ISC/12-2/PBFWG/07

A Sensitivity Analysis of Stock Assessment 2012 for Pacific bluefin tuna.

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May.-June. 2012

Working document submitted to the ISC Pacific bluefin tuna Working Group, International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC), 23 May-6 June 2012, Shimizu-ku, Shizuoka, Japan. **Document not to be cited without author's permission.**

ABSTRACT

Uncertainties in the SS3 base case candidate model (Iwata et al., 2012) for the Pacific bluefin tuna (PBF) regarding some biological parameters, input data and model settings were evaluated by the full sensitivity analysis for each parameter. The results suggested that the base case candidate used in this document was quite sensitive to the growth parameters such as von Bertalanffy K, and L@Amin, L@Amax, and CV for those parameters. On the other hand, old age M that was thought as a source of uncertainties did not have large impact on the result comparing with those of the ISC11/PBFWG/10. Some of the changes in the newly updated fishery definitions such as fleet 4, 7, 8, and 9 had significant effects on results. The function of the selectivity curves of each fleet also had significant effects on conclusions. PBFWG need to treat those data and settings carefully if any further changes on those are considered with some new problems are arose. The other parameters were also tested one by one in this document.

INTRODUCTION

During the last data preparation meeting of the Pacific bluefin tuna working group (PBFWG) of the ISC at La Jolla in 2012, the fisheries, surveys data (CPUE series) and size information were significantly updated until 2010, and also the model settings and some biological parameters were changed (Anonymous, 2012).

Furthermore, stock assessment in 2011 pointed out the sensitive behavior of the estimated absolute spawning stock biomass (SSB) depending on the natural mortality parameter M of the old age fish (Teo, ISC11/PBFWG/10).

Thus, PBFWG still need to consider some specifications of the model to conduct the full stock assessment using with currently updated data and model settings. The purpose of this document is to evaluate the effect of the changes in model setting and the sensitivity of some important parameters such as old age M.

METHODS

Updated fishery and survey data until 2010 (fishing year) and SS3 model which was set by Iwata et al. (2012) were used as the base case candidate. Settings for the sensitivity analysis basically followed the Report of the meeting of the data preparation workshop of the PBFWG 2012 (Anonymous, 2012).

1.) BIOLOGICAL PARAMETERs

Natural mortality

In the PBF base case candidate, natural mortality M at age-0 (M0), age-1 (M1), and age-2+ (M2+) were assumed to be 1.6, 0.386, and 0.25 respectively. The sensitivity analysis which assumed different M for the younger age fish were conducted by changing M0 and M1 (SB2Run1 and SB2Run2), and that assuming for older fish were conducted by changing M2+ or M3+ (SB2Run3, SB2Run4, and SB2Run5). SB2Run5 was set to assume the scenario that proposed by Whitlock et al (2012) which estimates natural mortality with Bayesian mark-recapture model for electronically tagged Pacific bluefin tuna. A scenario which assumed seasonal changes in M was also arranged by estimating M0 and M1 of each quarter.

Growth curve

During the data preparation workshop of the PBFWG 2012, dealings of the growth curve was a matter of argument due to the change in methods used for counting bands of otoliths. In the previous stock assessment for PBF in 2010 at Nanaimo, Shimose et al. (ISC/08/PBF/01/08) was used, Since then this growth curve was updated by Shimose et al. (ISC11-1/PBFWG/11) and Shimose et al. (ISC12-1/PBFWG/12) in succession by re-reading same otoliths by changing the procedures. Also he used additional new samples.

In the PBF base case model, growth curve which was suggested by Shimose et al. (2009) was assumed. The sensitivity analysis which assumed the growth curves of Shimose et al. (ISC/08/PBF/01/08) and Shimose et al. (ISC12-1/PBFWG/12) were conducted by changing growth parameter K, L@Amin, and L@Amax (SB6Run1 and SB6Run2).

The sensitivity analysis which assumed seasonal growth was also conducted by estimating seasonal K, L@Amin, and L@Amax by SS3 (SB6run4). In this case, “growth_age_for_L2” which is an age for L@Amax was set as 20.

A run estimating growth curve parameters with conditional AGE@LENGTH from otolith data were also conducted, and noted in details by Kai et al. (2012, ISC12-2/PBFWG/11).

Other Biological parameters

The maturity level, length weight relationship, and steepness index were also subjected to the sensitivity analysis.

In the base case candidate, the maturity levels in each age are set as 0.2, 0.5, and 1 for age 3, age 4, and age 5+, respectively. The sensitivity analysis which assumed 1-year-delayed maturity was conducted by changing maturity level as 0.2, 0.5, and 1 for age 4, age 5, and age 6+.

The length weight relationship which assumed seasonal change was also set as a sensitivity run. The length weight relationships for each season were derived from Watanabe et al. (ISC/06/PBFWG/06).

The steepness index was set as 0.999 in the base case candidate to assume an extremely weak spawner/recruit relationship. The sensitivity analysis are set by changing this index as 0.8 (stronger relationship) (SB5run2), and estimating this index with Hockey-stick model (SB5run1).

2.) FISHERIES DATA and PARAMETERs

Survey lambda (λ)

Survey lambda is used to control the inclusion and exclusion of the survey data, and the value is multiplied by the likelihood components of indices to calculate the negative log likelihood to be minimized. Thus, a better fit to the indices will be gained if higher survey lambda is given. Nine scenarios are set to examine the influence of the newly proposed survey data (Ichinokawa et al., 2012; Kanaiwa et al., 2012), withhold survey data (Aires-da-Silva et al., 2012; Yokawa, 2008), and the different weightings among the survey data.

Fisheries data definition

In the previous meetings of PBFWG there was a lengthy discussion on the size selectivity of JLL, because length composition data clearly showed differences between non-spawning and spawning seasons (ISC/11-1/PBFWG/13). Then, a sensitivity run that assumed separating JLL in two fleets (JLL at non-spawning and spawning season) (SF2run1) was conducted.

Furthermore, during the data preparation workshop 2012, Japanese purse seine and set net were separated in two or three fleet depending on the characteristics of data or the size selectivity of each separated fleet. The sensitivity runs to evaluate the effects of this new fleet definitions were conducted by combining the catch and size composition data of Fleet 8 & Fleet 9 (SF2run3).

Another issue that raised in the data preparation workshop 2012 was the size composition of Fleet 4 (Japanese Purse seine that operated in the Pacific Ocean), because of the change in the quality of the size data preferably after 1993 (ISC/12-1/PBFWG/03). Then, the sensitivity run that used the size composition data of Fleet 4 only after 1993 was set (SF2run4).

Effective sample size (EffN)

In the PBF base case candidate, EffN was calculated only for Japanese purse seine operated in Japan Sea (Fleet 3) and EPO purse seine (Fleet 11). Other Fleets are assumed to be same EffN with the average of those two EffN. The sensitivity analysis was conducted by assuming that the EffN of all fleets are same as Fleet 3 (SF3run1), or Fleet 11 (SF3run2).

Other sensitivity run concerning about Fisheries data

In the PBF base case candidate, “Super period” was used for Fleet 4. Then, the sensitivity analysis that assumed periodical fishery for Fleet 4 was set as SF5run1.

The sensitivity run that used IATTC catch data for Fleet 11 instead of USA & Mexico data was also set (SF6run1).

3.) MODEL SETTINGs

Coefficient of Variation for the L@Amin and L@Amax

In the PBF base case candidate, CV for L@Amin was estimated in the model, and CV for L@Amax was set as 0.08. For the sensitivity analysis, the scenarios that used fixed higher or lower values than the base case candidate, and a run that both of CV for L@Amin and L@Amax were estimated were set (Table 3: SM2run1 to SM2run7).

Selectivity curves

In the PBF base case candidate, the selectivity curve for Japanese long line (JLL) was assumed dome shape. As a sensitivity run, the shape of selectivity curve for JLL was assumed a flattop. The details of the setting was written in Iwata et al. (2012, ISC/12-2/PBFWG/06).

In the previous data preparation meeting, PBFWG agreed to use cubic spline function to estimate a selectivity curve. Then, a run, which used double normal to estimate a selectivity curve, was set for the sensitivity analysis. The details of the setting was also written in Iwata et al. (2012, ISC/12-1/PBFWG/06).

Other sensitivity run concerning about model settings

A Coefficient of variation (CV) pattern of CV=F(L@A) was used in the base case candidate model, and CV=F(A) was set for the sensitivity analysis (SM1run1).

The catch standard errors were set to 0.1 in the base case candidate. They are used when calculating the likelihood for the initial equilibrium catch and for calculating the likelihood for catch. For the sensitivity run, the catch standard errors were set to 0.01 (SM5run1).

