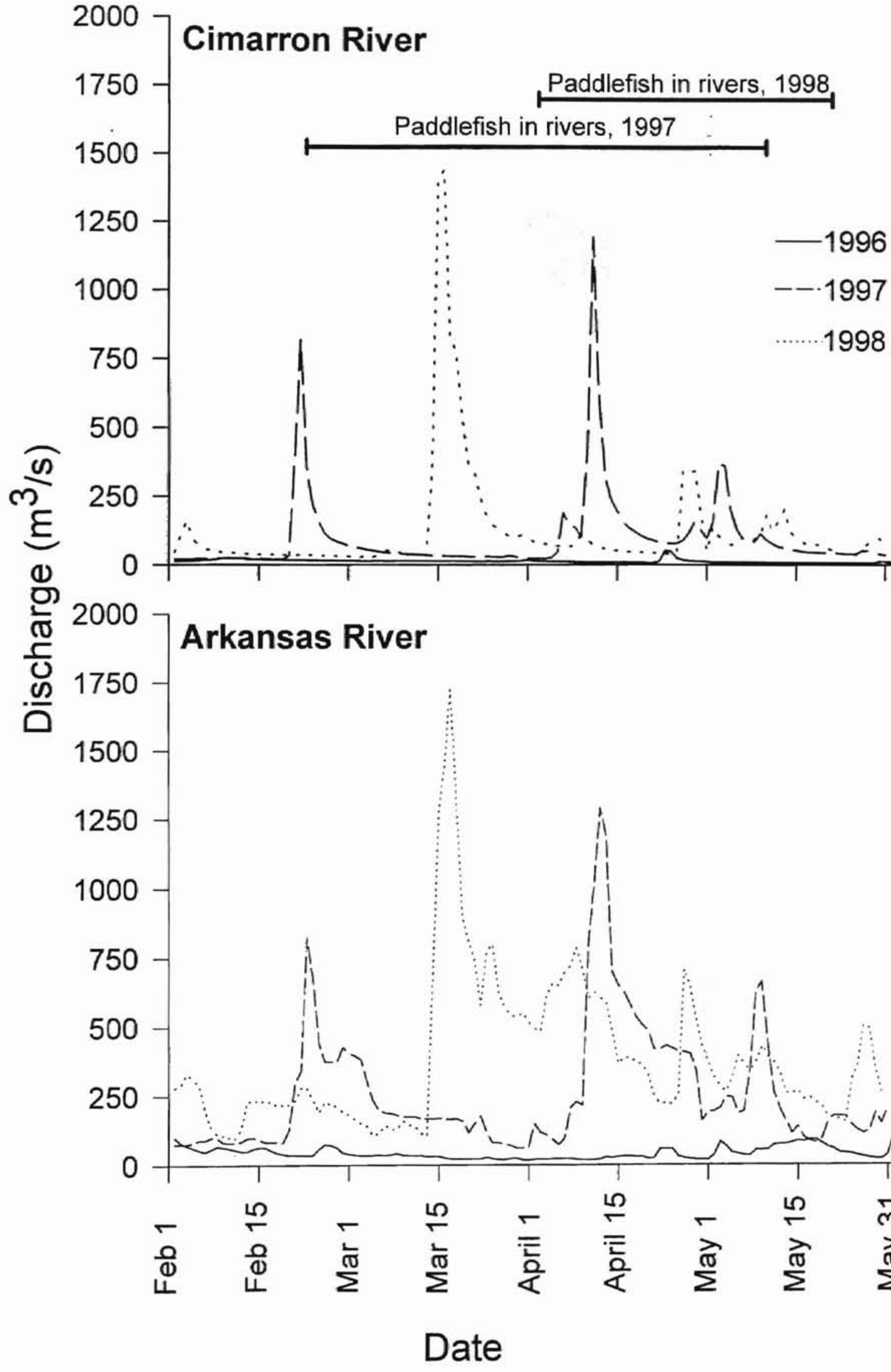
Figure 9. Location of suitable paddlefish spawning substrate within the Keystone Reservoir system.

Figure 10. Mean length (EFL, mm) at age for selected paddlefish populations in the United States. Data from Keystone Reservoir, OK are from this study; The Arkansas River, OK from Linton (1961); Grand Lake, OK from Combs (1982); Lake Pontchartrain, LA from Reed et al. (1992); Alabama River data from Hoxmeier and DeVries (1997); Kentucky Lake, KY are from Hoffnagle and Timmons (1989); and the Mississippi River, Iowa are from Gengerke (1978).

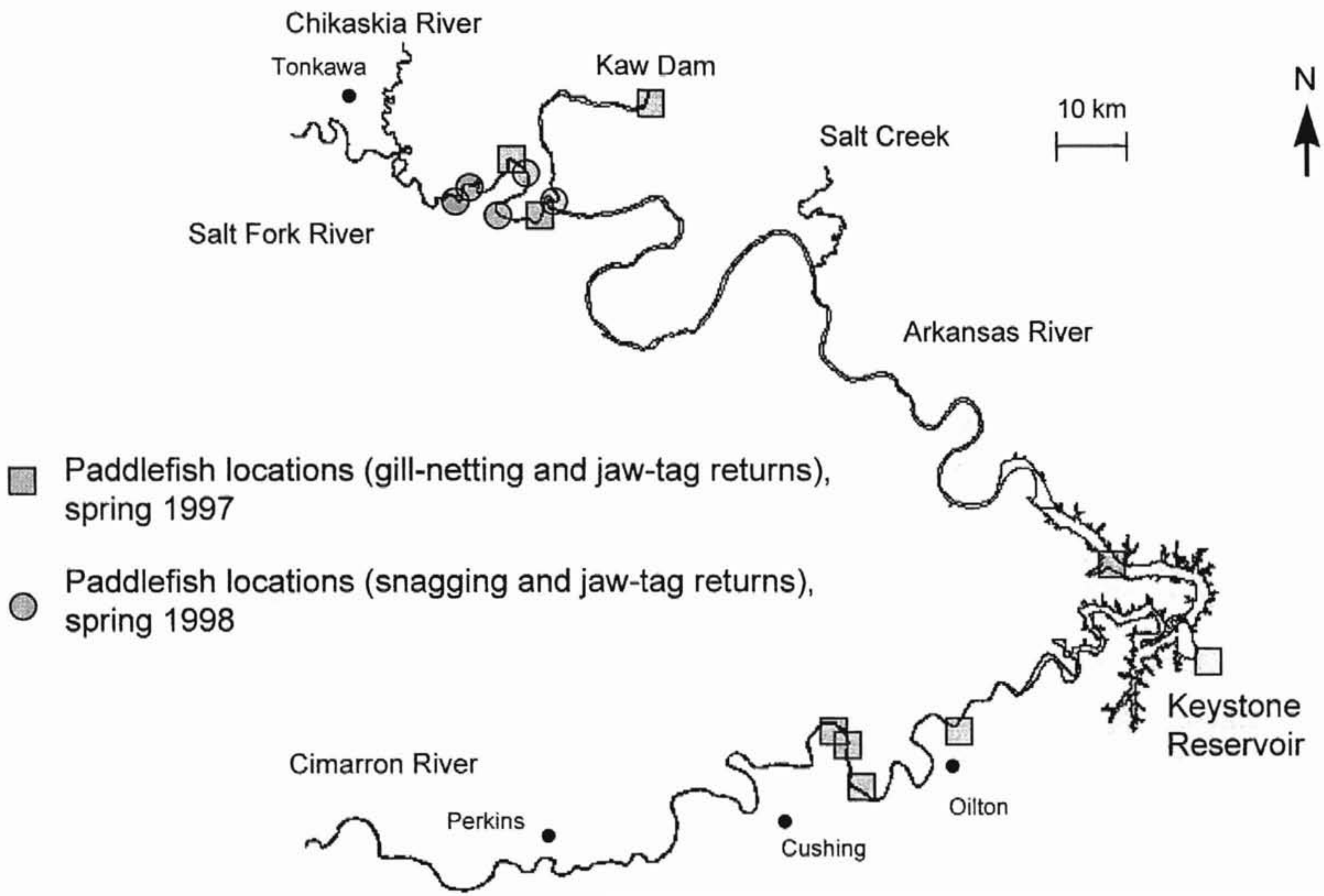


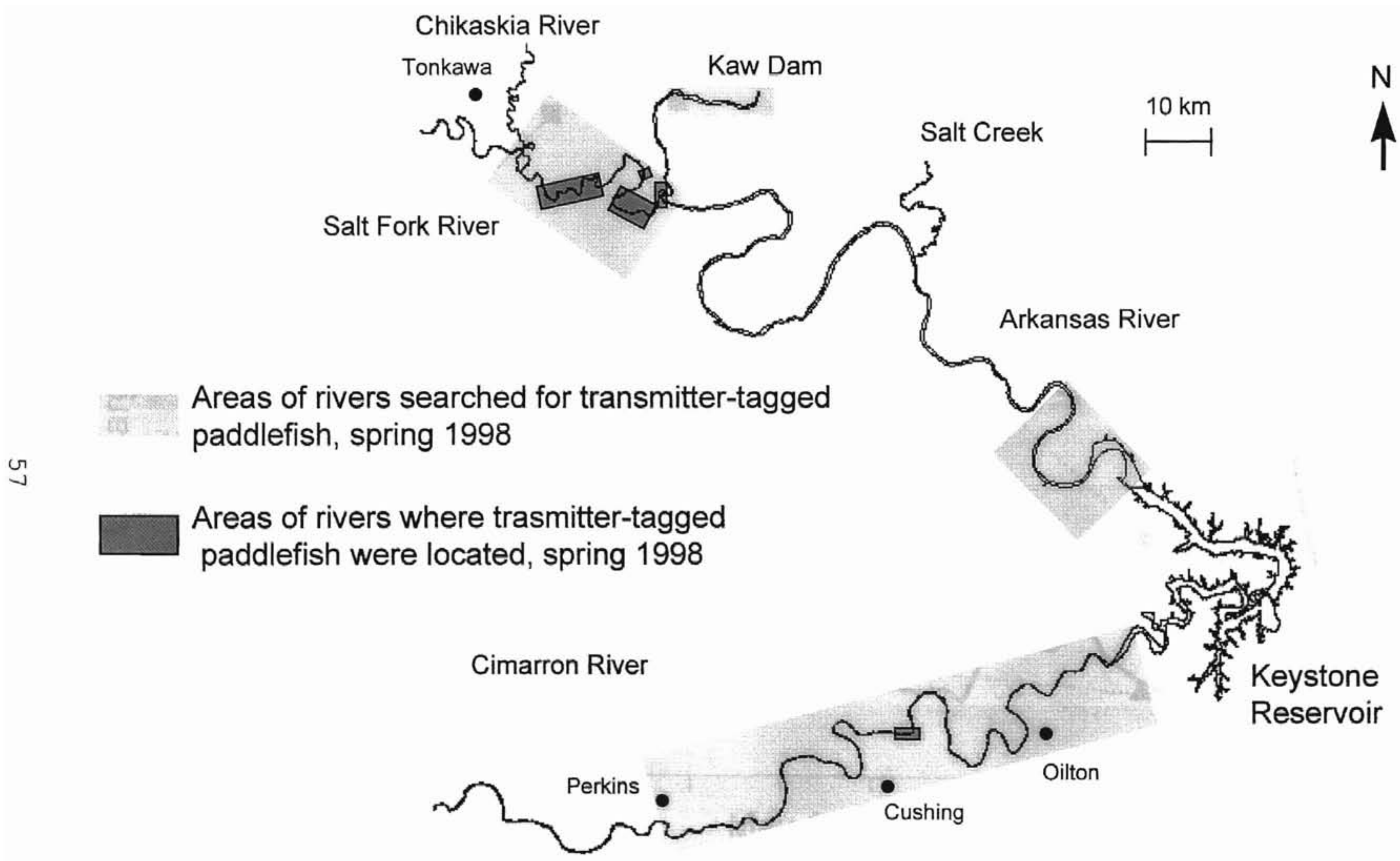
1996
N = 443
1997
N = 499
1998
N = 419
Number collected
0
10
20
30
40
50
60
70
300
400
500
600
700
800
900
1000
1100
1200
1300
Length (mm)

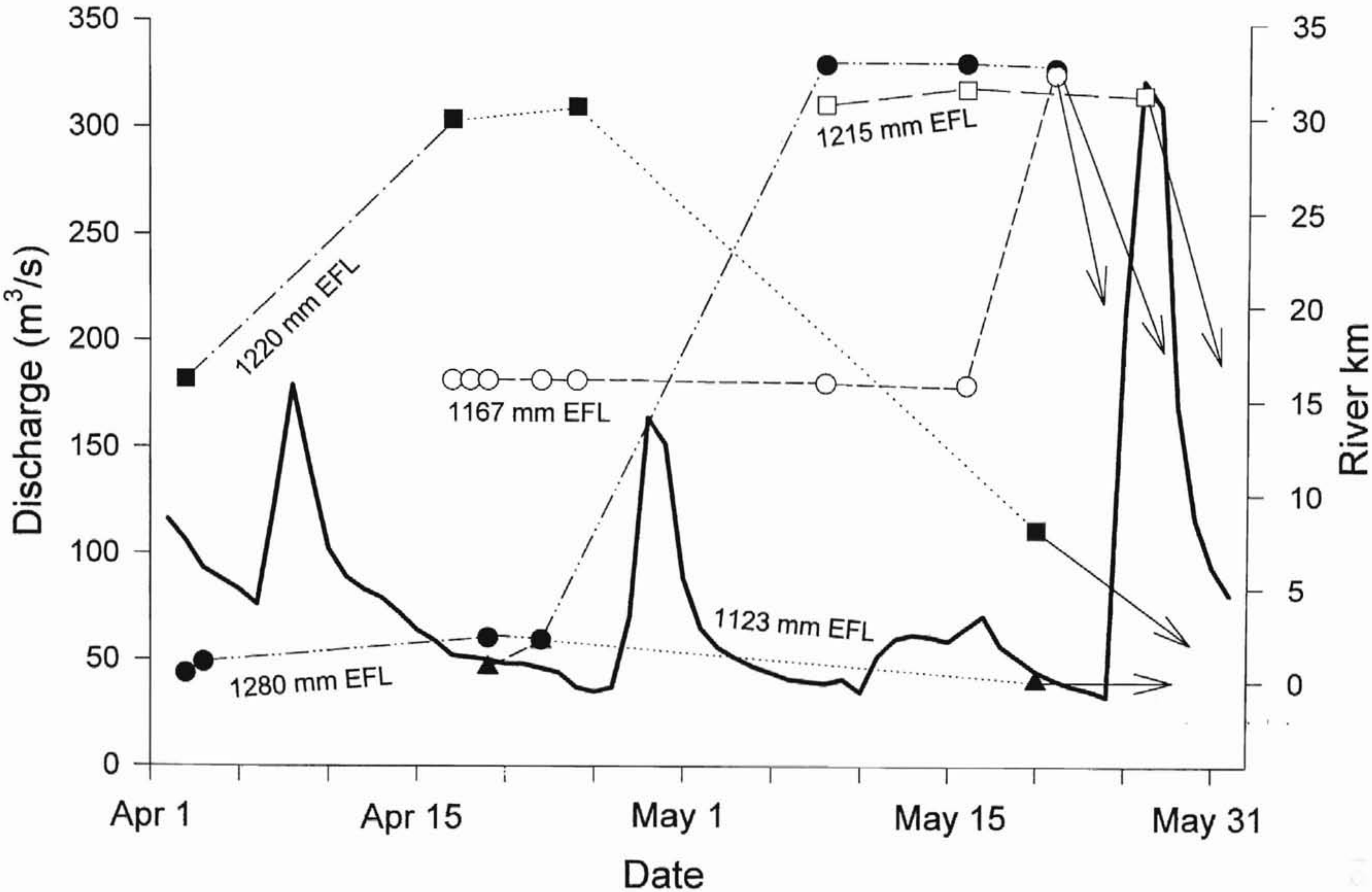

1996
Z = -0.414
Ages 3-12
1997
Z = -0.315
Ages 2-12
1998
Z = -0.310
Ages 3-12
Number collected
250
200
150
100
50
0
95 94 93 92 91 90 89 88 87 86 85 84
96 95 94 93 92 91 90 89 88 87 86 85
97 96 95 94 93 92 91 90 89 88 87 86
Year class



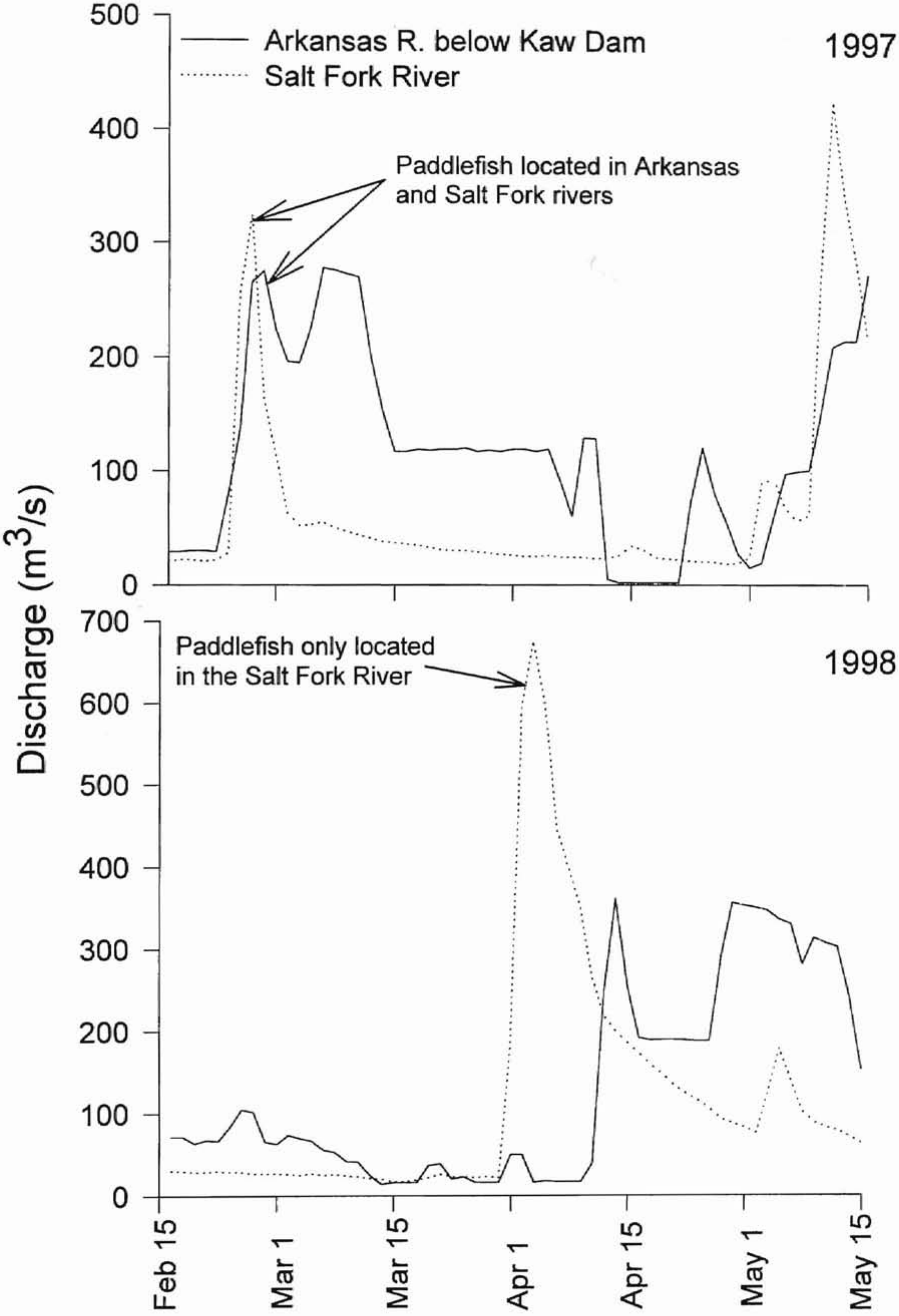
Cimarron River
Paddlefish in rivers, 1998
Paddlefish in rivers, 1997
1996
1997
1998
Arkansas River
Discharge (m3/s)
2000
1750
1500
1250
1000
750
500
250
0
Feb 1
Feb 15
Mar 1
Mar 15
April 1
April 15
May 1
May 15
May 31
Date


