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A review of the model setting for the update of stock assessment for Pacific bluefin tuna

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Abstract

Stock assessment of Pacific Bluefin Tuna is updated with the fishery data of additional 2 years until 2012 in accordance with the original work plan endorsed at the 13th ISC Plenary. In this document, we describe the setting of the updated stock assessment model. Four subjects regarding the catch unit of Fleet 13 (US Sports Fishery), the selectivity parameters of Fleet 8 and 10 (Japanese Set-net), the input Effective sample size of Fleet 12 (Eastern Pacific Ocean Commercial Fisheries), and the catch time series for farming in Western Pacific Ocean (Fleet 5), are modified after confirming their effect. These modifications did not have any fatal effect on the model parameter estimations and the population dynamics estimated.

1 Introduction

The 13th ISC Plenary, held in Busan, Republic of Korea from 17-22 July 2013, approved the proposal of the Pacific Bluefin Tuna Working Group (PBFWG) to conduct an updated stock assessment with the additional recent 2 years data (from 3rd quarter of 2011 to 2nd quarter of 2013 in calendar year). The stock assessment update was planned as follows (ISC/PBFWG, 2013):

(1) Conduct model run with an additional two years (2011 and 2012 in fishing year) of data using the same Stock Synthesis (SS) model (version 3.23b from the 2012 stock assessment) for the stock assessment platform and using the same model structure and parameters as the representative run (base-case run) from the 2012 stock assessment.

(2) The stock assessment time period will be from July 1952 to June 2013 (calendar year).

(3) The WG will not change the fishery data (quarterly catch, size composition) from 1952-2010 in fishing year (July 1952-June 2011 in calendar year) that was used in the 2012 stock assessment.

(4) In the case of CPUE time series, due to the nature of the CPUE standardizations method, the whole time series will need to be re-standardized with the additional 2 years data. The statistical method used to standardize CPUE (error structure, etc.) will be the same as that used in the 2012 stock assessment. Also note that this year the WG reviewed updated Japanese longline and troll CPUEs with one additional year of data. Therefore, Japan will only be required to include one additional year of data.

The stock assessment model is tuned and updated mostly according to this plan, however, some modifications are required. In this document, we reviewed the model setting for the updated stock assessment and investigated the effect of each modification.

2 Model descriptions

2.1 Basic Configurations

The model is implemented using SS Version 3.23b (Methot, 2011; http://nft.nefsc.noaa.gov/Stock_Synthesis_3.htm). The model assumes a single well-mixed stock for Pacific bluefin tuna *Thunnus orientalis* (PBFT), and does not consider a spatially explicated structure. All the catch and size composition data are temporally stratified into the following 4 quarters of July-September, October-December, January-March, and April-June. Those quarters (Jul-Sept, Oct-Dec, Jan-Mar, and Apr-Jun) are assigned to 1st, 2nd, 3rd, and 4th quarters, respectively as the fishing year of Pacific bluefin tuna. The time period modeled in this assessment is 1952-2012 including the updated recent two years (2011-2012). The biological and demographic assumptions have not been changed from the 2012 stock assessment as written in the original work plan.

Annual recruitment deviates are estimated from 1953 to 2011 as the main recruit deviations, and an expected mean recruitment from Stock Recruit Relationship is used for 2012. In the updated stock assessment model, the ending year of early deviation as well as the ending year and starting year of no or full bias adjustment are chosen, based on the results of the 'fitbiasramp' function of R4SS package (Taylor et al., 2013: http://cran.r-project.org/web/packages/r4ss/index.html).

The definition of the fisheries on the stock assessment has not been changed from the last stock assessment. Fourteen Fleets are defined as follows; Japanese longline (Fleet 1), purse seine fisheries operating in the East China Sea (Fleet 2), the Sea of Japan (Fleet 3), and off the Pacific coast of Japan (Fleet 4), Japanese troll (Fleet 5), Japanese pole and line (Fleet 6), Japanese set net (Fleet 7 to 10), Taiwanese longline (Fleet 11), EPO commercial fisheries (Fleet 12), US sport (Fleet 13) and other miscellaneous fisheries (Fleet 14). Fleet 2 also includes Korean purse seine fishery operating in the East China Sea.

2.2 Input Data

The catch data for recent two years are updated as written in Oshima et al. (2014). The quarterly catch data from 1952 to 2010 are not changed in accordance with the original work plan except Fleet 5. The catch of this Fleet is revised in ISC 2013 PBFWG held in Korea to take into consideration the age 0 PBFT catch for farming by the Japanese troll fishery (ISC13 Plenary Report, Annex 14, Appendix 2, Appendix A). According to this report, the catch of age 0 PBFT in summer for farming are not negligibly small (more than a million individuals per year in several years). In order to include the catch for farming into the updated stock assessment and future projection, those catch data are added during 1998-2012. The effect of this modification is written in below (3.1).

Although the catch data for Fleet 13 (US sport) was provided in the number of fish (thousands of fish) by US scientists for the last stock assessment, the units of catch in the stock assessment model were defined as a biomass for all fleets at that time. The PBFWG overnighted this difference of unit at that time and find it during the data updating process for the update stock assessment. The, WG confirmed the effect of modification of catch unit for Fleet 13 from biomass to number to be minimal, and decided to collect the catch unit (See 3.2).

The size composition data from 1952 to 2010 has not been changed except the 4th quarter of Fleet 1 (Japanese longline). At the 2012 stock assessment, there was no available size composition data for 4th quarter of 2010 due to the difficulty of data collection. Currently a raised size compositions (Catch at size) of Fleet 1 for 2010 and 2011 are additionally available. The size composition data until 2012 including Fleet 1 have also been updated as written in Oshima et al. (2014).

