Preliminary Stock Assessment for Bigeye Tuna in the Indian Ocean using Stock Synthesis II (SS2)

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Abstract:

We conducted the preliminary stock assessment for bigeye tuna in the Indian Ocean using Stock Synthesis II (SS2) (made by Rechard, Methot: Methot, 2005; Methot, 2006), a kind of length-based integrated model, as a feasibility study. The year trends of SSB, total biomass and recruitment obtained from the SS2 model are similar to those by ASPM (age-structured production model) and these absolute levels are a little low compared with the ASPM results (Nishida and Shono 2006).

Introduction

We tried to assess for bigeye tuna in the Indian Ocean as a feasibility study using Stock Synthesis II (SS2), a kind of length-based integrated and statistical approach. The advantages to utilize such length-based integrated model (e.g. MULTIFAN-CL, A-SCALA, CASAL etc.) instead of traditional stock assessment model (such as ASPM, ASPIC or Tuned VPA and so on) are:

- To reduce the aging error (i.e. error from the catch-at-size to catch-at-age) because SS2 (and other integrated models) can be dealt with the various length information (i.e. length-composition, length-based selectivity etc.)
- To introduce the prior information (regarding the unknown parameters)
- To use the flexible conditions/assumptions about selectivity, catch-ability, spawning-recruitment relationship and biological parameters (growth, M, maturity etc.) and so on.

In this paper, we carried out the preliminary stock assessment for bigeye tuna in the Indian Ocean by SS2 model using the similar conditions/ assumptions to the ASPM and/or CASAL analyses for the comparison purpose of other stock assessment results.

Material and Methods

The following data and model structures are utilized in our analyses and population dynamics are calculated from 1960 to 2004.

1) Data used

We utilized the quarterly-based data (catch amount, CPUE and length-frequency) in our SS2 calculation.

- Fleet definitions and Catch

Longline: fishery-1 and Purse seine: fishery-2

Quarterly catch entered the model as number and biomass in longline and purse seine, respectively.

- CPUE series

Japanese longline CPUE: fishery-3

Standardized quarterly CPUE caught by Japanese longline fishery (Okamoto and Shono, 2006) was used for SS2 calculation as a tuning index. Standard deviation of Log(CPUE) is also integrated into the SS2 model.

- Length-frequency

The proportion of quarterly catch-at-size in each length-bin (2cm) (from 10cm to 208cm) for both longline and purse seine was utilized. Age-frequency is not used.

2) Model structures

The following conditions/assumptions in each component were used for our SS2 computation.

- Selectivity patterns

Selectivity was modeled as length-based not age-based. We assumed the following selectivity shape and estimated unknown parameters.

Scenario	Longline	Purse seine
Base (and sensitivity)	Double-Logistic	Double-Logistic

- Stock-Recruitment relationship

Recruitment was modeled assuming a Beverton and Hold curve and (h, R0) was defined as the parameters instead of (a, b) in the B-H function. In our analysis, we fixed h(steepness)=0.8, sigmaR=0.6 and estimated R0 (equilibrium recruitment in an un-fished state corresponding to S0). With regard to the steepness, we tried to estimate this value. However, because we did not obtain the reasonable solution, we finally used the fixed value of steepness at 0.8 (maybe same as the CASAL analyses). We also changed the value of steepness (from 0.6 to 0.9) and the results were omitted in this document since the differences of these values (total biomass, SSB and R etc.) are not so large. Recruitment deviations were estimated for 1960-2004.

- Biological parameters

We basically fixed the following biological parameters based on the agreement in the IOTC-WPTT-2004 meeting for bigeye assessment. This biological information is also used for our ASPM (Nishida and Shono, 2006).

1) Growth curve

We used the von-Bertalanffy growth curve and fixed the parameters (Linf=169, K=0.32 and t0= -0.336).

2) Weight-Length relationship

The weight at length relationship was taken from the past analyses,

$$W=3.661*10^{-5} L^{2.901} \tag{1}$$

3) Natural mortality (M)

M was assumed to be the following equation similar to our ASPM.

$$M = \left\{ \begin{array}{l} 0.8 \ (age \le 1) \\ -0.4 * age + 1.2 \ (1 < age < 2) \\ 0.4 \ (age \ge 2) \end{array} \right\} \tag{2}$$

4) Maturity

We used similar maturity vector to ASPM analysis in 2004 as follow:

$$Ma(L) = \frac{1}{1 + \exp\{-0.25 * (L - 110.888)\}} \quad (3)$$

- Model scenarios

We adopted the flat-shaped selectivity at older age in longline as the sensitivity (Figure 6). In this case, we used the double-logistic curve for longline fishery as well as the base case and changed the parameterization. (We also estimated the value of unknown parameters in our selectivity case.)

Results and Discussion

Table 1 and 2 shows the summary of likelihood components and indicators for model diagnostic in the base model and sensitivity case.

Figure 1-6 show the results of SS2 calculations in both cases with regard to the estimated year trends of SSB and total biomass (Figure 1), estimated number of recruitment in each year (Figure 2), observed and estimated CPUE year trends (Figure 3), spawner-recruitment relationship (Figure 4), estimated length-composition (Figure 5) and estimated length based selectivity in each fishery (longline and purse seine, Figure 6).

Both results (i.e. base model and sensitivity case) are wholly very similar (i.e. year trends of SSB, total biomass and R, CPUE fitting, proportion of each likelihood component and indicators for stock diagnostics etc.) and main difference is the absolute level of SSB, total biomass and recruitment (Figure 1 and 2).

Note that F (fishing mortality) in recent years drastically increase and exceed the Fmsy (Table 2) in our sensitivity case under the assumption of the flat-shaped selectivity in the longline. In addition, the observed and estimated length compositions seem not to be fitted well (Figure 5). Therefore, more consideration about the selectivity is necessary and useful.

In terms of the comparison between SS2 and ASPM analyses (Nishida and Shono 2006), the results are rather similar, especially overall year trends of SSB, total biomass and recruitment. The reason seems that we fixed the values of biological parameters (such as growth curve, natural mortality, maturity and weight-length relationship etc.) at the same as our ASPM analyses. Therefore, it may be useful to estimate these parameters for the near future (i.e. at the next stage), if the reasonable values are obtained.

Note: We would like to try to compute of stock assessment for bigeye tuna in the Indian Ocean by stock synthesis II (SS2) using the new agreed conditions/assumptions (and/or revised data) during the IOTC-WPTT-2006 meeting (24-28, July 2006) at Rep. of Seychelles, if necessary and if possible.

Remark) We did not use the Taiwanese standardized CPUE by longline fishery this time different from our ASPM analyses. If this index is included into our SS2 model, some quarterly-based CPUE is necessary and preferable.

Acknowledgement

We sincerely acknowledge Dr. Richard D. Method, developer of the Stock Synthesis II (SS2), for his useful advice and essential suggestions. We also thank Dr. Tsutomu NISHIDA, National Research Institute of Far Seas Fisheries, for his comments.

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Method, R. D. (2006) Used manual for the integrated assessment program stock synthesis II (SS2): Version 1.23d (May, 2006), 62p.

