MOVEMENTS AND DYNAMICS OF A RIVERINE STOCK OF STRIPED BASS (*MORONE SAXATILIS*)

By

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Chapter I

INTRODUCTION

This thesis is comprised of one manuscript written for submission to the Transactions of the American Fisheries Society. Chapter I is an introduction to the rest of the thesis. The manuscript is complete as written and does not require additional support material. The manuscript is contained in Chapter II and is titled 'Movements and dynamics of a riverine stock of striped bass (*Morone saxatilis*).'

Chapter II

MOVEMENTS AND DYNAMICS OF A RIVERINE STOCK OF STRIPED BASS (*MORONE SAXATILIS*)

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Abstract.-I assessed movements of striped bass in the Arkansas River, Oklahoma, from Keystone Dam to Zink Dam. Movements were assessed using both radio telemetry and anchor tags. A year-long creel survey was conducted in the tailwaters of Keystone Dam to characterize the sport fishery. Gill netting was conducted from December 1986 through May 1987 and from October 1987 through May 1988, to collect striped bass for tagging and transmitter implantation. Return of tags from angler recaptures provided most information on movements. Radio telemetry was largely unsuccessful. Striped bass residing in the Keystone-Zink pool usually inhabited the tailwater area and not downstream portions of the pool. However, some fish moved great distances (>100 km) downstream. Minimum estimates of emigration rates of striped bass from the Keystone-Zink pool of the Arkansas River were 17.9% in 1987 and 8.3% in 1988. Downstream movements appeared to be related to high water discharges. The estimated striped bass stock abundances were 12,645 adult fish in 1987 and 9,803 in 1988. Fourteen taxa were represented in the creel census. Striped bass ranked first in both harvest and catch among all species. Anglers harvested an estimated 21,564 striped bass from the Keystone Dam tailwaters in one year. Because the stock is frequently supplemented by immigrants from upstream and reduced by downstream emigration, restrictive regulations would not likely enhance yields.

The striped bass (Morone saxatilis) is an anadromous species native to the Atlantic and Gulf coasts (Pearson 1938; Merriman 1941; Barkuloo 1961) that has historically supported important sport and commercial fisheries. Atlantic coast populations contributed almost 16 million fish to the sport fishery in 1965 and 6.7 kilotons to the commercial fishery in 1973 (Boreman and Austin 1985). The species was introduced to the Pacific coast in 1879 (Scofield 1931; Morgan and Gerlach 1950) and is now found from the Columbia River, Washington, to Ensenada, Mexico (Miller and Lea 1972).

In recent years, coastal stocks have declined dramatically in abundances and yields (Boreman and Austin 1985), but land-locked fisheries established through artificial propagation and stocking in at least 34 (Bailey 1975; Axon 1985) have been successful and have resulted in popular and productive sport fisheries. The striped bass is a valuable predator in freshwater lakes and reservoirs because it feeds on underutilized gizzard shad (Dorosoma cepedianum) and threadfin shad (D. petenense) populations (Bailey 1975; Dudley et al. 1977; Morris and Follis 1978). The species is one of the most popular game fishes in Oklahoma (Summers 1978). Among all species of sport fish in Oklahoma, striped bass rank first in both reservoirs and stilling basins in average weight, and second and fifth in average catch rate in stilling basins and reservoirs, respectively (Summers 1978).

The popularity of inland riverine striped bass fisheries among anglers has increased recently. As coastal populations have dwindled and reservoir fisheries have become overfished, anglers have become more familiar with effective techniques for catching striped bass in rivers. Fisheries managers have become more attentive to the need to manage these strictly riverine stocks, but the majority of research on inland striped bass has focused on reservoir stocks. For example, striped bass have been the subject of extensive research in Keystone Reservoir in Oklahoma (Mensinger 1971; Erickson et al. 1972; Summerfelt and Mosier 1976; Peltz and Combs 1979; Combs 1979a; Combs 1979b; Combs and Peltz 1982; Zale et al. 1990), but only two studies (Combs 1978; Hamilton et al. 1985) have addressed the stock in the Arkansas River below the dam. Combs (1978) studied food habits, and Hamilton et al. (1985) examined angler harvest. In other inland rivers, studies have been limited to assessments of distribution of eggs and larvae (Dudley and Black 1978), exploitation rates (Wooley and Crateau 1983), and movements (Dudley et al. 1977; Wooley and Crateau 1983; Moss 1985; Lamprecht and Shelton 1986). The paucity of both basic biological and applied information on inland riverine stocks has precluded their effective management.

In an effort to augment information needed to manage inland riverine striped bass fisheries, I examined applied aspects of the riverine striped bass stock in the Arkansas River from the Keystone Dam tailwaters downstream to the

Zink Dam in Oklahoma. Specifically, my objectives were to determine movements of striped bass in this river reach and characterize and quantify the popular recreational fishery. Estimates of downstream emigration, in combination with stock abundance and angler exploitation rates will be useful for formulating harvest regulations for this stock.

STUDY AREA

I studied striped bass in the Arkansas River from Keystone Dam (Creek County) downstream to Zink Dam and its tailwaters (Tulsa County) in northeastern Oklahoma. Keystone Dam is operated by the U.S. Army Corps of Engineers and was designed for flood control and power generation for Tulsa, Oklahoma, and surrounding communities. The Arkansas River is characterized by shifting coarse-sand substrates and high silt loads. The channel of the Arkansas River is braided, which makes navigation during low flows difficult, if not impossible. High flows and releases ranging from 300-1700 cubic meters per second (cms), are typical during spring and fall. During periods of low flow (typically summer and winter) and when Keystone Reservoir water levels are low, water is released only through hydroelectric generation turbines, or not at all. Tainter and sluice gates are used to release flood water from Keystone Reservoir when water levels exceed the power-pool elevation. Water flow and depth fluctuations in the river are extreme and occur frequently during low flow periods.

Zink Dam is a low-water dam located near downtown Tulsa; the resulting impoundment (Zink Lake) is used for recreation. During periods of high flow, water passes over the entire structure. A bascule gate located on the west end of the dam is lowered for at least 12 hours weekly from early April through mid-June in an effort to facilitate upstream movements of striped bass.

METHODS

Movements

Movements of striped bass were assessed using radio telemetry and recaptures of anchor-tagged fish. Striped bass were tagged after capture with monofilament gill nets of 64, 76, 89, 102, and 114 mm bar mesh. Gill netting was conducted at available sites throughout the Keystone-Zink pool when water levels permitted. When water levels remained low, netting was concentrated in the Keystone Dam and Zink Dam tailwaters. Gill netting was initiated in December 1986 and continued through May 1987. No netting was conducted during summer months when high water temperatures stress netted fish. Gill netting resumed in October 1987 and continued through May 1988.

Radio transmitters were used for the telemetry portion of the study because the effectiveness of sonic transmitters in the Arkansas River was questionable. High silt loads and substrate morphology in the Arkansas River are incompatible with sonic telemetry (Summerfelt and Mosier 1976; Stasko and Pincock 1977; Tyus 1982). High conductivities in the Arkansas River (800-2400 micromhos) result in radio signal attenuation; however, I presumed that the use of transmitters with large batteries that emit strong signals at low frequencies would enhance my ability to locate fish. Effective ranges of transmitters were tested prior to implantation by submerging transmitters in a net bag at differing depths and conductivities and measuring distances at which signals were lost.

