Update of Age-0 PBF index based on catch per unit effort data from Japanese troll fishery and its associated issues.

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1. Introduction

The index of juvenile Pacific bluefin tuna (PBF) abundance based on catch and effort data of troll fisheries is one of the most important indices which enables to monitor the relative strength of recruitment and has been inputted in the assessment model of PBF to inform the trend of recruitment. Ichinokawa et al. (2012) provided three CPUE series from troll fisheries which operated in the different area, such as Kochi, Wakayama, and Nagasaki Prefectures, and the ISC PBFWG has been included an index obtained from Nagasaki Prefecture in the assessment model due to its representativeness over the stock (ISC 2014). This troll fishery operating in the coastal waters of Nagasaki prefecture is basically targeting age-0 PBF which would come 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 annual recruitment strength of whole PBF population.

In the past couple of assessments, this index has performed well in terms of the consistency of the information among the other important data sources (e.g. spawner indices from longline fisheries, catch time series etc...), and thus this index was considered as a good source of information of recruitment for the assessment. However, because of the strict fishery management based on the Western and Central Pacific Fisheries Commission (WCPFC) conservation and management measure (WCPFC 2014), the catch amount of the small size PBF (< 30 kg) has been controlled for all fisheries in Japan since 2015. As for the coastal fisheries such as the troll and set-net, which were licensed by the prefectural government, the catch upper limit were allocated by the national government to the prefectural government. In the case of Nagasaki prefecture, Individual quota (IQ) has been allocated to all of the licensed vessels (ca. 350 kg per a vessel) equally since 2017 FY and, so far, any official transferring framework did not work well to consume the quota efficiently.

In addition, an unexpected huge amount of catch of small PBF occurred at the different coastal fishery in 2017 and all the fishery targeting small PBF throughout

Japan, including the troll fishery in Nagasaki prefecture, were suspended by the national government to avoid the annual catch exceeding the catch upper limit of the country. Since this fishery ban occurred from January to June of 2018 (3rd and 4th quarters of 2017 FY) which is the second half of main fishing season for troll fishery, the fishery data for this period were not available for the index estimation. The estimated standardized CPUE showed a larger confidence interval than the rest of years, and consequently, the PBFWG decided not to include 2017 data point of Japanese Troll CPUE index in the assessment model of the 2020 stock assessment.

In this document, the Japanese troll CPUE was updated using the fishery data up to 2019 fishing year and the same standardization method with the previous assessment was applied (Nishikawa et al., 2020, ISC PBFWG 2019). The trend of the estimated index was compared with the other information (e.g. Japanese real-time monitoring survey index, Tsukahara and Chiba, 2019) and difference between them were discussed. To comprehend the possible effect of the fishery management on the conventional troll CPUE index as well as the real-time monitoring survey index, we also conducted some interviews to the troll fishermen including the captains of the real-time monitoring vessels.

2. Materials and Methods

2.1 Data

The catch-and-effort data used in this document were based on the sales slip data, which have been collected and archived by Fisheries Resources with cooperation from the Nagasaki prefectural 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). The sales slip data 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 (Figure 1). These data were based on the sales slip sold as "yokowa" category which means small PBF. The catch data is total PBF (in the unit of weight (kg)) in each day at each fishing port). The original data includes

landing weight for Sashimi market and fry weight for farming with notation. Due to the different natures between the trolls for the market and farming, we exclude the catch and effort data for farming from the analysis. The number of vessels associated with each landing, which is collected through separate report from each fishing ports, were collected and used as the effort data.

2.2 Update of the current recruitment index up to 2019 FY

The same 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): 1980-2016, 2018-2019… 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).

2.3 Comparison between standardized conventional troll CPUE and real-time monitoring survey index.

For the comparison, the CPUE based index from real-time troll monitoring survey in East China Sea was also updated up to 2019 as below (Tsukahara and Chiba, 2019). The data were collected using a data logger and transmitter which are equipped on the 14 troll participating vessels in Tsushima and Goto island(Table 1, Figure 2). The fishermen input the number of caught PBF into data logger when

they caught PBF even if they release that PBF. The catch information together with the global positioning system data and sea surface temperature are sent to the FRA via cellular network in real-time. The received data are assembled as catch data per day and are analyzed for standardization. The CPUE standardizations were conducted using zero inflated negative binomial GLM model, which was same model used by Tsukahara and Chiba (2019). The best models were determined by the Bayesian information criterion (BIC). The candidate explanatory variables used for standardization were below;

1) Year: 9 fishing years (2011-2019)
2) Season: 4 months in November to February
3) Area: 2 area: Tsushima and Goto island.

3. Results

3.1 Catch and Effort

Catch-and-effort data by each landing port are summarized in Table 2 and Table 3. In accordance with the introduction of the stricter management based on the WCPFC CMM2014-04 in 2015 calendar year (second half of 2014 FY and first half of 2015 FY), both of the catch and effort in 5 ports became smaller. In addition, effort in 2017 FY dropped to the historical lowest where no operation (effort) was confirmed in the second half of 2017 FY at the most of all ports due to the introduction of the temporal fishery ban (Table 3).

Although the calculation of this conventional troll CPUE does not include the catch and effort data from the operation for farming due to its possible difference in catchability from the conventional troll for the Sashimi-market, the ratio of troll operation for farming was increased and the highest in 2015 FY (about 20% of total catch).

3.2 Standardized index from the conventional troll fishery

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 6), which was presented by Nishikawa et al. (2020). The time series of standardized CPUE showed a similar trend with the previous update (Nishikawa et al., 2020), and the updated data point estimation in 2019 FY was the lowest during 1980 -2019 (Figure 3). Residuals distributed centrally around zero, although those distributions showed slightly left-skewed shapes (Figures 4 and 5). The standardized CPUE, CV and 90% confidence limits are shown in Table 8.

The range of coefficient of variation (CV) for standardized CPUE in each year were 0.012-0.037 in 1980-2016, 2018-2019, on the other hand, the CV in 2017 was 0.043. CPUEs between standardized without 2017 FY and including 2017 FY show almost identical result (Figure 6).

