Differences in Growth Rate between Sexes of Florida Largemouth Bass[1]

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Abstract: Differences in growth rates between sexes were compared for Florida largemouth bass (*Micropterus salmoides floridanus*) from 5 north-central Florida lakes using lengths back-calculated for the most recently formed annulus on otoliths. Growing rates of Ages 1–6 fish differed between sexes in all lakes. Males were larger than females before Age 1 in 3 of the 5 populations, but by Age 2 females were larger than males in all lakes. Female fish were larger than male fish of the same age when the females attained total lengths of from 243 to 292 mm. Based on the samples collected, female Florida largemouth bass lived longer and attained larger sizes than males. Similar trends have been shown for several populations of northern largemouth bass (*M. s. salmoides*) and for comparisons of the growth rates of the 2 largemouth bass subspecies. We recommend consideration of sex differences in evaluations of growth rate of Florida largemouth bass.

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Differences in growth rates between sexes can be important in age and growth analyses of fish populations. The growth rate of largemouth bass (*Micropterus salmoides*) has been extensively investigated (see Carlander 1977), but few investigators have reported comparisons of growth rate between sexes. No differences in growth rates between sexes were found for largemouth bass populations from California ponds (Schultze and Vanicek 1974). No differences in growth between sexes were found for fingerling largemouth bass (Kramer and Smith 1960), but yearling males were larger than females (Pardue and Hester 1966). Male and female largemouth bass in Norris Reservoir, Tennessee, had similar growth rates through Age 3, but all larger and older (Age 7) fish were females (Stroud 1948). Comparisons

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of back-calculated standard lengths at the last annulus of Ages 1–6 largemouth bass indicated females were 0.3 to 5.1 cm larger than males in Auburn Lake, Alabama, and 1.0 to 7.1 cm larger in Silver Lake, Georgia (Padfield 1951). Comparisons of back-calculated total lengths of largemouth bass from Pickwick Reservoir, Alabama, indicated similar sizes of Ages 3 and 4 males and females, but females were consistently larger than males for Ages 5–9 (Hubert 1975). Because the largemouth bass in Pickwick Reservoir were endemic to the Tennessee River drainage, Hubert (1975) considered his study population to be northern largemouth bass (*M. s. salmoides*). Based on the geographic locations of the other studies, the largemouth bass populations evaluated probably were also northern largemouth bass. Porak et al. (1986) recently reported differences in growth rates between sexes for largemouth bass (*M. s. floridanus*) from Florida waters. In this paper, we demonstrate differences in growth rate between sexes of Florida largemouth bass from 5 Florida lakes.

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Methods

Largemouth bass were collected year-round by pulsed DC electrofishing from Newnans and Santa Fe lakes during 1981 and 1982, from Henderson and Orange lakes during 1983 and 1984, and from Lake George during 1984 and 1985. All are large (1,000 to 45,000 ha), natural lakes in north-central Florida. Largemouth bass populations in George, Henderson (part of Tsala Apopka Lake), and Orange lakes have been verified to be Florida subspecies (Philipp et al. 1983). Based on geographic proximity to Orange Lake and no evidence for introductions of northern largemouth bass (T. L. Vaughn, pers. commun.), the largemouth bass populations in Santa Fe and Newnans lakes also are assumed to be Florida subspecies.

The fish were measured (total length, mm), sexed by observation of the gonads, and their otoliths removed. Ages were determined by inspection of whole otoliths (surface view) (Schramm and Doerzbacher 1982) and otolith cross sections (Hoyer et al. 1985) for a subsample of 27–55 fish that represented all ages in each lake. For fish assigned Ages 1–9 by inspection of cross sections, agreement of ages assigned by inspection of surface views (independent analysis) averaged 79% (Table 1). Cross sections and surface views were then simultaneously compared for each fish. Simultaneous comparison revealed that for 17 fish a newly-formed annulus was apparent on the surface view but not on the cross section. Furthermore, simultaneous comparisons of otoliths preparations resulted in changes in independently-assigned ages for both cross sections and surface views. An independently-assigned age was changed if, during simultaneous comparison, a present but indistinct an-

Table 1. Comparisons of agreement of age assigned by analysis of cross sections and surface views of largemouth bass otoliths. OCS age is the age determined from otolith cross sections. Numbers in parentheses are number of fish compared.

