Main spawning season of yellowfin tuna, *Thunnus albacares*, in the western tropical Pacific Ocean based on the gonad index

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Abstract

The main spawning season of yellowfin tuna in the western tropical Pacific Ocean was examined for specimens over 100 cm caught by Japanese longline and purse seine vessels. For female, percentage of fish with gonad index (GI) of 2.0 and over was used as an index of spawning season. Also, seasonal change of log transformed GI was examined for female and male.

The sexual maturity of yellowfin tunas caught by the longliners was substantially lower than that by the purse seiners. No regular seasonal change in sexual maturity was observed for the longline samples, but a regular seasonal pattern occurred from year to year for the samples by the purse seiners. It was assumed that those differences were caused by movement of matured fish from midwater to surface layer for spawning. Based on purse seine samples, the main spawning season was estimated to be from November to April.

Introduction

Yellowfin tuna, *Thunnus albacares*, is widely distributed in the tropical and partly in the temperate waters of the Pacific, Indian and Atlantic Oceans. According to the larval distribution of this species, main spawning areas can be defined fairly well in the tropical waters with the surface temperature over 26.0°C (UEYANAGI, 1969). Stock structure of yellowfin tuna in the Pacific Ocean is still unclear, but it was noted that main spawning season differed among the western, central and eastern tropical Pacific (KIKAWA, 1959, 1962, 1966 ; SUZUKI, TOMLINSON and HONMA, 1978), which might be indicative of heterogeneity of the population.

In the western tropical Pacific Ocean, it is known that the spawning takes place throughout the year, based on occurrence of larvae, with the main season in the fourth quarter (NISHIKAWA, HONMA, UEYANAGI and KIKAWA, 1985). The main spawning season was studied also based on the samples caught by longliners, but results did not well coincide with each other (KIKAWA, 1959, 1962, 1966 ; SUZUKI *et al*., 1978). Since the mid 1970s, purse seine fishery has developed in the western tropical Pacific. Based on preliminary analysis of the samples obtained from those purse seiners,

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SUZUKI (1988) noted that female yellowfin tuna caught by the purse seine gear had a higher sexual maturity than those taken by the longline gear in the western tropical Pacific. The same phenomenon has been reported in the eastern tropical Pacific (SUZUKI *et al.*, 1978) and in the eastern tropical Atlantic (YANEZ and BARBIERI B., 1980). The present study examined the main spawning season of yellowfin tuna in the western tropical Pacific Ocean by use of the specimens captured both by longline and purse seine vessels.

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Materials and methods

The data used consist of fork length and gonad weight measurements of specimens caught in the western tropical Pacific Ocean by the Japanese commercial purse seine vessels from March 1985 to February 1988 and by the Japanese prefectural longline vessels from January 1968 to December 1970. The latter comprised the research vessels of fisheries experimental stations belonging to prefectural government and the training vessels of fisheries high schools.

The longline samples were measured on board, and the gonad weight was rounded to the nearest 10 gm. The annual distribution of the longline operations from which samples were obtained is shown in Fig. 1. Although there exists a slight difference in the areal extent of the operations among the years, the longlining is mainly operated in three fishing grounds, the western tropical Pacific, the southwestern Pacific and the central Pacific. A complete record on fishing location and date is known for the samples caught by the longline vessels.

The purse seine samples were measured in cannery in partially thawed condition. The purse seine fishing grounds for these samples are shown in Fig. 2. No information on area and time of catch was available for individual samples taken by the purse seiners due to the aggregated fishes for canning. Since a trip length of the purse seiner usually extends to 30 to 50 days, month of fishing was assigned to the month in which largest monthly yellowfin tuna catch was recorded.

Considering the area where both the longliners and purse seiners operate simultaneously, a model area for this study was set up to cover an area between 5°S and 10°N and between 130°E and 170°E (Figs. 1 and 2).

