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Standardized CPUE of North Pacific Bluefin tuna caught by Japanese coastal longliners: updates until 2011

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Introduction

Pacific bluefin tuna (PBF) spawn off the southeastern coast of Japan in the western Pacific from late April to early June. The spawning fish has been fished by Japanese longliners for more than 50 years since 1950's. CPUE of PBF derived from logbook data of the longline fisheries have been used as one of the most important abundance indices in the stock assessment of PBF. CPUE from offshore and distant-water longliners since 1951 (Yokawa et al. 2007), and coastal longliners during 1994-2006 (Ichinokawa and Takeuchi 2007, Ichinokawa 2007) was used for the last stock assessment conducted in 2008. For the updated stock assessment in 2010, CPUE from the coastal longliners are updated until 2008 (Abe et al 2010).

This document updates standardized CPUE of PBF caught by Japanese coastal longliners from 1994 to 2011, to be used as an abundance index for the next stock assessment of PBF. Because data and methods for standardization of CPUE are basically same as previous studies (Ichinokawa and Takeuchi 2007, Ichinokawa 2007, Abe et al. 2010), this document mainly describes changes and updates from the previous studies.

Materials and Methods

Logbook data

The set-by-set data from Japanese coastal longline logbooks are used for standardizing CPUE. These logbook data contain, for each set of operation, information on latitude and longitude by 1x1 degree, day, month, year, catch in number of fish of each species, gear configurations, and so on. The logbook data of coastal longliners have been collected and complied by the National Research Institute of Far Seas Fisheries since 1994. Longline vessels with 10-20 GRT with permission to operate in the high seas had been defined as ‘coastal’ longline by vessel registration system until 2002, but the vessels are re-categorized into ‘offshore’ longline since then. However, in order to keep consistency of data, the longline vessels of 10-20 GRT are used and continuously called as ‘coastal’ longline in this document.

For standardizing CPUE, we use the data of longline operations during the spawning season of PBF, April to June, at fishing ground of PBF by Japanese longliners. The fishing area is defined as 1x1 degree blocks where at least one PBF per year have been caught in more than 9 years (Fig. 1). This definition is similar with the previous analysis, which used the area where PBF have been caught in more than 7 years (Ichinokawa and Takeuchi 2007).

Total number of operations, hooks and catch, and nominal CPUE north of 15°N and those used for standardization are shown in Table 1. This analysis includes the data from 1994 to 2011 in calendar year, which is corresponding to the period from 1993 to 2010 in fishing year. Note that the number of operations in the most recent year of 2011 is smaller than that of previous years. Total numbers of operations reported for this year in the area north of 15°N are 4934, of which 3404 data were used for standardization. The number of data is approximately 70% of recent 10 years average (2001-2010). This is because some data are still missing because of late submission of logbook from by fishers.

Standardization of CPUE

Explanatory variables used for standardizing CPUE are listed below.

- ✓ Year: 18 years from 1994 to 2011 in calendar year.
- ✓ Day10: Periods during the fishing season from April to June defined by 10 days interval (day10). This effect has 9 categories of early-April, mid-April, late-April, early-May, mid-May, late-May, early-June, mid-June and late-June. This explanatory variable takes over the effect of 'month' used in the previous analysis. This is because spatiotemporal CPUE distribution has changed drastically even within a same month, especially in April and June (Fig. 2).
- ✓ Area: 2 regions are defined, northwest and southwest area of the defined fishing ground (Fig. 1)
- ✓ Sets: shallow sets (<16 hooks per basket) vs deep sets (>=16 hooks per basket)
- ✓ Ship-type: defined by the number of days of a cruise and GRT class of vessels. 'Large-Long' indicates vessels of 17 GRT or more and a cruise lasts 21 days or more; 'Large-Short' for vessels of 17 GRT or more and a cruise lasts less than 21 days; , and 'Small-Short' for vessels smaller than 17 GRT and a cruise lasts less than 21 days.
- ✓ Ship name as random effects: Random effect of ship name is included only in the binomial model of 1st step. The effect slightly improved over-dispersion in the binomial model from 1.39 without the random effect of ship name to 1.22 with the effect.

Although most of variables are the same as used in the previous analysis, a variable of 'month' is replaced with 'day10'. In addition, the effect of 'target', defined as the ship that have caught bigeye tuna 4 times or more in number than PBF to be non-targeting, or otherwise to be 'targeting' PBF (details are in Ichinokawa and Takeuchi 2007), has been removed. This is because the effect of 'target' is minor compared with other effects in this analysis.

Delta-type two-step method (Lo et al. 1992) is used for standardizing CPUE of PBF as used in the previous studies. In the delta method, the proportions of zero catch sets (or non-zero catch sets) to the total number of sets are estimated with binomial generalized linear model with logit link function at the 1st step. At the 2nd step of the delta model, log (CPUE) is estimated using lognormal model, only for the sets with positive catch of PBF.

The formulation of the 1st step model is following:

$$\text{Logit}(p) = \text{intercept} + \text{main effects} + \text{interaction effects} + \text{error term (1st step)},$$

where the function named "Logit" means logit function of log (p/(1-p)), and p is the proportion of non-zero catch. This calculation is conducted by GLIMMIX procedure by SAS 9.2, where Laplace method is used for calculating marginal likelihood. The second step is assuming lognormal distribution as error term, to explain log CPUE for the data excluding zero-catch sets.

$$\log(\text{CPUE}) = \text{intercept} + \text{main effects} + \text{interaction effects} + \text{error term (2nd step)},$$

where CPUE is the catch in number of fish of PBF per 1000 hooks among the non-zero catch sets. This calculation is conducted by GLM procedure by SAS 9.2. Standardized CPUE as an abundance index of this fishery is calculated by the product of estimated values of least squared means derived from the two models: non-zero catch ratios × CPUE of positive catch. Confidence intervals of the estimated CPUE are calculated according to Shono (2008).

Explanatory variables incorporated into the 2 models are selected by model-selection with BIC. At the binomial model of 1st step, the model selection is conducted manually by sequentially adding the effect that most improves the fit (BIC) from simplest model only including the effect of year. As for the lognormal model of 2nd step, stepwise method was used by GLMSELECT procedure of SAS 9.2, starting with null model only with intercept.

