Recent status of resources of tuna exploited by longline fishery in the Indian Ocean*

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Foreword

The IPFC/IOFC Ad Hoc Working Party of Scientists on Stock Assessment of Tuna was held at FAO Headquarter in Rome, from 7 to 9, June, 1972 to examine the recent status and needs to implement measures for a conservation of tuna resources in the Indian Ocean (FAO 1973, SUDA 1973). Several working papers were submitted to the Party. A paper, " Observation on the recent status of the tuna longline fishery in the Indian Ocean ", prepared by the present author was one of such working papers. In the paper, activities of the Japanese, Korean and Taiwanese longline fleets in the ocean as well as status of resources of tunas exploited by the fisheries were reviewed and analysed.

The author intends to update his previous paper mentioned above, which will be cited as " 1972-Report " hereafter and, in the present paper, the latest status of longline fishery and its resources are followed up on the basis of data up to 1971-fishing year.

Acknowledgements

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Recent activities of longline fishery in the ocean

FAO Catch Statistics (FAO 1972) indicates combined catch of tunas snd tunalike fishes taken from the Indian Ocean amounts to 222 and 243 thousand metric tons in

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1970 and 1971 respectively. Regarding the respective longline catch among them, Japanese, Korean and Taiwanese fleets produced 112 and 118 thousand tons, each of which corresponds to 50 and 48% of the total tuna and tuna-like production from the ocean.

As was explained in "1972-Report", it is difficult to obtain long-term series of direct measures on amounts of fishing effort and resultant catch per unit effort for the whole fleets. Unfortunately, the Annual Meeting for 1973 year of Asian Tuna Fishermen's Roundtable Conference, which has been held once a year previously, is being postponed, so that exchange of data on the fishing activities in 1972 among related longline fishing nations is not yet realized. The author was further informed that Japanese Statistical and Information Department needs a few more months to complete their 1972-catch statistics by FAO-area division. Under these circumstances, Table 1 is not partly completed for 1971 (see details in Table 1) and not inclusive for 1972.

As is illustrated in Table 1 and was noted in "1972-Report", the longline fishing activities reached to a maximum level in 1968 and 1969 and turned to decrease in 1970. In 1971, the activity is considered to be of a similar intensity to that of 1970. For 1972, though the conclusive information is not yet available, the author assumes

Table 1. Summary of the whole catch (including sharks and other misceraneous fishes) and effort data of Japanese, Korean and Taiwanese longline fisheries in the Indian Ocean, 1964-1971.

	1964	1965	1966	1967	1968	1969	1970	1971
Japan								
Total	81,427	90,653	87,394	118,192	118,171	95,702	60,438	56,800**
Boats	307	341	308	397	411	363*	252*	263**
Catch/boat	265	266	284	298	288	264*	240*	216**
Cruise	567	669	545	633	616	512	330	
Korea								
Total			800†	3,700†	11,600†	16,060	8,808	16,786
Boats			3††	10††	25††	41	36	52
Catch/boat						389	245	323
Taiwan								
Total	9,007††	7,658††	11,968††	14,137	37,295	38,125	35,637	28,942
Boats	14††	9††	36††	105	152	172	171	157
Catch/boat				135	245	221	208	184
Total catch	90,434	98,311	100,162	136,029	167,066	152,877	104,833	102,528

Notes; * Estimates by number of cruise in the respective years. "Cruise per boat" is determined from the data in the four years from 1964 to 1968.

** Preliminary estimates based on log-books made available to the Japanese Fishery Agency as of 1 May, 1972. On the date, still unnegligible boats which operated in 1971 did not yet return to home ports.

† Tunas and tunalike fishes only excluding sharks and misceraneous fishes (From FAO statistics)

†† Based on the data submitted to the Asian Tuna Fishermens Roundtable Conference.

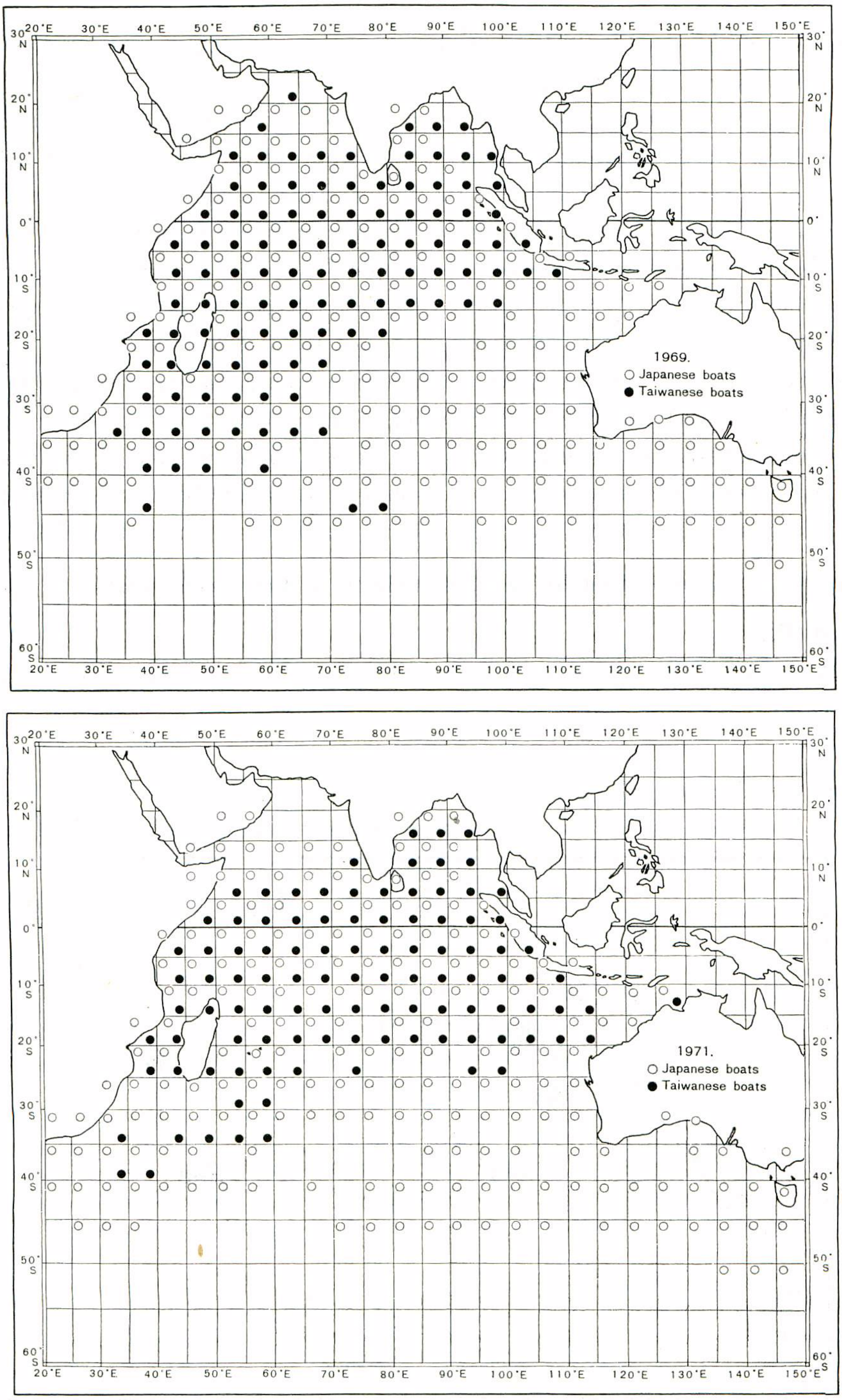


Fig. 1. Comparison of distribution of fishing efforts between Japanese and Taiwanese flees, for 1969 and 1971.

Closed circle: Taiwanese fleet Open circle: Japanese fleet that considering ship-building-plans of countries concerned, it was around on the preceding year's level or a little higher.

In Fig 1, the distribution of longline operation by Japanese and Taiwanese fleets is given for 1969 and 1971 calendar year. There appears remarkable difference in the preference of fishing grounds between the two nations. Taiwanese boats concentrate in the tropical waters fishing mainly yellowfin tuna and seasonally albacore, while Japanese boats disperse widely over the tropical and subtropical waters pursuing southern bluefin tuna as a major objective and other species of tunas as byproducts. Probably, such a difference by nationality comes from that of a charcter of market to which their products are supplied. In this meaning, Japanese domestic market is characterized by steady demand for *Sashimi*. This seems to be the main reason of difference of distribution of fishing effort between Japanese and Taiwanese fleets. Presumably, though data on Korean activities are not available in the present report, the author assums that Korean fleet operates in a similar manner to that of Taiwanese.

Status of resources exploited by longline fishery in the recent years

(I) **ALBACORE**

In this section, a fishing season for albacore covers a period from April to March of a following year.

(I)-1. Catch and effort relations

In Fig. 2, is demonstrated the relationship between amounts of standardized effort

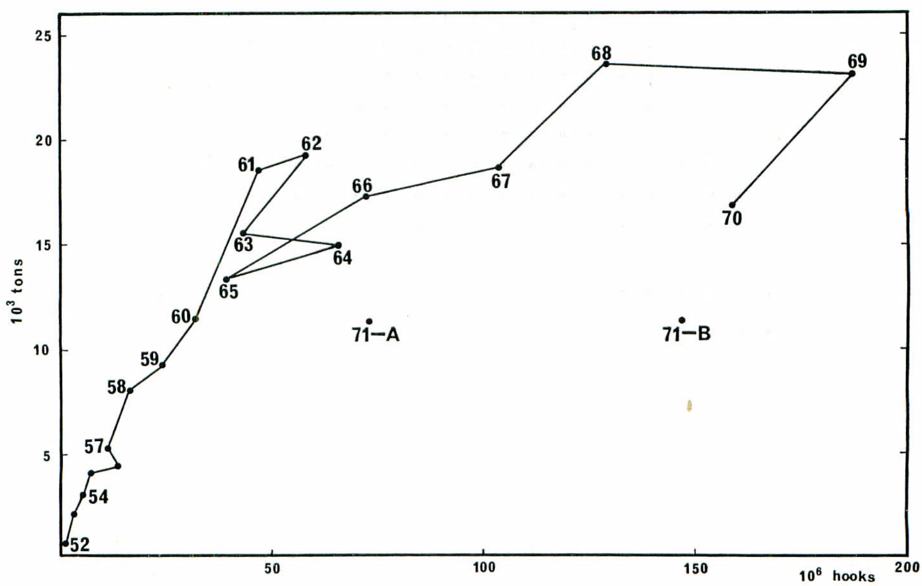


Fig. 2. Annual amount of catch of albacore from the whole Indian Ocean plotted against standardized hooks. For 1971-fishing season, estimate-A and -B are plotted on the basis of Taiwanese and Japanese catch statistics respectively.
(Prepared by SHIOHAMA, FAR SEAS FISH. RES. LAB.)

and resultant catches for the whole albacore fishing ground of the ocean. The statistics for the years since 1966 are revised a little from those in "1972-Report" on the basis of additionally submitted data thereafter. Also, the statistics for 1970 in "1972-Report" which was based on the data for the 1970-calendar year is revised to on the whole season basis. In the same figure, two tentative estimates, estimate-A and -B, are plotted for 1971-season. The estimate-B suggests, as will be discussed below, a significant change in the feature of albacore fishery in the ocean. Amounts of standardized effort in estimate-A and -B are calculated on the basis of the statistics of 1971-calendar year, through the following procedures respectively:

$$A = \text{Amounts of standardized effort of Taiwanese fleet} \times \frac{\text{Catches by Japanese, Korean and Taiwanese fleets combined}}{\text{Catch by Taiwanese fleet}}$$

$$B = \text{Amounts of standardized effort of Japanese fleet} \times \frac{\text{Catches by Japanese, Korean snd Taiwanese fleets combined}}{\text{Catch by Japanese fleet}}$$

As was reported in "1972-Report", fishing effort in 1969-fishing season showed an increase of 50% over the preceding season. However, the resultant catches in 1968 and 1969 remained on the almost same level, the largest ones recorded in the history of this fishery. It was also noted that the marginal increae in catch was not appraisable for the range of fishing effort beyond 10^8 standardized hooks. In 1970-fishing season, amount of catch decreased by 5,000 metric tons in spite of fishing effort on sufficiently high level, which corresponded to the mean value of 1968- and 1969-fishing seasons.

Significant difference between estimate-A and -B in 1971-fishing season is attributable to that of average CPUE of albacore between Japanese and Taiwanese fleets. Recently, fishing ground of Japanese boats substantially expanded southerly and they are fishing in almost entire albacore area including the southern part of the ocean.

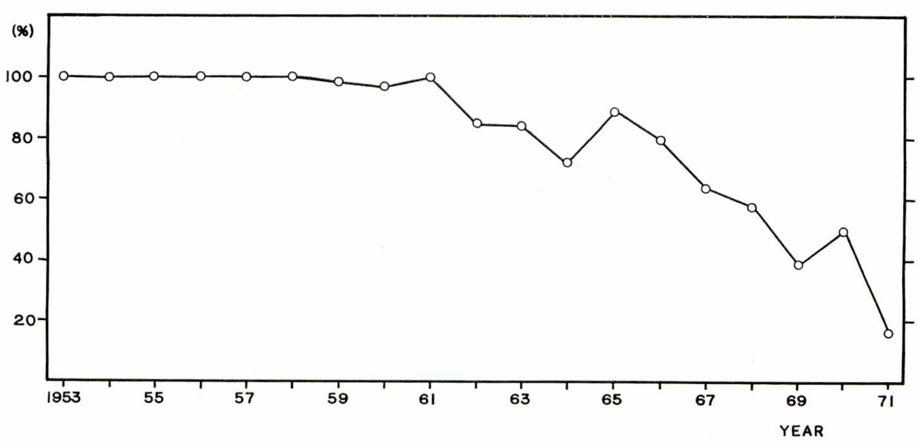


Fig. 3. Yearly change in the proportion of albacore caught by Japanese fleet from the area north of 30°S in those from the whole Indian Ocean.

