ISC/22/ALBWG-02/05

Updated CPUE standardization for adult North Pacific albacore caught by Japanese longline fishery from 1996 to 2021: the GLMM analysis using STAN

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This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 6-12 December 2022, held at the Fisheries Resources Institute, Japan Fisheries Research and Education Agency, Kanagawa, Japan.

Summary

As per the working group's request, we calculated adult abundance index (i.e. standardized CPUEs) of albacore from operational data reported by Japanese longline fisheries using the same procedures and assumptions of previous study (Fujioka et al., 2019) as a backup data for stock assessment in 2023. In order to keep the same area and quarter delineation as the previous stock assessment, the data used were quarter 1 in the Area 2 from 1996 to 2021 and generalize liner mixed model analysis with Bayesian inference was used for the CPUE standardization. The result showed similar trends with the previous CPUE, suggesting that the estimated CPUE is considered reasonable as a backup to the previous one.

Introduction

At the International Science Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) Albacore Working Group Assessment Improvement Meeting on May 9-13, 2022, Japan proposed the use of the new Japanese longline fleet definition and the calculation of standardized CPUE using a geostatistical model as an adult abundance index of the north Pacific albacore (*Thunnus alalunga*) stock (Ijima et al. 2022). In response to these proposals, the Working Group requested that two types of standardized CPUE data be produced in case the new fleet definition and geostatistical model are not used in the 2023 stock assessment. One is data using the geostatistical model and the other is backup standardized CPUE data estimated using exactly the same method as in the previous stock assessment (Ochi et al. 2017; Fujioka et al. 2019).

In this document, standardized CPUE for the adult abundance index of albacore were calculated for data from 1996 to 2021 using the same method as Fujioka et al. (2019) as backup data, and the trends of the standardized CPUE were compared with the previous results in 2019. In the previous stock assessment, the abundance index of adult albacore was based on longline fisheries data of quarter 1 in the Area 2 (Fujioka et al. 2019; Fig. 1), while that of juvenile albacore were obtained from the data of pole-and-line (ref). Fujioka et al. (2019) calculated the standardized CPUE by using the generalized liner mixed with Bayesian inference methods from Japanese longline fisheries data, which was originally proposed by Ochi et al. (2017).

Data and Methods

Updated data, definitions of data period, area and quarter for adult abundance index

The dataset for longline operations includes the number of albacores caught in each operation, year, quarter, fleet location type (Distant, Offshore, Coastal), hooks per basket, totals hooks and vessel ID. We updated the data for the period 1976-2021 and tabulated them with the number of records and albacore catches for each year and compared them to the previous one (Fujioka et al., 2019; Table 1). As the summary of the data, decadal spatial distributions of albacore catch, effort (number of hooks) and nominal CPUE (catch/effort*1000) are shown in Fig. 2.

For the 2019 stock assessment, standardized CPUE calculated using data since 1996 were used as inputs to the resource assessment model. This is because the method of collecting logbook data for Japanese longline has changed since 1994, and stable data with the new collection methods is considered to have been available since approximately 1996 (Ijima et al. 2017; Ochi et al., 2017; Fujioka et al., 2019; ISC 2019).

In the previous stock assessments, the definition of the area and quarter that best represent the abundance index of adult albacore was determined by considering the migration patterns of this species (Fig. 1a). Based on the catch at length frequency recorded in the longline fishery operating areas, Area 2 had larger fish (adults) regardless of quarters in the catch at length data compared to the other area (Ijima et al., 2017). In addition, previous stock assessment focused on quarter 1 of Area 2 which has with higher albacore catches compared to other the quarters (Fujioka et al. 2019; Table 2).

In addition to the data definitions described above, we excluded data where the fleet location type was Distant and hooks per basket is smaller than 10 in order to extract only fisheries targeting albacore, which are the same operations used in the previous stock assessment.

CPUE standardization

Details of the statistical methods used in this study for estimating standardized CPUE can be found in Ochi et al. (2017). Briefly, a generalized linear mixed model assuming zero-inflated negative binomial error distribution was adopted for the estimation of the standardized CPUE and coefficient of variation (CV). Year, hooks per basket, fleet type (offshore or coastal) for each operation were set as fixed effects, and vessel name and location of operation (rounded to the nearest 5 degrees of latitude and longitude) were set as random effects. Posteriors and predicted standardized CPUE were calculated with the variational Bayesian method (Automatic differentiation variational inference; ADVI), and 95% Bayesian credible interval and CV of standardized CPUE could be calculated from *lsmean* based on the posteriors. We used R 4.0.2 for data processing and summarizing the estimation output, and Stan 2.18.2 (http://mc-stan.org/) for parameter estimation by ADVI. The ADVI algorism maximizes its lower bound of marginal likelihood (ELBO) by automatic differentiation. The standardized CPUE computed an expected value that followed a negative binomial distribution and did not account for the zero-catch probability. Technically, the positive catch rate, estimated by a linear regression model of the Bernoulli distribution, was not multiplied.

