Updated standardized CPUE for 0-age Pacific bluefin tuna caught by Japanese troll fisheries: Updated up to 2017 fishing year

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Summary

To update the recruitment abundance index for Pacific bluefin tuna up to 2017 fishing year, Japanese troll CPUE in the East China Sea (coastal waters of western Kyusyu), which is used for stock assessment, was standardized for the period of 1980-2017 fishing year. The standardized CPUE in 2017 fishing year was lower than one in 2016 and similar to the historical average with relatively wider confidential intervals because of artificial constraint by fishery management. In addition, a revised version of this CPUE to better align with the fleet definition of the assessment is presented.

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 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 same method as used for the previous benchmark assessment (Sakai and Oshima, 2015). 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).

In addition, a revised recruitment index, which better reflects the decision on the fleet definition in the 2016 assessment, is calculated. In the 2016 assessment, it was agreed to split the fleet of troll fishery by two seasons into July-September and October-June because of the difference in size, but the CPUE which was calculated based on annual data was used without revision as the catch in July-September was considered relatively minor. In order to be consistent, a revised CPUE which matches the current fleet definition is standardized and proposed for the use in the upcoming benchmark assessment.

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. It needs to be noted that in fishing year 2017 (July 2017 – June 2018) the operation of this fishery was basically halted 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 operation due to the exhaustion of national allowed catch limit. Therefore, it was not possible to obtain data for the fishery for whole fishing year as in the past years.

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); 1980-2017… Fishing year is starting in July and ending in June.

2) FISHING MONTH (FM); 1-12 … Fishing months are aligned with fishing year, i.e. FM1 is July.

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).

A revised standardized CPUE of recruitment index for next benchmark assessment

PBFWG agreed to split Japanese troll fleet into 2 fleets for FM 1-3 and FM 4-12 in the 2016 stock assessment. Fleet 6 (FM 4-12) was used as the correspondence fleet for the selectivity setting of the above CPUE which is based on annual data (ISC 2016). Therefore, a revised CPUE using sales slip data in FM 4-12 was standardized in order to better align with the fleet definition and compared with the existing standardized CPUE.

Results and Discussions

Catch-and-effort data by each landing port are summarized in Table 1. In 2017 fishing year, no data in Kami-Tsushima and Kami-Agata were used due to self-regulation. Catch weight and efforts in 2017 have also decreased in the other ports than in 2016 fishing year. Catch for farming has been observed since 2012 in this area. The ratio of catch for farming was highest in 2015 fishing year (about 20% of total catch), then decreased after 2016 fishing year (Fig. 2). 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 assessment; a combination of fixed main effects, "FY", "FM" and "PORT" (Table 2), which was presented by Sakai and Oshima (2015). The time series of standardized CPUE showed a similar trend with the previous update (Fukuda et al., 2018, Fig 5), and the updated estimation in 2017 fishing year was similar with its historical average from 1980 to 2016. 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 4. The range of coefficient of variation (CV) for standardized CPUE was 0.012-0.037 in 1980-2016 and was 0.043 in 2017 fishing year. The decreased number of landing ports and data in 2017 fishing year led to a wider CV than in the past years.

The best model of the revised CPUE was also the same as the best model for the present standardized CPUE and showed a similar trend (Fig. 6). The data used for the standardization of the revised CPUE (FM4-12) reflects more accurately the fleet definition in the current stock assessment. Thus, it is recommended that the revised CPUE presented here (FM4-12) be used as abundance index of recruitment in the next benchmark assessment. The results of standardization of the revised CPUE is provided in Appendix.

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.

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), effort (number of landing per day, excluding zero PBF catch) and CPUE (kg/landing) by year and by fishing port, recorded in catch-and-effort data used for standardization of CPUE in Nagasaki Prefecture.

Fishing year	Catch (mt)						Effort (Number of landing)						CPUE (kg / landing)					
	Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total	Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total	Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total
1980	210.4	7.2	11.2	18.2	11.4	258.3	5330	670	142	339	723	7204	39.5	10.7	78.7	53.7	15.7	35.9
1981	423.0			118.1	125.7	666.8	9740			1633	2952	14325	43.4			72.3	42.6	46.5
1982	62.5	14.3	8.9	45.9	17.9	149.5	1301	694	274	1503	725	4497	48.1	20.7	32.4	30.5	24.7	33.3
1983	242.9	51.3	153.4	350.9	102.4	900.9	6264	1756	2012	3958	2278	16268	38.8	29.2	76.2	88.7	45.0	55.4
1984	482.2	72.8	63.5	355.0	132.6	1106.2	12383	1591	1130	6715	3381	25200	38.9	45.8	56.2	52.9	39.2	43.9
1985	182.7	78.3	85.0	130.8	91.4	568.1	6932	1753	1035	2470	1787	13977	26.4	44.6	82.1	53.0	51.1	40.6
1986	378.5	67.0	24.0	130.5	77.3	677.2	11457	1729	338	2420	2367	18311	33.0	38.7	70.9	53.9	32.6	37.0
1987	115.1	14.3	23.2	132.3	15.1	300.0	4406	500	447	2502	658	8513	26.1	28.6	51.8	52.9	23.0	35.2
1988	281.2	6.0	37.3	150.3	51.1	525.9	9115	283	555	2465	1079	13497	30.8	21.1	67.3	61.0	47.3	39.0
1989	119.5	17.4	36.1	81.2	24.8	279.0	5744	776	696	1583	868	9667	20.8	22.4	51.8	51.3	28.6	28.9
1990	240.9	46.3	145.4	173.2		605.8	6733	903	1537	1739		10912	35.8	51.3	94.6	99.6		55.5
1991	79.0	44.0	95.5	111.7	127.1	457.3	1546	865	1008	1603	2195	7217	51.1	50.9	94.7	69.7	57.9	63.4
1992	66.4	1.9	23.1	12.9	15.1	119.4	2416	234	630	446	953	4679	27.5	8.0	36.7	29.0	15.9	25.5
1993	42.4	17.8		60.1	4.9	125.2	1810	986		2040	487	5323	23.4	18.0		29.4	10.1	23.5
1994	464.1	105.3		874.2	426.3	1869.9	5363	1343		5719	3668	16093	86.5	78.4		152.9	116.2	116.2
1995	104.6			243.4	41.0	389.0	2981			2055	1116	6152	35.1			118.4	36.7	63.2
1996	340.5	104.5		507.1	127.6	1079.8	6134	1543		4793	2065	14535	55.5	67.7		105.8	61.8	74.3
1997	90.4	23.4	59.1	138.8	39.5	351.2	2334	761	690	2605	767	7157	38.7	30.7	85.6	53.3	51.6	49.1
1998	234.3	45.4	196.0	268.8	21.5	766.0	4525	1236	2348	3908	399	12416	51.8	36.7	83.5	68.8	53.9	61.7
1999	202.0	101.8		355.9	74.7	734.4	4294	1167		2691	833	8985	47.1	87.3		132.3	89.6	81.7
2000	48.4	113.4	207.2	318.3	48.2	735.5	2571	1213	1353	2216	668	8021	18.8	93.5	153.1	143.6	72.2	91.7
2001	87.5	76.4	163.8	159.3	48.0	535.1	1582	1111	1682	1729	776	6880	55.3	68.8	97.4	92.2	61.8	77.8
2002	105.5	34.5	44.4	69.1	24.6	278.2	2725	902	951	1495	806	6879	38.7	38.3	46.7	46.2	30.5	40.4
2003	18.0	30.0	68.5	8.1	13.0	137.6	853	631	842	239	357	2922	21.2	47.6	81.3	33.8	36.4	47.1
2004	117.5	83.4	188.2	324.1	40.0	753.3	2304	923	1478	3101	692	8498	51.0	90.4	127.3	104.5	57.7	88.6
2005	22.5	15.2	125.9	68.2	23.6	255.4	550	365	1014	721	354	3004	40.9	41.8	124.1	94.6	66.5	85.0
2006		9.5	30.7	20.0	0.4	60.7		231	437	490	28	1186		41.3	70.4	40.8	16.0	51.2
2007	5.3	22.6	91.8	163.8	29.8	313.3	64	376	753	1920	393	3506	82.6	60.1	121.9	85.3	75.9	89.4
2008	179.7		142.0	53.8	60.9	436.3	2668		854	760	792	5074	67.3		166.3	70.8	76.9	86.0
2009	97.3	35.7	75.6		5.3	213.9	1339	743	693		175	2950	72.7	48.0	109.1		30.1	72.5
2010	115.3	14.7	76.7	171.9	6.5	385.1	2119	439	806	2350	135	5849	54.4	33.4	95.1	73.2	48.4	65.8
2011	28.7	13.2	96.9	216.6	1.7	357.0	979	195	665	2286	55	4180	29.4	67.4	145.7	94.7	31.2	85.4
2012	7.7	18.9	0.6	62.2	3.2	92.6	234	767	19	1526	94	2640	32.9	24.6	33.6	40.8	33.6	35.1
2013	98.0	77.9	6.8	179.7	12.0	374.4	1240	1048	148	1742	179	4357	79.0	74.4	45.9	103.1	67.1	85.9
2014	8.2	3.9	0.0	0.1	0.7	12.9	312	196	4	5	37	554	26.4	19.7	11.5	16.7	18.7	23.3
2015	5.5	20.1	0.3	12.1	0.6	38.7	177	806	16	184	23	1206	31.2	25.0	20.9	65.8	25.3	32.1
2016	39.4	9.9	5.1	42.6	0.8	97.9	854	70	47	269	37	1277	46.1	142.0	109.4	158.3	22.8	76.7
2017	35.4	0.9			0.1	36.3	368	27			7	402	96.2	32.3			9.7	90.4

