REPRODUCTIVE CYCLE, FECUNDITY, AND SEX RATIOS OF THE RED PORGY, *PAGRUS PAGRUS* (PISCES: SPARIDAE) IN NORTH CAROLINA

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ABSTRACT

Macroscopic examination of gonads and gonad indices demonstrated that March and April were the peak spawning months in Raleigh and Onslow bays, N.C. Ripe fish were collected over irregular bottom from January to April in water ranging from 21 to 100 m in depth. Bottom temperatures during the spawning period ranged from 16.4° to 21.5°C. Three predictors of fecundity, total length, weight, and age were evaluated and regression equations derived. Fish weight proved to be the most precise predictor of fecundity: ln fecundity = 1.7369 + 1.5178 (ln weight of the fish) where fecundity is the total number of eggs in both ovaries. Fecundity estimates ranged from 48,660 for a 304-mm (390-g) red porgy to 488,600 for a 516-mm (1,783-g) fish. Although some individuals reached sexual maturity at age II, most spawn for the first time at age III. Chi-square tests revealed a significant departure from the expected 1:1 sex ratio when data were stratified by month, year, and size. Females were encountered more frequently each month for all 3 yr, and in the smaller size intervals.

The red porgy, *Pagrus pagrus* Linnaeus, is one of the most important demersal marine fishes taken by recreational anglers fishing from headboats[2] between Cape Hatteras, N.C., and Charleston, S.C. In 1972 and 1973, 513,700 red porgy weighing 1.3 million pounds were taken by this sport fishery (Sekavec and Huntsman 1972; Huntsman 1976). In spite of the importance of the species, published information on the red porgy in the western Atlantic is scarce. Dias et al. (1972) described the length-weight relationship for *Pagrus* collected off South Carolina; Ciechomski and Weiss (1973) reported on egg, embryo, and larval development of red porgy from the Argentine Sea; and Manooch et al. (in press); Manooch (in press), discussed the taxonomic status and the food habits of *P. pagrus*, respectively.

This study investigated reproduction of red porgy in North Carolina to determine: 1) spawning season, 2) size and age of females at sexual maturity, 3) prediction equations for estimating fecundity, 4) sex ratios by month and size, 5) spawning ecology, and 6) a description of the eggs and young. This research is part of a National Marine Fisheries Service project which is studying the bottom fishes of the outer continental shelf of the Carolinas.

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[2]Headboats are those that charge for a day's fishing on a per person basis.

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MATERIALS AND METHODS

Length, weight, sex, stage of gonad development, and gonad length and weight were recorded for fish sampled from North Carolina headboats and by experimental fishing aboard the RV *Onslow Bay* from 1972 to 1974. Gonads were preserved in 10% Formalin[3] and macroscopically examined to determine maturity using modified criteria from Orange (1961): Stage 1-S: infantile, gonads small and ribbonlike (sex determination by gross examination not possible); Stage 1: immature, gonads elongated, slender, but sex discernible by gross examination; Stage 2: early maturing, gonads slightly enlarged, individual ova not visible to naked eye; Stage 3: late maturing, gonads enlarged, individual ova visible to naked eye; Stage 4: ripe, ovary greatly enlarged, many ova translucent and easily dislodged from follicles or loose in lumen of ovary; and Stage 5: spawned, includes recently spawned fish with mature ova occurring as remnants in various stages of reabsorption.

