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CONTRIBUTIONS TO THE BIOLOGY OF THE PACIFIC TUNAS

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SPAWNING OF YELLOWFIN TUNA (*NEOTHUNNUS MACROPTERUS*) AND SKIPJACK (*KATSUWONUS PELAMIS*) IN THE PACIFIC OCEAN OFF CENTRAL AMERICA, WITH DESCRIPTIONS OF JUVENILES

By Milner B. Schaefer and John C. Marr

Although the commercial fishery for Pacific tunas has become one of the leading fisheries of the United States, being in value second only to salmon, the life histories of the species which furnish the raw material of this industry are little known. An opportunity to conduct preliminary studies of the biology of these important fishes became available during the late winter and spring of 1947 when the factory ship *Pacific Explorer*, operated by the Pacific Exploration Co., made a voyage to Costa Rica for a cargo of frozen tuna. The authors, who were aboard this vessel and the fishing craft supplying her, as scientific observers of the Fish and Wildlife Service, were able to gather material in waters off Costa Rica between January 21 and May 10, 1947.

It was particularly fortunate that this trip occurred at a season when it was possible to obtain valuable data on the reproduction of the tunas. The places and seasons of spawning of Pacific tunas have long been a mystery. The only reference we have found in the literature to the location of a tuna spawning area in the Pacific is a Japanese paper, cited by Fisher (1947), by an unknown author (Anon. 1942) the title of which indicates that at least one species spawns in the vicinity of the Palau Islands. We have not yet been able to examine a copy of this paper. Kishinouye (1923) made a few incidental remarks on the occurrence of maturing and spent specimens of *Thunnus orientalis* (Temminck and Schlegel) in the summer fishery along the Japanese coast, and on the spawning of *Euthynnus yaito* Kishinouye, which "seems to take place about May in Taiwan." Of *Auxis hira* Kishinouye, he said, "seem to spawn in summer. Reproductive elements are ripe in August."

OBSERVATIONS ON ADULTS

Neothunnus macropterus (Temminck and Schlegel 1850)

The yellowfin tuna was the principal species caught during this voyage of the *Pacific Explorer*. Some 2,200 tons of this species were taken, compared with about a tenth of this amount of skipjack.

In the first catches examined, in late January, most of the larger fish, those more than about a meter in length, were in rather advanced stages of sexual maturity as judged by examination of the gonads. This condition was typical of these large yellowfin through February. The upper panel of figure 1 shows the size composition of representative samples of the catch during late January and early February. Smaller fish, below about a meter in total length, were in many cases found to have gonads little developed at this time. Many of the maturing fish examined seemed to be imminently ready to spawn, although no running-ripe specimens were captured. Females were taken in which the ovaries were large and turgid and filled with relatively large, yolk-filled ova measuring about 0.6 mm. in diameter (measured as formalin-preserved material). Several males were taken with running milt in the central duct of the testis.

Ova of the above diameter have probably attained nearly full size, as judged by information available on other species. Ova from a preserved ovary of a running-ripe *Euthynnus lineatus* Kishinouye from Costa Rica measure 0.72 mm. to 0.81 mm. in diameter. Sanzo (1929) stated that the fertilized ovum of *Thunnus thynnus* (Linnaeus) of the Mediterranean is between 1.0 mm. and 1.12 mm. This is larger than the ova in the ovary because the diameter is increased by absorption of water after the ovum is liberated into the sea.

As the season progressed, the largest yellowfin (fig. 1), became relatively less numerous in the landings. At the same time, examination of the gonads showed that the smaller fish were on the average in more advanced stages of maturity than those examined earlier. In April many of the fish down to 70 cm. in length appeared almost ready to spawn.

It may be seen from figure 1 that there was also a group of small fish, of a modal length of about 60 cm., which were particularly numerous in the purse-

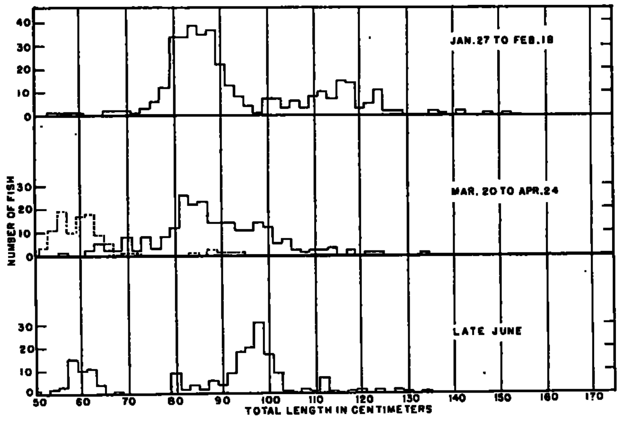

FIGURE 1.—Length frequencies of samples of catches of *Neothunnus macropterus* off Costa Rica. Solid lines represent catches by bait boats. Broken lines show catches by purse seiners.

seine catches in March and April. The gonads of these fish were completely immature in all samples taken, and it is presumed that these fish represent an age group which has not attained the age of first spawning.

It must be noted that our studies of the gonads are based on relatively few samples. Since it is the commercial practice to freeze tuna in the round, we were not able to open large numbers of specimens, because this decreases their commercial value. We examined about 150 specimens from 15 landings. To make any quantitative study of the relative degrees of maturity of different size groups would, of course, necessitate much more extensive sampling.

Our observations were discontinued in Costa Rica in early May, and the ship returned to her home port early in July. Two large bait-boat catches of yellowfin tuna made off Costa Rica during the last week in June had been taken aboard the mother ship just before her departure and were stowed so that they were separable from the remainder of the cargo. These fish were processed at the cannery immediately after unloading and were examined at that time for sexual condition. The size composition of these landings is shown in the lower panel of figure 1. The fish of the small size group, near 60 cm., were all completely immature, as were those examined before. The larger fish, of which more than 50 were examined, were all spent, some apparently rather recently so.

These observations indicate that the yellowfin tuna spawn somewhere in the vicinity of Costa Rica in the early spring months. The capture of fish in advanced stages of maturity during a 3-month period indicates that the spawning season is rather long. It seems also that the smaller tuna tend to mature somewhat later than the larger ones. This conclusion corresponds to the results obtained for *T. thynnus* of the Mediterranean. Heldt (1930) stated—

> Sella fait remarquer qu'il y a lieu de distinguer ici suivant la taille des sujets. Les petits thons marquent effectivement un retard dans leur formation, ce qui fait que pour eux la ponte est plus tardive. Sur les côtes de Sicile, par example, la ponte commence dès juin et se termine dans la second décade de juillet pour les thons gros et moyens; elle se prolonge jusqu'en août pour les petits. Il arrive même de trouver en Adriatique, en août, de petits thons avec des boutargues développées.

T. thynnus is captured in the Atlantic, along the southern coasts of Spain and Portugal, and along the shores of the Mediterranean by means of pound nets, or "madragues." Tunas in various stages of maturation are taken during the direct migration, the "époque du course," and spent fish are taken later during the "époque de retour." Running-ripe males are sometimes captured, but fully ripe females are seldom taken. (Heldt 1930; Frade and Manaças 1933; Frade 1937). According to Heldt (1930), Sella thinks—

> Pour l'émission des produits sexuels l'animal accomplirait un mouvement au large, probablement assez limité. Il est possible * * * que ce mouvement ne se produise pas une seule fois, mais qu'il y ait une succession d'éloignments et de rapprochements de la côte, ce qui expliquerait la présence dans les boutargues de fin de saison du course de glandes partiellment vidées.

He also gives deBuen as the authority that "Les différentes phases de dévelopment et les diamètres variés des ovules qui s'y trouvent prouvent en effet que la ponte doit être fractionnée." Frade and Manaças (1933), by a histological study of the gonads, demonstrated that all the ova are not matured at once but that they are developed and spawned fractionally.

It seems likely that a similar spawning of several batches of ova occurs in *N. macropterus*. Measurement of the sizes of ova in an ovary in an advanced stage showed that in addition to the largest group of ova, near 0.65 mm., there is another pronounced mode near 0.44 mm. representing, presumably, the group maturing for the next spawning.

Our failure to observe any running-ripe females and the disappearance of the largest fish from the bait-boat catches as the season progressed might be taken to indicate that as the fish mature they migrate elsewhere for spawning. If so, it must be to a place in the vicinity, since, as will be shown later, juvenile tunas as small as one centimeter were captured off Costa Rica, and it seems unlikely that these had migrated very far. An alternative hypothesis is that as the tunas approach spawning time they cease feeding, and so are not taken by fishermen on the bait boats. Even fish in less advanced stages of maturity probably do not feed as actively as during the season of sexual inactivity. Many schools encountered on this voyage were notably disinclined to take live bait, and time after time not a single fish was captured from a large school. The catch statistics and the experience of the fishermen reflect the poorness of the bait fishing in the late winter and spring months, and indicate that the yellowfin normally do not bite well during this season. Purse-seine catches examined (fig. 1) consisted almost entirely of fish of the size group which is completely immature.

Katsuwonus pelamis (Linnaeus 1758)

Very few skipjack were taken by bait boats during the period of our observations, but purse seine fishermen who operated in the area in late March and April were more successful. Six specimens were examined from a catch of a few hundred pounds made by a bait boat on February 21. These six specimens, four males and two females, were maturing, one male and one female appearing to be imminently ready to spawn. From a purse-seine catch on March 30, four females and six males were examined; the four females all appeared to be spent fish, having flaccid, empty gonads; the males were either spent or just beginning to mature, these two stages appearing much the same in male fishes.

OBSERVATIONS ON JUVENILES

When overtaken by darkness on the fishing grounds, the fishing vessels heave to and drift until daylight, unless it is desired to move to a new locality for the next day's fishing. When aboard such vessels at night, we took advantage of the opportunity to collect organisms attracted to a drop light suspended outboard close above the surface of the water. A large number of species of fishes and other organisms were collected in this manner, including juveniles of four species of scombroid fishes belonging to the genera *Neothunnus*, *Katsuwonus*, *Euthynnus*, and *Auxis* (Schaefer and Marr 1948). In this paper we shall deal only with the juveniles of the yellowfin tuna, *Neothunnus*, and the skipjack, *Katsuwonus*.

