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以1971-1985年間臺灣遠洋鮪釣漁業資料分析南太平洋長鰭鮪分佈的季節性變動

SEASONAL CHANGES OF THE DISTRIBUTION OF SOUTH PACIFIC ALBACORE BASED ON TAIWAN'S TUNA LONGLINE FISHERIES, 1971-1985

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SEASONAL CHANGES OF THE DISTRIBUTION OF SOUTH PACIFIC ALBACORE BASED ON TAIWAN'S TUNA LONGLINE FISHERIES, 1971-1985[1]

CHIEN-HSIUNG WANG[2]

ABSTRACT

Analysis of seasonal changes of south Pacific albacore based on the catch statistic data of Taiwan's tuna longline fisheries operating in the south Pacific in 1971-1985 shows that:

(1) Taiwan's longliners only target on albacore. The seasonal changes of fishing grounds relate closely to the movement of south Pacific albacore.

(2) The principal fishing grounds of Taiwan's longliners shift southward to the higher latitude area during summer of the southern hemisphere, and return northward to the lower latitude in the winter.

(3) Concentration areas of hooking rate form a band between 15°S-25°S in summer, and present as a band between 30°S to 40°S in winter.

(4) The seasonal movement is significantly southward during January to April, and northward in July to October. Comparatively speaking, no significant changes of distribution can be found during November-January and April-June.

(5) The distribution area expands with the cool season, especially in May-August, and contracts with the warm season, January-March.

INTRODUCTION

Albacore in the Pacific Ocean are believed to be divided into two populations, one in the north Pacific and the other in the south Pacific. In the south Pacific, albacore occurred from the equator to 40°S in the central and western areas (Koto, 1966) and concentrated in the area bounds between 10°S and 30°S and between 150°E and 120°W (Suda, 1971). Kume (1974) reported that longline catches have been made near the coast of Chile.

In the southwestern Pacific, Slack (1969, 1972), Roberts (1974), and Habib and Cade (1978) describe a surface fishery on both coasts of New Zealand. The most important commercial fisheries in the New Zealand areas is the domestic trolling fishery which lands approximately 2000 to 3000 mt each year (SPC, 1986). A survey carried out by the NOAA R. V. Townsend Cromwell in 1986–1987 indicates that it is economically feasible for U. S. albacore fishing vessels to operate in the south Pacific Ocean (Laurs *et al.*, 1987).

As shown in Table 1, Japanese longliners entered the south Pacific in 1952. In this year, only 210 mt was caught by Japanese longliners. Annual catch of south Pacific albacore of Japanese longliners shows a rapid rise from 210 mt in 1952 to 38880 mt in 1962. From then on, it reveals a decreasing trend year by year. The lowest annual catch is 1045 mt in 1975. Recently, it maintained at a rather low level. The annual catch was lower than 6000 mt since 1970's.

Korea in 1958 and then Taiwan in 1963 also entered south Pacific albacore fishing

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Table 1. Catch statistics of south Pacific albacore fisheries, 1952-1985*

unit in M. T.

Year	Japan	Taiwan	Korea	Others	Total
1952	210	—	—	—	210
1953	1091	—	—	—	1091
1954	10200	—	—	—	10200
1955	8420	—	—	—	8420
1956	6220	—	—	—	6220
1957	9764	—	—	—	9764
1958	21558	—	146	—	21704
1959	19344	—	456	—	19800
1960	23756	—	610	—	24366
1961	25628	—	330	—	25958
1962	38880	0	599	—	39479
1963	33500	608	1367	—	35475
1964	21435	629	2911	—	24975
1965	19305	1640	6405	100	27450
1966	23401	6669	10817	500	41387
1967	16640	14910	13717	105	45372
1968	7707	14496	10138	14	32355
1969	5559	9883	9963	—	25405
1970	6560	12463	11599	50	30672
1971	4339	19677**	14482	200	38698
1972	2796	21965	14439	468	39668
1973	2381	26795	17452	584	47212
1974	1847	19009	12194	890	33940
1975	1045	13343	9015	1827	25230
1976	1906	18129	12212	2462	34709
1977	2240	23056	13176	4610	43082
1978***	3127	18732	10989	2965	35813
1979	2540	12376	8682	3346	26944
1980	2666	27007	10852	3640	44165
1981	5565	12041	14793	3317	35716
1982	5505	10157	12586	3434	31685
1983	5701	7822	6669	3464	23626
1984	4260	6771	5730	3405	20166
1985	4122	6095	14267	3434	27918

* Data listed in 1952-1977 are adopted from Table 1, FAO Fish. Tech., Paper No. 200, 1980.

** Catch of Taiwan's longliners after 1971 are adopted from "Annual catch statistics of Taiwanese tuna longline fishery", NTUIO, 1971 to 1985.

*** Provisional estimates by the author.

grounds. Since the 1970's, Taiwan's longliners have become the most important fishery in the exploitation of south Pacific albacore. After 1980, it has been replaced by Korea's longlinears.

The general trend in the annual total catch of south Pacific albacore from 1952 through 1967 shows a rapid rise from 210 mt in 1952 to 45372 mt in 1967, and fluctuates around an average of about 36000 mt in the 1970's. Peaks in the catch occurred in 1962, 1967, 1973, 1977 and 1980, and lows in 1956, 1964, 1969, 1975 and 1979.

Yoshida (1971, 1975), Skillman (1975, 1978), and Wetherall *et al.* (1979) calculate indexes of relative abundance for south Pacific albacore. There is a general agreement that a downward trend in CPUE (cath per unit of fishing effort) has been evident in recent years. Skillman (1978) observes that the CPUE corresponding to the MSY in south Pacific is about 0.79 mt/day, and the effort corresponding to this level is surpassed by the fishery in 1970. The relative abundance has since declined steeply, indicating that south Pacific albacore stock has been overfished, and he noted that the decline in the index of relative abundance in the southern winter fishery for small albacore may indicate that the adult stock has been reduced to levels sufficiently low as to reduce the recruitment. Experience with other tuna fisheries has indicated that an MSY calculated from longline statistics does not necessarily reflect the potential yield of all fisheries. It is likely to increase the south Pacific albacore yield by further development of surface fisheries (SPC, 1986). On the other hand, Japanese longliners develop a new type of deeper longliners, and it has been used in areas where albacore are found at greater depths (up to 380 m) than regular longliners (Saito, 1973; Suzuki *et al.*, 1977).

Taiwan's tuna longliners pay special attention to exploitting south Pacific albacore. Since 1971, a rather complete data collection system has been organized at National Taiwan University. In this paper, the author tries to examine the seasonal changes of south Pacific albacore. All of the analysis are based on the catch statistic data of Taiwan's tuna longline fisheries in 1971 to 1985. When Japanese and Korea's longline catch statistics are included in the future, the results will be used as the basic data of stock assessment of south Pacific albacore.

MATERIALS AND METHODS

All of the analysis is based on the monthly catch statistics of Taiwan's commercial tuna longline fisheries. Catch statistics are arranged by month and by 5-degree squares. Here, "south Pacific" is defined as the area in the south of equator from 150°E to 70°W including the nothern water of Australia and those areas around New Guinea as used in "Annual Catch Statistics of Taiwanese Tuna Longline Fishery" (NTUIO, 1985).

Catch in number and effort in hook are used in this study and all of these data are expressed by Lat. 5-degree×Lon. 5-degree squares. Effective fishing efforts are estimated by Honma's method (Honma, 1974). This method is summarized as follows.

CPUE or average hooking rates $D(i, j)$ are represented as follows.

$$D(i,j)=\left(\sum_{k=1}^{L(i,j)} C(i,j,k)/H(i,j,k)\right)/L(i,j) \qquad (1)$$

where, i=i-th 5-degree square,
j=j-th month,
k=k-th year,
C=catch in number,
H=per 100 hooks used,
L=number of years of which Taiwan's longline fishery occurred in that subarea,

Relative abundance indexes $R(i, j)$ are represented as follows,

$$R(i,j)=D(i,j)/\left(\left(\sum_i A(i,j)^*D(i,j)\right)/\left(\sum_i A(i,j)\right)\right) \qquad (2)$$

where, A=area index of fishing ground.

Availability index denoted by $a(j)$ can be estimated by formula (3).

$$a(j)=\left(\sum_i A(i,j)^*D(i,j)\right)/\left(\sum_{j=1}^{12}\left(\sum_i A(i,j)^*D(i,j)\right)\right)/12 \qquad (3)$$

Relative efficiency index of fishing effort $E(i, j)$ can be estimated by multiplying the availability index $a(j)$ and relative abundance index $R(i, j)$.

$$E(i, j)=a(j)*R(i, j) \quad (4)$$

Effective fishing effort $X(j, k)$ can be calculated by formula (5).

$$X(j, k)=\sum E(i, j)*H(i, j, k) \quad (5)$$

RESULTS

(1) Seasonal change of fishing ground

As shown in Figs. 10. 1–10. 12, there is a clear seasonal change of fishing grounds. $L(i, j)$ means the number of years which Taiwan's longliners occurred in i-th subarea is j-month during these 15 years. $L(i, j)$ can be considered an attractive index of fishing ground. For a traditional fishing ground, greater values of $L(i, j)$ may be considered more interest expressed by fishermen in that area. By experimenting for a longer time period, if they operate on a certain spot, they can catch their objects there as expected.

Fig. 10. 1 reveals that higher frequencies occur in the north of 20°S, and form three groups around 170°E, 170°W and 125°W. Concentration areas shift westward and disappear gradually after February (Fig. 10. 2). In March, a higher frequency areas presents around 35°S to 40°S, 145°W to 155°W. Concentration area seem to shift southward, form a band around 30°S in the west of 130°W during April to July (Figs. 10. 4–10. 7), and then begin to return to the lower latitude areas thereafter (Figs. 10. 8–10. 11). During November to January, the distribution of fishing grounds and the concentration areas are very similar.

Monthly changes of the front of fishing grounds of Taiwan's tuna longliners are shown in Fig. 1. In January, fishing grounds are limited in the north of 25°S and extended to 110°W, and then, as shown by arrows, they tend to move westward and southward month by month. In April, fishing grounds are limited in the west of 140°W and extend southward to 40°S. During April to June, almost no seasonal change of fishing grounds can be found. Then, they begin to shift in an opposite direction as shown by arrows. The movement is rapid in July-October. It seems to have the same boundary as that appeared in November to January.

Taiwan's tuna longliners target on albacore only, so that the seasonal changes of fishing ground can be considered an indication of seasonal movement of south Pacific albacore, at least for the objects of regular longliners. It reveals that there are two types of seasonal movement. One is westward and southward during summer (January-April). The other is eastward and northward during winter (July-October). In April-June and in November-January, no greater change of distribution can be found.

(2) Variation of area index of fishing grounds

Fig. 2 shows the annual fluctuation of average area index of fishing ground during 1971–1985. This is estimated with a correcting factor given by Shiohama (1971, adopted from Table 1). It shows a heavy fluctuation. Before 1976, they reveal a decreasing trend, and increase gradually after this year. Peaks present in 1981. Recently, they showed a heavily decreasing trend. On the other hand, monthly average area index shows a slight fluctuation (Fig. 3). Peaks are in September, and lows in March and April.

