Japanese coastal longline CPUE for Pacific bluefin tuna: Preliminary update up to 2018 fishing year

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November 2019

Working document submitted to the ISC Pacific bluefin tuna Working Group, International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC), from 18 to 23 November 2019, La Jolla, CA, USA.

Summary

Japanese coastal longline CPUE was updated up to 2018 fishing year. The CPUE was standardized by the best model based on Bayesian Information Criteria using the updated dataset until June 2019 in the same procedure used for the previous stock assessment in February 2016 and March 2018, which is called simple update hereinafter. There were the periods of bans on catch for PBFs in the last two years during main fishing season due to fishery management for Pacific bluefin tuna in Japan. The result showed that the values of nominal CPUE during whole main fishing season in 2017 and 2018 fishing year were lower than those excluding data during the period of the ban. This paper, therefore, also presents an ad-hoc CPUE estimated by excluding data in accordance with bans in 2017 and 2018 fishing year. This result showed a different trend from simply updated one only in 2017 fishing year, and a consistent trend in the other years, continuously increasing from 2011 fishing year. The CPUE standardized by the ad-hoc update would be relatively representative for the abundance index of adult PBFs rather than the CPUE standardized by simple update because of the smoothness of recent trend and the fit to historical values, although both of these approaches have some issues.

Introduction

Catch per unit effort (CPUE) is a relative abundance index, which is commonly used to draw inferences about fish population dynamics (Pope et al. 2010). For Pacific bluefin tuna (PBF) assessment, some series of longline CPUE has been used as important monitoring indices for the adult population; Japanese longline CPUE and Taiwanese longline CPUE (ISC 2016, ISC 2018).

Because of the changes of operational patterns of Japanese longliners, the CPUE was split into three time-series; fishing year (FY) 1952-1973 (Fujioka et al. 2012), 1974-1992 (Yokawa 2008), and after 1993. The current CPUE series (after 1993) used since 2016 assessment has been standardized by zero inflated negative binomial (ZINB) model (Sakai et al. 2016, Tsukahara et al. 2019). The ZINB model was applied to standardize the CPUE which was based on the aggregated data in fishing trip resolution. The cluster indicator in the current model as explanatory variable is based on the catch composition by species, except for PBF, in each fishing trip, which could represent the target shift of this fishery. Although the approach using cluster analysis is a common method for the CPUE analysis (e.g. He et al. 1997, McKechnie et al. 2014, Tremblay-Boyer et al. 2015), it was found that the clustering algorithms could be the cause for retrospective change of standardized CPUE (ISC 2017).

In Japan, the domestic regulation for adult PBF, greater than 30kg, based on the fishery management which was adopted in the Western and Central Pacific Fisheries Commission (WCPFC) since 2015 FY has started. In 2017 and 2018 FY, the great part of longliners stopped their landings of PBF during main fishing season of each year because their catch amount almost reached their own quota. Additionally, only in 2018 FY, they resumed the landings at the later of the season in accordance with the additional quota from reservation quota. These artificially imposed bans of landings of PBF led to disturbance of fishing information and misinterpretation of indices estimated from the information. It is therefore necessary to investigate the influence of the fishery regulations on the standardization of CPUE.

The purpose of this document is to show the abundance indices for the adult PBF, preliminarily updated on the basis of the latest fishery information. This document presents two kinds of updated CPUE series for detecting trends of adult PBF, following the previous approach (Tsukahara et al. 2019). One was using the same data filtering and procedure which were used for the previous stock assessment in 2018, hereinafter called “simple update”. The other was the same as the previous one, except that data in constraint period were filtered out from original data in 2017 and 2018 FY, which could be regarded as without regulation, hereinafter called “ad-hoc update”.

Materials and Methods

Data sources and filtering

Catch and effort data from logbooks of Japanese coastal longliners from 1993 to 2018 FY (1994-2019 calendar year) were used for the CPUE analysis. Note that logbook data in recent years has not been collected completely because of the delay in reporting and tallying process at this time. The dataset for standardized CPUE will be updated up until next March. The data resolution is originally set-by-set, and each contains individual records of fishing operation: location (latitude and longitude) of longline set, the number of hooks per set, hooks per basket (hpb), and the number of fish caught of various species. The set-by-set data were filtered through the following criteria described by the previous documents and were aggregated in each trip (Ichinokawa and Takeuchi 2012, Hiraoka et al. 2015);

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

The number of hooks and catches were added up, and median values of location and hpb were calculated for each fishing trip. In accordance with Hiraoka et al. (2015) and Sakai et al. (2016), we divided the fishing location into three sub-areas (“CORE”, “SW”, and “NE” area: Fig. 1). The definition of each area was described by Oshima et al. (2012): the “CORE” area is located around Nansei-islands which includes a major spawning ground of PBF (Suzuki et al. 2011), where higher CPUE of PBF tends to be observed compared to the other two areas. The border between “SW” and “NE” area was defined by Ichinokawa and Takeuchi (2012).

The present paper also investigates the impacts of domestic regulation due to the fishery management on this CPUE by longline in the fishing season of 2017 and 2018 FY. In 2017 FY, the catch amount by the nation-wide cooperative of longliners grew close to their annual catch quota at the middle of the main fishing season, then the longliners in the cooperatives refrained from landings since May 13th, 2018. In 2018 FY, they also stopped their operations after May 19th, 2019 for the same reason as 2017 FY. However, they restarted the operations on June 12th in accordance with the additionally allocated quota. These regulations would alter the nature of operation data because there was less information in analysis objectives only in 2017 and 2018 FY than information in the other years. A standardization as "ad-hoc update" was therefore conducted using the data from which the data during the regulation was active were removed (data from 13th May through 30th June 2018 and from 20th May through 11th June 2019 were excluded). This index can avoid the issues of apparent decline of CPUE due to the regulation, though it causes the difference in data periods between 2017, 2018 FY, and the others. In addition, a standardization as "simple update" was also conducted by using whole data of the period, from 1st April to 30th June, with following the same procedure as abundance index estimated for previous stock assessment in order to compare the results of each update.

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. 3.6.0 (R Core Team 2019).

