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

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Abstract:

We conducted the preliminary stock assessment for yellowfin tuna in the Indian Ocean using Stock Synthesis II (SS2) (made by Rechard, Methot: Methot, 2005; Methot, 2006 ; Methot, 2007), a kind of length-based integrated model, as a feasibility study. The main purpose of this document is to compare the results of stock assessment such as the year trends of estimated stock level and various indices for stock diagnostics (e.g. MSY Bmsy etc.) obtained from the SS2 with those by ASPM (age-structured production model, Nishida and Shono, 2005: Nishida and Shono?, 2007) and CASAL (Hillary and Mosqueira, 2007: Stock assessment for IOTC-YFT by CASAL?).

Introduction

We tried to assess for yellowfin tuna in the Indian Ocean as a feasibility study using Stock Synthesis II (SS2), a kind of length-based integrated and statistical approach, in succession to the stock assessment for bigeye tuna in the Indian Ocean by SS2 last year (Shono *et. al.*, 2006). The advantages to use 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 as follow:

- 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 yellowfin 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 like Bayesian-PM etc.

Material and Methods

The following data and model structures are utilized in our analyses and population dynamics are calculated from 1968 to 2005.

1) Data used

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

- Fleet definitions and Catch

Longline (LL): fleet-1 (fishery-1), Purse seine (PS): fleet-2 (fishery-2), Gillnet: fleet-3 (fishery-3), Line: fleet-4 (fishery-4) and Baitboat: fleet-5 (fishery-5)

Quarterly catch entered the model as biomass in (caught by) all gear.

- CPUE series

Japanese longline CPUE: survey-1 (fishery-6)

Standardized quarterly CPUE caught by Japanese longline fishery (Okamoto *et al.*, 2007) was used for SS2 calculation as a tuning index. Standard deviation of the natural logarithm of CPUE, std.dev. 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 210cm) for every gear (Longline (LL), Purse seine (PS), Gillnet, Line and Baitboat) 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 selectivity of "double-logistic" shape and estimated unknown parameters in each fishery (Longline (LL), Purse seine (PS), Gillnet, Line and Baitboat).

- **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 estimated the value of h (steepness), fixed sigmaR at 0.6 and estimated R0 (equilibrium recruitment in an un-fished state corresponding to S0). With regard to the steepness, we tried to estimate the value in the Base case. In addition, we also calculated fixing the value of steepness at 0.8 (maybe same as or similar to the CASAL analyses). Recruitment deviations were estimated for 1968-2005.

- **Biological parameters**

We basically fixed/estimated the following biological parameters based on the agreement in the IOTC-2005-WPTT for stock assessment yellowfin tuna and discussion through e-mail before this meeting. The following biological information is also the same as and/or similar to those used for our ASPM (Nishida and Shono?, 2007).

1) Growth curve

We used the transformed von-Bertalanffy growth curve as follow:

$L(t) = Linf + (64 - Linf) * Exp[-0.38*(t-1)]$

where $Linf=64+(166-64)/(1-Exp[-0.38*(20-1)])$ (≒166.0747)

2) Weight-Length relationship

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

$W=1.585*10^{-5} L^{3.045}$ (1)

4) Maturity

We used similar maturity vector to that agreed in the 2005 meeting, Ma(L)=0 (if L<=100) and 1 (otherwise: L>100).

$$Ma(L) = \frac{1}{1+\exp\{-0.25*(L-100.75)\}} \quad (2)$$

3) Natural mortality (M)

M was assumed to be the following equation which is close to one of the two M vectors (ICCAT-proxy) agreed in the IOTC-WPTT-2005 meeting.

$$M = \begin{cases} 0.8 \ (age = 0) \\ -0.2 * age + 0.8 \ (0 < age < 1) \\ 0.6 \ (age \geq 1) \end{cases} \quad (3)$$

Results and Discussion

Table 1 and 2 shows the summary of likelihood components and indicators for model diagnostics both in the Base case (where the value of steepness was estimated at 0.99) and optional one (in which the value of steepness was fixed at 0.8). Figure 0-6 show the results of SS2 calculations with regard to the estimated S-R relationship (Figure 0), annual catch by fleet (Figure 1), fixed growth curve (Figure 2), observed and estimated CPUE year trends (Figure 3), estimated year trends of total biomass, SSB (tonnage) and recruitment in number (Figure 4), estimated total exploitation rate, average F and maximum F at age (Figure 5), estimated length-based selectivity in each fleet (Figure 6) and observed and estimated length-composition (Figure 7) by gear (1-LL), 2-PS), 3-Gillnet, 4-Line and 5-Baitboat). All figures are the corresponding to our Base model because the LIKELIHOOD (negative log-likelihood) is better than that in the option one.