Table 2 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	30928.5
b) fy*fm+port	31150.7
c) fy*port+fm	31175.9
d) fy+fm*port	30956.8
e) fy*fm+fy*port	31576.9
f) fy*fm+fm*port	31187.5
g) fy*port+fm*port	31195.6
h) fy*fm+fm*port+fy*port	31530.0

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

Efffects	df	Type IIISS	Mean squire	F value	Pr>F
Model	52	2656.5	51.1	51.31	<.0001
Error	10704	10657.6	1.0		
Corrected Total	10756	13314.1			

Efffects	df	Type IIISS	Mean squire	F value	Pr>F
fy	37	1383.3	37.4	37.6	<.0001
fm	11	280.8	25.5	25.6	<.0001
port	4	892.4	223.1	224.1	<.0001

Table 4 Nominal and standardized troll CPUE comparing with previous study (Fukuda et al., 2018). All CPUEs are normalized by each average.

Fishing year	Nominal CPUE	Record Number	Updated standardized CPUE				Revised standardized CPUE				Fukuda et al.(2018)	
			Estimation	CV	Lower 5%	Upper 5%	Estimation	CV	Lower 5%	Upper 5%	Estimation	CV
1980	0.58	255	0.7	0.0	0.6	0.8	0.7	0.0	0.6	0.8	0.67	0.02
1981	0.88	265	1.2	0.0	1.0	1.4	1.2	0.0	1.0	1.3	1.18	0.02
1982	0.55	183	0.6	0.0	0.5	0.7	0.6	0.0	0.5	0.7	0.62	0.03
1983	0.88	328	0.9	0.0	0.8	1.0	0.9	0.0	0.8	1.0	0.92	0.02
1984	0.74	396	0.9	0.0	0.8	1.1	0.9	0.0	0.8	1.0	0.94	0.02
1985	0.81	375	0.9	0.0	0.8	1.0	0.9	0.0	0.8	1.0	0.87	0.02
1986	0.70	492	1.0	0.0	0.9	1.1	1.0	0.0	0.9	1.1	0.99	0.02
1987	0.58	310	0.7	0.0	0.6	0.8	0.7	0.0	0.6	0.8	0.72	0.02
1988	0.70	356	0.8	0.0	0.7	0.9	0.8	0.0	0.7	0.9	0.83	0.02
1989	0.51	351	0.7	0.0	0.6	0.7	0.7	0.0	0.6	0.7	0.65	0.02
1990	1.15	333	1.3	0.0	1.1	1.5	1.3	0.0	1.1	1.4	1.28	0.02
1991	1.09	271	1.3	0.0	1.2	1.5	1.3	0.0	1.2	1.5	1.34	0.02
1992	0.48	308	0.6	0.0	0.5	0.7	0.6	0.0	0.5	0.7	0.58	0.02
1993	0.40	330	0.5	0.0	0.4	0.6	0.5	0.0	0.4	0.5	0.49	0.02
1994	1.76	439	2.0	0.0	1.8	2.3	2.0	0.0	1.8	2.3	2.02	0.01
1995	0.94	243	1.1	0.0	1.0	1.3	1.1	0.0	1.0	1.3	1.10	0.02
1996	1.18	448	1.6	0.0	1.4	1.8	1.6	0.0	1.5	1.8	1.62	0.01
1997	0.93	251	1.0	0.0	0.8	1.1	1.0	0.0	0.8	1.1	0.95	0.02
1998	0.96	350	0.8	0.0	0.7	0.9	0.8	0.0	0.8	0.9	0.83	0.02
1999	1.46	286	1.5	0.0	1.3	1.7	1.5	0.0	1.4	1.7	1.52	0.02
2000	1.54	273	1.2	0.0	1.0	1.3	1.2	0.0	1.0	1.3	1.16	0.02
2001	1.28	265	1.2	0.0	1.0	1.3	1.2	0.0	1.0	1.3	1.16	0.02
2002	0.72	275	0.8	0.0	0.7	0.9	0.8	0.0	0.7	0.9	0.75	0.02
2003	0.79	184	0.7	0.0	0.6	0.8	0.7	0.0	0.6	0.8	0.65	0.03
2004	1.48	369	1.3	0.0	1.2	1.5	1.3	0.0	1.2	1.5	1.30	0.02
2005	1.65	230	1.4	0.0	1.2	1.7	1.4	0.0	1.3	1.7	1.44	0.02
2006	1.04	106	0.7	0.0	0.6	0.9	0.7	0.0	0.6	0.9	0.74	0.03
2007	1.57	244	1.4	0.0	1.2	1.7	1.4	0.0	1.3	1.6	1.43	0.02
2008	1.65	285	1.5	0.0	1.3	1.7	1.5	0.0	1.3	1.6	1.46	0.02
2009	0.99	206	1.2	0.0	1.0	1.4	1.2	0.0	1.0	1.3	1.16	0.02
2010	1.08	324	1.1	0.0	1.0	1.3	1.1	0.0	1.0	1.3	1.13	0.02
2011	1.36	266	1.0	0.0	0.9	1.1	1.0	0.0	0.9	1.1	0.98	0.02
2012	0.48	245	0.5	0.0	0.4	0.6	0.5	0.0	0.4	0.6	0.49	0.03
2013	1.32	350	0.9	0.0	0.8	1.0	0.9	0.0	0.8	1.0	0.88	0.02
2014	0.34	99	0.4	0.0	0.4	0.5	0.4	0.0	0.4	0.5	0.44	0.04
2015	0.66	225	0.5	0.0	0.4	0.6	0.5	0.0	0.5	0.6	0.51	0.03
2016	1.50	196	1.2	0.0	1.0	1.4	1.1	0.0	0.9	1.3	1.21	0.02
2017	1.26	48	0.9	0.0	0.7	1.2	0.9	0.0	0.6	1.2		

