# SKIPJACK TUNA SPAWNING IN THE MARQUESAS ISLANDS AND TUAMOTU ARCHIPELAGO

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## ABSTRACT

**Spawning of skipjack tuna (*Katsuwonus pelamis*) in the Marquesas and Tuamotu areas was investigated by examining ova from 402 pairs of ovaries collected during exploratory fishing cruises, August 1956 to June 1958. Investigated were size at first spawning, spawning season, frequency of spawning, fecundity, use of the gonad index as a measure of maturity of skipjack, and the relation of stage of sexual development to schooling behavior.**

**The length at first spawning of skipjack in the two areas was found to be about 43 cm., although a few fish as large as 50.7 cm. apparently were not yet ready to spawn. Spawning activity reached a peak during November–April. The data indicate a possibility that individual skipjack may spawn more than once during a season. Number of ova extruded per spawning was estimated at 0.1 to 2 million. The gonad index could not be used as a measure of sexual development. Skipjack schools tended to have fish in a similar stage of sexual development.**

From 1956 to 1959 the staff of the Bureau of Commercial Fisheries Biological Laboratory at Honolulu investigated the tuna resources of waters of French Oceania around the Marquesas Islands and the Tuamotu Archipelago. A study of the spawning of the skipjack tuna, *Katsuwonus pelamis* (Linnaeus), which appears to be the most abundant surface-schooling species of tuna in this area, was included in the investigations.

This study is based on the systematic microscopic examination and measurement of the ova in skipjack ovaries, generally following the method described by Clark (1934). Skipjack spawning studies, based generally on the examination of gonads or on the capture of larvae and juveniles, have been made in many different areas of the Pacific. On the basis of the examination of gonads, Matsui (1942) inferred that skipjack may spawn throughout the year in the vicinity of Palau; Marr (1948) concluded that spawning occurs in the northern Marshall Islands, and confirmed this by the capture of two juveniles; Yabe (1954) and Yao (1955) found evidence of spawning in the southern waters of Japan; Brock (1954) postulated that they spawn in Hawaii from late February, March, or April to the first part of September; Schaefer and Orange (1956) and Orange (1961) hypothesized that they spawn in the vicinity of the Revilla Gigedo Islands in the eastern Pacific; and Wade (1950a) found evidence of their spawning in Philippine waters.

By virtue of the capture of larvae and juveniles, Schaefer and Marr (1948) demonstrated the existence of a spawning ground off Central America; Wade (1950b and 1951) found further evidence that skipjack spawn in Philippine waters; Shimada (1951) deduced that spawning occurs around the Phoenix Islands; and Matsumoto (1958) showed that they spawn in a wide area in the central Pacific Ocean. The present study demonstrates the existence of yet another spawning locality in the Pacific.

NOTE.—Approved for publication Oct. 22, 1964.

## MATERIALS AND METHOD

### COLLECTION OF OVARIES

This study is based on 402 pairs of ovaries collected on seven exploratory fishing cruises from August 1956 through June 1958. The approximate locales of collection are shown in figure 1. Most of the ovaries were collected from fish caught at the surface by pole and line. This method of fishing, as used in the Hawaiian skipjack fishery, was described by June (1951).

Plans for all of the pole-and-line fishing cruises called for sampling 25 skipjack from each school fished in order to obtain an estimate of their size and sex composition. From the 25 fish thus selected, the first 5 females picked at random were cut open and their ovaries removed for examination. Skipjack were caught by pole and line from 92 schools during this study, and ovary samples were secured from fish from 81 of these schools. Longline fishing and incidental trolling provided the few remaining samples. A description of the longline fishing method was given by Mann (1955).

