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**Provisional study on comparison of CPUE trend of bigeye and yellowfin tuna  
between Japanese and Taiwan-China longline fisheries based on whole and shared strata  
in the Indian Ocean.**

**Hiroaki OKAMOTO**

National Research Institute of Far Seas Fisheries  
5 chome 7-1, Orido, Shimizu-Ku, Shizuoka-City, 424-8633, Japan

**Abstract**

Fishing effort and bigeye and yellowfin catch data of Japanese and Taiwan-China longline fisheries in the Indian Ocean was analyzed to develop the core area where the effort of both fleets has historically covered to be used for CPUE standardization. The region from 10N to 15S showed relatively high coverage of effort and catch of both species of both fleets, this tropical area was defined as core area for both species.

If different trend of CPUE of both fleet is mainly derived from the difference of fishing ground, both CPUE trend should be closer by applying core area. Tropical area from 10N to 15S was selected as core area. Bigeye and yellowfin CPUEs are standardized applying simple model for whole strata and for strata shared by both fleet in the core area (15N-15S was used in this case), and their trends are provisionally compared between both fleets. Standardized CPUE of both fleet applying whole strata in core area still showed large difference especially for bigeye, and this difference could not be improved by applying shared strata. Therefore, difference of fishing ground should not be the main reason of their different trend of CPUE.

**Inroduction**

In the CPUE Work Shop held at San Sebastian, Spain in 21-22 October, 2013, it was recommended to explore the reason of different CPUE trend between major longline fleet operating in the Indian Ocean (Anonymous 2013). In the several suggestions to be studied, it is included to assess how core area standardization works along with out of core or boundary area effects. Although there is no clear definition of “core area”, several analyses were conducted in this study under the following concepts.

- 1) If the difference in the CPUE trend between two fleets is mainly derived from the difference in the fishing ground of them, both CPUE trends must become similar by restricting analyzed area to core area in which both fleets has historically operated in common.
- 2) As the common fishing area between two fleets would have been changing through the period, it might be difficult to define one core area which can be used to compare the trend through long time period, or selected core area must be too small to grasp stock status trend in ocean scale.
- 3) One of the core area definitions might be using only shared strata (year, month, 5degree longitude, 5degree latitude, for example) between two fleets.
- 4) Both standardized CPUE trends must become similar if both CPUEs are standardized using only shared strata than those using whole strata in core area.
- 5) In this study, distribution and coverage of effort and catch of bigeye and yellowfin are compared between Japanese and Taiwan-China longline fisheries, and shared and whole strata in some block regions of the Indian Ocean to define the core area to be used for CPUE standardization. Furthermore, bigeye and yellowfin CPUEs are standardized applying simple model for shared and whole strata in the core area, and their trends are provisionally compared between both fleets.

**Materials and methods:**

Data of catch in number of bigeye and yellowfin tuna and effort (the number of hooks) of Japanese (JPN)

and Taiwan-China (TWN-CHN) longline fisheries from 1967 to 2011 aggregated by year, month, 5 degree latitude and 5 degree longitude downloaded from IOTC homepage (<http://www.iotc.org/documents/ce-longline>) was used in this study. The catch and effort data of strata in which the effort of each of both fleets was less than 5000 hooks was not used.

As the area studied, five sub-areas with different latitudinal range, 1: 15N-0N, 2: 0S-15S, 3: 15S-35S, 4: 15N-15S, 5: 15N-35S, were defined. In each sub-area, shared strata (5 degree latitude, 5 degree longitude and month) in which the number of hooks was larger than 5000 for both of Japanese and Taiwan-China longline fisheries were selected to calculate nominal and standardized CPUE for bigeye and yellowfin tunas. Nominal and standardized CPUE using whole strata in each sub-area were also calculated for comparison.

CPUE of both longline fleets were standardized separately using the same GLM model (CPUE-LogNormal error structured model ) as follow.

$$\text{Log (CPUE}_{ijkl} + \text{const}) = \mu + \text{YR}(i) + \text{MN}(j) + e(ijkl\dots)$$

Where Log : natural logarithm,

CPUE : catch in number of bigeye per 1000 hooks,

Const : 10% of overall mean of CPUE

$\mu$  : overall mean (i.e. intercept),

YR(i) : effect of year,

MN(j) : effect of fishing season (month),

$e(ijkl\dots)$  : error term.

## Results

Distribution of longline effort for both fleets (Fig. 1):

In order to overview the historical change in the fishing ground of JPN and TWN-CHN longline fisheries, distributions of effort was observed by fleet in each of five sample years (1970, 1980, 1990, 2000 and 2010). Solid and open circles mean shared and non-shared effort, respectively, with indicating largeness of effort as diameter of the circle. There are some fundamental differences in the effort distribution between Japanese and Taiwan-China longline effort.

- In all years, JPN effort exist at South of 40S while no or sparse for TWN-CHN effort. Similar is true at the West off Australia, 25S-40S and 100E-120E.
- In the Arabian Sea of north of 10N or 15N, highly concentrated effort was observed for TWN-CHN longline in 1990 and 2000, while JPN LL shows no or very few effort in this area.
- In the temperate area of southwestern Indian Ocean, 15S-40S and 45E-80E, TWN LL showed relatively large effort, while effort of JPN LL in this area has been relatively scarce.

Distribution of coverage of shared strata (Fig. 2):

In order to grasp the coverage of shared strata, the monthly based strata (month, 5 degree latitude and 5 degree longitude) which include 5,000 or more hooks for both fleets, was counted for each five years. As five years include 60 months, if 60 observations are included in the stratum (by month, 5 degree latitude and 5 degree longitude) in five years, coverage is 1.0. Relatively high coverage ratio of shared strata higher than 0.3 distribute mainly tropical area of Indian Ocean from 10N to 15S and South of Mozambique Channel from early 1990s. In the area from 15S to 45S and from 50E to 115E, shared strata were very scarce for the period before 1990s.

Historical change in the coverage of shared strata (Fig. 3 & 4):

Coverage of shared strata in whole strata for each fleet was compared in each region. Basically coverage showed similar trend between JPN and TWN-CHN longline fisheries (Fig. 3), and the ratio of shared strata to all JPN and TWN-CHN strata is relatively low, less than 0.2 in middle to late 1970s in 15N-0N and 0S-15S regions, and extremely low less than 0.05 from late 1970s to late 1980s in 15S-35S. This extreme low ratio was caused by very scarce distribution of Japanese longline effort in the area from 40E-100E and south of 15S in this period as shown in Fig. 1.

