CPUE standardization of southern bluefin tuna caught by Taiwanese longline fishery*

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Abstract

The CPUE of southern bluefin tuna caught by Taiwanese longline fishery was standardized using delta-lognormal GLM. The standardized CPUE of positive catches were very low before 1986, then increased slightly until 1996, and fluctuated thereafter. The standardized proportion of positive catches revealed the increasing pattern until 1990 except in 1985 and 1986, and then fluctuated during 1990 to 1998, and decreased thereafter. The trend of relative abundance indices was similar to the CPUEs of positive catches but with a stable trend in 2000s.

台湾はえ縄漁業が漁獲したみなみまぐろ(SBT)の CPUE は delta-lognormal GLM によって標準化されている。1986 年以前、標準化された CPUE は非常に低くて、1986-1996 年は小幅に増加し、その後は変動の傾向を示していた。1985 年と 1986 年を除けば、1990 年以前標準化された漁獲率は上昇傾向にある。1990-1998 年は変動していたが、その後は減少し続けていた。豊度指標の傾向と CPUE の傾向は似ていたが、2000 年代は安定している。

Introduction

Taiwanese tuna longline fishery caught the southern bluefin tuna (SBT) as a bycatch in the past. In recent years, SBT has been a seasonal target species during two seasons (June to September and October to next February) in different areas by some vessels with super cold freezers, while most of the products were still bycatches to the albacore fishery. Therefore, the SBT catches were low except in the main SBT seasons, and consequently a substantial proportion of zero catches of SBT were contained in the Taiwanese fishery data. The estimation bias could be raised while analyzing the data with large number of zero catches using standard general linear model (GLM). This problem would be reduced by treating the zero catches and positive catches separately (Pennington, 1983; Hinton and Maunder, 2004). In this

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report, therefore, the CPUE standardization of SBT caught by Taiwanese longline fishery was conducted based on the delta-lognormal GLM.

Materials and methods

The catch and effort of Taiwanese longline fishery used in the report were based on the data from the CCSBT data base that submitted by Taiwan. The data including number of hooks, catch in number of SBT and catch in weight of SBT were monthly aggregated by 5x5 degree from 1981 to 2003 and were also split up into 13 sub areas based on the SBT statistical areas (Fig. 1).

The 1x1 degree aggregated sea surface temperature (SST) data during 1982 to 2005 were collected from Jet Propulsion Laboratory, California Institute of Technology, NASA (NASA/JPL PO.DAAC). The 5x2 degree aggregated SST and mixed layer depth (MLD) data during 1955 to 2003 were also collected from Joint Environmental Data Analysis Center, Scripps Institution of Oceanography (JEDAC).

The delta-lognormal GLM (Pennington, 1983; Lo et. al., 1992; Pennington, 1996) was applied to standardize the CPUE of SBT caught by Taiwanese longline fishery. The effects included in the models were year, month, area, SST and MLD and theirs interactions. The analyses were divided into two models for CPUE of positive catches and proportion of positive catches. The log-transformed model with a normal error assumption was used for CPUE of positive catches:

$$\log(CPUE) = Y + M + A + SST + MLD + \varepsilon_1$$

where Y is the year effect;
M is the month effect;
A is the area effect;
SST is the SST effect;
MLD is the MLD effect;
ε_1 is the error term and ($\varepsilon_1 \sim N(0, \sigma^2)$).

The estimation of the log-transformed model was based on the Gaussian PDF and the identity as the link function. The delta model with a binomial error assumption was used for probability of positive catches:

$$P = Y + M + A + SST + MLD + \varepsilon_2$$

where ε_1 is the error term and ($\varepsilon_1 \sim Bin(n, p)$).

The estimation of the delta model was based on the binomial PDF and the logit as the link function. Akaike's Information Criterion (AIC) is used to select among alternative models of which the one with the lowest value of AIC is selected as the final model. The standardized results were computed from the adjusted means (least square means) of the estimates of the year effects. The analyses were conducted using R version 2.1.1 (The R Development Core Team, 2005).

The relative abundance index is calculated by the product of the standardized CPUE and the standardized proportion of positive catches:

$$index = e^{\log(CPUE)} \times \left(\frac{e^P}{1+e^P} \right)$$

Results and Discussion

Fig. 2 and Fig. 3 show the geographic distribution of CPUE of SBT caught by Taiwanese longline fishery during 1982 to 2003. Before 1990, CPUEs of Taiwanese longline fishery were very low in all areas. Thereafter, CPUEs increased and almost distributed in the southern of 20S and concentrated in the central Indian Ocean and southeast waters around Africa and some distributed in the western waters of Africa. The CPUE were very low except these areas. Therefore, the data in the area 2, 8, 9, 11 and 13 were used in this study and the data in the north of 20S and in the west of 20W were excluded. The data of Area 11 was temporarily used in this study although the catch might need to be further verified.

Fig. 4 shows the monthly variation of CPUE of SBT caught by Taiwanese longline fishery during 1982 to 2003 for area 2, 8, 9, 11 and 13. CPUEs were higher during June to September in area 2, 8 and 13. In area 9, CPUEs were higher during September to next February or March and extended to June or July for some years. In area 11, CPUEs were low before 1990, although they increased thereafter but have no significantly monthly patterns.

The effect of MLD was statistically significant for preliminary analyses with the data in the central Indian Ocean. However, the MLD data were absent for the area around the southeast of Africa. The missing data led to the problem for standardizing the CPUE for the selected SBT fishing area. Thus MLD effect was excluded in this study.

The results of stepwise analyses for two models were listed in Table 1 and 2. The selected final models were represented as follows:

$$\log(CPUE) = Y + M + A + SST + Y * A + M * A + M * SST + A * SST$$

$$P = Y + M + A + SST + Y * A + A * SST + M * SST + M * A$$

The both finial models were statistically significant and explained 61% of the variance for log-transform model and 25% of the variance for delta model. Figs. 5 and 6 show the distribution of the standardized residuals and the normal probability plot for log-transform model and do not appear to differ much from those expected under the normal distribution.

The trends of nominal and standardized CPUE of positive catches were similar but standardized CPUE was much more stable than nominal one (Fig. 7). Before 1986, nominal and standardized CPUE were very low, then nominal CPUE obviously increased until 1996 but the standardized CPUE increased slightly during the same period, and both of them fluctuated thereafter.

Fig. 8 shows the nominal and standardized proportion of positive catches. The trend of standardized proportion of positive catches was very close to nominal one but the standardized values were slightly less than nominal ones. The proportions of positive catches revealed the increasing pattern until 1990 except in 1985 and 1986, and then fluctuated during 1990 to 1998, and decreased thereafter.

The trend of relative abundance indices was similar to the CPUEs of positive catches (Fig. 9) but with a stable trend in 2000s. The values were very low before 1990, and then increased until 1995, and fluctuated thereafter.

A new definition of SBT statistical areas has been proposed by CCSBT. In this study, however, the analyses were temporarily based on the previous definition. The new statistical areas by CCSBT will be used for further study in the future. Owing to that Taiwanese SBT distribution is different from other fleet, a revised area stratification specifically for the standardization of Taiwanese SBT catch rate might be proposed at that time.

Based on the results of the CPUE standardization of SBT caught by Taiwanese longline fishery, the abundance of SBT was likely to be under a relatively stable status. However, SBT were mainly exploited by fisheries of Japan and Australia. Therefore, trends of CPUE of Japan and Australia should be referred to discuss the variation of SBT abundance. In addition, more analyses of stock assessment models were necessary to evaluate the status of SBT.

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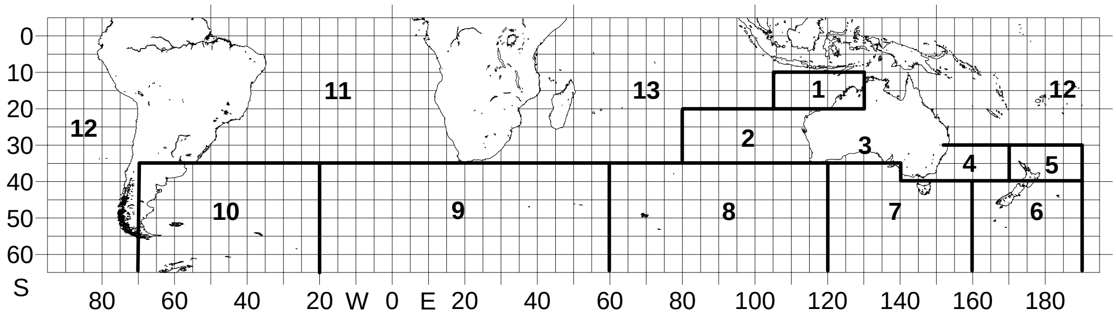


Fig. 1. Statistical area for southern bluefin tuna.

