Estimated ages of red porgy (*Pagrus pagrus*) from fishery-dependent and fishery-independent data and a comparison of growth parameters

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Abstract—The red porgy, *Pagrus pagrus*, is an important reef fish in several offshore fisheries along the southeastern United States. We examined samples from North Carolina through southeast Florida from recreational (headboat) and commercial (hook and line) fisheries, as well as samples from a fishery-independent source. Red porgy attain a maximum age of at least 18 years and 733 mm total length. The weight-length relationship is represented by the ln-ln transformed equation: $W = 8.85 \times 10^{-6}(L)^{3.06}$, where W = whole weight in grams, and L = total length in mm. The von Bertalanffy growth equation fitted to the most recent, back-calculated lengths from all the samples is $L_t = 644(1 - e^{-0.15(t + 0.76)})$. Our study revealed a difference in mean length at age of red porgy from the three sources. Red porgy in fishery-independent collections were smaller at age than specimens examined from fishery-dependent sources. The difference in length-at-age may be related to gear selectivity and have important consequences in the assessment of fish stocks.

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Red porgy, *Pagrus pagrus*, inhabit continental shelves in temperate and tropical waters throughout the Atlantic Ocean and Mediterranean Sea. The species supports fisheries in many countries and is heavily exploited. Since 1992, red porgy has ranked relatively high (38 of 200) in value among all finfish landed commercially in the southeastern United States.[1] Red porgy form a substantial part of overall reef fish landings, especially in North Carolina and South Carolina, although there is little directed fishing for the species. Commercial landings of red porgy from the southeastern U.S. peaked in 1982 at 535 metric tons (t) and declined to 134 t in 1993 (Potts and Burton[2]). Red porgy ranked second by weight for reef fish landed by recreational headboat[3] anglers through the early 1980s. Since then, headboat landings of red porgy have declined, and landings of vermilion snapper, *Rhomboplites aurorubens*, which are also declining, have now surpassed red porgy. White grunt, *Haemulon plumieri*, and gray triggerfish, *Balistes capriscus*, which were less preferred than other members of the snapper grouper complex, have increased in landings and now surpass red porgy.[4]

Mean weight of red porgy from the commercial and recreational fisheries has declined from 1.06 kg in the 1970s to 0.66 kg in 1997.[2] Minimum size regulations (305 mm total length) for recreational and commercial fisheries enacted in 1992 did little to increase mean weight in catches, although the headboat fishery did show a slight increase from 0.48 kg in 1991 and 1992 to 0.60 kg in 1997. Additionally, population biomass estimates for red porgy in the southeastern United States have plummeted from a peak of 3.27×10^6 kg in 1978 to 0.43×10^6 kg in 1992 (Huntsman et al.[5]). These trends suggest that red porgy stocks are being overexploited.

Age determination studies have been conducted throughout the range of red porgy. Manooch and Huntsman (1977) conducted the first comprehensive study using scales (n=1777) and whole otoliths (n=222) to age red porgy that were caught by recreational fishermen using hook-and-line gear off North Carolina and South Carolina when the species was lightly exploited (1972–74). Harris and McGovern (1997) aged red porgy from whole otoliths (n=4281) of

1 General canvas. 1998. Unpubl. data. Miami Laboratory, National Marine Fisheries Service, 75 Virginia Beach Dr., Miami, Florida 33149.

2 Potts, J. C., and M. L. Burton. 1999. Trends in catch data for fifteen species of reef fish landed along the southeastern United States. Unpubl. data. South Atlantic Fishery Management Council, 1 Southpark Circle, Charleston, SC 29407.

3 A “headboat” is a fishing vessel that carries more than six passengers who pay per person (or by the “head”) to go offshore fishing.

4 Headboat annual summaries. 1998. Unpubl. data. Center for Coastal Fisheries and Habitat Research, Beaufort Laboratory, 101 Pivers Island Rd., Beaufort, NC 28516-9722.

