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DEMARCATION OF OPERATING AREAS AND FISHING STRATEGIES FOR TAIWANESE LONGLINE FISHERIES IN THE SOUTH ATLANTIC OCEAN

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SUMMARY

*Three sub-areas in the south Atlantic Ocean where Taiwanese longline fisheries operate were classified by three clusters, which were grouped from a total of 121 5×5 degree statistical blocks using cluster analysis. The annual mean CPUE from 12 species or species groups in number, and the average weight of albacore (*Thunnus alalunga*) in each of the statistical block were considered as the variable attributes in the cluster analysis. Fishing strategies were estimated from the number of branch lines between floats in 18,358 longline sets for 4 years (1995-1998) of commercial fishery data. The changes of temporal nominal CPUEs series of four dominant catch species, i.e., albacore, bigeye tuna (*Thunnus obesus*), yellowfin tuna (*Thunnus albacares*) and swordfish (*Xiphias gladius*), in each sub-area were examined, and fishing strategies among sub-areas were compared to reveal the geographical differences in fishing patterns. The possible use of these three areas in separating the non-albacore-directed effort is discussed.*

RÉSUMÉ

Trois sous-secteurs de l'Atlantique sud où pêchent les palangriers du Taïpei chinois ont été classées selon trois grappes de points qui ont été regroupés sur un total de 121 carrés de 5ºx5º par l'analyse des grappes. La CPUE annuelle moyenne en nombre de 12 espèces ou groupes d'espèces, et le poids moyen du germon (Thunnus alalunga) *dans chacun des blocs statistiques ont été jugés comme était les attributs variables dans l'analyse des grappes. La stratégie de pêche a été estimée d'après le nombre d'avançons entre flotteurs de 18.358 mouillages de palangres sur 4 années (1995-1998) de données de pêche commerciale. Les modifications des séries temporelles de CPUE nominale de quatre espèces dominantes capturées, à savoir le germon, le thon obèse* (Thunnus obesus), *l'albacore* (Thunnus albacares) *et l'espadon* (Xiphias gladius) *dans chaque sous-secteur ont été examinées, et la stratégie de pêche des sous-secteurs a été comparée pour déceler les différences géographiques du mode de pêche. L'utilisation éventuelle de ces trois sous-secteurs pour isoler l'effort ne visant pas le germon est abordée.*

RESUMEN

Las tres subzonas del Atlántico Sur donde operan tres pesquerías palangreras de Taipei Chino se clasificaron en tres grupos, partiendo de 121 bloques estadísticos de 5 x 5º usando análisis de conglomerados. La media anual de CPUE de 12 especies o grupos de especies en números y el peso medio del atún blanco (Thunnus alalunga) en cada uno de los bloques estadísticos fueron considerados como los atributos variables en el análisis de conglomerados. Las estrategias de pesca se estimaron partiendo del número de brazoladas entre flotadores en 18.358 lances de palangre de cuatro años de datos de la pesquería comercial (1995-1998). Los cambios en la serie temporal de CPUEs nominales de cuatro especies predominantes en las capturas, es decir, atún blanco, patudo (Thunnus obesus), rabil (Thunnus albacares) y pez espada (Xiphias gladius) en cada una de las subzonas, fueron examinados, comparándose las estrategias de pesca entre las subzonas con el fin de observar las diferencias geográficas en los tipos de pesca. Se discute la posible aplicación de estas tres zonas en la separación del esfuerzo no dirigido al atún blanco.

KEYWORDS

Taiwan, South Atlantic Ocean, albacore, Operating area, Fishing strategy

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1. INTRODUCTION

The practice of Taiwanese distant water longline fisheries commenced around the 1960s, and began to operate in the Atlantic Ocean in the mid-1960s. Traditionally, albacore was the main target species for Taiwanese longline fisheries in the South Atlantic, and its corresponding fishing efforts were usually distributed from 10° S to 40° S (Wu and Yeh, 2000a; 2000b). Since late-1980s, when bigeye tuna was demanded by the Japanese sashimi market, many longliners upgraded their facilities with super cold freezer (below minus 60 °C) and operated more northward. Thus, the fishing pattern of Taiwanese longline fisheries has changed since then (Wu and Yeh, 1996; 2000a; 2000b; and Yeh and Wu, 1996).

These changes were exhibited not only in extending northward the fishing ground but also in the lower catch rate and species composition of albacore for the Taiwanese tuna longline fisheries in the South Atlantic Ocean. Consequently, an underestimation of CPUE of albacore in recent years may result due to the incorporation of non-targeted effort in the analysis (Wu and Yeh, 2000a; 2000b).

Albacore is considered as a temperate tuna species, whereas bigeye tuna and yellowfin tuna are tropical tunas. Although tunas are highly migratory species and their schools may mingle with each other sometimes, their geographical distributions, either horizontally or vertically, are more or less distinct from each other. For example, bigeye tuna inhabit the tropical waters a little deeper than the thermocline, whereas albacore are distributed mainly in temperate waters above the thermocline. Thus, the fishing strategies of tuna longline fisheries 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).

In general, tuna fisheries are species-directed fishery. The operation program, which includes the branch lines between floats, bait, fishing ground, etc, is designed according to the specific target species. However, Taiwanese longline fishermen frequently switch target species, altering their operations and gear configuration to exploit the changing availability or marketability of different resources efficiently. Therefore, the information on the number of lines between hooks in each operation is used as a criterion to discriminate the operation pattern.

The objectives of this study were (1) to classify the operating area of Taiwanese longliners into several subarea-groups according to the similarity of the fishery structure, then (2) to examine the characteristics of each subarea-groups based on the spatial distribution of efforts between regular and deep longlining and the temporal changes of the CPUEs series for main target species, and (3) to supply the essential information on the classification of the subarea for the standardization of CPUE of Taiwanese albacore fishery in the South Atlantic Ocean.

