# Japanese coastal longline CPUE and catch-at-length for Pacific bluefin tuna: Update up to 2015 fishing year

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## Summary

Japanese coastal longline CPUE and catch-at-length were updated. The CPUE was standardized using the agreed procedure in the ISC PBFWG. In the standardization, the effect of target shift was addressed by the indicator from cluster analysis. The cluster indicator was based on the species composition except for PBF by fishing trip, and it was used for the explanatory variable of the standardization model. Zero inflated negative binomial (ZINB) model was applied as the model to standardize the CPUE which was based on the aggregated data in fishing trip resolution. The final model selected by the Bayesian information criterion (BIC) included the main effect and some 1$^{st}$ order interactions of cluster indicator. The standardized CPUE showed a consistent increase after 2011 fishing year. Catch-at-length indicated a new mode of smaller fish in the catch since 2014 fishing year. These are positive information for the adult stock population of PBF.

## Introduction

The ISC agreed future assessment schedule for Pacific bluefin tuna (PBF) in the plenary meeting in 2016 (ISC16): Every four years a “benchmark” assessment will be conducted, and “update” assessment will be planned in the second intervening year. In addition, it was agreed that the trend of stock abundance indices should be checked if anything unexpected is happening in the intermediate years (ISC 2016a). In 2017, ISC PBF working group does not plan the assessment work, and need to review the abundance indices.

Japanese longline CPUE is one of important monitoring indices for the adult population. This CPUE index has been used as the input data of PBF assessment model, as with Taiwanese longline CPUE and Japanese Troll CPUE (ISC 2016b). Because of the change of operational patterns of Japanese longliners, the CPUE has been split up into three time-series; fishing year 1952-1973 (Fujioka et al. 2012), 1974-1992 (Yokawa 2008), and after 1993. Current CPUE series (after 1993) is standardized using zero inflated negative binomial (ZINB) model, including the indicator from cluster analysis as an explanatory variable (Sakai et al. 2016). The cluster indicator is based on the catch composition by species (except for PBF) in each fishing trip, which can address the effect of target shift of this fishery. The ZINB model was applied as the model to standardize the CPUE which was based on the aggregated data in fishing trip resolution. The approach using cluster analysis is a standard method for the CPUE analysis (e.g. He et al. 1997, McKechnie et al. 2014, Tremblay-Boyer et al. 2015).

This document presents a simple update of the current CPUE series using exactly the same calculation method as the one used for the stock assessment in 2016. To help translation of the longline catch information, we also update the catch-at-length data of Japanese longliners. Both the CPUE and catch-at-length are presented up to the 2015 fishing year (June 2016 calendar year).

## Materials and Methods

### 1) CPUE

### Data sources and filtering

Catch and effort data from logbooks of Japanese coastal longliners from 1994 to 2016 (calendar year) 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 date and location (latitude and longitude) of longline set, the number of hooks set, hook per basket (hpb), and the number of fish caught of various species were reported. The data were filtered through the following criteria described by the previous studies (Ichinokawa and Takeuchi 2012, Hiraoka et al. 2015a);

- April to June (spawning season);
- 1x1 degree grids in latitude and longitude where at least one PBF per year has been caught for more than 10 years.

We aggregated the data by trip level to use for the cluster analysis and standardization by ZINB method. The number of hooks and catches were added up, and location and hpb were calculated median values for each fishing trip. In accordance with Hiraoka et al. (2015a) and Sakai et al. (2016), we divided the fishing location into three sub-areas (Fig. 1).

### Cluster analysis

Cluster analysis is generally 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). In this document, clustering was based on the relative number of key species except for PBF; the species composition in proportions of bigeye tuna (BET), yellowfin tuna (YFT), albacore (ALB) and other fishes (billfish and shark species). We used a hierarchical clustering using Ward's method (Ward 1963) on Euclidean distance. The analysis was conducted using algorithm of "hclust" (available in R package "stats") for R software ver. 3.2.5 (R Core Team 2016).

### Standardization of CPUE

The data used for standardization was trip resolution (Table 1). 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**: 23 calendar years, from 1994 to 2016 (1993 to 2015 fishing year);
- **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").
- **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).
- **Cluster**: Three clusters derived from the cluster analysis.

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

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

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.

