Standardization of age aggregated and specific abundance indices for north Pacific albacore caught by the Japanese large and small longline fisheries, 1966-2008[1]

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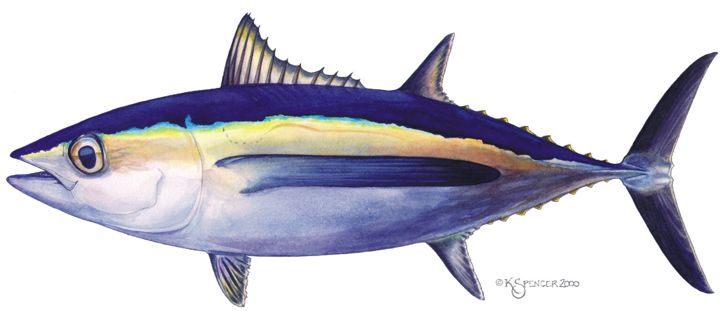

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SUMMALY

Standardization of age aggregated and age-specific abundance indices of albacore caught by Japanese large and small longline fisheries (L-LL and S-LL) in the north Pacific during 1966-2008 was conducted using the method similar to previous study with minor modifications. Effects of area, season (quarter), fishing gear (number of hooks per basket) and several interactions between them were used for standardization. Age aggregated abundance index was almost stable during 1960s-1980s, increased during 1990s, decreased sharply during 2001-2003, and then gradually increased. Age specific indices were also constant during 1960s-1980s and were high during 1990s except for that of age 3, which was mostly constant except in 2006 and 2008.

1. INTRODUCTION

Recently, VPA-2BOX and stock synthesis (SS) models are used for stock assessment of north Pacific albacore at ISC meetings, and abundance indices of Japanese longline fishery are used as a part of input data for these models. At the last (2006) stock assessment, Watanabe *et al.* (2006) reported standardization of CPUE (age aggregated and age specific) for Japanese large (distant water and offshore) and small (coastal) longline combined for the period 1966-2005, which involved several improvements from the past studies. In this study, similar method to Watanabe *et al.* (2006) was applied with minor changes. Main purpose of this study is to create abundance indices for VPA analyses as well as to obtain abundance index of adult fish.

2. MATERIAL AND METHOD

Basic procedure to compute the age specific abundance indices was the same as Uosaki (2004) and Watanabe *et al.* (2006). The rough outline of the procedure is: (1)Albacore CPUE (age aggregated) was first standardized using a General Linear Model (GLM); (2) the CPUE was multiplied by the proportion of length frequency; (3) this CPUE was converted to CPUE-at-age using a software MULTIFAN assuming fix growth curve. Procedures of substitution and aging used here are the same as that in developing catch-at-age for the Japanese large longline (Watanabe and Uosaki, 2006).

2.1. Data

Catch and effort data used in this study were obtained from the Japanese large longline (L-LL) and small longline (S-LL) fisheries statistics. The method is the same as that by Watanabe *et al.* (2006). Data for 1966-2008 were created. These data were compiled at National Research Institute of Far Seas Fisheries (NRIFSF) based on the logbooks that were submitted from the L-LL and S-LL fishermen operating with the vessels larger than 20GRT and smaller than 20 GRT, respectively. Information of number of hooks per basket is available only from 1975 onward. Number of hooks per basket was assumed to 5 before 1975.

Length data for North pacific albacore were utilized to determine age compositions (Ages 3 to 9+ group) of estimated CPUEs. The length data were collected by port sampling and on-board measurement (Uosaki, 2002) and were compiled at the NRIFSF. The length data were aggregated by year, month and 5^o x 10^o block. Since the software MULTIFAN allows up to 85-length class, the data of the length class ranged from 50 cm to 134 cm with 1-cm interval was used.

2.2. Area classification

Area classification applied in this study is based on that of Watanabe *et al.* (2006) (Fig. 1). In this study, we excluded the area north of 25˚N and east of 170˚W because of drastic change in CPUE in recent years due to spatial shift of longline operation (Matsumoto, 2010).

2.3. Standardization of CPUE

CPUE was standardized using GLM. The model includes main effects (year, season, area and fishing gear) and interaction term (season*area, year*area, year*season, year*gear). Quarter was used as fishing season, and number of hooks per basket (hereafter, NHB) was used as gear effect. Watanabe *et al.* (2006) incorporated effect of "fishery" as a main effect, which was categorized as 1 (L-LL) and 2 (S-LL). But in this study, due to the fact that NHB changes with time and that catch rate of albacore changes depending on NHB (Matsumoto, 2010), NHB was incorporated as effects, which is similar to the study of Uosaki (2004). To avoid that natural logarithm, *ln* (CPUE), becomes 0, the ICCAT Bluefin Species Group (ICCAT, 1997) recommended adding actual CPUE to 10% of mean CPUE. Therefore the constant 0.88, which is 10% of mean CPUE, was added to CPUE. The model was selected based on AIC. The final model for standardization of CPUE, M-2010, was,

