Intensive Stocking of Striped Bass to Restructure a Gizzard Shad Population in a Eutrophic Texas Reservoir

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Abstract: Buffalo Springs Reservoir is highly eutrophic with a dense population of large gizzard shad *(Dorosoma cepedianum)* and limited production of young gizzard shad. Fingerling (40 mm total length) striped bass *(Morone saxatilis)* were stocked into Buffalo Springs Reservoir in 1992 and 1993 at a rate of 550/ha to restructure the gizzard shad population. Three to 4 years after these stockings, density of large gizzard shad declined and a strong gizzard shad year class was produced. White crappie *(Pomoxis annularis)* recruitment paralleled gizzard shad recruitment. White crappie growth declined during 1991–1995 when age-0 gizzard shad were scarce or absent but increased in 1997, presumably a result of the abundant forage provided by the 1996 gizzard shad year class. No clear effects on largemouth bass *(Micropterus salmoides)* or bluegill *(Lepomis macrochirus)* growth were apparent, but relative abundance of both species increased.

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Gizzard shad *(Dorosoma cepedianum)* are important forage fish, and populations often reach high densities and biomass in southern United States reservoirs (e.g., Grinstead et al. 1978, Tody 1979, Noble 1981). Prey management problems arise when large portions of the gizzard shad populations are too large to be used as forage by native piscivores (Jenkins and Morais 1978, Noble 1981). Resource

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managers have tried a variety of techniques to reduce or restructure gizzard shad populations to improve their use by sport fish. Total and partial chemical renovations usually provide only temporary benefits; water level manipulations are often impractical and usually provide only temporary changes in gizzard shad populations (Noble 1981). A variety of piscivorous fishes have been stocked into southern reservoirs to diversify sportfishing opportunities and to use abundant clupeids (Pritchard et al. 1978). Striped bass *(Morore saxatilis)* and hybrid striped bass *(M. saxatilis* × *M. chrysops)* have been frequently selected to control gizzard shad populations.

By 1982, more than 100 reservoirs had been stocked with striped bass (Axon and Whitehurst 1985). Impacts of striped bass on gizzard shad populations have varied widely. Although substantial gizzard shad reductions have been reported (e.g., Bailey 1975, Morris and Follis 1979), most striped bass introductions have had little impact on gizzard shad populations (e.g., Bailey 1975, Combs 1982, Harper and Namminga 1986, Nash et al. 1987).

In Buffalo Springs Reservoir and other Texas panhandle reservoirs we observed high densities of large (>200 mm total length [TL]) gizzard shad and low abundance of small (<150 mm TL) gizzard shad. Because the vast majority of these gizzard shad were large adults, they provided little benefit to piscivorous sport fishes. Eutrophic reservoirs with similar gizzard shad populations exist in many areas across the United States. Smith (1959) reported limited production of young gizzard shad in reservoirs where gizzard shad grow rapidly to high biomass. Thus, we hypothesized that reduction of adult gizzard shad abundance would increase age-0 gizzard shad abundance and, therefore, provide more forage for largemouth bass *(Micropterus salmoides)* and white crappie *(Pomoxis annularis).*

Although striped bass have, in some applications, reduced gizzard shad populations, stocking striped bass into Buffalo Springs Reservoir at 75–225 fingerlings/ha annually in 7 of 9 years during 1983–1991 produced a sport fishery but failed to reduce abundant (>1,000 fish/hour electrofishing) large gizzard shad (Kraai 1988, Munger 1993). Recreational harvest of striped bass throughout the period of the study was regulated with a 457-mm minimum length and a 5 fish per day bag limit. A higher density of large striped bass may have reduced the abundance of large gizzard shad, but evaluating this would have required a substantial increase in the striped bass length limit.

In this study we further attempted to restructure the gizzard shad population in Buffalo Springs Reservoir with higher-density stockings of striped bass fingerlings. We hypothesized that if we could stock enough striped bass to almost eliminate age-0 gizzard shad by predation (i.e., reduce recruitment), the adult gizzard shad population would decline by natural mortality, resulting in increased reproduction and, ultimately, a wider diversity in length distribution. Assuming a 5-year life span of gizzard shad in Buffalo Springs Reservoir, the anticipated time frame to reduce the population of large gizzard shad and stimulate high production of young was 3–5 years. Therefore, the objectives of this study were: (1) to determine if high-density stocking of fingerling striped bass would restructure the gizzard shad population and (2) to measure effects of high-density striped bass stocking on largemouth bass, white crappie, and bluegill *(Lepomis macrochirus)* abundance and growth.

