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Chub mackerel stock assessment using KAFKA

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Abstract

Chub mackerel stock assessment has been conducted using cohort analysis with Kalman filter (KAFKA). Calculations are provided for different scenarios with a set of biological uncertainties such as natural mortality, weight at age and maturity at age. Scenarios with the highest maturity and weight have led to higher SSB values compared to the other scenarios. Stock assessment best corresponds with SSB indices.

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Introduction

The chub mackerel stock assessment technical working Group (TWG CMSA) at NPFC have decided to compare the participants' stock assessment models (VPA, ASAP, KAFKA and SAM) using an operating model, based on POPSIM-A. At TWG CMSA04, preliminary results of stock assessment of chub mackerel were demonstrated using KAFKA, a candidate model proposed by the Russian Federation (Mikheev, 2018). Data provided by participants were used (Nishijima, 2020).

In preliminary calculations, only biomass indices provided by Japan were used. This was due to the fact that the original version of KAFKA model did not support handle of recruitment indices. Biomass indices provided by China and Russia were excluded due to small number of observations (5 and 4 years, respectively). The working group decided to carry out the assessment using all indices. This paper presents updated stock assessment using all indices provided by members (Nishijima, 2020) for six scenarios (NPFC, 2020).

Model

The KAFKA model belongs to the class of statistical cohort models that take into account the presence of random factors that affect the dynamics of stock abundance and fishing process (Gavaris, 1988; Methot, 1989; Vasilyev, 2001; Mikheev, 2003). Kalman filter (KF) (Kalman, 1960) was used to separate stochastic noise in the estimated system variable (stock abundance) and accidental observations errors (catches per effort). Therefore, the total uncertainty is decomposed into observation errors and noise in the state variable. The status assessment of the system in the FK is determined as a weighted sum of observations from available information sources (fishing gear, fleets, fishing periods in long-term and seasonal aspects, etc.) and model prediction. Parametric tuning of the KAFKA model is performed based on minimizing the likelihood function relative to the available observations using the hybrid method (Mikheev et al., 2006). The above mentioned method combines classical gradient optimization methods and method of evolutionary stochastic search, known as the genetic algorithm (GA) (Rutkovskaya et al., 2004).

Initially, KAFKA was designed to reduce the number of estimated parameters, since a large number of parameters in nonlinear models can lead to incorrect estimates (Auger-Méthé et. Al.). The model used an incomplete observational matrix, which included abundance indices for fully exploited age groups. Therefore, the model did not need to estimate the parameters of ogives for selectivity and natural mortality. When using external estimates of maturity and mortality, this advantage turns into a disadvantage.

In order to carry out the calculations in accordance with the scenarios defined by the CMSA, the observation model was transformed to include a sample of the maturity ogive. The catchability coefficient for the recruitment index also has been added to the observation matrix.

Results

Abundance estimate and fishing mortality

Maximum SSB estimates were obtained for scenarios with the highest weight and maturity values. This is due to the fact that at the stage of cohort analysis, with the same natural mortality rates, the same initial numbers were obtained (due to properties of reverse calculation). Thus, commercial biomass estimates were determined primarily by weights of different age groups. Recruitment estimates at the left side of the curves are grouped by natural mortality rates for yearlings — for scenarios A, C, E they are lower and for B, D, F — higher (Fig. 1).

The obtained commercial biomass estimates ranged from 736.3 (scenario F) to 2999.7 (scenario C) thousand tons. The highest estimates were obtained for scenarios with the highest values of maturity and weight (2999.7 and 2691.0 thousand tons), and the lowest with the smallest values (819.0 and 736.3 thousand tons).

Fishing mortality had similar dynamics for all scenarios, with the exception of the last 5 years (Fig. 2). For scenarios with higher estimates of maturity at age (C, D), its estimate was the highest, due to earlier entry into the fishable stocks of younger age groups.

Retrospective analysis

Retrospective analysis showed no serious biases under the base-case scenarios (Table 4, Figs. 3-8). Scenarios A and B had higher performances than other scenarios in terms of retrospective bias.

Basic biological parameters and biological reference points

Biological reference points based on hockey-stick stock-recruitment relationship (FIg. 9) were estimated. Results are represent in table 5.

Indices adjustment

Across all scenarios, the best matches were observed for the abundance indices. The replenishment indices were significantly smoothed (Figures 10-15). The index provided by Russia generally followed the dynamics of the SSB estimate. The index provided by China matched the estimates least of all. Nevertheless, for scenarios A, B, E and F it can be seen that the dynamics of the index repeats features of biomass estimates. At the same time, we will refrain from making any conclusions about the properties of indices provided by Russia and China due to the fact that they have short series of observations.

