Taiwanese albacore-targeting longline fisheries in the North Pacific Ocean, 1995-2011

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Abstract

This working paper is to describe the features of Taiwanese albacore-targeting longline fisheries operated in the North Pacific Ocean, 1995-2011. Albacore-targeting fishery, as well as non-albacore-targeting fishery was defined based on the results of clustering and discriminant analyses. In order to conduct CPUE standardization using General Linear Model, sub-areas were defined based on the similarity of catch compositions of each 5° X5^o square. The results reveal that the albacore-targeting fishery mainly operated in the waters north of 25^oN and applied less than 13 hooks per basket in their operations. Majority (98%) of Taiwanese albacore catch was found to be contributed by albacore-targeting fishery. Several trials of area segregation were adopted in the GLM model, and results show that 2 sub-areas divided by the latitude of 25^oN can explain the highest variance. The standardized CPUE shows a stable trend after 2000, which is believed to be more informative to the stock status of North Pacific albacore exploited by Taiwanese longline fisheries.

Introduction

Taiwanese longline fisheries operating in the North Pacific Ocean was known to include two type of fishing strategies, i.e., albacore-targeting and non-albacore-targeting (Chen & Cheng, 2013). The albacore-targeting fishery normally operated in the temperate area while the non-albacore-targeting mainly operated in the tropical area. The former tended to fish in shallower water by applying less number of hooks per basket during their daily operation, and the latter normally fish in deeper water. Hence, majority of Taiwanese albacore catch were contributed by the former, while albacore catch of the latter were taken as bycatch. However, it is important to discriminate the albacore-targeting fishery statistics from the data set when conducting albacore CPUE estimation. Owing to the geographical distribution of albacore, it is also essential to define the area factor during the standardization of albacore CPUE using general linear model. In this study, we intend to segregate Taiwanese longline fisheries into albacore-targeting and non-albacore-targeting

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fisheries, based on the fishing activities and resultant catch compositions. Sub-area definitions will also be made in accordance with geographical distributions of historical catch compositions. Then, general linear model analysis will be applied to obtain the albacore CPUE trend.

Materials and methods

Task 2 data by month and by $5^{o} \times 5^{o}$ square, daily logbook data of each fishing boat and albacore length data measured on board were kindly made available by the Overseas Fisheries Development Council, Taiwan. These data cover the time period of 1995-2011.

Following the methods of Chen and Cheng (2013), in order to divide the catch statistics of entire Taiwanese longline fisheries into groups, cluster analyses were carried out based on catch compositions of daily logbook records. Similarly, cluster analyses based on task 2 data were also conducted to define the sub-areas for further GLM analyses. Discriminant analyses were conducted to verify the grouping of catch statistics obtained from cluster analyses, and to define the albacore-targeting and non-albacore-targeting fisheries. Then, general linear model was adopted to standardize the albacore CPUE of Taiwanese longline fisheries.

Results and Discussion

Fishing efforts of Taiwanese longline fisheries operated in the North Pacific Ocean fluctuated between 4 million and 35 million hooks in the period 1995-2011 (Fig. 1). Albacore tuna comprised most of the catch, particularly before the year of 2000, since then increasing catch of other species was recorded (Fig. 2 a). In the year of 2001 and 2002, the bigeye catch is even more than albacore. In the same period, a drastic decline of nominal albacore CPUE was observed (Fig. 2 b).

Chen and Cheng (2013) reported that the catch compositions of Taiwanese longline fisheries can be segregated into 2 clusters, in which one is much more efficient in catching albacore than another (Fig. 3, Table 1). The segregation was further verified and defined as albacore-targeting and non-albacore-targeting fisheries by discriminant analyses based on fishing activities of Taiwanese fleet, such as fishing season, fishing area and fishing methods. Following their methods, the catch compositions in terms of CPUE were obtained for albacore-targeting (group 1) and non-albacore-targeting (group 2) Taiwanese longline fisheries, 1995-2011, respectively (Table 2). Not surprisingly, most of the albacore catch are contributed by

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group 1 fishery no mater before or after the year of 2000 (Fig. 4 a), implying that the group 1 data is more informative in explaining the population abundance status of albacore exploited by Taiwanese longliners. The group 1 data are mainly derived from longliners operated in the north of $25°N$, while group 2 data are those mainly from waters of 0-15 $°N$, and a mixing area is noted between $15°N$ and $25°N$ (Fig. 8 b). The longliners of group 1 mainly applied less than 13 hooks per basket in their daily fishing operation, while those of group 2 mainly applied more number of hooks per basket (Fig. 8 c). Difference in fishing season was also observed that group 1 began the fishing season in October and ended in March of the following year, and group 2 mainly fished from January to June (Fig. 8 d).

Prior to the general linear model (GLM) standardization of albacore CPUE, sub-areas were defined by aggregating those $5°$ X $5°$ squares with similar catch compositions in 1995-2011. The results show that 3 clusters, namely cluster A, B and C, can be clearly separated (Fig. 5). Cluster A mainly distribute in the waters north of $25°N$, cluster C distribute mainly in the waters of $0°$ -10 $°N$, and cluster B scatter around in between cluster A and C (Fig. 6a). Cluster A includes those $5°$ X $5°$ squares with the highest albacore CPUE, and followed by cluster B and C, respectively (Fig. 6b). It is also noted that less fishing efforts were contributed by cluster B (Fig. 6c). Based on the results, two area segregations were tentatively adopted as shown in Figure 6 d and e. For the first option of area segregation, area A25 locates in the north of $25°N$, area C25 locates in the south of $25°N$, and area B25 only covers a small area of the central North Pacific Ocean (Fig. 6d). Similarly, the second option of area segregation divides the North Pacific Ocean into area A20, B20 and C20, mainly based on the $20°N$ line (Fig. 6e). For either option, the albacore CPUE of A25 or A20 are significantly higher than the rest areas (Table 3). The length frequencies of albacore obtained from 3 areas also demonstrate difference in the size of albacore, in which those from area C25 tend to be larger than those from area B25 and A25. Similarly, those from C20 are larger than B20 and A20 (Fig. 7).

The area factor, coupled with year, season, and interaction term were then included in the GLM analyses. In the GLM model, four scenarios were arranged for the area factor, i.e., (1) A25, B25, C25, (2) A25, B25+C25, (3) A20, B20, C20 and (4) A20, B20+C20. As shown in the Table 4 and 5, four scenarios of area arrangement all demonstrate significant results. It is noticed that the area arrangement "A25, B25+C25" is the most significant among 4 scenarios either for the model or for the area factor itself (Table 4b). Nevertheless, standardization of albacore CPUE for four

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area scenarios were all conducted, and results are shown in Figure 8 and Table 6. The standardized CPUE trends are rather stable, and the drastic decline of nominal CPUE around the year of 2000 is not shown. Geographical distributions of albacore are also demonstrated by the annual length frequencies of albacore. Figure 9 and 10 shows the annual length distribution of albacore in area A25, B25 and C25, respectively. The albacore caught from B25 and C25 tend to be larger than those from A25, particularly in the period after 2002. Similar results are also obtained that albacore from B20 and C20 tend to be larger than those of A20 (Fig. 11, 12).

Non-albacore-targeting data (group 2) were also reviewed with similar processes for the albacore-targeting data (group 1). Figure 13a shows that the fishing efforts of group 2 increased significantly since 2001. However, these increasing efforts concentrated mainly in the area C25, and did not contribute much to the albacore catch (Fig. 13b). It is also reflected by the very low albacore CPUE (Fig. 13c, d). On the contrary, much higher albacore catch and albacore CPUE were observed for the albacore-targeting fishery (group 1), particularly in the area A25. Similar results were also obtained for the area aggregation of "A25, B25+C25" (Fig. 14), "A20, B20, C20" (Fig. 15) and "A20, B20+C20" (Fig. 16). It reveals that although the fishing area of Taiwanese longliners covered most of the pelagic waters of North Pacific Ocean, majority of albacore catch were made by the albacore-targeting fishery operated in the waters north of $25°$N.

In summary, Taiwanese longline fisheries, 1995-2011, operated in the North Pacific Ocean contain two type of fishing strategies, i.e., albacore-targeting and non-albacore-targeting. The albacore-targeting fishery is characterized in fishing in temperate waters, applying less than 13 hooks per basket, and catching smaller albacore. By contrast, the non-albacore-targeting fishery tends to fish in tropical waters, apply more than 14 hooks per basket, and catch larger albacore. Taking the fishing strategies and area segregation into account would be essential to estimate the albacore CPUE. By doing so, this working paper obtained the standardized albacore CPUE trend of Taiwanese longline fisheries in the North Pacific Ocean, 1995-2011.

Reference

Chen, C. Y. & F. C. Cheng. 2013. Development of Taiwanese albacore-targeting longline fisheries in the North Pacific Ocean, 1995-2010. ISC working paper, ISC/13/ALBWG/16.

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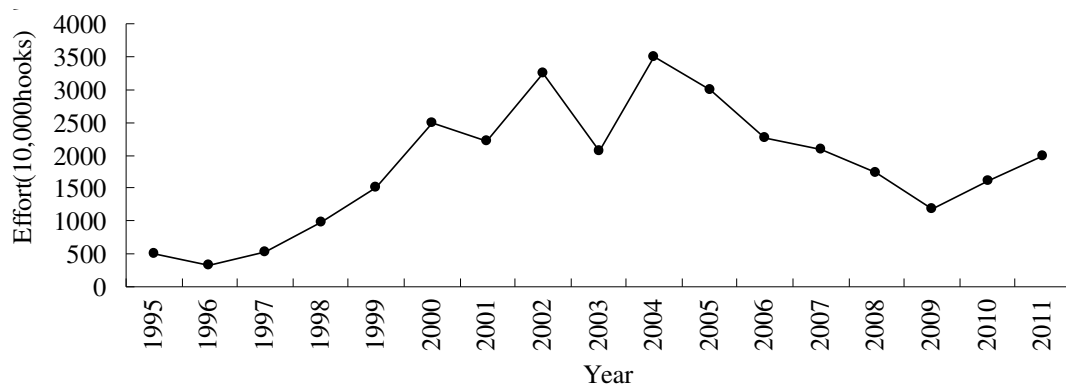
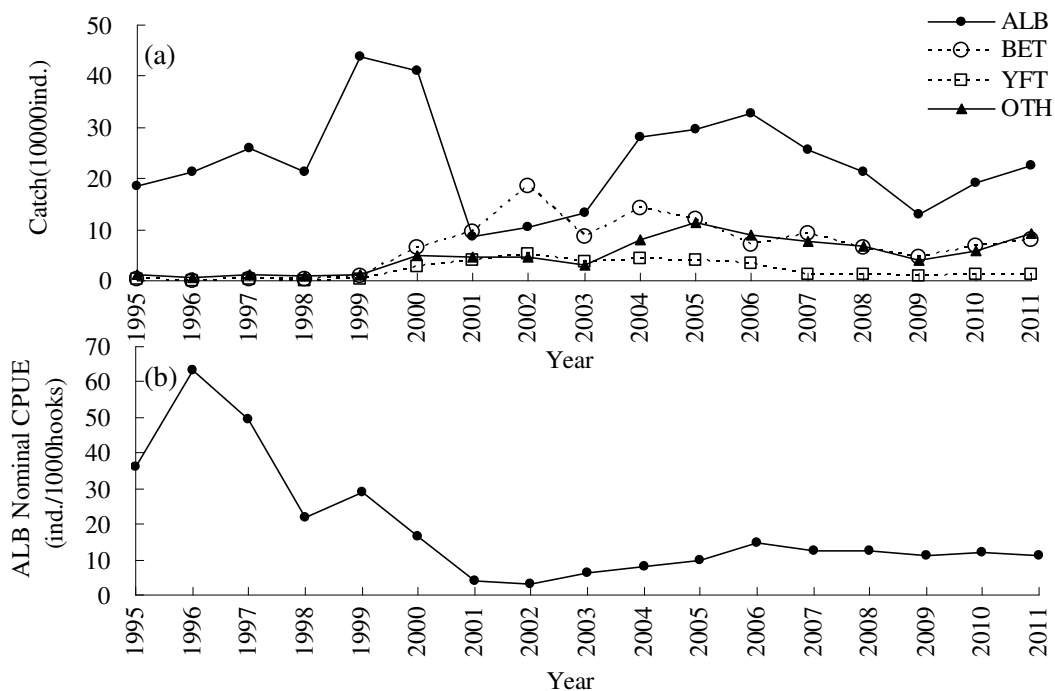Fig. 1. Annual fishing efforts of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2011.