Sometimes standardized CPUE is sensible to CPUE standardization procedure and the way to extract the data. This analysis arbitrarily determine threshold of number of years (>9 years) to define fishing ground where data are extracted. Sensitivity analysis is conducted with alternative threshold of number of years as run1 (>7 years), run2 (>12 years) and run3 (>5 years) (Table 2).

Results and discussion

Spatiotemporal distribution of nominal CPUE of PBF (Fig. 3) and number of longline operations (Fig. 4) are shown. The fishing ground of PBF was located around main Okinawa Island before 1998. Then, the fishing ground has extended to Yaeyama Islands (southwest to Okinawa main island), and also to Kuroshio extension area. However, while the fishing area has extended, zero catch area (no PBF catch regardless efforts exist) has increased in recent years, as decreasing nominal CPUE. Fig. 5 shows average weight frequency distribution of PBF caught by coastal longliners during 1994 to 2011.

Explanatory variables selected by BIC have changed from the previous analysis (Table 3). In the previous analysis, variables selected by BIC were month*year, target*gear, gear*year, month*area, area*target, area*shiptype and shiptype*year in the binomial model, and month, area, shiptype, target*gear and gear*year in the lognormal model (Ichinokawa 2007). On the other hand, BIC selected variables of year*day10, area*shiptype, day10*area, year*area, gear*shiptype and area*gear, and year, day10*gear and area*shiptype in the lonormal model in this analysis. This is because the effect of ‘day10 (10 days interval)’, taking over the effect of ‘month’, explained larger amount of residuals than the effect of ‘month’ (Table 4) to make contribution of other explanatory variables relatively minor. Consequently, it improvs model fits. Dispersion-scale parameter calculated in the binomial model of 1st step is 1.22 (Table 4), which is smaller than 1.50 in the previous analysis (Ichinokawa 2007). R squared value in the lognormal model of 2nd step is also slightly improved from 0.116 to 0.124. Distribution of residuals are still slightly skewed negatively, both in 1st and 2nd steps (Fig. 6). Least squares mean of the effect of day10*year is shown by Fig. 7

The CPUE shown in Fig. 8c is the standardized CPUE as an abundance index of this fishery, which is generated by multiplying standardized positive catch ratio (Fig. 8a) and standardized CPUE when positive catch occurs (Fig. 8b). The relative trends of standardized CPUE during 1994-2008 are similar with the previous estimation by Abe et al. (2010), although the absolute values are different because of difference in explanatory variables used. The newly added CPUEs of 2009, 2010 and 2011 show constant decline. The CPUE of 2011 (normalized by its average) is 0.15, which is 10% of the highest CPUE observed in 1994 (1.5) and 15% of average CPUE during 1994-2010 (Table 5). This trend has changed only slightly when different data sets are used (run 1-3) (Fig. 9).

Summary

This document updated standardized CPUE of PBF derived from Japanese coastal longliners during 1994-2011, by adding data of 2009-2011. Data and methods used for standardization of CPUE are basically same as those used in the previous study (Abe et al. 2010), although fishing area definition and explanatory variables used for the standardization have slightly changed. The estimated CPUE during 1994-2008 is similar with estimation by the previous study, and newly added CPUE of 2009-2011 show constant declines until 2011. Consequently, the estimated CPUE in Japanese longline fishery tends to decline from the highest value of 1.5 in 1994 to the lowest of 0.15 in 2011, fluctuating annually with 2 local maximum at 1997, 2005 and 2007. While sensitivity analysis shows robust annual trends of CPUE to the changes of the way to select the data used for standardization, skewed distribution of residuals indicates that the model for standardizing CPUE could be improved further more to some extent in future study.

References

Abe M, Oshima K, Kai M, Ichinokawa M, Hsu C-C, Aires-da-Silva A, Yamazaki I, Takeuchi Y (2010) The update of input data of stock assessment of Pacific Bluefin Tuna for Stock Synthesis III. ISC/10-1/PBFWG/09.

Ichinokawa M (2007) An update of standardized CPUE for North Pacific bluefin tuna caught by Japanese coastal longliners. ISC/07/PBF-WG-3/18.

Ichinokawa M, Takeuchi Y (2007) Standardized CPUE of North Pacific bluefin tuna caught by Japanese coastal longliners. ISC/07/PBF-WG-1/16.

Lo NCH, Jacobson LD, Squire JL (1992) Indexes of Relative Abundance from Fish Spotter Data Based on Delta-Lognormal Models. Can J Fish Aquat Sci 49:2515-2526

Shono H (2008) Confidence interval estimation of CPUE year trend in delta-type two-step model. Fish Sci 74:712-717

Yokawa K, Ichinokawa M, Oshima K (2007) Estimation of the abudance indices of Pacific bluefin tuna using data of Japanese offshore and distant-water longliners. ISC/07/PBF-WG-3/25.

Table 1. Total number of operations, hooks and PBF catch, and nominal CPUE, recorded in coastal longline logbook north of 15°N and the data set used for standardization of CPUE. (*1) The fishing year is defined to start from July and end to June.

Calendar year	Fishing year (*1)	All data (north to 15°N)				Data used for standardization of CPUE			
		N of operations	N of hooks (x1000 hooks)	N of PBF catch	Nominal CPUE	N of operations	N of hooks (x1000 hooks)	N of PBF catch	Nominal CPUE
1994	1993	3408	5410	2804	0.518	3175	5051	2771	0.549
1995	1994	2947	4771	1593	0.334	2634	4272	1527	0.357
1996	1995	3270	5357	2462	0.460	2910	4740	2383	0.503
1997	1996	3492	5759	2486	0.432	3025	4958	2312	0.466
1998	1997	3970	6583	2893	0.439	3499	5750	2772	0.482
1999	1998	6343	10388	3995	0.385	5571	9076	3769	0.415
2000	1999	6210	10523	2440	0.232	4935	8193	2230	0.272
2001	2000	6701	11639	1898	0.163	5490	9362	1837	0.196
2002	2001	6659	11496	2229	0.194	5113	8600	2008	0.233
2003	2002	6879	12099	3002	0.248	4318	7259	2449	0.337
2004	2003	6648	11742	3762	0.320	5097	8760	3296	0.376
2005	2004	6868	12324	4254	0.345	4837	8293	3660	0.441
2006	2005	7088	12601	2311	0.183	4636	7714	1851	0.240
2007	2006	6568	11734	3489	0.297	4602	7790	3103	0.398
2008	2007	6418	11735	1855	0.158	4445	7804	1432	0.183
2009	2008	6922	12656	1469	0.116	4638	8026	1214	0.151
2010	2009	7140	12919	765	0.059	4713	7978	719	0.090
2011	2010	4934	9356	594	0.063	3404	6126	437	0.071

Table 2. Configurations of alternative data sets used for sensitivity analysis

Run	Threshold year	Total N of operations used	Total PBF catch in number
Base	9 years	77042	39770
Run1_7_year	7 years	81426	40965
Run2_12_year	12 years	69847	37226
Run3_5_year	5 years	87949	42250

Table 3. Results of model selection with BIC.

