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Updated 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 (YFT) in the Indian Ocean using Stock Synthesis II (SS2) (made by Richard, Methot: Methot, 2005; Methot, 2006 ; Methot, 2007; Methot, 2008), a kind of length-based integrated model. The main purpose of our document is to compare this to the past stock assessment results for YFT (Shono *et al.*, 2007a; Shono *et al.*, 2007b) and also compare with the current results obtained from the other stock assessment models such as ASPM (Nishida and Shono, 2008) and MULTIFAN-CL (Langley et al., 2008) etc. regarding the various indicators for stock diagnostics such as the year trends of estimated stock level, MSY-related indices (e.g. MSY, SSBmsy) and so on.

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 yellowfin tuna in the Indian Ocean by SS2 last year (Shono *et. al.*, 2007a, 2007b) and also for bigeye tuna in the Indian Ocean two years ago (Shono *et. al.*, 2006). The advantages to use such length-based integrated models (e.g. MULTIFAN-CL, A-SCALA, CASAL) instead of traditional stock assessment model (such as ASPM, ASPIC or Tuned VPA and so on) are as follows:

- To reduce the aging error (i.e. error from the catch-at-size to catch-at-age) because SS2 (and other integrated models) can deal with 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 stock assessment for yellowfin tuna in the Indian Ocean by SS2 model using the updated latest data (up to 2007).

Material and Methods

The following data and model structures are utilized in our analyses and population dynamics are calculated from 1968 to 2007.

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 (i.e. *Handline and Troll line*): fleet-4 (fishery-4),
Baitboat: fleet-5 (fishery-5)
Quarterly catch was entered into 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 and Shono, 2008) 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 (fork length, 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) as our Base-case and fixed h at 0.8 as the option-B, fixed sigma-R at 0.6 and estimated the natural logarithm of R0 (equilibrium recruitment in an un-fished state corresponding to S0). With regard to the steepness, we tried to estimate the value in our Base-case. Recruitment deviations were estimated for 1968-2007.

- Biological parameters

We basically fixed/estimated the following biological parameters based on the agreement in the IOTC-2005-WPTT and IOTC-2007-WPTT for stock assessment of 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 the ASPM (Nishida, 2008).

1) <u>Growth curve</u>

We used the following transformed von-Bertalanffy growth curve, which becomes the approximation to the previous formula, as our Base-case.

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

where $Linf=64+(166-64)/(1-Exp[-0.38*(20-1)])$ (≒166.0747) and L(t) is the fork length at age t in year.

In addition, we utilized the following growth formula as the Option-A, which is similar and corresponding to that distributed by IOTC secretariat (Miguel Herrera-san) through E-mail before this WPTT meeting.

$L(t) = Linf + (48-Linf) * Exp[-0.39*(t-1)]$ (2)

where $Linf=48+(148-48)/(1-Exp[-0.39*(20-1)])$ (≒148.9261) and L(t) is the fork length at age t in year.

2) Weight-Length relationship

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

$W=1.585*10^{-5} L^{3.045}$ (3)

where W is the body weight in kg.

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).

$$Ma(L) = \frac{1}{1+\exp\{-0.25*(L-100.75)\}} \quad (4)$$

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-2007 meeting.

$$M = \begin{Bmatrix} 0.8 \ (age=0) \\ -0.2*age+0.8 \ (0<age<1) \\ 0.6 \ (age \geq 1) \end{Bmatrix} \quad (5)$$

Results and Discussion

Table 1 and 2 shows the model assumption of the scenarios, indicators for model diagnostics and the summary of likelihood components among in the Base case (where the old growth in 2007 is used), option-A (in which the approximation of new suggested growth is utilized) and option-B (where the value of steepness is fixed at 0.8). We obtained the estimated value of h (steepness) at almost near 1.0 in both the Base-case and Option-A.

