Impacts of Thermal Stress on the Condition of Striped Bass

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Abstract: Striped bass (*Morone saxatilis*) were sampled during summer and winter in the St. Johns River, Florida, to determine effects of summertime thermal stress on fish condition. Regressions of log weight on log length for winter and summer fish had significantly different slopes ($P < 0.001$) indicating larger fish were less robust than smaller fish in summer as compared to winter. Data were arbitrarily separated into 3 size categories (small = <331 mm TL; medium = 331–500 mm TL; large = >500 mm TL) to investigate thermal related stress by size. No negative seasonal impacts could be detected for the small fish category. Although the seasonal slopes were not significantly different for either the medium or large fish categories, significant differences ($P < 0.001$) in line elevations indicated that summer fish weighed less for any given length than winter fish. Analysis of back-transformed, adjusted, mean log weights generated during analysis of covariance indicated, a 2.3%, 16.3%, and 22.0% difference between winter and summer weights for small, medium, and large fish, respectively.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 45:361–369

Common limnological processes affecting many water bodies in the United States during the summer (heating of surface water, stratification, and deoxygenation of the hypolimnion) have been reported to severely restrict the amount of suitable habitat available to striped bass and cause problems with management of the species (Axon and Whitehurst 1985, Coutant 1985). McLane (1958) described the physical condition of striped bass collected during the summer from Black Creek, a tributary of the St. Johns River, Florida, as "thin with concave bellies, protruding skull bones and lacking in vitality." More recent studies dealing with striped bass have also documented poor physical conditions and varying degrees of mortality directly attributed to elevated water temperatures during summer months (McCloskey and Stevens 1980, Schaich and Coutant 1980, Waddle et al. 1980, Summers 1982, Wooley and Crateau 1983, Coutant 1985).

Thermal preference of striped bass has been described as being size-specific with subadults exhibiting a higher temperature tolerance than adults (Davies 1973, Bryce 1982, Van Den Avyle et al. 1983). Coutant (1980) developed a hypothesis of thermal niche partitioning among striped bass age groups whereby individuals of a specific size group performed best physiologically under specific thermal conditions. Further investigation of the size/thermal preference relationship revealed that an additional factor, dissolved oxygen concentration, also played a key factor in determining the distribution of adult striped bass (Coutant 1985). In many instances, survival of adult striped bass is a function of fish being able to locate areas having cooler water temperatures and acceptable oxygen concentrations (>2 mg/l), commonly referred to as "thermal" refuges.

Many studies dealing with habitat selection of striped bass have been conducted using fish fitted with radio or radio/thermal transmitters. Although results from many of these studies indicated water temperature during the summer months played a major role in habitat selection, little quantification of weight loss related to thermal stress has been reported.

Age and growth analysis, as well as field observations, indicated that severe thermal stress negatively impacts the striped bass population in the St. Johns River (Snyder et al. 1987). The purpose of this paper is to define the effects of summertime thermal stress on the physical condition of this Florida population of striped bass.

We wish to thank Levi J. Jenkins, James E. Hayes, Robert L. Testa and Terry E. Cheek for their assistance in data collection. This study was funded, in part, through the Dingell-Johnson Federal Aid in Sport Fish Restoration Act, Project F-33, Florida.

Methods

The St. Johns River is a large coastal river located in east-central Florida and represents the largest river wholly within the state. It drains approximately 22,000 km^2, roughly one-sixth of the state. Total gradient for the entire 512-km river, which flows north from the marshlands west of Vero Beach to the Jacksonville area, is only 7.5 m. Most of the gradient occurs in the first 220 km, considered the upper St. Johns River section, where river elevation drops 6.5 m. Water levels have been affected as much as 260 km upstream by the tidal influence of the Atlantic Ocean (Seaman 1985).

The middle river section from Lake Harney to Palatka, where a large contingent of the striped bass population occurs, is characterized by sluggish flow and includes many sloughs and shallow lakes. The lower river section becomes more estuarine in nature until it ultimately discharges into the Atlantic Ocean near Mayport (U.S. Geol. Surv. 1987).

