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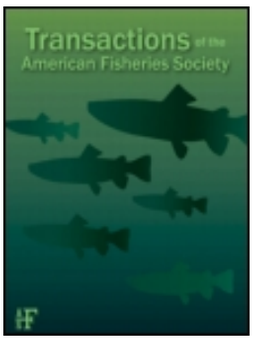

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Age, Growth, and Mortality of Blueline Tilefish from North Carolina and South Carolina

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Abstract

On otoliths from 283 blueline tilefish *Caulolatilus microps* captured off North Carolina and South Carolina, annulus formation occurred between February and April and was related to gonadal development and photoperiod. Mean back-calculated total lengths (TL, mm) were: age I, 165; II, 284; III, 358; IV, 415; V, 464; VI, 505; VII, 544; VIII, 577; IX, 608; X, 633; XI, 656; XII, 676; XIII, 693; XIV, 709; XV, 727. The oldest fish captured were age XV, and the largest was 780 mm TL and 5.6 kg. Growth in length by year t is described by the equation $TL_t = 813.5\{1 - \exp[-0.137(t + 1.03)]\}$. The length–weight relationship is $\log_e W = -12.286 + 3.142 \log_e TL$, where W = total weight in kg. Males generally were larger at age and lived longer than females. Blueline tilefish captured on headboats off South Carolina (mean = 609 mm TL) were larger than those from North Carolina (mean = 554 mm TL). Blueline tilefish are susceptible to hook-and-line fishing at age IV and are fully recruited by age VI. Instantaneous total mortality (Z) was 0.22 for 1972–1977.

In this paper, we describe the aging of blueline tilefish *Caulolatilus microps* (Goode and Bean 1878) by means of otoliths, discuss growth, length–weight equations, and size and age composition of the recreational catch, and estimate total annual mortality rates in North Carolina and South Carolina waters.

The blueline tilefish is a marine, semitropical demersal branchiostegid that attains a total length of at least 780 mm and a weight of 5.6 kg. The species inhabits the outer continental shelf, shelf break, and upper slope (Struhsaker 1969) along the Atlantic coast of North America from Cape Charles, Virginia south to Campeche, Mexico (Dooley 1978). Blueline tilefish generally are captured in depths of 75 to 200 m and occur to at least 236 m. Off North Carolina and South Carolina, blueline tilefish are a component of a fish assemblage that includes red porgy *Pagrus pagrus,* snowy grouper *Epinephelus niveatus,* warsaw grouper *E. nigritus,* yellowedge grouper *E. flavolimbatus,* vermilion snapper *Rhomboplites aurorubens,* silk snapper *Lutjanus vivanus,* and goldface tilefish *Caulolatilus chrysops.* This community is exploited by a recreational headboat fishery (Manooch 1975; Huntsman 1976) and by an expanding commercial fishery.

Recreational fishing vessels from North Carolina and South Carolina captured an estimated 1,267 to 5,623 blueline tilefish with a total weight varying between 2,963 and 13,336 kg during the 1972 through 1977 fishing seasons. These catches represented only 0.3% to 2.1% by number and 0.8% to 3.2% by weight of the total estimated recreational catch of all species from the offshore fishing grounds (45 to 140 meters depth). In hook-and-line samples from waters 80 meters and deeper, blueline tilefish ranked second to red porgies in abundance and third to red porgies and snowy groupers in total weight (Manooch 1975).

Of the few existing life-history reports on tilefishes, only three (Lim and Misu 1974; Hayashi 1976a, 1976b) dealing with red tilefish *Branchiostegus japonicus japonicus* describe age and growth in detail. The remaining published life-history work is embodied in two reports, one on ocean whitefish *Caulolatilus princeps* by Fitch and Lavenberg (1971), the other on tile-

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fish *Lopholatilus chamaeleonticeps* by Freeman and Turner (1977).

This study was part of a project conducted by personnel of the Beaufort Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, and was designed to provide information for managing demersal fish stocks off the southeastern United States.

Methods

We obtained blueline tilefish by hook and line from the R/V *Onslow Bay* off Cape Lookout, North Carolina and from headboats in North Carolina and South Carolina from 1972 to 1977 (Huntsman 1976). Total length in millimeters, weight in grams, and otoliths (sagittae) were obtained for all specimens. Otoliths were selected as aging structures because most scales were regenerated (Dooley 1974) and because otoliths had a readable pattern of concentric rings.

