Updated stock assessment for bigeye tuna in the Indian Ocean up to 2008 using Stock Synthesis III (SS3)

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Abstract:

We conducted the updated stock assessment for bigeye tuna in the Indian Ocean using Stock Synthesis III (SS3) (made by Rechard, Methot: Methot, 2005; Methot, 2009), a kind of length-based integrated model, as a feasibility study. The year trends of SSB, R and values of MSY, Bmsy etc. obtained from the SS3 model are similar to those of the previous assessment conducted in 2006 using SS2 (Stock Synthesis II) and these absolute levels are a little lower compared with the ASPM or ASPIC results (Nishida, 2009).

Introduction

We tried to assess for bigeye tuna in the Indian Ocean using Stock Synthesis III (SS3), 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 and so on) instead of traditional stock assessment model (such as ASPM, ASPIC or Tuning VPA etc.) are as follow:

- To reduce the aging error (i.e. error from the catch-at-size to catch-at-age) because SS3 (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 again carried out stock assessment for bigeye tuna in the Indian Ocean by SS3 model using the similar assumptions to the previous assessment and updated datasets up to 2008 for the comparison purpose of stock assessment results in 2006 using SS2 and by other models.

Material and Methods

The following datasets and model structures are utilized in our analyses and population dynamics are calculated from 1960 to 2008.

1) Data used

We utilized the quarterly-based data (catch amount, CPUE and length-frequency) in our SS3 calculation.

- Fleet definitions and Catch

LL (longline): fishery-1 and PS (purse seine): fishery-2

Quarterly catch entered the model as biomass (i.e. in weight) in both longline and purse seine.

- CPUE series

Japanese longline CPUE: fishery-3

Standardized quarterly CPUE (1960-2008, 5by5_degree) caught by Japanese longline vessels (Okamoto, Satoh and Shono, 2009) was used for SS3 in our basecase as a tuning index. Standard deviation of Log(CPUE) is also integrated into the SS3 model. Standardized quarterly CPUE including various environmental factors (1980-2008, 1by1_basis) of Japanese longline fisheries (Satoh *et., al,* 2009) was also utilized for SS3 as an option instead.

- Length-frequency

The proportion of quarterly catch-at-size in each length-bin (2cm) (from 10cm to 214cm: processed by IOTC secretariat) for both longline and purse seine was utilized. Age-frequency is not used at all.

2) Model structures

The following conditions/assumptions in each component were used for our SS3 computation.

- Selectivity patterns

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

Scenario	Longline	Purse Seine
Base&Option	Double-logistic (dome-shaped)	Double-logistic (dome-shaped)

Remark) We adopted dome-shaped double-logistic curve with 8 parameters in longline & purse seine fisheries as the length-based selectivity (Figure 3).

- Stock-Recruitment relationship

Recruitment was modeled assuming a Beverton and Holt 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)=0.75, sigmaR=0.6 and estimated R0 (equilibrium recruitment in an un-fished state corresponding to S0). With regard to the steepness, we used the fixed value of steepness at 0.75 as the default because the steepness was computed at 0.99 if estimated. 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 trends (total biomass, SSB and R etc.) are not so large. Recruitment deviations were estimated for 1960-2008.

- Biological parameters

We basically fixed the following biological parameters based on the agreement in the IOTC-WPTT-2006 meeting for bigeye assessment. This biological information is also used for ASPM and/or ASPIC (Nishida, 2009).

1) Growth curve

We used the von-Bertalanffy growth curve (Linf=169, K=0.32 and t0= -0.336) close to Paige's form. However, the influence on the assessment result is very small compared to other models since we used CAS (catch-at-size) not CAA (catch-at-age) as the input. i.e. We hardly used age-specific information.

