INTERPRETATION OF HIGH CATCH RATES OF BIGEYE TUNA IN 1977 AND 1978 OBSERVED IN THE JAPANESE LONGLINE FISHERY IN THE INDIAN OCEAN

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ABSTRACT

In order to explain the jump of Japanese longline CPUE for bigeye in 1977 and 1978 in the Indian Ocean, two hypotheses were tested. Hypothesis 1) Concentration of fishing effort had occurred in the relatively narrow and high CPUE region in the Indian Ocean, and 2) in 1977 and 1978, enormous recruitment had occurred in the bigeye stock that was exploited by the longline fishery. Observing geographical distribution of effort and CPUE, and distribution of size specific CPUE, the first hypothesis was not supported. Sample length frequencies in tropical area in this Ocean did not indicate of strong year class, then second hypothesis was not also supported. Considering that this jump of CPUE in this period is detectable in other country CPUE data for bigeye in this Ocean, in Japanese longline CPUE for bigeye in other Oceans (Pacific and Atlantic) and the CPUE for yellowfin in the Indian and Pacific Ocean, it seems hard to seek the reason for this phenomenon in the introduction of deep longline. As other possibility, drastic oceanographic change (regime shift) occurred around 1976 in the global scale was suggested.

INTRODUCTION

Longline CPUE for bigeye in the Indian Ocean has been standardized by GLM under log-normal and/or Poisson error assumptions. In the yearly change of the bigeye CPUE based on Japanese longline data, 1977 and 1978 data points in both nominal and standardized CPUE were much higher than before and after these two years as shown in Figure 1. (Okamoto and Miyabe, 1999). Similar phenomenon was also observed in the standardized CPUE of Korean longline fishery in this Ocean (Figure 2; Hsu and Liu, 2000) and, to the lesser extent, in Japanese longline CPUE in the western Pacific Ocean in 1977 (Figure 3). In the Atlantic Ocean, there is a peak of CPUE in 1977 though another peak of same level exists in 1974 (Figure 4; Miyabe and Okamoto, 1999). It is generally considered that this level of CPUE change does not reflect the real change in the abundance but may indicate changes in fishing area, season, targeting, availability, catchability, oceanographic condition and so on, although the possibility of that such phenomenon reflect real population size chance can not be completely rejected. This paper provides some results of a study which might explain such higher CPUE in 1977 and 1978, mostly based on the Japanese longline data.

MATERIALS AND METHODS

Two hypotheses were tested to explain higher CPUE in two years (1977 and 1978).

Hypothesis 1: Concentration of fishing effort had occurrred in the relatively narrow and high CPUE region in the Indian Ocean.

For example, this situation might have occurred under following reasons ......

(1) In the middle of the 1970s, as the demand of bigeye for the material of SASHIMI became higher, longline effort might have concentrated to the area where the CPUE was higher.

(2) It is reported that higher longline CPUE is often associated with the catch of young bigeye in large quantity (Uosaki and Bayliff, 1999). In 1977 and 1978, fishing effort might have concentrated in the area where young fish dominates in the catch.

Hypothesis 2: In 1977 and 1978, enormous recruitment had occurred in the bigeye stock that was exploited by the longline fishery. This means year classes two to three years before those two years were much large than the average.

If this hypothesis is true, the existence of such strong year class(es) may be traceable in length frequency data in those years, 1977 in particular.

In order to check the geographical distribution of fishing effort and bigeye CPUE, Japanese longline catch and effort data from 1967 through 1997 aggregated by month, and 1 degree of latitude and 1 degree of longitude was used.

Using this data, the level of concentration in fishing effort was defined by the following expression.

Level of concentration in fishing effort = $(\Sigma h^2)^{1/2} / \Sigma h$

: where h is the number of hooks used in one degree square aggregated to quarter of the year.

Data of the number and weight of bigeye catch and the number of hooks in each operation from 1994 through 1998 were used. In order to identify the area where young fish dominates in the catch in large quantity, average weight was caluculated between 1994 and 1998 for each operation using logbook data, and categorized to either larger than 50kg or less than 35 kg. Then, the catch in number and weight from these two categories were quarterly aggregated and used to calculate quarterly average weight by 1-degree square. With the same data, CPUE (number/hook*1000) was similarly calculated.

In order to see whether large year class had occurred or not, all available sample length data measured in the Indian Ocean north of 20°S were summed up annually from 1965 to 1996. Due to the time constraint, catch at size composition was not compiled. It should be further pursued in that way.

RESULTS AND DISCUSSION

In Figure 5, the unraised total number of hooks aggregated in each five years except for 1967 through 1970 (four years) and for 1996 through 1998 (three years) are shown in left panels, and corresponding bigeye CPUE were shown in right panels. Longline effort, which covered almost all area of the Indian Ocean until 1970, had shrank its distribution to the high CPUE area of bigeye during early 1970s, and the distribution was kept in a similar pattern thereafter until around 1990. Since then, the effort started a dispersion again possibly due to the time and area regulation and a set of quota imposed for southern bluefin tuna fishery. Concentration of fishing effort along the 30S latitude appears to have caused by this time and area closure of this species. In Figure 6, the level of concentration in longline effort (upper figure) and the number of hooks (lower figure) from 1967 to 1998 was shown quarterly. The level of concentration before 1980s increased gradually from 1967 to 1973, and was low in 1974 and 1975, quite high between the third quarter of 1976 and third quarter of 1977. However, since the years of hihger CPUE were 1977 and 1978, the period of high concentration of effort did not coincide well.

The distributions of size specific CPUE for each year from 1994 to 1998, and each quarter using summed data of the same years were shown in Figures 7 and 8, respectively. Although there are some seasonal change in their distributions especially in south of 20°S, the patterns of their distribution are basically similar among years and quarters. It is interesting to note that in the area north of 20°S, large bigeye (average GG weight is larger than or equal 50 kg) distributes at the area off Somalia north of 10°S and west of 60-70°E, and east of Sri Lanka, while that of small bigeye (average GG weight is less than 35 kg) is mostly limited to east of 60°E - 70°E. Looking at the distribution of CPUE from 1972 to 1979 (Figure 9), CPUE in 1977 and 1978 was high in the most part of Indian Ocean north of 20°S.Thus, it seems that both CPUE for large and small bigeye were high in those two years.

As far as basing on the results in the above analyses, it is hard to believe that high concentration of the effort to high CPUE area had occurred in 1977 and 1978.

The second hypothesis was tested in Figure 10, which indicates length frequencies of bigeye in the longline catch measured in the Indian Ocean north of 20°S. Since size frequencies are different by year to some extent, the existence of strong year class is not observed in both of 1977 and 1978. As described in the method section, the aggregated length data was not properly processed to reflect the differences in size by area and number of fish measured. Although it is premature to draw any conclusion and need further careful investigation, there is not strong sign of the existence of strong year class(es) which recruited to the stock exploited by the longline fishery.

In summary, we could not find any data, which support either of two hypotheses. Other possibilities were briefly reviewed in the following sections.

Introduction of deep longline:

During the middle to late 1970s, deep longline was introduced to the fleet operating in all three Oceans in order to catch bigeye more effectively. Before that, mainly less than 10 hooks between float (the number of hooks per basket) was used, but more than 10 hooks (from 10 to 15 hooks) became very common thereafter. The period when the deep longline was introduced was slightly different between the Ocean. In the Indian Ocean, deep longline started to be used at off Sumatra and Java around 1977 and spread to all tropical area by 1981 (Figure 11; Matsumoto, 2000). In the Atlantic Ocean, it was introduced around 1979 and most of regular longline was replaced by deep longline by 1983 (Figure 12; Miyabe and Okamoto, 1999). In the case of the Pacific Ocean, deep longline started to be used in 1974 (Figure 13; Suzuki *et al*., 1977), and the percentage of deep longline exceeded 50% in the Eastern Pacific Ocean in 1978 (Figure 14). Suzuki *et al*. (1977) compared hook rate between regular and deep longline for main species caught, and clarified that hook rate of deep longline is higher than that of regular one for bigeye, and the opposite is true for yellowfin. Although the effect of the number of hooks between float has been included in the model to standardize CPUE, if effect of this factor was not standardized effectively, introduction of deep longline may bring the sudden peak in bigeye CPUE. However, similar jump in CPUE is observed in standardized CPUE of yellowfin caught by Japanese (Figure 15; Nishida, 2000) and Taiwanese (Figure 16; Lee and Liu, 2000) longline fishery in the Indian Ocean in 1977, and is also clearly found in the equatorial region of the western Pacific Ocean (Japanese longline) in 1978 (Figure 17). The facts that 1) the similar jump of CPUE was detected for both of bigeye and yellowfin in the same period, and 2) the period when deep longline started to be used is not necessarily accordant with that of jump, seem to indicate that the high CPUE was not caused by introduction of deep longline.

Environmental factor:

Considering that the year(s) of higher CPUE occurred synchronously in the Indian, Pacific and Atlantic Ocean, and similar jump is also observed for yellowfin in the same period, they might be derived from some global environmental shift. Mizuno and Yukinawa (1991) showed annual and long-term variability of SST in the Indian Ocean (40 S – 20 N and 40 E - 130 E) for the period of 1970-1984 using COADS monthly SST data (2 ×2 latitude/longitude). Figure 18 shows variability of anomalous SST, which was analyzed by empirical orthogonal function (EOF) shown. The most important variability (1st mode of EOF, 24% of total interannual RMS was explained) showed that the entire Indian Ocean anomalous SST changed simultaneously (left panel in Fig. 18). Time series of 1st mode (right panel in Fig. 18) showed a cold period in the first half of 1970s, except for 1972 when an El Nino event occurred, and a warm period from 1977-1978 to 1984. The 1st mode of EOF highly correlated to ENSO signal temporally with 3 months time lag (Fig. 19).

In the later half of the 1970s, regime shift (climatic jump) was occurred in the North Pacific Ocean, which was shown in strengths of the Aleutian Low and the prevailing westerlies, SLP (sea level pressure at the center of North Pacific), SST (sea surface temperature), subsurface temperature, and so on (Nitta and Yamada, 1989; Trenberth, 1990; Tanimoto *et al* , 1993,1997; Watanabe and Mizuno, 1995). The strength of Aleutian Low and SLP connected with ENSO events. And a quarter of SST variability (the 1st mode of anomalous SST) in the Indian Ocean also connected with ENSO events. So, these phenomena may correspond with global atmospheric and oceanic changes. Marsac and Blanc (1998) already suggested the relationship between ENSO and recruitment and catchability of tropical tunas. Incorporation of the environmental factors into the CPUE standardization process seems to be quite important not only for the explanation of higher CPUE in 1970s but also better development of abundance index for the stock assessment.

