Summary of Fisheries Indicators of Southern Bluefin Tuna Stock in 2015

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Abstract : Fisheries indicators along with fishery-independent indices were carefully examined to overview the current status of southern bluefin tuna stock. The longline CPUE indicators suggest that the current stock levels for 4, 5, and 6&7 age groups are well above the historically lowest levels observed in the late 1980s or the mid-2000s. CPUE indices for age 4 and 5 classes show somewhat decreasing trends in recent years. The CPUE indices for age 8-11 group have increased gradually in recent 4 years. The indices for age class 12+ decreased from 2008 to 2010 and have fluctuated around at a low level afterward. The current levels for these older age groups are still very low similar to ones observed in past. Other age-aggregated (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.

要旨：ミナミマグロの資源状態を概観するため、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。はえ縄 CPUE 指標は、現在の 4、5、及び 6&7 年齢グループの資源水準が 1980 年代後半と 2000 年代中頃に見られた歴史的最低レベルより十分上にあることを示している。近年、4 及び 5 歳クラスに対する指数はいくぶん減少傾向を見せている。8-11 歳グループの CPUE 指数は最近 4 年間徐々に増加している。12+歳クラスの指数は 2008 年から 2010 年まで減少し、その後は低水準で変動している。これらのより高齢グループの現在の水準は、依然として過去に見られた極めて低い水準に近い。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+ 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 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。

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. Also, the 3rd Meeting of Management Procedure Workshop in 2004 agreed to review fisheries indicators every year to monitor whether the SBT stock status stays within an expected range of uncertainty which is considered in the operating model (OM) (CCSBT 2004). 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 of 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. These indicators based on Japanese longline fishery data, including those of joint-venture with Australia and New Zealand[2]. Data in the most recent year exclusively rely on information collected by the Real Time Monitoring Program (RTMP) which covers only 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). So 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 (2015). 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 commercial value of small fish is low.

When focusing on trends for the recent past years, nominal CPUE for age 3 has fluctuated around the past 5-year mean over 2009-13 (Fig. 1-1). The 2014 value for this age was lower than the mean. The points of the recent 4 years show a decreasing trend. CPUE for age 4 largely increased between 2008 and 2009, and then consecutively decreased afterward. The age 4 CPUE in 2014 was slightly lower than the past 5-year mean. The trend of CPUE for age 5 has a very similar pattern to that for age 4 with 1-year lag. The most recent CPUE for age 5 was at the same level as the past 5-year mean. CPUE for age class 6&7 increased around 2010 and the value of 2014 was above the 5-year average. Recent nominal CPUE for ages 8-11 showed an increasing trend and CPUE in 2014 was greater 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 almost similar to 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

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

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 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 and 2004-2011 cohorts (Fig. 1-3). Within each period, variations of the CPUE levels were small (except for age 3 CPUEs in 1999-2003 and 2004-2011 cohorts) and decease rates were similar. For 1999-2003 and 2004-2011 cohorts, catch rates for age 3 varied considerably. As mentioned above, these large variations in catch rate would be due to change in catchability, population fluctuation, and/or releases 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 2004-2008 cohorts were similar to the late 1980s 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 2004-2011 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 2014 (Areas 4, 7, 8, and 9) and 2015 (Areas 4, 7 and 9) obtained from 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 5 and 10 while the overall age composition ranged from about age 3 to over age 15. Most of smaller fish (5 years old and younger) were caught in Areas 4, 7, and 9, whereas many catches of larger fish (over 10 years old) were observed in Area 8. There is no unusual event detected in age composition of CPUE in recent years.

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). The standardization model used was the same as that of Nishida and Tsuji (1998). Estimates of the CPUE indices for 2014 (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 mentioned above, CPUE in recent years must be examined carefully because Japanese longline fishery has introduced the IQ system since 2006 (Itoh 2015).

Looking to trends in recent years, the w0.5 and w0.8 indices for age 3 have alternatively repeated increase and decrease by 2 or 3 years cycle (Fig.1-5a). The 2014 indices for this age were lower than the past 5-year averages over 2009-13. The CPUE index for age 3 has varied from year to year, especially in recent years (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 release 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 continuously increased from 2006 to 2009 and have tended to decrease gradually since 2009 although there was slight increase from 2010 to 2012 (Fig. 1-5b). The 2014 indices for age 4 were lower than the past 5-year means over 2009-13.

The CPUE indices for age 5 showed continuous increasing trends from 2007 to 2010 and have declined afterward (Figs. 1-5c). This increase between 2007 and 2010 may be corresponding to ones observed in the grid type trolling index (GTI) between 2003 and 2006 (Fig. 3-1). The indices for age 5 in 2014 were slightly lower than the past 5-year means.

As same as age 5, the CPUE indices for age group 6&7 increased steadily from 2007 to 2012 and then decreased in 2013 (Figs. 1-5d). The increasing trend between 2007 and 2012 may relate to ones observed in the GTI between 2001 and 2007 (Fig. 3-1). The indices for this age class in 2014 were slightly above the past 5-year averages.

The CPUE index values for age 8-11 decreased slightly and gradually from 2008 to 2011 and have increased afterward (Fig. 1-5e). The declining trend between 2008 and 2011 may correspond to low recruitments of 1999-2002 cohorts observed in the 2000-2003 GTI (Fig. 3-1). The increasing trend after 2011 might indicate that 2003 to 2006 cohorts which came after the weak recruitments between 1999 and 2002 have started entering into the 8-11 age group. The 2014 indices for this age class were increased to the levels higher than the past 5-year average.

The CPUE indices for age 12+ showed a decline from 2008 to 2010 and have fluctuated around at a considerably low level afterward (Fig. 1-5f). This decline and staying at the low level of the indices may relate to weak cohorts of 1999 to 2001 observed in the 2000-2002 GTI (Fig. 3-1). The indices in 2014 for this age group were at similar levels to the 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 Vessel data and the standardization model agreed in the CPUE modeling Group (CCSBT 2010b, Itoh and Takahashi 2015); “Base with SxS” series which used the same data and model as the Base except that data resolution was by shot-by-shot basis; “Base 40&45 combined” series which is same as the Base except for combining data of 40S and 45S latitudes (CCSBT 2014); “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 2015); “GAM” series which was based on standardization by a general additive model (GAM) using 5x5-degree aggregated all vessel data (Chambers 2014); “N&T model” series which used Nishida and Tsuji (1998) model and 5x5-degree aggregated all vessel data.

The Base series is the one used for the operating model (OM) conditioning and management procedure (MP) inputs in the ESC. Other series are used for monitoring to check if there is any unexpected thing happened to both SBT and the fishery along with the Base series. The N&T model series had been used in stock assessment 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 except that the trends of

Reduced Base series in recent years were different from those of other indices (Fig. 1-6). These differences is to continue to be monitored and examined in the CPUE Working Group. All the indices had increased from 2007 to 2010 and then appear to stay at the similar level afterward.

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 decided to include this series in this document.

The trend of the ST windows is shown in Fig. 1-7. The index increased gradually from 2007, when the historically lowest level was observed, to 2011, and then has kept at the same level about 0.5 thereafter. It would be worthwhile to mention here that the trend of the ST windows looks similar to those of CPUE indices for 8-11 or 12+ age groups (Fig. 1-1 and Fig. 1-5e and 1-5f), suggesting that the series could partly capture some signal of spawning stock dynamics. The index value in 2014 was at the similar level to the past 5-year average.

2. Recruitment indices (Australia purse seine fishery and its related indices):

Changes of catch (in weight) per effort and age composition of Australia purse seine fishery catches were plotted in Figs. 2-1 and 2-2. 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 the aerial survey index and SAPUE (below).

Both catch per shot and catch per searching hours 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 GTI and Japanese longline CPUE (Figs. 1-1, 1-4, and 1-5 for the longline, and Fig. 3-1 for the GTI). There were large upturns of both CPUEs observed in 2009/10 season, then the CPUEs decreased toward 2011/12 and show increasing trends afterward. Both CPUEs in 2013/14 season were higher than the past 5-year means over 2009-13.

Generally the proportions for age 2 fish in purse seine catch between 2004 (03/04 season) and 2014 (11/14 season) were greater than any of previous years except for 2010 and 2014 (Fig. 2-2). Contrary, proportions for age 3 and 4 decreased for the same years except for age 4 in 2010, 2011, and 2014. In 2012, the age composition largely increased for age 2, and decreased for age 3. If the trend of the age composition (or frequency) for age 2 is compared with the trends of aerial survey index and SAPUE (Fig. 2-3, see below), all the trends show similar increasing tendencies between 2003 and 2014 although there are some differences in fluctuation patterns. This possibly suggests that aerial survey index and SAPUE could detect signals more for age 2 than those for ages 3 or 4, or 2-4 combined.

