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DISTRIBUTION AND BIOLOGY OF THE SKIPJACK TUNA *KATSUWONUS PELAMIS* (LINNAEUS) TAKEN BY THE LONGLINE FISHERY IN THE INDIAN OCEAN

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ABSTRACT

The skipjack tuna *Katsuwonus pelamis* remains to be one of the least exploited species of commercially important tunas in the Indian Ocean. At present they are taken mainly by the surface fishery and they form a minor component in the long line catches. The present communication provides information on their distribution, availability, abundance, length composition and spawning of skipjack based on the catch statistics and biological data obtained by the longline operations of Japanese commercial and research vessels.

Relative density indices show that they were widely distributed in the western Indian Ocean during the first quarter, in the eastern Indian Ocean and northwest coast of Australia in the second quarter and in the third and fourth quarters they were widely distributed in the tropical waters. Their overall abundance and average density were at its peak in June, although they evinced seasonal variation. The fishes of the size group 58–70 cm dominated the longline catches, especially from the northern sector. In the central and eastern Indian Ocean, the specimens examined were relatively smaller. Available information on the gonad indices reveals that spawning activity is an extended one and it is relatively high in the northern and central Indian Ocean areas during September through April.

INTRODUCTION

OUR KNOWLEDGE on the distribution and biology of the skipjack tuna *Katsuwonus pelamis* (Linnaeus) is mainly confined to certain studies based on isolated fisheries (Jones, 1959; Raju, 1964; Thomas, 1964; Stequert, 1976; Marcille and Stequert, 1976; Appukuttan *et al.* (1977) and general observations and reviews on this fish and its fisheries (Jones and Silas, 1963; Matsumoto *et al.*, 1984). Marcille and Suzuki published the results of observations on the distribution of this species in the Indian Ocean caught by the Japanese longline fishery for tunas during the period 1965–1971 and indicated some aspects of the biology therein. At present the species is taken on a commercial scale by the pole and line fishery in the Lakshadweep and Maldive Islands and by shore based gears by Sri Lanka and Thailand and from the oceanic areas by the longline fishery.

The present account is aimed at adding to the existing knowledge of the distribution and biology of skipjack tuna in the Indian Ocean based on the records of incidental catches of the Japanese tuna longline fishery for the period 1965–1975. Since their biological aspects for the period 1965–1971 are already available, in this report the biological aspects of skipjack tuna have been dealt with for the years 1972–1975.

DATA : SOURCE AND PROCESSING

The data used in the present paper were collected by the Fisheries agency, Japan from the Japanese commercial longline and research vessels which operated in the Indian Ocean area during the period 1965–1975 and processed at the Far Seas Fisheries Research Laboratory (Anon., 1967–1977). The data include: (i) fishing effort in number of hooks and number of fish caught by 5° × 5° area and month of

the year; (ii) body length (fork length) by 5°×5° area and measurement of gonad weight and length of fish by month.

Data processing method is essentially on the lines presented earlier by Pillai and Ueyanagi (1978). Data on the fishing effort (number of hooks) and the number of fish caught by 5°×5° areas in the Indian Ocean has been processed and indicated in a series of figures 'relative density indices' (d_{ij}) which were calculated in the form of monthly averages for the 11 years' period (1965–1975) as follows:

$$d_{ij} = \frac{I}{m_{ij}} \sum_{k=I}^{m_{ij}} d_{ij}k = \frac{I}{m_{ij}} \sum_{k=I}^{m_{ij}} \left(C_{ijk} / G_{ijk} \right) \ldots I$$

where,

m_{ij} = number of years when the i^{th} 5°×5° areas where occupied in the j^{th} month;

C_{ijk} = catch in the i^{th} 5°×5° area occupied in the j^{th} month of the k^{th} year;

G_{ijk} = Nominal effort used in the i^{th} 5°×5° area occupied in the j^{th} month of the k^{th} year.

The d_{ij} indices are indicated in the figures as per 100 hooks in four different ranges.

The body length is expressed by the fork length. Sexual maturity of the skipjack dealt with in the present study was determined by the analysis of gonad indices (G.I.) which was calculated as follows:

$$G.I. = (W/L^3) 10^4$$

where,

W= Weight of the ovaries in grams;
L= the fork length of the fish.

In order to facilitate comparison of the results in the length composition and maturity of the skipjack in the Indian Ocean, the data has been presented for 6 sub-areas as follows:

Area 1 = Arabian Sea, No. of 0° and W. of 80°E.
Area 2 = Bay of Bengal, No. of 0° and E. of 80°E.
Area 3 = Western Indian Ocean, 0° – 20° S., 35° –80°E.
Area 4 = Central Indian Ocean, 0° – 20° S., 80° – 100° E.
Area 5 = Eastern Indian Ocean, 0° – 20° S., 100° – 130° E.
Area 6 = Southern Indian Ocean, S. of 20° S., 20° – 130° E.

Status of Skipjack Tuna Fishery

The area of occurrence and the areas where pole and line fishery and shore based fishery is in vogue in the Indian Ocean are presented in Fig. 1. According to FAO statistics, the total production of skipjack tuna during the period 1965–1975 was around an average of 26,000 MT from the surface fisheries. The trend of skipjack tuna fishery by the Japanese tuna longliners in the Indian Ocean is given in Fig. 2. It is evident that there was an increase in catch from 1965 and the landings were relatively high with peak catch recorded during 1972. Subsequently, there was a decline in the catches. CPUE (number per thousand hooks) also evinced a similar trend, showing gradual increase with fluctuations till 1972 and a steep fall during the ensuing period.

However, the limitations of the catch and effort data should also be considered while assessing the trend of production of skipjack tuna by the longline fishery. One of the major limitations was that the Japanese research vessel data on the catch, effort and biological parameters were restricted in space and time. In the

commercial longline fishery, the catches of skipjack has a limited unit value. Also, the skipjack catches are grouped with miscellaneous category. Further, error is often made by the log book copiers who may copy only the information pertaining to commercially important tunas such as yellowfin tuna, big-eye tuna, bluefin tunas and club skipjack along with "other tunas". In view of these limitations, it is not often possible to make meaningful comparisons of the distribution of the skipjack, as recorded by the research and commercial vessels.

Distribution of Relative Density Indices (d_{ij})

The average monthly distribution of skipjack tuna (per 100 hooks) for the years 1965–1975 is shown in a series of figures according to 5° x 5° area (Figs. 3–14).

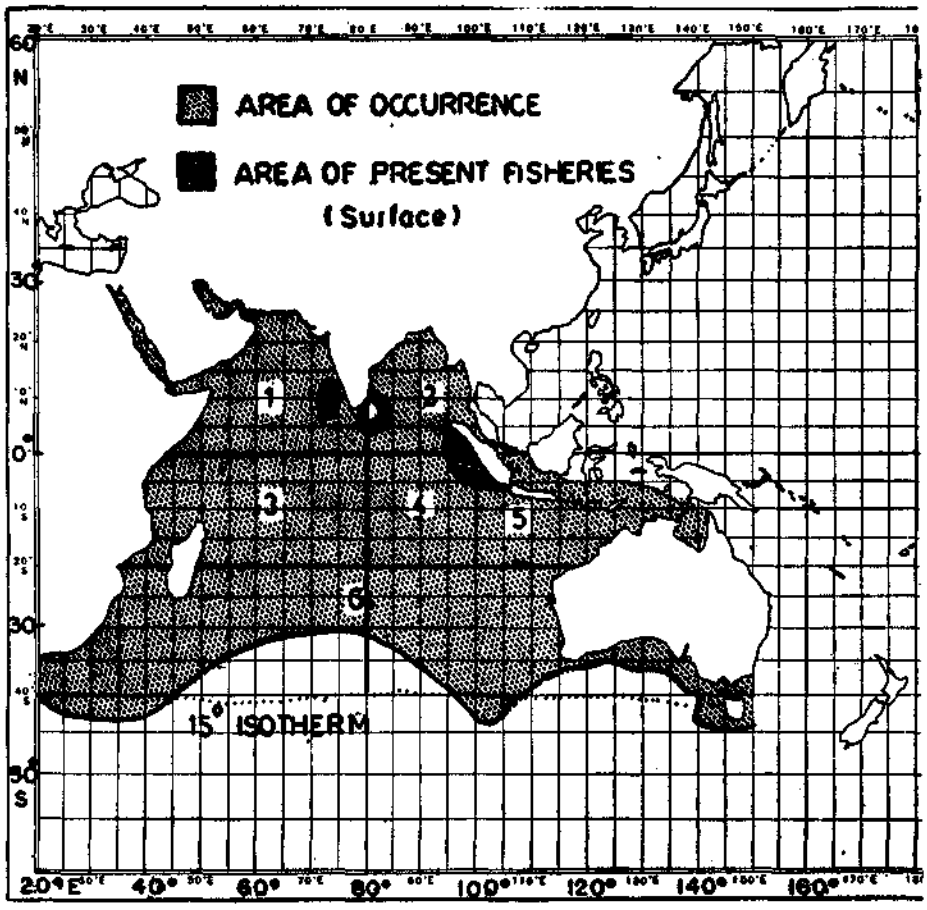

Fig. 1. Area of occurrence and area of present fisheries (surface) for skipjack tuna in the Indian Ocean.

The d_{ij} distribution indicates that the skipjack is primarily distributed in the warmer waters of the Indian Ocean. The general pattern of distribution occupies the area from 20°N to 30°S. Areas of high average relative density occur during different months as follows:

January : Western and Central eastern Indian Ocean
February : Arabian Sea and Central Indian Ocean
March : Western, Central and eastern Indian Ocean
April : Western and north-eastern Indian Ocean
May : Tropical Indian Ocean, north of 10° S and northwest coast of Australia.
June : Arabian Sea, central and south eastern Indian Ocean and north western coast of Australia.
July : Tropical waters of Indian Ocean between 10° N and 10° S.
August : —Do—
September : Tropical waters of Indian Ocean and northwestern Australian Coast.
October : Tropical waters of Indian Ocean between 10° S and 10° N.
November : —Do—
December : Tropical Indian Ocean between 10° S and 10° N and south western Indian Ocean.

dweep and Maladives from September to April.

According to Marcille and Suzuki (1974), the hook rate of skipjack taken by the Japanese longline tuna fishery during the period 1965–1971 was relatively high in the equatorial waters between 15° N and 15° S. Areas of concentration varied remarkably from season to season and in the first and fourth quarters of the high hook-rate (more than 0.2%) was confined to western Indian Ocean, west of longitude 80° E while in the second and third quarters it is also observed in the eastern waters off Sumatra, Java and north western Australia. This is in agreement with the present findings.

