AGE, GROWTH, AND REPRODUCTION OF RED SNAPPER IN FLORIDA WATERS

Rena Barco Futch and Gerard E. Bruger

Reprinted from

PROCEEDINGS: COLLOQUIUM ON SNAPPER-GROUPER FISHERY RESOURCES OF THE WESTERN CENTRAL ATLANTIC OCEAN

Harvey R. Bullis, Jr. and Albert C. Jones, Editors

FLORIDA SEA GRANT COLLEGE PROGRAM REPORT
NUMBER 17 NOVEMBER 1976

AGE, GROWTH, AND REPRODUCTION OF RED SNAPPER IN FLORIDA WATERS 1/

Rena Barco Futch / Gerard E. Bruger 2/
Marine Research Laboratory
Florida Department of Natural Resources
St. Petersburg, Florida

ABSTRACT

Investigations of the life history of red snapper, _Lutjanus campechanus_, were conducted in the Gulf of Mexico off the west coast of Florida from 1972 to 1975. Catches from party boats fishing west of Clearwater Beach, Fla. at depths of 15-30 fathoms were sampled regularly.

Two hundred and forty fish were used in age and growth analyses. Ages, derived from otolith examination, ranged from 1 to 5 years, but ages greater than 20 years can be expected. Annuli are formed on otoliths at a time coinciding with spawning season. Sexual dimorphism is not apparent in the length-weight relationship, and the equation for this relationship is Log W = 2.99420 Log FL - 4.77239. Back-calculated fork lengths are consistent with data from tagging and other studies.

Red snapper are opportunistic, polyphagous feeders, often consuming items not associated with reef-type environments.

Sexual maturity is reached at 2+ years, and spawning occurs from July through October. Spawning apparently does not occur within our study area.

Data on the fishery are presented and show that a large proportion of immature fish are being caught.

1/ Contribution No. 275, Florida Department of Natural Resources, Marine Research Laboratory, St. Petersburg, FL 33701.

2/ Co-authors.

INTRODUCTION

The red snapper, Lutjanus campechanus (Poey), has been the object of an intense commercial fishery in the Gulf of Mexico for over a century. In addition, the number of party boats and sport fishermen seeking this highly regarded food fish have increased in recent years. Declines in commercial production have caused concern about the status of this valuable resource since at least 1935. Since 1965, a record year for landings in Florida and the Gulf States, commercial production has decreased over 35% (Fig. 1).

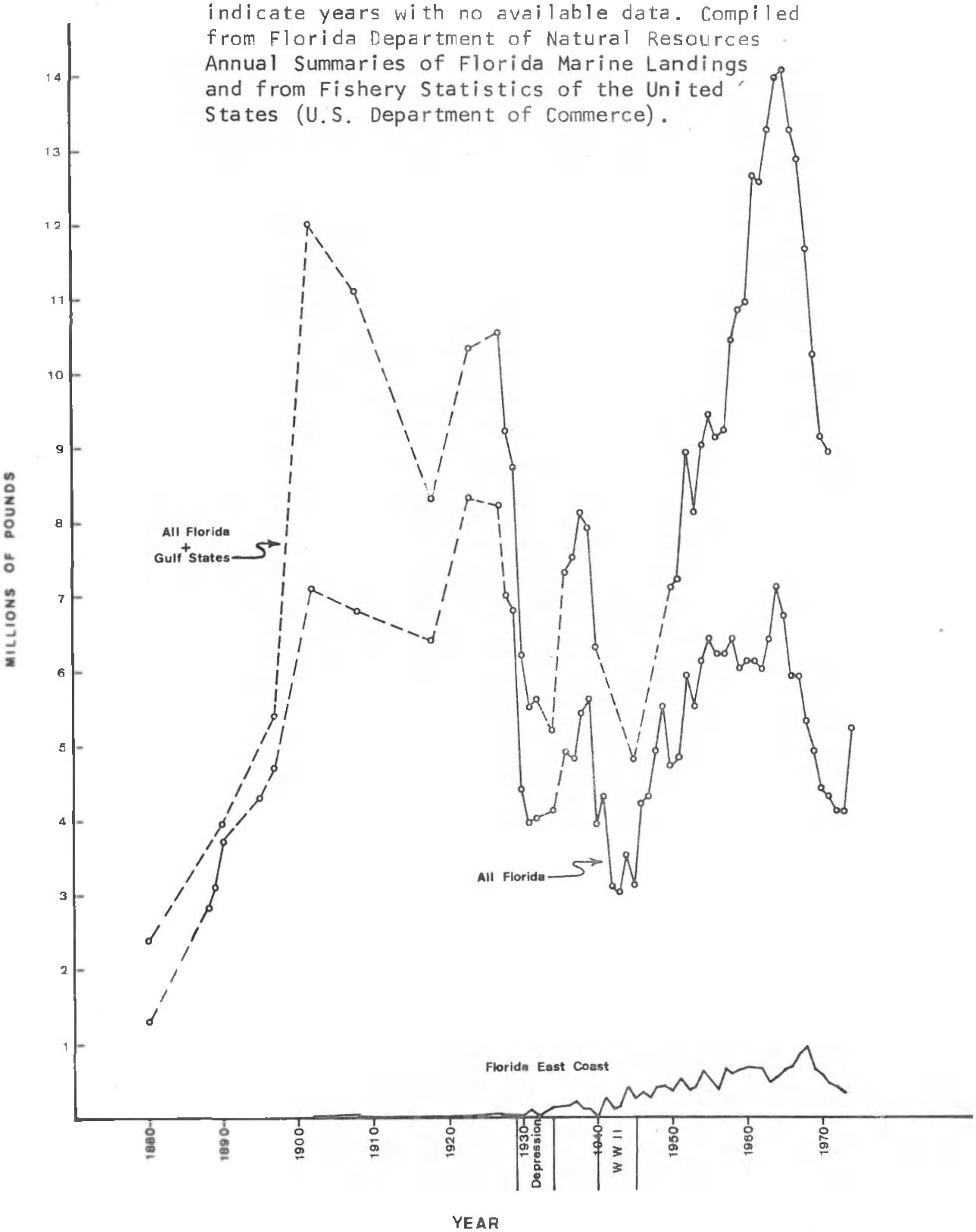
Although literature concerning red snapper is abundant, little emphasis has been placed on the life history and biology of this species until recent years. Most papers have dealt with the fishery, which has remained virtually unchanged for 100 years, and with methods for increasing its efficiency. Other papers presented at this Colloquium will provide more extensive data on the present fishery.

