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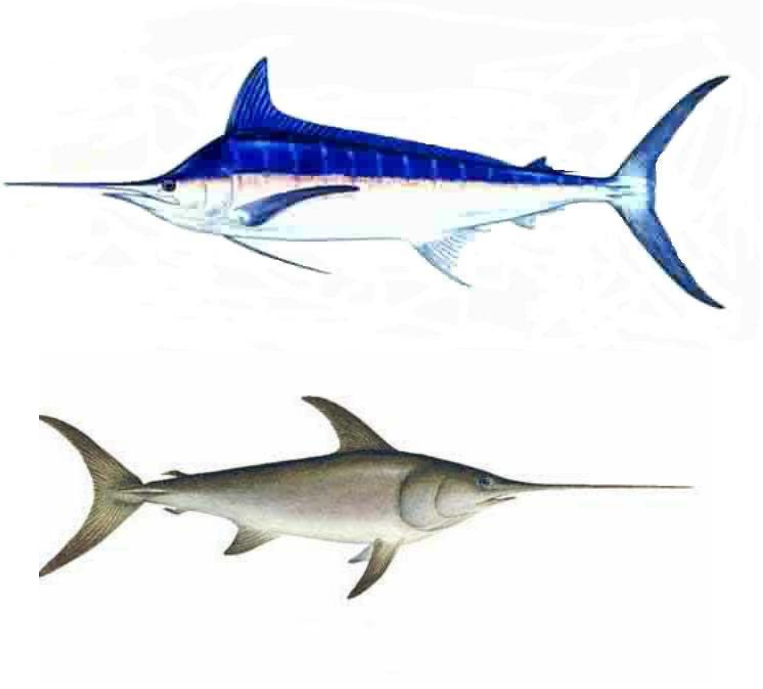

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Analysis of the operation pattern and catch-rates of blue marlin for the Japanese and Taiwanese longline fisheries in the Pacific Ocean*

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Abstract

Blue marlin is one of the most important bycatch species of tuna longline fisheries, and distributed throughout tropical, sub-tropical, and temperate waters of the Pacific Ocean. The use of deep and super deep operational setting types (defined by the number of hooks per basket) have been increasing since 1975 in the Japanese longline fleets in tropical waters, whereas the shallow and regular operational setting types are still the primary operation types in temperate waters. For the Taiwanese longliner fleet, the deep and super deep operation types have become the most popular operation types in the tropical waters in recent years while the regular settings are still the main fishing gear in temperate waters. The spatial heterogeneity in the fishing effort is evident for these two fleets in the Pacific Ocean. The overlapping fishing grounds between the Japanese and Taiwanese longline fleets mainly locate at the tropical areas of the eastern Pacific Ocean, which could be the region if we want to further compare the catch-rates of blue marlin historically between these two fisheries.

1. Introduction

Blue marlin, *Makaira nigricans*, is a cosmopolitan species distributed throughout tropical, sub-tropical and temperate waters between 50˚N and 50˚S (Shaklee et al., 1983). Blue marlin are generally found in surface waters and are an important bycatch species in the high seas longline fisheries targeting tunas and billfishes in the Pacific Ocean (Molony, 2005). Small catches of blue marlin are also caught in surface gears, such as gillnets and harpoons, as well as by recreational, purse seine, and baitboat fisheries (Hinton, 2001). According to the landing data of blue marlin reported to the FAO, the Japanese and Taiwanese longline fleets are the main fleets catching blue

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marlin in the Pacific Ocean. The objectives of this study is to analyze and examine the operation pattern and catch-rates of blue marlin for the Japanese and Taiwanese longline fisheries in the Pacific Ocean, because the gear setting of longline fisheries had significantly changed during the past decades both for these two fleets, i.e., the deep settings have become popular in recent years to target bigeye tuna.

2. Materials and methods

Catch and effort data from the Japanese and Taiwanese longline fleets operating in the Pacific Ocean were collected from the National Research Institute of Far Sea Fisheries (Japan) and the Overseas Fisheries Development Council of the Republic of China (Taiwan), respectively. In addition to the temporal information (year and month), information on location (latitude and longitude in 5˚ blocks), fishing effort (number of hooks), gear operation (number of hooks between baskets), and catch (number) of blue marlin is also available in the catch-effort records. Data span the years 1975 to 2006 for Japanese longliners, and from 1995 to 2006 for Taiwanese longline fleets operating in the Pacific Ocean (Table 1). While catch and effort data are available back to the 1950s, gear operations data were not collected.

The operating type is defined as the number of hooks between each float, i.e. hooks per basket (HPB). The operation setting for the Japanese and Taiwanese longline fleets was divided into four categories according to HPB. The HPB of shallow sets for both fleets is defined as 3 to 6, whereas 7-11 HPB is for regular sets, 12-16 HPB for deep sets, and 17-22 HPB for the super deep sets (Yokawa and Uozumi, 2001). The operating sets of the Japanese and Taiwanese longline fleets with more than 22 or less than 3 HPB were excluded from this analysis because these data may contain some biased and extreme information.

The nominal catch-rates (CPUE, catch-per-unit-of-effort) of blue marlin caught by the Japanese and Taiwanese longline fleets were plotted by operation type for each area within a region in the Pacific Ocean (Figure 1).

The “overlap rate” of fishing effort between the Japanese and Taiwanese longline fleets operating in the Pacific Ocean was calculated as the minimum of the probability of fishing effort employed in each 5-degree grid. The probability was defined as the number of hooks associated with a particular operation type in each 5-degree grid divided by the total number of fishing effort. Grid specific overlap rates were computed by summing the probability over all grid cells at a particular temporal scale, e.g. by month or by year, to obtain an “overlap rate” between these two longline fleets.

Overlap rates were mapped to examine the main fishing grounds for the Japanese and Taiwanese longline fleets, and as a means to compare operation patterns and catch-rates of blue marlin.

3. Results and discussion

Temporal trends in fishing effort (number of hooks) associated with Japanese longline fleets for each area within a region is depicted in Figures 2-5. Within regions, the distribution of Japanese longline fishing effort among areas exhibited significant spatial heterogeneity. The use of deep and super deep setting generally increased in recent years in tropical waters, whereas the shallow and regular settings remained the primary operation types in temperate areas.

