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Standardized CPUE of Indian Albacore caught by Taiwanese longliners from 1980 to 2014 with simultaneous nominal CPUE portion from observer data

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ABSTRACT

Albacore is one of the main target species of Taiwanese longline fishery in the Indian Ocean. It is essential to provide faithful CPUE for the albacore resource assessment and management need, to ensure the sustainable exploitation of this resource. In this paper, first we constructed temporal and spatial distributions of albacore nominal CPUE, which independently reported by fishing logbook and observer in the Indian Ocean, for quickly and comprehensively reviewing. And then, factors including year, quarter, subarea, code of CPUE and relative interactions, etc. were used to standardize the CPUEs of albacore caught by Taiwanese longliners in Indian Ocean from 1980 to 2014, by whole area and IOTC core area, respectively.

INTRODUCTION

In the Indian Ocean, albacore is one of the main target species of commercial tuna fishery and has a long history of scientific research. Albacore in the Indian Ocean has, for the last four decades, been mainly exploited by Taiwan, Japan, and Korea. Taiwanese catch of Indian Albacore increased steadily from the 1960's to average around 10,000 tons by the mid-1970s. During 1998 to 2002, catches ranged between 21,500 tons to 26,900 tons, comprising about 60% of the total Indian Albacore catch. In the recent decade, the catch of Indian Albacore by Taiwanese longliners fluctuated between 10,000 tons to 18,000 tons. Nevertheless, historic CPUE data series compiled by Taiwanese fisheries managerial sector and reported to the IOTC thus became one of the important data sources to investigate the long-term abundance fluctuation of this resource.

To meet the goal of responsible fishing, the Taiwanese Fisheries Agency has strengthened collection and analysis of fisheries data (such as catch statistics and resource estimates) in order to improve management of the deep-sea fishing industry and effectively enforce the law. Fishery observers were assigned to execute at-sea observation. These observers took biological samples as well as fishery operation data. Since observer required passing professional training and examination in advance, the quality of data from observer should be superior. In this study, we constructed temporal and spatial distributions of albacore nominal CPUE, which independently reported by fishing logbook and observer in the Indian Ocean, for quickly and comprehensively reviewing the abundance index information from different sources.

For the Indian Albacore caught by Taiwanese longliners, CPUE standardization using the General Linear Model (GLM) had been carried out for 1980-2010 (Chang et al., 2011), for 1980-2011 (Lee et al., 2012) and for 1980-2013 (Lee et al., 2014). Because of the conflict of CPUE trends between Taiwanese and Japanese longliners, assessing of Indian Albacore in core area (15°-45°S, 60°-90°E) was recommended (IOTC, 2012). The main purposes of this study were prepared standardized albacore CPUE using Taiwanese 1980-2014 longliners logbook data series, by GLM, in whole and core areas, to provide faithful abundance index for the albacore resource assessment and management need.

MATERIALS AND METHODS

At the IOTC 17th WPTT (Working Party on Tropical Tunas), the WPTT NOTED: the updated CPUE analysis and encouraged to continue the analysis as part of the multi-nation collaborative effort to improve CPUE standardizations. While some progress has been made, additional joint analyses of Taiwanese, Japanese, and Korean operational level longline fishery data are needed. Also, at the IOTC 18th SC (Scientific Committee), the SC RECOMMENDED: it is necessary to develop standardized CPUE series for albacore including incorporation of changes in species targeting. Taiwanese, Japanese and Korean scientists and an independent scientist have agreed to conduct collaborative work on albacore CPUE. Thus, "The 1st Taiwanese, Japanese, and Korean joint meeting of CPUE standardization for albacore" (Abbreviated as The Joint Meeting) was held in Taipei during April 4-8, 2016.

The Taiwanese longliners operational-level data set in the Indian Ocean from 1980 to 2014, which were compiled and provided by the Overseas Fisheries Development Council of Taiwan, for the Joint Meeting, was used as logbook data in this study. Data set included the following information:

a. Vessel identity;
b. Day of cruise start;
c. Date of set;
d. Position of set (daily);
e. Effort in number of hooks;
f. Hooks between floats (where available);
g. Catch in number of bigeye, yellowfin, albacore, southern bluefin tuna, swordfish, striped marlin, blue marlin and black marlin;

Observer data, which also provided by the Overseas Fisheries Development Council of Taiwan, was available from 2002 to 2014.

In order to find the appropriate sub area, cluster analysis based on the CPUE and catch ratio of albacore, bigeye and yellowfin tunas were applied. Fig. 15 and 17 showing the subareas of the Indian Ocean whole area and core area, those were obtained based on the results of cluster analysis (Fig. 14 & 16) on Taiwanese longliners catch statistics.

GLM with normal error structure (Robson, 1966; Gavaris, 1980; Kimura, 1981) was used in present study to standardize yearly CPUE series of albacore in the Indian Ocean whole area and core area, which are:

Yearly GLM with normal error structure in whole area

$$\ln(CPUE_{ijklmn} + const) = \mu + YEAR_i + QUARTER_j + SUBAREA_k + CODECPUE_l$$
$$+ QUARTER*SUBAREA_m + QUARTER*CODECPUE_n + \xi_{ijklmn}$$

Where,

ln: natural logarithm;

$CPUE_{ijklmn}$: Norminal CPUE (N/1000 Hooks);

μ: Overall mean for correction;

const: Constant (10% of the overall mean albacore nominal CPUE, value is 0.2559);

$YEAR_i$: Effect of Year *i*;

$QUARTER_j$: Effect of Quarter *j*;

$SUBAREA_k$: Effect of Subarea *k*;

$CODECPUE_l$: CPUE Code (CPUE≧11.59 value is 1,CPUE<11.59 value is 2);

$QUARTER*SUBAREA_m$: Effect of interaction on Quarter and Subarea;

$QUARTER*CODECPUE_n$: Effect of interaction on Quarter and CPUE Code;

ξ_{ijklmn} : Error with distribution character of $N(0,\sigma^2)$.

Yearly GLM with normal error structure in core area

$$\ln(CPUE_{ijklmn} + const) = \mu + YEAR_i + QUARTER_j + CODECPUE_l$$
$$+ YEAR*CODECPUE_n + \xi_{ijklmn}$$

Where,

ln: natural logarithm;

$CPUE_{ijklmn}$: Norminal CPUE (N/1000 Hooks);

μ: Overall mean for correction;

const: Constant (10% of the overall mean albacore nominal CPUE, value is 0.2559);

$YEAR_i$: Effect of Year *i*;

$QUARTER_j$: Effect of Quarter *j*;

$CODECPUE_l$: CPUE Code (CPUE≧11.59 value is 1,CPUE<11.59 value is 2);

$YEAR*CODECPUE_n$: Effect of interaction on Quarter and CPUE Code;

$\xi_{ijkl\ mn}$: error with distribution character of $N(0,\sigma^2)$.

SAS Ver. 9.4 Statistical package was used to obtain solutions.

RESULTS AND DISSCUSSIONS

In the Joint Meeting, we developed a technique to constructed temporal and spatial distributions of albacore nominal CPUE distributions by year and by area (5X5 degree), which are shown in Fig. 1 to Fig. 13. In the figures, CPUE is calculated by no. of catch/Hooks and divided into 12 classes. Table 1 lists the up and low boundaries of each CPUE class. Data from logbook and observer are represented by green and red, respectively. Frequency of CPUE distributions are in percentage and logarithmic scale are applied. The IOTC albacore core area (15°-45°S, 60°-90°E) are marked by red rectangle. In the figures, we observed very high similarity of albacore nominal CPUE distribution between fishing logbook and observer within the same temporal (year) and spatial (5X5 degree) condition.

Regards to CPUE standardization, the yearly CPUE trends of whole area are shown in Fig. 18 and Table 4; in whole area, the yearly CPUE trend of Indian Albacore thus obtained indicated that the values of CPUEs have decreased from 1980 to 1989 while the values between 1990 and 2012 had the stable trend with a slight variation but year 1992 and year 2010, then raised slightly again from 2013. In core area, the yearly CPUE trends are shown in Fig. 21 and Table 5. In core area, the yearly CPUE trend of Indian Albacore indicated that CPUEs were decreased from 1980 to 1990, then showed a stable trend with a slight variation up to 2014.

Plots of standardized residuals and QQ-plots of standardized residuals for GLMs of whole area and core area are shown in Fig. 19, 20, 22 and 23, separately. Table 2 and 3, which were obtained by SAS solver, are analysis of variance results on standardizing Indian Albacore yearly CPUE using Taiwanese longliners data set, from 1980 to 2014, by GLM procedures, in whole area and core area, respectively.

ACKNOWLEDGMENTS

We are grateful for the Fisheries Agency and Overseas Fisheries Development Council of Taiwanese fisheries managerial sectors for their financial supports and tremendous efforts devoted to fisheries catch and effort statistical data collection and compilation.