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Methods

Buffalo Springs Reservoir is a 91-ha impoundment located 14.5 km southeast of Lubbock, Texas. Maximum depth is 15 m and the lake develops an anoxic hypolimnion during summer months. Average chlorophyll *a* levels are 41 μg liter and Carlson's Trophic State Index is 67 (Carlson 1977).

Striped bass fingerlings (approximately 40 mm TL) were stocked at a rate of 550/ha in the spring of 1992 and 1993. To substantiate growth and survival, striped bass were sampled with monofilament experimental gill nets at 5 fixed stations during March or April 1991–1997. Each gill net was 60.7-m long, 2.4-m deep, and consisted of 8 7.6-m panels with mesh sizes increasing from 13- to 102-mm square by 13-mm increments. Nets were bottom set perpendicular to the shoreline and fished overnight. Differences in relative abundance (catch rate) were evaluated with repeated-measures analysis of variance. Average striped bass catch rates measured with the same gill nets in January were available for 1987 (Kraai 1988) and 1989 (Munger 1993); however, data for replicate samples were not available and these data were not statistically analyzed.

Relative abundance and population structure of gizzard shad, bluegill, and largemouth bass were determined by electrofishing from 1991 through 1997 with a Smith-Root 5.0 GPP electrofishing unit operated at 60 Hz pulsed DC output. Gizzard shad samples were collected during daylight at 10 fixed stations each month June through October. Each station was initially sampled for 5 minutes of actual (pedal time) electrofishing effort. If 50 or more gizzard shad were collected, the sample for that station was completed. If less than 50 gizzard shad were collected, an additional 5 minutes of electrofishing was conducted continuing from the end point of the first 5-minute sample. Differences in catch rate were evaluated with repeated-measures analysis of variance.

Largemouth bass and bluegill were sampled by night electrofishing in late September-early October each year at the same 10 stations sampled for gizzard shad. Each station was sampled for 10 minutes of actual electrofishing time with 2 people dipping fish. Differences in catch rate were evaluated with repeated-measures analysis of variance.

White crappie were collected by trap nets in October 1991–1997. One trap net was set at each of 5 fixed stations. Nets had 0.9-m high × 1.8-m wide frames, a 0.9-m deep × 20-m long lead net, and 1.3-cm square knotless nylon webbing throughout. Nets were fished overnight. Differences in relative abundance (catch rate) were evaluated with repeated-measures analysis of variance.

Except for fish sacrificed for aging, all fish collected were measured to the nearest mm TL and released near the area of collection. Bluegill, largemouth bass, white crappie, and striped bass were aged by examination of otoliths removed from the first 5 fish collected in each 25-mm group. Ages were assigned from inspection of whole otoliths (Schramm and Doerzbacher 1983, Maceina and Betsill 1987, Schramm 1989). Fish age and TL were used to calculate mean length at capture for each age. Assigned ages for all species were based on a 1 January "birthday." Difference in length at age among years was tested by analysis of variance.

Length-frequency distributions of gizzard shad were used to assess recruitment and growth through the first year of life. Length-frequency distributions for July-October samples were generally similar. To simplify the presentation of results, we elected to use July and September data for qualitative and quantitative analysis of population structure. July samples represent the abundance of age-0 gizzard shad early in the recruitment process and indicate spawning success; September samples represent the abundance of age-0 fish remaining after a summer of natural mortality.

Results

Striped bass stocked in 1992 recruited to the gill nets in 1993, and both stocked year classes were fully recruited to the gill nets by 1995 (Fig. 1). The abundance of striped bass in Buffalo Springs Reservoir differed during 1991–1997 ($F_{6,24}=2.77$, $P=0.03$); catch rate was highest during 1995. Catch rates from 1993–1997 appeared similar to or greater than the abundance in 1987–1992. Length at capture of striped bass stocked in 1992 and 1993 did not differ from length at capture of fish stocked prior to 1992 for ages 1 ($F_{2,5}=0.76$, $P=0.51$), 2 ($F_{1,19}=0.93$, $P=0.35$), 5 ($F_{2,13}=3.51$, $P=0.06$), and 6 ($F_{1,4}=4.28$, $P=0.11$). Thus, we considered the mean length at capture of all striped bass aged throughout the study as the best estimate of length at age (Table 1).

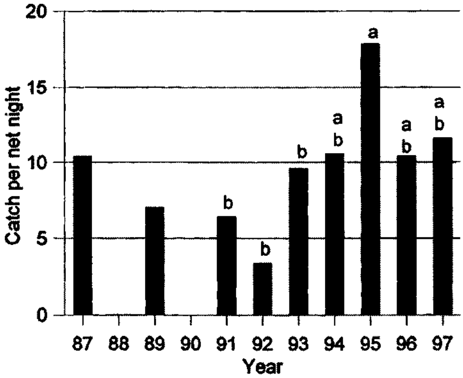

Figure 1. Mean (least-squares mean) catch per net night of striped bass caught in gill nets in Buffalo Springs Reservoir, Texas, in January 1987 and 1989 and March–April 1991–1997. Data for 1987 and 1989 are from Kraai (1988) and Munger (1993). Catch rates with different letters are significantly different ($P < 0.05$).