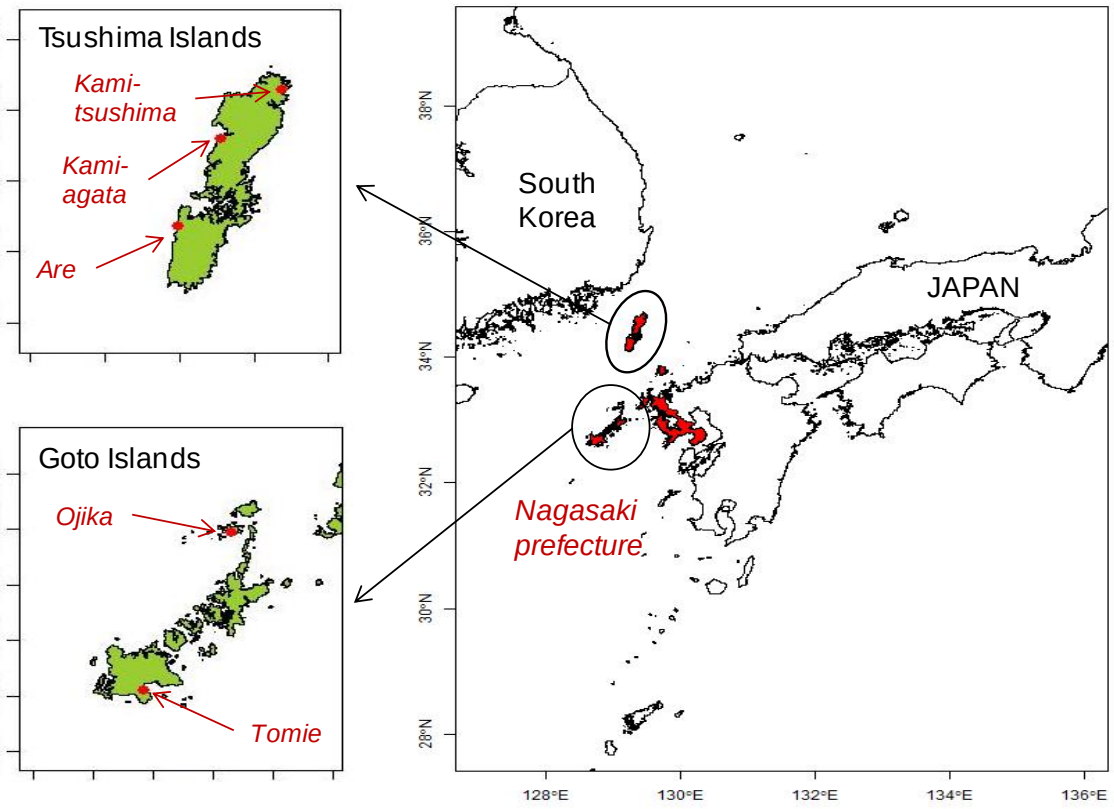

Fig. 1 Location of fishing ports where catch-and-effort data of troll fisheries have been collected in coastal waters of western Kyusyu.

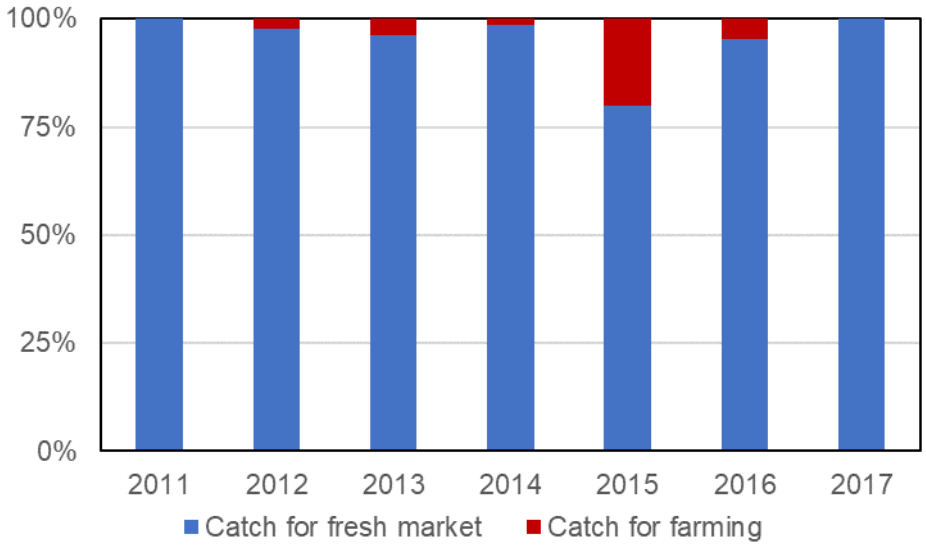

Fig. 2 Ratio of catch for fresh market and for farming. Catch for farming was not recorded before 2011.

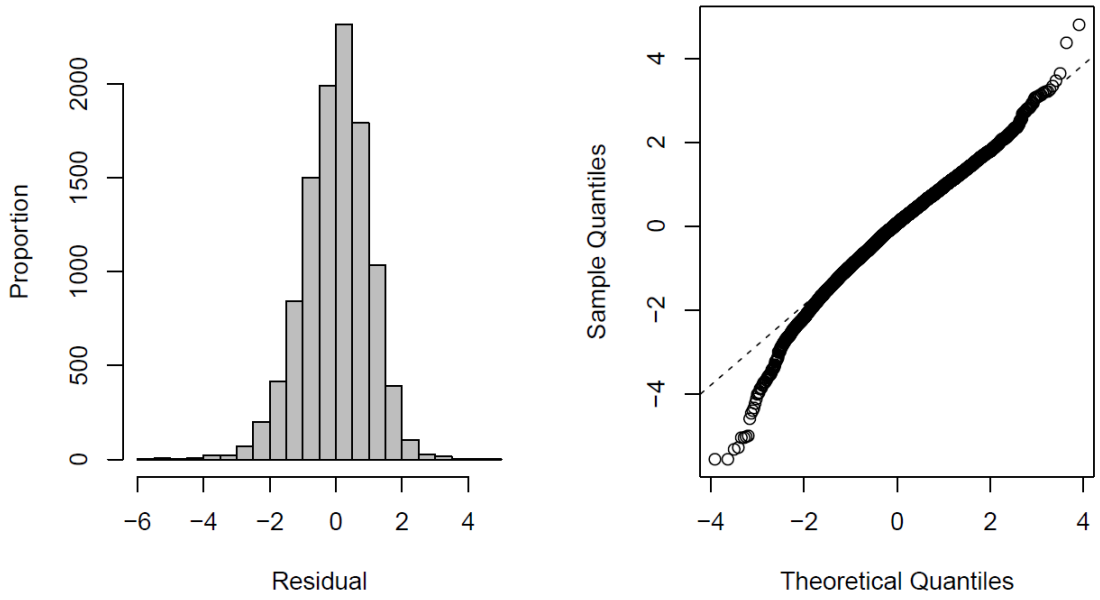

Fig. 3 Standardized residuals (left panel) and Q-Q plot of them (right panel).

