Preliminary Stock assessment of yellowfin tuna in the Indian Ocean using SS3

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Abstract

Stock assessment for the Indian Ocean yellowfin tuna was attempted using Stock Synthesis III (SS3) based on available data up to 2011 on catch, abundance indices (standardized CPUE series), length frequencies and tagging data. In the result of reference case (all CPUE CV=0.2, Fixed f size selectivity for fishery 3, 7, 10, 11, 19 and 21), the maximum sustainable yield (MSY) was estimated at 423,796 ton, and the current stock indicators, F_{2011}/F_{MSY} and B_{2011}/B_{MSY}, were estimated 0.922 and 0.857, respectively. The robustness/sensitivity of results under the reference case was further investigated based on several extended runs. The resultant outcomes revealed that it is sensitive to use tagging data for SS3 in the Indian Ocean yellowfin tuna stock assessment.

1 Introduction

Yellowfin tuna (*Thunnus albacares*) is one of commercially valuable species in the Indian Ocean tuna fisheries. The fisheries have been operated by a variety of gear types, and several kinds of data have been compiled (catch, length frequency, effort, tagging data, and so on). Last year, the stock assessment was carried out using MULTIFAN-CL (MFCL) software (Fournier et al., 1998, Hampton and Fournier 2001) and Stock Synthesis III (SS3) software (Methot 2011). We turned over previous assessment at WPTT11 (Shono et al., 2010) and independently investigate the effects of tagging data for SS3 output. This document describes the process of preliminary yellowfin tuna stock assessment using SS3.

2 Data

2.1 Definition of areas and fisheries

In this assessment, we used same area definition used so far for the yellowfin tuna assessment (Langley et al., 2011; Figure 1). A total of 21 fisheries are defined according to difference in gear, operation area, and strategy. For example, the purse seine fishery is classified into free schools and log schools (Table 1).

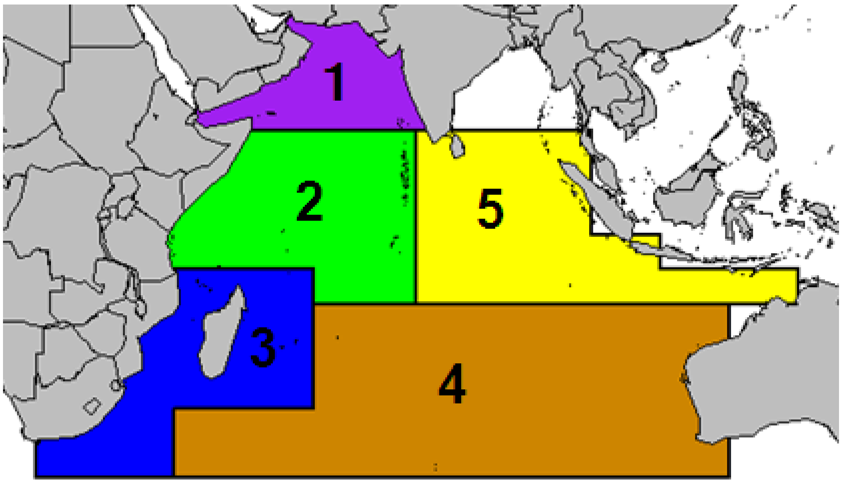

Figure 1 Assessment area definition in the Indian Ocean for the SS3 model.

Table 1 Fishery definition for the stock assessment

Fishery	Gear and strategy	Assessment area
Fishery 1	Gillnet (GI)	Area 1
Fishery 2	Handline (HD)	Area 1
Fishery 3	Longline (LL)	Area 1
Fishery 4	Other (OT)	Area 1
Fishery 5	Baitboat (BB)	Area 2
Fishery6	Purse-seine - free schools (FS)	Area 2
Fishery 7	Longline (LL)	Area 2
Fishery 8	Purse-seine - log schools (LS)	Area 2
Fishery 9	Troll (TR)	Area 2
Fishery 10	Longline (LL)	Area 3
Fishery 11	Longline (LL)	Area 4
Fishery 12	Gillnet (GI)	Area 5
Fishery 13	Longline (LL)	Area 5
Fishery 14	Other (OT)	Area 5
Fishery 15	Troll (TR)	Area 5
Fishery 16	Purse-seine - free schools (FS)	Area 3
Fishery 17	Purse-seine - log schools (LS)	Area 3
Fishery 18	Troll (TR)	Area 3
Fishery 19	Purse-seine - free schools (FS)	Area 5
Fishery 20	Purse-seine - log schools (LS)	Area 5
Fishery 21	Fresh-tuna longlines (LF)	Area 5

2.2 Catch data

Yellowfin tuna catch data were summarized by fisheries defined above and the quarter. The time span of catch data is 1963-2011, and that unit is metric ton. Figure 2 shows quarterly yellowfin tuna catch aggregated by fisheries and assessment area. In the Indian Ocean, the main yellowfin tuna fishery area is reason 2.

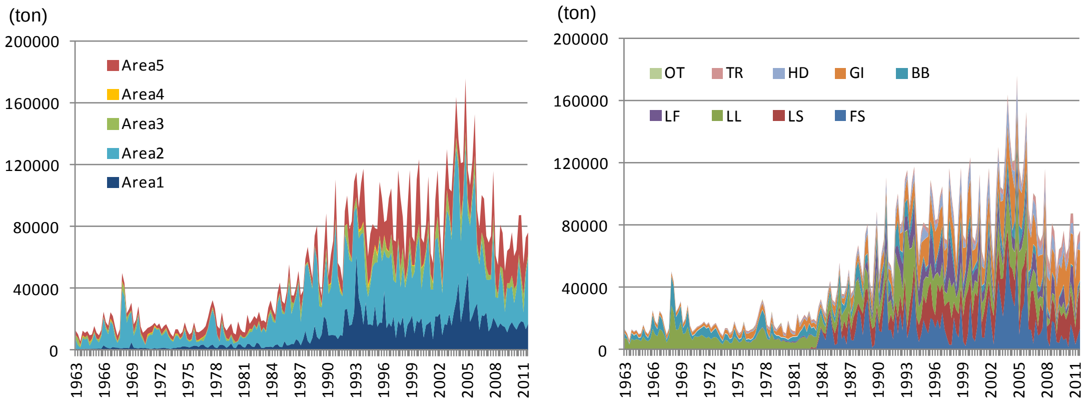

Figure 2 Quarterly yellowfin tuna catch (ton) by fisheries (Right) and assessment area (Left) from 1963 to 2011.

2.3 CPUE data

Quarterly tandardized CPUE series for Japanese and Taiwanese longline fisheries were employed (Japanese: Areas 2-5, and Taiwanese Area 1, see Fig 3). All the indices were estimated with generalized linear models (Matsumoto et al., 2012, Yeh and Chang 2011).

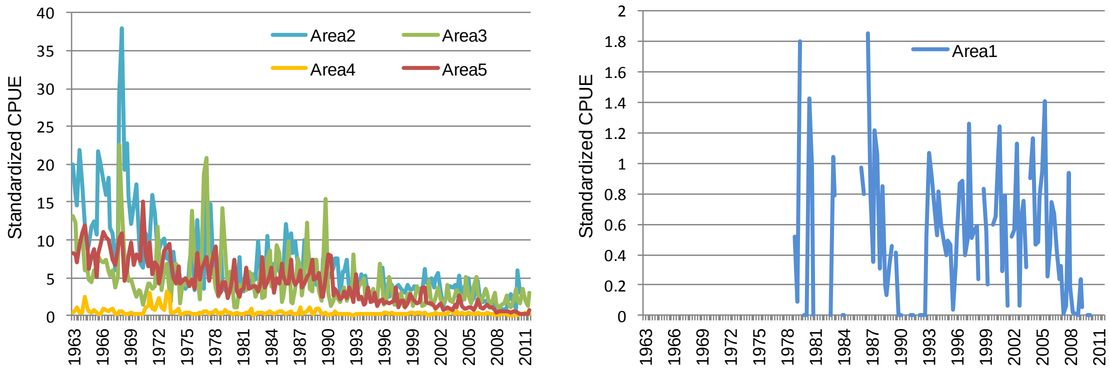

Figure 3 A comparison of Japanese (left) and Taiwanese (right) longline CPUE series. Japanese CPUE indices correspond to area2-5. Taiwanese CPUE series correspond to area1.

