The development of Taiwanese longline fishery in the North Pacific Ocean and estimation of albacore CPUE exploited by albacore-targeting fishery, 1995-2015

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Abstract

The historical development of Taiwanese longline fisheries operated in the North Pacific Ocean was reviewed in this study. Before 2000, fishing effort was not much, and mainly concentrated in the central North Pacific Ocean north of Lat. 25° N. Their catch was mostly contributed by albacore. Thereafter, increasing fishing efforts expanded to the tropical waters and increasing catch of tuna species other than albacore were reported. During this period, a gradual change in the fishing strategy of the longline fleets was observed, and it was coincided with a quite different species composition in their catch. Taking these changes in fishing strategy and species composition into account, the catch statistics of Taiwanese longline fishery were then categorized into albacore-targeting and non-albacore-targeting fisheries for further analyses. Then, general linear model was applied to estimate the CPUE trend, which is believed to be more informative to the stock status of North Pacific albacore exploited by Taiwanese longline fishery.

Introduction

Taiwanese longline fishery operated in the North Pacific Ocean can be traced back to 1995 (Anon. 2011). From 1995 to 2015, albacore always comprised a major part of annual total catch, ranging 2378 - 9456 mt. During this time period, changes in fishing activities, fishing areas and resultant catch compositions of this Taiwanese longline fishery were observed. In the beginning of this century, increasing number of fishing vessels tended to fish at a deeper layer of the waters by applying more than 14 hooks between two floats. Also, their fishing area started to expand to the tropical waters. As a result, the catch of bigeye tuna, yellowfin tuna and other tuna-like species increased, while the albacore catch remained fluctuated or even declined. This working paper is aiming to review the historical development of Taiwanese longline fishery in the North

Pacific Ocean, with emphases to describe the changes in fishing strategy, and resultant fishing performance. Effort were also made to segregate this fishery into albacore-targeting and non-albacore-targeting fisheries, in an attempt to provide a better basis to estimate the abundance index of the albacore stock in the North Pacific Ocean.

Materials and methods

The catch statistics of Taiwanese longline fishery operated in the North Pacific Ocean from 1995 to 2015, were kindly made available by the Overseas Fisheries Development Council, Taiwan. These included Task 2 data by month and by 5°X5° grid, daily logbook data of each fishing boat and albacore length data measured on board.

Methods similar to Chen and Cheng (2013) were adopted to define the albacore-targeting and non-albacore-targeting data. Firstly, hierarchical cluster analysis based on species compositions of daily logbook records were conducted to categorize original data into groups. Then, discriminant analyses were carried out to verify the grouping of catch statistics obtained from cluster analyses, and to define the albacore-targeting and non-albacore-targeting fisheries. Standardized albacore CPUE of Taiwanese longline fisheries were then estimated with the general linear model using the following equation:

$Ln(CPUE+c)=\mu+Y+Q+A+QxA+\varepsilon$, where

c is 10% of overall mean nominal CPUE

Y is year

Q is quarter

A is area defined by Chen and Cheng (2013)

ε is error term

Results and discussion

In the early years, Taiwanese longline fleets mainly operated in the central North Pacific Ocean north of Lat. 25°N. Around 2000, fishing efforts began to expand to tropical waters, however capture of albacore was not so successful in the tropical waters comparing to that of temperate waters (Fig. 1). The annual fishing efforts fluctuated between 4 million and 35 million hooks with an increasing trend in the early years and then a dropping after 2004 (Fig. 2). Albacore tuna comprised most of the catch,

particularly before the year of 2000, then a sharp decline in albacore catch occurred and increasing catch of bigeye, yellowfin and other tuna-like species was recorded (Fig. 3(a)). As a result, the nominal albacore CPUE declined significantly (Fig. 3(b)). The increasing fishing efforts, expansion of fishing area and reduction in the efficiency of catching albacore may be explained by the commencement of deep-longliner in the North Pacific Ocean around 2000, which is known to target on bigeye and yellowfin tunas, instead of albacore.

One of the main features of deep-longliners is that they tend to fish at deeper layer of the water by applying more number of hooks per basket (HPB) in their daily operations. The bi-modal distribution of HPB clearly demonstrates two types of fishing strategy operated in the North Pacific Ocean (Fig. 4(a)). Those with less than 13 HPB are apparently more efficient in catching albacore, whereas those with 14-20 HPB are much less efficient (Fig. 4(b)). It is noted that high efficiency in catching albacore are also observed for those with more than 21 HPB. However, these fleets appeared in recent years and only composed of a small proportion to the total fishing effort (Fig. 5). Since 2001, the fishing effort of those with 14-20 HPB increased significantly and remained a major part to the total fishing effort (Fig. 5). The three fishing types, defined as 4-13, 14-20 and 21-25 HPB, also show differences in their fishing area and corresponding nominal albacore CPUE, as shown in Fig. 6.

In order to segregate the historical catch statistics into albacore-targeting and non-albacore-targeting groups, methods reported by Chen and Cheng (2013) were adopted, in which cluster analysis on the daily catch composition was conducted to group the catch statistics and followed by discriminant analysis to verify the cluster grouping. The results of non-hierarchical and hierarchical clustering analyses show a clear separation of two clusters (Fig. 7). Cluster 1 is composed of records obviously targeting on albacore, while cluster 2 is those of non-albacore-targeting (Table 1). A discriminant analysis was then conducted based on fishing activities, i.e., fishing month, fishing area and number of HPB to verify the clustering grouping results. Table 2(a) shows the results that high consistency was obtained between the segregations of cluster analyses and discriminant analysis, with only 3% error count. Following the results, group 1 is defined as albacore-targeting catch statistics with a mean albacore CPUE of 30.43 individuals/1000 hooks, while group 2 is defined as non-albacore-targeting data with a mean albacore CPUE only 0.28 individuals/1000 hooks (Table 2 b).

By examining the albacore catch, fishing area, fishing season and fishing type of each group (i.e., albacore-targeting and non-albacore-targeting), it is not surprised to reveal that most of the albacore catch are contributed by group 1 data no matter before or after the year of 2000 (Fig. 8(a)), implying that the group 1 data is more informative in explaining the abundance status of albacore exploited by Taiwanese longliners. Moreover, group 1 data are mainly derived from longliners operated in the north of 25°N, while group 2 data are those 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 HPB in their daily fishing operation, while those of group 2 mainly applied more number of HPB (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)).

General linear model (GLM) was then applied to standardize the CPUE of North Pacific albacore exploited by Taiwanese albacore-targeting longline fisheries. Year, season, and area factor were included in the GLM analyses The model itself and the factors applied are all statistically significant (Table 3) to the CPUE. The Q-Q plot and normal probability plot were obtained and both showed rather good fitting (Fig. 9). The standardized albacore CPUE trends of Taiwanese longline fisheries is shown in Fig. 10 and Table 4. It is noted that the standardized CPUE before 2000 does not drop as drastically as that of nominal CPUE, and remain rather stable afterwards.

As noted that fishing effort with more than 20 HPB began to appear in 2012. Some of these fishing efforts were categorized into group 1, and they only distributed in a small area mostly north of Lat. 25°N (Fig. 11). The albacore CPUE made by these fishing efforts were similar to that of group 1 fisheries, although differences in some of 5-degree square were observed (Fig. 12). Attempt was made to include the HPB as a factor in the GLM model to examine the influence of HPB to the CPUE estimation. In the GLM model, number of HPB was categorized into two groups, i.e., greater than 20 HPB and equal to or less than 20 HPB. The results were shown in Fig. 13 and Table 5 that the model itself remains significant, but its F value is lower than that of GLM excluding HPB factor, as shown in Table 3. Moreover, the HPB is also significant to the model, although the probability value shows less significant than those of the other factors. The standardized CPUE were then obtained and its yearly trend was shown in Fig. 14. The CPUE trend including HPB factor in GLM model is almost identical to that of excluding HPB factor. Currently, it is suggested that the CPUE standardization may not be necessary to include the HPB factor until more of these data are available.

Yearly length distributions of albacore are also presented in this working paper. Before 2002, the distributions change year form year and do not show a stable pattern. It can be observed that most of fish are smaller than 90 cm FL. From 2003 till 2015, the distributions are more consistent between years, with a mode around 90 cm or so (Fig. 15). Length measurement is supposed to be made randomly from the catch of albacore, hence, the number of length measurement would be proportional to the albacore catch in a given time-area. Figure 16 shows the latitudinal distributions of the length measurement and albacore catch in number, they appear to be consistent to each other, suggesting these length measurements were likely made randomly from the albacore catch. However, it seems remain difficult to explain the length distribution of albacore catch before 2002.

