Transactions of the American Fisheries Society 128:751–757, 1999
American Fisheries Society 1999

Observations on the Age and Growth of Graysby and Coney from the Southeastern United States

JENNIFER C. POTTS* AND CHARLES S. MANOOCH III

National Marine Fisheries Service, Southeast Fisheries Science Center, Beaufort Laboratory, 101 Pivers Island Road, Beaufort, North Carolina 28516-9722, USA

Abstract.—The graysby *Epinephelus cruentatus* and coney *E. fulvus* are two uncommon groupers occurring off the southeastern coast of the United States. Limited recreational fishery data suggest that graysbies are being landed with increasing frequency in the area. From 1979 to 1997, 118 graysbies and 55 coneys were collected from the headboat fishery operating from North Carolina through the Dry Tortugas, Florida. Ages were estimated using transverse sections of sagittal otoliths. Graysbies ranged in total length (TL) from 180 to 405 mm and in age from 4 to 13 years. Coneys ranged from 150 to 397 mm TL and from 2 to11 years old. Growth of the graysby is represented by the following models derived from back-calculated lengths (L) at ages (t) and observed lengths at ages, respectively: $L_t = 451(1 - e^{-0.12(t+1.24)})$ and $L_t = 446(1 - e^{-0.13(t+1.51)})$. Coneys grew faster and had a smaller theoretical maximum size than graysbies: from back-calculated lengths at ages, $L_t = 372(1 - e^{-0.32(t-0.20)})$, and from observed lengths at ages, $L_t = 385(1 - e^{-0.32(t-0.49)})$. The weight–length relationships for graysby and coney are $W = 8.81 \times 10^{-6}(L)^{3.12}$ and $W = 2.59 \times 10^{-5}(L)^{2.94}$, respectively, where W = whole weight (g) and L = total length (mm).

The graysby *Epinephelus cruentatus* and coney *E. fulvus* are two closely related, small tropical groupers that range from Bermuda and North Carolina through Brazil (Nagelkerken 1979), although they are most abundant in the Caribbean. In the Caribbean, the coney is found on shallow patch reefs, whereas the graysby is more closely associated with continuous, deepwater coral reefs (Nagelkerken 1981).

Although graysbies and coneys are important components of the commercial fishery in the Caribbean (Thompson and Munro 1978), they constitute only a very minor portion of the commercial and recreational landings from North Carolina through the Florida Keys. Most commercial landings for the two species in the southeastern United States occur on the East Coast of Florida, where they are rare and are often categorized as "unclassified grouper." In the southeastern USA, the recreational headboat[1] fishery landings from 1981 to 1996 of coneys were less than 300 kg (600 fish) annually. Headboat landings of graysbies were less than 500 kg (740 fish) per year until 1992 when landings began to rise, reaching 1,850 kg (3,586 fish) in 1996. The most dramatic increase in the headboat landings of graysbies occurred off the Carolinas. Before 1992, less than 20 kg were landed annually. In 1992 landings rose to 313 kg and increased to 1,215 kg in 1996. The other recreational landings database, Marine Recreational Fishery Statistical Survey (MRFSS), had a paucity of landings for coneys and none for graysbies.

This study was undertaken because little is known of the life history parameters of the graysby and its closely related congener coney, which are increasingly landed in the reef fish fisheries of the southeastern USA. Both species are included in the Fishery Management Plan for reef fish developed by the South Atlantic Fishery Management Council (SAFMC 1983). We describe the mean size at age and the growth patterns of these two tropical groupers.

