

## Growth, Mortality, and Age Composition of a Lightly Exploited Tilefish Substock off Georgia

MICHAEL J. HARRIS AND GARY D. GROSSMAN<sup>1</sup>

School of Forest Resources, University of Georgia  
Athens, Georgia 30602

### Abstract

We collected 1,351 male and 632 female tilefish *Lopholatilus chamaeleonticeps* off Georgia with bottom longlines between May 1982 and August 1983. Anal fin rays formed a single annulus yearly between May and October. Tilefish reached 33 years of age and growth of males was significantly faster than females. Length-frequency histograms indicated that exploitation had not yet truncated the size structure of this substock. Males were fully recruited to the fishery at age 12 (mean standard length 606 mm) whereas females were fully recruited at age 10 (mean standard length 525 mm). Three estimates of instantaneous total mortality ranged from 0.10 to 0.25; most of this was attributable to natural mortality. Because these fish are long-lived and slow-growing and possess low natural mortality rates, they are vulnerable to overexploitation by a relatively low fishing effort. Consequently, fishing effort may have to be tightly regulated if optimal yields are to be sustained in this fishery.

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Tilefish *Lopholatilus chamaeleonticeps* are distributed along the outer continental shelf of eastern North America from Nova Scotia to Key West, Florida, along the Gulf of Mexico coast to Campeche Bank, and off South America from Venezuela to Surinam (Dooley 1978). They are most common at depths of 100 to 400 m and bottom water temperatures of 9 to 14°C. Tilefish occur in greatest numbers where substrates are suitable for burrow construction (Able et al. 1982; Grossman et al., in press) or afford other shelter such as scour depressions around boulders or rubble piles (Valentine et al. 1980; Low and Ulrich 1983). Based on electrophoretic and morphometric data, Katz et al. (1983) concluded that separate stocks existed in the Middle Atlantic Bight (Cape Cod, Massachusetts, to Cape Hatteras, North Carolina) and the Gulf of Mexico. They also suggested that tilefish in the South Atlantic Bight (Cape Hatteras to south Florida) should be managed as a separate unit even though they were statistically indistinguishable from the Gulf stock.

A commercial fishery for tilefish has existed in the northwestern Atlantic since 1915. Landings were small, however, until the early 1970s, when a substantial longline fishery developed off

New York and New Jersey (Grimes et al. 1980). Fishing effort and monetary value of the catch increased steadily from 1972 through 1981 (dockside value of the 1981 catch in the Middle Atlantic Bight was estimated to be over \$6,000,000), although annual landings have declined since 1979 (K. Able, Zoology Department, Rutgers University, personal communication). This has been accompanied by a steady decline in the mean size of tilefish taken by the fishery. In 1974, when this stock was lightly exploited, 71% of the catch was greater than 70 cm fork length (FL). In 1980, when effort had increased greatly, approximately 18% of the catch was greater than 70 cm FL. Catch per unit effort (CPUE) also declined during this period (Grimes et al. 1980). These phenomena commonly are observed as fisheries pass from moderately exploited to fully exploited stages.

The tilefish stock in the South Atlantic Bight virtually was unexploited until fishermen off South Carolina started making substantial landings in 1980. In less than 2 years, CPUE of fishermen using snapper reels had declined as had the mean length of tilefish caught, and Low et al. (1983) suggested that the South Carolina portion of the stock already was exploited at the maximum sustainable level. In contrast, the Georgia portion of this stock was very lightly exploited until 1983 (Georgia DNR 1980, 1982, 1983; D. Harrington, University of Georgia Ma-

<sup>1</sup> Person to whom reprint requests should be addressed.



FIGURE 1.—Fin ray cross section from a 14-year-old male tilefish. FRR = fin ray radius = 0.593 mm (heavy black bar).

rine Extension Service, Brunswick, Georgia, personal communication).

