The comparison of catches by regular and deep tuna longline gears in the Western and Central Equatorial Pacific

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Abstract

The catches of tunas and billfishes made by the two types of longline gear, regular and deep longline gears, were compared in terms of hook rates using the data collected at Yaizu Fish Port during 1974 and 1975. Recently, aiming at bigeye tuna, the deep longline method has become common among small and medium sized Japanese vessels operating in the Western and Central Equatorial Pacific, and now this method has mostly replaced the regular longline gear in that area. The hooks of the regular longline gear are estimated to hang at the depth of around 50 to 120 m while those of the deep longline gear cover between 50 and 250 m.

With exception of bigeye tuna, the hook rates of the regular gear are higher than those of the deep one for all species of tunas and billfishes studied. Generally, billfishes, to a lesser extent swordfish, are inferred to be relatively surface swimmer and the bigeye tuna seems to be the deepest inhabitants among tunas and billfishes. The most remarkable differences with regard to the distributional patterns of hook rate between the two types of longline gear were observed in the case of bigeye tuna, and the differences were attributed to the relative depths of hook and thermocline in the sea. It seems reasonable to assume that bigeye tuna has much broader and denser distribution in the Western and Central Equatorial Pacific than hitherto known.

Introduction

Generally, in the longline fishery, the construction of the gear and the fishing method have been quite uniform regardless of the areas and species except on a few limited occasions. However, the conservative characteristics of the longline fishing method recently began to change when small and medium sized Japanese boats*** started to set the longlinehooks deeper than before to catch bigeye tuna more effectively in the Western and Central Equatorial Pacific. The deep longline method has quickly gained prevalence, and at present, most of the Japanese longline boats except the large sized vessels employ this method in the area.

The introduction of the new longline method would be an unique phenomenon that offers certain additional information on the distribution, particularly the vertical distribution of

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*** It is known that some of South Korean tuna longline boats have been fishing with the similar deep longline method several years earlier than the employment of the same by the Japanese boats. However, no data are available so far on this aspect of South Korean fishery.

tunas and billfishes. Furthermore, this information may provide some clue to analyze the selectivity of the longline gear.

We would like to express our appreciation to many fishermen for their cooperation in providing us information needed for this study, and to the personnel of the Computing Center for Research in Agriculture, Forestry and Fishery at the Ministry of Agriculture and Forestry for their assistance in making the various computations with the HITAC 8000 SERIES. The original draft manuscript of this paper written in Japanese and presented at the Japanese Tuna Conference held in February 1977, was translated into English by Mr. Tamio OTSU, Southwest Fisheries Center Honolulu Laboratory of the National Marine Fisheries Service. We owe very much to his translation in preparing the present paper. The authors are also indebted to Messrs. S. UEYANAGI, M. HONMA, P. Parameswaran PILLAI, S. KIKAWA, S. KUME and T. YONEMORI for their helpful suggestions to our manuscript.

Materials and methods

Data

The data used in this study include log books collected from the longline boats that returned to Yaizu in 1974 and 1975 (therefore, including the data for the end of 1973), covering 265 vessels reporting on 9, 945 fishing operations and BT records for 1974 which were obtained by the training vessels of the fisheries high schools and research vessels of the prefectural fisheries experimental stations. The BT records were made available in the form of section diagrams to the present study by the Oceanographic Division of the Far Seas Fisheries Research Laboratory.

During the survey period, deep longline fishing was restricted to the Western and Central Equatorial waters and in the Banda Sea (Fig. 1), one of the major fishing grounds for the small and medium sized boats under about 100 gross tons. Accordingly, for the purpose of comparing the hook rates by two gear types, the log books were selectively collected from the boats operating in those areas and the area between lat. 20°N and 10°S and between long. 120°E and 160°W was set up for this study. Most of the logged data thus obtained came from commercial boats although a small portion was supplemented by the research and training vessels.

The construction of the longline gear and the differences between regular and deep longline gear

The longline gear is made up of the mainline, branch lines, float lines and floats. The section between two floats is called a "basket" of the gear and this unit normally includes 4 to 6 branch lines. As typical examples of regular and deep gear, Fig. 2 shows the 6-branch-line gear to represent the former and the 13-branch-line gear for the latter.

Table 1 shows the number of branch lines per basket of gear and average number of baskets per operation by the various vessels studied during the survey period. The number

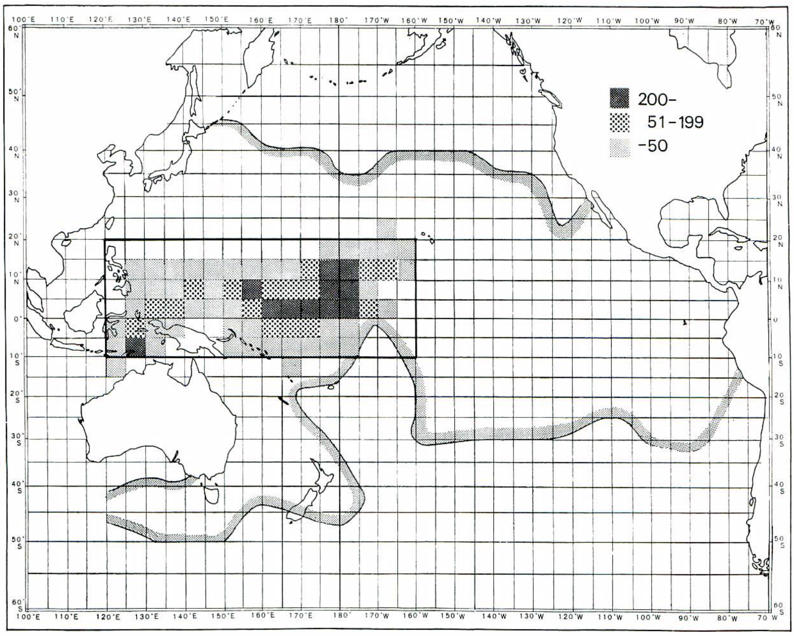


Fig. 1. The area fished by vessels, using deep longline gear which entered Yaizu in 1974 and 1975.

The numerals represent the number of fishing operations in various 5°-square areas. The contour lines enclose the whole tuna longline fishing grounds and the quadrangle denotes the areas studied in the present investigation.

Table 1. The number of branch lines per basket of gear and average number of basket set per fishing operation for the longline vessels entered Yaizu in 1974 and 1975.

Gear type	No. of branch lines	No. of baskets per operation	No. of vessels
Regular	4	326	6
	5	356	33
	6	332	81
	7	274	12
	8	233	4
	9	222	13
Deep	10	189	36
	11	159	58
	12	161	40
	13	148	51
	14	150	1
	15	157	6

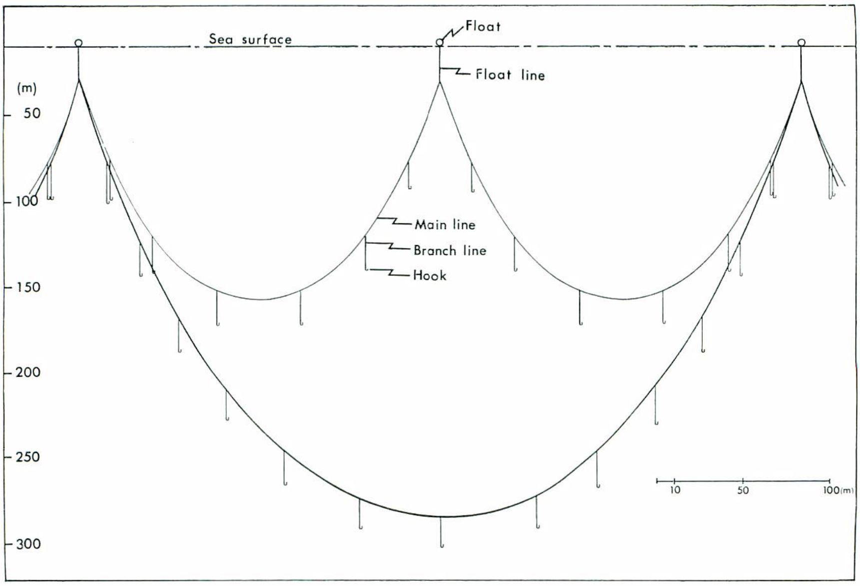


Fig. 2. Catenary curves of regular longline (above, represented by gear having 6 branch lines per basket) and deep longline (below, represented by gear having 13 branch lines per basket).
Float lines were figured at 20 m in length, branch lines 30 m, and distance between branch lines 50 m with sagging rate (see text) 0.6.

of branch lines varied from 4 to 15, and the number of baskets set per fishing operation ranged from about 150 to 350 thus showing considerable variation among the monitored vessels. However, generally all vessels were reported to use approximately 2,000 hooks per operation. Furthermore, through interview with vessel personnel, it was determined that certain gear components were more or less uniform in that the float lines were about 20 m in length, branch lines about 30 m, and distance between branch lines about 50 m. From this it can be inferred that the gear having more branch lines per basket fished deeper.

In this report the authors have arbitrarily defined the regular and deep longline gears

Table 2. The number of vessels of various size groups (gross tonnage) fishing regular and deep longline obtained from the survey for the boats entered Yaizu in 1974 and 1975.

Vessel size	Number of vessls	
	Deep longline	Regular longline
51– 60	4	4
61– 70	51	33
71– 80	88	23
81– 90	—	—
91–100	48	31
>100	5	20

as follows: regular gear has 4 to 6 branch lines; deep gear has 10 and more branch lines. However, it should be borne in mind that the two fishing methods thus defined are not basically different, but convertible by adjusting the number of the branch lines per basket. There was generally no difference in the size of the vessels utilizing the two types of gear (Table 2).

Depths reached by the hooks

The hanging depths of the longline hooks may vary considerably depending on many factors such as currents and sagging rates. Here, sagging rate is the ratio of horizontal distance between the two floats to the stretched length of the mainline per unit basket. Sicne there were no actual measurements of the hook depths in the present data, we had recourse to theoretical method of calculating the hook depths described by YOSHIHARA (1951, 1954) in which the mainline was assumed hanging in a catenary:

$$D_j = h_a + h_b + L\left\{(1+\cot^2\varphi^\circ)^{\frac{1}{2}} - \left[\left(1-2\frac{j}{n}\right)^2 + \cot^2\varphi^\circ\right]^{\frac{1}{2}}\right\}$$

where: D_j; depth of j-th hook
h_a; length of branch line
h_b; length of float line
L; half of length of the mainline in unit basket
n; number of intervals between the branch lines in unit basket (number of branch lines plus 1)
j; j-th branch line in unit basket (sequential number of the branch lines or hooks counted from either one end of the unit basket)
φ°; angle made between horizontal line and tangental line of the mainline at the connecting points of mainline and float lines.

Neither data for the angle φ° nor k, the sagging rate, which could be used as a parameter to estimate φ° indirectly (YOSHIHARA, 1954) were available for the present study. However, the k value of 0.60 (approximately $\varphi^\circ = 72^\circ$ was chosen as a representative for the calculation judging from the relevent studies (HANAMOTO 1974, FUJII and OKAMOTO 1971).

Changes in the shape and depth of the mainline in unit basket are shown in Figure 3 with various sagging rates ranging from 0.40 to 0.80 for the cases of the 6-branch-line and 12-branch-line. The calculated theoretical muximum hook depths in the case of $k=0.60$ were around 170 m and 300 m in the typical regular gear with 6 branch lines and deep longline gear with 13 branch lines, respectively. However, the observed actual depths are considered to be shallower by about 30 m to 50 m than the calculated hook depths due to force of the currents as observed by HANAMOTO (1974).

Calculation of hook rates

Hook rates (HR) was used as an index which represents the density of fish exploited by the longline fishery:

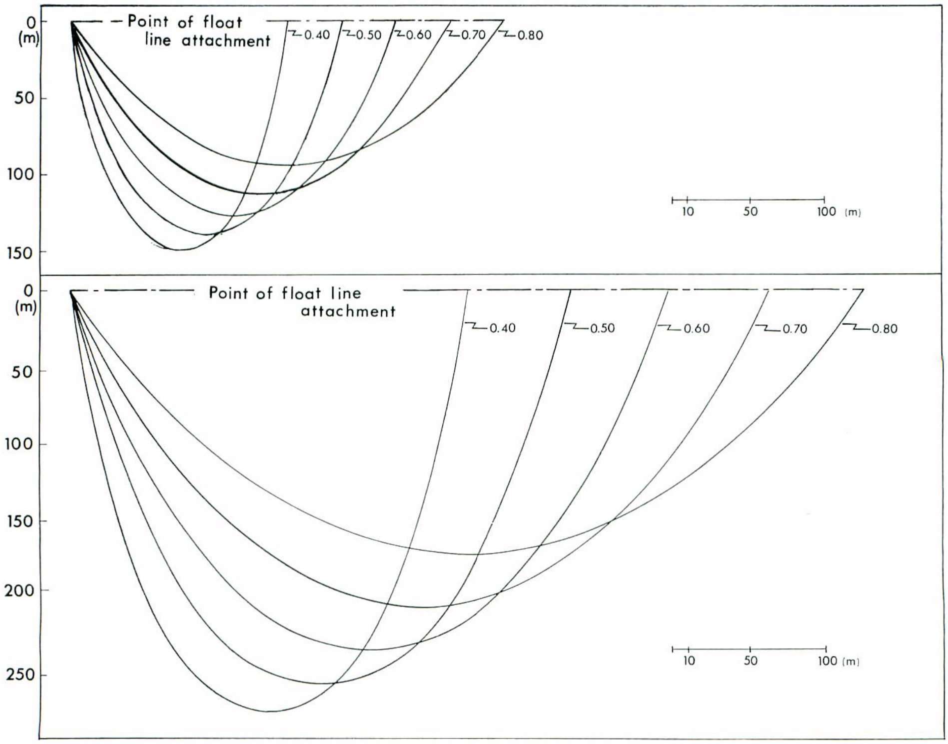


Fig. 3. Changes in the shape and depth of the mainline in unit basket with various sagging rates ranging from 0.40 to 0.80 for typical regular (6 branch lines, above) and deep (12 branch lines, below) gears.

$$HR = (\textit{Number of fish taken} / \textit{Number of hooks set}) \times B$$

Where B is multiplier changing according to the species, 100 for bigeye and yellowlfin tunas, 1,000 for albacore and blue marlin, 10,000 for swordfish, striped marlin, black marlin and sailfish and shortbill spearfish. The calculation was made for each fishing operation by species (sailfish and shortbill spearfish were combined, see next section) and gear type on the basis of one degree square and quarter of the year stratum:

$$HR_{ijkls} = \frac{1}{n} \sum_{o=1}^{n} HR_{ijklso}$$

where HR_{ijkls}; average hook rate of s-species taken by l-gear type in i-square, j-quarter of k-year

HR_{ijklso}; hook rate in o-operation in the $ijkls$ stratum

n; total number of the fishing operations in the $ijkls$ stratum.

The following calculation by one degree square was utilized for further analysis:

(1) Average hook rates by species, gear type and quarter regardless of the year.

(2) Quarterly average of (1).

(3) Deviation of regular longline from that of deep longline in quarterly averaged hook rates (2).

Limitations

It is preferable in the present study that the data to be compared are those obtained from the same detailed spatial-temporal stratum. However, as stated earlier, the transition from fishing with regular gear to deep one occurred very rapidly to a significant extent. The drastic changeover, shown in terms of quarterly number of boats by gear type (Fig. 4), causes problem in the analysis. That is, the number of cruises using the regular longline method predominated over the counterparts in the first two quarters of 1974 while the reverse held true after the third quarter of 1974. Therefore, the comparison of the hook rates in most of the periods is hampered by the scarce number of the observations of either one of the two types of gears. Compromise made with this problem is quarterly stratification of the data regardless of the years in which the seasonally changing patterns of apparent abundance for tunas and billfishes were assumed to be consistent among the different years. This quarterly stratification was applied to computing the spatial distribution of hook rates by one degree square obtained through two types of gear.

