North Pacific Fisheries Commission

NPFC-2020-TWG CMSA03-WP10

Chub mackerel stock assessment using KAFKA model (report for the intersessional period 2019-2020)

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Purpose

To obtain parameter estimates and make stock assessment using KAFKA model and data provided by Russia, Japan and China.

Methods

The study was planned according to paragraphs 2-4 of the WG preliminary workplan (NPFC, 2020) based on the Operating model development Protocol (OM) (NPFC, 2019) (Fig. 1).

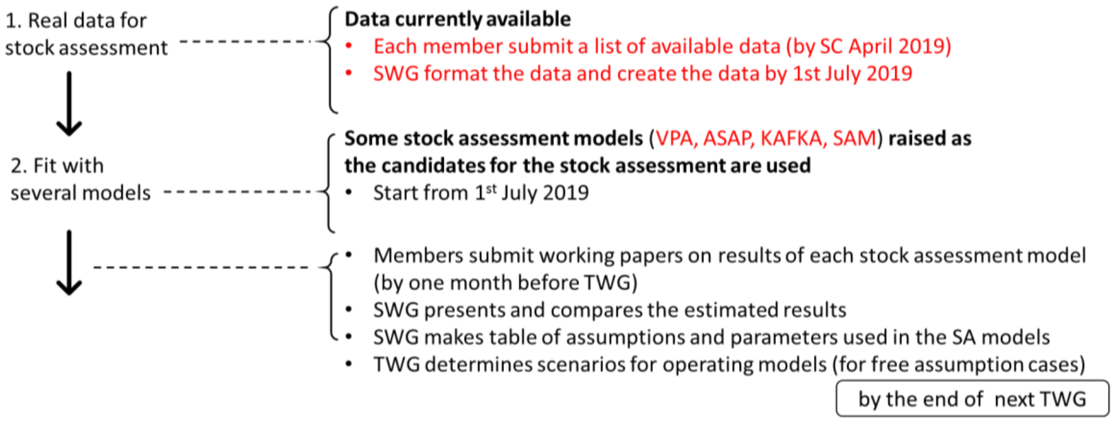

Figure 1. The flowchart fragment of the operating model development protocol for the third meeting of the working group TWG CMSA03

KAFKA model was used (Mikheev, 2016; Metodicheskiye rekomendatsii ..., 2018). The following steps were made:

1. The analysis of information provided by WG members was carried out, and initial datasets were formed according to the requirements of the KAFKA model.

2. There were 15 scenarios prepared to perform calculations using the KAFKA model and assumptions regarding the model parameters and sources of information related to stock indices.

3. By using the KAFKA model, estimates of a number of biological and fishery data were obtained, retrospective and predicted dynamics of the commercial stock were modeled, and the statistical characteristics of the stock assessment were calculated.

Results

The results can be divided into two parts. The first part relates to systematization and analysis of biological and fishery data that are available for sharing among participants and the second part contains assessment of parameters and stocks which was calculated using the KAFKA model.

Data analysis

The WG members provided data for models-candidates according to general structure and requirements developed during the second meeting of the TWG CMSA02 which was held from February 28 to March 2, 2019 (NPFC, 2019). The metadata are described in Table 1.

Table 1. Data requirements for models-candidates for stock assessment and further exchange to estimate parameters for operating models.

Data requirements							Data availability for exchange		
Fishery statistics	VPA	SAM	KAFKA	ASAP	Production model		Japan	China	Russia
Total catch	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes
Catch by age	Yes	Yes	Yes	Yes			Yes	Yes	Yes
Outliers by age				If possible			No	No	No
Selectivity by fleet				If possible					
Biological characteristics									
Weight by age	Yes	Yes	Yes	Yes			Yes	Yes	Yes
Maturity by age	Yes	Yes	Yes	Yes			Yes	Yes	Yes
Mortality by age	Yes	Yes	Yes	Yes			Yes	No	Yes
Abundance index									
Replenishment index (surveys)	Yes	Yes	Yes	Yes			Yes	No	No
SSB index (including spawning surveys)	Yes	Yes	Yes	If possible	Yes		Yes	No	No
CPUE index by age				Yes			No	No	No
CPUE index (commercial)				Yes	Yes		?	Yes	Yes
Catchability							No		
Observations									
Fishery									
CPUE by all periods, fleet, fishing gear (if possible)			Yes	If possible			No	Yes	Yes
Surveys									
Stock assessment			Yes	If possible			No	No	Yes?