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Page 25 NPFC-2020-TWG CMSA03-Final Report. (available at www.npfc.int)

Figures

1. Stock Assessment

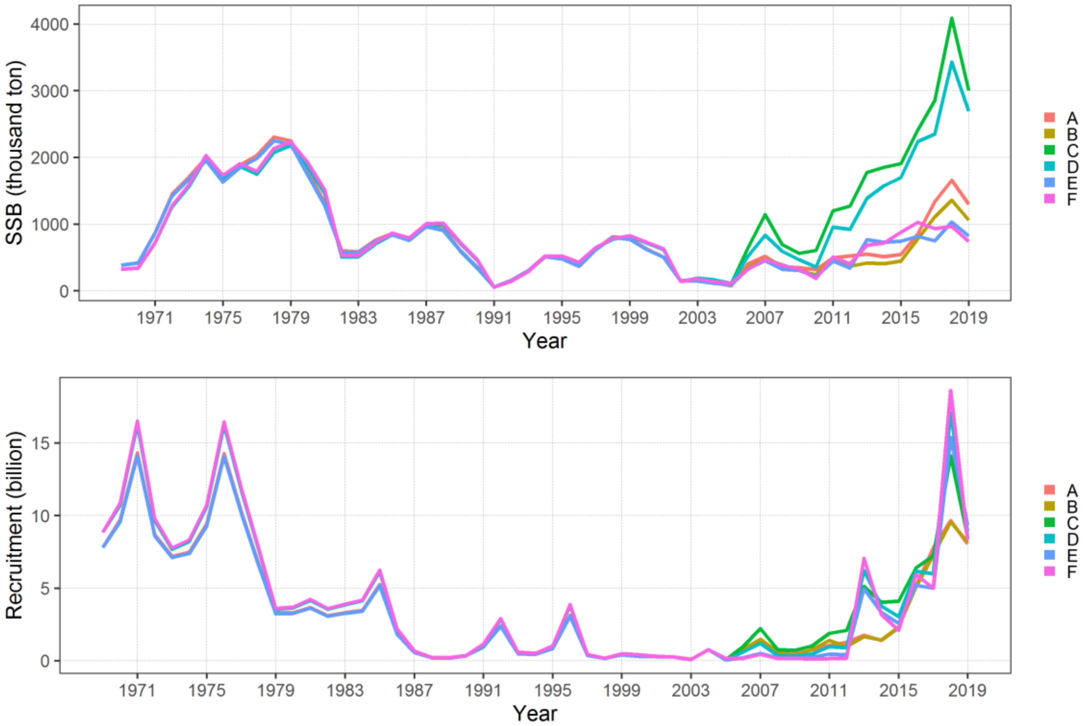

Figure 1. Estimates of SSB and recruitment number with KAFKA under the scenarios A to F.

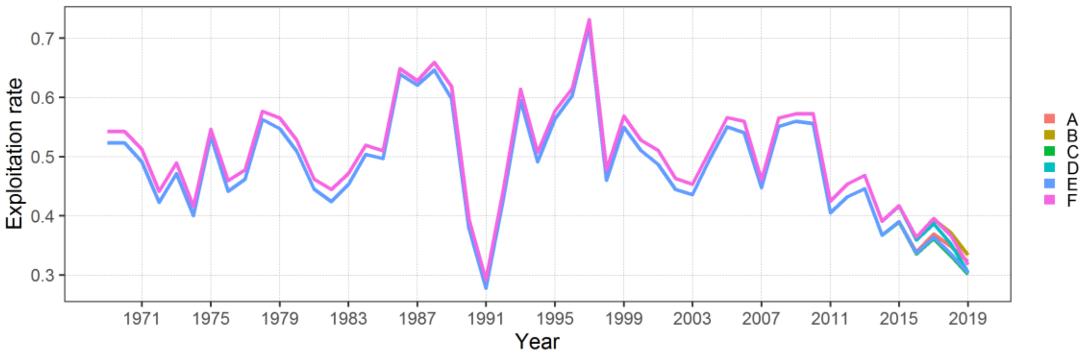

Figure 2. Estimates of exploitation rate with KAFKA under the scenarios A to F.

