# Investigating Striped Bass Recruitment in the Neuse River, North Carolina

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*Abstract:* Investigating trends in striped bass (*Morone saxatilis*) juvenile abundance is important for determining which factors may affect recruitment. We evaluated the abundance and distribution of juvenile striped bass in the Neuse River from 2006–2007 using beach seines and electrofishing techniques. Overall, little evidence of recruitment was found. Juvenile striped bass were not documented in the system during summer 2006 and were collected in low densities from isolated areas (2 of 34 sample sites) during summer 2007. Because catch was low, we could not adequately describe nursery habitat. These fish collection techniques may not be appropriate for quantifying recruitment for populations with low juvenile production. We suggest that poor recruitment will be a major impediment to stock recovery and reasons for poor recruitment should be investigated.

*Key words:* recruitment, striped bass, streamflow, seine, electrofishing

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In the Neuse River, adult striped bass (*Morone saxatilis*) have been surveyed by North Carolina Wildlife Resources Commission staff using electrofishing techniques each spring since 1994 to assess spawning stock characteristics. This time series encompasses the removal of a low-head dam on the mainstem Neuse River that blocked access to striped bass spawning grounds upstream of Goldsboro (rkm 225). In 1998, Quaker Neck Dam was removed and striped bass used upper basin spawning habitat that was previously blocked by the dam (Burdick and Hightower 2006). Since the removal of the dam, analysis of catch data suggests that fish distribution differs among years and spring streamflows seem to be an important determinant of spawning distribution (Homan and Barwick 2006). These results corroborate well with identification of spawning areas as determined by the presence of striped bass eggs and larvae (Burdick and Hightower 2006). Relationships between streamflow and fish abundance near the upper extent of available spawning grounds suggested that access to upper-basin habitat was likely restricted by low streamflow (Barwick and Rundle 2005). Because of this restriction, recruitment is a concern when spring streamflow is low.

Investigating striped bass recruitment is important for determining factors that may limit natural production. Past investigations have identified environmental factors such as dissolved oxygen, water temperature and rainfall (Uphoff 1989, Coutant and Benson 1990), as well as biotic factors such as variation in size of female spawners and larval prey densities (Cowan et al. 1993) to be important for survival of young striped bass. Of the factors investigated, streamflow has been demonstrated to be an important determinant of year class strength. In the Sacramento-San Joaquin estuary, striped bass year-class abundance was correlated with the amount of river flow (Turner and Chadwick 1972), which was also determined to be partly responsible for adult population abundance fluctuations (Stevens 1977). In the Roanoke River, juvenile abundance indices were highest when spawning flows were moderate; reproductive success declined for lower or higher flows (Rulifson and Manooch 1990). Bulak et al. (1997) also recommended that instream flows be managed to improve striped bass recruitment in South Carolina.

Because year-class strength can be determined by the end of the postlarval stage (Uphoff 1989), annual changes in abundance of post-metamorphic striped bass (>12 mm TL) should yield reliable information about recruitment dynamics. In the Chesapeake Bay, juvenile catches were correlated to commercial landings (Goodyear 1985a) and seining techniques were validated as a reliable index of recruitment in that system. Additionally, seines have been successfully used to collect juvenile striped bass in the Santee-Cooper system (Bulak et al. 1997), Choptank River (Uphoff 1989), Potomac River estuary (Setzler-Hamilton et al. 1981), Lake Texoma (Matthews et al. 1992, Neumann et al. 1995, Schaffler and Winkelman 2008), and the Hudson River estuary (Dey

1981). In addition, Richards and Rago (1999) review the history of the Chesapeake Bay striped bass population decline and the role that striped bass juvenile abundance surveys have had in the management and recovery of the population. These early-life indicators of reproductive success are useful as a triggering mechanism for interstate management of coastal striped bass stocks (Atlantic States Marine Fisheries Commission 2003) and have been demonstrated as a reliable technique for indexing juvenile striped bass abundance.

Because striped bass populations are at low levels of abundance in the Neuse River (Thomas et al. 2009), juvenile striped bass are stocked annually to improve population quality. A total of 146,340 hatchery-produced striped bass fingerlings (~39 mm TL) were stocked into the Neuse River in 2006, while 173,382 fingerlings were stocked in 2007. With the exception of 25,500 fingerlings stocked in 2007, all fish were marked with a 5-d oxytetracycline (OTC) sequence. All striped bass were released at the North Carolina Wildlife Resources Commission boating access area at Bridgeton, North Carolina.

To investigate recruitment dynamics of Neuse River striped bass, we implemented a sampling program from 2006 to 2007 to collect juveniles using beach seine and electrofishing gears during summer (June–October). Our primary objectives were: (1) to determine the distribution of juvenile striped bass in the Neuse River and characterize temperature, oxygen, and salinity patterns of striped bass nursery habitat, and (2) establish long-term monitoring protocols that can be used to monitor striped bass recruitment.

