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Preliminary stock assessment of Pacific Bluefin Tuna through Stock Synthesis 3

Shigehide Iwata, Shuhei Uematsu, Kazuhiro Oshima, Momoko Ichinokawa, Mikihiko Kai, Masayuki Abe, Ko Fujioka, Hiromu Fukuda, Akiko Mizuno and Yukio Takeuchi

National Research Institute of Far Sea Fisheries, Fisheries Research Agency
5-7-1 Orido, Shimizu, Shizuoka 424-8633, Japan

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Summary

In this document, the result before ISC PBF meeting (May, 2012) is summarized. The model setting does not achieve to agree among WG members in ISC PBF meeting (May, 2012). So the stock status is not the consensus among working group. The characteristics of model setting in this document are to apply three functions, 1) cubic spline, 2) super period, 3) generalized size composition. The dynamics indicate the previous stock assessment result (Total biomass, SSB, recruitment, the trend of fishing mortality F).

Introduction

Stock assessment of Pacific Bluefin tuna (PBF: *Thunus Olientalis*) has been conducted by PBF Working group of International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC). The latest stock assessment of PBF was conducted in July 2010 using the Stock Synthesis (Methot 2011, http://nft.nefsc.noaa.gov/Stock_Synthesis_3.htm). In the previous stock assessment, the catch and length data (Abe et al. 2010) were simply updated until 2007 fishing year (until June 2008 in calendar year). CPUE series are also updated until 2007 as for Japanese coastal long line, Japanese coastal troll and Taiwanese long line fisheries. This document updates stock assessments of PBF up to 2010 by adding the data of fishing years of 2008, 2009 and 2010 to evaluate the most recent stock status. As the stock assessment model, the Stock Synthesis 3.23b (SS) is applied. SS is software program that implements a length /age-based structure, forward-simulation population model with flexibility to address parameterization (Such as selectivity, catchability, stock recruitment relationship, biological parameters, etc.) and uncertainty within the overall model.

This working paper presents: 1) the preliminary result of stock assessment in the base case; 2) the general description of the model setting based on the ISC PBF working group (WG) in February, 2012 and introduction of new functions of SS 3.23b using he base case; 3) the differences between the previous stock assessment and preliminary result of base case run; 4) the sensitivity analysis for options which were selected in the last ISC PBF WG in February, 2012 (About Growth curve and super period setting for fleet 4. Other sensitivity runs are introduced in the Fukuda et al., 2012).

1. Data and model configuration

In this section, short introduction is made on input data (See, detail of input data, Uematsu et al. 2012), new function in the SS 3.23b and model descriptions.

1.1 Fishery data and CPUE time series

Temporal stratification

The time period converted by this assessment is 1952-2010. Within this period, fishery-catch and size (length or weight) composition data were compiled into quarters (1st quarter as July-September, 2nd October-December, 3rd January-March and 4th April-June). Especially, in the PBF stock assessment fishery year is applied. Fishery year starts on July 1st and ends on June 30th. In this document we use the fishing year even for the quarters as described above. (See. Uematsu et al. 2012).

Fishery and CPUE definition

After the discussions at the data preparatory meeting of ISC PBF WG in February, 2012, WG agreed to use 13 fishery definitions instead of previous ten fisheries as had been adopted in past assessments (see. Table 1) and use 11 CPUE time series, but not 17 (See Oshima, 2012). The updating of PBF catch, the details of fishery definitions and CPUE time series are listed on Uematsu et al. 2012.). Particularly changes of fishery definitions from previous Stock Assessment in July, 2010 are that the Japanese Tuna Purse Seine fishery has been divided into two fisheries (Pacific and Sea of Japan) and separate a Japanese Set net fishery into three fisheries. With the CPUE time series, 9 CPUE series used for Japanese coastal longline has been reduced to 3 series (1952 until 1973, Fujioka, et al., PBFWG12-1/WP10, 1974 until 2001, Yokawa, PBFWG8-2/WP5, 1993 until 2010, Ichinokawa, PBFWG12-1/WP8). The CPUE for Tuna purse seine of Sea of Japan was added (Kanaiwa, et al., PBFWG12-1/WP9). Four CPUE series are adopted for Japanese Troll fishery instead of 3 in the past (See. Table 2). Four time series for troll fisheries were revised as presented by Ichinokawa et al. (PBFWG12-1/WP11). Taiwanese long line CPUE series are expected to be revised (Hsu et al., PBFWG12-2/14). Finally, CPUE series for the eastern Pacific Ocean (EPO) commercial fishery was presented by Aires-da-Silva et al. (PBFWG12-1/WP18). As seen in Table 2, the weighting factor, lambda, of CPUE for Tuna purse Seine for (S4), Japanese Troll fishery (for Kochi, S7, Wakayama, S8), commercial fishery (S10) and sports fishery (S11) of Eastern Pacific Ocean (EPO) are set to 0 by the agreement in the data preparatory ISC meeting in February, 2012. Uematsu et al. (2012) introduce how the coefficient of variation (CV) for each CPUE time series was given.

Size (length or weight) composition data

In this PBF stock assessment, the size composition data of Japanese set net (north part of Japan, Fleet 7) and others (Fleet 13) are in weight and the other fleets are in length. For the weight 40 bins are defined (See. Table 3 and Fujioka et al. 2012.). For the length data 65 bins are defined (bins with 2cm intervals are adopted for fish ranging 16-58 cm, 4cm bins for 58-110cm, and 6 cm bins for 110-290cm. The length and weight composition data with their weighting procedures are summarized in Uematsu et al. (2012).

1.2 Biology

Biological parameter (Growth curve)

In the ISC PBF WG in February, 2012, Shimose et al. 2009 was determined to apply base case setting tentatively. There are following options of candidate growth curve.

1. Shimose et al. (2009) - Merit: Peer reviewed article.
2. Shimose et al. (2012) - Merit: the number of data which used in the analysis increase rather than Shimose et al. (2009). Richard equation

Kai et al. (2012) discuss especially on the growth curve and Fukuda et al. (2012) shows the sensitivity analysis of other options

For the functional form of growth CV, it was decided to be length based. In the previous stock assessment, this functional form of growth CV is based on the age (See, Table 3.). The CV for young (age 1) was estimated in the current evaluations, while CV for old (age 3) was fixed at 0.08. For the CV for young, was fixed at 0.25 in the previous assessment.

Biological parameters (except for growth curve)

The biological parameters except for growth parameters used in the analysis were summarized in Table 3.

The maturity schedule is unchanged from the setting, 0.2 for age 3, 0.5 for age 4, 1.0 after age 5 (This setting of maturity in previous stock assessment model is introduced by Yamada, (2007), by the biological evidence which was presented by Tanaka (2006). The length-weight relationship of Kai (2007) is applied. The mortality schedule is the same as previous stock assessment (1.6 for age 0, 0.386 for age 1, 0.25 for age 1 over).

1.3 Overview of Stock Synthesis 3 and descriptions

We introduce the general information about Stock Synthesis. Stock Synthesis (SS, Methot, 2011) is developed in the AD Model Builder software environment, which is essentially a C++ library of automatic differentiation code for nonlinear statistical optimization (ADMB-project, http://admb-project.org/)

The SS model comprises of three sub-models: 1) A population dynamics sub-model, where abundance, mortality and growth patterns are incorporated to create a synthetic representation of the true population; 2) An observation sub-model that defines various processes and filters to derive expected values for different types of data; and 3) A statistical sub-model that quantifies the difference between observed data and their expected values and implements algorithms to search for the set of parameters that maximizes the goodness of fit. Another part of the model is the estimation of management quantities. Finally, these sub-models are fully integrated across all relevant sources of variability and goodness of fit is estimated in terms of the original data. Also, the SS model use forward-algorithms, which begin estimation prior to or in the first year of available data and continue forward up to the last year of data (Methot 2011).

From 2010 stock assessment, the SS model has been upgraded to version 3. This version is more flexible with applicability to more situations and more reporting options. Improvements in this version include better control of seasonally varying parameters, addition of weight frequency data, better control of movement parameters, capability to include tag-recapture data, an enhanced forecast module, 3 parameter spawner-recruitment function, ageing error as parameters, capability to read effort observations, and a super-period option, etc. (Methot 2011). For the preparation of this report SS Version 3.23b, compiled in January 2011, is used, while SS Version 3.10b was used in 2010 stock assessment.

Likelihood components

Likelihood components of the model include total catch, equilibrium initial catch, recruitment deviation, survey abundance indices, length compositions, and priors. Likelihood estimates for various data components were obtained by comparing expected values from the model with the actual observations (i.e. goodness of fit). No prior assumptions were made regarding the estimated parameters, i.e., no prior are used.

However, bounds were established on all parameters. The modeled population was configured as follows.

1.3.1 Introduction of applied new functions of SS 3

In this section, we introduce new functionality applied to the base case (e. g. Generalized size composition, Cubic spline and super period) and population length bin which related to the generalized size composition.

Generalized Size composition (the function start with SS_v3)

"Generalized size composition" is a generalized approach to multiple size composition information. It was designed initially to provide a means to include weight frequency data, but was implemented to provide a generalized capability. The user can define as many size frequency methods as necessary (Methot, 2011). In the method, users can define arbitral method for setting of size bin which can be expressed length or weight composition dataset. The method have each 'units (biomass or number)' and 'scale (weight or length)' which including ability to convert bin definitions in pounds or inches to kg or cm). When this functionality is used, weighting on size composition data through multiplier of input sample size does not work. Instead, we can use the lambda of size composition likelihood since, by definition of multinomial likelihood function, multiplier of input sample size and lambda of size composition likelihood function is equivalent. .

Population length bin

In the SS model, population length bin is basic unit describing length-based population dynamics. So, the population length bins must not be wider than the length data bins, but the boundaries of the bins do not have to be aligned. Predicted size composition is translated from size composition defined with Population length bin. In SS_v3.02B and earlier, the data boundaries needed to align with the population boundaries but this requirement has been removed. When using more population length bins than data bins, SS will run slower (more calculations to do).

When the bin structure is coarse (note that some applications have used 10 cm bin widths for the largest fish), it is possible for a selectivity slope parameter or a retention parameter to become so steep that all of the action occurs within the range of a single size bin. In this case, the model will lose the gradient of the logL with respect to that parameter and convergence will be hampered. A generic guidance to avoid this situation is not yet available (Methot, 2011). So when we use the function, generalized size composition, we have to pay attention to the setting of population length bin.

Super Period (the function start with SS_v3.20)

The 'Super-Period' capability allows the user to introduce data that represent a blend across a set of time steps and to cause the model to create an expected value for this observation that uses the specified set of time steps. The option is available for all types of data and a similar syntax is used. The syntax is revised for V3.23.

Cubic spline (the function start with SS_v3.21d)

Usually the selectivity curve is either asymptotic or dome-shape. Standard selectivity function has forms like flat top, logistic double normal etc. On the other hand, the cubic spline is not parametric one. This means that there is no format and selectivity curve used cubic spline fit along the size composition data. Cubic spline in SS uses the ADMB implementation of the cubic spline function (Methot, 2011).

1.3.2 Details of model settings

The Model descriptions are summarized in Table 4. In the Table 4, the transition of SS3 model description from previous stock assessment, agreement in February, 2012, and the base case were tabled.

Model descriptions (Spawning and Recruitment)

Based on previous biological studies, we assumed that the spawning season ranged from 4th quarter, April to June (fishing year). Recruitment in the SS model is modeled as the appearance of age 0 fish in the population.

In this assessment, the Beverton-Holt model was used to describe the stock-recruitment relationship. Typically, fisheries data are very uninformative about the Beverton-Holt stock-recruitment relationship parameters. When there is no independent outside information about the relationship, it is generally necessary to constrain (fix) the parameters in order to have stable model behavior. The steepness, h, of the stock-recruitment relationship was fixed at a value of 0.999 by the agreement in the PBF WG in February, 2012, which implies that practically recruitment is unrelated to spawning biomass but theoretically recruitment should be related to spawning biomass. Steepness was defined as the fraction of recruitment from a virgin population (R0) when the spawning stock biomass is 20% of its virgin level (B0). The log of the virgin recruitment (R0) was estimated in the model to assess the magnitude of the hypothetical initial stock size.

