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Distribution and biology of the striped marlin, *Tetrapturus audax* (PHILIPPI) taken by the longline fishery in the Indian Ocean

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Abstract

Fishery biological data of the striped marlin, *Tetrapturus audax* (PHILIPPI) (Jap: Makajiki) obtained by the Japanese commercial longline vessels in the Indian Ocean during the period 1965-1975 were analysed, the results presented and discussed. The annual catch has decreased considerably since 1967, but the catch rate showed no definite tendency to increase or decrease. Distribution of the average monthly relative density showed that seasonal concentration occurred in the east African coast between equator and 10°S.; southern and western Arabian Sea, Bay of Bengal and north-western Australian waters. Seasonal north-south migratory movements of the fish is evident in the waters off the coast of East Africa and Bay of Bengal, and also the onshore-offshore movements occur in the north-western Australian waters. Analysis of the data revealed that the operational extent for this species was relatively large during the first half of the year. The abundance, average density and availability were high during March to June with a peak in April (Fig. 2). Studies carried out on the size composition of this species indicate that they occur in the size range from 91 to 230 cm (eye-fork length) with mode occurring around 171-175 cm class (Fig. 4). Regional and seasonal variation in size composition of striped marlin has been recorded. There seems little difference in the size composition by area and by season. Data on the sexual maturity, although limited, evince that Indian Ocean specimens attain sexual maturity at the size of 140-150 cm, in both the hemispheres. Analyses of data on the gonad index and larval occurrence indicate that the spawning activity in the western Indian Ocean resembles that in the western Pacific, but the data on the spawning activity in the eastern sector of the Indian Ocean suggest a different pattern in the Indian and Pacific Oceans. Available information also indicate that the possibility of the existence of different populations in the Indian Ocean cannot be ruled out.

Introduction

Our knowledge on the distribution and biology of the striped marlin in the Indian Ocean was mainly confined to certain regional studies based on isolated fisheries (WILLIAMS, 1964, 1967,1970; JONES and KUMARAN, 1964; SILAS and RAJAGOPALAN, 1964; MERRETT, 1970; 1971), and general observations and reviews on this fish and its fisheries (TALBOT and PENRITH, 1962; UEYANAGI, 1963 a, b, 1964, 1974; KOGA, 1967; KIKAWA *et al.*, 1969; DE SYLVA, 1974;

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PENRITH and CRAM, 1974; UEYANAGI and WARES, 1975) until HOWARD and STARCK II (1975) published the results of a study on the distribution and relative abundance of the billfishes (Istiophoridae) from the overall Indian Ocean, based mainly on the data obtained during 1953–1959. Fullscale commercial operations of longline fisheries in the Indian Ocean began since 1954, and despite the fact that considerable data have been accumulated much work remain to be done in this region. Limited coastal fisheries for billfishes occur in the Indian Ocean near Ceylon, Malindi (Kenya), Zanzibar and Maldive Islands; and definite records of striped marlin are chiefly available from Mauritius and East Africa where small sport fisheries exist (HOWARD and STARCK II, 1975). However, detailed information on the catch statistics for these fisheries are scanty and incomplete.

The present paper aims at adding to the knowledge of the distribution and biology of the striped marlin in the Indian Ocean, and comprises a synoptic study based on the data obtained by the Japanese commercial longline fishing vessels and other research and training vessels operated in the area during the period 1965–1975.

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Data-sources and processing

The data used in the present paper were collected by the Fisheries Agency, Japan, from the Japanese commercial and research longline vessels, which operated in the Indian Ocean area during the period 1965–1975, and processed by the Far Seas Fisheries Research Laboratory (ANONYMOUS, 1967–1977). The data include: (i) fishing effort in number of hooks and number of fish caught by $5° \times 5°$ area and month of the year; (ii) body length by area ($5°$ lat. $\times 10°$long.) and quarter of the year, and (iii) measurements of gonad weight and length of fish by month. The length frequency and gonad data used in this report are from January, 1971 through December, 1975.

Data on the fishing effort (number of hooks) and the number of fish caught by $5° \times 5°$ area in the Indian Ocean has been processed and indicated in a series of figures (App. Fig. 1) using the "Relative-density indices" (d_{ij}) which were calculated in the form of monthly averages for the 11-year period 1965–1975, as follows:—

$$d_{ij} = \frac{1}{m_{ij}} \sum_{k=1}^{m_{ij}} d_{ijk} = \frac{1}{m_{ij}} \sum_{k=1}^{m_{ij}} (C_{ijk}/G_{ijk}) \quad \cdots\cdots (1)$$

Where, m_{ij}=number of years when the ith $5° \times 5°$ areas were occupied in the jth month;

C_{ijk}=catch in the ith $5°\times5°$ area occupied in the jth month of the kth year;

G_{ijk}=nominal effort used in the ith $5°\times5°$ area occupied in the jth month of the kth year.

The d_{ij} indices are indicated in the maps as per 100 hooks (App. Fig. 1). With a view to distinguish the variations in the d_{ij} in the maps, these indices were divided into five ranges which are represented on the maps by symbols placed in the $5°\times5°$ area.

The body length is expressed by the "eye-fork length" which is the distance from the posterior margin of the orbit to the mid-point of the fork of the caudal fin. Sexual maturity of the striped marlin, dealt with in this report was determined by the analyses of "gonad indices" (G. I.) which was calculated as follows:—

$$\text{G. I.}=(W/L^3)\times10^4 \cdots\cdots (2)$$

Where, W=weight of both ovaries in gram;

L="eye-fork length" in cm.

In order to facilitate comparison of the results on the length composition and maturity of striped marlin with those of the previous studies, the Indian Ocean has been divided into six major areas as follows (Fig. 3).

AREA-A=Arabian Sea, north of 5°N. and west of 80°E.

AREA-B=Bay of Bengal, north of 5°N. and east of 80°E.

AREA-C=Central western Indian Ocean, 5°N-10°S, west of 80°E.

AREA-D=Central eastern Indian Ocean, 5°N-10°S, east of 80°E.

AREA-E=South-western Indian Ocean, south of 10°S., west of 80°E.

AREA-F=South-eastern Indian Ocean, south of 10°S., east of 80°E.

Recent status of striped marlin production in the Indian Ocean

The total catch of the striped marlin from the Indian Ocean during the period 1965–1975 ranged from about 1,200 to 6,200 M.T. (FAO, 1974, 1976). This showed a downward trend from the peak in 1967, to the minimum in 1973, which recovered to a level of 2,000 M.T. in 1974 (Fig. 1A). On the average, striped marlin catches constituted about 25% of the total billfish landings made from the Indian Ocean by longline fishery. Taking into consideration the Japanese longline fishery in the overall Indian Ocean area, it is evident that the decreasing trend of the annual catch since 1967 was more steady (Fig. 1B). This decreasing tendency can be attributed to the shift in the geographical area for longline fishery since 1966, when the Japanese longline fishermen began to focus their attention on the economically important southern bluefin tuna in the southern Indian Ocean area where the billfishes in general, and striped marlin in particular, are caught sporadically.

An analysis of the catch of striped marlin from the area north of 30°S., where they are chiefly distributed, shows that the pattern of variations in the total catch from the whole Indian Ocean follows that for the area north of 30°S (Fig. 1B). In the northern sector, the longline effort (number of nominal hooks) diminished considerably since 1967, reaching a low

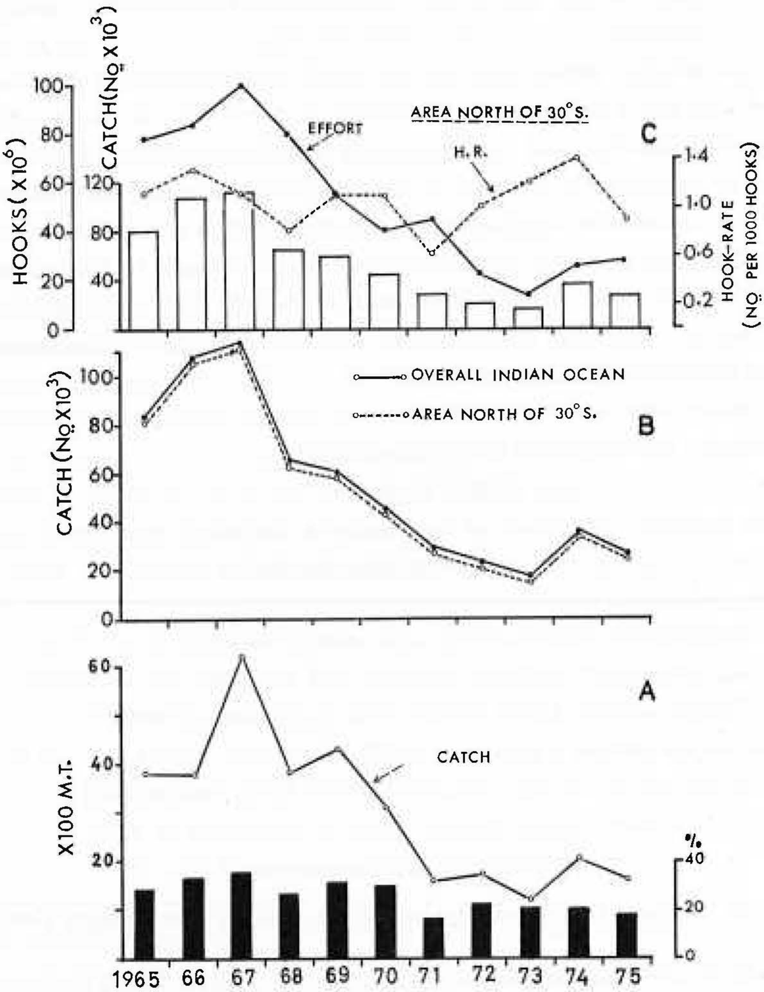

Fig. 1. (A) Annual variation in the catch of striped marlin from the Indian Ocean during 1965–1975 (FAO, 1974; 1976). Shaded portion indicates the percentage composition of striped marlin to the total billfish catch during different years. (B) Annual variation in the striped marlin catches (number) by the Japanese longline fishery in the Indian Ocean, 1965–1975. (C) Annual variation of catches (number), efforts (number of hooks) and hook-rate of striped marlin in the area north of 30° S. of the Japanese longline fishery in the Indian Ocean, 1965–1975.

