Reconsideration of CPUE for albacore caught by the Japanese pole and line fishery in the northwestern North Pacific Ocean. [1]

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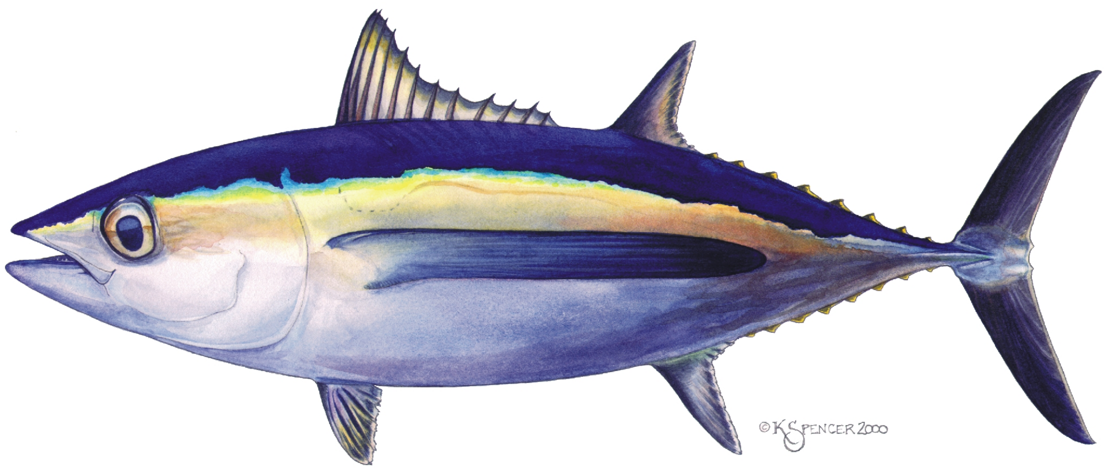

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Summary
In this document, catch per unit effort (CPUE) of North Pacific Albacore (NPALB) caught by the Japanese pole and line (JPN PL) were reconsidered after 2011 stock assessment. Two characteristics of the CPUE by JPN PL in 2011stock assessment were estimated. Two main features are 1. target fish size are different by latitude. Smaller and larger fish are caught in north and in south. 35°N latitude was selected as a boundary of north and south based on length data analysis. 2. vessel size (20GRT-199GRT and ≥200GRT) were considered as one of main effect in the model. However, it is difficult to separate target fish size clearly by latitude and two type of vessel size could be separated by their fishing characteristics such as fishing strategy and equipment. New CPUE of NPALB caught by the JPN PL were considered by the two types of JPN PL fisheries. Technological innovation for onboard devise to search fish schools effectively by bird radar, sonar, meteorological satellite image receiver and to keep live bait longer time during long cruise by bait tank with low temperature were also considered as explatonary variables in the model.

Key words: Japanese pole and line fishery (JPN PL), catch per unit effort (CPUE), technological innovation of onboard device

Introduction

Standardized north pacific albacore Catch Per Unit Effort (CPUE) caught by Japanese pole line fisheries were estimated by delta-lognormal model because of high percentage of zero catch in 2011 stck assessment (Kiyofuji and Uosaki, 2010). Area was defined by latitudinal differences because target fish size were assumed smaller and larger fish in north and south of 35°N based on length data analyses (Ichinokawa and Uosaki, 2009). However, it is difficult to separate target fish size clearly by specific latitude since fish or fishing location possibly could be affected by various factors such as oceanic conditions (Kiyofuji, 2013). In this document, CPUE of north pacific albacore caught by the Japanese pole and line (JPN PL) were reconsidered after 2011 stock assessment and proposed the idea based on fisheries characteristics of the Japanese pole and line.

Technological innovation for onboard devise to search fish schools effectively and to keep live bait longer such as bird radar, sonar, meteorological satellite image receiver bait tank were also considered as predictable variables in the model. These variables were considered in previous research mainly focusing on skipjack (Ogura and Shono, 1999a,1999b; Shono and Ogura, 2000; Langley et al., 2010; Kiyofuji et al., 2011).

Data and Methods

Fisheries Data

The operational level of catch and effort data for the Japanese pole and line during 1972 and 2011 with noon position in equidistant 1° × 1° grid cells was used. Date, number of poles, catch in weight and vessel size in gross register tonnage (GRT) were employed. In this document, JPN PL were categorized by vessel size and their equipment. Vessel size between 20-299 GRT as offshore PL (JPN PLOS) and larger than 300 GRT as distant-water (JPN PLDW) (Table 1).

Japanese pole and line fisheries (hereafter JPN PL) are categorized three, which are inshore, offshore and distant-water. Those categorized basically correspond to vessel size less than 20 GRT, 20-120GRT and larger than 120 GRT based on fishing license. These can also be categorized into small, middle and large size vessel witch correspond to less than 20GRT, 20-199GRT and larger than 200GRT in vessel size until 1999. Since 2000, categorization of vessel size has been changed to less than 20 GRT, 20-299 GRT and larger than 300 GRT because one vessel(220 GRT) were launched and operated in same way and equipments as the middle sized vessels. These characteristics are summarized in Table1. Number of registered vessel calculated from logbook data is shown in Fig.1. Number of vessel shows gradual decrease from 1977 (596 in total) and recent number of vessel from 2007 is around 100 in total which is about 1/6 of 1977.

Inshore JPN PL fish in coastal area within approximately 60 n.m. from their landing port and not target on albacore which proportion is about 1% or less of entire catch by JPN PL. Offshore and distant water JPN PL have different strategies of fishing, for example, offshore vessel conduct fishing activity in shorter cruise (approximately one week per one cruise) and distant water vessel conduct longer cruise (approximately more than month per one cruise). Distant water vessels can go much further area than the offshore vessel due to larger size of vessel and produce frozen fish.

Information on the fishing technology used by the fleet has been collected via interview, as described in Shono and Ogura (1999). Vessel specific information details the implementation of five important technological innovations only in the JPN PLDW: the low temperature live bait tank (LTLBT), onboard NOAA meteorological satellite image receiver (NOAA receiver), first and second generation bird radar, and sonar. The application of these components is described in detail in Ogura and Shono (1999a) and these technologies can be summarized as follows;

- **LTLBT:** Though there had been some method for keeping live bait as long as possible in each period of history of the fishery, the low temperature live bait tank (LTLBT) with cooling system and filtering, purifying, and bubbling tank developed in 1978 was the prototype of present live tank. The survival rate of anchovy in this type of live tank was reported in 1981 more than 85% after 30 days rearing, compared to 50% by the previous system with natural or mechanical water circulation system. Rearing density of one tank by the LTLBT was more than one point five times larger than that by previous systems. Keeping lots of baits and high survival rate for long period made fisherman spent an enough number of baits for one skipjack school, resulting being able to keep and excite the school more than before.

