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Update of albacore CPUE and length distribution of Taiwanese longline fishery in the North Pacific Ocean, 1995-2018

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Abstract

In this working paper, the time series trend of albacore CPUE exploited by Taiwanese longliners in the North Pacific Ocean was estimated. The albacore-targeting catch statistics were extracted from the daily operational data, 1995-2018. The extraction procedures was carried out based on their catch compositions and fishing activities, i.e. fishing area, fishing month and number of HPB, by using clustsering and discriminant analyses, which were adopted in previous studies. The albacore-targeting fishery apparently contributed majority of the albacore catch throughout the years. Then, general linear model was applied to estimate the CPUE trend. This estimation is believed to be more informative to the stock status of North Pacific albacore exploited by Taiwanese longline fishery.

Introduction

This working paper is aiming to update the CPUE and catch-at-size of albacore made by Taiwanese longline fishery operated in the North Pacific Ocean (NPO), 1995-2018. In the beginning of this fishery, the longline fishing effort concentrated in a rather small area mainly in the northern NPO, and gradually, increasing fishing effort expanded to cover most of the NPO from tropical waters up to Lat. 45°N (Fig. 1). It was also noted that higher albacore CPUE normally occurred in the temperate waters while very low CPUE mainly appeared in the tropical waters. During the expansion of fishing area, changes in fishing activity, in terms of number of hooks per basket (HPB) and catch composition were recorded, and thereafter albacore-targeting and non-albacore-targeting fisheries were defined, respectively (Chen & Cheng, 2013, 2016). This current study will focus on the time series trends of standardized CPUE and length distribution for the albacore-targeting longline fishery.

Materials and methods

The catch statistics of Taiwanese longline fishery operated in the North Pacific Ocean from 1995 to 2018, 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, 2016) were adopted to define the albacore-targeting and non-albacore-targeting data. Firstly, non-hierarchical and hierarchical cluster analyses based on species compositions of daily logbook records were conducted to categorize original data into clusters. Then, discriminant analyses were carried out to verify the clustering of catch statistics, 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 time period of 1995-2018, the annual fishing efforts fluctuated between 4 million and 35 million hooks with an increasing trend in the early years (Fig. 2). Albacore tuna always comprised most of the catch, particularly before the year of 2000, then a sharp decline in albacore catch and nominal CPUE coincided with an increasing catch of bigeye, yellowfin and other tuna-like species was recorded (Fig. 3). The expansion of fishing area, increasing fishing efforts and decline in albacore nominal CPUE may partly 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 differences between deep-longliners and regular-longliners is the number of HPB applied in their daily operations. The bi-modal distribution of HPB clearly demonstrates two types of fishing strategy operated in the North Pacific Ocean. The differences between two fishing strategies are also reflected by the efficiency in catching albacore. Those with 4-13 HPB are apparently more efficient in catching albacore than those with 14-20 HPB (Fig. 4). It is noted that high efficiency in catching albacore are also observed for those with more than 21 HPB. These fleets started to appear in 2012 and showed increasing importance to the total fishing effort in recent years (Fig. 5). Figure 6 shows the yearly geographical distribution of fishing effort of those with more than 21 HPB. Similarly, higher nominal albacore CPUE mostly appeared in the temperate waters. In general, we noticed that there are 3 types of fishing strategies operated in the NPO, i.e. 4-13, 14-20 and 21-25 HPB respectively, and they demonstrated differences in fishing area and corresponding nominal albacore CPUE (Fig. 7).

Fleets targeting on albacore or other species are believed to be reflected by their fishing activities and resultant catch compositions. In order to segregate the historical catch statistics into different clusters based on their target species, methods reported by Chen and Cheng (2013, 2016) were adopted, in which cluster analysis on the daily catch composition was conducted to segregate the catch statistics and followed by discriminant analysis to verify the cluster grouping. The results of clustering analyses show a clear separation of two clusters (Fig. 8). Cluster 1 bears much higher efficiency in catching albacore, while cluster 2 is apparently targeting on other species (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 results. Table 2(a) shows the results that high consistency is obtained between the segregations of cluster analyses and discriminant analysis, with only 3.1% error count. On average, the albacore CPUE of group 1 reached 28.96 ind./1000 hooks, while those of group 2 were only 0.27 ind./1000 hooks (Table 2(b)). Moreover, apparent differences in terms of albacore catch, fishing area and fishing strategy are demonstrated between these two groups (Fig. 9). Most of the albacore catch are contributed by group 1 data no matter before or after the year of 2000 (Fig. 9(a)). 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 (Fig. 9(b)). The longliners of group 1 mainly applies less than 13 HPB in their daily fishing operation, while those of group 2 mainly applied more number of HPB (Fig. 9(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. 9(d)). Following the above results, it suggests that the group 1 data is more informative in explaining the abundance status of albacore exploited by Taiwanese longliners, and group 1 is thus defined as albacore-targeting catch statistics, while group 2 is defined as non-albacore-targeting data.

General linear model (GLM) was then applied to standardize the CPUE of 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. 10). The standardized albacore CPUE trends of Taiwanese longline fisheries is shown in Fig. 11 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. A slight drop of the standardized CPUE was noted since 2014, however, the data in recent years is still preliminary and may subject to changes.

Yearly length distributions of albacore are also updated in this working paper. These albacore length measurements were derived and summed up from the first 30 fish caught every boat/day. It is noticed that the distributions before 2002 do not show a stable pattern between years, and most of the fish are smaller than 90 cm FL. Nevertheless, from 2003 to 2018, the distributions are more consistent between years, with a mode around 90 cm or so (Fig. 12). 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 13 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 is also noticed that the latitudinal area where albacore catch and length measurement were made are varied between years before 2003, and it might explain the fluctuations of yearly length distributions in the early years.

In summary, Taiwanese longline fisheries in the NPO, 1995-2018, can be categorized into two fisheries, i.e., albacore-targeting and non-albacore-targeting. Although increasing fishing effort of non-albacore-targeting occurred since 2000, the albacore-targeting fishery always contributed most of the albacore catch throughout the years, and hence the standardized CPUE of the albacore-targeting fishery is

believed to be more informative to the stock status of North Pacific albacore exploited by Taiwanese longline fishery.

References

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.

Chen, C. Y., and Cheng, F. C. 2016. The development of Taiwanese longline fishery in the North Pacific Ocean and estimation of albacore CPUE exploited by albacore-targeting fishery, 1995-2015. ISC working paper, ISC/16/ALBWG-02/09.