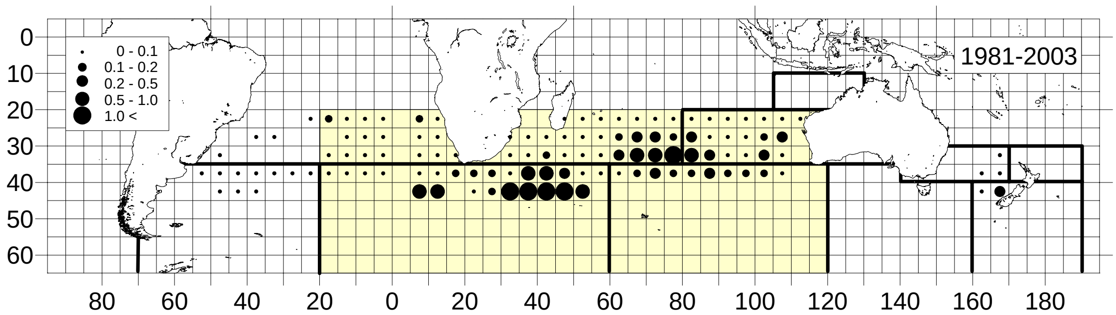


Fig. 2. CPUE distribution of southern bluefin tuna caught by Taiwanese longline fishery during 1982-2003.

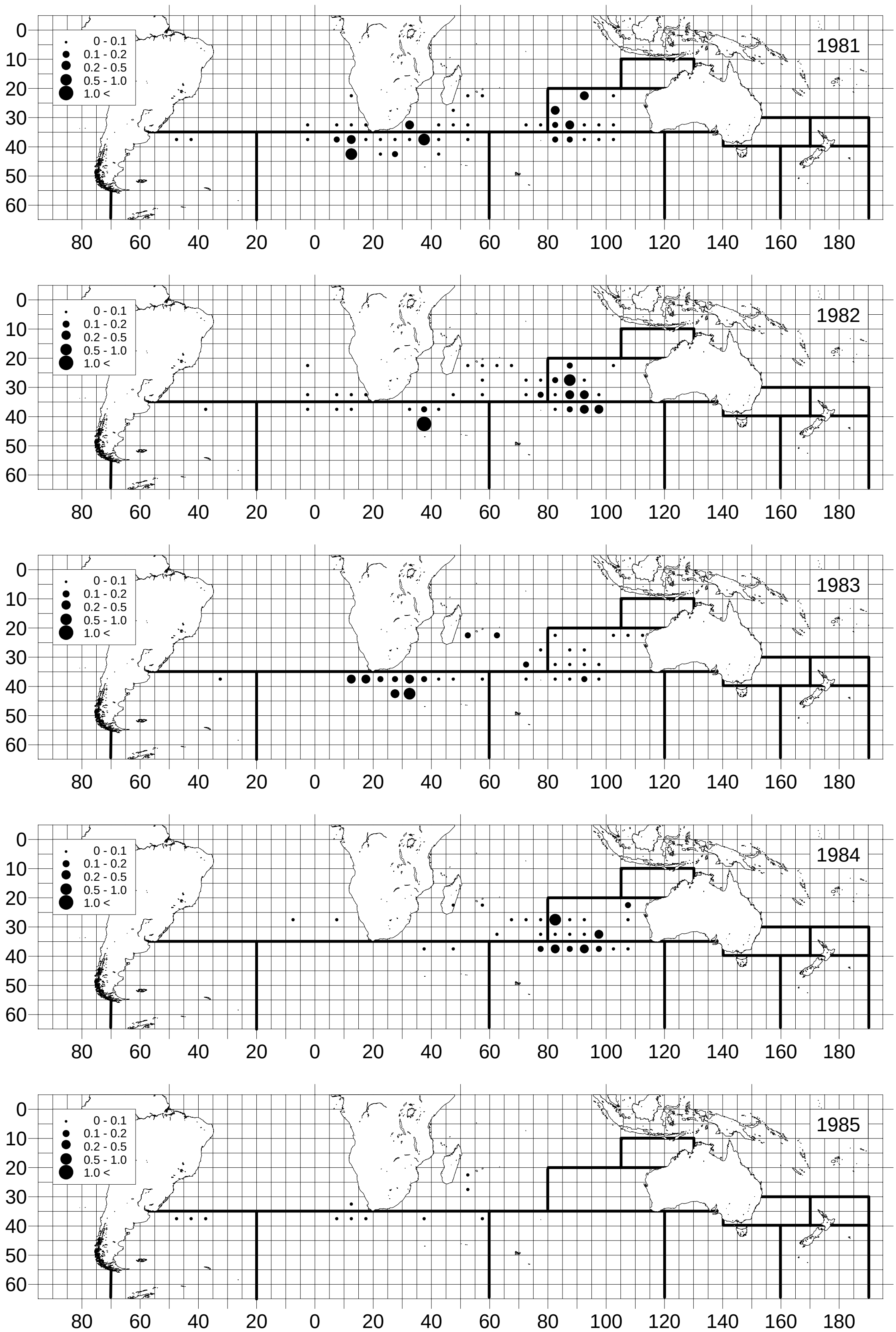


Fig. 3. Annual CPUE distribution of southern bluefin tuna caught by Taiwanese longline fishery.

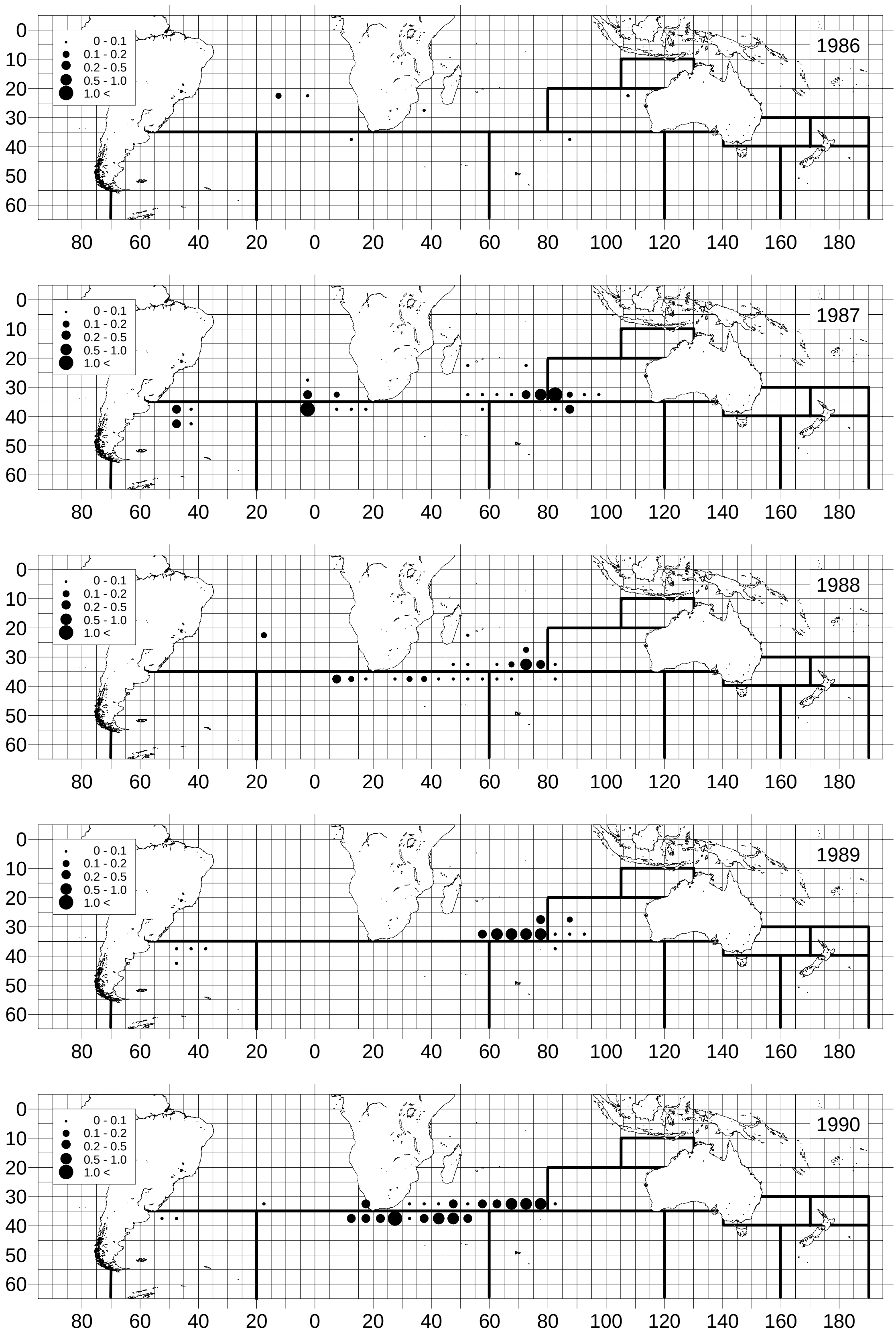


Fig. 3. (Continued).