The positive phototropism of very young tunas in the Mediterranean has been noted by several authors. Sparta (1933) collected post-larval *T. thynnus* and *Auxis bisus* Bp. (=*A. thazard* Lacépède) by this means. Sella (1929) refers to the collection of young stages of *T. thynnus* under lights. According to Heldt (1928), Sanzo has found that young *T. thynnus* up to 15 cm. are attracted by light, but that above this size they develop a negative phototropism.

Neothunnus macropterus

Among the scombroid fishes collected by drop-light fishing is a series, which we regard as *N. macrop-terus*, characterized by a relatively deep body, and by heavy pigmentation of the first dorsal fin, the posterior edge of which reaches almost to the insertion of the second dorsal. Photographs of representative specimens of the series, preserved in alcohol, are shown in figure 2, and a 19-mm. specimen is drawn in figure 3. Specimens of this sort were collected at the following localities on the dates indicated: 2 specimens, 14 and 15 mm. total length, from 9°22.5′ N., 85°47.5′ W., Jan. 28, 1947. (These and other total-length measurements in this paper were taken from the tip of the snout to the tip of the shortest median ray of the caudal fin.) Six specimens, 26 mm. to 43 mm. total length, from 9°10′ N., 85°20′ W. March 20, 1947; 20 specimens, 10 mm. to 24 mm. total length, from 9°20′ N., 85°10′ W. April 1, 1947; 1 specimen, 41 mm. total length, from 8°7.5′ N., 83°8.5′ W., May 7, 1947.

In addition to the examination of specimens in alcohol, 4 specimens of 15, 18, 31, and 43 mm. were prepared for study of the bony parts by staining in alizarin and clearing, according to the procedure of Hollister (1934).

As illustrated in figure 2, fish of all sizes had a heavily pigmented first dorsal fin. The second dorsal fin remains unpigmented until the fish reaches about 24 mm., when the lower part of the second dorsal fin begins to assume a dark coloration. In specimens from about 30 mm. up to the largest in our collections, the second dorsal fin is pigmented rather heavily in its lower half; the distal half remains unpigmented. In addition to that of the first dorsal fin, there is no external dark pigmentation of the smallest individuals, 10 mm. to 12 mm., except a thin strip on the back at the base of the first dorsal fin. There is a dark area on the top of the head forward of the nape, which is subcutaneous, being the pigmented covering of the brain. At 16 mm. the tips of the jaws are lightly pigmented, as are the sides of the

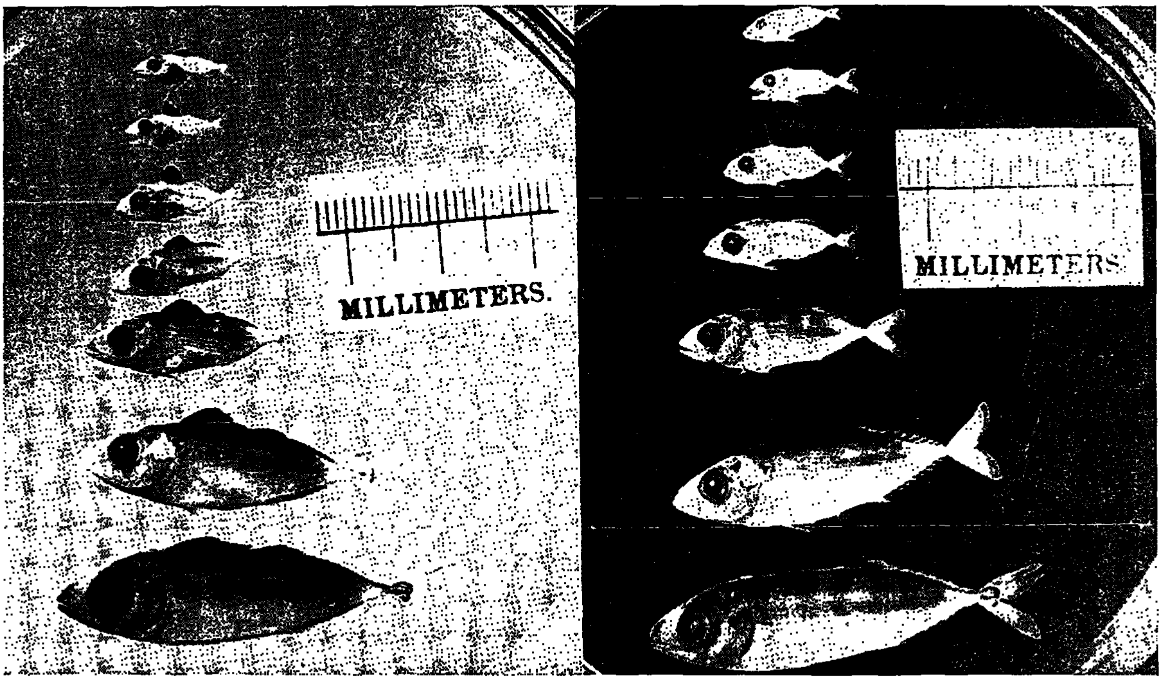

FIGURE 2.—Juvenile *Neothunnus macropterus* photographed against light and dark backgrounds.

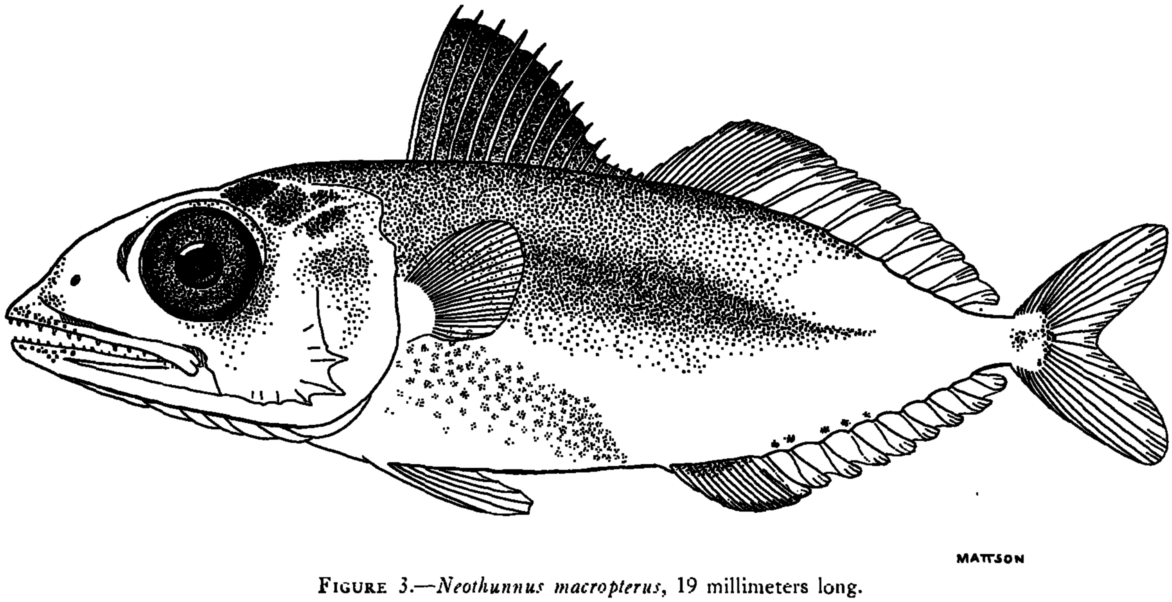

FIGURE 3.—*Neothunnus macropterus*, 19 millimeters long.

body down to the midline and posteriorly to about the level of the posterior edge of the second dorsal fin. The pigmentation of the body deepens, and extends farther down the sides and farther back at 19 mm., the operculum becomes lightly pigmented, while the posterior margin of the orbit is rather heavily darkened, and the posterior dorsal region of the head bears large pigmented areas. On a 24-mm. specimen there is, in addition, a little dark pigment on the bases of the caudal rays, and the dark pigment on the back and upper sides begins to become concentrated in patches which in larger specimens form five dark vertical bars. The peritoneum of juveniles of all sizes in our collections bears numerous closely spaced black spots. In fishes below about 25 mm. these may be seen through the body wall.

On the smallest specimens there are three prominent spines at the lower posterior angle of the preoperculum, with two lesser spines on the vertical margin above, and two on the horizontal margin forward of the larger spines. These spines become less and less prominent as the bone of the preoperculum grows to fill in the spaces between them until they are not easily discernible in a specimen of 24 mm. and are quite absent in a specimen of 35 mm.

Examination of the vertebral columns of the four alizarin-stained specimens showed the vertebrae to be 18 precaudal and 21 caudal in each case (counting the urostyle), bearing closed haemal arches on some precaudal as well as on the caudal vertebrae. In the largest specimen the muscles were dissected away from one side to allow a careful examination from which it was possible to determine with certainty that the first closed haemal arch occurs on the eleventh vertebra. The 15-mm. and 18-mm. specimens were determined with some uncertainty to have the first closed haemal arch on the tenth and eleventh vertebrae, respectively. Determination was not possible on the 31-mm. specimen without dissection, and this was not desirable. On all specimens the haemal canal is large; beneath the posterior precaudal and anterior caudal vertebrae it is as wide as or wider than the vertebral column. Inferior foramina are not yet developed on any of the vertebrae of the 15-mm. or 18-mm. specimens, but in the 31-mm. and 43-mm. specimens there are moderately large, well-developed inferior foramina on the fourth to fourteenth caudal vertebrae. These foramina become progressively smaller going posteriorly. There are no ventral foramina on any precaudal vertebrae. The characteristic lateral processes on the posterior caudal vertebrae (Kishinouye 1923; Frade 1932) are not yet developed in the two smallest specimens, but are slightly developed in the 31-mm. specimen and are quite well developed in the 43-mm. specimen. The lateral processes of the anterior precaudal vertebrae are not yet developed in any of our specimens.

