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Summary of Fisheries Indicators of Southern Bluefin Tuna Stock in 2020

Norio TAKAHASHI and Tomoyuki ITOH

Fisheries Resources Institute
Fisheries Research and Education Agency

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 age 4, 5, and 8-11 classes have more or less fluctuated around the past 5-year mean of 2014-18 in recent years. CPUE for age 6&7 group shows some decreasing trend in past three years. The indices for age class 12+ have gradually declined since 2011. This decline may relate to very low cohorts of 1999 to 2001. 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 in recent 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 very 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 2020 and the TRP recruitment index records zero values in 2018 and 2019, suggesting some concern of potential low recruitment in recent years. A high recruitment level of the 2013 cohort estimated from the OM in the 2017 stock assessment (directly pertained to the highest value of the 2016 AS index) is not supported by longline CPUE indices by age (4 and 5 years old) obtained in 2017 and 2018, 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指標は、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。近年、4歳、5歳、および8-11歳クラス魚の指数は過去5年間（2014-18）の平均の周りを大体変動している。6&7歳グループのCPUEは過去3年間にいくらか減少傾向を示している。12+歳クラスの指数は2011年以降徐々に減少してきている。この減少は1999年級から2002年級の非常な低加入に関係しているのだろう。このより高齢グループの現在の指数水準は依然として低い。オペレーティングモデルや管理方式に使用されている、年齢でまとめたその他のCPUE指数（4+歳グループ）は、近年、増加傾向を示している。それら指標の現在の水準は、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、近年の加入水準が、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年級の非常な低加入が起こる以前）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2020年まで多少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おり、近年の潜在的な低加入の懸念を幾分示していることには留意しておくべきである。2017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年級の高い加入水準（2016年航空目視指数の最高値に直接関係している）は、2017年および2018年に得られた年齢別延縄CPUE指数（4歳と5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。

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). Therefore, CPUE in the most recent year should be looked at with caution. However, those differences have disappeared gradually and almost no difference has been found in recent years because the RTMP covers more than 95% of efforts in SBT distribution.

CPUE indicators must be further looked to carefully from year 2006 onward because Japanese longline fishery has introduced Individual Quota (IQ) system since 2006. Changes in the number of catch and the distribution pattern of effort before and after 2006 were examined and discussed in detail in Itoh (2020a). 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 2020), both nominal CPUE and standardized CPUE (below) were calculated without including the

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

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 2019 value for this age was higher than the past 5-year mean over 2014-18. CPUE for age 4 has increased between from 2015 to 2019 except 2016. The age 4 CPUE in 2019 was higher than the past 5-year mean. The trend of CPUE for age 5 showed a decline from 2015 to 2016 and then has increased afterward. The most recent CPUE for age 5 was above the past 5-year mean. CPUE for age class 6&7 has increased since around 2010 and the value of 2019 was above the past 5-year average. Recent nominal CPUE for ages 8-11 showed an increasing trend except 2016 and 2017, and CPUE in 2019 was higher than the 5-year mean. CPUE for 12+ age group declined from 2008 to 2011 and has fluctuated around the same level as 2008 since 2011. 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 2010-2015 cohorts (Fig. 1-3). Within each period, variations of the CPUE levels were relatively small (except age 3 CPUEs in the 1999-2003 cohort) and deceasing rates were similar. For the 1999-2003 cohort, catch rates for age 3 varied considerably. As mentioned above, this large variation in catch rate would be due to change in catchability, population fluctuation, and/or releases/discards of small fish. 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 2010-2016 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 2019 (Areas 4, 7, 8, and 9) and 2020 (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 3 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 Area

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[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.

9, overall CPUE for 2020 was lower than previous years throughout April to July. No increase of CPUE was observed in 2017, 2018, 2019 and 2020 as corresponding to the recent 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 very high as shown by the scientific aerial survey index in 2016 for age 3 SBT, CPUE would also be very high in age 6 in 2019 and age 7 in 2020 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 2019 (the most recent year when catch and effort data are available) were based not on logbooks but RTMP data only, and thus should be looked at with caution as described in the Nominal CPUE section above. These estimates may be changed when logbook data become available the subsequent year (Takahashi et al. 2001). Further, as also mentioned above, CPUE in recent years must be examined carefully because Japanese longline fishery has introduced the IQ system since 2006 (Itoh 2020a).

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 2019 indices for this age were above the past 5-year averages over 2014-18. The CPUE index for age 3 has varied from year to year (see Fig. 1-2), and thus its trend is not necessarily consistent with 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 show increase trends in recent years (Fig. 1-5b). This age 4 indices may also be influenced by small fish releases/discards in recent years. The 2019 indices for age 4 were higher than the past 5-year averages.

The CPUE indices for age 5 dropped in 2017 and increased back to the 2016 level in 2019 (Figs. 1-5c). The indices for age 5 in 2019 were higher than the past 5-year means.

The CPUE indices for age group 6&7 decreased from 2017 to 2019 (Figs. 1-5d). The indices for this age class in 2019 were lower than the past 5-year averages.

The CPUE index values for age group 8-11 decreased from 2015 to 2016 and then upturned in 2018 (Fig. 1-5e). The 2019 indices for this age class were at the similar level to the past 5-year average.

The CPUE indices for age 12+ have shown gradual declining trends in recent years (Fig. 1-5f). 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 2019 for this age group were lower 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 2020); "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 2020); "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 is newly agreed CPUE index used for the 2020 stock assessment (CCSBT 2020, Hoyle 2020); "Base glmm_YearArea" which used the same data and model as the Base except using a generalized linear mixed model (GLMM) and treating Year*Area term as a random effect (Itoh 2020b).

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). The Base GAM shows the most divergent trend among the series. Itoh (2020b) 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+ have showed increasing trends since 2009.

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 2019. The 2019 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 (Hoyle et al. 2020) while Japanese core vessels CPUE was based on data aggregated by 5x5 degree square and age (age 4+) (Itoh and Takahashi 2020). 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)* [3] with GLM standardization estimates (cf. Informal Record of the June 2017 CPUE Web Meeting). "glmm" and "GAM" are based on the core vessels data and the Base model except analyses were based on GLMM and GAM, respectively (Tomoyuki Itoh, *pers. comm.*)

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 larger, especially in 2018 and 2019.

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 appeared to decline gradually from 1999/00 to 2008/09 seasons (Fig. 2-1). This decline of juvenile fish probably corresponded to very low recruitments that were observed in the grid-type trolling index (TRG) and Japanese longline CPUE (Figs. 1-1, 1-4, and 1-5 for the longline, and Fig. 3-1 for the TRG). There were large upturns of both CPUEs observed in 2009/10 season, then the CPUEs decreased toward

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[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.

2011/12. The CPUEs increased again toward 2013/14 season and have fluctuated more or less around the same levels afterward except that catch/shot dropped 2017/18. Both catch/shot and catch/search hour in 2018/19 season were below the past 5-year mean over 2014-18.

Generally, the proportions for age 2 fish in purse seine catch between 2004 (03/04 season) and 2019 (18/19 season) were greater than any of other years except for 2010, 2014, and 2017 (Fig. 2-2). 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, and 2016, 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 has been conducted by Australia since 1993. Full scale line transect AS was suspended between 2001 and 2004. The AS has 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 is now 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 is not available after 2017, 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 2018, in total, 6,295 fish were tagged in 2018, 11,980 fish were included in the harvest sample set of 2019, and 66 matches were detected (Preece et al. 2020, Table 1). The abundance estimate is 1,142,638 with CV of the estimate of 0.123. The age 2 abundance estimate for 2017 decreased to about half of 2016 and the estimate for 2018 was similar to 2017.

Table 1. The results of the gene-tagging programs 2016-2018.

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

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 and Tsuda (2019a). In addition, standardization of the trolling survey index (called "grid-type trolling index (TRG)") was described in Itoh and Tsuda (2020b). 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 2020. 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 of previously reported trolling indices and of the TRG. For the previous trolling indices, only the bootstrap estimates of median were plotted. The median relative trends of both previous index and TRG appeared similar although there were 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.

Cohorts of 1999, 2000, and 2001 (corresponding to the 2000, 2001, and 2002 trolling surveys) showed considerably low levels of recruitment. These cohorts have already entered to age class 12+ and appeared in CPUE series in 2011 onward, showing somewhat slight and gradual declining trends (Fig. 1-5f).

