Japanese coastal longline CPUE for Pacific bluefin tuna: Re-update up to 2014 fishing year for stock assessment

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Summary

Japanese coastal longline CPUE was re-updated. The CPUE was standardized using the agreed procedure in the November meeting of ISC PBFWG. In the standardization, the effect of target shift was addressed by the indicator from cluster analysis. 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. This analysis was conducted using sufficient data-set including re-updated 2014 fishing year data.

Introduction

Target shift of Japanese longline was one of the pending issues to be solved. The effect of target shift could not be adequately addressed at the standardization of the previous Catch per Unit Effort (CPUE) series (Oshima et al. 2012) of Pacific bluefin tuna (PBF) by the Japanese coastal longliner. Thus the higher CPUE CV was inputted after 2005 at the stock assessment in 2014 for this CPUE series: a liner ramp of increasing CV in the index from 2005 (0.24) to 2010 (0.43) and constant (0.43) thereafter (ISC 2014). The ISC PBF working group suggested the application of zero inflated negative binomial (ZINB) model to improve the CPUE standardization (ISC 2012). Because of this situation, a new approach for the standardization has been developed during the intersessional workshops of ISC PBF working group in April and November, 2015 (Hiraoka et al. 2015, Sakai et al. 2015, ISC 2015a, ISC 2015b).

In the new approach for the CPUE standardization, the effect of target shift was addressed by the indicator from cluster analysis. 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. 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). The ISC PBF working group discussed this new approach and approved after some modification in the data filtering and clustering method (ISC 2015b).

This document presents a final update of the CPUE using the approved standardized method for the upcoming stock assessment. In the previous update of this CPUE conducted by Sakai et al. (2015), there was only a small number of data-set in most recent year (2015 calendar year = 2014 fishing year); about 30% of the previous year in fishing effort (hooks). For this re-update, we added 262 fishing trips in the data-set for most recent year.

Materials and Methods

Data sources and filtering

Catch and effort data from logbooks of Japanese coastal longliners 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 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 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. The number of hooks and catches were added up, and location and hpb were calculated median values for each fishing trip. According to Hiraoka et al. (2015) and Sakai et al. (2015), 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 the "ward.D" algorithm of "hclust" (available in R package "stats") for R software ver. 3.2.1 (R Core Team 2015).

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**: 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").
- **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. 3.2.1 (R Core Team 2015).

Results and Discussion

Data and nominal CPUE

In total, 12460 fishing trips are recorded in the data-set we used for the cluster analysis and CPUE standardization (Table 1). Of these, 448 records are the fishing trip in 2014 fishing year. This is about 15% decrease over the previous year (2013 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 (0.044) in 2011 fishing year. In 2013-2015, it is moving around 0.076-0.086, which is the level of 2009 fishing year (0.082).

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 (80.1%) and YFT (79.9%), respectively. In Cluster 2, the highest proportion was "Other" species (47.2%).

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) were drop down 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

For a new method using ZINB, we selected "Final model" including main effects and 1st order interactions using BIC (BIC=51270.78);

[Final 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 + Cluster + Ship-size*Cluster + error term

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). There is an opposite trend in the most recent year compared with the tentative result in November meeting. This would be because the tentative result in November was based on the limited data-set in the most recent year.

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 interaction means the different impact of targeting by areas (Fig. 5-(4)). These factors work to reduce the large fluctuation of the CPUE in 2005-2008 calendar years which was shown in the nominal CPUE. The Pearson residual patterns are not distinctly different among these models (Fig. 6).

The analyses undertaken here address the target shift for the standardization of the Japanese coastal longline CPUE. The cluster approach without PBF data was able to detect the target shift by fishing trip level, and the “Final model” of ZINB selected by BIC included the “Cluster” variable. This analysis was conducted using the sufficient data-set including re-updated 2014 fishing year data.