(1) Binomial model (1st step)

Added explanately variables	BIC	
(1) year	46222.20	
(2) +year*day10	42529.00	
(3) +area*ship type	42243.17	
(4) +day10*area	42139.91	
(5) +year*area	42049.38	
(6) +gear*shiptype	42040.38	
(7) +area*gear	42036.08	Final model

(2) Lognormal model (2nd step)

Added explanately variables	BIC	
(1) Intercept	-29614.48	
(2) +day10*gear	-31318.98	
(3) +year	-32024.96	
(4) +area*shiptype	-32431.38	Final model

Table 4. Results of type 3 analysis of the explanatory variables. The table shows the hypothesis tests for each of the variables in the model individually.

(1) Binomial model (1st step)

Effects	Num DF	Den DF	Chi squared value	F value	Pr>Chi	Pr>F
year*day10	136	15506	1135.85	8.35	<.0001	<.0001
area*shiptype	2	15506	9.83	4.91	0.0073	0.0074
area*day10	8	15506	178.68	22.33	<.0001	<.0001
year*area	17	15506	183.7	10.81	<.0001	<.0001
shiptype*gear	2	15506	26.2	13.1	<.0001	<.0001
area*gear	1	15506	10.36	10.36	0.0013	0.0013

Variance parameter of shipname with SD in parenthes 0.392 (0.04)

Extra-dispersion scale 1.22

(2) Lognormal model (2nd step)

Effects	Num DF	Type III SS	Mean Square	F value	Pr > F
Model	39	878.7	22.5	87.91	<.0001
Error	24048	6163.2	0.3		
Corrected Total	24087	7041.8			

R squared value 0.125

Effects	Num DF	Type III SS	Mean Square	F value	Pr > F
year	17	261.69	15.39	60.06	<.0001
day10*gear	17	342.05	20.12	78.51	<.0001
area*shiptype	5	118.01	23.60	92.09	<.0001

Table 5. Nominal and standardized CPUE of Japanese coastal longliners from April to July, comparing with estimation by Abe et al. (2010). Normalized CPUE is calculated by dividing CPUE by each average.

Clendar year	Fishing year	This document					Abe et al. (2010)		
		Nominal	Nominal (normalized)	Standardized	Standardized (normalized)	CV	Standardized	Standardized (normalized)	CV
1994	1993	0.549	1.510	0.301	1.769	0.021	0.353	1.544	0.017
1995	1994	0.357	0.984	0.218	1.280	0.017	0.252	1.102	0.017
1996	1995	0.503	1.384	0.271	1.596	0.019	0.323	1.411	0.017
1997	1996	0.466	1.283	0.281	1.654	0.018	0.310	1.354	0.017
1998	1997	0.482	1.326	0.248	1.460	0.017	0.303	1.324	0.017
1999	1998	0.415	1.143	0.177	1.041	0.013	0.218	0.953	0.013
2000	1999	0.272	0.749	0.135	0.797	0.012	0.164	0.715	0.012
2001	2000	0.196	0.540	0.106	0.621	0.011	0.129	0.564	0.010
2002	2001	0.233	0.642	0.121	0.711	0.011	0.144	0.629	0.011
2003	2002	0.337	0.928	0.201	1.182	0.013	0.224	0.977	0.013
2004	2003	0.376	1.035	0.216	1.272	0.011	0.244	1.067	0.012
2005	2004	0.441	1.214	0.256	1.508	0.013	0.294	1.282	0.013
2006	2005	0.240	0.660	0.126	0.741	0.012	0.151	0.660	0.012
2007	2006	0.398	1.096	0.180	1.056	0.012	0.204	0.889	0.013
2008	2007	0.183	0.505	0.098	0.578	0.011	0.121	0.527	0.011
2009	2008	0.151	0.416	0.063	0.370	0.013	-	-	-
2010	2009	0.090	0.248	0.033	0.194	0.013	-	-	-
2011	2010	0.071	0.196	0.029	0.172	0.018	-	-	-

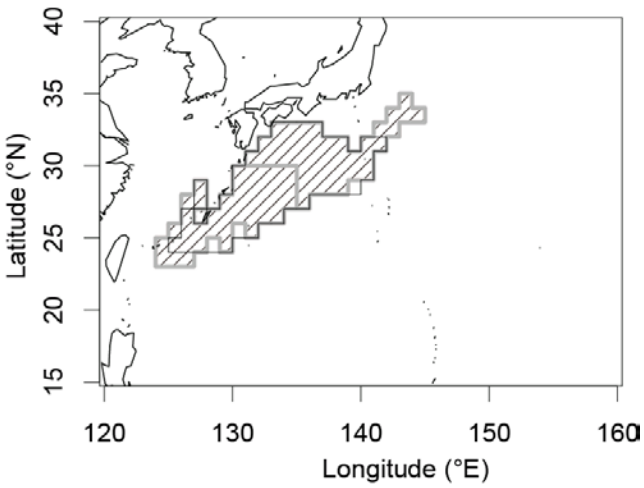


Fig.1. The fishing area selected for standardization of CPUE derived from Japanese coastal longline logbook, shown by hatched area surrounded by gray line. The fishing area is defined as 1x1 degree blocks where at least one PBF per year have been caught in more than 9 years. The area surrounded by black line represents the fishing area used in the previous studies (Abe et al. 2010).

