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HYDROGRAPHY IN RELATION TO TUNA FISHERIES IN THE INDIAN OCEAN

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ABSTRACT

Tuna fishing grounds in relation to hydrographic conditions were studied from the data obtained during the IIOE (1960-64). The most abundant catch of the yellowfin tuna was found in the equatorial countercurrent area and in the south equatorial current areas. The Indian Ocean central water area and subtropical convergence area (75°E) formed good ground for albacore tuna. The big-eye tuna occurred in subtropical convergence area with the maximum concentration of fishes along the marginal areas. The results indicate that the upwelling areas are favourable for tuna fishing in the equatorial zone.

INTRODUCTION

Subpolar intermediate waters coming from the higher latitudes to lower subtropical and tropical latitudes have potentialities to enrich the upper euphotic zone through the physical processes such as upwelling or upward flow, convectional mixing, overturn or turbulent mixing due to the transport of nutrient-rich water. Gales such as hurricanes, cyclones and strong monsoons also cause upwelling, convection and turbulent mixing. Accompanying eddies along the boundaries of major oceanic currents may result in mixing of deeper nutrient-rich-water in the upper sun-lit layer of the above mentioned storm-breeding vorticity zone. The cyclonic eddies in particular of the northern hemisphere and anti-cylonic eddies of the southern hemisphere give rise to highly fertile water respectively from the deep layer in their cores.

As usual, intense photosynthetic activity of phytoplankton starts, in the euphotic zone, which leads to grazing of zooplankton and successive prey predators interactions in the food-web at each tropic level and consequently results into the successful abundance of commercial fishes. In this way, a productive zone is established in the equatorial belt of the Indian Ocean, similar zones can also be recognised as a result of equatorial undercurrent and equatorial counter-current in the open sea of the Indian Ocean.

From the data obtained during the IIOE (1960-1964), we have studied tuna fishing grounds in relation to hydrographic conditions and some of the results have been reported below :

Tuna Fishing Grounds In Relation To Hydrography In The Eastern Indian Ocean

The Japanese participation (1960-1964) of the IIOE included 4 fisheries training and research vessels (*Umitaka Maru, Koyo Maru, Kagoshima Maru* and *Oshoro Maru*). During the northern winter, we found a remarkable zone of discontinuity at the meridional sections of the Indian Ocean near the latitude 15°S. In the northwestern offing of the Australian continents, wherein a conspicous cold and fertile upwelling area is located, the mixed subantarctic intermediate water in the upper layers, south of Sunda Islands can be recognised. This is intercepted by the north Indian saline water having its origin in the

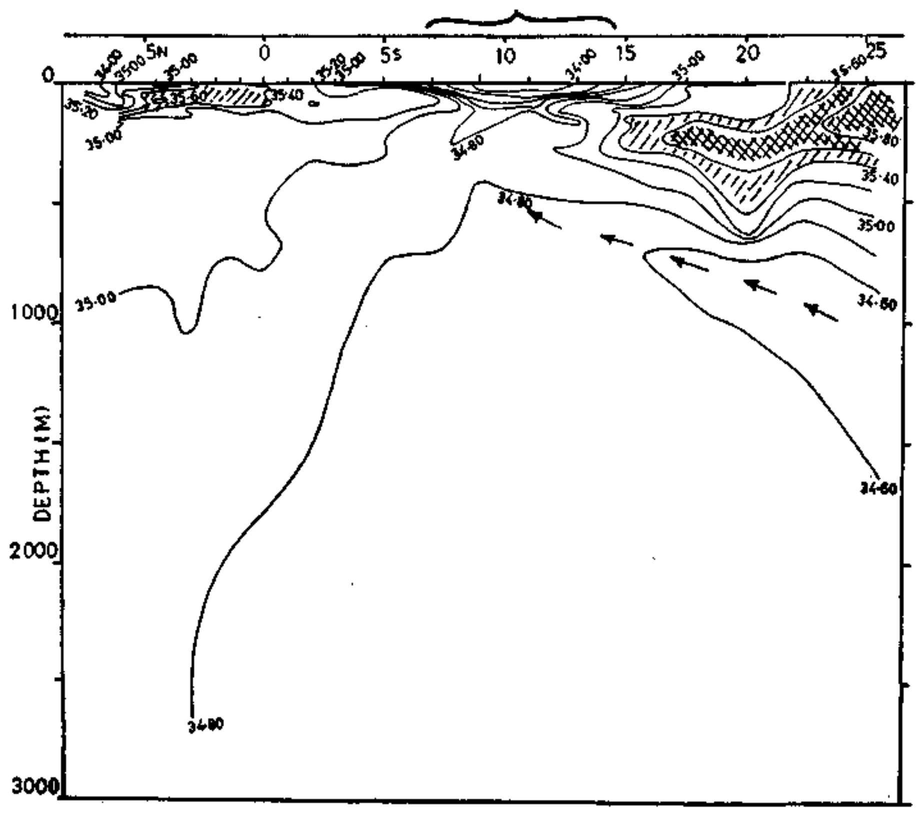

Fig. 1. Vertical distribution of salinity (‰) along the maridional line 78°E (1962/'63)

Arabian Sea and the south Indian saline central water (Figs. 1 and 2). In the northern summer, the line of discontinuity (equatorial oceanic front) still existed and continued till winter. (See the result of the Australian survey CSIRO, 1963-65). The productive zone coincided with the intertropical convergence zone (a train of atmospheric anticyclonic eddies or the breeding zone of cyclones and hurricanes) which corresponded to the above upwelling zone.