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 and Tsuda (2020b)). The trolling indices, especially for the TRG, could be used as quantitative indicators for recruitment.

3. Indonesian Catch (Spawning ground fishery):

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 Sulistyaningsih et al. 2020). 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, based on revised length data analyzed for most recent spawning seasons (up to 2018/19) which only included SBT catches by vessels predominantly operating in Area 1 (spawning ground), Sulistyaningsih et al. (2020) advise that catches of small/young SBT appear to be from the spawning ground. Further examination to resolve identified uncertainties of the catch location of these small/young fish and refinement/improvement of the quality control of the monitoring program need to continue to be pursued.

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 afterward. Catches for both age groups increased in 2017/18.

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 age 4, 5, and 8-11 classes have more or less fluctuated around the past 5-year mean of 2014-18 in recent years. CPUE for age 6&7 group shows some decreasing trend in past three years. The indices for age class 12+ have gradually declined since 2011. This decline may relate to very low cohorts of 1999 to 2001. 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 in recent 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 very 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 2020 and the TRP recruitment index records zero values in 2018 and 2019, suggesting some concern of potential low recruitment in recent years. A high recruitment level of the 2013 cohort estimated from the OM in the 2017 stock assessment (directly pertained to the highest value of the 2016 AS index) is not supported by longline CPUE indices by age (4 and 5 years old) obtained in 2017 and 2018, 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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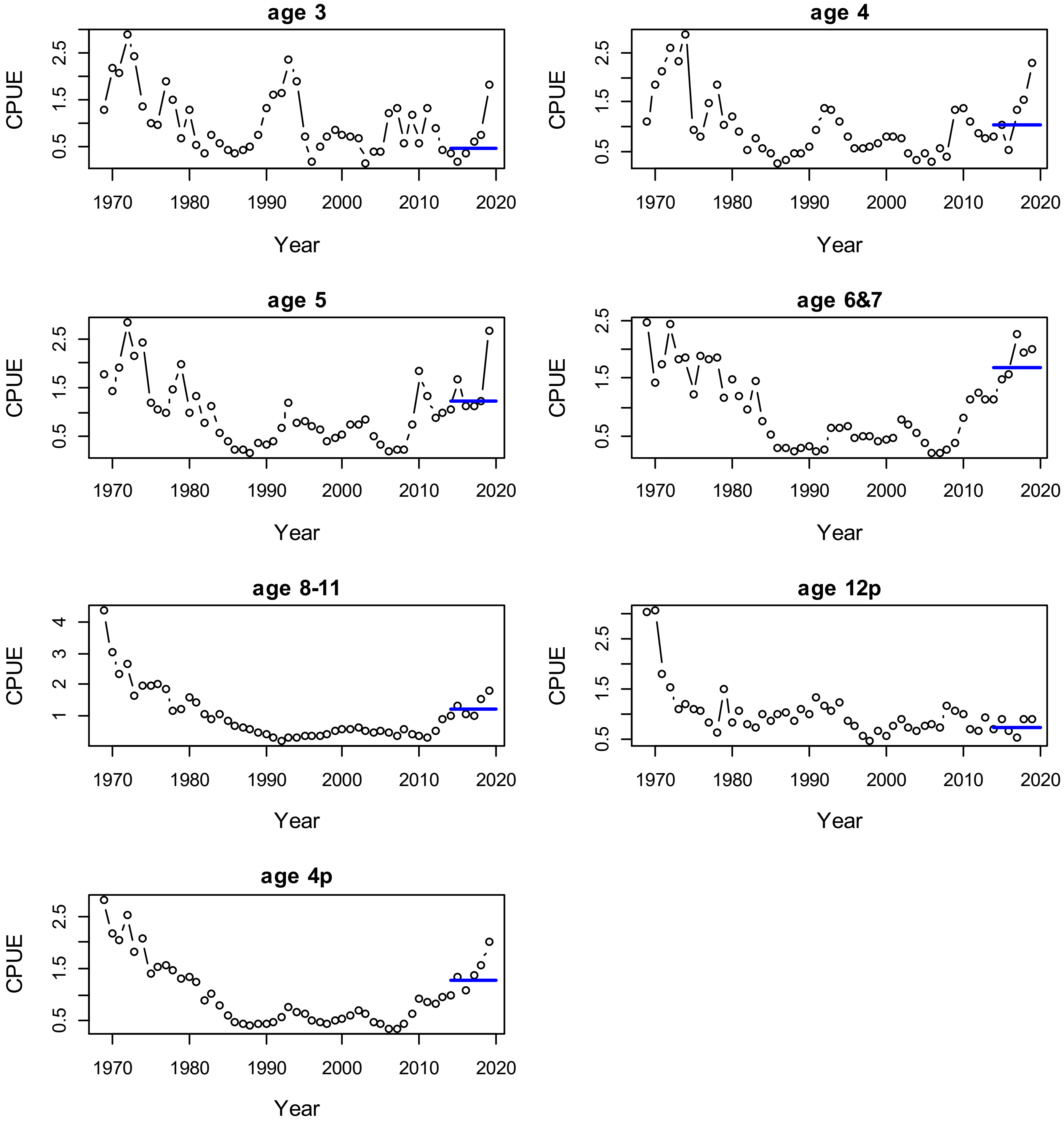


Fig. 1-1. Nominal CPUE of Japanese longline fishery by age groups. The horizontal lines indicate the past 5-year averages over 2014-18.

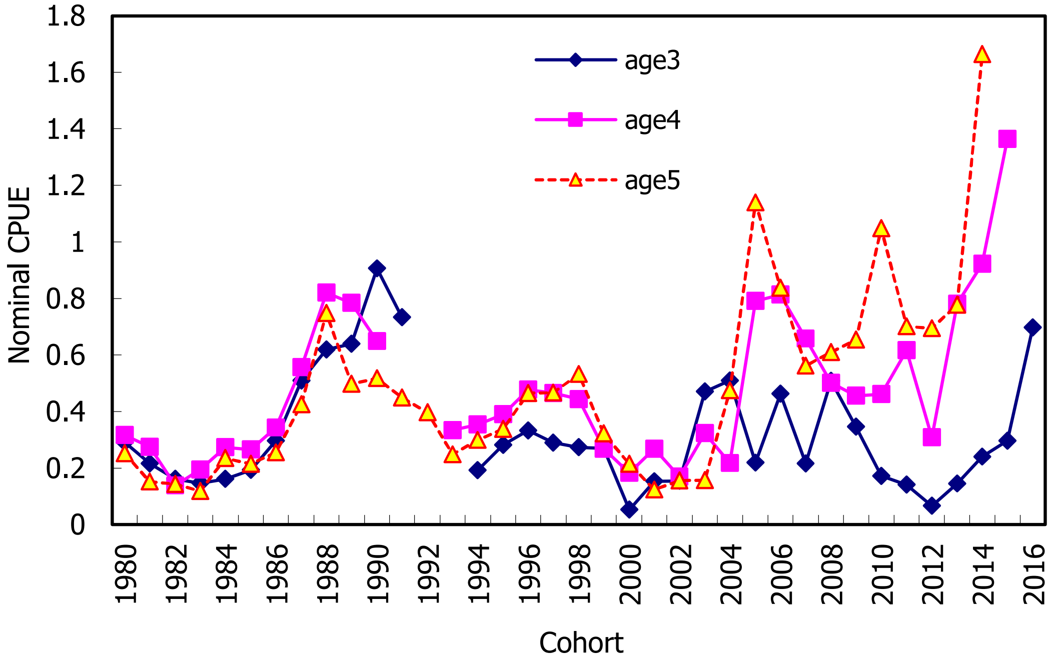


Fig. 1-2. Nominal CPUE of Japanese longline fishery by cohorts for age 3, 4, and 5.

