Summer Habitat Selection of Striped Bass in Lake Norman

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Abstract: Lake Norman is a 13,516-ha reservoir frequently devoid in late summer of the cool, well-oxygenated water preferred by mature striped bass (*Morone saxatilis*). Large summer striped bass kills, however, are rare. The objective of this study was to determine the summer temperature and dissolved oxygen (DO) levels in habitat used by striped bass in Lake Norman. We tagged 48 striped bass (2.2–7.8 kg) with temperature-sensing radio tags (40–50 MHz) during spring 1992 and 1993. Tag frequency, tag temperature, location, and a water column temperature/DO profile were recorded for each tag encounter. Mean tag temperatures (25.6 and 26.1 C) and associated mean DO concentrations (4.0 and 3.1 mg/liter) were similar for large (≥4.5 kg) and small (<4.5 kg) striped bass in the warmest weeks of summer 1992. Habitat ≤28.0 C and containing ≥2.0 mg/liter DO was always present in most of Lake Norman both years. No striped bass mortalities attributed solely to environmental conditions were observed. We suggest DO ≥2.0 mg/liter and water temperature ≤27.0 C will prevent summer striped bass mortalities in Lake Norman. Water temperatures up to 28.0 C can be tolerated, but the exposure period must be <4 weeks to avoid mortalities.

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Striped bass have been stocked in southeastern reservoirs since the 1960s (Bailey 1975, Axon and Whitehurst 1985). A survey of 80 reservoirs in the United States containing striped bass revealed 27 impoundments had experienced some summer striped bass mortality (Matthews 1985). Fish as small as 1 kg were affected in some impoundments. Coutant (1985) argued warm water temperatures and a need for cooler water among striped bass ≥age 2 cause summer striped bass mortalities in many southeastern reservoirs.

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Lake Norman is a 13,516-ha cooling reservoir on the lower Catawba River in south central North Carolina operated by Duke Power Company (DPC) to serve 2 electric generating facilities. The North Carolina Wildlife Resources Commission (NCWRC) has stocked the reservoir with striped bass since the late 1960s (Bailey 1975). A stocking rate of 7.5 fingerlings/ha has supported an important regional striped bass fishery in the reservoir. Baker (1983) reported striped bass fishing effort was 37 hours/ha in 1982 and the popularity of striped bass fishing on the reservoir remains high.

Few late summer striped bass mortalities (<30 fish annually) have been observed on Lake Norman in most years; however, 163 fish died in 1983. DPC subsequently initiated studies to help define the relationship between power production and striped bass habitat in Lake Norman (Lewis 1983). DPC adopted water temperature (≤26.0 C and DO ≥2.0 mg/liter as a minimum habitat condition (critical habitat) to sustain adult striped bass. Their studies (DPC, unpubl. data) demonstrated that often little or no critical habitat was present in Lake Norman in late summer. The few adult striped bass mortalities observed on Lake Norman concurrent with the apparent absence of water ≤26.0 C with ≥2.0 mg/liter DO suggests either a better definition of striped bass critical habitat is needed or undetected thermal refuges (Coutant 1985) are present in Lake Norman.

Zale et al. (1990), studying striped bass summer mortality in Keystone Reservoir, Oklahoma, accepted the 2.0-mg/liter DO criterion, but reported adult striped bass can survive exposure to water temperatures between 27.0 and 28.0 C for about a month. They reported Keystone striped bass quit feeding near 27.0 C. They found more prolonged exposure resulted in striped bass deaths and exposure to water >28.0 C produced mortalities within a few weeks.

Striped bass management in Lake Norman has included varying the stocking rate, using size and creel limits, and modifying power plant operations to manage heat input and distribution patterns. Understanding the relationship between striped bass and water temperature is important to the proper application of each of these management tools. The objective of this study was to determine summer water temperature and dissolved oxygen concentrations of habatits used by Lake Norman striped bass >2 kg.

Methods

We used low frequency (40–50 MHz), temperature-sensing, radio tags with an expected life span >6 months. Each tag was calibrated by recording changes in tag pulse intervals with changing tag temperatures (15–32 C) in a water bath. A regression equation using ln-transformed temperature and pulse count data was developed for each tag and used to determine tag temperatures from radio signals received from tagged fish.