Table 1. Mean total lengths (TL) of age 1–7 striped bass collected in March–April, 1991–1997, Buffalo Springs Reservoir. *N* is sample size, SE is standard error.

Age	*N*	Mean TL	SE
1	8	219.6	5.3
2	21	399.4	5.6
3	13	519.5	10.5
4	29	527.1	5.8
5	16	627.6	22.6
6	6	682.0	67.7

Young gizzard shad were first collected by electrofishing at 40 mm TL (Fig. 2). Age-0 gizzard shad in the 1991–1996 cohorts were first collected in July and grew to 120 mm by September. Survivors of the 1991–1995 cohorts grew to lengths greater than 160 mm by June of their second summer. The relatively abundant 1996 year class grew slowly and many were less than 160 mm in September 1997.

Relative abundance of large (>175 mm) gizzard shad differed significantly for July ($F_{6,54}$=7.58, P<0.001) and September ($F_{6,54}$=14.32, P<0.001) samples. July samples indicated increasing catch rates from 1991–1992 and declining catch rates from 1993–1995; despite the increased catch rate of large gizzard shad in 1996, catch rates in 1994–1997 were lower than in 1992–1993 (Fig. 3). September samples indicated a steady decrease in large gizzard shad from 1991–1995, then higher catch rates in 1996. Catch rate of small (<150 mm) gizzard shad did not significantly differ among years for either July ($F_{6,54}$=2.22, P=0.055) or September ($F_{6,54}$=2.26, P=0.051) samples. However, catch rates in both months indicated low abundance of small gizzard shad from 1991–1995, then increased abundance in 1996 and 1997. The small gizzard shad in 1991–1996 were age-0 fish, but most small gizzard shad collected in 1997 were slowly growing age-1 fish (Fig. 2).

The catch rate of largemouth bass <200 mm fluctuated without trend and did not differ significantly ($F_{6,54}$=1.68, P=0.143) during 1991 to 1997 (Fig. 4). Catch rates during 1991–1997 were significantly different for 200–300 mm ($F_{6,54}$=13.22, P<0.001) and >300 mm ($F_{6,54}$=4.23, P=0.001) largemouth bass. Catch rates for both size groups were highest in 1997.

Although not significantly different ($F_{6,54}$=1.28, P=0.284) over time, catch rates of white crappie <130 mm were low during 1991–1995, increased sharply in 1996, and decreased in 1997 (Fig. 4). Catch rates of 130–200 mm white crappie declined form 1991 to 1992, fluctuated at low levels during 1992–1996, and increased in 1997; these differences in catch rate were not significant ($F_{6,54}$=2.26, P=0.051). Catch rates of white crappie >200 mm differed significantly ($F_{6,54}$=2.42, P=0.038) during 1991–1997; catch rate was higher in 1997 than in 1991–1996.

Catch rates of bluegill <80 mm were low and did not differ significantly during 1991–1997 ($F_{6,54}$=1.36, P=0.249). Catch rates of 80–150 mm bluegill differed significantly during 1991–1997 ($F_{6,54}$=9.08, P<0.001); catch rates fluctuated without