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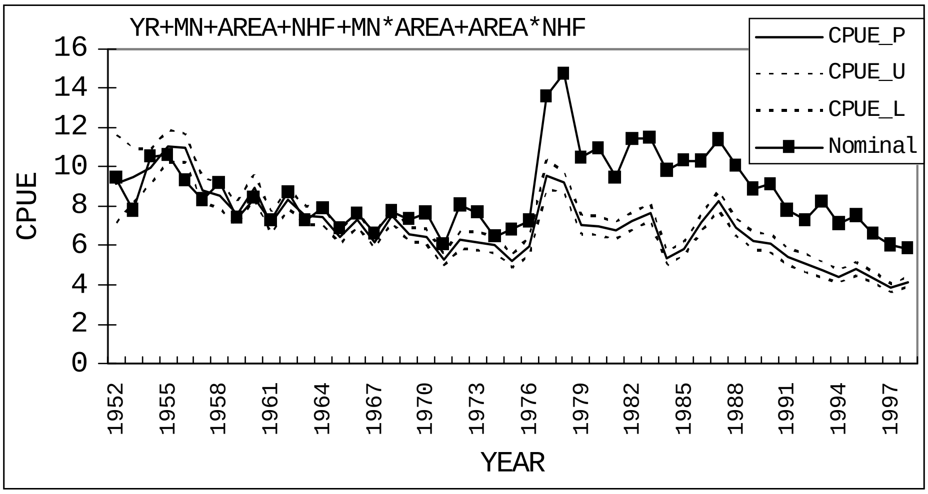


Fig. 1. Standardized and nominal CPUE (scaled) of bigeye caught by Japanese longline fishery in the tropical area of the Indian Ocean (after Okamoto and Miyabe, 1999).

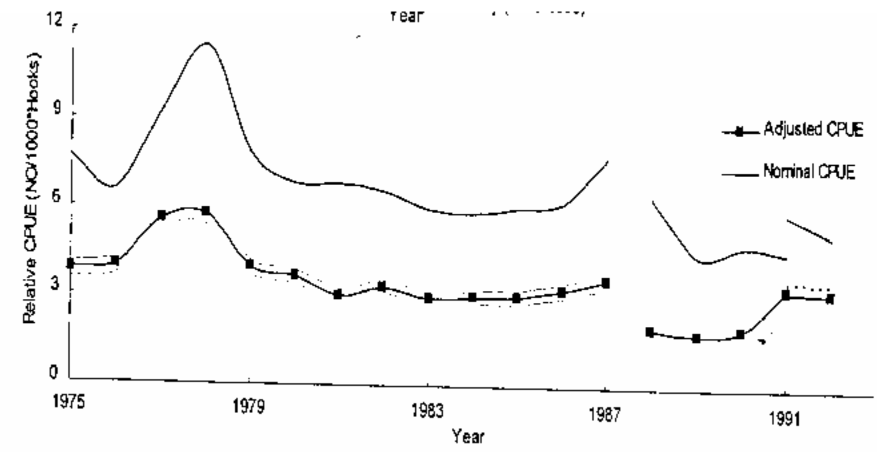


*Fig. 2. Trend of nominal and adjusted CPUE (No. of fish/hooks*1000) for bigeye caught by Korean longline fishery in the Indian Ocean (after Hsu and Liu, 2000).*

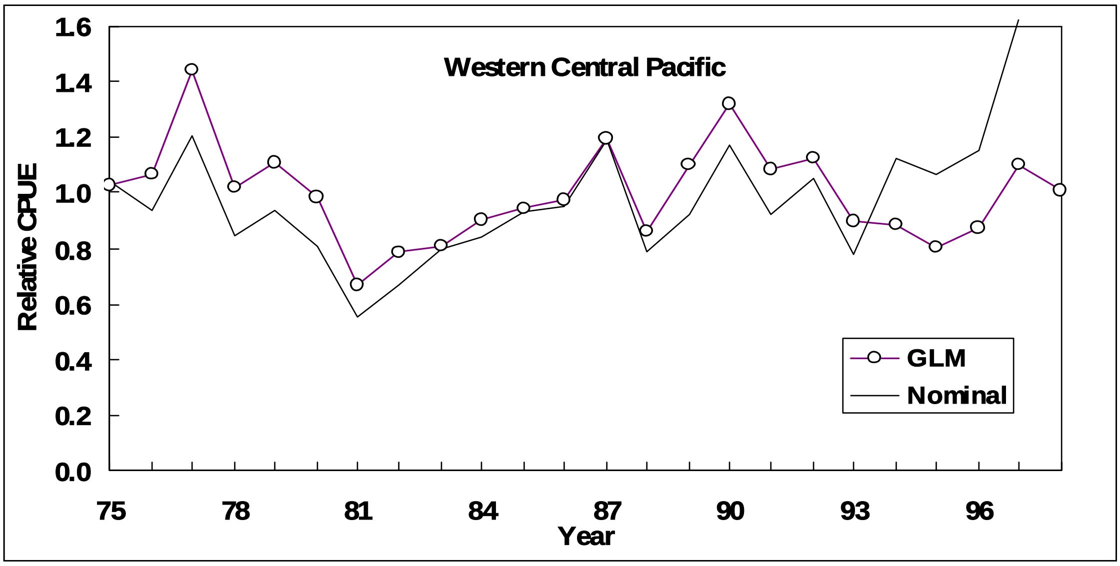


Fig. 3. Nominal and standardized CPUE of bigeye caught by Japanese longline fishery in the western Pacific Ocean.

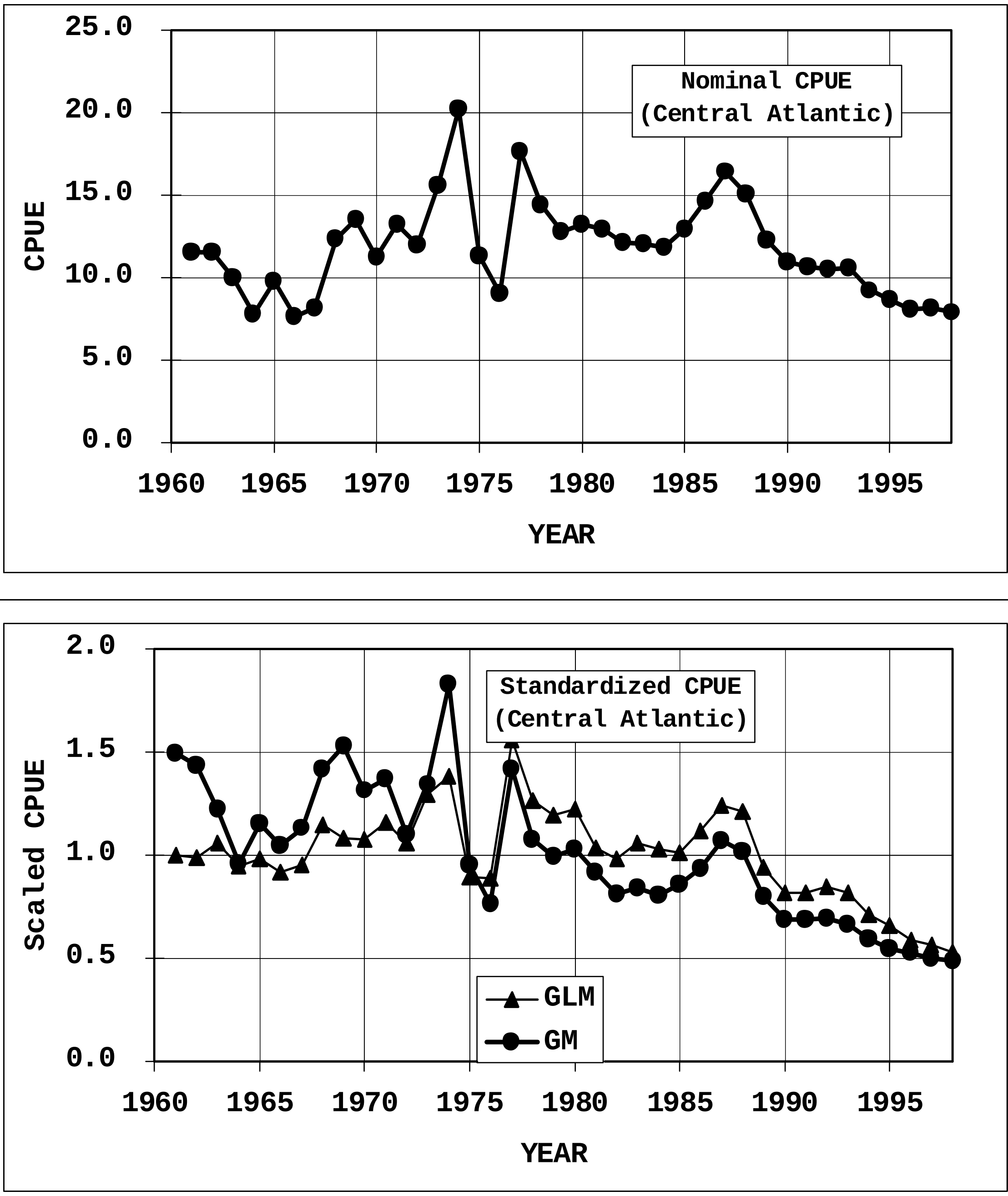


Fig. 4. Nominal (upper) and standardized (lower) CPUE of bigeye caught by Japanese longline fishery in the central Atlantic Ocean (after Miyabe and Okamoto, 1999).

