ISC/16/ALBWG-02/04

Update standardized CPUE for North Pacific albacore caught by the Japanese pole and line data from 1972 to 2015[1]

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[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 8-14 November 2016, held at the Pacific Biological Station, Nanaimo, BC, Canada. Document not to be cited without the author's permission.

Summary

In this document, we estimated standardized catch per unit effort (CPUE) of North Pacific Albacore (NPALB) that were caught by the Japanese distant-water pole and line (JPN PLDW) from 1972 to 2015, with delta-lognormal GLM model in the same way as previous document (Kiyofuji 2014). In this model, we used four explanatory variables—year, quarter (two levels: 1st and 2nd quarters combined; 3rd and 4th quarters combined), 5° × 5° grid squares as area, and vessel ID—as categorical factors and separated the period (1972–2015) into two periods (1972–1989 and 1990–2015). We also updated and reformed data set for estimating CPUE; accordingly, relative abundance indices are mostly same with previous values, but the index in 1987 largely increases compared with the previous index. In addition, the index in 2015 shows the lowest level, which seems not to represent decrease of NPALB abundance because ALB catch by Japanese offshore pole and line is high. Further comparison between simple-updated estimates and quarter-changed estimates indicates that quarter-changed estimates appear to be more suitable trend.

Introduction

In this study, we updated standardized CPUE in the same way proposed at the ISC14/ALBWG-01/06 (Kiyofuji, 2014). In this model, four explanatory variables—year, quarter (two levels: 1st and 2nd quarter; 3rd and 4th quarter), 5°×5° grid squares as area, and vessel ID, which would reflect each fleet's fishing capacity and intention to target albacore—are employed as categorical factors, and the whole period (1972–2015) is separated into two periods (1972–1989 and 1990–2015) because main fishing season changed from 2nd quarter to 3rd quarter since 1990 and because equipped ratios of searching devices increased from the late 1980s to the early 1990s (Kiyofuji, 2014). Differences between this study and previous study are presented in **Table 1.**

Data and Methods

Fisheries Data

We used the operational level of catch and effort data for the JPN PLDW, which are larger than 200 gross register tonnage (GRT), with noon position in equidistant 1°×1° grid cells from 1972 to 2015. From the data, date, positon, number of poles, and catch in weight were employed, and we reformed data set to estimate standardized CPUE.

CPUE standardization

In this analysis, delta-lognormal model (Lo et al., 1992) was used for estimating standardized NPALB CPUE. We conducted following procedures and accomplished parameterization using two step generalized linear model: a first step for estimating non zero catch and second step for estimating positive catch, respectively.

Definition of the explanatory variables are shown in **Table 2**, and area definition is-represented in **Figure 1**. In this analysis, technology information such as bird radar, sonar, bait tank and NOAA receiver were not considered because no significant effects were found through the previous analysis (Kiyofuji, 2013).

Vessel ID of each fleet was identified by the license number from log sheet and assigned to evaluate fishing strategy or skipper's experiences through the period (e.g. Langley et al., 2010; Kiyofuji et al., 2011). When vessels change target species (e.g. from skipjack to albacore), catch rate of target species possibly change. Vessel effect potentially represents factors that are likely affect fishing capability. Including vessel ID in the model can explain changes in fishing capacity along time—from the beginning of new vessel to the retirement. It can also account for differences in fishing techniques and targeting strategies among vessels.

Each vessel is identified by license number and call sign, but license numbers have renewed on every five years—1987, 1992, 1997, 2002, 2007, and 2012. For the JPN PLDW fleet, a reference table with ship name and license number was created in each year. This table was used to create a unique vessel index in the log sheet dataset. The few log sheet records that had no associated record in the vessel reference table were deleted from the data set. Furthermore, for analyzing, core vessels were extracted defined as operating five years continuously and more than ten days a year.

The total number of unique vessels in each year and operating years of each core vessel were shown in **Figure 2**. Total number of unique vessels in 1987 in this study increases compared with previous values, which is due to updating vessel reference table. **Figure 2** also revealed that a considerable number of vessels retired from the fishery from the late 1980s to the early 1990s although some of the vessels continued to operate in the fishery throughout the next two decades. During the 1990s, new vessels continued to enter the fishery replacing vessels that retired from the fishery. In recent years, fleet has reduced to about 25 core vessels (**Fig. 2a**).

The delta-lognormal indices were calculated by multiplying the two sets of indices. At the first step, we estimated the probability of non-zero catch of albacore whether albacore catch was present or absent (that is zero) for a fishing day; at the second step, we estimated the positive albacore catch for a fishing day after zero catch records were excluded. Standard error for delta-lognormal model was derived from the method described by Shono (2008).

First Step: estimate non-zero catch rate

$$log(rate) = year + qtr + latlong + Vessel\,ID + \epsilon, \epsilon \sim binominal$$

Second Step: estimate positive catch

$$log(CPUE) = year + qtr + latlong + Vessel\,ID + \epsilon, \epsilon \sim (0, \sigma^2)$$

An unbiased relative abundance index can be calculated as follows:

$$Indices = \frac{\exp(\hat{\alpha})}{1+\exp(\hat{\alpha})} \times \exp(\hat{\beta} + \hat{\sigma}^2/2)$$

where $\hat{\alpha}$ is the estimated year factor for the binomial GLM, $\hat{\beta}$ and $\hat{\sigma}^2$ are the estimated year factor for the positive catch (lognormal) GLM and the standard error of $\hat{\alpha}$, respectively.

We also tried to estimate CPUE by changing qtr variable: In the period of 1972–1989, only 2nd quarter data were selected; In the period 1990–2015, 2nd and 3rd quarter data were selected. The reason why we picked up these quarters is to remove possible biases due to including quarters with low catches.

Results and Discussion

Figure 3 shows spatial distributions (by 1°×1° grid square) of effort (vessel-day), total catch of albacore, and albacore catch ratio (albacore catch divided by albacore plus skipjack catches) in recent five years. Efforts are identified in area between 135°E-180°E and 25°N-45°N (**Fig. 3a**). Total catch and ratio are higher in area south of 35°N (**Fig. 3b, c**).

Figure 4 shows time series of effort (total number of poles), total catch of albacore, albacore catch ratio, and nominal CPUE. Effort (the number of poles) by JPN PLDW increases from 1972 to 1978 due to increasing number of fleet (**Fig. 2a**), and then, it decreases steeply until 1988 (**Fig. 4a**). After 1988, gradual increase of effort lasts until 1997, and then the value remains at the level around 100 (× 1,000 poles) till 2005. The number of poles decreases again in 2006 and has remained at the level about 70,000. Total catches by JPN PLDW are high in the mid of 1970s, from the end of 1990s, and the start of 2000s (**Fig. 4b**). Catches after 2005, however, are low (around 10,000 tones) and further decreases from 2013 to 2015; on the other hand, ALB catch by Japanese offshore pole and line (JPN PLOS) are not low during 2013–2015. Albacore catch ratio by JPN PLDW in most of years is around 50%, but it is low during 1988–1993 and 2015 around 20% (**Fig. 4c**). Nominal CPUE by JPN PLDW likely shows similar trend with total catch (**Fig. 4d**); also, there likely exist three phases at nominal CPUE level (1972–1992, 1993–2004 and 2005–2015).