5 Huntsman, G. R., D. S. Vaughan, and J. C. Potts. 1994. Trends in population status of red porgy, *Pagrus pagrus*, in the Atlantic Ocean of North Carolina and South Carolina, USA, 1971–1992. Unpubl. data. South Atlantic Fishery Management Council, 1 Southpark Circle, Charleston, SC 29407.

fish caught from North Carolina to Florida with fishery-independent gear during 1979–81 and 1988–94. Nelson (1988) aged red porgy with scales (n=126) from fish caught in the northwestern Gulf of Mexico with fishery-independent hook-and-line gear and trap gear during 1980–82. In the eastern Gulf of Mexico, Hood and Johnson (2000) aged red porgy from sectioned otoliths (n=852) collected from headboat and commercial catches during 1995–96. Vassilopoulou and Papaconstantinou (1992) used scales from 138 red porgy that were taken with fishery-independent hook and line and trammel nets in the Mediterranean Sea during 1985–86, and Serafim and Krug (1995) aged red porgy from whole otoliths (n=358) that were collected by using commercial longlines and fishery-independent gear in the Azores during 1991–93. Researchers in the Canary Islands aged 1505 red porgy from commercial trap and longline samples during 1985–86 and 1991–93 (Pajuelo and Lorenzo, 1996), and researchers off the Argentinian coast used trawl-caught samples during 1972–81 to obtain 5859 red porgy that were aged from scales (Cotrina and Raimondo, 1997).

Predictions of fish populations from models rely heavily on input data sets, including age and growth. If samples used in the aging study are not representative of the entire population (i.e. the entire geographic range of the stock, full range of fish size, and different gear types), model predictions (e.g. spawning potential ratio [SPR]) can mislead management decisions. A comparative stock assessment of red porgy was done by using growth parameters and age-length keys generated from two studies: 1) fishery-independent data (Harris and McGovern, 1997) and 2) fishery-dependent data (Manooch and Huntsman, 1977; Potts et al.[6]). Each set of age and growth data was applied to fishery-dependent landings and length frequencies. The fishery-independent age and growth data produced a static SPR of 46%, which is well above the overfished definition (SPR<30%) as set forth by the South Atlantic Fishery Management Council (SAFMC). The fishery-dependent age and growth data produced a static SPR of 19% (Potts et al.[6]), which makes red porgy, by definition, overfished and which necessitates that stringent management measures be put in place to protect the stock.

The purpose of our study was to update the age and growth information on red porgy caught in the recreational and commercial fisheries operating along the southeastern United States. We present the von Bertalanffy growth model, weight-length relationship, and age-length keys for red porgy collected from the headboat hook-and-line fishery, commercial hook-and-line fishery, and fishery-independent samples. We also compare mean age at length of red porgy collected from recreational fisheries, commercial fisheries, and fishery-independent sources. We discuss how data source selection affects the growth parameters.

[6] Potts, J. C., M. L. Burton, and C. S. Manooch, III. 1998. Trends in catch data and estimated static SPR values for fifteen species of reef fish landed along the southeastern United States. Unpubl. data. South Atlantic Fishery Management Council, 1 Southpark Circle, Charleston, SC 29417.

Materials and methods

Sagittal otoliths were collected from red porgy landed by hook-and-line fishermen from the headboat (recreational) fishery (n=249) between 1989 and 1998 (59% from 1996 to 1998) and the commercial fishery (n=264) between 1997 and 1998 operating from North Carolina to southeast Florida. From the two fisheries, 64% of the samples came from North Carolina, 14% from South Carolina, and 22% from the east coast of Florida. Because of minimum size limit regulations (305 mm total length), the South Carolina Department of Natural Resources (SCDNR) Marine Monitoring and Prediction (MARMAP) Program supplied us with otoliths from red porgy that were smaller than those available from the fisheries (n=59) and an additional 62 samples ranging from 300 to 425 mm total length. These fish were caught primarily with Chevron traps off South Carolina during 1996 and 1997. Total length, whole weight, port of landing, and date of capture were recorded for each sample. The otoliths were stored dry in coin envelopes.

