CHARACTERISTICS OF OVOGENESIS AND SOME DATA ON MATURATION AND SPAWNING OF SKIPJACK TUNA, *KATSUWONUS PELAMIS* (LINNAEUS, 1758), FROM THE WESTERN PART OF THE EQUATORIAL ZONE OF THE INDIAN OCEAN

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ABSTRACT

Based on histological analysis of gonads taken from 616 specimens of skipjack tuna in the western part of the equatorial Indian Ocean, a thorough description of all stages of maturity and cells is given at different stages of ovogenesis. Different phases of cell development have been defined for each stage, and size of cells is given. A comparison of visual and histological determinations of maturity stages is made. We suggest fish sizes and ages at which mass maturation is observed, sex ratio and its variation for different size groups in the area studied. Mass onset of maturity (50%) is observed when females reach 43 cm and males 40 cm in length and 1.5 years of age. Assessment of portioned fecundity is given. The spawning period of this species has been outlined in the western part of the equatorial zone of the Indian Ocean.

INTRODUCTION

Reproduction of skipjack tuna, *Katsuwonus pelamis* (Linnaeus, 1758), in the Indian Ocean remains one of the least studied problems in its biology. At the same time as assessing the possible level of exploitation of this species and solving other problems related to practice of fisheries and fishery management, it is necessary to understand a complex of issues pertaining to reproduction, particularly about the maturity age, sex ratio in different age groups, life span, fecundity, ovogenesis features and spawning type and other items connected with reproduction.

The aspects of this species' reproductive biology are relatively well studied in the Atlantic and Pacific Oceans (Wade, 1950; Frade and Postel, 1955; Bunag, 1956; Yoshida, 1966; Simmons, 1969; Alekseeva and Alekseev, 1976, 1984; Alekseev and Alekseeva, 1981; Cayre, 1981; Matsumoto *et al.*, 1984; Cayre and Farrugio, 1986; Goldberg and Au, 1986; Batalyants, 1989; and others).

One of few papers describing histological features of maturation of Indian Ocean skipjack tuna caught in the area of the Madagascar is the research by B. Stequert (1976). Other not numerous studies in the area of Sri Lanka and Java (Amarasiri and Joseph, 1987; Uktolseja and Purwasasmita, 1991) are based on visual assessment of fish maturity stages and estimates of fecundity.

The objective of this paper is to reveal peculiarities in skipjack tuna reproduction in the western part of the equatorial zone of the Indian Ocean.

MATERIALS AND METHODS

Material collected in the western part of the equatorial zone of the Indian Ocean (10°N-12°S, 42°-70°E) is used in this paper. Samples were taken from longline catches by YugNIRO scientists in 1980-1989 in research cruises of this institute; samples from purse-seine catches were collected by YugNIRO observers on board commercial tuna purse seiners in 1990-1991. When determining stages of maturity of sex products in field and laboratory conditions, the 6-degree scale was used that is adopted in research institutes of the Former Soviet Union (FSU) for description of maturation of multi-batch spawning species (Sakun and Butskaya, 1963). The scale of female maturity stages is given below. It was used by us earlier for yellowfin tuna (Timochina and Romanov, 1991), as well as by other researchers in the FSU for description of tuna maturation (Alekseeva and Alekseev, 1984; Batalyants, 1989, 1992, 1993).

Samples for histological study were fixed in Bouin's liquid and processed by the standard methods: gonad sections were stained by Mallory, with ferric hematoxylin by Hendengein and with sudan (Roskin and Levinson, 1957). In the course of studying ovogenesis, we determined values for the diameter of oocytes, their nuclei, the size of yolk granules and vacuoles, and the thickness of the oocyte membrane. The above indices were determined by means of tenfold measurements of histological preparations from 5-6 females of each maturity stage.

Table 1. *Morphometric characteristics of sex cells at different stages of oogenesis*

Phase/ Stage of cell develop-ment	*Oocyte diameter (mcm)*	*Nucleus diameter (mcm)*	*Number of nucleolii*	*Nucleolus diameter (mcm)*	*Vacuole diameter (mcm)*	*Yolk granule diameter (mcm)*	*Thickness of zona radiata (mcm)*	*Thickness of follicular membrane (mcm)*	*Number of fat drops*	*Diameter of fat drops (mcm)*
Period of protoplasmatic growth										
Juvenile	20-60	6-35	2-9	2-8						
One-layered follicle	55-120	30-55	16-20	2-5						
Period of trophoplasmatic growth										
(D1)	145-190	55-85	22-24	2-5	2,5-5		2	2-3		
(D2)	200-345	75-110	23-30	2-5	3-8	1,5-5	3-4	2-4		
(D3)	360-440	120-150	11-13	2-5	5-10	15	19	4-5	3-5	
(D4)	510-600	140-170	10-12	2-5	10-14	15-20	10-12	5-8		
Maturity										
(F1)	620-845	140-170				16-28	12-16	8-10	4-5	40-60
(F2)	850-1130								1	200-220

The length composition of males and females of skipjack tuna, sex ratio in different length groups, and length of maturation were assessed, based on the data of biological analyses for the whole period of investigations (616 specimens).

Microscopic characteristics were obtained by means of a "Biolam R-14" microscope with x140, x280, and x630 magnification. Estimation of fecundity was executed with a "MBS-9"[1] binocular microscope under x32 magnification To reveal the nature of ovogenesis and fecundity, we counted and measured all oocytes of trophoplasmatic growth and maturation period in ovary weights of 12-16 mg.

When describing the ovogenesis process, we represented the data on oocyte size to take into account a compression rate of 1.5, *i.e*. they correspond to the real size of the fresh material. Measurement of 150 oocytes at different maturity stages was carried out for determining the compression rate value. On the graphs of size composition of oocytes, the measurements are given without the compression rate.