Relative Abundance

As seen in the relative density indices of skipjack tuna in the Indian Ocean, areas of high concentration are due to variable distribution of the fish during different months. Since d_{it} reflects the density of fish in a given locality, the d_{ij} multiplied by the area of the region would be the index of abundance fish at that

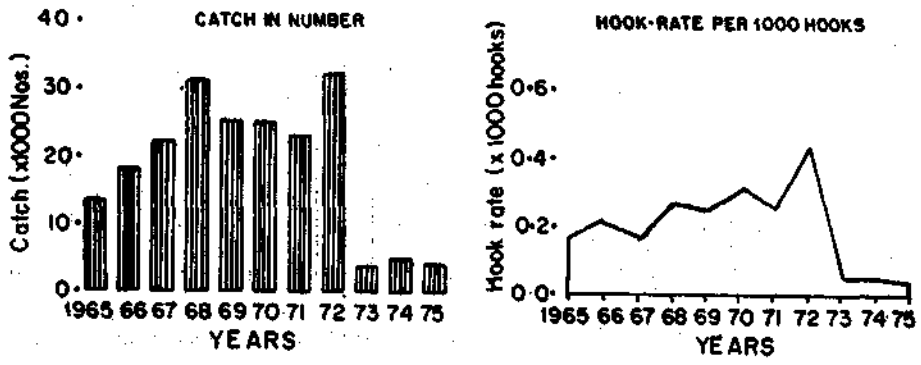

Fig. 2. Catch (in number) and hook rate (per 1000 hooks) of skipjack tuna from the Indian Ocean, 1965–1975.

It is interesting to note that their concentration in the tropical waters during the period of July to February coincide with the pole and line surface fishery season in the Laksha-

time. The abundance (Nj) can be calculated from the following equation:

$$N_j = \sum_{i=1}^{n} d_{ij} \cdot A_{ji}$$

where,

N_j = Total abundance of the fish during the j^{th} month.

A_{ij} = Index of the geographical extent of the i^{th} area during the j^{th} month excluding the land; the unit is an area of $5° \times 5°$ along the Equator, and

n = Number of $5° \times 5°$ areas.

Thus, the average density d_{ij} of the fish can be expressed by the relationship:

$$\bar{d}_{ij} = N_j / A_j = N_j / \sum_{i=1}^{n} A_{ij}$$

where,

A_j = extend of the whole fishing grounds during the j^{th} month.

Temporal changes in the abundance (availability: a_j) can be calculated by:

$$a_j = N / \bar{N}$$

where, $\bar{N} = \frac{1}{12} \sum_{j=i}^{12} N_j$

and a_j = availability of the fish during the j^{th} month.

The indices of areas operated, average density and availability which were calculated from the d_{ij} indices are shown in Fig. 15. It is evident that the operational area of skipjack tuna was high during the period January to July. The abundance and average density of this species in the Indian Ocean was at its peak during June, since when they gradually declined and reached the lowest ebb in October. Subsequently, the indices increased and reached a relatively high position in November.

The availability of skipjack tuna was high during March to June and relatively low during the rest of the year. It is evident from the d_{ij} distribution that the catch rates were high in the major fishing grounds of tropical waters of the Indian Ocean between 10°N and 10°S, western Indian Ocean and northwestern coast of Australia during March to October. It would appear that the months when the availability indices are more than 1.0 will be more productive than the averages. From the d_{ij} maps it is also evident that the fishing effort was apparently absent in the northern part of the Indian Ocean especially in the Arabian Sea and Bay of Bengal from July when the fishes are widely dispersed.

Size Composition

The size composition data presented in this account pertain to 6474 measurements of skipjack caught by the longline vessels in the Indian Ocean from January, 1972 to December, 1975 and is shown in Fig. 16 as percentages. The skipjack tuna in this area ranged in size from 31–87 cm forklength. However, the majority of them were between 50–72 cm size and the size frequency (cumulative) were multimodal, with a major peak at 54–56 cm and 68–70 cm size range.

In order to examine the size composition and its variation in detail, percentage frequency distribution were prepared by pooling the data within four quarters of the years 1972–1975 and shown for 6 fishing areas in Figs. 17–19. Data are relatively insufficient for the Arabian Sea, Bay of Bengal and the southern Indian Ocean.

In Area 1 (Arabian Sea), they occurred in the size range 54–66 cm with peak occurrence at 58–60 cm. In Area 2 (Bay of Bengal) they were present in the size range 40–78 cm. During quarter I, small sized specimens were recorded and the major modes were at 52–54 cm and 64–66 cm. In Area 3 (Western Indian Ocean) they occurred in the size range 32–86 cm with major modes at 36–38 cm and 68–70 cm. Fishes of

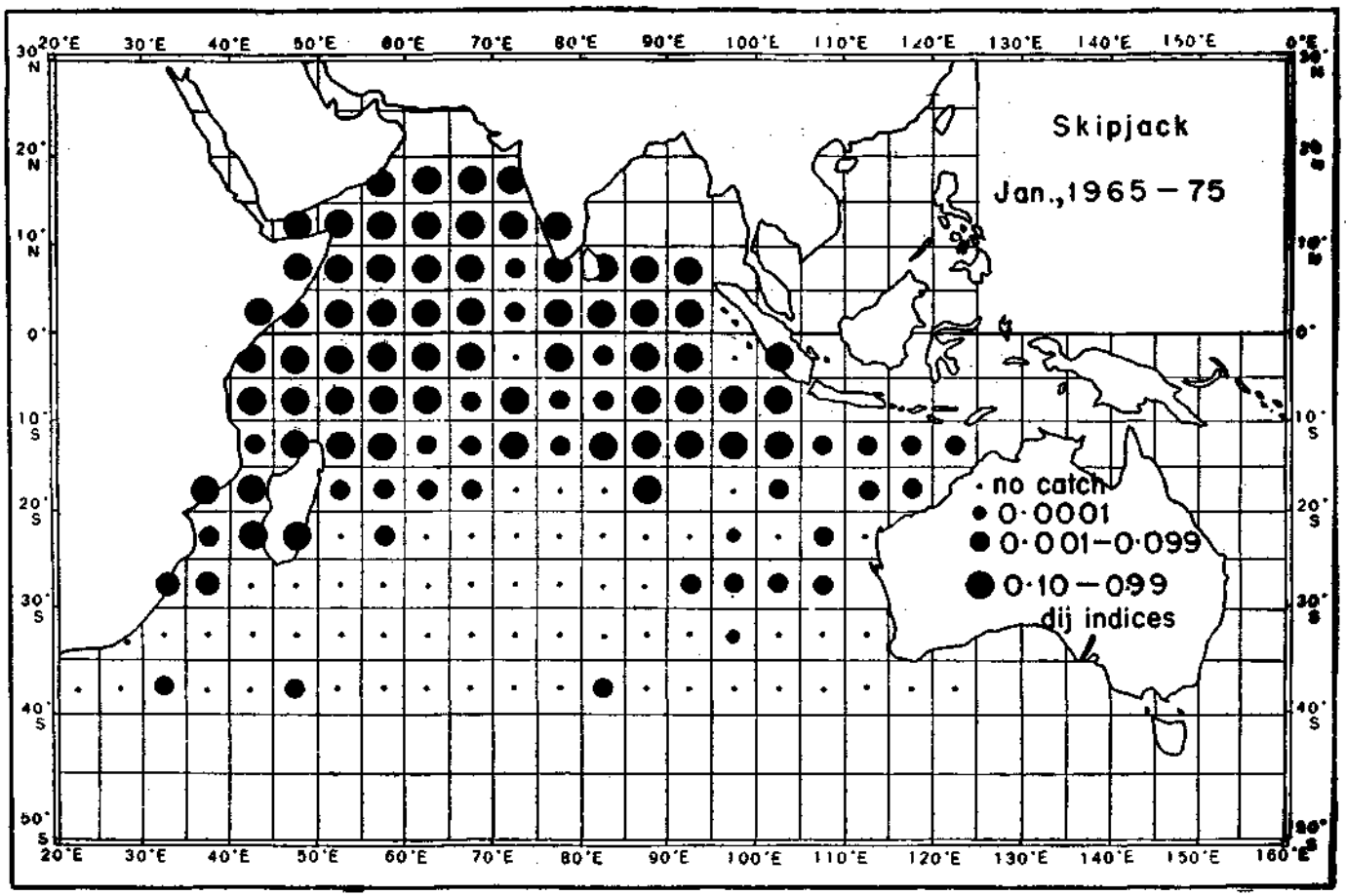

Fig. 3. Monthly distribution of relative density indices (d_{ji}) of skipjack tuna taken by the longline fishery in the Indian Ocean, 1965–1975 : January.

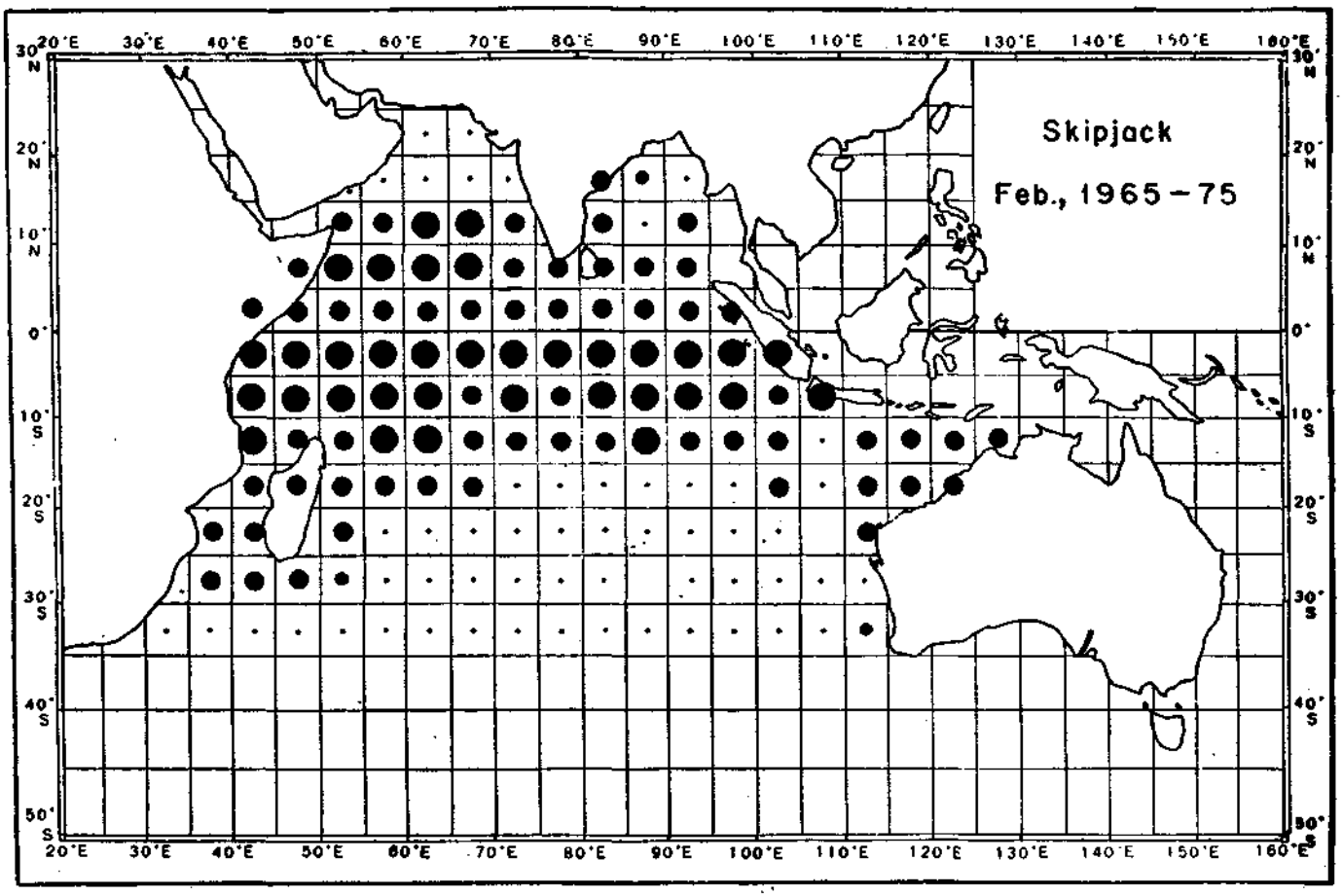

Fig. 4. Monthly distribution of relative density indices (d_{ij}) of skipjack tuna taken by the longline fishery in the Indian Ocean, 1965–1975 : February.