Radio transmitters (40-41 MHz) were surgically inserted into the body cavities (Hart and Summerfelt 1975; Summerfelt and Mosier 1976; Mulford 1984) of four striped bass in April 1987, and 10 striped bass in January, February and March 1988. Each fish was marked with three anchor tags to increase the chances of angler identification. Telemetrized fish were tracked until August 1988 using various types of antennae (Yagi, loop, and whip) from a boat. Frequent attempts (at least twice weekly) were made to locate telemetrized fish at varied water flow conditions and temperatures.

Anchor tags were used in conjunction with telemetry to provide an additional method of assessing movements in the event that radio telemetry was not effective. Tag number, total length (mm), weight (g), location of capture, and date of capture of each anchor-tagged striped bass were recorded.

Anglers were asked to cooperate by returning tags with information on date and location of capture. Return of tags was encouraged by a reward system and publicized by personal communication with anglers, posting of signs at river access areas and area bait and convenience stores, newspaper articles, and television announcements explaining the objectives of the research. Each person who returned a tag received a reward cap.

Fishery Characteristics

Creel surveys were conducted twice weekly from September 1987 to August 1988 at the Keystone Dam tailwaters. During each week, one survey was completed during a weekday (Monday-Friday) and one was conducted during the weekend (Saturday, Sunday, and holidays). Most angling for striped bass at this site occurs during daylight hours. Surveys were conducted during daylight hours. Starting time for each survey period was selected randomly. Creel surveys were conducted on both the north and south sides of the Keystone tailwaters; most of the angling activity in the pool occurred in this area. All surveys were performed as roving creels; i.e., the creel clerk interviewed anglers while they fished (Hudgins and Malvestuto 1985; Van Den Avyle 1986). All anglers present were interviewed during each survey. Total counts were made of all anglers on the north and south banks and in boats at the beginning and end of each creel period to estimate angling effort (Lambou 1961). The mean daily angler count was multiplied by the number of daylight hours to estimate daily fishing pressure. The numbers of fish caught and harvested from the Keystone Dam tailwaters during each month were estimated by multiplying mean monthly catch and harvest rates by monthly angling effort totals.

Angler Exploitation

Population abundances of striped bass were estimated using Chapman's Modified Schnabel/Schumacher multiple censusing method (Ricker 1975) during periods when striped bass were tagged (December through May 1986-1987, and October through May 1987-1988). The Schnabel/Schumacher estimate is an approximation of the maximum likelihood estimate of N (estimated population abundance), and Chapman's simple adjustment gives a better estimate of N (Ricker 1975). The equation for N is $N=(C_t dx\ M_t)/R + 1$, where C_t is the total sample taken on day t, M_t is the total number of marked fish at large on day t, and R is the total number of recaptures during the experiment. Confidence limits were obtained by treating R as a Poisson variable (Ricker 1975).

Annual angler exploitation rates were determined from angler-reported recaptures of striped bass within one year of tagging. The number of recaptures (by anglers) divided by the total number of tagged fish provided estimates of minimum annual exploitation. An independent estimate was derived by comparing harvest (from the creel survey) to population abundance estimates.

RESULTS

Movements

Ranges of radio transmitters used were minimal due to high conductivities typically encountered in the Arkansas River below Keystone Dam, despite their low frequency, high output, and the use of large antennae. During periods of low discharge, highly mineralized hypolimnetic waters were released through Keystone's hydropower generators; conductivities at such times usually exceeded 2000 micromhos. At 2550 micromhos, transmissions were completely attenuated when transmitters were located at depths >1.7 m (Figure 1); useful ranges (i.e., allowing a realistic possibility of location in a system as wide as the Arkansas River) were achieved only at depths <0.3 m (Figure 1). During periods when tainter gate discharges supplemented penstock releases or when the reservoir was not stratified, intermediate conductivities (1200-2000 micromhos) were present in the tailwaters. Transmission ranges at these intermediate conductivities were greater than at high conductivities (Figure 1), but these conditions necessitated that transmitters be located within a meter of the surface to allow realistic possibility of location. Conductivities <1200 micromhos were present only during periods of high discharge. At such times, realistic ranges could be expected when depths of transmitters were <2 m (Figure 1);

however, the total depth of the water column in the river was also much greater at such times.

Based on this experiment, I expected that it would be difficult to locate telemetrized striped bass. Telemetrized fish near the bottom in deep water would be impossible to locate, but fish inhabiting shallow reaches or swimming near the surface of the water could potentially be located. Accordingly, most of the surveys were scheduled to coincide with hydropower releases during the early morning hours (when anglers reported enhanced angling success and fish could be expected to be feeding near the surface). Apparently, striped bass in the Arkansas River below Keystone Dam seldom inhabited shallow areas and approached the surface very infrequently. Despite considerable effort (about 450 hours), few locations were determined.

One of the four fish implanted with transmitters in 1987 (Number 302, Table 1) was never located following release. Another (Number 202) was located only once (on 14 May 1987) one month after implantation in the stilling basin. Fish Number 403 was located on 30 April 1987 (two days after implantation) in the stilling basin and on 7 May 1987 about 5.6 km downstream from Keystone Dam near the mouth of a small tributary stream. Fish Number 101 was located on four occasions (13, 14, 15, and 28 May 1987); on all four occasions it was located in the stilling basin.

These fish were successfully located only during a period of relatively low flows in April and May 1987. None were found after the onset of high discharges in late May 1987. Subsequent searches, including a telemetric survey of downstream reaches of the river to the Arkansas state border, did not result in successful location of any of the four fish implanted in 1987.

Of the 10 fish fitted with transmitters in 1988, six (Numbers 602, 851, 652, 049, 449, and 550; Table 1) were never located telemetrically. However, fish Number 652 was taken by an angler on 11 June 1988 in the Zink Dam tailwaters 29.5 km downstream from the release site. Three individuals (Numbers 150, 353, and 951) were located successfully only once; all were found in the Keystone stilling basin and all were located on 29 June 1988. Number 353 was caught by an angler two weeks later (13 July 1988) about 3 km downstream from Keystone Dam. Number 501 was successfully located on 10 occasions in the stilling basin from 12 April 1988 (2.5 months after implantation) through 10 August 1988.

All telemetric location determinations in the Keystone Dam tailwaters in both years were within 250 m of the dam. In general, these fish tended to be found in the central area of the stilling basin, in close proximity to the dam over the tainter gate plunge pool, or near the penstock wall. Only one location determination was made in the proximity of the penstock discharge, despite the popularity of this area among striped bass anglers.

Recapture locations of 67 striped bass tagged with anchor tags in the Keystone Dam stilling basin during the 1986-87 tagging season were documented. Of these, 49 (73.1%) were recaptured at the release site, and 18 were recaptured at downstream locations (Figure 2). Five fish were caught about 2-3 km below the dam (Figure 2) in an area frequented by anglers using boats. One fish was caught about 11 km below the dam, upstream from the Highway 97 bridge at Sand Springs. Six tagged fish were caught in the Zink Dam tailwaters, 29.5 km downstream (Figure 2). Six tagged fish moved >100 km downstream from the release site. Two were caught by anglers in the lower Illinois River below Tenkiller Reservoir (191 km downstream) and three were taken by a commercial fisherman gill netting on Lake Dardanelle at Russellville, Arkansas, 442 km downstream (Figure 2). One fish travelled >1800 km and was caught by a commercial fisherman about 15 km from the South Pass of the Mississippi River in the Gulf of Mexico.