2) Weight-Length relationship

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

$$W=3.661*10^{-5} L^{2.901} \quad (1)$$

3) Natural mortality (M)

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

$$M = \begin{cases} 0.8 \ (age \le 1) \\ -0.4 * age + 1.2 \ (1 < age < 2) \\ 0.4 \ (age \ge 2) \end{cases} \quad (2)$$

4) Maturity

We used similar maturity vector to ASPM analysis in 2009 as follow:

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

- Model scenarios

Two kinds of standardized quarterly CPUE for bigeye in the Indian Ocean by Japanese longline fishery, from 1960 to 2008 and from 1980 to 2008 including various environmental factors such as IOI or temperature etc., are incorporated into SS3 model as our base model and sensitivity, respectively.

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 0 shows the annual trend of catch in weight (MT) in each gear (LL and PS).

Figure 1-5 show the results of SS3 in our base model regarding the estimated year trends of SSB, TB (total biomass) and recruitment (Figure 1), estimated year trends of total exploitation rates, SPR and YPR (Figure 2), estimated length based selectivity by gear (LL and PS, Figure 3), spawner-recruitment relationship (Figure 4) and harvest rates (LL and PS, Figure 5).

Note that F (fishing mortality) in recent years increase and the latest F is not exceed the Fmsy (around 0.29, Table 1). Estimated MSY (190,561 MT) and Bmsy (SSB at MSY; 461,477 MT) obtained from our basecase are consistent with the previous results in 2006 using SS2/ASPM to some extent.

In terms of the comparison between base model and sensitivity case, the latter is a little optimistic because the CPUE index is starting from 1980. This implies that we should be careful about the condition setting of starting year of SS3 model (i.e. it seems to be essential in conjunction with CPUE index used for tuning), which is the most appropriate, 1960, 1968 or 1980 etc.

Remark) We are now trying to calculate including the tagging data with seven sub-areas (which are similar to those used in the YFT assessment by MFCL). However, the influence of tagging data on the assessment result of BET seems not to be so large on the whole and at least rather than YFT case. (We would like to try to include the Taiwanese LL CPUE during the meeting)

Note: We would like to try to compute of stock assessment for bigeye tuna in the Indian Ocean by stock synthesis III (SS3) using the new agreed conditions/assumptions (and/or revised data) during the IOTC-WPTT-2009 meeting (15-23, Sep., 2009) at Mombasa, Kenya, if necessary and if possible.

Acknowledgement

We sincerely acknowledge Dr. Richard D. Method (NMFS), developer of the Stock Synthesis II and Stock Synthesis III (SS2 and SS3), for his useful advice and essential suggestions. We also thanks Mr. Miguel Herrera, Mr. Julien Million (IOTC secretariat) and Dr. Yu-Min Yeh (Nanhua University), for processing and providing various fishery data for SS3 inputs.

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

Base model (use Okamoto's CPUE)

LIKELIHOOD	50483.4
Component	logL*Lambda
TOTAL	50483.4
Equil_catch	6.18E-06
Survey	152.39
Length_comp	50351.7
Recruitment	-20.7782
Forecast_Recruitment	0
Parm_priors	0.0442977
Parm_softbounds	0.00180256
Parm_devs	0
Crash_Pen	0.00742746

Sensitivity case (use Satoh's CPUE)

LIKELIHOOD	52496.1
Component	logL*Lambda
TOTAL	52496.1
Equil_catch	6.04E-06
Survey	1971.57
Length_comp	50542.2
Recruitment	-17.797
Forecast_Recruitment	0
Parm_priors	0.114037
Parm_softbounds	0.0016426
Parm_devs	0
Crash_Pen	0.000454335

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

Indicator	Base model (Okamoto's)	Sensitivity case (Satoh's)
SSB0	1,716,600	2,135,100
R0	81,064,400	100,828,000
SSB2008	611,162	737,239
SSB2008/SSB0	0.356031	0.345295
MSY	190,561	242,197
SSBmsy	461,477	571,298
SSBmsy/SSB0	0.268832	0.267574
Fmsy	0.290391	0.291228