level in 1973. The catches of striped marlin were high during 1965–1967 which decreased in the following years. However, the catch-rate showed no definite tendency to increase or decrease but evinced annual fluctuations (Fig. 1C).

Relative density distribution

The average monthly density distribution of striped marlin (expressed in number per 100 hooks) for the years 1965–1975 is shown within $5° \times 5°$ areas in App. Fig. 1. Seasonal pattern of abundance showed variations and it was observed that some fishes are distributed in most of the regions at all the times.

The d_{ij} distribution shows that the striped marlin is primarily distributed in the warmer waters in the Indian Ocean. The general pattern of distribution occupies the area from 20°N. to 40°S. Areas of high relative density occur in the nearshore waters. Latitudinal distribution was extensive in the north during March to June and in the south during November to March. Based on the pattern of distribution of d_{ij}, the following areas of high catch-rates could be distinguished:—

(i) East African coast between equator and 10°S.
(ii) Western Arabian Sea
(iii) Bay of Bengal, and
(iv) North-western Australian Coast

In the south African waters apparent concentration of striped marlin begins by November and low catches are recorded from the south and south-east areas till March, and from April the catches show definite decrease and ensuing disappearance. TALBOT and PENRITH (1962) and PENRITH and CRAM (1974) reported in detail the occurrence of striped marlin around the Cape of Good Hope as far as the Cape Town. The latter authors recorded the specimens "between the middle of January and the end of March" and opined that they inhabit in the Cape of Good Hope area only in summer.

In the equatorial western Indian Ocean area comprising the region between 5°N. and 10°S., the striped marlin are observed to be distributed throughout the season. High catch-rates in this area appear during October and the catch-rates gradually increase from November, attaining highest values during the period February to March. WILLIAMS (1964, 1967, 1970), and MERRETT (1971) opined that the concentration of striped marlin along the coast of East Africa occurs mainly during the NE monsoon period from November to March. MERRETT (1971) further opined that the catch-rates of striped marlin were increased by 60% during this period. Present findings agree with the conclusions of these authors.

From the Arabian Sea, fewer catches are recorded in the southern part during August. The catch-rates increase from November, recording high values during March to June. In the western sector, along the Arabian coast high catch-rates appear during March to June since when they diminish and disappear in August. Scattered records appear during October in the northern Arabian Sea and the catch-rates further increase, reaching maximum during April to June, mainly in the area north-west of the Lakshadweep Islands. Information on fishing from this area from July to December are lacking.

In the Bay of Bengal low catch-rates appear in the north-eastern part of Sri Lanka during December and the fishing generally extends northwards from January onwards. Maximum concentration of fish occurs in this area during February to May, and the catches become lower in June. It appears that the fishes disperse during the rest of the period and fishing data from this area of the Indian Ocean are wanting from July to December.

No discernible concentration occurs between the equatorial eastern Indian Ocean and north-west Australia during January to May. From June, low catches appear along the north-western Australian coast and maximum values were recorded during September to November. In December, the catch-rates become low in this area.

In the central eastern Indian Ocean area, low catch-rates occur during most part of the year. The present findings are in concurrence with those of HOWARD and STARCK II (1975), who reported on the occurrence of striped marlin in the area between Bay of Bengal and north-western Australian waters during most part of the year in lesser numbers.

Relative abundance of striped marlin—Monthly variations

As seen in the distribution of relative density indices (d_{ij}) of the striped marlin in the Indian Ocean, areas of high concentration are due to the variable distributions of the fish during different months. Relative density has been calculated in the form of monthly averages for the 11-year period 1965–1975. If the d_{ij} indices reliably reflects the density of fish at a given locality, then d_{ij} multiplied by a given area of that region would be an index of the abundance of the fish at that time. The abundance (N_j) can be calculated from the following equation:—

$$N_j=\sum_{i=1}^{n} d_{ij}\cdot A_{ij} \qquad (3)$$

Where, N_j =total abundance of the fish during the jth month;

A_{ij}=an index of the geographical extent of the ith area during the jth month, excluding the land; the unit is "an area of 5°×5° along the equator" (HONMA, 1974);

n=number of 5°×5° areas.

Thus the average density ($\bar{d}_j$) of the fish can be expressed by the relationship:

$$\bar{d}_j=N_j/A_j=N_j/\sum_{i=1}^{n}\cdot A_{ij} \qquad (4)$$

Where, A_j=extent of the whole fishing grounds during the jth month.

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

$$a_j=N_j/\bar{N} \qquad (5)$$

$$\text{Where, } \bar{N}=\frac{1}{12}\sum_{j=1}^{12} N_j$$

and a_j=availability of the fish during the jth month.

The indices of areas operated, abundance, average density and availability which were

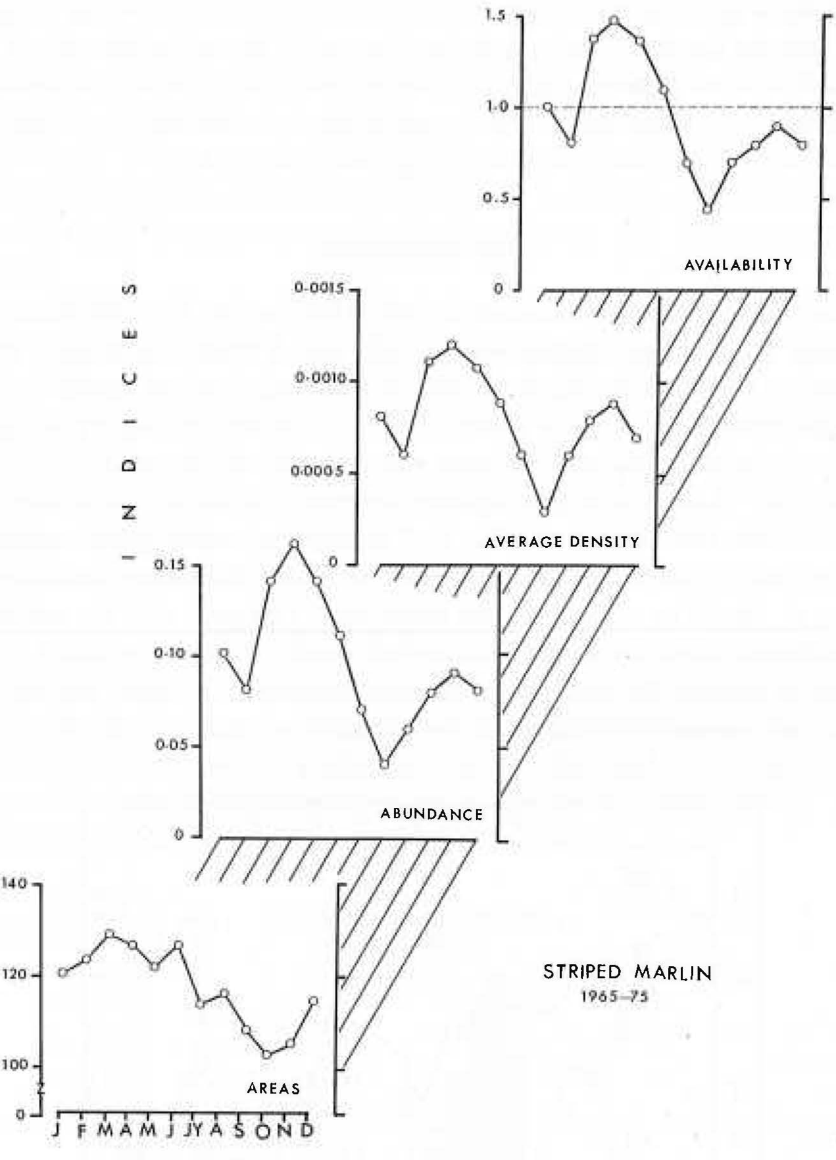

Fig. 2. Average monthly variation in the areas of operational extent, abundance, density and availability of striped marlin taken by the Japanese longline fishery in the Indian Ocean during the period 1965–1975.

calculated from the original d_{ij} values are shown in Fig. 2. It is evident that the operational extent for striped marlin was high during the first half of the year. The abundance and average density of this species in the Indian Ocean were at their peak during April since when they gradually declined and reached the lowest ebb in August. Subsequently, these indices increased and reached a relatively high position in November.