2.4 Length frequency data

Quarterly length frequency data are available for all the defined fisheries. These length data were compiled with 2 cm-interval and the span is 10-198cm.

2.5 Tagging data

SS3 ver.3.23b can handle with tagging data which contribute to drawing the information on the movement and recruitment distribution. The tagging data are obtained from a total of 63 release events aggregated by year, quarter, age, and number and area, and 573 recaptures aggregated by year, quarter and defined fishery.

Most of tags were released in 2006 at area2 and recaptured at within the same area. There are few released opportunities in areas 4 and 5 (Figure 4).

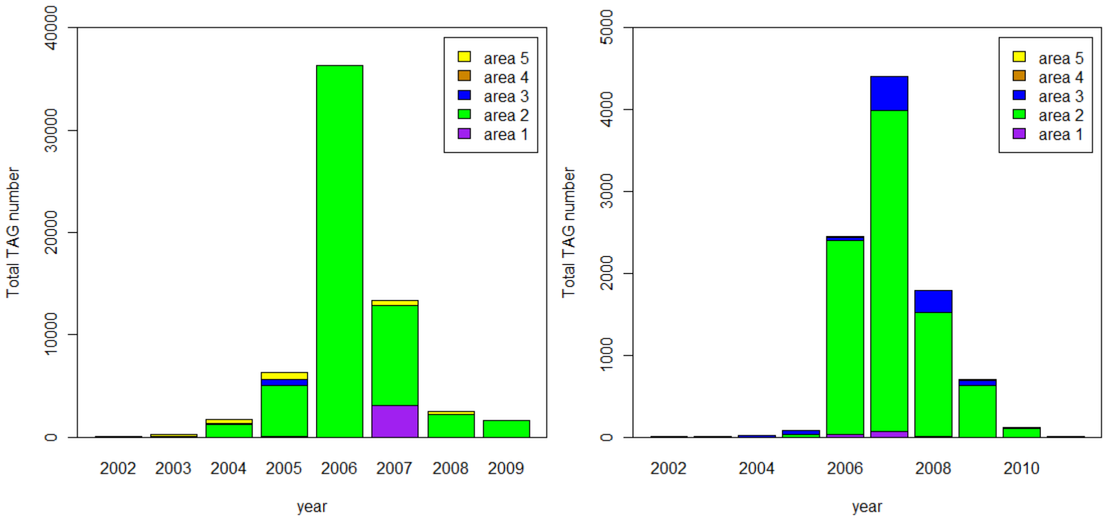

Figure 4 Released (Right) and recaptured (Left) tag numbers used for the yellowfin tuna stock assessment. X label is released or recaptured year. Y label is released or recaptured tag number.

3 Model configuration

We used stock assessment software Stock Synthesis III (version 3.23b) that was downloaded from NOAA website http://nft.nefsc.noaa.gov/Stock_Synthesis_3.html.

The output of stock assessment results were drawn by “R” software package of “r4ss” that was downloaded from http://code.google.com/p/r4ss/ .

3.1 Spawning and Recruitment relationship

In this stock assessment, we assumed that yellowfin tuna spawn all season with a common Beverton-Holt spawner-recruitment relationship.The steepness (h) was not estimated but fixed at 0.7 in the base-case, We have not tested any sensitivity/robustness to the assumption of other values 0.6 and 0.8 The extent of recruitment deviation (sigma R) was assumed 0.6.

3.2 Catchability

The catchability in each of 5 areas was held constant and that value was fitted to the standardized CPUE indices.

3.3 Selectivity

Fundamentally, we assumed that the size selectivity was the flexible double-normal size selectivity for fishery 1 to 21 and all parameters were estimated (In the some analytical runs, we used flat-top size selectivity for a part of fishery). We assumed TR (Troll) fisheries (9, 15 and 18) have the same selectivity patters because there is no size data for fishery 9 and 18.

3.4 Movement

We set 24 movement parameters that were associated with neighbor area combinations in the Indian Ocean. To estimate these movement parameters, SS3 needs initial tag loss ratio, chronic tag loss ratio, tag over dispersion ratio and tag reporting ratio. However, there is no information about these parameters. We assumed appropriate fix values (Table 2).

Table 2 A tag loss and tag reporting parameters assumed in this attempt.

Parameter	Value
Initial tag loss ratio	0.00012
Chronic tag loss ratio	0.00012
Tag over dispersion ratio	0.88
Tag reporting ratio	0.80
Exponential decay rate in reporting rate for each fleet	1.00

4 Biological parameters

4.1 Natural mortality

We used age-specific quarterly natural mortality ratio (Figure 5). This value was estimated in the western and central Pacific Ocean yellowfin tuna stock assessment (Langley et al., 2007).

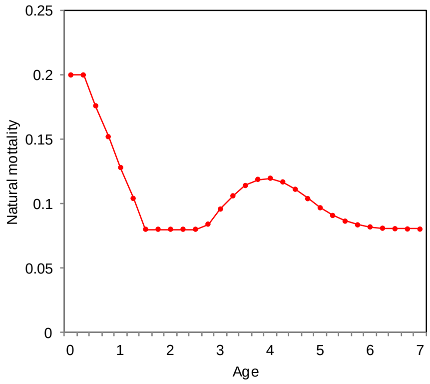

Figure 5 The estimated age-specific natural mortality from WCPFC yellowfin tuna stock assessment (Langley et al., 2007).

4.2 Growth

For the current assessment, yellowfin tuna growth parameters used for MFCL were fixed value given by Fonteneau (2008). In contrast, we used generally used model von Bertalanffy growth equation (Figure 6).In SS3, the von Bertalanffy parameters were fixed as $L_\infty = 145$, $K = 0.455$.

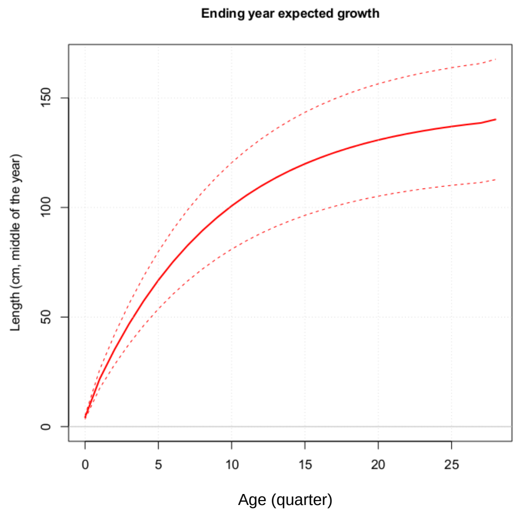

Figure 6 Growth function for the yellowfin tuna stock assessment.

4.3 Length-weight relationship

Length-weight relationship was available previous analysis that was estimated by data from the Indian Ocean (Marsac et al., 2006). Figure 7 shows length-weight relationship curve, and we used following equation and parameters.

$W = aL^b$ where W is body weight in kg, L is fork length in cm, $a = 1.886 \times 10^{-5}$, $b = 3.0195$.

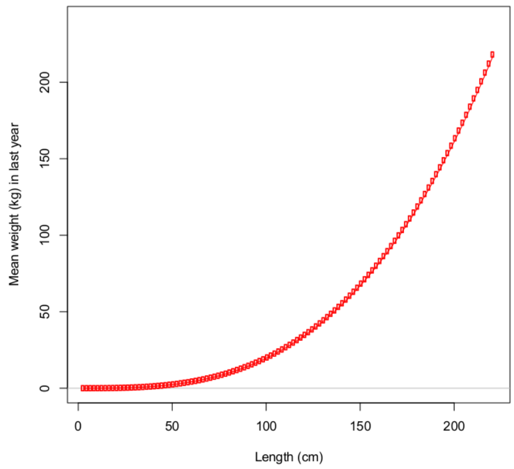

Figure 7 Length-weight relationship for the yellowfin tuna stock assessment.

