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Potential Competition between Hybrid Striped Bass (*Morone saxatilis* × *M. americana*) and Striped Bass (*M. saxatilis*) in the Cape Fear River Estuary, North Carolina

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ABSTRACT: Gillnet surveys from 1990 to 1992 and from 1996 to 1999 indicated a two-fold decrease in native striped bass (*Morone saxatilis*) populations and a concomitant two-fold increase in hybrid striped bass (*Morone saxatilis* × *M. americana*) in the Cape Fear River estuary, North Carolina. Gut content analysis indicated high diet overlap, and tag-recapture data suggested that hybrid striped bass participate in spawning migrations. These data provide circumstantial evidence that hybrid striped bass compete with striped bass for food and that they may compete for mates or habitat on the spawning grounds. Increasing abundance of adult hybrid striped bass in this system elevates the likelihood of hybrid introgression. We recommend that stocking of hybrid striped bass be terminated to preserve native striped bass populations.

Introduction

The dramatic recovery of striped bass (*Morone saxatilis*) populations in many river systems along the East Coast of the United States has not been observed in the Cape Fear River drainage, North Carolina. In response to critical declines in striped bass abundance and recruitment, a coastwide harvest moratorium was imposed from 1985–1990 (Richards and Rago 1999). After 1990, striped bass landings in most North Carolina drainages gradually increased; landings in the Cape Fear River drainage did not rebound (Fig. 1). Since 1994, when the North Carolina Division of Marine Fisheries began to collect data on striped bass fishing effort, effort in the Cape Fear River drainage has declined by 30% (Rohde unpublished data). From 1994–1999 catch per unit effort (CPUE) in the Cape Fear River drainage averaged 0.8 kg striped bass per trip, while in other North Carolina drainages mean CPUE was 3.3 kg per trip.

The Cape Fear River is the only coastal river system in North Carolina where hybrid striped bass (*Morone saxatilis* × *M. americana*) are stocked. Hybrid fingerlings have been stocked nearly every year since 1983 to support a recreational fishery in Lake Jordan, North Carolina (Bryant unpublished data). Some stocked fish escape into the headwaters of the Cape Fear River at Jordan Dam. Concerns have been raised that hybrid striped bass negatively affect native striped bass populations. Pond enclosure experiments indicate that juvenile *Morone* hybrids enjoy a growth and survival advantage over striped bass (Houde and Lubbers 1986; Secor et al. 1995). Adult hybrid striped bass may also compete with native striped bass for food, favorable habitat, and/or mates. Interaction on the spawning grounds could result in diminished striped bass reproduction and/or hybrid introgression (Harrell et al. 1993).

We hypothesized that hybrid striped bass abundance in the Cape Fear River estuary has increased during the past decade due to yearly stocking of juveniles in Jordan Lake and that striped bass compete with hybrids for food and/or on the spawning grounds for habitat or mates. To test the idea that hybrid striped bass have successfully colonized the lower river and estuary, we conducted a fisheries-independent survey of the relative abundance of striped bass and hybrid striped bass over a 9-yr period. To assess the potential for competitive interactions between these fishes, we examined their food habits and migration behavior. High niche overlap and simultaneous occupation of spawning grounds would indicate the potential for competitive interactions between hybrid striped bass and the native striped bass population. Complementary dynamics in abundance of these fishes can provide further evidence for competition (Crowder 1990). Such information is needed to determine whether

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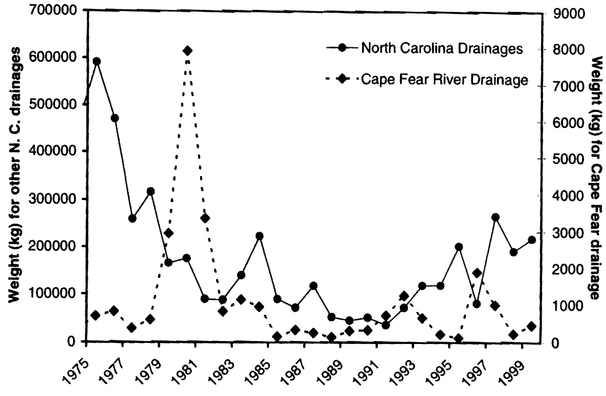

Fig. 1. Commercial striped bass landings (kg) from 1976–1998 (Rohde unpublished data). The dashed line indicates Cape Fear River landings, and the solid line indicates landings for all other North Carolina drainages.