2. MATERIALS AND METHODS

2.1 Catch and effort database

Two kinds of database were used, one is the TASK-II of ICCAT, and the other one was compiled from the daily operation logbooks. Both databases were provided by the Overseas Fisheries Cooperation Council, the Republic of China. The covered periods for TASK-II and logbook data are from 1967 to 1998 and from 1995 to 1998, respectively. Each record consisted of the monthly catch in number by species and by 5×5° statistical blocks. Moreover, logbook data included additional information in number of hooks between floats. Finally, a total of 18,358 longline sets, which included the information on the gear configuration, were available for the analysis.

2.2 Fishing ground boundary for Taiwanese longline fishery

The boundary of fishing ground was decided by the operation frequency in each 5×5°statistical block. The total operation frequency was calculated on monthly basis for the period of 1968-1998. After an examination of the geographical distribution of the operation frequency, blocks having a total number of operations less than or equal to 4 were excluded.

2.3 Cluster analysis and sub-area stratification

More than the mean nominal CPUEs of 12 species groups, the mean weight of albacore from 121 5×5° statistical blocks in the period 1968-1998 were used as the variable attributes in the cluster analysis. The CPUE was expressed as the number of fish per 1,000 hooks.

Hierarchical cluster analysis (Ward method; Statistical Analysis System Institute Inc., 1989) was applied in the study. The choice for the number of clusters to be produced was somewhat arbitrary. It was determined by the grouping the number of consistent 5×5°statistical blocks. Additional clusters were considered as the smallest cluster contained less than 10% of the total number of observations.

2.4 Classification of the fishing strategies

Tuna longlining is a species-directed fishing method. The fishing ground, bait, duration of set, and more importantly, the number of hooks per set, all rest with the target species. In this case, the distributions of catch composition in albacore, bigeye tuna and yellowfin tuna by number of lines between floats may provide necessary information to define the fishing strategies for the operation of Taiwanese longline fleets.

3. RESULTS AND DISCUSSION

31. Fishing ground boundary for Taiwanese longline fishery

Taiwanese longliners exerted almost all of their efforts in the South Atlantic Ocean, mainly from 5° N to 45° S. In recent decade, operations were also extended southward of 45° S. However, these areas are not considered as traditional fishing grounds because of the low frequency of operations. Finally, a total of 121 5×5°statistical blocks were selected and considered as the fishing ground for the Taiwanese longline fleets (Fig. 1).

3.2 Cluster analysis and subarea stratification

Three clusters from 121 5×5° statistical blocks were constructed by the cluster analysis (Fig. 2). Comparison of the Euclidean distance among these three cluster centroids showed that Cluster 1 was totally different from the other two clusters, and its relative distance was higher by up to 100%. Clusters 2 and 3 were more related, and the relative distance between both was over 52%. Generally, the similarity of fishery structure for 5×5° statistical blocks within each cluster were relative high, especially for those blocks in Cluster 1.

According to the result from cluster analysis, the greatest variation was among clusters, and least variation within blocks of each cluster (Fig. 2). Furthermore, after mapping each statistical block from three different clusters into the chart of South Atlantic, three subareas were shown evidently. All statistical blocks from Cluster 1 were grouped into a complete homogeneous Subarea 1. Examination of the statistical block composition of Subareas 2 and 3, which were mostly determined from Clusters 2 and 3 respectively, showed that only one and five statistical blocks were from Clusters 2 and 5 respectively. Because three subareas were categorized based on the grouping of 5×5° statistical blocks in which similar fishery structure was observed, therefore we can conclude that this area stratification of the South Atlantic is reasonable.

3.3 Classification of fishing strategies

Several segregating methods have been developed to account for variation in effective effort of fishing strategies. For examples, Suzuki et al. (1977) and Koido (1985) classified the regular and deep longlining by number of branch lines between floats, and Punsly and Nakano (1992) incorporated the gear depth in GLM. Furthermore, the similarity of species composition from each deployment was also applied to categorize fishing effort (Rogers and Pikitch, 1992; Chang, 1993; Lewy and Vinther, 1994; Lin *et. al.*, 1998).

Table 3 shows the frequency distributions of the catch ratios for three dominant species by number-of-lines-between-floats. The data reveal that the target species, especially for albacore and bigeye tuna, are related to the depth of deployed hooks. Bigeye tuna species composition was found higher by using 12 or more number-of-lines-between-floats groups, whereas albacore catch ratio became higher by using 9 or less number-of-lines-between-floats groups. As for 10 or 11 number-of-lines-between-floats groups, the catch ratios of both albacore and bigeye tuna are higher. Thus, we can define three kinds of fishing strategies as regular (less than or equal to 9 number-of-lines-between-floats), deep (greater than or equal to 12 number-of-lines-between-floats) and mixed (just 10 or 11 number-of-lines-between-floats) longline fisheries. The relationship between the catch ratio and number-of-lines-between-floats for yellowfin tuna was not clear. The role of yellowfin tuna played in Taiwanese longline fisheries seems not so important as before because its catch ratio was relatively low in all number-of-lines-between-floats groups.

3.4 Fishing strategies among subareas

Percentage of effort and catch ratios of 12 species and species groups by fishing strategy and by subarea are shown in Table 4. Geographical effort distribution of three Taiwanese longline fisheries, *i.e.*, regular longline fishery, mixed longline and deep longline fishery, are respectively shown in Figs. 3, 4 and 5.

Geographical effort distributions and target species among three different fishing strategies are different. Almost all efforts of regular longline fishery concentrated in subareas 2 and 3, targeted albacore, while null in Subarea 1 (Table 4 and Fig. 3). This geographical distribution of efforts from regular longliners just agreed on the distribution of South Atlantic albacore (Laevastu and Horacio, 1962). On the other hand, the deep longliners deployed the hooks mainly on Subarea 1, targeting bigeye tuna, but quite few operations were conducted in subareas 2 and 3. As for mixed fishery, more than 60% of the efforts were exerted on Subarea 1 for tunas and marlin. The geographical separations for different fishing strategies and their corresponding target species are quite distinct. The deep longlining operations are concentrated in the tropical waters for bigeye and/or yellowfin tuna (Hsu, 1999), whereas traditional regular longliners operate mainly in temperate and subtropical waters for albacore. Thus, these two fishing patterns can be segregated by their geographical distinction (Nakano, 1996; 1997).