Historical change in the distribution of bigeye and yellowfin catch (Figs. 5 & 6):

Distribution of catches in shared and non-shared strata of both fleets aggregated by each of five years (1970, 1980, 1990, 2000 and 2010), 5 longitudinal degree and 5 latitudinal degree were shown in Figs 5 & 6 for bigeye and yellowfin, respectively. For both species, catch in shared strata is mainly distributed 10N to 15S and the area from Mozambique Channel to off Cape Town. As for the yellowfin, relatively large non-shared catch for JPN LL exists off Cape Town and that for TWN-CHN LL occurred mainly at Arabian Sea and Bay of Bengal. As for the bigeye non-shared catch for JPN LL sometimes occurred at the area from south off Java to west off Australia, and south off Cape Town and that for TWN-CHN LL mainly occurred at the area from 15S to 40S and 40E to 80E.

Coverage of bigeye and yellowfin catches (Fig. 7):

Historical trend of coverage ratio of bigeye and yellowfin catches in shared strata to those in whole strata is similar and the trend is basically similar to that of coverage ratio of the effort. In the most part of observed period, the coverage of the catches of both species in the range 15N-0N and 0S-15S are larger than 0.4 except extremely low value, about 0.1 or less in around 1978, and relatively low value around 0.2 to 0.4 from 1973 to 1982. In the range from 15S to 35S, the coverage was lower than 0.4 in the most period, and quite low, 0.1 or less during the period from 1972 to 1990, which indicates that the fishing ground for JPN and TWN-CHN LL has been considerably different in this south region of the Indian Ocean.

Basing on the above observations on the effort and catch in the shared strata, it seems that the area from 10N to 15S would be appropriate for the purpose of comparison of bigeye and yellowfin CPUE trends between whole and shared strata for both fleets.

Comparison of CPUE trends between whole and shared strata (Figs. 8 - 11):

Fig. 8 and 9 show standardized (solid line) and nominal (broken line) CPUEs of JPN (blue) and TWN-CHN (red) longline derived from whole (left) and shared (right) strata for yellowfin (Fig. 8) and bigeye (Fig. 9), are shown in real scale. The CPUE was calculated for three regions, 15N - 0N, 0S - 15S, and 15N - 15S. Figs. 10 and 11 show the standardized CPUE in same way as Figs. 8 and 9, but in relative scale. The following observation will be made basing on the relative CPUEs.

As for the yellowfin, CPUE trends derived from shared and whole strata are basically similar in all region categories, and also similar between both fleets.

As for the bigeye, standardized CPUE trends of two fleets were largely different in most regions and CPUE of each fleet were basically similar among regions. As for the CPUE derived from whole strata, JPN longline CPUE showed large increase after 1976 and was kept in higher level than before that 1975 until middle of 1990s, while TWN-CHN CPUE did not show remarkable trend in the same period (1967 - middle 1990s). After then JPN CPUE showed large declining trend until 2003 and increasing trend until 2007, while that of TWN-CHN CPUE showed opposite trend in this period.

Since the bigeye CPUE derived from shared strata showed basically similar trend as that from whole

strata, JPN and TWN-CHN CPUE trends in the region 15N – 0N before middle 1990s seems to become nearer to some extent although large difference after this period was still remained. In other region categories, there was not so large difference in CPUE trends between CPUE derived from shared and whole strata.

### **Discussion**

In the comparison of CPUE trends, the area between 15N and 15S in the Indian Ocean was used for the analysis. Therefore, longline fishing operation targeting on other than bigeye and yellowfin tunas, for example targeting on albacore or southern bluefin tuna could mostly be excluded from this analysis. Although the CPUE trends of both fleets became closer to some extent, large differences are still remained. One remarkable difference is that the JPN LL CPUE showed increasing trend since 1975 and it was kept in clearly higher level than that before that until around 1990, while TWN-CHN CPUE did not show remarkable change in the CPUE level before and after 1975. This dynamic change in CPUE level of JPN LL which started around 1975 would be caused by shift of target species from yellowfin to bigeye (Suzuki et al., 1977). The effect of target shift on the CPUE level of JPN LL could at least partly be relieved by applying gear configuration information into the GLM model for standardization as previous analyses (Okamoto 2004).

Another remarkable difference is CPUE trends of bigeye after middle 1990s, that is, declining trend until 2003 and upward trend after that for JPN CPUE and opposite trend for TWN-CHN CPUE. This difference in CPUE trend can't be explained by the difference in fishing ground nor mixing of longline operation targeting on albacore for TWN-CHN LL. One plausible reason on the difference would be shift of main target species for TWN-CHN LL fishery from albacore and/or yellowfin to bigeye which started around 1986 (Hsu et al. 2001, Lee et al. 2004). This shift of target species must have caused shift of fishing ground and have also affected on the bigeye catchability to some extent at the main fishing ground of bigeye. Another possibility which has affected on the bigeye catchability of JPN LL fishery after early 1990 might be change in gear configuration of JPN LL which occurred with the change in gear materials (Okamoto 2005). Perhaps this type of change in gear configuration caused by change in gear material might also have occurred in the TWN-CHN LL fishery with some difference of period.

