Response to the Request from the Committee of Stock Management Policy (1st session) on Walleye Pollock Northern Sea of Japan Stock

The first Committee of Stock Management Policy on this stock (held on August 20 and 21, 2020) requested four examination items on walleye pollock Pacific stock and Northern Sea of Japan stock in response to the information presented by the Research Institute Meeting on Reference Points (held on April 19, 2019). Response to the examination items regarding the Northern Sea of Japan stock (A, B and D below) is as follows.

Examination Item A

Reflect the latest stock assessment results in the explanation of stock status, while simply updating the proposed reference points, proposed fishing ban level, proposed Harvest Control Rules (HCRs) and future projection results to the values based on the latest stock assessment.

1. Introduction

In response to the request, first, we updated the values of the stock-recruitment (S-R) relationships based on the stock assessment results of this year. Next, we showed the results of recalculation of the proposed reference points, proposed level, proposed HCRs based on the updated S-R relationships by using the method that is used by the Research Institute Meeting. We also made a future projection based on the updated values.

The proposal at the Research Institute Meeting held in April 2019 is based on the latest stock assessment results at the time (results of the 2018 stock assessment). The stock assessment results used in this material are based on the 2020 stock assessment. The latest stock assessment includes two more assessment years of abundance, etc. compared with the 2018 stock assessment.

2. S-R relationship

As the S-R relationship of this stock, the Research Institute Meeting proposed the hockey stick (HS) S-R relationship. The least squares method is used for parameter estimation of the relationship. A model that considers autocorrelation in residuals of observation values of recruitment against the predicted values is not used. Parameters of this S-R relationship are updated using the recruitment and spawning biomass of the 1980-2017 year class based on the latest stock assessment. The result is shown in the table below and Figure A-1. Inclination of the HS model (parameter a in the table below) and break point (parameter b in the table below) of the updated relationship are almost the same as before the update. Recruitment that can be obtained on average with the spawning biomass above the break point of the HS model is 614 million individuals (617 million with the relationship before the update).

Proposal	S-R relationship	Optimization method	Autocorrelation	a	b	S.D.
Proposal by the Research Institute Meeting (2019)	Hockey stick	Least squares method	No	1.805	341,742	0.812
Updated value	Hockey stick	Least squares method	No	1.797	341,743	0.799

Here, a represents the steepness of the S-R curve to the break point, while b represents the spawning biomass (tons) at the break point.

Because the S-R relationship of this stock shows a strong linear relationship between the spawning biomass and recruitment, and no density effect is found in Ricker (RI) and Beverton-Holt (BH) S-R curves, almost the same values are estimated in the HS, RI and BH models (Figure A2, Table A-1). However, when the inflection point is not within the observation range of the HS model, it can be set at the maximum value of spawning biomass. For this reason, it is judged that the HS model is suitable for the S-R relationship of this stock. Regarding the optimization method, the small-sample-size-corrected version of Akaike information criterion (AICc) is smaller with the least squares method compared with the least absolute value method (Table A-1). The trend of residuals over time and autocorrelation plot of the HS model (Figure A-2) are the same as those before the update (Yamashita et al. 2019). Yamashita et al (2019) found significant autocorrelation in residuals, but concluded that the significance of the autocorrelation coefficient greatly depended on the estimates of recruitment and spawning biomass before the 1988 year class and that autocorrelation was not found in residuals of the 1989 year class and after. For this reason, we did not consider the autocorrelation of residuals in this updating of the S-R relationship either.

3. Proposed target reference point / limit reference point / fishing ban

At the Research Institute Meeting on Reference Points in 2019, we proposed for this stock: SBmsy, which is the spawning biomass that produces the maximum sustainable yield (MSY) for the target reference point (SBtarget); SB0.6msy, which is the spawning biomass that produces 60% of MSY for the limit reference point (SBlimit); and SB0.1msy, which produces 10% of MSY for the fishing ban (SBban) level. The results of updating these values using the 2020 stock assessment result are shown in the table below and Table A-2.