The standardized CPUE was calculated from the 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. 3.2.5 (R Core Team 2016).

### 2) Catch at length

The catch-at-length of PBF which were caught by Japanese longliners were estimated using exactly the same method as proposed by Hiraoka et al. (2015b). In this method, the length frequency (fork length) was estimated by "number" of actual measured fish with relative "weight" for measured fish and total catch. When fish weight was not measured for the size measurement, the weight of measured fish was calculated from measured length using existing weight-length relationship (Kai 2007). The estimation method can be described by the following equations:

$$N_{iy} = \sum_{k=1}^{K} \left(n_{iykt} \times c_{ykt} / w_{iykt}\right)$$

where $N_{iy}$ is the fish at the length bin of $i$ occurred in the population at 2nd quarter of calendar year $y$. $K$ is the total number of special stratification. $n_{iykt}$ is the number of measured fish at the length bin of $i$ in prefecture stratum $k$ at time stratum $t$ for year $y$. $w_{iykt}$ is the weight of them. $c_{ykt}$ is the total catch weight in prefecture stratum $k$ at time stratum $t$ for year $y$. We used 6 groups as the prefecture strata (Miyagi, Chiba, Wakayama, Miyazaki, Okinawa, and Others). As the time stratum, quarter (1 stratum: only 2nd quarter of calendar year) was used. The size measurement data for longline is based on the "Research Project on Japanese bluefin tuna (RJB)" which has obtained at 13 main landing ports (7 prefectures).

## Results and Discussion

### Data and nominal CPUE

In total, 13,325 fishing trips are recorded in the data-set we used for the cluster analysis and CPUE standardization (Table 1). Of these, 351 records are the fishing trip in 2015 fishing year. This is about 45% decrease over the previous year (2014 fishing year). After 2009, the number of fishing trip is on a declining trend. Nominal CPUE of this data-set had also been on declining trend since 2007 and hit a record low (0.045) in 2011 fishing year. In most recent year (2015 fishing year), the nominal CPUE increased to 0.119, which is the level of 2008 fishing year (0.125).

### Cluster analysis

The cluster analysis divided the fishing trips into three groups (Table 2, Fig. 2). Species compositions of Cluster 1 and 3 showed that they generally represent targeting ALB (80.4%) and YFT (82.4%), respectively. In Cluster 2, the highest proportion was “Other” species (44.0%).

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 2005 fishing year, reached a peak in 2009 fishing year, and then decreased. Meanwhile, those of Cluster 1 (targeting ALB) dropped in 2009 fishing year. Those of Cluster 2, which have high proportion of “Other” species, were relatively stable. These trends would reflect the change of targeting of the longline fishermen after 2005, which was pointed out by Oshima et al. (2012).

### CPUE standardization

We selected “Final model” including main effects and 1$^{st}$ order interactions using BIC (BIC=53343.06);

**[Final model]**

(Count model)

Log(μ) = intercept + Year + Day10 + Area + Gear + Days-per-trip + Movement + Cluster + Year*Area + 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

Selected explanatory variables and 1$^{st}$ order interactions were different from previous model used for the 2016 assessment; “Gear” was selected instead of “Ship-size” and “Area*Ship-size” in count model. The final model had the interaction effects between Year and Area, thus the area weighting value was estimated as the standardized CPUE. The standardized CPUE has a similar trend with that from nominal CPUE, but a large fluctuation in 2005-2008 calendar year was reduced (Fig. 4). After 2011 fishing year, the values were consistently increasing.

Fig. 5 shows the effect of each explanatory variable in the final model. Year*Area interaction has impact on the yearly trend for standardized CPUE (Fig. 5-(1)). Area*Cluster and Ship-size*Cluster interactions mean the different impact of targeting by areas and ship-size, respectively (Fig. 5-(3) and 5-(4)). The Pearson residual patterns are not distinctly different among years (Fig. 6).

### Catch-at-length

Estimated catch-at-length data shows that the main part of the Japanese coastal longline catch has been constituted by some strong cohorts (e.g. 1990, and 1994 year classes), but these catches has not been composed of only a single cohort (Fig. 7). In 2015 fishing year, the main size of PBF caught by Japanese coastal longliners were 194-218 cm FL which would be 2007 and/or 2008 year classes—these year classes have been seen since 2011. In addition, the length frequencies indicate a new mode of smaller fish in the catch since 2014 fishing year (between 170 and 182 cm FL in 2015 fishing year, which could be 2010 and/or 2011 year class).