Results and Discussion

The standardized CPUE calculated in this document was similar to Fujioka et al. (2019: Figure 3), but was slightly higher overall throughout the 1996-2017 period. Our estimates are rather closer to Ochi et al. (2017) than to the previous stock assessment. Updated standardized CPUE for each year of 2019-2021 were 32.1, 16.5, 38.5, respectively. With the data summary, calculated standardized CPUEs, fitted value of the GLMM and Pearson residuals of adults were illustrated in Figure 4. Calculated values of standardized CPUEs and CVs for both adult and juvenile abundance indices were given in Table 3.

Similar to Ochi et al. (2015) and Fujioka et al. (2019), standardized CPUE was considerably high compared with nominal CPUE in this study (mean value of 36.7 for standardized CPUE compared to 19.5 for nominal CPUE). This is due to the fact that the data generated based on a negative binomial distribution were not taken into account when calculating the standardized CPUE. In other respects, the trends of variation in nominal CPUE and standardized CPUE were almost identical, suggesting that the data were uniform and not biased toward specific fishing vessels or operating locations.

Reference

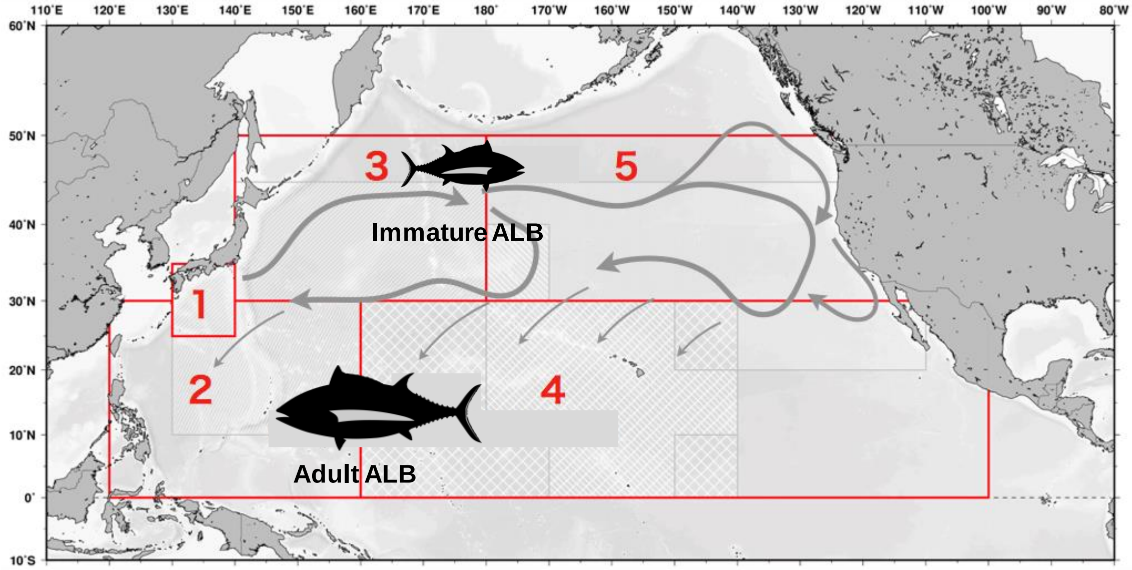
Ijima, H. Ochi, D. and Kiyofuji, H. (2017) Estimation for Japanese catch at length data of North Pacific albacore tuna (*Thunnus alalunga*). ISC/17/ALBWG/04.

ISC (2017) Stock assessment of albacore tuna in the north Pacific Ocean in 2017. Report of the albacore working group, 12-17 July 2017, Vancouver, Canada.

Ochi, D., Ijima, H. and Kiyofuji, H. (2017) Abundance indices of albacore caught by Japanese longline vessels in the North Pacific during 1976-2015. ISC/17/ALBWG/01

Fujioka, K., Ochi, D., Ijima, H., Kiyofuji, H. (2019) Update standardized CPUE for North Pacific albacore caught by the Japanese longline data from 1976 to 2018. ISC/19/ALBWG-02/01.