OCS age	Independent analysis % agreement	Simultaneous analysis % agreement
1	88 (33)	94 (33)
2	86 (49)	98 (45)
3	76 (25)	92 (26)
4	80 (25)	88 (26)
5	67 (27)	100 (26)
6	81 (16)	100 (18)
7	79 (19)	90 (20)
8	50 (4)	75 (4)
9	33 (3)	100 (3)
All ages	79 (201)	95 (201)

nulus in 1 preparation was distinct in the other preparation or if an indistinct annulus in 1 preparation was absent in the other preparation. Hoyer et al. (1985) accurately aged 20 5-year-old (known-age) largemouth bass by inspection of otolith cross sections; however, they underestimated the age of 7 of these fish by inspection of whole otoliths. They found underestimation of age by analysis of surface views was more likely for slow-growing fish. The fish used by Hoyer et al. (1985) had relatively slow growth rates from stocking at Age 1 to harvest at Age 5 (0.15 mm/day for females and 0.10 mm/day for males, D. E. Colle, pers. commun.). The average growth rates from Age 1 to Age 5 of the largemouth bass from the 5 lakes used in this study ranged from 0.21–0.22 mm/day for females and 0.15–0.17 mm/day for males. We used surface views for ageing and measuring all otoliths because 1) cross sections were no more reliable than surface views for ageing the fish in our sample, 2) recently-formed annuli did not appear in the cross sections, and 3) otolith radius and distance to annuli could be measured more precisely in surface views than in cross sections (Hoyer et al. 1985, Maceina and Betsill 1987). We found no differences between ages assigned by microscopic examination and analysis of enlarger-produced photographs (Doerzbacher and Schramm 1984) of surface views. Enlarger-produced photographs were, therefore, used to measure otolith radius and distance to the last (most recently-formed) annulus.

Total length was linearly related to otolith radius (R^2 = 0.86–0.95) in all lakes (Table 2). Lengths at last annulus were back-calculated by direct proportion as recommended by Gutreuter (1987). Relationships between total length and age were estimated by linear regression. A comparison of response functions suggested that total length (Y) was best described as a function of age (X) with the equation $Y = a + b(\log_{10} X)$. Growth rates (slopes of the lines) were compared between sexes in each lake with analysis of covariance (Snedecor and Cochran 1980). When heterogeneous slopes were detected, the Johnson-Neyman technique (Johnson and Ney-

Table 2. Relationships between total length (TL, mm) and otolith radius (OR, micrometer units) for 5 populations of Florida largemouth bass.

Lake	Equation	N	R^2
George	TL = −39.9 + 330.8 (OR)	153	0.93
Henderson	TL = −56.9 + 339.3 (OR)	80	0.86
Newnans	TL = −62.8 + 353.9 (OR)	71	0.95
Orange	TL = −66.5 + 358.5 (OR)	76	0.90
Santa Fe	TL = −53.2 + 343.4 (OR)	61	0.95

man 1936) was used to identify ages at which lengths did not differ ($P > 0.05$) between sexes. Data for fish of Ages 1–6 were used for these comparisons for consistency between sexes and among lakes.

Results

Linear regression models of total length on $\log_{10}$ (age) accounted for 81% to 95% of the variation (Fig. 1). Growth rates of Age 1–6 male and female fish differed in Lake George ($N = 153$, $F = 19.51$, $P < 0.01$), Henderson Lake ($N = 80$, $F = 4.14$, $P = 0.05$), Newnans Lake ($N = 71$, $F = 30.52$, $P < 0.01$), and Orange Lake ($N = 75$, $F = 28.43$, $P < 0.01$), and Santa Fe Lake ($N = 61$, $F = 2.33$, $P = 0.13$).

Female fish were larger than males at ages older than 1.7 to 2.0 years among lakes (Fig. 1). Total lengths (estimated from regression equations) at the age above which females were significantly larger than males were 257 mm for females and 242 mm for males in Lake George, 287 mm and 270 mm in Henderson lake, 292 mm and 278 mm in Newnans Lake, 257 mm and 243 mm in Orange Lake, and 243 mm and 225 mm in Santa Fe Lake. Males were larger than females at ages younger than 1-year-old in George, Newnans, and Orange lakes. Total lengths were not predicted below Age 1 because fish of these ages were not part of the population samples. Based on regression equations, males were smaller than females at all ages in Santa Fe Lake.

Among the 250 male and 234 female largemouth bass collected, the oldest fish were Age 7 and Age 9, respectively (Table 3). The largest male fish was 532 mm long, and 0.8% were longer than 500 mm. The largest female fish was 636 mm; 28.2% were longer than 500 mm and 3.4% were longer than 600 mm.