Figure 1-8 show the results of SS2 calculations with regard to the estimated annual catch by fleet (Figure 1), fixed growth curve and estimated S-R relationship (Figure 2), observed and estimated CPUE year trends (Figure 3), estimated year trends of total biomass (TB), SSB (tonnage) and recruitment in number (Figure 4), estimated total exploitation rate, SPR and YPR (Figure 5), estimated length-based selectivity in each fleet (Figure 6), estimated exploitation rate by gear (Figure 7) and observed and estimated length-composition (Figure 8) by gear (1-LL, 2-PS, 3-Gillnet, 4-Line and 5-Baitboat). All figures are the corresponding to our Base-case because the general trends of these indicators are similar to those in the options (A & B).

Estimated exploitation rates increase from 1990s to the present, especially in PS and Line (Figure 6), but TB and SSB for the middle of 1990s until now seem to be stable (Figure 4). The fitting of length-frequency seems to be improved compared to that in 2007 (Shono, *et. al.*, 2007a; Shono, *et. al.*, 2007b) and the estimated selectivity by fleet is reasonable.

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-2008-WPTT meeting (for 23 Oct. to 31 Oct, 2008) at Bangkok, if necessary and if possible.

Remark) Our shopping list for conducting the model-based stock assessment of yellowfin tuna in the Indian Ocean derived from SS2 analysis is as follow:

- Values of the biological parameters (e.g. M, Maturity, growth formula etc.)
- Setting of the value of steepness (h)
- Parameterization of length (or age) based selectivity pattern in each fleet
- Handling of Taiwanese CPUE index, and so on.

Acknowledgement

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Table 1 Likelihood in our Base-case (Left), Option-A (Middle) and B (Right).

LIKELIHOOD	25532.8	LIKELIHOOD	20419.6	LIKELIHOOD	25113
indices	741.696	indices	780.578	indices	735.039
discard	0	discard	0	discard	0
length_comps	24699.1	length_comps	19632.6	length_comps	24373.6
age_comps	0	age_comps	0	age_comps	0
size-at-age	0	size-at-age	0	size-at-age	0
mean_body_wt	0	mean_body_wt	0	mean_body_wt	0
Equil_catch	64.6812	Equil_catch	5.49746	Equil_catch	0.094347
catch	0	catch	0	catch	0
Recruitment	-10.3402	Recruitment	-6.1674	Recruitment	-13.9419
Parm_priors	0.008145	Parm_priors	0.002379	Parm_priors	0.005859
Parm_devs	0	Parm_devs	0	Parm_devs	0
penalties	37.6203	penalties	7.02843	penalties	18.2119
Forecast_Recruitment	0	Forecast_Recruitment	0	Forecast_Recruitment	0

Remark) There values of LIKELIHOOD (i.e. negative log-likelihood) are based on our runs where the value of effective sample-size for length frequency in each year, quarter and fleet was replaced. (Although we uniformly set to 100 at first because there is little information about the number of fish with which the length was measured.) Thus, we can obtain the small values of likelihood, and the statistical performance was improved.

Table 2 Conditions and indicators for diagnostics obtained from SS2 results

Conditions/Indicators	Base-case	Option-A	Option-B
Growth curve	Old (Linf-166cm)	New (Linf-148cm)	Linf-166cm
Steepness (h)	Estimated (at 1)	Estimated (at 1)	Fixed at 0.8
SSB0 (B0) (MT)	3,070,360	2,609,960	3,177,330
Average R (2004-5)	154,867,500	140,002,700	153,036,500
SSB2007(B2007)(MT)	1,291,130	1,242,240	1,286,140
SSB2007/SSB0	0.4205142	0.4759613	0.4047864
MSY (MT)	345,258	290,119	294,305
SSBmsy (Bmsy) (MT)	661,701	530,567	919,728
SPRmsy	0.215513	0.207897	0.333874