Information on age, growth, and mortality is available for the heavily exploited Middle Atlantic Bight stock (Turner et al. 1983), but no comparable information exists for lightly or unexploited tilefish stocks. The objectives of this paper are to provide information on growth, mortality, and age composition of a lightly exploited segment of the South Atlantic Bight–Gulf of Mexico tilefish stock. This information will be useful in managing the rapidly developing fishery for tilefish in the South Atlantic Bight, and the estimates of natural mortality rates can be used in harvest models for other geographical areas.

#### Methods

Sampling was conducted aboard the R/V *Georgia Bulldog* during semimonthly cruises. Most sampling took place between May 1982 and October 1983 in an 18- by 5-km area 144 km due east of St. Catherines Island, Georgia,

and an 8- by 5-km area 149 km due east of Wassaw Island, Georgia.

Tilefish were captured on bottom longlines similar to those used by commercial fishermen: galvanized cable ground line; monofilament snoods snapped on at 3–6-m intervals; circle hooks of sizes 4/0 and 5/0, and whole squid (and sometimes cut fish) bait. Tilefish less than 10 kg were weighed to the nearest 0.1 kg, larger fish to the nearest 0.5 kg, and their standard (SL) and total lengths (TL) were measured to the nearest mm. After November 1982, fork length (FL) also was measured. Sagittal otoliths, dorsal spines, and anal rays then were removed. When catches were small, all fish were examined; however, large catches were haphazardly subsampled although a minimum of 90% of the catch was examined from all cruises.

Approximately 50 otoliths, dorsal fin spines, and anal fin rays collected during the first two cruises were examined microscopically to determine the best structure for aging. Cross sections of anal fin rays had clearer patterns of alternating hyaline and opaque bands than cross sections of dorsal spines or dorsoventral, diagonal, or longitudinal otolith sections. All aging was done from fin ray sections. Three to five cross sections (0.25 to 0.35 mm thick) were taken from the base of the third ray with a low speed saw and diamond grit blade. Sections were viewed in transmitted light at 100× magnification and hyaline bands were considered to be annuli (Beamish 1981). The distances from the focus to the distal edge of each hyaline band and to the edge of the section were measured along a plane extending from the long axis of the centrally located rectangular structure designated the focus (Fig. 1). Bimonthly mean marginal increments were calculated to validate annuli by the formula of Hayashi (1976a):

$$I = \frac{(R - r_n)}{r_n - r_{n-1}};$$

$R$  = radius to edge of ray;  
 $r_n$  = radius at the most recent complete annulus  $n$ .

Standard length at age was back-calculated for each fish by the Lee method, which corrects for variation in body part size in fish of the same length (Carlander 1981). Because the relationship of SL and fin ray radius was nonlinear, the data were transformed by  $\log_e$  so that intercepts

could be calculated through linear regression (Everhart et al. 1975). Von Bertalanffy growth curves then were fitted to weighted mean back-calculated SLs by nonlinear regression (SAS Institute 1982).

Mortality estimates were calculated separately for males and females by the catch curve regression method of Ricker (1975). This method is not sensitive to variations in recruitment (Ricker 1975). We also calculated mortality rates by the methods of Alverson and Carney (1975) and Pauly (1980).

### Results

We collected 1,351 male and 632 female tilefish during 13 cruises from May 1982 to August 1983. Anal fin ray sections were prepared for 1,337 male and 620 female tilefish; sections from 1,145 males (86%) and 523 females (84%) were readable. The number of fish aged per month ranged from 16 to 249 males and 6 to 83 females. Samples could not be obtained for October 1982 or May or July 1983.

#### Validation of Aging Technique

Tilefish anal fin ray sections contained numerous hyaline bands when viewed in transmitted light. These were followed around the entire section to identify an annulus. A single hyaline band sometimes became divided in the larger (presumably faster growing) posterior portion of the ray. Annulus measurements included the outermost section of split annuli.