Since most of the south Pacific countries have established a 200-mile EEZ in the latter half of the 1970s, the Japanese prefectural longline vessels have been scarcely operating in the model area, whereas only the recent data are available from the newly developing purse seine fishery. Therefore, the data from 1968 to 1970 were used for the longline fishery in this study as the observation was most abundant during that period.

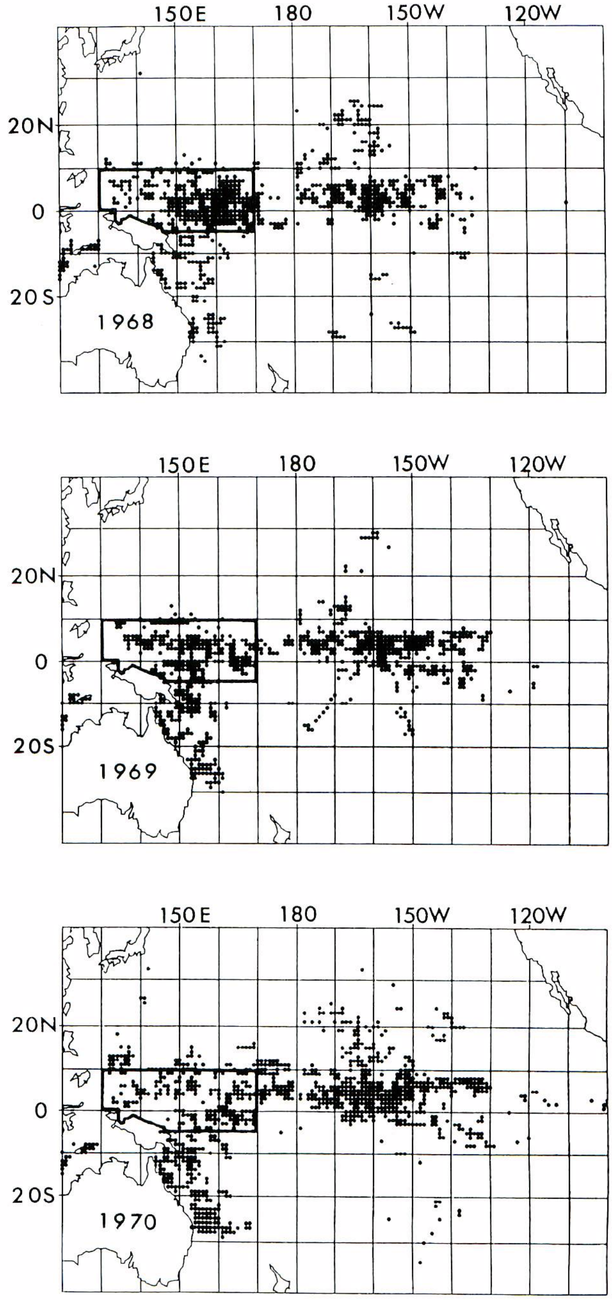

Fig. 1. Annual distribution of Japanese prefectural longline operations from 1968 to 1970. Heavy line denotes the model area for this study (5°S and 10°N and 130°E and 170°E).

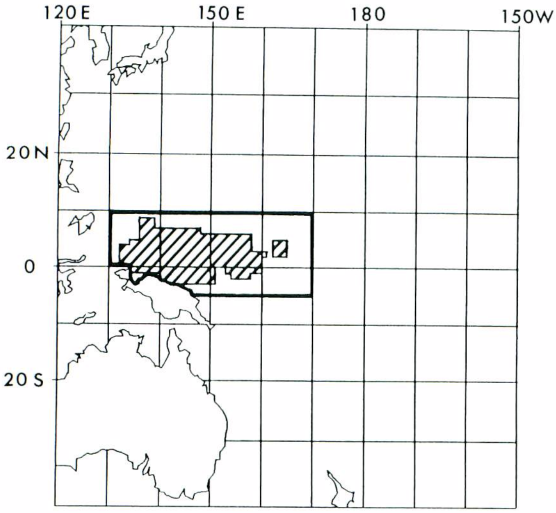

Fig. 2. Fishing grounds of the Japanese commercial purse seiners in the western tropical Pacific Ocean from 1985 to 1988 (shaded area). Heavy line denotes the model area for this study.