Of 20 striped bass that were tagged 3 to 7 km downstream from Keystone Dam during the 1986-87 season, three were caught by anglers. All three were caught in the stilling basin and had moved upstream about 2 km.

Recapture locations of 121 of the 536 striped bass tagged in the Keystone Dam tailwaters during the 1987-88 season were documented. Of these, 95 (78.5%) were recaptured at the release site (Figure 2). The frequency distribution of days-at-liberty (Figure 3) suggested these fish tended to be recaptured somewhat earlier, in general, than the 1986-87 group. Twenty-six fish tagged during 1987-88 in the Keystone Dam tailwaters were recaptured in downstream areas; 15 were caught several km below the dam (Figure 2). One was caught about 15 km downstream (below the Highway 97 bridge), and eight were recaptured by anglers in the Zink Dam tailwaters (Figure 2). Only two fish moved >100 km. One was taken in the tailwaters of Ft. Gibson Reservoir (148 km) and the other moved 305 km downstream to Lock & Dam 13 below Ft. Smith, Arkansas (Figure 2).

Although only eight striped bass were tagged and released in the area 3 to 7 km downstream from Keystone Dam during the 1987-88 season, two were recaptured. As in the previous year, both fish had moved upstream and were caught in the stilling basin.

The emigration rates of striped bass out of the Keystone-Zink pool of the Arkansas River were 17.9% (12 of 67 tag returns) in 1987, and 8.3% (10 of 121 tag returns) in 1988.

Six of the 52 striped bass tagged in the Zink Dam tailwaters during the 1987-88 season were recaptured. Five were caught by anglers at the release site and one had moved 115 km downstream to below Lock & Dam 17 on the McClellan-Kerr Navigation System (Figure 2). None of the fish tagged in the Zink Dam tailwaters were recaptured above Zink Dam.

Fishery Characteristics

Fourteen taxa were represented in the catch and harvest estimates by the creel survey (Tables 2 and 3). Striped bass ranked first among all species in both total catch (45.4%) and harvest (43.5%). Striped bass ranked first in angler harvest in eight of the 12 months surveyed and ranked second in angler harvest in three of the months surveyed (Table 2). Striped bass ranked first in angler catch estimates in five of the 12 months surveyed.

The catch-per-unit-effort (CPUE) rates of striped bass temporally reflected the rates of all species in aggregate except during two months (Figure 4); i.e., striped bass catches largely dictated total catch dynamics. CPUE rates of striped bass were low from January to May (Figure 4), probably as a result of flood water releases through Keystone Dam that often reduce striped bass angling success. The high CPUE rates of all species in aggregate in October and June (Figure 4) resulted from increased catches of both striped bass and white bass (Table 3). The relatively high CPUE rate of all species in aggregate in April (Figure 4) was almost entirely the result of increased catches of white bass (Table 3).

Harvest-per-unit-effort (HPUE) rates of striped bass reflected those of all species in aggregate (Figure 5). HPUE rates of striped bass (Figure 5) were low from late winter through spring and peaked in October and June when striped bass composed the majority of the harvest (Table 2).

The increased HPUE rates of all species in aggregate in April and May (Figure 5) resulted from increased harvests of white bass (Table 2).

CPUE rates of anglers specifically seeking striped bass and those seeking other species (or no species in particular) were similar throughout most of the year (Figure 6), except in April and June when increased catches of white bass and striped bass, respectively, elevated catch rates of non-striped-bass anglers. HPUE rates of anglers specifically seeking striped bass were higher than HPUE rates of those seeking other species during most months (Figure 7). However, the HPUE rate of non-striped-bass anglers was drastically higher in April as a result of increased harvest of white bass (Figure 7; Table 2).

Only nine (3.7%) of 243 harvested striped bass measured during the creel surveys were <400 mm TL (Figure 8). The majority of harvested striped bass ranged from 400 to 800 mm TL. The length-frequency distribution appeared to be trimodal with peaks at 500, 600, and 700 mm TL (Figure 8).

The striped bass was the species primarily sought by 373 of 733 anglers surveyed (51%). Anglers who had no species preference composed 20% of the total. Anglers fishing for catfish, white bass, and crappie composed 18%, 6%, and 5% of the total, respectively.

Weekday angler effort was higher than weekend angler effort during most months (Figure 9). Overall, angler effort was highest in summer and lowest in winter. The increased effort in October and March (Figure 9) coincided with increased harvest of striped bass during those two months (Table 2).

Angler Exploitation

Anglers reported recapture of 49 of 468 (10.5%) striped bass tagged in the vicinity of the Keystone Dam tailwaters during the 1986-87 tagging season within one year of tagging. Of 544 striped bass tagged during the 1987-88 season, 110 (20.2%) were recaptured by anglers within one year.

Abundance estimates of striped bass conducted in conjunction with tagging in the Keystone Dam tailwaters were 12,645 individuals in spring 1987 and 9,803 individuals in spring 1988. Confidence intervals (95%) for 1987 and 1988 estimates were 7,951-30,855 and 6,594-19,099, respectively. However, the estimated total number of striped bass harvested during the creel period (September 1987 to August 1988) was 21,564 fish (Table 2), which suggested that exploitation exceeded 100%.

DISCUSSION

Movements

Accurate telemetric tracking of striped bass in the Arkansas River below Keystone Dam was effectively impossible using radio equipment. High conductivities present in the river usually precluded location of telemetrized fish. Although it was possible to locate fish swimming near the surface, the lack of success suggested that striped bass in this river segment rarely frequented shallow depths. In retrospect, it appears likely that more location determinations could have been made using sonic telemetry equipment. During periods of low or no discharge, sonic gear probably would have been useful in locating fish within the stilling basin, regardless of their depth. However, fish in other segments of the river would have been extremely difficult, if not impossible, to locate and sonic gear would have been useless during periods of moderate or high discharge. It appears that telemetric tracking of striped bass in the Arkansas River will be possible only upon development of radically different telemetry techniques (i.e., other than radio or sonic equipment).

Conventional tagging using anchor tags was more productive than telemetry in assessing movements of striped bass in the Arkansas River. The success of this program was largely a result of the enthusiastic support provided by local anglers who conscientiously returned tags. In addition to providing information on gross movements, conventional tagging also allowed determination of population abundances and exploitation rates.

Striped bass in the Arkansas River tended to congregate in the Keystone Dam tailwaters throughout the year. Roughly 78% of the recaptured striped bass were recaptured in the area where they were tagged during both the 1986-87 and 1987-88 tagging seasons. The majority of striped bass in the Apalachicola River, Florida, also stayed in the same area where they were tagged (Wooley and Crateau 1983). Striped bass in the Savannah River, Georgia, moved upstream after spawning and no downstream movements were detected; although a few fish moved great distances in a short period of time (one moved 240 km in less than three weeks), the majority of the fish never moved more than 10 km from the tagging site (Dudley et al. 1977). Some striped bass in the Arkansas River moved great distances in a short period of time, but the majority remained within a few km of the area where they were tagged.

Movements of striped bass in the Alabama River were influenced by temperature preferences (Moss 1985; Lamprecht and Shelton 1986). Suitable water temperatures and depths for striped bass in the Keystone Dam tailwaters probably encouraged striped bass to inhabit this area. Abundant clupeid forage in the Keystone tailwaters (Combs 1979) also may be responsible for sustaining concentrations of striped bass there throughout the year. Other segments of the

Keystone-to-Zink reach were probably inhabited only temporarily during transit out of the pool.