In summary, Taiwanese longline fisheries, 1995-2015, operated in the North Pacific Ocean contain two type of operations, i.e., albacore-targeting and non-albacore-targeting. The albacore-targeting fishery is characterized in fishing in temperate waters, and applying less than 13 HPB. By contrast, the non-albacore-targeting fishery tends to fish in tropical waters, and apply more than 14 HPB. Before 2000, the albacore-targeting fishery dominates the entire Taiwanese longline fisheries in North Pacific Ocean. As a result, most of the catches were albacore. Around 2000, the non-albacore-targeting started to share the importance with albacore-targeting fishery. The increasing catch of species other than albacore also reflects the increasing number of non-albacore-targeting longliners since 2000.

References

Anon. 2011. Stock assessment of albacore tuna in the North Pacific Ocean in 2011. Report of the Albacore Working Group Stock Assessment workshop. ISC/11/Plenary.

Chen, C. Y., and Cheng, F. C. 2013. Taiwanese albacore-targeting longline fisheries in the North Pacific Ocean, 1995-2011. ISC working paper, ISC/13/ALBWG-03/01.

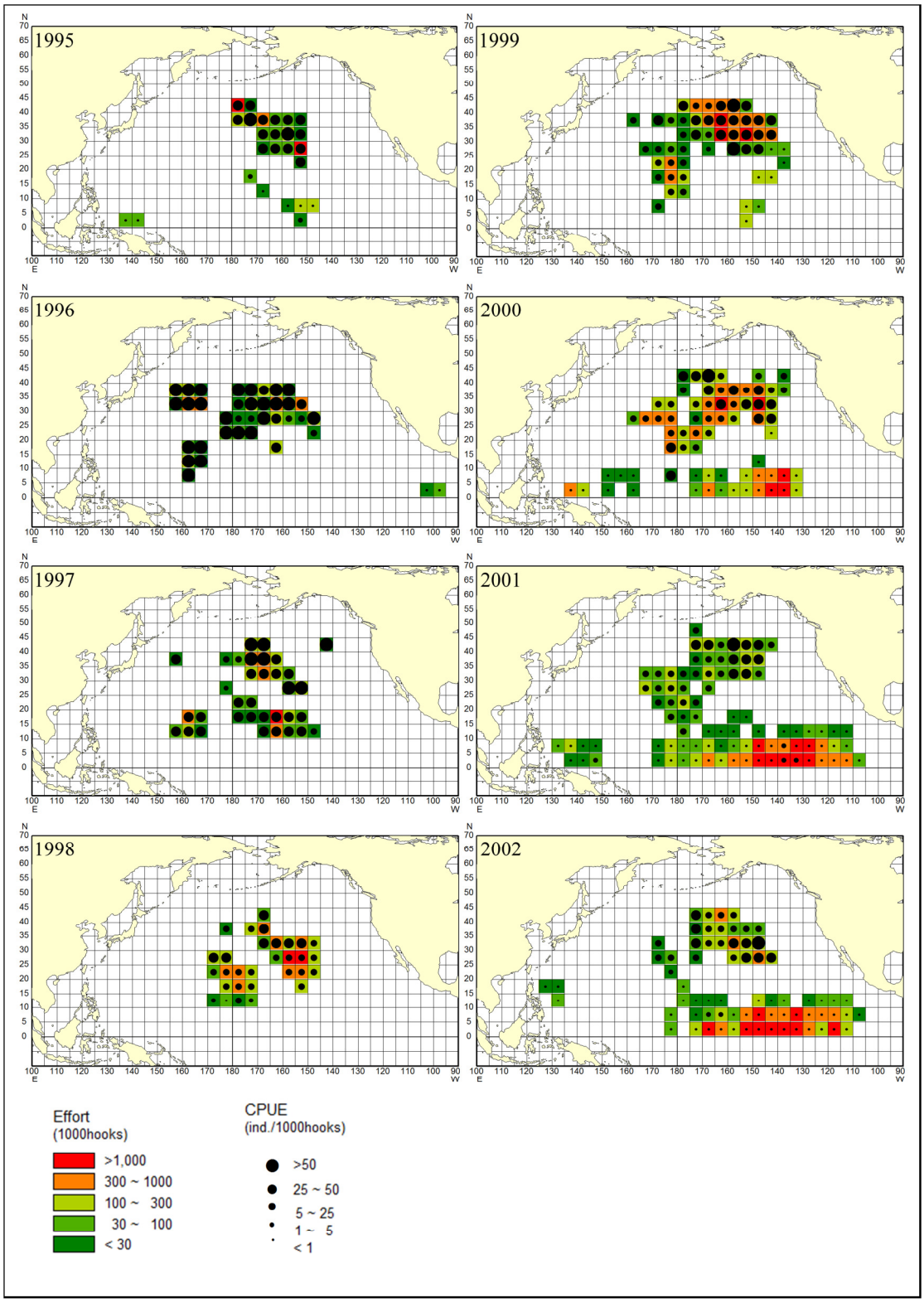


Fig. 1. Geographical distributions of fishing effort and nominal albacore CPUE made by Taiwanese longline fishery in the North Pacific Ocean, 1995-2015.