And major portion of Japanese catch comes from the area south of 30°S, and as shown in Fig. 3, in 1971-fishing season more than 80% of the catch consists of those from such area. Average size of recent Japanese catch is 13 kg in weight. On the other hand, Korean and Taiwanese boats has been traditionally fishing in the tropical area north of 20-30°S and average weight of fish is assumed to be 19.5 kg. The major species exploited by Japanese and Taiwanese fleets are also different. The former fleet mainly operates on southern bluefin but albacore is less interesting species for it. On the other hand, albacore is one of major purpose of the later fleet and thus effieiency of effort for albacore (ratio of number of standardized hooks for albacore to actual number of hooks used) is higher in Taiwanese fleet. Thus the different size of albacore in the commercial catch as well as dissimilar interest in fishing albacore between Japanese and Taiwanese fleets result in a significant difference in catch per unit effort in weight between the two fleets. Catches of albacore per 1000 hooks in 1971 are 77.23 kg and 168.26 kg for Japanese and Taiwanese fleets respectively and the later is 2.2 times of the former. And the catch and effort relationship for the overall albacore fishing ground that had been observed for the previous years is no longer applicable. Nowadays, the albacore fishery in the Indian Ocean is a combination of two different types of fisheries in nature: the one is that on the spawning group north of 30°S and the other on the immature group south of 30°S.

(I)-2. Size composition of catch

In Fig. 4 is illustrated a remarkable geographic change in the length composition in the commercial catch between the waters south and north of 30°S. Albacore from north of 30°S is mainly composed of advanced age groups of 6 years old and greater, which are at the same time a spawning group. The other group from south of 30°S is immature fish younger than 6 years, mainly 3- to 5-age groups.

The average lengths of albacore caught north of 30°S for each half-year period, which are shown in Table 2, decreased by 3-4 cm since 1961-fishing season. The spawners range in size over narrow length interval, 85-115 cm. It seems that the mean length of recruitment to the spawning area lies between 90 and 95 cm and recruitment completes at a length range between 95 and 100 cm. The lessend average length since 1961-fishing season, around 96-97 cm, is very close to that of completion of recruitment, being suggestive of a result of heavy fishing rate in the recent years.

Several modal groups occur in the length frequency of the albacore caught in the area south of 30°S. Average length and weight of the catch in the same area are shown in Table 3.

(I)-3. Analyses of catch and effort data

In "1972-Report", the analyses were done on the basis of the relationship between effort and catch for the entire Indian Ocean, suggesting no substantial increase in

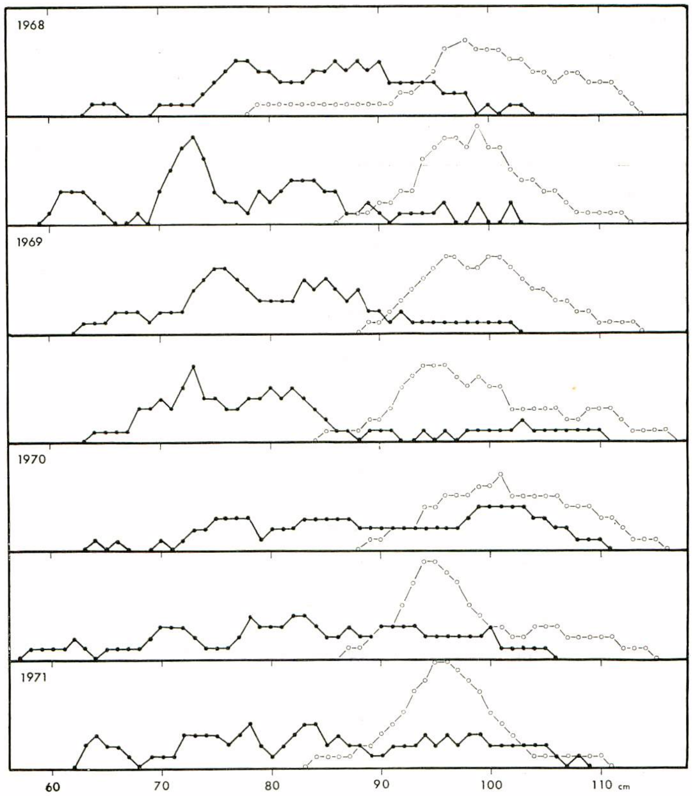


Fig. 4. Comparison of length frequency distribution of albacore caught by Japanese longline gear between areas south and north of 30°S.
Open circle: north of 30°S Closed circle: south of 30°S

amount of catch with increased effort. In the same report, in spite of the intensified exploitation of the younger member, any significant change in catch and effort relationship was not drawn. However, as already mentioned, a analysis on the pooled relationship for the entire Indian Ocean appears to be no longer meaningful due to recent change in the character of the fishery. Considering this circumstances, the analysis of catch and effort relation of albacore is done over again for two albacore groups: the mature group in the area north of 30°S and the immature group south of 30°S.

(I)-3-1. Mature group north of 30°S

The relationship between effort and resultant catch for the group is shown in Fig. 5 for the fishing seasons from 1955 through 1971. In general, the relationship is of the similar character to the one that was treated as a pooled relationship for the entire Indian Ocean in "1972-Report". No significant increase in catch for the range of effort beyond 5×10^7 in terms of standardized hooks in one fishing season is suggested. The parameters for this relationships are estimated in the same manner as the one that was applied to bigeye tuna in "1972-Report". The detail of the

Table 2. Semiannual mean length (fork-length, cm) and weight (round weight, kg) of albacore caught by longline gear from the subtropical area north of 30°S of the Indian Ocean.

Year	Length		Weight	
	Apr.-Sep.	Oct.-Mar.	Apr.-Sep.	Oct -Mar.
1953	102.5	101.8		
4	99.5	99.6		
5	92.3	101.1		
6	98.7	99.4		
7	101.0	99.6		
8	102.4	100.8		
9	95.5	98.7		
1960	98.2	98.8		
1	97.1	96.6		
2	96.6	98.7		
3	95.8	98.1		
4	95.5	98.7		
5	96.2	97.1		
6	95.2	95.8		
7	96.1	99.8		
8	99.1	98.2	20.31	19.32
9	98.1	97.7	18.97	19.63
1970	100.8	98.2	20.99	19.06
1	95.9		17.79	

Table 3. Semiannual mean length (fork-length, cm) and weight (round weight, kg) of albacore caught by longline gear from the area south of 30°S of the Indian Ocean.

Year	Length		Weight	
	Apr.-Sep.	Oct.-Mar.	Apr.-Sep.	Oct.-Mar.
1968	84.6	78.4	11.90	9.94
9	80.6	81.0	10.51	10.73
1970	90.7	83.0	15.37	11.76
1	85.0		13.20	

method should be referred to the author's another report (SUDA 1970). In this analysis, the data from 1955- through 1967-fishing season are utilized but those since 1968 because of a possible decrease in amount of recruitment to this area caused by the increased catch south of 30°S since 1967-fishing season. The standardization of effort is based on average pattern of distribution of albacore in the area north of 30°S from 1962- to 1965-fishing season. Amount of catch is expressed in number of fish caught. In Fig. 6 are shown relationships among hooking rate (number of fish/100 hooks), its reciprocal and standardized effort. On the basis of expected relationship between reciprocal of CPUE and effort, as indicated by a follwing equation,

$$\frac{f}{c}=\frac{M}{qR}=\frac{f}{R},$$

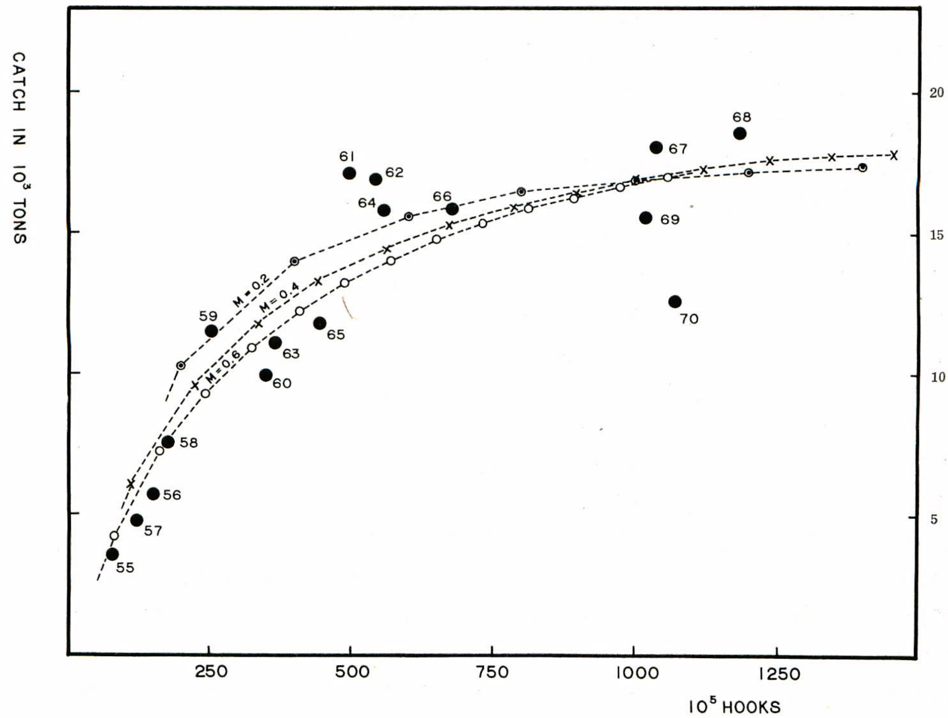


Fig. 5. Yearly number of standardized hooks and resultant catch of albacore (10^3 tons) in the area north of 30°S, 1955–1970, with calculated yield curve under supposed M from 0.2 to 0.6.

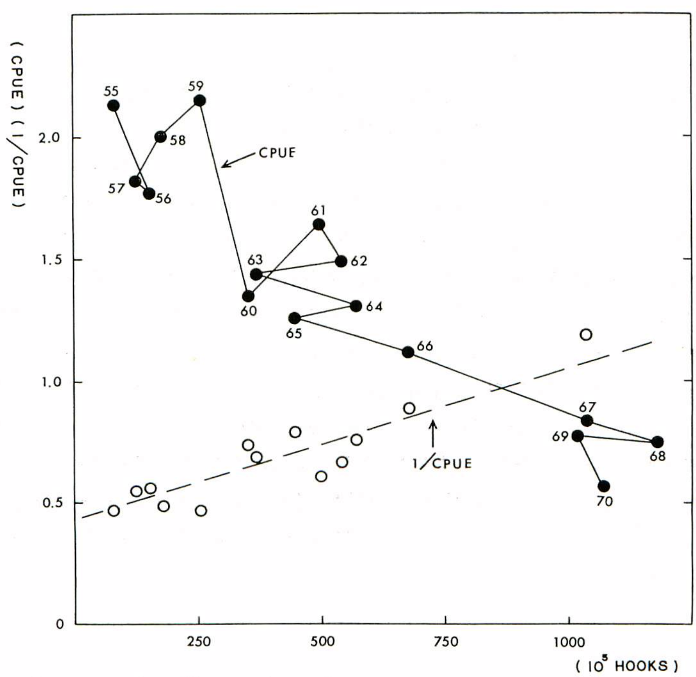


Fig. 6. Annual change in CPUE (number of albacore caught by 10^2 hooks) and its reciprocal plotted against number of standardized hooks.

R and q are estimated through iteration under the various supposed values of M, and resultant estimates are given in Table 4. Y/R for M from 0.2 through 0.8 are calculated (see foot-note*) and the results for M from 0.2 to 0.6 are shown in Fig. 5 with dotted lines. Supposed values of M from 0.4 to 0.6 appear to fit with the observed values better than those less than 0.4. In case of the spawning group of the North Pacific albacore, SUDA (1966) estimated M at 0.6 on the average and M at 0.4 for younger component of the group. Taking this into accout, M of the spawning group of Indian albacore is hypothesized to be between 0.4 and 0.6. For the range of M from 0.4 to 0.6, R and q are estimated to be 1.13–1.21 million fish and 0.000891–0.001232 respectively. The calculated catch curve suggests no significant increase in catch beyond the present level of fishing effort. Depressed catch per 100 hooks in Fig. 6 also support this supposition. The yield curves also indicate the expected maximum catch from the area noth of 30°S is between 17 and 18 thousand tons if there is no significant amount of catch of immature fish in the area south of 30°S. Somewhat declined catch in 1970–fishing season might be related to more or less the recent incresed catch south 30°S.

Table 4. Average amount of annual recruitment (R at 6 years old) and catchability coefficient of 10^5 standardized longline hooks (q) for the albacore in the area north of 30°S of the Indian Ocean, estimated under various suppositions on natural mortality coefficient(M), with SUDA's method(1970).

