# Size, Growth, and Condition of Flathead Catfish in Sutton Lake, North Carolina: Implications for Managing an Introduced Species in Thermally-Influenced Reservoirs

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*Abstract.:* A total of 747 flathead catfish (*Pylodictis olivaris*) were collected from Sutton Lake cooling reservoir located near Wilmington, North Carolina (1999 to 2006), using boat-mounted electrofishing techniques. Individuals >600 mm total length accounted for 70% of all fish collected and trophy-sized fish (>1,020 mm total length) accounted for 9% of all fish collected. Mean total length (TL) at age was described by the von Bertalanffy growth curve as TL = 1,200 (1–e–0.17[age + 0.93]). Sutton Lake flathead catfish total annual mortality (A) was 0.32. The well-established flathead catfish population of Sutton Lake exhibited rapid growth rates and trophy-sized fish, but the potential for establishing a trophy flathead fishery seems no greater than in area rivers despite Sutton Lake's longer growing season.

*Key words:* flathead catfish, age and growth, mortality, thermally influenced reservoir

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Flathead catfish (*Pylodictis olivaris*) are not native to eastern North Carolina and have been introduced into many of North Carolina's river basins through accidental or intentional stockings. Although cause-and-effect relationships have not often been clearly demonstrated, negative impacts to native fish communities may be possible after the establishment of flathead catfish (Guier et al. 1980, Nelson et al. 1985, Ashley and Buff 1989, Thomas 1995). However, preferential feeding habits that could result in prey population declines in Atlantic and Gulf-slope rivers have been identified in other studies (Quinn 1989, Pine et al. 2005, 2007). It is apparent that establishment and expansion of flathead catfish populations can occur relatively quickly (<10 years) as evidenced by studies on the Cape Fear River, North Carolina (Guier et al. 1980), and Altamaha River, Georgia (Thomas 1995).

Angler opinions of flathead catfish management strategies have been mixed. Harvest-oriented catfish anglers in Texas generally opposed restrictive regulations whereas Mississippi flathead catfish anglers enjoyed catching trophy-sized fish (Schramm et al. 1999, Wilde and Ditton 1999). In North Carolina, many anglers target large catfish for sport, and flathead catfish tournament trails are starting to become popular in several of North Carolina's river systems. Other anglers complain that this highly piscivorous catfish adversely affects existing largemouth bass (*Micropterus salmoides*) and sunfish (*Lepomis spp.*) fisheries.

Flathead catfish were first discovered in Sutton Lake during a 1993 rotenone sample conducted by Progress Energy (2003). Additional sampling conducted by North Carolina Wildlife Resources Commission (NCWRC) biologists during summer 1998 resulted in the collection of six flathead catfish in approximately 30 minutes of electrofishing ranging in size from 376 to 975 mm (Hammers and Herndon 1998). Since that time, additional sampling by Progress Energy and NCWRC biologists indicate flathead catfish are an apex predator in Sutton Lake.

Characterization of flathead catfish populations subjected to extreme environmental conditions, such as a thermally-altered growing season, is important for an understanding of growth capacity and fish condition. Diet studies conducted at Sutton Lake confirm centrarchids are an important food item for flathead catfish with the frequency of occurrence of fish in Sutton Lake flathead catfish stomachs (92.3%) (Rundle et al. 2005) much higher than values reported for the Cape Fear River, North Carolina (Ashley and Buff 1989), and the Altamaha River, Georgia (R. Weller, Georgia Department of Natural Resources [GADNR], personal communication). Herndon and Waters (2002) reported "it was not uncommon to remove a 300-to 480-mm largemouth bass from the stomach of a flathead catfish that was 722 to 994 mm." They also reported a 144-mm warmouth sunfish (*Lepomis gulosus*) was removed from the stomach of a 738-mm flathead catfish (TL) and that 18 sunfish were found in the stomach of one flathead catfish.