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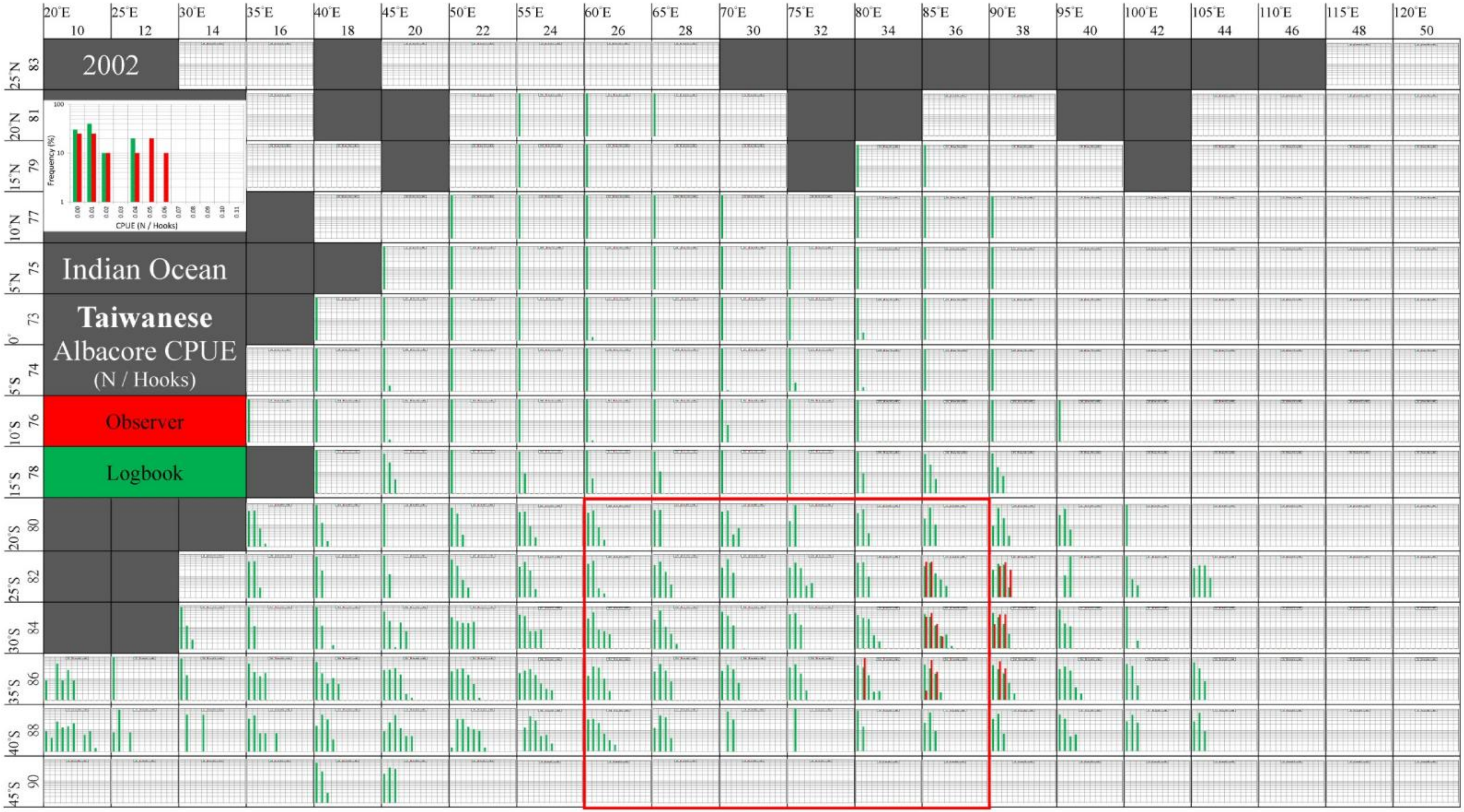


Fig. 1. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution from logbook (green) vs observer (red) in 2002

Fig. 2. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution of logbook (green) vs observer (red) in 2003

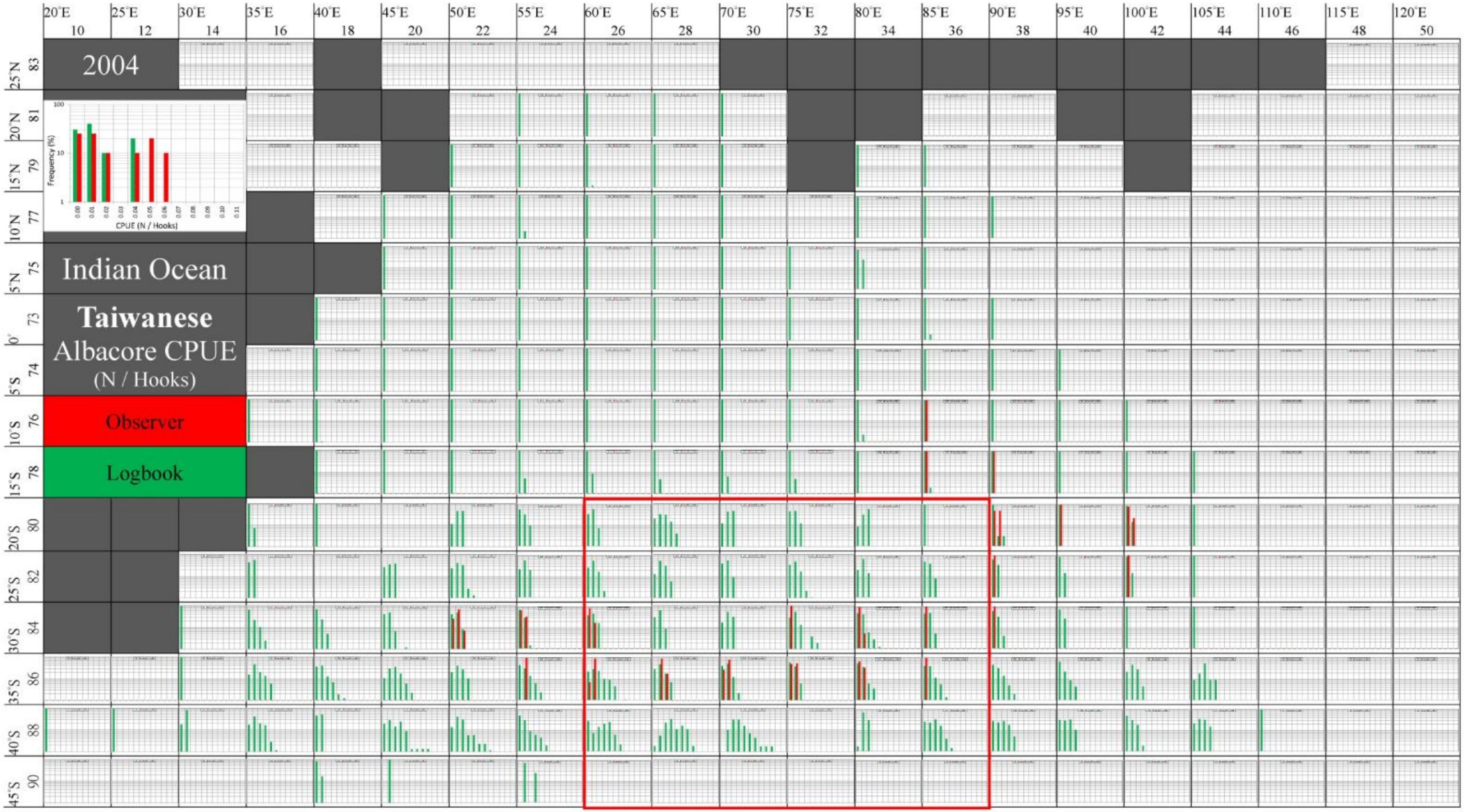


Fig. 3. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution of logbook (green) vs observer (red) in 2004

Fig. 4. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution of logbook (green) vs observer (red) in 2005

Fig. 5. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution of logbook (green) vs observer (red) in 2006

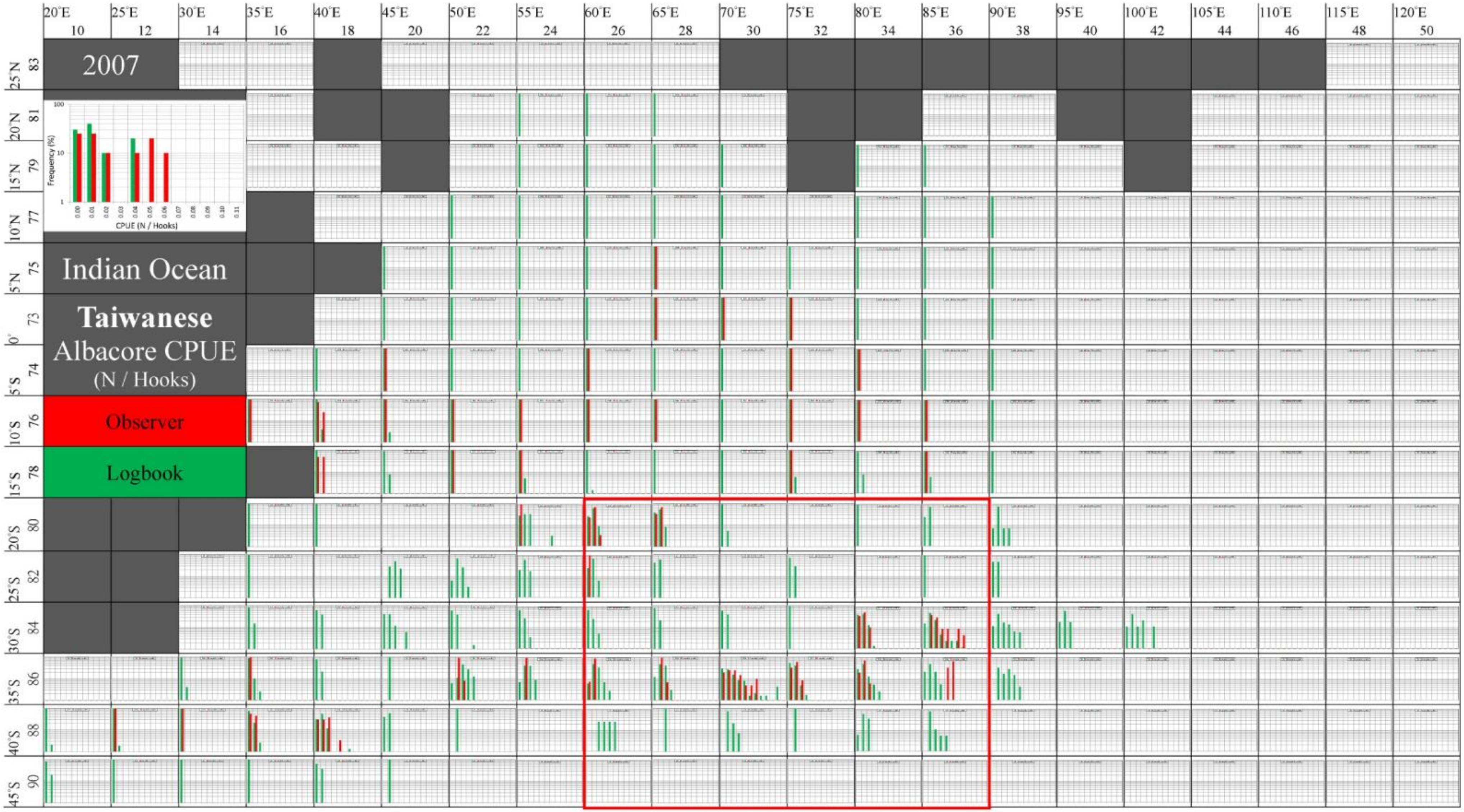


Fig. 6. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution of logbook (green) vs observer (red) in 2007