Nishida and Shono (2006) Updated stock assessment of bigeye tuna (*Thunnus obesus*) resource in the Indian Ocean by the age structured production model (ASPM) analyses (1960-2004). IOTC-WPTT-2006/___, 17p.

Okamoto and Shono (2006) Japanese longline CPUE for bigeye tuna in the Indian Ocean up to 2004 standardized by GLM applying gear material information in the model. IOTC-WPTT-2006/___, 16p.

Table 1 Likelihood components from the base model and sensitivity case.

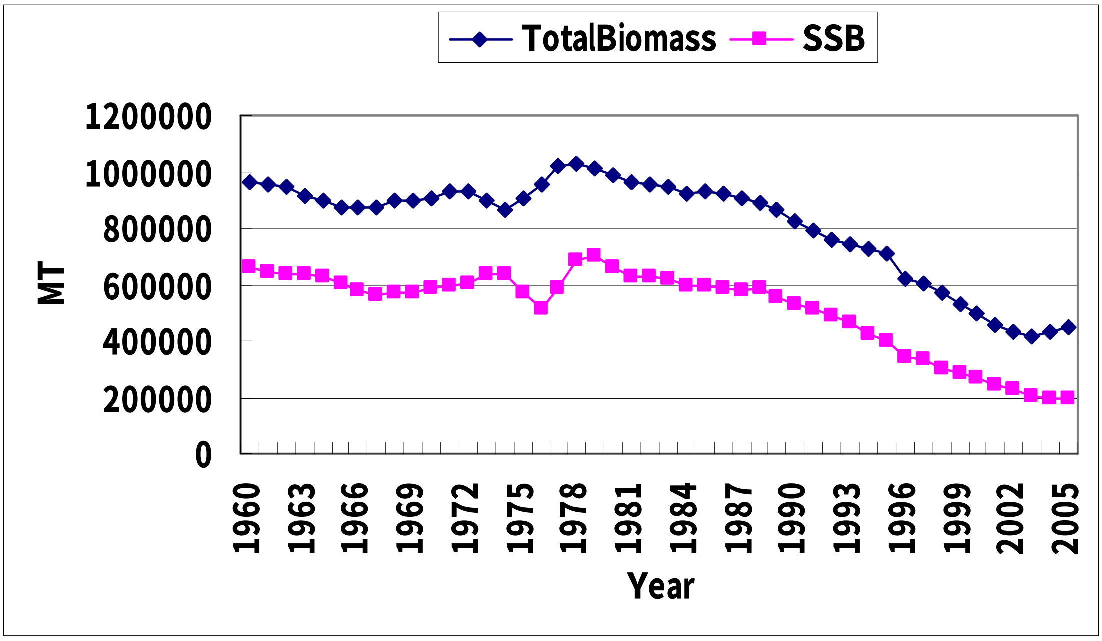
Base model		Sensitivity case	
Component	Likelihood	Component	Likelihood
Total	40190.4	Total	40328.3
indices	52.3573	indices	63.8394
discard	0	discard	0
length_comps	40159.7	length_comps	40286.2
age_comps	0	age_comps	0
size-at-age	0	size-at-age	0
mean_body_wt	0	mean_body_wt	0
Equil_catch	2.79E-07	Equil_catch	1.36E-05
Recruitment	-20.6974	Recruitment	-20.7179
Parm_priors	0.022865	Parm_priors	0.058517
Parm_devs	0	Parm_devs	0
penalties	0	penalties	0
Forecast_Recruitment	-1.02165	Forecast_Recruitment	-1.02165

Table 2 Indicators for diagnostic from the base model and sensitivity case.

Indicator	Base model	Sensitivity case
B0	819,660	679,930
R0	47,946,000	39,772,000
B2004/B0	0.23613	0.20733
MSY	137,040	114,550
Bmsy	186,450	158,110
Bmsy/B0	0.227477	0.232539
F2004	0.221407	0.491228
Fmsy	0.296513	0.294795

Figure 1 Estimated total biomass and SSB from the base model and sensitivity case

Base model



Sensitivity case

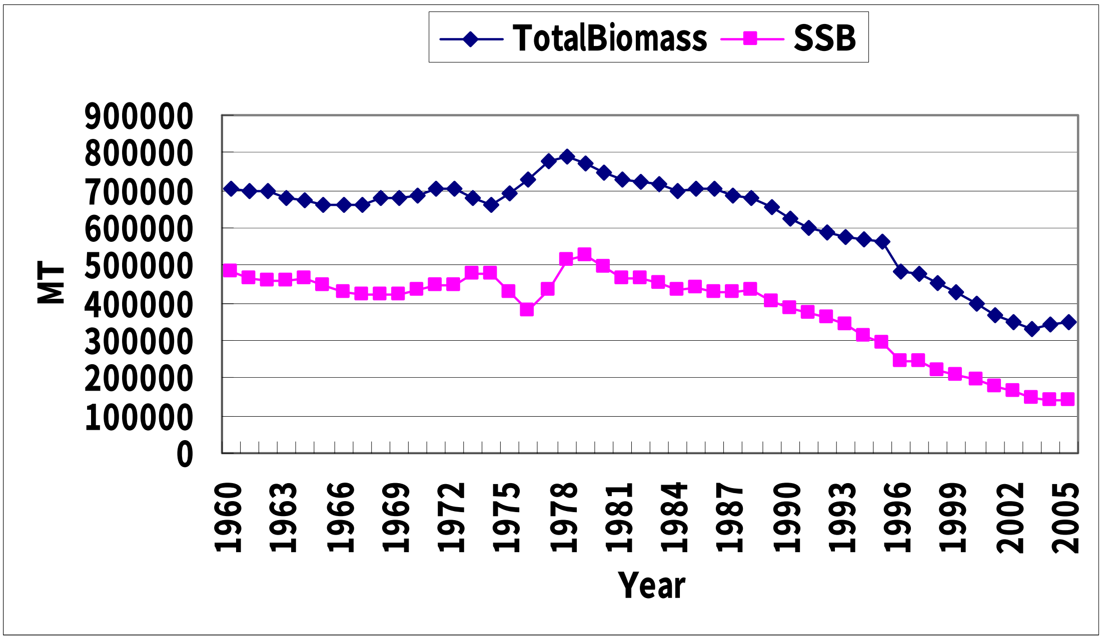
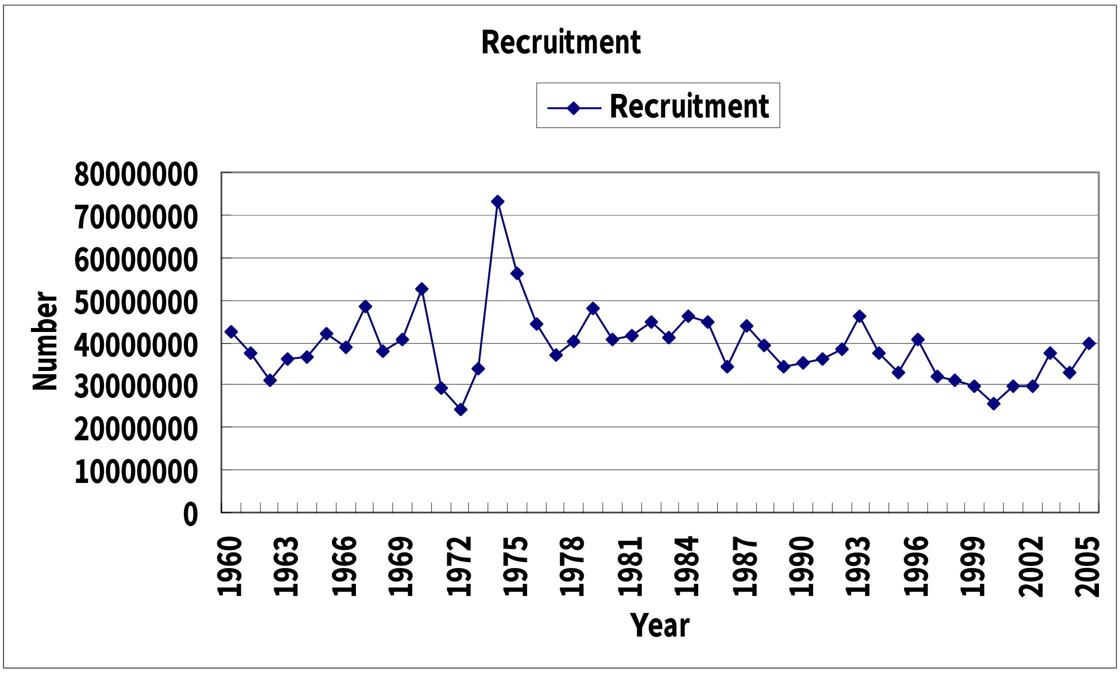