3.3 Comparison with the real-time monitoring index

The time series of the real-time monitoring index showed a large fluctuation (Figure 7), which has a peak in 2017 FY. The updated data point in 2019 FY was higher than that of 2018 FY and being at around the average of the time series. The range of confidence interval for the real-time monitoring index in each year were 0.123-1.875 during 2011-2019, and the range of confidence interval in 2017 was the largest during the period. A very large range in 2017 FY would be affected by the ban of the coastal fisheries during the second half of the 2017 FY.

As Figure 8, the indices from the conventional troll and real-time monitoring survey showed a similar trend for the early period (2011-2016) but those became different in recent years (2016-2019).

4. Discussion

4.1 Fishery information via interview from fisherman

To comprehend how the fishery management introduced by the national and local

government affected to their operation, we conducted interviews with some people from the Nagasaki prefectural government and troll fishermen as well as the fishermen participating to the real-time monitoring survey.

There were several distinct shifts in the management of the coastal fishery in Nagasaki prefecture. In 2015, the current management measures were firstly introduced based on the WCPFC CMM2014-04. To comply the CMM, the national government allocated country's catch upper limit to each fishery and area. However, since a couple of consecutive recruitments in 2014 and 2015 were historically low, the catch amount by troll in this area were not substantial in 2015 FY, and the fishing season finished without any significant problem.

In 2016 FY, a large amount of small (<30 kg) PBF caught in an area of Tsushima island and that suppressed to the quota of the island. As a countermeasure, the individual quota system has introduced by the local government to manage all licensed coastal fisheries since 2017 FY in Nagasaki prefecture. To utilize the limited quota with the economical efficiency, some operational changes of the troll fishery were also occurred at the same timing such as the minimum landing size (i.e. 1.5 kg in body weight) and/or increase of the farming operation. Because of the minimum landing size regulation, live-release of a PBF smaller than 1.5 kg BW became an usual manner for the troll fishermen in Tsushima island. Although the IQ was introduced in the Nagasaki prefecture in 2017 FY, an unexpected huge amount of catch overage of small PBF occurred at a different prefecture in 2017 FY, and the troll fishery in Nagasaki prefecture were also suspended to land the small PBF by the national government to avoid the annual catch exceeding the catch upper limit of the country.

Since April 2019 (5th management period in Japan), the management period for Japanese coastal fisheries has changed from July-June to April-March (WCPFC 2019). In the previous management period starting in July to an end in June, the troll generally operated for farming in the summer (when the size of age-0 PBF is small (20-30 cm, 0.2-0.4 kg)) and for fresh market in winter. For the conventional troll CPUE calculation, we used the catch and effort data mainly from the operations

in winter. In the new management scheme starting 2019, the troll may operate for farming in the spring (April-June) to get a larger fly for aquaculture born in the previous year (age 0.825 in the assessment), and consequently, they may have limited IQ leavings in the winter. This operational shift to the farming in the spring season can lead the data for the conventional troll CPUE to further decrease in the future.

4.2 Effect of the management to the conventional troll CPUE

The information described above illustrates the changes of the fishing operation by Japanese troll targeting PBF for the fresh market. Due to the nature of each change, the uncertainty and possible bias of the CPUE from this fishery would have been increasing in recent several years.

In here, we roughly introduced three time periods which have different nature of fishing operation and management scheme:

– to 2014: Managed by the effort control without catch upper limit.

– 2015-2016: Introduction of the catch quota in area basis for the troll vessels licensed by the local government.

– 2017-present: Introduction of the IQ management for the troll fishery targeting PBF by the local government. This period includes the introduction of the minimum size regulation in some areas of Nagasaki prefecture as well as the temporal suspension of the PBF landing by the coastal fisheries in 2017 FY.

In terms of the possible effect to the conventional troll CPUE, a period prior to 2015 might not be affected very much since there was no significant changes in the management scheme. The introduction of the total catch limit in 2015 for the coastal fisheries in area basis may have affected to the temporal distribution of the effort

because it is reasonable for each fisherman to shift their effort to earlier season to catch larger amount of PBF given a total catch upper limit, or they might shift their effort to the penning operation which is more economically efficient given a catch upper limit. Those would lead the decrease or bias in the temporal effort distribution, and consequently, the uncertainty of the estimated CPUE might become higher than the previous years.

Because there has been a certain amount of the live-release of small PBF due to the minimum landing size regulation, CPUE based on the sales slip data, which does not include those information, could be biased to the downward. In particular, 2017 data point would be affected by both of the temporal suspension of PBF landing and live-release of the small PBF. The difference in the trends between the conventional troll CPUE and real-time monitoring CPUE would be caused by the availability of the live-release information.

According to the change of nature of conventional troll fishery due to the management change, we propose not to include the CPUE based index from Japanese conventional troll fishery in the future stock assessment for the period when management change is considered to have biased the index. The PBF working group may want to discuss the length of the time series to exclude from the assessment model and it could be depending on the availability of an alternative recruitment index.

4.3 Effect to the current management advise published by the ISC

The ISC published and submitted the latest stock status and management advice (scientific information) in 2020 based on the 2020 stock assessment which include available data up until 2018 FY (ISC, 2020). In the latest assessment, the PBFWG decided not to include 2017 data point of this conventional troll CPUE (ISC, 2020), so that the possible bias of this index would affect to the recruitment of the 2018 year-class only. Since the Spawning Stock Biomass (SSB) in the terminal year of the assessment, which is the key information to decide the stock status, was consisted

by the 2015 and prior recruitment year-classes (ages 3 and above), the effect of the biased information to the stock status would be limited.

Also, the future projection, which is the another key information for the management advice, included the uncertainty associated with the parameter estimation through the bootstrap replicates (Fukuda et al, 2020), the current management advice would be robust to the possible uncertainty or bias included the 2018 data point of the conventional troll CPUE. It also would be worth to note that since the possible bias associated with the live-release of small PBF would be worked to the index pessimistically, the current results of the projection (e.g. the probability achieving the rebuilding targets) could unintentionally be conservatively biased.