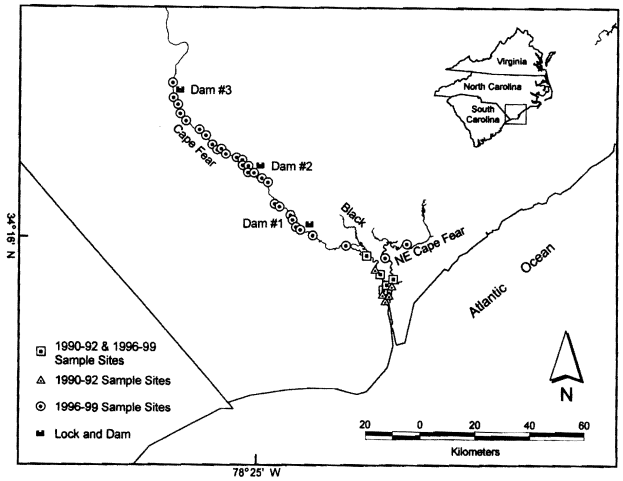

Fig. 2. Study sites sampled during 1990–1992 (triangles), 1996–1999 (circles), and both periods (squares).

further study and/or management of hybrid striped bass would aid striped bass recovery in the Cape Fear River estuary.

Materials and Methods

Gillnet surveys were conducted during 1990–1992 and 1996–1999. We used 30 and 50 m long, 3.5 m deep sinking gillnets with 14 cm stretched mono-filament mesh. Nets were positioned perpendicular to shore, in depths ranging from 2 m near shore to 10–15 m in mid-channel. Each month, nets were set on the first day, checked on the second day, and retrieved on the third day of sampling (48 h total soak time). Our unit of effort was a net day, which we defined as a 50 m net set for 24 h. CPUE was the number of striped bass captured per net day. More sites were sampled in 1996–1999 than in 1990–1992 (Fig. 2). We made paired comparisons (Wilcoxon paired sample tests, Zar 1996) of monthly CPUE obtained in each study period for each species using only those sites sampled in both periods. We also calculated relative abundance of the two species in each study period using all stations.

All fish captured were identified, measured (to the nearest mm), and weighed (to the nearest 25 g). For each species, we used the Wilcoxon paired sample test to compare mean condition factor $K = (\text{Weight (g)} \times \text{Length (mm)}^{-3}) \times 10^6$) of fish from 50 mm size groups that were collected in the two study periods. Throughout the 1990–1992 survey, striped bass and hybrids in good condition were tagged with cinch-up tags (Floy Model FT-4 Cinch-Up) to document seasonal movement patterns. Each tag was threaded through the dorsal musculature and the two ends were fastened together, leaving enough space to accommodate fish growth. Return and reward information was clearly marked on the tags and rewards were widely advertised to promote the return of tags by fishers. Gut contents of all dead fish were identified to the lowest possible taxon, and gonad development was also noted. We used Schoener's Index (Hurlbert 1978) to test for overlap in striped bass and hybrid striped bass diets:

$C_{xy} = 1 - 0.5 \Sigma |p_{xi} - p_{yi}|$ where p_{xi} is the proportion of striped bass that contained prey i, and p_{yi} is the proportion of hybrid striped bass that contained prey i. A Schoener's Index value of 1.0 indicates complete diet overlap and 0.0 indicates no overlap.

Results

We expended 695 net days of effort in 1990–1992 and 840 net days of effort in 1996–1999. In 1990–1992 striped bass captures exceeded hybrid striped bass captures by 2.0:1, while in 1996–1999 the ratio of striped bass to hybrids was 0.3:1. These comparisons were based on different stations. When we re-calculated the relative abundance using stations common to both study periods we obtained similar results: 2.2:1 in 1990–1992, and 0.5:1 in 1996–1999. Using only data from these stations we found that the mean monthly CPUE of striped bass in 1990–1992 (0.2 fish per net day) was significantly higher than in 1996–1999 (0.1 fish per net day, $p < 0.05$, $T_{0.05(2),12} = 13$). Mean monthly hybrid striped bass CPUE in 1990–1992 (0.08 fish per net day) was significantly lower than in 1996–1999 (0.18 fish per net day, $p < 0.05$, $T_{0.05(2),12} = 13$).

During 1990–1992 striped bass ranged from 226 to 928 mm (mean = 532 mm TL), and hybrid striped bass in that survey ranged from 262 to 670 mm (mean = 505 mm TL). In 1996–1999, striped

TABLE 1. Frequency of occurrence of prey items for hybrid and striped bass collected from the Cape Fear River estuary, North Carolina. In addition to clupeids and mullet, we were able to distinguish spot (*Leiostomus xanthurus*), American eel (*Anguilla rostrata*), and blue crab (*Callinectes sapidus*) remains.