4.4 Maturity and Sex structure

We assumed 1:1 sex structure and age specific maturity ratio. These values were used for 2009 yellowfin tuna stock assessment in the Indian Ocean (Figure 8).

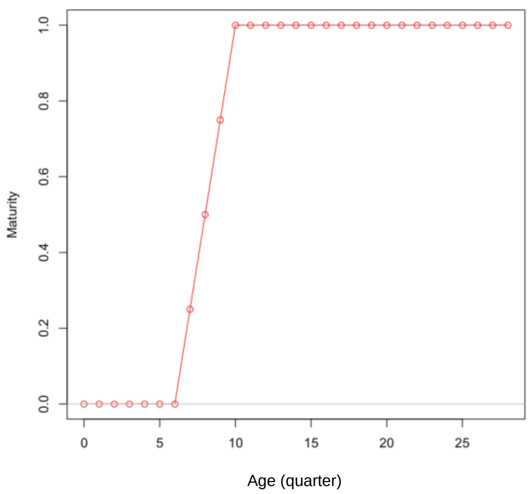

Figure 8 Fixed age-specific maturity (Murua et al., 2011).

5 An approach for the stock assessment

To carry out stock assessment in the first step, we made simple input files. These files did not use tagging data and did not divide assessment areas (Run 0). Figure 9 shows total biomass result of Run 0. This result of total biomass was approximately similar to previous stock assessment. Secondly, we addressed a lot of trials to converge on SS3 using tagging data. However, we couldn't calculate reasonable yellowfin tuna stocks. It is because most of area distribution of biomass, movement ratio and size frequency outputs were significantly sensitive and these parameters showed unrealistic values. To clear up these problems, we carried out ad hoc approach for SS3 (Table 3).

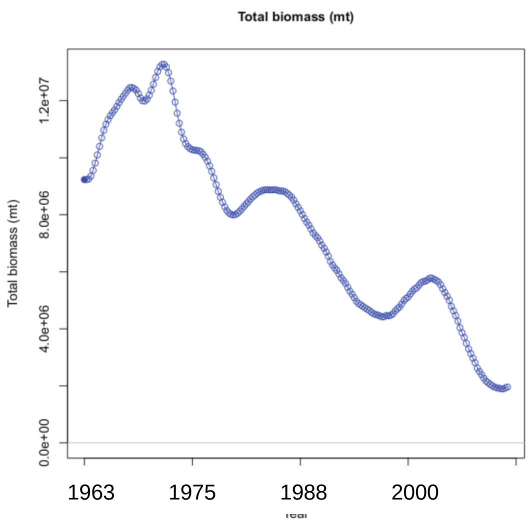

Figure 9 Total biomass (Run 0 result).

Table 3 The ad hoc approach for SS3.

	Error distribution of CPUE	Size selectivity	Movement ratio	Recruitment distribution ratio by area
Run 1	Fix 0.1 (for all CPUE)	Estimate	Estimate	Estimate
Run 2	Fix 0.2 (for all CPUE)	Estimate	Estimate	Estimate
Run 3	Fix 0.3 (for all CPUE)	Estimate	Estimate	Estimate
Run 4	Fix 0.1 (for all CPUE)	Fixed value for LL Fishery 21 (flat top shape)	Estimate	Estimate
Run 5	Fix 0.2 (for all CPUE)	Fixed value for LL Fishery 21 (flat top shape)	Estimate	Estimate
Run 6	Fix 0.1 (for all CPUE)	Estimate	Estimate	Fix 0.2
Run 7	Fix 0.1 (for all CPUE)	Estimate	Estimate	0.1,0.35,0.1,0.35,0.1 (Area specific)
Run 8	Fix 0.1 (for all CPUE)	Fixed value for LL fishery 3, 7, 10, 11, 21 and PS fishery 19 (flat top shape)	Estimate	Estimate
Run 9	Fix 0.2 (for all CPUE)	Fixed value for LL fishery 3, 7, 10, 11, 21 and PS fishery 19 (flat top shape)	Estimate	Estimate
Run 10	Fix 0.3 (for all CPUE)	Fixed value for LL fishery 3, 7, 10, 11, 21 and PS fishery 19 (flat top shape)	Estimate	Estimate
Run 11	Fix 0.4 (for all CPUE)	Fixed value for LL fishery 3, 7, 10, 11, 21 and PS fishery 19 (flat top shape)	Estimate	Estimate
Run 12	Fix 0.1 (for all CPUE)	Estimate	No move	Estimate

6 Result

Table shows estimates of management quantities for the trial runs. Our attempt detail and result as follows:

1) Run 1-3: These trials were simple and basic runs and that intent is to identify effect of the error distribution for the CPUE indices. These results showed three major conflicts in this trial (distribution of biomass for the 5 area, movement ratio, size selectivity).

2) Run 4 and 5: To improve size selectivity conflict, we fixed size selectivity parameter for fishery 21. Fishery 21 is longline fishery and tends to catch the largest fish. For that reason, we assumed flat top shape selectivity. However, these runs couldn't solve the conflicts.

3) Run 6 and 7: To investigate recruitment allocation, we used two fixed recruitment allocation parameters (equable values and weighting values that are weighted value for tropical area). However, these runs couldn't solve the conflicts.

4) Run 8-11: To get better size selectivity, we tried to set fixed size selectivity parameter again. We assumed that longline fishery (fishery 3, 7, 10, 11, 21) and free school purse seine fishery (fishery 21) caught a large fish. These fisheries selectivity was given flat top shape values. In this some trial result, each area biomass was possible distribution.

5) Run12: To investigate movement effects, we defied movement assignment as area 1 to area 1, area 2 to area 2, area 3 to area 3, area 4 to area 4 and area 5 to area 5. This setting means no movement for SS3. However, trend of area 1 biomass was not realistic.

Through these trials, we assumed Run 9 was a reference case. This result might be not the best reasonable for yellowfin tuna stocks. But, we set realistic size selectivity and the result of each area biomass was possible distribution. These reference case results show Appendix1-Appendix 7.

Table 4 The estimates of management quantities for the trial runs (4th quarter).

Run	Final Convergence	F_{2011}/F_{MSY}	B_{2011}/B_{MSY}	MSY (ton)	Comment
0	0.003	1.08867	0.578852	489,056	No area consideration.
1	0.013	1.30112e+013	0.564977	NA	Fixed error distribution of CPUE (0.1).
2	0.023	0.355813	0.83207	1,037,324	Fixed error distribution of CPUE (0.2).
3	0.014	8 .89138e+012	0.550903	NA	Fixed error distribution of CPUE (0.3).
4	0.140	NA	0.442602	NA	Fixed value for fishery 21.
5	0.137	NA	0.402014	NA	Fixed value for fishery 21.
6	0.004	NA	0.548759	NA	Fixed value for recruitment distribution ratio by area.
7	0.003	NA	0.526433	NA	Fixed value for recruitment distribution ratio by area.
8	0.298	NA	0.541419	NA	Fixed value for fishery 3, 7, 10, 11, 21 and fishery 19.
9	**0.001**	**0.921844**	**0.856807**	**423,796**	**Reference case** Fixed value for fishery 3, 7, 10, 11, 21 and fishery 19.
10	0.002	0.88412	0.938705	403,072	Fixed value for fishery 3, 7, 10, 11, 21 and fishery 19.
11	0.790	0.815897	1.16383	316,194	Fixed value for fishery 3, 7, 10, 11, 21 and fishery 19.
12	0.001	NA	0.420633	NA	No move

7 Acknowledgements

We would like to grateful thanks for Adam Langley and Ian Taylor. Adam Langley supported to make SS3 input files. Ian Taylor provided valuable advice to use tagging data via email communication.

