Effects of Gizzard Shad Introduction on a Small-impoundment Fishery

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Abstract: Gizzard shad (*Dorosoma cepedianum*) were introduced into an 83-ha public fishing lake in central Missouri in an attempt to improve populations of high density, slow growing largemouth bass (*Micropterus salmoides*), white crappie (*Pomoxis annularis*), and bluegill (*Lepomis macrochirus*). A 380-mm length limit on largemouth bass was introduced at the same time. Growth rates of both bass and crappie increased. The annual catch of largemouth bass increased from 80 per hectare to 212 per hectare after gizzard shad were introduced, and that of white crappie from < 5 kg per hectare to 27 kg per hectare. The growth rate, population structure, and condition of bluegills improved somewhat.

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The use of gizzard shad (*Dorosoma cepedianum*) as forage for sport fishes is not a universally accepted management procedure, even though the species appears to have many desirable qualities of a prey species (Miller 1960). It is an important food for many game fishes (Jester and Jensen 1972) and can serve as alternate prey and lessen the predation on young-of-year (YOY) game fish (Mitzner 1980). However, an ideal prey species is stable in abundance and vulnerable to predation (Ney 1981), and gizzard shad often do not meet these criteria. Shad densities vary greatly among reservoirs and the growth rates of young-of-the-year vary tremendously from year to year (Mitzner 1980). Young gizzard shad may grow too large for predators by the end of the first growing season (Berry 1957), and gizzard shad have been

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shown to adversely affect sport fish populations by competing for food (Davies et al. 1982, Phillippy 1964).

The effect of shad in small impoundments is especially controversial. Participants at a small lakes management workshop on shad dynamics held in Des Moines, Iowa, in 1983 were generally of the opinion that, overall, shad were a negative influence on sport-fish populations in small midwestern water bodies. This paper is an extension of that workshop and will report a situation where shad are of apparent benefit.

Methods

Little Dixie Lake, an 83-ha (205-acre) fishing lake 19.3 km east of Columbia, Missouri, is owned and managed by the Missouri Department of Conservation. It was built in 1957 and stocked with largemouth bass (*Micropterus salmoides*) in July 1958, bluegill (*Lepomis macrochirus*) and redear sunfish (*Lepomis microlophus*) in March 1959, and channel catfish (*Ictalurus punctatus*) in October 1959. The lake was opened to public fishing on 28 May 1960.

Since its creation, Little Dixie Lake has supported a less than optimum fishery, and a series of management actions have been taken to improve it. Within a year after the lake opening, 72% of the largemouth bass ≥ 229 mm had been harvested (Turner 1963). By 1963, the bluegill population had become overabundant and stunted—undesirable characteristics for a recreational fishery.

A lake drawdown in 1964 concentrated bluegills and increased their vulnerability to bass predation (Heman et al. 1969). Although growth rates of largemouth bass increased temporarily, bluegills 76–127 mm long again became overabundant and slow growing from 1965 to 1968—a condition perhaps influenced by the continued overharvest of bass (Norwat 1978).

In 1968, a 305-mm minimum length limit regulation on largemouth bass was imposed to increase predator density as well as the size of bass harvested by anglers. The density of bass 178–254 mm long increased and that of bluegills 76–127 mm long decreased (Choate 1970). Growth rates of bass began to decline, suggesting that there was inadequate forage to support the increased numbers of bass that resulted from the 305 mm minimum size regulation.

White crappies (*Pomoxis annularis*) were not stocked but were first reported in 1966 and were seen in the creel in 1968 (Norwat 1978). The population grew rapidly and by 1974 consisted of large numbers of small, slow-growing fish.

An effort was made to improve undesirable population characteristics of bass, bluegills, and crappies by increasing the prey base. Threadfin shad (*Dorosoma petenense*) were stocked in 1973 and 1974, but the growth rates of bass and crappie did not improve (Norwat 1978). Apparently winter mortality completely eliminated the threadfin shad. In spring 1975, adult gizzard shad were stocked at a rate of 11.3 kg per hectare. A 380-mm length limit regulation for largemouth bass was established in January 1975 to increase the average size of bass in the population.