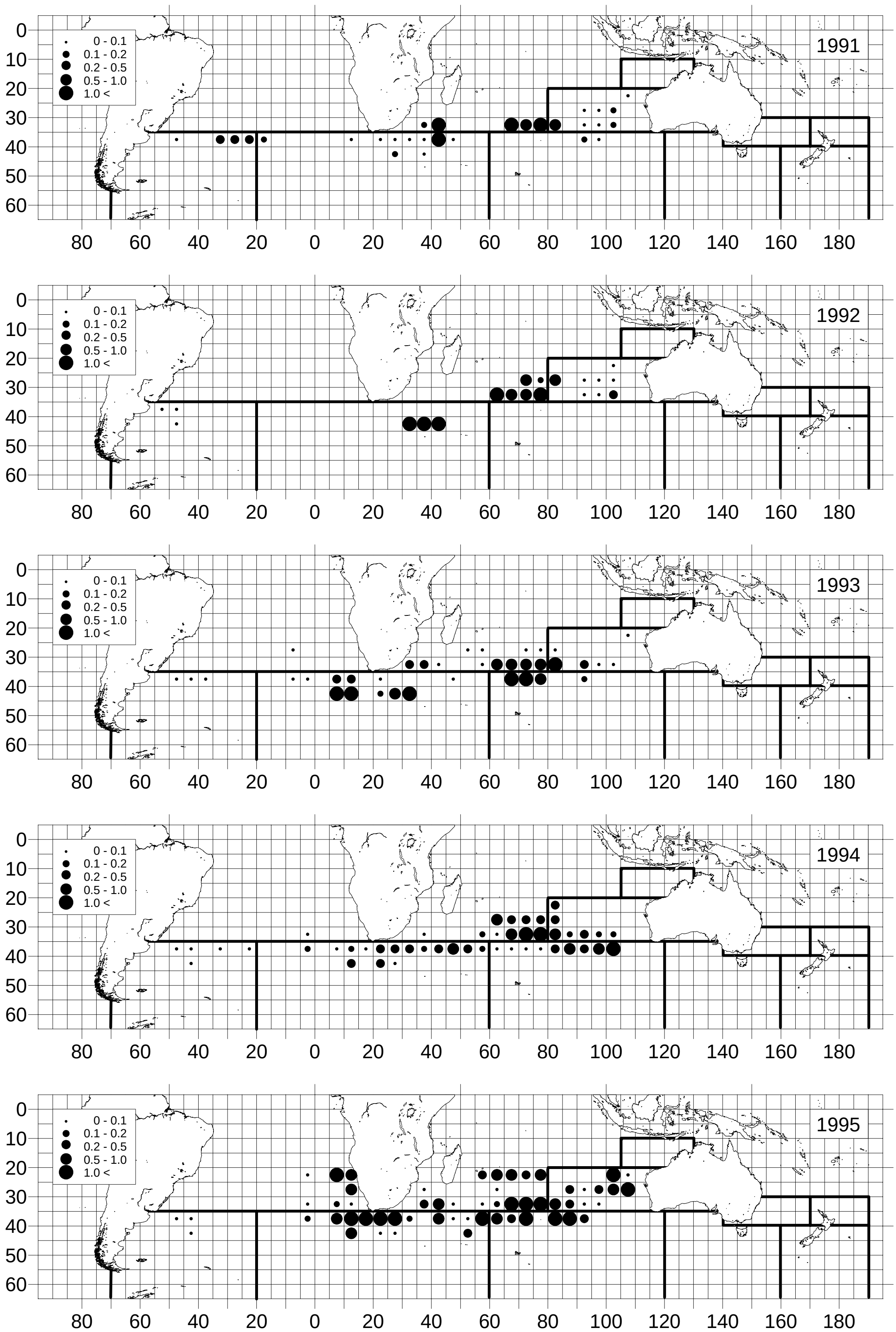
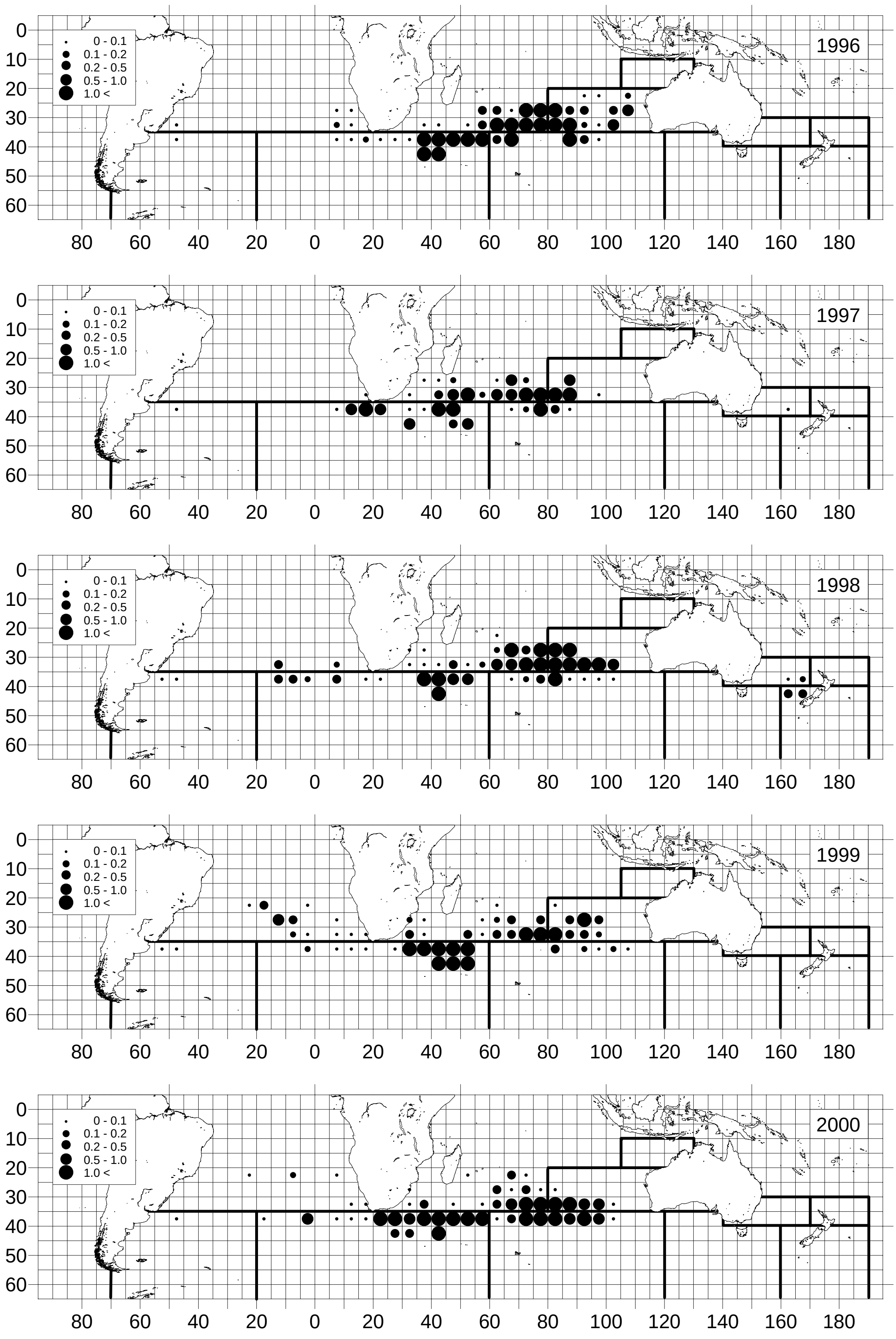


Fig. 3. (Continued).