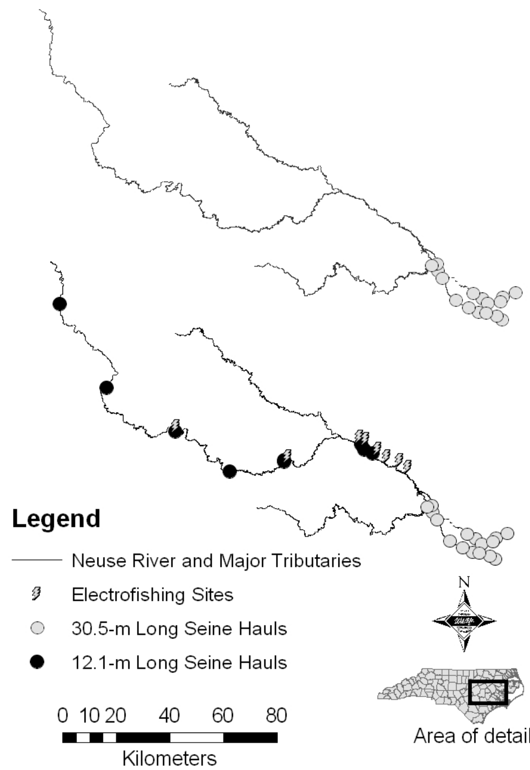


**Figure 1.** Locations of sample sites in 2006 (upper map) and 2007 (lower map). All 2006 locations were sampled with a 30.5-m long seine, while seining and electrofishing techniques were used to collect juvenile striped bass in 2007.

## Methods

During summer months 2006 to 2007, we used beach seine and electrofishing techniques to collect juvenile striped bass from the Neuse River (Figure 1). Our study design was developed according to recommendations by Wilson and Weisberg (1993) including their recommendations to sample more sites and to avoid replicate hauls at each site. The only exception for our study was that we elected to use a 30.5-m seine which Wilson and Weisberg (1993) found to be nearly as precise as a 60-m seine and logistically easier to use in the Neuse River.

In 2006, a 30.5-m long, 2.4-m deep bagless beach seine with 4.8-mm delta mesh was used to collect fish from estuarine areas of the Neuse River (hereinafter "estuarine" sites). Estuarine sample sites were characterized by salinities that ranged from 0–20 ppt with sandy substrates near prominent points of the Neuse River. Sample sites that did not contain structure (e.g., woody debris, stumps) were selected for seining. At each sample site, one end of the seine was anchored to the shoreline and the other end deployed perpendicular to the shoreline until the net was fully extended or a depth contour of approximately 1.5 m was encountered. The offshore end of the net was pulled with the current to the shoreline in a semicircle, sampling an approximate 730-m$^3$ quadrant at each sample site. During 2006, 16 sites were established in estuarine reaches of the Neuse River. Each site was sampled three to four times from June to October 2006.

During 2007, the same estuarine sites were sampled using techniques identical to 2006, but we included additional sites (hereinafter referred to as "inland" sites) that were located upstream of the estuarine sites established in 2006. These inland sites were located between Milburnie Dam, the upper extent of striped bass spawning grounds in the Neuse River, and the estuarine sites established during 2006. This expansion included approximately 200 km of inland spawning grounds and potential nursery habitat not sampled in 2006. Inland seine sites were located in freshwater areas of the river and were characterized by substrates containing sand, silt, and detritus. Sample sites did not contain structure that would interfere with deployment and retrieval of a seine. In 2007, all inland sites were sampled using a 12.1-m long, 2.1-m deep bagless seine with 6.35-mm bar mesh stretched parallel to shore at a depth of approximately 1.5 m and pulled perpendicularly to the shoreline. Estuarine sites were sampled with the 30.5-m long, 2.4-m deep bagless beach seine with 4.8-mm delta mesh (quadrant hauls). In 2007 we also sampled juvenile striped bass using boat-mounted electrofishing techniques (Smith-Root 7.5 GPP, 1000 V, 60 pps, 4–6 A) in inland areas of the Neuse River. Nine 1000-m sites were established and sampled during August when surface water temperatures were 28–32 C. At all sample sites, temperature (C), dissolved oxygen (mg/L), and salinity (parts per thousand), were recorded. All striped bass were measured (mm, TL) and sacrificed for otolith removal.