(a)



(b)

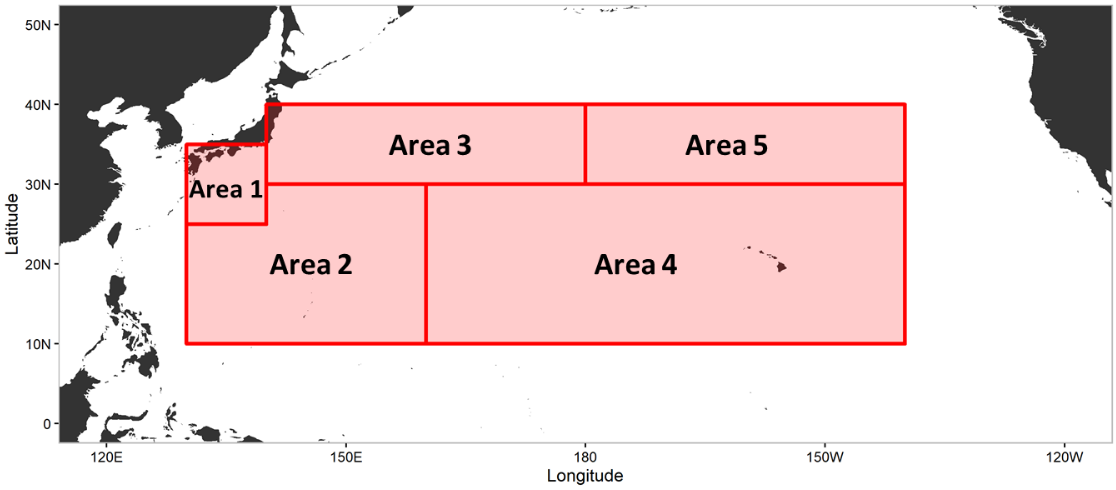


Figure 1. (a) A schematic model of immature and adult albacore (*Thunnus alalunga*) migration routes and the five areas used in the 2017 stock assessment. (b) An area definition for Japanese longline fishery.

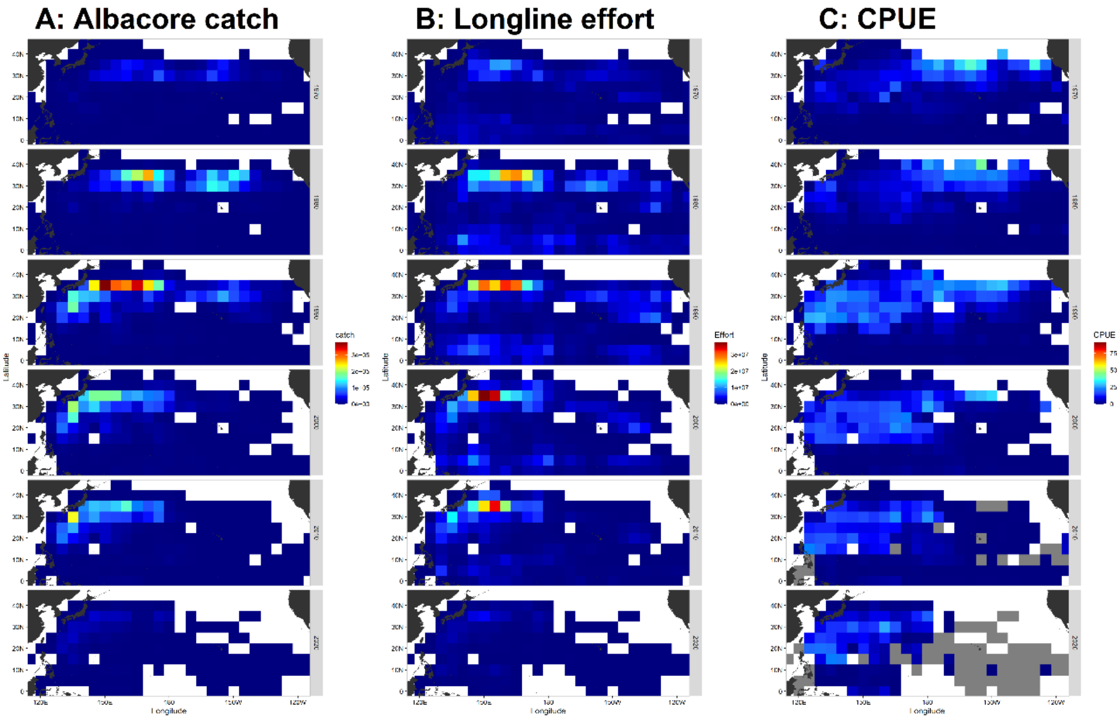


Figure 2. Decadal spatial distributions of (a) albacore catch, (b) effort (number of hooks), and (c) CPUE (catch/effort*1000) that were aggregated by 5 × 5 degrees in the all area during 1976-2021.