As written in the original work plan, the whole CPUE time series need to be re-standardized with additional recent 2 years data. Japanese longline CPUE (S1), Japanese troll CPUE (S5), and Taiwanese longline CPUE (S9) were re-standardized and became available until 2012 (Hiraoka et al., 2014, Fujioka et al., 2014, Wang et al., 2014). In addition to those CPUEs, S2 and S3 (past periods of Japanese longline CPUE) are used in this updated stock assessment.

The inputs coefficient of variation (CV) for each CPUE time series are set as 0.2 to each year in S2, S3, S5 and S9, and from 0.2 to 0.46 for S1, respectively. For S1, CV of updated recent 2 years (2011 and 2012) are carrying over of the value of year 2010.

2.3 Selectivity

The fishery-specific length (or weight) based selectivity patterns are used. The same as the last stock assessment, an asymptotic selectivity fleet (Fleet 11) and 13 domed shaped selectivity fleets (the rest of the fleets) are assumed. For asymptotic selectivity fleet, the length at 50% selectivity and the difference between the length at 95% and 50% selectivity, are estimated. For the domed shaped selectivity fleets, the beginning size for the plateau, ascending width and descending width are estimated. The PBFWG members found that the estimation of ascending and descending width are sometimes interfered by the upper and lower limit of the estimation. In these cases, the ascending/descending width parameters will be fixed when the effects of parameter fix to the other parameter estimations are limited (discussed in below).

In the last stock assessment, time varying selectivity via the time blocks were deployed for Fleet 1 (Japanese longline), Fleet 3 (Japanese tuna Purse Seine operated in the Sea of Japan), and Fleet 12 (EPO Commercial fishery). In those Fleets, two time periods were defined (1952-1992 and 1993-2010 for Fleet 1, 1952-2006 and 2007-2010 for Fleet 3, 1952-2001 and 2002-2010 for Fleet 12), and the selectivity parameters were estimated for each time periods. In the updated stock assessment, the selectivity in 2011 and 2012 of those fleets are identical to that in the latter time periods.

2.4 Weighting of data

The same as the last stock assessment, all size compositions except for Fleets 6, 13 and 14 are fitted in the model with full weight (lambda=1). The selectivity parameters of Fleets 6 and 13 are mirrored to Fleets 5 and 12 respectively, and their size compositions are not fitted in the model (lambda=0). The selectivity of Fleet 14 is fixed to the selectivity estimated in a preliminary run with lambda=0.1, and the size composition data is not fitted in the final model (lambda=0).

The input effective sample size (EffN) of all fleets except Fleet 3 and 12 are determined by following steps:

1.) Maximum and minimum input sample size (quarterly number of fish measured) are set to 200 and 100 respectively. The sample size larger than 200 is set to 200, that lower than 100 is not used.

2.) The quarterly input sample size of each fleet is scaled by an average sample size of Fleet 3 and 12 from 1952 to 2010. To keep the consistency with the last stock assessment, scaling of effective sample size is conducted using the average value of Fleet 3 and 12 from 1952 to 2010 (12.11).

Those methods for the weighting of the size frequency data are same as the last stock assessment (Table 1). Note that a difference from the last stock assessment is the input EffN of Fleet 12. In the last stock assessment, the input EffNs of Fleet 12 in some quarters were set as 0.5. This value indicates that there is only a trip of purse-seiner with well size sampling. In the past stock assessment (for example 2008 full stock assessment), however, the input EffN of below 1.0 was changed to 1.0 ad hoc to avoid technical error happen in a bootstrap work. In this updated stock assessment, some quarters of the input EffNs of Fleet 12 which are less than 1.0, are changed to 1.0 after confirming its effect (see. 3.4).

3 EFFECT OF MODIFICATION

3.1 Catch for farming by Japanese troll

The effect of adding the catch data for farming by Japanese troll (Fleet 5) during 1998-2010 is investigated using the representative model of 2012 stock assessment conducted in Hawaii (Hawaii 2012 model).

The estimated average annual catch in number of Fleet 5 during 1998-2010 is around 1.6 hundred thousand individuals larger in the model, which includes catch for farming, than that of Hawaii 2012 model (Fig. 1). The observed annual catch in number for farming was around 7.9 hundred thousand individuals in average during 1998-2010 (ISC13 Plenary Report, Annex 14, Appendix 2, Appendix A), so the model tends to underestimate the catch for farming.

Estimated recruitments and Spawning Stock Biomass (SSB) during 1998-2010 are 2.1% and 0.8% larger in the model, which includes catch for farming, than that of Hawaii 2012 model (Fig. 2).

3.2 Catch Unit

As mentioned above (2.2), there was a modeling error on the catch unit of Fleet 13. Here, we revised that catch unit from biomass to number based on the Hawaii 2012 model, and compared the result with the Hawaii 2012 model.

The estimated annual catch in number by the Hawaii 2012 model is clearly smaller than the observed value though (Fig. 3), the absolute values of the catch in number of Fleet 13 are not high comparing with Fleet 12 which shared its selectivity with Fleet 13. Thus, relative increments of quarterly catches in number caused by the modification of catch unit seem to be small. In view of the estimated SSB and recruitment, the effect of the modification on the stock dynamics is limited (Fig. 4). Estimated fishing mortality (F) in Fleet 13 is larger in the revised model than in the Hawaii 2012 model (Fig. 5). Even though the effect of modification on the F value of Fleet 13 is strong, the absolute value of F is smaller than the other Fleet such as Fleet 2 and 12, which have similar selectivity with Fleet 13. Thus this modification will not affect strongly to the other analysis which uses the F value such as future projection analysis.

The influence of the modification of the catch unit of Fleet 13 on the estimated stock dynamics is limited as mentioned above. Thus, the authors recommend correcting the catch unit of Fleet 13 from biomass to number in the updated stock assessment 2014.