Histological researches were supplemented by mass measurements and counting of yolk and mature oocytes in ovaries of mature specimens. That enabled us to give here our opinion about the forming of the spawning fund. The gonadosomatic index (GSI) was determined by the formula:

$$GSI=GW/TW*100\%,$$

where GW = gonad weight and TW = total weight of the fish. In total 170 samples were under histological study.

RESULTS AND DISCUSSION

Ovogenesis character, spawning fund formation, maturity stages

When describing skipjack tuna ovogenesis, Meyene's periodization system (1939), supplemented by Kazansky (1949), was taken as a base. In accordance with this system we mark out four periods in skipjack tuna ovogenesis: nuclear transformations (or synaptene way), protoplasmic growth, trophoplasmic growth, and maturation. Maturity stages are determined based on analysis of oocyte ratios at the stages of proto- and trophoplasmatic growth as well as occurrence of mature oocytes. We did not examine the period of nuclear transformations especially.

Period of protoplasmic growth.

At this period of skipjack tuna ovogenesis two phases are specified: juvenile (immature) and one-layered follicle.

Juvenile phase.

In the beginning of the phase oocytes have irregular shape, their size is 20-30 mcm. The oocyte membrane is poorly expressed. The nucleus is of rounded shape, sometimes oval. Nucleus diameter is from 6 to 15 mcm. Nucleoli are situated under the membrane all over the periphery of the nucleus, they are closely adjoined to the nuclear membrane and are of various shapes. 2-9 Nucleoli of various size are counted in the nucleus, as a rule two of them are large, of 8 mcm, the other are of from 2 to 5 mcm. At the end of the

[1] "Biolam R-14" and "MBS-9" are trademarks of St. Petersburg Optico-Mechanical Corporation (LOMO).

Table 2. **Gonadosomatic indices for different maturity stages of skipjack tuna**

Number	*Female stage of maturity*	*Range of variability*	*Average*
3	II	0.33-0.77	
52	III	1.0-3.5	1.73
46	IV	1.64-7.4	2.77
5	V	2.2-11.32	3.94
40	Vin-IV	1.7-8.3	2.78
10	VI-III	1.31-5.11	1.99
4	VI-II	0.60-2.61	1.73

juvenile phase increases of oocyte diameter to 60 mcm and nucleus to 35 mcm take place (Table 1).

One-layered follicle phase.

Oocytes at this phase gain a more regular rounded shape, their size reaches 120 mcm, and nucleus diameter increases to 55 mcm. The number of Nucleoli increases considerably as well, to from 16 to 20. Above the non-structural oocyte membrane (*zona radiata*) a number of plane follicular cells is seen.

The one-layered follicle phase terminates the protoplasmatic growth of oocytes. Oocytes at this period are noted in all females, both immature and mature, and are present in gonads at all stages of the sexual cycle. Reaching maturity by a female is determined by transition of some of the oocytes to the period of trophoplasmic growth, the main feature of which is a quick growth of oocytes, initially by means of the accumulation of trophic matter.

Period of trophoplasmic growth

At this period of skipjack tuna development four phases may be outlined: fat accumulation and vacuolization (D1); initial yolk accumulation (D2); intensive yolk accumulation (D3); and filling of oocyte with yolk (D4).

Phase of fat accumulation and vacuolization (D1)

This phase comes after the end of the protoplasmatic growth period and is characterized by the appearance of fat vacuoles in the oocyte cytoplasm. As the result of conducting through spirits and chloroform fat is dissolved, therefore vacuoles are not stained and look like empty spaces, specific staining with sudan reveals lipid inclusions.

The first small vacuoles appear in oocytes of 145-190 mcm diameter. Well-defined zones are seen in the cytoplasm. In such oocytes a narrow layer of homogeneous cytoplasm is formed, above which the lipid-containing zone with foam structure is situated, it is surrounded with a layer of fine-grained cytoplasm. A nucleus of rounded shape is situated in the centre of the oocyte, the nucleus diameter is 55-85 mcm. The nuclear membrane is wave-like, the carioplasm is fine-grained. Under the nuclear membrane Nucleoli of rounded shape are seen, their number reaches 22-24 and their size 2-5 mcm. In oocytes of 190 mcm diameter scattered vacuoles of 5 mcm diameter appear all over the periphery of the cytoplasm.

Following the appearance of large vacuoles, the next period begins in the oocytes, the phase of yolk accumulation. More vacuoles concentrate on the periphery of the oocytes, forming a zone along the membrane. The oocyte *zona radiata* is thin (2 mcm). The follicle is represented by the follicular epithelium and conjunctive tissue flow. The thickness of the follicular membranes is 2-3 mcm (Table 1).

Oocytes at phase (D1) appear in the ovary when females reach maturity, and they are observed in the ovaries of females at the III; IV; IV-V; V; and VI-III maturity stages.

Phase of initial yolk accumulation (D2)

The appearance of yolk inclusions in the oocyte cytoplasm is a peculiar feature of this stage. The beginning of yolk accumulation is noted when oocytes reach 200-250 mcm in size. Small spherical yolk granules appear in the cytoplasm between its peripheral border and lipid-containing zone. In the beginning, along with yolk accumulation, some increase in the number of vacuoles takes place. Their diameter increases to 8 mcm. The wavy character of the nuclear membrane strengthens, the number of Nucleoli increases to 30, and the nucleus diameter to 75-110 mcm. At the end of the phase, in which oocytes reach 345 mcm, larger yolk granules up to 5 mcm appear. The *zona radiata* thickens up to 4 mcm and the height of follicular epithelium reaches 2-4 mcm.

Oocytes at the (D2) phase are found in gonads of females at the same stages of development as those at the initial period of vitellogenesis (D1).