Blueline tilefish sagittae are concave, elliptical structures with convoluted margins that are most irregular anteriorly and dorsally. When immersed in glycerine and viewed over a dark background by reflected light, the hyaline (slow-growth) zones are narrower than the opaque (fast-growth) zones and are considered the annuli (Panella 1974). Numerous supernumerary hyaline growth checks, which are thin and discontinuous, are considered spawning checks (Williams and Bedford 1974) because (1) they occur after fish attain sexual maturity, (2) they are most pronounced in females and perhaps reflect greater metabolic debt of this sex during spawning, and (3) their multiplicity corresponds to the multiple spawnings and protracted spawning season (April through October) exhibited by blueline tilefish (Ross 1978). Measurements were taken along a line from the nucleus to the inner edge of each opaque zone and to the posteriodorsal margin. Marginal increments were measured from the inner margin of the last opaque zone to the sagitta edge.

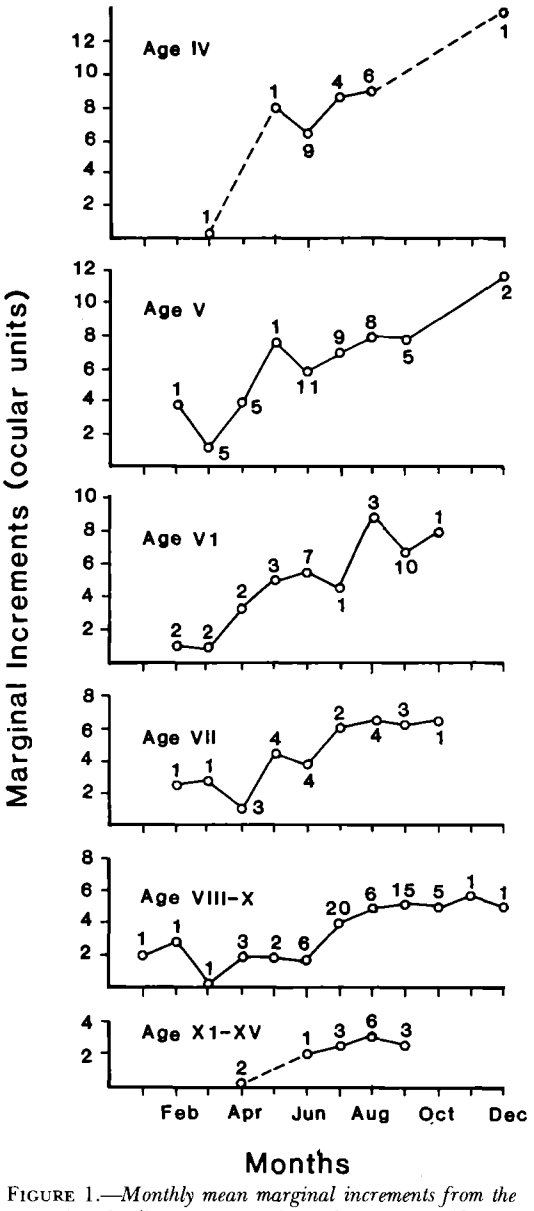

FIGURE 1.—*Monthly mean marginal increments from the previous hyaline zone on otoliths of age-IV–XV blueline tilefish. Numbers within each panel represent sample size.*

Results and Discussion

Validation of Aging Technique

We tested the hypothesis that hyaline rings were annuli by critically examining the formation of hyaline rings and analyzing the size frequencies of marginal increments (Fig. 1). Of 283 otolith pairs, 201 (71%) were legible and were measured.

Annuli (hyaline rings) formed on the sagittae from about February to April. Annulus formation in mature fish corresponded with the start of gonad development, which, in turn, appeared to be correlated with increasing photoperiod (Fig. 2). Formation of annuli in immature fish could have arisen from an innate