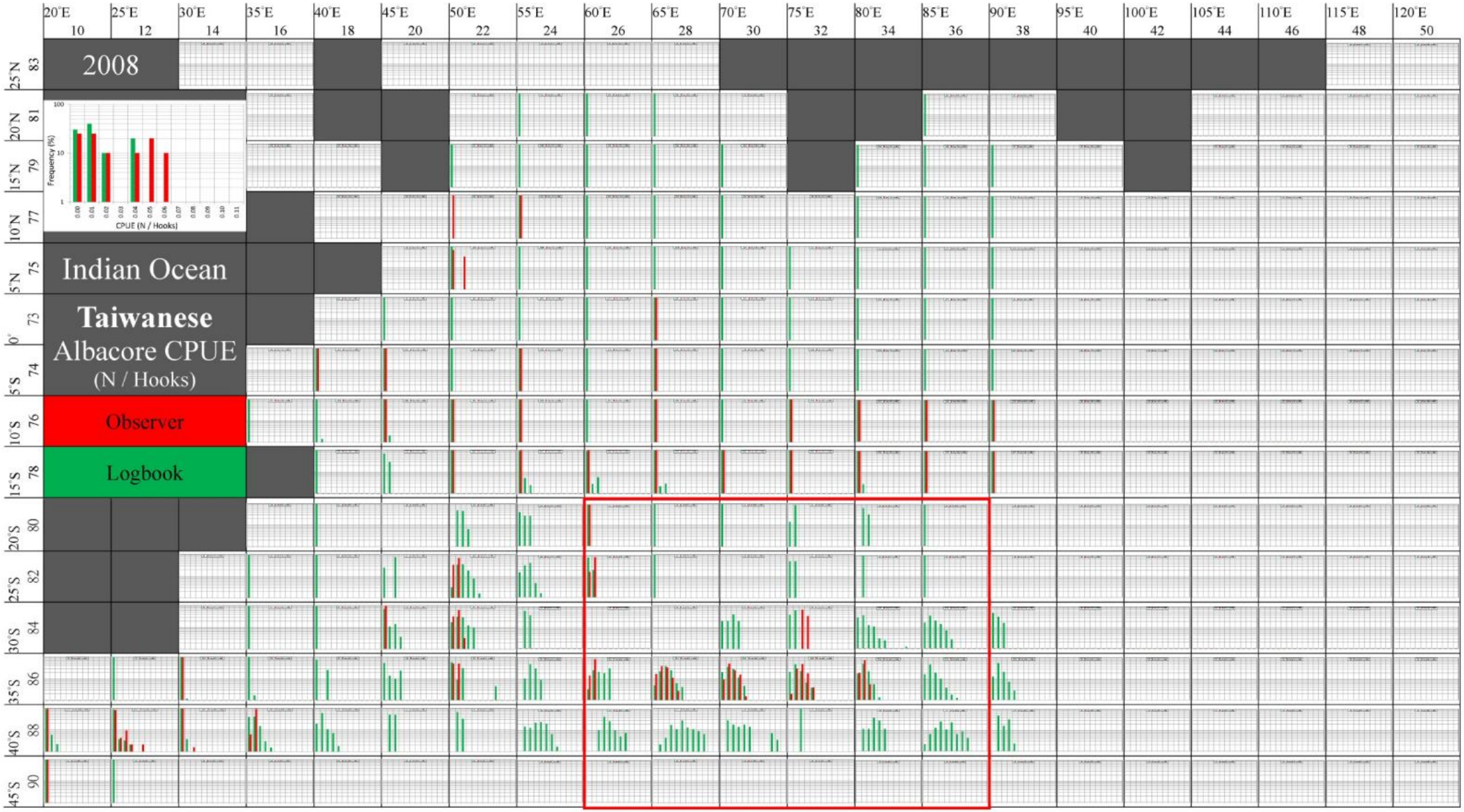


Fig. 7. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution of logbook (green) vs observer (red) in 2008

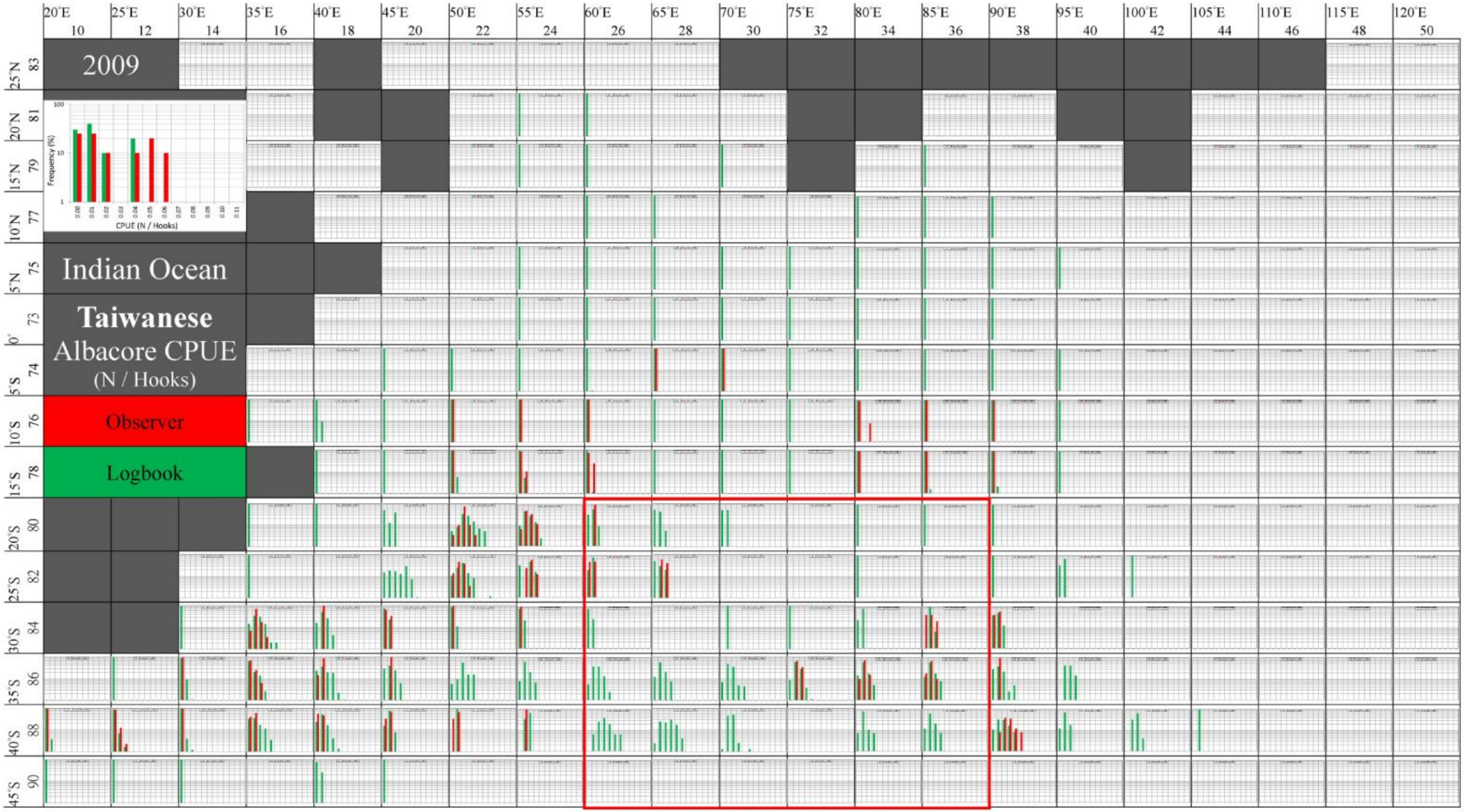


Fig. 8. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution of logbook (green) vs observer (red) in 2009