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Table 1 Comparison table between sales slip CPUE and Real-time monitoring survey CPUE.

		Sales slips	**Real-time monitoring survey in East China Sea**
Collection method		Sales slips from 5 ports	participating vessels equipped data logger and transmitter
data	**Spatial information**	5 ports	Latitude, Longitude(GPS)
	Temporal resolution	Day	10 Min
	SST	unavailable	available
	Zero catch information	unavailable	available
	Data period	1980-2019	2011-2019
	Live-release information	unavailable	available
Model	**Standardization**	GLM with lognormal error distribution	Zero inflated negative binomial GLM model
	CPUE	weight/day/vessel	Number/day/vessel
	Spatial stratum	Port name	Tsushima or Goto island
	Temporal Stratum	month (4 to 12 Fishing Month)	month（5 to 8 FM）

Table 2 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					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		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												118.1			118.1		122.7	3.0		125.7	666.8
1982		8.4	54.1		62.5		14.3			14.3		8.9			8.9		45.9			45.9		17.9			17.9	149.5
1983		72.7	170.1		242.9		51.3			51.3		153.4			153.4		350.9			350.9		94.1	8.4		102.4	900.9
1984		7.7	367.0	107.5	482.2		72.8			72.8		63.5			63.5		355.0			355.0		55.6	77.1		132.6	1106.2
1985		58.9	123.7	0.1	182.7		78.3			78.3		85.0			85.0		130.8			130.8		75.4	16.0		91.4	568.1
1986		91.9	274.7	12.0	378.5		67.0			67.0		24.0			24.0		130.5			130.5		72.0	5.3		77.3	677.2
1987		55.5	59.6		115.1		14.3			14.3		23.2			23.2		132.3			132.3		15.1			15.1	300.0
1988		127.0	139.8	14.4	281.2		6.0			6.0		37.3			37.3		150.3			150.3		51.1			51.1	525.9
1989		36.2	77.2	6.1	119.5		17.4			17.4		36.1			36.1		76.4	4.8		81.2		24.8			24.8	279.0
1990		34.7	193.8	12.3	240.9		21.4	24.9		46.3		145.4			145.4		156.6	16.6		173.2						605.8
1991		63.9	15.0		79.0		44.0			44.0		95.5			95.5		111.7			111.7		112.1	14.9		127.1	457.3
1992		10.5	44.7	11.2	66.4		1.3	0.6		1.9		23.1			23.1		12.9			12.9		14.2	0.9		15.1	119.4
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	30.5		30.6	0.0	1.7	12.9	0.0	14.7	0.3	0.4	2.1	0.0	2.8	3.0	9.8	9.8	1.1	23.8	0.0	0.1	1.4		1.5	73.4
2019		2.4	16.0	3.5	22.0	0.0	0.1	11.0	0.9	12.0	0.5	0.0	0.5		1.1	2.4	9.1	1.2	0.3	13.1		0.3	1.1	0.1	1.5	49.7

Table 3. 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	712		724	1	48	172	1	222	9	18	25	1	53	40	184	164	17	405	1	4	40		45	1449
2019		116	743	280	1139	1	11	324	25	361	16	1	11		28	123	193	36	12	364		25	95	9	129	2021

Table 4 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.

Tomie					Are					Kami-tsushima					Kami-agata					Ojika					kg/num of ves w/o fqt1
Qt1	Qt2	Qt3	Qt4	Average	Qt1	Qt2	Qt3	Qt4	Average	Qt1	Qt2	Qt3	Qt4	Average	Qt1	Qt2	Qt3	Qt4	Average	Qt1	Qt2	Qt3	Qt4	Average	
	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
	39.9	46.8	44.8	44.3												67.8			67.8		37.2	24.5		34.7	46.5
	25.8	59.6		47.1		15.9			15.9		20.1			20.1		24.0			24.0		20.2			20.2	33.3
	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
	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
	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
	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
	25.7	22.7		23.8		26.4			26.4		39.9			39.9		50.0			50.0		21.0			21.0	35.2
	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
	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
	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
	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
	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
	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
	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
	30.6	38.5	42.7	36.6												97.9	42.3		90.0		35.8	40.0		37.6	63.2
	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
		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
	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
	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
		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
		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
	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
	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
	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
	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
						37.2	14.2		33.6		98.4			98.4		32.3			32.3		15.0	23.8		18.2	51.2
		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
	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
	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
	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
	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
	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
	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
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
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
	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
	114.1			114.1	87.0	16.8	35.7		30.1												11.0			11.0	90.4
	6.5	24.6		23.6	5.6	35.0	65.3	5.0	56.2	40.6	26.1	83.7	8.2	46.2	67.4	40.7	47.4	57.5	52.1	7.0	25.7	35.6		32.5	50.2
	12.0	15.9	16.7	15.9	4.5	9.7	26.7	33.6	25.1	25.3	7.0	54.4		35.9	17.7	24.6	30.2	33.0	24.2		14.9	15.9	7.6	14.6	24.8