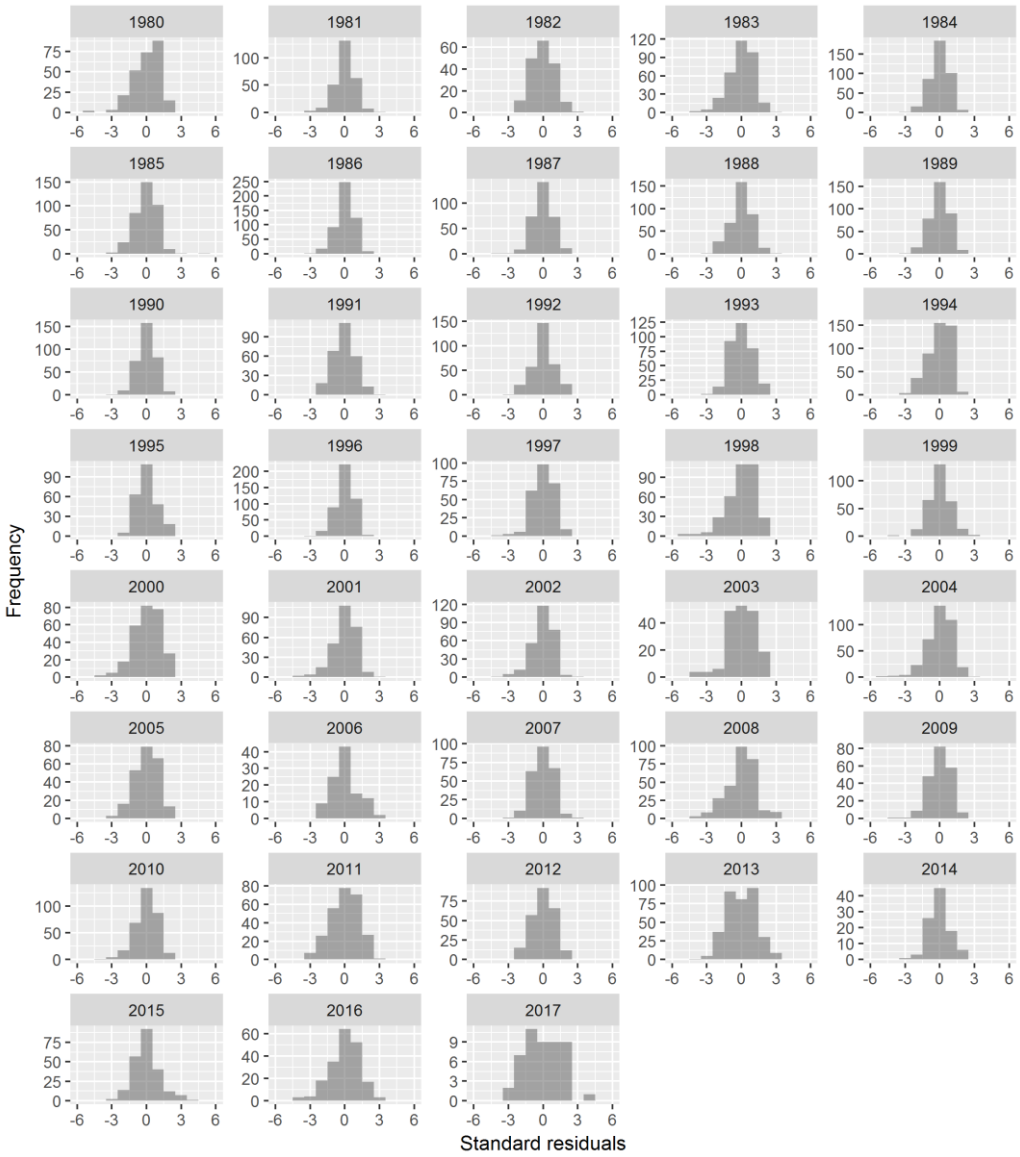

Fig. 4 Standardized residuals by year.

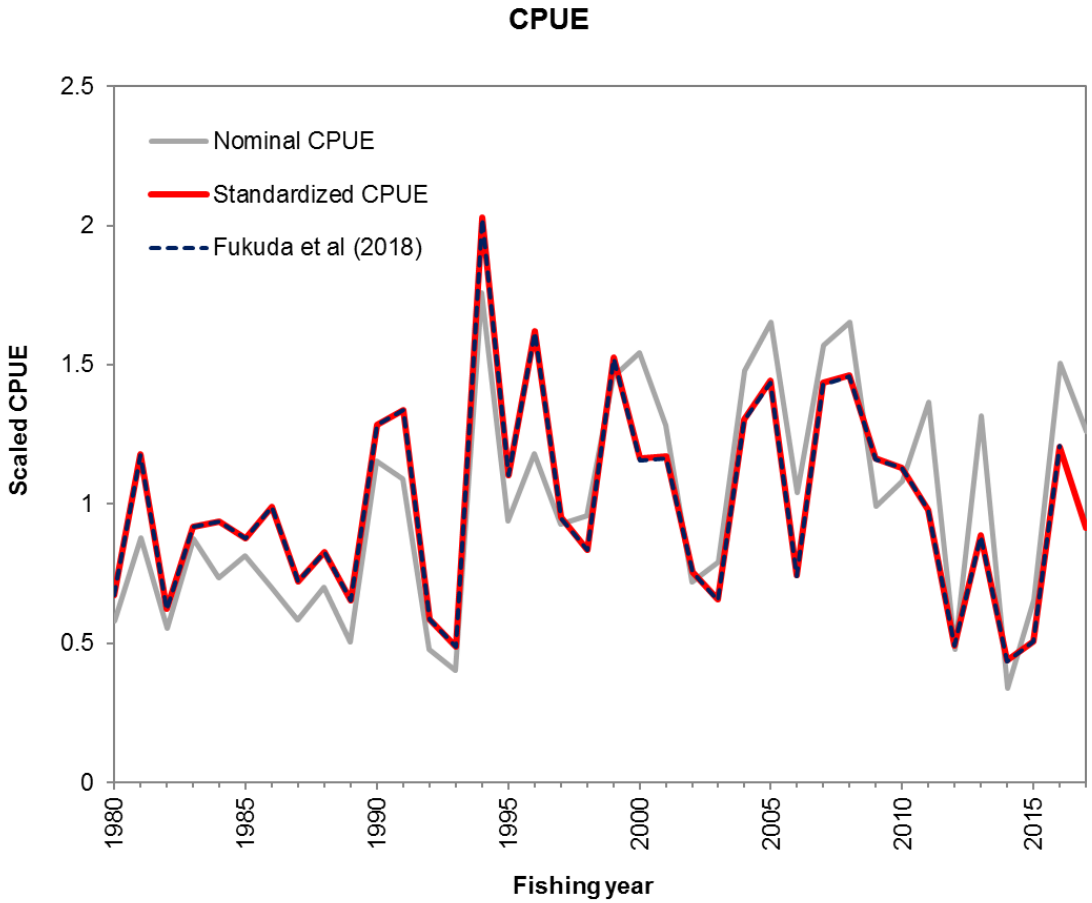

Fig. 5 Comparison of time series of CPUE. Gray and redlines indicates nominal and standardized CPUE from 1980 to 2017 fishing year, respectively. Dashed line shows the standardized CPUE previously estimated by Fukuda et al. (2018).