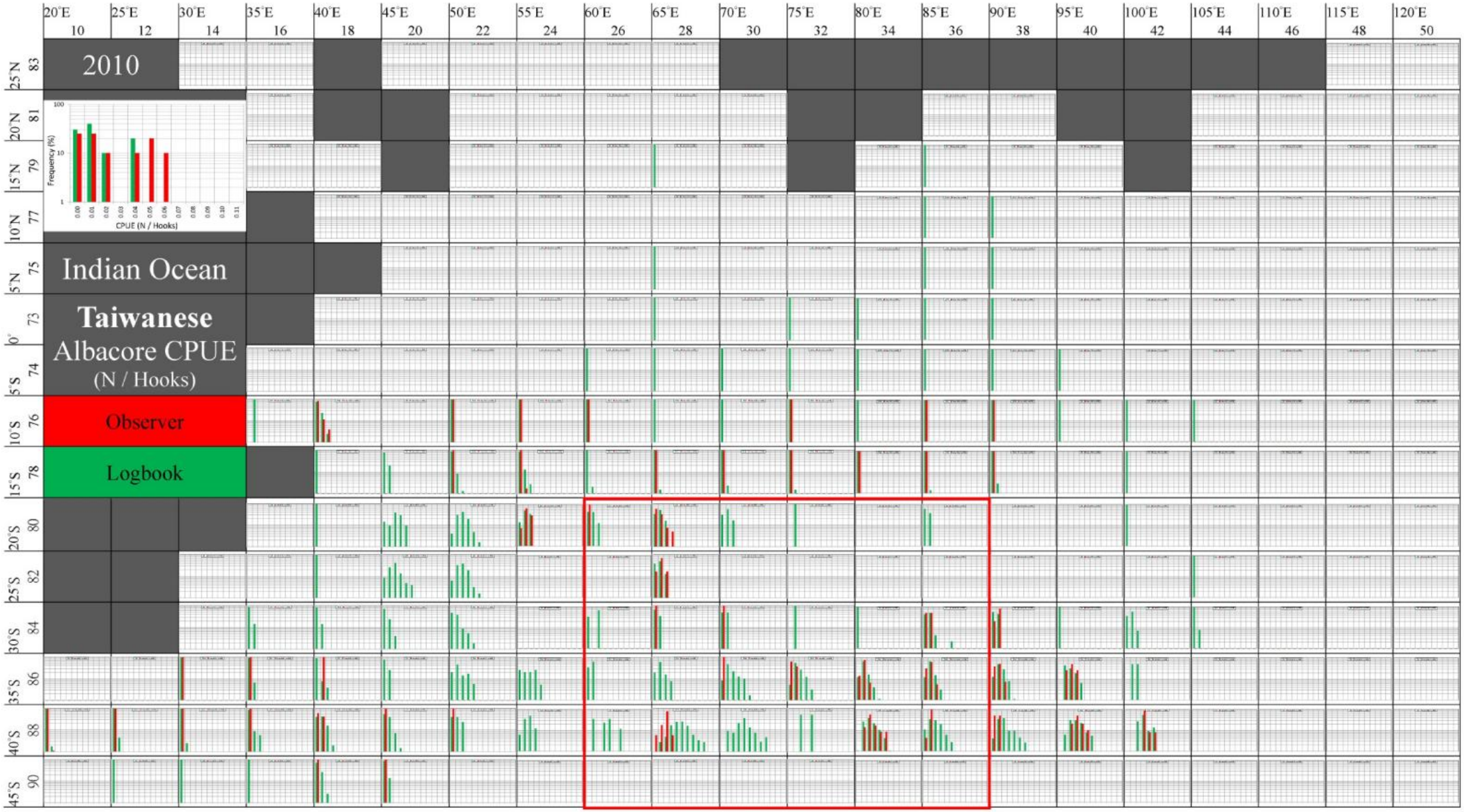


Fig. 9. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution of logbook (green) vs observer (red) in 2010

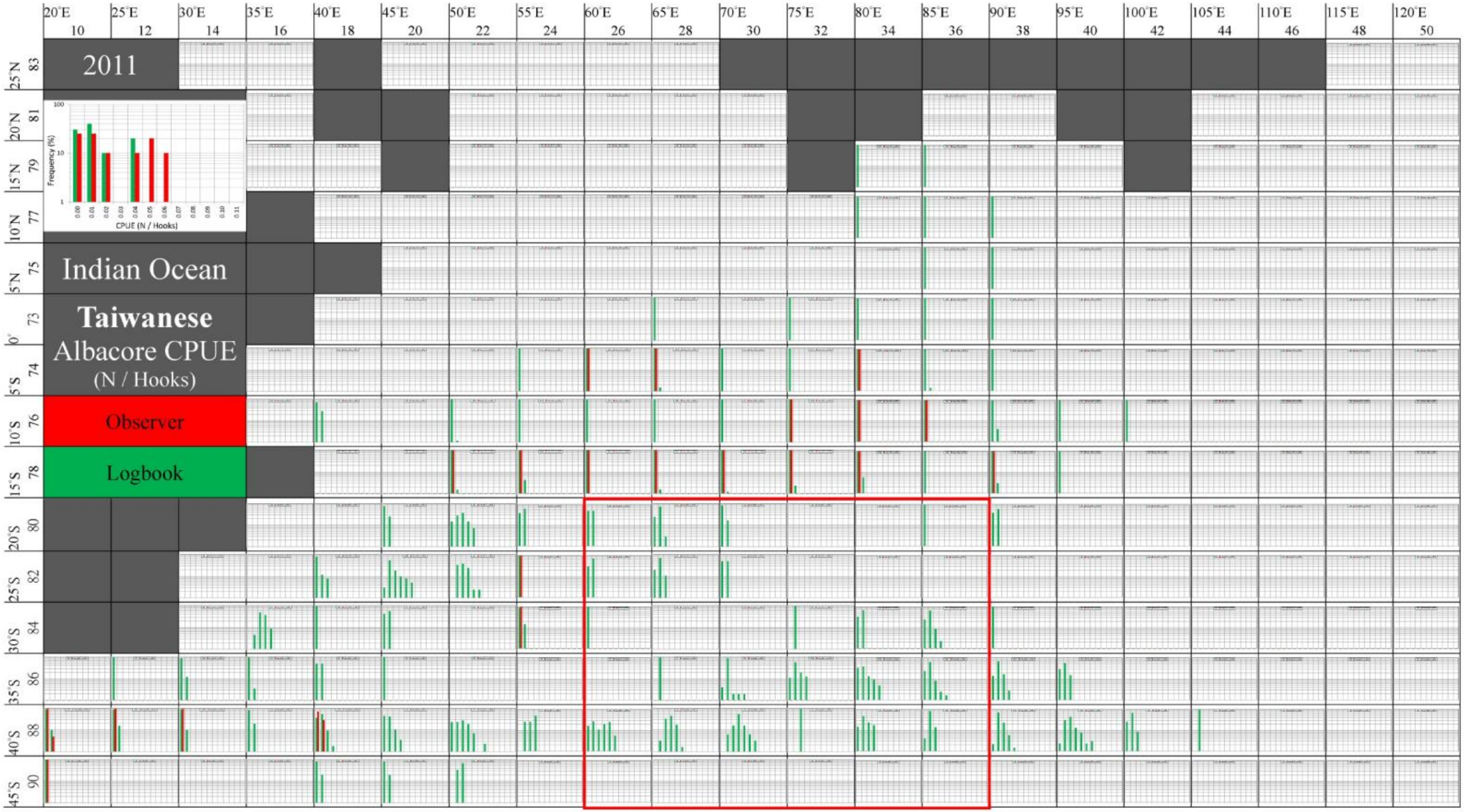


Fig. 10. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution of logbook (green) vs observer (red) in 2011

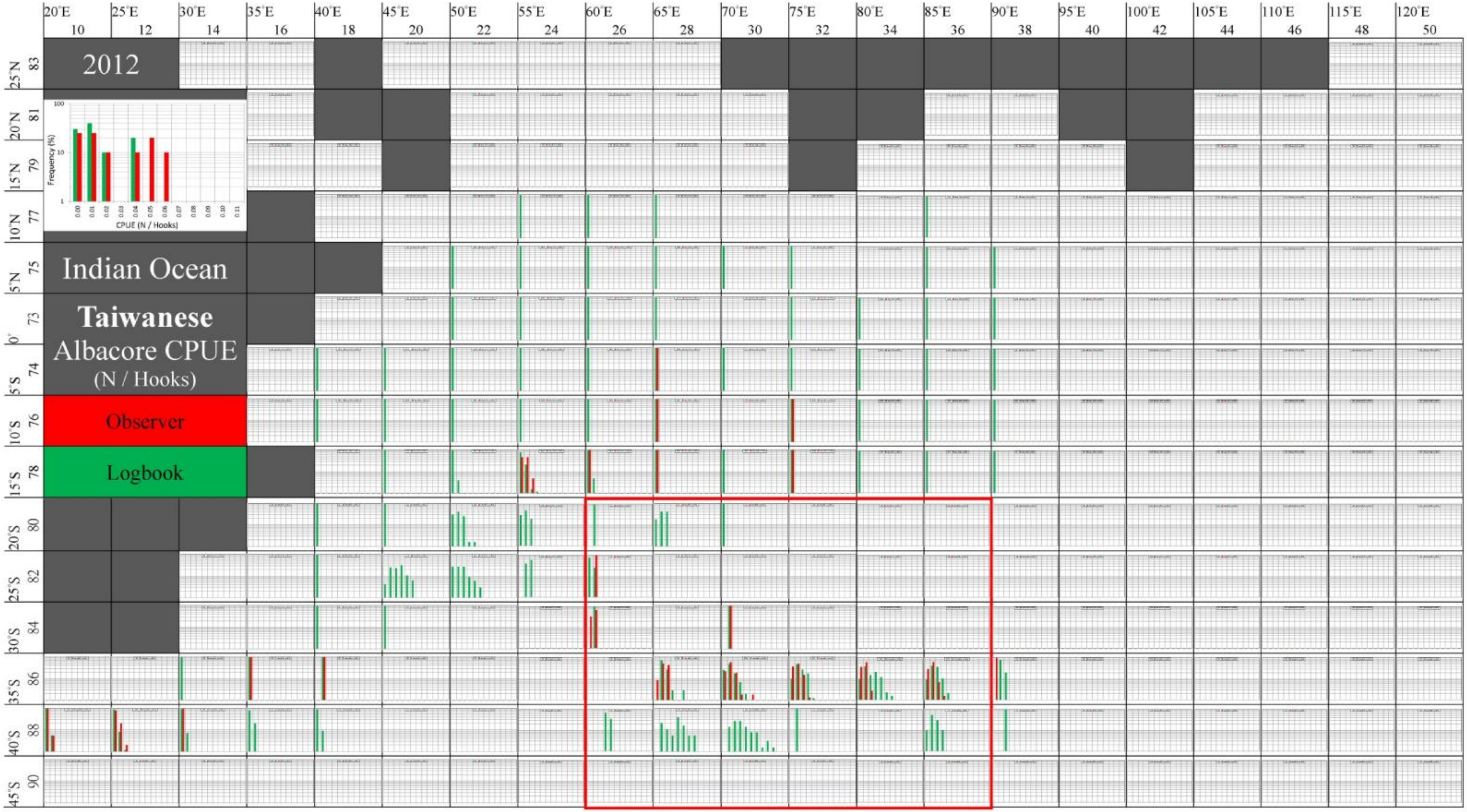


Fig. 11. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution of logbook (green) vs observer (red) in 2012