Marginal-increment data indicated that a single annulus was formed each year between May and October. Mean increment ratios reached a minimum in September–October and a maximum in March–April (Fig. 2). The maximum increment should occur immediately before annulus formation. Interpretation of increment data was difficult because skin sometimes remained on the exterior of the ray, which made exact radius measurements difficult. In addition, hyaline bands at the margin were not easily recognized as annuli, because they frequently could not be observed around the entire ray section. Nonetheless, there was excellent agreement among back-calculated lengths at age for different age classes and between back-calculated and empirical lengths at age (Table 1). These results indicate that annuli on fin rays probably were formed once yearly and that fin ray sections were

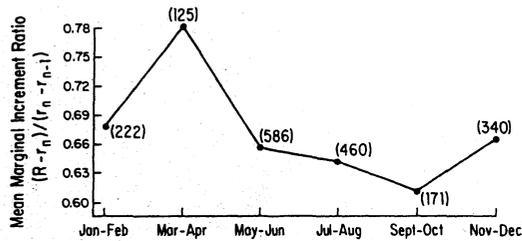


FIGURE 2.—Bimonthly marginal increment ratios for anal fin rays from Georgia tilefish.  $R$  is the radius to the edge of a ray;  $r_n$  is the radius to the outermost hyaline band. Sample sizes are in parentheses.

appropriate structures for age and growth analyses.

#### Age and Growth

Male tilefish aged in this study ranged from 376 to 925 mm SL and from 5 to 33 years old; females were from 385 to 778 mm SL and 6 to 32 years old (Figs. 3 and 4). Within this size range, SL, TL, and FL were highly correlated ( $r^2 = 0.99$  for all cases) and length relationships (in mm) for both sexes pooled were:

$$TL = 5.533 + 1.211SL;$$

$$TL = -16.036 + 1.083FL;$$

$$FL = 22.541 + 1.112SL.$$

Length–weight regressions (SL, mm;  $W$ , kg) were calculated separately for males, females, and all fish combined:

males ( $N = 1,145$ ;  $r^2 = 0.98$ ):

$$\log_e W = -18.653 + 3.141 \log_e SL;$$

females ( $N = 523$ ;  $r^2 = 0.96$ ):

$$\log_e W = -17.594 + 2.974 \log_e SL;$$

all fish ( $N = 1,668$ ;  $r^2 = 0.98$ ):

$$\log_e W = -18.417 + 3.104 \log_e SL.$$

Slopes of length–weight regressions of males and females were significantly different (analysis of covariance;  $P < 0.0001$ ).

Linear regressions of SL (mm) on fin ray radius ( $R$ , mm) are:

males ( $N = 1,145$ ;  $r^2 = 0.81$ ):

$$-\log_e SL = 6.895 + 0.642 \log_e R;$$

females ( $N = 523$ ;  $r^2 = 0.69$ ):

$$-\log_e SL = 6.764 + 0.530 \log_e R;$$

all fish ( $N = 1,668$ ;  $r^2 = 0.80$ ):

$$-\log_e SL = 6.882 + 0.639 \log_e R.$$

TABLE 1.—Back-calculated and empirical (at capture) standard lengths (mm) of tilefish captured off Georgia, May 1982–August 1983. Abbreviations:  $\overline{BC}$  = mean back-calculated length;  $\overline{E}$  = mean empirical length;  $I$  = annual growth increment (mm).