Year-specific recruitment deviations were estimated for each year between 1952 and 2009, which was the period best informed by the data based on evaluation of the variance of the recruitment deviations. It was assumed that the logarithm of the recruitment deviates was normally distributed with a mean of 0 and a fixed standard deviation at moderate value of 0.6 (σR). This assumption was used to penalize the temporal recruitment deviates.

Model descriptions (Size selectivity pattern)

In the base case, we use the two types of selectivity curve, one is flat top (logistic curve, for Taiwanese long line Fleet 10) and the other is dome shape (See, Table 1. The pattern of size selectivity curve for EPO sports fishery, Fleet 12, is mirrored with EPO commercial fishery, Fleet 11). The main changes from previous stock assessment are followings:

1) Dome shape selectivity which is realized by using cubic spline selectivity function (In 2010 stock assessment, the double normal selectivity was applied).

2) Selectivity curve for Japanese coastal long line (Fleet 1) changes from flat top to dome shape selectivity.

As a basis for setting knots, we set the first knot (last knot) near right (left) side of first bin (last bin) with size composition input data. The number of knots was initially set to 5 and visually changed depending on the number of flexion point. Furthermore, at least the one knot should be fixed. The detail of parameters for selectivity curve is summarized in Table 5. For the EPO commercial fishery (fleet 11), the size composition data during 1988-1989 is different from other year, so we use time varying selectivity for fleet 11. This means that two selectivity curves are applied depending on the time period, 1988-1989 or the other.

The reason why we chose the dome shape selectivity of Japanese coastal long line is that this fishery manly catch 150 to 200 cm, but occasionally more larger size of PBF were caught (The catch frequency is relatively law.). On the other hand, for the

Taiwanese long line catch is mainly 200 cm over. In the reason, for the selectivity of Japanese coastal long line changes and Taiwanese long line take flat top selectivity.

Model descriptions (Other matters)

The size selectivity pattern and settings are summarized in the Table 5 (This table show which parameters fix or estimate).
As described previously, we should set the more small size bin range than data existing range of size bin population length bin. In this base case, to avoid the error during reading input data, we set 52 bins: In intervals, 16 cm -222 cm, 252 -290 cm (224 cm - 252 cm), the size bin is 2 cm (resp. 1cm).

2. The stock dynamics and the effect of several model description change
In this section we introduce the stock dynamics.
NOTICE: In this section, we discuss the effect to PBF stock dynamics of differences of model descriptions (like a sensitivity analysis) by using the preliminary base case. However, in this section is only discussed about the effect to stock dynamics by descriptive change.

2.1 The review of base case scenario
The preliminary result of stock assessment is displayed in Figure 1. The characteristics of spawning stock biomass and recruitment is as follows;

Spawning stock biomass:
Maximum value : 115,853 MT (1961)
Minimum value : 10,843.1 MT (1983)
Historical Median : 42,626.8 MT
Virgin SSB (B0) : 619, 530 MT

Recruitment:
Maximum value : 40,305.4 MT (1994)
Minimum value : 2,501.32 MT (1958)
Historical Median :11,708.75 MT
R at B0 level (=R0) : 14,421.2 MT
LN(R) : 9.57645

In the 2010 stock assessment, the virgin spawning stock biomass is 619,530 MT and the recruitment at virgin biomass level is 12, 135.8MT (and logR0 is 9.40392). In figure 1, we show the result of 95 % confidence interval. This confidence interval is calculated from boot strap 300 replication with size weighting factor (lambda) set to original value times 1/100 and original effective sample size times 100.

The estimated time series of PBF recruitment is shown in Figure 2. The temporal residuals of recruitment are shown in the upper panel of figure 2. In figure 2, we introduce temporal dynamics of recruitment residuals and ±1 and ±2 standard deviations). Greater-than-average recruitments (R residuals have been ranging interval > standard deviation) occurred in 1953, 1956, 1963, 1973, 1977, 1990, 1994, 2004 and 2007. Particularly, extremely large recruitment (R residuals have been ranging interval > 2*standard deviation) occurred in 1994. In this class, this class appears due to change fleet definitions (See section 2. 2. 2.). On the other hand, lower-than-average recruitments (value of R residuals have been ranging interval < - standard deviation) occurred in 1952, 1958, 1959, 1969, 1989, 1991, 1992 and 1993. Particularly, extremely lower recruitment (R residuals have been ranging interval > 2*standard deviation) occurred in 1958 and 1993.

By the bottom panel of figure 2, the recruitment deviation is belonging to normal distribution (mean 0, deviation 0.6). So, the recruitment estimated in base case is appropriate.

Fishing mortality, F, during assessment period (1952-2010) and recent period (1990-2010) are shown in figure 3. Fishing mortality, F for age 0, 1, 2 are relatively higher than F for other age. F for age 0, 1, 2 increase recently, F for age 3-7, keep almost same level, but F over age 8 is tend to decrease. As described previously, the selectivity pattern except fleet 10 are dome shape (no asymptotic selectivity) are applied. The residual plot of CPUE and size composition data are shown in the figure 5 and 6, respectively.

2.2 The comparison of previous stock assessment

In this section, we consider the effect of model description to the stock dynamics. Especially, in section 2.2.1, we compare the result of previous stock assessment and current one. From the comparison, we can find the differences of the estimated strength of 1990 and 1994 class. In section 2.2.2, we show the effect of separation of Tuna purse seine fishery from one to two fleets. As a result, the increase of 1990 class can be explained by the setting of fleet definition of Tuna Purse Seine.

2.2.1 The comparison with previous stock assessment

The comparison of spawning stock biomass (SSB) and Recruitment dynamics between current and of 2010 stock assessment is shown in figure 7. Both of two runs show same trend both SSB and recruitment. There are differences; for the dynamics of SSB, absolute value in 1960s (after 1995) tends to increase (keep decline) and the historical median decrease. Because of decrease of historical median, relative value in 1960s is almost same, but the one in recent year is relatively higher than previous result. In terms of the recruitment estimates, 1990 and 1994 year class became higher, especially on the 1990 class. This is the big differences between current and 2010 stock assessment.

In figure 8, we compare the trend of fishery mortality during assessment period (1952-2010) and recent period (1990-2010). The trend of fishing mortality, F, is same as previous assessment.

2.2.2 The effect of separation of Tuna purse seine

The comparison of spawning stock biomass (SSB) and Recruitment dynamics between base case and base case combined with Japanese Tuna Purse Seine for Sea of Japan and Pacific Ocean (fleet 3 and 4) is shown in figure 9. For the dynamics of SSB, absolute value in 1960s (after 1995) tends to decrease and the historical median decrease. By decreasing of historical median, relative value in 1960s is almost same. For the recruitment, 1990 class increase. This is the big differences between current and previous result. So, one reason for increases of 1990 year class recruitment was attributed from separation of tuna purse seine.

2.3 Key sensitivity analysis (see Fukuda et al., 2012. More sensitivity analysis)

Growth curve

The comparison of spawning stock biomass (SSB) and Recruitment dynamics between base case and base case combined with using Shimose (2012) is shown in figure 10. For the dynamics of SSB, absolute value after 1995 tends to increase. Historical median is almost same, so the trend of relative value of SSB is also same. For the recruitment, there are no differences.

Super Period

The comparison of spawning stock biomass (SSB) and Recruitment dynamics between base case and base case with no super period in Tuna Purse Seine for Pacific Ocean (fleet 4) is shown in figure 11. With regard to the dynamics of SSB, absolute value during 1952-2010 tends to increase and the historical median also increases. By increase of historical median, relative value in 1960s decrease, but the relative value increase after 1995. For the recruitment, there are no differences between with and without super period. From the characteristics of catch data, the catch in 4th qt and next 1st qt of fishing year was continuing, therefore to apply super period is expected to reflect the realities of fishery.

2. 4 Residual analysis

2.4.1 Retrospective analysis (Figure 12)

Retrospective analysis is another common approach used to evaluate the reliability of current estimates of biomass, recruitment, fishing mortality and other quantities of interest. Retrospective analysis involves rerunning the model by consecutively removing 1 (or more) year of data. It is assumed that as more data is available, the estimates from prior years converge towards the true value.

Comparisons of estimates with a reduced number of years with the analysis of all years of data are used to indicate bias in the recent estimates. If the direction of the bias is consistent with each run, then it is often assumed that there is a nonrandom bias in the analysis.

The retrospective analysis indicated no tendency (Figures 12). This implies that the recent estimates of biomass are subject to retrospective no bias or the unstable model setting.

2.4.2 Likelihood profile (Figure 13)

In figure 13, we show the likelihood profile. In figure 13 (a), we plot the total likelihood and the SSB at 2000 (SSB after 1995 is more sensitive to changing $\log R_0$ than the other time period) with horizontal axis as $\log R_0$. From upper of figure 13 (a), total likelihood takes lowest value when $\log R_0$ is around 9.7. However, at $\log R_0$=9.6, the SSB at 2000 also increase. In figure 13 (b), the differences likelihood for each fleet (likelihood for each fleet at $\log R_0$ minus likelihood for each fleet at $\log R_0$ =9.7) is shown. From the Figure 13 (b), the likelihood of fleet 1 and 5 are extremely increase. As a result, the SSB increase.

In current base case, $\log R_0$ is estimated about 9.57, so current setting is very sensitive to the dynamics of $\log R_0$. In this meaning, the setting of base case is still unstable. Therefore, more improvement of the model setting is required.

3 Stock assessment results

3.1 Fishing mortality

The estimated instantaneous fishing mortality is displayed in Figure 3. There have been important temporal changes in age-specific level of fishing mortality due to changes in effort for each fishery, which catches different ages of pacific bluefin tuna. Fishing mortality, F for ages 0, 1, and 2 are relatively higher than F for other ages. F for ages 0, 1, and 2 has increased recently, F for ages 3-7, stayed at an almost same level, but F for over age 8 is tend to decrease.

3.2 Recruitment

The values of recruitment are as follows:

Recruitment:
Maximum value : 40,305.4 MT (1994)
Minimum value : 2,501.32 MT (1958)
Historical Median :11,708.75 MT
R at B0 level (=R0) : 14,421.2 MT
LN(R) : 9.57645

In general, recruitment has substantially fluctuated over the period 1952-2009. Strong year classes appear in 1953, 1956, 1990 and 1994. Especially, recruitment in 1990 year class was recognized as extra-strong year class, for the first time in this stock assessment. The reason of such recognition seems to be related to two factors. In the Japanese pelagic Tuna purse seine fishery, the annual catch has increased rapidly after fishing year of 1990, especially in the 2nd qt of fishing year 1991 (i.e. 5211.2 MT). This high catch is quite different from the catches of neighboring years; 140.5 MTin the 2nd qt 1990, 19.3 MT in the 2nd qt 1993. Furthermore, this , changing fleet definitions this time demonstrated the dominancy of the 1990 year class much clearly (Figure 9).

The estimated recruitment deviations show relatively low variability in both periods between 1996 and 2010, and betweem1960 and 1988, the periods best informed by the data (lower panel in Figure 2). The input value of 0.6 was used as the standard deviation of log recruitment, used to define offset of the stock recruitment curve when recruitment deviations were estimated. From the figure 2, the uncertainty of recruitment seems to be low.

3.3 Biomass

The estimated time series of spawning biomass are shown in Figure 1. The values of spawning stock biomass are as follows:

Spawning stock biomass:

Maximum value : 115,853 MT (1961)

Minimum value : 10,843.1 MT (1983)

Historical Median : 42,626.8 MT

Virgin SSB (B0) : 619, 530 MT

There are three peaks during 1951-2010, for temporal dynamics of Spawning stock biomass: Fishing year 1961 (117878 MT), 1978 (34344.3 MT) and 1995 (83294.9 MT). SSB has experienced fluctuations around the modeled time series average of 46,554 MT.

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Table 1. The definition of fleets. The settings of previous setting, WG agreement in February, and current setting.(Cont'd.)