Proposal	Item	Value	Remarks
Proposal by the Research Institute Meeting (2019)	Proposed target reference point (SBtarget)	382 thousand tons	Spawning biomass that produces MSY (SBmsy)
	Proposed limit reference point (SBlimit)	171 thousand tons	Spawning biomass that produces 60% of MSY (SB0.6msy)
	Proposed fishing ban (SBban)	25 thousand tons	Spawning biomass that produces 10% of MSY (SB0.1msy)

Updated value	Proposed SBtarget	380 thousand tons	Spawning biomass that produces MSY (SBmsy)
	Proposed SBlimit	171 thousand tons	Spawning biomass that produces 60% of MSY (SB0.6msy)
	Proposed SBban	25 thousand tons	Spawning biomass that produces 10% of MSY (SB0.1msy)

We calculated SBmsy to be proposed as the target reference point with assumption of the proposal by the 2019 Research Institute Meeting: namely assuming equilibrium after the simulation period that is 50 times the average generation time (8.19 years) and setting as Fmsy the F value at which the average catch at equilibrium is maximized and setting as SBmsy the average spawning biomass at equilibrium when fishing is conducted at the Fmsy. For the simulation, we used the S-R relationship updated based on the results of the 2020 stock assessment (as mentioned above). The selectivity we used is based on the average F value at age in the 2013-2019 fishing seasons. The selectivity used in the Research Institute Meeting proposal in 2019 was based on the average F value at age of the latest five years at the time, namely the 2013-2017 fishing seasons. The latest five years of this update are the 2015-2019 fishing seasons. The selectivity based on the average F value at age of the 2015-2019 fishing seasons (Table A-3) is particularly low for fish of age 7. However, considering the fishing condition of this stock, it is difficult to imagine that the big difference in F depending on age would continue in the future. In addition, the selectivity varies greatly from the selectivity used in the Research Institute Meeting proposal in 2019 (Table A-3). For these reasons, for this update we decided to use the selectivity based on the average F value at age in the 2013-2019 fishing seasons by adding the data of the succeeding two years to the data used for the proposal by the Research Institute Meeting. As current fishing mortality (F2015-2019*), we used the %SPR-converted F value that puts the same fishing mortality as that of the average F value at age in the 2015-2019 fishing seasons under this selectivity. For the average body weight of the catch, we used the average of the 2015-2019 fishing seasons. The settings of other biological parameters used for the simulation are shown in Table A-4.

Average spawning biomass at equilibrium when F is changed variously and the corresponding average catch at age are shown in Figure A-4.

The updated value of SBmsy that maximizes the average catch is 380 thousand tons, which is almost the same value as that of the proposal by the 2019 Research Institute Meeting. The updated proposed limit reference point (SB0.6msy) and fishing ban level (SB0.1msy) are spawning biomass of 171 thousand tons and 25 thousand tons, respectively, which are almost the same as those of the 2019 Research Institute Meeting proposal.

4. Kobe plot

The updated proposed target reference point (SBmsy) and Kobe plot based on the corresponding fishing mortality (Fmsy) or exploitation rate (Umsy) are shown in Figure A-5. Fishing mortality (F) of this stock is judged to have been below the fishing mortality that produces MSY in the 2017 and 2019

fishing seasons. Exploitation rate (U) is judged to have been under the level that produces MSY in the 2017 and 2019 fishing seasons and after. Spawning biomass has been below the proposed target reference point (SBmsy) for the whole period.

5. Proposed HCRs

The HCRs are rules to set the fishing mortality (F) corresponding to the spawning biomass, etc. considering the probability of maintaining or recovering the spawning biomass above the proposed target reference point. The HCRs set for the first group of stocks of the "Basic Guidelines for the Harvest Control Rules and the Estimation of the Allowable Biological Catch (ABC)" presents a rule to lower the fishing mortality directly to the proposed fishing ban level when the spawning biomass has fallen below the proposed limit reference point, while multiplying the Fmsy that is the upper limit of fishing mortality by safety coefficient β. Figure A-6 shows an example where safety coefficient β is set to 0.8.

6. Future projection

(1) Setting of future projection

We updated the future projection results by using the updated S-R relationship and the proposed HCRs. For future projection, we advanced cohort calculation from the abundance of the 2019 fishing season estimated by the 2020 stock assessment to the 2020-2051 fishing seasons. Recruitment for the future projection is given from the S-R relationship where values projected based on the spawning biomass of the respective year are updated. We assumed errors in logarithmic normal distribution as the uncertainty of recruitment, and repeated calculation 10,000 times. However, the recruitments of the 2020 fishing season (2018 year class) and 2021 fishing season (2019 year class) have high recruitment index values surveyed by research ships and estimated values of standing stock of fish of age 0 and 1, respectively. The recruitment is considered to be greatly larger than the recruitment estimated based on the spawning biomass using the S-R relationship. For this reason, we adopted the value of the recruitment of the 2014 fishing season (2012 year class) as the recruitment of the 2020 fishing season (2018 year class), and the average of the recruitments of the 2008 fishing season (2006 year class) and the 2014 fishing season (2012 year class) as the recruitment of the 2021 fishing season (2019 year class). For details, see Appendix 8 of the 2020 stock assessment. We set the catch of the 2020 fishing season to 6.7 thousand tons, which is the TAC quantity. As current fishing mortality (F2015-2019*), we used the value for the calculation of the proposed reference points. As fishing mortality in the 2021 fishing season and after, we used the fishing mortality provided by the proposed HCRs based on the spawning biomass projected for the respective fishing year. For mathematical equations used for the calculation, see Appendix 9 of the 2020 stock assessment.