- **bird radar:** In 1987, the bird radar that was a radar adjusted to show a bird and birds school around 15 miles of the vessel (first bird radar) was developed. This meant that the ability of searching birds associated fish school progressed remarkably. The improved type of the bird radar (high powered bird radar) was introduced in 1991, with being searching area about 25 miles.

- **NOAA reciever:** The sea surface temperature is one of the indicator of fishing grounds. Onboard NOAA meteorological satellite image receiver (NOAA receiver) was began to use for searching fish ground in 1988. In these days, except for fishing grounds near Japan, there was limited information on sea surface temperature for fisherman.

- **sonar:** The sonar system is other important device for the pole and line fishery. The primitive sonar began to generalize throughout distant water pole and line vessel from 1960s. Low frequency scanning sonar for fishing vessel was developed early 1970s and higher frequency type had been started to develop from early 1980s. Both types of sonar have been sophisticated. The tilt scanning sonar that was popular for purse seiner has been introduced into pole and line vessels recently. The range of the low frequency sonar is about 1,500m with lower resolution and the range of high frequency one is up to 500 m with high resolution. These sonar are effective for searching fish schools without events on the surface and observing school behavior.

CPUE standardization

Although issue of high percentage of zero catch has been raised in earlier research (Ichinokawa and Uosaki, 2009; Kiyofuji and Uosaki, 2010), we start to model from simple configuration in order to compare model predictability. Following model configuration was used as base model configuration to estimate standardized CPUE .

(1) base model

$$log(CPUE + const.) = year + mon + latlong + skje + \epsilon,\ \epsilon \sim (0, \sigma^2)$$

(2) base model with device (sonar, 1st BR, 2nd BR, bait tank and NOAA receiver)

$$log(CPUE + const.) = year + mon + latlong + skje + device + \epsilon,\ \epsilon \sim (0, \sigma^2)$$

Definitions of each predictor variables are summarized in Table 3. JPN PLOS usually start fishing season from February but target on only skipjack. Based on non zero albacore catch, albacore target period for JPN PLOS is from April to July and for JPN PLDW is from April to November (Table 3). Total number of JPN PLDW are shown in Table 4. The individual logsheet records include the presence or absence of each component of the technology on board the vessel. Where no information is available it is recorded as unknown. The LTLBT was first recorded in the fleet in 1981. For records prior to 1981 where the presence/absence of a LTLBT is recorded as unknown, it was assumed to be absent. Similarly, for records prior to 1987, it was assumed that sonar, first generation bird radar and NOAA receiver were absent if they were recorded as unknown. The second generation bird radar was introduced from 1991, and for earlier records it was assumed that the technology was absent (where recorded as unknown). Area for standardization were determined as encircled area shown in Fig.6 based on their spatial coverage.

Final models for JPN PLDW were chosen based on the results of reduction of parameters from the full model (included all devices) and model selection was made by the Akaike Information Criterion and Bayesian information criterion (BIC) (Table 5). Base model was selected as the final model, which indicate that no technological equippment were statistically important for the JPN PLDW fisheries to catch albacore. This is a opposite result turned skipjack into an objective of CPUE analysis (Langley et al., 2010; Kiyofuji et al., 2011). This is because vertical habitat of albacore is deeper than skipjack which make bird cannot aggregate fish school, or sonar cannot detect fish school due to similar reason.

Results and Discussion

Time series of effort, catch and nominal CPUE

Figure 2 shows effort (total number of poles $\times$ 1000), total catch ($\times$ 1000 mt) and nominal CPUE by JPN PLOS (gray) and PLDW (black), respectively. Effort by PLOS shows gradual decrease after 1980 until 1990, then remain at the same level around 100 ($\times$ 1000 poles). There is no specific change in total catch by PLOS until 2002 but gradual increase was identified after 2002. Nominal CPUE by PLOS shows similar trend of catch that it increase after 2005 gradually. Overall, remarkable change of nominal CPUE has not occurred during whole period, because PLOS usually does not target on albacore which percentage of catch relative to total of skipjack and albacore is below 20 % (Fig.3).

Although effort trend by JPN PLDW is relatively stable through whole period, one remarkable differences is catch during 1994 and 2003 were higher than the period between 1980 and 1992 that shows two-threefold increase. Catch after 2003 (around 40,000 mt) shows sharp decrease until 2006 (around 9,000 mt) and then stay at same level until 2011. Possible reason for this is that target fish by JPN PLDW shift from albacore to skipjack (Kiyofuji, 2013). Nominal CPUE likely shows similar trend with catch, however, there likely exist three phase at nominal CPUE level (1972-1992, 1993-2003 and 2004-2011). When comparing JPN PLOS, albacore catch ratio is higher at the average of 49 %. JPN PLDW likely target on albacore rather than skipjack.

Decadal and spatial distribution of effort, catch and albacore catch ratio

Figure 4 - 6 represent decadal and spatial distribution of effort (total number of vessel-day), catch (mt) and albacore catch ratio (albacore/ albacore + skipjack) in 1°× 1 ∘ aggregated in decadal scale.

Significant change were not identified in JPN PLOS. Their main fishing ground formed areas around 130°E - 150°E, 30°N (Fig.4 and Fig.5), however, this fishing ground did not correspond to the area of high albacore ratio where was formed at east of 150 °E (Fig.3). This result and low albacore ratio in Fig.3 indicate that JPN PLOS does not always target on albacore. This is consist with their fishing strategies, that their target is mainly on skipjack. However, albacore ratio after 2001 around [140°E,30°N] likely increased in comparison to before 2001 (Fig.3 (c) and (d)). Additionally, albacore ratio has been increasing in recent year (fig.3). Tease results implies that target fish by the JPN PLOS has been shifting to albacore in recent years. In fact, it is reported that skipjack has been decreasing especially at the beginning of main fishing season (May or June) in recent years (e.g. Uosaki et al., 2010).

JPN PLDW fishing location extended wider than JPN PLOS, they sometimes went over the corder of date line (Fig.4 - 6). Fishing area has been shrinking with total number of vessel and their distribution has also changed around 1991. Their spatial distribution tend to be formed more northern area (around 160°E,40°N) after 1991. It is worth noting that main fishing area targeting albacore was formed souther area of 35°N. These fact, combined with sharp decline in same period shown in Fig.3, indicate that albacore stock in this area has been declined and this is consist with the 2011 stock assessment results. Further analysis will be necessary to investigate any factors caused these changes.

Standardaized CPUE

Standardized CPUE for both JPN PLOS and PLDW were overlaid with nominal CPUE in Fig.7 and ANOVA results are summarized in Table 6. These indices were represented as relative scale by the average from 1972 to 2011 (Fig.7). Both residual of base case model did not show large differences from the normal distribution (Fig.8). Both CPUE kept at the same level and gradually increased in recent years after 2005. JPN PLDW indices slightly increased after 1990 and keep at the same level until end of the period.