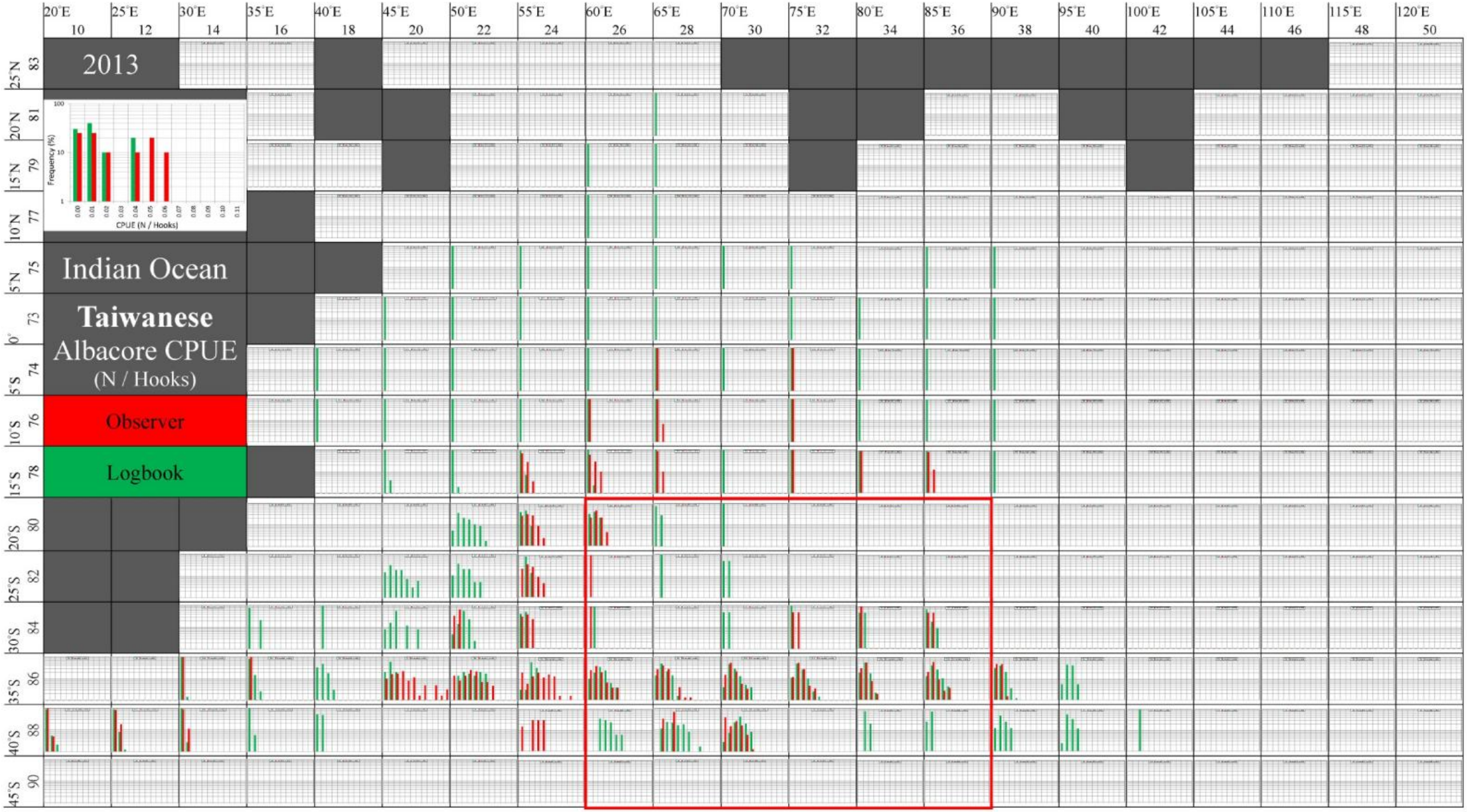


Fig. 12. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution of logbook (green) vs observer (red) in 2013

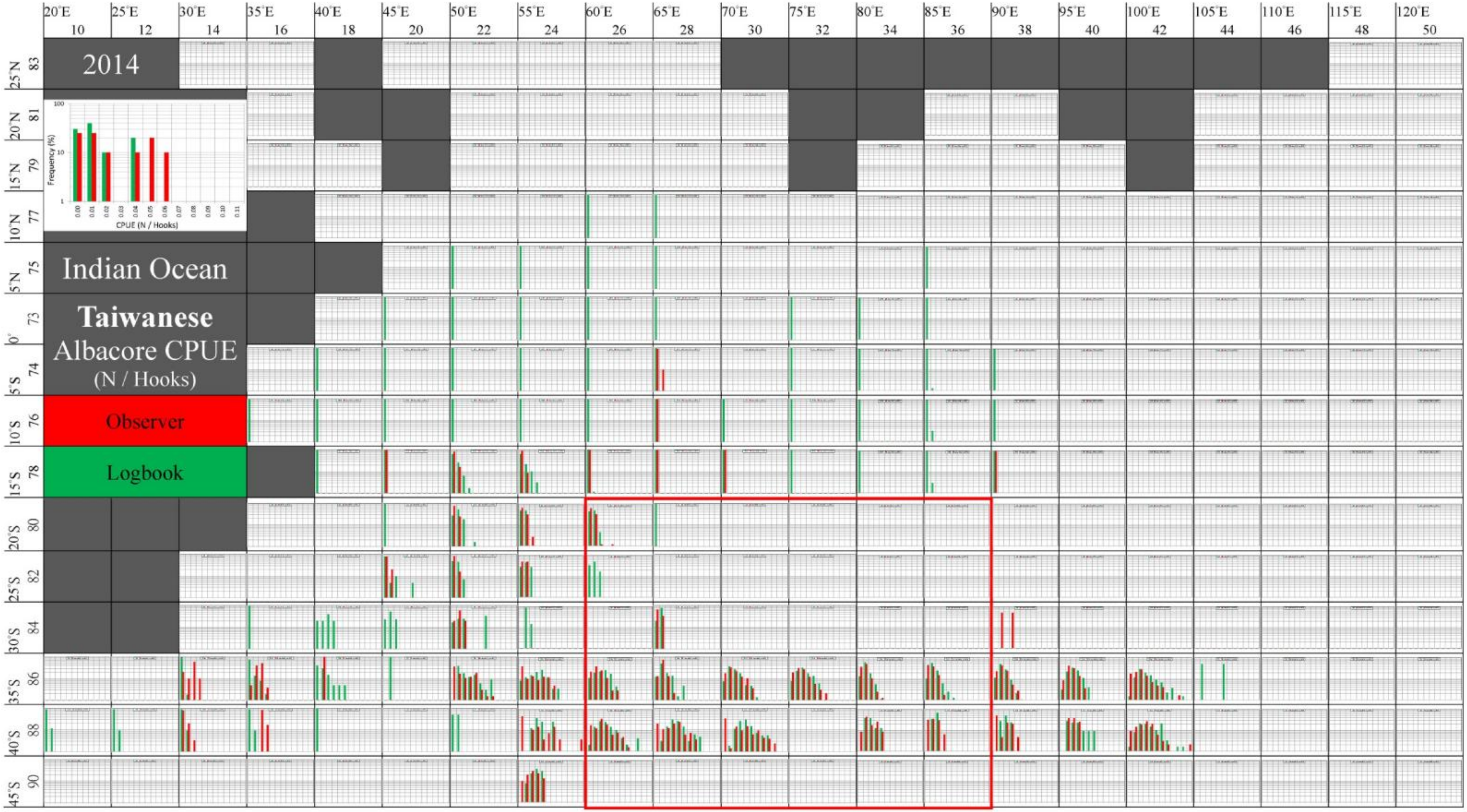


Fig. 13. Indian Ocean Taiwanese Longline fishery albacore nominal CPUE distribution of logbook (green) vs observer (red) in 2014

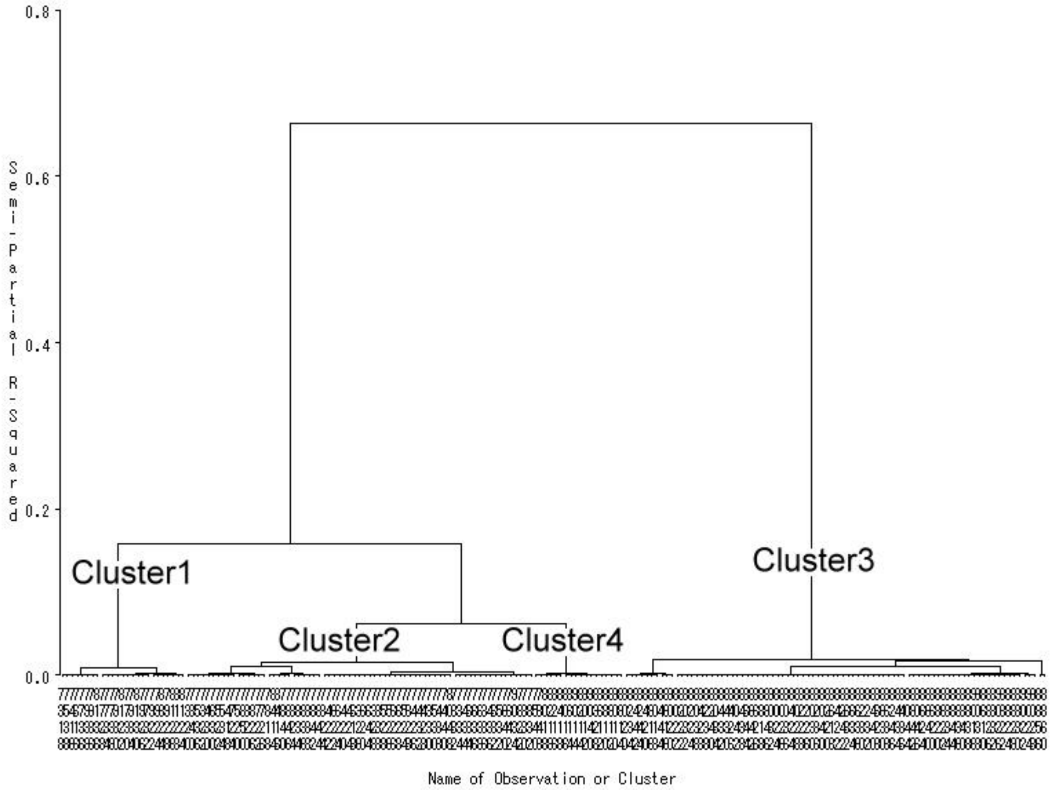


Fig. 14. Hierarchical structure of cluster analysis based on the CPUE and catch ratio of Taiwanese longliners (logbook data) in Indian Ocean whole area, 1980-2014

