Summary of Fisheries Indicators of Southern Bluefin Tuna Stock in 2021

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Abstract: Fisheries indicators along with fishery-independent indices were examined to provide information for overviewing the current stock status of southern bluefin tuna. The Japanese longline CPUE indicators for 4, 5, 6&7, and 8-11 age groups are well above the historically lowest levels observed in the late 1980s or the mid-2000s. CPUE indices for these age groups have more or less fluctuated in an aperiodic way and showed no clear increasing or decreasing trend over past 10 years. Gradual declines of the indices for age class 12+ observed from 2011 appear to cease in recent years while the current levels for this older age group are still low. Other age-aggregated (age 4+ group) CPUE indices that have been used in the operating model and/or management procedure show increasing trends over past 10 years. The current levels of these indices are well above the historically lowest observed in the mid-2000s. Various recruitment indicators inspected suggest that recruitment levels in recent years have been similar to or higher than those observed in the 1990s (before markedly low recruitments of 1999 to 2002 cohorts occurred) but the levels of recruitment have varied from year to year. It should be noted that among the two indices derived from the trolling survey for age-1 fish, the TRG recruitment index shows somewhat a decreasing trend from 2011 to 2021 and the TRP recruitment index recorded zero values in 2018 and 2019, suggesting some concern of potential low recruitment in recent years. A high recruitment level of the 2013 and 2014 cohorts estimated from the operating model in the 2020 stock assessment (directly pertained to the highest value of the 2016 AS index) is not supported by longline CPUE indices by age (from 4 to 7 years old) from 2017 to 2020, and not supported by the TRG value in 2014.

要旨：ミナミマグロの資源状態を概観するための情報を提供することを目的に、漁業に依存しない指数とともに各種漁業指数を精査した。4、5、6&7、および 8-11 年齢グループの日本はえ縄 CPUE 指数は、1980 年代後半あるいは 2000 年代中頃に見られた歴史的最低水準より十分上にある。過去 10 年間、これらの年齢グループの指数はおおむね非周期的に変動しており、明確な増減傾向は示していない。指数の水準は依然として低いが、近年、12+歳クラスの指数の緩やかな減少は止まってきているようだ。オペレーティングモデルや管理方式に使用されている、年齢をまとめたその他の CPUE 指数（4+歳グループ）は、過去 10 年間、増加傾向を示している。それら指数の現在の水準は、2000 年代中頃に見られた歴史的最低値より十分上にある。精査した様々な加入指標は、近年の加入水準は年によって変動するものの、1990 年代に見られた水準（1999 年級から 2002 年級の顕著に低い加入が起こる以前）と近いか、あるいはより高いことを示唆している。1 歳魚を対象にした曳縄調査から得られた 2 つの加入指標において、グリッドタイプ曳縄加入量指数（TRG）が 2011 年から 2021 年まで多少の減少傾向を見せていること、また、ピストンライン曳縄加入量指数（TRP）が 2018 年および 2019 年にゼロ値を記録していることは、近年の潜在的な低加入の懸念を幾分示しており、留意しておくべきである。2020 年の資源評価においてオペレーティングモデルから推定された 2013 年級および 2014 年級の高い加入水準（2016 年の航空目視指数の最高値に直接関係している）は、2017 年から 2020 年までの年齢別はえ縄 CPUE 指数（4 歳から 7 歳）によって、また 2014 年の TRG 値によっては支持されていない。

Introduction

Southern bluefin tuna (SBT, *Thunnus maccoyii*) stock is one of valuable fisheries resources distributed throughout the southern hemisphere. The Commission for the Conservation of Southern Bluefin Tuna (CCSBT) is responsible for the management of the SBT stock throughout its distribution. The CCSBT's objective is to ensure, through appropriate management, the conservation and optimum utilization of the stock.

The 2001 Scientific Committee (SC) of CCSBT selected a set of fisheries indicators to overview the SBT stock status (CCSBT 2001). These indicators have been revised and used in past Stock Assessment Group (SAG), SC and Extended Scientific Committee (ESC) meetings to examine whether unexpected changes of stock status that require urgent full stock assessment occur. After adopting a management procedure (MP) in 2011 to guide the setting of the global total allowable catch (TAC) for SBT, as a part of the "metarule" process for the MP, the ESC annually reviews stock and fishery indicators to monitor whether the SBT stock stays within an expected range of uncertainty which is considered in the operating model (OM) (CCSBT 2012). This document summarizes examinations of updated fishery-dependent indicators and our overall interpretations. Fishery-independent indices based on research surveys were also reviewed along with the fisheries-dependent indicators.

It should be noted that conclusions on past catch anomalies of longline and purse seine fisheries in the reports by the Japanese Market and Australian Farming Investigation Panels were not taken into account in this summary because how to incorporate information of the catch anomalies into past CPUE data is difficult.

1. Japanese longline CPUE [1]:

Nominal CPUE

Nominal CPUE indicators by age group were plotted in Fig. 1-1. Age was estimated from fork length based on the growth curve used in CCSBT. These indicators based on Japanese longline fishery data, including those of joint-venture with Australia and New Zealand occurred in past. Data in the most recent year exclusively rely on information collected by the Real Time Monitoring Program (RTMP) which covers all SBT targeting vessels. When all data from the other non SBT-targeting vessels (based on logbooks) become available and are included in the existing dataset the following year, CPUE of the most recent year tends to decrease slightly (Takahashi et al. 2001). Almost no difference of CPUE based on the RTMP and logbook data has been found in recent years.

CPUE indicators must be looked to carefully from year 2006 onward because Japanese longline fishery has introduced Individual Quota (IQ) system since 2006 (Itoh 2012). Changes in the number of catch and the distribution pattern of effort before and after 2006 were examined and discussed in detail in Itoh (2021a). Additionally, in concurrence with the implementation of the IQ system, releases and discards of small SBT from Japanese longline fishery began to occur (Itoh et al. 2014). These releases and discards are probably due to fishermen's motives to desire to use their limited IQ because of low commercial value for small fish. Although these release and discards have been reported through the RTMP and documented in the national report of Japanese SBT fisheries every year (Itoh and Morita 2021), both nominal CPUE and standardized CPUE (below) were calculated without including

[1] Catch per Unit Effort. In southern bluefin tuna case, CPUE is the number of catch per 1000 hooks.

the releases/discards.

When focusing on trends for the recent past, nominal CPUE for age 3 [2] showed an increasing trend from 2015 to 2019 (Fig. 1-1). The 2020 value for this age was higher than the past 5-year mean over 2015-19. CPUE for age 4 increased between from 2016 to 2019 and dropped in 2020. CPUE for age 4 in 2020 was lower than the past 5-year mean. CPUE for age 5 from 2016 to 2020 was almost the same level except 2019 showing a large increase. The most recent CPUE for age 5 was below the past 5-year mean. CPUE for age class 6&7 increased from around 2010 to 2017 and then shows a decreasing trend afterward. The value of 2020 was slightly below the past 5-year average. Recent nominal CPUE for ages 8-11 showed an increasing trend, and CPUE in 2020 was higher than the 5-year mean. CPUE for 12+ age group fluctuated around the same level as 2007 from 2011, but increased greatly in 2020. The most recent CPUE value for 12+ was above the past 5-year average. CPUE for 4+ age group has increased since 2007 and the most recent value was above the 5-year mean.

Trends of nominal CPUE of Japanese longline by cohort were plotted in Figs. 1-2 and 1-3. Fig. 1-2 is a comparison of nominal CPUE of juveniles among different cohorts and Fig. 1-3 compares decrease rate by cohort in the logarithmic scale. CPUEs for age 3, 4 and 5 fish show consistent trends between 1980 and 2004 cohorts. However, some variations in trend and divergence from trends of CPUEs for age 4 and 5 have been observed for age 3 after 2004 cohort (Fig. 1-2) which suggest that age 3 CPUE cannot be used as an indicator of relative cohort strength for recent years. Cause(s) of this variation and divergence might be change in catchability, population fluctuation, and/or releases/discards of small fish in recent years.

Overall levels of CPUE across age 3 to 11 by cohort can be grouped as the periods of 1980-1986, 1987-1992, 1993-1998, 1999-2003, 2004-2009, and 2010-2017 cohorts (Fig. 1-3). Within each period, variations of the CPUE levels were relatively small (except age 3 CPUEs in the 1999-2003 and 2010-2017 cohort groups) and deceasing rates were similar. The 1987-1992 cohorts showed more drastic declines than other cohorts, which was probably due to targeting towards smaller fish in the early 1990s caused by stock depletion of the cohorts recruited in pre-1987 years and less structured management schemes at that time. The cohorts recruited from 1993 to 1998 showed slower decline rates, suggesting a reduced level of exploitation rates for these cohorts. Fig. 1-3 also indicates acute decreases of overall CPUE level of 1999-2003 cohorts to about the same or lower levels comparable to those experienced by the early 1980s cohorts, while showing that 2004-2009 cohorts were higher overall CPUE levels. Cause(s) of these weak 1999-2003 cohorts has been unknown, whether it would be a reflection of change in oceanographic and/or fish availability, or it be an indication of a consequence of excessive fishing pressure. Although the CPUE levels for age 3 of 2004-2009 and 2010-2017 cohorts varied depending on cohorts, most of the CPUE levels for age 4 to 10 were similar to or higher than ones of any cohorts in past.

Age composition of nominal CPUE for 2020 (Areas 4, 7, 8, and 9) and 2021 (Areas 4, 7 and 9) obtained from the RTMP were plotted in Fig. 1-4. Data for past years are also shown for comparison. A large portion of catches occurred approximately between ages 4 and 10 while the overall age composition ranged from about age 2 to over age 15. Most of small fish (5 years old and younger) were caught in Areas 4, 7, and 9 only, whereas catches of large fish (over 10 years old) were observed in all Areas depending upon month. For Areas 4, 7 and 9, the age composition of CPUE was skewed toward younger ages (< age 5) in 2021 compared to 2020. No marked increase of CPUE was observed in 2017, 2018, 2019,

[2] Caution is necessary for interpretation of age 3 and 4 CPUE in 1995 and 1996 because fish smaller than 25 kg were released in these two years.

2020 and 2021 as corresponding to the highest value in 2016 observed in the scientific aerial survey index (assuming that the aerial survey index primarily represents age 3 SBT abundance, see Fig. 2-3). For example, if the recruitment level were markedly high as shown by the scientific aerial survey index in 2016 for age 3 SBT, CPUE would also be substantially high in age 6 in 2019 and age 7 in 2020 compared to other years but this has actually not occurred clearly.

