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Cluster Analysis for Defining the Resource Distributed Area of North Atlantic Albacore Stock

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ABSTRACT

Albacore is the traditional target species for Taiwanese longline fleet in Atlantic Ocean. Three main geographical sub-areas in North Atlantic Ocean where Taiwanese longline fleet operated frequently were produced from three distinguished clusters, which were grouped from a total of 79 and 5×5 degree statistical blocks using cluster analysis. The overall mean CPUE (no. of fish per thousand hooks) from 4 main catch species, *i.e.*, albacore (*Thunnus alalunga*), bigeye tuna (*Thunnus obesus*), yellowfin tuna (*Thunnus albacares*) and swordfish (*Xiphias gladius*) in the 5×5 degree statistical blocks during 1968-2002 were used in the cluster analysis. The changes of temporal nominal CPUE series from 4 dominant catch species in three sub-areas were examined. Sub-areas 2 and 3, located in subtropical and temperate waters respectively, were closely related for the higher albacore CPUE. Sub-area 1, in tropical waters, had the higher CPUEs of bigeye tuna and yellowfin tuna but the lower and fluctuated albacore's CPUE. The delineation of the sub-area in this study could be used in constructing the General Linear Models for standardizing the catch rate of this stock.

***Key words**: Cluster analysis, North Atlantic Ocean, Albacore.*

INTRODUCTION

The practice of Taiwanese distant water longline fishery commenced around the 1960s, and began to operate in the Atlantic Ocean in the mid-1960s. The Atlantic Ocean is divided into the North Atlantic and South Atlantic by equatorial countercurrents at about 8°N. Also, for the stock management purpose, north and south stocks of Atlantic albacore, which were separated by 5°N, were assumed (ICCAT, 2001; Bard, 2003). Traditionally, North Atlantic albacore (NAA) was the main target species for Taiwanese regular longline fishery (RLL) in North Atlantic Ocean, and fishing efforts were usually distributed from 10°N to 40°N (ICCAT, 2001). Since mid-1980s, for the demanding of "sashimi" in Japan market, many longliners upgraded their facilities with super cold freezer (below minus 60°C) and operated more southward to catch the bigeye tuna, yellowfin tuna and swordfish. Thus, in addition the RLL to catch albacore, the deep longline fishery (DLL) for tropical tunas was also included in Taiwanese longline fishery (Wu and Yeh, 1996; 2000; 2002; and Yeh and Wu, 1996).

The temporal series of catch and effort data set of Taiwanese longline fishery in North Atlantic is important to elucidate the stock status of NAA. Not only the fishing effort was exerted in an extent wide area of North Atlantic Ocean, but also albacore was the main target species for the fleet. However the catch statistics data of Taiwanese longline fishery in Atlantic Ocean were somewhat heterogeneous since the deep longline fishery

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joined in late-1980s. Although longline fisheries may classify to multi-species fisheries for the diversity of catch species, yet the fishing method is species-directed. The fishing ground, bait, duration of set, and gear configuration are all depend on the target species closely (Gulland, 1983). Therefore, before conducting stock assessment for a given stock; it is usually necessary to determine and extract the specific species-directed efforts from the historical catch and effort data in logbooks.

Several methods of identifying "species-directed" catch and effort were developed. For examples, Suzuki *et al.* (1977) and Koido (1985) classified the regular and deep longline by number of branch lines between floats. In addition catch composition, which is an end-product of fishing practice, is also used to identify the type of fishing operations and/or fishing strategies (Rogers and Pikitch, 1992; Chang *et. al.,* 1993; Lewy and Vinther, 1994; He *et al.*, 1997; Lin *et. al.*, 1998).

The allocation patterns of fishing efforts are related to the stock abundance in their operating areas. Thus by means of the area classification on the NAA resource not only can elucidate the geographical distribution of this stock, but also provide an indirect method to identify the species-directed catch and effort from which originates RLL or DLL (Wu *et al.*, 2006).

The present paper attempts to (1) classify the traditional operating area of Taiwanese longliners into several sub-area-groups according to the similarity of the fishery structure, and (2) the sub-area defined in the present paper can be used in the further study of CPUE standardization on North Atlantic albacore.