As shown in Table 2, actual fishing efforts of Taiwan's longliners operating in the south Pacific show a heavy fluctuation during these 15 years. A peak used 62373 thousand hooks in 1980. It is about 4.5 times that used in 1985, 13746 thousand hooks. This reflect in the annual changes of area index as shown in Fig. 2. More hooks they used imply

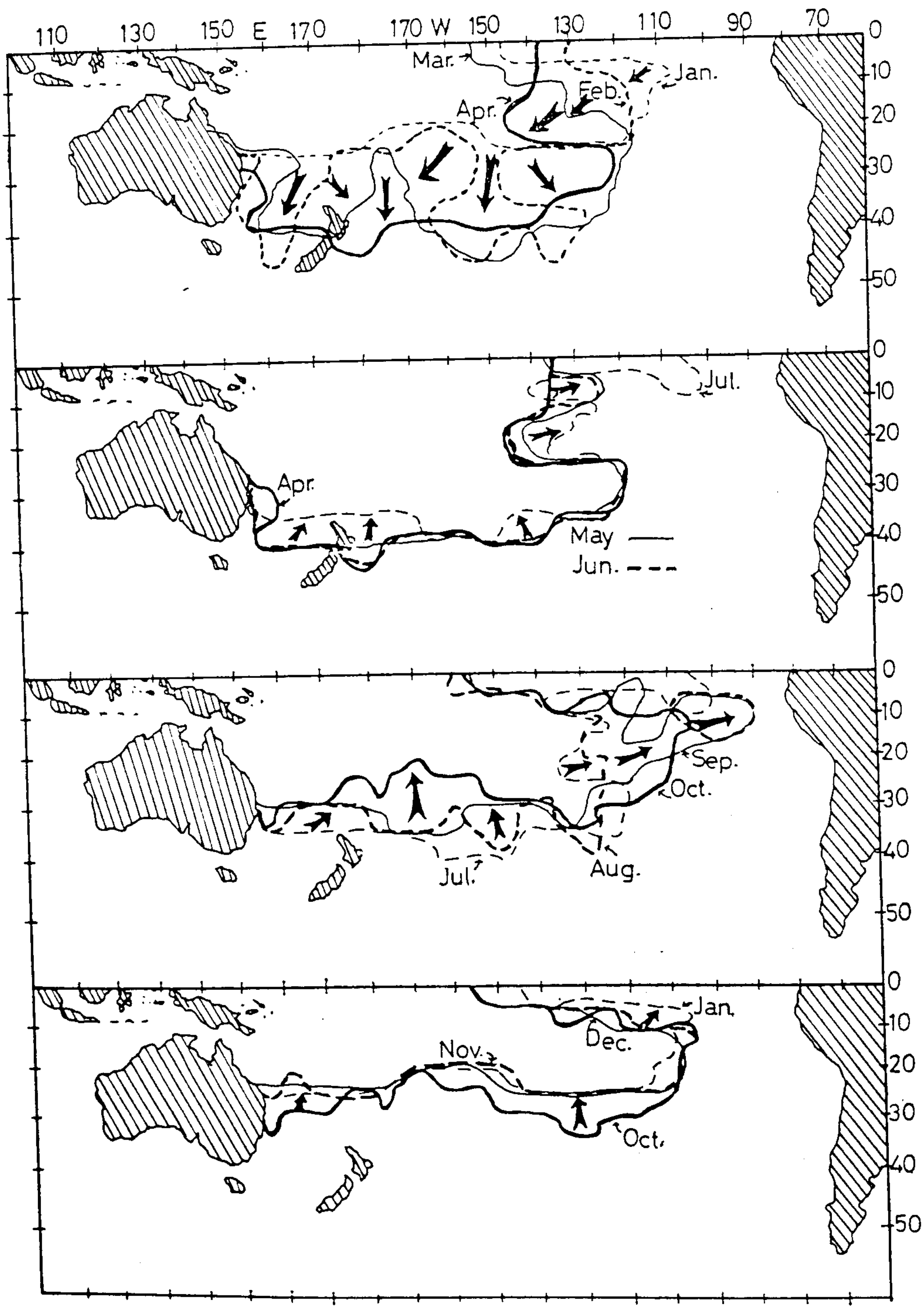

Fig. 1. Monthly changes of fishing grounds of Taiwan's tuna longliners operating in the south Pacific Ocean.

Table 2. Annual fishing efforts, fishing intensity, and catch per unit of fishing effort

Year	Actual fishing effort	Effective fishing effort	Catch in number	CPUE (/100 H)	
				Actual	Effective
1971	35801×1000H	43097×1000	12325×100	3.443	2.860
1972	40138	41385	13565	3.380	3.270
1973	54148	52512	16276	3.006	3.099
1974	50070	48351	13178	2.632	2.726
1975	34216	31235	8626	2.521	2.762
1976	36808	29875	11192	3.041	3.746
1977	46527	45857	16929	3.638	3.692
1978	30381	33581	11569	3.808	3.445
1979	28865	32850	8130	2.816	2.475
1980	62373	82970	18302	2.934	2.206
1981	37623	44810	8743	2.324	1.951
1982	26533	30157	7014	2.644	2.326
1983	17376	15359	5562	3.201	3.621
1984	20128	18432	4658	2.314	2.527
1985	13746	12774	4113	2.992	3.220
Mean	35649	37550	10679	2.980	2.929

Fig. 2. Annual changes of average area index of fishing grounds.

greater area of fishing grounds they occupied. On the other hand, no heavy change of monthly average area index can be found. This seems to imply that (a) Taiwan's longliners are very familiar with the seasonal movement of south Pacific albacore. They follow closely the movement of south Pacific albacore. (b) Main fishing grounds are concentrated in the principal distribution areas of south Pacific albacore. (c) Seasonal distribution of fishing grounds can be considered a reflection of the seasonal change of the distribution areas of south Pacific albacore. It seem impossible to reflect the seasonal change of population size.

(3) Seasonal change of catch per unit of fishing effort

Figs. 11.1-11.12 show the seasonal changes of relative abundance index. It can be seen that the higher concentration area of relative abundance index can be found at around 20°S, and seems to separate into two groups. One is near the western part of the south Pacific along the coastal area, and the other is at around 120°W (Fig. 11.1). This separation becomes more clear during February-March (Figs. 11.2-11.3) and after October

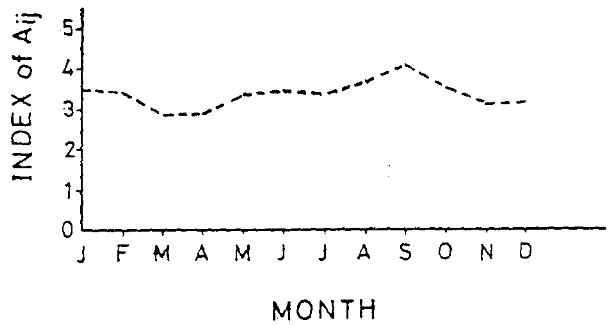

Fig. 3. Monthly changes of average area index of fishing grounds.

(Figs. 11.10–11.12). Concentration areas shift southward gradually and form a band at around 35°S on the west of 130°W. It also forms a concentration area along the coastal area in the western part of the south Pacific before June (Figs. 11.4–11.6). After July, the concentration area begins to shift northward (Figs. 11.7–11.9), and it seems to separate into two groups. One is a westward movement, and the other eastward (Figs. 11.10–11.12). The seasonal movement of concentration areas are very similar to the seasonal change of principal fishing grounds.

As stated above, fish population of south Pacific albacore shows a clear seasonal movement, they moved westward and southward in the first half of the year, and have an opposite movement in the second half of that year. Higher concentration areas of abundance index only appeared during May to August in the narrow band between 30°S and 40°S on the west of 130°W and near the western coastal area. The concentration areas seem to separate in the central Pacific (about 170°W) into two groups: one is in the western part near the coastal area, and the other in the eastern part of the south Pacific during September to March. These two groups merge into one in the higher latitude area, forming a band during April to August.

Honma and Kamimura (1957) and Otsu and Sumida (1968) found that the mean length of albacore taken within 5-degree latitude bands tended to increase from north to south in the south Pacific, with size reaching a maximum in the 20°–25°S band, and diminishes thereafter. It seems to have a close relationship between the seasonal change of concentration area and the change of size composition.

It is necessary to obtain more detailed biological data and/or information of tagging experiments for understanding the ecological meanings of these seasonal movements. The author will re-examine the seasonal movements when Korean and Japanese catch statistic data are available.

(4) Variation of relative efficiency index

As a relative efficiency index of fishing efforts, $E(i, j)$ will be evaluated by formula (4). $E(i, j)$ can be considered a correction coefficient of spatial and temporal variations of the distribution of fishing efforts. The seasonal changes of relative efficiency index are dependent on the appearence of the concentration area of abundance index.

According to Honma's study, effective fishing efforts can be estimated by formula (5) (Honma, 1974). The ratio (effective fishing effort/actual fishing effort) will be calculated as an index of concentration. As shown in Fig. 4, almost no change of the annual concentration index can be found for each month. In general, it shows a slightly concave upward trend before 1978 and an unclear concave downward trend thereafter. As shown in the dotted line, the average concentration index maintain at a rather stable level.

Comparatively, monthly concentration index (Fig. 5) shows a clear pattern of seasonal

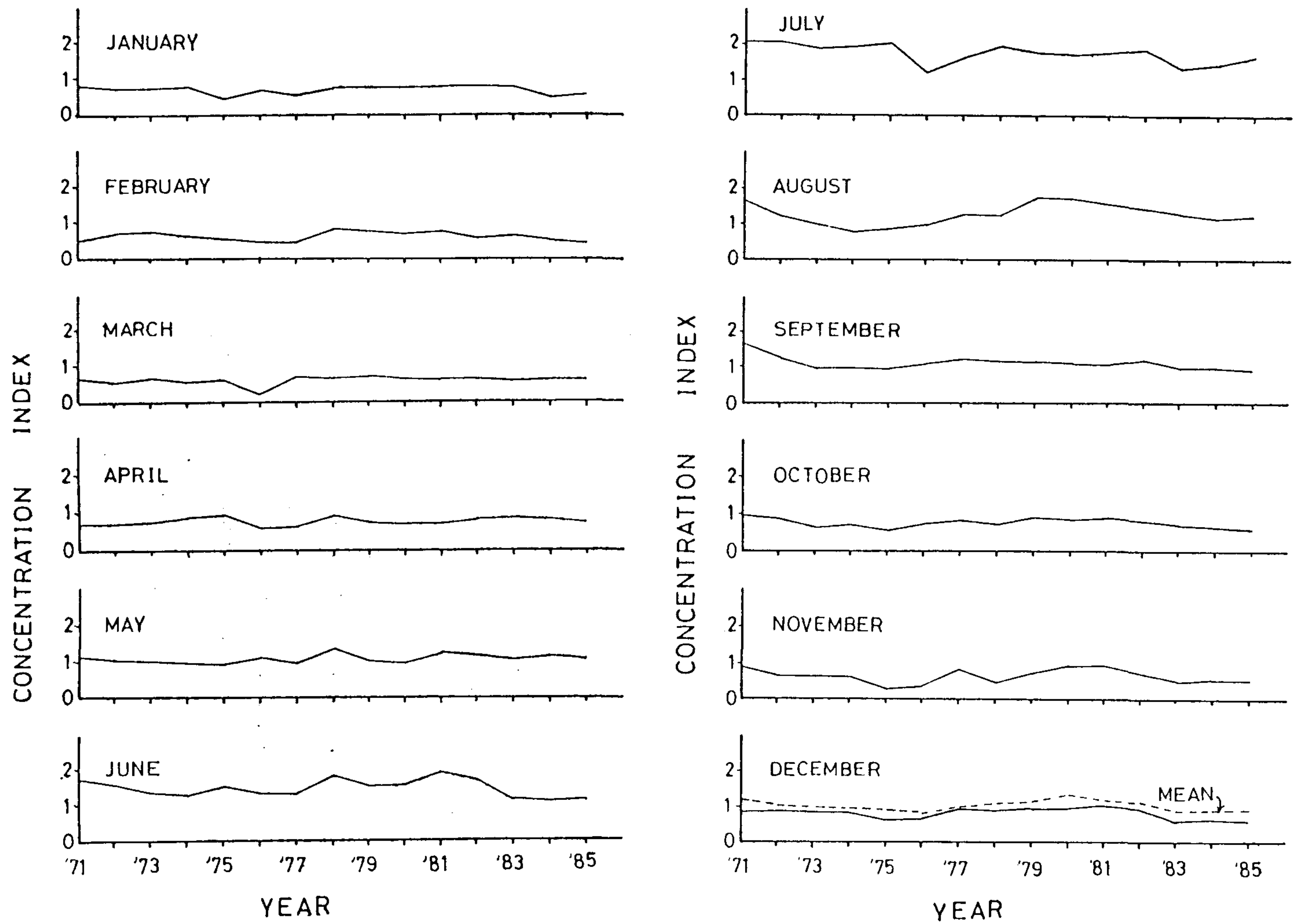

Fig. 4. Annual changes of concentration index of fishing efforts (effective effort/actual effort) by month.