Standardized CPUE

Two GLM standardized CPUE indices of w0.5 (B-ratio proxy) and w0.8 (Geostat proxy) were updated (Fig. 1-5) using the same method as described in Takahashi et al. (2001; see also Takahashi 2008 for correction of editorial errors in the formulae for calculating the indices) except some modification described below. The standardization model used was the same as that of Nishida and Tsuji (1998).

At the ESC for the SC21 in 2016, New Zealand and Japan advised that no Japanese-flagged foreign charter vessels in the NZ SBT fishery (NZ joint-venture) operated in 2016 due to amendment of the NZ domestic law for vessels operating within the NZ exclusive economic zone, and therefore there would be no observations from the charter vessels for Areas 5 and 6 in the CPUE dataset from 2016 onward (CCSBT 2016). To minimize the impact of the loss of these data on the CPUE series, an approach that the statistical areas in which the charter fishery operated historically with those immediately adjacent were combined (Area 5 into 4 and Area 6 into 7) was proposed (Takahashi 2017) and agreed to be used for future analysis (CCSBT 2017). This approach retained the historical data in the standardization and did not have an appreciable impact on the indices, although there were some divergence/differences in trends between CPUE indices by this and previous approaches, especially for age groups 5, 8-11, and age 12+ (see Appendix Fig. A-1 in Takahashi and Itoh 2017).

Estimates of the CPUE indices for 2020 (the most recent year when catch and effort data are available) were based not on logbooks but RTMP data only as described in the Nominal CPUE section above. These estimates may be changed slightly when logbook data become available the subsequent year (Takahashi et al. 2001). Almost no change has been found between the RTMP and logbook in recent years.

As also mentioned above, CPUE in 2006 and subsequent years must be examined carefully because Japanese longline fishery has introduced the IQ system since 2006 (Itoh 2012).

Looking to trends in about past 5 years, the w0.5 and w0.8 indices for age 3 have increased consistently (Fig.1-5a). The 2020 indices for this age were above the past 5-year averages over 2015-19. As in the case of nominal CPUE (Fig. 1-2), the trend of CPUE index for age 3 has diverged from ones for age 4 and 5 by various reasons (e.g., incomplete recruitment of age 3 fish into Japanese longline fishery, small fish releases/discards in recent years). Therefore, as a signal of recruitment fluctuation, the age 3 indices should be looked at and interpreted with caution.

The indices for age 4 increased from 2016 to 2018 and decreased afterward (Fig. 1-5b). The age 4 indices may also be influenced by small fish releases/discards in recent years. The 2020 indices for age 4 were lower than the past 5-year averages.

The CPUE indices for age 5 were at the same level from 2017 except in 2019 (Figs. 1-5c). The indices for age 5 in 2020 were lower than the past 5-year means.

The CPUE indices for age group 6&7 decreased from 2017 to 2019 and was back to the same level as 2017 (Figs. 1-5d). The indices for this age class in 2020 were higher than the past 5-year averages.

The CPUE indices for age group 8-11 increased from 2017 and markedly upturned in 2020 (Fig. 1-5e). The 2020 indices for this age class were markedly higher than the past 5-year averages.

The CPUE indices for age 12+ show gradual declining trends from 2011 except a markedly large upturn in 2020 (Fig. 1-5f). Aside from 2020, this decline and staying at the low level of the indices may partly relate to very low cohorts of 1999 to 2001 observed in the 2000-2002 TRG (Fig. 3-1). The indices in 2020 for this age group were higher than the past 5-year means.

Fig. 1-6 compares trends of various CPUE indices for age 4+. These indices are: "Base" series which used 5x5-degree aggregated core vessels data and the standardization model agreed in the CPUE modeling Group (CCSBT 2010b, Itoh and Takahashi 2021); "Base with SxS" series which used the same data and model as the Base except that data resolution was by shot-by-shot basis; "Reduce Base" series which used the same data and model as the Base except for excluding by-catch and year interaction terms from the standardization model (Itoh and Takahashi 2021); "GAM" series which was based on standardization by a general additive model (GAM) using 5x5-degree aggregated all vessel data (Helidoniotis 2016); "N&T model" series which used Nishida and Tsuji (1998) model and 5x5-degree aggregated all vessel data; "Base GAM" series which was the agreed CPUE index used for the 2020 stock assessment (CCSBT 2020, Hoyle 2020).

The Base series is the one used for the operating model (OM) conditioning and management procedure (MP) inputs in the ESC. The Base GAM is to be used as the main CPUE series for the reference set OM in the 2020 stock assessment. Other series are used for monitoring to check if there is any unexpected event happened to both SBT and the fishery along with the Base series. The N&T model series had been used in stock assessments by the OM until the Base series was developed. The N&T model series (from 1969 to 2008 only) was also applied to calibrate the Base series (only available between 1986 and the most recent year) to obtain one historical series from 1969 to the most recent year for stock assessment by the OM (Attachment 5 of CCSBT 2010a, Attachment 10 of CCSBT 2013).

All trends of these indices for age 4+ showed similar patterns up to about 2009, but divergences have occurred since then (Fig. 1-6). Itoh (2020) investigated cause(s) of a drastic upturn of 2018 in the Base series and found that this was caused by an abnormal estimate of the Year*Area effect due to unbalanced data in Areas 8 and 9 regarding latitude. Overall, the indices for age 4+ show increasing trends from 2009 except Base GAM.

Spatial-Temporal (ST) windows CPUE for age 4+

"Spatial-temporal (ST) windows" CPUE index for age 4+ (Takahashi et al. 2002) was also updated using the new method as described in Takahashi (2006). "ST windows" represent Area 9/May and June, and Area 8/September and October. By inspecting historical Japanese longline catch/effort data, these spatiotemporal strata were so defined as to persistently observe substantial effort of the longline fishery. However, it was noted that the assumption on such persistency in the ST windows concept was no longer valid due to changes in operation pattern of Japanese longliners (Takahashi and Itoh 2012). Given this, the ESC agreed that while the ST windows series had been a useful "extreme" series for contrast with the Base series, there was a need to replace the ST Windows series (CCSBT 2012) and therefore the series is no longer submitted to the CCSBT Secretariat as a data exchange requirement. Yet we consider that it may be useful to continue monitoring the ST windows series because the series would still be able to capture some aspect of stock trend, and thus we include this series in this document.

The trend of the ST windows is shown in Fig. 1-7. Overall, the index has increased gradually since 2007, when the historically lowest level was observed, to 2020. The 2020 point was above the past 5-year average. It would be worthwhile to mention here that the trend of the ST windows looks similar to those of CPUE indices for 8-11 age group (Fig. 1-1 and Fig. 1-5e), suggesting that the series could partly capture some signal of stock dynamics for this age group.

Comparison of standardized CPUEs between Korean and Japanese longline fisheries

Comparisons of standardized CPUE trends between Korean and Japanese longline fisheries by CCSBT statistical area (Areas 8 and 9) are shown in Fig. 1-8. Korean CPUE was based on age-aggregated (all ages), operational (set-by-set) catch and effort data (Lee et al. 2021a) while Japanese core vessels CPUE was based on data aggregated by 5x5 degree square and age (age 4+) (Itoh and Takahashi 2021). Japanese core vessels CPUE was separately calculated for Area 8 and for Area 9 considering spatiotemporal overlaps of operations of Japanese fishery with Korean fishery for comparison (Lee et al. 2014). Note the core vessels CPUE was computed by using the equation *exp(intercept + year + year*area + (lat35*year + lat40*year)/2)* with GLM standardization estimates (cf. Informal Record of the June 2017 CPUE Web Meeting) [3].

For both Areas 8 and 9, overall trends of the Korean CPUE series appeared similar to those of the Japanese core vessels CPUE series and the consistency between the trends seemed reasonable up to about 2014, although there were some divergence/differences in trend between Korean and Japanese CPUE. However, after 2014, these divergence/differences are getting greater in Area 9. The amounts of effort of Korean and Japanese fisheries has not been small, and the effort spatial coverages of both fisheries has not differed since 2014 (Itoh and Morita 2021, Lee et al. 2021b). Potential cause(s) of the divergence/differences may be differences of ages of fish targeted or differences of months when each fisheries operated.

2. Recruitment indices:

Australia purse seine fishery

Changes of catch (in weight, t) per effort and age composition of Australia purse seine fishery catches were plotted in Figs. 2-1 and 2-2, respectively. Although interpretation of the CPUE of this fishery is contentious, monitoring changes of the CPUE merits having some insight into status of juvenile fish along with other recruitment indices.

Both catch per shot and catch per searching hour appear to decline gradually from 2015/16 to 2019/20 seasons (Fig. 2-1). This decline of juvenile fish probably corresponded to one that were observed in the grid-type trolling index (TRG) (Fig. 3-1). Both catch/shot and

[3] Here, in principle, CPUE should be calculated as *exp(intercept + year + year*area + (lat35*year + lat40*year)/2) - 0.2*. Subtraction of 0.2 causes CPUE values to become negative in this case of using a simple equation and GLM estimates for a more complex model. However, the equation without the subtraction will do as long as we need know relative trend of CPUE.

catch/search hour in 2020 (2019/20 season) were below the past 5-year mean over 2015-19.

Generally, the proportions for age 2 fish in purse seine catch between 2004 (03/04 season) and 2020 (19/20 season) were greater than any of other years except for 2010, 2014, and 2017 (Fig. 2-2). In 2020, the age 2 fish dominated the catch and its proportion (ca. 80%) was the highest among past years. Contrary, proportions for age 3 and 4 decreased for the same years except for age 4 in 2010, 2011, 2014, and 2017. In 2007, 2012, 2016, 2019 and 2020, the age compositions for age 2 largely increased, and those for age 3 and 4 decreased.

It should be noted that applying cut points of the new growth curve (as from the 2010 SC) made almost all age 1 fish proportions disappear from the age composition chart. This is because fish being classified as age 1 by the previous growth curve are now categorized as age 2 by the new growth curve.

Scientific aerial survey (AS) index

Trend of aerial survey (AS) index (Eveson and Farley 2017) in the Great Australian Bight (GAB) are shown in Fig. 2-3. This index is considered to monitor surface abundance of ages 2-4 fish combined distributed in the GAB region. The AS had been conducted by Australia since 1993. Full scale line transect AS was suspended between 2001 and 2004. The AS had been financially assisted by other CCSBT members through the Secretariat since 2013. The AS was not conducted in 2015 for budgetary reasons and resumed in 2016. The AS was not conducted in 2018 for both budgetary and logistic reasons and probably would not be conducted from 2018 onward. The AS index was replaced with an index for age 2 fish abundance obtained from the gene-tagging (GT) project (CCSBT 2015, Preece et al. 2015).