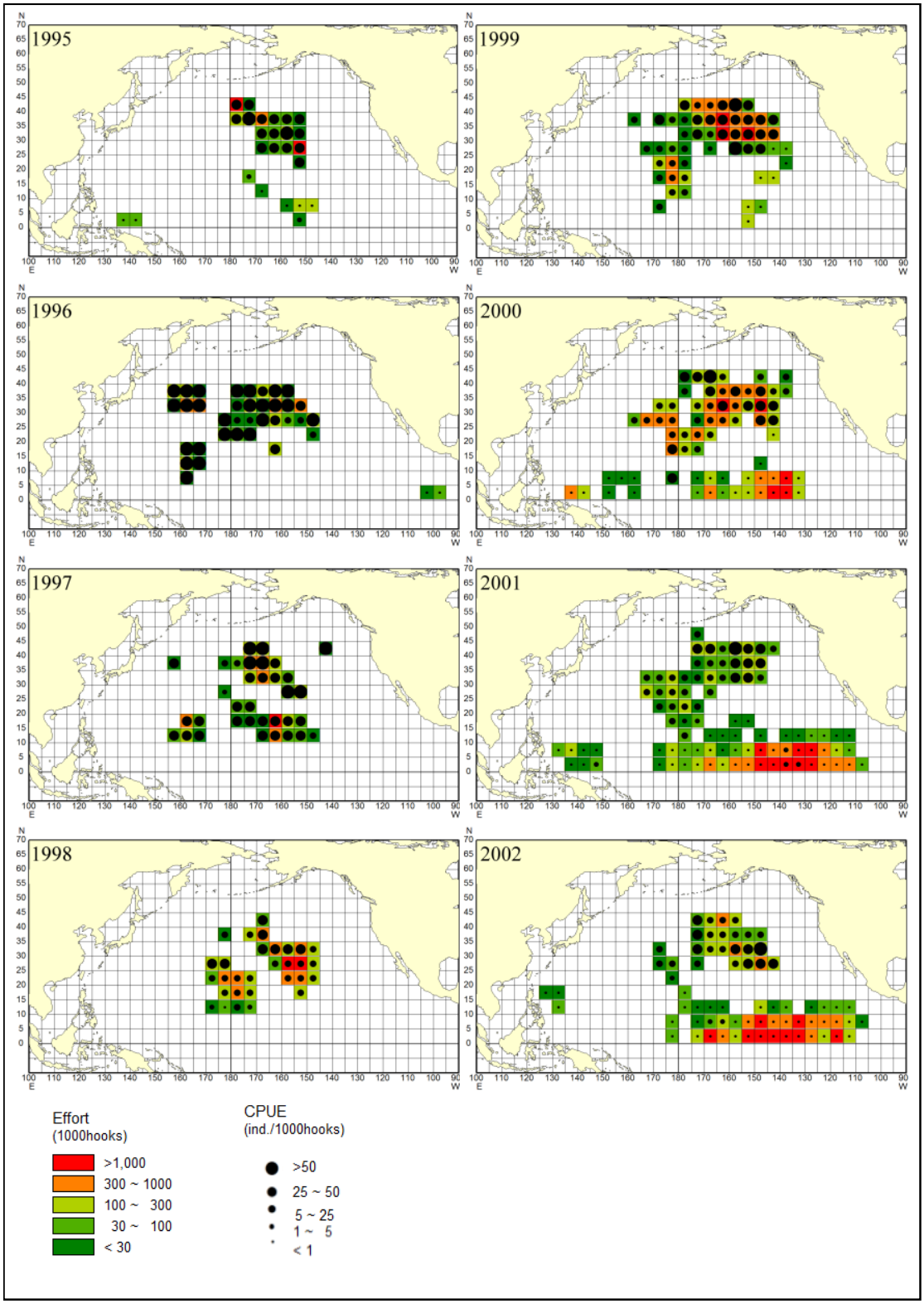
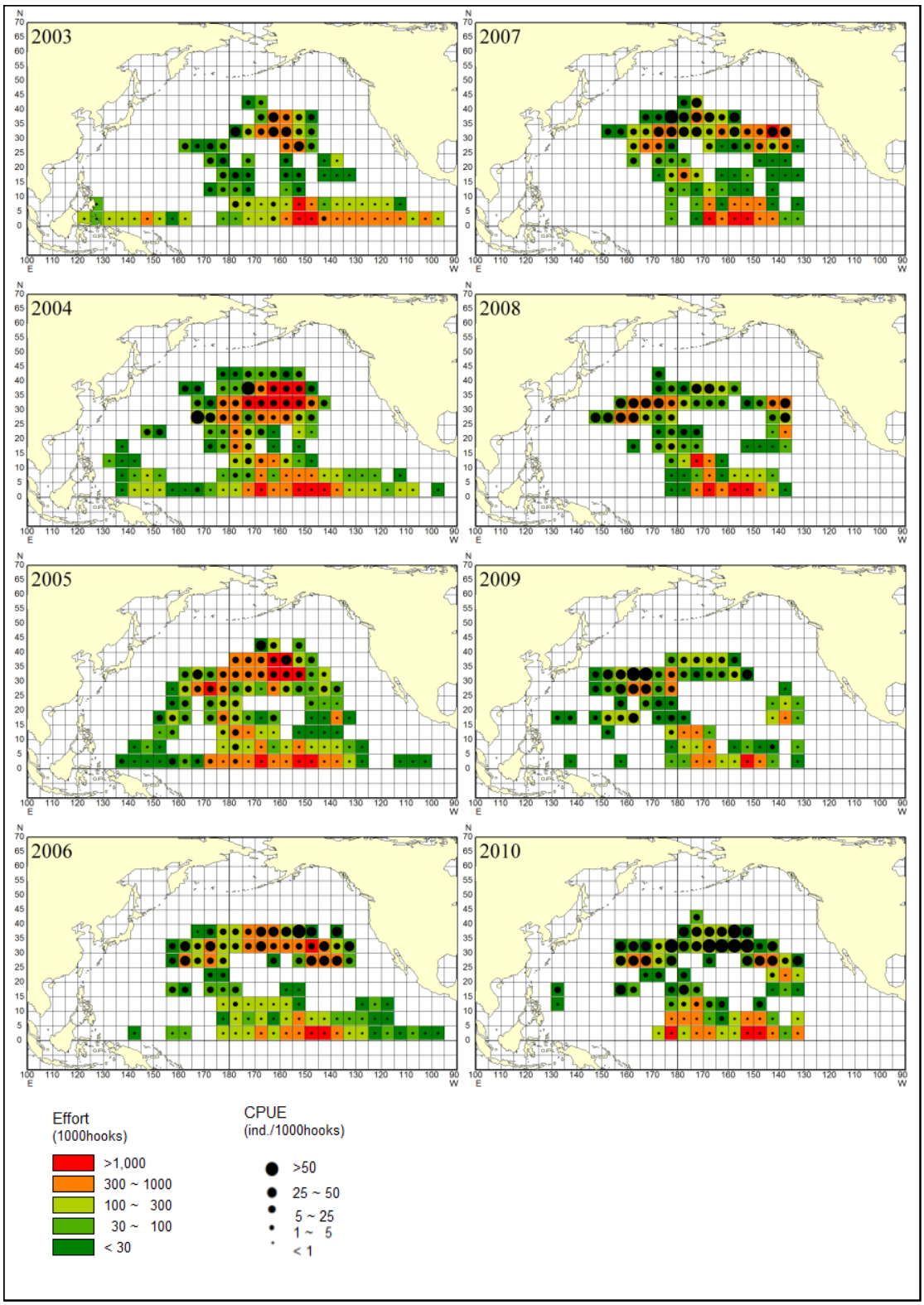


Fig. 1. Geographical distributions of fishing effort and nominal albacore CPUE made by Taiwanese longline fishery in the North Pacific Ocean, 1995-2018.