Time of spawning based on 243 females was determined by using: 1) the gonad index (G.I.) of Schaefer and Orange (1956), and 2) the index: 100G.W./F.W., where G.W. is the fresh gonad weight to the nearest 0.01 g and F.W. is the body weight of the fish to the nearest 1.0 g. Mean values

[3]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

of these indices were plotted monthly, to thus indicate duration and peak of spawning, and age and size at sexual maturity. The linear regressions fecundity on length, weight, and age were calculated based on mature (Stage 4) ovaries from 50 females (ages II-IX, 304 to 520 mm TL) collected from January through March for the years 1973 and 1974. One ovary randomly selected from each pair was blotted dry and weighed to the nearest 0.01 g. The selected ovary was crumbled and all ovarian tissue removed. The eggs were then filtered, blotted dry, and weighed. One sample from each ovary of 0.2-0.4 g was weighed to the nearest 0.001 g and placed in a 6 × 6 counting grid and all ova were counted. The formula:

$$Y = \frac{(W)(W_i')}{(W_i)(w)}\ y$$

was used to estimate the number of eggs in the ovaries, where Y = total number of eggs in both ovaries, W = weight of both ovaries, W_i = weight of selected ovary, W_i' = weight of ovary after removal of ovarian tissue, w = weight of sample, and y = number of eggs in the sample (Lassiter 1962).

RESULTS AND DISCUSSION

Sexual Maturity

Ovary condition progressed from ripe, Stage 4, dominant from January through March, to spawned, Stage 5, dominant from May through June, indicating that peak spawning occurred in March and April (Figure 1). Ovaries collected in April and May were flaccid and showed resorption of eggs. By June all of the fish were early maturing. The ovaries gradually became more firm after resorption in early summer and little change in gonad condition was noted in late summer and early fall. Maturation of ovaries occurred between October and January. Stratification of the sexual maturity data by month supported the hypothesis of late winter to early spring spawning. Approximately 23% of the fish examined in January were late maturing and 77% were ripe. By February, 12.5% were classified as late maturing, and 87.5% were ripe. The first spawned (Stage 5) fish were collected in March and their frequency of occurrence increased to 60.5% in April (Figure 2). Walker (1950) reported ripe *P. pagrus* in January and February off North Carolina, and Ranzi (1969) found that they were sexually mature from April to June in the Mediterranean Sea off Algeria.

Early maturing and ripe stages of males were easily discernible by gross examination of the testes, but the late maturing and ripe classes were difficult to separate. Milt could be pressed from the

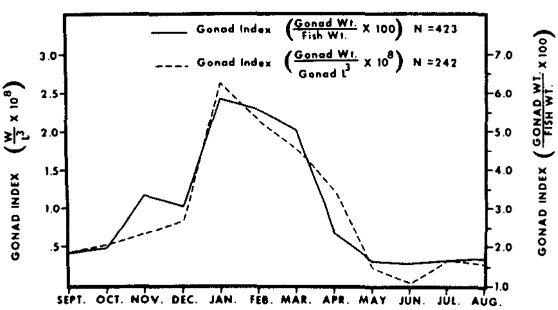


FIGURE 1.—Mean monthly gonad indices for female *Pagrus pagrus* collected from Onslow Bay, N.C., 1972 to 1974.

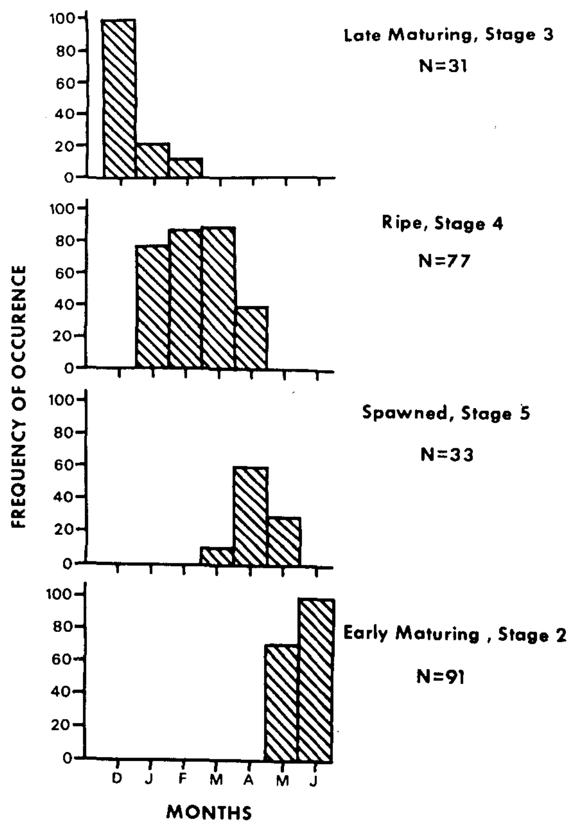


FIGURE 2.—Percentage of female red porgy at various stages of sexual maturity, collected in Onslow and Raleigh bays, N.C., by month.

central canal of testes from January through April.