The data were presented by every participant in accordance with metadata as the following files:

From Japan – «JapanData(chub_mackerel)200204.csv»;

From China – «China_chub mackeral data_to NPFC 20190426.xlsx»;

From Russia – «Russia Data Chub Mackerel_Jan2020.xlsx».

The received data were systematized and grouped into 8 fleets (Table 2).

Table 2. Sources, names and options of catch and stock index datasets for stock assessment models-candidates.

Source of data	Data name	Data type	Data dimension	Type of fishing/survey
Japan	Fleet1	catch	*quantity*	Trawl and deep-net fishing
	Fleet 2	recruits	*quantity*	Trawl survey (summer)
	Fleet 3	recruits	*quantity*	Trawl survey (autumn)
	Fleet 4-1*	SSB	*non-dimensional*	Deep-net fishing

	Fleet 4-2	SSB	*kg / fisherman per hour*	Deep-net fishing
	Fleet 4-3	SSB	*mill. inds. / fisherman per day*	Deep-net fishing
	Fleet 5	Egg (SSB)	*quantity*	Egg and larval survey
China	Fleet 7	CPUE	*tons / fishing day*	Purse seine fishing
Russia	Fleet 8	CPUE	*tons / fishing day*	Trawl and purse seine fishing
Notes:	SSB — spawning stock of biomass; Egg — fish roe; CPUE — catch per unit effort; * — stock indices are scaled by division by mean.			

Considering that stock observations play an important role in the KAFKA model, first a detailed visual analysis of the stock index data was carried out. The primary interest of studying the dynamics of stock indices was identification of their synchronicity and similar trends. Data presented by the participants suggest synchronous dynamics of all stock indices over selected time interval (Fig. 2).

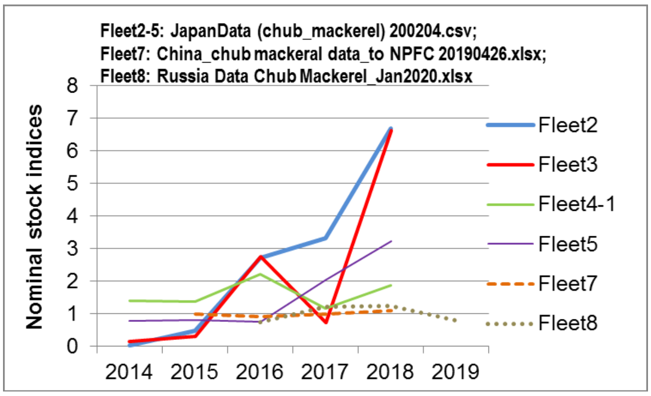

Figure 2. Dynamics of the scaled (non-dimensional) stock indices by fleet in 2014-2019

Furthermore, stock indices presented by Japan were also compared between each other. Such a selection was made because Japanese data series were almost three times longer than similar data series from Russia and China. These stock indices were divided into two types: first included all scaled indices, for fleets 2-5 (Fig. 3, left), second comprised nominal and standardized indices for fleets 2-4, which were presented at the first WG meeting (Nishijima et al., 2017) (Fig. 3, right).