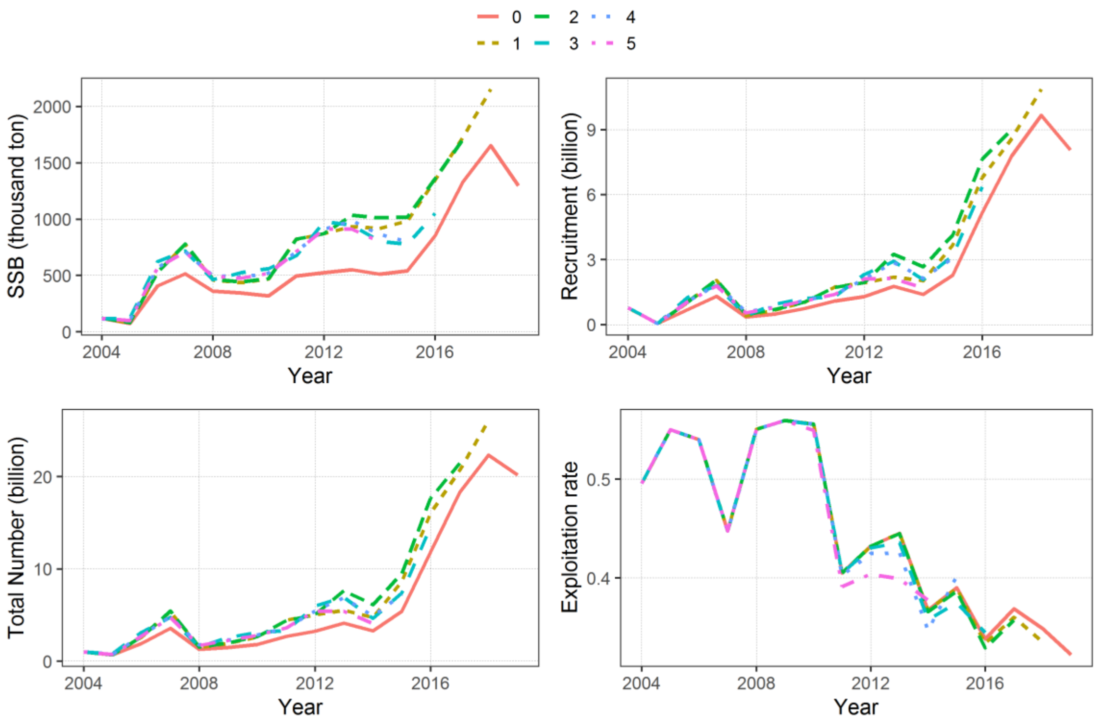

Figure 3. The retrospective patterns under the Scenario A.

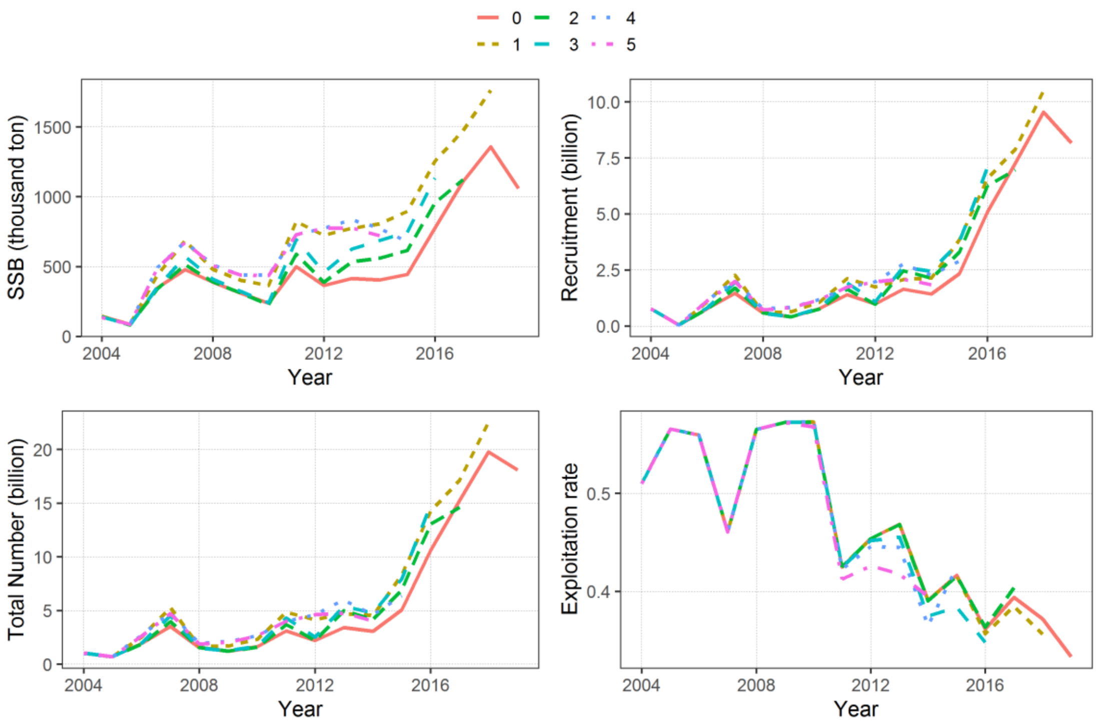

Figure 4. The retrospective patterns under the Scenario B.