Chikaskia River
Tonkawa
Kaw Dam
Salt Creek
10 km
N
Salt Fork River
Arkansas River
Paddlefish locations (gill-netting and jaw-tag returns), spring 1997
Paddlefish locations (snagging and jaw-tag returns), spring 1998
Keystone Reservoir
Cimarron River
Perkins
Cushing
Oilton

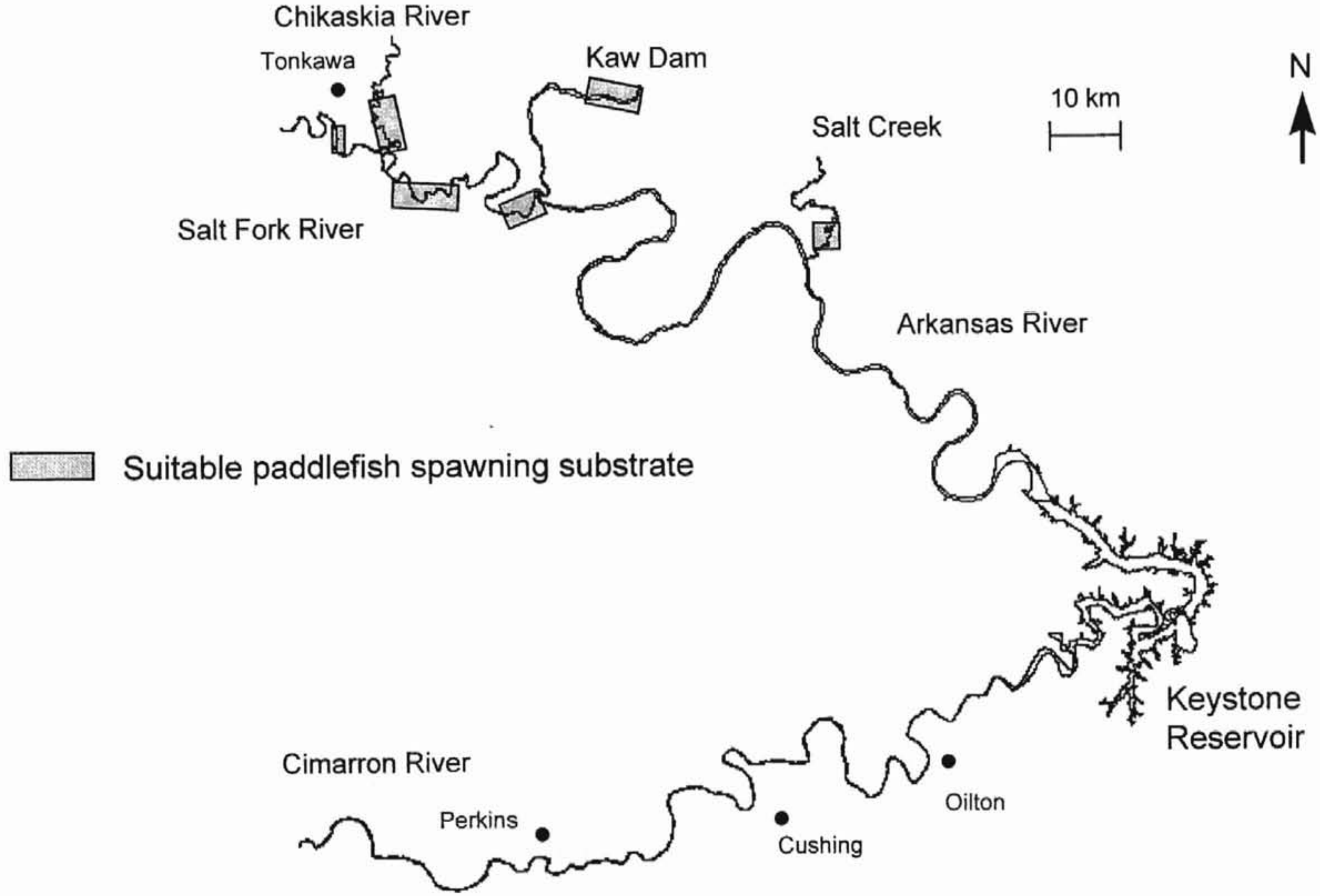

Chikaskia River
Tonkawa
Kaw Dam
N
10 km
Salt Creek
Salt Fork River
Arkansas River
Areas of rivers searched for transmitter-tagged paddlefish, spring 1998
Areas of rivers where trasmitter-tagged paddlefish were located, spring 1998
Cimarron River
Keystone Reservoir
Perkins
Cushing
Oilton

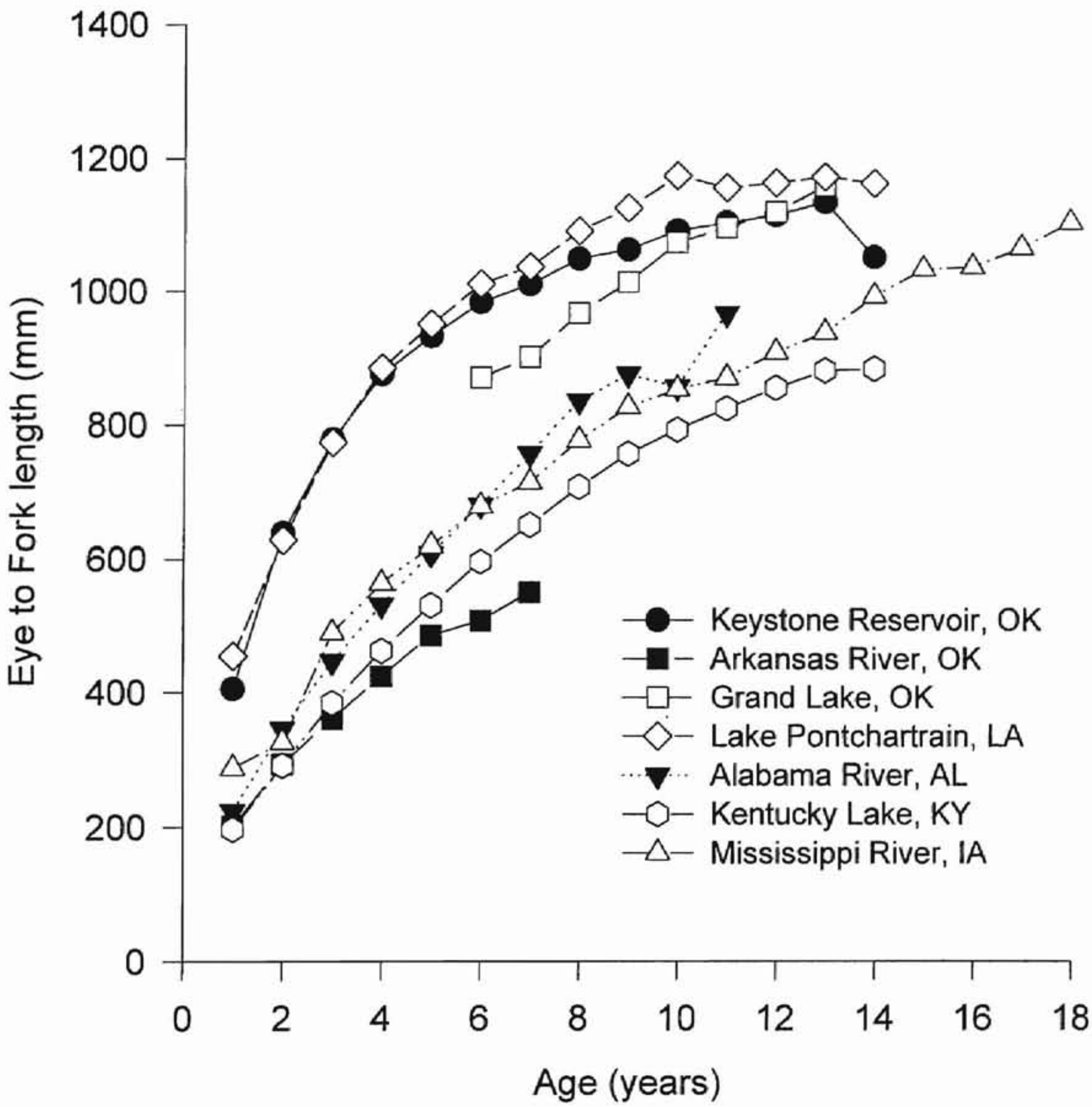


1220 mm EFL
1215 mm EFL
1167 mm EFL
1123 mm EFL
1280 mm EFL
Discharge (m3/s)
River km
Date
Apr 1
Apr 15
May 1
May 15
May 31
350
300
250
200
150
100
50
0
35
30
25
20
15
10
5
0



Arkansas R. below Kaw Dam
Salt Fork River
1997
Paddlefish located in Arkansas and Salt Fork rivers
1998
Paddlefish only located in the Salt Fork River
Discharge (m3/s)
500
400
300
200
100
0
700
600
500
400
300
200
100
0
Feb 15
Mar 1
Mar 15
Apr 1
Apr 15
May 1
May 15
Date


Chikaskia River
Tonkawa
Kaw Dam
Salt Creek
10 km
N
Salt Fork River
Arkansas River
Suitable paddlefish spawning substrate
Keystone
Reservoir
Cimarron River
Perkins
Cushing
Oilton


1400
1200
1000
800
600
400
200
0
Eye to Fork length (mm)
0
2
4
6
8
10
12
14
16
18
Age (years)
Keystone Reservoir, OK
Arkansas River, OK
Grand Lake, OK
Lake Pontchartrain, LA
Alabama River, AL
Kentucky Lake, KY
Mississippi River, IA

Appendixes

Appendix A.- Summary of population gill netting for paddlefish on Keystone Reservoir, 1996.

DATE	TOTAL CAPTURED	NUMBER MARKED	MORTALITIES	<500 mm EFL	RECAPTURES
24 Jan 96	6	5	1	0	0
27 Jan 96	3	3	0	0	0
8 Feb 96	4	3	1	0	0
9 Feb 96	1	1	0	0	0
10 Feb 96	8	8	0	0	0
15 Feb 96	74	74	0	0	0
16 Feb 96	1	1	0	0	0
17 Feb 96	37	34	2	0	1
21 Feb 96	16	16	0	0	0
21 Feb 96	7	7	0	0	0
24 Feb 96	7	7	0	0	0
25 Feb 96	48	34	12	1	1
25 Feb 96	0	0	0	0	0
29 Feb 96	2	2	0	0	0
1 Mar 96	7	7	0	0	0
2 Mar 96	13	12	0	0	1
2 Mar 96	17	14	3	0	0
9 Mar 96	11	11	0	0	0
10 Mar 96	84	65	6	8	5
14 Mar 96	21	14	4	2	1
15 Mar 96	10	8	1	1	0
16 Mar 96	84	42	35	4	3
17 Mar 96	0	0	0	0	0
21 Mar 96	17	14	3	0	0
25 Mar 96	1	0	0	1	0
TOTAL	479	382	68	17	12

Appendix B.- Summary for paddlefish population gill netting on Keystone Reservoir, 1996-1997.

DATE	TOTAL CAPTURED	NUMBER MARKED	MORTALITIES	<500 mm EFL	1997 RECAPS	1996 RECAPS
1 Nov 96	20	10	10	0	0	0
2 Nov 96	10	5	5	0	0	0
15 Nov 96	25	20	5	0	0	0
30 Nov 96	6	5	1	0	0	0
6 Dec 96	3	2	0	0	1	0
7 Dec 96	25	23	2	0	0	0
8 Dec 96	4	4	0	0	0	0
13 Dec 96	11	11	0	0	0	0
14 Dec 96	19	8	8	0	0	3
15 Dec 96	0	0	0	0	0	0
20 Dec 96	1	1	0	0	0	0
21 Dec 96	7	6	0	0	0	0
1 Jan 97	51	43	6	0	0	1
2 Jan 97	10	9	1	0	0	0
3 Jan 97	29	25	1	0	2	1
4 Jan 97	46	33	8	0	2	3
5 Jan 97	26	23	2	0	0	1
8 Jan 97	37	33	2	0	0	2
17 Jan 97	8	8	0	0	0	0
18 Jan 97	34	27	3	0	1	2
19 Jan 97	13	13	0	0	0	0
25 Jan 97	2	2	0	0	0	0
28 Jan 97	26	24	2	0	0	0
31 Jan 97	6	6	0	0	0	0
1 Feb 97	0	0	0	0	0	0
2 Feb 97	3	3	0	0	0	0
7 Feb 97	0	0	0	0	0	0
7 Feb 97	2	2	0	0	0	0
8 Feb 97	48	45	1	0	1	1
9 Feb 97	35	29	0	0	3	3
TOTAL	507	420	57	0	10	17

Appendix C.-Summary for paddlefish population gill netting on Keystone Reservoir, 1997-1998.

DATE	TOTAL CAPTURED	NUMBER MARKED	MORTALITIES	1998 RECAPS	1997 RECAPS	1996 RECAPS
28 Nov 97	16	14	1	0	0	1
29 Nov 97	10	6	3	0	0	1
19 Dec 97	22	18	2	0	1	1
20 Dec 97	10	10	0	0	0	0
5 Jan 98	15	13	2	0	1	0
13 Jan 98	13	11	2	0	0	0
14 Jan 98	22	21	1	0	0	0
15 Jan 98	2	2	0	0	0	0
15 Jan 98	1	1	0	0	0	0
16 Jan 98	15	12	0	0	0	3
17 Jan 98	1	0	1	0	0	0
18 Jan 98	13	13	0	0	0	0
18 Jan 98	6	4	1	0	0	1
22 Jan 98	15	15	0	0	0	0
23 Jan 98	12	11	0	0	1	0
24 Jan 98	69	37	3	0	0	2
27 Jan 98	8	8	0	0	0	0
30 Jan 98	17	16	0	0	0	1
31 Jan 98	2	2	0	0	0	0
5 Feb 98	8	6	1	0	1	0
6 Feb 98	38	30	3	1	0	3
14 Feb 98	31	26	2	2	0	1
19 Feb 98	15	12	1	2	0	0
20 Feb 98	24	19	3	1	1	1
21 Feb 98	2	2	0	0	0	0
5 Mar 98	15	11	4	0	0	0
6 Mar 98	24	16	6	0	1	1
TOTAL	426	336	36	6	6	16

Appendix D.-Summary spring paddlefish sampling in the Keystone Reservor System, 1997.

DATE	LOCATION	OBJECTIVE[A]	METHOD[B]	TOTAL CAPTURED	RECAPS
28 Feb 97	Arkansas Arm of Keystone Reservoir	Implant	Gill net	1	0
1 Mar 97	Arkansas Arm of Keystone Reservoir	Implant	Gill net	1	0
2 Mar 97	Arkansas Arm of Keystone Reservoir	Implant	Gill net	3	1
2 Mar 97	Cimarron Arm of Keystone Reservoir	Implant	Gill net	5	1
7 Mar 97	Cimarron Arm of Keystone Reservoir	Implant	Gill net	7	1
7 Mar 97	Cimarron Arm of Keystone Reservoir	Implant	Gill net	8	1
8 Mar 97	Cimarron Arm of Keystone Reservoir	Implant	Gill net	3	0
9 Mar 97	Cimarron Arm of Keystone Reservoir	Implant	Gill net	6	0
9 Mar 97	Cimarron Arm of Keystone Reservoir	Implant	Gill net	3	0
10 Mar 97	Arkansas Arm of Keystone reservoir	Implant	Gill net	0	0
10 Mar 97	Main Pool of Keystone Reservoir	Implant	Gill net	3	0
12 Mar 97	Kaw Dam Tailwaters	Spawn	Gill net	10	2
15 Mar 97	Cimarron River to Oilton	Spawn	Gill net	11	1
18 Mar 97	Arkansas River near Celeveland	Spawn	Gill net	0	0
22 Mar 97	Salt Fork River near White Eagle	Spawn	Drift net	9	0

Appendix D. (continued)

DATE	LOCATION	OBJECTIVE[A]	METHOD[B]	TOTAL CAPTURED	RECAPS
23 Mar 97	Salt Fork River near White Eagle	Spawn	Snagging	1	0
24 Mar 97	Salt Fork R. at Ark. R. Confluence	Spawn	Snagging	1	0
24 Mar 97	Salt Fork R. At Ark. R. Conflluence	Spawn	Gill net	1	0
26 Mar 97	Salt Fork River near White Eagle	Spawn	Drift net	0	0
26 Mar 97	Salt Fork River near White Eagle	Spawn	Snagging	4	0
27 Mar 97	Cimarron River near Yale	Spawn	Snagging	1	0
28 Mar 97	Cimarron River near Yale	Spawn	Drift net	2	0
29 Mar 97	Salt Fork River near Tonkawa	Spawn	Drift net	0	0
1 Apr 97	Cimarron River near Yale	Spawn	Snagging	1	0
2 Apr 97	Salt Fork River near White Eagle	Spawn	Snagging	2	0
11 Apr 97	Kaw Dam Tailwaters	Spawn	Gill net	10	0
24 Apr 97	Cimarron River near Yale	Spawn	Drift net	0	0
27 Apr 97	Cimarron River near Oilton	Spawn	Drift net	0	0
30 Apr 97	Kaw Dam Tailwaters	Spawn	Drift net	0	0
6 May 97	Salt Fork River near White Eagle	Spawn	Drift net	0	0
9 May 97	Arkansas Arm of Keystone Reservoir	Spawn	Gill net	7	1

Appendix D. (continued)

DATE	LOCATION	OBJECTIVE[A]	METHOD[B]	TOTAL CAPTURED	RECAPS
9 May 97	Cimarron Arm of Keystone Reservoir	Spawn	Gill net	3	0
15 May 97	Main Pool of Keystone Reservoir	Spawn	Gill net	4	0
15 May 97	Arkansas Arm of Keystone Reservoir	Spawn	Gill net	0	0
16 May 97	Cimarron Arm of Keystone Reservoir	Spawn	Gill net	1	0
16 May 97	Salt Creek Arm of Keystone Reservoir	Spawn	Gill net	9	1
20 May 97	Salt Creek Arm of Keystone Reservoir	Spawn	Gill net	2	0
TOTAL				119	9

A: Implant was sampling paddlefish to implant ultrasonic transmitters.
Spawn was sampling todetermine spawing activity and locations.
Reservoir sampling from 9 May to 20 May was to determine when paddlefish moved back into the reservoir from the rivers.

B: Gill net was using stationary gill nets nets.
Drift net was floating gill nets in a particular area of the rivers.
Snagging was using large treble hooks and fishing rods and reel to collect paddlefish.

Appendix E.- Summary spring paddlefish sampling in the Keystone Reservor System, 1998.