M	R (1000fish)	q
0.2	969.93	0.000500
0.3	1071.81	0.000684
0.4	1129.94	0.000891
0.5	1187.65	0.001056
0.6	1212.12	0.001232
0.8	1295.34	0.001548

(I)-3-2. Immaure group south of 30°S

Yearly numbers of standardized hooks and fish caught for the area south of 30°S and resultant catch per unit effort are illustratrated in Fig. 7. Effort and catch increased with remarkable yearly fluctuation. Catch in number was kept around 400 thousand fish from 1967– through 1969–fishing season and then it dropped to 200 thousand fish in 1970–fishing season. CPUE (hooking rate) decreased significantly since 1967–fishing season and is recently around half of the level for the fishing seasons before 1966. The average age of catch in this area is about 4 years old, and average duration of stay in the area of the captured fish is about two years. Therefore, annual catch of 400 (in 1967-1969 fishing seasons) or 200 (in 1970–fishing season) thousand fish in number may decrease the recruitment to the spawning group by about 400 or 200 thousnad fish multiplied by exp. (–2M). Under an assumption of M=0.2 for the immature group, the possible decrease in the recruitment to the adult group is 270 or 135 thousand fish, corresponding to 24 or 12% and 22 or 11% reduction

* In the calculation with computer, M value of 0.8 was not included in the program because the necessity of such a high value was not considered. Simple calculation for M=0.8 by hand resulted in a smaller amount of yield than those calculated under the assumption of M of 0.6 and less.

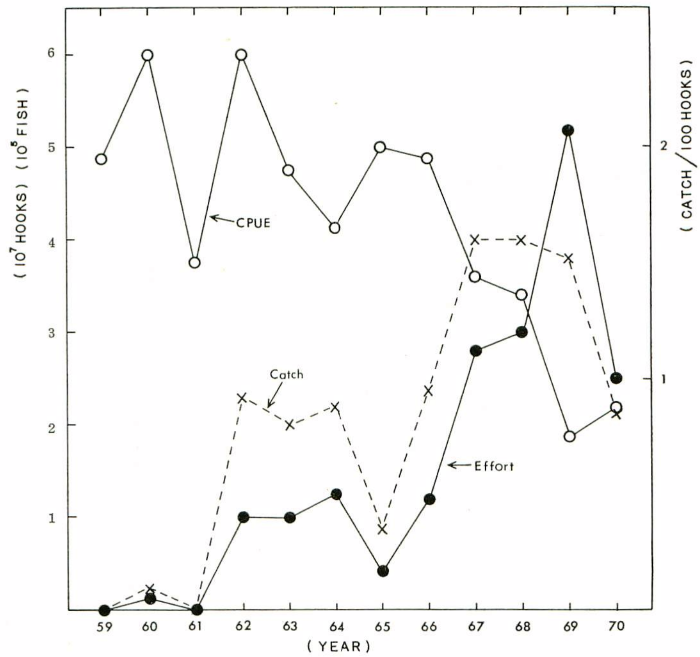


Fig. 7. Yearly number of standarized hooks, number of albacore caught and catch per 100 hooks for the area south of 30°S of the Indian Ocean. (Prepared by SHIOHAMA)

of the average recruitments of 1.13 and 1.21 million fish, respectively.

If recruitment to spawning group of 1.13–1.21 million fish and supposed M at 0.2 are not unreasonable estimates, approximate estimate of average number of fishable fish south of 30°S is calulated to be 5.5–5.9 million fish in a virgin stage (see footnote*). Then, the past largest amount of catch in this area of 0.40 million fish generates a following relationship:

$(5.5 \text{ or } 5.9) \times F = 0.4$

and F is calculated to be approximately 0.07. The calculated level of CPUE with catch of 0.40 million fish is 88% of that of the virgin stock. So it is the author's consideration that the recent significant drop in CPUE can not be explained by the intensified exploitation only. Perhaps, it is furthermore related to either biased standardization of fishing effort or/and natural fluctuation in the year class strength.

Whether the intensified catch of younger fish reduces Y/R is another problem. Y/R value is calculated for various type of exploitaion, employing a computer program (HONMA 1973), supposing natural mortality coefficients are different between mature and immature group. Resultant yield values are demonstrated in Fig. 8 a and b. In the model, age of dispersion is supposed at fifteen years old and age of recruitment from south to north 30°S is six years old, and natural mortality coefficients are assumed to be 0.2 before six years old and 0.4 (a) or 0.6 (b) beyond that age.

* $2 \times (1.13 \text{ or } 1.21) \times \frac{e^{2\times 0.2} \times (1 - e^{-2\times 0.2})}{0.2} = 5.5 \text{ or } 5.9$

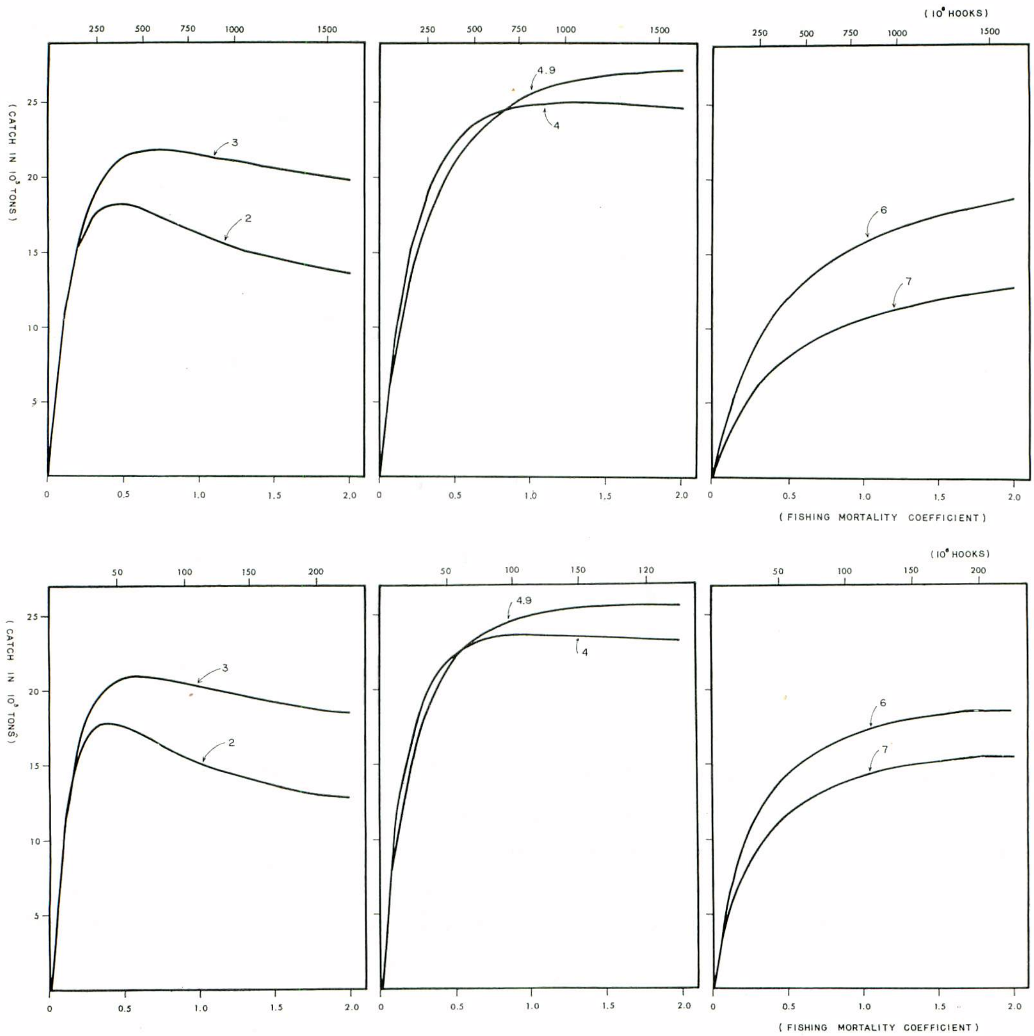


Fig. 8. Change in calculated Y/R curve with age of first capture, under two suppositions on magnitude of M of mature group, 0.4 (a, top) and 0.6 (b, bottom).

Y/R may not be reduced beneath the present value unless age of first capture is lowered below 2.0 years old under the recent fishing intensity. The most efficient exploitation would be achieved when age of first capture is between 3.5 and 5.5 years old and, in this case, amount of catch is to be more than 23 thousand tons.

(II) YELLOWFIN TUNA

In IPFC/IOFC Ad Hoc Working Party-1972, it was discussed that more precise consideration must be given on the treatment of the species if stocks in the ocean be composed of more than one component which are more or less independent each other. The matter in this connection was already discussed by MORITA and KOTO (1971), and they suggested two local groups which border each other at about 100°E through the examination of size composition in catch. As will be examined below, the uniformity of the stock is again rather questionable in the present analysis, and it is suggested that the stock assessment will be better planned on the local stock basis.

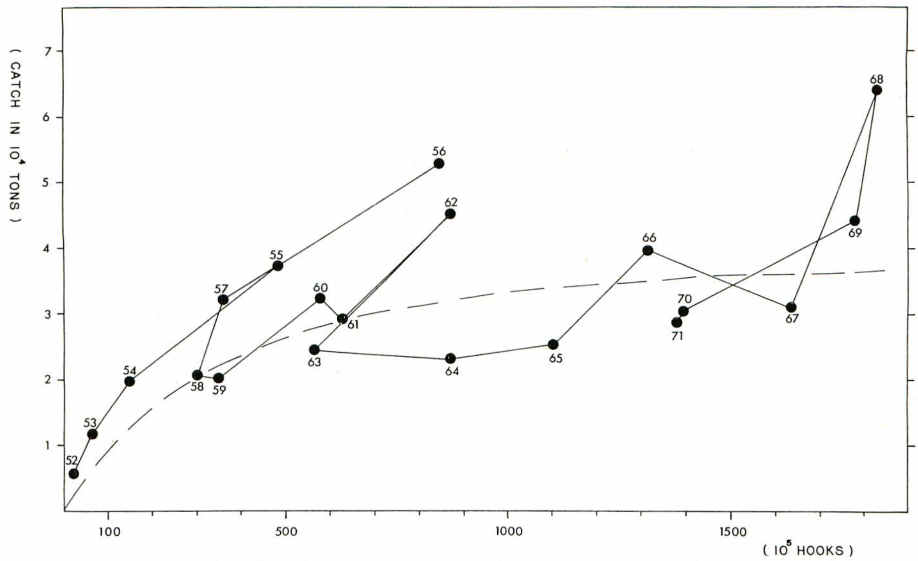


Fig. 9. Yearly catch of yellowfin (in 10^4 tons) and number of standardized hooks from 1952 through 1971 (Prepared by HONMA and SUZUKI) with calculated yield curve.

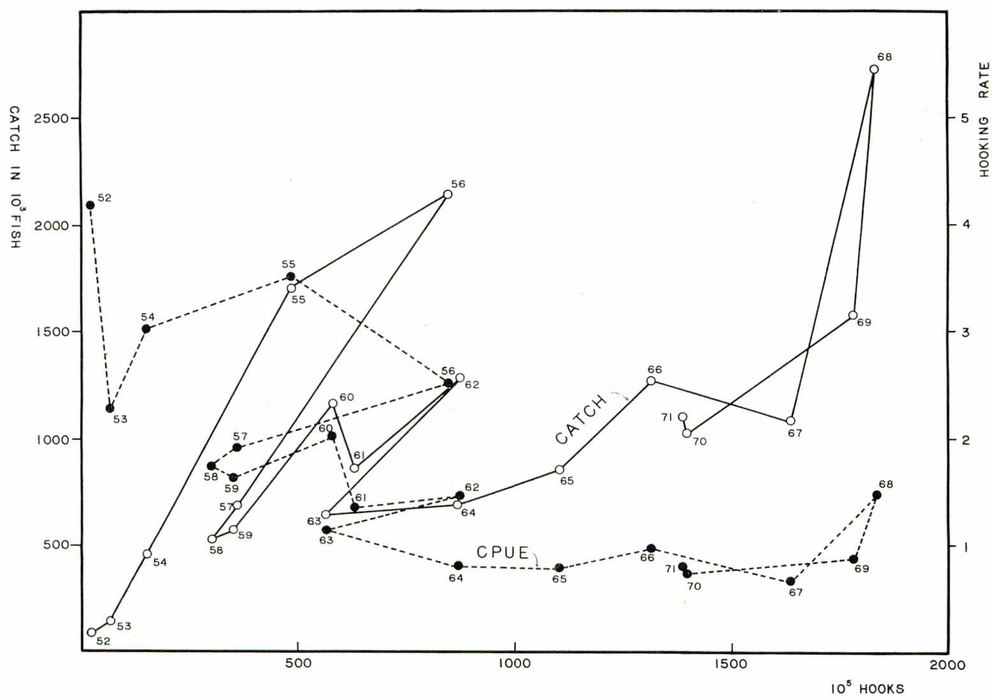


Fig. 10. Observed relationship between standardized hooks, amount of catch in number and CPUE (catch in number per 10^2 hook), 1952–1971.

However, detailed statistics by area are not available for the fleets of all the countries concerned and, therefore, desirable and elaborate analysis could not be tried in the present study. Consequently, the analysis is again subjected to mainly on the basis of whole stocks in the ocean.

In this section, a fishing season corresponds to a calendar year.

(II)-1. Catch and effort statistics

Renewed catch and effort statistics are graphed in Fig. 9 (catch in weight) and Fig. 10 (catch in number), which are revised on the basis of recently calculated efficiency rate of hooks. Compared with "1972-Report", the most substantial difference caused by this revision is increased efforts for 1955, 1956, 1965 and 1966 fishing seasons. Also, in the new series of data, catch and effort statistics for 1970- and 1971-fishing seasons are added. In spite of such revision and additions of data, there seems to be no significant change in the nature of the relationship between catch and effort. The two major observations on this series of catch and effort data are:

(1) almost leveled off average catch over the range of fishing effort beyond 50 million standardized hooks, and
(2) marked fluctuation in yearly catch probably caused by that in year class strength. Coefficients of variance are as large as about 35% in weight and 50% in number of fish.