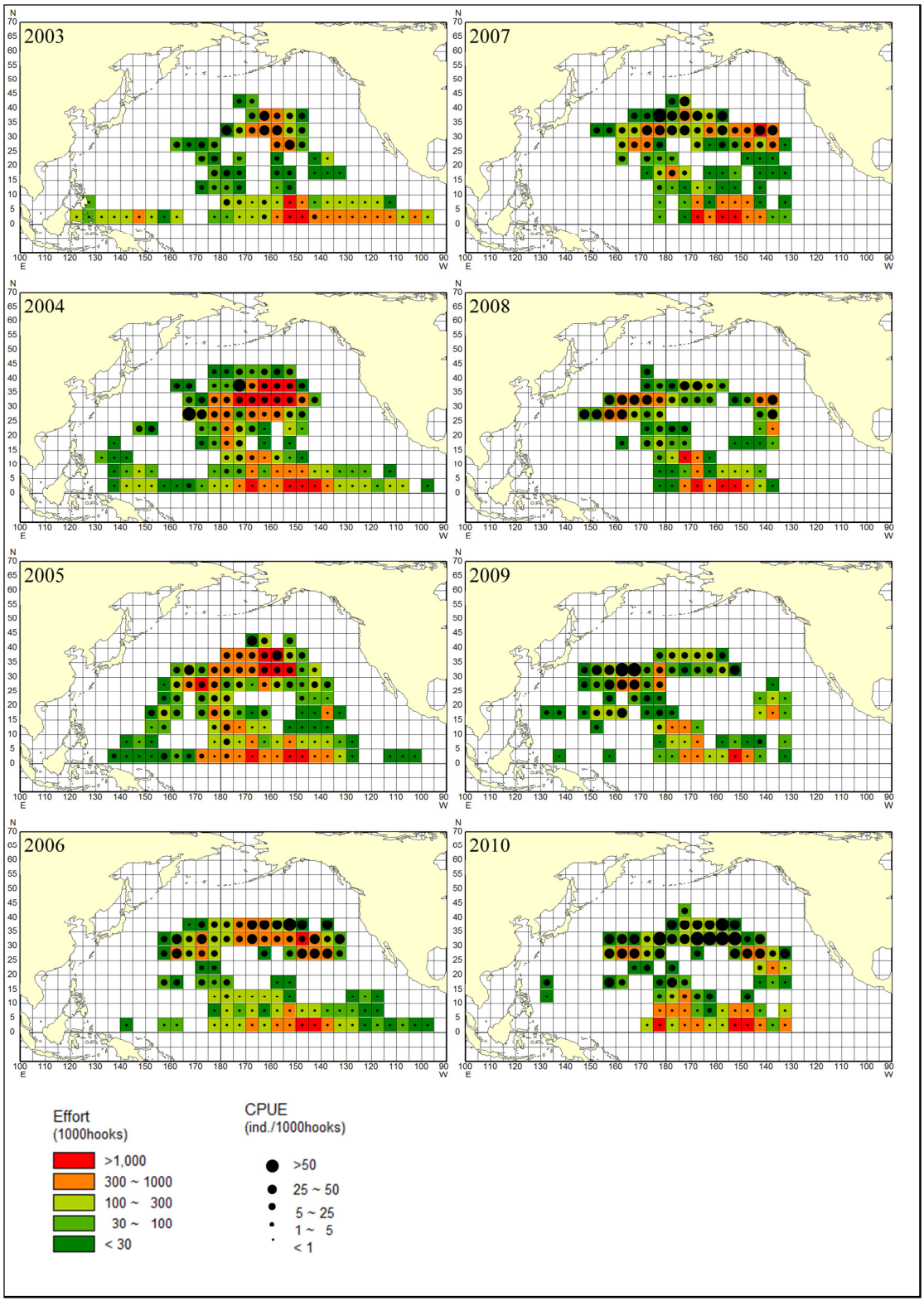
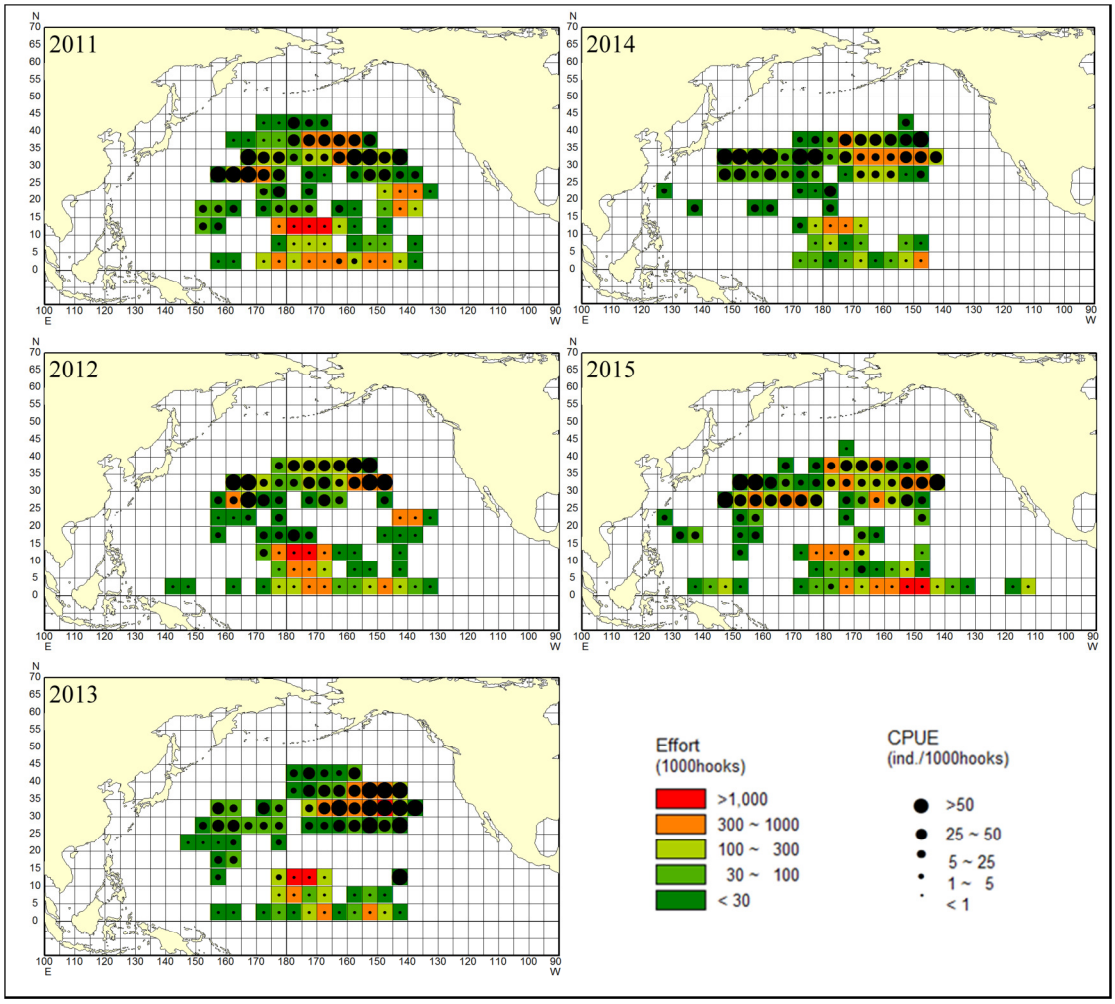


Fig. 1. continued



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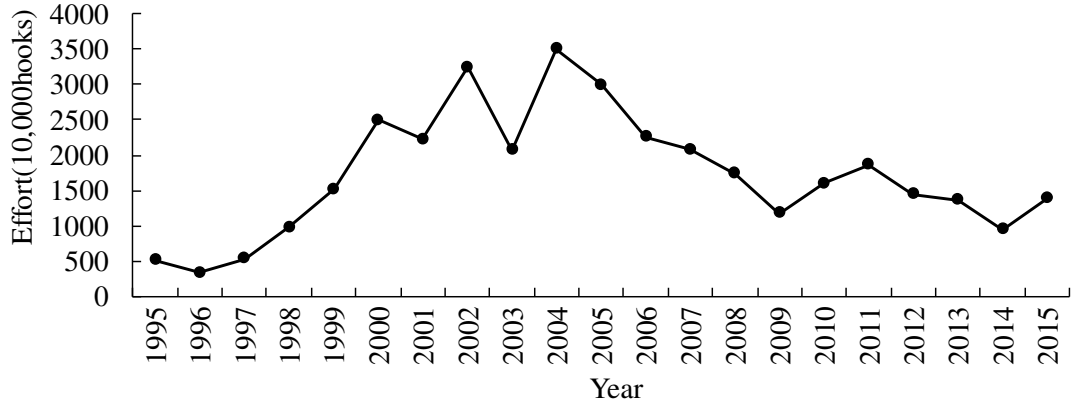


Fig. 2. Annual fishing efforts of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2015.

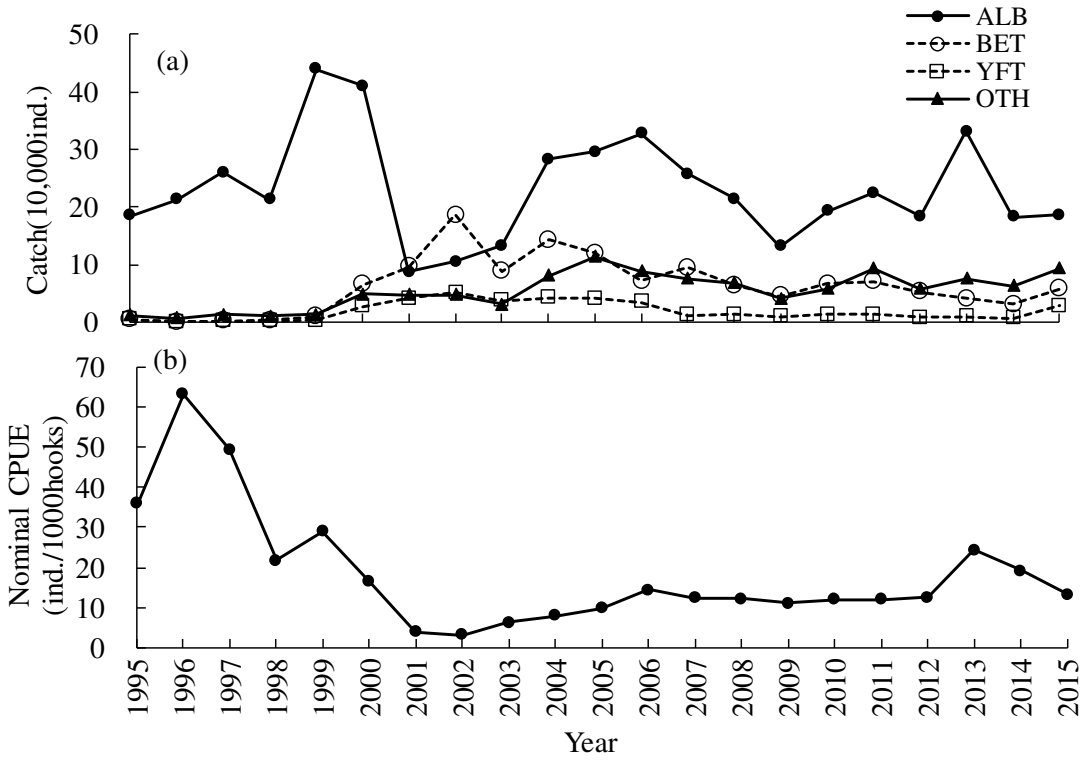


Fig. 3. Yearly catch statistics of Taiwanese longline fisheries in North Pacific Ocean, 1995-2015. (a) catch in number by species (b) nominal CPUE of albacore.