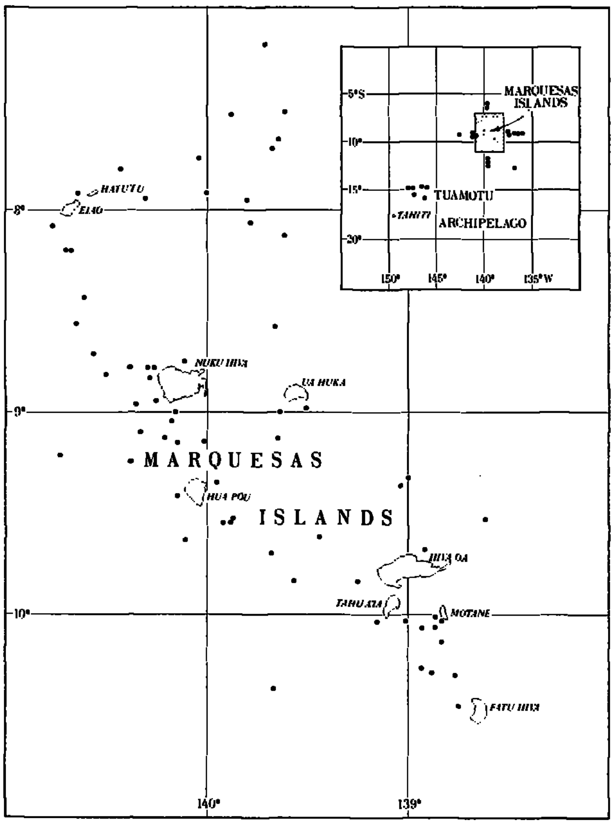


FIGURE 1.—Locations where skipjack ovaries used in this study were collected.

The ovaries were preserved in about 10 percent formalin. At the time of collection a record was made of the date, locality, method of fishing, and the fork length of the fish.

### EXAMINATION OF OVARIES

Several investigators made detailed studies of the distribution of mature ova within ovaries: June (1953) for yellowfin (*Thunnus albacares*); Yuen (1955) for bigeye (*Thunnus obesus*); and Otsu and Uchida (1959) for albacore (*Thunnus alalunga*). All showed that a representative sample of ova could be obtained anywhere along the length of an ovary or from either member of a pair.

Similarly, an analysis of variance of the mean size of mature ova within a skipjack ovary indicated that they were homogeneously distributed. Therefore, the following sampling method was adopted for this study. The formalin-preserved ovaries were weighed after excess moisture and tissue had been removed. A cross-section about ⅛-inch thick was taken, usually from the middle of the right ovary, from which a wedge-shaped (triangular) sample was cut. In many instances it was not possible to distinguish the right ovary from the left. In these instances the smaller of the pair was selected for examination; it appeared that the right ovary was usually the smaller of the two. I assumed that the distribution of ova within the right and left ovaries is similar, as has been reported for the tuna cited above.

The ova from the triangular section were teased apart in a shallow dish and measured in a Sedgwick-Rafter counting chamber. Measurements were made with an ocular micrometer having a magnification of 0.016 mm. per micrometer division. Since the ova were not perfectly spherical, the diameter which was measured was the random diameter that fell parallel to the lines in the counting chamber.

At the outset of the study, 300 randomly selected ova, 10 micrometer divisions (0.16 mm.) or larger, were measured from each ovary in order to characterize the size of ova at the different developmental stages. Since this required a great amount of time, and since the determinations of the stage of development of the ovaries were based on the most developed ova, the sample size was later reduced to a random sample of 25 of the most developed group. Following Snedecor (1946, p. 457), I analyzed the data on ova size distributions; my analysis showed that 25 was an adequate number to approximate the mean size.

### DEVELOPMENTAL STAGES OF OVA

Four rather distinct developmental stages were recognized and designated as "early developing," "developing," "advanced," and "ripe". The early developing category includes ova which, at their most primitive, appear as simple transparent cells present in all ovaries. The larger ova in this stage contained a relatively large nucleus. The mean diameter of the early developing ova ranged from 0.16 to 0.33 mm. The ova assigned to the developing stage were completely opaque because of the deposition of yolk granules. Their mean diameter was 0.37 to 0.66 mm. The advanced stage comprised ova that were still relatively opaque in appearance and contained a cluster of small oil droplets to ova that were semitransparent and had a well-developed, bright yellow oil globule. The mean diameter of these ova was 0.49 to 0.74 mm. The collection had no ripe ovaries; however, a sample of ova from a running ripe skipjack caught on January 26, 1957, was available for examination. This skipjack was caught by pole and line at 9°33′ S., 139°55′ W., about 10 miles southeast of the island of Hua Pou in the Marquesas. Its ova were used in an unsuccessful attempt at artificial fertilization and were preserved and brought to the laboratory. They are almost perfectly spherical and transparent, with a distinct straw-colored oil globule. Fifty were measured. Their diameters were 0.85 to 1.12 mm., with a mean of 0.96 mm. The oil globule was about 0.14 mm. in diameter.