Camber (1955) presented limited data on length-weight relationships, size at maturity, sex ratios, food habits, and spawning of red snapper from Campeche Bank. Dawson (1963) calculated length-weight relationships of juvenile red snapper from the northern Gulf of Mexico. Limited data on snapper movement and growth, deduced from tag returns, were given by Topp (1963), Beaumariage (1964, 1969), Beaumariage and Wittich (1966), and Moe (1966). Perhaps the most extensive biological work has been done by Moseley (1965, 1966) and Bradley and Bryan (1973) along the Texas coast. However, few biological data are available for Florida stocks, which support the largest red snapper fishery among the Gulf States (Fig. 1). Therefore, the Florida Department of Natural Resources Marine Research Laboratory (FDNR/MRL) initiated a program in September 1972 to evaluate age, growth, reproduction, and food habits of a portion of Florida's red snapper stocks.

METHODS AND MATERIALS

At the outset of this program, we randomly sampled catches from party boats fishing an area west of Clearwater Beach, Fla. (Fig. 2). During the first 16 months, we were able to collect only the carcasses of filleted fish. In 1974 we weighed and measured whole fish, as well as collected their carcasses. Reproductive data were evaluated for all fish, unless otherwise indicated; age and growth data are presented only for whole fish. From all whole fish we measured standard, fork, and total lengths (SL, FL, TL) in millimeters (mm) according to Lagler's (1952) methods. Weights were measured to the nearest 5 grams (g). Otoliths, gonads, and stomachs were excised and retained for analyses. Otoliths used for age evaluations were washed in water and stored in glycerin from the time of collection until evaluation. All otolith radii were measured from the kernel point to the most posterior point of the otolith. They were read once by each investigator and a third time by joint effort to resolve previous discrepancies. Any otolith readings not agreed upon by both investigators were not used in further analyses. One reading was made approximately 6 months before the second reading; the joint reading was made 1 year after the first. We found that greatest clarity was achieved when otoliths were stored for at least 1 year, preferably longer. Gonads were fixed whole, most in Davidson's fixative and some in Bouin's

Figure 1. Commercial red snapper landings 1880-1974. Broken lines indicate years with no available data. Compiled from Florida Department of Natural Resources Annual Summaries of Florida Marine Landings and from Fishery Statistics of the United States (U.S. Department of Commerce).



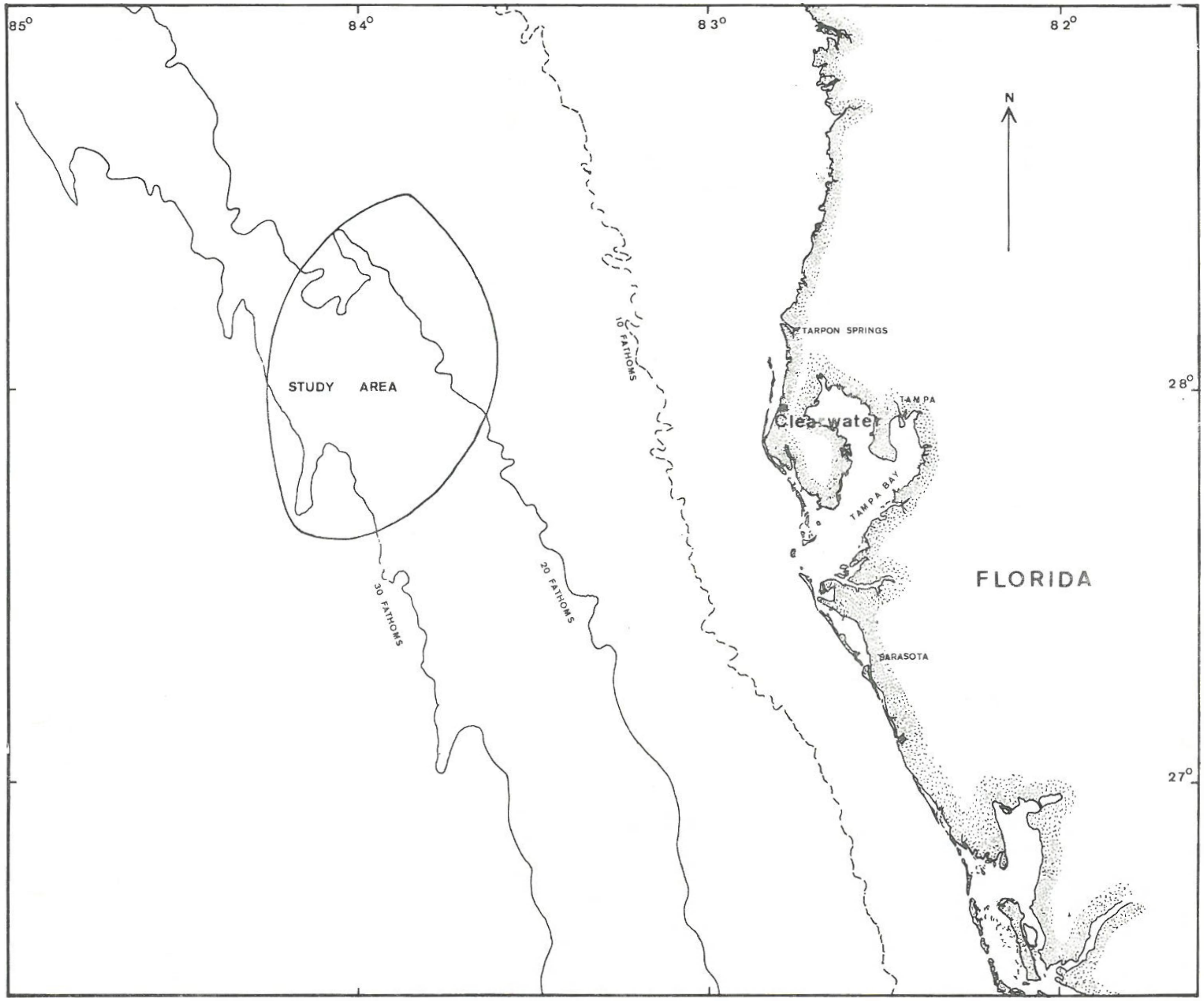


Fig. 2. Study area off west coast of Florida frequented by Clearwater Beach party boat fishery.

fixative. Midsection pieces were dehydrated, cleared, embedded in paraffin, sectioned at 6 microns (μm), and stained with Harris hematoxylin/eosin Y. Analysis of reproductive status follows Moe (1969), except for our grouping of immature and resting stages. In addition, we designated a category for "ripe" gonads, indicated by the presence of mature oocytes.