Methods

Sagittal otoliths of graysbies and coneys were collected from specimens caught by anglers on headboats operating from Morehead City, North Carolina, through the Dry Tortugas, Florida, and a few from commercial fishermen operating off northeast Florida. Total length (mm), whole weight (g), and date and location of landing were recorded for each specimen. Otoliths were mounted on cardboard tabs with a thermo-plastic cement for transverse sectioning on a low-speed saw. Two or three thin sections (0.3–0.5 mm) were removed near the primordium of the sagitta. The sections were viewed under a dissecting microscope at 10× magnification with reflected light. Clove oil was added to the sections to enhance the appearance of growth zones. If the opaque zones were distinct

* Corresponding author: jennifer.potts@noaa.gov

Received July 2, 1998; accepted September 18, 1998

[1] Headboats are those usually carrying more than six passengers and charge on a per-person basis, thus by the "head."

and made continuous orbits around the primordium, they were counted as presumed annuli. Ages were assigned to each sample, and lateral measurements on the dorsal side of the section from the focus to each opaque zone and the otolith margin were recorded.

Marginal increment analysis was used to determine if opaque zones were annual. Monthly mean distance plots from the last zone to the otolith margin for all age-groups were analyzed. If the opaque zones were formed once each year, then the plot should reveal a minimum zone-to-margin increment followed by increased increment width as additional growth followed annulus formation. To further substantiate estimated ages, two independent readers assigned an age to each sample and the results were compared.

The fish length and otolith radius relationship was described by regressing the observed total length on otolith radius (R_C). The linear equation was $L = a + b(R_C)$, where L = total length in millimeters. The back-calculated total lengths at each age were determined from the otolith proportional equation (Carlander 1981; Johnson et al. 1996):

$$L_A = a + (L_C - a)(R_A/R_C);$$

L_A = back-calculated length to annulus A,
a = intercept from the linear total length–otolith radius regression,
L_C = total length at capture,
R_A = otolith radius to annulus A, and
R_C = total otolith radius at capture.

Growth parameters L_∞ (theoretical asymptotic fish length), K (growth coefficient), and t_0 (theoretical age at beginning of growth) were estimated using SAS PROC NLIN with the Marquardt Option (SAS Institute 1982). These parameters were derived from the von Bertalanffy equation $L_t = L_\infty\{1 - \exp[-K(t - t_0)]\}$ and were fitted to back-calculated length-at-age data from the most recent annulus to not violate the statistical assumption of independence of errors (Ricker 1975; Everhart et al. 1981; Vaughan and Burton 1994). We also estimated the growth parameters from observed lengths at ages. Because the samples were spread out over the whole year and the annulus was laid down predominantly in April, we added 0.5 to all the whole ages (e.g., 4.5, 5.5, etc.). By adjusting the ages, we accounted for the continuous growth throughout the year. To describe the relationship of fish weight to fish length we used a $\log_e$–$\log_e$ regression and transformed the equation to $W = a(\mathrm{TL})^b$, where W = weight in grams, and TL = total length in millimeters.

Results and Discussion

A total of 118 graysby (115 headboat; 3 commercial) and 55 coney (52 headboat; 3 commercial) samples was collected between 1979 and 1997. The graysbies ranged from 180 to 405 mm in total length (TL) and from 110 to 1,200 g in whole weight. The coneys ranged from 150 to 397 mm TL and from 65 to 1,160 g in whole weight. Because of the relative rarity of these two species in the southeastern USA and the lack of emphasis put on them from a management viewpoint, samples were difficult to obtain. Many more years of sampling most likely would not result in a significant increase in the number of samples.

Otoliths were easily read for both species. Wide translucent zones alternated with thin opaque zones. The opaque zones were considered annuli for both species. Most of the otoliths formed one opaque zone per year, though some double banding was present. The double banding was distinguished by discontinuous orbits around the focus of the false opaque zone. For the graysbies from the Caribbean, Nagelkerken (1979) described seeing as many as three zones per year on the sagittae. Thompson and Munro (1978) attempted to age coneys with whole otoliths, and described the otoliths as having numerous light and dark zones, but the zones were not related to seasonal factors. They also noted that otoliths from epinephiline species were dense, making them hard to read. Instead, the authors used length-frequency analysis to estimate growth. In a review of aging techniques for tropical reef fish, Brothers (1982) discussed the lack of strongly expressed annual or seasonal growth and reproductive cycles as found in temperate fish, hence making the interpretation of time markers on otoliths of tropical species difficult. Because the waters off the southeastern USA are subtropical to temperate, the growth zones on the otoliths of these two species may have been enhanced. And, by thin-sectioning the otoliths, the zones were more easily read.