Fig. 2. Yearly catch statistics of Taiwanese longline fisheries in North Pacific Ocean, 1995-2011. (a) catch in numbers by species (b) nominal CPUE of albacore.
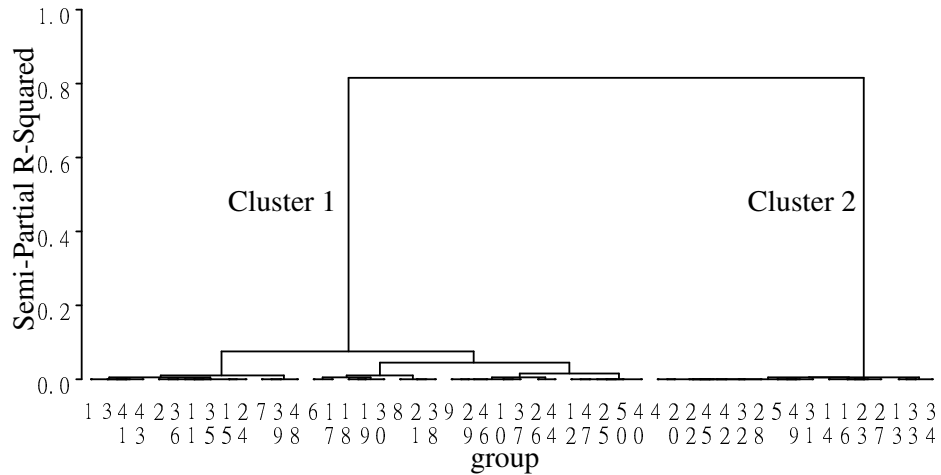
Fig. 3. Hierarchical tree obtained from cluster analyses on the catch compositions of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2009.

Table 1. Results of cluster analyses based on the catch compositions of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2009.

	CPUE Unit：ind./1000hooks			
	Cluster 1		Cluster 2	
Species	CPUE	SE	CPUE	SE
ALB	27.64	0.187	0.12	0.003
BET	1.17	0.015	6.24	0.031
YFT	0.27	0.005	2.05	0.018
Other tuna	0.02	0.003	0.01	0.001
SWO	0.14	0.002	0.57	0.006
WHM	0.12	0.002	0.10	0.002
BLZ	0.06	0.002	0.31	0.003
BLM	0.01	0.001	0.00	0.000
BIL	0.06	0.003	0.02	0.001
SKJ	0.35	0.011	0.06	0.003
SKX	0.45	0.009	0.51	0.007
OTHER	1.86	0.023	1.00	0.012
ALB ratio%	81.00		0.89	
Effort(hooks)	71,099,957		90,515,324	

Table 2. Results of discriminant analyses (a) and catch compositions of albacore-targeting and non-albacore-targeting fisheries defined by discriminant analyses (b)

(a)

Data Year	1995-2009		2010-2011	Total
Group	Correct	Error	Correct	
Group1_ALB-targeting	17500	718	2125	20343
Ratio%	96	4		
Group2_Non-ALB-targeting	29736	677	7761	38174
Ratio%	98	2		
Total	47236	1395	9886	58517
Ratio%	97	3		

(b)   CPUE Unit:ind./1000hooks

Species	Group1		Group 2	
	CPUE	SE	CPUE	SE
ALB	28.53	0.181	0.41	0.018
BET	1.30	0.018	5.96	0.027
YFT	0.26	0.006	1.83	0.015
Other tuna	0.02	0.003	0.00	0.001
SWO	0.13	0.002	0.56	0.005
WHM	0.12	0.002	0.09	0.002
BLZ	0.05	0.002	0.34	0.003
BLM	0.01	0.000	0.00	0.000
BIL	0.06	0.003	0.02	0.001
SKJ	0.38	0.011	0.05	0.003
SKX	0.51	0.009	0.72	0.008
OTHER	2.06	0.024	1.06	0.010
ALB ratio%	79.61		2.06	
Effort(hooks)	80,176,895		112,595,422	
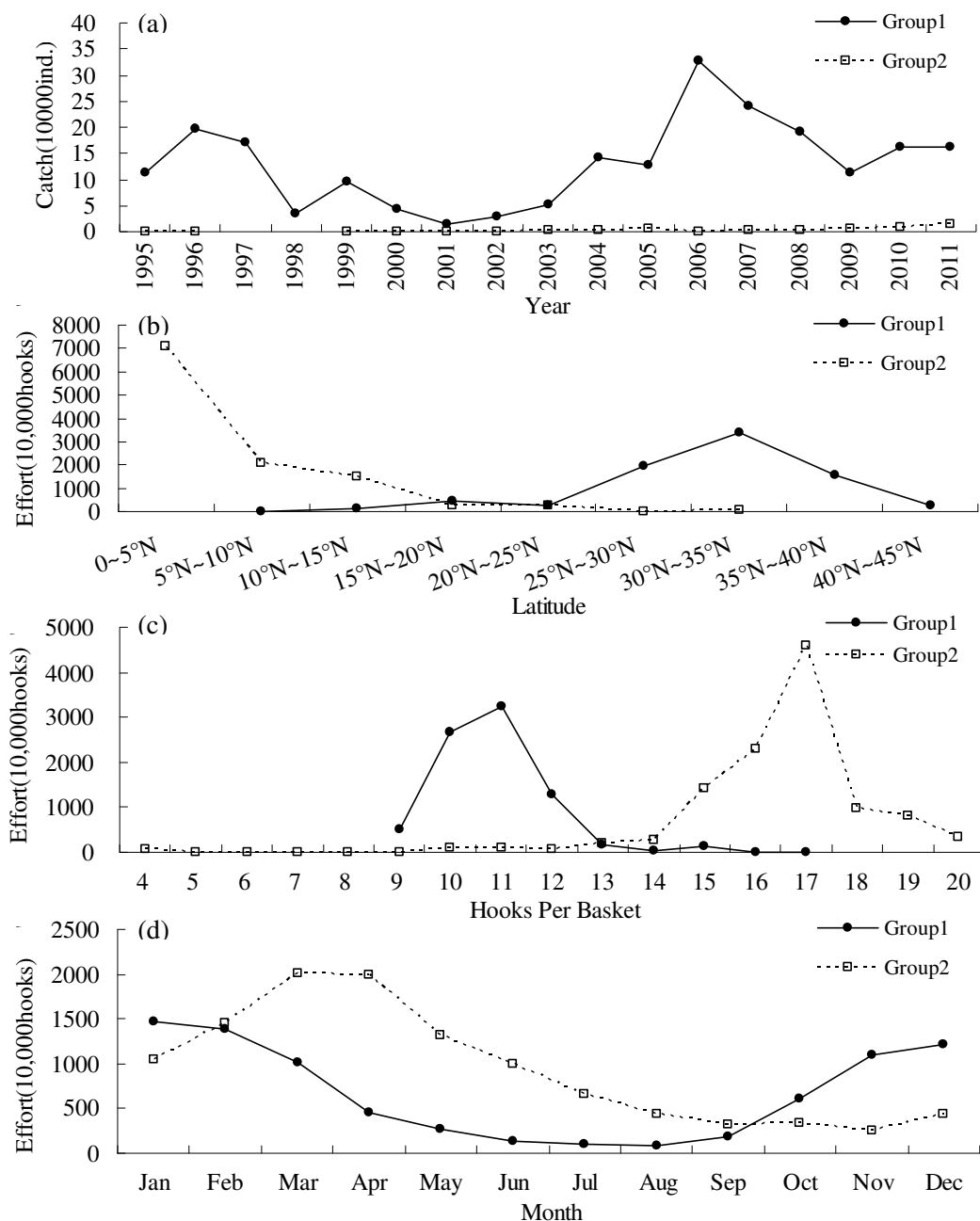
Fig. 4. Characteristics of Taiwanese longline fisheries (by group; group 1 denotes albacore-targeting and group 2 denotes non-albacore-targeting) operated in North Pacific Ocean, 1995-2011. (a) yearly albacore catch in number (b) latitudinal distribution of fishing efforts (c) fishing efforts vs. number of hooks per basket (d) monthly distribution of fishing efforts
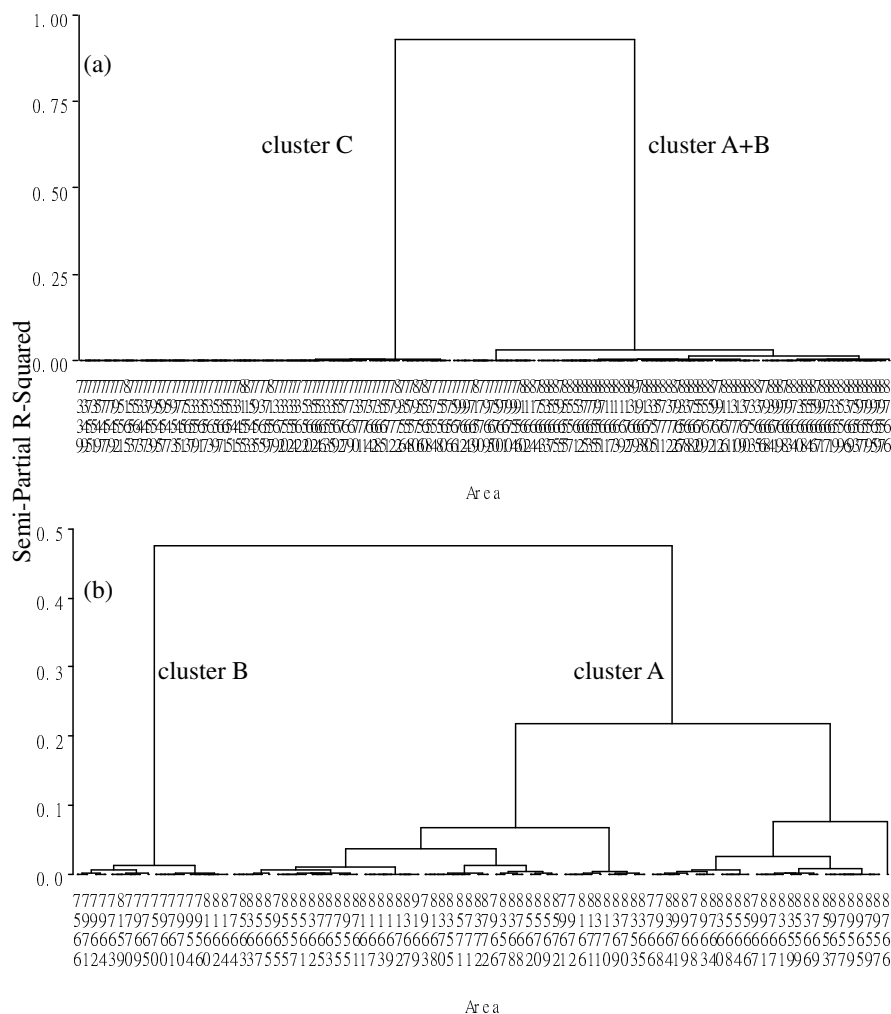
Fig. 5. Hierarchical tree to define sub-areas of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2011. (a) entire north Pacific Ocean (b) cluster A and B only
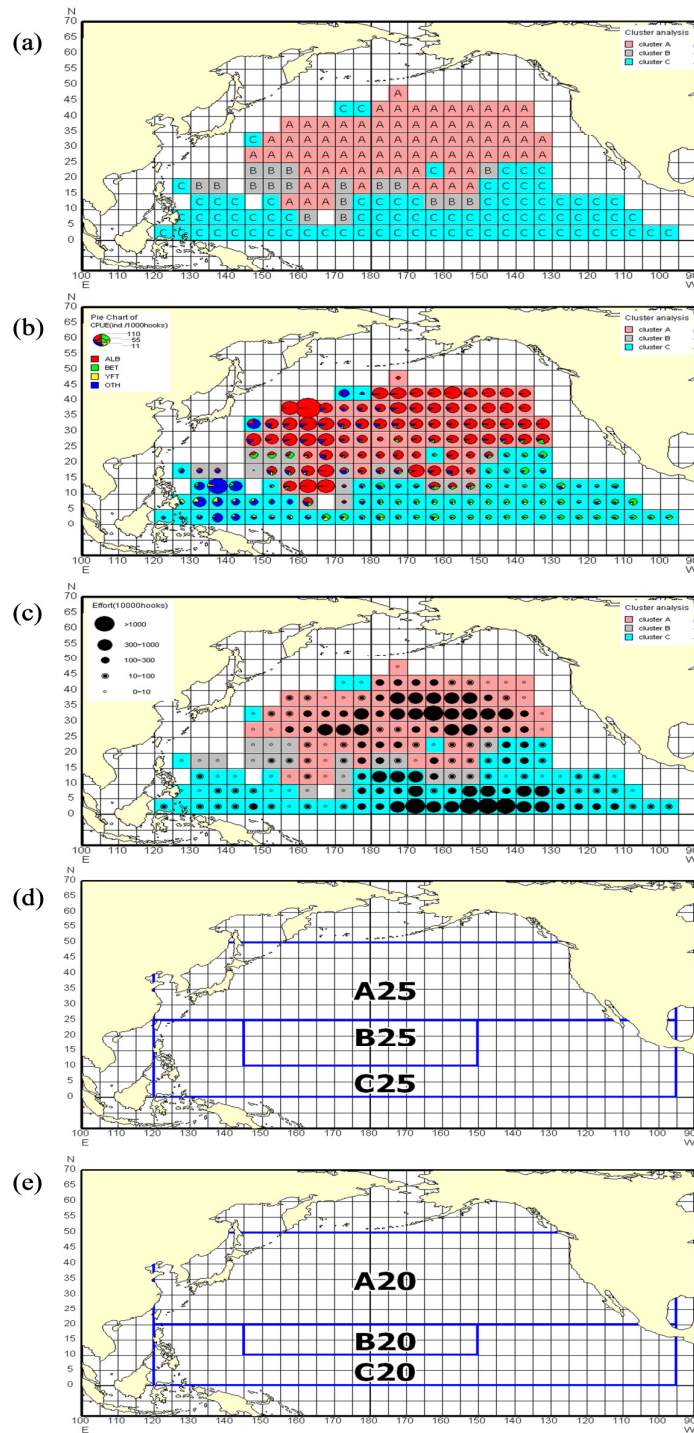
Fig. 6. Definitions of area A, B and C for GLM analysis. (a) geographical distributions of
cluster A, B and C (b) catch compositions of cluster A, B and C (c) fishing efforts of
cluster A, B and C (d) definitions of area A, B and C (e) alternative definitions of
area A, B and C

