Updated standardized CPUE for 0-age Pacific bluefin tuna caught by Japanese troll fisheries: Updated up to 2018 fishing year

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Summary

To update the recruitment abundance index for Pacific bluefin tuna up to 2018 fishing year, Japanese troll CPUE in the East China Sea (coastal waters of western Kyushu), which is used for stock assessment, was standardized for the period of 1980-2018 fishing year. The standardized CPUE in 2018 fishing year was lower than one in 2017 and lower than the historical average.

Introduction

The index of juvenile Pacific bluefin tuna (PBF) abundance based on catch and effort data of troll fisheries is one of the important indices available for monitoring of the recruitment and assessment of the PBF stock. Ichinokawa et al. (2012) provided three CPUE series of troll fisheries landed in Kochi, Wakayama, and Nagasaki Prefectures, and ISC PBFWG decided to fit time series obtained around Tsushima and Goto Islands's from Nagasaki Prefecture in the assessment model due to representativeness (ISC 2014). This troll fishery which operates in the coastal waters of Tsushima and Goto Islands is targeting age-0 PBF which comes from both of the two major spawning grounds (in waters near the Ryukyu Islands to the east of Taiwan, and in the southern portion of the Sea of Japan), thus their CPUE is expected to reflect the whole annual recruitment strength of PBF population. The standardized CPUE from this fishery was used as a recruitment abundance index for the previous stock assessments (ISC 2016, ISC 2018).

This document presents an update of the standardized CPUE using the procedure agreed in last PBFWG (Nishikawa et al., 2019, ISC PBFWG 2019). The catch-and-effort data used in this document have been collected and archived by National Research Institute of Far Seas Fisheries with cooperation from local fishery institutes, as a part of the Marine Ranching Project during 1980's (Secretariat of Forestry and Fisheries Research Council 1989) and Research Project on Japanese bluefin tuna (RJB) since 1994 (Ichinokawa et al. 2012).

Materials and Methods

Update of the current recruitment index

The troll CPUE is based on the catch-and-effort data which have been collected at the 5 main fishing ports in Tsushima and Goto Islands since 1980s; Izuhara-Are, Kami-tsushima, Kami-agata, Ojika and Tomie (Fig. 1). These data were based on the sales slips sold as "yokowa" brand which mean small PBF. The catch data is total PBF weight of sales per day in each fishing port, which includes landing weight for fresh market and fry weight for farming. The effort data is the number of ships which sold PBF per day in each fishing port. In 2017 fishing year (2017 FY: July 2017 – June 2018) the landings of this fishery basically stopped in the middle of high fishing season (on January 23, 2018) because Japanese Fisheries Agency requested all Japanese fisheries targeting small PBF (< 30kg) to suspend landing of PBF due to the exhaustion of national allowed catch limit. Therefore, there is no data for the fishery for the entire fishing year as in the past years. After 2017 FY many fishermen and fisheries cooperatives introduced self-restriction for compliance with the national fisheries regulation.

Generalized liner model (GLM) with lognormal error distribution was applied to

standardize the CPUE, because the effort data have no zero-catch trip. The following three effects were used for the standardization;

   1) FISHING YEAR (FY); 1980-2018… Fishing year is starting in July and ending in June.

   2) FISHING MONTH (FM); 4-12 … Fishing months are aligned with fishing year, i.e. FM4 is October.

   3) PORT; five ports… Izuhara-Are, Kami-tsushima, Kami-agata, Ojika and Tomie.

      Objective variable was log(CPUE) and candidate combination of explanatory variables were the three effects listed above and all possible first-order interactions. The GLM was carried out through GLM procedure of SAS 9.4. The standardized CPUE was calculated from least square mean of 'FY' effect. The "best model" was explored based on Bayesian Information Criteria (BIC).

Results and Discussions

Catch-and-effort data by each landing port are summarized in Table 1.　In Japan, the domestic restriction for PBF landing based on the fishery management which was adopted in the Western and Central Pacific Fisheries Commission (WCPFC) since 2015 FY has started. In accordance with the introduction of restriction, efforts became small since 2015 FY. Decreasing the effort mean a smaller number of data for standardization than the previous years, thus reliability of standardized CPUE were generally degraded. The whole residual pattern (Fig. 3 left) were similar shape to last update (Nishikawa et al. 2019), although those in recent years showed spiked and skewed distribution. Note that in 2017 FY, the Japan Fishery Agency requested the self-restriction for small fish, less than 30 kg, on January 23th 2018, and operations in 2017 FY were ended on that day. These restrictions may make fishermen's operation style and strategy change, for example releasing relatively smaller PBF.

      Catch for farming has been observed since 2012 in this area. The ratio of catch for farming was highest in 2015 FY (about 20% of total catch), then decreased after 2016 FY (Fig. 2). After 2017 FY, the catch for farming were not observed. This fluctuation is apparently due to the change in demand for PBF farming.

      The "best model" which was selected by BIC was exactly the same model as used in the previous stock assessment; a combination of only fixed main effects, "FY", "FM" and "PORT" (Table 4), which was presented by Fukuda et al. (2018). The time series of standardized CPUE showed a similar trend with the previous update (Nishikawa et al., 2019, Fig 5), and the updated estimation in 2018 FY was lower than its historical average from 1980 to 2017. Residuals distributed centrally around zero, although those distributions showed slightly left-skewed shapes (Figs. 3 and 4). The standardized CPUE, CV and 90% confidence limits are shown in Table 6. The range of coefficient of variation (CV) for standardized CPUE was 0.012-0.043 in 1980-2017 and was 0.023 in 2018 FY. The decreased number of landing ports and data in 2017 FY led to a wider CV than in the past years. However, as residual pattern showed, the values of CPUE after fishery management might be biased. It is necessary to do further investigation of recruitment index for stock assessment.