Eighteen striped bass were collected for tagging from Lake Norman by electrofishing or angling in April and May 1992. An additional 11 fish were collected by electrofishing in May 1992 from Gaston Reservoir near the North Carolina-Virginia

border for tagging and release in Lake Norman. Striped bass collected from both reservoirs combined ranged in total length from 596 to 850 mm and weighed 2.3–7.8 kg. The fish were all descendants of striped bass brood fish from the Roanoke River basin. We collected 17 striped bass for tagging from Lake Norman by angling in spring 1993. Fish total lengths ranged from 568 to 801 mm. Weights ranged from 2.2 to 6.2 kg.

Tags were surgically implanted into the body cavity of each fish using methods described by Hart and Summerfelt (1975). All fish were released near Cowan's Ford Dam.

We tracked fish from 8 July to 10 September 1992 and 4 July to 29 August 1993 using a boat-mounted yagi antenna and ATS R2100™ receiver approximately 2 days/week. The entire reservoir was searched approximately weekly. Location, pulse frequency, and radio frequency were recorded for each fish encountered. A Hydrolab™ was used to collect a water column temperature and DO profile at each tag encounter location. Measurements were taken at approximately 1-m intervals. No temperature/DO profile was done at any fish location after 27 August in 1992 when DPC's water quality monitoring indicated complete restoration of water ≤26 C at DO ≥2 mg/liter to Lake Norman (DPC, unpubl. data).

Tag pulse frequencies were used to calculate tag temperatures. Tag temperatures were compared with their associated water profile data to estimate the DO available to each fish at each encounter.

Because striped bass temperature preference continues to change with changing fish size (Coutant 1985), data from 1992 were segregated into 2 size groups, fish <4.5 kg and ≥4.5 kg. The data were further segregated into a period of declining habitat (Period 1, 8–26 July), a period of maximum habitat stress (Period 2, 27 July–17 August), and a habitat recovery period (Period 3, 18 August–10 September). We compared mean temperatures and DOs between the 2 size groups of striped bass within each period using the Mann-Whitney independent 2-sample nonparametric test ($\alpha = 0.05$) (Wilkinson 1990).

Water temperature and DO conditions available to each fish at each encounter site were assigned to categories based on the Zale et al (1990) discussion of striped bass thermal tolerance. The categories were based on the coolest available oxygenated water (DO ≥2.0 mg/liter) as follows: (1) ≤26.0 C, (2) 26.1–27.0 C, (3) 27.1–28.0 C, or (4) >28.0 C.

The radio tag temperature-sensing functions failed in 1993. Data analysis that year was restricted to categorizing the habitat available to each tagged fish found.

Results

We found 19 active fish in 1992 and made 114 tag field measurements. Equipment failures prevented obtaining DOs the first 3 tracking days. The warmest tag temperature encountered was 28.6 C. We also recorded several striped bass using water with <1 mg/liter DO. Mean tag temperatures and associated DOs were generally similar between large and small striped bass in 1992 (Figs. 1, 2). Mean temperature