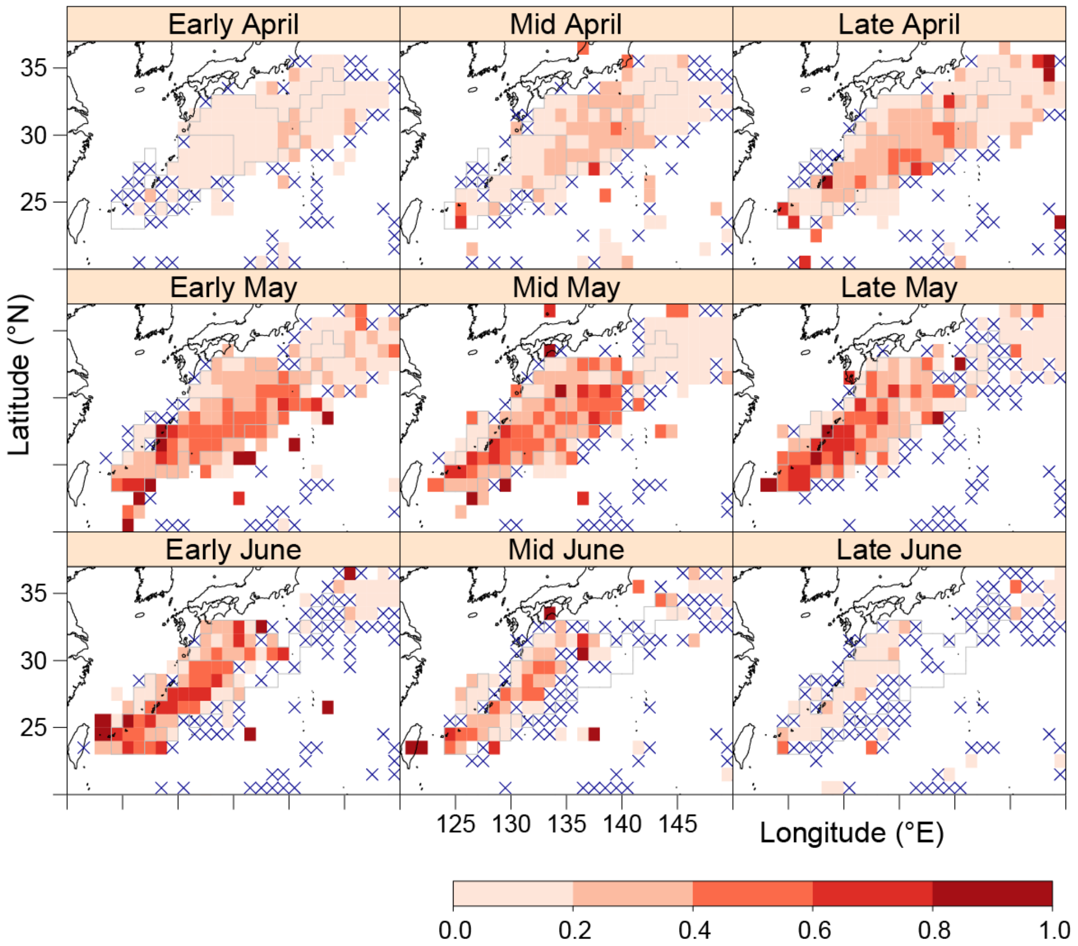


Fig.2. Nominal CPUE distribution of PBF (individuals/1000 hooks) in Japanese coastal longliners from April to July. The CPUE is averaged during 1994-2011.

