Aspects of the Life History of Three Deepwater Snappers around Puerto Rico

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RESUMEN

Para estudiar la abundancia y la biología de los peces de aguas profundas alrededor de Puerto Rico se llevó a cabo una investigación utilizando nasas antillanas en forma de flecha. Las nasas se calaron a profundidades entre 40 y 150 brazas. La tasa de captura por nasa levada fue de 9.0 libras; encontrándose una fluctuación desde 1.9 hasta 22.2 libras por nasa levada en 19 estaciones estudiadas. La comparación de estos datos con otros previamente obtenidos demuestra una reducción en la tasa de captura actual. Esto se debe, posiblemente, a un incremento en la actividad pesquera. De un total de 62 especies de peces capturados, tres de ellas fueron las mas abundantes y correspondieron al chillo *(Lutjanus vivanus)* 56%, rubia *(Rhomboplites aurorubens)* 19%, y negra *(L. buccanella)* 11%. La rubia y la negra son más abundantes entre 41 a 60 brazas, mientras que el chillo se capturo mas de 61 y 90.

Significativamente, se encontró que había mayor número de hembras en el caso de la negra y el chillo. Sin embargo, hallamos que en la rubia la proporción se acercó a 1:1. Se encontró que las tres especies desovan durante todo el año.

INTRODUCTION

Puerto Rico's near-shore fishery has long been characterized by artisanal fishermen using small boats. These fishermen have traditionally caught small numbers of coralline reef fishes, mollusks, crustaceans and coastal pelagic fishes using 15-to 17-foot (5-6m) skiffs. As late as 1967, Holmsen reported only a few dozen inboard-powered sailboats, 20 to 30 feet long (6-9m), capable of fishing deepwater snapper around Puerto Rico. The yola, a small dory-like boat, is now, as it was then, the mainstay of the near-shore fishery. Through various government-sponsored educational and incentive programs, a growing fleet of modern fully-equipped snapper boats has developed. By 1977 there were 66 snapper boats in the 25-to 51-foot (8-16m) length-range, fishing the insular slope as well as the fishing banks of neighboring countries. These boats accounted for a large proportion of the 369,000 pounds of deepwater snappers landed in 1977 which were worth $360,000 or 15.2% of the total value of fish landed in Puerto Rico (Suárez-Caabro; pers. comm.).

The remarkable improvement of the snapper fleet over the past 10 years was in part due to the early projects sponsored by PL 88-309, the Commercial Fisheries Research and Development Act. Assistance to the fishing community included onboard fishermen training, resource evaluation and exploratory fishing (Juhl 1969, 1972; Cole, 1976). The program for fiscal

years 1976-78, "Commercial Fisheries Surveys around Puerto Rico" continued the cooperative effort between the National Marine Fisheries Service and the Commonwealth of Puerto Rico. The purpose of this program was to evaluate the abundance of deepwater demersal fish and to obtain biological information on the important species.

MATERIALS AND METHODS

Sampling effort was conducted from the research vessel *Agustín Stahl,* a 11.3 m Florida-style lobster boat. It is a fiberglass-sheathed wood vessel powered by a 130 hp diesel engine and equipped with a hydraulic trap hauler, electric snapper reels and outriggers. The electronic equipment consists of a 150-fm (274m) range white-line depth recorder, radar and VHF radio.

Arrowhead fish traps, typical of the Puerto Rican fishery, were used for the entire project. The fish traps were chevron shaped and the frame was constructed of ⅜ inch steel bars (concrete reinforcing rods). The total dimensions were 75 x 50 x 20 inches (190 x 127 x51 cm). The frame was covered with galvanized, hexagonal wire mesh 1¼ x 1½ inch (3.2 x 3.8 cm). A single funnel, in the shape of a down-turned horse-neck, was fixed in the crotch of the chevron. The minimum funnel dimension of the oval entrance was approximately 48 inches (122 cm) in circumference. A bait envelope of slightly smaller mesh wire was attached to the bottom of the trap during fishing.

The traps were fished in areas of relatively gentle sloping bottom. They were buoyed with 5/16 inch (.79 cm) diameter polyethylene rope using three groups of two or three floats. A group of floats was added at about half depth, another group was added when the trap reached bottom and a final group was added with 10 to 20 fm of extra rope to provide scope. The floats were polyvinyl chloride 4¾ inches (12 cm) in diameter and 11 inches (28 cm) in length.