Figure 2 Estimated number of recruitment from the base model and sensitivity case

Base model



Sensitivity case

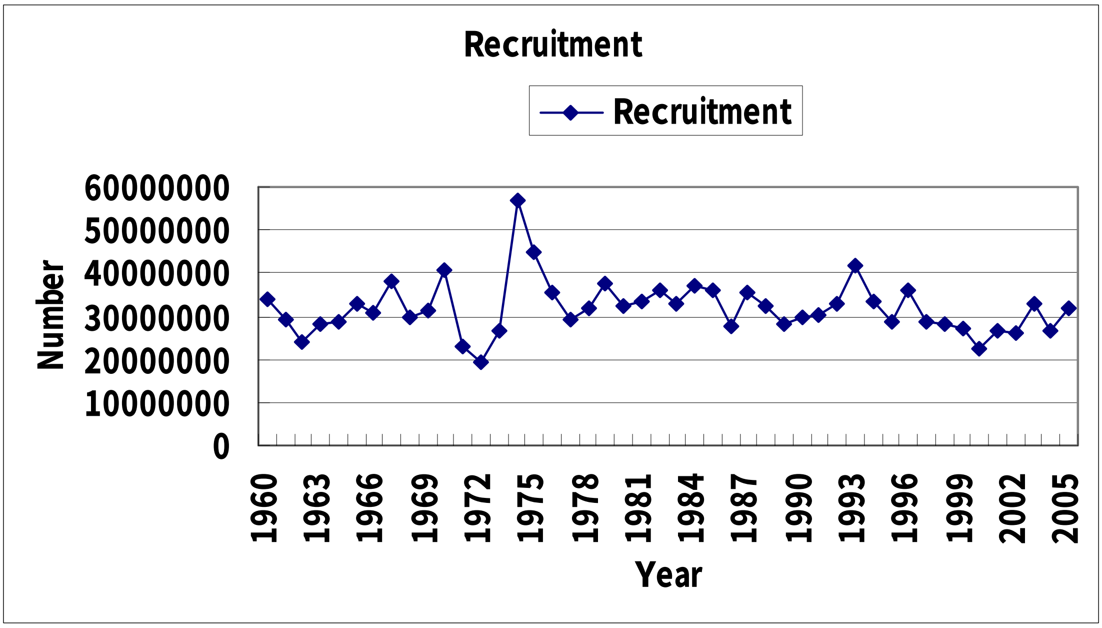
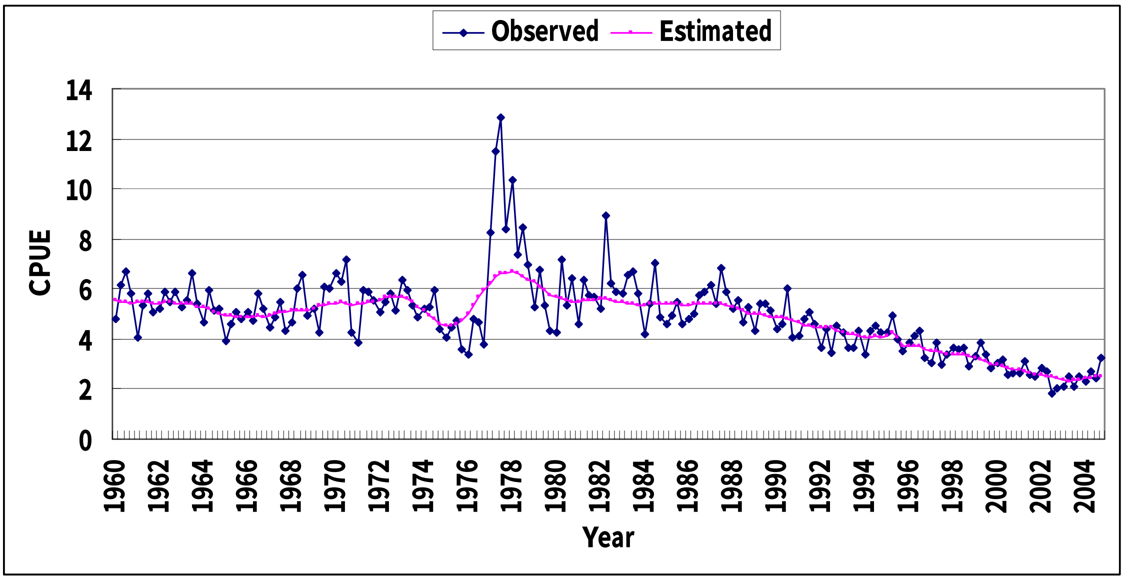