The trend of relative abundance indices is shown in **Figure 5**, and the estimates and standard errors are represented in **Table 4** (1972–1989) and **Table 5** (1990–2015). The trend of each period is mostly same with that of the previous value (Kiyofuji 2014), but the indices in 1987 largely increases compared to the previous value.

GLM diagnostics of each period are represented in **Table 6** (1972–1989) and **Table 7** (1990–2015). Residual distributions of the model are skewed in 1st step (**Figure 6a** and **Figure 7a**) but in 2nd step these are distributed almost normally (**Fig. 6b** and **Fig. 7b**).

Figure 8a and **Table 3** show albacore catches in each quarter by the JPN PLDW in area for estimating standardized CPUE. These indicate that the main season shifts from 2nd quarter to 3rd quarter since 1990; this shift is due to changes of fishing area (Kiyofuji, 2013) in order to target more fat albacore. **Figure 8b** represents ratios of five kinds of equipment. Low temperature bait tank was first equipped in 1981 with keeping lots of baits and high survival rate for long period. The 1st generation bird radar was developed in 1987, which is radar adjusted to show a bird and birds' school around 15 miles of the radar. The 2nd generation bird radar was introduced in 1991 with expanding searching area to around 25 miles. NOAA receiver began to use for searching fishing ground in 1988. Sonar started to develop and be introduced in the early 1980s. After introducing these devices, equipped ratio increased, and almost all vessels have had every device since 1994.

Figure 9 shows comparison of estimated CPUEs in this study between simple-updated values and quarter-changed values. As a result, quarter-changed estimates appear to be more suitable trend than simple-updated estimates.

In summary, we recommend updated CPUE of NPALB caught by the JPN PLDW with new quarter definition.

Reference

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Table 1. Comparison between this study and previous study (2014)

	previous study	**this study**
Period (whole)	1972–2012	1972–2015
Region	(Kiyofuji, 2014)	same as in 2014
Model	delta-lognormal	same as in 2014
Variables	see Table 2	1: same as in 2014
		2: qtr was changed (1972–1989: 2nd only; 1990–2015: [2nd + 3rd] only)
Vessel ID		updated

Table 2. Definition of explanatory variables included in the model

Variable	**Data type**	**Description**
year	Categorical	unique year (1972–2015)
qtr	Categorical	unique quarter
		I: 1st + 2nd (Jan. – Jun.)
		II: 3rd + 4th (Jul. – Dec.)
latlong	Categorical	5°× 5°
vessel ID	Categorical	unique vessel identification

Table 3. Total catches (tons) of NPALB by the JPN PLDW in the area for estimating standardized CPUE

Year	Quarter			
	1st	2nd	3rd	4th
1972		12922.8	1507.8	26.2
1973	491.6	22714.9	2599.9	0.2
1974	18.7	31530.5	1985.5	75.5
1975	95.3	25942.1	985.1	
1976	150.3	40588.5	202.4	5052.5
1977	85.2	16223.4	172.7	4345.8
1978	1.2	17089.8	14868.6	3453.3
1979	1.0	15529.8	8663.3	3458.8
1980	16.1	19537.2	3282.6	457.0
1981	19.8	8873.3	166.9	257.1
1982	72.0	7799.3	181.1	763.7
1983	41.0	10721.0	476.8	523.5
1984		17130.9	703.6	30.0
1985	5.4	10237.6	80.9	181.5
1986	1.5	6339.9	698.6	270.2
1987		7986.7	204.9	6.1
1988		1064.1	7.7	0.7
1989		3117.3	519.5	1.8
1990		2157.5	2851.9	154.5
1991		157.4	2478.4	155.8
1992		1370.0	1863.9	
1993		3175.7	3659.1	0.2
1994		3860.1	17473.4	45.5
1995		2743.4	13878.9	1660.6
1996		4466.8	7016.1	0.6
1997		5142.0	13974.6	3443.4
1998		113.2	12514.4	361.8
1999		12209.4	21115.7	6697.7
2000		4878.3	11270.5	1141.6
2001		6966.5	18133.7	654.5
2002		9531.4	31182.6	323.8
2003		7862.2	14857.0	5941.8
2004	24.0	14020.0	2270.9	
2005		3650.0	8181.9	330.1
2006		4559.8	1649.2	843.4
2007		10835.8	1214.2	
2008		4867.8	1346.4	
2009		10892.3	1145.1	80.6
2010		7288.7	5614.8	66.6
2011		9106.8	2985.3	
2012		9585.0	6460.5	38.4
2013		12054.1	2535.0	
2014		8471.9	1633.5	
2015		5044.1	1018.4	

Table 4. Abundance indices for NPALB caught by the JPN PLDW between 1972 and 1989

I: 1st and 2nd quarters

Year	non-zero rate		positive catch			Relative abundance Index	by Shono (2008)	
	estimate	SE	estimate	SE	adjusted		σ[CPUE]	σ[logCPUE]
1972	0.587	0.032	0.151	0.039	0.151	0.991	0.004	0.237
1973	0.675	0.028	0.141	0.032	0.141	1.058	0.003	0.285
1974	0.659	0.029	0.196	0.032	0.197	1.444	0.004	0.276
1975	0.629	0.030	0.162	0.031	0.162	1.136	0.003	0.259
1976	0.660	0.029	0.157	0.030	0.157	1.153	0.003	0.276
1977	0.605	0.031	0.093	0.031	0.093	0.627	0.002	0.245
1978	0.747	0.024	0.134	0.029	0.134	1.119	0.003	0.328
1979	0.685	0.028	0.141	0.029	0.141	1.074	0.003	0.290
1980	0.575	0.031	0.135	0.031	0.135	0.863	0.003	0.229
1981	0.572	0.032	0.088	0.034	0.088	0.562	0.002	0.228
1982	0.548	0.032	0.140	0.038	0.140	0.855	0.004	0.216
1983	0.604	0.031	0.141	0.036	0.142	0.953	0.003	0.246
1984	0.594	0.031	0.189	0.035	0.190	1.255	0.004	0.240
1985	0.657	0.030	0.180	0.038	0.180	1.321	0.005	0.276
1986	0.545	0.033	0.141	0.040	0.142	0.860	0.004	0.215
1987	0.576	0.033	0.182	0.045	0.182	1.169	0.005	0.232
1988	0.408	0.036	0.124	0.082	0.125	0.568	0.006	0.167
1989	0.487	0.034	0.183	0.053	0.183	0.994	0.006	0.190