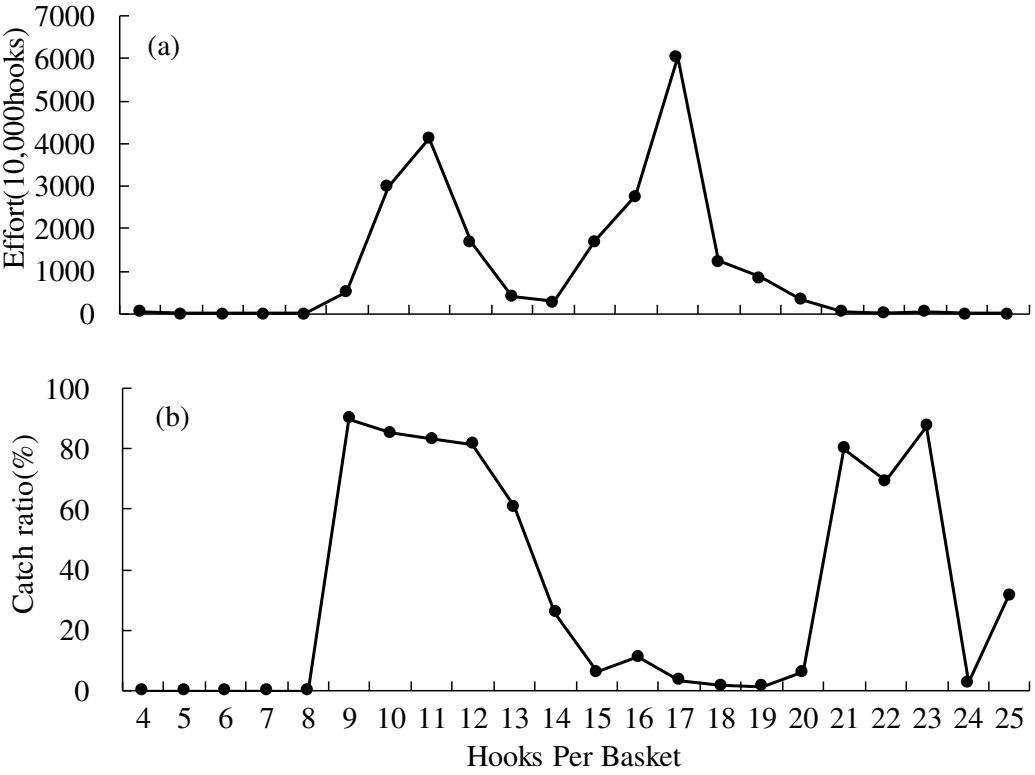


Fig. 4. Distributions of number of hooks per basket (a) and catch ratio (b; albacore/total catch) made by Taiwanese longline fisheries in North Pacific Ocean, 1995-2015.

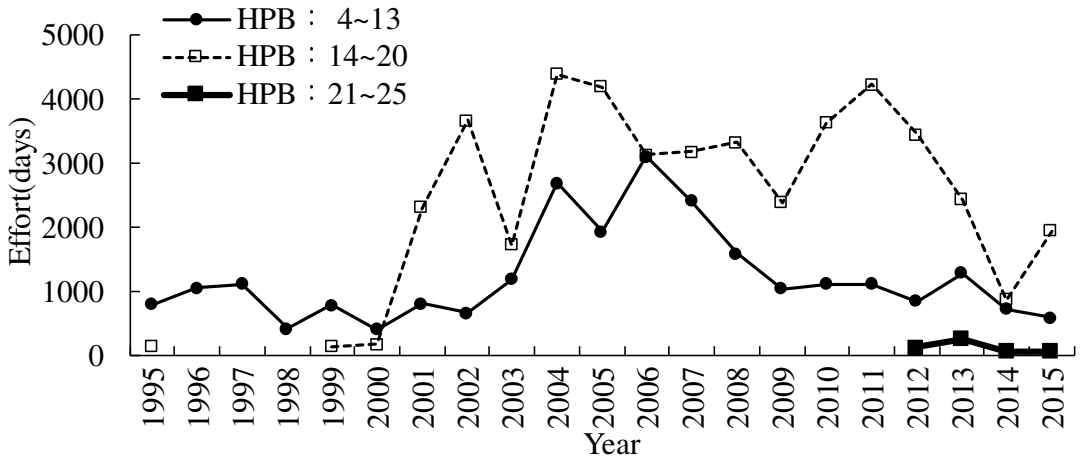


Fig.5. Yearly fishing efforts of 3 fishing types, defined by the number of hooks per basket, made by Taiwanese longline fisheries in North Pacific Ocean, 1995-2015.

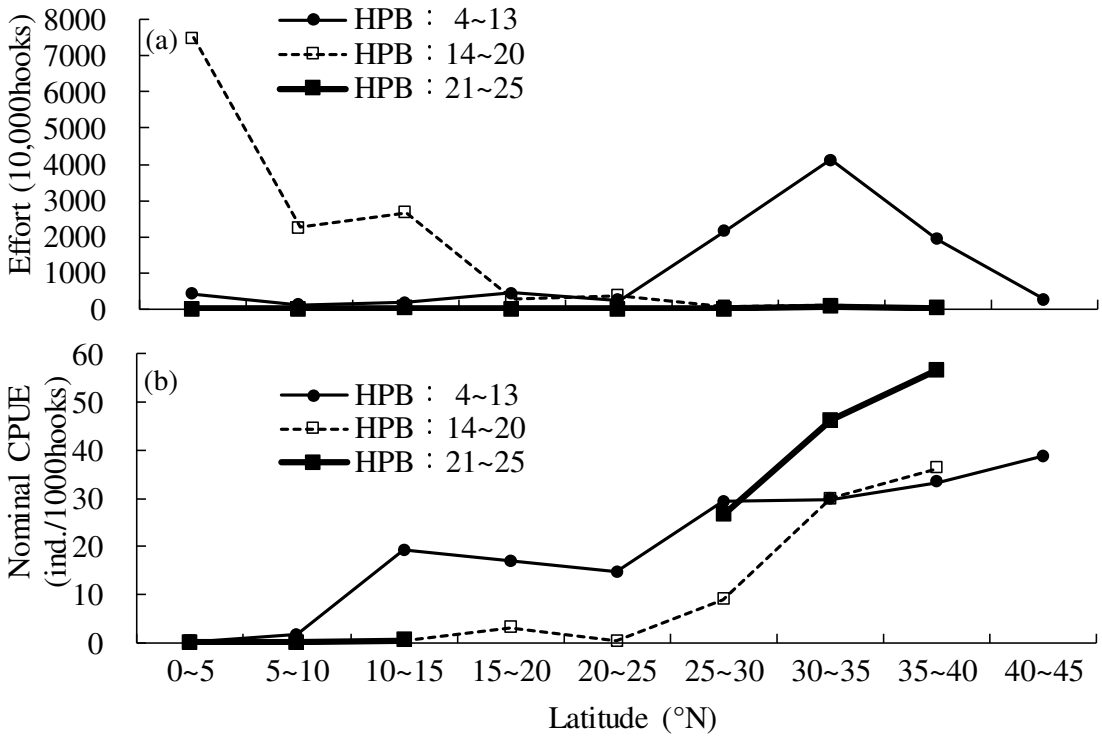


Fig.6. Latitudinal distribution of 3 fishing types, defined by the number of hooks per basket, made by Taiwanese longline fisheries in North Pacific Ocean, 1995-2015. (a) fishing efforts (b) albacore nominal CPUE.