	The basecase setting in the previous Stock Assessment in 2012						WG agreement in February, 2012				Basecase setting	
Serial number	Fleet	Short Name	corresponding fisheries	Descriptions (selectivity patterns, data sources etc.)	Weighting factor	Variance adjustment factor for length data	Renumbered Fleet	Short Name	corresponding fisheries	Descriptions (selectivity patterns, data sources etc.)	Descriptions (selectivity patterns, data sources etc.)	Weighting factor
1	FL1	JLL	Japanese coastal longline	Flat top	1	3.27	F1	JLL	Japanese coastal longline	Flat Top (L)	Dome shape (L)	x
2	FL2	SPSS	Small pelagic fish purse seine	Double normal	1	2.1	F2	SPSS	Small pelagic fish purse seine	Dome shape (L)	Dome shape (L)	x
3	FL3	TPS	Tuna purse seine	Double normal	1	1.83	F3	TPS	Tuna purse seine (Sea of Japan)	Dome shape (L)	Dome shape (L)	x
4	-	-	-	-	1	1.83	F4	TPS	Tuna purse seine (Pacific ocean)	Dome shape (L)	Dome shape (L)	x
5	FL4	TR	Japanese Coastal Troll	Double normal	1	3.58	F5	TR	Japanese Coastal Troll	Dome shape (L)	Dome shape (L)	x
6	FL5	PL	Japanses Pole-and-line	Double normal	1	1.08	F6	PL	Japanses Pole-and-line	Dome shape, (L)	Dome shape, (L)	x
7	FL6	SN	Japanese set net	Flat top	1	1.74	F7	SN	Japanese Set net (Northern part of Japan)	Dome shape (W)	Dome shape (W)	x
8					1	1.74	F8	SN	Japanses Set net (Q3&Q4 Hokuriku, Japan)	Dome shape (L)	Dome shape (L)	x
9					1	1.74	F9	SN	Set net (Other area)	Dome shape (L)	Dome shape (L)	x
10	FL7	TWLL	Taiwanese long line	Double normal	1	6.46	F10	TWLL	Taiwanese long line	Flat Top (L)	Flat Top (L)	x
11	FL8	EPOCOM	Eastern Pavific Ocean commercial fishery	Doublr normal	1	1	F11	EPOCOM	Eastern Pavific Ocean commercial fishery	Dome shape (L)	Dome shape (L)	x
12	FL9	EPOSP	Eastern Pavific Ocean Sports fishery	Mirror in FL9	0	1	F12	EPOSP	Eastern Pavific Ocean Sports fishery	Dome shape (L)	Dome shape (L)	x
13	FL10	OTH	Others	Lenear segment	0.01	2.11	F13	OTH	Others	Dome shape (W)	Dome shape (W)	x

Table 2. The definition of surveys. The setting of previous setting, WG agreement in February, and current setting.

	The basecase setting in the previous Stock Assessment in 2012						WG agreement in February, 2012				Basecase setting	
Serial number	Fleet	Short Name	corresponding fisheries	Descriptions (selectivity patterns, data sources etc.)	Weighting factor	Variance adjustment factor for length data	Renumbered Fleet	Short Name	corresponding fisheries	Descriptions (selectivity patterns, data sources etc.)	Descriptions (selectivity patterns, data sources etc.)	Weighting factor
14	S1	JpCLL	JLL	Japanese coastal long line conducting spawning area and season (April to June) (WP 18 in PBF07-2)	5	1	S1	JpCLL	JLL	Japanese coastal long line conducting spawning area and season (April to June) (WP 8 in PBF12-1)	Japanese coastal long line conducting spawning area and season (April to June) (WP 8 in PBF12-1)	1
15	S2	JpnDWLLOshima60to80	JLL	CPUEs with set by set data in Japanese offshore longlines from 1960's to 1980's (WP 16 in PBF07-2)	-	-	-	-	-	-	-	-
16	S3	JpnDWLLOshima80to00	JLL	CPUEs with set by set data in Japanese offshore longlines from 1980's to 2000's (WP 17 in PBF07-2)	-	-	-	-	-	-	-	-
17	S4	JpnDWLLYokawaRevto74	JLL	CPUEs with aggregated data in Japanese offshore and distant water longliners using all quarters and area until 1974 (Yokawa WP "25+26", revisited)	5	1	S2	JpnDWLLRevto74	JLL	CPUEs with aggregated data in Japanese offshore and distant water longliners using all quarters until 1974 (WP 10 om PBF-WG 12-1)	CPUEs with aggregated data in Japanese offshore and distant water longliners using all quarters until 1974 (WP 10 om PBF-WG 12-1)	1
18	S5	JppDWLLYokawaRevfrom75	JLL	CPUEs with aggregated data in Japanese offshore and distant water longliners using all quarters and area until 1975 (Yokawa WP "25+26", revisited)	5	1	S3	JppDWLLRevfrom75	JLL	CPUEs with aggregated data in Japanese offshore and distant water longliners using all quarters and area until 1975 (Yokawa WP "25+26", revisited)	CPUEs with aggregated data in Japanese offshore and distant water longliners using all quarters and area until 1975 (Yokawa WP "25+26", revisited)	1
19	S6	JppDWLLYokawaOrgto74	JLL	CPUEs with aggregated data in Japanese offshore and distant water longliners using 1 st, 3rd and 4th quarters until 1974 (Yokawa WP "25+26", original)	-	-	-	-	-	-	-	-
20	S7	JppDWLLYokawaOrgfrom75	JLL	CPUEs with aggregated data in Japanese offshore and distant water longliners using 1 st, 3rd and 4th quarters from 1974 (Yokawa WP "25+26", original)	-	-	-	-	-	-	-	-
21	S8	JppDWLLYokawaWP27to74	JLL	CPUEs with aggregated data in Japanese offshore and distant water longliners using 3rd and 4th quarters and selected regions until 1974 (WP 26 in PBF07-2)	-	-	-	-	-	-	-	-
22	S9	JppDWLLYokawaWP27from75	JLL	CPUEs with aggregated data in Japanese offshore and distant water longliners using 3rd and 4th quarters and selected regions from 1974 (WP 26 in PBF07-2)	-	-	-	-	-	-	-	-
23	-	-	-	-			S4		TPS	Sea of Japan after 1982(L), Dome shape selectivity, share length data with FL4	Sea of Japan after 1982(L), Dome shape selectivity, share length data with FL4	0
24	S10	JpnTrollChinaSea	TR	CPUEs of Japanese troll fisheries in Nagasaki prefecture (Sea of Japan and east china sea) from 1980 to 2007	1	1	S5	JpnTrollChinaSea	TR	CPUEs of Japanese troll fisheries in Nagasaki prefecture (Sea of Japan and east china sea) from 1980 to 2010	CPUEs of Japanese troll fisheries in Nagasaki prefecture (Sea of Japan and east china sea) from 1980 to 2010	1
25	S11	JpnTrollPacific	TR	CPUEs of Japanese troll fisheries in Kochi prefecture (Pacific side) from 1980 to 2005	0	1	S6	JpnTrollPacific	TR	CPUEs of Japanese troll fisheries combine with Kochi and Wakayama prefecture (Pacific side) from 1980 to 2010	CPUEs of Japanese troll fisheries combine with Kochi and Wakayama prefecture (Pacific side) from 1980 to 2010	1
26	-	-	-	-			S7			CPUEs of Japanese troll fisherieswith Kochi prefecture (Pacific side) from 1980 to 2010	CPUEs of Japanese troll fisherieswith Kochi prefecture (Pacific side) from 1980 to 2010	0
27	-	-	-	-			S8			CPUEs of Japanese troll fisheries with Wakayama prefecture (Pacific side) from 1980 to 2010	CPUEs of Japanese troll fisheries with Wakayama prefecture (Pacific side) from 1980 to 2010	0
28	S12	JpnTrollAverage	TR	Simple average of S10 and S12 from 1980 to 2005	-	-	-	-	-	-	-	-
29	S13	TWLL	TWLL	CPUEs of Taiwanese longline from 1998 to 2007	5	1	S9	TWLL	TWLL	CPUEs of Taiwanese longline from 1998 to 2007	CPUEs of Taiwanese longline from 1998 to 2007	1
30	S14	USPSto82	EPOCOM	CPUEs in US purse seine until 1982	1	1	S10	USPSto82	EPOCOM	CPUEs in US target purse seine until 1982	CPUEs in US target purse seine until 1982	0
31	S15	MexPSto98	EPOCOM	CPUEs in Mexico purse seine from 1963 to 1998				-	-	-	-	
32	S16	MexPSto06	EPOCOM	CPUEs in Mexico purse seine from 1999 to 2006	0	1	S11	MexPSto06	EPOCOM	CPUEs in Mexico purse seine from 1999 to 2006	CPUEs in Mexico purse seine from 1999 to 2006	0
33	S17	Ussports	EPOSO	CPUEs in US sports from 1995 to 2005	-	-	-	-	-	-	-	-

Table 3. Weight bin definition. North part of Japan set net (Fleet7) and others (Fleet 13).

Serial number of bin	1	2	3	4	5	6	7	8	9	10
kg	1	2	5	10	16	24	32	42	53	65
cm	37.1	46.6	62.9	79.1	92.3	105.5	116	126.8	136.9	146.4
Serial number of bin	11	12	13	14	15	16	17	18	19	20
kg	77	89	101	114	126	138	150	161	172	182
cm	154.8	162.4	169.3	176.2	182.1	187.6	192.8	197.4	201.7	205.5
Serial number of bin	21	22	23	24	25	26	27	28	29	30
kg	193	202	211	220	228	236	243	250	256	262
cm	209.5	212.7	215.7	218.7	221.3	223.8	226	228.1	229.9	231.7
Serial number of bin	31	32	33	34	35	36	37	38	39	40
kg	273	282	290	297	303	309	313	317	320	323
cm	234.8	237.3	239.5	241.4	243	244.6	245.6	246.7	247.4	248.2

Table 4. Model description

	Setting in 2010	Agreement at the WG February in 2012	Current base case setting
SS version	SS-V3.10b	SS-V3.23b	SS-V3.23b
Year definition	July to June	July to June	July to June
Time step	Quarter	Quarter	Quarter
Stock (spawning population)	Single spawning population	Single spawning population	Single spawning population
Area	Single	Single for assessment; two area for research	Single
Number of age class	21(0-20)	21(0-20) -default; 21-25 lumped	21(0-20)
Ngender	Single sex	Single sex; explore two-sex model	Single sex
Fishery definition	See Uematsu et al. (2012)	separate tuna PS, separate JLL # of fisheries could be reduced: JPN-PL & JPN-troll	See Table 1
Natural mortality	Age specific,year is time step Age0 =:1.6 Age 1=0.386 Age2+=0.25	Age specifc, year is time step Explore Agespecific, linear interporation Further updated analysis will be made at the 2012 WS	Age specific,year is time step Age0 =:1.6 Age 1=0.386 Age2+=0.25
Maturity	Age specific Age3=0.2 Age4=0.5 Age 5+=1.0	Age3=0.2 Age4=0.5 Age 5+=1.0	Age3=0.2 Age4=0.5 Age 5+=1.0
Growth curve	Shimose et al. 2008	Shimose et al. 2009 for single sex model Richards curve Prepare conditional A@L input vectors Explore seasonal change in K	Shimose et al. 2009 for single sex model
#of growth patterns	1	1	1
#of morphs, sub-morphs	1	1	1
Functional form of CV growth	CV=F(A)	CV=F(L)	CV=F(L)

Table 4. Model description (Cont'd)