At each station a record was made of trap lifts and catch per trap, including depth of set, soak time, species caught, total number and total weight by species. Catch per unit of effort (CPUE) was considered either as pounds or number of fish caught per trap lift. Trap soak was usually one day, morning to morning.

Certain biological parameters were examined for three deepwater snapper species caught during this project. In the laboratory a subsample of individual fork lengths, weights, sex and gonad conditions was examined. Ripe males were defined as those that discharged sperm when the testis was cut. Ripe females were determined by the presence of loose eggs in the ovaries. Length at maturity was defined as the length group that demonstrated 30% or more ripe. Data were analyzed for sex ratio, size at maturity, spawning time, length-weight relationships and length-frequency distribution.

The depth of sampling was between 40 and 150 fm (70-270m) in areas suitable for trap fishing. Areas of gradually sloping bottom were limited on the often rugged topography of Puerto Rico's insular slope. Features of the bottom included nearly vertical walls of 100 fm (180 m) and drop-offs of 200 to 300 fm (360-540 m) across a horizontal distance of ¼ to ½ mile (0.4-0.6 km). The overall area of fishable bottom was therefore limited.

Initial emphasis was on covering a wide range of stations to determine baseline estimates of pre-exploitation abundance and biological parameters. This objective was partly precluded by the rapid expansion of the snapper boat fleet by the time the project was begun. Emphasis of the project was then placed on biological sampling and, in the final year, to replication of certain stations to enhance biological data. Replicate sampling met with only limited success due to a major engine repair of the research vessel and other logistics problems. Thus data on abundance were analyzed by station, while analysis of biological parameters included data from all stations combined.

A total of 19 sampling stations was occupied, which represented at least four different habitat types (Fig. 1). Four stations were located on the north coast of Puerto Rico, which is characterized by a rocky narrow shelf (½ to 2 miles or 0.8-3.2 km wide) exposed to seasonal high-energy waves originating from north Atlantic winter storms. Sufficient siltation occurred from island run-off to prevent major coralline formation. Lack of harbors except San Juan made this area dangerous for fishing during the unpredictable wave and/or weather conditions of winter. Five stations were located on the western end of Puerto Rico, three of which were on the edge of the relatively wide, shallow shelf characterized by sea grass flats and coralline patch reefs with a relatively gentle slope. Two others were at the southwest corner of the island where they were influenced by the Caribbean Sea and characterized by narrow, precipitous shelf edge and a limited fishing area. There were four stations on the southern or Caribbean shore of Puerto Rico. The shelf edge was fairly narrow, 1 to 2 miles (1.6 to 3.2 km) wide, but with well developed coralline reefs and sea grass beds inshore. The drop-off was rather steep initially, but had a more gentle incline after 100 to 200 fm (180-360 m). Five stations were near small outlying islands. They were located 6 to 40 miles from Puerto Rico and had typically limited insular shelves. Three stations were located to the west in the Mona Passage (one was actually a submerged bank). Two others were off the east coast along the steep, southern shelf edge of Vieques Island.

RESULTS AND DISCUSSION

Species Composition and Distribution

Of the 62 species from 20 families caught during this study, three species of

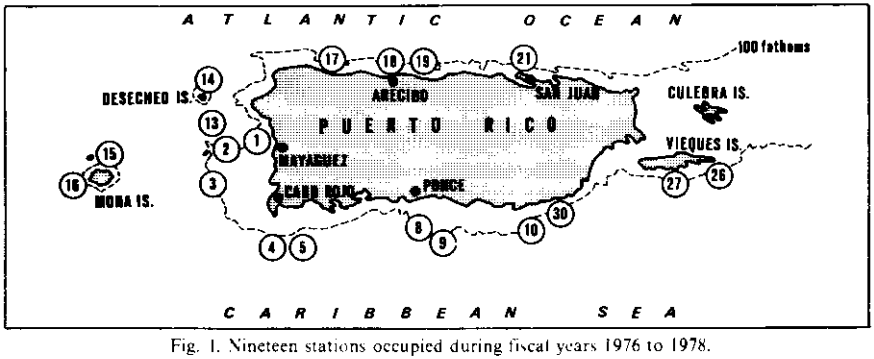

Fig. 1. Nineteen stations occupied during fiscal years 1976 to 1978.