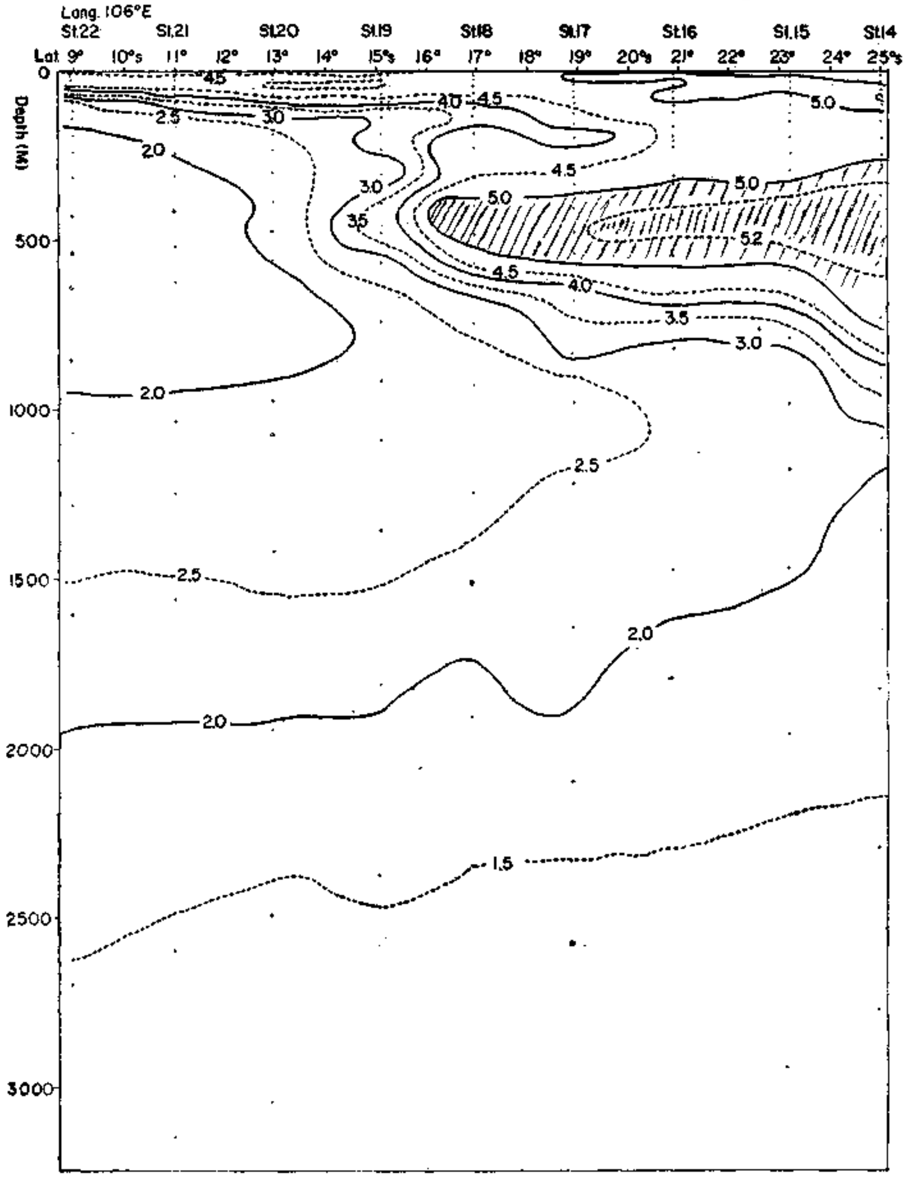

Fig. 2. Distribution of dissolved oxygen (ml/l) along the meridional line of 106°E.

We have noticed considerable variation in the distribution patterns of water temperature, salinity etc. between the winters of 1962/'63 and 1963/'64. This indicates the general northern shift of the current systems and the upwelling area of the above-mentioned cold water in the eastern Indian Ocean, in response to changes in meteorological conditions, e.g. a contrast in the distribution of salinity at 100 m depth in both years. (Figs. 3a and 3b). The world-wide abnormal climatic year 1963 is noted by the prevalence of northeast monsoon with abnormal coldness in the southeast Asian region in response to southerly invasion of jet-stream (planetary development of three waves pattern).

The biosphere was closely related to the above oceanographical structure and variation. The distribution maps of primary production prepared by Sugawara and Saijo, sea-birds and fishes by Ozawa and total tuna catch by Uda (Nat. Comm. for IIOE, Japan, 1966) agreed with the distribution of salinity-minimum belt (upwelling zone of the subantarctic intermediate water) as shown in Figs. 1 and 2.

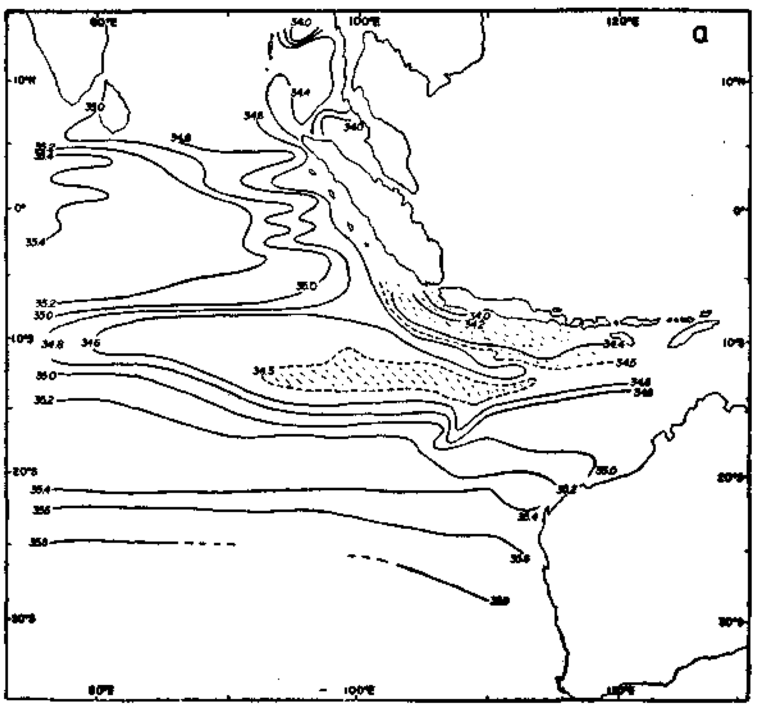

Fig. 3a. Horizontal distribution of salinity (‰) at the depth of 100 m in the winter of 1962/'63.

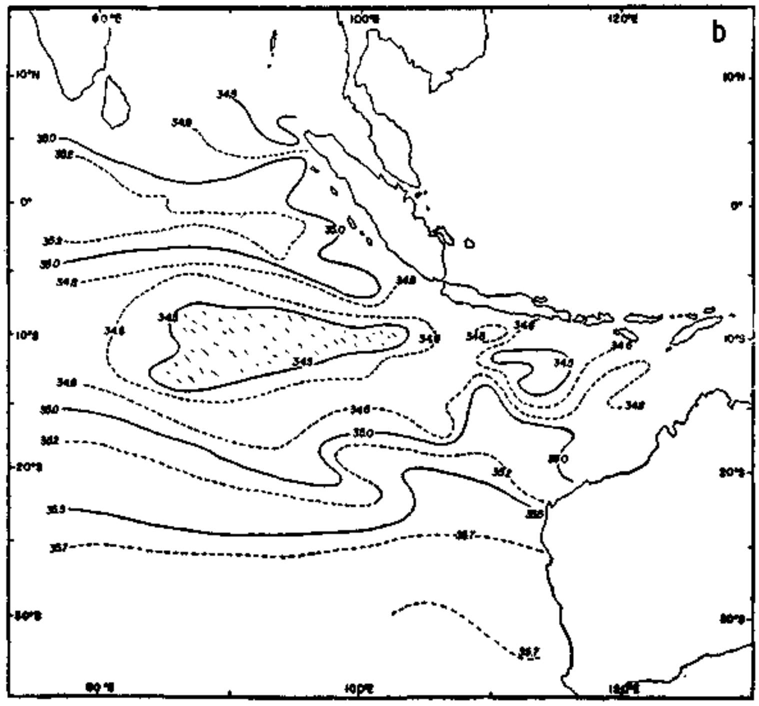

Fig. 3b. Horizontal distribution of salinity (‰) at the depth of 100 m in the winter of 1963/'64.

Water masses in the eastern Indian Ocean were analysed as indicated in Fig. 4 and the following areas were identified:

A .... South Indian Ocean central water (highly saline)
B .... Arahura sea water (low saline, high temperature)
C .... Arabian Sea origin north Indian water (highly saline)
D .... North Indian Ocean origin of waters in the Bay of Bengal (low salinity)
E .... mixed water, upwelled in the area, south to Sunda Islands
F .... mixed water, flowing to west in the south equatorial current.