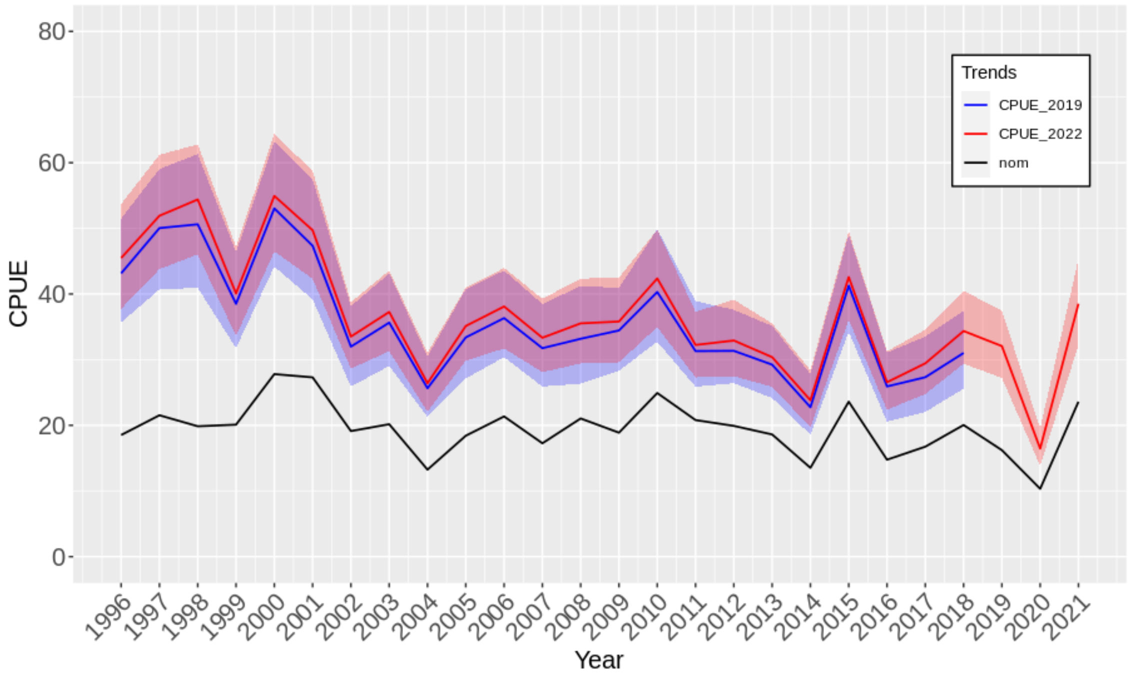


Figure 3. Comparison of two standardized CPUEs with 95% Bayesian credible interval (blue; Fujioka et al. 2017, red; the present study) and nominal CPUE (black) in area 2.