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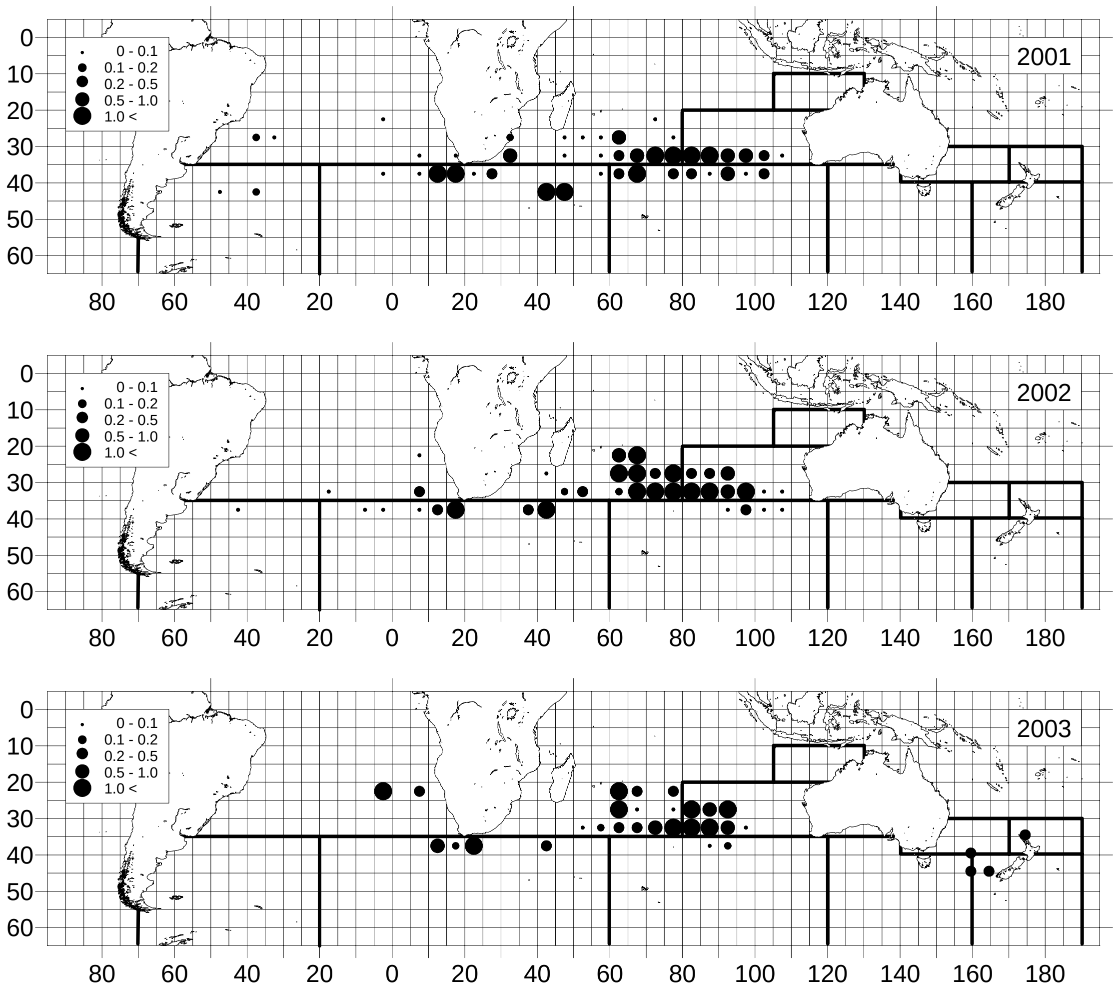

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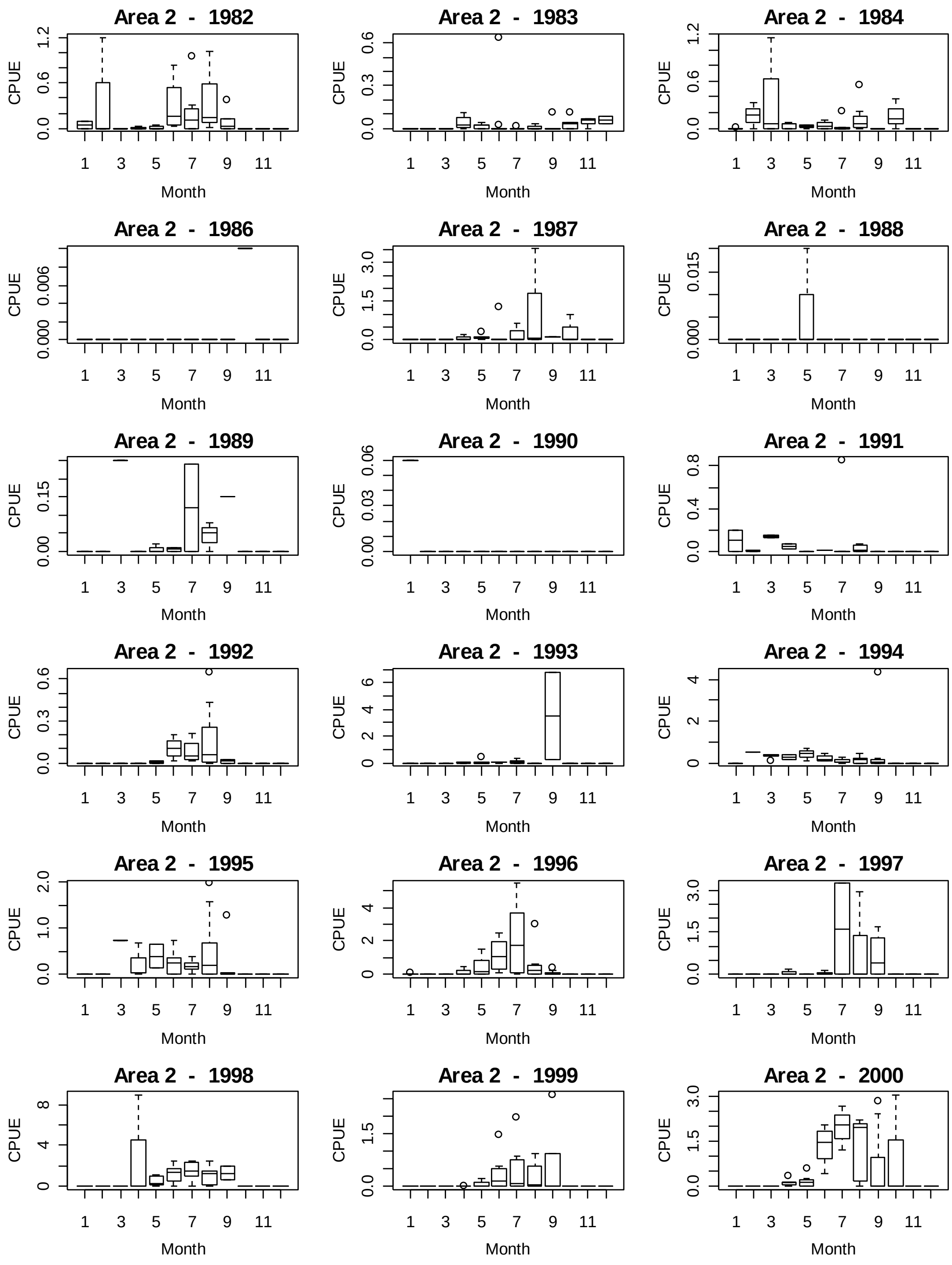
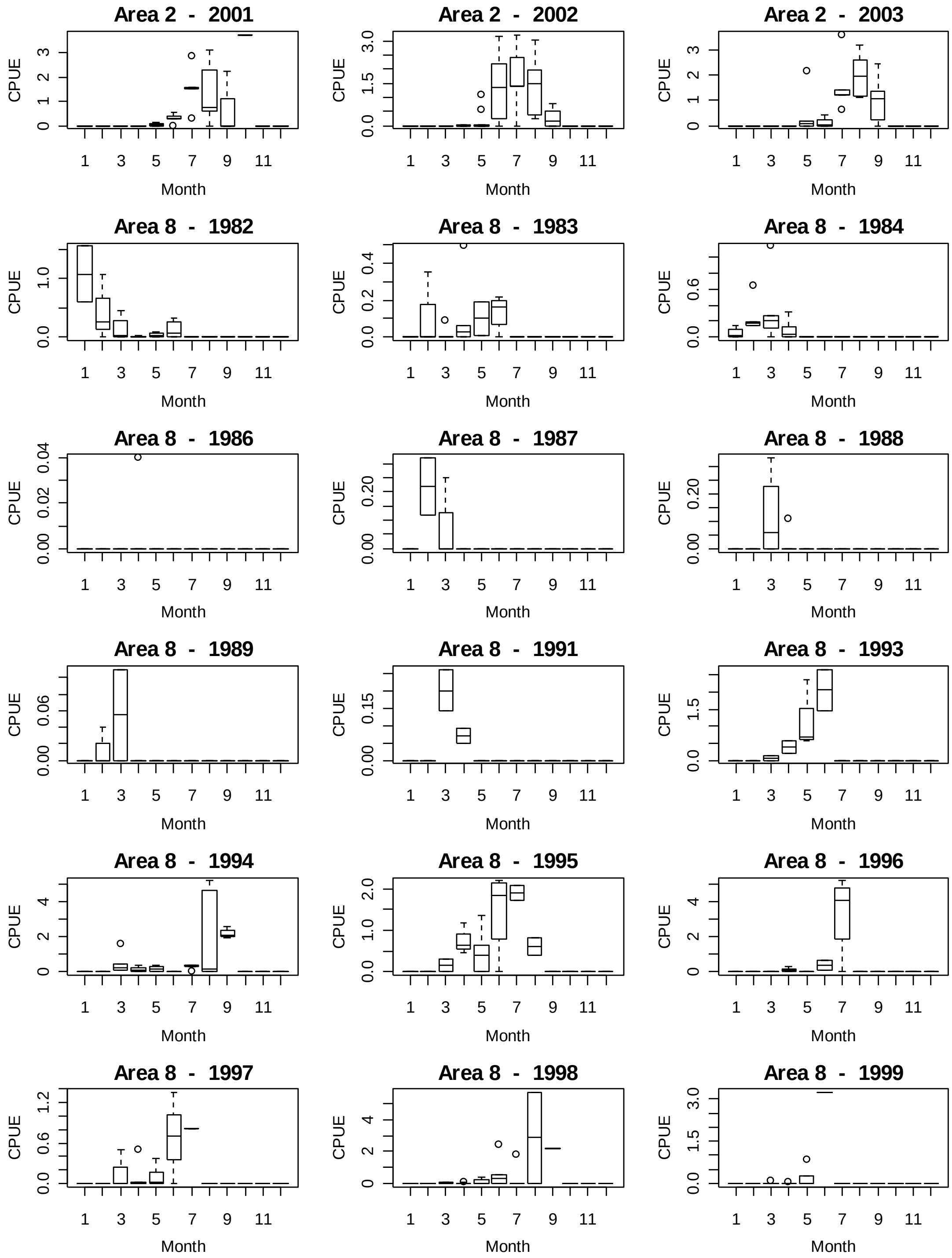