Summarizing the above, we can conclude that the most favourable tuna fishing grounds are located mainly around the marginal areas of the above mentioned upwelling zone. We recognize similar oceanographic and fisheries conditions in the western Indian Ocean as described later (IIOE-Japan, 1966; Suda, 1971; Ramanathan, 1969). In conclusion, it seems that from the west to the east belt, located along 10°S-15°S in the Indian Ocean, has the zone of demarcation, which is a highly productive area. It has water of relatively low salinity due to the mixing of upwelled subantarctic intermediate water, with the highly saline watermasses of the north and south Indian Ocean (see above A and C).

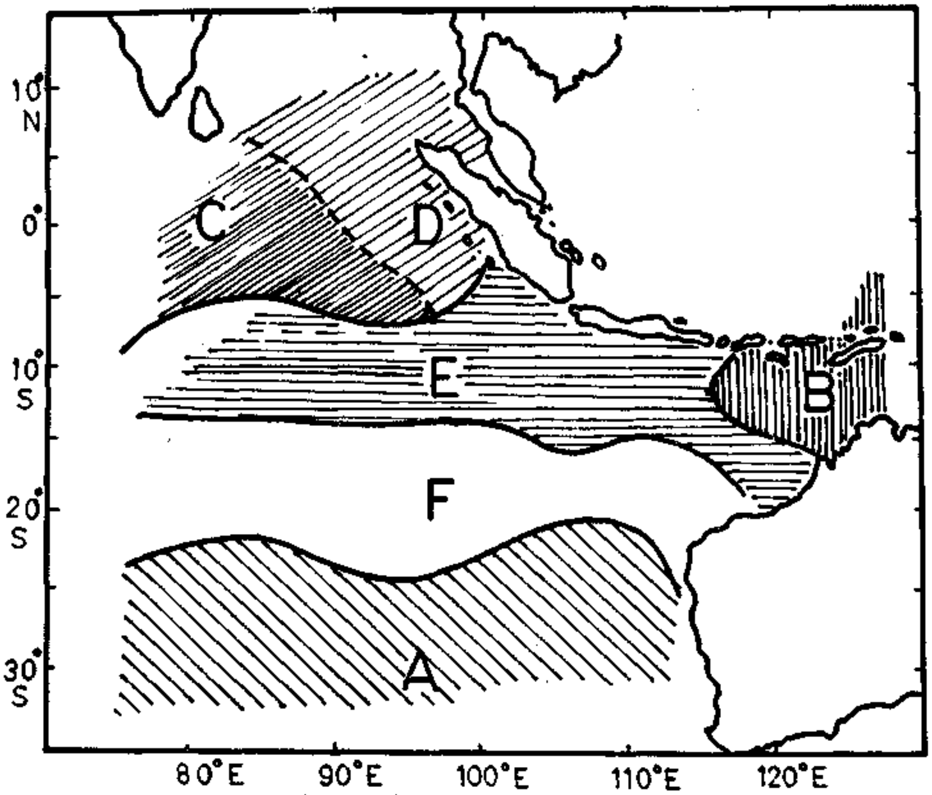

Fig. 4. Distribntion of water masses

The southward expansion of the lower salinity water in the surface layer, west of Sumatra, changes from year to year. The variation in the core pressure which is low in summer is also important. Variability in the oceanic climate was illustrated by isotherms and isohalines at the meridional sections and along the horizontal levels above 600 m depth. Seasonal oceanic changes—the most remarkable one in the pre-monsoon period, from April to May, and the year by year changes induced by the incoming monsoon—are very well pronounced. These may be responsible for the dominant year-classes of tunas and consequently to their abundance.

Tuna Fishing Grounds and Oceanic Fronts in the Western Indian Ocean, Basing on the Data by the *Anton Bruun's* Survey.

The surveyed areas by the *Anton Bruun* (Cruise 5, January 26-May 4) during the US Program in Biology of IIOE, can conveniently be divided into the following three regions : i) Arabian Sea (January 27-February 3), ii) 10°N-36°S along 55°E line (February 5-March 9), and iii) 43°S - 5°N along 75°E line (April 4-30), (Fig. 5). Experimental fishing using Japanese tuna long-line was carried out at 38 stations (5 along i, 17 along ii, 16 along iii) with 45 baskets at each station and 6 hooks per basket on the average.

(a) *Hydrographic results of the survey along 55°E and 75°E*
55°E (Fig. 6 a, b, c, d)