Estimated stock levels in the base case are higher than those in the option one as a whole and this seemed to be derived from the estimated/fixed value of the steepness. Note that F (fishing mortality) in recent years drastically increase and exceed the Fmsy in both cases. Especially, the values of F and R in 2005 are extreme high. These seem to be caused from a gap of the year trend of between catch by gear (increase) and CPUE (stable). As a result, TB (total biomass) and SSB in recent years may drastically decrease.

Note: We would like to try to compute of stock assessment for yellowfin tuna in the Indian Ocean by stock synthesis II (SS2) using the new agreed conditions/assumptions (and/or revised data) during the IOTC-2007-WPTT meeting (16-20, July 2007) at Rep. of Seychelles, if necessary and if possible.

Remark) We did not use the Taiwanese standardized CPUE by longline fishery. If this index (and/or other CPUE e.g. by purse seine etc.) 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. Momoko Ichinokawa for giving us her scripts by R to display SS2 output/results graphically and Dr. Tom Nishida for his useful comments.

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Table 1 Likelihood components in the base case (Left) and option (Right).

LIKELIHOOD	19526.1	LIKELIHOOD	23808.8
indices	610.091	indices	697.699
discard	0	discard	0
length_comps	18786.3	length_comps	23074.3
age_comps	0	age_comps	0
size-at-age	0	size-at-age	0
mean_body_wt	0	mean_body_wt	0
Equil_catch	25.3609	Equil_catch	31.1937
Recruitment	-11.1575	Recruitment	-8.93744
Parm_priors	0.264545	Parm_priors	0.374728
Parm_devs	0	Parm_devs	0
penalties	120.39	penalties	19.2794
Forecast_Recruitment	-5.10826	Forecast_Recruitment	-5.10826

Table 2 Various indicators for diagnostics obtained from our SS2 results.

Indicator	Base case (h-estimated)	Option (fixed h at 0.8)
B0 (SSB0)	2,818,800	1,927,390
R0 (Recruitment-0)	186,850,000	127,758,000
B2005 (SSB2005) / B0	0.33509	0.18401
MSY	309,740	227,083
Bmsy	378,006	538,898
B2005	944,543	354,654
F2005	0.14886	0.419102
Fmsy	0.12632	0.324624

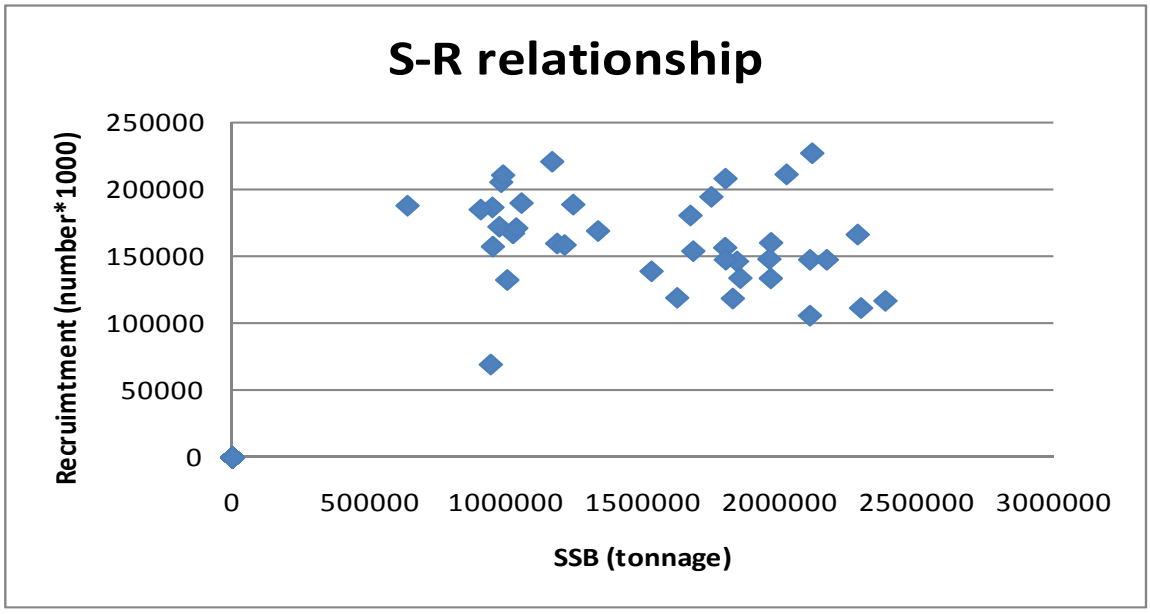

Figure 0 Estimated the annual Spwaner-Recruitment relationship.