Numerous springs are found in, or discharge into, the St. Johns River system. These spring flows and several cool-water tributaries provide summertime thermal refuge areas for striped bass (Synder et al. 1987). Known thermal refuges located in the lower St. Johns River were actively investigated during September and October 1986 and July 1990 to observe striped bass behavior and evaluate physical condition of the fish during habitation of these environs. Observations were made using standard scuba and snorkeling gear. Refugia of specific interest included Silver Glen Springs, Salt Springs, and the Croaker Hole, a 14-m deep spring located in Little Lake George. Pertinent physicochemical parameters were determined during each observation utilizing a YSI Model 57 temperature/oxygen meter.

Striped bass were collected during the period 19 December 1983 through 9 September 1989 from various areas along the middle and lower St. Johns River sections using electrofishing gear and pound nets as described by Snyder et al. (1987). Sampling date, surface water temperature, and dissolved oxygen concentration were recorded for each collection. Total length (TL) in millimeters and weight (WT) in grams were measured for each captured fish. Data sets were composed of fish collected during cool weather (December–March), hereafter referred to as "winter," and fish collected during warm weather (June–September), hereafter referred to as "summer."

Ordinary least square regressions of log transformed length and weight for all fish collected were compared between seasons using analysis of covariance (ANCOVA; Snedecor and Cochran 1967, Wilkinson 1990). In order to assess impacts of thermal stress by size, data were arbitrarily separated into 3 size categories (small = <331 mm TL; medium = 331–500 mm TL; large = >500 mm TL). Seasonal weight-length regressions were compared with ANCOVA for each size category. For further comparative analysis, fish were divided into 25-mm groupings and average winter and summer weight differences were determined.

Results

Fish were located almost exclusively in what we consider to be thermal refuge areas during summer but were dispersed throughout the system during winter. General physical condition of fish collected and observed in thermal refuges was considered very poor with many specimens exhibiting an emaciated and often heavily ulcerated/parasitized state. Although limited forage was sometimes noted co-inhabiting thermal refuges with striped bass, feeding activity was not documented.

A total of 1,360 striped bass collected during winter and summer (N = 1,204 and N = 156, respectively) were utilized for weight-length comparisons. Weights for fish collected during the summer ranged from 138 to 5,350 g as compared to 134 to 9,500 g for fish collected in the winter. Length ranges for fish measured during summer and winter were 252 to 834 mm and 231 to 875 mm, respectively.

During the summer, surface water temperatures in the river proper often exceeded 29 C, while temperatures in thermal refuge areas ranged from 22.2 C to 25.8 C. Dissolved oxygen concentrations in thermal refuges ranged from 3.5 to 4.2 mg/l. Water temperatures and dissolved oxygen concentrations encountered in the river during winter ranged from 10.5 C to 25.0 C and 3.6 to 13.0 mg/l, respectively.

There were statistically significant linear regressions ($P < 0.001$) between log TL and log WT for both summer ($r^2 = 0.99$) and winter ($r^2 = 0.97$) (Fig. 1). The slopes of these 2 regression lines were significantly different ($P < 0.001$). No significant differences were found between seasonal slopes for any of the 3 size categories (Figs. 2, 3, 4). There was no significant difference in line elevation between seasons for the small size category; however, line elevations were significantly different ($P < 0.001$) for both the medium and large size categories. The adjusted mean log weights generated by the ANCOVA, when back-transformed, were 2.3%, 16.3%, and 22.0% less for summer fish in the small, medium, and large size categories, respectively. Similar results were obtained by computing mean weights per 25-mm size grouping for summer and winter (Table 1).

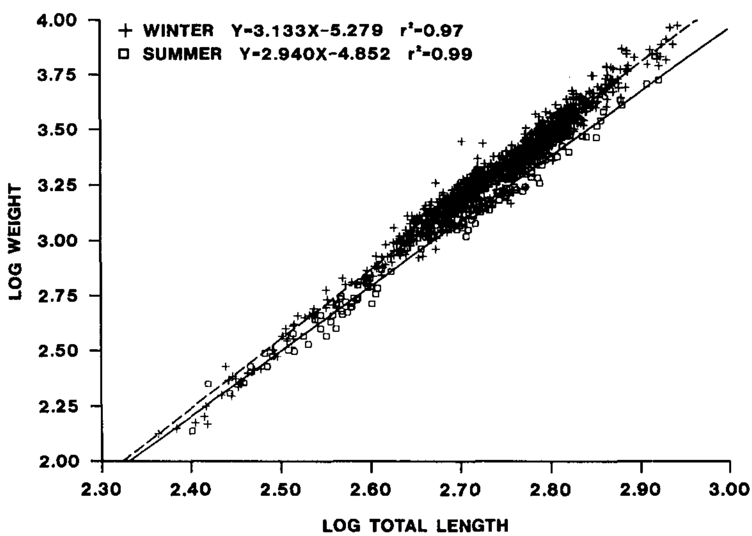

Figure 1. Linear regression for striped bass collected during summer (June–September) and winter (December–March) from the St. Johns River between 19 December 1983 and 9 September 1989 (summer: $N = 156$; winter: $N = 1,204$).