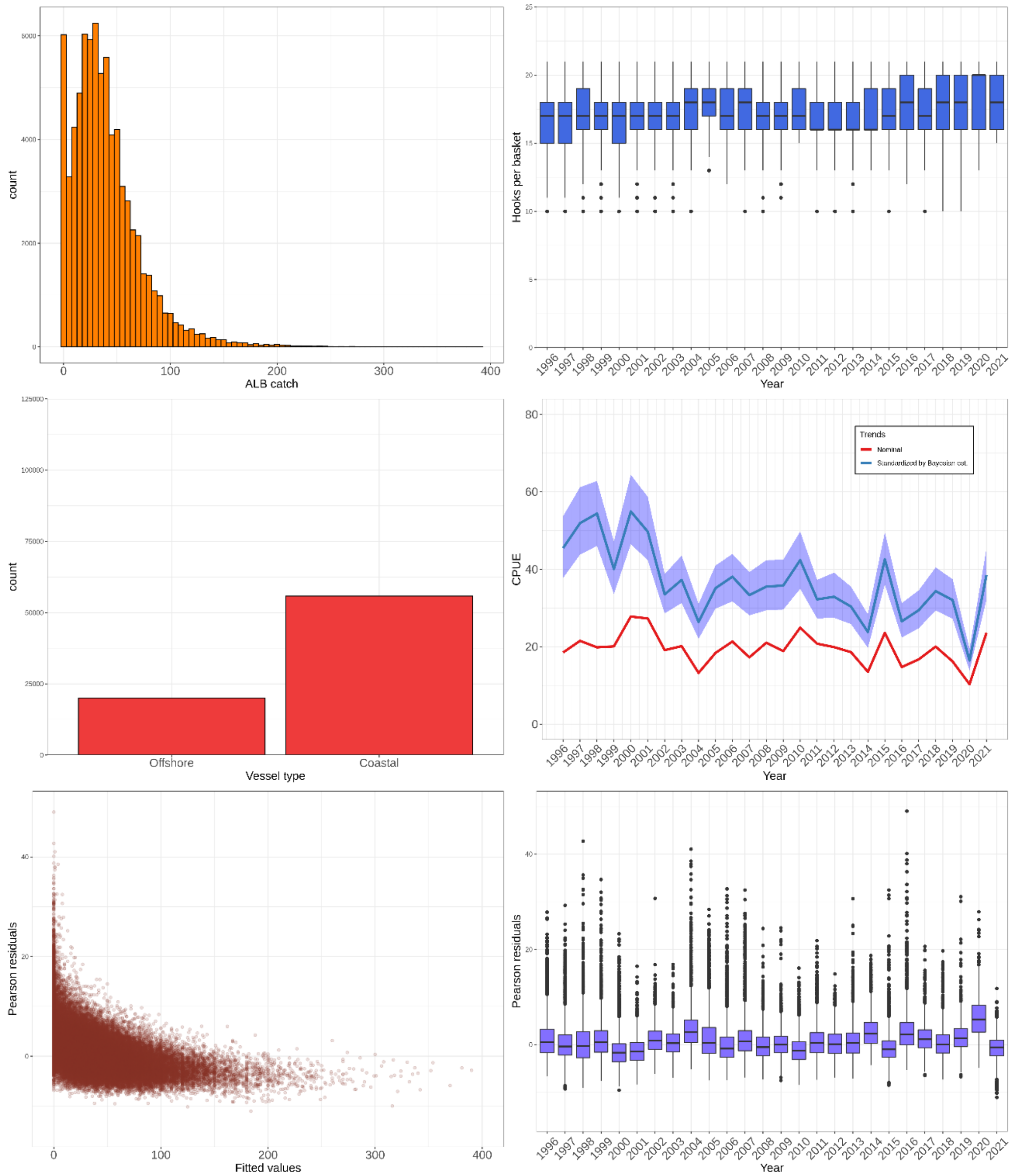


Figure 4. Data summary and CPUE standardization results for the data from 1996 to 2021 for area 2 in quarter 1. Distribution of albacore catch (top left), annual change in hooks per basket (top right), frequency of fleet type (middle left), nominal and standardized CPUE and 95% Bayesian credible interval (blue shaded area; middle right), scatter plot of GLMM fitted values and Pearson residuals (bottom left) and distribution of Pearson residuals for each year (bottom right).

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Table 1. An overview of Japanese longline operation data since 1976 as updated in this study and data used in the 2019 stock assessment (Fujioka et al. 2019)