For calculation of fishing mortality, a hybrid method, which does a Pope's approximation to provide initial values for iterative adjustment of the continuous F values to closely approximate the observed catch (F-method 3), was used in the base case. A F-method 2 (a continuous F with each F as a model parameter) was used for a sensitivity run (SM6run1).

The Upper limit of F was set to 10, which was changed from stock assessment 2010@Nanaimo (Iwata et al., ISC/12-2/PBFWG/06). In the sensitivity run, 5 (same value with the stock assessment 2010@Nanaimo) was used for upper limit of F (SM7run1).

The SPR function of Beverton-Holt model with steepness H=0.999 was used in the base case candidate model. For the sensitivity analysis, SPR function of hockey-stick model (SM8run1), re-tuned Beverton-Holt model with steepness H=0.8 (SM8run2), Shepard model (SM8run3) were used.

The sigma R, which is the standard deviation of the log recruitment, was set to 0.6 in the base case candidate model. In one of the sensitivity runs, the sigma R was estimated in the model (SM9run1) , and in another run, it was set as 1 (SM9run2).

The Main recruitment deviations begin year was set as 1946 in the base case, and 1936 and 1941 were set for the sensitivity runs (SM10run1 and SM10run2).

The log (R1), which is the offset for initial equilibrium recruitment relative to the recruitment of initial stock, was set to estimate in the base case candidate model (the estimated value was around -0.03). The log (R1)=0 was set as the sensitivity run (SM11run1).

In the base case candidate, recruitment autocorrelation was not used, but it was used in a sensitivity run (SM12run1).

The lambda for the logL for initial equilibrium catch was given 0 for Fleet 1 (Japanese longline), fleet 4 (Japanese purse seine operated in Pacific Ocean), and Fleet 5 (Japanese trolls) in the base case candidate. The lambda for each =1, 0.5, or 2 were set as the sensitivity runs (SM17run1, SM17run2, and SM17run3).

RESULTS and DISCUSSIONS

1.) BIOLOGICAL PARAMETERs

Natural mortality

As showen by the sensitivity analysis in the previous stock assessment (Ichinokawa et al., 2010; Teo, 2011), absolute SSB was more sensitive to the changes in M for older fish (M2+) than those for younger fish (M0 & M1) (Fig. 1a). In contrast with the results in Teo (ISC11/PBFWG/10), which showed quite sensitive behavior of absolute SSB values when M of the older fish were set higher than 0.25, higher M value than base case (SB2Run4) for the older fish did not result in an explosive increase of absolute SSB, though (Fig. 1b). On the contrary, old fish M less than 0.25 produced sensitive behavior of absolute SSB; absolute SSB of 1995 in scenario SB2run3 was less than a half of than with the base case candidate. The seasonal M for younger fish estimated in the SB2run6 was lower than those of the base case candidate; therefore, the SB2run6 showed similar results with SB2run2.

Growth curve

Growth curves which was set or estimated by the sensitivity runs were shown in Fig. 2. The trends of the curves of the base case candidate and SB6Run2 (Shimose et al., 2012) were very similar. The curve by the SB6run1 tended to show larger size in each age until around age 15. The curve of SB6run4 which was assumed seasonal growth showed rapid growth in summer and mild growth in winter.

The growth curve had a large impact on the results of the SS3 (Fig. 3). The results of SB6run1 showed an excessively high SSB such like about 290 million ton at 1995 (Fig. 3a). The likelihood of size data were also increased those arose from Fleet 1, 2, 3, and8 (Japanese long line, Japanese small purse seine, and purse seine operated in the Japan Sea, and Japanese set-net operated in north area).

Even though the trends of the growth curves used for the base case candidate and SB6run2 were similar, (Shimose et al., 2012), total SSB of SB6run2 at 1995 indicated 25 % lower value than that of the base case candidate (Fig. 3b).

SB6run4 (Seasonal growth) tended to mark higher SSBs for recent years (Fig. 3c). However, only this run showed decrease of likelihood arose from the good fit on the size data of Japanese troll (Fleet 5). SB6run6, which used conditional LENGTH@AGE showed a similar result as SB6run4. The estimated parameters of K, L@Amin, and L@Amax which were used in both of above growth curves (seasonal and conditional) were similar.

Those results suggested that growth parameters have a strong effect.

Other biological parameters

The sensitivity run for 1-year-delayed maturity (SB3run1) showed 1 year phase difference in SSB. There are a few differences in absolute SSB values (Fig. 4a). On the other hand, no phase difference was confirmed in the recruitment, and a few difference in absolute and relative recruitment between two runs (Fig. 5).

The sensitivity run, which assumed a seasonal length-weight relationship (SB4run1), showed similar result with the base case candidate in relative SSB, recruitment, but showed slightly higher values in absolute SSB than the base case candidate (Fig. 4a).

The value of the steepness H estimated with hockey-stick model (SB6run1) was 0.999998, being nearly the same as the base case. However, the results were different with the base case candidate, ie; absolute SSB in 1995 was about 60 % level of the base case (Fig. 4b). The sensitivity run which assumed steepness H = 0.8 (Fig. 4b) did not converge adequately (final gradient > 1000) and was eliminated from further analysis.

The above mentioned results about the sensitivity runs for the Biological parameters suggested that the sensitive behavior of results such as absolute SSB values according to M2+, Growth curve, and steepness H. Based on the current knowledge, M2+ and steepness H in the base case candidate model were adequate values. However, the selection of a reasonable growth curve was unsettled, as was discussed in the data preparation workshop 2012. Therefore, it is suggested that the growth curve should not be changed easily, unless there is a strong support for changes in biological data.

2.) FISHERIES DATA and PARAMETERS

Survey lambda (λ)

The inclusion of the newly proposed survey data (SF1run2, SF1run4) and withhold survey data (SF1run3, SF1run13) did not have large impact on the results except the scenario which use the

CPUE proposed by Yokawa (ISC/08/PBF-1/05) (SF1run1) (Fig. 6ab). SF1run1 showed high absolute SSB in recent years (ie; about 1.5 times higher than the base candidate in 1999), and only this CPUE made the results to move upward.

The exclusion of the troll CPUE (SF1run11) also had an impact on the absolute SSB and recruitment (Fig. 6c). "Troll CPUE weighting" (SF1run9), which was conducted by changing lambda from 1 to 5, marked lowest total likelihood. The results of SF1run9 are much same with the base case candidate. "Longline CPUE weighting" (SF1run8, SF1run12) had a large impact on the absolute SSB in recent years by making recent SSB to align with longline CPUE, which declined rapidly in recent years.

Fisheries data definition

SF2run1, which assumed the separated Japanese longline (JLL) into two fleets of non-spawning and spawning area, showed an excess of SSB after 1975 (Fig. 7a). The likelihood was increased that arose from a bad fit on the size data of fleet 11 (EPO purse seine).

SF2run3 which assumed Fleets 8 & 9 as one fleet resulted in slightly lower absolute SSB than base case candidate (Fig. 7b). SF2run4 which used size composition data of Fleet 4, only after 1994, showed low absolute SSB through the assessment years. Especially, SSB in recent years were relatively less than the base case candidate. SF2run4 also showed slightly different recruitment with the base case.

Effective sample size

The settings of several EffN patterns did not have strong impact on the results. SF3run2 which assumed same EffN for all fleets as that for fleet 11 showed slightly lower absolute SSB but the trend was nearly same with the base case candidate (Fig. 8).

Other sensitivity run concerning about Fisheries data

SF5run1, which did not use Super period for Fleet 4, showed excessive large SSB, and accordingly affect on the recruitment (Fig. 9). Total negative (log) likelihood was also higher than that of the base case. Detailed results would be noted in Iwata et al. (ISC/12-2/PBFWG/06).

SF6run1, which used IATTC catch data for Fleet 11 instead of USA & Mexico data, showed almost no effect on the results (Fig. 9).

3.) MODEL SETTINGs

Coefficient of Variation for the L@Amin and L@Amax

Coefficient of Variation (CV) of L@A affected well on the results (Fig. 10) more than the sensitivity analysis for stock assessment 2008 (Kai, ISC08/PBF/01/12). Every scenario made total SSB drastically higher or lower than the base case candidate. Changing CV of L@Amin tended to increase total likelihood (the effects are relatively high on the size selectivity of trolls).

SM2run3 and SM2run6, which used fixed L@Amax at 0.05 and estimated L@Amax respectively, tended to decrease total likelihood. By SM2run3 and SM2run6, the effects are high on the size selectivity of several fisheries which caught older age fish such as Japanese longline (Fleet 1), Japanese purse seine in the Japan Sea (Fleet 3), and Taiwanese longline (Fleet 10). L@Amax estimated by SM2run6 was 0.047, which was similar to the fixed value used in SM2run3 (0.05).