Table 5 Number of records 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		51	61		112		42			42		22			22		25			25		44	10		54	255
1981		44	76	24	144												60			60		49	12		61	265
1982		24	41		65		34			34		14			14		45			45		25			25	183
1983		34	80		114		73			73		36			36		68			68		25	12		37	328
1984		24	84	32	140		77			77		49			49		73			73		43	14		57	396
1985		56	141	2	199		59			59		22			22		66			66		21	8		29	375
1986		83	138	31	252		77			77		47			47		76			76		36	4		40	492
1987		50	86		136		38			38		50			50		59			59		27			27	310
1988		51	129	15	195		20			20		49			49		72			72		20			20	356
1989		47	124	6	177		60			60		33			33		55	8		63		18			18	351
1990		36	108	22	166		27	21		48		50			50		59	10		69						333
1991		68	5		73		47			47		40			40		53			53		43	15		58	271
1992		68	92	52	212		10	10		20		17			17		17			17		34	8		42	308
1993		59	76	40	175		50	7		57							63	10		73		17	8		25	330
1994		49	114	37	200		70	10		80							76	18		94		27	38		65	439
1995		56	64	35	155												54	9		63		14	11		25	243
1996		58	109	49	216		75	15		90							75	16		91		22	29		51	448
1997			46	22	68		41	2		43		40			40		73	2		75		19	6		25	251
1998		18	53	36	107		60	17		77		56			56		69	19		88			22		22	350
1999		33	53	31	117		39	20		59							54	22		76		8	26		34	286
2000			44	10	54		48	22		70		37			37		54	20		74			38		38	273
2001			40		40		53	16		69		47			47		47	21		68		8	33		41	265
2002		5	46	30	81		51	19		70		31			31		47	17		64		9	20		29	275
2003		12	16	16	44		39	22		61		33			33		13	8		21			25		25	184
2004		36	43	23	102		64	21		85		56			56		72	23		95		8	23		31	369
2005		5	8		13		41	24		65		64			64		60			60		11	17		28	230
2006							27	5		32		40			40		23			23		7	4		11	106
2007			2	21	23		25			25		71			71		56	23		79		19	27		46	244
2008		45	66	27	138							52			52		21	4		25		26	44		70	285
2009		5	58	10	73		51	9		60		43			43							14	16		30	206
2010		42	74	33	149		41	9		50		51			51		65	1		66		8			8	324
2011		24	53	7	84		13	19		32		59			59		64	4	1	69		11	5	6	22	266
2012		14	32	4	50	10	51	32	4	97		10	7		17		61	1	3	65		7	9		16	245
2013		14	62	6	82	4	37	60	29	130	3	34	3		40		53	20	1	74		6	18		24	350
2014	1	2	28		31		22	12	14	48		2			2		2			2		5	10	1	16	99
2015	1	15	27	11	54	2	44	38	48	132		1		12	13	2	2	2	9	15		1	3	7	11	225
2016		23	54		77	4	21	22	3	50	28				28	26				26		9	6		15	196
2017		23			23	2	11	6		19												6			6	48
2018		3	49		52	1	11	37	1	50	7	11	8	1	27	29	35	24	13	101	1	4	17		22	252
2019		9	65	36	110	1	10	34	14	59	13	1	9		23	30	43	20	7	100		21	42	9	72	364

Table 6 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	31969.1
b) fy*fm+port	32247.3
c) fy*port+fm	32262.9
d) fy+fm*port	31954.7
e) fy*fm+fy*port	32716.2
f) fy*fm+fm*port	32256.1
g) fy*port+fm*port	32238.1
h) fy*fm+fm*port+fy*port	32645.1

Table 7 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	2926.7	58.5	59.28	<.0001
Error	11111	10971.7	1.0		
Corrected Total	11161	13898.4			

Efffects	df	Type III SS	Mean squire	F value	Pr > F
fy	38	1715.1	45.1	45.7	<.0001
fm	8	277.5	34.7	35.1	<.0001
port	4	941.2	235.3	238.3	<.0001

Table 8 Nominal and standardized troll CPUE comparing with previous study (Nishikawa et al., 2020). All CPUEs are normalized by each average.

Fishing year	Nominal CPUE	Record Number	w/o FY2017standardized CPUE				Nishikawa et al.(2020)	
			Estimation	CV	Lower 5%	Upper 5%	Estimation	CV
1980	0.60	255	0.69	0.02	0.61	0.79	0.68	0.02
1981	0.90	265	1.22	0.02	1.08	1.39	1.20	0.02
1982	0.57	183	0.64	0.02	0.55	0.74	0.63	0.02
1983	0.90	328	0.94	0.02	0.84	1.06	0.93	0.02
1984	0.76	396	0.97	0.01	0.87	1.07	0.95	0.01
1985	0.84	375	0.90	0.02	0.81	1.00	0.89	0.02
1986	0.72	492	1.02	0.01	0.93	1.12	1.00	0.01
1987	0.60	310	0.74	0.02	0.66	0.83	0.73	0.02
1988	0.72	356	0.85	0.02	0.76	0.95	0.84	0.02
1989	0.52	351	0.67	0.02	0.60	0.75	0.66	0.02
1990	1.19	333	1.32	0.01	1.18	1.47	1.30	0.01
1991	1.12	271	1.38	0.02	1.22	1.57	1.35	0.02
1992	0.49	308	0.60	0.02	0.54	0.68	0.59	0.02
1993	0.41	330	0.50	0.02	0.45	0.56	0.49	0.02
1994	1.81	439	2.09	0.01	1.89	2.31	2.05	0.01
1995	0.96	243	1.14	0.02	1.00	1.30	1.12	0.02
1996	1.22	448	1.67	0.01	1.51	1.84	1.64	0.01
1997	0.96	251	0.98	0.02	0.86	1.11	0.96	0.02
1998	0.99	350	0.86	0.02	0.77	0.96	0.84	0.02
1999	1.50	286	1.57	0.02	1.39	1.77	1.54	0.02
2000	1.59	273	1.19	0.02	1.05	1.34	1.17	0.02
2001	1.32	265	1.20	0.02	1.06	1.35	1.17	0.02
2002	0.74	275	0.78	0.02	0.69	0.88	0.76	0.02
2003	0.81	184	0.67	0.02	0.58	0.77	0.66	0.02
2004	1.52	369	1.34	0.01	1.20	1.49	1.32	0.01
2005	1.70	230	1.48	0.02	1.29	1.69	1.45	0.02
2006	1.07	106	0.76	0.03	0.63	0.92	0.75	0.03
2007	1.61	244	1.48	0.02	1.30	1.68	1.45	0.02
2008	1.70	285	1.51	0.02	1.34	1.70	1.48	0.02
2009	1.02	206	1.19	0.02	1.04	1.37	1.17	0.02
2010	1.11	324	1.16	0.02	1.03	1.30	1.14	0.02
2011	1.40	266	1.01	0.02	0.89	1.14	0.99	0.02
2012	0.51	235	0.51	0.02	0.45	0.58	0.50	0.02
2013	1.38	343	0.92	0.02	0.82	1.02	0.91	0.02
2014	0.35	98	0.43	0.04	0.36	0.53	0.43	0.04
2015	0.69	220	0.50	0.02	0.44	0.58	0.51	0.02
2016	1.23	138	1.12	0.02	0.95	1.33	1.11	0.02
2017	1.28	46						
2018	0.80	214	0.65	0.02	0.57	0.75	0.64	0.02
2019	0.40	320	0.36	0.02	0.32	0.41		