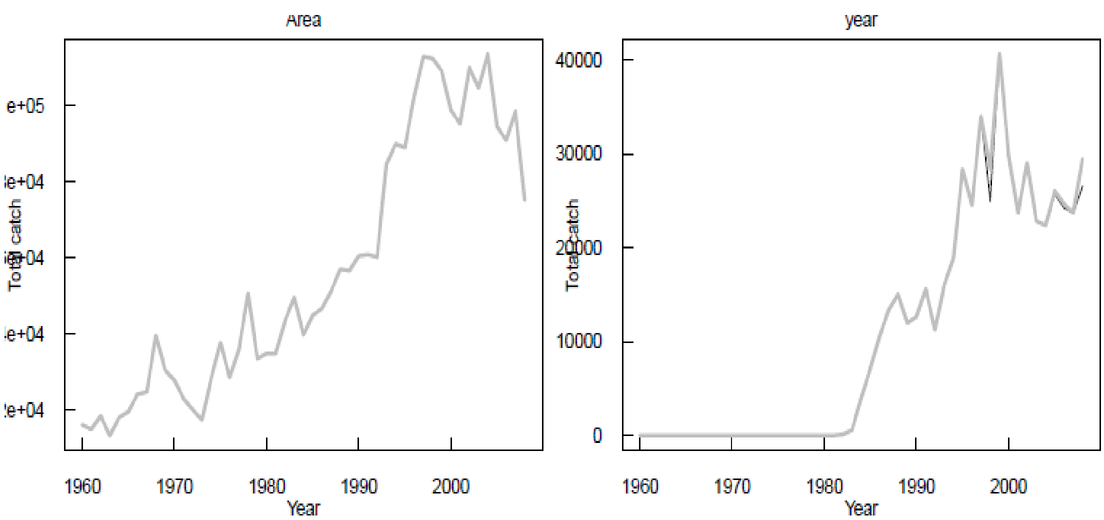

Figure 0 Annual catch in weight by gear (Left-longline, Right-purse seine).