Marginal increment (MI) analysis for graysbies validated the annular deposition of the opaque zones by showing the smallest mean MI occurring in April, similar to the findings of Nagelkerken (1979). Sagittae with MI = 0 occurred only during February and April (Figure 1a). The monthly ranges of the marginal increments clearly showed increasing increment widths after a low in April. The wide range of increment widths by month could

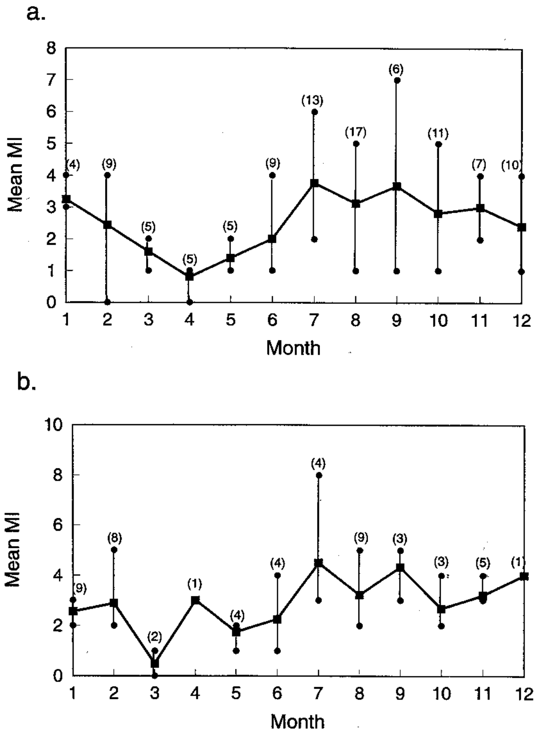

FIGURE 1.—Marginal increment (MI) analysis of **(a)** graysbies and **(b)** coneys from the southeastern USA, illustrating the mean marginal increments, their ranges, and samples sizes (in parentheses) by month from all age-classes.

be due to the older fish having opaque zones closer and closer together as the rate of growth decreases, thus the marginal increments are smaller. This is in contrast to younger fish in the same month with wider spacing of zones and wider marginal increments. Marginal increment analysis of coneys exhibited a similar pattern, but MI values of zero occurred in March (Figure 1b).

Both authors assigned ages to each sample, resulting in 70% agreement for graysbies; 29 of 34 disagreements were ±1 year. Seventy-five percent of paired readings agreed for coneys; 9 of 14 disagreements were ±1 year. One-year discrepancies were primarily due to interpretation of the opaque zone near the margin. The remaining samples, which disagreed ±2 years, were mostly due to double banding of the opaque zones. The samples in contention were reread by both authors, and agreement was reached on the assigned age.

Estimated ages of graysbies ($N = 115$) ranged from 4 to 13 years; mean observed size at age ranged from 242 to 405 mm (Table 1). Of those aged, 104 were legible enough to record the measurements to each opaque zone and the margin. During our aging process, we observed that the graysbies from southeast Florida were smaller at age than those from North Carolina. Because of the small sample size, we were not able to test this hypothesis, but Figure 2 illustrates our findings. At all ages with paired means, except age 7, the total lengths of fish from the Carolinas were larger than the means from Florida, and the 95% confidence intervals followed the same pattern.

TABLE 1.—Total length (TL, mm) of graysbies from the southeastern USA, back-calculated using the otolith proportional equation, and observed TL.

