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MATURATION, SPAWNING, AND FECUNDITY OF OPAKAPAKA, *PRISTIPOMOIDES FILAMENTOSUS*, IN THE NORTHWESTERN HAWAIIAN ISLANDS

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ABSTRACT

The reproductive biology of opakapaka, *Pristipomoides filamentosus*, from the Northwestern Hawaiian Islands was studied. Development of ova within the paired ovaries was heterogeneous, and the stages of maturation, based on the development of ova in the most advanced mode in ova diameter size-frequency distributions, were positively related to the gonadal somatic indices. The data indicated that the spawning season for opakapaka is from June through December, with spawning peaks in August. Fork length appeared to be the best predictor of fecundity. Estimates of annual fecundity ranged from 477,990 ova for a 48.7-cm fish to 1,461,875 ova for a 76.3-cm fish. The species reaches sexual maturity at about 42.5 cm and spawns at 52 cm. The sex ratio (data pooled by years) showed a significant departure from 1:1. More males were observed in January and more females in August. Females predominated in the samples at sizes >70 cm.

fecundity	*Pristipomoides filamentosus*
maturation	snapper
sex ratio	spawning

INTRODUCTION

In 1978 a tripartite cooperative agreement was signed by the U.S. Fish and Wildlife Service, Hawaii Division of Aquatic Resources, and the Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service (NMFS) to investigate the marine and terrestrial resources in the Northwestern Hawaiian Islands (NWHI). Under this agreement, NMFS was responsible for the survey and assessment of benthic and pelagic fishery resources (Uchida et al., 1979).

Part of the Honolulu Laboratory's work included life history studies of commercially important species such as opakapaka, Pristipomoides filamentosus (Cuvier and Valenciennes). Opakapaka have been extensively fished around the main Hawaiian islands for decades. Prized for its good taste and pleasing appearance, opakapaka is one of the most important bottomfish in terms of landed weight and cash value.

In this study the spawning season, size at sexual maturity, sex ratio, and fecundity of the opakapaka was examined.

There is a limited amount of data in the literature on the life history and reproductive biology of this deepwater snapper. Ralston (1981) studied the commercially caught opakapaka in the Hawaiian Archipelago and determined that opakapaka was sexually mature at 38-cm fork length (FL) and spawned from July to November.

MATERIALS AND METHODS

For a major portion of the NWHI resource assessment program, the NOAA ship Townsend Cromwell was used to survey the bottomfish resource. The opakapaka, as well as other bottomfishes, were caught on handline gear using four hooks (No. 28 size) per line. Samples were collected from most of the banks and reefs from Necker Island to Northampton Seamount at depths of 73 to 220 m.

Landed fish were measured for fork length (FL) and standard length (SL) in millimeters and weighed to the nearest 10 g. Ovaries from 150 fish were collected and preserved in 4 percent buffered formaldehyde-seawater solution. Ovaries were not examined until 6 or more months had passed and shrinkage had stabilized. The developmental stage of all the ovaries was determined by the physical characteristics of the ova (Table 1).

Homogeneity of Ova Development

A pair of ovaries was examined for homogeneity of ova development. A cork borer with an inside diameter of 10.026 mm was used to sample ovarian tissue from the anterior, middle, and posterior regions of both lobes. Each of the core samples extended from the outer layer of the ovary to the central lumen. Each core sample was sectioned into three equal parts, the outer epithelial layer, middle layer, and inner layer adjacent to the lumen, for a total of 18 subsamples. From each of the subsamples, ova were teased from the connective tissue and 200 randomly selected ova was measured. Diameters of the irregularly shaped ova were measured in a petri dish etched with parallel lines. An ocular micrometer was used to measure the ova following the methods of Clark (1934).

TABLE 1. DEVELOPMENTAL STAGES OF THE OVA

Stage	Description	Size Range (mm)
Primordial	Found in all the ovaries; usually ovoid and transparent.	No measurements taken
Early developing	Ova are transparent to translucent; opaque yolklike material may be present in the ovum. Ova usually ovoid or wedgelike.	0.15-0.39
Developing	Ova are completely opaque and ovoid.	0.16-0.67
Advanced developing	Ova are ovoid and have a translucent margin. The fertilization membrane has formed.	0.39-0.60
Early ripe	Ova are usually round or spherical. Yolk material is translucent and oil globules may be present.	0.47-0.58
Ripe	Ova are transparent and contain oil globules.	No ripe ovary collected
Residual	Ova are degenerating and show signs of degradation.	