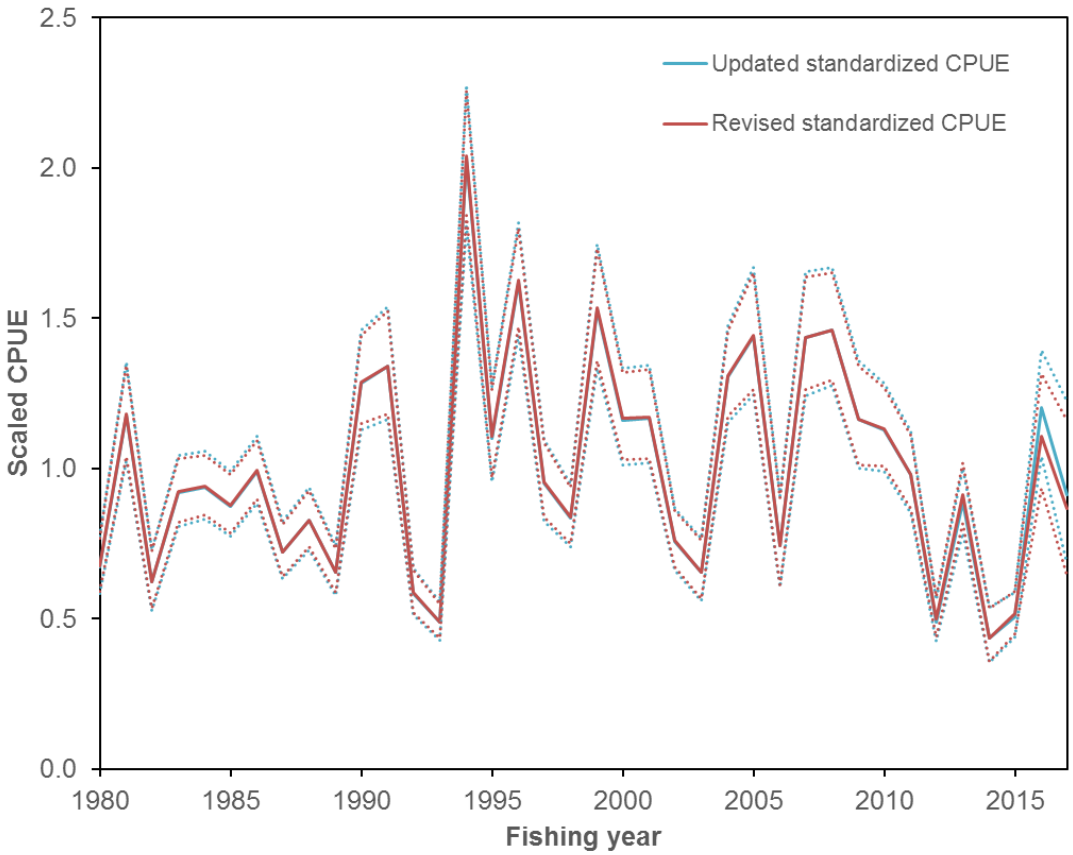

Fig. 6 Comparison of time series of standardized CPUEs. Blue lines indicates updated standardized CPUE from 1980 to 2017 fishing year. Red line shows the revised CPUE using FM4-12 data.

Appendix 1 Information about revised standardized CPUE

Table 1 Total catch (mt), effort (number of landing per day, excluding zero PBF catch) and nominal CPUE (kg/landing) by Quarter and by fishing port, recorded in catch-and-effort data used for standardization of CPUE in Nagasaki Prefecture.

Fishing year	Qt	Catch (mt)						Effort (Number of landing)						CPUE (kg / landing)					
		Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total	Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total	Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total
1980	1	132.3				0.5	132.8	3565				24	3589	37.1				21.5	37.0
1980	2																		
1980	3																		
1980	4	78.1	7.2	11.2	18.2	10.8	125.5	1765	670	142	339	699	3615	44.2	10.7	78.7	53.7	15.5	34.7
1981	1	311.2				3.0	314.2	7136				80	7216	43.6				37.4	43.5
1981	2	38.4					38.4	697					697	55.1					55.1
1981	3																		
1981	4	73.4			118.1	122.7	314.2	1907			1633	2872	6412	38.5			72.3	42.7	49.0
1982	1	54.1					54.1	1037					1037	52.2					52.2
1982	2																		
1982	3																		
1982	4	8.4	14.3	8.9	45.9	17.9	95.4	264	694	274	1503	725	3460	32.0	20.7	32.4	30.5	24.7	27.6
1983	1	170.1				8.4	178.5	4574				155	4729	37.2				53.9	37.7
1983	2																		
1983	3																		
1983	4	72.7	51.3	153.4	350.9	94.1	722.4	1690	1756	2012	3958	2123	11539	43.0	29.2	76.2	88.7	44.3	62.6
1984	1	367.0				77.1	444.0	9501				1535	11036	38.6				50.2	40.2
1984	2	107.5					107.5	2650					2650	40.6					40.6
1984	3																		
1984	4	7.7	72.8	63.5	355.0	55.6	554.7	232	1591	1130	6715	1846	11514	33.4	45.8	56.2	52.9	30.1	48.2
1985	1	123.7				16.0	139.7	5452				375	5827	22.7				42.7	24.0
1985	2	0.1					0.1	2					2	55.5					55.5
1985	3																		
1985	4	58.9	78.3	85.0	130.8	75.4	428.3	1478	1753	1035	2470	1412	8148	39.8	44.6	82.1	53.0	53.4	52.6
1986	1	274.7				5.3	279.9	7915				135	8050	34.7				39.0	34.8
1986	2	12.0					12.0	306					306	39.1					39.1
1986	3																		
1986	4	91.9	67.0	24.0	130.5	72.0	385.3	3236	1729	338	2420	2232	9955	28.4	38.7	70.9	53.9	32.3	38.7
1987	1	59.6					59.6	2494					2494	23.9					23.9
1987	2																		
1987	3																		
1987	4	55.5	14.3	23.2	132.3	15.1	240.4	1912	500	447	2502	658	6019	29.0	28.6	51.8	52.9	23.0	39.9
1988	1	139.8					139.8	5377					5377	26.0					26.0
1988	2	14.4					14.4	161					161	89.4					89.4
1988	3																		
1988	4	127.0	6.0	37.3	150.3	51.1	371.7	3577	283	555	2465	1079	7959	35.5	21.1	67.3	61.0	47.3	46.7
1989	1	77.2			4.8		82.0	4115			92		4207	18.8			52.1		19.5
1989	2	6.1					6.1	110					110	55.8					55.8
1989	3																		
1989	4	36.2	17.4	36.1	76.4	24.8	190.8	1519	776	696	1491	868	5350	23.8	22.4	51.8	51.2	28.6	35.7

Table 1 Cont.