The sizes of these ripe ova are similar to those described by other investigators. Brock (1954) found ripe ova from a skipjack in Hawaii to average 1.125 mm. in diameter. Yabe (1954) measured some ova from a ripe skipjack caught in the southern waters of Japan and found that they were 0.80 to 1.17 mm. in diameter, averaging 1.00 mm.

### DEGREE OF MATURITY

Skipjack were classified according to the stage of development of the most developed group of ova: the nomenclature used was the same as for the stages of ova development. Throughout this report, unless otherwise stated, the designations early developing, developing, advanced, and ripe will be used interchangeably to describe a skipjack, its ovaries, and the most developed ova contained therein.

The early developing category included ovaries as small as 2 g., from a sexually immature fish, and those (from adult fish) which were relatively large but which contained only early developing and a few residual ova. This category also included some ovaries containing ova that appeared to have attained the developing stage but had begun to degenerate. These ova were grayish, relatively soft, and easily broken.

### TREATMENT OF DATA

Skipjack from the Marquesas and the Tuamotu areas were considered together in all aspects of this study, because I assumed that they belonged to the same population or at least were similar physiologically insofar as spawning was concerned. It would have been interesting to determine whether skipjack from the two areas did indeed have similar spawning habits; however, the samples from the Tuamotus were too few to treat that area separately. Of the 402 pairs of ovaries collected, 372 came from around the Marquesas and 30 from the Tuamotus.

## SIZE AT FIRST SPAWNING

The approximate body length at first spawning was determined by arranging the lengths and the stage of development of all the skipjack used in this study into a frequency distribution (fig. 2). The smallest skipjack measured 39 cm. This fish had thin, ribbonlike ovaries which weighed 2 g. and contained only primitive ova. Presumably it had never spawned. The ovaries of a few fish, 43.7 to 50.7 cm. long, were classified as early developing and also showed no positive evidence of past spawning. A greater number in that size range, however, had either developing or advanced ovaries. The smallest fish that had advanced or developing ovaries was 43 cm. long. The few fish more than 55 cm. long that were classified as early developing either showed evidence of past spawning or at least of having attained a stage of development past early developing, for their ovaries contained residual or degenerating ova.



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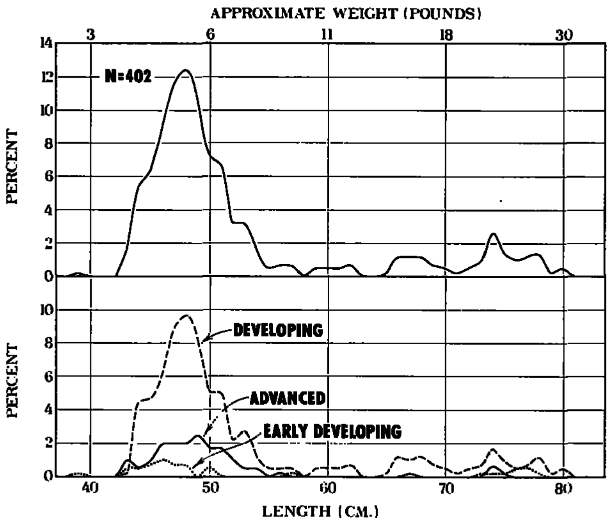


FIGURE 2.—Skipjack length-frequency distribution and stage of development.

It was noted earlier that one skipjack with running ripe ovaries had been caught. Unfortunately, the length of this specimen was not recorded. However, a sample from the school from which this fish was taken showed their size to range from 45.6 to 56.9 cm., and in all likelihood this specimen fell within this length range.

It seems from these observations that, although some skipjack as large as 50.7 cm. were apparently not ready to spawn, those in the Marquesas-Tuamotu areas are capable of first spawning when they are about 43 cm. long.

The size at first spawning has been determined for skipjack in other areas of the Pacific. Brock (1954, p. 102), discussing skipjack in Hawaii, states, "The smallest fish that possessed maturing ova during the spawning season were around 40 to 45 cm. long. Fish 35 to 40 cm. in length had ovaries that, with a few exceptions, seemed immature." In the southern waters of Japan, Yabe (1954) noted that no definite information was available because of the scarcity of data, but that the smallest skipjack in his samples with mature ova was 46.8 cm. long. In the eastern Pacific, Orange (1961) found the minimum size at first spawning for skipjack around the Revilla Gigedo Islands to be about 55 cm., and around the Cocos Island area about 40 cm.