Phase of intensive yolk concentration (D3)

In oocytes of 360-440 mcm intensive accumulation of yolk in the cytoplasm starts. Yolk granules gradually increase up to 15-19 mcm and fill all the cytoplasm except the peripheral border. The nucleus is 120-150 mcm in diameter, and the nuclear membrane has a wavy shape. Up to 30 Nucleoli are observed in the carioplasm only at the beginning of the phase. The *zona radiata* increases insignificantly up to 5 mcm. The height of the follicular membranes is 3-5 mcm.

Oocytes at the (D3) phase are found in ovaries in pre-spawning and spawning females and partially after spawning of separate batches.

Table 3. **Estimates of fecundity of skipjack**

Area	*No of fish*	*Fish length range (cm)*	*Estimated fecundity*	*Authors*
Western Indian Ocean (Equatorial Area)	7	52-69	906,500-2,773,333[(1)]	This study
Western Indian Ocean Northwest of Madagascar	64	44.1-56.5	87,600-824,000	Stequert, 1976
Central Indian Ocean (Sri Lanka)	-	44-68	211,410-2,952,253	Amarasiri & Joseph, 1987
Central Indian Ocean (Laccadive Islands)	-	41.8-70.3	151,900-1,977,900	Raju, 1964 (cit. from Stequert, Marsac, 1989)
Eastern Indian Ocean (Java, Pelabuhan Ratu)	7	40.3-47.4	542,981-1,282,950	Uktolseja & Purwasasmita, 1991
Pacific Ocean (Ryuku Island)	5	46.8-61.0	113,364-859,897	Yabe, 1954 (cit. from Uktolseja, Purwasasmita, 1991)
Pacific Ocean (Hawaiian Islands)	3	44-87	280,000-1,900,000	Rothschild, 1963
Eastern Pacific	42	61.4-71.5	210,000-1,490,000	Joseph, 1963
Pacific Ocean (Marquesas Islands)	4	43-75	100,000-2,000,000	Yoshida, 1966
Atlantic Ocean (Caribbean).	13	46.5-80.9	262,000- 1,331,000	Simmons, 1969
Atlantic Ocean (North Carolina)	31	49.8-70.4	141,000-1,200,000	Batts, 1972
Central Atlantic	231	41-70	100,000-1,000,000	Cayre & Farrugio, 1986

[(1)] Batch fecundity

Phase of oocyte filled with yolk (D4).

The process of yolk formation finishes when the oocyte reaches 600 mcm in diameter. The nucleus reaches 140-170 mcm, its shape does not change considerably. Fat vacuoles join and as a result their size increases to 14 mcm and their number is reduced to 15; they are situated around the nucleus in the form of a ring. The size of the yolk granules and the density of their location in the cytoplasm differ slightly from those at the end of the intensive trophoplasmatic growth phase. At the same time the thickness of the *zona radiata* increases significantly to 10-12 mcm and the height of follicular epithelium to 5-8 mcm (Table 1). The peripheral cytoplasm border is seen distinctly. At the end of the phase in separate oocytes the beginning of nucleus shift to the animal polar is noted. Oocytes at the (D4) phase are found in ovaries of fish not long before spawning.

Maturity period

At the period of skipjack tuna maturity two phases may be distinguished: fat confluence (F1) and hydration (F2).

Phase of fat confluence(F1).

The size characteristics of oocytes at the (F1) phase of the maturity period differ slightly from those at the final period (D4) of vitellogenesis, but their cell morphology differs greatly. Small fat drops in the near-nuclear zone combine into larger ones. Their number falls to 4-5 in the section of oocytes. The nucleus has a rather eccentric position, shifting to the animal pole. Yolk granules at the vegetative pole increase to 28 mcm. The wavy character of the nuclear membrane becomes smooth in the sections. Nucleoli are situated in the carioplasm. The thickness of the *zona radiata* increases to 12-16 mcm and the height of the follicular epithelium to 10 mcm (Table 1).

Oocytes at the first phase of the maturity period are found in ovaries of fish not long before spawning. At the end of the phase the oocytes reach 845 mcm.

Phase of hydration (F2).

Oocytes come into the phase of hydration immediately before ovulation. Along with this they gain a great deal of water and increase to 1130 mcm. At the beginning of the phase the oocyte becomes partially transparent, and the nucleus shift ends with disappearance of the nuclear membrane. Simultaneously with yolk homogenization there is considerable extension of fat drops, which combine into a large one of 200-220 mcm diameter. The nucleus is dissolved and as a result the carioplasm joins with the ovoplasm to form mixoplasm, where maturity divisions take place. The oocyte membrane becomes thin. Mature oocytes are completely transparent.

Oocytes at the phase of hydration are found in ovaries of fish in spawning. As is well known, this process is rather quick and its duration is measured in hours.

Description of maturity stages of females.

Stage I

The sex glands look like thin transparent threads. Sex cells cannot be differentiated with the unaided eye. It is difficult to tell the sex by the appearance of the sex cells. This is possible only at the end of maturity stage I, when oocyte-carrying plates appear, which look like longitudinal lamellar cecum.

Stage II

Ovaries remain, as previously, almost colourless. Sometimes they have a lemon tint, they do not increase

considerably in size and weight. When observing ovaries through a magnifying lens, separate eggs are easily distinguished. They are transparent and almost colourless. During microscopic observation, sex cells in females are represented by oocytes in the period of nuclear transformation and oocytes of protoplasmatic growth. The most developed cells are at the period of one-layered follicle. The diameter of the latter is from 55 to 120 mcm.

Stage III

During stage III of maturity, the greatest differences are observed in the external appearance of the ovaries. They occupy a considerable part of the abdominal cavity, increasing in size and weight. The eggs at this stage lose transparency, becoming yellow to orange in colour and are easily seen with the unaided eye. Correspondingly, the colour of ovaries changes from colourless to yellow. At the section of ovaries, well-formed oocyte-carrying plates are seen inside.