RESULTS AND DISCUSSION

AGE AND GROWTH

Of 240 sets of otoliths examined, 200 sets (83.3%)were readable, and agreement could not be reached on the remainder (16.7%). To demonstrate proportionality between otolith radius and fork length, a regression line was fitted to the 240 data pairs. This relationship is given by the equation $Y = 8.3187 X - 67.0435$, where Y is FL and X is otolith radius in ocular micrometer units (1 omu = 0.0815 mm). The calculated correlation coefficient is sufficiently high ($r = 0.9047$) to demonstrate proportionality between the variables (otolith radius range, 35-78 omu).

From 200 legible sets of otoliths, we aged snapper from I to V years. We collected fish considerably larger and presumably older, but their otoliths were illegible.

The formation of annuli on hard parts of fish at a specific time of year is a criterion that must be satisfied before an aging technique is considered valid (Van Oosten, 1929). Hypotheses concerning annulus formation in fishes inhabiting tropical waters are varied (Chevey, 1933; Menon, 1953; Voss, 1953, Voss, 1954; Clancey, 1956; de Sylva, 1963; Beardsley, 1967; Moe, 1969; Beaumariage, 1973; Bruger, 1974). Although data were limited, Moseley concluded that red snapper formed annuli during the spawning season.

Marginal increments on aging structures have been widely used to show time of annulus formation in many fishes (Tabb, 1961; de Sylva, 1963; Moe, 1969; Beaumariage, 1973). Table 1 presents these data for red snapper collected during 1974 and shows that snapper form annuli from June to October, a time coinciding with their spawning season. However, spawning would not account for annulus formation in age I fish, which are apparently still immature (see Reproduction section).

Table 2 presents back-calculated fork lengths of ages I-V derived from 200 sets of otolith readings. Lengths were calculated using the direct proportion method described by Van Oosten (1929) and the equation $Fl_a = \frac{R_a(FL_c)}{R_c}$, where FL_a = calculated fork length at any year, R_a = otolith radius to any annulus, FL_c = fork length at capture, and R_c = otolith radius at capture. There is a wide range of size within a particular age. This has also been observed in length frequency-age data by Moseley (1965) and can be expected for a fish which has a protracted spawning season.

Analyses of *L. campechanus* (Moseley, 1965) and its closely allied congener *L. purpureus* Poey (Menezes and Gesteira, 1974) indicate that the

Table 1. Monthly Marginal Increments from Red Snapper Otoliths.

Month	Number	Mean Increment (omu)	Range (omu)	Standard Deviation (omu)
Jan.	32	11.47	6-17	3.62
Feb.	19	9.53	6-16	3.32
Mar.	20	10.50	5-20	3.33
Apr.	18	11.56	6-18	4.30
May	16	10.44	6-15	2.87
June	14	7.07	0-18	5.40
July	16	2.44	0-15	4.43
Aug.	11	3.55	0-11	3.45
Sept.	5	2.80	0- 5	2.17
Oct.	17	2.82	0-11	2.79
Nov.	14	5.00	3-14	1.52
Dec.	5	7.25	5-11	2.87

Table 2. Back-calculated Fork Lengths of Red Snapper, Ages I through V.

Age	Mean FL at Capture (mm)	Number	Annulus (mm) I	II	III	IV	V
I	242	6	200				
II	389	83	147	306			
III	415	83	130	286	373		
IV	459	27	129	285	375	444	
V	523	1	112	291	366	441	516
Number of back-calculations		200	200	194	111	28	1
Grand mean back-calculated fork length (mm)			139	294	373	444	516
Average annual increment (mm)			139	155	79	71	72
Range of back-calculated fork lengths (mm)			79-250	218-396	255-493	373-558	
Standard deviation (mm)			33.3	34.1	37.3	48.4	

first annulus does not form until maturity and spawning, at an age of 2+ years. However, both studies were based on ages obtained from scale readings. Growth rate data reported by Moseley (1965), Bradley and Bryan (1973), and unpublished data cited by Bradley and Bryan suggest that mean growth during the first year is approximately 200 mm SL. This compares favorably with our back-calculated data (Table 2).

Ontogenetic and seasonal inshore-offshore movement (Moseley, 1965) and non-random sampling (caused by hook size) may have contributed to "Rosa Lee's phenomenon" (Tesch, 1968) apparent in our back-calculated data. Fishing is done offshore, and uniform hook size is probably selective for the faster growing, age I fish; slower growing, smaller fish either are not in the same area or simply cannot bite the hook. As these fish are recruited into the fishery, they create a wide size range within age groups, thus inducing "Rosa Lee's phenomenon." Despite the fact that this factor is apparent in our back-calculations, we feel that the aforementioned growth rates, from other studies and from our work, show that an age I fish (with annulus) will be approximately 200 mm.

Our calculated annual increments between ages II and V are consistent with data from tag returns and with data from Moseley (1965) and Bradley and Bryan (1973).

Data from red snapper returns compiled from Topp (1963), Beaumariage (1964, 1969), and Beaumariage and Wittich (1966) yield a mean annual growth of 78.0 mm TL and 62.6 mm SL for fish 205-419 mm SL at time of release. In addition, we have one return of a snapper at liberty 1 day less than 10 years (Table 3). Growth averaged 44.4 mm TL per year; a large portion of this growth probably occurred in the first 3 or 4 years following release.

Table 3. Data for One Long-Term Red Snapper Tag Recovery.

	Date	SL (mm)	TL (mm)
Release	20 July 1962	238	291
Recapture	19 July 1972	620	735
Total growth		382	444
Mean growth per year		38.2	44.4

Length-weight relationships were calculated from 240 fish ranging from 228 to 676 mm FL (8.98-26.61 inches) and from 495 to 5175 g (1.09-11.41 lb). Ninety-five males, 118 females, and 27 fish of undetermined sex were used in the calculations. Sexes were considered separately to evaluate possible dimorphism. The equations are:

Males: $W=1.54728 \times 10^{-5} FL^{3.00777}$ or $\text{Log } W=3.00777 \text{ Log } FL - 4.81043$;

Females: $W=1.37477 \times 10^{-5} FL^{3.02834}$ or $\text{Log } W=3.02834 \text{ Log } FL - 4.86177$.