### **Acknowledgements**

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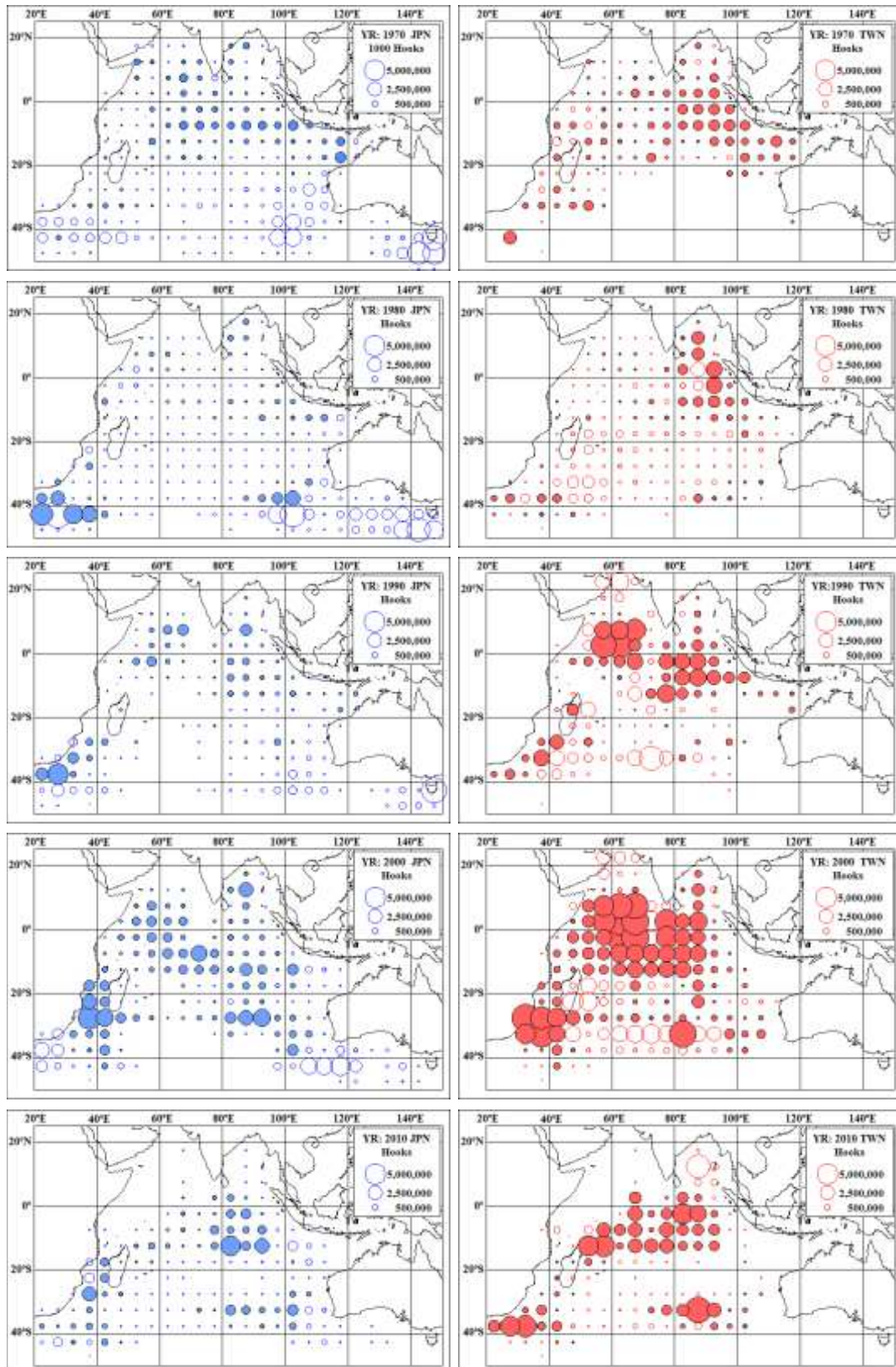


Fig. 1 Distribution of longline effort for Japanese (left) and Taiwan-China (right) longline fisheries in each sample year (1970, 1980, 1990, 2000 and 2010). Solid circle and open circle mean shared and non-shared strata between both fleets, respectively.

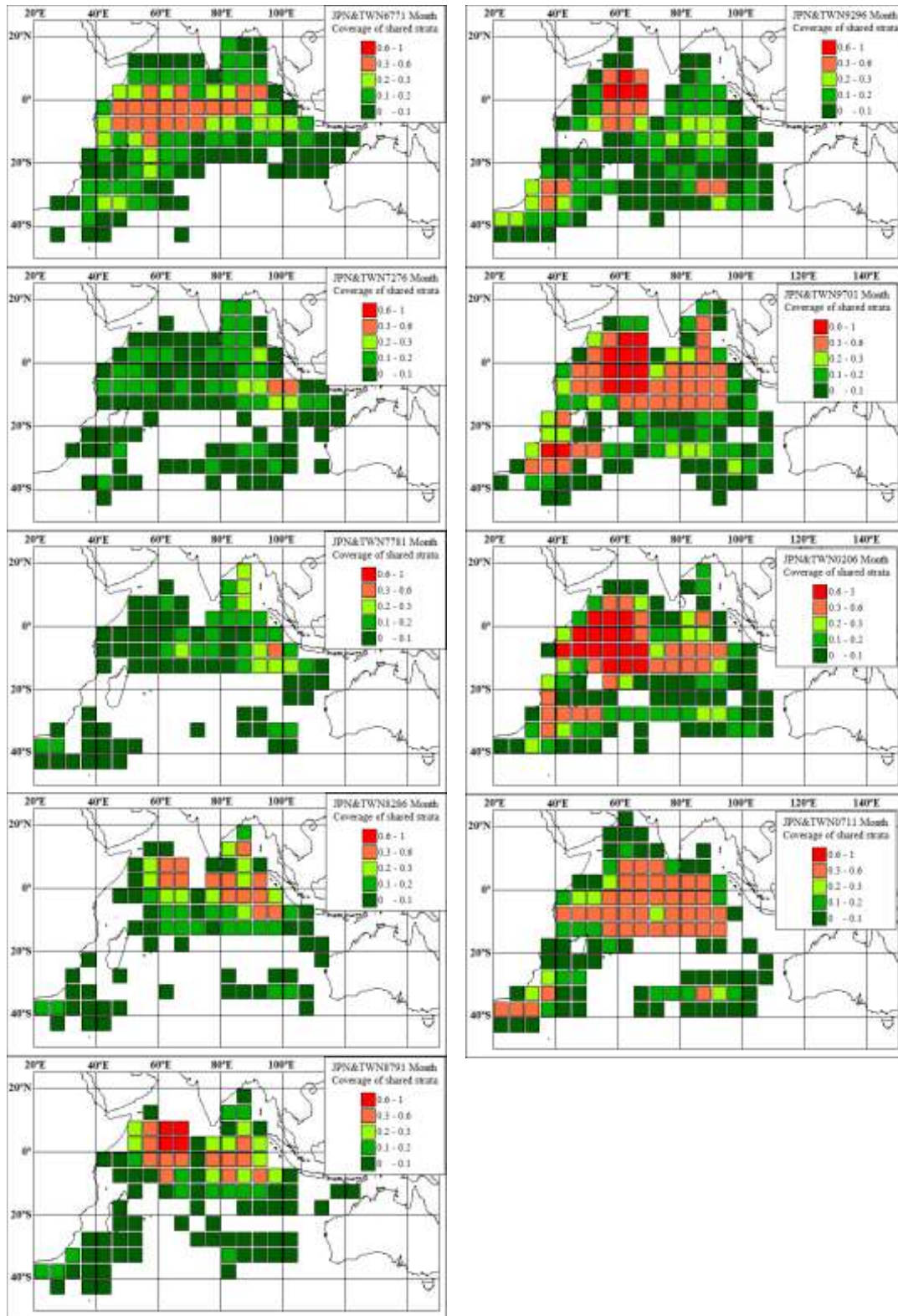


Fig. 2 Distribution of coverage of shared strata. Coverage ratio of the monthly based strata (month, 5 degree latitude and 5 degree longitude) which include 5,000 or more hooks for both fleets, was counted for each five years.