Female red porgy were separated into two maturity classes: Immature fish, and mature (maturing, ripe, and spawned). No individuals less than 260 mm and all fish greater than 360 mm were sexually mature (Table 1). The linear regression of percent maturity (Y) on total length (X):

$$Y = -211.2946 + 0.8576X, r = 0.94,$$

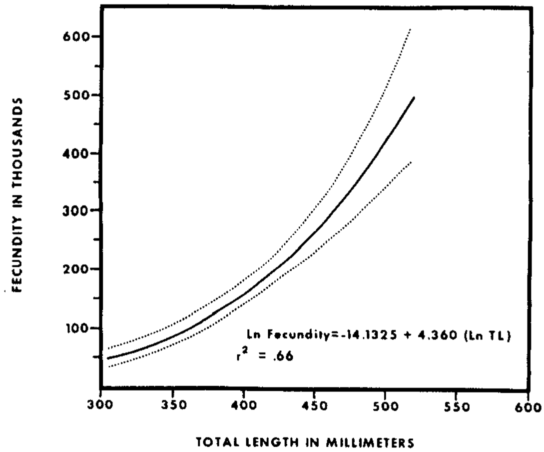
was significant at $\alpha = 0.01$. Half the females were mature at 304 mm. By inserting age data (Manooch 1975) to the graph, age at sexual maturity was determined. Regression of age with length suggests that none of the age I fish, 37% of the age II, 81% of the age III, and 100% of the age IV fish were mature. Some age II and III females apparently showed the characteristic, seasonal maturation of ovaries but did not spawn the first year, because several specimens had ovaries containing absorbed ova during the peak spawning period.

TABLE 1.—Number and percentage of female red porgy, grouped into 20-mm size categories, staged as immature and mature (maturing, ripe, and spawned) off North Carolina 1972-74.

Total length (mm)	Immature (no.)	Mature (no.)	Mature (%)
<220	22	0	0.0
220-239	1	0	0.0
240-259	4	0	0.0
260-279	8	4	33.3
280-299	11	2	15.4
300-319	5	7	58.3
320-339	4	29	87.9
340-359	5	34	87.2
360-379	0	57	100.0
380-399	0	80	100.0
400-419	0	75	100.0
420-600	0	214	100.0
Total	60	502	

Fecundity

Regression analyses indicated total length, weight, or age could be used to predict fecundity of red porgy, but weight proved to be the best predictor of fecundity ($r^2 = 0.70$) and had the lowest error mean square. Combinations of two independent variables, weight and length, improved predictability only slightly, therefore, separate equations were derived by using weight on fecundity, and length on fecundity. The equations describing the relationships (Figure 3) and coefficients of determination (r^2) are:



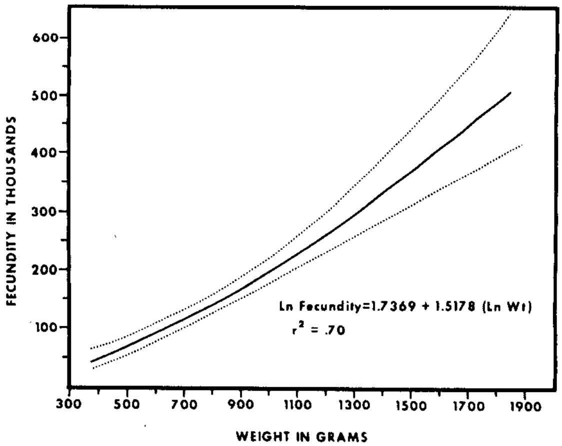


FIGURE 3.—Relationship between fecundity and two predictors: (top) length and (bottom) weight of 50 red porgy collected in Onslow Bay, N.C.