From the above discussion it appears that the size at first spawning may vary with locality. Skipjack in the Marquesas and Tuamotus, in Hawaii, and in the southern waters of Japan all seem to mature at about the same size, while in certain areas in the eastern Pacific they attain a larger size before reaching maturity.

It is interesting that all samples from the Marquesas and Tuamotus were composed primarily of adult fish. The Hawaiian summer skipjack fishery also exploits mostly adult fish (Brock, 1954, fig. 1). In the eastern Pacific, if the size-frequency samples presented by Hennemuth (1957) are typical, the fishery depends on both juvenile and adult fish. The Japanese skipjack fishery probably exploits adult as well as juvenile fish (Yabe, 1954; Yao, 1955).

## SPAWNING SEASON

It would be relatively simple to determine the spawning season of skipjack if all the ovaries ripened at the same time and if ripe fish were readily taken. Small numbers then could be examined to follow the development of ova to the time of spawning. My data show, however, the presence of a diversity of developmental stages in any one period; therefore, another method had to be employed to define the spawning season.

The temporal distribution of skipjack possessing ripe or advanced ovaries should give some indication of the spawning season, the implication being that these fish are actively spawning or very close to spawning. The percentage distribution of skipjack by month of capture and stage of development is presented in figure 3. Only those larger than the size at first spawning, and therefore, presumably only adult fish, were used in this analysis. All but one specimen in my collection

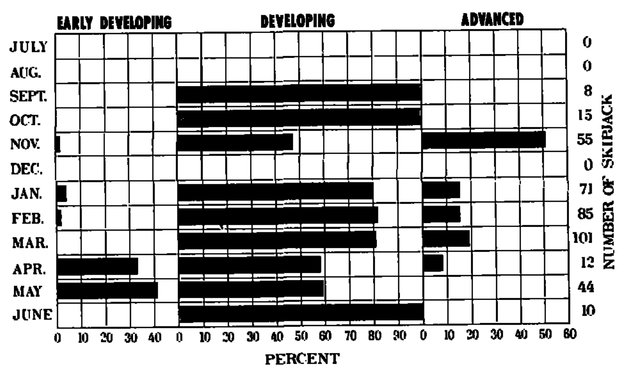


FIGURE 3.—Seasonal distribution of early developing, developing, and advanced skipjack.

were included. As indicated earlier, aside from one running ripe fish, which was caught in January 1957, no ripe skipjack were available during the periods of sampling. Those in the advanced stage were found, however, in November, and January to April. This suggests that their major spawning season in this area is from about November through April.

The spawning season may be further defined by determining the temporal distribution of non-spawning; i.e., early developing skipjack. It was noted earlier that some classified as early developing possessed ovaries that either (1) contained only early developing ova, aside from a few residual ova from a previous spawning, or (2) contained ova that had reached the developing stage but were apparently degenerating. These observations suggest that during certain periods of the year the ovaries may revert to a dormant or early developing stage. A few skipjack classified as early developing were found in November, January, and February; however, the greatest numbers occurred in April and May, the months in which fish in the advanced stage were declining in number or were totally absent. I assumed that such a distribution of early developing and advanced skipjack indicated a decrease in spawning activity during these 2 months. However, the situation is probably more complex, since skipjack in all stages of development were found simultaneously, and fish with developing ovaries were found in all months sampled. In all probability, scattered spawning occurs throughout the year, but the peak activity is from November through April (or, roughly, the Southern Hemisphere summer). The results of a study of the distribution of skipjack larvae in this area, described by Nakamura and Matsumoto,[1] substantiate this conclusion. The larvae were caught in greater abundance contemporaneously with the greatest numbers of fish with advanced ovaries.

Skipjack spawning seasons in other areas, as in Hawaii, appear to be typically long. The season in Hawaii extends from late February, March, or April to the first part of September (Brock, 1954). Schaefer and Orange (1956) indicated that skipjack spawn in the vicinity of the Revilla Gigedo Islands from April to December, and that spawning is more intense in summer and fall. Concerning the fish in the Philippines, Wade (1951, p. 469) states, ". . . there are indications that the period from September to April, inclusive, may be the principal spawning period." The spawning season in the southern waters of Japan, however, is relatively short. Yao (1955) postulated that skipjack spawn during June–August in the waters south of Kyushu and the Ogasawara area.