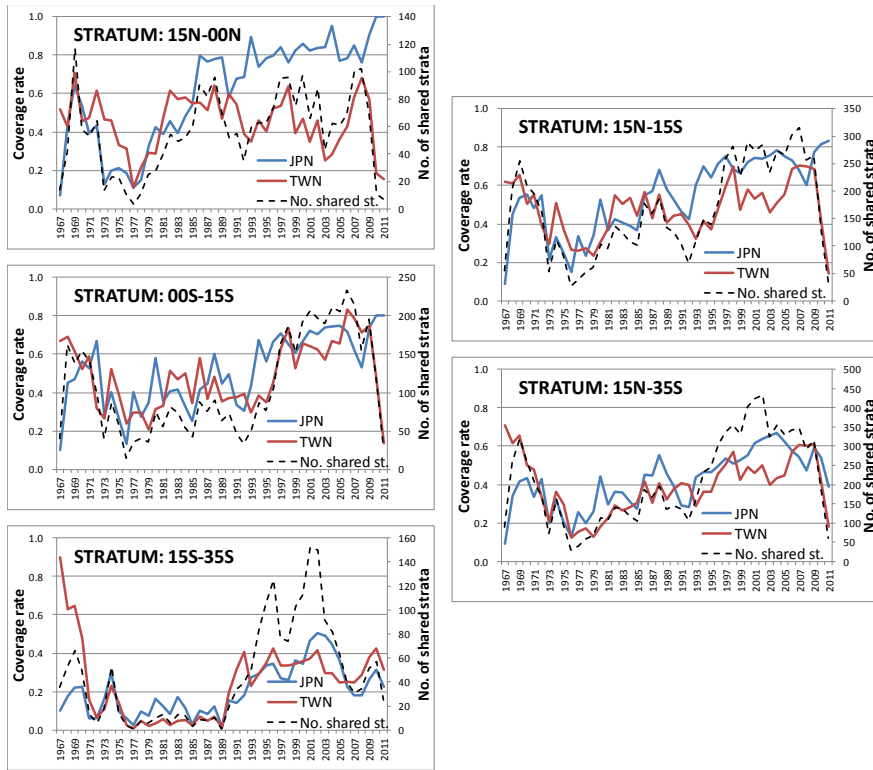


Fig. 3 Historical change in coverage ratio of shared strata in all strata of Japanese (blue) and Taiwan-China (red) longline, and the number of shared strata (broken line) in each region.

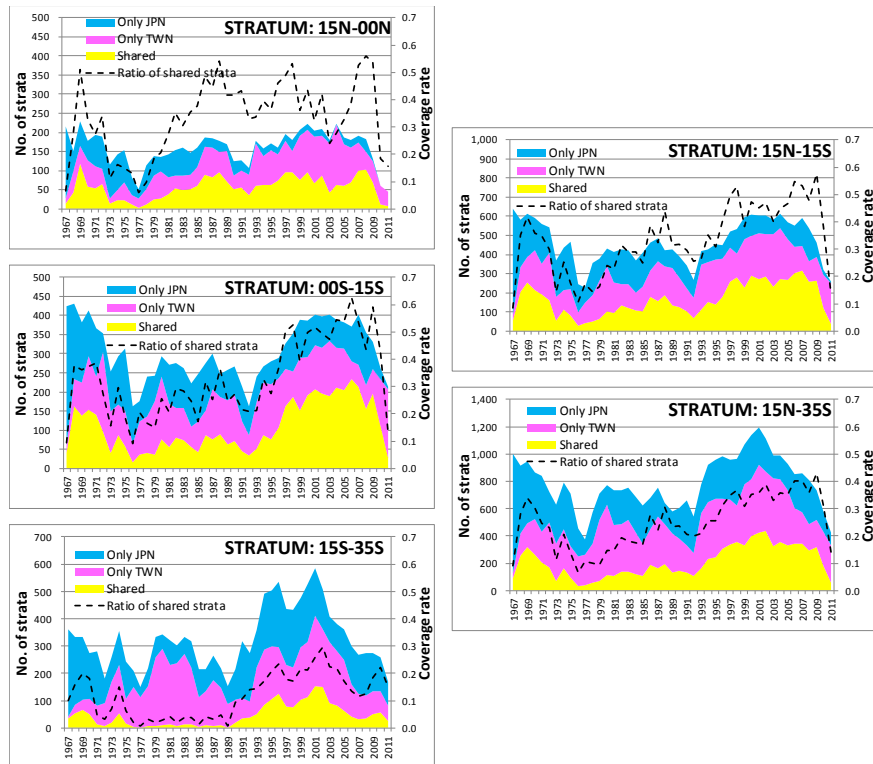


Fig. 4 Historical change in the number of shared (yellow), non-shared Japanese (blue) and non-shared Taiwan-China (pink) strata, and ratio of shared strata (broken line) in all strata covered by both fleets in each region.