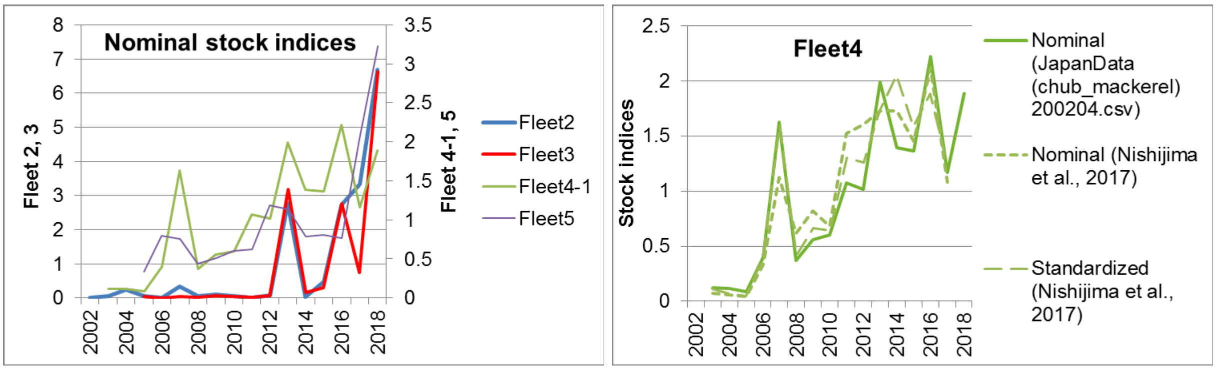

Figure 3. Dynamics of stock indices provided by Japan for the observation period: scaled and for all Fleet units (left); scaled, nominal and standardized for Fleet4 (right).

The analysis of stock indices suggested that data provided by Russia and China are not very informative due to their weak variability over years and short observation periods (Fig. 2). Besides, although different indices provided by Japan showed similar trends (Fig. 3, left), their scaled versions differed significantly from the nominal values for all Fleet units, in particular for Fleet 4 (Fig. 3, right). However, the difference between these nominal and standardized values was significantly smaller. Therefore, when calculations were carried out, variants of the scaled indices were used for all Fleet units and additionally two nominal indices of biomass and number, were used for Fleet 4, respectively. The second type of data (age composition of the catch) with application for cohort model was analyzed. Figures 4 and 5 represent age composition of catch in different years and dynamics of age classes represented by the participants for the total observation period.

China presented the age composition of catch that was constant over the years, which was possibly obtained by averaging over the years. For some unknown reason, Russian data showed predominance of juveniles in catch all over the years: fingerlings in 2019, one-year-olds in 2014 and 2015, and two-year-olds in 2016-2018, which did not show any dynamics of generations. On the other hand, data provided by Japan seemed to be consistent with the processes of birth and mortality rate for abundant generations, in particular, the generation of 2013. Therefore, only Japanese data on age composition of catches was used for modeling.