Fig.9 shows effect of each explanatory variable on standardized CPUE. Effect of month in June was high and month effect decrease after June (PLDW). Increased area effect of PLDW was identified from 28 to 37 where is between 40°N-45°N and 140°E-175°E. Skipjack effects were significant both of PLOS and PLDW which can be identified from F-value in Table 6.

Summary and recommendations

In this document, catch per unit effort (CPUE) of North Pacific Albacore (NPALB) caught by Japanese pole and line were reconsidered after 2011 stock assessment and proposed the idea based on fisheries characteristics of the Japanese pole and line. The ideas of standardized CPUE estimates are as follow;

- It is difficult to separate target albacore size clearly by the specific latitude because fish or fishing location possibly affected by various factors such as oceanic conditions.
- Albacore size caught by both JPN PLOS and PLDW is assumed as similar size during fishing season and in areas for CPUE definition (Figure 6).
- Fishery should be defined by their unique characteristics such as their strategy, equipment and targeting.

JPN PL CPUE estimates in this study were reflected by the idea described above and following recommendations are raised to apply the JPN PL CPUE in stock assessment model;

- it would be better to estimate standardized CPUE by reflecting fishery characteristics rather than separating area by target fish size.
- CPUE by JPN PLDW would be a better indices for albacore in the northwestern North Pacific Ocean than CPUE by JPN PLOS because of lower albacore catch rate.

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Table 1. Summary of JPN PL category.

Category	Vessel size (license)	(equipment)	days per cruise	area and equipment
coastal PL	< 20 GRT	< 20 GRT	1 or 2	near landing port
offshore PL	20-119 GRT	-		
middle sized PL	-	20-299 GRT	2-10	only in northern area
		-		water cooler, unload fresh fish
distant water PL	120 GRT $<$	-		
large sized PL	-	300 GRT $<$	30-50	both in north and south area
		-		brain and deep freezer, unload frozen fish

Table 2. Definition of the predictor variables included in the model.

(a) base model for JPN PLOS

Variable	Data type	Description
year	Categorical	unique year
mon	Categorical	unique month (April - July)
latlong	Categorical	$5° \times 5°$
skje	Categorical	skipjack effect (percentage of skipjack catch to total catch) 1. < 25% 2. 25 - 75% 3. 75% <

(b) base model for JPN PLDW

Variable	Data type	Description
year	Categorical	unique year
mon	Categorical	unique month (April - Nov.)
latlong	Categorical	$5° \times 5°$
skje	Categorical	skipjack effect (percentage of skipjack catch to total catch) 1. < 25% 2. 25 - 75% 3. 75% <

(c) base model with device data

Variable	Data type	Description
year	Categorical	unique year
mon	Categorical	unique month
latlong	Categorical	$5° \times 5°$
skje	Categorical	skipjack effect (percentage of skipjack catch to total catch) 1. < 25% 2. 25 - 75% 3. 75% <
bird radar	Categorical	1: not equipped, 2: 1st generation, 3: 2nd generation
sonar	Categorical	1: not equipped, 2: equipped
bait tank	Categorical	1: not equipped, 2: equipped
NOAA reciever	Categorical	1: not equipped, 2: equipped

Table 3. Number of non-zero albacore catch data record.

(a) JPN PLOS

Year/month	1	2	3	4	5	6	7	8	9	10	11	12
1972	10	11	121	253	575	636	65	18	2	0	0	0
1973	4	190	244	278	361	732	180	45	36	0	0	0
1974	0	7	23	306	587	166	56	15	1	0	0	0
1975	0	8	89	684	493	173	31	11	8	0	0	7
1976	1	7	145	391	1025	1271	168	14	2	2	0	0
1977	3	19	191	216	848	469	198	5	1	2	4	0
1978	3	10	93	142	1141	1046	58	4	7	1	6	0
1979	3	15	292	278	222	802	783	52	5	10	12	14
1980	5	20	155	233	740	1385	545	4	15	268	102	6
1981	3	3	105	1778	1554	503	52	2	3	1	0	6
1982	29	22	399	202	2236	1172	258	15	30	51	1	0
1983	13	31	149	104	119	632	221	20	3	5	2	0
1984	16	10	5	5	396	939	178	34	5	5	11	11
1985	20	19	72	364	1204	515	33	24	16	11	5	4
1986	55	30	10	94	145	688	174	22	4	19	7	13
1987	11	7	22	12	122	785	73	8	5	6	6	1
1988	9	11	62	50	68	776	210	10	5	5	0	1
1989	8	16	15	36	255	691	331	1	0	2	5	0
1990	5	11	107	17	29	679	618	12	1	37	12	0
1991	2	1	169	199	337	119	38	17	2	8	16	3
1992	0	18	78	26	53	382	760	228	0	1	1	0
1993	4	3	64	34	12	196	78	6	2	1	0	7
1994	8	6	63	112	24	243	40	2	1	9	193	41
1995	0	3	8	12	47	66	14	1	0	21	7	1
1996	0	20	27	17	84	461	262	2	0	14	19	13
1997	5	6	24	14	136	875	73	5	5	5	133	25
1998	1	7	147	507	168	529	134	43	15	10	5	0
1999	0	2	55	66	675	451	17	10	9	9	10	0
2000	0	25	12	32	94	87	35	8	3	10	13	3
2001	0	9	0	15	243	324	201	2	0	0	1	2
2002	0	1	4	121	70	504	96	7	1	3	187	0
2003	0	0	4	56	5	5	14	4	0	244	279	0
2004	0	0	106	585	439	302	8	3	4	17	22	0
2005	0	1	30	60	86	140	60	47	118	2	4	0
2006	0	2	0	26	171	601	177	6	0	15	29	0
2007	0	3	33	91	850	768	108	27	0	0	0	0
2008	0	1	19	6	58	804	154	5	0	0	0	0
2009	0	0	13	30	461	571	54	1	9	99	26	0
2010	0	2	23	45	106	447	93	1	0	0	98	0
2011	0	6	39	18	163	587	177	1	0	2	4	0

Table 3. (continue).