	2010	Agreement at the WG February in 2012	Base case setting
Amin	0	0	0
Amx	3	3 (revisit this choice)	3
L-W	Kai et al. 2007	Kai et al. 2007	Kai et al. 2007
Length bin definition	see other sheet	Explore wider pop. length bin for younger ages	See Fujioka et al. (2012), especially on Fleet 7 and 13
Popo length bin		if necessary	2 cm bin(16 cm - 222 cm and 252 cm - 290 cm), 1 cm bin interval (224 cm-251 cm)
Catch unit	Weight	Weight/numbers ex: EPO-sport (numbers), fraction of JP-LL Fleet 2 may have possibility	Weight/numbers
Catch error	0.1	0.1	0.1
F-method	3 (solve catch eq)	3 (solve catch eq) - catch exact	3 (solve catch eq) - catch exact
iteration	5	5	5
upperF	5	Explore reason for high F estimates in Epo (aroud 5, first qrt)	10
CPUE likelihood	t(df=30)	lognormal	lognormal
CPUE (JLL) selectivity	Same selectivity for all age class	Test dome shape	Same selectivity for all age class
CPUE lambda	5 for LL 1 for other	1(0 for EPO CPUE)	1(0 for EPO CPUE)
CPUEcv effN for LenComps	Lowest CV is set as 0.2 Scale to have same effN to FL8	Lowest CV is set as 0.2 Scale to have same effN to FL8,FL3(SOJ)	Lowest CV is set as 0.2 Scale to have same effN to FL8,FL3(SOJ)
SRR	B-H	B-H, explore H-S model, retune model w different h values(estimate H by hockey-stick) explore Sheperd S-R	B-H
R0	Estimated	Estimated	Estimated
Steepness	1	0.999	0.999
sigmaR	0.6	0.6, run estimate	0.6
1st year of main Rdev	1946	Tune later	1946
R0 offset	Estimated	Estimated	Estimated
SR auto correlation	No	No	No
Initial F	LL, tuna PS, troll with eqC	Estimate Finit without fitting to EqC if unsuccessful LL, tuna PS, troll with eqC	LL, tuna PS, troll with eqC
Diagnostics of the model	Bootstrap, retrospective analysis	Same method is used, and try MCMC. Delta method	Bootstrap, retrospective analysis

Table 5. The setting of size selectivity curve

		Fleet 1	Fleet 2	Fleet 3	Fleet 4	Fleet 5	Fleet 6	Fleet 7	Fleet 8	Fleet 9	Fleet 11	Fleet 11 (1988-1989)	Fleet 13
		Cubic Spline											
The number of Node		6	4	5	5	5	5	5	5	6	11	11	6
Gradient of first node		est	est	est	est	est	est	1.11E-05	est	est	est	est	est
Gradient of last node		est	est	est	est	est	est	est	est	est	est	est	est
The location of node	1	100.863	30.25	76.25	35.95	25.25	16.25	30	20.25	30.25	50.5		17.25
	2	150.987	60.95	116.3	75.3	40.95	30.95	50.95	41.95	54.25	70.5		41.95
	3	176.686	90.3	124.05	100.05	50.3	60.3	140.3	75.3	62.3	80.5		75.3
	4	190.744	110.05	200.15	200.15	120.05	80.05	160.05	132.05	90.05	85.5		110.05
	5	200.899		260.25	280	220.15	102.15	248.15	245.15	120.15	90.5		130.15
	6	280.932								263.25	110.5		240.15
	7										134.5		
	8										180.5		
	9										200.5		
	10										230.5		
	11										264.5		
Estimate or fixed value	1	est	est	est	est	est	est	est	est	est	-9	-9	est
	2	est	est	est	-0.21465	est	est	est	est	est	est	est	est
	3	est	est	est	est	est	est	est	est	est	est	est	est
	4	est	-9	set	est	est	est	est	-1	-1	est	est	-1
	5	est		-9	est	-9	-9	-9	-9	est	-1	est	est
	6	5								est	est	est	est
	7										est	est	
	8										-9	est	
	9										-9	6.99865	
	10										-9	est	
	11										-9	est	

	Fleet 10
	Flat top
P1	Estimate
P2	Estimate

Fleet 12	Mirror of Fleet 11

Table 6. The components for base case

	Base
Time	19m21s
Final Gradie	0.00
Convergen	0.00
TOTAL	6240.99
Catch	0.00
Equil_catch	0.00
Survey	39.82
SizeFreq	6199.38
Recruitmer	1.65
Forecast_R	0.00
Parm_priors	0.00
Parm_softb	0.16
Parm_devs	0.00
Crash_Pen	0.00

Size likelihood (likelihood which times lambda value)

Fleet	1	2	3	4	5	6	7	8	9	10	11	12	13
Base	962.37	338.32	398.91	470.55	907.90	323.90	414.36	350.01	1002.33	174.91	563.42	0.00	292.41

Size likelihood (not times weighth parameter)

Fleet	1	2	3	4	5	6	7	8	9	10	11	12	13
Base	346.43	261.54	398.91	369.14	368.14	317.74	239.60	152.98	439.14	47.42	563.42	225.62	137.97

Weight parameters (lambda)

Fleet	1	2	3	4	5	6	7	8	9	10	11	12	13
Base	2.78	1.29	1.00	1.27	2.47	1.02	1.73	2.29	2.28	3.69	1.00	0.00	2.12

Survey likelihood

Fleet	14	15	16	17	18	19	20	21	22	23	24
Base	24.02	-18.71	-14.34	27.71	-27.06	70.71	74.77	67.33	5.19	3.19	9.44

Weight parameters (lambda)

Fleet	1	2	3	4	5	6	7	8	9	10	11
Base	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00

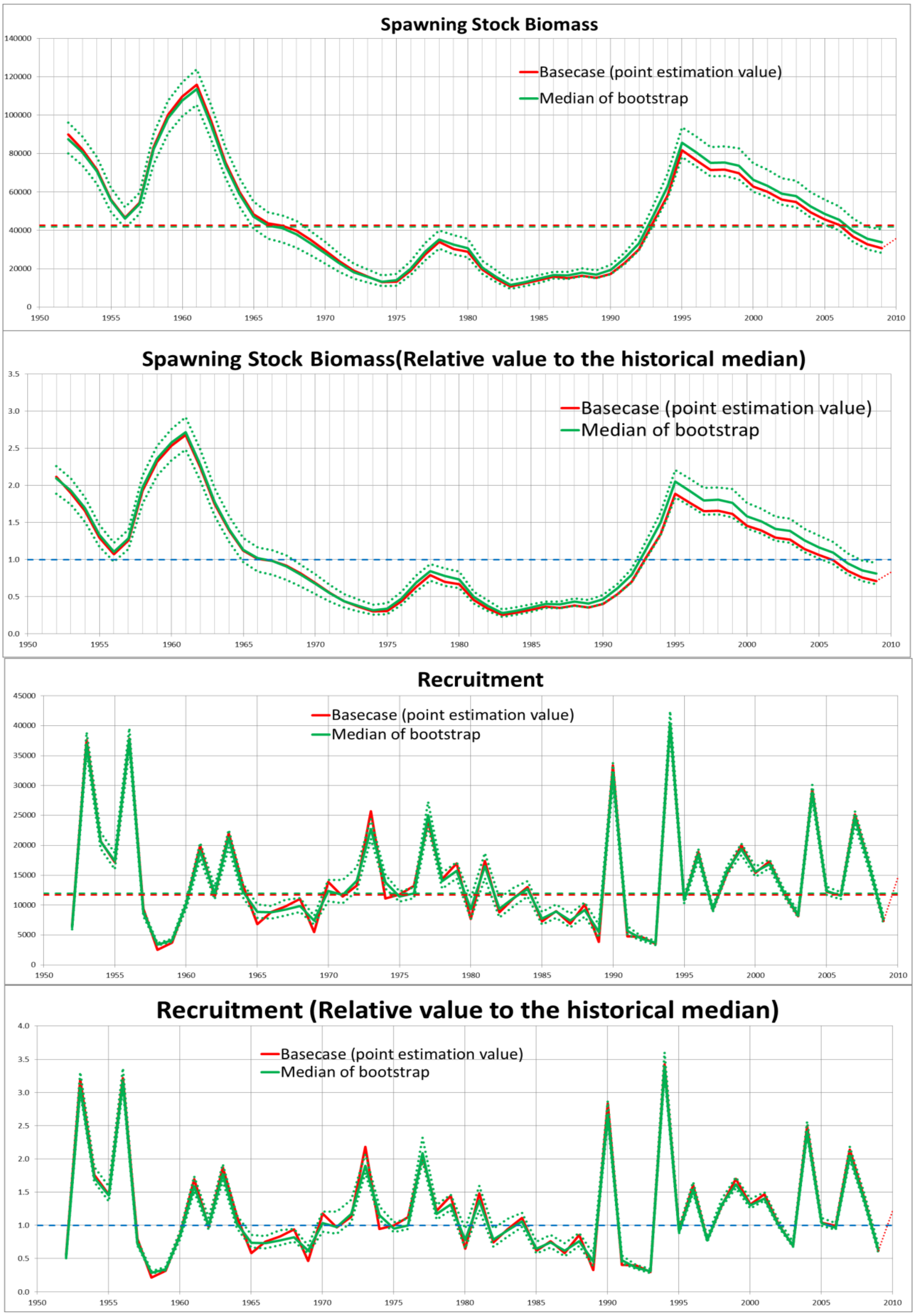


Figure 1. The time-series of Spawning Stock Biomass and Recruitment of base case. (Top: Spawning stock biomass Bottom: Recruitment. Left: Absolute value Right : Relative value to the historical median)

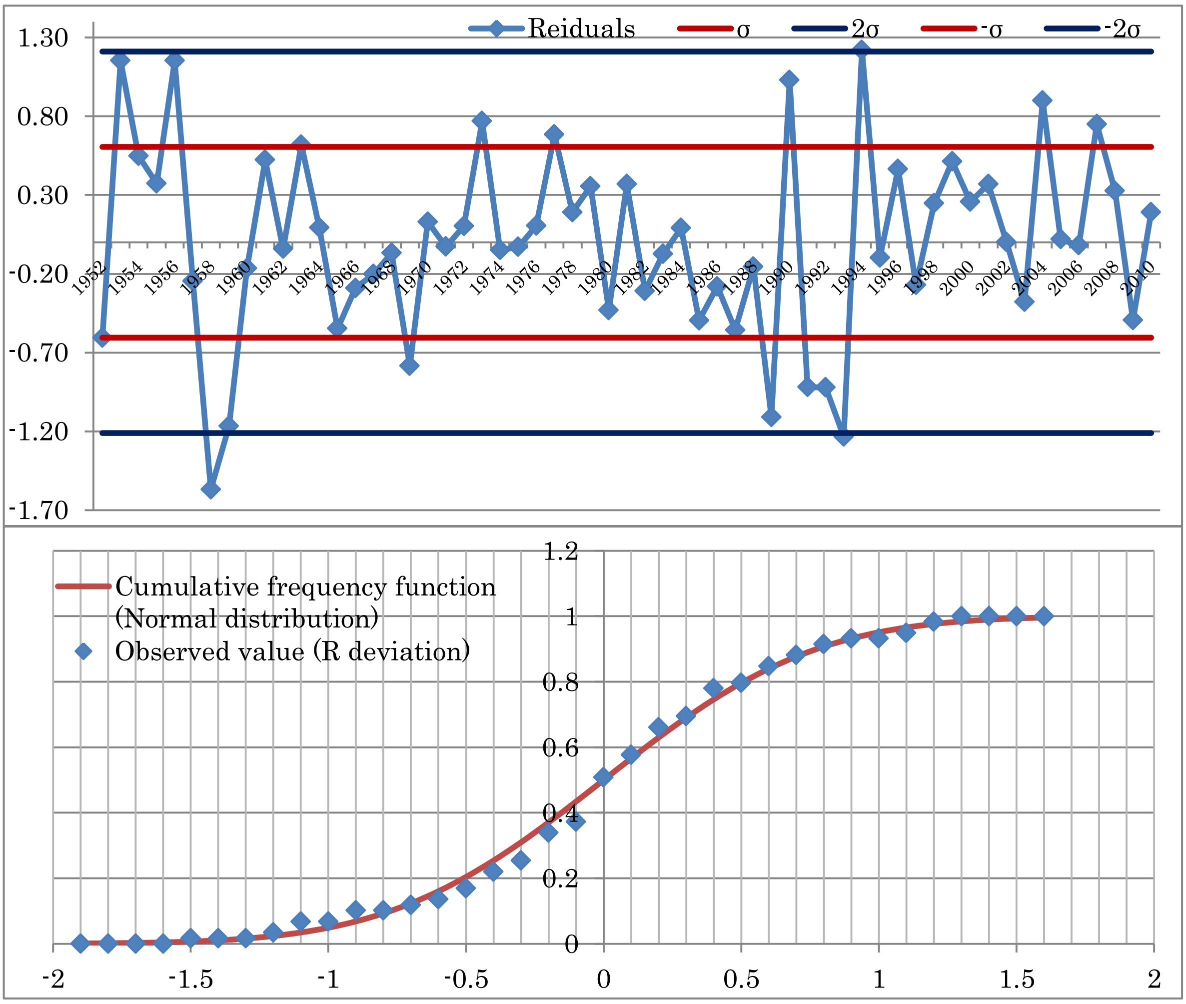


Figure 2. Residuals of recruitment deviation. Top: Temporal dynamics of observed value (R deviation). Red line indicates σ and -σ. Deep blue line indicates 2σ and -2σ. Bottom: Observed value (R deviation) and Cumulative frequency function (Normal distribution with mean 0, deviation 0.6).