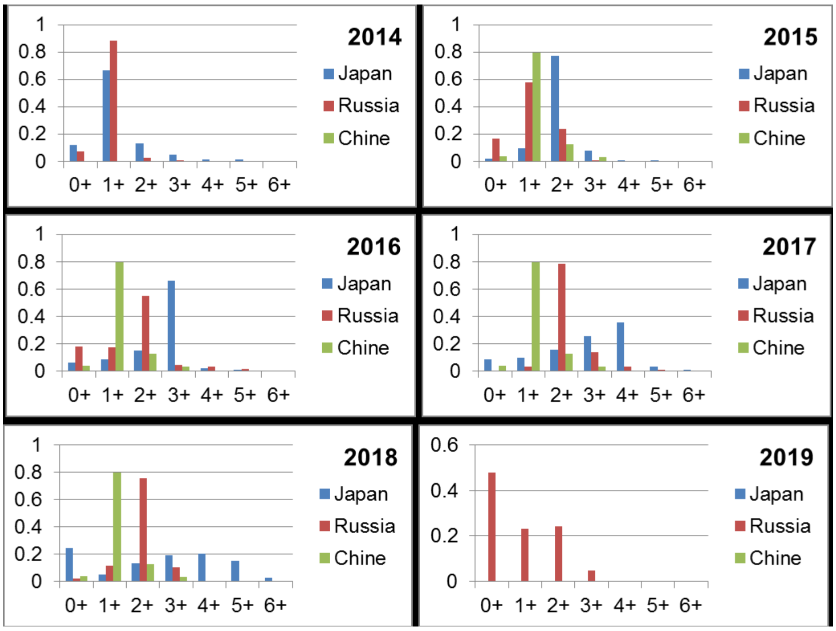

Figure 4. Age composition of catches in 2014-2019

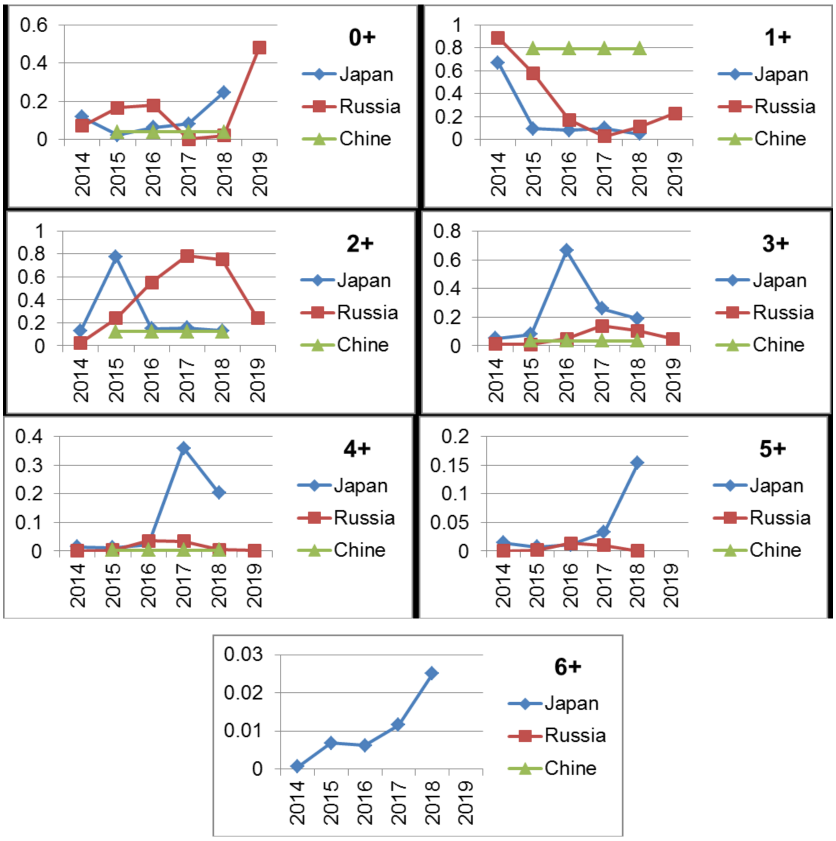

Figure 5. Age classes of fish from catches in 2014-2019

The next type of data relates to weight characteristics of chub mackerel. Changes in body weight by age and dynamics of the average body weight by years are shown in Figure 6.

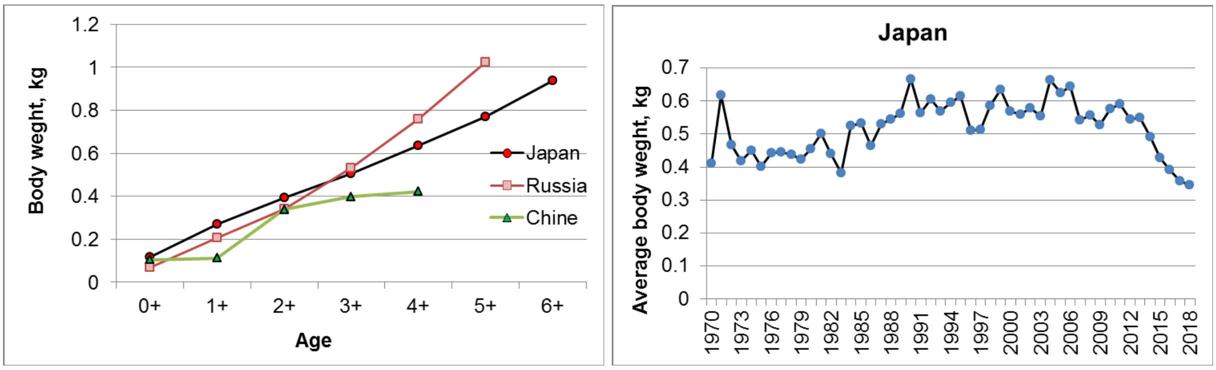

Figure 6. Average body weight at age for chub mackerel (left); average body weight of chub mackerel in 1970-2018 (right).