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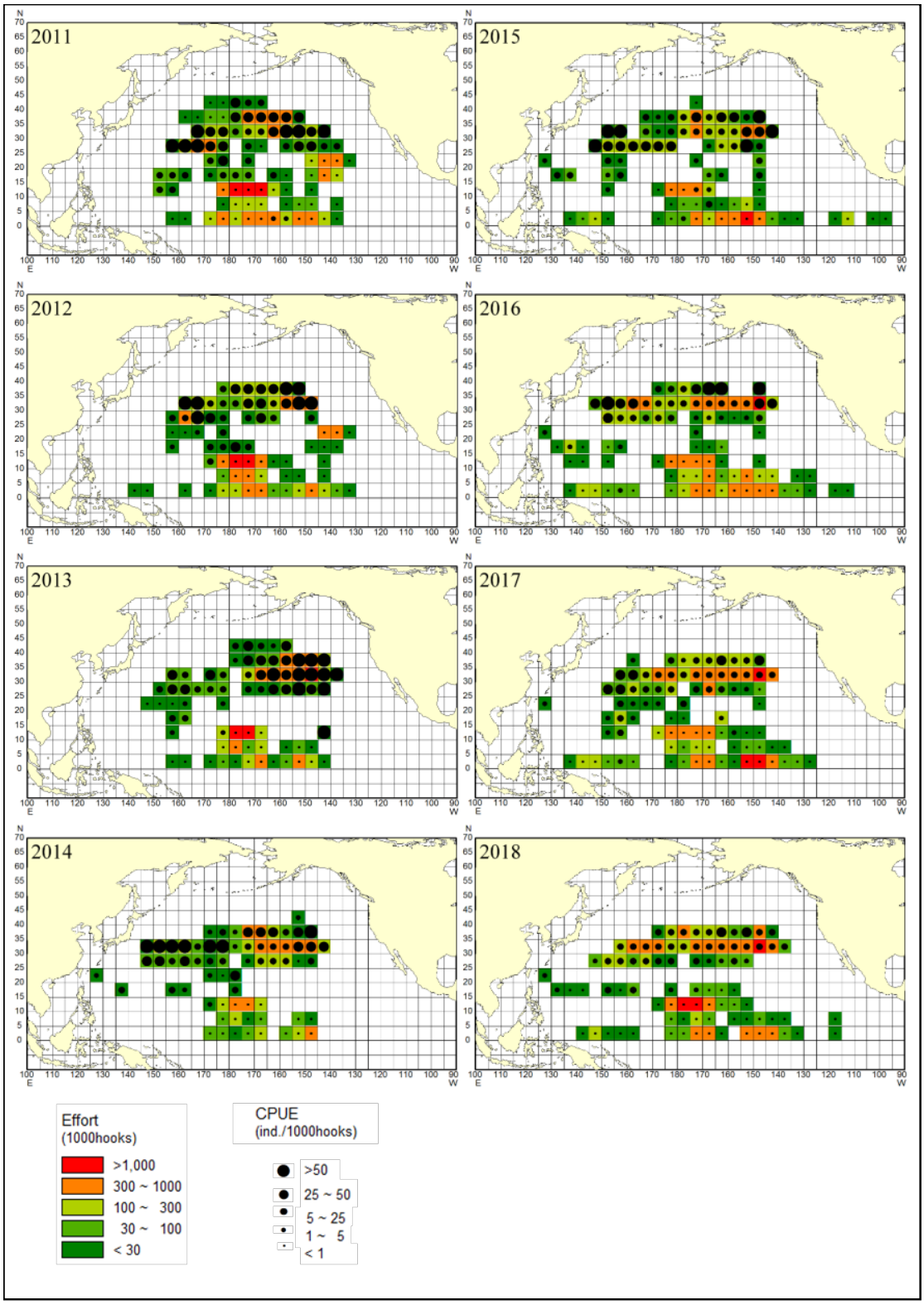

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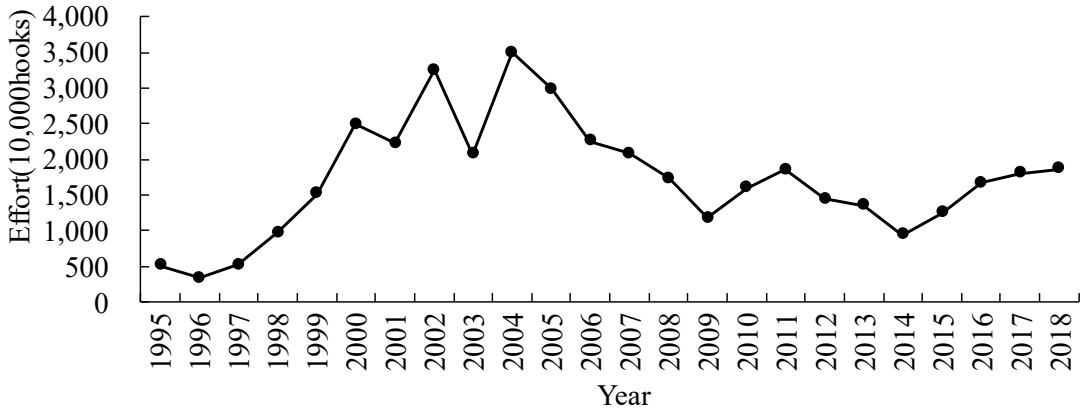

Fig. 2. Annual fishing efforts of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2018.

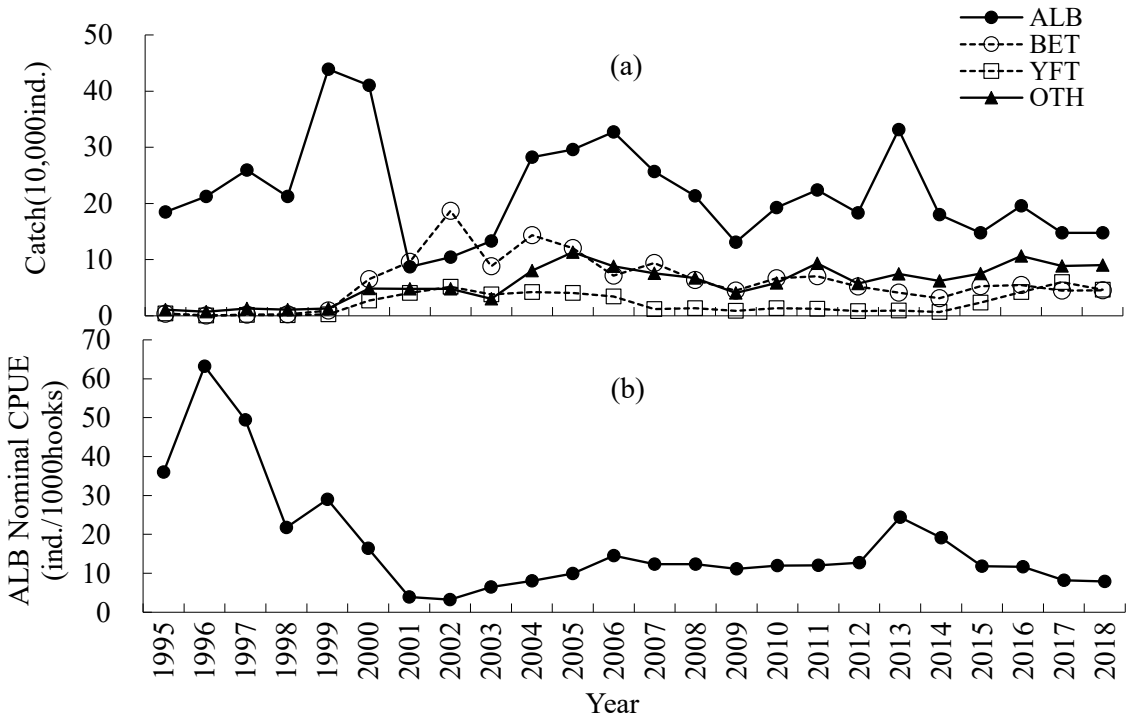

Fig. 3. Yearly catch statistics of Taiwanese longline fisheries in North Pacific Ocean, 1995-2018. (a) catch in number by species (b) nominal CPUE of albacore.