References

Fukuda, Y., Tsukahara, Y. and Sakai, O. 2018. Updated standardized CPUE for 0 age Pacific Bluefin Tuna caught by Japanese troll fisheries: Updated up to 2016 fishing year. ISC/18/PBFWG-1/03.

Ichinokawa, M., Oshima, K. and Takeuchi Y.　2012.　Abundance indices of young Pacific bluefin tuna, derived from catch-and-effort data of troll fisheries in various regions of Japan. ISC/12-1/PBFWG/11.

ISC　2014.　Stock assessment of bluefin tuna in the Pacific Ocean in 2014. Report of the Pacific bluefin tuna working group.　121p.

ISC　2016.　2016 Pacific bluefin tuna stock assessment. Report of the Pacific bluefin tuna working group.　140p.

ISC　2018.　Stock assessment of Pacific Bluefin Tuna (*Thunnus orientalis*) in the Pacific Ocean in 2018. Report of the Pacific bluefin tuna working group.　154p.

ISC PBFWG　2019. Report of the Pacific Bluefin Tuna Working Group Intersessional workshop. ISC/19/ANNEX/08

Nishikawa, K., Tsukahara, Y. and Nakatsuka, S. 2019. Updated standardized CPUE for 0 age Pacific Bluefin Tuna caught by Japanese troll fisheries: Updated up to 2017 fishing year. ISC/19/PBFWG-1/03.

Sakai, O. and Oshima, K. 2015. Japanese troll CPUE targeting age-0 Pacific bluefin tuna: Updated up to 2014 fishing year. ISC/15/PBFWG-2/08.

Table 1 Total catch (mt) by Quarter and by fishing port, recorded in catch-and-effort data without Qt 1 used for standardization of CPUE in Nagasaki Prefecture.

FY	Tomie Qt1	Qt2	Qt3	Qt4	Total	Are Qt1	Qt2	Qt3	Qt4	Total	Kami-tsushima Qt1	Qt2	Qt3	Qt4	Total	Kami-agata Qt1	Qt2	Qt3	Qt4	Total	Ojika Qt1	Qt2	Qt3	Qt4	Total	Total
1980		78.1	132.3		210.4		7.2			7.2		11.2			11.2		18.2			18.2		10.8	0.5		11.4	258.3
1981		73.4	311.2	38.4	423.0										8.9		118.1			118.1		122.7	3.0		125.7	675.7
1982		8.4	54.1		62.5		14.3			14.3		8.9			153.4		45.9			45.9		17.9			17.9	294.0
1983		72.7	170.1		242.9		51.3			51.3		153.4			63.5		350.9			350.9		94.1	8.4		102.4	811.1
1984		7.7	367.0	107.5	482.2		72.8			72.8		63.5			85.0		355.0			355.0		55.6	77.1		132.6	1127.7
1985		58.9	123.7	0.1	182.7		78.3			78.3		85.0			24.0		130.8			130.8		75.4	16.0		91.4	507.1
1986		91.9	274.7	12.0	378.5		67.0			67.0		24.0			23.2		130.5			130.5		72.0	5.3		77.3	676.4
1987		55.5	59.6		115.1		14.3			14.3		23.2			37.3		132.3			132.3		15.1			15.1	314.2
1988		127.0	139.8	14.4	281.2		6.0			6.0		37.3			36.1		150.3			150.3		51.1			51.1	524.7
1989		36.2	77.2	6.1	119.5		17.4			17.4		36.1			145.4		76.4	4.8		81.2		24.8			24.8	388.3
1990		34.7	193.8	12.3	240.9		21.4	24.9		46.3		145.4			95.5		156.6	16.6		173.2						555.8
1991		63.9	15.0		79.0		44.0			44.0		95.5			23.1		111.7			111.7		112.1	14.9		127.1	385.0
1992		10.5	44.7	11.2	66.4		1.3	0.6		1.9		23.1					12.9			12.9		14.2	0.9		15.1	96.3
1993		20.0	15.3	7.0	42.4		16.9	0.8		17.8							57.4	2.7		60.1		3.4	1.5		4.9	125.2
1994		73.0	338.0	53.1	464.1		96.5	8.8		105.3							717.6	156.6		874.2		107.8	318.5		426.3	1869.9
1995		48.7	39.8	16.1	104.6												241.0	2.3		243.4		31.9	9.0		41.0	389.0
1996		51.9	216.7	71.9	340.5		100.1	4.5		104.5							481.1	26.0		507.1		61.8	65.8		127.6	1079.8
1997			70.0	20.4	90.4		23.0	0.3		23.4		59.1			59.1		137.7	1.1		138.8		33.5	6.0		39.5	351.2
1998		3.3	160.7	70.3	234.3		38.9	6.5		45.4		196.0			196.0		248.2	20.6		268.8			21.5		21.5	766.0
1999		19.4	133.0	49.6	202.0		69.4	32.4		101.8							266.1	89.8		355.9		24.3	50.4		74.7	734.4
2000			45.2	3.1	48.4		61.4	52.0		113.4		207.2			207.2		165.2	153.1		318.3			48.2		48.2	735.5
2001			87.5		87.5		49.2	27.2		76.4		163.8			163.8		106.7	52.7		159.3		9.5	38.5		48.0	535.1
2002		1.7	56.2	47.6	105.5		15.3	19.2		34.5		44.4			44.4		59.4	9.7		69.1		4.3	20.3		24.6	278.2
2003		1.4	6.5	10.1	18.0		17.1	12.9		30.0		68.5			68.5		6.2	1.9		8.1			13.0		13.0	137.6
2004		20.5	83.7	13.4	117.5		45.6	37.8		83.4		188.2			188.2		191.7	132.5		324.1		1.3	38.6		40.0	753.3
2005		17.5	5.0		22.5		11.1	4.1		15.2		125.9			125.9		68.2			68.2		18.8	4.8		23.6	255.4
2006							9.2	0.4		9.5		30.7			30.7		20.0			20.0		0.3	0.1		0.4	60.7
2007			0.3	5.0	5.3		22.6			22.6		91.8			91.8		143.8	20.0		163.8		17.8	12.1		29.8	313.3
2008		19.3	150.8	9.6	179.7							142.0			142.0		47.6	6.2		53.8		12.8	48.1		60.9	436.3
2009		4.3	91.5	1.5	97.3		30.7	5.0		35.7		75.6			75.6							0.8	4.5		5.3	213.9
2010		19.1	66.8	29.3	115.3		12.5	2.2		14.7		76.7			76.7		171.9	0.0		171.9		6.5			6.5	385.1
2011		1.1	23.1	4.5	28.7		7.0	6.1		13.2		96.9			96.9		216.5	0.1	0.0	216.6		0.4	0.3	0.9	1.7	357.0
2012		0.4	6.5	0.7	7.7	0.4	10.6	7.9	0.1	18.9		0.3	0.3		0.6		61.5	0.3	0.4	62.2		0.2	3.0		3.2	92.6
2013		2.2	91.7	4.1	98.0	0.2	13.8	56.2	7.8	77.9	0.0	5.6	1.2		6.8		122.8	56.8	0.1	179.7		5.0	7.0		12.0	374.4
2014	0.0	0.0	8.2		8.2		0.9	1.0	1.9	3.9		0.0			0.0		0.1			0.1		0.3	0.4	0.0	0.7	12.9
2015	0.0	0.3	4.9	0.3	5.5	0.0	6.7	6.0	7.4	20.1		0.2		0.2	0.3	0.3	3.7	0.1	8.0	12.1		0.1	0.0	0.4	0.6	38.7
2016		1.8	37.6		39.4	0.5	1.9	7.5	0.1	9.9	5.1				5.1	42.6				42.6		0.8	0.1		0.8	97.9
2017		35.4			35.4	0.2	0.3	0.4		0.9													0.1		0.1	36.3
2018		0.1	25.1		25.1	0.0	1.7	12.9	0.0	14.7	0.3	0.4	0.5	0.0	1.2	3.0	9.8	9.8	1.1	23.8	0.0	0.1	1.4		1.5	66.3