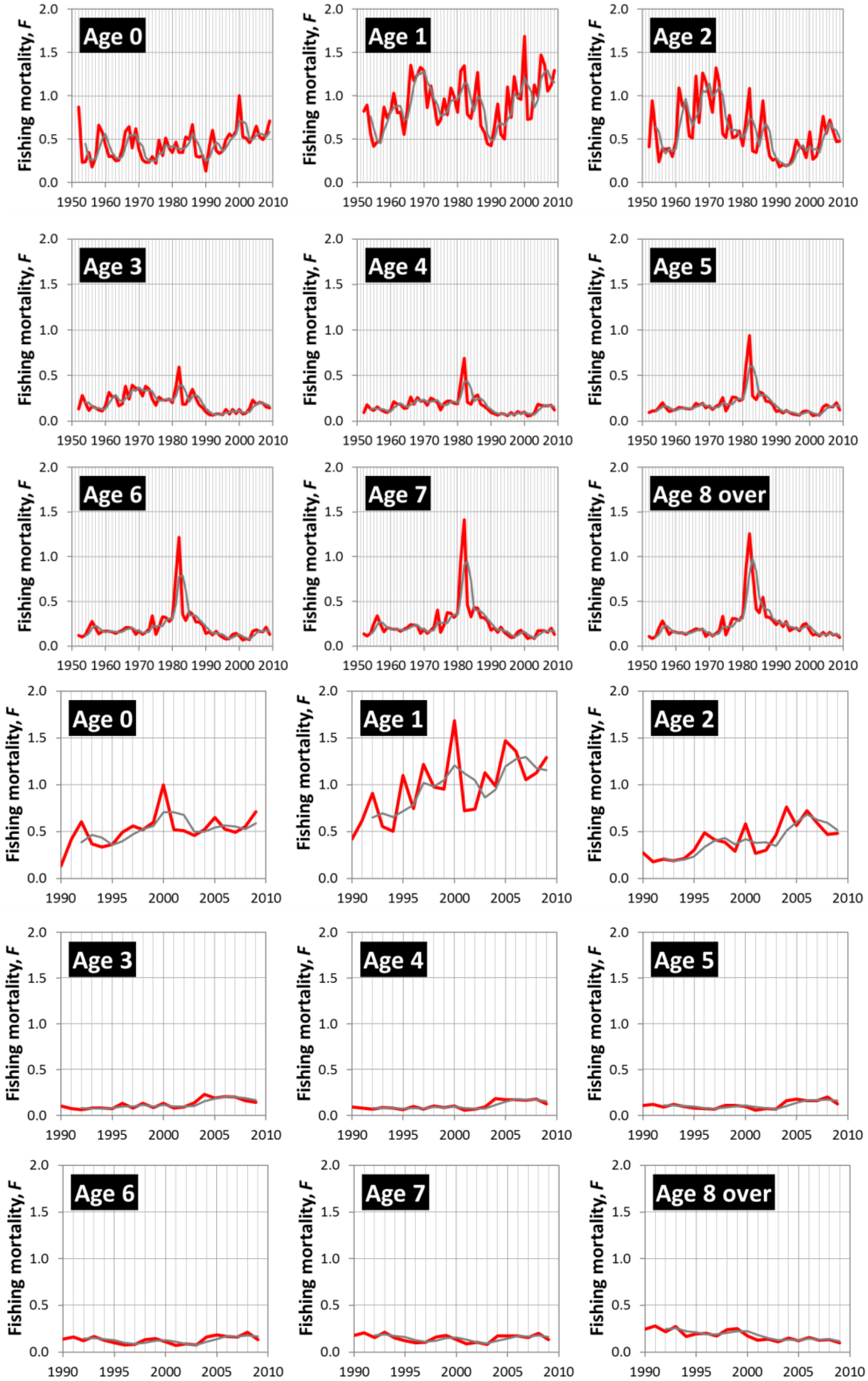


Figure 3. Dynamics of fishing mortality, F (or exploitation rate). (a) Plot of fishing mortality, F during 1952-2010. (b) Plot of fishing mortality, F during 1990-2010.

(b)

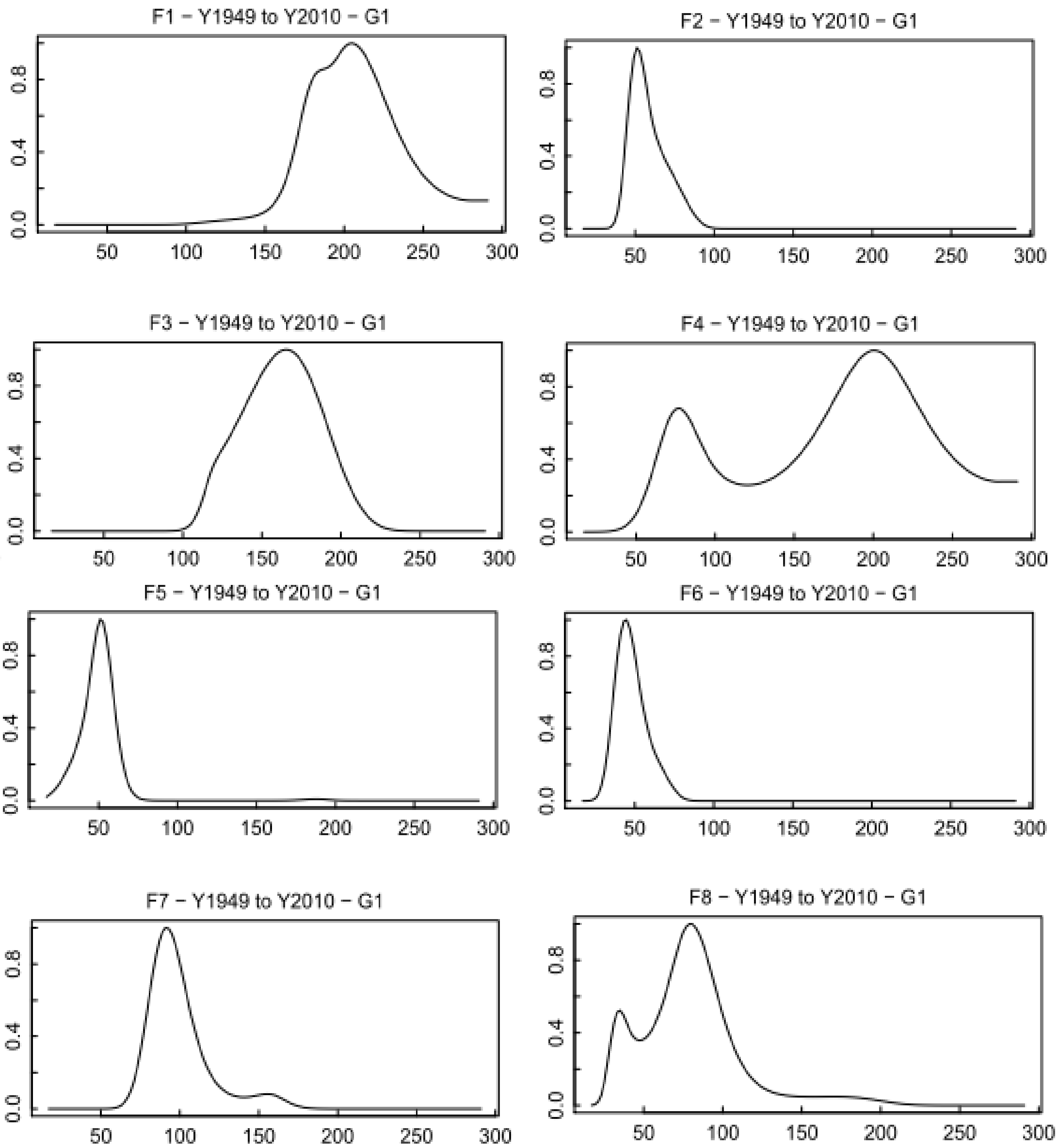


Figure 4. Selectivity curve

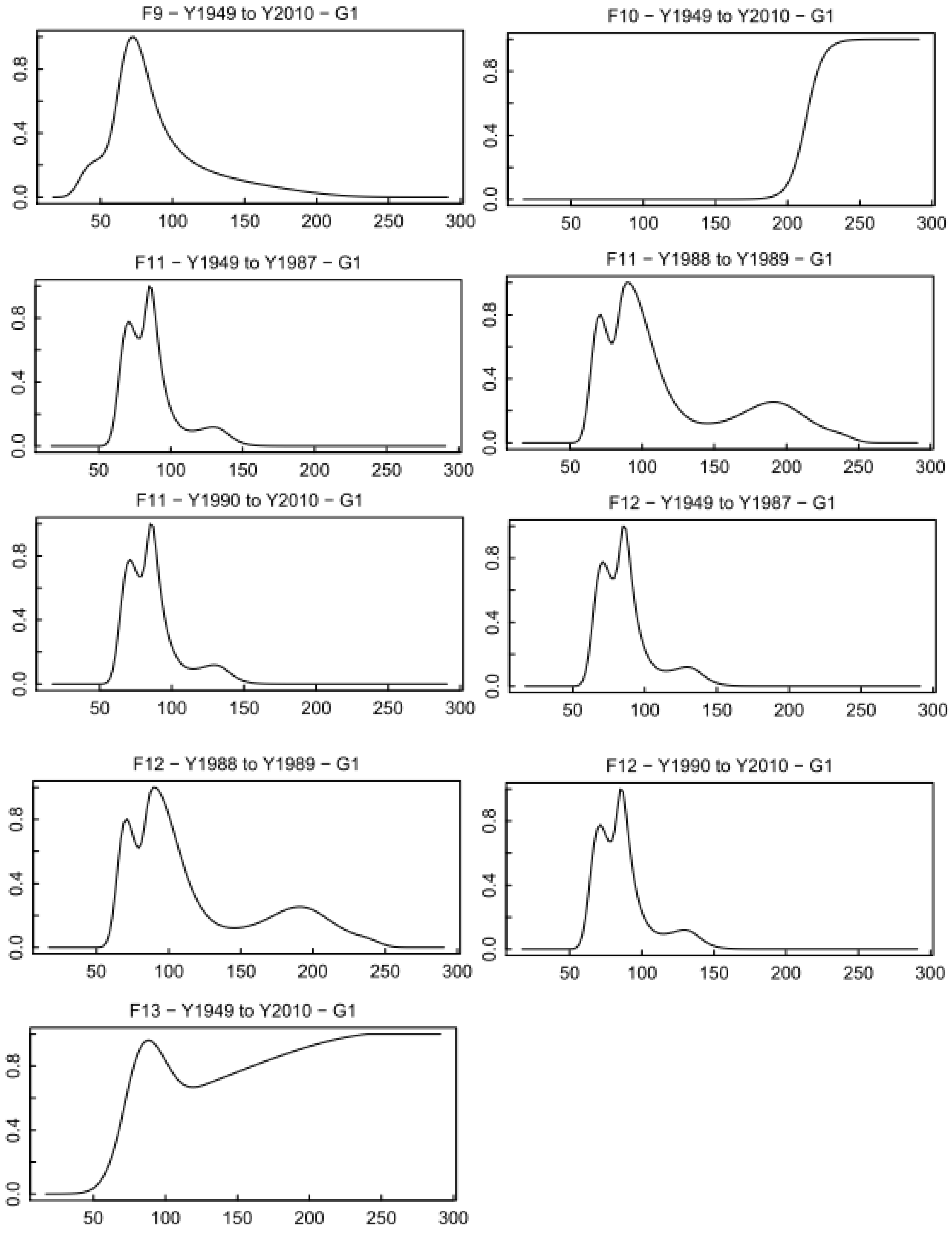


Figure 4. Selectivity curve (Cont'd.)