(b) JPN PLDW

Year/month	1	2	3	4	5	6	7	8	9	10	11	12
1972	0	0	3	208	1303	908	346	165	4	10	34	31
1973	0	2	193	852	2453	2369	574	1	1	3	21	14
1974	0	8	5	477	2951	2371	527	9	1	2	47	26
1975	0	0	17	1021	2885	1905	340	1	0	0	1	0
1976	0	0	84	740	3647	2960	149	0	5	446	552	113
1977	0	0	94	1243	3434	710	87	6	42	676	841	169
1978	0	0	2	611	3630	1679	2216	1601	174	609	402	118
1979	0	1	1	764	2138	2494	1876	480	244	588	621	187
1980	0	0	17	391	2170	1495	937	80	304	229	37	10
1981	0	0	5	499	1346	1068	25	204	267	157	54	18
1982	0	0	33	300	1211	565	77	52	12	176	98	17
1983	0	0	39	216	1189	892	185	41	34	147	98	1
1984	0	0	4	19	1259	1160	183	21	13	12	19	3
1985	0	0	1	300	816	735	29	2	0	86	197	1
1986	0	0	2	67	556	734	166	46	28	63	34	0
1987	0	0	0	23	696	815	68	2	5	0	20	0
1988	0	0	0	48	178	127	15	8	1	9	1	1
1989	0	0	1	35	187	541	132	0	0	3	2	2
1990	0	0	0	0	45	329	445	54	46	52	5	0
1991	0	0	0	0	18	44	25	35	188	22	10	2
1992	0	0	0	6	9	206	182	16	1	0	0	0
1993	0	0	0	0	21	378	292	12	5	2	4	0
1994	0	0	0	8	76	451	519	398	88	34	28	1
1995	0	0	0	0	57	303	322	479	65	118	118	0
1996	0	1	0	0	8	390	450	318	91	1	0	0
1997	0	0	0	0	55	497	367	667	518	367	73	1
1998	0	0	1	5	8	23	305	478	457	78	0	0
1999	0	0	0	0	235	641	167	666	532	656	363	2
2000	0	1	1	0	62	524	473	608	662	44	50	190
2001	0	0	2	4	156	814	673	653	613	107	0	0
2002	0	0	0	7	309	686	762	723	431	73	5	0
2003	0	0	0	2	8	522	714	566	192	481	427	0
2004	0	0	5	111	735	517	307	9	3	2	2	3
2005	0	0	4	6	202	521	487	432	167	129	201	0
2006	0	0	0	1	110	490	211	13	3	104	81	0
2007	3	0	1	7	357	611	115	103	7	1	0	0
2008	0	0	0	0	10	498	196	0	2	1	0	0
2009	0	0	0	6	151	519	149	7	5	42	5	0
2010	0	0	2	14	164	503	338	261	0	2	34	1
2011	0	0	0	0	73	567	230	39	0	0	0	0

Table 4. Total number of PLDW fleet with device (bird radar, sonar, bait tank and NOAA reciever). Note that 1 and 2 in sonar, bait tank and NOAA reciever represent no device and with device, respectively. For bird radar, 1 is no device and 2 and 3 represent 1st and 2nd generation of bird radar.

	birdradar			sonar		bait tank		NOAA receiver	
Year	1	2	3	1	2	1	2	1	2
1972	1722	0	0	1722	0	1722	0	1722	0
1973	3619	0	0	3619	0	3619	0	3619	0
1974	3655	0	0	3655	0	3655	0	3655	0
1975	3822	0	0	3822	0	3822	0	3822	0
1976	5538	0	0	5538	0	5538	0	5538	0
1977	4342	0	0	4342	0	4342	0	4342	0
1978	7172	0	0	7172	0	7172	0	7172	0
1979	6623	0	0	6623	0	6623	0	6623	0
1980	5146	0	0	5146	0	5146	0	5146	0
1981	2727	0	0	2727	0	2727	0	2727	0
1982	2577	0	0	1728	849	2504	73	2577	0
1983	2377	0	0	1600	777	2138	239	2377	0
1984	3500	0	0	2185	1315	1262	2238	3500	0
1985	1720	0	0	987	733	524	1196	1720	0
1986	1983	0	0	721	1262	776	1207	1983	0
1987	80	7	0	17	70	63	24	87	0
1988	2	406	0	2	406	274	134	2	406
1989	0	2022	0	59	1963	353	1669	142	1880
1990	0	2311	0	256	2055	323	1988	333	1978
1991	0	865	225	25	1065	160	930	252	838
1992	0	765	137	0	902	75	827	54	848
1993	0	1201	969	0	2170	101	2069	0	2170
1994	0	974	1791	0	2765	0	2765	0	2765
1995	0	1339	1873	0	3212	82	3130	0	3212
1996	0	481	1475	0	1956	0	1956	0	1956
1997	0	980	3585	0	4565	0	4565	0	4565
1998	0	624	2401	0	3025	0	3025	0	3025
1999	0	863	3669	0	4532	0	4532	0	4532
2000	0	772	4290	0	5062	0	5062	0	5062
2001	0	726	3688	0	4414	0	4414	0	4414
2002	0	649	3470	0	4119	0	4119	0	4119
2003	0	653	3775	0	4428	0	4428	0	4428
2004	0	422	2454	0	2876	0	2876	0	2876
2005	0	610	4043	0	4653	0	4653	0	4653
2006	0	168	2801	0	2969	0	2969	0	2969
2007	0	201	2276	0	2477	0	2477	0	2477
2008	0	183	2653	0	2836	0	2836	0	2836
2009	0	190	1904	0	2094	0	2094	0	2094
2010	0	197	3027	0	3224	0	3224	0	3224
2011	0	195	2338	0	2533	0	2533	0	2533

Table 5. AIC and BIC for JPN PLDW base cans and base case with each device.

Model	**AIC**	**BIC**
(1) base model for JPN PLDW	291593	291603
(2) (1) + all devices	291614	291625
(3) (1) + bait tank	291596	291606
(4) (1) + sonar	291597	291607
(5) (1) + noaa	291598	291608
(6) (1) + bird radar	291602	291606
(7) (1) + bird radar + sonar	291607	291617
(8) (1) + sonar + bait tank	291602	291612

Table 6. TYPE3 ANOVA (deletion of 1 variable from the final model).

(a) base model for JPN PLOS

Factor	**DF**	**Type III SS**	**Mean Square**	**F Value**	Pr > F
year	39	6001.2	153.9	574.7	< .0001
mon	3	507.7	169.2	632.0	< .0001
area	18	601.2	33.4	124.7	< .0001
skje	2	479596.1	239798.1	895528	< .0001

(b) base model for JPN PLDW

Factor	**DF**	**Type III SS**	**Mean Square**	**F Value**	Pr > F
year	39	4115.1	105.5	205.6	< .0001
mon	7	1177.6	168.2	327.8	< .0001
area	38	972.8	25.6	49.9	< .0001
skje	2	217679.1	108839.5	212090	< .0001

(b) base model for JPN PLDW with devices (include all device)

Factor	**DF**	**Type III SS**	**Mean Square**	**F Value**	Pr > F
year	39	7161.4.1	183.6	348.5	< .0001
mon	7	2438.5	348.4	661.1	< .0001
area	38	1869.9	245.2	458.3	< .0001
skje	2	330814.1	165407	313921	< .0001
bait tank	1	0.66	0.66	1.28	0.26
bird radar	2	0.04	0.02	0.04	0.96
sonar	1	0.39	0.39	0.75	0.39
NOAA	1	0.26	0.26	0.50	0.48