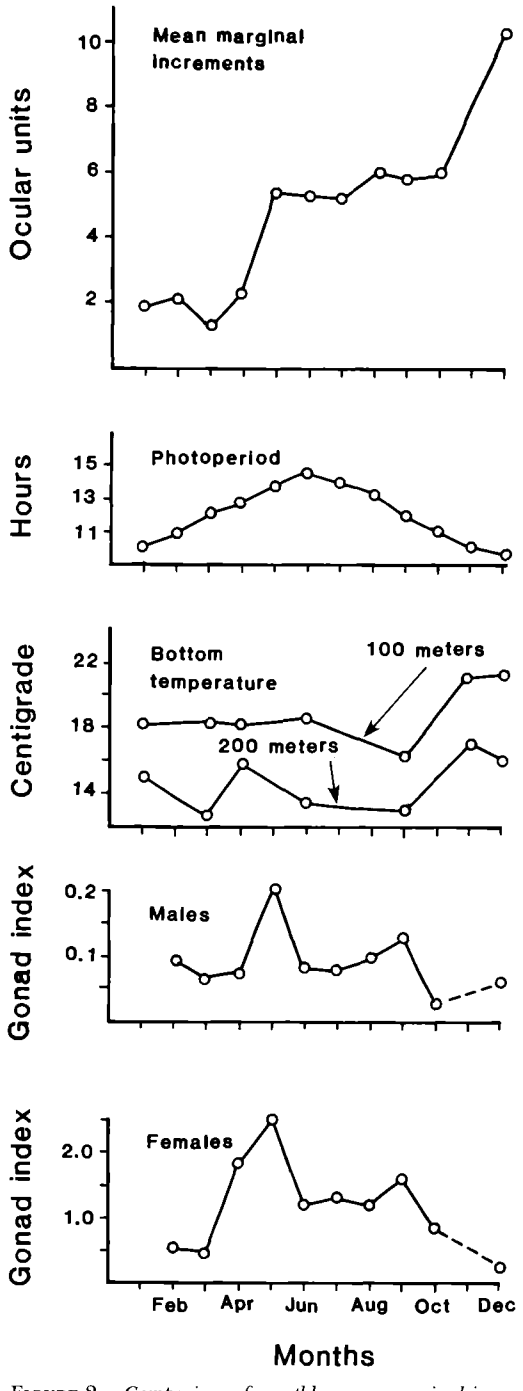

FIGURE 2.—*Comparison of monthly mean marginal increments (age classes pooled) of blueline tilefish otoliths with photoperiod, bottom water temperature (Steffanson and Atkinson 1967) and gonad indices [(gonad weight/total body weight) × 100] of females and males.*

physiological rhythm or feeding cycle attuned to photoperiod (Hartley 1947; Panella 1974). Temperature was not considered a critical triggering factor because the annual range of bottom temperatures (4–5 C) along the shelf-edge zone off the Carolinas is just equivalent to the minimum range that could induce decreased growth in fish (Chevey 1933). Steffanson and Atkinson (1967) reported bottom-temperature variations at times that would not correlate with time of annulus formation.

Although a linear relationship exists between total length (TL) and otolith radius (OR)—$TL = -13.16 + 90.13OR$; $r^2 = 0.86$)—we chose to estimate the total lengths of individual fish at precapture ages (Table 1) by the direct proportion back-calculations method: $L_n = (s_n/S)L$; L_n = total length at time of annulus formation; L = total length at time of capture; s_n = radius to respective annulus; S = total radius of sagitta (Carlander 1981). The assumptions that (1) blueline tilefishes maintain essentially the same body contour throughout their lives and (2) otolith and body growth are isometric (Tesch 1973; Everhart et al. 1975) were confirmed by the relation between length and weight (r^2 = 0.96), total length and standard length (r^2 = 0.99), and total length and sagitta radius (r^2 = 0.86). No correction term was employed because we had too few fish smaller than 400 mm TL to estimate it accurately.

Lengths at capture were consistently higher than back-calculated lengths for each age group; the difference was within the limit of a season's growth and related to the marginal increment.

Our collections did not yield fish small enough to verify the time of year that the first annulus formed, but the mean length (182.3 mm) of four specimens captured March 13, 1961 off North Carolina was within one standard deviation (SD = 21.3 mm) of our back-calculated length for age-I fish.