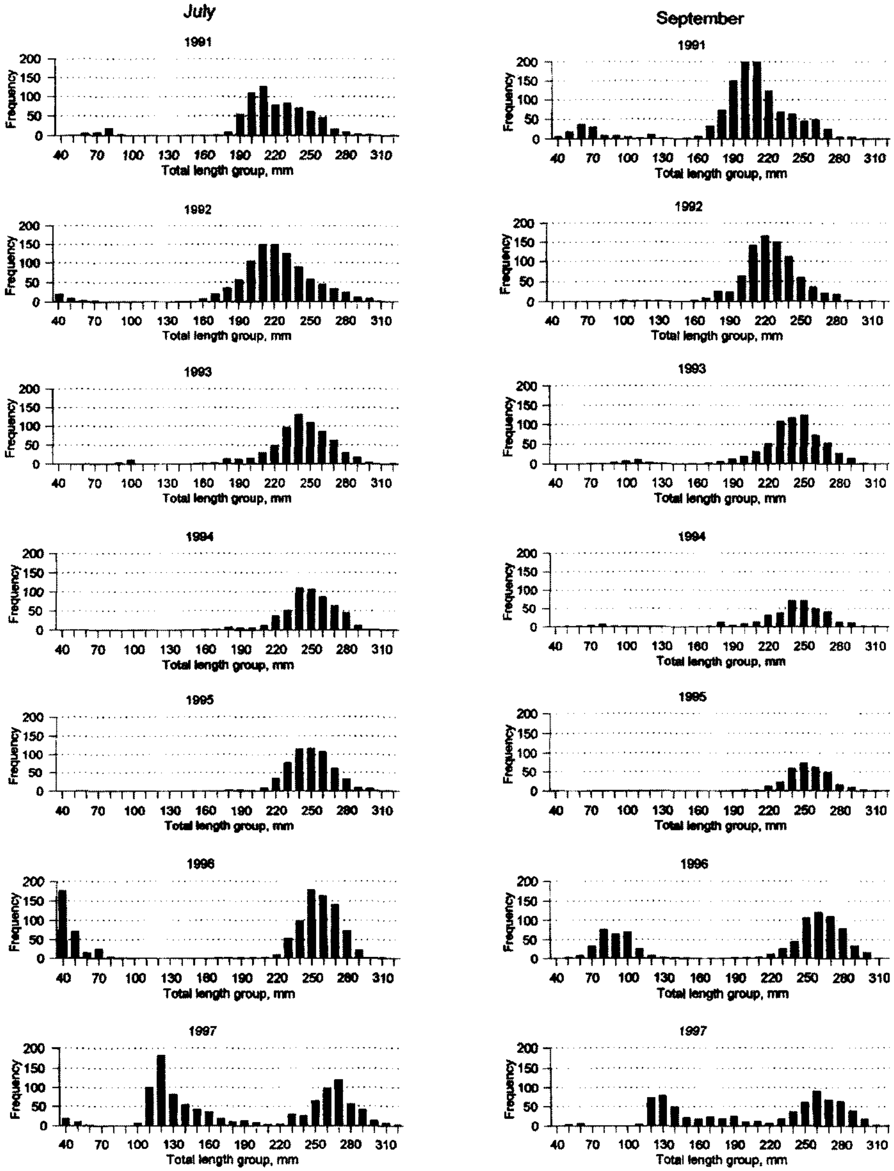

Figure 2. Length distribution of gizzard shad sampled by electrofishing, Buffalo Springs Reservoir, Texas, July and September 1991–1997.

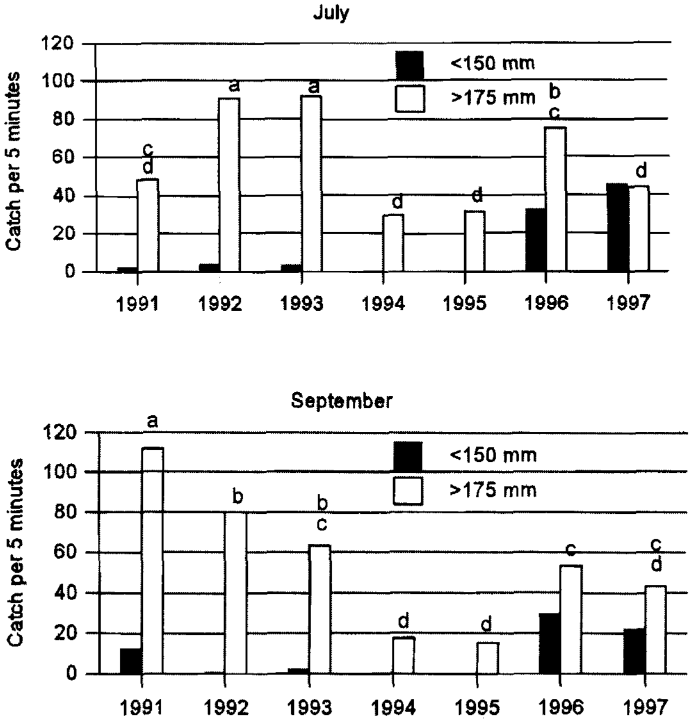

Figure 3. Mean (least-squares mean) catch rates of small (<150 mm) and large (>175 mm) gizzard shad sampled by electrofishing, Buffalo Springs Reservoir, Texas, 1991–1997. For each month, catch rates with different letters are significantly different ($P < 0.05$).

trend during 1991–1996, then increased in 1997 (Fig. 4). Catch rates of bluegill >150 mm differed over time ($F_{6,54}$=2.85, P=0.018) and were higher in 1995 and 1997 than in 1991–1993.