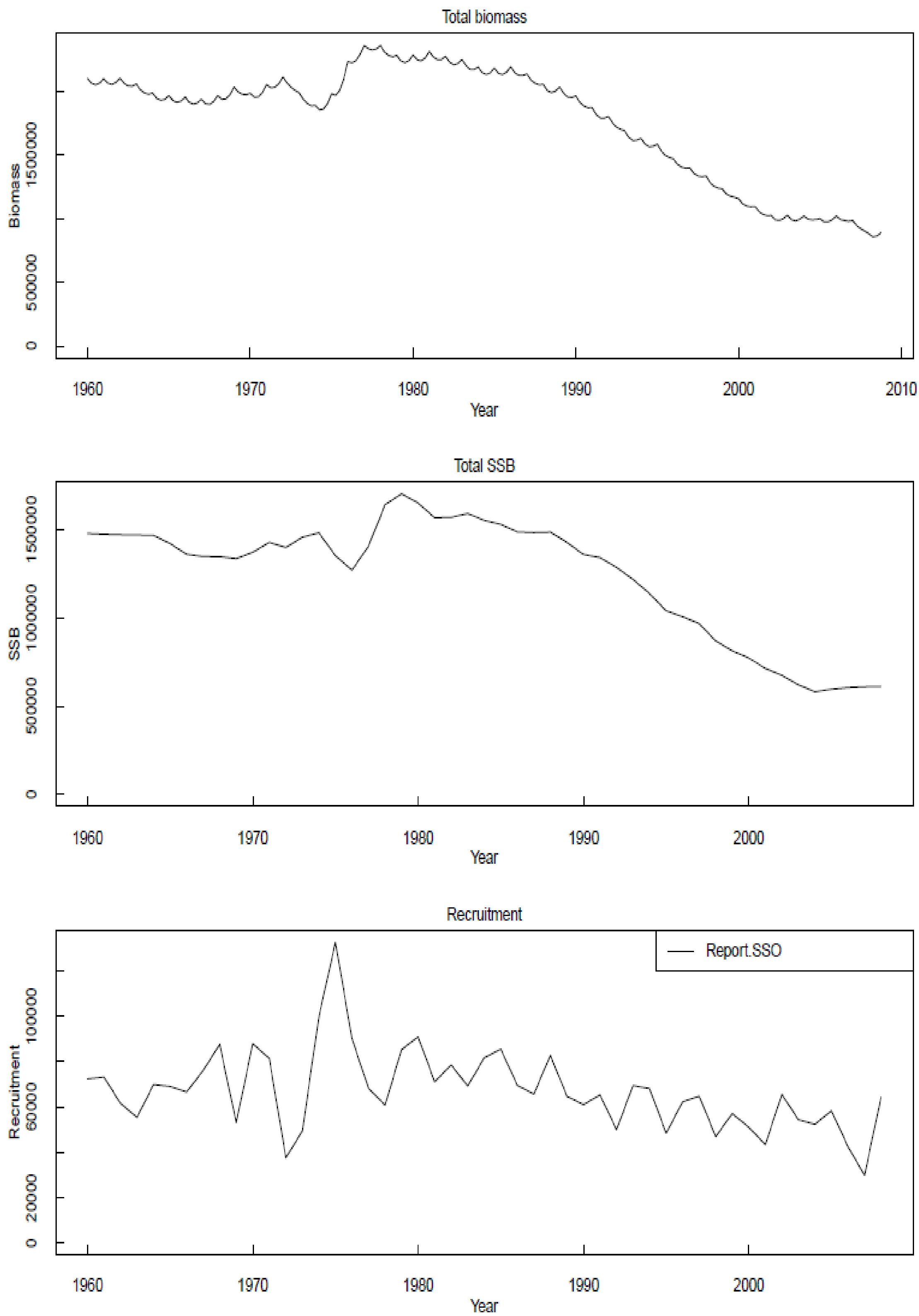

Figure 1 Estimated year trends of total biomass (TB), spawning stock biomass (SSB) and recruitment (R) using SS3 for bigeye in the Indian Ocean.