Table 1. Mean number per lift for three species of snapper caught during 1978 at 10 stations

No.	Station Name	Total Effort (trap lifts)	$\bar{x}$ C/f Silk Snapper	$\bar{x}$ C/f Blackfin Snapper	$\bar{x}$ C/f Vermilion Snapper
West Coast					
2	Tourmaline Reef	107	8.1	0.6	0.9
3	Abrir La Sierra	22	5.7	0.0	2.5
Southwest Coast					
4	Cabo Rojo Lighthouse	48	15.9	1.3	2.0
South Coast					
9	Caja de Muertos Island	36	9.0	2.8	3.3
Mona Passage					
14	Sponge Bank	42	1.7	0.4	0.5
15	Mona Island	16	4.6	1.4	1.1
North Coast					
17	Isabela	18	11.8	0.1	0.4
21	San Juan	53	4.3	0.2	0.9
Eastern Insular Platform					
26	Vieques Island, East	29	1.6	3.4	0.2
27	Vieques Island, West	18	6.7	2.1	1.7
Totals		389	7.3	1.1	1.3

snapper (Lutjanidae) constituted 86% of the total catch. Singly, none of the 59 other species contributed more than 2% of the total number of specimens. Silk snapper *(Lutjanus vivanus),* vermilion snapper *(Rhomboplites aurorubens)* and blackfin snapper *(L. buccanella)* made up 56.2, 18.7 and 10.7% respectively, of the total number of fishes.

General geographic distribution of the three snappers is well documented. They have been recorded in the western central Atlantic from the Carolinas and Bermuda, and from the Gulf of Mexico to northern South America (Böhlke and Chaplin, 1968).

Employing catch per effort to indicate relative distribution around Puerto Rico showed that catches at all stations were dominated by silk snapper. During 1978 the total catch per effort of silk, blackfin and vermilion snappers was 7.3, 1.1 and 1.3 fish per trap lift (Table 1). Catch per effort by weight was determined by multiplying number of fish times mean weight for a given species which resulted in pounds (kgs) per lift as follows: silk snapper 7.8 (3.54), blackfin 1.1 (0.50) and vermilion 0.6 (0.26). Our results concurred with findings from the Virgin Islands (Dammann et al., 1970) and northern Leeward Islands (Wolf and Chislett, 1974). Cole (1976) reported silk to be second in abundance to blackfin snapper around Puerto Rico.

Silk snapper were caught most commonly at 61 to 90 fathoms (112-165m) yielding a CPUE of 11.0 fish per trap (Table 2). Both blackfin and vermilion were most abundant in the next shallower depth range, 41 to 60 fm (75-110m). Vertical distribution of these deepwater fishes has been reported on by

Table 2. Mean number per lift of silk, blackfin and vermilion snappers by depth ranges for fiscal year 1978

Depth range fathoms	Silk $\bar{x}$ C/f	Blackfin $\bar{x}$ C/f	Vermilion $\bar{x}$ C/f	Effort (lifts)
< 40	0.0	1.1	0.0	27
41-60	3.8	2.8	2.8	53
61-90	11.0	1.4	0.8	115
91-120	7.2	0.5	1.4	147
121-150	5.5	0.2	0.4	40
> 150	1.5	0.0	0.5	2
Totals	7.7*	1.1	1.3*	384

*computation does not include effort from first depth range, < 40 fathoms

various authors (Rivas, 1970; Sylvester and Dammann, 1973; Grimes et al., 1977) and varied for a given species between areas. As Rivas (1970) pointed out, suitable bottom type is probably more important than depth in influencing distribution.

Catch patterns during this project indicated schooling tendencies. A single trap would often contain large numbers of snappers, especially vermilion snapper of similar size and gonad condition. Schooling behavior of vermilion snapper was indicated by Grimes (1976a). Silk snapper have also been reported to travel in size groups (Dammann et al., 1970).

Length-frequency

For a given species over time and location, length-frequencies were combined due to apparent homogeneity of modes, year round spawning, collection of juveniles throughout the year and unequal sample sizes. Fork lengths were graphed as mid-point of 3-cm intervals.

The predominant lengths for male and female silk snapper were 29- and 26-cm fork-length as determined from length-frequency curves (Fig. 2a). Specimens of undeterminable sex which included juveniles and unsexable adult fish had a modal length of 23 cm. The maximum size for a silk snapper was 71 cm. Trap-caught silk snapper tended to be smaller than those caught by hook and line (Dammann et al., 1970; Thompson and Munro, 1974). Modal lengths of silk snapper from this work compared well with those of trapped silk snapper from Jamaica, approximate mode 27-cm fork-length (Thompson and Munro, 1974).