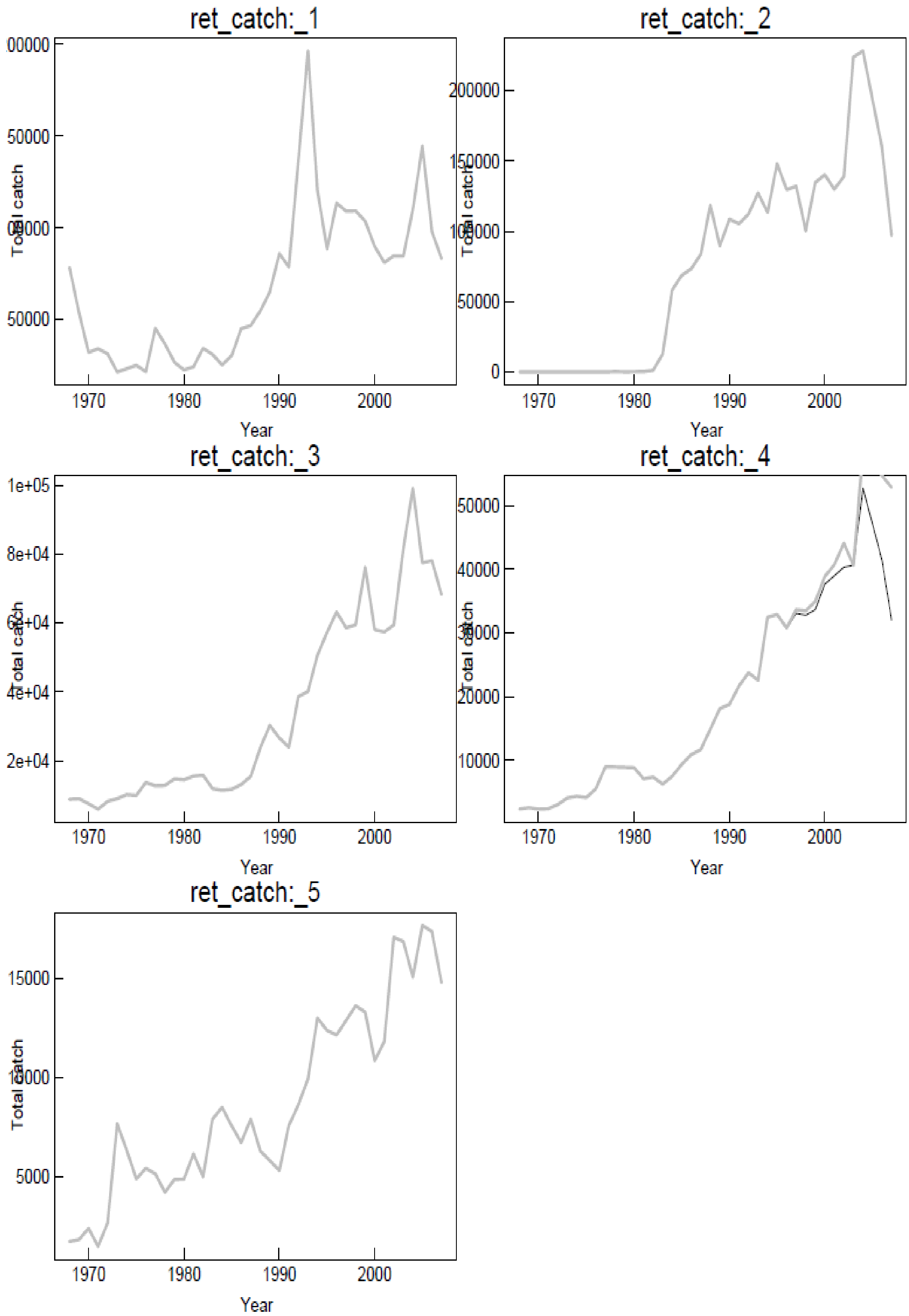

Figure 1 Annual catch by gear (1-LL, 2-PS, 3-Gillnet, 4-Line and 5-Baitboat).

Figure 2 Fixed growth curve in our Basecase and estimated S-R relationship.