	Frequency of Occurrence (%)						
Species	Clupeidae	Mugilidae	Spot	Eel	Crab	Unidentified Fish Remains	Other
Striped bass	56.5	4.8	9.7	1.6	3.2	21.0	3.2
Hybrid	25.0	6.3	2.1	8.3	0.0	43.8	14.6

bass were 440–850 mm (mean = 602 mm TL), while hybrid striped bass were 407–790 mm (mean = 532 mm TL). Striped bass from the same 50 mm size categories had a significantly lower condition factor in 1990–1992 than those in 1996–1999 ($p < 0.05$, $T_{0.05(2),7} = 2$). Hybrid striped bass showed the opposite trend, with significantly higher condition factors in 1990–1992 than in 1996–1999 ($p < 0.05$, $T_{0.05(2),6} = 0$).

Gut contents of 49 native striped bass and 78 hybrid striped bass were analyzed. Of these, 25 natives (51%) and 51 hybrids (65%) had empty guts. Most empty stomachs occurred in March–June. Schoener's index was 0.95, indicating very high diet overlap. Both species were piscivorous. The most abundant, identifiable fishes found in the gut were clupieds, including menhaden (*Brevoortia tyrannus*) and threadfin shad (*Dorosoma petenense*). Spot (*Leiostomus xanthurus*) and *Mugil* species (mullet) were also present (Table 1). Eleven hybrids captured from April to June (21% of all hybrids caught in this period) had ripened gonads and the only hybrid caught in September was spent. Three striped bass (14%) had ripened gonads in the months of April–June and one of the two striped bass collected in August was spent. Sex ratios determined for both hybrid striped bass (n = 17) and striped bass (n = 40) in the 1990–1992 survey were 2 females:1 male. In 1996–1999 the striped bass (n = 32) sex ratio remained at 2:1, while for hybrids (n = 80) the relative abundance of females increased to 5:1.

A total of 92 striped bass and 54 hybrids were cinch tagged in the estuary in 1990–1992. Thirty-two striped bass (35%) and 21 hybrids (39%) were recaptured and on two occasions striped bass were recaptured twice. Of the recaptured striped bass, 47% were caught by commercial fishers, 31% were caught by recreational fishers, and 22% were caught in our survey sampling. For hybrid striped bass, 52% were recaptured by commercial fishers, 38% by recreational fishers, and 10% were recaptured in our survey. Three native striped bass and six hybrid striped bass were recaptured above Lock and Dam #1 (river kilometer 96); four of these hybrids were recaptured at Buckhorn Dam (river kilometer 296; Fig. 3). Seven percent of the striped bass and 26% of the hybrids were recaptured > 10 km upstream of their release site. All of these recaptures occurred between March 18 and May 28. Catch per unit of effort of both fish also increased in the Cape Fear River estuary during pre-spawning months (Fig. 4).

Discussion

We found that adult native striped bass CPUE in the Cape Fear River estuary declined from 1990 to

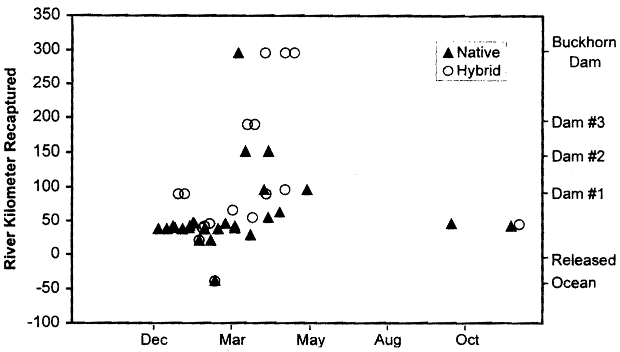

Fig. 3. Time of hybrid (circles) and native (triangles) striped bass recaptures. All fish were tagged between river kilometer 39 and 55. The river kilometer and area where fish were recaptured are indicated on the y-axes.

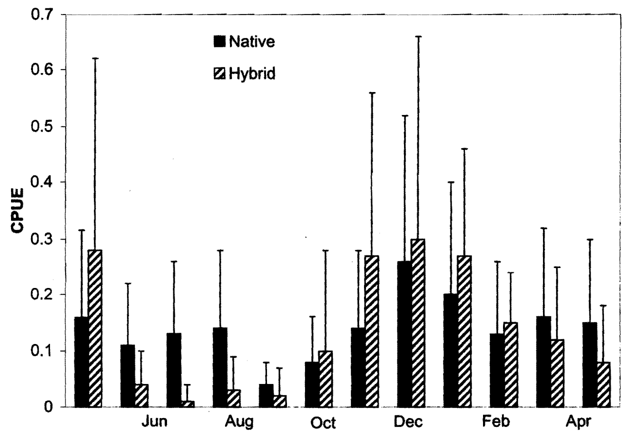

Fig. 4. Mean monthly catch per unit of effort (CPUE) of striped bass (solid bars) and hybrid striped bass (hatched bars) in the lower Cape Fear River estuary for both study periods. Error bars indicate standard deviation.