Blackfin snapper caught during this survey were generally smaller than silk snapper. The modal lengths for male and female blackfin were 26 and 23 cm respectively (Fig. 2b). The curve for specimens of undetermined sex was polymodal because both juveniles with undeveloped gonads and adults with resorbed gonads were included. The largest blackfin caught was 47 cm. Thompson and Munro (1974) reported a modal length of about 31-cm fork-length for trap-caught fish which was considerably larger than blackfin snapper taken during this project. Modes for males of both silk and blackfin snappers were one interval greater than that of females.

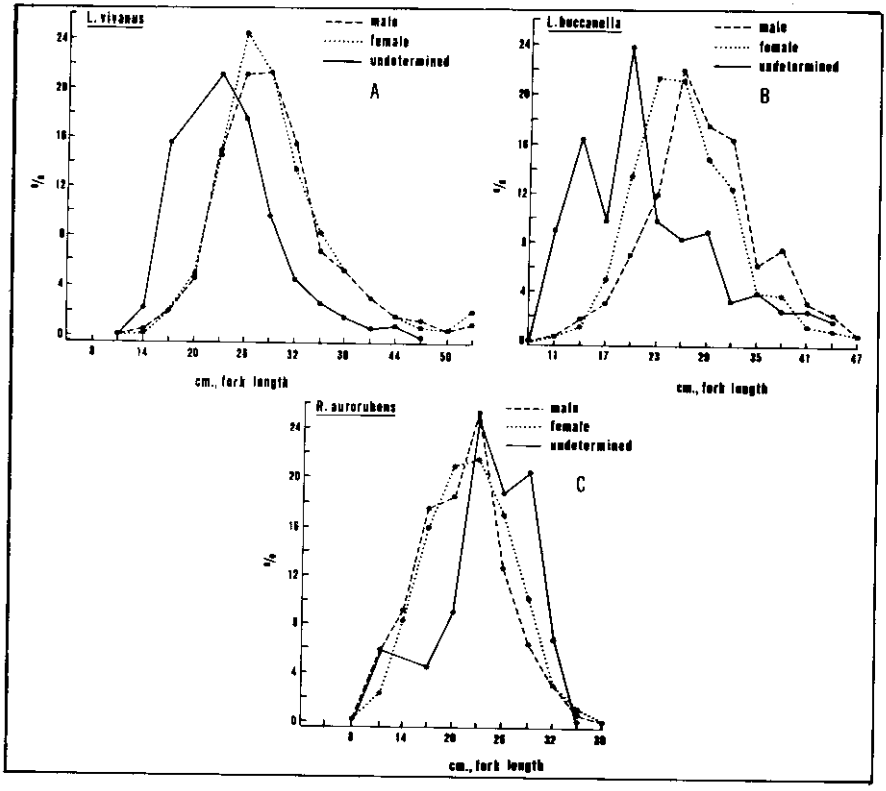

Fig. 2. Length-frequency distribution graphed as mid-point of 3 cm intervals for percentages of each category; (a) *L. vivanus* males (n = 1423), females (n = 1820) and undetermined (n = 901); (b) *L. buccanella* males (n = 226), females (n = 449) and undetermined (n = 122); (c) *R. aurorubens* males (n = 714), females (n = 612) and undetermined (n = 133).

Vermilion snapper were smaller than the silk snapper or male blackfin. The modal length for both sexes was 23 cm (Fig. 2c). Modal length was also 23 cm for undetermined specimens which were probably fish with resorbed gonads. Vermilion snapper reached a maximum of 38 cm. We had no comparable data available for this species in the Caribbean.

Smaller fishes of blackfin and silk snapper were collected shallower with length modes increasing progressively with depth (Figs. 3a and b). Although length distributions of the vermilion snapper did not clearly show this phenomenon (Fig. 3c) it has been suggested that the tendency for smaller fishes to occur in shallower depths is true of most, if not all, species of snappers (Rivas, 1970; Thompson and Munro, 1974).