3.5 Time series of geographical nominal CPUE

Time series of nominal CPUE by subarea for four species (albacore, bigeye tuna, yellowfin tuna, and swordfish) were compared and results are shown in Fig. 6. The nominal CPUE trends of albacore in subareas 2 and 3 showed similar patterns, and the one in Subarea 3 was higher and fluctuated between 20 and 40 fish per thousand hooks. From the higher CPUE of albacore occurred, and the more efforts exerted in Subarea 3, suggesting that Subarea 3 is the most important fishing ground for the Taiwanese regular longline fishery. On the other hand, CPUEs of both bigeye tuna and yellowfin tuna in Subarea 1 are much higher and fluctuated greatly than other subareas. No clear CPUE trend was found for swordfish among subareas, except the great fluctuations.

4. ACKNOWLEDGMENTS

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Table 1. Specification of facilities between regular and deep longline (after Hsu and Lui, 1992 and Chang *et al.*, 1993).

Item	Regular Longline	Deep Longline
Temperature in freeze room (℃)	below -40	below –60
Specification of hook	No. 4	No.2
Number of hooks in a set	4-6 or 8-12	10-15 or 14-20
Depth of the hooks set (m)	50-120	50-200
Target species	albacore	bigeye, yellowfin tunas

Table 2. Definition of regular and deep longline fisheries by the number of hooks between floats in various studies.

Author	Regular longline	Deep longline
Yang *et. al.*, 1986	6-9	10-16
Chang *et al.*, 1993	8-12	14-20
Uozumi, 19964-78-11, 12-15 and 16-20 groups		
Lin, 1998	9-10	>12
Present study ≦9	≧12	

Table 3. Frequency distributions of catch compositions (in number) with different number of lines between floats in albacore, bigeye tuna and yellowfin tuna.

(a) Albacore

	Number of lines between floats														
%	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20
0	1		4	6	34	2151	179	763	55	196	897	1684	1494	1033	66
10	7		4		1	196		14	49	12	69	142	106	364	7
20	19		3	2	5	6		8		1	33	41	62	219	
30	5		2	2	19	5		13			11	34	33	115	
40			1	3	21	20	2	5			11	12	20	43	
50				6	36	28		6			1		15	7	
70				63	215	119		2				1	18	8	
80				140	494	173		1					3	1	
90				415	908	146		2					2		
100		1	1	755	3583	899									
Total	32	1	15	1392	5316	3743	181	814	104	209	1022	1914	1753	1790	73

Table 3. Continued.

(b) Bigeye tuna

%	Number of lines between floats														
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20
0	32		3	688	3601	711	4			3	8	23	18	13	1
20				14	143	192	11	4	1	13	12	46	45	21	
30				1	34	104	11	8	2	14	23	65	66	54	
40					16	131	1	23	1	21	31	104	106	151	
50					9	363	13	42	5	10	70	204	182	241	5
60						6									
70			1		12	1062	34	203	7	53	229	571	470	537	23
80			1		4	512	36	172	40	42	172	382	337	332	12
90						213	39	174	39	30	213	332	296	251	21
100		1	10	689	1497	449	32	188	9	23	264	187	233	190	11
Total	32	1	15	1392	5316	3743	181	814	104	209	1022	1914	1753	1790	73

(c) Yellowfin tuna

%	Number of lines between floats														
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20
0	32	1	12	920	3508	982	64	336	14	63	549	745	781	784	33
10			1	456	1704	1189	37	167	57	14	189	430	327	421	19
20			2	13	68	806	41	132	20	43	145	358	289	369	15
30				2	8	437	10	98	4	25	70	187	178	135	2
40				1	1	233	6	58	6	12	31	101	86	46	2
50					7	49	4	11	1	17	16	39	47	23	1
60					20	47	19	12	2	35	22	53	45	12	1
70												1			
Total	32	1	15	1392	5316	3743	181	814	104	209	1022	1914	1753	1790	73

Table 4. Percentage of deployed hooks and catch composition (in no.) of twelve fish species and/or fish species groups by subarea of various fishing strategies employed by Taiwanese longline fleets in the South Atlantic Ocean during the period 1995-98.

	Regular longline fishery(1)					Mixed longline fishery(2)					Deep longline fishery(3)				
	Subarea 1 (%)	Subarea 2 (%)	Subarea 3 (%)	Other (%)	Total	Subarea 1 (%)	Subarea 2 (%)	Subarea 3 (%)	Other (%)	Total	Subarea 1 (%)	Subarea 2 (%)	Subarea 3 (%)	Other (%)	Total
No. of hooks	0.0	35.1	60.8	4.1	22,487,859	61.1	20.4	18.4	0.1	11,806,260	99.0	1.0	0.0	0.0	20,141,855
Albacore	0.0	27.4	70.1	2.6	906,681	8.9	38.7	52.4	0.0	123,418	94.1	4.9	1.0	0.0	4,677
Bigeye tuna	0.4	6.0	84.8	8.8	11,202	92.3	1.2	6.5	0.0	52,110	97.2	2.8	0.0	0.0	110,236
Yellowfin tuna	0.1	33.2	42.4	24.3	10,532	81.4	6.6	11.8	0.2	16,228	98.2	1.7	0.1	0.0	17,962
Swordfish	0.0	46.7	42.7	10.6	4,522	95.9	1.4	2.5	0.2	5,846	99.3	0.7	0.0	0.0	19,085
Other tunas	0.0	0.2	8.2	91.6	478	0.0	13.3	86.7	0.0	30	100.0	0.0	0.0	0.0	58
Striped marline	0.0	90.8	7.5	1.7	6,399	84.4	11.3	4.1	0.1	3,764	99.8	0.2	0.0	0.0	560
Blue marline	0.1	95.3	0.3	4.3	1,267	97.0	2.0	1.1	0.0	1,607	99.0	1.0	0.0	0.0	4,993
Black marline	0.0	0.0	86.2	13.8	29	88.8	0.0	10.0	1.2	170	100.0	0.0	0.0	0.0	184
Billfish	0.0	96.8	2.9	0.3	1,819	26.4	1.6	72.1	0.0	129	100.0	0.0	0.0	0.0	302
Skipjack	0.0	15.8	59.3	24.9	1,161	0.0	3.2	96.8	0.0	186	100.0	0.0	0.0	0.0	137
Sharks	0.0	46.7	51.9	1.3	18,070	92.7	0.4	6.8	0.0	2,529	98.2	1.8	0.0	0.0	765
Other fishes	0.0	74.4	22.8	2.7	23,730	64.1	17.2	18.7	0.0	3,774	77.8	22.1	0.1	0.0	4,353