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Table 3. Catch compositions of Taiwanese longline fisheries operated in area A, B,C
and B+C of North Pacific Ocean, 1995-2011.

(a)

CPUE Unit：ind./1000hooks

Species	area A25		area B25		area C25		area B25+C25	
	CPUE	SE	CPUE	SE	CPUE	SE	CPUE	SE
ALB	28.78	1.057	10.62	0.913	0.62	0.158	3.98	0.371
BET	1.11	0.084	2.78	0.186	5.02	0.159	4.27	0.129
YFT	0.18	0.015	1.07	0.123	1.74	0.079	1.51	0.068
Other tuna	0.01	0.004	0.02	0.010	0.00	0.001	0.01	0.003
SWO	0.13	0.007	0.18	0.022	0.58	0.047	0.45	0.033
WHM	0.11	0.011	0.26	0.037	0.12	0.011	0.17	0.014
BLZ	0.04	0.005	0.26	0.020	0.42	0.035	0.37	0.024
BLM	0.01	0.001	0.01	0.003	0.01	0.002	0.01	0.002
BIL	0.04	0.007	0.08	0.018	0.04	0.009	0.06	0.009
SKJ	0.27	0.029	0.35	0.068	0.13	0.034	0.20	0.033
SKX	0.55	0.070	0.79	0.130	1.10	0.138	1.00	0.102
OTHER	1.70	0.108	1.77	0.210	1.01	0.094	1.26	0.095
ALB ratio%	82.63		45.26		3.82		17.73	

(b)

CPUE Unit：ind./1000hooks

| Species	area A20		area B20		area C20		area B20+C20	
	CPUE	SE	CPUE	SE	CPUE	SE	CPUE	SE
ALB	26.02	0.959	9.37	1.091	0.58	0.160	3.04	0.364
BET	1.41	0.097	3.09	0.218	4.95	0.161	4.43	0.135
YFT	0.24	0.019	1.23	0.162	1.82	0.082	1.65	0.075
Other tuna	0.01	0.003	0.02	0.014	0.00	0.001	0.01	0.004
SWO	0.13	0.007	0.21	0.027	0.60	0.050	0.49	0.037
WHM	0.14	0.016	0.21	0.027	0.11	0.010	0.14	0.011
BLZ	0.05	0.005	0.30	0.024	0.45	0.037	0.41	0.027
BLM	0.01	0.001	0.01	0.004	0.01	0.002	0.01	0.002
BIL	0.05	0.009	0.05	0.016	0.04	0.010	0.05	0.008
SKJ	0.26	0.026	0.37	0.088	0.13	0.036	0.20	0.036
SKX	0.54	0.061	0.93	0.174	1.13	0.145	1.07	0.116
OTHER	1.68	0.103	1.77	0.241	1.00	0.098	1.22	0.098
ALB ratio%	77.67		37.74		3.51		13.09	
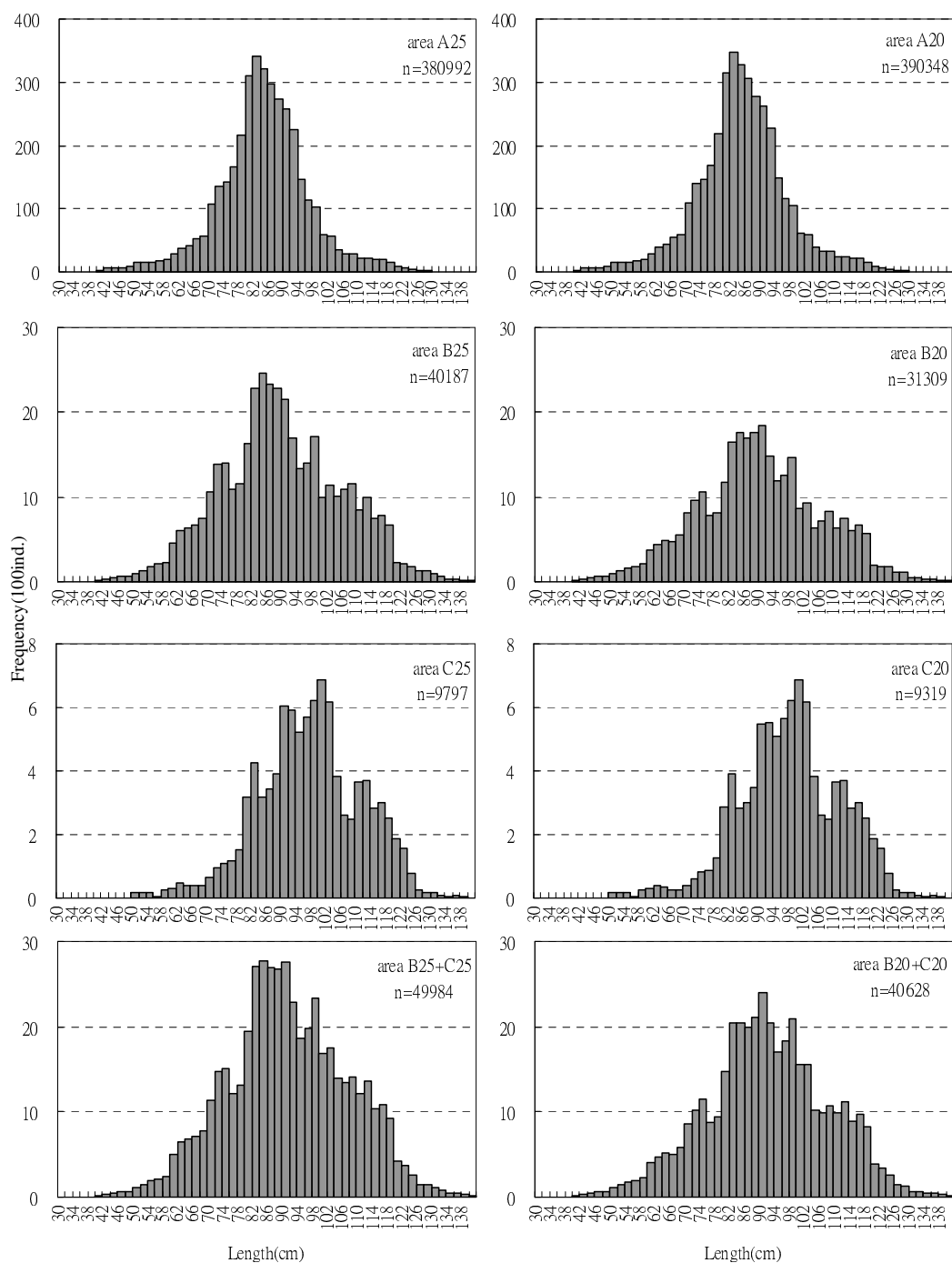
Fig. 7. Length frequency distributions of albacore caught in area A, B and C, by
Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2011.