Table 2 Total effort (number of landing per day, excluding zero PBF catch) by Quarter and by fishing port, recorded in catch-and-effort data without Qt 1 used for standardization of CPUE in Nagasaki Prefecture.

FY	Tomie					Are					Kami-tsushima					Kami-agata					Ojika					Total
	Qt1	Qt2	Qt3	Qt4	Total	Qt1	Qt2	Qt3	Qt4	Total	Qt1	Qt2	Qt3	Qt4	Total	Qt1	Qt2	Qt3	Qt4	Total	Qt1	Qt2	Qt3	Qt4	Total	
1980		1765	3565		5330		670			670		142			142		339			339		699	24		723	7204
1981		1907	7136	697	9740												1633			1633		2872	80		2952	14325
1982		264	1037		1301		694			694		274			274		1503			1503		725			725	4497
1983		1690	4574		6264		1756			1756		2012			2012		3958			3958		2123	155		2278	16268
1984		232	9501	2650	12383		1591			1591		1130			1130		6715			6715		1846	1535		3381	25200
1985		1478	5452	2	6932		1753			1753		1035			1035		2470			2470		1412	375		1787	13977
1986		3236	7915	306	11457		1729			1729		338			338		2420			2420		2232	135		2367	18311
1987		1912	2494		4406		500			500		447			447		2502			2502		658			658	8513
1988		3577	5377	161	9115		283			283		555			555		2465			2465		1079			1079	13497
1989		1519	4115	110	5744		776			776		696			696		1491	92		1583		868			868	9667
1990		1641	4582	510	6733		606	297		903		1537			1537		1557	182		1739						10912
1991		1364	182		1546		865			865		1008			1008		1603			1603		1817	378		2195	7217
1992		956	1192	268	2416		138	96		234		630			630		446			446		903	50		953	4679
1993		1074	539	197	1810		902	84		986							1908	132		2040		336	151		487	5323
1994		1445	3096	822	5363		1254	89		1343							5049	670		5719		1427	2241		3668	16093
1995		1541	1095	345	2981												1991	64		2055		928	188		1116	6152
1996		1739	3425	970	6134		1425	118		1543							4401	392		4793		1004	1061		2065	14535
1997			1461	873	2334		739	22		761		690			690		2561	44		2605		667	100		767	7157
1998		264	3163	1098	4525		1075	161		1236		2348			2348		3620	288		3908			399		399	12416
1999		720	2590	984	4294		733	434		1167							1821	870		2691		351	482		833	8985
2000			2061	510	2571		781	432		1213		1353			1353		1462	754		2216			668		668	8021
2001			1582		1582		850	261		1111		1682			1682		1112	617		1729		181	595		776	6880
2002		110	1453	1162	2725		630	272		902		951			951		1271	224		1495		270	536		806	6879
2003		366	304	183	853		347	284		631		842			842		195	44		239			357		357	2922
2004		868	1215	221	2304		599	324		923		1478			1478		2246	855		3101		153	539		692	8498
2005		304	246		550		222	143		365		1014			1014		721			721		212	142		354	3004
2006							207	24		231		437			437		490			490		23	5		28	1186
2007			5	59	64		376			376		753			753		1561	359		1920		259	134		393	3506
2008		556	1946	166	2668							854			854		673	87		760		99	693		792	5074
2009		83	1236	20	1339		641	102		743		693			693							46	129		175	2950
2010		517	1348	254	2119		374	65		439		806			806		2349	1		2350		135			135	5849
2011		119	831	29	979		118	77		195		665			665		2280	5	1	2286		14	20	21	55	4180
2012		32	194	8	234	31	526	203	7	767		12	7		19		1508	4	14	1526		22	72		94	2640
2013		46	1173	21	1240	16	382	521	129	1048	3	133	12		148		1388	350	4	1742		69	110		179	4357
2014	1	2	309		312		75	75	46	196		4			4		5			5		14	22	1	37	554
2015	1	35	128	13	177	2	244	129	431	806		3		13	16	13	37	9	125	184		1	3	19	23	1206
2016		95	759		854	4	25	37	4	70	47				47	269				269		28	9		37	1277
2017		368			368	2	15	10		27													7		7	402
2018		12	567		579	1	48	172	1	222	5	14	5	1	25	40	184	164	17	405	1	4	40		45	1276