There was a similarity between Russian and Japanese data on relationship between weight and age; however, Chinese data appeared significantly different (Fig. 6, left). The first two data sets indicated a linear increase of weight with age, up to a maximum value of 1 kg; however, data provided by China demonstrated weight-age relationship, which was close to the logistic form with an asymptote of no more than 0.5 kg. Those differences were especially noticeable starting from age 3+, weight curves were quite different at age 4+ for all the countries. Fish weighted by age composition of catches and divided by years for the entire observation period were obtained for Japanese data. The average fish body weight has decreased by almost one half over the past years: from 0,68 kg in 2004 down to 0,35 kg in 2018 (see Fig. 6, right). It was assumed that long-term change of chub mackerel weight might be related to a noticeable increase in abundance during last years.

Data on chub mackerel maturation was tabulated, formatted and expressed graphically (Fig.7).

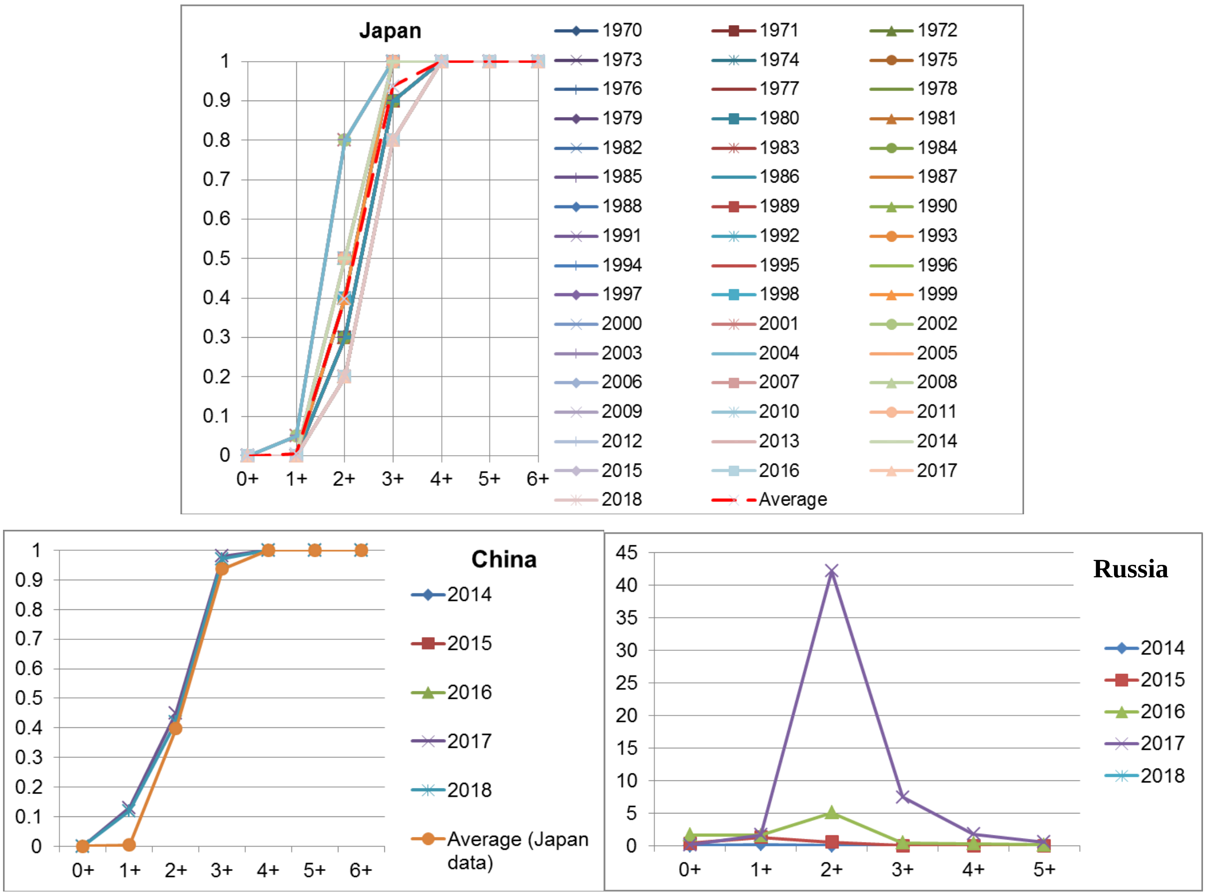

Figure 7. Maturing ogives for chub mackerel: Japanese data in 1970-2018 (top), Chinese (bottom, left) and Russian (bottom, right) data in 2014-2018.

