Japanese coastal longline CPUE for Pacific bluefin tuna: Tentative update up to 2014 fishing year

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Note:
This document was revised to attach the presentation explaining the modified method as suggested by the WG. The modified method used cluster analysis without catch composition of Pacific Bluefin tuna, and didn't filer after the cluster; the data used for the cluster analysis and standardization was same (see Attachment 1).

Summary

Japanese coastal longline CPUE was updated using Zero-inflated Negative Binomial model (ZINB) for the standardization. This approach was proposed in ISC PBF WG in April; firstly a cluster analysis was conducted to define the targeting, then the result of cluster analysis was used for an explanatory variable of ZINB model. Dataset using this approach was aggregated to trip-level, the model was selected by BIC. The standardized CPUE has similar trend with that from previous method (Delta-type 2 step method), but a large fluctuation in 2005-2008 calendar year was reduced. The data-size in most recent year (2015 calendar year = 2014 fishing year) is still small, thus this standardized CPUE should be noted as a provisional result. In this document, we also presented the results of ZINB model without interactions and some main variables (e.g. cluster index and area index) as the explanatory variables for comparison.

Introduction

Regarding Japanese coastal longliner, it is known that fishermen can change their target species by each trip, of which length ranges approximately from ten days through one month. This targeting would provide strong impact for the Catch Per Unit Effort (CPUE) of Pacific bluefin tuna (PBF), but the effect could not be adequately addressed at the previous CPUE standardization (Oshima et al. 2012). In previous ISC PBF working group workshop (2015 April), new approach for the CPUE standardization was proposed to include the effect of target shift (Hiraoka et al. 2015). In this approach, the cluster analysis for species composition by fishing trip was conducted to make the target indicator, then the indicator was used for the explanatory variable of the zero-inflated negative binomial model (ZINB model) for the CPUE standardization. This approach is a standard method for stock analysis— such clustering method has been used for many CPUE works for various fish stocks (e.g. He et al. 1997), and the idea to use the clustering result as the explanatory variable has been also used for the analysis of the other tunas in WCPFC (McKechnie et al. 2014, Tremblay-Boyer et al. 2015).

This document presents an update of the CPUE which was standardized by a new approach using cluster analysis and ZINB model. According to the discussion of ISC PBF working group in April (ISC 2015), it is also presented that the results of analysis without using some variables (e.g. cluster index and area index) and interactions for the explanatory variables. Moreover, the result using previous standardization method (Ichinokawa and Takeuchi 2012) is also presented for comparison. Updated data for most recent fishing season (for 2014 fishing year; April-June, 2015) is still limited, thus the results in this document is tentative.

Materials and Methods

Data sources

Catch and effort data from logbooks of Japanese coastal longliners operated from 1994 to 2015 were used for the CPUE analysis. The data resolution is originally set-by-set, and it refers to individual records of fishing operation, whereby on a given day and location (latitude and longitude) of longline set and the number of hooks set, hook per basket (hpb), and the number of fish caught of various species reported. The data were filtered through the following criteria described by previous studies (Ichinokawa and Takeuchi 2012, Hiraoka et al. 2015);

- April to June (spawning season);
- 1x1 degree grids in latitude and longitude where at least one PBF per year has been caught.

We aggregated the data by trip level to use for the cluster analysis and standardization by ZINB method according to Hiraoka et al. (2015). The number of hooks and catches were added up, and location and hpb were calculated median values for each fishing trip. For the standardization using previous method (Delta-type two-step method), we used set-by-set data without aggregation according to Ichinokawa and Takeuchi (2012).

Cluster analysis

Cluster analysis is used to assign fishing activity to general categories representing the different targeting practices (He et al. 1997, McKechnie et al. 2014, Tremblay-Boyer et al. 2015). Clustering was based on the relative number of key species (the species composition in proportions of PBF, bigeye tuna (BET), yellowfin tuna (YFT), and albacore (ALB)) or other fishes (billfish and shark species) caught in sequential groups of fishing trips. We used a hierarchical clustering using Ward's method (Ward 1963) on Euclidean distance. The analysis was conducted using the "hclust" algorithm (available in R package "stats") of R software ver. 3.2.1 (R Core Team 2015).

Area definition

According to Hiraoka et al. (2015), two different types of areas were defined (Fig. 1 A and B). All 1x1 degree blocks in defined area has at least one PBF per year has been caught in more than 10 years. We divided it into two and three sub-area for the analysis using previous method (Delta-type two-step method) and new method (ZINB method), respectively.

Standardization of CPUE

<u>Previous method (Delta-type two-step model)</u>

The data used for standardization was set-by-set resolution (Table 1). First, the proportions of zero-catch sets to the total sets were estimated with binomial generalized liner model (1st step), then log(CPUE) was estimated using lognormal model only for the sets with positive catch (2nd step).

Explanatory variables incorporated into these models were selected using BIC form following;

- **Year**: 22 calendar years, from 1994 to 2015;
- **Day10**: Periods during the spawning season, from April to June, defined by 10 days interval (last period of May contained 11days);
- **Area**: Northeast ("NE") and Southwest ("SW") area of the fishing ground (two-area definition; Fig.1A) for each operation.
- **Ship-type**: Duration of fishing trip and vessel size ("Large-Long", "Large-Short", or "Small-Short")
- **Gear**: "Shallow set" (< 16 hooks per basket) and "Deep set" (≥ 16 hooks per basket) defined by hooks per basket for each operation.
- **Ship name**: random effect of ship name is included only in 1^{st} step (Binomial model).

The Standardized CPUE was calculated from least square means (LSMEANS) from best models selected by BIC in each step: non-zero catch ratios (1^{st} step) × CPUE of positive catch (2^{nd} step). The CV was calculated using bootstrapping 1000 times. This analysis was carried out through GLM and GLIMMIX procedure of SAS 9.4.

<u>New method (ZINB model)</u>

The data used for standardization was trip resolution (Table 2). ZINB allows for "excess zeros" in count models through the splitting process, one where members always have zero counts (count model), and one where members have zero or positive counts (zero-inflation model). The explanatory variables used in this analysis were as follows;

- **Year**: 22 calendar years, from 1994 to 2015;
- **Day10**: Periods during the spawning season, from April to June, defined by 10 days interval (last period of May contained 11days);
- **Area**: Core area ("CORE"), Northeast area ("NE"), and Southwest area ("SW") of the fishing ground (three-area definition; Fig.1B) for the median position of each fishing trip;
- **Ship-size**: Small vessel (< 16 GRT; "Small") or large vessel (≥ 16 GRT; "Large");
- **Days per trip**: Short duration (< 14 days; "Short") or long duration (≥ 14 days; "Long"). According to Hiraoka et al. (2015), fishing tips which have longer than 28 days were removed;
- **Gear**: "Shallow set" (< 16 hooks per basket) and "Deep set" (≥ 16 hooks per basket) defined by median value of the hooks per basket for each fishing trip;
- **Movement**: Three categories defined by combining the total moving distance per trip with the mean moving distance per day ("Not moving": both total and mean distance were zero, "Short distance": total distance is <300 miles, and "Long distance": total distance is ≥300 miles). According to Hiraoka et al. (2015), fishing tips which move more than 60 miles per day in average were removed;
- **Cluster**: Three clusters derived from cluster analysis.

We include main effect and first-order interactions for the "Best model", which was determined using BIC by following stepwise variable selection;

1^{st}) The initial models for both count model and zero-inflation model were constructed with all variables as only main effect;

2nd) The main effect was determined through the backward method (decreasing variables) for both count model and zero-inflation model;

3rd) The first-order interaction which consists of selected main effects was determined through the forward method (increasing variables) for both count model and zero-inflation model.