Age	N	Fin ray age (years)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<i>All fish</i>																	
5	4	92	238	311	373	425											
6	38	93	218	294	353	409	455										
7	70	97	220	289	349	404	453	494									
8	142	96	210	281	336	386	436	478	514								
9	224	96	206	271	323	370	412	452	489	522							
10	221	95	202	267	317	362	402	441	476	509	538						
11	215	99	204	269	319	362	401	438	472	506	535	561					
12	190	100	204	270	319	362	400	437	469	501	529	557	582				
13	134	101	213	278	328	370	409	444	479	511	541	570	597	621			
14	96	104	211	280	331	378	416	453	487	519	551	579	605	629	652		
15	74	106	213	281	332	379	417	454	487	521	553	582	608	633	655	677	
16	62	112	221	292	340	385	427	465	501	532	565	594	624	650	675	697	719
17	49	110	218	288	337	381	422	457	491	523	552	580	608	635	660	684	706
18	41	111	219	284	330	376	416	454	487	519	548	577	604	631	654	675	696
19	27	109	214	285	337	379	411	444	480	511	539	564	588	611	635	657	677
20	23	114	222	292	347	394	435	474	506	536	564	589	612	633	656	679	700
21	11	106	202	270	324	371	414	443	476	508	531	559	582	605	625	648	669
22	14	109	191	263	305	343	383	422	460	489	518	549	578	607	630	651	670
23	9	113	194	255	309	350	390	428	459	491	521	553	575	599	621	651	673
24	1	104	187	225	292	328	362	399	435	469	493	516	538	573	581	602	615
25	1	103	161	257	329	378	409	448	476	503	538	572	601	616	644	674	708
26	5	106	216	288	326	376	402	430	455	478	504	533	557	584	611	631	661
27	9	113	227	282	330	368	401	433	464	489	520	547	573	594	618	640	665
28	2	121	217	260	319	352	391	439	463	482	511	529	554	572	589	609	634
29	1	104	240	293	318	341	364	391	412	447	486	514	546	576	597	619	635
30	2	113	216	292	345	375	411	447	467	487	508	530	560	589	606	632	644
31	1	128	175	224	254	288	315	346	376	399	431	479	509	524	538	562	576
32	2	102	226	291	326	359	391	421	445	464	480	509	533	561	589	618	647
33	1	134	251	301	336	369	385	400	445	459	487	514	536	558	583	623	635
$\overline{BC}$		100	209	276	327	373	414	450	483	512	540	568	597	626	651	674	694
$I$							41	36	33	29	28	28	29	29	25	23	20
$\overline{E}$					471	481	516	534	540	554	577	596	635	666	689	730	
<i>Males (N in parentheses)</i>																	
$\overline{BC}$		103	214	282	334	380	422	459	493	524	552	581	610	641	668	691	712
$\overline{E}$						471	492	539	552	558	571	591	606	647	687	709	748
						(4)	(24)	(30)	(80)	(130)	(138)	(151)	(144)	(103)	(77)	(57)	(50)
<i>Females (N in parentheses)</i>																	
$\overline{BC}$		126	232	295	341	380	416	448	473	495	516	538	560	581	596	617	633
$\overline{E}$							461	500	512	517	525	544	562	595	582	624	655
							(14)	(39)	(62)	(94)	(83)	(64)	(46)	(31)	(19)	(17)	(12)

Intercepts from these equations were used to back-calculate length at age; due to differences in the  $SL-R$  relationship, separate intercepts were used for males and females.

Based on back-calculated lengths at age, males grew to 380 mm at age 5 and 887 mm at age 33 (Table 1). Female tilefish averaged 416 mm SL at age 6 and grew to 775 mm SL at age 32 (Table 1). Mean annual growth increments for ages 7–23 were consistently larger for males. Although the difference between sexes in any one year was

not large, by age 12, males were 50 mm longer (SL) than females and by age 20, 102 mm longer. The greatest differences occurred at ages 8–14, which corresponds with the onset of sexual maturity in females (Erickson and Grossman, unpublished).

Mean empirical length at age of males and females exceeded mean back-calculated lengths for almost all age classes (Table 1). This difference probably is due to growth since formation of the last annulus. Both sexes exhibited varia-

TABLE 1.—Extended.