The pectoral fin has 31 and 35 rays, respectively, on the two largest stained specimens. The first dorsal fin has 14 spines in all 4 specimens, but in one of these the last spine is completely subcutaneous and would not be observed except in a special preparation. The first spine is usually the longest one, but sometimes it is the second. The combined count of second dorsal rays and of dorsal finlets was found to be 23 in each of 3 specimens and 22 in 1. The finlets appear to be eight or nine in number, it being impossible to distinguish accurately between the last ray of the second dorsal fin and the first finlet. The combined count of anal rays and anal finlets is 22 in all 4 specimens. The anal finlets are eight or nine, it again being impossible to distinguish accurately which is the first finlet behind the fin.

In the smallest specimens the finlets are connected together and to the fin by a continuous membrane extending almost to the tips of the finlets. As the fish grows, this membrane gradually disappears except sometimes between the fin and the first, or the first and second, finlets behind the fin. In specimens of 25 mm. the membrane extends only about half way to the tips of the finlets. At 40 mm. it has almost completely disappeared, there being only a remnant at the bases of the finlets.

The intestine passes posteriorly along the right side of the body cavity. It is straight, without a fold, in specimens below about 35 mm., at which size there is a slight kink which is the beginning of the formation of the folds. In fishes of 40-mm. total length the intestine has the two folds characteristic of adult Thunnidae, but the ascending portion of the intestine between folds is relatively much shorter than in adults.

The liver was examined in six specimens from 24 mm. to 43 mm. in total length. In each case the right lobe was noticeably larger than the center or left lobes, which were nearly equal in size. In one case the left lobe was itself divided into two parts.

The anterior portion of the lateral line is visible in specimens of more than about 24 mm. in length. Its unusual course above the pectoral fin is that peculiar to the Thunnidae (Kishinouye 1923; p. 304 and pl. XXVI and XXVII).

The gill rakers on the first arch are just becoming visible as very small projections in fishes 18 mm. long, and cannot be counted with any accuracy. At 31 mm. the gill rakers are still very short and were counted as 6+18. At 40 mm. they are fairly well developed and can be counted with better accuracy; those of a 41-mm. specimen were counted as 8+21 and of a 43 mm. specimen as 7+20.

The specimens of this series are readily identified as belonging to Kishinouye's family Thunnidae by the vertebrae (18+21 in number, with complete haemal arches on some, but no inferior foramina on any, of the precaudal vertebrae), by the shape of the lateral line, and by the folded intestine. Of the four species of this family which are known from the eastern Pacific, two, *T. thynnus* and *Thunnus germo*

(Lacépède), have ranges which probably do not extend to the latitudes of Central America. Herre (1936) has recorded *T. thynnus* from the Galapagos Islands, but this seems likely to be in error. In any event, our specimens may be shown as not belonging to these species because in the genus *Thunnus* the first complete haemal arch occurs typically on the tenth vertebra (Godsil and Byers 1944; Frade 1932), the inferior foramina on the vertebrae are very poorly developed (Kishinouye 1923), and the center lobe of the liver is the largest of the three (Kishinouye 1923; Godsil and Byers 1944).

There remains then to decide to which of the remaining two species, *Parathunnus mebachi* (Kishinouye) or *Neothunnus macropterus*, both of which occur in the region of this study, our specimens belong. (*P. mebachi* is seldom taken in the commercial catches.) Many of the characters pointed out by Godsil and Byers (1944) are not available for our purpose. The relative lengths of the intestinal folds cannot be used because this is changing rapidly in these juvenile fishes. The same is true of the size and shape of the air bladder. The shape of the postero-ventral margin of the cranium, which these authors stated to be "the most useful and distinctive difference," resembles that of the adult *Neothunnus*, but again this character is probably undergoing modification and is, therefore, not reliable. The peculiarities in the circulatory system, which is the basis of Kishinouye's differentiation of *Parathunnus*, cannot be studied in our small specimens.

We have concluded that these specimens are most probably *N. macropterus* for the following reasons: The haemal canal is large, being as broad as the vertebral column beneath the posterior precaudal and anterior caudal vertebrae, and the inferior foramina on the caudal vertebrae are well developed. Both of these characters correspond to those of adult *Neothunnus* and differ from those of adult *Parathunnus* in which the haemal canal is narrow and in which the inferior foramina are poorly developed. If the assumption is correct that these characteristics are fixed at these early stages, this is definitive. The larger right lobe of the liver is also definitive according to Kishinouye (1923, p. 363), but Godsil and Byers state that in one of their two specimens of *Parathunnus* the right lobe was "slightly the longest." It seems most probable, therefore, that our juveniles are *N. macropterus*, but there is some possibility they may be *P. mebachi*. This problem cannot be settled with certainty until juveniles of both species are available for comparison.

Lütken (1880) depicted in his plate III, figures 1 and 2, juvenile tunas 17 mm. and 10 mm. in length which may perhaps be juvenile *Neothunnus*. He identified them as being probably juveniles of *Orcynus germo* (Lac.), in which species he includes all the "long-winged" tunas. He wrote:

> These tuna fishes with the long pectoral fins which the seamen generally call "Albacora" or "Albicora" are divided into a whole series of species: *Th. alalonga, albacora, germo, pacificus, argentivittatus, balteatus, sibi* and *macropterus*, all of which, perhaps, represent only one species which most fittingly could be called *Orcynus germo* (Lac.)

Thus, he included in this single species the yellowfin tunas, *Neothunnus*, the Atlantic and Pacific forms of which, at least, now appear to be distinct (Frade 1931), and the albacore or germon *T. germo*.

Lütken's figures of these juveniles show the posterior quarter of the first dorsal as being unpigmented, or lightly pigmented, while the anterior three-quarters appears heavily pigmented. This is not mentioned in the text. Otherwise the figures are very similar to our specimens. His 17-mm. specimen was taken by the *Galatheas* on June 3, 1836 in a tow net at an unspecified location (probably in the East Indies since the ship was at Singapore on August 9). Lütken described this specimen:

> * * * rather plump and short; the height one quarter of the total length, and the length of the head contained 2½ times in the latter. Sparse teeth, palatine teeth; 5 to 6 spines on the anterior gill cover. The finlets could hardly be said to be present as they were too closely situated, but 8 or 9 rays could be identified. The sides of the head behind the large eyes, which took up almost the whole height of the head, and the sides of the abdomen were of shiny silvery color; otherwise, the fish was dark.

Of smaller specimens, taken at a number of localities in the Atlantic Ocean and at one station in the South China Sea on unspecified dates, he said:

> The author strongly suspects that some even smaller fishes (8 to 10 mm.) represent developmental stages of the same type. These small fishes are completely colorless except for the eyes and first dorsal fin, which are black. They are noticeably short with large heads, the latter being almost as long as the rest of the body. Three anterior gill cover spines are visible. The mouth slit reaches till under the middle of the eye. At the most 14 scattered curved teeth in each mandibular row. No trace of "pinnulae"; however, in the larger ones, one can point out the eight or nine rays which later will form such "pinnulae."

Ehrenbaum (1924) found among the *Thor* collections, made with the young-fish trawl in the Mediterranean and Atlantic, two kinds of tuna larvae which, following Lütken's terminology, he referred to the genus *Orcynus* (=*Thunnus*) on the basis of vertebral counts of 18+21 and other characters. These larvae, the largest of which was 13.5 mm. long, preserved, were too small to identify as to species by morphological characteristics. Ehrenbaum considers only two species of the genus to occur in these waters, the "red" tuna *O. thunnus* L. and the "white" tuna, or germon, *O. germo* (Lac.). He tentatively identified the larvae in question with these two species on the basis of their relative abundance:

> In Ermangelung eines zuverlässigen Unterscheidungsmerkmals habe ich mich nun entschlossen, die in Mittelmeer häufigere Larvenform dem grossen Thun, die im Atlantik häufigere dem Germon zuzuteilen. Das kann mit Recht als unzulässig bezeichnet werden; aber ich tue es auf die Gefahr hin, eine spätere Korrektur zu erfahren; * * *

We have compared our smallest specimens of *N. macropterus* in detail with Ehrenbaum's descriptions of *O. germo* of similar size (pp. 20–22). They agree in all respects with the exception of the pigmentation of the first dorsal, and perhaps the preopercular spines. It should be noted that the nasal "rosette" is a subcutaneous structure visible in our material only in a carmine-stained and cleared specimen. His specimens have the first dorsal fin only partly pigmented whereas ours have it completely covered with heavy pigmentation at all sizes, including those corresponding in size to his larvae. The preopercular spines on his larvae of 12 mm. to 13.6 mm. as described and figured appear one or two more numerous than on our specimens of similar sizes. It seems likely that these specimens may be the young of *Neothunnus albacora* (Lowe), because of the similarity to our specimens of *N. macropterus*. They may, however, be young *T. germo*, juvenile specimens of which are not available for comparison.

Ehrenbaum also reexamined Lütken's specimens because the drawings in his paper show the first dorsal ray as very short, which led Kishinouye (1923) to doubt that they are tunas at all. From this reexamination Ehrenbaum concluded that the fin rays had been broken and that the specimens undoubtedly are tunas (*Orcynus*). However, Ehrenbaum also found that all of Lütken's specimens were probably not of the same species:

> Allerdings ist sehr bemerkenswert, dass die beiden von Lütken abgebildeten Stadien von 17 und 10 mm wahrscheinlich nicht derselben Art angehören, sondern das grössere zu der von mir hier als O. germo charakterisierten Form und das kleinere zu O. thynnus. Diese Verschiedenheit ist aus den Abbildungen allerdings nicht mehr zu erkennen.

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Katsuwonus pelamis

Two specimens which, as will be shown, can be definitely identified as this species were captured, as follows: 1 specimen 21 mm. total length, from 9°22.5′ N., 85°47.5′ W., January 28, 1947; 1 specimen 44 mm. total length, from 9°10′ N., 85°20′ W., March 20, 1947. The smaller specimen is depicted in figures 4 and 5. The larger was prepared for bone study.