8 References

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Appendix 1 Fitting to the Log CPUE data (reference case)

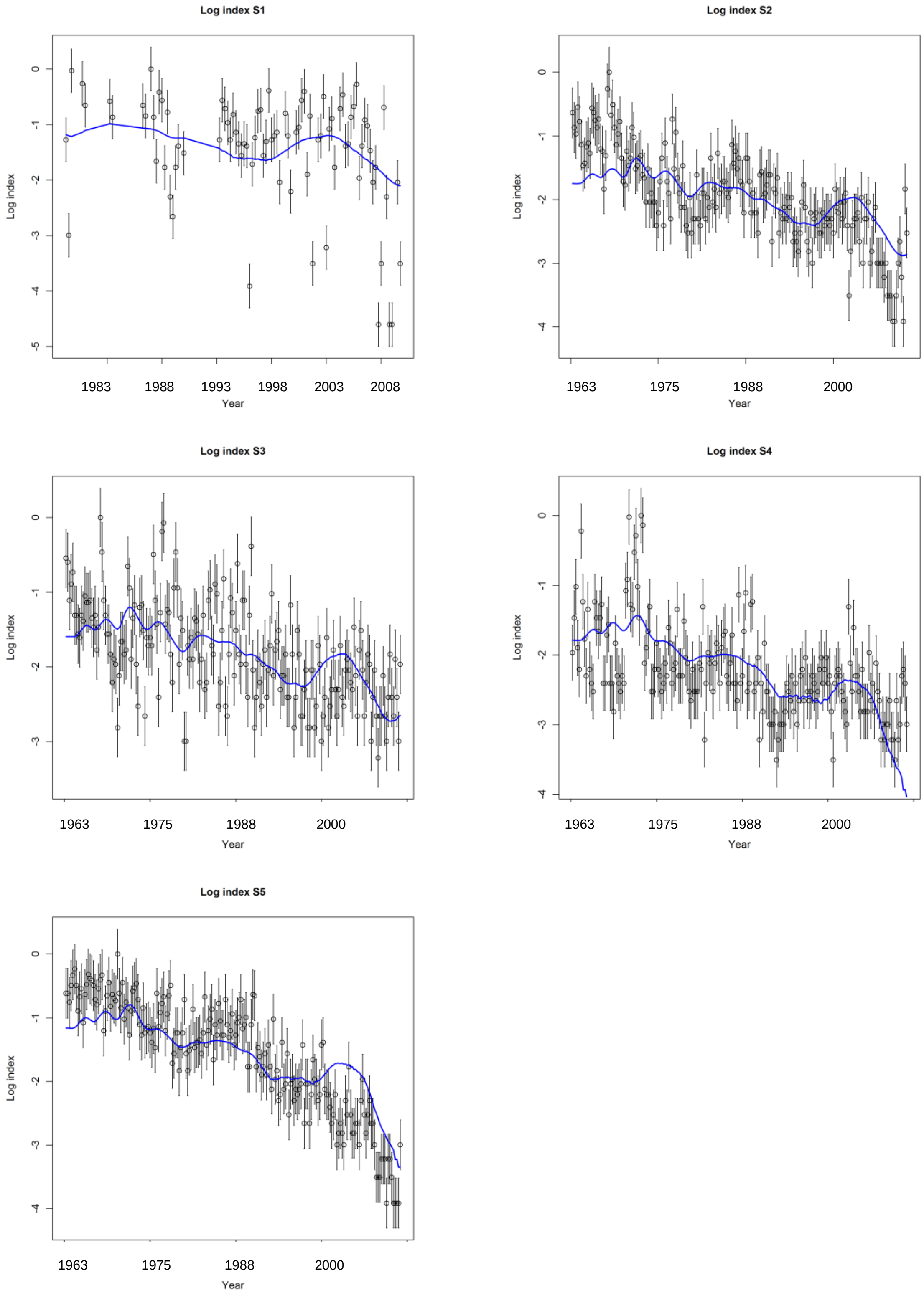


Figure 10 Model fitting log CPUE indeces in each area for the reference case. The blue line are the estimated value and open circles are standardized relative CPUE.

Appendix 2 Size selectivity estimation (reference case)

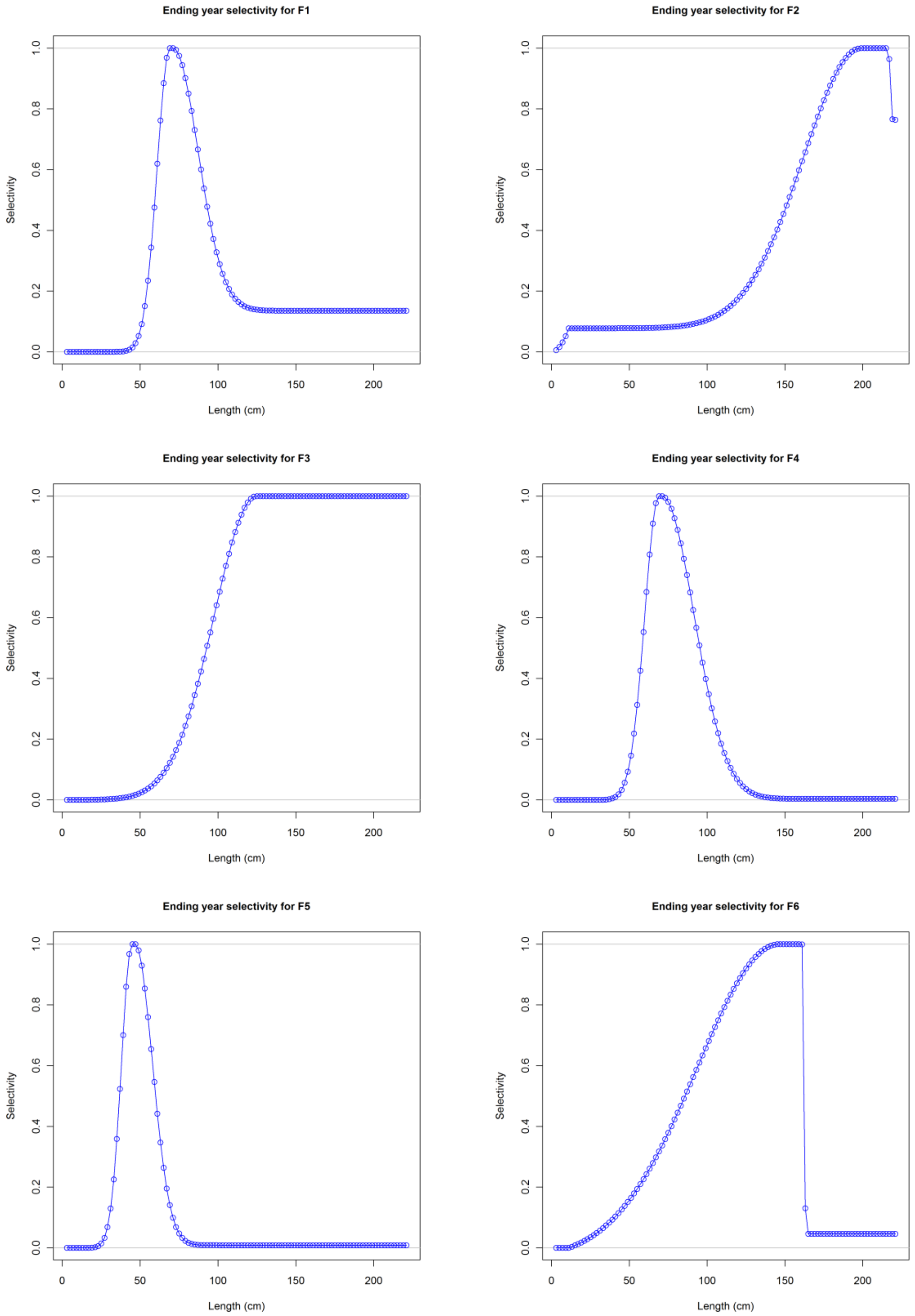


Figure 11 Estimated size selectivity patters for each fishery under the reference case (area1-6). We assume that TR (Troll) fisheries (9, 15 and 18) are same selectivity patters.