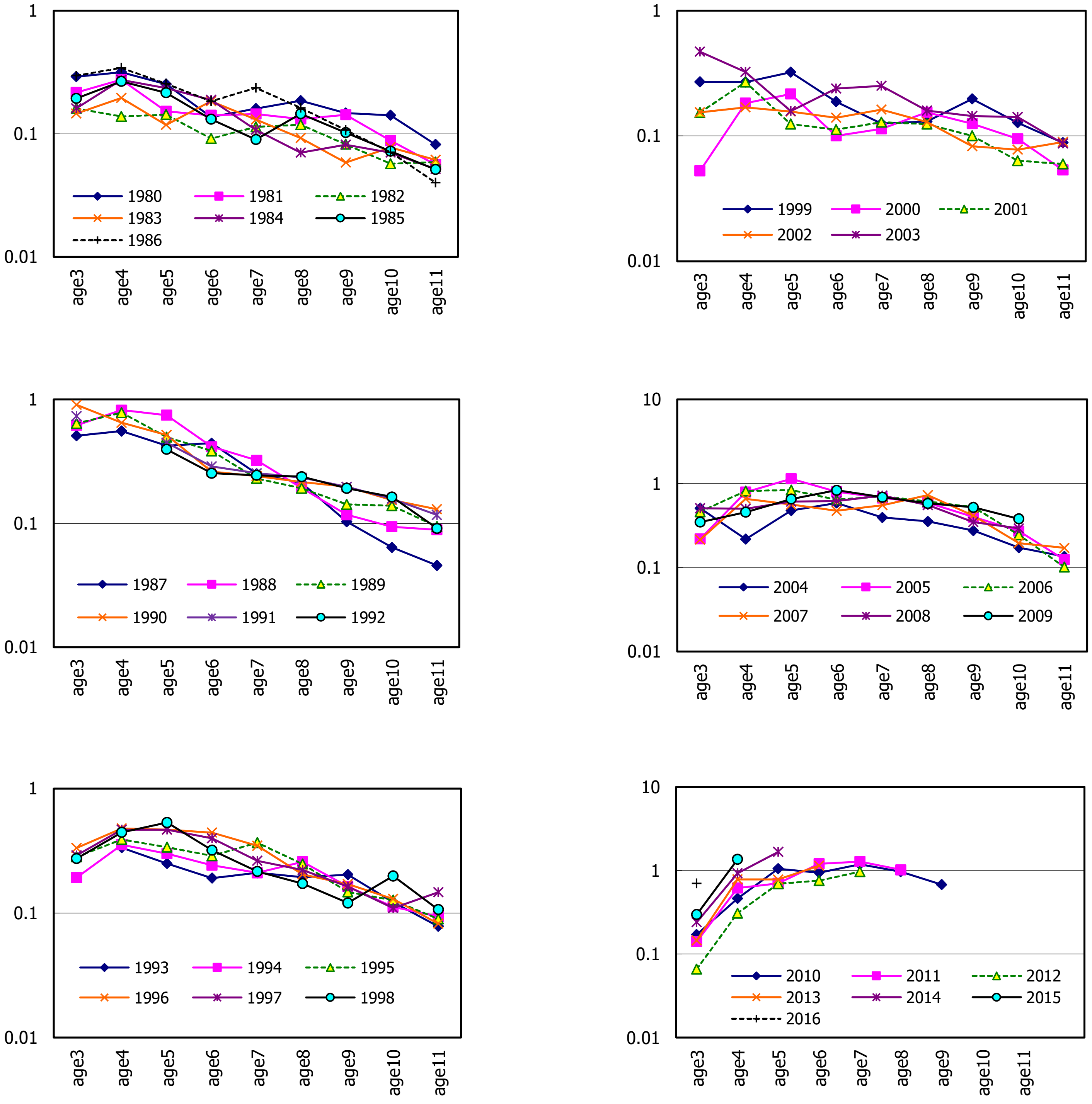


Fig. 1-3. Nominal CPUE of Japanese longline fishery by cohorts in log-scale.

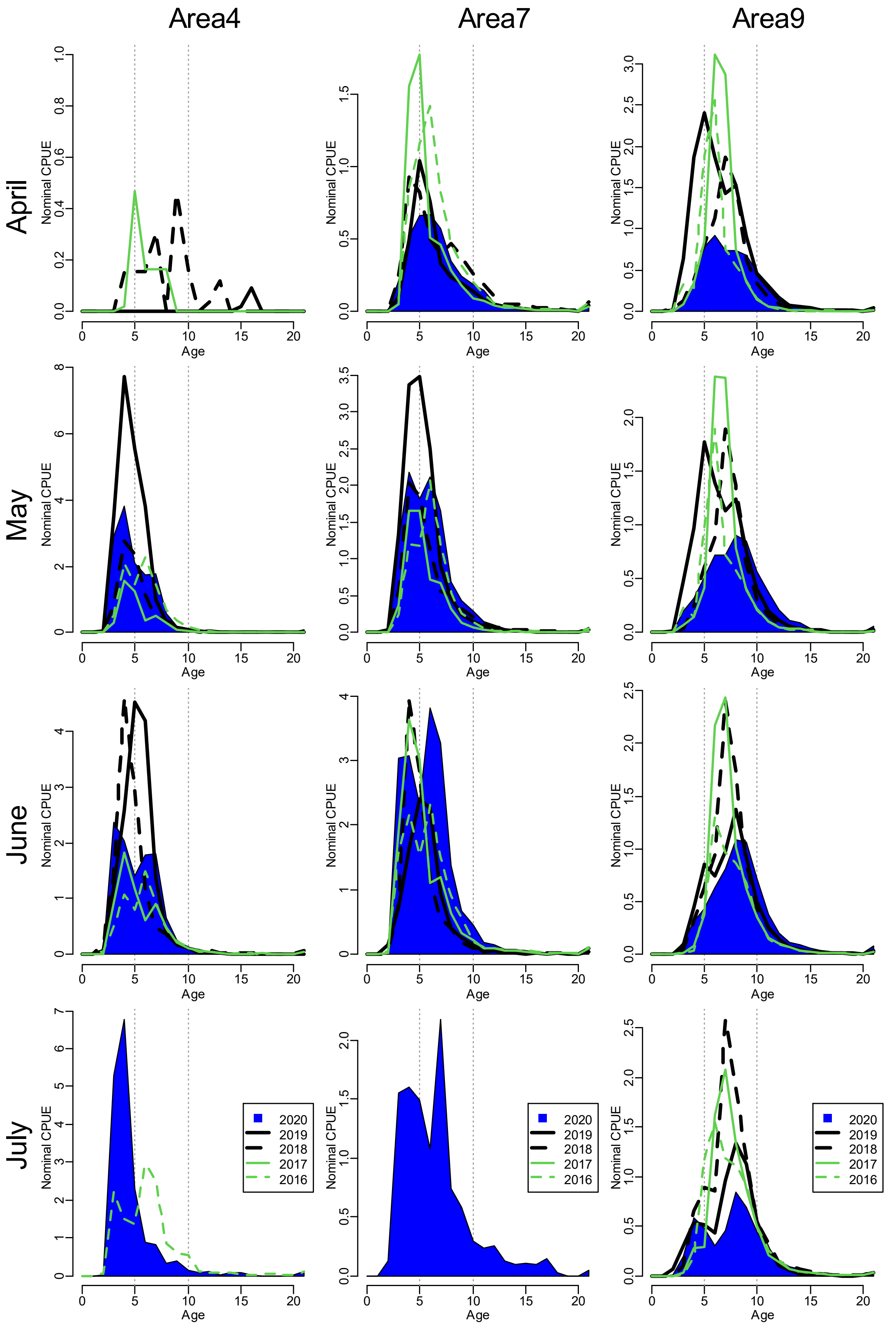


Fig. 1-4. Age composition of nominal CPUE of RTMP data for recent five years by month and areas.