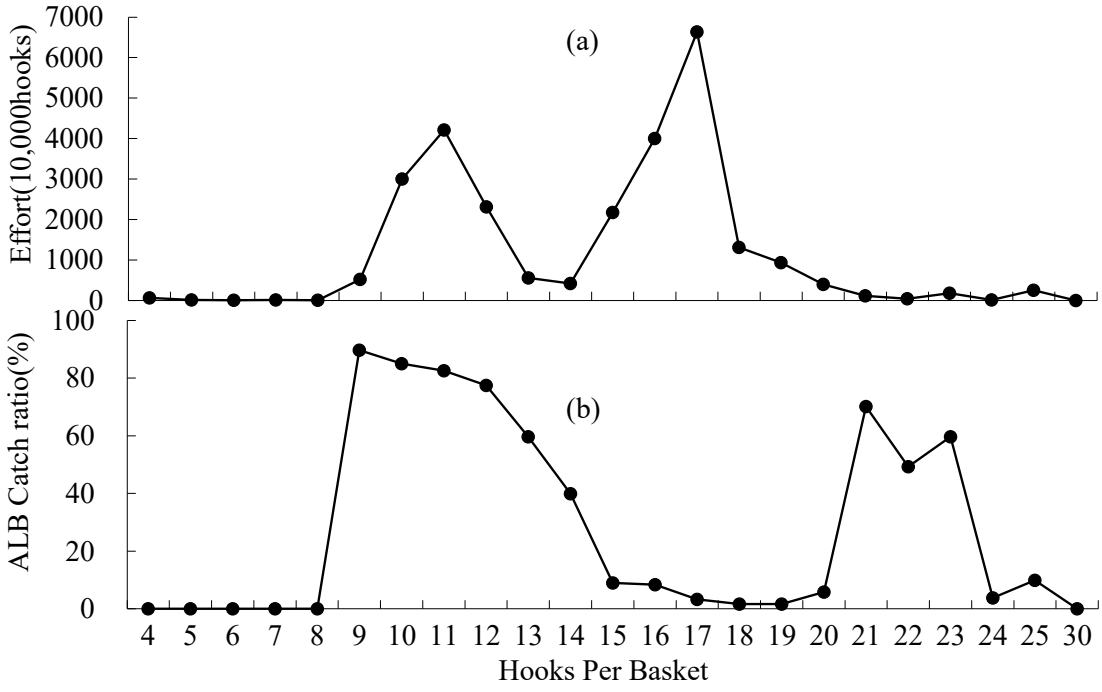

Fig. 4. Distributions of number of hooks per basket (a) and catch ratio (b; albacore/total catch) made by Taiwanese longline fisheries in North Pacific Ocean, 1995-2018.

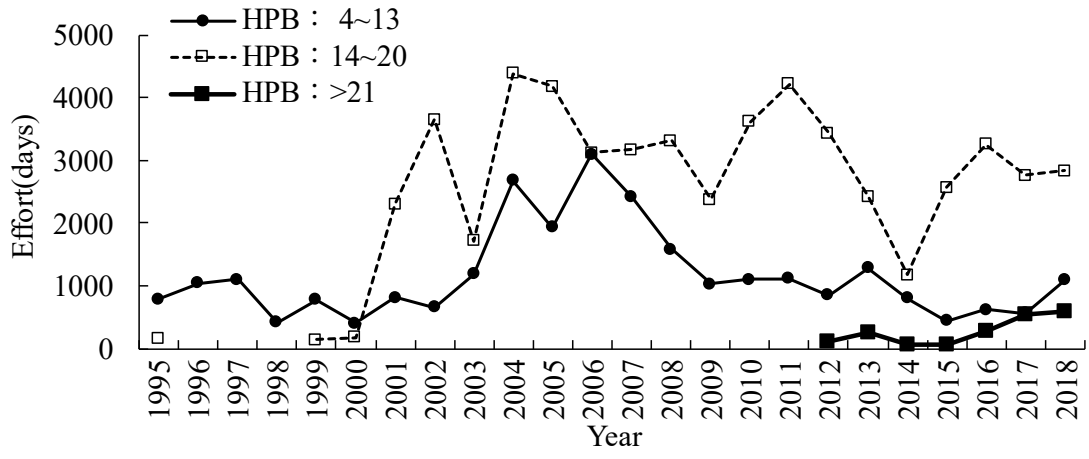

Fig.5. Yearly fishing efforts of 3 fishing types, defined by the number of hooks per basket, made by Taiwanese longline fisheries in North Pacific Ocean, 1995-2018.