Table 1. Number of specimens used in this study.

Sex	Fishing Gear	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Female	Longline	1968	529	652	203	79	535	857	947	618	101	772	633	762	6,688
		1969	28	339	165	163	312	888	380	270	95	991	471	758	4,860
		1970	177	321	214	93	71	21	272	159	64	370	399	276	2,437
	Purse seine	1985	-	-	9	-	9	7	13	11	-	7	9	7	72
		1986	-	14	-	10	9	-	14	9	13	10	10	10	99
		1987	16	19	17	-	8	7	-	-	15	-	6	-	88
		1988	7	10	-	-	-	-	-	-	-	-	-	-	17
Male	Longline	1968	288	476	44	61	442	593	675	527	54	680	827	749	5,416
		1969	29	298	194	100	230	702	280	193	77	882	427	713	4,125
		1970	152	259	130	52	68	30	191	152	59	285	290	151	1,819
	Purse seine	1985	-	-	11	-	14	13	7	4	-	13	11	13	86
		1986	-	7	-	10	11	-	17	14	7	9	10	10	95
		1987	28	21	13	-	10	9	-	-	5	-	14	-	100
		1988	12	10	-	-	-	-	-	-	-	-	-	-	22

All specimens were larger than 100 cm in fork length and caught by Japanese prefectural longliners (research vessels of fisheries experimental stations and training vessels of fisheries high school) and by Japanese commercial purse seiners.

Gonad index (GI) was calculated for female and male yellowfin tuna as a measure of maturity,

$$GI = GW \times 10^4 / FL^3$$

where GW is the gonad weight in gm and FL is the fork lenght in cm.

Size of female yellowfin tuna at first maturation was assumed to be around 60 cm (HENNEMUTH, 1961), 70 cm (YUEN and JUNE, 1957) and 80 cm (KIKAWA, 1959), respectively. However, SHUNG (1973) pointed out a risk that the maturity of yellowfin tuna under 100 cm could be overestimated with the use of GI. Therefore, in this study females and males over 100 cm were used as adult for investigation of the maturity. Number of individuals used is shown in Table. 1.

For female, percentage of matured fish to the total (group maturity) has been frequently used for the index of seasonal spawning activity on yellowfin tuna. From the comparison of female GI with visual observation on stage of ovary maturity and/or frequency distribution of egg diameter in ovary, critical GI values of 1.6 (KIKAWA, 1959, 1966), 2.0 (SHUNG, 1973) and 2.1 (KIKAWA, 1962) were used to calculate group maturity of females in the past works. Fig. 3 shows relationship between the fork length and GI on female caught by the longline and purse seine vessels. The number of females with GI of 2.0 and over appears to increase with length over 100 cm both for longline and purse seine samples. In this study, group maturity was defined as percentage of the specimens with GI of 2.0 and over in individuals larger than 100 cm FL. Since the critical value of GI for the male yellowfin tuna was difficult to determine, the group maturity was not applied for the male.