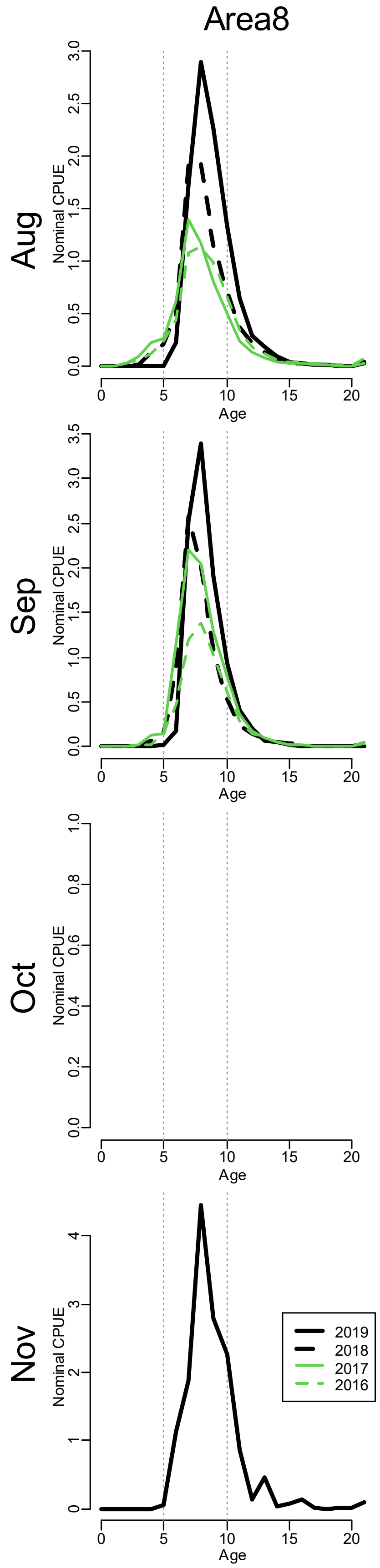
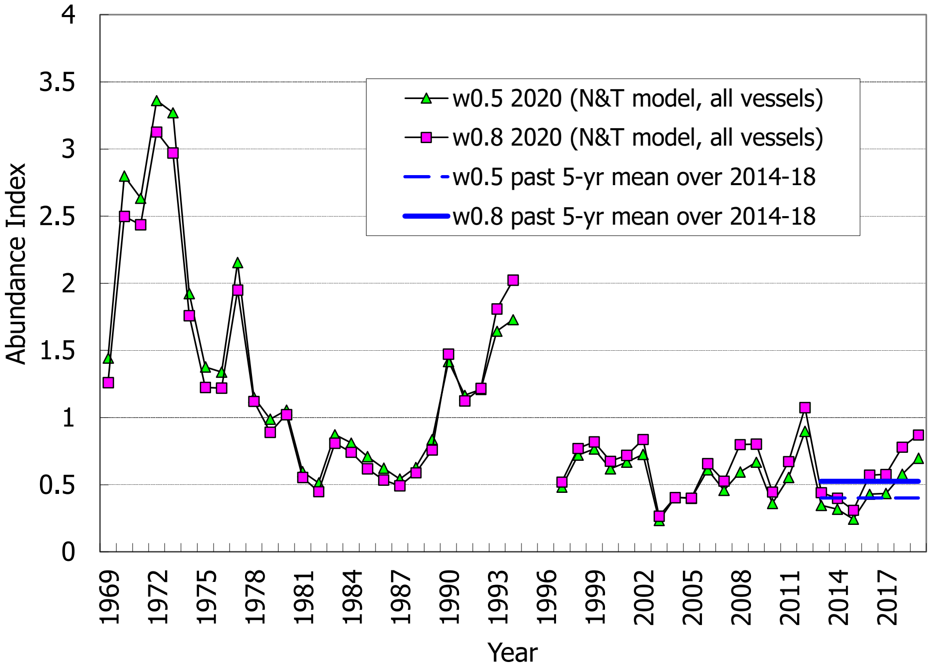


Fig. 1-4 (cont'd). Age composition of nominal CPUE of RTMP data for recent four years by month and areas.

(a) Age 3



(b) Age 4

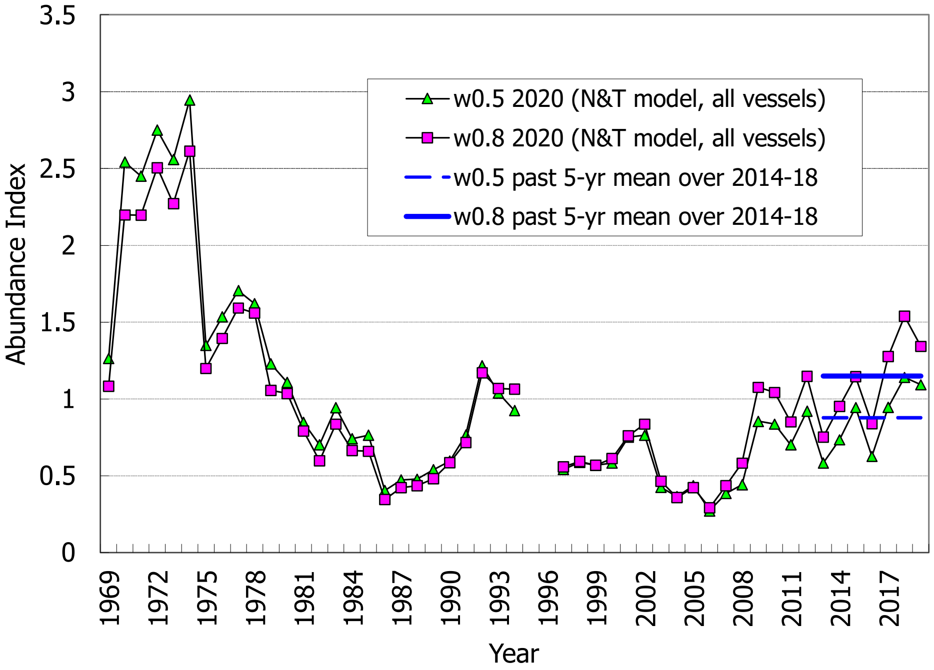
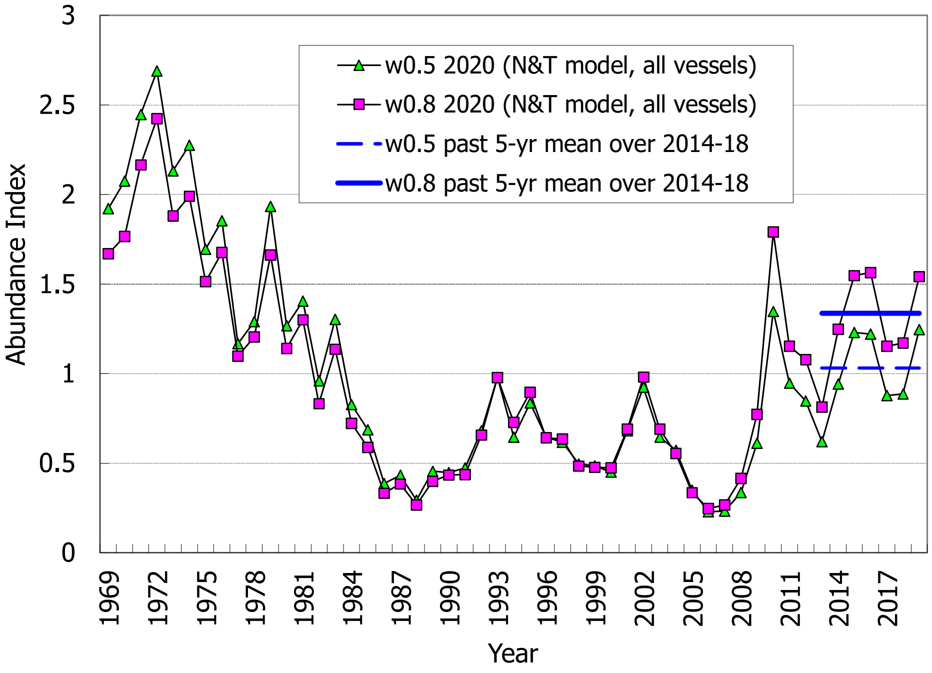


Fig. 1-5. Trends of normalized w0.5 (B-ratio proxy) and w0.8 (Geostat proxy) abundance indices. The standardization model used was the same as that of Nishida and Tsuji (1998).