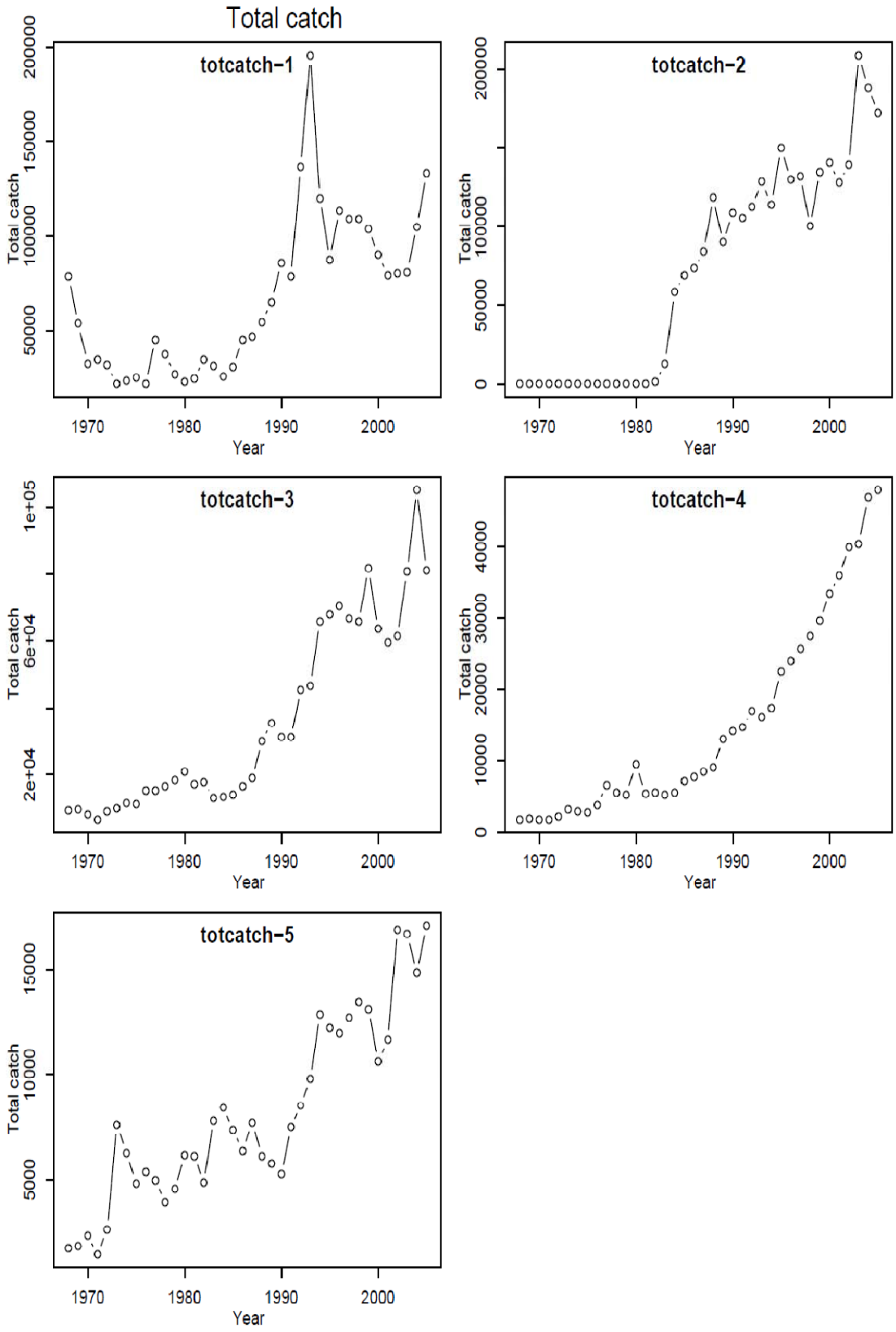

Figure 1 Annual catch by gear (1-LL, 2-PS, 3-Gillnet, 4-Line and 5-Baitboat).