Moreover we determined the model without interactions as a "Main effect model" at the above 2nd step, and then, the model without cluster or area effects were determined as a "Main without 'Cluster' model" or "Main without 'Area' model" to remove the "Cluster" or "Area" variables from "Main effect model". The Standardized CPUE was calculated from least square means (LSMEANS) using the same estimation procedure as the SAS package. The CV was calculated using bootstrapping 1000 times. The analysis was conducted using the "zeroinfl" algorithm (available in R package "pscl") of R software ver. 3.2.1 (R Core Team 2015).

Results and Discussion

Cluster analysis

The cluster analysis divided the fishing trips into three groups (Table 3, Fig. 2). Species compositions of Cluster 1 and 3 showed that they generally represent targeting ALB (78.2%) and YFT (71.5%), respectively. In Cluster 2, the highest proportion was "Other" species, whereas relatively high proportion of PBF was observed (13.4%) compared to the other clusters (1.4% in Cluster 1 and 2.5% in Cluster 3).

The yearly changes of number of fishing trips by Clusters are shown in Fig. 3. The number of fishing trips of Cluster 3 (targeting YFT) had increased since 2007, reached a peak in 2010, and then decreased. Meanwhile, those of Cluster 1 (targeting ALB) were relatively stable. Those of Cluster 2, which have high proportion of PBF, have been decreasing since 2006. These trends would reflect the change of targeting of the longline fishermen.

Oshima et al. (2012) concluded that the target shift relating to the PBF CPUE happened after 2005. Following their results, the ISC PBFWG noted that the behaviors of these fisheries have been changed, and they decided to use high CV of CPUE from 2005 in the previous assessment model (ISC 2014). Our cluster analysis could detect this target shift, thus the including the cluster index in the CPUE standardization process would be useful to improve the CPUE modeling to address the effect of target shift.

CPUE standardization

<u>Previous method (Delta-type two-step model)</u>

Final model have not changed from Ichinokawa and Takeuchi (2012) in both 1st and 2nd step (Table 4). The variables selected by BIC were as follows;

[Final model]

(1st step: Binomial model)

Logit(p) = intercept + Year + Year*Day10 + Area*Ship-type + Day10*Area + Year*Area + Gear*Ship-type + Area*Gear + error term,

(2nd step: Lognormal model)

Log(CPUE) = intercept + Year + Day10*Gear + Area*Ship-type + error term

Year trend of least squares mean as the standardized CPUE remain at a low level in recent 6 years compared to those of 1990s (Fig, 4). Distributions of residuals are still slightly left-skewed both in 1st and 2nd steps compared to previous study (Fig, 5). The estimated value of most recent year (2015 calendar year = 2014 fishing year) has high CV because of the limited small data-set (Table 1).

<u>New method (Zero-Inflated Negative Binomial model)</u>

For new method using ZINB, we selected "Best model" including main effects and 1st order interaction using BIC (df=143, BIC=48292.62);

[Best model]

(Count model)

Log(μ) = intercept + Year + Day10 + Area + Ship-size + Days-per-trip + Movement + Cluster + Year*Area + Area*Ship-size + Day10*Area + Area*Cluster + error term,

(Zero-inflation model)

Logit(p) = intercept + Year + Day10 + Area + Ship-size + Days-per-trip + Movement + Cluster + Days-per-trip*Cluster + error term

The best model had the interaction between Year and Area, thus the area weighting value was estimated as the standardized CPUE. The standardized CPUE has similar trend with that from previous method, but a large fluctuation in 2005-2008 calendar year was reduced. There is upward trend in most recent year whereas an opposite trend is shown in previous method. However, as mentioned above, the data-size in most recent year (2015 calendar year = 2014 fishing year) is still small, and the CV of estimated value is relatively high (Table 2). Thus this standardized CPUE should be noted as a provisional result.

The "Main effect model" was consisted to remove the 1st order interaction variables from "Best model". We also examined two additional models named "Main without 'Cluster' model" and "Main without 'Area' model" to remove the "Cluster" and "Area" variables, respectively;

[Main effect model] (df=77, BIC=48708.94)

(Count model)

Log(μ) = intercept + Year + Day10 + Area + Ship-size + Days-per-trip + Movement + Cluster + error term,

(Zero-inflation model)

Logit(p) = intercept + Year + Day10 + Area + Ship-size + Days-per-trip + Movement + Cluster + error term

[Main without "Cluster" model] (df=73, BIC=49456.11)

(Count model)

Log(μ) = intercept + Year + Day10 + Area + Ship-size + Days-per-trip + Movement + error term,

(Zero-inflation model)

Logit(p) = intercept + Year + Day10 + Area + Ship-size + Days-per-trip + Movement + error term

[Main without "Area" model] (df=73, BIC=49807.95)

(Count model)

Log(μ) = intercept + Year + Day10 + Ship-size + Days-per-trip + Movement + Cluster + error term,

(Zero-inflation model)

Logit(p) = intercept + Year + Day10 + Ship-size + Days-per-trip + Movement + Cluster + error term

Fig.6 shows the comparison of standardized CPUEs from these models. The difference of standardized CPUEs between "Best model" and "Main effect model" comes from the effects of interactions (Fig. 7). In particular, Year*Area interaction is included in "Best model", which has impact on the yearly trend for standardized CPUE (Fig. 7-(1)). Area*Cluster interaction means the different impact of targeting by areas (Fig. 7-(3)). Comparison among the results from "Main effect model", "Main without 'Cluster' model", and "Main without 'Area' model" suggests that both "Cluster" and "Area" variables affect the yearly trend of standardized CPUE: they work to reduce the large fluctuation of the CPUE especially in 2005-2008 calendar year. The Pearson residual patterns are not distinctly different among these models (Fig. 8).

Conclusions

The analyses undertaken here address the target shift for the standardization of the Japanese coastal longline CPUE. The target shift has been arguably considered as a critical issue for the CPUE standardization. Our cluster analysis was able to detect the target shift by fishing trip level, thus the inclusion of cluster index in the CPUE standardization would be one of effective approach to address it. The "Best model" of ZINB selected by BIC includes the "Cluster" variable, thus the model using this variable would adequately explain the CPUE trend.

As noted above, the number of the data in most recent year (2015 calendar year = 2014 fishing year) is still small, about 30% of previous year in fishing effort (hooks). Thus the update result in this document should be noted as a provisional result, and it is necessary to re-update this CPUE information before next stock assessment.

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Table 1 Total number of operations, hooks, PBF catch, nominal CPUE, and standardized CPUE using previous method (Ichinokawa and Takeuchi 2012). Data set was based on logbook from Japanese coastal longliner in 2nd quarter (April-June) of 1994-2015 calendar year (1993-2014 fishing year).

Calender year	Fishing year	Data set used for standardization of CPUE					Standardized CPUE using previous method (Delta-type two-step method)		
		N of operations	N of hooks (x1000 hooks)	N of PBF catch	Nominal CPUE	Nominal CPUE (normalized)	Standardized	Standardized (normalized)	CV
1994	1993	3175	5054	2771	0.548	1.996	0.312	2.098	0.085
1995	1994	2685	4348	1555	0.358	1.302	0.224	1.506	0.059
1996	1995	2917	4754	2396	0.504	1.835	0.282	1.892	0.085
1997	1996	3045	4988	2337	0.469	1.706	0.296	1.985	0.051
1998	1997	3471	5691	2743	0.482	1.755	0.257	1.723	0.056
1999	1998	5556	9047	3754	0.415	1.511	0.183	1.230	0.046
2000	1999	4904	8133	2220	0.273	0.994	0.142	0.952	0.051
2001	2000	5487	9355	1835	0.196	0.714	0.110	0.736	0.046
2002	2001	5116	8597	1981	0.230	0.839	0.124	0.834	0.060
2003	2002	4440	7502	2488	0.332	1.207	0.203	1.361	0.042
2004	2003	5239	9016	3358	0.372	1.356	0.223	1.496	0.033
2005	2004	4848	8330	3638	0.437	1.590	0.261	1.749	0.031
2006	2005	4734	7880	1892	0.240	0.874	0.131	0.882	0.043
2007	2006	4612	7800	3102	0.398	1.448	0.183	1.227	0.042
2008	2007	4541	7986	1458	0.183	0.665	0.100	0.673	0.047
2009	2008	5106	9030	1254	0.139	0.506	0.062	0.416	0.050
2010	2009	4957	8405	756	0.090	0.327	0.033	0.224	0.074
2011	2010	4434	7797	569	0.073	0.266	0.033	0.221	0.079
2012	2011	4558	8364	394	0.047	0.171	0.021	0.141	0.078
2013	2012	4702	8412	708	0.084	0.306	0.036	0.240	0.058
2014	2013	4036	7190	673	0.094	0.341	0.040	0.269	0.062
2015	*2014*	*1265*	*2218*	*179*	*0.081*	*0.294*	*0.022*	*0.146*	*0.566*

Table 2 Total number of fishing trips, hooks, PBF catch, nominal CPUE, and standardized CPUE using “Best model” of new method (Hiraoka et al. 2014). Data set was based on logbook from Japanese coastal longliner in 2nd quarter (April-June) of 1994-2015 calendar year (1993-2014 fishing year).