$$LOG\ (CPUE + 0.88) = \mu + Yi + Qj + Ak + Bl + QAjk + YAik + YQij + ABkl + eijkl, \quad (1)$$

where LOG is the natural logarithm, $CPUE$ is the catch in number per 1000 hooks, μ is the intercept, Yi is the effect of year i (i = 1966, 2008), Qj is the effect of fishing season (quarter) j (j = 1, 4), Ak is the effect of area k (k = 1, 12), Bl is the effect of fishing gear (NHB divided into categories) s (s = 1, 4), $QAjk$ is the interaction between fishing season and subarea, $YAik$ is the interaction between year and subarea, $YQij$ is the interaction between year and fishing season, $ABkl$ is the interaction between subarea and fishing gear, and $eijk$ is the error term with $N\ (0,\sigma)$. NHB was categorized as 3-4, 5-9, 10-14 and 15-20 hooks per basket. Analyses were done through the statistic package program, "SAS version 9.1.3".

2.4. Abundance index

The CPUE of interested strata (year, quarter, fishery and area) were calculated as follows:

$$CPUE_{ijk} = \exp(\hat{\mu} + \hat{Y}_i + \hat{Q}_j + \hat{A}_k + \hat{B}_l + \hat{B}A_{kl} + \hat{Q}A_{jk} + \hat{Y}A_{ik} + \hat{Y}Q_{ij}) - 10\% \text{ of mean CPUE}, \quad (2)$$

Where

$\hat{\mu}$: estimated intercept,

$\hat{Y}_i$: estimated parameter for year term in i year,

$\hat{Q}_j$: estimated parameter for quarter term in j th quarter,

$\hat{A}_k$: estimated parameter for subarea term in subarea k,

$\hat{B}_l$: estimated parameter for fishing gear (NHB) term in NHB category l,

$\hat{BA}_{kl}$: estimated parameter for interaction between NHB category j and area k,

$\hat{QA}_{jk}$: estimated parameter for interaction between quarter j and area k,

$\hat{YA}_{ik}$: estimated parameter for interaction between year i and area k,

$\hat{YQ}_{ij}$: estimated parameter for interaction between year i and quarter j

The abundance index by length class of interested strata (year, quarter) was calculated by summing up over 3 month and whole area.

$$AI_{ijl} = \sum_{u,m}\left[CPUE_{ih(o)f(\omega)} \cdot S_{\omega} \cdot (\sum_{\omega} S_{\omega})^{-1} \cdot F_{ih(o)g(\omega)l} \cdot (\sum_{l} F_{ih(o)g(\omega)l})^{-1}\right] \quad , \quad (3)$$

where

AI_{ijl} : abundance index in year i , j th quarter and length class l,

ω: sufix for unit area (5x10 degree),

$f(\omega)$: function based on the relationship between the subarea for CPUE standardization k and unit area ω, $k = f(\omega)$,

$g(\omega)$: function based on the relationship between the subarea for length frequency data n and unit area ω, $n = g(\omega)$,

o : sufix for month,

$h(o)$: function based on the relationship between month o and quarter j, $j = h(o)$,

$S\omega$: size of area in unit area ω,

F_{ijnl} : length frequency of the catch in year i, j th quarter, subarea n and length class l.

2.5. Substitution of length data

First, the length data was compiled into three kinds of length composition datasets in term of size of strata:

Level 0: by 5x10-month;

Level 1: by area-month;

Level 2: by area-quarter.

Fig. 1 indicates the area used here. Each abundance index of the 5x10-month first referred to the 5x10-month length composition data of Level 0 corresponding with time and position. If the sample size (number of fish measured) of referred length composition data of Level 0 was less than 100 fish, upper level (wider cell) of length composition data were referred. The changing level was repeated until the condition was satisfied. If the condition is not satisfied at Level 2, the record referred to the specific length composition data after a substitution table (Table 1). The substitution table is made after following principal:

1) Not allow substituting from different year;
2) Allow substitution between 1st and 2nd quarter, or between 3rd and 4th quarter in the case of the substitution from different quarter, considering the length composition that only larger fish are caught in the beginning of longline fishing season, then the rate of middle size fish increased gradually, and finally only juveniles are caught;
3) Allow substitution between areas 1, 2, 5 and 6, or between areas 3 and 4, considering the characteristic of

length composition that large size fish are caught in areas 3 and 4 in all quarters and that middle and large size fish are caught in the other areas;

4) If substitution could not be done based on the conditions above, substitution was made in the same quarter between areas other than those mentioned in 3).

In the substitution table, changing levels is repeated as well. In this way, each abundance index in month and unit area was broken down into length class using referred length data, and then summed up over 3 months and whole area (quarterly abundance index).