For age analysis, three transverse (dorsoventral) sections from the left otolith of each fish were taken by using a low-speed saw. One section was made on either side of the core, and the other encompassed the core. The sections were mounted on glass slides with thermal cement, and examined through a microscope at 80× and illuminated with reflected light. Clove oil was applied to each section to enhance the legibility of the growth zones on the section. The samples were put in sequential order from smallest to largest, and one reader counted the number of opaque zones in the otolith section. A second reader examined a random sample of the otoliths. If the readers disagreed on the age of a sample, they examined it again. If consensus was reached, the sample was retained; otherwise, the sample was discarded. Measurements from the core to the outer edge of each successive opaque zone and the otolith margin were taken along the lateral plane on the dorsal lobe of the section by using an ocular micrometer.

Analysis of the marginal increment (the distance between the last opaque zone and otolith margin) was used to validate the annual deposition of the opaque zones in the otoliths. For each age and month, the mean of the relative marginal increment, the ratio of the marginal increment to the distance between the last two opaque zones, was plotted. An opaque zone was considered an annulus if a minimum ratio was recorded for one month or season.

The relationship of fish length and otolith radius 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 mm.

The back-calculated total lengths at each age were determined from the body proportional equation (Francis, 1990):

$$L_A = \left[(a + b\,R_A)/(a + b\,R_C)\right] L_C,$$

where L_A = back-calculated total length to annulus A;
a = intercept from the linear total length-otolith radius regression;
b = slope from the linear total length-otolith radius regression;
L_C = total length at time of capture;
R_A = otolith radius to annulus A; and
R_C = total otolith radius at time of capture.

The von Bertalanffy equation, $L_t = L_\infty[1 - \exp(-K(t-t_0))]$, was fitted to back-calculated lengths-at-ages for the most recently formed annuli (Ricker, 1975; Everhart et al., 1981; Vaughan and Burton, 1994). Growth parameters were estimated by using SAS PROC NLIN with the Marquardt Option (SAS Institute, 1982) for all aged fish and for fish obtained from fishery-dependent sampling.

Differences in mean back-calculated length at age for the most recently formed annulus for the three sample sources, i.e. recreational, commercial, and fishery-independent, were tested by using the general linear model analysis of variance.

To estimate the whole weight of gutted red porgy landed in the commercial fishery and to estimate stock biomass from assessment models, a regression of ln(*fish weight*) on ln(*fish length*) was performed and transformed to $W = a(L)^b$, where W = weight in g, and L = total length in mm.

Age-length keys were constructed from observed age at length by sample source in which the ages were unadjusted for time of year. Fish that were aged were assigned to 25-mm length intervals.

Results

Red porgy sampled for our study ranged from 176 to 733 mm TL and from 117 to 5895 g in whole weight. Ages were determined for 631 of 634 (99%) sectioned sagittal otoliths. Of those aged, 603 (95%) otoliths were considered legible to record measurements from the core to each successive opaque zone and the otolith margin. On twenty additional samples, we were able to measure only the otolith radius. Sectioned otoliths exhibited a recurrent pattern of alternating wide translucent zones and thin opaque zones. Estimated ages ranged from 1 to 18 years.

Analyses of marginal increment data indicated that the opaque zones were annular in nature and were formed in the spring (Fig. 1). Mean relative marginal increments for ages 2 through 8 were lowest in March through May and were the only months that had marginal increments equal to zero. They then steadily increased from June through October and remained high through February.

Back-calculated total lengths at age of red porgy were estimated from the parameters from the regression equation of total length (L) on otolith radius (R_c). The plot of length on radius was linear, and the linear regression equation that best fitted the data was $L = -132.84 + 10.87(R_c)$ (r^2=0.91, n=623). Using the Francis (1990) body proportional hypothesis, we found that weighted mean back-calculated lengths ranged from 103 mm for age-1 fish to 721 mm for age-18 fish (Table 1).