From June through October in both 1999 and 2000, the NC-

WRC conducted an extensive removal program for flathead catfish from Sutton Lake using low frequency, pulsed electrofishing techniques; 517 flathead catfish were removed during this time period (Herndon and Waters 2002). However, during the five-month sampling period each year, monthly catch rates did not decline and no significant changes in flathead catfish size structure were observed. The removal program was considered unsuccessful (Herndon and Waters 2002). GADNR reported similar results for a three-year electrofishing removal study on the Altamaha River, Georgia (R. Weller, GADNR, personal communication). The Sutton Lake removal study also examined flathead catfish size composition and concluded that a well-established, reproducing flathead population existed at that time with individuals ranging from 234 to 1,124 mm TL (Herndon and Waters 2002).

Impacts of an introduced predator may take place over an extended period of time and little information currently exists in the scientific literature regarding population characteristics of flathead catfish existing in a thermally-altered environment; therefore, we initiated follow-up surveys in 2001, 2003, and 2006 to examine trends in flathead catfish size and condition over time. Other studies have demonstrated that introduced flathead catfish in North Carolina's coastal rivers experience rapid individual growth rates and can suppress native populations through competitive or predatory interactions (Pine et al. 2007); we sought to determine if the population characteristics of Sutton Lake flathead catfish were consistent with these results. Furthermore, age, growth and condition, and mortality data will be useful for addressing angler concerns about changes in the Sutton Lake sport fish community over time. This information will also assist fisheries managers with making decisions about how to manage harvest of Sutton Lake flathead catfish. These results will also supplement the existing life history information on southeastern flathead catfish populations. With these data needs in mind, the objectives of our study were to (1) determine individual growth rates, condition, and quantify the age structure of the Sutton Lake flathead catfish population, and (2) to determine total mortality rates of flathead catfish in Sutton Lake, a thermally-altered environment.

## Methods

Sutton Lake is a 445-ha cooling reservoir for the L. V. Sutton Steam Plant located adjacent to the Cape Fear River near Wilmington, North Carolina. Fly ash from the plant's coal combustion process is currently wet-sluiced to two adjacent ash ponds followed by discharge to the lake or nearby Cape Fear River. Sutton Lake is thermally-influenced by the plant's discharge (Table 1). The lake contains a long central dike with finger dikes extending from both the central dike and the shoreline. The configuration of dikes forms a series of eight connected pools that enhance circulation of cooling water. Average depth in the lake is 1.9 m with a maximum depth of 10 m in the old submerged creek channel.

**Table 1.** Selected physical and chemical characteristics of Sutton Lake, North Carolina.

| Characteristic | Description |
|---|---|
| Year of construction[a] | 1972 |
| Generating capacity[a] | 613 MW |
| Surface area[a] | 445 ha |
| Volume[a] | $8.64 \times 10^6$ m$^3$ |
| Mean depth[a] | 1.9 m |
| Secchi disk transparency[a] | 2.9 m |
| Shoreline distance[a] | 22 km |
| Surrounding land use[a] | Primarily forested |
| Annual temperature range[a] | 18–38 C |
| Mean water retention time[a] | 140 days |

a. Progress Energy 2003

For fish sampling, each "pool" served as a discrete sample site (Figure 1). Flathead catfish were collected monthly from June–October in 1999 and 2000 and during September–October annually during 2001, 2003, and 2006 using boat-mounted electrofishing techniques (Smith-Root 7.5 GPP, 500 V, DC, 15 pps, and 1–2 amps). To collect fish, electrofishing boats (one or two) were driven parallel across each site, and pickup boats (one or two) were used to assist in capturing stunned flathead catfish. Sample sites were not standardized by length or time; however, sampling was conducted in the same general areas established initially in 1999 which targeted habitats near deep channels, sunken logs, log drifts and fish attractors located in deeper pools (Herndon and Waters 2002). Sampling was restricted to water temperatures >20 C as recommended by Quinn (1988).