(2) Predicted values of the 2021 fishing season

Spawning biomass predicted in the 2021 fishing season is below the limit reference point in all repeat calculations and projected to be 121 thousand tons on average. For this reason and because the spawning biomass is below the fishing mortality of the limit reference point, the fishing mortality of

the 2021 fishing season is calculated by multiplying by the coefficient corresponding to the spawning biomass: γ(SBt) × βFmsy. Here, γ(SBt) of the 2021 fishing season was calculated as 0.66 with the equation below based on the HCRs set for the first group of stocks of the "Basic Guidelines for the Harvest Control Rules and the Estimation of the Allowable Biological Catch (ABC)"

$$\gamma(SB_t) = \frac{SB_t - SB_{ban}}{SB_{limit} - SB_{ban}}$$

Average catch of the 2021 fishing season as calculated based on the updated proposed HCRs is 8.8 thousand tons when β is set to 1.0, while it is 7.1 thousand tons when β is set to 0.8.

Spawning biomass in the 2021 fishing season (average projection value): 121 thousand tons			
Item	Catch in the 2021 fishing season (thousand tons)	Ratio to the current fishing mortality (F/F2015-2019)	Exploitation rate in the 2021 fishing season (%)
Other strategy (when using different β in the proposed HCRs)			
β=1.0	8.8	0.67	4
β=0.8	7.1	0.53	3
β=0.6	5.3	0.40	3
β=0.4	3.6	0.27	2
β=0.2	1.8	0.13	1
β=0	0	0	0
F2015-2019*	12.9	1.00	6

Selectivity of F2015-2019* is different from the selectivity in the 2020 Stock Assessment Report (F2015-2019). F2015-2019 is obtained by %SPR-conversion of the F value that gives the fishing mortality of the average F value at age of the 2015-2019 fishing seasons under the selectivity used for the calculation of MSY reference points at the 2019 Research Institute Meeting. F2015-2019* is obtained by %SPR-conversion of the F value that gives the fishing mortality of the average F value at age of the 2015-2019 fishing seasons under the selectivity used for this update of MSY reference points.

(3) Estimated values for the 2022 fishing season and after

Results of the medium- to long-term future projection based on the updated HCR proposal are shown in Figure A-7, Tables A-5 and A-6. When control based on the proposed HCRs is continued for 10 years, predicted spawning biomass of the 2031 fishing season is 182 thousand tons on average (80% confidence interval: 117 thousand to 265 thousand tons) with β set to 1.0, and 199 thousand tons (80% confidence interval: 127 thousand to 292 thousand tons) with β set to 0.8. However, even when β is set to 0, spawning biomass is 309 thousand tons on average (80% confidence interval: 195 thousand to 449 thousand tons) and the probability that the prediction value will exceed the proposed target reference point is 20%. The probability of exceeding the proposed limit reference point is 46% with β

set to 1.0 and 57% with β set to 0.8. The probability of exceeding the proposed fishing ban level is 100% for all proposed HCRs.

When control based on the proposed HCRs is continued, the spawning biomass will exceed the proposed target reference point with the probability of 50% or higher after 2051 fishing season with β set to 1.0 or 0.8 and if fishing is continued with the current fishing mortality (F2015-2019*). The fishing year of exceeding the limit reference point with the probability of 50% or higher is predicted to be before the 2030 fishing season if β is set to 0 to 0.8. Even when fishing mortality is zero (β = 0), it is predicted that spawning biomass will exceed the proposed target reference point with the probability of 50% or higher in the 2035 fishing season.