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.

The trends of both aerial (Eveson et al. 2014) and commercial spotting (SAPUE; Farley et al. 2014) survey indices in the Great Australian Bight (GAB) are shown in Fig. 2-3. These indices are considered to monitor surface abundance of age 2-4 fish combined distributed in the GAB region. The aerial surveys have been conducted by Australia since 1993. Full scale line transect aerial surveys were suspended between 2001 and 2004. Although a limited number of lines was continued to be surveyed during this period, it was concluded that the indices of limited scale survey were not able to provide information comparable to the full scale aerial survey. The survey has been financially assisted by other CCSBT members through the Secretariat since 2013.

The aerial survey was ceased in 2015 due to a budgetary issue, and thus the result described below is same as last year.

Overall the aerial survey index (AI) showed a moderate decline from 1993 to the early 2000s. The AI values were more or less at a similar level in the rest of the 2000s. The AI increased in 2010 and 2011, two years in a row, then largely dropped in 2012 and drastically upturned toward 2014. The 2014 value of the AI was far higher than the past 5-year average over 2009-13 and this was the highest level throughout the entire survey period. The overall trend of SAPUE appeared to be increasing during 2004-2011 period. The 2011 SAPUE also declined in 2012 and then increased in 2013 and 2014. The 2014 value of SAPUE was also above the past 5-year average, but did not drastically increase such like the AI.

The AI is an indicator for age 2 to 4 fish combined which distribute over the GAB, and we cannot know an exact proportion of each age that constitutes the AI. If some year-class moves back again to the GAB next year, then the AI is expected to change in a gentle manner. In contrast, if a year-class of which abundance is markedly different from that of other year classes comes in, then the AI would sharply change. However, even if so, then a high or low value of the AI due to such change should continue for 2 to 3 years. Any indication of such sudden change in year-class abundance is not observed in the age composition of catch (Fig. 2-2). Sharp changes in the AI had been observed since 2011 suggest that the AI has not been able to properly capture changes in abundance of recruitment.

3. Other recruitment index:

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 has been currently being developed. Details of the trolling survey design, estimation method, results and its interpretation were documented in Itoh (2007), and Itoh and Tokuda (2014). Besides the first attempt to standardize the trolling survey index (called “grid-type trolling index (GTI)”) was described in Itoh (2014). The GTI 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 GTI provides a single consistent indicator for age 1 SBT from 1996 to 2014 except that Fig. 3-2 and a description of it were added.

The trolling survey was not conducted in 2015 to use time effectively for analyzing other data. Thus, the result discussed below is same as last year.

Fig. 3-1 compares trends between of previously reported trolling indices and of the GTI. For the previous trolling indices, only the bootstrap estimates of median were plotted. The median trends of both previous index and GTI appeared fairly similar although there were some differences in trend due to standardization for the GTI. All these indices increased from 2005 to 2008 and have gradually declined while fluctuating since then.

Cohorts of 1999, 2000, and 2001 (corresponding to the 2000, 2001, and 2002 trolling surveys) showed considerably low levels of recruitment. Now these cohorts have entered to age class 12+ and appeared in CPUE series between 2011 and 2013, showing somewhat slight and gradual declining trends (Fig. 1-5f). Overall trends of the indices from 2005 to 2012 surveys (from 2004 to 2011 cohorts) were similar to those observed in the longline CPUE indices for age 3 from 2007 to 2014, for age 4 from 2008 to 2014, for age 5 from 2009 to 2014, for age 6&7 from 2010 to 2014 (Figs. 1-5a, 1-5b, 1-5c, and 1-5d).

As compared above, trends of trolling indices seem compatible with those of other indicators (e.g., Japanese longline CPUE), of course there are some exceptions though. 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 (2014) and in this document). The trolling indices, especially for the GTI, could be used as quantitative indicators for recruitment.

Four types of recruitment index are compared in Fig. 3-2. These are the AI, SAPUE, GTI, and average of w0.5 and w0.8 (Japanese longline CPUE) for ages 5-7 combined. Regarding the GTI, the moving average of values for 3 consecutive years (e.g. average of 2011-13 for a 2014 value) was taken to be comparable with the AI and SAPUE (e.g. the 2014 AI and SAPUE for age 2-4 correspond to the moving average of 2011-13 GTI for age 1). The moving averages from 2005 to 2007 could not be calculated because the GTI value was not available for 2004. Plots for the average of w0.5 and w0.8 were shifted 3 years to past (e.g. the 2014 value was plotted as the 2011 point) to correspond to AI and SAPUE years for comparison.

The trend of the moving average of GTI fairly agrees with that of the average of w0.5 and w0.8 where data points of both indices are available except 2011. The AI and SAPUE show similar trends, but these trends are different from the GTI and average of w0.5 and w0.8.

4. 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 much lower than those for 8-16 ages since 2000/01 season. Spiky increases of catch in 2001/02, 2004/05, 2006/07, 2008/09, and 2012/13 seasons may be mainly due to large increase of younger age classes under 17. No information has been available to conclude whether this replacement in the age composition reflected changes in fish abundance and/or distribution, or changes in fishing ground (Farley et al. 2015).

Catch trends of both in number and in weight for age 8-16 and 17+ combined appear to gradually decline with fluctuations from 1997/98 season to 2009/10 season. The trends have increased since 2009/10 season.

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

5. Overall Conclusion:

Fisheries indicators examined generally support a view that the current SBT stock levels for 4, 5, and 6&7 age groups are well above the historically lowest levels observed in the late 1980s or the mid-2000s. CPUE indices for age 4 and 5 classes show somewhat decreasing trends in recent years. The CPUE indices for age 8-11 group have increased gradually in recent 4 years. The indices for age class 12+ decreased from 2008 to 2010 and have fluctuated around at a low level afterward. The current levels for these older age groups are still very low similar to ones observed in past. Other age-aggregated (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.

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 5 years were summarized in Fig. 5-1. For comparison of recruitment indices, the moving average of the GTI and average of w0.5 and w0.8 (Japanese longline CPUE) for ages 5-7 combined were plotted with the AI and SAPUE as same as Fig. 3-2.

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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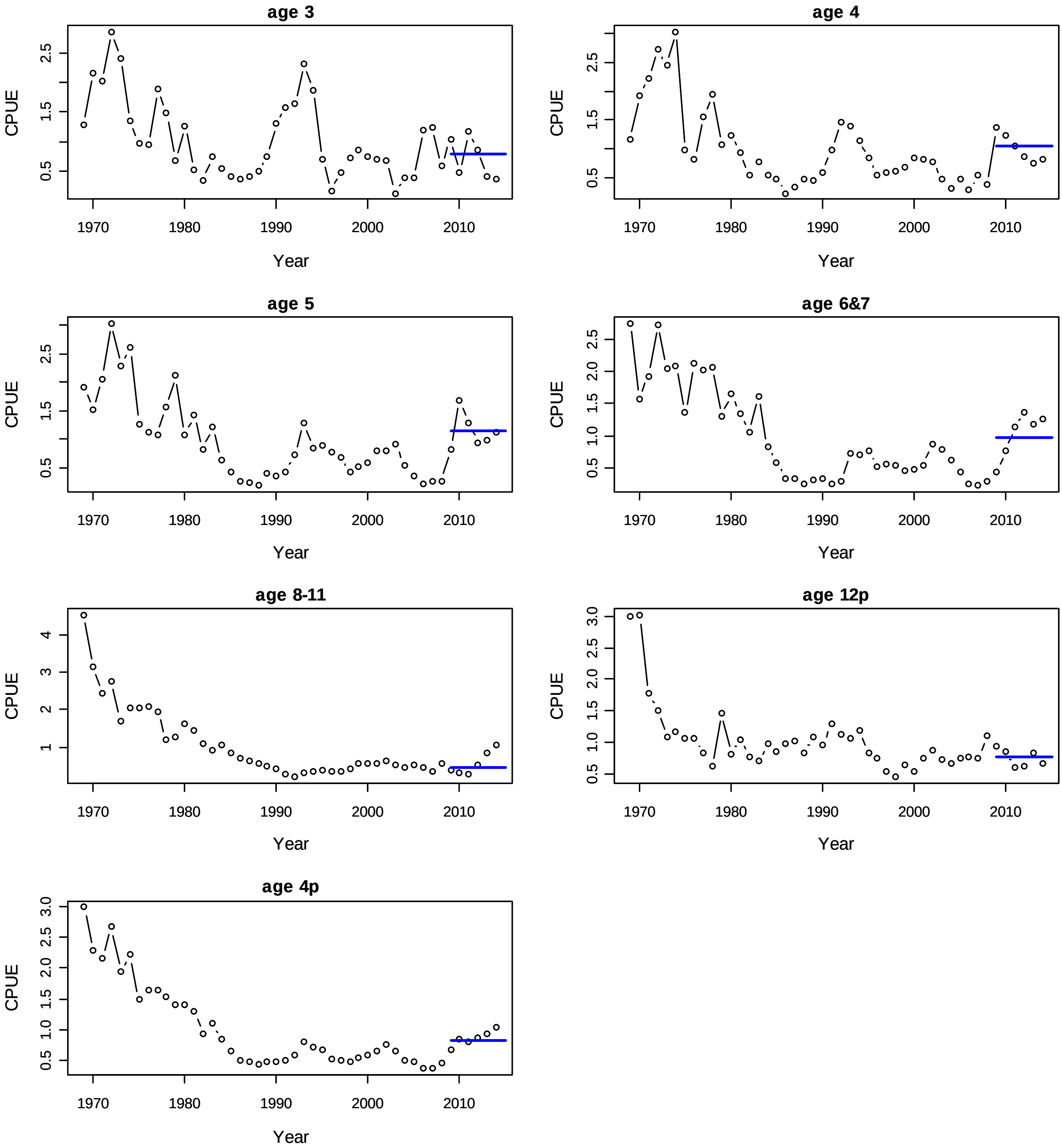