DATE	LOCATION	METHOD[a]	TRANS-MITTERED FISH FOUND	NUMBER CAUGHT[b]	RECAPS
17 Mar 98	Keystone Reservoir	Telem.	17		
21 Mar 98	Arknasas River from Keystone - Blackburn	Telem.	2		
22 Mar 98	Arkansas River below Kaw Dam	Telem.	0		
28 Mar 98	Cimarron River from Keystone to Oilton	Telem.	0		
28 Mar 98	Cimarron River from Keystone to Oilton	Gill		0	0
29 Mar 98	Arkansas River below Kaw Dam	Telem.	0		
2 Apr 98	Salt Fork from mouth to Marland	Telem.	4		
3 Apr 98	Salt Fork near mouth	Telem.	1		
4 Apr 98	Arkansas River below Kaw Dam	Telem.	0		
9 Apr 98	Salt Fork from mouth to White Eagle	Telem.	0		
10 Apr 98	Cimarron River from Cushing to Markham	Telem.	1		
11 Apr 98	Cimarron River from Perkins to Cushing	Telem.	1		
15 Apr 98	Keystone Reservoir	Telem.	8		
17 Apr 98	Salt Fork from Tonkawa to White Eagle	Telem.	3		
17 Apr 98	Salt Fork from Tonkawa to White Eagle	Snag		3	0
18 Apr 98	Arkansas River below Kaw Dam	Telem.	0		

Appendix E. (Continued)

DATE	LOCATION	METHOD[a]	TRANS-MITTERED FISH FOUND	NUMBER CAUGHT[b]	RECAPS
18 Apr 98	Salt Fork near White Eagle	Telem.	1		
18 Apr 98	Salt Fork near White Eagle	Snag		1	0
19 Apr 98	Salt Fork from White Eagle to mouth	Telem.	4		
19 Apr 98	Salt Fork from White Eagle to mouth	Snag		1	0
22 Apr 98	Salt Fork near mouth	Telem.	2		
22 Apr 98	Salt Fork near mouth	Snag		3	0
24 Apr 98	Salt Fork from Tonkawa to White Eagle	Telem.	3		
24 Apr 98	Salt Fork from Tonkawa to White Eagle	Snag		10	2
29 Apr 98	Salt Fork from White Eagle to mouth	Telem.	0		
29 Apr 98	Salt Fork from White Eagle to mouth	Snag		1	0
3 May 98	Keystone Reservoir	Telem.	9		
5 May 98	Salt Fork from White Eagle to mouth	Telem.	0		
5 May 98	Salt Fork from White Eagle to mouth	Snag		1	0
8 May 98	Salt Fork from Tonkawa to White Eagle	Telem.	3		
8 May 98	Salt Fork from Tonkawa to White Eagle	Snag		5	0
15 May 98	Kaw Dam Tailwaters	Telem.	0		

Appendix E. (Continued)

DATE	LOCATION	METHOD[a]	TRANS-MITTERED FISH FOUND	NUMBER CAUGHT[b]	RECAPS
16 May 98	Salt Fork from Tonkawa to White Eagle	Telem.	3		
16 May 98	Salt Fork from Tonkawa to White Eagle	Snag		3	0
17 May 98	Salt Fork from Tonkawa upstream 5 km	Telem.	0		
17 May 98	Chickaskia from Salt Fork upstream to Hwy	Telem.	0		
18 May 98	Keystone Reservoir	Telem.	13		
20 May 98	Salt Fork from White Eagle to mouth	Telem.	2		
20 May 98	Salt Fork from White Eagle to mouth	Snag		3	0
21 May 98	Salt Fork from Tonkawa to White Eagle	Telem.	3		
21 May 98	Salt Fork from Tonkawa to White Eagle	Snag		4	0
27 May 98	Salt Fork from Tonkawa to mouth	Telem.	0		
29 May 98	Keystone Reservoir	Telem.	21		
Total				35	2

a: "Gill" was using stationary gill nets nets.
"Telem." was using ultrasonic telemetry to located 24 trasnmittered fish.
"Snag" was using large treble hooks and fishing rod and reel to collect paddlefish.

B: Number caught refers to number collected by gill netting or snagging.

Appendix F. Vital statistics of paddlefish implanted with ultrasonic transmitters in Keystone Reservoir, 1997-98.

Jaw tag number	Transmitter code	Implant date	Length (EFL, mm)	Weight (kg)	Sex
284[1]	2-4-9	2 Mar 97	890	12.0	Male
636[2]	2-2-4-6	2 Mar 97	843	11.5	Male
934	2-2-5-5	2 Mar 97	918	14.0	Male
919	2-2-3-7	7 Mar 97	1000	19.0	Male
940	2-3-4-5	7 Mar 97	942	13.0	Male
910	2-3-3-6	7 Mar 97	912	14.0	Male
1207	3-4-8	27 Jan 98	1280	39.5	Female
1213	2-6-7	27 Jan 98	1215	35.5	Female
1263	4-4-7	27 Jan 98	1168	41.0	Male
1210	3-6-6	30 Jan 98	1220	33.0	Female
1278	2-3-2-7	30 Jan 98	1034	21.0	Male
1217	3-5-7	30 Jan 98	1132	29.5	Male
1240	3-3-9	30 Jan 98	974	22.0	Male
1280	2-7-6	6 Feb 98	1291	33.5	Female
1265	5-5-5	6 Feb 98	1123	29.0	Female
1292	2-5-8	7 Feb 98	1069	27.0	Male
1261	3-8-4	7 Feb 98	1167	30.5	Female
1143[3]	4-6-5	15 Feb 98	1130	27.5	Male
1218	2-4-2-6	15 Feb 98	1290	33.5	Female
1231	4-5-6	19 Feb 98	1181	34.5	Female
1131[4]	3-7-5	19 Feb 98	1260	34.0	Male
1302	8-8	20 Feb 98	1200	28.5	Female
1318	2-9-4	21 Feb 98	1095	24.0	Male
345[5]	2-8-5	6 Mar 98	1095	26.5	Male

1. Recapture from 1996. Fish was originally tagged on 9 March 1996.
2. Recapture from 1997. Fish was originally tagged on 3 January 1997.
3. Recapture from 1998. Fish was originally tagged on 22 January 1998.
4. Recapture from 1998. Fish was originally tagged on 18 January 1998.
5. Recapture from 1996. Fish was originally tagged on 16 March 1996.

Appendix G. Tag returns by anglers of paddlefish caught from 1 July 1995 to 30 June 1998 in the Keystone Reservoir System.

Tag No.	Date Caught	Location Caught	Method	Tagging Date	Len at tagging (mm)	Wt at tagging (kg)
126	28 May 96	Keystone Reservoir	trot line	10 Mar 96	855	15.5
212	4 Aug 96	Keystone Reservoir	Found dead	17 Feb 96	1035	22.0
011	N/A	N/A	N/A	14 Feb 96	812	12.0
121	2 Feb 97	Lock and Dam 17, Muskogee	Snagged	25 Feb 96	760	9.0
036	Feb 97	Kaw Dam Tailwaters	Snagged	14 Feb 96	863	13.0
150	1 Mar 97	Kaw Dam Tailwaters	Snagged	14 Mar 96	875	12.5
108	2 Mar 97	Keystone Reservoir	Trot line	21 Feb 96	892	12.0
033	23 Mar 97	Cimarron River near Yale	Snagged	14 Feb 96	764	9.0
196	23 Mar 97	Keystone Reservoir	Trot line	N/A	N/A	N/A
690	29 Mar 97	Cimarron River near Yale	Snagged	1 Jan 97	875	12.5
353	2 Apr 97	Keystone Dam Tailwaters	Angling	21 Feb 96	1158	31.0
655	5 Apr 97	Cimarron River near Yale	Snagged	4 Jan 97	1263	32.0
709	10 May 97	Kaw Dam Tailwaters	Snagged	8 Jan 97	1045	N/A
953	11 May 97	Keystone Dam Tailwaters	Angling	9 Feb 97	1027	20.0
922	27 May 97	Arkansas River near Jenks	Snagged	9 Feb 97	633	4.0
936	9 Jun 97	Kaw Dam Tailwaters	Snagged	12 Mar 97	840	12.5
357	17 Jun 97	Keystone Reservoir	Found dead	21 Mar 96	756	6.0
826	20 Jun 97	N/A	N/A	28 Jan 97	914	13.5

Appendix G. (Continued)

Tag No.	Date Caught	Location Caught	Method	Tagging Date	Len at tagging (mm)	Wt at tagging (kg)
539	21 Jun 97	Arkansas River near I44	Found dead	30 Nov 96	1000	20.0
050	7 Jul 97	Keystone Reservoir	Found dead	14 Feb 96	782	11.0
954	4 Jan 98	Kaw Dam tailwaters	snagged	12 Mar 97	870	13.0
1086	1 Feb 98	Keystone Reservoir	trot line	20 Dec 97	1128	30.0
1089	15 Feb 98	Keystone Reservoir	trot line	14 Jan 98	1100	27.0
860	12 Apr 98	N/A	N/A	8 Feb 97	988	16.5
211	3 May 98	Salt Fork River	Snagged	16 Feb 96	1154	32.5
683	29 May 98	Fork Gibson tailwaters	Snagged	1 Jan 97	614	4.0
757	3 Jun 98	Keystone Dam Tailwaters	angling	18 Jan 97	879	14.0
502	4 Jun 98	Arkansas River near Jenks	angling	2 Nov 96	647	5.0
228	15 Jun 98	Keystone Reservoir	Found dead	17 Feb 96	825	12.5

Appendix H. Vital statistics of all paddlefish jaw-tagged in the Keystone Reservoir System, 1996-1998. CIM represents the Cimarron River; POL represents the main pool of Keystone Reservoir; ARK represents the Arkansas River; SCR represents the Salt Creek area of Keystone Reservoir; SFR represents the Salt Fork of the Arkansas River. ARK 176 is the tailwaters of Kaw Dam; CIM 54 is the Cimarron River near Oilton, Oklahoma; CIM 86 is the Cimarron River near Yale, Oklahoma; SFR 16 is the Salt Fork of the Arkansas River near Markam, Oklahoma. All other locations are within Keystone Reservoir.

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
1	14-Feb-96	CIM	24	801	8.5	31	1-Mar-96	ARK	10	1130	30.0
2	14-Feb-96	CIM	24	814	10.5	32	24-Jan-96	SCR	3	1060	21.5
3	14-Feb-96	CIM	24	1235	41.5	33	14-Feb-96	CIM	24	764	9.0
4	14-Feb-96	CIM	24	768	10.0	34	14-Feb-96	CIM	24	810	12.0
5	14-Feb-96	CIM	24	820	11.0	35	14-Feb-96	CIM	24	730	7.0
6	27-Jan-96	POL	5	1013	24.0	36	14-Feb-96	CIM	24	863	13.0
7	14-Feb-96	CIM	24	762	8.0	37	14-Feb-96	CIM	24	889	14.5
8	14-Feb-96	CIM	24	868	11.5	38	14-Feb-96	CIM	24	1074	22.0
8	14-Dec-96	ARK	22	828	12.0	39	14-Feb-96	CIM	24	885	14.0
9	9-Feb-96	POL	5	635	5.5	40	21-Feb-96	ARK	13	820	10.5
11	14-Feb-96	CIM	24	812	12.0	41	14-Feb-96	CIM	24	700	6.5
12	14-Feb-96	CIM	24	813	10.5	42	14-Feb-96	CIM	24	830	11.0
13	14-Feb-96	CIM	24	876	13.0	43	14-Feb-96	CIM	24	782	9.0
14	27-Jan-96	POL	5	1150	30.5	44	9-Feb-96	POL	5	1171	38.5
15	14-Feb-96	CIM	24	781	8.5	45	14-Feb-96	CIM	24	766	8.0
16	9-Feb-96	POL	5	774	9.3	46	9-Feb-96	POL	5	1113	26.5
17	14-Feb-96	CIM	24	877	14.5	47	14-Feb-96	CIM	24	865	15.0
18	14-Feb-96	CIM	24	830	10.5	48	9-Feb-96	POL	5	982	17.5
19	9-Feb-96	POL	5	815	11.0	49	14-Feb-96	CIM	24	790	10.5
20	7-Feb-96	POL	3	1176	29.0	50	14-Feb-96	CIM	24	782	11.0
21	14-Feb-96	CIM	24	779	9.0	51	14-Feb-96	CIM	24	903	10.0
22	14-Feb-96	CIM	24	724	9.0	52	9-Feb-96	POL	5	819	12.0
23	14-Feb-96	CIM	24	770	10.5	53	14-Feb-96	CIM	24	826	11.0
24	14-Feb-96	CIM	24	780	9.0	54	10-Mar-96	CIM	16	762	8.0
25	9-Feb-96	POL	5	1122	25.5	55	14-Feb-96	CIM	24	942	15.5
26	14-Feb-96	CIM	24	780	11.0	56	14-Feb-96	CIM	24	942	16.0
27	14-Feb-96	CIM	24	922	13.0	57	14-Feb-96	CIM	24	761	8.0
28	1-Mar-96	ARK	10	1080	21.5	58	14-Feb-96	CIM	24	883	15.5
29	14-Feb-96	CIM	24	984	17.5	59	14-Feb-96	CIM	24	865	16.0
30	14-Feb-96	CIM	24	976	15.0	60	14-Feb-96	CIM	24	823	9.5

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
61	14-Feb-96	CIM	24	813	10.0	96	14-Feb-96	CIM	24	782	9.0
62	14-Feb-96	CIM	24	821	10.5	97	14-Feb-96	CIM	24	850	9.0
63	14-Feb-96	CIM	24	772	9.5	98	14-Feb-96	CIM	24	843	12.0
64	8-Feb-96	POL	2	1145	29.5	99	14-Feb-96	CIM	24	864	12.0
65	7-Feb-96	POL	3	822	9.0	100	14-Feb-96	CIM	24	814	10.5
66	14-Feb-96	CIM	24	823	9.5	101	10-Mar-96	CIM	16	776	6.0
67	14-Feb-96	CIM	24	919	17.0	102	10-Mar-96	CIM	16	1134	26.0
68	24-Jan-96	POL	3	1200	33.0	103	24-Feb-96	ARK	16	1212	38.0
69	10-Mar-96	CIM	16	794	11.0	104	10-Mar-96	CIM	16	785	8.5
70	14-Feb-96	CIM	24	820	9.5	105	10-Mar-96	CIM	16	934	18.5
71	14-Feb-96	CIM	24	744	9.0	106	14-Mar-96	CIM	6	1172	32.0
72	14-Feb-96	CIM	24	902	14.5	107	9-Mar-96	CIM	5	823	9.0
73	9-Mar-96	CIM	5	1036	20.5	108	21-Feb-96	ARK	13	892	12.0
74	14-Feb-96	CIM	24	784	9.5	109	25-Feb-96	CIM	14	786	9.0
75	14-Feb-96	CIM	24	775	10.0	110	2-Mar-96	ARK	18	1159	35.5
76	14-Feb-96	CIM	24	774	9.5	111	10-Mar-96	CIM	16	965	14.5
77	14-Feb-96	CIM	24	805	9.0	112	10-Mar-96	CIM	16	975	20.5
78	14-Feb-96	CIM	24	783	11.5	113	10-Mar-96	CIM	16	751	10.5
79	14-Feb-96	CIM	24	786	9.5	114	24-Feb-96	ARK	16	1006	15.5
80	27-Jan-96	POL	5	1070	26.0	115	25-Feb-96	CIM	14	815	9.5
81	14-Feb-96	CIM	24	912	15.0	116	10-Mar-96	CIM	16	650	7.0
82	24-Jan-96	POL	3	715	18.0	117	10-Mar-96	CIM	16	960	20.0
83	14-Feb-96	CIM	24	773	9.5	118	14-Mar-96	CIM	6	745	8.0
84	14-Feb-96	CIM	24	817	10.0	119	21-Feb-96	CIM	8	1084	23.5
85	14-Feb-96	CIM	24	742	7.5	120	10-Mar-96	CIM	16	800	11.0
86	24-Jan-96	POL	3	1035	20.5	121	25-Feb-96	CIM	14	760	9.0
87	14-Feb-96	CIM	24	934	16.5	122	2-Mar-96	ARK	18	778	13.5
88	24-Jan-96	POL	3	1130	31.5	123	25-Feb-96	CIM	14	780	6.0
89	7-Feb-96	POL	3	840	10.5	124	9-Mar-96	CIM	5	768	9.0
90	14-Feb-96	CIM	24	775	10.0	125	25-Feb-96	CIM	14	830	10.0
91	14-Feb-96	CIM	24	820	9.0	126	10-Mar-96	CIM	16	855	15.5
92	14-Feb-96	CIM	24	755	9.0	127	2-Mar-96	ARK	18	805	15.5
93	14-Feb-96	CIM	24	785	9.5	128	10-Mar-96	CIM	16	871	16.5
94	14-Feb-96	CIM	24	840	9.0	129	21-Feb-96	ARK	13	796	12.5
95	14-Feb-96	CIM	24	772	9.5	130	17-Feb-96	CIM	10	744	11.0

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
131	10-Mar-96	CIM	16	1175	31.0	166	25-Feb-96	CIM	14	788	8.5
132	9-Mar-96	CIM	5	645	5.0	167	10-Mar-96	CIM	16	810	12.5
133	10-Mar-96	CIM	16	1125	34.5	168	10-Mar-96	CIM	16	710	8.5
134	9-Mar-96	CIM	5	814	9.0	169	25-Feb-96	CIM	14	810	9.5
135	10-Mar-96	CIM	16	743	8.5	170	9-Mar-96	CIM	5	1075	22.0
136	10-Mar-96	CIM	16	811	13.0	171	10-Mar-96	CIM	16	913	17.0
137	10-Mar-96	CIM	16	799	10.5	172	25-Feb-96	CIM	14	906	16.0
138	21-Feb-96	ARK	13	865	12.0	173	10-Mar-96	CIM	16	806	11.5
139	2-Mar-96	ARK	18	1038	27.5	174	21-Feb-96	CIM	8	1224	28.5
140	10-Mar-96	CIM	16	912	15.5	175	10-Mar-96	CIM	16	830	13.0
141	10-Mar-96	CIM	16	790	10.5	176	10-Mar-96	CIM	16	778	10.5
142	10-Mar-96	CIM	16	776	7.5	177	1-Mar-96	ARK	10	809	9.0
143	17-Feb-96	CIM	10	781	12.0	178	25-Feb-96	CIM	14	800	9.0
144	24-Feb-96	ARK	16	1248	35.5	179	10-Mar-96	CIM	16	835	12.5
145	10-Mar-96	CIM	16	774	7.5	180	1-Mar-96	ARK	10	1138	23.0
146	10-Mar-96	CIM	16	887	16.0	181	14-Mar-96	CIM	6	891	15.0
147	2-Mar-96	ARK	18	1110	31.0	182	10-Mar-96	CIM	16	1020	16.5
148	14-Mar-96	CIM	6	712	7.5	183	10-Mar-96	CIM	16	778	10.5
149	25-Feb-96	CIM	14	787	9.0	184	10-Mar-96	CIM	16	980	14.5
150	14-Mar-96	CIM	6	875	12.5	185	25-Feb-96	CIM	14	1160	29.0
151	25-Feb-96	CIM	14	800	9.8	186	2-Mar-96	ARK	18	778	14.0
152	10-Mar-96	CIM	16	841	9.0	187	25-Feb-96	CIM	14	1104	21.0
153	21-Feb-96	ARK	13	1057	24.5	188	10-Mar-96	CIM	16	774	10.5
154	2-Mar-96	ARK	18	1008	23.5	189	25-Feb-96	CIM	14	1160	24.5
155	10-Mar-96	CIM	16	886	14.5	190	10-Mar-96	CIM	16	770	10.0
156	10-Mar-96	CIM	16	829	9.0	191	25-Feb-96	CIM	14	855	11.0
157	10-Mar-96	CIM	16	805	8.5	192	21-Feb-96	ARK	13	1143	35.5
158	14-Mar-96	CIM	6	1256	37.0	193	25-Feb-96	CIM	14	820	10.5
159	21-Feb-96	CIM	8	1030	22.5	194	10-Mar-96	CIM	16	785	9.0
160	10-Mar-96	CIM	16		11.0	195	25-Feb-96	CIM	14	820	10.5
161	2-Mar-96	ARK	18	804	14.5	196	5-Jan-97	CIM	10	1028	19.0
162	24-Feb-96	ARK	16	940	15.5	197	10-Mar-96	CIM	16	806	6.5
163	14-Mar-96	CIM	6	770	8.0	198	21-Feb-96	CIM	8	1084	21.5
164	21-Feb-96	ARK	13	798	11.0	199	10-Mar-96	CIM	16	785	10.0
165	10-Mar-96	CIM	16	876	15.0	200	10-Mar-96	CIM	16	770	8.5