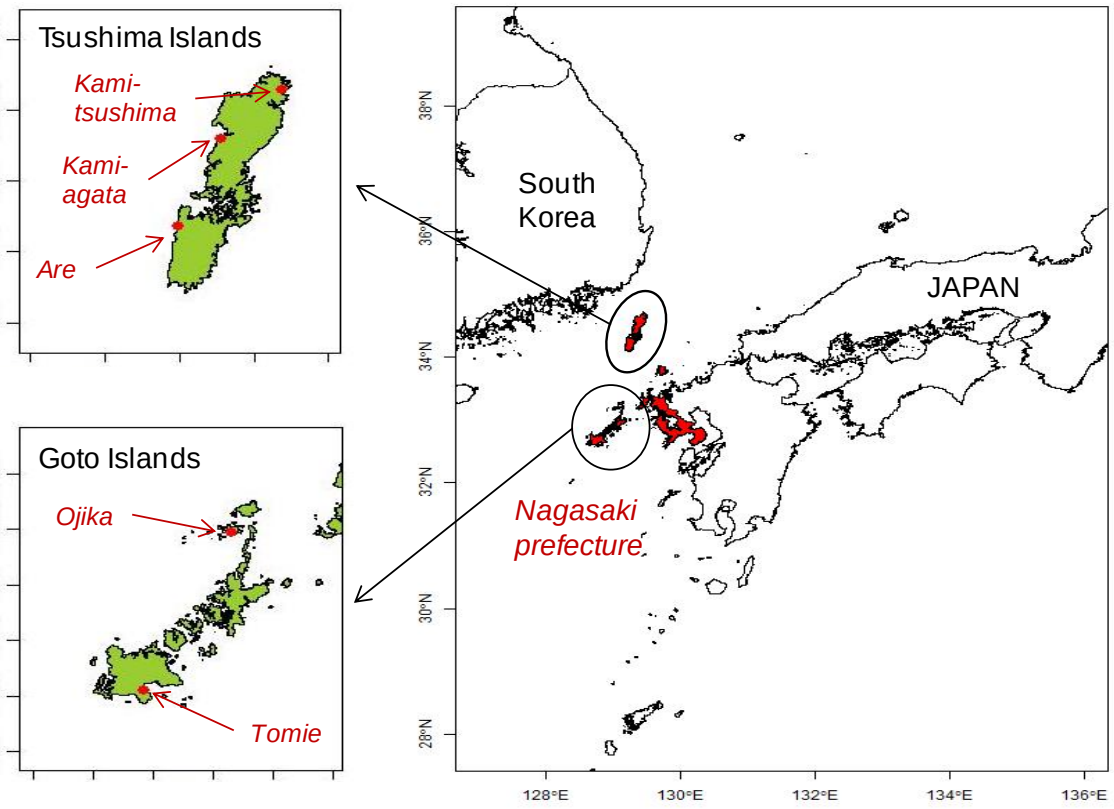

Figure 1 Location of fishing ports where catch-and-effort data of troll fisheries have been collected in coastal waters of western Kyusyu.

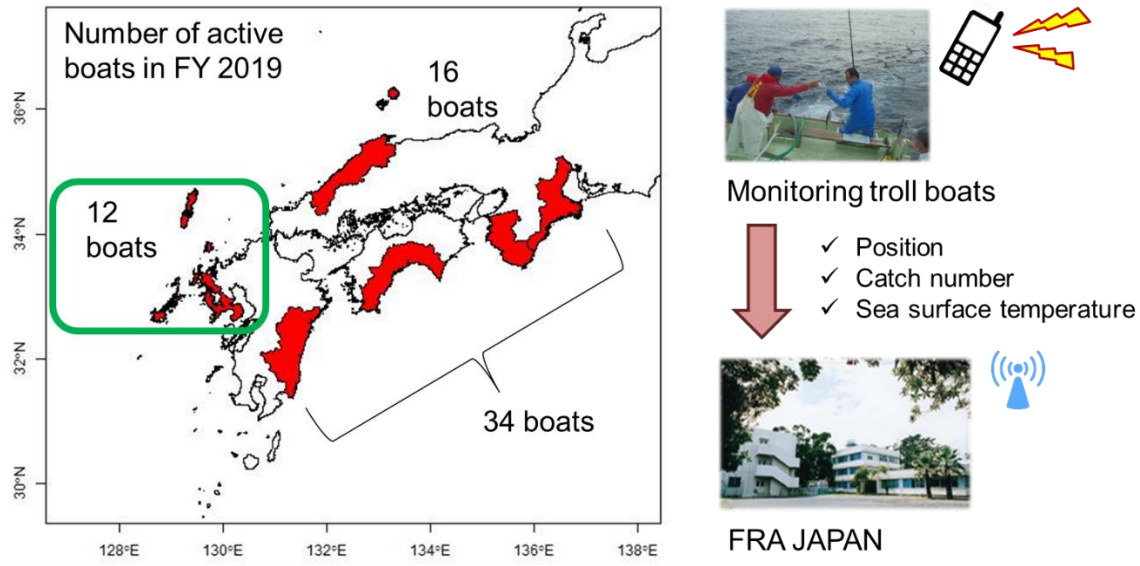

Figure 2 Concept of Japan's real-time recruitment monitoring in 2019 fishing year. Area surrounded by green line.