Fig. 1-1. Nominal CPUE of Japanese longline fishery by age groups. The horizontal lines indicate the past 5-year averages over 2009-13.

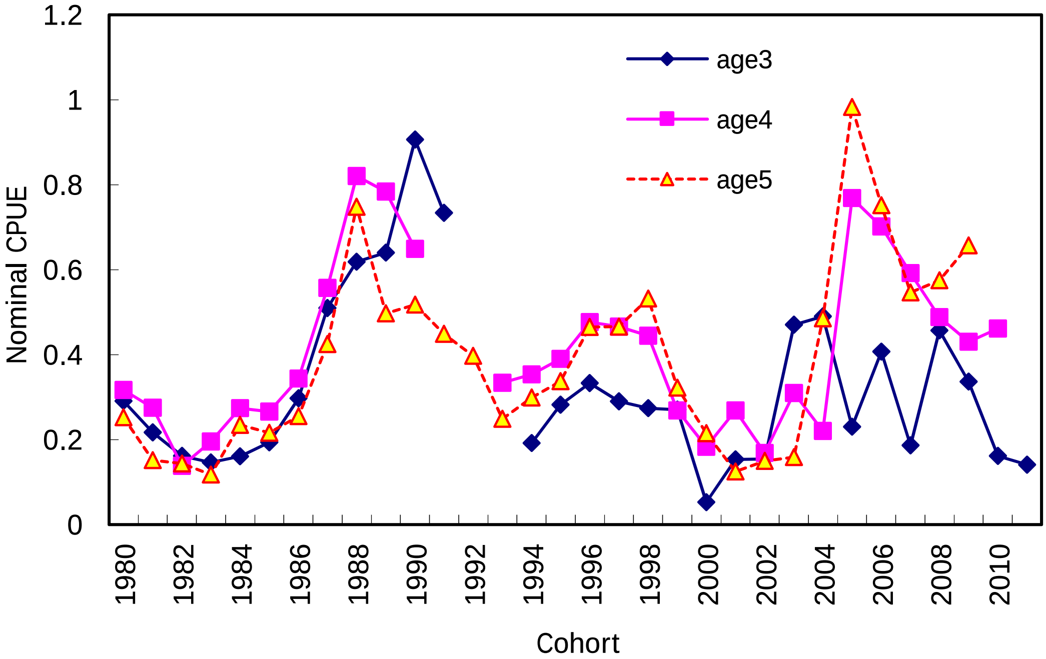


Fig. 1-2. Nominal CPUE of Japanese longline fishery by cohorts for age 3, 4, and 5.

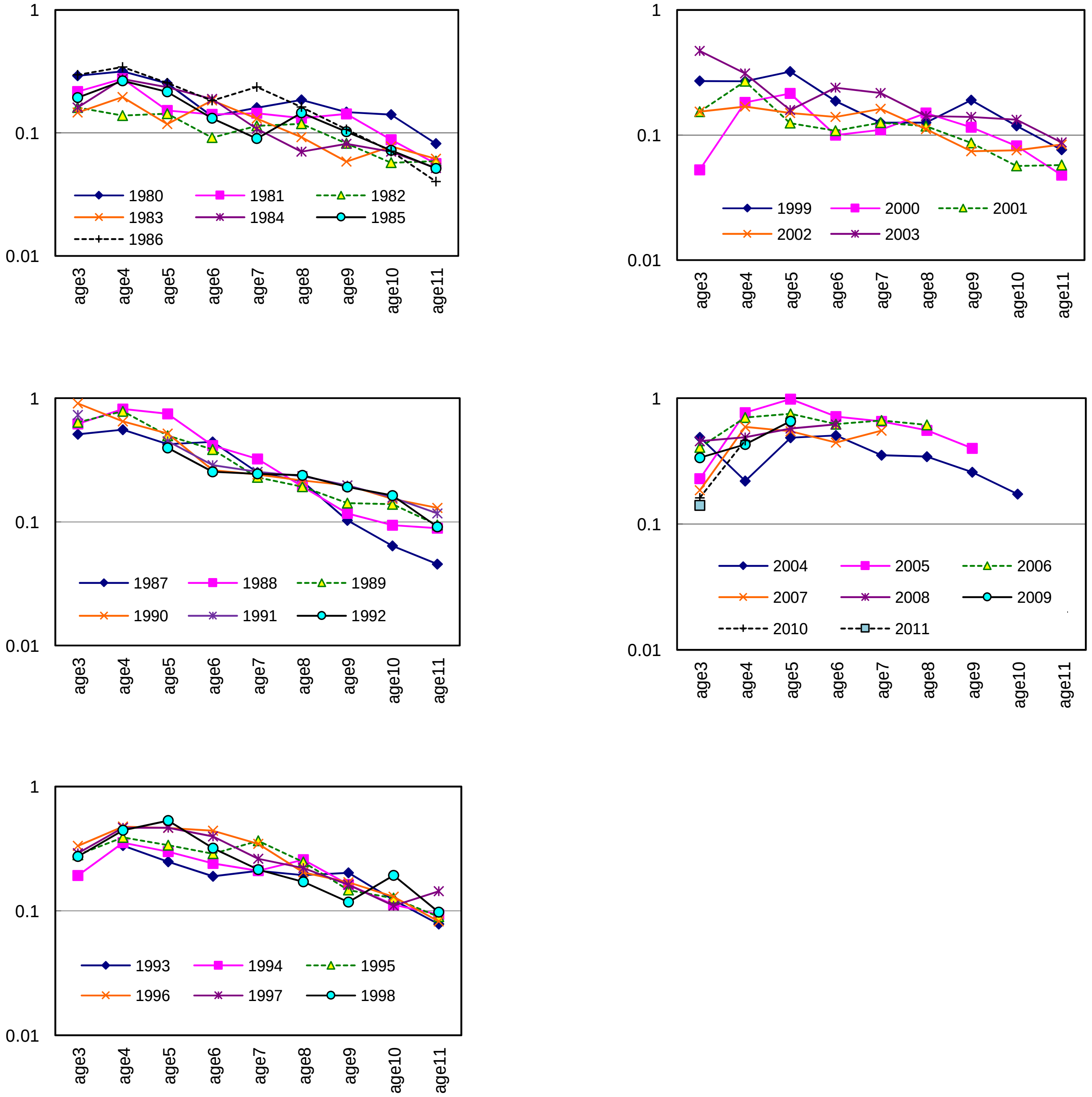


Fig. 1-3. Nominal CPUE of Japanese longline fishery by cohorts in log-scale.