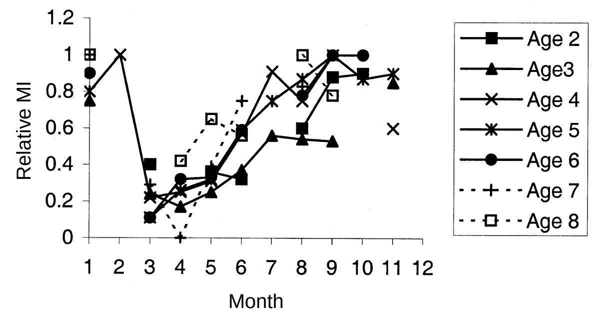

Figure 1
Mean monthly relative marginal increment (MI) of red porgy from the southeastern United States plotted by age.

The back-calculated lengths at the last annulus formation were used to estimate the von Bertalanffy equation. The equation parameters (±1 SE) were L_∞ = 644.72 ±17.93, K = 0.15 ±0.01, and t_0 = –0.76 ±0.10. The theoretical lengths at age ranged from 149 mm at age 1 to 605 mm at age 18. Theoretical lengths closely fitted the observed and back-calculated lengths through age 14 (Table 1). When we used fishery-dependent samples only to generate the von Bertalanffy growth equation, the resulting parameters (±1 SE) were L_∞= 773.73 ±39.49, K = 0.09 ±0.01 and t_0 = –1.96 ±0.21. The fishery-dependent theoretical lengths at age ranged from 181 mm at age 1 to 646 mm at age 18.

We used ages 2 through 6 and data years 1996 through 1998 to compare length at age of the three data sources because the three sets overlapped for those ages and years. The ANOVA on the mean back-calculated length at age of the most recently formed annulus between sample sources indicated a significant difference in age at size between the MARMAP, headboat, and commercial red porgy samples (r^2=0.88; F-value=522.21; P=0.0001 for all combinations) and were represented by the model

$$TL = \alpha_0 + \gamma_C c + \gamma_h h + \sum_{j=1}^{5} \beta_j A_j,$$

where c = 1 if fishery = commercial, or c = 0 if fishery ≠ commercial;
h = 1 if fishery = headboat, or h = 0 if fishery ≠ headboat;
A_1 = 1 if age = 2, or A_1 = 0 if age ≠ 2, etc.; and
j = age categories.

Average $TL = \alpha_0$ for fishery = fishery-independent and age = 6; average $TL = \alpha_0 + \gamma_c c$ for fishery = commercial and age = 6; etc. The model indicated no year effect, and no interaction between fishery and age. MARMAP (fishery-independent) samples were smaller at age than those from the commercial and headboat fisheries. Although mean back-calculated lengths at age between headboat and commercial data sources were statistically different, the differences were slight (<15 mm) (Fig. 2).

Table 1

Mean back-calculated, mean observed, and theoretical total lengths (mm) of red porgy from the southeastern United States.

		Annulus number																	
Age (yr)	*n*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	15	134																	
2	33	96	206																
3	136	98	208	274															
4	158	104	212	274	327														
5	136	105	212	274	326	363													
6	56	104	215	275	329	367	399												
7	31	107	216	284	342	381	413	441											
8	26	100	213	278	332	371	400	427	449										
9	6	106	221	283	337	377	410	438	461	483									
10	1	121	221	278	334	379	412	457	491	513	536								
11	2	112	215	275	329	362	395	427	449	476	498	520							
12	1	108	219	274	330	374	407	440	462	485	507	529	551						
14	1	111	226	294	351	385	419	442	465	487	510	533	556	567	579				
18	1	116	247	306	365	413	448	484	506	531	555	567	591	614	638	662	686	709	721
Total	603																		
Weighted mean TL		103	211	275	329	368	404	436	455	489	517	534	566	591	608	662	686	709	721
Incremental growth		103	108	64	54	39	36	32	19	34	28	17	32	25	17	54	24	24	12
Observed TL		198	236	303	350	386	423	459	470	508	547	536	562		590				733
Theoretical TL		149	218	278	329	374	410	443	471	495	516	534	549	562	574	583	592	599	605