Another problem is related to the area dealt with. Although this area covers a vast extent, some species, for example striped marlin and albacore spend only fractional periods of their life histories there. Furthermore, habitat segregation by size or by developmental and physiological stages is not rare in the case of tunas and billfishes. Therefore, it should be recognized that the result of the present study might not necessarily hold true of the rest of the area.

Lastly, the present data acquisition systems of the Japanese tuna longline fishery do not

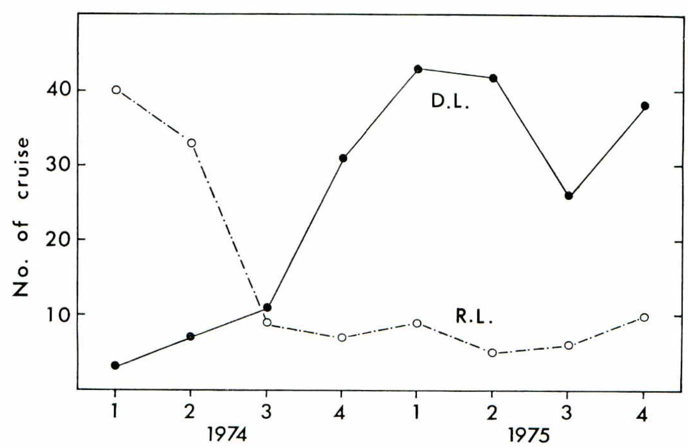


Fig. 4. The number of cruises of vessels fishing with regular longline (R.L.) and deep longline (D.L.) by quarters of the year in 1974 and 1975.

discriminate spearfishes (shortbill spearfish in this study for the Pacific Ocean) from sailfish. Therefore, those two species were treated combined for the analysis.

Result

General aspects in the difference of the hook rates by gear type and species

Average hook rates for the whole surveyed area between lat. 20°N and 10°S and between long. 120°E and 160°W were compared by gear type and species (Fig. 5). The hook rate by the regular longline was consistently higher throughout the surveyed quarters than that by the deep longline in striped marlin, blue marlin, black marlin and sailfish and shortbill spearfish while for the bigeye tuna, the reverse held true. As for yellowfin tuna and swordfish, the regular gear showed better fishing efficiency than the deep gear in most of the quarters. There seems to be little difference in the hook rates between the two types of gear in the case of albacore.

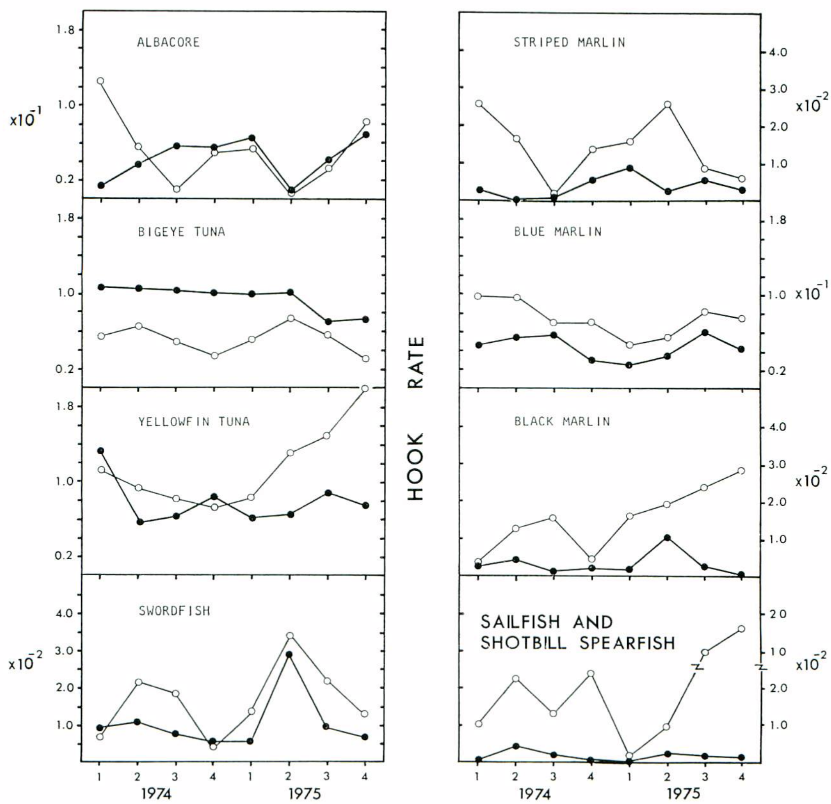


Fig. 5. Comparison of hook rates by gear type, species and quarters of the year in 1974 and 1975.

Open and solid circles denote the hook rates by regular and deep gear, respectively.

Patterns of temporal changes in the hook rates by gear types are more or less similar in swordfish, bigeye and blue marlin, but they differ from each other sometimes erratically for the rest of the species.

Tunas

Albacore: In case of both the regular and deep gear, distributional patterns of the hook rates are almost similar (Fig. 6 and Appendix Fig. 1). That is, two bands of the high hook rates, separated by the areas of low hook rate in the equatorial region, were observed, one in the area of north of lat. 10°N and the other south of approximately lat. 5°S to east of

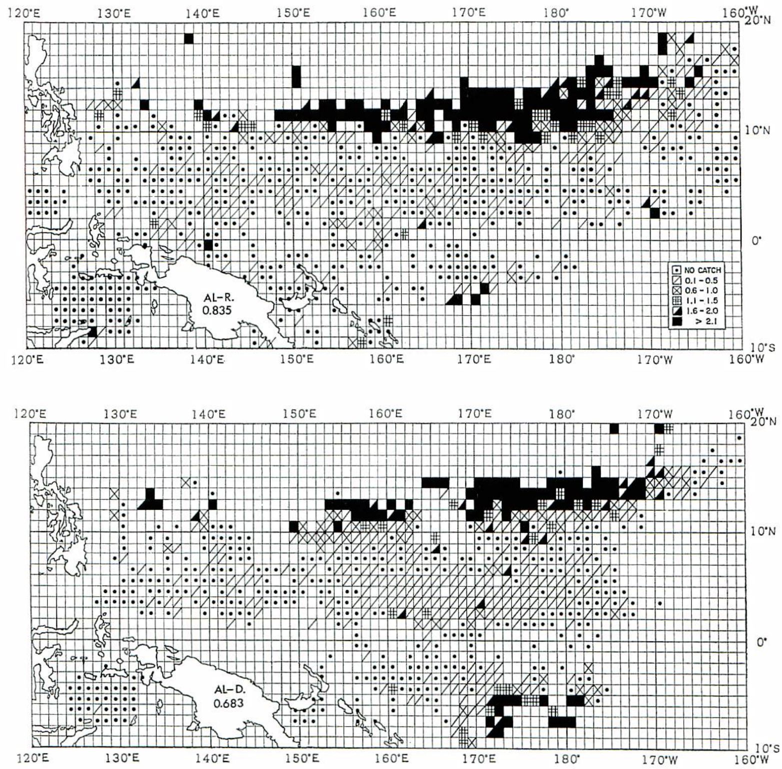


Fig. 6. The distribution of quarterly averaged hook rates by regular (above) and deep (below) longline combining data for 1974 and 1975 (small numbers of data for the end of 1973 are included) for various species of tunas and billfishes.

The figures in the charts indicate the quarterly averaged catch rates over the whole area obtained by the two types of gear. Legend: First two capital letters before hyphen denote species, D=deep longline, R=regular longline.

Albacore: AL (hook rates: catch per 1,000 hooks) long. 170°E. The minor difference in this pattern between the two types of gear is the slightly northward shift of the southern margin of the northern band with high hook rate to lat. 10°N in the deep gear, in comparison with its location in lat. 10°N in the case of regular gear.

Bigeye tuna: The hook rates for bigeye tuna were higher with deep longline gear in all the quarters of the year (Fig. 6 and Appendix Fig. 1). The hook rates obtained with regular longline were generally lower in waters south of lat. 5°N. Although the area along lat. 10°N to the east of long. 180° is generally considered to be a principal fishing ground for bigeye tuna by regular longlining, the deep longline encountered better fishing farther to the south, *i. e.*, in waters between lat. 5°N and 10°S as well as in the Banda Sea. The hook rate by both gear types tended to be lower in water along the equator. Also, in waters along. lat. 10°N, the deep longline method appears to have relatively lower catch rates than on either side of this latitude which is not the case with the regular gear.

Yellowfin tuna: Unlike bigeye tuna, the hook rates by regular longline were higher than

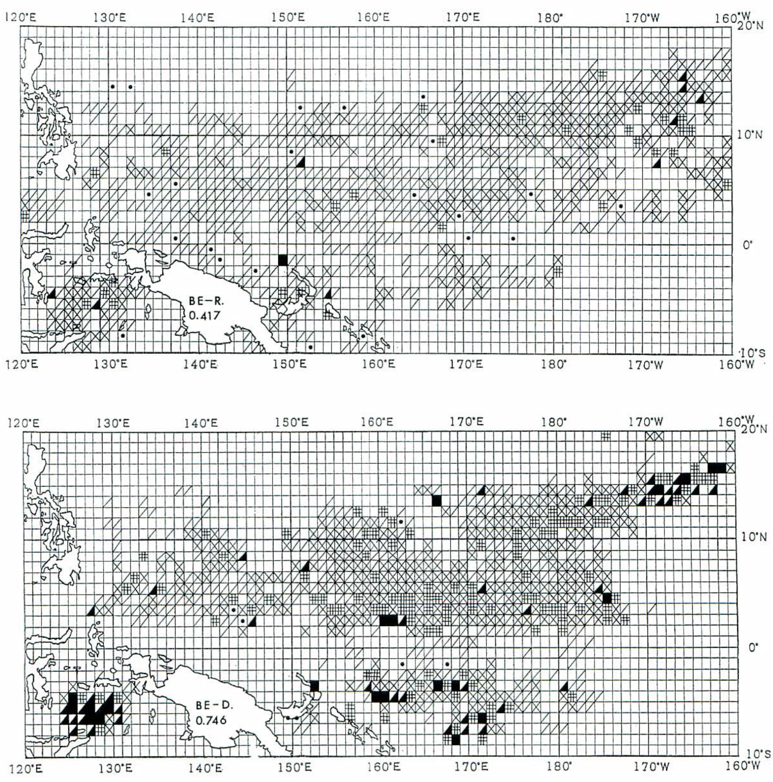
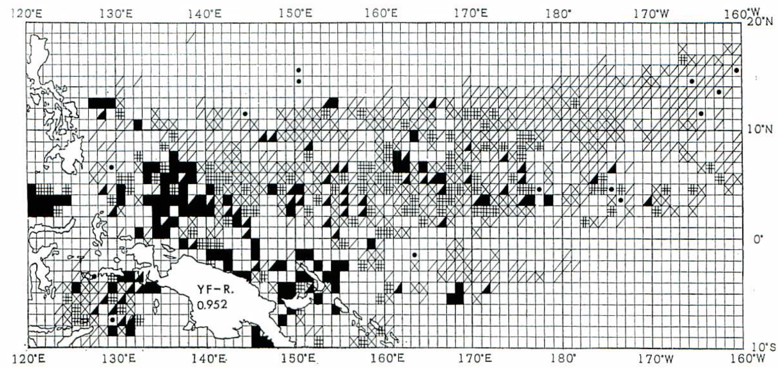


Fig. 6. Continued. Bigeye tuna: BE (hook rates: catch per 100 hooks)



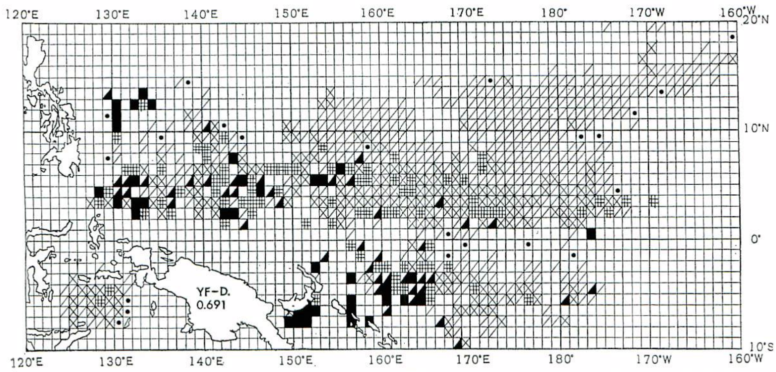
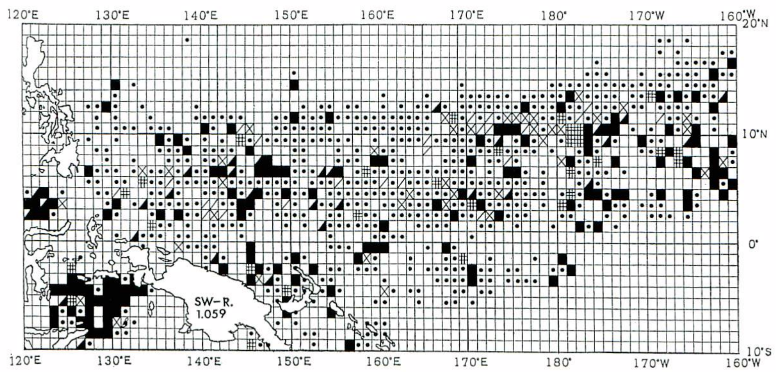


Fig. 6. Continued. Yellowfin tuna: YF (hook rates: catch per 100 hooks)



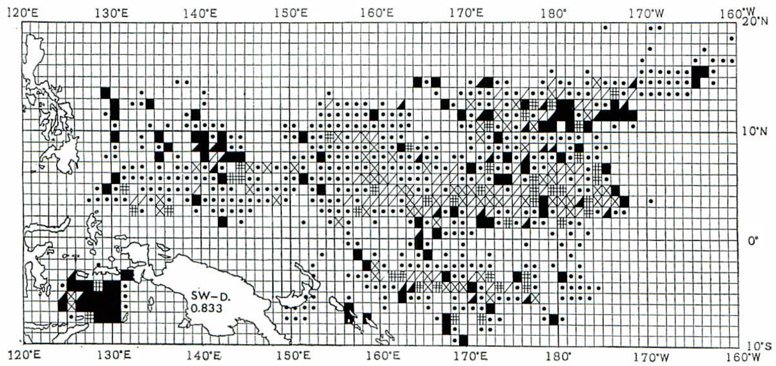


Fig. 6. Continued. Sword fish: SW (hook rates: catch per 10,000 hooks)

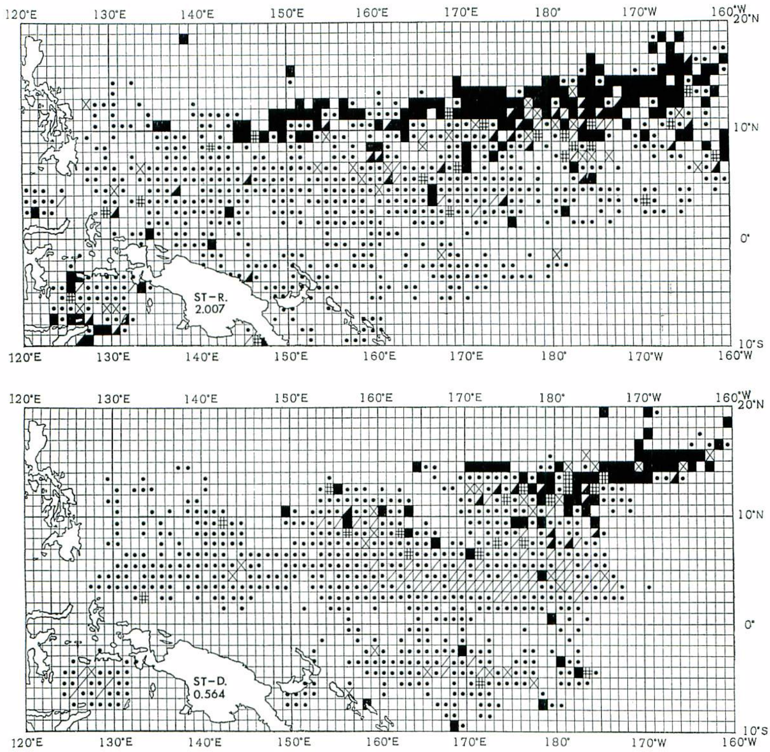


Fig. 6. Continued. Striped marlin: ST (hook rates: catch per 10,000 hooks)

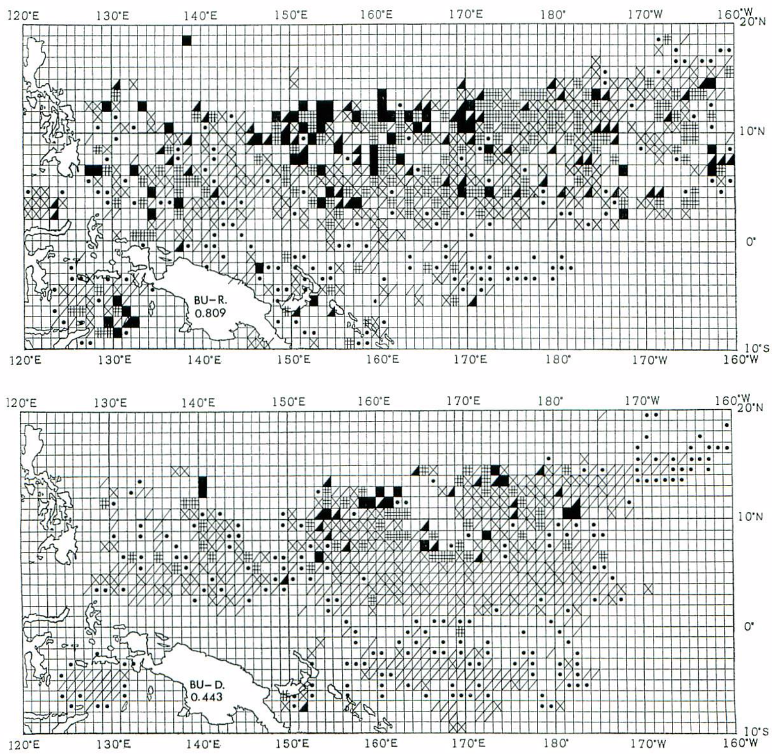


Fig. 6. Continued Blue marlin: BU (hook rates: catch per 1,000 hooks)

those by deep longline in all quarters of the year (Fig. 6 and Appendix Fig. 1). Furthermore, the distributional pattern of hook rates did not differ from that indicated by the regular longline. The hook rates by both gear types tended to be lower towards the east.