In the course of the ovaries passing from stage II to stage III of maturity, the growth character of the most advanced group of oocytes changes. Their growth takes place not only due to the increasing volume of protoplasm, but also because of the accumulation of trophic matter. Reaching of maturity by a female is determined by the transition of some of the oocytes to the period of trophoplasmatic growth. Ovary maturity stage III is characterized by the presence of oocytes of the period of trophoplasmatic growth (phases D1 and D2). But in ovaries in this state there are still sex cells of the reserve fund, consisting of ovogonies and oocytes of the period of protoplasmatic growth. The diameter of the biggest eggs of the phase of the initial accumulation of yolk (D2) reaches 345 mcm. The mean value of the GSI reaches 1.73 (Table 1).

Stage IV

The ovaries acquire a more pronounced yellow colour. Eggs are yellow in colour and are well visible. Microscopically, gonads on this stage are characterized by the presence of oocytes of the period of nuclear transformations, the protoplasmatic growth period, and all phases of protoplasmatic growth. The diameter of the biggest oocytes of the phase of filling oocyte with yolk (D4) reaches 600 mcm. By the end of stage IV, occasional oocytes of the maturation period appear (F1). The mean value of the GSI is 2.77.

Stage V

In the course of this very short stage, the preparation of oocytes for fertilisation is completed. Mature oocytes in fish ovaries are located at the edge of oocyte-carrying plates. The diameter of the biggest eggs reaches a maximum of 1130 mcm. A complete confluence of yolk and fat takes place in the oocytes, and as a result the oocytes become transparent again. During the transition of a female into the spawning state, when the follicular membrane is broken, the oocyte falls down to the ovary cavities. Microscopically, ovaries are characterized by the presence of oocytes of all periods of growth. The mean value of the GSI is 3.94.

Stage VIn-IV

This stage of maturity is noted in individuals spawning one or more batches of eggs. Visually the gonads are like the gonads at the fourth stage of maturity, but they appear slightly inflamed and have a yellow-reddish tint. On histological preparations of ovaries all the complex of oocytes is noted. which is characteristic of the fourth stage of maturity, as well as resorption oocytes and follicular membranes. The mean value of the GSI is 2.78.

After each succeeding portion is spawned, the ovaries pass to maturity stages VI-III and then for a short period of time into stages VIn-IV. After spawning of the last portion the ovaries pass into stage VI-II and do not contain oocytes of definitive sizes of phase (D4; F1 and F2).

Stage VI-II

The cavity inside the ovary is red and the sex glands are inflamed. This stage characterizes the post-spawning state of the ovaries. Empty follicles, resorting eggs, ovogonies and oocytes of protoplasmatic growth can be seen on histological preparations. The mean value of the GSI is 1.73.

Fishes maturing for the first time have stages I and II, and fishes spawning repeatedly may be at stage II at the beginning of the spawning season. The following stages apply to all mature fishes spawning for the first time and repeatedly.

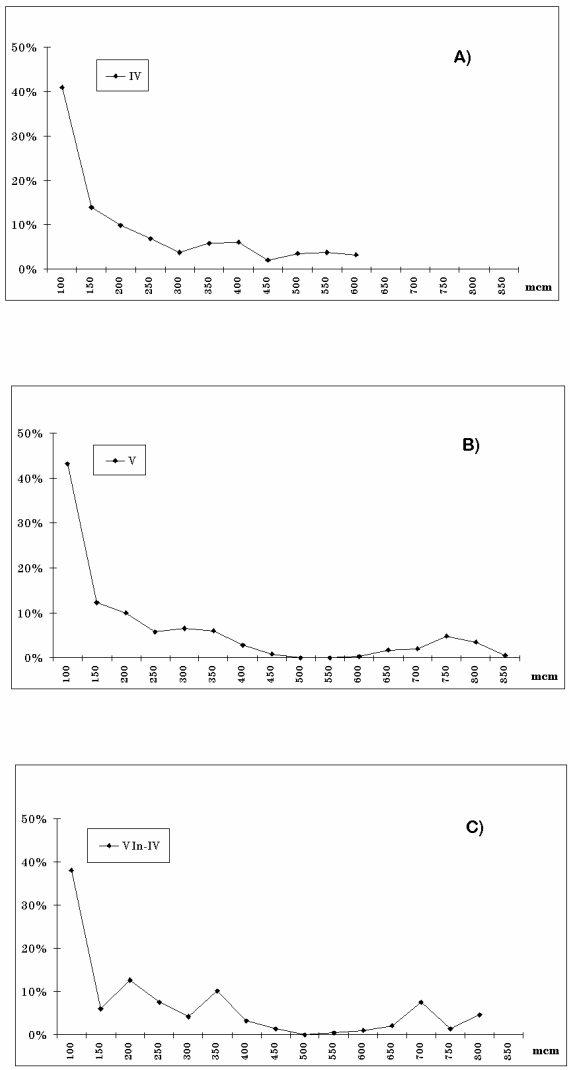
Fluctuations of GSI values for females at the various stages and corresponding mean values are given in Table 2.

Formation of spawning fund and fecundity assessment

Histological analysis showed that in the beginning of vitellogenesis, with oocyte size of 150-350 mcm, a continuous asynchronous process is observed which changes into an intermittent one with further growth. Three variation curves confirm this observation, characterizing size composition of oocytes of the periods of trophoplasmatic growth and maturation in ovaries of fish of maturity stages IV, V, and VIn-IV (Figure 1).

Differentiation of the expense fund into isolated groups starts after completion of the phase of the initial accumulation of yolk (D2), *i.e.* with the transition into phase D3.