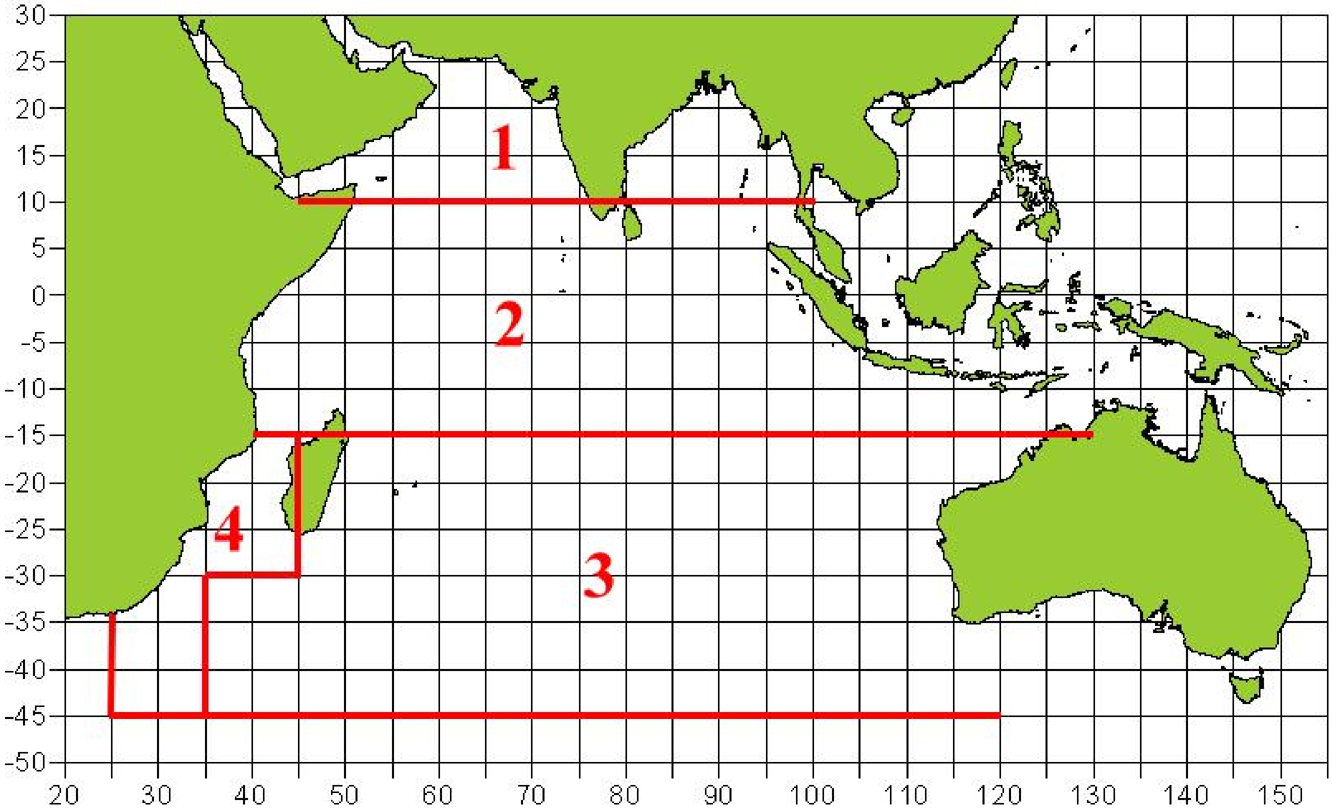


Fig. 15. Map showing the 4 subareas of Indian Albacore whole area, based on the results of cluster analysis and the fishing characteristic on Taiwanese longline catch statistics, 1980-2014

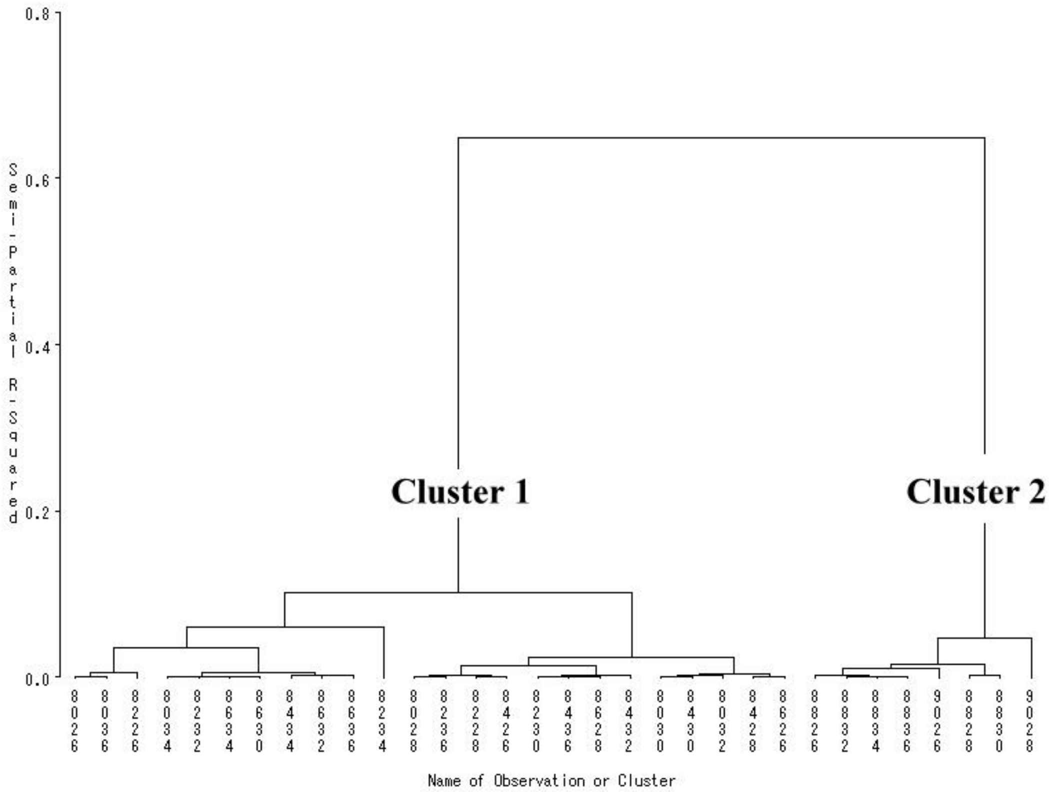


Fig. 16. Hierarchical structure of cluster analysis based on the CPUE and catch ratio of Taiwanese longliners (logbook data) in Indian Ocean Albacore core area, 1980-2014

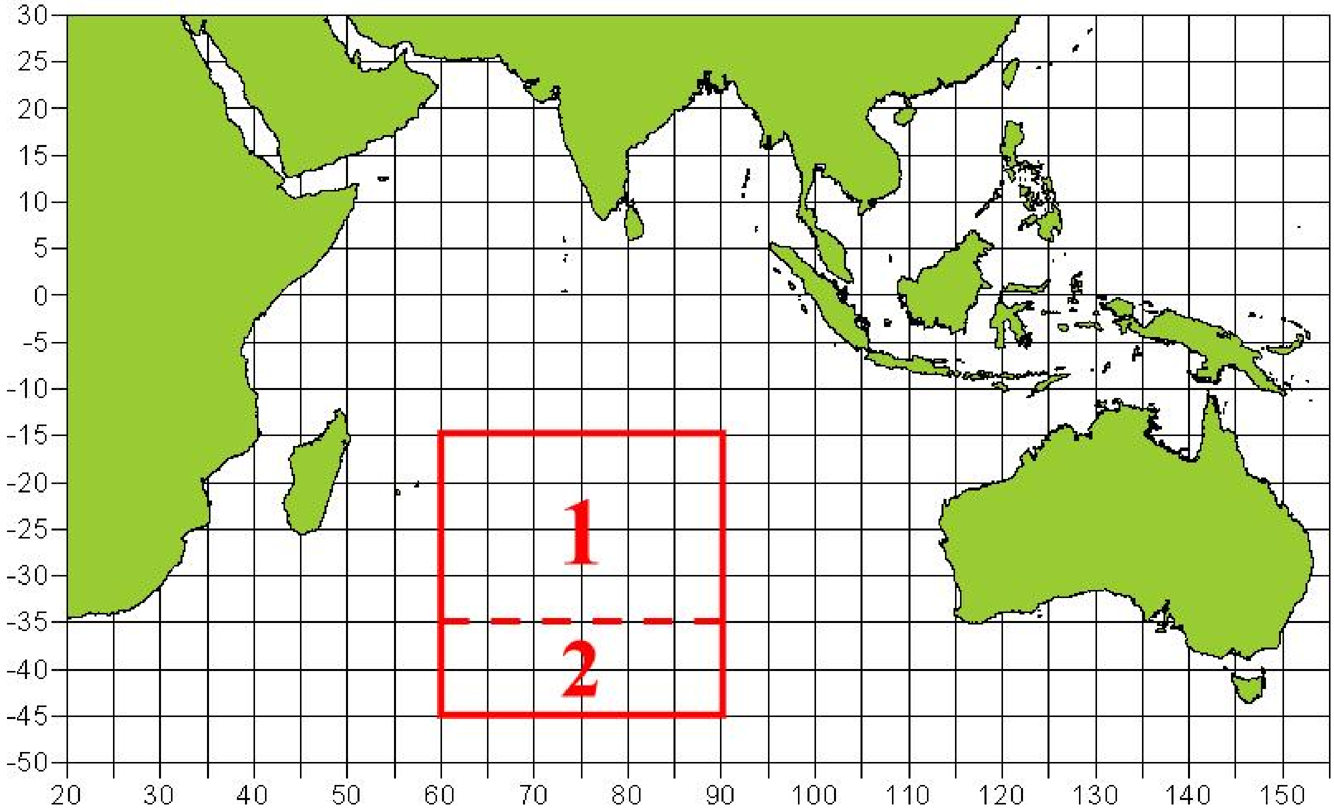


Fig. 17. Map showing the 2 subareas of Indian Albacore core area, based on the results of cluster analysis and the fishing characteristic on Taiwanese longline catch statistics, 1980-2014