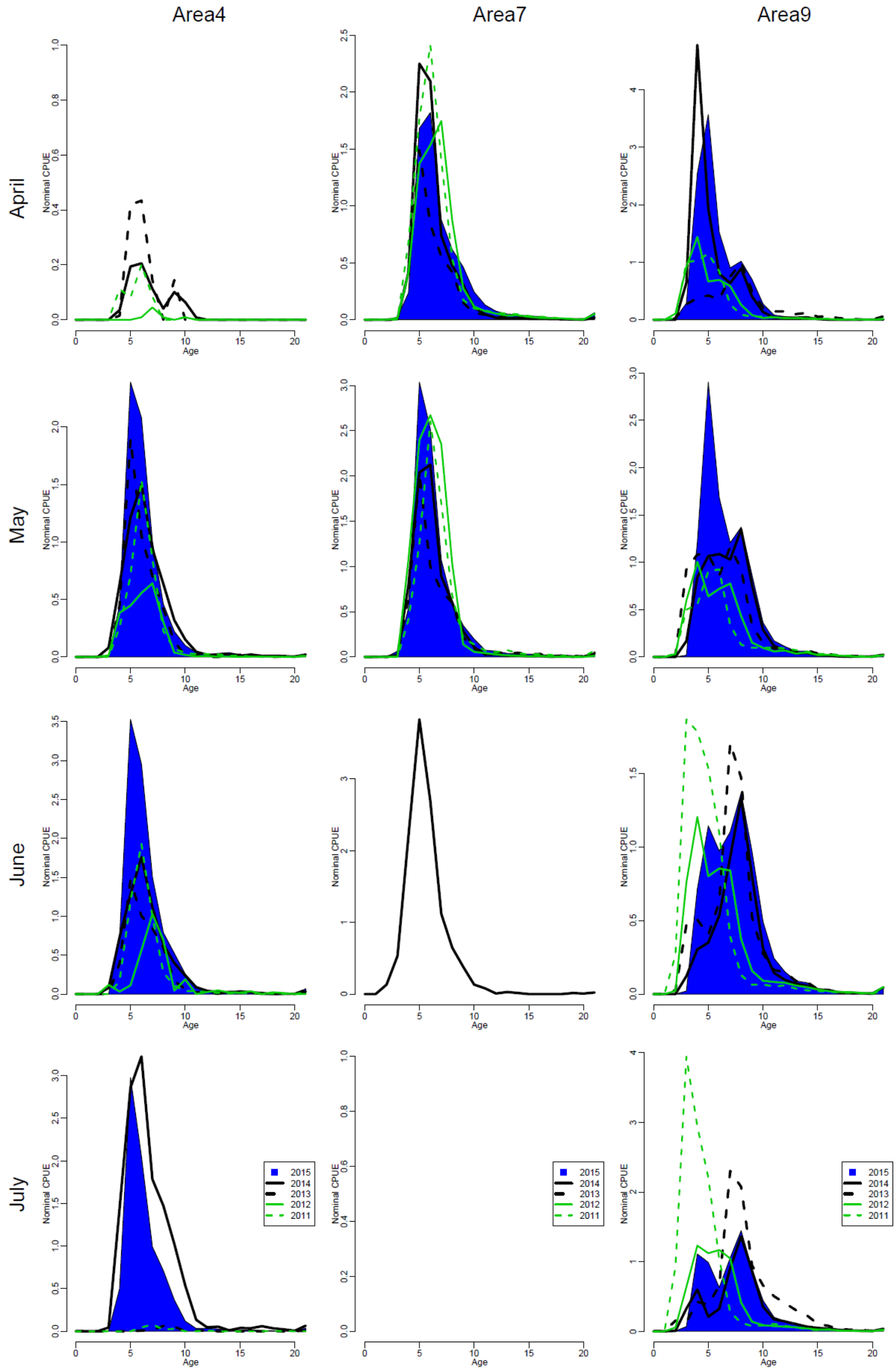


Fig. 1-4. Age composition of nominal CPUE of RTMP data for recent five years by month and areas.

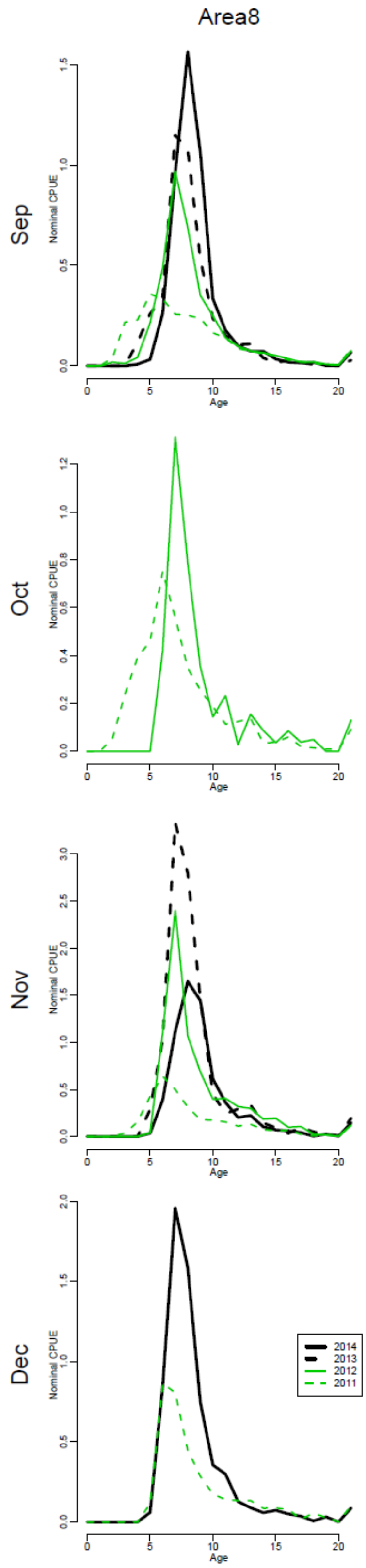
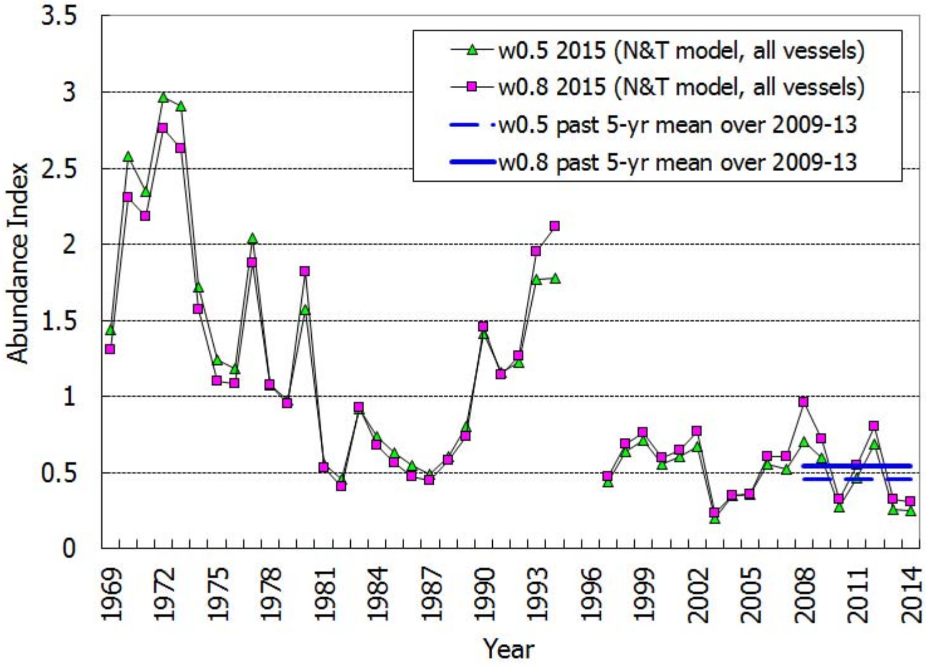


Fig. 1-4 (cont'd). Age composition of nominal CPUE of RTMP data for recent four years by month and areas.