2.6. Aging

Aging was done by fitting length frequencies to mixed normal distributions so that the mean of normal distribution follows growth equation derived from Suda (1966),

$$L_t = 146.46(1 - e^{-1.492(t+0.8996)}), \quad (4)$$

which was altered from Yabuta and Yukinawa (1963). For this calculation, computer software MULTIFAN (Otter Research Ltd., 1991) was conducted. MULTIFAN can provide several functions of length frequency analysis such as the estimation of parameters of von Bertalanffy growth curve, standard deviation of the mode of each age, etc. In this analysis, MULTIFAN calculated only aging, namely, von Bertaranfy growth parameter K was fixed at 0.149, lengths of start and last were 61.5 cm (at age 2.75 in first quarter) and 120.7cm, respectively, and standard deviation-at-age was the same among ages. Quarterly abundance indices were converted to annual indices by summing up from first to fourth quarter.

3. RESULTS AND DISCUSSIONS

GLM and annual trajectory of abundance index

Fig. 2 shows annual trend of age aggregated abundance index. Abundance index was comparatively stable during 1960s-1980s. It increased during 1990s, peaked in 1998, decreased sharply during 2001-2003, and then gradually increased with fluctuation. Recent (2005-2008) level is higher than that in the early period (1960s-1980s), but lower than that around 2000 when it was the peak. Fig. 3 shows comparison of abundance index with that derived from Watanabe *et al.* (2006). Scaled index was almost same as that of Watanabe *et al.* (2006) during the same period (1966-2005).

Table 3 shows summary of the ANOVA for M-2010 (Table 2). This revealed that all main effects and interactions were significant at 0.1% level for the model. In this model, effect of quarter was very large and effect of area followed. In the case of the interaction term, quarter*area and bran*area contributed for fitting of the model.

Substitution of length data

Results of the substitution proved to be substituted 300 strata (29%) of the total number of the strata (1032) (Table 6). In the subareas 1, 2, 5 and 6, most of the strata in the second and third quarter, there were not enough measurement during the period studied (less than 100 fish) especially regarding before 2000. However, the bias, which may have resulted from not being measured enough, is considered to be not so serious, because the catch of albacore is smaller in the second and third quarters than that of the other quarters due to not being the season for the longline fishery. Fig. 4 shows annual catch (in number) composition by substitution level for longline fishery. There was approximately 89% of the catch in number which does not require the substitution using the substitution table during the period. Namely, substitution made in this analysis is not large part in respect of catch in number. In the recent years, the portion of shallower substitution (until Area-month) was large due to the better coverage of the length measurement for longline catch.

Aging

Table 5 shows summary of the aging by MULTIFAN for 1966 to 1983, 1984 to 2001 and 2002 to 2008 datasets. Estimated standard deviations of length at age by the periods were 3.14, 2.71 and 3.48, respectively, which was only one parameter to be allowed to estimate due to fixing all of growth parameter for this aging.

Age specific abundance indices

Indices of age 3 were almost constant throughout the period except in 2006 and 2008 when were relatively high (Fig. 5(a)). Indices of age 4 roughly remained invariant over the period for 1966 to 1991, but, after then they sharply rose in the early 1990s, particularly, the index peaked in 1996, and fluctuated after that. Indices of age 5 decreased sharply during 1966-1968, decreased gradually from 1968 to 1982, kept low during 1983-1991, and became high after that with fluctuation (Fig. 5 (a)). Index of age 6 was almost constant during 1966-1993, then had a high trend with fluctuation during 1994-2001, became low in 2007, and recovered in 2008 (Fig. 5 (b)). Index of age 7 was constant until 1993, which is almost similar to that of age 6. After that, it fluctuated with the level relatively high (Fig. 5 (b)). Fluctuations in indices of ages 8 and 9+ synchronized each other over the period studied except for a part of periods (Fig. 5 (c)). They increased during late 1990s and declined around 2000.

The index of ages 3-5 corresponding to juvenile fish was relatively low until around 1990, increased after that, and then stayed at higher level except for 2004 (Fig. 6). The index of ages 6-9+ corresponding to adult fish was stable during 1966-1993, increased during 1994-1997 and decreased during 2001-2003. Its trend is similar to that of all ages aggregated. Therefore, it possible to see the trend of abundance index of adult fish by age aggregated index of Japanese longline fishery.

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Table 1. Substitution table for the longline length data.