Uncertainty considered: recruitment					
Item	Spawning biomass in the 2031 fishing season (thousand tons)	80% confidence interval (thousand tons)	Probability for spawning biomass to exceed the reference points in the 2031 fishing season		
			Proposed SBtarget	Proposed SBlimit	Proposed SBban
Other strategy (when using different β in the proposed HCRs)					
β=1.0	182	117 – 265	2	46	100
β=0.8	199	127 – 292	3	57	100
β=0.6	219	138 – 322	4	69	100
β=0.4	244	153 – 358	7	81	100
β=0.2	273	171 – 400	12	90	100
β=0	309	195 – 449	20	96	100
F2015-2019*	163	97 – 246	1	35	100

Uncertainty considered: recruitment			
	Fishing year for spawning biomass to exceed the reference points with the probability of 50% or higher		
	Proposed SBtarget	Proposed SBlimit	Proposed SBban
Other strategy (when using different β in the proposed HCRs)			
β=1.0	After 2051 fishing season	2033 fishing season	2019 fishing season
β=0.8	After 2051 fishing season	2030 fishing season	2019 fishing season
β=0.6	2047 fishing season	2029 fishing season	2019 fishing season
β=0.4	2041 fishing season	2027 fishing season	2019 fishing season
β=0.2	2038 fishing season	2026 fishing season	2019 fishing season
β=0	2035 fishing season	2025 fishing season	2019 fishing season
F2015-2019*	After 2051 fishing season	2037 fishing season	2019 fishing season

References

Yamashita, Y., O. Sakai, M. Chimura, M. Ishino (2019) Report of the Research Institute Meeting on Reference Points for the walleye pollock Northern Sea of Japan stock in 2019. http://www.fra.affrc.go.jp/shigen_hyoka/SCmeeting/2019-1/detail_suketou_n.pdf

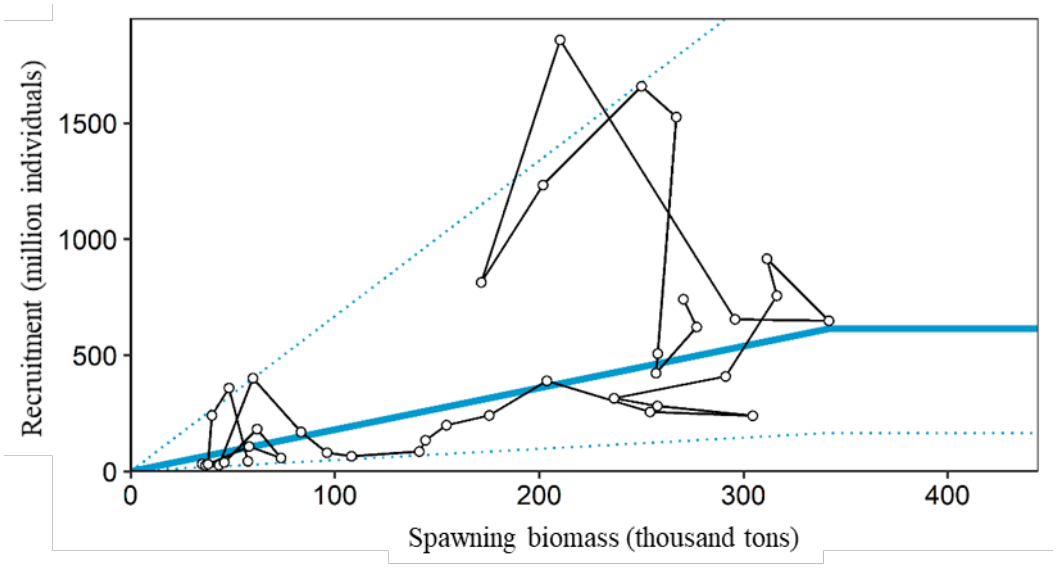


Figure A-1. Updated S-R relationships (relationship between spawning biomass and recruitment)
The blue line expresses the HS S-R relationship as estimated based on the recruitment and spawning biomass of the 1980-2017 year class, which are estimated in the 2020 stock assessment. The dotted lines show the range supposed to include 90% of spawning biomass and recruitment.