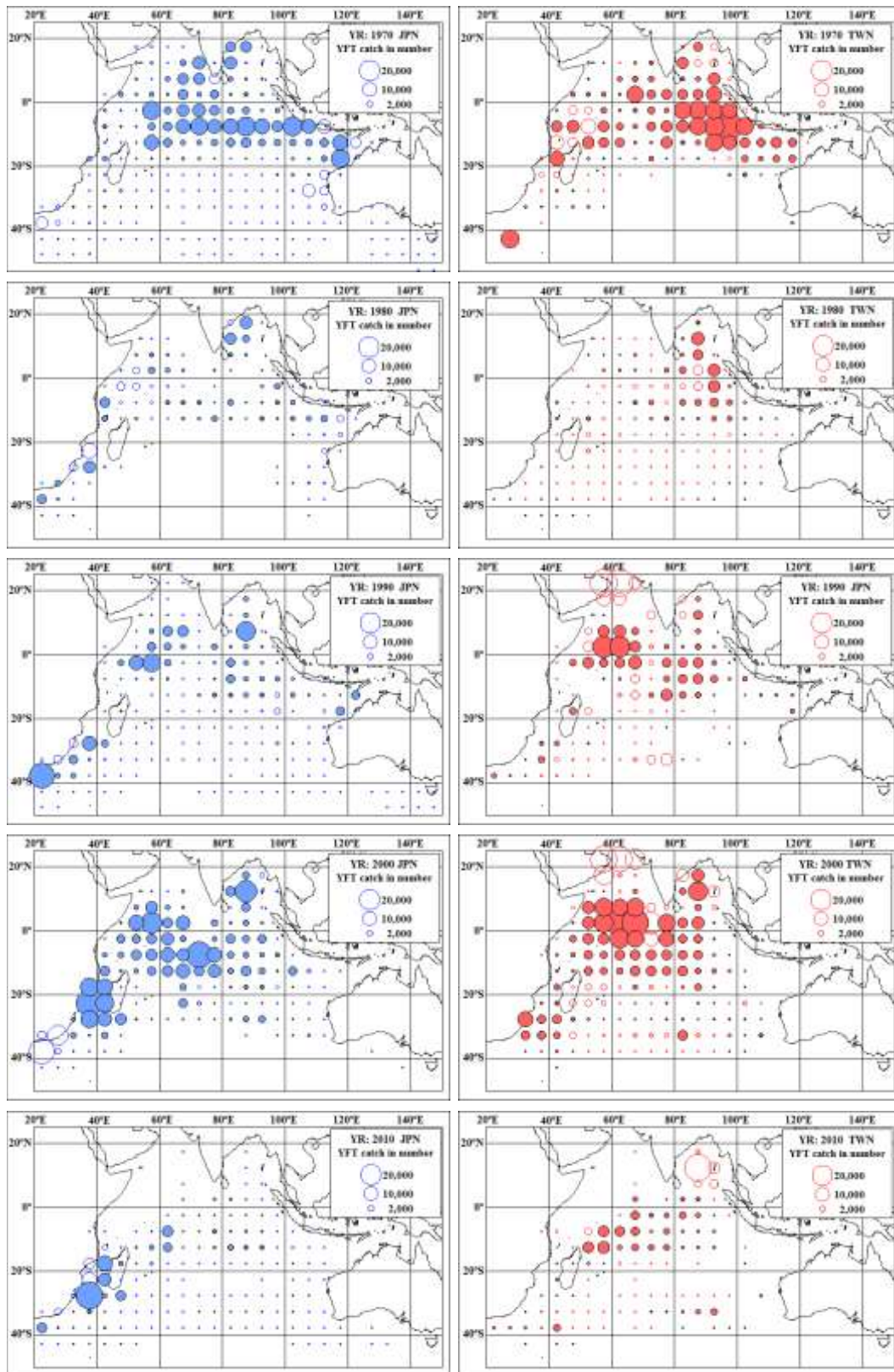


Fig. 5 Distribution of yellowfin catch in number for Japanese (left) and Taiwan-China (right) longline fisheries in each sample year (1970, 1980, 1990, 2000 and 2010). Solid circle and open circle mean shared and non-shared strata, respectively.

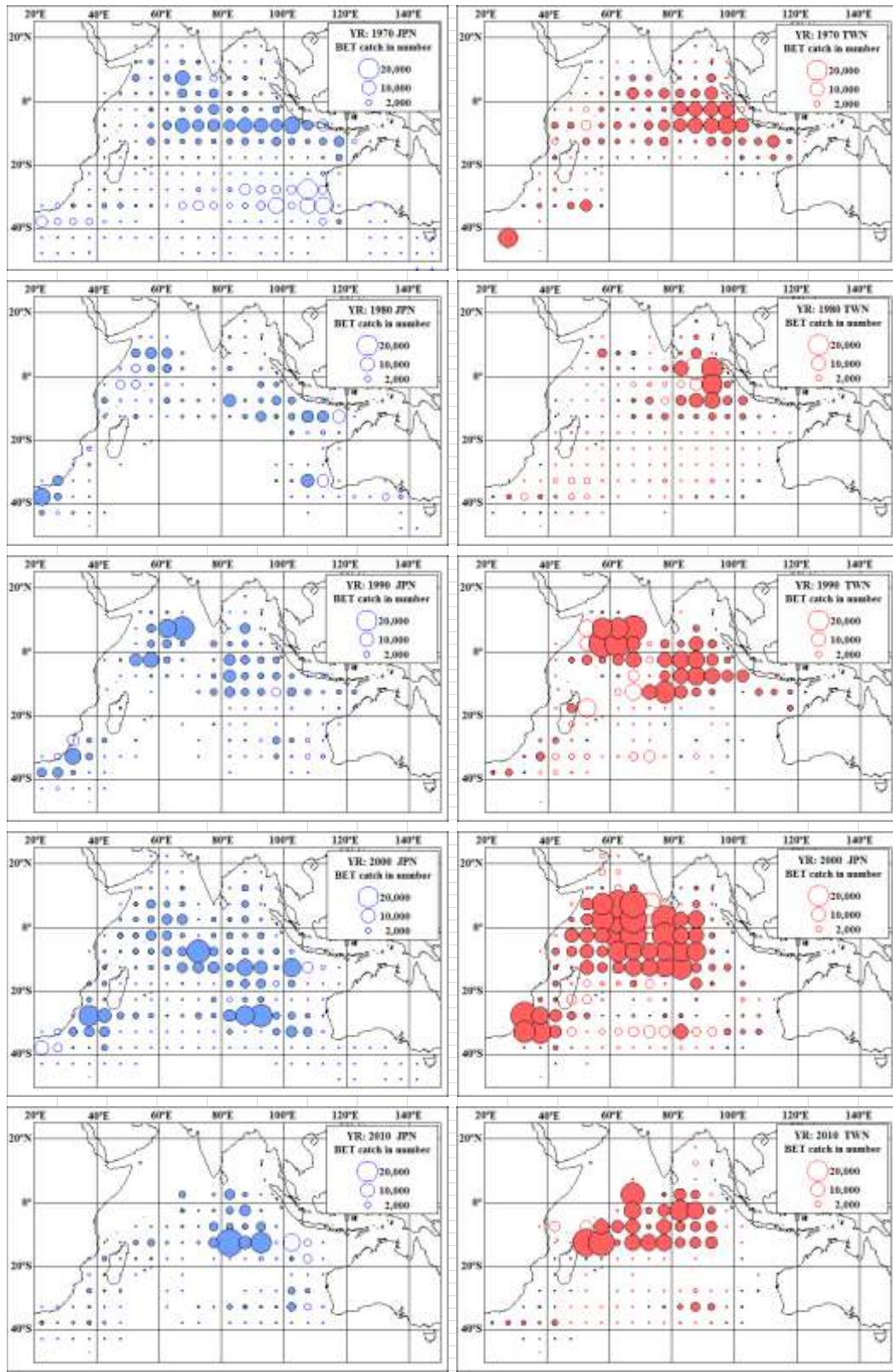


Fig. 6 Distribution of bigeye catch in number for Japanese (left) and Taiwan-China (right) longline fisheries in each sample year (1970, 1980, 1990, 2000 and 2010). Solid circle and open circle mean shared and non-shared strata, respectively.