These specimens may be recognized easily by the relatively less deep body at a given length, and by the pigmentation of the dorsal fins. The second dorsal fin was entirely unpigmented in both specimens. The first dorsal fin of the smaller individual, as may be seen in the figures, has only a few moderately large pigment spots toward the distal ends of the rays. The same was true of the larger fish but it had, in addition, some pigment along the anterior edge of the fin to the base.

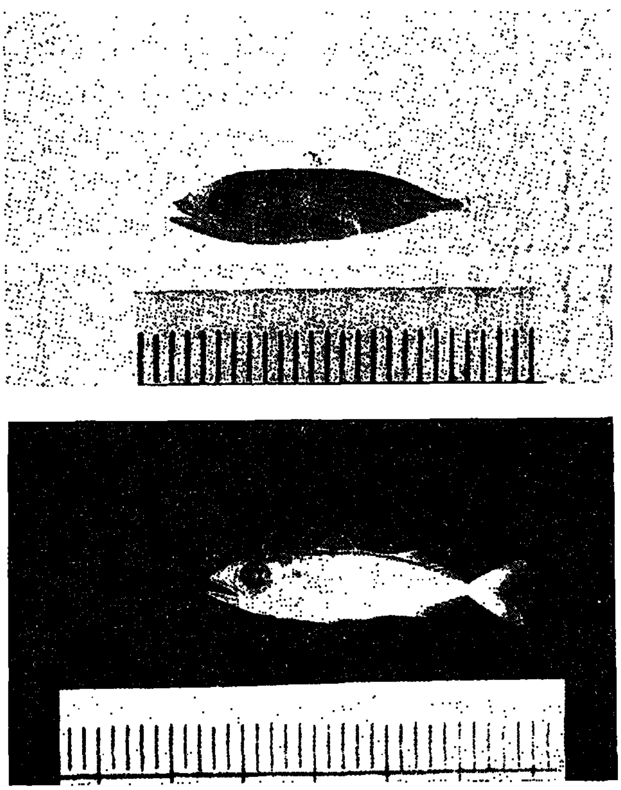

FIGURE 4.—Juvenile *Katsuwonus pelamis* photographed against light and dark backgrounds.

The smaller fish, as may be seen, is unpigmented on the belly; scattered pigment spots appear on the sides at about the level of the pectoral fin and become more concentrated dorsally. The concentration laterally is rather even, and there is no suggestion of bars on the sides. The dorsal and lateral pigmentation extends on the caudal peduncle to the bases of the caudal rays. There is a conspicuous series of black spots along the bases of the anal fin and following finlets. The posterior part of the top of the head forward of the nape is very dark; this is actually subcutaneous pigment on the brain covering. The snout and both jaws bear rather conspicuous dark pigmentation. There is a light pigmentation of the operculum, and the posterior margin of the orbit is rather dark. The larger specimen had essentially the same pigmentation except that it was heavier, and the whole dorsal part of the head was dark. No bars were present on the sides as in *Neothunnus*. The peritoneum dorsally is quite heavily pigmented, but is light below.

The 21-mm. specimen has two fairly conspicuous spines at the corner of the preopercle, preceded by a tiny spine on the inferior margin. There might be more small spines discernible at a smaller size. The spines have entirely disappeared in the 44-mm. specimen.

The vertebrae, examined in the 44-mm. specimen stained with alizarin, number 20+21, counting the urostyle. Haemal spines are present on some precaudal as well as on the caudal vertebrae. The inferior foramina are large and well developed in precaudal vertebrae 14 to 20, as well as on the anterior caudal vertebrae. The haemal canal is very large. The inferior foramina and large haemal arches form what Kishinouye calls the "trellis" and Godsil and Byers call a "complex basket work." The first closed haemal arch is found on the twelfth vertebra. The lateral processes on the posterior caudal vertebrae are fairly well developed; there are no lateral processes on the anterior precaudal vertebrae.

The pectoral fin has 26 rays. The first dorsal fin has 16 spines, the second being the longest in both our specimens. Spines following the second decrease in length successively; the first spine is longer than the fourth. The first dorsal extends to the insertion of the second. The combined count of second dorsal rays and dorsal finlets is 23. There are, apparently, eight dorsal finlets, but here again it is not easy to decide between the last ray of the fin and the first finlet. The anal consists of 15 rays and 7 finlets; the combined count is accurate but the segregation of rays and finlets may be one in error. In our 21-mm. specimen the finlets are joined to one another and to the fin by a membrane extending almost to their tips. This has entirely disappeared in the 44-mm. specimen, except between the fin and the first finlet behind the fin. The intestine passes posteriorly along the right side of the body cavity and is not folded in either specimen. The left lobe of the liver is much longer than the other two lobes, extending about half the length of the body cavity, and is somewhat attenuated distally. The anterior portion of the lateral line is visible in the larger specimen and has a gentle curve over the pectoral fin, rather than the sharp dip of the Thunnidae. The gill rakers on the first arch of the smaller specimen are short and tiny; they appear numerous, but cannot be accurately counted. In the large specimen the gill rakers on the first arch were counted as 8+33.

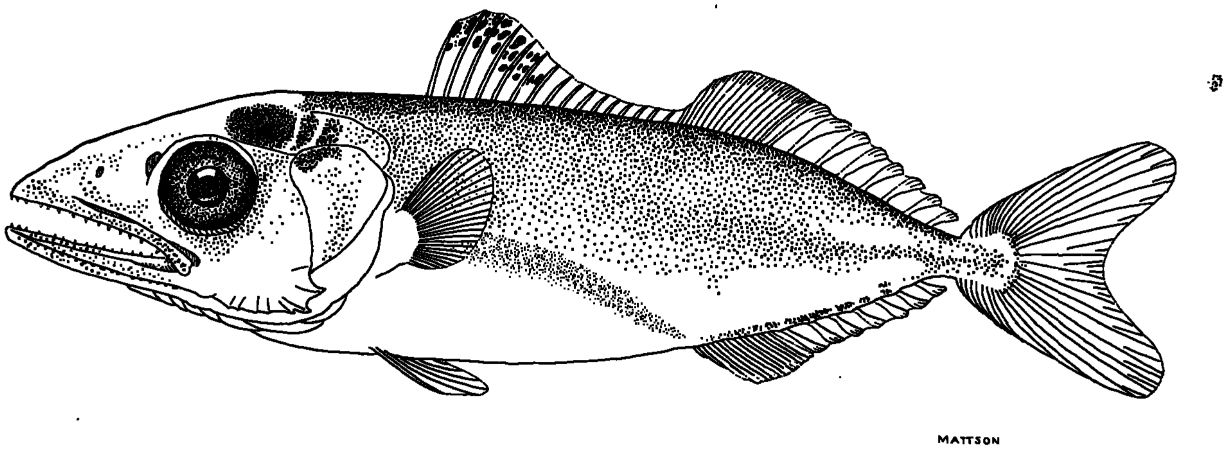

FIGURE 5.—*Katsuwonus pelamis*, 21 millimeters long.

The characteristics of the vertebral column, as described, are sufficient to identify these specimens as belonging to the "Katsuwonidae" of Kishinouye (1923), and other characters agree, such as the relative size of the liver lobes and shape of lateral line. Of the Katsuwonidae the only known species having 20+21 vertebrae is *K. pelamis*. This character alone is sufficient to identify these specimens beyond any doubt (Kishinouye 1923; Godsil and Byers 1944; Frade and deBuen 1932), and numerous other characters are in agreement.

Ehrenbaum (1924) described specimens of *Euthynnus pelamis* L.(=*Katsuwonus pelamis*) up to 10 mm. in length, the larger of which could be identified with fair certainty by the vertebrae counts as belonging to this species. Since these specimens were all much smaller than ours, we cannot verify their identification by comparison of his descriptions with specimens of similar sizes. So far as our material is comparable, however, there seems to be no reason to doubt the correctness of Ehrenbaum's identification. It appears that the light pigmentation of the first dorsal fin of our specimens was characteristic of his smaller ones also.

DISCUSSION

The observation of sexually maturing and of spent adults of *Neothunnus macropterus* and *Katsuwonus pelamis*, and the capture of juveniles of these species during the late winter and spring months in the oceanic waters off Central America, demonstrate the existence of a spawning area of these species in that vicinity at that time of year. That the juveniles were probably moderately numerous in this region may be inferred from the fact that, out of 17 stations off Costa Rica and northern Panama at which we captured organisms under a drop light between January 28 and May 7, we took *Neothunnus* at 4 stations, of which 2 also furnished specimens of *Katsuwonus*. Three of these four stations were off Costa Rica and one off Panama. From these scattered observations no conclusions regarding the geographic concentration or extent of occurrence of juveniles can be drawn.

Although this region is now the only definitely known spawning area of yellowfin tuna and skipjack in the eastern Pacific, these species both have wide ranges, and it would be highly desirable to investigate other areas in order to determine over what part of the total ranges spawning occurs.

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SIZE COMPOSITION OF CATCHES OF YELLOWFIN TUNA (*NEOTHUNNUS MACROPTERUS*) FROM CENTRAL AMERICA, AND THEIR SIGNIFICANCE IN THE DETERMINATION OF GROWTH, AGE, AND SCHOOLING HABITS

By Milner B. Schaefer

The factory ship *Pacific Explorer* was employed during the late winter and spring months of 1947 in collecting and freezing a cargo of tuna, mostly yellowfin, from Pacific waters adjacent to Costa Rica. Aboard the vessel were biologists of the Fish and Wildlife Service until mid-May (the author until mid-March when relieved by J. C. Marr). It was possible for us to examine the catches of the accompanying fishing boats, both at sea as they were being made and aboard the mother ship. Among the data gathered on the biology of the yellowfin tuna were a series of length-frequency samples of the catches. These shed some light on the age and growth, and on the manner of aggregation into schools.