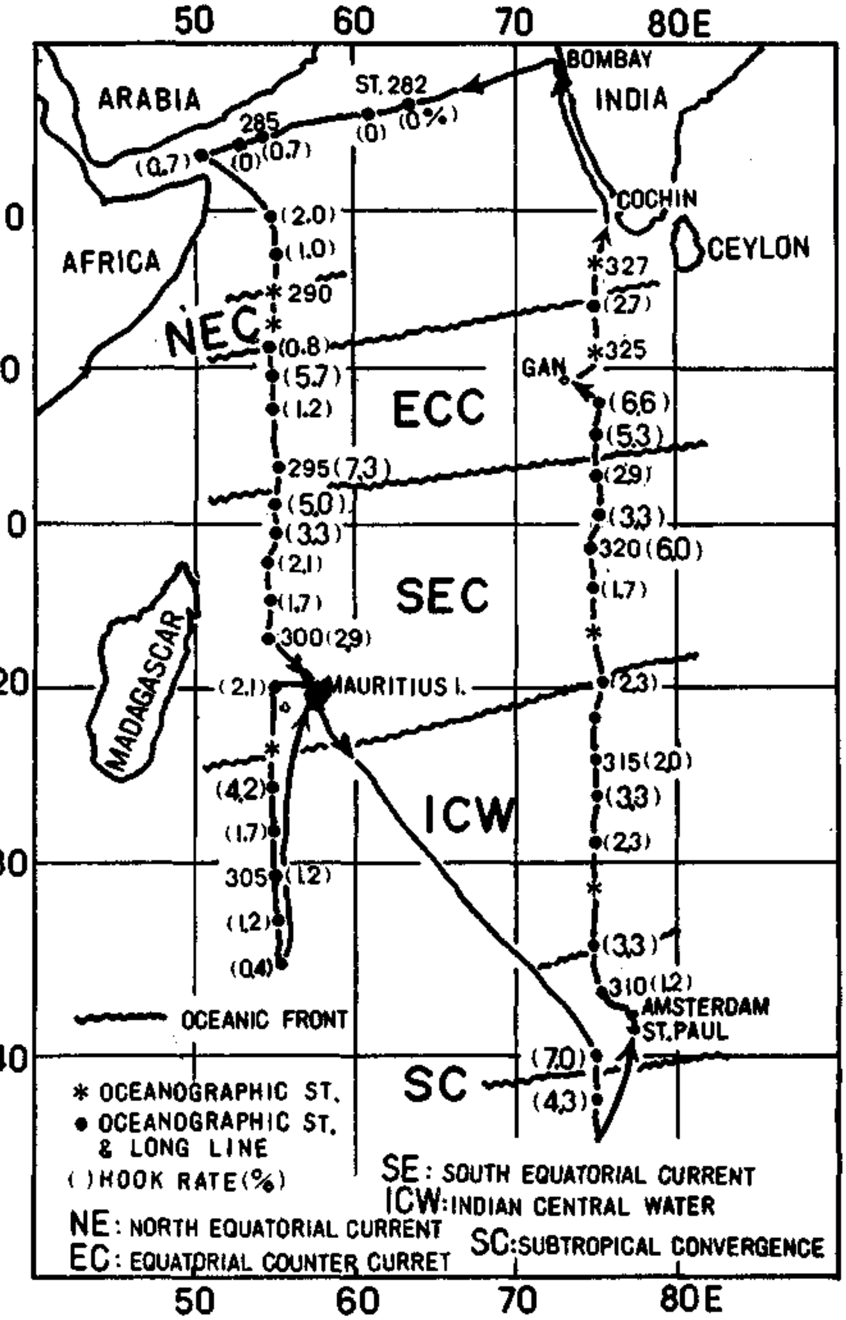

Fig. 5. Cruise track and station positions by the *R. V. Anton Bruum* Cruise 5, Jan. 26–May 4, 1964 Figures indicate the mean hook rate (%) by the long-line and current system based on data by the *R. V. Anton Bruum* Cruise 5.

Temperature and salinity profiles are shown in Fig. 7. Dissolved oxygen profile denotes a discontinuity layer at about 50-100 m, similar to thermocline indicated in the figures. From these figures we can notice the north equatorial current area (5°N-1°N), the equatorial counter-current area (1°N-8°S) and the south equatorial current area (8°S-23°S). Consequently the existence of oceanic fronts are evident at about 1°N between north equatorial current (most developed in north-east monsoon season) and the equatorial counter-current, at about 8°S between the equatorial counter-current and south equatorial current, and also at about 24°S, as a line of convergence between the south equatorial current and the south Indian Ocean central water.

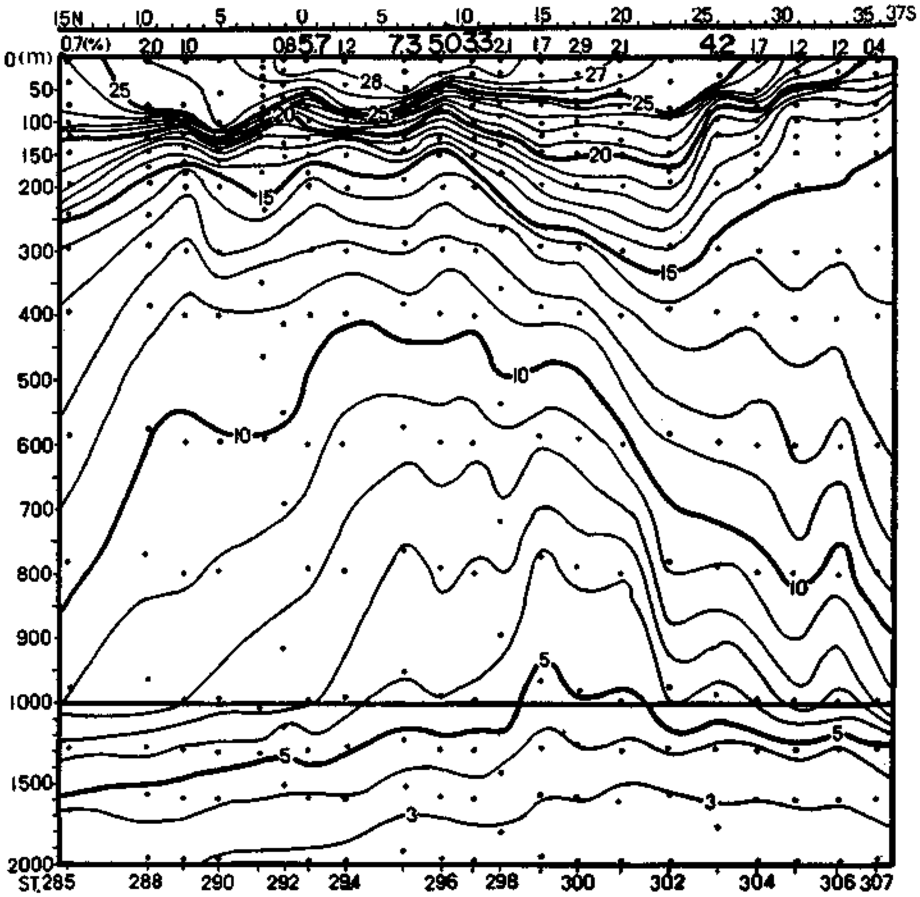

Fig. 6a. Vertical distribution of water temperature (°C), along 55° E.-line, Feb. 5- Mar. 9, 1964. Figures along 0 m-line indicate hook rate (%) by the long-line at each station (See Fig. 1)

Further, we can remark thermal spreading pattern of isotherms below the equator, suggesting the existence of equatorial undercurrent at about the depth of 150 m near about 1°N and also upwelling pattern under the equator, 75°E profiles (Fig. 7 a, b, c, d).

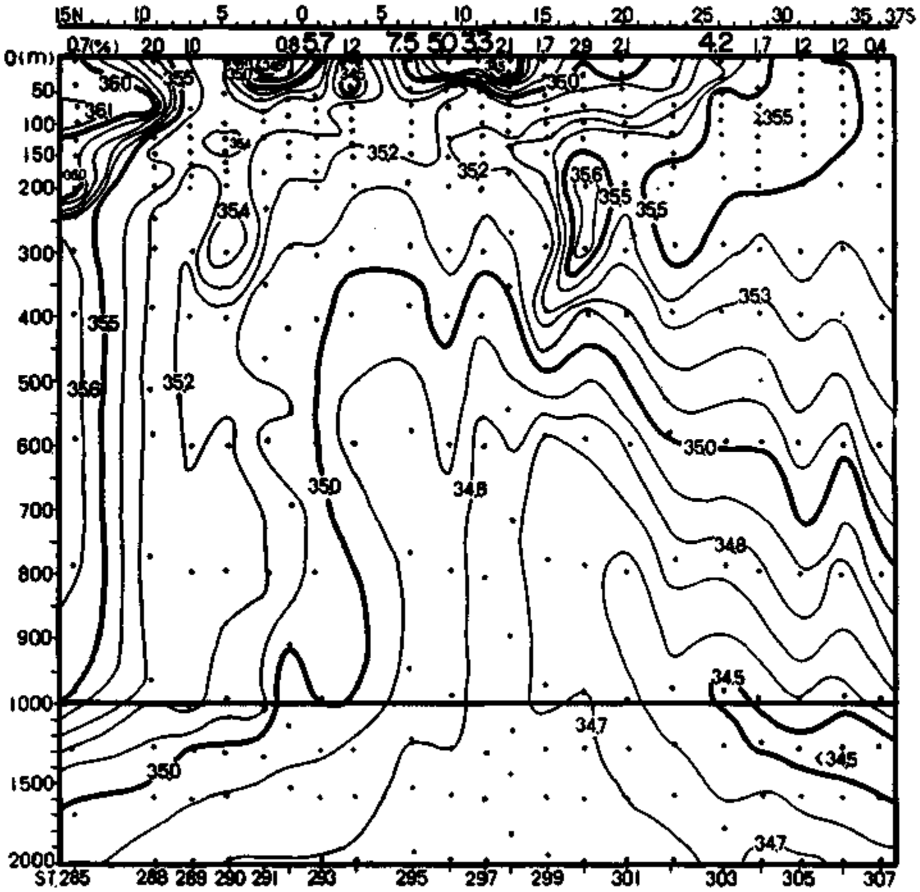

Fig. 6b. Vertical distribution of salinity (‰), along 55° E.-line, Feb. 5- Mar. 9, 1964. Figures along O m-line indicate hook rate (%) by the long-line at each station.