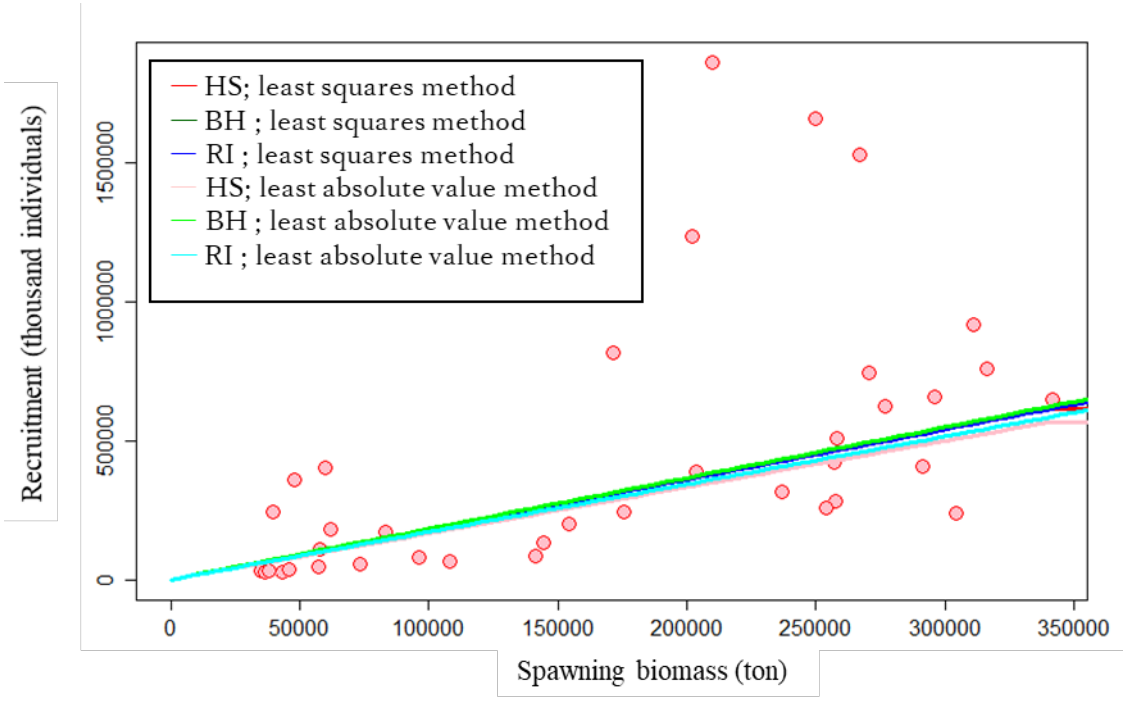


Figure A-2. Comparison of the S-R relationships
HS, Ricker RI and BH S-R relationships are applied using the least squares method and the least absolute value method. For the parameters of the relationships, see Table A-1.

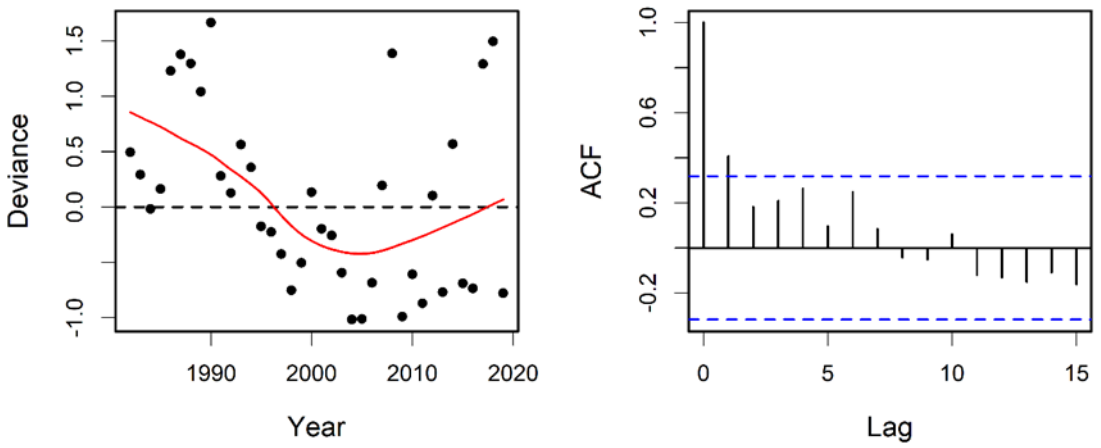


Figure A-3. Residual trend in the HS S-R relationship and autocorrelation plot

Based on the results when the HS S-R relationship is applied using the least squares method. The blue dashed lines in the right figure of autocorrelation plot express the 95% confidence interval.