To check for the presence of OTC marks and to confirm the age of juvenile striped bass, otoliths were extracted, dried, and later placed in Permount mounting medium on a glass microscope slide. The Permount was heated using a hotplate and the otoliths were bonded to the Permount. Proximal surfaces of otoliths were sanded first with 400-grit wet/dry sandpaper until daily growth rings were visible. Otoliths were then remounted and the distal surfaces sanded until the daily growth rings were visible. Otoliths were then viewed at 200×–400× magnification. To determine the presence of OTC, otoliths were viewed with a Nikon Eclipse 50i microscope equipped with an EXFO X-Cite 120 epi-fluorescence illumination unit.

## Results

During summer 2006, no juvenile striped bass were collected at any sample site. During 2007, five juvenile striped bass were collected from two sites in the Neuse River (Table 1; Figure 2). Of this total, three were collected from a single estuarine site during July and September using the 30.5-m beach seine. Two juveniles were collected from the same inland sample site by electrofishing. The five juveniles ranged in length from 65 to 115 mm at the time of capture. Overall, mean catch rates using the 30.5-m seine were 0.00

**Table 1.** Capture date, gear and origin of juvenile striped bass as determined by presence of oxytetracycline (OTC) on otoliths, river area of capture, distance from stocking point, days at large, and length at capture in the Neuse River 2006–2007.

| Capture date | Gear | Juvenile origin | Area of capture | Distance from stocking site (km) | Days at large | Length at capture (mm TL) |
|---|---|---|---|---|---|---|
| 11 Jul 2007 | 30.5-m seine | hatchery | estuarine | 11 | 21 | 65 |
| 15 Aug 2007 | electrofishing | –[a] | riverine | 80 | – | 104 |
| 15 Aug 2007 | electrofishing | –[a] | riverine | 80 | – | 114 |
| 27 Sep 2007 | 30.5-m seine | hatchery | estuarine | 11 | 99 | 115 |
| 27 Sep 2007 | 30.5-m seine | hatchery | estuarine | 11 | 99 | 109 |

a. Fish did not contain an OTC mark, but the stocking of 25,500 unmarked fish approximately 80 km downstream precludes determination of origin.

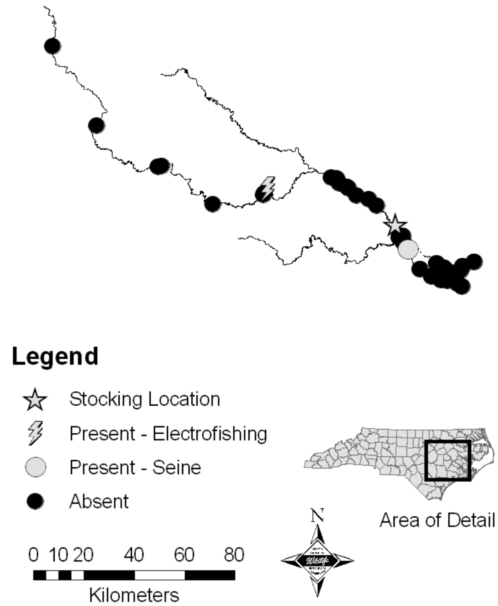


**Figure 2.** Locations where juvenile striped bass were present and absent as determined using seines and electrofishing techniques in the Neuse River, summer 2007. No striped bass were collected during summer 2006.

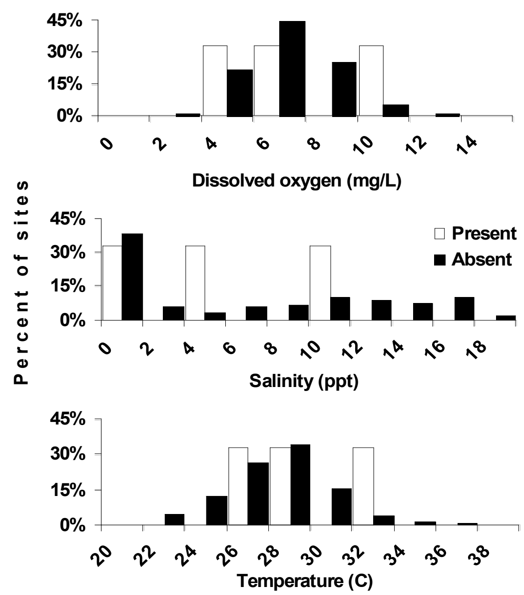


**Figure 3.** Frequency distributions of dissolved oxygen, salinity, and temperature from sites where striped bass were collected (present; open bars) and not collected (absent; closed bars).

catch/haul in 2006 and were low in 2007 (12.1-m seine = 0.00 fish/haul; 30.5-m seine = 0.05 fish/haul; electrofishing = 0.49 fish/h).