II: 3rd and 4th quarters

Year	non-zero rate		positive catch			Relative abundance Index	by Shono (2008)	
	estimate	SE	estimate	SE	adjusted		σ[CPUE]	σ[logCPUE]
1972	0.211	0.026	0.089	0.041	0.089	0.936	0.002	0.077
1973	0.286	0.030	0.083	0.035	0.083	1.179	0.002	0.100
1974	0.270	0.029	0.116	0.035	0.116	1.557	0.002	0.094
1975	0.243	0.028	0.096	0.034	0.096	1.157	0.002	0.085
1976	0.271	0.029	0.092	0.033	0.093	1.247	0.002	0.094
1977	0.224	0.027	0.055	0.033	0.055	0.611	0.001	0.078
1978	0.368	0.032	0.079	0.030	0.079	1.454	0.002	0.131
1979	0.295	0.030	0.083	0.030	0.083	1.219	0.002	0.102
1980	0.202	0.026	0.080	0.033	0.080	0.797	0.002	0.071
1981	0.199	0.026	0.052	0.036	0.052	0.516	0.001	0.071
1982	0.183	0.025	0.083	0.039	0.083	0.754	0.002	0.069
1983	0.223	0.027	0.084	0.038	0.084	0.928	0.002	0.080
1984	0.215	0.027	0.112	0.037	0.112	1.199	0.002	0.077
1985	0.268	0.029	0.106	0.040	0.106	1.420	0.003	0.096
1986	0.181	0.025	0.084	0.042	0.084	0.754	0.002	0.070
1987	0.203	0.026	0.107	0.047	0.108	1.082	0.003	0.078
1988	0.109	0.020	0.073	0.083	0.074	0.398	0.003	0.089
1989	0.147	0.023	0.108	0.054	0.108	0.791	0.003	0.070

Table 5. Abundance indices for NPALB caught by the JPN PLDW between 1990 and 2015

I: 1st and 2nd quarters

Year	non-zero rate		positive catch			Relative abundance Index	by Shono (2008)	
	estimate	SE	estimate	SE	adjusted		σ[CPUE]	σ[logCPUE]
1990	0.432	0.038	0.200	0.066	0.200	0.809	0.008	0.169
1991	0.308	0.035	0.300	0.086	0.301	0.868	0.015	0.134
1992	0.377	0.038	0.352	0.087	0.353	1.247	0.018	0.158
1993	0.404	0.037	0.280	0.071	0.281	1.063	0.012	0.160
1994	0.534	0.038	0.311	0.057	0.311	1.556	0.012	0.214
1995	0.506	0.038	0.305	0.058	0.305	1.446	0.011	0.201
1996	0.598	0.036	0.217	0.059	0.218	1.219	0.008	0.247
1997	0.607	0.035	0.215	0.054	0.215	1.223	0.008	0.250
1998	0.565	0.037	0.240	0.059	0.241	1.274	0.009	0.230
1999	0.622	0.035	0.254	0.054	0.255	1.482	0.009	0.258
2000	0.554	0.037	0.141	0.055	0.141	0.734	0.005	0.223
2001	0.597	0.036	0.154	0.054	0.154	0.861	0.005	0.245
2002	0.626	0.035	0.250	0.054	0.250	1.465	0.009	0.261
2003	0.623	0.035	0.187	0.054	0.187	1.092	0.007	0.259
2004	0.516	0.038	0.184	0.056	0.184	0.889	0.007	0.205
2005	0.450	0.037	0.127	0.055	0.127	0.537	0.004	0.174
2006	0.439	0.037	0.131	0.061	0.131	0.539	0.005	0.171
2007	0.508	0.038	0.174	0.060	0.175	0.831	0.007	0.202
2008	0.364	0.035	0.148	0.066	0.148	0.504	0.006	0.142
2009	0.499	0.038	0.272	0.062	0.273	1.273	0.011	0.198
2010	0.438	0.037	0.180	0.058	0.180	0.739	0.007	0.169
2011	0.440	0.037	0.255	0.062	0.255	1.051	0.010	0.171
2012	0.567	0.037	0.192	0.057	0.193	1.022	0.007	0.230
2013	0.478	0.038	0.203	0.060	0.203	0.910	0.008	0.188
2014	0.511	0.038	0.190	0.062	0.191	0.912	0.008	0.204
2015	0.387	0.036	0.125	0.067	0.125	0.452	0.005	0.151

Table 5 (continued).

II: 3rd and 4th quarters

Year	non-zero rate		positive catch			Relative abundance Index	by Shono (2008)	
	estimate	SE	estimate	SE	adjusted		σ[CPUE]	σ[logCPUE]
1990	0.134	0.019	0.155	0.065	0.155	0.664	0.005	0.076
1991	0.074	0.012	0.233	0.087	0.233	0.549	0.010	0.089
1992	0.105	0.016	0.272	0.087	0.274	0.913	0.013	0.092
1993	0.119	0.017	0.217	0.071	0.217	0.823	0.008	0.079
1994	0.207	0.025	0.241	0.057	0.241	1.594	0.008	0.086
1995	0.185	0.023	0.236	0.059	0.236	1.393	0.008	0.082
1996	0.269	0.030	0.168	0.059	0.169	1.449	0.006	0.106
1997	0.279	0.030	0.167	0.055	0.167	1.483	0.005	0.106
1998	0.236	0.027	0.186	0.059	0.186	1.401	0.006	0.095
1999	0.296	0.031	0.197	0.055	0.197	1.864	0.006	0.112
2000	0.225	0.026	0.109	0.056	0.110	0.786	0.003	0.090
2001	0.268	0.029	0.119	0.055	0.119	1.021	0.004	0.103
2002	0.301	0.032	0.193	0.055	0.194	1.861	0.006	0.114
2003	0.298	0.031	0.145	0.055	0.145	1.379	0.005	0.113
2004	0.192	0.024	0.142	0.058	0.143	0.875	0.005	0.083
2005	0.146	0.019	0.099	0.056	0.099	0.458	0.003	0.071
2006	0.139	0.019	0.101	0.061	0.102	0.449	0.003	0.074
2007	0.186	0.023	0.135	0.061	0.135	0.803	0.005	0.084
2008	0.098	0.014	0.114	0.067	0.114	0.359	0.004	0.073
2009	0.179	0.023	0.211	0.062	0.211	1.206	0.007	0.083
2010	0.138	0.019	0.139	0.059	0.140	0.614	0.004	0.072
2011	0.139	0.019	0.197	0.063	0.198	0.877	0.007	0.075
2012	0.237	0.028	0.149	0.058	0.149	1.128	0.005	0.095
2013	0.164	0.021	0.157	0.060	0.157	0.825	0.005	0.078
2014	0.188	0.024	0.148	0.062	0.148	0.888	0.005	0.085
2015	0.109	0.016	0.097	0.067	0.097	0.338	0.003	0.074

Table 6. ANOVA for 1st step (a) and TYPE III ANOVA for 2nd step (b) in the period 1972–1989.