Source: Adapted from Uchiyama and Shomura, 1974

Fecundity

Estimates of fecundity for five individual fish were obtained by the gravimetric method (Bagenal and Braum, 1968). Preserved ovaries were dried on paper towels and gently squeezed to expel any liquid within the lumen. An electronic balance was used to weigh each pair of ovaries to the nearest 0.1 mg. A middle core sample was extracted from the left lobe and sectioned into three equal layers and each layer was weighed to the nearest 0.1 mg.

Ova were teased from the connective tissues and a random sample of 300 ova were measured to establish the size range of the ova in the most advanced mode. Ova in the most advanced mode were then counted.

Fecundity was estimated from each subsample by multiplying the number of ova in the most advanced mode by the ratio of the total ovary weight divided by the subsample weight. The mean of these estimates was used to represent the fecundity of the fish.

Relationships of fecundity to fish length and body weight were examined by plotting fecundity estimates against lengths and weights. Regression lines of the form $Y = a + bX$ (where Y = log of the number of ova, X = fish length in centimeters or weight in kilograms) were fitted by the least squares method.

RESULTS

Homogeneity of Development

Because the frequency distributions of the ova diameters (see Table 1) from the 18 subsamples were skewed to the right of the means, a Kruskal-Wallis, nonparametric test (Sokal and Rohlf, 1969) was used to compare the 18 subsamples. The results showed that the variances among the sites were significantly different ($\chi^2 = 191.45$, d.f. = 17, $P < 0.01$), indicating that the ova in opakapaka ovaries developed heterogeneously.

Fecundity

Fecundity estimates ranged from 478,000 for a 48.7 cm fish to 1,462,000 for a 76.3 cm fish. Relationships of the log fecundity to fork length and weight were determined by the least squares method. The relationship between fecundity and fork length gave the best fit ($r^2 = 0.90$) (Figure 1). The relationships of fecundity to length and weight were:

$$\log \text{fecundity} = 4.74 + 0.0187\ FL \quad (1)$$
$$r^2 = 0.90 \text{ and}$$
$$\log \text{fecundity} = 5.43 + 0.108\ wt$$
$$r^2 = 0.87$$

where FL is in centimeters and wt in kilograms.

Spawning Seasonality

The gonadal somatic index (GSI) can be used to estimate the spawning season, provided that it can be shown to have a positive relationship with the various stages of ovarian maturity. A test to determine the relationship between fish size and GSI indicated that fish size was positively correlated with GSI ($r = 0.447$, d.f. = 137, $P < 0.01$). A test between fish size and stages of maturity also showed positive correlation ($r = 0.873$, d.f. = 131, $P < 0.01$) (Figure 2). It appeared that as the female developed sexually, the weight of the ovary not only increased faster than that of the total body weight, but also rose and fell in relation to ovary development, spawning, and redevelopment.

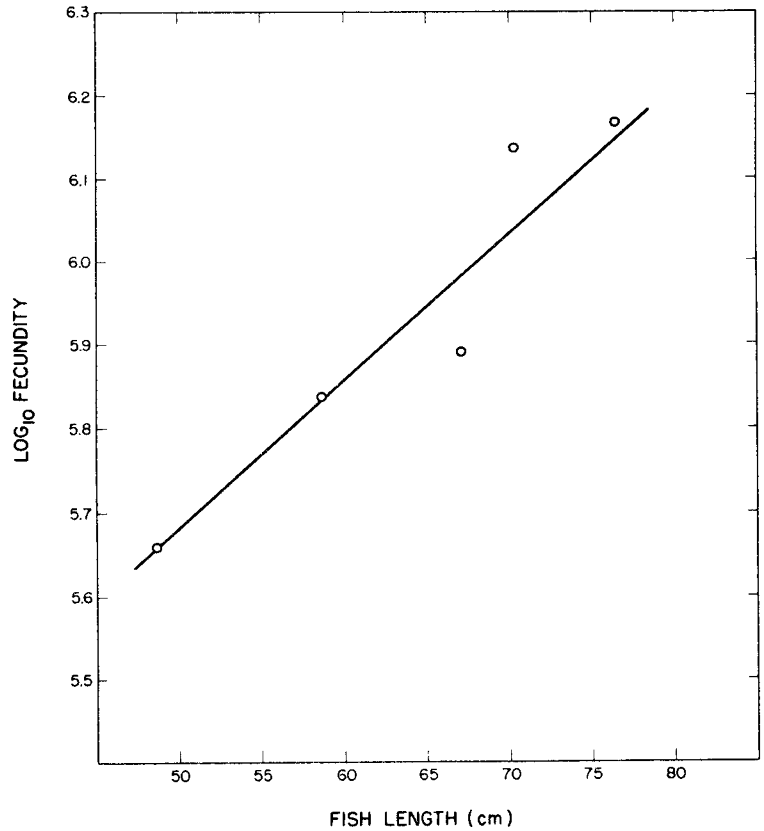

Figure 1. Relationship between the log of fecundity and the fish length (fork length) of opakapaka from the Northwestern Hawaiian Islands