Figure 3 Estimated and observed CPUE from the base model and sensitivity case

Base model



Sensitivity case

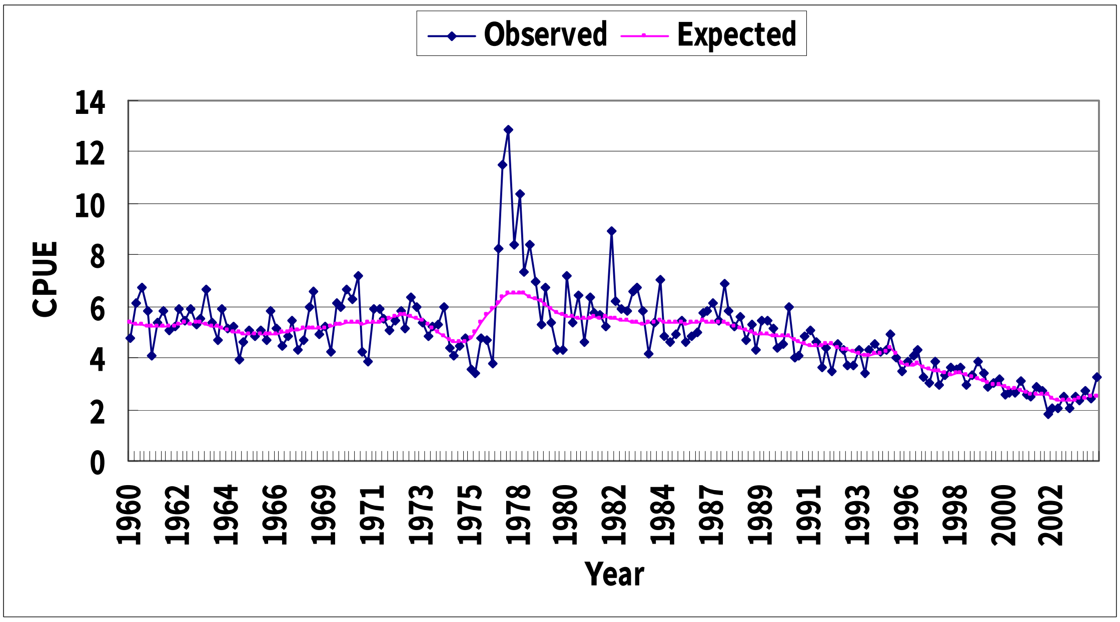
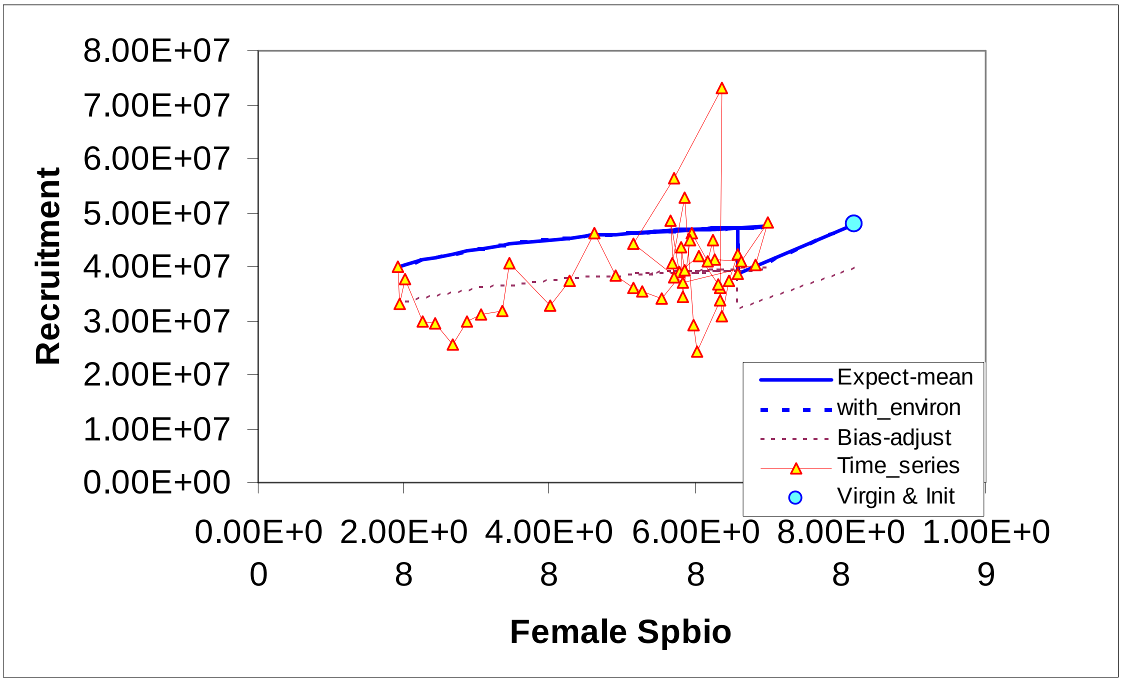


Figure 4 Estimated spawner-recruitment relationships from the base model and sensitivity case.

Base model



Sensitivity case

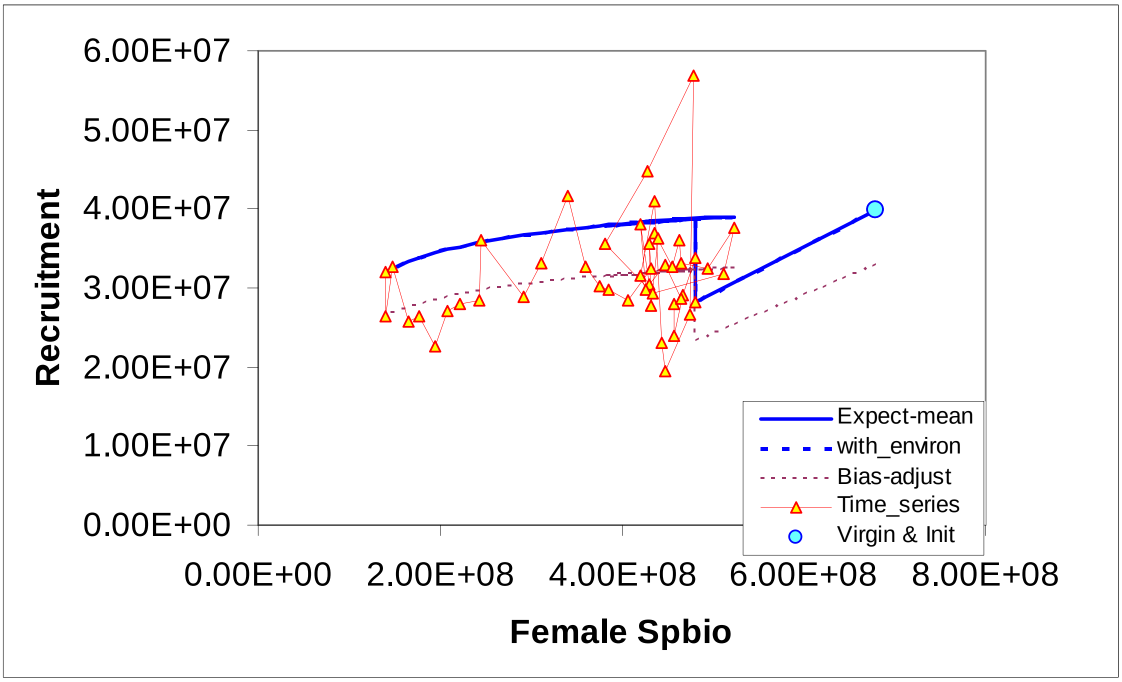
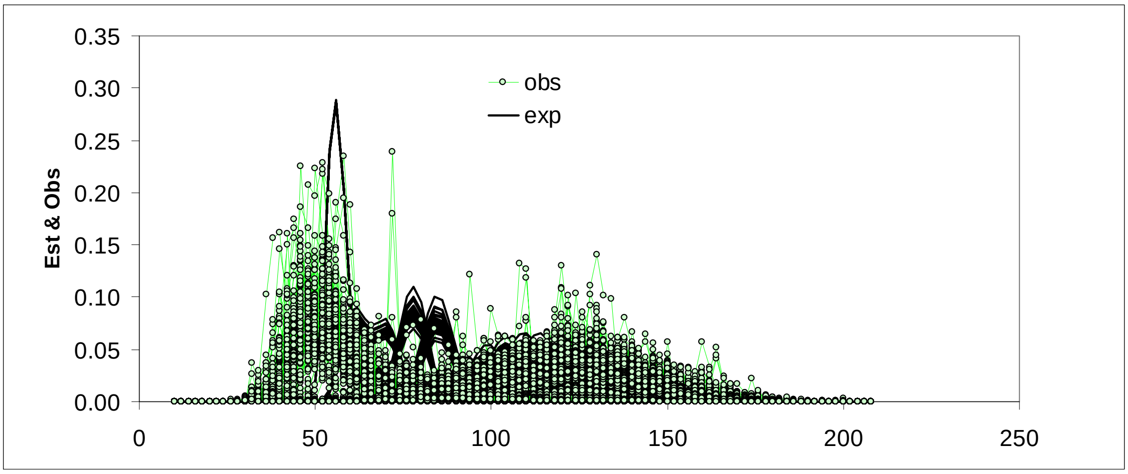