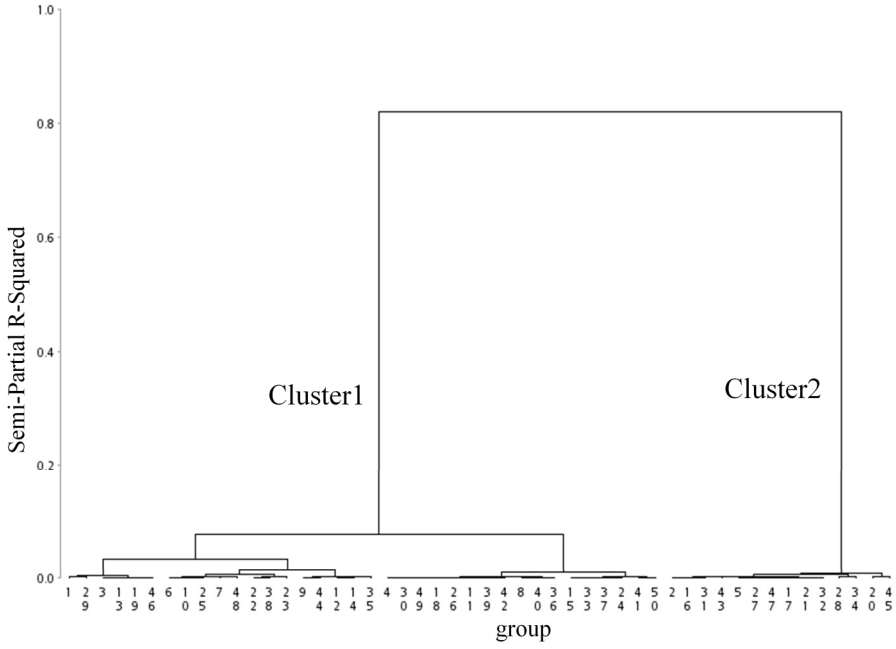


Fig. 6. Hierarchical tree obtained from cluster analyses on the catch compositions of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2015.

Table 1. Results of cluster analyses based on the catch compositions of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2015. (a) total and within standard deviations of 50 groups obtained from the non-hierarchical cluster analyses (b) catch compositions of cluster 1 and 2

(a)

Variable	Total STD	Within STD	R-Square	RSQ/ (1-RSQ)
ALB	21.40	2.48	0.99	73.23
BET	5.00	2.21	0.80	4.11
YFT	2.56	1.44	0.68	2.14
Other tuna	0.22	0.22	0.00	0.00
SWO	0.81	0.78	0.08	0.08
WHM	0.30	0.30	0.01	0.01
BLZ	0.55	0.52	0.10	0.11
BLM	0.05	0.05	0.00	0.00
BIL	0.26	0.26	0.01	0.01
SKJ	1.42	1.05	0.46	0.85
SKX	1.55	1.14	0.46	0.85
OTHER	2.79	1.79	0.59	1.41
ALB ratio	39.31	2.52	1.00	242.02
OVER-ALL	12.55	1.42	0.99	77.17
Approximate Expected Over-All R-Squared=0.96221				

(b)

CPUE Unit：ind./1000hooks

	Cluster1		Cluster2	
Species	CPUE	SE	CPUE	SE
ALB	31.38	0.174	0.22	0.004
BET	1.26	0.016	5.74	0.024
YFT	0.34	0.010	1.65	0.013
Other tuna	0.01	0.002	0.01	0.001
SWO	0.13	0.002	0.55	0.004
WHM	0.11	0.002	0.09	0.001
BLZ	0.04	0.001	0.36	0.003
BLM	0.01	0.000	0.00	0.000
BIL	0.05	0.002	0.02	0.001
SKJ	0.55	0.015	0.07	0.003
SKX	0.60	0.008	0.81	0.008
OTHER	2.09	0.022	1.27	0.011
ALB ratio%	82.10		1.72	
Effort(hooks)	92,805,063		139,563,981	

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

(a)

	Cluster1	Cluster2	Total
Group1_ALB-targeting	23149	1308	24457
Group2_Non-ALB-targeting	654	46144	46798
Error Ratio%	2.7	2.8	2.8

(b) CPUE Unit：ind./1000hooks

	Group1		Group2	
Species	CPUE	SE	CPUE	SE
ALB	30.43	0.173	0.28	0.007
BET	1.42	0.019	5.72	0.024
YFT	0.36	0.011	1.65	0.013
Other tuna	0.01	0.002	0.00	0.001
SWO	0.13	0.002	0.56	0.004
WHM	0.12	0.002	0.09	0.001
BLZ	0.04	0.001	0.36	0.003
BLM	0.01	0.000	0.00	0.000
BIL	0.05	0.002	0.02	0.001
SKJ	0.57	0.015	0.05	0.002
SKX	0.63	0.009	0.79	0.007
OTHER	2.14	0.022	1.23	0.011
ALB ratio%	79.23		2.10	
Effort(hooks)	95,935,342		136,433,702	

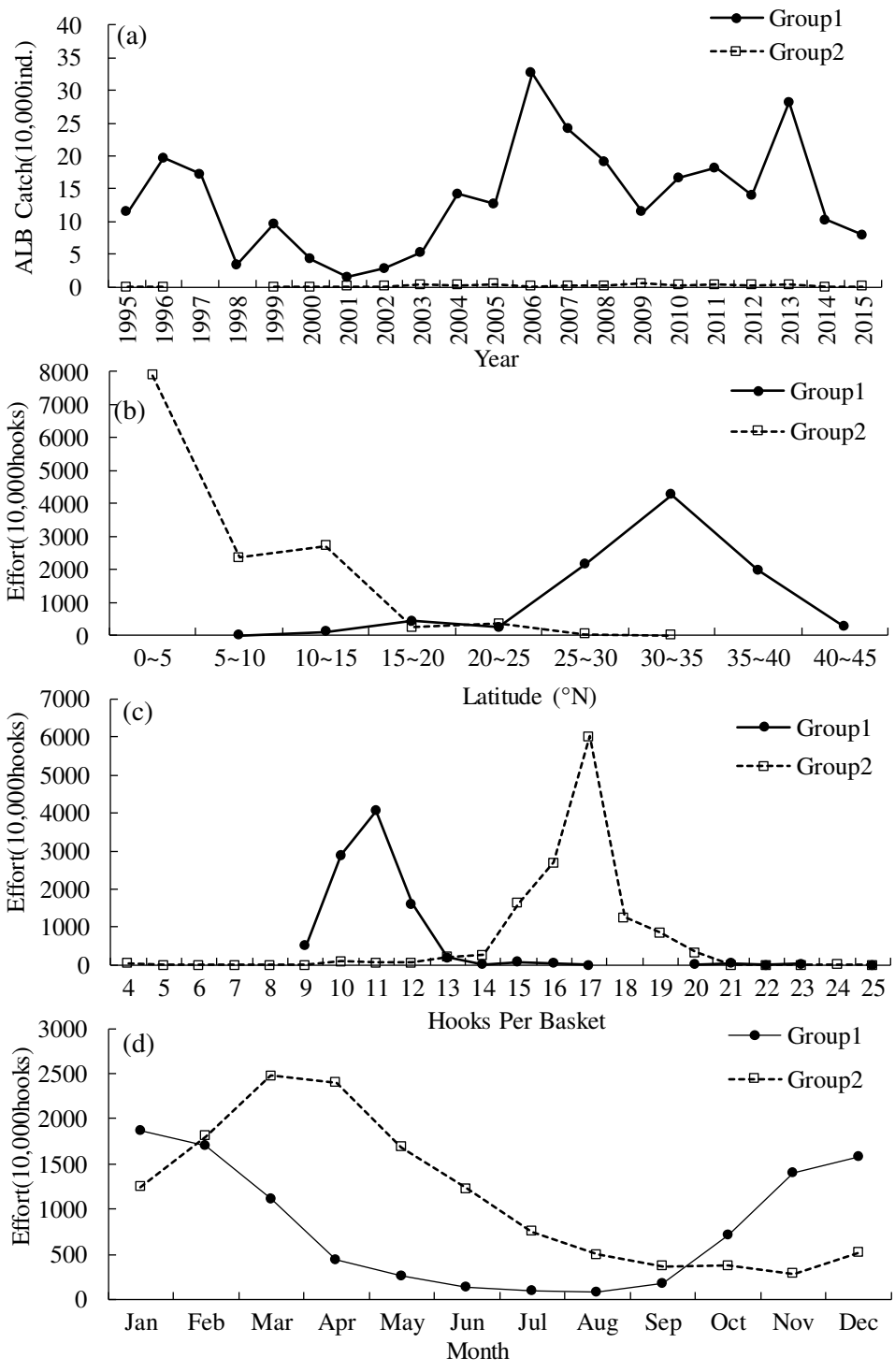


Fig. 8. Characteristics of Taiwanese longline fisheries (by group; group 1 denotes albacore-targeting and group 2 denotes non-albacore-targeting) operated in North Pacific Ocean, 1995-2015. (a) yearly albacore catch in number (b) latitudinal distribution of fishing efforts (c) fishing efforts vs. number of hooks per basket (d) monthly distributions of efforts