MATERIALS AND METHODS

1. Catch and effort database

The analyzed catch and effort data, aggregated by monthly, by 5 × 5 degree statistical block and by species were provided by Oversea Fisheries Development Council (OFDC), the Republic of China from 1967 to 2002, and the 2002 data was preliminary. This data set is identical to TASK-II which was submitted to ICCAT for stock assessment use. The catch statistics data were divided into two data sets by 5°N latitude, which was the assumed geographic boundary for northern (including 5°N latitude) and southern Atlantic albacore stocks (ICCAT, 2001).

2. Fishing ground boundary for Taiwanese longline fishery

The boundary of fishing ground was decided by the operation frequency in each 5 × 5 degree statistical block. The total operation frequency was calculated on monthly basis for the period of 1968-2002. After an examination of the geographical distribution of the operation frequency, blocks having a total number of operations less than or equal to 17 were excluded (except the statistical block "8711").

3. Cluster analysis and sub-area stratification

The overall mean CPUEs (no. of fish per caught by thousand hooks) from four main catch species, *i.e.*, albacore (*Thunnus alalunga*), bigeye tuna (*Thunnus obesus*), yellowfin tuna (*Thunnus albacares*) and swordfish (*Xiphias gladius*) in each of the statistical block during 1968-2002 were used in the cluster analysis. The CPUE was expressed as the number of fish per 1,000 hooks.

Hierarchical cluster analysis (Ward method; SAS Institute Inc., 1989) was applied in the study. Dendogram was produced based on the Mahalanobis distance between the assemblages' centroids of the CPUEs from four main catch species. The choice for the number of clusters to be produced was somewhat arbitrary. In this study three clusters were determined.

After the cluster analysis, the CPUEs of albacore, bigeye tuna, yellowfin tuna and swordfish at a yearly scale from 1968 to 2002 were calculated and compared from each clusters.

RESULTS

1. Fishing ground boundary for Taiwanese longline fishery

Taiwanese longliners mainly exerted the efforts in North Atlantic Ocean from 5°N to 45°N. In recent decade (1993-2002), operations were also extended far beyond 45°N. However, these areas are not considered as traditional fishing grounds because of the low frequency of operations (Fig. 1).

Finally, a total of 79 and 5 × 5 degree statistical blocks was selected and considered as the fishing ground for the Taiwanese longline fleet operated in North Atlantic Ocean.

2. Cluster analysis and sub-area stratification

Three clusters from 79 and 5 × 5 degree statistical blocks were constructed by the cluster analysis. Comparison the Euclidean distance among the centroids of these three clusters, it shows that Cluster 1 (blocks in tropical waters) was totally different from the other two clusters, the relative distance was 100%. Clusters 2 and 3 were more related, and the relative distance was about 35% (Fig. 2).

After mapping each statistical block from three different clusters into the chart of North Atlantic, three sub-areas were shown evidently (Fig. 3). Except only 1 statistical block (block code "8509") from Cluster 1 was mapped into sub-area 2 incidentally, each sub-area was totally grouping from the statistical blocks which belong to the identical Cluster.

3. Geographical distribution of the resource abundance of NAA

In this study, we take the geographical distributions of albacore's catch rate, fishing efforts and catch species composition in 1999 as examples to illustrate the geographical abundance distribution of NAA for more observations in this year. The species composition in five-degree square has shown a geographical discrepancy (Fig. 4). The higher catch composition of albacore was found in sub-areas 2 and 3 where lying between 15-45°N of the North Atlantic Oceans, whereas