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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 1994-2015 calendar year (1993-2014 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	2.075	4.725	1.999	0.029
1995	1994	323	4679	1710	0.365	1.380	3.282	1.389	0.033
1996	1995	363	5180	2561	0.494	1.867	4.647	1.966	0.033
1997	1996	383	5477	2526	0.461	1.742	4.073	1.723	0.032
1998	1997	420	6307	3010	0.477	1.802	3.901	1.650	0.032
1999	1998	713	9866	4028	0.408	1.542	3.149	1.332	0.033
2000	1999	635	8871	2366	0.267	1.007	2.516	1.065	0.036
2001	2000	611	10002	1878	0.188	0.709	1.997	0.845	0.021
2002	2001	600	9469	2080	0.220	0.829	2.502	1.059	0.024
2003	2002	589	8434	2585	0.306	1.157	3.064	1.296	0.027
2004	2003	719	10267	3783	0.368	1.391	3.543	1.499	0.024
2005	2004	617	9663	3897	0.403	1.523	4.135	1.749	0.022
2006	2005	644	9066	2013	0.222	0.838	1.896	0.802	0.030
2007	2006	621	8783	3202	0.365	1.377	2.171	0.919	0.034
2008	2007	628	9235	1579	0.171	0.646	1.651	0.698	0.037
2009	2008	697	11018	1412	0.128	0.484	0.870	0.368	0.074
2010	2009	654	9751	795	0.082	0.308	0.606	0.256	0.058
2011	2010	645	9202	590	0.064	0.242	0.500	0.212	0.097
2012	2011	634	9796	433	0.044	0.167	0.422	0.178	0.059
2013	2012	624	9973	792	0.079	0.300	0.757	0.320	0.044
2014	2013	530	8454	728	0.086	0.325	0.812	0.344	0.038
2015	2014	448	6453	492	0.076	0.288	0.783	0.331	0.054

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

	Cluster		
	1	2	3
Yellowfin tuna	5.2%	34.5%	79.9%
Albacore	80.1%	16.6%	5.4%
Bigeye tuna	6.6%	1.7%	0.8%
Other species	8.1%	47.2%	14.0%
Number of fishing trip	7,140	2,967	2,353

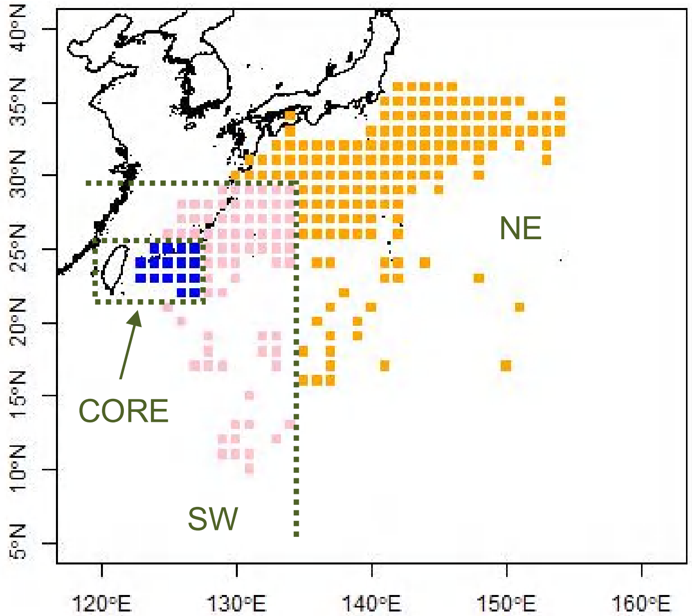

Fig. 1 Area definition for the analysis. The area surrounded by the dotted line represents the fishing area selected for the standardization of CPUE according to Hiraoka et al. (2015). "CORE" area was defined by Oshima et al (2012) as the higher CPUE area for PBF.