Age	Fin ray age (years)																
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
<i>All fish</i>																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17	725																
18	716	737															
19	697	716	735														
20	725	746	763	781													
21	688	706	722	740	756												
22	690	708	725	740	753	776											
23	695	715	734	751	766	782	797										
24	627	647	667	682	694	717	724	732									
25	733	769	776	790	810	837	850	860	870								
26	690	709	721	734	750	763	774	785	797	808							
27	685	705	724	746	764	782	799	814	826	839	850						
28	652	671	691	716	741	756	769	784	799	813	824	838					
29	663	690	713	751	766	798	816	834	851	865	875	882	892				
30	655	667	681	697	718	734	752	767	779	794	811	824	837	843			
31	598	621	647	669	686	694	711	727	743	759	775	799	806	822	841		
32	662	673	686	697	710	719	738	756	762	771	783	793	808	824	832	846	
33	666	677	692	715	718	722	729	740	751	765	793	821	841	854	864	880	887
$\bar{BC}$	707	721	732	749	752	768	782	790	805	814	829	824	833	835	842	854	887
I	13	14	11	17	3	16	14	6	15	9	15		9	2	7	12	33
$\bar{E}$	738	747	746	790	765	777	808	739	883	816	857	847	889	852	852	848	900
<i>Males (N in parentheses)</i>																	
$\bar{BC}$	726	742	755	773	776	792	799	803	819	829	835	833	846	850	867	894	887
$\bar{E}$	754	768	771	816	787	826	845	739	883	883	857	847	899	852	852	919	900
	(40)	(33)	(20)	(18)	(8)	(9)	(7)	(1)	(1)	(3)	(9)	(2)	(1)	(2)	(1)	(1)	(1)
<i>Females (N in parentheses)</i>																	
$\bar{BC}$	642	652	661	671	675	678	684	702	710	720	747	750	756	763	769	775	
$\bar{E}$	665	662	675	697	706	688	680			716						778	
	(9)	(8)	(7)	(5)	(3)	(5)	(2)			(2)						(1)	

tion in mean empirical lengths at age indicating that individual growth rates varied considerably.

Von Bertalanffy growth curves were fit to back-calculated lengths at age:

$$L_t = L_\infty[1 - e^{-K(t-t_0)}];$$

- $L_t$  = length at age  $t$ ;
- $L_\infty$  = theoretical maximum length;
- $K$  = growth coefficient;
- $t$  = age (years);
- $t_0$  = age at which the fish would have had

zero length had it always grown in the manner described by the equations.

Resulting fits (Fig. 5) were:

- males:  $L_t = 922[1 - e^{-0.086(t+0.920)}];$
- females:  $L_t = 865[1 - e^{-0.090(t+1.774)}];$
- all fish:  $L_t = 907[1 - e^{-0.084(t+0.989)}].$

Estimates for  $L_\infty$  generally matched maximum lengths observed for both sexes during

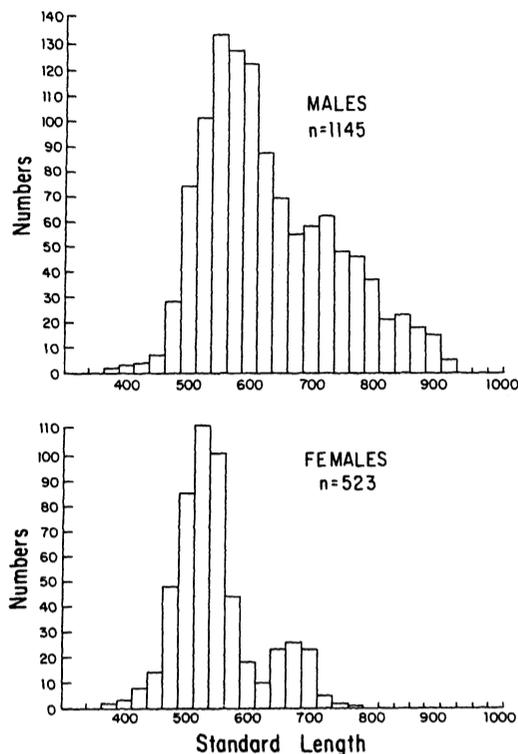


FIGURE 3.—Size composition for male and female tilefish from Georgia (May 1982–August 1983).