3.3 Fixed Ascending/Descending Width Parameter

With the current data and model setting, the ascending width parameter of Fleet 8 and descending width parameter of Fleet 10 often hit to the upper limit of estimation. In here, we note the effect of those parameters fixation using the Hawaii 2012 model.

Without any handling, ascending width parameter of Fleet 8 and descending width parameter of Fleet 10 hit to the upper limit of estimation in the Hawaii 2012 model. Then, we tried two types of modification; one is setting these values as very close to upper limit and fixing, the other is spreading these upper limits as wider.

The selectivity curves of Fleet 8 and 10 depicted by the model which fixed ascending and descending width parameters are not different from those of the Hawaii 2012 model (Fig. 6). In the case we estimated those parameters with higher upper limits, a tail of the selectivity curve of Fleet 10 tended to spread wider (Fig. 6). There is no influence of those modifications to the estimation of selectivity of the other Fleets.

The estimated recruitments by the model which fixed ascending and descending width parameters and Hawaii 2012 model are not different (Fig. 7). On the other hand, the model which estimates those parameters with higher upper limits showed 0.3% lower recruitment in average than that of Hawaii model (Fig. 7). Then, SSB estimated by the model which estimates those parameters with higher upper limits showed 3.2% lower value in average than that of the Hawaii 2012 model (Fig. 7). However, relative SSB indicated similar dynamics of population among above mentioned models.

As mentioned above, the fixed or estimated ascending and descending width Parameters of Fleet 8 and 10 do not make any substantial difference in the results. Thus the authors recommend to fix those parameters for the updated stock assessment 2014 without changing possible widths of the selectivity of those fleets from the Hawaii 2012 model.

3.4 Input Effective Sample Size of Fleet 12

In total, 10 quarters (1st quarter of 2005, 2nd quarters of 1954, 1955, 1956, 1963, 1964, 1971, and 1976, 3rd quarter of 1964, 4th quarter of 2006) of the input EffN were 0.5 in the last stock assessment, and we change those to 1.0 from 0.5 (Table 1). As for the estimated selectivity curves, there is no difference between the Hawaii 2012 model and the EffN changed model (Fig. 8). Although the SSB and recruitments are slightly higher in the EffN changed model than those of the Hawaii 2012 model during 1950's and 1960's, the difference between those two models is not clear after 1970 (Fig.

9). The fittings to the size data of those two models show similar distributions (Fig. 10). Because the effect of modification about the input EffN of Fleet 12 is limited, the authors recommend to modify this to smoothly execute bootstrap works.

4 References

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Table 1 Input effective sample size for each Fleet. The numbers in red indicate newly updated or changed quarter from the last stock assessment model. The blank indicates a quarter of no size data or not used in the Stock Synthesis model.

Year–Quarter		Fleet1	Fleet2	Fleet3	Fleet4	Fleet5	Fleet6	Fleet7	Fleet8	Fleet9	Fleet10	Fleet11	Fleet12	Fleet13	Fleet14
1952	1	12.8											5.0		
1952	2														
1952	3														
1952	4	12.8													
1953	1												4.5		
1953	2												1.5		
1953	3	9.2											1.5		
1953	4	12.8											4.5		
1954	1	12.8											11.5		
1954	2												1.0		
1954	3	9.2											1.5		
1954	4	12.8											5.5		
1955	1	12.8											13.0		
1955	2	10.4											1.0		
1955	3														
1955	4	12.8											3.5		
1956	1	10.3											24.5		
1956	2												1.0		
1956	3												1.5		
1956	4	12.8											9.0		
1957	1	6.7											37.5		
1957	2														
1957	3	6.7											3.0		
1957	4	12.8											21.0		
1958	1	11.8											40.0		
1958	2	12.8											2.0		
1958	3	12.8											1.0		
1958	4	12.8											27.0		
1959	1	12.8											36.0		
1959	2	12.8													
1959	3	12.8											1.0		
1959	4	12.8											9.5		
1960	1	12.8											21.0		
1960	2	12.8													
1960	3	12.8													
1960	4	12.8											8.0		
1961	1	12.8											44.5		
1961	2	12.8											1.0		
1961	3	12.8											1.5		
1961	4	12.8											11.5		
1962	1	12.8											36.0		
1962	2	11.3													
1962	3	12.8											1.0		
1962	4	12.8											7.0		
1963	1	12.8											50.0		
1963	2	9.5											1.0		
1963	3	12.8													
1963	4	12.8											7.5		
1964	1	12.8											40.0		
1964	2	12.8											1.0		
1964	3	8.9											1.0		
1964	4	12.8											4.0		
1965	1												45.5		
1965	2	12.8											5.0		
1965	3														
1965	4	12.8													
1966	1	12.8													
1966	2	12.8													
1966	3														
1966	4	12.8													
1967	1	12.8													
1967	2														
1967	3														
1967	4														

Table 1 Continued.

Year-Quarter		Fleet1	Fleet2	Fleet3	Fleet4	Fleet5	Fleet6	Fleet7	Fleet8	Fleet9	Fleet10	Fleet11	Fleet12	Fleet13	Fleet14
1968	1	10.9													
1968	2														
1968	3	12.8													
1968	4	12.8													
1969	1														
1969	2														
1969	3														
1969	4												3.5		
1970	1												6.0		
1970	2														
1970	3														
1970	4												8.0		
1971	1												5.0		
1971	2												1.0		
1971	3														
1971	4														
1972	1														
1972	2														
1972	3														
1972	4												1.0		
1973	1												6.5		
1973	2														
1973	3														
1973	4												4.5		
1974	1												4.0		
1974	2														
1974	3														
1974	4												2.5		
1975	1												6.0		
1975	2												2.5		
1975	3												1.0		
1975	4												4.5		
1976	1												27.5		
1976	2												1.0		
1976	3														
1976	4												6.0		
1977	1												8.0		
1977	2												2.0		
1977	3														
1977	4												2.5		
1978	1												12.5		
1978	2														
1978	3														
1978	4												5.5		
1979	1												7.0		
1979	2														
1979	3														
1979	4												3.0		
1980	1												12.0		
1980	2														
1980	3														
1980	4												1.5		
1981	1												6.0		
1981	2														
1981	3														
1981	4														
1982	1												17.0		
1982	2												2.5		
1982	3														
1982	4														
1983	1														
1983	2														
1983	3														
1983	4														

Table 1 Continued.