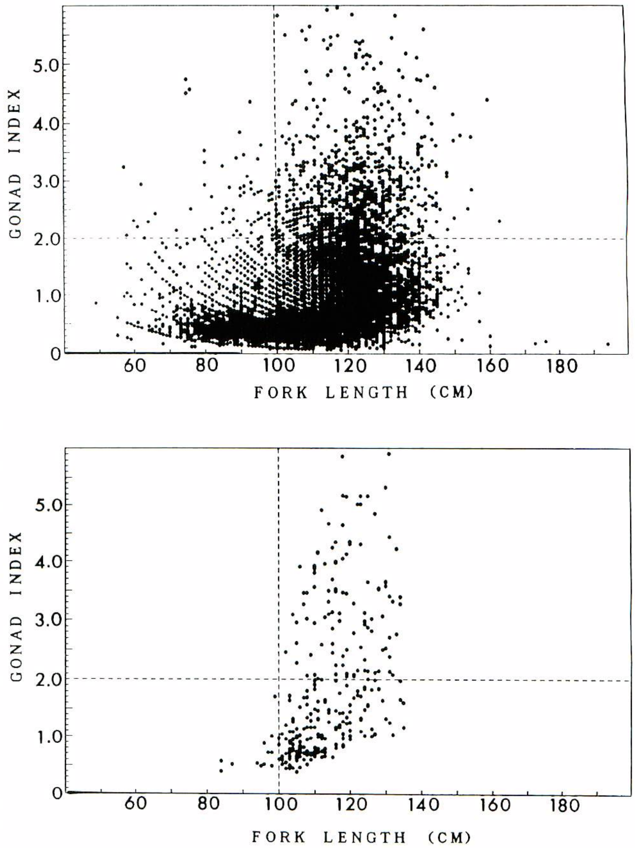

Fig. 3. Relationship between fork length (cm) and gonad index for female yellowfin tuna caught by the Japanese prefectural longliners (1968-1970, upper panel) and the Japanese commercial purse seiners (1985-1988, lower panel).

Monthly composition of calculated GI for both sexes sampled by the longliners skewed toward the lower value and did not appear to be normally distributed. Those by the purse seiners did not show any significant pattern of distribution, as the number of specimens larger than 100 cm in each month was as few as about 10 fish. Then logarithmic transformation was made for GI.

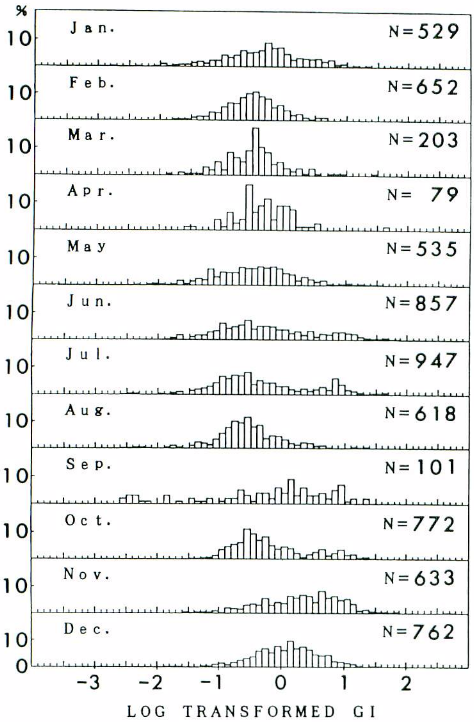

Fig. 4. Monthly composition of log transformed GI for female yellowfin tuna caught by the Japanese prefectural longliners in 1968.

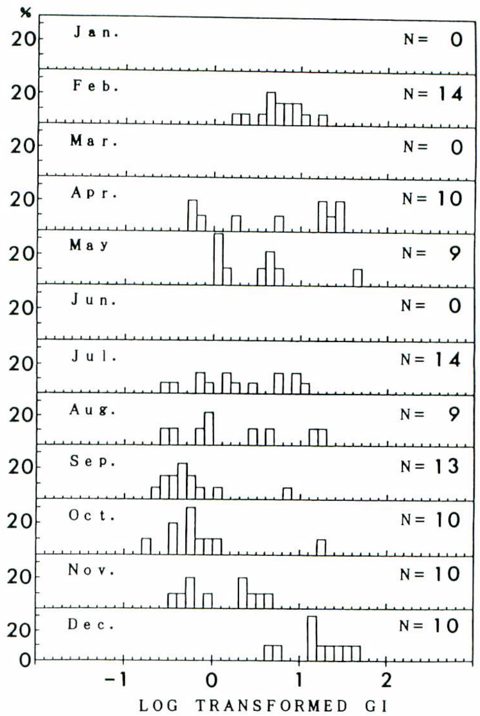

Fig. 5. Monthly composition of log transformed GI for female yellowfin tuna caught by the Japanese commercial purse seiners in 1986.