COLLECTION OF DATA

Most fish in the samples were measured at sea as caught, and the sample from each school was kept separate. When less than 50 fish were caught from a school, ordinarily the entire catch was measured. When more than 50 fish were caught, a minimum of 50 fish were taken at random from the catch and measured. In a few cases, samples from catches were measured when the fish were landed aboard the mother ship. In such cases, the samples were usually from several schools combined.

The total length of the fish, from the tip of the snout to the fork of the tail, was measured with a large pair of slide calipers.[1] In making this measurement, one arm of the calipers was seated firmly against the tip of the snout and the other against the cartilaginous tissue in the fork of the tail.

In addition to the measurements made in the field on freshly caught fish, two landings of fish taken in the waters off Costa Rica during the last week in June and landed aboard the *Pacific Explorer* were sampled when unloaded at Astoria (Oreg.) in mid-July. These were measured at the cannery of Columbia River Packers, Inc., after being thawed in vats of water preparatory to butchering for canning.

In figure 1, we have summarized the data for *Neothunnus macropterus* (Temminck and Schlegel), the yellowfin tuna, by three periods. The upper length-frequency graph represents fish measured from January 27 to February 8. Included are 233 fish from the individual schools which are graphed by separate schools in figure 2, plus 118 other fish, consisting of 62 from four individual schools and 56 drawn at random from two landings of mixed schools which were landed aboard the mother ship. All these fish were taken by bait boats. The middle graph of figure 1 includes the following fish taken between March 20 and April 24: 184 fish caught by bait boats and 100 fish caught by purse seiners, graphed by individual schools in figure 3, plus 47 other fish taken by bait boats from four other individual schools and 10 fish drawn at random from a bait-boat landing on the mother ship. The bottom graph in figure 1 includes samples of fish from each of two landings aboard the mother ship; these fish, which total 199, were caught in each instance by bait boats from waters off Costa Rica. These two samples were measured after the frozen fish had been thawed at the cannery. They are presumed to include representatives from several schools.

In all the graphs the fish, which were measured to the nearest millimeter, have been grouped by two-centimeter length classes, each class including the millimeters from zero to nine in an odd centimeter and the following even centimeter. The class intervals are, thus, for example, 610 mm. to 629 mm., 630 mm. to 649 mm., etc., with mid-points 619.5 mm., 639.5 mm., etc.

AGE AND GROWTH

Some inferences as to age and growth can be made from the modes in figure 1. The youngest group, near 60 cm., is represented by only scattered individuals in the bait-boat catches of the first two periods,

[1] The calipers used were very kindly loaned to us by H. C. Godsil of the California State Fisheries Laboratory.

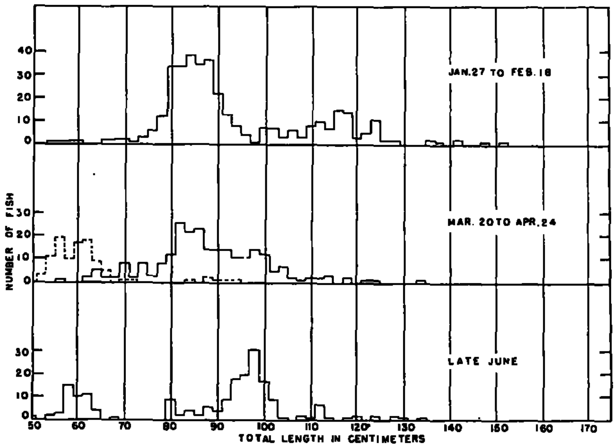

FIGURE 1.—Length frequencies of samples of yellowfin-tuna catches, summarized by periods, 1947. (Solid line, bait-boat catches; broken line, purse-seine catches.)

but is well represented in the June samples. This group also made up the major part of the two purse-seine catches sampled. The difference in the size composition of the catches of bait boats and seiners in March and April appears to the author to be primarily a matter of the selectivity of the bait fishing. During cruises on bait boats in these waters, we saw large numbers of small yellowfin, very often schooled with skipjack, *Katsuwonus pelamis* (Linnaeus), of similar size, but they did not respond to the methods of the bait fishery. The modal size of this group in the population may not be accurately reflected in the corresponding modes in the samples, both because of the schooling habits of the fish and because of the probable selectivity of the fishing methods. The fish in this group are probably the one-year-olds, although it is possible that they are the two-year-olds. This conclusion is based on the relation of the position of this mode to the next, that at 85 cm. in the January-February samples, which is presumed to be composed primarily of fish a year older than this smallest group. The fish in the smallest group were completely immature in all samples, while those of larger sizes were nearly all undergoing maturation of the gonads in the samples taken through April, many of them being very close to spawning as judged by the presence of large, opaque, yolk-laden ova in many of the females, and the presence of running milt in the ducts of the testes of some males. These larger sizes among the fish taken in late June were spent fish, some apparently rather recently so.

Although little progression of the mode of the smallest fish is evident, there appears to be a progressive increase in the size of the fish making up the second mode. This may be spurious, however. Tracing the growth over such a short period by means of progression of modes of size frequencies is made difficult by the tendency of the fish to school by sizes, with the attendant sampling errors, which will be discussed in more detail later.

It is not possible to trace the growth of the fish beyond the second year by means of these length frequencies. The mode near 115 cm. in the first period in figure 1 is very likely composed of fish of more than one age group. Even the second mode may contain fish of more than one age. In a longer series, however, made up of samples of more schools, it may prove possible to identify older age groups by means of size frequencies.

It seems probable from these data that the yellowfin tuna of the Pacific off Central America grow at a very rapid rate, and that the bulk of the catch is made up of members of relatively few year classes, a considerable number of fish caught being probably only 1 year old.

The rapid rate of growth of these tunas, inferred from the length frequencies, agrees with the findings of other authors regarding yellowfin and bluefin tunas from other parts of the world. Kishinouye (1923) says,

> The growth of tunnies seems to be very rapid. The common tunny, *Thunnus orientalis*, most probably reaches maturity in the third year of age. *Thunnus orientalis*, ca 22 cm. in the total length, is the smallest specimen I have seen * * * such small individuals are found in August and in September. Some of them grow to a length of 30 cm. or more. By next spring they grow to a length of ca 60 cm. When 2 years old they are about 1 metre in length and 11 kg. in weight * * * The growth of *Thunnus germo* and *Neothunnus macropterus* in the first and second years seems to be nearly the same as that of the common tunny * * *.

Sella (1929) states that tuna (*Thunnus thynnus*) hatched in May and June in the Mediterranean weigh 300 to 500 grams in September. He has determined the ages of fish of this species by marks on the vertebrae, and gives the following average sizes at various ages:

Age	Length in centimeters	Weight in kilos
1	64	4.4
2	81.5	9.5
3	97.5	16
4	118	25
5	136	40
6	153	58
7	169	76

Westman and Neville (1942) have been able to determine the ages of *Thunnus thynnus*, from waters off New York, by length frequencies up to three years of age and by scale readings for those and also older ages. They state:

> In the July 1–15 sample, the fish between 20 and 24 inches [50 and 60 cm.] were in their second summer of growth; those between 27 and 34 inches [68 and 86 cm.] were in their third summer; those between 35 and 40 inches [88 and 101 cm.] were in their fourth summer; and those between 42 and 46 inches [106 and 116 cm.] were in their fifth summer of growth.

The metric values in brackets have been inserted by the author. Westman's and Neville's figure 9 shows the following approximate positions of the modes of size groups in the length frequencies of August and September caught fish: 1-year-olds, 60 cm.; 2-year-olds, 85 cm.; and 3-year-olds, 105 cm.

SCHOOLING HABITS

In figures 2 and 3 we have graphed, by separate schools, those samples of yellowfin tunas which were drawn from individual schools, and which were large enough to characterize the size composition of the school. It is quite evident from the figures that each school is not a random aggregation of members from the whole population of the area, but that there is a distinct tendency for fish of the same size to school together. The members of any given school are more nearly of the same size than would be expected if they were merely drawn at random from the whole population. The degree to which fish of a school tend to be of the same size varies between schools. The school sampled on January 29, for example, was composed of fish of rather uniform size, while the one sampled on February 3 was a mixture of a larger range of sizes.

The tendency to aggregate by similar sizes may be, in some cases, stronger than the tendency to aggregate by species. As stated previously, the small, 1-year-old yellowfin, during the period of our observation, very often were seen schooled with skipjack of about the same size, rather than with larger fish of their own species. The purse seine catch sampled on March 28 was from a single mixed school of this sort. The size distributions of the samples of each of the two species in this catch are shown in figure 4; the similarity of sizes of the two species in this school is obvious.

The tendency of the tunas to school by sizes has important implications in the design of any sampling program for determining the size composition of the population. In order that the size composition of the total sample be representative of the size composition of the population it is necessary that the different strata of the population—in this case types of schools—be each represented in proportion to the

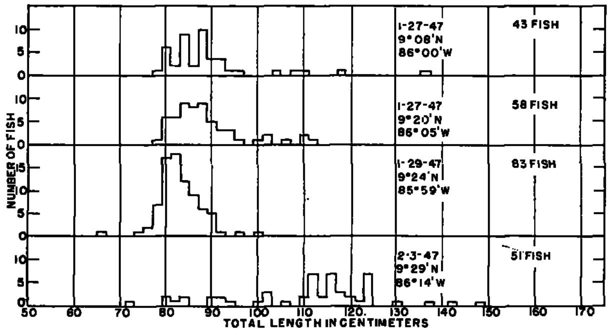

FIGURE 2.—Length frequencies of samples of yellowfin tuna from individual schools, caught by a bait boat in late January and early February 1947.