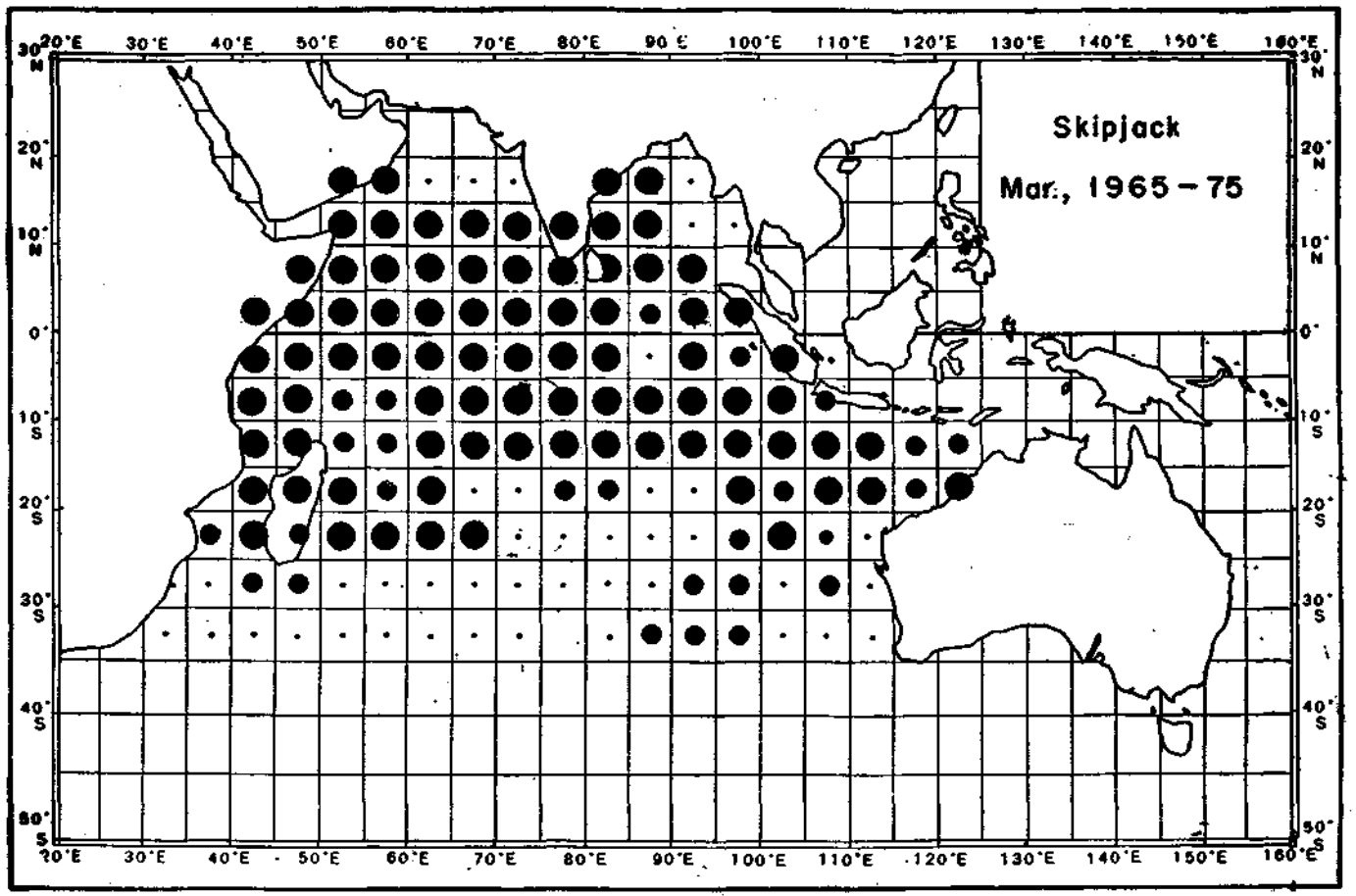

Fig. 5. Monthly distribution of relative density indices (d_{ij}) of skipjack tuna taken by the longline fishery in the Indian Ocean, 1965–1975 : March.

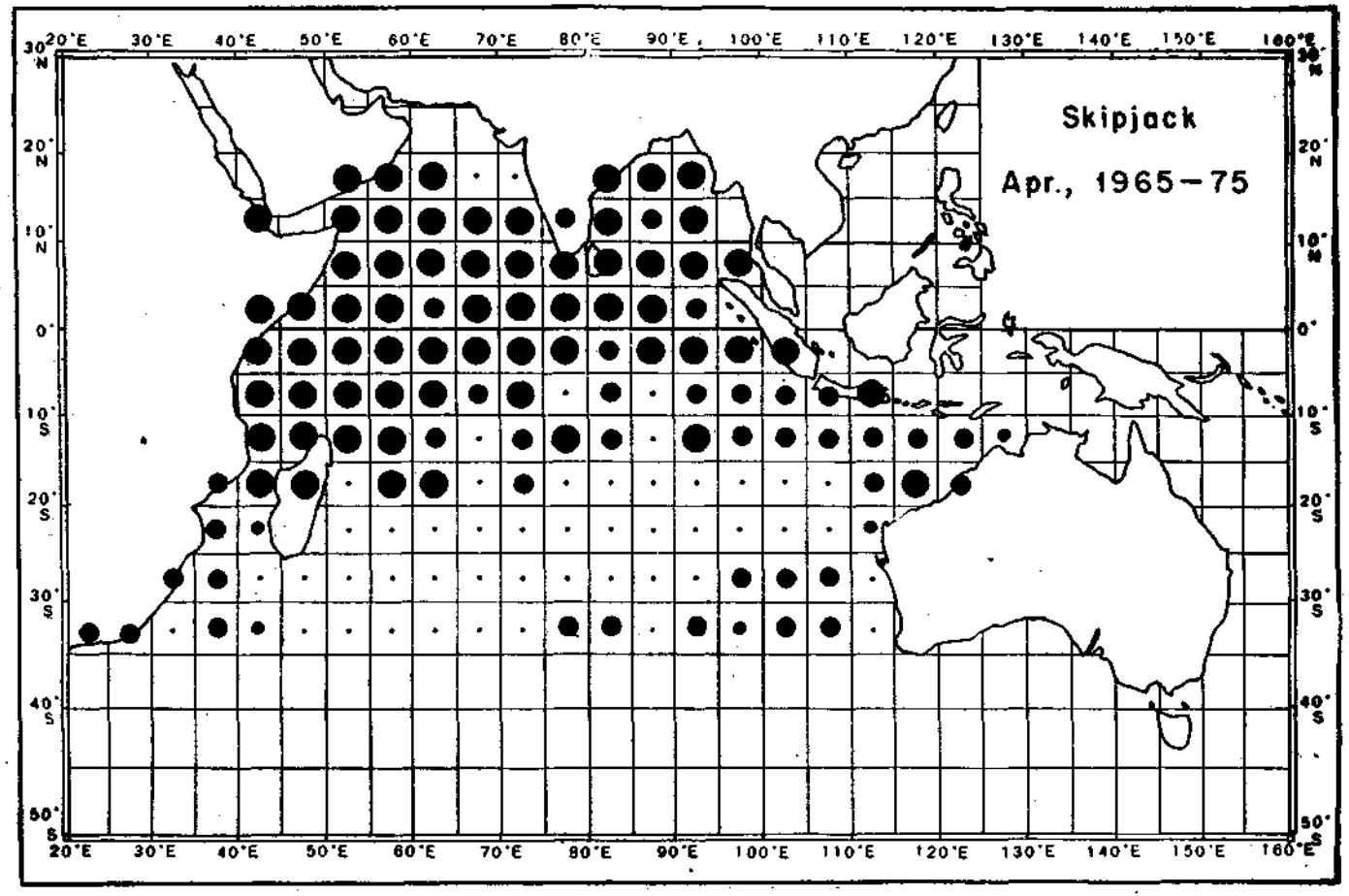

Fig. 6. Monthly distribution of relative density indices (d_{ij}) of skipjack tuna taken by the longline fishery in the Indian Ocean, 1965–1975 : April.