Although the AS index has not been available since 2018, the figure for the AS index is presented to compare with other indicators.

Overall the AS index showed a moderate decline from 1993 to the early 2000s. The AS index values were more or less at a similar level in the rest of the 2000s. The AS index increased in 2010 and 2011, largely dropped in 2012, and then drastically upturned in 2014 and 2016. The 2017 value of the AS index decreased to the similar level of the 2014 AS index and was near the past 5-year average over 2011-16. However, the 2017 estimate was significantly above the long-term average (Eveson and Farley 2017).

Age 2 SBT abundance from the gene-tagging (GT) project

The pilot study of gene-tagging project for SBT (Preece et al. 2015) commenced in 2016. The aims of the pilot study are to test the logistics and feasibility of gene-tagging and to obtain an estimate of absolute abundance of age 2 SBT as a fisheries-independent recruitment indicator in place of the AS index.

For estimation of age 2 abundance in 2019, in total, 4,242 fish were tagged in 2019, 11,109 fish were included in the harvest sample set of 2020, and 31 matches were detected (Preece et al. 2021, Table 1). The abundance estimate is 1.52 million with a CV of the estimate of 0.180. Although the age 2 abundance estimates increased from 2018 to 2019 with respect to point estimates, this increasing trend is unclear given the CVs.

Table 1. The results of the gene-tagging programs 2016-2019.

Year	N releases	N harvests	N matches	Abundance estimate (millions)	CV
2016	2952	15389	20	2.27	0.224
2017	6480	11932	67	1.15	0.122
2018	6295	11980	66	1.14	0.123
2019	4242	11109	31	1.52	0.180

Trolling survey index

Because a vast amount of costs was necessary for conducting the Recruitment Monitoring acoustic surveys using a sonar unit in the past, a recruitment index of age 1 fish estimated from results of much lower-cost trolling surveys was developed. Details of the trolling survey design, estimation method, results and its interpretation were documented in Itoh (2007), and Itoh (2021b). In addition, standardization of the trolling survey index (called "grid-type trolling index (TRG)") was described in Itoh (2021c). The TRG was standardized by using all data which included those of trolling catch collected in past acoustic sonar surveys and those of trolling catch in past and current trolling surveys over the whole survey area containing survey-piston lines. Therefore, the TRG provides a single consistent indicator for age 1 SBT from 1996 to 2021. The trolling survey was not conducted in 2015 to use time for doing in-depth analyses of other data.

Fig. 3-1 compares trends between the trolling indices and the TRG. For the trolling indices, only the bootstrap estimates of median were plotted. The trolling index on piston line (TRP) for 2021 could not be estimated because the survey design for 2021 had to be modified (no piston line was surveyed) due to the COVID-19 situation.

The median relative trends of trolling index and TRG appear similar although there are some differences in trend due to standardization for the TRG. Both TRG and TRP indices increased from 2005 to 2008 and have fluctuated afterward showing somewhat decreasing trends. It should be noted that levels of TRG in recent years are near 2003 and 2005 levels, and TRP values in 2018 and 2019 are zero, suggesting potential lower recruitments in recent years.

Trends of trolling indices seem compatible with those of other indicators (e.g., Japanese longline CPUE), though there are some exceptions. Therefore, usefulness of the trolling indices to monitor age 1 SBT is apparent. Reliability of the trolling indices is still being verified and it is necessary to compare these indices with CPUE indicators for corresponded cohorts recruited into longline fishery for further verification (some comparisons are done in Itoh (2021c)). The trolling indices, especially for the TRG, could be used as quantitative indicators for recruitment.

3. Indonesian Catch (Spawning ground fishery):

NOTE: The Indonesian longline SBT age and size composition data were unable to be exchanged this year (for 2019/20 season) because Australia would like to review the recent length-weight data further, in collaboration with Indonesia, to ensure the length frequency distribution data analyzed is representative of the SBT catch in the fishery on the spawning ground. Therefore, values of the bar plots for 2019/20 in Fig. 4-1 were tentatively calculated assuming that the age frequencies for this year (for 2019/20 season) were same as last year (for 2018/19 season). Thus, no interpretation was given for the 2019/20 bar plots. On the other hand, catches in number and weight in 2019/20 are not affected by this assumption and thus definitive.

Indonesian SBT catch both in number and weight as well as catches by two age groups, 8-16 and 17 and older, have varied from year to year (Fig. 4-1).

Catches for age class 17+ were higher than those for 8-16 ages throughout the 1990s. In contrast, many of yearly catches for the 17+ group have been similar to or lower than those for 8-16 ages since 2000/01 season. Spiky increases of catch in 2001/02, 2004/05, 2006/07, 2012/13, 2013/14, 2014/15, 2015/16, 2016/17, and 2017/18 seasons may be mainly due to large increase of younger age classes under 17 (also see Farley et al. 2021). Some earlier investigations suggested that the catch of small/young SBT was likely to have come from catches made in the south of the spawning ground (Farley et al. 2017). However, data which only included SBT catches by vessels predominantly operating in Area 1 (spawning ground) indicate that catches of small/young SBT came from the spawning ground (Farley et al. 2021).

Catch trends of both in number and in weight for age 8-16 and 17+ combined appear to gradually decline with fluctuations from 2001/02 season to 2009/10 season. The trends increased from 2009/10 to 2012/13, and then continued to decrease until 2016/17. The catches in number and weight have increased since 2016/17.

Smaller proportions of the older ages of Indonesian catch since 2001/02 season raise some concern of potentially low reproduction in spawning ground.

4. Overall Conclusion:

Fisheries indicators examined generally support a view that the current SBT stock levels for 4, 5, 6&7, and 8-11 age groups are well above the historically lowest levels observed in the late 1980s or the mid-2000s. CPUE indices for these age groups have more or less fluctuated in an aperiodic way and showed no clear increasing or decreasing trend over past 10 years. Gradual declines of the indices for age class 12+ observed from 2011 appear to cease in recent years while the current levels for this older age group are still low. Other age-aggregated (age 4+ group) CPUE indices that have been used in the operating model and/or management procedure show increasing trends over past 10 years. The current levels of these indices are well above the historically lowest observed in the mid-2000s.

Various recruitment indicators inspected suggest that recruitment levels in recent years have been similar to or higher than those observed in the 1990s (before markedly low recruitments of 1999 to 2002 cohorts occurred) but the levels of recruitment have varied from year to year. It should be noted that the TRG recruitment index shows somewhat a decreasing trend from 2011 to 2021 and the TRP recruitment index recorded zero values in 2018 and 2019, suggesting some concern of potential low recruitment in recent years. A high recruitment level of the 2013 and 2014 cohorts estimated from the OM in the 2020 stock assessment (directly pertained to the highest value of the 2016 AS index) is not supported by longline CPUE indices by age (from 4 to 7 years old) from 2017 to 2020, and not supported by the TRG value in 2014.

Fishery indicators for spawning stock based on Indonesian catch were difficult to interpret and thus no specific conclusion was drawn.

The trends of the recruitment indices and the CPUE-based indicators in recent years were summarized in Fig. 5-1.

Considering uncertainty inherent in all the indicators examined, both fishery-dependent and fishery-independent indicators should continue to be further monitored and carefully examined in a synthetic way.

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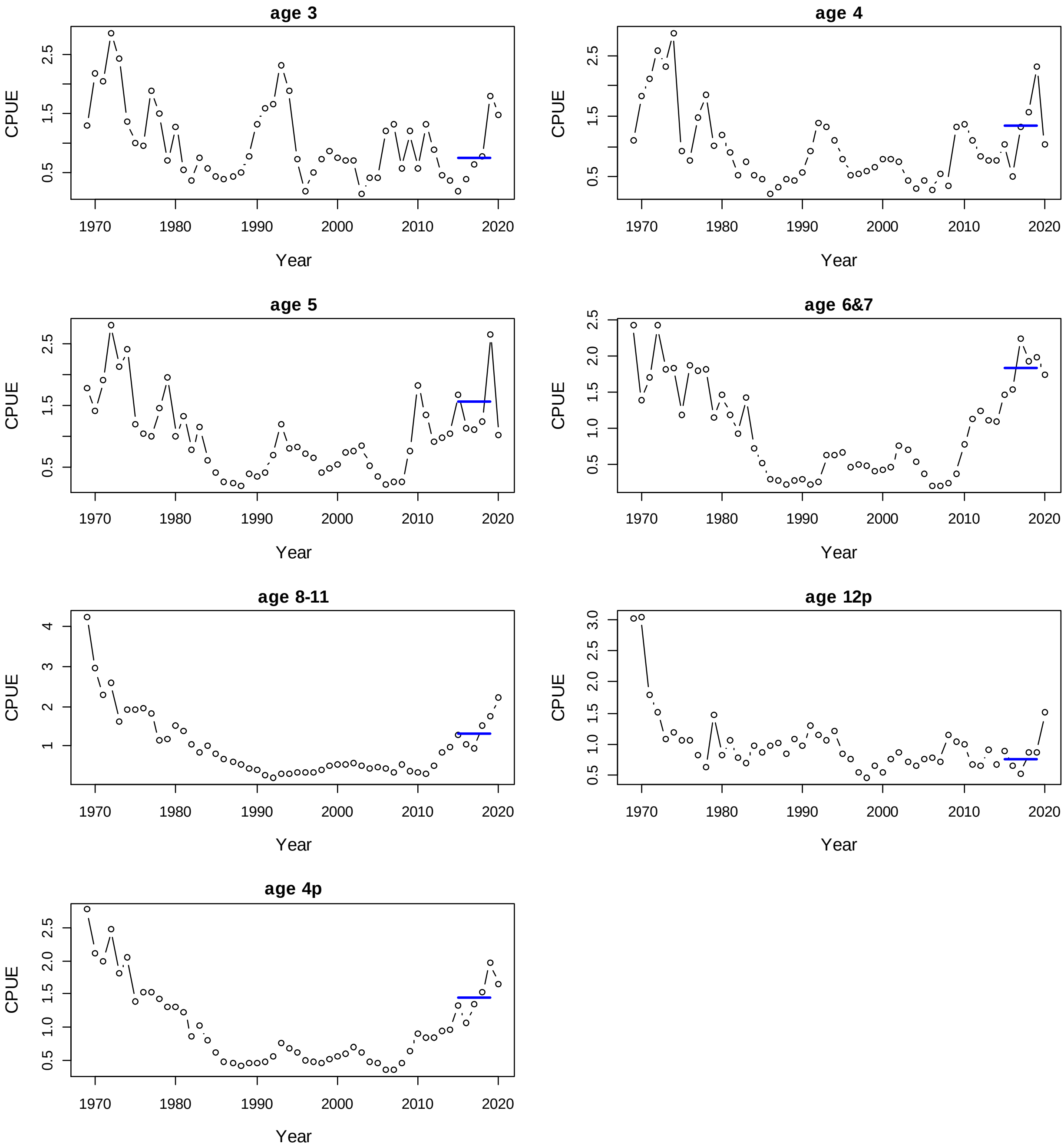


Fig. 1-1. Nominal CPUE of Japanese longline fishery by age groups. The horizontal lines indicate the past 5-year averages over 2015-19.