1999, even though striped bass have shown strong recovery in other North Carolina drainages during the same period. We documented a concomitant increase in adult hybrid striped bass abundance. Similarly, a North Carolina Division of Marine Fisheries survey of striped bass and hybrid striped bass catches at fish houses in the Cape Fear River drainage area revealed that striped bass made up only 28% (n = 170) of the 1996 catch, and 5% (n = 38) in 1997 (Rohde unpublished data). These data confirm that hybrid striped bass have become established in the lower Cape Fear River and that native striped bass abundance has not rebounded in this system as it has in other North Carolina drainages.

While we documented complementary dynamics in abundance of the adults of these species, we made no attempt to capture juveniles. Juvenile striped bass were periodically captured (n = 31) in 1998 and 1999 electrofishing surveys in the lower Cape Fear River at the same stations that we sampled with gillnets in those years (Mallin et al. 1998, 1999). Very few juvenile hybrid striped bass were caught in the electrofishing surveys (n = 2), indicating that fish stocked as fingerlings in Lake Jordan do not recruit to the lower river in their first year. We believe that competitive interactions are most likely to occur between adults of the two species.

Gut content analysis of both native and hybrid striped bass indicated overlap in their diets. As in Bayless (1972) and Manooch (1973), we found that striped bass fed primarily on clupeids. Hybrids in the Cape Fear River system also preyed on clupeid fishes. Studies of growth rates indicated that *Morone* hybrids grow faster and are more vigorous than striped bass (Logan 1967; Kerby 1972; Bonn et al. 1976). Presumably then, hybrid striped bass have higher consumption rates and may be more aggressively competing for food resources than native striped bass. Hybrid striped bass condition declined over the course of this study but striped bass condition was inexplicably higher when hybrid striped bass were abundant in 1996–1999. This suggests that while these fishes share the same food resources, condition of striped bass that co-occur with hybrid striped bass was not compromised. Perhaps food in this system is not limiting at current population sizes.

Competitive interactions between native striped bass and hybrids may also occur on the spawning grounds. The onset of spawning migration is heralded by an increase in striped bass abundance in estuarine areas during the months before spawning takes place (Hocutt et al. 1990; Carmichael et al. 1998). Sonic tracking of native striped bass in the Cape Fear River drainage indicated that they reside in the estuary through winter and embark on rapid, discrete upstream migrations in March–May (Moser and Ross 1993). In this study, both hybrid and native striped bass abundance increased in winter and early spring, and tag returns showed that hybrid striped bass in this study were participating in spawning runs at the same time as native striped bass. Similarly, Bishop (1967) noted that *M. saxatilis* × *M. chrysops* hybrids participate in spawning runs with striped bass. Interactions on the spawning grounds pose a potential problem if hybrids are occupying striped bass spawning habitat and competing for mates. Reproductive success of native striped bass may also be compromised if mating events with hybrid striped bass result in sterile or diseased embryos (Bishop 1967; Bayless 1972).

With the recent increases in hybrid striped bass abundance, the likelihood of hybrid introgression also increases. Although we did not document hybrid reproduction, hybrids we caught had well-developed gonads during pre-spawning periods and one spent hybrid was captured. We found that hybrid striped bass in the Cape Fear River drainage are often difficult to distinguish from striped bass because they exhibit characters of both fishes. This may result from successful back crosses. *M. saxatilis* × *M. chrysops* hybrids can backcross with *M. saxatilis* in nature (Harrell et al. 1993), and have been successfully crossed in aquaculture (Bayless 1968).

In conclusion, we documented overlaps in diet and found that both hybrid striped bass and native striped bass occurred in the same estuarine habitats at the same time. Hybrids appear to make spawning runs with natives and it is likely that they both occupy spawning grounds at the same time. In addition to sharing these resources, it is clear that striped bass abundance is declining while hybrid striped bass are thriving in this system. Is the increased abundance of hybrid striped bass having a negative effect on native striped bass in the Cape Fear River drainage? Low native striped bass abundance is probably partly attributable to recent declines in water quality (Mallin et al. 1998, 1999), and to the high fishing mortality indicated by our tag recapture data. However, we contend that if food resources, habitat, or mates are limiting, hybrid striped bass could be contributing significantly to the decline in striped bass populations. Surveys are needed to confirm whether these fishes occupy the spawning grounds at the same time. In the interim, we recommend that efforts to stock hybrid striped bass in Lake Jordan be terminated and that management measures to remove hybrid striped bass from the Cape Fear River be instituted.

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