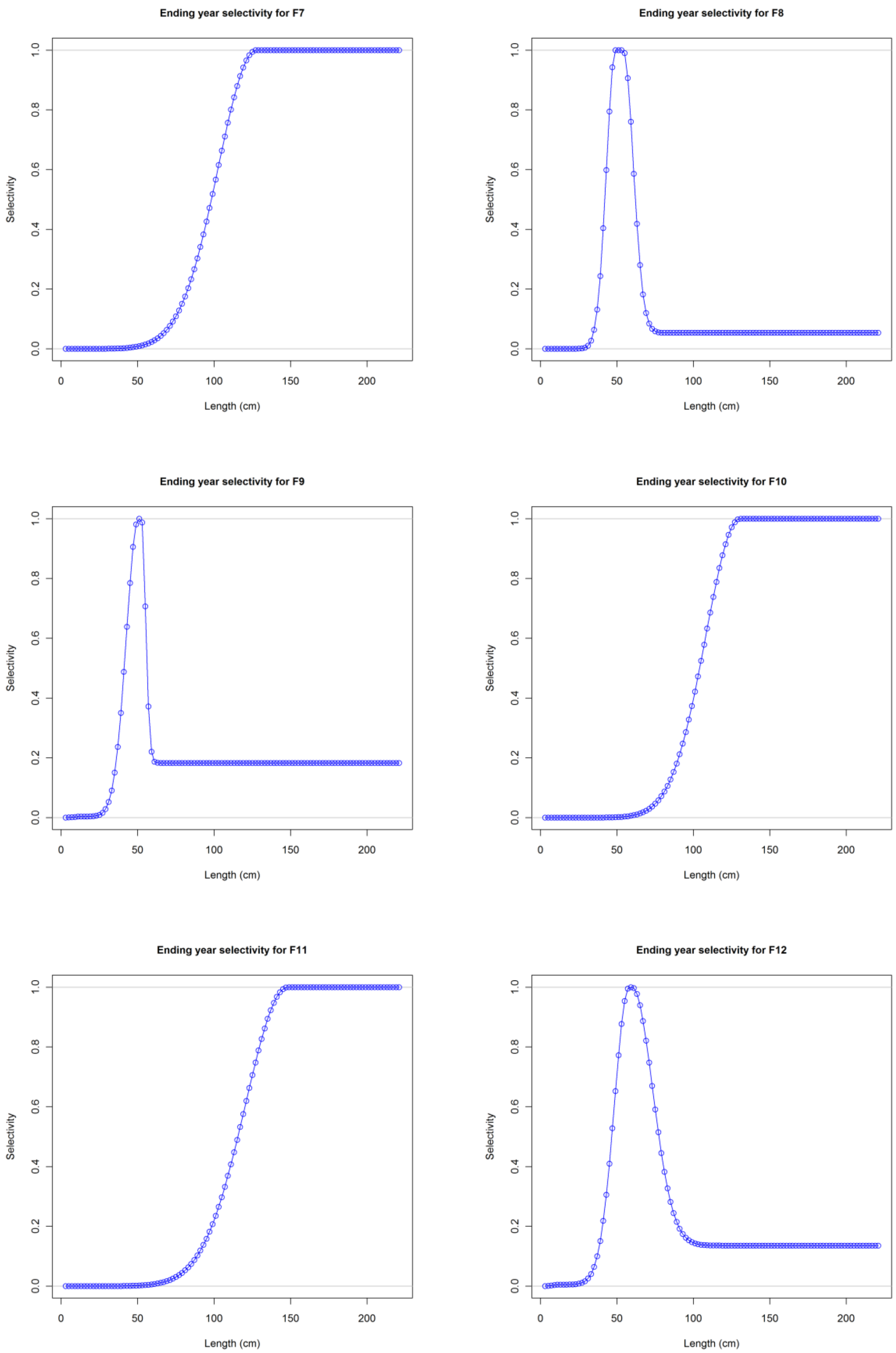


Figure 12 Estimated length selectivity patters for each fishery under the reference case (area7-12). We assume that TR (Troll) fisheries (9, 15 and 18) are same selectivity patters.

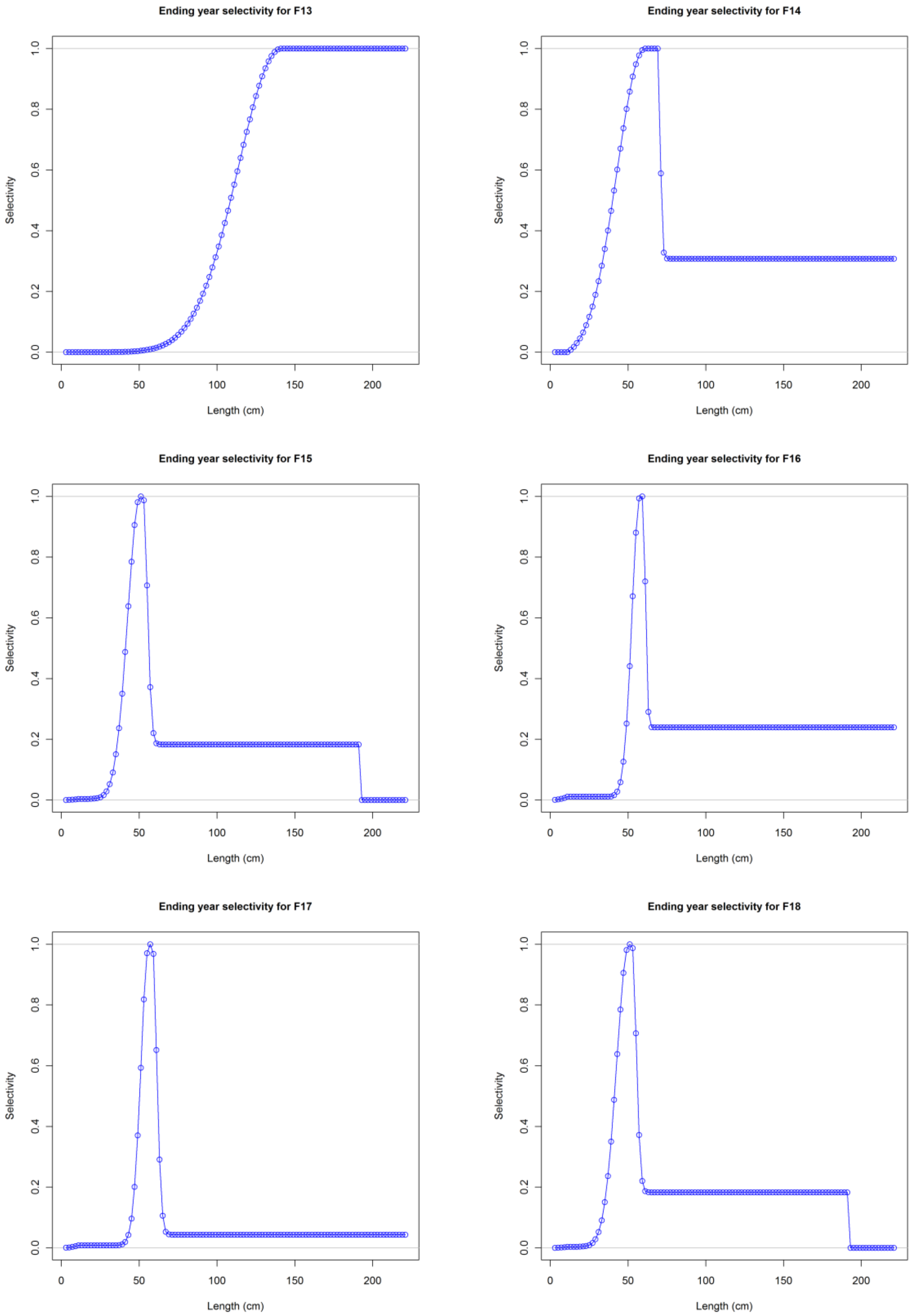


Figure 13 Estimated length selectivity patters for each fishery under the reference case (area13-18). We assume that TR (Troll) fisheries (9, 15 and 18) are same selectivity patters.