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
201	21-Feb-96	ARK	13	1049	21.0	236	25-Feb-96	CIM	14	906	15.0
202	17-Feb-96	CIM	10	800	11.0	237	21-Feb-96	ARK	13	784	10.5
203	17-Feb-96	CIM	10	764	9.5	238	25-Feb-96	CIM	14	905	15.0
204	17-Feb-96	CIM	10	799	10.0	239	25-Feb-96	CIM	14	900	14.5
205	17-Feb-96	CIM	10	809	11.0	240	21-Feb-96	ARK	13	1145	29.5
206	17-Feb-96	CIM	10	1072	19.5	241	17-Feb-96	CIM	10	746	10.0
207	21-Feb-96	ARK	13	1173	34.0	242	10-Mar-96	CIM	16	798	11.0
208	21-Feb-96	ARK	13	1165	29.0	243	14-Mar-96	CIM	6	1168	31.5
209	17-Feb-96	CIM	10	800	12.0	244	17-Feb-96	CIM	10	815	12.0
210	17-Feb-96	CIM	10	743	10.5	245	17-Feb-96	CIM	10	1025	24.5
211	16-Feb-96	ARK	19	1154	32.5	246	17-Feb-96	CIM	10	750	11.5
212	17-Feb-96	CIM	10	1035	22.0	247	10-Mar-96	CIM	16	817	12.0
213	29-Feb-96	CIM	30	1075	27.0	248	2-Mar-96	ARK	18	812	17.0
214	17-Feb-96	CIM	10	1134	30.0	249	10-Mar-96	CIM	16	988	21.0
215	17-Feb-96	CIM	10	790	11.0	250	10-Mar-96	CIM	16	984	19.5
216	25-Feb-96	CIM	14	940	14.5	251	24-Feb-96	ARK	16	1245	35.5
217	17-Feb-96	CIM	10	1020	23.5	252	10-Mar-96	CIM	16	830	11.0
218	17-Feb-96	CIM	10	816	11.5	253	10-Mar-96	CIM	16	934	19.0
219	17-Feb-96	CIM	10	1065	23.0	254	17-Feb-96	CIM	10	764	13.0
220	10-Mar-96	CIM	16	921	16.0	255	21-Feb-96	ARK	13	827	11.5
221	17-Feb-96	CIM	10	765	11.0	256	10-Mar-96	CIM	16	902	15.0
222	17-Feb-96	CIM	10	1013	27.0	257	14-Mar-96	CIM	6	785	8.5
223	17-Feb-96	CIM	10	825	10.0	258	17-Feb-96	CIM	10	825	14.0
224	25-Feb-96	CIM	14	905	13.0	259	17-Feb-96	CIM	10	835	17.0
225	10-Mar-96	CIM	16	820	13.0	260	21-Feb-96	ARK	13	617	5.5
226	17-Feb-96	CIM	10	795	10.5	261	25-Feb-96	CIM	14	750	8.0
227	17-Feb-96	CIM	10	815	11.0	262	25-Feb-96	CIM	14	792	9.0
228	17-Feb-96	CIM	10	825	12.5	263	25-Feb-96	CIM	14	784	8.5
229	17-Feb-96	CIM	10	1035	19.5	264	10-Mar-96	CIM	16	734	6.5
230	24-Feb-96	ARK	16	804	9.5	265	10-Mar-96	CIM	16	668	7.5
231	17-Feb-96	CIM	10	1046	26.0	266	21-Feb-96	CIM	8	1083	19.0
232	17-Feb-96	CIM	10	1035	26.0	267	25-Feb-96	CIM	14	770	10.0
233	10-Mar-96	CIM	16	807	8.0	268	10-Mar-96	CIM	16	960	14.5
234	10-Mar-96	CIM	16	799	10.5	269	17-Feb-96	CIM	10	1205	35.0
235	24-Feb-96	ARK	16	810	10.0	270	29-Feb-96	CIM	30	1019	23.5

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
271	17-Feb-96	CIM	10	1060	27.0	307	15-Mar-96	ARK	14	790	9.0
272	2-Mar-96	ARK	18	728	12.5	308	15-Mar-96	ARK	14	1084	23.0
273	25-Feb-96	CIM	14	1110	20.5	309	16-Mar-96	CIM	22	839	9.0
274	14-Mar-96	CIM	6	836	10.5	310	16-Mar-96	CIM	22	821	10.0
275	25-Feb-96	CIM	14	809	10.0	311	16-Mar-96	CIM	22	652	5.0
276	21-Feb-96	ARK	13	826	11.5	312	14-Mar-96	CIM	6	796	9.5
277	25-Feb-96	CIM	14	809	9.0	313	14-Mar-96	CIM	6	925	15.5
278	25-Feb-96	CIM	14	1155	36.0	314	16-Mar-96	CIM	22	816	9.0
279	25-Feb-96	CIM	14	1210	29.0	315	16-Mar-96	CIM	22	968	18.5
280	2-Mar-96	ARK	18	794	14.5	316	16-Mar-96	CIM	22	962	14.5
281	9-Mar-96	CIM	5	755	7.0	317	16-Mar-96	CIM	22	834	9.0
282	9-Mar-96	CIM	5	1040	20.5	318	15-Mar-96	ARK	14	821	10.5
283	1-Mar-96	ARK	10	1050	19.0	319	16-Mar-96	CIM	22	910	14.5
284	9-Mar-96	CIM	5	809	8.5	320	15-Mar-96	ARK	14	835	10.5
285	1-Mar-96	ARK	10	820	9.5	321	16-Mar-96	CIM	22	810	10.0
286	10-Mar-96	CIM	16	860	13.0	322	16-Mar-96	CIM	22	868	13.5
287	9-Mar-96	CIM	5	1172	29.0	323	16-Mar-96	CIM	22	1000	19.5
288	25-Feb-96	CIM	14	810	9.0	324	16-Mar-96	CIM	22	769	9.0
289	10-Mar-96	CIM	16	760	7.5	325	16-Mar-96	CIM	22	970	18.0
290	25-Feb-96	CIM	14	810	9.5	326	15-Mar-96	ARK	14	1048	20.0
292	21-Feb-96	CIM	8	1101	22.5	327	16-Mar-96	CIM	22	806	11.5
293	21-Feb-96	CIM	8	1160	36.0	328	14-Mar-96	CIM	6	1025	15.5
294	25-Feb-96	CIM	14	1025	21.0	329	16-Mar-96	CIM	22	815	10.0
295	10-Mar-96	CIM	16	860	15.0	330	16-Mar-96	CIM	22	921	17.5
296	21-Feb-96	ARK	13	741	9.5	331	16-Mar-96	CIM	22	772	9.0
297	2-Mar-96	ARK	18	1040	29.0	332	16-Mar-96	CIM	22	938	16.0
298	9-Mar-96	CIM	5	815	10.5	333	16-Mar-96	CIM	22	823	8.5
299	17-Feb-96	CIM	10	775	11.0	334	16-Mar-96	CIM	22	746	8.5
300	10-Mar-96	CIM	16	855	16.0	335	21-Mar-98	CIM	27	957	17.0
301	15-Mar-96	ARK	14	620	5.0	336	16-Mar-96	CIM	22	765	9.0
302	14-Mar-96	CIM	6	772	8.5	337	16-Mar-96	CIM	22	965	16.5
303	16-Mar-96	CIM	22	652	5.0	338	21-Mar-98	CIM	30	752	6.5
304	14-Mar-96	CIM	6	759	7.0	339	16-Mar-96	CIM	22	902	13.0
305	15-Mar-96	ARK	14	1165	27.0	340	16-Mar-96	CIM	22	1019	15.0
306	15-Mar-96	ARK	14	1256	38.5	341	16-Mar-96	CIM	22	849	9.5

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
342	16-Mar-96	CIM	22	592	3.5	507	1-Nov-96	ARK	13	1128	23.0
343	16-Mar-96	CIM	22	940	18.0	508	7-Dec-96	ARK	8	1047	26.5
344	16-Mar-96	CIM	22	982	15.0	509	7-Dec-96	ARK	8	836	12.0
345	16-Mar-96	CIM	22	960	18.0	510	14-Dec-96	ARK	22	979	17.0
346	16-Mar-96	CIM	22	928	16.5	511	21-Dec-96	ARK	5	1150	27.0
347	16-Mar-96	CIM	22	823	10.0	512	20-Dec-96	CIM	19	894	11.0
348	16-Mar-96	CIM	22	923	14.5	513	14-Dec-96	ARK	22	979	16.5
349	16-Mar-96	CIM	22	781	9.5	514	13-Dec-96	POL	3	614	4.0
350	21-Mar-98	CIM	27	777	8.5	515	7-Dec-96	ARK	8	932	13.0
351	16-Mar-96	CIM	22	740	8.0	516	14-Dec-96	ARK	22	631	4.0
352	21-Mar-98	CIM	27	865	10.0	517	1-Nov-96	ARK	13	905	14.0
353	21-Mar-98	CIM	30	1158	31.0	518	13-Dec-96	POL	3	1056	19.0
354	16-Mar-96	CIM	22	768	8.5	519	15-Nov-96	CIM	8	555	2.5
355	21-Mar-98	CIM	30	1188	27.0	520	14-Dec-96	ARK	22	548	2.5
356	16-Mar-96	CIM	22	945	14.0	521	15-Nov-96	CIM	8	635	4.5
357	21-Mar-98	CIM	27	756	6.0	522	1-Nov-96	ARK	13	907	17.0
358	21-Mar-98	CIM	30	759	7.0	523	7-Dec-96	ARK	8	925	13.0
359	16-Mar-96	CIM	22	905	14.0	524	30-Nov-96	CIM	16	619	4.0
360	21-Mar-98	CIM	27	1200	30.0	525	15-Nov-96	CIM	8	1179	26.0
361	16-Mar-96	CIM	22	836	10.0	526	7-Dec-96	ARK	8	1059	19.0
362	21-Mar-98	CIM	30	784	8.0	527	7-Dec-96	ARK	8	911	13.0
363	21-Mar-98	CIM	30	800	9.0	528	7-Dec-96	ARK	8	651	4.5
364	21-Mar-98	CIM	27	782	9.0	529	1-Nov-96	ARK	13	633	4.5
365	16-Mar-96	CIM	22	960	17.0	530	1-Jan-97	SCR	3	600	3.0
366	16-Mar-96	CIM	22	845	10.0	531	14-Dec-96	ARK	22	882	14.0
367	21-Mar-98	CIM	30	745	7.0	532	1-Nov-96	ARK	13	576	6.0
368	21-Mar-98	CIM	30	795	9.0	533	14-Dec-96	ARK	22	664	4.0
370	28-Nov-97	POL	5	1040	24.5	534	7-Dec-96	ARK	8	627	4.0
371	14-Dec-96	ARK	22	889	11.0	535	7-Dec-96	ARK	8	880	12.0
501	1-Jan-97	SCR	3	810	9.5	536	8-Dec-96	CIM	18	655	4.5
502	2-Nov-96	POL	5	647	5.0	537	2-Nov-96	POL	5	850	13.0
503	7-Dec-96	ARK	8	875	11.5	539	30-Nov-96	CIM	16	1000	20.0
504	1-Nov-96	ARK	13	879	13.0	540	7-Dec-96	ARK	8	1160	34.0
505	7-Dec-96	ARK	8	855	10.0	541	30-Nov-96	CIM	16	615	4.0
506	2-Nov-96	POL	5	642	4.5	542	21-Dec-96	ARK	5	1105	27.0

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
543	13-Dec-96	POL	3	847	10.0	578	2-Nov-96	POL	5	950	15.5
544	1-Nov-96	ARK	13	948	21.5	579	13-Dec-96	POL	3	928	13.5
545	21-Dec-96	ARK	5	946	18.0	580	13-Dec-96	POL	3	945	18.5
546	15-Nov-96	CIM	8	670	5.0	581	1-Jan-97	SCR	3	915	14.5
547	7-Dec-96	ARK	8	929	13.0	582	7-Dec-96	ARK	8	1217	35.5
548	15-Nov-96	CIM	8	835	9.5	583	13-Dec-96	POL	3	1250	38.0
549	15-Nov-96	CIM	8	833	10.5	584	15-Nov-96	CIM	8	599	3.5
550	1-Nov-96	ARK	13	604	4.0	585	15-Nov-96	CIM	8	650	4.5
551	7-Dec-96	ARK	8	633	4.0	586	1-Jan-97	SCR	3	954	16.5
552	15-Nov-96	CIM	8	890	13.0	587	15-Nov-96	CIM	8	948	17.0
553	21-Dec-96	ARK	5	864	14.0	588	13-Dec-96	POL	3	652	4.5
554	15-Nov-96	CIM	8	995	20.5	589	7-Dec-96	ARK	8	865	12.0
555	15-Nov-96	CIM	8	623	3.5	590	8-Dec-96	CIM	18	882	11.5
556	8-Dec-96	CIM	18	649	4.5	591	1-Nov-96	ARK	13	824	12.0
557	15-Nov-96	CIM	8	960	13.5	592	14-Dec-96	ARK	22	626	4.0
558	6-Dec-96	CIM	14	1055	19.5	593	13-Dec-96	POL	3	860	13.0
559	15-Nov-96	CIM	8	974	16.5	594	7-Dec-96	ARK	8	1121	34.0
560	21-Dec-96	ARK	5	641	4.5	595	13-Dec-96	POL	3	905	13.0
561	15-Nov-96	CIM	8	572	3.0	596	21-Dec-96	ARK	5	1109	26.0
562	1-Nov-96	ARK	13	950	16.0	597	1-Jan-97	SCR	3	600	3.0
563	7-Dec-96	ARK	8	639	5.0	598	15-Nov-96	CIM	8	620	4.0
564	15-Nov-96	CIM	8	635	4.0	599	15-Nov-96	CIM	8	812	10.5
565	14-Dec-96	ARK	22	1113	26.0	600	7-Dec-96	ARK	8	840	12.0
566	30-Nov-96	CIM	16	964	17.5	601	2-Jan-97	SCR	6	612	4.0
567	6-Dec-96	CIM	14	952	N/A	602	1-Jan-97	SCR	3	900	13.5
568	7-Dec-96	ARK	8	895	13.0	603	1-Jan-97	SCR	3	638	4.5
569	13-Dec-96	POL	3	706	5.0	604	3-Jan-97	CIM	13	639	4.0
570	15-Nov-96	CIM	8	915	17.0	605	1-Jan-97	SCR	3	888	15.0
571	13-Dec-96	POL	3	789	12.5	606	1-Jan-97	SCR	3	869	11.5
572	15-Nov-96	CIM	8	1070	23.0	607	4-Jan-97	SCR	2	943	15.5
573	30-Nov-96	CIM	16	639	4.0	608	3-Jan-97	CIM	13	845	11.0
574	7-Dec-96	ARK	8	926	14.5	609	1-Jan-97	SCR	3	613	3.5
575	8-Dec-96	CIM	18	625	4.0	610	4-Jan-97	SCR	2	820	8.5
576	7-Dec-96	ARK	8	635	4.5	611	4-Jan-97	SCR	2	658	4.0
577	2-Nov-96	POL	5	624	4.0	612	3-Jan-97	CIM	13	874	13.0

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
613	2-Jan-97	SCR	6	917	13.0	648	3-Jan-97	CIM	13	838	10.0
614	4-Jan-97	SCR	2	1023	21.5	649	1-Jan-97	SCR	3	610	4.0
615	1-Jan-97	SCR	3	818	10.5	650	9-May-97	ARK	16	732	8.0
616	4-Jan-97	SCR	2	600	3.5	651	1-Jan-97	SCR	3	1047	21.0
617	1-Jan-97	SCR	3	950	13.0	652	4-Jan-97	SCR	2	868	12.0
618	1-Jan-97	SCR	3	619	4.5	653	4-Jan-97	SCR	2	830	10.0
619	4-Jan-97	SCR	2	1030	19.0	654	1-Jan-97	SCR	3	880	12.5
620	1-Jan-97	SCR	3	621	5.0	655	4-Jan-97	SCR	2	1263	32.0
621	4-Jan-97	SCR	2	948	15.0	656	1-Jan-97	SCR	3	777	9.0
622	2-Jan-97	SCR	6	1109	27.0	657	4-Jan-97	SCR	2	900	13.0
623	3-Jan-97	CIM	13	624	4.0	658	1-Jan-97	SCR	3	904	12.0
624	3-Jan-97	CIM	13	1059	21.5	659	3-Jan-97	CIM	13	655	4.0
625	3-Jan-97	CIM	13	960	13.5	660	4-Jan-97	SCR	2	860	11.5
626	1-Jan-97	SCR	3	639	4.0	661	1-Jan-97	SCR	3	699	5.5
627	2-Jan-97	SCR	6	888	13.5	662	4-Jan-97	SCR	2	994	17.0
628	1-Jan-97	SCR	3	872	11.5	663	4-Jan-97	SCR	2	614	3.5
629	4-Jan-97	SCR	2	869	12.5	664	3-Jan-97	CIM	13	907	13.0
630	1-Jan-97	SCR	3	657	4.5	665	3-Jan-97	CIM	13	1142	31.0
631	1-Jan-97	SCR	3	812	11.5	666	1-Jan-97	SCR	3	905	13.0
632	1-Jan-97	SCR	3	1242	36.0	667	4-Jan-97	SCR	2	657	3.5
633	3-Jan-97	CIM	13	955	19.0	668	2-Jan-97	SCR	6	830	11.5
634	1-Jan-97	SCR	3	641	4.5	669	4-Jan-97	SCR	2	948	12.0
635	4-Jan-97	SCR	2	616	4.5	670	1-Jan-97	SCR	3	686	5.5
636	3-Jan-97	CIM	13	866	11.5	671	4-Jan-97	SCR	2	677	3.0
637	3-Jan-97	CIM	13	600	4.0	672	2-Jan-97	SCR	6	945	15.5
638	3-Jan-97	CIM	13	638	4.5	673	1-Jan-97	SCR	3	884	12.5
639	3-Jan-97	CIM	13	873	11.5	674	1-Jan-97	SCR	3	845	11.0
640	3-Jan-97	CIM	13	924	18.5	675	4-Jan-97	SCR	2	863	10.5
641	1-Jan-97	SCR	3	969	16.0	676	4-Jan-97	SCR	2	598	4.0
642	1-Jan-97	SCR	3	624	4.0	677	1-Jan-97	SCR	3	633	4.5
643	3-Jan-97	CIM	13	593	3.5	678	2-Jan-97	SCR	6	658	5.5
644	4-Jan-97	SCR	2	860	13.0	679	3-Jan-97	CIM	13	967	16.5
645	4-Jan-97	SCR	2	1085	25.5	680	1-Jan-97	SCR	3	944	15.5
646	2-Jan-97	SCR	6	1094	24.0	681	3-Jan-97	CIM	13	855	12.0
647	1-Jan-97	SCR	3	966	17.0	682	4-Jan-97	SCR	2	885	12.0