The availability of striped marlin was high during March to June and relatively low during the rest of the year. It is evident in the distribution of d_{ij} that the catch-rates were at the highest in the major fishing grounds of the Arabian Sea and Bay of Bengal during March to June. It seems that the periods (months) when the availability indices are more than 1.0 will be more productive than the average. From the d_{ij} maps it is also evident that the fishing effort for striped marlin was apparently absent in the northern Arabian Sea and Bay of Bengal since July when the fishes are probably dispersed.

Size composition

The size composition data discussed in this report pertain to 5,940 measurements of striped marlin caught by the longline vessels in the Indian Ocean from January, 1971 to December, 1975 and is shown in Fig. 4 in terms of percentage. Striped marlin in the Indian Ocean ranged from 91 to 230 cm in eye-fork length. However, the majority of the samples were between 155-185 cm and the frequency was unimodal with the mode occurring in the 171-175 cm class. The annual length frequency distribution of the fish for all areas combined for the period 1971-1975 is shown in Fig. 5. The dominant modal group usually occurred between 151-185 cm. But in 1975, the occurrence of bimodal distribution was noticed and the modes were at 146-150 cm and 171-175 cm respectively. Compared with the previous years, in 1975 small-sized fishes (less than 150 cm eye-fork length) frequently appeared in the catch.

In order to examine the variations in the size composition in detail, percent frequency distributions are prepared by pooling the data within four quarters of the years 1971-1975,

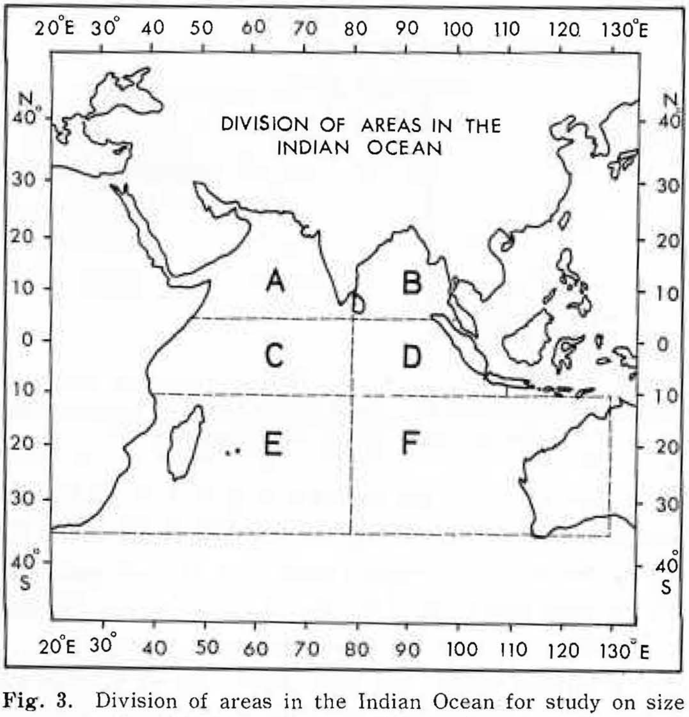

Fig. 3. Division of areas in the Indian Ocean for study on size composition and maturity of striped marlin.

and shown for six fishing areas (see Fig. 3) in Fig. 6. Data are relatively insufficient for the Arabian Sea (A), Bay of Bengal (B), central and south-western Indian Ocean (C and E).

There seems to be no significant difference in the size compositions by area and quarter. However, the following characteristics are observed: small-sized specimens were proportionately higher in the area F than in the area D during the first and second quarters, while *vice versa* is the case in the fourth quarter. Size composition of striped marlin in the area F during the third quarter is multi-modal in comparison with the unimodal one in the fourth quarter.

Howard and Starck II (1975) based on the length composition data collected from the longline fishery in the Indian Ocean during 1953–1959 opined that in the Bay of Bengal striped marlin occurred most frequently in the range 171–190 cm, whereas in the Arabian Sea the common frequency was between 141–190 cm. According to them, the southern Indian Ocean (south of 10°S. and west of 100°E.) specimens were large-sized, the mode being at 201–210 cm and the eastern Indian Ocean specimens showed bimodal distribution (specimens from the area south of 10°S. and east of 100°E.), with modes at 131–140 cm and 171–180 cm respectively within a range of 100–240 cm. The present data conform to this pattern in the broad details.

Merrett (1971) observed that the striped marlin recorded from the equatorial western Indian Ocean falls between 120–200 cm with modes at 145–154 cm (70–79 lbs) and 165–179 cm (100–129 lbs). Williams (1963) also recorded two modes for the striped marlin at 145–152 cm and 176–183 cm. We could observe multimodal nature of the length distribution in the area C (Fig. 3) which region coincides with that investigated by the above authors. However, the major modal group occurred in the size range 161–180 cm.

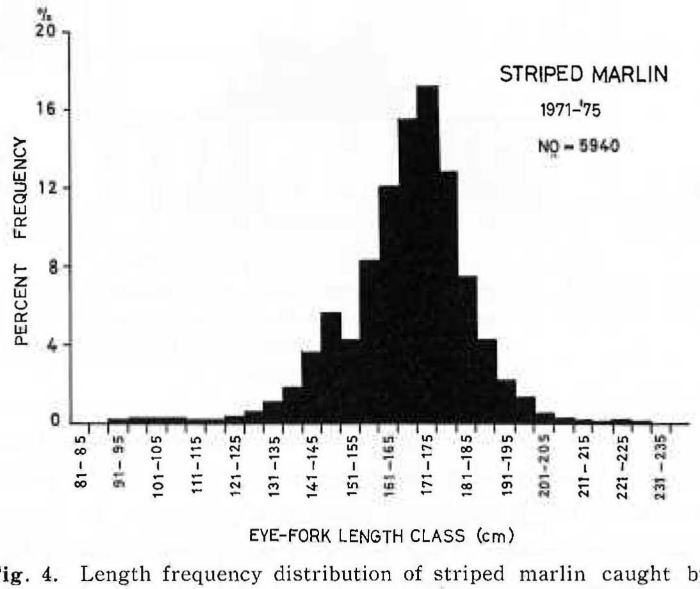

Fig. 4. Length frequency distribution of striped marlin caught by Japanese longline fishery in the Indian Ocean during 1971–1975 (combined). No. --- Number of fish measured.

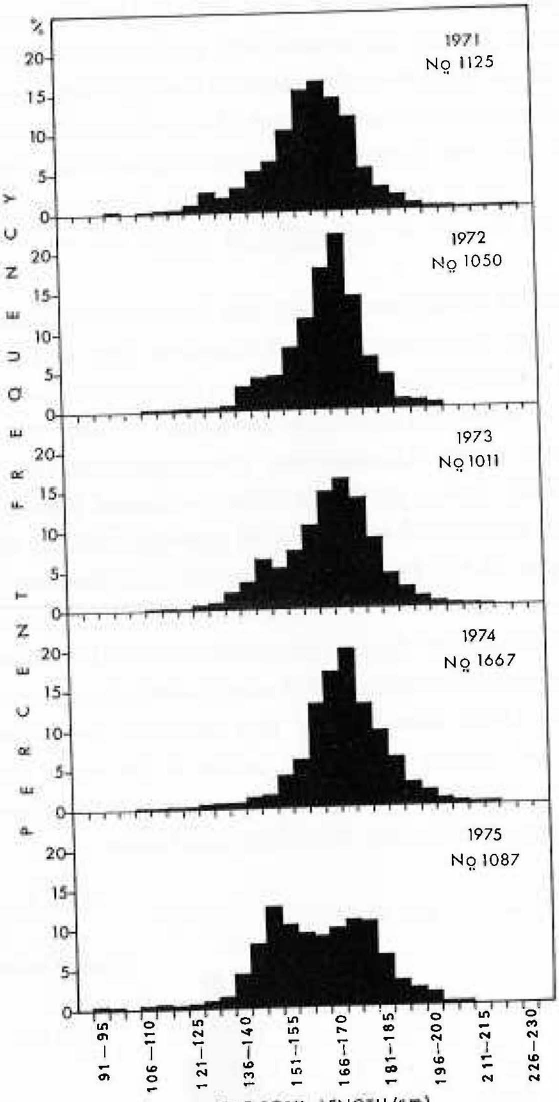

Fig. 5. Annual length frequency distribution of striped marlin taken by Japanese longline fishery in the Indian Ocean during the years 1971–1975. No. --- Number of fish measured.