(c) Age 5



(d) Age 6&7

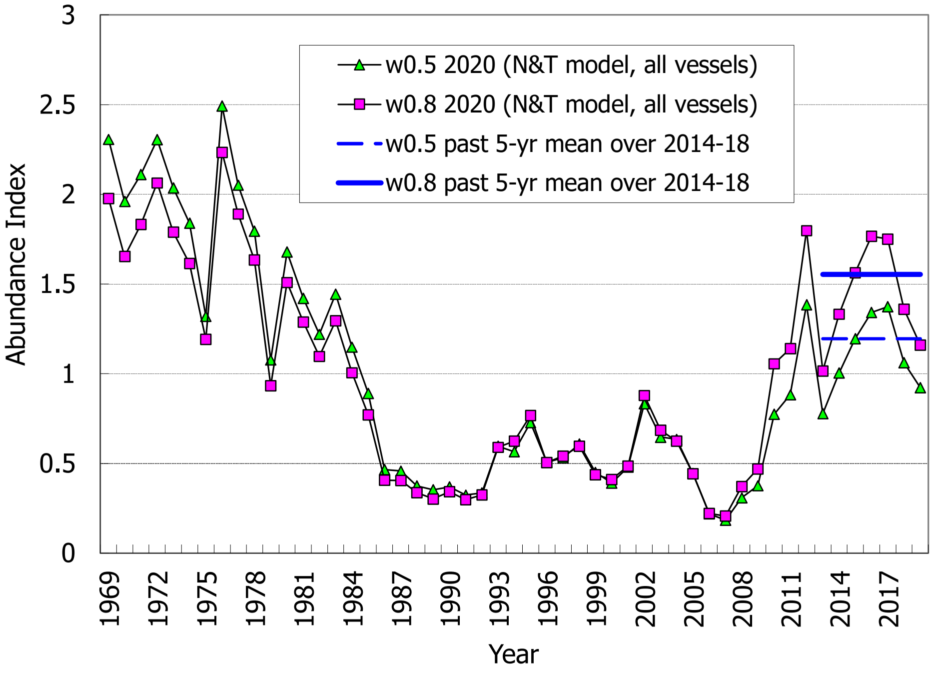
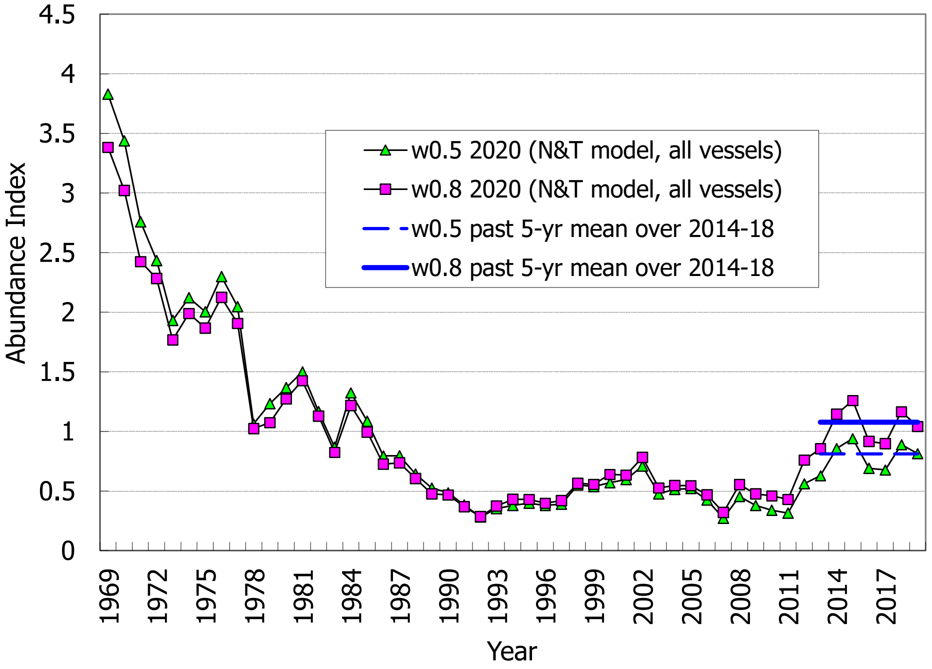


Fig. 1-5. Trends of normalized w0.5 (B-ratio proxy) and w0.8 (Geostat proxy) abundance indices. The standardization model used was the same as that of Nishida and Tsuji (1998). (cont'd)

(e) Age 8-11



(f) Age 12+

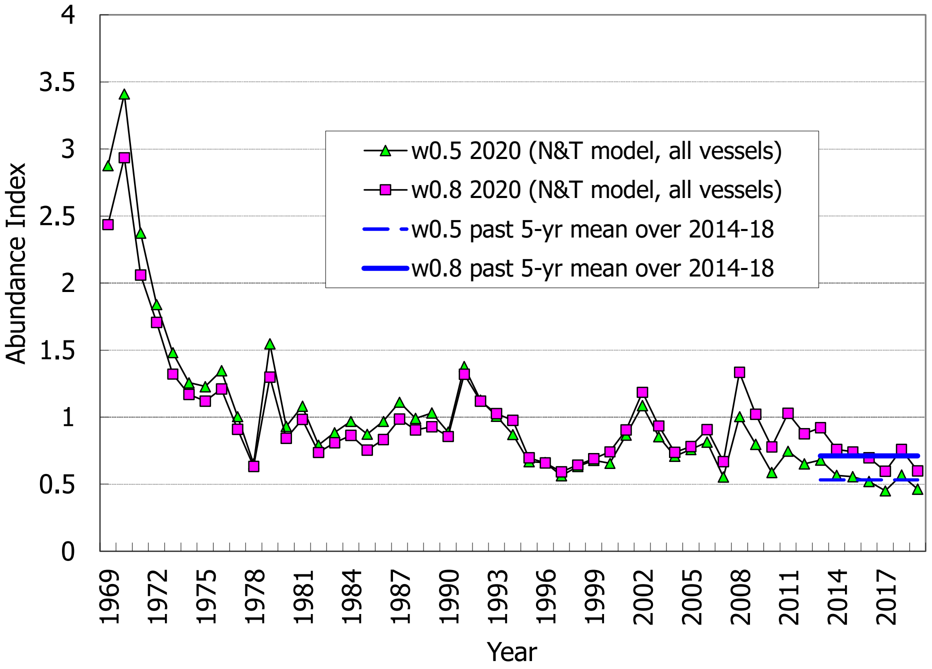
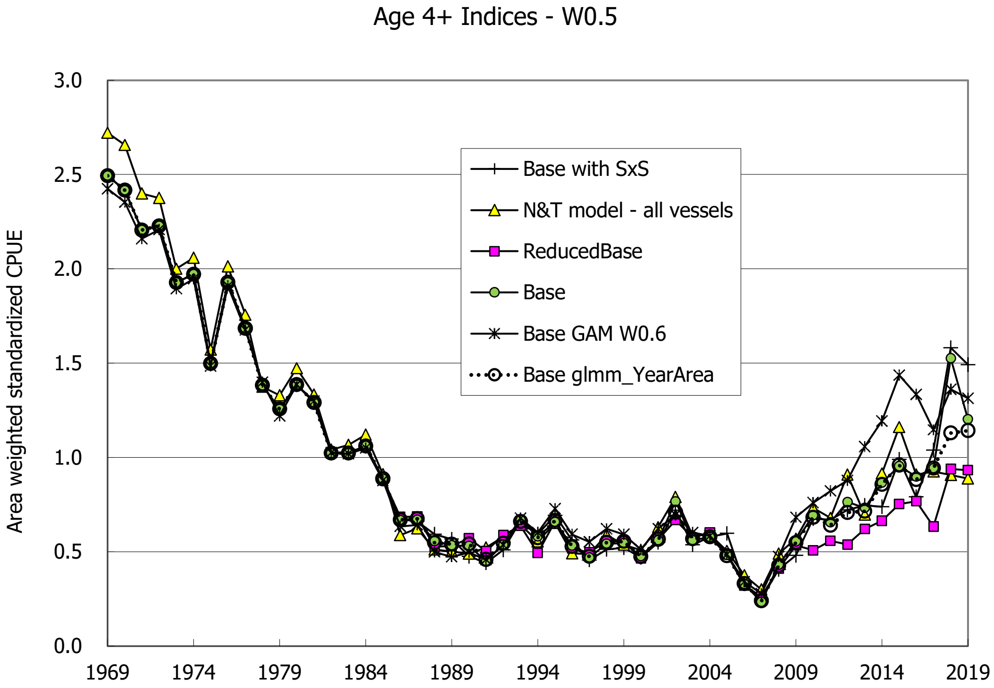