Table 3 Nominal CPUE (kg/landing) by Quarter and by fishing port, recorded in catch-and-effort data without Qt 1 used for standardization of CPUE in Nagasaki Prefecture.

FY	Tomie Qt1	Qt2	Qt3	Qt4	Total	Are Qt1	Qt2	Qt3	Qt4	Total	Kami-tsushima Qt1	Qt2	Qt3	Qt4	Total	Kami-agata Qt1	Qt2	Qt3	Qt4	Total	Ojika Qt1	Qt2	Qt3	Qt4	Total	Total
1980		36.8	32.0		34.2		14.0			14.0		77.8			77.8		42.3			42.3		12.5	24.4		14.7	35.9
1981		39.9	46.8	44.8	44.3												67.8			67.8		37.2	24.5		34.7	46.5
1982		25.8	59.6		47.1		15.9			15.9		20.1			20.1		24.0			24.0		20.2			20.2	33.3
1983		31.8	38.9		36.8		32.1			32.1		64.2			64.2		78.3			78.3		33.0	40.4		35.4	55.4
1984		20.7	38.7	32.6	34.2		37.6			37.6		48.4			48.4		53.9			53.9		24.1	47.1		29.8	43.9
1985		67.6	22.4	55.5	35.5		46.5			46.5		61.9			61.9		50.6			50.6		76.2	45.1		67.6	40.6
1986		26.9	34.4	35.6	32.1		34.4			34.4		55.9			55.9		50.8			50.8		33.8	42.8		34.7	37.0
1987		25.7	22.7		23.8		26.4			26.4		39.9			39.9		50.0			50.0		21.0			21.0	35.2
1988		31.3	24.3	85.5	30.8		20.0			20.0		53.1			53.1		50.8			50.8		38.9			38.9	39.0
1989		21.1	19.0	62.1	21.0		21.8			21.8		41.6			41.6		40.6	55.8		42.5		26.9			26.9	28.9
1990		19.7	46.0	29.3	38.1		32.7	83.0		54.7		96.8			96.8		101.1	96.7		100.5						55.5
1991		54.0	157.6		61.1		42.4			42.4		64.5			64.5		70.0			70.0		54.7	56.3		55.1	63.4
1992		9.9	37.6	38.2	28.8		8.0	5.3		6.7		41.1			41.1		19.7			19.7		14.7	15.5		14.9	25.5
1993		16.7	25.0	31.5	23.7		17.3	8.7		16.3							26.0	21.1		25.3		8.4	11.5		9.4	23.5
1994		45.6	97.9	54.9	77.1		65.1	84.2		67.5							135.2	205.3		148.6		61.7	136.5		105.5	116.2
1995		30.6	38.5	42.7	36.6												97.9	42.3		90.0		35.8	40.0		37.6	63.2
1996		27.8	65.5	66.2	55.5		64.5	31.1		58.9							99.6	63.6		93.2		53.3	55.0		54.3	74.3
1997			42.3	21.6	35.6		31.0	14.2		30.2		97.6			97.6		50.6	24.3		49.9		46.2	54.4		48.2	49.1
1998		11.7	49.4	69.5	49.9		36.6	34.6		36.2		71.3			71.3		55.8	55.4		55.7			48.8		48.8	61.7
1999		19.1	47.8	52.1	40.9		147.5	69.4		121.0							108.6	102.2		106.7		67.8	73.3		72.0	81.7
2000			19.3	5.6	16.7		76.1	116.3		88.7		131.1			131.1		104.1	172.7		122.6			43.8		43.8	91.7
2001			60.5		60.5		44.8	94.0		56.2		94.5			94.5		79.6	81.1		80.0		52.8	51.6		51.9	77.8
2002		15.9	40.0	40.8	38.8		20.5	68.1		33.4		35.7			35.7		38.9	41.5		39.6		15.3	70.8		53.6	40.4
2003		3.9	18.3	58.8	29.1		49.4	36.7		44.8		75.8			75.8		26.2	45.0		33.4			25.7		25.7	47.1
2004		23.8	80.4	57.1	55.2		64.7	105.1		74.7		122.8			122.8		79.4	147.6		95.9		9.4	60.2		47.1	88.6
2005		48.7	22.9		32.8		50.2	31.8		43.4		135.0			135.0		125.8			125.8		60.7	23.8		38.3	85.0
2006							37.2	14.2		33.6		98.4			98.4		32.3			32.3		15.0	23.8		18.2	51.2
2007			38.7	91.7	87.1		55.6			55.6		124.0			124.0		78.2	53.4		71.0		51.9	68.3		61.5	89.4
2008		27.6	79.2	74.6	61.5							131.3			131.3		69.0	70.9		69.3		212.6	63.6		118.9	86.0
2009		46.8	66.5	53.9	63.4		37.1	49.3		38.9		75.4			75.4							14.4	37.9		26.9	72.5
2010		21.7	43.6	87.1	47.1		28.6	30.2		28.9		104.0			104.0		73.6	6.0		72.6		39.3			39.3	65.8
2011		6.4	24.9	124.0	27.9		52.9	73.1		64.9		138.8			138.8		97.7	12.5	4.4	91.4		28.3	17.3	42.9	29.8	85.4
2012		8.5	27.1	104.2	28.0	8.1	16.9	21.1	7.3	17.0		24.6	44.3		32.7		35.4	74.3	28.6	35.7		10.2	34.9		24.1	35.3
2013		22.8	57.1	184.4	60.6	8.5	27.3	126.5	83.9	85.2	9.7	30.8	66.1		31.9		75.4	122.5	26.9	87.5		55.5	40.6		44.3	86.3
2014	5.0	3.3	21.5		19.8		12.1	11.5	31.8	17.7		10.9			10.9		15.6			15.6		17.0	19.1	2.4	17.4	23.3
2015	2.7	9.7	22.8	29.6	20.2	14.7	46.0	70.5	16.5	41.9		55.0		13.5	16.7	15.2	100.8	15.8	60.7	54.0		125.1	9.6	24.8	29.7	32.2
2016		22.0	48.4		40.5	115.8	68.1	185.1	18.5	120.4	80.5				80.5	163.2				163.2		23.6	6.1		16.6	51.9
2017		114.1			114.1	87.0	16.8	35.7		30.1												11.0			11.0	90.4
2018		6.5	24.5		23.3	5.6	35.0	65.3	5.0	56.2	54.9	27.1	88.0	8.2	43.1	67.4	40.7	47.4	57.5	52.1	7.0	25.7	35.6		32.5	51.3