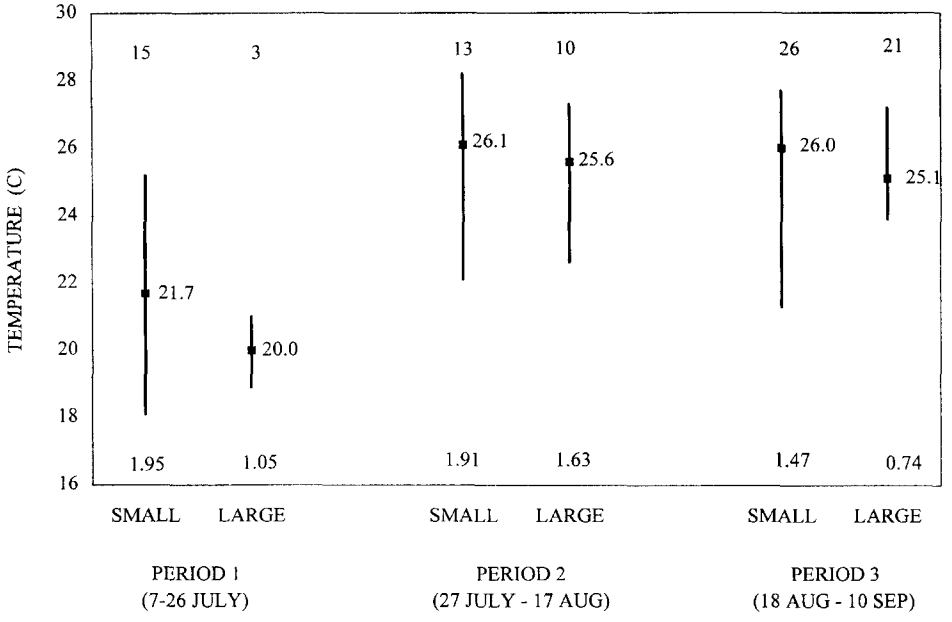

Figure 1. Temperature selection of tagged striped bass (mean and range) by time period and fish size (small <4.5 kg <large) from Lake Norman, North Carolina, 1992. Sample sizes are reported above and SDs are reported below range bars. Means are significantly different in Period 3 only.

(20.0 C) of large striped bass was 1.7 C cooler than the mean temperature of smaller striped bass in Period 1, when water temperatures were rising rapidly, but 26.0-C water with ≥2.0 mg/liter DO was still available throughout the reservoir (DPC, unpubl. data). However, the sample size of large fish was low ($N = 3$) and the difference was not statistically significant. Mean DOs for large and small fish (2.5 and 2.3 mg/liter) were also not statistically different in Period 1. During the stressful conditions of Period 2, tag temperatures of large and small fish remained similar (25.6 C and 26.1 C), as did associated DO concentrations (4.0 and 3.1 mg/liter). A statistically significant difference between large and small fish mean tag temperature (25.1 and 26.0 C) was present following the rapid mid-August cooling in Period 3. Differences in DO concentrations associated with the large and small size groups (3.7 and 4.7 mg/liter) were not statistically significant.

We observed 1 fish in water >28.0 C in 1992. The fish weighed 5.1 kg and was found 4 August. A 2.5-kg fish was observed 30 July and a 7.2-kg fish was observed 6 August at sites with no water ≤27.0 C. Fifteen fish were found at locations with at least some water between 26.1 and 27.0 C in the water column. The remainder (82) were found at sites with water ≤26.0 C.

Six active fish were encountered in 1993 during the tracking period. Twenty-one encounters with active fish provided location and limnological observations. Summer conditions were harsh in 1993 and reached their most critical level in late July (DPC,

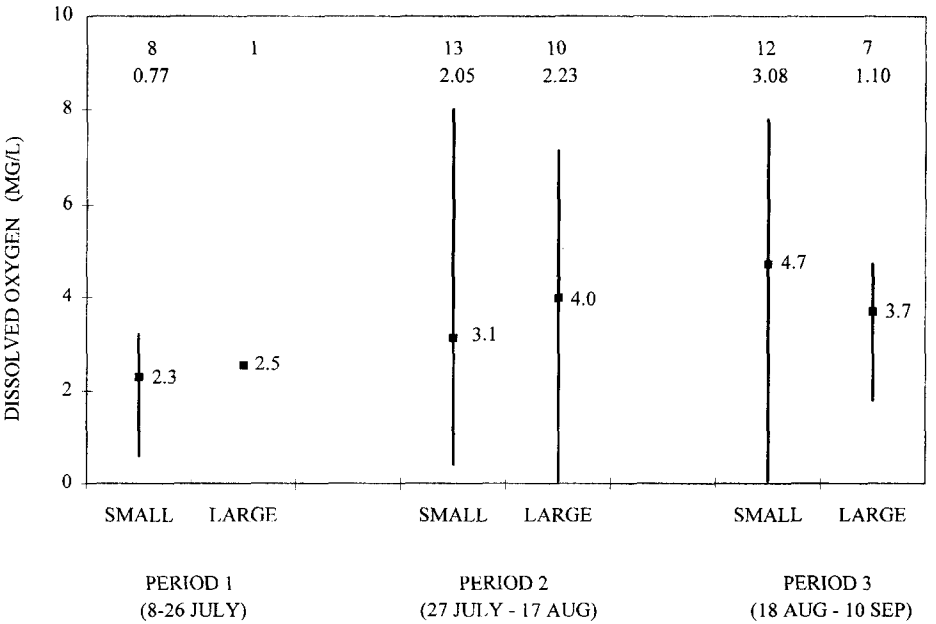

Figure 2. Dissolved oxygen selection of tagged striped bass (mean and range) by time period and fish size (small <4.5 kg ≤large) from Lake Norman, North Carolina, 1992. Sample sizes and SDs are reported above range bars.

unpubl. data). From 28 July through 1 September there were few days and locations on the lake where any oxygenated water ≤27.0 C was present.