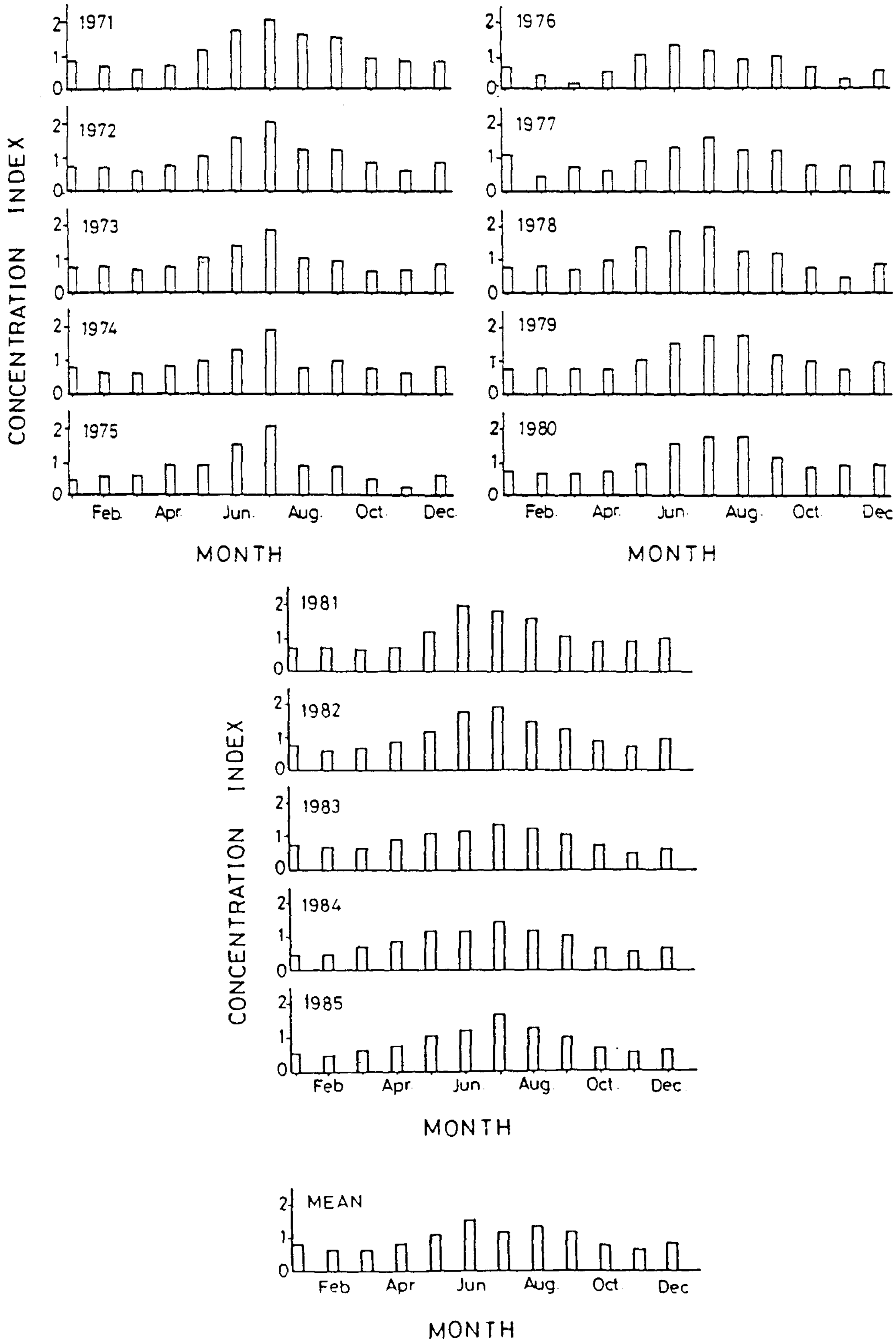

Fig. 5. Monthly changes of concentration index of fishing effort (effective effort/actual effort) by year.

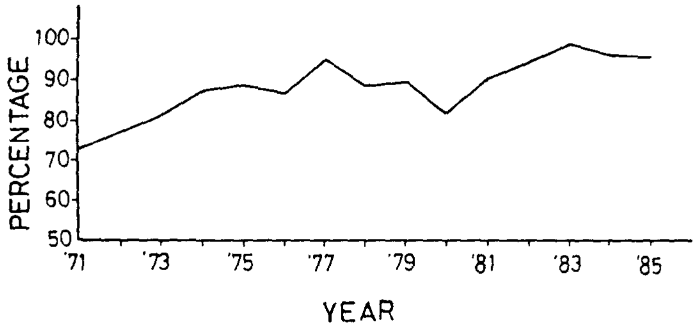

Fig. 6. Annual fluctuation of percentage of albacore occupied in the total catch of Taiwan's south Pacific longliners.

change. Peaks appear in the seasons during June to August when higher concentration areas of abundance index appear in the higher latitude band, and lows in November-February.

As stated above, some conclusions can be drawn as follows.

(a) According to the long time fishing experiments, Taiwan's tuna longliners seem very familiar with the seasonal movement of south Pacific albacore, when and where a good fishing ground formed and disappeared. Because of Taiwan's longliners target being on albacore only, the movement of longline vessels follows the movement of albacore schooling month by month tightly. They target on albacore only, so that they ignore other tunalike resources. This implies that the seasonal changes of fishing grounds and catch statistics of Taiwan's longliners can be considered a good reflection of the movement of south Pacific albacore and the seasonal changes of abundance index, respectively.

(b) Albacore is always the target species of Taiwan's tuna longliners operating in the south Pacific Ocean through these 15 years. As shown in Fig. 6, the percentage of albacore in the total catch of Taiwan's tuna longliners is over 70% each year. Furthermore, it is over 90% after 1981. As shown in Fig. 7, percentages are higher in winter and lower in summer. It implies that when south Pacific albacore concentrate in higher latitudes during May to August (Figs. 11.5-11.8), Taiwan's longliners also concentrated in this area and target on albacore only (Figs. 10.5-10.8). During other seasons, concentration areas disappear gradually, and fish begin to more northward. During this period, some of Taiwan's longliners also shift their target to other species such as yellowfin and/or bigeye tuna, hence the percentage drops as shown in Fig. 7.

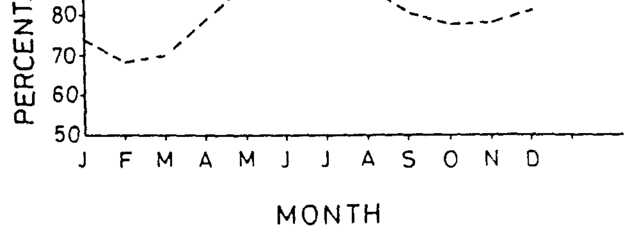

Fig. 7. Monthly changes of average percentage of albacore occupied in the total catch of Taiwan's south Pacific longliners.

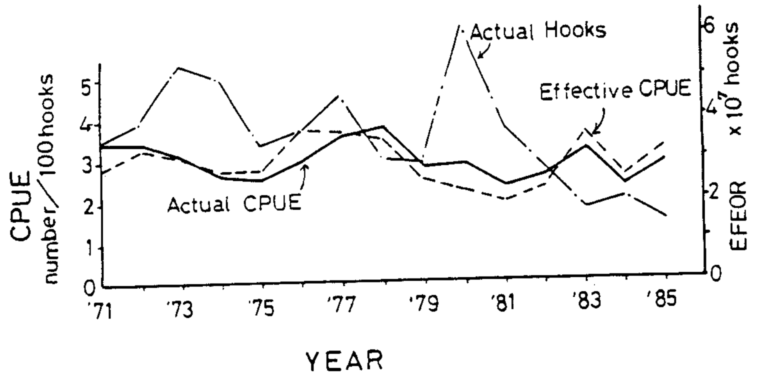

Fig. 8. Annual changes of catch per unit of fishing effort (catch in number/100 hooks) and actural number of hooks used.

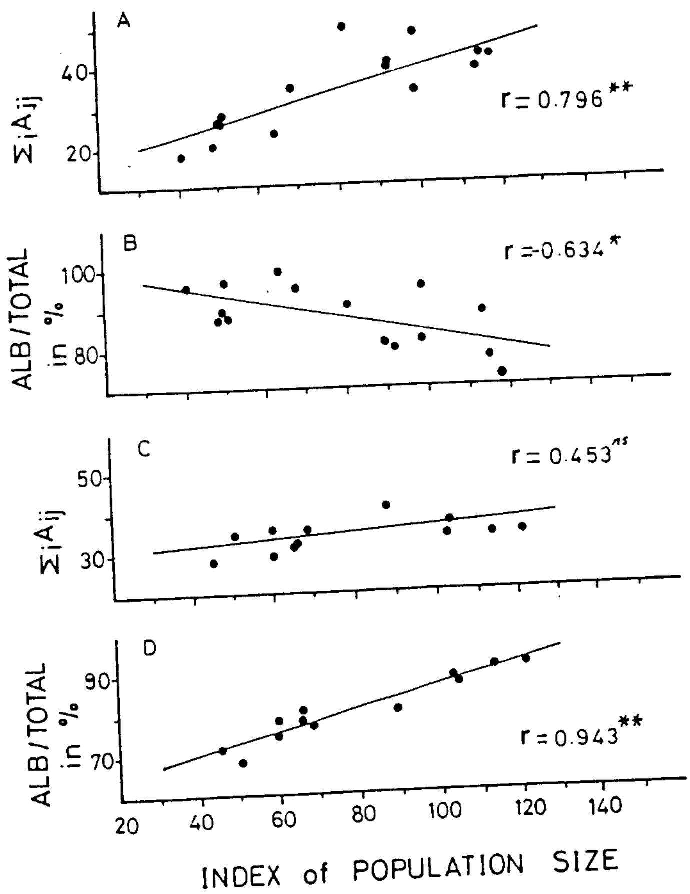

Fig. 9. Regression analysis of area index of fishing ground on index of stock size (A by year, C by month) and of percentage of albacore occupied in total catch on index of stock size (B by year, D by month). See text for explaination

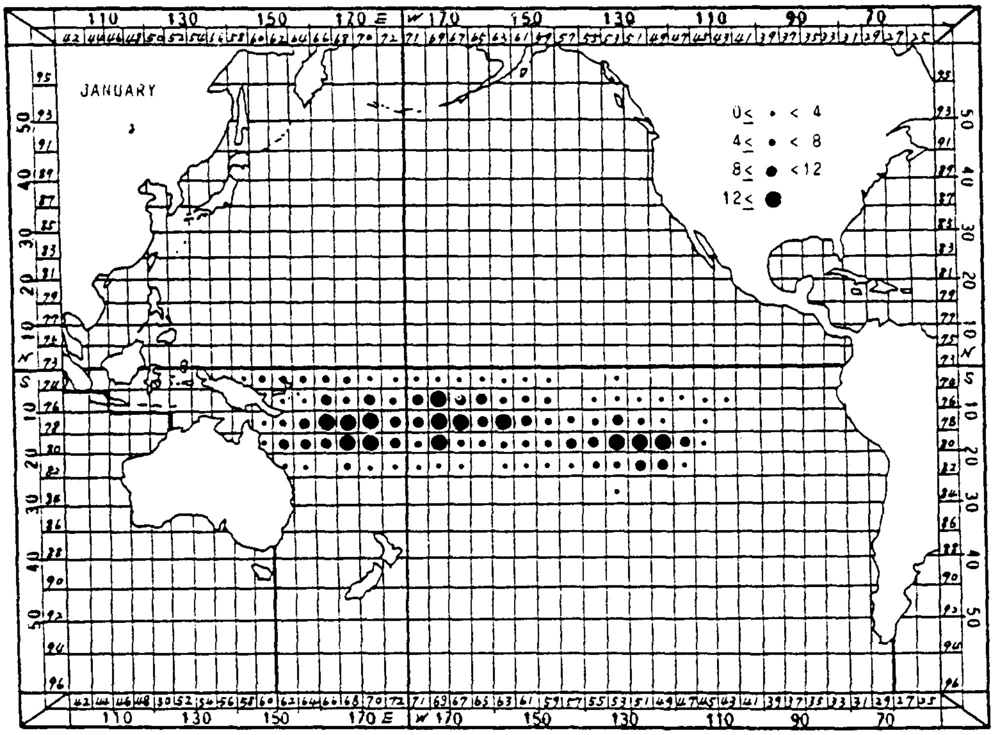

Fig. 10. 1. JANUARY. Distribution of fisning grounds of Taiwan's tuna longliners expressed by the number of years occurred in each 5-degree square.