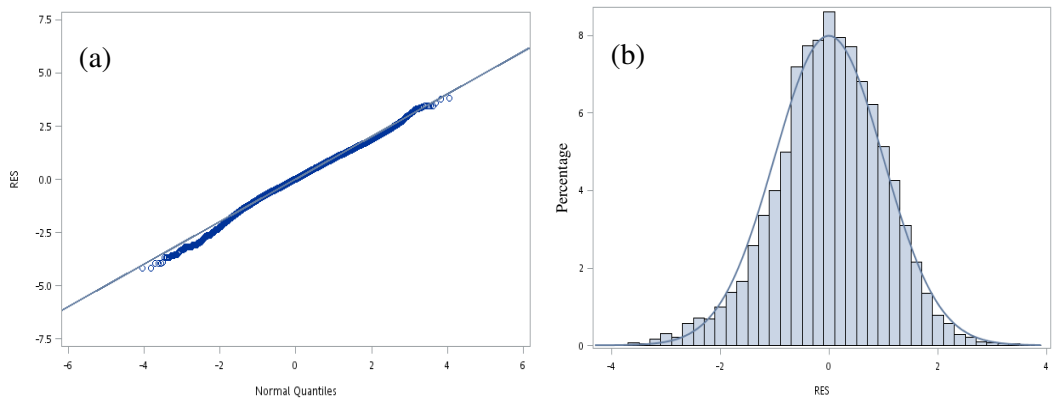


Fig. 9. Results of GLM standardized CPUE of albacore-targeting fishery caught by Taiwanese longline fisheries operated in North Pacific Ocean. (a) Q-Q plot (b) Normal Probability Plot.

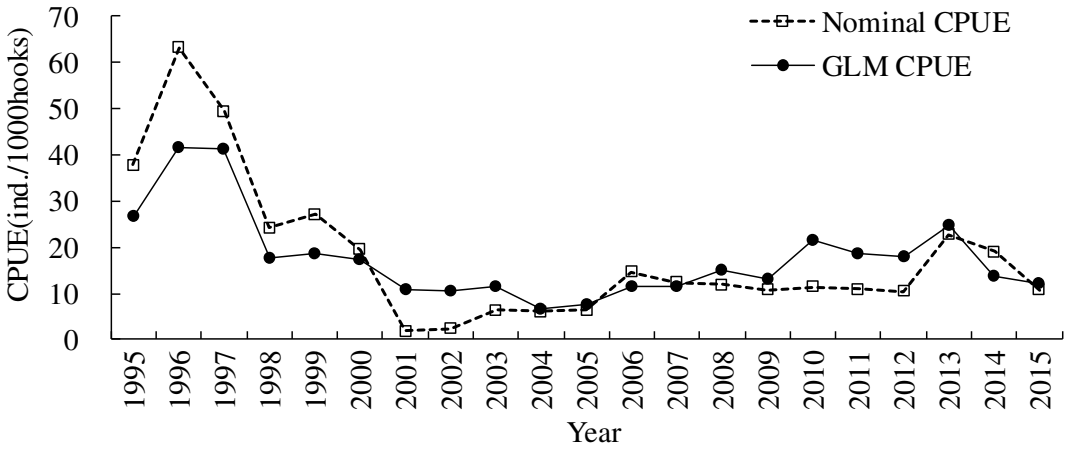


Fig. 10. Yearly fluctuations of nominal CPUE and GLM standardized CPUE of albacore caught by Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2015.

Table 3. Results of GLM analyses on the albacore CPUE of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2015.

Source	DF	Sum of Squares	Mean Square	F Value	p
Model	27	4930.43	182.61	412.28	<.0001
Error	24429	10820.15	0.44		
Corrected Total	24456	15750.57			

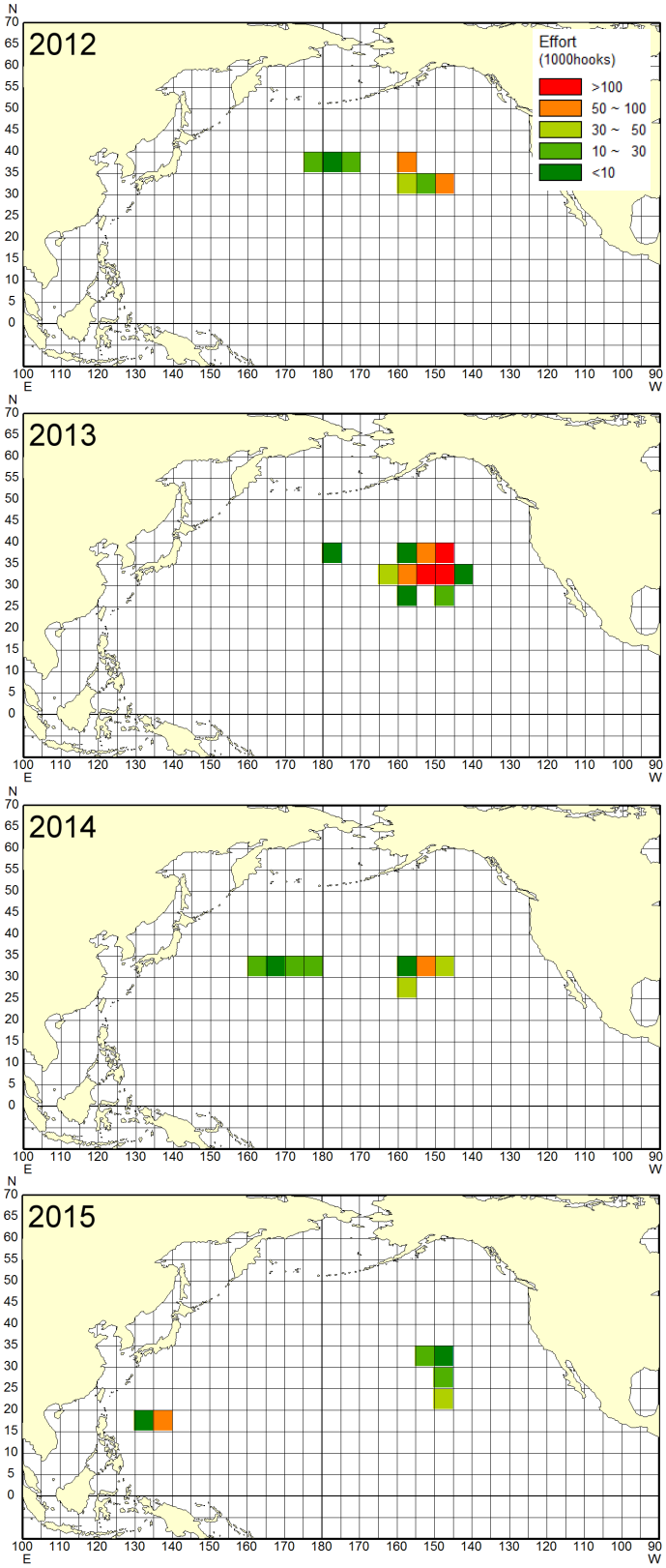
R^2=0.313

Source	DF	Type III SS	Mean Square	F Value	p
Year	20	3849.50	192.47	434.56	<.0001
Season	3	18.16	6.05	13.67	<.0001
Area	1	349.70	349.70	789.53	<.0001
Season*Area	3	17.82	5.94	13.41	<.0001

Table 4. The standardized CPUE of albacore exploited by Taiwanese longline fisheries in North Pacific Ocean, 1995-2015.