Billfishes

Swordfish: In this area, it is difficult to find any distributional characteristics for this species in both gear types (Fig. 6 and Appendix Fig. 1). The hook rates appear almost randdomly distributed and the difference in fishing efficiency by gear type is relatively small with the tendency of slightly higher hook rates for the regular gear.

Striped marlin: Distributional pattern of hook rate of this species is similar in both the types of gear. The hook rates by the regular gear, however, show generally higher values. Waters along lat. 10°N show the high hook rates in which the hook rates tended to be higher towards the east. This area with high density along lat. 10°N extended farther westward in the case of the regular gear than the deep gear.

Blue marlin: In both regular and deep gear, areas with high hook rates appear to be located in the north of the equator. As in case of striped marlin, the hook rates by the regular gear in general are higher than those by the deep gear.

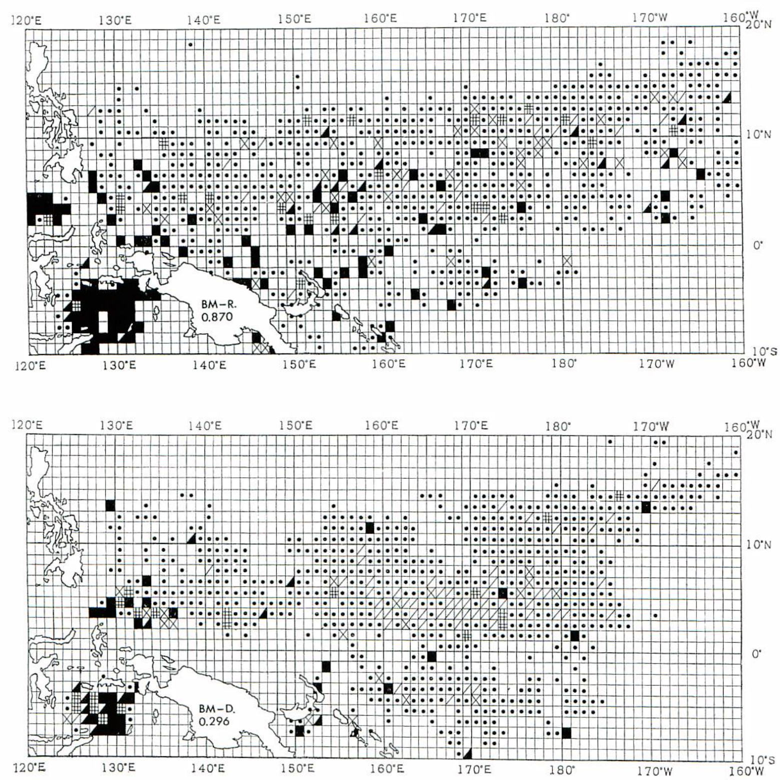


Fig. 6. Continued. Black marlin: BM (hook rates: catch per 10,000 hooks)

Black marlin: No difference in the pattern of distribution of hook rates by gear type was observed, except for generally higher hook rates for the regular longline. Areas with high hook rates are markedly localized in the Banda Sea and its adjacent coastal areas.

Sailfish and shortbill spearfish: The hook rates by the regular gear are much higher than those by the deep gear. However, in both types of gear, the areas with high density seem to be located off the coast of New Guinea and around islands as well as in the Banda Sea. The localized distribution of high hook rates to coastal areas seems to reflect the character of sailfish rather than that of shortbill spearfish (Kikawa 1974, Beardsley *et al.* 1974).

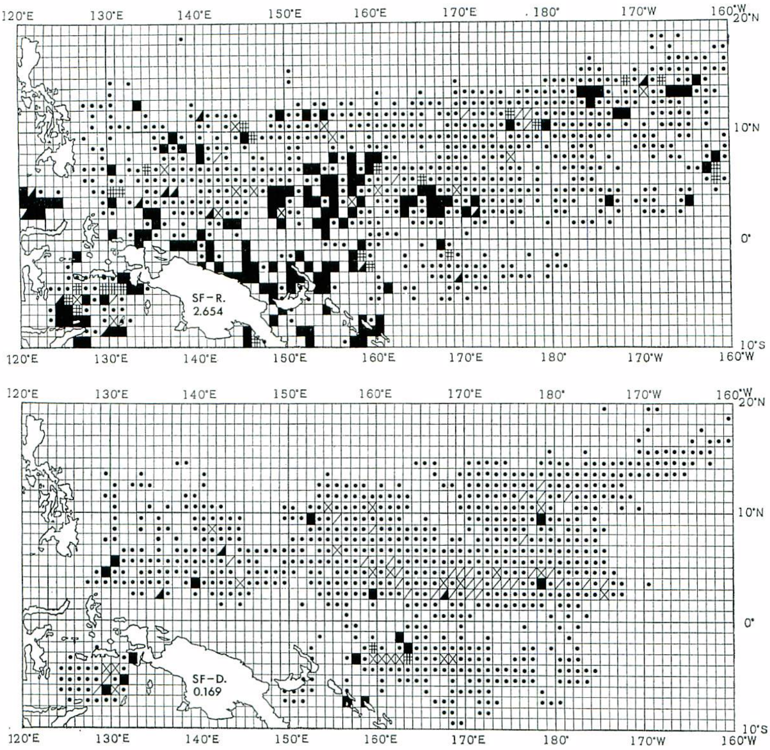


Fig. 6. Continued. Sailfish and Shortbill spearfish: SF (hook rates: catch per 10,000 hooks)

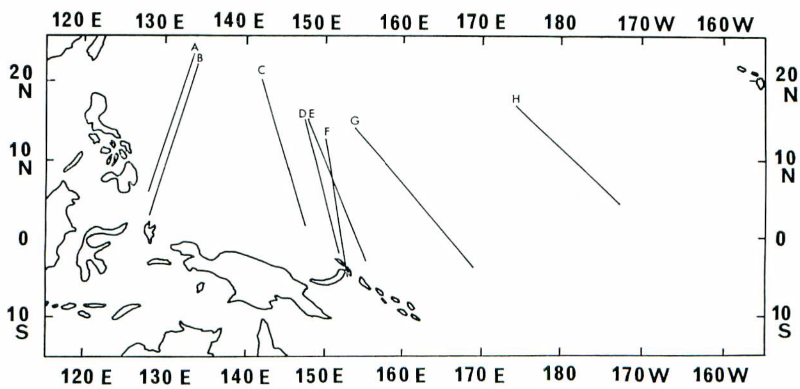


Fig. 7. Station lines along which BT observations were made in 1974.

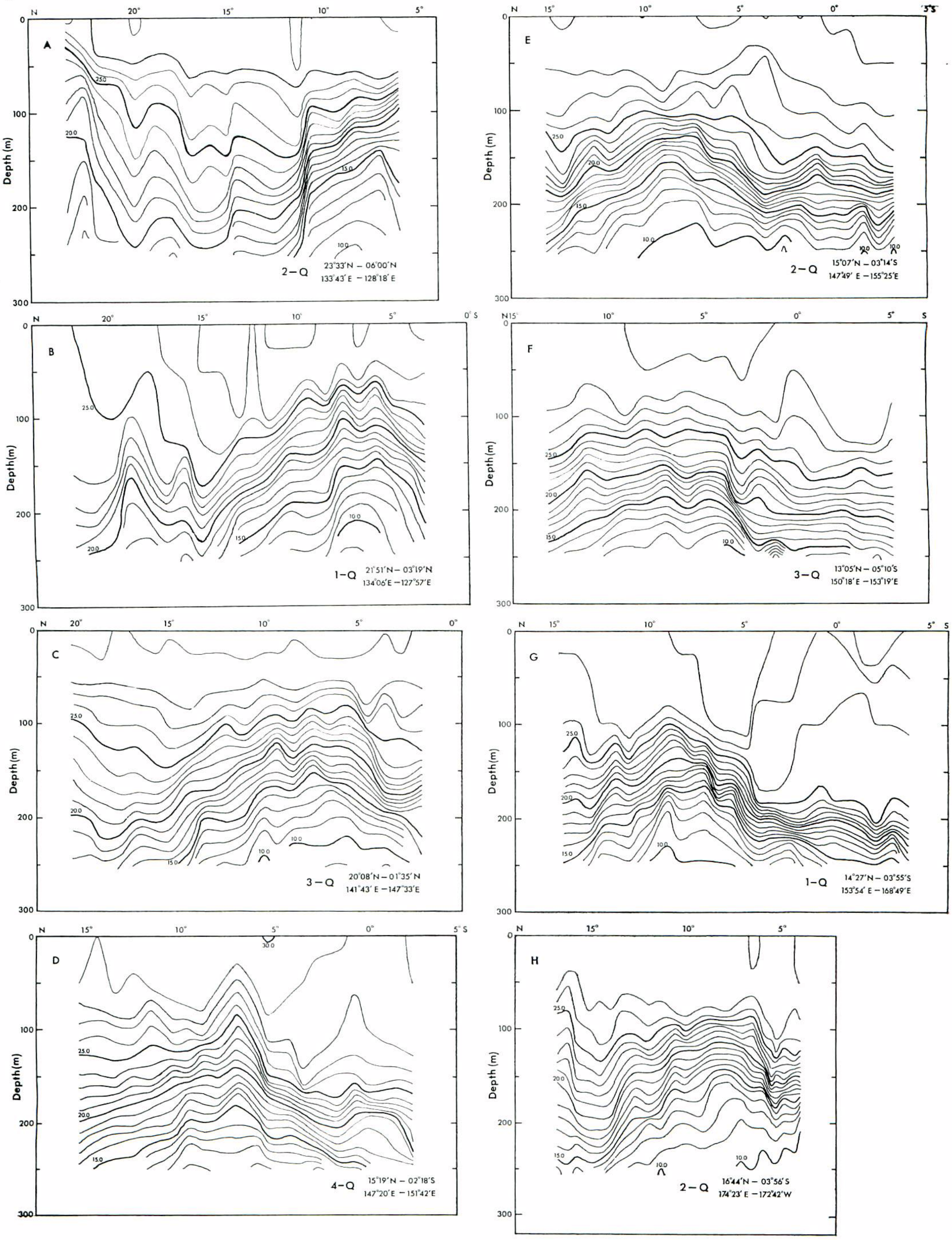


Fig. 8. Vertical temperature structure along station lines A–H as shown in Figure 7. The quarter of the year and position of the station lines are indicated on lower right-hand corner of each chart.

Vertical temperature structure

In general the thermocline is well developed throughout the Western and Central Equatorial Pacific. There is a marked thermocline ridge in the vicinity of lat. 10°N, and the thermocline deepens towards the north as well as the south. Also, the thermocline becomes shallow in an eastward direction (Robinson and Bauer 1971). The station lines and their vertical temperature structures as determined from BT observations made by the research and training vessels in 1974 are shown in Figs. 7 and 8.

The present study generally confirms the thermocline topography reported previously. However, probably due to selection of the specific single year for this study, the following differences are recognized. The observations which are limited to areas west of long. 170°W did not show any tendency of the thermocline to become shallow from west to east. Also, the reported thermal ridge near lat. 10°N appeared to be shifted southerly to around lat. 8°N–9°N.

According to the BT observations, the temperature changed suddenly from 25℃ to 15℃ with the depth in all the areas exmined. Thus, for this report, the authors shall consider the temperature (15℃ and 25℃) as the enclosure of the thermocline.

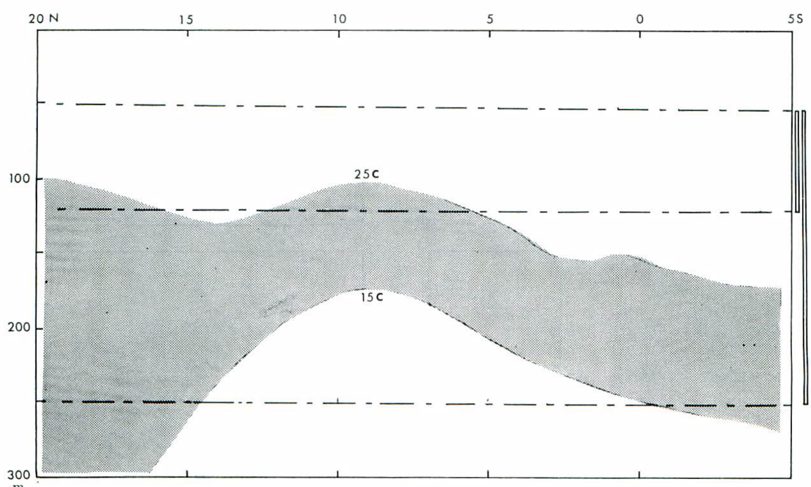


Fig. 9. Schematic representation of the thermocline structure between lat. 20°N and 5°S in the area between long. 130°E and 170°W.
The two vertical bars on the right edge show the range in hook depths of regular and deep longline gear.

Discussion

There have been no systematic studies on the vertical distribution of tunas and billfishes. However, several researchers have reported on the greater depths inhabited by bigeye tuna and relatively shallower distribution of yellowfin tuna and billfishes. Here, the authors shall consider this subject in the light of data available at present.

A generalized hypothesis was set forth by SUDA *et al.* (1969) regarding the distribution of bigeye tuna. They examined the mechanisms involved in the formation of longline fishing grounds and postulated that the swimming layer of bigeye tuna was either within or just below the thermocline. This hypothesis was originally developed from KAWAI's (1969) study which pointed out the significance of the thermocline in relation to the distribution of tunas. The hypothesis advanced by SUDA *et al.* has been confirmed by SAITO (1975) who worked on the vertical distribution of tunas using the experimental vertical longline gear.

Using the 1974 BT data which were combined with further observations not shown in Figs. 7 and 8, the thermocline distribution within the area between long. 130°E and 170°W was schematically charted for lat. 20°N to 5°S (Fig. 9).