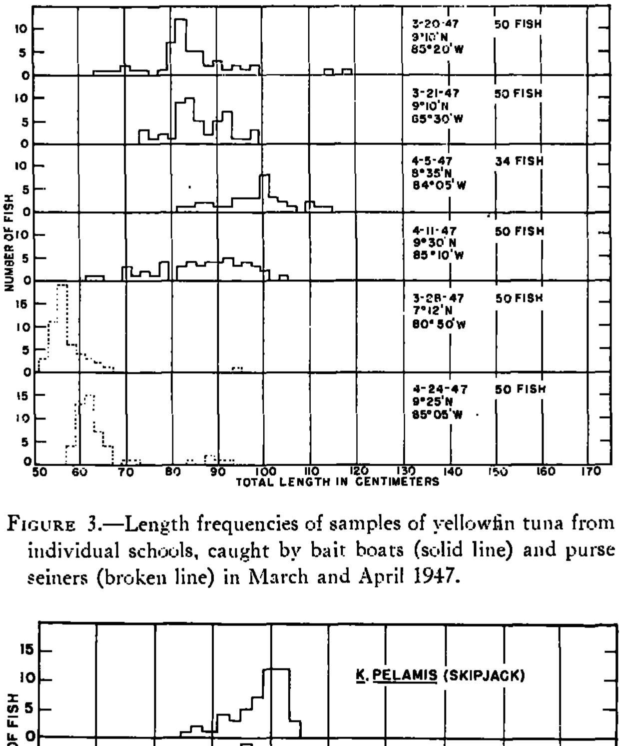

FIGURE 3.—Length frequencies of samples of yellowfin tuna from individual schools, caught by bait boats (solid line) and purse seiners (broken line) in March and April 1947.

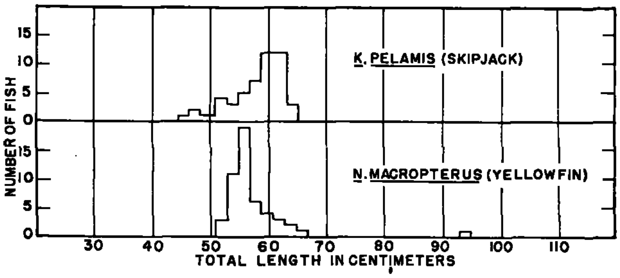

FIGURE 4.—Length frequencies of samples of 50 skipjack and 50 yellowfin from a mixed school caught by purse seine near 7°12′ N. 80°50′ W. on March 28, 1947.

number of members in the stratum. It would seem desirable, since we know that the population is grouped into schools by sizes, that the school be made the basic unit of sampling. That is, it is desirable that the total sample be composed of subsamples drawn by either representative or random methods from each of a large number of schools selected randomly from the population. A large number of fish drawn from only a few schools will not likely be as representative of the population as the same number drawn a few each from a large number of randomly chosen schools. Our own samples suffer from a lack of being drawn from a sufficient number of schools to give a very reliable estimate of the positions of the modes in the population at large. As a consequence, the interpretation of the length frequencies of figure 1 lacks precision; it is possible to determine only roughly the size frequencies in the population from the frequencies in these samples.

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OBSERVATIONS ON THE SPAWNING OF OCEANIC SKIPJACK (*KATSUWONUS PELAMIS*) AND YELLOWFIN TUNA (*NEOTHUNNUS MACROPTERUS*) IN THE NORTHERN MARSHALL ISLANDS

By John C. Marr [1]

A spawning area of the oceanic skipjack, *Katsuwonus pelamis* (Linnaeus 1758), and the yellowfin tuna, *Neothunnus macropterus* (Temminck and Schlegel 1850), off the Pacific Coasts of Costa Rica and Panama has been recorded, on the basis of the examination of gonads of adult fishes and the capture of juveniles, by Schaefer and Marr (p. 187). No other spawning localities of these species have been recorded in the Pacific, although Matsui (1942), on the basis of the relation of gonad weight to body weight in *Katsuwonus* taken near Japan and near Palau, concluded that those taken near Palau were more mature than those from Japanese waters and that a spawning region might exist in the vicinity of Palau. (I have not seen this paper; the above is based on an abstract of it by Yoshio Hiyama.)

From March to August 1946, and in July and August 1947, I was detailed to duty with the United States Navy in the northern Marshall Islands area. My duties were largely concerned with studies of the biology of the pelagic fishes, particularly in the vicinity of Bikini, Rongerik, and Rongelap Atolls in 1946, and Bikini and Rongerik Atolls in 1947. On the basis of examinations of the gonads of adults of these 2 species, it seems probable that spawning occurs in or near this region. This is confirmed for *Katsuwonus pelamis* by the incidental capture of 2 juveniles. No other juveniles were taken, since virtually no collecting was done in the open sea where spawning probably takes place. All adult specimens examined were taken by trolling feather or bone jigs in the open sea or adjacent to the atolls, never in the lagoons. Large yellow-fin tuna carried away the gear employed, and the larger sizes are not represented in the catch. The oceanic skipjack did not do this, since they do not attain such large sizes, and the catch should be representative of the sizes present in the area or, at least, in the schools fished.

The degree of sexual maturity of the fishes of all species taken was evaluated for as many fishes as possible. It was not possible to do this for all fishes in 1946 due to the lack of personnel; it was done for almost all fishes taken during 1947. Some of the 1946 observations were made by commercial fishermen who had been trained to distinguish between the different stages of maturity; the 1947 observations were made by biologists. When the visceral cavity of the fish was opened to determine the sex, the degree of maturity of the gonads was classified as follows: immature, ripening, ripe, spawning, or spawned out.

Gonads not at all enlarged, merely a small, ribbon-like body, were classified as immature. Without microscopic examination, it is difficult to distinguish males from females at this stage and some sex determinations may be in error. Ovaries, which are tubular, may often roll between the fingers (as would a piece of glasss tubing) and the opposite walls of the ovary may be felt sliding over each other. Testes, which are solid and not round in cross section, do not roll but turn over between the fingers (as would an object which is angular in cross section) and the opposing walls do not slide over each other.

Ripening gonads are somewhat enlarged, but not fully ripe. No difficulty is experienced in determining the sex at this stage; ovaries are enlarged, turgid bodies, round in cross section; testes are solid, pinkish bodies not round in cross section.

Ripe gonads are greatly enlarged. The ova are distinguishable by the naked eye and may be easily dislodged. The testes are whitish and often have milt in the central duct. For *Katsuwonus* and *Neothunnus* no running-ripe individuals were noted and this stage might be more properly termed "ripening, advanced" for there is a possibility that the gonads of *Katsuwonus*, at least, remain in this enlarged state some time before spawning actually takes place. However, in the present data this situation can not be distinguished from one in which the actively spawning individuals are present in the area but not present in the catch.

Gonads classified as "spawning" have the same general characteristics as the "ripe" gonads, but the

[1] Valuable field assistance was rendered in this work by M. A. Traylor, Chicago Natural History Museum, in 1946, V. E. Brock, Director, Division of Fish and Game, Territory of Hawaii, in 1946 and 1947, and Dr. Osgood R. Smith, of the Fish and Wildlife Service, in 1947.

sexual products may in some cases be expressed by external pressure. Ovaries may appear to be partially emptied. This latter criterion was most often employed for these two species.

Spawned out ovaries are hollow, more or less flabby, sac-like tubes. Testes at this stage are pinker, tougher, and less turgid than those which are ripening, but it is often difficult to distinguish between these two stages in males.

The methods employed are somewhat subjective, but are exact enough to permit the detection of major changes such as would be brought about by a spawning season. Data on approaching maturity and time of spawning are probably more reliable for females than for males.

KATSUWONUS PELAMIS (LINNAEUS 1758)

In 1946, a total of 144 skipjack were taken between April 3 and August 14. Of these, information on sex and degree of maturity are available for 107; length data are available for 143. In table 1 are given the dates of capture, locality, fork length (the straight line distance from the tip of the snout with the jaws closed to the end of the cartilage, with the small fleshy flap depressed, in the median part of the caudal fork), sex, and degree of maturity for the 107 fish mentioned. The following fish were considered to be immature: males, 451 mm., July 26; 467 mm., July 29; 661 mm., August 7; females, 457 mm. August 3; 443 mm., August 9; 444 mm., August 9. The females and all but one of the males are all in the lower end of the size-range covered by the catch. From April 11 to August 13, 98 males and females were considered to be ripe. Among these fish are included some that probably should have been classified as ripening and some of the males may have been spawned out. The following fish, all females, were found to be spawned out: 611 mm., April 22; 673 mm., July 20; 453 mm., July 26.

These data might be interpreted as indicating that the oceanic skipjack spawn in or near this area, but most of them at some time after the date upon which the last fish was examined. An alternative explanation is that the spawning season falls within the period covered by field work, but that the spawning and spawned out fish were largely unavailable to the fishery (this would include the possibility that large-scale spawning takes place during the entire year).

In 1947, a total of 84 skipjack were taken between July 19 and August 22. Of these, information on sex and degree of maturity are available for 72; length data are available for 80. Table 1 includes these and other data. During this period no fish were judged to be immature. From July 23 to August 21, 15 fish were considered to be ripening. All but one of these are males and some may have been spawned out fish that were mis-classified. A total of 46 fish were considered to be ripe. A total of 11 fish were classified as spawning or spawned out. The first of these was taken on July 29 and the remainder were taken on or after August 12.

The 1947 data support conclusions similar to those drawn from the 1946 data. There is, perhaps, a little more evidence to indicate that the spawning season is actively under way in August.

Ovaries that were classified as ripe, from two skipjack taken on July 24, 1947, were preserved in formaldehyde. Subsequent examination indicates that a small percentage of the ova may have been spawned before the fish were caught; i. e., the most posterior portions of the ovaries were partially hollow, resembling the condition of ovaries that were considered to be spawned out. Ova from the posterior portion of these ovaries were measured with an eyepiece micrometer under a compound microscope. In an ovary of one fish the largest ovum measured had a diameter of 0.65 mm. This ovum was associated with a mode centering at 0.53 mm. Two other size groups were present, one centering at 0.35 mm. and the other at 0.18 mm. Similar size-groups of ova with perhaps slightly smaller modal diameters were present in an ovary of the other fish. This suggests that the ova are spawned in batches. Fractional spawning has been demonstrated in *Thunnus thynnus* (Linnaeus) by Fradé and Manaças (1933) and suggested in *Neothunnus macropterus* by Schaefer and Marr (p. 188). The largest ova are probably approaching full size. According to Schaefer and Marr "Ova from a preserved ovary of a running-ripe *Euthynnus lineatus* Kishinouye from Costa Rica measure 0.72 to 0.81 mm. in diameter." Sanzo (1929) gives 1.0 mm. to 1.2 mm. as the diameter of the fertilized ova of *Thunnus tyhnnus*. It is to be expected that oceanic skipjack ova would increase in diameter after emission into sea water.