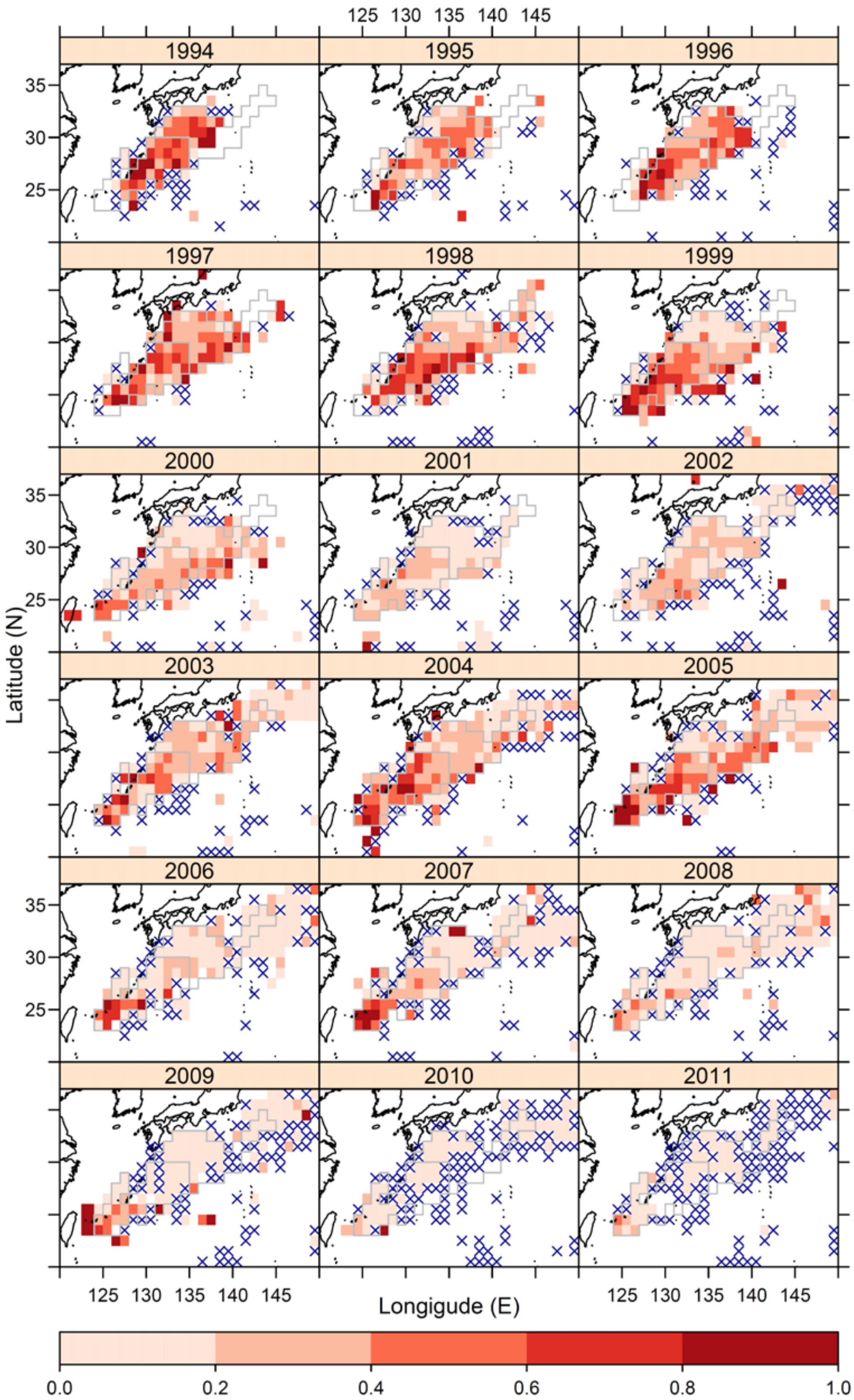


Fig. 3. Nominal CPUE of PBF (individuals/1000 hooks) from April to June by year. The area surrounded by gray lines is where data is used for standardization of CPUE. Blue crosses show zero catch regardless efforts exist.

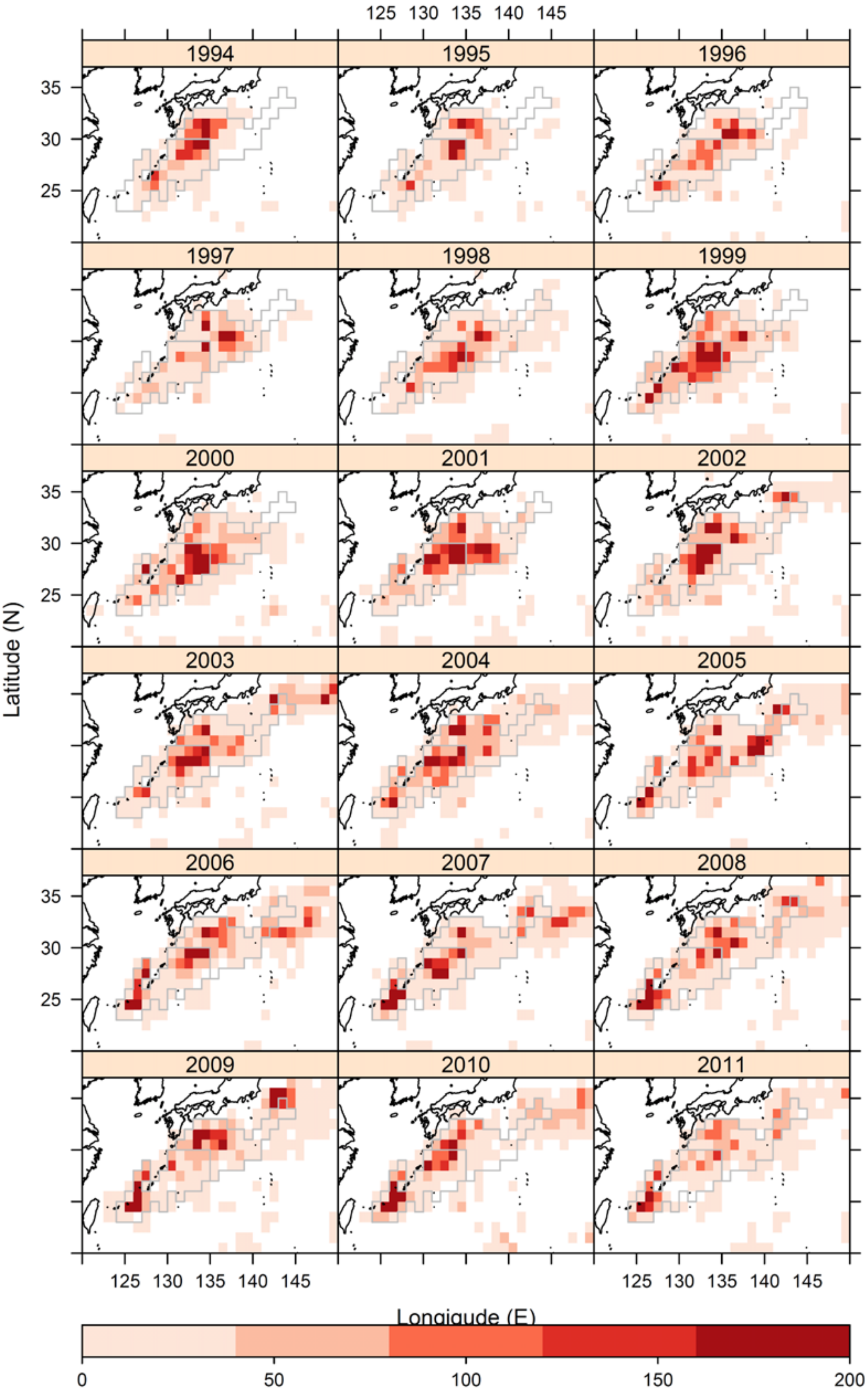


Fig. 4. Spatiotemporal distribution of number of longline operations by year from April to June. The area surrounded by gray lines is where data is used for standardization.