Let us examine this figure along with Figure 10, which shows the average quarterly difference in the hook rates for various tunas and billfishes between the deep longline and regular longline. First, in the case of bigeye tuna, if it is assumed that the actual hook depths of the regular longline gear would be from about 50 to 120 m, the areas where the regular longline gear would fish effectively within the thermocline would be limited to waters north of lat. 5°N. This may explain why the hook rate for bigeye tuna by regular longline was relatively high along lat. 10°N. On the other hand, the hooks of the deep longline may fish at depths of around 50 to 250 m. If so, then this gear is effectively fishing within the thermocline in all areas between lat. 5°S and 20°N. This would explain why the hook rates by deep longline exceed those by regular longline throughout the areas fished. Considering the above, it is not unreasonable to surmise that the distribution of bigeye tuna is much broader vertically than hitherto believed, and also that the abundance is also greater within these fishing grounds.

It has been pointed out earlier that the hook rates of bigeye tuna by deep longline are relatively lower along lat. 10°N than on either side of this latitude. According to the BT data, the thermocline is shallower at around lat. 8°N-10°N, and the range of hook depths for the deep longline should adequately cover the thermocline. However, since bigeye tuna are believed to occur within and just below the thermocline, it appears that many of the deep longline hooks are located outside of relatively narrow thermocline in this area. This may possibly be the explanation for the relatively lower hook rates by the deep gear at around lat. 10°N, but further examination is needed to confirm whether this is really the case as explained in this paper. Also, it is unable at present to explain the apparently low catches of bigeye tuna along the equator.

For yellowfin tuna, the catches by regular longline were relatively high in waters north of lat. 5°N, where the thermocline is shallower. There also appeared to be little difference

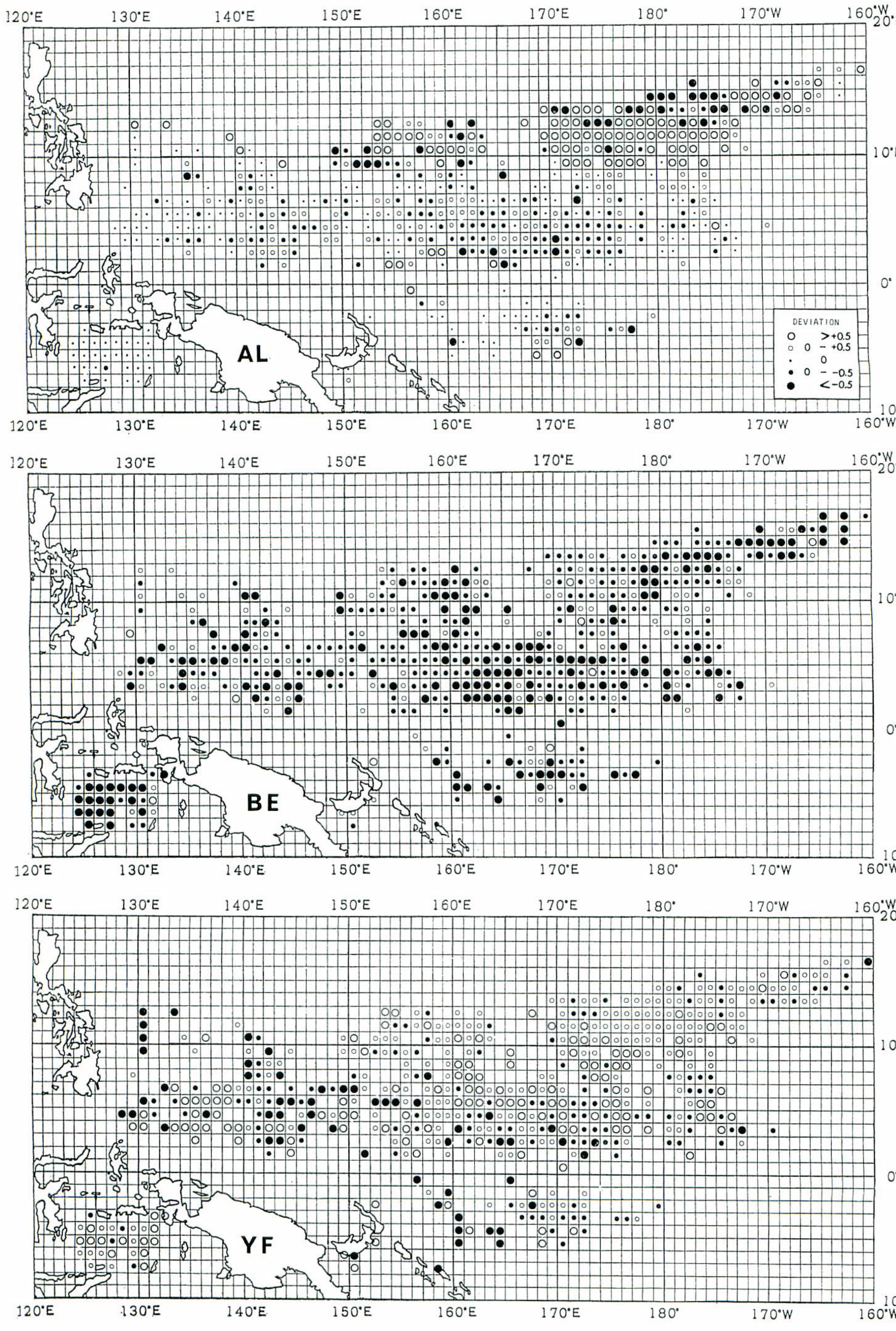


Fig. 10. Positive or negative deviation in quarterly averaged hook rate of regular longline from that of deep longline plotted by 1° square for various species of tunas and billfishes.

From top, albacore (AL), bigeye tuna (BE) and yellowfin tuna (YF). As for the multiplier of the hook rates for each species, see captions in Figure 6.

in hook rates between the two types of gear in waters south of lat. 5°N. The above facts suggest that the yellowfin tuna generally inhabits waters above the thermocline.

Albacore seems to have an intermediary character between that of yellowfin tuna and bigeye tuna *in terms of* vertical distribution (Fig. 10). In areas between lat. 5°N and 12°N where the thermocline is shallower, the hook rates by the regular gear are higher than those by the deep gear as in the case of yellowfin tuna. However, relative fishing efficiency of the deep gear to the regular one on either side of the shallow thermocline area is better in albacore than in yellowfin tuna. This is more evident in the northern region.

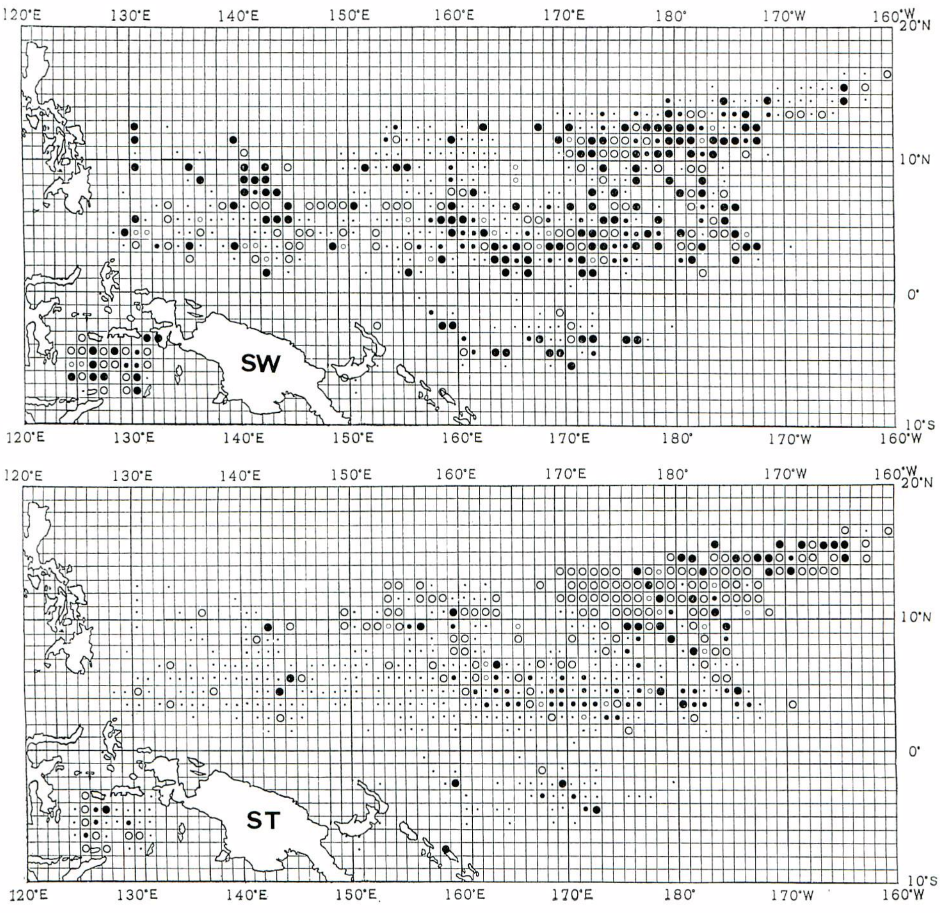


Fig. 10. Continued. Swordfish (SW: above) and striped marlin (ST: below).

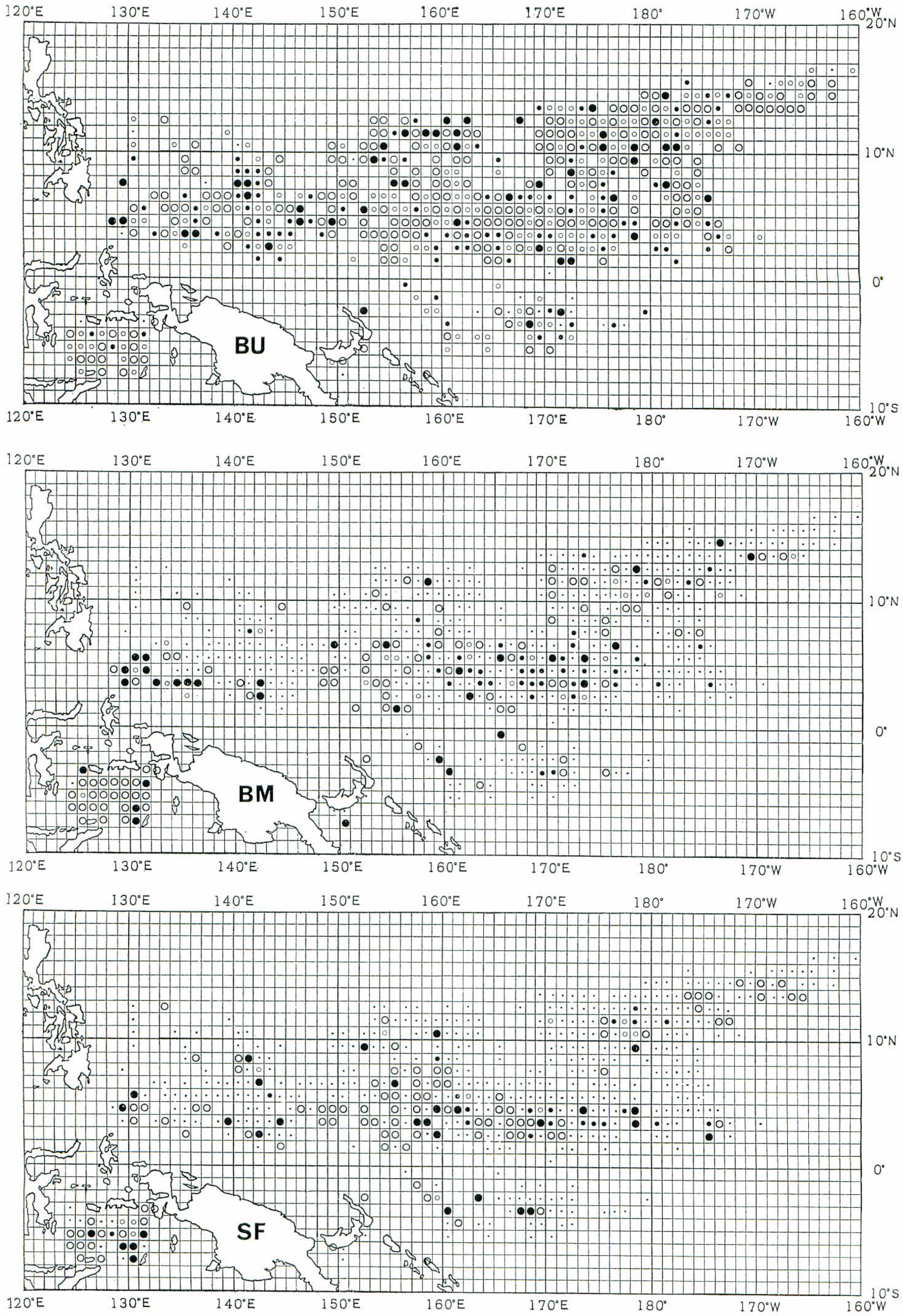


Fig. 10. Continued. From top, blue marlin (BU), black marlin (BM) and sailfish and sortbill spearfish (SF).

Table 3. Quarterly averaged hook rates and its variance by gear type and the ratio of the hook rate of deep gear over regular gear for various species of tunas and billfishes basing on 1° square data totaling 776 deep and 873 regular longline samples.

Species	Mean		Variance		Ratio of Mean
	Deep	Regular	Deep	Regular	Deep/Regular
Sailfish and Shortbill spearfish	0.169	2.654	1.788	93.410	0.06
Striped marlin	0.564	2.007	3.461	42.198	0.28
Black marlin	0.296	0.870	1.485	6.383	0.34
Blue marlin	0.443	0.809	0.336	0.558	0.55
Yellowfin tuna	0.691	0.952	0.651	0.951	0.73
Swordfish	0.833	1.059	1.502	6.835	0.79
Albacore	0.683	0.835	2.840	4.531	0.82
Bigeye tuna	0.746	0.417	0.246	0.118	1.79

Multipliers for the calculation of the hook rates are 100 for bigeye tuna and yellowfin tuna, 1,000 for albacore and blue marlin and 10,000 for swordfish, striped marlin, black marlin and sailfish and shortbill spearfish.

The regular gear shows considerably higher hook rates than the deep gear for billfishes, except swordfish, for which the hook rates are almost uniform over the areas surveyed (Fig. 10). No marked difference in the regional dominance of the hook rates by regular gear over deep gear for the billfishes was observed, and this seems to be associated partly with relatively deep location of the thermocline in the Western and Central Pacific. In other words, it might be able to expect regional difference of the hook rates by deep and regular gears in the Eastern Equatorial Pacific where the thermocline is situated shallower and changes its depth drastically even within the limited areas.

In Table 3, the mean and variance of the quarterly averaged hook rates by gear type and the ratio of the hook rates of deep longline over regular longline for the various species of tunas and billfishes are summarized. The smaller the ratio, the more "surface dwelling" a species is, at least for fish taken by longline in this area.

Information on fish size, probable change of their vertical distribution by day and night and their feeding ecology is needed in addition to the accumulation of more data available for the deep longline gear to promote the study on this line.