Growth

Based on weighted mean back-calculated lengths (Table 1), the von Bertalanffy (1938) growth model is $L_t = 813.5[1 - e^{-0.137(t+1.03)}]$, where L is total length and t is years. The theoretical maximum length, $L_\infty = 813.5$ mm, is reasonably close to the size of the largest fish that we sampled, 780 mm. The growth coefficient, $K = 0.137$, indicates slow attainment of maximum size and is similar to that of other

TABLE 1.—*Mean back-calculated and observed total lengths (mm) at age for 201 blueline tilefish aged by otoliths.*

Age group	N	Mean length at capture	Mean calculated total length at end of year														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
II	2	306	136	245													
III	5	402	161	278	360												
IV	22	447	163	285	357	411											
V	44	487	164	283	358	414	463										
VI	32	525	169	285	353	410	459	500									
VII	19	558	166	285	358	415	463	501	536								
VIII	29	594	162	278	354	412	460	503	540	571							
IX	13	619	166	279	355	416	464	507	544	577	605						
X	17	648	169	292	364	425	475	517	554	584	610	633					
XI	4	677	189	315	389	456	494	527	561	595	618	639	661				
XII	7	690	167	282	360	411	457	497	537	570	602	633	656	677			
XIII	2	698	156	276	376	447	497	533	569	597	621	643	662	683	698		
XIV	2	718	181	301	381	441	484	518	551	581	609	632	656	675	692	712	
XV	3	731	148	264	338	401	456	500	536	569	602	623	649	672	691	706	727
Weighted means			165	284	358	415	464	505	544	577	608	633	656	676	693	709	727
Growth increments			165	119	74	57	49	41	38	33	31	25	23	20	17	16	18

species from Carolina reefs: red porgy, 0.096 (Manooch and Huntsman 1977); white grunt *Haemulon plumieri*, 0.108 (Manooch 1978); gag *Mycteroperca microlepis*, 0.122 (Manooch and Haimovici 1978); vermilion snapper, 0.198 (Grimes 1978). The slow attainment of maximum size seems to reflect a pervasive ecological influence on upper-trophic-level reef fishes. Blueline tilefish, red porgies, white grunts and gags are benthic predators with slower growth rates than vermilion snappers, which feed at a lower trophic level (Grimes 1978; Huntsman and Manooch 1978; Ross 1982).

Blueline tilefishes exhibit differences in growth rates and longevity between the sexes that likely are related to their reproductive biology. Growth for both sexes was most rapid during their first 2 years. Males were consistently larger at comparable ages than females after age IV (Fig. 3), which corresponds to the age of female maturity and active ovary development (Ross 1978). Maximum growth and longevity of males also generally exceeded that of females (Fig. 4). Males constituted 87% of the blueline tilefish larger than 700 mm, 83% of the fish ages X–XV, and the average male (593 mm) was longer than the average female (527 mm). Nevertheless, females attained a maximum observed length of 759 mm and age of 15 years ($N = 1$). Similar sex-related variations in age and growth have been observed for other tilefish species. Male red tilefish grow faster and are consistently larger than females after age I, the time of attainment of sexual maturity by females (Lim and Misu 1974; Hayashi 1976b). Earlier female maturity, the preponderance of males in the largest size classes, and greater maximum sizes attained by males likewise has been observed for tilefish (Freeman and Turner 1977), goldface tilefish (Ross, unpublished data), and anchor tilefish *Caulolatilus*

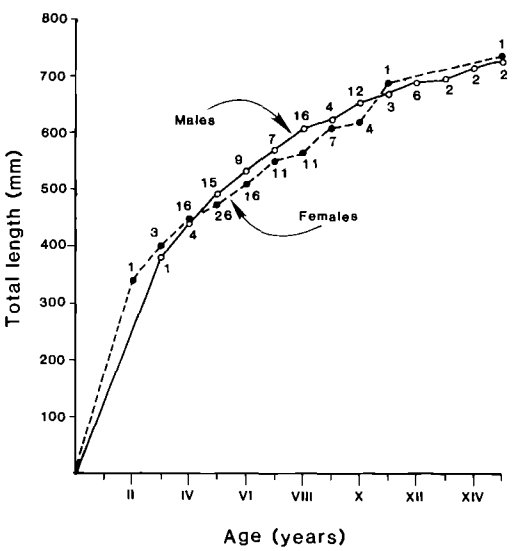

FIGURE 3.—*Empirical mean total lengths of female and male blueline tilefish captured off North Carolina and South Carolina by recreational and research hook-and-line fishing. Sample sizes are presented adjacent to the respective size at age.*