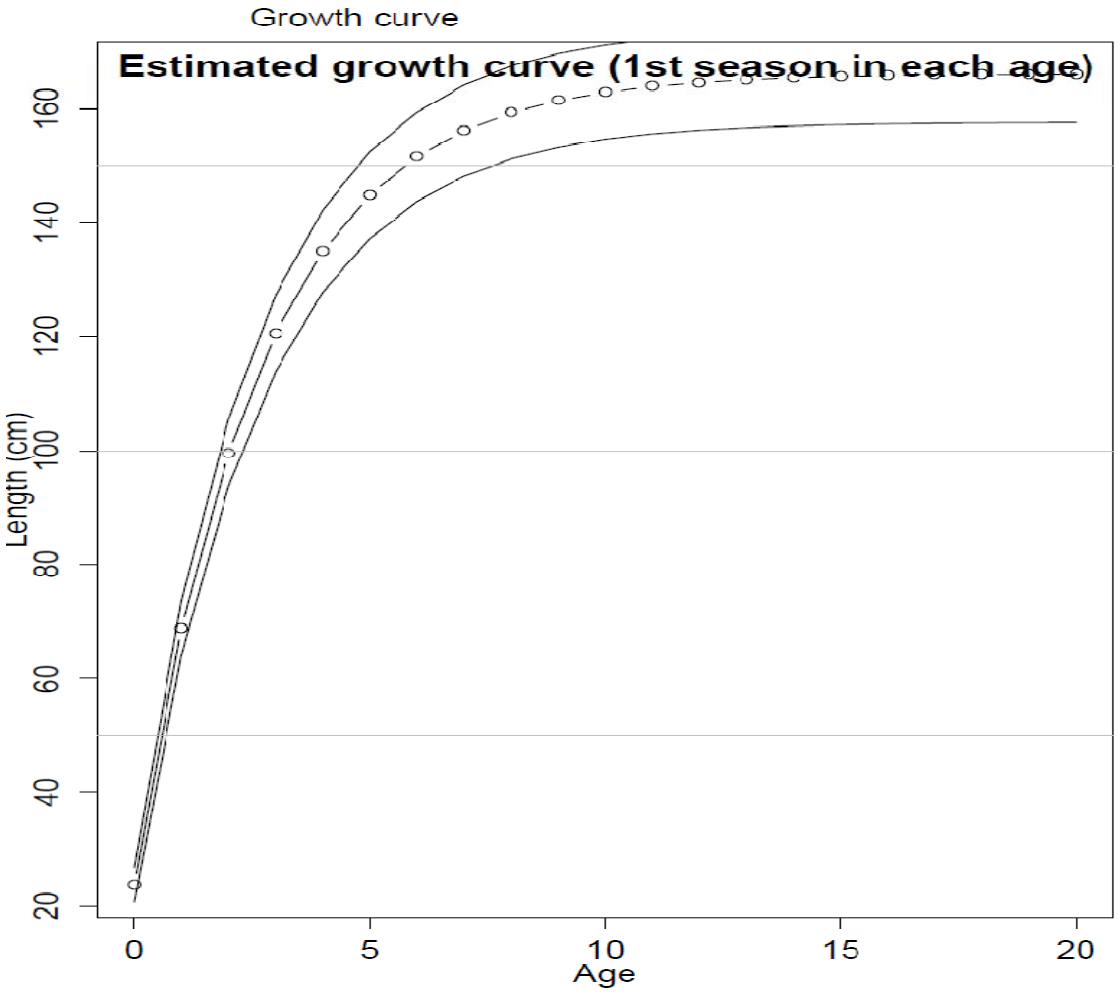

Figure 2 Fixed growth curve (i.e. Transformed von Bertalanffy) used for SS2.