Length-weight Relationship

No statistically significant differences were found for length-weight relationships between sexes for any of the three species (F test, Snedecor and

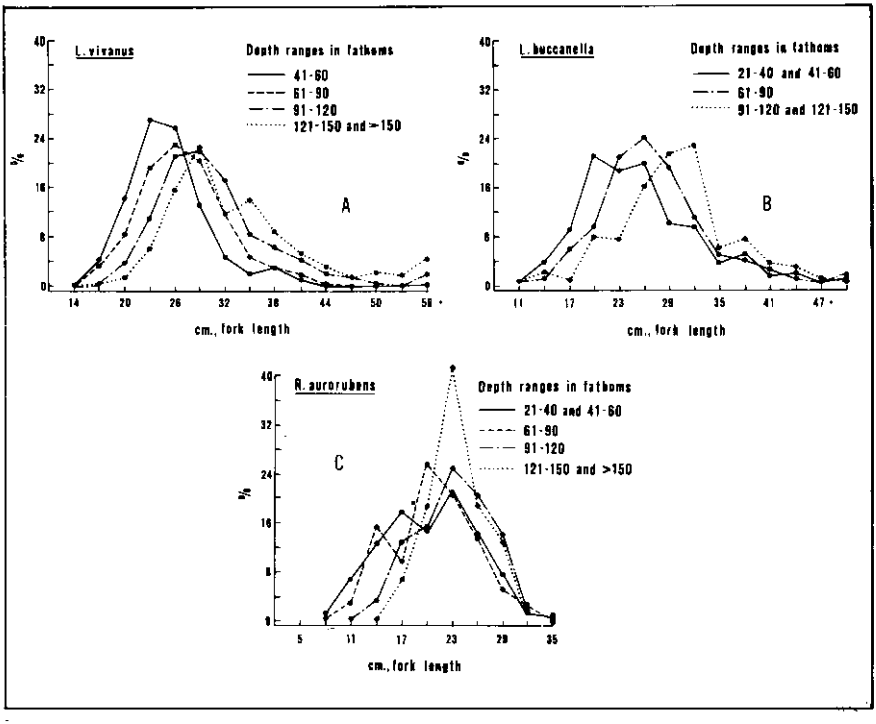

Fig. 3. Length-frequency distribution graphed as mid-point of 3 cm intervals for percentages of each depth range: (a) *L. vivanus* 41-60 fathoms (n = 212), 61-90 fathoms (n = 1411), 91-120 fathoms (n = 1219) and 121-150 and >150 fathoms (n = 243); (b) *L. buccanella* 21-40 fathoms and 41-60 fathoms (n = 216), 61-90 fathoms (n =278) and 91-120 and 121-150 fathoms (n = 60); (c) *R. aurorubens* 21-40 and 41-60 fathoms (n = 277), 61-90 fathoms (n = 430), 91-120 fathoms (n = 296) and 121-150 and >150 fathoms (n = 69).

Cochran, 1967). The length-weight relationship for combined sexes was calculated where W = weight in grams and FL = fork length in milimeters. The results were: silk snapper, Log W = 3.10 Log FL-5.00 with n = 30 and r = .99; blackfin snapper, Log W = 3.05 Log FL-4.86 with n = 30 and r = .98; vermilion snapper, Log W = 2.94 Log FL-4.63 with n = 30 and r = .99.

Both *L. vivanus* and *L. buccanella* demonstrated significantly greater numbers of females. Male to female ratios were 0.8:1 and 0.5:1 respectively (Table 3). Data analyzed for each year also showed significantly more females. Possible reasons for this were (1) differential mortality, (2) differences in habit between sexes or that (3) males were more difficult to recognize, especially in developmental stages where there were often accumulations of fat in the body cavity.

Vermilion snapper were found to have approximately a 1:1 sex ratio for two of the three study years. Data in 1976 indicated significantly more males than females. The overall ratio was 1.1:1 males to females (Table 3). In contrast Grimes (1976b) found a significantly greater number of female

Table 3. Percent female, sample size and Chi-square value to test 1:1 sex ratio

Species	% Female	Sample size	Chi-square
L. vivanus	56.0	3,247	46.6
L. buccanella	64.6	646	54.8
R. aurorubens	46.5	1,353	6.7

1 df, $p^{.01} = 6.6$

vermilion snapper off North Carolina and reported that sex ratio varied with latitude, size of fish and year of capture.

Spawning

Female silk snapper reached maturity, as defined previously, at 50-cm fork-length and males at 38 cm (Table 4). Thompson and Munro (1974) found female silk snapper size at maturity to be 50 to 55 cm which was comparable to our estimate. Males, however, were reported as mature at 55- to 60-cm fork-length which was considerably larger than our findings. Estimated lengths of maturity for blackfin females and males were 20-and 38-cm fork-length (Table 5). These figures differed from those of Thompson and Munro (1974) who presented 23 to 25 cm for females and 25 to 27 cm for males. Size of maturity for vermilion snapper was remarkably small. Males appeared mature at 14 cm and females at 20 cm (Table 6). Grimes (1976b) gave sexual maturity as 35- to 40-cm total length (32- to 36-cm fork length) for vermilions off North Carolina. Comparison between Grimes' work and ours should take into account differences in gear and latitude.