(a) 1st step

Variable	***df***	**Chisq** (χ^2)	***p*** (> Chi)
year	17	4206.3	< 2.2e-16 ***
qtr	1	15799.8	< 2.2e-16 ***
latlong	39	11750.7	< 2.2e-16 ***
Vessel ID	212	4015.9	< 2.2e-16 ***

(b) 2nd step

Variable	**TYPE III SS**	***df***	***F***	***p*** (> *F*)
year	1945	17	92.116	< 2.2e-16 ***
qtr	1086	1	874.854	< 2.2e-16 ***
latlong	3127	38	66.274	< 2.2e-16 ***
Vessel ID	2271	212	8.626	< 2.2e-16 ***

Table 7. ANOVA for 1st step (a) and TYPE III ANOVA for 2nd step (b) in the period 1990–2015.

(a) 1st step

Variable	***df***	**Chisq** (χ^2)	***p*** (> Chi)
year	25	7739.2	< 2.2e-16 ***
qtr	1	5611.6	< 2.2e-16 ***
latlong	39	8823.0	< 2.2e-16 ***
Vessel ID	82	1129.4	< 2.2e-16 ***

(b) 2nd step

Variable	**TYPE III SS**	***df***	***F***	***p*** (> *F*)
year	2029	25	75.953	< 2.2e-16 ***
qtr	225	1	210.796	< 2.2e-16 ***
latlong	1443	34	39.722	< 2.2e-16 ***
Vessel ID	627	80	7.341	< 2.2e-16 ***

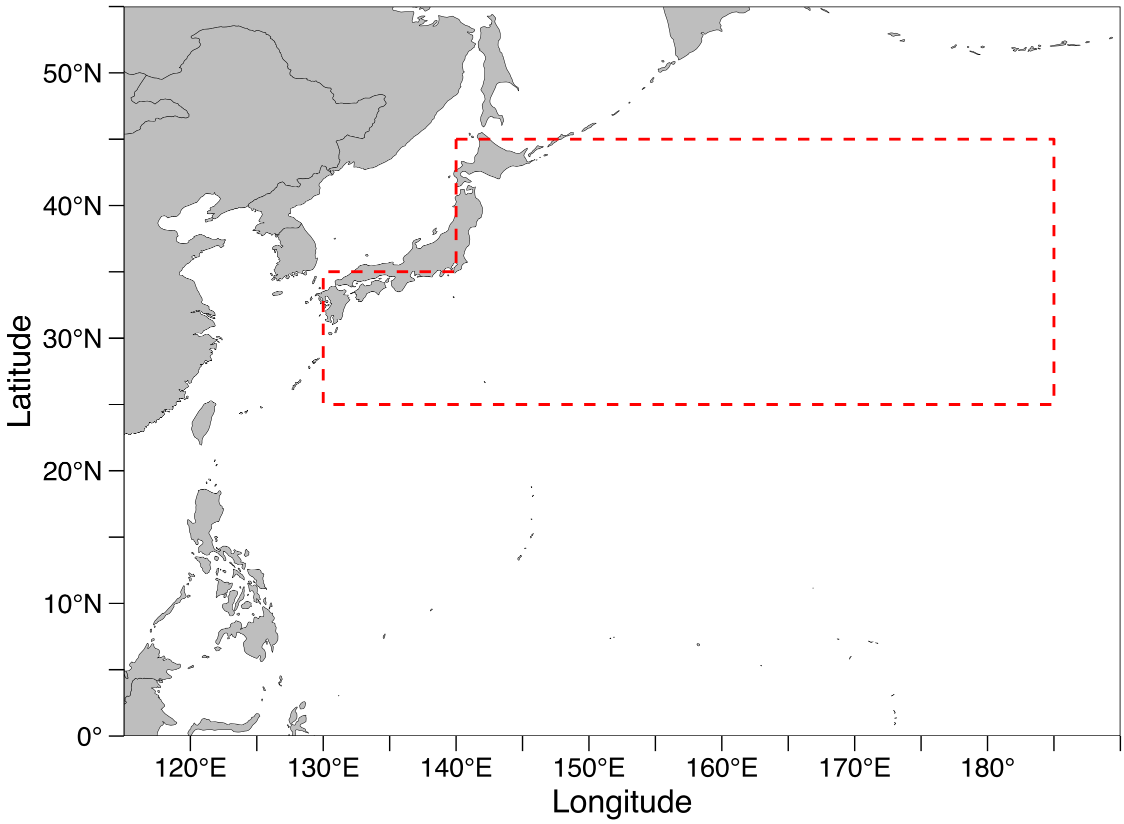


Figure 1. Area for estimating standardized CPUE for north pacific albacore (NPALB) caught by the Japanese distant water pole and line (JPN PLDW)