Fig. 1-5. Trends of normalized w0.5 (B-ratio proxy) and w0.8 (Geostat proxy) abundance indices. The standardization model used was the same as that of Nishida and Tsuji (1998). (cont'd)



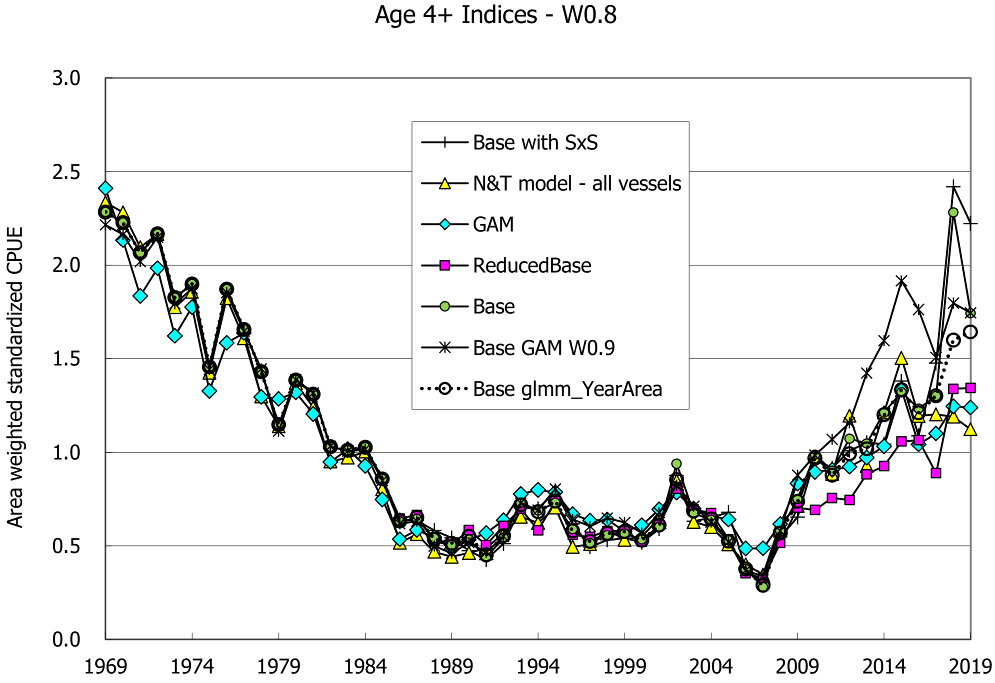


Fig. 1-6. Trends of various abundance indices for age 4+: Base model (Base) with core vessel data (Core); Reduced Base model with Core; Base with shot-by-shot Core; Base without area 7 data; Nishida & Tsuji model with all vessel data; GAM with all vessel data. GAM series was plotted together with w0.8 series as overall levels of these indices are similar.

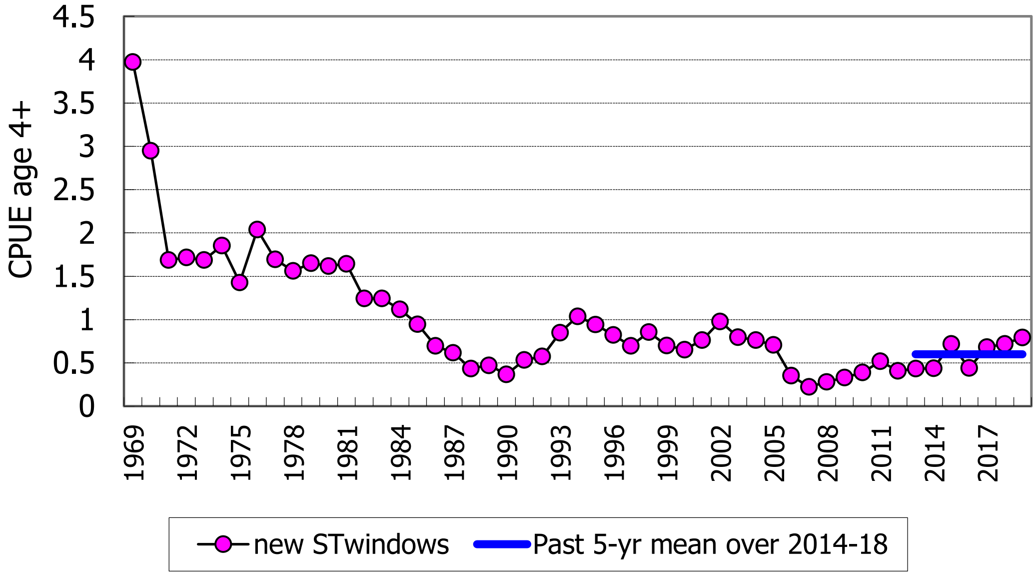


Fig. 1-7. Trend of normalized "ST Windows" index for age 4+ fish by the new calculation method.

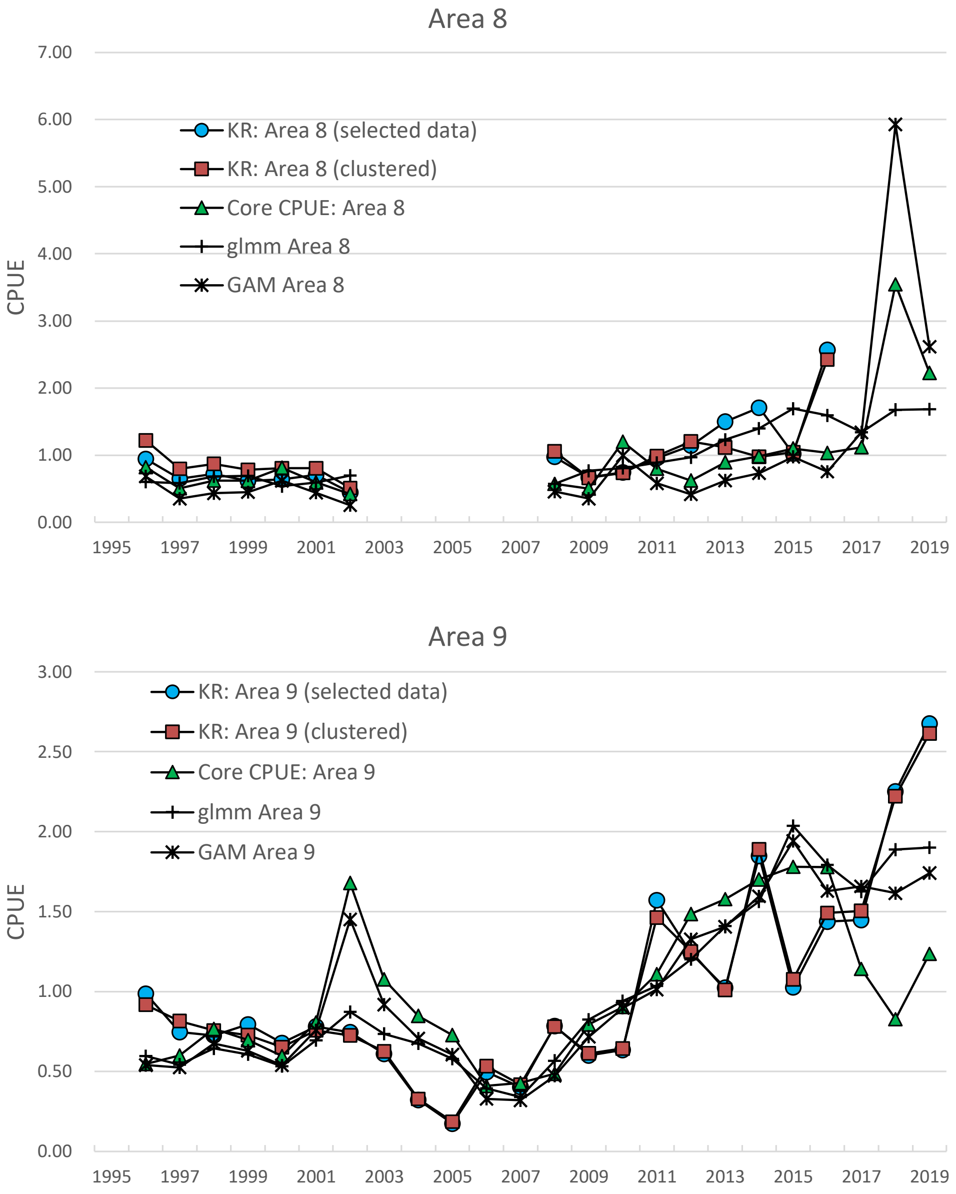


Fig. 1-8. Comparison of CPUE index trends between Korean longline CPUE (lognormal and clustering standardization approaches) and Japanese core vessels longline CPUE.