Fig. 10 also demonstrates the yearly change in the relation between effort and catch per unit effort on the whole ocean basis. Of course, CPUE gradually decreased with the increased effort and recent level is one fourth of that of the initial days of the fishery.

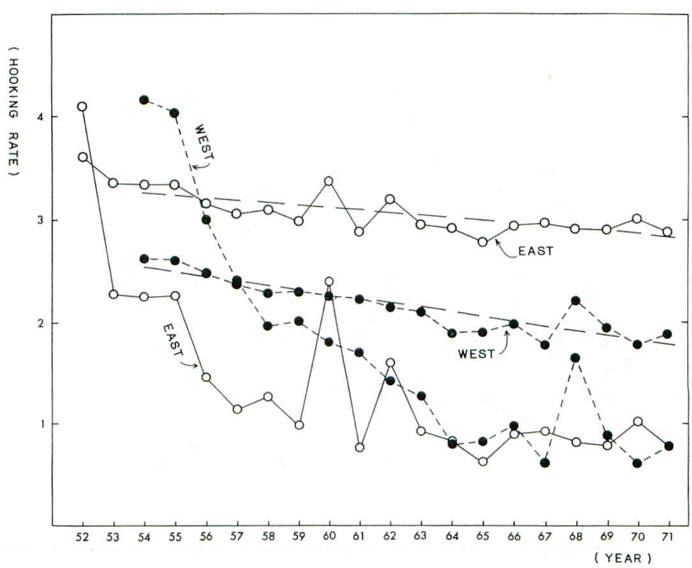
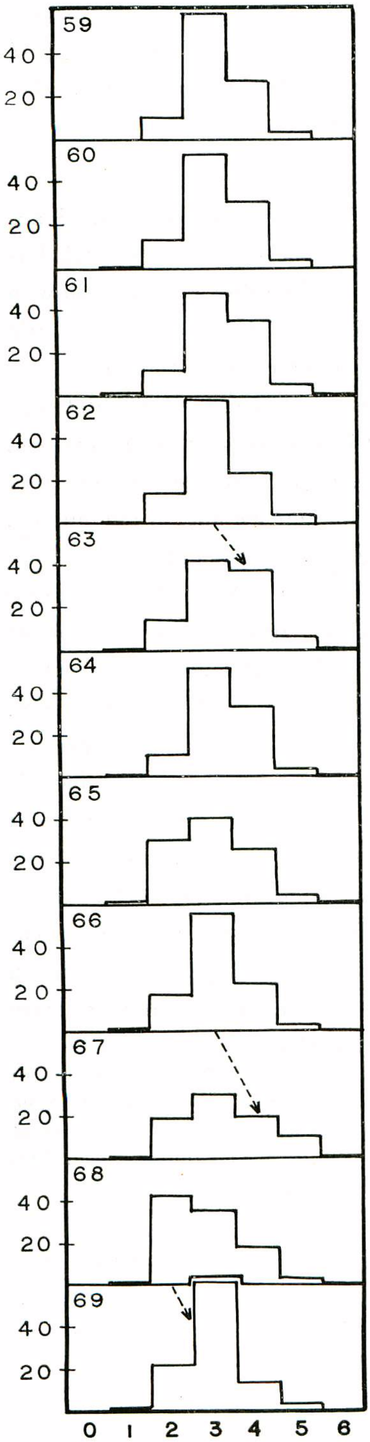


Fig. 11. Yearly change in hooking-rate and its logarithum for yellowfin tuna in the eastern and western halves of the Indian Ocean. In plotting logarithum of hooking rate, 3 and 2 are added respectively to original value for the eastern and western areas.

Another interested item is the analysis of the catch and effort relationship for some divided areas of the ocean, for instance, western and eastern halves of the ocean. However, as was mentioned above, it is unable to compile catch and effort statistics for divided areas of the ocean in the present study. Only comparison of yearly CPUE between western and eastern halves of the ocean is tried with use of Japanese statistics as is demonstrated in Fig. 11. The hooking rates in both areas are depleted simultaneously and substantially with the increased fishing effort since the initiation of the fishery in the ocean. Thus the author is afraid that the superficial pattern of change in CPUE resulted from the influence of fishing effort covers the inherent characteristic variation of abundance in each of stocks in different areas. To eliminate such effects of fishing, a linear regression is first applied to the series of logarithmic hooking rate as a trend line and then annual level of abundance is reevaluated as a discrepancy from the trend line. Reevaluated annual level of abundance is compared between western (west of 90°E) and eastern (east of 90°E) areas, and resultant coefficient of correlation is only +0.2550, indicating statistically insignificant. Similar comparison is also tried between two selected areas, the one surrounded by 10°N and 15°S and west of 90°E and



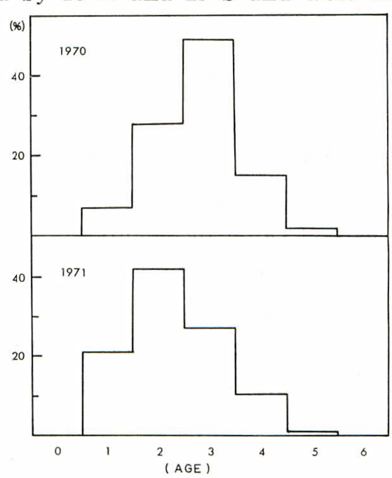


Fig. 12. Annual age composition of yellowfin tuna caught by Japanese longline fleet in the Indian Ocean.
Left-hand side : 1959–1969 (HONMA and SUZUKI, 1972) Right-hand side : 1970–1971

the other by 5°N and 15°S and east of 90°E, both of which constitute major fishing grounds of yellowfin in the ocean. Again, coefficient of correlation is as low as +0.2547. Both results indicate, at least, manners of yearly change in hooking rate are rather independent each other between areas east and west of 90°E.

(II)-2. Size composition of catch

The major component of longline catch consists of 2.5 to 3.5 years old fish. Since 1965, however, proportion of 1.5 to 2.5 years old fish in the commercial catch has been on the increase and, as a result, the average age of longline caught yellowfin was lowered (Fig. 12). The mean age of first capture is around 2.5 years or a little younger in the recent years and appears to be getting younger year after year.

The reason of relative increase of younger age group in the commercial catch was once discussed by HONMA and SUZUKI (1972) but still it is not completely understood. However, at least, they suggested that it seems to be related to the recent concentration of fishing in the western part of the ocean where the younger members predominate. It was their point that maintained recruitment size might be a just apparent one reflected by a change in an operational selection of fishing area. As to their interpretation, at the meeting of the IPEC/IOEC Ad Hoc Working Party-1972, an unanimous agreement was not arrived at. Also, a necessity to consider the regional separation of fish stock in examining the influence of the fishery on the stock was discussed. Therefore, change in age composition over the ocean is re-examined in the present study. The author likes to consider the lessened average age in the recent years is attributable rather to the decrease in number of fishing operations in the central part of the ocean where advanced age groups predominate than to the shift of effort from the eastern to the western part of the ocean as was once suggested in the "1972-Report". In addition, the relative abundance of younger fish not only in the commerical catch but also in the stocks themselves in the eastern and western parts of the ocean is examined separately. The following equation is a procedure to calculate relative abundance in the stocks by length ranges:

$$D_l = \Sigma r_{li} D_i A_i$$

where D_l : relative abundance of l-length group

r_{li} : proportion of l-length group in a commercial catch in sub-area-i

D_i : hooking rate in sub-area-i

A_i : expansion of sub-area-i

Neither significant increase nor decrease in abundance of younger fish are evident in both areas. So, on the average, annual amount of recruit is retained in spite of decreased abundance of adult stocks.

Another noted fact is that coefficient of cor-

Table 5. Coefficient of correlation (r) between annual abundances of yellowfin tuna by length range in the areas east and west of 90°E of the Indian Ocean, 1965-1971.

Length range	Coefficient of correlation (r)
70- 90cm	+0.3143
90-110	+0.0083
110-130	−0.0445
130-150	+0.3272
150-170	+0.5534
70-130	−0.5698
130-170	+0.3837

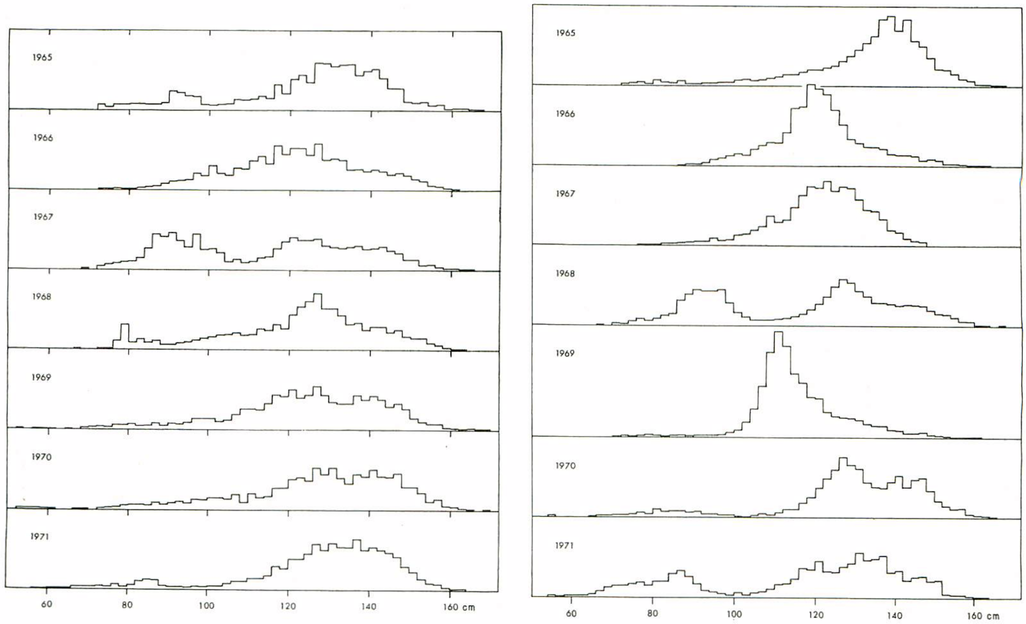


Fig. 13. Yearly change in length composition of yellowfin in the 1st. quarter of the year, 1965-1971.

Left-hand side : Area E-1, : area between 5°N and 15°S, east of 90°E

Right-hand side : Area W-3, : area between 5°N and 15°S, between 80°E and 90°E and area between 10°N and 15°S, west of 80°E.

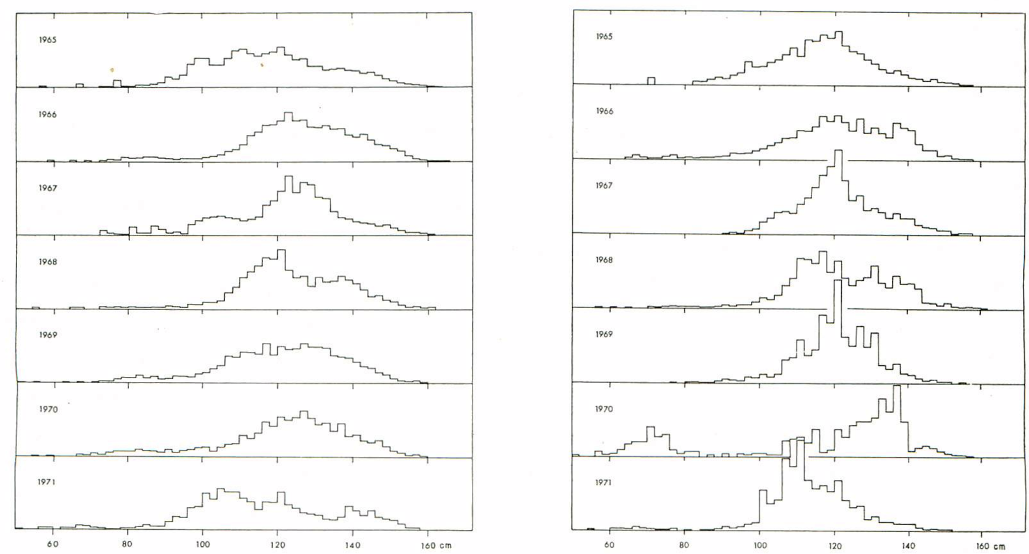


Fig. 14. Yearly change in length composition of yellowfin tuna in the 4th. quarter of the year, 1965-1971.

Left-hand side: Area E-1

Right-hand side: Area W-3

relation of annual abundances by length range (D_l) between the eastern and western halves of the ocean, as is shown in Table 5, are not significant, particularly for the younger fish than 130 cm. Perhaps, it is suggested that the abundance of younger fish fluctuates independently between the two regions. However, such an independency is weakened to some extent for the older groups. This suggests dispersion of fish to spread widely over the whole ocean with age. Thus, both groups, western and eastern ones, are more independent for the earlier stage of life span and then intermingling of fish between two groups is furthered with age.

Quarterly length frequencies in catch weighted by hooking rate, that indicates relative abundance, are illustrated for first quarter in Fig. 13 and for fourth quarter in Fig. 14 for the selected areas in the eastern and western parts of the ocean. It is remarkable that 130 cm modal group in 1967 and 1970 in the eastern area and 100 cm modal group in 1968 in the western area were predominated. Probably this predominance was related to the occurrence of strong year class, though it was observed in the limited time and area. For example, the conspicuous predominance of 100 cm modal group in the western area in 1968 (1966 year class) occurred just in the western part of the ocean and was not so positive in the successive years though the level of abundance in 1969 was a little higher than the average. Thus, predominance of year class is limited in time and area, as to its contribution being to be unexpectative.