Fig. 4. Boxplot of monthly CPUE of southern bluefin tuna caught by Taiwanese lognline fishery for area 2, 8, 9, 11 and 13 during 1982-2003.



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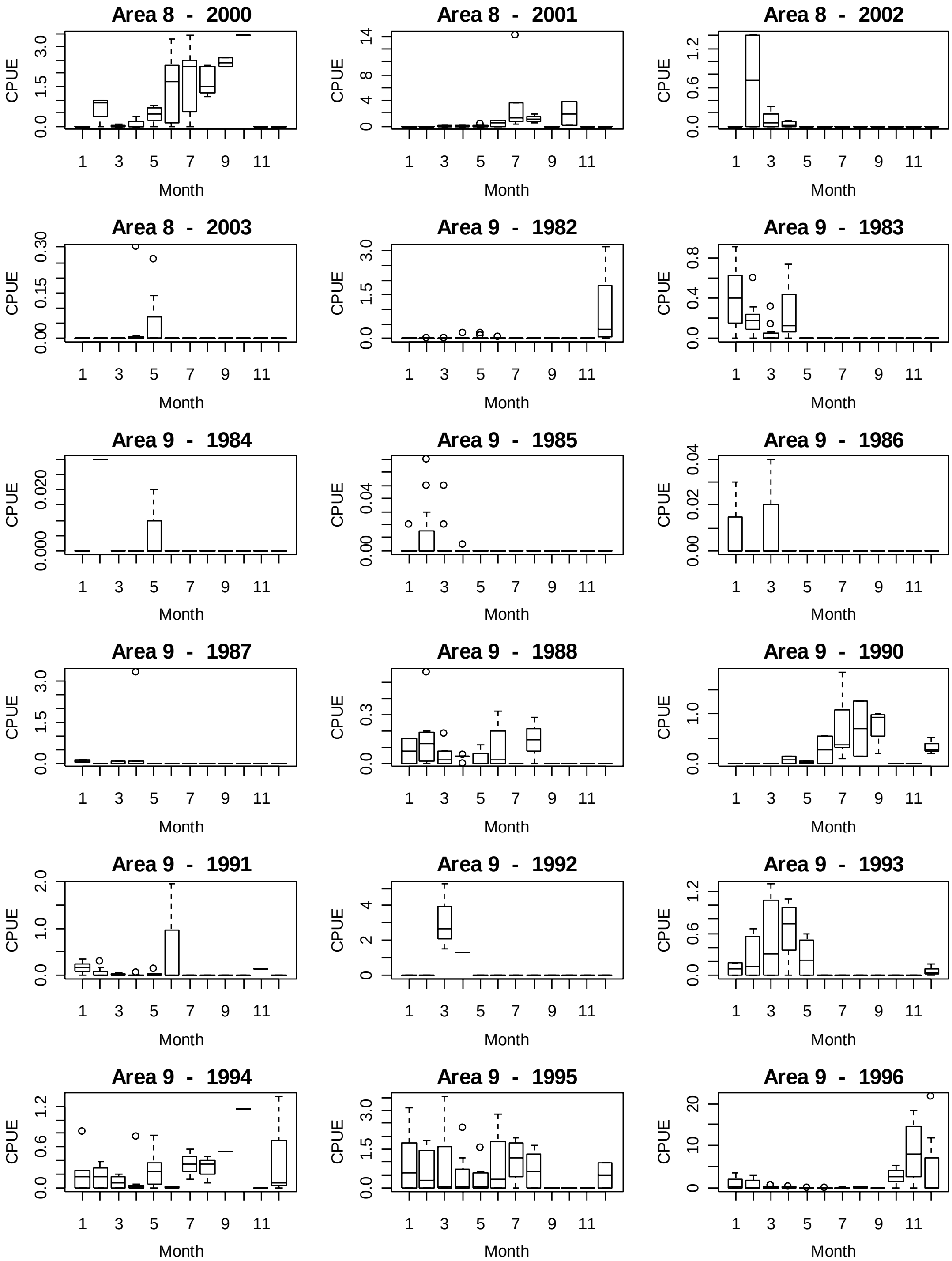