Temporal trends in fishing effort associated with Taiwanese longline fleets for each area within a region is depicted in Figures 6-9, and also exhibited significant spatial heterogeneity. Taiwanese longliner fishing in the eastern tropical areas of the Pacific Ocean commenced in the mid 1990s (HPB data are not available before 1995) and thereafter increased significantly (Figure 8). The deep and super deep operation types have become the most popular operation types in tropical waters, while regular settings is still the primary fishing gear in temperate areas.

Temporal trends in blue marlin nominal CPUE by operation type in each area within a region for Japanese longline fleets is depicted in Figures 10-13. Nominal CPUE for deep setting operations of the Japanese longliners provides the most reliable time-series of catch-rates when compared to CPUE trends from the shallow, regular, and super deep operation settings. The utility of CPUE trends from the Taiwanese longline fleets is limited due to the paucity of data (Figures 14-17) However, there are several areas within a region where CPUE associated with the Taiwanese longliners may be reliable and these areas could be considered the main fishing grounds of Taiwanese longline fleets.

In tropical waters, there is no obviously seasonal change on gear setting for the Japanese longliners. However, the shallow settings are the most predominant operation type during the second quarter of the year (April to June) in the northern temperate areas of the Pacific Ocean for the Japanese longline fleets, especially in the waters off Japan. In contrast, regular settings is the most frequent gear type used by Taiwanese longliners in the southern temperate waters throughout the year. For both the Japanese and Taiwanese longline fleets, the deep and super seep settings have

become the most popular fishing gear in the tropical Pacific Ocean in recent years.

For Japanese longline fleets, bigeye tuna is the main target species in the eastern Pacific Ocean while yellowfin tuna is the main target species in the western Pacific Ocean. Albacore tuna have historically been the target species of Taiwanese longline fleets in the Pacific Ocean, especially in the southern temperate waters (results not shown). However in recent years, deep and super deep operation settings of the Taiwanese longline fleets have become the most popular fishing gear in the eastern tropical Pacific Ocean targeting bigeye tuna.

Figure 18 indicated that the “overlap rate” for each year and by quarter between the Japanese and Taiwanese longline fleets increased significantly since 1995. The same pattern is observed at the quarterly time step. The maps of spatially “overlap rate” in fishing effort between these two fleets were plotted for two different periods, 1995-2006 and 2000-2006. The “overlap rate” in spatial distribution between these two fleets overlapped primarily in the eastern tropical Pacific Ocean (Figures 19 and 20). All the results suggested that the major overlapping fishing grounds between the Japanese and Taiwanese longline fleets occurs in the eastern Pacific Ocean and future between fleet comparisons in CPUE, size structure of the catch and operational characteristics if the fishery may be appropriate in this area, in particular areas E.Trop(4) and E.Trop(5).

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Table 1. The catch and effort dataset for the Japanese and Taiwanese longline fleets in the Pacific Ocean.

Variable	Abbreviation	Japanese fleet	Taiwanese fleet
Fishing effort	Hooks	1975~2006	1975~2006
Hooks per basket	HPB	1975~2006	1995~2006
Year	Yr	1975~2006	1975~2006
Month	Mo	1975~2006	1975~2006
Latitude (5˚)	Lat	1975~2006	1975~2006
Longitude (5˚)	Lon	1975~2006	1975~2006
Catch of blue marlin	BUM	1975~2006	1975~2006

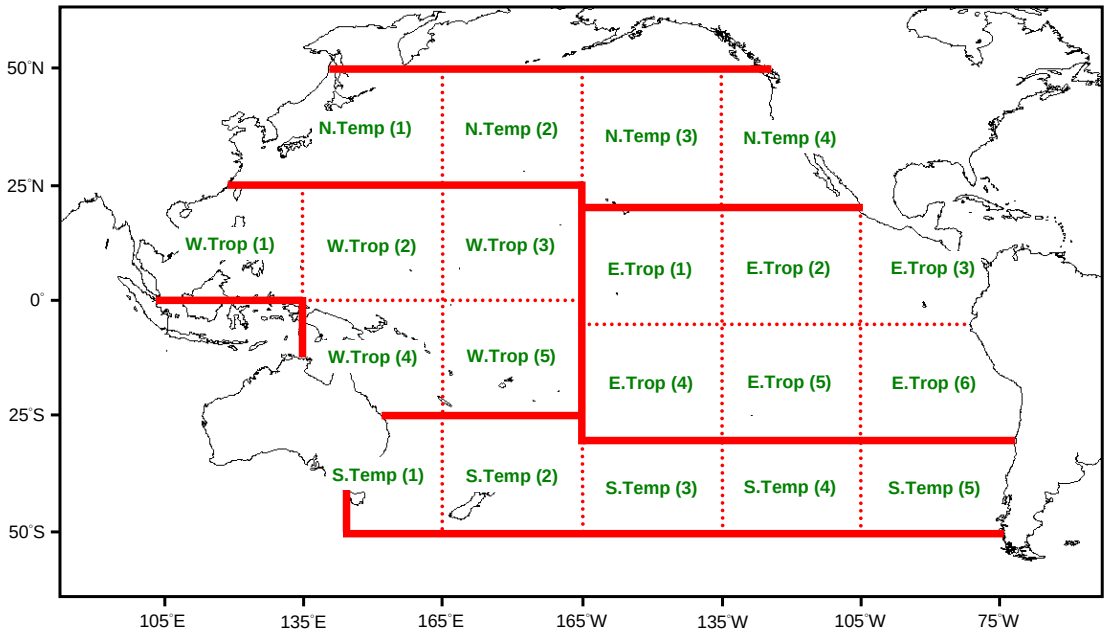

Fig. 1. The region (divided by solid lines) and area (denoted by numbers) stratification of the Pacific Ocean used in this study.