In 2007, all juveniles collected from the estuarine site were of hatchery origin ($n = 3$) and were recaptured approximately 11 km downstream from the Bridgeton stocking location (Table 1). Juvenile striped bass collected from the inland site ($n = 2$) did not show evidence of an OTC mark. Because more than 25,000 unmarked striped bass fingerlings were stocked into the Neuse River during 2007, it cannot be determined whether these unmarked fish were wild or stocked juveniles. Overall, striped bass were only collected from two sites on three different sample days. Such low catches precluded formal analysis of nursery habitat characteristics. However, catch did not appear to be related to water chemistry differences between sites. Water chemistry from the locations of capture were not consistently different from sample sites where no juvenile striped bass were collected (Figure 3).

## Discussion

In this study, we found that juvenile striped bass are uncommon in the Neuse River. Low catches of juvenile striped bass were unexpected in light of earlier research by Burdick and Hightower (2006) who commonly collected striped bass eggs and larvae throughout the upper reaches of the Neuse River. Results from our study suggest that survival to a juvenile stage may be low. Other factors can also affect striped bass recruitment including weather patterns during early-life development (Coutant and Benson 1990), suspended sediment concentrations (Morgan et al. 1983), contaminants (Goodyear 1985b, Hall et al. 1985, Finger and Bulak 1988), as well as parental stock characteristics and zooplankton prey densities (Cowan et al. 1993). Cowan et al. (1993) determined that a combination of factors could result in high recruitment variability, but that an important predictor of recruitment was the size of female spawners. In 2006 and 2007, more than 75% of the Neuse River spawning stock was comprised of young adult striped bass aged 2 and 3 years with few fish over age 6 collected in either year. The absence of older fish suggests that the Neuse River stock experiences high adult mortality (Homan and Barwick 2007, Thomas et al. 2009) and the absence of older spawners may be responsible for poor recruitment. Fecundity and survival of offspring produced by young spawners has been low in other systems (Miranda and Muncy 1987, Olsen and Rulifson 1992).

We cannot rule out that larger aggregations of juvenile striped bass may be present in the Neuse River. However, we suggest that these aggregations of fish, if present, are distributed such that they are unlikely to be encountered. The observed distribution of fish in the Neuse River may, in itself, suggest low population abundance. Hewitt et al. (2007) reported that juvenile nursery habitat area in Chesapeake Bay tributaries increased with increasing juvenile abundance. The collection of juveniles from only two sites in the Neuse River suggests a very restricted range and may be related to low abundance.

Seining has been demonstrated as an effective gear for collection of juvenile striped bass in coastal and inland waters (Dey 1981, Setzler-Hamilton et al. 1981, Goodyear 1985a, Uphoff 1989, Matthews et al. 1992, Neumann et al. 1995, Bulak et al. 1997, Richards and Rago 1999, Godwin and Winslow 2006, Hewitt et al. 2007, Schaffler and Winkelman 2008), and juvenile catches in other Atlantic-slope coastal river systems are generally higher than what we observed in the Neuse River despite few differences in the gear or environmental conditions. In the Virginia portion of the Chesapeake Bay, 40,102 striped bass have been collected in 4,929 seine hauls since 1967 for an average of over 8 fish per haul (Hewitt et al. 2007). In the Potomac River estuary, most juvenile striped bass were caught by beach seines in 1975 and 1976 (Setzler-Hamilton et al. 1981) and despite using a smaller seine than what we used in our study, Bulak et al. (1997) were able to collect sufficient numbers of juvenile striped bass to investigate recruitment dynamics in the Santee-Cooper system.

In addition to using a similar gear, water chemistry parameters in our study were comparable to other studies where striped bass were collected. Hewitt et al. (2007) reported peak striped bass catches in the Virginia portion of the Chesapeake Bay when water temperatures were between 25 and 35 C. In our study, more than 86% of our sampling was conducted within this temperature range in 2006 and more than 91% of our sampling was conducted within this temperature range in 2007. Although only 10% of our 2006 samples occurred in waters within the preferred temperature range of juvenile striped bass (24–27 C) (Coutant et al. 1984), more than 30% of our 2007 samples occurred in water within this temperature range. In Chesapeake Bay tributaries, catch was highest from sites with salinities <5 ppt (Hewitt et al. 2007) whereas in our study, almost half (both years combined) of our sample sites had salinities <5 ppt. Because of the similarities in gear and environmental conditions between our study and others, we suggest that Neuse River juvenile striped bass would have been captured, if present.

Because juvenile catches were low, few observations of water chemistry could be collected from sites where striped bass were caught. This precluded any formal comparisons of fish catch-water chemistry relationships. The lack of a clear relationship between catch and water chemistry characteristics will likely result in the inclusion of sample sites where no fish are caught. Continuing to include these sites will result in low and possibly variable estimates of juvenile abundance and recruitment until nursery areas are better defined. Estimating changes in recruitment will continue to be difficult if juvenile abundance and distribution remain unchanged. Poor recruitment as observed in this study will likely impede the recovery of the Neuse River striped bass population if the factors affecting recruitment are not investigated and managed.

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