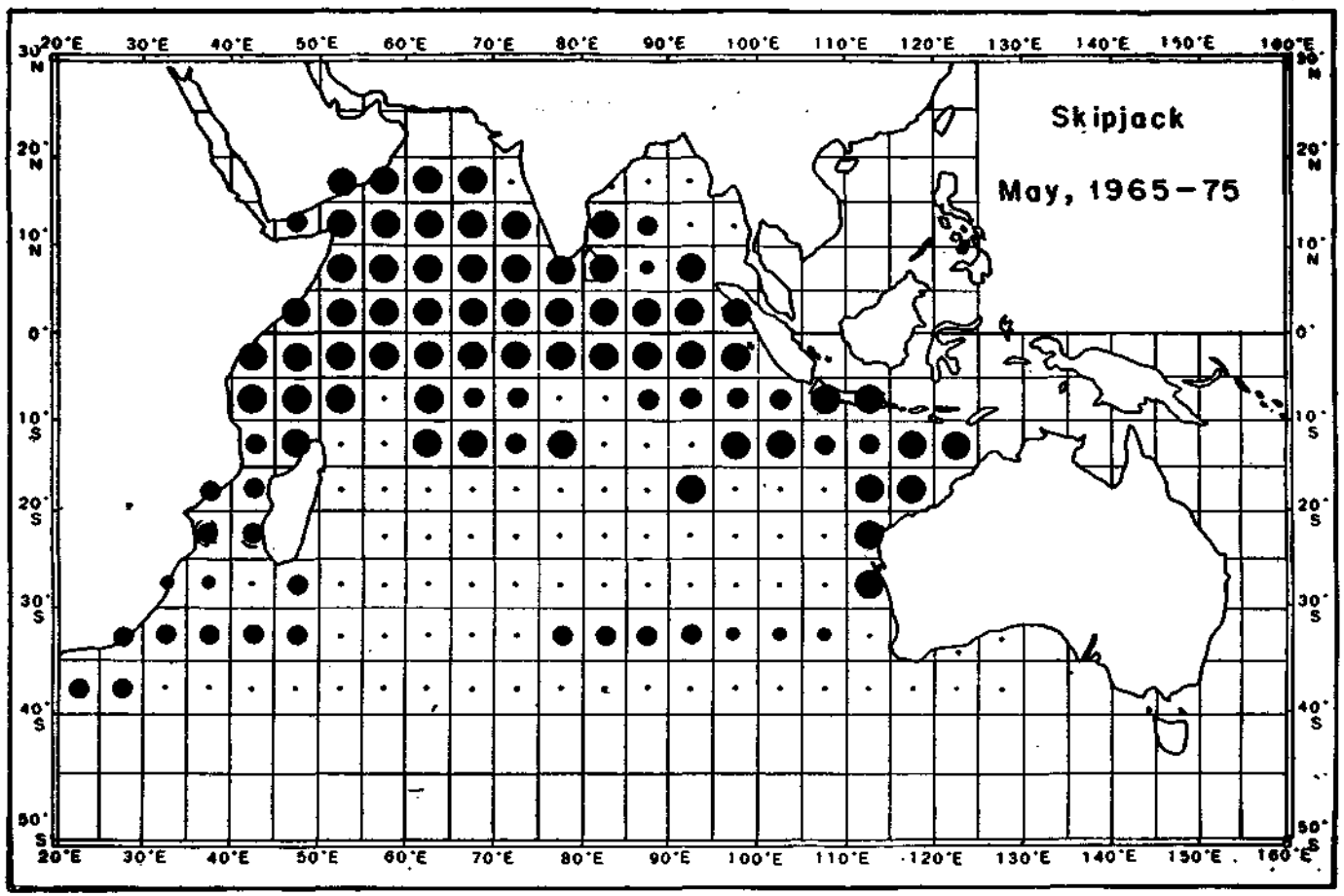

Fig. 7. Monthly distribution of relative density indices (d_{ij}) of skipjack tuna taken by the longline fishery in the Indian Ocean, 1965–1975 : May.

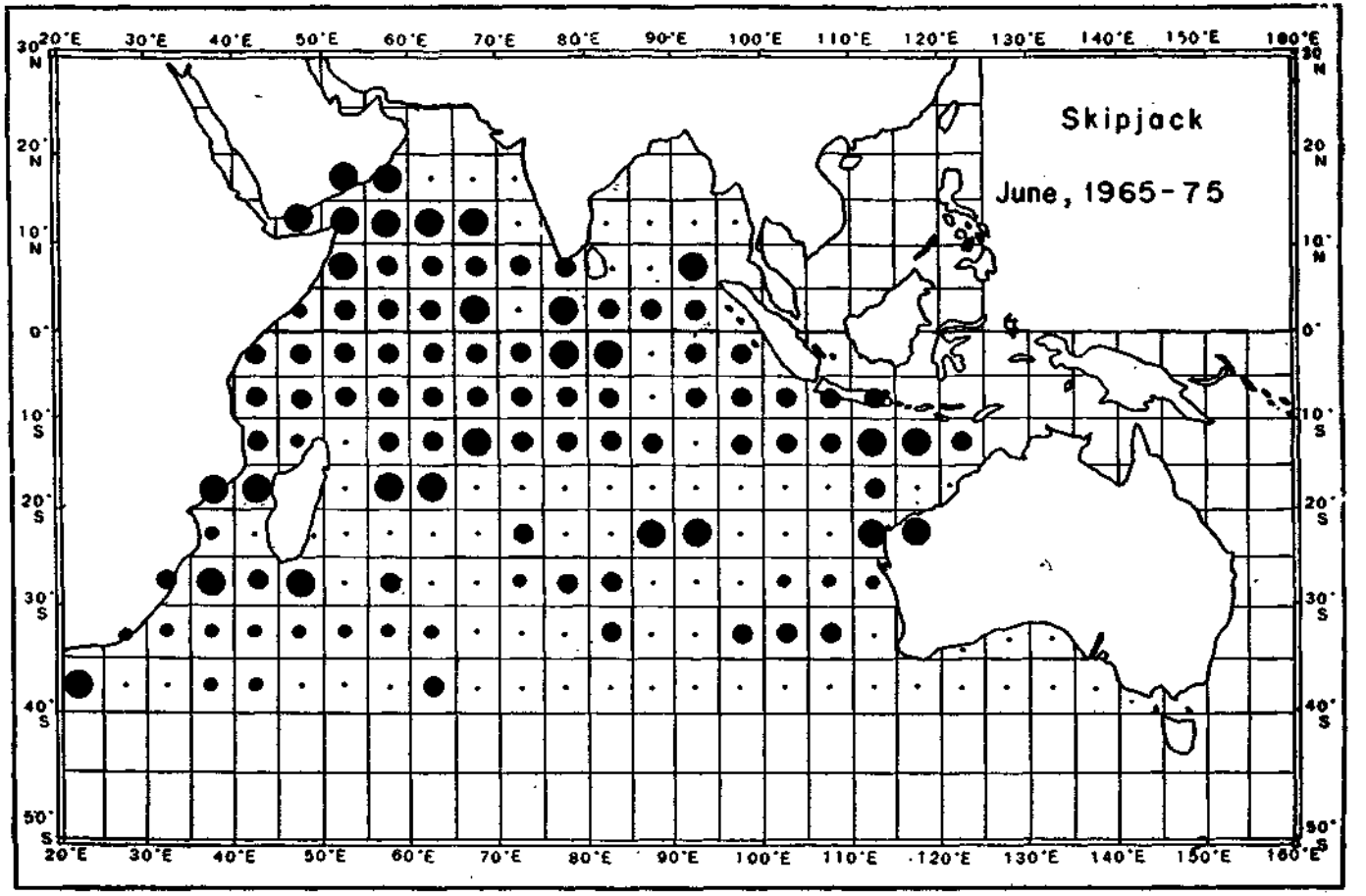

Fig. 8. Monthly distribution of relative density indices (d_{ij}) of skipjack tuna taken by the longline fishery in the Indian Ocean, 1965–1975 : June.

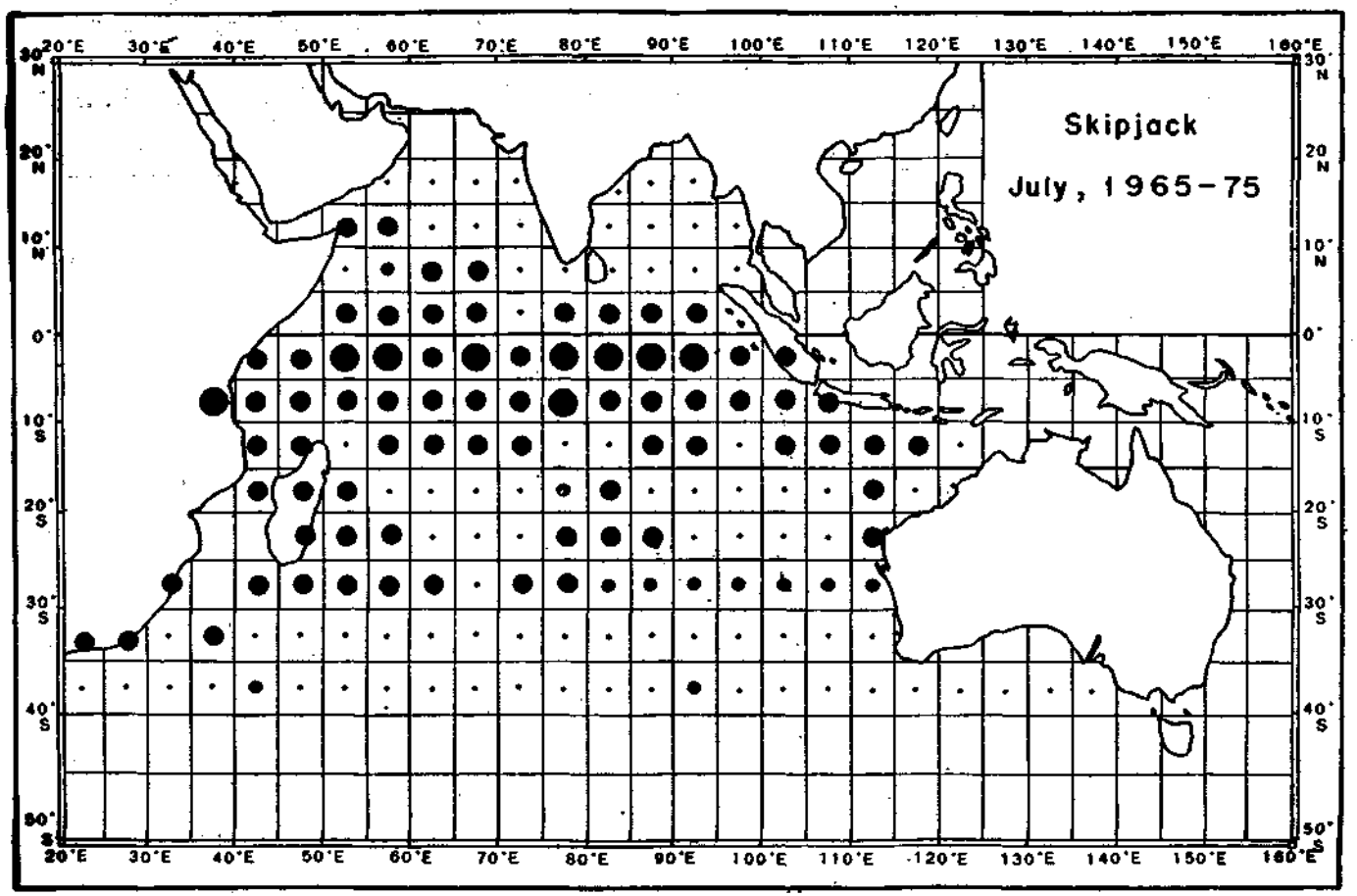

Fig. 9. Monthly distribution of relative density indices (d_{ij}) of skipjack tuna taken by the longline fishery in the Indian Ocean, 1965–1975 : July.

