Effects of Intensive Stocking of Hybrid Striped Bass on the Population Structure of Gizzard Shad in a West Texas Impoundment, a Case Study

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Abstract: Lake Tanglewood, Texas, is a eutrophic reservoir with an excessively abundant gizzard shad *Dorosoma cepedianum* population comprised of primarily large individuals (>180 mm total length [TL]). Fingerling (40 mm TL) hybrid striped bass *(Morone saxatilis* x *M. chrysops)* were stocked at high rates in 1992 (490/ha) and 1993 (245/ha) to restructure the gizzard shad population. Small gizzard shad (<180 mm TL) declined in abundance 1 year after hybrid striped bass were introduced, presumably as a result of hybrid striped bass predation. With reduced recruitment, large gizzard shad abundance steadily declined. Gizzard shad year class production increased after the abundance of large gizzard shad declined, suggesting that a high density of large gizzard shad may suppress gizzard shad year class production. Largemouth bass *Micropterus salmoides*, and black crappie *Pomoxis nigromaculatus* abundance and size appeared to be positively related to the presence of abundant smaller size classes (<180 mm TL) of gizzard shad.

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Many eutrophic impoundments, including those in west Texas support excessively abundant populations of gizzard shad *Dorosoma cepedianum* that are too large for consumption by piscivorous fishes (Grinstead et al. 1978, Noble 1981, Morello 1987, Ebert et al. 1988, Moczygemba et al. 1991, Schramm et al. 1999). In these systems, gizzard shad quickly outgrow sizes vulnerable to predation, and stockpile prey

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biomass at larger, uncontrollable sizes (Jahn et al. 1987, Michaletz 1998). To control gizzard shad and enhance sportfishing, exotic predators such as striped bass *Morone saxatilis* and hybrid striped bass *M. saxatilis* x *M. chrysops* have been introduced.

Striped bass and hybrid striped bass, based on their size and feeding behavior, are considered to have the potential to control gizzard shad. In the southern United States, striped bass have been introduced into more than 100 reservoirs, and hybrid striped bass into 456 (Axon and Whitehurst 1985, Matthews et al. 1992). These reservoirs encompass more than 57% of the total reservoir area in the United States (Smith and Jenkins 1985). Fisheries managers stock striped bass and hybrid striped bass primarily because they are a good sportfish, have rapid growth during early life, and feed almost exclusively on gizzard shad after they attain at least 100 mm TL (Crandall 1979, Ott and Malvestuto 1981, Gilliland and Clady 1984, Chervinski et al. 1989). Fisheries managers deduced that hybrid striped bass and striped bass would feed on the most available forage first, mainly gizzard shad (Ott and Malvestuto 1981, Borkowski and Synder 1982, Jahn et al. 1987), and then prey on other forage populations. Hybrid striped and striped bass populations are projected to reduce total gizzard shad populations through predation of smaller size classes (<178 mm TL) (Morris and Follis 1979, Ott and Malvestuto 1981, Germann and Bunch 1985).

Although there is a general consensus in the literature (see Dettmers et al. 1996) that *Morone* spp. can reduce gizzard shad populations, introductions of striped bass and hybrid striped bass have had variable success (see Dettmers at al. 1996). Nash et al. (1988) and Schramm et al. (1999) reported reductions in gizzard shad populations after striped bass introductions; however, England (1977) and Walker (1977, 1979) were unable to determine significant reductions in the abundance of gizzard shad populations. Several studies have reported reductions in the overall abundance of gizzard shad populations following hybrid striped bass introductions (Bailey 1974, Crandall 1979, Douglas 1986, Jahn et al. 1987). However, other hybrid striped bass introductions, including reciprocals (female *M. chrysops* x male *M. saxatilis*), have failed to reduce or restructure gizzard shad populations (Kleinholz and Maughan 1984, Germann and Bunch 1985, Morello 1987, Muoneke et al. 1987, Ebert et al. 1988). The lack of consistent effects of striped bass and hybrid striped bass introductions on gizzard shad populations may be the result of inadequate stocking rates (12.4 to 338 fingerlings/ha) and the lack of successive stocking (see Dettmers et al. 1996). Intuitively, higher stocking rates or more successive annual stockings should have a greater impact on gizzard shad populations.