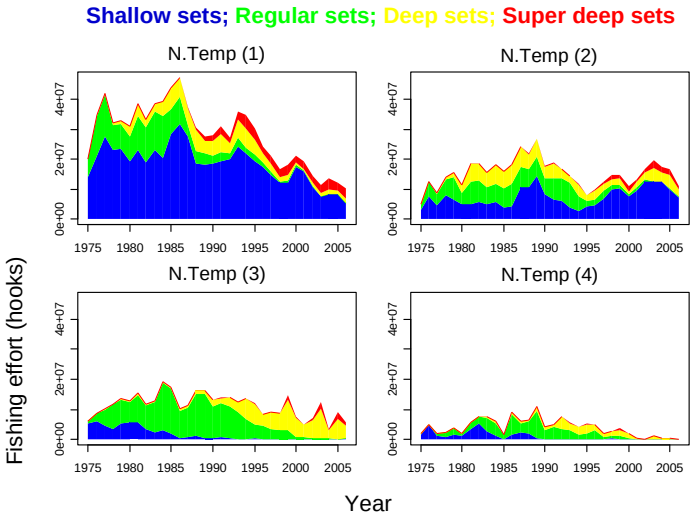

Fig. 2. The fishing effort (in hooks) by gear set in the region “N.Temp” for the Japanese longline fleet in the Pacific Ocean during 1975-2006.

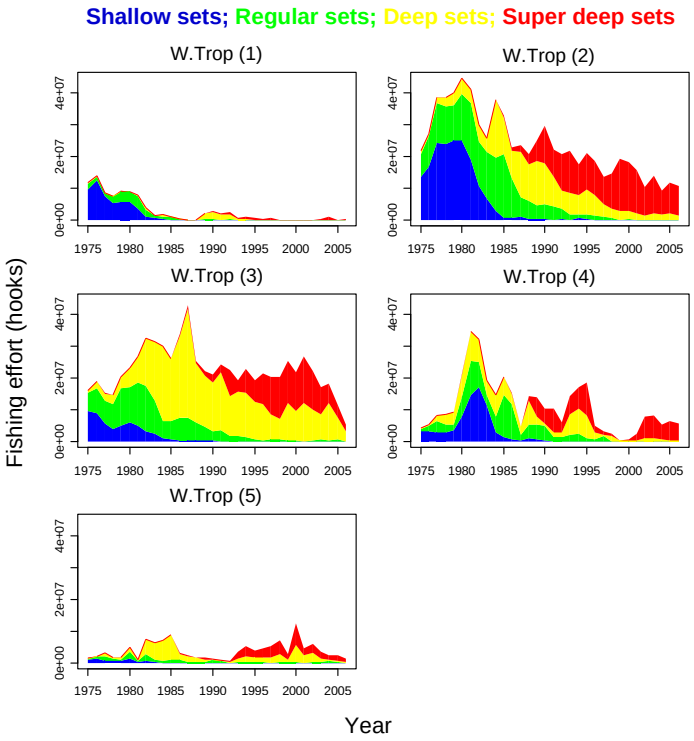

Fig. 3. The fishing effort (in hooks) by gear set in the region “W.Trop” for the Japanese longline fleet in the Pacific Ocean during 1975-2006.

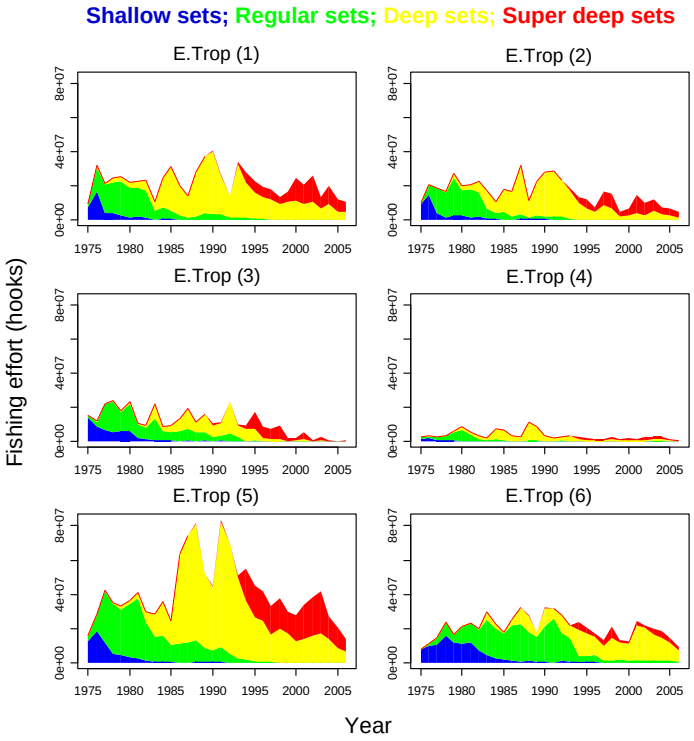

Fig. 4. The fishing effort (in hooks) by gear set in the region “E.Trop” for the Japanese longline fleet in the Pacific Ocean during 1975-2006.

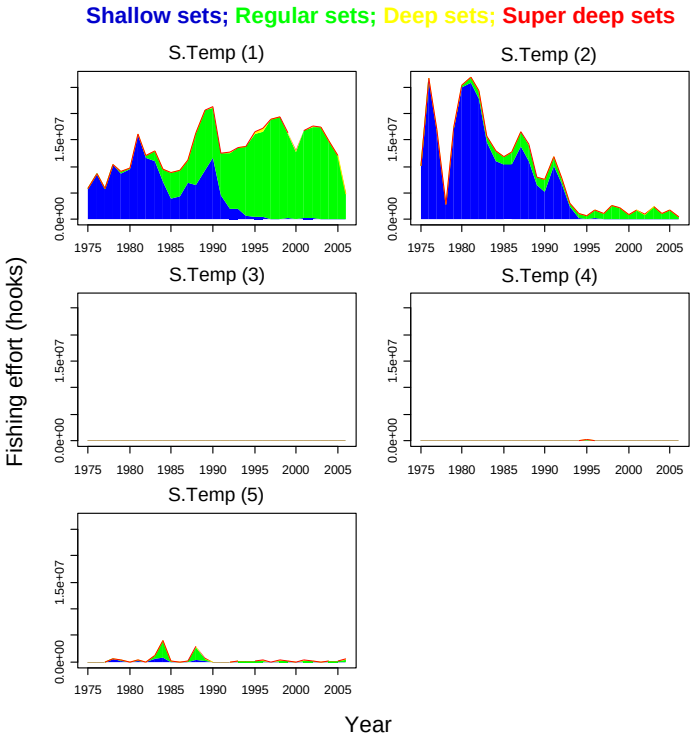

Fig. 5. The fishing effort (in hooks) by gear set in the region “S.Temp” for the Japanese longline fleet in the Pacific Ocean during 1975-2006.