Calender year	Fishing year	Data used for cluster analysis			Data set used for standardization of CPUE					Standardized CPUE using New method (Zero-inflated negative binomial model)		
		N of trip	N of hooks (x1000 hooks)	N of PBF catch	N of trip	N of hooks (x1000 hooks)	N of PBF catch	Nominal CPUE	Nominal CPUE (normalized)	Standardized "Best model"	Standardized "Best Model" (normalized)	CV
1994	1993	438	5708	2921	387	5273	2902	0.550	1.990	3.503	1.885	0.028
1995	1994	394	5062	1676	344	4582	1642	0.358	1.296	2.422	1.303	0.038
1996	1995	427	5690	2592	372	5051	2517	0.498	1.802	3.536	1.903	0.032
1997	1996	473	6130	2593	389	5185	2427	0.468	1.693	3.130	1.684	0.035
1998	1997	521	7041	3077	435	6038	2907	0.481	1.741	2.997	1.613	0.029
1999	1998	806	10696	4100	711	9119	3822	0.419	1.516	2.449	1.318	0.036
2000	1999	819	10857	2460	635	8097	2208	0.273	0.986	2.002	1.077	0.032
2001	2000	781	11856	1917	620	9306	1864	0.200	0.724	1.651	0.888	0.027
2002	2001	800	11632	2242	595	8418	1961	0.233	0.842	2.032	1.093	0.026
2003	2002	882	12426	3007	591	7214	2469	0.342	1.238	2.601	1.400	0.026
2004	2003	898	11994	3814	698	9046	3394	0.375	1.357	2.760	1.485	0.022
2005	2004	848	12703	4318	600	8394	3700	0.441	1.594	3.092	1.663	0.025
2006	2005	915	12953	2345	620	7884	1885	0.239	0.865	1.498	0.806	0.030
2007	2006	887	12041	3517	602	7688	3106	0.404	1.461	1.733	0.932	0.041
2008	2007	859	12078	1882	602	8184	1485	0.181	0.656	1.279	0.688	0.039
2009	2008	927	13414	1501	662	9376	1303	0.139	0.503	0.644	0.347	0.063
2010	2009	970	13951	814	663	8667	785	0.091	0.328	0.515	0.277	0.057
2011	2010	916	12236	773	673	7866	583	0.074	0.268	0.432	0.232	0.053
2012	2011	864	12923	512	635	8511	410	0.048	0.174	0.345	0.186	0.058
2013	2012	865	12799	818	612	8499	734	0.086	0.312	0.601	0.324	0.043
2014	2013	780	12129	789	518	7215	698	0.097	0.350	0.759	0.408	0.039
2015	*2014*	*284*	*4019*	*269*	*170*	*2169*	*183*	*0.084*	*0.305*	*0.910*	*0.489*	*0.071*

Table 3 Species composition and number of fishing trip by each cluster.

	Cluster		
	1	2	3
Yellowfin tuna	5.9%	22.5%	71.5%
Albacore	78.2%	14.6%	8.1%
Bigeye tuna	8.3%	1.8%	1.2%
Pacific bluefin tuna	1.4%	13.4%	2.5%
Other species	6.2%	47.6%	16.7%
Number of fishing trip	10,530	2,601	3,223

Table 4 Results of model selection for the previous method.

(1) Binomial model (1st step)

Added explanatory veriables		BIC
(1)	year	52619.08
(2)	+year*day10	48737.61
(3)	+area*shiptype	48434.74
(4)	+day10*area	48299.87
(5)	+year*area	48208.89
(6)	+gear*shiptype	48205.65
(7)	+area*gear	<u>48203.95</u>

(2) Lognormal model (2nd step)

Added explanatory veriables		BIC
(1)	Intercept	-32412.47
(2)	+day10*gear	-34139.06
(3)	+year	-35427.33
(4)	+area*shiptype	<u>-35953.71</u>

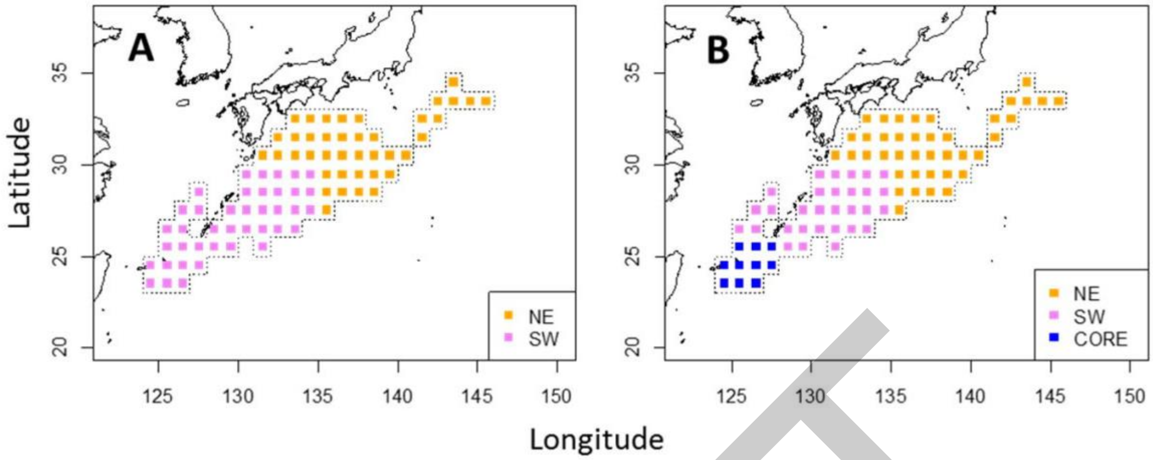


Fig. 1 Area definition for the analysis. The area surrounded by the dotted line represents the fishing area selected for the standardization of CPUE. Left figure (A) shows "two-area" definition used for the previous standardization method (Delta-type two-step method) by Ichinokawa and Takeuchi (2012). Right figure (B) shows "three-area" definition for the new method (ZINB method) by Hiraoka et al. (2015). "CORE" area was defined by Oshima et al (2012) as the higher CPUE area for PBF.