High or successive hybrid striped bass and striped bass introductions may also enhance the size and condition of valued game species by reducing inter-and intraspecific competition within the existing fish community. Neal et al. (1999) showed that introductions of hybrid striped bass increased the size and quality of sunfish *Lepomis* spp. and black crappie *Pomoxis nigromaculatus* through predation pressure on centrarchid fry during their early life history. Conversely, largemouth bass *Micropterus salmoides* were shown to have poorer condition following introductions presumably because hybrid striped bass reduced prey recruitment to the size preferred by largemouth bass. Although the results of Neal et al. (1999) have important implications, the study was conducted in ponds void of gizzard shad. Hybrid striped bass introductions in systems having a large population of gizzard shad may affect the fish community differently than that shown by Neal et al. (1999).

Therefore, we attempted to restructure the gizzard shad population in Lake Tanglewood from a population with a high density of large adults and little production of young to a population with an abundance of small, young fish by intensively stocking hybrid striped bass fingerlings for 2 successive years (490/ha in 1992 and 245/ha in 1993). We hypothesized that intense predation on age-0 gizzard shad combined with natural mortality of older individuals would, over time, result in a reduction of the large shad, which would in turn stimulate production of young shad, and thus provide a wider diversity in length distribution of gizzard shad skewed toward smaller size classes. Furthermore, this case study assesses the changes in largemouth bass, black crappie, and bluegill *Lepomis macrochirus* abundance and size following the introduction of the hybrid striped bass.

Methods

Lake Tanglewood is a private, shallow (maximum depth = 10 m), eutrophic, 104-ha impoundment constructed on a tributary of the Red River about 30 km east of Canyon, Texas. Harvest regulations were concordant with statewide regulations from 1990 to 1997, except for mandatory catch and release policies imposed for largemouth bass and hybrid striped bass.

Fingerling hybrid striped bass (~40 mm TL) were stocked into Lake Tanglewood at 490 and 245 fingerlings per hectare per year in the spring of 1992 and 1993, respectively. Hybrid striped bass were collected with horizontal, bottom-set experimental gill nets fished overnight at 4 fixed stations in April or May from 1990 to 1996. Gill nets were 92 m long, 2 m deep with 4 23-m panels increasing from 2- to 5-cm square mesh. Abundance and growth rates of hybrid striped bass were inferred from length-frequency histograms. Differences ($P < 0.05$) in TL at capture for both the 1992 and 1993 cohorts, collectively, among years were evaluated with repeated-measures analysis of variance.

Gizzard shad, largemouth bass, black crappie, and bluegill were collected by electrofishing from 1991 to 1997 with a Smith-Root 5.0 GPP electrofishing unit operated at 60 Hz pulsed DC output. All fish were measured (TL) to the nearest mm and released. Gizzard shad were sampled monthly from June to October by daytime electrofishing at 10 fixed stations. Each station was electrofished for an initial 5 minutes (actual pedal time); however, if fewer than 50 gizzard shad were caught during the initial 5 minutes of sampling, electrofishing continued for an additional 5 minutes beginning at the endpoint of the initial 5-minute sample. Year class production of gizzard shad among years was inferred from length-frequency histograms of pooled data for June to October for each year (i.e., 1991 to 1997). Largemouth bass, black crappie, and bluegill were sampled once a month by nighttime electrofishing during September and October 1991 to 1997 at the same 10 stations sampled for gizzard shad. These stations were sampled for 10 minutes of actual electrofishing time with 2 dipnetters. Differences ($P < 0.05$) in log transformed catch rates and TL at capture for gizzard shad, largemouth bass, black crappie, and bluegill among years were evaluated with repeated-measures analysis of variance.

Results

One year after each stocking, the 1992 hybrid striped bass cohort was more abundant than the 1993 cohort, and length at age 1 was greater for the 1992 cohort than the 1993 cohort (Fig. 1). Collectively, the 1992 and 1993 hybrid striped bass cohorts significantly ($F_{3,12} = 30.3$; $P < 0.01$) increased in TL ($\bar{x} = 41.4$ mm TL per year) from 1992 to 1996 (Fig. 1).