At the $\alpha = 0.05$ level, there was no significant difference between males and females (Table 4). Therefore, sexes were combined and this relationship can be expressed by the equation $W = 1.68892 \times 10^{-5} FL^{2.99420}$ or $\text{Log } W = 2.99420 \text{ Log } FL - 4.77239$ (Fig. 3) for fish ranging from 200 to 676 mm FL.

Table 4. Statistical Comparison of Male and Female Red Snapper Length-Weight Regression Lines.

Residual variances:	26187.1933 Males
	24279.1866 Females
$F_{.05}$ (calculated) 98,116 df = 1.0786 n.s.	
(tabulated) 120,120 df = 1.43 1/	
Slopes (b) Males:	3.00777
Females:	3.02834
$t_{.05}$ (calculated) ∞ df = 0.17219 n.s.	
(tabulated) ∞ df = 1.96	
Elevations:	
$F_{.05}$ (calculated) 1,210 df = 0.1688 n.s.	
(tabulated) 1, ∞ df = 3.84	

1/ Two-tailed F-test from Snedecor and Cochran (1967).

Table 5. Comparison of Length-Weight Relationships of Red Snapper Less Than 300 mm.

Camber (1955)		Dawson (1963)	Futch/Bruger
Juvenile $W=1.614x10^{-5}FL^{3.01}$	Adult $W=2.98x10^{-5}FL^{2.917}$	Juvenile $W=1.1715x10^{-4}TL^{2.6051}$	All $W=1.6889x10^{-5}FL^{2.9942}$
g			
0.26		0.51	0.26
2.10		3.12	2.06
7.11		8.98	6.95
16.90		19.01	16.40
33.08		33.99	32.08
57.27		54.66	55.37
91.09	104.03	81.67	87.84
136.15	153.58	115.65	131.02
	216.54	157.19	186.43
	294.45	206.83	255.57
	388.82	265.12	339.98
	501.16	332.58	441.16

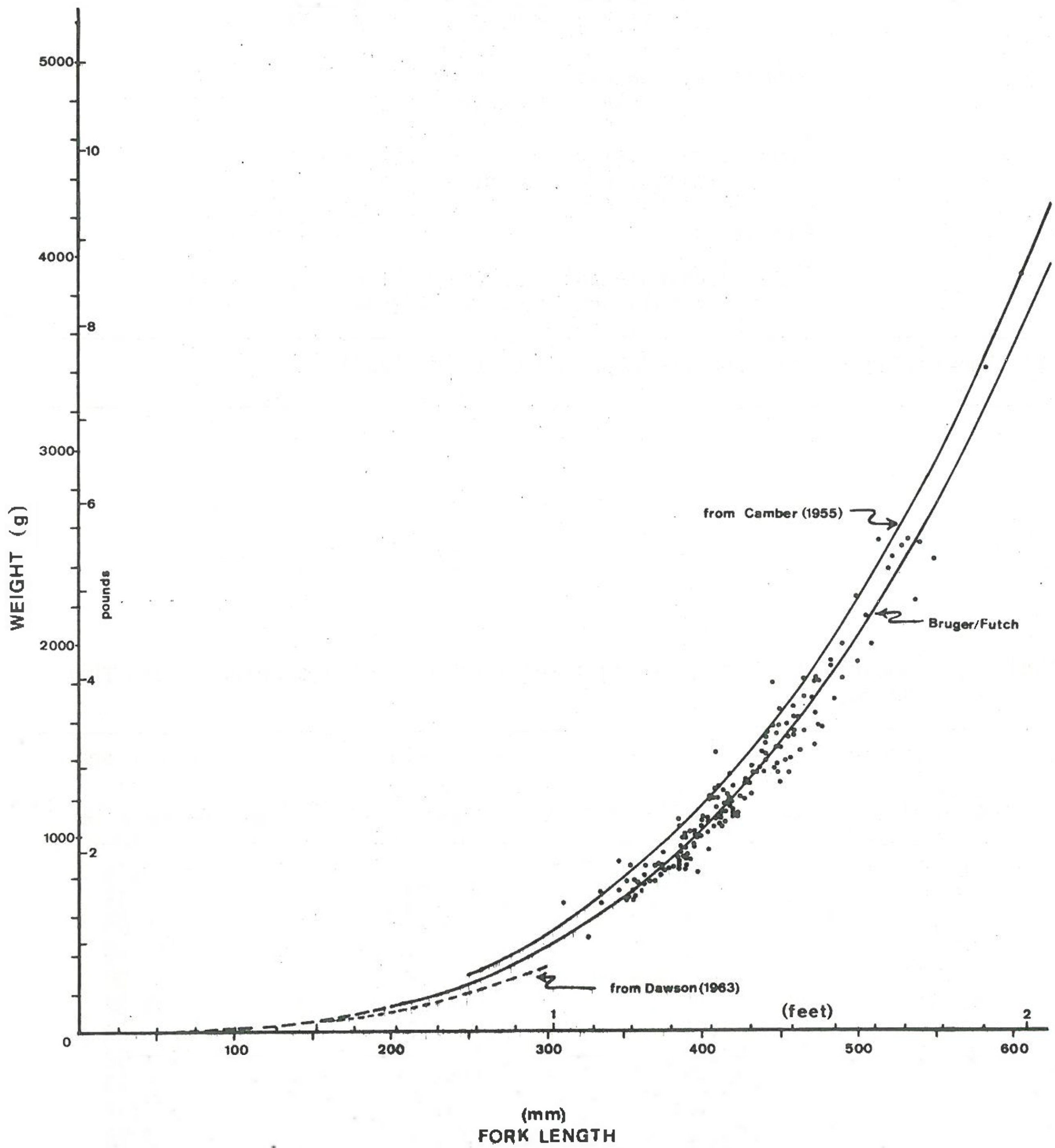


Figure 3. Length-weight relationship of 240 red snapper collected in the present study, compared with data from Camber (1955) and Dawson (1963).

Camber's (1955) length-weight relationships for fish between 290 and 750 mm FL produce higher weights for a given length than does our equation (Fig. 3). However, Camber sampled fish primarily from Campeche Bank.

Camber (1955) also presented a length-weight relationship for juvenile red snapper of 90-190 mm FL and Dawson (1963) gave a relationship for 252 juveniles from the northern Gulf, ranging from 37 to 354 mm TL (only 31 specimens were larger than 155 mm TL). These data, when compared with an extrapolation of our length-weight relationship to include fish less than 200 mm FL, are similar (Table 5) up to approximately 150 mm, where weights from Camber's and Dawson's equations begin to diverge. Both Camber and Dawson felt that a change in growth rate occurred when fish reached 155 mm TL and 160 mm FL, respectively. Our equation may, therefore, be more representative of snapper growth over a greater size range.