Field collections were made between June 1977 and October 1979. The YOY gizzard shad were captured by towing a conical net 1-m diameter with a mesh size of 3.17 mm at depths of 0–4 m. White crappies were sampled with trap nets each year in October. Sampling effort ranged from 15 to 35 net days. The proportional stock density (PSD) and relative stock density (RSD_{250}) of Anderson (1976) were calculated for the crappies captured. These indices quantify aspects of the length-frequency distribution; higher numbers indicate a greater percentage of large fish in the population. The PSD expresses the number of fish $\geq$ 203 mm long as a percentage of all fish captured $\geq$ 127 mm long. The RSD_{250} expresses the proportion of fish $\geq$ 250 mm.

Largemouth bass and bluegills were collected by night electrofishing near the shoreline during April and May. Age and growth were determined from scale samples collected in October. Five scale samples per 10-mm length group were collected when possible. Back-calculation of lengths at annulus formation were made with the aid of a nomograph (Hile 1960).

Annual mortality rates for largemouth bass were calculated by using scales collected and aged to convert length-frequency distributions to age-frequency distributions. Electrofishing capture rates were then calculated for each year class. In calculating PSD and RSD_{380} for bass captured, we used 203, 305, and 380 mm as the stock, quality, and preferred lengths, respectively (Anderson and Gutreuter 1983).

Food of white crappies and largemouth bass was determined from stomach contents of fish collected by electrofishing, trap netting, and angling. Angler effort and harvest were determined by a daytime creel survey conducted daily from 1 April to 15 October each year. Detailed procedures for the methodology and data expansion were given by Heman et al. (1969) and Choate (1970).

Results

Gizzard Shad

The sampling for larval gizzard shad done once each year during June in 1975 and 1977–79 showed that they were reproducing. We documented successful, but variable, reproduction; the catch rate ranged from 42 to 1,350 fish per minute. A single fall sample, October 1980, showed YOY to be relatively slow growing with a majority of individuals between 60 and 100 mm. A related study (Schonhoff 1983) showed shad to reach a mean of 103 mm at the end of the first growing season.

Largemouth Bass

Electrofishing catch rates for largemouth bass (Norwat 1978), before the introduction of gizzard shad and setting of the 380-mm minimum length limit for largemouth bass, indicated that densities of bass were low. In 1974 electrofishing yielded largemouth bass at the rate of only 39 per hour. Electrofishing capture rates of largemouth bass collected in spring 1978 and 1979 indicated that the 380-mm minimum length regulation, established in 1975, had been effective in increasing the number of bass in the lake. Electrofishing capture rates (largemouth bass per hour) were 68 in 1978 and almost 80 in 1979.

Proportional stock density values increased to 50% in 1978 and 55% in 1979. However, the percent of bass > 380 mm declined, as indicated by the RSD $_{380}$ values of 2% for 1978 and 1979. Proportional stock density values for 1973 and 1974 (Fig. 1) were below the optimum range of 40%–60%. Mortality became high soon after largemouth bass reached 305 mm in length, which was then the minimum length limit. However, the creel survey indicated no high angling mortality of bass; the harvest was only 6.2 largemouth bass per hectare in both 1973 and 1974.

The catch and release of sublegal largemouth bass by anglers increased after the 1975 change in the minimum length limit regulation. The number of sublegal bass caught and released decreased from 121 per hectare in 1976 to 74 per hectare in 1977 for unknown reasons. From 1977 to 1979, however, the number of sublegal bass caught and returned increased by 188% to 212 per hectare (Fig. 2).

The average relative weight (Wege and Anderson 1978) for bass > 300 mm declined slightly after the introduction of gizzard shad and the change in the largemouth bass minimum size regulation from 307 to 380 mm (Table 1). However, the relative weights of bass < 300 mm long remained constant, suggesting that the amount of available prey for bass of this size remained adequate.

Growth rates of largemouth bass were slow before the introduction of gizzard shad. Norwat (1978) reported that bass collected in November 1974 averaged 109, 193, 229, 267, and 292 mm at ages 1–5. By 1979, after the introduction of gizzard shad in 1975, the growth rates had increased and the fish averaged 135, 211, 270, 342, and 385 mm at ages 1–5.