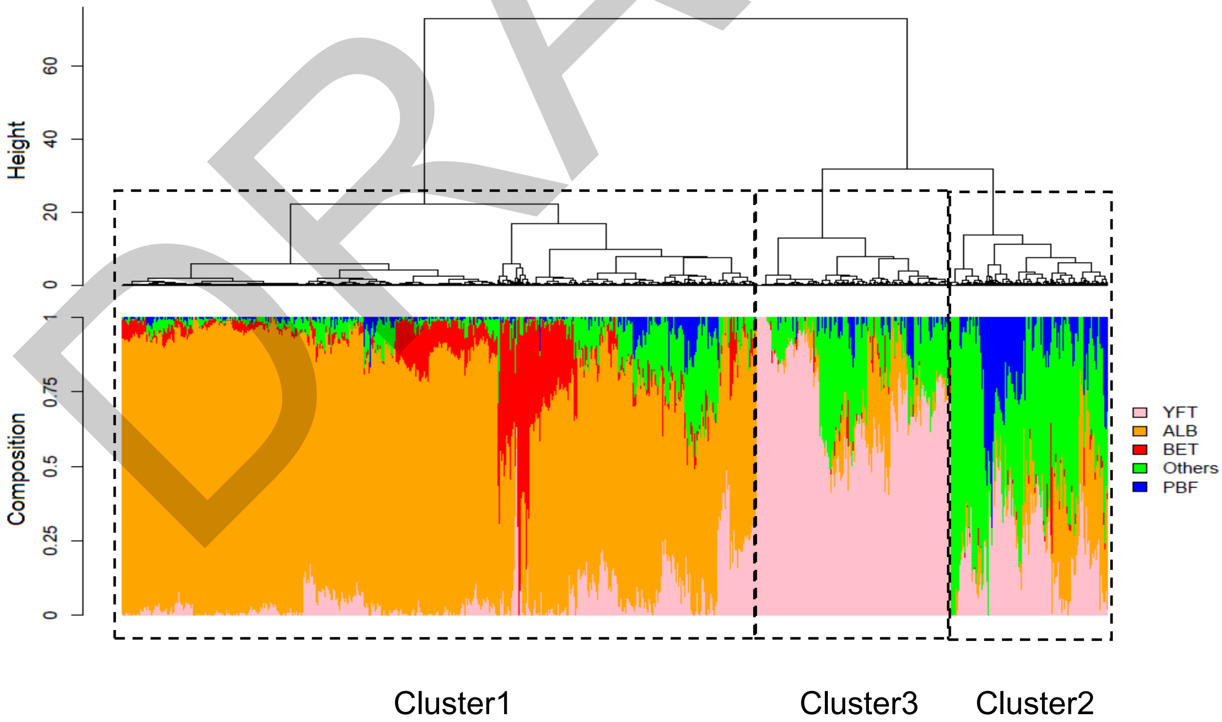


Fig. 2 Result of cluster analysis (Word's methods). Upper panel shows the dendrogram obtained by cluster analysis and the lower panel shows the species composition by fishing trip corresponding to each cluster.

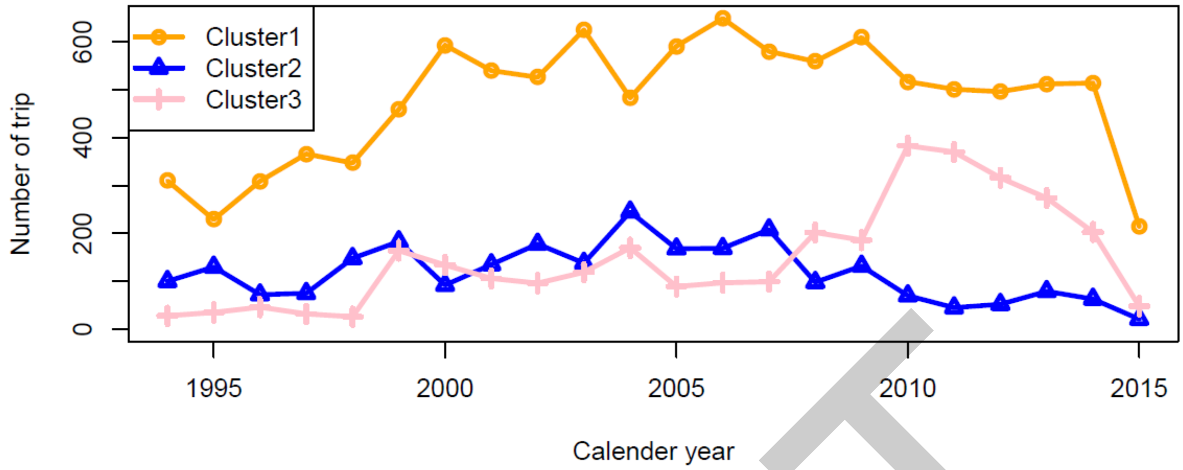


Fig. 3 Yearly change of the number of fishing trip grouped in each cluster.

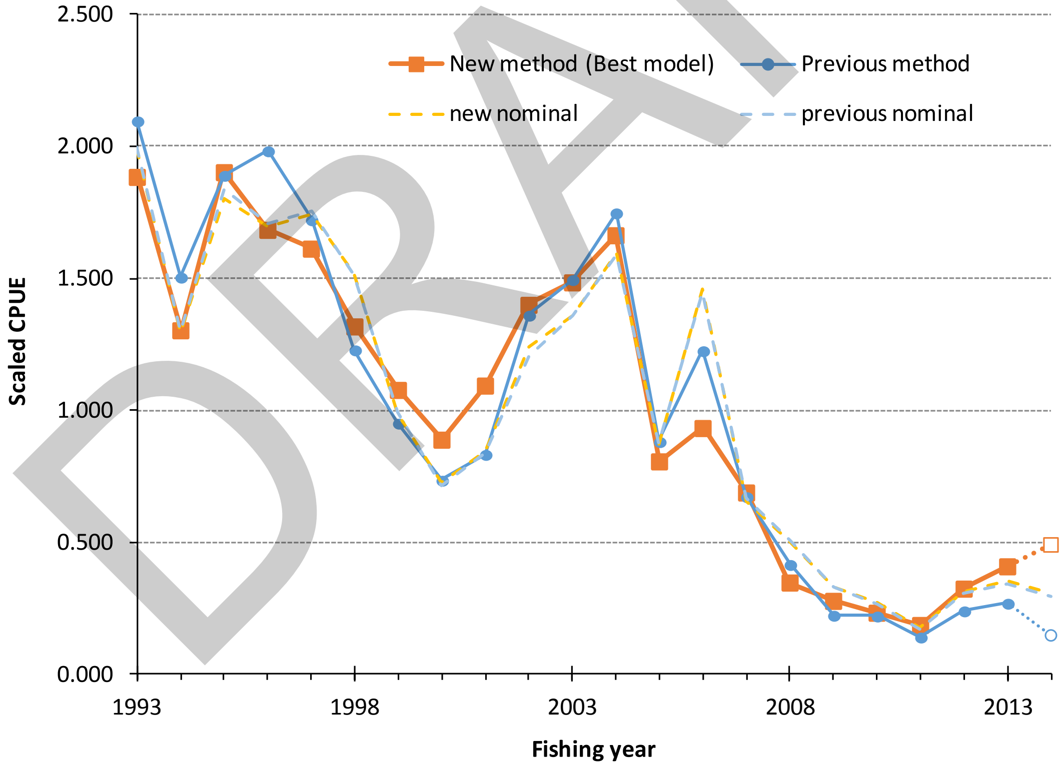
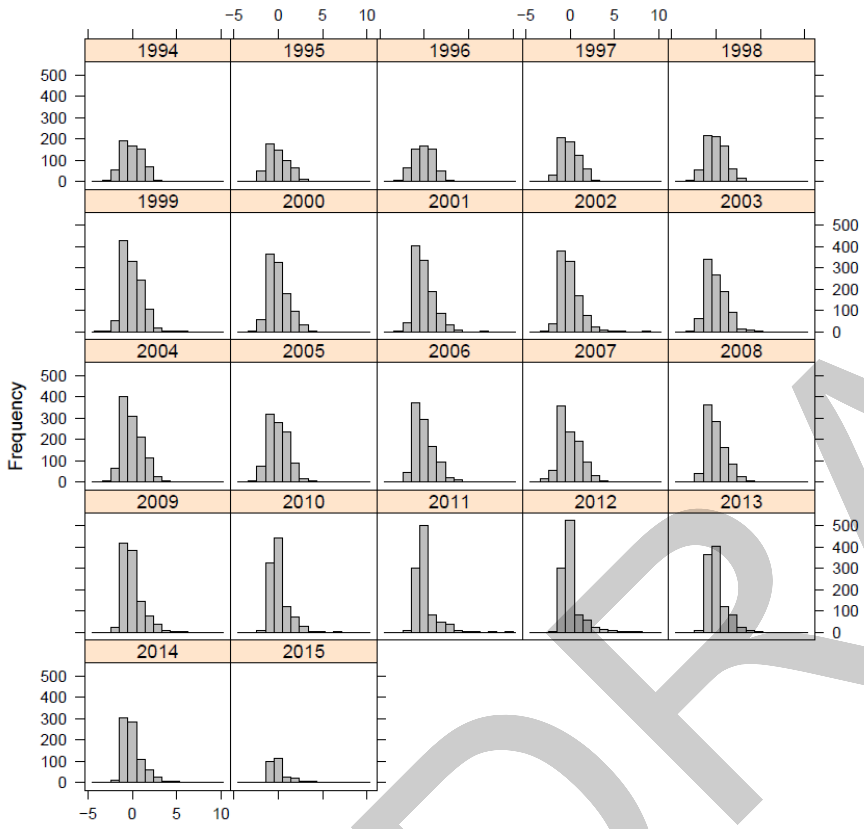