Fishing year	Qt	Catch (mt)						Effort (Number of landing)						CPUE (kg / landing)					
		Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total	Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total	Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total
1990	1	193.8	24.9		16.6		235.3	4582	297		182		5061	42.3	84.0		91.0		46.5
1990	2	12.3					12.3	510					510	24.2					24.2
1990	3																		
1990	4	34.7	21.4	145.4	156.6		358.1	1641	606	1537	1557		5341	21.2	35.3	94.6	100.6		67.1
1991	1	15.0				14.9	30.0	182				378	560	82.7				39.5	53.5
1991	2																		
1991	3																		
1991	4	63.9	44.0	95.5	111.7	112.1	427.3	1364	865	1008	1603	1817	6657	46.9	50.9	94.7	69.7	61.7	64.2
1992	1	44.7	0.6			0.9	46.1	1192	96			50	1338	37.5	5.8			18.1	34.5
1992	2	11.2					11.2	268					268	41.8					41.8
1992	3																		
1992	4	10.5	1.3	23.1	12.9	14.2	62.1	956	138	630	446	903	3073	11.0	9.5	36.7	29.0	15.7	20.2
1993	1	15.3	0.8		2.7	1.5	20.3	539	84		132	151	906	28.5	9.9		20.1	9.9	22.4
1993	2	7.0					7.0	197					197	35.6					35.6
1993	3																		
1993	4	20.0	16.9		57.4	3.4	97.8	1074	902		1908	336	4220	18.7	18.8		30.1	10.2	23.2
1994	1	338.0	8.8		156.6	318.5	822.0	3096	89		670	2241	6096	109.2	99.1		233.7	142.1	134.8
1994	2	53.1					53.1	822					822	64.6					64.6
1994	3																		
1994	4	73.0	96.5		717.6	107.8	994.9	1445	1254		5049	1427	9175	50.5	76.9		142.1	75.5	108.4
1995	1	39.8			2.3	9.0	51.1	1095			64	188	1347	36.3			36.3	47.9	38.0
1995	2	16.1					16.1	345					345	46.7					46.7
1995	3																		
1995	4	48.7			241.0	31.9	321.7	1541			1991	928	4460	31.6			121.1	34.4	72.1
1996	1	216.7	4.5		26.0	65.8	313.0	3425	118		392	1061	4996	63.3	37.8		66.4	62.0	62.6
1996	2	71.9					71.9	970					970	74.2					74.2
1996	3																		
1996	4	51.9	100.1		481.1	61.8	694.9	1739	1425		4401	1004	8569	29.8	70.2		109.3	61.6	81.1
1997	1	70.0	0.3		1.1	6.0	77.4	1461	22		44	100	1627	47.9	15.6		24.8	60.4	47.6
1997	2	20.4					20.4	873					873	23.4					23.4
1997	3																		
1997	4		23.0	59.1	137.7	33.5	253.3		739	690	2561	667	4657		31.1	85.6	53.8	50.2	54.4
1998	1	160.7	6.5		20.6	21.5	209.3	3163	161		288	399	4011	50.8	40.1		71.6	53.9	52.2
1998	2	70.3					70.3	1098					1098	64.1					64.1
1998	3																		
1998	4	3.3	38.9	196.0	248.2		486.4	264	1075	2348	3620		7307	12.4	36.2	83.5	68.6		66.6
1999	1	133.0	32.4		89.8	50.4	305.6	2590	434		870	482	4376	51.3	74.7		103.2	104.5	69.8
1999	2	49.6					49.6	984					984	50.4					50.4
1999	3																		
1999	4	19.4	69.4		266.1	24.3	379.3	720	733		1821	351	3625	27.0	94.7		146.1	69.2	104.6

Table 1 Cont.

Fishing year	Qt	Catch (mt)						Effort (Number of landing)						CPUE (kg / landing)					
		Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total	Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total	Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total
2000	1	45.2	52.0		153.1	48.2	298.6	2061	432		754	668	3915	21.9	120.4		203.0	72.2	76.3
2000	2	3.1					3.1	510					510	6.1					6.1
2000	3																		
2000	4		61.4	207.2	165.2		433.8		781	1353	1462		3596		78.7	153.1	113.0		120.6
2001	1	87.5	27.2		52.7	38.5	205.9	1582	261		617	595	3055	55.3	104.2		85.4	64.7	67.4
2001	2																		
2001	3																		
2001	4		49.2	163.8	106.7	9.5	329.2		850	1682	1112	181	3825		57.9	97.4	95.9	52.3	86.1
2002	1	56.2	19.2		9.7	20.3	105.4	1453	272		224	536	2485	38.6	70.6		43.3	37.9	42.4
2002	2	47.6					47.6	1162					1162	41.0					41.0
2002	3																		
2002	4	1.7	15.3	44.4	59.4	4.3	125.2	110	630	951	1271	270	3232	15.8	24.3	46.7	46.8	15.8	38.7
2003	1	6.5	12.9		1.9	13.0	34.3	304	284		44	357	989	21.3	45.6		43.5	36.4	34.7
2003	2	10.1					10.1	183					183	55.4					55.4
2003	3																		
2003	4	1.4	17.1	68.5	6.2		93.1	366	347	842	195		1750	3.9	49.3	81.3	31.6		53.2
2004	1	83.7	37.8		132.5	38.6	292.6	1215	324		855	539	2933	68.9	116.7		154.9	71.7	99.8
2004	2	13.4					13.4	221					221	60.6					60.6
2004	3																		
2004	4	20.5	45.6	188.2	191.7	1.3	447.3	868	599	1478	2246	153	5344	23.6	76.2	127.3	85.3	8.7	83.7
2005	1	5.0	4.1			4.8	13.9	246	143			142	531	20.2	28.9			33.7	26.1
2005	2																		
2005	3																		
2005	4	17.5	11.1	125.9	68.2	18.8	241.5	304	222	1014	721	212	2473	57.7	50.1	124.1	94.6	88.5	97.7
2006	1		0.4			0.1	0.5		24			5	29		15.4			21.4	16.4
2006	2																		
2006	3																		
2006	4		9.2	30.7	20.0	0.3	60.2		207	437	490	23	1157		44.3	70.4	40.8	14.9	52.1
2007	1	0.3			20.0	12.1	32.3	5			359	134	498	59.7			55.6	89.9	64.9
2007	2	5.0					5.0	59					59	84.6					84.6
2007	3																		
2007	4		22.6	91.8	143.8	17.8	276.0		376	753	1561	259	2949		60.1	121.9	92.1	68.6	93.6
2008	1	150.8			6.2	48.1	205.0	1946			87	693	2726	77.5			71.0	69.3	75.2
2008	2	9.6					9.6	166					166	57.7					57.7
2008	3																		
2008	4	19.3		142.0	47.6	12.8	221.8	556		854	673	99	2182	34.7		166.3	70.8	129.6	101.6
2009	1	91.5	5.0			4.5	101.0	1236	102			129	1467	74.0	49.4			35.0	68.9
2009	2	1.5					1.5	20					20	74.5					74.5
2009	3																		
2009	4	4.3	30.7	75.6		0.8	111.4	83	641	693		46	1463	52.3	47.8	109.1		16.4	76.1

Table 1 Cont.