Figure 5 Observed and Estimated length-composition from the base model and sensitivity case.

Base model



Sensitivity case

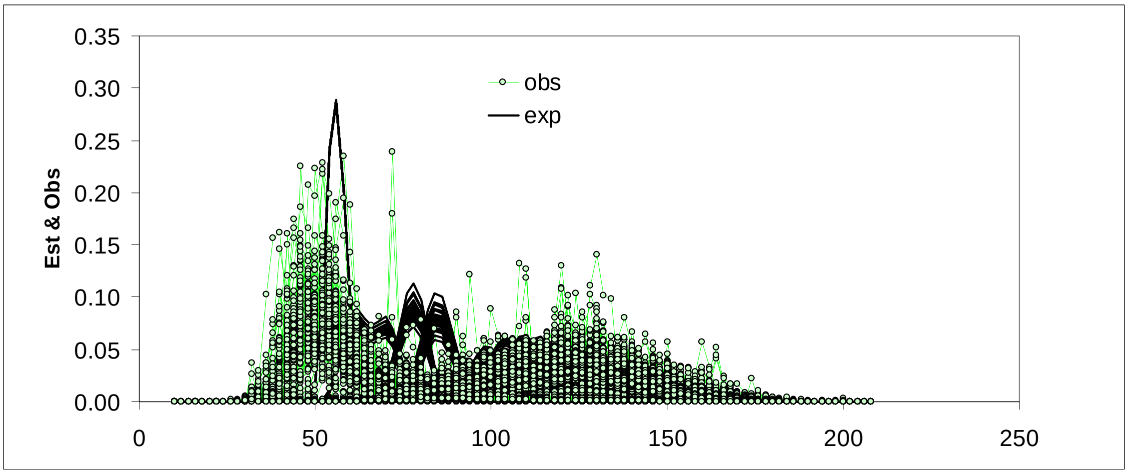
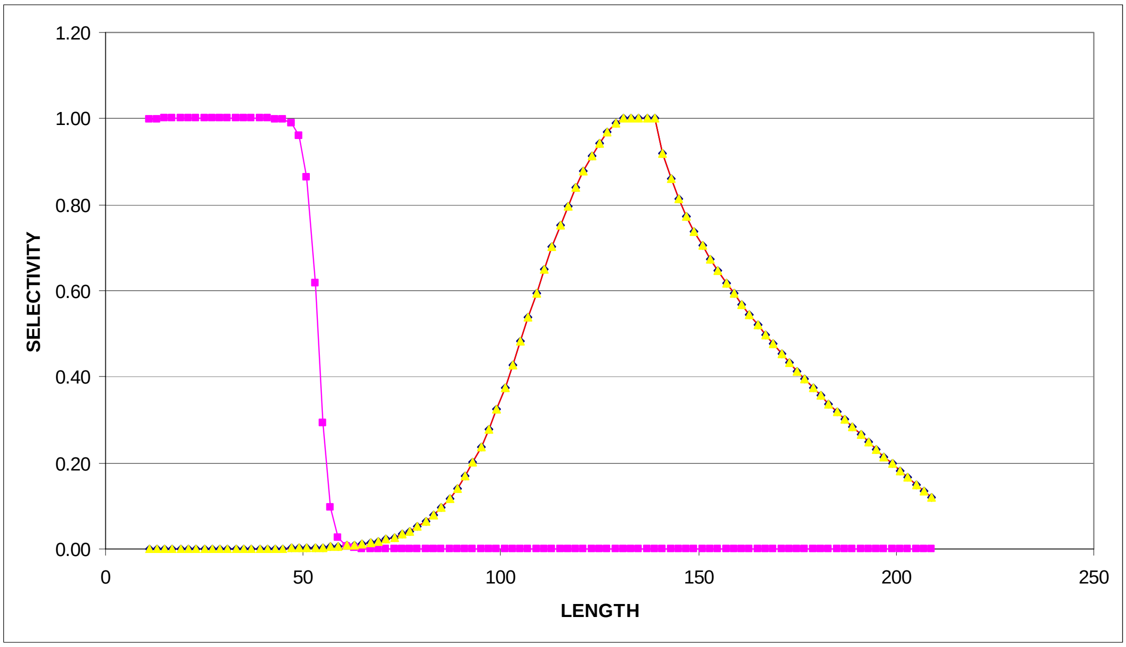
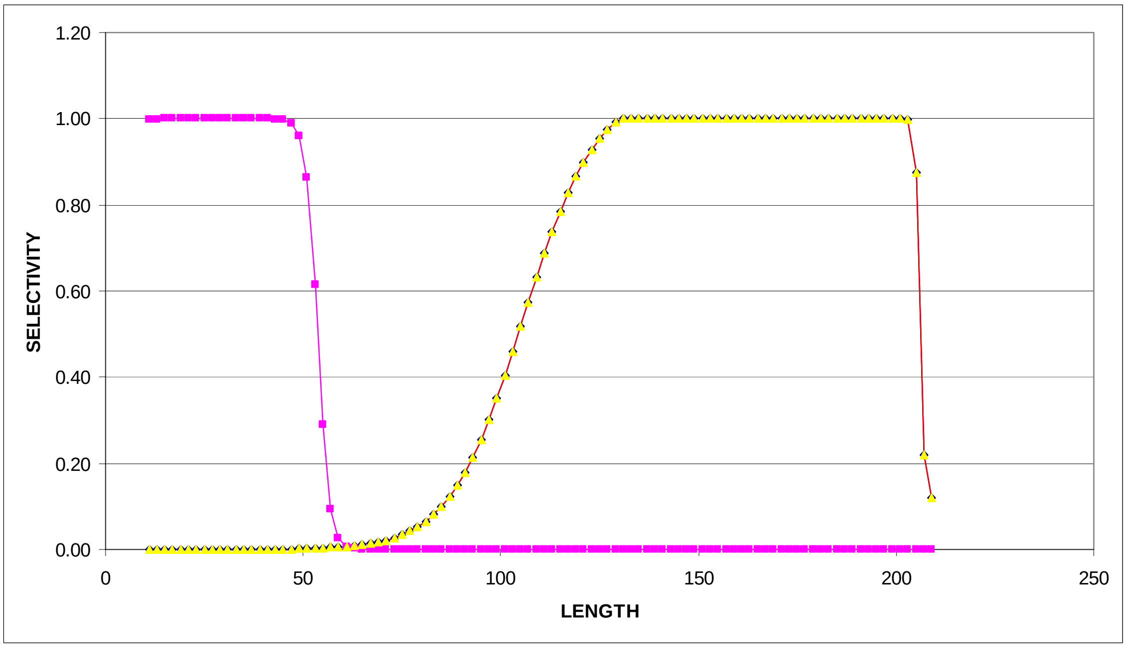


Figure 6 Estimated length-based selectivity in longline and purse seine fishery from the base model and sensitivity case.