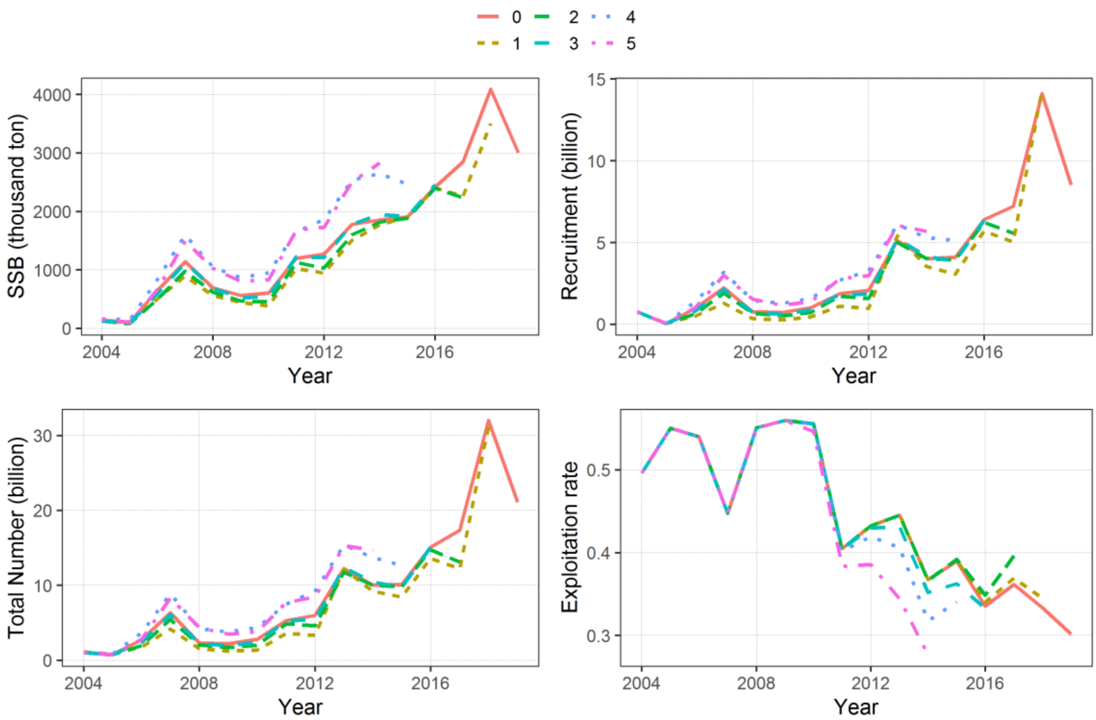

Figure 5. The retrospective patterns under the Scenario C.

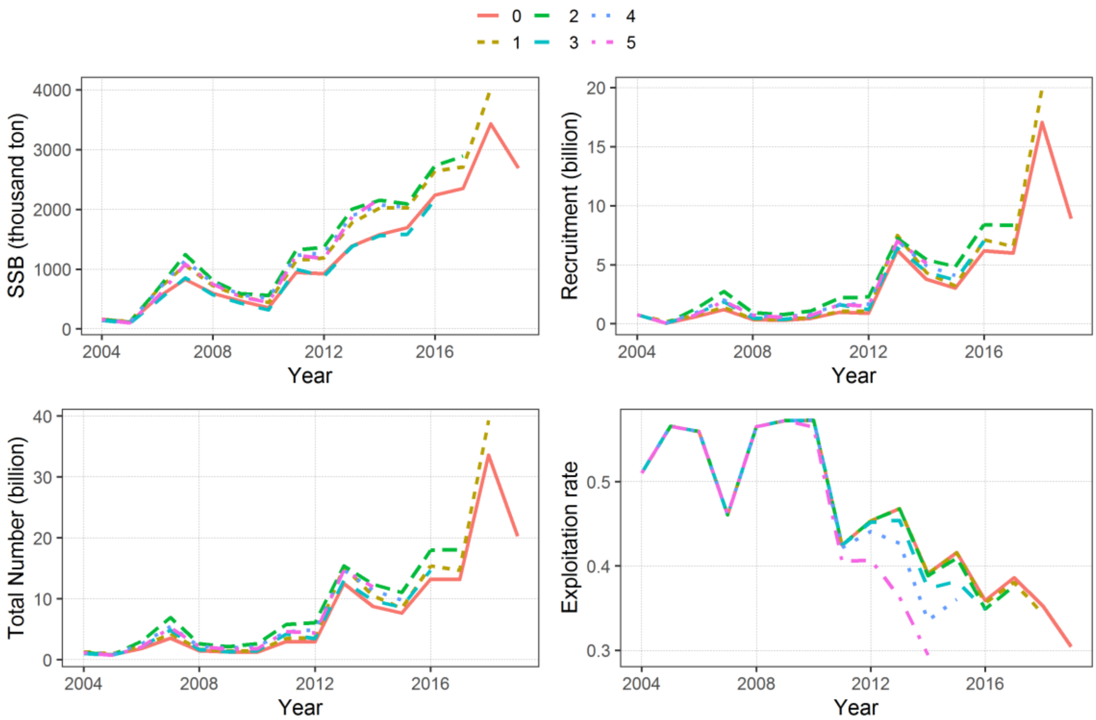

Figure 6. The retrospective patterns under the Scenario D.