Selectivity curves

The results of SM15run1 showed a change in the selectivity curves not only on Fleet1 (Japanese longline) but also on Fleet 4 (Japanese purse seine operated in Pacific Ocean). Both of Fleet 1 and 4 marked higher likelihood values than that of the base case candidate. The SSB resulted from SM15run1 tended to be lower than that of base case, but trends of yearly fluctuations were similar (Fig. 11a). The detailed results would be noted in the Iwata et al. 2012 (ISC/12-2/PBFWG/06).

The SSB resulted from SM16run1, which used double normal functions for the size selectivity curve, was extremely high (Fig. 11b).

Other sensitivity run concerning about model settings

SM1run1, which used the CV pattern of CV=F(A), tended to have higher SSB than that of the base case candidate especially in recent years (Fig 12a). The catch standard errors, which was set as 0.01 for the sensitivity run (SM5run1), did not has impact on the results (Fig. 12). A change in F-method from F-method 3 to F-method 2 (SM6run1) affects recent SSB to be lower (Fig. 12a). Less effects were shown in the recruitment (Fig. 12b), but F@old age (age 3+) were slightly higher in SM6run1 than base case (Fig. 12cd). SM7run1 showed slightly lower SSB through the assessment years (Fig. 12a). Differences in SSB between SM7run1 and the base case were relatively larger after 1995. The F@age for age10+ was twice as high as that of the base case. The likelihood was increased in the size selectivity of fleet 1 (Japanese longline).

SM8run1 which changed SPR function got total SSB to decrease by more than 10000 tons (Fig. 13), and neither SM8run2 nor SM8run3 converged well (final gradient > 1000).

Estimated sigma R by SM9run1 was 0.63 which was similar with that of the base case candidate (0.6). The results of SM9run1 were also almost same with the base case. SM9run2, which was set sigma R as 1, tended to estimate about 15% higher SSB than that of the base case, although the trends in SSB were similar between these two (Fig. 14a). Sensitivity runs for the main recruitment deviations begin year (SM10run1, SM10run2), the log (R1)=0 (SM11run1), use of the recruitment autocorrelation (SM12run1) did not show impact on the results (Fig. 14b).

The absolute SSB marked lower values than the base case as the lambda for the logL for initial equilibrium catch was set lower value (Fig. 15a).

CONCLUSIONS

These results suggested that the base case candidate used in this document was quite sensitive to the growth parameters such as von Bertalanffy K, L@Amin and L@Amax, and CV for those parameters (Fig. 3, Fig. 10). Last data preparation meeting of PBFWG had an argument about which growth curve is the best available one for the stock assessment. Several growth curves such as Shimose et al. (2008), Shimose et al., (2009), Shimose et al. (2012) were examined. Present document tried to compare those. Results of SB6run1 (use Shimose et al. (2008)) resulted in unlikely high estimated SSB. Furthermore, the results of SB6run2 (use Shimose et al. (2012)) showed clear difference with those of the base case (use Shimose et al. (2009)), even though the differences between both growth curves used were very little. All of the growth curves estimated by the SS3 showed faster growth than that of Shimose et al. (2009) until age 5. And then, the results, which used those estimated growth curve (SB6run4, SB6run6, SB6run7), indicated lower likelihood than the base case candidate. One of the causes of lower likelihood was derived from better fit of selectivity curve to the size data.

In the previous stock assessment, old age M was treated as a source of uncertainties. However, present document showed relatively mild effect of the old age M comparing with Teo (2011, ISC11/PBFWG/10). Under this situation, PBFWG could keep using the current M scenario, unless any new biological evidence about mortality is provided.

The fisheries data definitions tested in this document (separate JLL into 2 fleet, SF2run1; combine fleet 8 & 9, SF2run3; to not use super period for fleet 4, SF2run4) had large impact on the results (Fig. 7). The selectivity curves could also be the source of uncertainties in this model. However, in the base case candidate model, fishery data and model settings such as selectivity curves were prepared and practically fixed according to new fishery definitions after the discussions made at the data preparation workshop. PBFWG should treat those data and settings carefully if the group discuss any changes on those when some of new problems are arose.

Sensitivity-B2
Natural mortality

	Age0	Age1	Age2	Age3	Age4+	Assumption
Base	1.6	0.386	0.25	0.25	0.25	
Run1	1.8	0.46	0.25	0.25	0.25	Higer M @ age0-1
Run2	1.3	0.3	0.25	0.25	0.25	Lower M @ age0-1
Run3	1.6	0.386	0.2	0.2	0.2	age2+(base-0.05)
Run4	1.6	0.386	0.3	0.3	0.3	age2+(base+0.05)
Run5	1.6	0.386	0.25	0.25	0.15	Whitlock (2012)
Run6	1.6(seasonal)	0.386 (seasonal)	0.25	0.25	0.25	Age0_seasonal

Sensitivity-B3
Maturity

	Age3	Age4	Age5	Age6+	Assumption
Base	0.2	0.5	1	1	
Run1	0	0.2	0.5	1	1 year delay

Sensitivity-B4
Length-weight

Base	Kai (2007)
Run1	Seasonal LW

Sensitivity-B5
Steepness Parameter

		Assumption
Base	0.999	
Run1	Estimated H by Hochey stick model	Iwata-san
Run2	0.8 (fix)	

Sensitivity-B6
Growth curve

	K	L∞	t0	L@Amin (0.125	L@Amax(0.312	Assumption
Base	0.173	249.6	-0.254	15.8	110.5	Shimose (2009)
Run1	0.195	245.4	-0.472	27.0	123.7	Shimose (2008)
Run2	0.165	252.1	-0.259	15.5	107.9	Shimose (2012)
Run3	0.15	249.6	-0.254	13.8	99.2	k=0.15
Run4	0.173	249.6	-0.254	15.8	110.5	seasonal K
Run5	0.2	249.6	-0.254	18.2	122.6	k=0.2
Run6						ConditionalA@L

Sensitivity-F1

CPUE lambda(CPUE data)

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	Assumption
CPUE code	JpCLL	JpnDWLLFujiokaRevto74	JppDWLLYokawaRevfro	TPSKanaiwa	JpnTrollChinaSea	JpnTrollPacific	JpnTrollPacific(Kochi)	JpnTrollPacific(Wakayama	TWLL	USPSto82	MexPSto06	
Base	1	1	1	0	1	1	0	0	1	0	0	
Run1	1	(Yokawa ver. CPUE)	1	0	1	1	0	0	1	0	0	use Yokawa instead of Fujioka(2012
Run2	1	1	1	1	1	1	0	0	1	0	0	S4 lambda=1
Run3	1	1	1	0	1	0	1	0	1	0	0	S6 lambda=0,
Run4	1	1	1	0	1	0	0	1	1	0	0	S6 lambda=0,
Run8	5	1	1	0	1	1	0	0	1	0	0	S1 lambda=5
Run9	1	1	1	0	5	1	0	0	1	0	0	S5 lambda=5
Run11	1	1	1	0	0	0	0	0	1	0	0	S5,S6 lambda=0
Run12	5	1	1	0	1	1	0	0	5	0	0	S1 lambda=5,
Run13	1	1	1	0	1	1	0	0	1	1	1	EPO

Sensitivity-F2

Fishery data difinition

		Assumption
Base	27 (14 fleets&13 survays)	
Run1	28 (15 fleets&13 survays)	Separate JLL (FL1) into Spawning and the other
Run3	26 (13 fleets&13 survays)	Combine FL8&FL9
Run4	27 (14 fleets&13 survays)	FL4 (after1994)

Sensitivity-F3
EffN

	Age0	Assumption
Base	same EffN with FL3,	
Run1	same EffN with FL3	
Run2	same EffN with FL11	

Sensitivity-F4
Input N for Length composition

	upper limit	lower limit	Assumption
Base	200	100	
Run1	200	70	
Run2	400	100	
Run3	200	100	

Sensitivity-F5
Super period

Base	FL4
Run1	-

Sensitivity-F6
EPO-catch data

Base	Mex&USA
Run1	IATTC

Sensitivity-M1
Functional form of CV

Base	CV=F(L)
Run1	CV=F(A)

Sensitivity-M2
CV

	age0	old	Assumption
Base	Estimate	0.08	
Run1	0.25(fix)	0.08	
Run2	0.6(fix)	0.08	
Run3	Estimate	0.05	
Run4	Estimate	0.02	
Run5	Estimate	0.11	
Run6	Estimate	Estimate	
Run7	0.45	Estimate	