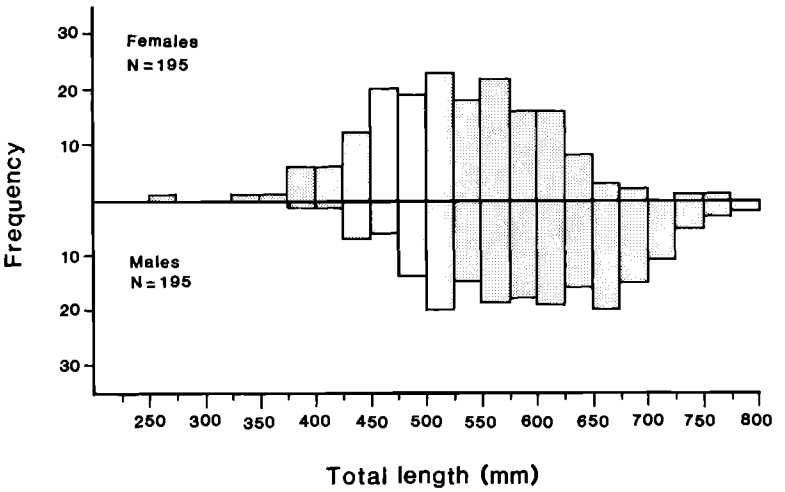

FIGURE 4.—*Length frequencies (25-mm size classes) of male and female blueline tilefish captured from North Carolina and South Carolina waters by recreational and research hook-and-line fishing.*

intermedius (Ross, Pavela, and Chittenden, unpublished data). Whether this is related to decreased growth rates and longevity due to the much greater relative gonadal production by females or protogynous sex reversal has not yet been established.

Morphometric Relationships

The relationship between body weight (W, g) and total length (TL, mm), based on 601 fish, is $\log_e W = -12.286 + 3.142 \log_e TL$; $r^2 = 0.96$. For fish captured off North Carolina, the relationship for females is $\log_e W = -11.495 + 3.024 \log_e TL$; $r^2 = 0.96$; $N = 120$; for males: $\log_e W = -10.498 + 3.297 \log_e TL$; $r^2 = 0.97$; $N = 113$. Females are significantly heavier at size than males ($P < 0.01$), probably because of greater gonad development. Mature ovaries range from 6 to 143 g whereas mature testes weigh only 0.8 to 12.0 g (Ross 1978).

Total length and standard length (SL) are linearly related and highly correlated: $SL = -19.21 + 0.864TL$; $r^2 = 0.99$.

Size and Age Composition

Blueline tilefish generally are not susceptible to capture by hook and line until they attain 400 mm (about age IV) and are not fully recruited to the recreational fishery until they are 500 to 525 mm (about age VI) (Fig. 5). Of the total catch (research and recreational fishing), 4.6% was under 400 mm and 23.8% was smaller than 500 mm. Because females average 400–425 mm and males approximately 500 mm at maturity (Ross 1978), few immatures are taken.

Blueline tilefish are recruited to the North Carolina and South Carolina fisheries at about the same size (350–500 mm), but disproportionately more large fish were captured off South Carolina (609-mm mean) than off North Carolina (554-mm mean) (Fig. 5). Of those taken off North Carolina, 31% exceeded 600 mm and 4.4% were 700 mm or larger; of those cap-

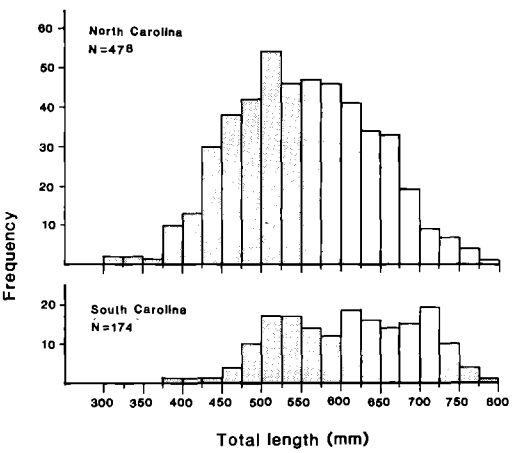

FIGURE 5.—*Length frequencies (25-mm size classes) of blueline tilefish captured from North Carolina and South Carolina waters by recreational and research hook-and-line fishing, 1972–1977.*