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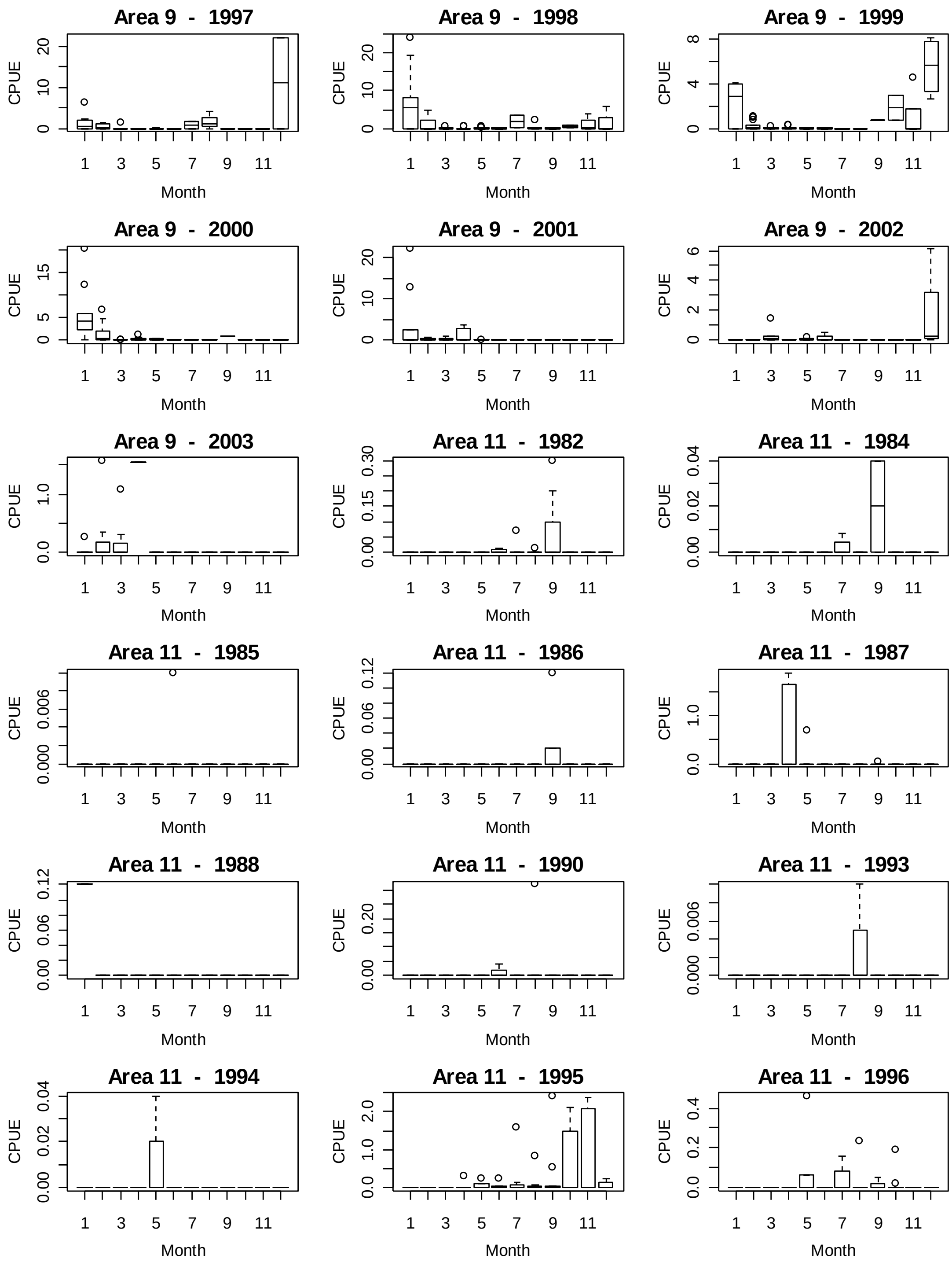

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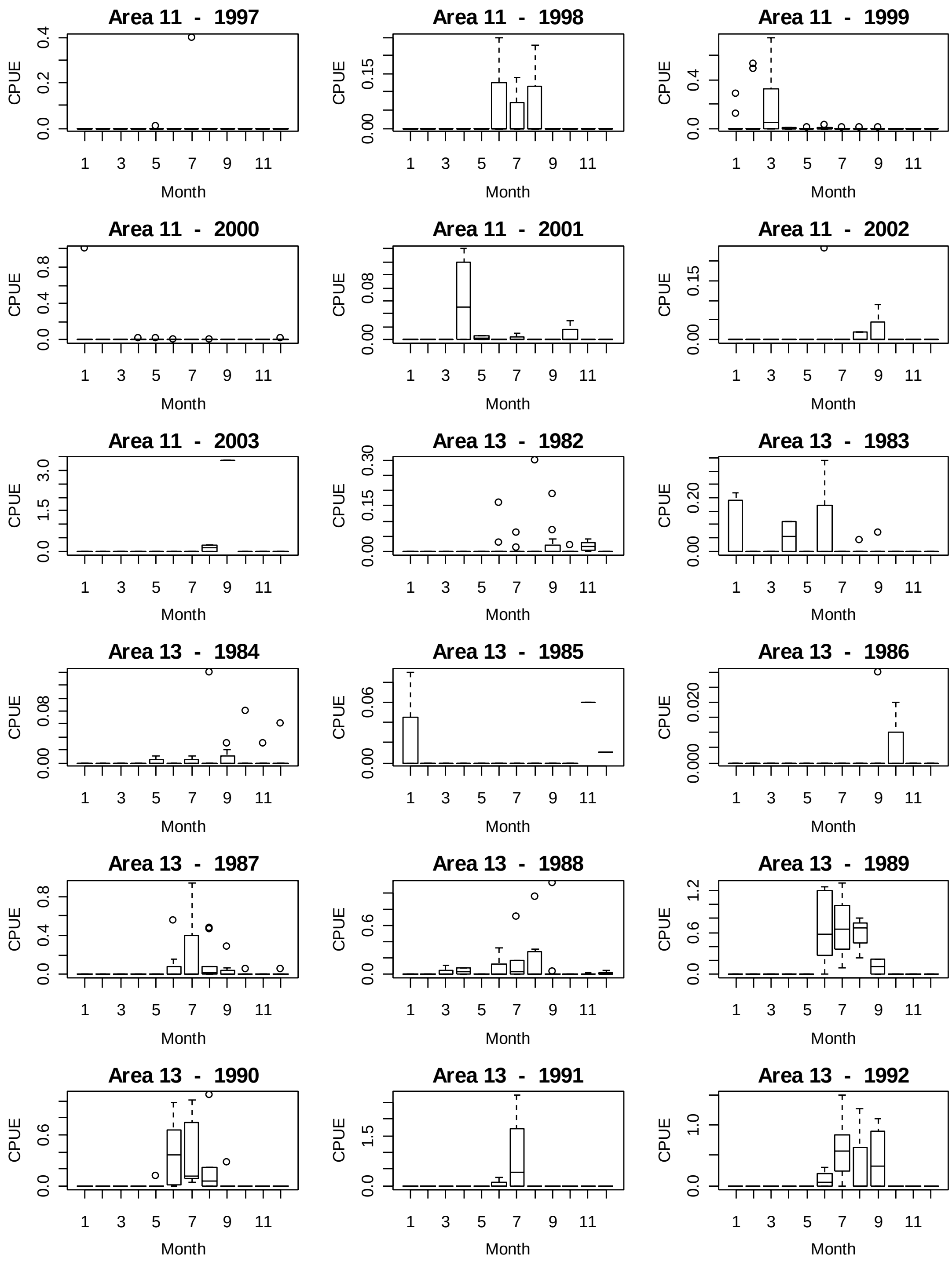

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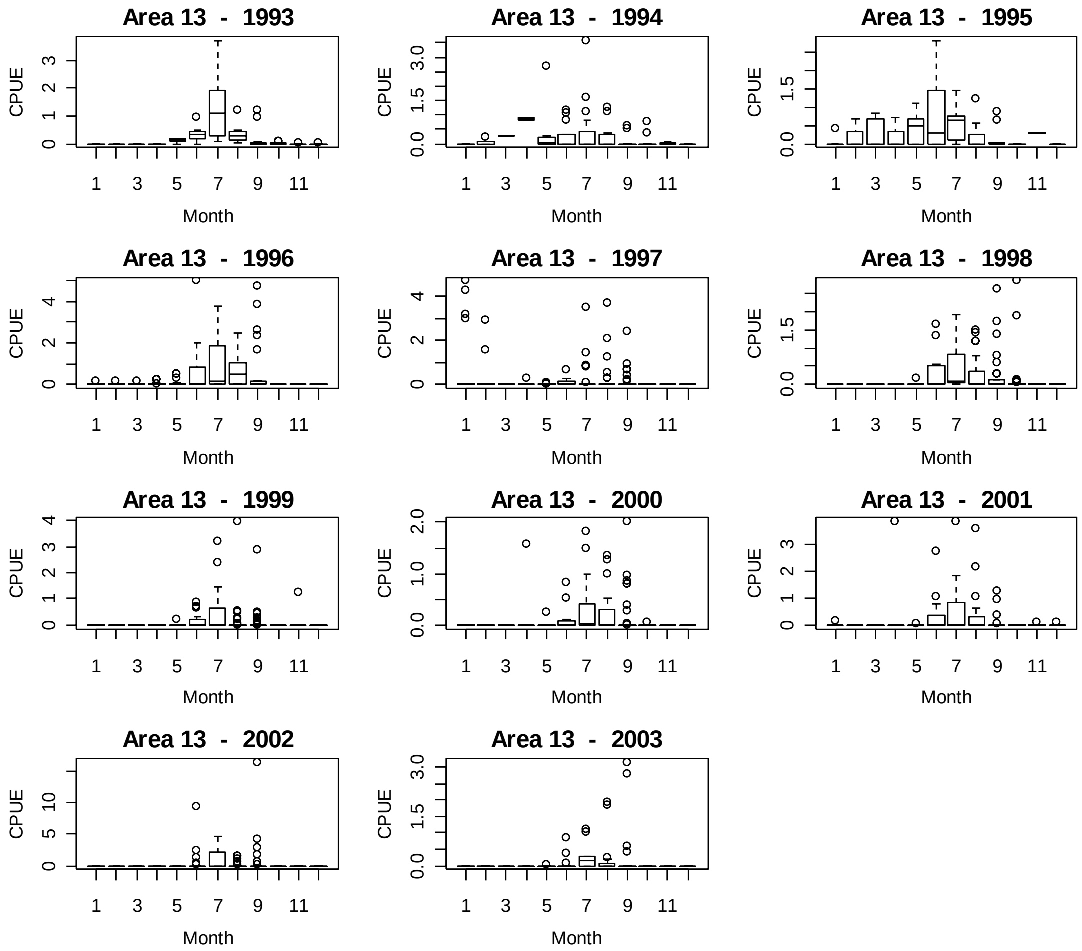