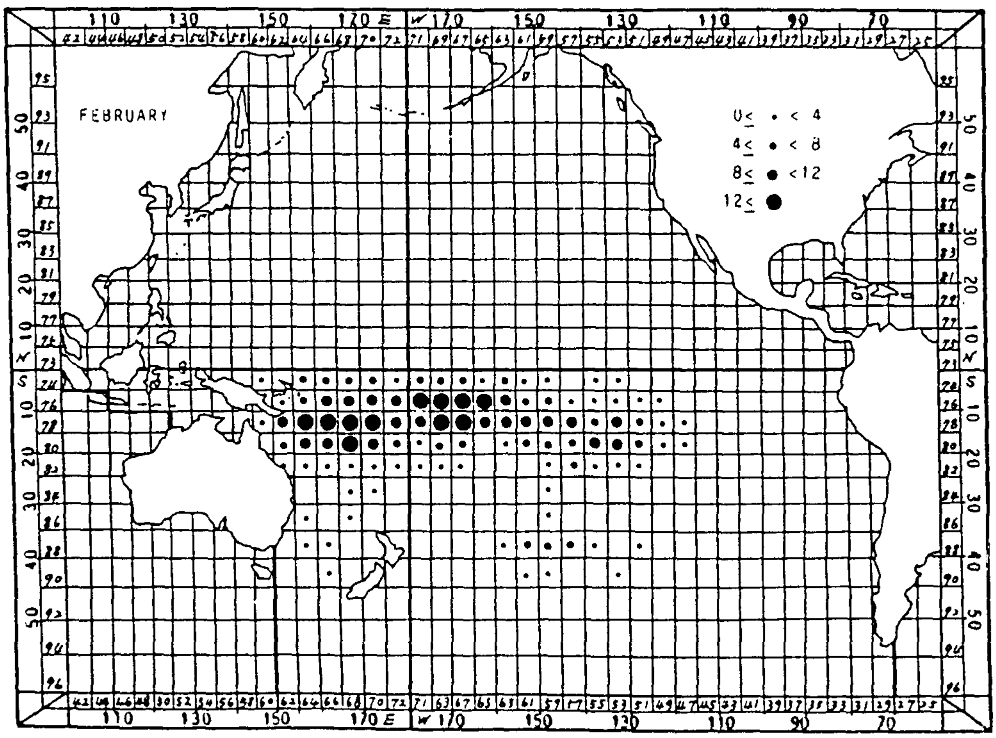

Fig. 10. 2. FEBRUARY. (refer to Fig. 10. 1).

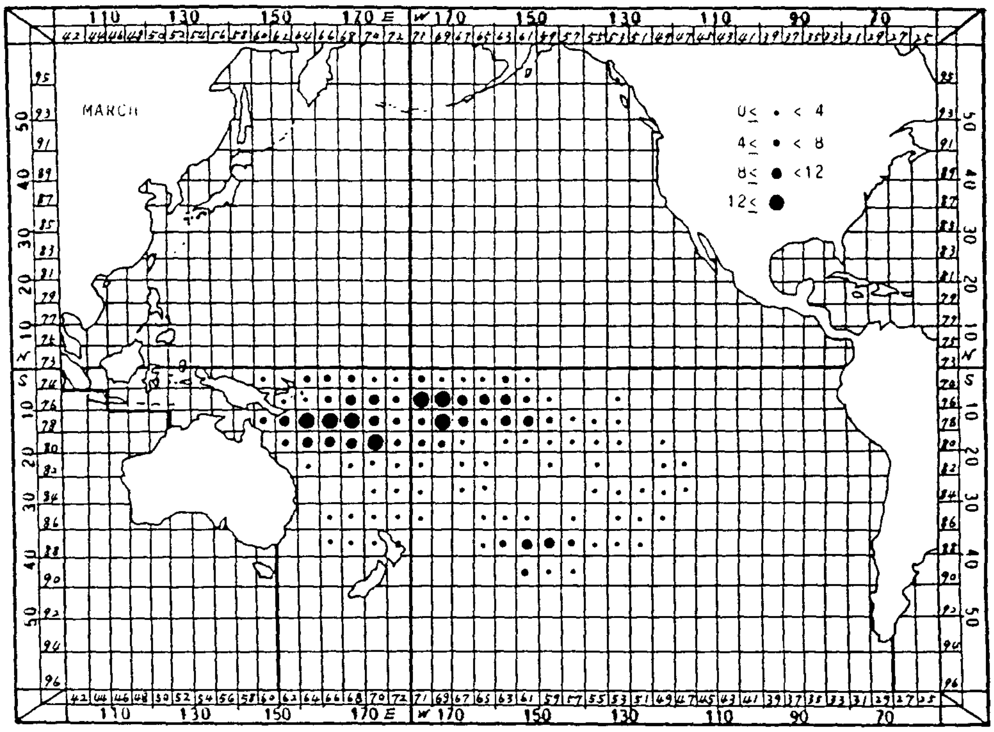

Fig. 10.3. MARCH. (refer to Fig. 10.1).

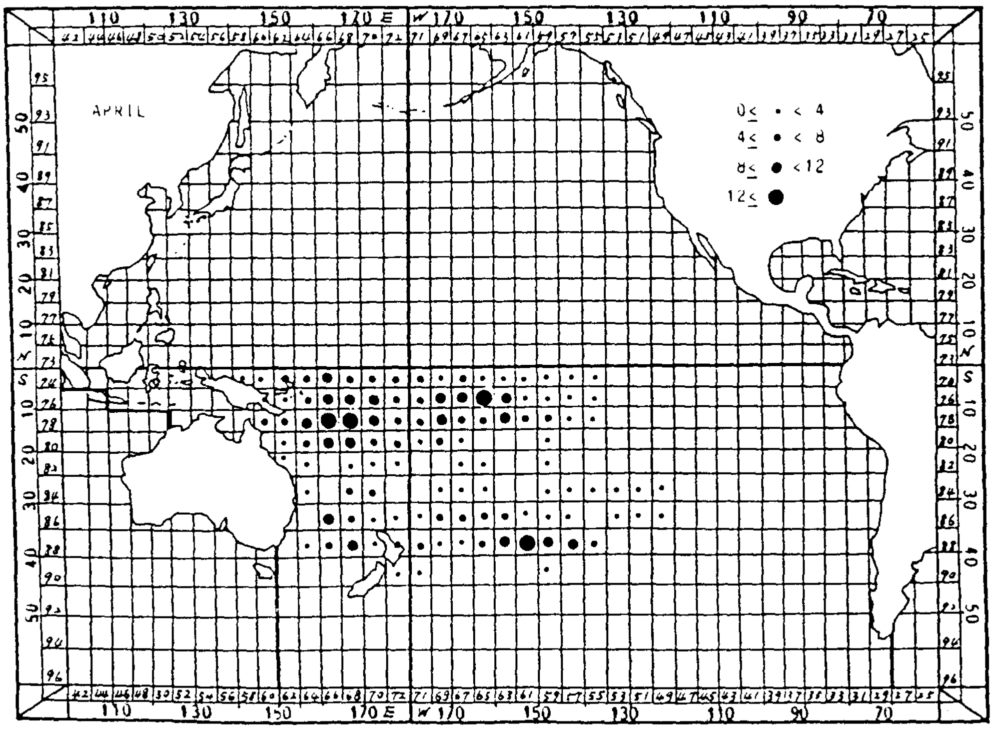

Fig. 10.4. APRIL. (refer to Fig. 10.1).

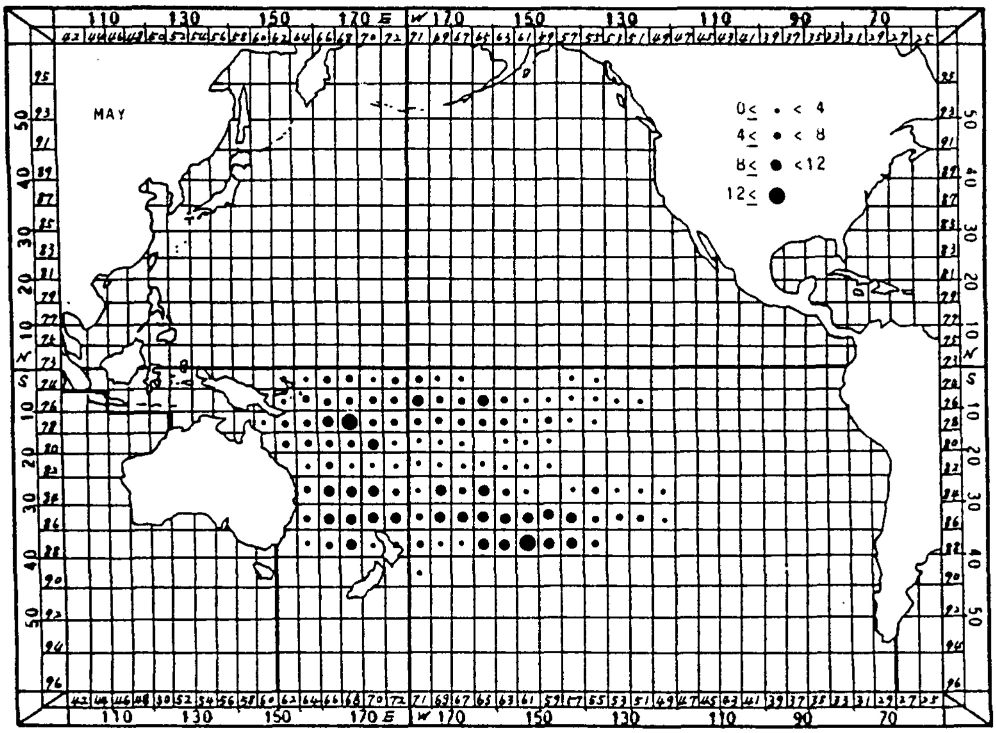

Fig. 10.5. MAY. (refer to Fig. 10.1).

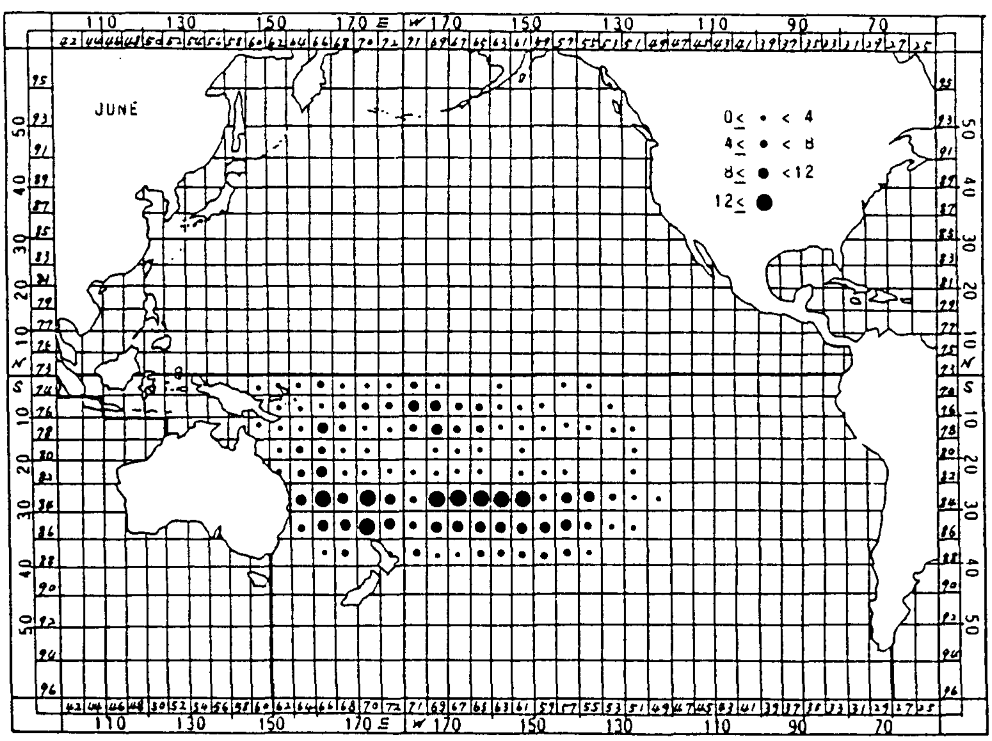

Fig. 10.6. JUNE. (refer to Fig. 10.1).

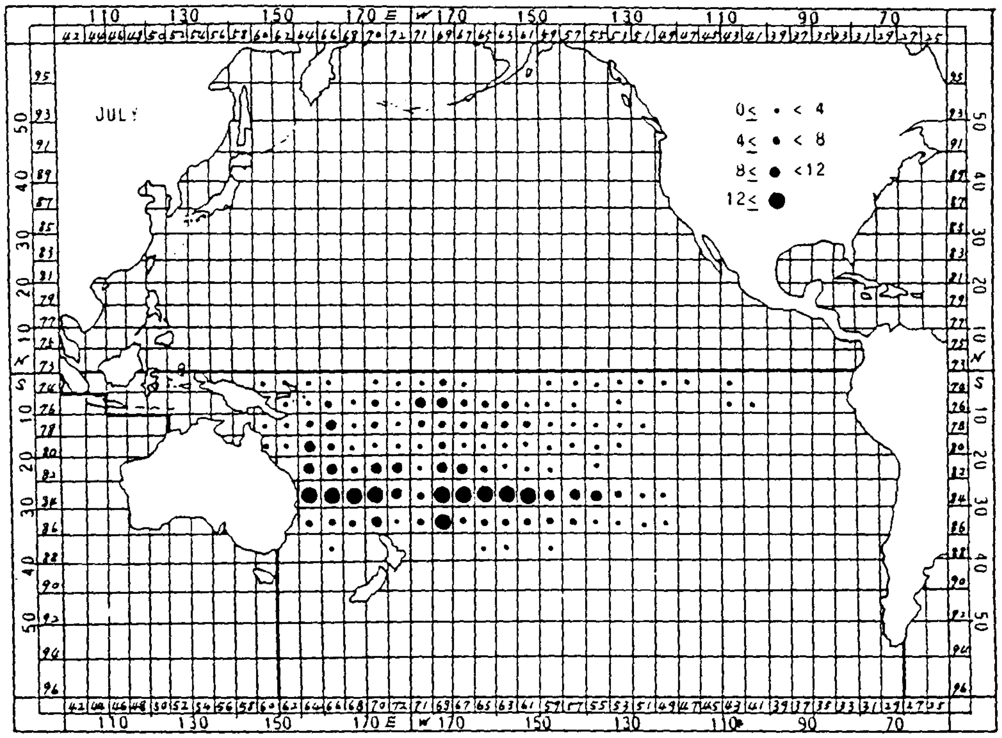

Fig. 10.7. JULY. (refer to Fig. 10.1).