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中西部赤道太平洋における普通はえ縄と深はえ縄によるマグロ・カジキ類の漁獲状況

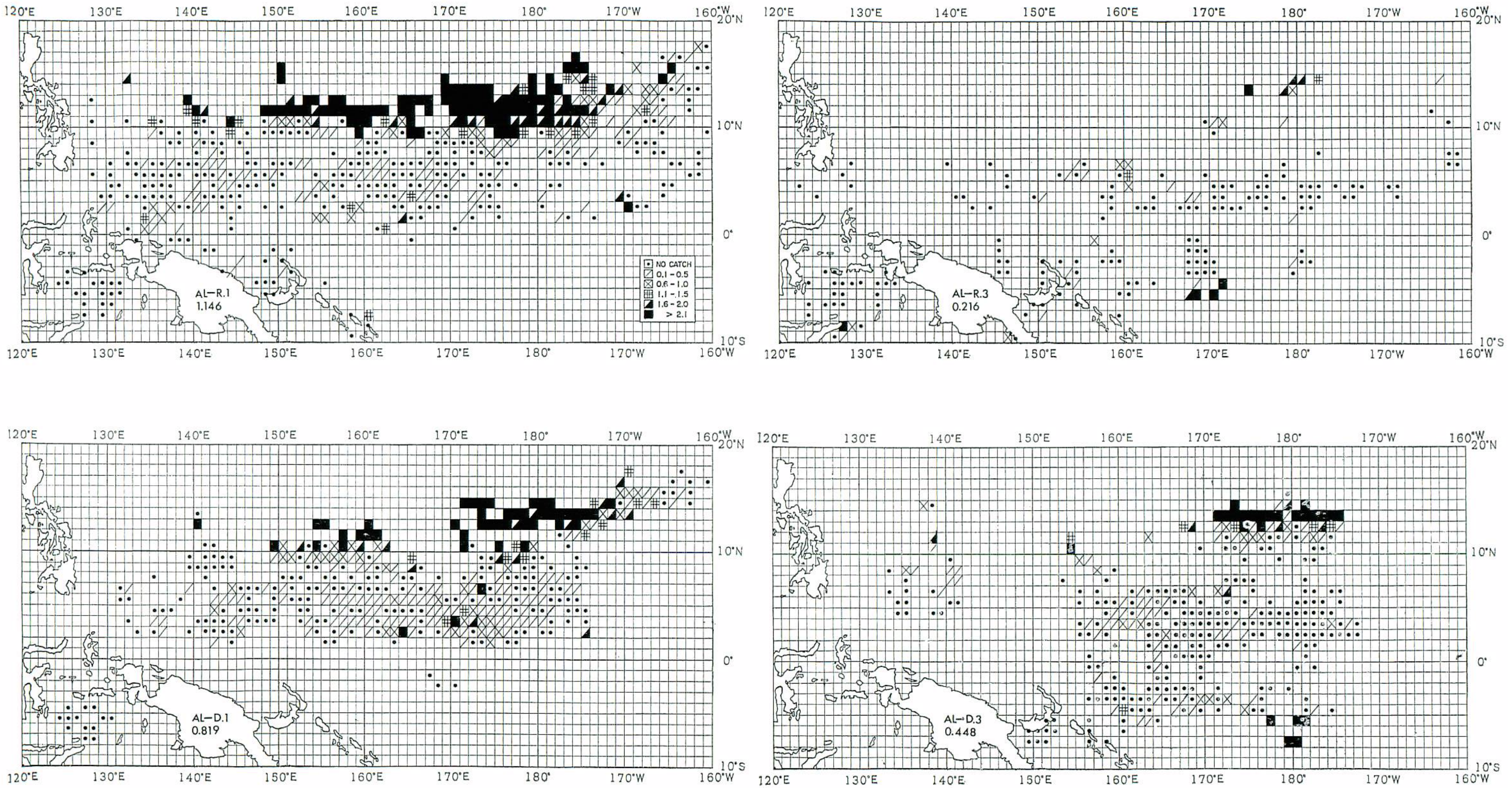
鈴木治郎・藁科侑生・岸田正通

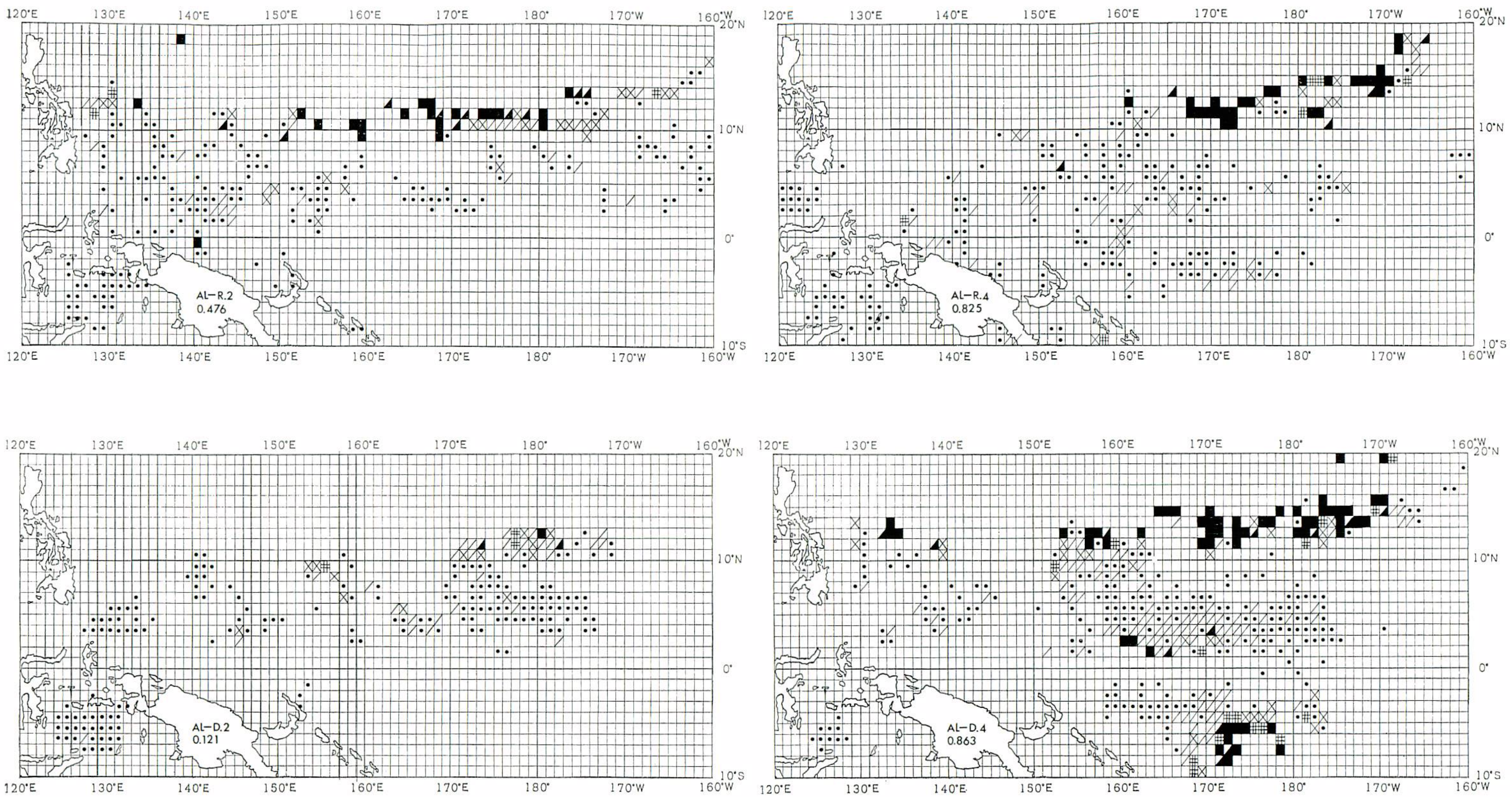
要　　約

1974 年と 1975 年に焼津港に入港した漁船のデータから，普通はえ縄と深はえ縄という 2 つののタイプのはえ縄で獲えられたマグロ・カジキ類の漁獲状況が，釣獲率を通して比較された。近年メバチを狙って，中西部赤道太平洋で操業する中小型の日本のマグロ漁船の間で深はえ縄が普及し，現在では，当海域での操業は，ほとんどこの深縄漁法にとってかわられている。

普通縄の鉤は 50～120 m の深度を，また深縄のそれはほぼ 50～250 m の深度をカバーして漁獲していると推定される。

一般にマグロ・カジキ類の中で，メカジキを除くカジキ類は比較的表層を，メバチはもっとも深層を遊泳していると判断される。深縄の釣獲率が普通縄よりも高いのはメバチのみで，他のマグロ・カジチ類はすべて普通縄による釣獲率が高い。さらにメバチの場合には，普通縄と深縄とを通して得られた釣獲率の分布パターンに顕著は差異がみられた。この差異は水温躍層とはえなわの釣の到達深度との関係で説明された。メバチは中西部赤道太平洋では，これまで考えられていたよりは高密度でかつ広範囲に分布すると推定される。


120°E
130°E
140°E
150°E
160°E
170°E
180°
170°W
160°W
20°N
10°N
0°
10°S
NO CATCH
0.1 – 0.5
0.6 – 1.0
1.1 – 1.5
1.6 – 2.0
> 2.1
AL–R.1
1.146
AL–R.3
0.216
AL–D.1
0.819
AL–D.3
0.448

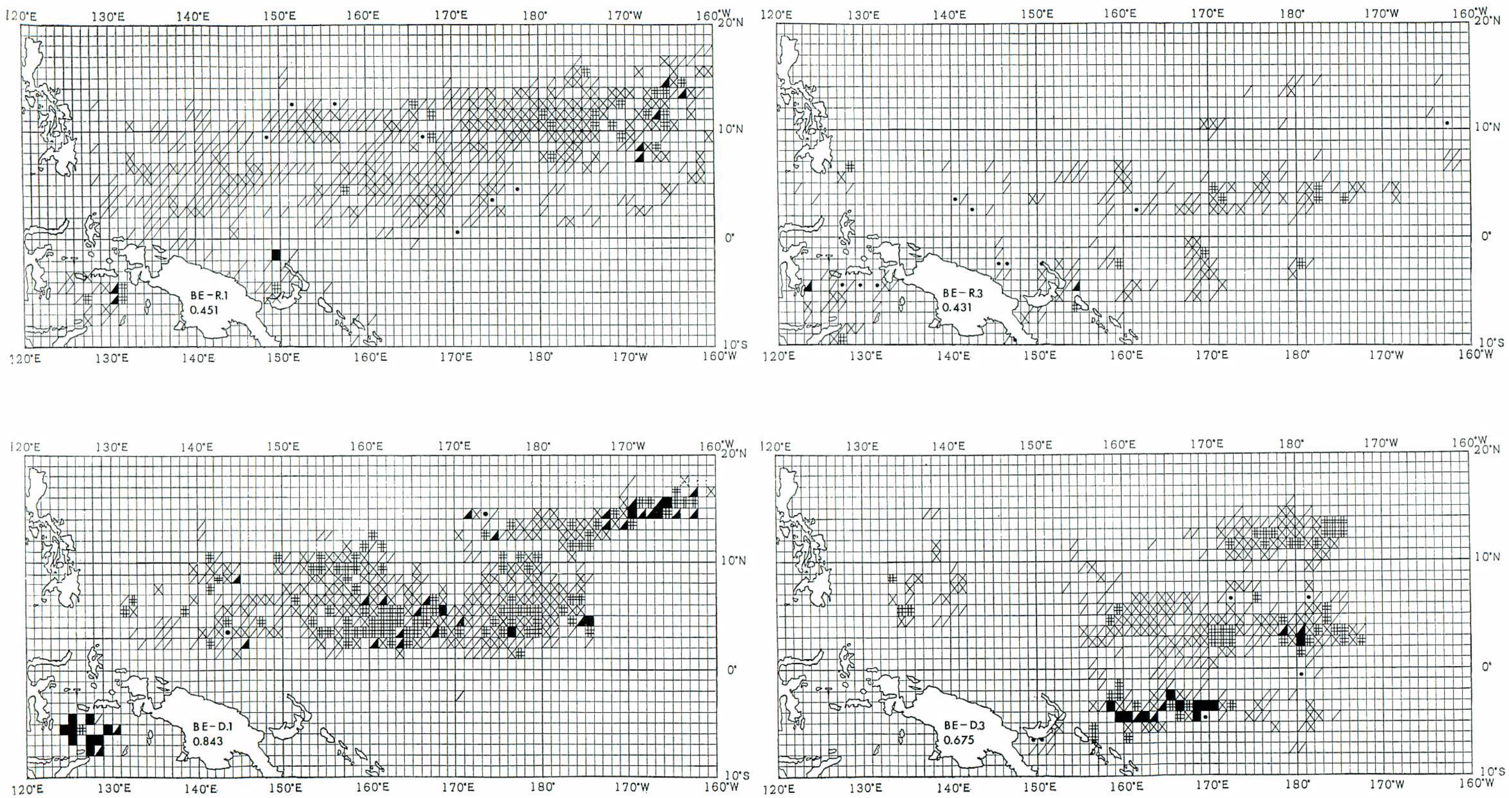


Appendix Fig. 1. The distribution of quarterly hook rate by regular and deep longline gears, combining data for 1974 and 1975 (Small numbers of data for the end of 1973 are also included) for various species of tunas and billfishes.

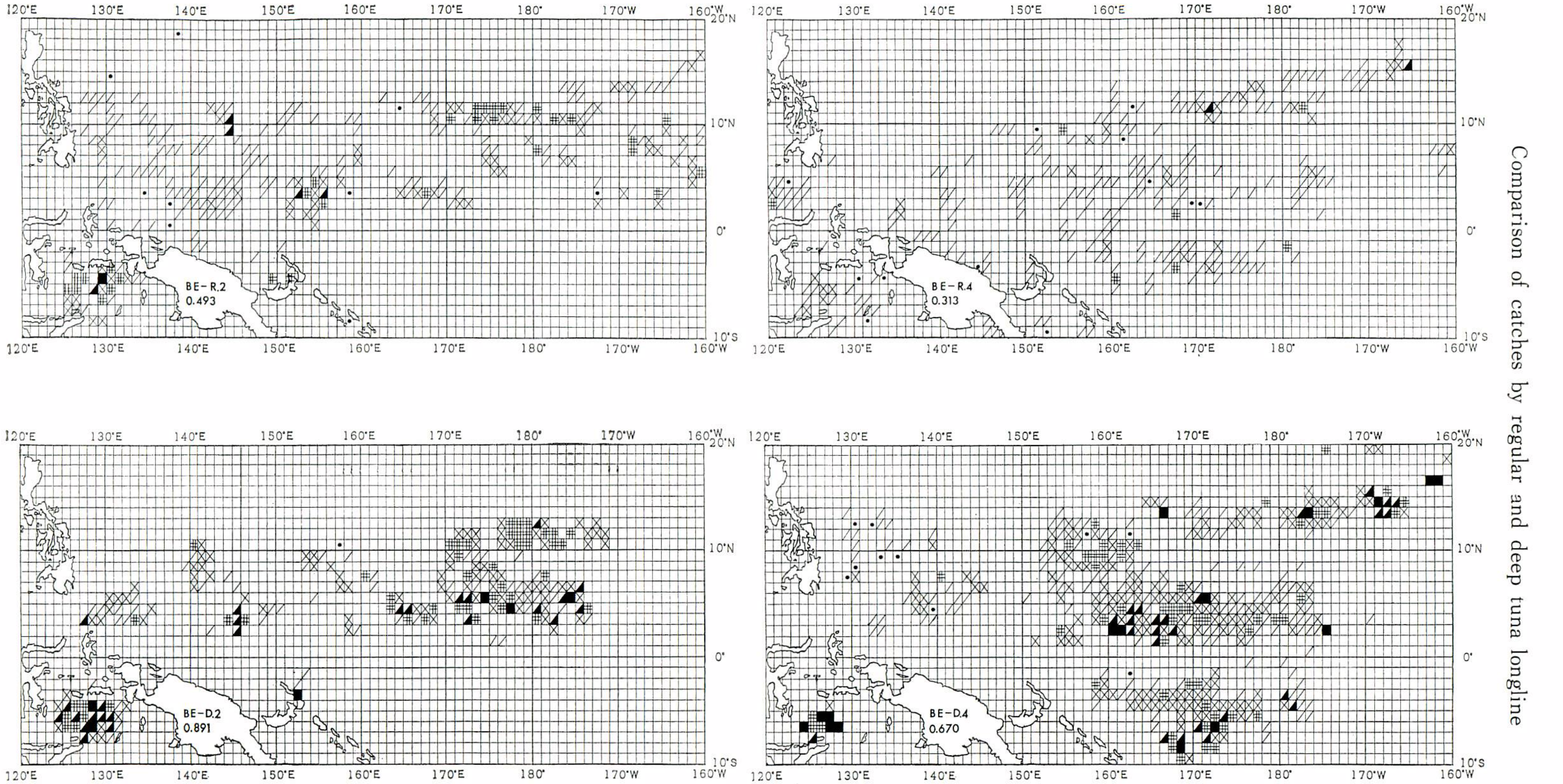
The figures in the charts indicate the quarterly hook rates obtained over the whole area by the two types of gears. (Legend: First two capital letters before hyphen denote species, D=deep longline, R=regular longline and the following one digit numeral denotes quarter of the year)

As for the multiplier of the hook rates for each specis, see captions in Figure 6.