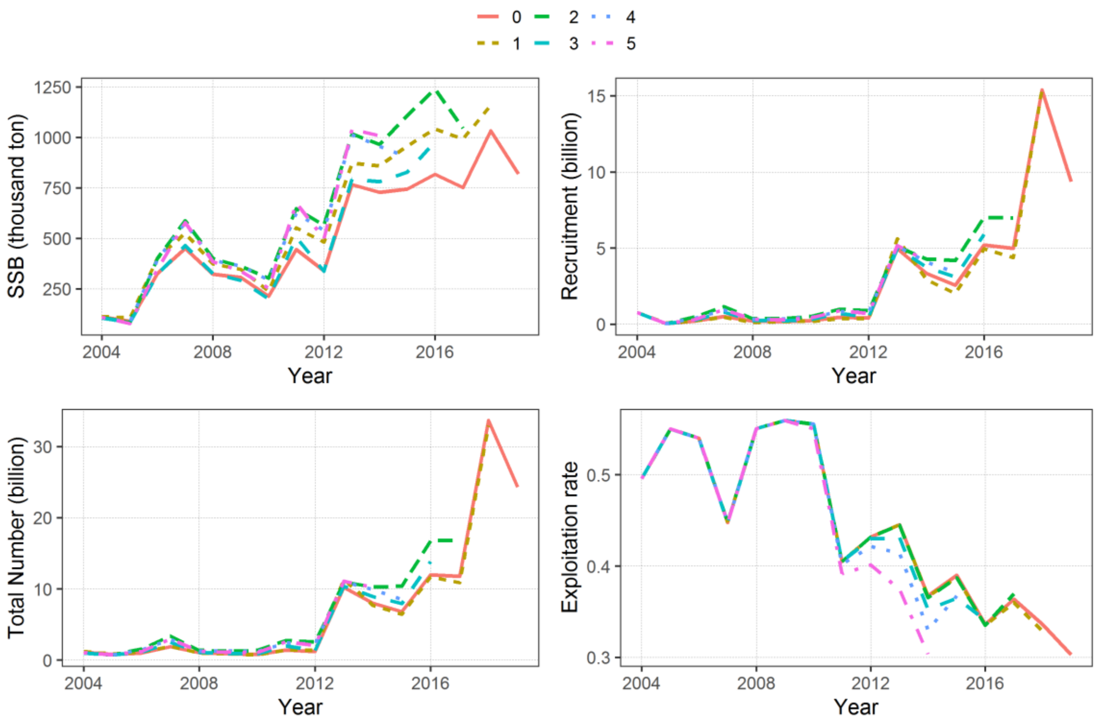

Figure 7. The retrospective patterns under the Scenario E.

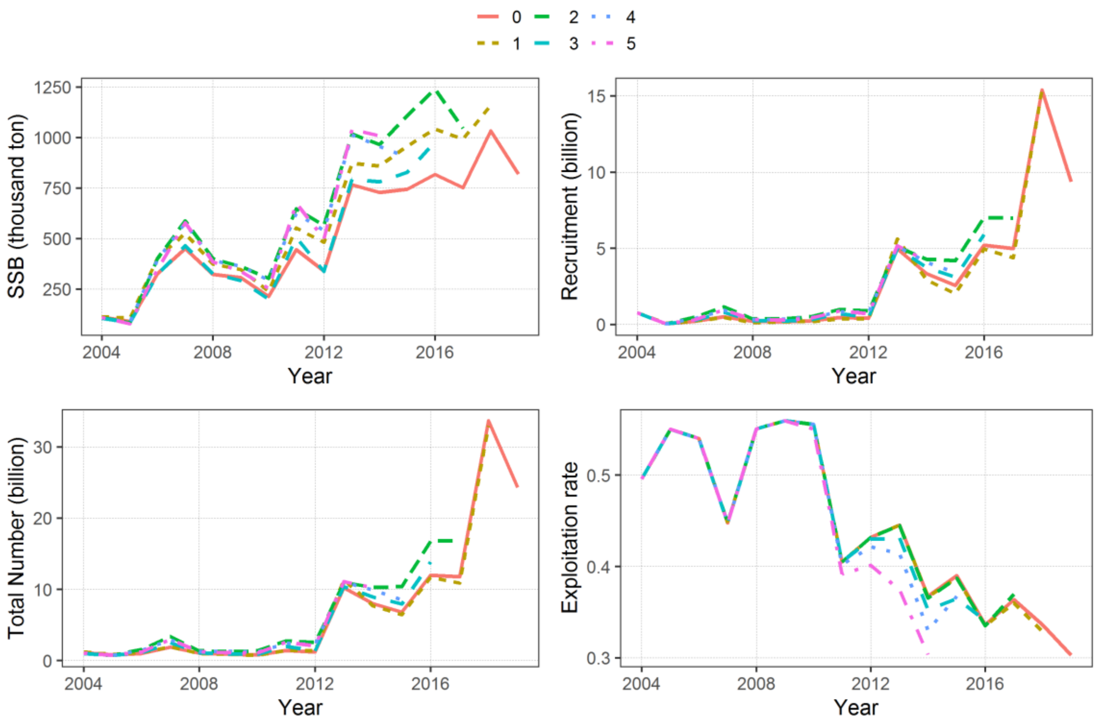

Figure 8. The retrospective patterns under the Scenario F.