Maturation ogives appeared similar for data provided by China and Japan, except for age 1+, and since they were obtained independently, they can be considered realistic. The ogives for data provided by Russia were hard to interpret. However, since maturation ogives are not used in KAFKA model, they were excluded from further analysis.

Results of stock calculations using KAFKA model

A total of 15 scenarios were formed for KAFKA model, depending on the sources of information about the stock indices and assessment of the standard deviation for process noise sN (Table 3).

Table 3. Different scenarios for calculations using KAFKA model

Scenario №	**Fleet**	**M***	**sN**
1	1	0.41	1600.151
2	4-1	0.41	1600.151
3	4-1	0.41	500-2000
4	4-2	0.41	1600.151
5	4-2	0.41	500-2000
5.1**	4-2	0.41	500-2000

6	4-3	0.41	1600.151
7	4-3	0.41	500-2000
8	2	0.41	1600.151
9	2	0.41	500-2000
10	3	0.41	1600.151
11	3	0.41	500-2000
12	5	0.41	1600.151
13	3, 4-1, 4-3, 5	0.41	1600.151
14	4-1, 5	0.41	1600.151
15	4-3, 5	0.41	1600.151
Notes	* — The instant rate of a natural mortality M was accepted as a base estimation in accordance with paragraphs 25 and 26 of the final report of the working group (NPFC, 2019); ** — Starting from scenario 5.1, the number of iterations during optimization by parameters was increased from 50 to 100.		

Based on the simulation results, the parameter estimates were obtained and their appropriate minimum values of the loss functions that characterize the quality of fitting the model to observations, also the predicted biomass 2018 for each of the selected scenarios was compiled in Table 4.

Table 4. Parameter estimates of KAFKA model for scenarios 1-15 and their appropriate minimum values of the loss functions (L min) and the predicted biomass 2018 (Bpr 2018), thousand tons

Parameter	Scenarios №																	
	1	**2**	**3**	**4**	**5**	**5.1**	**6**	**7**	**8**	**9**	**10**	**11**	**12**		**13**		**14**	**15**
sN	1600.151	1600.151	1871.552	1600.151	1637.772	1999.988	1600.151	758.8532	1600.151	1742.989	1600.151	1620.744	1600.151	**sN**	1600.151	**sN**	1600.151	1600.151
Q1	0.147751	0.127567	0.127579	0.023438	0.031263	0.023438	0.056046	0.056047	0.023911	0.02391	0.14325	0.143235	0.098456	**Q1**	0.156739	**Q1**	0.062241	0.035648
s1	209.7273	344.758	403.2946	0.004768	17.08508	0.004768	95.56293	45.32337	114.9035	125.1364	550.2367	557.2557	0.004768	**Q2**	0.134888	**Q2**	0.03515	0.043017
s	0.66365	0.66365	0.66365	0.66365	0.66365	0.66365	0.66365	0.66365	0.66365	0.66365	0.66365	0.66365	0.66365	**Q3**	0.064698	**s1**	9999.919	2568.822
delta	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	**Q4**	0.13379	**s2**	0.004768	14.03332
CT+1	0	0	0	0	0	0	0	0	0	0	0	0	0	**s1**	1289.067	**s**	0.66365	0.66365
RT+1	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	**s2**	9372.258	**delta**	0.5	0.5
RT+2	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	3764.267	**s3**	173.955	**CT+1**	0	0
P0	10	10	10	10	10	10	10	10	10	10	10	10	10	**s4**	625.1574	**RT+1**	3764.267	3764.267
														s	0.66365	**RT+2**	3764.267	3764.267
														delta	0.5	**P0**	10	10
														CT+1	0			
														RT+1	3764.267			
														RT+2	3764.267			
														P0	10			
L min	**11.54752**	**10.53971**	**10.53971**	**13.15323**	**13.56585**	**13.15323**	**11.66637**	**11.66637**	**45.83011**	**45.83011**	**23.7795**	**23.7795**	**5.136356**		**56.60398**		**10.35786**	**13.47975**
Bpr 2018	**2932.752**	**3355.13**	**3354.905**	**10961.43**	**8689.482**	**10961.43**	**4454.289**	**4454.202**	**11135.4**	**11137.62**	**11987.84**	**11988.98**	**6959.181**		**4659.217**		**17303.73**	**13973.99**
Notes	Variable notation is described in (Metodicheskie rekomendatsii…, 2018)																	