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
683	1-Jan-97	SCR	3	614	4.0	718	5-Jan-97	CIM	10	1060	21.0
684	1-Jan-97	SCR	3	1027	19.5	719	8-Jan-97	ARK	11	619	3.5
685	3-Jan-97	CIM	13	919	14.0	720	18-Jan-97	ARK	10	585	4.0
686	3-Jan-97	CIM	13	1055	20.5	721	5-Jan-97	CIM	10	902	11.5
687	4-Jan-97	SCR	2	918	15.0	722	8-Jan-97	ARK	11	680	4.5
688	2-Jan-97	SCR	6	632	4.5	723	4-Jan-97	SCR	2	584	3.5
689	3-Jan-97	CIM	13	589	4.0	724	18-Jan-97	ARK	10	835	13.0
690	1-Jan-97	SCR	3	875	12.5	725	5-Jan-97	CIM	10	902	13.0
691	1-Jan-97	SCR	3	860	12.0	726	5-Jan-97	CIM	10	966	15.5
692	4-Jan-97	SCR	2	638	4.0	727	8-Jan-97	ARK	11	625	N/A
693	1-Jan-97	SCR	3	625	4.0	728	18-Jan-97	ARK	10	539	4.0
694	1-Jan-97	SCR	3	605	4.0	729	8-Jan-97	ARK	11	873	N/A
695	3-Jan-97	CIM	13	644	4.0	730	5-Jan-97	CIM	10	1205	34.5
696	1-Jan-97	SCR	3	636	4.0	731	5-Jan-97	CIM	10	911	14.5
697	3-Jan-97	CIM	13	619	4.5	732	8-Jan-97	ARK	11	1140	25.5
698	3-Jan-97	CIM	13	1124	24.0	733	8-Jan-97	ARK	11	883	N/A
699	1-Jan-97	SCR	3	643	5.0	734	18-Jan-97	ARK	10	845	10.0
700	4-Jan-97	SCR	2	883	11.5	735	5-Jan-97	CIM	10	1048	20.0
701	4-Jan-97	SCR	2	590	3.5	736	5-Jan-97	CIM	10	914	13.5
702	5-Jan-97	CIM	10	1150	32.5	737	18-Jan-97	ARK	10	870	16.0
703	8-Jan-97	ARK	11	645	N/A	739	8-Jan-97	ARK	11	636	N/A
704	8-Jan-97	ARK	11	645	3.5	740	8-Jan-97	ARK	11	627	4.0
705	18-Jan-97	ARK	10	850	14.0	741	8-Jan-97	ARK	11	610	3.5
706	5-Jan-97	CIM	10	941	13.5	742	18-Jan-97	ARK	10	600	3.0
707	8-Jan-97	ARK	11	575	N/A	743	8-Jan-97	ARK	11	642	4.0
708	5-Jan-97	CIM	10	635	4.5	744	18-Jan-97	ARK	6	845	14.0
709	8-Jan-97	ARK	11	1045	N/A	745	18-Jan-97	ARK	10	650	4.0
710	18-Jan-97	ARK	10	810	12.0	746	8-Jan-97	ARK	11	948	15.5
711	8-Jan-97	ARK	11	882	N/A	747	8-Jan-97	ARK	11	627	N/A
712	18-Jan-97	ARK	10	640	6.0	748	18-Jan-97	ARK	10	895	17.0
713	4-Jan-97	SCR	2	901	14.0	749	8-Jan-97	ARK	11	965	16.5
714	18-Jan-97	ARK	6	913	12.5	750	18-Jan-97	ARK	10	555	3.0
715	5-Jan-97	CIM	10	632	4.0	751	18-Jan-97	ARK	6	895	11.0
716	5-Jan-97	CIM	10	960	16.5	752	5-Jan-97	CIM	10	613	4.0
717	5-Jan-97	CIM	10	600	4.0	753	18-Jan-97	ARK	6	1200	35.0

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
754	18-Jan-97	ARK	10	855	13.0	789	5-Jan-97	CIM	10	1232	28.0
755	8-Jan-97	ARK	11	619	4.0	790	18-Jan-97	ARK	6	1202	34.5
756	18-Jan-97	ARK	10	545	4.0	791	19-Jan-97	CIM	11	621	3.0
757	18-Jan-97	ARK	10	879	14.0	792	18-Jan-97	ARK	10	550	4.0
758	18-Jan-97	ARK	6	1144	32.5	793	5-Jan-97	CIM	10	1141	33.5
759	8-Jan-97	ARK	11	973	15.0	794	5-Jan-97	CIM	10	750	7.0
760	8-Jan-97	ARK	11	859	10.0	795	8-Jan-97	ARK	11	1080	24.0
761	8-Jan-97	ARK	11	1205	N/A	796	8-Jan-97	ARK	11	880	13.5
762	4-Jan-97	SCR	2	630	4.5	797	18-Jan-97	ARK	10	1000	25.0
763	18-Jan-97	ARK	10	635	N/A	798	5-Jan-97	CIM	10	610	4.0
764	5-Jan-97	CIM	10	646	4.5	799	8-Jan-97	ARK	11	1055	22.0
765	19-Jan-97	CIM	11	1046	21.0	800	18-Jan-97	ARK	6	1123	33.0
766	8-Jan-97	ARK	11	672	N/A	801	28-Jan-97	CIM	6	910	13.0
767	18-Jan-97	ARK	10	860	15.0	802	28-Jan-97	CIM	6	1136	26.5
768	18-Jan-97	ARK	10	615	5.0	803	19-Jan-97	CIM	11	810	9.5
769	5-Jan-97	CIM	10	880	11.5	804	31-Jan-97	CIM	5	925	13.5
770	18-Jan-97	ARK	10	1095	30.0	805	25-Jan-97	CIM	21	849	10.0
771	18-Jan-97	ARK	10	575	4.0	806	31-Jan-97	CIM	5	846	11.0
772	8-Jan-97	ARK	11	891	N/A	807	19-Jan-97	CIM	11	630	4.0
773	18-Jan-97	ARK	10	958	15.5	808	28-Jan-97	CIM	6	903	14.0
774	18-Jan-97	ARK	6	973	16.0	809	19-Jan-97	CIM	11	590	3.0
775	8-Jan-97	ARK	11	633	3.5	810	2-Feb-97	ARK	19	873	9.0
776	8-Jan-97	ARK	11	1255	34.0	811	28-Jan-97	CIM	6	892	11.5
777	4-Jan-97	SCR	2	925	11.5	812	28-Jan-97	CIM	6	1027	20.5
778	8-Jan-97	ARK	11	1105	25.0	813	19-Jan-97	CIM	11	628	4.0
779	5-Jan-97	CIM	10	1165	34.0	814	28-Jan-97	CIM	6	641	4.5
780	8-Jan-97	ARK	11	1067	N/A	815	19-Jan-97	CIM	11	884	11.0
781	4-Jan-97	SCR	2	938	13.5	816	28-Jan-97	CIM	6	932	13.0
782	18-Jan-97	ARK	10	830	11.0	817	19-Jan-97	CIM	11	960	20.0
783	19-Jan-97	CIM	11	917	12.0	818	19-Jan-97	CIM	11	858	10.5
784	18-Jan-97	ARK	10	792	9.0	819	31-Jan-97	CIM	5	1130	24.0
785	5-Jan-97	CIM	10	1126	29.5	820	19-Jan-97	CIM	11	820	8.0
786	18-Jan-97	ARK	10	585	4.0	821	28-Jan-97	CIM	6	955	13.0
787	8-Jan-97	ARK	11	1140	N/A	822	19-Jan-97	CIM	11	1008	17.5
788	18-Jan-97	ARK	10	885	17.0	823	8-Feb-97	ARK	16	625	3.5

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
824	31-Jan-97	CIM	5	1074	22.5	859	8-Feb-97	ARK	16	603	4.0
825	28-Jan-97	CIM	6	893	13.0	860	8-Feb-97	ARK	16	988	16.5
826	28-Jan-97	CIM	6	914	13.5	861	8-Feb-97	ARK	16	882	12.0
827	7-Feb-97	ARK	24	881	13.0	862	8-Feb-97	ARK	16	1290	43.0
828	28-Jan-97	CIM	6	631	3.0	863	8-Feb-97	ARK	16	620	4.0
829	25-Jan-97	CIM	21	634	4.5	864	8-Feb-97	ARK	16	1167	28.0
830	28-Jan-97	CIM	6	1128	40.5	865	8-Feb-97	ARK	16	1195	29.5
831	28-Jan-97	CIM	6	1097	23.0	866	8-Feb-97	ARK	16	1165	32.0
832	28-Jan-97	CIM	6	1102	24.5	867	9-Feb-97	ARK	18	649	4.0
833	7-Feb-97	ARK	24	1010	20.0	868	8-Feb-97	ARK	16	641	4.5
834	28-Jan-97	CIM	6	1102	25.0	869	8-Feb-97	ARK	16	589	3.5
835	8-Feb-97	ARK	16	623	4.0	870	8-Feb-97	ARK	16	615	4.0
836	2-Feb-97	ARK	19	1034	22.0	871	8-Feb-97	ARK	16	983	19.5
837	28-Jan-97	CIM	6	629	3.5	872	8-Feb-97	ARK	16	886	12.0
838	19-Jan-97	CIM	11	950	14.0	873	8-Feb-97	ARK	16	644	4.5
839	28-Jan-97	CIM	6	1200	27.5	874	9-Feb-97	ARK	18	1114	25.0
840	28-Jan-97	CIM	6	589	3.0	875	9-Feb-97	ARK	18	588	3.5
841	31-Jan-97	CIM	5	684	4.5	876	8-Feb-97	ARK	16	884	12.5
842	28-Jan-97	CIM	6	1170	32.5	877	8-Feb-97	ARK	16	1229	32.5
843	28-Jan-97	CIM	6	940	13.0	878	9-Feb-97	ARK	18	1210	28.0
844	28-Jan-97	CIM	6	1121	30.5	879	9-Feb-97	ARK	18	1099	28.0
845	28-Jan-97	CIM	6	850	10.0	880	8-Feb-97	ARK	16	644	4.0
846	8-Feb-97	ARK	16	1030	22.5	881	8-Feb-97	ARK	16	631	4.0
847	2-Feb-97	ARK	19	1229	30.0	882	8-Feb-97	ARK	16	912	13.0
848	31-Jan-97	CIM	5	1095	22.0	883	8-Feb-97	ARK	16	839	12.5
849	28-Jan-97	CIM	6	587	2.5	884	8-Feb-97	ARK	16	1140	23.5
850	28-Jan-97	CIM	6	850	12.0	885	8-Feb-97	ARK	16	684	4.5
851	8-Feb-97	ARK	16	583	3.5	886	8-Feb-97	ARK	16	570	2.5
852	8-Feb-97	ARK	16	960	15.0	887	8-Feb-97	ARK	16	605	3.5
853	8-Feb-97	ARK	16	1170	29.0	888	8-Feb-97	ARK	16	1092	18.0
854	8-Feb-97	ARK	16	967	15.5	889	8-Feb-97	ARK	16	790	7.5
855	9-Feb-97	ARK	18	1263	35.0	890	8-Feb-97	ARK	16	895	12.0
856	8-Feb-97	ARK	16	1148	32.5	891	8-Feb-97	ARK	16	582	3.0
857	8-Feb-97	ARK	16	1005	18.5	892	8-Feb-97	ARK	16	627	4.0
858	8-Feb-97	ARK	16	635	4.0	893	9-Feb-97	ARK	18	582	3.0

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
894	8-Feb-97	ARK	16	609	3.5	929	9-Feb-97	ARK	18	941	15.0
895	8-Feb-97	ARK	16	900	13.0	930	9-Feb-97	ARK	18	990	15.5
896	9-Feb-97	ARK	18	906	12.5	931	7-Mar-97	CIM	14	600	3.5
897	8-Feb-97	ARK	16	626	4.0	932	2-Mar-97	ARK	21	607	5.0
898	8-Feb-97	ARK	16	1120	28.5	933	2-Mar-97	CIM	14	635	5.0
899	8-Feb-97	ARK	16	850	12.0	934	2-Mar-97	CIM	14	918	14.0
900	8-Feb-97	ARK	16	650	4.5	935	9-Feb-97	ARK	18	610	3.5
901	9-Mar-97	CIM	27	925	14.5	936	12-Mar-97	ARK	176	840	12.5
902	9-Feb-97	ARK	18	634	4.5	937	9-Feb-97	ARK	18	635	4.5
903	12-Mar-97	ARK	176	769	6.0	938	9-Feb-97	ARK	18	875	11.5
904	28-Feb-97	ARK	14	805	11.0	939	7-Mar-97	CIM	14	620	4.0
905	2-Mar-97	CIM	14	920	14.0	940	7-Mar-97	CIM	14	948	13.0
906	8-Mar-97	CIM	8	620	4.0	941	9-Feb-97	ARK	18	916	13.0
907	9-Feb-97	ARK	18	940	14.5	942	9-Feb-97	ARK	18	967	18.0
908	12-Mar-97	ARK	176	911	18.0	943	9-Mar-97	CIM	27	610	4.0
909	10-Mar-97	POL	3	880	11.0	944	9-Feb-97	ARK	18	796	9.5
910	7-Mar-97	CIM	14	912	14.0	945	9-Mar-97	CIM	22	580	4.0
911	9-Feb-97	ARK	18	777	9.0	946	9-Feb-97	ARK	18	1187	34.0
912	9-Mar-97	CIM	22	632	5.0	947	7-Mar-97	CIM	19	606	3.5
913	1-Mar-97	ARK	14	880	11.0	948	9-Feb-97	ARK	18	840	10.0
914	7-Mar-97	CIM	19	652	4.5	949	7-Mar-97	CIM	19	614	4.0
915	9-Feb-97	ARK	18	1034	24.0	950	9-Feb-97	ARK	18	877	12.0
916	7-Mar-97	CIM	14	945	15.0	951	8-Mar-97	CIM	8	880	14.0
917	9-Feb-97	ARK	18	985	17.0	952	2-Mar-97	CIM	14	644	4.5
918	7-Mar-97	CIM	19	837	9.5	953	9-Feb-97	ARK	18	1027	20.0
919	7-Mar-97	CIM	19	1000	19.0	954	12-Mar-97	ARK	176	870	13.0
920	9-Feb-97	ARK	18	594	4.0	955	12-Mar-97	ARK	176	931	16.0
921	9-Mar-97	CIM	22	619	4.5	956	15-Mar-97	CIM	54	885	12.5
922	9-Feb-97	ARK	18	633	4.0	957	15-Mar-97	CIM	54	874	11.0
923	10-Mar-97	POL	3	903	13.0	958	12-Mar-97	ARK	176	875	15.0
924	9-Feb-97	ARK	18	712	5.5	959	15-Mar-97	CIM	54	810	10.0
925	9-Mar-97	CIM	22	651	4.5	960	12-Mar-97	ARK	176	755	6.0
926	9-Feb-97	ARK	18	617	4.0	961	23-Mar-97	SFR	16	899	10.5
927	7-Mar-97	CIM	14	636	4.5	962	23-Mar-97	SFR	16	910	12.5
928	8-Mar-97	CIM	8	588	3.5	963	15-Mar-97	CIM	54	856	10.0

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
964	12-Mar-97	ARK	176	874	13.0	1000	9-May-97	ARK	16	960	15.0
965	15-Mar-97	CIM	54	644	4.5	1001	9-May-97	ARK	16	770	9.0
966	15-Mar-97	CIM	54	885	12.5	1002	9-May-97	CIM	14	650	5.0
967	23-Mar-97	SFR	16	1150	28.0	1003	15-May-97	POL	3	912	15.0
968	15-Mar-97	CIM	54	871	10.0	1004	15-May-97	POL	3	680	6.0
969	23-Mar-97	SFR	16	908	13.0	1005	15-May-97	POL	3	971	17.5
970	23-Mar-97	SFR	16	911	11.0	1006	15-May-97	POL	3	678	5.5
971	23-Mar-97	SFR	16	855	8.0	1007	16-May-97	SCR	3	1130	29.0
972	23-Mar-97	SFR	16	877	11.0	1008	16-May-97	SCR	3	937	17.0
973	15-Mar-97	CIM	54	867	10.5	1009	16-May-97	SCR	3	929	16.0
974	15-Mar-97	CIM	54	904	12.0	1010	16-May-97	SCR	3	914	15.0
975	15-Mar-97	CIM	54	906	13.0	1011	16-May-97	SCR	3	913	14.5
976	23-Mar-97	SFR	16	891	13.0	1012	16-May-97	SCR	3	945	15.0
977	23-Mar-97	SFR	16	785	9.0	1013	16-May-97	SCR	3	689	7.0
978	11-Apr-97	ARK	176	833	11.0	1014	20-May-97	SCR	3	1083	27.0
979	11-Apr-97	ARK	176	893	10.0	1015	20-May-97	SCR	3	985	17.0
980	11-Apr-97	ARK	176	861	10.0	1016	13-Jan-98	CIM	18	761	8.0
981	11-Apr-97	ARK	176	690	5.0	1017	5-Jan-98	ARK	14	795	8.5
982	26-Mar-97	SFR	16	849	9.0	1018	5-Jan-98	ARK	14	798	9.0
983	26-Mar-97	SFR	16	966	15.0	1019	29-Nov-97	ARK	8	945	16.0
984	28-Mar-97	CIM	86	925	13.5	1020	13-Jan-98	CIM	18	831	11.0
985	2-Apr-97	SFR	16	855	11.0	1021	13-Jan-98	CIM	18	977	16.5
986	11-Apr-97	ARK	176	781	7.5	1022	5-Jan-98	ARK	14	999	16.5
987	11-Apr-97	ARK	176	870	12.0	1023	13-Jan-98	CIM	18	890	12.0
988	24-Mar-97	SFR	16	835	7.5	1024	14-Jan-98	ARK	11	797	8.0
989	11-Apr-97	ARK	176	935	15.5	1025	19-Dec-97	CIM	8	1173	26.0
991	24-Mar-97	SFR	16	955	13.0	1026	19-Dec-97	CIM	8	756	7.0
992	11-Apr-97	ARK	176	736	6.5	1027	29-Nov-97	ARK	8	941	15.0
993	24-Mar-97	SFR	16	975	14.5	1028	5-Jan-98	ARK	14	946	15.0
994	1-Apr-97	CIM	86	1037	19.0	1029	14-Jan-98	ARK	11	740	8.0
995	26-Mar-97	SFR	16	868	10.5	1030	13-Jan-98	CIM	18	790	9.0
996	28-Mar-97	CIM	86	825	10.0	1031	14-Jan-98	ARK	11	799	9.0
997	26-Mar-97	SFR	16	835	8.5	1032	13-Jan-98	CIM	18	919	14.5
998	2-Apr-97	SFR	16	880	11.0	1033	13-Jan-98	CIM	18	730	8.0
999	11-Apr-97	ARK	176	850	9.0	1034	28-Nov-97	POL	5	1055	27.0