Figure 1. *Distribution of oocytes by size classes in gonads of skipjack tuna at different maturity stages.*



For fishes at maturity stage IV the curve of oocyte size composition is constant, but according to modal peaks one can outline three groups of oocytes corresponding to the different stages of cell maturity. The first group consists of oocytes in the period of fat accumulation and vacuolization (D1) and initial accumulation of yolk (D2); the second group consists of oocytes in the phase of intensive yolk accumulation (D3); and the third group consists of the phase of filling oocyte with yolk (D4) and single oocytes of the phase of confluence of fat (F1).

In ovaries of females at maturity stage V one can observe the gaps between oocyte groups at the different stages of maturity that are a feature of the intermittent asynchronous process of vitellogenesis (Figure 1B).

The same phenomenon is noted in ovaries of fishes at stages VIn-IV of maturity (Figure 1C).

After spawning of the successive portion of eggs, the relative quantity of oocytes of phase D2, D3 and F1 increases (Figure. 1C); these form the successive portions. At the same time the share of D1 oocytes changes slightly. This indicates partial replenishment of oocytes from the reserve fund in the course of spawning season.

Ovogenesis of this species in the Atlantic (Alekseev and Alekseeva, 1981) is characterized by intermittent asynchronous trophoplasmatic growth, which in the opinion of the above authors indicates considerable intervals between consecutive spawnings (up to three weeks).

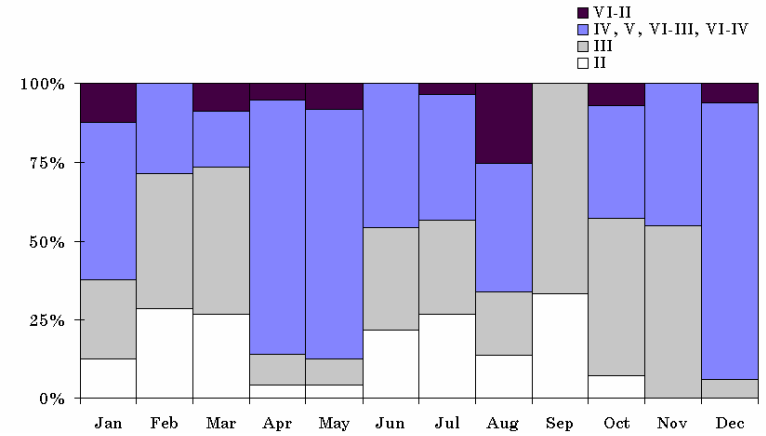
In our opinion the continuous character of vitellogenesis at the early stages of trophoplasmatic growth permits faster replenishment of the expense fund and makes breaks between consecutive spawnings considerably shorter. It is rather difficult to estimate the volume of replenishment of the spawning fund from the reserve fund by the oocytes of protoplasmatic growth. Therefore we give here only the portion of skipjack fecundity which was determined with regard to the most developed yolk oocytes of trophoplasmatic growth (phase D4).

While determining the fecundity of individuals at stage IV of maturity, the following values were obtained: for fishes 52-69 cm long the number of eggs in one portion was from 906500 to 2773333 (Table 3).

Spawning period

We made an attempt to determine the spawning period for skipjack tuna on the basis of frequency of occurrence of spawning individuals. It is known that spawning females are rarely found by researchers in field collections (Batalyants, 1989; Goldberg and Au, 1986). Therefore, we used frequency of occurrence of fishes at stages IV, V, VI-III and VIn-IV (Figure 2) as a reference point for establishing spawning season. Females at maturity stage IV were found during almost all the year except July and September. Individuals at stage V were noted from April to June, and two females were observed in August. As we remarked earlier, gonads of fishes do not remain in spawn-ripe state for more than a few hours, so although the frequency of occurrence of such fishes is a reliable sign of spawning, their absence does not indicate that spawning does not take place.

Figure 2. *Frequency distribution of skipjack maturity stages by month.*



On the base of grouped data on the occurrence of pre-spawning, spawning and post-spawning specimens, two peaks of spawning activity, in April-June and in November-January, stand out against a background of all-year-round spawning.

The described chart (Figure 2) was obtained by analysis of all the samples collected in the vast area of the western Indian Ocean both south and north of the equator. The two spawning peaks, in the spring-summer and in the autumn-winter periods, may therefore indicate the presence in the sample specimens of not less than two populations with opposite-phase sexual cycles.

The same situation with year-round spawning was observed while examining large samples in the near-equatorial Atlantic area (Alekseeva and Alekseev, 1984; Cayre, 1984; Cayre and Farrugio, 1986).

However, Alekseeva and Alekseev (1984) analyzing materials on spawning activity of Atlantic skipjack tuna in the area far from the equator observed spawning activity only in summer (warm period) of the corresponding hemisphere. Analysis of spatial distribution of spawning specimens shows the presence of groups that lay eggs at opposite phases, and because of their migrations to the equatorial zone give the impression of spawning all year round.

In our opinion premises for the reproductive isolation at the opposite phases exist also for skipjack tuna in the Indian Ocean, but the volume of our samples is not sufficient for conducting such analyses.

Length composition, sex ratio, length of maturation

The length of analyzed fish varied from 31 to 92 cm. Length of males varied from 31 to 92 cm (mean length 59.3 cm), and that of females varied from 32 to 85 cm (mean length 57.5 cm) (Figure 3).

Sex ratio for the whole sample, without separation by size groups, was 1.08:1, with some predominance of males.

Figure 3.Size composition of skipjack by sex.