Standardization of CPUE

The detail of two types of the data used for standardization are shown in Table 1. ZINB allows "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 two standardization models were determined for each update by exploration of "best model" which was selected by Bayesian Information Criteria (BIC). The candidate explanatory variables used in this analysis are as follows;

- **Year**: 26 years, from 1993 to 2018 FY;
- **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.1) 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 are zero, "Short distance": total distance is <300 miles, and "Long distance": total distance is ≥300 miles).
- **Cluster**: Three clusters derived from the cluster analysis.

The standardized CPUEs were defined as the least square means (LSMEANS) estimated in best models. The CV was calculated using bootstrapping about 1,000 times. The analysis was conducted using the "zeroinfl" algorithm (available in R package "pscl") for R software ver. 3.6.0 (R Core Team 2019).

Results and Discussion

Data and nominal CPUE

In total, 15,679 fishing trips were recorded in the dataset for "simple update", among which 234 trips, that occurred during the fishery bans of 2017 and 2018 FY, were excluded for "ad-hoc update" (Table 1). The sharp decline of number of fishing trips, being considered to be caused by the regulation, was continuous from 2016 FY, although the data in recent years, especially in the latest year, is being updated continuously. While the number of trips and hooks in 2018 FY decreased, the number of caught PBF increased in both "simple" and "ad-hoc" updates. This trend led both of the nominal CPUEs in 2018 FY increase rapidly, and these CPUEs were highest among recent years (Fig. 2). The nominal CPUEs of "ad-hoc update" in 2017 and 2018 FY were higher than those of "simple update" in each year, as a result of eliminating data during the periods of ban, when the nominal CPUEs of both years were quite low (crosses in Fig. 2).

Figures 3 and 4 (lower panels) show the changes of the geographical pattern of nominal CPUE during the period of the ban (right panel) or without regulation (left panel) in 2017 (Fig. 3) and 2018 (Fig. 4) FY. To compare with them, the spatial nominal CPUE of recent 3 years, when the suspension did not occur (2014-2016 FY), are also shown in Figures 3 and 4 (upper panels), with their fishing periods divided into 2 terms in accordance with the regulation of 2017 or 2018 FY. In both 2017 (Fig. 3) and 2018 (Fig. 4) FY when the suspension was introduced, spatial nominal CPUE during the suspension decreased remarkably from those during the period of non-suspension as well as from the same period of the non-suspension years (2014-2016 FY) especially at "core" area, where higher CPUE of PBF tends to be observed compared to the other areas. These differences are considered to be caused by the changes of spatial availability of PBF and operation strategy before and after the regulations. The regulations can lead not only decreasing data but also changing the nature of data.

Cluster analysis

The cluster analysis divided the fishing trips into three groups (Table 2). Species compositions of Cluster 1 and 3 showed that they generally represent operations targeting ALB and YFT, respectively. In Cluster 2, the highest proportion was other species. These characteristics of clusters were roughly consistent between "simple update" and "ad-hoc update", although the rates of the total number of trips divided into each cluster changed as shown in Table 3. Cluster 2 in "simple update" have second most trips while it has the fewest trips among three cluster in "ad-hoc update". The number of trips among clusters in previous result used for 2018 assessment (Sakai and Tsukahara, 2018) were similar to "simple update". This difference could affect the result of standardization.

Update of standardized CPUE by best model

ZINB models used for standardization of "simple update" and "ad-hoc update" are as below. BIC values for "simple update" and "ad-hoc update" were 61021.24 and 60786.16, respectively. Note that these were not comparable values because the numbers of data in each dataset were different due to filtering in 2017 and 2018 FY.

[The best model for "simple update" standardization]

(Count model)

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

(Zero-inflation model)

Logit(p) = intercept + Year + Day10 + Area + Cluster + error term

[The best model for "ad-hoc update" standardization]

(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

These models had the interaction effects between Year and Area, thus the area weighting values for LSMEANS were calculated as the standardized CPUE. The result of the standardized CPUE of "simple" and "ad-hoc" updates are shown in Table 4 and Fig.5. Both CPUEs matched well to the index used in the 2018 assessment up to 2016 FY. The standardized CPUE of simple update decreased in 2017 FY and then increased in 2018 FY, while the CPUE of ad-hoc update kept continuous increasing trend since 2011 FY. The CPUE of ad-hoc update seems to be more appropriate to evaluate the trend of stock abundance because of the smoothness of recent trend and fit to historical values.

Figure 6 shows the effects of each explanatory variable in the "ad-hoc update". The Year*Area effects (Fig. 6-(1)) in "ad-hoc update" showed similar trends with abundance index in all area, while the trend only in SW of 2017 FY was clearly different because of the regulation. The Day10*Area effects (Fig. 6-(2)) showed the peak in SW area after the middle of May. It indicates that the year effect in SW would be underestimated especially in 2017 FY because there were no records during its highest fishing season. Similarly, the year effects of 2017 and 2018 FY in NE area would be overestimated because there were no records during the lowest fishing season in both 2017 and 2018 FY.

The detailed results in the "simple update" are also shown in present paper (Appendix, Fig. A1, Fig. A2).

Conclusion

Japanese longline CPUEs were updated following the procedure of the last benchmark assessment. This update was much affected by the ban of landings in 2017 and 2018 FY. The ban led to drastic change of fishing operation and nominal CPUE. Therefore, "ad-hoc update" standardization, using data of the period only when the regulation was invalid, seemed to be appropriate for stock abundance. While this approach removes the data whose nature was altered, it causes other issues. The data availability in 2017 and 2018 FY is different from other fishing years. It means that the used data lacks the information on the highest or lowest period in SW or NE area for those two years. These can make the indices underestimated or overestimated.

Although the best model used for the standardization has changed from the previous standardization, the standardized CPUE was mostly consistent with previous one, following recent trends which is increasing since 2011 FY. Note that logbook data in recent years has not been collected completely. The standardized CPUE will be revised with updated dataset up until next benchmark stock assessment.

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Table 1 Total number of fishing trips, hooks, PBF catch, and nominal CPUE for “simple update” and “ad-hoc update”. The rows showed by gray background mean the data used for “ad-hoc update” of 2017 and 2018 FY, and the rows of 2017 and 2018 FY without background color mean those for “simple update”.