## FREQUENCY OF SPAWNING

The presence of two or more modes in ova-size frequency distributions and that of residual ova in ovaries containing mature ova have been used to hypothesize multiple spawning. Among investigators studying tuna, June (1953) concluded on the basis of such evidence that yellowfin in Hawaiian waters spawn more than once during a season. So did Brock (1954) for Hawaiian skipjack, Yuen (1955) for the bigeye in the Pacific, and Otsu and Uchida (1959) for the Pacific albacore.

The ova-diameter frequency distributions for skipjack in northeastern French Oceania were typically bimodal, or sometimes multimodal in the more advanced ovaries (fig. 4). Furthermore, residual ova were found in ovaries of 23 of the 72 skipjack that were judged to be in the advanced stage.

MacGregor (1957) discussed this problem of multiple spawning in some detail in an analysis of Pacific sardine fecundity. He disagreed with several criteria that have been used in the past to

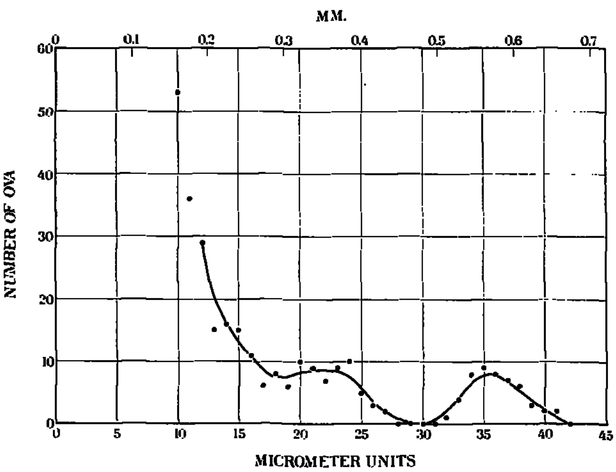


FIGURE 4.—Ova-diameter distribution for a developing skipjack ovary.

[1] Nakamura, E. L. and W. M. Matsumoto. MS. Distribution of larval tuna in Marquesan waters. Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii. (Manuscript.)

hypothesize multiple spawning; he objected to the criterion of the presence of two or more modes in ova-size frequency distributions. He pointed out that the presence of two or more such modes in developing ovaries does not necessarily mean that all the groups mature and that multiple spawning will occur.

Support for MacGregor's contention may be found in Yabe's (1954) work on skipjack in Japanese waters. He noted that skipjack smaller than 47 cm. had relatively large ovaries from June to August, but that the relative size of the ovaries decreased after September. He suggested that the ovaries shrank without spawning having occurred.

As noted earlier, my data also show some ovaries that were classified as developing but contained what appeared to be degenerating ova; this finding, one may argue, is in agreement with MacGregor's thesis. It also may be argued, however, that these data merely indicate that there may be a cessation of spawning during part of the year and do not necessarily indicate that none of the intermediate-sized ova will be spawned. Furthermore, skipjack as small as 43 cm. possessed advanced ovaries which also had residual ova from a previous spawning. If their growth rate in this area is similar to that of the species in Hawaii (Brock, 1954), which is not entirely unreasonable since skipjack in both areas seem to reach adulthood at about the same length, then these small fish must have spawned no more than 3 or 4 months previously. Earlier than that they would not have been large enough to be sexually mature. These observations, although not conclusive, indicate the possibility of multiple spawning within a season for individual skipjack.

## FECUNDITY

Four skipjack with fork lengths of 43 to 74 cm. and with advanced ovaries were selected for fecundity determinations. Small sections were obtained from each of the ovaries and weighed to the nearest thousandth of a gram. The number of ova in the most advanced group in the sample was determined and multiplied by the ratio of ovary weight to sample weight to get an estimate of the total number of mature ova in the ovary. The results are presented in table 1, which also includes results obtained by Yabe (1954) for skipjack in Japanese waters. Estimates of the number of ova extruded at one spawning ranged from 0.1 million to 2 million, with an indication that the number spawned is related to the size of the skipjack, the larger fish spawning more ova. Joseph (1963) made fecundity determinations for 42 skipjack taken from the eastern Pacific Ocean. His estimates ranged from about 0.2 million to 1.5 million ova per spawning for skipjack with total lengths from 61.4 to 71.5 cm. Within the limits of his data, the size of the skipjack and the number of ova per spawning seemed to be related. Among some of the other tuna, a relation between the number of ova spawned and size of fish was found for the bigeye in the Pacific (Yuen, 1955) and Hawaiian yellowfin (June, 1953).