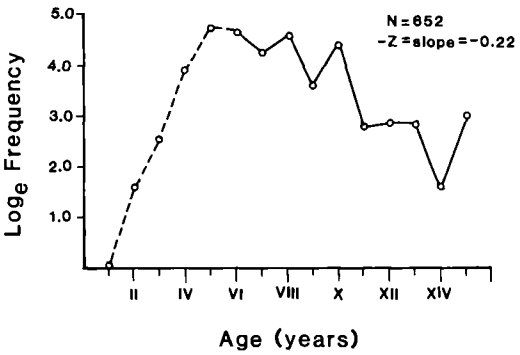

FIGURE 6.—*Catch curve of estimated age frequency (log_e) for blueline tilefish captured from North Carolina and South Carolina waters by recreational and research hook-and-line fishing, 1972–1977. Solid line indicates age groups from which instantaneous mortality rate (Z) was calculated.*

tured off South Carolina, the comparable percentages were 55.7 and 19.5. The larger and older fish from South Carolina could be the result of more favorable conditions for growth and longevity but also might reflect the shorter and less intense exposure of the South Carolina population to fishing.

To determine age frequencies of the catch and to subsequently predict mortality rates from 1972 through 1977, we grouped blueline tilefish of known age by 25-mm TL intervals. The percentages of fish of each age in each group were used in combination with the length-frequency distribution of 652 fish captured off North and South Carolina to estimate the number of fish of each age.

We estimated instantaneous total mortality (Z) from 1972 to 1977 to be 0.22 by calculating the slope of the descending leg of the catch curve (Fig. 6) from age VI. This is potentially an underestimation of Z if larger fish are increasingly vulnerable to hook-and-line fishing gear. However, it is comparable to estimated values of Z during 1975 for co-occurring speckled hind *Epinephelus drummondhayi* ($Z = 0.23$; maximum age $\cong$ 15+ years), slightly higher than longer-lived snowy grouper ($Z = 0.17$; maximum age $\cong$ 17+ years) and lower than shorter-lived red porgy ($Z = 0.58$; maximum age $\cong$ 12 years) (Manooch and Huntsman 1977; Matheson 1982).

Estimates of Z for the individual years (1973–1977) for pooled recreational fishery and research cruise age-composition data indicated an increase from 0.15 in 1974 and 1975 to 0.30–0.31 in 1976 and 1977. The expansion of offshore bottom fishing off the Carolinas in the early 1970s (Huntsman 1976) to recent levels (Table 2) might have caused these increased mortality rates. These data do not necessarily

TABLE 2.—*Recreational landings and average weights of blueline tilefish from North Carolina and South Carolina, 1972–1977.*

Sampling area	Year	Angler-days	Number caught	Total weight (kg)	Average weight (kg)
Cape Lookout, North Carolina	1972	9,954	4,727	10,130	2.14
	1973	13,342	728	1,534	2.11
	1974	10,604	1,138	2,055	1.81
	1975	5,263	81	180	2.22
	1976	5,109	1,005	2,275	2.26
	1977	6,207	936	2,016	2.15
Cape Romain, South Carolina	1972	13,244	452	1,051	3.32
	1973	20,837	984	3,267	3.32
	1974	13,136	4,306	11,049	2.56
	1975	13,428	1,373	4,177	3.04
	1976	19,127	2,125	5,797	2.73
	1977	20,105	331	947	2.86
Total area[a] (includes Cape Hatteras and Cape Fear)	1972	25,080	5,623	13,282	2.36
	1973	43,270	2,065	4,919	2.38
	1974	31,035	5,488	13,336	2.43
	1975	27,290	1,510	4,481	2.97
	1976	34,932	3,141	8,103	2.58
	1977	33,002	1,267	2,963	2.34

[a] Offshore only; see Huntsman (1976).

represent the entire North Carolina and South Carolina shelf region but, rather, the regularly fished, more accessible fishing grounds of single-day fishing trips. Similar increased mortality rates from 1975 to 1979 have been noted for snowy grouper (Z increased from 0.17 to 0.34) and speckled hind (Z increased from 0.26 to 0.40) due to increased and expanded commercial fishing effort (Matheson 1982). The increased mortality rates for blueline tilefish, while not necessarily representative of the entire shelf population, could indicate the need for conservative harvesting of this species in light of their presumably nonmigratory nature.

Acknowledgments

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