Year-Quarter		Fleet1	Fleet2	Fleet3	Fleet4	Fleet5	Fleet6	Fleet7	Fleet8	Fleet9	Fleet10	Fleet11	Fleet12	Fleet13	Fleet14
1984	1														
1984	2														
1984	3														
1984	4														
1985	1														
1985	2														
1985	3														
1985	4														
1986	1														
1986	2														
1986	3														
1986	4														
1987	1			12.2											
1987	2														
1987	3														
1987	4														
1988	1			8.6											
1988	2														
1988	3														
1988	4														
1989	1			12.5											
1989	2														
1989	3														
1989	4														
1990	1														
1990	2														
1990	3														
1990	4														
1991	1			3.0											
1991	2														
1991	3														
1991	4														
1992	1			2.5											
1992	2														
1992	3														
1992	4											12.4			
1993	1			1.2											
1993	2														
1993	3					10.0		12.4		12.1					
1993	4							12.4			12.1	12.4			
1994	1	12.8		51.2		12.2		10.3	12.9	12.1					12.6
1994	2					12.2		12.4	12.9	12.1					12.6
1994	3					12.2				12.1					
1994	4	12.8				12.2		12.4			12.1	12.4			
1995	1			7.3		12.2		12.4	11.1	12.1					12.6
1995	2					12.2		12.4	12.9	12.1					12.6
1995	3	12.8				12.2				12.1					
1995	4	12.8				12.2		12.4			12.1	12.4			
1996	1			51.2		12.2		12.4		12.1					12.6
1996	2					12.2		12.4	12.9	12.1					12.6
1996	3	12.8				12.2				12.1					
1996	4	12.8				12.2		10.9			12.1	12.4			
1997	1			23.2		12.2		12.4		12.1					12.6
1997	2	12.8				12.2		12.4	12.9	12.1					12.6
1997	3	12.8				12.2				12.1					
1997	4	12.8				12.2		12.4			12.1	12.4			
1998	1	12.8		2.6		12.2		12.4	9.7	12.1					12.6
1998	2	12.8				12.2		12.4	12.9	12.1					12.6
1998	3	12.8				12.2				12.1					
1998	4	12.8				12.2		12.4			12.1	12.4			
1999	1			7.9		12.2		12.4		12.1					12.6
1999	2	10.9				12.2		12.4	12.9	12.1					12.6
1999	3	9.5				12.2				12.1					
1999	4	12.8				12.2		12.4			12.1	12.4			

Table 1 Continued.

Year	Quarter	Fleet1	Fleet2	Fleet3	Fleet4	Fleet5	Fleet6	Fleet7	Fleet8	Fleet9	Fleet10	Fleet11	Fleet12	Fleet13	Fleet14
2000	1			15.7		12.2		12.4	9.5	12.1					12.6
2000	2					12.2		12.4	12.9	12.1					12.6
2000	3	8.6				12.2				12.1					
2000	4	12.8				12.2		12.4			12.1	12.4			
2001	1			51.2		12.2		12.4		12.1					12.6
2001	2					12.2		12.4	12.9	12.1					12.6
2001	3		12.1			12.2				12.1					
2001	4	12.8	12.1			12.2		12.4			12.1	12.4			
2002	1		12.1	11.4		12.2		12.4		12.1					12.6
2002	2		12.1			12.2		12.4	12.9	12.1					12.6
2002	3		12.1			12.2				12.1					
2002	4	12.8	12.1					12.4			12.1	12.4			
2003	1		12.1	9.8		12.2		12.4		12.1					12.6
2003	2	8.8	12.1			12.2		12.4	12.9	12.1					12.6
2003	3	12.8	12.1			12.2				12.1					6.7
2003	4	12.8	12.1					12.4			12.1	12.4			
2004	1			13.6		12.2		12.4	6.6	12.1					12.6
2004	2		12.1			12.2		12.4	12.9	12.1					12.6
2004	3	7.7	12.1			12.2		12.4		12.1					
2004	4	12.8	12.1			12.2		12.4			12.1	12.4			
2005	1		12.1	51.2		12.2		12.4	8.8	12.1			1.0		12.6
2005	2		12.1			12.2		12.4	12.9	12.1					12.6
2005	3		12.1			12.2		6.2		12.1			3.0		
2005	4	12.8	12.1			6.5		12.4			12.1	12.4	2.5		12.6
2006	1		12.1	41.1		12.2		12.4	12.9	12.1			4.0		12.6
2006	2		12.1			12.2		12.4	12.9	12.1					12.6
2006	3		12.1			12.2		12.4		12.1					
2006	4	12.8	12.1			12.1		12.4			12.1	12.4	1.0		
2007	1		12.1	22.9		12.2		12.4		12.1					12.6
2007	2		12.1			12.2			12.9	12.1					12.6
2007	3	9.2	12.1			12.2				12.1					6.9
2007	4	12.8	12.1			12.2		12.4			12.1	12.4			
2008	1		12.1	35.7		12.2		12.4	12.9	12.1			13.5		12.6
2008	2		12.1			12.2		12.4	12.9	12.1					12.6
2008	3		12.1			12.2				12.1					6.4
2008	4	12.8	12.1			12.2		12.4			12.1	12.4			
2009	1		12.1	8.9		12.2		12.4		12.1		6.9	1.5		12.6
2009	2		12.1			12.2		12.4		12.1					12.6
2009	3		12.1			12.2				12.1					
2009	4	12.8	12.1								12.1	12.4	5.5		
2010	1		12.1	22.6		12.2		9.0		12.1			21.0		12.6
2010	2		12.1			12.2			12.9	12.1					12.6
2010	3		12.1			12.2				12.1					
2010	4	12.8	12.1			12.2		12.4			12.1	12.4	1.5		
2011	1			23.8		12.2		6.5		6.1			3.5		
2011	2		12.1			12.2			12.9	12.1					12.6
2011	3					12.2				12.1					
2011	4	12.8						12.4			12.1	12.4	5.5		
2012	1			27.6				12.4		12.1			19.0		
2012	2					12.2			12.9	12.1					12.6
2012	3					12.2				12.1					
2012	4		12.1					12.4			12.1	12.4	1.0		