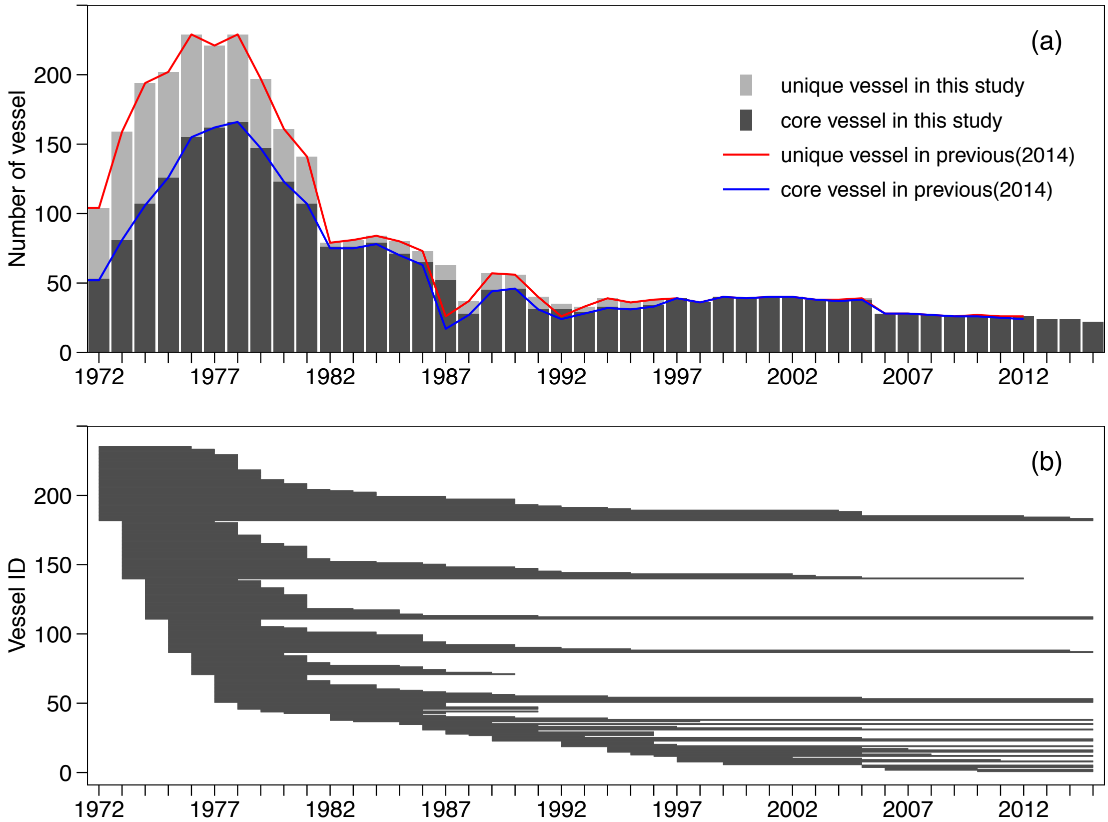


Figure 2. (a) Total number of unique vessels and (b) operating periods of each core vessel. We defined core vessels as fleets operating at least 5 years and 10 days in each year.

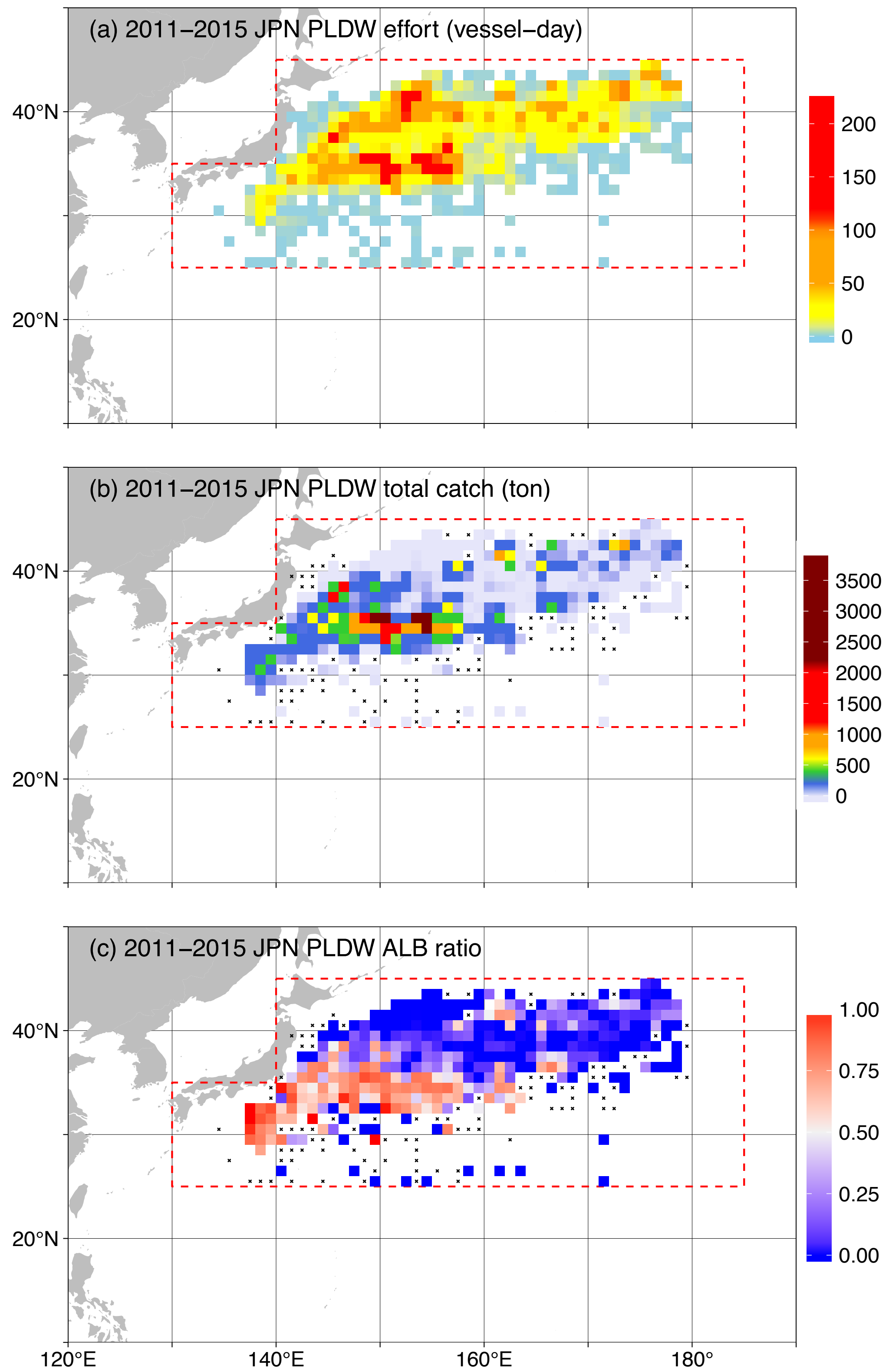


Figure 3. (a) JPN DWPL effort (vessel-day), (b) total NPALB catch (tons) and (c) NPALB catch ratio in recent five years (2011-2015).