(a) Age 3



(b) Age 4

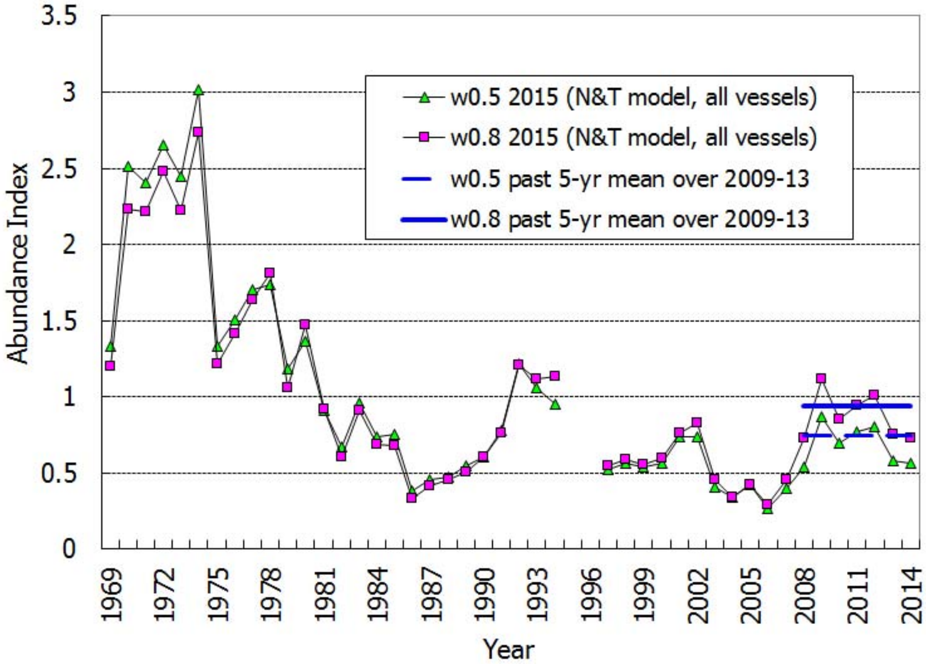
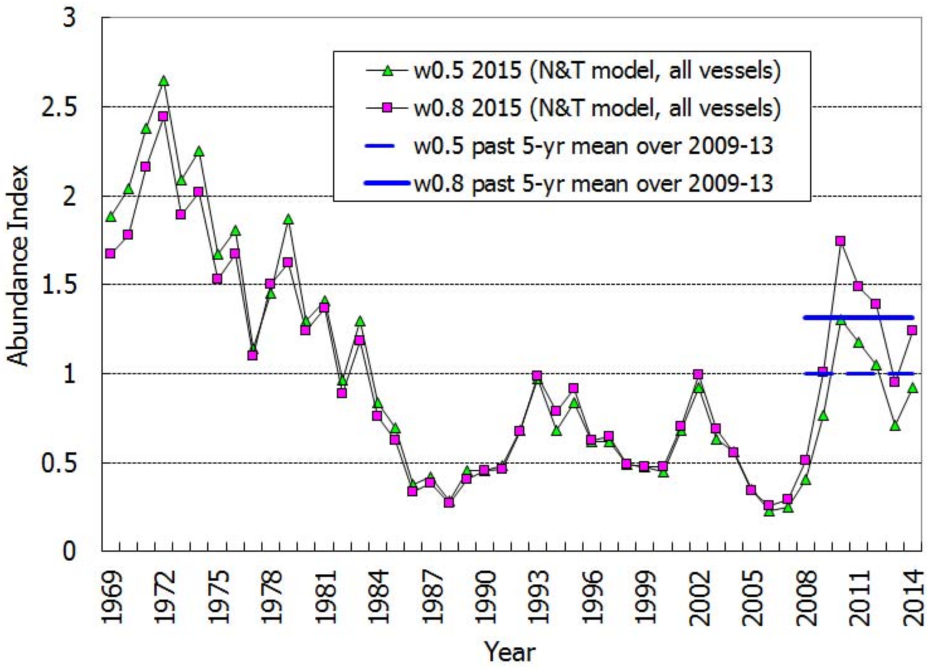


Fig. 1-5. Trends of normalized w0.5 (B-ratio proxy) and w0.8 (Geostat proxy) abundance indices. The standardization model used was the same as that of Nishida and Tsuji (1998).

(c) Age 5



(d) Age 6&7

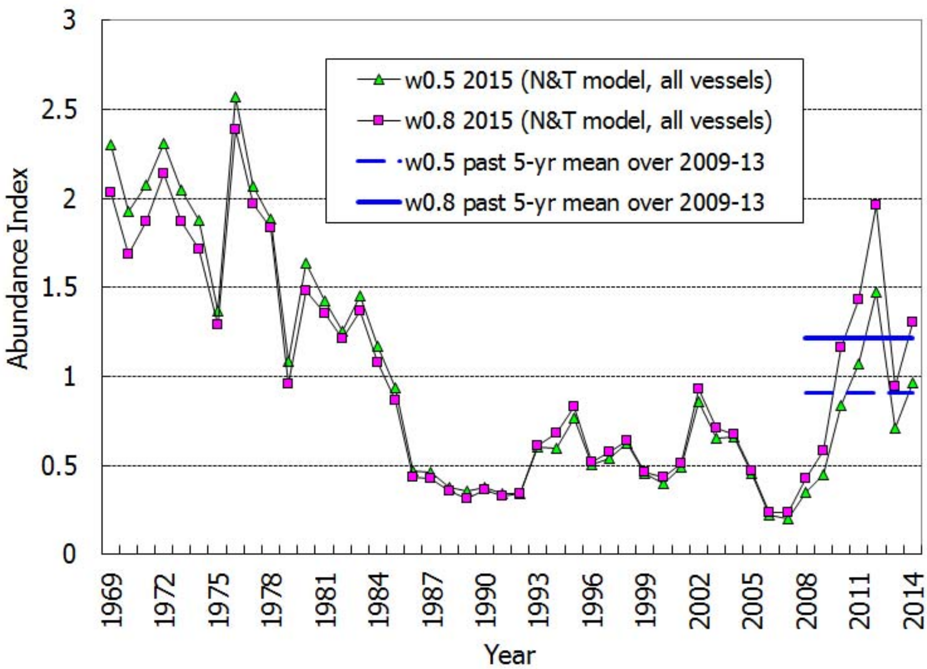
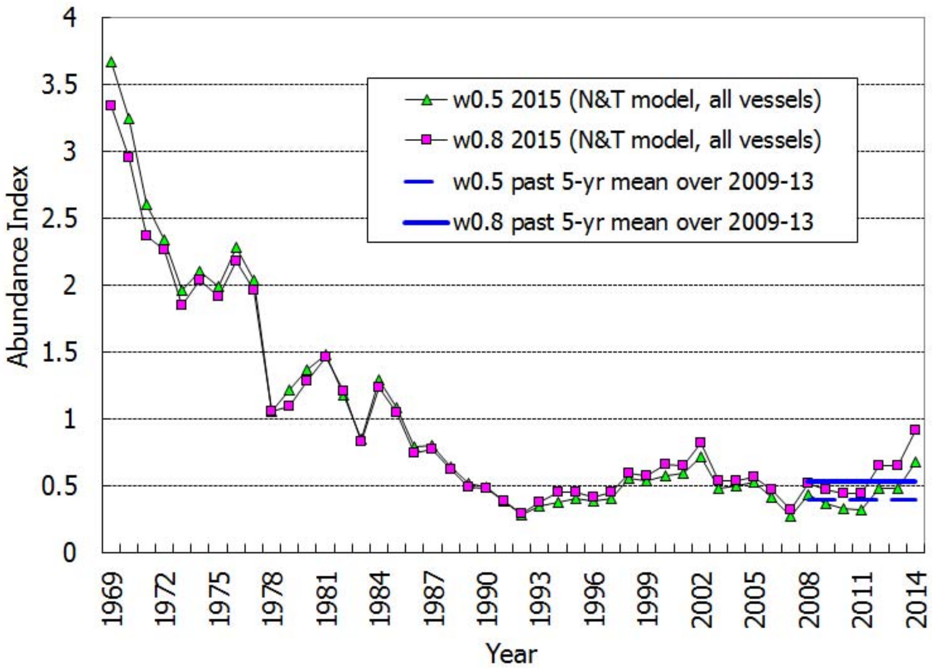


Fig. 1-5. Trends of normalized w0.5 (B-ratio proxy) and w0.8 (Geostat proxy) abundance indices. The standardization model used was the same as that of Nishida and Tsuji (1998). (cont'd)