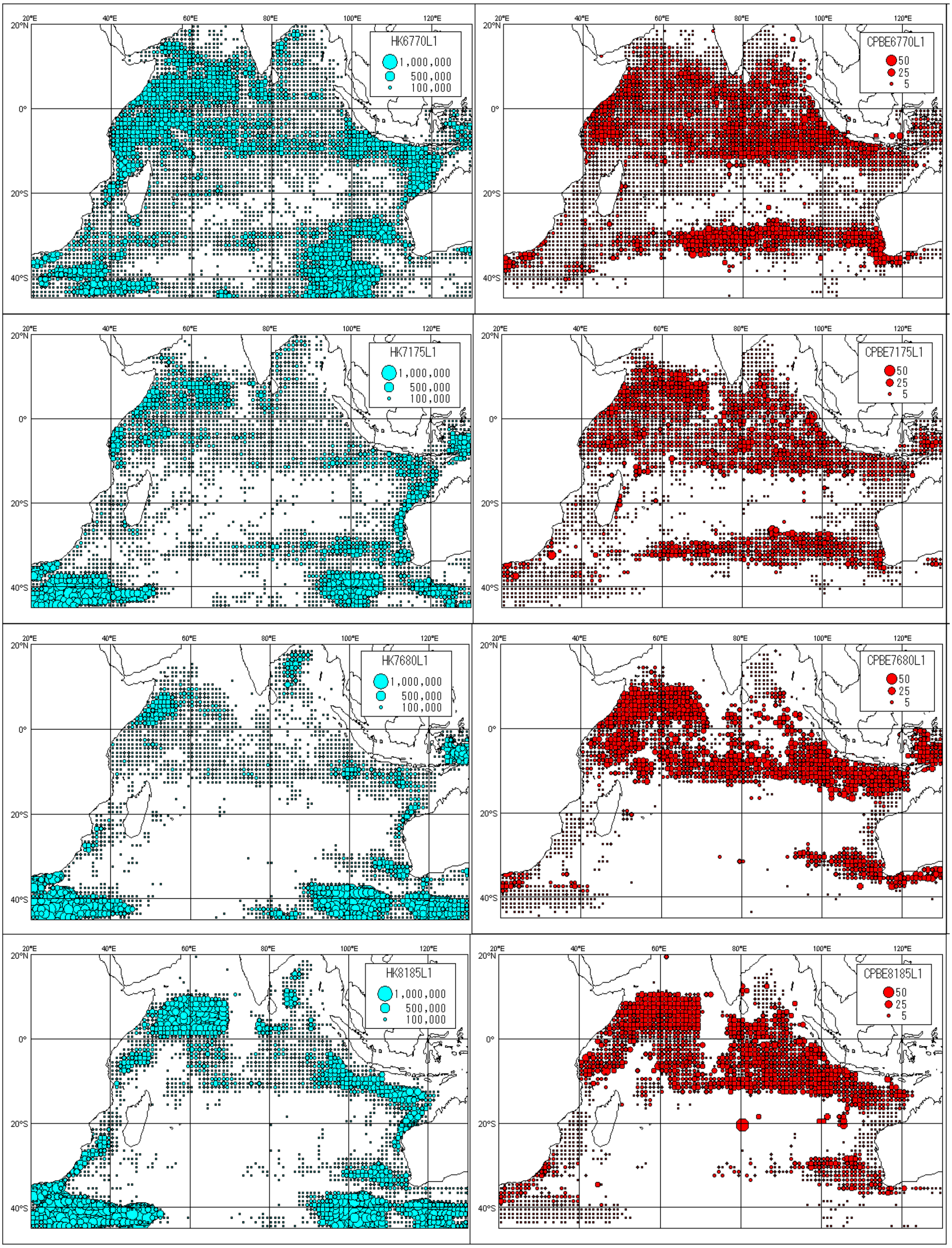
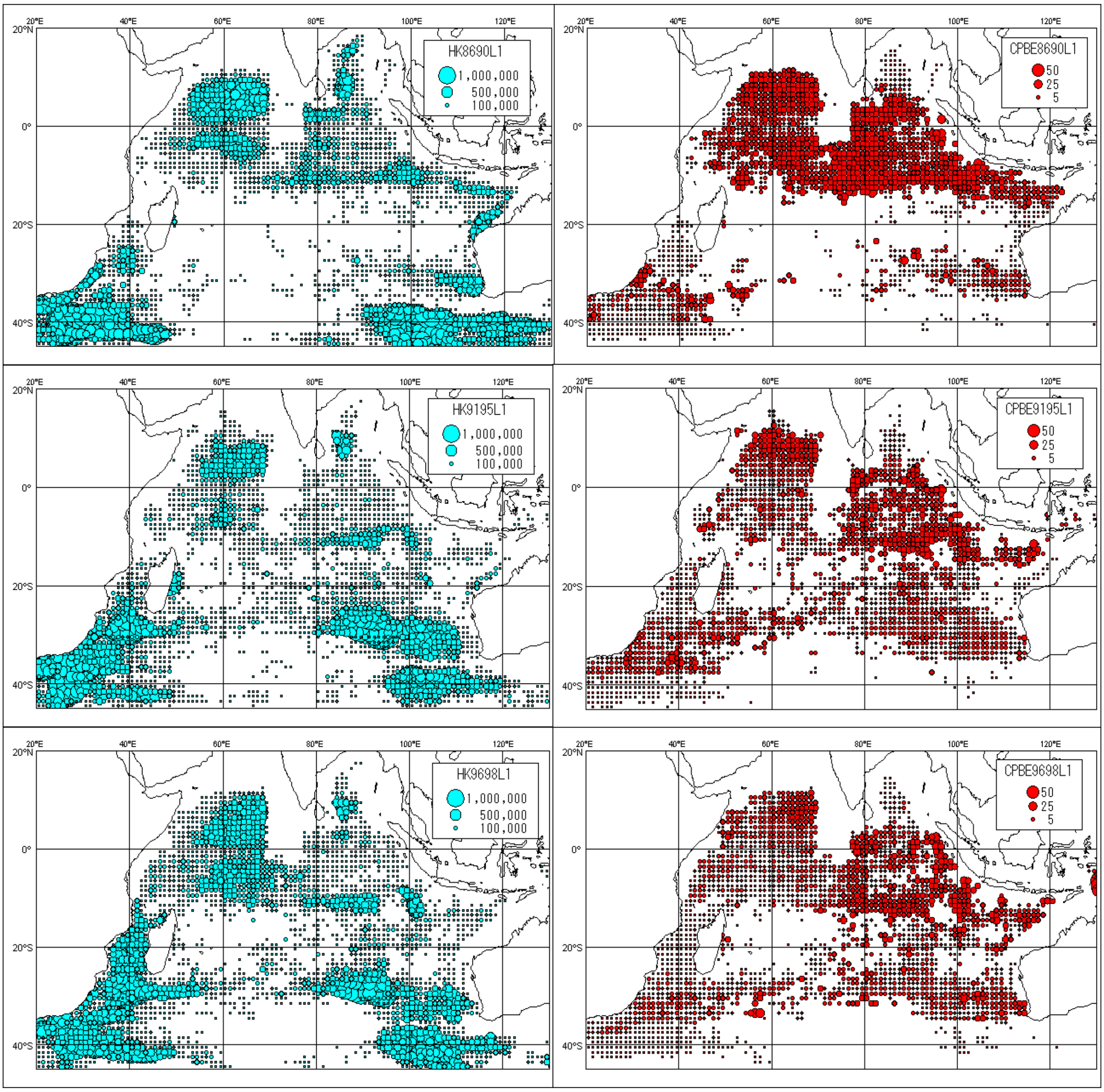


*Fig. 5. Geographical distribution of number of hooks aggregated for each of the five years except for 1967 through 1970, 1996 through 1998, left row) and bigeye CPUE (No. of fish /hooks*1000, right row) in the same period.*



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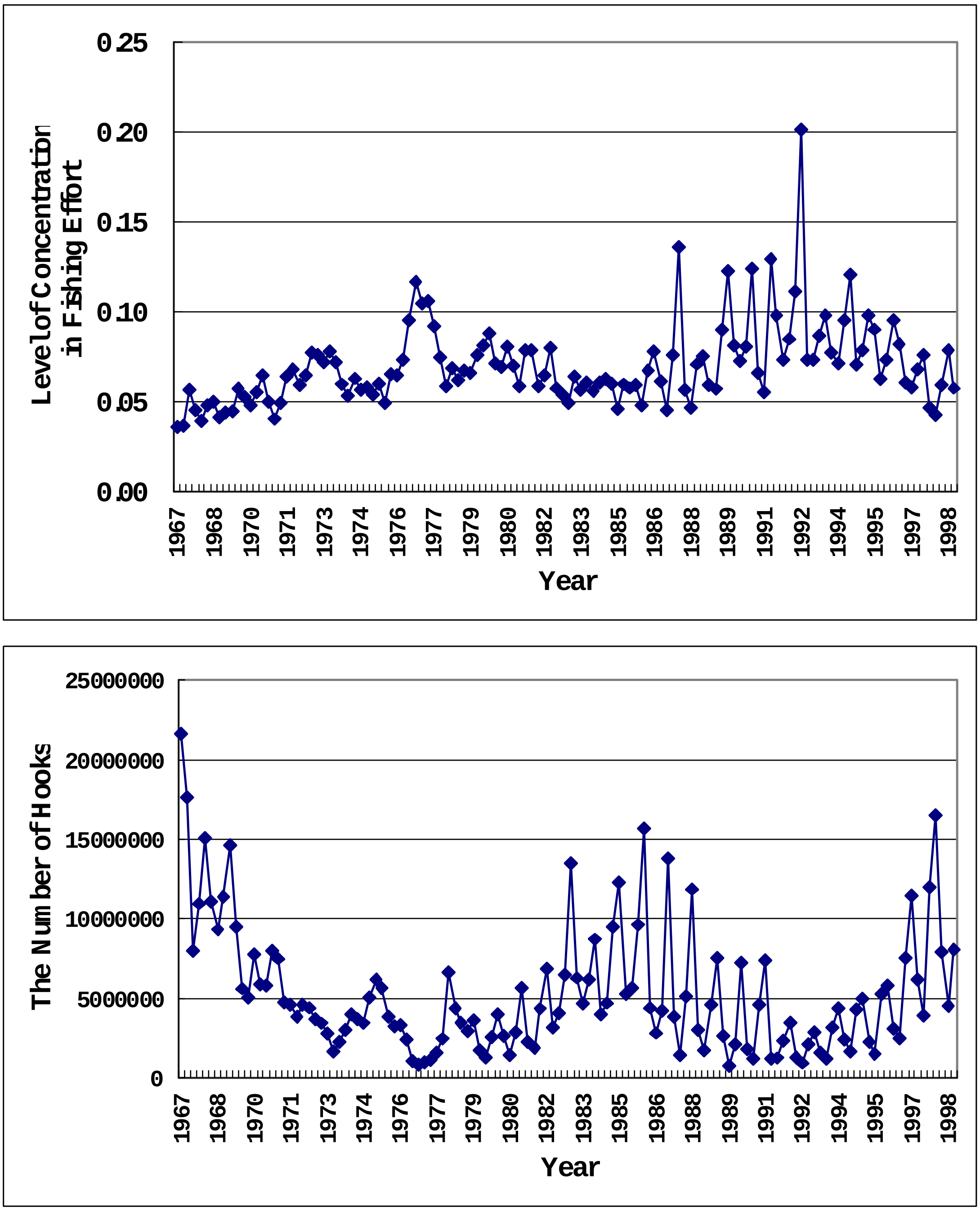


Fig. 6. Quarterly changes in level of concentration of longline effort (upper figure) and the number of hooks (lower figure) from 1967 to 1998. Time scale between each plot is quarter.