MERRETT (1971) also postulated a distribution of "length frequencies by age-groups" from the total data from September, 1964 to December, 1967, and the modal progression observed in the composite monthly length frequency distribution. However, in the present study no clear trend of seasonal progression of the modes in the quarterly length frequency data is evident. If the estimates of age-groups postulated by MERRETT (1971) are directly applicable to the striped marlin in the Indian Ocean in general, then the age-group "n+1" (165–179

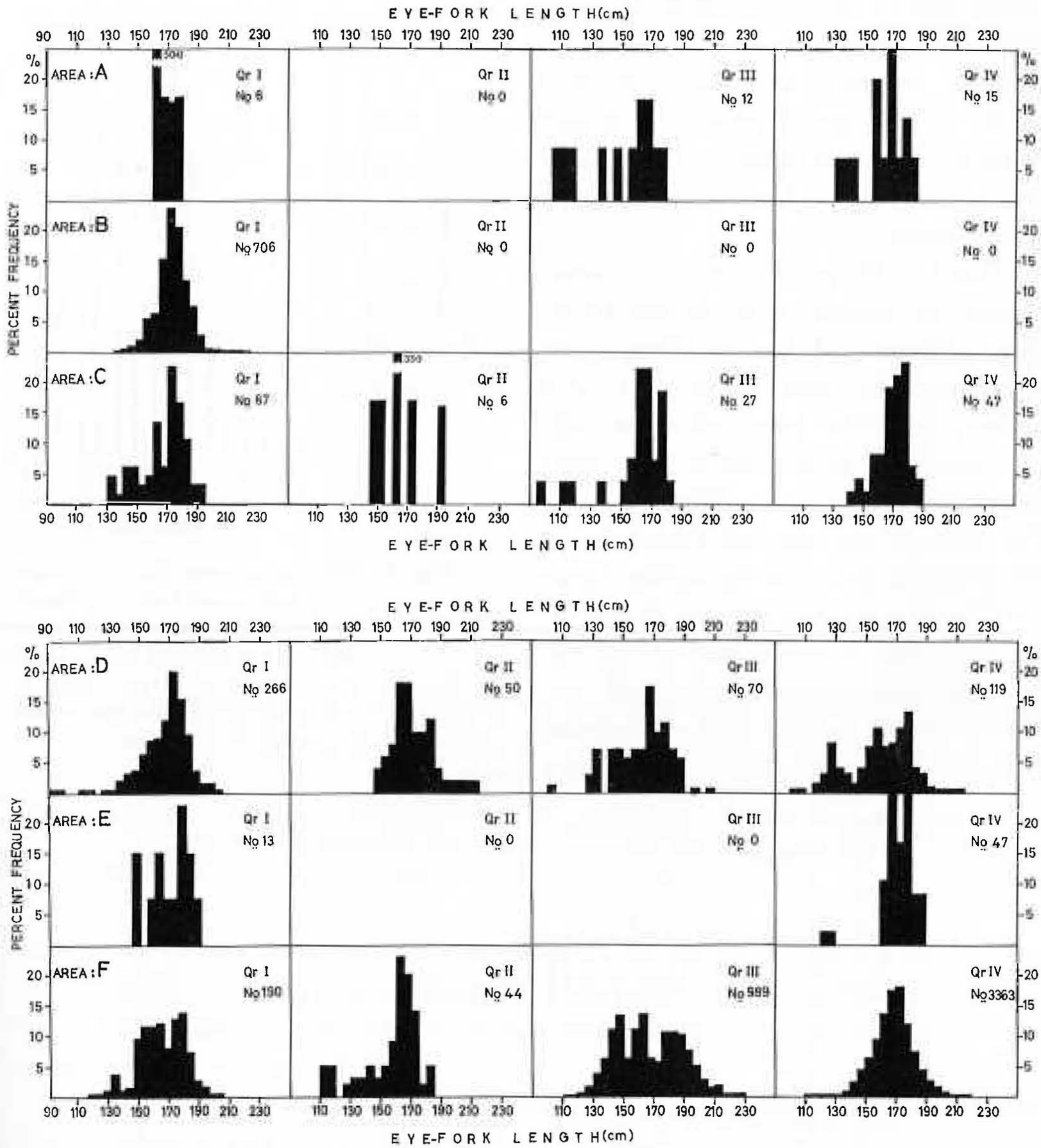

Fig. 6. Length frequency distribution of striped marlin taken by Japanese longline fishery in the Indian Ocean, grouped by major areas and quarters, 1971–1975. No. --- Number of fish measured.

cm) will be the major component of the longline catch in this area followed by the "n" age-group (140–164 cm) (Fig. 5).

Sexual maturity and spawning

As stated earlier, sexual maturity of the striped marlin was determined by the analyses of gonad indices (G.I.). Data from the Bay of Bengal are available only during January to

March, and no data are available from the Arabian Sea and south-western Indian Ocean. However, in view of the paucity of information on the sexual maturity of striped marlin in the Indian Ocean, an analysis of the available data has been carried out in the present study.

Based on the previous studies on sexual maturity of striped marlin in the Pacific Ocean (HOWARD and UEYANAGI, 1965; KUME and JOSEPH, 1969; SHINGU *et al.*, 1974), it is assumed here that female specimens with G. I. equal to or greater than 3.0 are ready to spawn and belong to the spawning group. The quarterly and area-wise distribution of the spawning group in the Indian Ocean could be deduced from the Figs. 7-10.

In the Bay of Bengal, most of the matured specimens occurred in the range 166-210 cm although one ripe adult was observed in the 141-145 cm class (Fig. 7). The pattern

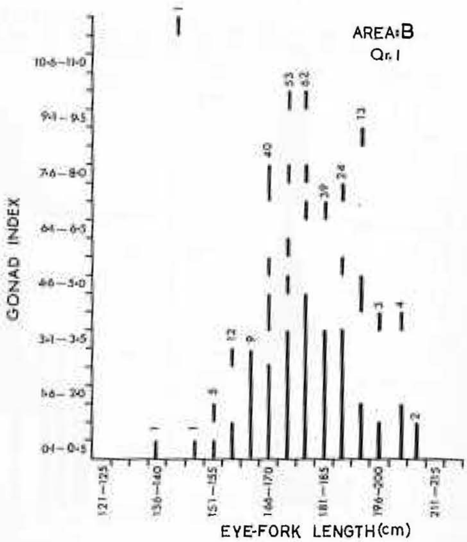

Fig. 7. Relation between eye-fork length (cm) and gonad index of female striped marlin taken by Japanese longline fishery in the Indian Ocean, 1971-1975, in the area B (Fig. 3). The numerals indicate the number of specimens examined.

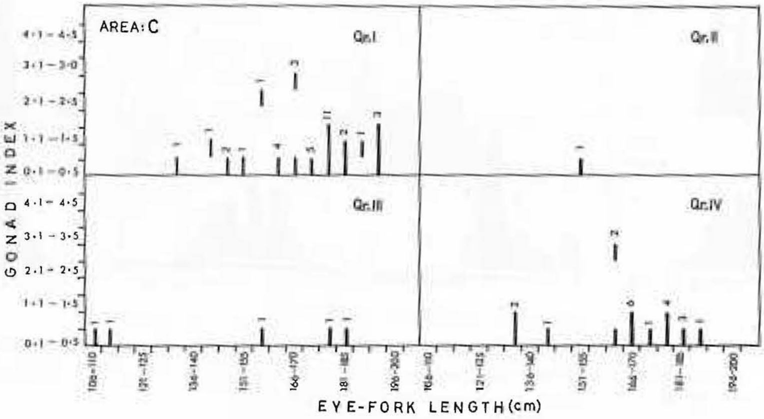

Fig. 8. Relation between eye-fork length (cm) and gonad index of female striped marlin taken by Japanese longline fishery in the Indian Ocean, 1971-1975, in the area C (Fig. 3). The numerals indicate the number of specimens examined.

of distribution of G. I. in the central western Indian Ocean showed that no matured fish occur in this area during any quarter of the year (Fig. 8). From the central eastern Indian Ocean (Area D) scattered occurrence of matured females were observed during the first