Annual average mortality rates, based on 1978 and 1979 age frequency distributions, were calculated to be 38% from age 4 to age 5 and 80% from age 5 to age 6. As judged from an analysis of scale samples collected in October 1979, less than 50% of the 5-year-old bass reached legal size by the end of the growing season. It was evident that few bass in Little Dixie Lake were likely to live long enough to reach legal size.

Stomachs were collected from 388 largemouth bass between July 1977 and August 1979. The incidence of gizzard shad as a food item varied widely and ranged from 3.2% by number of the food items in August 1977 to 70% in September 1978. The incidence of empty stomachs ranged from 14% to 30%.

White Crappie

Before the introduction of gizzard shad, the white crappie population was characterized by small, slow-growing fish. Less than 1% of the fish captured in trap nets in 1973 and 1974 were 250 mm long or longer (Fig. 1). By 1977, when gizzard shad had been present during the 3 previous growing seasons, the crappie population structure had improved, as indicated by the PSD value of 18% and the RSD_{250} value of 8%. This improvement continued as October PSD values increased to 27% in 1978 and 32% in 1979, and the respective RSD_{250} values to 15% in 1978 and 5% in 1979 (Fig. 1).

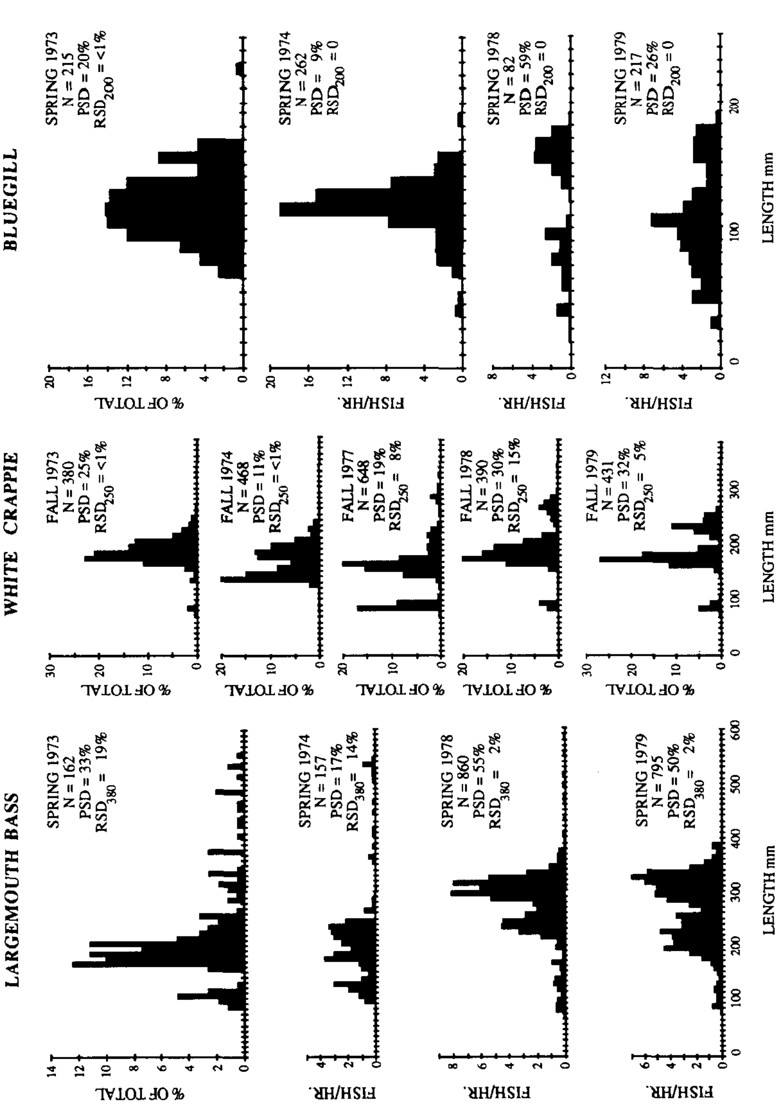

Figure 1. Length-frequency distributions of 3 species of sport fishes in spring, in different years, Little Dixie Lake.