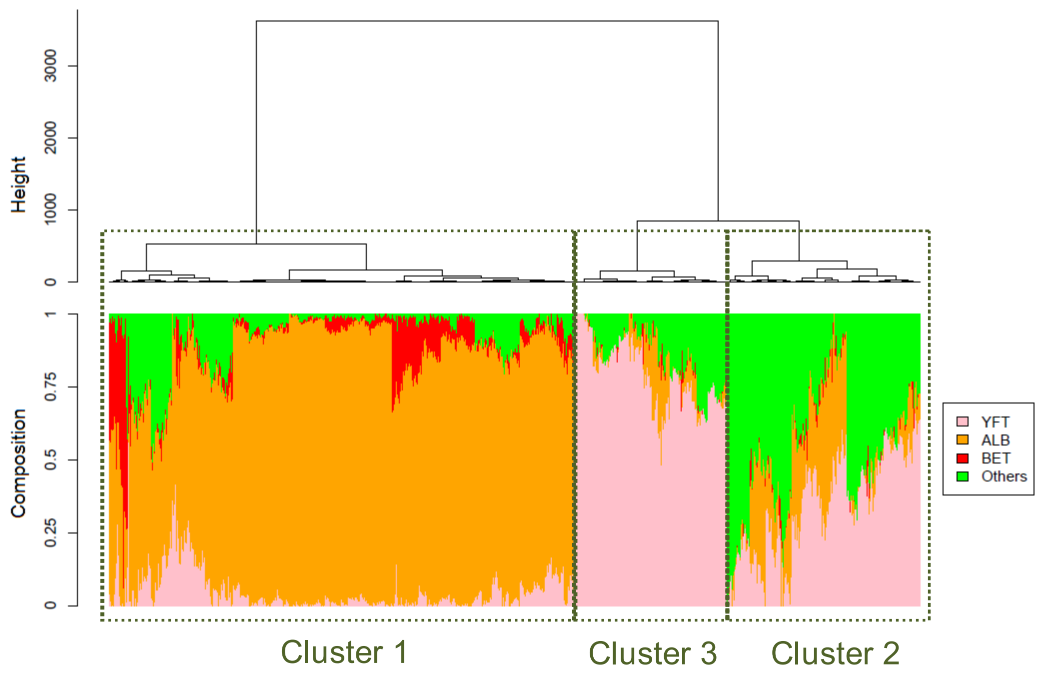

Fig. 2 Result of cluster analysis (Word's methods). Upper panel shows the dendrogram obtained by cluster analysis and the lower panel shows the species composition by fishing trip corresponding to each cluster.

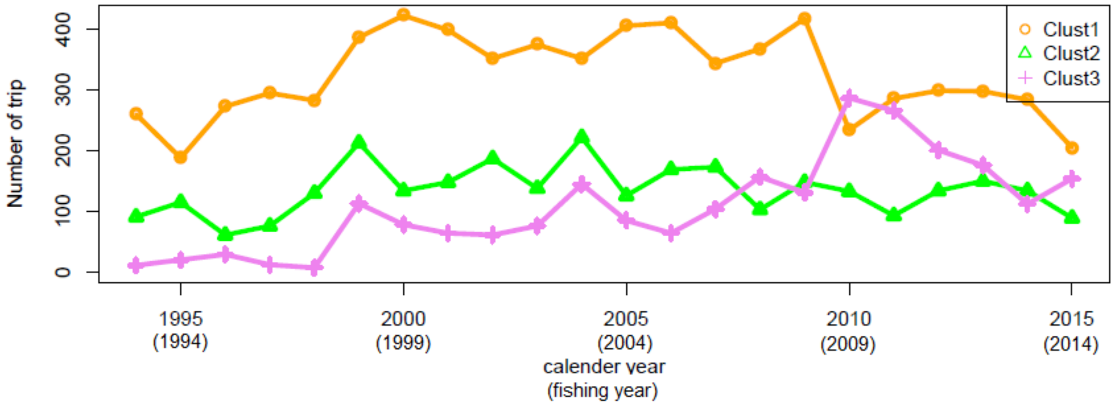

Fig. 3 Yearly change of the number of fishing trip grouped in each cluster.