(II)-3. Stock assessment

In 1968 fishing season, the amount of catch was largest, 64 thousand tons, throughout the history of the fishery (Fig. 9). Probably this properous yield was brought about through the entry of strong 1966 year class, as was mentioned in the above discussion. This year class was carried over to 1969 fishing season when amount of catch was again fairly large. In the following two fishing seasons, fishing effort decreased to three fourths of that of 1968 or 1969 fishing season and amount of catch decreased to half of 1968 catch. Thus, over the range of fishing effort beyond 50 million standardized hooks, the average amount of catch is almost leveled off though there observed remarkable annual fluctuation.

For more understanding, with an analysis of the relationship between fishing effort and reciprocal of hooking rate from 1952 through 1971, amount of recruitment and the ratio of q to M are calculated. Supposing M of 0.8, the amount of recruitment is estimated to be about 1.90 million fish at the age of first capture by longline and the ratio q to M is 0.3722. So the estimate of q is 0.001133 for 10^5 hooks. With q and M above estimated and t_c of 2.5 (perhaps, this value will become younger with year), Y/R is calculated and resultant amount of yield at various level of effort is plotted in Fig. 9. In the calculation, growth equation by HONMA *et al.* 1971 ($w_\infty = 122$ kg, $k = 0.33$) is employed. Yield curve indicates that significant increase in catch cannot be expected with the increased effort beyond the present level of effective hooks. Also, the feasible maximum catch from the resources is about 35 thousand tons.

It is noted that the number of fish in the virgin stock is estimated to be 2.4 million fish on the average (1/0.8×1.90). On the other hand, as is shown in Fig. 10, catches in number in some years, for instance in 1956 and 1968 with evaluated F of 0.96 and 2.07 respectively, were almost same as or even larger than the virgin stock size. Considering that the average amount of recruitment is not sufficiently large enough to support such large yields, this only possible with an entrance of unusually strong year class to the stock.

Recent decrease in the adult stock to one fourth of initial level raises another concern if the size of recruitment is being retained. In this regard, as above mentioned, HONMA and SUZUKI (1972) revealed that the relative abundance of two years old fish, the youngest substantial member in the longline catch, has been kept on a certain level up to 1969 fishing season. But they were anxious that it could be of an only apparent case reflected by the shift of fishing effort to the western area of the ocean where proportion of younger fish is larger. As already mentioned, the analysis in the present study reveals that abundances of younger member in both eastern and western parts of the ocean have been leveled off. However, taking into account of time lag between spawning and recruitment and significantly depleted abundance of older fish to less than one fourth of the initial level, possibility of decrease of recruitment in future is still to be a matter of concern.

(III) **BIGEYE TUNA**

Southerly expansion of longline operation in the recent years brought about the

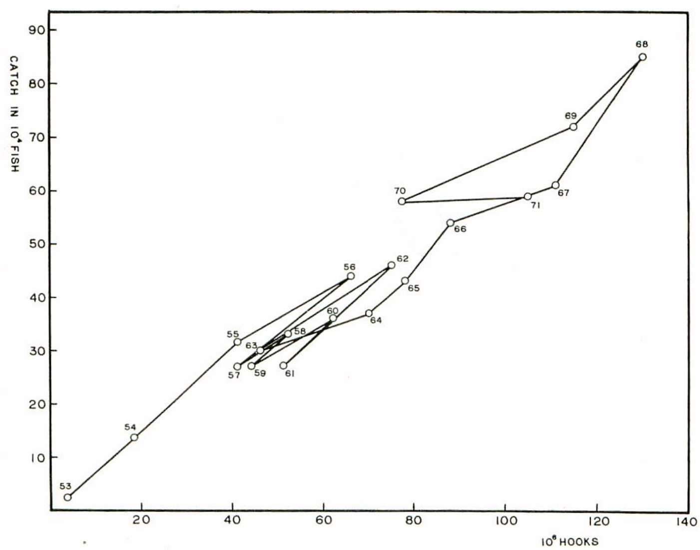


Fig. 15. Yearly number of bigeye tuna caught by longline gear from the whole Indian Ocean plotted against number of standardized hooks in the corresponding year. (Prepared by KUME, FAR SEAS FISH. RES. LAB.)

substantial change in the character of albacore fishery in the ocean. On the contrary, as far as the available data are concerned, such indication of change in the nature of bigeye fishery as in the albacore case is not clear and, generally speaking, discussion in "1972-Report" still seems to be valid to some extent.

The fishing season agrees with a calendar year for this species.

(III)-1. Catch and effort statistics

Amount of fishing effort directed to this species traced somewhat similar course of change to that of yellowfin, attaining at its maximum in 1968, 130 million hooks, being followed by a little decrease in 1969 and remarkable decrease in 1970 as being less than 80 million hooks, which was less than 60% of 1968 effort (Fig. 15). However, it increased again in 1971 to the almost same level as those in 1966, 1967 and 1969, which were between 100 and 120 million hooks, contrary to the decrease in fising effort directed to yellowfiin. The number of fish caught in 1971 remained at the almost same level to that in 1970, which means catch in number per unit effort dropped in 1971 by about 15%. CPUE in the last year of the series of data was one of the lowest encountered in the past of the fishery. The amount of catch in weight in 1971 was 20 thousand tons, a little less than those in 1966, 1967 and 1969 (Fig. 16).

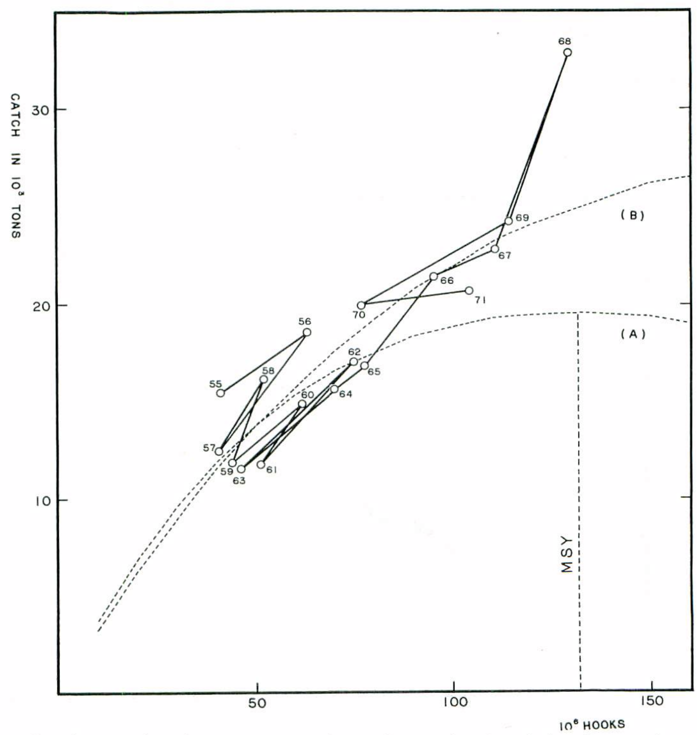


Fig. 16. Observed relationship between number of standardized hooks and resultant amount of catch (10^3 ton) for the bigeye tuna from the overall tuna longline fishing ground of tha Indian Ocean, 1955-1971, with calculated yield curve for the fishing ground in the equatorial area (A) and thet for the whole Indian Ocean (B).

(III)-2. Size composition in catch

The bigeye tuna in the area south of 30°S are mainly young immature fish and, on the contrary, adult fish predominate in the low latitudinal area. Recently, increased effort directed to the southerly area resulted in an increase in catch of immature fish from this area.

Yearly relative abundance by age group derived from KUME's unpulished data for the whole Indian Ocean is illustrated in Fig. 17. It is noted that relative abundance of 5 years old fish and older ones had been on the course of decrease for the years before 1967 but since that year, the rate of decrease has become smaller. Relative abundance of younger fish which had been on the increase before 1967 has been stable for the last two or three years. As a result, annual age composition of any year after 1967 is almost similar each other, indicating that 2 years old fish and younger occupy about 20% of the total and that, on the other hand, proportion of older fish of 5 years and greater reaches to the minimum level throughout the series of data, that is 16% on the average.

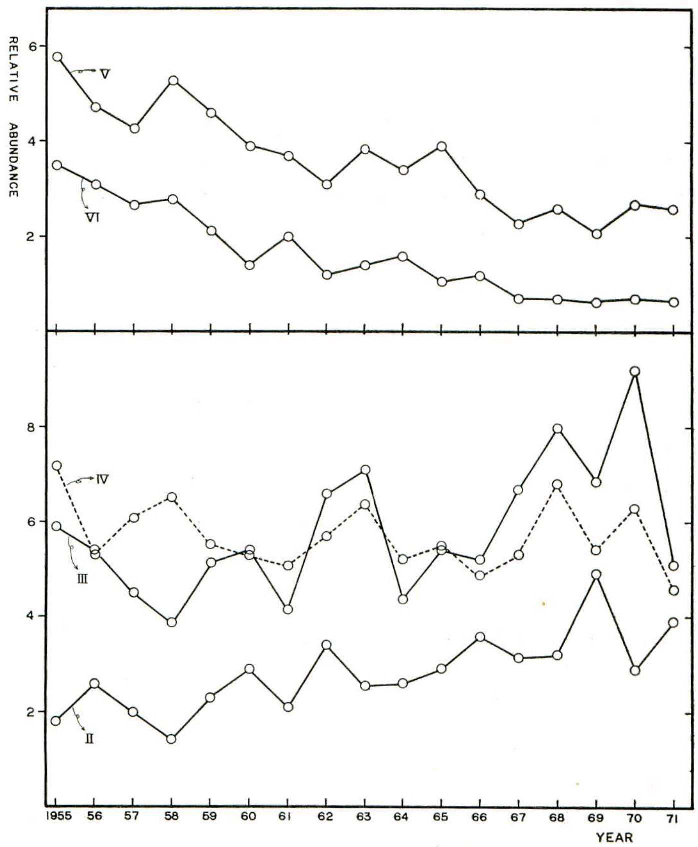


Fig. 17. Yearly change in abundance by age, 1955–1971, for the bigeye tuna from the whole tuna longline ground in the Indian Ocean. (Prepared by KUME, FAR SEAS FISH. RES. LAB.)

Table 6. Yearly catch in number of fish per 10^2 standardized hooks (A), catch in weight (tons) per 10^4 standardized hooks (B) and average weight of fish caught by longline gear (C) for bigeye tuna in the entire Indian Ocean (prepared by KUME)

Year	Standardized hooks(10^6)	A	B	C
1955	41.2	0.76	3.75	49.7kg
6	65.7	0.66	2.82	42.6
7	40.8	0.65	3.05	46.7
8	52.2	0.64	3.09	48.7
9	44.2	0.61	2.68	44.3
1960	61.9	0.58	2.41	41.3
1	51.2	0.53	2.29	43.3
2	75.2	0.61	2.26	37.2
3	46.3	0.64	2.49	38.9
4	70.2	0.54	2.22	42.1
5	78.0	0.55	2.17	39.4
6	98.3	0.55	2.17	39.3
7	111.0	0.55	2.05	37.2
8	129.7	0.66	2.53	38.5
9	114.5	0.63	2.11	33.6
1970	77.2	0.67	2.58	34.5
1	104.5	0.56	1.97	35.1

Yearly average weight of commercially caught bigeye, catches per unit effort in number as well as in weight from the ocean are prepared by KUME in Table 6. The lowest value of catch per unit effort in terms of weight in 1971 fishing season is concomitant results of decline in CPUE in number and average weight of catch.

(III)-3. Analysis of catch and effort data

In the catch-effort relations given in Figs. 15 and 16, the marginal increment of catch has not been remarkably lessened with recent incrase in fishing effort. CPUE's in the recent years are still retained at fairly high level, around two thirds of the five years' average from 1954 through 1958.

It should be noted that since 1967 fishing season fishing activity has been expanded to the south where younger group predominates. Such change in character of the fishery may have resulted in a diminished age of first capture, which possibly raises a change in the course of relationship between fishing effort and resultant catch. However, as is observed in Figs. 15 and 16, for bigeye, there is no definite indication of such an expected change. However, the author likes to note the raised hooking rate in 1968–1970 fishing seasons which happened together with a southerly expansion of longline fishery. This can be a consequence of additional exploitation of immature group that had not been substantially exploited before.

In the present paper, two types of areas for analysis are designated. The one is an area north of 30°S where mature bigeye predominates. In this case, data for the years from 1954 through 1967 are employed. During these years, fishing effort was mainly concentrated to the mature group north of 30°S without any substantial fishing

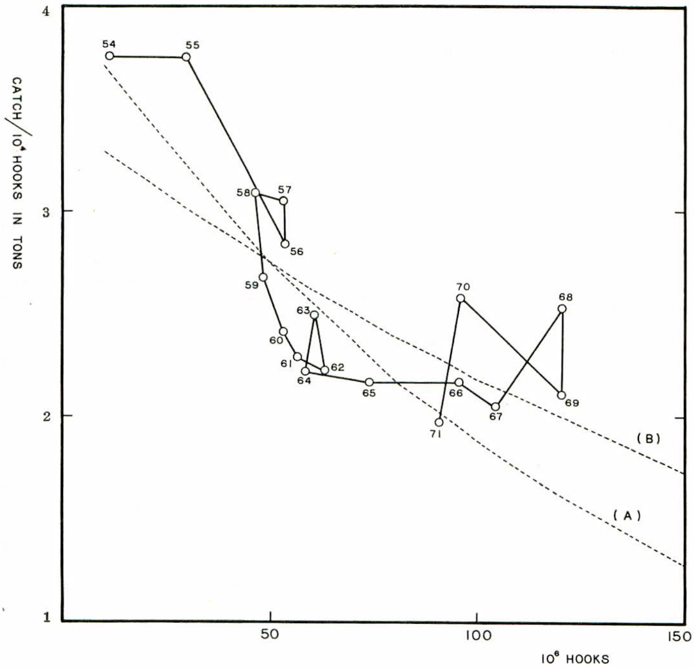


Fig. 18. Annual catch of bigeye tuna in weight per 10^4 standardized hooks plotted againet the average number of standardized hooks in corresponding and preceding seasons.

south of 30°S. The other area for the study covers whole the Indian Ocean for which all the data available from 1954 through 1971 are examined.