Discussion

Growth rates differed between sexes for Florida largemouth bass populations in 5 lakes. In all lakes, females were larger than males of the same age at ages above 1.7 to 2.0 years old and at predicted total lengths of 243 to 292 mm. Porak et al. (1986) found female Florida largemouth bass were conspicuously larger than males by Age 2. Furthermore, the size ranges of male and female fish and length

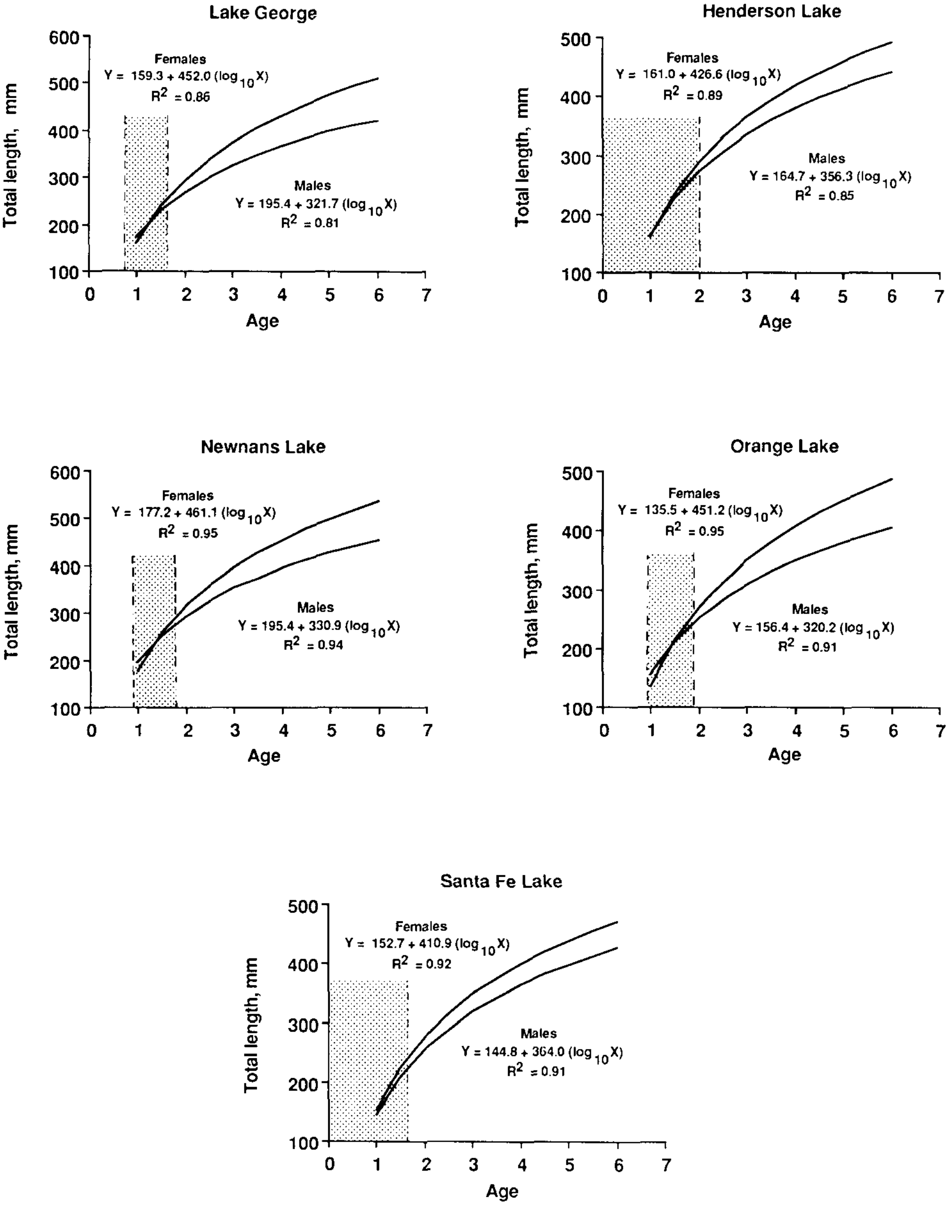

Figure 1. Growth of male and female largemouth bass from north-central Florida lakes. Shaded area is region of no significant difference ($P > 0.05$) in length between sexes.

Table 3. Mean back-calculated total lengths at last annulus for male and female largemouth bass in Florida lakes. Values in parentheses are sample size, standard error.