Fig. 1 Estimated total catch in number for each Fleet. Y-axis and X-axis indicate the number of fish (thousands of fish) and the year, respectively. The red and black lines show the results from the Hawaii 2012 model and the model, which includes the catch for farming, respectively.

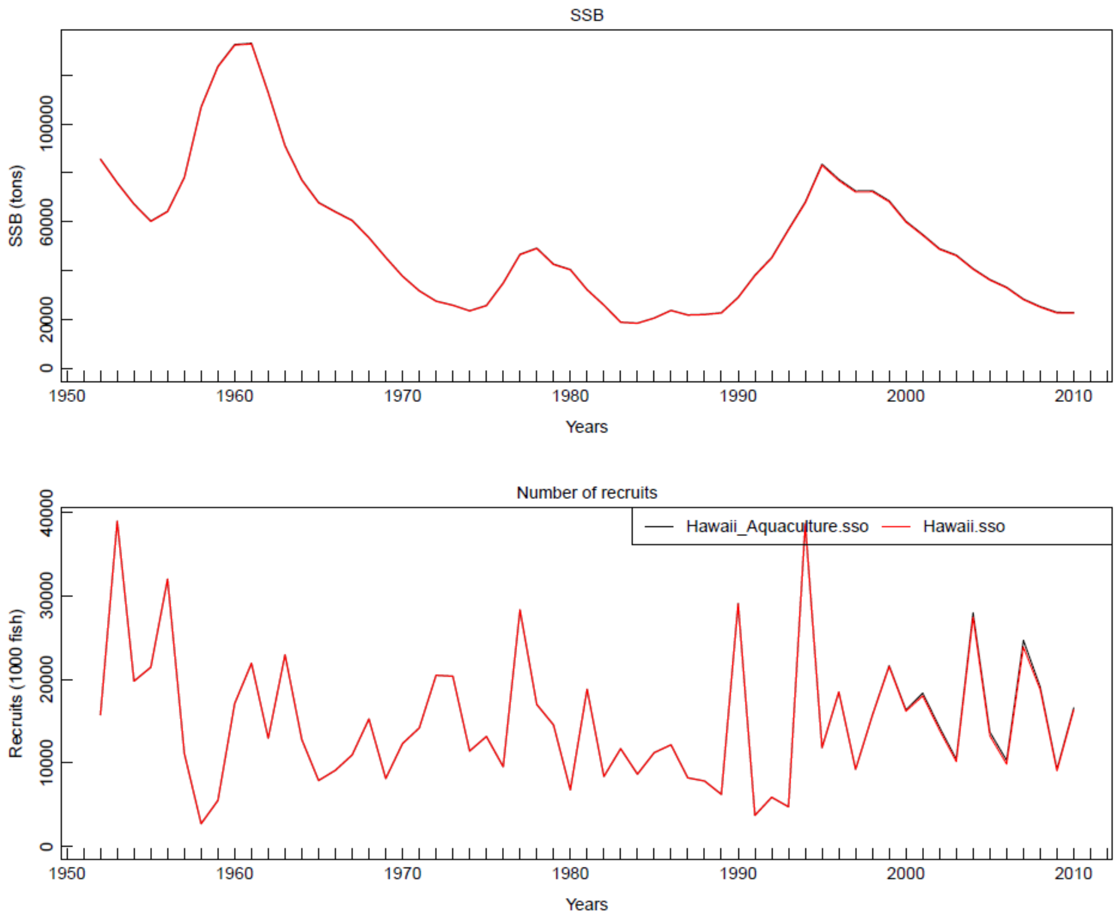

Fig. 2 Estimated Spawning stock biomass (SSB) and the recruitment by the Hawaii 2012 model and the model, which includes the catch for farming.