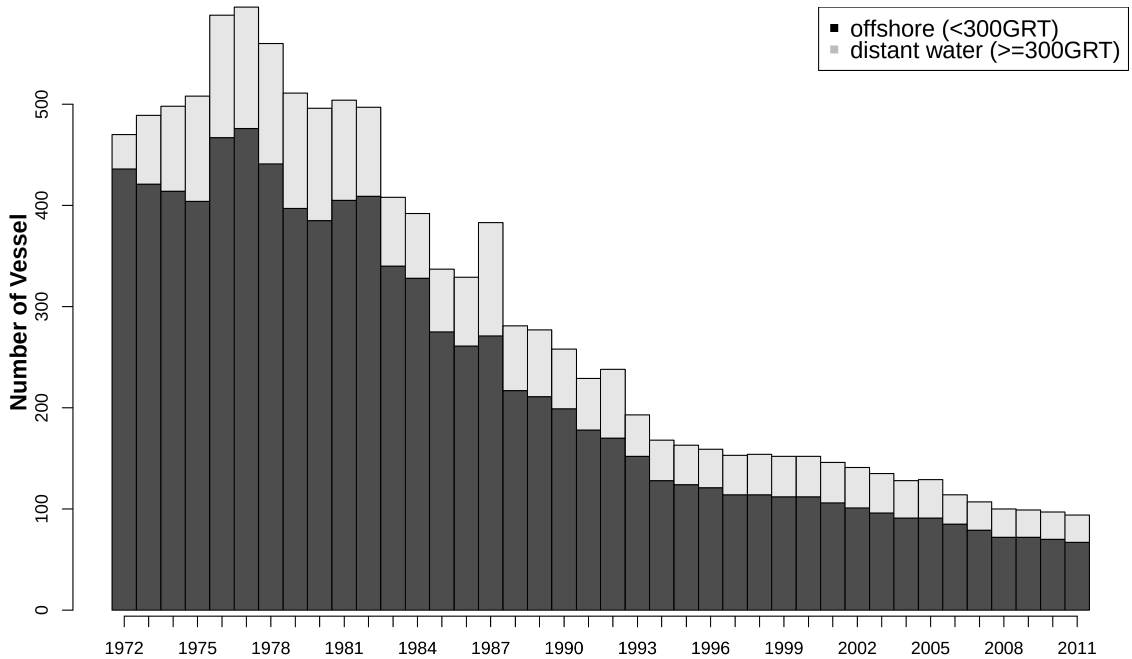

Figure 1. Number of registered vessel both of offshore ($<$300GRT) and distant water ($\geq$300GRT) PL.

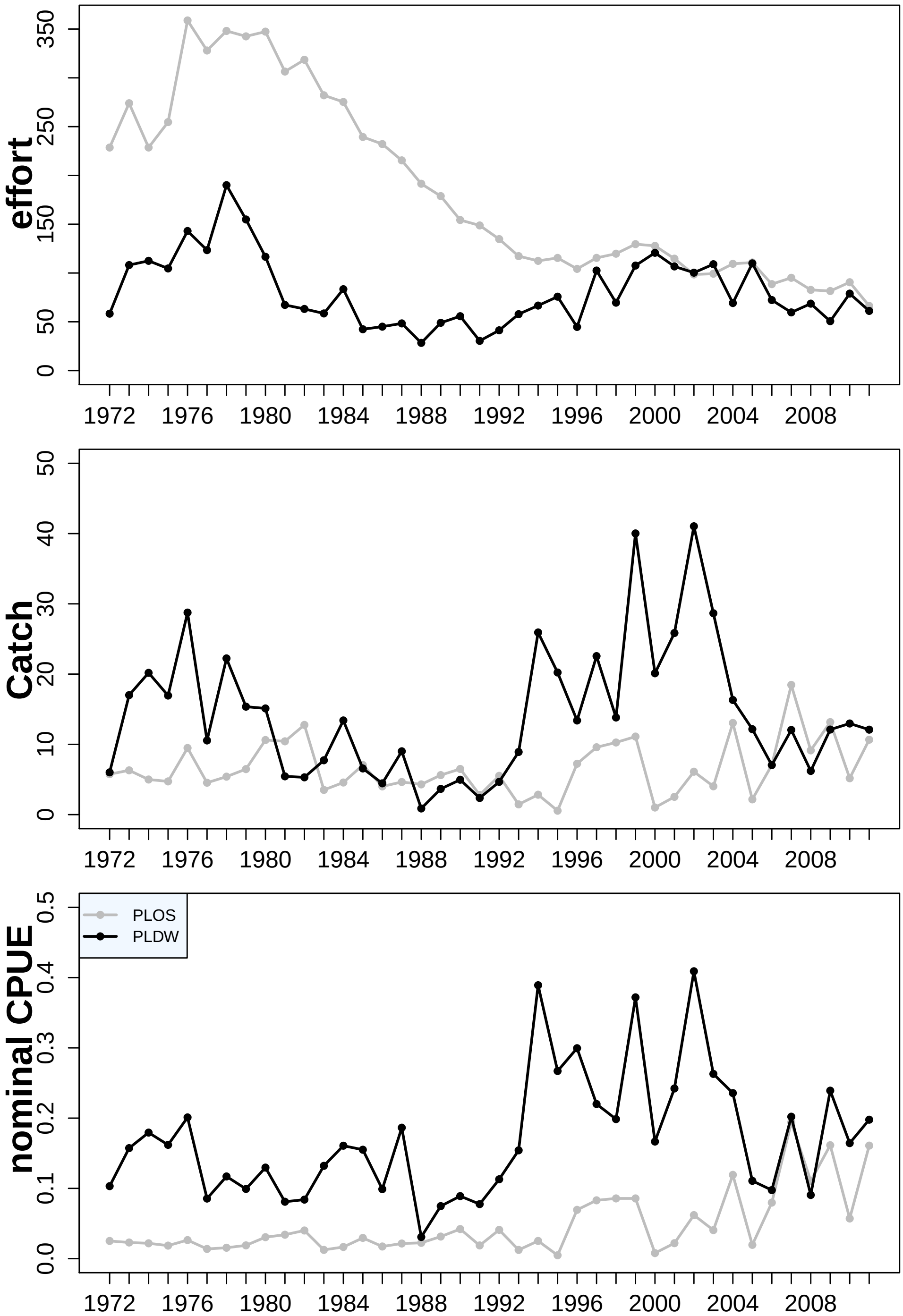

Figure 2. Effort (total number of pole × 1000), total catch (× 1000 mt) and nominal CPUE (catch/pole-day) for North Pacific albacore caught by the JPN PLOS (gray) and JPN PLDW (black).