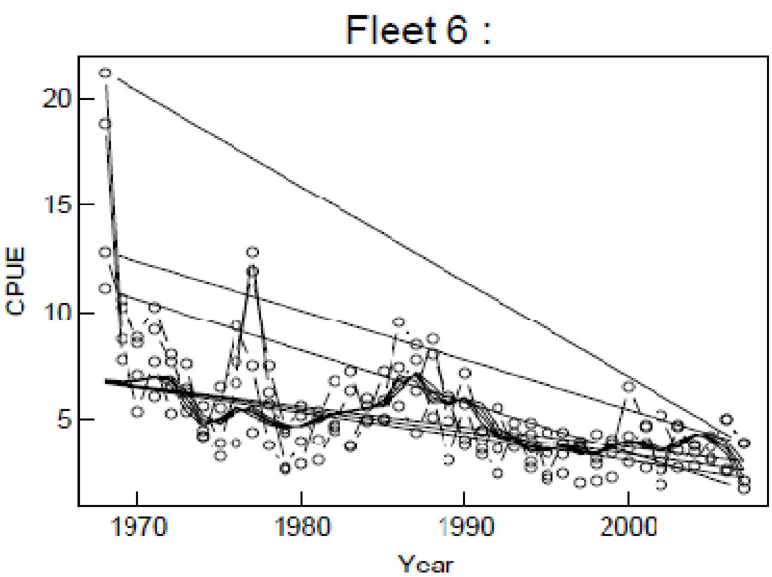

Figure 3 Expected (i.e. estimated) and observed CPUE obtained from SS2.