Where number of lines between floats are (1) less than or equal to 9, (2) 10 or 11 and (3) greater than or equal to 12, respectively.

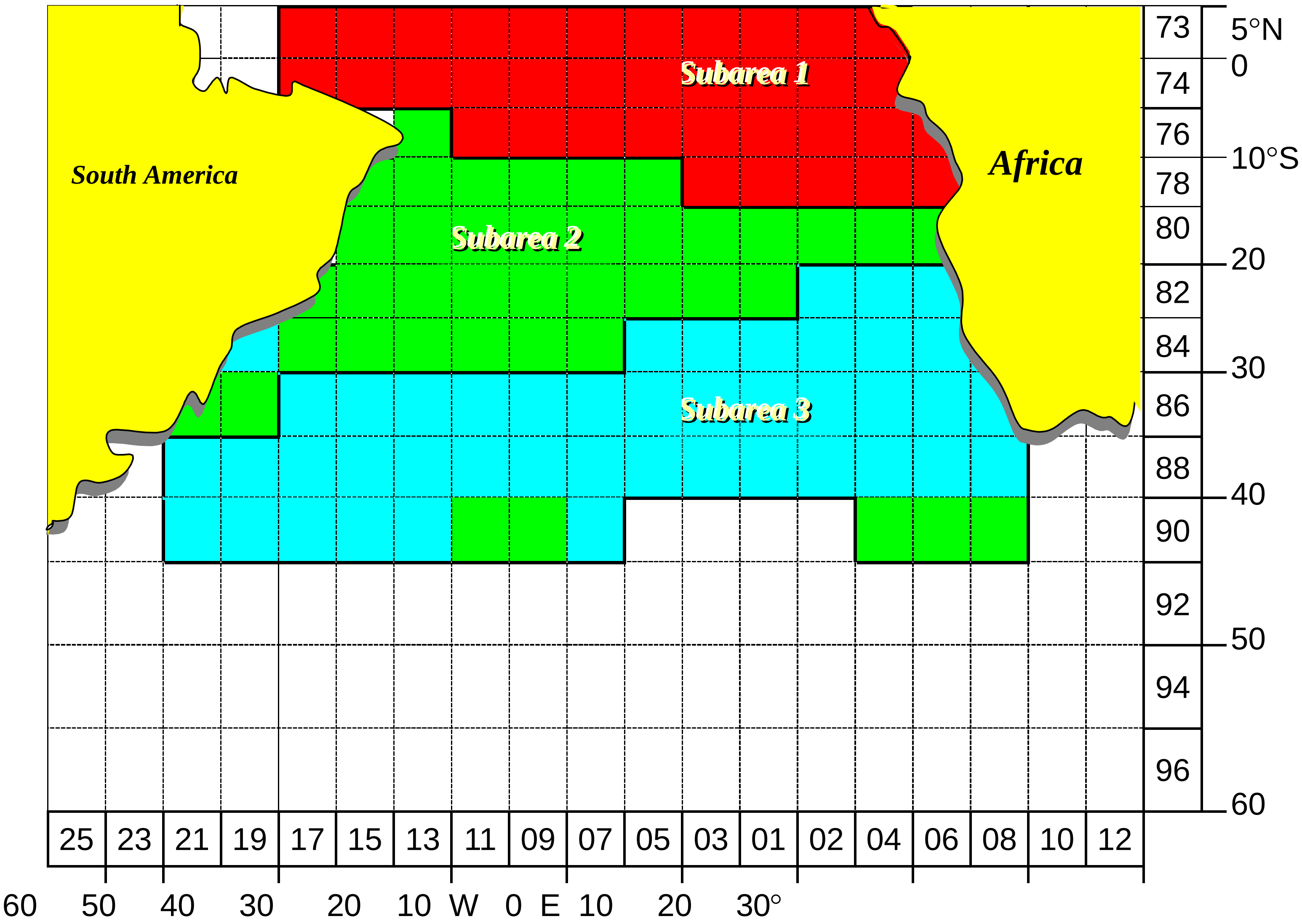


Fig. 1. Spatial distribution of statistical blocks for three clusters.