Table 4. Results of GLM analyses on the albacore CPUE of Taiwanese longline

fisheries operated in North Pacific Ocean, 1995-2011.

(a) area A25, B25, C25

Source	DF	Sum of Squares	Mean Square	F Value	p
Model	27	4334.07	160.52	380.95	<.0001
Error	20315	8560.17	0.42		
Corrected Total	20342	12894.24			

Source	DF	Type III SS	Mean Square	F Value	p
Year	16	3359.29	209.96	498.27	<.0001
Season	3	7.59	2.53	6.00	0.0004
Area	2	336.77	168.38	399.61	<.0001
Season*Area	6	29.17	4.86	11.54	<.0001

(b) area A25 and B25+C25

Source	DF	Sum of Squares	Mean Square	F Value	p
Model	23	4262.78	185.34	436.30	<.0001
Error	20319	8631.45	0.42		
Corrected Total	20342	12894.24			

Source	DF	Type III SS	Mean Square	F Value	p
Year	16	3419.51	213.72	503.11	<.0001
Season	3	26.92	8.97	21.12	<.0001
Area	1	300.77	300.77	708.04	<.0001
Season*Area	3	15.61	5.20	12.25	<.0001

Table 5. Results of GLM analyses on the albacore CPUE of Taiwanese longline

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fisheries operated in North Pacific Ocean, 1995-2011.

(a) area A20, B20, C20

Source	DF	Sum of Squares	Mean Square	F Value	p
Model	27	4137.23	153.23	355.47	<.0001
Error	20315	8757.01	0.43		
Corrected Total	20342	12894.24			

Source	DF	Type III SS	Mean Square	F Value	p
Year	16	3381.14	211.32	490.24	<.0001
Season	3	1.60	0.53	1.24	0.2943
Area	2	274.25	137.13	318.12	<.0001
Season*Area	6	22.44	3.74	8.68	<.0001

(b) area A20 and B20+C20

Source	DF	Sum of Squares	Mean Square	F Value	p
Model	23	4059.82	176.51	405.98	<.0001
Error	20319	8834.42	0.43		
Corrected Total	20342	12894.24			

Source	DF	Type III SS	Mean Square	F Value	p
Year	16	3445.71	215.36	495.32	<.0001
Season	3	29.58	9.86	22.68	<.0001
Area	1	233.28	233.28	536.54	<.0001
Season*Area	3	12.93	4.31	9.91	<.0001
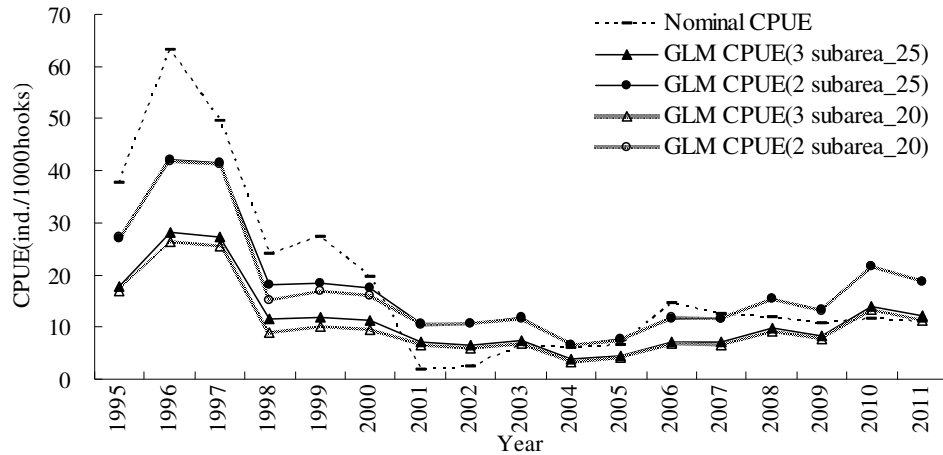
Fig. 8. Yearly fluctuations of nominal CPUE and GLM standardized CPUE of albacore caught by Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2011.

Table 6. The standardized CPUE of albacore exploited by Taiwanese longline fisheries in North Pacific Ocean, 1995-2011.

CPUE Unit：ind./1000hooks

| Year	area A, B, C_25				area A, B, C_20			
	3 subarea GLM CPUE	SE	2 subarea GLM CPUE	SE	3 subarea GLM CPUE	SE	2 subarea GLM CPUE	SE
1995	17.80	0.04	26.98	0.03	17.04	0.04	27.38	0.03
1996	28.14	0.04	41.98	0.02	26.48	0.04	41.81	0.02
1997	27.28	0.04	41.39	0.02	25.54	0.04	41.13	0.02
1998	11.55	0.04	17.99	0.03	8.92	0.05	15.03	0.04
1999	11.80	0.04	18.42	0.03	10.10	0.04	16.88	0.03
2000	11.19	0.04	17.53	0.03	9.52	0.05	15.96	0.04
2001	7.18	0.05	10.81	0.05	6.50	0.05	10.47	0.05
2002	6.43	0.05	10.54	0.04	6.01	0.05	10.62	0.04
2003	7.38	0.04	11.91	0.03	6.70	0.04	11.63	0.03
2004	3.71	0.03	6.65	0.02	3.21	0.04	6.41	0.02
2005	4.56	0.03	7.63	0.02	4.11	0.04	7.49	0.02
2006	7.23	0.03	11.70	0.02	6.82	0.04	11.83	0.02
2007	7.08	0.03	11.49	0.02	6.60	0.04	11.50	0.02
2008	9.69	0.03	15.28	0.02	9.21	0.04	15.48	0.02
2009	8.27	0.04	13.21	0.02	7.72	0.04	13.19	0.02
2010	14.09	0.04	21.56	0.02	13.34	0.04	21.73	0.02
2011	12.12	0.04	18.64	0.02	11.31	0.04	18.57	0.02
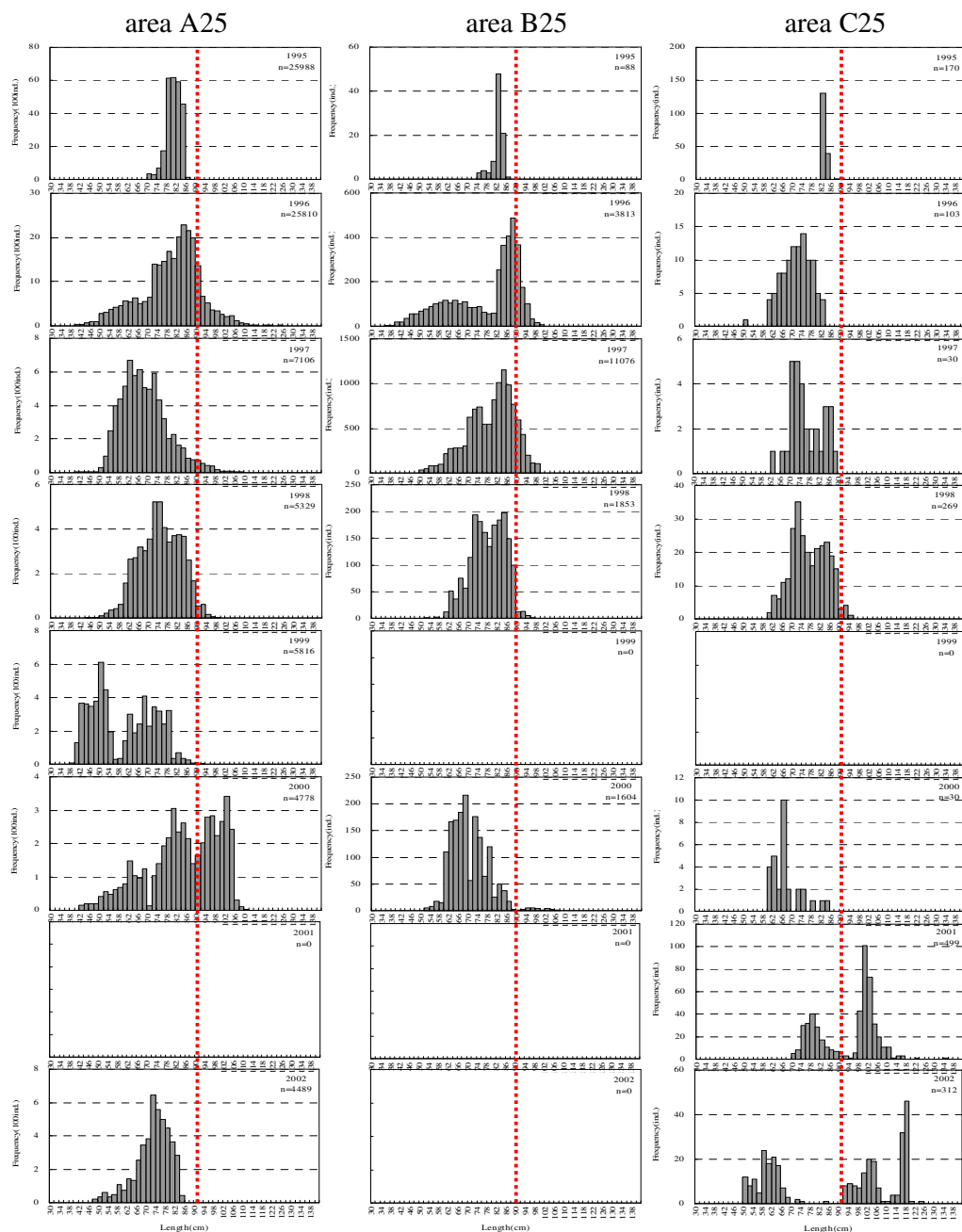
Fig. 9. Annual length distributions of north Pacific Ocean albacore caught from area A25, B25 and C25 by Taiwanese longliners, 1995-2011. Dotted line indicates 90cm of fork length.