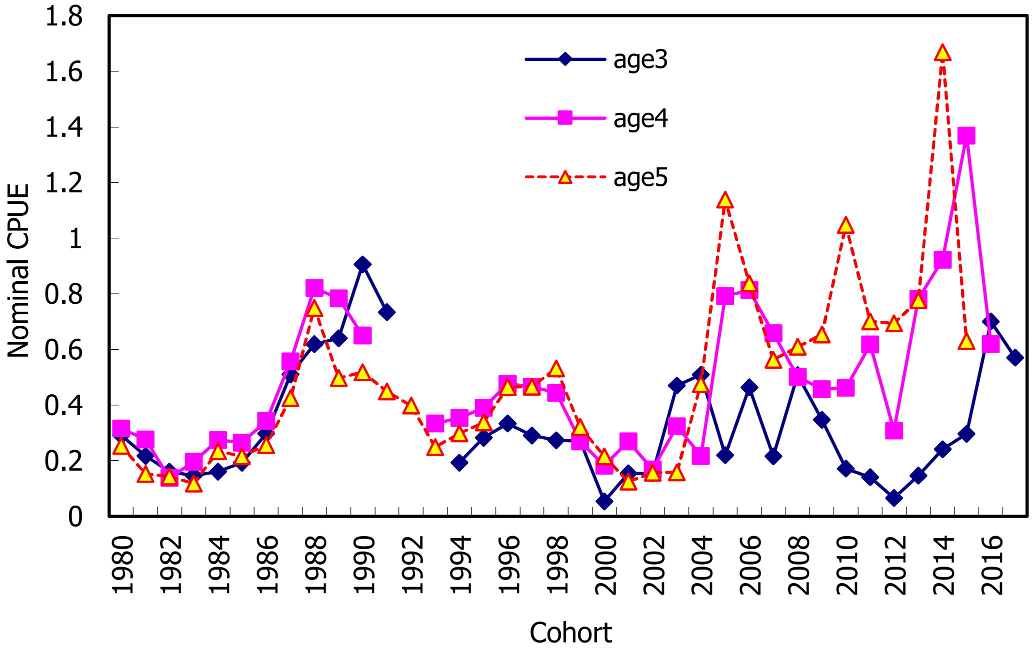


Fig. 1-2. Nominal CPUE of Japanese longline fishery by cohorts for age 3, 4, and 5.

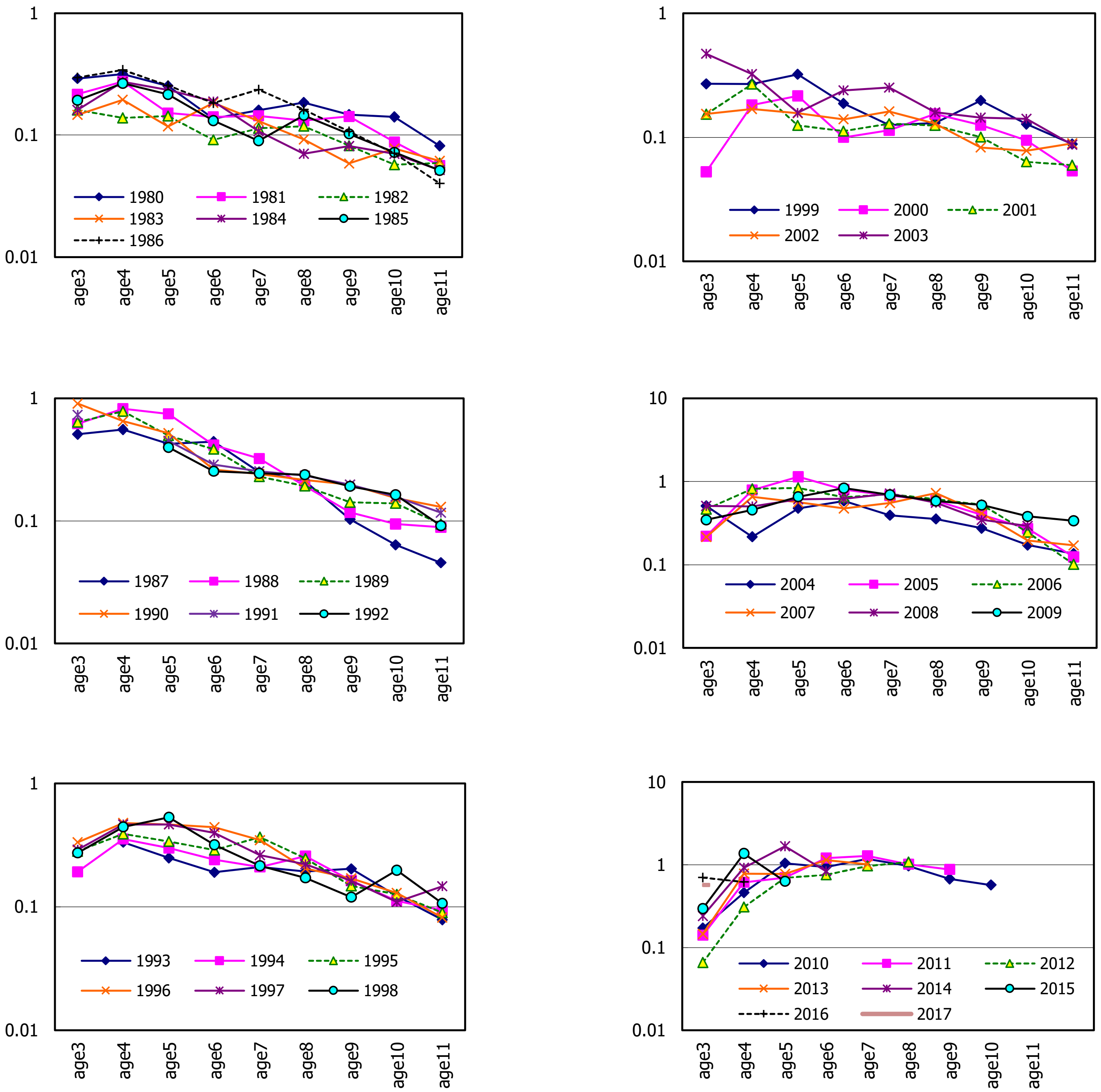


Fig. 1-3. Nominal CPUE of Japanese longline fishery by cohorts in log-scale.

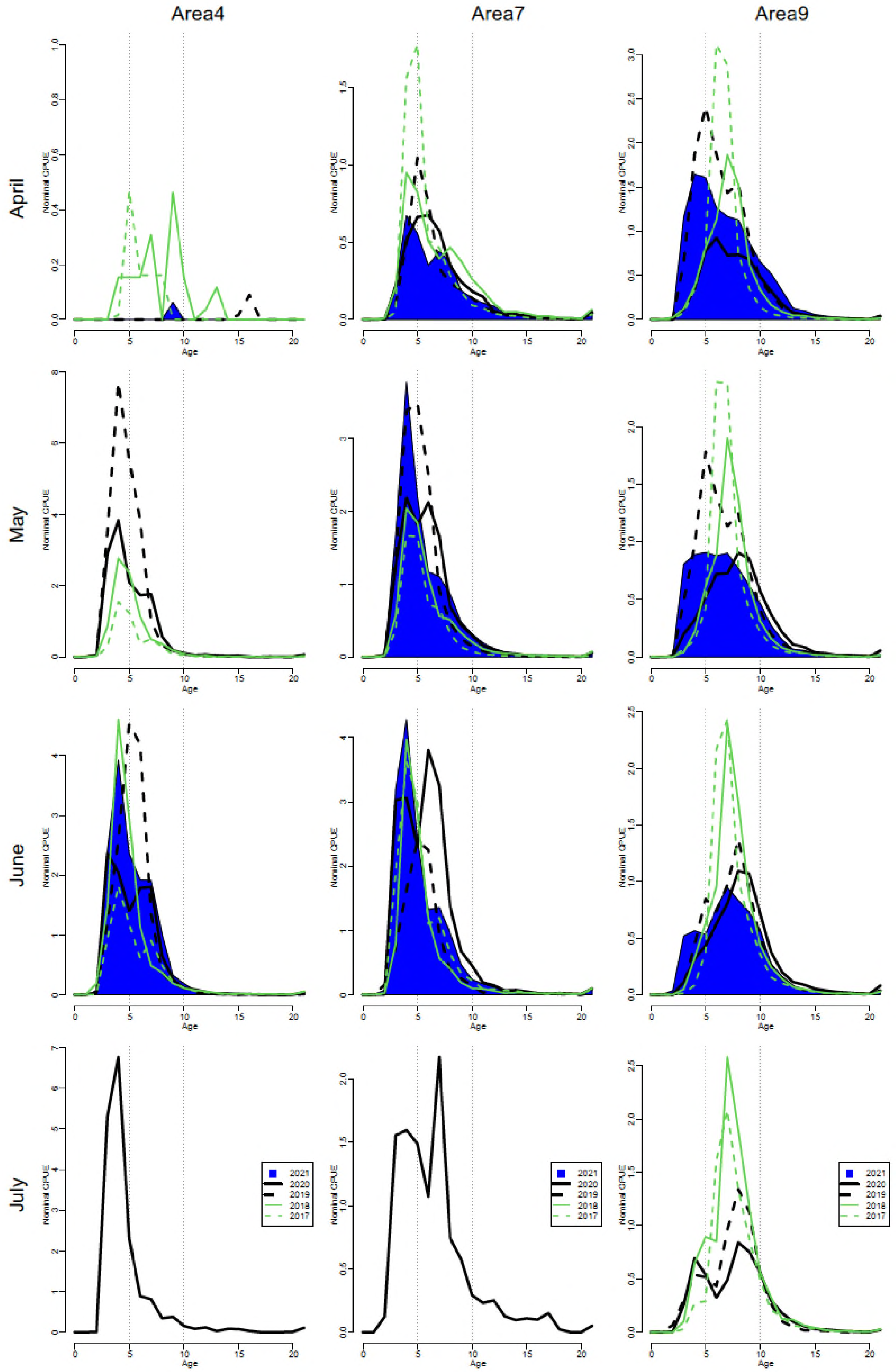


Fig. 1-4. Age composition of nominal CPUE of RTMP data for recent five years by month and areas.