	Number of total records			Number of ALB catches		
Year	Fujioka et al. (2019)	This study	Difference	Fujioka et al. (2019)	This study	Difference
1976	184952	184952	0	881781	881781	0
1977	183284	183284	0	836220	836220	0
1978	184291	184291	0	723254	723254	0
1979	220229	220229	0	952351	952351	0
1980	236820	236820	0	990846	990846	0
1981	246888	246888	0	1422739	1422739	0
1982	223291	223291	0	1289776	1289776	0
1983	200810	200810	0	1217265	1217265	0
1984	211832	211832	0	1180879	1180879	0
1985	204778	204778	0	1145105	1145105	0
1986	202123	202123	0	1064261	1064261	0
1987	195750	195750	0	1013851	1013851	0
1988	195092	195092	0	1124801	1124801	0
1989	193051	193051	0	994689	994689	0
1990	187018	187018	0	1139052	1139052	0
1991	190861	190861	0	1080452	1080452	0
1992	177520	177520	0	1158391	1158391	0
1993	173546	173546	0	1489594	1489594	0
1994	213174	213174	0	2315490	2315490	0
1995	215780	215780	0	2315871	2315871	0
1996	209736	209736	0	2373051	2373051	0
1997	201354	201354	0	2681323	2681323	0
1998	198817	198817	0	2732157	2732157	0
1999	179480	179483	3	2225648	2225710	62
2000	178368	178368	0	2029797	2029797	0
2001	180748	180748	0	2122987	2122987	0
2002	171149	171149	0	1987395	1987395	0
2003	171374	171374	0	1770829	1770829	0
2004	165426	165496	70	1798401	1798411	10
2005	155365	155371	6	2147369	2147374	5
2006	147553	147553	0	2131829	2131829	0
2007	138882	138882	0	2071064	2071064	0
2008	132954	132954	0	1831252	1831252	0
2009	123737	123737	0	1951172	1951172	0
2010	123719	123720	1	1973829	1973846	17
2011	115712	115858	146	1956577	1957561	984
2012	112077	112077	0	2390665	2390665	0
2013	102692	102692	0	2084455	2084455	0
2014	95431	95431	0	1862206	1862206	0
2015	88576	88576	0	1863047	1863047	0
2016	86905	86905	0	1485119	1485119	0
2017	81968	81968	0	1437119	1437119	0
2018	78382	78957	575	1215975	1221001	5026
2019	-	82207	-	-	1084614	-
2020	-	83227	-	-	1205531	-
2021	-	71521	-	-	1320528	-

Table 2 Annual albacore catches by quarter in each area. Quarters with the highest albacore catch in each year and area are highlighted.