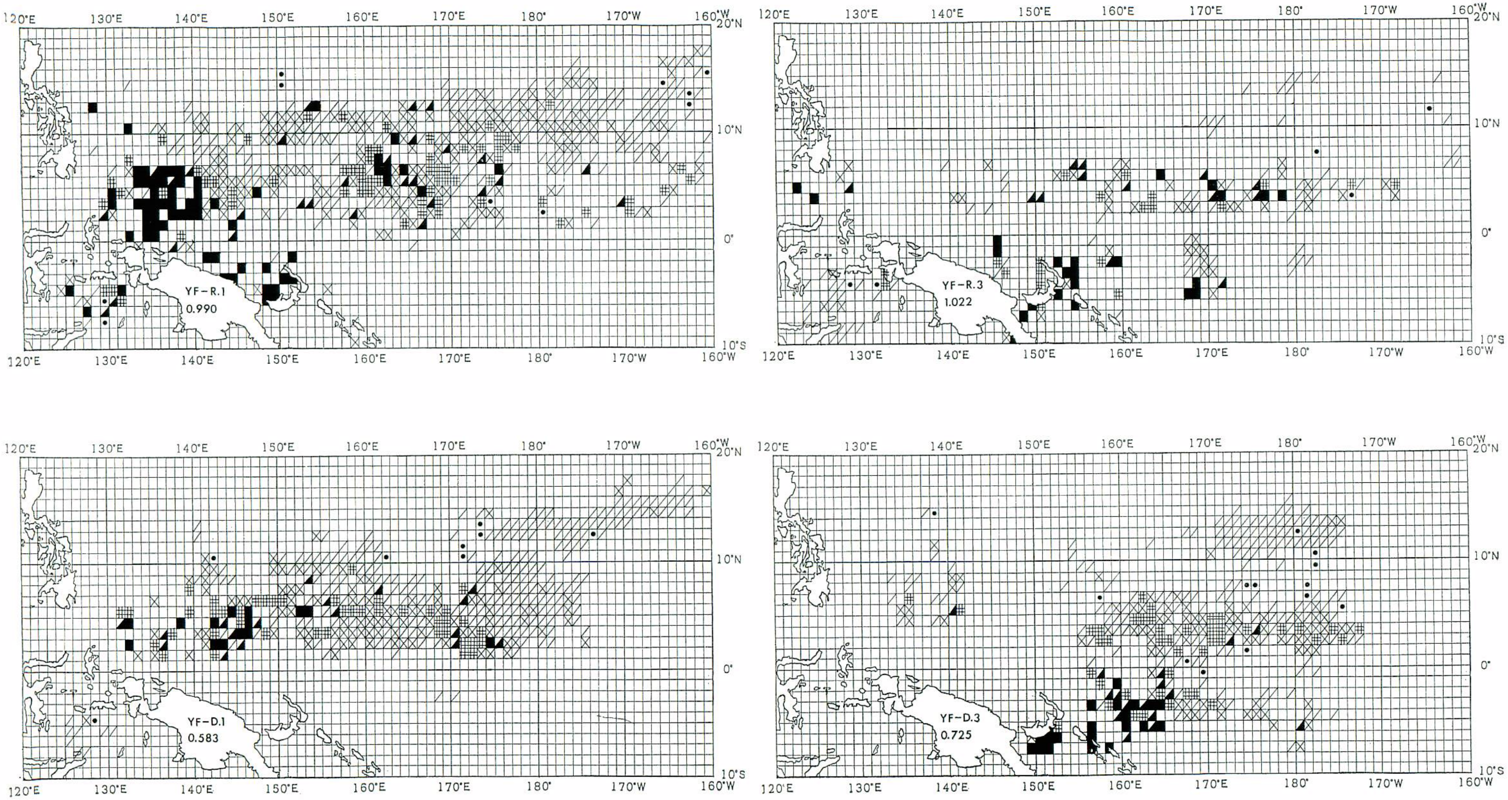
Albacore: AL

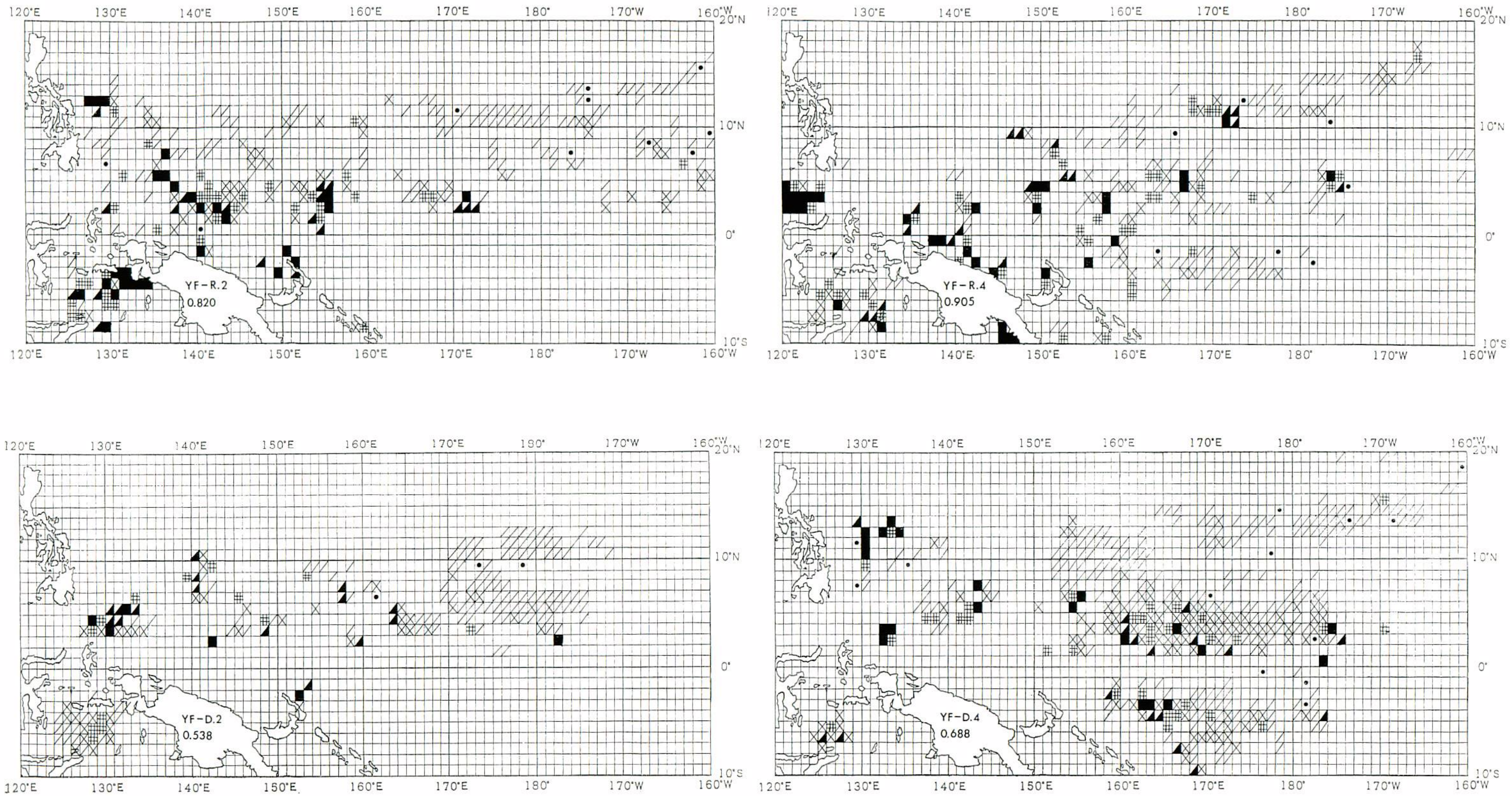


BE-R.1
0.451
BE-R.3
0.431
BE-D.1
0.843
BE-D.3
0.675
120°E 130°E 140°E 150°E 160°E 170°E 180° 170°W 160°W
20°N
10°N
0°
10°S

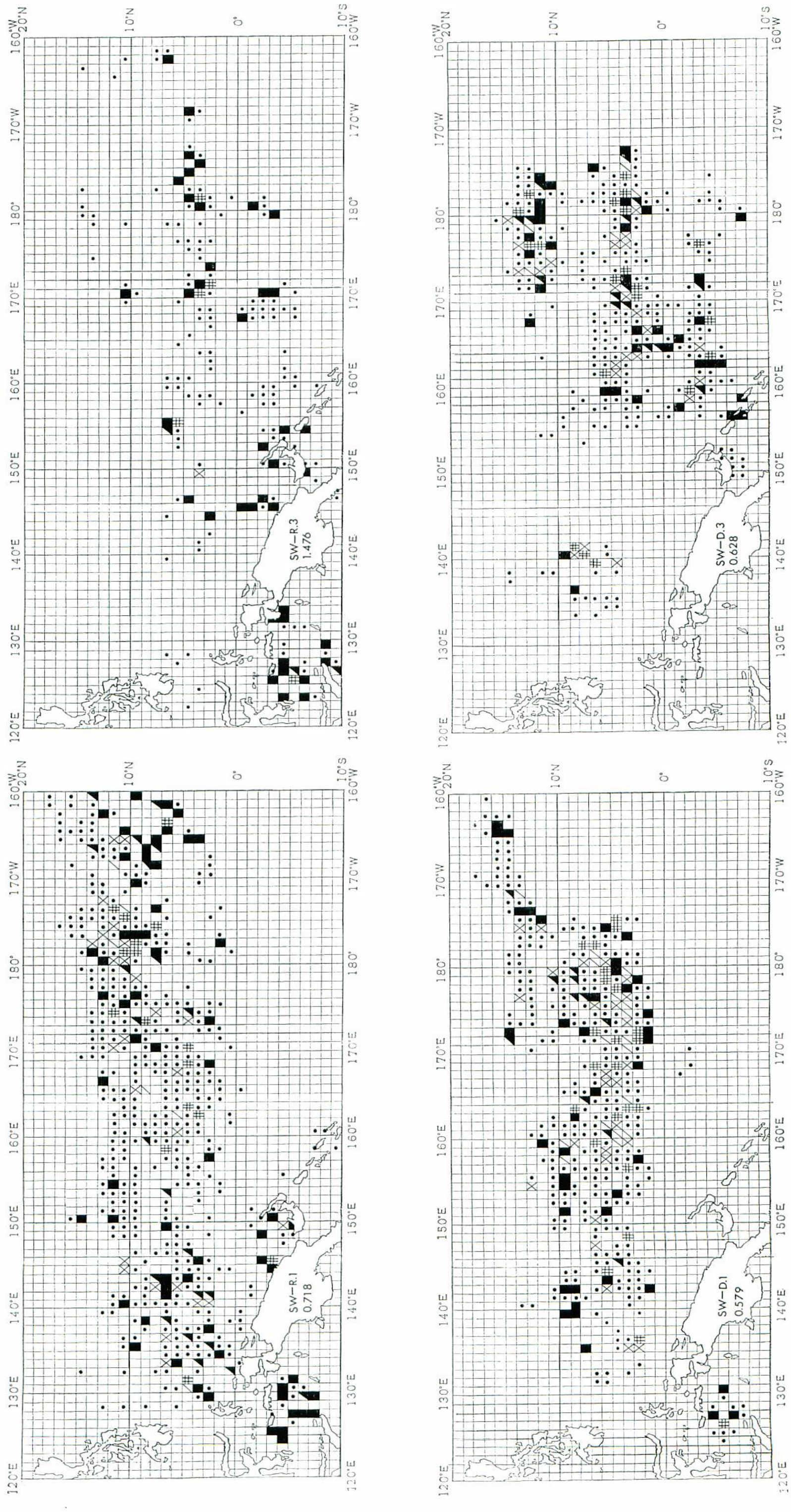


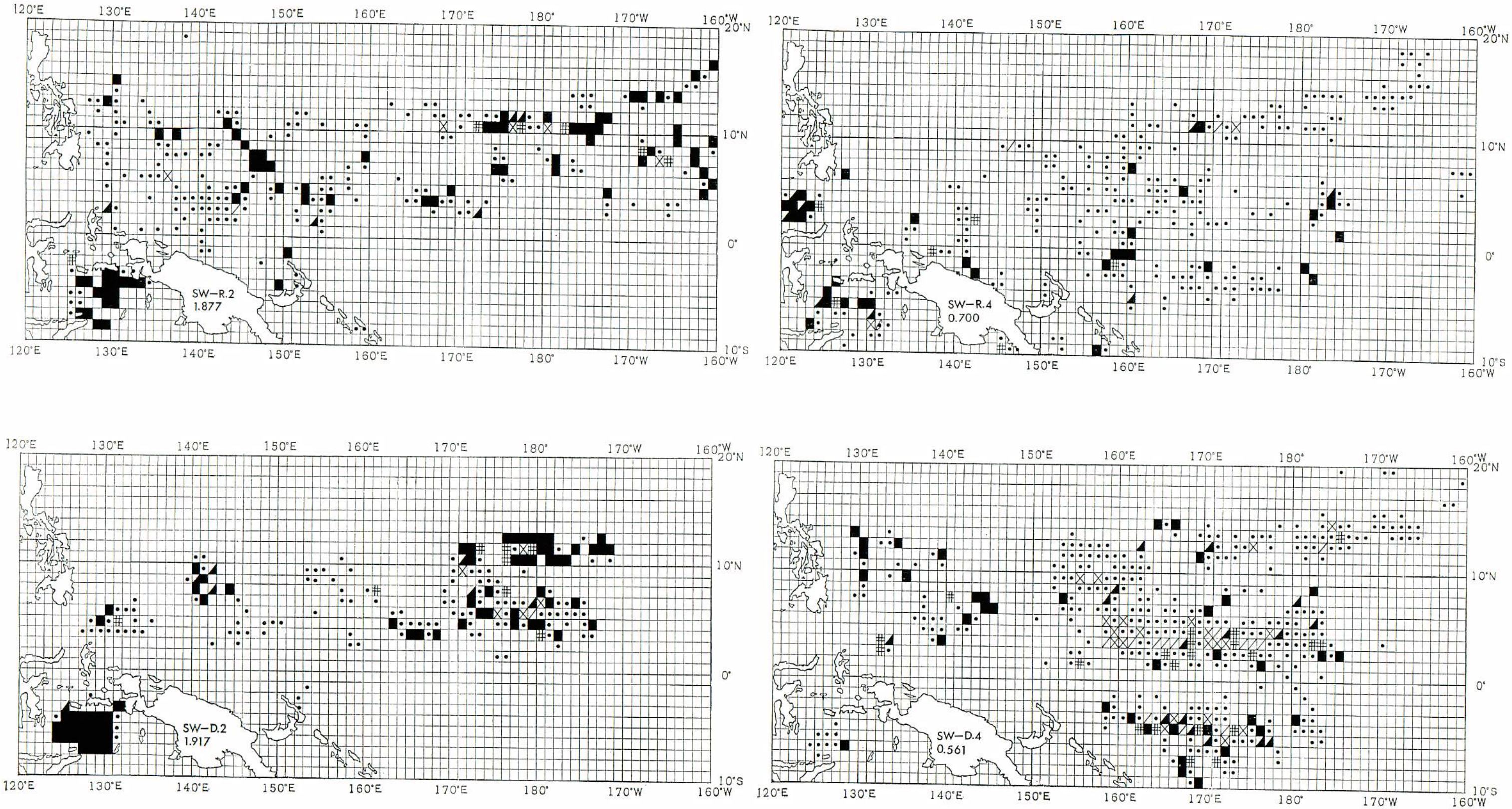
Appendix Fig. 1. Continued. Bigeye tuna: BE


YF-R.1
0.990
YF-R.3
1.022
YF-D.1
0.583
YF-D.3
0.725
120°E
130°E
140°E
150°E
160°E
170°E
180°
170°W
160°W
20°N
10°N
0°
10°S