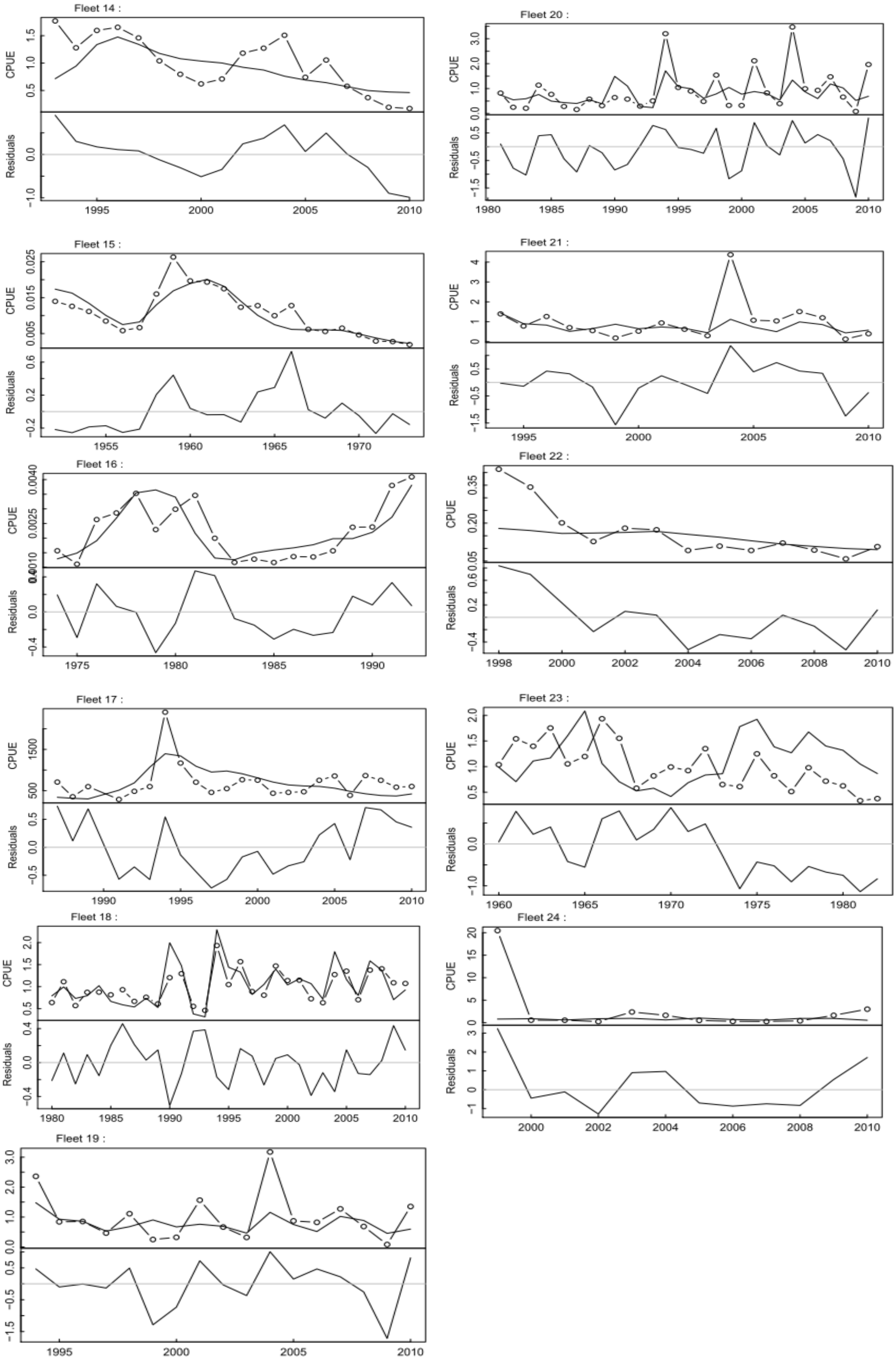


Figure 5. Observed and expected CPUE, and its residuals. Expected (line) and observed (line + circle)Residuals (Observed value – expected value)

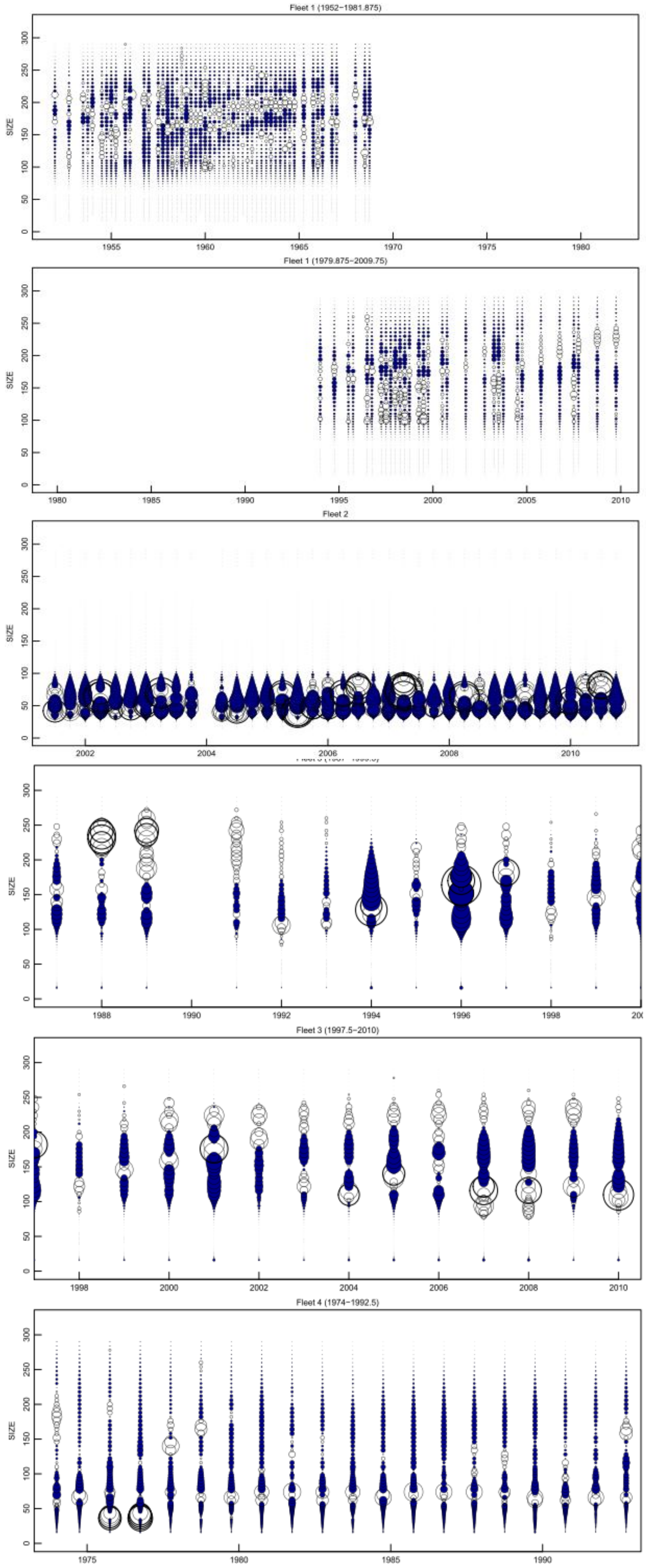


Figure 6. The model fits to the length composition data. Dark blue circle (observation value < expected value), white circle (expected value > observation value)

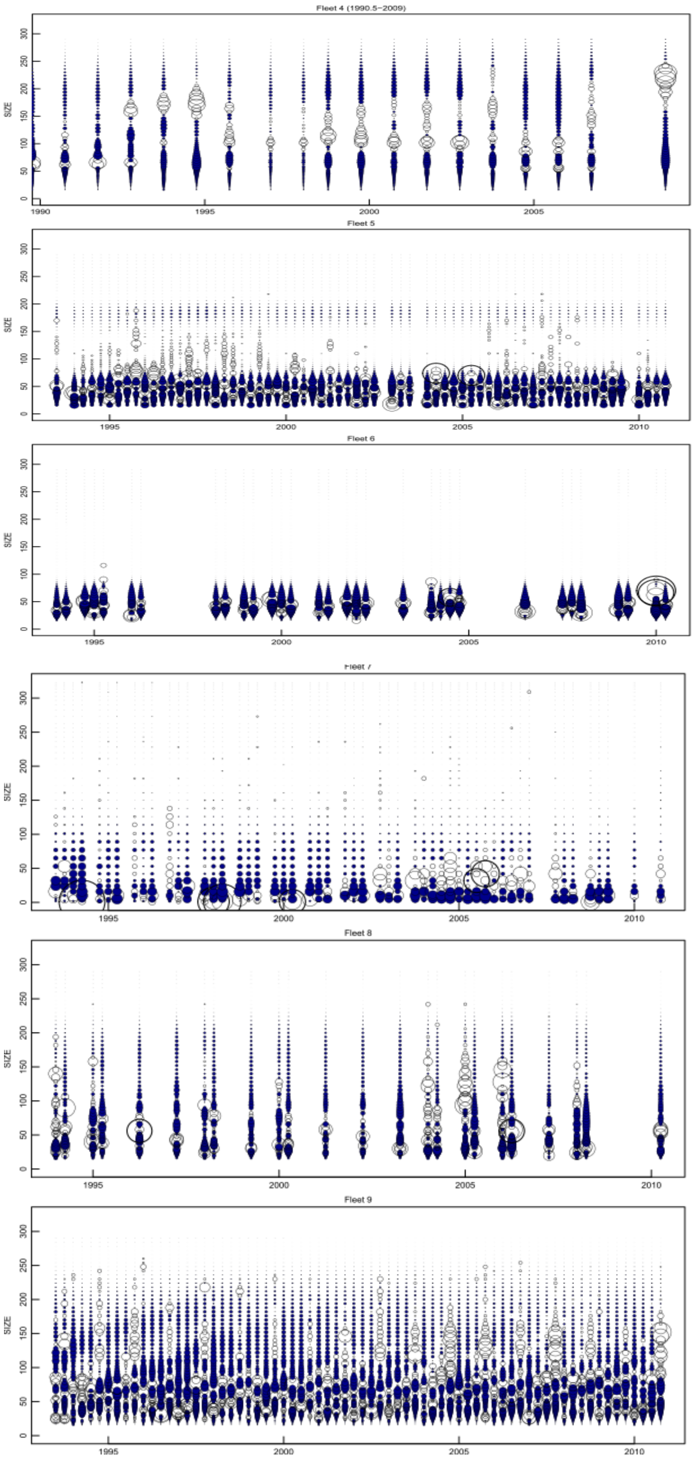


Figure 6 (cont'd). The model fits to the length composition data. Dark blue circle (observation value < expected value), white circle (expected value > observation value).