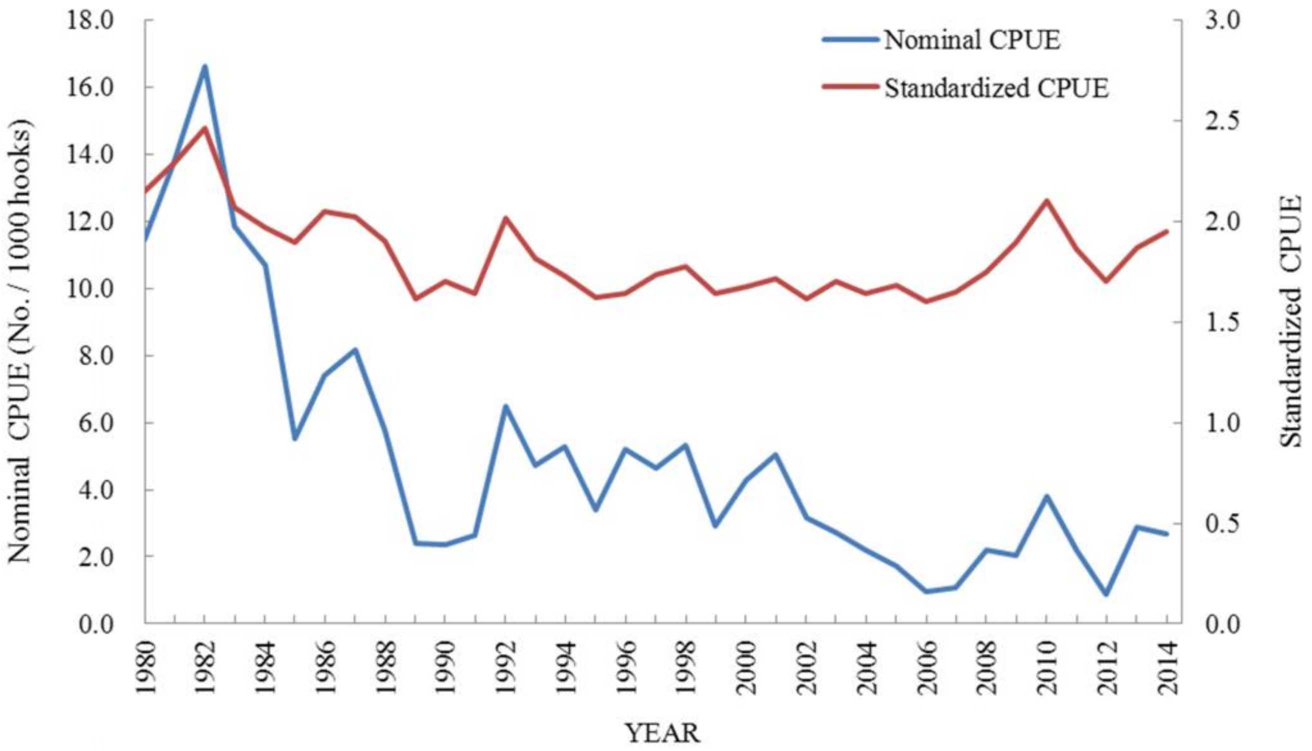
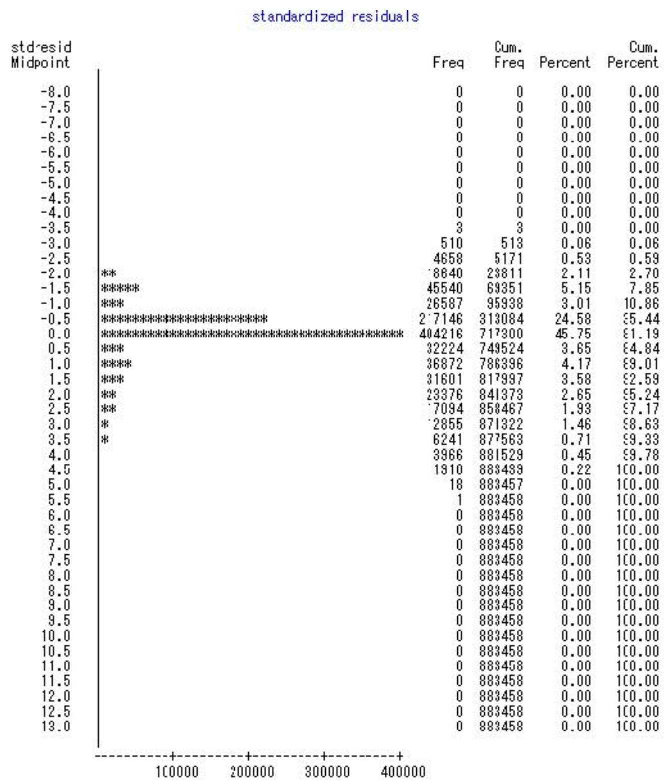


Fig. 18. Nominal and standardized CPUE for albacore in whole area of Indian Ocean by Taiwanese longliners



std-resid Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-8.0	0	0	0.00	0.00
-7.5	0	0	0.00	0.00
-7.0	0	0	0.00	0.00
-6.5	0	0	0.00	0.00
-6.0	0	0	0.00	0.00
-5.5	0	0	0.00	0.00
-5.0	0	0	0.00	0.00
-4.5	0	0	0.00	0.00
-4.0	0	0	0.00	0.00
-3.5	3	3	0.00	0.00
-3.0	510	513	0.06	0.06
-2.5	4658	5171	0.53	0.59
-2.0	18640	23811	2.11	2.70
-1.5	45540	69351	5.15	7.85
-1.0	26587	95938	3.01	10.86
-0.5	217146	313084	24.58	35.44
0.0	404216	717300	45.75	81.19
0.5	32224	749524	3.65	84.84
1.0	36872	786396	4.17	89.01
1.5	31601	817997	3.58	92.59
2.0	23376	841373	2.65	95.24
2.5	17094	858467	1.93	97.17
3.0	12855	871322	1.46	98.63
3.5	6241	877563	0.71	99.33
4.0	3966	881529	0.45	99.78
4.5	1910	883439	0.22	100.00
5.0	18	883457	0.00	100.00
5.5	1	883458	0.00	100.00
6.0	0	883458	0.00	100.00
6.5	0	883458	0.00	100.00
7.0	0	883458	0.00	100.00
7.5	0	883458	0.00	100.00
8.0	0	883458	0.00	100.00
8.5	0	883458	0.00	100.00
9.0	0	883458	0.00	100.00
9.5	0	883458	0.00	100.00
10.0	0	883458	0.00	100.00
10.5	0	883458	0.00	100.00
11.0	0	883458	0.00	100.00
11.5	0	883458	0.00	100.00
12.0	0	883458	0.00	100.00
12.5	0	883458	0.00	100.00
13.0	0	883458	0.00	100.00

Fig. 19 Plot of standardized residuals derived from GLM procedure for Indian Albacore in whole area

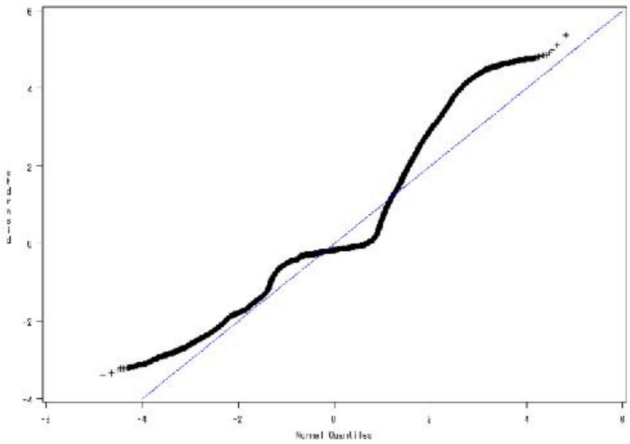


Fig. 20. QQ-plot of standardized residual for the GLM model for the Indian Albacore in whole area