Fig. 4 Scaled standardized CPUE and nominal CPUE. Orange lines and Blue lines indicate the result of standardization using new method (Zero-Inflated Negative Binomial model) and previous method (Delta-type 2 step method), respectively. Dotted lines show the nominal CPUE.

(1)



(2)

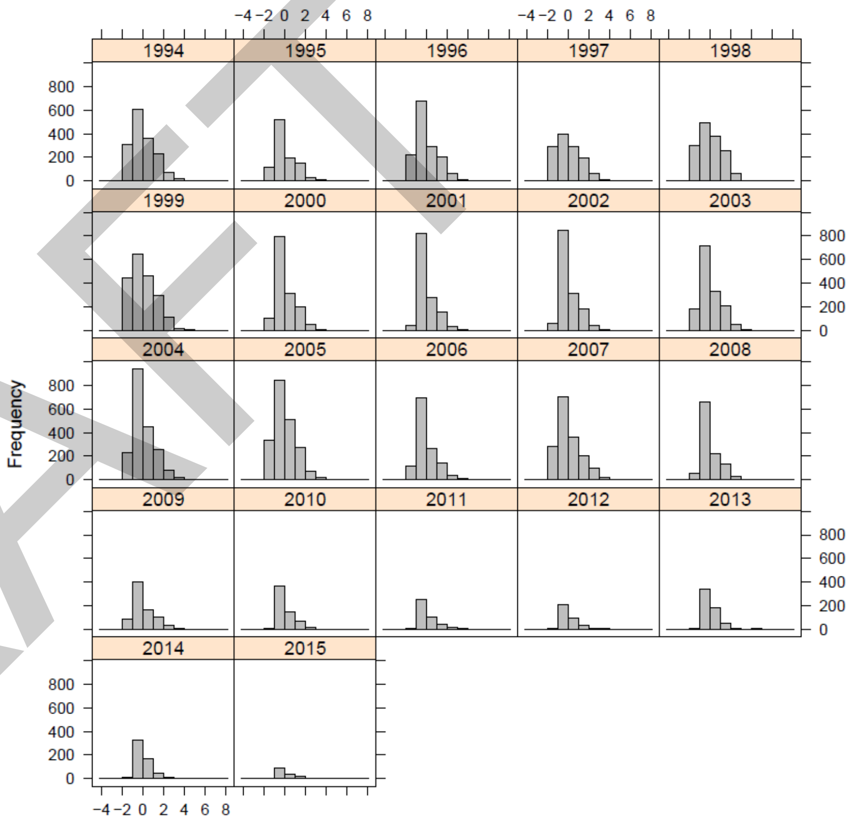
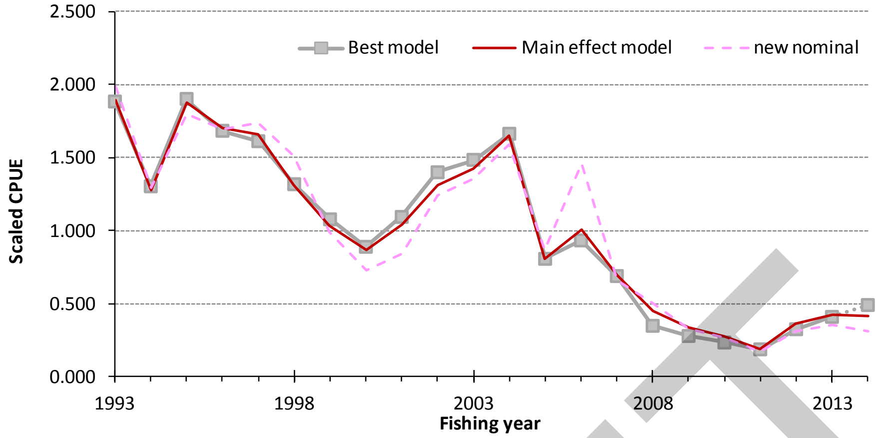
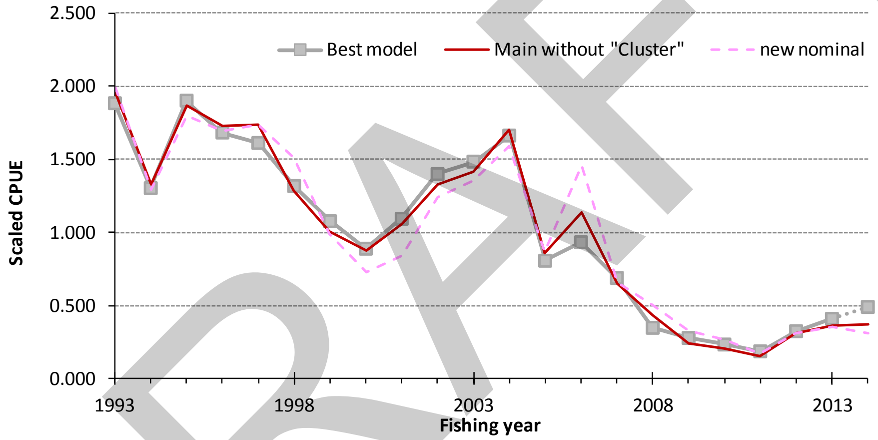


Fig. 5 Residual distributions for the previous method (Delta-type 2 step method) by year. (1) Left panels: Pearson residuals in the binomial model of the first step. (2) Right panels: standardized residuals in the lognormal model of the second step.

(1) "Best model" vs "Main effect model"



(2) "Best model" vs "Main without 'Cluster' model"



(3) "Best model" vs "Main without 'Area' model"