Mean length of age-1 largemouth bass did not change throughout 1991–1997 ($F_{4,6}$=1.02, P=0.407; Table 2). Mean lengths differed among years for largemouth bass ages 2 ($F_{4,44}$=6.63, P=0.001), 3 ($F_{4,32}$=4.59, P=0.001), and 4 ($F_{4,26}$=4.27, P=0.008); lengths of ages 2–4 fish tended to decline from 1991–1995 and then increased in 1997, but the increase in length in 1997 was significantly different from 1995 only for age-2 fish. Limited sample size precluded meaningful statistical analysis of lengths of age-5 and -6 fish, but no trend in length at age was apparent during 1992–1997.

Mean lengths of age-1 white crappie did not differ among years ($F_{4,54}$=1.37, P=0.255, Table 2). Mean lengths of age-2 ($F_{4,39}$=26.44, P=0.001), age-3 ($F_{3,94}$=31.65, P=0.001), and age-4 ($F_{3,10}$=8.18, P=0.011) white crappie declined from 1991 to 1995 but then increased in 1997 to lengths similar to those in 1991. Age-5 white crappie were collected only in 1993, 1995, and 1997; although showing

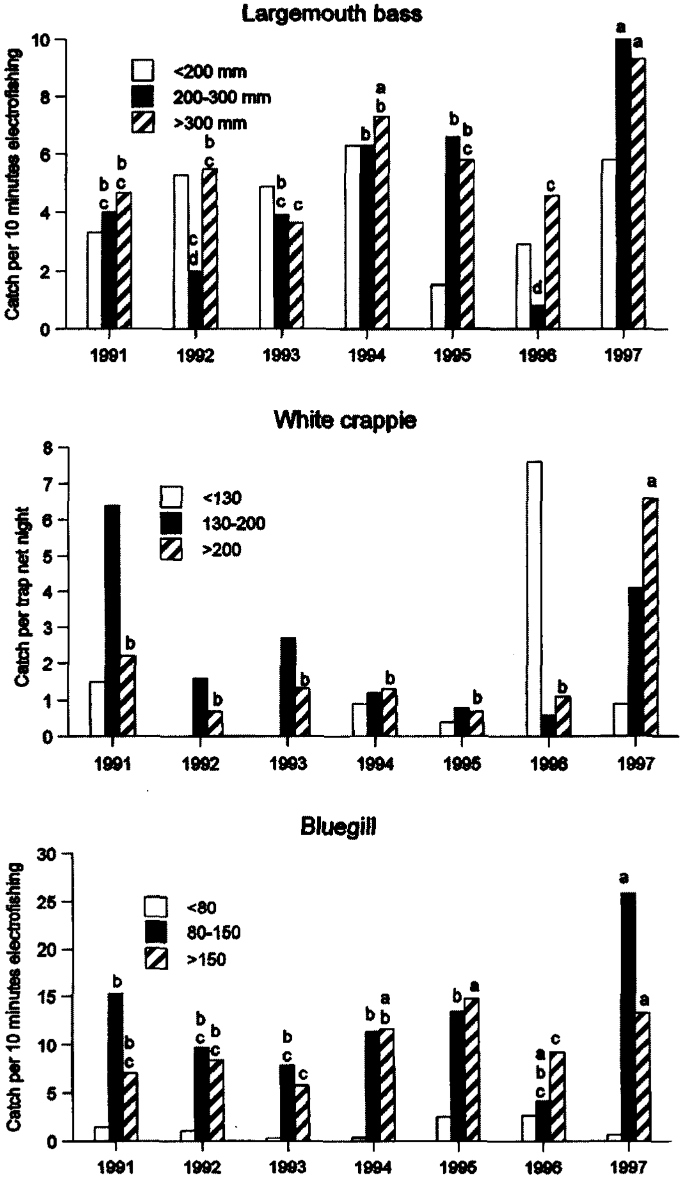

Figure 4. Mean (least-squares mean) catch rates of largemouth bass, white crappie, and bluegill, Buffalo Springs Reservoir, Texas, 1991–1997. For each size class of each species, catch rates with different letters are significantly different ($P < 0.05$).

Table 2. Mean lengths at capture of largemouth bass (sampled in September–October) white crappie (sampled in October), and bluegill (sampled in September–October). Values in parentheses are sample size, standard error.