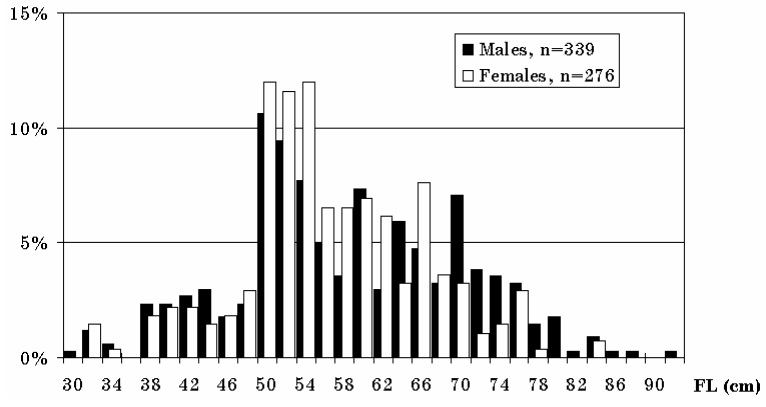
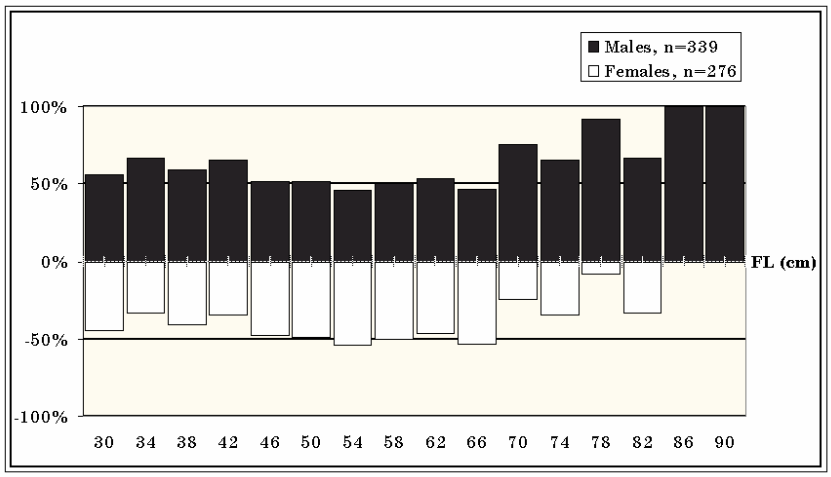


Figure 4. *Sex ratio of skipjack tuna by length groups.*



A sex ratio close to 1:1 is characteristic of all the large samples in other regions of the world's oceans if the impact of seasonal factors is excluded when collecting the samples (Cayre and Farrugio, 1986; Chur *et al.*, 1980).

As fishes grow and became older the proportion of females is reduced. In our samples this phenomenon is observed when tunas reach a length of 70 cm. In size groups of more than 86 cm females are completely absent (Figure 4). Age variability of sex ratios is characteristic of all the species of tropical tunas in different areas of the world's oceans (Miyabe, 1994; Stequert, 1976; Suzuki, 1994; Timochina and Romanov, 1991; Wild, 1994). The only report on divergence from this regularity of Atlantic skipjack tuna was a report of Cayre and Farrugio (1986).

Female skipjack tuna are observed spawning for the first time when they are 40 cm long and males when they are 39 cm long. Mass sexual maturity of females (50%) comes when they are 43 cm long, and males 40 cm (Figures 5 and 6).

In our observations mass sexual maturity of males is noted earlier than that of females. Cayre and Farrugio (1986) reported the opposite phenomenon in the Atlantic: females mature at a length of 42 cm, males at 44 cm. Females and males are noted maturing for the first time in the Atlantic when they are 38 cm long (Cayre, 1984), which is close to our observations of 40 and 39 cm, respectively.

In other areas of the world's oceans mass maturation of skipjack tuna takes place when fishes reach a length more than 40 cm (Cayre, 1984; Cayre and Farrugio, 1986; Matsumoto *et al.*, 1984; Wild and Hampton, 1994). According to our estimate the length at which mass sexual maturity occurs corresponds to the age of 1.5 years.

CONCLUSION

According to data from histological analysis the process of ovogenesis is characterized by a number of peculiarities:

A characteristic feature of this species is the continuous asynchronous process of oocyte development in the initial phases of trophoplasmic growth, which turns intermittent

Figure 5. *Percentage of mature males as a function of size.*

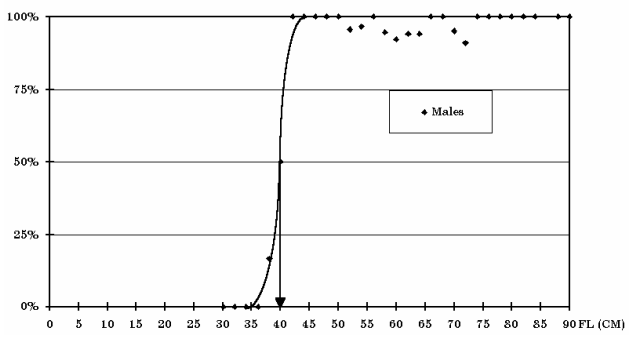
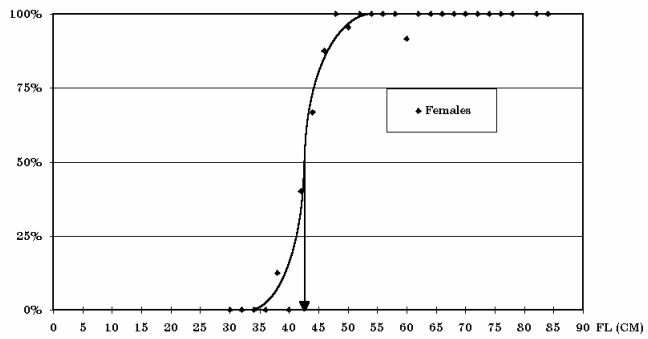


Figure 6. *Percentage of mature females as a function of size.*



at the end of this period.

During the protoplasmatic growth period sexual cells pass through two phases, in the course of vitellogenesis four, and during the period of maturation two phases.

Passing to trophoplasmic growth takes place at an oocyte diameter of 145 mcm, and yolk accumulation at a diameter of 200 mcm.