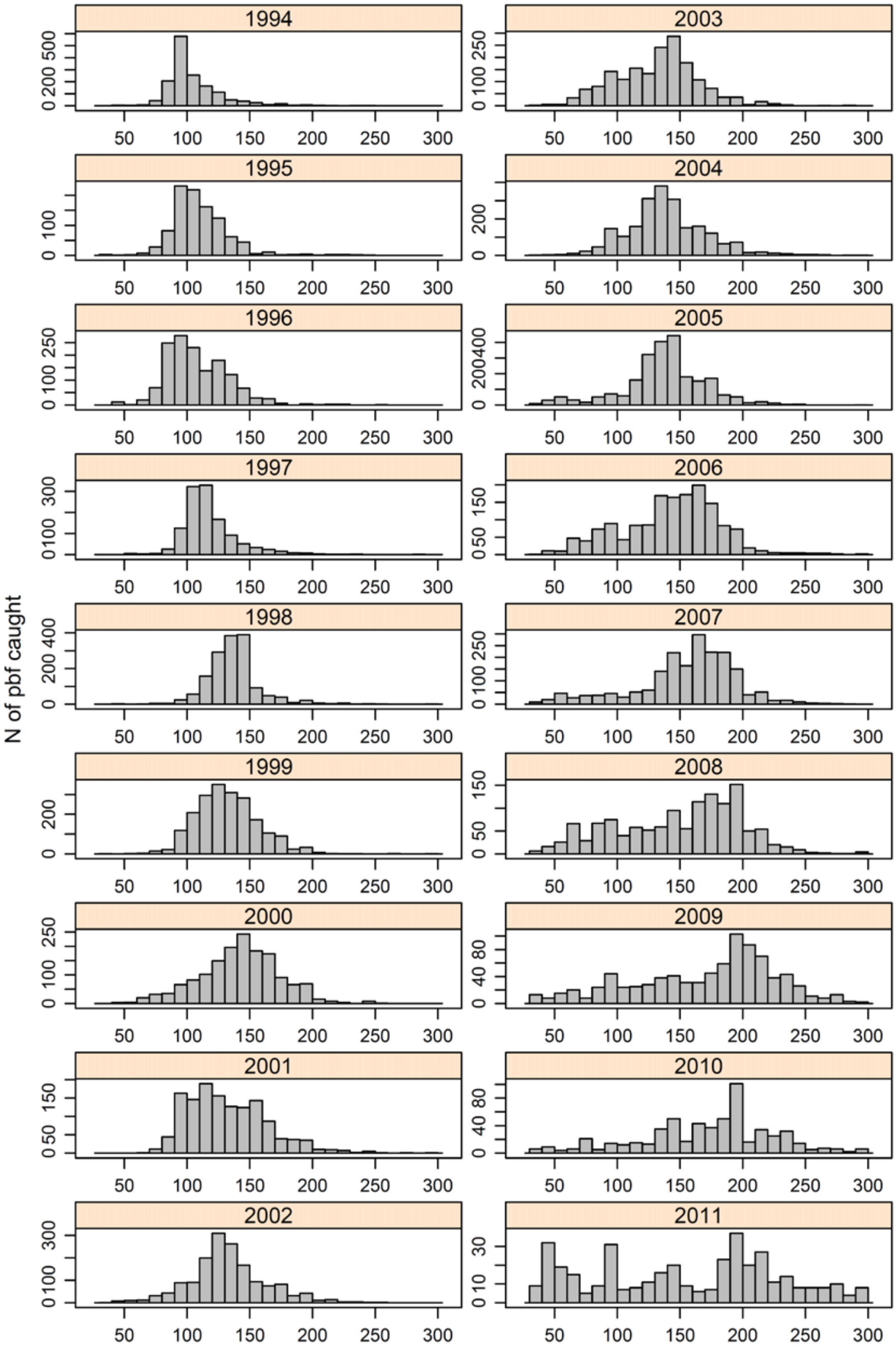
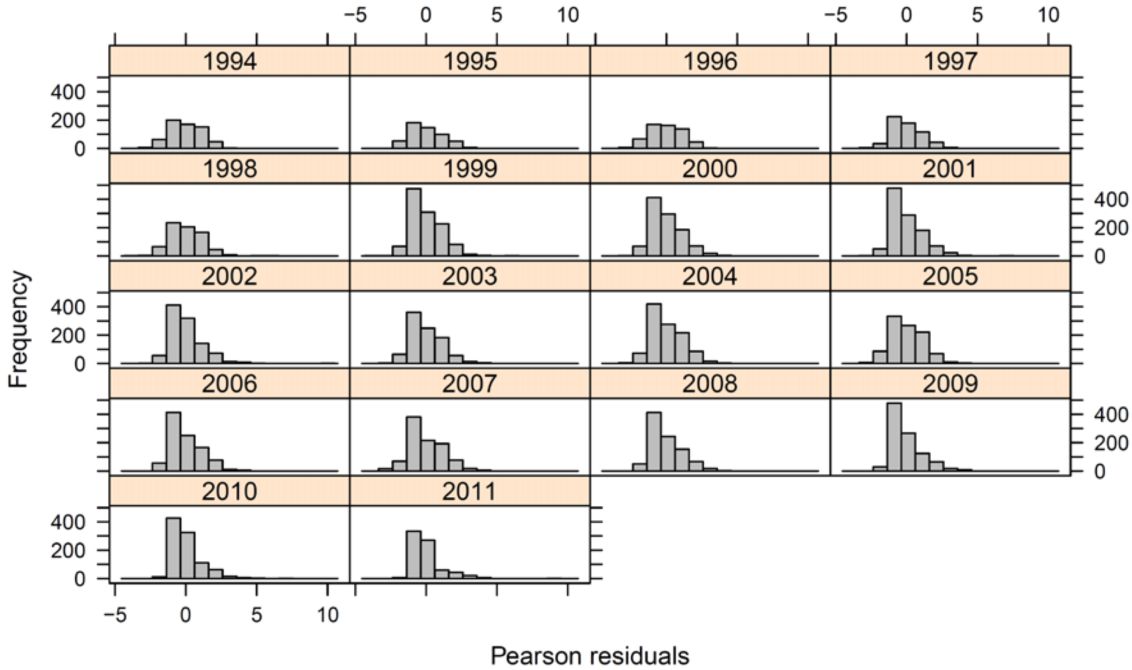


Fig. 5. Frequency distribution of average weight (kg, x-axis) fished by coastal longliners by year. The weight is recorded in logbook, averaged by each operation.