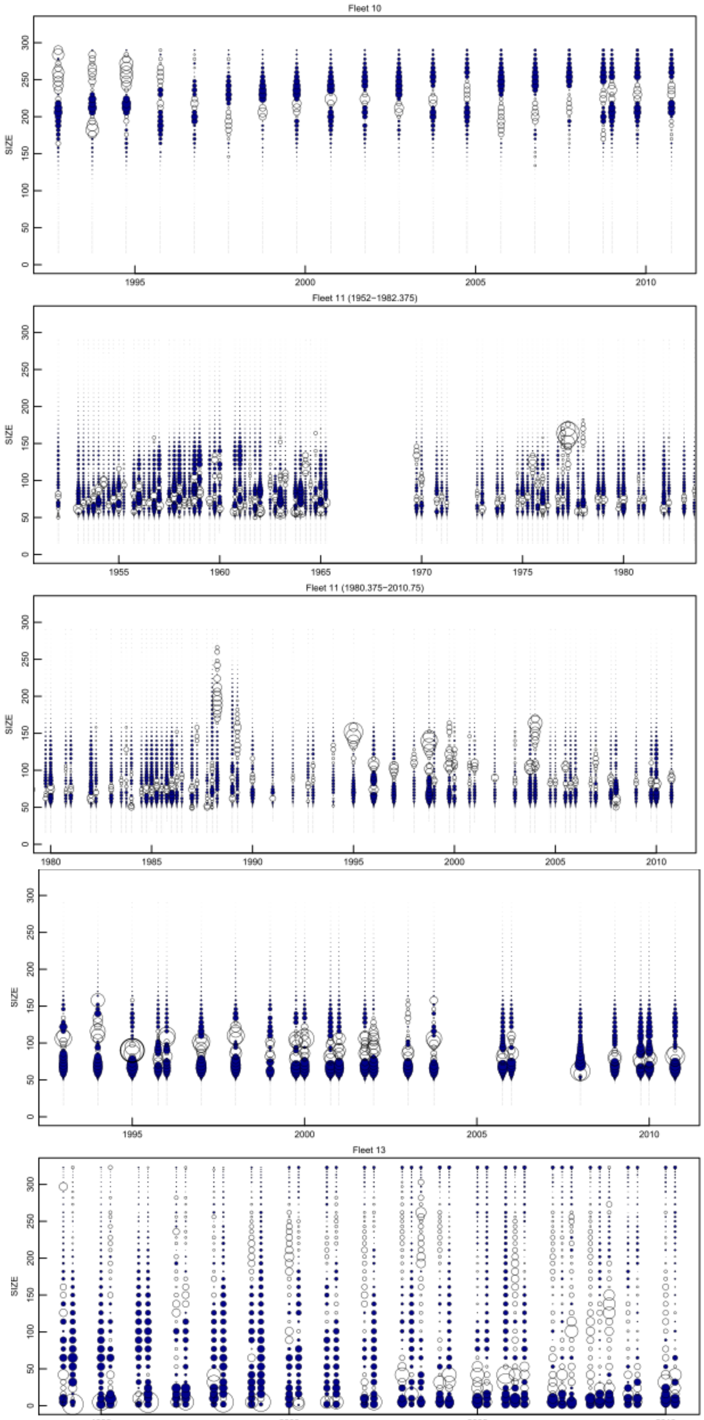


Figure 6 (cont'd). The model fits to the length composition data. Dark blue circle (observation value < expected value), white circle (expected value > observation value).

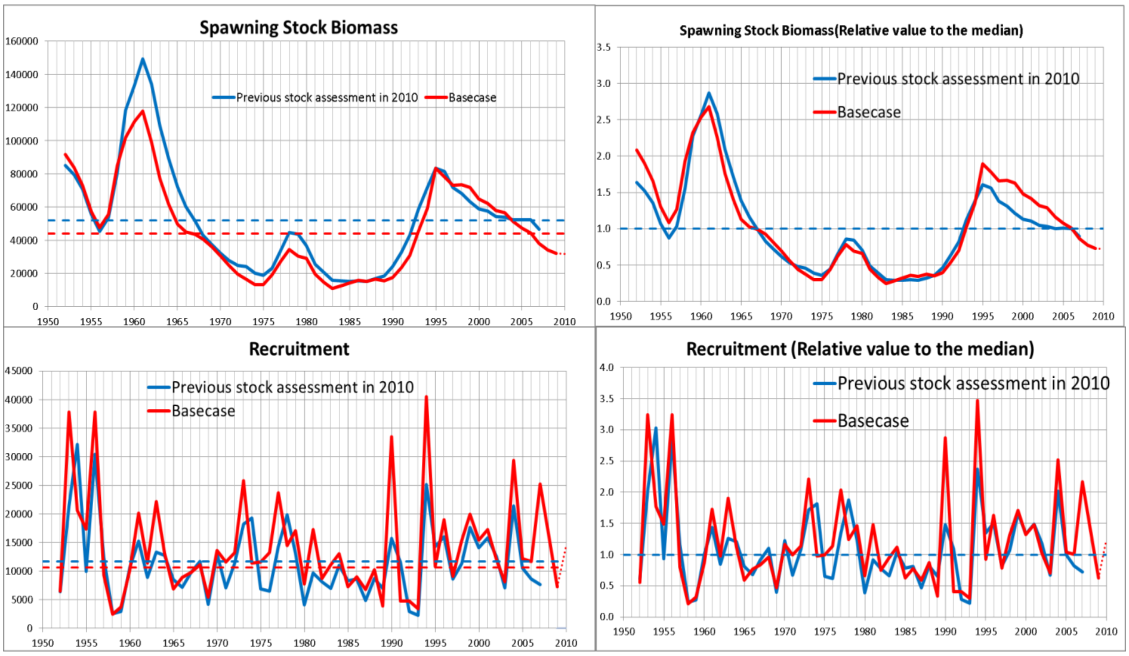
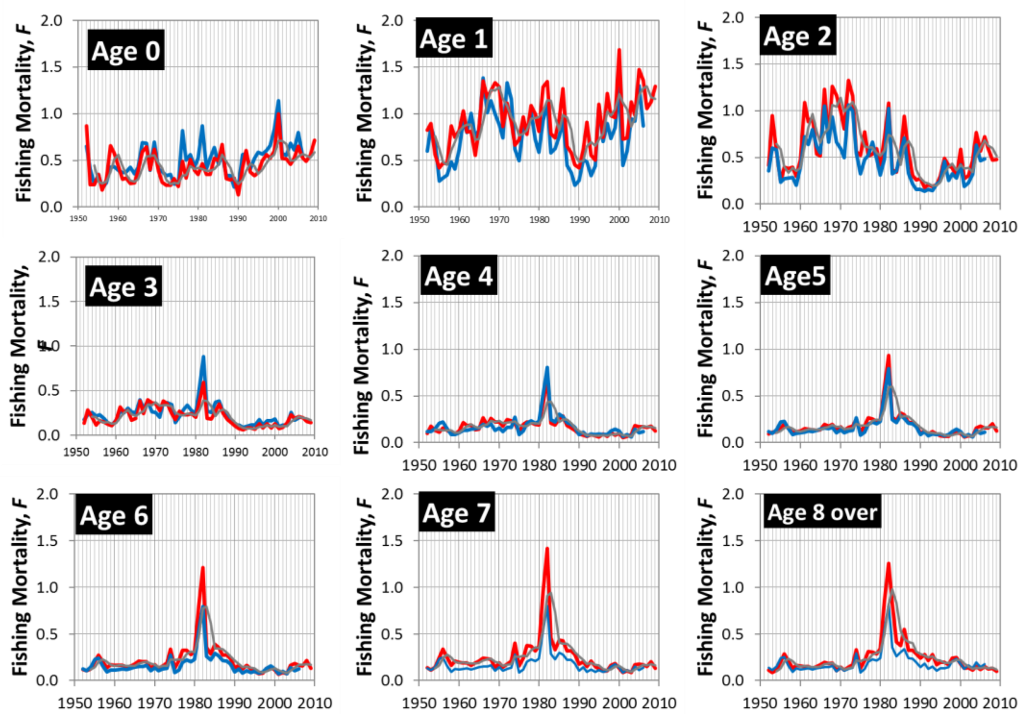
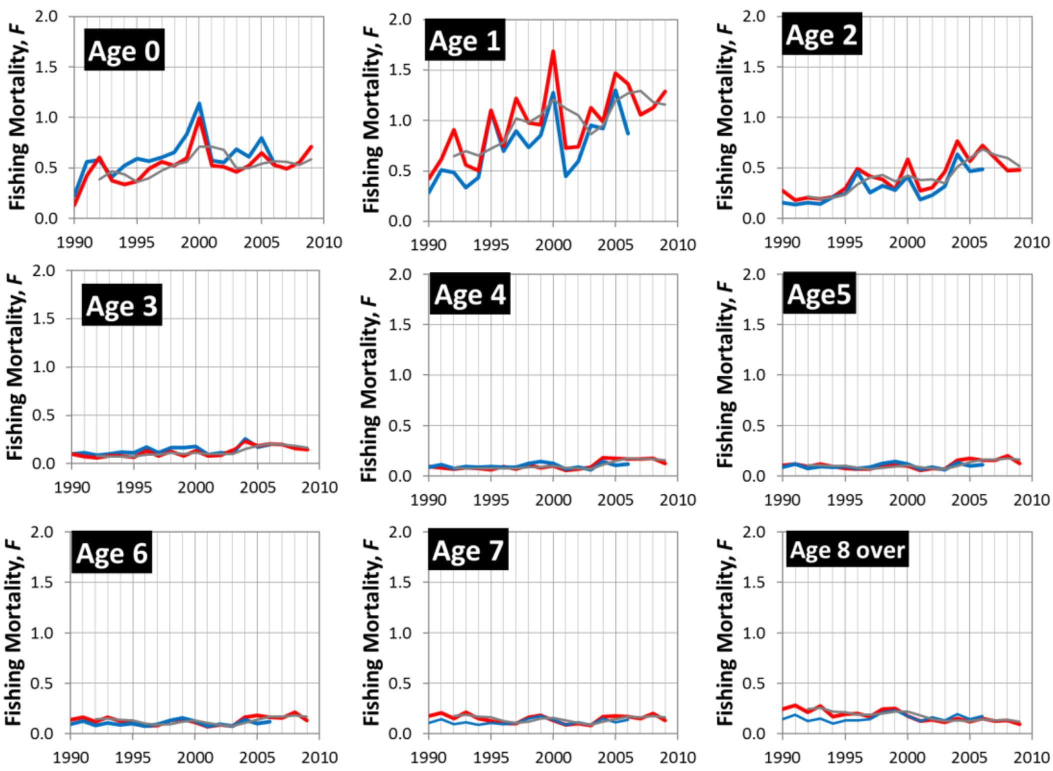


Figure 7. Compare the dynamics of Spawning Stock Biomass (SSB) and recruitment of base case (red line) with previous stock assessment (blue line). (Top :Spawning stock biomass Bottom: Recruitment. Left : Absolute value Right : Relative value to the historical median)



(a)



(b)

Figure 8. The comparison of the trend of Fishing Mortality, F. (a) Plot of fishing mortality, F during 1952-2010. (b) Plot of fishing mortality, F during 1990-2010.