(III)-3-1. Catch and effort relationship in the area north 30°S

(1) At first, an analysis of the catch in weight-effort relationship is empirically approached. In Fig. 18, yearly CPUE's (tons/10^4 standardized hooks) are plotted against average numbers of standardized hooks in two successive years, a corresponding year and its preceding one (curve A). Parameters are determined by fitting exponential as follows:

$$\mathrm{CPUE} = 40.2\ e^{-0.0007575X}$$

where X is an average number of hooks in a year and its preceding year. So, amount of annual yield (Y) is given with the equation;

$$Y = 40.2X\ e^{-0.0007575X}$$

and resultant yield curve is illustrated in Fig. 16. A possible maximum yield is 19 thousand tons when numder of standardized hooks reaches 132 million.

(2) The parameter of the catch (in terms of number of fish caught) and effort relationship, magnitude of amount of recruitment (R) and catchability coefficient (q) are estimated for mature group in the tropical waters through SUDA's method 1970, with the use of data from 1954 through 1967. In the calculation, M is assumed at 0.7. In the process, the discrepancy between actual catch and calculated equilibrium yield, due to annual change in fishing intensity, can be corrected. The

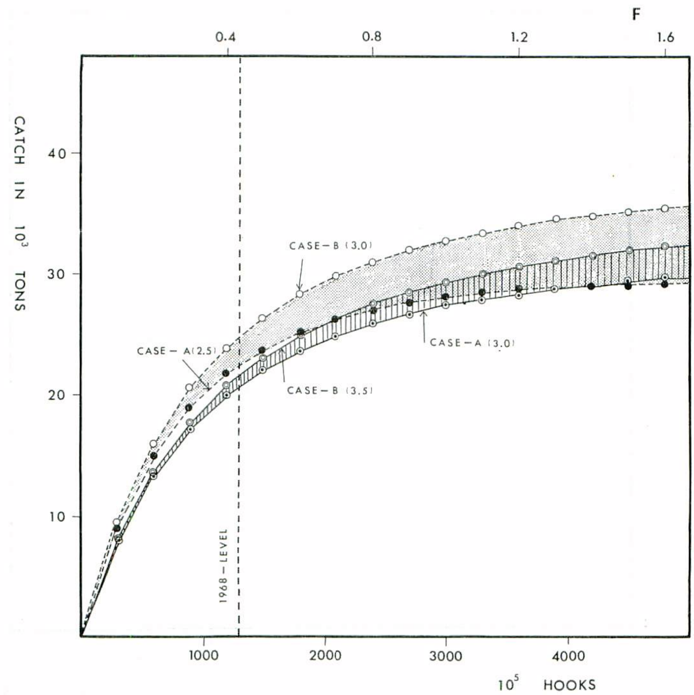


Fig. 19. Calculated yield curve for bigeye tuna in the Indian Ocean.

Yield from south of 30°S	Case-A : age of entry to the area north of 30°S : 3.0
	Case-B : age of entry to the area north of 30°S : 3.5
Yield from the whole ocean	Case-A : age of first capture for the entire ocean: 2.5
	Case-B : age of first capture for the entire ocean: 3.0

calculated amount of recruitment to the longline fishery north of 30°S is 1.61 million fish. And q is estimated at $0.000333/10^5$ hooks. Y/R is calculated for the ages of first capture, 3 (case-A) and 3.5 (case-B) years old, applying growth parameters by YUKINAWA and YABUTA (1963). The result is shown in Fig. 19, which indicates the possible amount of yield from the mature group north of 30°S being 27–30 thousand tons. However, if M-value is overstimated, R and consequently amount of yield are also inclined to be overstimated. Moreover, intensified fishing mortality might reduce the recruit size. Thus, the author is not confident of the calculated values of yield on the righthand side of the curve in the figure.

(III)-3-2. Catch and effort relationship for the whole Indian Ocean

(1) The equivalent analysis to (III)-3-1, (1) is applied to the data for the eighteen years from 1954 through 1971 and results are given as curve (B) in Fig. 18. For the whole Indian Ocean, the calculated largest catch is around 28 thousand tons, which is realized by 218 million standardized hooks. However, the fishery has changed its nature with time on the course of its history of development and the author likes to note that the result is a rather rough one.

(2) The result of analysis in (III)-3-1, (2) is the basis to evaluate the amount of

recruitment at 1 year old. Calculated R's with suppositions on M of immature fish of 0.36 and on the entry to the area north of 30°S at 3.0 (case-A) and 3.5 (case-B) years old, are 3.31 and 3.96 million fish, respectively. Y/R is calculated for the ages of first capture at 2.5 (case-A) and 3.0 (case-B) yeras old, which are chosen considering lowered ages of first capture by exploiting younger group south of 30°S. In calculation, M is supposed at 0.36 and 0.7 before and after the entry to the area north of 30°S. The calculated possible amount of yield is a little more than those calculated for the mature group in the tropical waters. Especially, under a level of fishing effort in the recent years, exploitation of whole stocks including younger member seems to produce a little increased catch though such increase in catch becomes insignificant under the more intensified effort.

(III)-3-3. Assessment

Through the analyses above, the possible largest yield from the whole stocks of bigeye tuna in the ocean seems to be around 30 thousand tons. And utilization of immature group may not reduce the total yield. The average number of standardized hooks and the average amount of commercial catch for the last five years (1967-1971) are 1074 in million and 24 thousand tons respectively. So the suggested increase of catch is not so large one and is several thousand tons or less. On the other hand, through the analyses above, the maximum yield from the whole ocean will be realized only by doubling the present fishing intensity. This means a plan to increase production of bigeye tuna is by no means an economically attractive one. At the same time, it is suggested that there is no definite indication that we experienced the harvest beyond the MSY level. As one possible interpretation about the insignificant influence of the fishery on this species, the author likes to suggest that the ineffectiveness of longline gear to capture this species swimming deeper layer of the tropical waters (SUDA *et al.* 1969).

(IV) SOUTHERN BLUEFIN TUNA

The species is the most heavily exploited one among tunas inhabiting in the Indian Ocean. Japanese longline fishermen have initiated voluntary closure of certain fishing grounds wherein younger immatures predominate (Fig. 20) since October 1971. So the activities of Japanese longline boats since 1971 are the matter of concern how the stock react upon this measure. About the late status of this fishery, WARASHINA and HISADA (1974) are publishing a paper recently. In the present paper, the author likes to summarize only the previously published information on the species.

A longline fishing season of the species covers a period from April of a year through March of next year.

(IV)-1. Catch and effort relationship

In Fig. 21, (WARASHINA and HISADA, 1974) catch and effort data for 1970, 1971 and 1972 (tentative value) fishing seasons are added. The notable fact in these three fish-

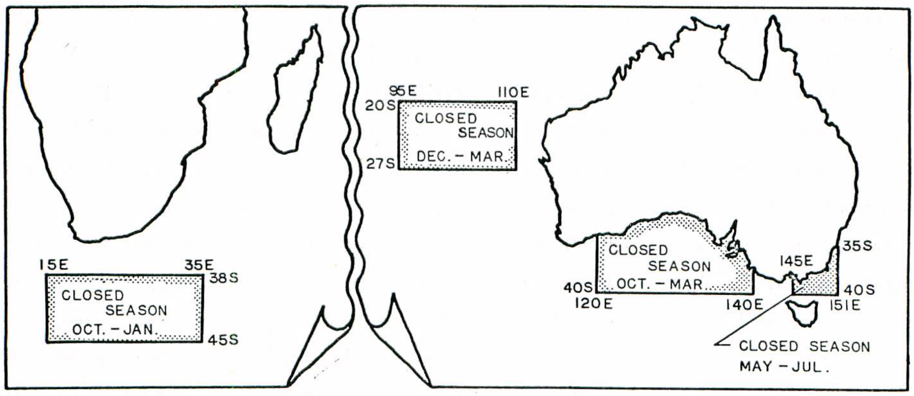


Fig. 20. Closed area for the Japanese longline boats according to the voluntary regulatory plan for southern bluefin tuna executed on 1st, Oct., 1971.

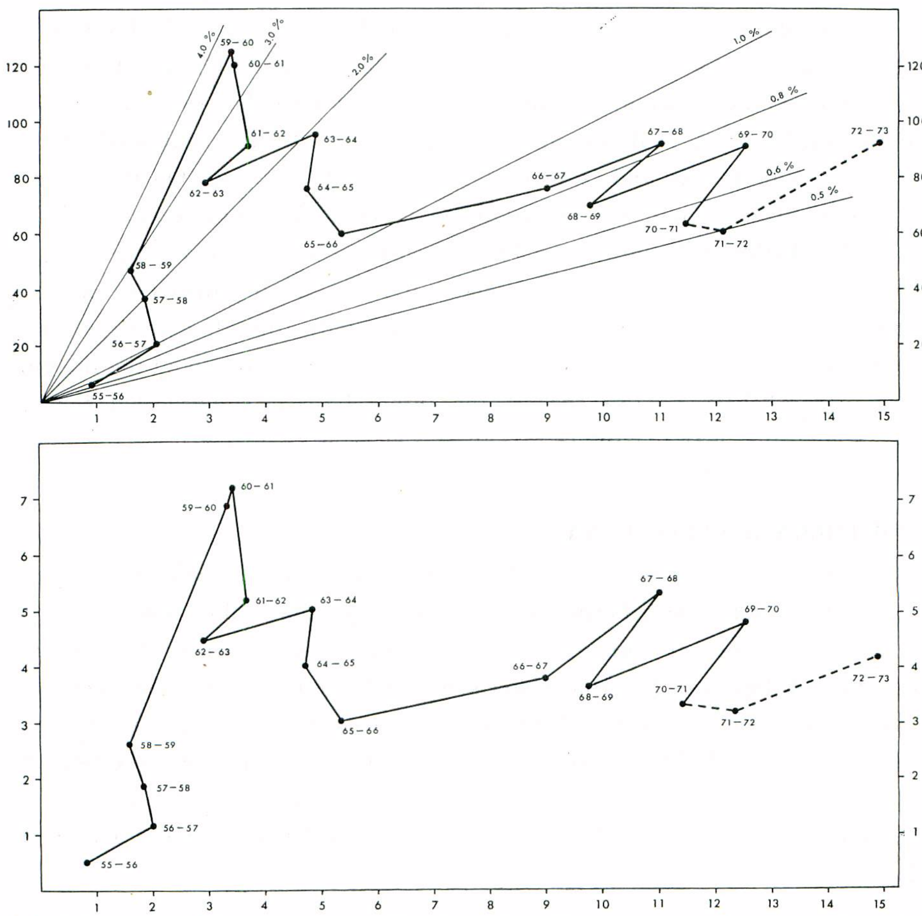


Fig. 21. Observed relation between yield of southern bluefin tuna and amount of standardized effort (10^7 hooks) in the Japanese longline fishery, 1955–1972 fishing seasons. (WARASHINA and HISADA, 1974)

Top : catch in 10^4 fish Bottom: catch in 10^4 tons ing seasons is that though the closure of several fishing areas was adopted by Japanese Tuna Fishermen's Association originaly to prevent exploitation of younger fish, the level of fishing effort did not change much. About the circumstances of the fishery during these fishing seasons, WARASHINA and HISADA describe in some details in their paper but the author likes to note the followings:

(1) As was suggested in "1972-Report", fishing effort on this species decreased a little in 1970 fishing season. In 1971 fishing season, the effort turned back to the almost same level as that of 1969 fishing season. However, in 1972 fishing season, it again increased by 20% of that of 1969 fishing season and number of hooks attained at 150 million hooks. Amounts of catch during the three fishing season, 1969–1971, ranged from 32 to 42 thousand tons, which were almost equivalent to the average catch of the last ten years.

(2) Australian surface catch amounted 7,000–9,000 tons for the last several fishing seasons including 1971–1972. Its CPUE based on the data provided by CSIRO is shown in Fig. 22. The point in the figure for New South Wales in 1969–1970 fishing season in the "1972-Report" was not correct and is revised in the present figure. The figure demonstrates that CPUE is still being fairly well leveled off up to 1972–1973 fishing season. This statistics suggests a steady recruitment of the species.

(IV)-2. Size composition in the comeracial catch

There appears only little decrease in size of fish in commercial catch from various sectors of fishing ground of longline fishery probably due to age dependent segregation in distribution, which brings about an occurrence of particular age groups in different parts of the fishing ground. A trend of the change in hooking rate by different parts of the fishing ground reveals more decrease of stock size of older members than those of younger ones.