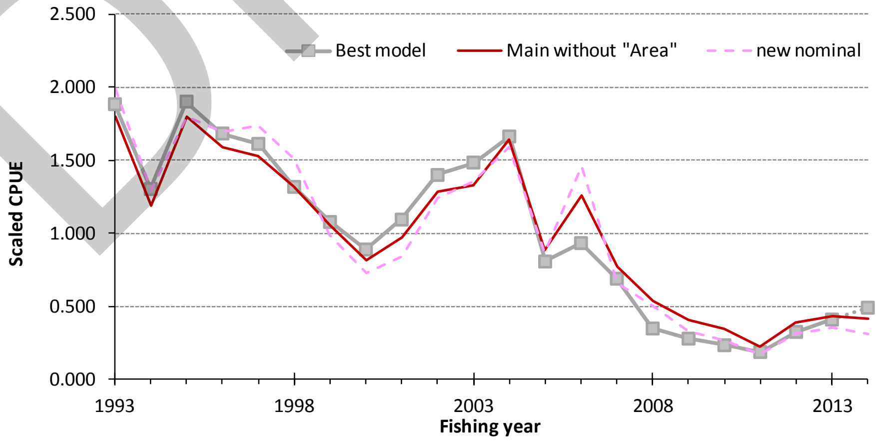
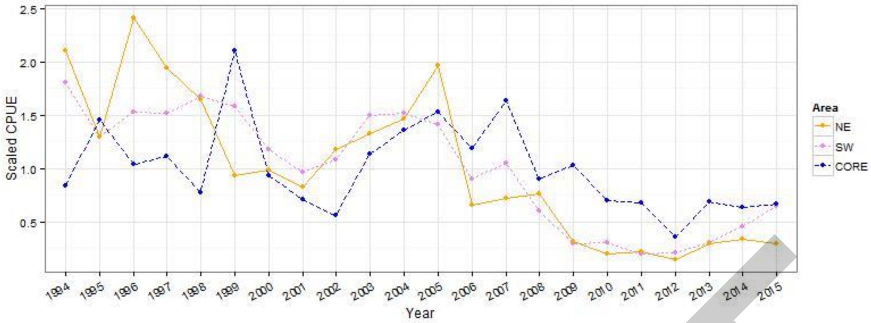
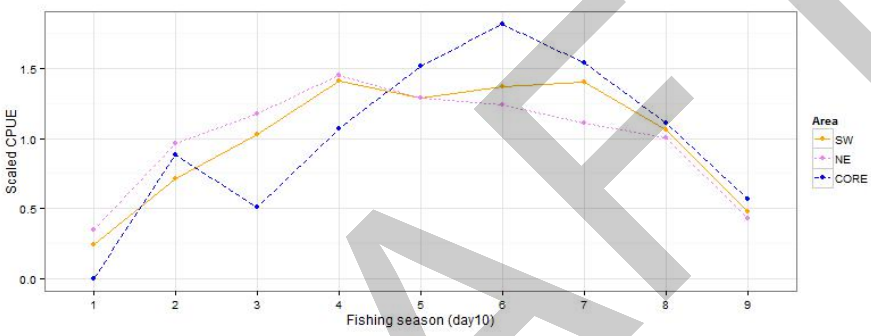


Fig. 6 Comparison of scaled CPUE by models using new method (Zero-Inflated Negative Binomial model). Dotted lines show the nominal CPUE.

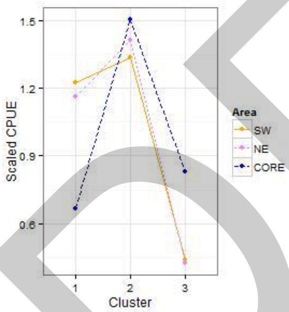
(1) Year*Area effect



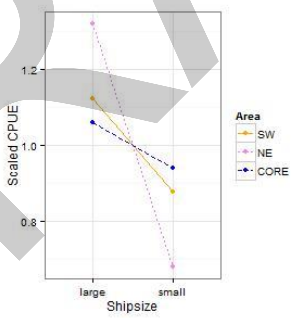
(2) Area*Day10 effect



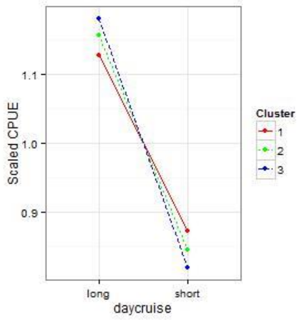
(3) Area*Cluster effect



(4) Area*Ship-size effect



(5)Days-per-trip*Cluster effect



(6) Movement effect

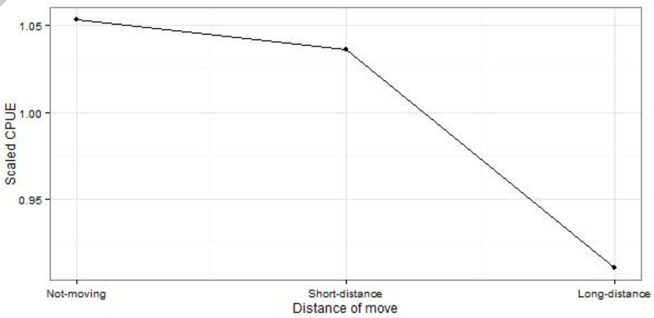


Fig. 7 Least squared means for each effect estimated by “Best model”.

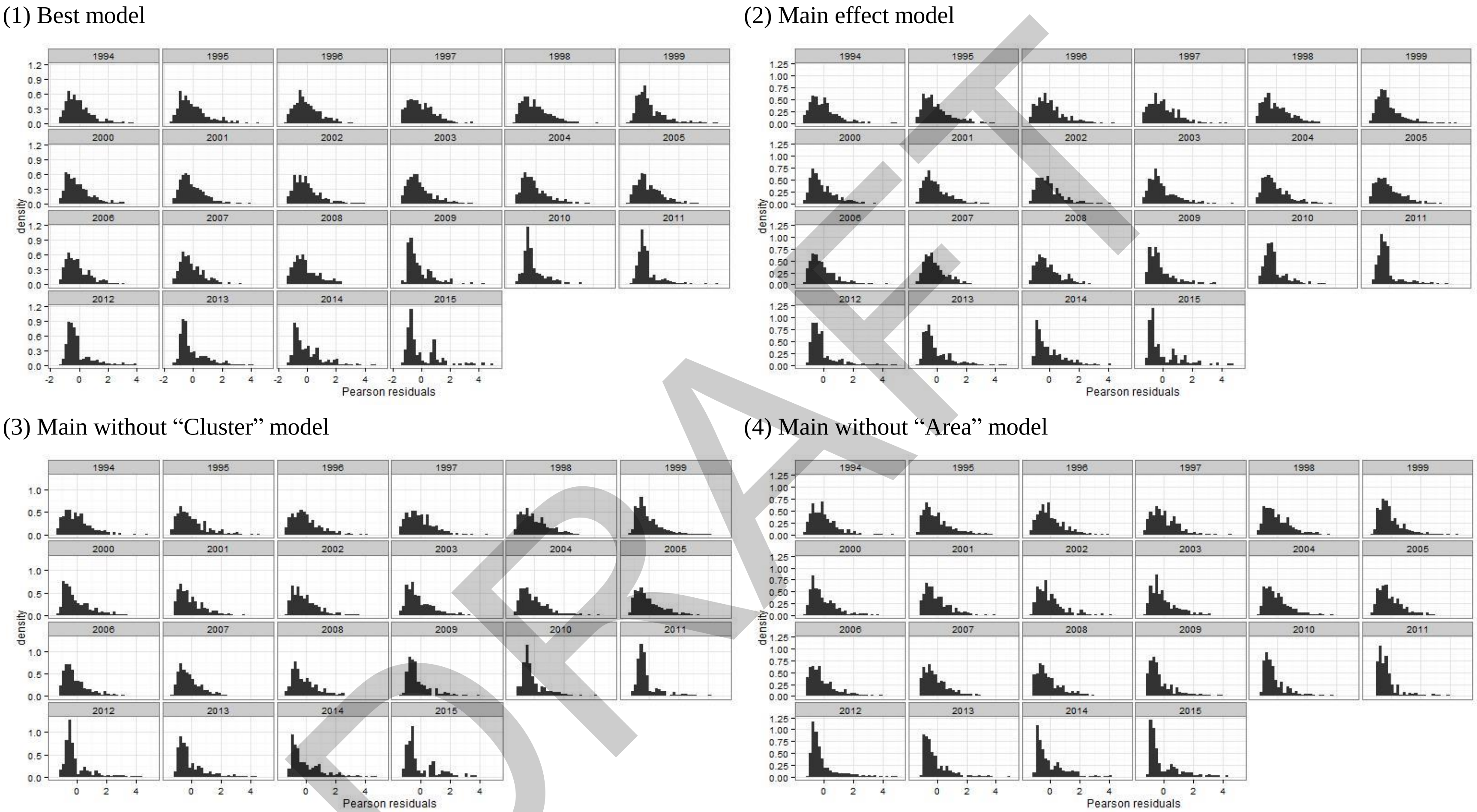


Fig. 8 Residual distribution for new method (Zero-inflated Negative Binomial model) by year. (1) Pearson residuals in "Best model", (2) Pearson residuals in "Main effect model", (3) Pearson residuals in "Main without 'Cluster' model", and (4) Pearson residuals in "Main without 'Area' model".