CPUE Unit：ind./1000hooks

Year	nominal CPUE	ALB targeting nominal CPUE	ALB targeting GLM CPUE	SE
1995	37.78	43.52	26.81	0.03
1996	63.23	64.09	41.58	0.02
1997	49.39	49.39	41.23	0.02
1998	24.13	24.13	17.73	0.03
1999	27.15	29.33	18.51	0.03
2000	19.48	24.66	17.25	0.03
2001	1.84	18.43	10.78	0.05
2002	2.26	23.32	10.38	0.04
2003	6.44	23.72	11.54	0.03
2004	6.05	14.29	6.62	0.02
2005	6.46	16.28	7.56	0.02
2006	14.57	24.31	11.54	0.02
2007	12.39	23.36	11.34	0.02
2008	11.89	29.80	15.12	0.02
2009	10.78	28.37	13.08	0.02
2010	11.43	37.65	21.44	0.02
2011	10.99	39.52	18.60	0.02
2012	10.48	38.59	18.04	0.03
2013	22.77	48.48	24.91	0.02
2014	18.99	33.40	13.65	0.03
2015	10.82	30.37	12.12	0.03



F.ig. 11. Distribution of those fishing effort with 21-25 HPB, 2012-2015.

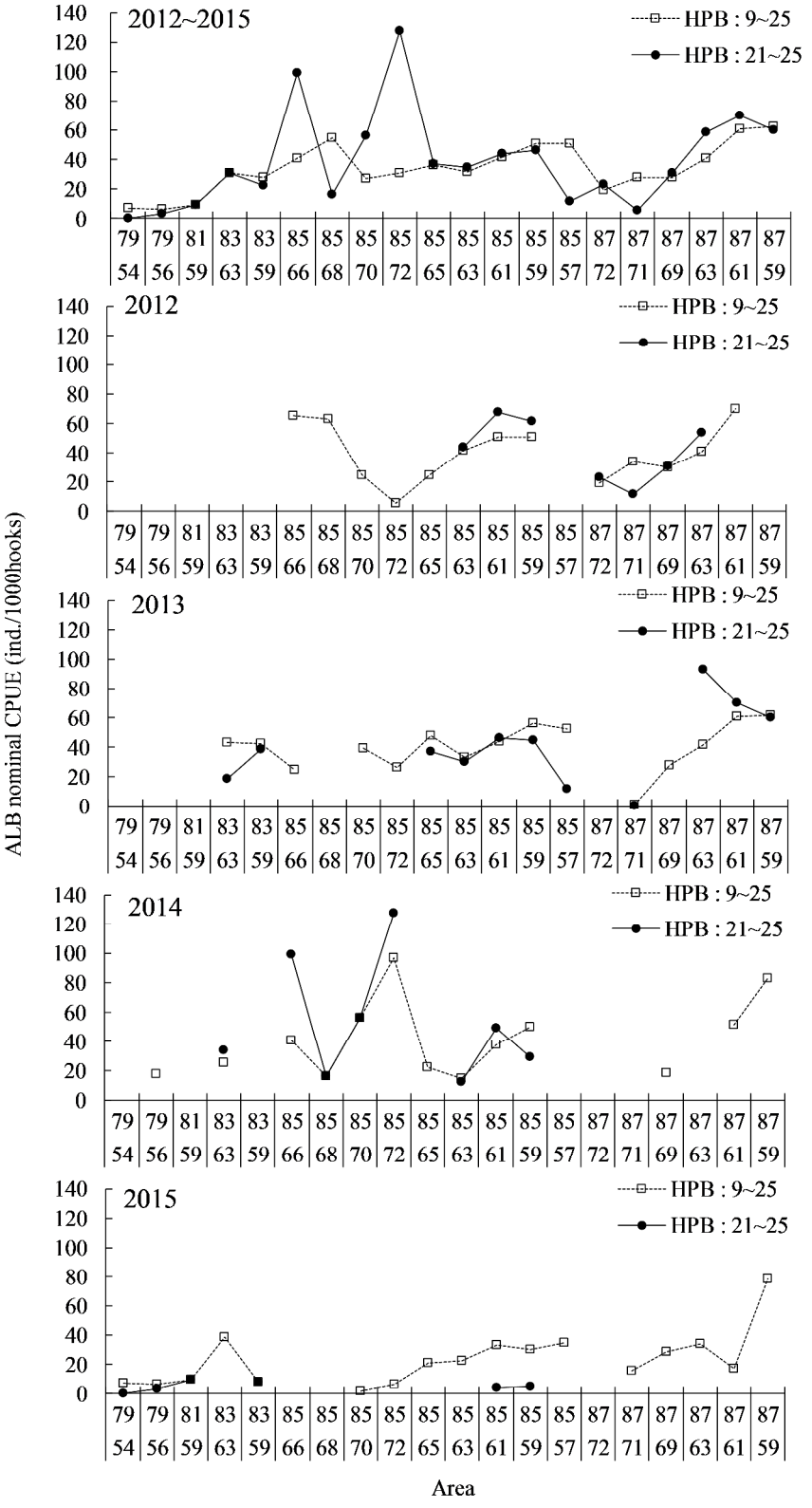


Fig. 12. Nominal CPUE of those with 21-25 HPB in each 5-degree square and corresponding total group 1 CPUE.

Table 5. Results of GLM analyses on the albacore CPUE of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2015.

GLM：Ln（CPUE+c）＝μ＋Y＋Q＋A＋HPB+Q×A＋ε

Source	DF	Sum of Squares	Mean Square	F Value	p
Model	28	4933.81	176.21	397.94	<.0001
Error	24428	10816.76	0.44		
Corrected Total	24456	15750.57			

R^2：0.313

Source	DF	Type III SS	Mean Square	F Value	p
Year	20	3793.47	189.67	428.35	<.0001
Season	3	17.96	5.99	13.52	<.0001
Area	1	352.99	352.99	797.17	<.0001
HPB	1	3.39	3.39	7.65	0.0057
Season*Area	3	18.61	6.20	14.01	<.0001

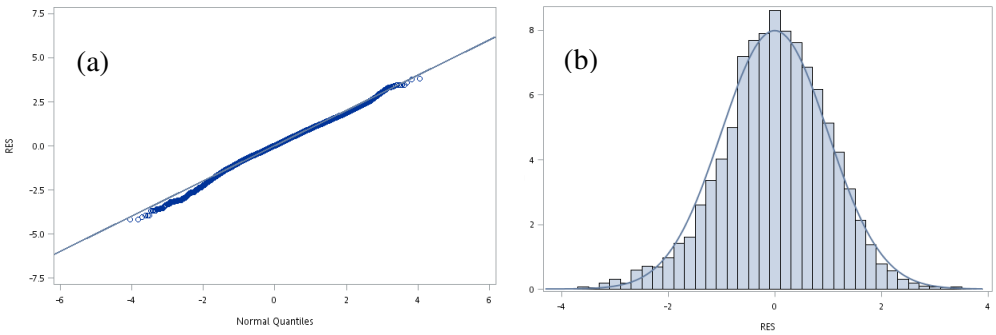
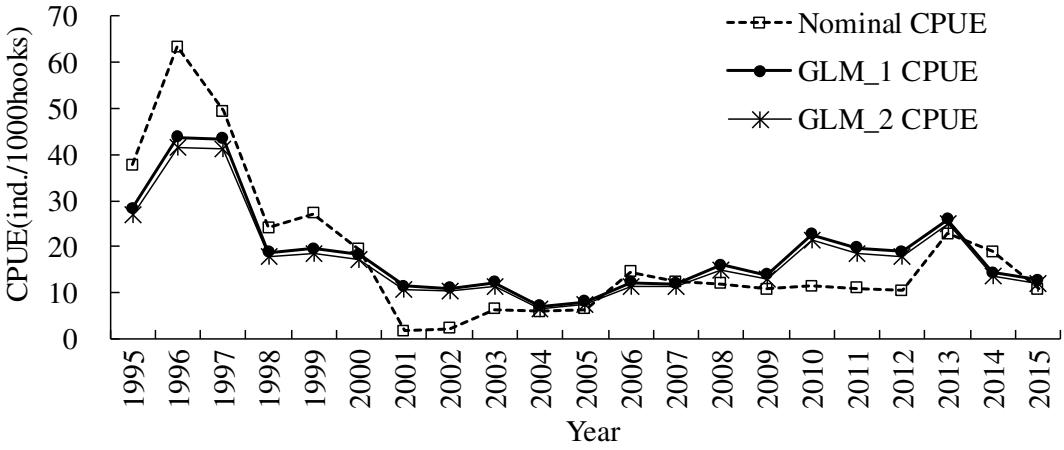


Fig. 13. Results of GLM standardized CPUE of albacore-targeting fishery caught by Taiwanese longline fisheries operated in North Pacific Ocean. (a) Q-Q plot (b) Normal Probability Plot.