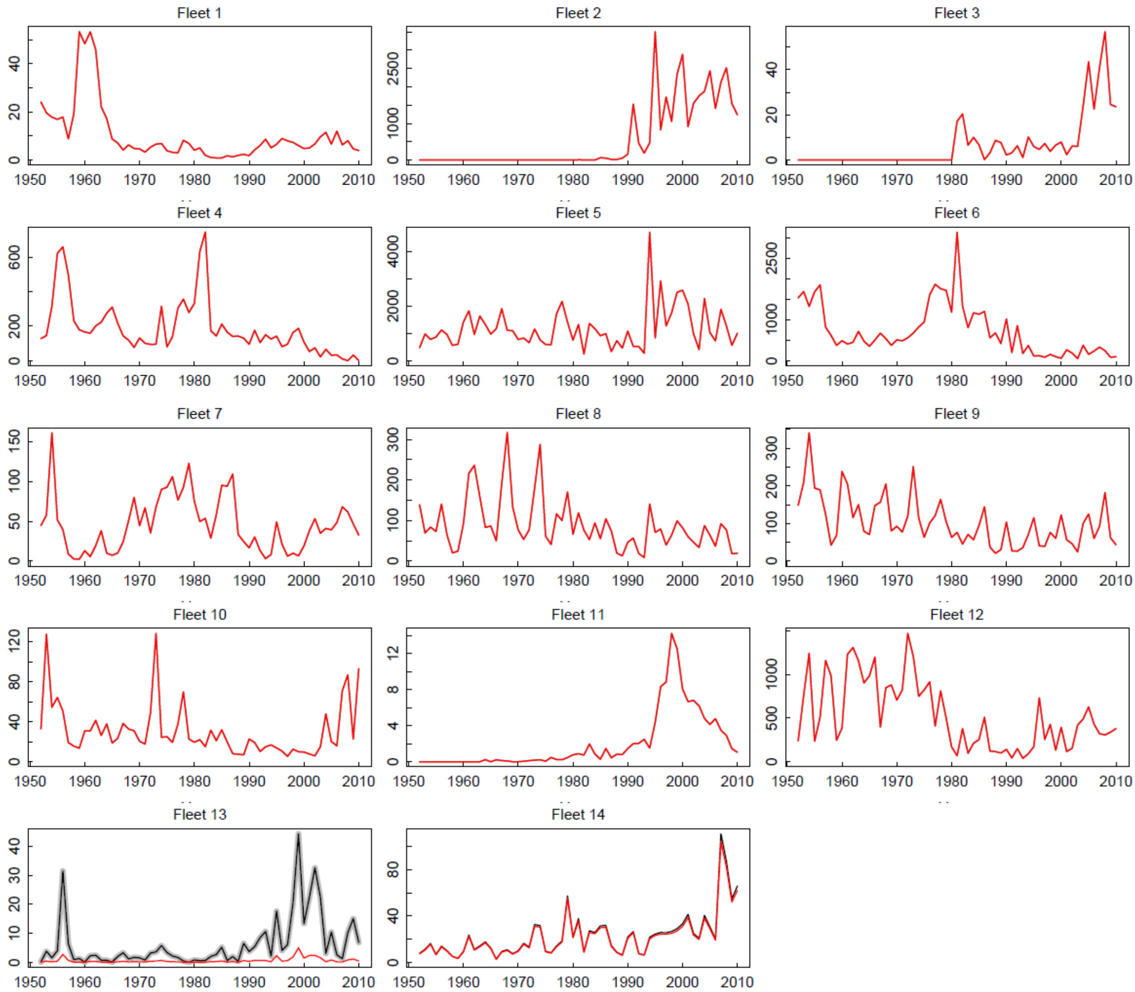

Fig 3. Estimated total catch in number for each Fleet. Y-axis and X-axis indicate the number of fish (thousands of fish) and the year, respectively. The black and red lines show the results from revised and original models, respectively. The gray line at the figure of Fleet 13 indicates the observed value.

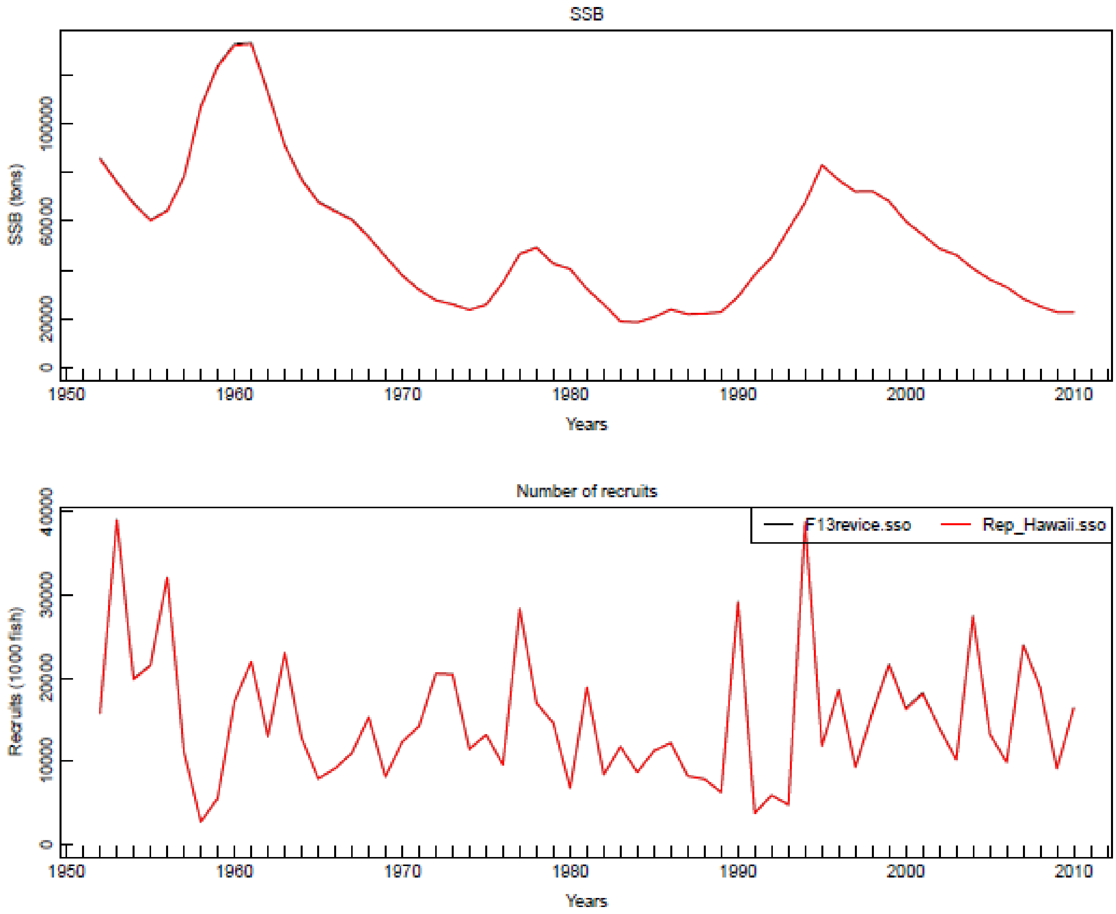

Fig. 4 Estimated Spawning stock biomass (SSB) and the recruitment by the catch-unit revised model and Hawaii 2012 model.