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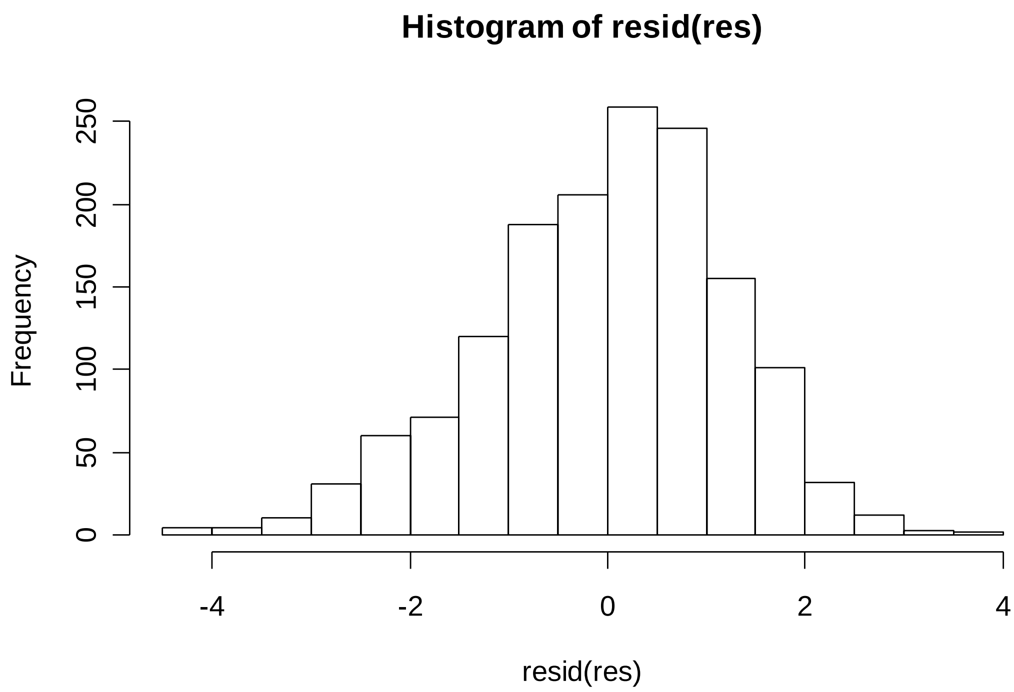

Fig. 5. The distribution for the standardized residuals for the delta-lognormal GLM model fitted to the CPUE of positive catch.

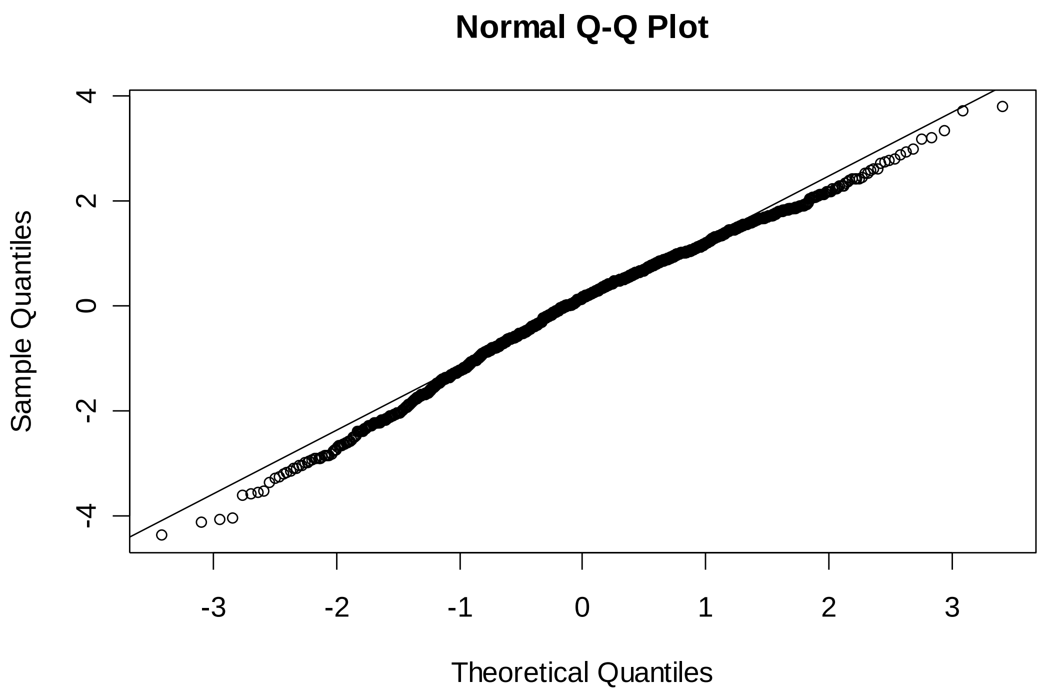

Fig. 6. The normal probability plots for the standardized residuals for the delta-lognormal GLM model fitted to the CPUE of positive catch.

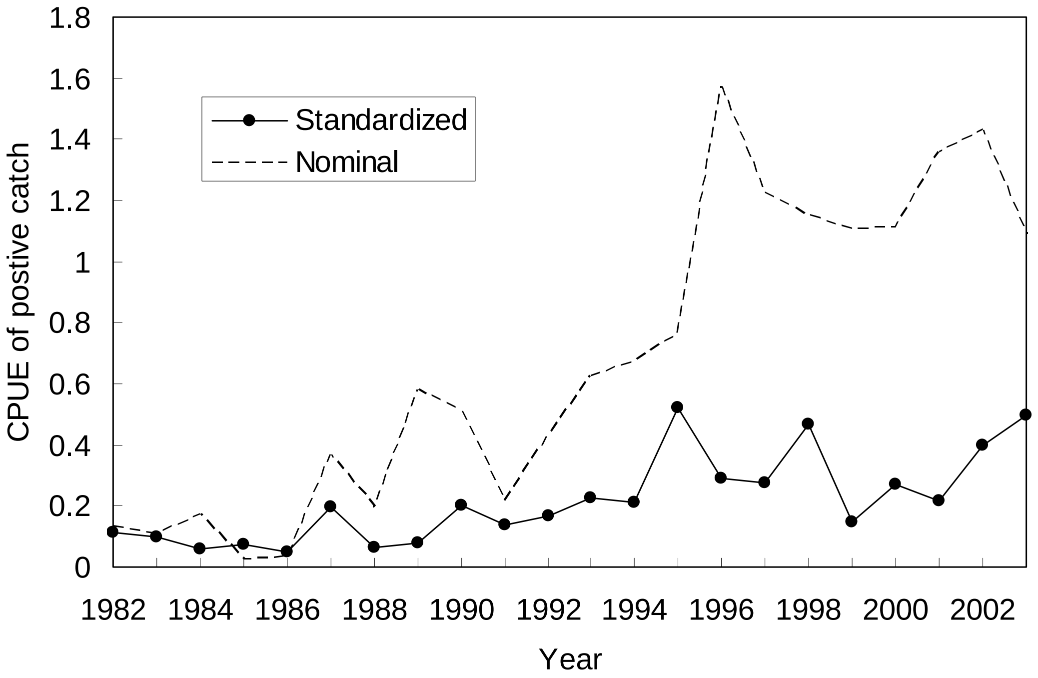

Fig. 7. Nominal and standardized CPUE of positive catch.