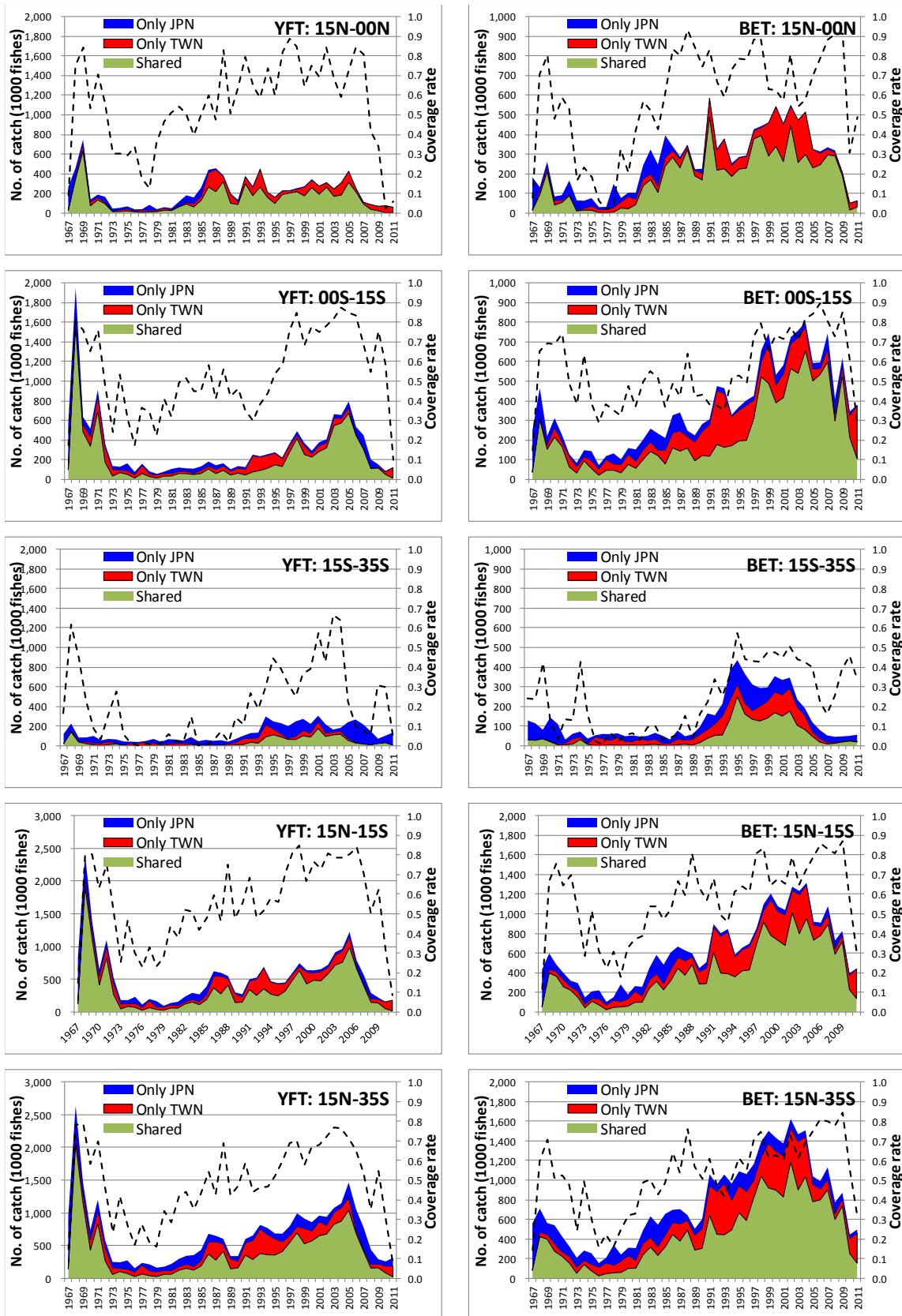


Fig. 7 Catch of bigeye and yellowfin in number in shared (green), non-shared Japanese (blue) and non-shared Taiwan-China strata in five different latitudinal categories. Broken line means coverage ratio of bigeye and yellowfin catches in shared strata to those in whole strata.