Base model (Dome-shaped): Left side-purse seine, Right side-longline



Sensitivity case (Flat-shaped): Left side-purse seine, Right side-longline



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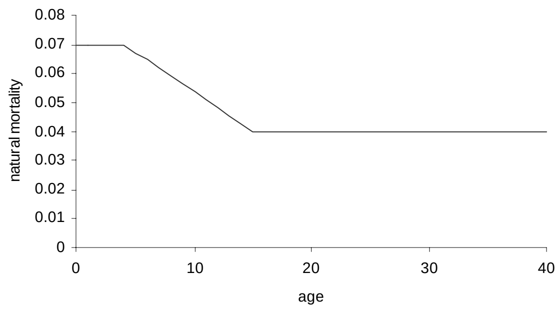
Appendix-1 Sensitivity SS2 runs for additional M vectors.

Due to the constraint regarding M vector in the SS2 model (i.e. only the following shape of M vector can be modeled), we changed the M vector for sensitivity a little to:

age	0	1	2	3	4	5	6+
M	1	0.8	0.6	0.4	0.4	0.4	0.4



$$M_{ga} = \begin{cases} M_{1g} & \text{for } a \le a_1, \\ M_{1g} + \dfrac{(a-a_1)(M_{2g}-M_{1g})}{a_2-a_1} & \text{for } a_1 < a < a_2, \\ M_{2g} & \text{for } a \ge a_2, \end{cases}$$

c.f. Two additional M vector

age	0	1	2	3	4	5	6+
M-1	1	0.6	0.3	0.4	0.4	0.4	0.4
M-2	1	0.6	0.3	0.4	0.4	0.4	0.6

Table 1 SS2 results

R0	62292000
B0	848360
MSY	128970
Bmsy	189880
B2004	187819
Fmsy	0.28522
F2004	0.20202
B2004/B0	0.22139
Bmsy/B0	0.22382
B2004/Bmsy	0.9891458
F2004/Fmsy	0.7082989

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Addendum-2. Projection based on the SS2 results (h=0.8, M1_vector, Jpn-CPUE).

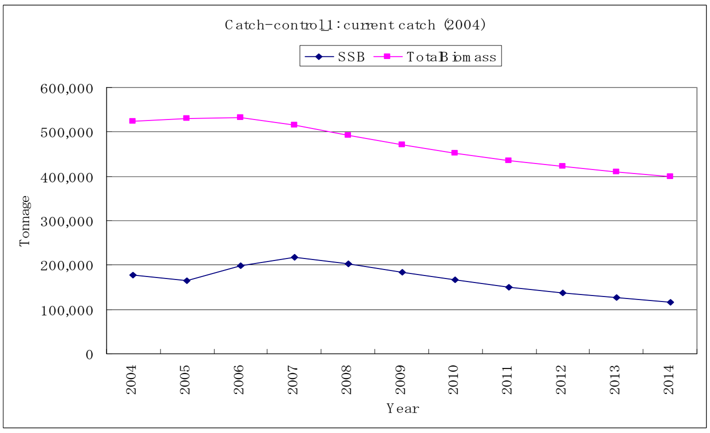

Table 1 Current catch (2004)

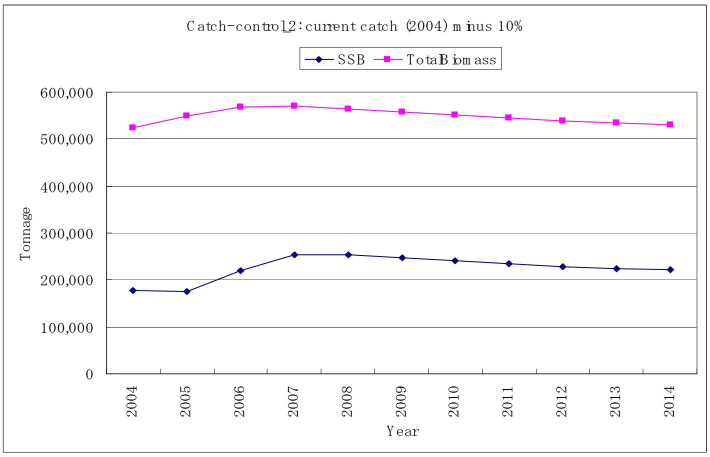

Table 2 Catch(2004) minus 10%

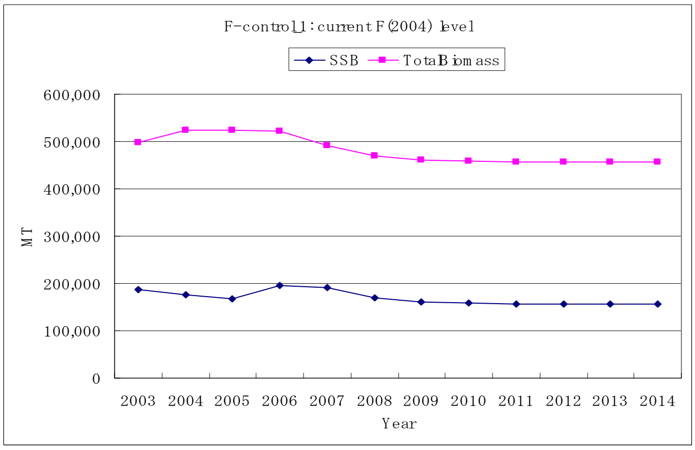

Table 3 Current F(2004) level

Note: We were not able to calculate other F-control scenarios due to lack of the output of F values in the SS2 model.