Table 4 Values of BIC (Bayesian Information Criterion) calculated for all models of possible combinations of main effects and first-order interaction terms. The model "a)" (shaded) is exactly same mode as used for previous assessment, and it was selected as "best model" by BIC.

Model	BIC
a) fy+fm+port	31242.7
b) fy*fm+port	31483.4
c) fy*port+fm	31516.7
d) fy+fm*port	31252.2
e) fy*fm+fy*port	31932.4
f) fy*fm+fm*port	31514.1
g) fy*port+fm*port	31498.5
h) fy*fm+fm*port+fy*port	31858.8

Table 5 Type 3 analysis of the explanatory variables in the model for CPUE standardization.

Efffects	df	Type III SS	Mean squire	F value	Pr > F
Model	50	2611.1	52.2	52.48	<.0001
Error	10825	10771.1	1.0		
Corrected Total	10875	13382.2			

Efffects	df	Type III SS	Mean squire	F value	Pr > F
fy	38	1408.1	37.1	37.2	<.0001
fm	8	259.6	32.4	32.6	<.0001
port	4	905.3	226.3	227.5	<.0001

Table 6 Nominal and standardized troll CPUE comparing with previous study (Nishikawa et al., 2019). All CPUEs are normalized by each average.

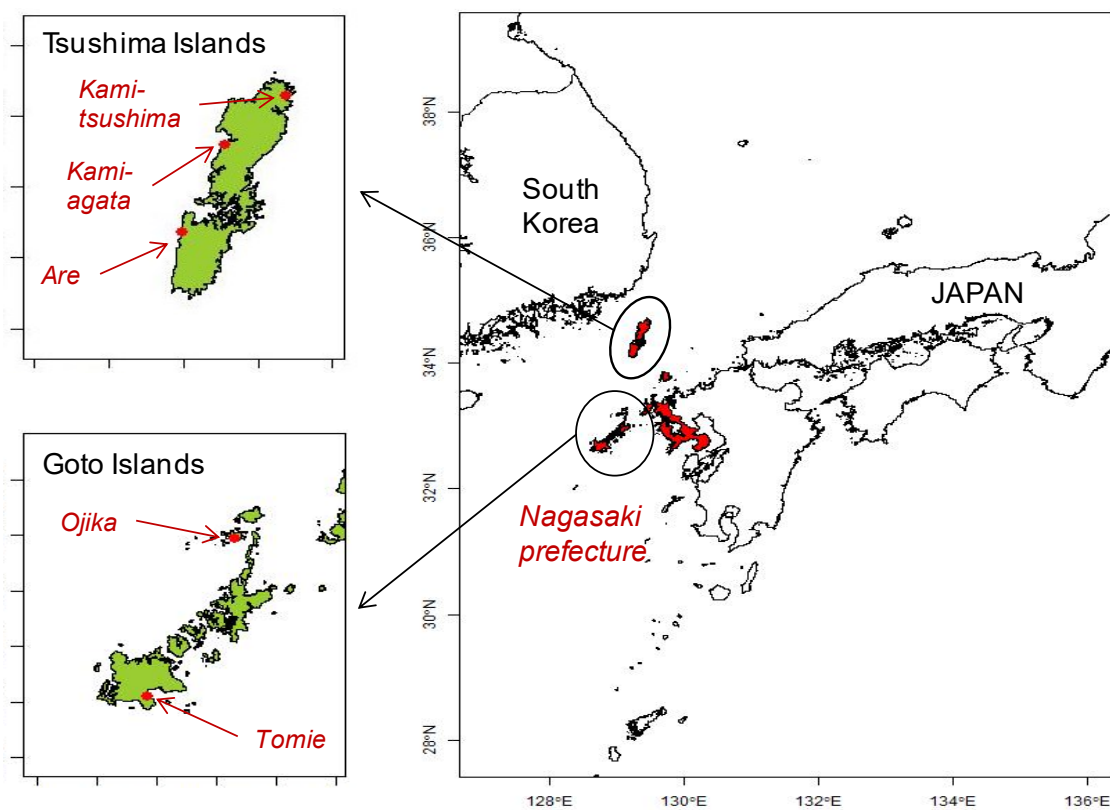| Fishing year	Nominal CPUE	Record Number	Updated standardized CPUE				Nishikawa et al.(2019)	
			Estimation	CV	Lower 5%	Upper 5%	Estimation	CV
1980	0.59	255	0.68	0.02	0.60	0.78	0.67	0.02
1981	0.89	265	1.20	0.02	1.06	1.36	1.18	0.02
1982	0.56	183	0.63	0.02	0.54	0.73	0.62	0.02
1983	0.89	328	0.93	0.02	0.83	1.04	0.92	0.02
1984	0.74	396	0.95	0.02	0.86	1.06	0.94	0.02
1985	0.82	375	0.89	0.02	0.80	0.99	0.88	0.02
1986	0.71	492	1.00	0.01	0.91	1.11	0.99	0.01
1987	0.59	310	0.73	0.02	0.65	0.82	0.72	0.02
1988	0.71	356	0.84	0.02	0.75	0.94	0.83	0.02
1989	0.51	351	0.66	0.02	0.59	0.74	0.66	0.02
1990	1.17	333	1.30	0.01	1.16	1.46	1.29	0.02
1991	1.11	271	1.36	0.02	1.20	1.54	1.34	0.02
1992	0.48	308	0.59	0.02	0.53	0.67	0.59	0.02
1993	0.41	330	0.50	0.02	0.44	0.56	0.49	0.02
1994	1.78	439	2.06	0.01	1.86	2.27	2.04	0.01
1995	0.95	243	1.12	0.02	0.98	1.28	1.11	0.02
1996	1.20	448	1.64	0.01	1.49	1.82	1.63	0.01
1997	0.94	251	0.96	0.02	0.85	1.10	0.95	0.02
1998	0.97	350	0.85	0.02	0.76	0.95	0.84	0.02
1999	1.48	286	1.55	0.02	1.37	1.75	1.54	0.02
2000	1.56	273	1.17	0.02	1.04	1.33	1.17	0.02
2001	1.30	265	1.18	0.02	1.04	1.34	1.17	0.02
2002	0.73	275	0.77	0.02	0.68	0.87	0.76	0.02
2003	0.80	184	0.66	0.02	0.57	0.77	0.66	0.02
2004	1.50	369	1.32	0.01	1.19	1.47	1.31	0.01
2005	1.68	230	1.46	0.02	1.27	1.67	1.44	0.02
2006	1.06	106	0.75	0.03	0.62	0.91	0.74	0.03
2007	1.59	244	1.45	0.02	1.28	1.66	1.44	0.02
2008	1.67	285	1.48	0.02	1.31	1.67	1.46	0.02
2009	1.00	206	1.18	0.02	1.02	1.35	1.16	0.02
2010	1.09	324	1.14	0.02	1.02	1.28	1.13	0.02
2011	1.38	266	0.99	0.02	0.88	1.12	0.98	0.02
2012	0.50	235	0.50	0.02	0.44	0.58	0.50	0.02
2013	1.36	343	0.91	0.02	0.82	1.02	0.91	0.02
2014	0.34	98	0.44	0.04	0.36	0.53	0.44	0.04
2015	0.68	220	0.51	0.02	0.45	0.58	0.52	0.02
2016	1.21	138	1.11	0.02	0.94	1.32	1.11	0.02
2017	1.26	46	0.87	0.04	0.65	1.17	0.87	0.04
2018	0.78	202	0.64	0.02	0.56	0.74		

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Fig. 1 Location of fishing ports where catch-and-effort data of troll fisheries have been collected in coastal waters of western Kyusyu.