Calendar year	Fishing year	Number of trips	Number of hooks (x 1,000 hooks)	Number of PBF catch	Nominal CPUE
1994	1993	362	5,275	2,899	0.550
1995	1994	323	4,679	1,710	0.365
1996	1995	363	5,180	2,561	0.494
1997	1996	384	5,481	2,526	0.461
1998	1997	420	6,307	3,010	0.477
1999	1998	713	9,866	4,028	0.408
2000	1999	636	8,895	2,366	0.266
2001	2000	611	10,002	1,878	0.188
2002	2001	648	10,442	2,161	0.207
2003	2002	694	10,735	2,897	0.270
2004	2003	759	11,047	3,875	0.351
2005	2004	684	11,093	4,143	0.373
2006	2005	707	10,477	2,143	0.205
2007	2006	698	10,380	3,325	0.320
2008	2007	691	10,444	1,712	0.164
2009	2008	746	11,971	1,481	0.124
2010	2009	722	11,375	808	0.071
2011	2010	690	10,284	693	0.067
2012	2011	696	11,290	506	0.045
2013	2012	654	10,465	831	0.079
2014	2013	648	10,625	811	0.076
2015	2014	656	9,871	681	0.069
2016	2015	630	9,234	908	0.098
2017	2016	724	10,474	1,401	0.134
2018	2017	517	6,516	775	0.119
2018	2017	313	4,722	736	0.156
2019	2018	303	4,861	1,016	0.209
2019	2018	273	4,401	1,016	0.231

Table 2 Species composition by each cluster for “simple update” and “ad-hoc update”.

	Simple update			Ad-hoc update		
	Cluster 1	Cluster 2	Cluster 3	Cluster 1	Cluster 2	Cluster 3
Yellowfin tuna	3.0%	20.1%	75.1%	4.9%	35.8%	74.2%
Albacore	86.9%	34.4%	7.4%	78.5%	9.4%	12.3%
Bigeye tuna	5.6%	9.4%	0.8%	8.5%	1.2%	1.1%
Other species	4.5%	35.9%	16.7%	8.0%	53.7%	12.3%

Table 3 The number of trips allocated into clusters.

Fishing	Simple update			Ad-hoc update			2018 assessment		
year	Cluster 1	Cluster 2	Cluster 3	Cluster 1	Cluster 2	Cluster 3	Cluster 1	Cluster 2	Cluster 3
1993	178	161	23	271	66	25	273	80	9
1994	140	154	29	192	106	25	205	104	14
1995	226	93	44	277	45	41	277	64	22
1996	238	110	36	295	48	41	299	76	8
1997	178	225	17	295	106	19	309	108	3
1998	284	256	173	407	131	175	386	237	90
1999	354	161	121	436	76	124	428	147	61
2000	316	206	89	410	126	75	415	141	55
2001	269	297	82	411	148	89	423	167	52
2002	250	340	104	483	117	94	479	145	64
2003	250	318	191	392	212	155	391	248	107
2004	371	202	111	477	125	82	468	131	64
2005	394	230	83	478	149	80	467	171	55
2006	385	170	143	424	176	98	403	191	75
2007	368	135	188	433	108	150	418	140	116
2008	421	157	168	472	134	140	466	174	103
2009	237	137	348	301	112	309	300	172	247
2010	232	145	313	324	66	300	323	129	226
2011	309	111	276	358	73	265	352	155	174
2012	270	141	243	319	130	205	329	194	124
2013	310	150	188	380	123	145	374	156	99
2014	226	190	240	356	72	228	348	135	166
2015	290	66	274	315	65	250	295	87	221
2016	279	150	295	352	90	282	286	101	162
2017	92	142	283	186	19	108			
2018	89	87	127	129	23	121			
Whole rate	44.4%	28.9%	26.7%	59.4%	17.1%	23.5%	60.2%	23.8%	16.0%

Table 4 Standardized CPUE by "simple update" and "ad-hoc update".

Calendar year	Fishing year	Standardized CPUE by simple update			Standardized CPUE by ad-hoc update			Standardized CPUE used in 2018 assessment		
		Stn. CPUE	Scaled Std. CPUE	CV	Std. CPUE	Scaled Std. CPUE	CV	Std. CPUE	Scaled Std. CPUE	CV
1994	1993	0.342	2.301	0.029	0.428	2.308	0.035	0.435	2.307	0.039
1995	1994	0.231	1.551	0.032	0.274	1.478	0.039	0.280	1.484	0.034
1996	1995	0.351	2.362	0.028	0.434	2.343	0.030	0.439	2.329	0.028
1997	1996	0.308	2.075	0.027	0.380	2.048	0.040	0.377	2.002	0.033
1998	1997	0.279	1.874	0.027	0.337	1.819	0.041	0.339	1.797	0.034
1999	1998	0.201	1.351	0.028	0.257	1.388	0.040	0.251	1.333	0.031
2000	1999	0.177	1.189	0.031	0.223	1.205	0.033	0.222	1.176	0.030
2001	2000	0.128	0.864	0.023	0.157	0.848	0.040	0.158	0.836	0.030
2002	2001	0.142	0.958	0.027	0.177	0.954	0.028	0.182	0.967	0.025
2003	2002	0.190	1.278	0.019	0.239	1.289	0.023	0.238	1.260	0.025
2004	2003	0.238	1.600	0.020	0.282	1.519	0.033	0.238	1.503	0.031
2005	2004	0.264	1.777	0.022	0.320	1.729	0.027	0.324	1.720	0.023
2006	2005	0.122	0.818	0.023	0.152	0.820	0.032	0.152	0.807	0.029
2007	2006	0.131	0.880	0.032	0.162	0.876	0.034	0.166	0.882	0.036
2008	2007	0.104	0.699	0.024	0.127	0.686	0.036	0.126	0.670	0.035
2009	2008	0.056	0.378	0.070	0.069	0.371	0.057	0.068	0.361	0.089
2010	2009	0.033	0.222	0.058	0.040	0.213	0.076	0.040	0.214	0.063
2011	2010	0.038	0.259	0.080	0.050	0.269	0.173	0.043	0.228	0.074
2012	2011	0.028	0.188	0.059	0.036	0.195	0.107	0.035	0.188	0.065
2013	2012	0.045	0.303	0.043	0.058	0.310	0.057	0.057	0.302	0.065
2014	2013	0.049	0.330	0.035	0.057	0.307	0.054	0.057	0.301	0.040
2015	2014	0.063	0.422	0.057	0.065	0.348	0.048	0.064	0.337	0.052
2016	2015	0.069	0.462	0.048	0.081	0.438	0.051	0.080	0.426	0.057
2017	2016	0.091	0.614	0.031	0.108	0.583	0.032	0.107	0.569	0.034
2018	2017	0.043	0.287	0.107	0.130	0.701	0.063			
2019	2018	0.143	0.962	0.049	0.177	0.953	0.039			