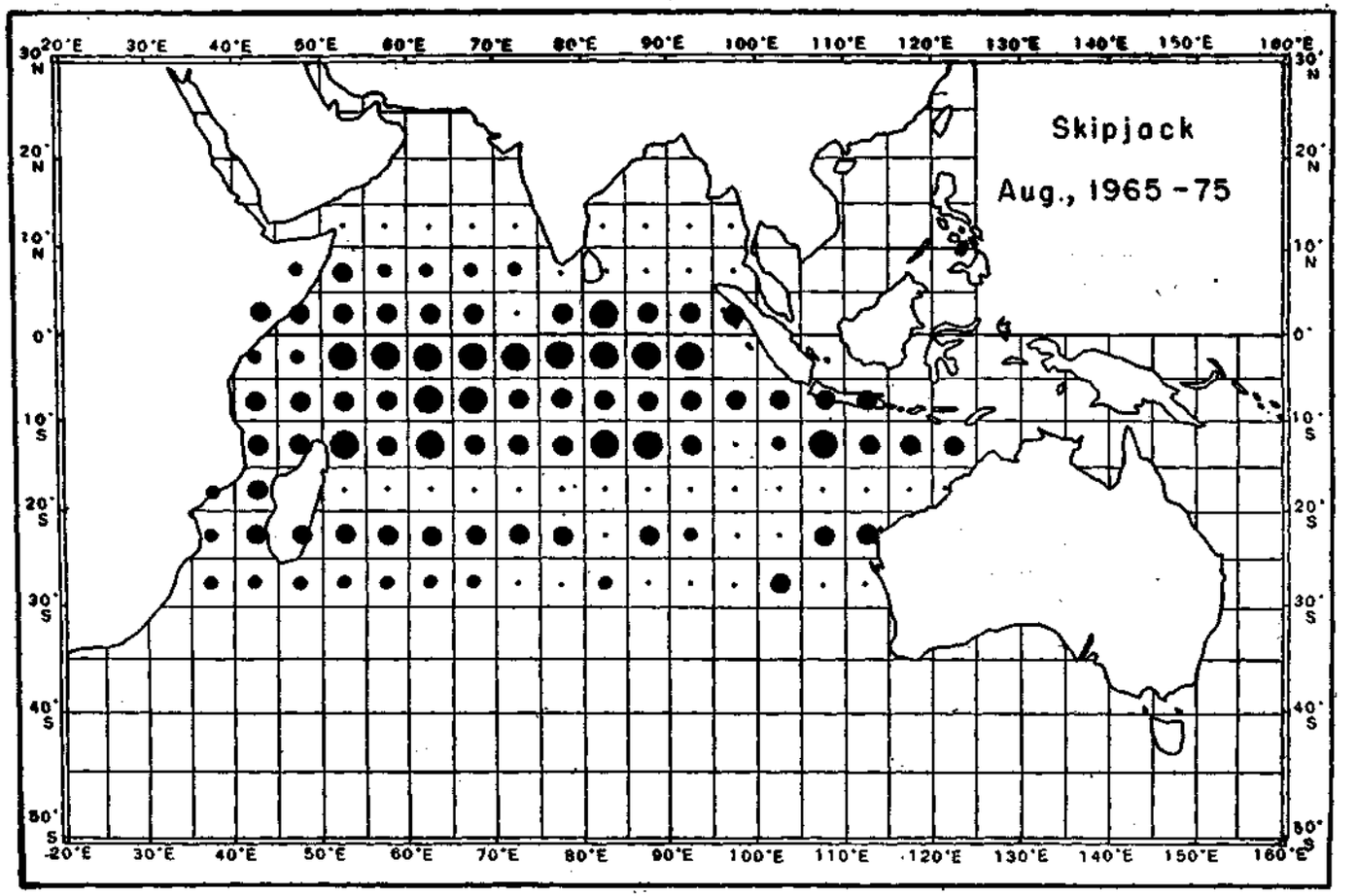

Fig. 10. Monthly distribution of relative density indices (d_{ij}) of skipjack tuna taken by the longline fishery in the Indian Ocean, 1965–1975 : August.

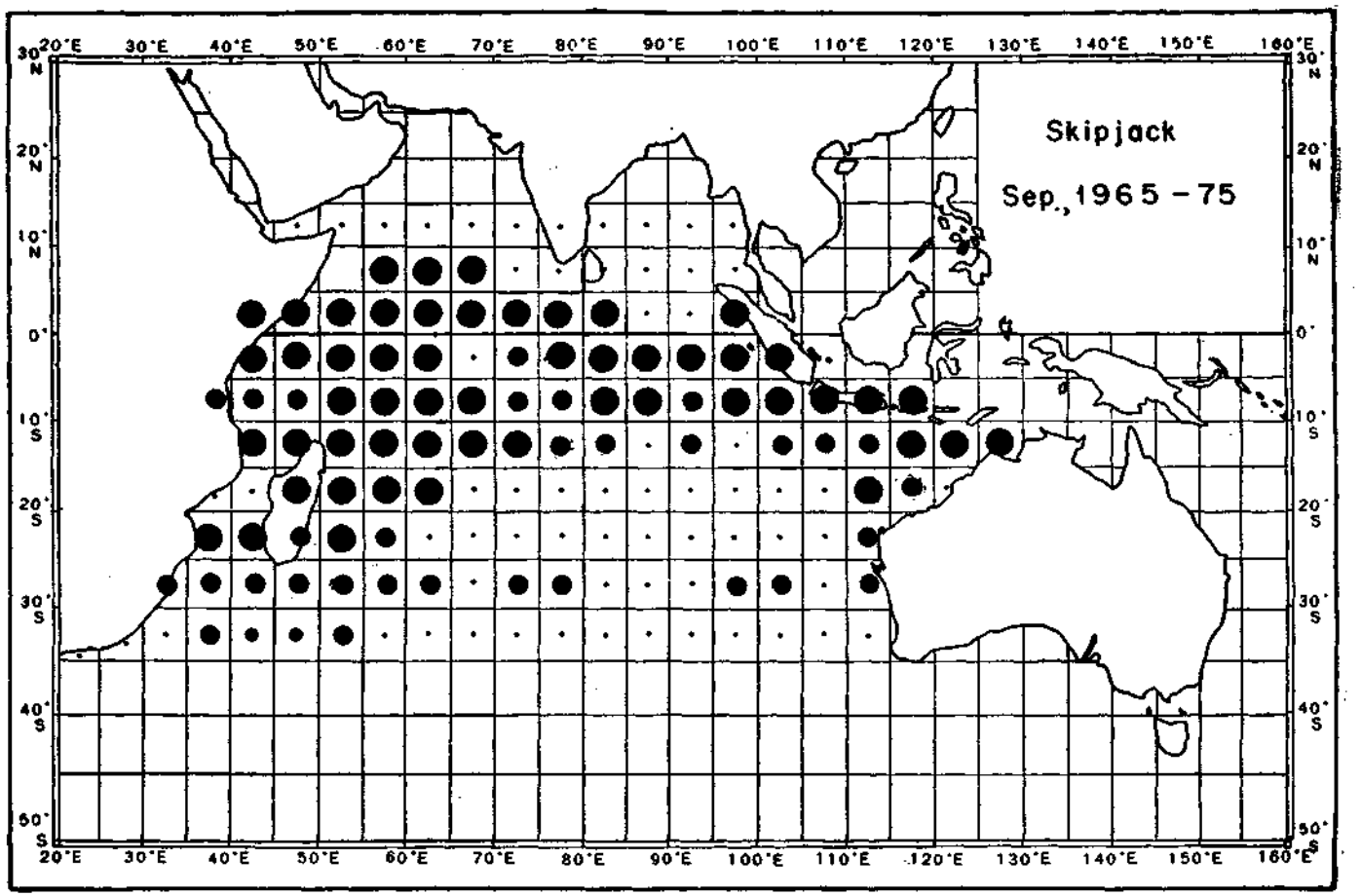

Fig. 11. Monthly distribution of relative density indices (d_{ij}) of skipjack tuna taken by the longline fishery in the Indian Ocean, 1965–1975: September.

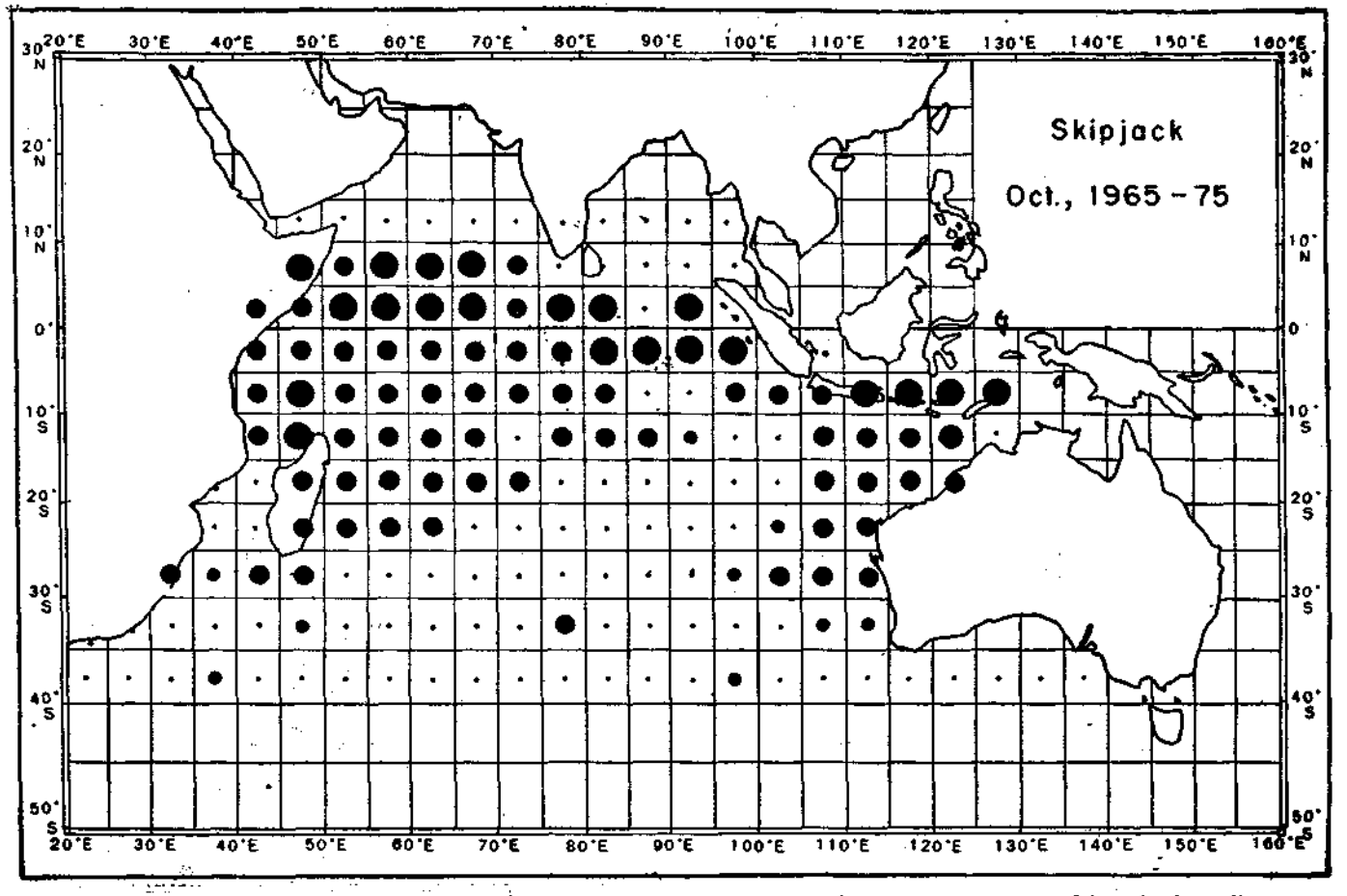

Fig. 12. Monthly distribution of relative density indices (d_{ij}) of skipjack tuna taken by the longline fishery in the Indian Ocean, 1965–1975 : October.