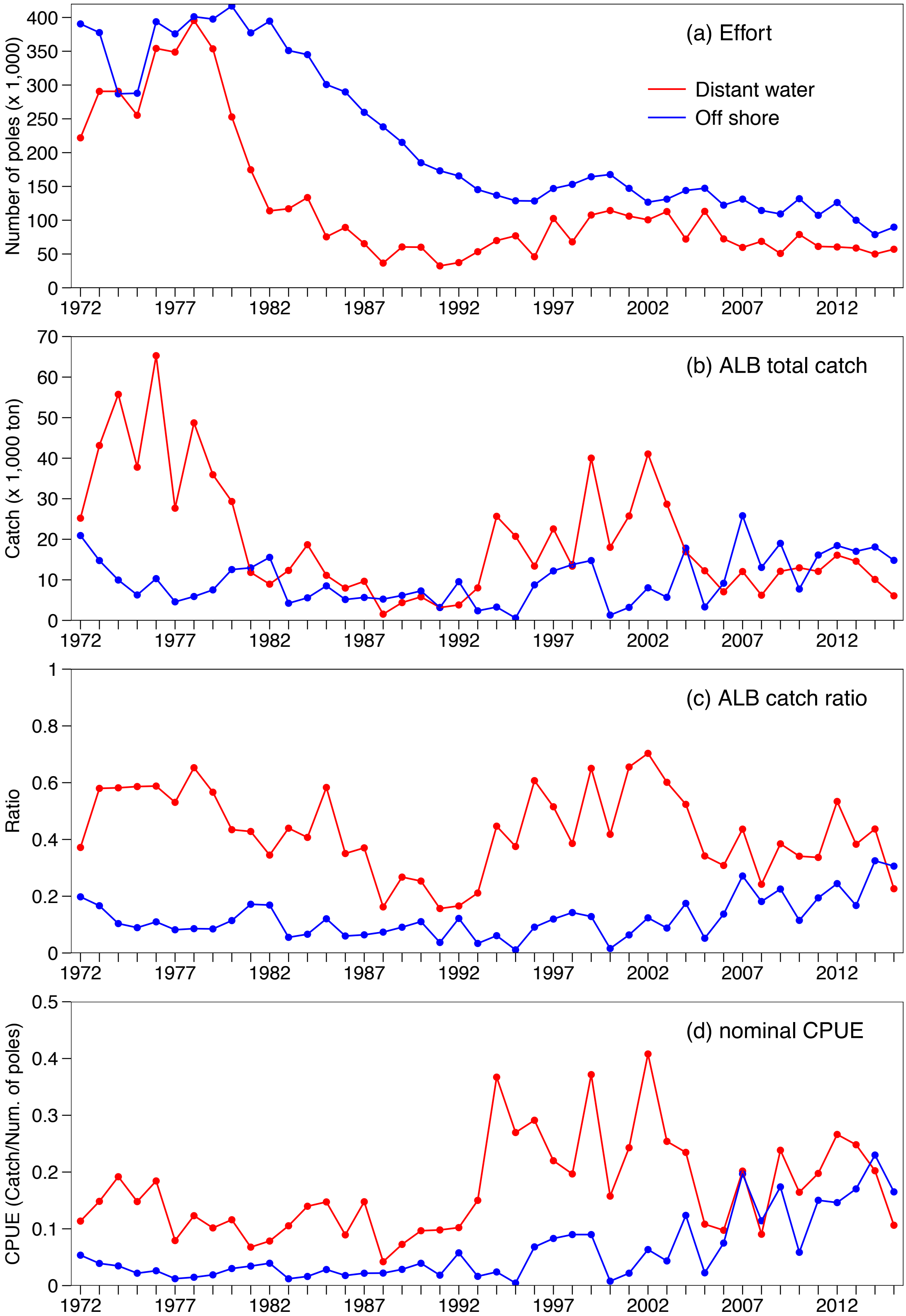


Figure 4. (a) Effort (number of poles, x 1000), (b) ALB total catch (x 1,000 ton), (c) ALB catch ratio and (d) nominal CPUE (ton/poles)

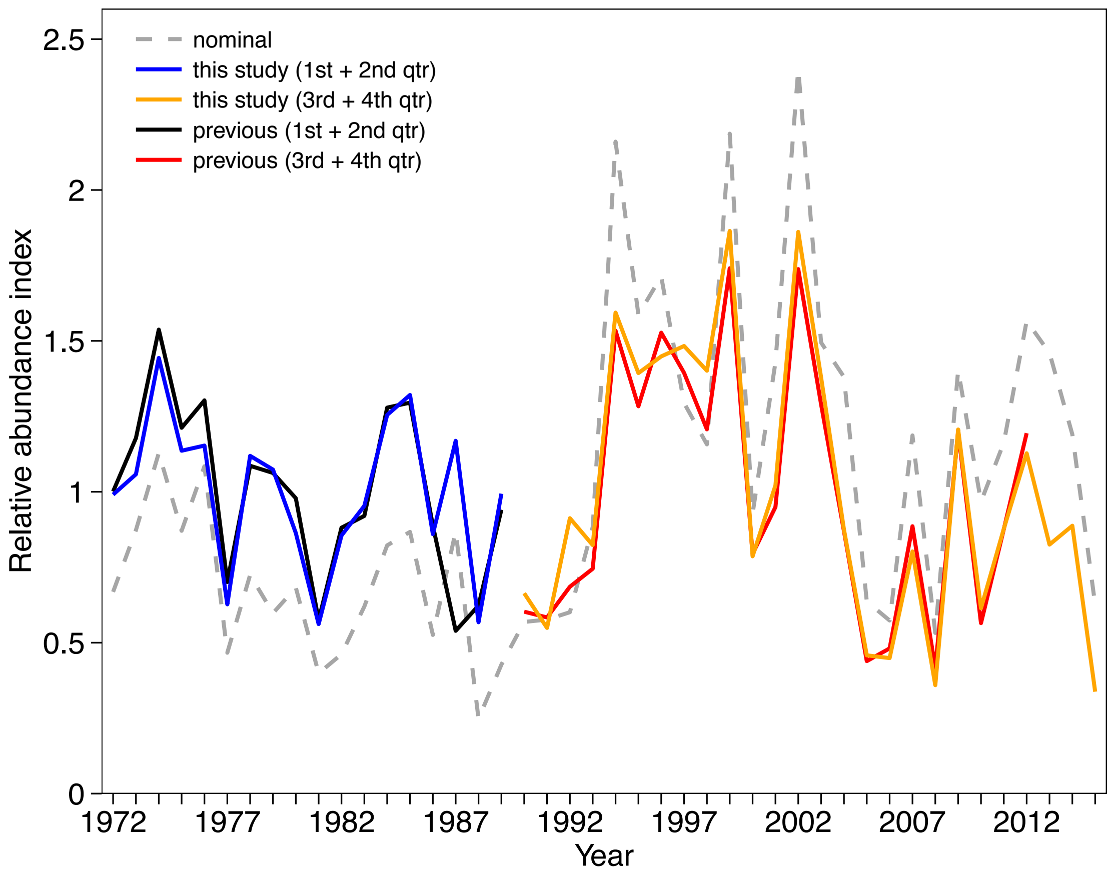
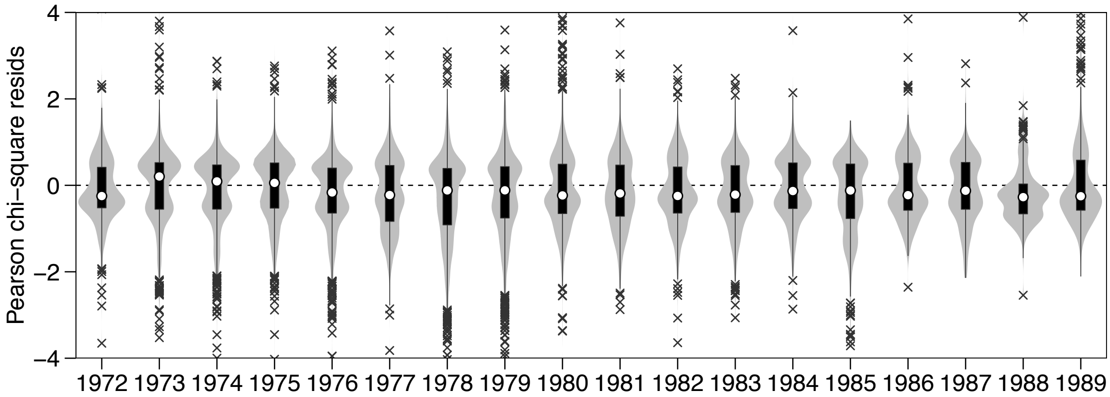


Figure 5. Estimated standardized CPUE of NPALB for JPN DWPL compared with previous result (ISC/14/ALBWG-01/06)

Dashed gray line: nominal CPUE; solid black and red lines: previous estimates (Kiyofuji, 2014); solid blue and orange lines: estimates in this study.