During all sample years, all flathead catfish collected from each sample "pool" were enumerated, measured (TL, mm) and weighed (g). Sagittal otoliths were removed from all flathead catfish collected in 1999 as described by Nash and Irwin (1999). Otoliths were read at 30× magnification using a Meiji binocular microscope according to the procedure described by Maceina (1988). Mean total length at age at time of capture was estimated and graphically depicted with Box and Whisker plots (Tukey 1977). Because monthly growth over the sample period was negligible, all fish collected from 1999 were compiled for age analysis and observed data were fitted to a Von Bertalanffy growth model using the equation,

$$L_t = L_\infty \left[1 - e^{-k(t - t_0)}\right]$$

where $L_t$ is the predicted length at a given time, $L_\infty$ is the average maximum size in the population, $k$ is the growth coefficient, $t$ is time (years), and $t_0$ is the hypothetical age (years) when the mean

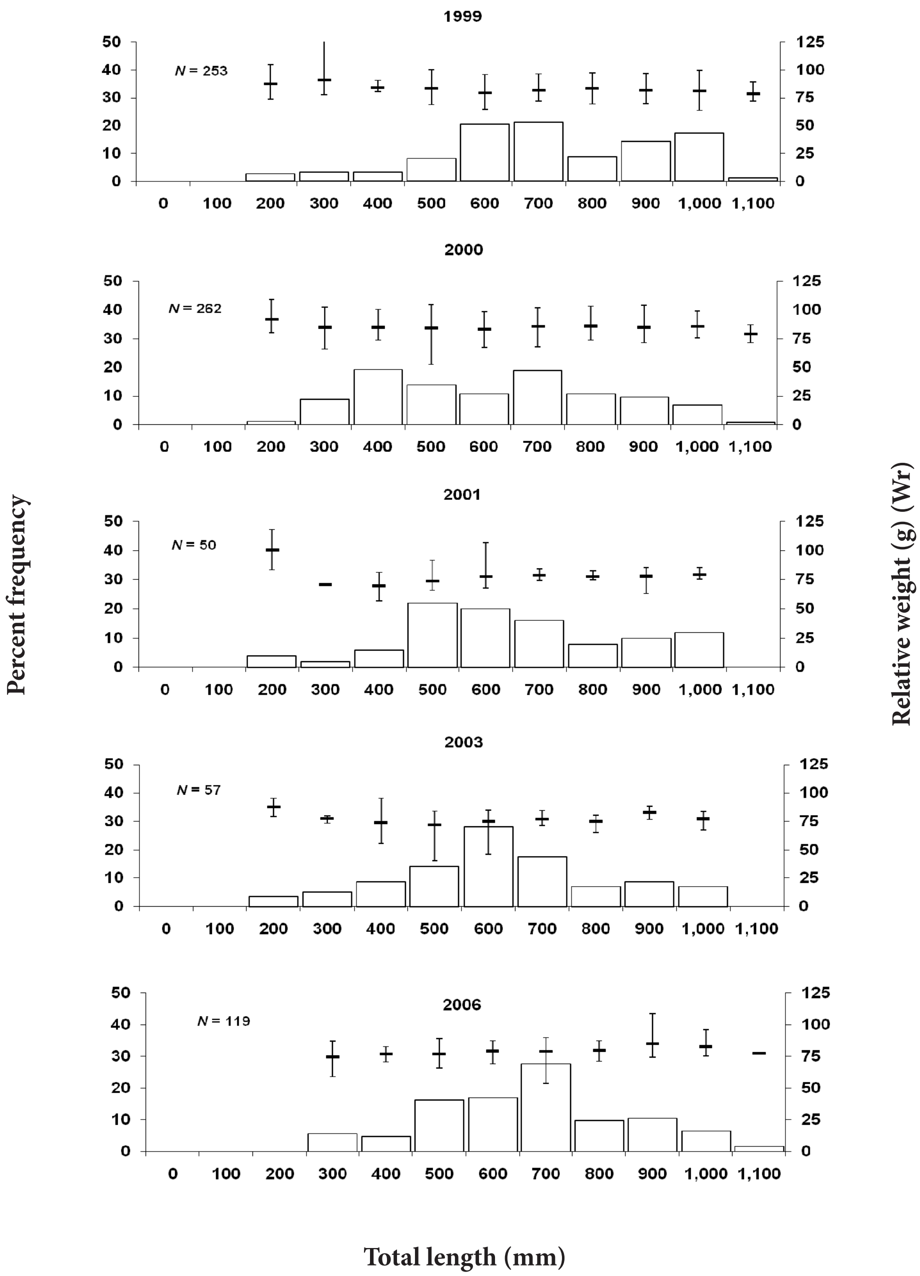


**Figure 1.** Flathead catfish sample sites (lakes), from Sutton Lake, North Carolina, 1999–2006.

fish total length is zero, to estimate growth parameters $L_\infty$ and $k$ (Ricker 1975). A catch curve generated from age data collected in 1999 was used to determine instantaneous mortality (Z), total annual mortality (A), and survival rates (S). Because recruitment appeared to vary over time, the catch curve was not unimodal. Thus, we selected age 4 as the first cohort of the descending limb for the purpose of mortality estimation.

We evaluated size structure using length-frequency distributions (100-mm length intervals). Proportional stock density values (PSD) (Anderson and Gutreuter 1983) were generated according to the formula:

$$\text{PSD} = \frac{\textit{number of fish} \geq \textit{minimum quality length}}{\textit{number of fish} \geq \textit{minimum stock length}} \times 100$$

PSD values were compared between years using a chi-square test of independence with Yates continuity correction and Holms adjusted $P$-values (Holm 1979) ($\alpha = 0.05$). Relative stock density values ($\text{RSD}_{71}$, $\text{RSD}_{86}$, $\text{RSD}_{102}$) (Anderson and Neumann 1996) were generated according to the formula:

$$\text{PSD} = \frac{\textit{number of fish} \geq \textit{specified length}}{\textit{number of fish} \geq \textit{minimum stock length}} \times 100$$

and compared within categories between years using a chi-square test of independence (Sokal and Rohlf 1981) ($\alpha = 0.05$).

The relationships between length and weight were evaluated by using length-weight regressions. Because greater variability in weight was observed for larger fish, we assumed a multiplicative error term for the length-weight function and estimated *a* and *b* parameters using linear regression of log transformed length and weight data ($Log_{10}(W) = -a + b\ log_{10}(L)$, where *W* is weight, *L* is length, *a* is the y-axis intercept and *b* is the slope). Because length-weight relationships did not differ among years, we estimated *a* and *b* parameters from all fish collected from 1999–2006.

Body condition was assessed by calculating relative weights (Wr) of fish ≥ stock size in 100-mm size groups according to the formula:

$$W_r = (W/W_r) \times 100$$

where *W* is the weight of the individual and $W_r$ is the length-specific standard weight predicted by a length-weight regression constructed to represent the species (Bister et al. 2000). Because $W_r$ did not appear related to fish size, we compared mean annual $W_r$ among sample years using ANOVA (Sokal and Rohlf 1981) ($\alpha = 0.05$). Minimum flathead catfish total lengths for each category were 35 cm for stock length, 51 cm for quality length, 71 cm for preferred length, 86 cm for memorable length, and 102 cm for trophy length (Bister et al. 2000).

## Results

Total annual catch varied from 50 (2001) to 262 (2000) flathead catfish over the course of the study period (1999–2006; Table 2). Total lengths ranged from 234 to 1,177 mm with a composite mean TL of 769 mm (Figure 2). Of the 747 fish collected from 1999–2006, 70% were >600 mm TL and 9% were >1,000 mm TL. Overall, weights ranged from 86–17,600 g, with a mean weight of 5,028 g. The instantaneous mortality rate for the Sutton Lake flathead catfish population was 0.38 while the total annual mortality rate was 0.32 (Table 3).