$$\ln \text{Fecundity} = 1.7369 + 1.5178(\ln \text{Wt}), \; r^2 = 0.70 \text{ and}$$

$$\ln \text{Fecundity} = -14.1325 + 4.3598(\ln \text{TL}), \; r^2 = 0.66.$$

The 95% confidence limits have also been calculated. Predicted fecundity ranges from 48,660 eggs for fish 304 mm TL and 390 g in weight to 488,600 ova for fish 516 mm TL and 1,783 g. Theoretically, a 600-mm red porgy which is not uncommon in the sport catch, could produce approximately 943,000 eggs if maximum ova production is not obtained at a smaller size.

Sex Ratios and Hermaphroditism

Sex of 736 red porgy collected in 1972, 1973, and 1974 was grouped by year and month, and data revealed females to be more abundant in the catch than males (Table 2). The sex ratio was not 1:1 males to females as hypothesized but actually 1:2.1 when the years were combined. Data for each year analyzed separately also provided significant deviations from expected. The sex ratio for each year was 1:2.1, 1:1.9, and 1:3.3 for 1972, 1973, and 1974, respectively (Table 2). The overall, higher deviation from 1:1 for 1974 is because most of the fish were collected in late winter and spring of that year, months which reflected the greatest deviation from 1:1. Of all months examined, only August, September, and November were nonsignificant, revealing equal number of males and females. The ratio for October could not be tested because of insufficient data. During the spawning season, chi-square values were very high and perhaps reflect monosexual schooling.

Sex ratios for males and females grouped into 50-mm length intervals had significant departures from the expected 1:1 ratio for most size categories (Table 3). In general, females predominated in the smaller size classes, whereas males predominated in the larger size classes. The nonsignificant value for the smallest size interval is probably unrealistic since the sample is very small and the sequential intervals are highly significant in favor of females.

Both protandrous and protogynous hermaphroditism are relatively common among the sparids (D'Ancona 1950, 1956). *Pagrus pagrus* collected from the west coast of Florida appear to display protogynous hermaphroditism although data available are insufficient for quantitative description (D. S. Beaumariage pers. commun.).

TABLE 2.–Number of male and female red porgy collected by month during 1972, 1973, and 1974 with chi-square values obtained from testing a 1:1 sex ratio in each month (a), and each year (b).

	Year					
Month	1972	1973	1974	Total[a]	df	X^2
May	9:12	17:41	0:5	26:58	2	12.08**
June	16:22	26:45	—	42:67	1	5.74*
July	9:27	27:44	—	36:71	1	11.44**
Aug.	11:15	30:33	—	41:48	1	.55
Sept.	3:9	21:26	—	24:35	1	2.04
Oct.	1:9	—	—	1:9		
Nov.	2:3	12:15	—	14:18	1	.50
Dec.	5:15	3:11	—	8:26	1	9.52**
Jan.	—	0:2	9:22	9:24	1	6.82**
Feb.	—	5:12	8:32	13:44	1	16.86**
Mar.	—	5:26	4:32	9:58	1	17.92**
Apr.	—	6:29	10:10	16:39	1	9.62**
Total[b]	56:112	152:284	31:101	239:497		
df	7	10	4	11		
X^2	18.6**	39.96**	37.12**	90.44**		

* = $P<0.05$.
** = $P<0.01$.

TABLE 3.–Number of male and female red porgy grouped into 50-mm size categories with chi-square values assuming a 1:1 sex ratio.

Length	Male	Female	Total	X^2
<300	1	6	7	3.57
300-350	2	53	55	47.28**
351-400	10	157	167	129.40**
401-450	48	161	209	61.10**
451-500	124	83	207	8.12**
501-550	51	27	78	7.38**
551-600	3	10	13	3.76
>600	1	0	1	—
Totals	240	497	737	

* = $P<0.05$.
** = $P<0.01$.