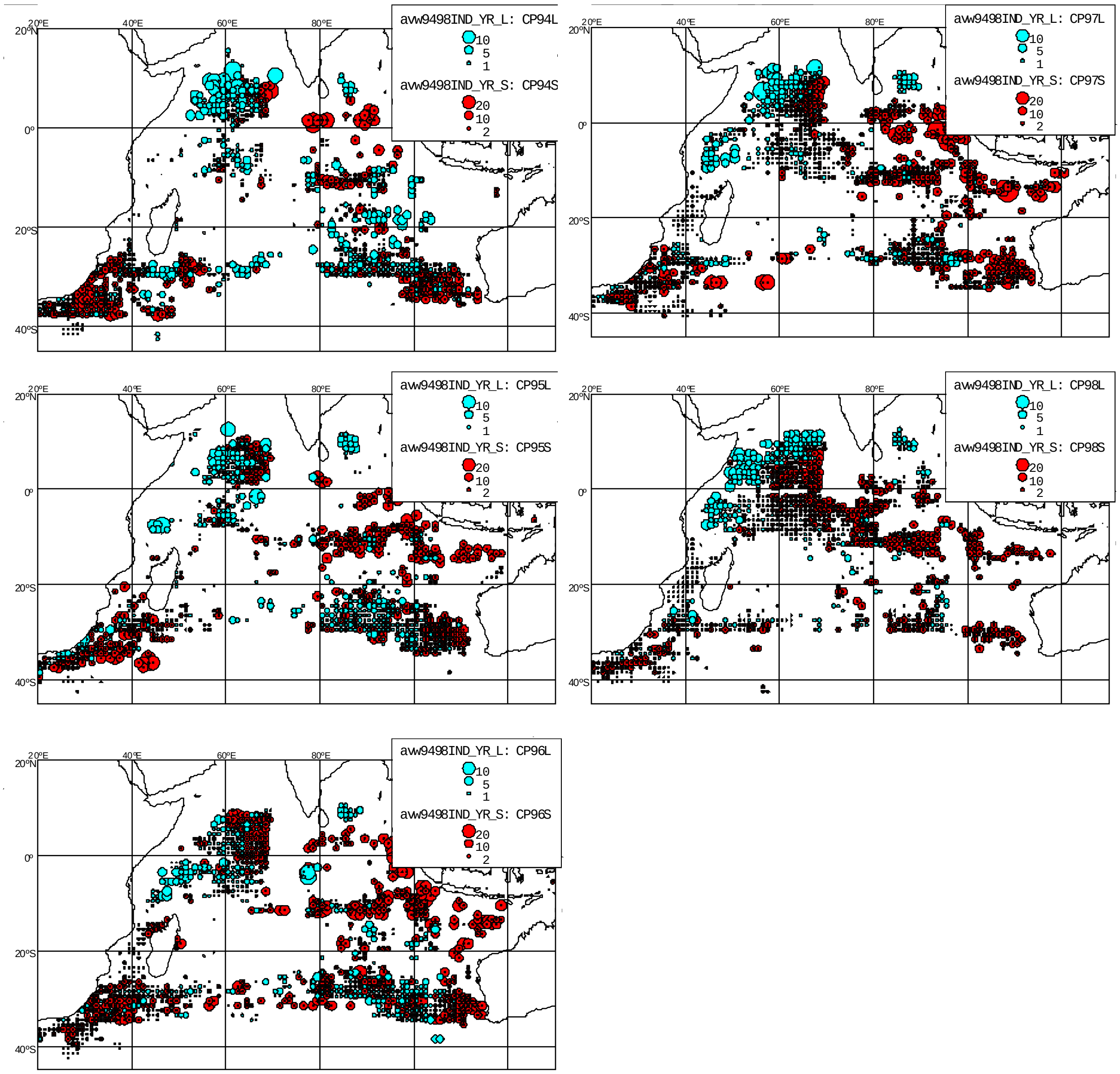


*Fig. 7. Geographical distributions of annual size specific CPUE (No. of fish /hooks*1000) from 1994 to 1998. Pale circle means CPUE of large fish (average weight is greater or equal than 50 kg), and dark circle means that of small fish (average weight is less than 35 kg).*

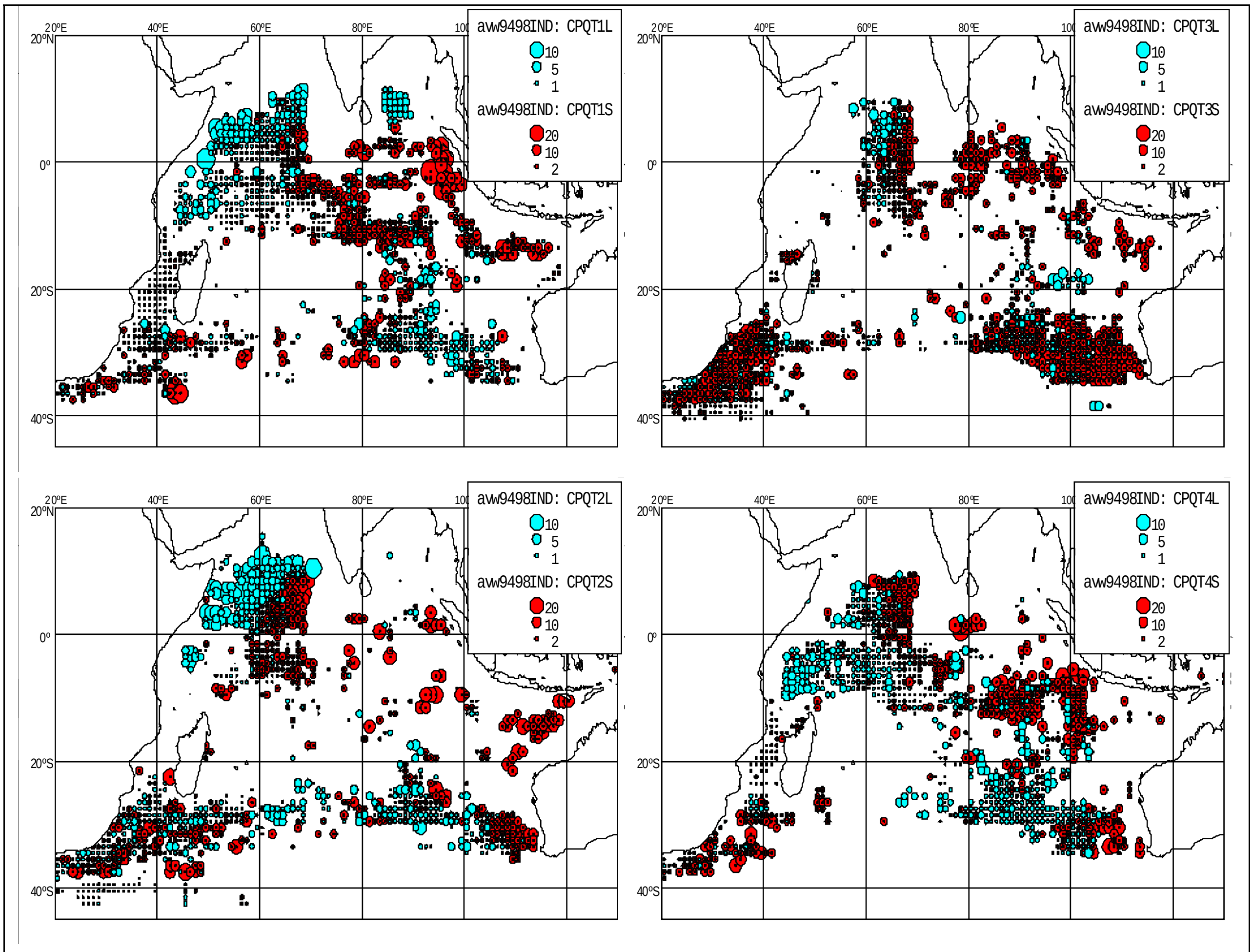
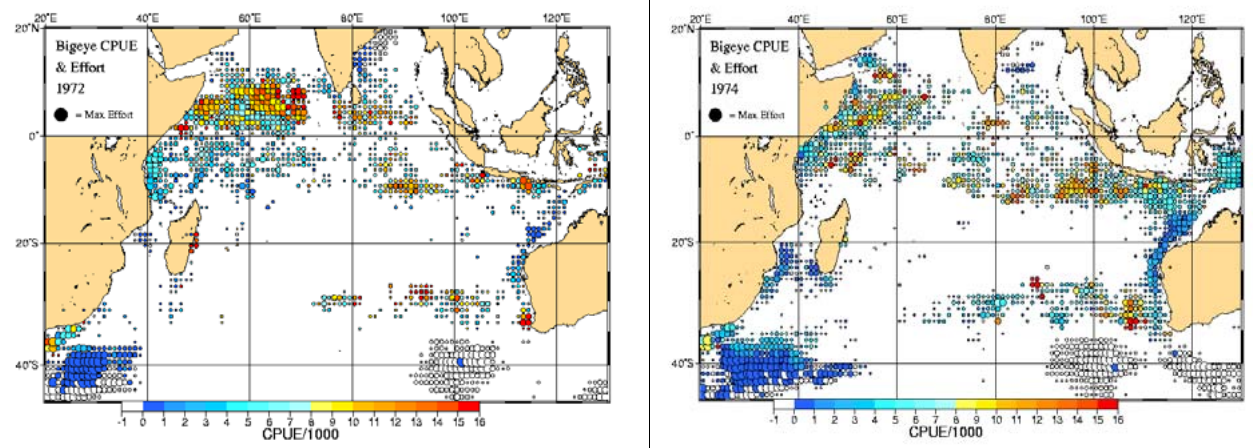