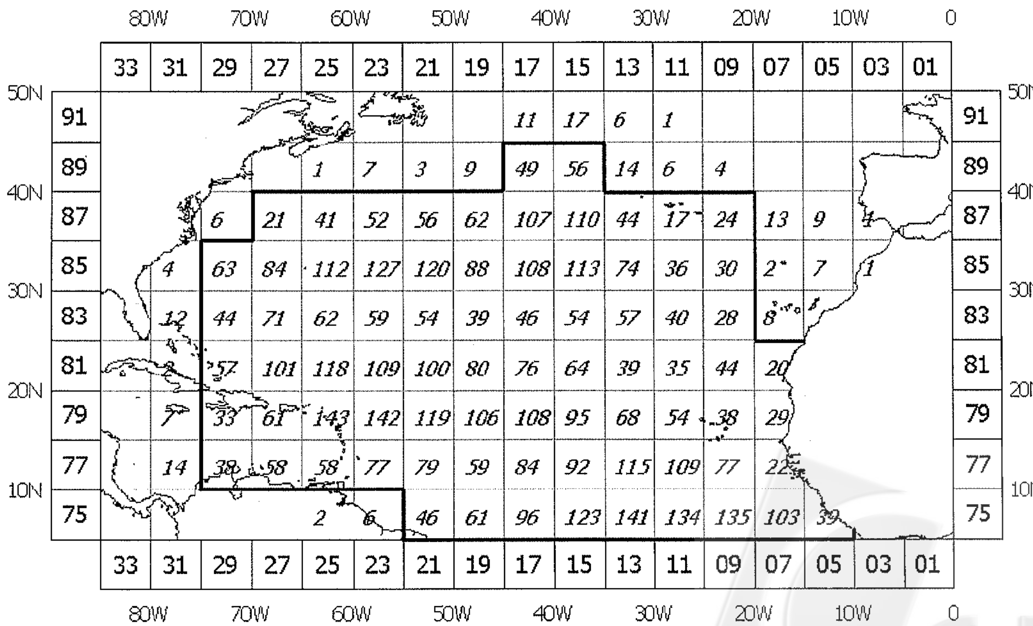

Fig. 1. Number of records of monthly 5×5 degree blocks available from the Taiwanese longline fisheries catch statistics, 1968-2002.

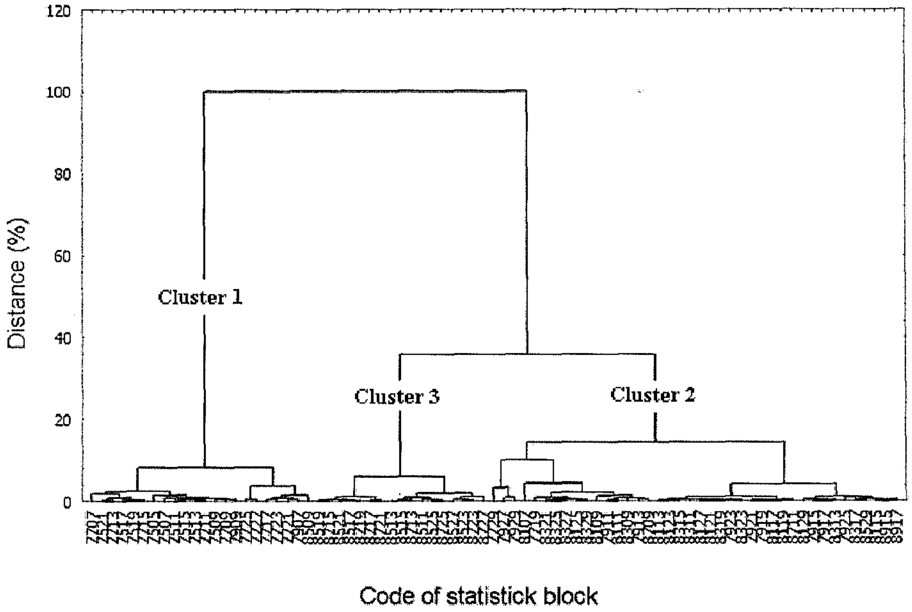

Fig. 2. Dendrogram showing the similarity of 5 × 5 degree statistical blocks, based on the catch rates of albacore, bigeye tuna, yellowfin tuna, swordfish etc.