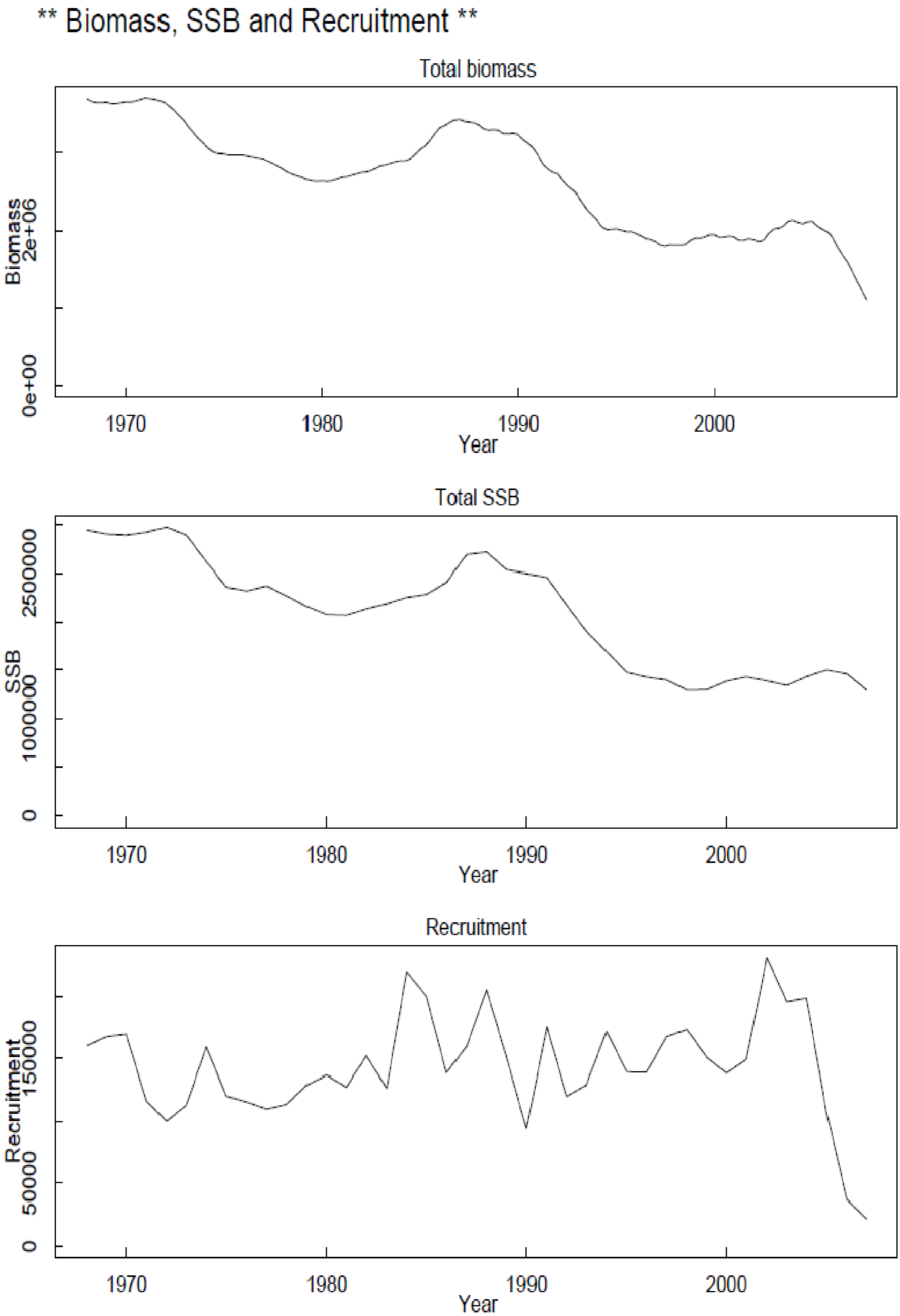

Figure 4 Estimated total biomass(TB), SSB and recruitment (1000*number).