	Year sampled				
Age	1991	1992	1993	1995	1997
Largemouth bass					
1	204.9^{a}	205.4^{a}	223.8^{a}	204.3a	210.8^{a}
	(18, 7.9)	(14, 8.2)	(16,9.5)	(9, 6.6)	(9, 8.8)
2	294.7^{a}	294.8^{a}	288.0^{a}	248.1^{b}	282.8^{a}
	(12, 8.7)	(5, 11.9)	(4, 9.2)	(15, 5.3)	(14, 8.2)
3	367.7^{a}	351.3^{ab}	322.0^{bc}	315.3^{c}	317.0^{c}
	(6, 11.5)	(8, 13.2)	(5, 6.6)	(10, 8.4)	(8, 10.6)
4	418.5^{a}	362.7^{b}	367.9^{b}	359.0^{b}	377.2^{b}
	(2, 15.5)	(4, 5.8)	(9, 5.2)	(10, 7.2)	(6, 8.9)
5		505.0	386.5	398.0	406.3
		(1,)	(2, 21.5)	(1,)	(3, 5.2)
6		419.0	439.4	412.0	405.0
		(2, 26.0)	(5, 13.1)	(1,)	(3, 50.6)
White crappie					
1	167.5^{a}	162.3^{a}	148.1^{a}	159.3^{a}	173.6^{a}
	(13, 7.2)	(12, 6.0)	(8, 3.7)	(3, 8.7)	(23, 7.3)
2	224.7^{b}	237.8^{ab}	179.0^{c}	158.0^{c}	256.2^{a}
	(7, 6.3)	(5, 7.3)	(22, 4.9)	(4, 7.8)	(6, 9.8)
3	257.5^{ab}	240.5^{b}	203.3^{c}		276.0^{a}
	(2, 5.5)	(2, 11.5)	(4, 6.7)		(5, 3.7)
4	294.0^{a}		264.7^{a}	216.5^{b}	290.0^{a}
	(1,)		(3, 16.4)	(4, 4.0)	(3, 15.5)
5			308.7^{a}	225.0^{a}	287.0^{a}
			(3, 27.0)	(4, 12.4)	(5, 25.1)
Bluegill					
1	106.3^{a}	115.9^{a}	110.0^{a}	124.6^{a}	110.3^{a}
	(6, 5.0)	(12, 5.5)	(1,)	(7, 2.3)	(11, 3.3)
2	126.4^{a}	164.0^{a}	138.8^{a}	146.3^{a}	148.0^{a}
	(5, 6.8)	(1,)	(9 5.1)	(3, 2.3)	(1,)
3	150.8^{c}	167.7^{ab}	176.8^{a}	170.7^{ab}	156.5^{bc}
	(6, 5.1)	(4, 2.5)	(6, 2.9)	(3, 7.8)	(4, 5.0)
4	161.7^{a}			173.3^{a}	172.7^{a}
	(7, 3.1)			(4, 4.4)	(3, 2.3)
5	170.3^{a}	184.0^{a}		186.0^{a}	167.3^{a}
	(4, 5.9)	(3, 4.7)		(2, 8.0)	(3, 11.6)

a, b, c. Values in the same row with different letters are significantly different, P<0.05.

the same trend in length as ages 2–4 white crappie, lengths were not significantly different ($F_{2,9}$=3.35, P=0.082).

Bluegill length differed among years only for age-3 fish (Table 2). Lengths at age varied without consistent trend for all ages.

Discussion

Buffalo Springs Reservoir historically had a high density of large gizzard shad and little production of young gizzard shad. Earlier stocking of striped bass at

75–225 fingerlings/ha failed to reduce or restructure the gizzard shad population. However, reduced abundance of large gizzard shad and increased production of young gizzard shad followed higher density (550 fingerling/ha) stockings in 1992 and 1993. The scarcity of young gizzard shad and the steadily declining catch rate of large gizzard shad during 1992–1995 suggest that stocking high densities of striped bass reduced the adult gizzard shad population by preventing gizzard shad recruitment and by natural mortality of adult fish. As predicted, recruitment increased when adult density decreased. The increase in production of young gizzard shad occurred 4 years after the first high-density stocking of striped bass.

Growth of the 1992 and 1993 stocked striped bass year classes was intermediate in the range of growth reported by Carlander (1997) and not significantly different from striped bass stocked into Buffalo Springs Reservoir at lower densities in previous years. Considering the high-density stockings and very few age-0 gizzard shad, we expected slower growth than occurred during the first several years after stocking. Within 2–3 years after stocking, the 1992 and 1993 striped bass year classes had grown large enough to consume a substantial proportion of the large gizzard shad (Combs 1979). Therefore, the decline in adult gizzard shad may have resulted from predation in addition to a lack of recruitment.

The low density of age-0 gizzard shad in 1997 did not follow the inverse relationship between adult density and recruitment. Whereas all age-1 and older gizzard shad were longer than 160 mm in the years sampled prior to 1997, the 1996 year class grew slowly and 100–160 mm gizzard shad were abundant throughout the summer of 1997. Possibly, the high density of small, age-1 fish interfered with spawning or survival of the 1997 year class.

The increased catch rate of gizzard shad larger than 175 mm in 1996 is not congruent with the low production of age-0 gizzard shad in 1995. The increased catch rate of large gizzard shad was seen in June, July, August, September, and October samples and, therefore, is not a result of monthly sample variability. Some of the increased abundance of large gizzard shad in 1996 may have resulted from elevated growth and survival rates of 1995 year class fish subject to less competition from the relatively low abundance of large gizzard shad in 1995.