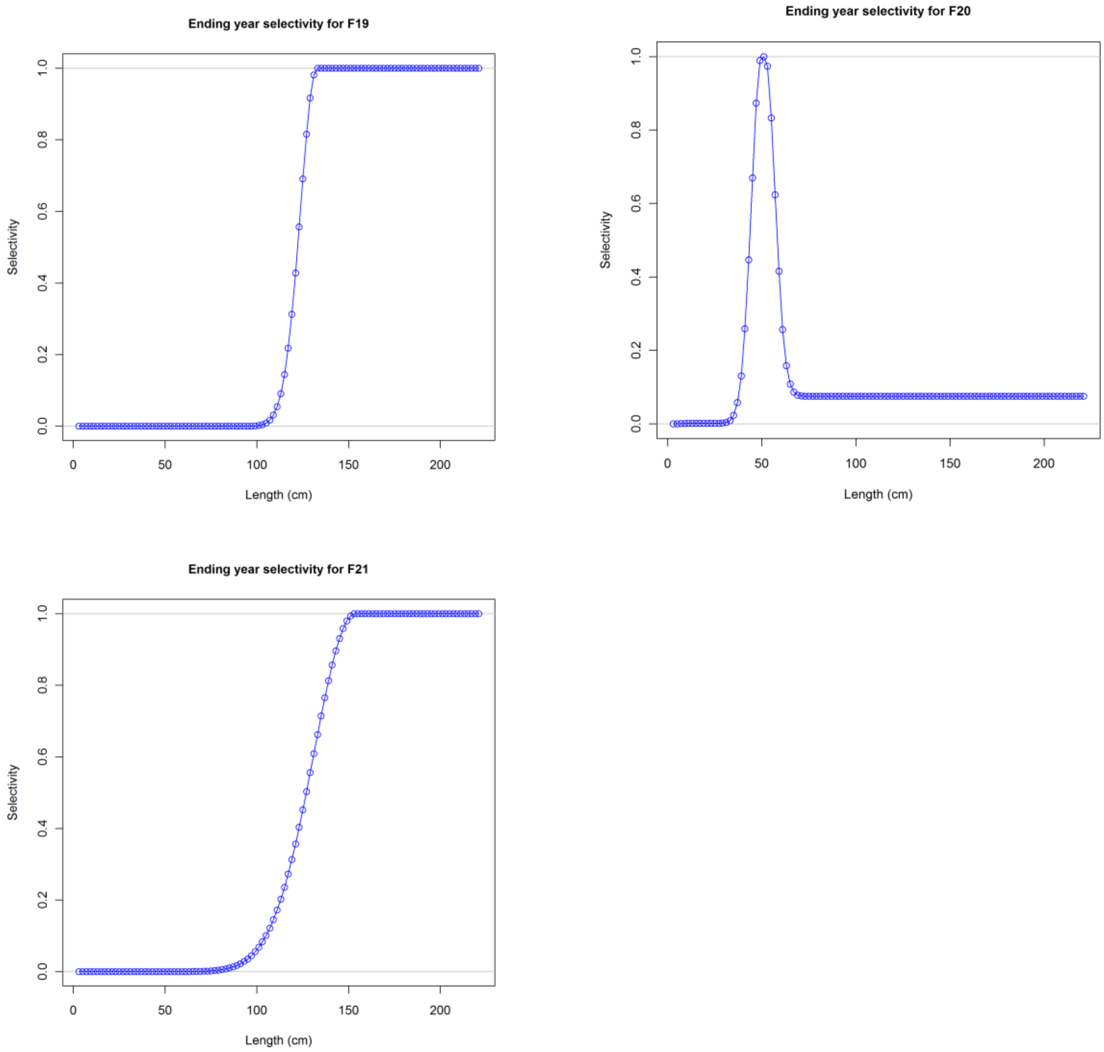


Figure 14 Estimated length selectivity patters for each fishery under the reference case (area19-21). We assume that TR (Troll) fisheries (9, 15 and 18) are same selectivity patters.

Appendix 3 Fitting to the Length composition (reference case)

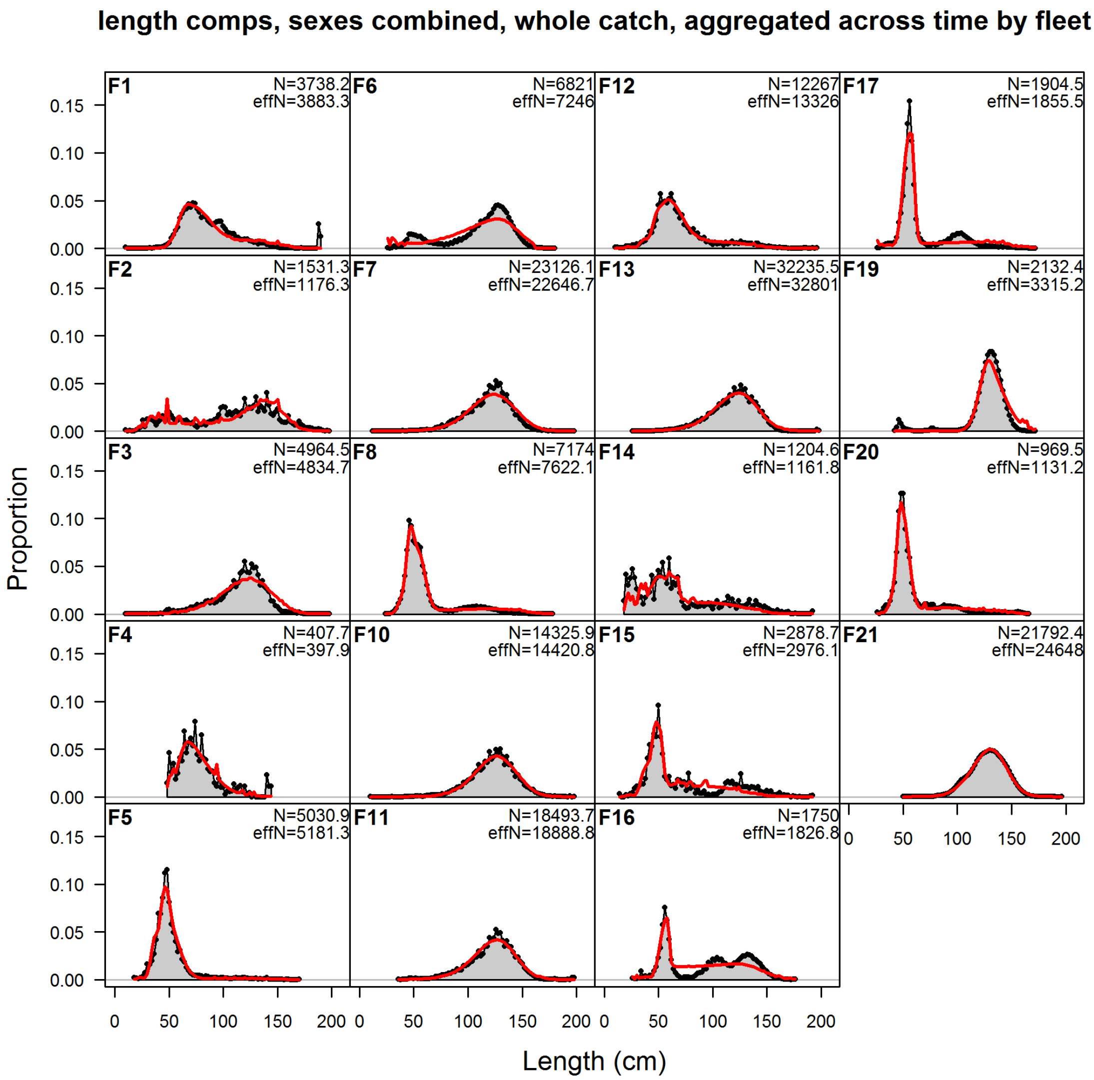
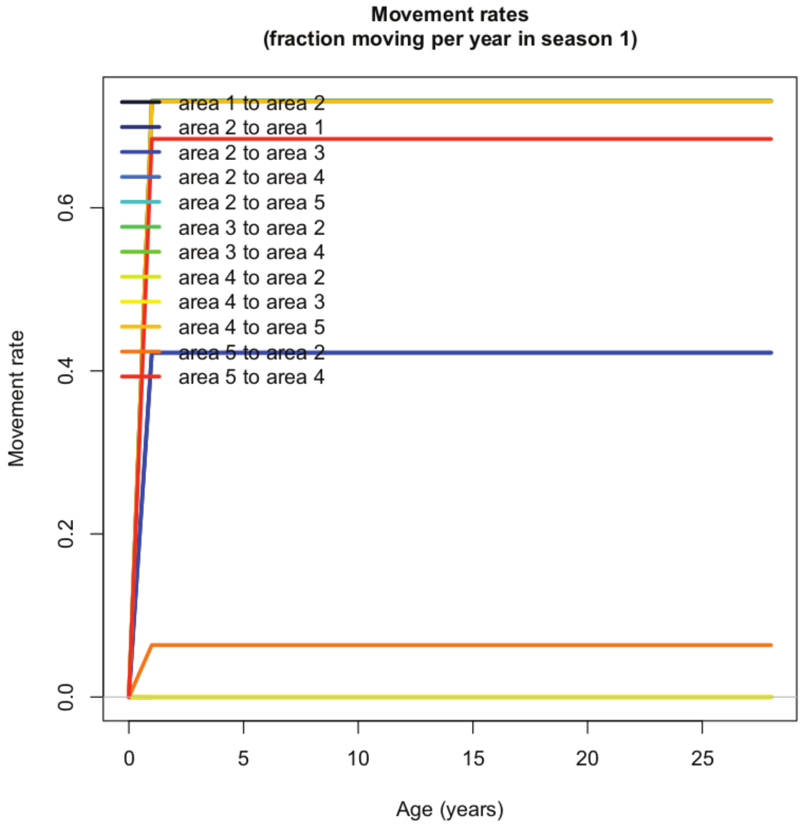