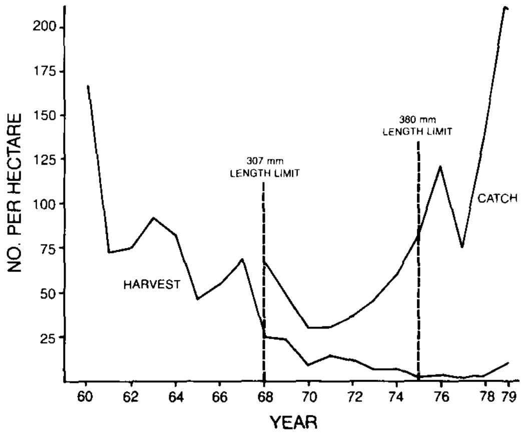

Figure 2. Estimated total catch and harvest of largemouth bass expressed as number per hectare, Little Dixie Lake, 1960–79.

Fishing pressure for white crappies also increased. Angler effort for white crappies increased each year after 1973, and the increase was largest between 1978 and 1979. Anglers fished an estimated 148 hours per hectare for white crappies in 1979 (Fig. 3).

The estimated harvest of white crappie, which was < 5 kg per hectare in 1973, increased to 27 kg per hectare by 1979 (Fig. 3). The estimated number of crappies harvested increased at a much lower rate, indicating that the average size of crappie harvested had increased. The average length of white crappies at age 3 also increased from 163 mm in 1974 (before the introduction of gizzard shad) to 218, 220, and 238 mm in 1977, 1978, and 1979, respectively.

Of 110 crappie stomachs collected in July 1979, 71% contained gizzard shad. Gizzard shad also comprised the largest proportion (29% by number) of all food items observed in crappies ≥ 254 mm.

Table 1. Average relative weight (Wr) of largemouth bass and bluegills by size class, Little Dixie Lake, 1973–74 and 1978–79 (sample size in parentheses).

	Year			
Length (mm)	1973	1974	1978	1979
		Largemouth bass		
<200	85 (65)	88 (69)	88 (33)	90 (66)
200–299	87 (57)	90 (66)	89 (341)	88 (332)
300–379	96 (8)	101 (3)	92 (406)	92 (319)
≥380	108 (16)	109 (12)	103 (19)	91 (4)
		Bluegill		
80–150	91 (80)	93 (230)	94 (14)	104 (108)
>150	82 (41)	92 (24)	94 (38)	97 (45)

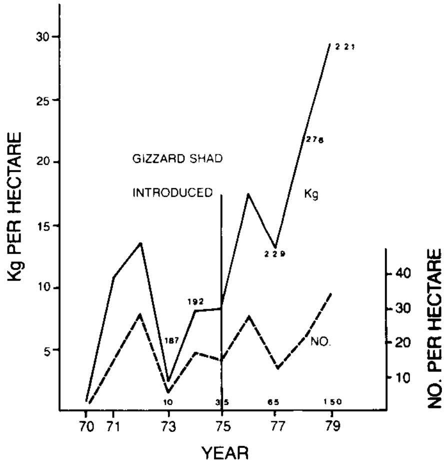

Figure 3. Estimated weight (kg/ha; scale at left) and density (*N*/ha; scale at right) of white crappies harvested by anglers, Little Dixie Lake, April–October 1970–79. Numbers just above the x axis refer to angler effort in hours per hectare fishing for crappie; numbers adjacent to weight line are the mean lengths (cm) of crappies harvested during that year by anglers.

Bluegill

Samples of bluegills in 1978 and 1979, after the establishment of gizzard shad, suggested some improvement in their size structure (Fig. 1). Bluegills < 76 mm long were abundant, but none > 200 mm were captured.

Comparisons of average relative weights by size group before and after the introduction of gizzard shad indicated that bluegills had higher relative weights when gizzard shad were present, in both 1978 and 1979 (Table 1). Length at age increased after gizzard shad were introduced. Norwat (1978) reported that the average length of bluegills at ages 1–5 were 56, 91, 127, 147, and 160 mm in 1974 compared with 66, 109, 145, 159, and 175 mm in 1979, after gizzard shad had been in Little Dixie Lake for 5 growing seasons.

The catch of bluegills remained relatively stable from 1973 to 1979, with anglers harvesting about 6 kg per hectare each year. Although increased numbers of bluegills were > 150 mm, the quality of the bluegill population was less than desired by anglers.