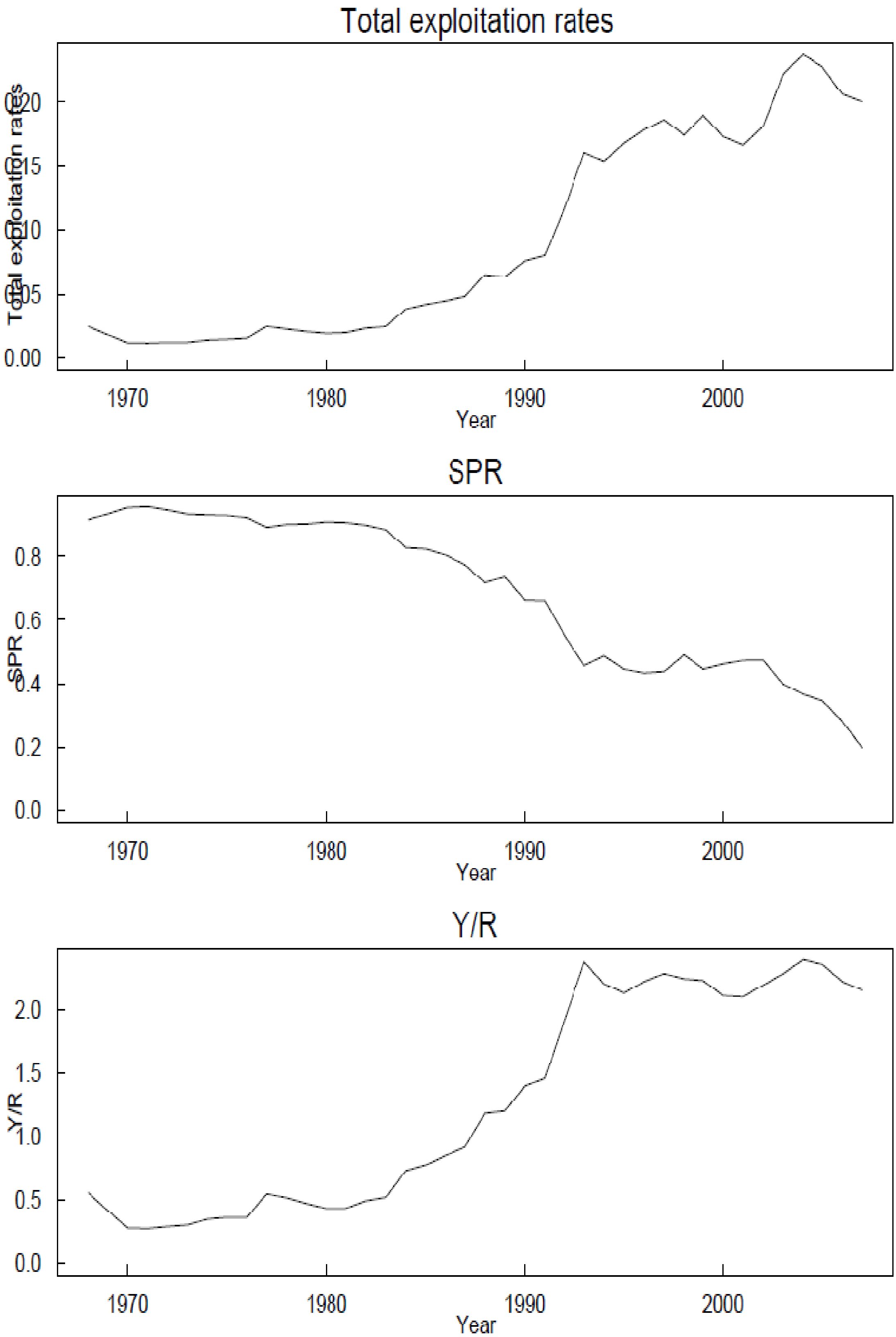

Figure 5 Estimated year trend of the total exploitation rate, SPR and YPR.