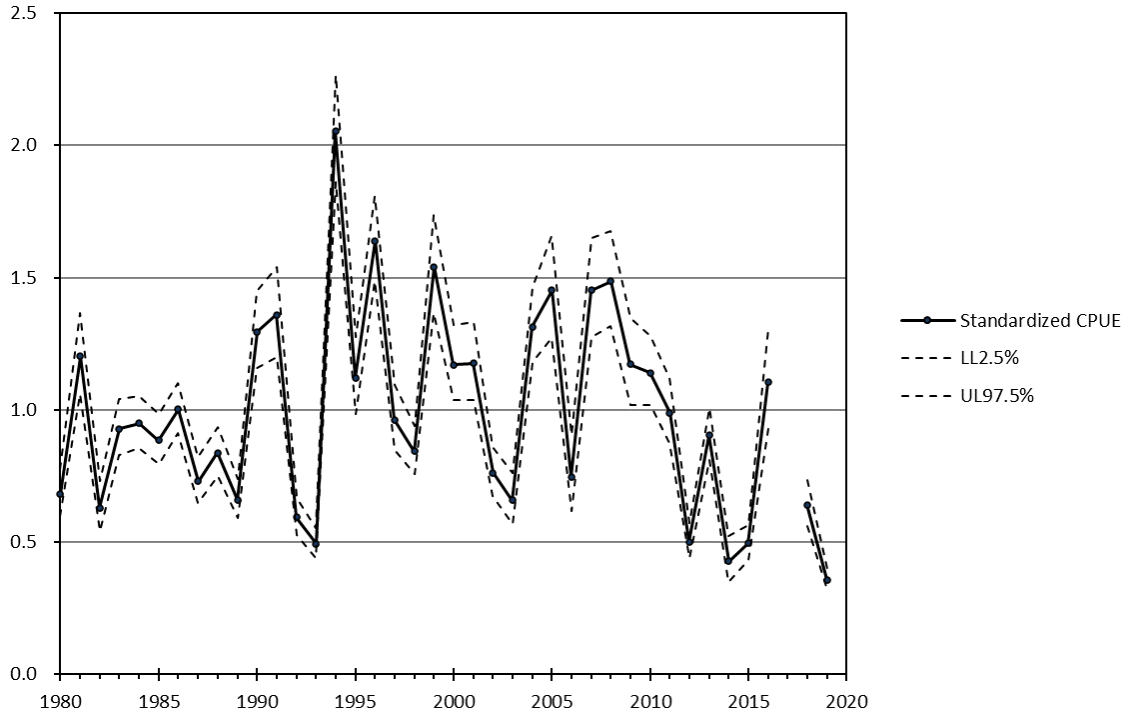

Figure 3 Time series of CPUE. Black line indicates standardized CPUE from 1980 to 2019 fishing year without 2017 fishing year, respectively. Dashed lines indicate 95% confidence interval.

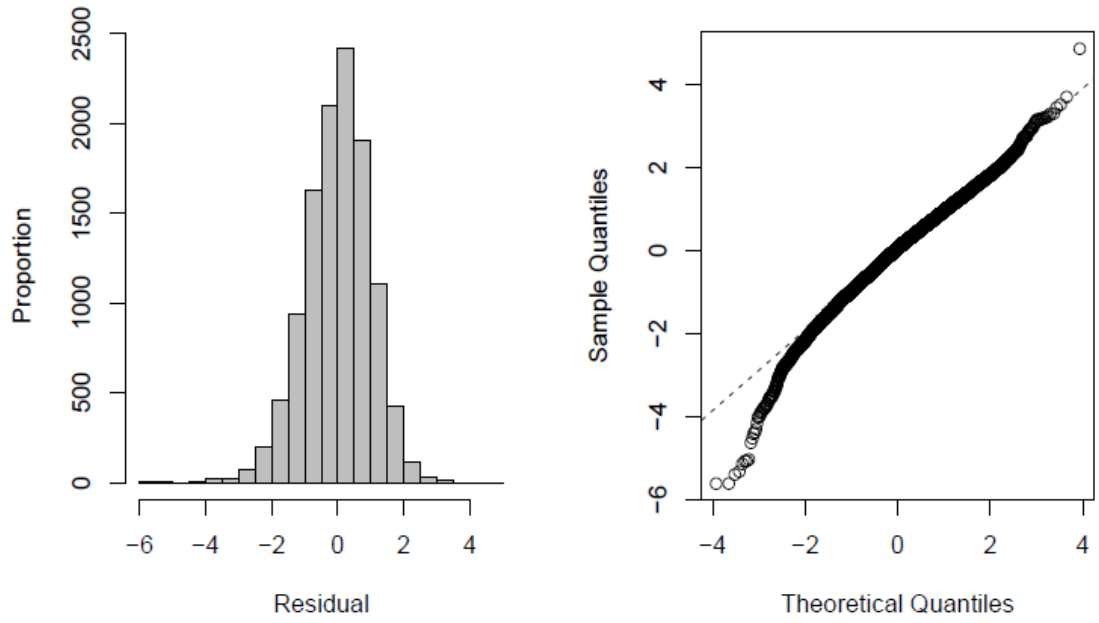

Figure 4 Standardized residuals (left panel) and Q-Q plot of them (right panel).