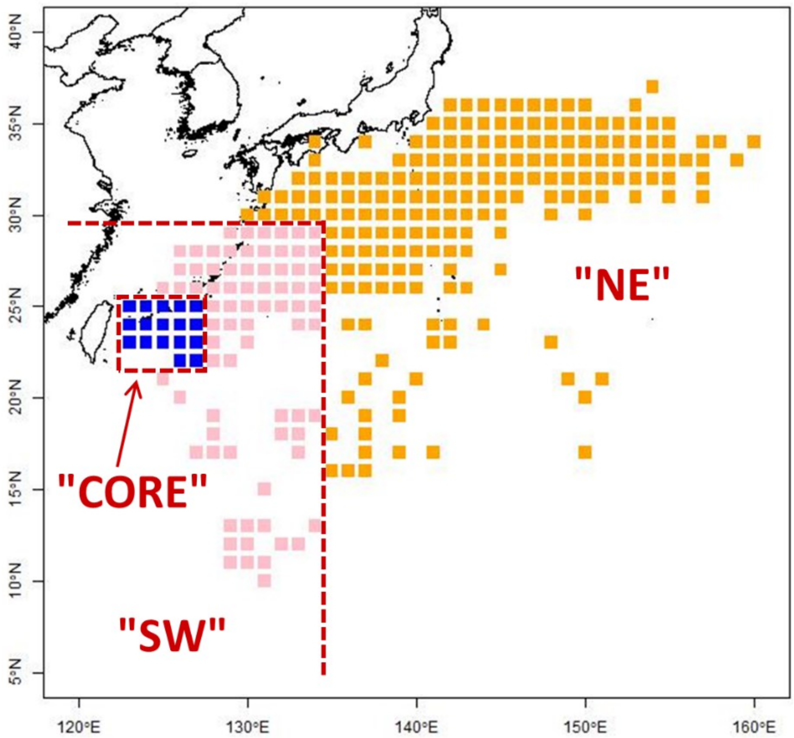


Fig. 1 Area definition for the analysis. According to Hiraoka et al. (2015), the fishing ground was divided into three sub-area (“CORE”, “SW”, and “NE”) for the standardization of CPUE.

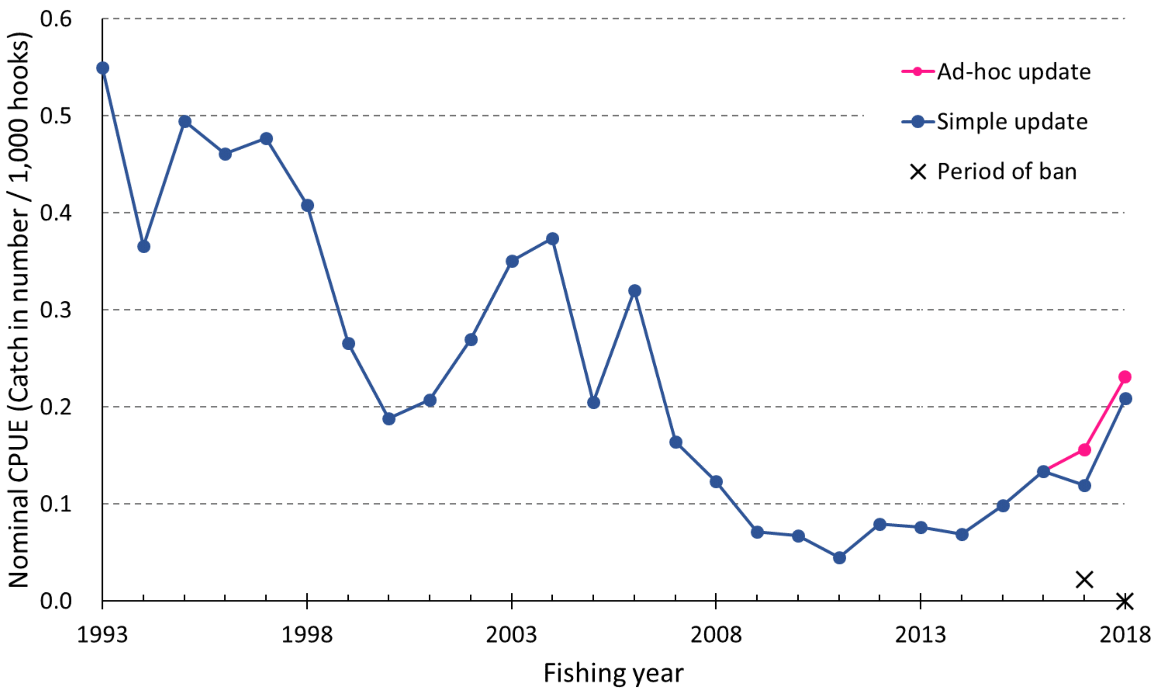


Fig. 2 Time series of nominal CPUE for “simple update” and “ad-hoc update”. Crosses in 2017 and 2018 fishing year indicate CPUE during PBF fishing suspension in each year.