Temperature, salinity and oxygen profiles commonly indicate the sharp spring layers. The existence of water boundaries were observed at about 4°N between the north equatorial current (table north-east monsoon current in the surface layer) at about 6°S between the equatorial countercurrent and the south equatorial current, at about 20°S between the south equatorial current water and the south Indian Ocean central water, at about 35°-40°S between the Indian Ocean central water and the west drift water as the line of subtropical convergence.

It is hard to distinguish clearly the peculiar thermal spreading feature characteristic of the equatorial undercurrent on this profile.

(b) *The experimental result of longline fishing* (Anton Bruun *cruise 5*) *in the western Indian Ocean* (Fig. 8, 9 and Table 1)

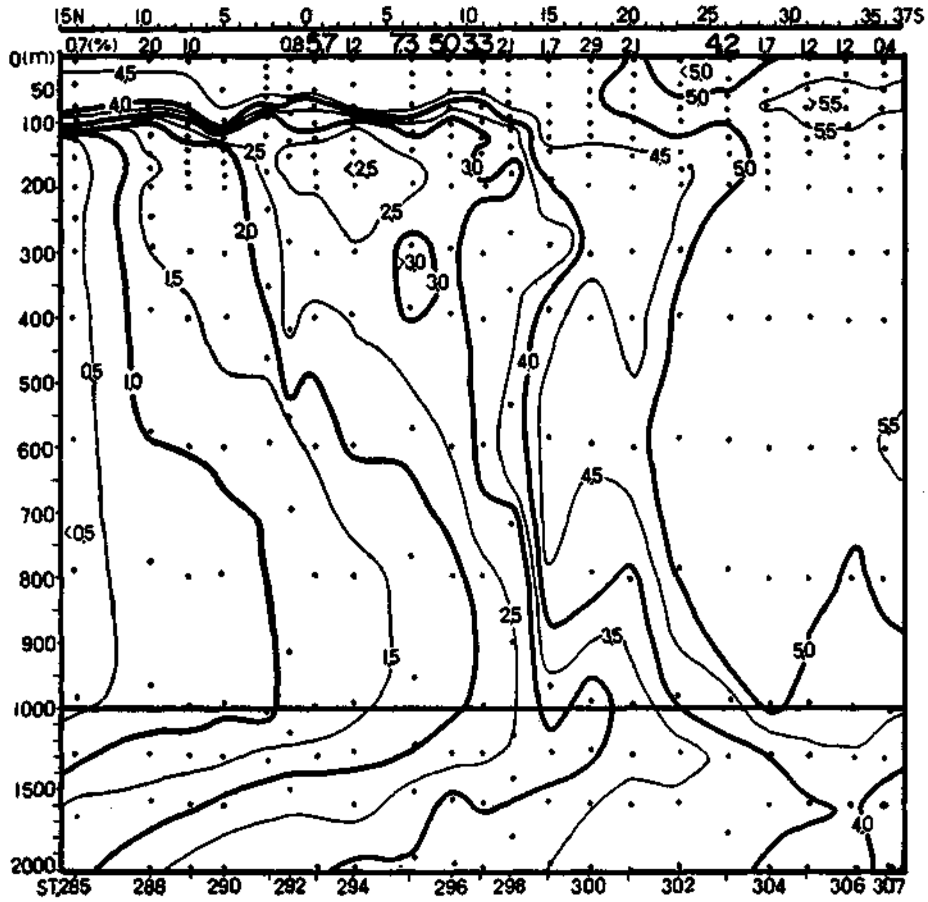

Fig. 6c. Vertical distribution of dissolved oxygen (ml/l), along 55° E.-line, Feb. 5– Mar. 9, 1964. Figures along O m-line indicate hook rate (%) by the long line at each station.

The hook-rate shown in the figure presents higher values around 8°-11°S and 26°S along 55°E line, and from the equator to near 3°S, 8°-11°S, near 26°S and near around 40°S-42°S along 75°E line. The appearance of tuna catch in the latitudal zones for each meridional profiles along 55°E and 75°E lines respectively has been indicated in Table 1-a and 1-b. Figs. 8 and 9 give the species composition of the tuna catches on each meridional profile. In the tuna catch along 55°E line, yellowfin was the highest, and the next were the big-eye and albacore, nearly of the same order. Along 75°E line, the albacore catches were most abundant, and the yellowfin and big-eye catches were nearly the same. Accordingly, we can see that the yellowfin was relatively more abundant in the western part and in the lower latitudes. In the south Indian Ocean, the more abundant catch was of albacore (20°-40°S) and there was no catch of this tuna north to 5°S.

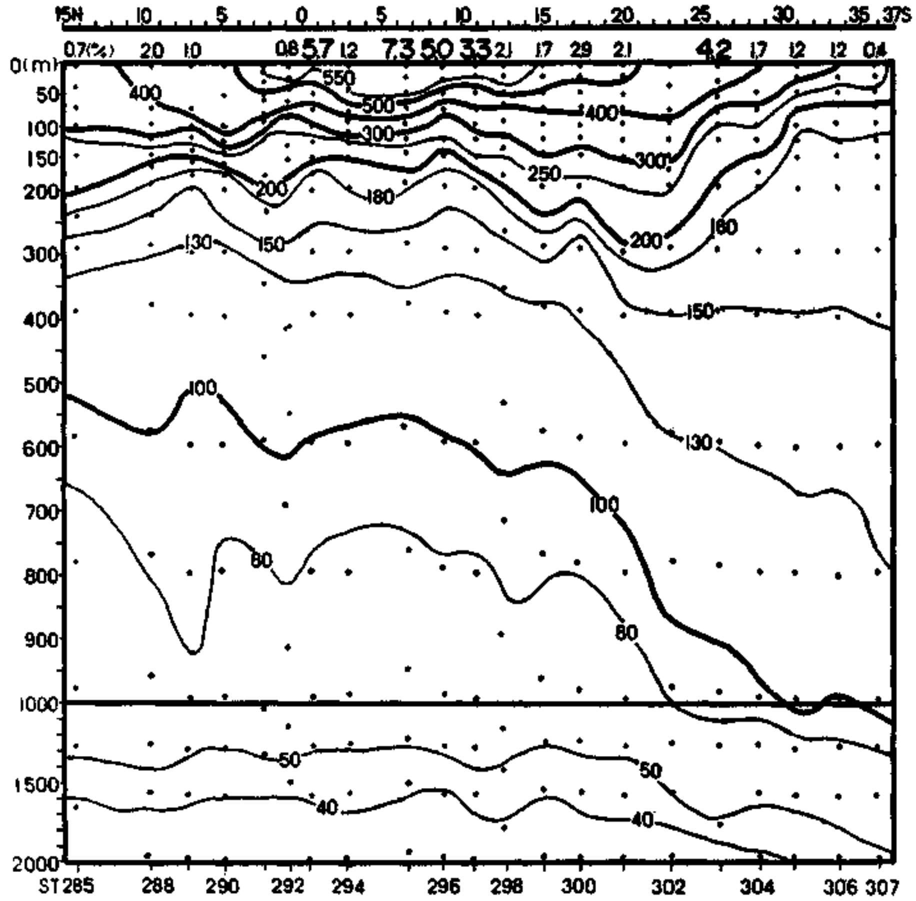

Fig. 6d. Vertical distribution of thermosteric anomaly (δ_T, cl/ton), along 55° E-line, Feb. 5-Mar. 9, 1964. Figures along O m-line indicate hook rate (%) by the long-line at each station.