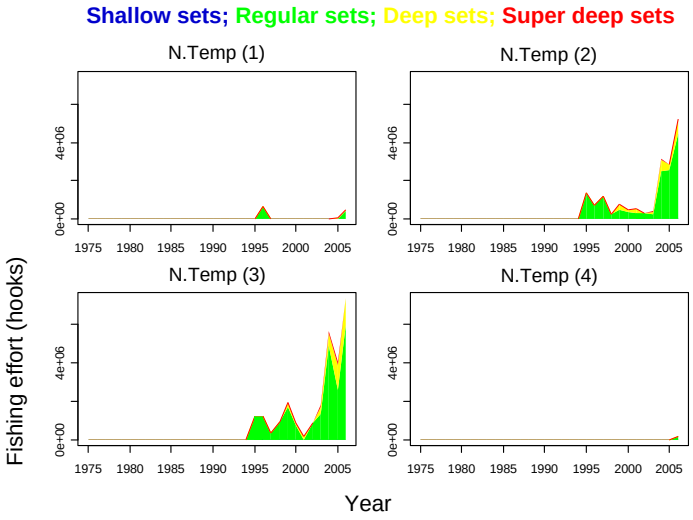

Fig. 6. The fishing effort (in hooks) by gear set in the region “N.Temp” for the Taiwanese longline fleet in the Pacific Ocean during 1975-2006.

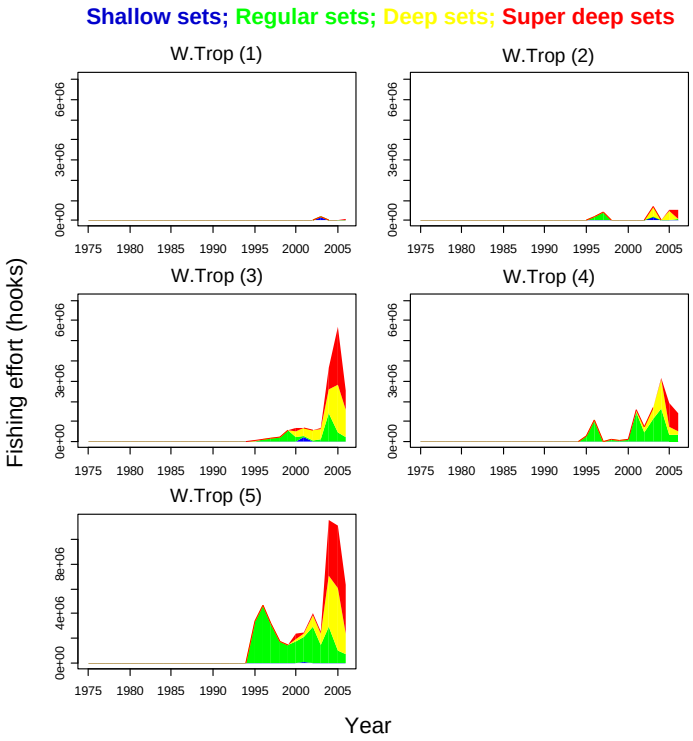

Fig. 7. The fishing effort (in hooks) by gear set in the region “W.Trop” for the Taiwanese longline fleet in the Pacific Ocean during 1975-2006.

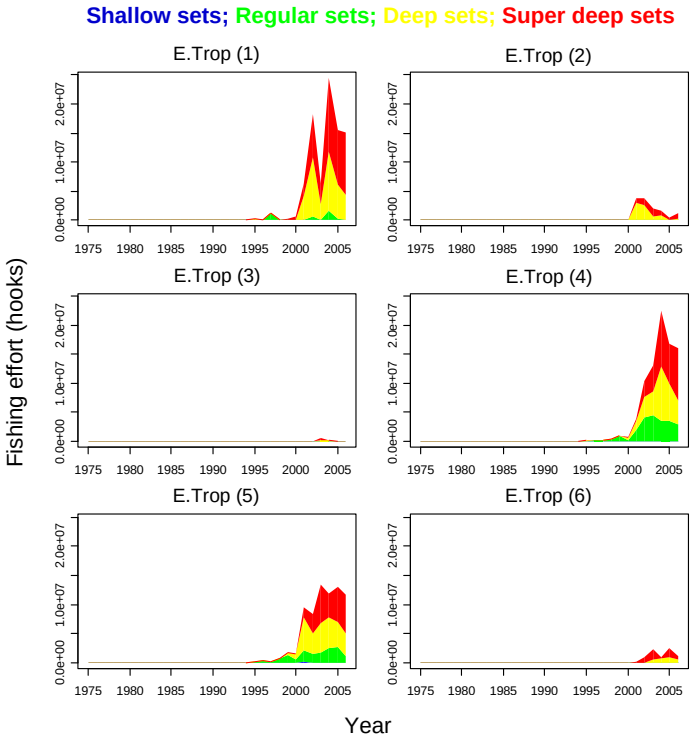

Fig. 8. The fishing effort (in hooks) by gear set in the region “E.Trop” for the Taiwanese longline fleet in the Pacific Ocean during 1975-2006.