The relationships of standard to fork and fork to total lengths are highly correlated and can be expressed by the equations:

$$FL = 1.1585\ SL + 13.2697\ (r = 0.9981,\ N = 21)\ \text{and}$$
$$TL = 1.0678\ FL + 3.4637\ (r = 0.9975,\ N = 100).$$

FOOD HABITS

Moseley (1965) and Bradley and Bryan (1973) gave excellent accounts of food habits of juvenile and adult red snapper from the northwestern Gulf of Mexico.

Previous studies of red snapper food habits have been hampered by stomach eversion when fish ascend from the depths (Stearns, 1884; Adams and Kendall, 1891; Camber, 1955; Moseley, 1965; Bradley and Bryan, 1973). This was also evident in our study, as 117 of 213 stomachs examined were empty or everted. Table 6 lists items found in stomachs. Forty of 96 stomachs with food contained only bait. Fish and squid bait were equally represented (26 contained one or the other, exclusively, and 14 contained both), indicating that snapper have no preference for either bait.

Camber (1955), Moseley (1965), and Bradley and Bryan (1973) found that fish constituted a majority of the adult snapper diet. Although invertebrates were represented slightly more than fish in our samples, this was probably due to fish being more thoroughly digested before stomachs were examined. Dietary items varied, indicating that red snapper are polyphagous and opportunistic (Moseley, 1965; Bradley and Bryan, 1973). Most invertebrates encountered are sand-shell dwellers (Williams, 1965; Lyons, 1970; D. K. Camp, pers. comm. 3/). One hemichordate worm encountered is probably of the class Enteropneusta, described by Barnes (1968) as shallow water inhabitants, some living under

3/ David K. Camp, Florida Department of Natural Resources, Marine Research Laboratory, St. Petersburg, FL 33701, pers. comm.

Table 6. Items Found in the Stomachs of Red Snapper.

Item	Number
Mollusca	
Gastropoda	
Tonnidae	
Tonna galea (Linne)	1 1/
Pelecypoda	
Cardiidae	
Laevicardium pictum (Ravenel)	1 2/
Arthropoda	
Crustacea	12
Stomatopoda	3
Squillidae	
Squilla deceptrix Manning	3
Squilla rugosa Bigelow	1
Decapoda	
Penaeidae	
Trachypeneus similis (Smith)	1
Alpheidae	2
Palinuridae	
Scyllarus chacei Holthuis	1
Leucosiidae	
Iliacantha intermedia Miers	1
Raninidae	
Raninoides sp.	1
Majidae	3
Portunidae	4
Portunus sp.	1
Goneplacidae	
Prionoplax atlantica Kendall	1
Hemichordata	1
Chordata	
Vertebrata	
Anguilliformes	
Ophichthidae	1
Clupeiformes	
Clupeidae	2
Gasterosteiformes	
Syngnathidae	1
Periciformes	
Serranidae	
Diplectrum formosum (Linne)	2
Fish remains	26
Fish bait only	13
Squid bait only	13
Both fish and squid bait only	14
Unidentifiable remains	3

1/ Larval stage.
2/ In gullet of fish with everted stomach.

stones and shells, but many common species burrowing in mud and sand. Presence of the larva of the gastropod Tonna galea suggests water-column feeding. None of the food organisms encountered are obligate rock dwellers, though party boat captains fish primarily on rock ledges or other areas of high relief. One captain noted, however, that a "sand bar" with a "show" of fish on the fathometer almost always yielded snapper.

Most accounts classifying snapper habitats have emphasized hard, rocky bottoms or reefs. Smiley (1885:92) quoted Mr. Silas Stearns of Pensacola, Fla. as saying, "In any part of the northern Gulf of Mexico where there is a rock coral or gravel there is a certainty of there being red snappers. Sometimes there are kinds of food on shelly bottoms which attract the snappers." Jarvis (1935) indicated that snapper are only caught in narrowly restricted areas of favorable bottom, usually depressions or gullies on coral or rock bottoms. He attributed this restriction to the fact that food material for snappers (mainly crustaceans and small fishes) settles more abundantly in these spots than in surrounding areas. Camber (1955:28) reported that most animals found in snapper stomachs inhabit coral reefs "...where red snappers presumably feed." Other researchers (Moe, 1963; Carpenter, 1965) mentioned that hard bottoms and rocky reefs are primary habitats, with areas of high relief producing the best catches; but fishermen also reported catches of snappers from areas of mud and sand bottoms. Moseley (1965:19) cited several reports of stomach contents, noting that many food organisms are sand dwellers. He concluded, "...red snappers are probably not as confined to reefs or rocky areas as previously believed." Sand and shell or mud bottoms typified 8 of 12 locations where snappers were caught off southwest Florida (Adams and Kendall, 1891). G. B. Smith (pers. comm.) 4/ noted while SCUBA diving that red snapper congregate over rocky bottom, but will feed up to 500-1000 ft away, thereby explaining the presence of sand-shell dwellers in snapper diets.

REPRODUCTION

Slides of 559 gonads were analyzed (results are summarized in Figures 4 and 5), gonadal activity presented in Table 7 was derived from examining the tissue from only those whole fish contributing legible otoliths to the age analysis. Spawning appears to occur from July through October, with a peak in August-September. Males show considerably more gonadal maturation during a greater part of the year than females. Spawning, therefore, must be coincident with the time that females are in ripe condition, July through October (Fig. 5). Ripe females are more indicative of spawning time than spent females, since the spent state may persist for several weeks after actual spawning. Adams and Kendall (1891) found no developing gonads between 15 February and 10 April off southwest Florida. Jarvis (1935) dressed 100 red snapper from Campeche Bank on 3 November and found partially developed milt or roe in each. Snapper from Campeche Bank purportedly spawn between early July and mid-September, with a peak in July-August (Camber, 1955). Moseley

---

4/ Gregory B. Smith, Florida Department of Natural Resources, Marine Research Laboratory, St. Petersburg, FL 33701, pers. comm.