Batch fecundity of fishes 52-69 cm long was from 906500 to 2773333 eggs. Two peaks of spawning activity, in April-June and in November-January, stand out against a background of year-round spawning.

As fishes grow and became older the proportion of females is reduced. In our samples this phenomenon is observed when tunas reach lengths of 70 cm. Females are completely absent in size groups of more than 86 cm.

First-time spawning was observed in female skipjack tuna at 40 cm long and in males at 39 cm long. Mass sexual maturity of females (50%) comes when they are 43 cm long, males 40 cm.

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REFERENCES

ALEKSEEV F. E., ALEKSEEVA E.I., 1981. Some aspects in reproductive biology of oceanic and neritic tuna (SCOMBRIDAE) in the tropical Atlantic. Journal of Ichthyology, Vol. 21, No 5, pp. 853-866 (in Russ.).

ALEKSEEVA E.I., ALEKSEEV F.E., 1976. Ecological and morphological principles of peculiarities in reproduction of neritic and oceanic tuna in the eastern part of the tropical Atlantic. In: Ecological physiology of fishes., Part II, Kiev, Naukova dumka, pp. 130-132 (in Russ.).

ALEKSEEVA E.I., ALEKSEEV F.E., 1984. Sexual cycles of fishes in the studying the species structure and functional structure of area. In: Intraspecific differentiation of marine commercial fishes and invertebrates. AtlantNIRO Proceedings, pp. 28-38 (in Russ.).

AMARASIRI, C.; JOSEPH, L., 1987. Skipjack tuna (*K. pelamis*) - aspects on the biology and fishery from the western and southern coastal waters of Sri Lanka. In: IPTP Coll. Vol. of Work. Doc., Vol. 2, pp. 1-10, TWS/86/16.

BATALYANTS, K. YA., 1989. On spawning of skipjack tuna (*Katsuwonus pelamis* L.) In: ICCAT Coll. Vol. Sci. Pap. Vol. XXX(1), p. 20-28, SCRS/88/30.

BATALYANTS, K. YA., 1992. On the study of spawning frequency for bigeye (*Thunnus obesus*) and yellowfin *tuna (Thunnus albacares*), based on the Atlantic longline fishery data. In: ICCAT Collect. Vol. Sci. Pap. Vol. XXXIX(1), pp. 31-38, SCRS/91/60.

BATALYANTS, K. YA., 1993. State of yellowfin tuna (*Thunnus albacares*) ovaries and oocytes longline and purse catches during spawning period. In: ICCAT Collect. Vol. Sci. Pap. Vol. XL(2), pp. 134-139 SCRS/92/46.

BATTS, B. S., 1972. Sexual maturity, fecundity and sex ration of skipjack tuna, *Katsuwonus pelamis* (Linnaeus), in North Carolina waters. Trans. Am. Fish. Soc., Vol. 101, No 4, p. 626-637.

BUNAG, D. M., 1956. Spawning habits of some Philippine tuna based on diameter measurement of the ovarian ova. J. Philipp. Fish., Vol. 4 No 2, p. 145-177.

CAYRE, P., 1981. Maturite sexuelle, fecondite et sex-ratio du listao (*Katsuwonus pelamis* L.) des cotes d'Afrique de l'ouest (20 N-0 N), etudes a partir des debarquements thoniers (1977 a 1979) au port Dakar, Senegal. In: ICCAT Coll. Vol. Sci. Pap. Vol. XV, pp. 135-149.

CAIRE, P., 1984. Biologie et comportements du listao. Peche Marit., No 1274, p. 274-282.

CAYRE, P.; FARRUGIO, H. 1986. Biologie de la reproduction du listao (*Katsuwonus pelamis*) de l'Ocean Atlantique. In: Proceedings of the ICCAT Conference on the International Skipjack Year Program. Madrid, p. 252-272.

CHUR V. N., 1977 (Ms). Biology and fishing of skipjack tuna, little tunny, frigate and bullet tunas in the Eastern Atlantic: Synopsis of P. D. Thesis, Sevastopol, Institute of Southern Seas Biology, 24 p. (in Russ.).

CHUR, V. N.; GRUDININ, V. B.; ZHAROV, V. I., 1980. Data on length-age composition and gonad maturity stages of skipjack (Katsuwonus pelamis) of the Eastern Tropical Atlantic. In: ICCAT Coll. Vol. Sci. Pap. Vol. IX (1), pp. 245-254.

FRADE F., POSTEL E., 1955. Contribution de l'étude de la reproduction des Scombrides et Thonidés de l'Atlantique tropical. Rapp. Cons. Explor. Mer., v 137., p. 33-35.

GOLDBERG S. R., AU D. W. K., 1986. The Spawning of Skipjack Tuna from Southeastern Brazil as Determined from Histological Examination of Ovaries. In: Proceedings of the ICCAT Conference on the International Skipjack Year Program. Madrid, p. 277-284.

HUNTER, J. R.; MACEWICZ, B. J.; SIBERT, J. R., 1986. The spawning frequency of skipjack tuna, *Katsuwonus pelamis*, from the South Pacific. Fish. Bull., Vol. 84, No 4, p. 895-903.

JOSEPH, J., 1963. Fecundity of yellowfin (*Thunnus albacares*) and skipjack (*Katsuwonus pelamis*) from the Pacific Ocean. I-ATTC, Bull., Vol. 7, No 4, p. 255-292.

KAZANSKY B.N., 1949. Peculiarities of ovaries and hypophysis functions of fishes with portional spawning. - Works of the Laboratory on Fish Culture Principles, Leningrad, Vol. 2, pp. 64-120.(in Russ.).

MARCILLE J., STEQUERT B., 1976. Etude preliminaire de la croissance du listao (*Katsuwonus pelamis*) dans l'Ouest de l'Ocean Indien tropical. Cah. ORSTOM, ser. Oceanogr., Vol. XIV, No 2, 139-151.