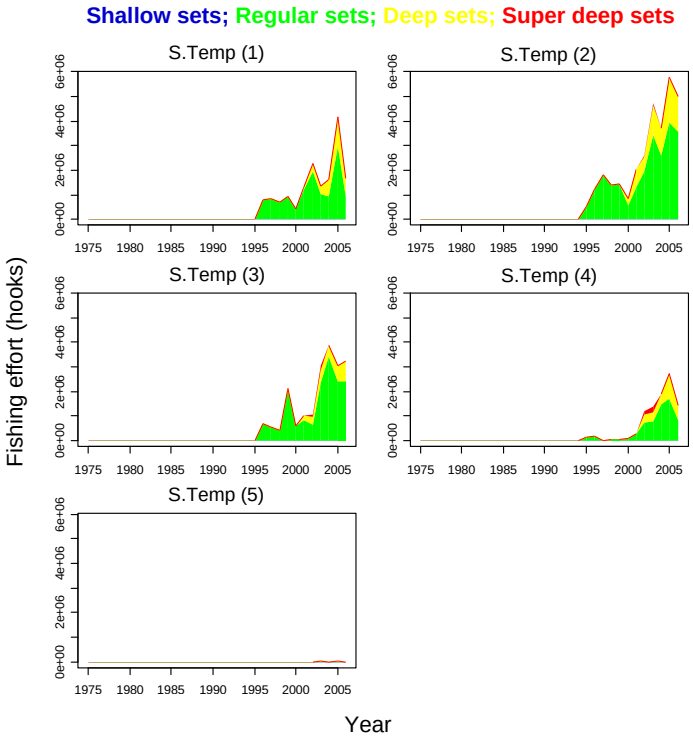

Fig. 9. The fishing effort (in hooks) by gear set in the region “S.Temp” for the Taiwanese longline fleet in the Pacific Ocean during 1975-2006.

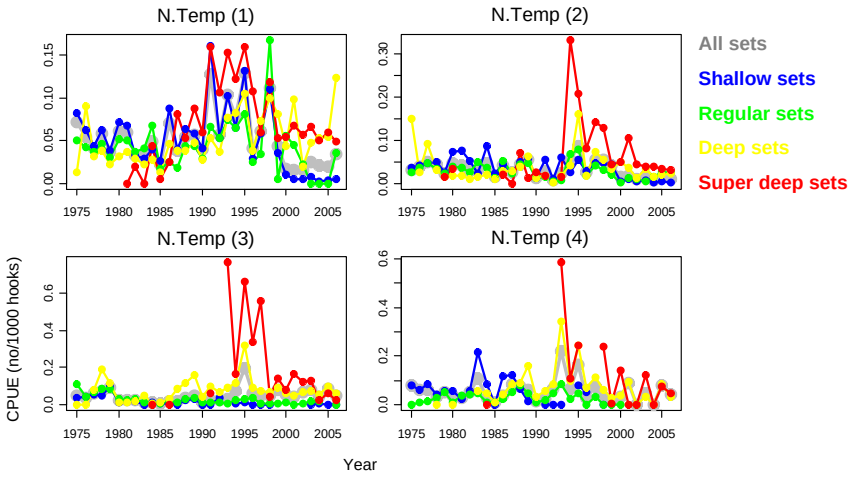

Fig. 10. Nominal CPUE by gear set for blue marlin caught by Japanese longline fleet in the region “N.Temp” of the Pacific Ocean during 1975-2006.

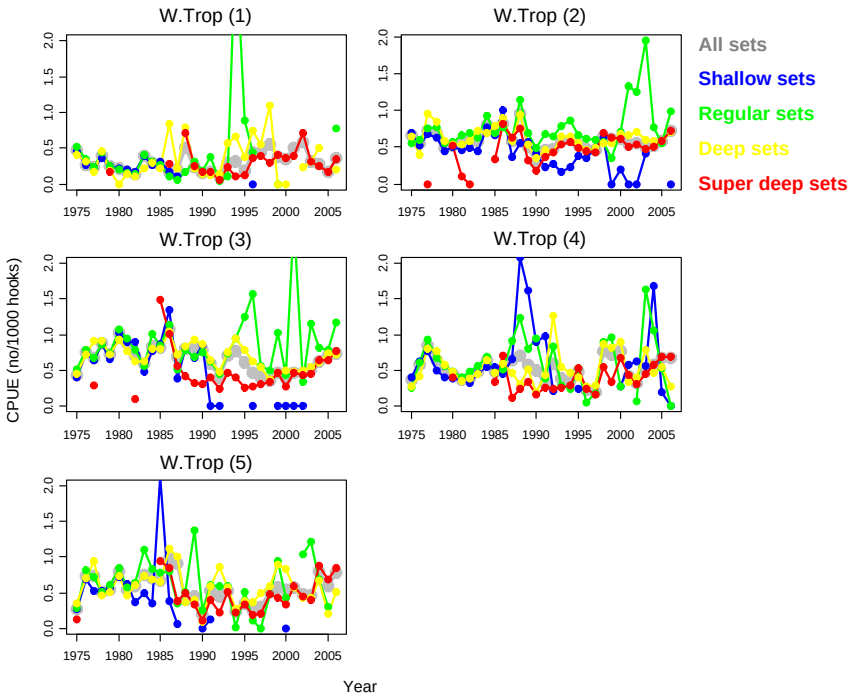

Fig. 11. Nominal CPUE by gear set for blue marlin caught by Japanese longline fleet in the region “N.Temp” of the Pacific Ocean during 1975-2006.