The predominance of females at smaller size intervals in this study and discovery of individuals with both ovarian and testicular tissue supports the theory of protogyny. Although hermaphroditic red porgy were found by macroscopic examination, only 16 specimens of the 752 examined (2%) contained both male and female gonadal tissues. Hermaphroditic red porgy ranged in size from 325 mm to 424 mm TL ($\bar{x}$ = 400 mm); possibly the length range over which sexual transition takes place. In each fish the ovaries were dominant with only redundant testicular tissue present. From preliminary studies with red porgy in the Gulf, M. A. Moe (pers. commun.) reported that the male portion of the gonad develops in the muscular tunica of the gonad wall and eventually completely takes over the gonad.

Spawning

Ripe red porgy were collected over irregular bottom from January through April in water depth ranging from 21 to 100 m and bottom temperatures of 16.4° to 21.5°C (Figure 4). *Pagrus pagrus* spawns from December through January in the Argentine Sea when water temperature is approximately 20° to 21°C (Ciechomski and Weiss 1973).

The relationship of the gonad index to photoperiod and bottom temperature were plotted monthly (Figure 4). By inspecting this figure one could conclude that photoperiod is more directly correlated to gonad maturation and spawning. Similarly, gonad maturation of red grouper, *Epinephelus morio*, another demersal reef species, was unrelated to bottom temperature (Moe 1969). Harrington (1956) demonstrated the importance of photoperiod to gonad maturation and spawning

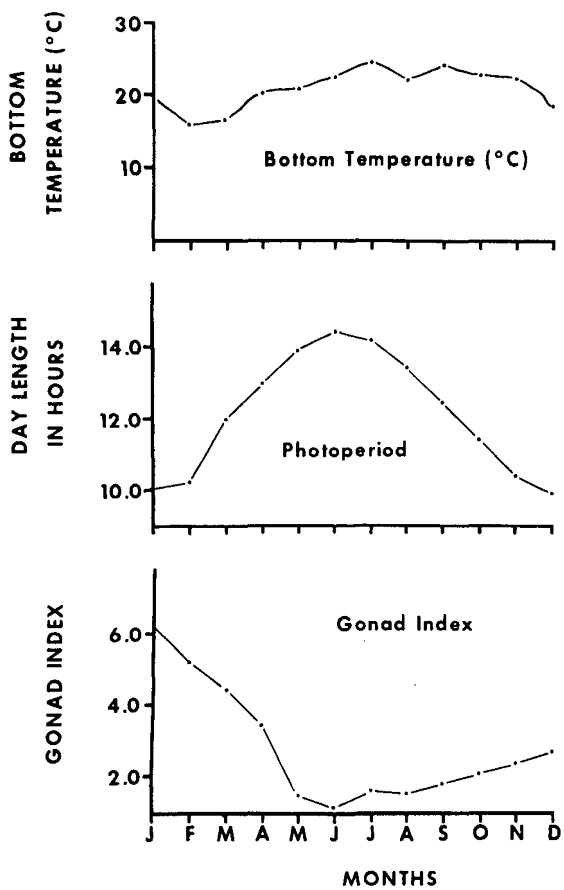


FIGURE 4.—Mean gonad indices for female *Pagrus pagrus* for each month compared with photoperiod and bottom temperatures.

for the banded sunfish, *Enneacanthus obesus*. *Pagrus pagrus* spawns between January and April, when photoperiod increases rapidly, but when bottom temperatures fluctuate irregularly. Gonads were in spent and resting stages during maximum photoperiod, May to August, and began developing as photoperiod decreased. The graphs suggest that seasonal increase in photoperiod in late winter and early spring initiates final maturation of ovaries and ultimately, the spawning of *P. pagrus*.