Age (years) or statistic	*N*	Annulus 1	2	3	4	5	6	7	8	9	10	11	12	13
							Back-calculated TL							
4	3	84	130	179	215									
5	15	88	142	182	212	240								
6	32	89	140	181	216	244	266							
7	14	86	145	184	218	249	278	300						
8	12	89	147	190	224	250	272	289	304					
9	11	91	151	186	227	251	274	291	306	320				
10	7	86	147	184	216	244	269	289	305	320	332			
11	1	87	159	220	258	280	297	308	319	330	341	346		
12	5	89	157	199	231	259	284	305	321	333	345	356	365	
13	1	96	167	209	250	286	310	334	351	363	375	387	393	399
Total *N*	101													
Mean		88	145	185	219	248	272	295	309	325	340	359	370	399
Interval			57	40	34	29	24	23	14	16	15	19	11	29
							Observed TL (*N*)							
Mean					242 (3)	261 (18)	284 (33)	317 (18)	315 (13)	328 (11)	351 (10)	355 (2)	371 (6)	405 (1)

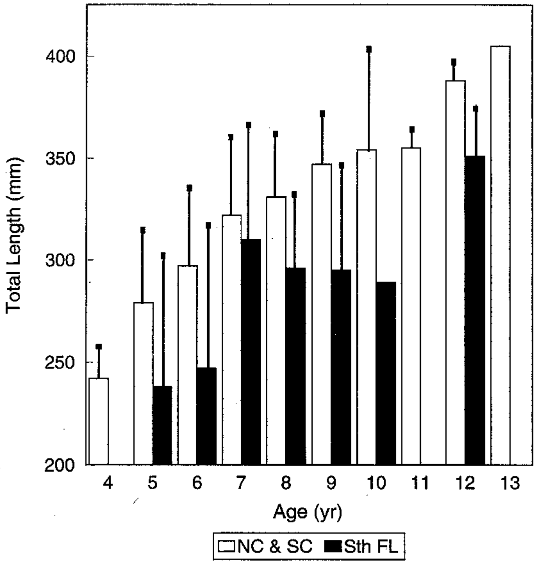

FIGURE 2.—Mean observed total length at age (years) of graysbies from North Carolina and South Carolina (NC & SC) versus southeast Florida (Sth FL) with 95% confidence intervals.

Coney (N = 53) ages ranged from 2 to 11 years; mean observed size ranged from 150 to 385 mm (Table 2). All of the coney samples were legible enough to take the measurements to each opaque zone and the margin.

The linear regression of the total length on otolith radius for graysby was TL = $-23.05 + 5.57(R_C)$, $r^2 = 0.77$, and for the coney was TL = $35.01 + 5.12(R_C)$, $r^2 = 0.83$. The back-calculated lengths at ages were estimated (Tables 1, 2) and used in subsequent analysis.

Because these species are protogynous hermaphrodites, their growth is continuous for both sexes, thus we present only one growth curve for each species. Furthermore, Nagelkerken (1979) found the pattern of growth of male and female graysbies in the Caribbean to be the same. The theoretical growth equation derived from the back-calculated lengths at ages for graysby is $L_t = 451(1 - e^{-0.12(t+1.24)})$, whereas the one derived from the observed lengths at ages is $L_t = 446(1 - e^{-0.13(t+1.51)})$ (Table 3). These two equations are very similar to that derived by Nagelkerken (1979): $L_t = 415(1 - e^{-0.13(t+0.94)})$ (Figure 3). The theoretical growth equation derived from the back-calculated lengths at ages for coney is $L_t = 372(1 - e^{-0.32(t-0.20)})$, and the one derived from the observed lengths at ages is $L_t = 385(1 - e^{-0.32(t-0.49)})$ (Table 3).

In comparing theoretical growth parameters for these two groupers, coneys attained a smaller asymptotic size, but grew faster than graysbies. Thompson and Munro (1978) estimated an L_∞ of 340 mm and K of 0.63 for the coney from length-frequency analysis, which also illustrates the smaller size and faster growth rate of coneys compared with graysbies. Though our sample size is small, we believe our estimates of L_∞ and K for coney are more reasonable (Figure 4) than those previously presented, because the value for K is

TABLE 2.—Total length (TL, mm) of coneys from the southeastern USA, back-calculated using the otolith proportional equation, and observed TL.