TABLE 1.—*Results of skipjack fecundity determinations*

| Fish length | Ovary weight | Weight of sample | Advanced ova in sample | Estimated advanced ova in ovary (millions) |
|---|---|---|---|---|
| *Centimeter* | *Gram* | *Gram* | *Number* | *Number* |
| 43.0 | 35 | 0.046 | 195 | 0.1 |
| 46.8 [1] | --- | --- | --- | .1 |
| 50.5 | 112 | .089 | 330 | .4 |
| 56.2 [1] | --- | --- | --- | .6 |
| 67.9 | 202 | .080 | 352 | .9 |
| 75.0 | 303 | .029 | 192 | 2.0 |

[1] Data from Yabe (1954).

## GONAD INDEX

Several investigators have discussed the possibility of using the relative ovary weight (ovary weight$\times 10^3$/fish weight) as a measure of maturity of tuna; e.g., June (1953), Yuen (1955), and Otsu and Uchida (1959). Schaefer and Orange (1956) also used the relative ovary weight to measure the maturity of skipjack, the only difference being that they used the cube of fish length instead of fish weight and a factor of $10^8$ instead of $10^3$. They called this relation the "gonad index," which is defined as $G.I.=\frac{w}{L^3}\times 10^8$, where "$G.I.$" is the gonad index, "$w$" the weight of the ovaries in grams, and "$L$" the fish length in millimeters. Schaefer and Orange plotted the gonad index against the 95th centile of the total ova-size frequency distribution and found a linear relation, the gonad index increasing with ova size, at least in their Area II of the eastern Pacific.

I calculated the gonad index for all the skipjack in my collection. Because only a sample of the most developed group of ova was measured, their mean sizes were plotted against the gonad index in lieu of the 95th centile of the total ova-size frequency distribution. This difference should not affect greatly the comparison of my results with those of Schaefer and Orange.

Figure 5 is a scatter diagram showing my results, with the regression line obtained by Schaefer and Orange for their Area II data superimposed. Schaefer and Orange concluded that the gonad index was a reasonably reliable measurement of the degree of ova development; however, the largest gonad index they found was about 36, as compared to my 96. My data fit Schaefer and Orange's regression line fairly well up to a gonad index of 36. Above this value the relation seems to break down. There is a big overlap in gonad index between developing and advanced ovaries; therefore, it was not possible to make any inferences about the stages of development of skipjack in this area from the gonad index.

## STAGE OF SEXUAL DEVELOPMENT AND SCHOOLING BEHAVIOR

As mentioned earlier, the sampling of skipjack by pole-and-line fishing was such that each sample represented fish captured from a single school. This circumstance made it possible to examine the within-school distribution of developmental stages.

A gross examination of the data (table 2) indicates that skipjack in the different stages of development were not distributed randomly within schools. Although fish in all stages of sexual development were found simultaneously in certain months, there was no instance in which all three stages of development were found within a school. Most of the schools were represented by skipjack in a single stage of development. A contingency test of homogeneity (Hoel, 1954, pp. 172–175) was applied to the data, testing the hypothesis that, with respect to stage of sexual development, skipjack are distributed randomly within schools. The probability ($X^2=510$, df$=144$) of obtaining the observed distributions by chance alone was less than 1 in 100. I conclude that there was indeed a relation between schools and stage of sexual development. The fact that fish of similar stages of sexual development tended to occur together, as well as the fact that those in several stages of development were found in a number of months, should be considered in the design of any study of spawning. Obviously, examination of a large number from only a few schools could lead to erroneous conclusions.