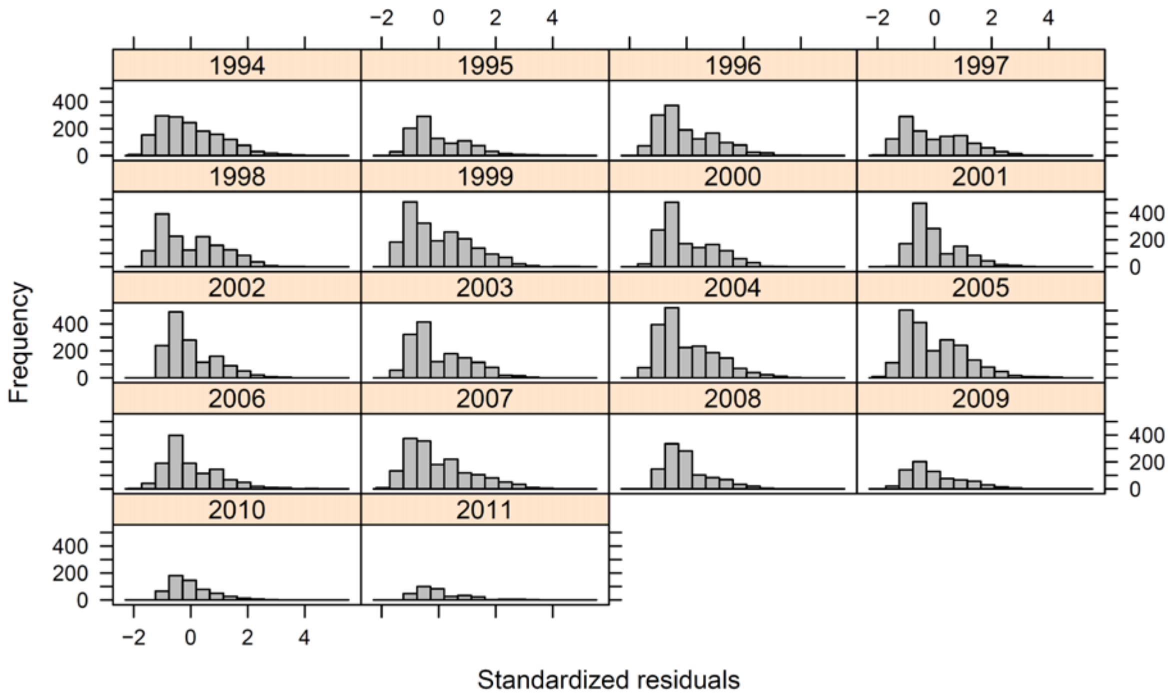


Fig. 6. Residual distributions by year. Upper panels; pearson residuals in the binomial model of 1st step. Lower panels; standardized residuals in the lognormal model of 2nd step.

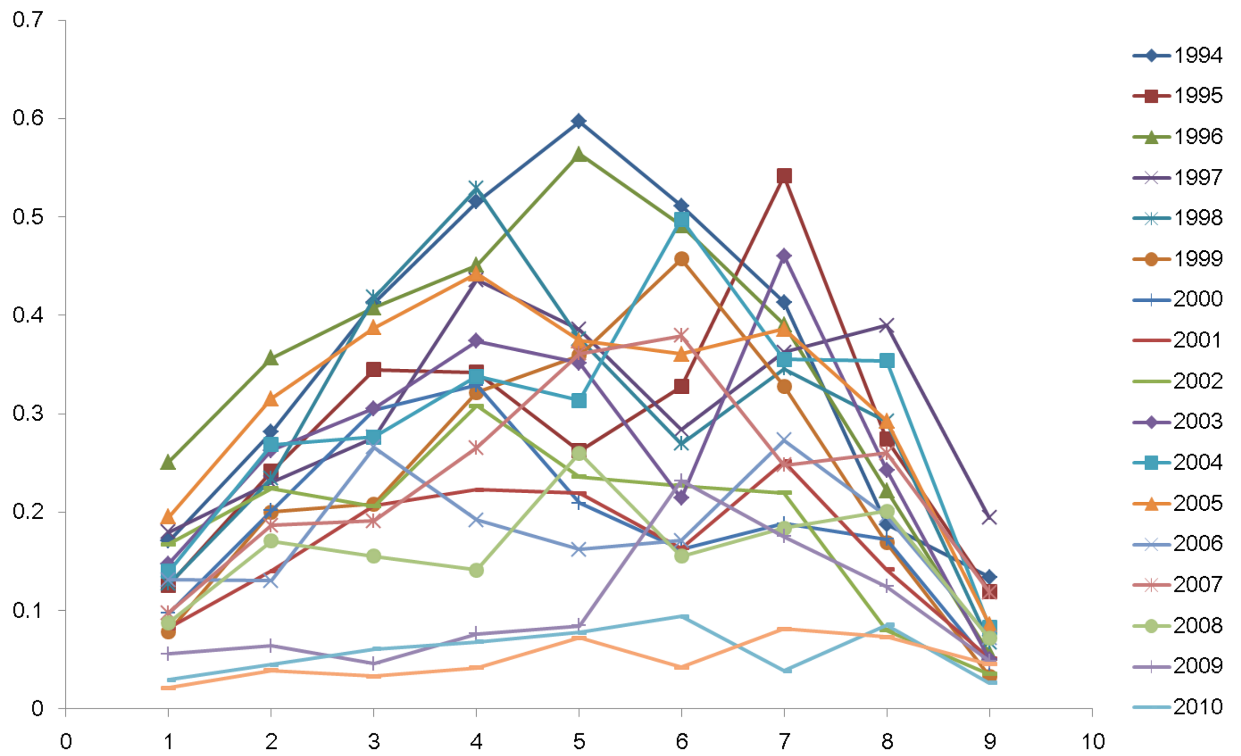


Fig. 7. Least squares mean of probability of positive catch by season and year. X-axis of 1-9 corresponds to fishing season starting from early-April and ending to late-June.