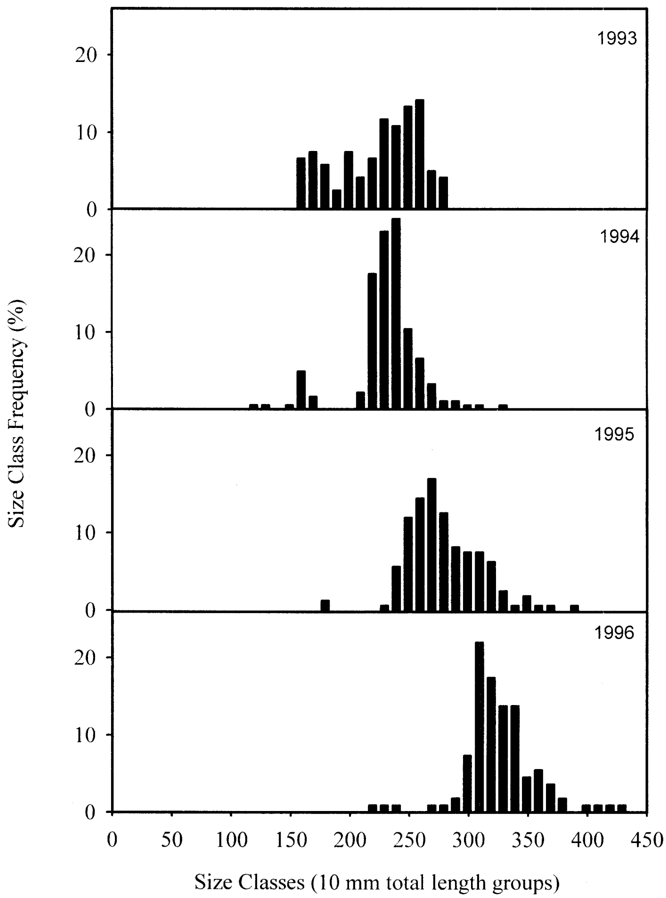

Figure 1. Length distribution of hybrid striped bass caught in gill nets in Lake Tanglewood, Texas, 1993 to 1996.

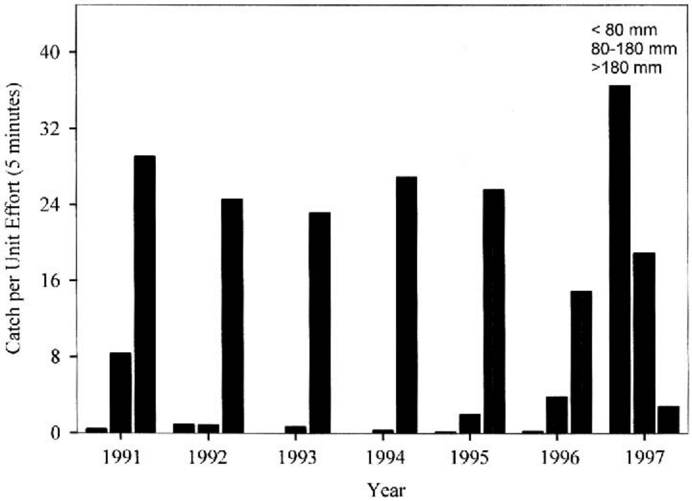

Figure 2. Catch per 5 minutes electrofishing of small, intermediate and large length classes of gizzard shad, Lake Tanglewood, Texas, 1991 to 1997.

Small (<80 mm TL) and intermediate (80- to 180-mm TL) gizzard shad densities declined ($F_{6,25} = 11.9$; $P < 0.01$) abruptly after 1992 and remained low through 1996 (Fig. 2). The reduction in densities of small and intermediate gizzard shad in 1992 and 1993 coincides with hybrid striped bass stocking. The catch rate of gizzard shad <80 mm TL increased in 1997 ($F_{6,26} = 10.3$; $P < 0.01$; Fig. 2). The increased recruitment of gizzard shad coincided with the decline in abundance of larger size class (>180 mm TL) gizzard shad and with reduction in hybrid striped bass predation due to natural mortality and cessation of stocking.