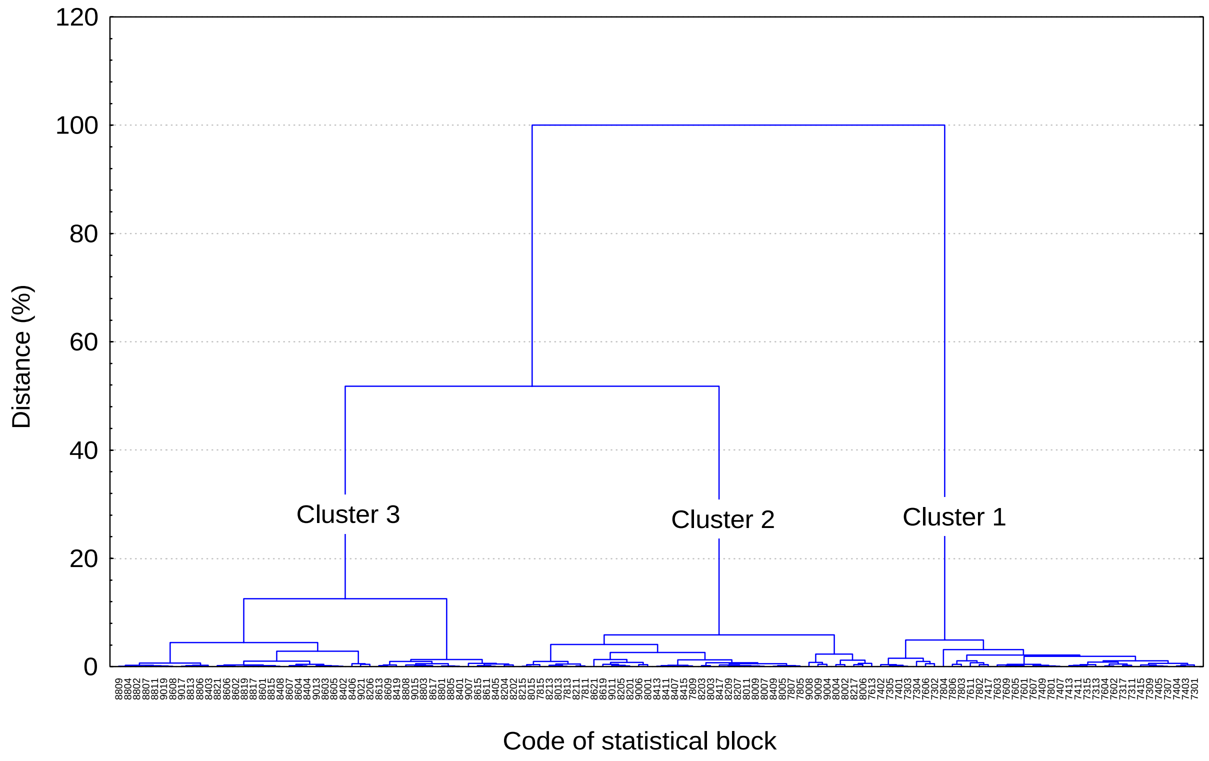


Fig. 2. Dendrogram showing the similarity of fishery structure for 121 statistical blocks.

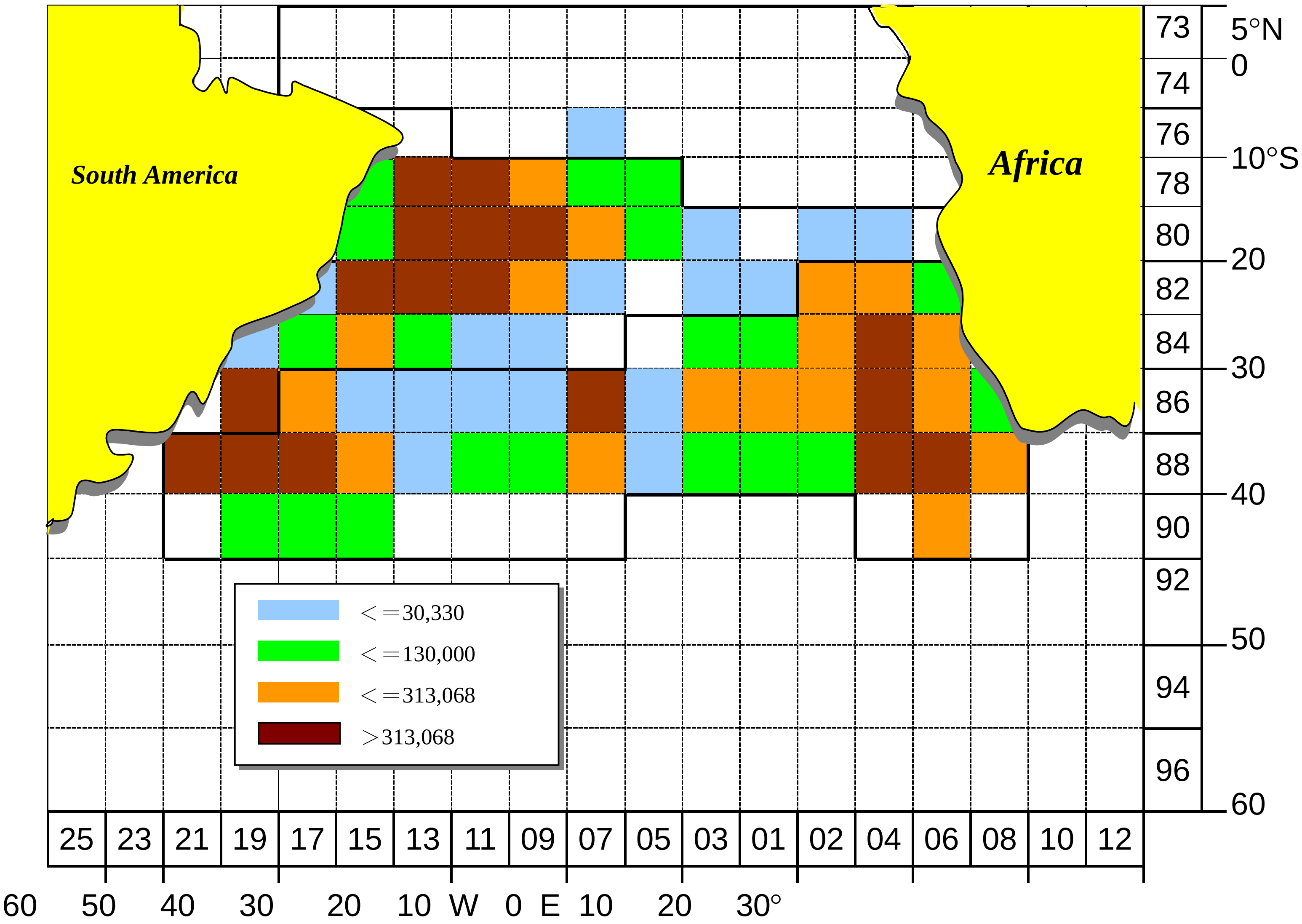


Fig. 3. Spatial distribution of total efforts (no. of hooks) of Taiwanese regular longline fishery in the period 1995-1998.