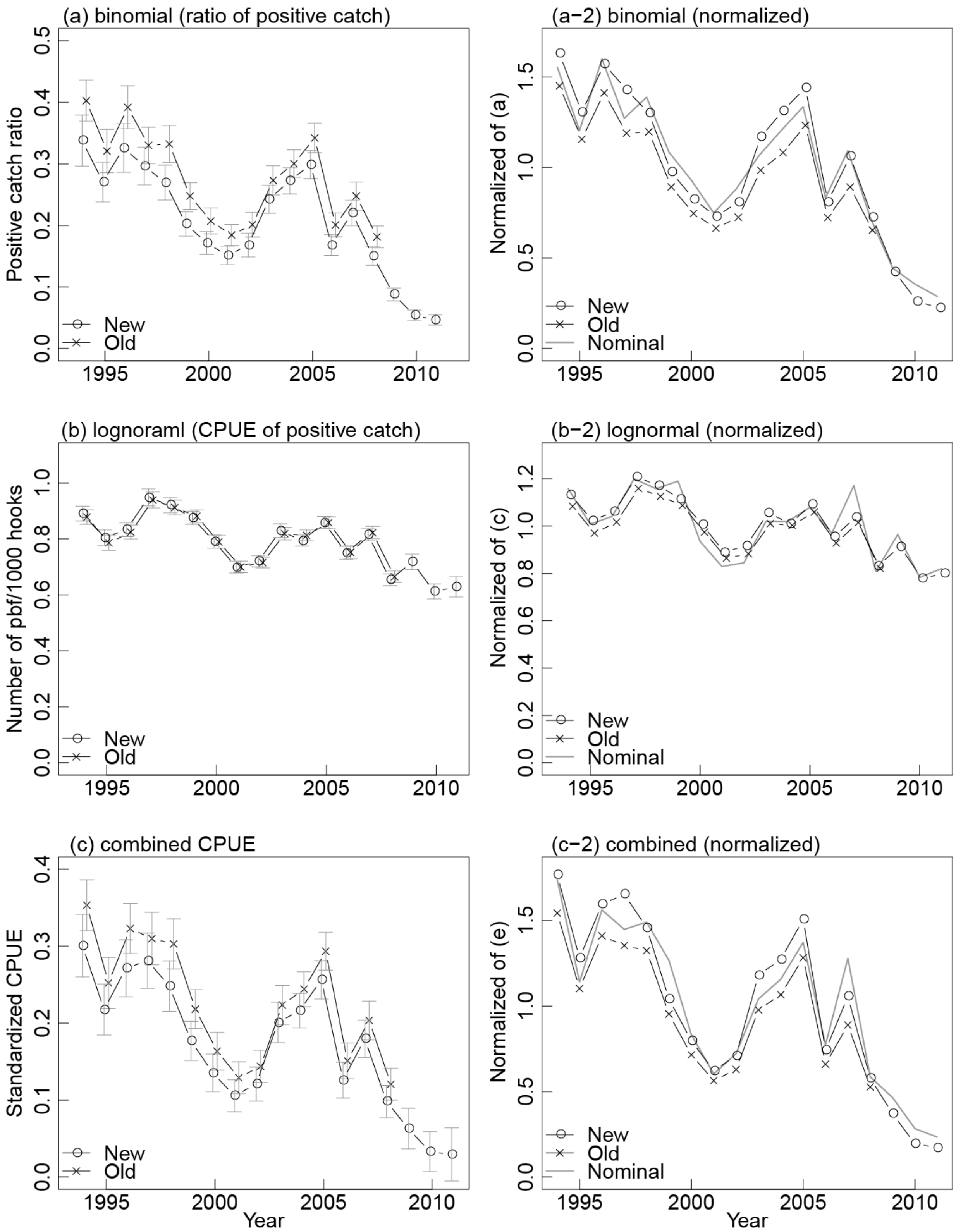


Fig. 8. Annual trends of (a) standardized positive catch ratio, (b) CPUE of positive catch and (c) combined CPUE. ‘New’ represents the estimation in this document, ‘Old’ is CPUE used in the stock assessment updated in 2010 (Abe et al 2010). The right figures show trends scaled by each average. In the scaled CPUE, nominal CPUE is also shown.

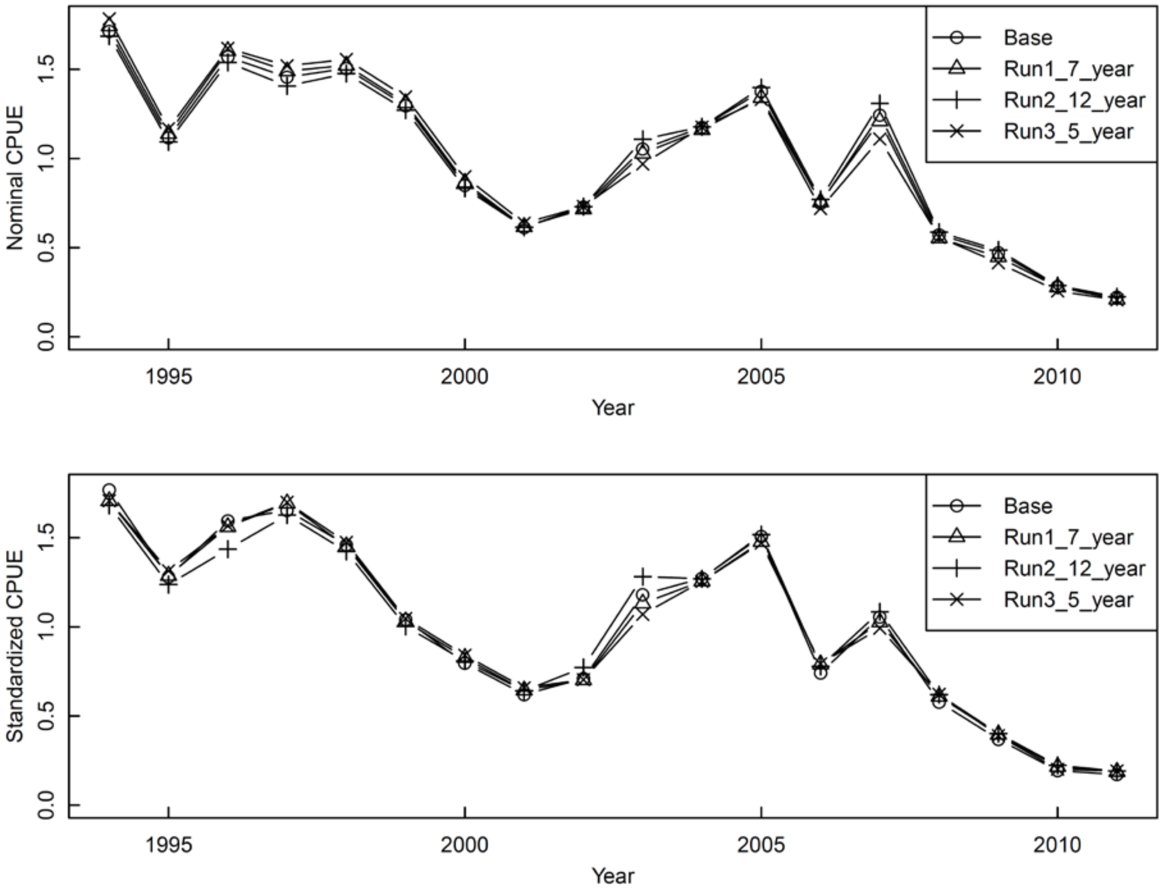


Fig. 9. Comparison of CPUEs with different data sets (base case vs. Run1-3). Upper panel shows nominal and lower shows standardized CPUE. All CPUEs are normalized by each average.