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
1035	19-Dec-97	CIM	8	895	14.0	1070	20-Dec-97	SCR	5	827	9.0
1036	28-Nov-97	POL	5	715	7.0	1071	28-Nov-97	POL	5	1240	27.0
1037	14-Jan-98	ARK	11	1003	19.0	1072	19-Dec-97	CIM	8	752	7.0
1038	5-Jan-98	ARK	14	812	9.0	1073	19-Dec-97	CIM	8	763	6.0
1039	13-Jan-98	CIM	18	804	9.0	1074	19-Dec-97	CIM	8	795	9.0
1040	19-Dec-97	CIM	8	1019	16.0	1075	13-Jan-98	CIM	18	784	9.0
1041	14-Jan-98	ARK	11	860	13.0	1076	19-Dec-97	CIM	8	748	6.5
1042	5-Jan-98	ARK	14	977	17.5	1077	29-Nov-97	ARK	8	1153	33.0
1043	14-Jan-98	ARK	11	922	17.0	1078	28-Nov-97	POL	5	785	7.5
1044	20-Dec-97	SCR	5	1058	25.5	1079	28-Nov-97	POL	5	980	17.0
1045	20-Dec-97	SCR	5	1110	29.0	1080	20-Dec-97	SCR	5	1076	24.5
1046	19-Dec-97	CIM	8	851	11.0	1081	13-Jan-98	CIM	18	755	7.5
1047	14-Jan-98	ARK	11	977	19.5	1082	28-Nov-97	POL	5	780	9.0
1048	5-Jan-98	ARK	14	768	7.0	1083	28-Nov-97	POL	5	1140	30.0
1049	20-Dec-97	SCR	5	942	15.0	1084	5-Jan-98	ARK	14	1064	19.5
1050	14-Jan-98	ARK	11	1045	21.5	1085	14-Jan-98	ARK	11	1063	20.0
1051	28-Nov-97	POL	5	820	10.0	1086	20-Dec-97	SCR	5	1128	30.0
1052	19-Dec-97	CIM	8	1031	20.0	1087	29-Nov-97	ARK	8	732	7.5
1053	29-Nov-97	ARK	8	851	11.0	1088	19-Dec-97	CIM	8	984	17.0
1054	14-Jan-98	ARK	11	755	8.0	1089	14-Jan-98	ARK	11	1100	27.0
1055	19-Dec-97	CIM	8	781	8.0	1090	5-Jan-98	ARK	14	1028	24.0
1056	20-Dec-97	SCR	5	770	8.0	1091	5-Jan-98	ARK	14	785	9.0
1057	14-Jan-98	ARK	11	822	10.0	1092	28-Nov-97	POL	5	940	14.0
1058	28-Nov-97	POL	5	980	19.0	1093	19-Dec-97	CIM	8	961	13.0
1059	5-Jan-98	ARK	14	726	7.0	1094	19-Dec-97	CIM	8	1185	29.0
1060	19-Dec-97	CIM	8	1136	19.5	1095	13-Jan-98	CIM	18	987	18.0
1061	28-Nov-97	POL	5	780	8.0	1096	29-Nov-97	ARK	8	775	7.5
1062	28-Nov-97	POL	5	765	9.0	1097	28-Nov-97	POL	5	795	10.0
1063	20-Dec-97	SCR	5	817	8.5	1098	14-Jan-98	ARK	11	1079	21.5
1064	19-Dec-97	CIM	8	1013	18.5	1099	28-Nov-97	POL	5	1010	17.0
1065	5-Jan-98	ARK	14	820	10.0	1100	14-Jan-98	ARK	11	1040	23.5
1066	20-Dec-97	SCR	5	819	9.5	1101	14-Jan-98	ARK	11	813	9.5
1067	19-Dec-97	CIM	8	796	9.0	1102	22-Jan-98	SCR	2	997	19.5
1068	19-Dec-97	CIM	8	754	7.0	1103	14-Jan-98	ARK	11	988	20.0
1069	20-Dec-97	SCR	5	802	9.5	1104	14-Jan-98	ARK	11	784	9.0

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
1105	14-Jan-98	ARK	11	1001	20.0	1140	24-Jan-98	SCR	3	1110	28.5
1106	14-Jan-98	ARK	11	872	14.0	1141	22-Jan-98	SCR	2	744	8.0
1107	24-Jan-98	SCR	3	785	8.5	1142	24-Jan-98	SCR	3	762	8.5
1108	24-Jan-98	SCR	3	750	8.0	1143	22-Jan-98	SCR	2	1130	28.5
1109	24-Jan-98	SCR	3	995	20.0	1144	23-Jan-98	CIM	11	783	9.0
1110	24-Jan-98	SCR	3	993	19.0	1145	24-Jan-98	SCR	3	848	11.5
1111	22-Jan-98	SCR	2	936	15.0	1146	18-Jan-98	CIM	19	990	16.0
1112	24-Jan-98	SCR	3	1035	22.5	1147	23-Jan-98	CIM	11	966	18.5
1113	23-Jan-98	CIM	11	1050	17.5	1148	24-Jan-98	SCR	3	757	8.5
1114	14-Jan-98	ARK	11	1012	19.0	1149	15-Jan-98	POL	2	1012	19.5
1115	18-Jan-98	CIM	19	1075	21.5	1150	23-Jan-98	CIM	11	920	15.0
1116	24-Jan-98	SCR	3	745	7.0	1151	22-Jan-98	SCR	2	844	10.5
1117	24-Jan-98	SCR	3	772	9.0	1152	24-Jan-98	SCR	3	1007	20.0
1118	22-Jan-98	SCR	2	996	19.0	1153	18-Jan-98	ARK	22	1035	19.5
1119	24-Jan-98	SCR	3	1104	22.0	1154	16-Jan-98	ARK	19	811	11.0
1120	24-Jan-98	SCR	3	996	22.5	1155	18-Jan-98	CIM	19	1000	16.5
1121	22-Jan-98	SCR	2	774	7.5	1156	24-Jan-98	SCR	3	1036	25.0
1122	16-Jan-98	ARK	19	1085	20.0	1157	18-Jan-98	CIM	19	746	8.0
1123	18-Jan-98	CIM	19	763	7.5	1158	18-Jan-98	ARK	22	931	13.0
1124	22-Jan-98	SCR	2	785	8.5	1159	16-Jan-98	ARK	19	891	13.0
1125	24-Jan-98	SCR	3	836	10.5	1160	24-Jan-98	SCR	3	1114	25.0
1126	23-Jan-98	CIM	11	760	6.5	1161	22-Jan-98	SCR	2	1060	17.5
1127	24-Jan-98	SCR	3	798	8.5	1162	22-Jan-98	SCR	2	815	9.0
1128	24-Jan-98	SCR	3	998	22.0	1163	22-Jan-98	SCR	2	856	10.5
1129	18-Jan-98	CIM	19	909	13.0	1164	24-Jan-98	SCR	3	1132	27.0
1130	24-Jan-98	SCR	3	830	10.0	1165	23-Jan-98	CIM	11	850	10.0
1131	16-Jan-98	ARK	19	1270	35.0	1166	22-Jan-98	SCR	2	994	19.0
1132	18-Jan-98	ARK	22	1032	17.0	1167	18-Jan-98	CIM	19	768	8.5
1133	16-Jan-98	ARK	19	969	16.0	1168	24-Jan-98	SCR	3	1090	29.5
1134	24-Jan-98	SCR	3	1011	20.5	1169	24-Jan-98	SCR	3	950	15.0
1135	18-Jan-98	CIM	19	1119	30.0	1170	18-Jan-98	CIM	19	797	9.5
1136	24-Jan-98	SCR	3	800	8.5	1171	16-Jan-98	ARK	19	923	18.0
1137	14-Jan-98	ARK	11	1010	18.5	1172	23-Jan-98	CIM	11	1123	23.5
1138	15-Jan-98	CIM	24	931	15.0	1173	24-Jan-98	SCR	3	764	9.0
1139	24-Jan-98	SCR	3	832	10.5	1174	18-Jan-98	CIM	19	825	9.0

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
1175	22-Jan-98	SCR	2	796	7.5	1210	30-Jan-98	POL	3	1220	33.0
1176	22-Jan-98	SCR	2	800	8.0	1211	6-Feb-98	ARK	16	920	11.0
1177	16-Jan-98	ARK	19	1064	21.5	1212	14-Feb-98	CIM	13	833	10.0
1178	22-Jan-98	SCR	2	779	9.0	1213	27-Jan-98	ARK	10	1215	35.5
1179	18-Jan-98	CIM	19	995	19.5	1214	31-Jan-98	CIM	19	1031	21.5
1180	24-Jan-98	SCR	3	798	10.0	1215	6-Feb-98	ARK	16	829	10.0
1181	24-Jan-98	SCR	3	1092	24.5	1216	6-Feb-98	ARK	16	807	9.5
1182	24-Jan-98	SCR	3	770	9.0	1217	30-Jan-98	POL	3	1132	29.5
1183	16-Jan-98	ARK	19	763	8.5	1218	14-Feb-98	CIM	13	1290	33.5
1184	24-Jan-98	SCR	3	917	15.5	1219	6-Feb-98	ARK	16	824	10.0
1185	24-Jan-98	SCR	3	927	17.0	1220	27-Jan-98	ARK	10	1012	22.0
1186	24-Jan-98	SCR	3	735	8.5	1221	5-Feb-98	CIM	5	951	16.0
1187	24-Jan-98	SCR	3	775	8.0	1222	14-Feb-98	CIM	13	779	8.0
1188	18-Jan-98	CIM	19	1112	25.5	1223	6-Feb-98	ARK	16	796	9.5
1189	23-Jan-98	CIM	11	1150	31.5	1224	19-Feb-98	ARK	21	1031	23.0
1190	24-Jan-98	SCR	3	838	10.5	1225	14-Feb-98	CIM	13	786	7.5
1191	24-Jan-98	SCR	3	800	9.5	1226	6-Feb-98	ARK	16	1149	28.0
1192	24-Jan-98	SCR	3	1112	20.0	1227	14-Feb-98	CIM	13	765	7.0
1193	18-Jan-98	CIM	19	1197	40.0	1228	6-Feb-98	ARK	16	821	105.
1194	16-Jan-98	ARK	19	1063	25.0	1229	14-Feb-98	CIM	13	816	9.0
1195	18-Jan-98	ARK	22	842	12.5	1230	14-Feb-98	CIM	13	774	8.0
1196	16-Jan-98	ARK	19	964	14.5	1231	19-Feb-98	ARK	21	1181	34.5
1197	23-Jan-98	CIM	11	928	15.5	1232	30-Jan-98	POL	3	812	8.5
1198	23-Jan-98	CIM	11	800	9.0	1233	14-Feb-98	CIM	13	774	9.0
1199	23-Jan-98	CIM	11	1010	18.5	1234	30-Jan-98	POL	3	922	11.5
1200	15-Jan-98	POL	2	789	8.5	1235	19-Feb-98	ARK	21	788	7.5
1201	30-Jan-98	POL	3	885	12.0	1236	19-Feb-98	ARK	21	930	15.0
1202	6-Feb-98	ARK	16	1006	19.5	1237	19-Feb-98	ARK	21	896	12.0
1203	6-Feb-98	ARK	16	1082	24.0	1238	14-Feb-98	CIM	13	769	8.0
1204	14-Feb-98	CIM	13	964	18.0	1239	14-Feb-98	CIM	13	810	8.0
1205	6-Feb-98	ARK	16	779	8.0	1240	30-Jan-98	POL	3	974	22.0
1206	27-Jan-98	ARK	10	955	14.5	1241	20-Feb-98	CIM	6	863	10.5
1207	27-Jan-98	ARK	10	1280	39.5	1242	6-Feb-98	ARK	16	923	14.0
1208	19-Feb-98	ARK	21	1120	24.0	1243	14-Feb-98	CIM	13	1018	20.0
1209	14-Feb-98	CIM	13	987	21.0	1244	31-Jan-98	CIM	19	978	17.0

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)	Tag	Date	strata	River km	Len (mm)	Wt (kg)
1245	6-Feb-98	ARK	16	802	8.5	1281	27-Jan-98	ARK	10	776	9.0
1246	6-Feb-98	ARK	16	1114	24.0	1282	14-Feb-98	CIM	13	776	8.0
1247	27-Jan-98	ARK	10	945	14.5	1283	14-Feb-98	CIM	13	954	14.5
1248	19-Feb-98	ARK	21	983	17.5	1284	19-Feb-98	ARK	21	914	14.0
1249	6-Feb-98	ARK	16	1141	30.0	1285	6-Feb-98	ARK	16	996	17.0
1250	6-Feb-98	ARK	16	1076	25.0	1286	6-Feb-98	ARK	16	827	9.0
1251	14-Feb-98	CIM	13	767	8.5	1287	6-Feb-98	ARK	16	748	7.0
1252	14-Feb-98	CIM	13	785	8.0	1288	14-Feb-98	CIM	13	995	15.0
1253	5-Feb-98	CIM	5	951	16.0	1289	6-Feb-98	ARK	16	925	11.0
1255	30-Jan-98	POL	3	981	18.0	1290	30-Jan-98	POL	3	1024	19.5
1256	6-Feb-98	ARK	16	1015	26.5	1291	6-Feb-98	ARK	16	970	17.0
1257	27-Jan-98	ARK	10	1008	20.0	1292	6-Feb-98	ARK	16	1069	27.0
1258	14-Feb-98	CIM	13	837	8.5	1293	14-Feb-98	CIM	13	1042	23.5
1259	6-Feb-98	ARK	16	1010	25.5	1294	19-Feb-98	ARK	21	1015	19.0
1260	14-Feb-98	CIM	13	774	9.0	1295	30-Jan-98	POL	3	768	8.5
1261	6-Feb-98	ARK	16	1167	30.5	1296	6-Feb-98	ARK	16	948	14.0
1262	30-Jan-98	POL	3	834	8.0	1297	5-Feb-98	CIM	5	968	19.0
1263	27-Jan-98	ARK	10	1168	41.0	1298	30-Jan-98	POL	3	963	17.0
1264	14-Feb-98	CIM	13	1111	22.5	1299	6-Feb-98	ARK	16	1097	26.0
1265	5-Feb-98	CIM	5	1123	29.0	1300	19-Feb-98	ARK	21	939	12.5
1266	19-Feb-98	ARK	21	920	12.5	1301	20-Feb-98	CIM	6	862	11.0
1267	30-Jan-98	POL	3	956	16.5	1302	20-Feb-98	CIM	6	1200	28.5
1268	14-Feb-98	CIM	13	1007	23.5	1303	20-Feb-98	CIM	6	875	12.5
1269	6-Feb-98	ARK	16	1056	20.0	1304	20-Feb-98	CIM	6	739	7.0
1270	30-Jan-98	POL	3	772	8.0	1305	20-Feb-98	CIM	6	754	7.0
1271	30-Jan-98	POL	3	790	7.0	1306	20-Feb-98	CIM	6	889	12.0
1272	14-Feb-98	CIM	13	971	13.0	1307	20-Feb-98	CIM	6	802	8.5
1273	14-Feb-98	CIM	13	760	7.0	1308	20-Feb-98	CIM	6	855	11.0
1274	6-Feb-98	ARK	16	1024	19.0	1309	20-Feb-98	CIM	6	740	7.0
1275	30-Jan-98	POL	3	766	9.0	1310	20-Feb-98	CIM	6	787	8.5
1276	14-Feb-98	CIM	13	833	9.5	1311	20-Feb-98	CIM	6	1135	28.5
1277	6-Feb-98	ARK	16	1006	20.0	1312	20-Feb-98	CIM	6	738	8.0
1278	30-Jan-98	POL	3	1034	21.0	1313	20-Feb-98	CIM	6	792	8.0
1279	6-Feb-98	ARK	16	1023	21.5	1314	20-Feb-98	CIM	6	761	7.0
1280	5-Feb-98	CIM	5	1291	33.5	1315	20-Feb-98	CIM	6	824	9.0

Appendix H. (continued)

Tag	Date	strata	River km	Len (mm)	Wt (kg)
1316	20-Feb-98	CIM	6	1025	24.5
1317	20-Feb-98	CIM	6	822	9.0
1318	20-Feb-98	CIM	6	752	7.0
1319	21-Feb-98	SCR	3	1095	24.0
1320	21-Feb-98	SCR	3	769	8.5
1321	22-Feb-98	CIM	8	750	6.5
1322	6-Mar-98	ARK	5	780	8.0
1323	6-Mar-98	ARK	5	1025	18.5
1324	6-Mar-98	ARK	5	785	8.0
1325	6-Mar-98	ARK	5	788	9.0
1326	5-Mar-98	CIM	10	910	14.5
1327	6-Mar-98	ARK	5	717	5.5
1328	6-Mar-98	ARK	5	973	17.0
1329	6-Mar-98	ARK	5	772	8.5
1330	5-Mar-98	CIM	10	1009	20.0
1331	5-Mar-98	CIM	10	817	11.0
1332	5-Mar-98	CIM	10	765	6.0
1333	5-Mar-98	CIM	10	686	7.0
1334	6-Mar-98	ARK	5	976	16.5
1335	6-Mar-98	ARK	5	735	6.5
1336	5-Mar-98	CIM	10	770	8.0
1337	5-Mar-98	CIM	10	883	14.5
1338	5-Mar-98	CIM	10	936	15.5
1339	5-Mar-98	CIM	10	756	7.5
1340	6-Mar-98	ARK	5	804	9.0
1341	6-Mar-98	ARK	5	926	13.5
1342	5-Mar-98	CIM	10	770	8.5
1343	5-Mar-98	CIM	10	772	8.5
1344	6-Mar-98	ARK	5	771	7.5
1345	6-Mar-98	ARK	5	792	8.0
1346	6-Mar-98	ARK	5	988	20.0
1347	6-Mar-98	ARK	5	947	17.5
1348	6-Mar-98	ARK	5	825	8.0
1349	6-Mar-98	ARK	5	1008	17.0

CHAPTER III.

Factors Affecting Summer Distribution and Movement of Paddlefish in a Prairie Reservoir

Abstract.--Six male paddlefish Polyodon spathula were implanted with ultrasonic transmitters and tracked from June through August 1997 to determine their distribution and movements in relation to physicochemical conditions in Keystone Reservoir, Oklahoma. Paddlefish moved about twice as much during nighttime than daytime. Paddlefish movement rates were dependent on reservoir water level, water inflow, and discharge from the reservoir, with discharge being the most important factor at night and water level and water inflow being most important during the day. Paddlefish distribution in the reservoir was related to these same three variables, with water level being the most important factor. Daytime distribution depended most on water level and nighttime distribution on water level and discharge. Paddlefish always avoided the highest available water temperatures, but did not always avoid low dissolved oxygen concentrations. Paddlefish avoided the Cimarron River arm of the reservoir in summer, possibly because of the high salinity levels. Our study demonstrates that summer paddlefish distribution and movement in Keystone Reservoir is strongly influenced by physicochemical and hydrologic conditions in the system.