Sensitivity-M5
Catch error

		Assumption
Base	0.1	
Run1	0.01	

Sensitivity-M6
F method

		Assumption
Base	3 (solve catch eq.)	
Run1	2	

Sensitivity-M7
Upper F

		Assumption
Base	10	
Run1	5	

Sensitivity-M8
SPR

		Assumption
Base	Beverton-Holt model	
Run1	Hockey stick model	
Run2	Retuned B-H	steepness h=0.8
Run3	Shepard S-R	

Sensitivity-M9
sigma R

		Assumption
Base	0.6	
Run1	Estimate	
Run2	1	

Sensitivity-M10
1st year of main Rdev

		Assumption
Base	1946	
Run1	1936-2009	10 yrs before Base
Run2	1941-2009	5 yrs before Base

Sensitivity-M11
R0 offset

		Assumption
Base	Estimate	
Run1	0	

Sensitivity-M12
SR auto correlation

		Assumption
Base	-	
Run1	w/Auto correlation	

Sensitivity-M15
JLL selectivity

		Assumption
Base	Dome shape	
Run1	Flattop	

Sensitivity-M16
selectivity curve

		Assumption
Base	Cubic spline (27)	
Run1	double normal (24)	

Sensitivity-M17
Initial Equibrium catch

	FL1	FL4	FL5	Assumption
Base	lambda=0	lambda=0	lambda=0	
Run1	lambda=1	lambda=1	lambda=1	
Run2	lambda=0.5	lambda=0.5	lambda=0.5	
Run3	lambda=2	lambda=2	lambda=2	

Sensitivity-M18
CV for CPUE (JLL)

		Assumption
Base	0.2	
Run1	0.1	

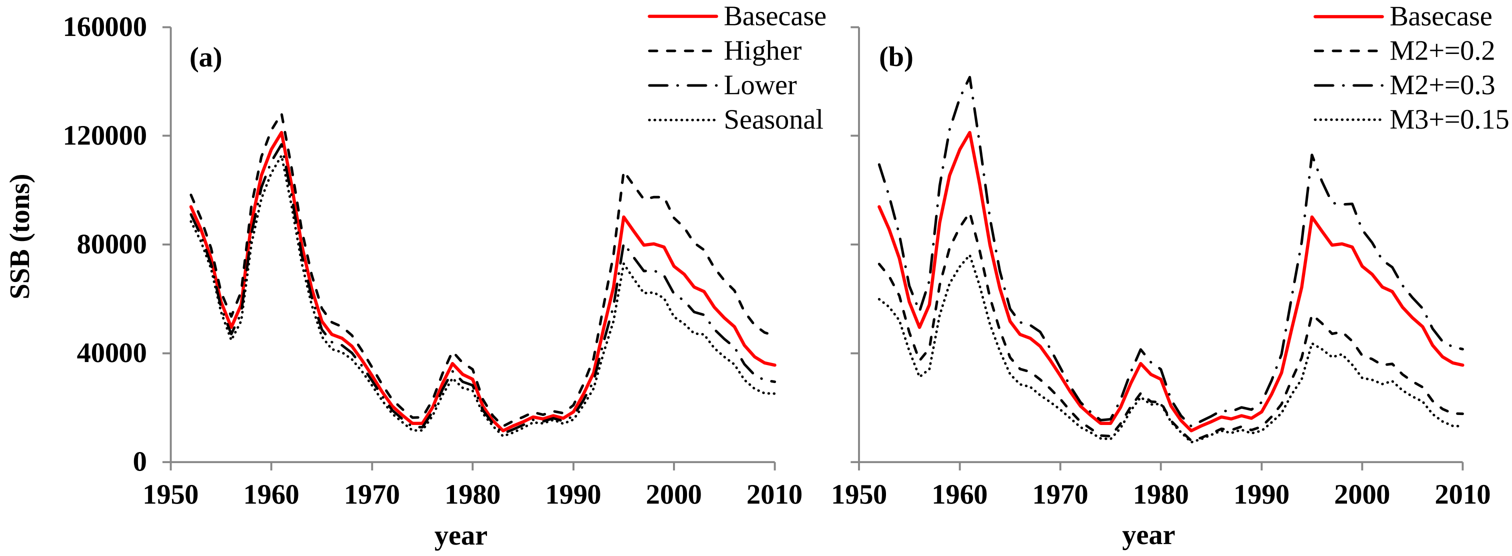

Fig. 1 SSB for each run which was set different M scenario.

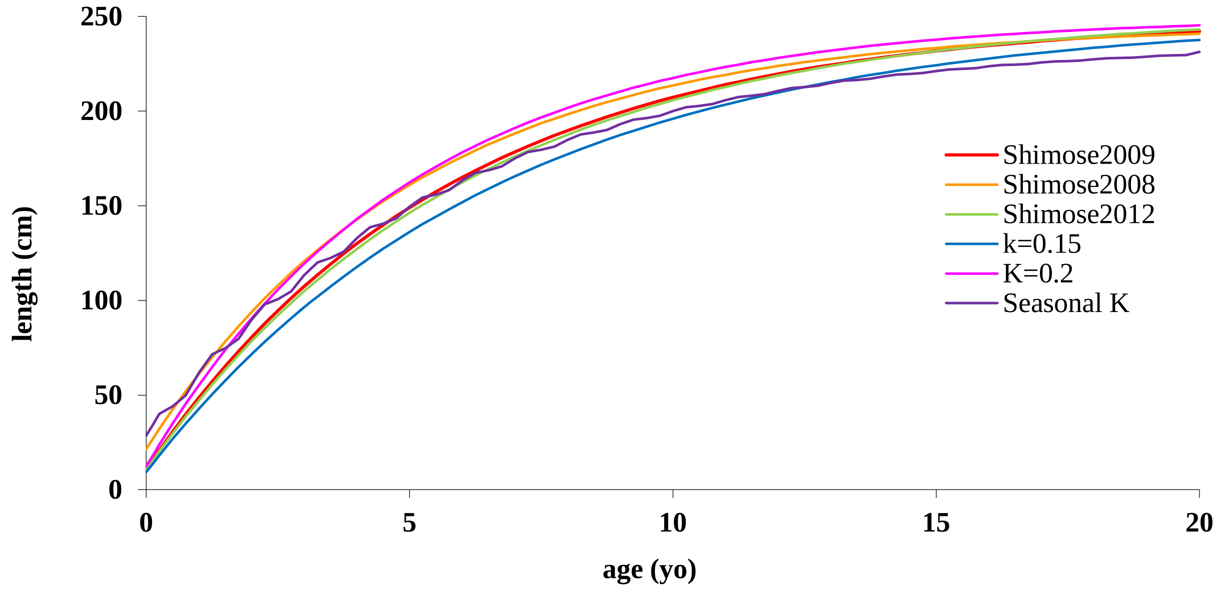

Fig. 2 Growth curves used.

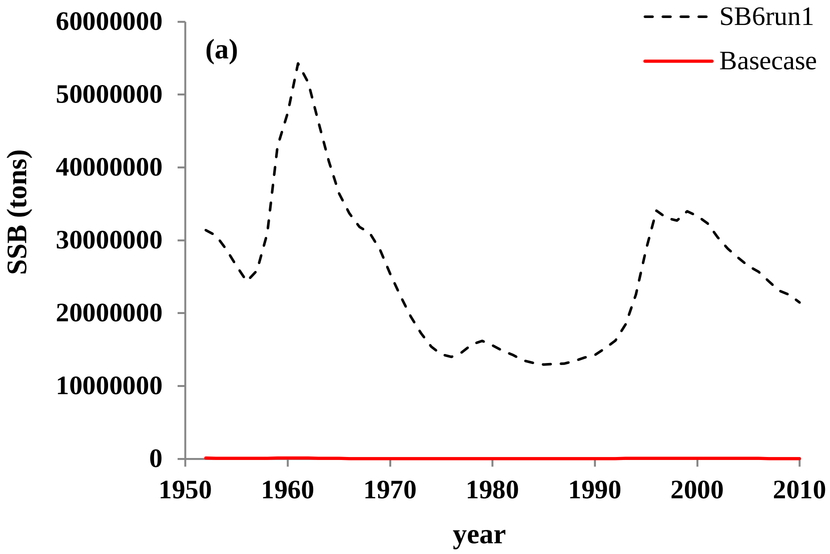

Fig. 3 SSB for the SB6run1 which used a growth curve of Shimose (2008).