Age (years) or statistic	N	Annulus 1	2	3	4	5	6	7	8	9	10	11
		Back-calculated TL										
2	1	94	125									
3	7	134	187	232								
4	8	136	198	234	264							
5	11	136	185	223	256	279						
6	10	140	204	241	272	295	315					
7	7	147	210	251	280	302	321	339				
8	3	136	192	232	258	285	307	323	340			
9	1	154	217	253	279	295	310	321	331	341		
10	3	145	189	216	243	264	284	301	316	331	344	
11	2	135	187	228	256	276	297	318	336	351	364	374
Total N	53											
Mean		138	194	234	265	287	311	325	330	339	352	374
Interval			56	40	31	22	24	14	5	9	14	12
		Observed TL (N)										
Mean			150	248	278	291	333	353	355	357	354	385
			(1)	(7)	(9)	(11)	(11)	(7)	(3)	(1)	(3)	(2)

TABLE 3.—von Bertalanffy parameters derived from back-calculated lengths at ages and observed lengths at ages for graysby and coney with 95% confidence intervals (CI).

Parameter	Value	SE	Lower CI	Upper CI
Graysby				
Back-calculated				
L_∞	451	87	279	623
K	0.12	0.07	−0.02	0.26
t_0	−1.24	1.94	−5.08	2.60
Observed				
L_∞	446	74	298	593
K	0.13	0.07	−0.02	0.27
t_0	−1.51	2.31	−6.09	3.05
Coney				
Back-calculated				
L_∞	372	14	343	401
K	0.32	0.06	0.20	0.44
t_0	0.20	0.44	−0.69	1.08
Observed				
L_∞	385	15	354	416
K	0.32	0.07	0.19	0.45
t_0	0.49	0.51	−0.54	1.52

closer to K values estimated for other groupers (Manooch 1987), and the L_∞ is closer to the maximum observed size.

The relationship of weight to length of graysby is represented by the equation $W = 8.81 \times 10^{-6}(L)^{3.12}$ ($N = 102$, $r^2 = 0.93$, MSE = 0.02), where W = whole weight (g) and L = total length (mm). This relationship is similar to those found by Nagelkerken (1979) and Thompson and Munro (1978) for this species from the Caribbean.

The weight–length relationship for coney is described by the equation $W = 2.59 \times 10^{-5}(L)^{2.94}$ ($N = 45$, $r^2 = 0.94$, MSE = 0.02). Coneys from Jamaica apparently weigh less at a given length than specimens from the southeastern USA (Thompson and Munro 1978), though this may be due to the limited sample size from our study.

Graysbies and coneys from the southeastern USA exhibit similar growth patterns to those from the Caribbean though subtle differences may exist. Graysbies may grow faster at the northern end of their range. Coneys appear to be slightly heavier for a given size in the southeastern USA. Another closely associated small tropical grouper, the red hind *E. guttatus,* exhibits a similar trend of larger, younger fish in the southeastern USA than in the Caribbean (Sadovy et al. 1992; Potts and Manooch 1995).

A recent upward trend in headboat landings of graysbies could suggest this grouper has become more abundant off the southeastern USA in the last two decades. This hypothesis is supported by diver observations as reported by Parker and Dixon (1998), who noted a significant increase in occurrence of the graysby on a reef site off the North Carolina coast between the periods of 1975–1977