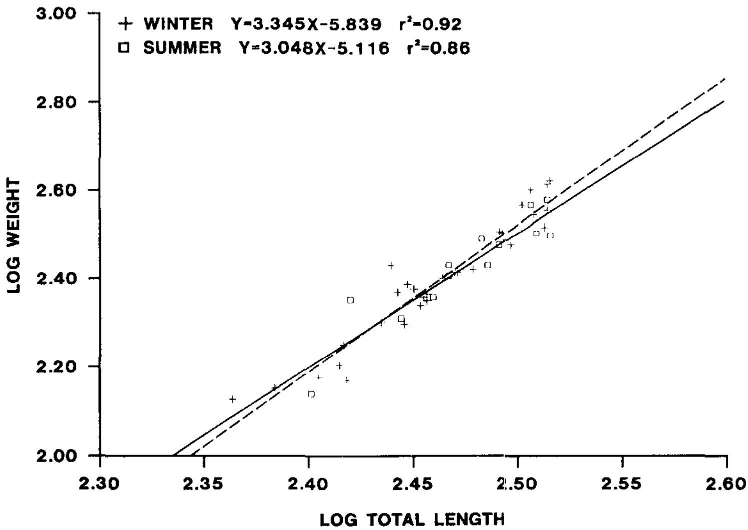

Figure 2. Linear regression for small (<331 mm TL) striped bass collected during summer (June–September) and winter (December–March) from the St. Johns River between 19 December 1983 and 9 September 1989 (summer: N = 13; winter: N = 31).

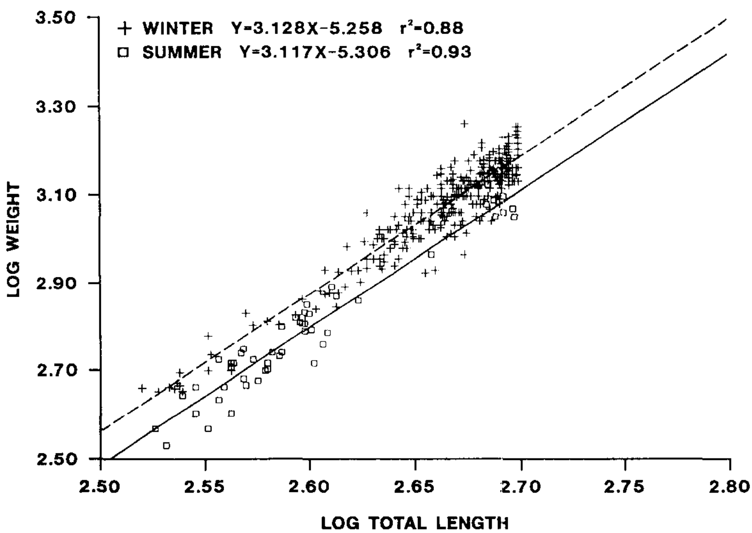

Figure 3. Linear regression for medium (331–500 mm TL) striped bass collected during summer (June–September) and winter (December–March) from the St. Johns River between 19 December 1983 and 9 September 1989 (summer: N = 51; winter: N = 315).