area A25　　　area B25　　　area C25
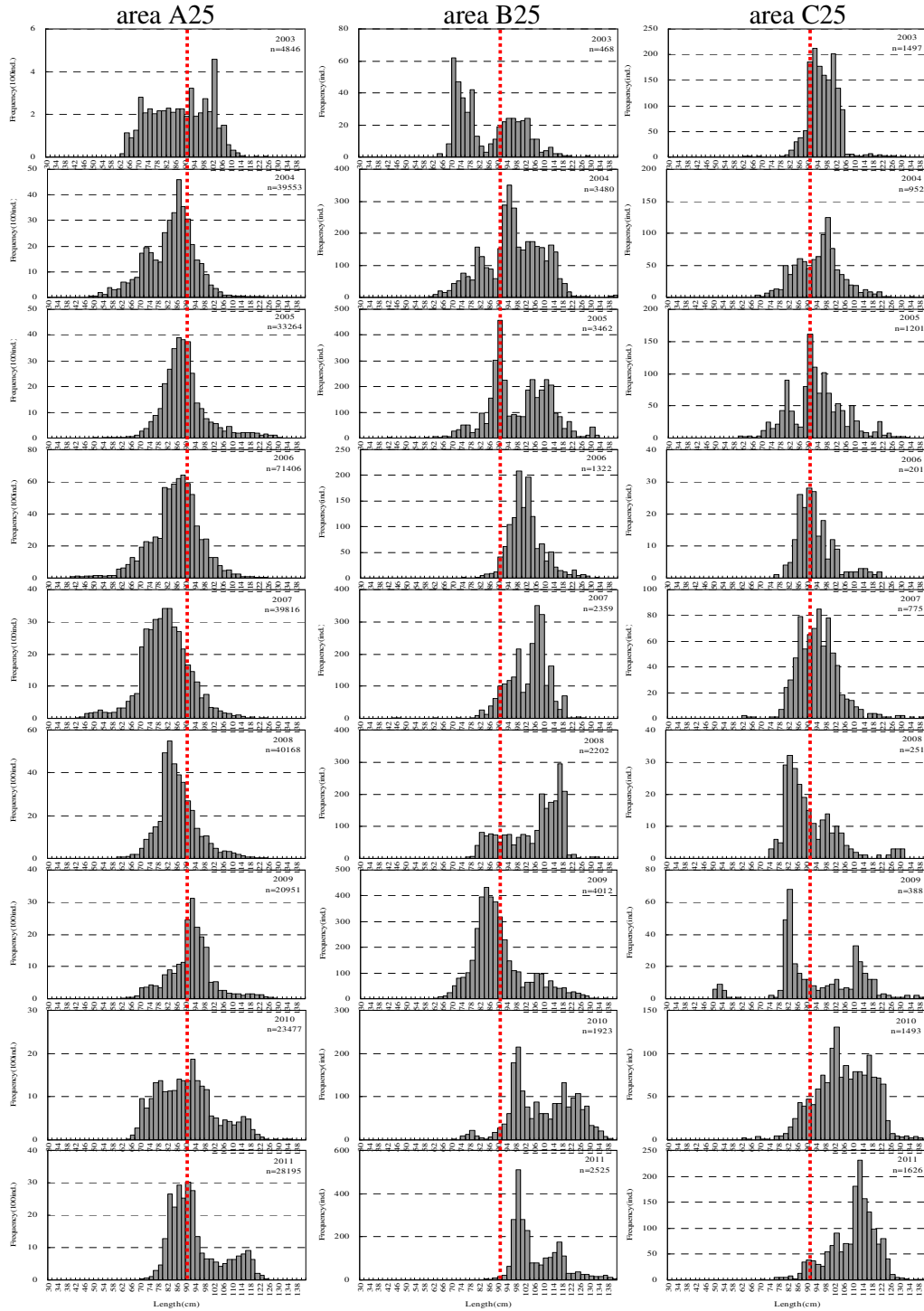
Fig. 9.(continued)
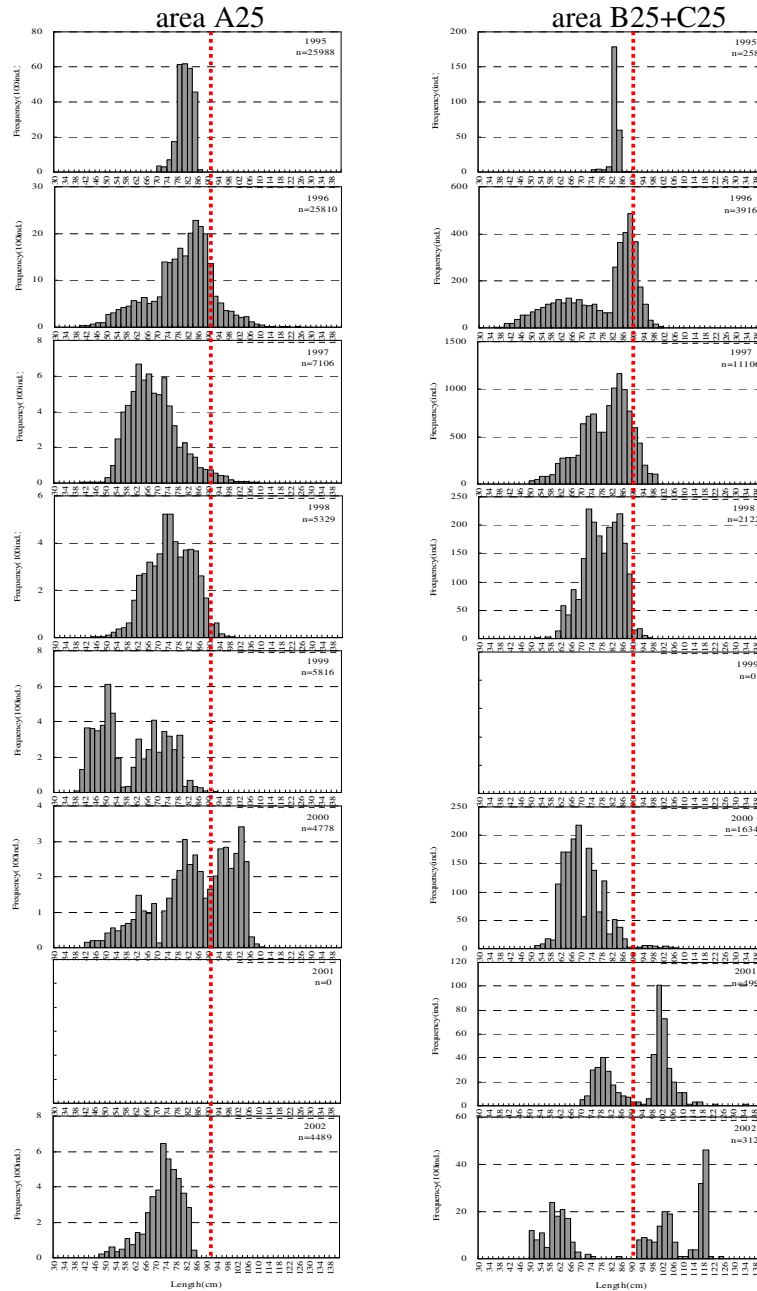
Fig. 10. Annual length distributions of North Pacific Ocean albacore caught from area
A25 and B25+C25 by Taiwanese longliners, 1995-2011. Dotted line indicates
90cm of fork length.

Fig. 10. (continued)