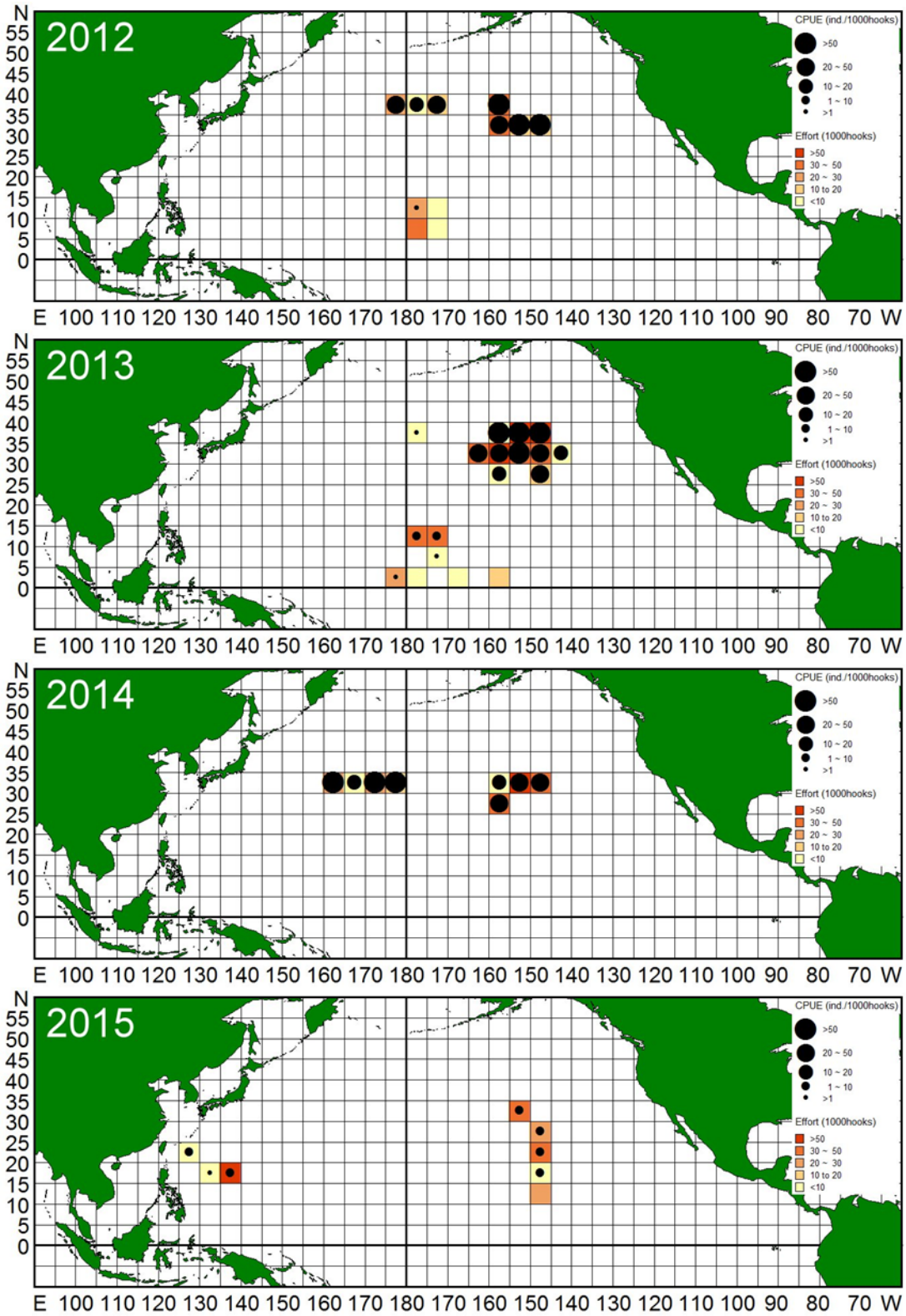

Fig.6. Geographical distribution of fishing effort and nominal albacore CPUE made by Taiwanese longline fisheries with ≥21 HPB.

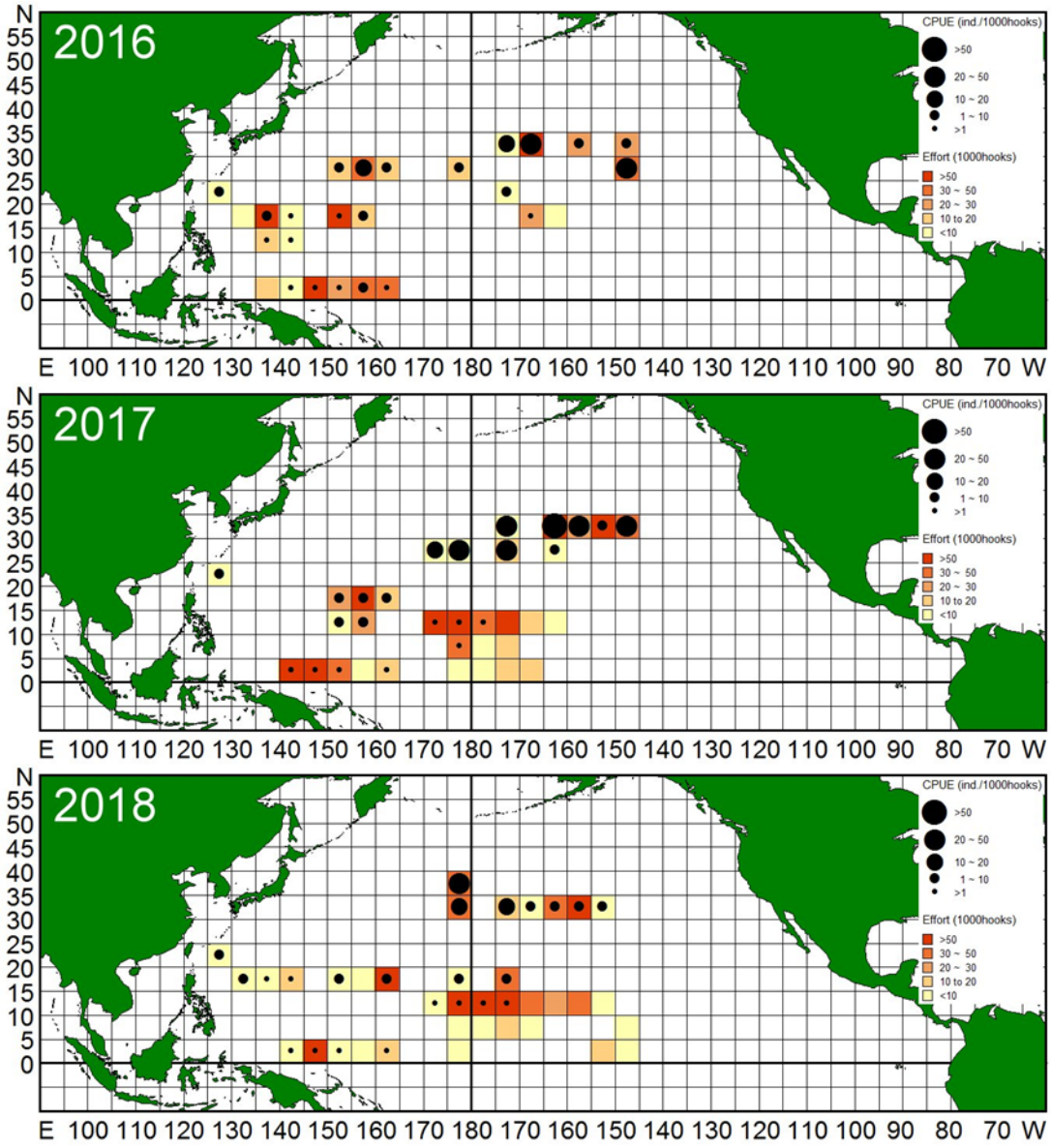

Fig. 6. Continued.

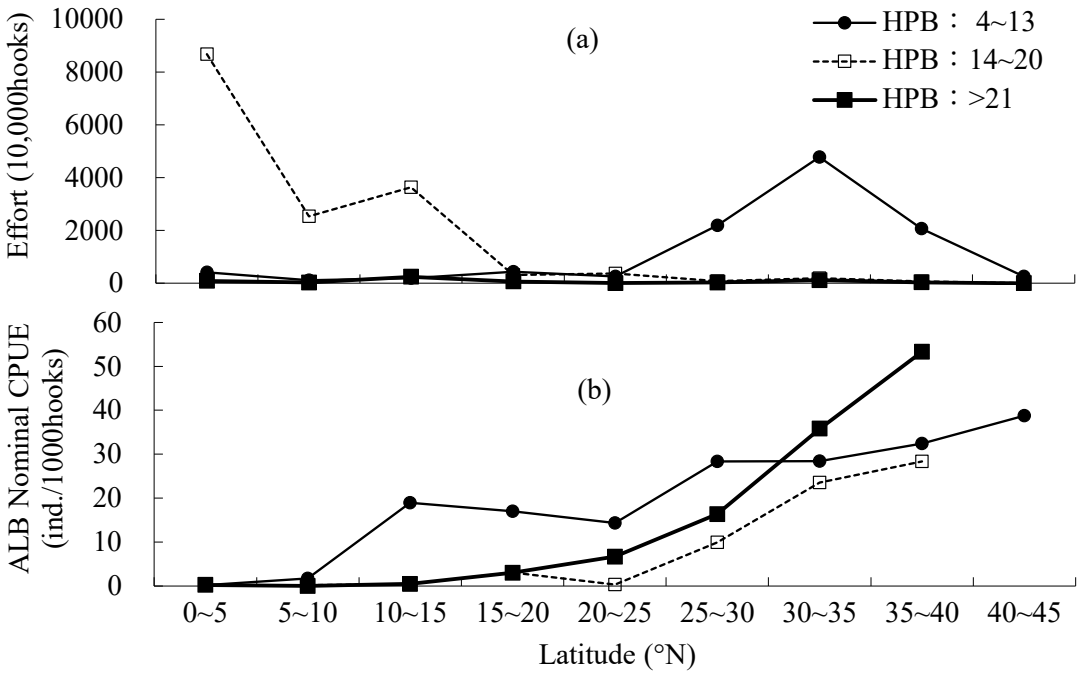

Fig.7. Latitudinal distribution of 3 fishing types, defined by the number of hooks per basket, made by Taiwanese longline fisheries in North Pacific Ocean, 1995-2018. (a) fishing efforts (b) albacore nominal CPUE.