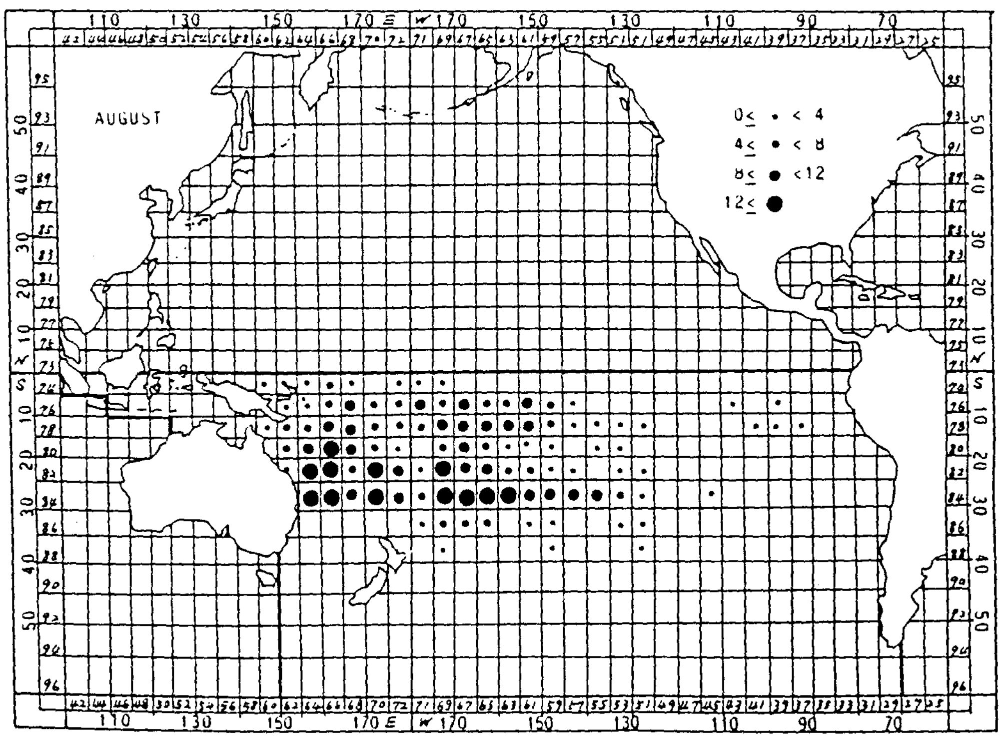

Fig. 10.8. AUGUST. (refer to Fig. 10.1).

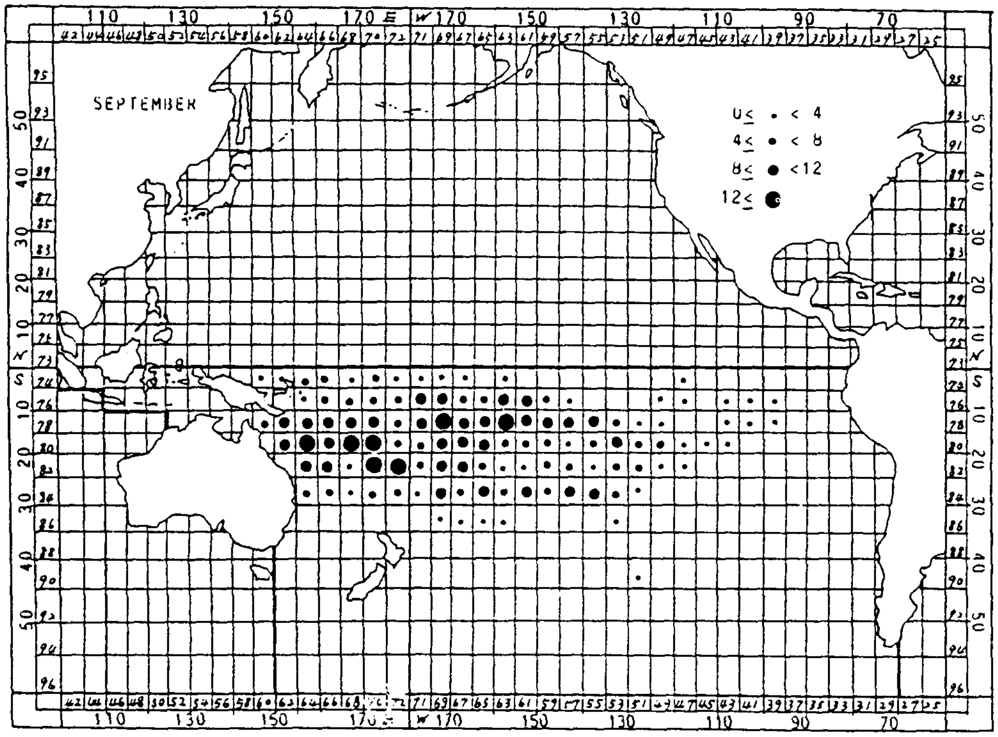

Fig. 10.9. SEPTEMBER. (refer to Fig. 10.1).

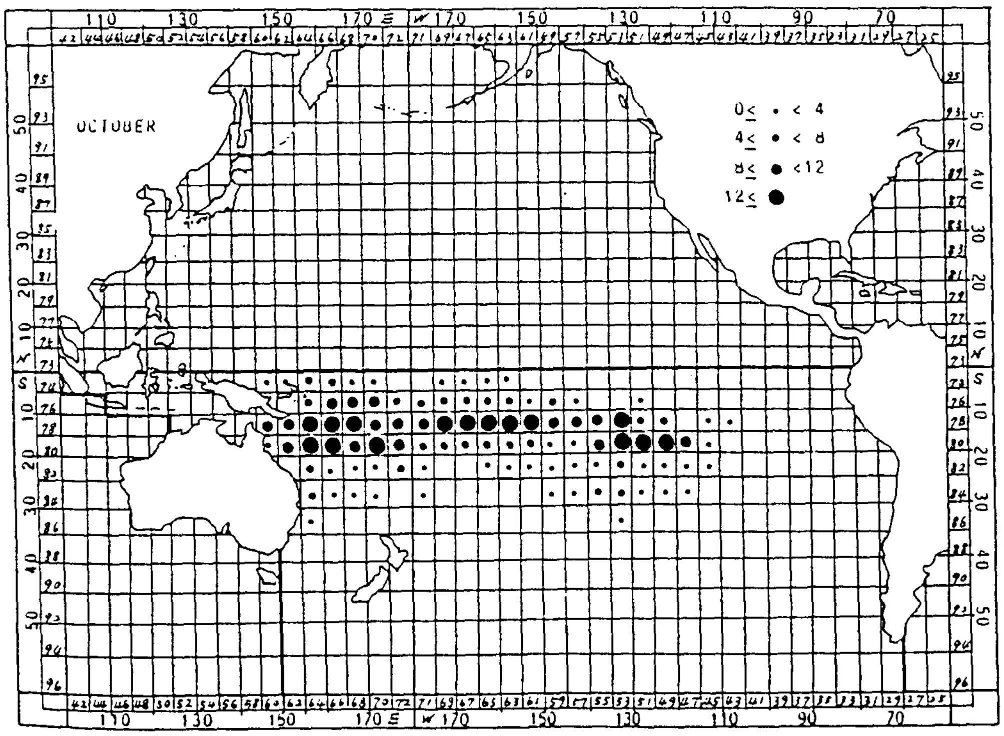

Fig. 10.10. OCTOBER. (refer to Fig. 10.1).

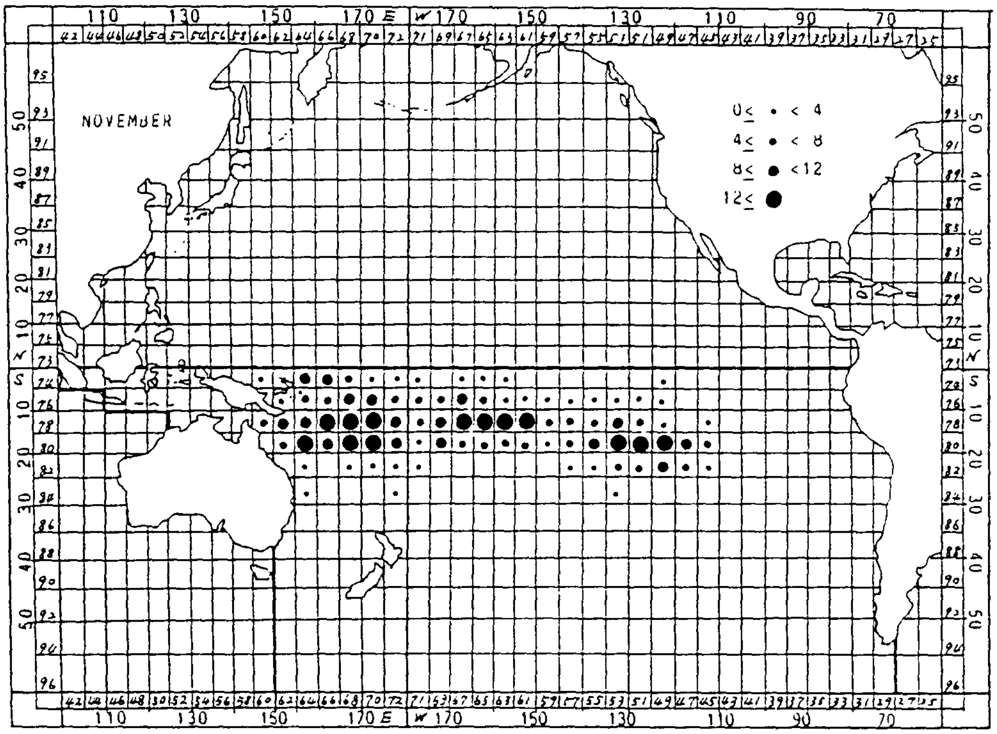

Fig. 10. 11. NOVEMBER. (refer to Fig. 10. 1).

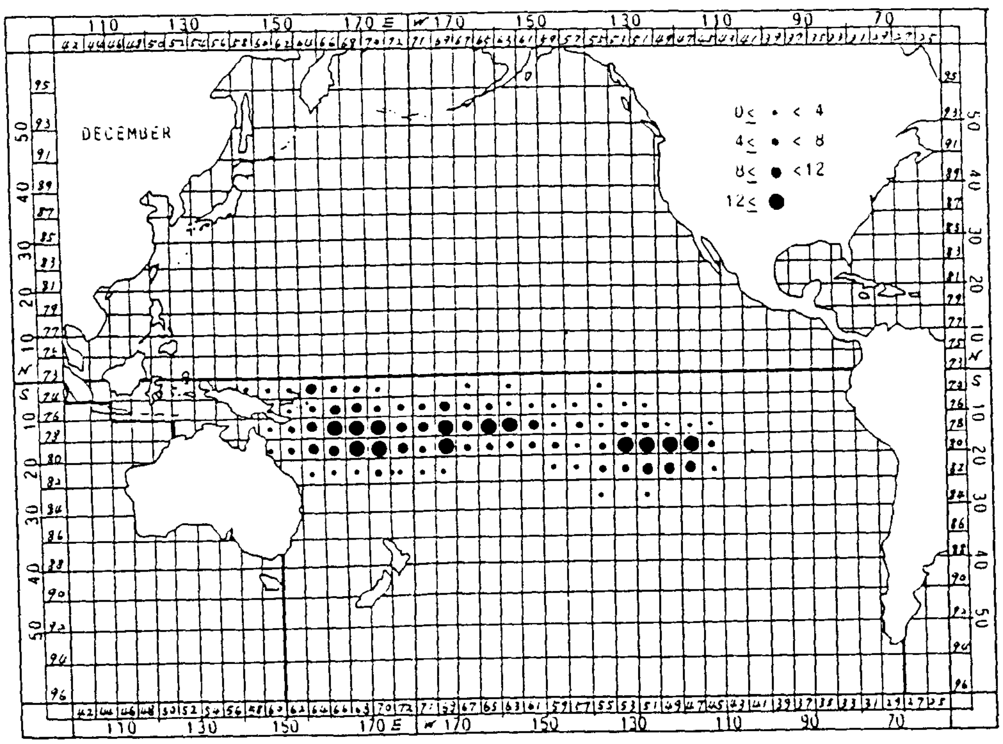

Fig. 10. 12. DECEMBER. (refer to Fig. 10. 1).