(a) 1st step



(b) 2nd step

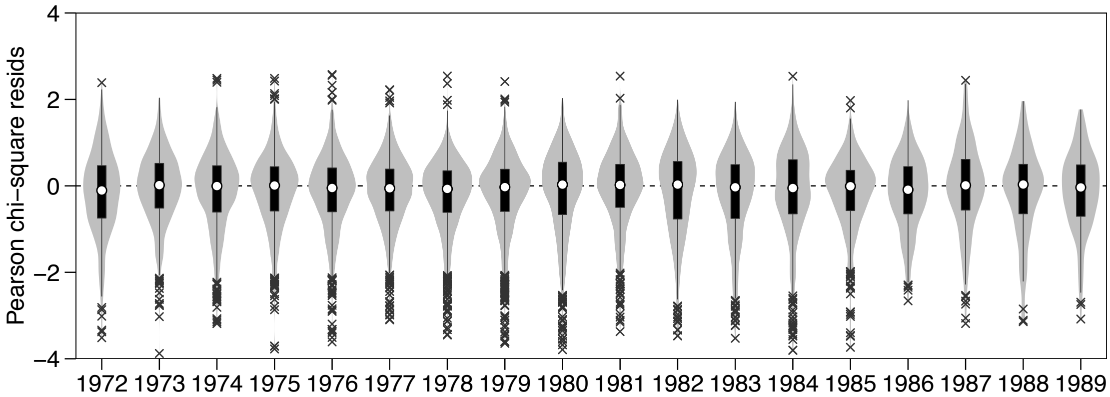


Figure 6. Residual plots of (a) 1st step and (b) 2nd step in the period 1972–1989

The edges at bottom and top of black box shows 25 and 75 percentiles, respectively, and white point shows the mean. Gray shadow represents density of distribution of residuals.

(a) 1st step

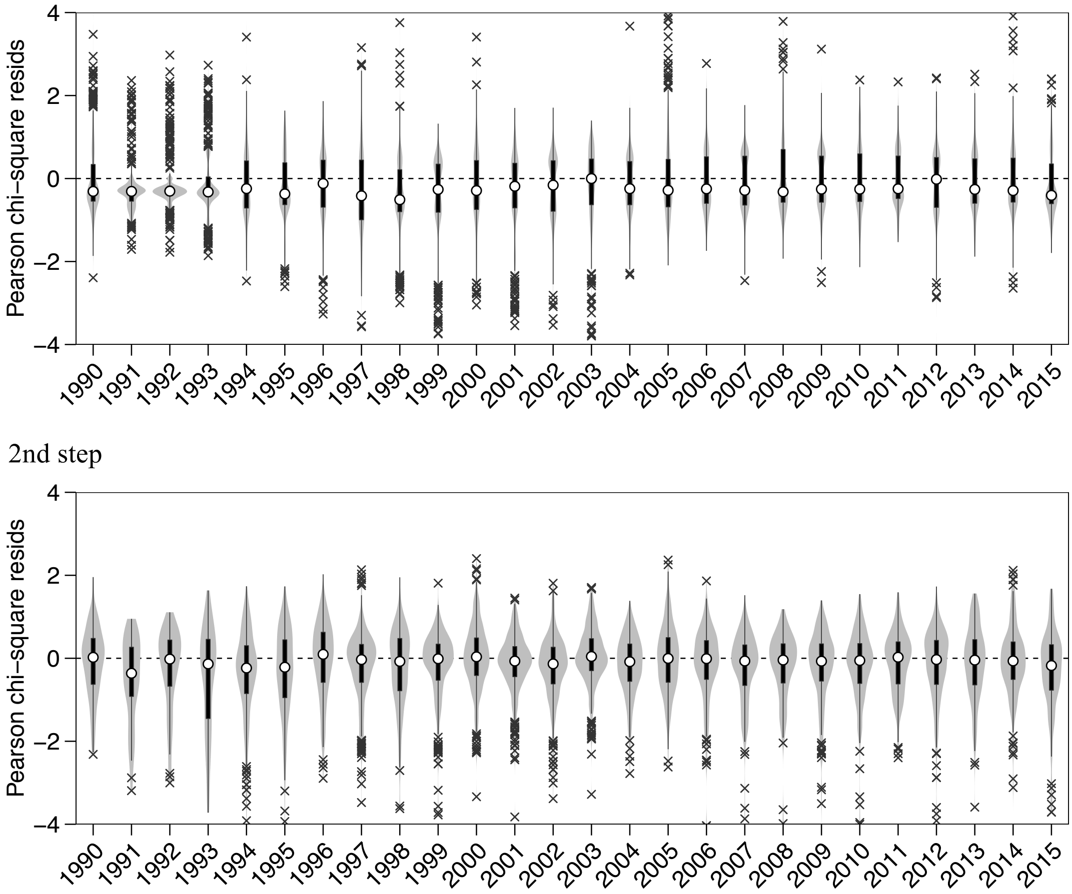


Figure 7. Residual plots of (a) 1st step and (b) 2nd step in the period 1990–2015

The edges at bottom and top of black box shows 25 and 75 percentiles, respectively, and white point shows the mean. Gray shadow represents density of distribution of residuals.