The catch rates of largemouth bass, black crappie, and bluegill were greatest in 1997; all 3 species showed a similar trend of decreasing abundance and low recruitment from 1993 to 1996 (Fig. 3). Although abundance decreased, the lengths of largemouth bass ($F_{5,578} = 9.7$; $P < 0.01$) and black crappie ($F_{6,275} = 5.6$; $P < 0.01$) increased from 1993 to 1997 (Table 1). Bluegill length did not vary significantly through time ($F_{6,1717} = 1.9$; $P = 0.07$); however, lengths generally tended to increase from 1991 to 1996 and then declined in 1997 (Table 1).

Discussion

Extensive sampling with electrofishing indicated large (>180 mm TL) gizzard shad were abundant and comprised most of the gizzard shad biomass in Lake Tanglewood prior to hybrid striped bass introductions. Within 1 year after the initial stocking of hybrid striped bass (490 per ha), densities of both age-0 (<80 mm TL) and in-

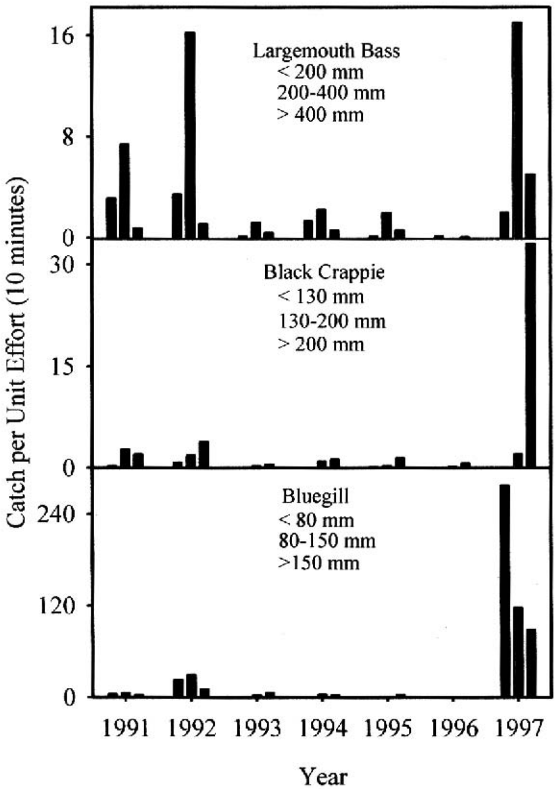

Figure 3. Catch per 10 minutes electrofishing of small, intermediate and large length classes of largemouth bass, black crappie, and bluegill sunfish, Lake Tanglewood, Texas, 1991 to 1997.

Table 1. Mean lengths (mm) at capture of largemouth bass, black crappie, and bluegill in Lake Tanglewood, 1991 to 1997. Values in parentheses are sample size, standard error. Values in the same row with different letters were significantly different ($P < 0.05$)

	Year collected						
Species	1991	1992	1993	1994	1995	1996	1997
Largemouth bass	244.7^{A} (225, 6.2)	274.2^{B} (207, 5.8)	315.1^{C} (34, 16.1)	260.8^{A} (41, 19.3)	321.5^{C} (53, 12.9)	515[a] (1, .)	329.5^{C} (24, 24.5)
Black crappie	185.8^{A} (99, 3.8)	195.4^{AB} (64, 5.9)	203.9^{ABC} (14, 9.4)	203.9^{BC} (21, 5.2)	211.4^{C} (34, 3.43)	210.5^{BC} (15, 2.4)	219.4^{C} (35, 1.75)
Bluegill	108.4^{B} (254, 3.0)	112.6^{A} (616, 15.6)	150.9^{C} (175, 2.7)	126.3^{D} (72, 4.9)	150.4^{CD} (110, 3.0)	155.8^{CD} (12, 3.4)	93.1A (485, 2.2)

a. Samples excluded from ANOVA due to small sample size.

termediate size (<180 mm TL) gizzard shad declined. We presume the change in the gizzard shad population resulted from hybrid striped bass predation (cf. Williams 1970, Crandall 1979).