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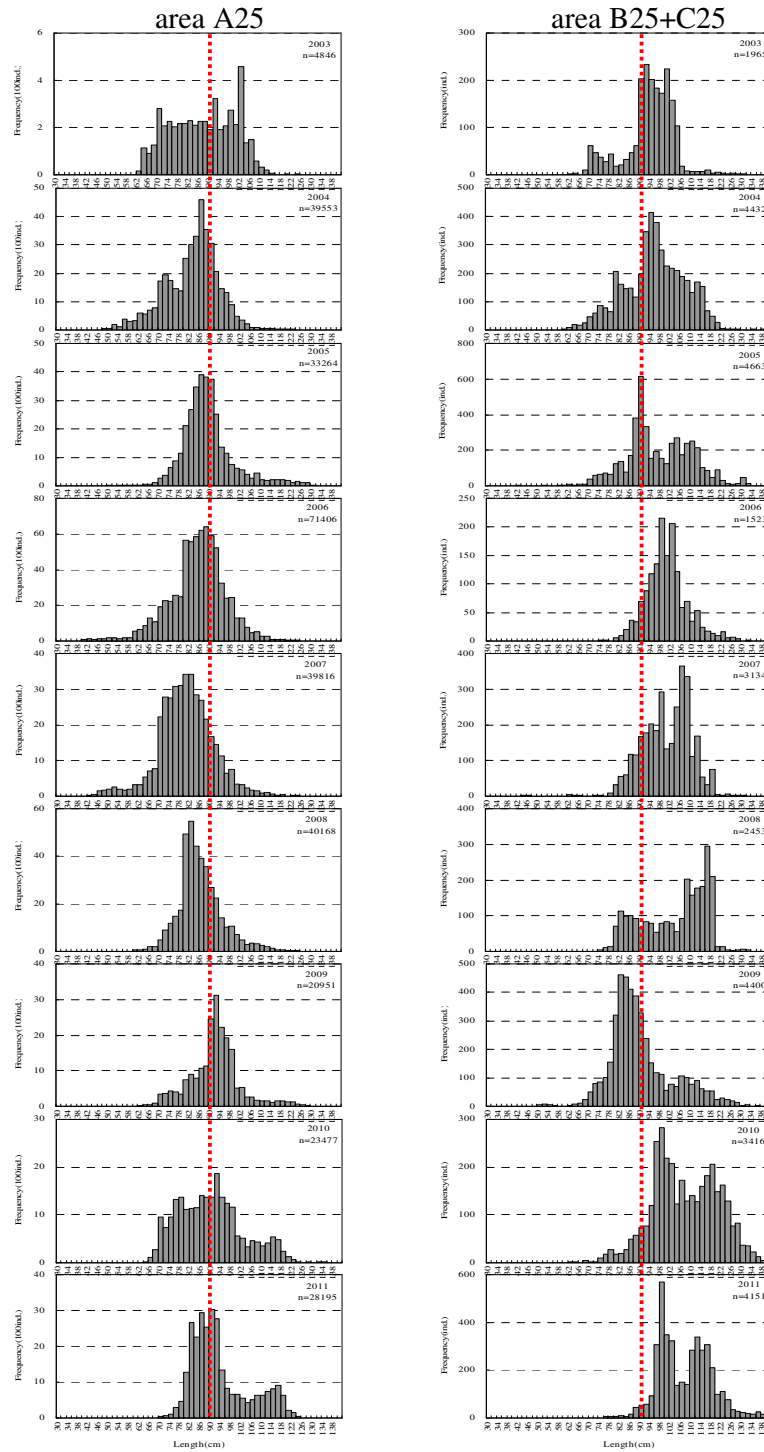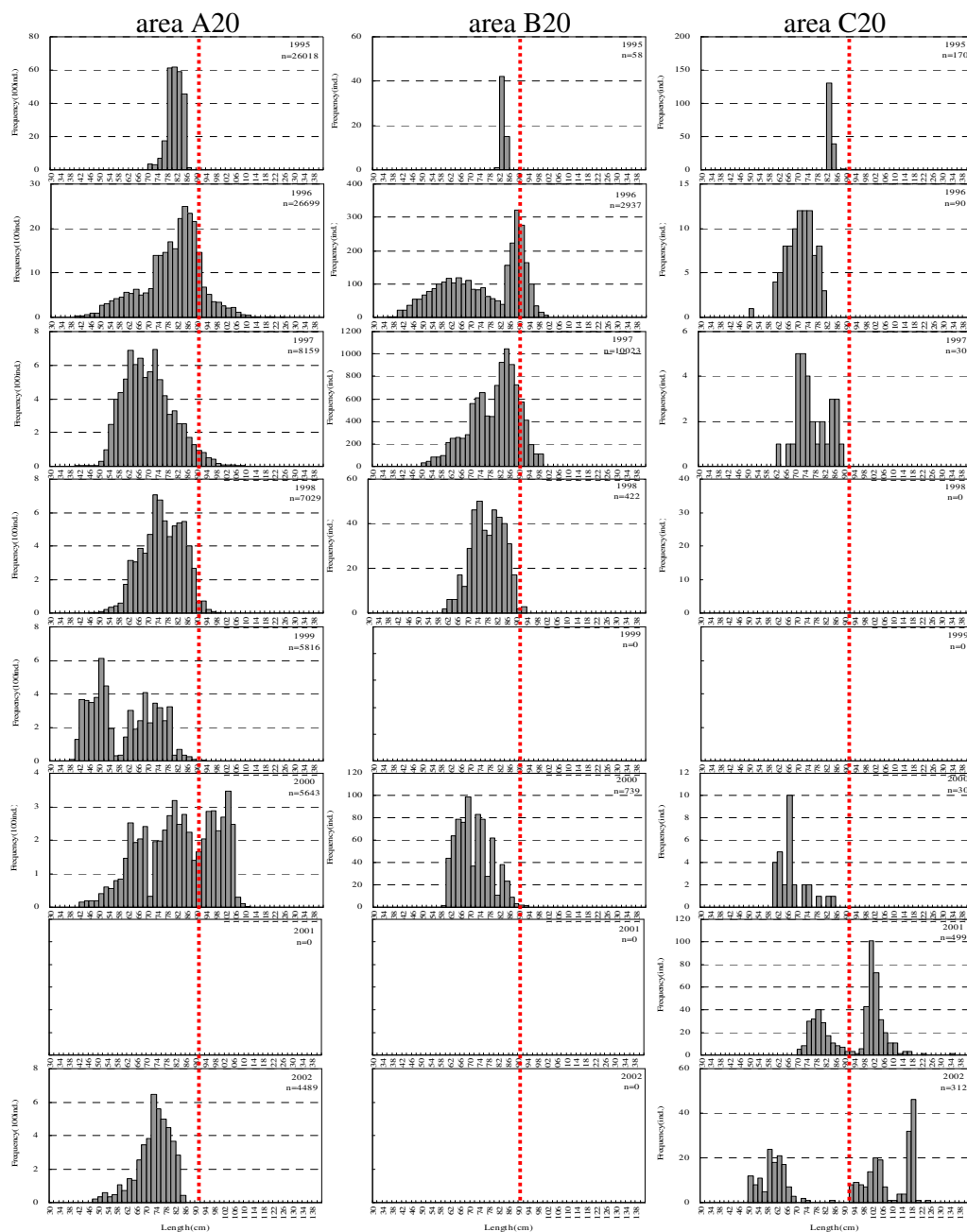
Fig. 11. Annual length distributions of North Pacific Ocean albacore caught from area A20, B20 and C20 by Taiwanese longliners, 1995-2011. Dotted line indicates 90cm of fork length.
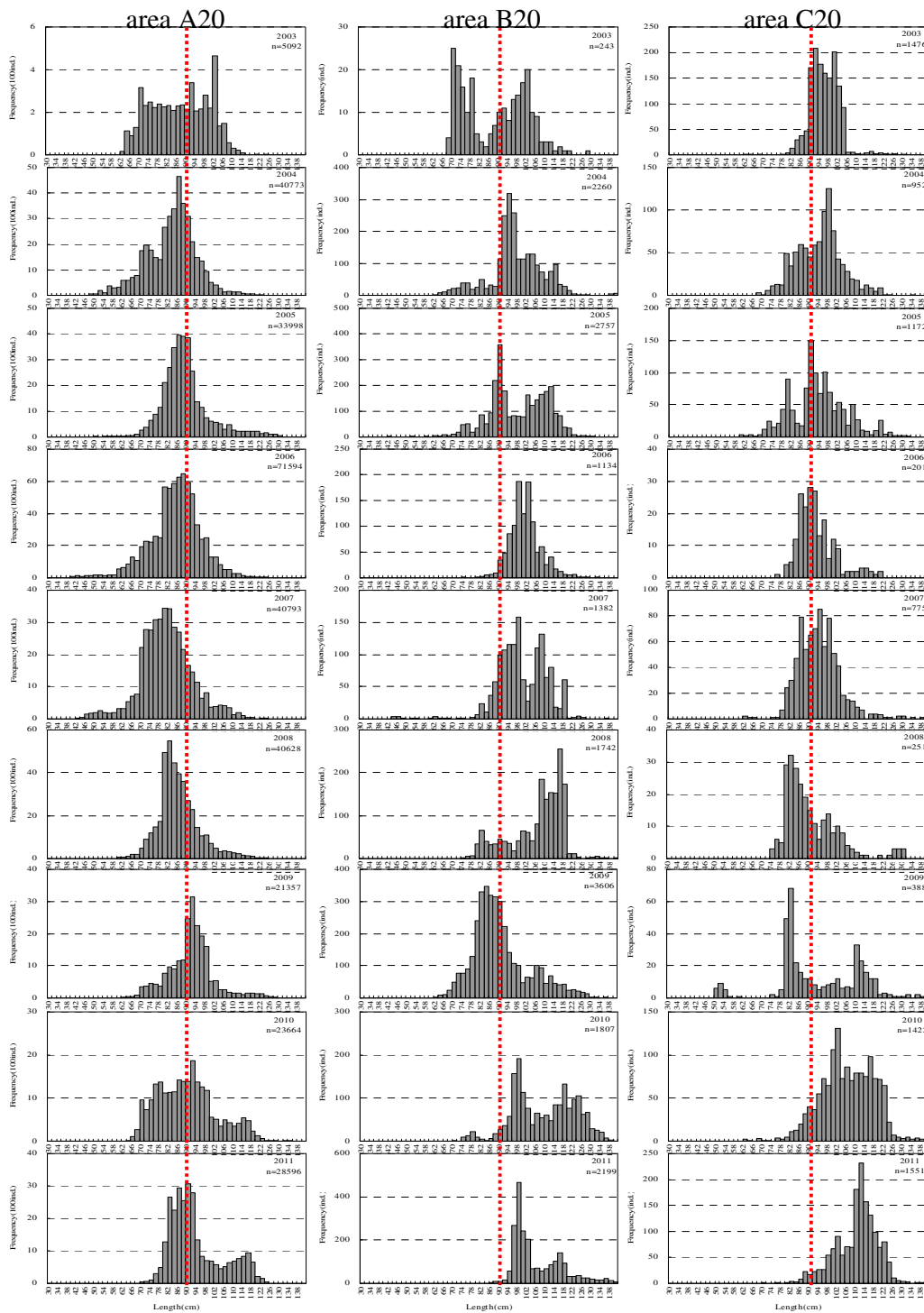
Fig. 11.(continued)