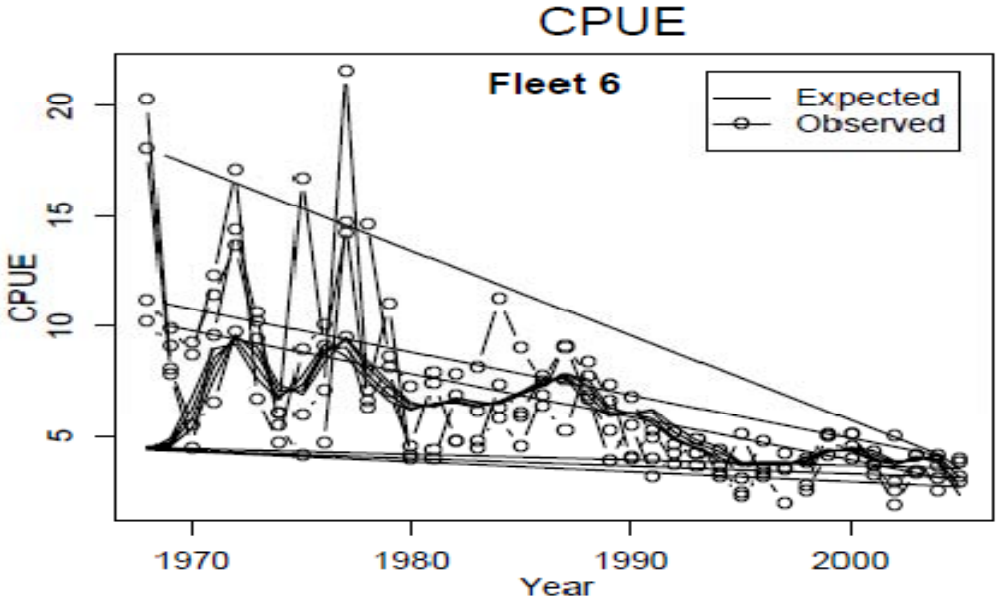

Figure 3 Expected (i.e. estimated) and observed CPUE obtained from SS2.