Whole strata

Shared strata

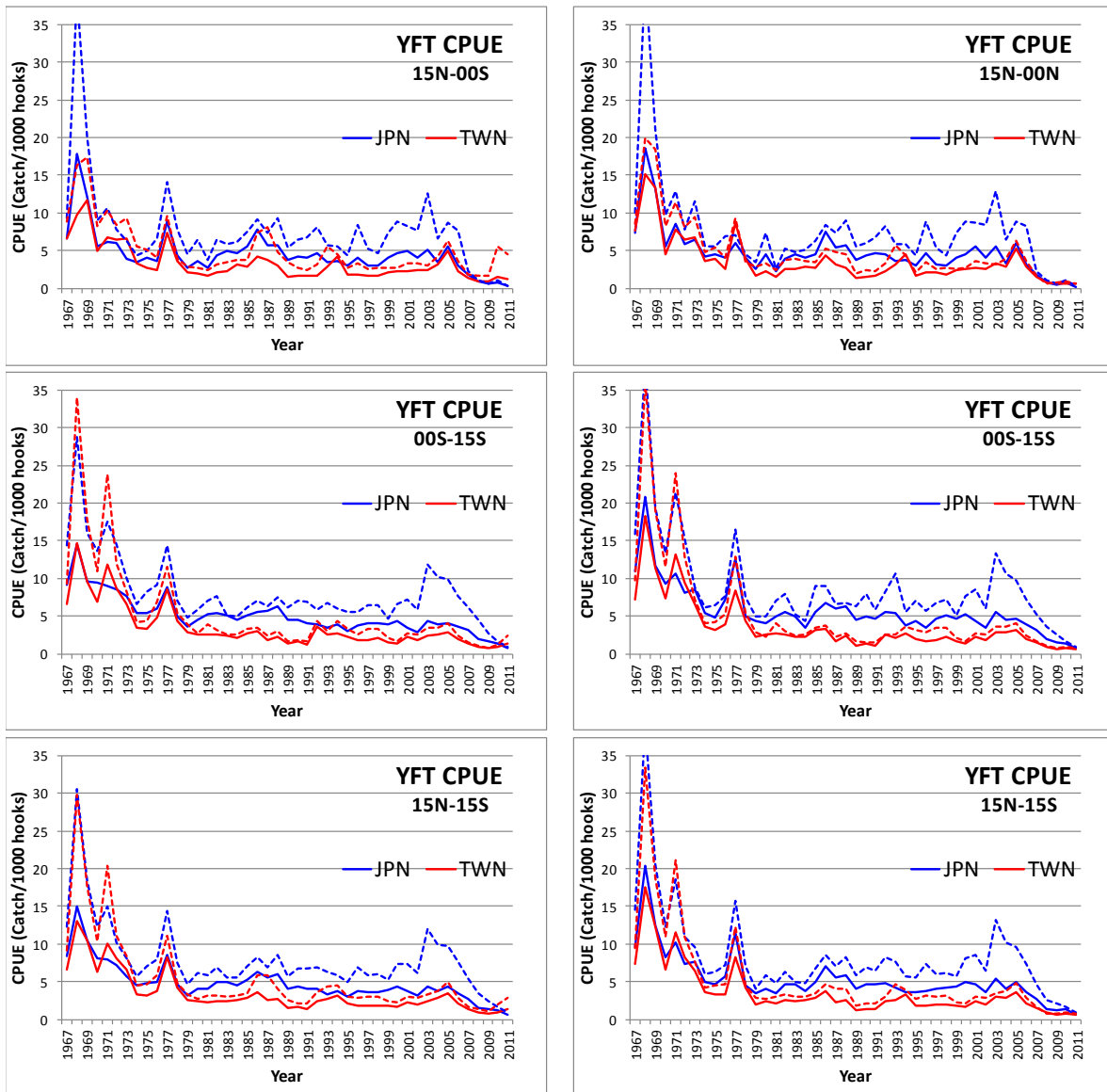


Fig. 8 Standardized (solid line) and nominal (dashed line) CPUEs of JPN (blue) and TWN-CHN (red) longline fisheries derived from whole (left) and shared (right) strata for yellowfin expressed in real scale.

Whole strata

Shared strata

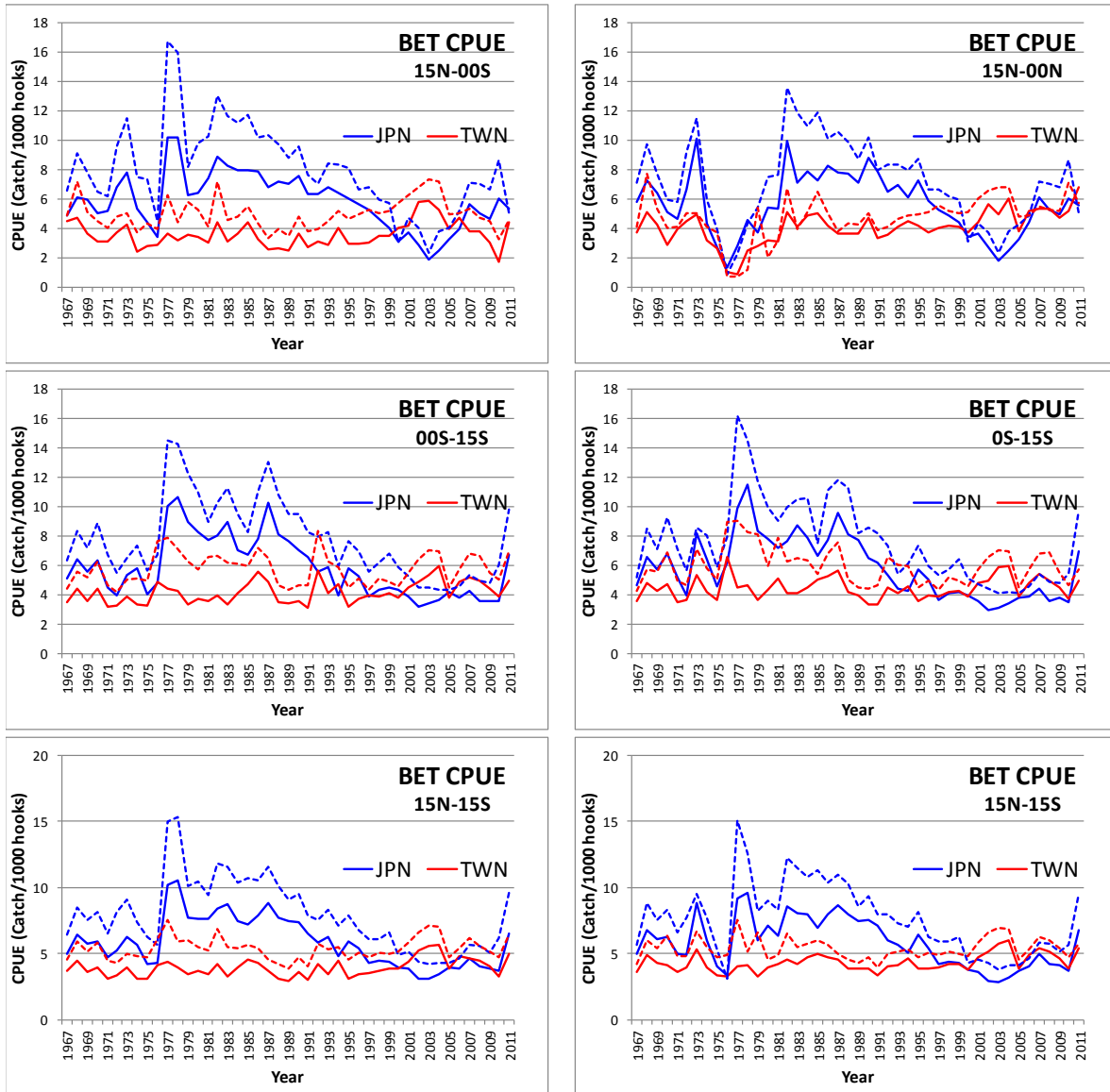


Fig. 9 Standardized (solid line) and nominal (dashed line) CPUEs of JPN (blue) and TWN-CHN (red) longline fisheries derived from whole (left) and shared (right) strata for bigeye expressed in real scale.