### Conclusion

Current slight increase trend of the standardized CPUE has been found since 2011 fishing year. Current strong cohorts (2007 and/or 2008 year classes) also have been caught by longliners since 2011 fishing year, and then, there are new recruitments of small fish into the longline catch after 2014 fishing year. These are positive information for the PBF stock: it would mean that the strong cohorts are still remaining, new cohorts are coming, and as the result, the adult population is recovering gradually.

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**Table 1** Total number of fishing trips, hooks, PBF catch, nominal CPUE, and standardized CPUE for "Final model" of ZINB. Data set was based on logbook from Japanese coastal longliner in 2nd quarter (April-June) of 1994-2016 calendar year (1993-2015 fishing year).

| Calender year | Fishing year | Data set used for this analysis | | | | | Standardized by Zero-inflated negative binomial model | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N of trip | N of hooks (x1000 hooks) | N of PBF catch | Nominal CPUE | Nominal CPUE (scaled) | Standardized CPUE | Standardized CPUE (scaled) | CV |
| 1994 | 1993 | 362 | 5275 | 2899 | 0.550 | 2.161 | 0.451 | 2.235 | 0.035 |
| 1995 | 1994 | 323 | 4679 | 1710 | 0.365 | 1.437 | 0.292 | 1.447 | 0.035 |
| 1996 | 1995 | 363 | 5180 | 2561 | 0.494 | 1.944 | 0.454 | 2.251 | 0.031 |
| 1997 | 1996 | 383 | 5477 | 2526 | 0.461 | 1.813 | 0.393 | 1.944 | 0.031 |
| 1998 | 1997 | 420 | 6307 | 3010 | 0.477 | 1.876 | 0.355 | 1.758 | 0.033 |
| 1999 | 1998 | 713 | 9866 | 4028 | 0.408 | 1.605 | 0.263 | 1.303 | 0.035 |
| 2000 | 1999 | 635 | 8871 | 2366 | 0.267 | 1.049 | 0.234 | 1.159 | 0.032 |
| 2001 | 2000 | 611 | 10002 | 1878 | 0.188 | 0.738 | 0.165 | 0.819 | 0.023 |
| 2002 | 2001 | 637 | 10184 | 2146 | 0.211 | 0.828 | 0.190 | 0.942 | 0.026 |
| 2003 | 2002 | 666 | 10080 | 2816 | 0.279 | 1.098 | 0.254 | 1.256 | 0.023 |
| 2004 | 2003 | 729 | 10493 | 3798 | 0.362 | 1.423 | 0.305 | 1.508 | 0.029 |
| 2005 | 2004 | 636 | 10046 | 3975 | 0.396 | 1.556 | 0.347 | 1.721 | 0.022 |
| 2006 | 2005 | 662 | 9451 | 2055 | 0.217 | 0.855 | 0.162 | 0.802 | 0.030 |
| 2007 | 2006 | 638 | 9164 | 3218 | 0.351 | 1.380 | 0.175 | 0.865 | 0.034 |
| 2008 | 2007 | 660 | 9810 | 1632 | 0.166 | 0.654 | 0.134 | 0.663 | 0.031 |
| 2009 | 2008 | 737 | 11816 | 1472 | 0.125 | 0.490 | 0.070 | 0.349 | 0.087 |
| 2010 | 2009 | 702 | 10932 | 804 | 0.074 | 0.289 | 0.042 | 0.207 | 0.064 |
| 2011 | 2010 | 672 | 9892 | 642 | 0.065 | 0.255 | 0.046 | 0.228 | 0.093 |
| 2012 | 2011 | 673 | 10869 | 486 | 0.045 | 0.176 | 0.037 | 0.184 | 0.073 |
| 2013 | 2012 | 635 | 10213 | 803 | 0.079 | 0.309 | 0.057 | 0.283 | 0.041 |
| 2014 | 2013 | 573 | 9492 | 756 | 0.080 | 0.313 | 0.060 | 0.297 | 0.040 |
| 2015 | 2014 | 544 | 8262 | 597 | 0.072 | 0.284 | 0.068 | 0.336 | 0.043 |
| 2016 | 2015 | 351 | 5517 | 657 | 0.119 | 0.468 | 0.089 | 0.442 | 0.057 |