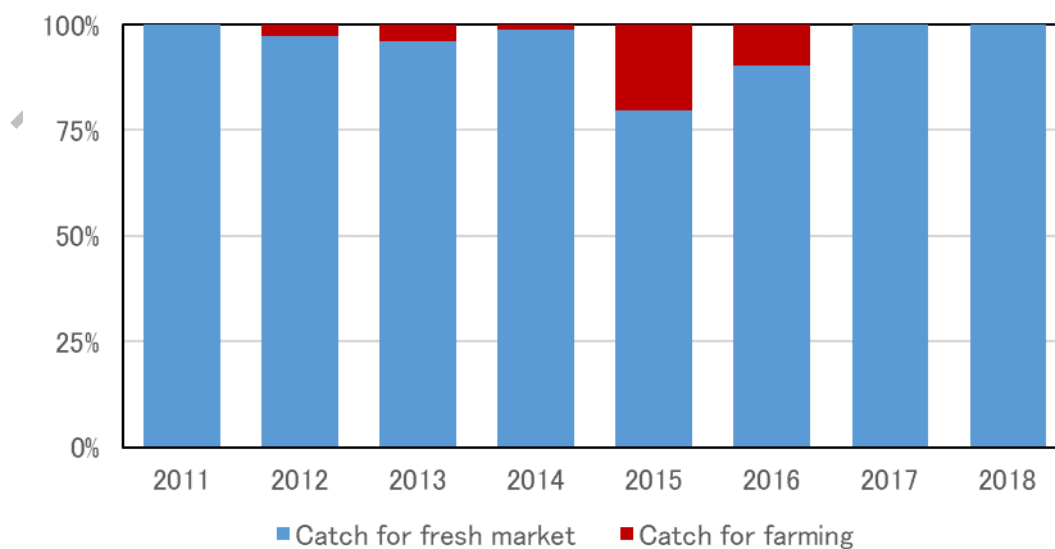**Fig. 2** Ratio of catch for fresh market and for farming. Catch for farming was not recorded before 2011.