	Age								
Sex	1	2	3	4	5	6	7	8	9
				Lake George					
Male	175	267	331	362	367	449	—	—	—
	(13,7)	(32,5)	(20,7)	(5,24)	(1,–)	(1,–)			
Female	172	269	388	428	484	508	568	582	—
	(16,6)	(21,12)	(26,7)	(6,21)	(5,19)	(7,12)	(8,15)	(3,9)	
				Henderson Lake					
Male	169	269	343	382	387	532	454	—	—
	(6,15)	(18,8)	(7,8)	(7,7)	(5,10)	(1,–)	(2,7)		
Female	166	297	349	400	468	537	569	—	—
	(4,9)	(11,7)	(9,13)	(5,18)	(5,12)	(2,37)	(1,–)		
				Newnans Lake					
Male	193	302	343	411	415	460	—	—	—
	(10,8)	(9,7)	(4,12)	(2,6)	(5,9)	(4,18)			
Female	180	295	380	470	511	527	614	—	571
	(19,8)	(4,24)	(3,19)	(4,3)	(4,14)	(3,19)	(1,–)		(1,–)
				Orange Lake					
Male	182	244	308	348	386	409	411	—	—
	(3,9)	(14,6)	(16,6)	(3,12)	(4,3)	(11,6)	(15,6)		
Female	143	275	312	416	479	504	530	—	—
	(7,6)	(7,10)	(5,8)	(1,–)	(2,27)	(3,8)	(7,9)		
				Santa Fe Lake					
Male	138	269	319	352	389	451	—	—	—
	(7,11)	(7,9)	(9,10)	(5,12)	(2,15)	(1,–)			
Female	178	258	343	407	445	491	551	—	621
	(4,17)	(8,10)	(9,6)	(4,8)	(2,19)	(3,18)	(1,–)		(1,–)

differential between sexes at Age 2 of the populations investigated by Porak et al. are the same as those in our study. These consistent trends and the significant differences in growth rates and size at age between sexes indicate any comparisons of growth rate of Florida largemouth bass should consider sex of the fish.

Discrepant conclusions exist concerning differences in growth rates between sexes of northern largemouth bass; however, the results of several investigations parallel the differential growth trend shown by Florida largemouth bass. Similar to results in this study, Pardue and Hester (1966) found males were larger than females in populations of yearling largemouth bass smaller than 280 mm. Hubert's (1975) analysis of a large sample of fish, including older fish, from Pickwick Reservoir demonstrated female fish were larger than males of the same age at Ages 5 and older. Hubert's results also showed females were consistently larger than males of the same age when they attained lengths of approximately 300 to 350 mm. Although the age and size range at which females are larger than males of the same age are higher for Pickwick Reservoir largemouth bass than found for Florida largemouth bass, the largemouth bass from Pickwick Reservoir show the same trend of faster growth of female fish than males after attaining older ages and larger sizes found for the Florida largemouth bass populations.

As found by Porak et al. (1986), female Florida largemouth bass also appear to grow larger and live longer than males. This trend was also evident for northern largemouth bass collected from Pickwick Reservoir, Tennessee (Hubert 1975) and for fish presumed to be northern largemouth bass collected from Norris Reservoir, Tennessee (Stroud 1948), Auburn Lake, Alabama, and Silver Lake, Georgia (Padfield 1951).

The different growth rates, longevity, and maximum size attained between sexes may have important implications for size limits and management for trophy fish. A high minimum length limit (e.g., 450 mm) would favor harvest of female largemouth bass and high natural mortality of males. With a protected size-range ("slot") limit, harvest of fish smaller than the protected size would be expected to result in a higher fishing mortality of the slower-growing males than the faster-growing females. Our results and those of others (Stroud 1948, Padfield 1951, Hubert 1975, Porak et al. 1986) indicate that "trophy-size" largemouth bass are predominantly or entirely female fish. Therefore, populations parameters used in establishing length limits or management for trophy fish (e.g., growth and mortality rates) should be estimated separately for males and females.

Several investigations have shown that the northern subspecies grows faster than the Florida subspecies during the first 1 to 2 years of life (Clugston 1964, Zolczynski and Davies 1976), but the growth rate of older (and larger) fish is greater for the Florida subspecies than the northern subspecies (Inman et al. 1976, Bottroff and Lembeck 1978, Wright and Wigtil 1980). It appears that the Florida subspecies attains larger size at age than the northern subspecies at sizes between 200 and 300 mm. This is the same pattern of differential growth between sexes found for Florida largemouth bass.

The growth rate of the hybrid of the 2 subspecies (northern × Florida) has been found to be intermediate to the growth of the parental subspecies (Bottroff and Lembeck 1978), greater than the northern largemouth bass and similar to the Florida largemouth bass (Wright and Wigtil 1980), and greater than both subspecies (Inman et al. 1976). It is possible that the direction of the cross (i.e., female *floridanus* × male *salmoides* vs. female *salmoides* × male *floridanus*) may influence the growth rate of the hybrid and explain these inconsistent results. The hybrids sampled by Bottroff and Lembeck (1978) were naturally occurring (random mating in El Capitan Reservoir, California), and those sampled by Wright and Wigtil (1980) were fish produced by both crosses. The hybrids evaluated by Inman et al. (1976) were female *floridanus* × male *salmoides*. Considering the differential growth and longevity between sexes of the Florida largemouth bass, best growth rate and maximum sizes of hybrids may result from crossing female *floridanus* with male *salmoides*. The results of Inman et al. (1976) substantiate this suggestion.

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