In the first twelve scenarios, 5 sources of observation data were processed with either fixed or optimized sN values (Table 3). The best results were achieved when using the indices from Fleet 4.1 (Scenarios 2 and 3), Fleet 4.3 (Scenarios 6 and 7) and Fleet 5 (Scenario 12). The stock assessment values varied from 3.3 to 7 million tons in these scenarios. Stock assessments for some scenarios are shown in Figure 8. The worst results of the loss function were obtained by using summer and autumn recruitment indices from Fleet 2 (Scenarios 8 and 9) and Fleet 3 (Scenarios 10 and 11), respectively. In those cases, predicted stock assessment values were significantly higher and reached 12 million tons (Table 4).

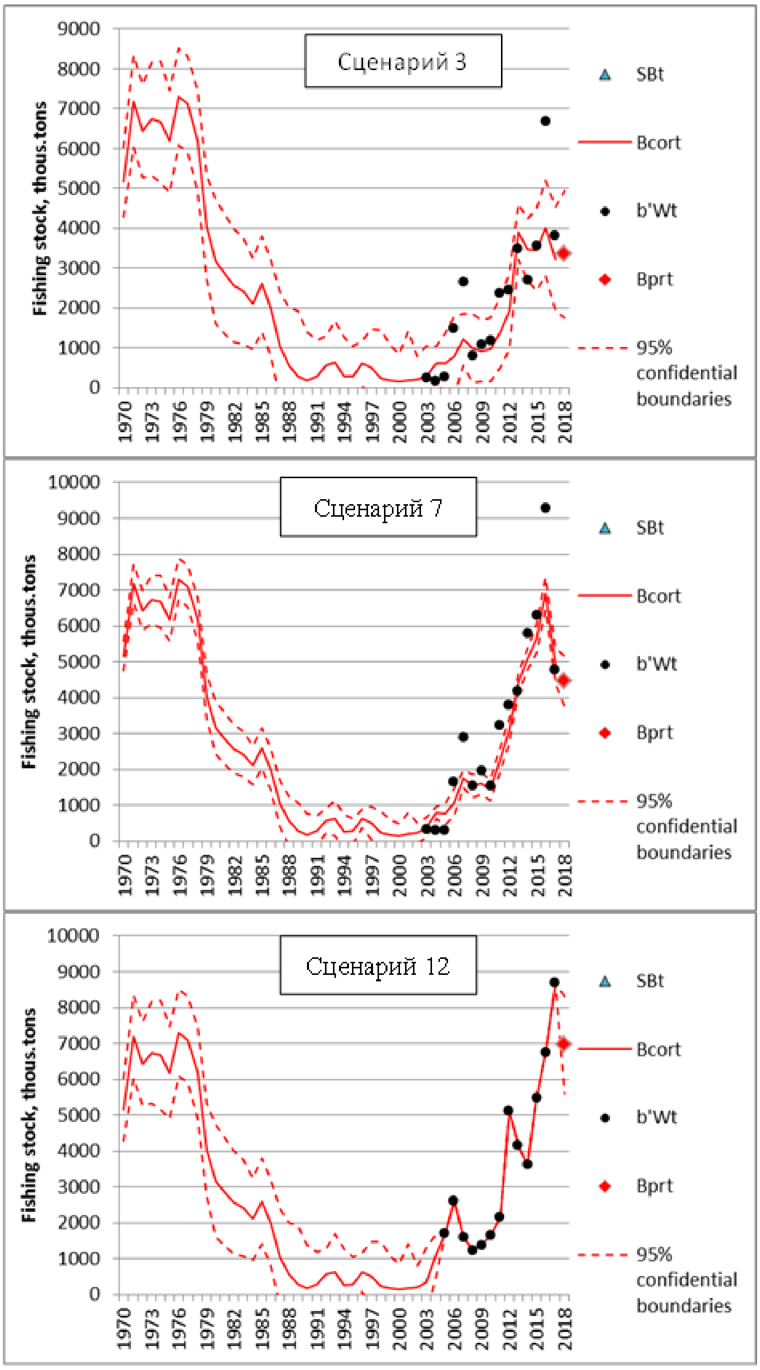

Figure 8. Chub mackerel stock dynamics in 1970-2018 based on simulation results in accordance with Scenarios 3, 7, and 12

For further modeling, which is based on the joint use of observations from various independent sources, Fleets 4.1, 4.3 and 5 representing recruitment indices, spawning stock biomass and fish egg indices, respectively, were selected, and Fleet 3, which contains recruitment indices, was also added (all the necessary definitions and characteristics of the Fleet units are described in Table 2). Also, Scenarios 14 and 15, in which the scaled and nominal indices of the spawning stock biomass were combined with fish egg indices, showed poor results (the stock was assessed at 17 and 14 million tons, i.e. at unrealistically high values). Scenario 13 is acceptable with stock assessed at a value of 4.7 million tons for 2018.