On July 24, 1947, several fishes were regurgitated by adult *K. pelamis* taken off the northwest end of Bikini Atoll (3 miles west of Bokobyaadaa Island). Among these fishes are 2 juvenile scombroids between 45 mm. and 50 mm. in length, partially digested and distorted. These have been identified as *Katsu-*

TABLE 1.—*Length, sex, and degree of maturity data for Katsuwonus pelamis taken in the northern Marshall Islands during 1946 and 1947*

Date	Locality	Length in millimeters	Sex	Degree of maturity
1946				
Apr. 11	Bikini	634	Female	Ripe.
15	do	498	do	Do.
20	Rongerik	620	Male	Do.
20	do	571	do	Do.
21	do	619	do	Do.
21	do	617	do	Do.
22	do	608	do	Do.
22	do	611	Female	Spawned out.
23	do	628	do	Ripe.
23	do	619	do	Do.
May 13	do	488	do	Do.
14	do	570	do	Do.
18	Rongelap	498	Male	Do.
18	do	491	Female	Do.
22	Bikini	675	Male	Do.
31	Rongelap	628	Female	Do.
June 1	do	625	do	Do.
19	Bikini	514	do	Do.
25	Rongelap	629	Male	Do.
July 3	do	470	Female	Do.
3	do	470	do	Do.
8	Bikini	684	Male	Do.
8	do	680	do	Do.
8	do	686	do	Do.
8	do	672	do	Do.
9	do	667	do	Do.
9	do	669	do	Do.
9	do	659	Female	Do.
9	do	660	Male	Do.
9	do	655	Female	Do.
9	do	703	do	Do.
9	do	661	Male	Do.
9	do	680	do	Do.
9	do	665	Female	Do.
9	do	640	do	Do.
9	do	691	Male	Do.
9	do	691	do	Do.
9	do	666	do	Do.
9	do	687	do	Do.
9	do	653	Female	Do.
9	do	692	Male	Do.
9	do	654	do	Do.
9	do	661	Female	Do.
9	do	691	Male	Do.
9	do	667	do	Do.
9	do	684	do	Do.
9	do	657	Female	Do.
20	Rongerik	638	Male	Do.
20	do	673	Female	Spawned out.
23	do	629	Male	Ripe.
26	Rongelap	453	Female	Spawned out.
26	do	451	Male	Immature.
29	Ailinginae	454	do	Ripe.
29	do	444	do	Do.
29	do	467	do	Immature.
Aug. 2	Bikini	654	do	Ripe.
2	do	651	Female	Do.
2	do	658	Male	Do.
2	do	628	Female	Do.
2	do	678	Male	Do.
2	do	688	do	Do.
2	do	659	do	Do.
3	do	457	Female	Immature.
3	do	647	Male	Ripe.
3	do	684	do	Do.
3	do	454	Female	Do.
3	do	454	Male	Do.
5	do	500	do	Do.
5	do	500	do	Do.
5	do	463	Female	Do.
5	do	435	Male	Do.
5	do	459	Female	Do.
5	do	496	Male	Do.
5	do	463	Female	Do.
5	do	506	Male	Do.
5	do	478	Female	Do.
5	do	483	Male	Do.
5	do	454	do	Do.
5	do	480	Female	Do.
5	do	470	Male	Do.
5	do	459	Female	Do.
5	do	477	Male	Do.
5	do	448	do	Do.
5	do	463	do	Do.
5	do	479	do	Do.
7	do	450	do	Do.
7	do	661	do	Immature.
7	do	668	do	Ripe.
7	do	431	do	Do.
7	do	489	Female	Do.
7	do	451	Male	Do.
1946				
Aug. 7	Bikini	460	Female	Ripe.
7	do	698	Male	Do.
7	do	644	Female	Do.
9	do	448	Male	Do.
9	do	443	Female	Immature.
9	do	439	do	Ripe.
9	do	442	Male	Do.
9	do	448	do	Do.
9	do	455	do	Do.
9	do	450	do	Do.
9	do	391	do	Do.
9	do	444	Female	Immature.
10	do	683	Male	Ripe.
10	do	654	Female	Do.
10	do	549	Male	Do.
13	do	664	do	Do.
1947				
July 19	do	588	do	Do.
23	do	672	do	Ripening.
24	do	543	Female	Ripe.
24	do	540	do	Do.
24	do	535	do	Do.
24	do	570	Male	Do.
24	do	547	Female	Do.
24	do	542	Male	Do.
24	do	514	Female	Do.
24	do	565	do	Do.
24	do	552	do	Do.
24	do	560	do	Do.
24	do	532	Male	Do.
24	do	598	Female	Do.
24	do	565	Male	Do.
24	do	488	Female	Do.
24	do	504	Male	Do.
24	do	488	Female	Do.
24	do	574	Male	Do.
24	do	598	Female	Do.
24	do	470	Male	Do.
24	do	544	Female	Do.
24	do	------	Male	Do.
24	do	475	do	Do.
24	do	545	do	Do.
24	do	460	do	Ripening.
26	do	598	do	Ripe.
26	do	732	do	Do.
28	do	482	do	Ripening.
28	do	572	do	Ripe.
28	do	461	Female	Ripening.
28	do	488	do	Ripe.
28	do	720	Male	Do.
28	do	718	do	Do.
29	do	656	do	Do.
29	do	698	do	Do.
29	do	642	do	Do.
29	do	407	Female	Spawned out.
30	do	458	Male	Ripening.
30	do	463	do	Do.
30	do	436	Female	Spawning or spawned out.
31	do	441	do	Ripe.
31	do	460	Male	Ripening.
31	do	432	do	Ripe.
31	do	467	Female	Do.
31	do	559	Male	Do.
31	do	453	do	Ripening.
Aug. 2	do	449	do	Ripe.
2	do	447	do	Do.
2	do	465	do	Do.
5	do	470	do	Ripening.
6	do	452	do	Do.
8	do	437	do	Ripe.
8	do	430	do	Ripening.
8	do	448	do	Ripe.
12	Rongerik	455	do	Ripening.
12	do	468	do	Do.
12	do	442	Female	Spawned out.
12	do	463	do	Do.
12	do	464	Male	Ripening.
13	do	675	Female	Spawning.
13	do	481	do	Do.
13	do	475	do	Spawned out.
14	do	450	Male	Ripe.
14	do	664	Female	Do.
20	do	459	Male	Do.
20	do	682	Female	Spawned out.
21	do	465	do	Spawning.
21	do	465	Male	Ripening.
22	do	463	do	Ripe.
22	do	482	Female	Spawned out.
22	do	459	do	Spawning.

wonus pelamis. One of these specimens was stained and cleared for study of the bony parts, using the methods described by Hollister (1934). The "complex basketwork" formed by the haemal arches and inferior foramina is characteristic of *Katsuwonus* and *Euthynnus* (Kishinouye 1923; Godsil and Byers 1944). That these specimens are *Katsuwonus* is indicated by the presence of 41 vertebrae. The gill rakers on the most anterior gill arches of both specimens were counted as 6+32. The full complement of rakers has probably not yet been attained. Gill-raker counts of adult *K. pelamis* taken in the same area are 16–21+33–40 and of *Euthynnus yaito* (Kishinouye 1915) are 8–10+23–26. This further indicates that the specimens are *K. pelamis*, rather than *E. yaito*. It is of interest to note that palatine teeth are present, although the absence of these teeth is supposedly characteristic of *Katsuwonus*. This is undoubtedly true of the adults. Reexamination of the 21-mm. specimen described by Schaefer and Marr (p. 193) disclosed that palatine teeth are present. These teeth are probably grown over by the time the fish attain adult sizes. A similar situation has been noted in *Auxis thazard* (Lácèpede 1802) by Schaefer and Marr.

The dates on which juvenile oceanic skipjack were collected in Central American waters by Schaefer and Marr (p. 189) indicate that spawning takes place in those waters, at least, from January into March. Further, six adults examined by them on February 21, 1947, were maturing; one male and one female were nearly ready to spawn. Ten adults examined by them on March 30, 1947, appeared to be spawned out. Ehrenbaum (1924: 33) records juvenile *Euthynnus pelamis* (=*K. pelamis*) under 10 mm. in length taken in the Atlantic Ocean and the Arabian Sea from July to December. Chapman (1946: 169) took young "skipjack" 8 to 10 inches long between Guadalcanal and Florida Island. However, it is not clear whether he refers to *E. yaito* or *K. pelamis* or both. Kishinouye (1923: 456) believed the spawning season to be from May to August, although the basis for his belief was not given. From the above it would seem that oceanic skipjack either spawn throughout the year in all spawning localities or that the time of spawning varies from locality to locality. The presence of modal size-groups in the catch in the northern Marshall Islands favors the latter alternative.

Ripe gonads were found over the entire size-range of northern Marshall Island fish examined for degree of maturity. The upper panel in figure 1 shows the length-frequency distributions for the oceanic skipjack taken in 1946 and 1947, including individuals for which information on the degree of maturity is not available.

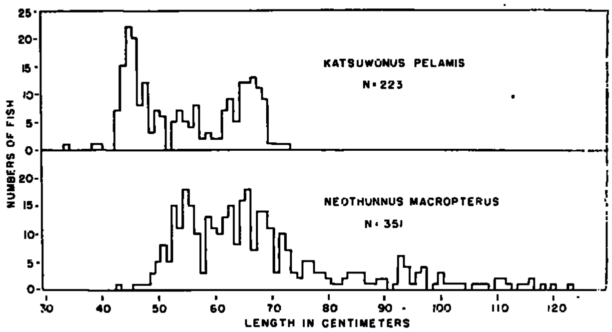

FIGURE 1.—Length frequency distributions of oceanic skipjack and yellowfin tuna taken in the northern Marshall Islands during 1946 and 1947.