Figure 15 Estimated and observed length frequencies for each fishery that was aggregated over time.

Appendix 4 Movement (reference case)



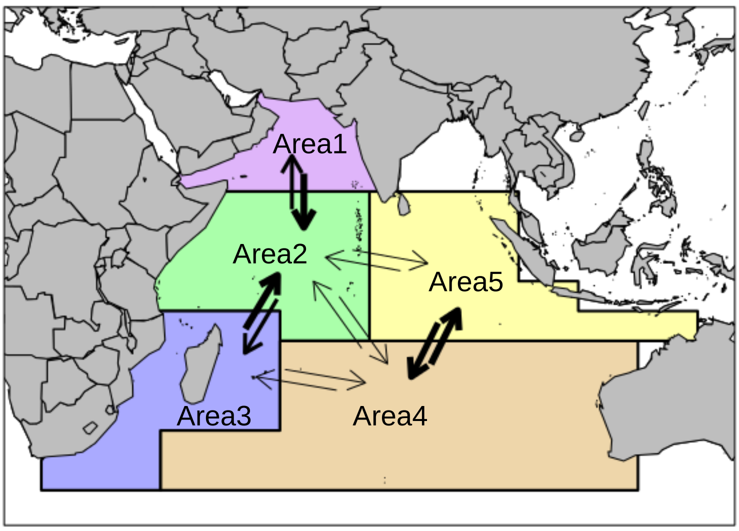
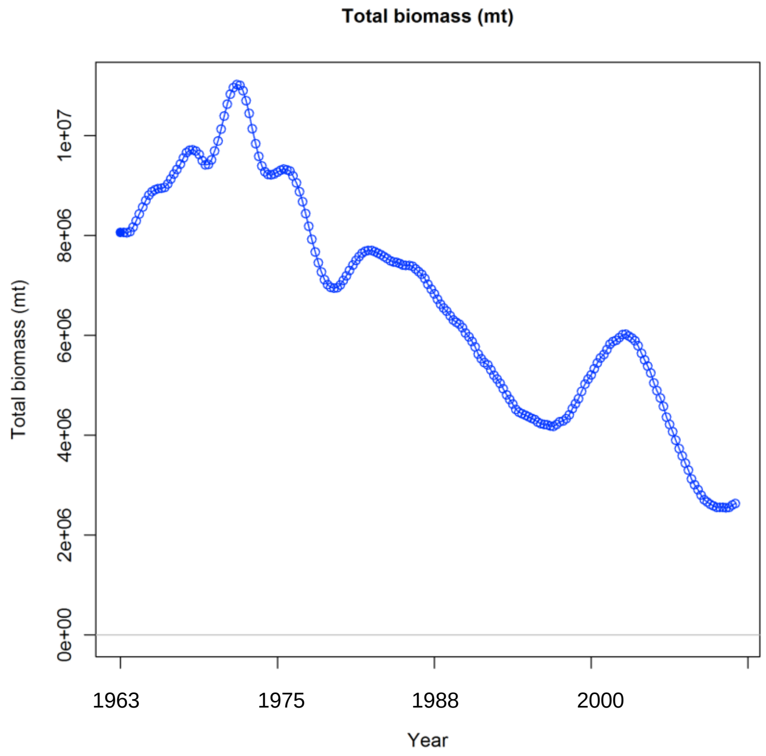


Figure 16 Estimated quarterly movement ratio (top) and movement combinations (bottom).

Appendix 5 Population trend and stock status indicators (reference case)