Emigration from the Keystone-to-Zink pool was appreciable (i.e., it approximated losses resulting from exploitation). Overall, 17.9% (12 of 67) of recaptured fish from the 1986-87 group emigrated downstream out of the Keystone-to-Zink pool compared to a 8.3% (10 of 121) emigration rate in 1988. Emigration rates were considered minima because fewer anglers downstream knew of our study and therefore were not inclined to return tags.

The instinctive behavior of striped bass in their native range (except during spawning runs) is to move in and out of estuaries with the tides (Koo and Wilson 1972; Finlayson 1980). Analogous behavior in an inland riverine system would promote downstream displacement during periods of high discharge. The apparent propensity for downstream movements during periods of high discharge would appear to decrease the likelihood that significant numbers of striped bass immigrate into the Keystone-to-Zink pool from downstream areas (or return following emigration) because physical upstream passage over Zink Dam is possible only during periods of relatively high discharge. The apparent disparity in propensities for downstream movement between the two years may have been a function of the magnitude of releases from Keystone Dam. Discharges reached higher levels and were high more often in 1987 than in 1988. Periods-at-liberty of the fish that moved downstream out of the Keystone-Zink pool all coincided with at least one major discharge event, which suggested that high discharges facilitated or encouraged downstream movements. Of note, downstream movements occurred during late winter and spring when adult striped bass typically move upstream in preparation for spawning.

Fishery Characteristics

The mean annual CPUE rate of striped bass in the Keystone Dam tailwaters was higher than in reservoirs and stilling basins throughout Oklahoma (Summers 1978) and the Roanoke and Dan rivers in Virginia (Neal 1976). My estimates of CPUE were lower than those reported by Hamilton et al. (1985) in the Keystone tailwaters.

The estimated total number of fishes in aggregate harvested annually by anglers in the Keystone Dam tailwaters as reported by Summers (1978) was nearly four times my estimate. Differences in harvest between Summers' (1978) study and mine were largely a result of fewer white bass being harvested during my study. However, my estimate of the number of striped bass harvested was almost twice the estimate of Summers (1978). My catch and harvest totals were higher than those in any stilling basin in Oklahoma.

Angler Exploitation

The lower exploitation rate observed in the first half of my study was probably a function of the increased discharges through Keystone Dam in the spring of 1987. These discharges caused a greater portion of striped bass to move out of the Keystone-Zink reach of the Arkansas River, and reduced the number of tagged fish available to anglers. Knowledge of the percentage of the population harvested annually by anglers allows implementation of creel limits to maintain stable stocks (Reed and Davies 1980; Wooley and Crateau 1983). However, fish are constantly moving into and out of the Keystone-Zink pool, and a reduced creel limit would do little to stabilize this striped bass stock.

Wooley and Crateau (1983) estimated that 182 striped bass >381 mm were harvested in one year from a population of 1,986 fish in the Apalachicola River, Florida. My creel survey showed that over four times the estimated striped bass population was caught and about two times the estimated population was harvested annually.

In view of the relatively high emigration rates (>10% annually) and the likelihood that upstream immigration over Zink Dam is negligible, the primary means by which the stock in the Keystone-to-Zink pool is maintained appears to be via immigration from Keystone Reservoir. The reach is too short for successful within-pool reproduction because rapid transport of the semi-buoyant eggs through the pool does not allow complete incubation (Combs 1979b). The young-of-the-year striped bass found in the pool are probably spawned above Keystone Reservoir and flushed through and over the dam as larvae by high spring flows. Entrainment of yearling striped bass through the penstocks during winter was observed; however, gas-bladder distension from rapid decompression exposed these individuals to intense predation by bald eagles (Haliaeetus leucocephalus) and other fish-eating birds in the tailwaters. Export of adult striped bass from Keystone Reservoir via the dam's tainter gates appears to be significant. Of a total of 95 striped bass tagged in Keystone Reservoir by Zale et al. (1988), 10 were caught by anglers within one year. Four of these recaptures occurred in the Keystone Dam tailwaters. Although the small sample size precludes validity of an annual estimated export rate of 40%, the conclusion that substantial downstream immigration from Keystone Reservoir occurs appears valid. Furthermore, it appears that it is correlated with discharge. Periods-at-liberty of the four fish coincided with at least one major discharge event. Thus, the high discharges that appear to cause emigration of striped bass out of the Keystone-to-Zink pool to downstream reaches also may be responsible for immigration from Keystone Reservoir.

Extrapolation of this scenario to the entire Arkansas River system suggests that striped bass stocks in each pool are not discrete and cannot be managed as separate stocks. Rather, each stock is periodically supplemented by new immigrants from upstream and reduced by downstream emigrants. Accordingly, regulations, management practices, and perturbations imposed on striped bass in a river segment may eventually affect striped bass fisheries in downstream reaches.

Management Recommendations

A major constraint on this stock is the inability of striped bass to move back into the Keystone-Zink pool after emigrating downstream. To increase the number of striped bass in the Keystone Dam tailwaters, either the population of striped bass in Keystone Reservoir must be increased or the flows through and over Zink Dam must be modified. The gates at Zink Dam should be opened more often throughout the year to allow upstream passage of striped bass beyond this barrier. Physical characteristics of the Zink Dam area should be improved to promote upstream passage of striped bass. At the present time there is a drastic change in substrate levels above and directly below Zink Dam. When the gates at Zink Dam are opened, the immediate change in water levels discourages upstream movement of striped bass. If Zink Dam was modified so that striped bass could immigrate back into the Keystone-Zink pool, the stock could be supplemented from downstream areas.

Because there is no reproduction of striped bass in the Keystone-Zink pool, the striped bass fishery is basically put-and-take. Striped bass move into the tailwaters via immigration from Keystone Reservoir and are removed either by anglers or downstream emigration. Creel limits or a closed season would not benefit the striped bass fishery under existing conditions. I recommend that no length or creel limit be placed on striped bass in this fishery.

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Table 1. Implantation dates, lengths, and weights of striped bass telemetrized in the Keystone Dam tailwaters, Arkansas River, Oklahoma, 1987 and 1988.

Fish No.	Frequency	Date	Total length (mm)	Weight (g)
202	40.202	14 APR 87	655	6400
302	40.302	14 APR 87	790	8150
101	40.101	28 APR 87	740	5950
403	40.403	28 APR 87	795	7800
602	40.602	28 JAN 88	823	7500
501	40.501	28 JAN 88	798	7050
851	40.851	28 JAN 88	756	6300
150	40.150	28 JAN 88	763	6500
353	40.353	28 JAN 88	777	6400
951	40.951	18 FEB 88	783	6300
652	40.652	25 FEB 88	801	6900
049	40.049	25 FEB 88	841	7000
449	40.449	25 FEB 88	773	5900
550	40.550	01 MAR 88	808	7000

Table 2. Estimated angler effort and numbers of fish harvested in the Keystone Dam tailwaters, Oklahoma, from September 1987 through August 1988.