Eggs and Young

Red porgy eggs are pelagic, spherical, without appendages and contain a single oil droplet. Preserved eggs were generally yellow to orange in color, they measured 0.31 to 0.94 mm in diameter and the oil droplet was 0.20 to 0.32 mm in diameter. This size description is similar to the unfertilized eggs of another sparid, *Stenotomus chrysops*, which were 0.66 to 0.95 mm and had an oil droplet 0.17 to 0.40 mm in diameter (Finkelstein 1969). I induced three females (355-560 mm TL) to release ova in aquaria in March 1975. These eggs appeared transparent and were noticeably larger than those described above. Since I considered these eggs to be most representative of mature, unfertilized eggs, I recorded size for 10 eggs from each fish. Their mean size was 0.88 mm in diameter and ranged from 0.64 to 0.92 mm; the oil droplet averaged 0.25 mm in diameter. Very little difference was found in egg size for each fish.

Prejuvenile red porgy were collected in April off South Carolina. An 18-mm specimen had minute spines along the dorsal and ventral outlines of the body, and five to six vertical pigment bands (Figure 5). These bars appeared red on stressed adults. Ranzi (1969) described young *P. pagrus* from the Bay of Naples and referred to the vertical bands in specimens 13 mm and larger.

Forty-four juvenile *P. pagrus* ranging in length from 42 to 59 mm ($\bar{X}$ = 51 mm) were collected by trawl off Charleston in relatively shallow water (9-20 m); bottom temperatures ranged from 17.5° to 18.5°C. The fish were also collected in April, indicating spawning may occur slightly earlier in that area compared with Onslow Bay and Raleigh Bay, N.C.

SUMMARY AND CONCLUSIONS

Red porgy spawn in North Carolina waters from January through April with a peak in spawning activity between March and April. Maturation of gonads and spawning appear to be correlated with increased photoperiod. Spawning fish were collected over irregular bottom ranging from 21 to 100 m in depth. Bottom temperatures at these depths ranged from 16.4° to 21.5°C. Collection of relatively large juveniles off Charleston in April indicates that spawning may occur earlier there.

Some female *P. pagrus* attain sexual maturity as 2-yr-old fish; however, the majority mature at 3 yr. All of the fish examined had reached sexual maturity by the fourth year. Approximately 50% of the females were mature at 304 mm TL, and 75% were mature at 334 mm. All fish 364 mm or more in length were sexually mature. Evidently, some of the age II and III fish experience regular, seasonal maturation of gonads but do not spawn that first year. This conclusion is based upon several fish I