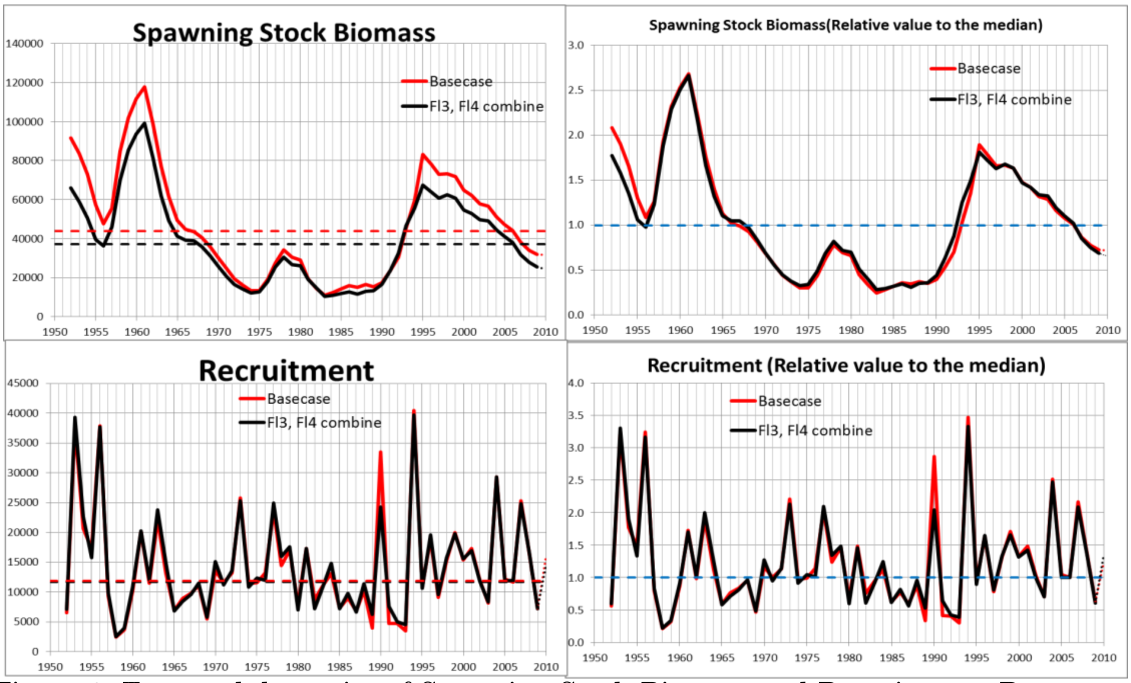


Figure 9. Temporal dynamics of Spawning Stock Biomass and Recruitment. Base case (Red line). Run with data which combined Fleet 3 and 4 for catch and length composition data (Black line) (Top :Spawning stock biomass Bottom: Recruitment. Left : Absolute value Right : Relative value to the historical median).

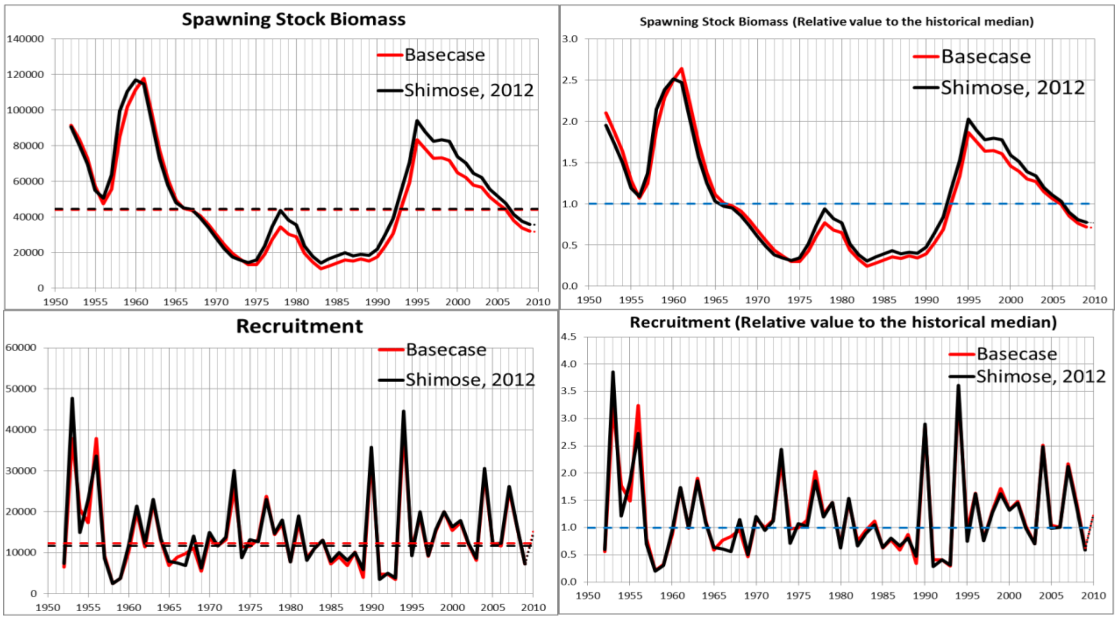


Figure 10. Temporal dynamics of Spawning Stock Biomass and Recruitment of base case (Red line) vs Run using growth curve (Shimose, 2012: black line), (Top:Spawning stock biomass Bottom: Recruitment. Left : Absolute value Right : Relative value to the historical median).

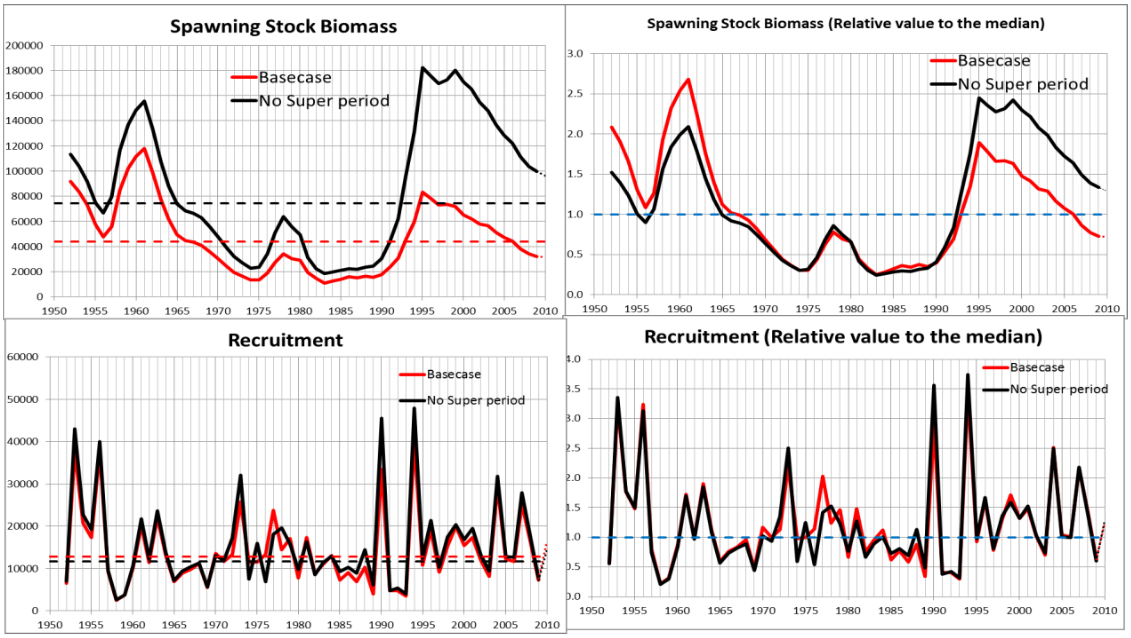


Figure 11. Temporal dynamics of Spawning Stock Biomass and Recruitment of base case (Red line), Run without super season for TPS for pacific ocean (black line), (Top:Spawning stock biomass Bottom: Recruitment. Left: Absolute value Right: Relative value to the historical median).

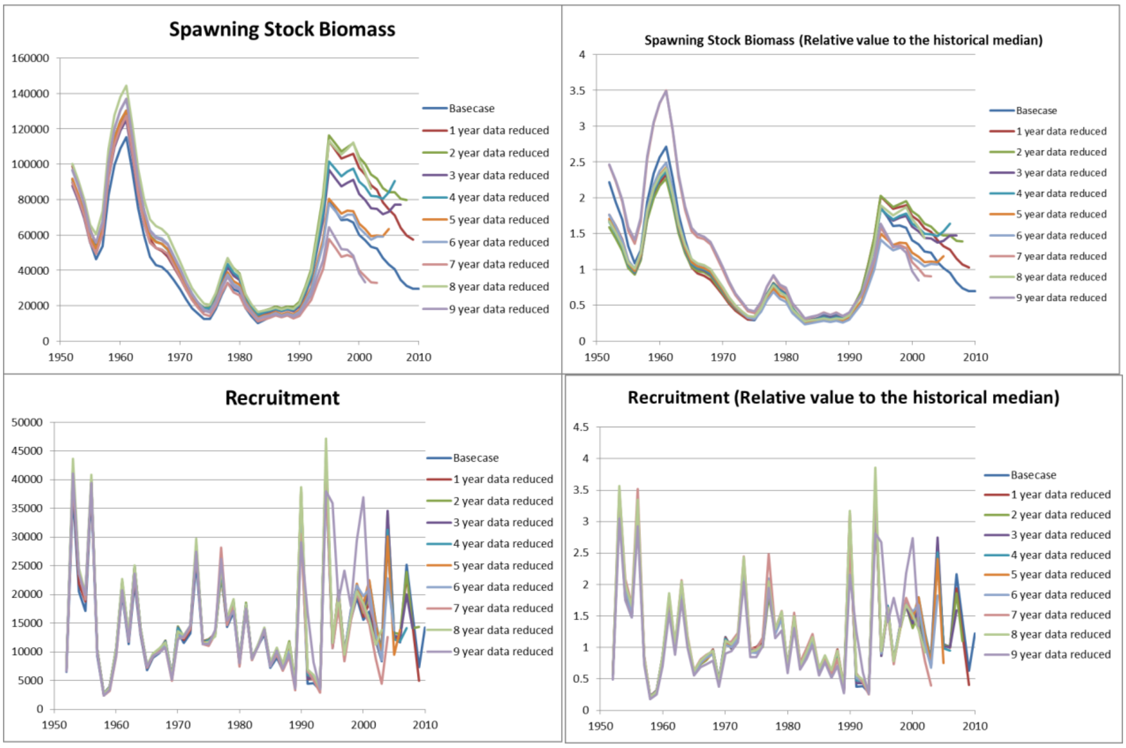


Figure 12. The result of retrospective analysis (Top :Spawning stock biomass Bottom: Recruitment. Left : Absolute value Right : Relative value to the historical median)

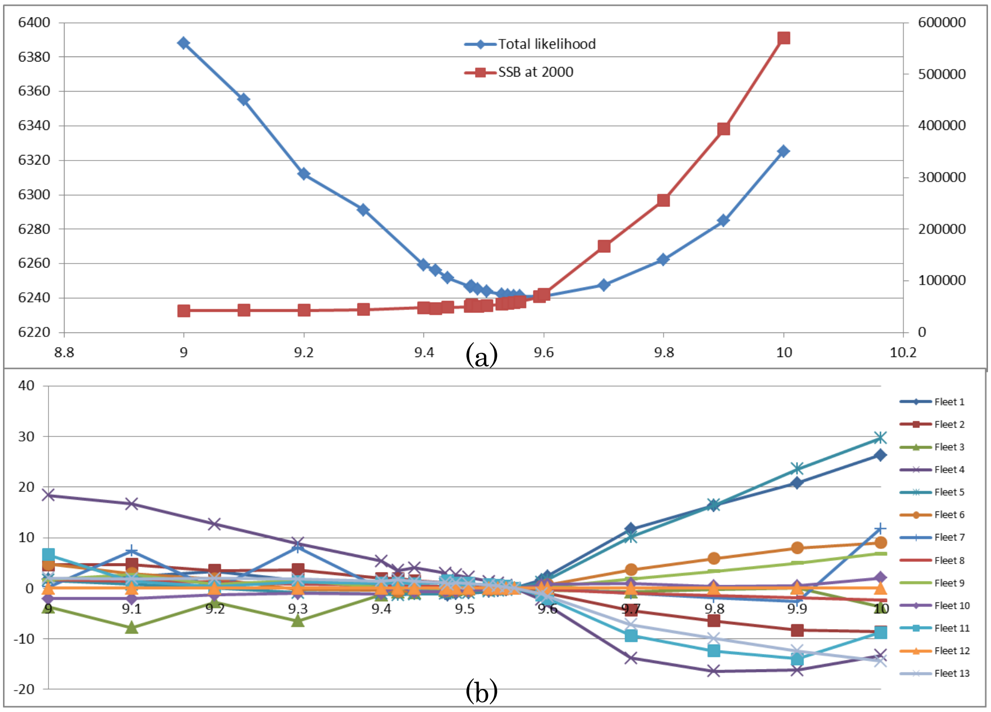


Figure 13. The result of likelihood profile. The horizontal axis means the logged initial recruitment, LN(R0). (a: Total likelihood (blue line) and SSB in 2000 (red line). b: the differences of likelihood for each fleet between each points and the point where is taken most lowest total likelihood, LN(R0)=9.7 in this case.)