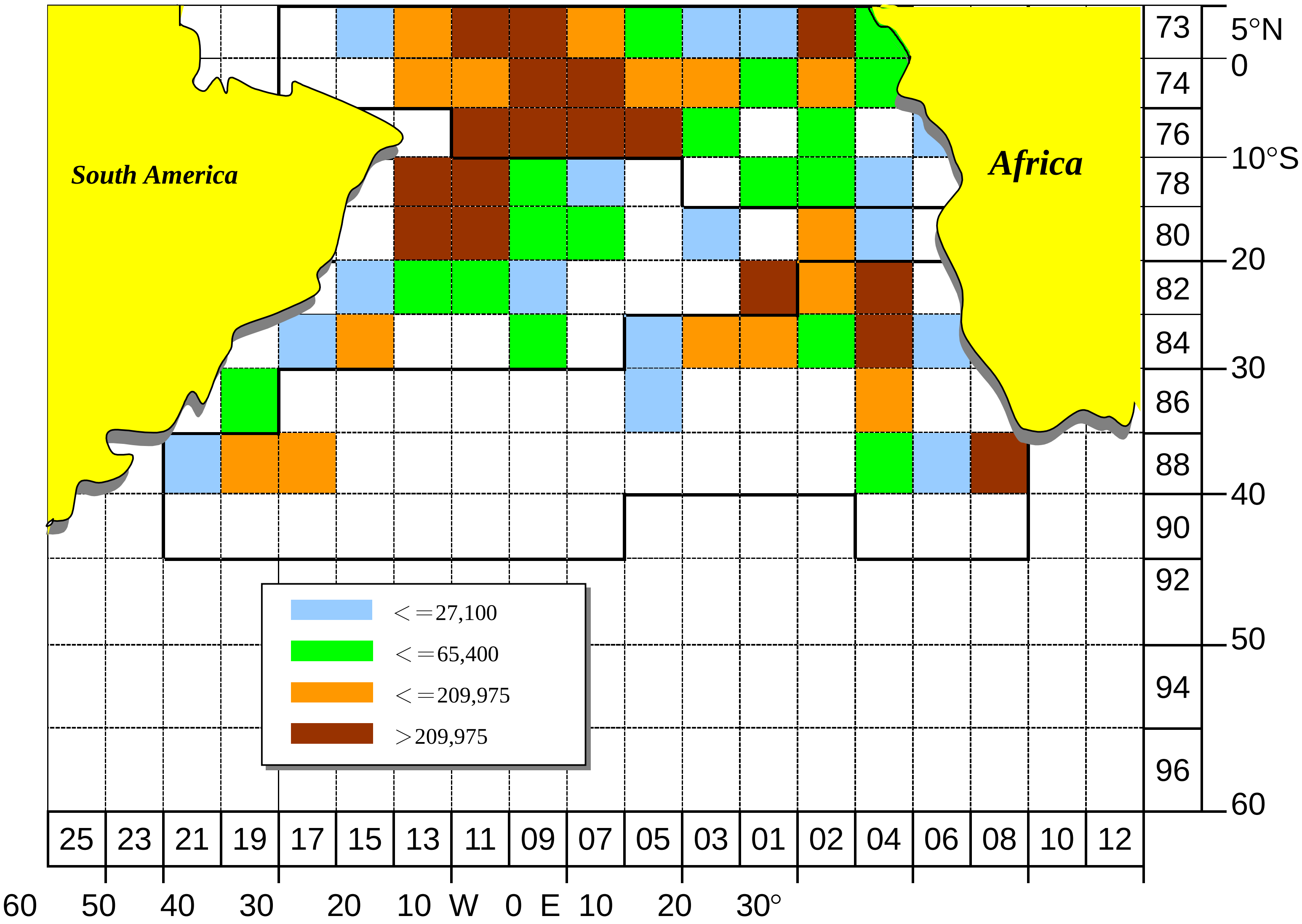


Fig. 4. Spatial distribution of total efforts (no. of hooks) from the operations of 10 or 11 lines between floats of Taiwanese longline fishery.