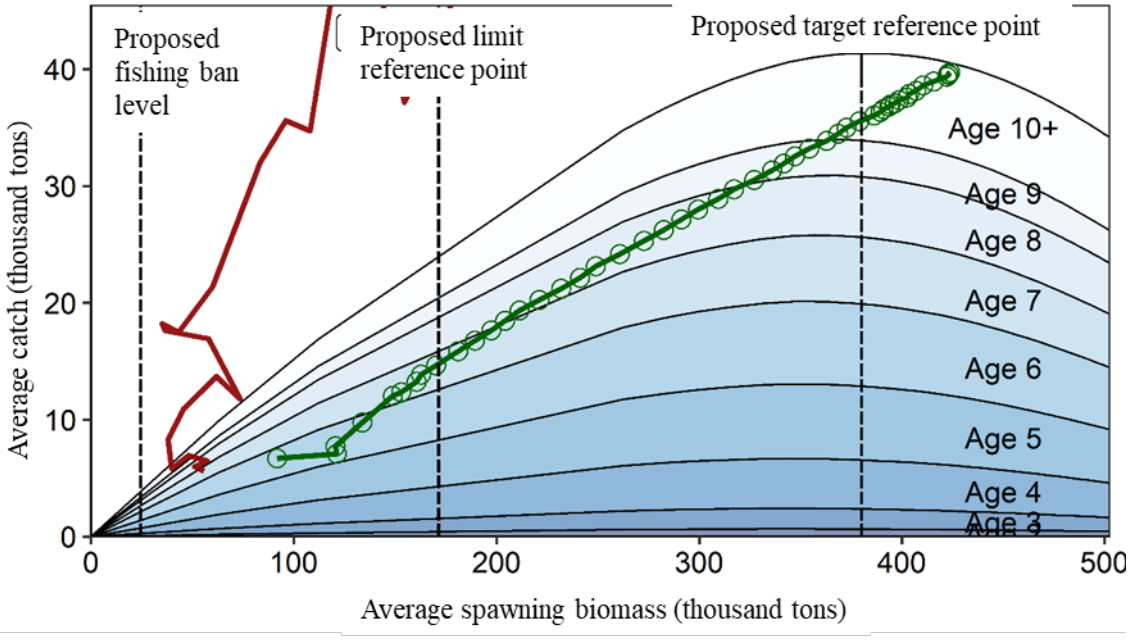
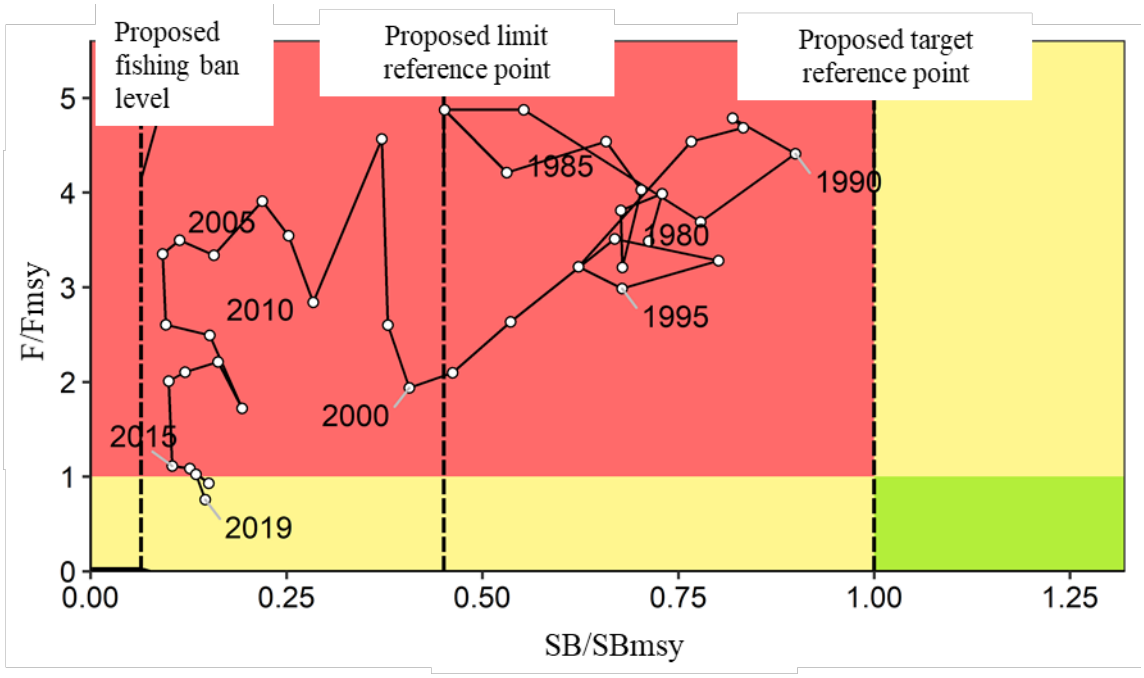