(e) Age 8-11



(f) Age 12+

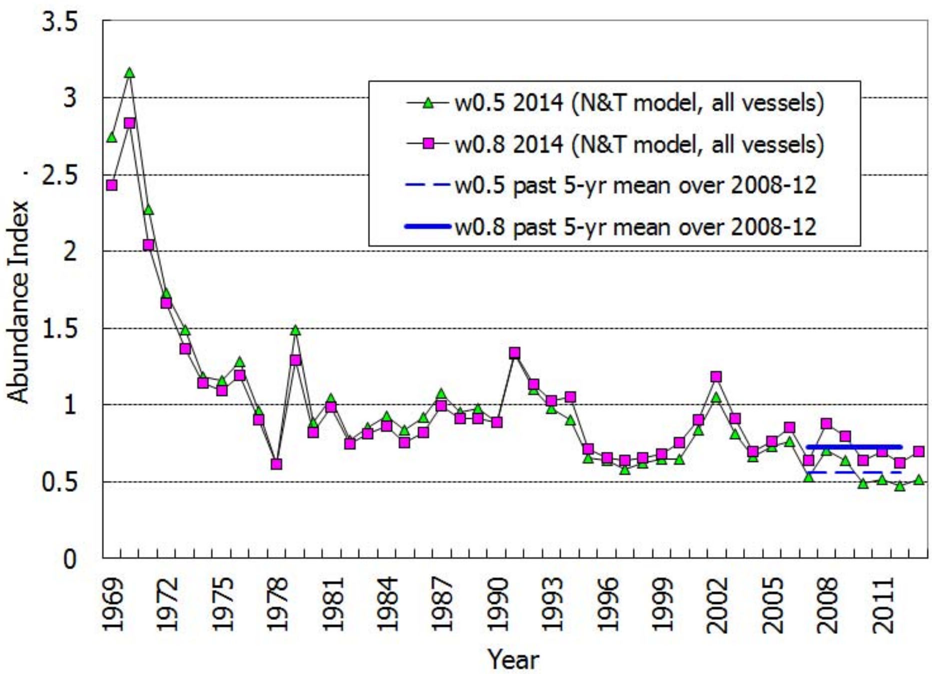
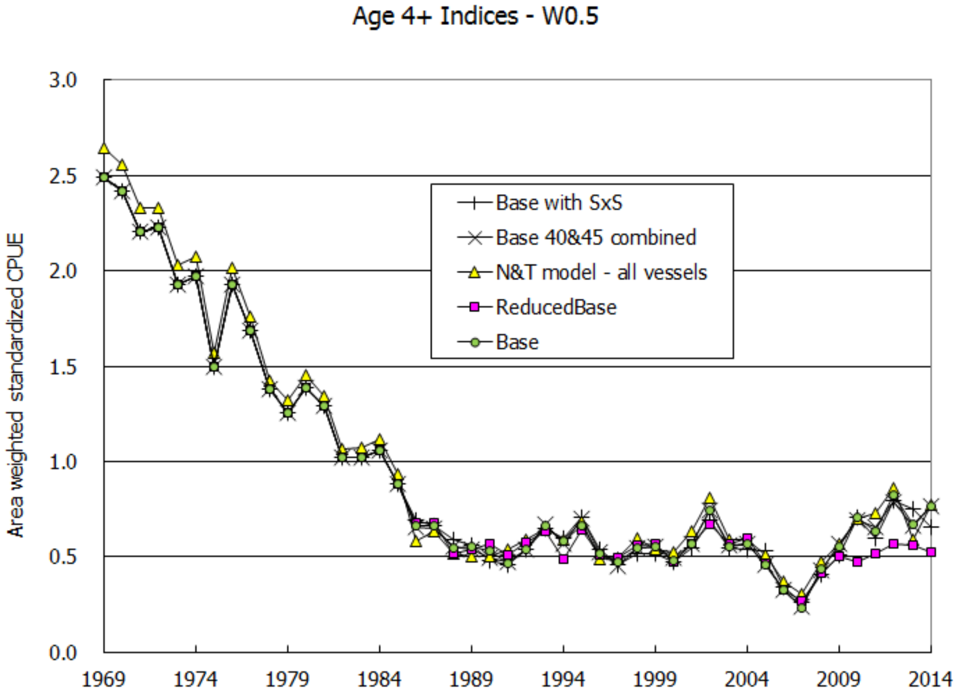


Fig. 1-5. Trends of normalized w0.5 (B-ratio proxy) and w0.8 (Geostat proxy) abundance indices. The standardization model used was the same as that of Nishida and Tsuji (1998). (cont'd)



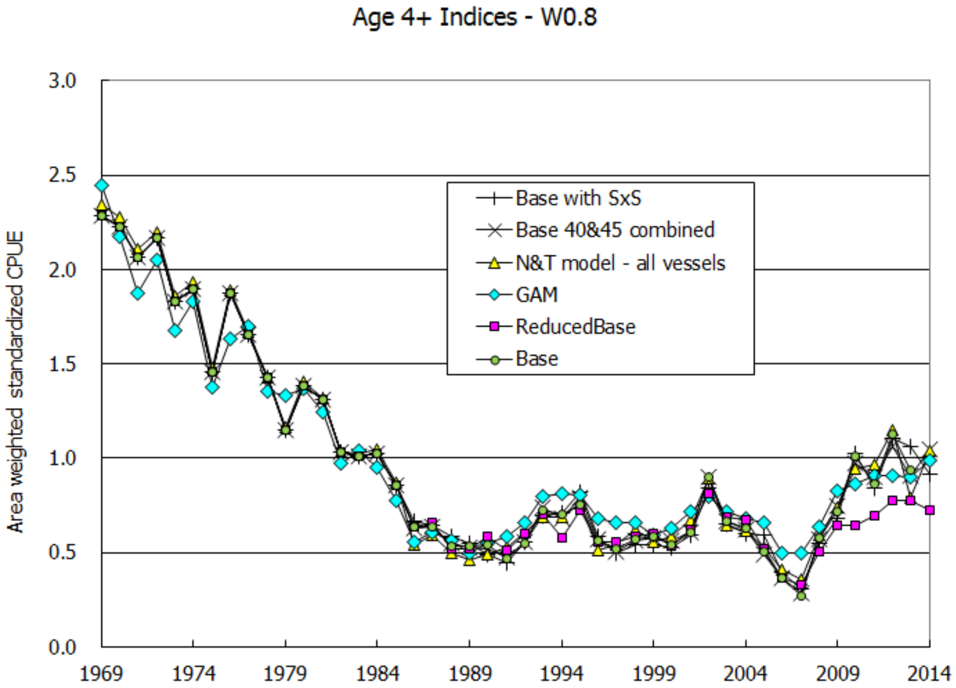


Fig. 1-6. Trends of various abundance indices for age 4+: Base model (Base) with core vessel data (Core); Reduced Base model with Core; Base with shot-by-shot Core; Base with Core, 40S and 45S latitude data combined; Nishida & Tsuji model with all vessel data; GAM with all vessel data. GAM series was plotted together with w0.8 series as overall levels of these indices are similar.

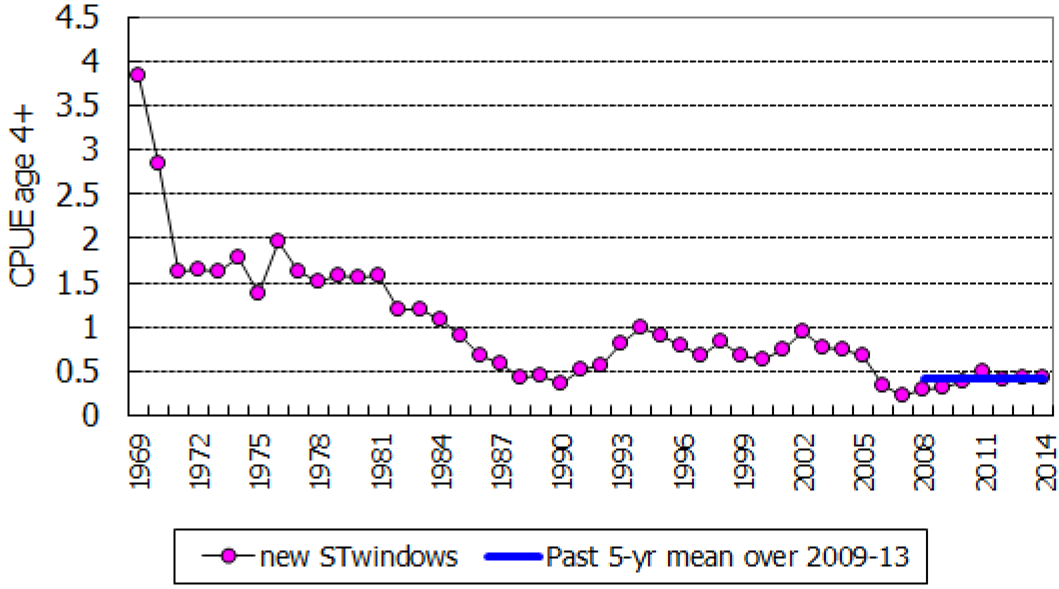


Fig. 1-7. Trend of normalized “ST Windows” index for age 4+ fish by the new calculation method.