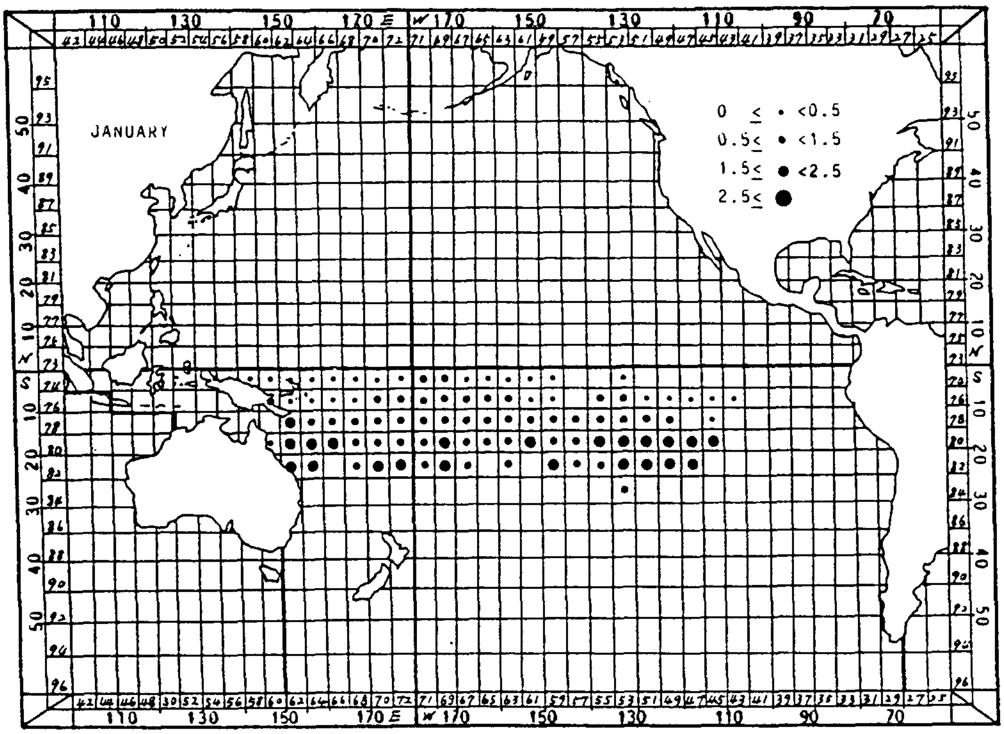

Fig. 11.1. JANUARY. Distribution of relative abundance index of south Pacific albacore by 5-degree squares.

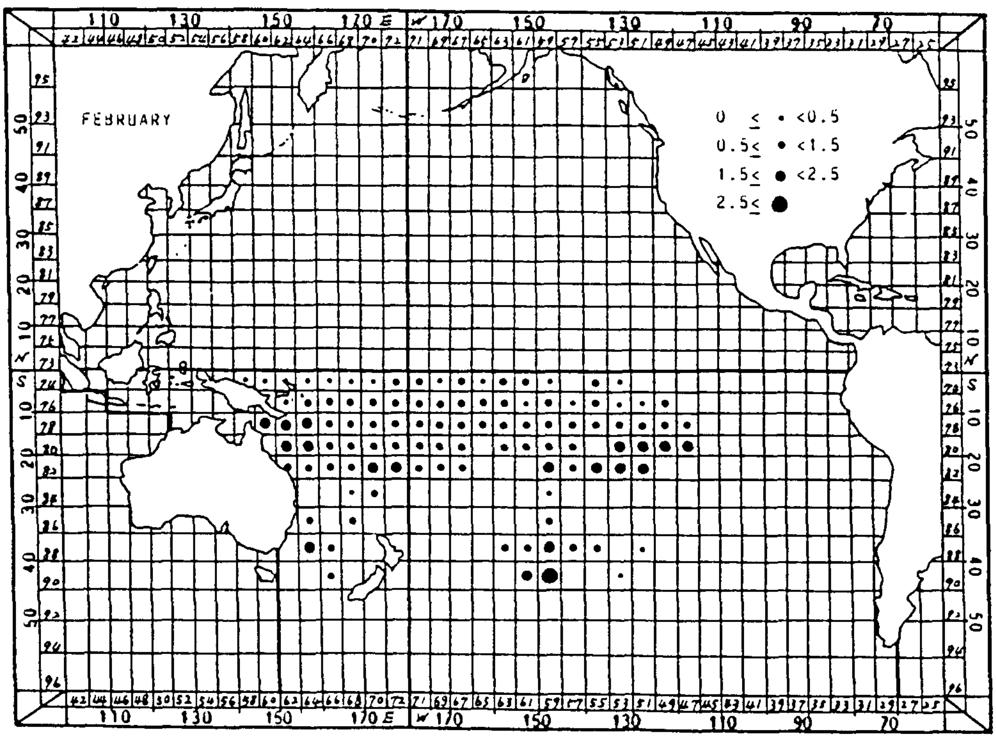

Fig. 11.2. FEBRUARY. (refer to Fig. 11.1).

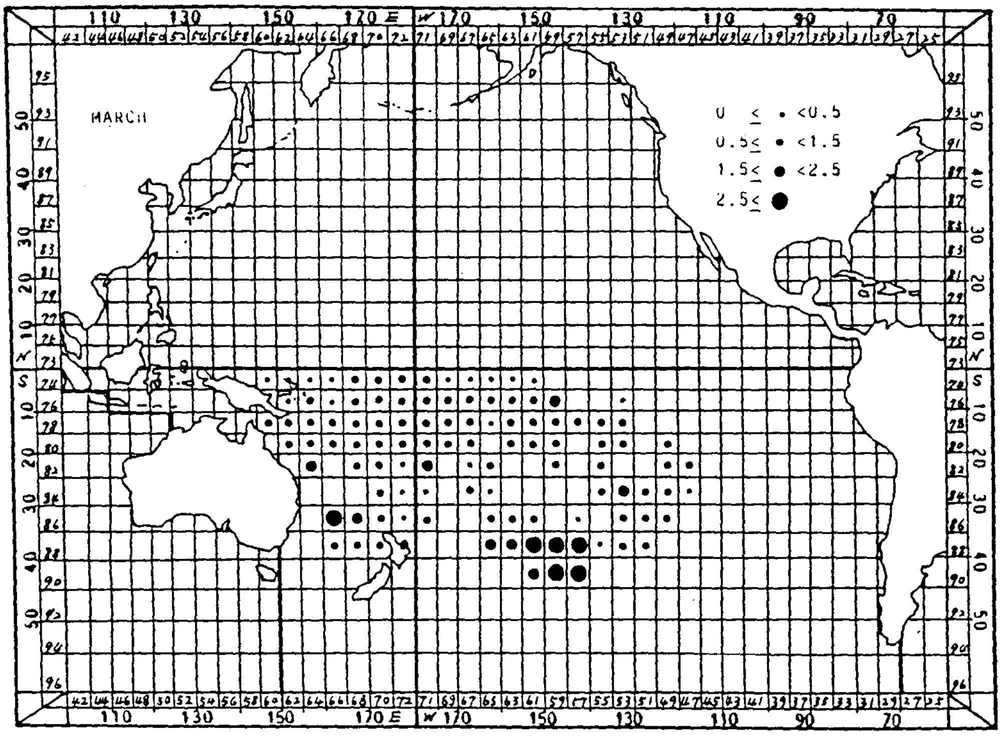

Fig. 11.3. MARCH. (refer to Fig. 11.1).

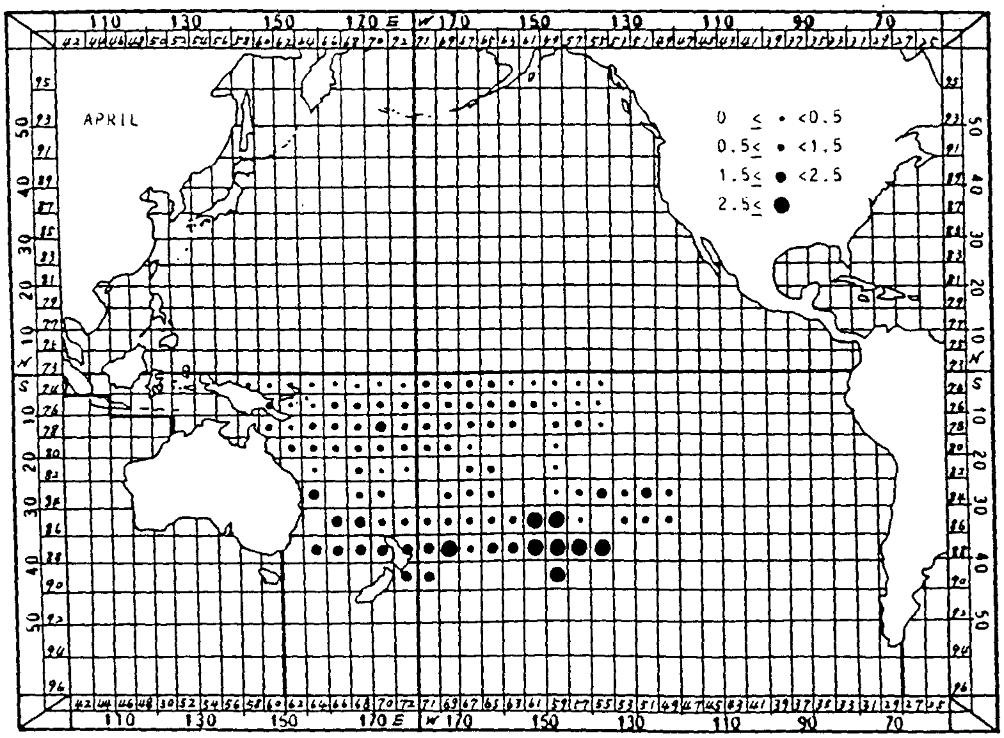

Fig. 11.4. APRIL. (refer to Fig. 11.1).

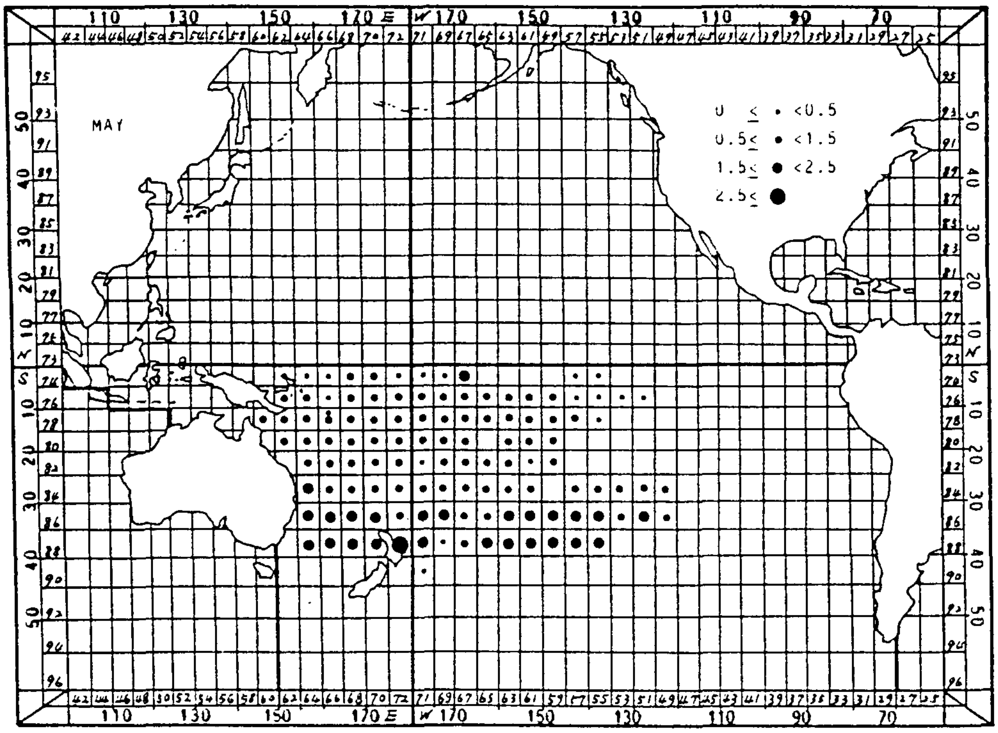

Fig. 11.5. MAY. (refer to Fig. 11.1).