Figure A-4. Relationship between the proposed reference points and curves of catch at age

The figure shows the average catch at age corresponding to the spawning biomass, and the relationship between each of the proposed reference points at equilibrium in the future projection simulation. The red line represents the relationship between the spawning biomass and catch, which are estimated by the stock assessment, while the green line represents changes in the average spawning biomass and average catch in the future projection when fishing is conducted based on the proposed HCRs ($\beta = 0.8$) under the proposed reference points.

a) When the vertical axis is the ratio of Fmsy to the fishing mortality of each year



b) When the vertical axis is the ratio of Umsy to the exploitation rate of each year

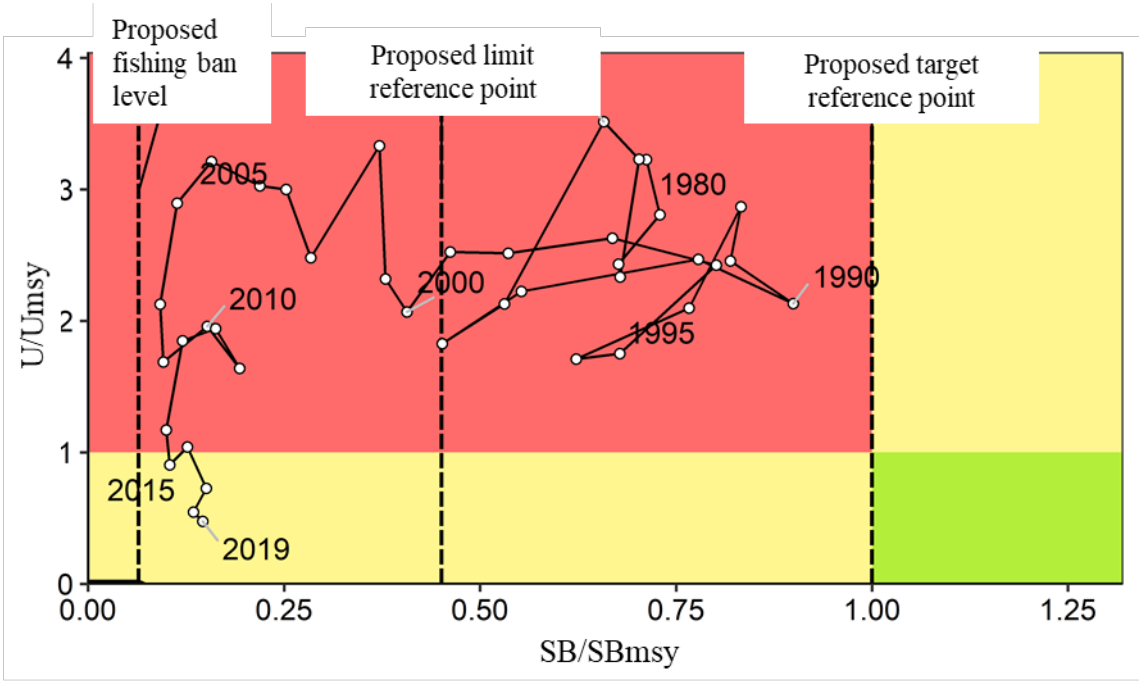
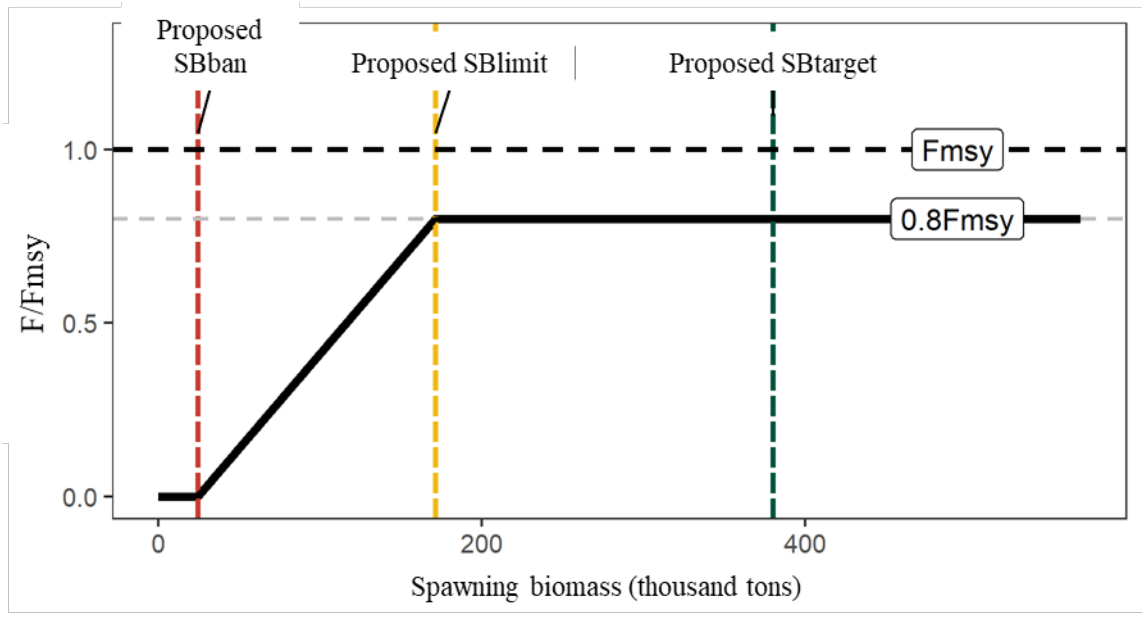