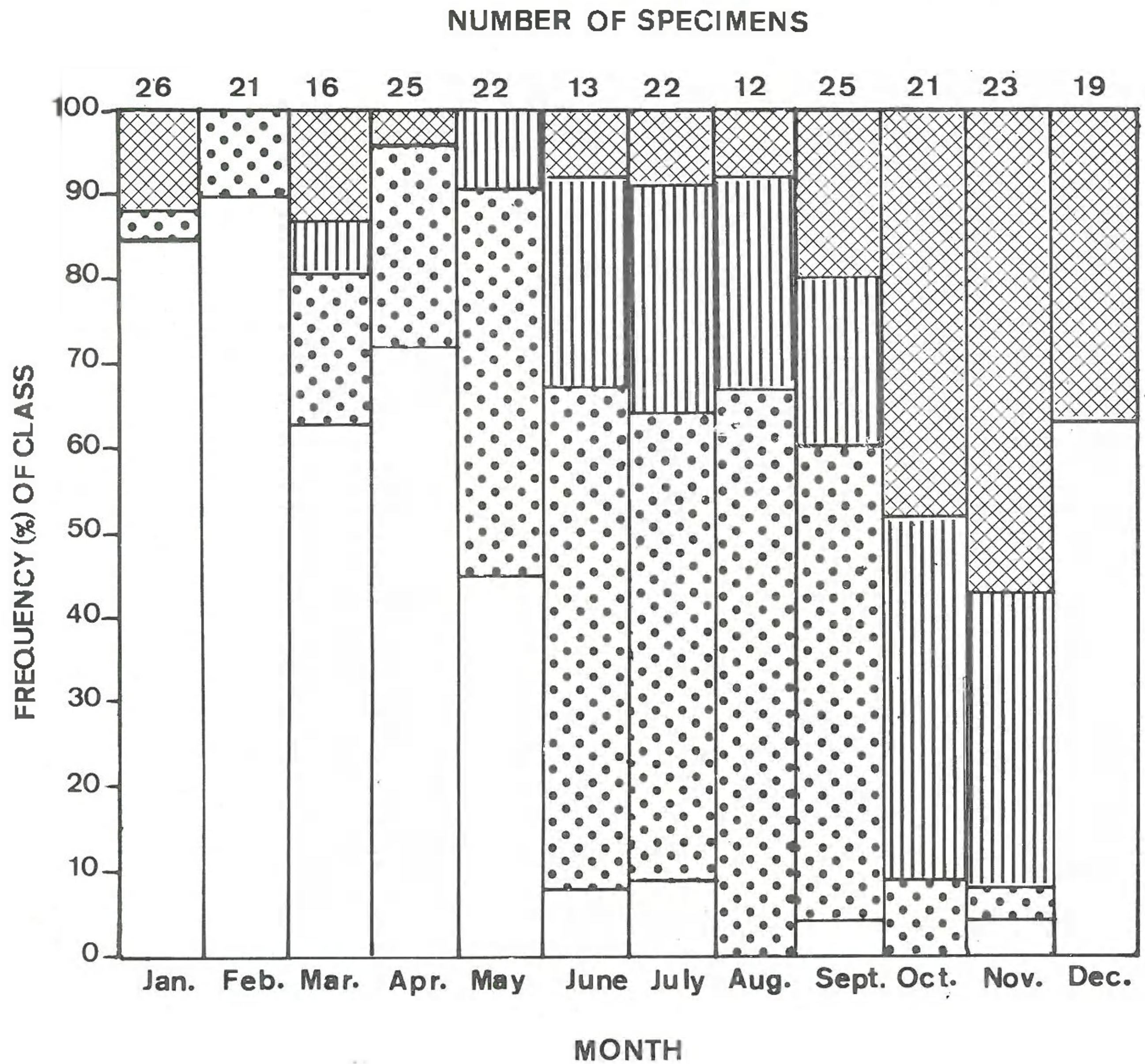


Fig. 4. Monthly gonadal state of male red snapper. White: resting or immature. Dots: active (developing). Lines: ripe. Cross-hatched: spent