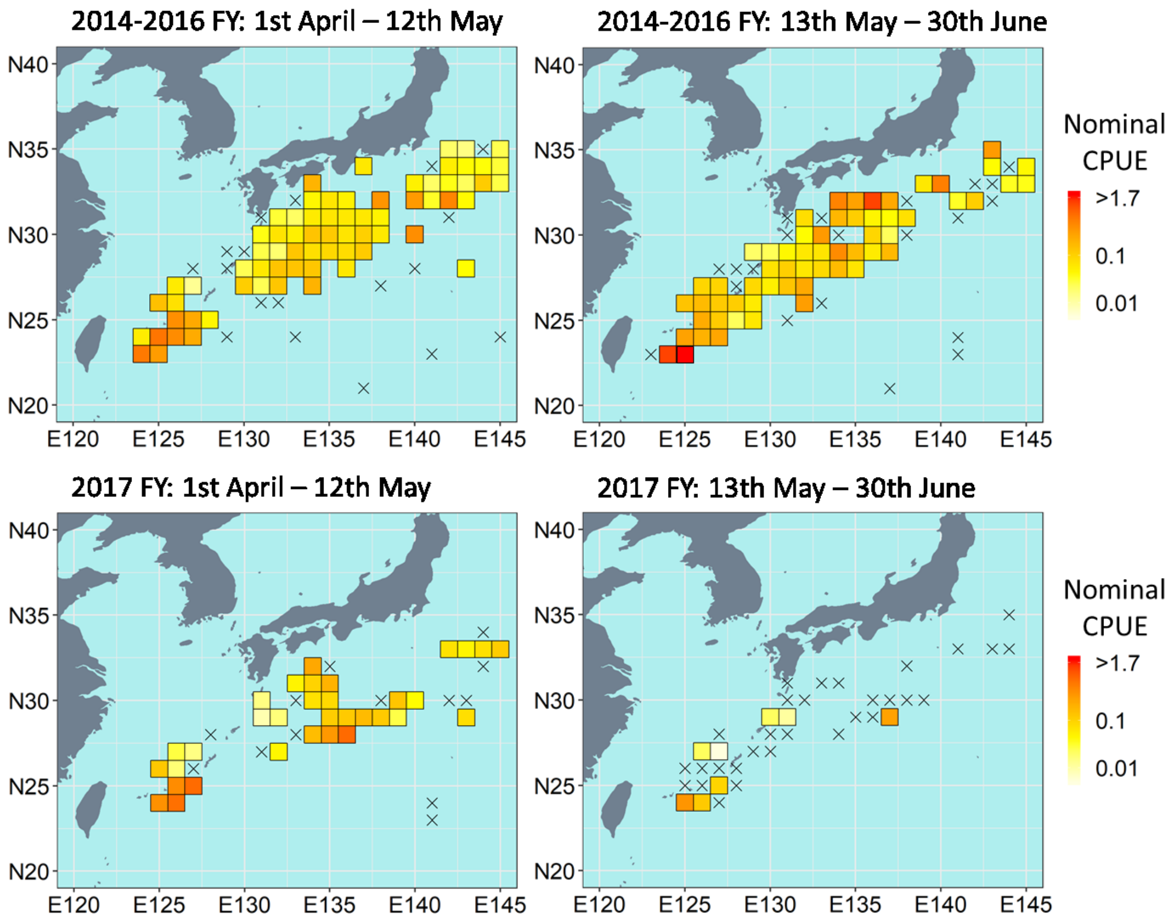


Fig. 3 Spatial distribution of nominal CPUE. Upper and lower panels show CPUEs in 2014-2016 and 2017 FY, respectively. Left and right panels show CPUEs before and during the regulation of 2017 FY, respectively. Cross indicates zero catch of PBF (nominal CPUE is 0).

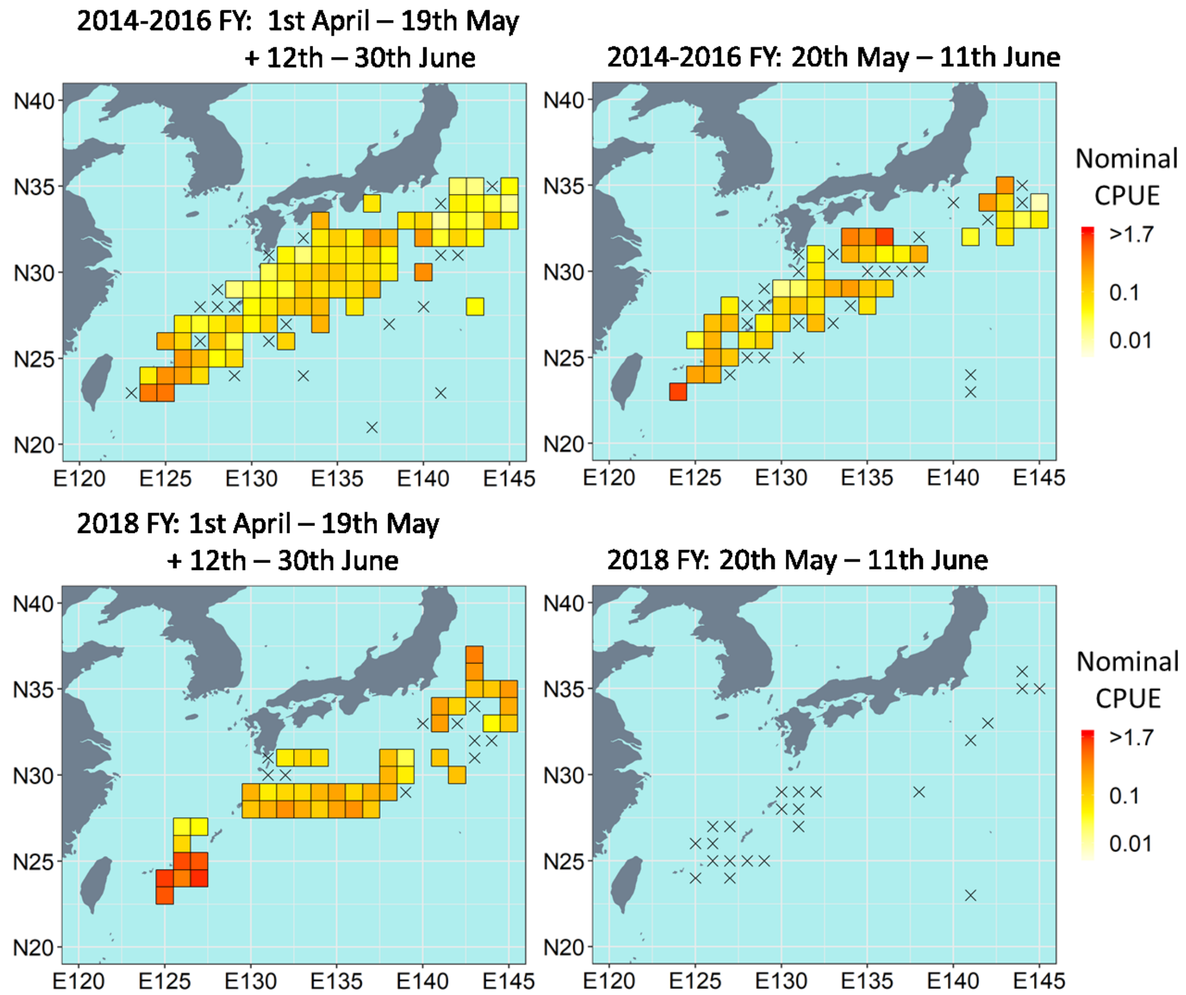


Fig. 4 Spatial distribution of nominal CPUE. Upper and lower panels show CPUEs in 2014-2016 and 2018 FY, respectively. Left and right panels show CPUEs during non-regulation and regulation of 2018 FY, respectively. Cross indicates zero catch of PBF (nominal CPUE is 0).