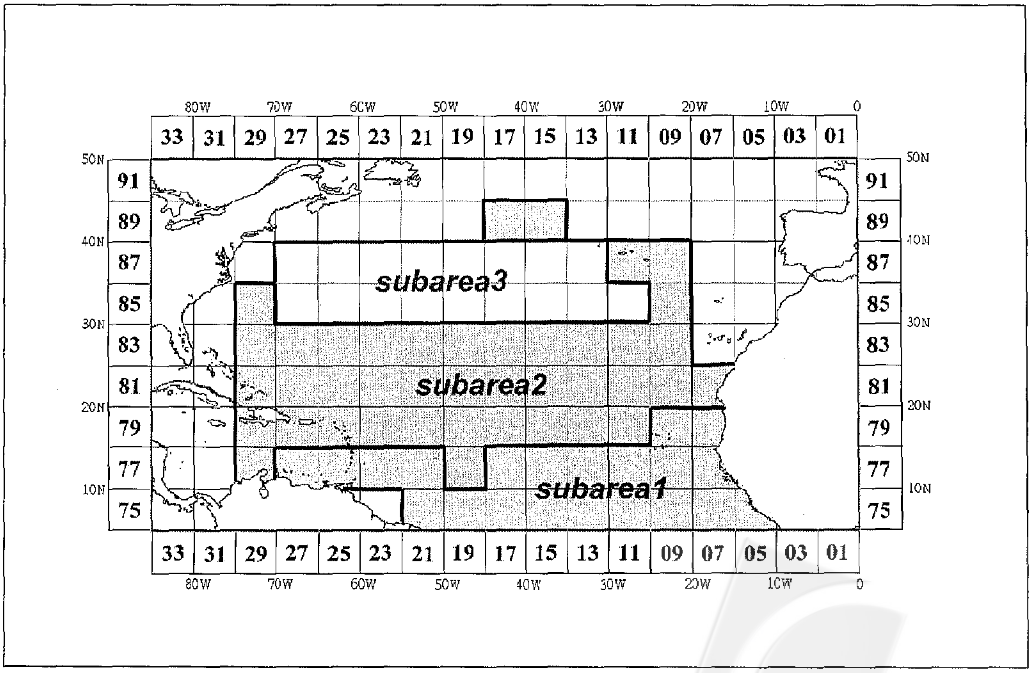

Fig. 3. Sub-areas obtained from neighboring the statistical blocks from three clusters.

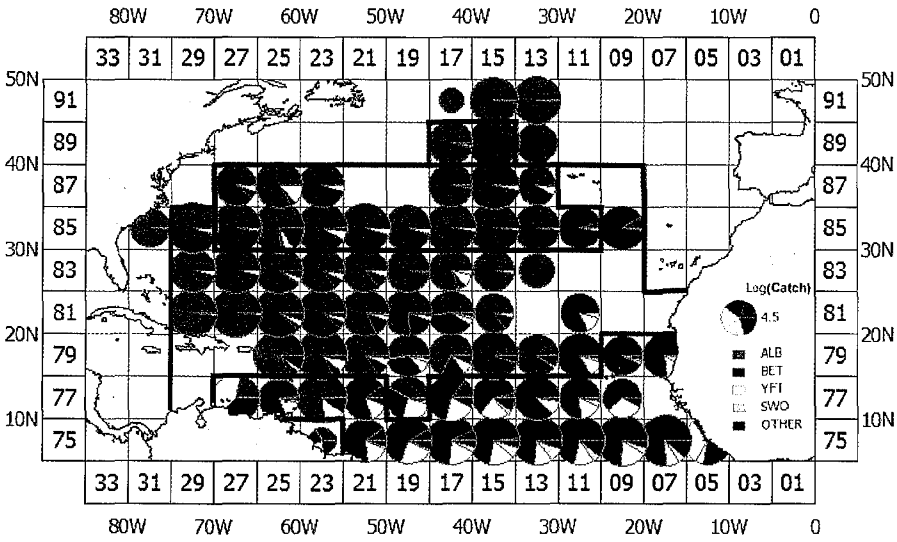

Fig. 4. Geographical distribution of catch species composition from Taiwanese longline fishery in 1999.

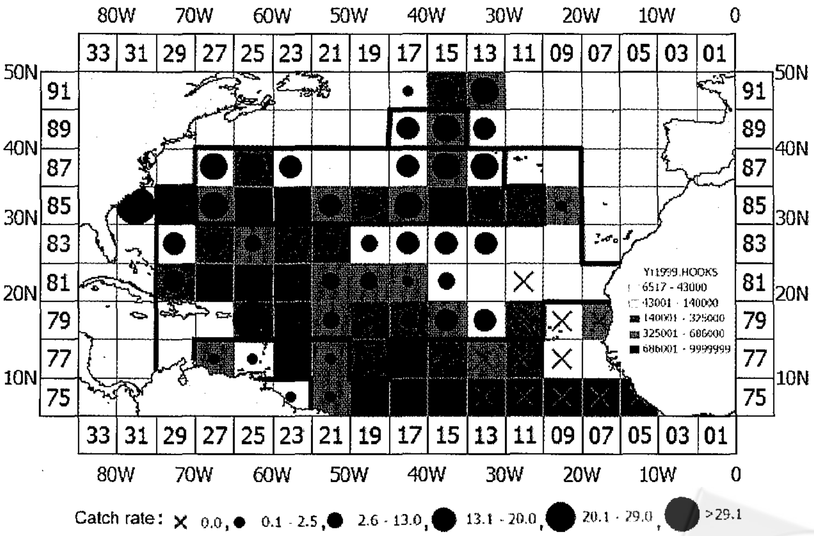

Fig. 5. Geographical distributions of albacore catch rate and fishing effort from Taiwanese longline fishery in 1999.

bigeye tuna and yellowfin tuna were more abundant in sub-area 1 (the tropical waters). It is worth notifying that albacore accounted for more than 80% of catch for Taiwanese longliners operated in sub-areas 2 and 3 (Fig. 4).