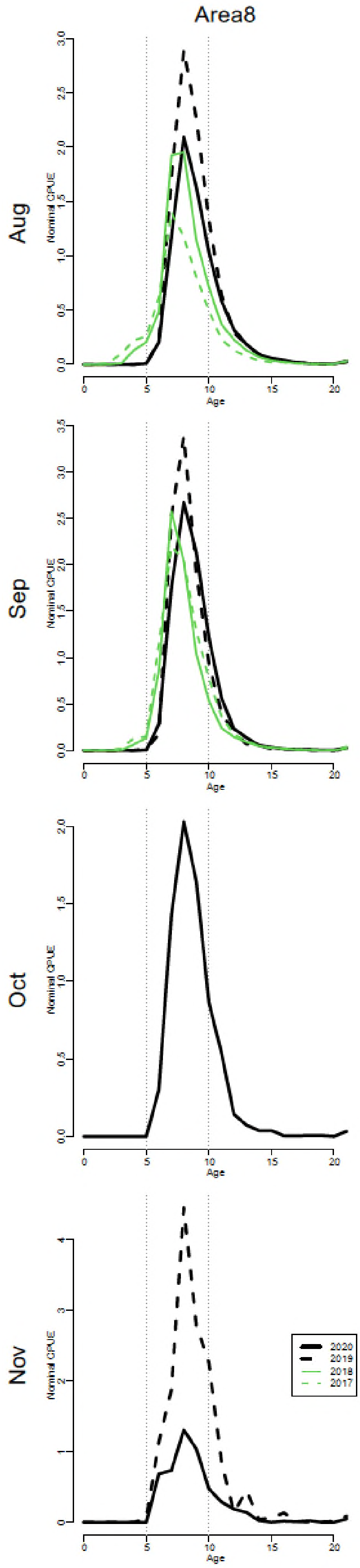
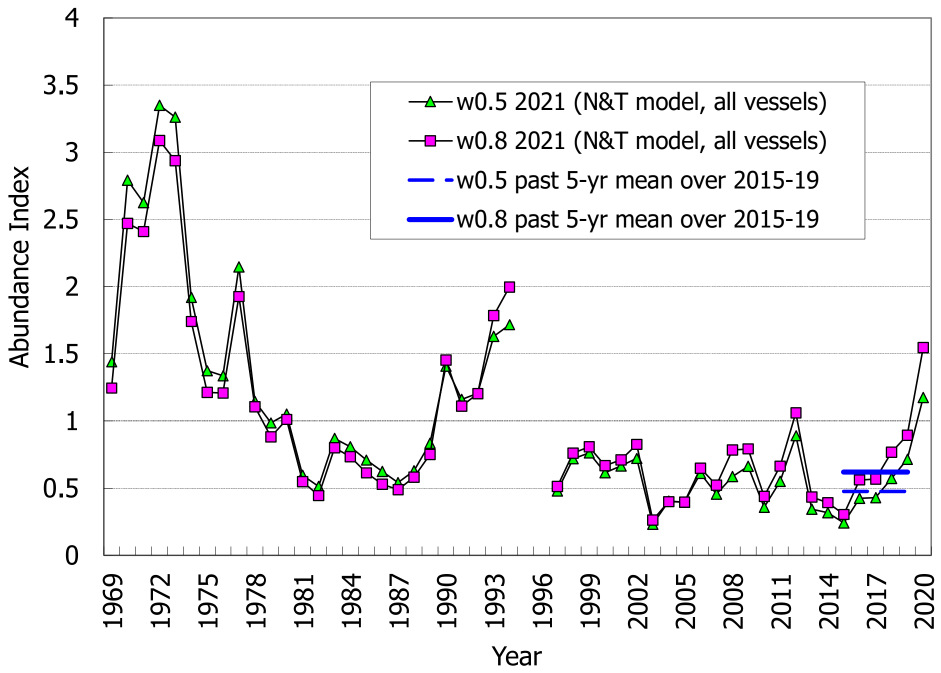


Fig. 1-4 (cont'd). Age composition of nominal CPUE of RTMP data for recent four years by month and areas.

(a) Age 3



(b) Age 4

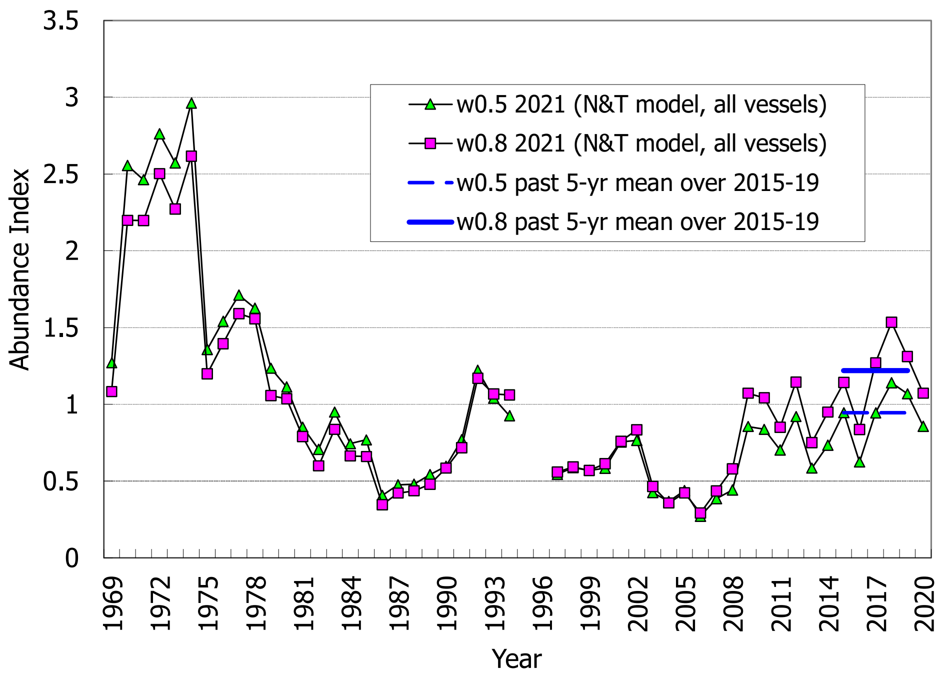
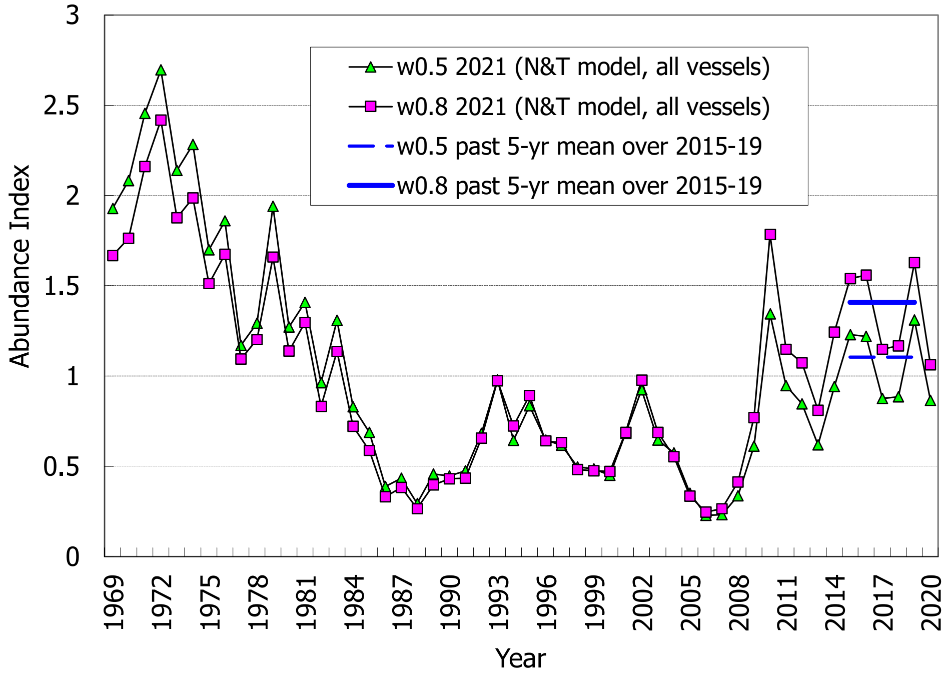


Fig. 1-5. Trends of normalized w0.5 (B-ratio proxy) and w0.8 (Geostat proxy) abundance indices. The standardization model used was the same as that of Nishida and Tsuji (1998).