In 1999, PSD was 94 whereas $RSD_{71}$ was 64 (Table 2). However, these values declined considerably in 2000 (PSD = 72; $RSD_{71} = 47$) as a collective result of increased contribution by fish <500 mm and reduced contribution by fish >900 mm (Figure 2). PSD values for 1999 were significantly higher than 2000 values ($F_4 = 0.000$, $P < 0.001$) but were not significantly different from any other year. PSD from 2001, 2003, and 2006 varied less among years but remained high and ranged from 84–90. With exceptions during 2001, stock-size fish were less frequently encountered relative to quality- and preferred-size fish. The $RSD_{71}$ value for 1999 was significantly higher than values for 2000 ($F_4 = 0.000$, $P < 0.001$) and 2003 ($F_4 = 0.000$, $P < 0.001$). The only comparison for $RSD_{86}$ which was not significantly different occurred between 1999 and 2001

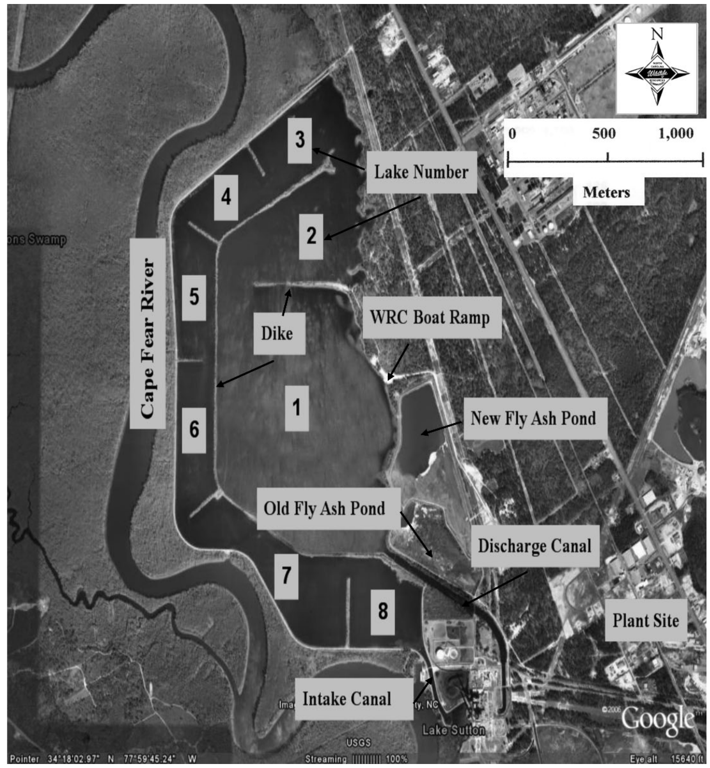


**Figure 2.** Length frequency distributions and relative weight of flathead catfish collected from Sutton Lake, North Carolina, from 1999 to 2006. The horizontal line represents the mean relative weight and the bars the standard error.

**Table 2.** Total catch, proportional stock density (PSD), relative stock density (RSD), and relative weight for flathead catfish collected from Sutton Lake, North Carolina 1999–2006. PSD and RSD values with different superscripts were significantly different ($P < 0.05$).

| | Year | | | | |
|---|---|---|---|---|---|
| **Characteristic** | **1999** | **2000** | **2001** | **2003** | **2006** |
| Total catch (*N*) | 255 | 262 | 50 | 57 | 123 |
| Total aged | 243 | | | | |
| PSD | $94^{A}$ | $72^{B}$ | $90^{AB}$ | $84^{AB}$ | $89^{AB}$ |
| $RSD_{71}$ | $64^{A}$ | $47^{B}$ | $48^{AB}$ | $42^{B}$ | $54^{AB}$ |
| $RSD_{86}$ | $39^{A}$ | $21^{B}$ | $25^{A}$ | $16^{B}$ | $21^{B}$ |
| $RSD_{102}$ | $14^{A}$ | $7^{B}$ | $13^{AB}$ | $5^{AB}$ | $7^{AB}$ |
| Total (*N*) for each $W_r$ size group | 253 | 262 | 50 | 57 | 119 |
| Relative weight | | | | | |
| Stock size (350–509) mm TL | 84 | 85 | 69 | 75 | 76 |
| Quality size (510–709) mm TL | 80 | 84 | 76 | 74 | 78 |
| Preferred size (710–859) mm TL | 83 | 86 | 79 | 76 | 79 |
| Memorable size (860–1019) mm TL | 81 | 85 | 78 | 82 | 84 |
| Trophy size (>1020) mm T L | 82 | 86 | 79 | 76 | 82 |
| All sizes | 82 | 85 | 78 | 76 | 79 |