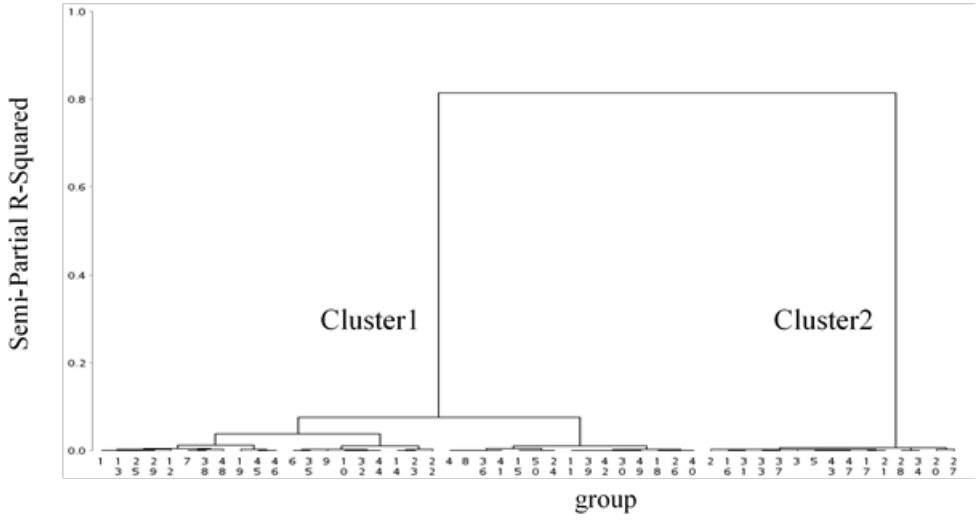

Fig. 8. Hierarchical tree obtained from cluster analyses on the catch compositions of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2018.

Table 1. Results of cluster analyses based on the catch compositions of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2018.

CPUE Unit：ind./1000hooks

	Cluster1		Cluster2	
Species	CPUE	SE	CPUE	SE
ALB	30.02	0.161	0.20	0.003
BET	1.26	0.015	5.45	0.021
YFT	0.65	0.014	1.63	0.012
Other tuna	0.01	0.002	0.00	0.001
SWO	0.15	0.002	0.57	0.004
WHM	0.11	0.002	0.10	0.010
BLZ	0.04	0.001	0.41	0.003
BLM	0.01	0.000	0.00	0.000
BIL	0.05	0.002	0.03	0.001
SKJ	0.58	0.014	0.08	0.003
SKX	0.59	0.008	0.73	0.007
OTHER	2.17	0.020	1.48	0.012
ALB ratio%	80.16		1.54	
Effort(hooks)	103,100,198		168,036,417	

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	25702	1701	27403
Group2_Non-ALB-targeting	844	56372	57216
Error Ratio%	3.2	2.9	3.1

(b) CPUE Unit：ind./1000hooks

	Group1		Group2	
Species	CPUE	SE	CPUE	SE
ALB	28.96	0.159	0.27	0.006
BET	1.37	0.016	5.46	0.021
YFT	0.74	0.016	1.60	0.012
Other tuna	0.01	0.002	0.00	0.000
SWO	0.15	0.002	0.57	0.004
WHM	0.14	0.020	0.08	0.001
BLZ	0.04	0.001	0.42	0.003
BLM	0.01	0.000	0.00	0.000
BIL	0.05	0.002	0.03	0.001
SKJ	0.62	0.014	0.05	0.002
SKX	0.61	0.008	0.72	0.007
OTHER	2.21	0.021	1.45	0.012
ALB ratio%	76.91		1.92	
Effort(hooks)	107,214,701		163,921,914	

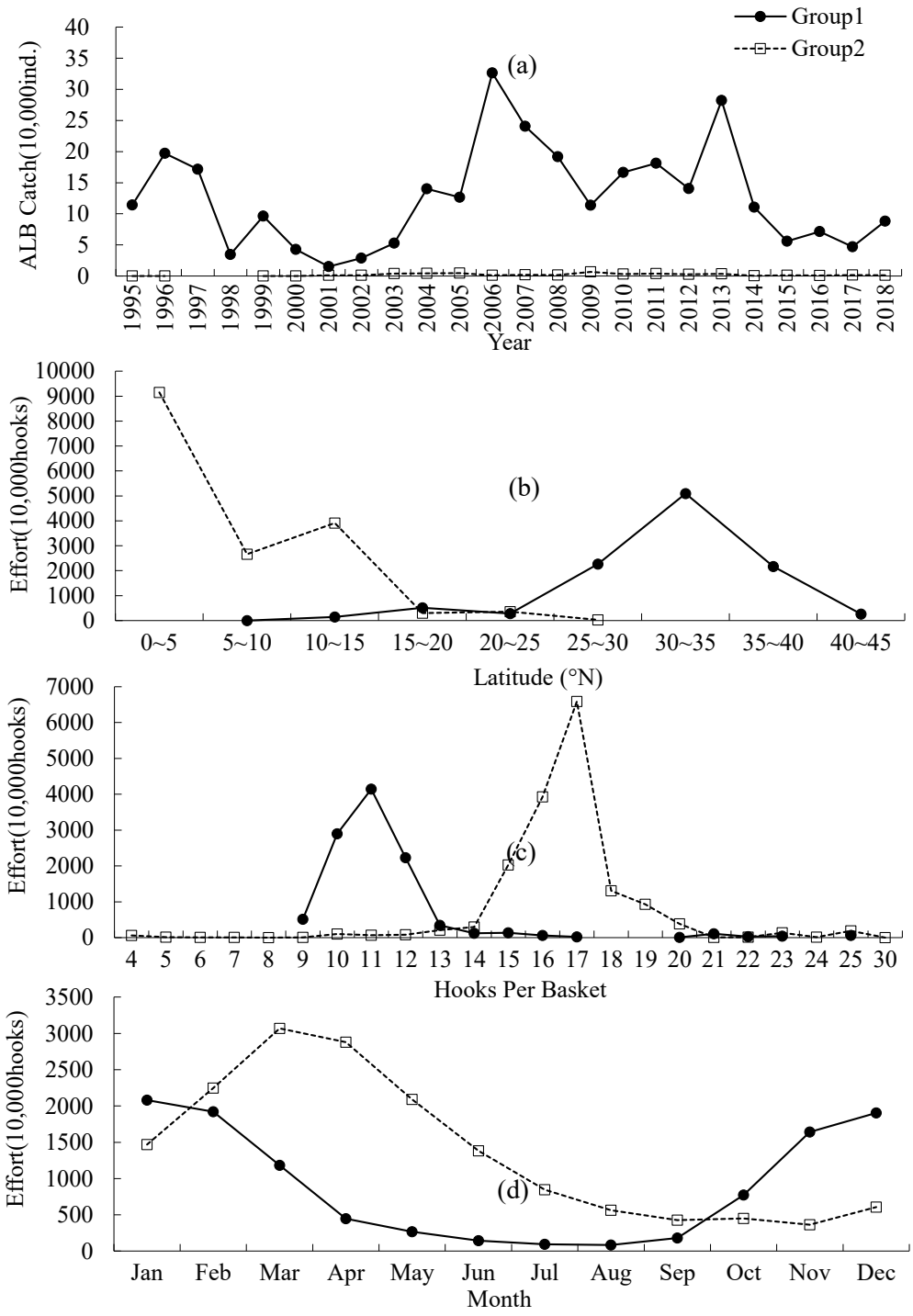

Fig. 9. Characteristics of Taiwanese longline fisheries (by group; group 1 denotes albacore-targeting and group 2 denotes non-albacore-targeting) operated in North Pacific Ocean, 1995-2018. (a) yearly albacore catch in number (b) latitudinal distribution of fishing efforts (c) fishing efforts vs. number of hooks per basket (d) monthly distributions of efforts