All three species demonstrated year round spawning which corroborated finds by Munro et al. (1973) in Jamaica and Erdman (1976; pers. comm.) in Puerto Rico (Table 7). Grimes et al. (1977), working in the temperate zone off North Carolina, reported that these three species were generally late spring through summer spawners. Blackfin and vermilion snappers spawned year round and in relatively large numbers. Silk snapper also spawned year round but in low percentages. The small number of ripe fish may have been due to the majority of the catch being smaller than size at maturity. Apparent peaks in spawning in July-September and October-December for silk snapper were probably due to chance collection of spawning groups of a few large fishes. Vermilion snapper were often collected as large numbers of ripe individuals in a single trap. It has been suggested that some shallow water snappers aggregate for spawning (Wicklund, 1969; Starck, 1971; Johannes, 1978). Our data for silk and vermilion snappers would seem to support that hypothesis.

Abundance

The total effort during this study was 934 trap lifts. Effort per station ranged from a minimum of six trap lifts for station No. 10 to a total of 206 trap lifts for No. 2. The mean catch per unit of effort (CPUE) per station ranged from a high of 22.2 lb (10.0 kg) and 18.7 fish per lift to a minimum of 1.9 lb (0.9 kg) and 3.8 fish per lift. Weighted mean per lift was 9.0 lb (4 kg) and 10.5 fish

Table 4. Percentage of ripe *L. vivanus* by length-frequency distribution as indicated by mid-point of 3 cm FL intervals

Interval of mid-point	Females % ripe	Females #examined	Males % ripe	Males #examined
21 and smaller	0.0	128	0.0	101
23	0.4	262	1.9	212
26	0.4	409	2.3	302
29	0.0	389	5.6	305
32	2.0	244	6.3	221
35	2.0	151	21.9	96
38	7.4	94	29.9	77
41	7.0	57	37.0	46
44	7.1	28	66.7	21
47	26.7	15	66.7	18
50	58.3	12	42.9	7
53 and larger	28.0	25	20.0	15
Totals		1,814		1,421

(Table 8). The average weight per fish was 1.1 lb (0.5 kg).

The highest catch rates seemed to occur at stations where bottom topography or other natural phenomena may cause reduced fishing pressure. Stations No. 4 and 5 at the southwest corner of the island yielded the highest catch rates. Here the upper shelf slope was particularly precipitous and accessible fishing area was quite limited. Fishing pressure on the north coast was restricted by seasonally severe weather conditions and limited harbors. In this study, two of the four stations on the north coast had higher than average catch rates. Another station which had a high catch rate was at Mona Island, located halfway between Puerto Rico and the Dominican Republic. Stations 8 and 9 off Ponce also were above average in catch rates but socioeconomic rather than natural conditions appeared to have caused reduced fishing pressure.

An evaluation of the different catch rates was made from results of three previous exploratory fishing programs from Puerto Rico. These programs, which incorporated surveys of fish abundance, exploratory fishing and onboard fishermen training, also provided historical trap catch data (Table 9).

Juhl reported the average pounds per lift for each of his 2-mile by 2-mile grids but detailed data on depth of capture and fishing effort were not available. For this comparison, catch per effort data for the grids within a general area were averaged. The number of grids sampled was indicated on the table. Most sampling grids extended over the shelf edge but data that were obviously from shallow nearshore grids were omitted.

In contrast with Juhl and our study, Cole (1976) employed catch per trap day. This approach may have been satisfactory for shallow water trapping where ingress was a slow continuous process (Munro et al, 1971) but for

Table 5. Percentage of ripe *L. buccanella* by length-frequency distribution as indicated by mid-point of 3 cm FL intervals

Interval of mid-point	Females % ripe	Females #examined	Males % ripe	Males #examined
14 and smaller	0.0	6	0.0	4
17	13.0	23	0.0	7
20	31.7	60	6.3	16
23	26.0	96	14.8	27
26	49.5	95	8.0	50
29	44.8	67	12.5	40
32	55.4	56	18.9	37
35	64.7	17	7.1	14
38	88.2	17	35.3	17
41	33.3	6	28.6	7
44	0.0	4	20.0	5
50	0.0	0	0.0	1
Totals		447		225

deepwater snappers in baited traps ingress appeared to be rapid and immediate. Wolf and Chislett (1974) found only a 9% daily increase in catch rate of traps after the first day's soak. By the third day their catch rate began to decline for baited traps in 70 to 80 fm. This finding was corroborated by successful trap lifts of only a few hours from this study, by Juhl (1972) and from observations made by commercial fishermen. We believed that abundance of these deepwater snappers was better represented by catch per lift rather than catch per trap day.