Addendum-2. (Con'd)

Confidence intervals of SSB (upper-5%, middle-point estimate, lower-95%)

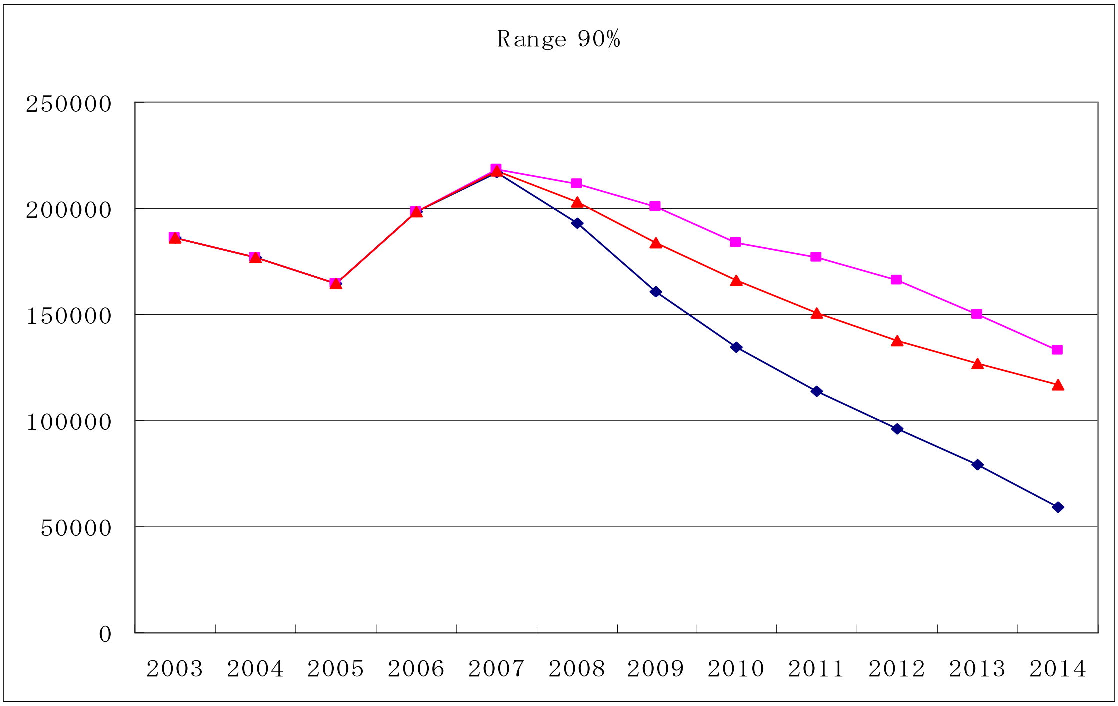

Table 1-b　Current catch (2004)

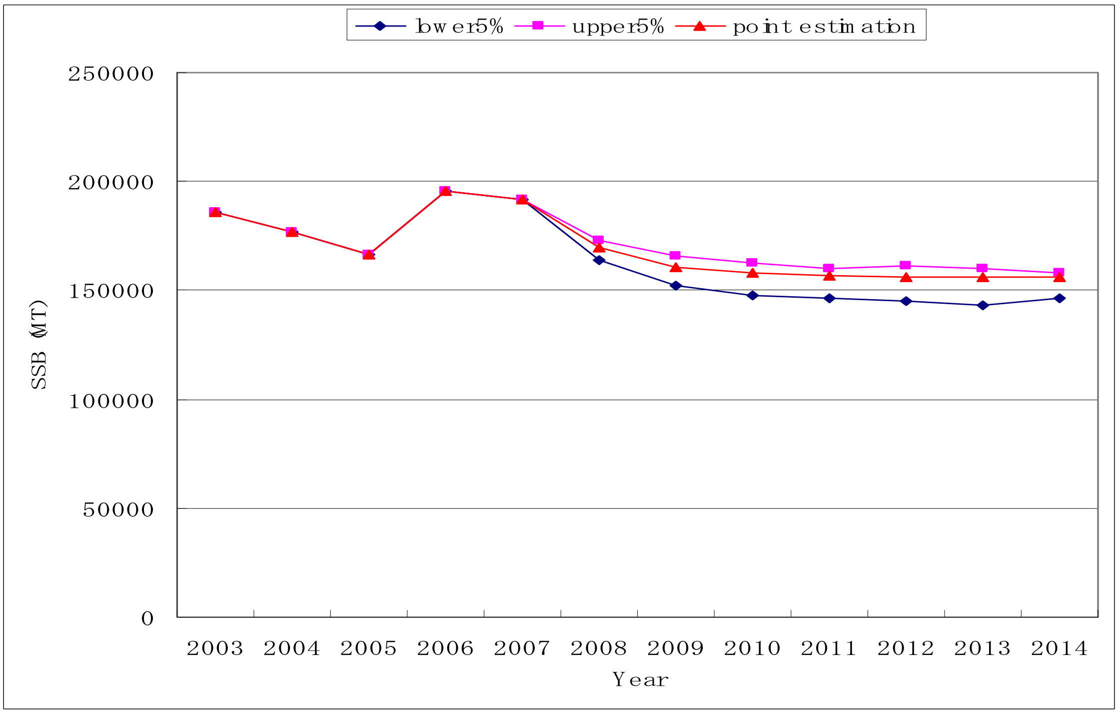

Table 3-b　Current F (2004) level

Note: We were not able to calculate other F-control scenarios due to lack of the output of F values in the SS2 model.

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Addendum-3:

As a result of changing the conditions/assumption for calculation about selectivity and unit of catch especially in order to obtain better fit of length-composition, we obtained the plausible results (except for the value of MSY) and different values (from those at the 2006-WPTT meeting) as follow:

Table A1 Indicators for diagnostic from the original and revised results.

Indicators	SS2 (2006-WPTT meeting)	SS2 (Revised at 2 October)
SSB_0	848,360 t	1,274,900 t
SSB_{2004}	187,819 t	343,415 t
SSB_{MSY}	189,880 t	289,040 t
ratio SSB_{2004} / SSB_{msy}	0.99	1.19
ratio SSB_{2004} / SSB_0	0.22	0.27
MSY	128 970 t	182,280 t
C_{2004}	126,518 t	126,518 t
F_{2004}	0.20	0.16
F_{MSY}	0.28	0.27
Ratio F_{2004} / F_{MSY}	0.71	0.59