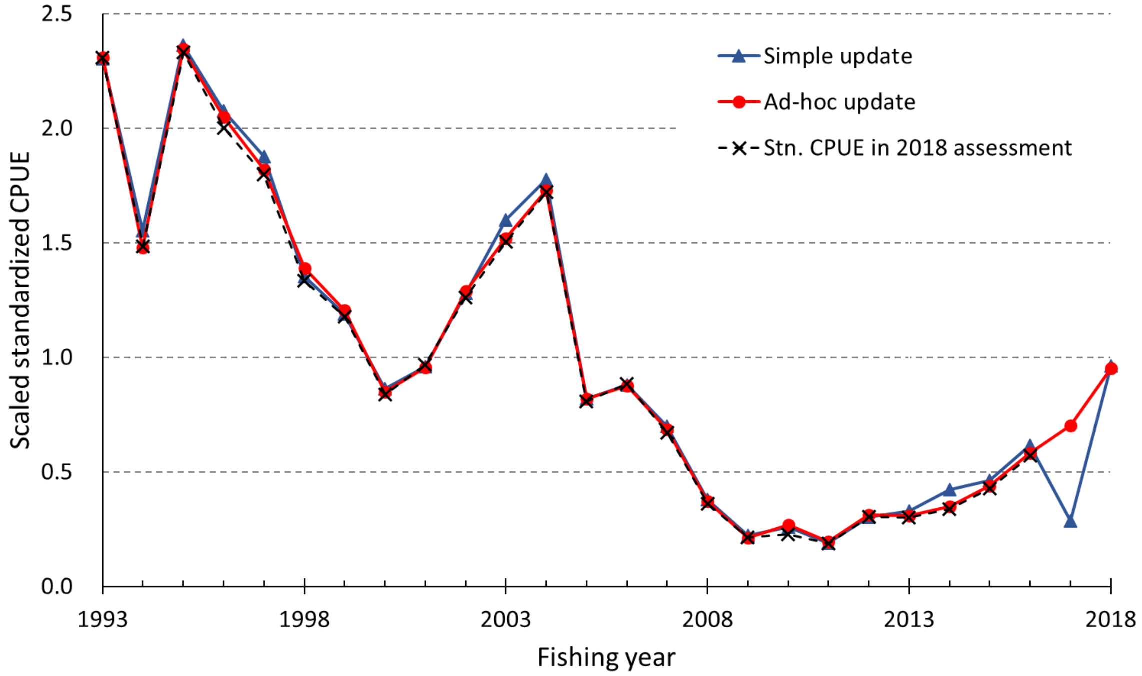


Fig. 5 Time series of three scaled standardized CPUEs. Blue triangles and solid line indicate the result of updated CPUE of “simple update”. Red circles and solid line indicate the result of updated CPUE of “ad-hoc update”. Black crosses and dashed line show the standardized CPUE used in 2018 stock assessment for abundance index of adult PBF.

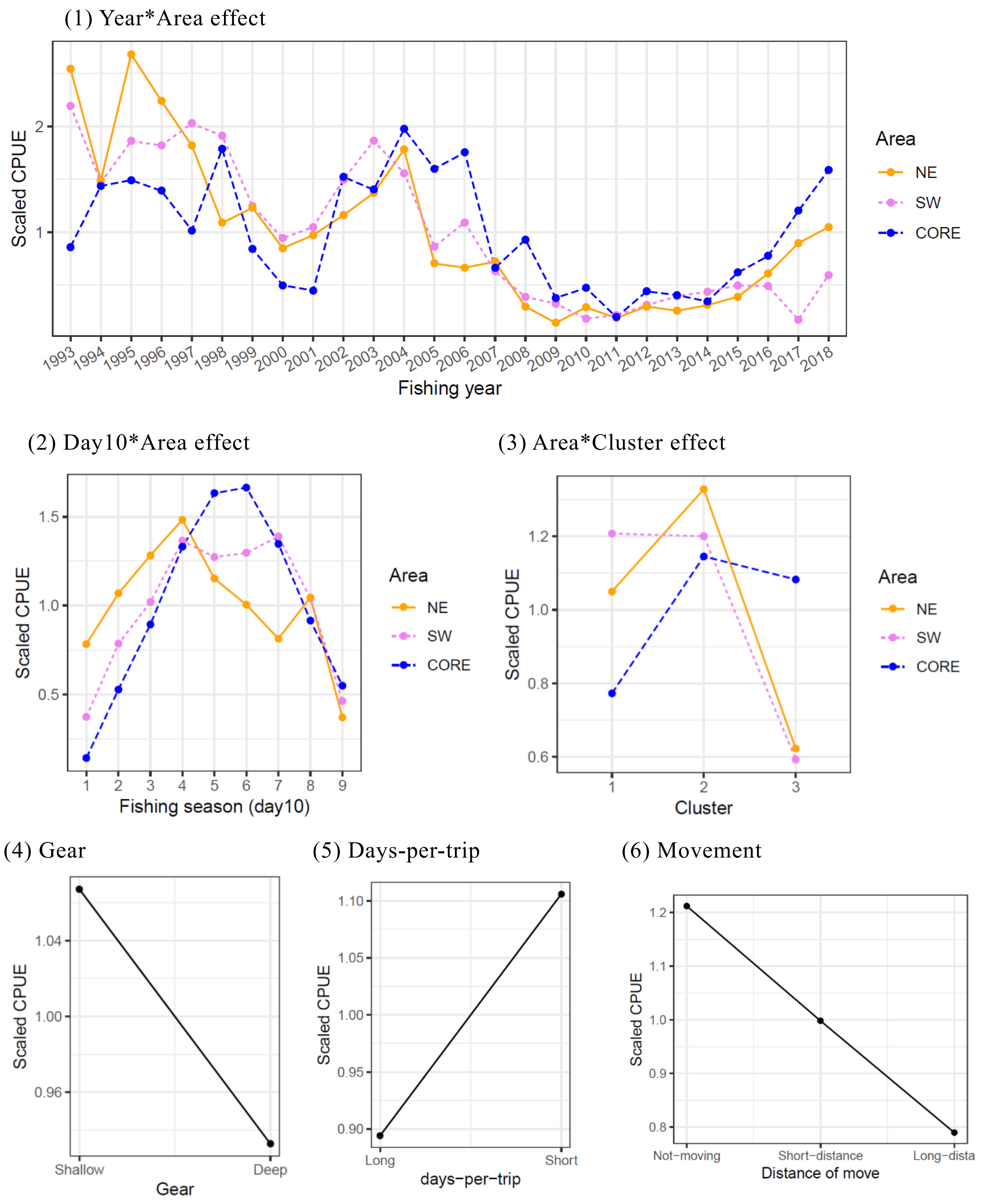


Fig. 6 Least squared means for each effect estimated by “ad-hoc update”.