Discussion

The management measures taken at Little Dixie Lake, though easily evaluated in the aggregate, are difficult to examine separately. Initial management efforts—the stocking of gizzard shad and imposition of length regulations—were directed at improving the largemouth bass fishery, but seemingly also improved crappie fishing and did not adversely affect bluegill fishing.

Gizzard shad were introduced concurrently with the increase of the length limit from 305 to 380 mm in largemouth bass to provide adequate forage for the anticipated increase in numbers of bass. There is ample evidence in the literature that gizzard shad are an important prey for piscivorous fishes. Of particular relevance to the present study are the findings that gizzard shad were important prey for black bass (Jester and Jensen 1972, Timmons et al. 1981, Stiefvater and Malvestuto 1985, Storck 1986), and crappies (*Pomoxis* spp.) (Mitzner 1980). Our study provided supporting evidence that gizzard shad were an important food of both largemouth bass and white crappies. Gizzard shad comprised 3%–70% of the number of food items observed in the stomachs of largemouth bass and a mean of 29% in white crappies.

The increase in spring electrofishing catch rates of largemouth bass from 39 per hour in 1974 to 80 per hour in 1979 indicated that the management efforts were successful. The small decrease in condition of bass > 305 mm long after the gizzard shad introduction suggests that the prey was barely adequate to support the increased numbers of larger fish. However, the fact that condition remained constant for fish < 305 mm long suggests an adequate forage base for these sizes.

Growth of YOY largemouth bass was positively correlated with abundance of YOY gizzard shad by Aggus and Elliott (1975). We found no major changes in the densities of YOY largemouth bass after the introduction of gizzard shad, but their growth rate increased. The average length of largemouth bass at age 1, which was 109 mm in 1974, had increased to 135 mm in 1979. It thus appears that, for largemouth bass, the gizzard shad introduction, in conjunction with length limit changes, was a success. However, Little Dixie Lake supports a multi-species fishery in which white crappies, channel catfish, and (to a lesser extent) bluegills, are important.

Gizzard shad may compete for zooplankton with YOY of such game fish as crappies, bass, or bluegills (Madden 1951, Jenkins 1957, Bodola 1966). In some reservoirs, gizzard shad are able to filter the entire volume of water in a few days and alter the zooplankton composition (Drenner et al. 1982). Work by Mallin et al. (1985) in Hyco Reservoir, North Carolina, indicated that diet overlap and competition between small YOY gizzard shad and small YOY sunfishes (*Lepomis* spp.) could occur but would decrease as the fish grew. Other research has shown that high densities of gizzard shad can limit the production of game fishes through fairly complex associations. For example, Kirk and Davies (1985) hypothesized that gizzard shad can filter sufficient zooplankton to affect bluegill reproduction which ultimately affects largemouth bass recruitment.

Fall trap netting showed no negative effects of the presence of gizzard shad on the survival of YOY white crappie. While no YOY white crappie were captured in 1974, before the introduction of gizzard shad, some were captured in trap nets each fall in 1977, 1978, and 1979. Gizzard shad had no apparent negative effect on the bluegill population; bluegills grew faster after the introduction of gizzard shad, and average condition (most notably in those fish 80–150 mm long), and population structure both improved.

We conclude that while the overall fishery of Little Dixie Lake improved subsequent to the management activities, it is difficult to determine the relative roles of length limit change, shad introduction, and chance events in this multivariable, single lake evaluation. In this low-productivity lake, the role of shad as forage was evident while their often-noted competition with YOY sportfish was apparently absent.

There is evidence that YOY shad in Little Dixie Lake are relatively slow growing and that adults are not overabundant. Schonhoff (1983) examined 8 Missouri small- to medium-sized impoundments and found the shad in Little Dixie Lake to have next to the slowest growing YOY, the slowest growing adults, the lowest adult condition, and the only significantly negative relation between Wr and fish length. Shad in poor condition have less reproductive success than those in good condition (Willis 1987), and slow growing YOY would be available as forage for longer time and experience higher mortality. These factors could combine to keep the population densities low and avoid the problems often associated with shad in many small impoundments.

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