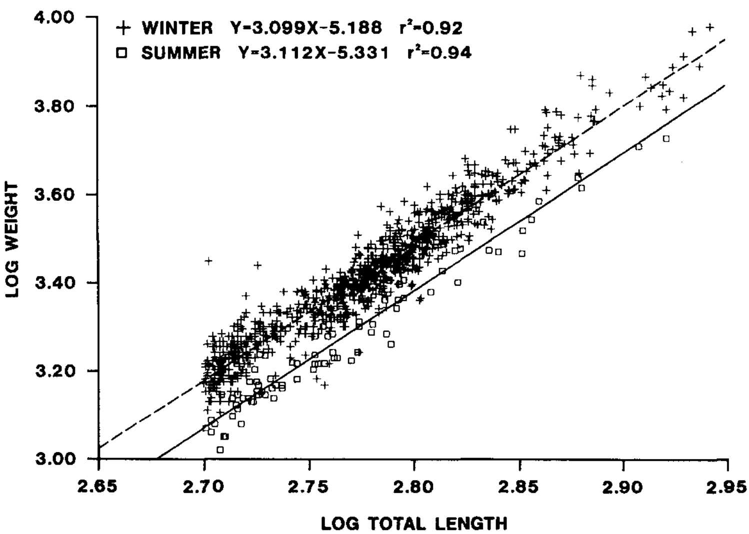

Figure 4. Linear regression for large (>500 mm TL) striped bass collected during summer (June–September) and winter (December–March) from the St. Johns River between 19 December 1983 and 9 September 1989 (summer: $N = 92$; winter: $N = 858$).

Discussion

The lack of observed striped bass feeding within thermal refuges is believed to be more a function of prey availability and the time of day these areas were investigated than a complete termination of foraging. Results from a roving creel survey conducted on an area of the river near Welaka, which encompasses the Croaker Hole, 1 of the major thermal refuges in the system, indicated the peak striped bass fishing season was during June and July (Cheek et al. 1984). Additionally, the majority of striped bass caught during this time frame were taken directly from the aforementioned refuge.

Typically, condition factor (*K*) or relative weight (*W*) have been used to assess differences in robustness between fish populations. Cone (1989) discussed some of the difficulties associated with these measures of condition, and recommended using the estimates of ordinary least squares regression parameters to assess fish condition. Populations with different weight-length regression slopes will have different incremental weight gains and will exhibit changes in relative robustness with changes in length. Populations with similar slopes and different line elevations will have similar incremental weight gains, but one will consistently have lower condition at all sizes.

The significant difference in slopes between the 2 seasons indicated larger fish were relatively less robust in summer, as compared to winter, than were smaller fish. As in earlier findings, our experience with juvenile fish indicated that these fish

Table 1. Mean weights and percent differences, per 25-mm length grouping, of striped bass collected during summer and winter seasons from the St. Johns River between 19 September 1983 and 9 September 1989 (summer: N = 156; winter: N = 1,204).

Total length range (mm)	Mean weight (g)		% difference (winter to summer)
	Winter	Summer	
226–250	138.0		
251–275	184.3	181.5	1.5
276–300	235.3	239.3	−1.7
301–325	329.5	314.0	4.7
326–350	435.4	369.2	15.2
351–375	575.7	478.8	16.8
376–400	671.0	596.5	11.1
401–425	837.9	686.4	18.1
426–450	1046.2		
451–475	1225.5	920.0	24.9
476–500	1430.7	1196.9	16.3
501–525	1664.3	1244.1	25.2
526–550	1956.0	1466.1	25.0
551–575	2156.5	1702.1	21.1
576–600	2455.9	1885.0	23.2
601–625	2816.2	2317.1	17.1
626–650	3153.1	2825.0	10.4
651–675	3709.7	2850.0	23.2
676–700	4041.9	3125.0	22.7
701–725	4571.1	3393.8	25.8
726–750	5270.0		
751–775	5875.0	4237.5	27.9
776–800	6775.0		
801–825	6866.0	5125.0	25.4
826–850	7039.3	5350.0	24.0
851–875	8858.3		

were less affected by higher water temperatures than large fish. We found no differences in the weight-length relationships for the small size category, and these fish had only a small percentage difference in weight between seasons.

Slopes for the medium and large fish categories were not significantly different by season; however, the significant differences in line elevations indicated that summer fish were less robust than winter fish at all lengths. Differences in line elevations indicated that striped bass in the large size category were more severely impacted than those in the medium size category.

A survey of 80 reservoirs in the United States with established striped bass populations indicated that 34% experienced some degree of summer mortality (Mathews 1985). Although fish in our study were shown to experience extreme loss of condition, die-offs during the summer were not documented. However, ramifications of thermal stress appear to be inhibited growth, decreased abundance, and lowered survival rates of adult striped bass in the St. Johns River and are perhaps the major reasons that specimens >9 kg or >7 years of age are rarely collected.

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