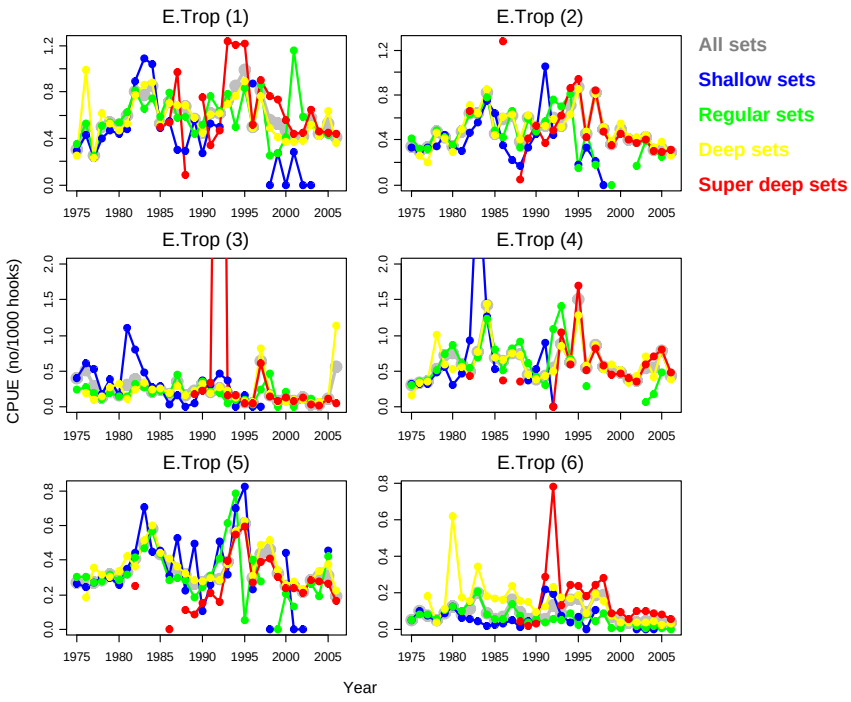

Fig. 12. Nominal CPUE by gear set for blue marlin caught by Japanese longline fleet in the region “N.Temp” of the Pacific Ocean during 1975-2006.

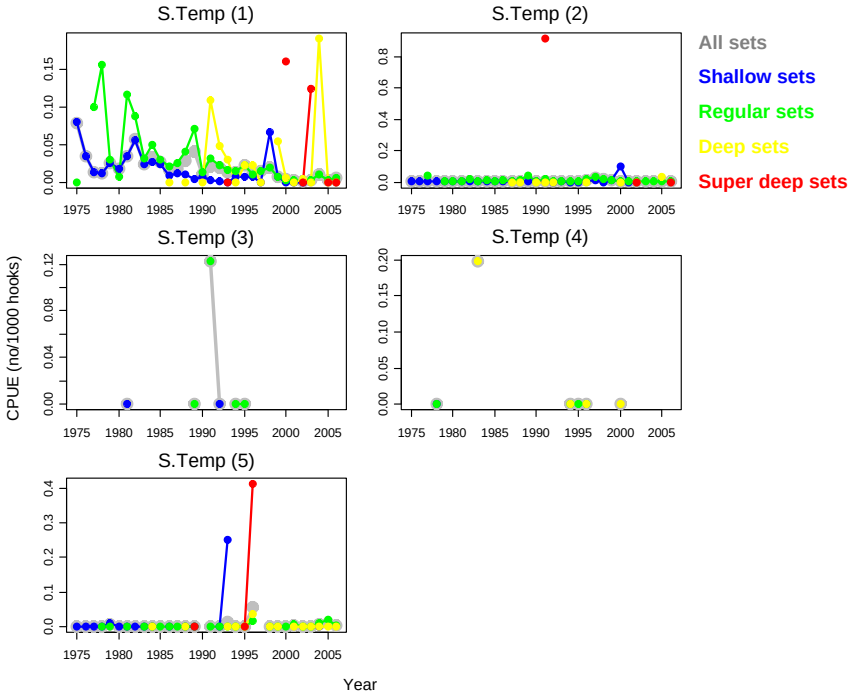

Fig. 13. Nominal CPUE by gear set for blue marlin caught by Japanese longline fleet in the region “N.Temp” of the Pacific Ocean during 1975-2006.

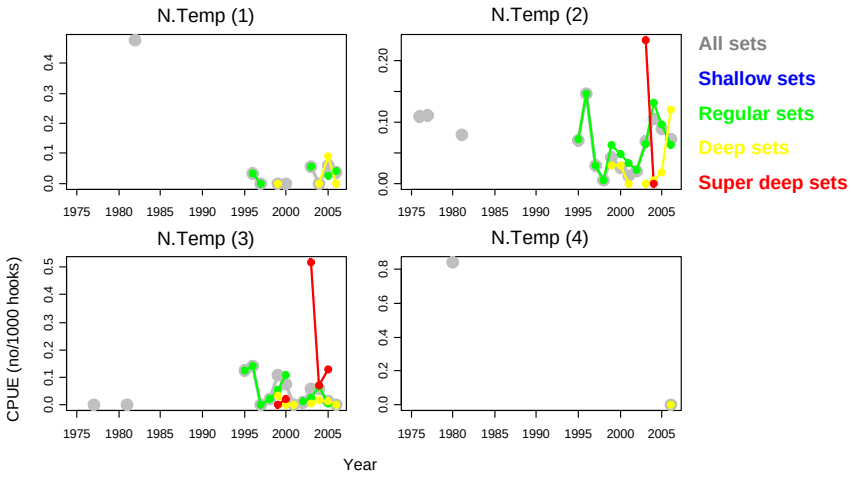

Fig. 14. Nominal CPUE by gear set for blue marlin caught by Taiwanese longline fleet in the region “N.Temp” of the Pacific Ocean during 1975-2006.

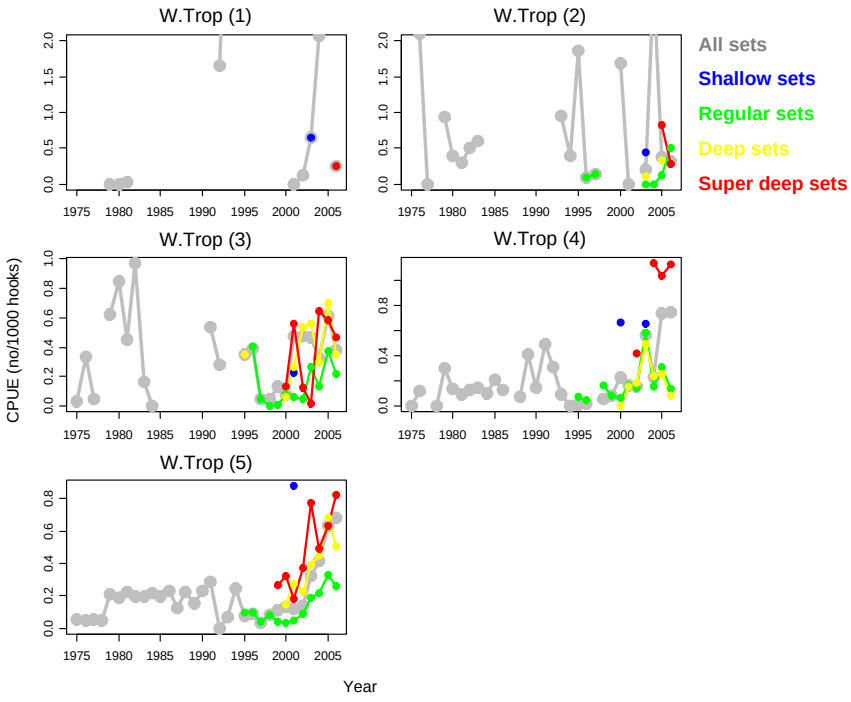

Fig. 15. Nominal CPUE by gear set for blue marlin caught by Taiwanese longline fleet in the region “N.Temp” of the Pacific Ocean during 1975-2006.