Table 3. Results of GLM analyses on the albacore CPUE of Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2018.

Source	DF	Sum of Squares	Mean Square	F Value	p
Model	30	5949.50	198.32	423.23	<.0001
Error	27372	12825.91	0.47		
Corrected Total	27402	18775.41			

R-Square：0.32

Source	DF	Type III SS	Mean Square	F Value	p
Year	23	4684.42	203.67	434.66	<.0001
Season	3	24.31	8.10	17.29	<.0001
Area	1	492.78	492.78	1051.65	<.0001
Season*Area	3	40.12	13.37	28.54	<.0001

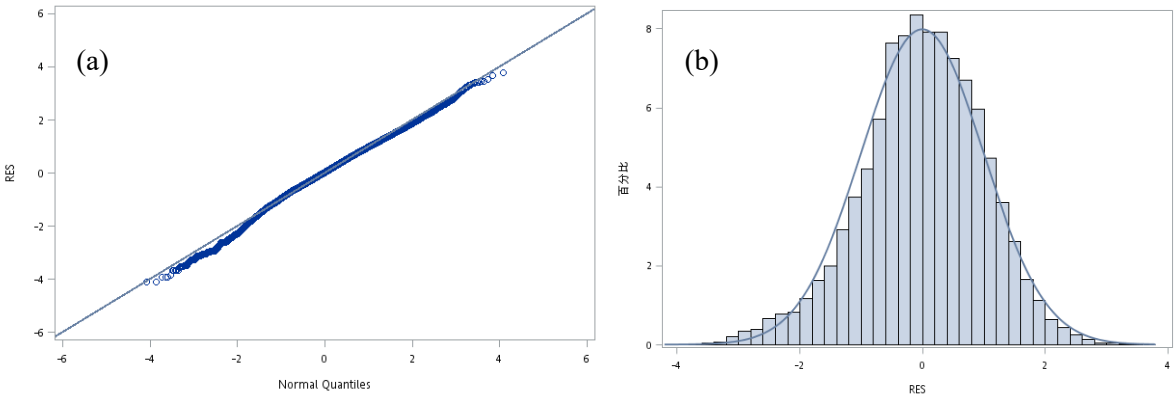

Fig. 10. Results of GLM standardized CPUE of albacore-targeting fishery caught by Taiwanese longline fisheries operated in North Pacific Ocean. (a) Q-Q plot (b) Normal Probability Plot.

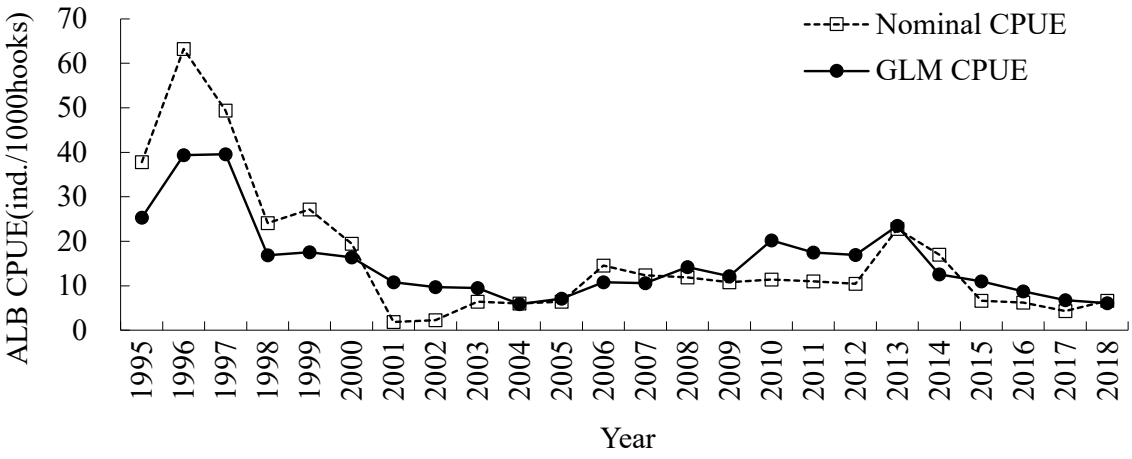

Fig. 11. Yearly fluctuations of nominal CPUE and GLM standardized CPUE of albacore caught by Taiwanese longline fisheries operated in North Pacific Ocean, 1995-2018.

Table 4. The standardized CPUE of albacore exploited by Taiwanese longline fisheries in North Pacific Ocean, 1995-2018.

CPUE Unit：ind./1000hooks

Year	nominal CPUE	ALB targeting CPUE	GLM CPUE	SE
1995	37.78	43.56	25.33	0.03
1996	63.23	64.09	39.39	0.02
1997	49.39	49.39	39.58	0.02
1998	24.13	24.13	16.86	0.04
1999	27.15	29.33	17.53	0.03
2000	19.48	24.66	16.36	0.04
2001	1.84	19.09	10.83	0.05
2002	2.26	23.32	9.69	0.04
2003	6.44	22.64	9.51	0.03
2004	6.05	14.14	5.86	0.02
2005	6.46	16.33	7.11	0.02
2006	14.57	24.29	10.80	0.02
2007	12.39	23.35	10.61	0.02
2008	11.89	29.54	14.17	0.02
2009	10.78	28.14	12.19	0.02
2010	11.43	37.65	20.23	0.02
2011	10.99	39.52	17.50	0.02
2012	10.48	38.59	16.95	0.03
2013	22.77	48.48	23.46	0.02
2014	16.97	32.79	12.59	0.03
2015	6.64	26.37	10.98	0.03
2016	6.20	22.69	8.77	0.03
2017	4.32	17.85	6.80	0.03
2018	6.62	15.93	6.07	0.02