Paddlefish _Polyodon spathula_ are native to large free-flowing rivers of the central United States where they thrive in backwaters, oxbows, and deepwater channel habitats. In spring, paddlefish in large rivers make extensive spawning migrations (Unkenholtz 1982; Russell 1986), moving between pools during high water periods and associating with tailwater and turbulent main-channel border habitats (Southhall and Hubert 1984, Moen et al. 1992). Over the past several decades substantial populations of paddlefish have developed in reservoirs of large rivers (Russell 1986). Paddlefish presumably exhibit similar springtime movement and habitat use patterns in reservoir systems compared to those in large river systems. However, we know little about summer distribution and movement patterns of paddlefish in reservoirs.

Paddlefish habitat preferences during the spring spawning period are generally well understood (Hubert et al. 1984; Southhall and Hubert 1984; Crance 1987; Brandtly 1987; Moen et al. 1992); however, summer habitat requirements are less well known, particularly in reservoirs. Because of the diverse and unpredictable physicochemical habitats that paddlefish occupy, due in part to anthropogenic alterations (impoundment, regulated flows) of riverine environments, there is a need to determine paddlefish habitat preferences under a variety of environmental conditions (Moen et al. 1992) and during different seasons. To our knowledge, no one has examined the physicochemical and hydrologic factors influencing summer distribution and movement of paddlefish in reservoir environments.

Keystone Reservoir is a prairie impoundment in northcentral Oklahoma with an established paddlefish population and diverse physicochemical and hydrologic properties. For example, the Cimarron River arm of Keystone Reservoir has salinities that are about four times higher than those in the Arkansas River arm, which creates a salt-heavy underlayment of water in the reservoir in summer (Eley 1967). Little is known about salinity preferences of paddlefish. Neill et al. (1994) determined that paddlefish avoid high salinity levels in the laboratory; however, no concurrent field studies were conducted. Our objectives were to determine the physicochemical and hydrologic factors affecting summer distribution and movement of paddlefish in Keystone Reservoir.

STUDY SITE

Keystone Reservoir is a 10,600-ha impoundment of the Arkansas and Cimarron rivers in northcentral Oklahoma, 13 km west of Sand Springs. The maximum depth is 23.3 m with an average depth of 7.7 m (Hicks, 1993). In spring and summer, large water-level fluctuations are common due to unpredictable inflows into the reservoir and outflows for flood control and power generation. Surface water temperatures can be extreme, reaching 34 C. Keystone Reservoir becomes thermally and chemically stratified in summer, with higher salinity concentrations in the hypolimnion. The Cimarron River drains highly mineralized subsurface deposits of natural salts and gypsum in western Oklahoma and, consequently, the Cimarron River arm of Keystone Reservoir has high salinity levels (Eley 1970). The Arkansas River drains the southern plains of Colorado and Kansas and has high concentration of calcium and magnesium sulfate (Eley 1970). The Salt Fork of the Arkansas River, a major tributary of the Arkansas River, is heavily influenced by naturally occurring salt flats in northwestern Oklahoma. However, conductivity readings are generally higher in the Cimarron River arm than in the Arkansas River arm of the reservoir (Eley 1970). The Cimarron River is unimpounded above Keystone Reservoir and exhibits highly fluctuating flows. The Arkansas River is impounded 176 km above Keystone Reservoir and has a regulated flow regime.

METHODS

We captured paddlefish for transmitter implantation with 152-mm and 203-mm bar measure monofilament gill nets, 91 m long and, either 7 m or 9 m deep. Nets were fished overnight on 1 and 6 March 1997. We used crystal-controlled, temperature-sensing ultrasonic transmitters (Sonotronics, Tucson, AZ) rated for a battery life of 24 months and a range of 3000 m. Ultrasonic transmitters were chosen over radio transmitters (Fisher and Wilkerson 1995) because of the high conductivity levels (up to 5,000 μS/cm) in the reservoir. Each transmitter had a unique aural code and was set at a frequency of either 74.0 kHz or 76.0 kHz allowing identification of individual fish. Captured fish were placed in a 538-l holding pen and weighed, measured (eye-to-fork length [EFL]; Ruelle and Hudson 1977), and jaw tagged with an individually numbered monel tag. They were then placed in a mesh sling and water was irrigated over their gills with a bilge pump. Transmitters were implanted by making a 35-mm incision along the ventral side of the fish, either right or left of the midline, anterior to the anal fin. All instruments were soaked in 90% ethanol prior to surgery and the transmitter was coated with oxytetracycline before it was inserted into the peritoneal cavity. The wound was closed by three interrupted sutures made of non-absorbable material. After suturing, oxytetracycline was applied to the wound to reduce infection. Fish were then held in the water at boat side until they were able swim off under their own power. The fish were monitored for about 30 min afterwards to verify movement away from the boat.

We searched the lower Keystone Reservoir system for transmitter-tagged fish by boat during June-August 1997 using a digital receiver (Sonotronics model USR 5W) and directional hydrophone (Sonotronics model DH-2). We searched three consecutive daytime periods (0700-1900) and three consecutive nighttime periods (2100-0600) at 3-h intervals from 17 June-12 August 1997. Fish were located no more than once during each 3-h period. When a fish was encountered, a 6 or 10 db attenuator was attached to the hydrophone cable to reduce signal strength, enabling us to pinpoint its location. A global positioning system receiver (Geoexplorer II, Trimble Navigation Inc., Sunnyvale, CA) was used to determine precise geographic coordinates of the transmitter-tagged fish when we could hear the signal equally in all directions.

At each fish location, water temperature, dissolved oxygen (DO), and conductivity were measured at 1-m depth intervals with a multi-parameter water quality meter (model H20, Hydrolab Inc., Austin, TX). When several fish were located in close proximity to one another, only one profile was taken. To characterize water chemistry conditions throughout the reservoir, we classified Keystone Reservoir into six areas, based on a previous temperature study of the reservoir (Zale et al. 1988), and recorded water chemistry profiles in each area during each three-day period when paddlefish were monitored.

Point locations of fish were overlaid onto a map of the reservoir using geographic information systems software (ARC/INFO, Environmental Systems Research Institute, Inc. Redlands, CA). Movement rates were then calculated by measuring the shortest over-water distance between two points. To determine distance from the dam, a reference point in the reservoir, 500-m sections of the reservoir were measured at intervals from the centerline of the reservoir starting at the dam.

Because water chemistry differed among reservoir areas during the study, we could not combine all areas to obtain overall available water chemistry conditions in the reservoir. Water chemistry conditions changed between each three-day sampling period, but remained relatively constant within each period. Thus, we combined areas in which the fish were located by arbitrarily categorizing our water temperature and DO data as high, moderate, or low. For water temperatures, high was >25 C on 17-19 June, >27 C on 30 June-2 July and 10-12 August, and >29 C on 28-30 July. Moderate water temperatures were 24-25 C on 17-19 June, 27 C on 30 June-2 July, 27-29 C on 28-30 July, and 26-27 C on 10-12 August. Low water temperatures were <24 C on 17-19 June, <27 C on 30 June-2 July and 28-30 July, and <26 C on 10-12 August. Dissolved oxygen was categorized similarly, with high DO being >6 mg/L, >5 mg/L, and >7 mg/L on 17-19 June, 30 June-2 July and 10-12 August, and 28-30 July, respectively. Moderate DO was 4-6 mg/L, 5 mg/L, 5-7 mg/L, and 4-5 mg/L on 17-19 June, 30 June-2 July, 28-30 July, and 10-12 August, respectively. Low DO was <4 mg/L on 17-19 June and 10-12 August, and was <5 mg/L on 30 June-21 July and 28-30 July. Areas of the reservoir were combined to include at least one vertical meter of the same temperature or DO category. For example, when we categorized moderate temperatures as 26-27 C, all areas that fish were located in had at least one vertical meter with a temperature from 26-27 C. To select or avoid a certain water chemistry category, a fish would need to move vertically within an area. To remain in the same category, a fish could move laterally among areas.

Hydrologic data (reservoir water level, discharge from the dam, inflow into the reservoir) were collected from the U.S. Army Corps of Engineers Keystone Dam facility.

To address the problem of pseudo-replication in fish movements, we determined if each fish location was independent. White and Garrot (1990) suggested that observations are independent if an animal has enough time to move from one end of their home range to another. We determined that summer home range for paddlefish was the entire area of Keystone Reservoir they occurred in throughout the study period. We then calculated the overall linear distance of the home range (20.8 km) and divided by the maximum movement rate of the fish (4.1 km/h), thus determining the minimum time it would take for a fish to cover the entire home range (5.1 hours). Using this criterion, we excluded all repeated observations that were ≤5.1 h for our distance from the dam and water chemistry measurements at the fish locations.

A Wilcoxon rank sum test was used to compare movement rates for daytime and nighttime periods and for upstream and downstream movement rates. Spearman rank correlation and stepwise multiple regression were used to determine relationships between movement rates and location within the reservoir to inflow, discharge, and water level. Paddlefish movement was categorized as either upstream, downstream, or static (movement of less than a 45 degree angle from the main channel axis). Water temperatures that fish used were determined from the implanted temperature-sensing transmitters. Conductivity and DO levels used by the fish were determined from the temperature data. Chi-square analysis was used to determine if fish selected or avoided areas of the reservoir based on temperature or DO conditions. Bonferroni multiple comparison procedures were used to determine differences among water chemistry categories (Neu et al. 1974). All analysis was performed with SAS (Schlotzhauer and Littel 1987); significance levels were set at $\underline{P}$ <0.05. Stepwise multiple regression significance levels were set at $\underline{P}$ <0.10.

RESULTS

We implanted transmitters in six male paddlefish (range, 843-1,000 mm EFL) on 2 and 7 March 1997. No females were collected, presumably because these fish and the larger males had moved up the rivers to spawn just prior to our sampling efforts. Surgery time ranged from 8-12 min. Fish moved considerable distances soon after implantation; therefore, we assumed no short-term effects of the surgery. Paddlefish were tracked from 0700-1900 h on 17-19 June, 30 June-2 July, 28-30 July and were tracked from 2100-0600 h on 6-8 July, 3-5 August, and 10-12 August. All six fish were located throughout the study period; however, not all fish were found during each 3-h interval. Fish congregated in the Arkansas River arm and the main pool of Keystone Reservoir; no fish were found upstream of river km 1.0 on the Cimarron River arm (Figure 1). Interestingly, five of the six fish were implanted in the Cimarron River arm (river km 12-18), and these five fish migrated into the Arkansas River arm in April and did not return to the Cimarron River arm.

We were unable to record water temperature, dissolved oxygen, and conductivity throughout the entire reservoir on all sampling dates because of time limitations. However, we were able to collect these data on 17-19 June, 7 July, 29 July, and 10 August. From these data, we determined differences in water chemistry conditions between the two reservoir arms. Using the water chemistry data, we quantified available habitat within the reservoir (Arkansas River arm and main pool) where paddlefish were located throughout the study. All water chemistry data were included in the analyses of movement rate and distance from the dam. When water temperatures were uniform in the reservoir, we were unable to infer depth, DO, and conductivity from the temperature sensing transmitters. Uniform nighttime temperatures occurred on all sample periods except 10-12 August. However, we excluded nighttime periods from our water chemistry selection analysis because of small sample size (N = 31). All daytime periods exhibited thermal stratification and were used in all analyses.

Movement.--Paddlefish moved significantly faster at night than during the day ($P < 0.01$). Paddlefish moved on average 784 m/h (SD = 830) at night and 348 m/h (SD = 248) during day. Movement rates were highly variable, ranging from near 0 m/h during the day to 4,007 m/h at night. Movement rates of paddlefish varied inversely with water level and rate of inflow ($r^2 = 0.24$, $P < 0.01$). Both water level and inflow variables were left in the model because they were not correlated with each other ($P = 0.57$). When daytime and nighttime movement rates were separated, we found nighttime movement rate increased as discharge from the dam and water level decreased (r^2 = 0.40, P < 0.01). However, water level and discharge were highly correlated ® = 0.48, P < 0.01) and only discharge was left in the model (r^2 = 0.36, P < 0.01). Daytime movement rate was not dependent on any hydrologic variables (P > 0.10). Paddlefish showed no difference in movement rates upstream or downstream (P = 0.25).

Distribution.--Longitudinal distribution of paddlefish in the reservoir was dependent on water level, discharge, and inflow (r^2 = 0.41, P < 0.01). However, inflow and discharge explained very little of the remaining variation (1.26% and 0.5%, respectively) after water level was incorporated into the model. The resulting model with only water level indicated that distance of paddlefish from the dam increased as water level decreased (r^2 = 0.39, P < 0.01). Daytime distance from the dam was dependent on discharge and water level (r^2 = 0.36, P < 0.01). However, discharge and water level were highly correlated ® = 0.88, P < 0.01), and a simple regression model indicated that daytime distance from the dam decreased as water level increased (r^2 = 0.32, P < 0.01). Distance from the dam during nighttime increased as water level decreased and discharge increased (r^2 = 0.67, P < 0.01).

Habitat preferences.--We could not combine data for all 18 sample days because water temperature varied throughout the study period. Conductivity data were not categorized because of low variability at sites where paddlefish were located. Consequently, chi-square analysis was not performed on this variable.

Paddlefish selected moderate temperatures in the reservoir throughout the study period. Paddlefish selected moderate temperatures (24-25 C) and avoided low (<24 C) and high (>25 C) temperatures on June 17-19 ($P < 0.01$). On 30 June-2 July, paddlefish selected a moderate temperature (27 C), avoided high temperatures (>27 C), but showed no selection for low temperatures (<27 C; $P < 0.01$). Fish avoided low (<25 C) and high (>29 C) temperatures on 28-30 July and selected for moderate temperatures in the 27-29 C range ($P < 0.01$).

Paddlefish selected water with moderate DO concentrations (4-6 mg/L), avoided high DO (>6 mg/L) and showed no selection for low DO (<4 mg/L) on 17-19 June ($P < 0.01$). On 30 June-2 July and 28-30 July, paddlefish avoided moderate and high DO levels (>4 mg/L) and selected for low DO (<5 mg/L; $P < 0.01$) waters.

Paddlefish appeared to avoid the highly saline Cimarron River arm of Keystone Reservoir. Temperature and dissolved oxygen profiles were relatively similar between the Arkansas and Cimarron River arms, but conductivity levels were much higher in the Cimarron River arm. Mean temperatures for the Arkansas River arm ranged from 25.2-29.3 C (SD = 0.7-1.8); corresponding means for the Cimarron River arm ranged from 26.6-28.4 C (SD = 0.6-1.3). Dissolved oxygen concentrations varied within the Arkansas River arm with means ranging from 3.4-5.8 mg/L (SD = 1.0-2.5) and corresponding Cimarron River arm mean DO concentrations ranging from 1.4-6.3 mg/L (SD 1.3-2.6). Conductivity levels in the Cimarron River arm averaged about 2-3 times higher than those of the Arkansas River arm (Figure 2); mean conductivity readings were 772 μS/cm (SD = 155) in the Arkansas River arm, 995 μS/cm (SD = 477) in the main pool, and 1,914 μS/cm (SD = 1,125) in the Cimarron River arm. Main pool conductivity levels were intermediate and highly variable because of the influence of the Cimarron River as it joined the Arkansas River at their confluence. Paddlefish were not observed in mean conductivities greater than 1,275 μS/cm (Figure 2). About 50% of the observations were in mean conductivities less than 700 μS/cm and 50% were in mean conductivities between 700 μS/cm and 1,275 μS/cm.

DISCUSSION

Our findings indicate that paddlefish distribution and movements in summer are influenced by physical and chemical characteristics of their environment. Brandtly (1987) found that summer movement of paddlefish in a run-of-the-river reservoir in Alabama was affected by water temperature and very high discharge, but movement was not affected at moderate discharge levels. Paddlefish movement in Keystone Reservoir was dependent on water level and inflow into the reservoir overall, and on discharge during the nighttime. Upstream orientation and movement in response to increased flows is common among many species of fish (McKeown 1984; O'Hara 1993). However, riverine fish may also move downstream as water levels and discharge increase (Hynes 1970), presumably to seek more favorable environmental conditions or food resources (McKeown 1984). Paddlefish distribution in Keystone Reservoir was dependent on water level changes. As water levels increased, paddlefish moved closer to the dam, and as water level decreased, paddlefish moved up the Arkansas River arm of the reservoir. Southall and Hubert (1984) found no response by paddlefish in the Mississippi River to water level changes in the summer. In addition, Moen et al. (1992) found no relationship between discharge and direction of movement of paddlefish in the Mississippi River. However, paddlefish are strongly influenced by water flow and river stage during spring migrations (Russell 1986; Paukert 1998). Summer downstream movements of paddlefish in Keystone Reservoir may be attributable to an innate response by riverine fishes to avoid harsh environmental conditions (McKeown 1984), such as poor water quality. Extreme water temperatures, low dissolved oxygen, and high salinities are typical of prairie rivers during low flow periods in summer.

Paddlefish distribution in Keystone Reservoir was influenced by temperature and dissolved oxygen. During the day paddlefish avoided the highest water temperatures near the surface and usually selected for moderate temperatures. Rosen and Hales (1981) determined the optimum temperature for paddlefish feeding was from 7-20 C, but that fish occurred in temperatures up to 28 C. Blackwell et al. (1995) found that paddlefish fed at temperatures greater than 20 C. Crance (1987) showed that optimum temperatures of paddlefish were between about 12 and 24 C. Keystone Reservoir paddlefish, however, selected water temperatures that ranged from 24-29 C.

Although paddlefish appeared to avoid high DO levels, the strong correlation between surface water temperatures and dissolved oxygen suggests they were avoiding high water temperatures and not DO levels. Although no information exists on the minimum DO requirements for adult paddlefish, Fry (1971) determined that DO concentrations less than 5 mg/L effects swimming speed, growth, feeding, and blood chemistry in some teleost fishes. Our results show that adult paddlefish may not require high (>6 mg/L) DO concentrations and can survive at DO levels lower than 5 mg/L.

Paddlefish avoided the Cimarron River arm of Keystone Reservoir during the entire study period. The morphometry of the lower Cimarron River arm, main pool, and lower Arkansas River arm are similar; however, conductivity levels were much greater in the Cimarron River arm than in the Arkansas River arm and main pool. The lack of paddlefish locations in the Cimarron River arm may be attributable to their avoidance of higher salinity levels in this arm of the reservoir. Neill et al. (1994) found that juvenile paddlefish avoided salinities greater than 4 ppt when available.

Food availability was not examined in this study; however, we do not believe that food was a limiting resource in the Cimarron River arm. Kochsiek (1970) found a greater density of zooplankton in the Cimarron River arm, but similar zooplankton diversity between both arms of Keystone Reservoir. He attributed a lack of certain rotifer species in the Cimarron River arm to high conductivity levels, which may have limited their distribution. Paddlefish are known to be indiscriminant feeders (Rosen and Hales 1981). Therefore, we do not believe paddlefish were selecting the Arkansas River arm over the Cimarron River arm because of food preference or availability. The only time paddlefish were located in the Cimarron River arm (i.e. 1 km upstream from the confluence) was when high water flows from the Arkansas River backed up water into the Cimarron River arm and reduced conductivity levels. The confluence of the Cimarron and Arkansas rivers produces a circular current in which the Arkansas River arm water flows up the Cimarron River arm and then returns to the Arkansas River arm (Kochsiek 1970). Paddlefish do, however, occur in the Cimarron River arm during other seasons. Paddlefish stage in the Cimarron River arm in late winter and move up this tributary in spring, presumably to spawn (Paukert 1998).