Fig. 5 Estimated fishing mortality of Fleet 13. Y-axis and X-axis indicate the annual fishing mortality and the year, respectively. The black and red lines show the results from the catch unit revised and original models, respectively.

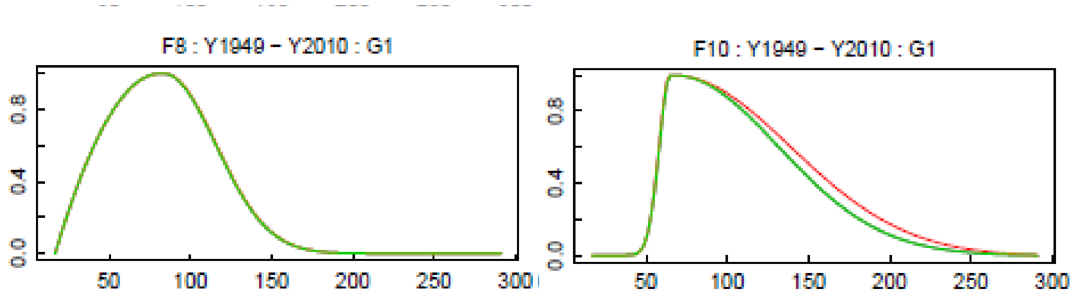

Fig. 6 Estimated selectivity curves of Fleet 8 (Left panel), and 10 (Right panel). Y-axis and X-axis indicate the relative selectivity and length, respectively. The black, red, and green lines show the result of Hawaii 2012 model without any modification (fix/wider upper limit), the model which estimated selectivity parameters of those Fleets with higher upper limits, and the model which had fixed selectivity parameters.

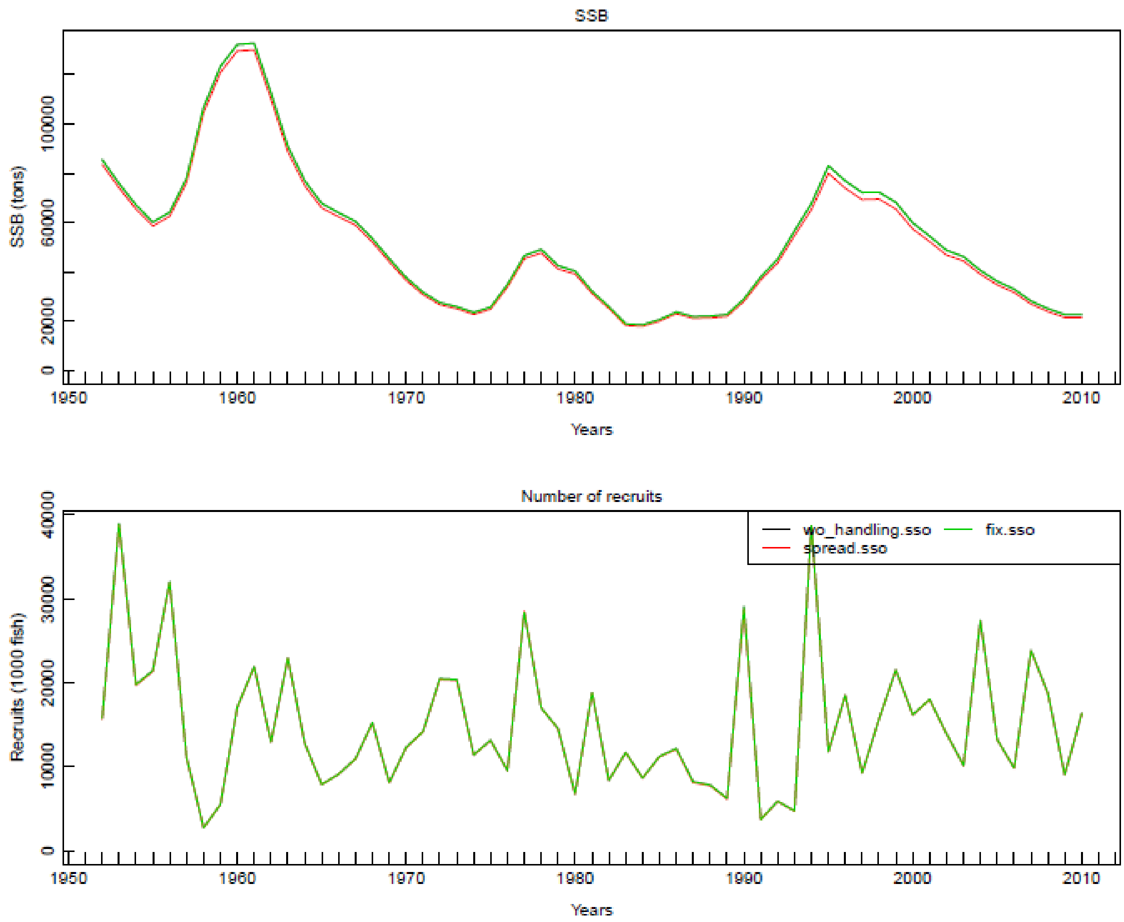

Fig. 7 Estimated Spawning Stock Biomass (Upper panel) and recruitment (Lower pannel). The black, red, and green lines show the result of the Hawaii 2012 model without any modification (fix/wider upper limit), the model which estimated selectivity parameters of those Fleets with higher upper limits, and the model which had fixed selectivity parameters.