Taxon	Month												
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
Striped bass (Morone saxatilis)	1067	3019	2996	915	96	82	908	514	2129	4801	1174	3863	21564
White bass (Morone chrysops)	94	373	476	188	96	54	277	1693	4509	1502	3995	126	13383
Crappie (Pomoxis spp.)	0	699	709	213	19	0	19	21	1246	98	0	0	3024
Blue catfish (Ictalurus furcatus)	188	434	20	427	38	162	210	369	1554	1744	1782	0	6928
Channel catfish (Ictalurus punctatus)	389	99	13	0	0	18	70	0	73	196	441	0	1299
Flathead catfish (Pylodictis olivaris)	0	0	6	0	0	0	0	42	439	98	0	84	669
Sunfish (Lepomis spp.)	0	352	6	0	0	0	0	0	0	0	0	0	358
Hybrid striped bass	0	99	0	0	0	0	0	0	0	0	0	0	99
Largemouth bass (Micropterus salmoides)	0	0	0	42	0	0	0	0	0	0	0	0	42
Walleye (Stizostedion vitreum)	0	0	0	0	0	0	0	0	0	0	0	42	42
Common carp (Cyprinus carpio)	0	0	0	42	0	0	0	0	0	0	0	0	42
Total	1738	5075	4226	1827	249	316	1484	2639	9950	8439	7392	4115	47450
Effort (angler hours)	7249	9197	6708	4884	3957	1609	9662	5887	16830	14827	18369	11354	105234

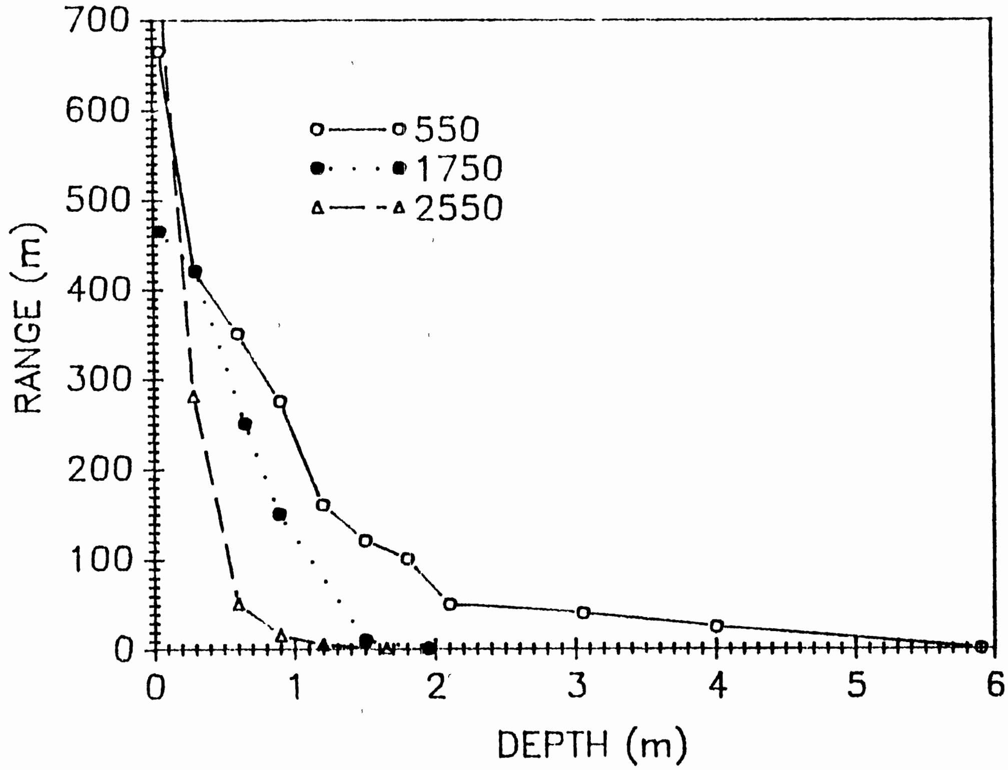
Table 3. Estimated numbers of fish caught in the Keystone Dam tailwaters, Oklahoma, from September 1987 through August 1988.

	Month												
Taxon	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
Striped bass (*Morone saxatilis*)	2417	5584	4336	3053	135	118	2274	1032	2630	14975	3995	8114	48663
White bass (*Morone chrysops*)	335	3549	5170	951	714	87	437	6831	7719	2952	9754	336	38835
Crappie (*Pomoxis* spp.)	0	999	1772	427	38	36	137	21	1246	98	0	0	4774
Catfish (*Ictalurus* spp., *Pylodictis* sp.)	966	1034	214	427	57	198	561	694	4182	3645	3416	1010	16404
Paddlefish (*Polyodon spathula*)	0	49	0	85	115	0	1861	87	106	0	0	0	2303
Sunfish (*Lepomis* spp.)	0	352	6	0	0	0	0	0	0	0	0	0	358
Largemouth bass (*Micropterus salmoides*)	0	0	6	42	0	0	0	0	0	0	0	0	48
Walleye (*Stizostedion vitreum*)	0	0	87	0	0	0	0	0	0	0	0	42	129
Hybrid striped bass	0	99	0	0	0	0	0	0	0	0	0	0	99
Common carp (*Cyprinus carpio*)	0	0	0	42	0	0	0	21	0	0	0	0	63
Gar (*Lepisosteus* spp.)	0	0	0	0	19	0	0	0	0	0	148	0	167
Freshwater drum (*Aplodinotus grunniens*)	0	0	0	0	0	0	0	0	146	0	0	0	146
Totals	3718	11666	11591	5027	1078	439	5270	8686	16029	21670	17313	9502	111989