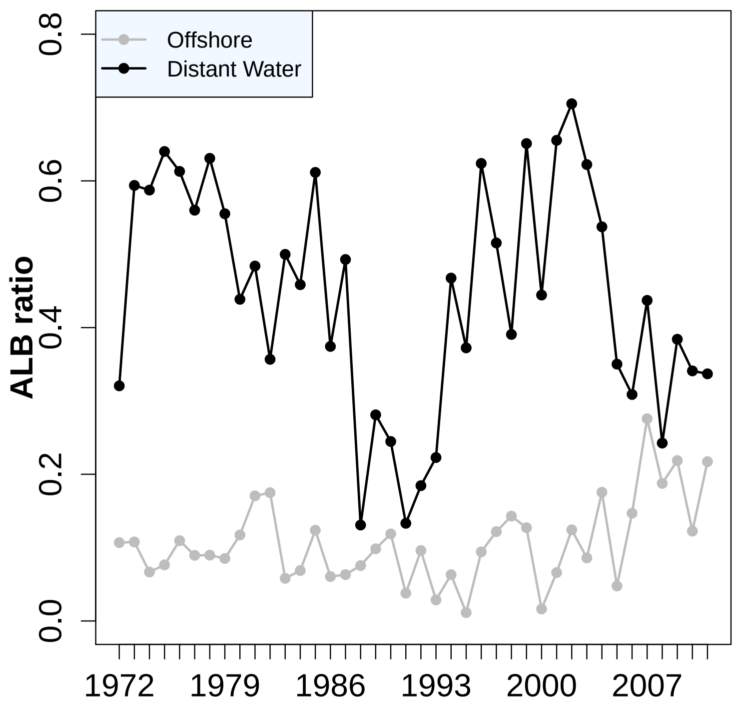

Figure 3. Time series of albacore catch ratio to skipjack caught by the JPN PLOS (gray) and JPN PLDW (black) from 1972 to 2011.

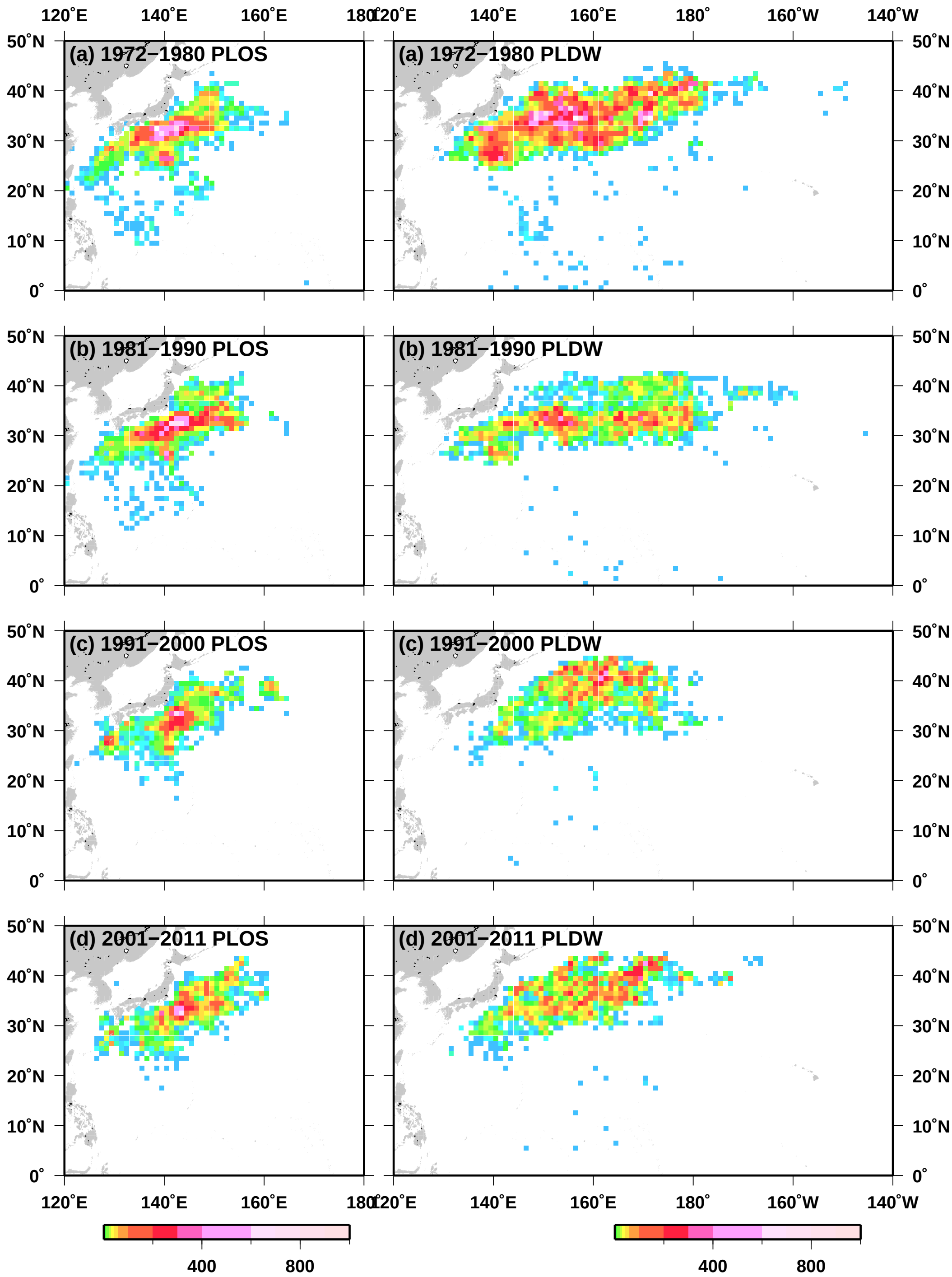

Figure 4. Total effort (vessel number-day) of JPN PLOS (left) and JPN PLDW (right). (a) 1972-1980, (b) 1981-1990, (c) 1991-2000 and (d) 2001-2011.