(c) *Tuna fisheries in relation to hydrography of the western Indian Ocean*

Almost 55°E line in general, higher hook-rate were found around the oceanic fronts, i.e. between north equatorial current and equatorial counter-current; between equatorial counter-current and south equatorial current, and in the zone of convergence near the southern boundary of such equatorial current.

Similarly, along 75°E line higher hook-rate were recorded around or adjacent to the oceanic fronts, i.e. around the water boundary of the equatorial counter-current and south equatorial current; near the water boundary (convergence) between the south equatorial current and the Indian Ocean central water; near the subtropical convergence in the southern hemisphere. However, the hook-rates of tunas along the 75°E line around the oceanic front, between the north equatorial current and the equatorial counter-current (near 4°N) appear to be lower as compared to that of 55°E line.

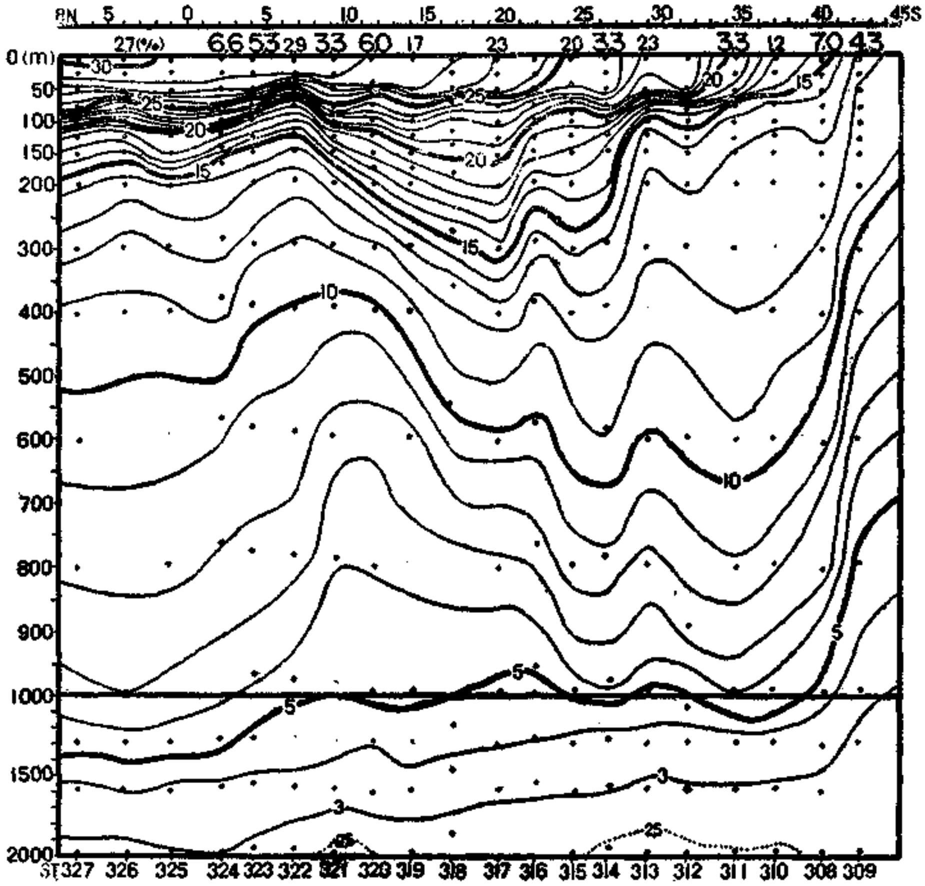

Fig. 7a. Vertical distribution of water temperature (°C), along 75° E.-line Apr. 4-30, 1964. Figures along O m-line indicate hook rate (%) by the long-line at each station (See Fig. 1).

It should be noted that particulary favourable catches along both the profiles of 55°E, and 75°E lines were found near the water boundary between the equatorial counter-current and the south equatorial current.

The hook-rate on an average along 55°E and 75°E lines, show a shift of the peak in the equatorial waters 8°-9°S, 55°E, near 6°S and on 75°E, which may be due to the shift of oceanic fronts. The peaks on both the profiles lie along the equatorial counter-current area or north of its southern boundary. The favourable tuna fishing grounds, therefore, are located along the oceanic frontal region.

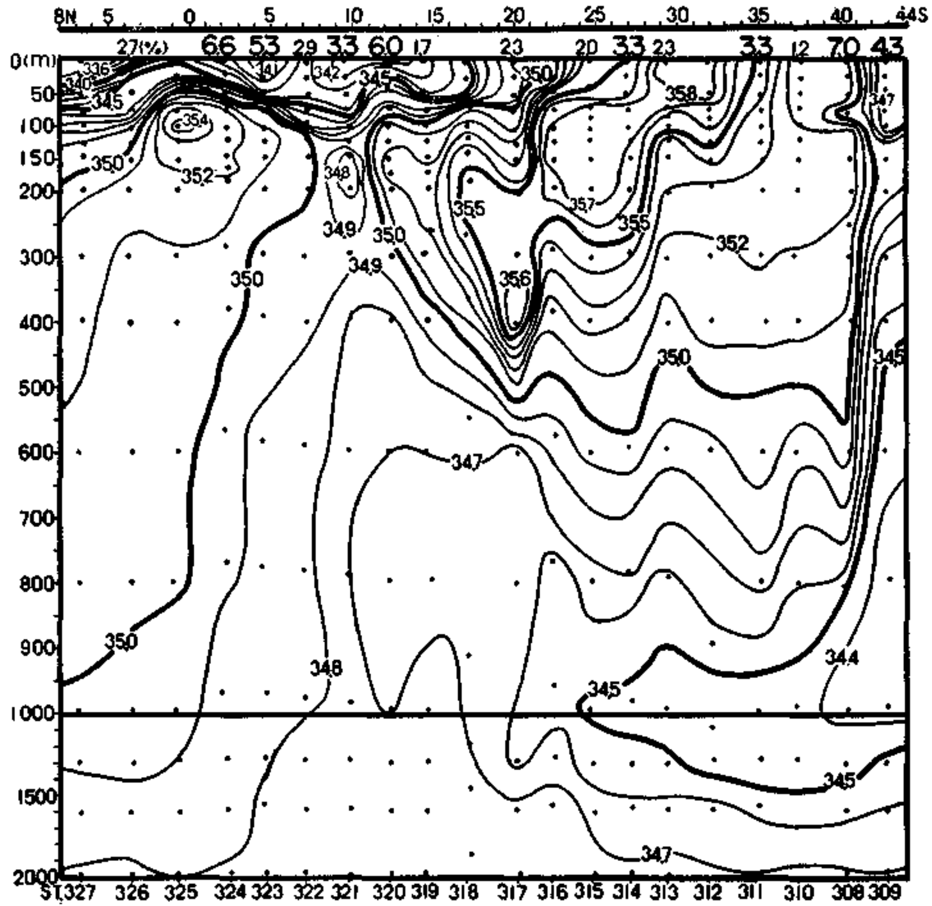

Fig. 7b. Vertical distribution of salinity (‰), along 75° E-line, Apr. 4-30, 1964. Figures along O m-line indicate hook rate (%) by the long-line at each station.