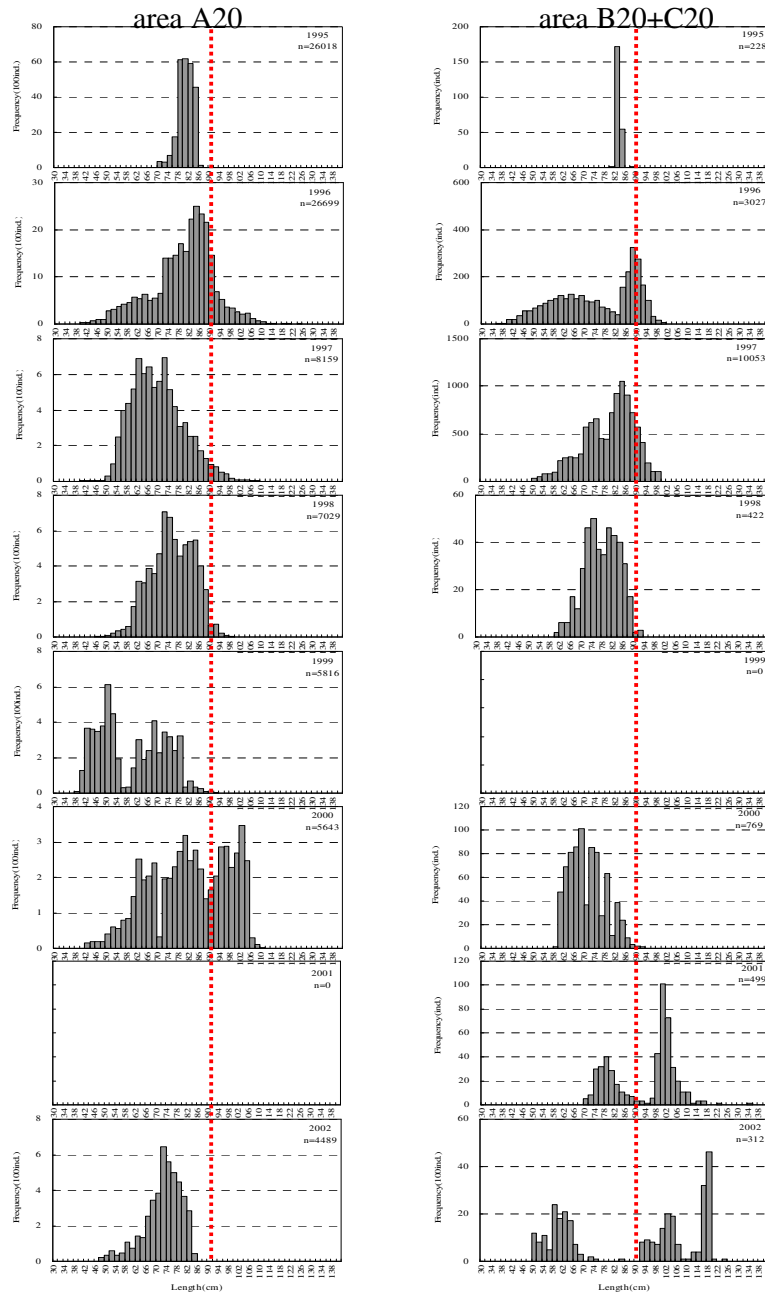
Fig. 12. Annual length distributions of north Pacific Ocean albacore caught from area A20 and B20+C20 by Taiwanese longliners, 1995-2011. Dotted line indicates 90cm of fork length.
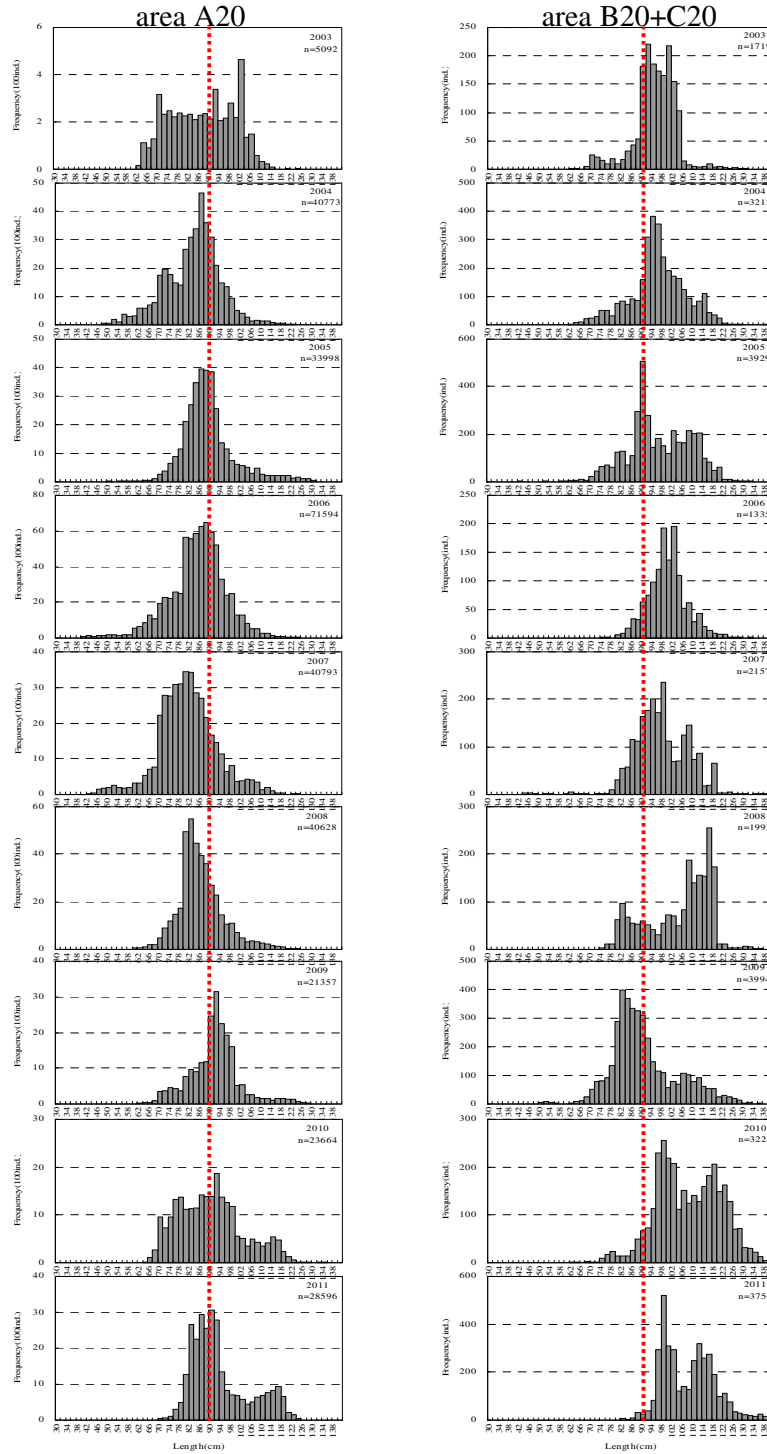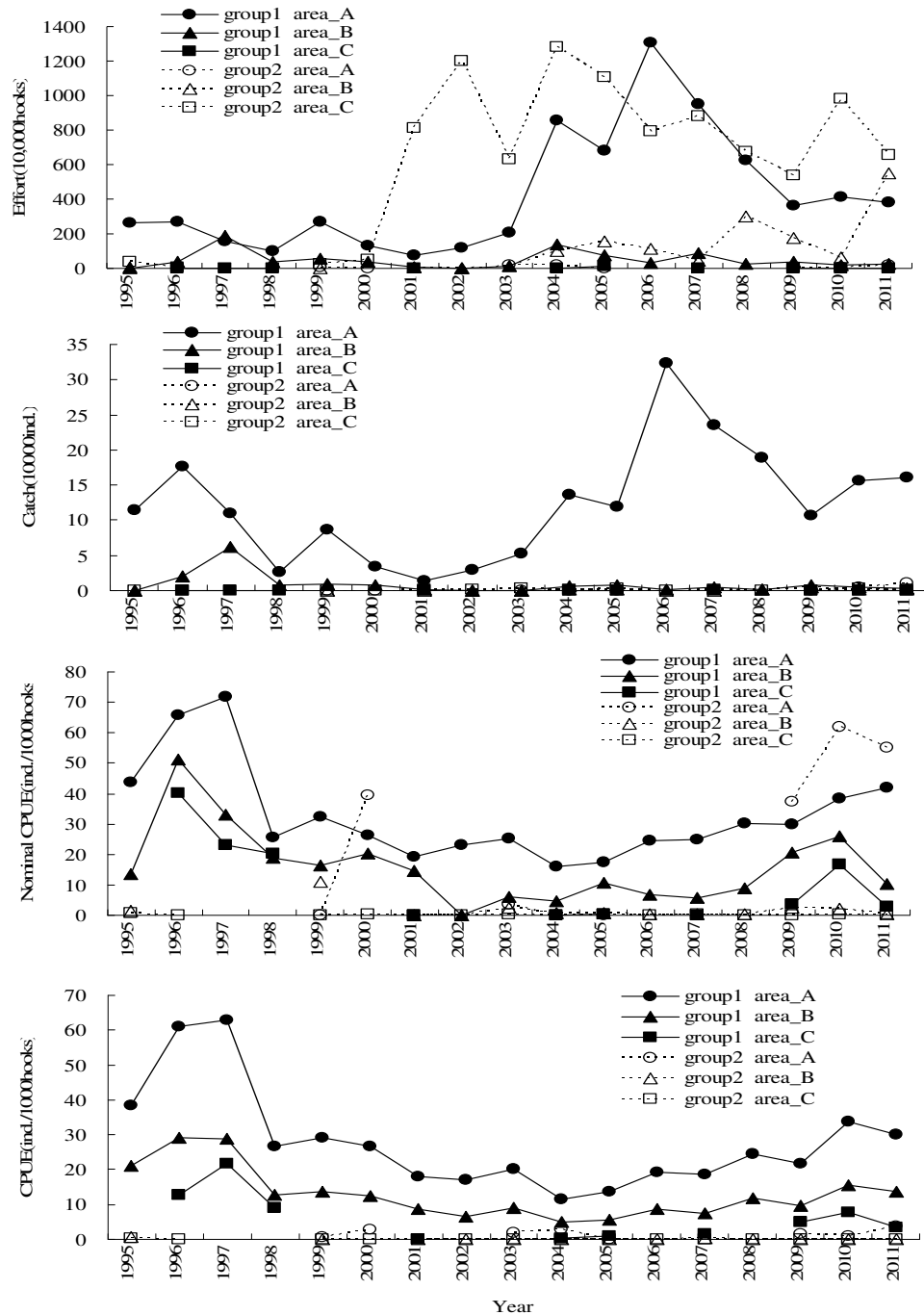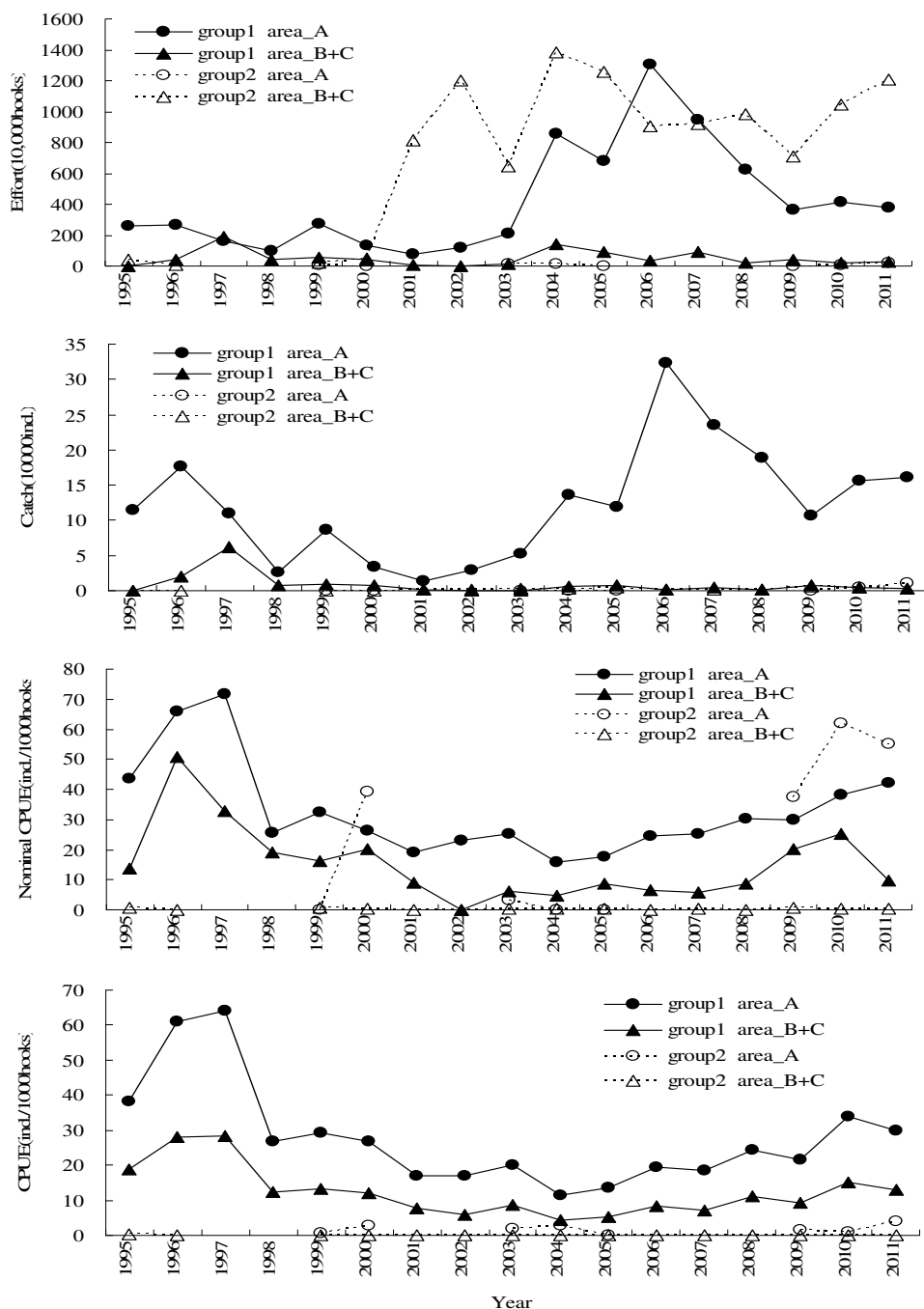
Fig. 12.(continued)