Increased abundance of white crappie in 1996 and 1997 coincided with increased recruitment of gizzard shad. The abundance of age-0 white crappie paralleled the abundance of age-0 gizzard shad, suggesting white crappie year class strength may be positively related to age-0 gizzard shad abundance in Buffalo Springs Lake. The greater abundance of age-0 white crappie during 1996 may have resulted from abundant small gizzard shad providing a forage resource for the white crappie, thus increasing white crappie growth and survival. Length at age of white crappie declined from 1991–1995, years of low abundance of age-0 gizzard shad and years when white crappie had to compete with stocked striped bass. As expected from other studies (e.g., Jenkins and Morais 1978, Michaletz 1997, 1998), lengths of white crappie increased substantially in 1997 (the year after the abundant gizzard shad year class), indicating a positive effect of abundant small gizzard shad on white crappie growth. The abundant small gizzard shad may also have provided an abundant forage resource for the striped bass and, thus, reduced striped bass predation on white crappie. However, crappies (*Pomoxis* spp.) are not frequently eaten by striped bass (e.g., Moore et al. 1986, Bettoli et al. 1995).

Abundant, small gizzard shad should also benefit largemouth bass (Jenkins and Morais 1978, Noble 1981, Michaletz 1998); however, the relationship between gizzard shad and largemouth bass was less clear than for white crappie. The abundance of age-0 (<200 mm) largemouth bass did not differ during 1991–1997, and the fluctuations in <200 mm largemouth bass abundance did not parallel those in age-0 gizzard shad abundance. Furthermore, growth of age-1 largemouth bass changed little during 1991–1997. Thus, abundance and growth of young largemouth bass appear to be independent of gizzard shad dynamics in Buffalo Springs Reservoir. Growth of ages 2–4 largemouth bass declined from 1991–1995, which was compatible with the scarcity of young gizzard shad and, possibly, competition with abundant striped bass; however, the expected increase in length-at-age following the strong 1996 gizzard shad year class was not observed. The increased abundance of largemouth bass >200 mm in 1997 suggest these fish may have benefitted from the restructured gizzard shad population. The abundant 200–300 mm largemouth bass included the 1996 largemouth year class. The greater abundance in 1997 of 200–300 mm fish, even though the 1996 largemouth bass year class was not more abundant than in other years, suggests higher survival of this cohort to age 1. Higher survival may be related to the abundance of young gizzard shad in 1996. Largemouth bass >300 mm were age 3 and older; thus their abundance was not affected by the 1996 gizzard shad year class. Overall, gizzard shad population changes provided little apparent benefit to the largemouth bass population within the time frame of this investigation.

Growth of bluegill changed little during 1991–1997 and did not appear to be affected by gizzard shad dynamics. DeVries and Stein (1992) and Dettmers and Stein (1996) found gizzard shad can substantially reduce zooplankton abundance and, thus, affect growth and recruitment of bluegill. Paralleling these results, the abundance of bluegill >80 mm increased from 1992–1995 while large gizzard shad abundance declined in Buffalo Springs Lake. However, we found no evidence to support increased growth of bluegill following reduction of gizzard shad abundance.

Striped bass stocking has frequently failed to reduce abundant gizzard shad. Our results in a eutrophic impoundment suggested high-density populations of large gizzard shad can be reduced by stocking high densities of fingerling striped bass. The stockings reduced recruitment and adult gizzard shad numbers decreased as a result of natural mortality. Furthermore, our results demonstrated high production of young gizzard shad occurred after the adult population density declined. Our results also suggest that striped bass may more effectively reduce gizzard shad populations if higher densities are stocked at multiple-year intervals (e.g., stock for 1 or 2 years, then not stock for 3 or 4 years) rather than stocking lesser numbers annually. These findings need to be evaluated in other reservoirs.

Although the density of large gizzard shad remained low, a strong year class was not produced in 1997. The abundant 1996 year class, which possibly interfered with production of the 1997 year class, would provide an abundant forage base for largemouth bass but would be too large to provide forage for white crappie in 1997. Thus, largemouth bass growth, which did not significantly increase within 1 year following the strong 1996 gizzard shad year class may have increased in later years. Conversely, white crappie growth, which significantly increased after the production of the strong 1996 gizzard shad year class, would be expected to decrease after 1997 when few small gizzard shad were produced. Further assessment of the long-term effects of high-density striped bass stocking on gizzard shad population dynamics is needed.

Literature Cited

Axon, J. R. and D. K. Whitehurst. 1985. Striped bass management in lakes with emphasis on management problems. Trans. Am. Fish. Soc. 114:8–11.