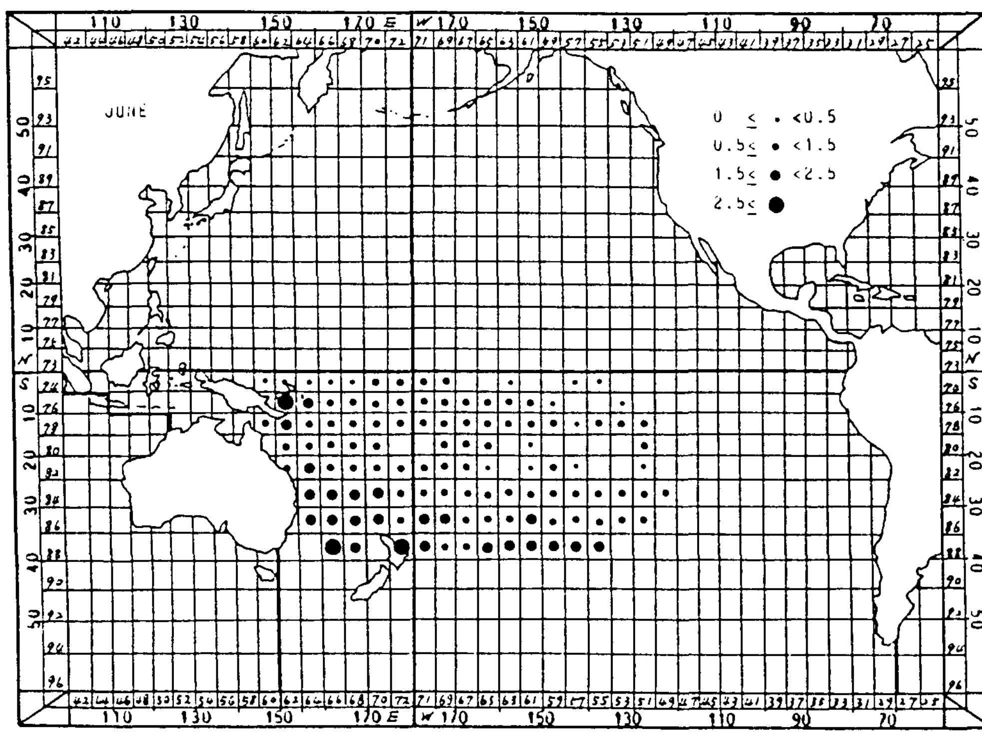

Fig. 11.6. JUNE. (refer to Fig. 11.1).

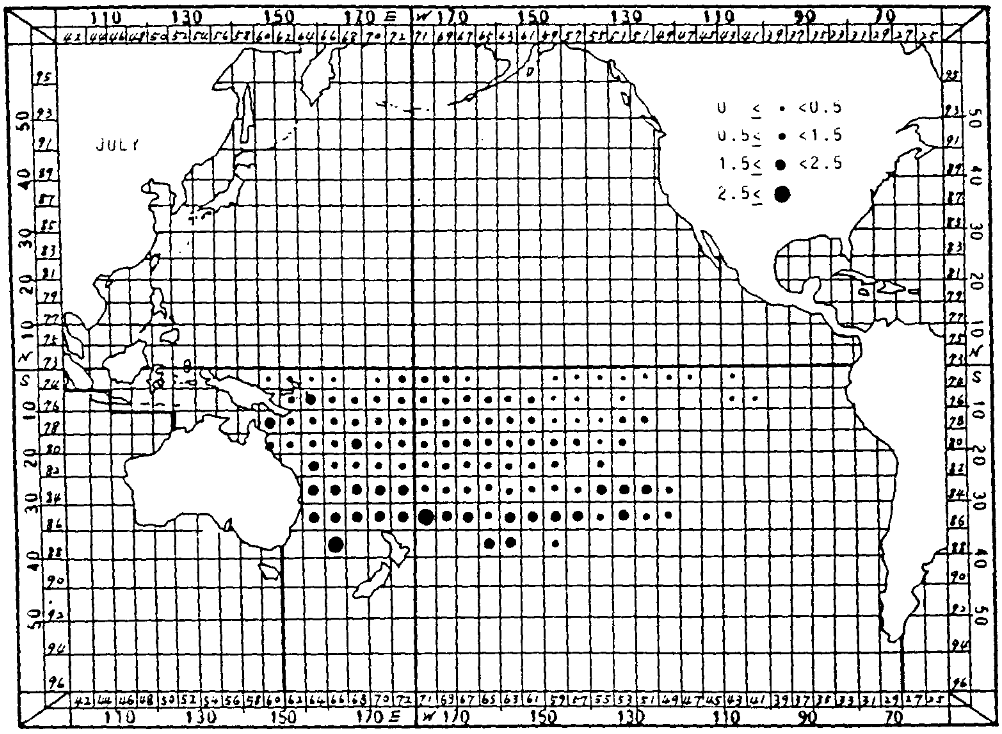

Fig. 11.7. JULY. (refer to Fig. 11.1).

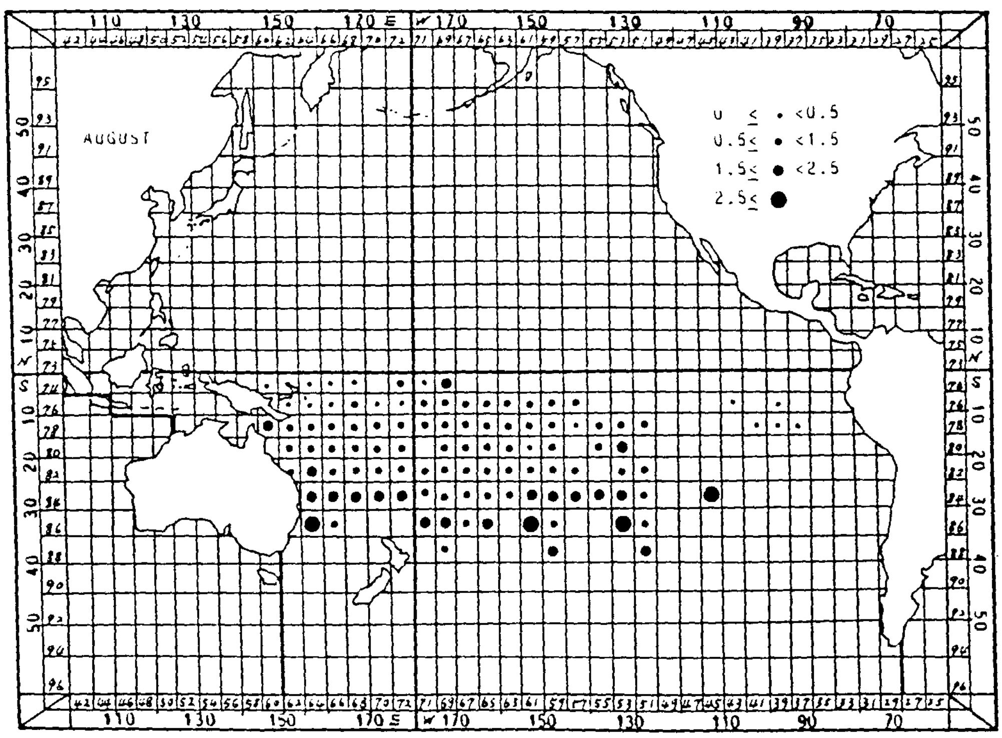

Fig. 11.8. AUGUST. (refer to Fig. 11.1).

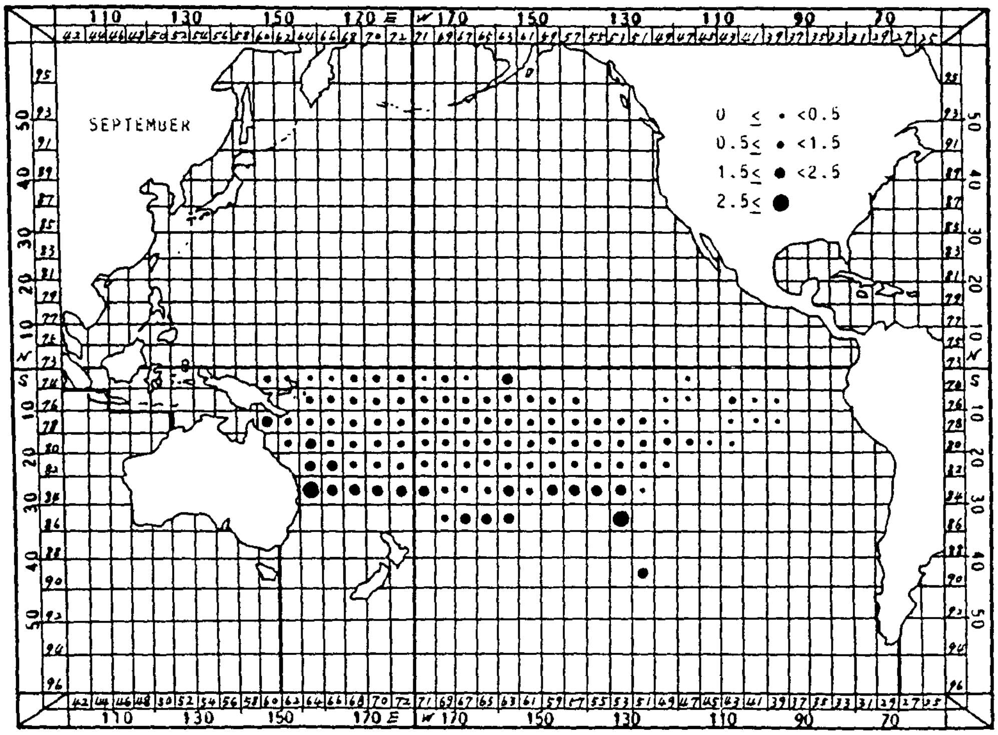

Fig. 11.9. SEPTEMBER. (refer to Fig. 11.1).

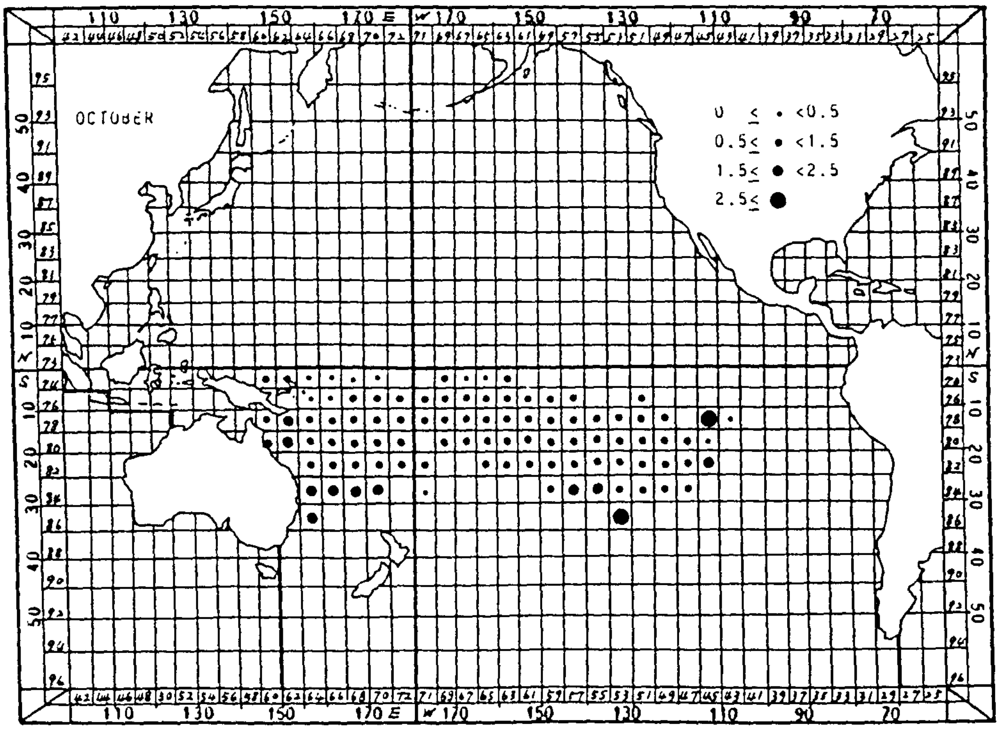

Fig. 11.10. OCTOBER. (refer to Fig. 11.1).