Attachment 1

Revision

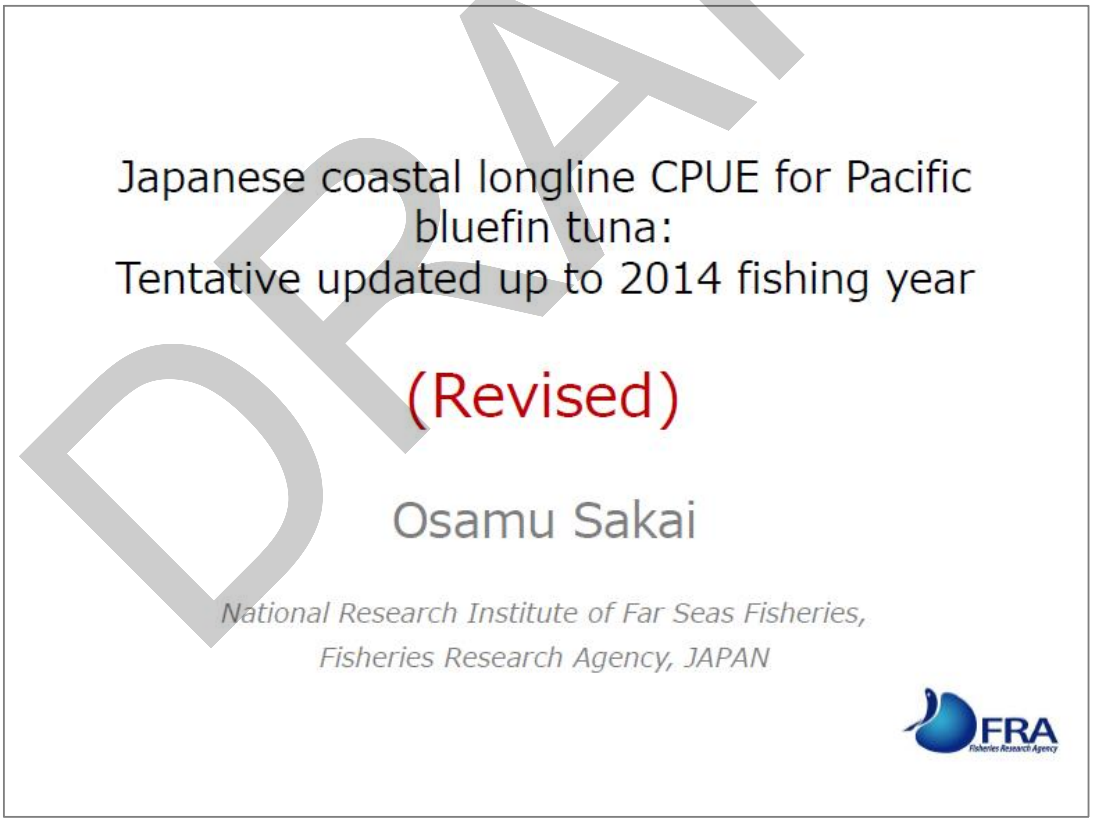
The method of the CPUE standardization for the Japanese longline CPUE was revised during the meeting. According to the advice from WG, the presentation of the revised method was attached in following “Attachment 1”.

Acknowledgment

We are thankful to ISC PBF WG members who provided valuable suggestion and advice that greatly assisted to finalize the standardization methods.

Presentation

1:



2:

Revised method in this meeting:

Data:

- Logbook data of Japanese longline (1994-2015).
- Aggregated by fishing trip level.

Filtering:

- Fishing trip including April-June operation.
- Fishing trip including 1x1 degree grids which have >1 PBF-catch more than 10 year.

Clustering:

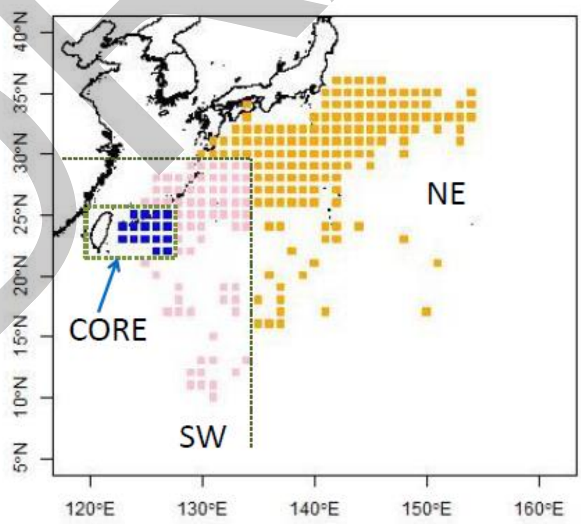
- Cluster analysis based on the species composition (exclude PBF) by fishing trip (Word's method).

Zero-inflated Negative Binomial (ZINB):

- Standardizing the CPUE by ZINB using the result of cluster analysis as a explanatory variable.

3:

Area definition:



Median position of each fishing trip is used for a explanatory variable for ZINB.

4:

Explanatory ZINB:

- Select main effects through the backward method, then select interactions through the forward method based on BIC.

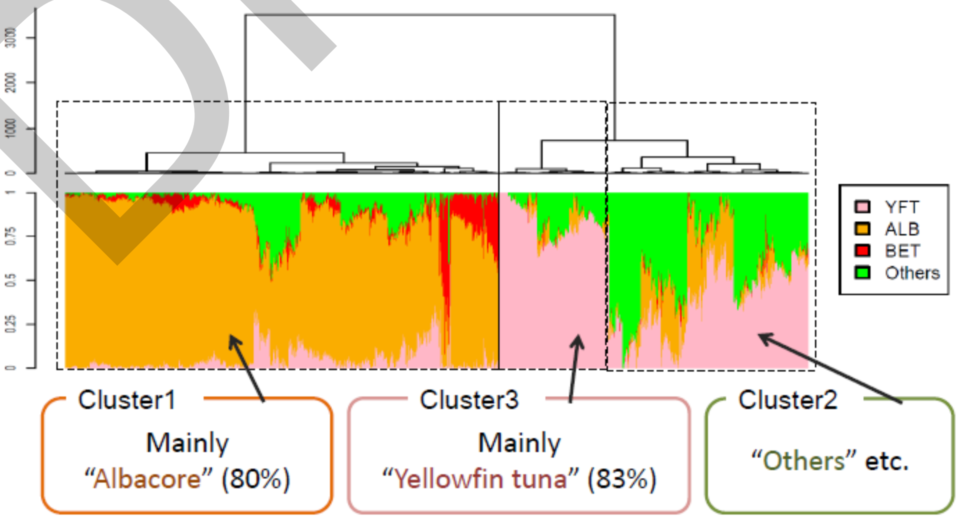
8 main effects and 1st order interaction

1) Year:	1994-2015
2) Day10:	10 days interval from Apr. to Jun.
3) Area :	3 areas (“CORE”, “SW”, and “NE”)
4) Ship-size:	“Small” (< 16 GRT) or “Large” (≥ 16 GRT)
5) Days-per-trip:	“Short” (< 14 days) or “Long” (≥ 14 days)
6) Gear:	“Shallow set” (< 16 hpb) or “Deep set” (≥ 16 hpb)
7) Movement:	“Not moving”, “Short distance”, and “Long distance”
8) Cluster:	3 groups defined by cluster analysis

5:

Results of cluster analysis:

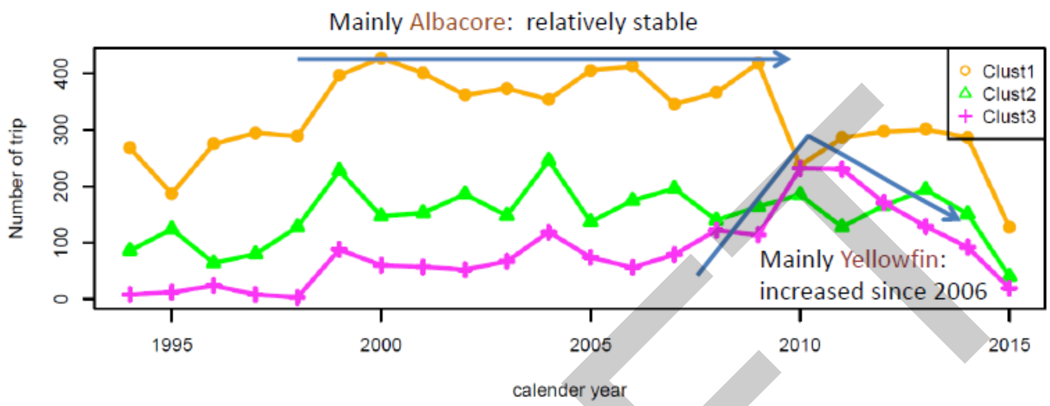
- In total 12,194 fishing trips were divided into 3 groups.
- Sp. Compositions would show the targeting of these trips.



6:

Results of cluster analysis:

- Yearly change of number of fishing trips in each cluster shows the change of behaviors of LL fishery.



- The cluster results would reflect the target shift.

7:

Revised ZINB model:

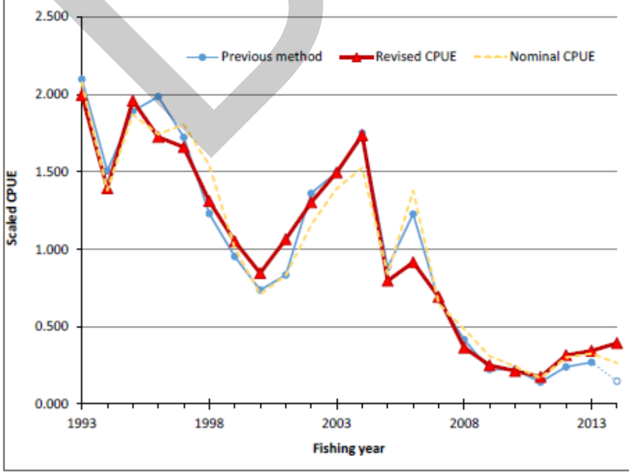
[Best model] (df=141, BIC=50587.76)

Count model:

Log(μ) = intercept + Year + Day10 + Area + Ship-size + Days-per-trip + Movement + Cluster + Year*Area + Area*Ship-size + Day10*Area + Area*Cluster + error term,

Zero-inflation model:

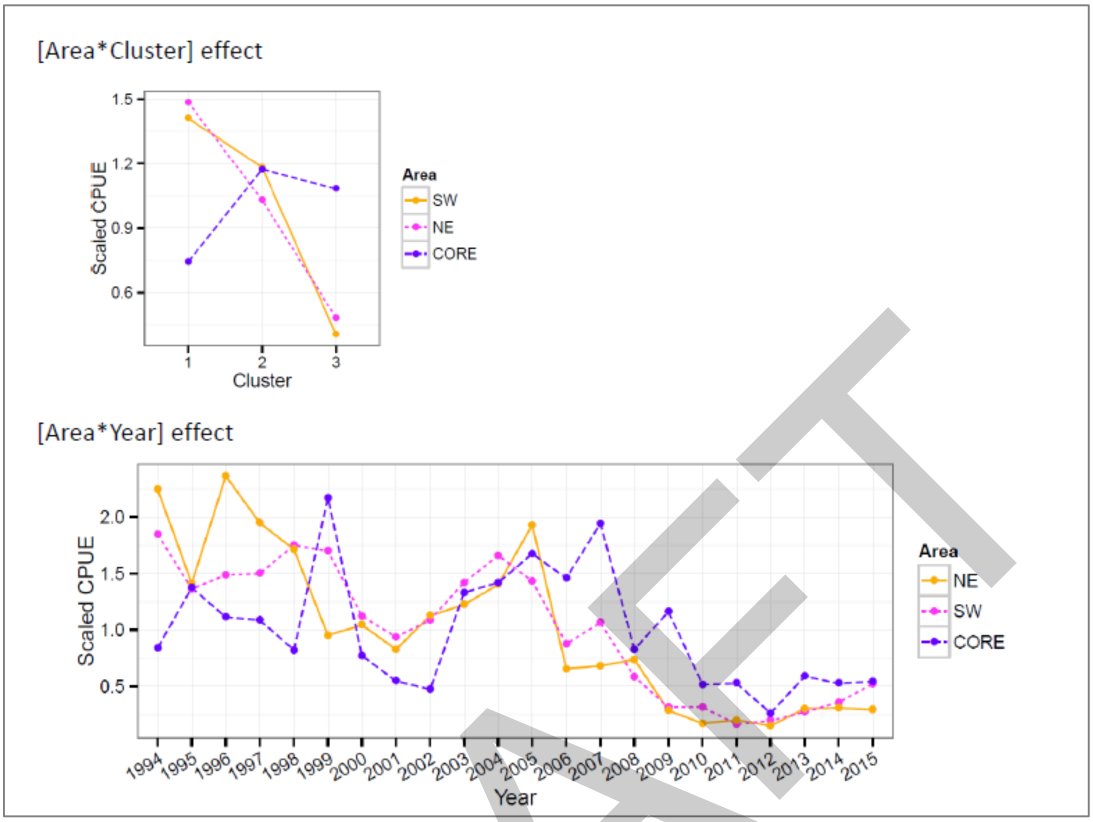
Logit(p) = intercept + Year + Day10 + Area + Ship-size + Days-per-trip + Cluster + Ship-size*Cluster + error term



A large fluctuation in 2005-2008 was reduced.

Result of latest year is provisional because of the small data size.

8:



9:

Note:

The number of the data in most recent year is still small, thus the updated result in this presentation is provisional...

Calender year	Fishing year	N of trip	N of hooks (x1000 hooks)	N of PBF catch	Nominal CPUE	Nominal CPUE (normalized)
		Data set used for this analysis				
1994	1993	362	5275	2899	0.550	2.078
1995	1994	323	4679	1710	0.365	1.381
1996	1995	363	5180	2561	0.494	1.869
1997	1996	383	5477	2526	0.461	1.744
1998	1997	420	6307	3010	0.477	1.804
1999	1998	713	9866	4028	0.408	1.543
2000	1999	635	8871	2366	0.267	1.008
2001	2000	611	10002	1878	0.188	0.710
2002	2001	600	9469	2080	0.220	0.830
2003	2002	589	8434	2585	0.306	1.159
2004	2003	719	10267	3783	0.368	1.393
2005	2004	617	9663	3897	0.403	1.525
2006	2005	644	9066	2013	0.222	0.839
2007	2006	621	8783	3202	0.365	1.378
2008	2007	628	9235	1579	0.171	0.646
2009	2008	697	11018	1412	0.128	0.484
2010	2009	654	9751	795	0.082	0.308
2011	2010	645	9202	590	0.064	0.242
2012	2011	634	9796	433	0.044	0.167
2013	2012	624	9973	792	0.079	0.300
2014	2013	530	8454	728	0.086	0.326
2015	2014	186	2916	204	0.070	0.264

The number of 2015 data-set is still about 30% of previous years.

10:

Summary:

- Cluster analysis was able to detect the target shift by fishing trip level, thus inclusion of cluster index in the CPUE standardization would be one of effective approach to address it.
- The best mode of ZINB selected by BIC includes the “Cluster” and interactions of “Area*Cluster”, which works adequately for the CPUE standardization.
- The number of the data in most recent year (Apr-Jun, 2015) is still small, thus we need to re-update this CPUE before upcoming stock assessment.