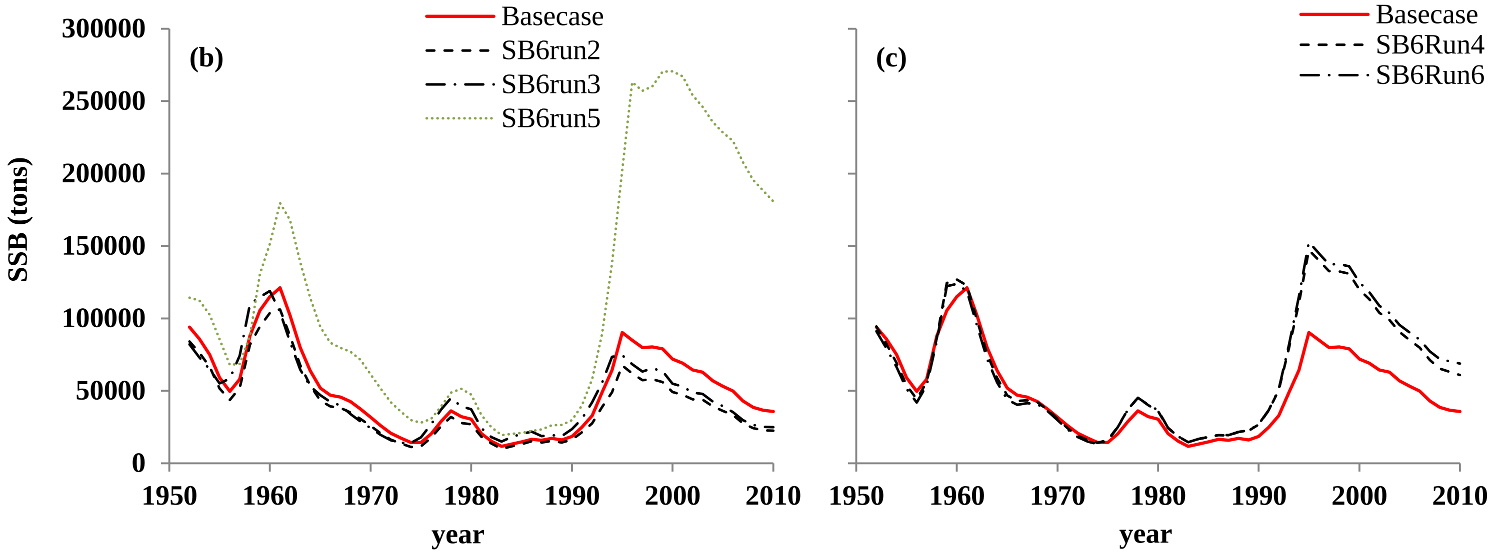

Fig. 3 (continued) SSB for each run which used different growth curves

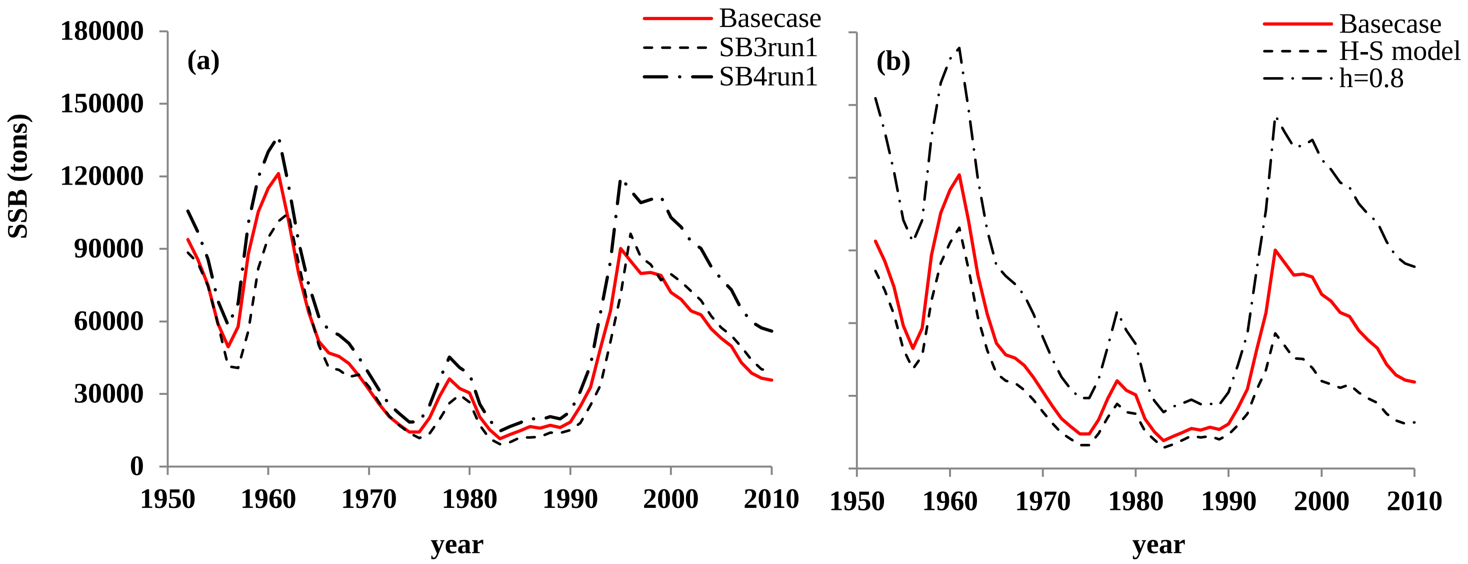

Fig. 4 SSB of the sensitivity runs for "Other biological parameters".

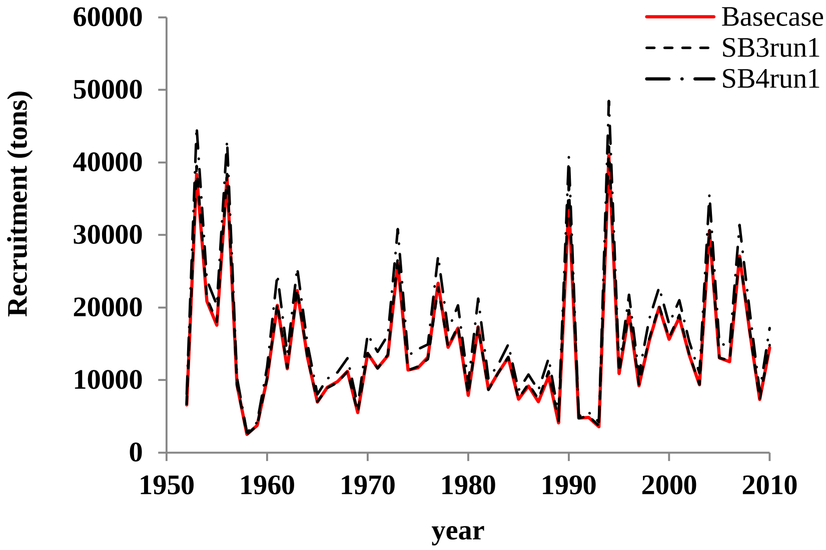

Fig. 5 Recruitment of the sensitivity runs for "Other biological parameters".