Bailey, W. M. 1975. An evaluation of striped bass introductions in the southeastern United States. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 28:54–68.

Bettoli, P. W., R. Osborne, and S. Owens. 1995. A review of the literature pertaining to the effects of striped bass on other fish populations. Final Rep. Tenn. Coop. Fish. Res. Unit, Cookeville, Tenn. 10pp.

Carlson, R. E. 1997. A trophic state index for lakes. Limnol. Oceanog. 22:361–369.

Carlander, K. D. 1997. Handbook of freshwater fishery biology. Vol. 3. Iowa. State Univ. Press, Ames, Iowa. 379pp.

Combs, D. L. 1979. Food habits of adult striped bass from Keystone Reservoir and its tailwaters. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 32:571–575.

———. 1982. Fish population changes in Keystone Reservoir fourteen years after striped bass introductions. Proc Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 34:167–174.

Dettmers, J. M. and R. A. Stein. 1996. Quantifying linkages among gizzard shad, zooplankton, and phytoplankton in reservoirs. Trans. Am. Fish. Soc. 125:27–41.

DeVries, D. R. and R. A. Stein. 1992. Complex interactions between fish and zooplankton: quantifying the role of an open-water planktivore. Can. J. Fish. Aquat. Sci. 49:1216–1227.

Grinstead, B. G., R. M. Gennings, G. R. Hooper, C. Schultz, and D. A. Whorton. 1978. Estimation of standing crop of fishes in the predator-stocking-evaluation reservoirs. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 30:120–130.

Harper, J. L. and H. E. Namminga. 1986. Fish population trends in Texoma Reservoir following establishment of striped bass. Pages 156–165 *in* G. E. Hall and M. J. Van Den Avyle, eds. Reservoir fisheries management: strategies for the 1980's. Am. Fish. Soc. South. Div., Res. Comm., Bethesda, Md.

Jenkins, R. M. and D. J. Morais. 1978. Prey-predator relations in the predator-stocking-evaluation reservoirs. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 30: 141–157.

Kraai, J. E. 1988. Job A: Existing reservoir and stream management recommendations, Texas Parks Wildl. Dep., Fed. Aid in Sport Fish Restor. F-30-R-13 Perf. Rep., Austin, Texas. 105pp.

Maceina, M. J. and R. K. Betsill. 1987. Verification and use of whole otoliths to age white crappie. Pages 267–278 *in* R. C. Summerfelt and G. E. Hall, eds. Age and growth of fish. Iowa State Univ. Press, Ames, Iowa.

Michaletz, P. H. 1997. Influence of abundance and size of age-0 gizzard shad on predator diets, diet overlap, and growth. Trans. Am. Fish. Soc. 126:101–111.

———. 1998. Population characteristics of gizzard shad in Missouri reservoirs and their relation to reservoir productivity, mean depth, and sport fish growth. North Am. J. Fish. Manage. 18:114–123.

Moore, C. M., R. J. Neves, J. J. Ney, and D. K. Whitehurst. 1985. Utilization of alewives and gizzard shad by striped bass in Smith Mountain Lake, Virginia. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 38:108–115.

Morris, D. J. and B. J. Follis. 1979. Effects of striped bass upon shad in Lake E. V. Spence, Texas Proc. Annu. Conf. Southeast. Assoc. Fish an191d Wildl. Agencies 32:697–702.

Munger, C. 1993. Statewide freshwater fisheries monitoring and management program. Survey report for Buffalo Springs Reservoir, 1992. Texas Parks Wildl. Dep. Fed. Aid in Sport Fish Restor. F-30-R Perf. Rep., Austin, Texas. 39pp.

Nash, V. E., W. E. Hayes, R. L. Self, and J. P. Kirk. 1987. Effect of striped bass introduction in Lake Wateree, South Carolina. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 41:48–54.

Noble, R. L. 1981. Management of forage fishes in impoundments of the southern United States. Trans. Am. Fish. Soc. 110:738–750.

Pritchard, D. L., O. D. May, Jr., and L. Rider. 1978. Stocking of predators in the predator-stocking-evaluation reservoirs. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 30:108–113.

Schramm, H. L., Jr. Formation of annuli in otoliths of bluegills. Trans. Am. Fish. Soc. 118:546–555.

——— and J. F. Doerzbacher. 1983. Use of otoliths to age black crappie from Florida. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 36:95–105.

Smith, W. A., Jr. 1959. Shad management in reservoirs. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 12:143–147.

Tody, W. H. 1979. Utilization of predator-prey relationships in fisheries management. Pages 361–364 *in* H. Clepper, ed. Predator-prey systems in fisheries management. Sport Fish. Inst., Washington, D.C.