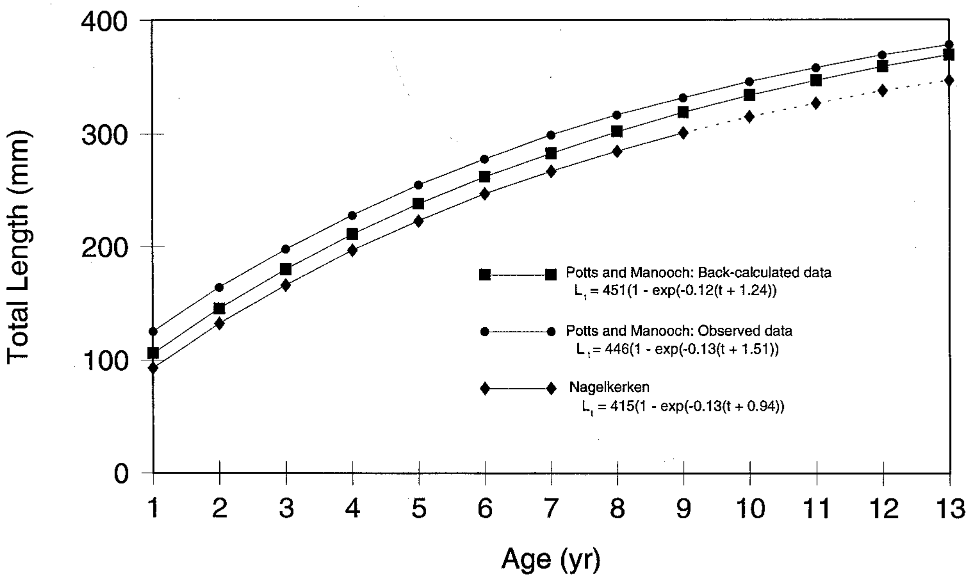

FIGURE 3.—Comparison of von Bertalanffy growth curves of graysbies from the southeastern USA and Curaçao, Netherlands Antilles (Nagelkerken 1979). The dashed line indicates the continuation of the curve beyond the reported maximum age (years).

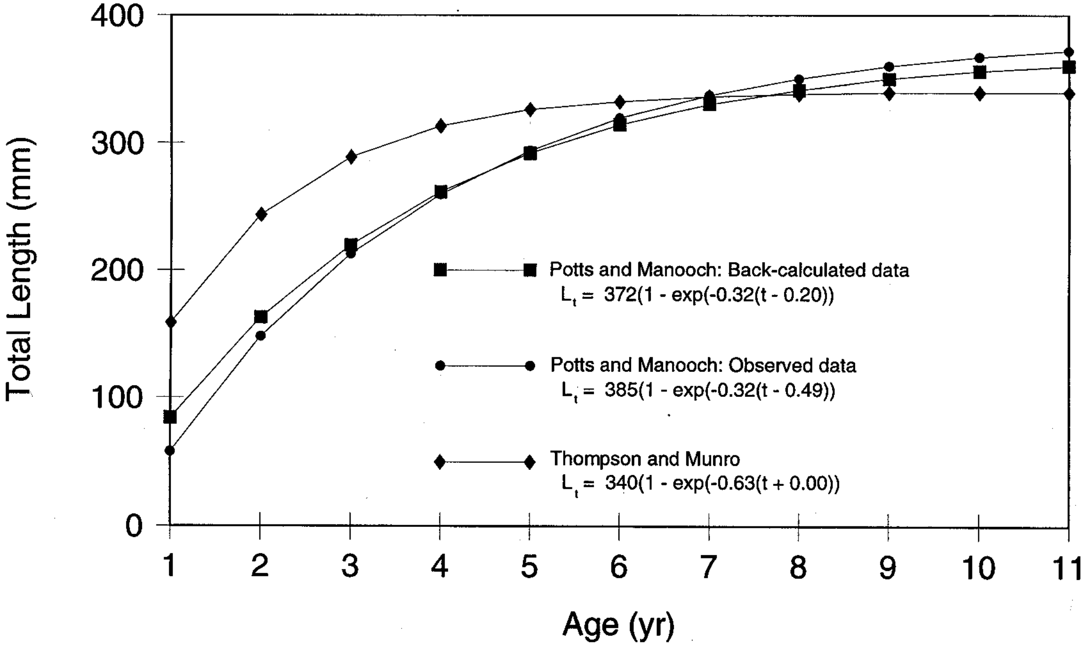

FIGURE 4.—Comparison of von Bertalanffy growth curves of coneys from the southeastern USA and Jamaica (Thompson and Munro 1978).

and 1990–1992. They also noted increases in other species of tropical fish at the North Carolina reef site, which could indicate either intense fishing pressure has changed the species composition or that the ocean water temperature is rising, allowing tropical species to occupy more northerly habitats.