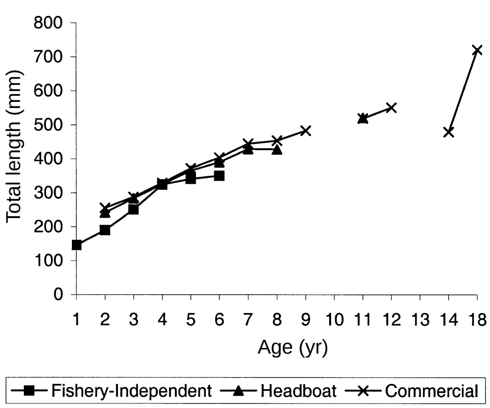

Figure 2

Mean back-calculated length at age of red porgy obtained from a fishery-independent source (MARMAP), headboat operations, and commercial fishery operations between 1996 and 1998.

The weight-length relationship for red porgy in the southeastern United States was best described by the converted ln-ln regression equation of $W = 8.85 \times 10^{-6}(L)^{3.06}$ (r^2=0.96, n=230, MSE=0.01).

Age-length keys by sample source are presented in Table 2. The fishery-independent key is appropriate for fishery-independent length data only. The headboat and commercial keys can be used to convert unaged length samples of red porgy from the fisheries operating in the southeastern United States to aged ones. Annual keys were not available owing to the small sample size from each year.

Discussion

In two previous aging studies on red porgy from the southeastern United States, populations were examined at two different levels of exploitation and different structures were used to determine age. Manooch and Huntsman (1977) sampled recreationally caught fish from an almost virgin stock off North Carolina and South Carolina during 1972–74. Although they used scales and whole otoliths, the main focus of their study and the analysis were on ages determined from scales. Of the 3278 scales analyzed, only 54% (1901) were legible enough to record ages. The main problem of aging red porgy with scales was the large number of regenerated scales.[7] Harris and McGovern (1997) used whole otoliths (n=4281) to age fish collected between 1979 and 1981 and between 1988 and 1994 from the MARMAP survey, a fishery-independent source. The 1988–94 samples in their study came from the area off North Carolina through northeast Florida, although 73% were collected in the area off Charleston, SC, between 32°N and 33°N. The samples were limited mainly to individuals below 450 mm TL (less than 1% of samples were

[7] Manooch, C. S. 1998. Personal commun. NOAA, Center for Coastal Fisheries and Habitat Research, 101 Pivers Island Road, Beaufort, NC 28516.

Table 2

Age-length keys for red porgy from the southeastern United States by sample source: fishery-independent, headboat, and commercial. Total length classes are in 25-mm intervals (i.e. 175 = 175–199).

		Age (yr)																	
TL class	*n*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Fishery-independent																			
175	11	10	1																
200	21	5	16																
225	7		1	6															
250	9			9															
275	10			10															
300	16			8	6	2													
325	20				11	9													
350	11				5	5	1												
375	14				6	8													
400	1					1													
425																			
450																			
475																			
500																			
525																			
550																			
575																			
725																			
Total	120																		
Headboat																			
175																			
200																			
225	3		3																
250	6		5	1															
275	28		5	23															
300	44			36	7	1													
325	48			15	31	2													
350	41			2	23	16													
375	37				11	21	5												
400	19					11	5	2	1										
425	11					2	5	2	2										
450	5						1	3	1										
475	2							2											
500	3							1		2									
525	2										1	1							
550																			
575																			
725																			
Total	249																		

continued

>450 mm). The data Harris and McGovern presented for the period between 1979 and 1981 showed that 8% of the samples for the reproductive study were greater than 450 mm TL. We sampled from a heavily exploited stock, and fish ranged up to 733 mm TL, and 14% of the fishery-dependent samples were greater than 450 mm TL. Additionally, our samples of red porgy were from a broader geographic range (52% from North Carolina, 30% from South Carolina, assuming all MARMAP samples were from South Carolina, and 18% from east coast Florida) than that of previous studies. Our distribution of samples more closely reflected the landings of red porgy in the southeastern United States. Also, we used sectioned otoliths, which have been determined to be the best struc-