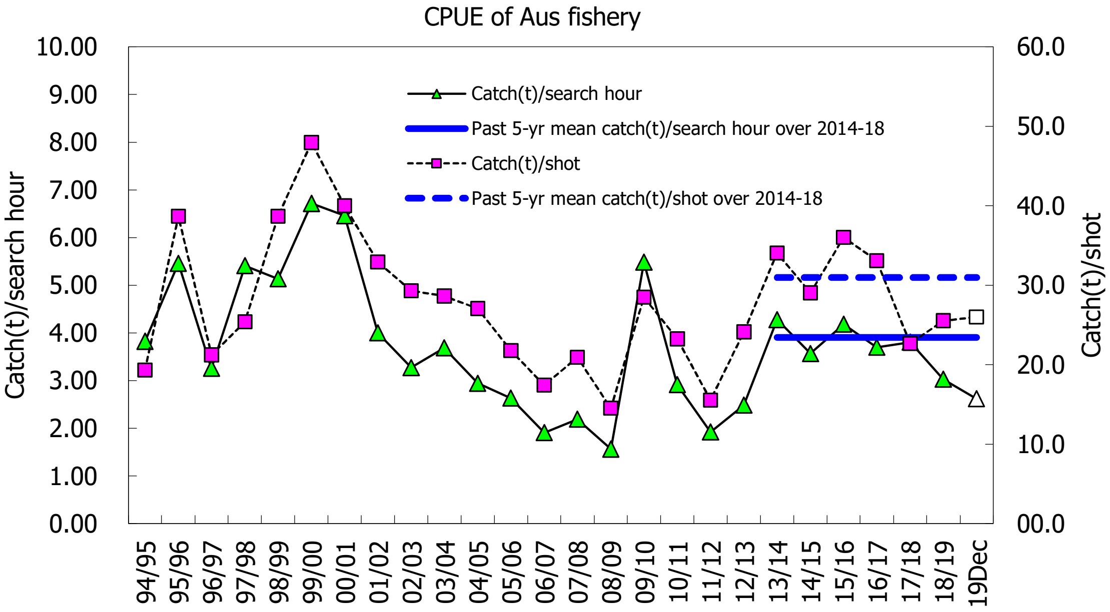


Fig. 2-1 Catch (in weight) per effort for Australia purse seine fishery.

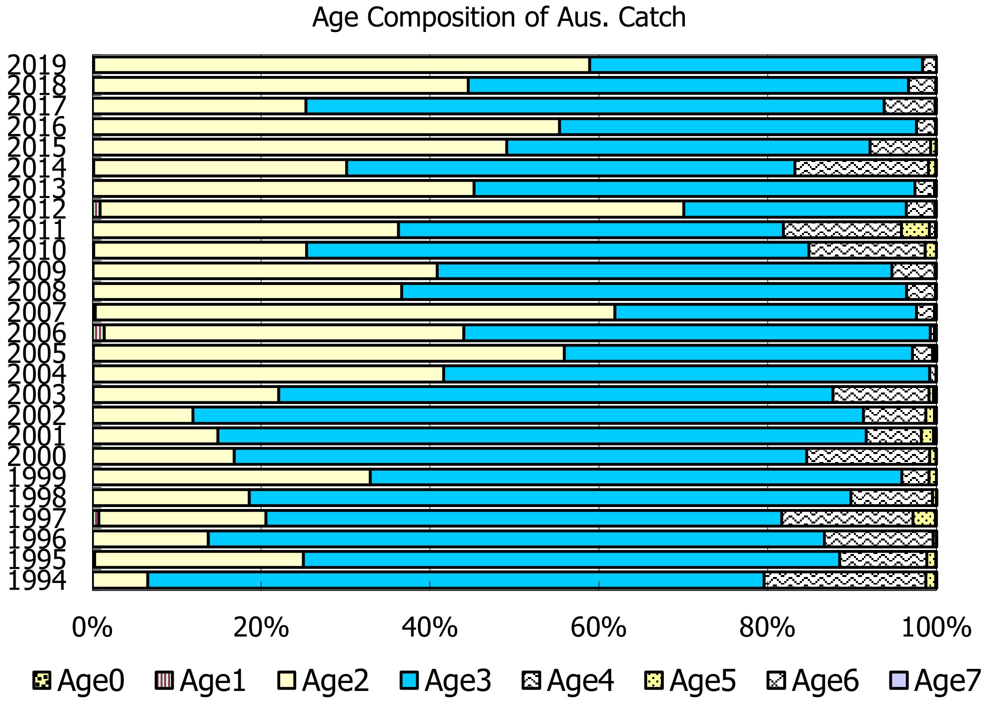


Fig. 2-2 Changes in the age composition of Australia purse seine catches.

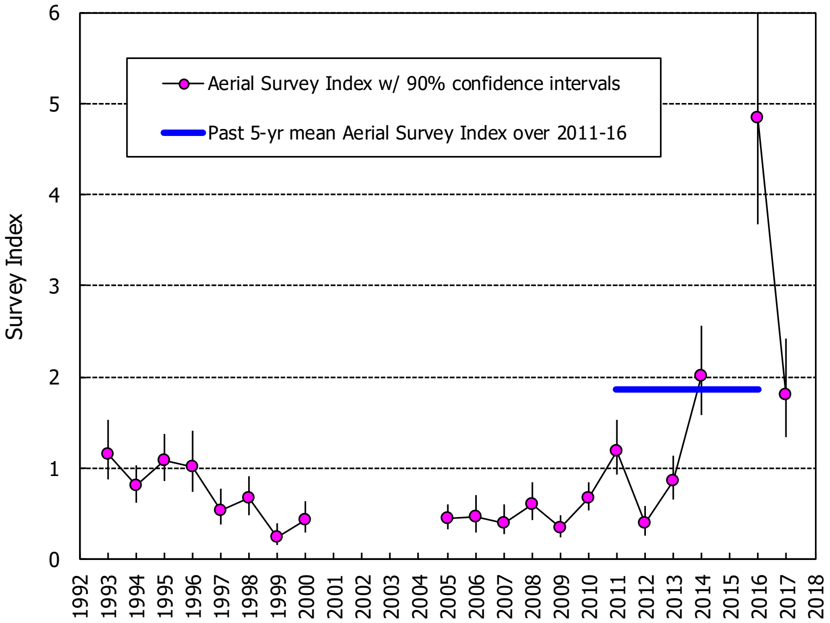


Fig. 2-3 Change in aerial survey index in the Great Australian Bight. Vertical bars indicate 90% confidence intervals.