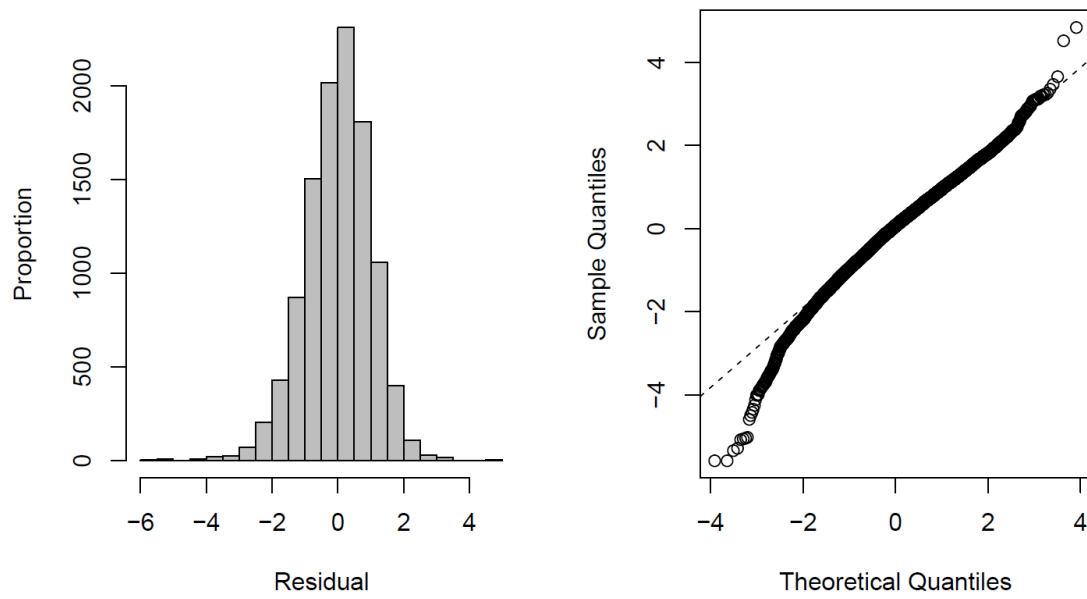
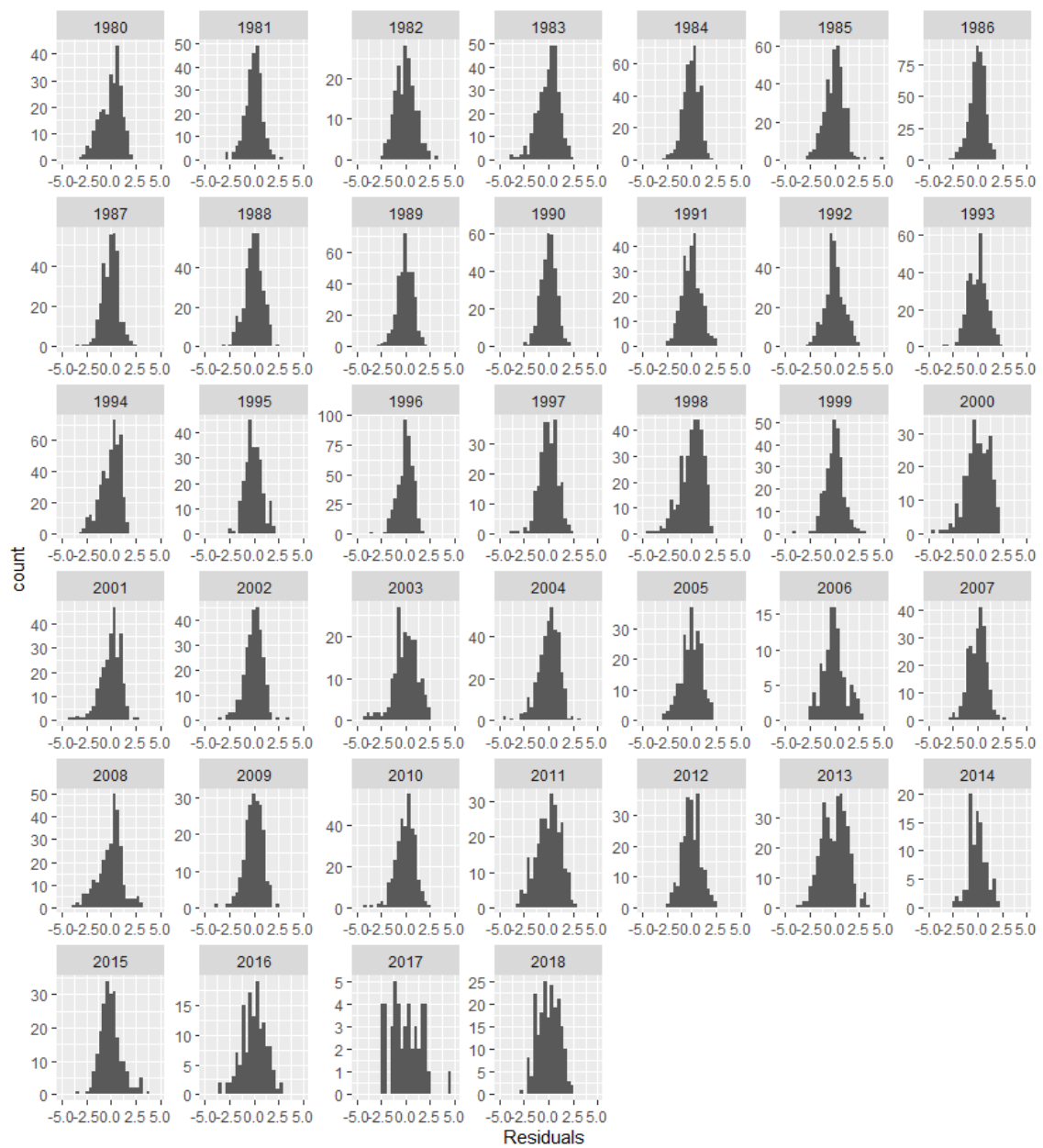**Fig. 3**   Standardized residuals (left panel) and Q-Q plot of them (right panel).