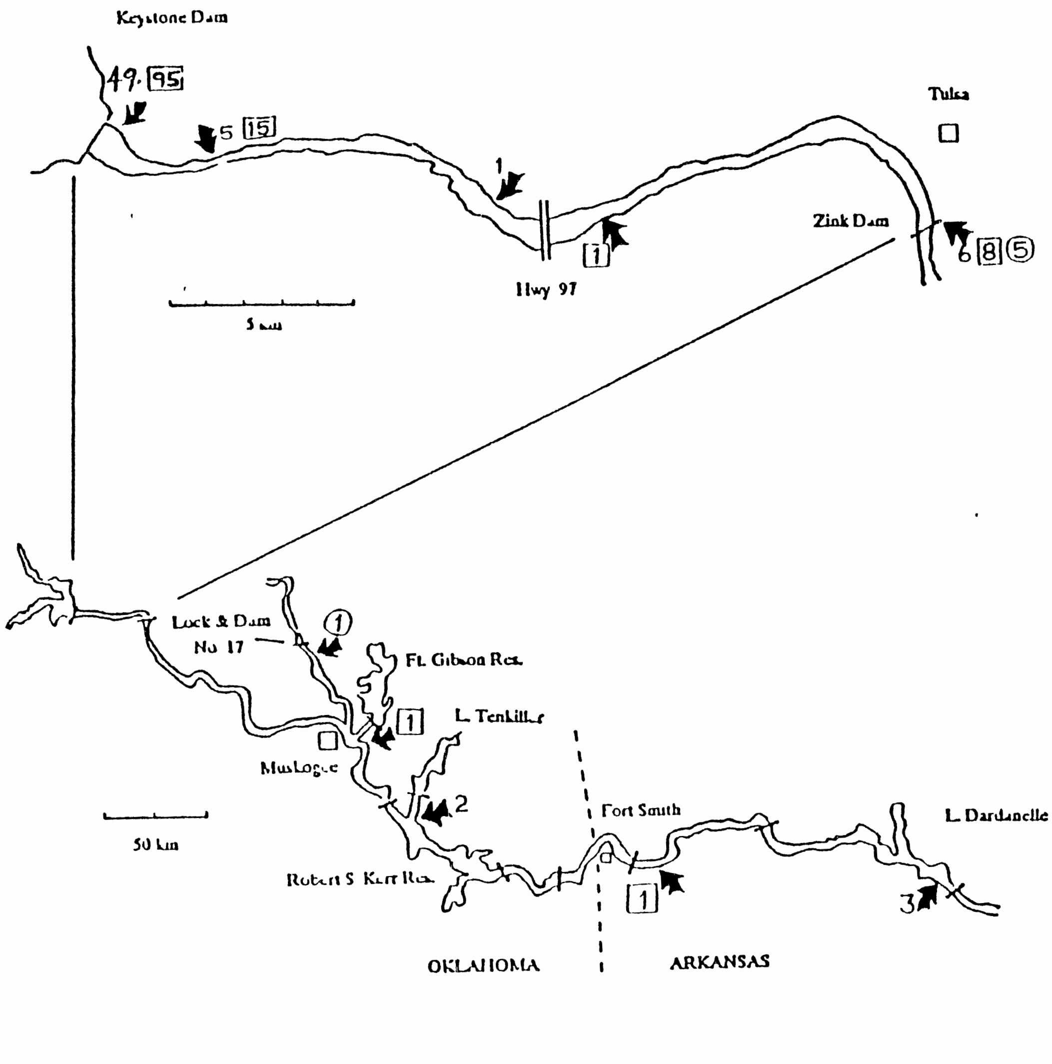
FIGURE CAPTIONS

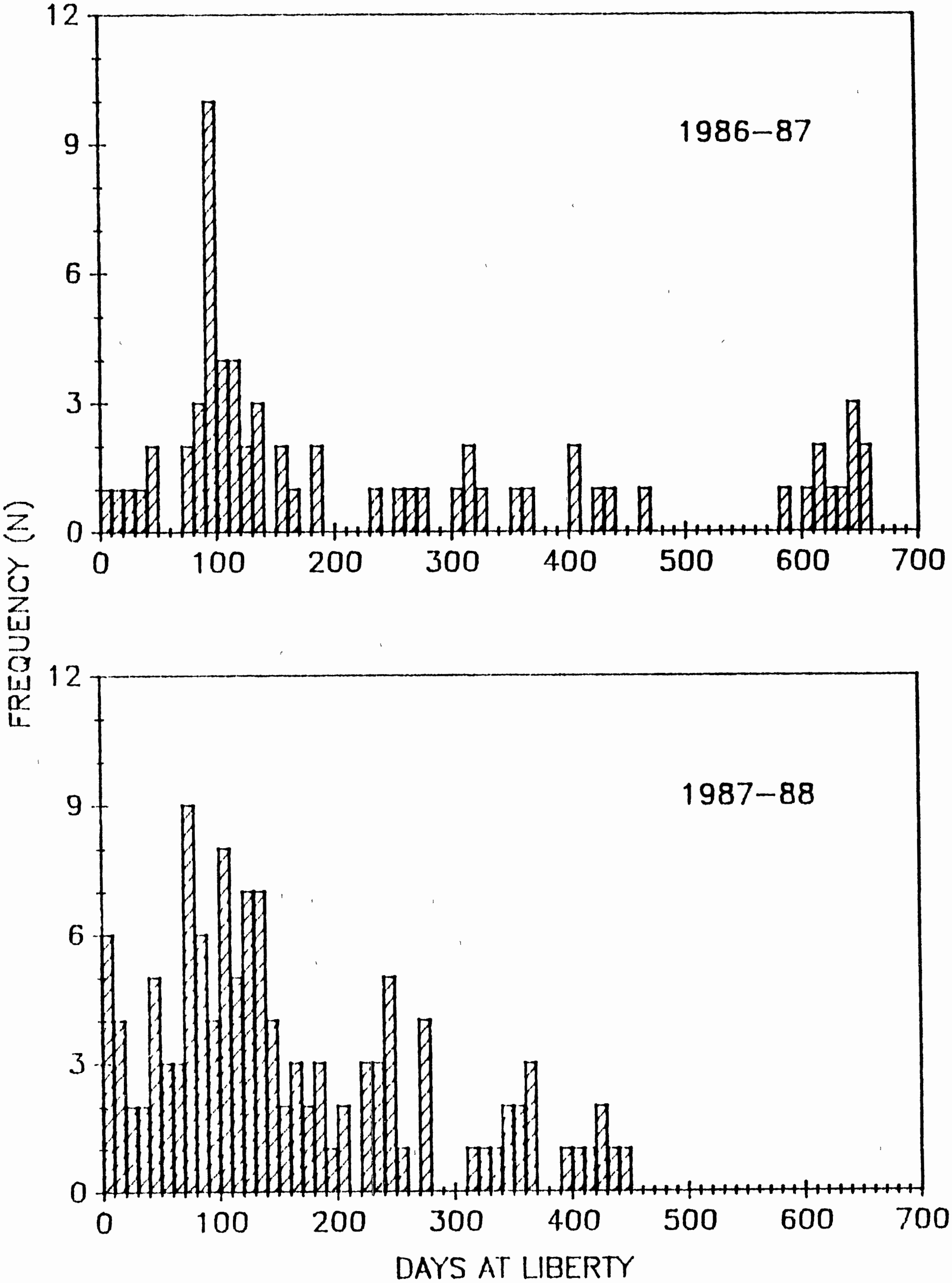
1. Relationships between transmission ranges and depths of radio transmitters at water conductivities of 550, 1750, and 2550 micromhos.
2. Recapture locations of striped bass conventionally tagged in the Arkansas River, Oklahoma. Number recaptured in 1986-1987 (N), number recaptured in 1987-1988 (N), and number recaptured that were tagged below Zink Dam (N).
3. Frequency distributions of days-at-liberty of striped bass conventionally tagged and recaptured by anglers, in the Arkansas River below Keystone Dam, Oklahoma, by tagging season.
4. Catch-per-unit-effort rates (number per hour) of all species in aggregate (solid line) and striped bass (dashed line), by all anglers in the Keystone Dam tailwaters, Oklahoma, September 1987 to August 1988.
5. Harvest-per-unit-effort rates (number per hour) of all species in aggregate (solid line) and striped bass (dashed line), by all anglers in the Keystone Dam tailwaters, Oklahoma, September 1987 to August 1988.
6. Catch-per-unit-effort rates (number per hour) of anglers specifically seeking striped bass (dashed line) and anglers seeking other species (solid line), in the Keystone Dam tailwaters, Oklahoma, September 1987 to August 1988.