Fishing year	Qt	Catch (mt)						Effort (Number of landing)						CPUE (kg / landing)					
		Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total	Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total	Tomie	Are	Kami-tsushima	Kami-agata	Ojika	Total
2010	1	66.8	2.2		0.0		69.0	1348	65		1		1414	49.6	33.6		6.0		48.8
2010	2	29.3					29.3	254					254	115.4					115.4
2010	3																		
2010	4	19.1	12.5	76.7	171.9	6.5	286.8	517	374	806	2349	135	4181	37.0	33.4	95.1	73.2	48.4	68.6
2011	1	23.1	6.1		0.1	0.3	29.7	831	77		5	20	933	27.8	79.8		14.2	17.3	31.8
2011	2	4.5			0.0	0.9	5.5	29			1	21	51	156.7			4.4	45.2	107.8
2011	3																		
2011	4	1.1	7.0	96.9	216.5	0.4	321.9	119	118	665	2280	14	3196	9.0	59.4	145.7	95.0	30.2	100.7
2012	1	6.5	7.9	0.3	0.3	3.0	18.0	194	203	7	4	72	480	33.7	38.8	44.3	74.3	41.0	37.5
2012	2	0.7	0.1		0.4		1.2	8	7		14		29	91.5	7.4		28.9		40.9
2012	3		0.4				0.4		31				31		12.1				12.1
2012	4	0.4	10.6	0.3	61.5	0.2	73.0	32	526	12	1508	22	2100	13.1	20.1	27.4	40.8	9.5	34.8
2013	1	91.7	56.2	1.2	56.8	7.0	212.9	1173	521	12	350	110	2166	78.2	107.8	97.8	162.2	64.0	98.3
2013	2	4.1	7.8		0.1		12.0	21	129		4		154	193.1	60.5		26.9		77.7
2013	3		0.2	0.0			0.2		16	3			19		12.6	9.7			12.1
2013	4	2.2	13.8	5.6	122.8	5.0	149.3	46	382	133	1388	69	2018	47.5	36.0	42.1	88.5	72.1	74.0
2014	1	8.2	1.0			0.4	9.6	309	75			22	406	26.6	13.5			18.5	23.7
2014	2		1.9			0.0	1.9		46			1	47		42.0			2.4	41.1
2014	3	0.0					0.0	1					1	5.0					5.0
2014	4	0.0	0.9	0.0	0.1	0.3	1.3	2	75	4	5	14	100	3.3	12.2	11.5	16.7	20.4	13.3
2015	1	4.9	6.0		0.1	0.0	11.1	128	129		9	3	269	38.3	46.5		15.6	9.6	41.2
2015	2	0.3	7.4	0.2	8.0	0.4	16.3	13	431	13	125	19	601	26.0	17.2	13.1	63.6	22.5	27.1
2015	3	0.0	0.0		0.3		0.3	1	2		13		16	2.7	14.7		21.2		19.3
2015	4	0.3	6.7	0.2	3.7	0.1	11.0	35	244	3	37	1	320	7.9	27.3	55.0	101.2	125.1	34.3
2016	1	37.6	7.5			0.1	45.2	759	37			9	805	49.5	204.0			9.9	56.2
2016	2		0.1				0.1		4				4		18.0				18.0
2016	3		0.5	5.1	42.6		48.2		4	47	269		320		115.8	109.4	158.3		150.6
2016	4	1.8	1.9			0.8	4.4	95	25			28	148	18.8	74.3			26.9	29.7
2017	1		0.4				0.4		10				10		40.7				40.7
2017	2																		
2017	3		0.2				0.2		2				2		87.0				87.0
2017	4	35.4	0.3			0.1	35.8	368	15			7	390	96.2	19.4			9.7	91.7

Table 2 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	30626.1
b) fy*fm+port	30800.2
c) fy*port+fm	30885.9
d) fy+fm*port	30636.5
e) fy*fm+fy*port	31235.4
f) fy*fm+fm*port	30820.2
g) fy*port+fm*port	30859.6
h) fy*fm+fm*port+fy*port	31161.5

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

Efffects	df	Type IIISS	Mean squire	F value	Pr>F
Model	49	2583.9	52.7	53.17	<.0001
Error	10624	10536.5	1.0		
Corrected Total	10673	13120.4			

Efffects	df	Type IIISS	Mean squire	F value	Pr>F
fy	37	1363.9	36.9	37.2	<.0001
fm	8	253.6	31.7	32.0	<.0001
port	4	883.7	220.9	222.8	<.0001

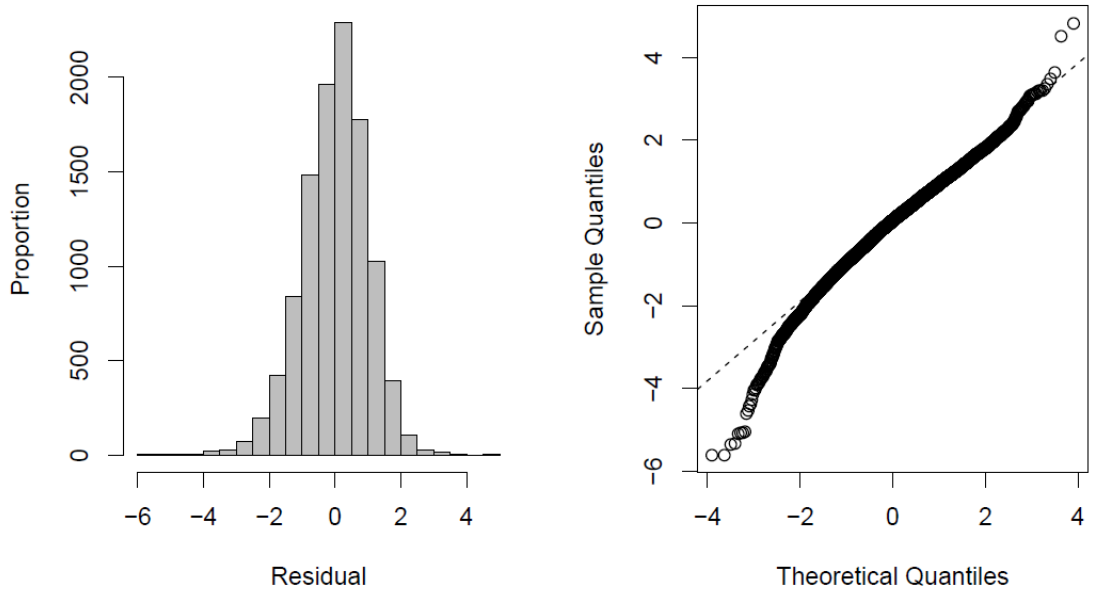

Fig. 1 Standardized residuals (left panel) and Q-Q plot of them (right panel) for revised standardized CPUE.