**Table 2** Species composition and number of fishing trip by each cluster.

| | Cluster | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Yellowfin tuna | 4.7% | 36.4% | 82.4% |
| Albacore | 80.4% | 17.8% | 4.1% |
| Bigeye tuna | 7.6% | 1.7% | 0.7% |
| Other species | 7.2% | 44.0% | 12.8% |
| Number of fishing trip | 7,653 | 3,472 | 2,200 |

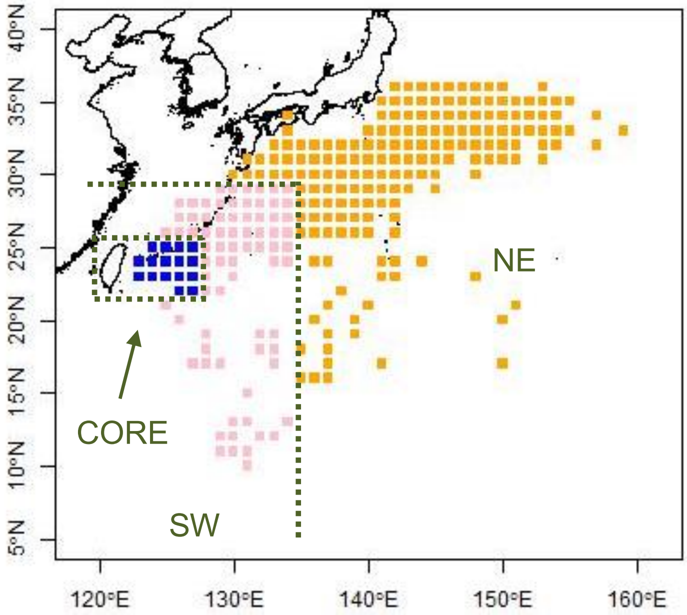


**Fig. 1** Area definition for the analysis. The area surrounded by the dotted line represents the fishing area selected for the standardization of CPUE according to Hiraoka et al. (2015a). "CORE" area was defined by Oshima et al (2012) as the higher CPUE area for PBF.

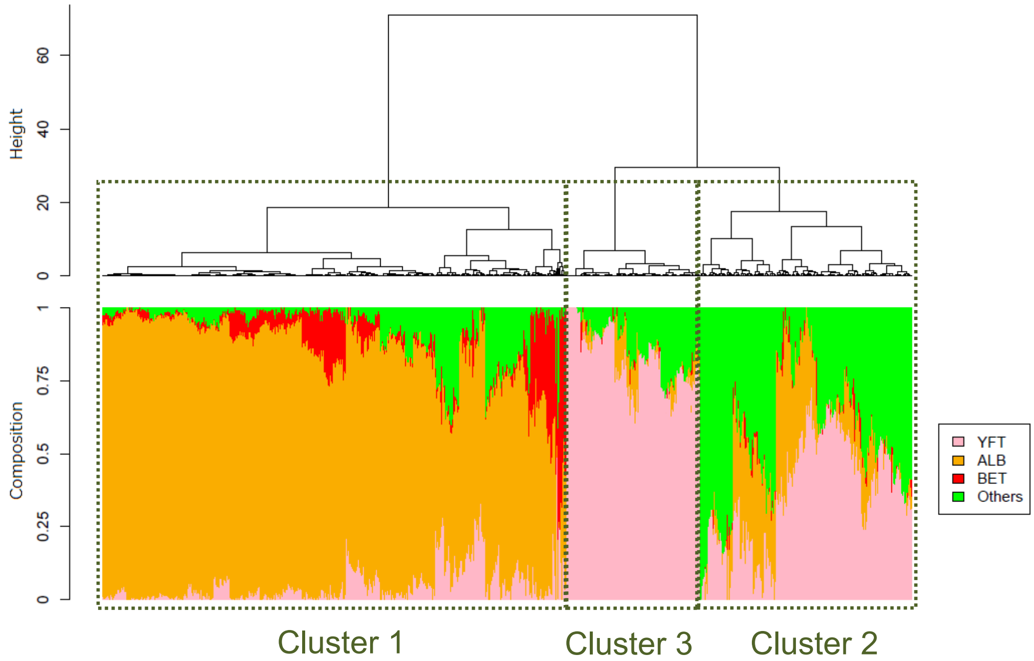


**Fig. 2** Result of cluster analysis (Word's methods). Upper panel shows the dendrogram obtained by cluster analysis and the lower panel shows the species composition by fishing trip corresponding to each cluster.