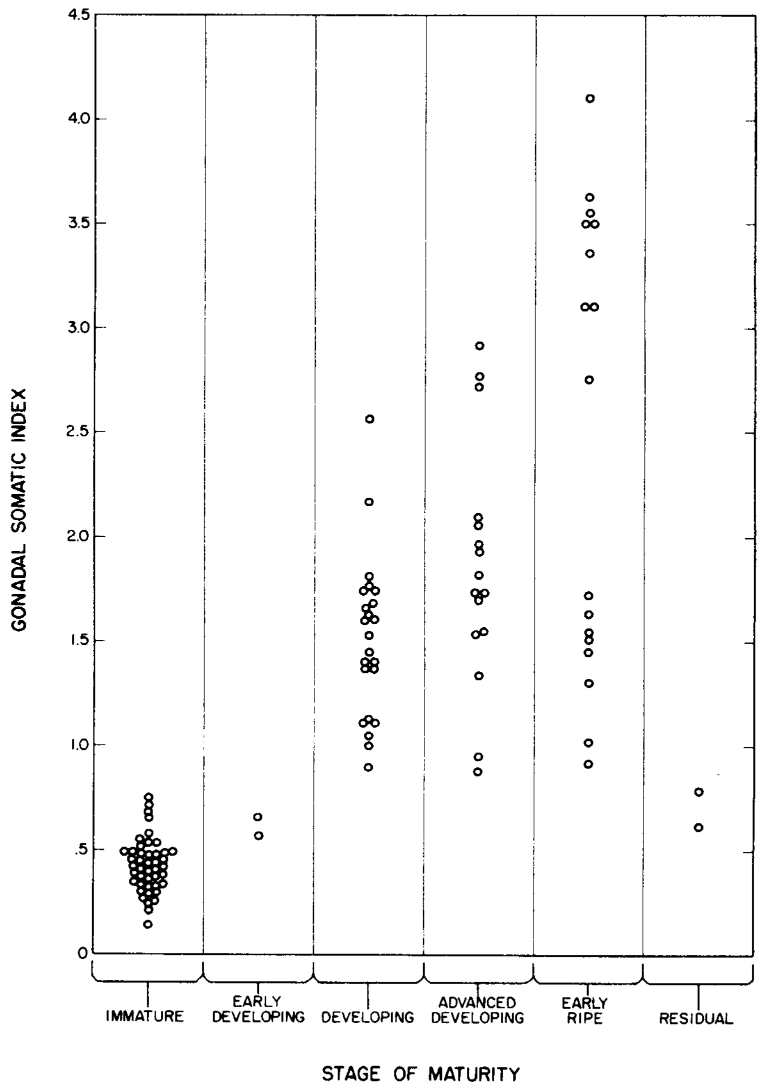

Figure 2. Relationship between stages of maturity and gonadal somatic index in the opakapaka

The spawning cycle of the opakapaka was determined by plotting the GSI against the month of capture (Figure 3). The results showed that spawning commenced in June (GSI = 3.5 percent) and peaked in August (GSI = 4.1 percent). At the conclusion of the spawning season in December, the GSI was 3.1 percent. The lowest GSI was found in January. However, the occurrence of ripening ovaries during this period suggests a protracted spawning season.