Recent changes in average weight as well as age of commercial catch, and average

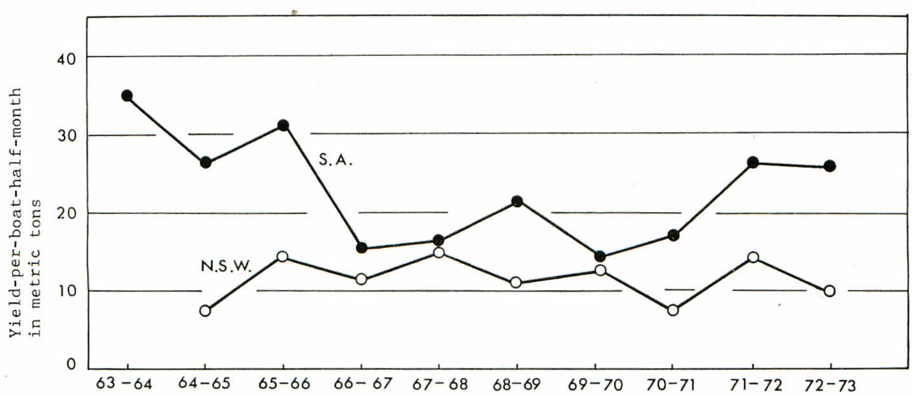


Fig. 22. Yield per boat-halfmonth of southern bluefin tuna in the Australian surface fishery.
Open circle : New South wales Closed circle : South Australia

Table 7. Yearly change in average weight (A), average age (B) and mean age of first capture (C) in the commercial catch of southern bluefin tuna caught by longline gear from 1957 fishing season through 1971 fishing season (prepared by SHINGU and HISADA)

Fishing season	Standardized hooks (10^6)	A	B	C
1957	18.7	49.73	6.75	5.82
8	15.9	55.06	7.20	6.62
9	33.9	55.10	7.22	6.71
1960	34.4	59.82	7.60	7.02
1	37.3	56.79	7.35	6.70
2	29.2	56.37	7.31	6.68
3	48.8	52.26	6.98	6.47
4	47.5	52.71	7.02	6.49
5	53.7	50.91	6.86	6.28
6	90.2	50.19	6.80	6.17
7	110.5	57.23	7.37	6.42
8	97.9	51.44	6.88	5.88
9	125.8	52.60	6.98	6.02
1970	115.3	52.90	6.99	6.22
1	122.2*	46.98	6.49	5.54

Note: *tentative value

age of first capture in longline fishery are shown in Table 7. Still, the trend of decrease of these values with year is observed though the rate of decrease is becoming smaller.

(IV)-3. Stock assessment

In 1969, the necessity of some conservatory measures for the species was announced first by the scientists. In 1970 fishing season, the amount of longline effort decreased a little. In 1971 fishing season when regulatory measures on a voluntary basis planned by the industry was implemented in Japanese fleet, amount of effort was around the same level in 1969 fishing season. However, in 1972 fishing season, it is estimated to be increased by 20 % of the one in 1969 fishing season. Such an increase in the latest fishing season is a matter of concern. This appears to the author to be related to a poor catch of bigeye tuna in the Atlantic Ocean in that year. Also, it is particularly related to the still expanding demanad for *Sashimi* for which southern bluefin and bigeye tunas are best qualified and as a matter of course these two species become more interested in by fishermen. Considering such a situation above, it is quite obvious that the voluntary conservatory activity is efficiently working at least as a break against an extreme increase of longline fleet on this species.

General conclusion on the status of the stock of this species in "1972-Report" and those by HAYASI et al. (1972) seem to be still valid and are summarized as follows:

(1) Amount of catch by longline may not change even though fishing effort be reduced to 5×10^7 hooks. It is clear, even on the empirical basis, that increased

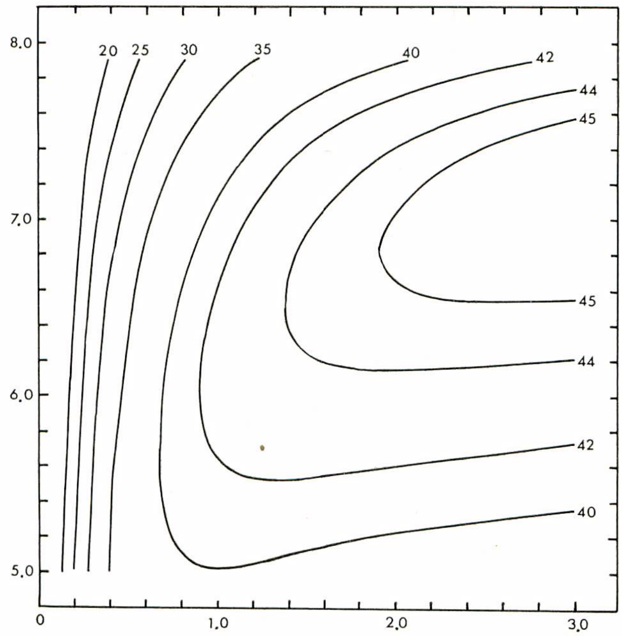


Fig. 23-a. Isopleth diagram of calculated yield of southern bluefin tuna against age of first capture, ordinate, and fishing coefficient, abscissa. Recruit at beginning of 5-age is 1,350,000 fish. Numerals denote calculated yield in thousand tons. (HONMA, 1973)

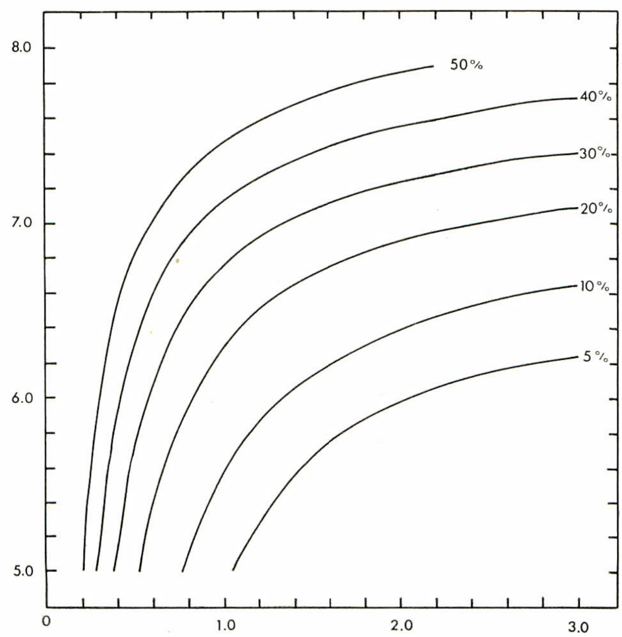


Fig. 23-b. Isopleth diagram of calculated relative stock fecundity in percent of southern bluefin tuna against age of first capture, ordinate, and fishing coefficient, abscissa. (HONMA, 1973).

effort will not result in any increase in catch.

(2) Surface and longline fishing mortality coefficients are approximated, simultaneously employing (a) observed ratio of density index of longline caught fish in i-th season to that in the initial stage of the fishery and (b) ratio of longline yield in i-th season to surface yield in (i-4)-th season based on theoretical Y/R values. Resultant coefficient for surface fishery from 1965- to 1968-fishing season is 0.10-0.13. Average catchability coefficient of unit longline gear (10^8 hooks), q, is calculated at 2.21 and on this basis longline fishing mortality coefficient in 1967 fishing season is estimated at 2.4.

(3) Theoretical calculation suggests Y/R is maximized for a fishery taking 7 age and older groups. Exploitation of such older members does not deplete seriously the stock-fecundity (Fig. 23, HONMA 1973). In this regard, recent decrease in average age of first capture by longline to below 6 years old should be improved.

(4) Insofar as the present level of reproduction of whole population is retained, the surface yield is not dependent upon the effect of longline effort.
On the other hand, increase in surface fishing mortality coefficient of 0.1 curtails the recruitment to the longline fishery by 25 %. Also, it is inferred that one third of the whole young stock enter the Australian surface fishery.

(5) Analysis of catch statistics reveals the spawning stock decreased substantially. The abundance in 1968 fishing season was lowered to one seventh of those in the 1950's. Scientists are anxious that such depletion of spawners might result in a reduced recruitment.
At the same time it is noted that fairly steady CPUE in the Australian surface fishery indicates that amount of recruitment is not yet essentially diminished up to 1971-1972 fishing season. Considering average age of surface catch is 3 years old, it is pointed out that 1968-year class strength was not weakened even by the increased longline fishing mortality in the two foregoing seasons, 1966 and 1967 fishing seasons, during which seasons fishing coefficients are estmated to be 2.0 and greater respectively.
However, calculation suggests recent fishing mortality coefficients of surface and longline fisheries, 0.1 and more than 2.5, respectively, made the stock-fecundity reduced less than 10 % of a virgin stock level.

Recently, HYND and LUCAS (1972), applying LUCAS's method (in press), examined the recapture data of tagging experiment for the estimation of the mean fishing mortality coefficient (F), coefficient of loss other than fishing mortality (X) and rate of movement of fish between the various components of the population. Through their analysis, they suggested:

(1) F and X for Australian fishery are estimated at 0.29 and 1.63 respectively.

(2) Amount of recruitment to the Australian surface fishery and that to Japanese longline fishery are 4.09 and 1.91 million fish respectively.

(3) F for Japanese longline fishery is estimated at around 0.1 and increase in catch by 25 % of the present amount can be expected with increased effort of intensity of twice or three times of the present level.

They also pointed out that one of some questions in their conclusion is concerned with fishing intensity of longline fishery. In this point, the present author considers that their estimate on F for longline be too small to explain the actual yearly change in hooking rate (R/Z) in the fishery (see foot-note*).

As already mentioned, the empirical relationship given in Fig. 21 as well as various calculation of Y/R with t_c of 5 years old or greater (see, for example, Fig. 41 of SUDA 1971, which was prepared by HAYASI *et al.*) indicate no increase in longline catch with increased effort beyond the present level. Even HYND and LUCAS's study suggests that an expected increase in catch with doubled or tripled fishing intensity is only 25 % of the present amount. So the matter of concern is rather how to secure the stabilized recruiment of present level than whether an increase in amount of catch is feasible or not.

Summary of analyses and problems that demand special attentions

(1) Amount of estimated maximum catch for each species is changed a little through the present study, and the comparison with previous estimates is as follows (in thousand tons):

Species	IOFC W. P. 1969	"1972-Report"	Present study
Yellowfin	30-35	30-35±*	35±*
Albacore	20-25	20-25	25-26 (17-18**)
Bigeye	22-28	30-32	28-30 (20-30(?)**)
Southern bluefin	35-40	35-40	35-40

Remarks: * varies with natural fluctuation.
** calculated maximum catch from the area north of 30°S without any significant exploitation on the immature group south of 30°S.

(2) Throughout the study, southern bluefin tuna is the most heavily exploited species

* Recent level of longline CPUE is lower than one fifth of that in 1959 or 1960 season. During these two fishing seasons, fishing intensity was one fifth of recent year's level for each of the coastal surface and the offshore longline fisheries. If F of longline is 0.1 in recent years as suggested by HYND and LUCAS (1972) and M is 0.2, the ratio of hooking rate in recent years to those from 1959 and 1960 season must be 0.6. $R_2/(0.2+0.1)$ divided by $R_1/(0.2+0.02)$ makes 0.6, where R_1 is annual number of recruit to the longline in 1959 or 1960 season and is calculated to be 0.585N (N: the estimated number of 2.5 years old recruit) with supposition on mortality coefficient of 0.06 for the surface fishery (annual surface catch in 1958 or 1959 season was approximately one fifth of the recent years' level), and R_2 is recruitment size in recent years that is estimated at 0.467N by HYND and LUCAS (op. cit.). However, the observed ratio of recent hooking rate to those in 1959 and 1960 season is not 0.6 but actually smaller than 0.2. The author's calculation of the recent value of longline-F must be more than 2.0 to explain the observed decrease in CPUE.

in the ocean. Maintenance of the stock-fecundity is an urgent subject, for which practical conservatory measures are to be implemented. And it is desirable that voluntary regulation taken by Japanese Tuna Fishermen's Association is further supported and encouraged.

(3) Through the present study, the author was seriously awaked by need of improved catch and effort statistics. To reach better conclusion, a study considering biological separation of stocks is an essential course in future. In the analysis of dynamics of yellowfin, local groups should be delineated better. For albacore and bigeye, dynamics of population must be examined on mature and immature groups separately. Southern bluefin is a species of remarkable age-dependent distribution. Thus, catch and effort statistics by 5° square as a smallest unit for longline fishery is earnestly desired, and at the same time cooperative preparation in this standpoint with the whole longline fleets operating in the ocean is strongly advocated.