The prevalence of the Red Sea water is recognised more along 55°E down to 8°N, (having salinity above 35.5‰) and less along 75°E. It is extended more to the south (near 1°N having salinity of 35.4‰). In general, the region of maximum hook-rate appears to localize in the marginal area or water boundaries or along the oceanic fronts.

We can thus conclude that the most abundant catch of the yellowfin tuna is found mainly in the equatorial counter-current area and in the south equatorial current area, that of albacore-tuna in the Indian Ocean central water area and subtropical convergence area (75°E), and that of big-eye tuna particularly in the subtropical convergence area with the maximum concentration of fishes along the marginal area.

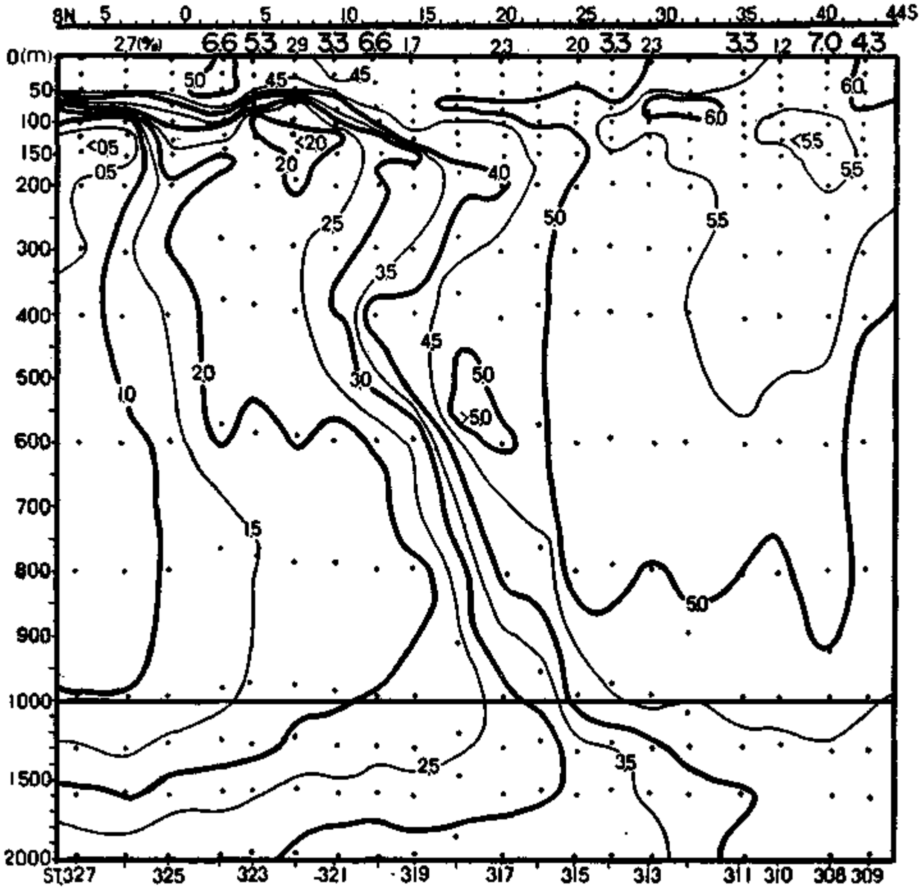

Fig. 7c. Vertical distribution of dissolved oxygen (ml/l), along 75° E.-line, Apr. 4-30, 1964
Figures along O m-line indicate hook rate (%) by the long-line at each station.

Panikkar and Jayaraman (1966) have pointed out the biological and oceanographic differences between the Arabian Sea and the Bay of Bengal with reference to upwelling areas and the fisheries of the oil sardine and mackerel in India. Our results of the IIOE (1966) confirm that upwelling areas are also favourable for tuna fishing in the equatorial zone.

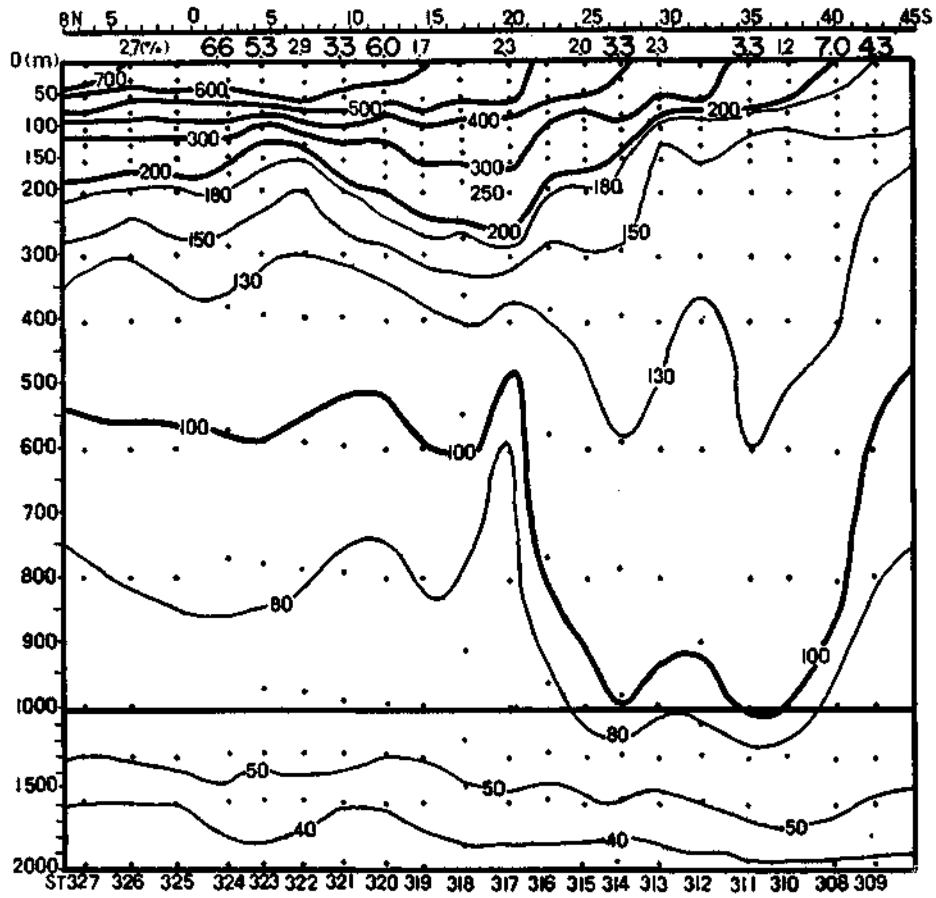

Fig. 7d. Vertical distribution of thermosteric anomaly ($\delta\tau$, cl/ton), along 75°E.-line, Apr. 4-30, 1964. Figures along O m-line indicate hook rate (%) by the long-line at each station