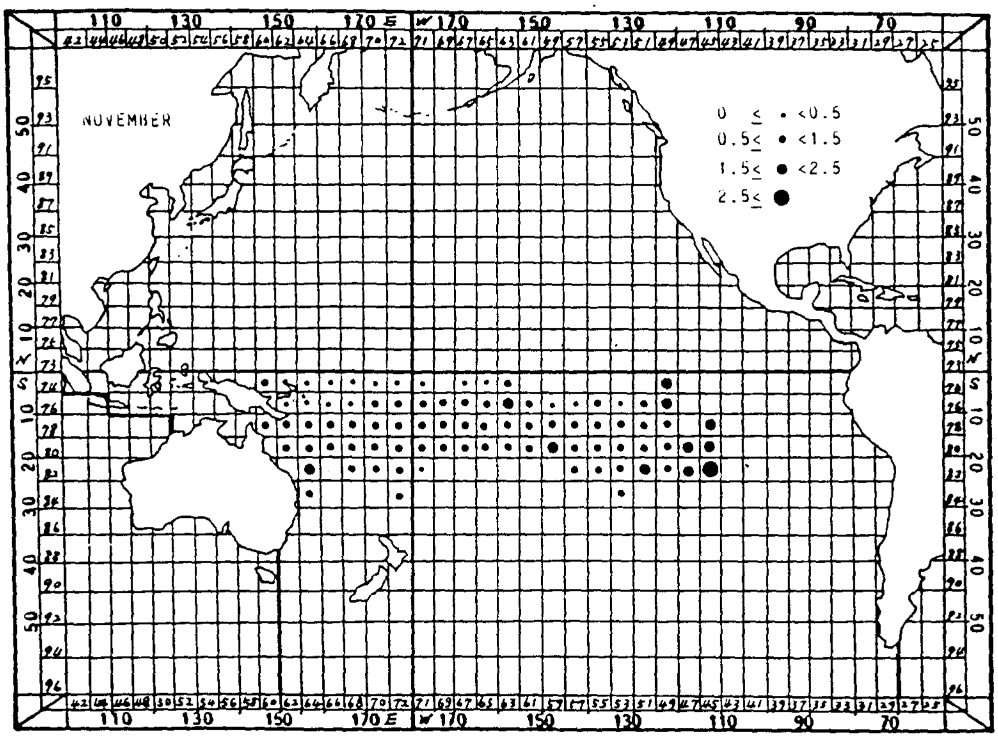

Fig. 11.11. NOVEMBER. (refer to Fig. 11.1).

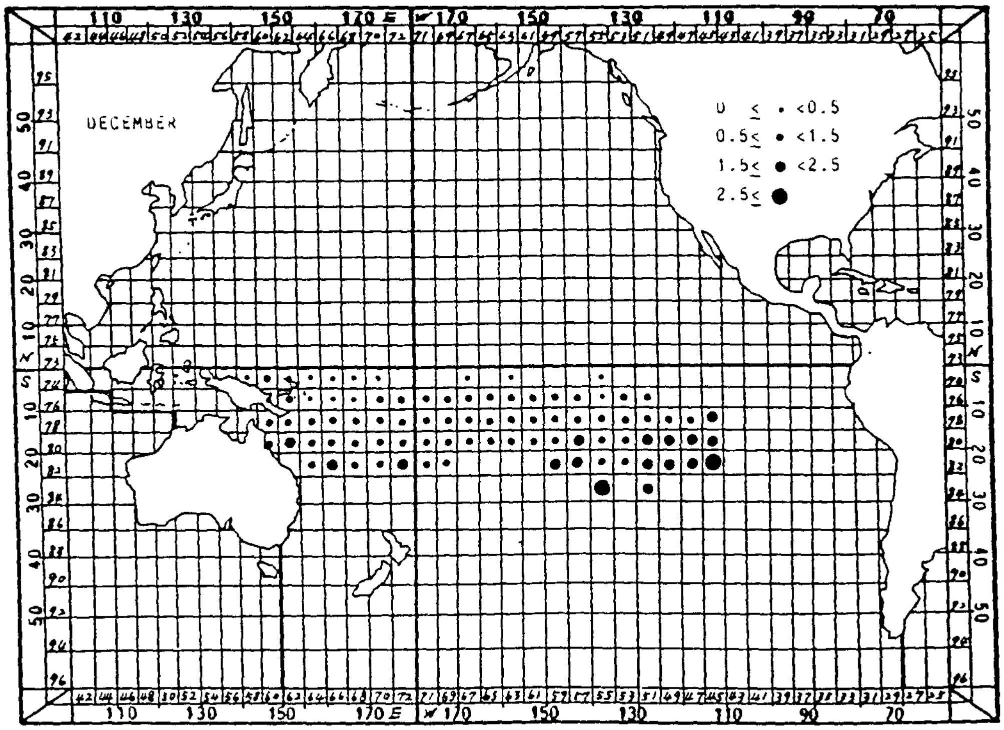

Fig. 11.12. DECEMBER. (refer to Fig. 11.1).

(c) South Pacific albacore is yet an attractive resource for Taiwan's tuna longliners. A rough estimate of the relative abundance index may be ascertained by examining the catch per unit of fishing effort (CPUE) statistics. As shown in Fig. 8, two kinds of CPUE, one being estimated by actual fishing efforts and the other by effective fishing efforts, seems to vary year by year around a rather high value. The average CPUE of these 15 years is about 3.0 in number per 100 hooks used. Many kinds of relative abundance index were discussed (Yoshida, 1971, 1975; Skillman, 1975, 1978; Wetherall *et al.*, 1979). As pointed out by Bayliff (1980), there is a general agreement that a downward trend in CPUE has been evident in recent years. As shown in Fig. 8, the downward trend seems very difficult to identify when only Taiwan's catch statistic data are used to estimate the abundance index. Roughly speaking, the abundance index before 1978 is certainly higher than those after this year. Attention is paid to the lows after 1979 and recovery trend after 1981. It seems to have a close relationship with the heavy drop of the actual fishing efforts of Taiwan's Pacific longliners after 1980.

Finally, the relations between different indexes will be examined. As shown in Fig. 9B, it reveals a clear negative relationship between the percentage which albacore occur in total catch of Taiwan's longlingers and the population index expressed in summation of $A(i, j)*D(i, j)$ (distribution area×density). Conversely, index of distribution area (summation of $A(i, j)$) and the population index show a positive relationship as given in Fig. 9A. It implies that richer population size may have a greater distribution area, and hence it may have a lower percentage of albacore in the total catch of Taiwan's longliners. On the other hand, monthly changes show a different type of fluctuations (Figs. 9C, 9D). The positive relationship is not significant at the 5% level between the index of distribution area and of population size. It shows a significantly positive relationship between the percentage of albacore and the index of population size. This seems to imply that seasonal movement of south Pacific albacore is a heavy effective factor of evaluating the percentage of albacore. This is why Taiwan's tuna longliners operating in the south Pacific Ocean are only interested in the exploitation of albacore.

DISCUSSION

The migration of south Pacific albacore has been described by Honma and Kamimura (1957), Koto (1966), Otsu and Sumida (1968) and Yoshida (1971). As pointed out by Honma and Kamimura (1957), hooking rate in the north of 20°S is higher in April to September, especially in June to July. It was low in October to March. And it showed a different type of seasonal changes of hooking rate in the band between 20°S to 30°S. Hooking rate was lower in April to September, and higher in October to March. They showed that south Pacific albacore migrated southward from October to March, and returned northward from April to September.

Koto (1966) described the distribution of south Pacific albacore based on Japanese longline catch statistic data. He pointed out that the concentration area was found in the band between 10°S and 30°S. Peaks appeared at 150°W, and shifted northward in the west-to-east direction from 150°E to 150W. It also shifted southward in the same direction from 150°W to 100°W. Otsu and Sumida (1968) found that the mean length of south Pacific albacore tended to increase from north to south in the south Pacific, with size reaching a maximun in the 20°S-25°S band, and diminishes thereafter. Yoshida (1971) pointed out that in the south Pacific juvenile albacore migrate southward as they grow.

In this study, the higher concentration areas extend to the band between 30°S and 40°S, and they also present in the western part of the south Pacific along the coastal area. It seems to form in the beginning of March. Peaks appeared in May to July, and then disappeared from August. During October to January, the concentration areas appear in the western and in the eastern part of the south Pacific Ocean. It seems to form a band along the 20°S during this season too.

As stated in this paper, south Pacific albacore shows a clear seasonal movement. They show a southward movement during summer (October to March) of the southern hemisphere, and have a northward movement during winter (April to September).

The migration of albacore in the north Pacific has been described by Clemens (1961), Flittner (1963), Otsu and Uchida (1963), Otsu and Yoshida (1966), Rothschild and Yong (1970), Laurs and Lynn (1977) and Laurs (1979). According to the seasonal changes of south Pacific albacore obtained in this study, it seems to have a symmetric pattern of seasonal movement as shown by north Pacific albacore. During summer, they move to the high latitude, and return to the low latitude during winter.

On the other hand, it is noticed that they seem to have a different type of aggregation. As pointed out by Ueyanagi (1969), albacore spawned during summer in the waters concentrated around 20°N and 20°S latitude, their distribution expanding with the warm season and contracting with the cool season. In this paper, it shows a higher area index of distribution during winter of southern hemisphere. Mode appeared in June. It contracted during summer. Lows appeared in January.

In the future, Korean and Japanese catch statistic data will be included to make the seasonal movement of south Pacific albacore more clear. It is necessary to obtain the biological data and/or information of tagging experiments to explain the difference and to the ecological meanings of the seasonal movement of south Pacific albacore.

SUMMARY

Generally, south Pacific albacore are discussed as a unique population. In this paper, seasonal movement of south Pacific albacore and distribution of fishing grounds are examined by month and by 5-degree squares. All of the calculations are based on the catch statistics of Taiwan's tuna longline fisheries. The results are summarized as follows.

(1) Monthly variation of fishing grounds reveals that (a) main fishing grounds move westward and southward in January to April. (b) During April to June, fronts of fishing grounds are distributed steadily in the north of 40°S and west of 120°W. (c) Principal fishing grounds shift northward and extend to northeastern part of the south Pacific thereafter. (d) After October, fishing grounds move to the north of 25°S and the western boundary extends to 110°W. Fishing grounds shift southward during summer and northward during winter in the south Pacific Ocean.

(2) As an index of population density, seasonal variation of effective CPUE (catch in number/effective fishing effort in 100 hooks) are examined by month and by 5-degree squares. The results reveal that (a) higher hooking rates appeared in the 15°S–25°S band in January. (b) The concentration areas shift southward during March to April. (c) They form a band between 30°S and 40°S during May to July, and appeared gradually in the western part along the coastal area of the south Pacific. (d) Then concentration areas begin to shift northward and northeastward thereafter. And they seem to disappear from the central part of the south Pacific Ocean in October. (e) During November to December, higher concentration areas present in the eastern part of the south Pacific, and they distribute in the north of 25°S only.

(3) Concentration indexes of fishing effort are expressed by effective fishing effort and actual fishing effort. It reveals that they varied in the same pattern. In monthly variation, peaks appeared during winter, especially in July. In this season, higher CPUE presented between latitude 30°S and 40°S as a band, and it also had a greater index of

distribution area. On the other hand, lows appeared during November to March.

(4) Albacore is the target species of Taiwan's tuna longliners operating in the south Pacific Ocean. It always shows a rather high percentage (over 70%) of catch composition in the total catch of Taiwan's south Pacific tuna longline fisheries. The present study indicates a negative regression relation between the CPUE and the percentage in the annual total catch. However, a positive regression relation shows in monthly fluctuation.

(5) Average catch per unit of fishing effort varied steadily during 1971 to 1985. CPUE varies in the range of 2.00-4.00 ind./100 hooks. No downward trend can be found in these 15 years.

Roughly speaking, distribution of south Pacific albacore shows a clear seasonal change. Seasonal changes of principal fishing grounds and the movement of concentration area seem to imply that south Pacific albacore may be divided into two subgroups: one mainly distributed in the eastern part of south Pacific and the other in the western part near the coastal area.

In the future, Korean and Japanese data will be used for analysis. It is necessary to make the ecological meanings of seasonal changes more clear.

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