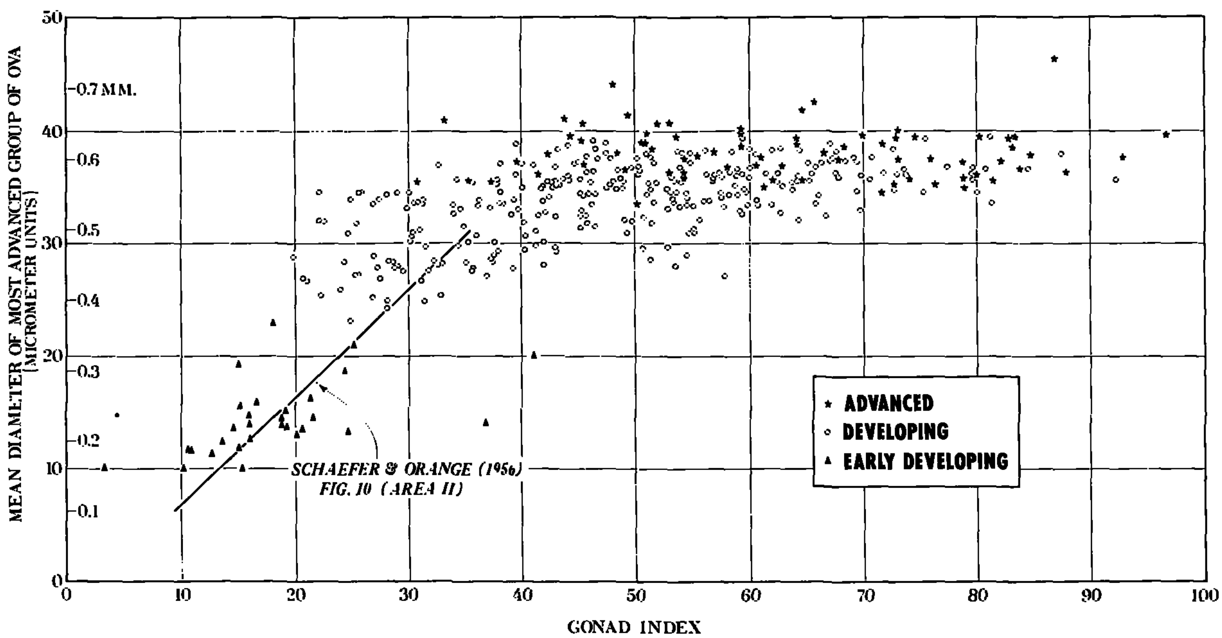


FIGURE 5.—Gonad index and mean diameter of largest group of ova.

TABLE 2.—*Numbers of skipjack in each stage of development in samples from single schools*

| School | Stage of sexual development | | | Total |
|---|---|---|---|---|
| | Early developing | Developing | Advanced | |
| 1 | 0 | 5 | 0 | 5 |
| 2 | 0 | 5 | 0 | 5 |
| 3 | 0 | 5 | 0 | 5 |
| 4 | 0 | 4 | 1 | 5 |
| 5 | 0 | 5 | 0 | 5 |
| 6 | 0 | 5 | 0 | 5 |
| 7 | 0 | 5 | 0 | 5 |
| 8 | 0 | 5 | 0 | 5 |
| 9 | 0 | 5 | 0 | 5 |
| 10 | 1 | 4 | 0 | 5 |
| 11 | 0 | 5 | 0 | 5 |
| 12 | 0 | 4 | 1 | 5 |
| 13 | 0 | 0 | 5 | 5 |
| 14 | 0 | 5 | 0 | 5 |
| 15 | 0 | 3 | 2 | 5 |
| 16 | 0 | 5 | 0 | 5 |
| 17 | 0 | 5 | 0 | 5 |
| 18 | 0 | 5 | 0 | 5 |
| 19 | 0 | 5 | 0 | 5 |
| 20 | 0 | 2 | 3 | 5 |
| 21 | 0 | 2 | 3 | 5 |
| 22 | 0 | 2 | 3 | 5 |
| 23 | 0 | 1 | 4 | 5 |
| 24 | 0 | 2 | 3 | 5 |
| 25 | 0 | 5 | 0 | 5 |
| 26 | 0 | 5 | 0 | 5 |
| 27 | 0 | 5 | 0 | 5 |
| 28 | 1 | 4 | 0 | 5 |
| 29 | 0 | 0 | 5 | 5 |
| 30 | 0 | 4 | 1 | 5 |
| 31 | 0 | 3 | 2 | 5 |
| 32 | 0 | 5 | 0 | 5 |
| 33 | 0 | 0 | 5 | 5 |
| 34 | 0 | 0 | 5 | 5 |
| 35 | 0 | 0 | 5 | 5 |
| 36 | 0 | 2 | 3 | 5 |
| 37 | 0 | 3 | 2 | 5 |
| 38 | 0 | 5 | 0 | 5 |
| 39 | 3 | 2 | 0 | 5 |
| 40 | 0 | 5 | 0 | 5 |
| 41 | 0 | 5 | 0 | 5 |
| 42 | 0 | 0 | 5 | 5 |
| 43 | 0 | 5 | 0 | 5 |
| 44 | 0 | 2 | 3 | 5 |
| 45 | 0 | 5 | 0 | 5 |
| 46 | 0 | 5 | 0 | 5 |
| 47 | 1 | 4 | 0 | 5 |
| 48 | 0 | 4 | 1 | 5 |
| 49 | 0 | 5 | 0 | 5 |
| 50 | 0 | 5 | 0 | 5 |
| 51 | 0 | 4 | 1 | 5 |
| 52 | 0 | 5 | 0 | 5 |
| 53 | 0 | 5 | 0 | 5 |
| 54 | 0 | 5 | 0 | 5 |
| 55 | 0 | 5 | 0 | 5 |
| 56 | 0 | 5 | 0 | 5 |
| 57 | 0 | 5 | 0 | 5 |
| 58 | 0 | 5 | 0 | 5 |
| 59 | 0 | 4 | 1 | 5 |
| 60 | 0 | 5 | 0 | 5 |
| 61 | 0 | 4 | 1 | 5 |
| 62 | 4 | 1 | 0 | 5 |
| 63 | 1 | 4 | 0 | 5 |
| 64 | 5 | 0 | 0 | 5 |
| 65 | 0 | 5 | 0 | 5 |
| 66 | 0 | 5 | 0 | 5 |
| 67 | 0 | 5 | 0 | 5 |
| 68 | 1 | 4 | 0 | 5 |
| 69 | 5 | 0 | 0 | 5 |
| 70 | 2 | 3 | 0 | 5 |
| 71 | 5 | 0 | 0 | 5 |
| 72 | 0 | 5 | 0 | 5 |
| 73 | 0 | 5 | 0 | 5 |
| Total | 29 | 271 | 65 | 365 |