Figs. 4 and 5 exemplify monthly composition of log transformed female GI caught by longliners in 1968 and purse seiners in 1986, respectively. Although the log transformed compositions sampled by the purse seiners showed little improvement, those by the longliners showed the distribution much more closer to normal distribution. Then, arithmetic mean of log transformed GI was calculated in each month for both males and females larger than 100 cm, and the monthly changes of the mean values were also examined for the index of spawning season.

Results

The monthly changes of female group maturity for longline samples are shown in Fig. 6. In 1968, the group maturity was low from January to May, and tended to increase after then except August. In 1969, it decreased from January to April, then remained in a low level. It showed a peak in September 1970. During 1968-1970, no annual consistency in seasonal change was found. The group maturity over 50% occurred only once in January 1969. The group maturity under 10% occurred in about two thirds of the total months.

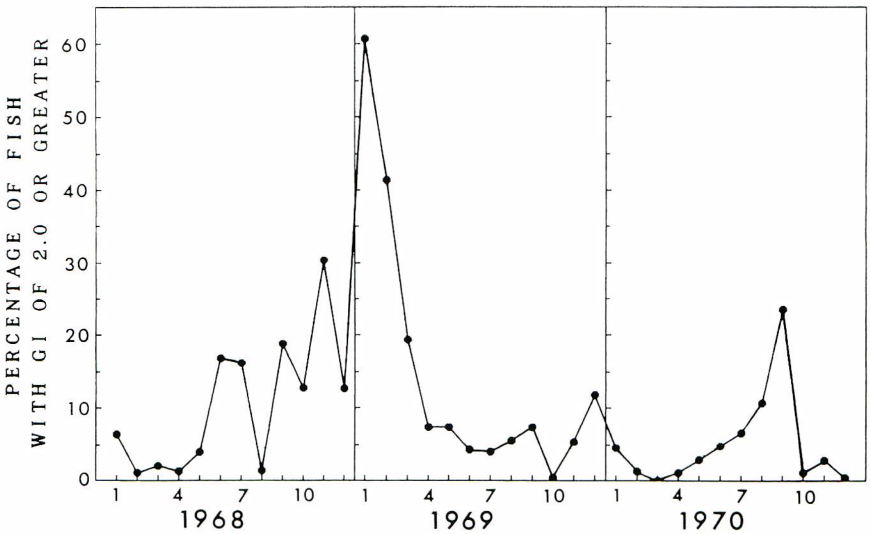

Fig. 6. Group maturity (percentage of fish with GI of 2.0 and over to the total) of female yellowfin tuna caught by the Japanese prefectural longliners in the model area from 1968 to 1970.

Trend of mean of log transformed GI sampled by longliners is shown for male and female (Fig. 7). The seasonal changes for both female and male were similar to that of the group maturity (Fig. 6), and the pattern of monthly change did not coincide between years as was observed in the group maturity. The mean value higher than 0 occurred scarcely (Fig. 7).

The monthly changes of group maturity for purse seine samples are shown in Fig. 8. A similar seasonal change in the group maturity is repeated during the period of 1985-1987, namely the group maturity showed a decreasing trend in the first half of the year and an increasing trend in the latter half. More than 50% of the fish matured approximately from November through April. From May to October, the group maturity dropped below 50% but most of them still remain above 10%. The seasonal changes of the mean of log transformed GI of both male and female yellowfin tuna during 1985-1988 (Fig. 9) coincide fairly well with those of group maturity (Fig. 8). Most of those means appeared higher than 0.