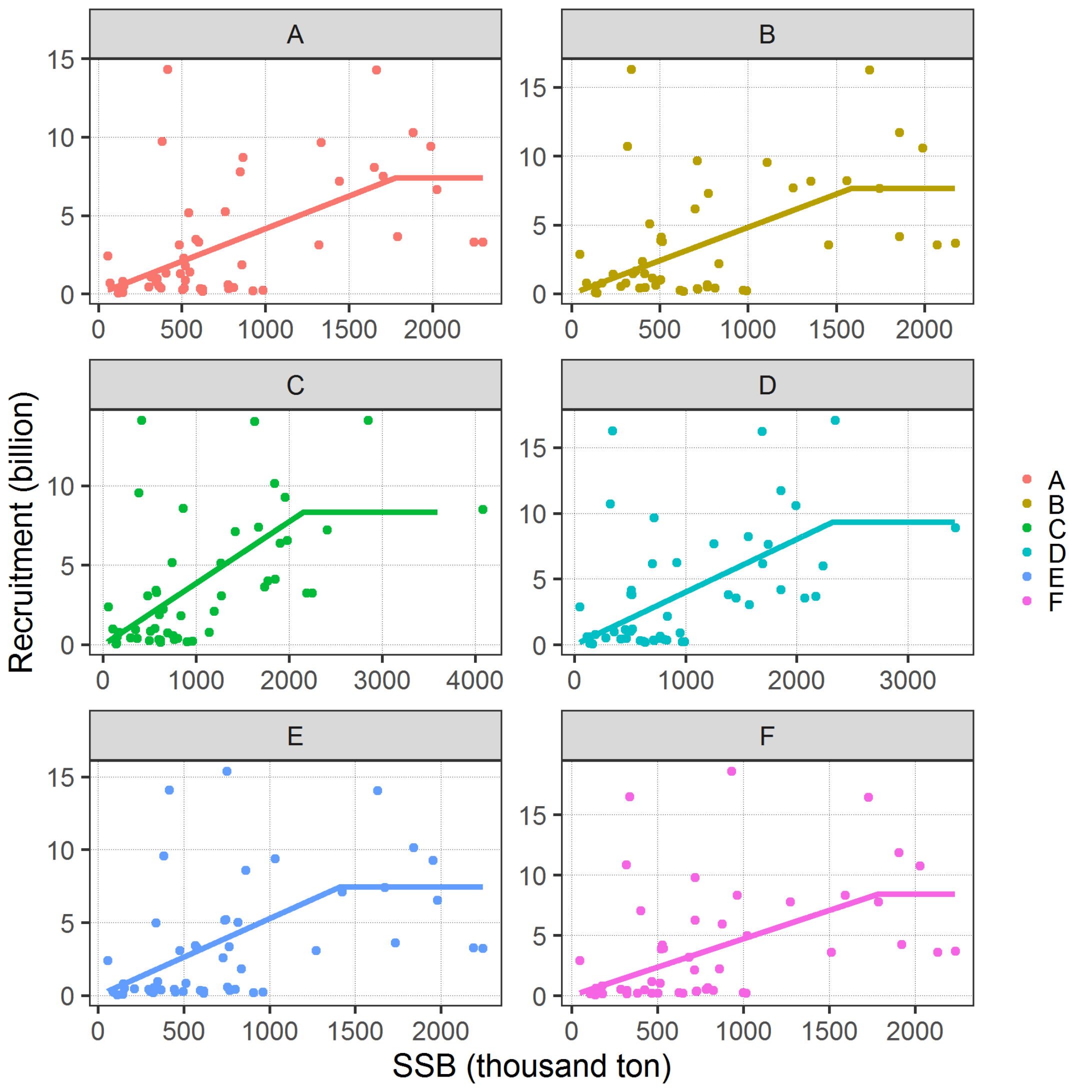

Figure 9. Stock-recruitment relationships under the Scenarios A to F

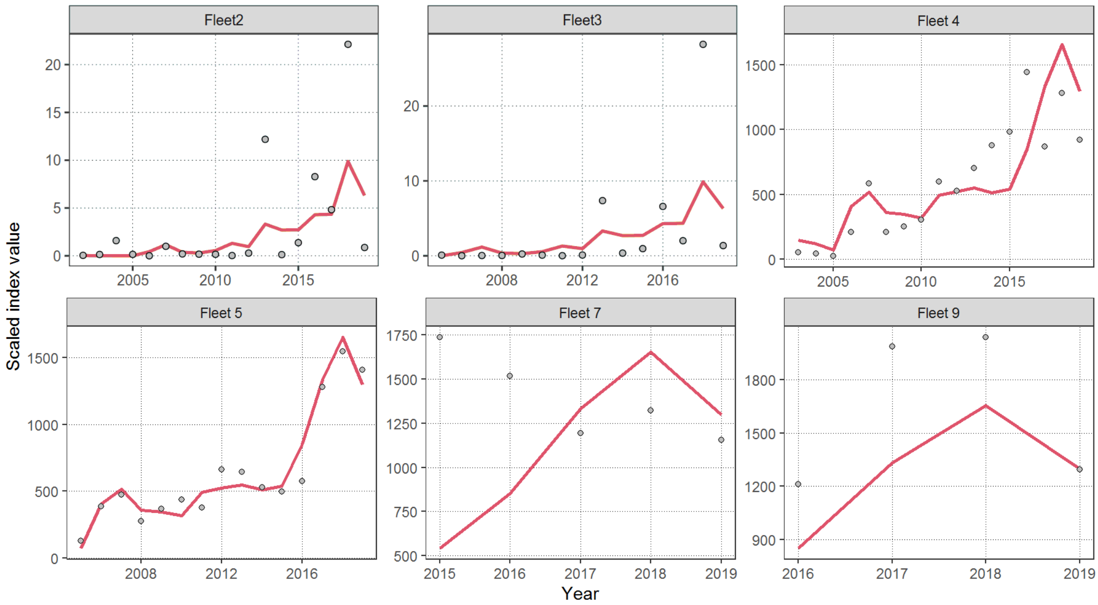

Figure 10: Index values scaled by catchability (points) and predicted values by under the scenario A.

Figure 10: Index values scaled by catchability (points) and predicted values by under the scenario B.

Figure 12: Index values scaled by catchability (points) and predicted values by under the scenario C.