Original data		Strata substituted for original				
Area 1	Qt1	Area 5, Qt1				
	Qt2	Area 5, Qt2	Area 1, Qt1	Area 5, Qt1		
	Qt3	Area 5, Qt4	Area 1, Qt4			
	Qt4					
Area 2	Qt1	Area 1, Qt1	Area 5, Qt1			
	Qt2	Area 1, Qt2	Area 2, Qt1	Area 1, Qt1	Area 2, Qt4	Area 5, Qt1
	Qt3	Area 1, Qt3	Area 2, Qt4			
	Qt4	Area 1, Qt4				
Area 3	Qt1					
	Qt2	Area 3, Qt1				
	Qt3	Area 4, Qt3	Area 3, Qt4	Area 1, Qt3	Area 3, Qt2	
	Qt4	Area 4, Qt4	Area 3, Qt3	Area 1, Qt4		
Area 4	Qt1	Area 3, Qt1				
	Qt2	Area 3, Qt2	Area 3, Qt1	Area 4, Qt1		
	Qt3	Area 3, Qt3	Area 4, Qt4	Area 3, Qt2		
	Qt4	Area 3, Qt4	Area 4, Qt3	Area 3, Qt2	Area 1, Qt4	
Area 5	Qt1	Area 1, Qt1				
	Qt2	Area 1, Qt2	Area 5, Qt1			
	Qt3	Area 1, Qt3	Area 5, Qt4	Area 1, Qt4		
	Qt4	Area 1, Qt4	Area 5, Qt3			
Area 6	Qt1					
	Qt2	Area 1, Qt2	Area 6, Qt1			
	Qt3	Area 1, Qt3	Area 6, Qt4	Area 1, Qt4		
	Qt4	Area 1, Qt4				

Table 2. Summary of the models used in this study and in the previous study.

Model	Period	Data**	Effect					Interaction				Reference
			year	quarter	area	bran	fishery	qt* area	yr* qt	yr* area	bran* area	
M-2006	1966-2005	L-LL, S-LL	*	*	*		*	*	*	*		Watanabe et al., 2006
M-2010	1966-2008	L-LL, S-LL	*	*	*	*		*	*	*	*	Present study

* shows utilized variables.

** L-LL: large (distant water and offshore) longline, S-LL: small (coastal) longline.

Table 3. Summary of the ANOVA for the model used in this study.

Model	Source	DF	Sum of Squares	Mean	F-Value	Pr >F
M-2010	Model	713	1619078.4	2270.8	2633.8	<.0001
	Error	1.53E+06	1316002.8	0.9		
	Corrected Total	1.53E+06	2935081.2			
	yr	42	9288.6	221.2	256.5	<.0001
	qt	3	16848.0	5616.0	6513.8	<.0001
	bran	3	1488.8	496.3	575.6	<.0001
	area	11	7914.0	719.5	834.5	<.0001
	yr*area	462	82959.3	179.6	208.3	<.0001
	qt*area	33	69295.7	2099.9	2435.6	<.0001
	bran*area	33	67097.7	2033.3	2358.3	<.0001
	yr*qt	126	41850.5	332.1	385.2	<.0001

Table 4. Summary of fitting of the model used in this study.

Model	*R-Square	Coeff Var	Root MSE	LogCPUE Mean
M-2010	0.55	74.96986	0.928535	1.238544
M-2006	0.00	79.12019	1.005882	1.271335

* R-Square indicates a value adjusted with degrees of freedom.

Table 5. Summary of MUTIFAN output for the aging. "Von Bertalanffy K", "first length" and "last length" were fixed according to Suda (1966) growth curve, and "ratio of first to last S.D." did not fixed. Consequently, most of the other growth parameters were automatically determined except for standard deviations at age.

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  MultiFan   32 (e)   Length-Frequency Analyzer   Copyright 1992 Otter Research Ltd.
File: a: North pacific ALB abundance index 1966-2008                      Page 1

Number of age classes: 9
Parameter Estimates:
   von Bertalanffy K = 0.149 (1/year); L infinity = 146.0
   First Length = 61.500; Last Length = 120.700; Brody rho   =     0.861 (1/year).
   Estimated age of the first age class =   3.65 years.
   Mean length at age in month 1:
     61.50   73.27   83.42   92.15   99.68 106.16 111.75 116.56 120.70
   Standard Deviations of length at age in month 1:
      2.50     2.50     2.50     2.50     2.50     2.50     2.50     2.50     2.50
   Average Standard Deviation >=   2.501; ratio of first to last S.D.=   1.000
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  MultiFan   32 (e)   Length-Frequency Analyzer   Copyright 1992 Otter Research Ltd.
File: b: North pacific ALB abundance index 1966-2008                      Page 1

Number of age classes: 9
Parameter Estimates:
   von Bertalanffy K = 0.149 (1/year); L infinity = 146.0
   First Length = 61.500; Last Length = 120.700; Brody rho   =     0.861 (1/year).
   Estimated age of the first age class =   3.65 years.
   Mean length at age in month 1:
     61.50   73.27   83.42   92.15   99.68 106.16 111.75 116.56 120.70
   Standard Deviations of length at age in month 1:
      3.03     3.03     3.03     3.03     3.03     3.03     3.03     3.03     3.03
   Average Standard Deviation =   3.030; ratio of first to last S.D.=   1.000
```

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  MultiFan   32 (e)   Length-Frequency Analyzer   Copyright 1992 Otter Research Ltd.
File: c: North pacific ALB abundance index 1966-2008                      Page 1

Number of age classes: 9
Parameter Estimates:
   von Bertalanffy K = 0.149 (1/year); L infinity = 146.0
   First Length = 61.500; Last Length = 120.700; Brody rho   =     0.861 (1/year).
   Estimated age of the first age class =   3.65 years.
   Mean length at age in month 1:
     61.50   73.27   83.42   92.15   99.68 106.16 111.75 116.56 120.70
   Standard Deviations of length at age in month 1:
      3.60     3.60     3.60     3.60     3.60     3.60     3.60     3.60     3.60
   Average Standard Deviation =   3.595; ratio of first to last S.D.=   1.000
```