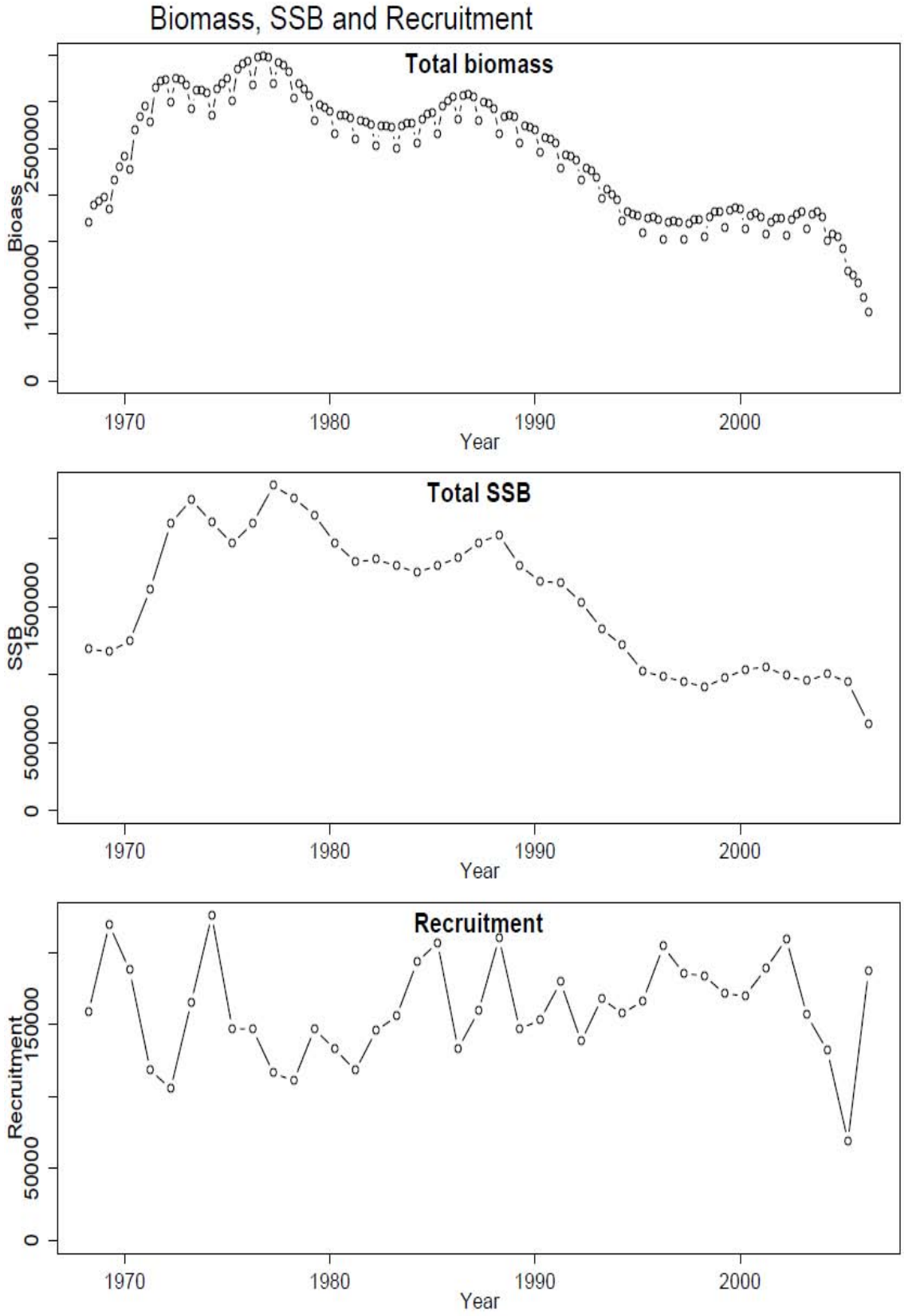

Figure 4 Estimated total biomass, SSB and Recruitment (1000*number).