Cole (1976) reported an overall catch rate of 3.18 lb of fish per trap day. The traps were normally fished 1 to 3 days. During his study, 2,143 lifts were made for the total effort of 4,971 trap days for an average of 2.31 days per lift. Applaying this conversion figure to his catch per trap day gave an equivalent of 7.3 lb per lift. Cole presented the results of trapping effort both by depth and location. For the comparison with our data, only the CPUE for the deeper depth ranges 41 to 125 fm (75-229m) were considered, so that similar deepwater habitats can be compared. The data listed by depth ranges did not have the number of trap days per lift. Therefore a similar conversion factor had to be calculated for each area and applied to the average pounds per trap day for the deeper depth ranges.

Juhl (1969) obtained low CPUE even though previously unexploited depths were sampled (Table 9). In his subsequent project, Juhl (1972) reported a considerably higher catch rate (average of 15.2 lb/lift). Cole's sampling in 1973-75 indicated a decrease in catch, and suggested a reduction in abundance. Reduction in catch rate coincided with an increase of the snapper boat fleet. Through government assistance the fleet of fully-equipped snapper boats in the 31 to 51 foot (9-16 m) range increased from 6 in 1973 to 45

Table 6. Percentage of ripe *R. aurorubens* by length-frequency distribution as indicated by mid-point of 3 cm FL intervals

Interval of mid-point	Females % ripe	Females #examined	Males % ripe	Males #examined
11	16.7	18	2.4	42
14	6.0	50	39.1	64
17	19.8	96	43.2	125
20	37.0	127	50.0	132
23	59.8	132	69.2	182
26	62.5	104	75.8	91
29	74.2	62	78.3	46
32	77.8	18	77.3	22
35	80.0	5	80.0	5
38	0.0	0	0.0	1
Totals		612		710

Table 7. Percentage of ripe females by quarters for 3-year study

Species	Quarters			
	Jan.-Mar.	Apr.-Jun.	Jul.-Sept.	Oct.-Dec.
L. vivanus				
% ripe	1.1	1.0	6.8	3.7
n	817	210	470	321
L. buccanella				
% ripe	34.4	48.1	34.1	33.9
n	180	77	101	59
R. aurorubens				
% ripe	59.5	55.6	57.6	12.1
n	222	135	181	91

in 1976 (Suárez-Caabro and Rolón, 1974; Suárez-Caabro, pers. comm.). Informal interviews with captains of commercial snapper boats indicated that most have had to begin fishing outside Puerto Rican waters because of marked reduction in deepwater snapper stocks. The consensus of fishermen was that intensive fishing quickly depleted local fish populations and that good catches of large fish can no longer be made consistently around Puerto Rico.

Our project work indicated slightly greater CPUE than Cole but not as great as Juhl for 1970-72. Several of the following factors probably contributed to a higher catch rate in this survey compared to the previous one: (1) differences in sampling techniques; Cole did wide-spread exploratory type sampling, whereas this project employed a directed effort at presumed better

Table 8. Mean catch per lift for 19 stations around Puerto Rico for fiscal years 1976-1978

Station No.	Station Name	Total Effort (trap lifts)	$\bar{x}$ C/f Number	$\bar{x}$ C/f Weight
West Coast				
1	Mayaguez	38	5.7	1.9
2	Tourmaline Reef	206	8.7	7.6
3	Abrir La Sierra	58	8.2	7.1
Southwest Corner				
4	Cabo Rojo Lighthouse	159	15.0	18.2
5	Margarita Reef	12	18.7	22.2
South Coast				
8	Ponce	19	17.6	16.0
9	Caja de Muertos Island	62	14.0	14.0
10	Salinas	6	8.0	7.2
30	Guayama Reef	15	6.9	9.3
Mona Passage				
13	Sponge Bank	52	5.5	6.9
14	Desecheo Island	48	7.2	9.7
15	Mona Island, North	16	13.4	15.2
16	Sardinera Beach (Mona Island)	9	3.6	3.0
North Coast				
17	Isabela	30	16.7	10.1
18	Arecibo	23	7.5	8.7
19	Arecibo (East)	14	3.3	3.6
21	San Juan	120	11.1	10.6
Eastern Insular Platform				
26	Vieques Island, East	29	7.4	6.6
27	Vieques Island, West	18	13.7	8.9
Totals		934	10.5	9.0