**Table 3.** Flathead catfish size and age summary, growth parameters, and mortality estimates from three North Carolina coastal rivers and Sutton Lake. ($L_\infty$ = asymptotic length; $k$ = growth coefficient; $t_0$ = hypothetical age at which fish length = 0; $Z$ = instantaneous total mortality rate; $A$ = annual total mortality rate).

| | Water body | | | |
|---|---|---|---|---|
| Variable | Lumber River[a] | Northeast Cape Fear River[a] | Neuse River[a] | Sutton Lake[b] |
| Sample size | 36 | 94 | 114 | 243 |
| Age (years) | | | | |
| Mean | 5.7 | 3.7 | 4.6 | 5.7 |
| SD | 3.1 | 2.9 | 3.1 | 2.5 |
| Range | 0–12 | 1–17 | 1–14 | 1–12 |
| Total length (mm) | | | | |
| Mean | 508 | 397 | 515 | 769 |
| SD | 237 | 250 | 227 | 201 |
| Range | 124–965 | 123–1,150 | 150–1,165 | 234–1,177 |
| Growth parameters | | | | |
| $L_\infty$ (mm) | 1,233 | 1,423 | 961 | 1,200 |
| $k$ | 0.09 | 0.11 | 0.20 | 0.17 |
| $t_0$ (years) | –0.42 | 0.45 | –0.03 | –0.93 |
| Mortality parameters | | | | |
| $Z$ | –0.208 | –0.170 | –0.221 | –0.379 |
| $A$ | 0.188 | 0.156 | 0.198 | 0.316 |

a. Summary data from adjacent North Carolina coastal rivers (Kwak et al. 2006)
b. Current study (1999 sample year)

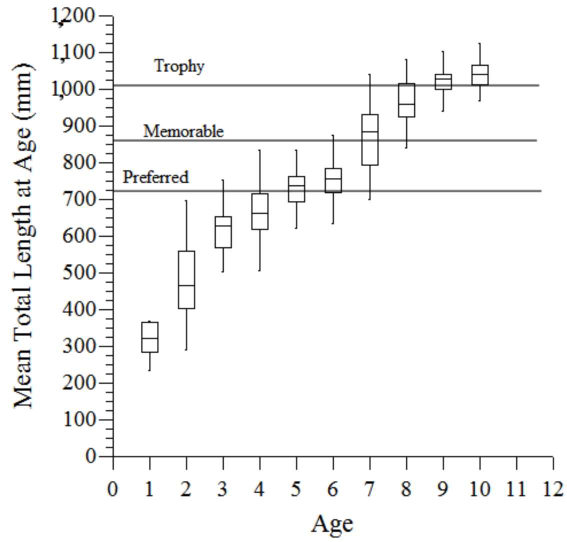


**Figure 3.** Mean total length (mm) at age at capture of flathead catfish collected from Sutton Lake, North Carolina, 1999. Box plots represent the median (50th percentile) the 25th (lower) and 75th (upper) percentiles and bars the 10th (lower) and 90th (upper) percentiles.

($F_4$ = 0.250, $P$ < 0.10). The only significant difference in $RSD_{102}$ values occurred between 1999 and 2000 with the 1999 value being significantly higher ($F_4$ = 0.020, $P$ < 0.001). Abundance of trophy-sized flathead catfish varied over time and contribution to the total annual catch varied by more than 49% between sample occasions.