*Fig. 8. Geographical distributions of size specific CPUE (No. of fish / hooks*1000) in each quarter using data from 1994 to 1998. Pale circle means CPUE of large fish (average weight is greater or equal than 50 kg), and dark circle means that of small fish (average weight is less than 35 kg).*



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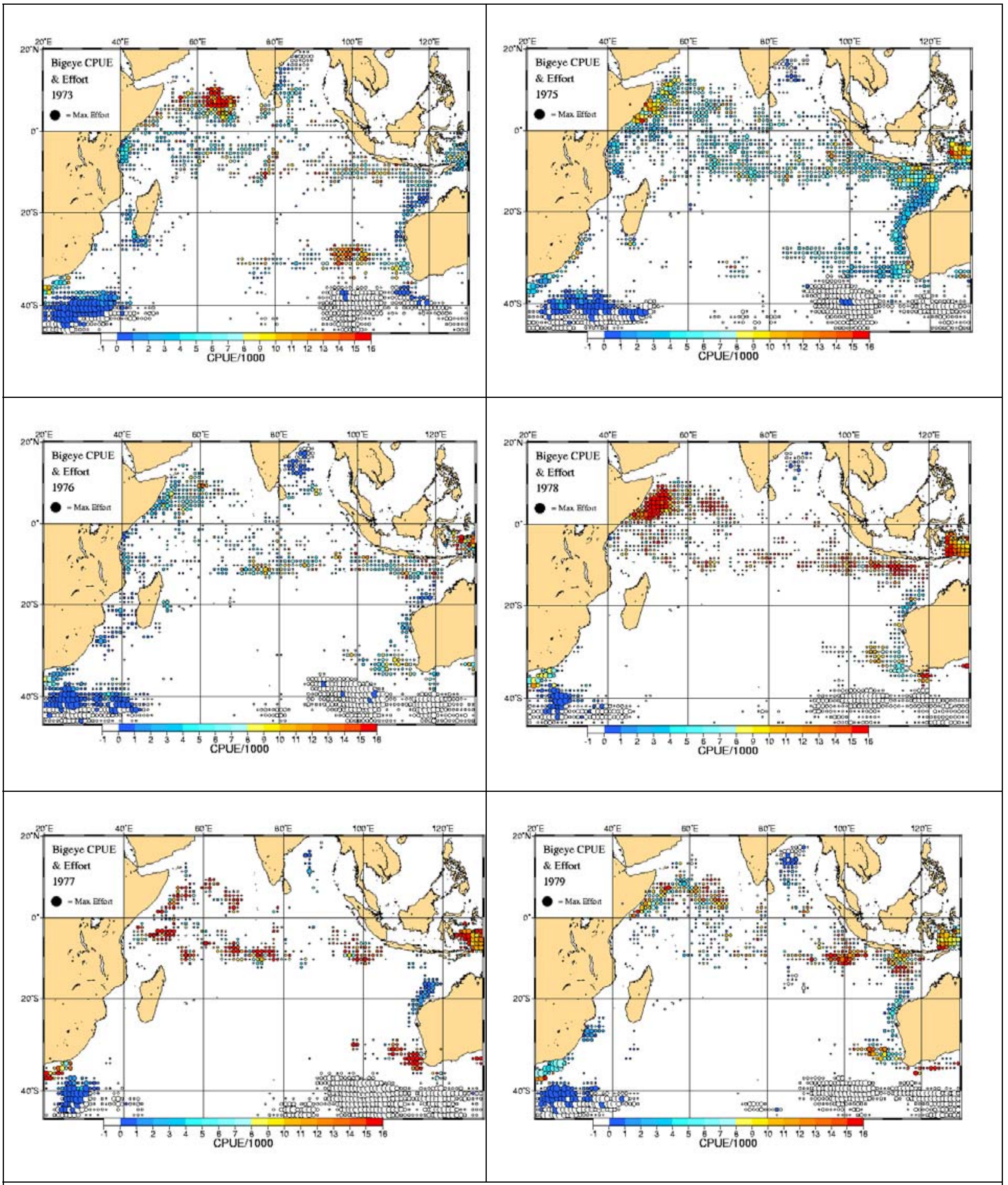

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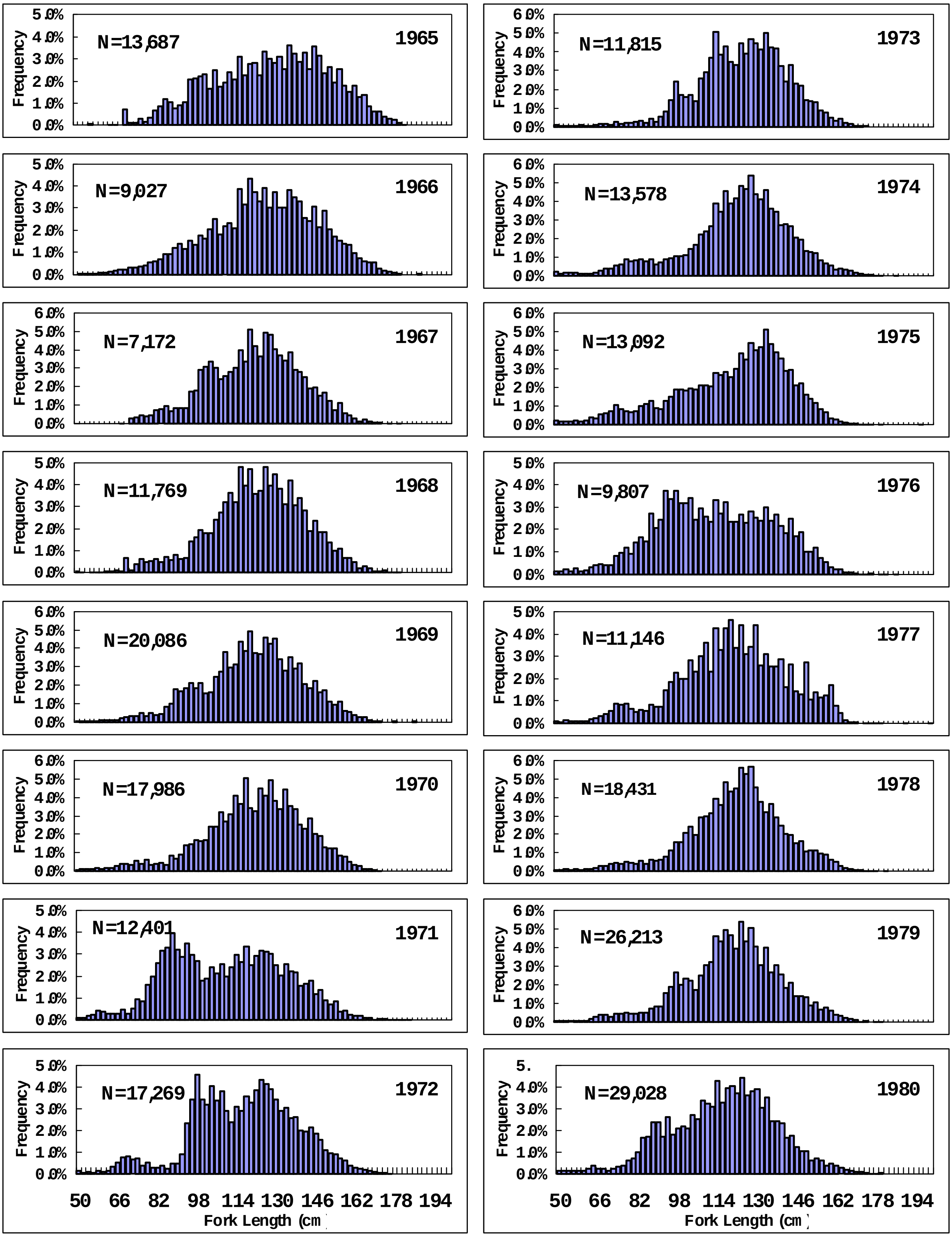
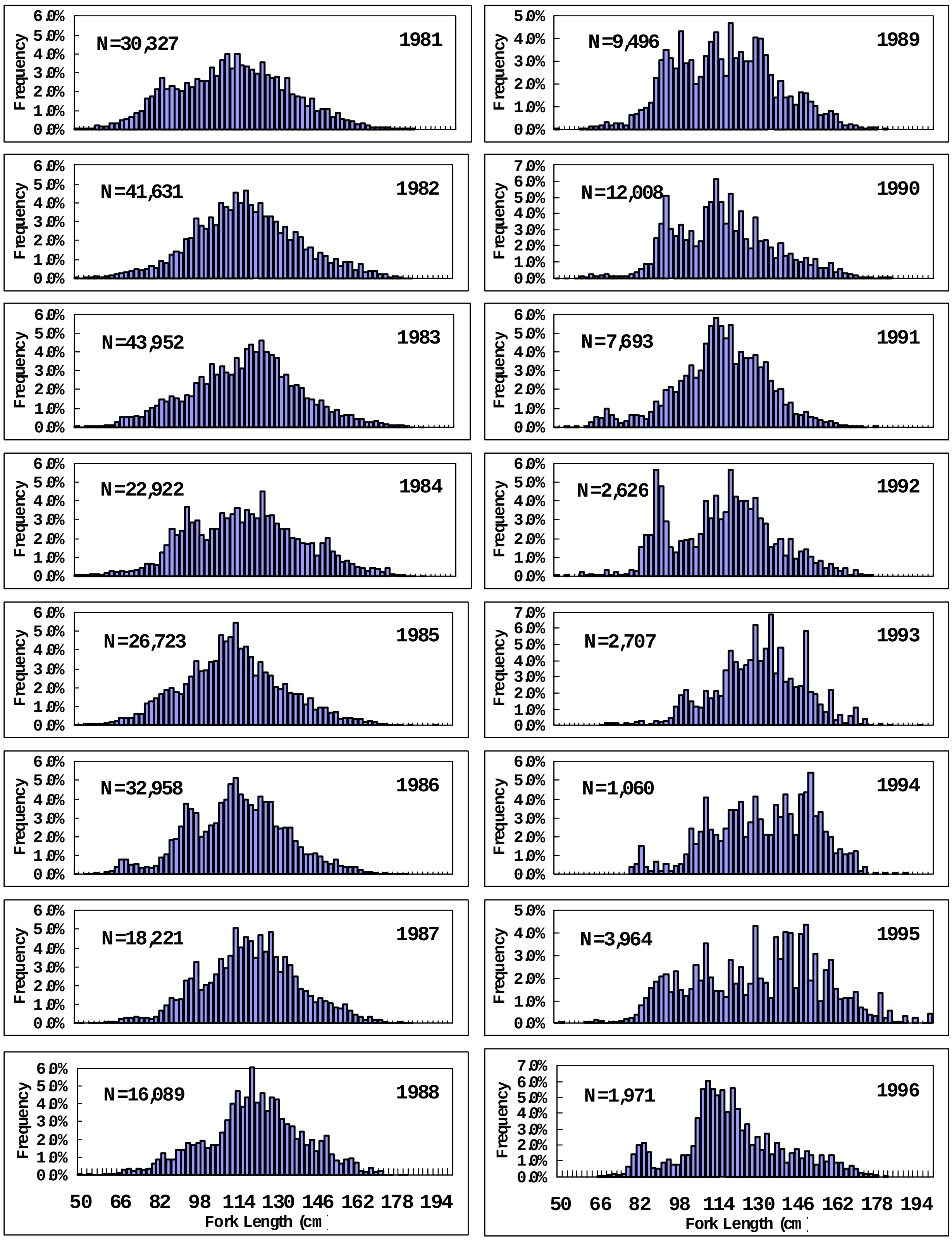