Table 6 The number of fish whose size was measured and summary of substitution of the data

	Area1				Area2				Area3				Area4				Area5				Area6			
Year	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1966	3255	100	134	3622	0	0	34	0	1939	76	32	1417	0	27	0	54	1331	100	0	101	200	0	0	0
1967	5033	398	624	8118	0	2	0	0	1757	175	33	1146	10	100	8	74	1242	573	0	77	517	0	0	27
1968	8129	80	297	4683	0	52	0	0	966	350	56	1772	6	297	0	6	2569	262	0	0	5932	284	0	0
1969	3915	208	414	7941	0	0	0	74	377	86	317	381	0	57	0	31	1110	0	0	0	1768	0	0	0
1970	5443	0	873	6303	0	0	0	1562	1725	811	317	1428	0	40	17	143	2137	0	0	0	3412	317	0	0
1971	3331	0	651	1410	0	0	0	160	320	113	75	22	4	26	35	66	39	2	0	6	1629	0	0	24
1972	727	0	275	1398	300	0	0	626	296	105	60	449	32	45	39	92	243	0	0	7	546	0	0	64
1973	201	100	0	260	0	0	0	601	462	162	164	2425	34	209	56	261	330	13	2	286	420	0	0	304
1974	5	0	0	939	200	0	0	872	1826	727	531	1178	59	116	298	242	612	41	0	170	704	0	0	89
1975	88	0	0	161	165	0	89	1416	1621	398	234	2117	39	310	186	300	318	175	0	0	785	0	0	293
1976	667	0	85	852	3581	17	311	3892	1176	832	59	1458	364	154	44	30	795	0	0	309	1090	0	0	1472
1977	878	0	0	2911	2894	0	131	8178	682	335	315	1078	72	380	139	258	2966	7	0	0	3028	0	0	666
1978	2136	41	2	2392	4366	0	0	150	1494	1381	83	175	90	1700	820	7	3280	18	0	140	1661	0	0	453
1979	2133	0	0	2285	159	80	35	1161	808	592	17	1149	31	1269	124	58	1688	324	0	107	920	0	0	201
1980	0	0	73	2353	796	0	0	965	2435	1499	138	716	89	559	113	90	3274	659	0	10	1898	0	5	75
1981	1001	0	260	3048	1402	31	0	503	1429	1448	224	787	142	433	1363	611	384	0	0	645	460	0	0	33
1982	270	0	0	990	580	0	0	360	1870	1356	546	796	590	236	68	4	4285	75	0	0	1717	0	0	437
1983	240	0	0	4507	574	0	0	651	267	1886	515	1305	177	536	185	73	1909	365	0	10	1327	0	0	103
1984	0	2	234	5129	880	133	12	2925	1314	1687	634	368	119	221	14	87	734	181	0	285	2195	0	0	0
1985	95	5	325	3170	143	0	33	1375	482	1828	534	60	247	60	109	6	2990	100	1	245	867	0	0	0
1986	790	0	760	4575	3	141	0	1656	1548	1879	1363	396	31	371	98	3	2988	0	0	1375	514	3	0	968
1987	2013	0	1332	8834	1186	121	127	253	1141	1229	220	485	57	376	154	21	2251	252	0	1142	1396	0	0	81
1988	1309	11	447	5960	141	178	37	388	1397	1924	485	1568	163	607	261	339	2159	2	0	432	2365	3	0	278
1989	271	0	2	5510	0	56	149	730	2517	1333	886	58	118	267	339	662	1303	617	0	61	5301	0	0	592
1990	875	69	0	4161	16	198	55	516	437	1372	457	79	33	487	51	102	837	4	0	0	7032	0	0	35
1991	826	0	1	7812	0	15	90	800	3359	2885	241	190	1680	695	390	688	895	79	0	7	5229	0	0	56
1992	0	11	0	7308	5	0	369	4991	1514	1473	597	829	157	497	738	3495	720	9	1	546	4746	12	0	866
1993	303	0	0	5167	303	311	778	2885	6652	2346	82	213	1590	408	76	2021	9154	270	12	11	2780	0	10	17
1994	277	36	20	2758	1394	0	1106	5712	3594	1294	410	1056	177	269	419	4656	15918	107	0	18	6966	0	4	863
1995	0	0	0	3926	0	0	1648	4640	13425	954	2	55	885	1220	1329	5181	6147	8	0	898	5389	247	0	2301
1996	0	0	0	3045	147	64	678	1851	3043	1572	95	1731	1273	472	238	5350	9213	1003	0	35	4993	0	0	2275
1997	866	392	0	1037	0	0	1858	2912	7322	3360	68	237	1997	1225	456	1537	11356	2266	0	98	5826	0	0	848
1998	0	1097	29	1554	0	0	1742	2875	2169	1189	23	561	849	566	25	945	20741	1750	3	763	4372	457	48	672
1999	299	448	9	10798	0	0	1242	3919	4544	660	0	1293	353	1584	1	1529	5573	1315	0	567	2880	0	0	759
2000	5350	495	14	8353	0	0	302	2321	6994	1957	280	1069	74	250	7	514	4635	231	0	9	1762	467	0	720
2001	5627	823	2155	17738	0	0	99	89	9006	10476	11556	8818	1181	836	0	45	18465	13931	114	4495	4053	33	5	1719
2002	11169	3334	1302	9348	0	0	58	32	11628	8762	4466	11111	542	190	0	49	45532	14195	1209	7972	5399	62	34	117
2003	3149	6398	372	10360	241	7	20	8	13878	4992	4064	6939	994	90	0	3	27947	11899	537	11161	2830	3	111	875
2004	4856	1168	547	8765	0	0	12	74	3642	4485	4044	3698	564	43	0	7	28575	13023	232	2116	1519	0	15	217
2005	2836	3416	1971	6418	0	0	0	0	6836	3742	2993	192	692	0	0	0	22459	10262	356	466	1402	174	342	0
2006	5473	2673	382	11048	0	0	6	2	3352	876	0	474	432	130	0	31	9074	935	0	0	885	474	0	0
2007	7501	2437	422	10085	0	0	0	0	4932	0	0	0	211	81	0	0	15436	847	0	0	154	0	0	0
2008	3352	4120	1954	3761	0	0	0	0	1294	1803	3132	185	0	0	0	0	18082	10559	14	1631	2035	14	197	731
Number of strata less than 100	7	21	17	0	23	30	18	8	0	1	4	1	6	2	14	10	0	12	36	13	0	32	36	9
Total number of strata			300																					
Total strata			1032																					
Proportion substituted			29%																					