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インド洋ではえなわ漁業の対象となるまぐろ類資源の近況（要約）

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インド・太平洋漁業理事会，インド洋漁業委員会合同まぐろ類資源評価臨時作業部会は，1972年（昭和47年）6月，ローマにて開催された。この部会の目的は，インド洋のまぐろ類資源の近況を評価するとともに，必要とあらば資源管理措置の必要性についても検討を行なうというものであった（FAO 1973, SUDA 1973）。この部会には数篇の報文が提出されたが，そのうちの1篇"インド洋のまぐろはえなわ漁業の近況"は著者のもので，このなかで日本，韓国および台湾のはえなわ船隊の活動状況と，これらの漁船隊の漁獲対象となっている資源の現状について観察と分析が行われている。

本報告は上述の論文（今後1972年報告とよぶ）に，1971年漁期迄のデータにもとづいた分析結果を附け加えインド洋のまぐろ類資源についての考え方を再整理してみたものである。

近年のまぐろはえなわ船隊の活動状況

1970年および1971年におけるインド洋でのまぐろ類ならびにその近縁種の漁獲量は，それぞれ22.2万トンおよび24.3万トンで，そのうち日本，韓国および台湾船による漁獲量の合計は11.2万トンおよび11.8万トンである。この値はインド洋水域からのまぐろ類ならびにその近縁種の総漁獲量のほゞ1/2にあたる。

1972年報告でも述べたように，インド洋におけるはえなわ船隊の活動は1968年から1969年にかけてピークに達した。1970年には漁獲努力量はやゝ減少している。しっかりした資料に基づく推定ではないが，1972年には漁獲努力量は全体としてやゝ増大したのではないかと思われる。

第1図に1969年と1971年を例に，日本船と台湾船の努力量分布を示す。両船隊の漁場撰択には著しい差があり，台湾船が主としてキハダ，季節的にはビンナガをねらって熱帯域に集中しているのに対し，日本船はミナミマグロを主対象に，他の種々のまぐろ類を合せ獲るという形で，熱帯から亜熱帯水域にかけて広く分散している。このような主対象魚種の相違は夫々の船隊の持つ市場のそれに由来するものであろう。韓国船については詳細な資料は得ていないが，おそらく台湾船とよく似た型の操業を行っているのであろう。

近年における主要はえなわ対象魚種の資源状態

I. ビンナガ

第2図に，インド洋のビンナガ漁場全体をこみにした標準努力量と漁獲量の関係を示す。1971年漁期の漁獲

努力量については２つの漸定値，A，Bが示してある。推定値Bは，従来インド洋のビンナガ漁場で観察されてきた努力量－漁獲量関係からはいちじるしくかけはなれたところにある。推定値Aは，台湾船隊による漁獲重量と日本，韓国，台湾船隊の漁獲量の合計の比を用いて，台湾船隊の努力量をひきのばして求めた全体の漁獲努力量であり，推定値Bは，日本船隊の漁獲量を基準に上述した手順にしたがって計算した全体の努力量である。推定値AとBの相違は日本船隊と台湾船隊の単位努力当り漁獲量のそれに基くものである。1971年漁期での日本船の鈎1000本当り漁獲量は77.23kg，一方台湾船のそれは168.26kgで，日本船の2.2倍になっている。そのため日本船の単位努力当り漁獲量を基準に韓国，台湾船隊の努力量を推定すると過大評価をまねくことになる。このように日本船の単位努力当り漁獲量が小さいのは，日本船が近年ミナミマグロを主対象として操業を行い，韓国，台湾船のようにすくなくとも季節的にはビンナガを主体象とすることがないためである。近年日本船の漁場は著しく南方に拡大している（第３図）。30°Sの南側と北側ではビンナガの大きさも密度も著しく異なる。このようにして，従来行ってきたインド洋のビンナガ漁場全体をこみにした努力量と漁獲量の関係の分析には意味がなくなりつゝある。

ところで1972年報告では，全インド洋からの資料をこみにして分析を行い，努力量を増加させても漁獲量は増えないだろうということを示唆した。同じ報告で，近年の小型魚の開発にもかかわらず，努力量と漁獲量の関係には顕著な変化は認められないと述べた。しかし，今回の分析結果によれば，近年の漁業の性格の変化に伴ってインド洋全体の資料をこみにした努力量一漁獲量関係には意味がなくなりつゝある。このような事情を考えて，努力量一漁獲量関係の分析は，２つの群一30°S以北の成熟群と以南の未熟群一のそれぞれについて別個にすゝめた。

1：30°S以北の成熟群

自然死亡係数Mは0.4―0.6と推定される。この推定値のもとでは加入尾数は113―121万尾と計算される。生産量曲線を計算してみると，現在の水準を超えて努力量を増しても漁獲量は増加しないと判断される。第６図に示すように，釣獲率も初期の 1/3 に低下しており，これも上述の推定を裏づける。30°S 以南の水域に未成熟魚を対象とする大きな漁業がないとして，30°S 以北からの最大漁獲量は 1.7―1.8 万トンである。1970年に 30°S 以北の海域である程度漁獲が減少したが，これは 30°S 以南の海域での小型魚の漁獲と関連しているように思われる。

2：30°S以南の未成熟群

釣獲率は1967年以降，明らかに低下し，近年は1966年以前の水準の 1/2 になっている。漁獲物の平均年令は４才，したがって，漁獲された魚がこの海域に滞在する平均期間は約２ケ年間であって，年間漁獲量が40万尾（1967-1969年漁期）および20万尾（1970年漁期）の場合，30°S以北の産卵群への加入量はそれぞれ22―24%および11―12%減少すると推定される。

さきに計算した産卵群への加入量113―121万尾と，未成熟群の自然死亡係数の推定値0.2がそんなに無茶な値でなければ，大きな漁業がない場合，30°S以南の漁獲対象群の尾数は550―590万尾となる。一方，過去のこの水域からの最大の漁獲量は40万尾であるが，これだけの漁獲がある場合の漁獲死亡係数Fは0.07と計算される。また，このときの単位努力当り漁獲量の水準は，計算上は処女資源の88%となる。だから近年のこの海域での釣獲率の急激な低下は，漁獲にだけ帰すことは出来ず，努力量の標準化がうまくいっていないことや，年級群の自然変動とも関連していると考えられる。

小型魚を開発することがビンナガ資源全体についてみたY/Rをどう変化させるかということも関心のもたれる問題である。未成熟群と成熟群のMが異なるという前提のもとに生産量曲線をもとめてみた（第８図）。近年の漁獲強度のもとでは，漁獲開始年令を2.0才以下にひきさげげない限り，Y/Rが小さくなることはない。もっとも効率的な資源利用は，漁獲開始年令が3.5―5.5才の時に実現され，この時のインド洋ビンナガからの総漁獲量は2.3万トン前後と計算される。

II. キハダ

本報では1972年報告で用いた統計数値をかなり修正している。しかし，努力量と漁獲量の関係には本質的な変化はおきていない。両者の関係について目ぼしい点は，(1) 標準鈎数 50×10^6 本を超えると漁獲量は殆んど

横這いになること，(2) 年級変動にもとづくと思われる顕著な漁獲量変動があること，そして，その変動係数は重量については35%，尾数について50%であることの２点である。勿論，釣獲率は漸次低下して初期の 1/4 になっている。

このような努力量と漁獲量の関係をインド洋全体をこみにして分析するだけでなく，本種の系群構造にある程度の地域性が示唆されている点も考慮しながら，小海区毎に観察してみることも重要である。しかし，全ての船隊についての海域別統計が入手できないため，今回はこの種の分析は行い得なかった。

努力量と漁獲量の関係をもっと詳細につかむために，はえなわ漁業への加入尾数を計算したところ 190 万尾となった。自然死亡係数0.8，漁獲開始年令2.5才として，Y/R と生産量曲線（第９図)をもとめてみた。生産量曲線をみると，現在の水準以上に努力量をふやしても漁獲増は期待できない。また，最大漁獲量の推定値は 3.5万トンである。処女資源尾数は240万尾という計算になるが，しかし，例えば1956年や1968年の漁獲量はそれぞれ処女資源尾数と同じか，それ以上になっている。平均加入量がそう大きくない（約 190 万尾）ことを考えると，このような大きな漁穫は異常に大きい年級群の加入があった時にのみ可能である。

近年，親魚量は初期の 1/4 になっているが，これで持続的な再生産が可能がどうかが問題である。この点については，本間，鈴木（1972）が1969年漁期迄は加入が維持されていたことを明らかにしている。しかし，彼等は，加入量が維持されているという現象は，実は漁場の中心が近年小型魚の割合の大きい西部インド洋海域へ移行したことに伴う単に見かけ上のものかもしれないと心配していたのである。今回，インド洋を東西に２分し，そのそれぞれについて年令別魚群量の年変動を分析した結果によれば，西側海域でも東側海域でも小型魚の量は横這いである。それにしても親魚の量が 1/4 というのは気になることがらである。

III. メバチ

ビンナガの場合，近年の南方への漁場拡大は漁業の性格に顕著な変化をもたらした。しかし，メバチについては，資料が示す限り，このような変化はビンナガ程には明瞭でなく，1972年報告で説明した研究結果が，ある程度まで，そのまゝ有効である。

第15，16図に示すように，近年の努力量の増加にもかかわらず，漁獲量の marginal increase は，そうはっきりとは小さくならなかった。近年の単位努力当り漁獲量，すなわち魚群量指数も依然として高い水準，すなわち，1954—1958年の間の５ケ年平均の 2/3 位のところにある。1967年以降，漁獲努力は若年魚の卓越する南方水域へと拡っていった。このような操業水域の変化は，努力量と漁獲量の関係に変化をもたらすと思われる。しかし，このような予想に反して決定的な兆候はまだ現われていない。たゞ，漁場が南方に拡大した1968—70年漁期の釣獲率がその前数ケ年間のそれより高かったことは留意しておくべきであろう。

今回は２種類の分析を行った。そのひとつは 30°S 以北の成熟メバチ群についての分析で，ここでは1954—67年の間の資料を用いた。この間 30° S以南水域での漁業規模はたいしたことはなかったからである。もうひとつの分析はインド洋メバチ全部をこみにしたもので，1954—71年の間の資料全部が吟味されている。これらの分析を綜合すると，全インド洋からの可能最大漁獲量は３万トン前後と思われる。また，30°S 以南の海域での若年魚の利用が全生産を減少させることはないと推定される。過去５ケ年間の平均投下鈎数および漁獲量はそれぞれ 1074×10^5 本および 2.4 万トンであった。だから，期待できる増産量はさして大きくなくて，数千トンというところであろう。一方，この数千トンの増産のために，上述の分析によれば，現在の努力量を２倍にしなければならない。

IV. ミナミマグロ

本種はもっとも強度に開発されている魚種である。日本のはえなわ漁業者は1971年10月以降小型魚の多い海域の自主的な閉鎖を行っている。したがって，1971年以降の日本のはえなわ船の動向は，資源のそれと関連して関心のもたれることがらである。

1972年報に示したはえなわの努力量と漁獲量の関係に，1970，71および72年（暫定値）のデーターを附け加えたのが第21図（薬科・久田，1974 より）である。この３ケ年間での注目すべき事実は，日カツ連による漁場の自主的閉鎖がこの間に発足したが，努力量の水準は大きく変らなかったということである。即ち，1972年報でも予測したとおり，1970年には努力量はすこし減った。1971年には努力量は1969年の水準に戻り，さらに

1972年には努力量の水準は1969年のそれの20%増で使用鈎数は 150×10[6] 本になった。1967年から 1971 年にかけての 3 ケ年間の漁獲量は3.2—4.2万トンで，その平均は過去10ケ年間の平均にほゞ一致する。

一方，オーストラリア沿岸表層漁業による過去数ケ年間の平均漁獲量は7000—9000トン。1972年漁期まで単位努力当り漁獲量は横這いを続けている。これは加入が安定していることを示唆するものであろう。

1972年のはえなわの努力量が1969年のそれの20%増であったことは既に述べたが，これは注目されることである。この努力量の増大は，この年の大西洋のメバチが不漁であったこととある程度関連しているように思われる。別に日本国内では刺身への需要が年々増大しており，これを反映して刺身材料としてすぐれたミナミマグロとかメバチへの努力量集中も当然年々顕著になってゆく筈である。これらの事情を考えると，最近3ケ年間での努力量の増大はむしろ予想外に小さかった。自主規制は少くともミナミマグロに対する極端な努力量集中に対する歯どめとしてかなり効果的に働いているとみてよさそうである。

近年，HYND と LUCAS が標識魚の再捕資料を使って漁獲死亡係数F，漁獲死亡を除いた全死亡係数Xや魚群の移動率を推定している。彼等の結果は以下のとおり。

(1) オーストラリア表層漁業のF＝0.29，X＝0.63

(2) オーストラリア表層漁業，日本のはえなわ漁業への加入尾数はそれぞれ409万および191万尾

(3) 日本のはえなわ漁業でのF＝0.1で，努力量を 2—3 倍に増加させることによって，はえなわの漁穫は25%前後増える筈。

彼等自身，上述のはえなわ漁業についての彼等の推論について多少の疑問をもっているし，著者も，彼等のはえなわのFについての推定値は，はえなわ漁業のなかで実際におきた釣獲率の変化を説明するには小さすぎるような気がしている。

実際に過去に観察された努力量と漁獲量の関係（第21図）や，Y/R についての計算値が示すように，ミナミマグロ資源に対し現在の水準以上に努力量を投下しても漁獲増は期待できない。HYND と LUCAS の推定でも，努力量を 2—3 倍にふやして漁獲増はやっと 25% である。したがって，漁獲増が可能であるか，否かという議論はすでに大きな課題ではなくなっている。問題は現在の加入量の水準をどういう風にして維持してゆくかということである。

結果の要約と残された問題点

(1) この研究の結果，過去の最大可能漁獲量の推定値に多少の修正が生じた。しかし，この修正は大きいものでなく，インド洋のまぐろ類資源の開発状況についてのこれまでの観方を変更する必要はない。以下に過去の最大可能漁獲量に関する推定値と今回の結果を比較しておく（単位1000トン)。

魚　種	IOFC・1969	1972年報告	今回の結果
キハダ	30 — 35	30 — 35±	35±
ビンナガ	20 — 25	20 — 25	25 — 26
メバチ	22 — 28	30 — 32	28 — 30
ミナミマグロ	35 — 40	35 — 40	35 — 40

(2) ミナミマグロはインド洋のまぐろ類のなかではもっとも開発の進んだ魚種である。資源の再生産力を確保するために実効の期待できる管理策がとらるべきである。したがって，日カツ連のやっている自主規制は望ましいことであり，もっと支持さるべきことがらである。

(3) キハダの場合，もっとしっかりした地域群の画定が必要であるし，ビンナガとメバチについては，資源評価は成熟群と未成熟群にわけて行わねばならない。ミナミマグロは年令によって顕著に分布を変える。したがって，はえなわ漁業については5°区画別統計が必要であり，このような統計がインド洋で操業する全ての船隊について整備されることを強く望むものである。