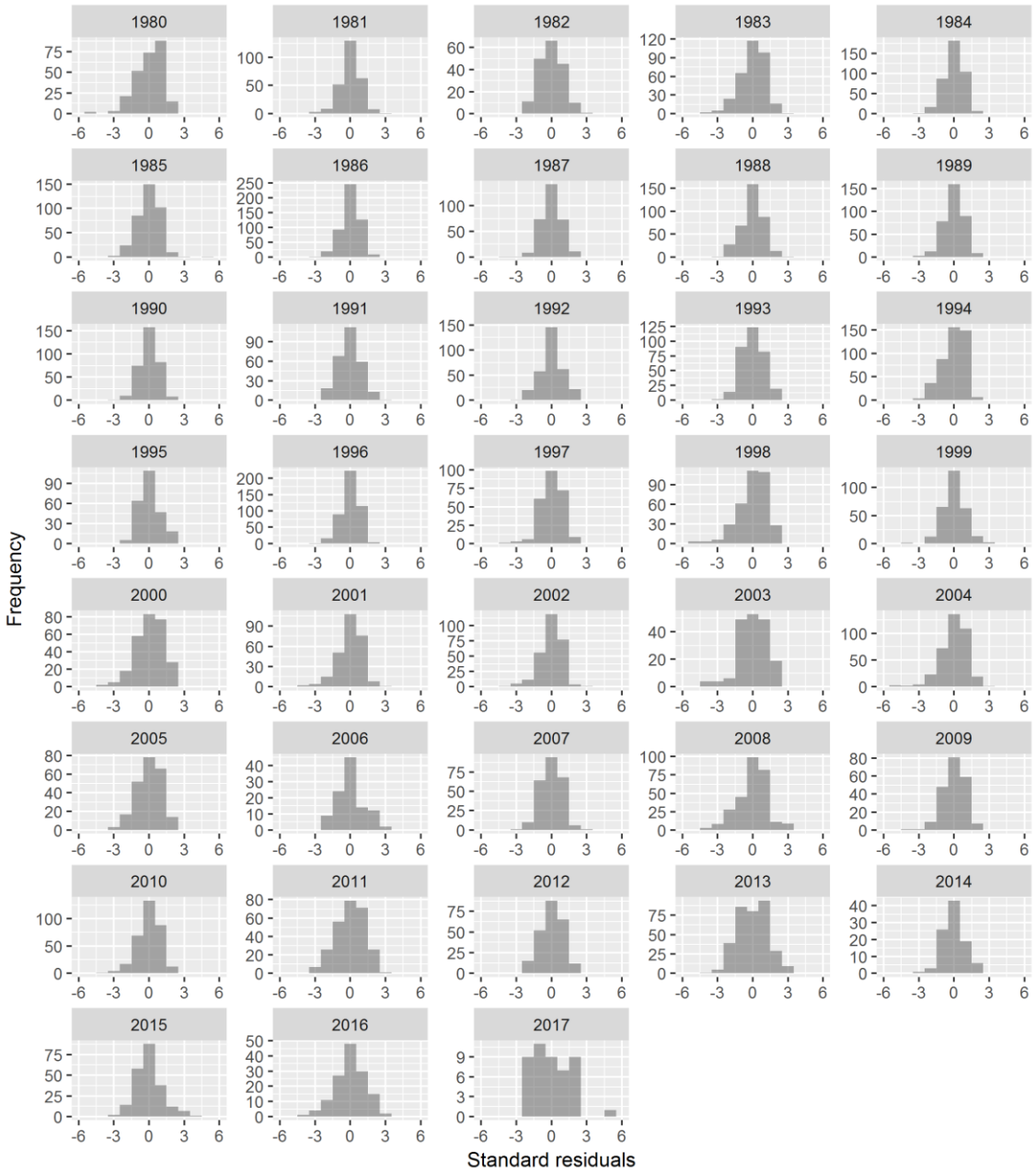

Fig. 2 Standardized residuals by year for revised standardized CPUE.

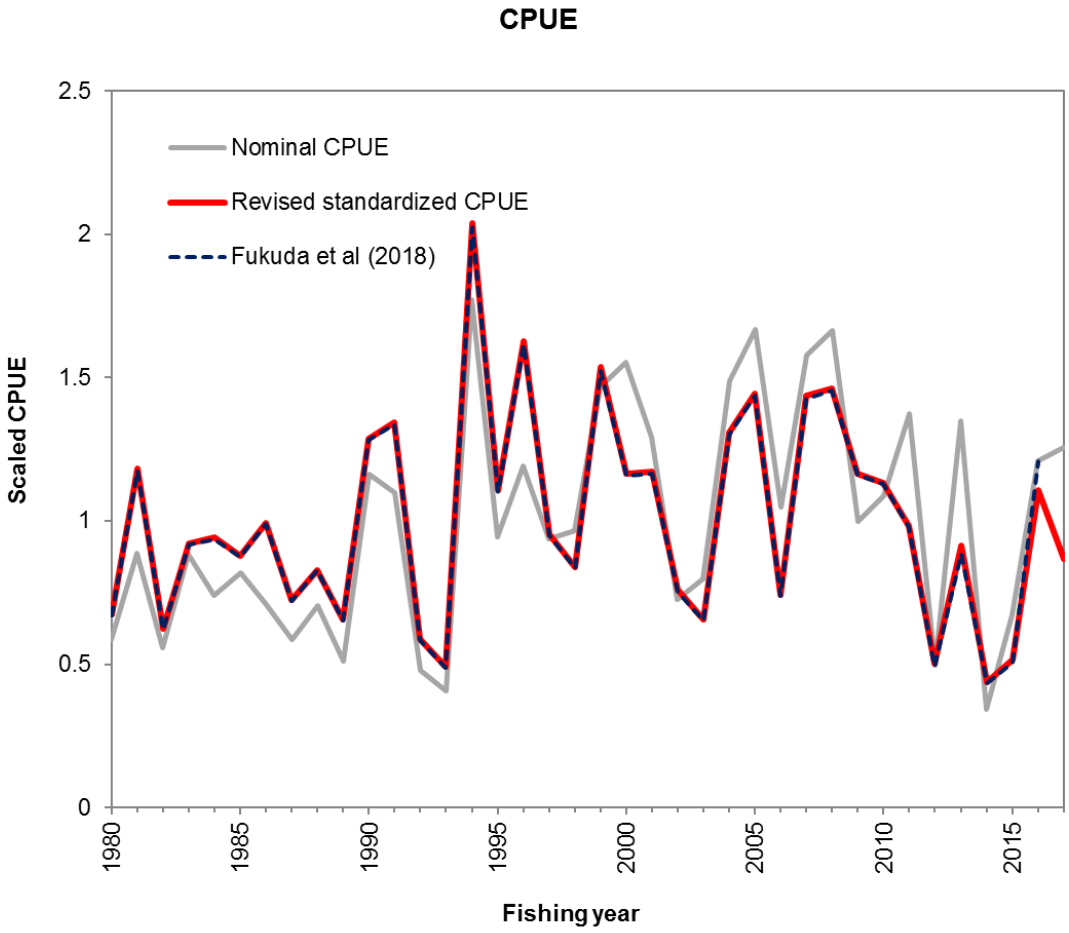

Fig. 3 Comparison of time series of CPUE. Gray and redlines indicates nominal and revised standardized CPUE from 1980 to 2017 fishing year, respectively. Dashed line shows the standardized CPUE previously estimated by Fukuda et al. (2018).