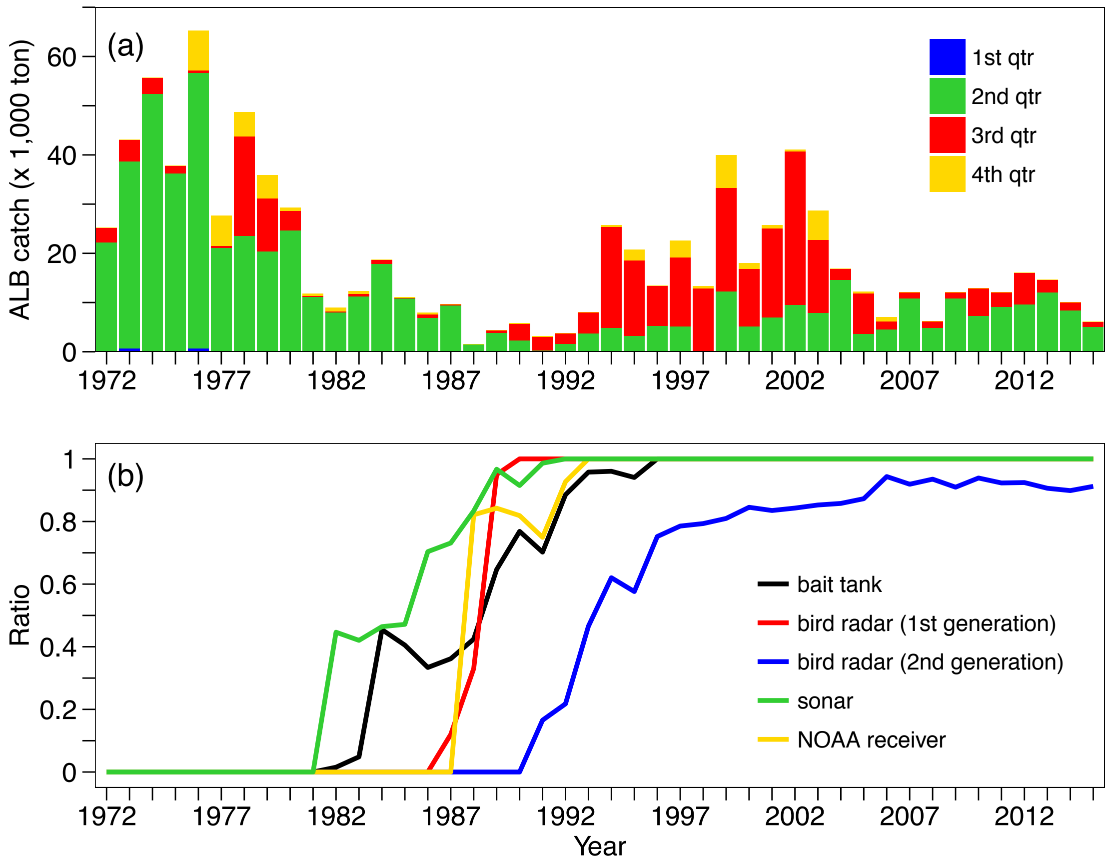


Figure 8. (a) ALB catch by quarter for the JPN PLDW and (b) equipped ratio of searching devices In ALB catch, catch data are aggregated by quarter (1st: Jan.–Mar., 2nd: Apr.–Jun., 3rd: Jul.–Sep., 4th: Oct.–Dec.). In equipped ratio, "bait tank" represents low temperature live bait tank, "bird radar (1st generation)" shows ordinary bird radar, "bird radar (2nd generation)" is high-powered bird radar and "NOAA receiver" shows satellite meteorological information receiver ("sonar" is sonar).

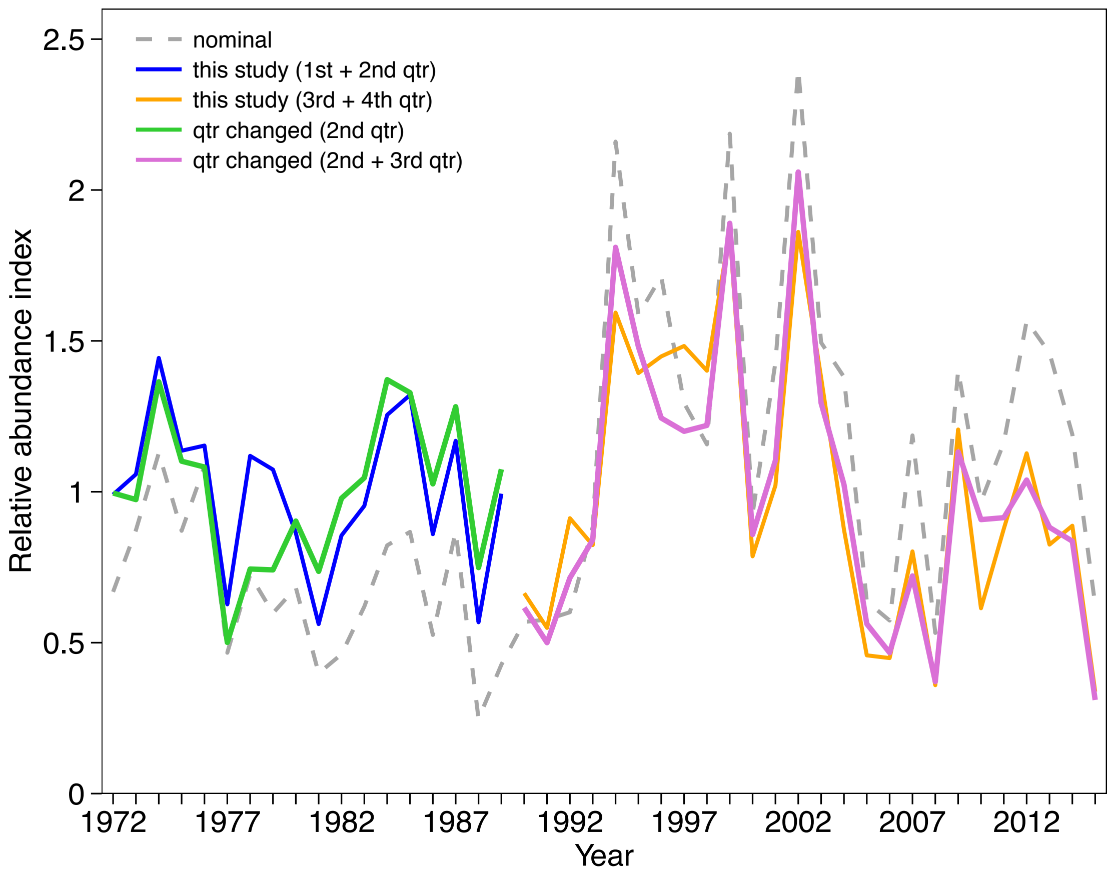


Figure 9. Estimated standardized CPUEs of NPALB caught by JPN PLDW from 1972 to 2015 Dashed gray line: nominal CPUE; Solid blue and orange lines: simple-updated estimates in this study (qtr definition follows **Table 2**); Solid green and purple lines: quarter-changed estimates in this study (only 2nd quarter in the period 1972–1989; only 2nd + 3rd quarters in the period 1990–2015) modeled as $log(rate\ or\ CPUE) = year + latlong + Vessel\ ID + \epsilon, \epsilon \sim binominal\ or\ (0, \sigma^2)$.