Our results indicate that paddlefish distribution and movements in Keystone Reservoir are strongly influenced by hydrologic factors in summer. Furthermore, paddlefish distribution may be limited by physicochemical conditions (i.e. high salinity levels and water temperatures), precluding their use of certain areas of the reservoir. Clearly, further work is needed to evaluate the effects of physical, chemical, and biological factors on paddlefish distribution and movements in reservoir environments, particularly during summer.

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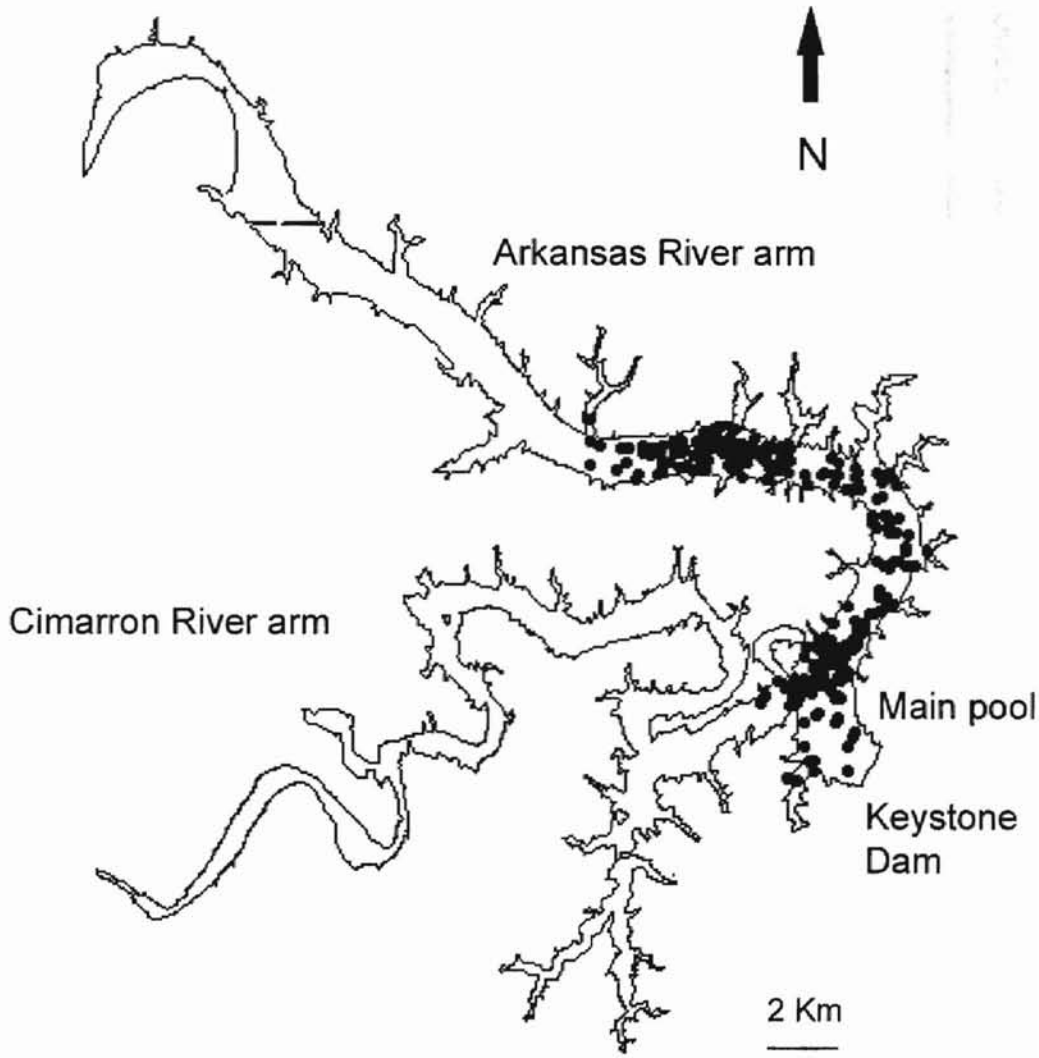
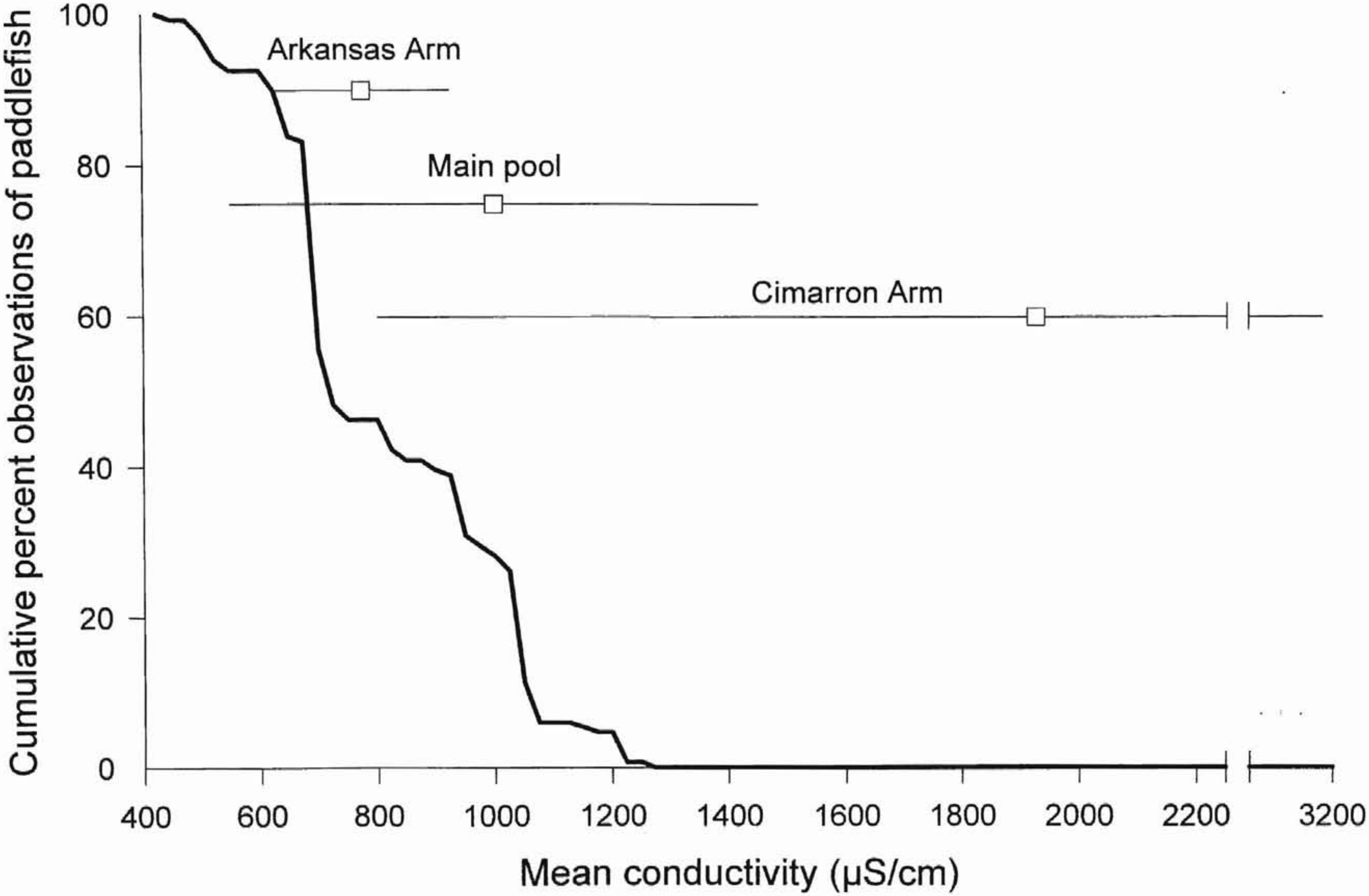
Figure 1. Map of all paddlefish locations in Keystone Reservoir, Oklahoma in summer 1997.

Figure 2. Mean conductivity levels in Keystone Reservoir, Oklahoma in relation to the cumulative percent of paddlefish observations. For example, 100% of our paddlefish observations occurred at conductivity levels above 400 μS/cm, and no paddlefish were observed above 1,275 μS/cm. Symbols are mean conductivity levels and horizontal bars are one standard deviation.


N
Arkansas River arm
Cimarron River arm
Main pool
Keystone
Dam
2 Km



Cumulative percent observations of paddlefish
100
80
60
40
20
0
Arkansas Arm
Main pool
Cimarron Arm
400
600
800
1000
1200
1400
1600
1800
2000
2200
3200
Mean conductivity (µS/cm)

Appendix

Appendix A. Vital statistics of paddlefish implanted with ultrasonic transmitters in Keystone Reservoir, 1997.

Jaw tag number	Transmitter code	Implant date	Length at implant (EFL, mm)	Weight at implant (kg)	Sex
284[1]	2-4-9	2 Mar 97	890	12.0	Male
636[2]	2-2-4-6	2 Mar 97	843	11.5	Male
934	2-2-5-5	2 Mar 97	918	14.0	Male
919	2-2-3-7	7 Mar 97	1000	19.0	Male
940	2-3-4-5	7 Mar 97	942	13.0	Male
910	2-3-3-6	7 Mar 97	912	14.0	Male

1. Recapture from 1996. Fish was originally tagged on 9 March 1996.
2. Recapture from 1997. Fish was originally tagged on 3 January 1997.

CHAPTER IV.

Evaluation of Paddlefish Length Distributions and Catch Rates in Three Mesh Sizes of Gill Nets with a Suggested Approach to Standardize Catch Rates

Abstract.--We evaluated the length distribution and catch rates of paddlefish Polyodon spathula collected in three mesh sizes of gill nets in Keystone Reservoir, Oklahoma. A total of 1,454 paddlefish were collected in 127-, 152-, and 203-mm bar measure monofilament gill nets during the winters of 1996-1998. Mean lengths of paddlefish increased with increasing mesh size, but mean length between 152- and 203-mm-mesh nets were not significantly different. The smallest and the largest mesh sizes caught young-of-year (YOY) paddlefish in 1996, a year when 152-mm mesh was not used and the only year we collected YOY paddlefish. Catch rates for all sizes of paddlefish were highest in 127-mm-mesh net and lowest in 203-mm mesh nets. For population size and age structure sampling, we recommend a range of mesh sizes (e.g. 127- and 203-mm) to collect the broadest size range of paddlefish. To collect sexually mature fish for brood stock, we recommend using large size mesh (e.g. 203-mm) to increase catch rates of adult paddlefish and reduce by-catch of other species. To standardize paddlefish catch rates for gill nets, we suggest recording and reporting the number of fish caught per surface area of gill net per duration of time set.

lengths of time, we standardized catch rates as the number of fish collected per 108 m^2 of netting per 24-h set.

To test for differences in length distributions and catch rates of paddlefish among gill net mesh sizes, we used a randomized complete block analysis of variance on the rank transformed length and catch rate data. Data were blocked by year because of variability in recruitment of paddlefish throughout the three-year study and because not all mesh sizes were used every year. Regression analysis was used to determine if catch rates were dependent on net height or duration of set, which would indicate bias in our catch rate calculation. All analyses were performed with SAS (SAS Institute 1985). The Scheffe's test was used to compare differences between means. Significance levels for all tests were set at $\underline{P} < 0.05$.

RESULTS

We collected 1,454 paddlefish during three winters of gill netting in Keystone Reservoir (Table 1). Gill nets with 203- and 127-mm mesh were used in all years; however, only 6 sets of 127-mm mesh were used in 1998. Gill nets with 152-mm mesh were used in 1997 and 1998. Both 127-mm and 203-mm mesh caught YOY (<500 mm) paddlefish in 1996; however, YOY were not collected in 1997 or 1998. The largest paddlefish caught (1,356 mm) was collected in 152-mm mesh, whereas the smallest paddlefish captured (294 mm) was in 203-mm mesh.

Mean length of paddlefish increased and catch rates decreased with increasing mesh size (Table 1, Figure 1). Paddlefish mean length was smaller in the 127-mm-mesh than in either the 152- or 203-mm-mesh nets ($\underline{P} < 0.01$; Table 1). Catch rates of paddlefish were highest in 127-mm mesh nets and lowest in 203-mm-mesh nets ($\underline{P} < 0.01$); however, catch rates for 152-mm mesh were not statistically different from 127-mm or 203-mm mesh. The smallest sexually mature female we collected was 960 mm. Therefore, to determine which mesh sizes collected sexually mature fish, we evaluated catch rate differences for paddlefish greater than 900 mm. Catch rates of paddlefish larger than 900 mm increased with increasing mesh size. Mesh sizes of 203 and 152 mm collected significantly more paddlefish over 900 mm than 127-mm-mesh nets ($\underline{P} = 0.02$). However, there was no difference in catch rates of paddlefish 900 mm and greater between 152- and 203-mm-mesh nets.

For all mesh sizes combined, catch rates were not dependent of net height ($\underline{P} = 0.22$). Catch rates were dependent on duration of net set ($\underline{P} < 0.05$), but the regression explained very little of the variation ($\underline{r}^2$ = 0.009). Catch rates did not depend on duration of net set for 127 mm-mesh nets ($\underline{P} = 0.45$), 152-mm-mesh nets ($\underline{P} = 0.86$), or 203-mm-mesh nets ($\underline{P} = 0.09$). Catch rates of 900-

mm and larger fish were not dependent on duration of net sets for 127-mm- (P = 0.67), 152-mm- (P = 0.25), or 203-mm-mesh nets (P = 0.70).

DISCUSSION

For paddlefish population age and size structure studies, we recommend using a range (e.g. 127-203-mm mesh) of gill net mesh sizes. If 203-mm mesh is not available (which, based on our experiences, can oftentimes occur), 152-mm mesh is adequate to collect the larger-sized paddlefish. In Norris Reservoir, Tennessee, smaller mesh sizes (106- and 127-mm) caught fewer paddlefish than larger mesh sizes (178-, 203-, and 229-mm; Alexander and Peterson 1984). In contrast, our highest catch rates occurred in the smallest mesh sizes, although this may have been because of the relatively low number of gill net sets of 127-mm-mesh nets (N = 63) compared with sets of 152-mm- (N = 157) and 203-mm- (N = 231) mesh nets. Variability was very high for all mesh sizes we used. Coefficient of variation estimates for catch rates were 209% for 127-mm-, 112% for 152-mm-, and 159% for 203-mm-mesh nets.

In population studies, collection of all ages of paddlefish is essential to determine recruitment patterns. Although we collected YOY paddlefish in both 127- and 203-mm-mesh nets in 1996, we do not believe we sampled them in proportion to their abundance. Because younger age fish are usually more abundant than older age fish in a population (Van Den Avyle 1993), we expected to collect a greater number of YOY fish, assuming they co-occur with adults and the gill nets used sampled them in proportion to their abundance. Apparently, neither of these two assumptions were consistently met in our study. Small mesh sizes of gill nets do not necessarily collect small paddlefish (Hoffnagle and Timmons 1989). In Kentucky, Hoffnagle and Timmons (1989) found that 152-mm-mesh nets caught smaller fish than all but 76-mm mesh, while 114- and 127-mm-mesh nets caught larger fish. Small paddlefish may get caught in larger mesh nets by entangling their rostrum while turning in the net (Hoffnagle and Timmons 1989). No standard technique has been developed to quantitatively sample juvenile paddlefish (Fredericks and Scarnecchia 1997); however, trawling (Ruelle and Hudson 1977) and surface visual counts (Fredericks and Scarnecchia 1997) have been found to be effective in determining juvenile abundance. Clearly, further research is needed on the habits of and collecting methods for YOY paddlefish.

For collection of sexually mature paddlefish for brood stock, we recommend using larger mesh nets, (e.g. 203-mm mesh). The 203-mm mesh size collected larger paddlefish (although it was not significantly different from 152-mm-mesh) and had the highest catch rate of fish >900 mm. By-catch can also be significantly reduced by using larger mesh nets. The 203 mm-mesh size caught fewer non-target species (e. g. blue catfish Ictalurus furcatus , flathead catfish Plyodictis olivaris , striped bass Morone saxatilis, and bigmouth buffalo Ictiobus cyprinellus) than the 127- and 152-mm-mesh nets in Keystone Reservoir (C. Paukert, personal observation). In Norris Reservoir, Tennessee, catch rates of non-target striped bass were much higher in 127-mm mesh than 178- and 203-mm mesh (Alexander and Peterson 1984). Paddlefish are also easier to remove from larger than smaller mesh sizes.

Relative abundance measures (CPUE) are essential when comparing results from different studies. In addition to providing estimates of relative abundance, catch rates have been used to assess habitat use (Hoxmeier and DeVries 1997; Paukert and Fisher 1998) and spring spawning migrations (Lein and DeVries 1994; Paukert and Fisher 1998). Oftentimes, nets with different heights are used during the same study (Alexander et al. 1985; Ambler 1994; Paukert and Fisher 1998), which may influence catch rate information. To facilitate comparisons among studies, we suggest standardizing catch rates based on number of paddlefish collected per surface area of the gill net per duration of time set.

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Table 1.--Mean length and catch per unit effort (CPUE) of paddlefish collected in three gill net mesh sizes in Keystone Reservoir, Oklahoma, 1996-1998. Catch rates and mean length with the same letters signify no difference between mesh sizes for all years combined ($P > 0.05$). Coefficient of variation (CV) values are percentages.

Year	Gill net mesh size(mm)	Length (mm, EFL)			CPUE (No./108m^2/24h set)			
		N	Mean	SD	N	Mean	SD	CV
1996								
	127	159	811	143	32	1.12	2.05	183
	203	300	884	184	64	0.75	1.17	155
1997								
	127	44	772	156	25	0.42	0.68	160
	152	290	830	181	71	0.68	0.71	104
	203	237	857	204	90	0.36	0.50	138
1998								
	127	2	856	175	6	0.09	0.13	155
	152	233	906	127	86	0.56	0.67	121
	203	189	935	150	77	0.35	0.37	107
Total								
	127	205	804 x	146	63	0.74 x	1.56	209
	152	523	864 y	163	157	0.61 xy	0.69	112
	203	726	888 y	185	231	0.46 y	0.74	159

Figure 1. Length distribution of paddlefish collected in three gill net mesh sizes in Keystone Reservoir, Oklahoma, from January 1996 through March 1998.

VITA

Craig Patrick Paukert

Candidate for the Degree of

Master of Science

Thesis: POPULATION ECOLOGY OF PADDLEFISH IN KEYSTONE RESERVOIR, OKLAHOMA

Major Field: Wildlife and Fisheries Ecology

Biographical:

Personal Data: Born in Livingston, New Jersey, September 9, 1969, son of Richard E. And Carol M. Paukert.

Education: Graduated from Stillwater High School, Stillwater, Minnesota in May 1988; received Bachelor of Science degree in Fisheries and Wildlife from the University of Minnesota in June 1993; completed the requirements for the Master of Science degree at Oklahoma State University in December 1998.

Professional Experience: Natural Resources Fisheries Census Clerk for the Minnesota Department of Natural Resources, Fish Research, May 1993-September 1993, December 1993-September 1994, December 1994-April 1995; Fisheries Technician, Wisconsin Department of Natural Resources, Fish Management, April 1995-September 1995; Graduate Research Assistant, Oklahoma Cooperative Fish and Wildlife Research Unit, October 1995-August 1998; Graduate Research Assistant, South Dakota State University, August 1998-present.

Organization Memberships: American Fisheries Society; Minnesota, Oklahoma, and Wisconsin Chapters of the American Fisheries Society; Education and Fish Management Sections of the American Fisheries Society; Southwestern Association of Naturalists.