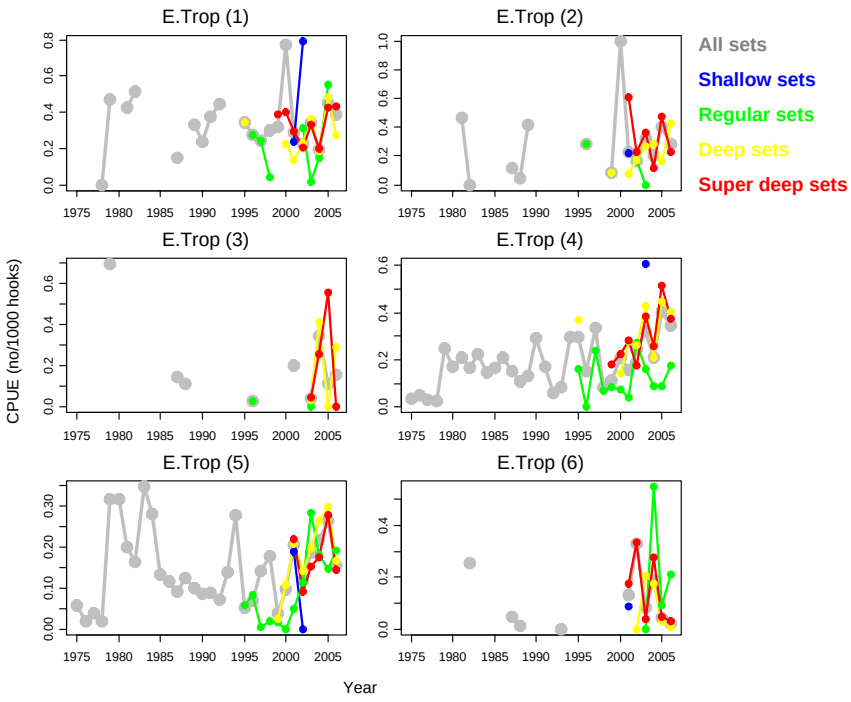

Fig. 16. Nominal CPUE by gear set for blue marlin caught by Taiwanese longline fleet in the region “N.Temp” of the Pacific Ocean during 1975-2006.

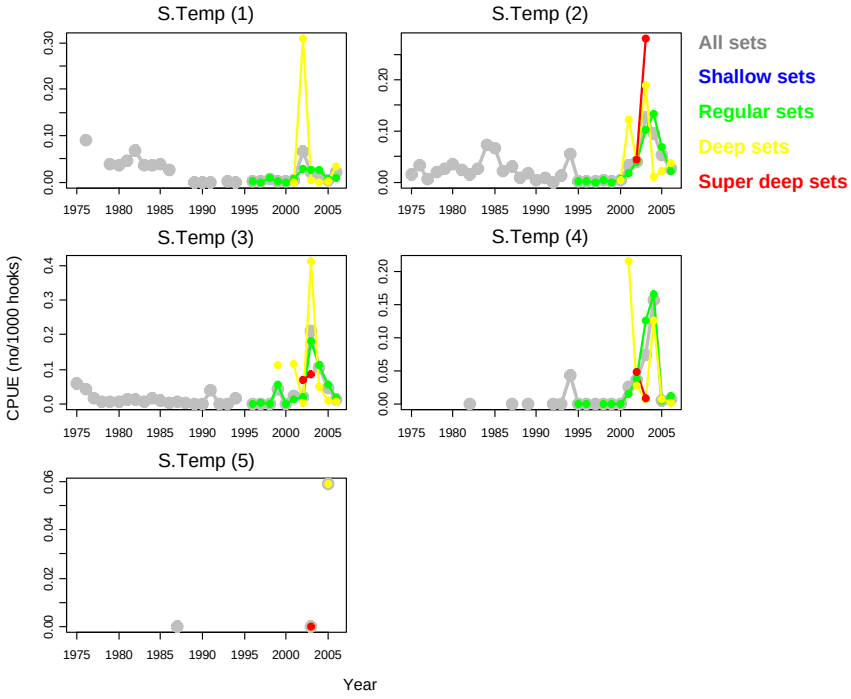

Fig. 17. Nominal CPUE by gear set for blue marlin caught by Taiwanese longline fleet in the region “N.Temp” of the Pacific Ocean during 1975-2006.