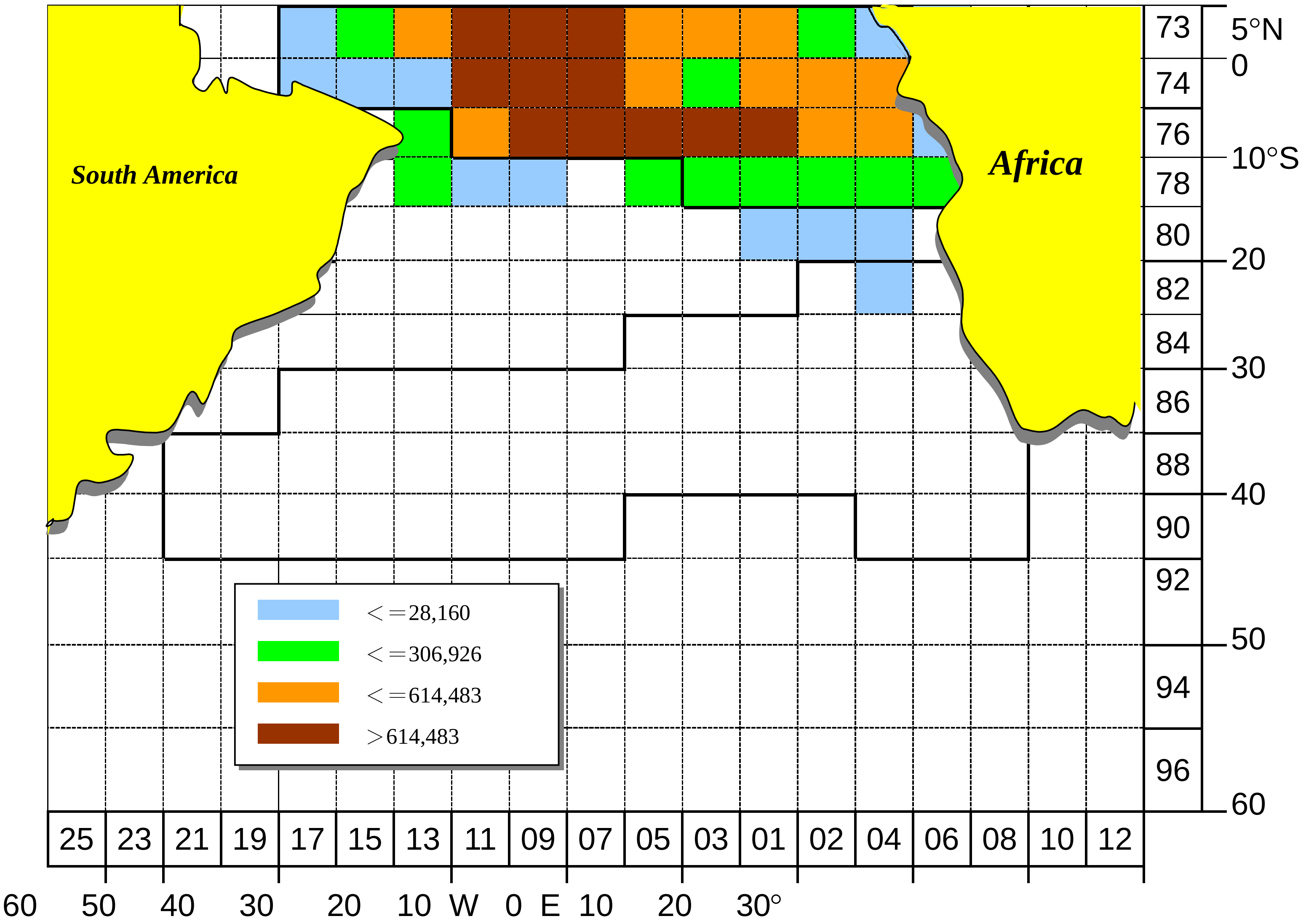


Fig. 5. Spatial distribution of total efforts (no. of hooks) of Taiwanese deep longline fishery in the period 1995-1998.