As far as could be determined, there is very little in the literature regarding skipjack sexual development and schooling behavior. What are the causes of their apparent segregation by stage of sexual development? One possibility may be that skipjack about to spawn seek one another out, resulting in schools of similarly developed individuals. This explanation appears reasonable, for such a situation is probably more efficient for spawning purposes than a random distribution of spawning and nonspawning fish. Another explanation is that skipjack schools are relatively stable aggregations, with individuals in the group responding similarly to the environment and, therefore, developing similarly. However, on the basis of his size analysis of skipjack schools in Hawaii, Brock (1954) concluded that their composition is not stable. The pattern of tagged fish returns in Hawaiian waters seems to substantiate Brock's conclusion (Yamashita[2]). There probably is no simple explanation for this phenomenon. Undoubtedly there are many factors that influence the schooling behavior of skipjack, and the observed similarity of sexual development of the fish in the schools is probably a manifestation of a complex of factors.

## SUMMARY


1. This study is based on the microscopic examination of ova from 402 pairs of ovaries collected from skipjack caught on exploratory fishing cruises from August 1956 through June 1958 around the Marquesas Islands and Tuamotu Archipelago.

2. The ova, ovaries, and skipjack were classified as being in the "early developing," "developing," "advanced," and "ripe" stages of development according to the physical characteristics of the most developed group of ova. Early developing ova ranged in appearance from simple transparent cells to cells with a well-developed nucleus; developing ova were opaque because of the deposition of yolk; advanced ova were opaque or semiopaque and contained a cluster of oil droplets or a single well-developed oil globule; ripe ova were almost perfectly spherical and transparent and contained a distinct straw-colored oil globule.

3. Skipjack in the Marquesas and Tuamotu areas are capable of first spawning when they are about 43 cm. long.

4. Scattered spawning may occur throughout the year, judging from the occurrence of developing skipjack in all months of sampling. The major spawning season, however, appears to be from November through April.


[2] Yamashita, Daniel T. Ms. Results of Hawaiian skipjack tagging. In files of the Bureau of Commercial Fisheries Biological Laboratory, Honolulu. (Manuscript.)

5. Although no conclusive statements can be made about the frequency of spawning of individual skipjack, the data indicate a possibility of more than one spawning per season.

6. Estimates of fecundity of skipjack ranged from 0.1 to 2 million ova per spawning.

7. It was not possible to make any inferences about the stage of development from the gonad index of skipjack.

8. A contingency test of homogeneity showed that there was a relation between skipjack schools and stage of sexual development; i.e., there was a tendency for skipjack in similar stages of sexual development to be found together in schools.

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