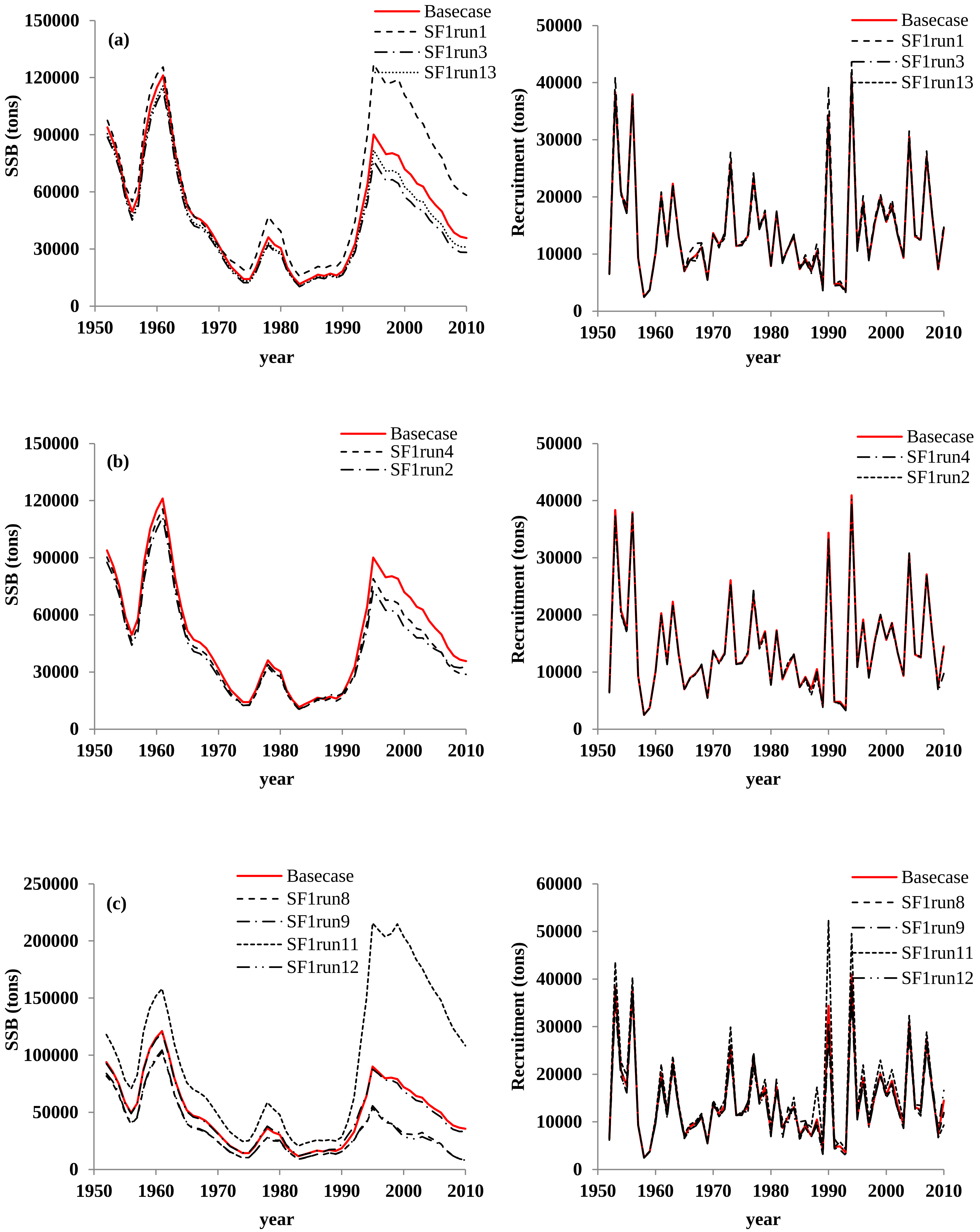

Fig. 6 SSB and Recruitment for each run which was set different lambda for CPUE scenario.

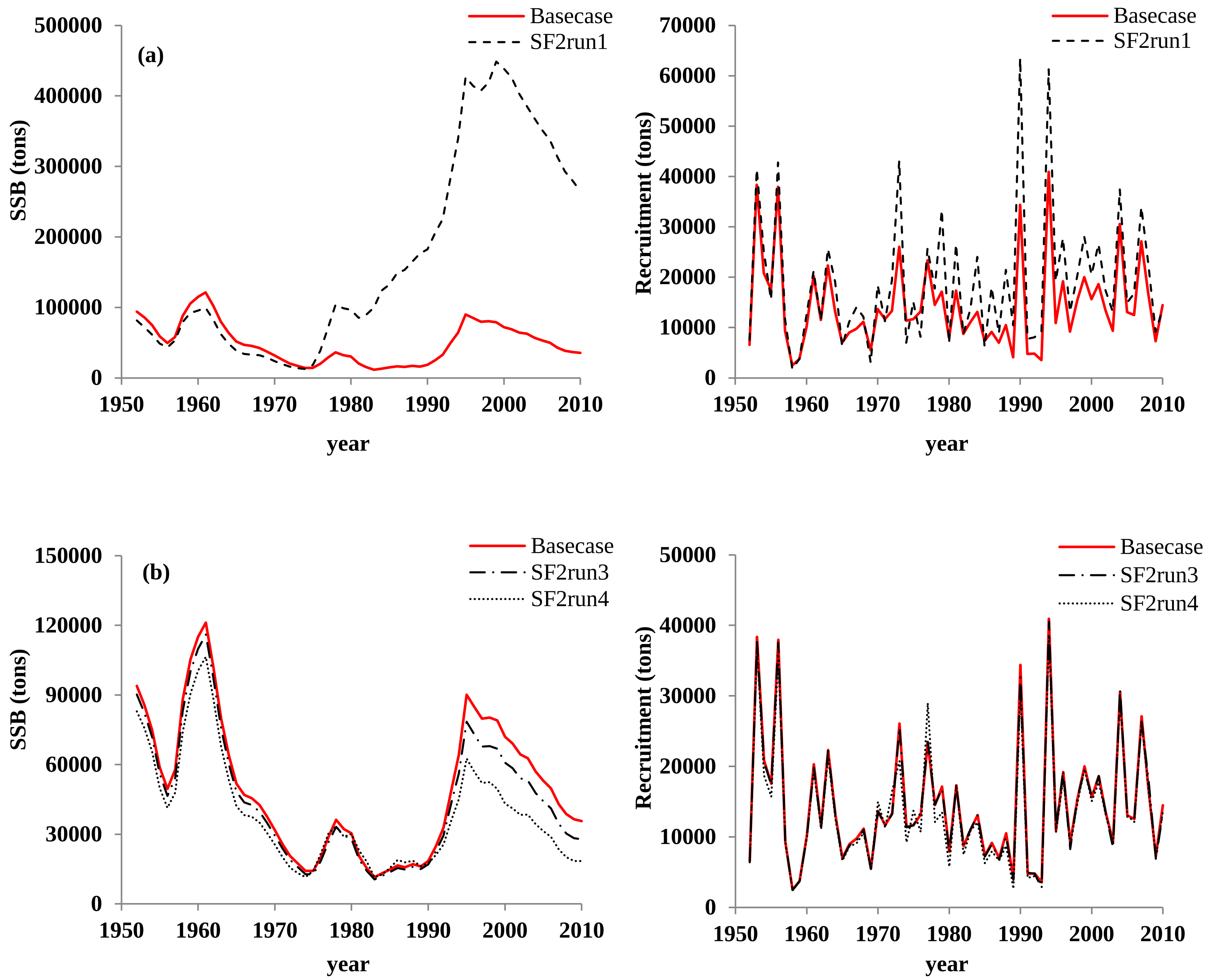

Fig. 7 SSB and recruitment for the sensitivity runs for each Fisheries data definitions.

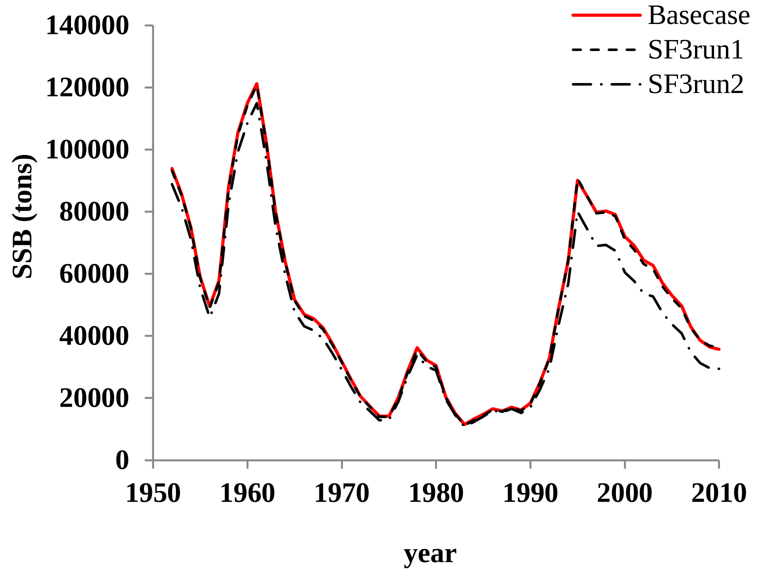

Fig. 8 SSB for the sensitivity runs for each Effective sample size scenario.