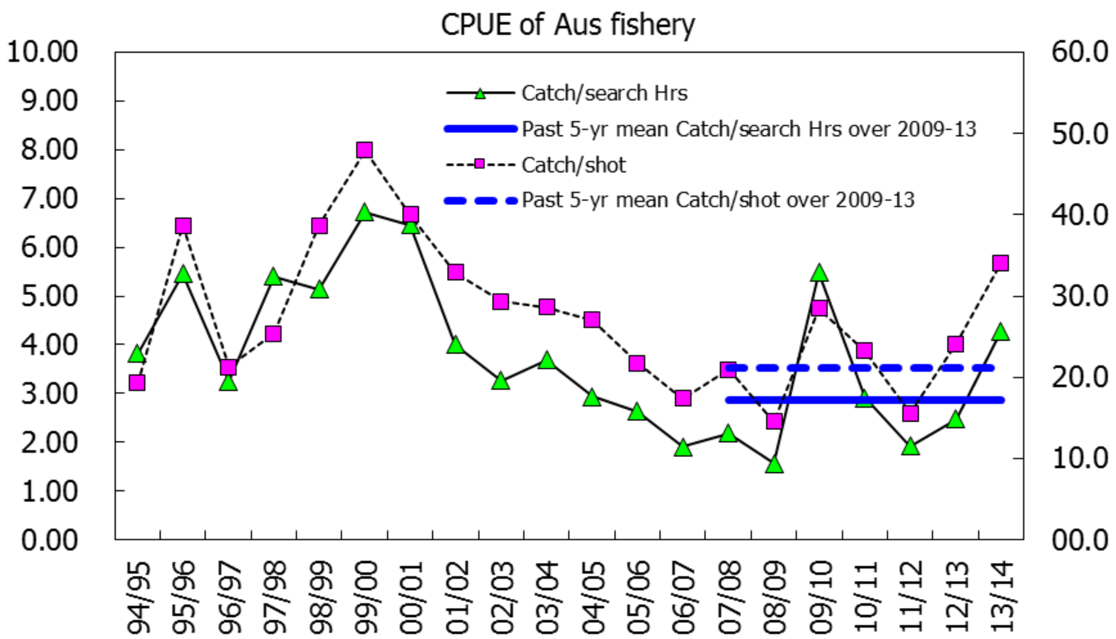


Fig. 2-1 Catch (in weight) per effort for Australia purse seine fishery.

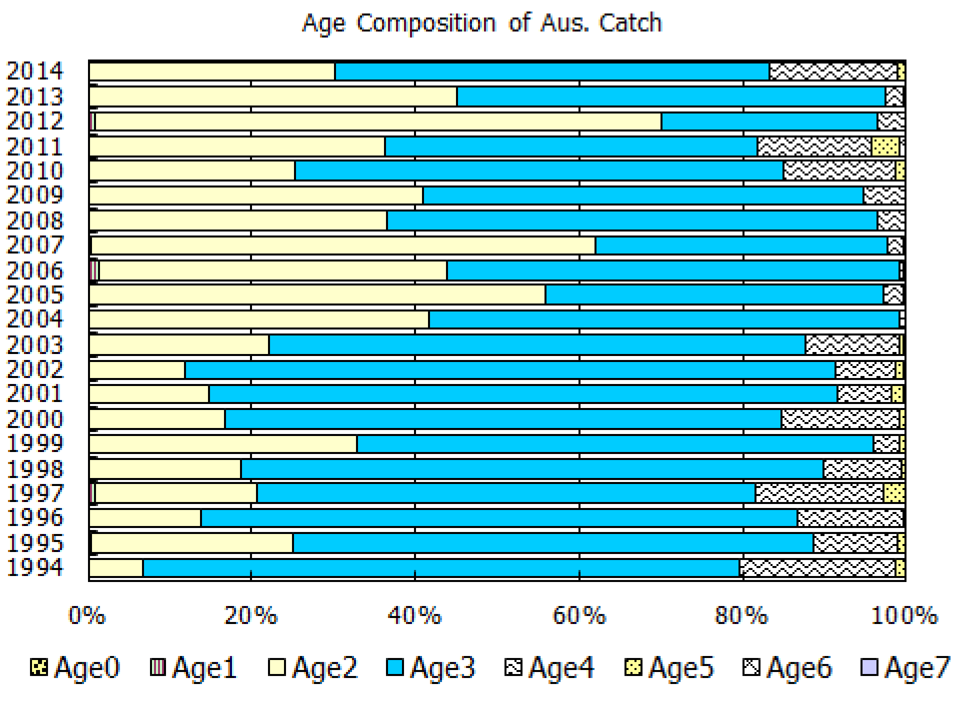


Fig. 2-2 Changes in the age composition of Australia purse seine catches.

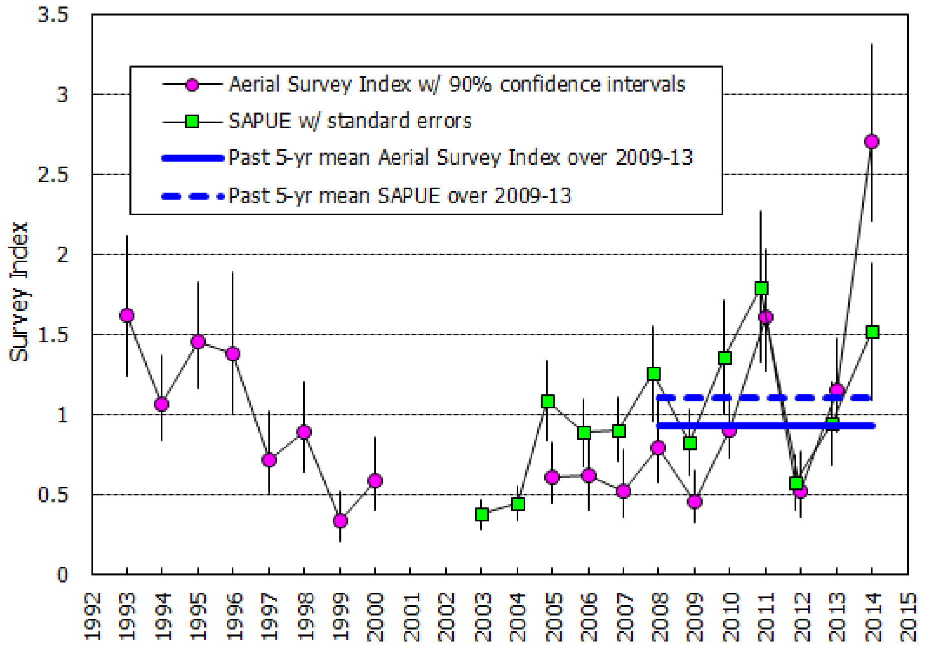


Fig. 2-3 Changes in aerial and commercial spotting (SAPUE) indices in the Great Australian Bight. Vertical bars indicate standard errors.

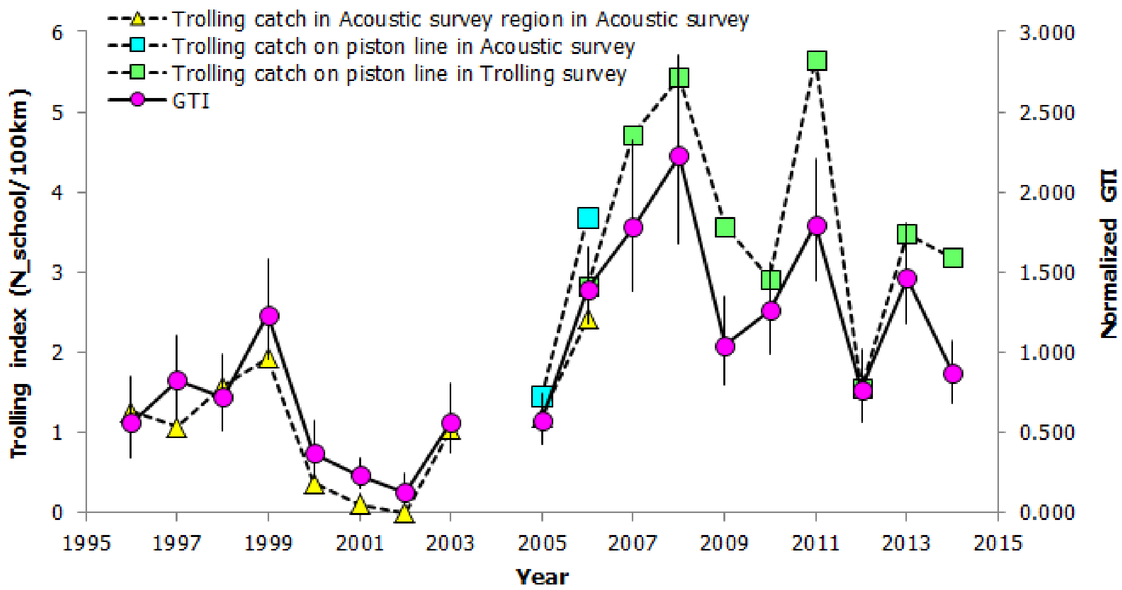


Fig. 3-1. Trends of various trolling catch index for age 1 SBT in the Western Australia. The previously reported trolling indices were indicated by dotted lines with symbols (Only the bootstrap estimates of median were plotted). “GTI” represents the standardized grid-type trolling index and vertical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