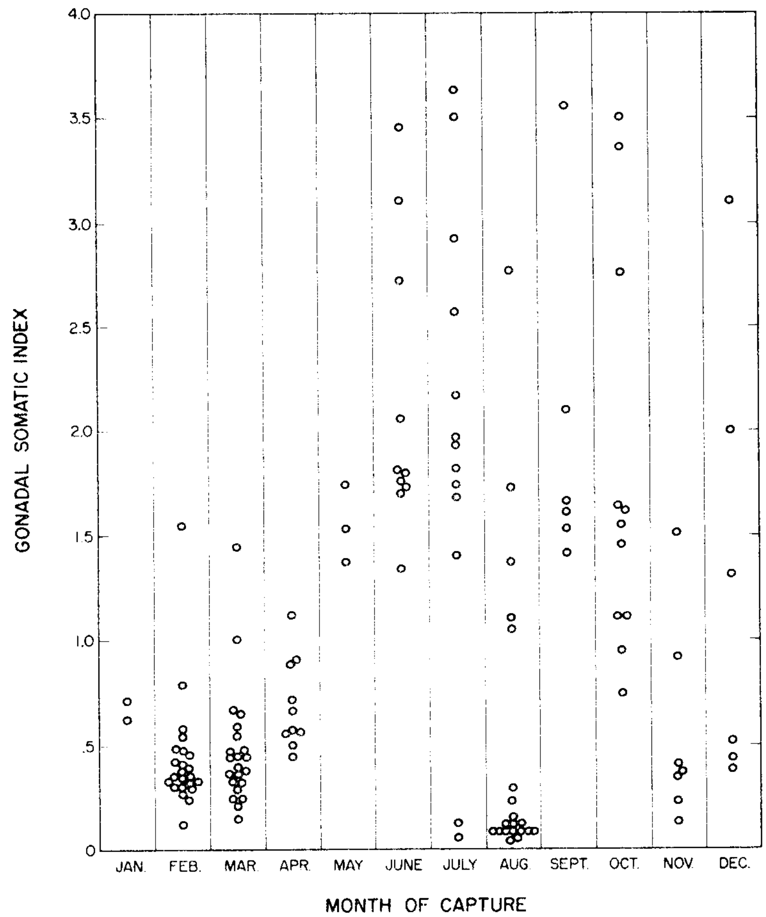

Figure 3. Gonadal somatic index of 135 female opakapaka by month of capture

Size of Maturity

Since it was determined that fish size was closely related to sexual development, size at maturity of the opakapaka was determined by the percentage of change in mean gonad weight at each 5-cm size class (Figure 4). The greatest percentage of increase in gonad weight is expected when a fish matures. For the opakapaka the greatest percentage of increase in gonad weight was observed at the 40 to 50-cm class. The data indicate that opakapaka mature at about 42.5 cm. The smallest mature fish was 42.7 cm. The smallest ripe fish was 37.4 cm and was probably a precocious fish.

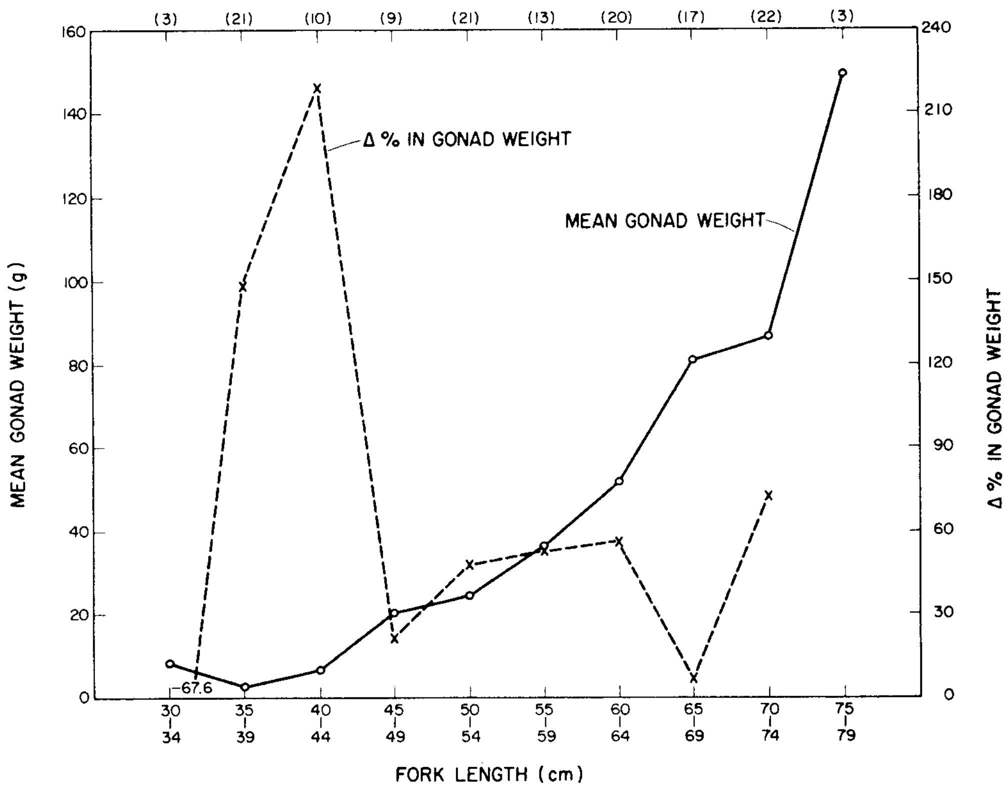

Figure 4. Ovary weight and percent change in ovary weight by 5-cm size classes (sample size in parentheses)