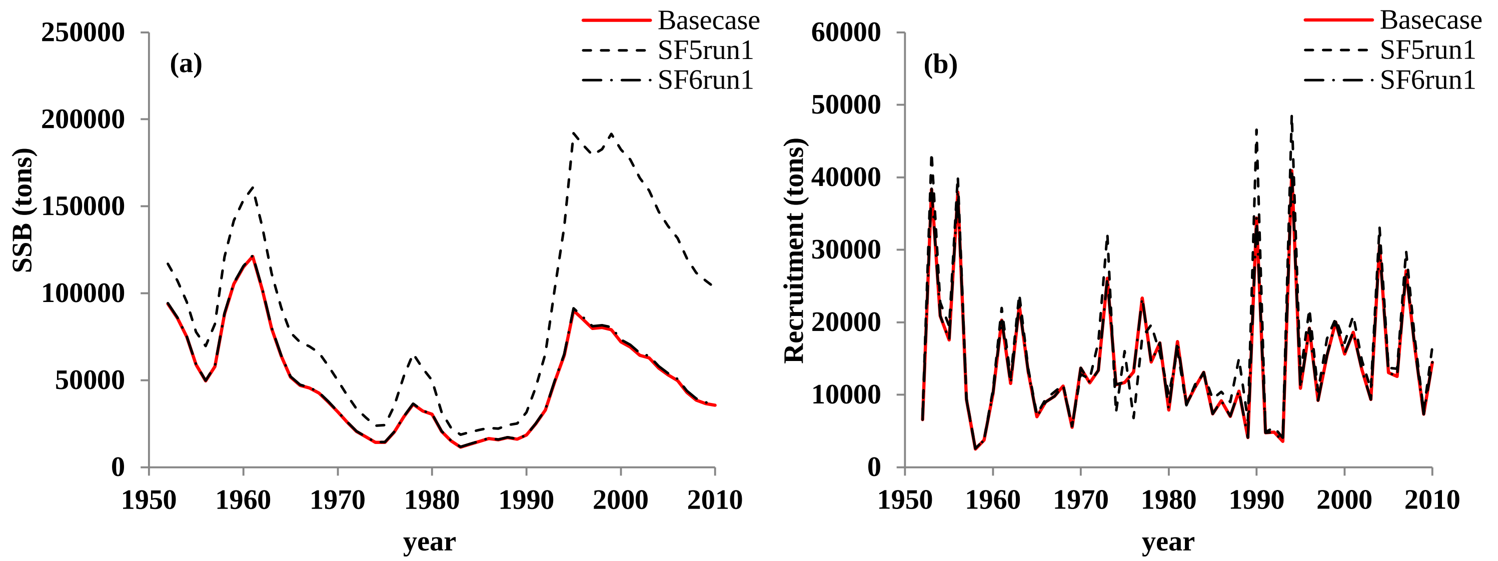

Fig. 9 SSB (a) and recruitment (b) for the base case and a scenario, which assumed super-period (for Fleet 4) was not used (SF5run1), and a scenario, which IATTC data was used instead of Mexico and USA data for Fleet 11, 12 (SF6run1).

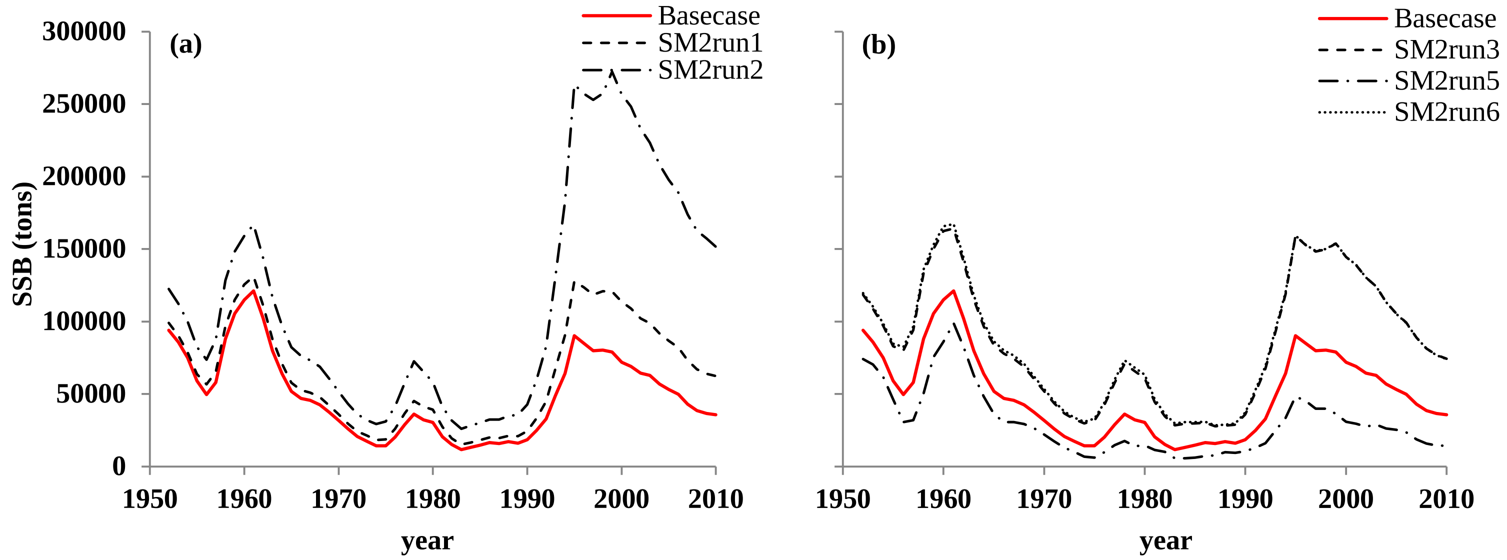

Fig. 10 SSB for each scenario, which was set different Coefficient of Variation values of Length@Age minimum and Length@Age maximum.

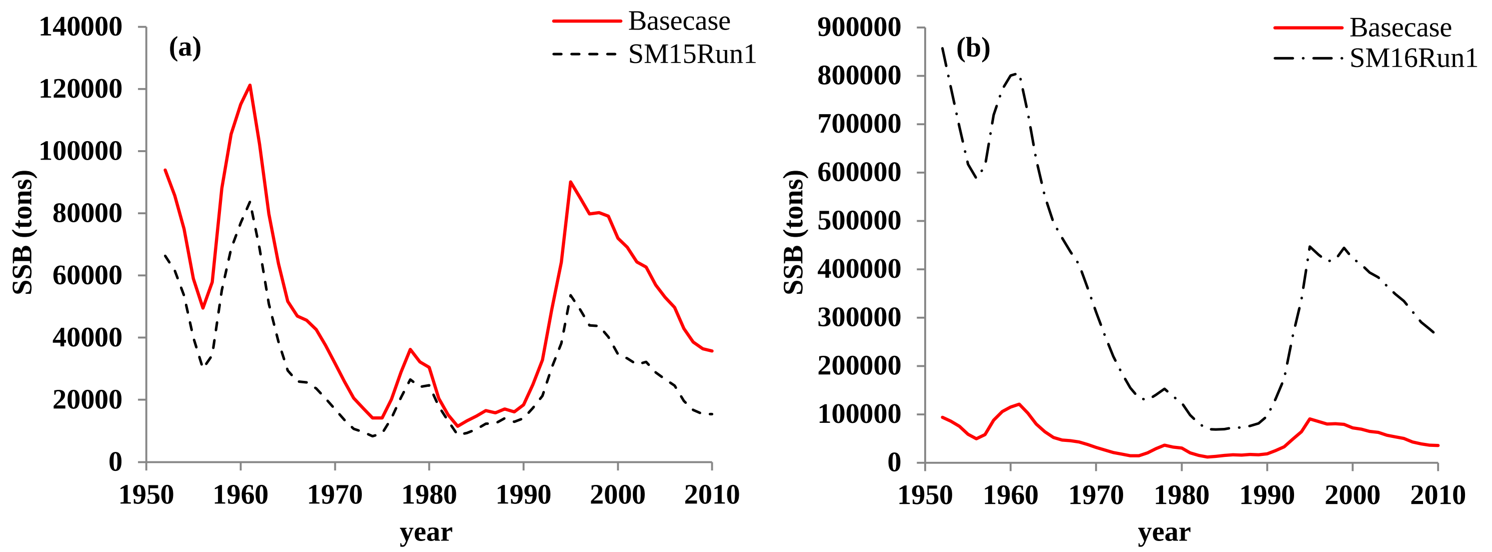

Fig. 11 SSB for each scenario, which assumed Flattop selectivity curve for Fleet 1 (Japanese longline) (a), and a scenario, which assumed parametric selectivity curves (double normal) for all Fleets (b).