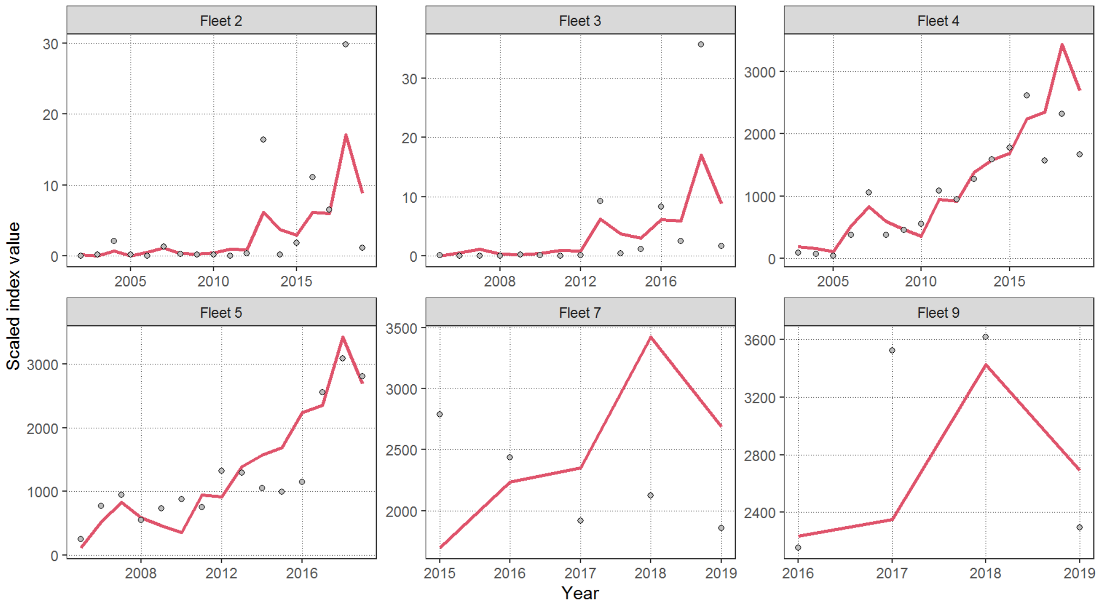

Figure 13: Index values scaled by catchability (points) and predicted values by under the scenario D.

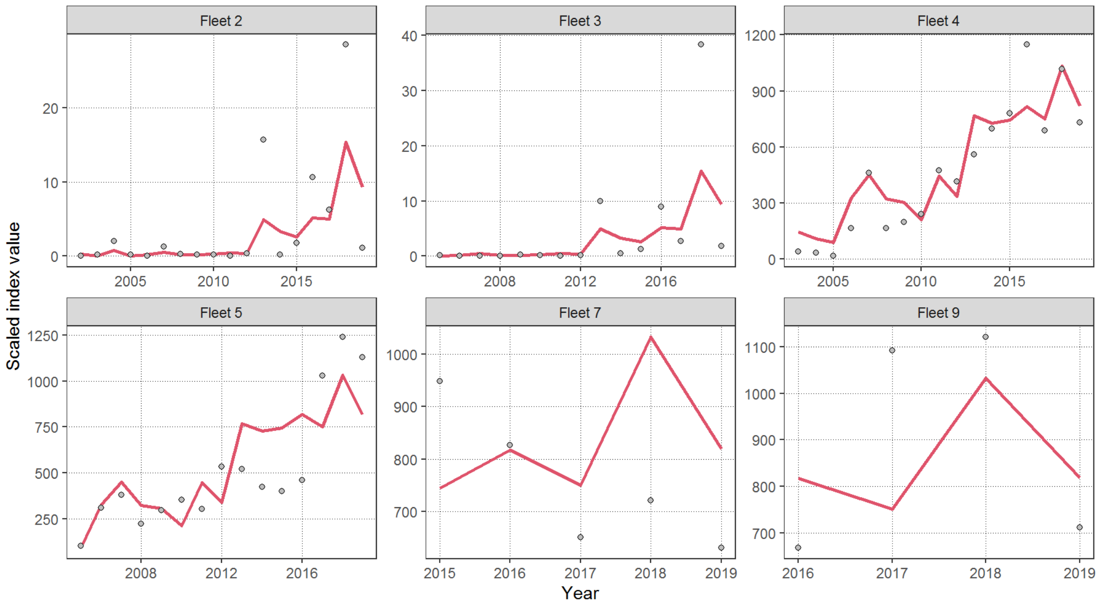

Figure 14: Index values scaled by catchability (points) and predicted values by under the scenario E.