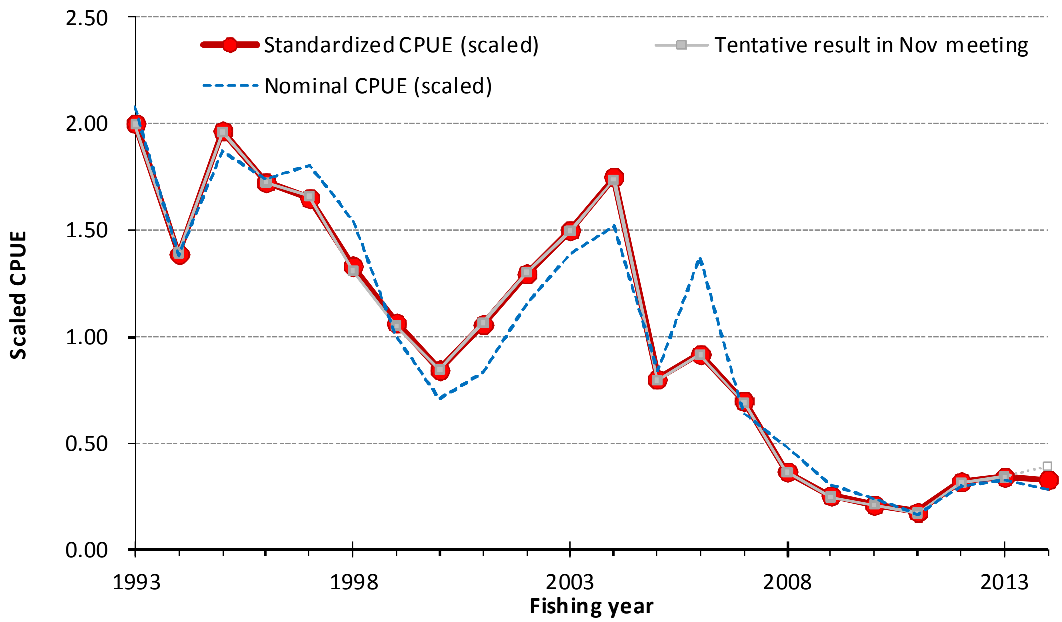

Fig. 4 Scaled standardized CPUE and nominal CPUE. Red and gray lines indicate the result of re-updated standardized series and previous series shown in November meeting (tentative result based on limited data-set), respectively. Dotted lines show the nominal CPUE.

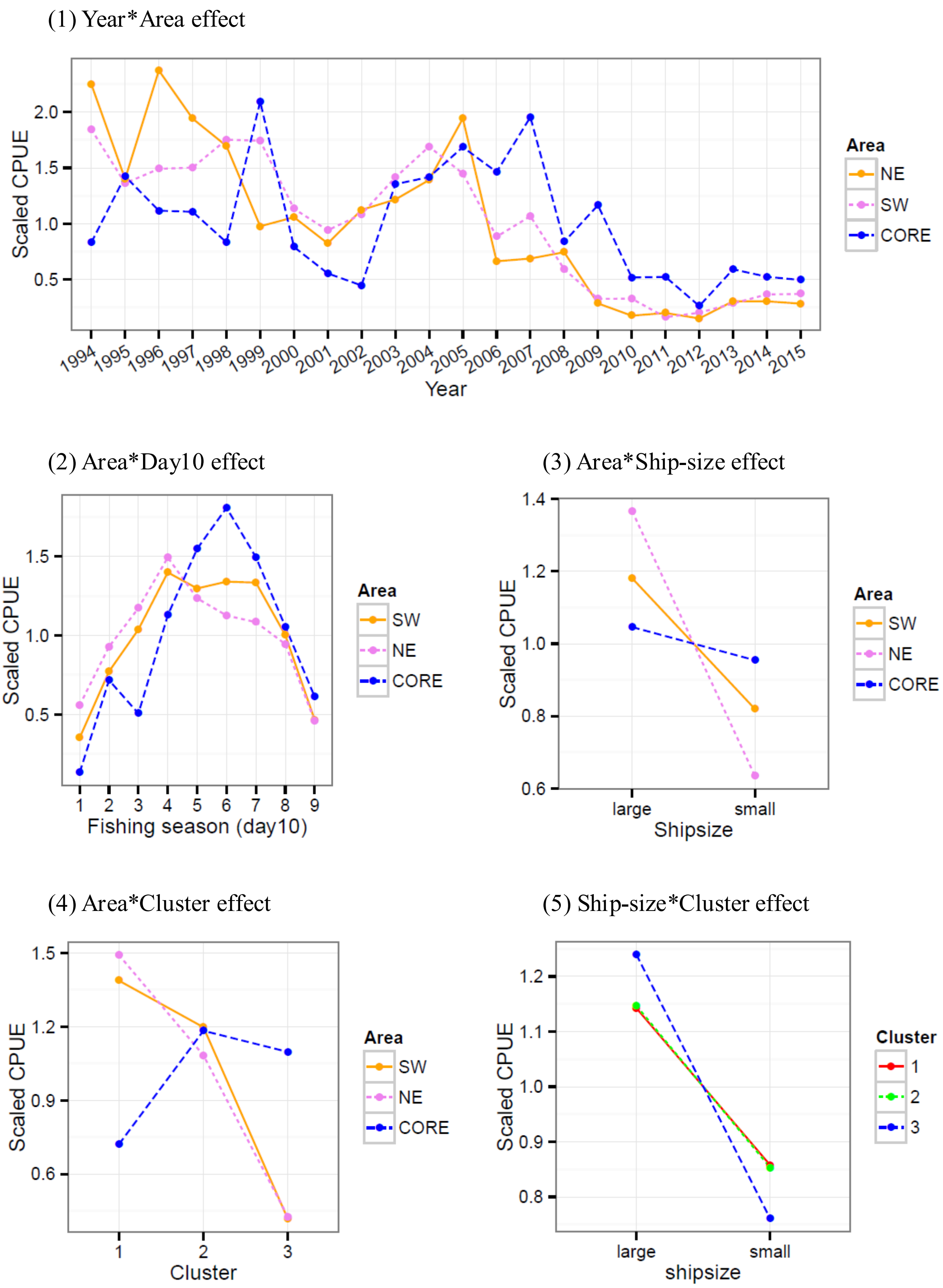

Fig. 5 Least squared means for each effect estimated by “Final model”.