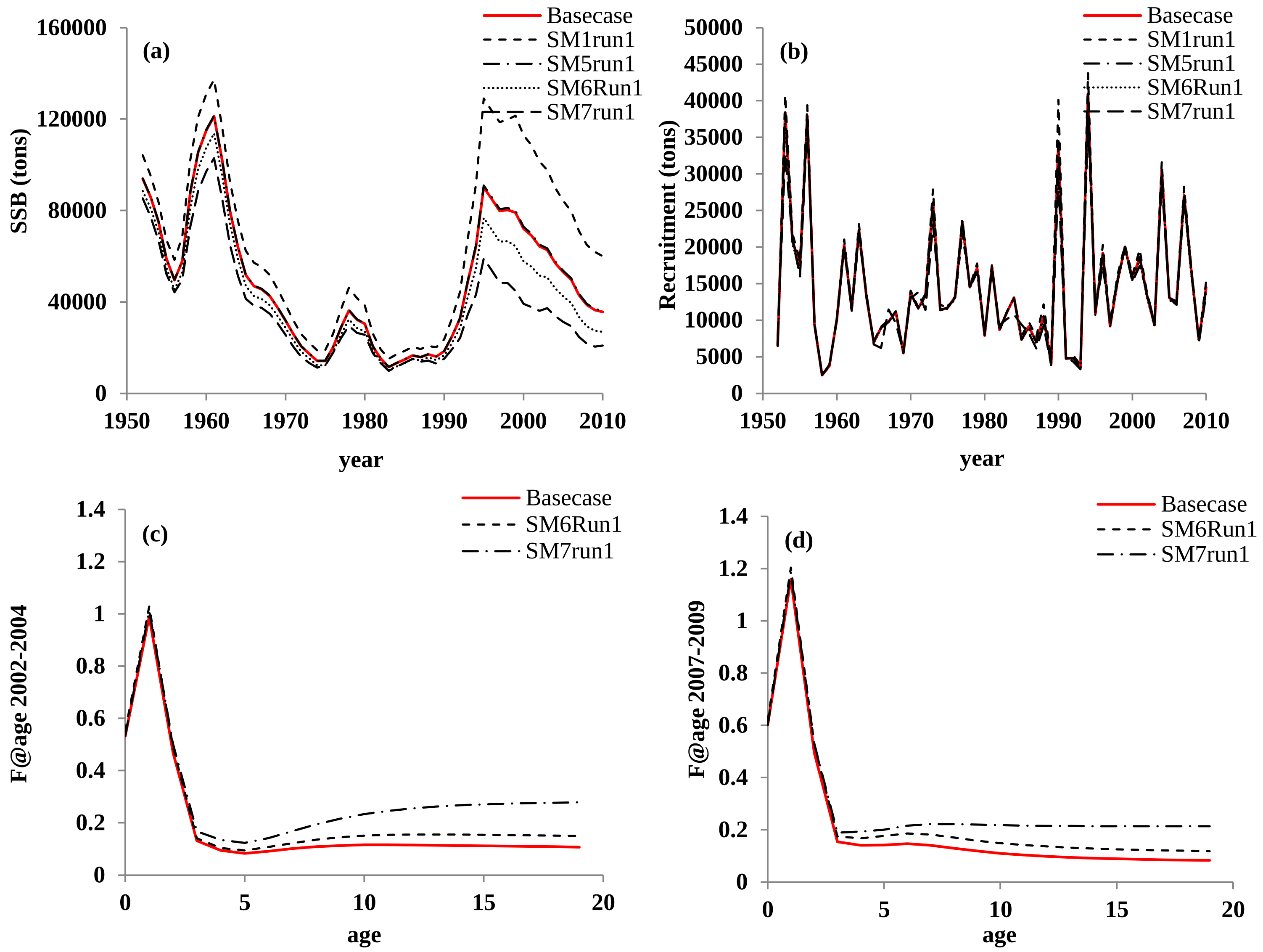

Fig. 12 SSB (a), recruitment (b), F@age 2002-2004 (c), and F@age 2007-2009 (d) in each model setting scenario.

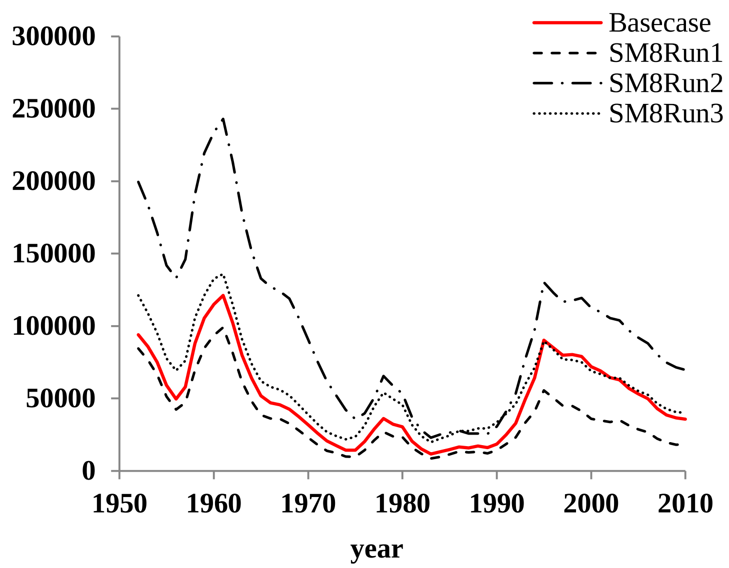

Fig. 13 SSB in each of the SPR function scenario.

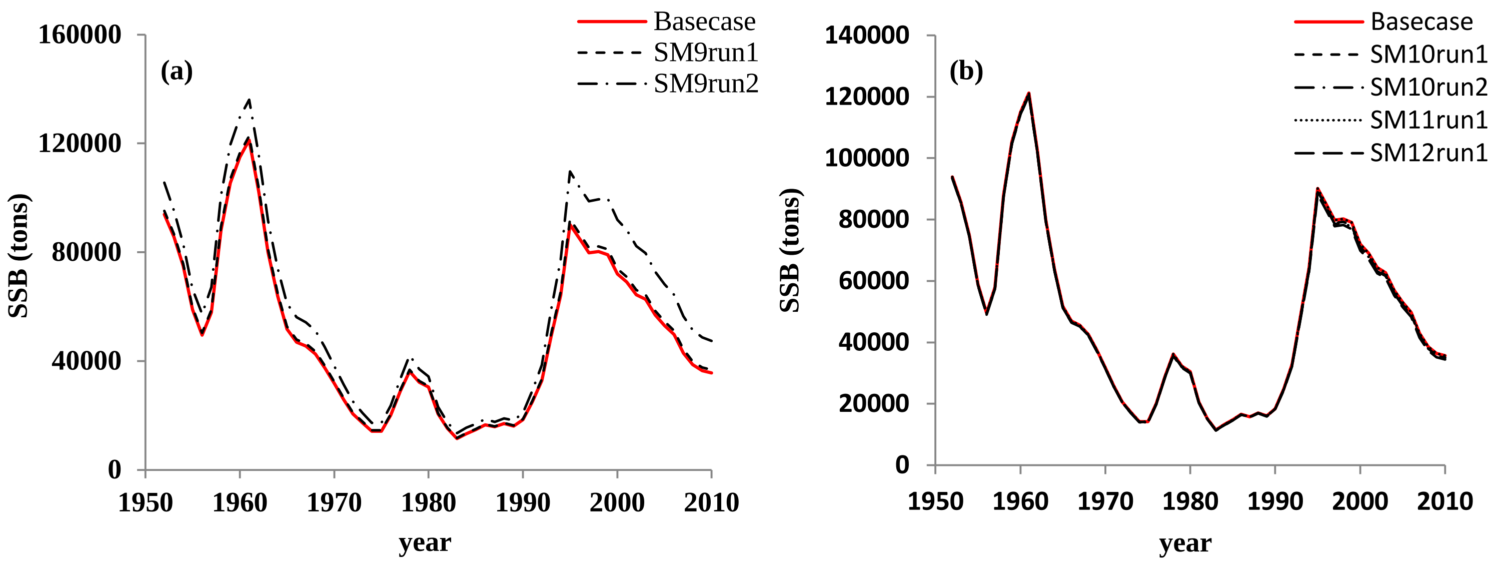

Fig. 14 SSB in each scenario, which was set different scenario of the spawning-recruitment sigmaR (SM9), R deviation (SM10), R0 offset value(SM11), and spawning-recruitment autocorrelation (SM12).

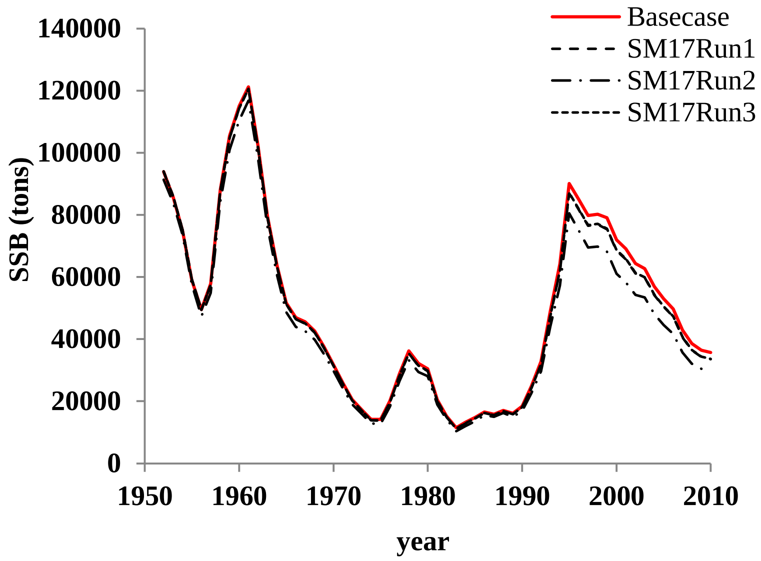

Fig. 15 SSB in each scenario, which was set different lambda values for initial equilibrium catch.