Length-weight regressions showed evidence of increased variability in weight for larger fish. For the Lake Sutton population, we estimated $Log_{10}(W) = 3.218(log_{10}(L)) - 5.600$ ($F_{746}$ = 0.005; $P$ < 0.001; $r^2$ = 0.978). Within each sample year, relative weight was low and variable within and among size groups (Figure 2). Mean annual relative weight (total catch) of flathead catfish was <85 from 1999–2006 (Table 2). Over the study period, mean relative weight was somewhat higher during 1999 ($W_r$ = 82) and 2000 ($W_r$ = 85), but dropped as low as 76 during 2003. Although differences in mean relative weight among years were small, they were statistically significant. Mean relative weight was significantly higher in 2000 than in 1999 and 2003 ($F_4$ = 24.663, $P$ < 0.001) but these were the only years in which a statistically significant difference occurred.

Fish ranging in age from 1–12 were collected, but those from the 1991 (age-8), 1994 (age-5), and 1995 (age-4), year classes accounted for 45% of all fish collected in 1999. Mean total lengths at age at capture for 1999 Sutton Lake flathead catfish indicate growth rates of 16–161 mm per year with a mean of 79 mm per year (Figure 3). Predicted flathead catfish growth corresponded to the observed length-at-age data over the range of ages collected. Maximum theoretical total length ($L_\infty$) was 1,200 mm and the estimated growth coefficient ($k$) was 0.17 (Table 3).

## Discussion

Poor condition in fish can be attributed to any number of factors including low angler exploitation, density-dependent competition for food, increased metabolism associated with temperature stress resulting from prolonged exposure to elevated water temperatures from occupying a thermally-heated reservoir, or some combination of these factors. Comparison of Sutton Lake flathead catfish length-weight relationships to those evaluated by Minckley and Deacon (1959), Mayhew (1969), Bister et al. (2000), and Sakaris et al. (2006) suggest fish in Sutton Lake weigh less than fish of similar size from these other populations. Poor condition has been documented in a Michigan river and attributed to low angler exploitation (Daugherty and Sutton 2005). Anderson and Neumann (1996) stated that when low $W_r$ values occur for an individual or size group, problems may exist in food or feeding and suggests competition, either within or between species, could be influencing growth.

The prolonged effect of elevated water temperatures on fish populations can result in low condition due to increased metabolic rates, reduced efficiencies and increased energetic costs resulting from temperature stress. McNeely and Pearson (1974) reported coefficients of condition for channel catfish and bluegill collected at the mouth of a thermally-altered effluent canal in North Lake, Texas, were lower than those reported for these species in other parts of the United States. Maximum temperatures in the effluent-outfall area of Sutton Lake can exceed 37 C in summer (July) and remain as high as 18 C in winter (January). Ambient water temperatures in the adjacent Cape Fear River rarely exceed 29 C. One may expect that the higher year round ambient water temperatures observed in Sutton Lake might result in increased growth rates over those seen for the same species in nearby waters. However, Bennett and Gibbons (1972) suspected that elevated metabolic and digestive rates were responsible for a higher percentage of empty stomachs in largemouth bass collected from the entrance to a heated effluent in Par Pond, South Carolina. These effects would likely be magnified in top level predators such as largemouth bass and flathead catfish since their energetic needs are constantly changing along with the energy content of their prey. Increased energetic demands, both short- and long-term, could ultimately affect weight and thus explain the low relative weight values exhibited by Sutton Lake flathead catfish. Additionally, game fish community data collected from Sutton Lake during 2005 and 2006 demonstrate low relative weight ($W_r \leq 85$) for largemouth bass, bluegill (*L. macrochirus*), and redear sunfish (*L. microlophus*), (B. Barwick, NCWRC, personal communication), suggesting that temperature may have a larger effect on fish relative weights than predator-prey interactions.