The CPUEs of NAA in five-degree square were higher in the sub-areas 2 and 3, whereas lower in sub-area 1. Furthermore many five-degree squares in sub-area 1 appeared the null catch of albacore. More hooks were exerted in sub-areas 2 and 3 in which abundant albacore was. This geographical distribution of efforts in sub-areas 2 and 3 was consistent with the CPUE distribution of NAA (Fig. 5). It may suggest that these two subareas are the most important fishing grounds for the Taiwanese regular longline fishery.

4. Nominal CPUE trends by sub-area

Time series of nominal CPUEs for 4 species (albacore, bigeye tuna, yellowfin tuna, and swordfish) by sub-area are shown in Fig. 6. The nominal CPUE trends of albacore in sub-areas 2 and 3 showed similar fluctuated patterns, and that in sub-area 3 was higher. In sub-area 3, the annual CPUE of albacore ranged from 15 to 45 fish per thousand hooks and from 13 to 28 fish in sub-area 2. In generally both annual albacore CPUE trends were decreasing gradually. On the other hand, regardless the low CPUE of albacore in sub-area 1, the CPUEs of bigeye tuna and yellowfin tuna were much higher. Besides no clear CPUE trend was found for swordfish among three sub-areas.

DISCUSSION

Taiwan has long history in exploiting the North Atlantic albacore. Taiwanese longline fishery started in mid-1960s in tropical waters and fishing operations took place all Atlantic Ocean swiftly. Traditionally this fishery was basically directed to catch albacore in temperate waters using conventional longline. Super freezing vessels joined to the fishery targeting bigeye tuna during spring and winter seasons for marketability reason since late-1980s (ICCAT, 2001). However, some vessels still took albacore as main target species. The catch of albacore outnumbered than other catch species, more than 65% of the albacore catch was contributed to Taiwanese longline fishery in recent decade (1993-2002) (Wu *et al.,* 2006).

Because of the joining of the deep longline fishery, an underestimation of CPUE of NAA may result from the incorporation of non-targeted effort in the analysis (Wu *et al.,* 2006). The stock assessment of NAA becomes more complicated, and then identifying and separating the fishing effort which is aiming for the NAA are necessary.

The geographical distribution of albacore is distinct from bigeye tuna (Figs 4 and 5). Bigeye tuna inhabits the tropical waters a little deeper than the thermocline, whereas albacore distributes mainly in temperate waters above the thermocline. Thus, the fishing strategy of tuna longline fishery can be distinguished based on the information such as fishing ground and deployment of number of lines between floats in operation (Lin *et. al.*, 1998; Wu and Yeh, 2000a). The information on the number of lines between hooks in each operation can be used as a criterion to tell the operation pattern. Up to now, this method is an effective and proper way to determine from whether the operation was RLL or DLL (Nakano, 1996; 1997; Uozumi, 1996).

Taiwanese longline fishery is characterized by its flexible operation. Fishermen altered their operations and gear configuration to exploit another target species for the changing availability or marketability of different target species. To segregate dissimilar types of fishing effort, Fishery Agency, R.O.C. requested the longline skippers should submit logbook with the information on gear configuration in each operation after fishing vessel returned base port since 1995. Consequently the historical catch statistics of Taiwanese longline fishery before 1995 is still missing the information on fishing strategies. As albacore is the main target species for Taiwanese longline fishery in North Atlantic Ocean, the allocation patterns of fishing efforts are related to the albacore stock abundance in their operating areas. In the present study, we simply