MATSUMOTO, W. M.; SKILLMAN R. A.; DIZON, A. E., 1984. Synopsis of biological data on skipjack tuna, *Katsuwonus pelamis*. NOAA Tech. Rep. NMFS Circ., No 451, 92 p.

MEYENE V.A., 1939. To a problem of annual cycle in changes of Teleostei ovaries. News of the Academy of Sciences, USSR. Biology, N 3, pp. 389-420.(in Russ.).

MIYABE, N., 1994. A review of the biology and fisheries for bigeye tuna, *Thunnus obesus* in the Western and Central Pacific Ocean. In: Shomura R. S.; Majkowski, J.; Langi, S. (Eds.) Interactions of pacific tuna fisheries. Proceedings of the first FAO Expert Consultation on Interactions of Pacific Tuna Fisheries, 3-11 December 1991, Noumea, New Caledonia. Volume 2: Papers on biology and fisheries. FAO Fish. Tech. Pap. No 336, Vol. 2, Rome, FAO, p. 207-243.

PRAVDIN I.F., 1966. Guidance to fish study. Moscow, Food Industry (Pishchevaya Promyshlennost), 376 p. (in Russ.).

RAJU, G., 1964. Studies of the spawning of the oceanic skipjack *Katsuwonus pelamis* (Linnaeus) in Minicoy waters. Symp. Ser. Mar. Biol. Assoc. India. Vol. 1, No 2, p. 744-768.

ROSKIN G.I., LEVINSON L.B. 1957. Technique of Microscopy. Moscow, Sovetskaya Nauka. 467 p. (in Russ.).

ROTHSCHILD, R. J., 1963. Skipjack ecology. In: W. G. van Campen (Ed.). Progress in 1961-1962. U.S. Fish. Wildl. Serv. Circ., No 163, p. 13- 17.

SAKUN O. F., BUTSKAYA N. A., 1963. Determination of maturity stages and study of fish sexual cycles. Moscow. "Rybnoye khozyaistvo", 36 p. (in Russ.).

SIMMONS, D. S., 1969. Maturity and spawning of skipjack tuna (*Katsuwonus pelamis*) in the Atlantic Ocean, with comments on nematode investigation of the ovaries. U. S. Fish. Wildl. Serv., Spec. Sci. Rep. Fish. No. 580, p.17.

SCHAEFER, K. M., 1987. Reproductive biology of black skipjack, *Euthynnus lineatus*, an Eastern Pacific Tuna. I-ATTC, Bull., Vol. 19, û 2, p. 165-260.

STEQUERT B., 1976. Etude de la maturité sexuelle, de la ponte et de la fecondité du listao (*Katsuwonus pelamis*) de la côte nord-ouest de Madagascar. Cah. ORSTOM, ser. Oceanogr., Vol. XIV, No 3, p. 227- 247.

STEQUERT, B.; MARSAC, F., 1989. Tropical tuna - surface fisheries in the Indian Ocean. FAO Fish. Tech. Pap., No 282, Rome, FAO, 238 p. Suzuki, Z., 1994. A review of the biology and fisheries for yellowfin tuna, (*Thunnus albacares*) in the Western and Central Pacific Ocean. In: Shomura R. S.; Majkowski, J.; Langi, S. (Eds.) Interactions of pacific tuna fisheries. Proceedings of the first FAO Expert Consultation on Interactions of Pacific Tuna Fisheries, 3-11 December 1991, Noumea, New Caledonia. Volume 2: Papers on biology and fisheries. FAO Fish. Tech. Pap. No 336, Vol. 2, Rome, FAO, p. 108-137.

TIMOCHINA O.I., ROMANOV E.V., 1991. Notes on reproductive biology of yellowfin tuna in the Western Indian Ocean. In: IPTP Coll. Vol. Work. Doc: Vol.6, pp. 60-69, TWS/91/32.

UKTOLSEJA, J. C. B.; PURWASASMITA R., 1991. Preliminary study of the fecundity of skipjack tuna from the waters adjacent to Pelabuhan Ratu In: IPTP Coll. Vol. Work. Doc: Vol.4, pp. 22-33, TWS/90/25. Wade, C. B., 1950. Observation on the spawning of Philippine tuna. Fish. Bull. Vol. 51, No 55, p. 409-423.

WILD, A., 1994. A review of the biology and fisheries for yellowfin tuna, Thunnus albacares in the Eastern Pacific Ocean. In: Shomura R. S.; Majkowski, J.; Langi, S. (Eds.) Interactions of pacific tuna fisheries. Proceedings of the first FAO Expert Consultation on Interactions of Pacific Tuna Fisheries, 3-11 December 1991, Noumea, New Caledonia. Volume 2: Papers on biology and fisheries. FAO Fish. Tech. Pap. No 336, Vol. 2, Rome, FAO, p. 52-107.

WILD, A.; HAMPTON, J., 1994. A review of the biology and fisheries for skipjack tuna, Katsuwonus pelamis in the Pacific Ocean. In: Shomura R. S.; Majkowski, J.; Langi, S. (Eds.) Interactions of pacific tuna fisheries. Proceedings of the first FAO Expert Consultation on Interactions of Pacific Tuna Fisheries, 3-11 December 1991, Noumea, New Caledonia. Volume 2: Papers on biology and fisheries. FAO Fish. Tech. Pap. No 336, Vol. 2, Rome, FAO, p. 1-51.

YABE, H, 1954. A study on spawning of skipjack in the Satsunan Sea area. In general view of fishery science. (In Japanese) Jpn. Assoc. Adv. Sci., p. 182-199.

YOSHIDA, H. O., 1966. Skipjack tuna spawning in the Marquesas Islands and Tuamotu Archipelago. Fish. Bull., Vol. 65 No 2, p. 479-488.