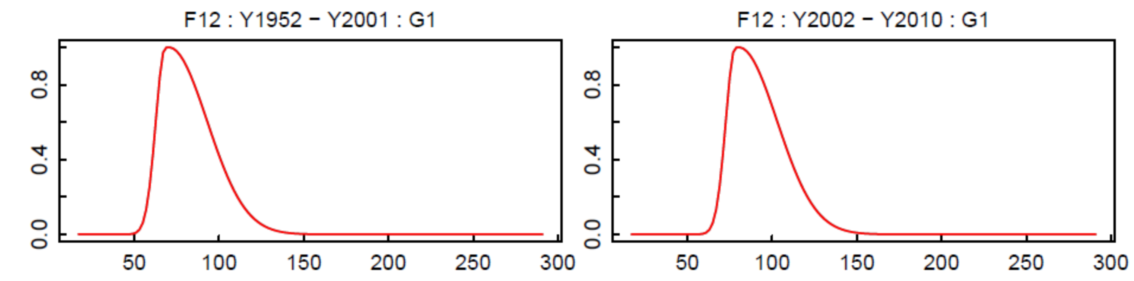

Fig. 8 Estimated selectivity curves of Fleet 12 by the EffN changed model (Black) and Hawaii 2012 model (Red). The left panel showed a selectivity during the time block from 1952 to 2001, and right panel showed that of 2002 to 2010.

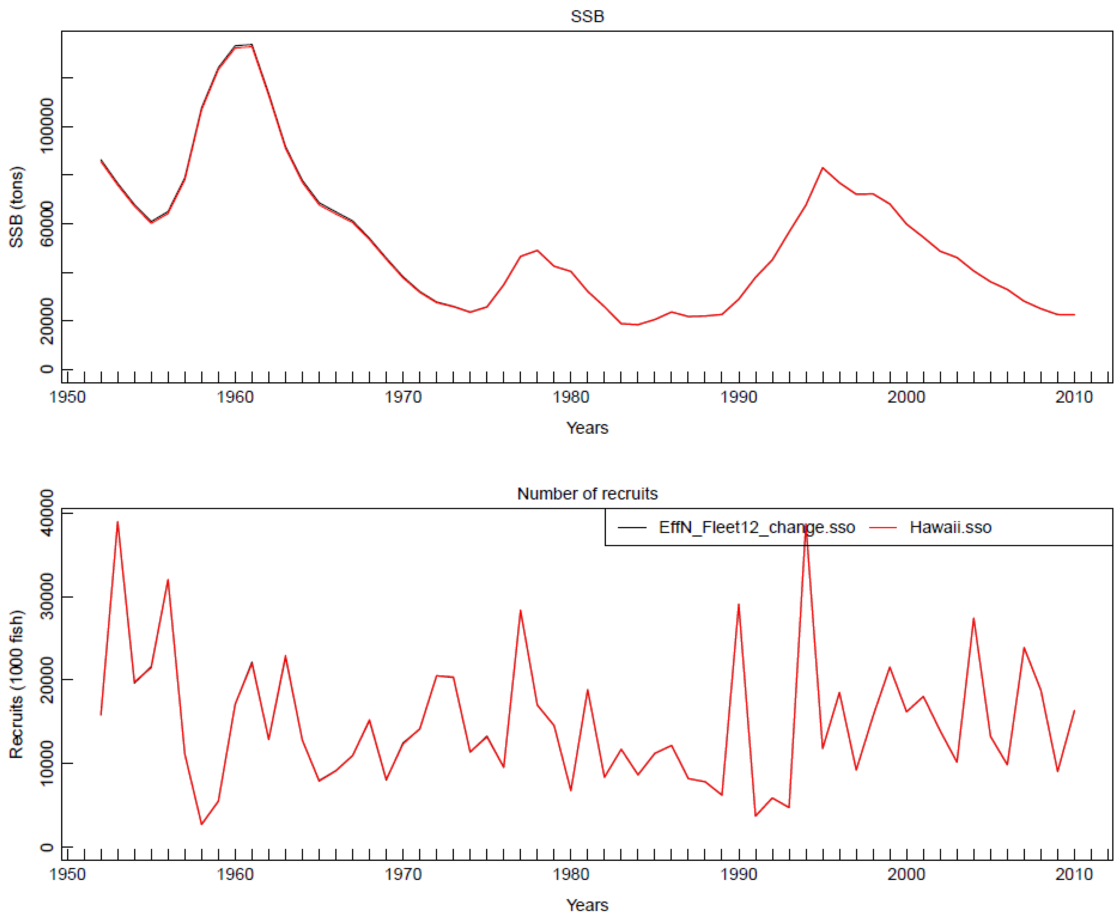

Fig. 9 Estimated SSB (Upper panel) and recruitment (Lower panel) by the EffN changed model (Black) and Hawaii 2012 model (Red).

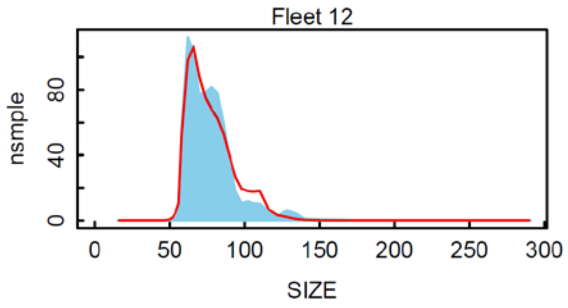

Fig. 10 Fit to the observed size composition data (Blue polygon) estimated by the EffN changed model (Black) and Hawaii 2012 model (Red).