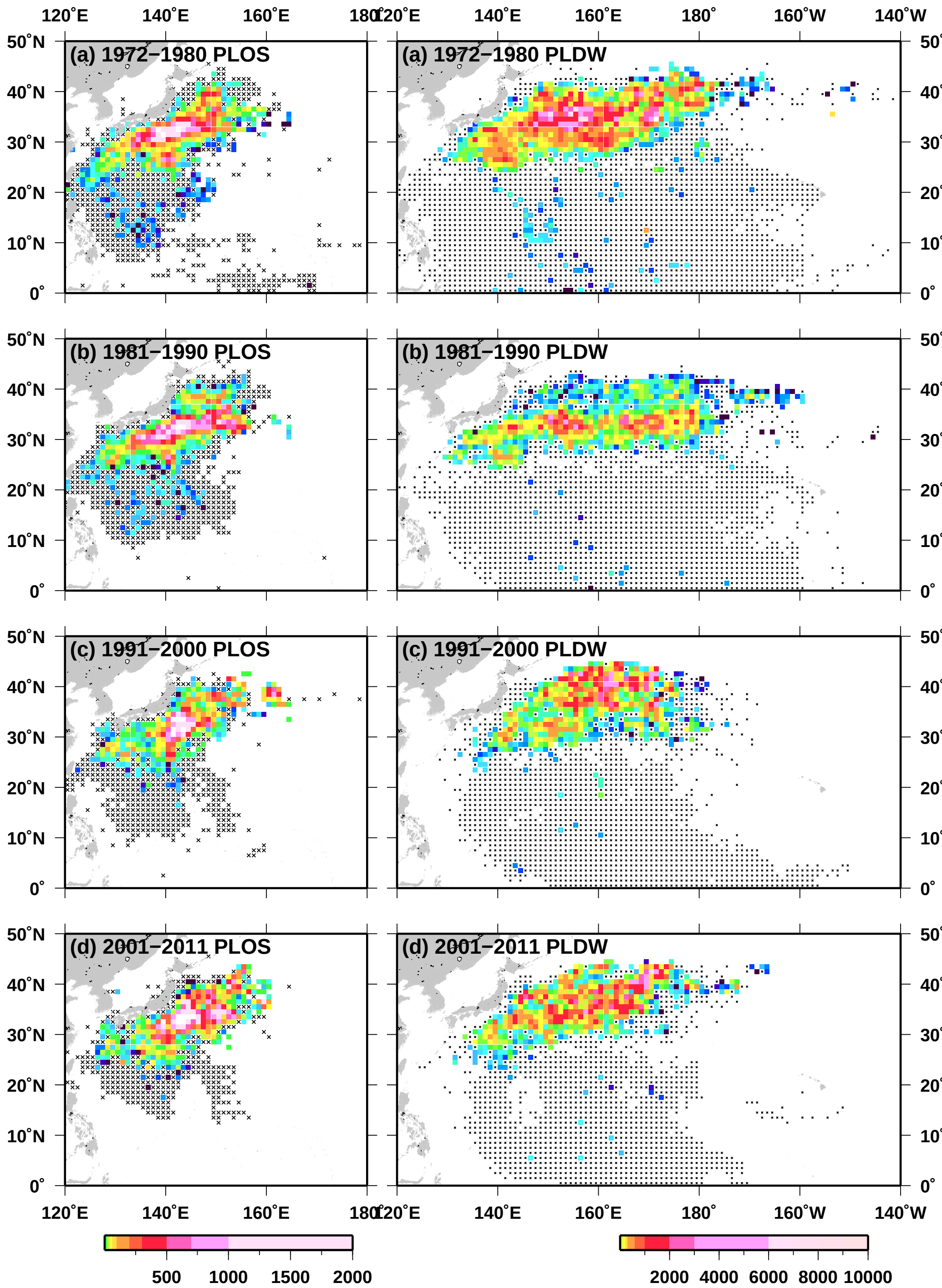

Figure 5. Total albacore catch caught by JPN PLOS (left) and JPN PLDW (right). (a) 1972-1980, (b) 1981-1990, (c) 1991-2000 and (d) 2001-2011.

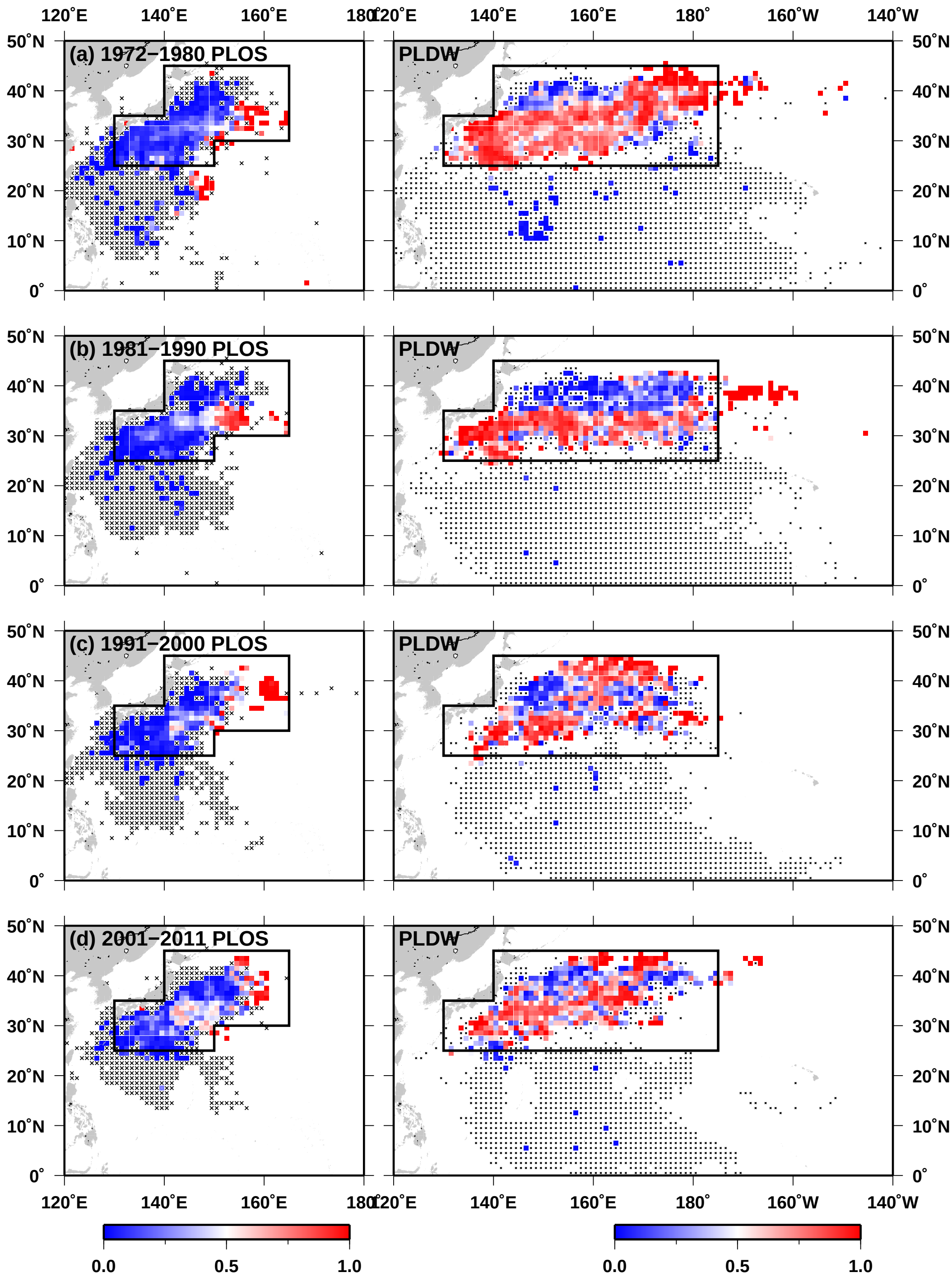

Figure 6. Albacore catch ratio to skipjack caught by JPN PLOS (left) and JPN PLDW (right). (a) 1972-1980, (b) 1981-1990, (c) 1991-2000 and (d) 2001-2011.