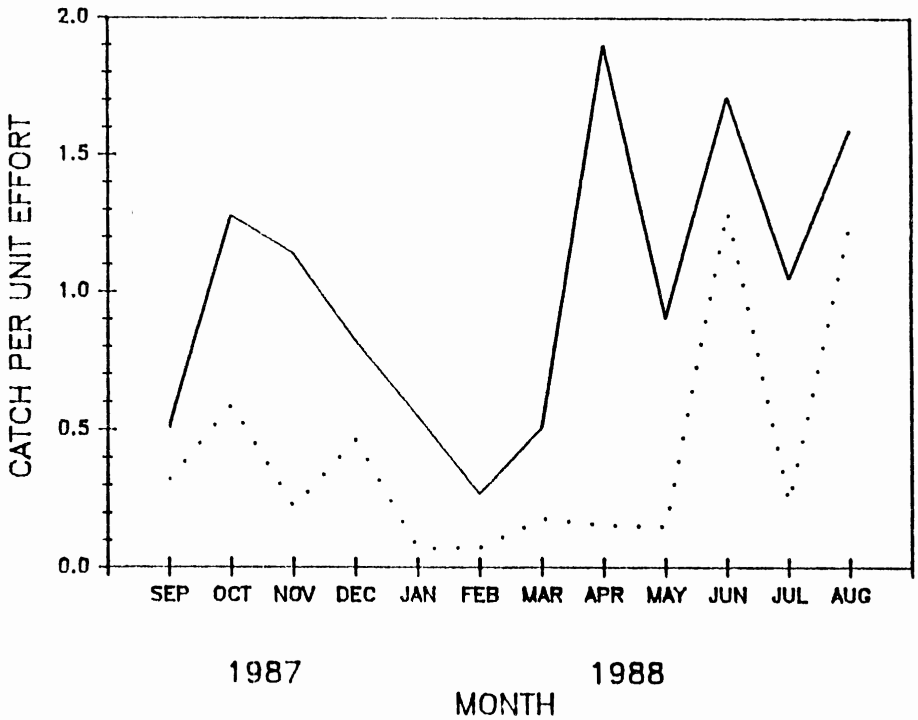
7. Harvest-per-unit-effort rates (number per hour) of anglers specifically seeking striped bass (dashed line) and anglers seeking other species (solid line), in the Keystone Dam tailwaters, Oklahoma, September 1987 to August 1988.
8. Length-frequency distribution of striped bass harvested in the Keystone Dam tailwaters, Oklahoma, September 1987 to August 1988.
9. Monthly angler effort (angler hours) by weekday and weekend, in the Keystone Dam tailwaters, Oklahoma, September 1987 to August 1988.



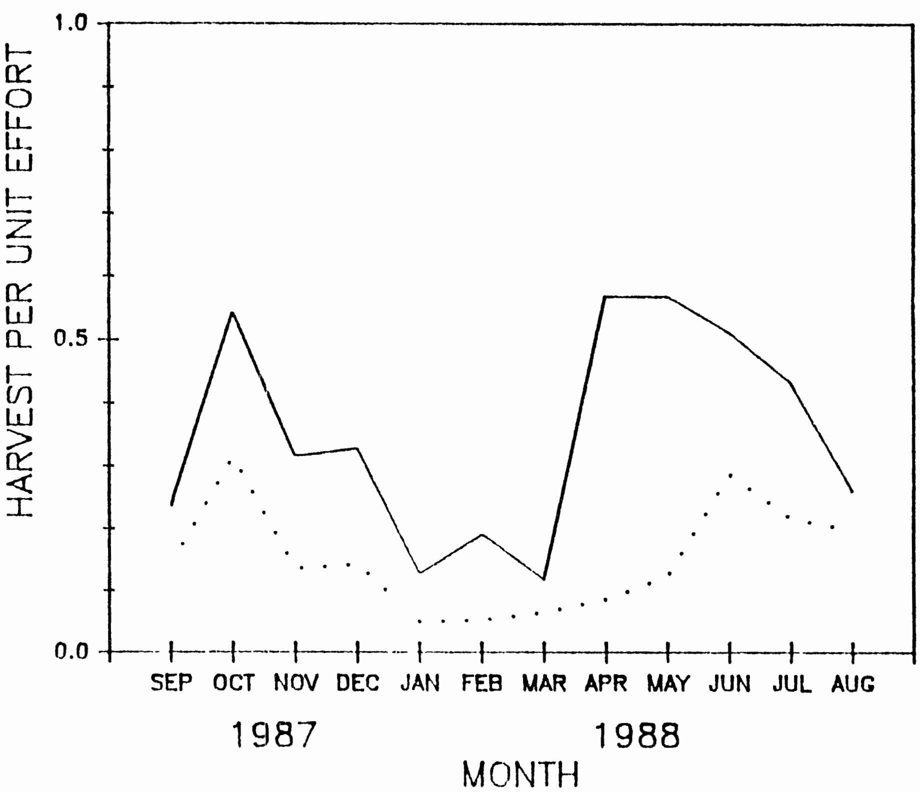
700
600
500
400
300
200
100
0
RANGE (m)
0
1
2
3
4
5
6
DEPTH (m)
550
1750
2550


Keystone Dam
49. 95
5 15
1
1
Hwy 97
Tulsa
Zink Dam
6 8 5
5 km
Lock & Dam
No 17
1
Ft. Gibson Res.
1
L. Tenkiller
Muskogee
2
50 km
Fort Smith
L. Dardanelle
Robert S. Kerr Res.
1
3
OKLAHOMA
ARKANSAS