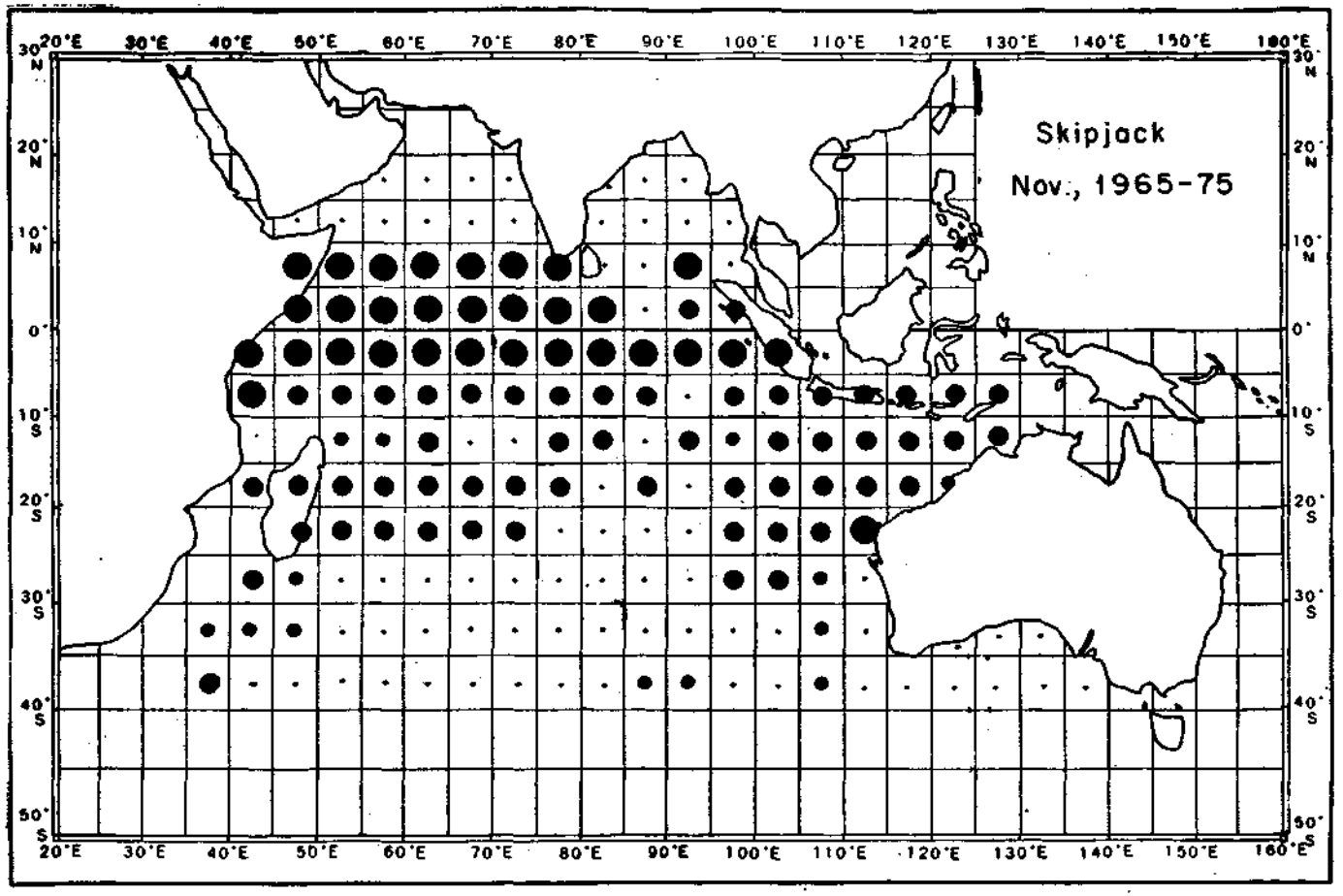

Fig. 13. Monthly distribution of relative density indices (d_{ij}) of skipjack tuna taken by the longline fishery in the Indian Ocean 1965–1975 : November.

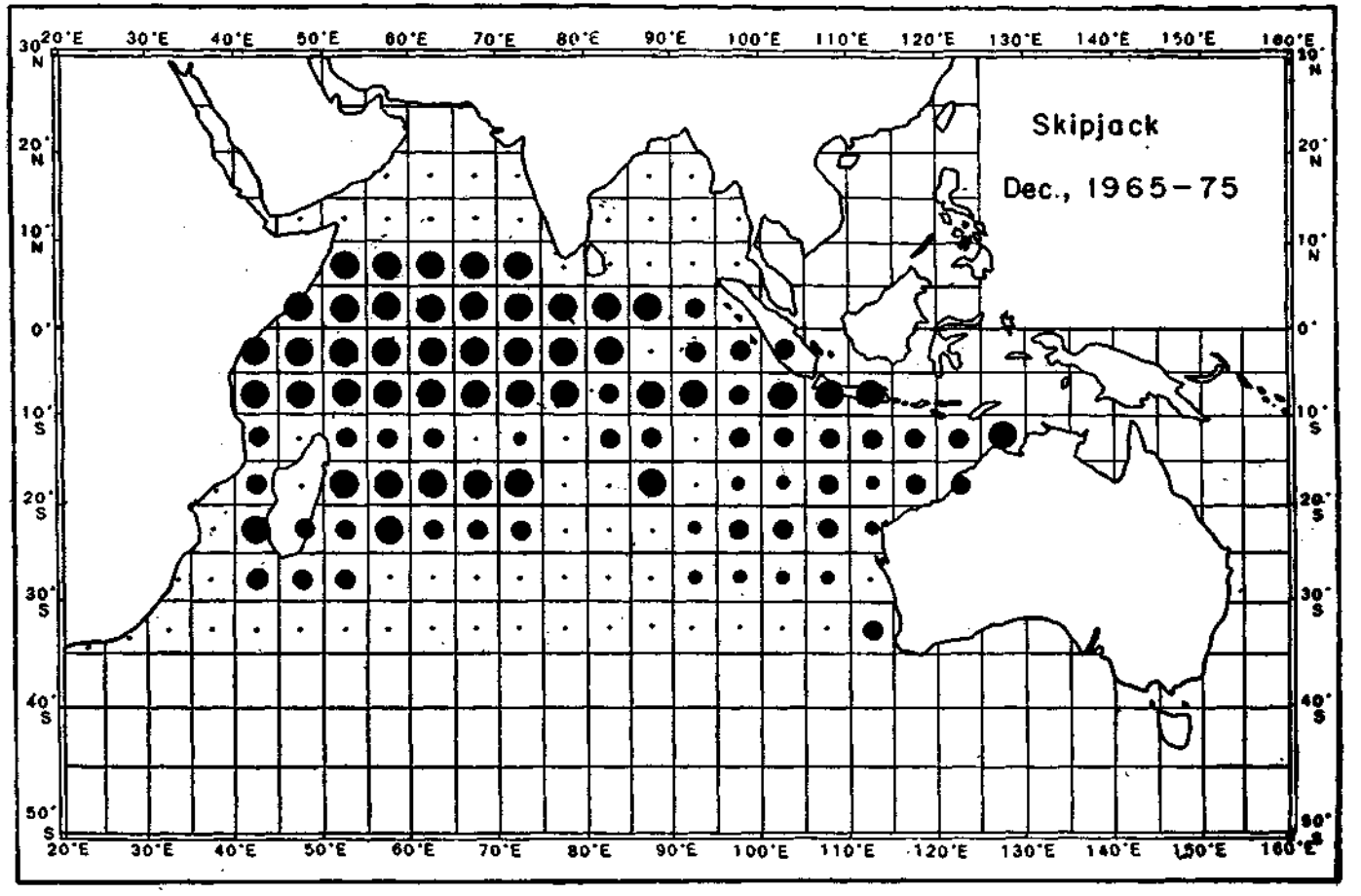

Fig. 14. Monthly distribution of relative density indices (d_{ij}) of skipjack tuna taken by the longline fishery in the Indian Ocean, 1965–1975 : December.

32 cm fork length were recorded during the second quarter. In Area 4 (CENTRAL INDIAN OCEAN), they occurred in the size range 40–90 cm, with a more or less uniform type of distribution during the four quarters. Major peaks were recorded at 56–58 cm and 66–70 cm. In Area 5 (EASTERN INDIAN OCEAN), they were present in the size range 30–86 cm and the major peak was around 52–60 cm. In Area 6 (SOUTHERN INDIAN OCEAN), data was insufficient, but the