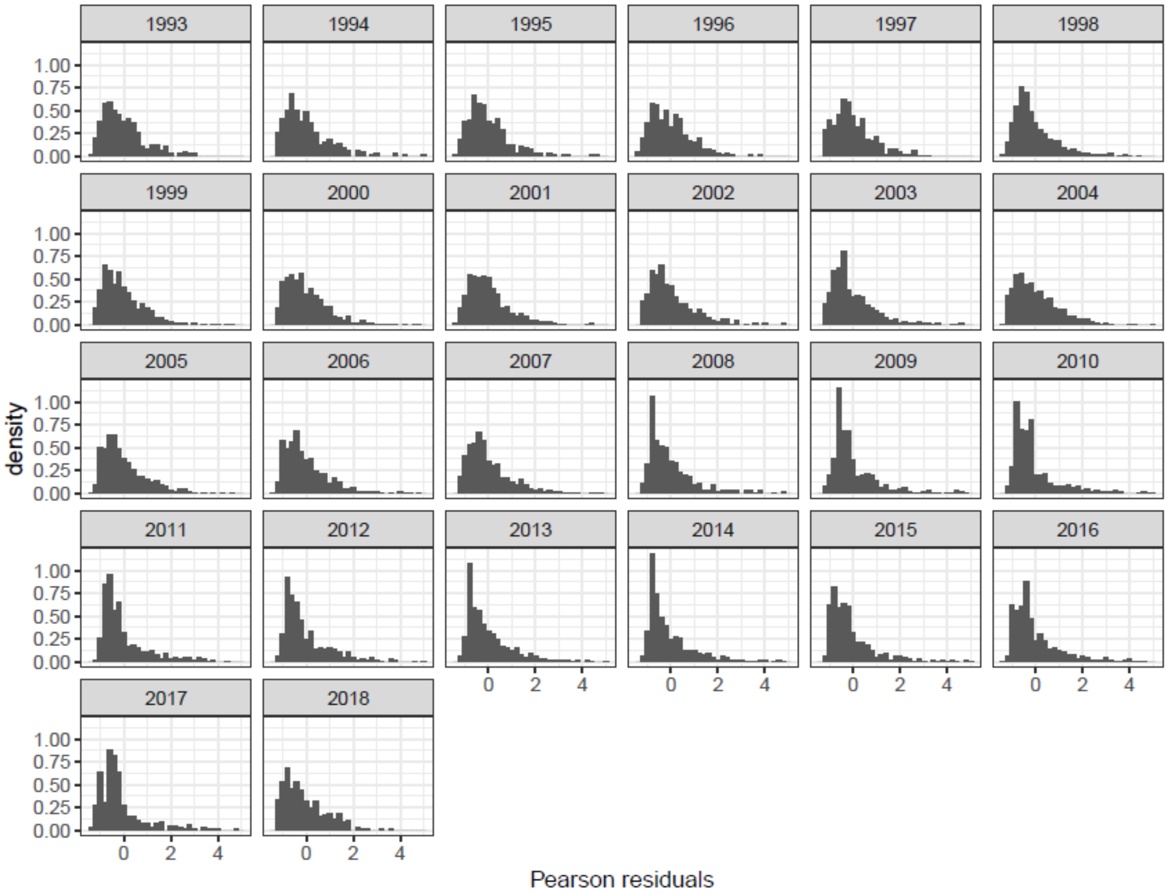
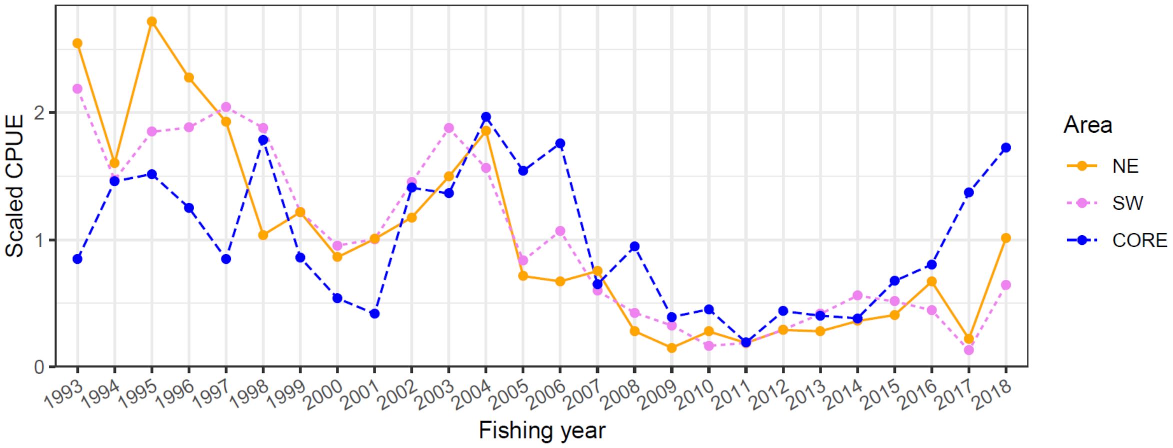


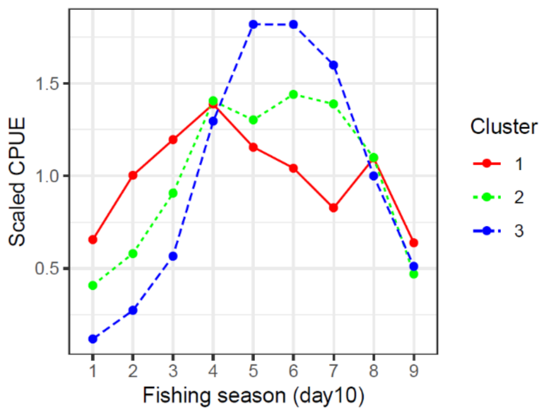
Fig. 7 Pearson residual distribution for ZINB for "ad-hoc update" by fishing year.