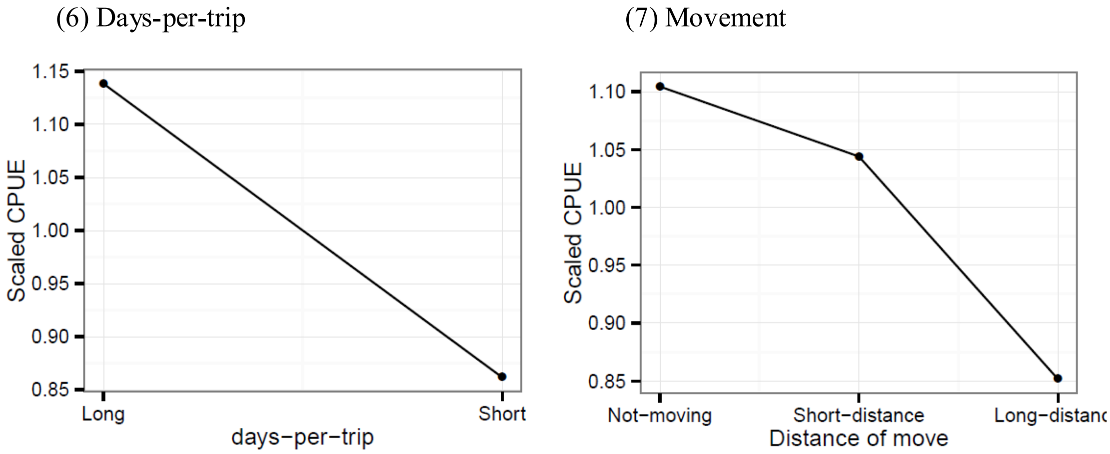

Fig. 5 Cont.

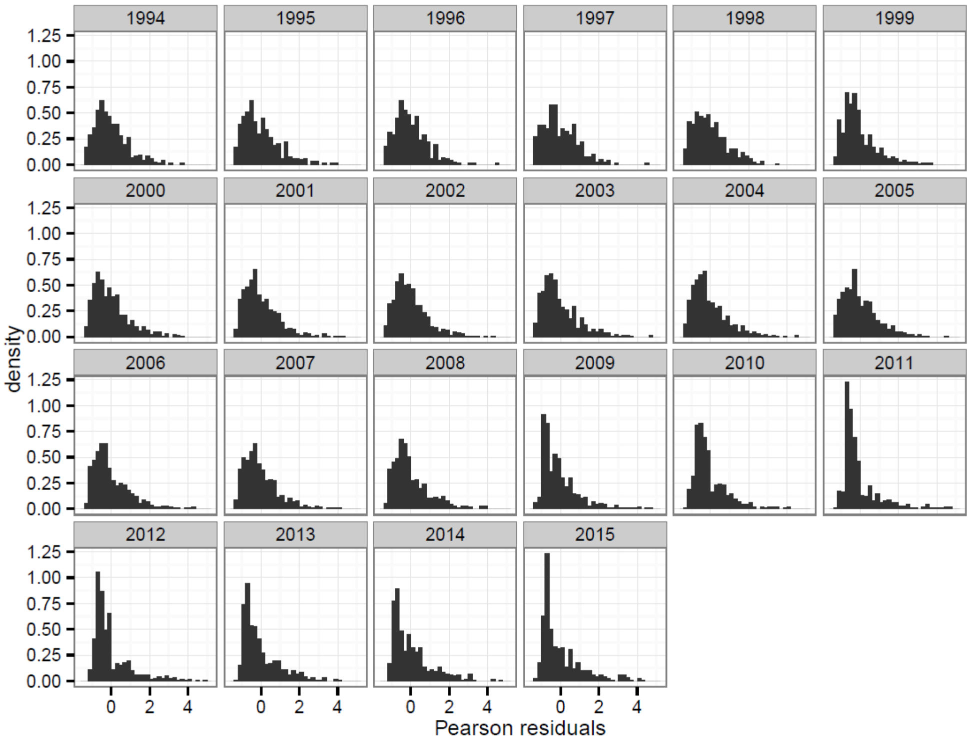

Fig. 6 Pearson residual distribution for ZINB for “Final model” by year.