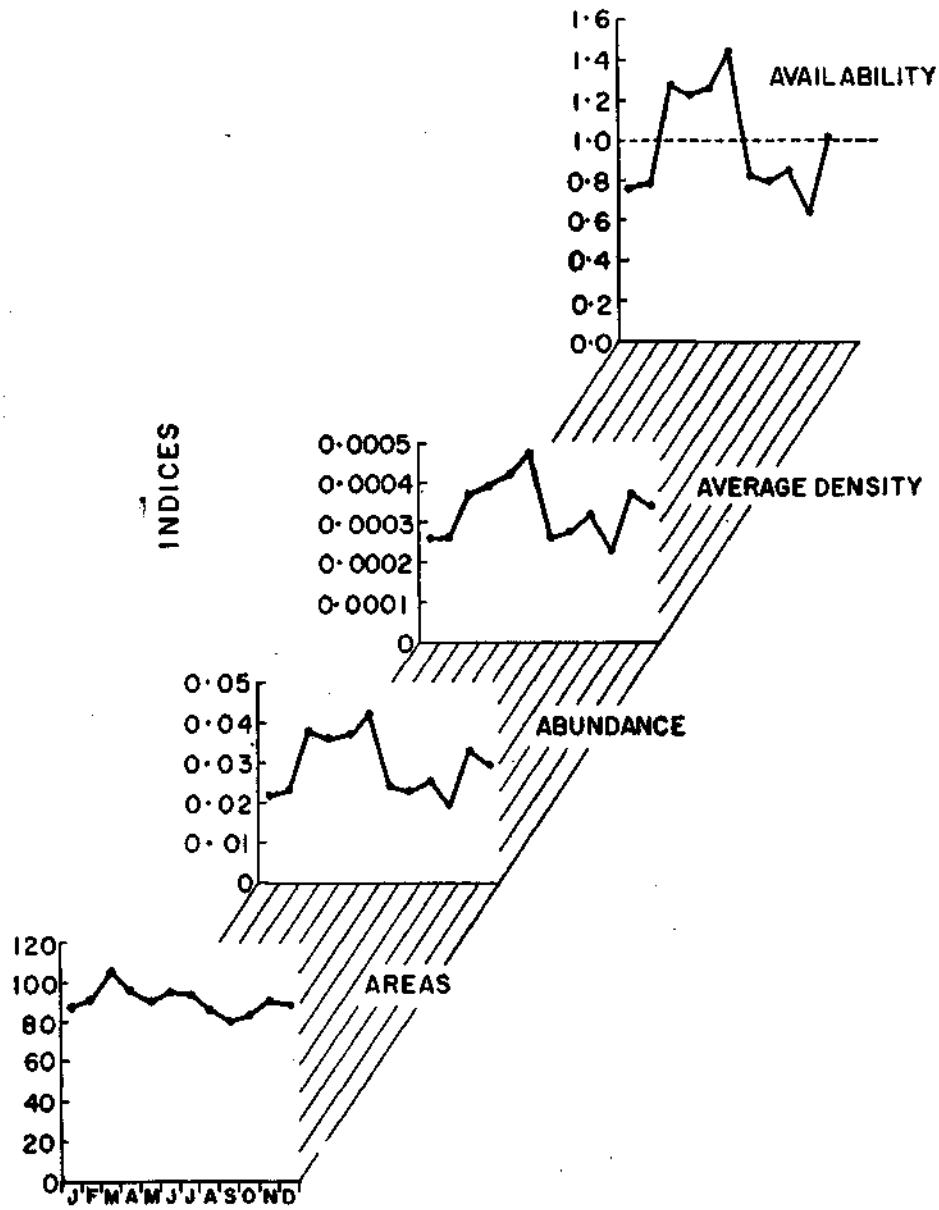

Fig. 15. Average monthly variation in the areas of operational extent, abundance, average density and availability of skipjack taken by the longline fishery in the Indian Ocean, 1965-1975.

available data indicate that they occurred in the size range 36–82 cm with major mode at 54–66 cm. Although there was difference in size composition by areas and quarters, the small sized specimens (<40 cm) occurred in the fishery during Quarter II in Area 3 and quarters I–IV in area 5. Fishes larger than 52 cm dominated in the area north of the Equator.

This view is in accordance with the present study. They have indicated that the major mode in the Arabian Sea, north of the Equator was 60–64 cm in all the quarters, in the the Bay of Bengal it was at 62–64 cm, in the central western Indian Ocean Area between 54–66 cm, in the central Indian Ocean Area between 58–60 cm and in the southern Indian Ocean Area between

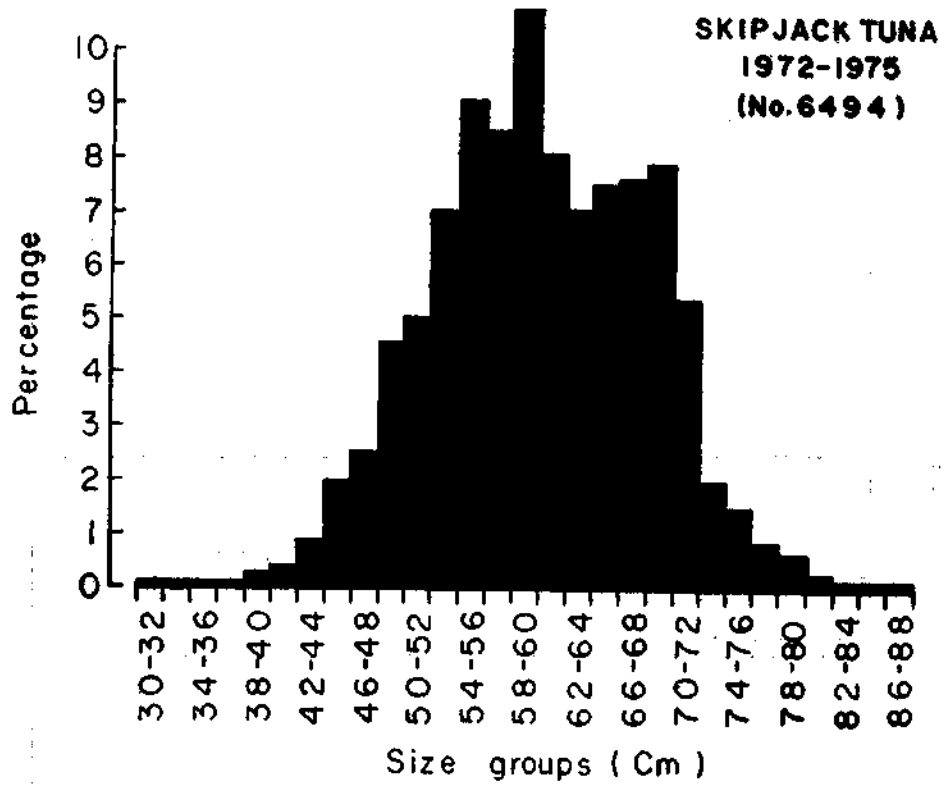

Fig. 16. Length frequency distribution of the skipjack taken by the longline fishery in the Indian Ocean, 1972–1975 (combined).

Marcille and Suzuki (1974) studied the size range of the skipjack tuna taken by the longline gear from the Indian Ocean and stated that larger fishes of more than 55 cm long dominated throughout the year in the area north of the Equator. The catches from the southern area comprised of small sized fishes below 55 cm.

66–70 cm in fork length. Raju (1964) and Thomas (1964) established the major annual modes of skipjack tuna taken by pole and line surface fishery as between 48–50 cm and 46–58 cm respectively. Appukuttan *et al.* (1977) stated that the size of skipjack in the commercial fishery (pole & line) as between 35.0 and 69.5

cm in the Minicoy waters. However, Marcille and Suzuki (1974) have indicated that the major modal size of skipjack tuna in the longline catches from the Arabian Sea is at 62–66 cm. Marcille and Velon (in press) and Marcille and Stequert (1976) have recorded the modes of skipjack tuna taken by the surface fishery around Madagascar at 50–54 cm and 43–50 cm respectively. Marcille and Suzuki (1974) based on the longline catches of skipjack tuna from the whole Indian Ocean

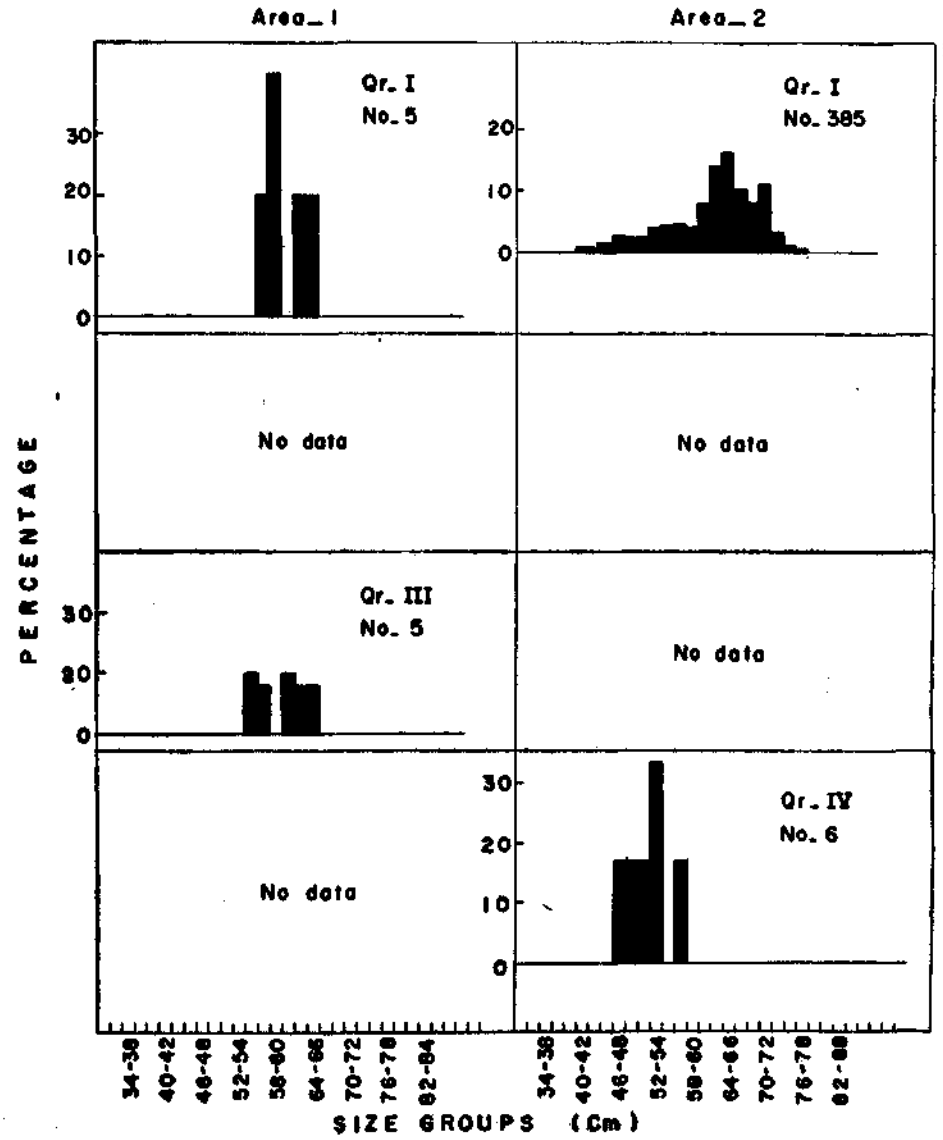

Fig. 17. Length frequency of the skipjack taken by the longline gear in the Indian Ocean, grouped by major areas and quarters, 1972–1975: Areas 1 and 2.

area have recorded major mode for this species at 60–66 cm. In the present study, it is concluded that the fishes of the size group 58–70 cm dominate the longline catches from most part of the Indian Ocean Area, especially in the northern sector.