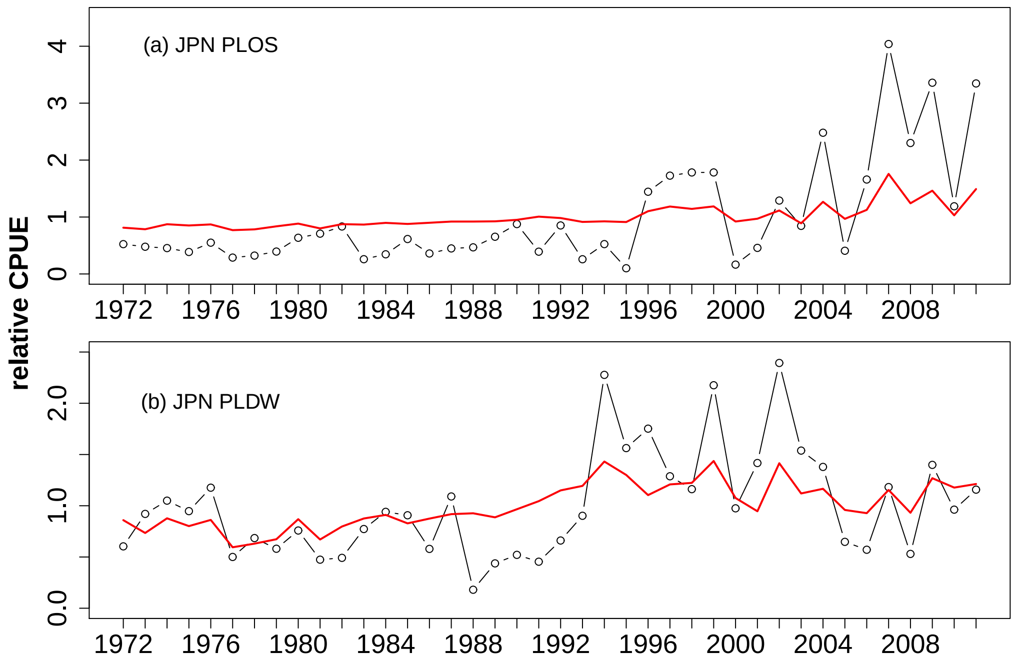

Figure 7. Relative CPUE of nominal (white circle) and standardized (red) for (a) JPN PLOS and (b) PLDW.

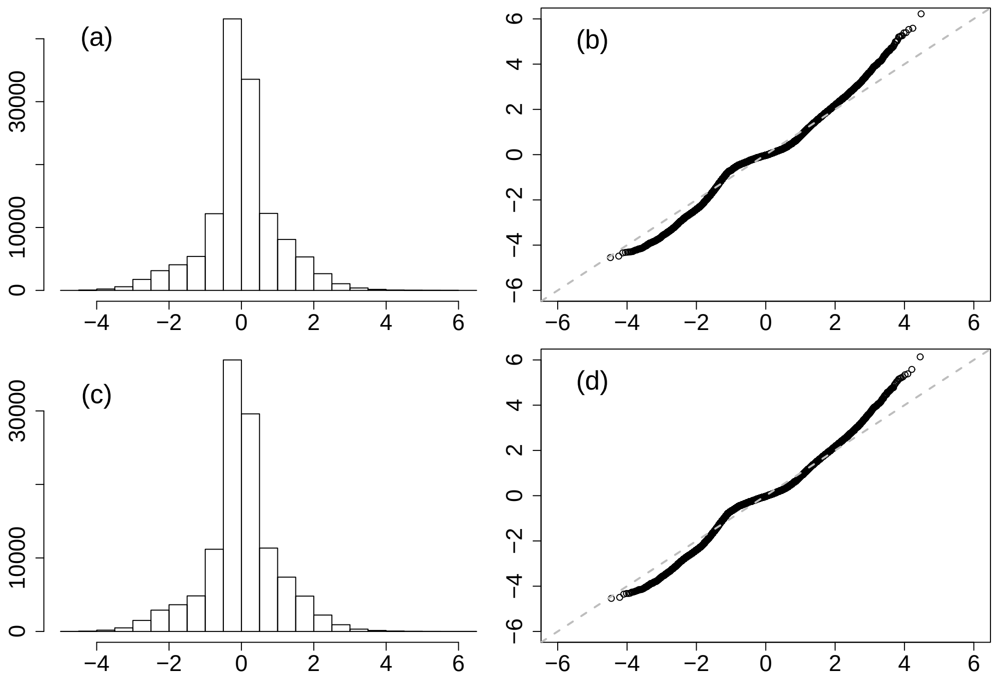

Figure 8. Standard residuals and QQ plot for JPN PLOS base case model (a,b) and for JPN PLDW base case model (c,d), respectively.

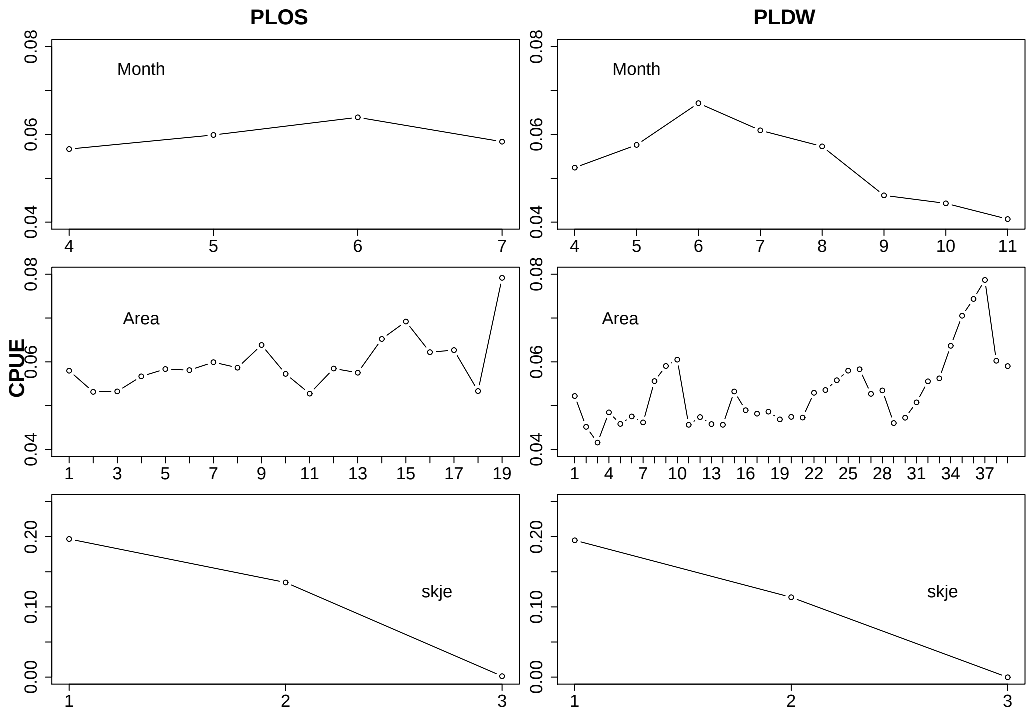

Figure 9. Effect of each variable for JPN PLOS (left) and JPN PLDW (right) .