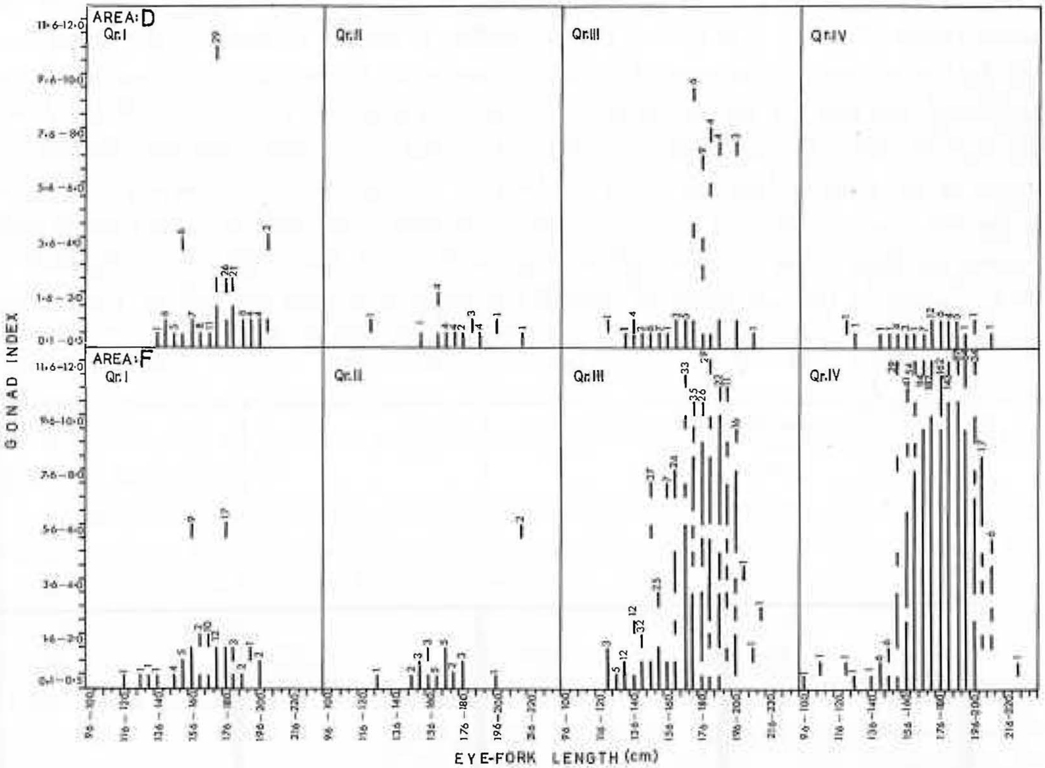

Fig 9. Relation between eye-fork length (cm) and gonad index of female striped marlin taken by Japanese longline fishery in the Indian Ocean, 1971–1975, in the areas D and F (Fig. 3). The numerals indicate the number of specimens examined.

quarter in the size groups 151–155 cm, 171–175 cm and 201–205 cm. During the third quarter matured females occurred within the range 171–200 cm (Fig. 9). In the south-eastern Indian Ocean (Area F) matured females were quantitatively high during the third and fourth quarters, in the size range 146–210 cm (Fig. 9).

UEYANAGI (1957) opined that 154 cm eye-fork length was the smallest size of adult female found in the spawning group in the north western Pacific. KUME and JOSEPH (1969) reported that individuals longer than 160 cm occur regularly in the spawning group, although they have reported on a matured specimen in the 148 cm class. Other data from the eastern Pacific agree with these conclusions (ELDRIDGE and WARES, 1974). Recently, HANAMOTO (1977) estimated that the minimum size of spawning striped marlin in the southern Coral Sea was at about 143 cm in eye-fork length. From the Indian Ocean, WILLIAMS (1967) concluded that in East Africa the first maturity of striped marlin was attained between 141–157 cm eye-fork length. MERRETT (1971) reported similar results, i. e. 140–160 cm or 62–93 lbs. In the present study it was observed that the size at first maturity of the striped marlin in the Indian Ocean is at 140–150 cm class, which is in accordance of the opinion of KOGA (1967) that "the striped marlin in the Indian Ocean attain sexual maturity earlier than those in the Pacific".

From the distribution of the percentage frequency of the G. I. of striped marlin in the Indian Ocean (Fig. 10) it is evident that in the Bay of Bengal, matured females appear during the first quarter. Occurrence of matured fishes seems to continue to the second quarter eventhough the data are not shown here. No matured specimen was recorded from the central western Indian Ocean (Area C) during any quarter of the year. Maturing females occurred off the coast of Java and Sumatra (Area D) during the third quarter and were scarce in the first quarter. Matured and ripe females of striped marlin were recorded from off north western Australia (Area F) intensively during the third and fourth quarters of the year. A similar pattern of the occurrence of matured specimens have been reported by Howard and Starck Il (1975) in the Bay of Bengal and south eastern Indian Ocean.

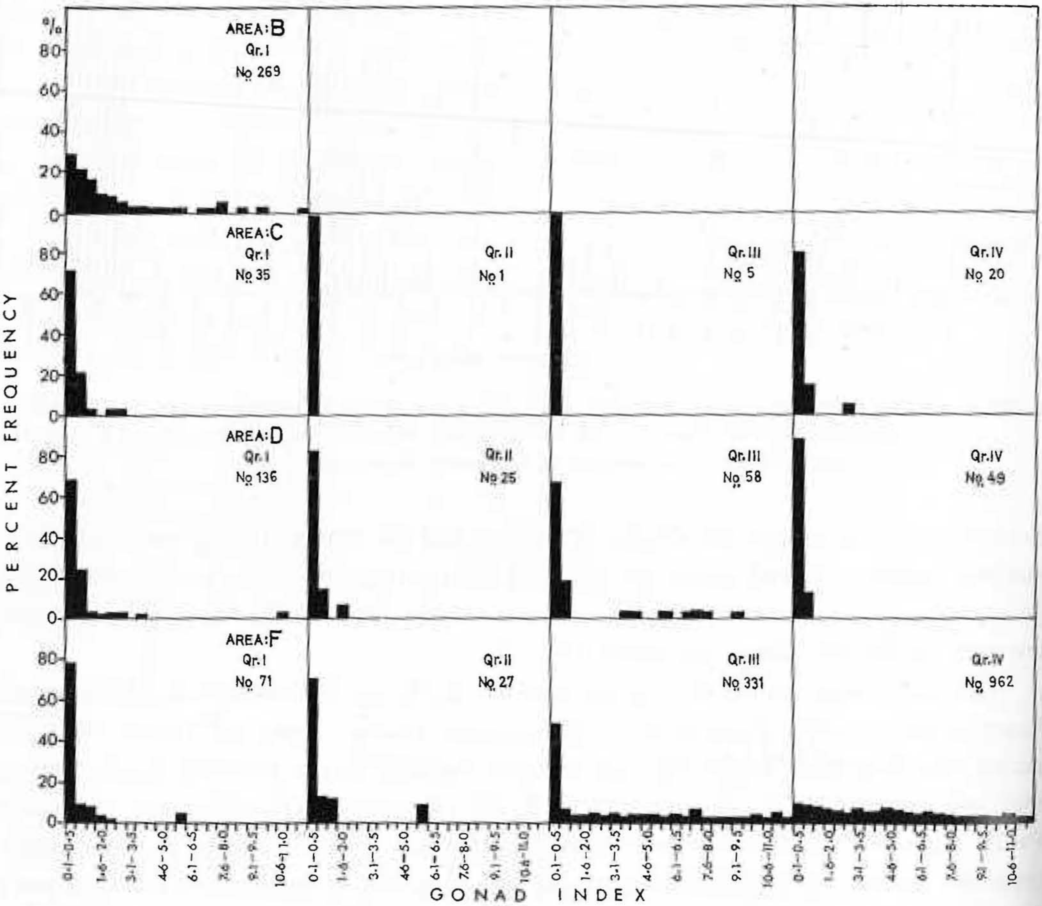

Fig. 10. Percent frequency distribution of gonad index (G. I.) (grouped by major areas and quarters) of female striped marlin taken by Japanese longline fishery in the Indian Ocean, 1971–1975.

Discussion

The tropical nature of the distribution of the adult striped marlin is evident from the d_{ij} distribution maps presented in this paper. Based on the variations in the d_{ij} distribution, some possible seasonal movements of the fish in the Indian Ocean could be deduced. The north-south type of seasonal movements are most evident off South-Africa, where the fishes concentrate only in summer of the southern hemisphere. The high seasonal density of striped marlin off East Africa during NE monsoon period has been reported to be a "post-spawning feeding migration", and the fish concentrate in the coastal area which is effected by the "tongue of Somali Current Water and increasing fertility" (WILLIAMS, 1964, 1967, 1970; MERRETT, 1971; HOWARD and STARCK II, 1975). In the Arabian Sea, especially in the western sector a northward movement is perceptible during March to June since when the fish appear to be dispersed.

In the eastern Indian Ocean, the striped marlin concentrate in the Bay of Bengal during February to May and since then their concentration becomes low. Apparently no high concentration of the fish is evident in the equatorial Indian Ocean area; but off the coast of Java and Sumatra, the specimens occur throughout the year. The seasonal changes in the density distribution is suggestive of a north-south movement between the equatorial eastern Indian Ocean area and the Bay of Bengal. From the d_{ij} distribution of the striped marlin, it is evident that high concentration of the fish occurs in the north-west Australian coast during September to December. During the other seasons, they are widely distributed in the oceanic area off the coast, thereby indicating an onshore-offshore seasonal pattern of migratory movements.