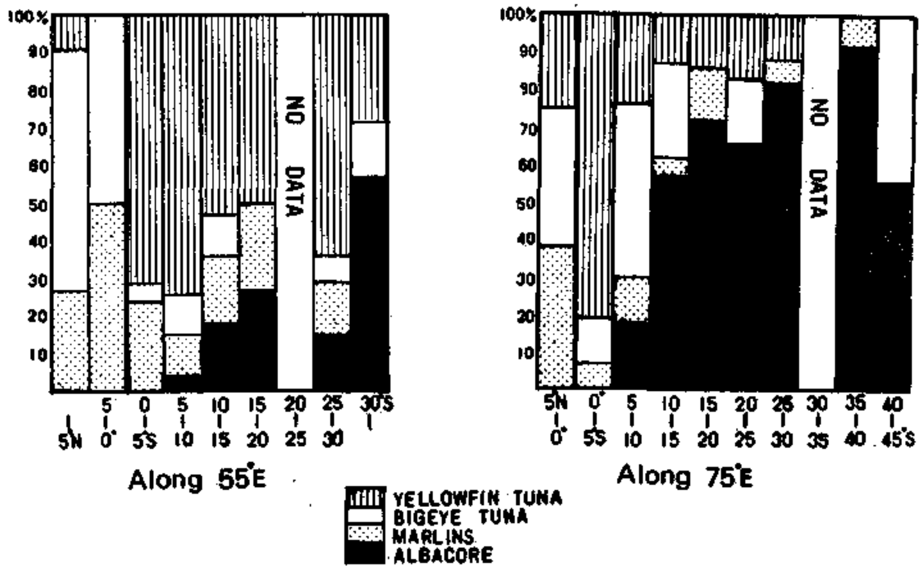

Fig. 8. Fish composition of Tunas at the intervals of 5° latitude.

TABLE 1. *A final result of longline-fishing by the R. V. Anton Bruun Cruise 5 in the Indian Ocean. Mean hook rate means arithmetical mean at the intervals of 5° latitude*

a. Along 55° E.-line (Feb. 5–Mar. 9, 1964)

Position of fishing round	No. of hooks	No. of operations	Fish Species: Yellowfin	Fish Species: Bigeye	Fish Species: Albacore	Fish Species: Marlins	Total catch	Mean hook rate
— 5°N	1208	4	1	7	0	3	11	0.93%
5° — 0°	242	1	0	1	0	1	2	0.80
0° — 5°S	484	2	12	1	0	4	17	3.45
5° — 10°	544	2	25	4	1	4	34	6.15
10° — 15°	725	3	9	2	3	3	17	2.37
15° — 20°	484	2	6	0	3	3	12	2.50
20° — 25°		NO DATA						
25° — 30°	484	2	9	1	2	2	14	2.95
30°S —	720	3	2	1	4	0	7	0.93
TOTAL	4891	19	64	17	13	20	114	2.33

b. Along 75°E.-line (Apr, 4–30, 1964)

Position fishing round	No. of hooks	No. of operations	Fish Species: Yellowfin	Fish Species: Bigeye	Fish Species: Albacore	Fish Species: Marlins	Total catch	Mean hook rate
5°N — 0°	302	1	2	3	0	3	8	2.70%
0° — 5°S	544	2	26	4	0	2	32	5.95
5° — 10°	544	2	4	8	3	2	17	3.10
10° — 15°	604	2	3	6	13	1	23	3.85
15° — 20°	302	1	1	0	5	1	7	2.32
20° — 25°	302	1	1	1	4	0	6	2.00
25° — 30°	604	2	2	0	14	1	17	2.80
30° — 35°		NO DATA						
35° — 40°	544	2	0	0	12	1	13	2.25
40° — 45°S	602	2	0	15	19	0	34	5.65
TOTAL	4348	15	39	37	70	11	157	3.61

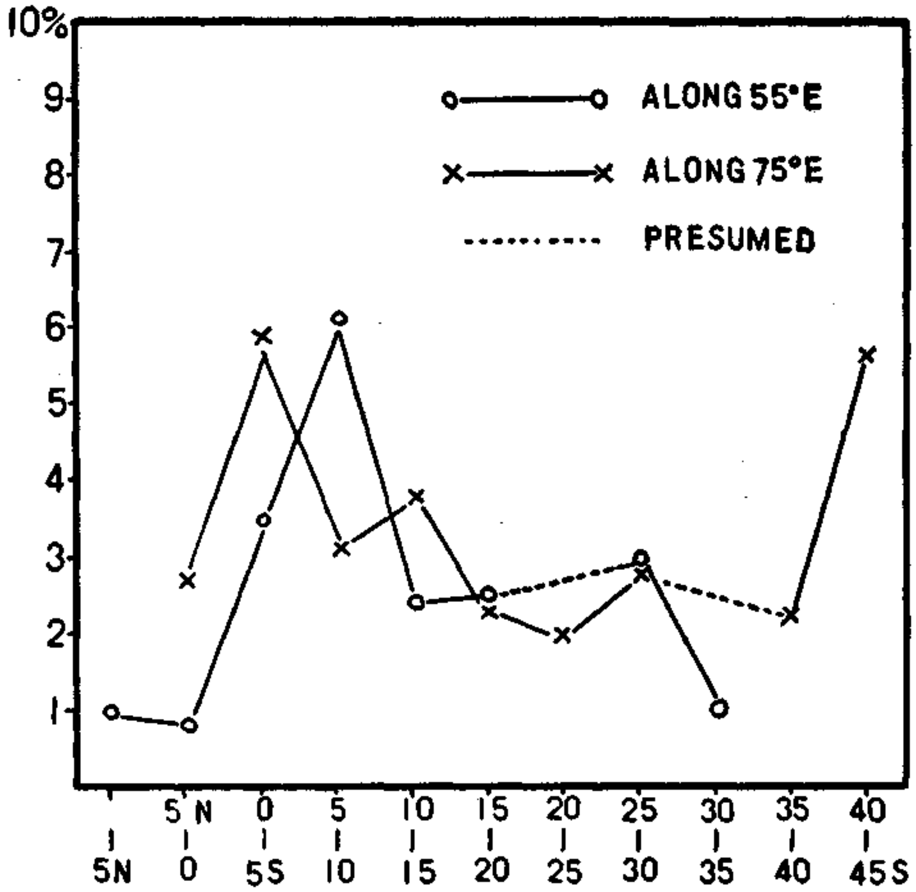

Fig. 9. Arithmetical mean hook rate (%) of Tunas at the intervals of 5° latitude.

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