Appendix

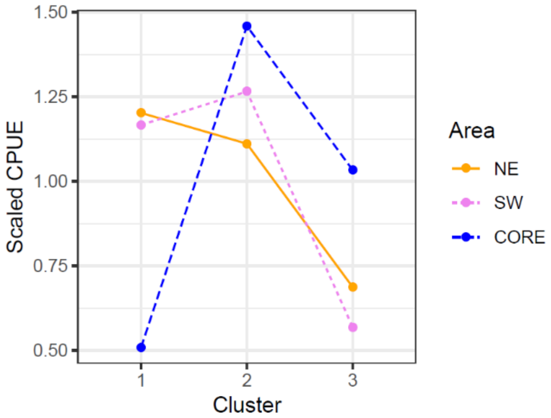
(1) Year*Area effect



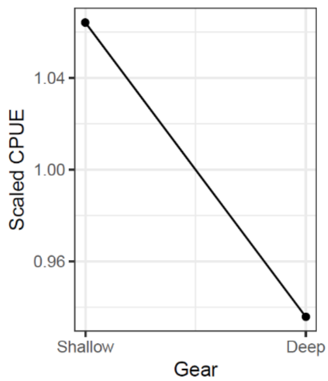
(2) Day10*Cluster effect



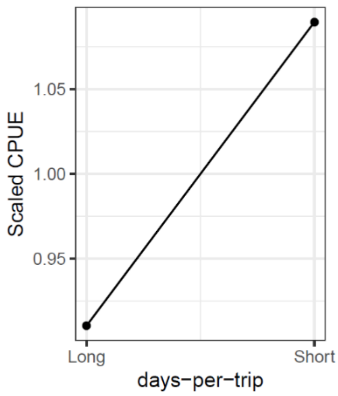
(3) Area*Cluster effect



(4) Gear



(5) Days-per-trip



(6) Movement

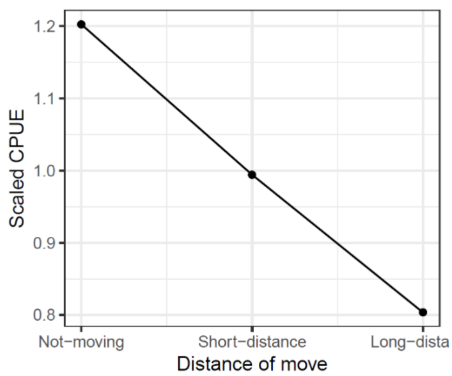


Fig. A1 Least squared means for each effect estimated by "simple update".

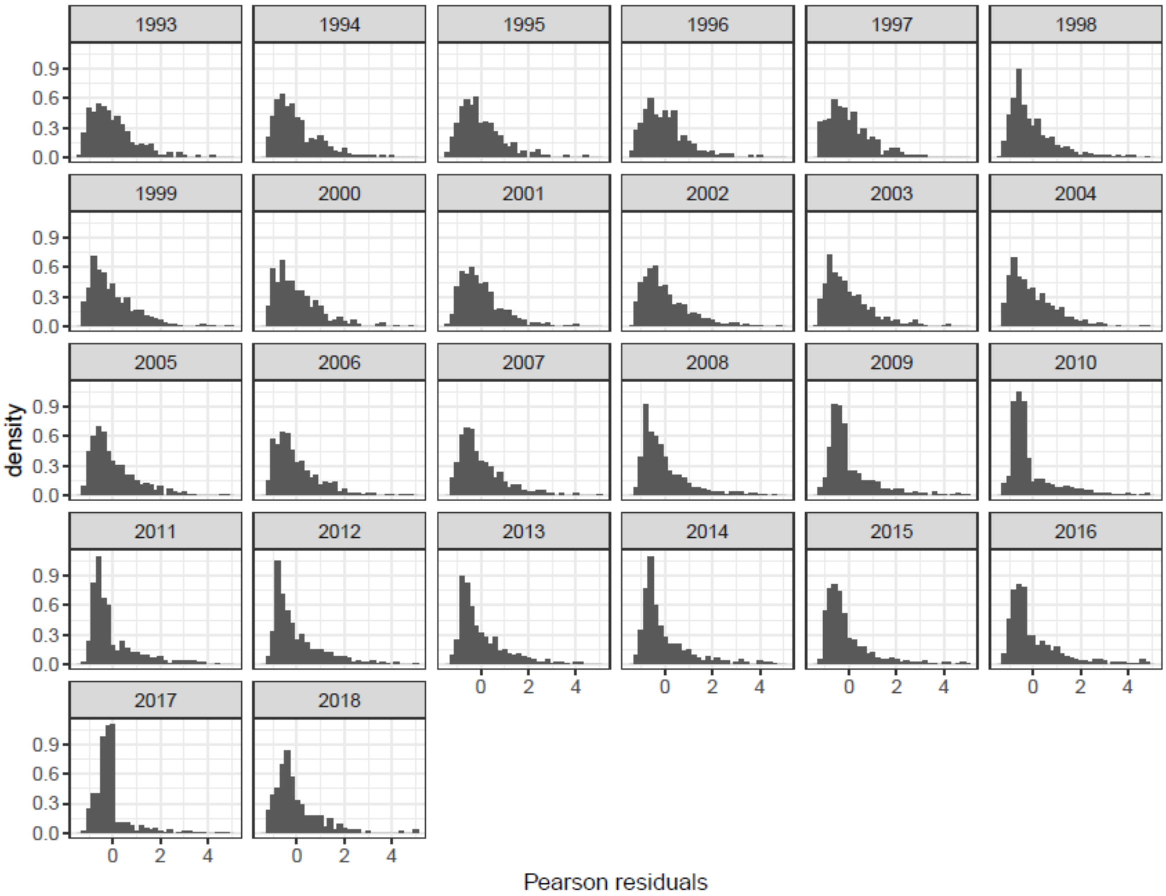


Fig. A2 Pearson residual distribution for ZINB for "simple update" by fishing year.