Available information on the larval distribution (Fig. 11) in the western Indian Ocean indicate two areas of larval occurrence, one in the southern hemisphere near Madagascar and the other off the western Maldive waters in the northern hemisphere (JONES and KUMARAN, 1964, fig. 5; UEYANAGI, 1974, fig. 17). The former authors, based on the larval distribution opined that spawning occurs in the area 10°–18°S. during December to January. Further, all specimens examined, from the central area of the western Indian Ocean, through the four quarters during the present study were all immature. These observations agree with those of WILLIAMS (1967) and MERRETT (1971) in that the peak occurrence of the striped marlin in the East Africa is associated with a post-spawning feeding migration, and that spawning occurs during the period July to November elsewhere. This pattern of spawning activity resembles that observed in the Pacific Ocean.

Data on the sexual maturity and size composition of the striped marlin analyzed during the present study indicate that spawning occurs in the Bay of Bengal during spring season. This view is in accordance with those by UEYANAGI (1964) and HOWARD and STARCK II (1975). Presence of maturing females in the central eastern sector during the third quarter, and matured and spent females in the north-west Australian waters in the third and fourth quarters indicate spawning activity in the southern area during this period. UEYANAGI (1964) based

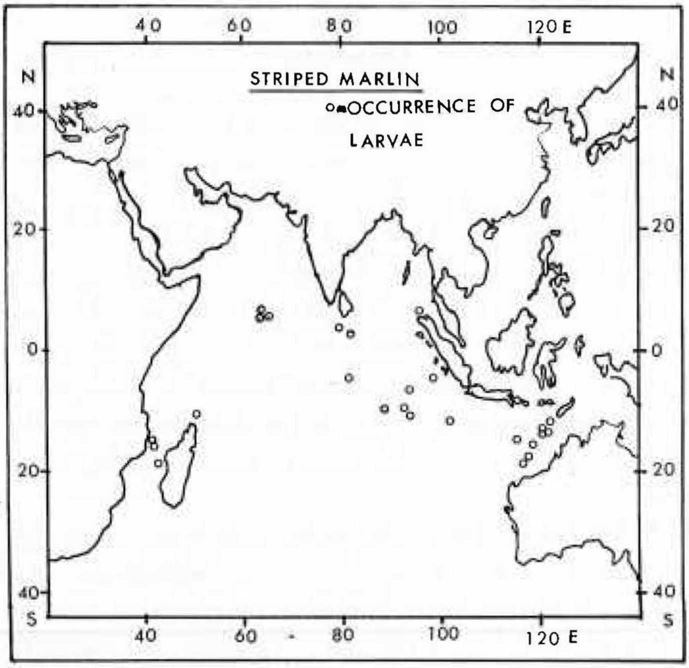

Fig. 11. Occurrence of larvae of striped marlin in the Indian Ocean (After Ueyanagi, 1974).

on the larval occurrence suggested that spawning of striped marlin takes place in the Banda, Flores and Timor Seas during January to February. He (1964) reported on the occurrence of matured females in the waters south of Lesser Sunda Islands during October and December. Jones and Kumaran (1964) stated that striped marlin spawns in the area between 6°05′N. and 10°55′S. during the period October to November. A perceptible resemblance in the spawning activity of the striped marlin in the western areas of Indian and Pacific Oceans is evident. But the larval occurrence and other information on the spawning of this species in the equatorial eastern sector of the Indian Ocean suggest a different pattern in the spawning activity of striped marlin in the Indian and Pacific Oceans.

Relying on the information at hand, no definite conclusion regarding the spawning segregation of the striped marlin in the Indian Ocean could be made. However, it appears that the uniformity of the population of this species in the different areas in the Indian Ocean is not clear, and that the possibility of the existence of different populations in this area cannot be ruled out.

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インド洋ではえなわ漁業の対象となるマカジキ *Tetrapturus audax* の分布と生態

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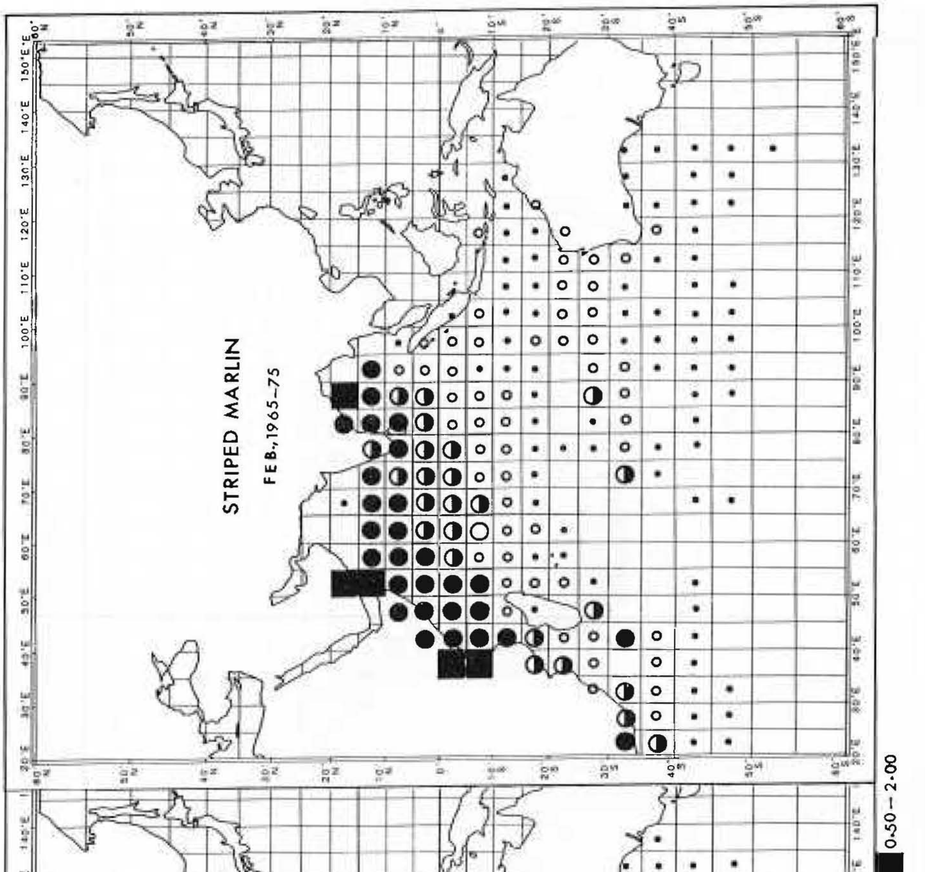
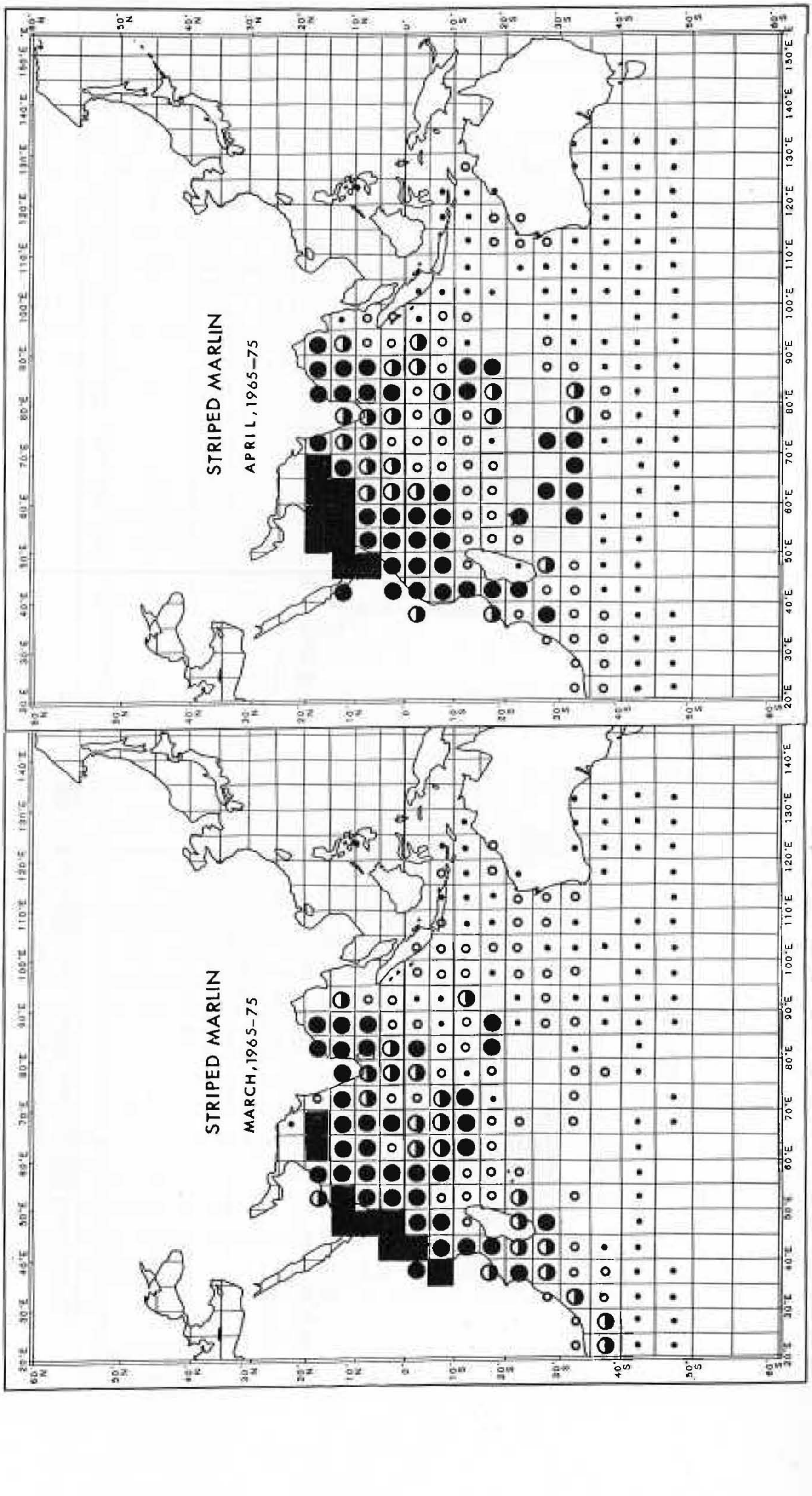
要　約