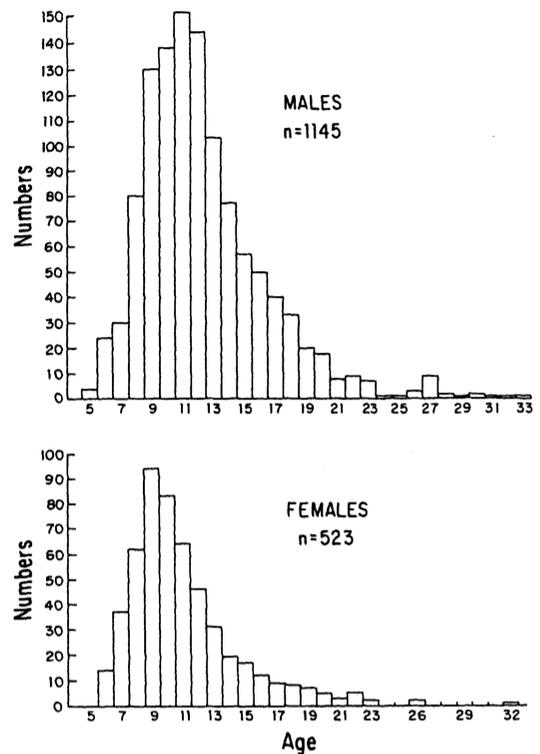


FIGURE 4.—Age composition for male and female tilefish from Georgia (May 1982–August 1983).

study (males, 925 mm SL; females, 778 mm SL). Estimates of  $K$  for males (0.086) and females (0.090) implied slow growth. Estimates of  $t_0$  for males (-0.920) and females (-1.774) were within the range expected given existing data from species with similar demographics (Manooch and Haimovici 1978; Nelson and Manooch 1982; Ross and Huntsman 1982; Huntsman et al. 1983; Turner et al. 1983; Moore and Labisky 1984).

A multivariate analysis of von Bertalanffy growth curves for males and females showed differences in growth (Hotelling's  $T^2 = 13,474$ ;  $P < 0.001$ ) (Bernard 1981). Roy-Bose simultaneous confidence intervals showed differences ( $P < 0.01$ ) between  $L_\infty$ ,  $K$ , and  $t_0$  for males and females.

#### Mortality

Modal ages at capture for male and female tilefish were 11 and 9, respectively (Fig. 4). We assumed that age at recruitment was 1 year greater than the modal age; hence, full recruitment for males occurred at age 12 whereas females

were fully recruited at age 10. To calculate mortality rates from a catch curve, two assumptions must be satisfied: first, recruitment and survival may not vary, and second, all fish above the age of recruitment must be equally vulnerable to capture (Robson and Chapman 1961). Length- and age-frequency histograms of tilefish showed no evidence of strong variation in year-class strength so an assumption of constant recruitment probably is valid (Figs. 3 and 4).

The assumption of constant survival only can be examined for May 1982 to August 1983. This assumption warrants testing, however, because commercial fishing began in the study area in August 1982. Comparison of length-frequency histograms of tilefish collected May–August 1982 ( $N = 1,456$ ), September 1982–February 1983 ( $N = 581$ ) and March–August 1983 ( $N = 361$ ) showed no clear evidence of truncation. In addition, Kolmogorov–Smirnov tests detected no significant differences in age-frequency distributions of tilefish 10 years and older (modal age from May 1982 to December 1983 was 10) for

May–August 1982 ( $N = 605$ ), March–August 1983 ( $N = 181$ ) and September–February 1983 ( $N = 405$ ). Although commercial fishing first was noted in August 1982 and continued throughout the study, increased fishing mortality did not appear to substantially alter the age or size composition of the catch through August 1983. Consequently, pooling of samples from May 1982 to August 1983 should be valid.

The assumption of equal vulnerability to capture cannot easily be addressed. The hook sizes (4/0 and 5/0 circle hooks) most commonly used for sampling were small enough to catch fully recruited fish (610-mm males and 516-mm females); hence, differential vulnerability due to gear selectivity probably did not occur. Differential vulnerability due to behavioral differences may have existed, especially because male and female tilefish were fully recruited at different ages and sizes. We assumed, however, that both sexes were equally vulnerable to longlining, although sex-linked differences in behavior might explain these disparities in age and length at recruitment.