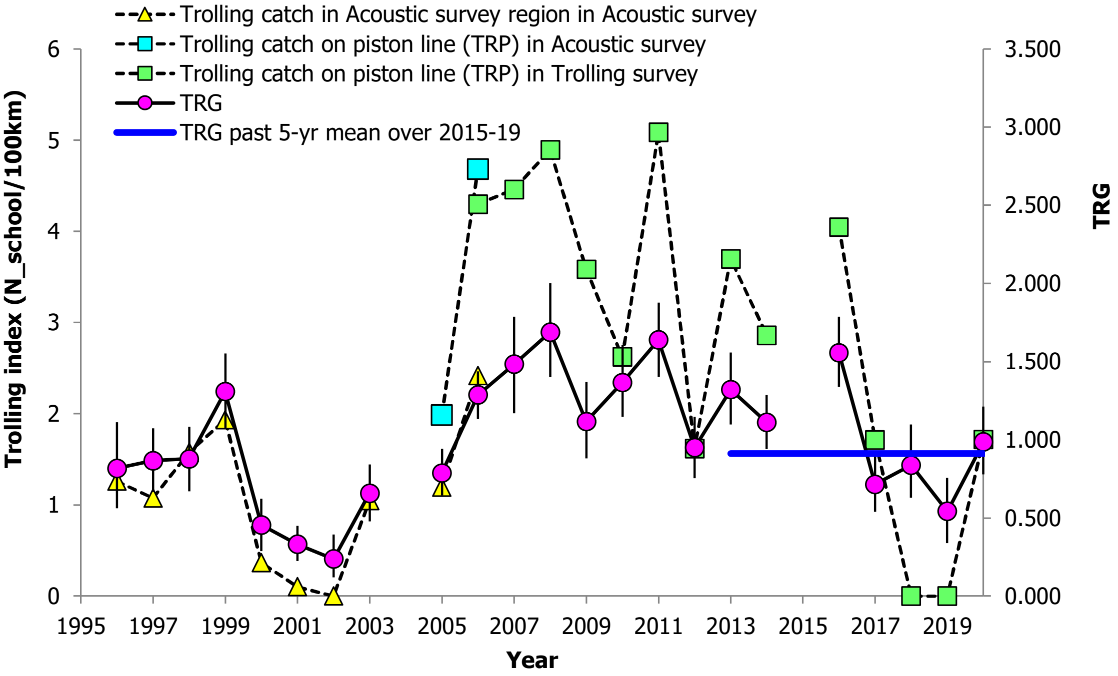


Fig. 3-1. Trends of various trolling catch index for age 1 SBT in the Western Australia. The previously reported trolling indices were indicated by dotted lines with symbols (Only the bootstrap estimates of median were plotted). "TRG" represents the standardized grid-type trolling index and vertical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

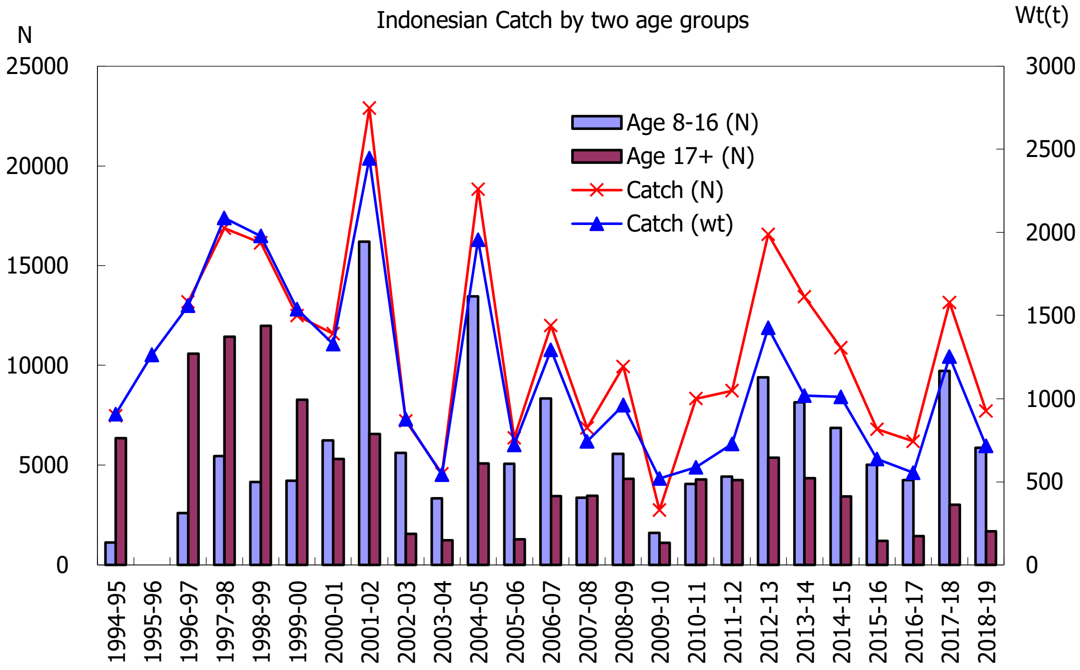


Fig. 4-1. Trends of Indonesian catches with proportion of two age groups occurrences.

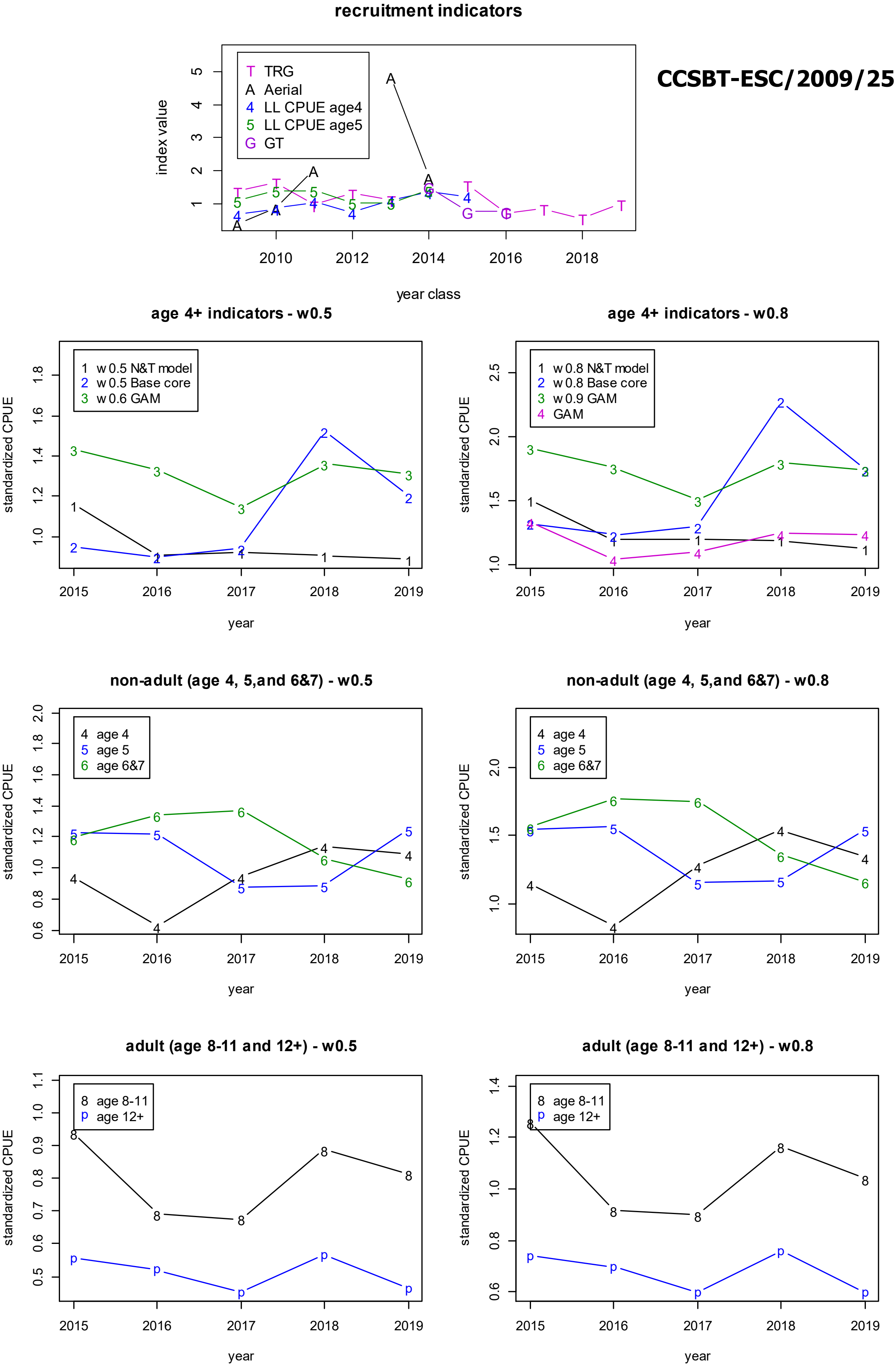


Fig. 5-1. Trends of recruitment and CPUE-based indicators in recent years. Note that in the top panel for recruitment indicators the x-axis is year class and the aerial survey (AS) index was plotted assuming that the AS index primarily represented the trend of age 3 SBT.