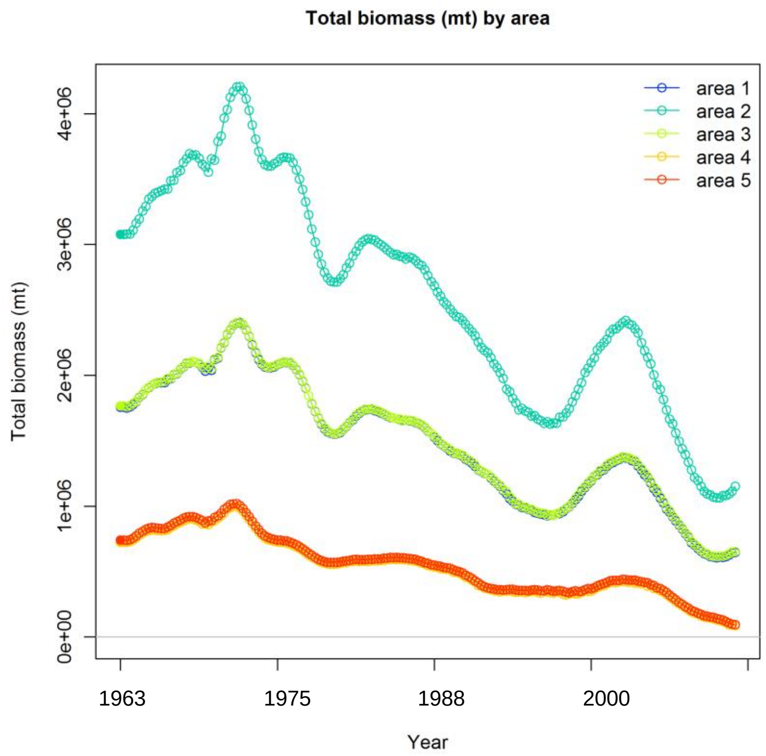
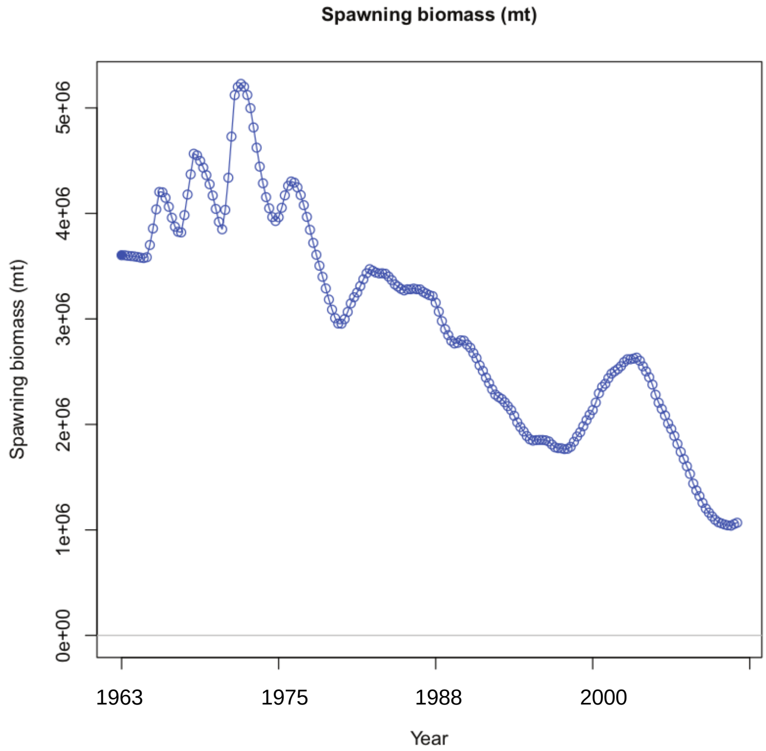


Figure 17 Estimated quarterly total biomass (top) and quarterly biomass (bottom) by region under the reference case.

Appendix 6 Spawning and Recruitment (reference case)



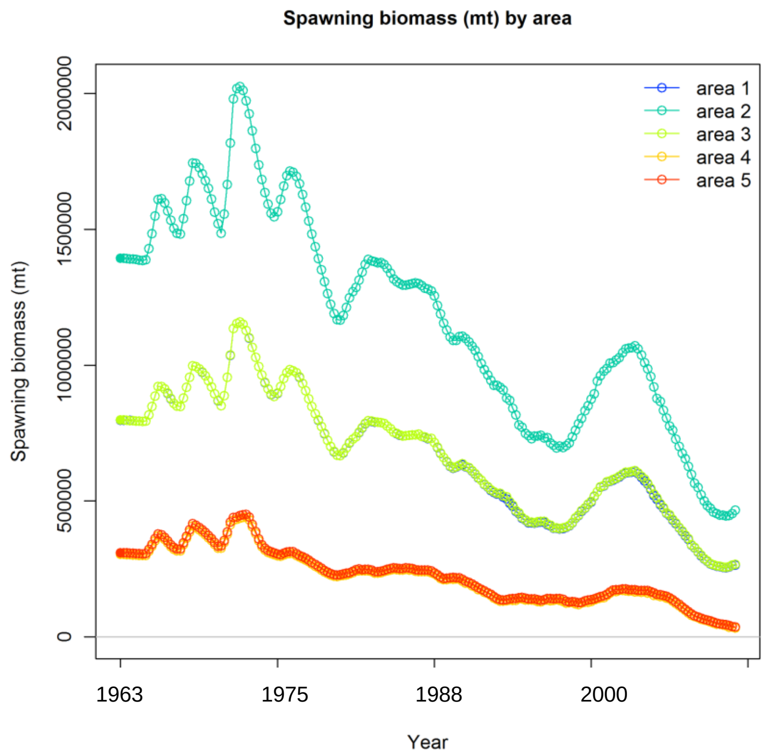


Figure 18 Estimated quarterly total spawning biomass (top) and quarterly spawning biomass (bottom) by region for the reference case.

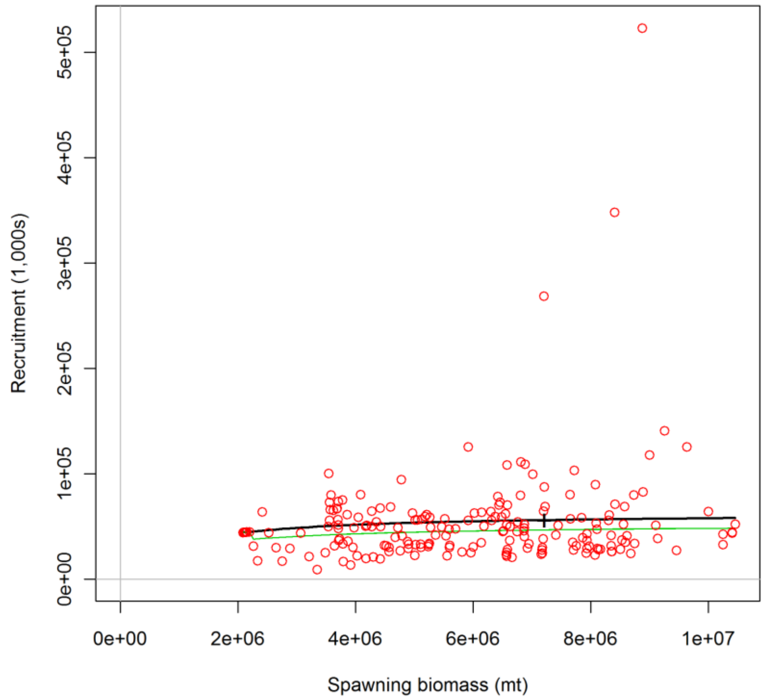


Figure 19 Estimated spawning biomass and recruitment from the reference case.

Appendix 7 Kobe plot (reference case)

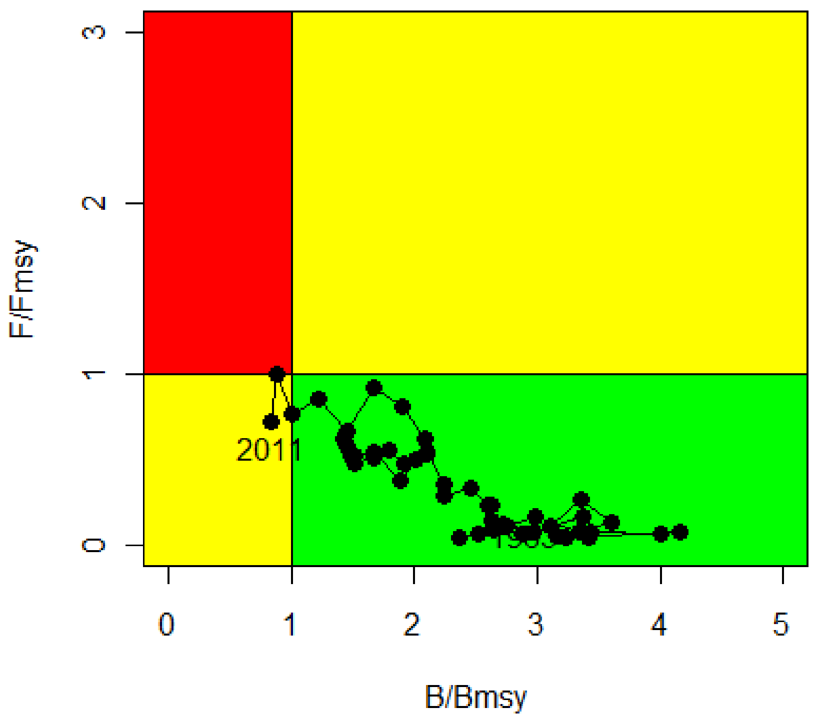


Figure 20 Kobe I plot for the reference case in 1st quarter.