Estimates of total mortality ( $Z$ ) for male and female tilefish were 0.252 and 0.247, respectively. For increased accuracy we deleted the single age-32 female. Analysis of covariance showed no difference ( $P > 0.19$ ) in the slopes of catch curves from which  $Z$  values were derived. If tilefish samples collected in this study were unbiased random samples from a lightly exploited substock, then estimates of total mortality should approximate natural mortality rates ( $M$ ). Given the longevity of tilefish, however, total-mortality estimates seemed too high to be attributable to natural mortality alone. For comparative purposes, we used the methods of Alverson and Carney (1975) and Pauly (1980), which do not require age structure data, to calculate  $M$  values for male and female tilefish. Mortality estimates were 0.118 for male and 0.107 for female tilefish by the Alverson–Carney method, whereas Pauly's method yielded estimates of 0.163 (males) and 0.175 (females).

Substantial fishing mortality could explain higher-than-expected  $Z$  values; however, the right limbs of catch curves for both sexes (Fig. 4) displayed no pronounced concavity such as would be expected if recent changes in fishing mortality had occurred (Ricker 1975). In addition,  $r^2$  values suggest a good linear fit to the descending limb (all  $r^2$  values were  $> 0.90$ ). Because esti-

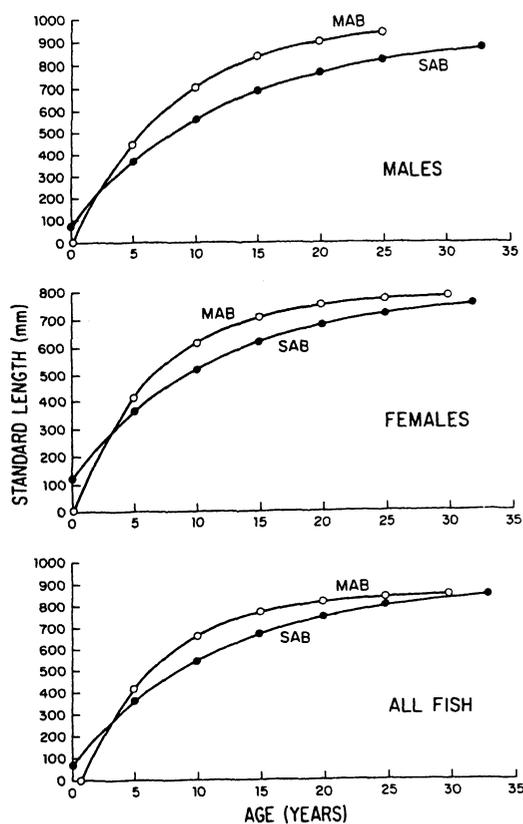


FIGURE 5.—Von Bertalanffy growth curves for tilefish from the Middle Atlantic (MAB) and South Atlantic (SAB) bights. Middle Atlantic Bight data are from Turner *et al.* (1983).

mates of  $Z$  for males and females were not significantly different, and estimates of  $M$  from the methods of both Alverson and Carney and Pauly were similar for males and females, a  $Z$  estimate was calculated for combined sexes. This value was 0.259 ( $r^2 = 0.89$ ). Given the estimates of the three methods it is likely that natural mortality for tilefish off Georgia is somewhere between 0.10 and 0.25.

#### Discussion

Anal fin ray sections were suitable for aging tilefish from the Georgia substock. Deterioration of the fin ray core was the most common problem affecting readability; however, 86% of male and 84% of female fin ray sections still were ageable. Fin ray sections have advantages over other aging structures in that they are much easier to obtain and section. In our samples, fin ray sections also

were more readable than otolith or dorsal spine sections.

Age and size structures of tilefish off Georgia were typical of lightly fished populations, with substantial numbers of old, large fish. Low et al. (1983) compared size structures of tilefish caught off South Carolina and Georgia with those of Middle Atlantic Bight catches from 1974 and 1978. Tilefish over 90 cm TL composed 17% of commercially caught Middle Atlantic Bight fish in 1974 and declined to 4% in 1978. Over 30% of the commercial catch from South Carolina between 1977 and the spring of 1981 was greater than 90 cm TL, whereas only 13% of research-caught tilefish after 1980 were greater than 90 cm TL. Low et al. (1983) attributed the difference in length between commercial and research catches to the selection of grounds that produce larger fish by commercial fishermen and suggested that research catches were a more accurate source of data for demographic analyses. Tilefish over 90 cm TL composed 13% of the catch in this study.