The increased production of young gizzard shad coincided with decreased abundance of large (>180 mm TL) gizzard shad. In Buffalo Springs Lake, Texas, a eutrophic reservoir with a high density of large gizzard shad, Schramm et al. (1999) found that year class production of gizzard shad increased when adult densities decreased. The decrease in adult gizzard shad and increased production of young gizzard shad occurred 4 years after the initial high density stocking of striped bass (Schramm et al. 1999). Corroborating the results obtained by Schramm et al. (1999) for striped bass, it appears that hybrid striped bass can be used to restructure a gizzard shad population by greatly reducing recruitment, thereby creating a situation where the abundance of large gizzard shad will decline as a result of natural mortality and possibly stimulate increased production of young gizzard shad. However, further experiments examining density-dependent mechanisms of gizzard shad recruitment are necessary to evaluate this. Nevertheless, the results suggest a promising means for managers to control gizzard shad populations. As hybrid striped bass succumb to natural mortality and as they grow through time it is likely that the preferred size of prey will change and predatory pressure should decrease. As a result of reduced hybrid striped bass predatory pressure they could be stocked every 4 years to control gizzard shad populations.

Hybrid striped bass stocked in 1992 and 1993 grew more slowly than those stocked in other small, shallow warm water impoundments (Ware 1974, Crandall 1979, Germann and Bunch 1983, Ebert et al. 1988). Crandall (1979) found depressed growth in hybrid striped bass stocked in Texas reservoirs when hybrid striped bass were stocked in successive years. The yearly additions of hybrid striped bass may deplete the vulnerable sizes of gizzard shad causing reduced survival and slower growth of fish stocked at later dates. This may be the case in Lake Tanglewood, where the abundance of vulnerable-size gizzard shad decreased after the initial introduction (i.e., 1992) of hybrid striped bass and thus impacted the survival and growth of those stocked in 1993.

Abundant game fish have been positively related to vulnerable-size gizzard shad populations (Michaletz 1997, 1998, Schramm et al. 1999). Decreased abundance of largemouth bass, black crappie, and bluegill from 1993 to 1996 in Lake Tanglewood are congruent with the low abundance of gizzard shad <180 mm TL. However, the substantial increase in 1997 estimates of larger (i.e., age 1 and older) game fish abundance suggests that recruitment must have occurred prior to 1997 and the increased abundance of age 0-gizzard shad. Thus, recruitment of largemouth bass, black crappie, and bluegill may have been underestimated during 1994–1996 sampling, possibly reflecting a change in the behavior of the 3 game species in response to the changing gizzard shad population structure. A similar, but less abrupt, increase of largemouth bass, white crappie, and bluegill was reported by Schramm et al. (1999) for Buffalo Springs Lake following intensive striped bass stocking and changes in the gizzard shad population similar to those observed in Lake Tanglewood. Nevertheless, the low abundance of largemouth bass, and possibly black crappie, could also be attributable to the lack of forage-size gizzard shad. Scarcity of small, vulnerable gizzard shad may also have led to hybrid striped bass predation on game fish populations, particularly sunfish and crappie fry (Neal et al. 1999). Although, the benefits of small gizzard shad may be positive for largemouth bass and possibly black crappie, changes in size structure in gizzard shad populations may not benefit bluegill populations unless the abundance of all size classes of gizzard shad are reduced because of interspecific competition for zooplankton among bluegill and gizzard shad (DeVries and Stein 1996).

Conclusions

We have shown that intensive stocking of hybrid striped bass can alter gizzard shad populations. However, anticipated improvements in the existing sport fishery, via increased year class production of gizzard shad, did not occur immediately. Possible negative repercussions on existing game fish populations should be considered before introduction of hybrid striped bass occurs, especially if game fish populations are potentially reduced until larger gizzard shad succumb to natural mortality. Annual stocking of hybrid striped bass is discouraged due to possible intraspecific and interspecific competition among year classes and cost-benefit considerations. Further research needs to be conducted to evaluate the effects of intensively stocked hybrid striped bass on forage and game fish populations on broader time scales. In addition, further research should be conducted on stocking rate refinement, particularly if manipulation and control of prey populations is desired.

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