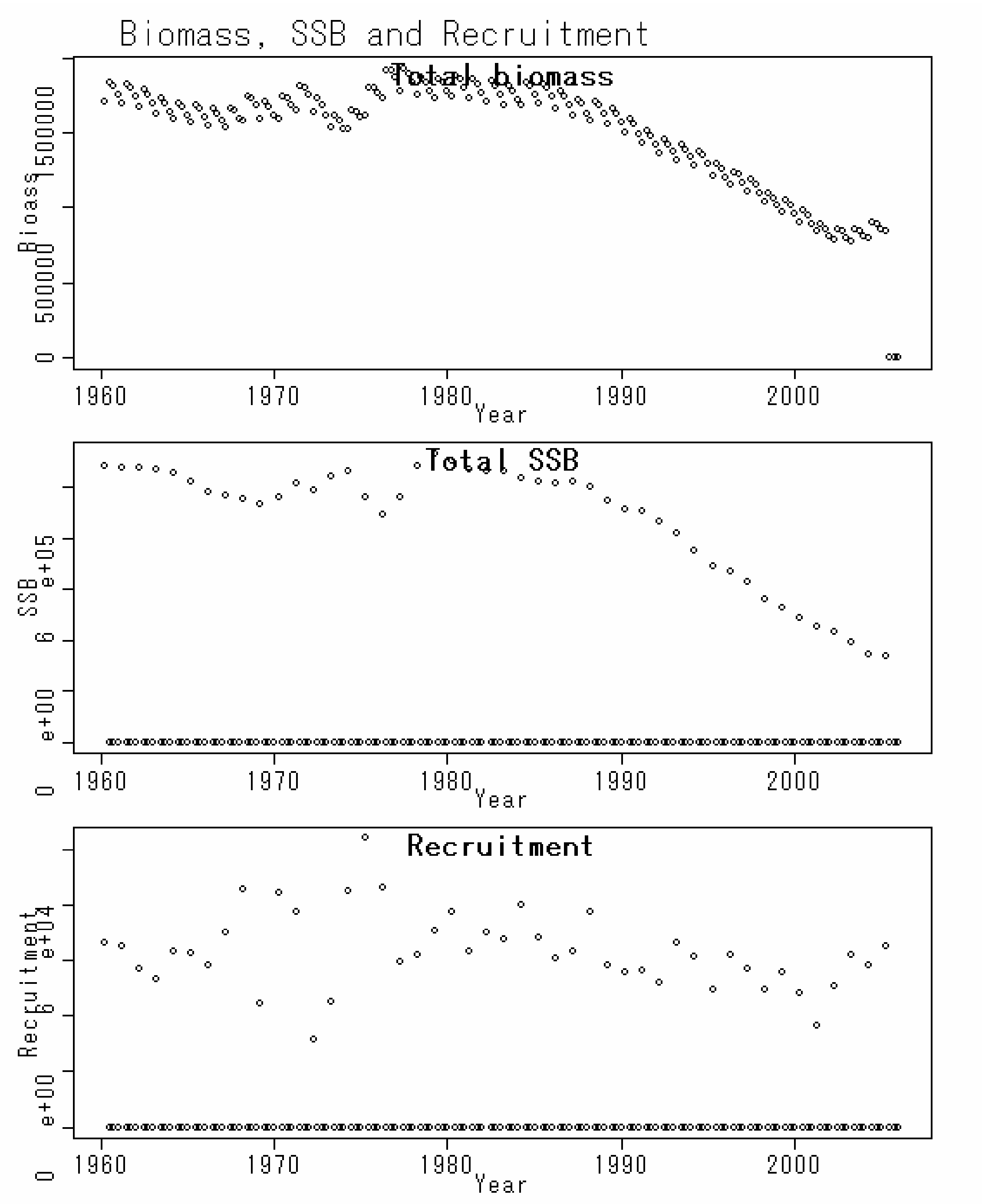

Figure A1 Estimated year trends of total biomass, SSB and recruitment.

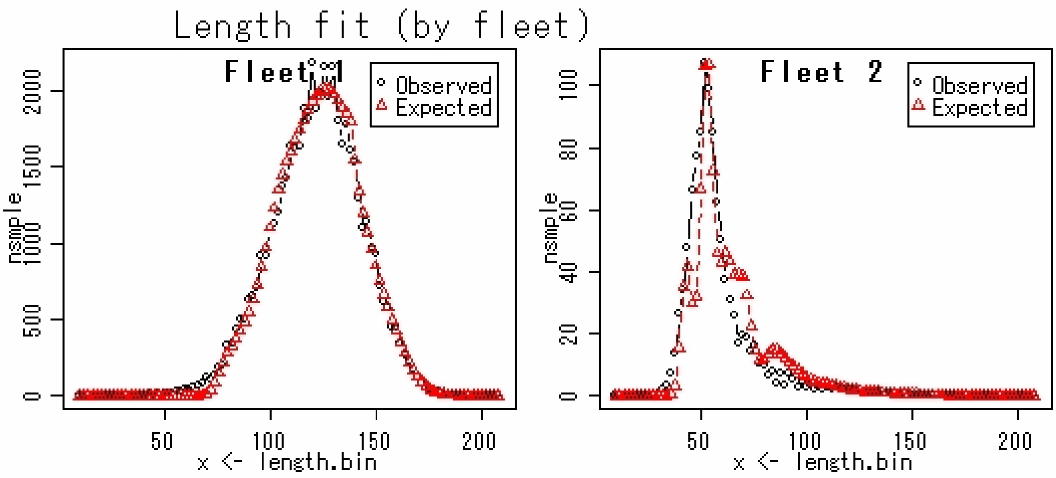

Figure A2 Length fit between observed and estimated in longline (Fleet 1) and Purse seine (Fleet 2).

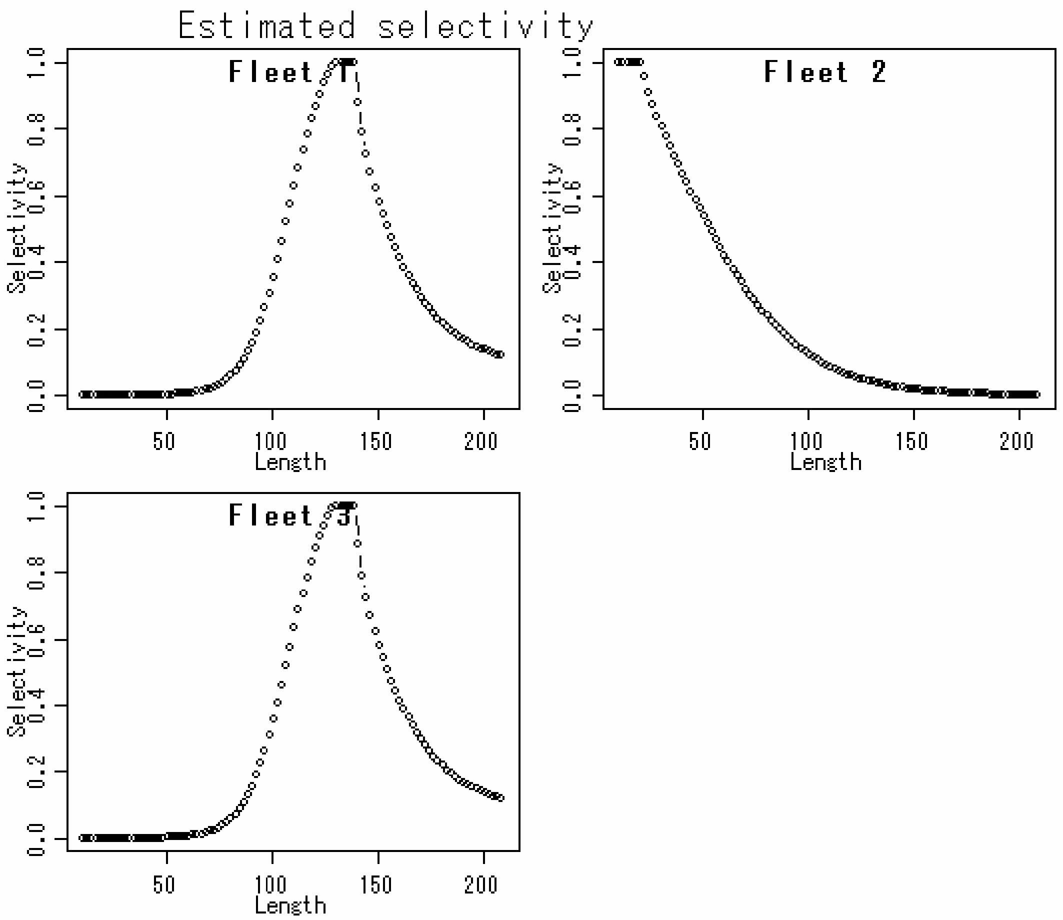

Figure A3 Estimated length-based selectivily in longline (Fleet 1) and purse seine (Fleet 2) fishery. (Fleet 3 is the same as Fleet 1)