Fig. 10. Sample length frequencies of bigeye measured in the Indian Ocean north of 20 S.



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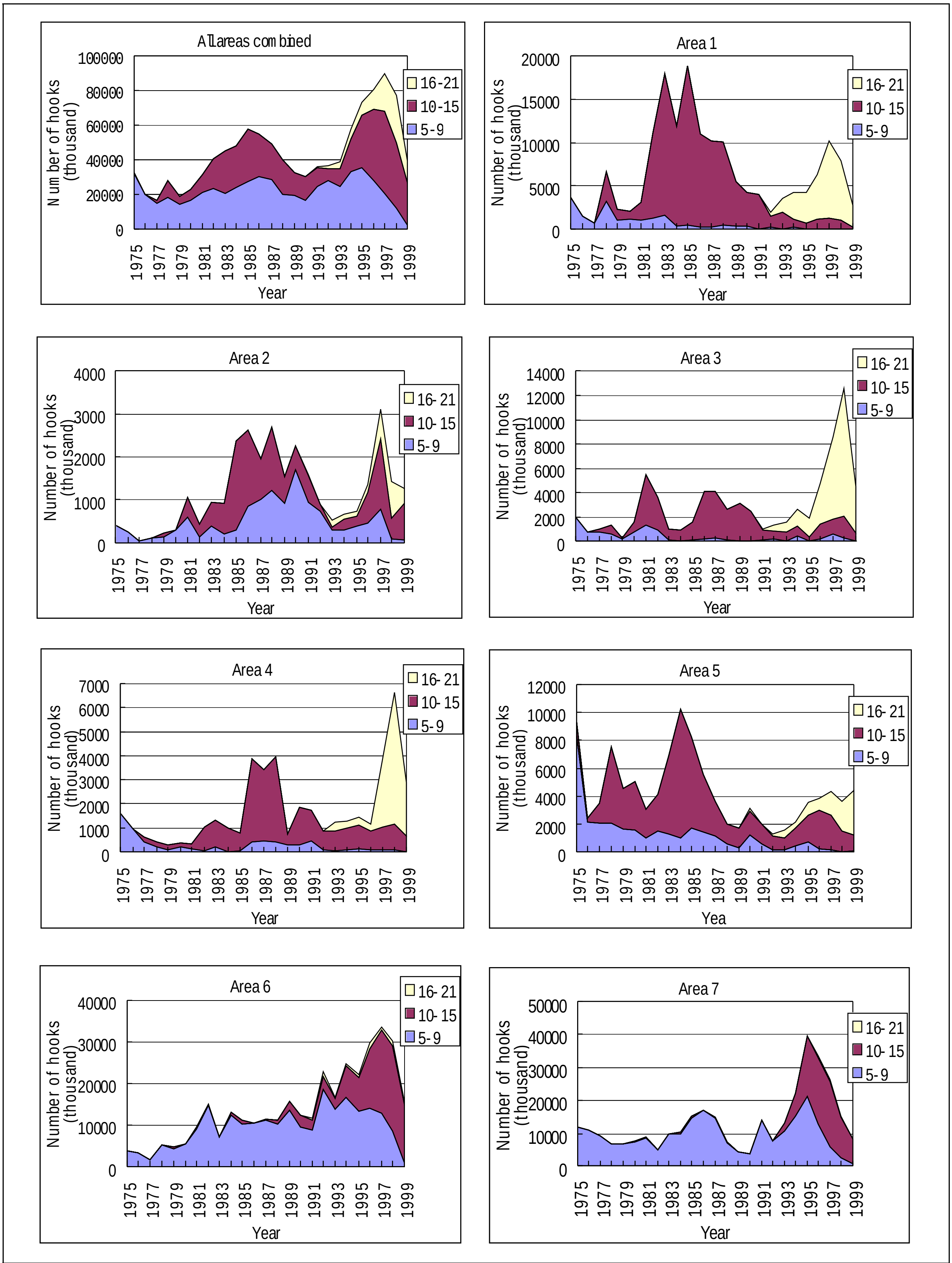

Fig. 11. Historical changes in the fishing efforts (number of hooks) by number of hooks between float in the Indian Ocean. Areas 1 – 5 are tropical area north of mainly 20 S. Areas 7 and 8 are south of 20 S (after Matsumoto, 2000).

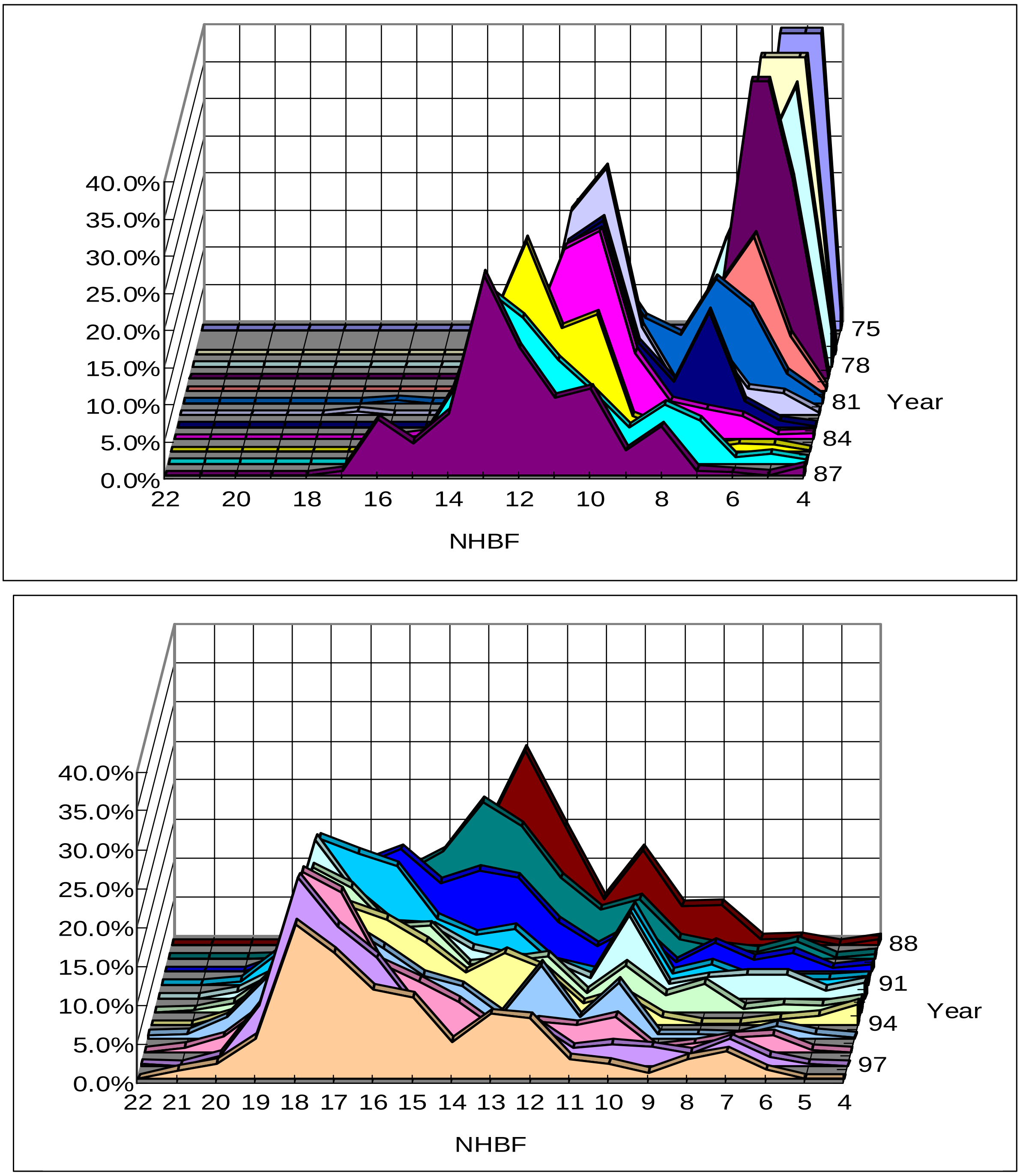

Fig. 12. Annual change of hooks between float deployed in the main longline fishing ground of the Atlantic Ocean (after Miyabe and Okamoto, 1999).