Three of the 21 tag encounters in 1993 occurred where oxygenated water (≤26.0 C was present. An additional 6 encounters occurred in the presence of oxygenated water between 26.1 and 27.0 C. Seven fish encounters occurred at temperatures between 27.1 and 28.0 C. Five fish were observed in locales devoid of any water ≤28.0 C. The largest of these 5 fish was 3.2 kg.

Discussion

Although small and statistically nonsignificant, the observed temperature selection differences between small and large fish in 1992 were generally consistent with the literature (Coutant 1985). It is unclear why striped bass encountered in Period 1 were found at such low DO conditions when better habitat was present in the reservoir.

The majority of tagged striped bass encountered had access to water ≤27.0 C and oxygenated at ≥2 mg/liter within the water column, particularly in 1992. Zale et al. (1990) described this as suitable temperature/DO conditions for striped bass. We did not collect any data that might be useful identifying potential sublethal effects (changes in striped bass condition, for example) of exposure to water 26.1–27.0 C at Lake Norman.

In 1993, about half the striped bass observed only had access to water >27.0 C.

Zale suggested larger striped bass would cease feeding and die if exposed to water >27.0 C for more than a month. Lewis (1983) found fish became scarce in striped bass stomachs from Lake Norman in late summer. He cited evidence that striped bass distribution in the reservoir did not overlap the distribution of threadfin shad (*Dorosoma petenense*) or juvenile gizzard shad (*D. cepedianum*) during the same time period, indicating habitat preferences may have separated predator and prey. Some mechanism is interfering with striped bass feeding in Lake Norman in late summer as mean relative weights in striped bass collected in November and December fishing tournaments can be as low as 70% for fish >500 mm (NCWRC, unpubl. data).

Weekly reservoir water temperature/DO monitoring indicated most fish in Lake Norman had access to oxygenated water ≤28.0 C (DPC, unpubl. data), the temperature at which Zale et al. (1990) predicted increased short-term mortalities. The few striped bass carcasses we observed (approximately 20) were small fish, many displaying hook wounds, which we suspect died when high water temperatures exacerbated hooking mortality.

Lake Norman striped bass were not found in persistent thermal refugia (water ≤26.0 C) during either summer. Large striped bass used >27.0-C water and at least briefly tolerated DO concentrations <2.0 mg/liter. The number of fish observed in these habitat conditions confirms that 26.0 C and 2.0 mg/liter DO does not represent a critical short term barrier to summer striped bass survival in Lake Norman. Our observations are consistent with those of Zale et al. (1990) that striped bass can survive water temperatures 27–28 C at DO ≥2 mg/liter for about a month. We suggest DO ≥2.0 mg/liter and water temperature ≤27 C will protect striped bass from unacceptable summer habitat squeeze mortalities in Lake Norman. Warmer temperatures up to 28.0 C can be tolerated, but the exposure period must be <4 weeks.

The abundance of habitat in the reservoir that meets the minimum conditions necessary for striped bass to survive the warmest summers allows Lake Norman to make a major contribution to North Carolina's striped bass fishery. The popularity of striped bass fishing among Lake Norman anglers is high, even though the fishery must annually accommodate a period of poor habitat quality that can decrease striped bass growth and condition. Forage considerations, fish community interactions, and angler preferences may play a larger role in future stocking decisions because summer habitat in the reservoir is often poor but not scarce. Minimum habitat requirements also will provide an additional parameter to use when assessing the effects of any reservoir or power production changes at Lake Norman on the striped bass fishery. Protecting the fishery from extensive summer die-offs is not, however, a substitute for managing to lower summer water temperatures where possible to reduce current undesirable sublethal effects of poor habitat quality on striped bass.

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