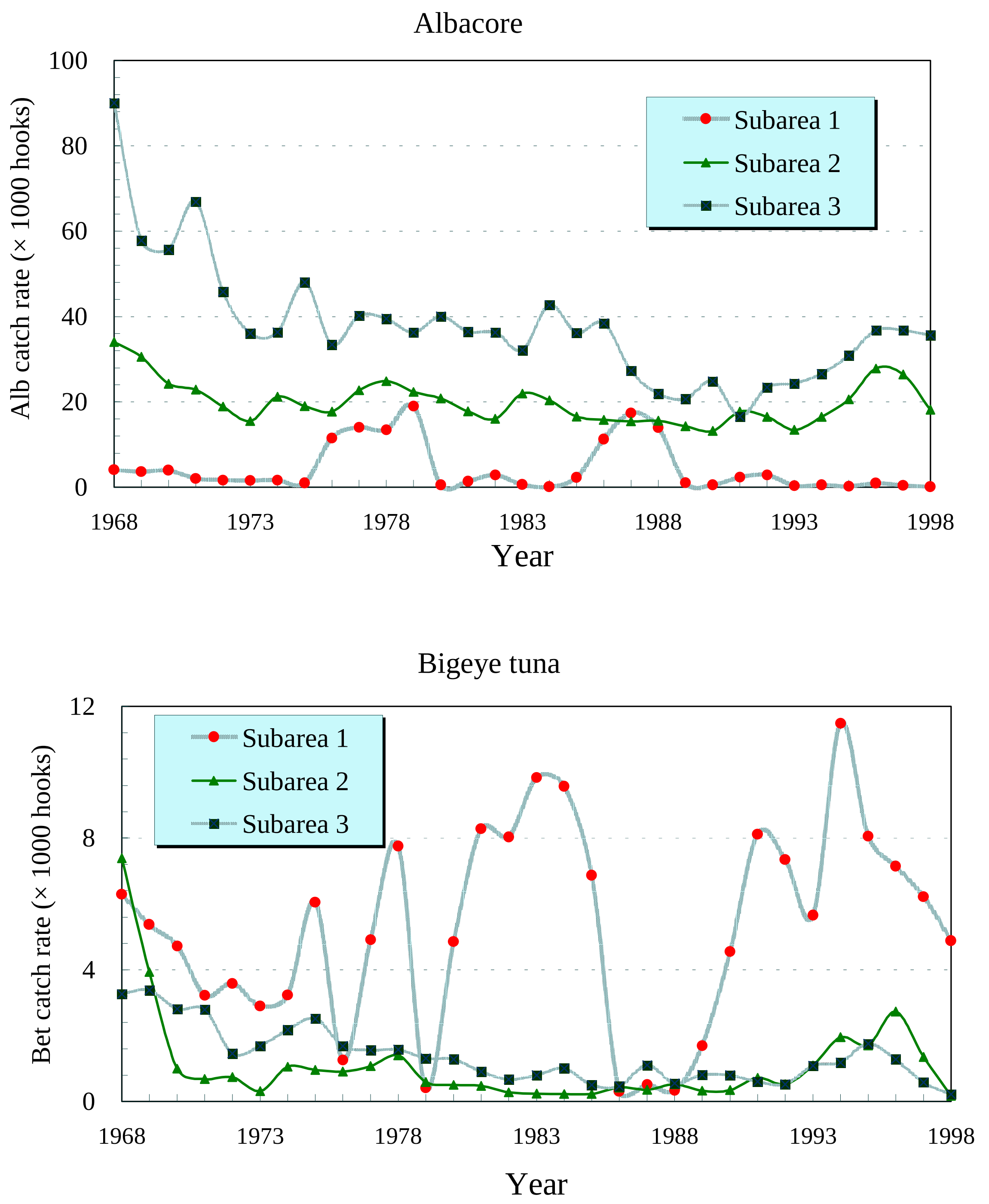
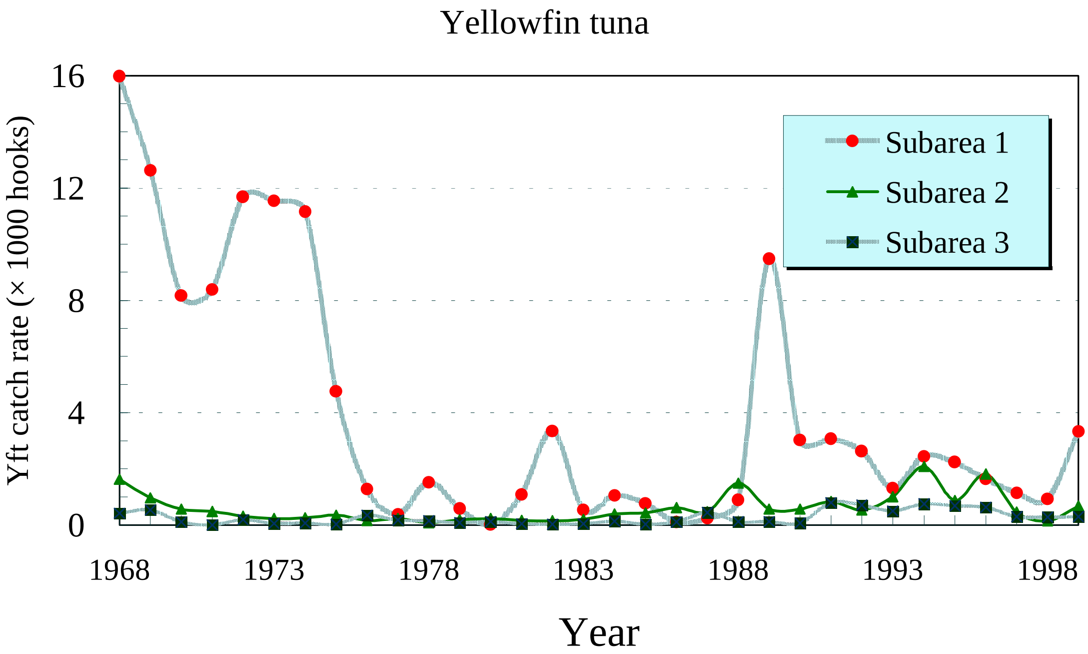


Fig. 6. Annual catch rate of four dominant species in catch by subarea of Taiwanese longline fisheries in the South Atlantic.



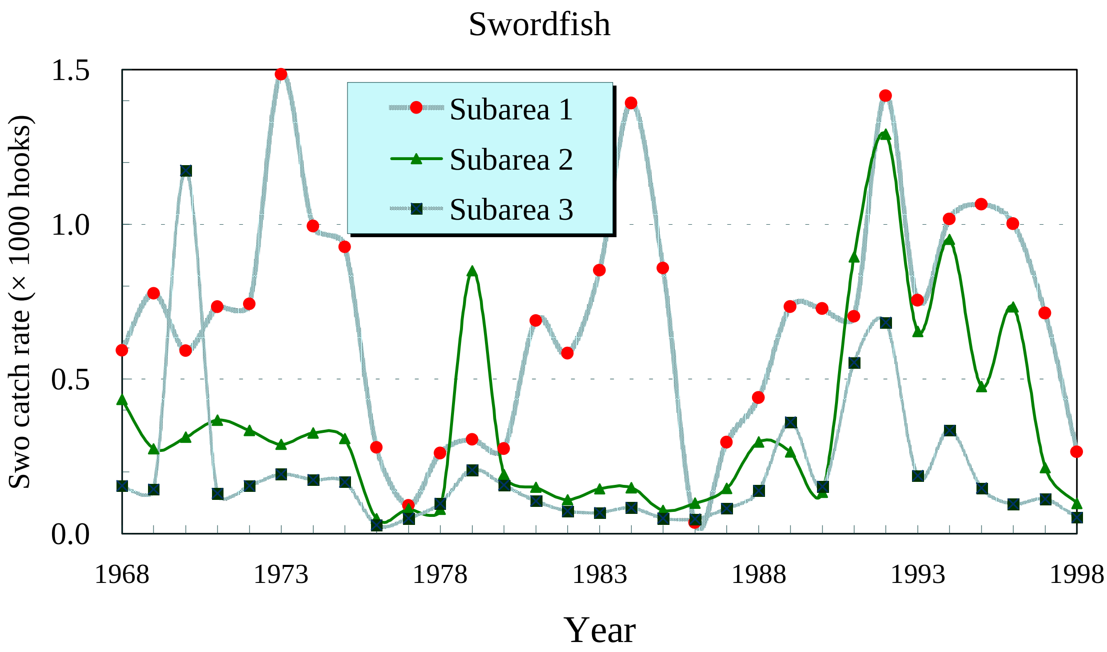


Fig. 6. Continued.