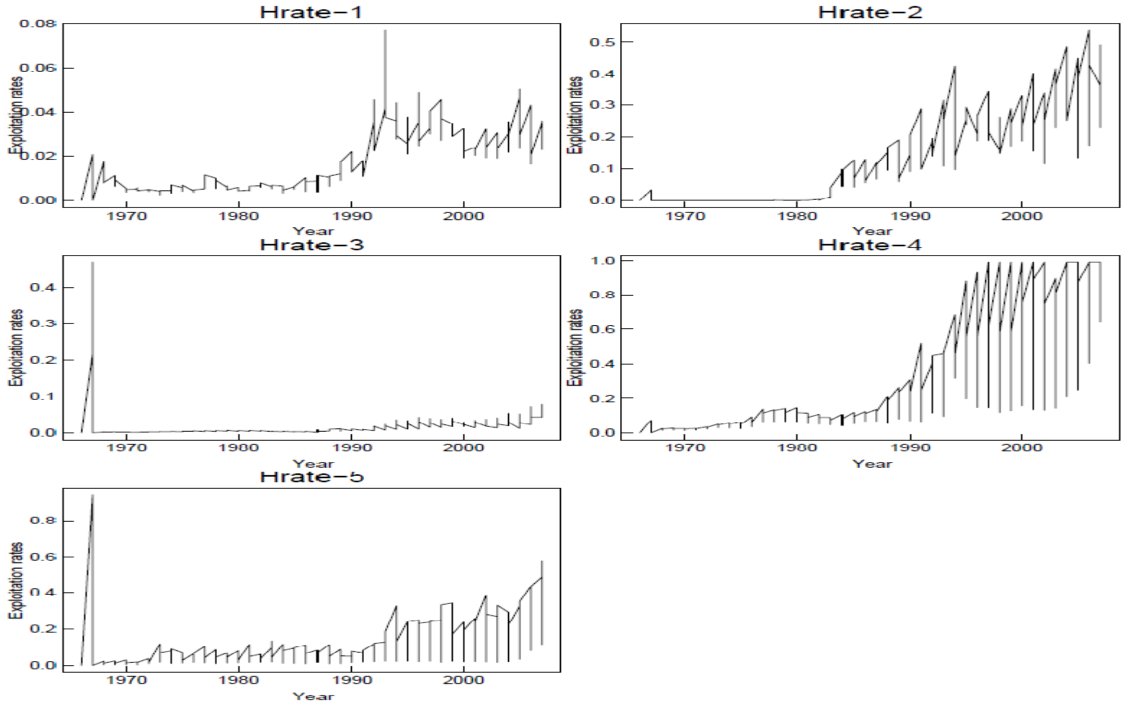

Figure 6 Estimated exploitation rate by each fleet. Please ignore before 1968. (1-Longline, 2-Purse seine, 3-Gillnet, 4-Line and 5-Baitboat).

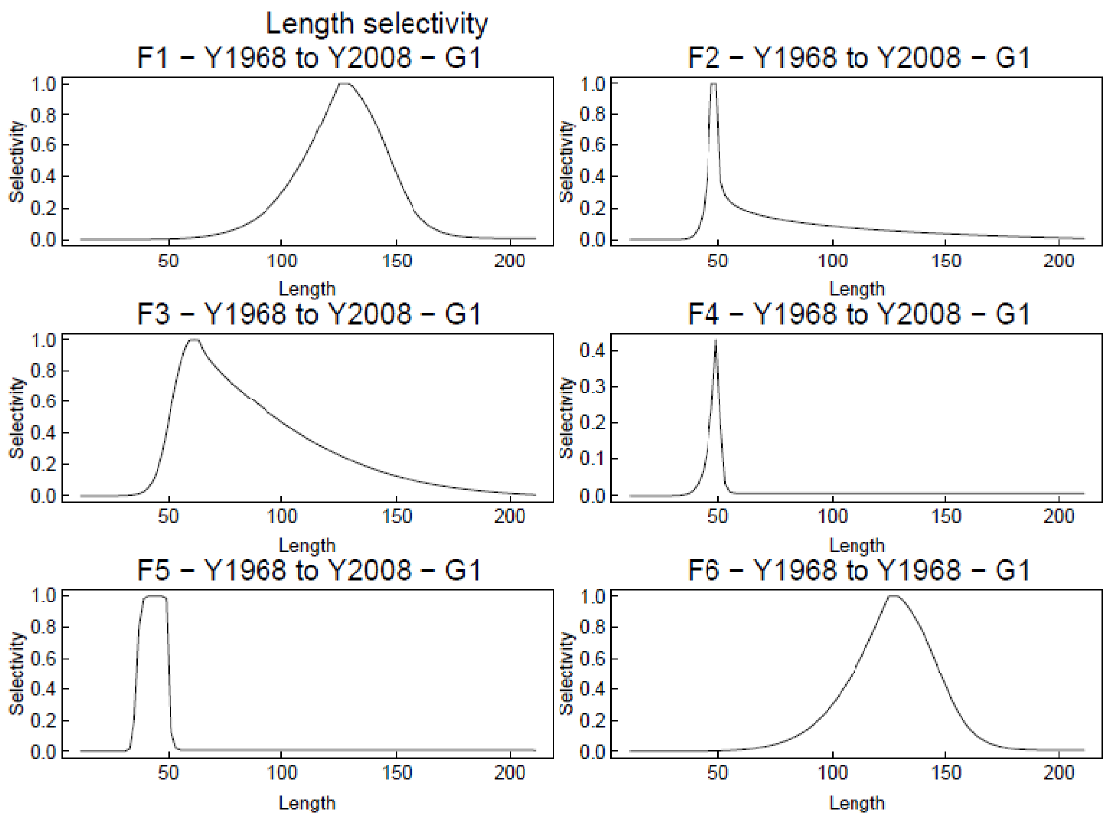

Figure 7 Estimated size-dependent (Double-logistic) selectivity by each fleet.