The stock-recruitment relationships were created as Beverton-Holt model based on the results of recruitment modeling (***R***) and Japanese data on the spawning stock biomass (***SSB***)

$$R = \frac{aSSB}{b + SSB}$$

and Ricker's model respectively

$$R = aSSBexp(-bSSB).$$

Maximum recruitment assessment is shown in Table 5, and curves of relationships as well as calculated data are shown in Figure 9.

Table 5. Regression statistics, maximum recruitment assessment and parameters of Beaverton-Holt and Ricker's models for chub mackerel

	Beverton - Holt	**Ricker**
Multiple R	0.340065	0.358171405
R-squared	0.115644	0.128286756
Normalized R-square	0.085149	0.098227678
Standard error	0.421124	1.044124485
Observations	31	31

Beverton - Holt				
	Ras=a	**St. deviation**	**Lower 95%**	**Upper 95%**
	981.01258	503.7643143	800.0550968	1161.970064
a	981.01258			
b	115.10019			
Ricker				
	Rmax=a/be	**St. deviation**	**Lower 95%**	**Upper 95%**
	1327.45	1050.935	949.9469	1704.961
a	9.67469			
b	0.00268			

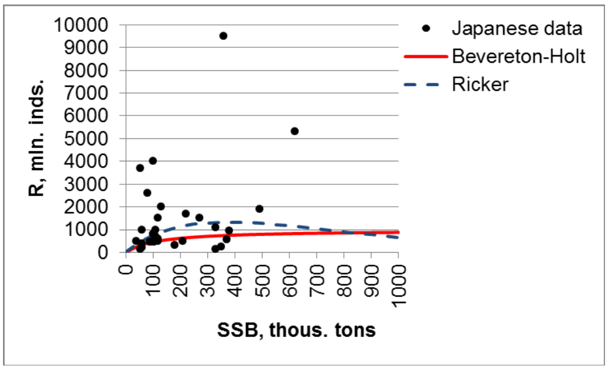

Figure 9. Beaverton-Holt and Ricker stock-recruitment relationships for chub mackerel

Implementation of results

Data used in this study can be considered as the initial information for stock modeling of chub mackerel. Calculations using KAFKA model can be utilized for stock assessment of chub mackerel, development of the operating model and assessment of fisheries management strategies. Parameter estimates of the stock-recruitment relationships can be used for assessing fishery management, development of fishing regulations and forecasting recruitment.

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