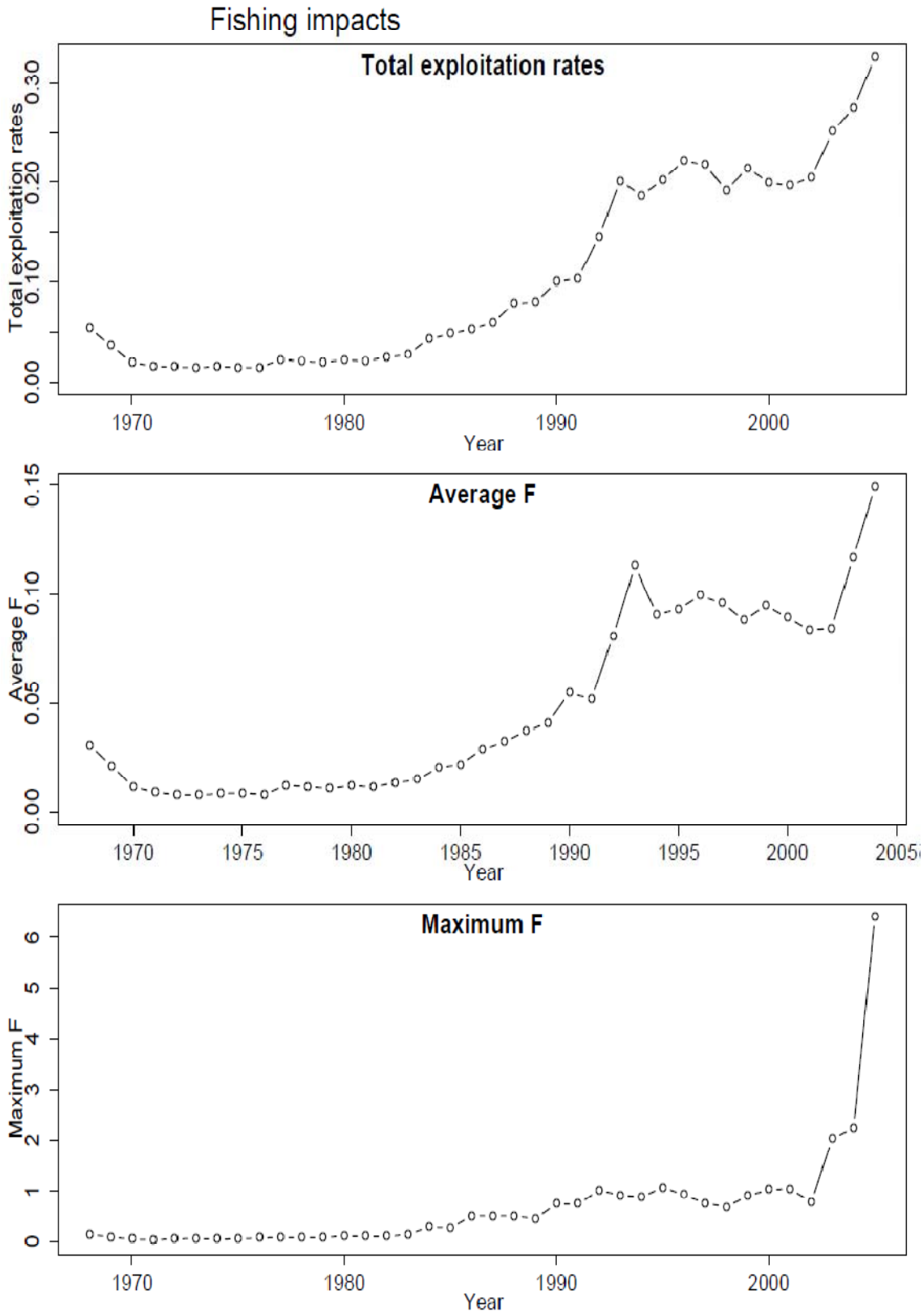

Figure 5 Estimated total exploitation rate, average F and maximum F at age

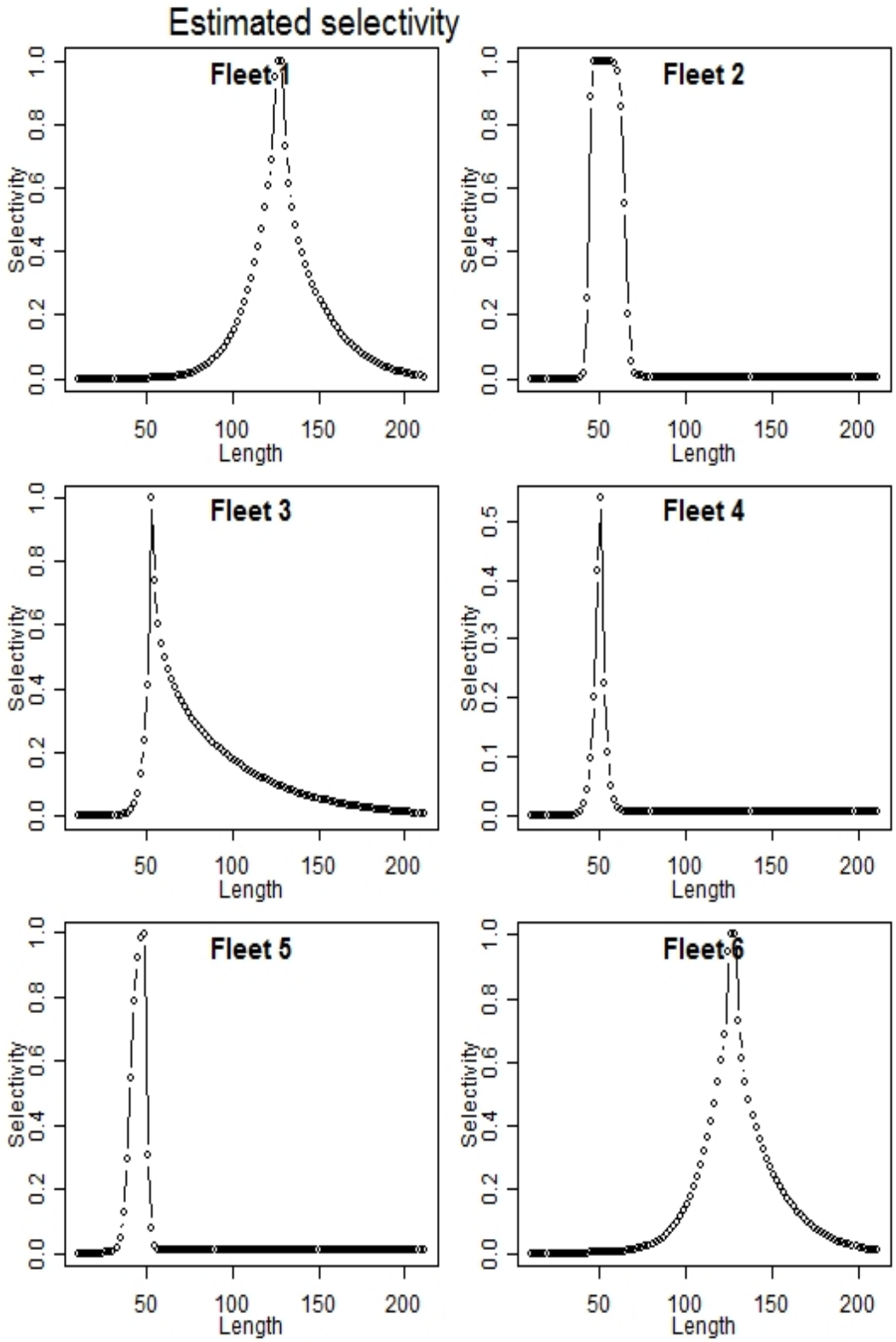

Figure 6 Estimated size-dependent (Double-logistic) selectivity by each fleet. (1-Longline, 2-Purse seine, 3-Gillnet, 4-Line and 5-Baitboat).