Table 2 (continued)

TL class	*n*	Age (yr) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Commercial																			
175																			
200																			
225																			
250																			
275	5		2	3															
300	25			22	3														
325	34			4	27	3													
350	28				24	4													
375	37				8	24	5												
400	44					29	14		1										
425	27					6	17	3	1										
450	31						7	16	8										
475	20							5	15										
500	7								1	6									
525	1											1							
550	1												1						
575	1														1				
725	1																	1	
Total	262																		

Table 3

Mean observed total length (mm) of red porgy from this study and others: 1 = our study (all data combined); 2 = Manooch and Huntsman (1977: scale data); 3 = Manooch and Huntsman (1977: otolith data); 4 = Harris and McGovern (1997: 1994 data year); 5 = Harris and McGovern (1997: 1988 data year).

Age (yr)	Study 1	2	3	4	5
1	198	238	229	218	224
2	236	290	288	294	297
3	303	342	331	306	329
4	350	382	374	328	379
5	386	419	402	344	445
6	423	451	425	362	399
7	459	483	453	386	431
8	470	505	474	374	406
9	508	527	496		448
10	547	543	534	449	
11	536	558	557		
12	562	604			
13		595			
14	590				
15		694			
16					
17					
18	733				

ture to age fish in many studies (Beamish, 1979; Boehlert, 1985; Smale and Punt, 1991).

Red porgy form their opaque zones during the spring along the southeastern United States. Both Manooch and Huntsman (1977) and Harris and McGovern (1997) reported that annulus formation occurred in red porgy during March and April. We found that the opaque zone formed from March through May. Springtime formation has also been reported from the Gulf of Mexico (Nelson, 1988; Hood and Johnson, 2000), from the Azores (May; Serafim and Krug, 1995) and from Argentinian waters (October; Cotrina and Raimondo, 1997). Pajuelo and Lorenzo, in their (1996) study of red porgy off the Canary Islands, found that the opaque zone was formed during the summer (June through October).

A comparison of the mean length at age from our study and that from Harris and McGovern's (1997) study from 1994 (Table 3) clearly reveals that red porgy caught with fishery-independent gear are much smaller at age for fish 3 years and older than fish caught with fishery-dependent gear. Mean size at age in our study was similar to data for fish 5 years and older reported by Manooch and Huntsman (1977) using otoliths, although our mean sizes were smaller that those reported for their scale data. Ages 1–5 of our study were a mix of MARMAP samples and fishery-dependent samples, which may explain why red porgy were smaller for those ages than those reported by Manooch and Huntsman (1977). The mean observed length at age from our study were on average 23 mm smaller than the corresponding lengths from Manooch and Huntsman (1977) for ages 6 through 12 as assigned by scales. The differences may