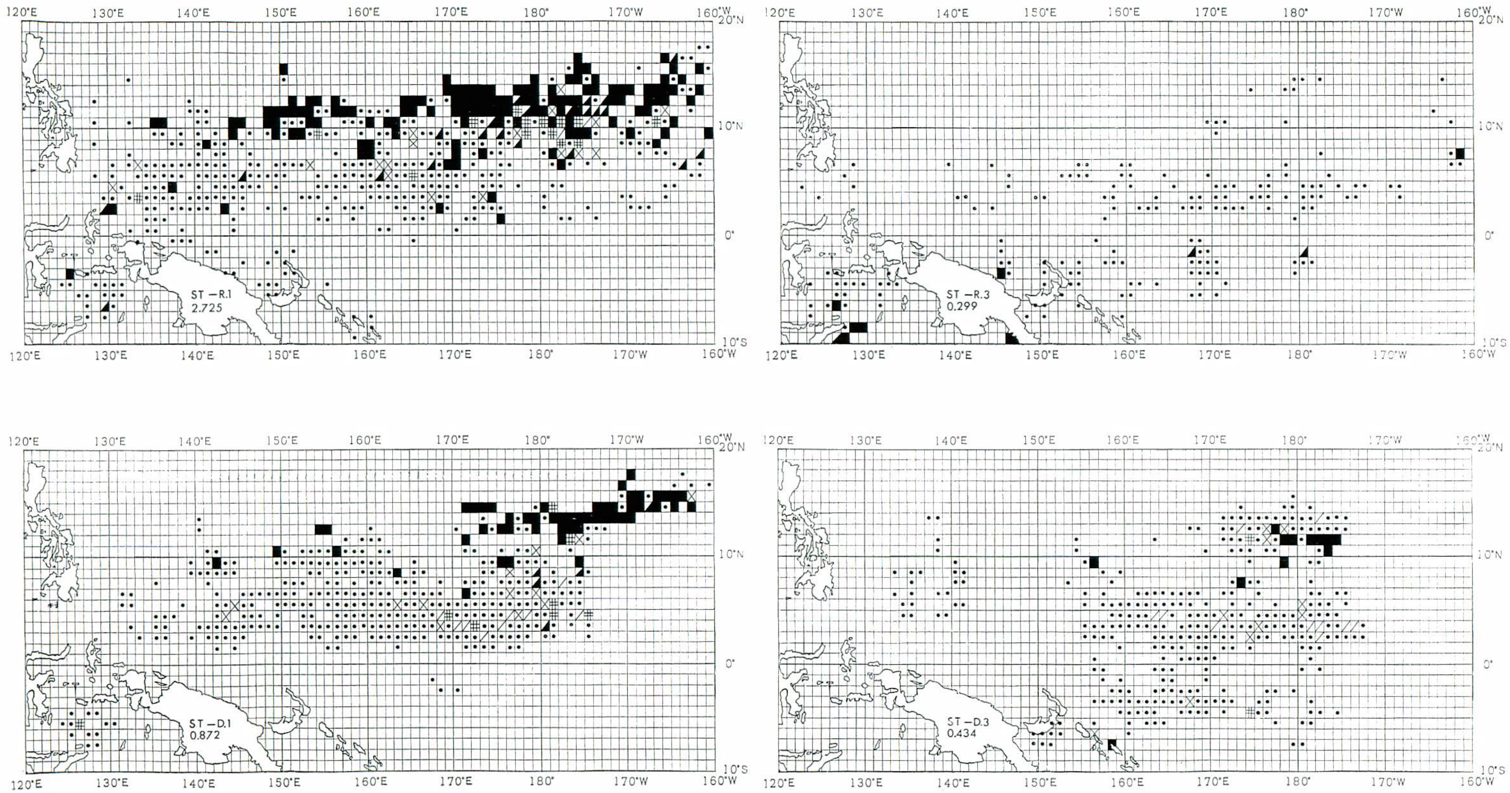


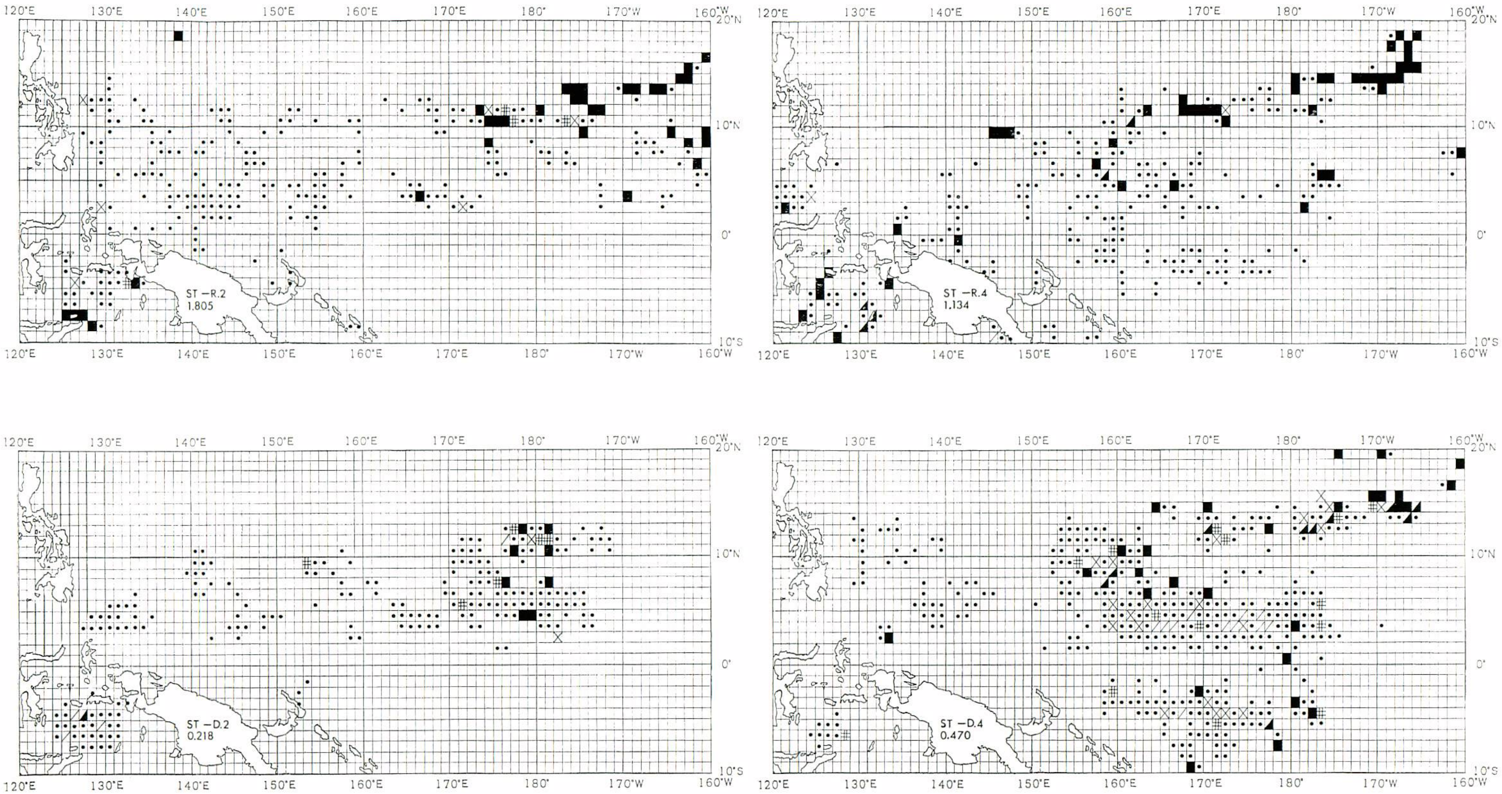
Appendix Fig. 1. Continued. Yellowfin tuna: BE


SW-R.3
1.476
SW-D.3
0.628
SW-R.1
0.718
SW-D.1
0.579
120°E
130°E
140°E
150°E
160°E
170°E
180°
170°W
160°W
20°N
10°N
0°
10°S

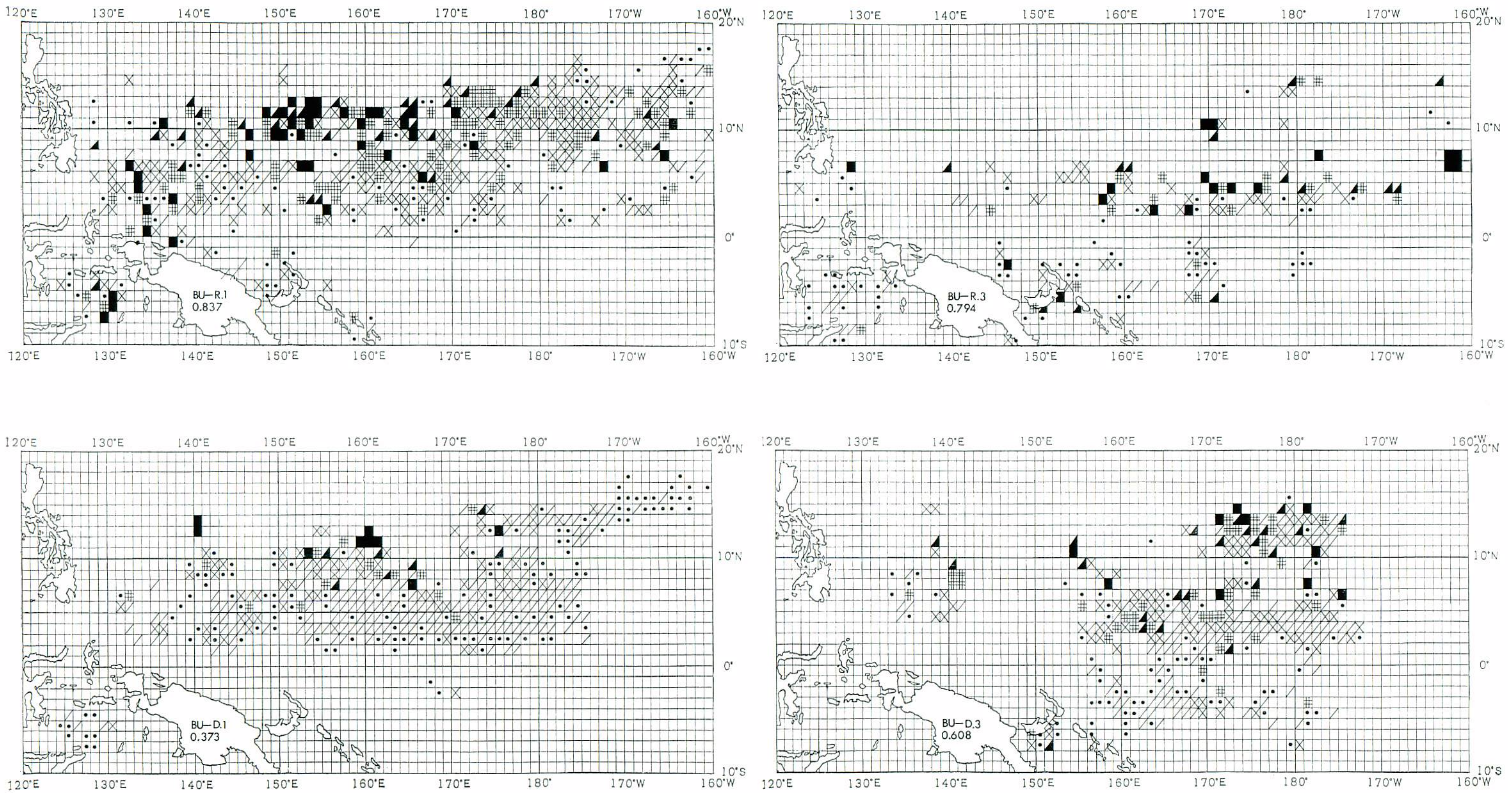


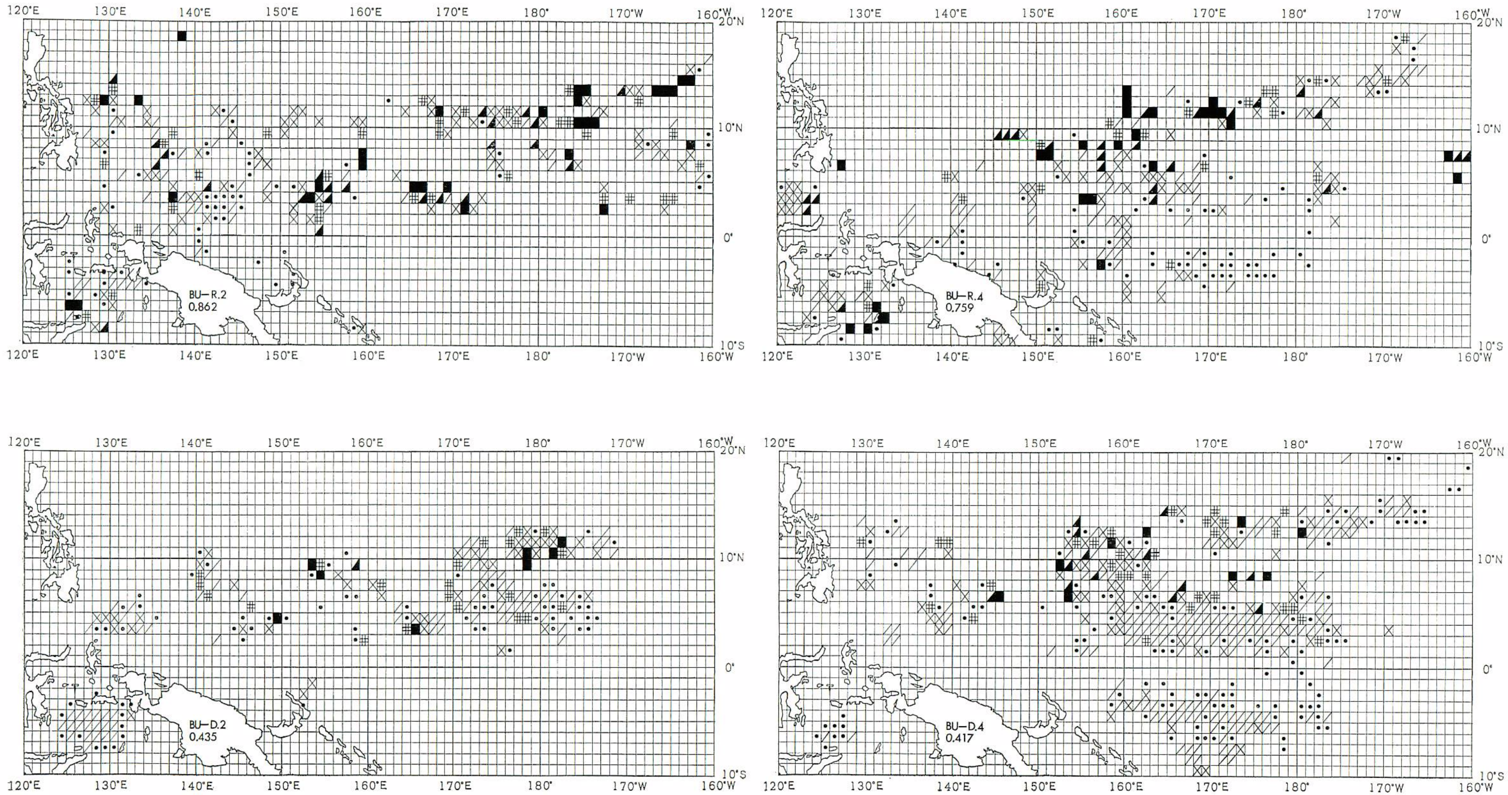
Appendix Fig. 1. Continued. Swordfish: SW


120°E
130°E
140°E
150°E
160°E
170°E
180°
170°W
160°W
20°N
10°N
0°
10°S
ST —R.1
2.725
ST —R.3
0.299
ST —D.1
0.872
ST —D.3
0.434