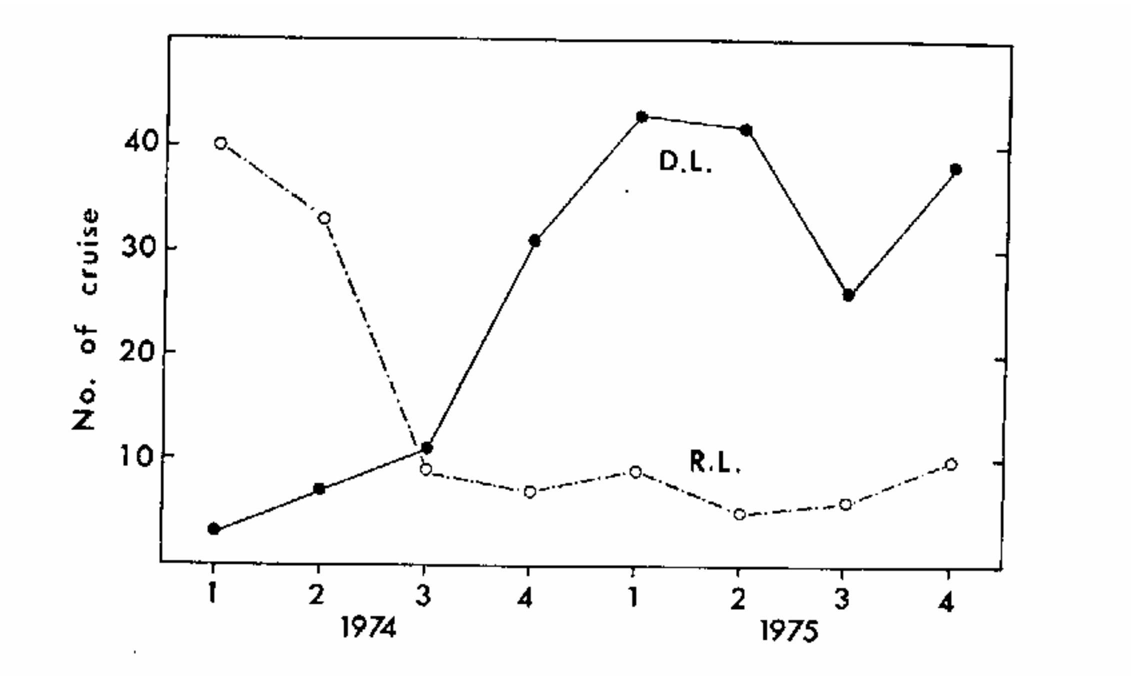

Fig. 13. The number of cruises of vessels fishing with regular longline (R.L.) and deep longline (D.L.) by quarter of the year in 1974 and 1975 (after Suzuki et al., 1977).

Western Pacific Ocean **Eastern Pacific Ocean**

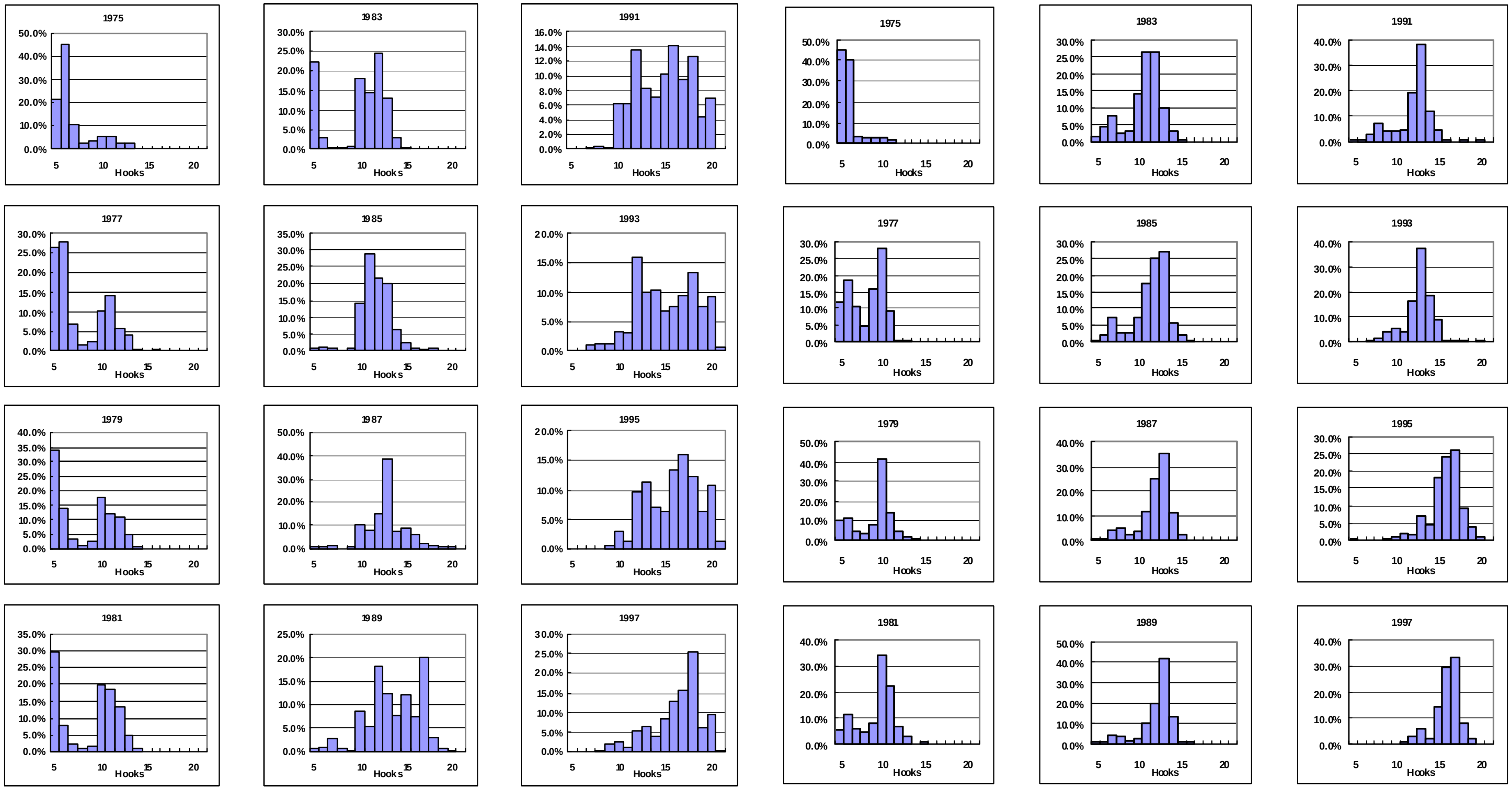

Fig.14. Annual change of hooks between float deployed in the Pacific Ocean.

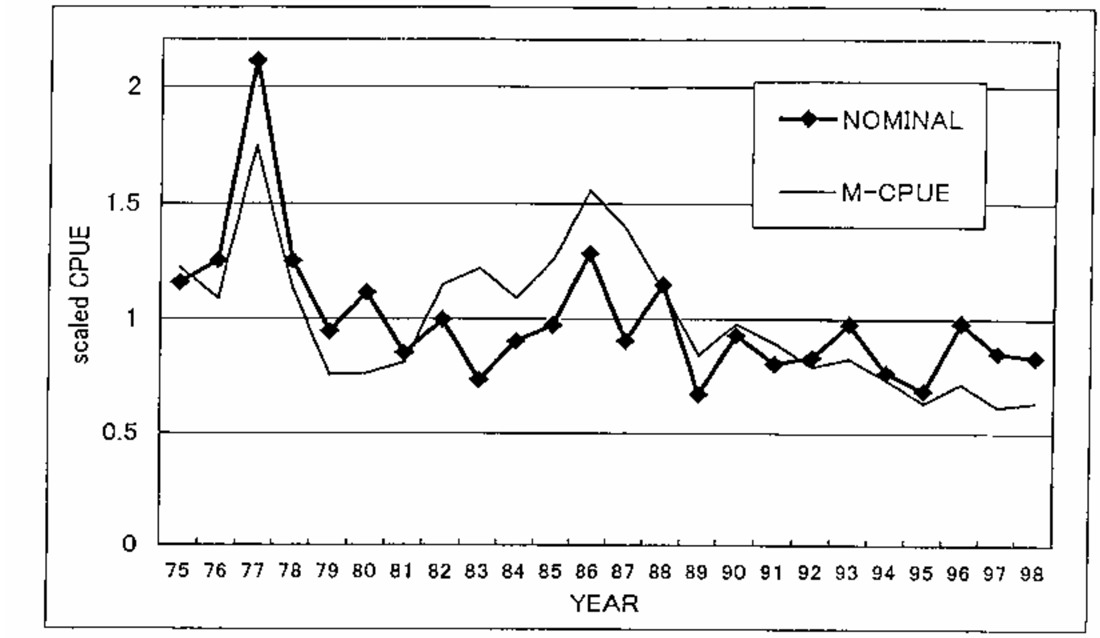

Fig. 15. Trends of the nominal and the standardized catch rates (M-CPUE) for yellowfin tuna caught by Japanese longline fishery in the Pacific Ocean (after Nishida, 2000).

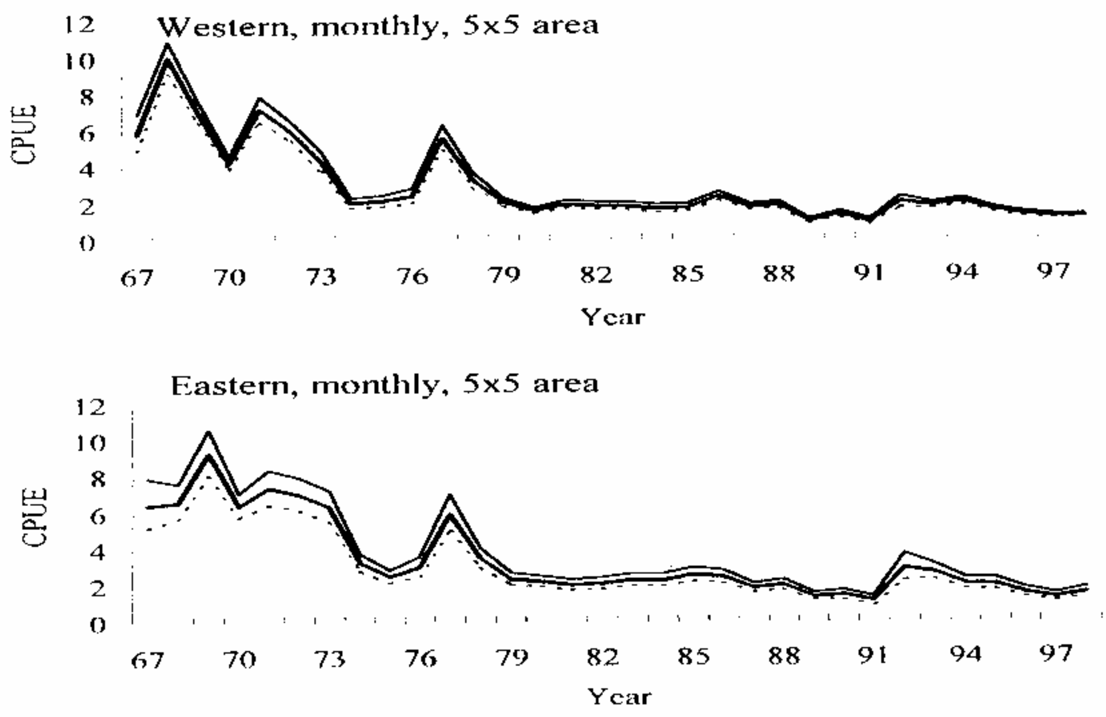

Fig. 16. Standardized CPUE of Indian yellowfin tuna using GLM method for Taiwanese longline fishery, 1967–1998 (after Lee and Liu, 2000).