Age composition of tilefish in the Middle and South Atlantic bights differed strikingly. Turner et al. (1983) reported that only 28 fish (4%) were older than 10 years in a 1978 sample of 682 tilefish (305 females, 233 males, and 144 unknown sex) from the Middle Atlantic Bight. In contrast, 58% of the 1,668 tilefish aged in this study were older than 10 years. This difference probably is due to the greater level of exploitation experienced by the Middle Atlantic Bight stock.

Growth rates of tilefish also differed in Middle and South Atlantic Bight stocks. Values of  $K$  for male and female tilefish from the Middle Atlantic Bight were 0.145 and 0.175 (Turner et al. 1983), compared to 0.086 and 0.090 for males and females in this study. A comparison of von Bertalanffy growth curves for the two stocks best illustrates differences in growth rates. At ages less than 5, there were few differences in growth rates between the two stocks; however, from age 5 to 9, growth rates for tilefish of both sexes were considerably greater in the Middle Atlantic Bight (Fig. 5). These patterns may be due to growth compensation in the heavily exploited Middle Atlantic Bight stock or to environmental differences between the two areas.

Larger maximum size of males appears common in malacanthids, and has been reported in Middle Atlantic Bight tilefish (Turner et al. 1983), blueline tilefish *Caulolatilus microps* (Ross and

Huntsman 1982), and red tilefish *Branchiostegus japonicus japonicus* (Hayashi 1976b). Turner et al. (1983) concluded that the onset of sex-linked differences in growth were correlated with female maturation. Sex-specific differences in growth of tilefish off Georgia also were greatest after age 5 when 50% of females reached maturity (Erickson and Grossman, in press), which supports the conclusion of Turner et al.

In the South Atlantic Bight, tilefish are exploited as part of a deepwater (>200 m) assemblage which includes blueline tilefish, snowy grouper *Epinephelus niveatus*, and yellowedge grouper *E. flavolimbatus* (Low and Ulrich 1983). Growth coefficients for tilefish obtained in this study were lower than those reported for blueline tilefish— $K = 0.137$  (maximum age = 15 years: Ross and Huntsman 1982)—but slightly higher than those of snowy grouper— $K = 0.063$  (maximum age = 17 years: Matheson 1982). Information for yellowedge grouper is not available.

Total mortality of male and female tilefish off Georgia did not differ, so a pooled estimate (0.259) probably is the best estimate of  $Z$ . Turner et al. (1983) estimated a pooled  $Z$  of 0.37 for Middle Atlantic Bight tilefish, although strong variations in recruitment made mortality estimation difficult. They also detected no sex-related differences in mortality and stated that their estimates possibly were low due to increasing fishing effort. Higher mortality rates for Middle Atlantic Bight tilefish would be expected, given the greater level of exploitation experienced by this stock. Total mortality of tilefish off Georgia was similar to that of blueline tilefish, estimated to be 0.22 from combined landings of 1972–1977 (Ross and Huntsman 1982). Matheson (1982) also reported similar mortality ( $Z$ ) values for snowy grouper, ranging from 0.17 in 1975 and increasing to 0.34 in 1979.

#### Conclusions

The demographic information presented in this paper will aid in tilefish management in the South Atlantic Bight and other geographical regions. Development of a management plan for this species is needed because of the rapid development of the fishery; landings of tilefish in South Carolina, Georgia, and the east coast of Florida increased from 61 t in 1980 to 1,409 t in 1982 (S. Carolina: John DeVane, Jr., National Marine Fisheries Service, James Island; Florida: Ernie Snell, National Marine Fisheries Service, Miami).

Combined landings in 1983 were slightly over 909 t. Considering the slow growth rate of tilefish, caution regarding further expansion of the fishery is warranted (see Low et al. 1983).

Tilefish, blueline tilefish, and snowy grouper probably could be managed as a multispecies unit. All three species have similar life histories characterized by slow growth and relatively low natural mortality. Because species with these characteristics are strongly affected by fishing pressure, harvesting policies that limit fishing effort may be necessary for the maintenance of sustained yields from these species.

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