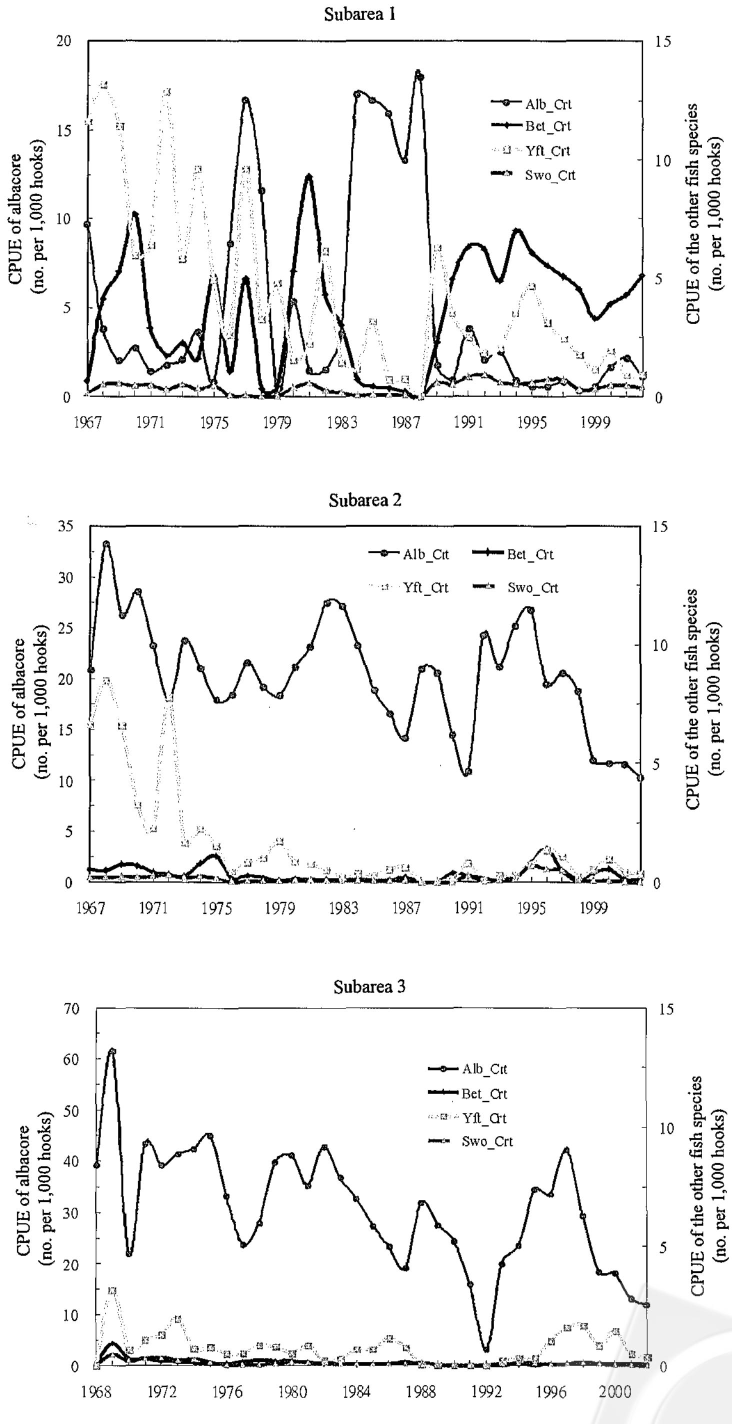

Fig. 6. Annual catch rates of albacore, bigeye tuna, yellowfin tuna and swordfish from Taiwanese longline fishery in North Atlantic Ocean.

classified three sub-areas according to the similarity of fishery structure. These three sub-areas may not only be adequate to reflect the geographical distribution of albacore stock abundance, but also subtly separate the variations in the CPUE standardization work of NAA caused from the dissimilar types of fishing effort (Punsly and Nakano, 1992; Hsu, 1999). Thus catch-per-unit-effort (CPUE) indices, obtained from the GLM analysis through the well defined sub-area measure, used in this stock resource monitoring can be expected more precisely.

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應用聚落分析法解析北大西洋長鰭鮪資源的地理分布

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長鰭鮪是臺灣大西洋鮪延繩釣漁業的傳統標的魚種。本研究使用聚落分析，依據歷年(1968-2002 年)臺灣鮪延繩釣漁船在北大西洋經常作業的 79 個 5 度方格漁區中的長鰭鮪、大目鮪、黃鰭鮪及劍旗魚的釣獲率，將具有類似漁業結構的方格漁區匯整成為 3 個聚落並對應為北大西洋的 3 個亞漁區。其中，亞漁區 1 位於 5°~15°N 的熱帶海域，亞漁區 2 及 3 則分別毗鄰其上，2 亞漁區間約以 30°N 為界。亞漁區 2 及 3 的長鰭鮪年別釣獲率明顯高於亞漁區 1，而大目鮪和黃鰭鮪的年別釣獲率明顯在亞漁區 1 較高。本研究所得的漁區劃分結果，將可應用於北大西洋長鰭鮪釣獲率標準化研究。

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