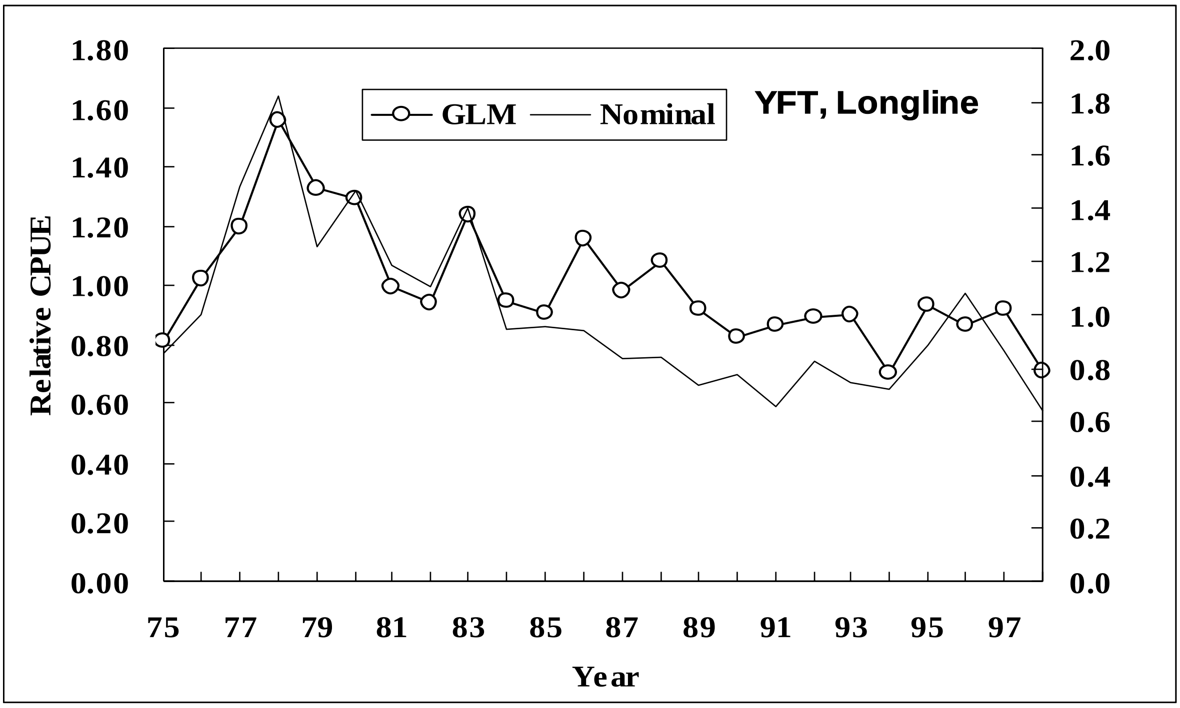

Fig. 17. Nominal and standardized CPUE for yellowfin caught by Japanese longline fishery in the Pacific Ocean.

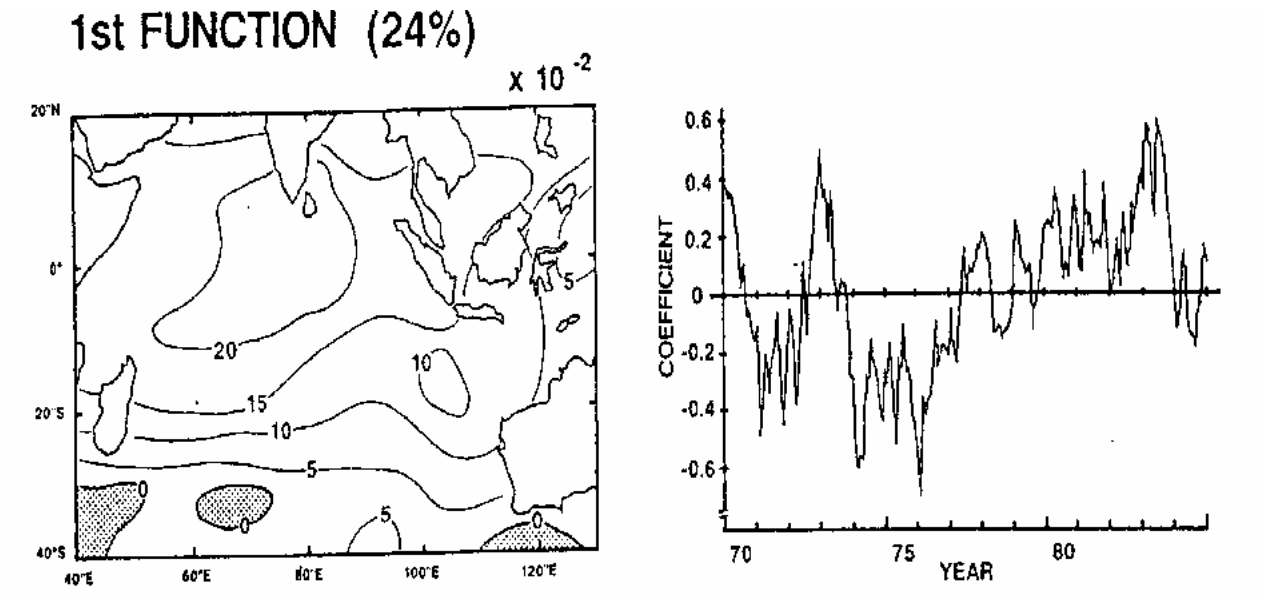

Fig. 18. EOF of anomalous sea surface temperature (after Mizuno and Yukinawa, 1991).

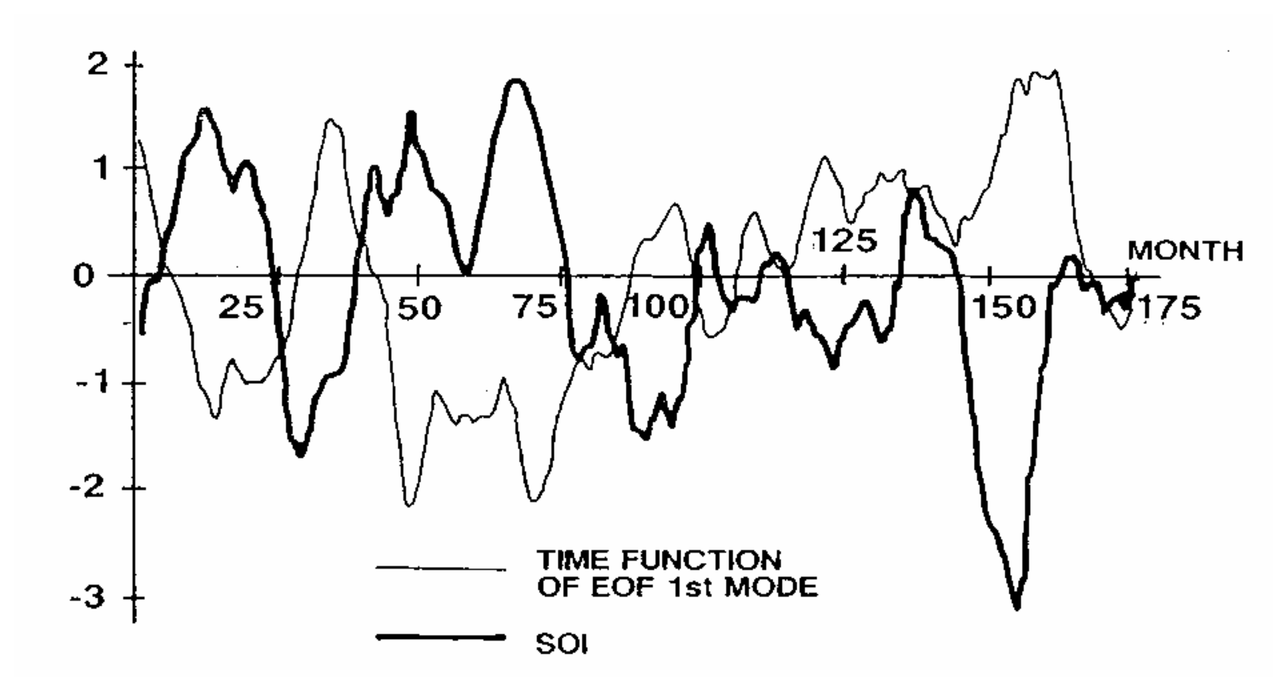

Fig. 19. Southern Oscillation Index (thick line) and normalized amplitude function of the 1st mode of EOF (thin line) from 1970 to 1984. Both time series are smoothed by five months running mean (after Mizuno and Yukinawa, 1991).

CAPTIONS OF FIGURES

Fig. 1. Standardized CPUE and nominal CPUE (scaled) of bigeye caught by Japanese longline fishery in the tropical area of the Indian Ocean (after Okamoto and Miyabe, 1999).

Fig. 2. Trend of nominal and adjusted CPUE (No. of fish/hooks*1000) for bigeye caught by Korean longline fishery in the Indian Ocean (after Hsu and Liu, 2000).

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Fig.5. Continued.

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