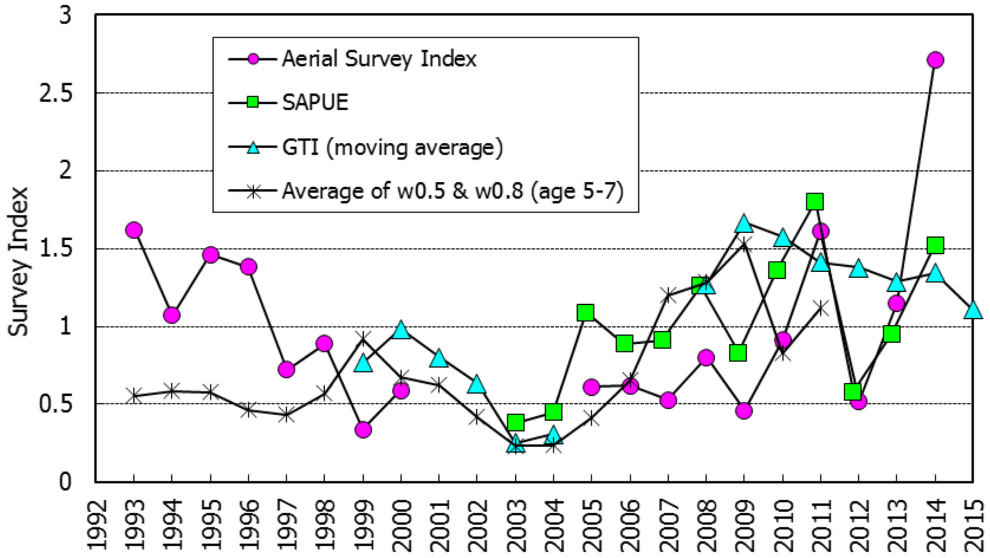


Fig. 3-2. Comparison between the grid-type trolling index (GTI), aerial survey index (AI), SAPUE and the average of w0.5 and w0.8 indices (Japanese longline CPUE) for ages 5 to 7. Regarding the GTI, the moving average of values for 3 consecutive years (e.g. the average of 2011-13 for a 2014 value) was taken to be comparable with the AI and SAPUE (e.g. 2014 AI and SAPUE for age 2-4 correspond to the moving average of 2011-13 GTI for age 1). The moving averages from 2005 to 2007 could not be calculated because the GTI value was not available for 2004. Plots for the average of w0.5 and w0.8 were shifted 3 years to past (e.g. the 2014 value was plotted as the 2011 point) to correspond to AI and SAPUE years for comparison.

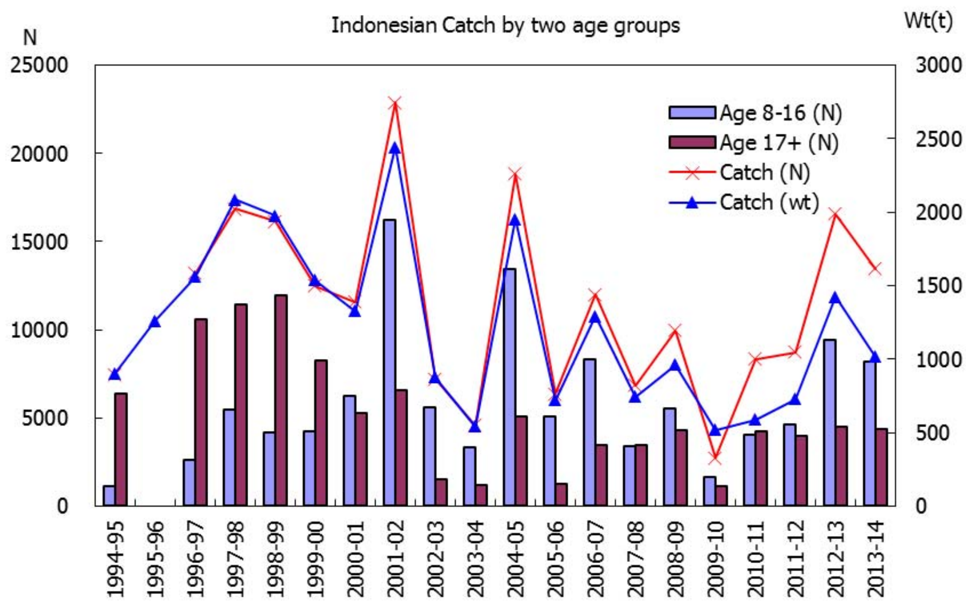


Fig. 4-1. Trends of Indonesian catches with proportion of two age groups occurrences.

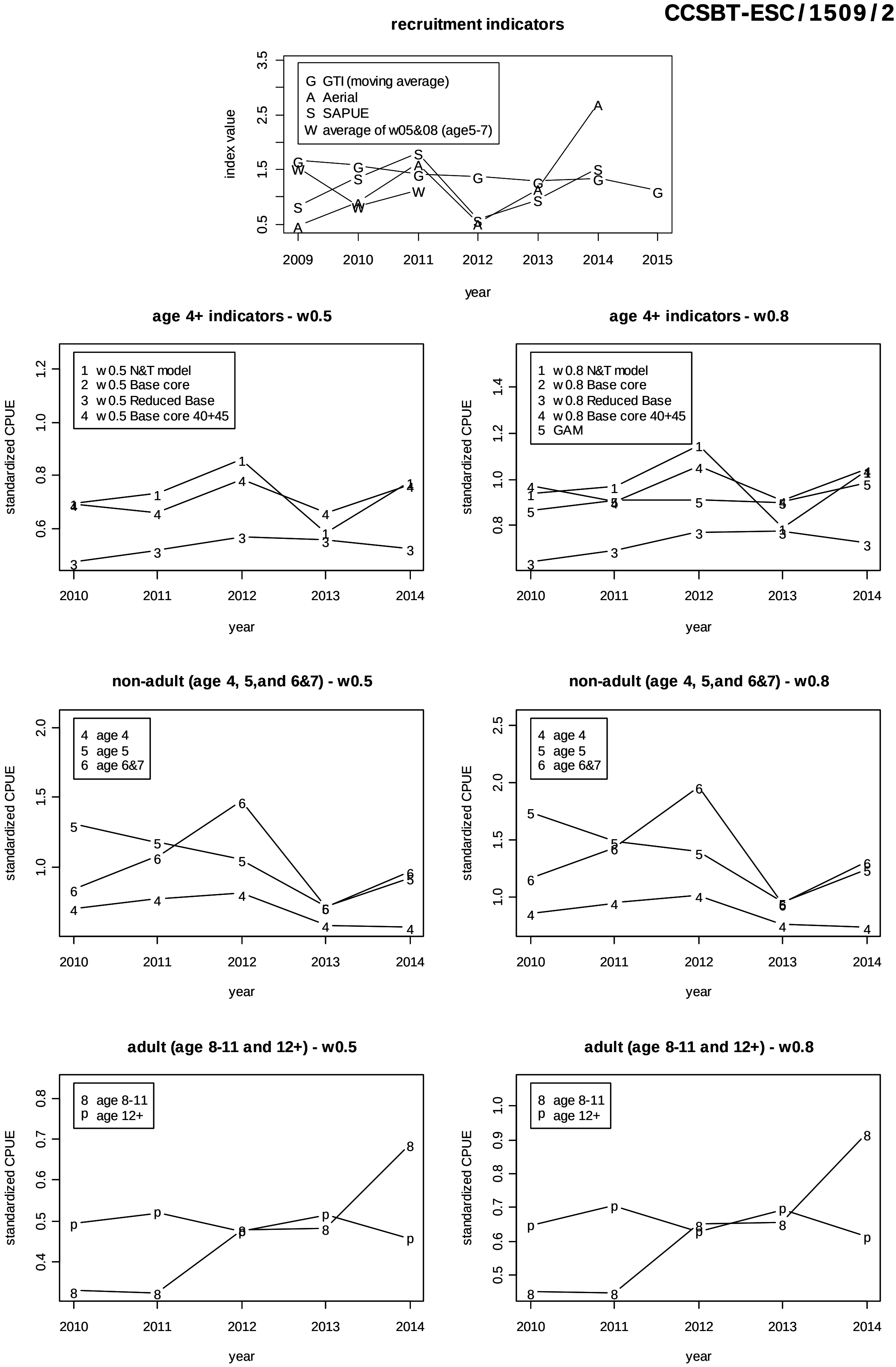


Fig. 5-1. Trends of recruitment surveys and CPUE-based indicators in recent 5 years. Regarding the GTI, the moving average of values for 3 consecutive years (e.g. the average of 2011-13 for a 2014 value) was taken to be comparable with the AI and SAPUE (e.g. 2014 AI and SAPUE for age 2-4 correspond to the moving average of 2011-13 GTI for age 1). Plots for the average of w0.5 and w0.8 were shifted 3 years to past (e.g. the 2014 value was plotted as the 2011 point) to correspond to AI and SAPUE years for comparison.