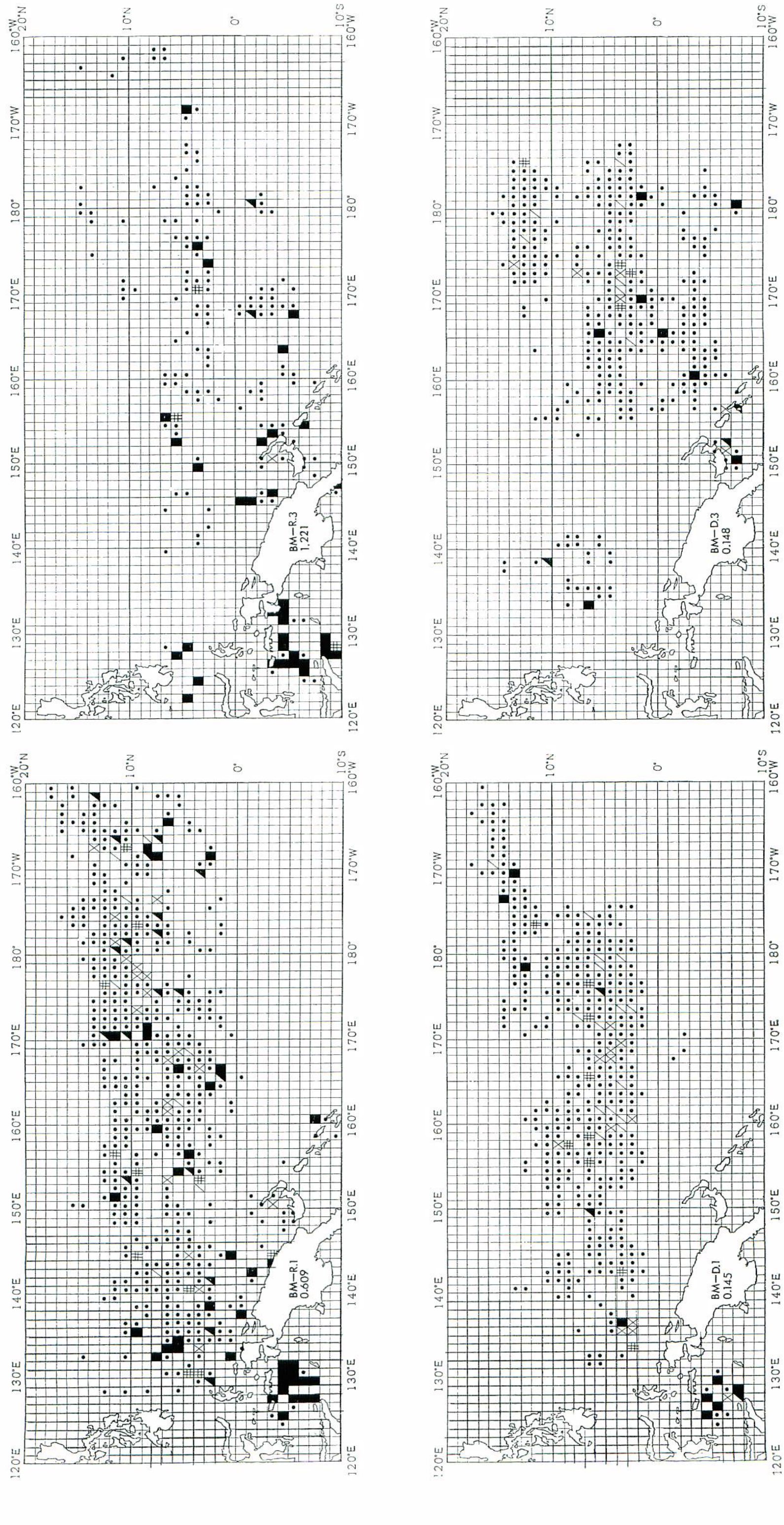


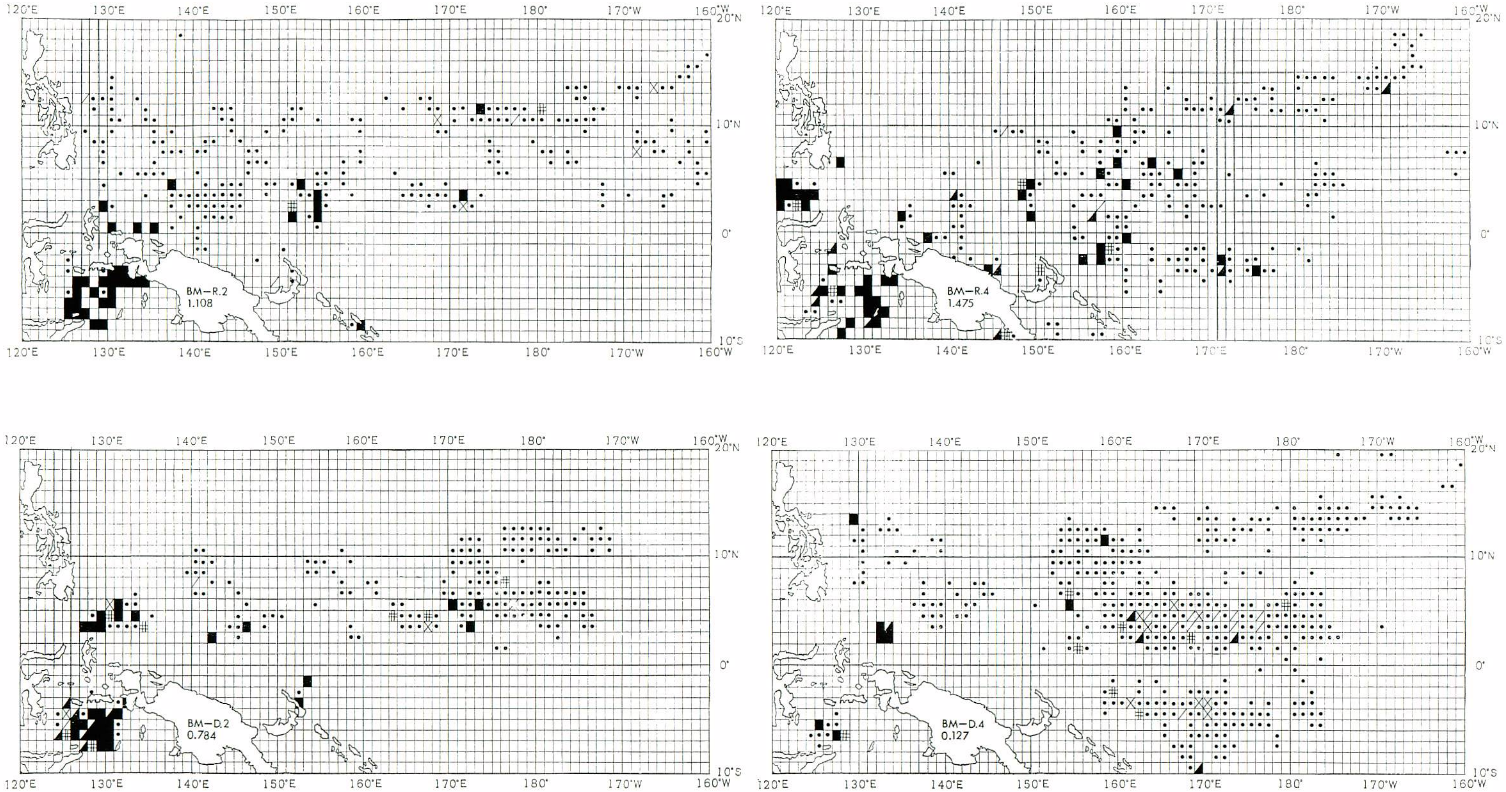
Appendix Fig. 1. Continued. Striped marlin: ST


120°E
130°E
140°E
150°E
160°E
170°E
180°
170°W
160°W
20°N
10°N
0°
10°S
BU—R.1
0.837
BU—R.3
0.794
BU—D.1
0.373
BU—D.3
0.608

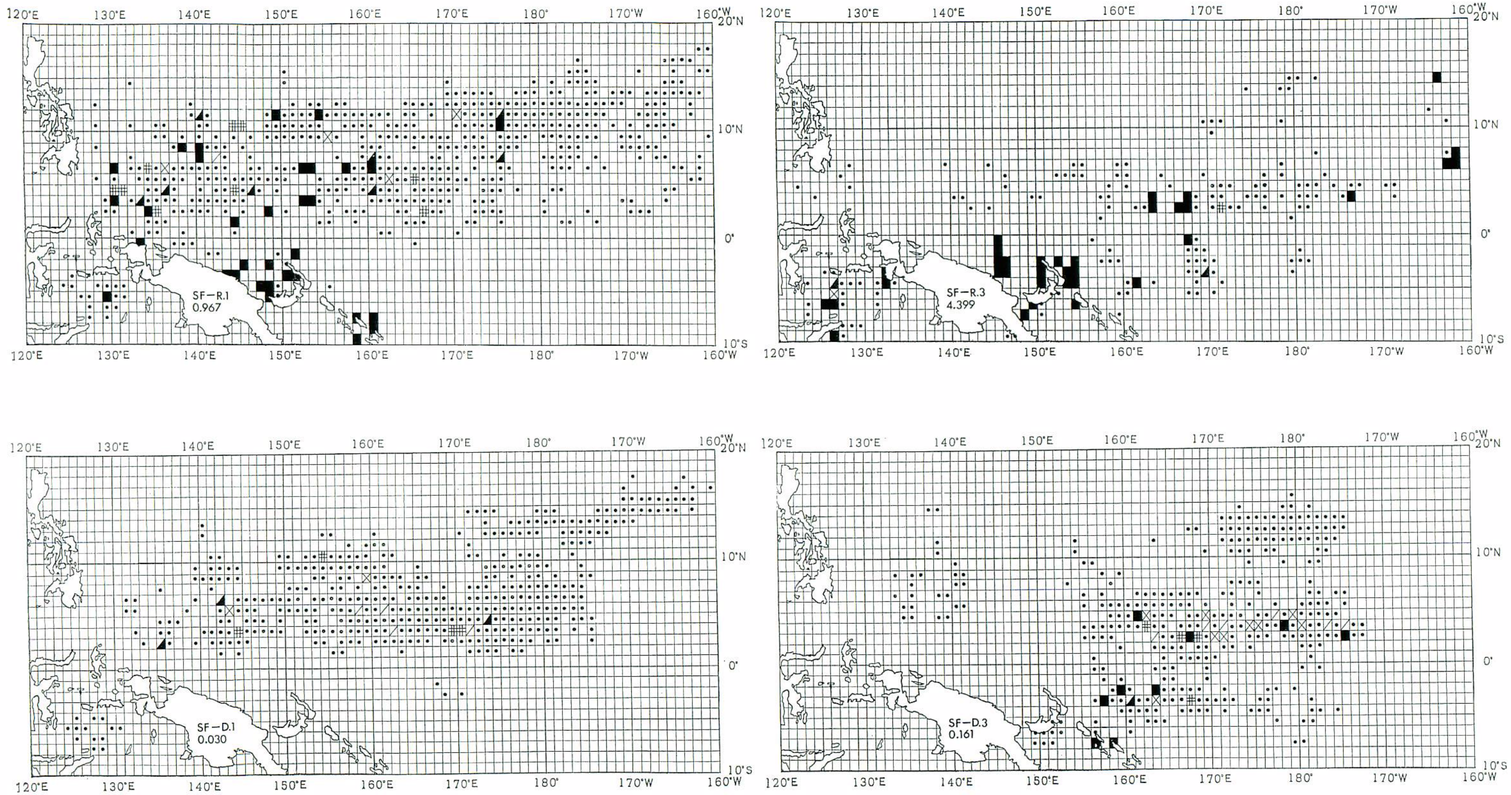


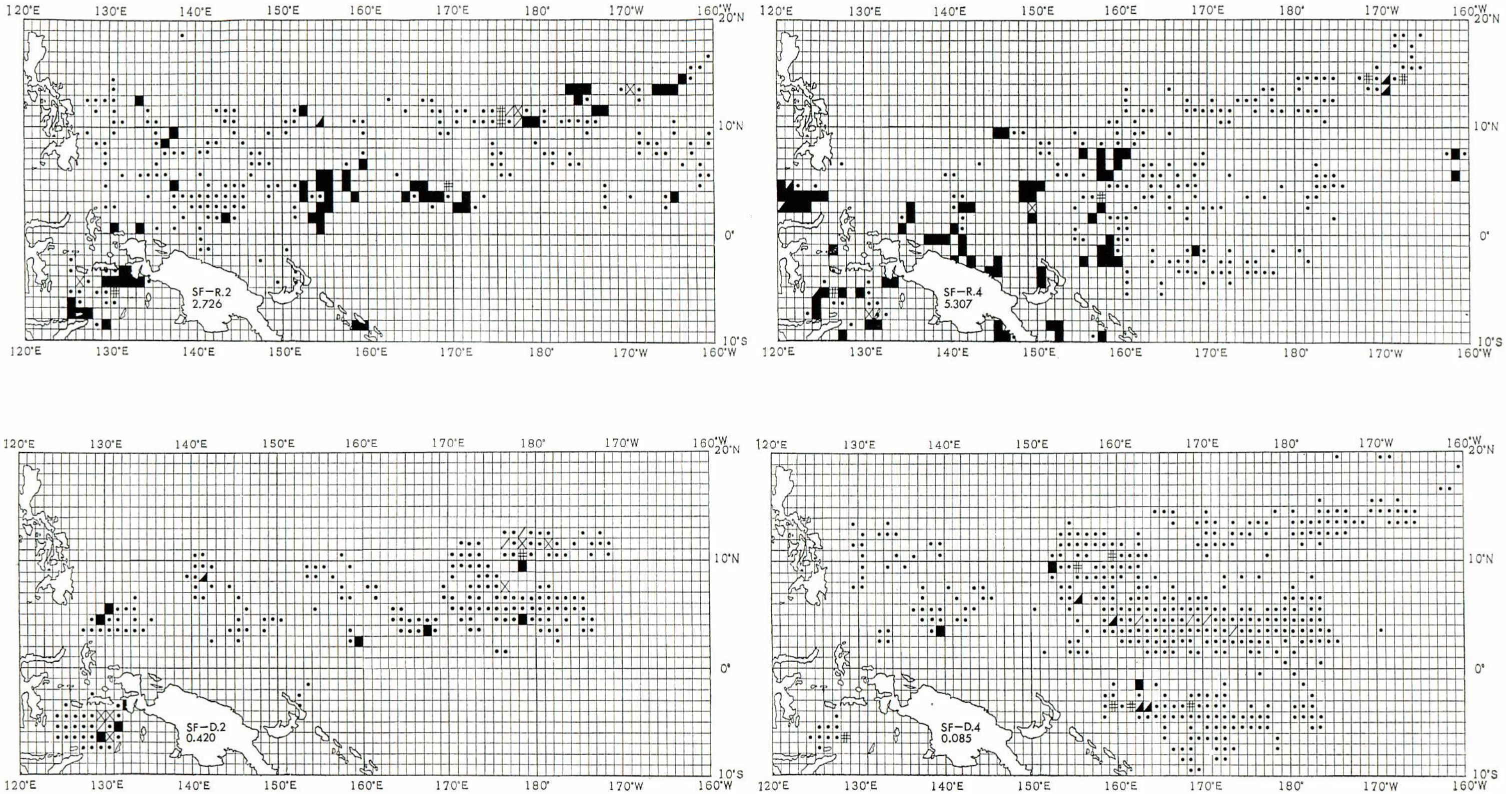
Appendix Fig. 1. Continued. Blue marlin: BU


BM−R.3
1.221
BM−D.3
0.148
BM−R.1
0.609
BM−D.1
0.145
160°W
170°W
180°
170°E
160°E
150°E
140°E
130°E
120°E
20°N
10°N
0°
10°S



Appendix Fig. 1. Continued. Black marlin: BM


120°E
130°E
140°E
150°E
160°E
170°E
180°
170°W
160°W
20°N
10°N
0°
10°S
SF−R.1
0.967
SF−R.3
4.399
SF−D.1
0.030
SF−D.3
0.161



Appendix Fig. 1. Continued. Sailfish and Shortbill spearfish: SF