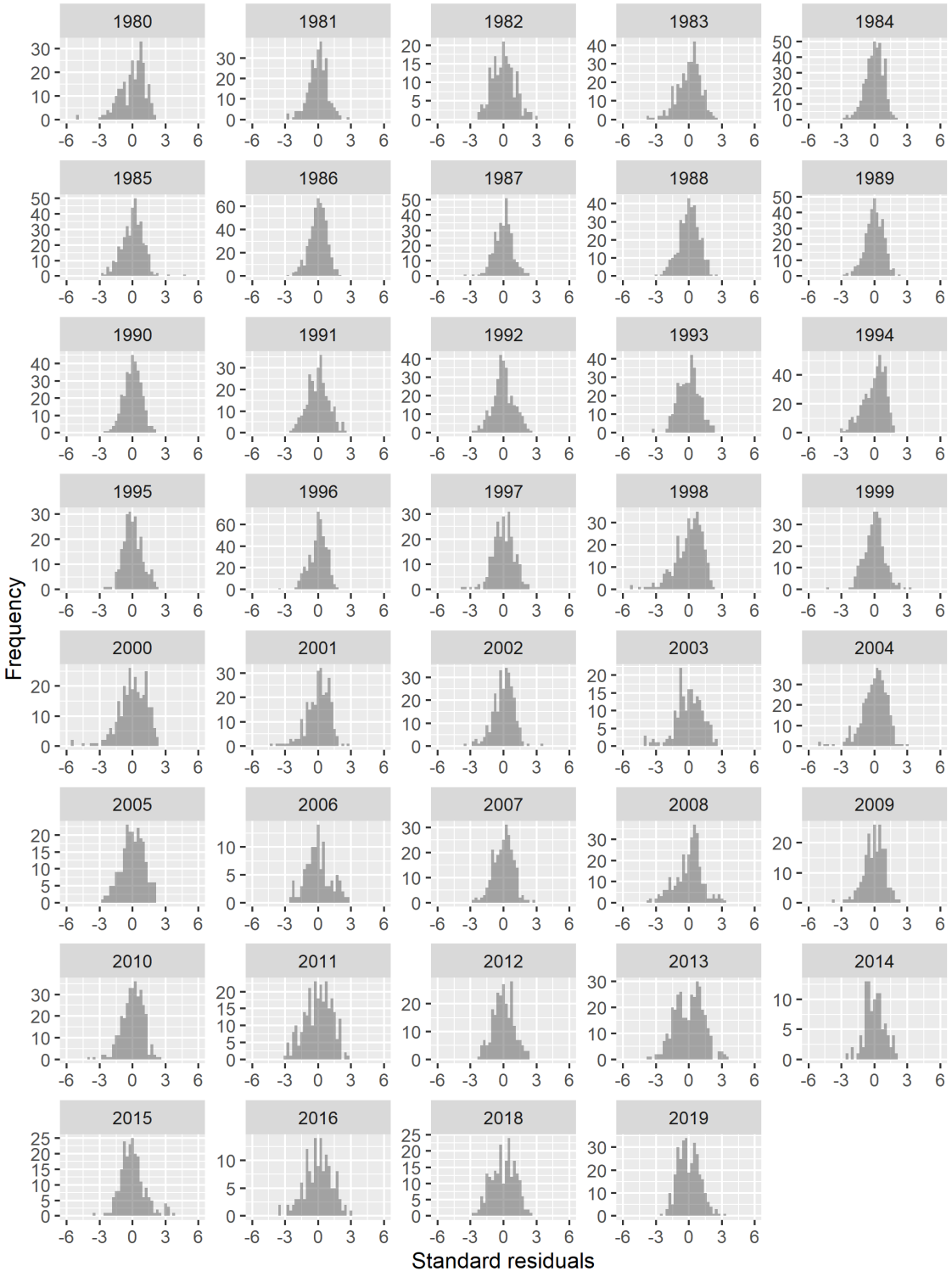

Figure 5 Standardized residuals by year.

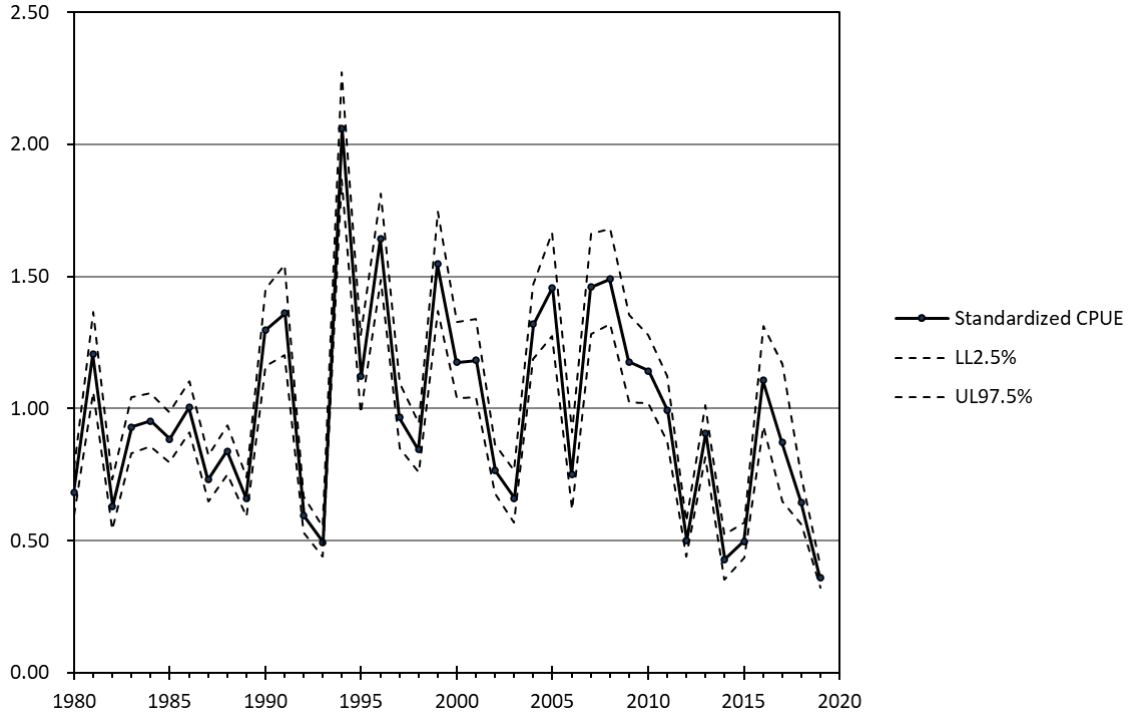

Figure 6 Time series of CPUE. Black line indicates standardized CPUE from 1980 to 2019 fishing year, respectively. Dashed lines indicate 95% confidence interval..