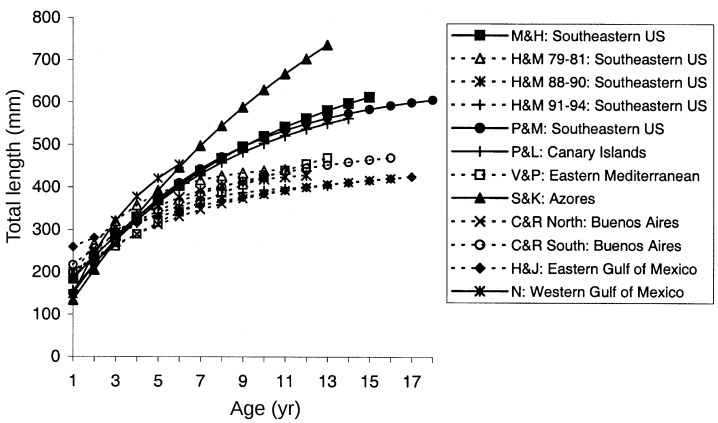

Figure 3

Comparison of von Bertalanffy growth curves from various locations in the Atlantic Ocean: M&H = Manooch and Huntsman (1977); H&M = Harris and McGovern (1997) from three separate data year sets; P&M = Potts and Manooch (this study); P&L = Pajuelo and Lorenzo (1996); V&P = Vassilopoulou and Papaconstantinou (1992); S&K = Serafim and Krug (1995); C&R = Cotrina and Raimondo (1997) from two study areas; H&J = Hood and Johnson (2000); N = Nelson (1988).

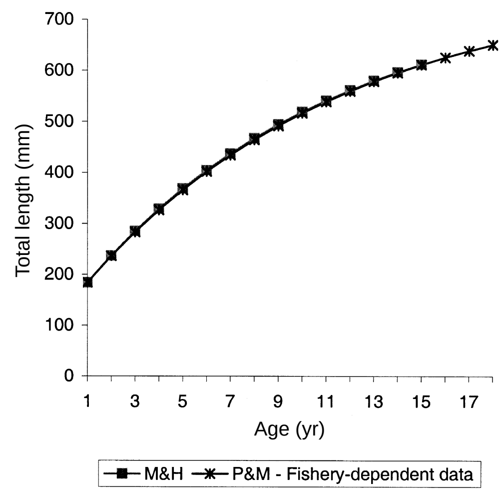

Figure 4

Comparison of the von Bertalanffy growth curve from Manooch and Huntsman (1977) using headboat data versus the resulting growth curves from headboat and commercial fisheries data from this study.

have been due to heavy fishing on the population, the small sample size of older age fish, or differences in assigned ages due to the structure used for aging, because the comparison of ages determined from otoliths was very close.

Harris and McGovern (1997) and Hood and Johnson (2000) have put forth the theory that heavy fishing pressure may cause a shift in the size and age structure of a population to smaller, slower growing fish. Our study does not support this theory. Cotrina and Raimondo (1997) demonstrated the differences in growth of red porgy caught from two areas off Argentina. Because we feel that our samples encompassed the full range of red porgy along the southeastern United States., our data more truly represents that population than the data from Harris and McGovern's (1997) study. We also feel that the perceived changes in length at age reported in Harris and McGovern's (1977) study may be confounded by the changes in sampling strategy of the MARMAP program between 1979 and 1994 (e.g. sampling gear used, locations of sampling, personnel, etc). Differences in growth of red porgy in the Gulf of Mexico between Hood and Johnson's (2000) study and Nelson's (1988) study may certainly be affected by the different locations the samples came from for the two studies. We suggest that further investigation into sample design and effects of habitat, temperature, fishing pressure, weather, fishing gear, etc. on fish populations is needed to help resolve differences between these studies.

The von Bertalanffy growth parameters L_∞ and K are integral components of stock assessment models. Samples for age determination should be representative of the target population (i.e. entire geographic range, all habitats, and all gear types used in the fisheries). Because back-calculated length-at-age information was unavailable to us from all previous studies, we compared the various von Bertalanffy growth curves with direct comparisons of length at age (Fig. 3). The growth curve of red porgy estimated by Manooch and Huntsman (1977), $L_t = 763(1 - e^{-0.096(t + 1.88)})$, is similar to our equation for all samples. Our calculated von Bertalanffy equation with fishery-dependent samples only was almost identical to that of Manooch and Huntsman (1977): $L_t = 774(1 - e^{-0.092(t + 1.96)})$ (Fig. 4). Although aging structures for the two studies were very different, ages were validated in both studies, and overall size ranges were similar.