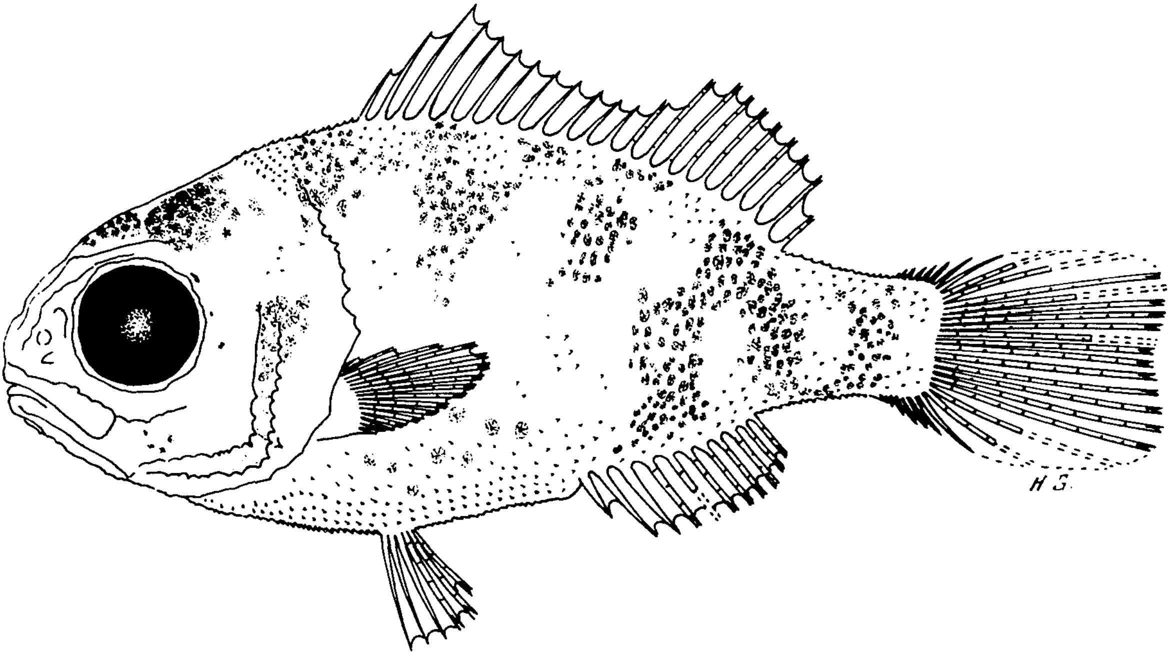


FIGURE 5.–Young red porgy, 18 mm total length, collected by trawl off Charleston, S.C., in April 1974 (drawing by Herbert Gordy, National Marine Fisheries Service, NOAA).

observed which had ovaries containing absorbed ova during the peak spawning period.

Fecundity estimation for red porgy ranged from 48,656 eggs for a 304-mm female to 488,600 ova for a 516-mm fish. Larger fish (>600 mm TL), which occasionally appear in the sport fishery, may produce over 900,000 eggs. Eggs removed from ripe females ranged in size from 0.31 to 0.94 mm in diameter. The developed *P. pagrus* eggs averaged 0.88 mm in diameter and contained a single oil droplet averaging 0.25 mm in diameter. While fecundity was correlated to three predictors; length, weight, and age, weight was the most accurate predictor of fecundity. Although age was not as satisfactory a predictor of fecundity as weight and length, it should not be overlooked, because the age-fecundity relation can have useful application in population modeling. High variability in fecundity estimates for age-groups is expected due to range in size and variation in gonad size among fish of the same size (Bagenal 1967).

Sex ratios for red porgy were usually unbalanced in favor of females. Analyzing data by month, year, and size, I observed a domination by females. The overall sex ratio observed was 1:2. The occurrence of females was higher during the spawning season. This predominance may be attributed to difference in feeding behavior of ripe fish, or to true population differences in the areas sampled. I do not believe gear selectivity influenced sex ratios. The dominance of females for the smaller size classes and actual documentation of hermaphroditic red porgy in the study lends some support to the theory of protogynous hermaphroditism reported for the species in the Gulf of Mexico (Beaumariage pers. commun.). Both protandrous and protogynous hermaphroditism are relatively common among the sparids (D'Ancona 1950, 1956). Although only 2% of the fish examined were obviously hermaphroditic, a complete histological study of gonadal development is needed to determine if the species displays sex reversal. Protogynous hermaphroditism may have selective advantages as Atz (1964:224) mentioned providing an endocrinologically better balanced fish, assuring presence of both sexes in isolated, insular areas, or a mechanism of population control. For the latter purpose, certain population pressures presumably stimulate sexual transition. Probably more applicable to red porgy hermaphroditism is the "size advantage model" proposed by Ghiselin (1969). The theory explains sequential hermaphroditism as occurring when an organism reproduces more efficiently as one sex when small and the opposite sex when larger. A male's potential, theoretically, is higher than a female's at larger sizes, and conversely, a female's reproductive potential is higher than a male's at smaller sizes. The female reproductive capabilities could continue to increase with age. Perhaps males function more efficiently at larger sizes because they can mate with numerous females. Evolutionary factors which favor protogyny are those which tend to depress male reproductive potential at early ages, such as inexperience, territoriality, or female mate selection (Warner 1975). Without additional information on the spawning behavior of *Pagrus*, it would be difficult to eliminate any of these factors.

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