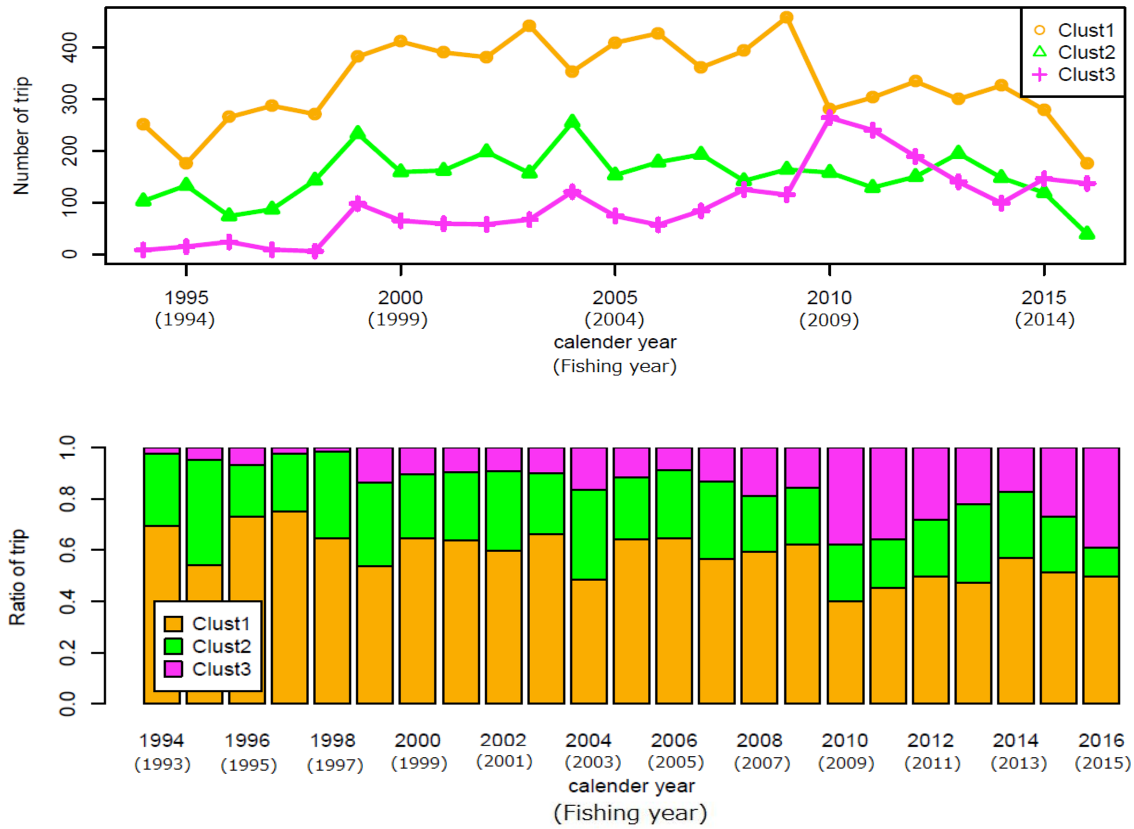


**Fig. 3** Yearly change of the number and ratio of fishing trip grouped in each cluster.

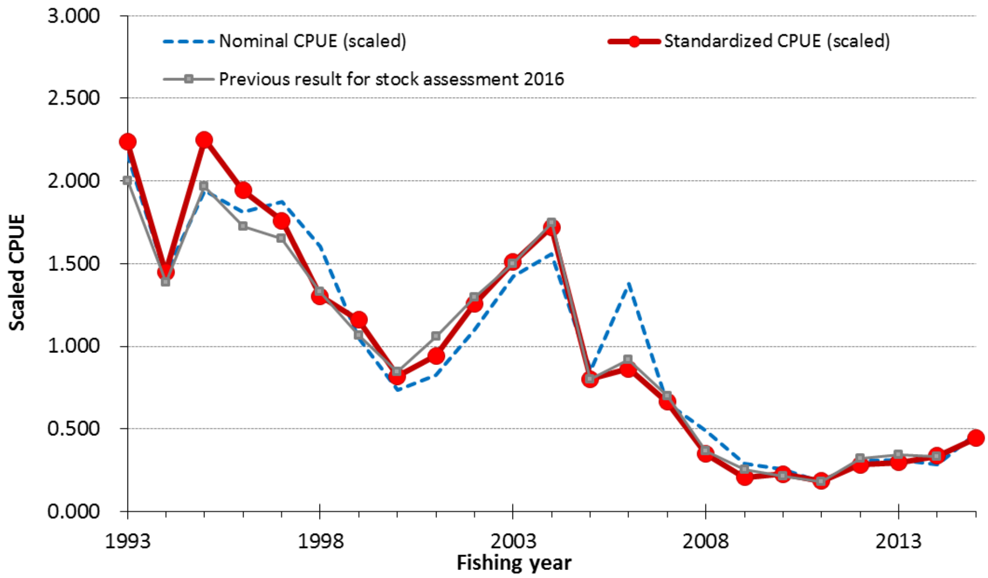


**Fig. 4** Scaled standardized CPUE and nominal CPUE. Red and gray lines indicate the result of updated standardized series and previous series for the stock assessment in 2016, respectively. Dotted lines show the nominal CPUE.