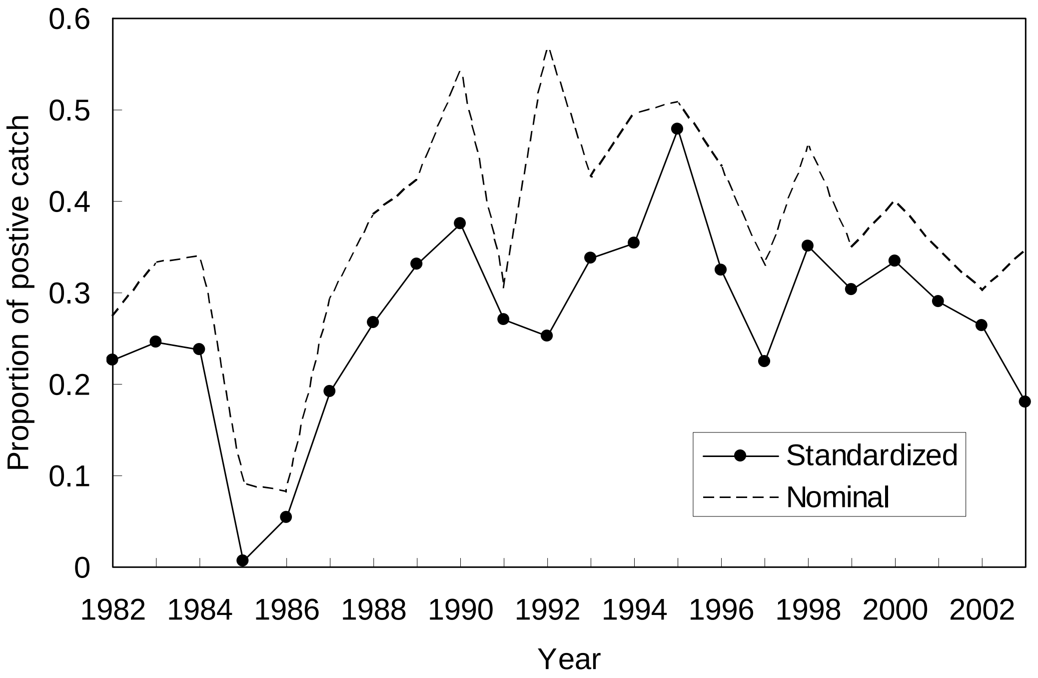

Fig. 8. Nominal and standardized proportion of positive catch.

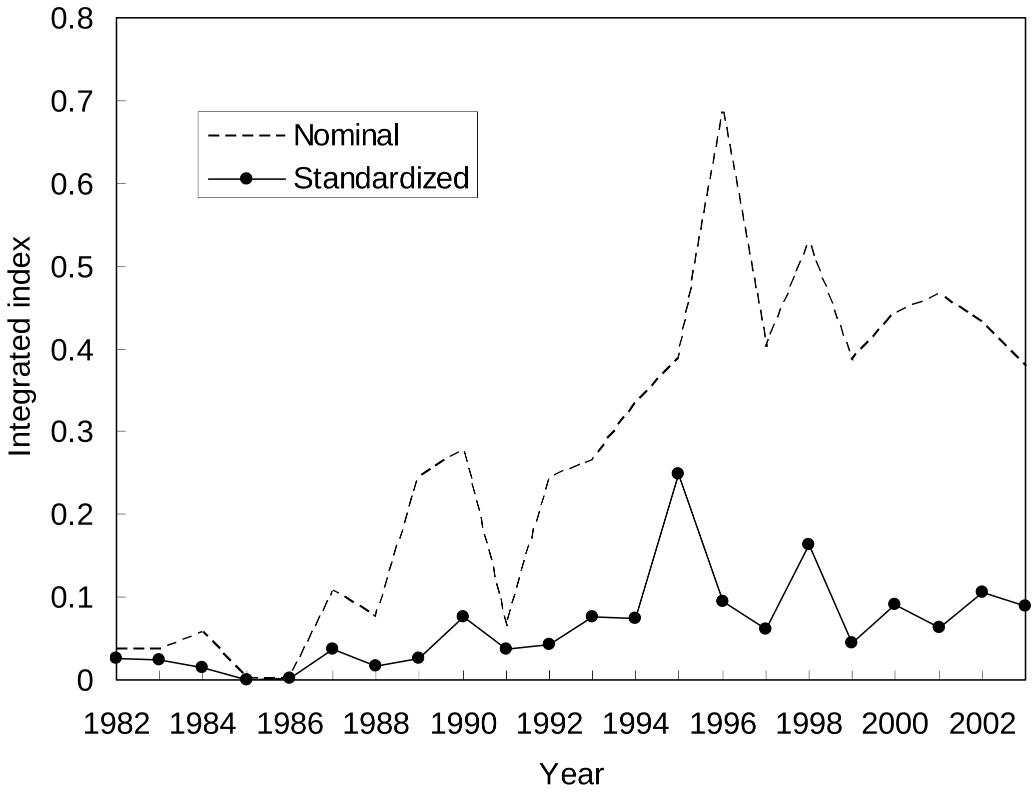

Fig. 9. Nominal and standardized CPUE estimated by integrating the CPUE of positive catch and the proportion of positive catch.

Table 1. Statistics related to the fit of the delta-lognormal GLM models for the CPUE of postive catch.

Model	Df	SS	MSE	F value	P value	R^2	AIC	Resid Dev	Resid Df
Null							5801.64	4158.12	1503
Y	21	2186.91	104.14	42.70	<0.0001	0.38	5633.01	3614.72	1482
Y+M	32	2545.79	79.56	35.94	<0.0001	0.44	5497.74	3255.85	1471
Y+M+A	36	2703.35	75.09	35.56	<0.0001	0.47	5431.14	3098.29	1467
Y+M+A+SST	37	2808.41	75.90	37.18	<0.0001	0.48	5381.26	2993.23	1466
Interaction									
Y+M+A+SST+Y*A+M*A	154	3438.63	22.33	53.37	<0.0001	0.59	5259.69	2363.01	1349
Y+M+A+SST+Y*A+M*SST	123	3309.56	26.91	61.31	<0.0001	0.57	5277.67	2492.08	1380
Y+M+A+SST+Y*A+A*SST	116	3312.33	28.55	65.22	<0.0001	0.57	5262.00	2489.31	1387
Y+M+A+SST+Y*A+M*A+M*SST	165	3509.96	21.27	52.32	<0.0001	0.60	5235.59	2291.68	1338
Y+M+A+SST+Y*A+M*A+A*SST	158	3472.76	21.98	53.26	<0.0001	0.60	5245.81	2328.88	1345
Y+M+A+SST+Y*A+M*A+M*SST+A*SST	169	3529.19	20.88	51.76	<0.0001	0.61	5230.91	2272.44	1334

Table 2. Statistics related to the fit of the delta-lognormal GLM models for the proportion of postive catch.

Model	Df	SS	MSE	F value	P value	R^2	AIC	Resid Dev	Resid Df
Null							5332.34	5330.34	4035
Y	21	192.58	9.17	7.16	<0.0001	0.04	5183.76	5139.76	4014
Y+M	32	319.85	10.00	7.98	<0.0001	0.06	5078.49	5012.49	4003
Y+M+A	36	611.86	17.00	14.40	<0.0001	0.11	4794.48	4720.48	3999
Y+M+A+SST	37	882.07	23.84	21.42	<0.0001	0.17	4526.27	4450.27	3998
Interaction									
Y+M+A+SST+Y*A+M*A	161	1212.95	7.53	9.46	<0.0001	0.23	4443.39	4119.39	3874
Y+M+A+SST+Y*A+M*SST	129	1105.45	8.57	10.55	<0.0001	0.21	4486.89	4226.89	3906
Y+M+A+SST+Y*A+A*SST	122	1218.36	9.99	12.65	<0.0001	0.23	4359.98	4113.98	3913
Y+M+A+SST+Y*A+A*SST+M*A	165	1303.96	7.90	10.14	<0.0001	0.24	4360.38	4028.38	3870
Y+M+A+SST+Y*A+A*SST+M*SST	133	1240.35	9.33	11.85	<0.0001	0.23	4359.98	4091.98	3902
Y+M+A+SST+Y*A+A*SST+M*SST+M*A	176	1340.51	7.62	9.84	<0.0001	0.25	4345.83	3991.83	3859