Year	Area 1				Area 2				Area 3				Area 4				Area 5			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1976	**22,093**	1,609	0	443	**61,073**	4,467	21,316	33,207	48,590	26,424	22,719	**121,570**	**73,027**	4,544	5,321	17,239	42,123	1,180	342	**114,783**
1977	**41,920**	511	4	1,076	**107,974**	2,003	3,057	18,716	39,767	23,312	7,316	**94,868**	**69,244**	4,695	5,431	29,004	24,638	25	705	**96,223**
1978	**4,131**	995	3	1,450	**42,164**	2,767	6,306	13,754	28,559	18,469	14,784	**99,857**	**146,830**	9,903	11,201	16,809	8,040	0	2,947	**50,185**
1979	**8,709**	1,158	0	1,535	**47,523**	4,383	9,170	19,457	72,444	31,139	35,270	**157,769**	**119,012**	12,734	4,764	32,141	56,977	273	1,838	**66,199**
1980	**22,819**	4,500	0	403	**65,186**	5,185	8,912	33,584	22,756	16,683	32,665	**139,502**	**114,365**	10,475	5,579	24,940	26,505	250	446	**176,981**
1981	**18,439**	365	0	5,282	**71,589**	11,584	53,601	49,171	50,502	27,993	66,289	**185,447**	**165,235**	20,184	11,718	35,705	56,798	1,679	5,919	**154,123**
1982	**46,355**	1,364	0	557	**79,716**	21,329	22,851	15,969	70,093	66,309	72,287	**168,803**	**170,441**	32,490	9,428	15,650	**85,764**	580	2,765	64,914
1983	**34,685**	3,644	92	965	28,576	**32,745**	32,367	34,410	54,898	75,903	56,306	**150,786**	**98,021**	18,806	6,884	22,118	39,423	1,477	3,789	**138,081**
1984	**18,483**	1,006	52	1,594	**41,897**	35,661	38,900	17,784	34,235	55,699	52,957	**141,089**	**88,175**	12,979	4,146	8,640	115,686	144	3,390	**155,401**
1985	**31,681**	966	1	4,214	19,461	28,733	**38,425**	13,441	35,097	54,512	53,263	**162,338**	**37,535**	15,826	6,907	22,193	94,875	101	512	**146,060**
1986	**31,109**	1,203	2	1,703	41,944	12,040	**48,796**	10,965	35,634	69,363	62,145	**102,379**	**96,505**	20,521	11,682	11,198	39,183	366	941	**51,231**
1987	**25,632**	1,154	0	6,399	25,151	5,027	**34,158**	19,957	20,600	66,243	70,905	**168,654**	**34,008**	8,034	9,496	10,158	41,284	4,259	2,624	**110,735**
1988	**28,707**	3,808	50	1,135	39,813	6,150	**63,338**	28,154	46,295	81,862	58,036	**158,408**	**33,591**	13,909	25,925	13,137	43,142	737	836	**106,743**
1989	**23,807**	4,395	0	232	37,953	9,022	**66,586**	11,536	46,929	87,974	94,885	**130,764**	**36,908**	17,499	16,890	20,810	**76,411**	2,070	417	65,409
1990	**35,282**	4,334	0	1,368	37,421	1,379	**66,909**	9,013	50,833	69,396	90,853	**173,334**	**49,481**	13,282	40,946	10,581	**98,603**	593	1,653	89,268
1991	**26,523**	5,570	173	2,424	27,767	2,071	**43,111**	9,181	47,542	54,446	63,344	**147,044**	**51,606**	16,859	18,439	14,287	**124,289**	2,204	2,170	104,367
1992	**28,841**	10,790	1	825	15,280	3,531	**46,192**	10,681	36,682	74,942	47,192	**214,459**	**54,470**	5,670	38,543	24,378	41,448	3,389	1,089	**145,462**
1993	**80,438**	24,927	6	2,469	38,123	10,837	**80,658**	26,189	55,610	81,008	90,403	**217,997**	**103,721**	12,518	45,533	22,134	61,438	654	154	**175,796**
1994	**407,255**	150,738	753	38,071	**109,639**	41,831	85,039	101,689	116,431	105,194	46,174	**315,008**	**81,755**	21,067	48,306	42,652	**65,135**	0	4	60,285
1995	**378,821**	113,971	2,287	63,956	**197,909**	52,751	62,632	74,754	73,852	114,278	100,587	**320,372**	**101,466**	52,243	35,817	49,458	**53,046**	910	67	45,512
1996	**390,166**	178,129	637	37,194	**169,052**	50,394	65,693	111,021	55,871	162,759	75,604	**315,815**	**109,943**	44,702	38,226	40,963	55,328	0	521	**61,169**
1997	**574,001**	180,547	2,521	53,535	**147,870**	52,617	123,683	72,583	56,621	170,912	76,163	**297,636**	**135,142**	31,637	28,136	41,246	45,074	450	1,667	**63,918**
1998	**511,038**	147,799	2,563	68,032	**210,539**	61,182	65,655	76,276	45,839	130,997	109,600	**304,693**	**92,521**	32,475	84,039	37,746	10,529	0	1,897	**57,130**
1999	**338,963**	130,243	3,167	83,792	**144,651**	43,285	46,997	104,189	81,159	54,904	115,357	**304,614**	**71,628**	42,068	27,348	31,984	31,557	0	3,052	**41,688**
2000	**360,431**	141,704	3,067	29,550	**242,865**	109,287	70,915	97,231	37,579	51,398	23,633	**152,877**	**86,949**	16,415	13,410	56,408	5,492	0	40	**12,628**
2001	**217,689**	119,300	1,416	29,033	**235,460**	108,846	37,785	65,320	24,009	43,285	61,905	**191,759**	**100,609**	28,229	69,970	47,364	15,890	0	357	**47,068**
2002	**422,574**	103,496	2,375	25,523	**154,656**	53,982	14,583	43,709	56,187	93,495	44,888	**118,201**	**131,683**	23,525	27,872	16,387	6,278	0	9	**13,149**
2003	**377,192**	106,264	837	32,780	**187,300**	46,074	39,714	47,538	40,264	119,045	82,392	**147,028**	35,118	5,206	**40,962**	8,155	1,199	0	81	**17,324**
2004	**291,283**	59,028	1,128	26,757	**77,780**	38,248	27,441	41,597	29,793	120,637	122,258	**149,565**	**38,594**	5,698	30,764	22,631	**4,796**	14	80	3,831
2005	**248,345**	71,355	2,780	26,873	**104,059**	58,168	36,274	58,546	75,297	**306,698**	81,427	121,146	52,152	15,227	**70,570**	10,502	193	5	131	**12,651**
2006	**292,175**	124,868	851	25,498	**130,585**	64,328	33,440	45,426	58,897	**215,100**	13,157	212,135	30,624	32,770	**60,589**	7,249	1,188	14	531	**1,373**
2007	**343,254**	90,059	748	49,138	**109,948**	71,916	38,493	25,296	219,842	209,323	23,362	**243,955**	**22,266**	14,815	18,939	4,256	**1,836**	6	1,066	77
2008	**226,241**	78,662	1,998	25,017	**108,670**	97,352	55,623	23,397	117,441	**148,097**	32,928	121,293	**40,839**	2,959	19,006	10,815	**24,773**	1	1,949	2,278
2009	**276,626**	129,854	1,148	88,531	**137,204**	88,259	48,329	49,180	115,103	151,705	34,939	**187,857**	13,593	4,744	**29,479**	3,925	**1,037**	1	591	840
2010	**310,031**	56,073	903	31,734	**205,021**	169,062	84,223	38,888	71,875	131,678	20,586	**162,349**	12,506	9,845	**16,643**	12,156	77	1	**80**	52
2011	**283,120**	60,470	719	52,742	**150,177**	111,078	32,873	43,913	36,893	91,558	53,042	**240,131**	29,668	22,509	**47,911**	11,886	13	0	**3,857**	2,077
2012	**534,050**	88,461	165	16,872	**138,526**	119,478	43,751	32,385	61,731	148,120	30,149	**179,826**	**26,574**	18,442	14,348	17,363	9	415	**493**	279
2013	**332,983**	77,118	460	34,902	111,828	**123,223**	75,144	25,690	44,944	97,593	29,157	**169,711**	32,216	17,192	**48,748**	7,899	0	132	927	**9,152**
2014	**329,379**	84,123	86	55,816	83,362	**107,078**	62,311	56,244	33,862	151,167	23,943	**210,275**	22,922	9,830	**27,030**	3,678	**1,433**	0	884	0
2015	**383,488**	24,441	176	59,904	**183,252**	107,341	60,741	48,583	45,678	**199,469**	39,425	129,552	8,429	8,245	**28,692**	2,129	0	126	**242**	102
2016	**167,523**	34,683	1,270	45,456	102,354	**143,304**	49,299	47,489	**120,059**	175,523	20,276	82,248	10,485	3,433	**20,745**	436	0	0	6	**2**
2017	230,524	39,322	427	**34,820**	**122,355**	94,367	75,000	99,947	**71,991**	149,095	14,227	58,209	4,798	4,766	**30,762**	1,654	0	0	5	**386**
2018	126,165	10,155	250	**21,621**	**139,986**	122,569	56,388	61,623	46,671	36,744	23,245	**48,715**	4,943	1,977	**5,000**	3,077	0	0	11	**19**
2019	93,548	12,886	718	**23,961**	**133,870**	92,655	47,508	23,982	80,457	72,677	19,161	**80,896**	5,500	11,410	**14,215**	2,989	111	0	**1,951**	6
2020	138,922	12,715	2,690	**29,943**	48,126	48,077	**48,857**	45,579	**205,704**	126,226	15,033	96,962	10,809	8,791	**20,932**	757	6	82	**108**	28
2021	207,782	**37,606**	897	25,452	**113,258**	87,621	76,256	40,553	**160,398**	28,930	25,126	89,155	2,123	6,280	**12,065**	737	1,692	0	72	**4,359**