Flathead catfish are known to expand rapidly into new, unoccupied habitats and our data suggests rapid establishment in Sutton Lake, consistent with other studies reporting establishment of flathead catfish populations over short time periods (<10 years) (Guier et al. 1980; Thomas 1995). However, some evidence exists that flathead catfish may have been introduced before the first specimen was collected in 1993. As evidenced by the collection of one age-12 fish, the species may have been introduced to the lake as early as 1987, or through unauthorized stockings of large fish.

First-year growth of flathead catfish in Sutton Lake far exceeded flathead catfish growth from all native and introduced populations reviewed by Kwak et al. (2006) and exceeded first year growth of Alabama populations by nearly three-fold (Grussing et al. 2000). Rapid growth continued among older fish at Sutton Lake with length at age-2 exceeding all but one South Carolina population (Bulak and Leitner 1999). Mean length at age-7 exceeded all populations from eastern North Carolina rivers and 86% of all populations outside of North Carolina (Kwak et al. 2006). Differences in growth between Sutton Lake fish and Alabama populations surveyed by Grussing et al. (2000) were also pronounced; age-7 fish from Sutton Lake were at least 175 mm larger than those surveyed in Alabama. Growth (Von Bertalanffy *k* parameter) of flathead catfish in our study was faster than native Alabama populations but slower than those from introduced Georgia populations (Sakaris et al. 2006).

Although length at age was generally longer in Sutton Lake when compared to other North Carolina coastal rivers (Kwak et al. 2006), the theoretical maximum size ($L_\infty$) of fish varied in comparison; less than that from the Lumber and Northeast Cape Fear rivers, but larger than that from the Neuse River (Table 3). This suggests that the potential for establishing a trophy flathead catfish fishery at Sutton Lake may be no better than that in area rivers, despite Sutton Lake's longer growing season. In addition, the probability of producing a record-sized fish in Sutton Lake may be lower compared to other rivers, growth to trophy-size commonly occurs and generally takes 9–10 years to accomplish, much sooner than in other areas around the state (Figure 3).

Although trophy-size (>1,020 mm) flathead catfish were captured, the proportion of these large catfish in the population varied annually. Nevertheless, our results indicate trophy-sized fish were available to anglers during each sample period and provide an excellent opportunity for anglers to catch large fish. Unlike the size structure reported from a Michigan river by Daugherty and Sutton (2005) which was comprised primarily of small fish, most of the flathead catfish collected during our study were larger than minimum quality size (510 mm). Because growth of small fish is rapid (mean length at age-1 = 318 mm TL), there is limited opportunity to collect small fish (<300 mm). The absence of small fish could also suggest that fish of this size are less vulnerable to being collected by electrofishing techniques, differential habitat utilization by fish size, or that recruitment is impaired. Future research should rule out gear selectivity as a possible factor that could disguise recruitment impairment of Sutton Lake flathead catfish.

For Sutton Lake flathead catfish, our estimate of total annual mortality (A = 0.32) was higher than mortality estimates for the Lumber, Northeast Cape Fear, and Neuse rivers (range = 0.20–0.16) (Kwak et al. 2006), but similar to those reported for a Michigan river (Z = 0.40) (Daugherty and Sutton 2005). Instantaneous mortality rate (Z) for flathead catfish in Sutton Lake (Z = –0.38) was higher than the Ocmulgee River, Georgia (Z = –0.23), and Coosa River, Alabama (Z = –0.16), but lower than the Satilla River, Georgia (Z = –0.60) (Sakaris et al. 2006). Thus, mortality does not appear to be excessive and is likely one of the reasons fish persist long enough to reach trophy size. While increased harvest by anglers may reduce density-dependent factors resulting in improved condition and growth, the additional mortality may result in a truncated age structure and less capacity for trophy fish production. Furthermore, encouraging anglers to harvest more flathead catfish is unlikely to improve stock characteristics of centrarchids since it is apparent that other factors play a larger role in determining stock characteristics of other game fish in Sutton Lake.

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