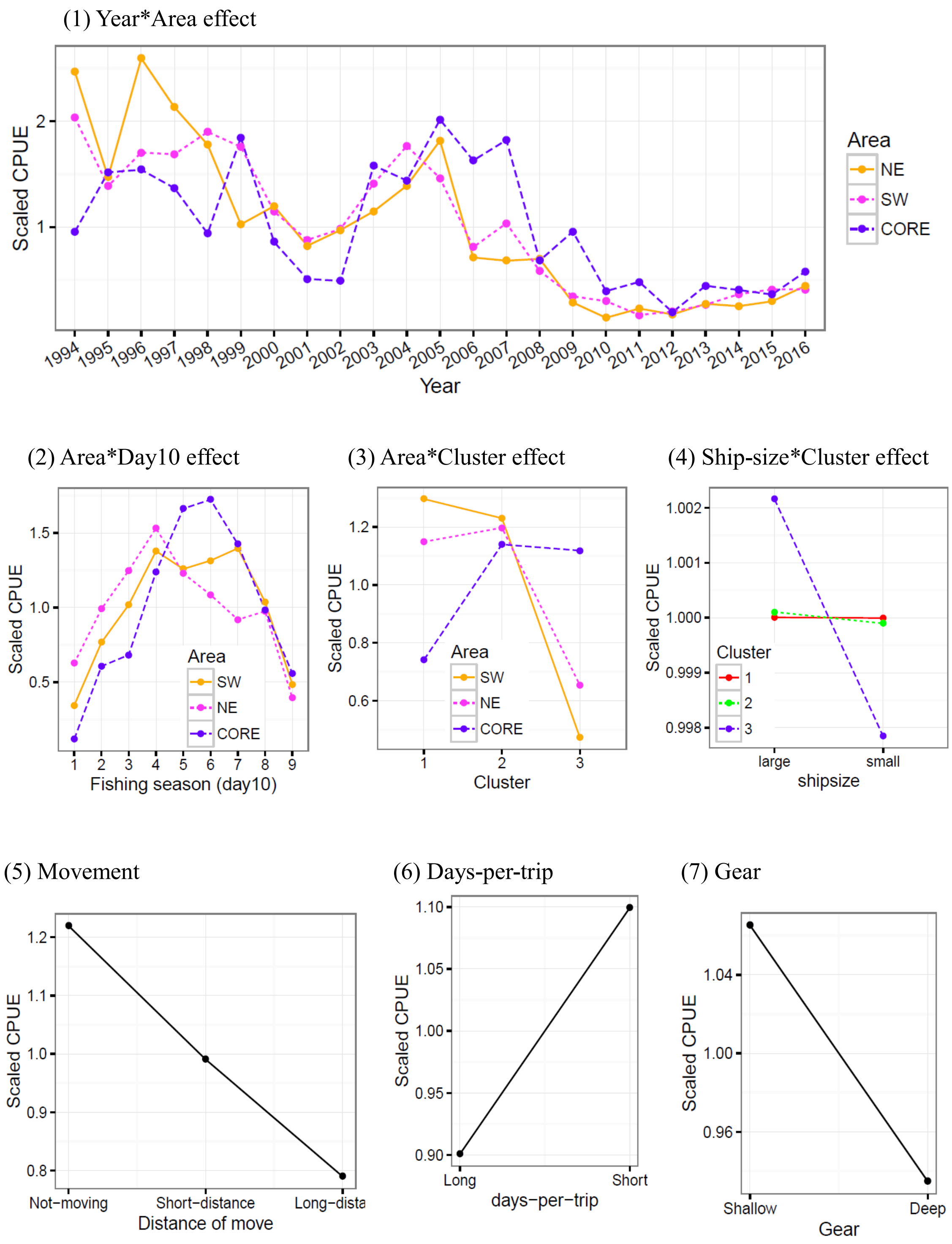


**Fig. 5** Least squared means for each effect estimated by "Final model".