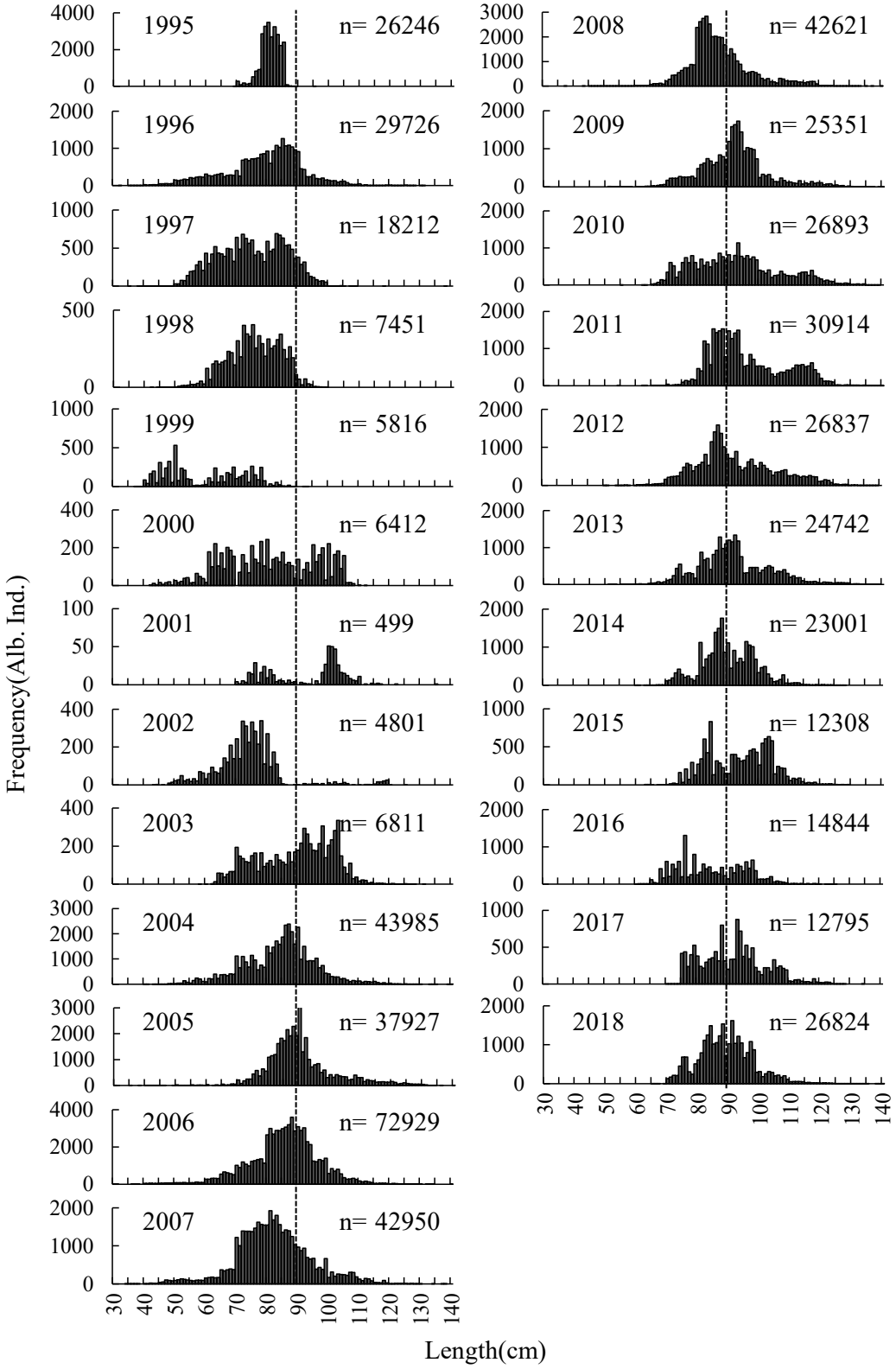

Fig. 12. Yearly length distributions of albacore collected by Taiwanese longline fisheries in North Pacific Ocean, 1995-2018.

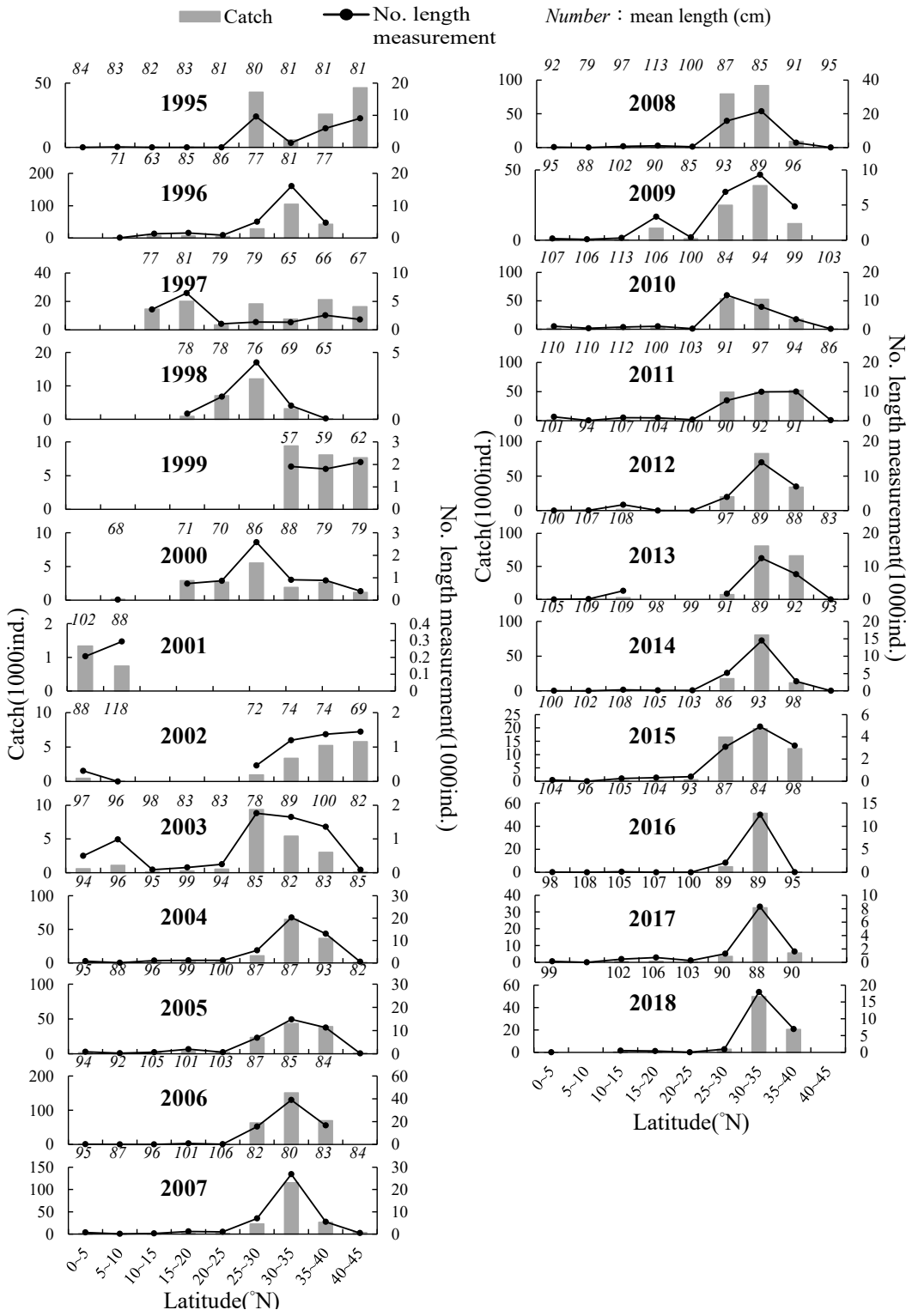

Fig. 13. Latitudinal distributions of albacore catch and corresponding number of length measurement made by Taiwanese longline fleets operated in the North Pacific Ocean, 1995-2018.