1965年から1975年にわたりインド洋において日本のマグロはえなわ漁船により得られたマカジキの漁業生物学的資料を解析した結果，次のような知見が得られた。

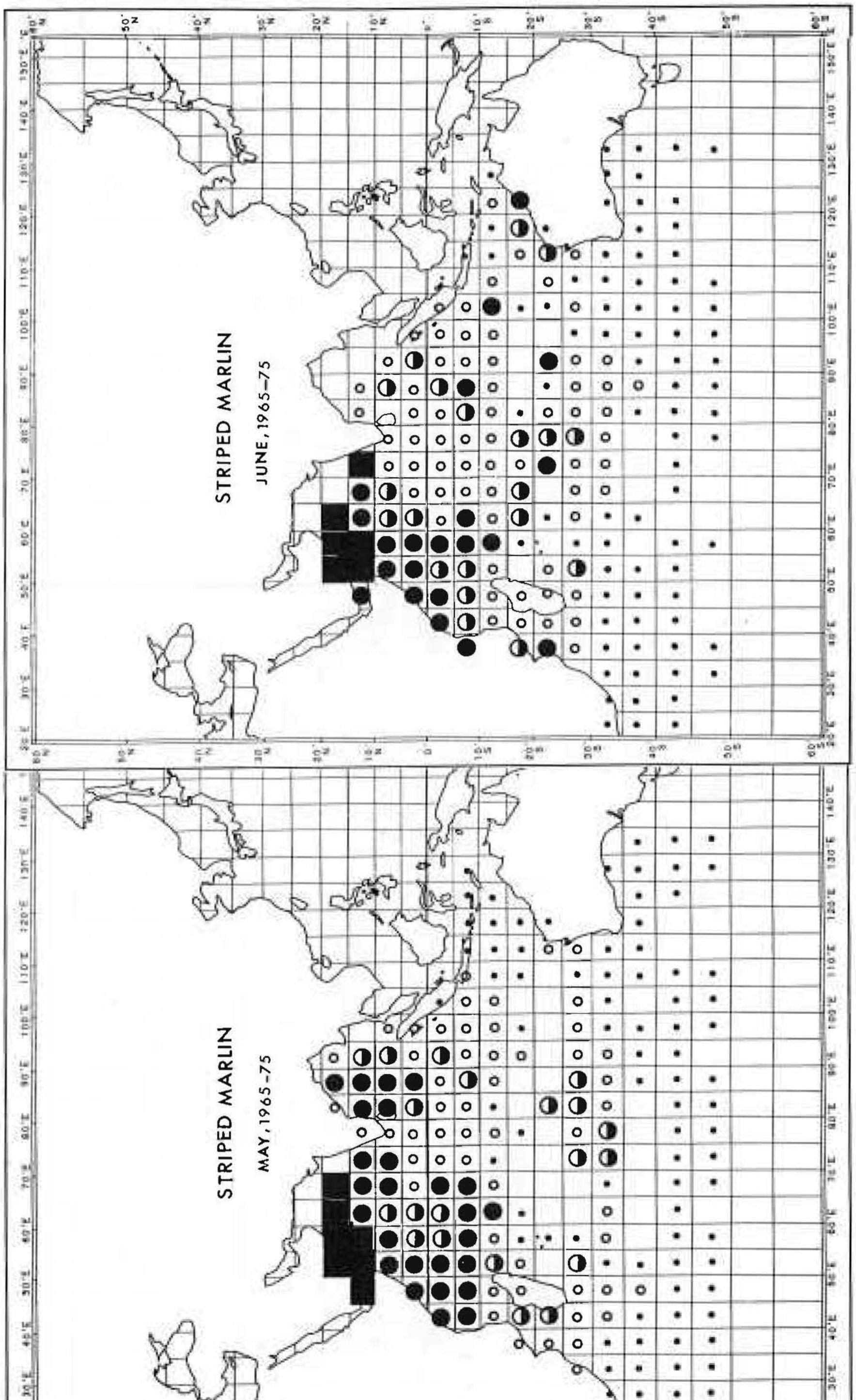
1) 1967年以降マカジキの年間漁獲量は著しく減少したが，釣獲率には傾向的な変化はみられなかった (Fig. 1)。
2) 魚群の地理的な分布密度は一様でなく，赤道から10°Sに至る東部アフリカ水域，南・西アラビア海，ベンガル湾，北西オーストラリア水域等において，分布密度の季節的な高まりがみとめられる。また，魚群の季節的な南北移動が，東アフリカ沿海やベンガル湾において明瞭にみとめられ，一方，北西オーストラリア水域では，季節的に沖合←→沿岸（東西方向）の魚群移動がみとめられる。
3) マカジキの主要漁場水域の範囲は，年の前半に拡大する傾向があり，また魚群量や平均密度等が，4月をピークとして3月から6月にかけて高くなる (Fig. 2)。
4) はえなわで漁獲されるマカジキの体長範囲は，91～230 cm であり，モードが 171～175 cm 級にある体長組成を示している (Fig. 4)。地域的，季節的な体長組成の差異は顕著ではないようである(Fig. 6)。
5) 最小成熟体長は 140～150 cm と推定される。
6) 生殖腺指数や仔稚魚出現のデータから，西インド洋におけるマカジキの産卵状況は，太平洋におけるそれに似ている（赤道水域では産卵活動がほとんどみられない）が，東インド洋においてはこれと異なっている（赤道水域でも産卵する）ことがみとめられる。
7) インド洋のマカジキには，複数の系統群が存在する可能性を否定出来ないようである。



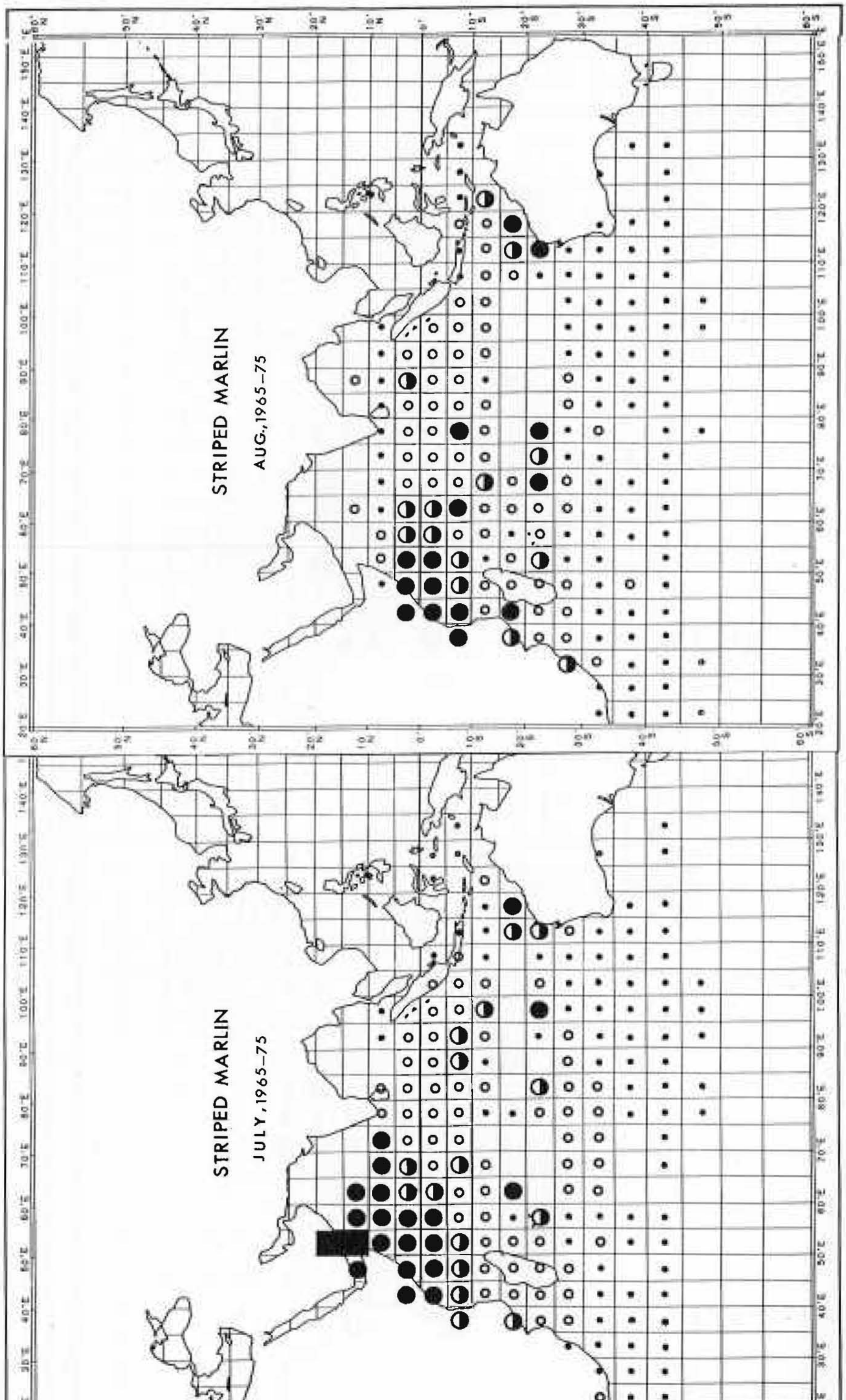
Appendix Fig. 1. Monthly distribution of relative density (d_{ij}) of striped marlin taken by the Japanese longline fishery in the Indian Ocean, 1965-1975, January and February.