(c) Age 5



(d) Age 6&7

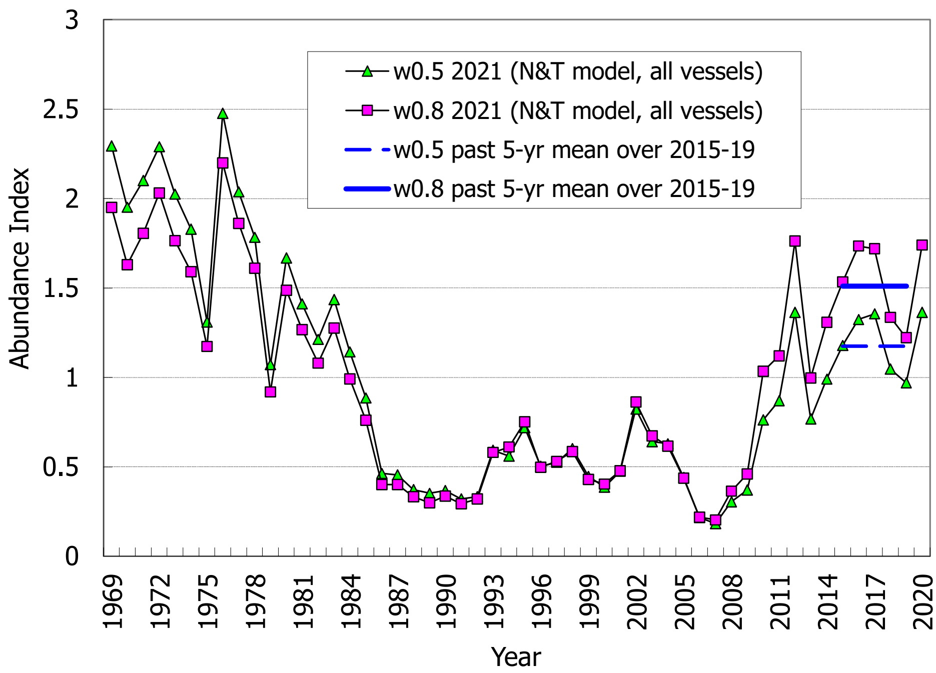
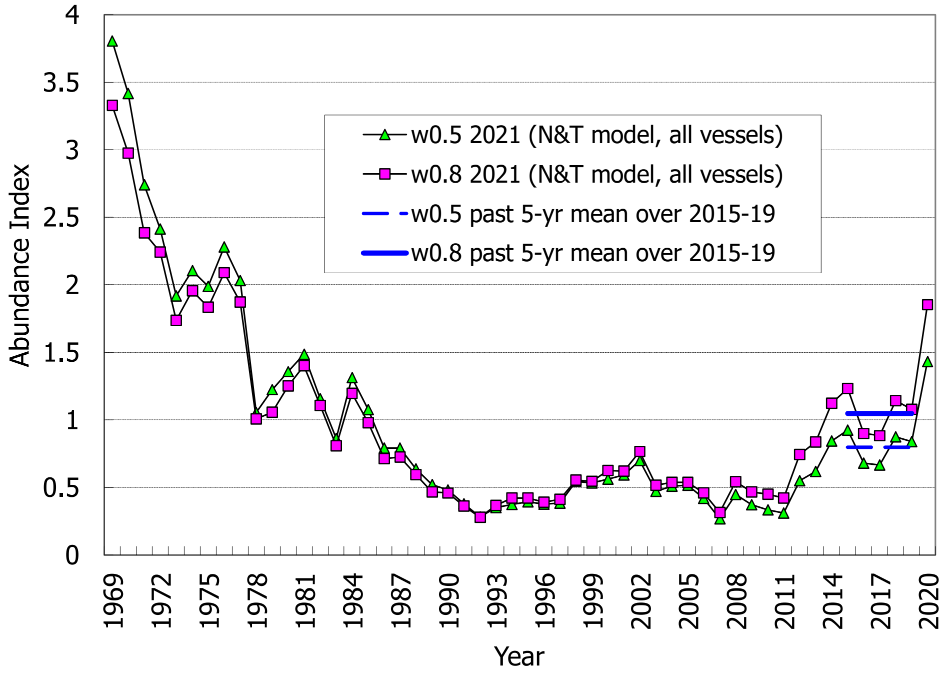


Fig. 1-5. Trends of normalized w0.5 (B-ratio proxy) and w0.8 (Geostat proxy) abundance indices. The standardization model used was the same as that of Nishida and Tsuji (1998). (cont'd)

(e) Age 8-11



(f) Age 12+

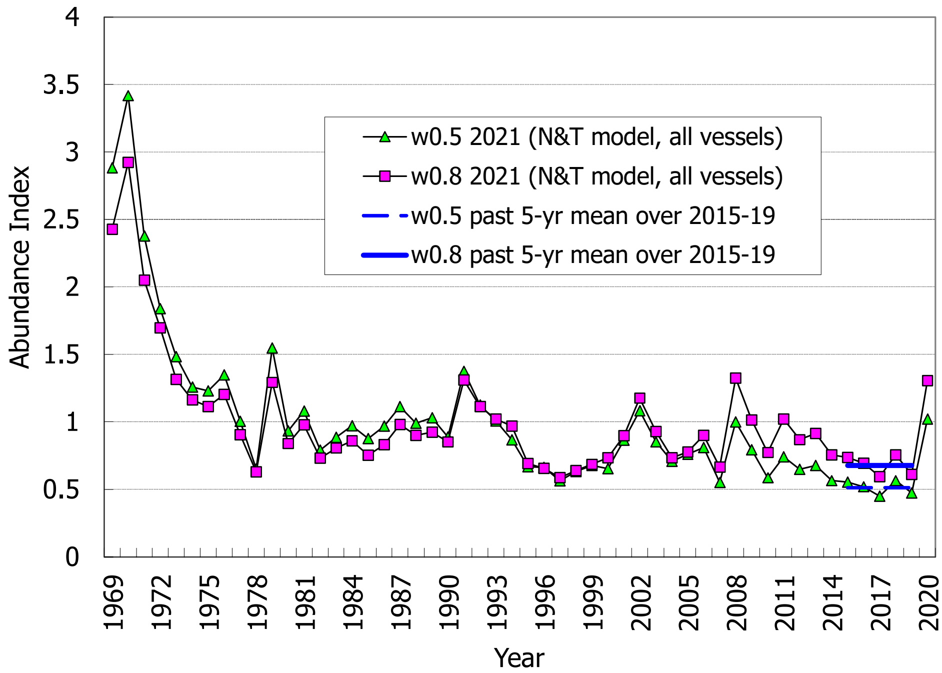
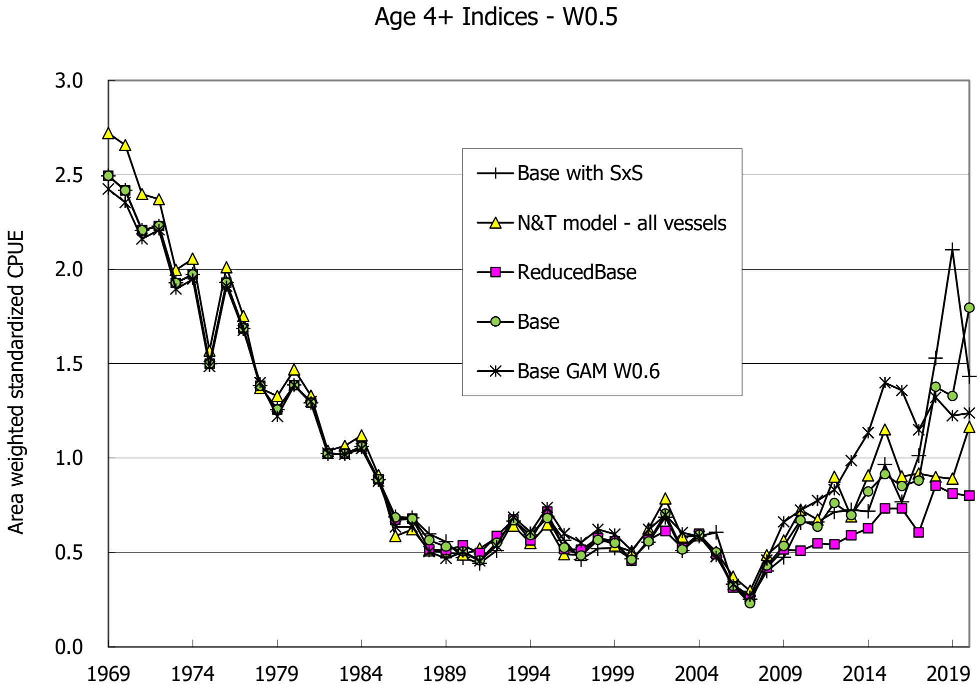


Fig. 1-5. Trends of normalized w0.5 (B-ratio proxy) and w0.8 (Geostat proxy) abundance indices. The standardization model used was the same as that of Nishida and Tsuji (1998). (cont'd)



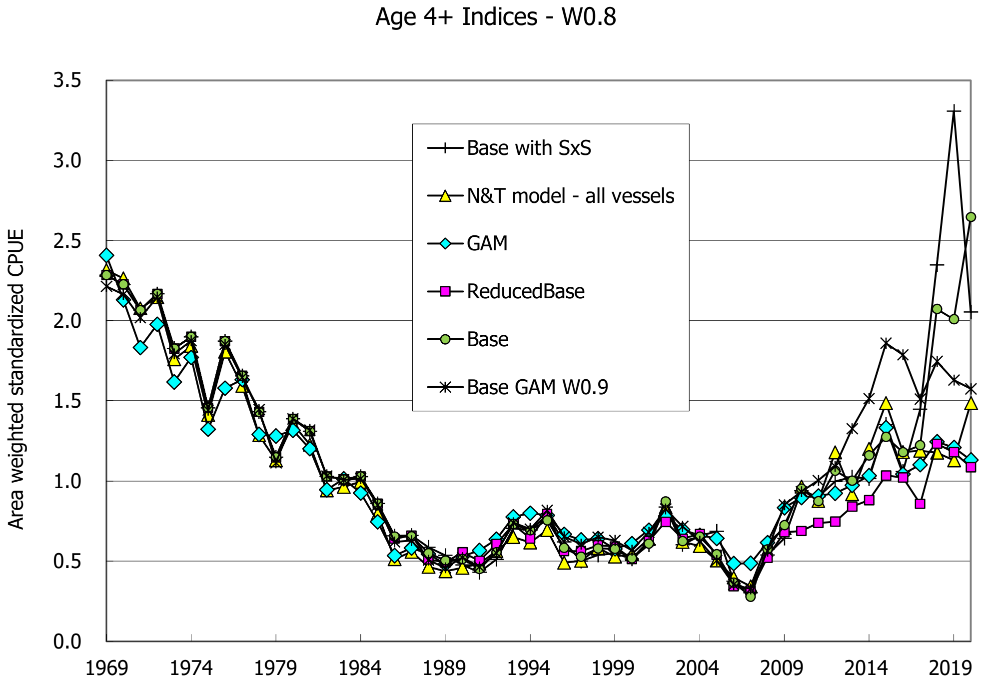


Fig. 1-6. Trends of various abundance indices for age 4+: Base model (Base) with core vessel data (Core); Reduced Base model with Core; Base with shot-by-shot Core; Nishida & Tsuji model with all vessel data; GAM with all vessel data; Base GAM series with Core.