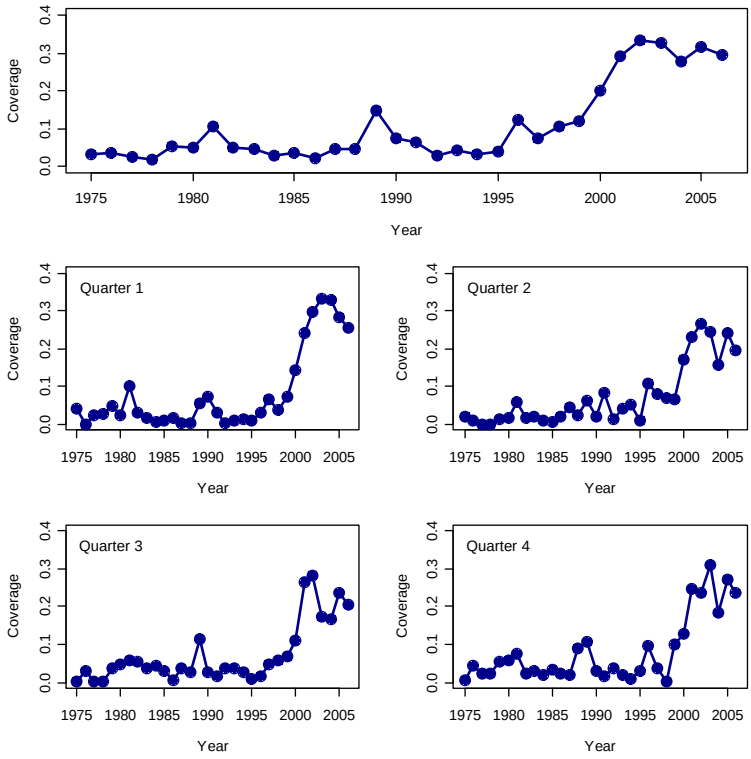

Fig. 18. The annual “overlap rates” of fishing effort and those calculated by quarter between Japanese and Taiwanese longline fleets in the Pacific Ocean.

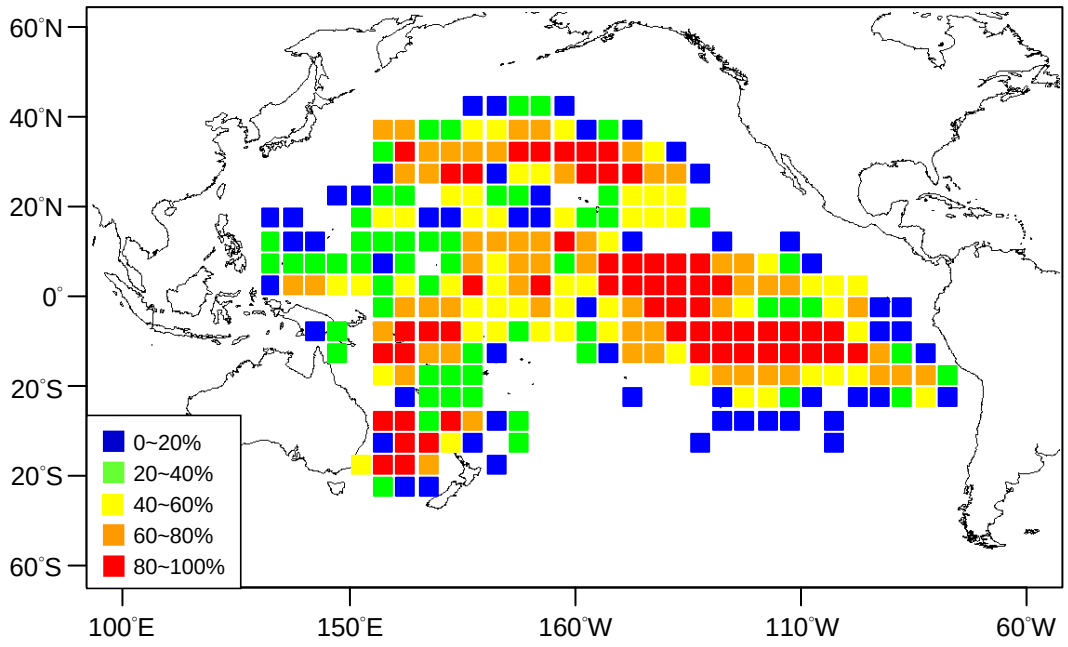

Fig. 19. The spatially “overlap rate” of fishing effort for each cell (1995-2006) between the Japanese and Taiwanese longline fleets in the Pacific Ocean.

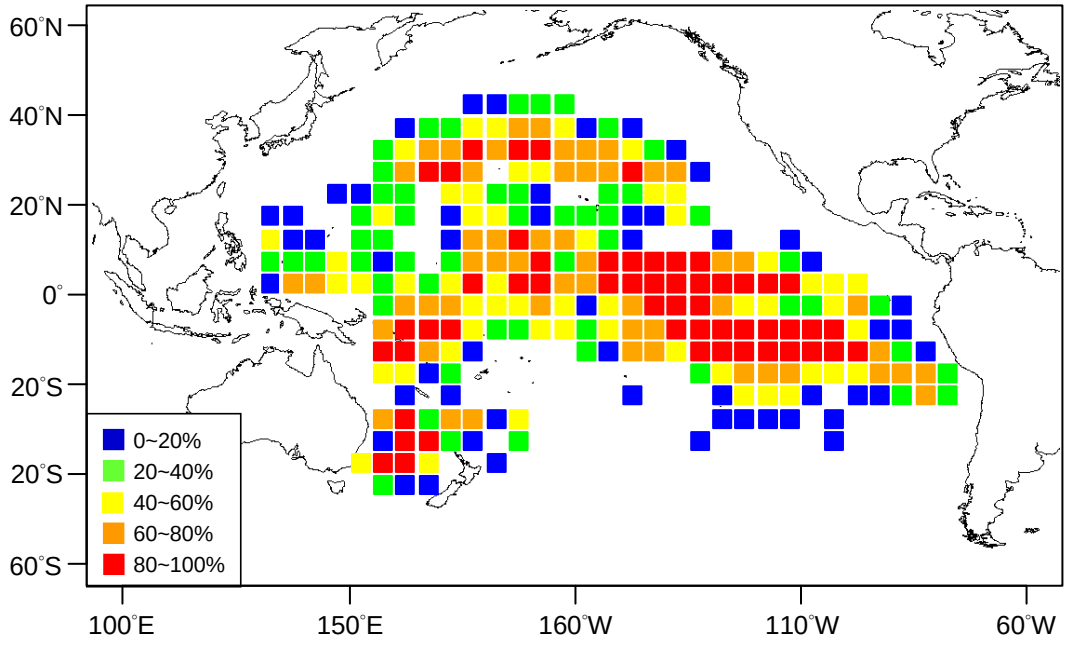

Fig. 20. The spatially “overlap rate” of fishing effort for each cell (2000-2006) between the Japanese and Taiwanese longline fleets in the Pacific Ocean.