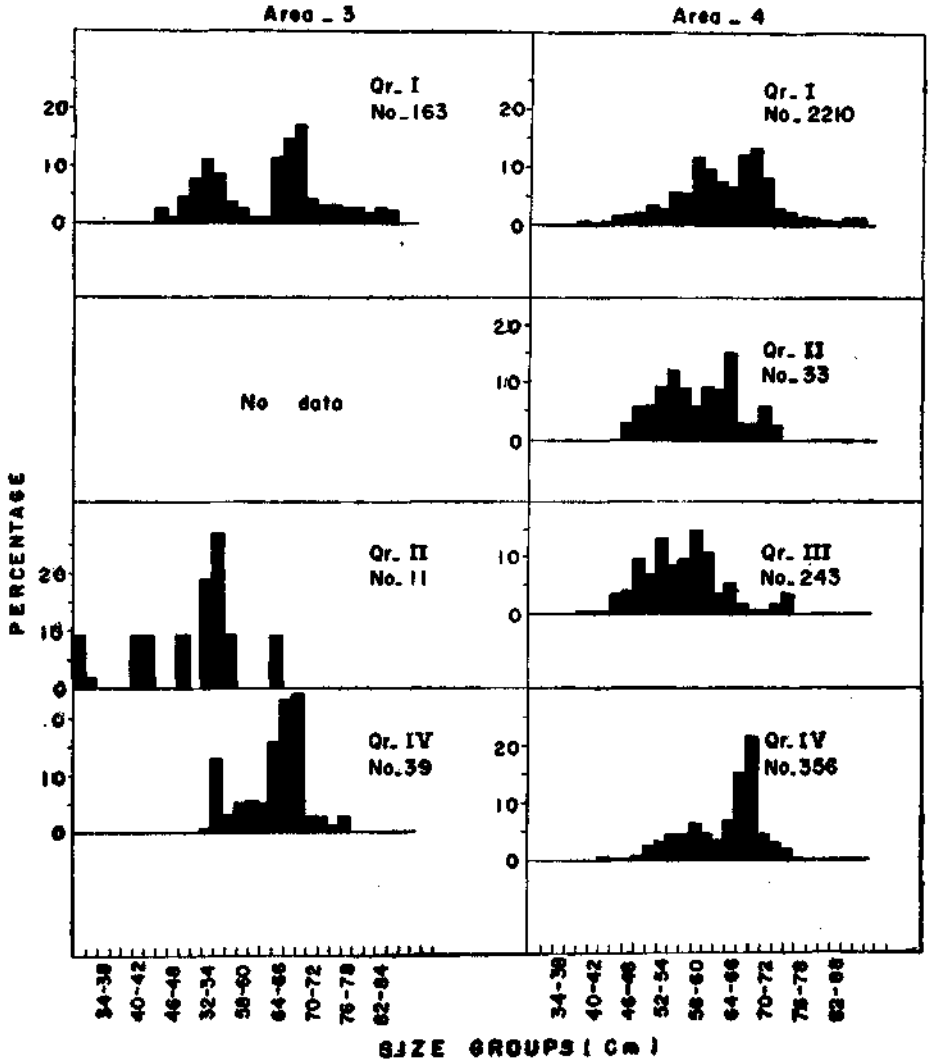

Fig. 18. Length frequency of the skipjack taken by the longline gear in the Indian Ocean, grouped by major areas and quarters, 1972–1975: Areas 3 and 4.

Sexual Maturity and Spawning

Sexual maturity of skipjack tuna was determined by the analysis of gonad indices (G.I.) (Table 1). Data from the Arabian Sea and Bay of Bengal are available only during January to March period. However, an analysis of the

available data has been made on the sexual maturity of skipjack tuna in the Indian Ocean in the present study.

were recorded during January and February. In the Bay of Bengal the incidence of mature specimens were relatively high during January,

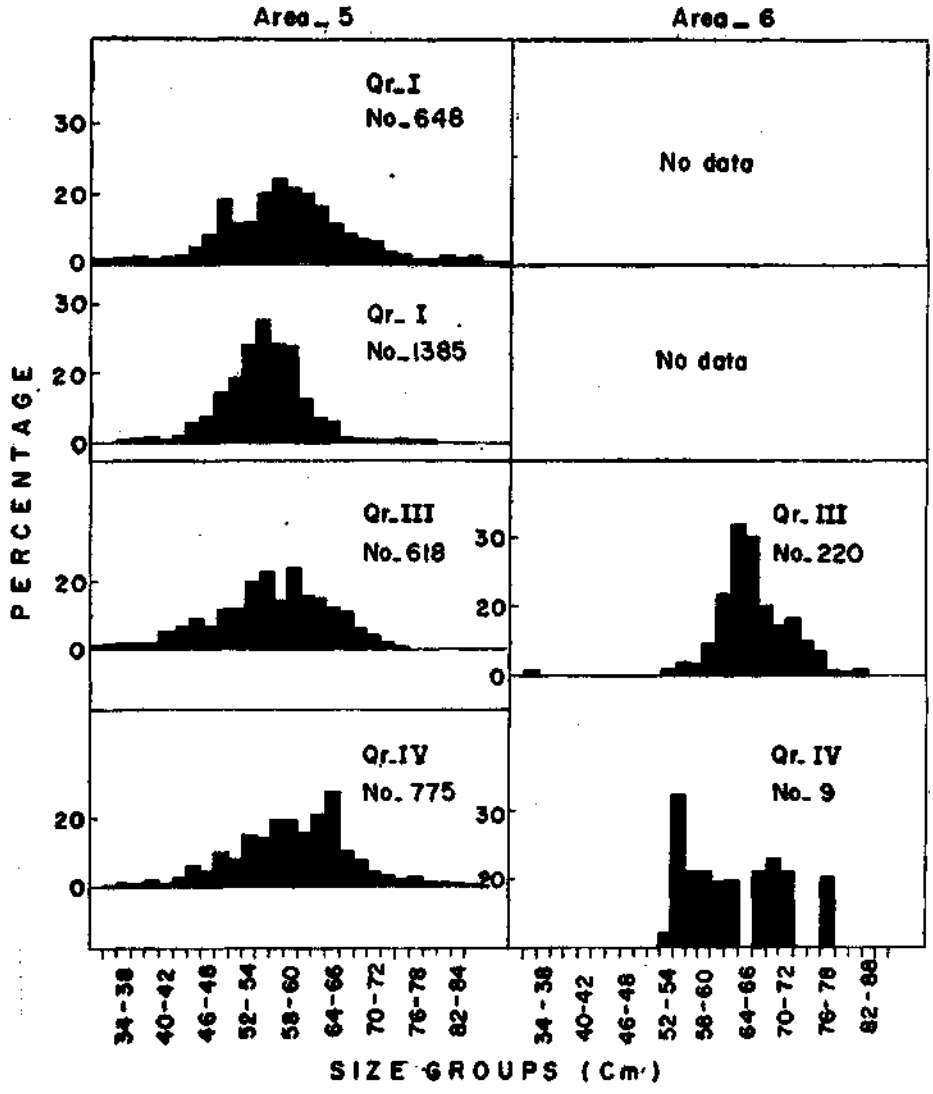

Fig. 19. Length frequency of the skipjack taken by the longline gear in the Indian Ocean, grouped by major areas and quarters, 1972–1975 : Areas 5 and 6.

It is assumed that the gonad index equal to or greater than 1.8 represent the specimens which are ready to spawn and belong to the spawning group. In the Arabian Sea, matured specimens

February, September and October. In the western Indian Ocean (0°– 20°S 35°– 80°E) the preponderance of matured females and males occurred during September to December.

In Area 4 (Fig. 1) spawning activity was relatively high between September to April and in Area 5 (Fig. 1) it was during August to September and in February. Data from the southern Indian Ocean (south of 20°S) are scanty and no definite conclusion on the spawning of skipjack in this area could be made. Available information indicate that during September to April an increase in their spawning activity occurs in the tropical waters of the Indian Ocean.

Discussion

The tropical nature of the distribution and abundance of skipjack tuna in the Indian Ocean is estimated from the density (d_{ij}) distribution maps. As discussed earlier, the monthly average relative abundance of skipjack tuna in the Indian Ocean occur in different months in different areas. In the first quarter of 1965–1975, they were widely distributed in the western Indian

Table 1. *Average gonad indices of skipjack by sex, month and the area taken by the Japanese longline vessels,* 1972–1975. (Numerals in parentheses denote numbers of fishes measured)

Area		J	F	M	A	M	J	Jy	A	S	O	N	D
1	F	6.0 (12)	5.1 (33)	—	3.4 (51)	—	—	—	—	—	—	—	—
	M	3.1 (15)	4.1 (28)	—	—	—	—	—	—	—	—	—	—
2	F	4.94 (25)	4.5 (68)	2.4 (5)	—	—	—	—	—	6.6 (2)	5.8 (61)	—	—
	M	3.1 (59)	3.08 (67)	2.5 (9)	—	—	—	—	—	5.4 (1)	4.5 (38)	—	—
3	F		6.2 (63)	—	—	—	2.9 (25)	—	4.7 (25)	5.5 (3)	3.8 (3)	7.3 (4)	4.9 (19)
	M		5.2 (37)				1.7 (50)		2.3 (1)	3.0 (29)	6.9 (1)	4.8 (9)	3.3 (21)
4	F	4.6 (82)	5.6 (66)	4.2 (66)	2.9 (60)	3.3 (85)	4.4 (186)	3.9 (42)	5.0 (39)	3.6 (24)	5.2 (58)	6.1 (43)	4.2 (11)
	M	4.7 (34)	4.5 (40)	3.1 (58)	3.3 (24)	2.0 (40)	2.5 (13)	2.9 (34)	4.2 (28)	2.2 (21)	3.0 (22)	4.3 (35)	3.8 (42)
5	F	—	4.8 (43)	—	—	3.8 (42)	3.9 (58)	—	5.2 (80)	4.1 (81)	5.2 (33)		
	M		3.8 (32)	3.9 (26)		3.6 (36)	2.8 (21)		2.9 (61)	2.8 (40)	3.1 (29)		
6	F									2.0 (12)	6.0 (2)		
	M	—	—	—	—	—	—	—	—	—	—	—	—
Total	F	119	243	71	111	127	269	42	144	122	137	46	30
	M	108	204	93	24	76	84	34	90	91	90	44	63

Ocean; in the second quarter in the eastern Indian Ocean; and the northwest coast of Australia and in the third and fourth quarters they were widely dispersed in the tropical waters.

The size distribution clearly indicates that the skipjack tuna taken by longline fishery are larger than those taken by the surface fishery. In the longline catches examined during the present study, 58–70 cm size groups dominated the landings in the Indian Ocean, which is in agreement with the findings of earlier authors from the same area (Marcille and Suzuki, 1974).

Jones and Silas (1963) stated that no definite range of spawning activity for skipjack has been established in any area in the Indian Ocean except that from the Lakshadweep Sea. Based on the skipjack larvae collections (Jones, 1959) and the examinations of the gonads (Raju, 1963), Jones and Silas (1963) concluded that the spawning of skipjack in the Minicoy waters is during an extended period from January to April and from June to September with peaks in January and June months respectively. In the present study, material available from the Arabian Sea and Bay of Bengal indicate that matured females and males dominate the longline catches during the January-February period. In the Central Indian Ocean, the spawning activity was relatively high during September through April, a matter which is in agreement with the findings of Marcille and Suzuki (1974). Due to the paucity of data from different parts of the Indian Ocean, no definite seasonal periodicity of spawning for skipjack tuna in the Indian Ocean could be derived at. However, available information indicate extended spawning activity for skipjack tuna in the warm waters of the Indian Ocean.

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