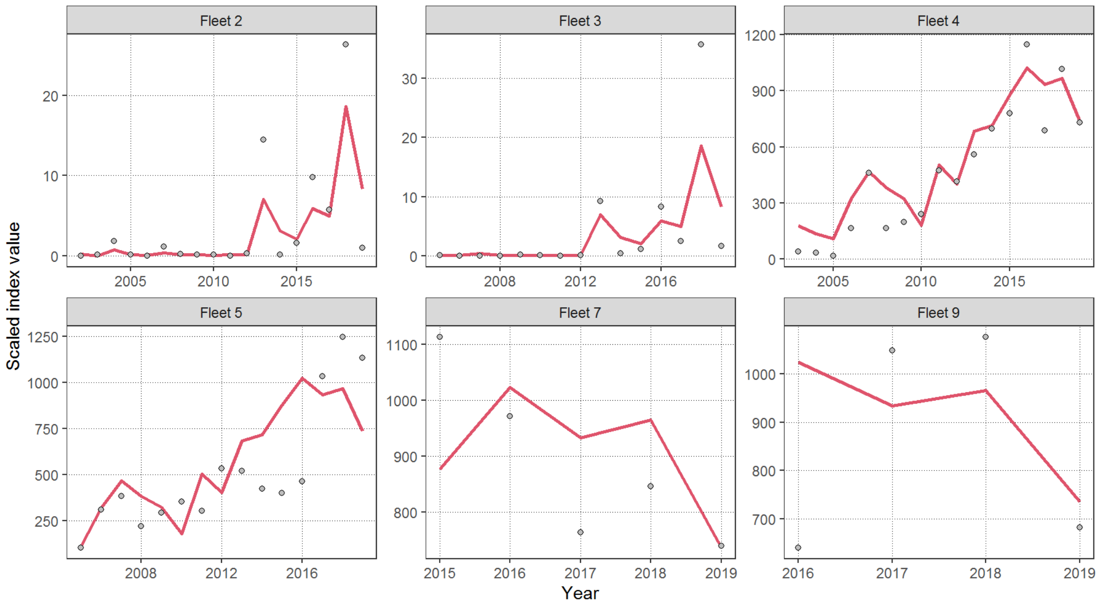

Figure 15: Index values scaled by catchability (points) and predicted values by under the scenario F.

Table 1: SSB estimates (1000 tons) for some years and summary statistics throughout the whole period

Scenario	1970	1980	1990	2000	2010	2019	Year$_{min}$	SSB$_{min}$	Year$_{max}$	SSB$_{max}$	SSB$_{mean}$	SSB$_{median}$
A	414,5	1791,7	354,3	625,4	317,3	1297,5	1991	57,9	1978	2303,6	822,4	601,3
B	339,8	1859,4	458,6	715,8	236,6	1058,7	1991	49,0	1979	2174,5	778,1	616,4
C	414,5	1736,2	346,5	615,7	603,5	2999,7	1991	57,1	2018	4086,3	1090,5	768,4
D	339,8	1859,5	458,8	715,9	354,8	2691,0	1991	49,0	2018	3427,9	1010,9	768,7
E	414,5	1736,6	346,9	616,1	213,0	819,0	1991	57,0	1978	2248,2	777,0	616,1
F	339,8	1921,1	468,7	726,6	182,3	736,3	1991	49,8	1979	2232,8	799,4	715,1

Table 2: Total Number estimates (billions) for some years and summary statistics throughout the whole period

Scenario	1970	1980	1990	2000	2010	2019	Year$_{min}$	N$_{min}$	N$_{max}$	N$_{max}$	N$_{mean}$	N$_{median}$
A	17,79	8,27	0,95	1,42	1,81	20,15	2003	0,53	1976	29,97	8,18	4,13
B	18,00	8,45	1,04	1,55	1,63	18,07	2003	0,58	1976	30,91	8,08	3,51
C	17,55	8,10	0,93	1,40	2,77	21,09	2003	0,56	2018	31,98	8,95	6,32
D	18,01	8,45	1,04	1,55	1,26	20,29	2003	0,58	2018	33,58	8,76	6,24
E	17,56	8,10	0,93	1,40	0,80	24,27	2003	0,52	2018	33,64	8,35	6,04
F	18,24	8,63	1,06	1,58	0,57	20,84	2003	0,55	2018	34,99	8,61	6,08

Table 3: Recruitment estimates (billions) for some years and summary statistics throughout the whole period

Scenario	1980	1990	2000	2010	2019	Year$_{min}$	R$_{min}$	Year$_{max}$	R$_{max}$	R$_{mean}$	R$_{median}$
A	3,30	0,33	0,32	0,73	8,05	2005	0,04	1971	14,29	3,47	1,76
B	3,65	0,36	0,39	0,77	8,16	2005	0,04	1971	16,27	3,82	1,65
C	3,25	0,33	0,31	1,01	8,51	2005	0,04	2018	14,11	3,77	2,36
D	3,65	0,36	0,39	0,46	8,89	2005	0,05	2018	17,06	4,09	2,86
E	3,25	0,33	0,31	0,24	9,35	2005	0,04	2018	15,38	3,55	2,36

F	3,70	0,36	0,40	0,12	8,33	2003	0,07	2018	18,61	4,05	2,18

Table 4: Mohn’s rho of the scenarios A to F

	A	B	C	D	E	F
SSB	0,0311	0,0172	0,0448	0,0733	0,0217	0,0225
R	-0,0497	-0,0615	0,1075	0,0837	0,1095	0,0823
N	-0,0326	-0,0397	0,0889	0,0815	0,0918	0,0650
ER	0,0314	0,0308	-0,0259	-0,0431	-0,0101	-0,0164

Table 5: Biological reference points

Scenario	SSBmsy	R0	MSY
A	1750	7,83	785
B	1560	8,11	767
C	2117	8,83	1071
D	2280	9,86	1351
E	1383	7,86	584
F	1750	8,89	785