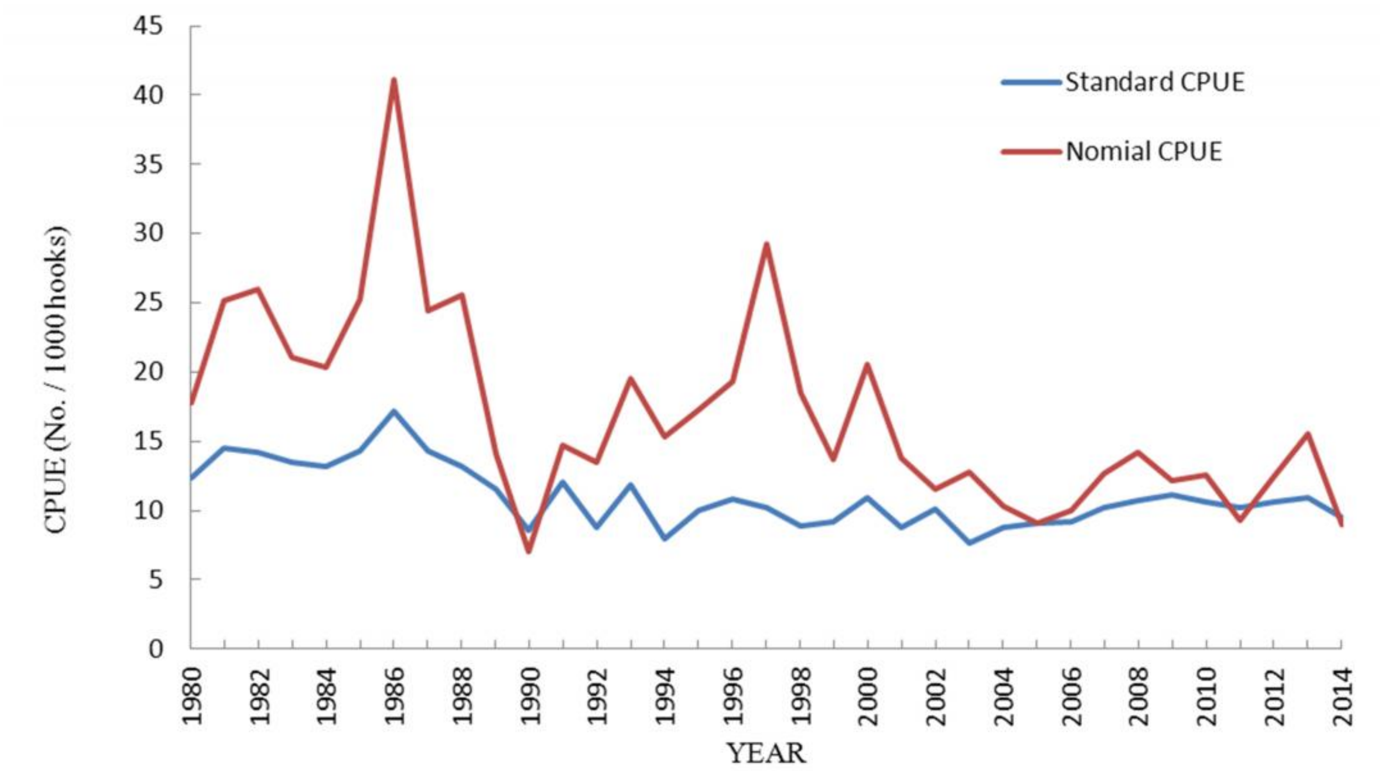


Fig. 21. Nominal and standardized CPUE for albacore in core area of Indian Ocean by Taiwanese longliners

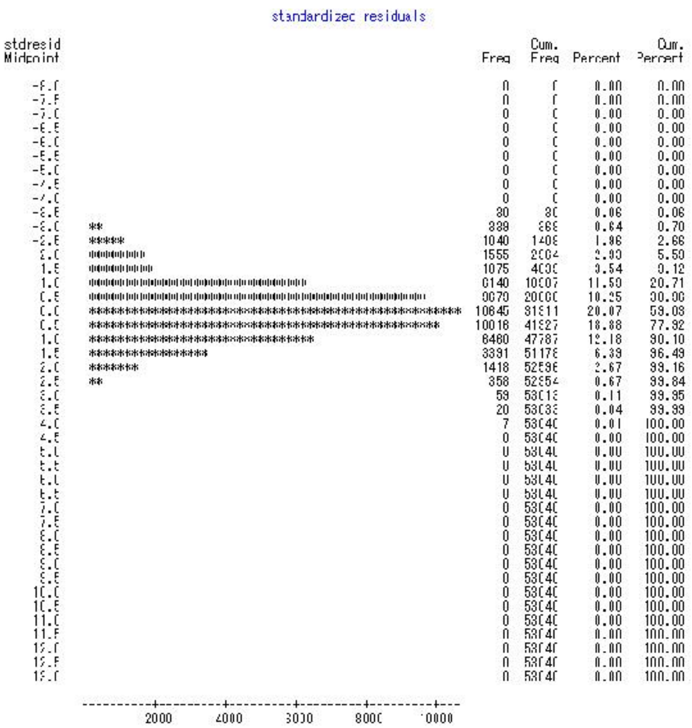


Fig. 22. Plot of standardized residuals derived from GLM procedure for Indian Albacore in core area

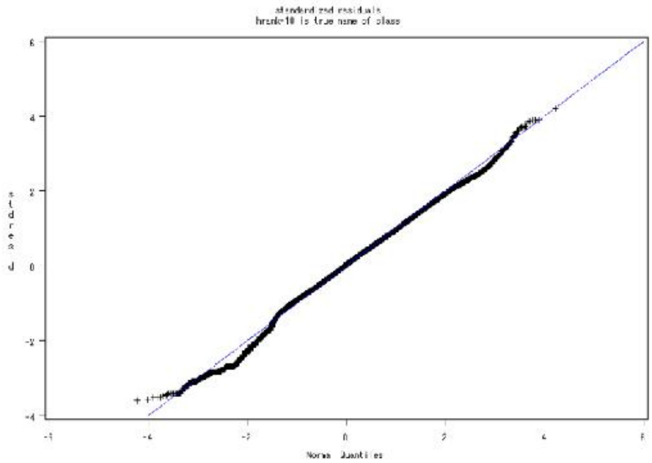


Fig. 23. QQ-plot of standardized residual for the GLM model for Indian Albacore in core area

Table 1. Up and low boundaries of CPUE classes in Fig. 1 to Fig. 13

CPUE (N/Hooks)	Class Label	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1	0.11
	low	≧0.000	≧0.005	≧0.015	≧0.025	≧0.035	≧0.045	≧0.055	≧0.065	≧0.075	≧0.085	≧0.095	≧0.105
	up	<0.005	<0.015	<0.025	<0.035	<0.045	<0.055	<0.065	<0.075	<0.085	<0.095	<0.105	<0.115

Table 2. Analysis of variance on standardizing Indian Albacore in whole area yearly CPUE using Taiwanese longliners data from 1980 to 2014 by GLM procedure

Whole Area

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	2300458.698	43404.881	143041	<.0001
Error	883404	268063.718	0.303		
Corrected Total	883457	2568522.415			
R-Square	Coeff Var	Root MSE	lalb Mean		
0.895635	-165.2005	0.550858	-0.333448		
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	34	6624.9332	194.851	642.13	<.0001
Quarter	3	393.3203	131.1068	432.06	<.0001
Subarea	3	34747.6545	11582.5515	38170.3	<.0001
CPUE Code	1	427296.8944	427296.8944	1408157	<.0001
Quarter*Subarea	9	499.3181	55.4798	182.83	<.0001
Quarter*CPUE Code	3	1021.1195	340.3732	1121.7	<.0001

Table 3. Analysis of variance on standardizing Indian Albacore in core area yearly CPUE using Taiwanese longliners data from 1980 to 2014 by GLM procedure

Core area

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	72	25704.01	357.0002	1496.9	<.0001
Error	52967	12632.23	0.23849		
Corrected Total	53039	38336.24			
R-Square	Coeff Var	Root MSE	lalb Mean		
0.670489	18.12257	0.488357	2.694744		
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	34	1136.64	33.43058	140.17	<.0001
Quarter	3	150.1996	50.06653	209.93	<.0001
CPUE Code	1	6578.361	6578.361	27583.1	<.0001
Year* CPUE Code	34	988.1894	29.06439	121.87	<.0001

Table 4. Nominal and standardized yearly CPUE of Indian Albacore in whole area fished by Taiwanese longliners, 1980-2014

Whole area		
Year	Nominal CPUE	Standardized CPUE
1980	11.44	2.15
1981	13.77	2.29
1982	16.59	2.46
1983	11.83	2.07
1984	10.69	1.96
1985	5.51	1.89
1986	7.41	2.05
1987	8.16	2.02
1988	5.76	1.90
1989	2.42	1.61
1990	2.37	1.70
1991	2.63	1.64
1992	6.47	2.01
1993	4.72	1.81
1994	5.27	1.72
1995	3.38	1.62
1996	5.21	1.64
1997	4.64	1.74
1998	5.31	1.77
1999	2.91	1.64
2000	4.30	1.68
2001	5.03	1.71
2002	3.17	1.62
2003	2.72	1.70
2004	2.20	1.64
2005	1.70	1.68
2006	0.96	1.60
2007	1.06	1.65
2008	2.22	1.75
2009	2.06	1.90
2010	3.81	2.10
2011	2.21	1.86
2012	0.87	1.70
2013	2.87	1.87
2014	2.70	1.95

Table 5. Nominal and standardized yearly CPUE of Indian Albacore in core area fished by Taiwanese longline, 1980-2014

Core area		
Year	Nominal CPUE	Standardized CPUE
1980	17.82	12.34
1981	25.11	14.53
1982	26.00	14.23
1983	21.10	13.49
1984	20.37	13.22
1985	25.25	14.28
1986	41.14	17.15
1987	24.46	14.35
1988	25.52	13.15
1989	14.07	11.57
1990	7.05	8.56
1991	14.71	12.03
1992	13.45	8.80
1993	19.50	11.84
1994	15.36	8.01
1995	17.24	10.05
1996	19.31	10.86
1997	29.29	10.17
1998	18.53	8.86
1999	13.68	9.19
2000	20.52	10.91
2001	13.78	8.77
2002	11.58	10.09
2003	12.81	7.66
2004	10.33	8.77
2005	9.10	9.11
2006	10.04	9.21
2007	12.71	10.19
2008	14.24	10.72
2009	12.18	11.13
2010	12.54	10.61
2011	9.25	10.23
2012	12.49	10.60
2013	15.50	10.88
2014	8.96	9.53