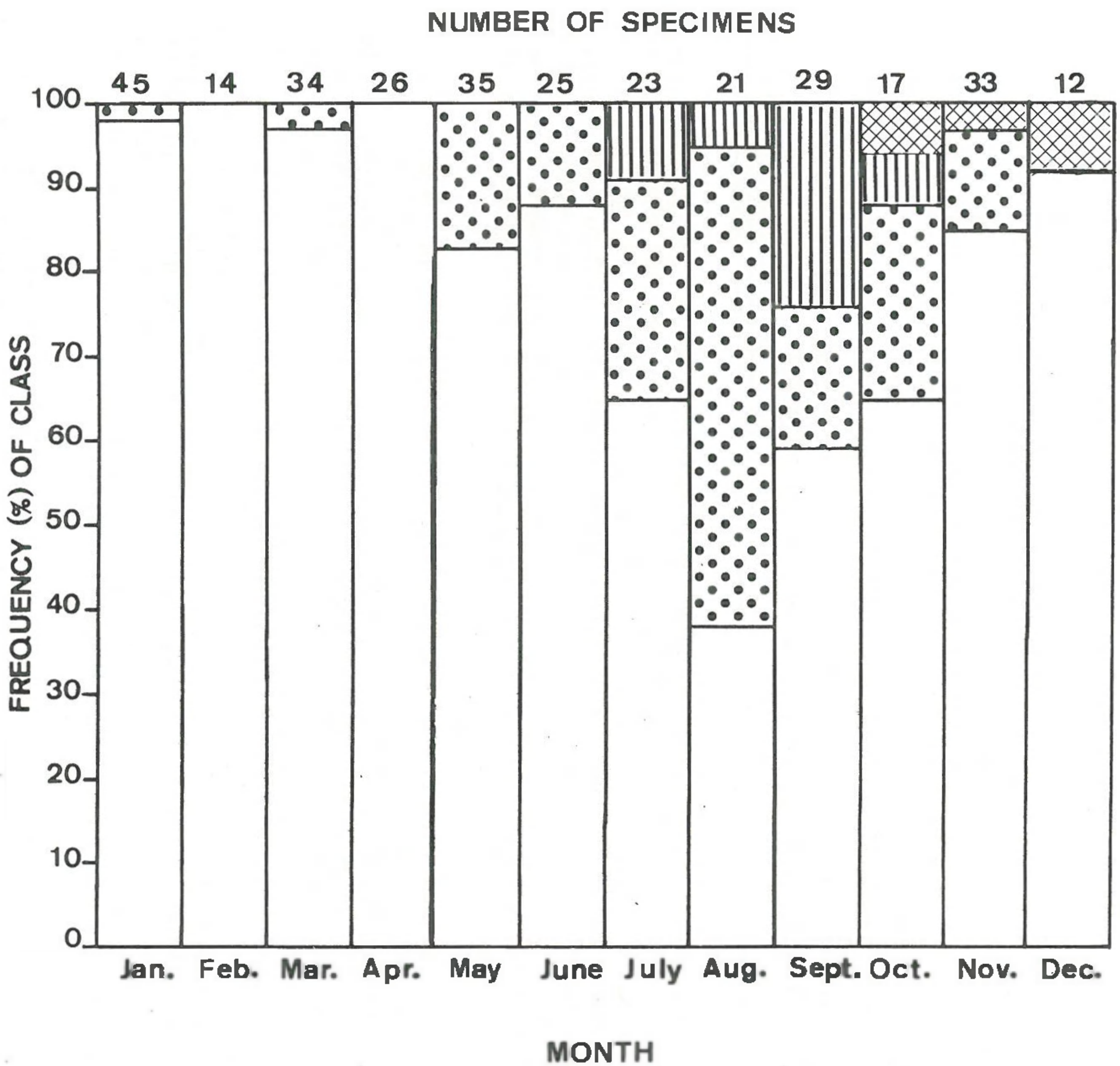


Fig. 5. Monthly gonadal state of female red snapper. White: resting or immature, Dots: active (developing). Lines: ripe. Cross-hatched: spent.

Table 7. Gonadal Activity of Red Snapper at Each Age 1/.

Age	Sex	Number	Gonadal Condition: Resting	Active 2/	Ripe	Spent
I	Male	2	2			
II	Male	34	18	8	1	7
	Female	47	41	6		
III	Male	39	15	15	6	3
	Female	44	30	9	3	2
IV	Male	10	2		7	1
	Female	17	8	6	2	1
V	Male	1		1		

1/ Six fish which were accurately aged could not be used in analysis.
2/ "Active" (Moe, 1969) refers to developing gonads.

(1965) reported that snapper spawn off Texas from early June through mid-September. Yet, Bradley and Bryan (1973) believed that the presence of small snapper (34-70 mm SL) off Texas in January, March, June through October, and December suggests a more protracted spawning season. In May, June, July, September, and November, they noted snapper gonads were developing, most ripening in June and July and a lesser number ripening in November. Baughman (1943:214) noted a large female *L. blackfordii* (=*L. campechanus*) "full of partly developed spawn" caught off Texas on 3 May.

Paucity of age I individuals and preponderance of individuals ages II-V in resting condition make it difficult to determine exact age of maturity. Nevertheless, an increase in gonadal activity of age III fish, compared to age II fish (Table 7), indicates that maturity is probably reached after the second year (age II+). The 194 individuals presented in Table 7 appear to be representative, with regard to gonadal development, of all individuals shown in Figures 4 and 5. This estimate of maturity compares favorably with Camber's (1955) conclusion that maturity is attained at approximately 300-320 mm FL and with Moseley's (1965) statement that a sudden change in condition factor at 190-300 mm SL reflects attainment of sexual maturity. In addition, Moseley's (1965) work on *L. campechanus* and that by Menezes and Gesteira (1974) on the closely allied species, *L. purpureus* Poey, substantiate the age of maturity and first spawning as 2+ years.

Reports of definite spawning locations of red snapper are few. Moe (1963) described two areas south of Panama City, Fla. in 13-16 fathoms where snapper formed large schools and, when caught, released eggs or milt on the deck without external pressure. These areas had been fished for only a few years, so little was known about the frequency of this occurrence. Moseley (1965) hypothesized that red snapper utilize similar areas off Texas. The intense fishing pressure of the Clearwater Beach party boats which fish inshore of 30 fathoms and the scarcity of active (developing) and ripe females in our collection indicate that red snapper do not spawn in the area we studied.

The histological examination to which the gonadal tissue was subjected in our study is a more precise technique than the gross examination or condition factor used by other authors. Our study was concentrated in an area which has not been of classical concern; however, the results of our work compare favorably with those conducted in other areas.

THE FISHERY

Ten major processors of red snapper from Sarasota to Port Richey, Fla., were contacted to determine the approximate number of commercial snapper boats now engaged in the fishery in this area. There are a minimum of 116 boats from Sarasota, Manatee, Pinellas, and Pasco Counties now fishing between the Dry Tortugas and Panama City at depths of 10-100 fathoms. Moe (1963) reported only 61 boats in these counties; therefore, the number of commercial boats has increased by at least 90% in 12 years. During this period, the ex-boat price of snapper has increased at least 300% (Carpenter, 1965, and personal observation).

Methods of fishing have not changed appreciably since Moe's (1963) excellent account.

Sarasota, St. Petersburg, and Clearwater all have party boat fisheries approximately the same size as reported by Moe (1963). Newer boats, however, are larger, faster, and capable of fishing productive areas farther offshore.

The large increase in the number of private boats capable of traveling the distances required to catch snapper has created an additional pressure on the resources. The number of private boats that actually do fish for snapper is not known, but many sport-caught fish end up on the commercial market (personal observations).

SUMMARY AND CONCLUSIONS

(1) Commercial red snapper production has declined, especially since the peak-production year of 1965, despite constant or increased effort.

(2) Increased pressure by the sport fishery (party boat and private) is evident. The magnitude of this pressure is not known. Therefore, the decline in commercial production may be due in part to competition from sport fishermen, even though some percentage of the sport catch reaches the commercial market.

(3) A large proportion of the total red snapper production (commercial and sport) consists of fish which have not reached sexual maturity and,

therefore, cannot perpetuate the species. Further evaluation of this finding is recommended and,if necessary, appropriate measures should be taken to insure continued availability of this resource.

(4) Examination of 240 otolith pairs produced 200 sets (83.3%) suitable for age and growth evaluations. Ages I-V are represented; otoloths from older fish were not legible. However, tag returns and infrequent examples of exceptionally large fish indicate that ages greater than 20 years may be attained.

(5) Annuli are formed yearly at a time coinciding with spawning season. Other factors may also influence annulus formation; therefore, a cause and effect relationship is not implied. Proportional growth between otolith radius and fish length is apparent.

(6) Back-calculated growth rates computed for ages I-V are consistent with estimates from tagging and other studies.

(7) The equation $W = 1.68892 \times 10^{-5} FL^{2.99420}$ expresses the length-weight relationship of red snapper. No sexual dimorphism was evident.

(8) Red snapper are opportunistic, polyphagous feeders, often foraging up to 1,000 ft away from reefs and consuming food items not associated with a reef-type environment.

(9) Spawning occurs from July through October, with a peak in August-September. There is no evidence that fish spawn within the study area; therefore, a spawning migration is indicated.