*If the number of fish in one strata is less than 100, the strata is substituted

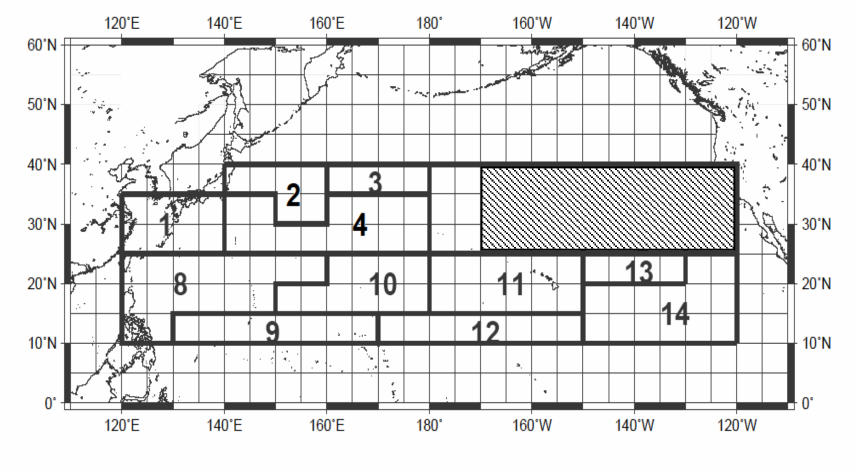

Fig. 1. Area classifications for CPUE standardization for the present study (the area excluding shaded area) and used by Watanabe *et al.* (2006) (area 7 was excluded).

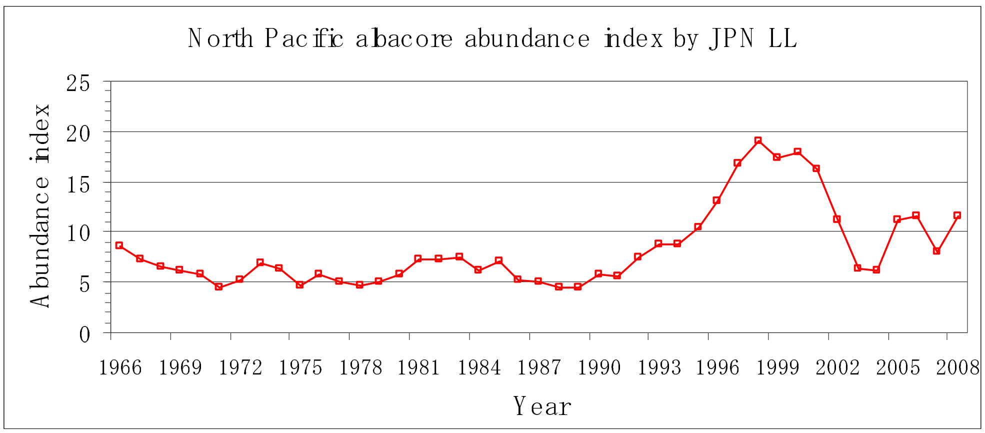

Fig. 2. Trajectories of relative annual abundance indices for the Japanese longline fisheries with weighting by area size.