Acknowledgments

We thank the National Marine Fisheries Service (NMFS) port agents in the southeastern USA who collected the otolith samples from graysbies and coneys. Thanks are due also to Michael Burton and Joseph Smith of NMFS, Beaufort Laboratory, Beaufort, North Carolina, for reviewing the initial drafts of this manuscript and to Bill Richards of NMFS, Miami Laboratory, for a final review.

References

Brothers, E. B. 1982. Aging reef fish. Pages 3–23 *in* G. R. Huntsman, W. R. Nicholson, and W. W. Fox, Jr., editors. The biological bases for reef fishery management. NOAA Technical Memorandum NMFS-SEFC-80.

Carlander, K. 1981. Caution on the use of the regression method of back-calculated lengths from scale measurements. Fisheries 6(1):2–4.

Everhart, W. H., A. W. Eipper, and W. D. Youngs. 1981. Principles of fishery science, 2nd edition. Cornell University Press, Ithaca, New York.

Johnson, A. J., L. A. Collins, and C. P. Keim. 1996. Age–size structure of gray snapper from the southeastern United States: a comparison of two methods of back-calculating size at age from otolith data. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 48(1994): 592–600.

Manooch, C. S., III. 1987. Age and growth of snappers and groupers. Pages 329–373 *in* J. J. Polovino and S. Ralston, editors. Tropical snappers and groupers biology and fisheries management. Westview Press, Boulder, Colorado.

Nagelkerken, W. P. 1979. Biology of the graysby, *Epinephelus cruentatus,* of the coral reef of Curaçao. Studies on the Fauna of Curaçao and Other Caribbean Islands 60:1–118.

Nagelkerken, W. P. 1981. Distribution of the groupers and snappers of the Netherlands Antilles. Pages 479–484 *in* C. E. Birkland and five coeditors. The reef and man. Proceedings of the fourth international coral reef symposium, volume 2. University of the Philippines, Quezon City, Philippines.

Parker, R. O., Jr., and R. L. Dixon. 1998. Changes in a North Carolina reef fish community after 15 years of intense fishing—global warming implications. Transactions of the American Fisheries Society 127: 908–920.

Potts, J. C., and C. S. Manooch III. 1995. Age and growth of red hind and rock hind collected from North Carolina through the Dry Tortugas, Florida. Bulletin of Marine Science 56:784–794.

Ricker, W. E. 1975. Computations and interpretations of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Sadovy, Y., M. Figuerola, and A. Roman. 1992. Age and growth of red hind, *Epinephelus guttatus*, in Puerto Rico and St. Thomas. Fishery Bulletin 90: 516–528.

SAFMC (South Atlantic Fishery Management Council). 1983. Fishery management plan, regulatory impact review, and final environmental impact statement for the snapper–grouper fishery of the South Atlantic Region. SAFMC, Charleston, South Carolina.

SAS Institute. 1982. SAS user's guide: statistics. SAS Institute, Cary, North Carolina.

Thompson, R., and J. L. Munro. 1978. Aspects of the biology and ecology of Caribbean reef fishes: Serranidae (hinds and groupers). Journal of Fish Biology 12:115–146.

Vaughan, D. S., and M. L. Burton. 1994. Estimation of von Bertalanffy growth parameters in the presence of size-selective mortality: a simulation example with red grouper. Transactions of the American Fisheries Society 123:1–8.