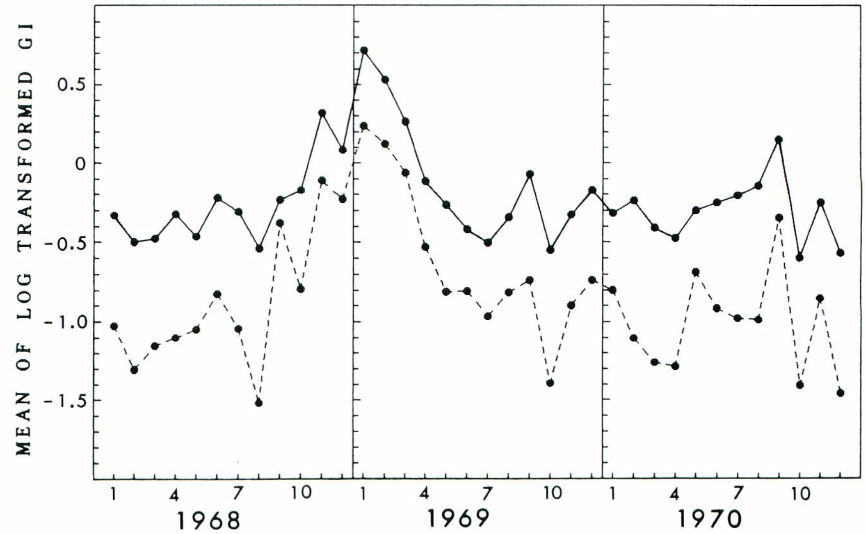

Fig. 7. Mean of log transformed GI for female (●——●) and male (●------●) yellowfin tuna caught by the Japanese prefectural longliners by month from 1968 to 1970.

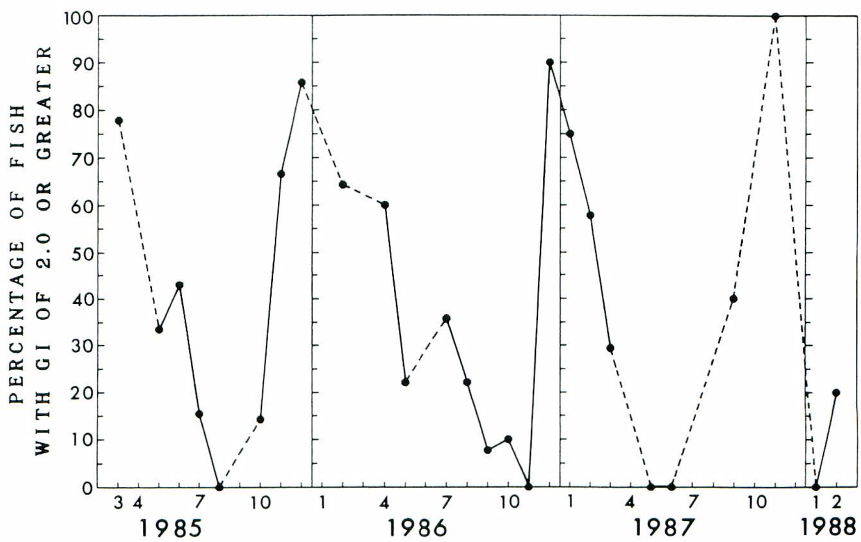

Fig. 8. Group maturity of female yellowfin tuna caught by the Japanese commercial purse seiners in the model area from 1985 to 1988. Dotted lines indicate the months without observations.