In comparison with our study and that of Manooch and Huntsman (1977), the growth curves estimated by Harris and McGovern (1997) from their 1979–94 data had L_∞ values ranging from 411 to 451 mm TL. Red porgy in their study exhibited theoretical growth only from 58 to 69 mm, between ages 5 and 11. Red porgy from our study (all data combined) and Manooch and Huntsman's (1977) study theoretically grew from 164 mm to 172 mm, between ages 5 and 11. Also, the growth coefficients (0.27 to 0.34: 1979–94 data) from Harris and McGovern's (1997) data seemed high for red porgy in relation to those reported in other red porgy age and growth studies (Table 4) (Manooch and Huntsman, 1977; Vassilopoulou and Papaconstantinou, 1992; Serafim and Krug, 1995; Pajuelo and Lorenzo, 1996; Cotrina and Raimondo, 1997; Hood and Johnson, 2000).

Studies using fishery-independent sources for red porgy showed smaller L_∞ and higher K values than those from most studies where a combination of commercial, recreational, or fishery-independent samples were used (Table 4). The differences in growth curves are likely a result of smaller fish in the fishery-independent samples and a consequent truncated upper-length range. Although Hood and

Table 4

Comparison of nine age and growth studies of red porgy from the eastern and western Atlantic Ocean. (Rec.=recreational fishery; Comm.=commercial fishery; F-I=fishery-independent). NC = North Carolina; SC = South Carolina SEFL = southeast Florida; NEFL = northeast Florida. *n* = number of fish in sample.

Study	Location	Aging structure	Age range (yr)	Total length range (mm)	Sample source and *n*	L_∞ (TL, mm)	K	t_0
Manooch and Huntsman (1977)	Southeastern U.S. (NC–SC)	scales	1–15	238–694[1]	Rec. *n*=1777	763	0.10	–1.88
Our study	Southeastern U.S. (NC–SEFL)	sectioned otoliths	1–18	176–733	Comm., Rec., and F-I *n*=631	644	0.15	–0.76
Pajuelo and Lorenzo (1996)	Canary Islands	sectioned otoliths	0–14	97–572	Comm. and F-I *n*=1858	640	0.14	–0.99
Serafim and Krug (1995)	Azores	whole otoliths	1–13	204–722[1,2]	Comm. and F-I *n*=358	1172–1193[2]	0.06–0.07	–0.70 through –1.70
Hood and Johnson (2000)	Eastern Gulf of Mexico	sectioned otoliths	1–17	194–489	Comm. and Rec. *n*=854	459	0.11	–6.6
Harris and McGovern (1997) 1979–94 data	Southeastern U.S. (NC–NEFL)	whole otoliths	1–13	218–449[1,2]	F-I *n*=4281	411–451[2]	0.27–0.34	–0.60 through –1.11
Vassilopoulou and Papaconstantinou (1992)	Eastern Mediterranean Sea	scales	1–13	193–465[1,2]	F-I *n*=151	639[2]	0.08	–3.56
Cotrina and Raimondo (1997)	Buenos Aires, Argentina	scales	0–16	124–480	F-I *n*=5859	447–499	0.15–0.15	–2.96 through –2.81
Nelson (1988)	Western Gulf of Mexico	scales	2–6	302–482[2]	F-I *n*=126	554[2]	0.28	–0.06

[1] Mean total length; actual range of lengths in sample were not readily available.
[2] Fork lengths were converted to total lengths by using $TL = 7.111 + 1.134(FL)$ (MARMAP data, South Carolina Department of Natural Resources, Charleston, SC).

Johnson (2000) used fishery-dependent samples, the largest fish in that study was 489 mm TL, and their samples came from primarily one location. Selectivity of fishing gear may also explain differences in growth parameters. For example, hook-and-line gear may catch faster growing and more aggressive fish, whereas traps and trawls may catch slower growing fish and overall smaller fish. We recommend that in future age and growth studies of any fish species, samples represent the full range of fish sizes in a population, including fish caught by many different gear types, and are obtained from the entire geographic range of the stock. Where practical, landings should be stratified and sampled accordingly.

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