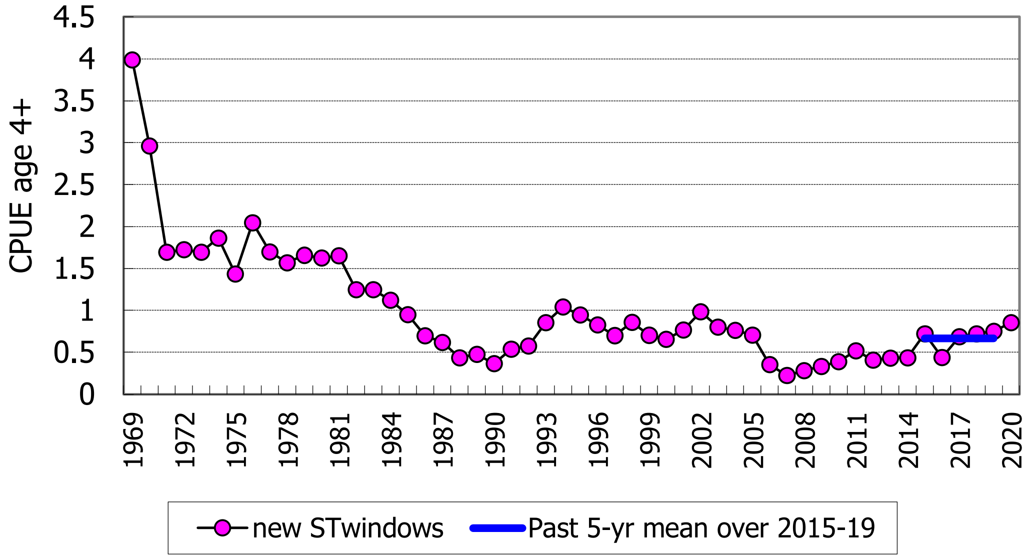


Fig. 1-7. Trend of normalized "ST Windows" index for age 4+ fish by the new calculation method.

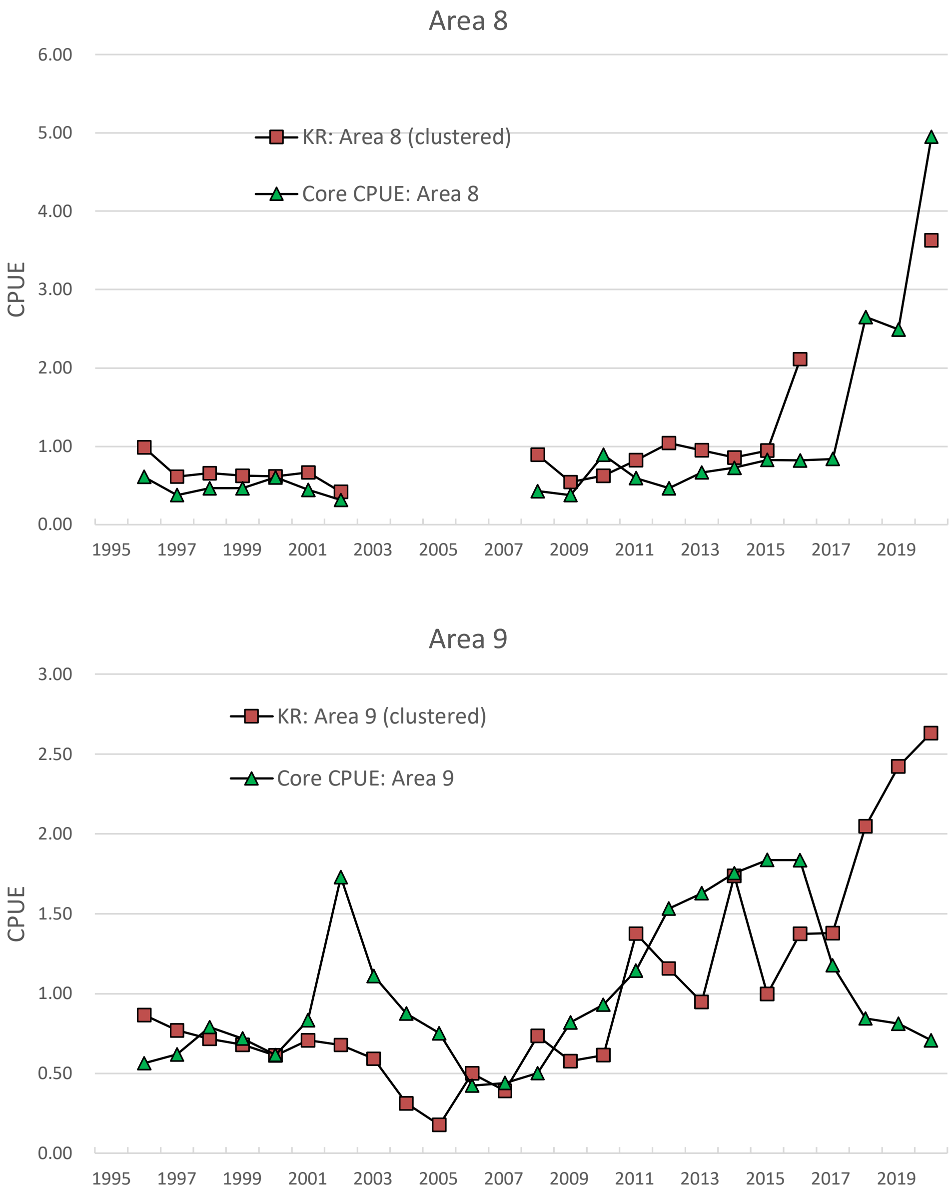


Fig. 1-8. Comparison of CPUE index trends between Korean longline CPUE and Japanese core vessels longline CPUE.

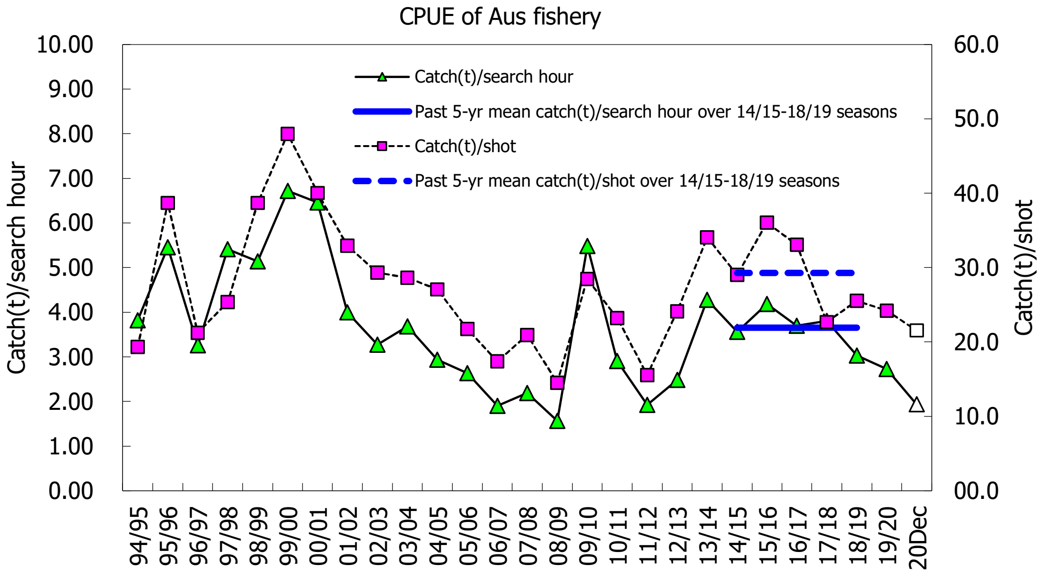


Fig. 2-1 Catch (in weight) per effort for Australia purse seine fishery.

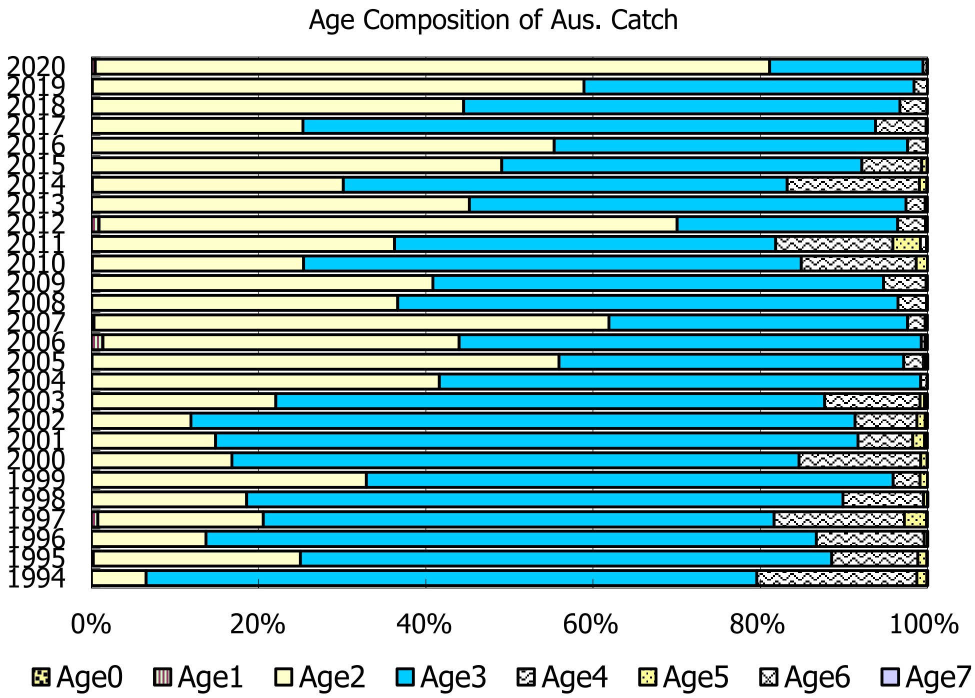


Fig. 2-2 Changes in the age composition of Australia purse seine catches.