Whole strata

Shared strata

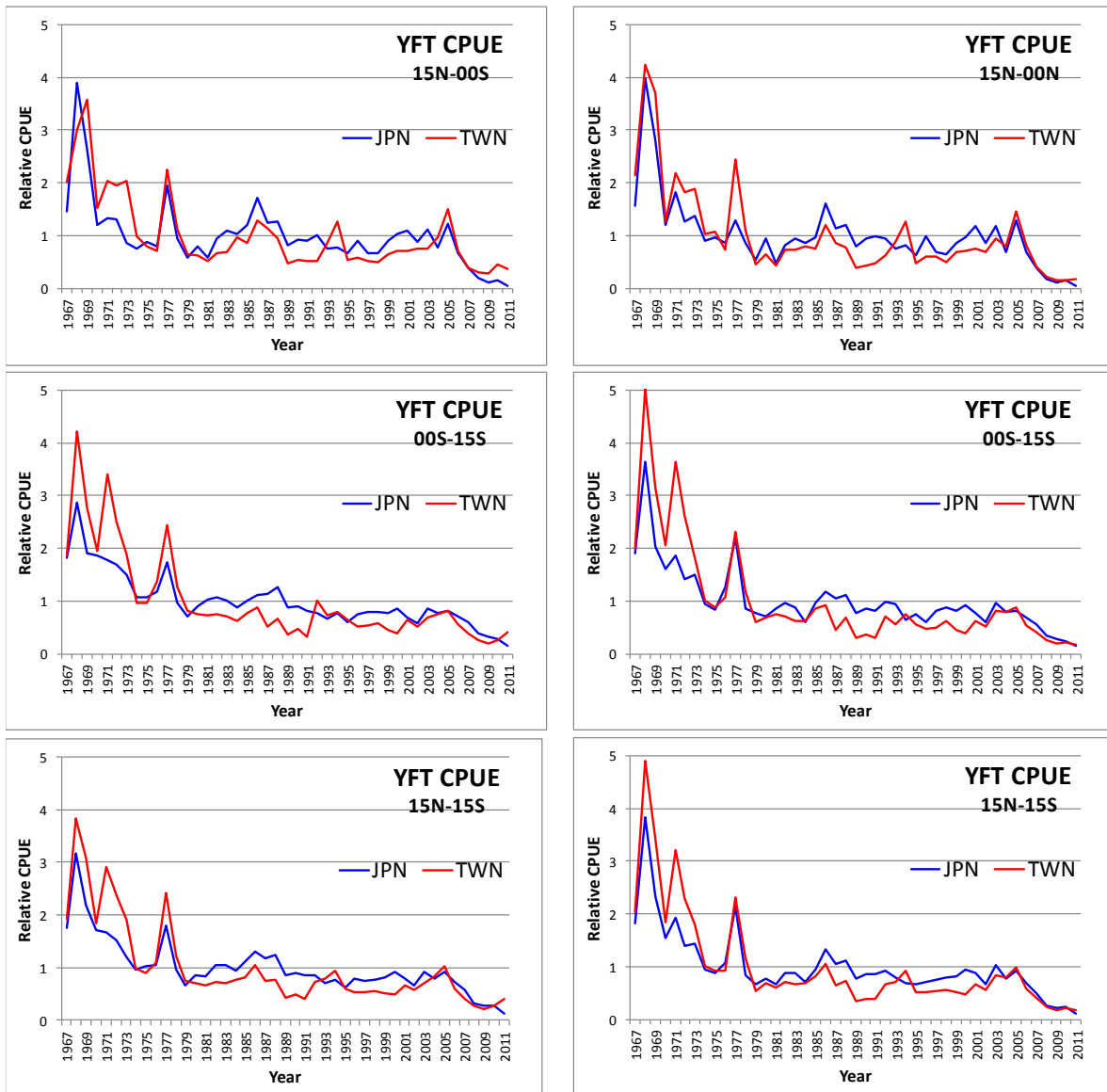


Fig. 10 Standardized CPUE of JPN (blue) and TWN-CHN (red) longline fisheries derived from whole (left) and shared (right) strata for yellowfin in relative scale expressed the average from 1967 to 2011 as 1.0.

Whole strata

Shared strata

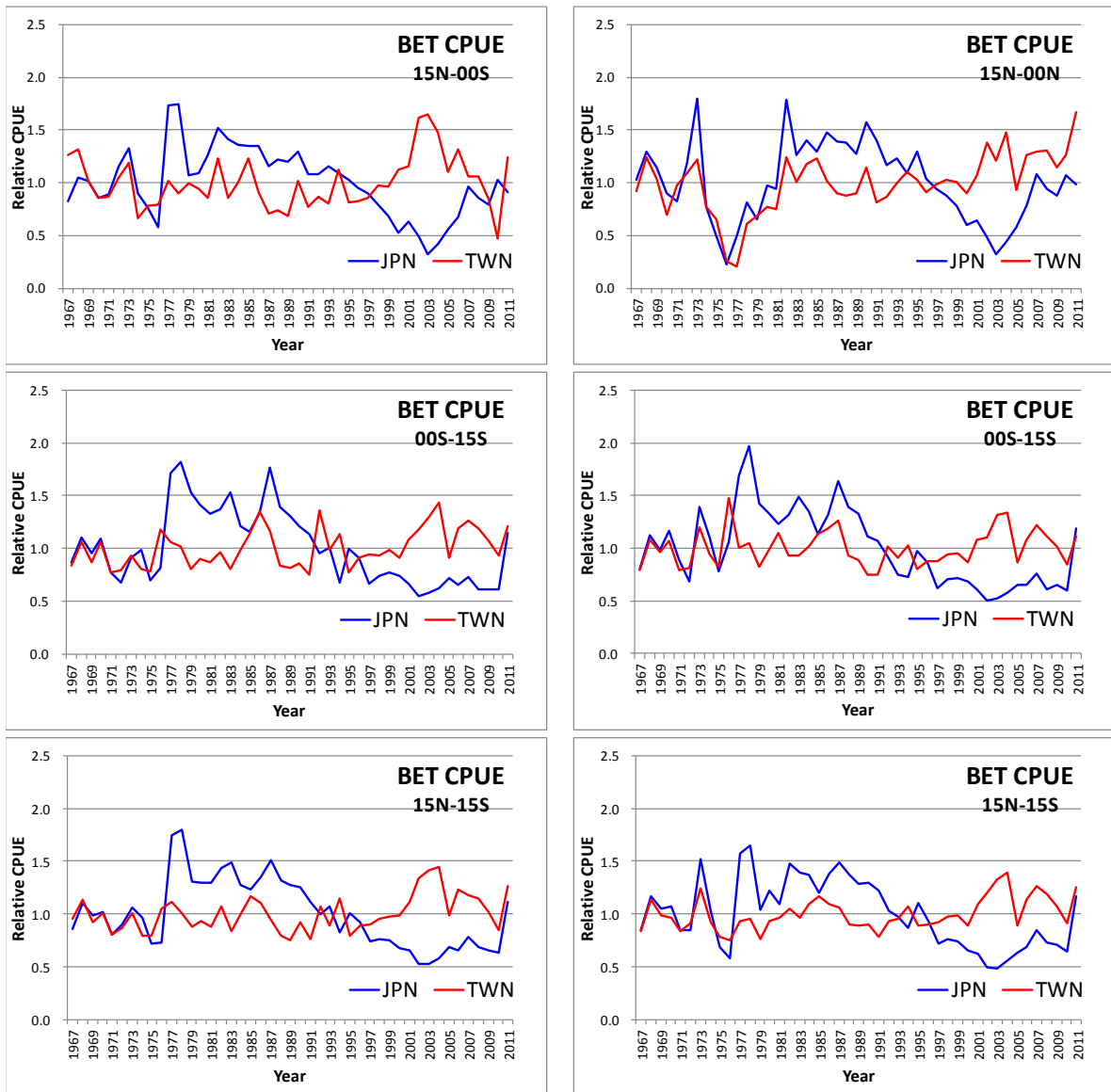


Fig. 11 Standardized CPUE of JPN (blue) and TWN-CHN (red) longline fisheries derived from whole (left) and shared (right) strata for bigeye in relative scale expressed the average from 1967 to 2011 as 1.0.