(10) Our work and that of other authors indicate that sexual maturity is reached at an age of 2+ years.

LITERATURE CITED

Adams, A. C. and W. C. Kendall.
1891. Report upon an investigation of the fishing grounds off the west coast of Florida. Bull. U. S. Fish. Comm. 9:289-312.

Barnes, R. D.
1968. Invertebrate zoology. 2nd Edition. W. B. Saunders Co., Philadelphia, 743 p.

Baughman, J. L.
1943. The Lutianid fishes of Texas. Copeia 1943:212-215.

Beardsley, G. L., Jr.
1967. Age, growth, and reproduction of the dolphin, Coryphaena hippurus, in the Straits of Florida. Copeia 1967:441-451.

Beaumariage, D. S.
1964. Returns from the 1963 Schlitz tagging program. Fla. Board Conserv. Mar. Lab., Tech. Ser. No. 43, 34 p.

__________,
1969. Returns from the 1965 Schlitz tagging program, including a cumulative analysis of previous results. Fla. Dep. Nat. Resour., Mar. Res. Lab., Tech. Ser. No. 59, 38 p.

__________,
1973. Age, growth, and reproduction of king mackeral, Scomberomorus cavalla, in Florida. Fla. Mar. Res. Pulb. No. 1, 45 p.

Beaumariage, D. S. and A. C. Wittich.
1966. Returns from the 1964 Schlitz tagging program. Fla. Board Conserv. Mar. Lab., Tech. Ser. No. 47, 50 p.

Bradley, E. and C. E. Bryan, III.
1973. Northwestern Gulf of Mexico marine fisheries investigation--Study No. 2, 1970-1973. Project No. 2-109-R, U. S. Dep. Commer., NOAA,NMFS, St. Petersburg, Fla., 134 p.

Bruger, G. E.
1974. Age, growth, food habits, and reproduction of bonefish, Albula vulpes, in south Florida waters. Fla. Mar. Res. Publ. No. 3, 20 p.

Camber, C. I.
1955. A survey of the red snapper fishery of the Gulf of Mexico, with special reference to the Campeche Banks. Fla. State Board Conserv., Tech. Ser. No. 12, 64 p.

Carpenter, J. S.
1965. A review of the Gulf of Mexico red snapper fishery. U. S. Dep. Inter., Fish Wildl. Serv., Circ. 208, 35 p.

Chevey, P.
1933. The method of reading scales and the fish of the intertropical zone. Pac. Sci.Congr. Proc. 5:3817-3829.

Clancey, J.F.
1956. A contribution to the life history of the fish, Bregmaceros atlanticus Goode and Bean, from the Florida current. Bull. Mar. Sci. Gulf Caribb. 6:233-260.

Dawson, C. E.
1963. Length and weight relationships of young red snappers from the northern Gulf of Mexico. Trans. Am. Fish. Soc. 92(3):310-311.

de Sylva, D. P.
1963. Systematics and life history of the great barracuda, Sphyraena barracuda (Walbaum). Stud. Trop. Oceanogr. (Miami) 1:128-179.

Jarvis, N. D.
1935. Fishery for red snappers and groupers in the Gulf of Mexico. U. S. Dep. Commer., Bur. Fish., Invest. Rep. 26, 29 p.

Lagler, K. F.
1952. Freshwater fishery biology. Wm. C. Brown Co., Dubuque, 360 p.

Lyons, W. G.
1970. Memoirs of the Hourglass Cruises: Scyllarid lobsters (Crustacea, Decapoda). Fla. Dep. Nat. Resour., Mar. Res. Lab., Vol. I, Pt. IV, 74 p.

Menezes, M. F. and T. C. V. Gesteira.
1974. Idade e crescimento do pargo, Lutjanus purpureus Poey, do norte e nordeste do Brasil. Arq. Cienc. Mar. 14(2):81-85.

Menon, M. D.
1953. The determination of age and growth of fishes of tropical and sub-tropical waters. J. Bombay Nat. Hist. Soc. 51:823-835.

Moe, M. A., Jr.
1963. A survey of offshore fishing in Florida. Fla. State Board Conserv. Mar. Lab., Prof. Pap. Ser. No. 4, 117 p.

________. 1966. Tagging fishes in Florida offshore waters. Fla. Board Conserv. Mar. Lab., Tech. Ser. No. 49, 40 p.

________. 1969. Biology of the red grouper Epinephelus morio (Valenciennes) from the eastern Gulf of Mexico. Fla. Dep. Nat. Resour., Mar. Res. Lab., Prof. Pap. Ser. No. 10, 95 p.

Moseley, F. N.
1965. Biology of the red snapper Lutjanus aya Bloch, of the northwestern Gulf of Mexico. Master's Thesis, Univ. Texas, Austin, 53 p.

_______ 1966. Biology of the red snapper Lutjanus aya Bloch, of the northwestern Gulf of Mexico. Publ. Inst. Mar. Sci. Univ. Tex. 11:90-101.

Smiley, C. W.
1885. Notes upon fish and the fisheries. Bull. U. S. Fish Comm. 5:65-96.

Stearns, S.
1884. On the position and character of the fishing grounds of the Gulf of Mexico. Bull. U. S. Fish Comm. 4:289-290.

Tabb, D. C.
1961. A contribution to the biology of the spotted seatrout, Cynoscion nebulosus (Cuvier), of east-central Florida. Fla. State Board Conserv., Tech. Ser. No. 35, 22 p.

Tesch, F. W.
1968. Age and growth. In W. E. Ricker (editor), Methods for assessment of fish production in fresh waters, p. 93-123. Blackwell Scientific, Oxford.

Topp, R. W.
1963. The tagging of fishes in Florida 1962 program. Fla. Board Conserv. Mar. Lab., Prof. Pap. Ser. No. 5, 76 p.

Van Oosten, J.
1929. Life history of the lake herring (Leucichthys artedi Le Sueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. Bur. Fish. 44:265-428.

Voss, G. L.
1953. A contribution to the life history and biology of the sailfish, Istiophorus americanus Cuv. and Val., in Florida waters. Bull. Mar. Sci. Gulf Caribb. 3:206-240.

Voss, N. A.
1954. The postlarval development of the fishes of the family Gempylidae from the Florida current. I. Nesiarchus Johnson and Gempylus Cuv. and Val. Bull. Mar. Sci. Gulf Caribb. 4:120-159.

Williams, A. B.
1965. Marine decapod crustaceans of the Carolinas. Fish. Bull. 65:1-298.