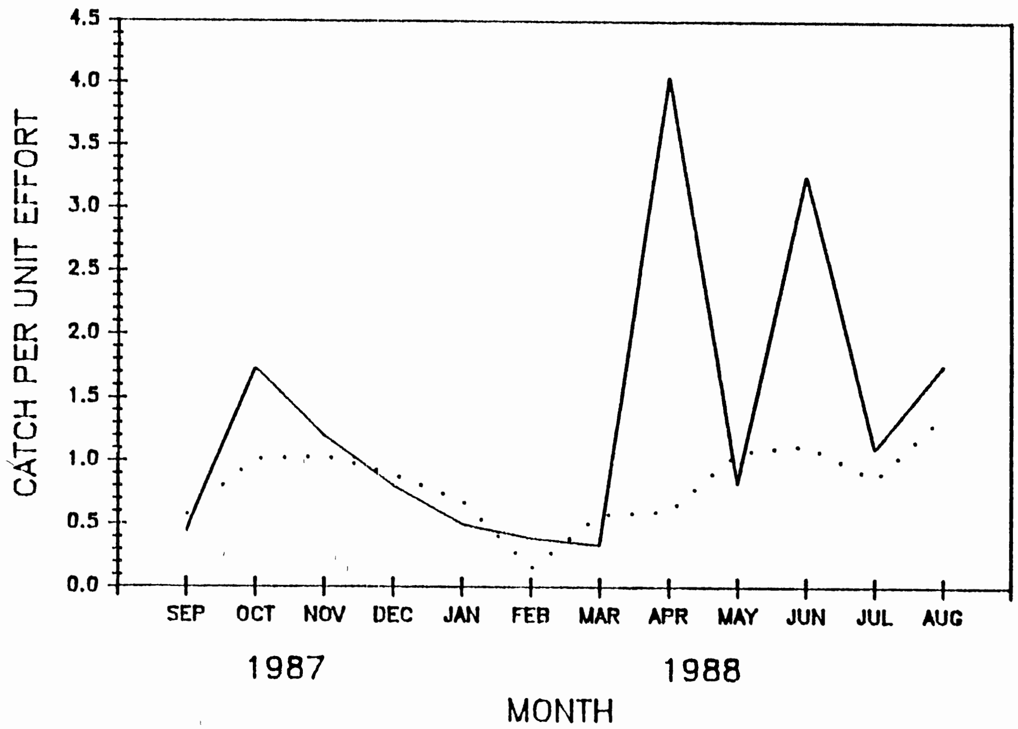

FREQUENCY (N)
1986–87
1987–88
0
3
6
9
12
0
100
200
300
400
500
600
700
DAYS AT LIBERTY

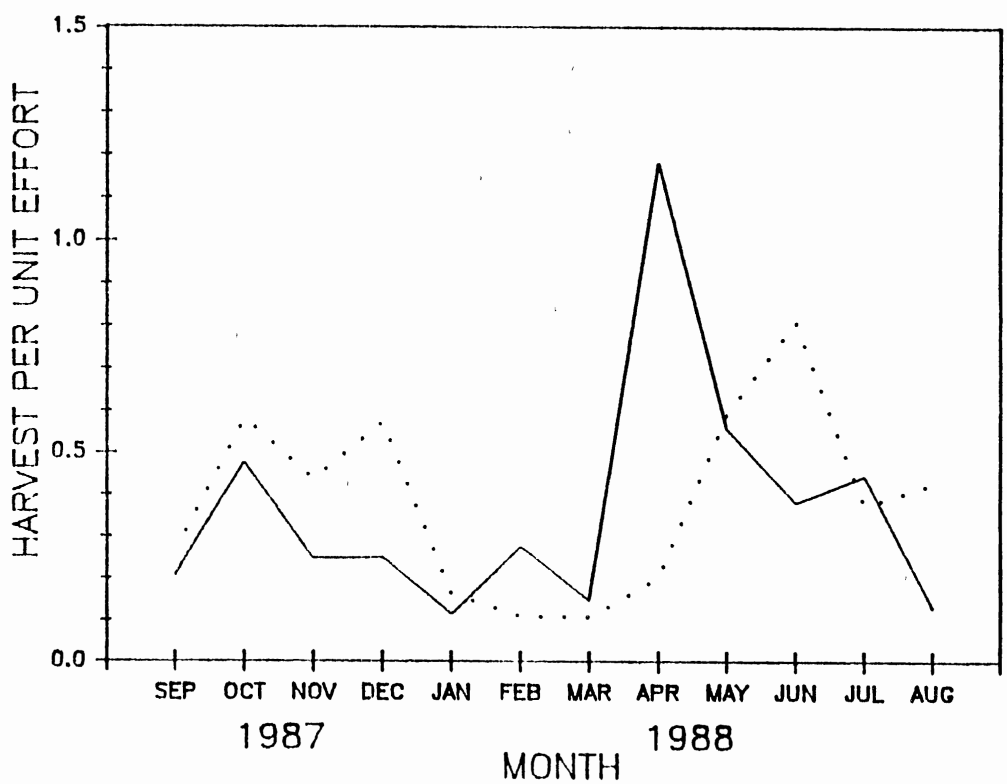


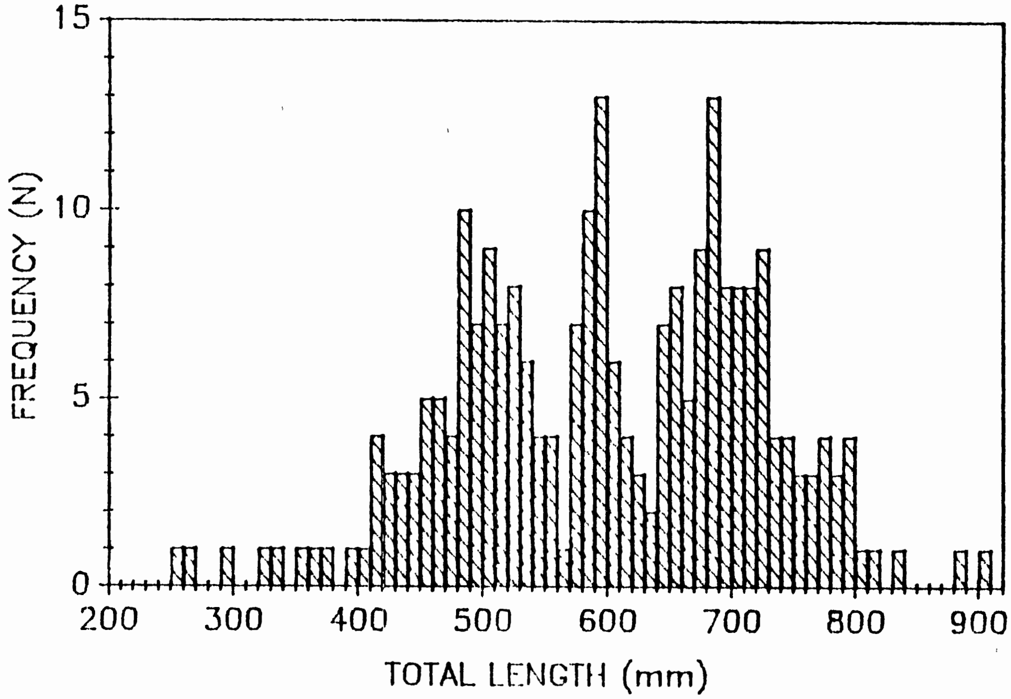
2.0
1.5
1.0
0.5
0.0
CATCH PER UNIT EFFORT
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG
1987
1988
MONTH

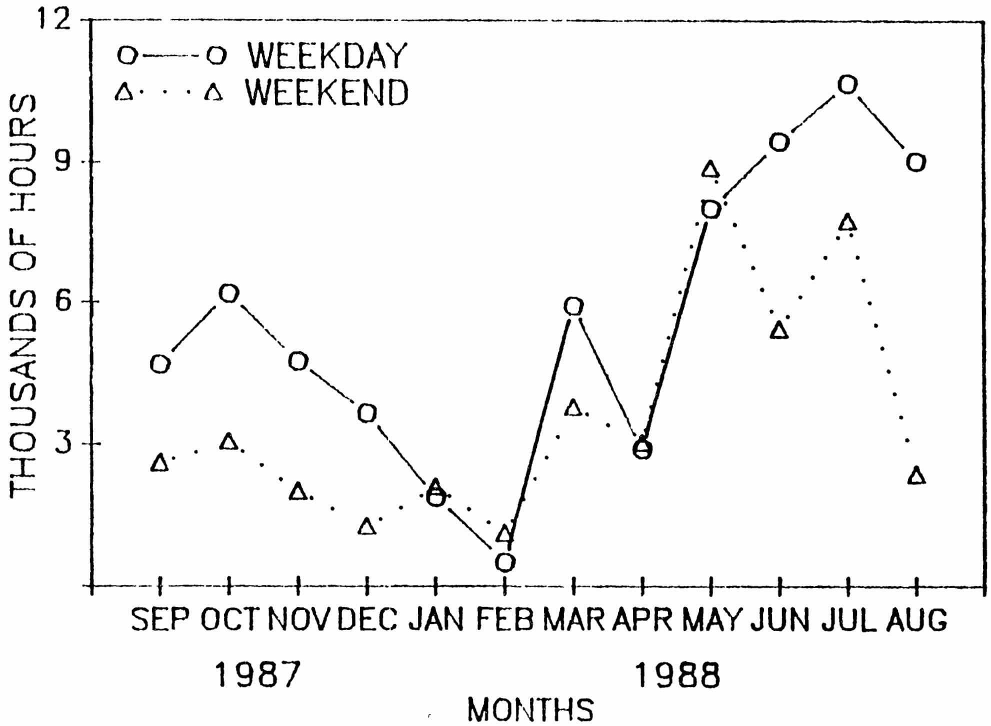


1.0
0.5
0.0
HARVEST PER UNIT EFFORT
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG
1987
1988
MONTH


4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
CATCH PER UNIT EFFORT
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG
1987
1988
MONTH


1.5
1.0
0.5
0.0
HARVEST PER UNIT EFFORT
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG
1987
1988
MONTH


15
10
5
0
FREQUENCY (N)
200
300
400
500
600
700
800
900
TOTAL LENGTH (mm)


12
9
6
3
THOUSANDS OF HOURS
WEEKDAY
WEEKEND
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG
1987
1988
MONTHS

VITA

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