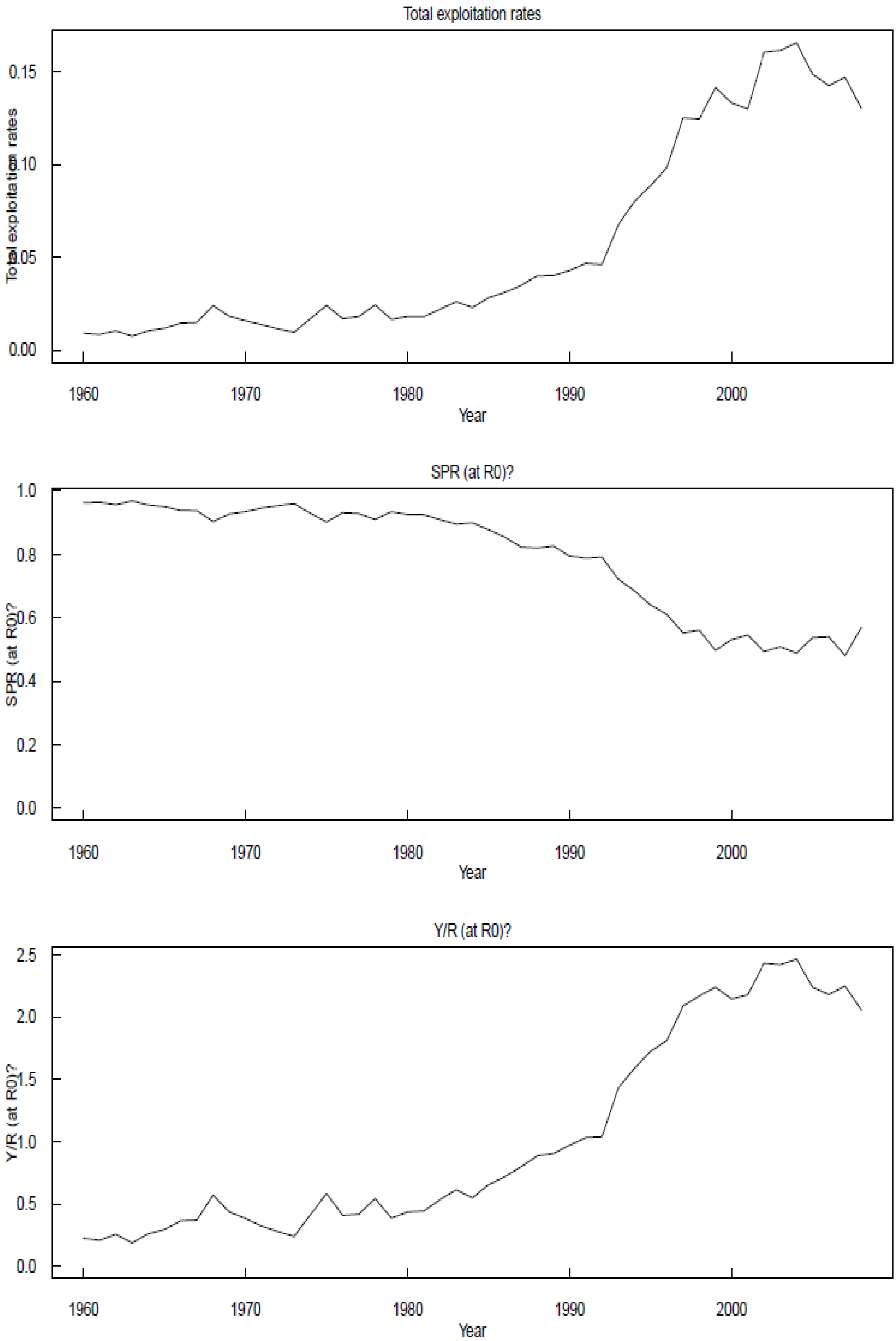

Figure 2 Estimated year trends of total exploitation rates, SPR and YPR.

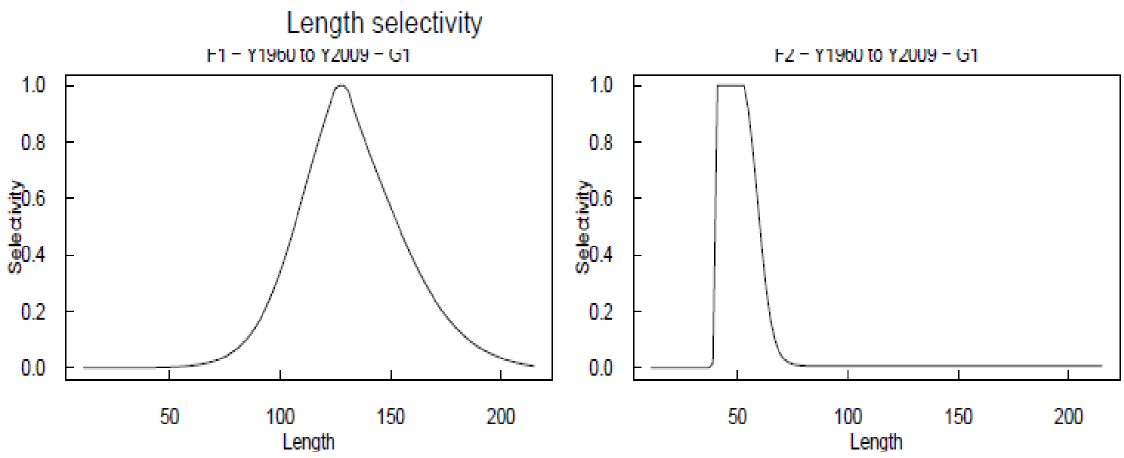

Figure 3 Estimated selectivity in the longline (left) and purse seine (right).