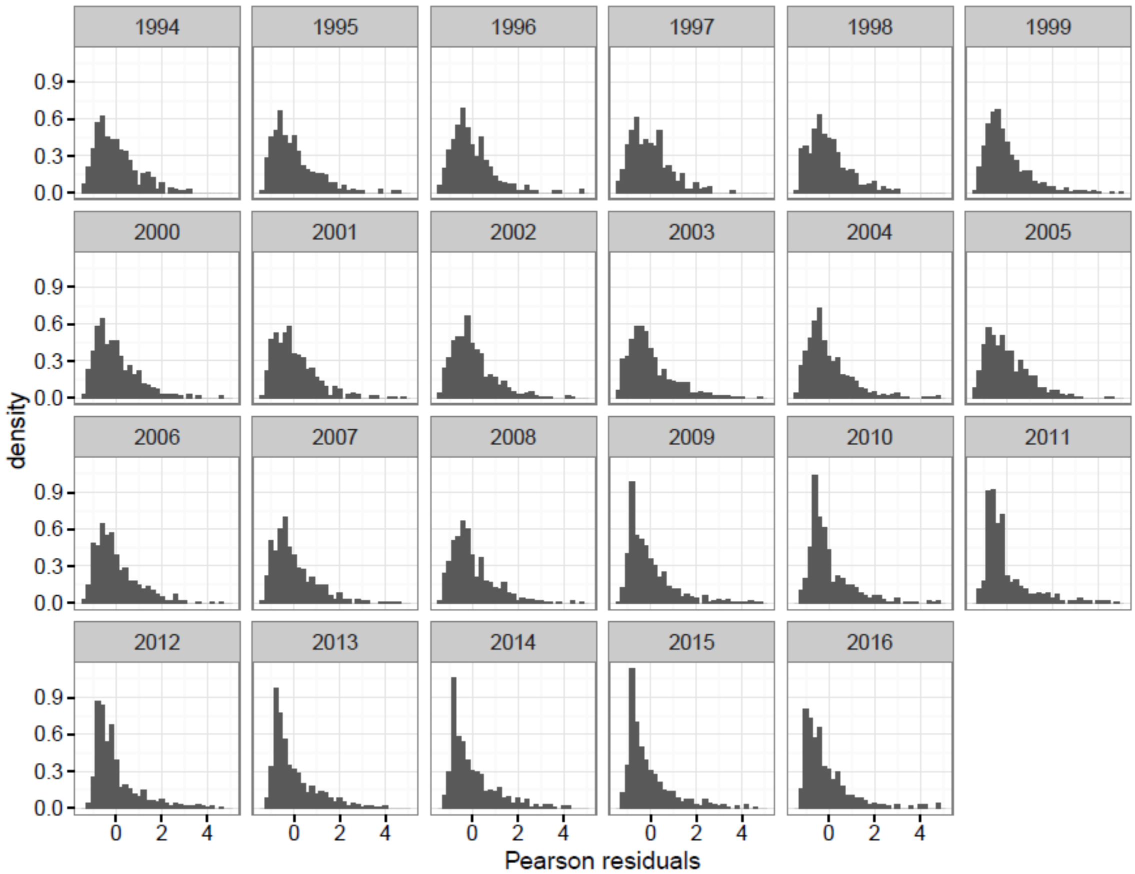


**Fig. 6** Pearson residual distribution for ZINB for "Final model" by year.

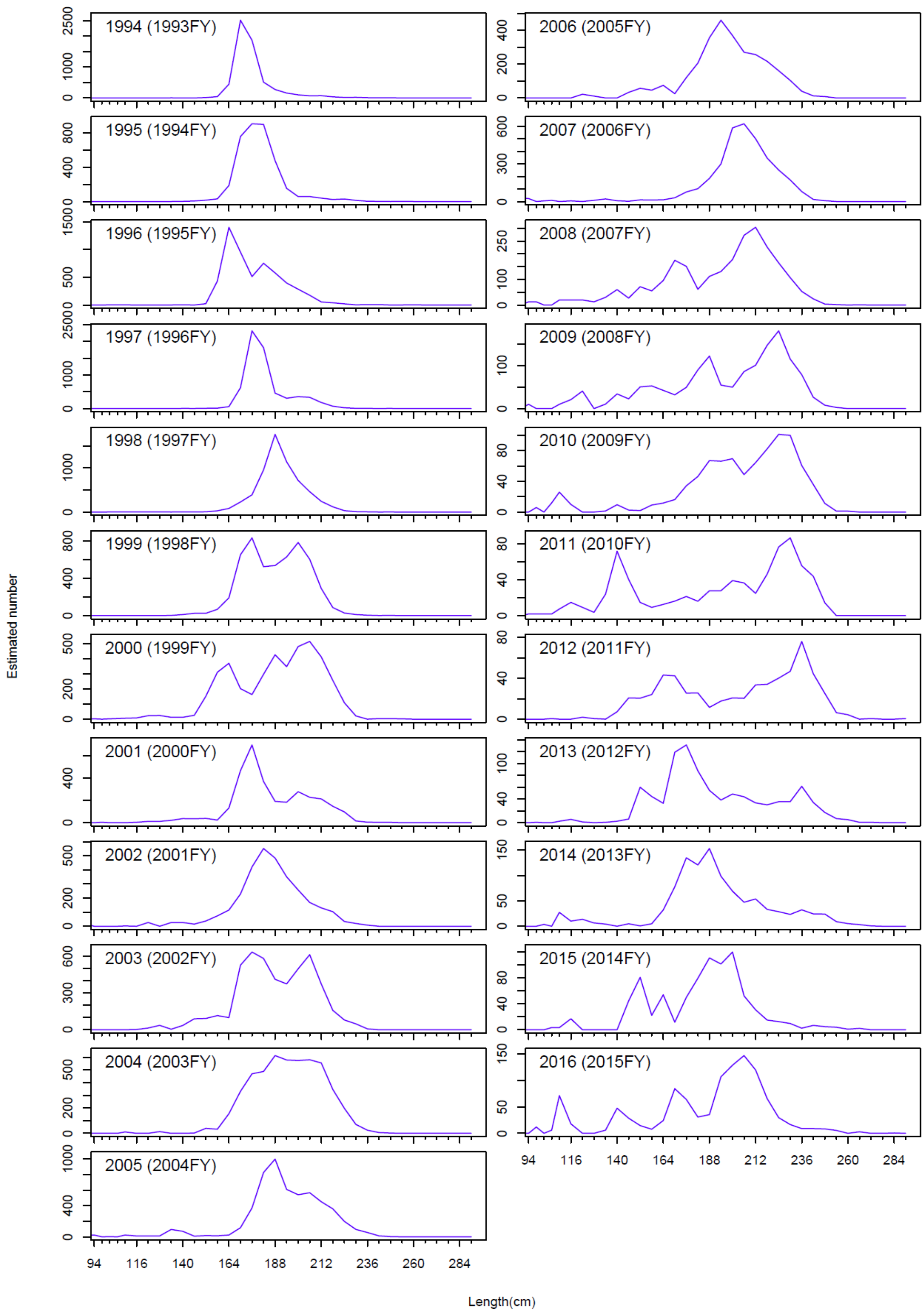


**Fig. 7** Estimated catch-at-size of PBF caught by Japanese coastal longliners in 2nd quarter of calendar year.