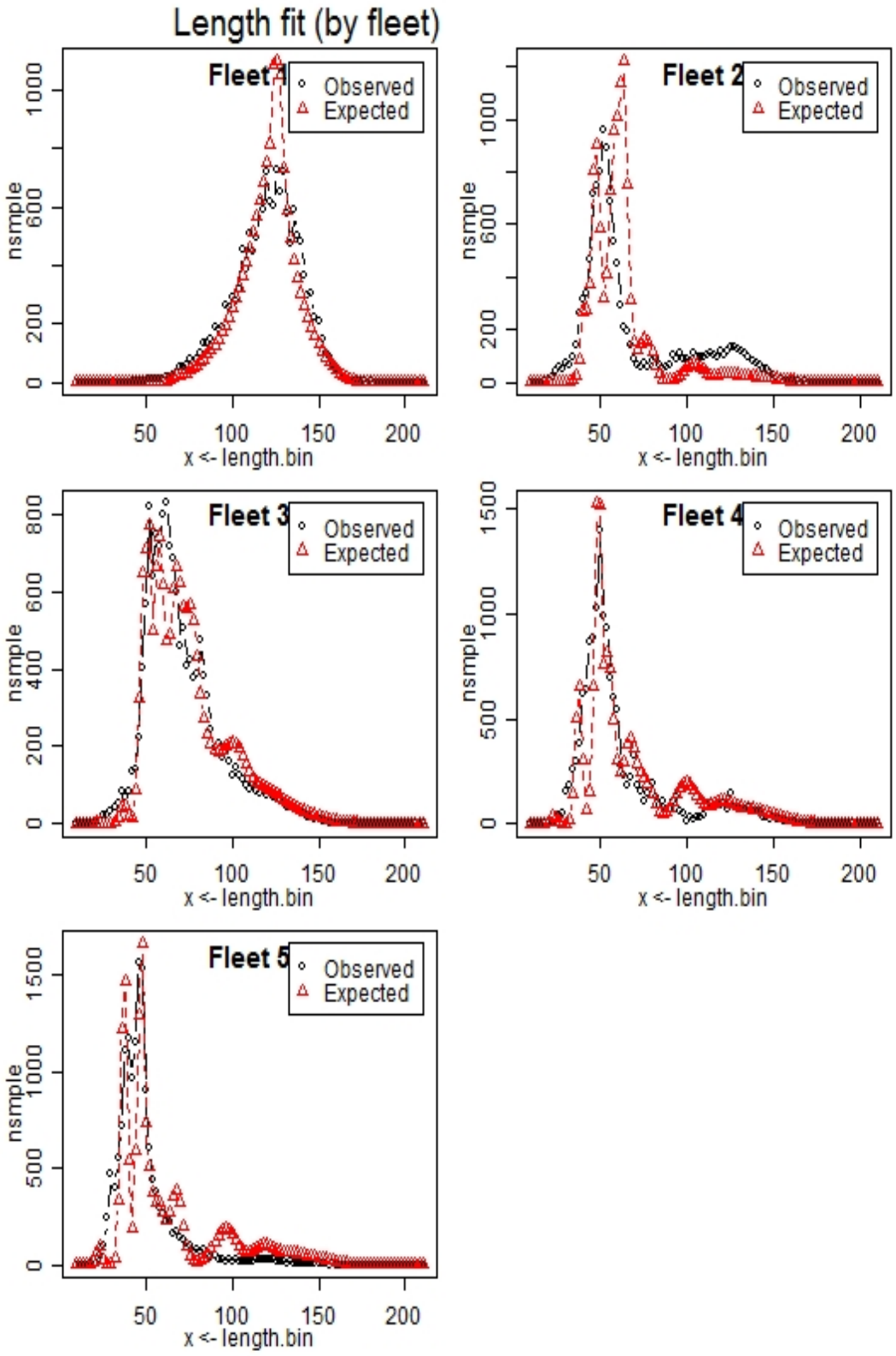

Figure 7 Observed and Estimated length-composition from our SS2 model. (1-Longline, 2-Purse seine, 3-Gillnet, 4-Line and 5-Baitboat).