Sex Ratio

Sex data were obtained for 643 opakapaka during the 4 years of the resource assessment program. Because the yearly sex ratios did not deviate significantly from the expected (Table 2), the data for 1978, 1979, 1980, and 1981 were pooled. Females

TABLE 2. NUMBER OF MALE AND FEMALE OPAKAPAKA COLLECTED BY MONTH AND YEARS, 1978 THROUGH 1981

Month	Year				Total	d.f.	χ^2
	1978	1979	1980	1981			
January	61:35	—	—	2:3	63:38	1	6.19*
February	3:8	—	—	11:19	14:27	1	4.12*
March	14:34	—	11:8	0:1	25:43	2	4.76*
April	—	10:9	4:10	4:0	18:19	2	0.03
May	3:5	0:1	—	6:11	9:17	2	2.46
June	12:10	—	9:17	5:11	26:38	2	2.25
July	—	3:5	—	22:21	25:26	1	0.02
August	10:18	—	4:16	9:22	23:56	2	13.78†
September	4:1	1:2	18:12	—	23:15	2	2.19
October	38:34	—	11:5	—	49:39	1	1.14
November	2:3	—	12:12	—	14:15	1	0.03
December	—	4:3	2:6	—	6:9	1	0.60
TOTAL	147:148	18:20	71:86	59:88	295:342		
d.f.	1	1	1	1			
χ^2	0.003	0.11	1.43	5.72*			

Note: The deviation of the male to female ratio from an expected 1:1 was tested by Chi-square.

*$P \leq 0.05$
†$P < 0.01$

were more abundant than males. For the pooled sample, the male to female ratio of 1:1.18 significantly differed from the expected 1:1 (χ^2 = 4.37; d.f. = 1; P = 0.05).

Monthly sex ratios deviated significantly from 1:1 on four occasions. Larger numbers of males were caught in January and by contrast females were more numerous in February. Also during the peak spawning period in August, females were more predominant than males by 2.43 times.

When size of the fish was considered, the sex ratio deviated from the expected in two size groups. Females were more numerous in the 30 to 39-cm class (1.92:1) and in the largest size class, 70 to 79 cm (1.96:1) (Table 3).

TABLE 3. NUMBER OF MALE AND FEMALE OPAKAPAKA GROUPED IN 10-CM SIZE CATEGORIES

Fork Length (cm)	Males	Females	n	χ^2
20-29	1	5	6	2.67
30-39	36	69	108	10.37*
40-49	59	66	125	0.39
50-59	86	74	160	0.90
60-69	88	83	171	0.15
70-79	25	49	74	7.78*

Note: Deviation of the sex ratio from the expected 1:1 was tested by Chi-square.

*$P < 0.01$

DISCUSSION

The distribution of ova in various stages of development throughout the 18 subsamples indicated that development of the ovary in the opakapaka was heterogeneous. Of the total 18 subsamples from 1 fish, only 6 subsamples had ova in the advanced developing stage and only 2 subsamples had ova in the ripe stage. In the test for homogeneity of location, developing ova were used because of their consistency throughout the 18 subsamples.

It appears likely that opakapaka spawn more than once in the protracted spawning period of 7 months. During the spawning season, only 2 percent of the females of mature size had indices lower than 1 percent which occurred only at the conclusion of the period. Also, all of the sexually mature females during that time exhibited either developing or ripening ovaries and none was found in a spent or resting condition. From the continuous development of the intraovarian ova and the absence of resting ovaries during the spawning period, it is concluded that the opakapaka is probably an intermittent spawner.

Spawning is probably initiated by transient environmental conditions that promote rapid ova development and optimize development and survival of the short planktonic life of the lutjanid larvae (Randall and Brock, 1960).

Occurrence of ripe ovaries substantiated the spawning period indicated by the seasonal distribution of GSI. More sexually developed fish were observed in October: 46 percent of the fish had ripening ovaries. Ralston's 1981 work on commercially caught opakapaka indicated that the fish spawns from July through November.

Although the yearly sex ratios for 1978-81 did not deviate significantly from the expected, the sex ratio for the pooled sample deviated significantly from 1:1 in favor of the females. Kami (1973) observed significantly higher catches of male opakapaka in Guam, whereas Ralston (1981) found no predominance of any sex in his study of P. filamentosus caught in Hawaii.

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