NEOTHUNNUS MACROPTERUS (TEMMINCK AND SCHLEGEL 1850)

In 1946, a total of 284 yellowfin tuna were taken between April 1 and August 14. Of these, information on sex and degree of maturity are available for 101; length data are available for 280. In table 2 are given the dates of capture, locality, fork length, sex, and degree of maturity for the 101 fish mentioned The observations recorded on July 29, August 4, 5, and 7 were made by an inexperienced observer and should be regarded as extremely questionable. They are not included in the following discussion. Of the remaining 91 fish, 64 were considered to be immature. These are all in the lower end of the size range covered in the catch. The following fish were classified as ripening: males; 925 mm., April 20; 660 mm., April 20; 768 mm., June 15; females: 943 mm., April 20; 856 mm., April 21; 992 mm., April 21; 663 mm., April 22; 718 mm., April 24; 716 mm., June 2; 965 mm., August 14. A total of 16 fish were considered to be ripe. These were taken between May 16 and July 26. The smallest was 741 mm., and all but 6 were longer than 900 mm. One female, 1,144 mm., taken on April 20, was considered to be spawned out.

It has been shown by Schaefer and Marr (p. 187), that among the yellowfin examined off Costa Rica in January and February, the fish more than 1,000 mm. in length were in advanced stages of sexual maturity. This was not true for fish under this length. However, by April many of the fish down to 700 mm. had

TABLE 2.—*Length, sex, and degree of maturity data for Neothunnus macropterus taken in the northern Marshall Islands during 1946 and 1947*

Date	Locality	Length in millimeters	Sex	Degree of maturity	Date	Locality	Length in millimeters	Sex	Degree of maturity
1946					*1946*				
Apr. 1	Bikini	683	Female	Immature.	July 26	Rongelap	925	Male	Immature.
1	do	645	do	Do.	26	do	601	do	Do.
1	do	643	do	Do.	26	do	593	do	Do.
1	do	595	do	Do.	26	do	621	Female	Do.
1	do	613	Male	Do.	26	do	891	do	Ripe.
1	do	528	do	Do.	27	Ailinginae	773	Male	Immature.
1	do	550	do	Do.	27	Rongelap	781	Female	Do.
2	do	588	do	Do.	29	Ailinginae	668	Male	Ripe.[1]
2	do	626	do	Do.	29	do	640	do	Do.
6	do	694	do	Do.	29	do	645	do	Do.
15	do	745	do	Do.	Aug. 4	Bikini	786	Female	Do.
15	do	693	Female	Do.	5	do	640	Male	Do.
15	do	653	do	Do.	7	do	652	do	Do.
15	do	647	do	Do.	7	do	527	do	Do.
15	do	572	Male	Do.	7	do	654	do	Do.
17	do	872	Female	Do.	7	do	635	Female	Spawned out.
17	do	704	Male	Do.	7	do	669	Male	Ripe.[1]
17	do	728	do	Do.	14	do	965	Female	Ripening.
20	Rongerik	1,144	Female	Spawned out.	*1947*				
20	do	672	do	Immature.	July 21	do	544	Male	Immature.
20	do	925	Male	Ripening.	23	do	540	do	Do.
20	do	611	do	Immature.	23	do	526	do	Do.
20	do	637	do	Do.	23	do	530	do	Do.
20	do	593	do	Do.	23	do	567	do	Do.
20	do	615	do	Do.	23	do	1041	Female	Spawned out.
20	do	943	Female	Ripening.	23	do	931	Male	Ripening.
20	do	619	Male	Immature.	25	do	541	Female	Immature.
20	do	660	do	Do.	26	do	611	do	Do.
20	do	660	do	Ripening.	26	do	666	Male	Do.
21	do	856	Female	Do.	26	do	552	Female	Do.
21	do	992	do	Do.	26	do	933	do	Ripening.[2]
21	do	509	Male	Immature.	27	do	935	do	Spawned out.
21	do	527	do	Do.	28	do	522	Male	Immature.
22	do	752	Female	Do.	29	do	600	do	Do.
22	do	578	Male	Do.	29	do	839	Female	Spawned out. (Or immature?)
22	do	626	do	Do.	30	do	547	Male	Immature.
22	do	684	do	Do.	30	do	533	do	Do.
22	do	801	do	Do.	30	do	561	Female	Do.
22	do	634	Female	Do.	Aug. 2	do	1078	do	Ripening.
22	do	663	do	Ripening.	2	do	1015	Male	Do.
22	do	634	Male	Immature.	7	do	943	do	Do.
24	do	667	do	Do.	12	Rongerik	547	do	Immature.
24	do	632	do	Do.	12	do	514	do	Do.
24	do	685	Female	Do.	12	do	787	do	Ripening.
24	do	676	do	Do.	12	do	739	do	Immature.
25	do	718	do	Ripening.	12	do	661	do	Do.
May 16	Rongelap	1060	do	Ripe.	12	do	546	do	Do.
16	do	1178	do	Do.	13	do	655	Female	Do.
16	do	1095	Male	Do.	13	do	534	Male	Do.
16	do	1160	do	Do.	14	do	676	do	Do.
16	do	1005	do	Do.	14	do	585	do	Ripening.
17	do	721	Female	Immature.	14	do	549	do	Do.
17	do	504	do	Do.	14	do	525	do	Do.
17	do	784	do	Do.	14	do	536	do	Immature.
18	do	995	do	Ripe.	14	do	553	do	Do.
18	do	967	do	Do.	14	do	565	do	Do.
18	do	702	Male	Immature.	19	do	551	do	Do.
June 1	Rongerik	683	Female	Do.	19	do	897	Female	Spawned out.
2	do	716	do	Ripening.	21	do	567	Male	Immature.
4	Rongelap	1000	do	Ripe.	21	do	543	do	Do.
4	do	842	Male	Do.	21	do	846	do	Do.
4	do	692	Female	Immature.	21	do	677	do	Ripening.
4	do	898	Male	Ripe.	21	do	561	do	Immature.
4	do	741	do	Immature.	21	do	536	do	Do.
4	do	778	Female	Ripe.	21	do	541	Female	Do.
4	do	717	Male	Immature.	21	do	527	Male	Do.
4	do	695	do	Do.	21	do	533	Female	Do.
11	Bikini	585	Female	Do.	21	do	531	Male	Do.
13	do		Male	Do.	21	do	551	do	Do.
13	do		Female	Do.	21	do	550	do	Do.
13	do		do	Do.	21	do	555	do	Do.
15	do	851	Male	Do.	21	do	553	do	Do.
15	do	768	do	Ripening.	21	do	562	do	Do.
15	do	686	do	Immature.	21	do	565	do	Do.
24	Rongelap	658	do	Do.	21	do	826	Female	Spawned out.
July 3	do	1204	Female	Ripe.	21	do	1,103	do	Do.
3	do	970	do	Do.	21	do	726	Male	Ripening.
3	do	625	Male	Immature.	22	do	763	do	Immature.
20	Rongerik	555	do	Do.	22	do	837	Female	Spawned out.
21	do	763	Female	Ripe.	22	do	552	Male	Immature.
21	do	741	do	Do.	22	do	556	do	Do.
26	Rongelap	628	Male	Immature.	22	do	569	do	Do.

[1] Estimate of degree of maturity probably unreliable.
[2] Microscopic examination of preserved ovary indicates that this fish was probably spawned out.

ripe gonads. Smaller fish, of a modal length of about 600 mm., were always immature during this period. By analogy, it may be inferred that a large part of the Marshall Island catch was made up of fish too small to furnish information on the time of spawning. Considering only the larger fish, ripening individuals were found from late April to mid-June and ripe individuals from mid-May to late July. This suggests that the spawning season may be in July and August or later, although one spawned-out female was taken on April 20.

In 1947, a total of 78 yellowfin tuna were taken between July 21 and August 22. Of these, information on sex and degree of maturity are available for 63; length data are available for 71. Table 2 includes these and other data. A total of 45 fish were judged to be immature and, as in 1946, these fish were all in the lower end of the size range. From July 26 to August 21, 11 fish were classified as ripening. No fish were considered to be ripe. From July 23 to August 22, 7 fish were classified as spawned out.

To check these allocations, ovaries and testes of several fish (3 ovaries classified as spawned out, and 2 ovaries and 1 testis classified as ripening) were preserved in formaldehyde and later examined under a compound microscope. The standard of comparison so obtained indicated that previous allocations had been correct, with one exception. One female, 933 mm., classified as ripening, was probably spawned out. The ovary probably never becomes as small as it was before the initial spawning, and between subsequent spawnings the stages "ripening" and "spawned out" will at some time during the cycle be identical.

The small numbers of large yellowfin in the catch in 1946 and 1947 make it difficult to define with certainty a spawning season in the northern Marshall Islands. It seems certain that some spawning does occur in the area and, if extensive, it may be concentrated in July and August and possibly later months.

The lower panel in figure 1 shows the length-frequency distribution of the yellowfin tuna taken in the northern Marshall Islands in 1946 and 1947.

The only definite record of the spawning of *N. macropterus* is given by Schaefer and Marr (p. 187). They demonstrate that yellowfin tuna spawn off the coast of Central America, at least from January into April, possibly into June. Kishinouye (1923: 448) states that "Some specimens examined in autumn at Kyushyu are said to have contained large ovaries." Herre (1940: 213) surmises that "extensive breeding grounds for yellowfin and oceanic bonito [=oceanic skipjack] exist in the Sea of Celebes and in that great section of the Pacific which lies east of Mindanao and north of New Guinea * * *." Lütken (1880) records a specimen of *Orcynnus germo* taken at 17° N., 115°40′ E. This may have been a young *Neothunnus macropterus*.

It seems not unlikely that more extensive studies over the entire ranges of the oceanic skipjack and the yellowfin tuna will reveal additional spawning areas. It is certain that extensive surveys will be necessary if the spawning habits of these fishes are to be understood.

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