locations; (2) possible reduction of local fishing effort: the more profitable snapper boats were fishing at distant banks; (3) change of bait: tuna eggs and/or viscera were used in this study and seemed to be more effective than trash fishes; (4) reduction in number of large fish by commercial boats: smaller fish caught in traps during our study may be replenished faster due to reduced intraspecific competition, if not predation, from large fish.

SUMMARY AND CONCLUSIONS

Sixty-two species were caught during this three year project but catches were dominated by three species of snappers: silk snapper *(L. vivanus)* which made up 56% of the total number caught, vermilion snapper *(R. aurorubens)* with 19% and blackfin snapper *(L. buccanella)* with 11% by number.

Catch patterns indicated widespread occurrence of the three primary

Table 9. Comparison of mean catch per unit of effort (pounds per trap lift*) between four 3-year projects for deepwater demersal fishes in Puerto Rico

Area	FY 1967-69 (Juhl, 1969) $\bar{x}$ C/f	Grids sampled	FY1970-72 (Juhl, 1972) $\bar{x}$ C/f	Grids sampled	FY 1973-75 (Cole, 1976) Estimated C/f	Total lifts	FY 1976-78 (Boardman & Weiler) $\bar{x}$ C/f	Total lifts
Mayaguez			1.0	1			1.5	38
Tourmaline Reef			13.5	8			7.6	206
Tourmaline Bank			16.8	4				
Sponge Bank			256.0	1			6.9	52
Mona					7.5	30	10.8	25
Abrir La Sierra	5.0	3					7.1	58
Cabo Rojo	6.3	5	10.3	3	5.2	294	18.2	171
Guanica			17.0	2				
Ponce	7.0	4	10.7	6			14.5	75
Salinas	7.6	3			8.2	79	7.2	6
Patillas	4.3	9			5.4	217	9.3	15
Vieques					8.4	79	7.5	47
Cabo San Juan			12.2	5				
Luquillo			8.9	8				
San Juan					23.9	36	10.6	120
Cerro Gordo			17.6	7				
Palmas Altas			15.0	6			3.6	14
Arecibo	10.7	7			12.1	14	8.7	23
Isabela							10.1	30
Desecheo			15.5	1			9.7	48
Rincon			7.9	12				
Totals	7.7	31	15.9	64	7.0	7	9.0	928

*For explanation of catch per unit of effort calculations see text

snapper species around Puerto Rico, with some evidence of schooling behavior. Blackfin and vermilion snappers were most abundant at 41 to 60 fm while silk were most common at the 61- to 90-fm range.

Modal lengths for silk snapper males were 29- and females 26-cm fork-length. Modal lengths for blackfin snapper were males 26 and females 23 cm. Vermilion snapper males and females had a modal length of 23-cm fork-length. Smaller silk and blackfin snappers were collected at shallower depths and size increased progressively with deeper sampling.

Length-weight relationships were as follows: silk snapper Log W = 3.10 Log FL-5.0; blackfin snapper Log W = 3.05 Log FL-4.86; vermilion snapper Log W = 2.94 Log FL-4.63.

Sex ratios differed from the expected 1:1 for both blackfin and silk snappers which had significantly more females.

All three species spawned year round. Percentages of ripe silk snapper were low apparently because the majority of fish caught were smaller than estimated size at maturity. High percentage of ripe blackfin and vermilion were found year round.

Average catch rate of all deepwater demersal fishes in chevron-shaped traps was 9.0 lb (4.0 kg) and 10.5 fish per lift. Catch rates of 19 stations sampled ranged from 1.9 lb (0.9 kg) and 3.8 fish per lift to 22.2 lb (10.0 kg) and 18.7 fish per lift. Variation in catch rates was believed to reflect differences in fishing pressure because stations where fishing was found most productive were those least accessible to fishermen.

Comparison of our data with that of previous studies indicated a declining catch rate since 1970 to 1972. This apparent reduction in catch may have been due to increased fishing pressure resulting from a rapidly growing fleet of modern snapper boats.

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