Table 3 Abundance indices for albacore caught by Japanese longline fisheries in Area 2 between 1996 and 2021 estimated in this study compared to the previous stock assessment (Fujioka et al. 2019).

	Fujioka et al. 2019		This study	
	Area 2, Quarter 1		Area 2, Quarter 1	
Year	Std CPUE	CV	Std CPUE	CV
1996	43.15	0.09	45.48	0.09
1997	50.04	0.10	51.92	0.09
1998	50.61	0.10	54.40	0.08
1999	38.51	0.10	40.08	0.09
2000	53.04	0.10	54.94	0.08
2001	47.35	0.10	49.71	0.08
2002	31.99	0.10	33.52	0.08
2003	35.64	0.10	37.27	0.08
2004	25.64	0.09	26.41	0.09
2005	33.39	0.10	35.13	0.08
2006	36.33	0.09	38.10	0.08
2007	31.75	0.11	33.34	0.08
2008	33.18	0.11	35.53	0.09
2009	34.45	0.09	35.81	0.09
2010	40.30	0.11	42.37	0.09
2011	31.30	0.11	32.24	0.08
2012	31.34	0.09	32.92	0.09
2013	29.24	0.10	30.38	0.08
2014	22.75	0.11	23.81	0.09
2015	41.26	0.09	42.58	0.08
2016	25.92	0.10	26.56	0.09
2017	27.33	0.11	29.44	0.09
2018	31.02	0.10	34.36	0.08
2019	-	-	32.07	0.08
2020	-	-	16.46	0.09
2021	-	-	38.53	0.09