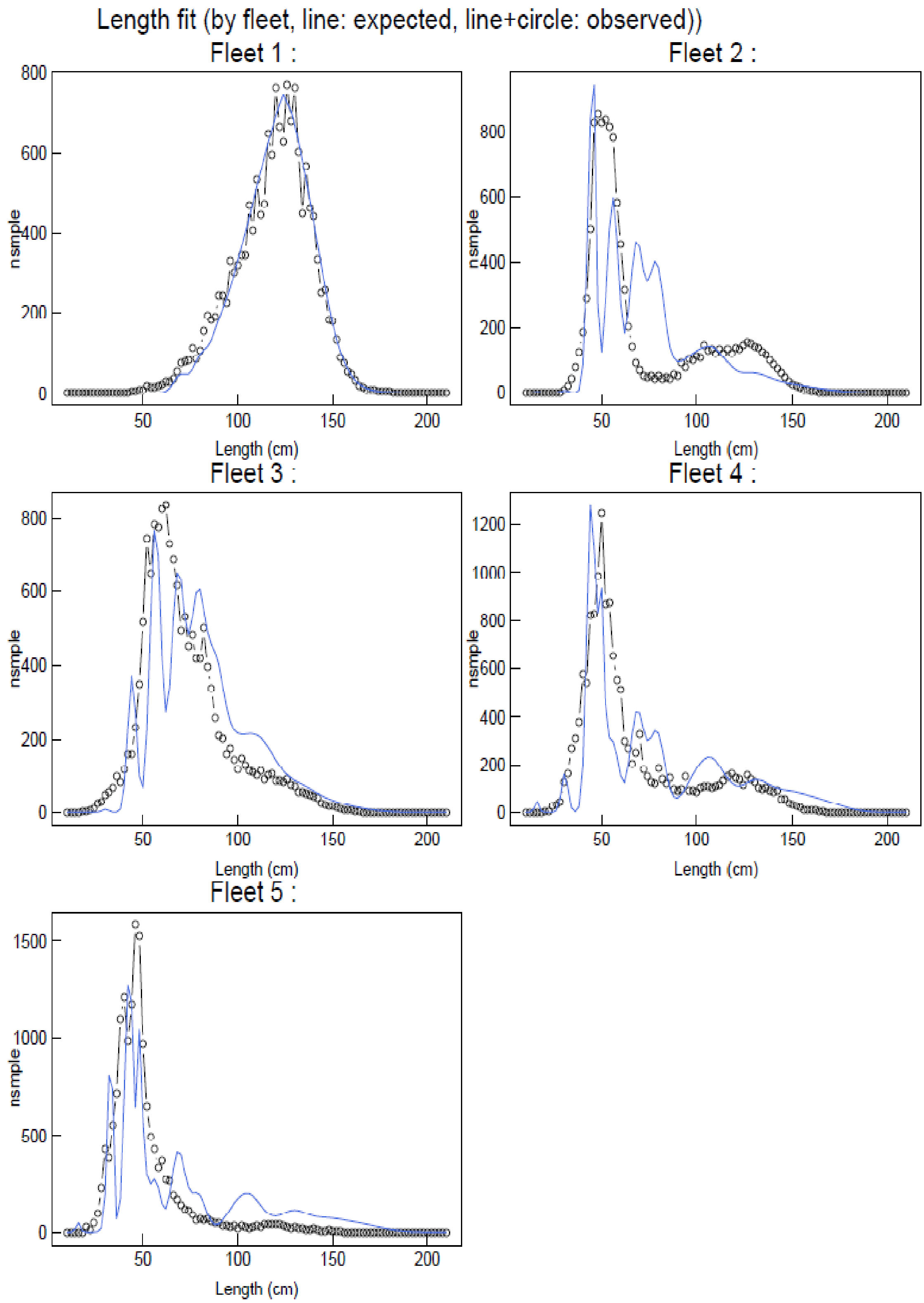

Figure 8 Observed and Estimated length-composition from our Base case. (1-Longline, 2-Purse seine, 3-Gillnet, 4-Line and 5-Baitboat).