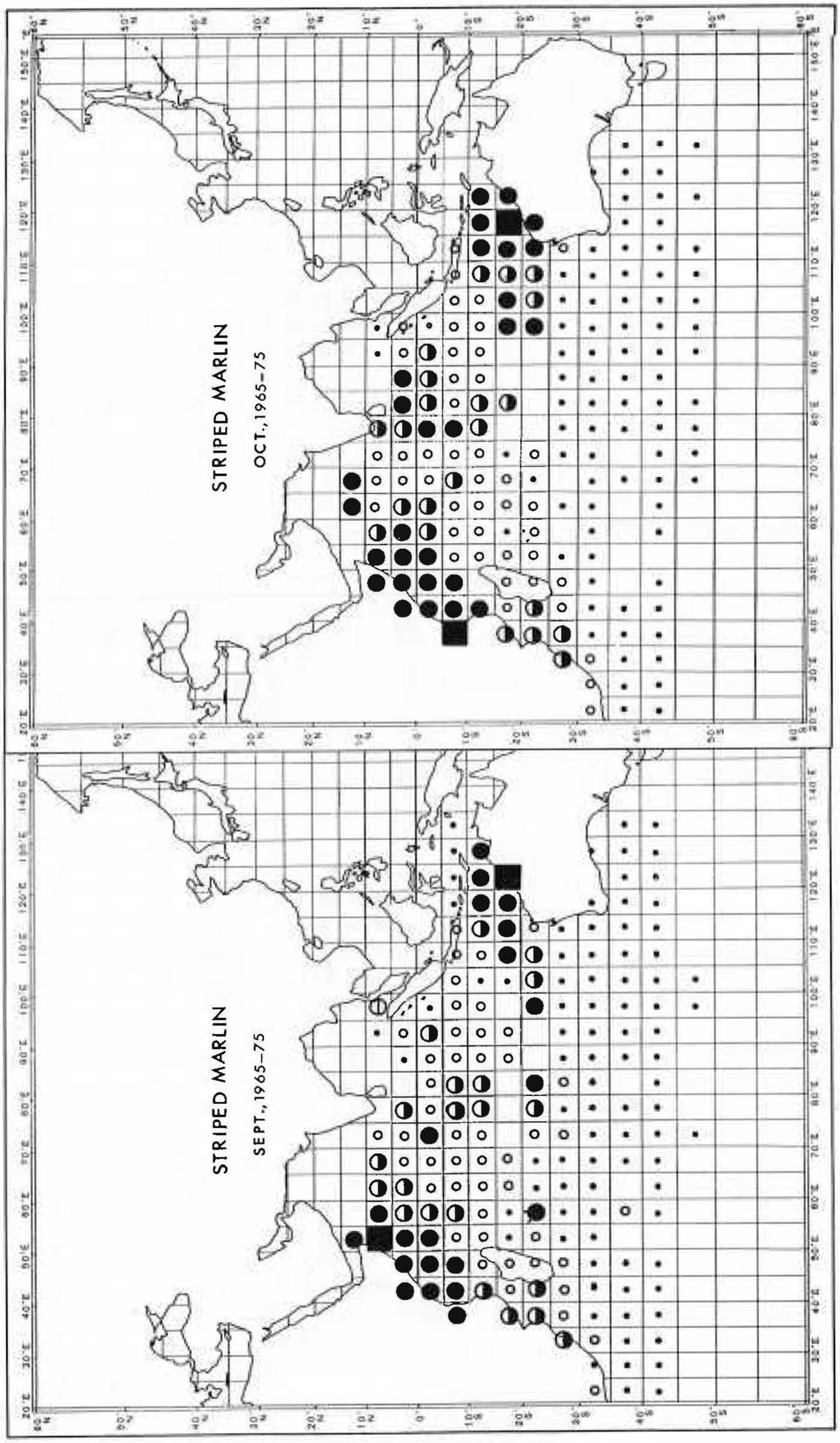
Appendix Fig. 1. Continued, March and April.



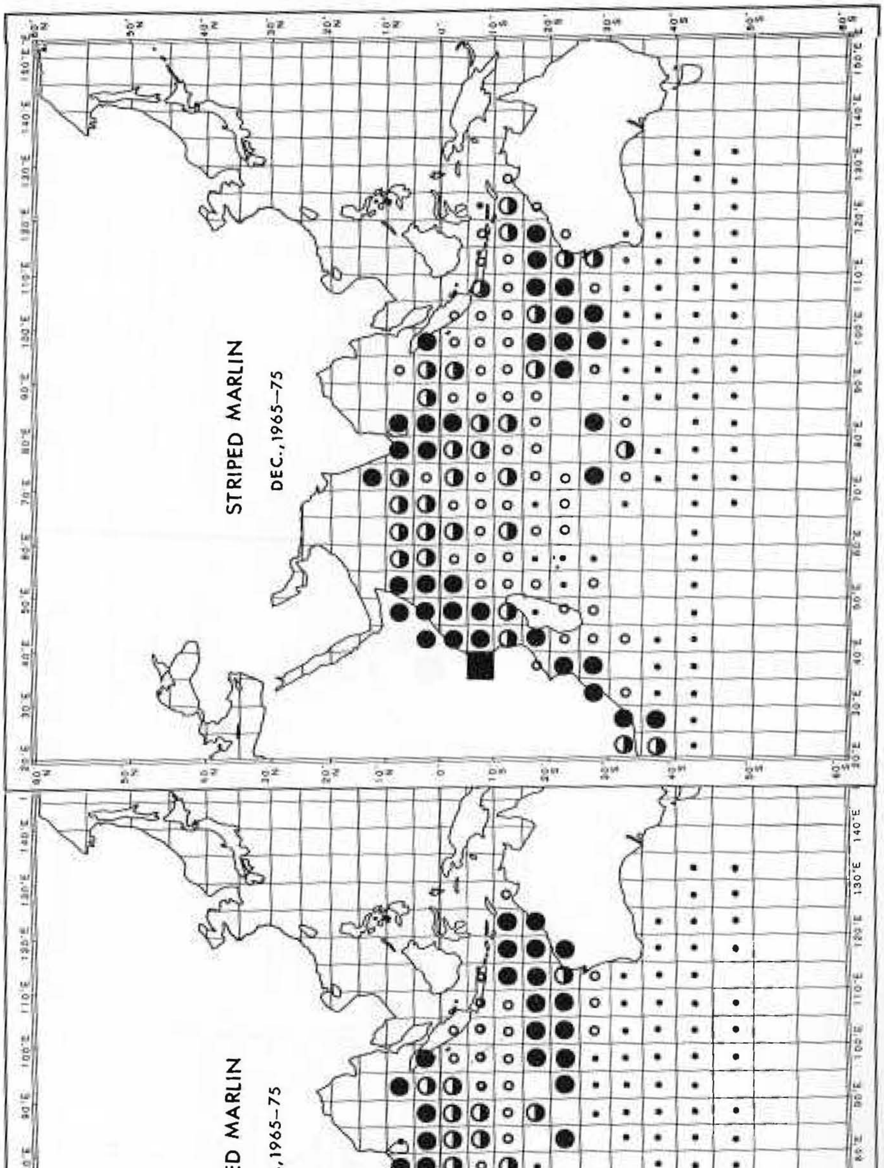
Appendix Fig. 1. Continued, May and June.



Appendix Fig. 1. Continued, July and August.



Appendix Fig. 1. Continued, September and October.



Appendix Fig. 1. Continued, November and December.