Fig. 13. Nominal fishing efforts, albacore catch, nominal albacore CPUE and standardized albacore CPUE of Taiwanese group1 (albacore-targeting) and group2 (non- albacore-targeting) longline fisheries operated in area A25, B25 and C25 of North Pacific Ocean, 1995-2011.

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Fig. 14. Nominal fishing efforts, albacore catch, nominal albacore CPUE and
   standardized albacore CPUE of Taiwanese group1 (albacore-targeting) and
   group2 (non- albacore-targeting) longline fisheries operated in area A25 and
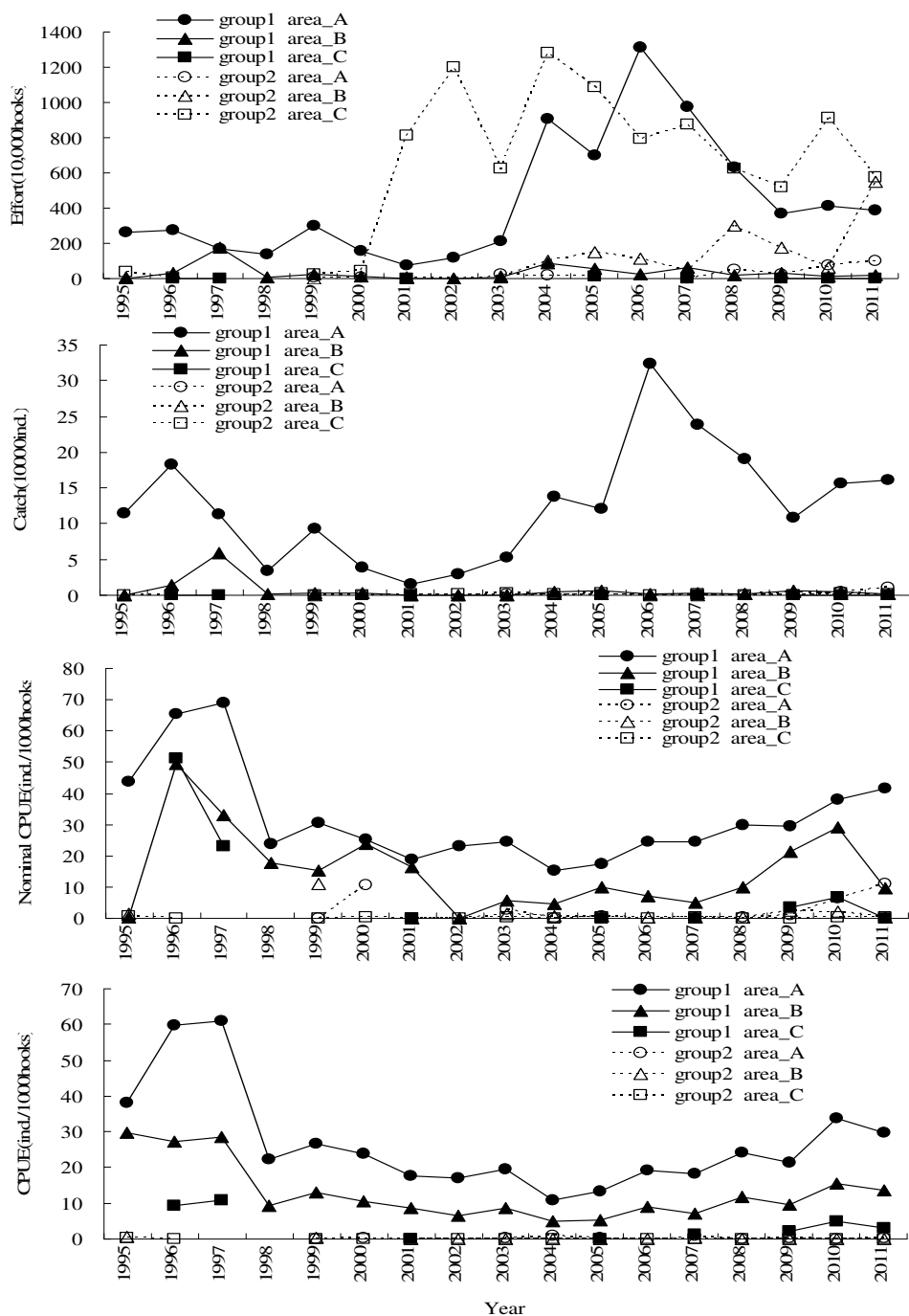   B25+C25 of North Pacific Ocean, 1995-2011.

Fig. 15. Nominal fishing efforts, albacore catch, nominal albacore CPUE and standardized albacore CPUE of Taiwanese group1 (albacore-targeting) and group2 (non- albacore-targeting) longline fisheries operated in area A20, B20 and C20 of North Pacific Ocean, 1995-2011.

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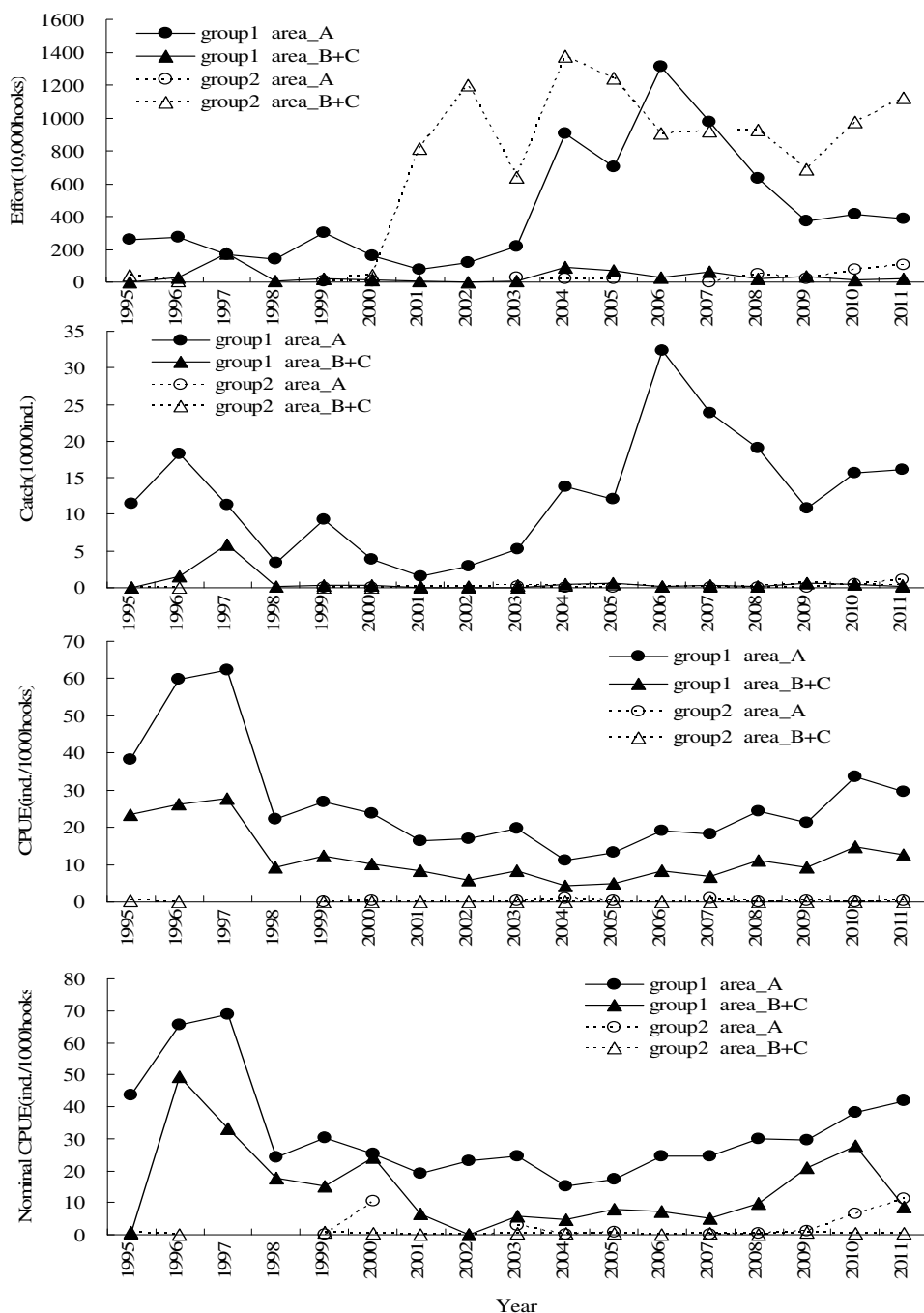
Fig. 16. Nominal fishing efforts, albacore catch, nominal albacore CPUE and
standardized albacore CPUE of Taiwanese group1 (albacore-targeting) and
group2 (non- albacore-targeting) longline fisheries operated in area A20 and
B20+C20 of North Pacific Ocean, 1995-2011.

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