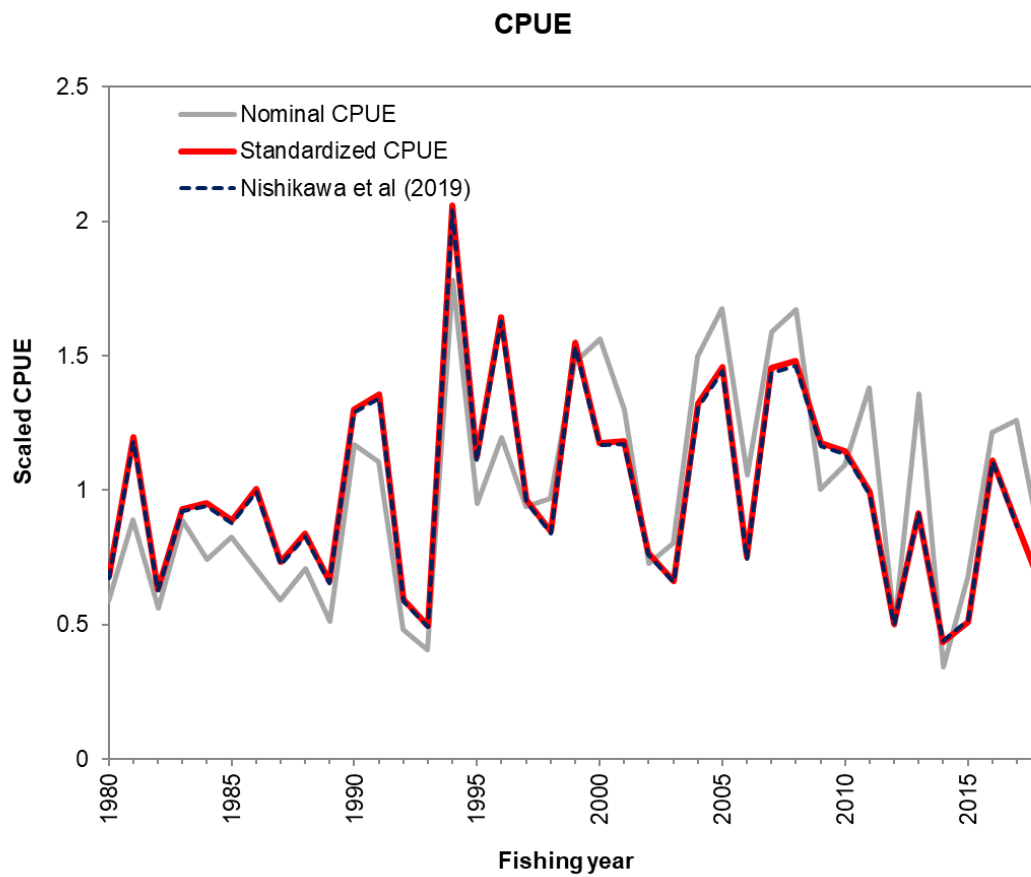**Fig. 4** Standardized residuals by year.

CPUE

Fig. 5 Comparison of time series of CPUE. Gray and redlines indicates nominal and standardized CPUE from 1980 to 2018 fishing year, respectively. Dashed line shows the standardized CPUE previously estimated by Nishikawa et al. (2019).