GLM：Ln（CPUE+c）＝μ＋Y＋Q＋A＋HPB+Q×A＋ε



GLM_1：$Y+Q+A+HPB+Q\times A+\varepsilon$

GLM_2：$Y+Q+A+Q\times A+\varepsilon$

Fig. 14. Yearly fluctuations of nominal CPUE and GLM standardized CPUE of albacore caught by Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2015.

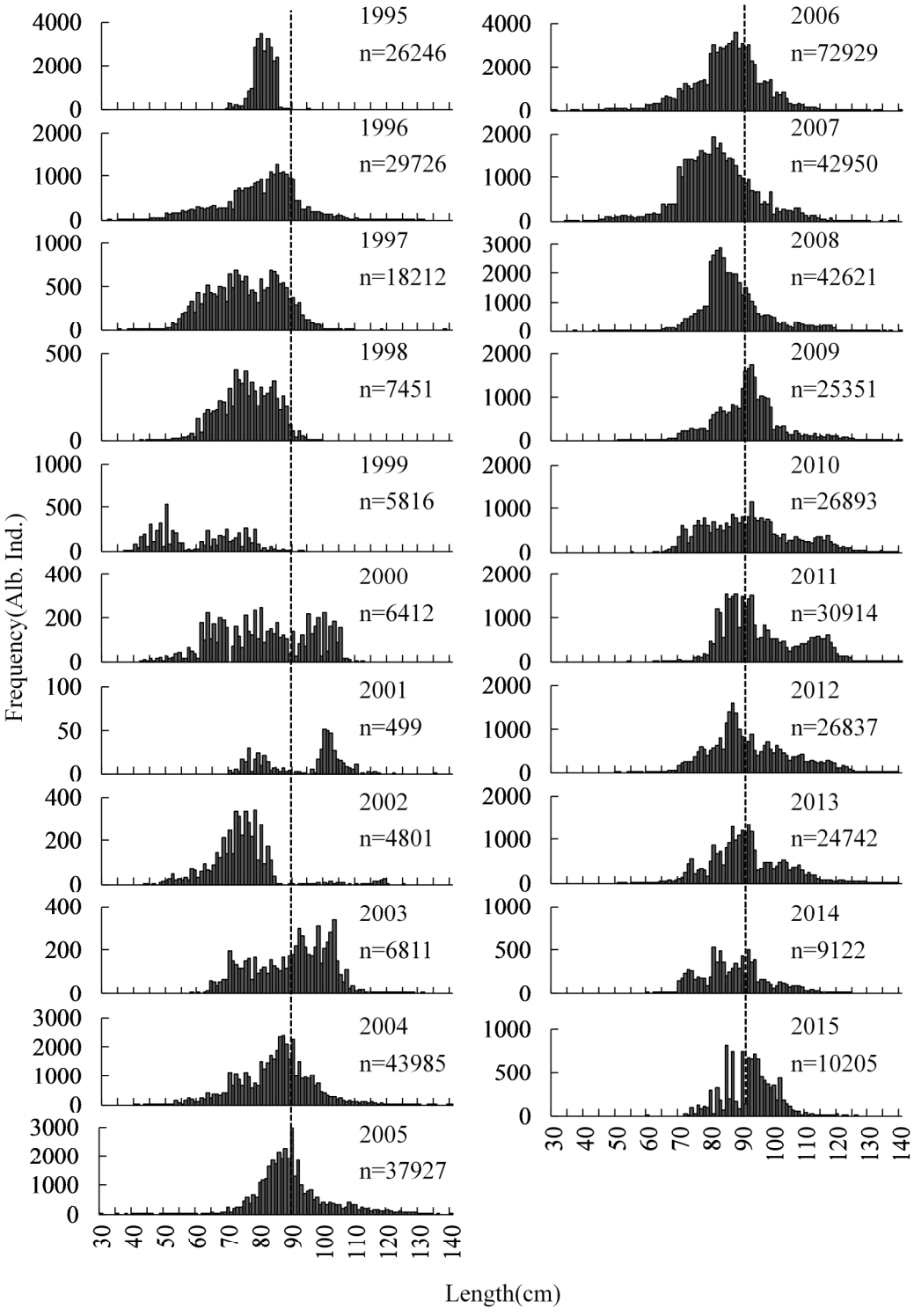


Fig. 15. Yearly length distributions of albacore collected by Taiwanese longline fisheries in North Pacific Ocean, 1995-2015.

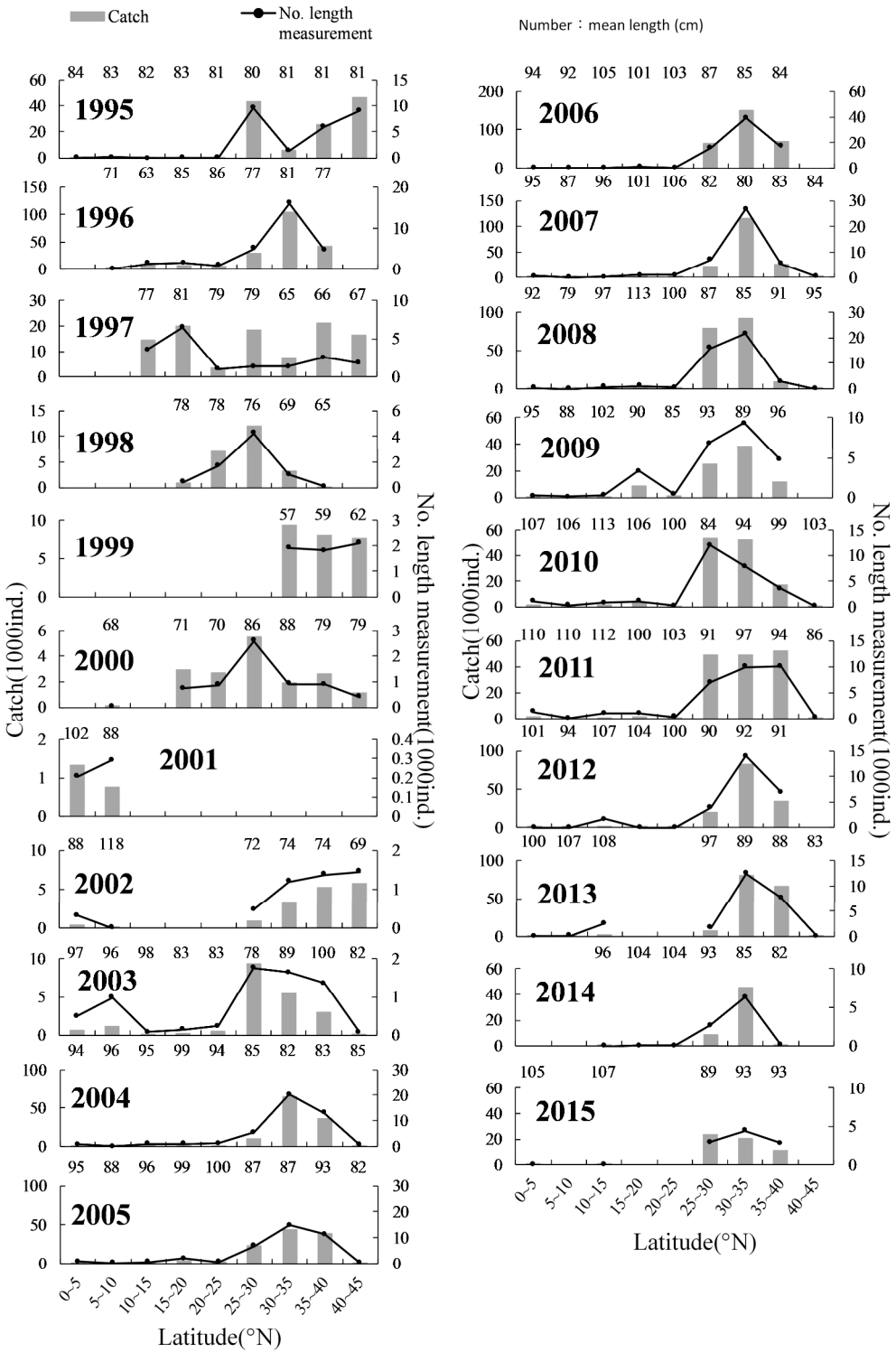


Fig. 16. Latitudinal distributions of albacore catch and corresponding number of length measurement made by Taiwanese longline fleets operated in the North Pacific Ocean, 1995-2015.