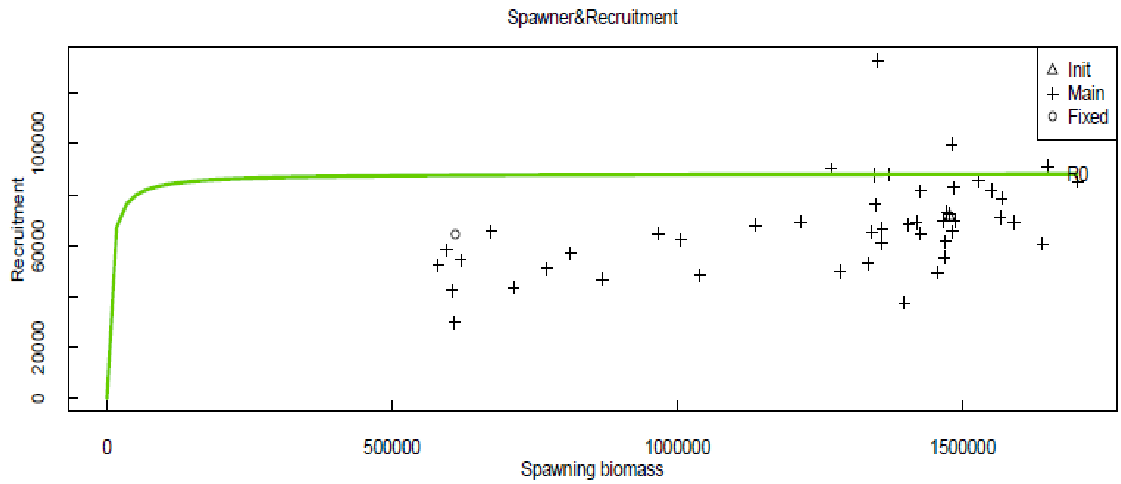

Figure 4 Esitmated annual Spawner-Recruitment relationship.

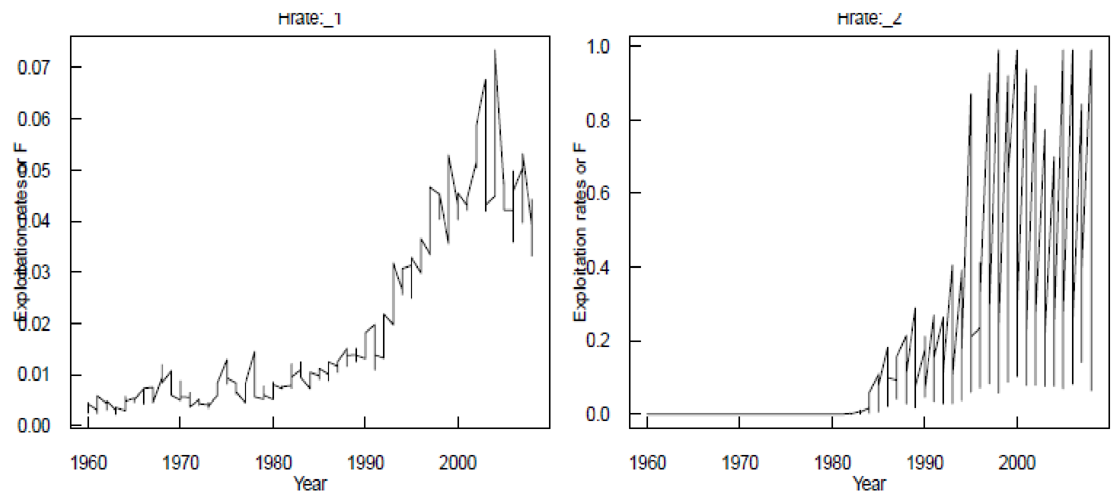

Figure 5 Estimated year trends of harvest rate by gear (left-LL, right-PS).