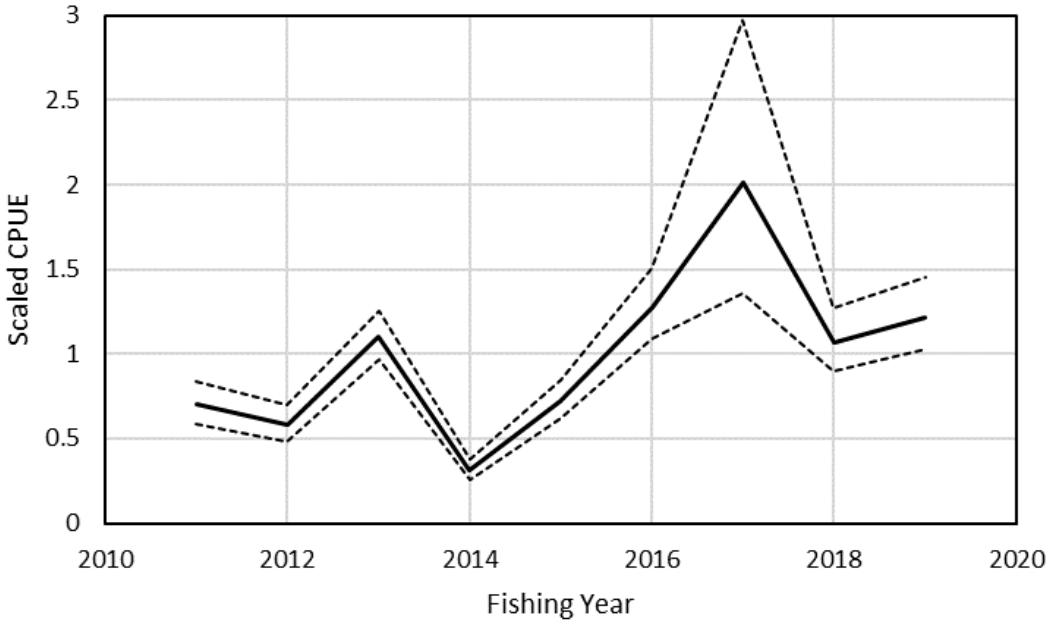

Figure 7 Time series of CPUE. Black line indicates standardized CPUE by real-time monitoring survey from 2011 to 2019 fishing year, respectively. Dashed lines indicate 95% confidence interval.

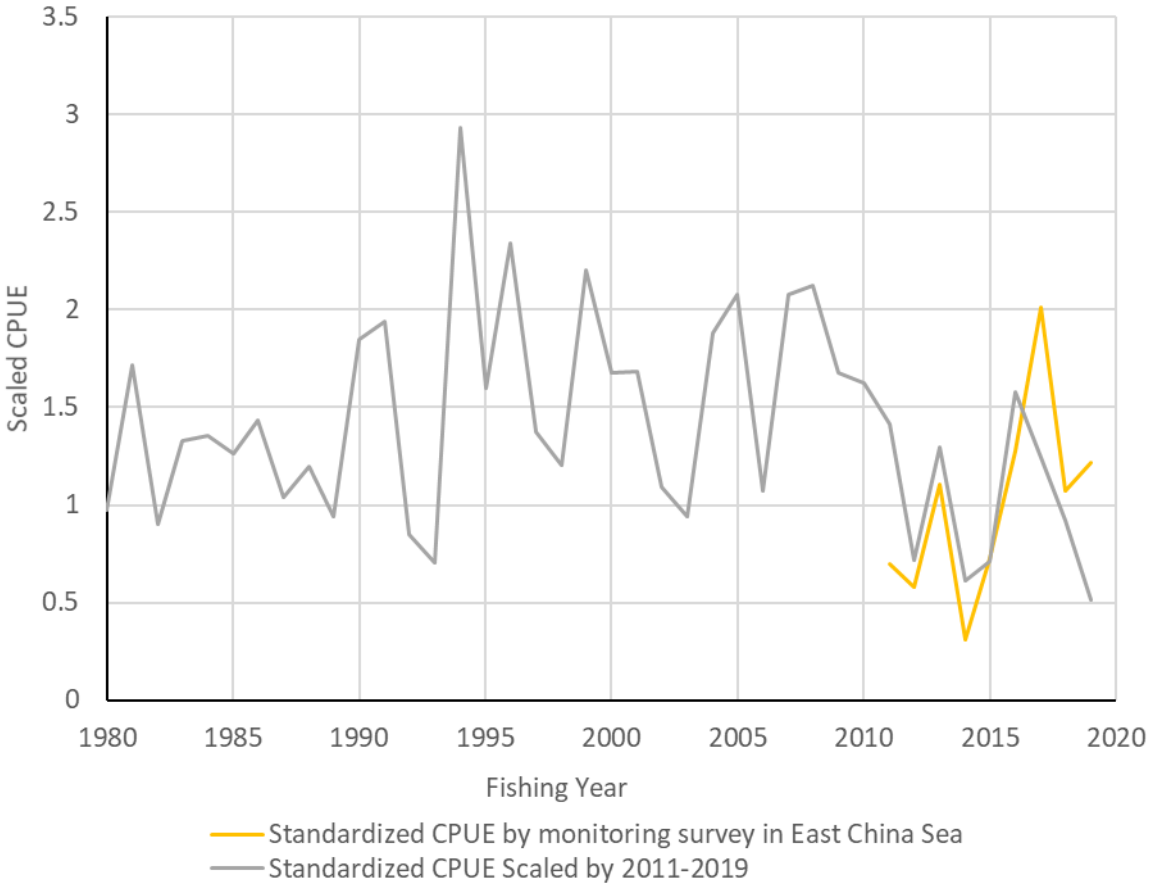

Figure 8 Comparison of time series of CPUE. Gray line indicates standardized CPUE by sales slip 1980 to 2019 fishing year without 2017 fishing year, respectively (scaled by 2011-2019). Yellow line shows the standardized CPUE by real-time monitoring survey in East China Sea.