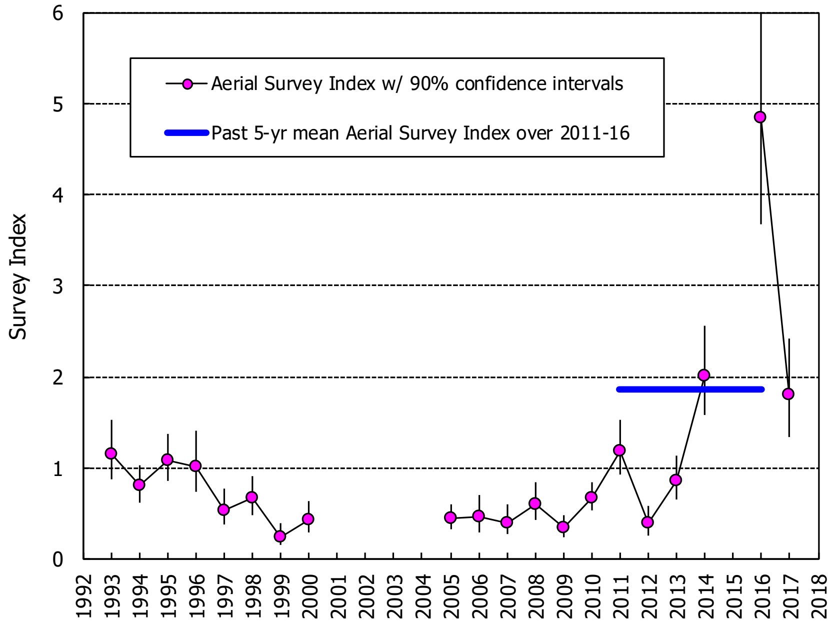


Fig. 2-3 Change in aerial survey index in the Great Australian Bight. Vertical bars indicate 90% confidence intervals.

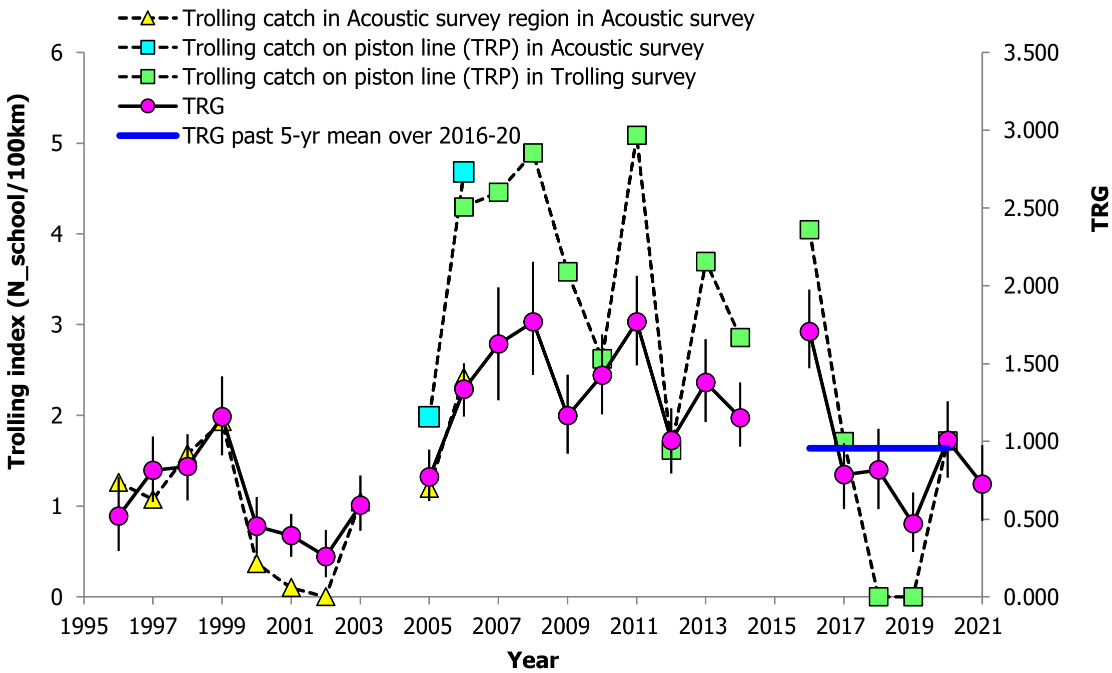


Fig. 3-1. Trends of various trolling catch index for age 1 SBT in the Western Australia. The previously reported trolling indices were indicated by dotted lines with symbols (Only the bootstrap estimates of median were plotted). "TRG" represents the standardized grid-type trolling index and vertical lines of each point indicate the bootstrap estimates of 90% confidence intervals.

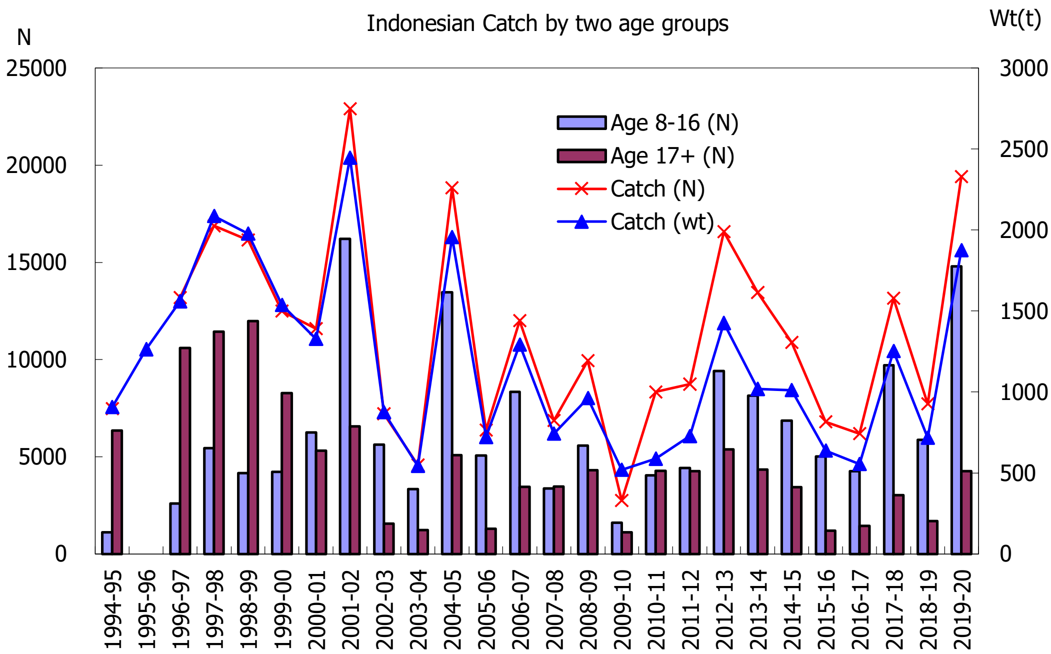


Fig. 4-1. Trends of Indonesian catches with proportion of two age groups occurrences.

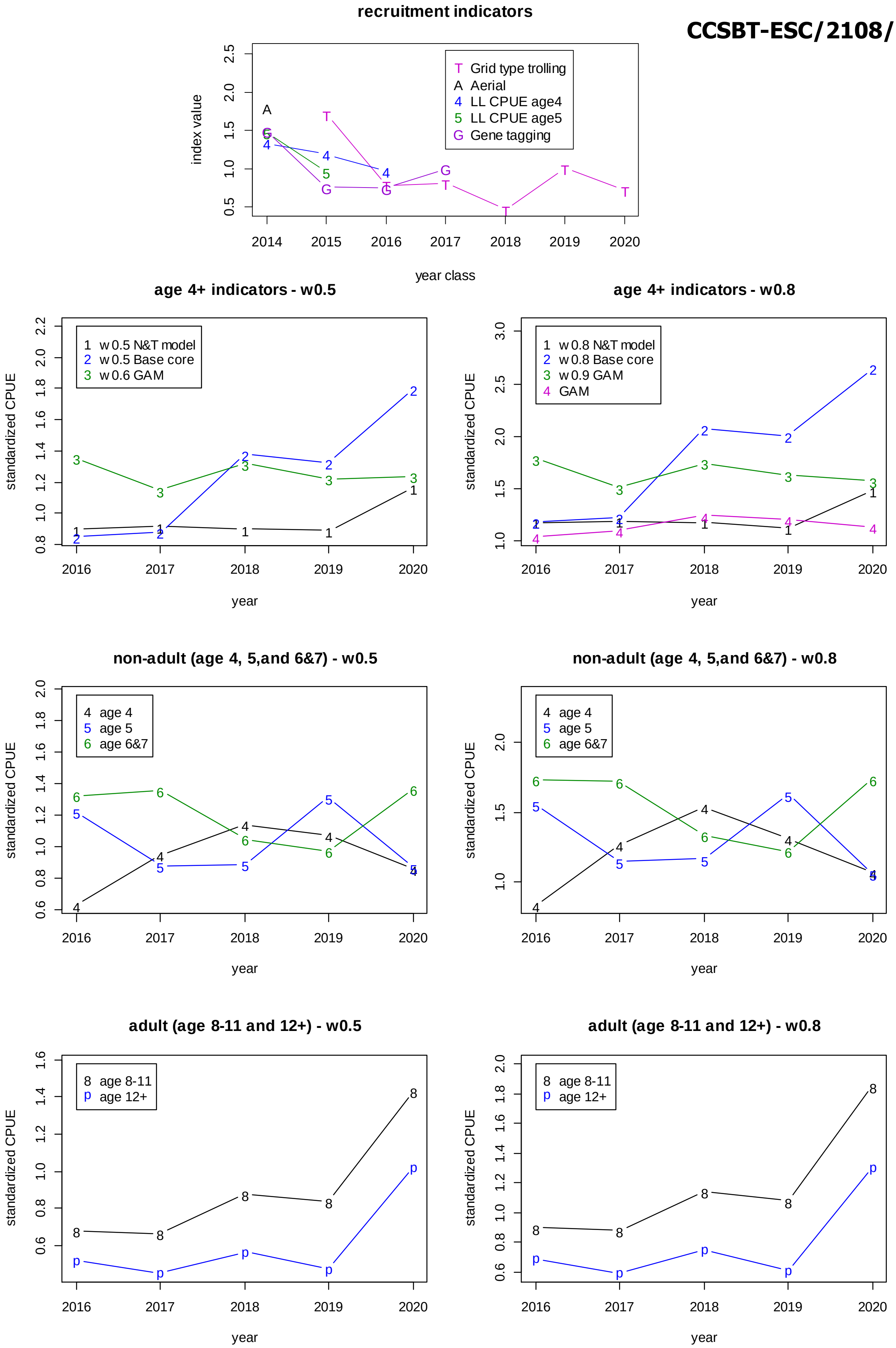


Fig. 5-1. Trends of recruitment and CPUE-based indicators in recent years. Note that in the top panel for recruitment indicators the x-axis is year class and the aerial survey (AS) index was plotted assuming that the AS index primarily represented the trend of age 3 SBT.