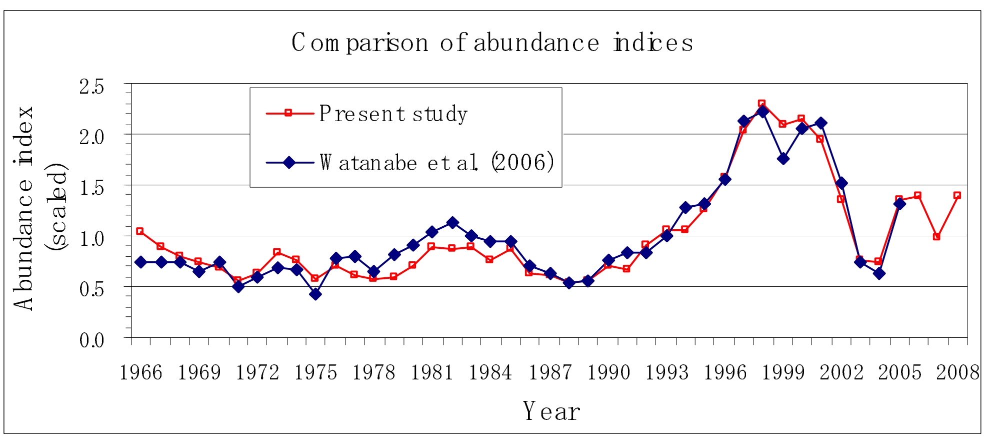

Fig. 3. Comparison of abundance indices (scaled) with that of the past study (Watanabe *et al.*, 2006: Fig.9).

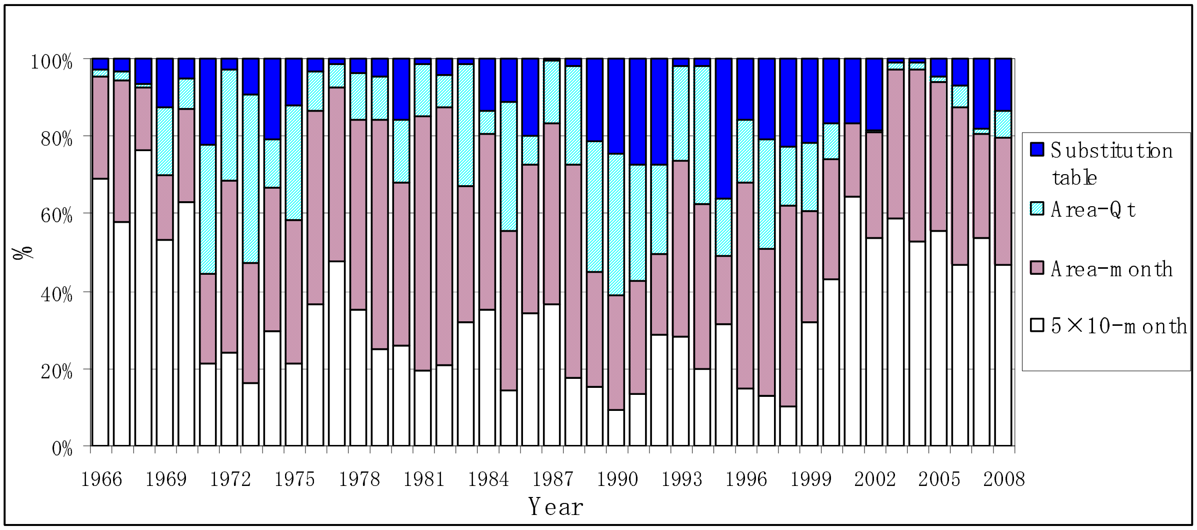

Fig. 4. Degree of substitution in respect of albacore catch in number for longline fishery.