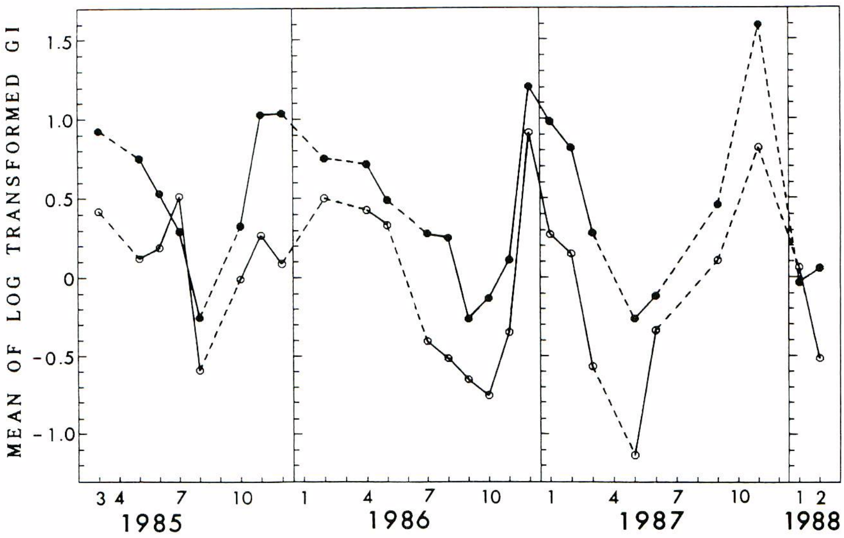

Fig. 9. Mean of log transformed GI for female (●——●) and male (○——○) yellowfin tuna caught by the Japanese commercial purse seiners by month from 1985 to 1988. Dotted lines indicate the months without observations.

Discussion

The previous results of studies on main spawning season of yellowfin tuna in the similar waters to the present study did not coincide with each other. KIKAWA (1962) and SUZUKI *et al.* (1978) reported it in the first and fourth quarters of the year, but KIKAWA (1959, 1966) reported it in the northern summer. Furthermore, KIKAWA (1966) pointed out that the seasonal changes of spawning activity were not always consistent every year even in the same area. All of those results were based only on longline samples. It should be noted that yellowfin tuna in sexually advanced stage have scarcely been caught by the longliners (KIKAWA, 1959, 1966).

On the other hand, a phenomenon that the samples taken by purse seiners were more matured than those taken by longliners was reported in the western tropical Pacific (SUZUKI, 1988), the eastern tropical Pacific (SUZUKI *et al.*, 1978) and the eastern tropical Atlantic (YANEZ and BARBIERI B., 1980). Some authors suggested that the difference in maturity between the fishing gears was derived from the difference in depth of catch, viz. purse seiner caught the fish in shallower water but longliners in deeper layer of 50-150 m. Furthermore, fully matured yellowfin tuna with running-ripe eggs ready to spawn have often been taken by the purse seiners (JOSEPH, 1963 ; MORI, 1970).

Seasonal trends of CPUEs obtained from longliners and purse seiners operating in the areas of 5°S-10°N and 140°E-160°E, showed negative correlation each other (SPC, 1988). The CPUE of purse seiners was high in beginning and end of the year but that of longliners high in the mid year. As aforementioned, fish caught in surface layer showed higher sexual maturity, compared with the fish caught in deeper layer. Those observations support the hypothesis that the spawning takes place in surface, as suggested by HISADA (1973). Therefore, based upon the data obtained by the purse seiners, it is considered that the main spawning season of yellowfin tuna in the western tropical Pacific Ocean is inferred to extend from November to April.

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生殖腺指数からみた西部太平洋熱帯域におけるキハダの主産卵期

小井土　隆・鈴木治郎

摘　要

西部太平洋熱帯域（5°S～10°N，130°E～170°E）におけるキハダの主産卵期を，生殖腺指数（GI）に基づき検討した。本研究で標本として用いたキハダは，1968年1月～1970年12月に地方公庁船のはえなわ操業及び1985年3月～1988年2月にまき網漁船で漁獲されたものである。GIは，尾叉長（FL；測定単位，cm）と生殖腺重量（GW；測定単位，gm）を用いて，産卵に関与すると考えられるFLが100 cm以上の個体について，$GI=GW\times10^4/FL^3$より計算した。雌の産卵期の指標として，GIが2.0以上の個体が全体に占める割合（群成熟度）を用いた。また，雌雄について対数変換したGIの季節変化を検討した。

はえなわにより漁獲されたキハダは，まき網漁獲魚に較べて性成熟度が低く、年々の性成熟度の季節変化傾向は一致していなかった。一方，まき網により漁獲されたキハダの性成熟度は，年々同じ季節変化を示し，11月から4月に高かった。はえなわ対象群とまき網対象群の性成熟度の差は，キハダの産卵に伴う表層への移動によって生じると考えられた。

以上の検討から，西部太平洋熱帯域におけるキハダ主産卵期は11月～4月と推測される。