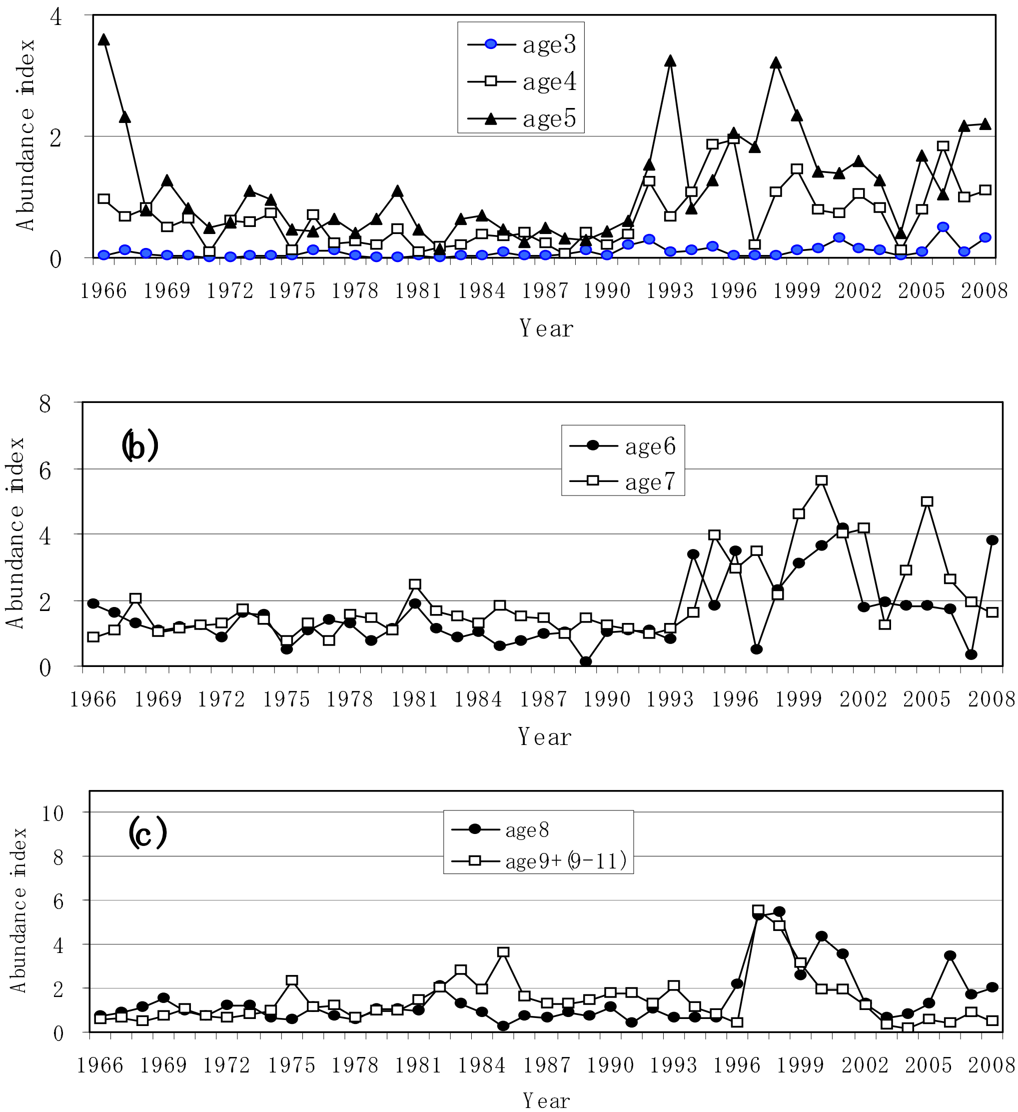

Fig. 5. (a) Annual abundance indices at ages 3, 4 and 5 (b) those at ages 6 and 7 and (c) those at ages 8 and 9+ for North Pacific albacore from the Japanese longline fisheries.

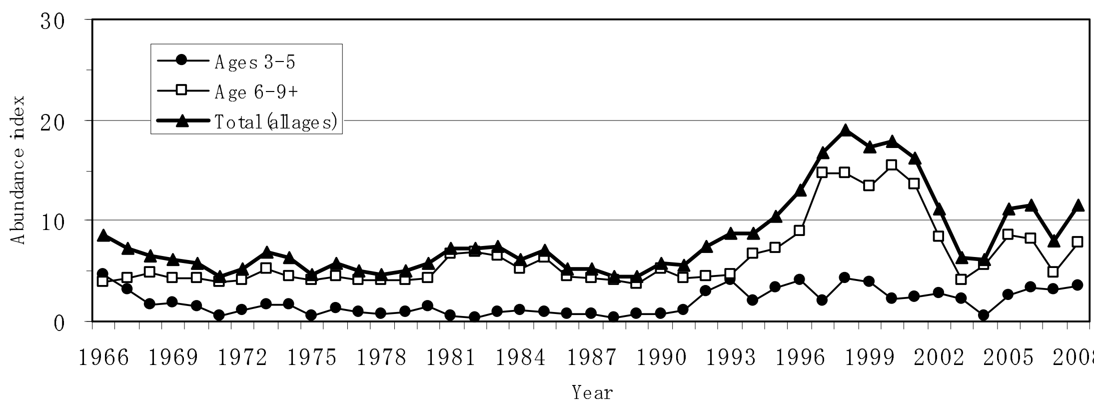

Fig. 6. Age combined annual abundance indices for North Pacific albacore from the Japanese longline fisheries.