Figure A-5. Kobe plot based on the reference points concerning the updated MSY

The upper chart (Figure 4a) shows the relationship of spawning biomass and fishing mortality (F) with the spawning biomass that produces MSY (SBmsy) and the fishing mortality that produces MSY (Fmsy). The lower chart (Figure 4b) shows the relationship when exploitation rate (U) is used instead of F value.

a)



b)

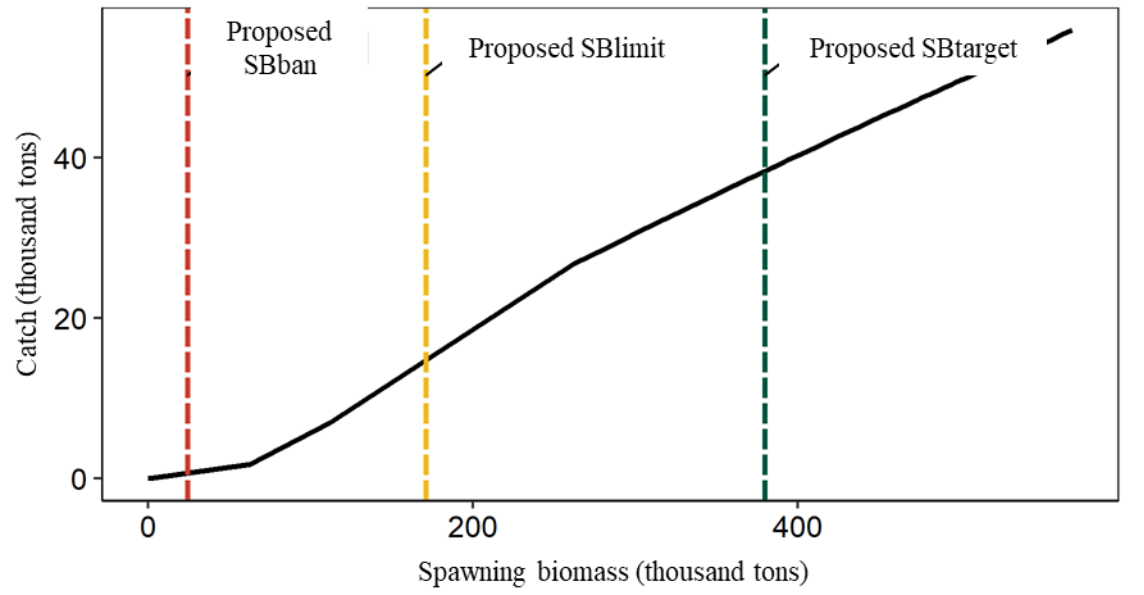


Figure A-6. Proposed HCRs (when β is 0.8)

The black dashed line represents Fmsy; the grey dashed line represents 0.8Fmsy; the black thick line represents the proposed HCRs; the red dashed line represents the proposed fishing ban level (SBban); the yellow dashed line represents the proposed limit reference point (SBlimit); and the green dashed line represents the proposed target reference point (SBtarget). The upper chart (a) expresses a schematic diagram of the proposed HCRs where fishing mortality is put to the vertical axis. The lower chart (b) where the catch is put to the vertical axis shows the catch that is expected based on the proposed HCRs under the respective spawning biomass.

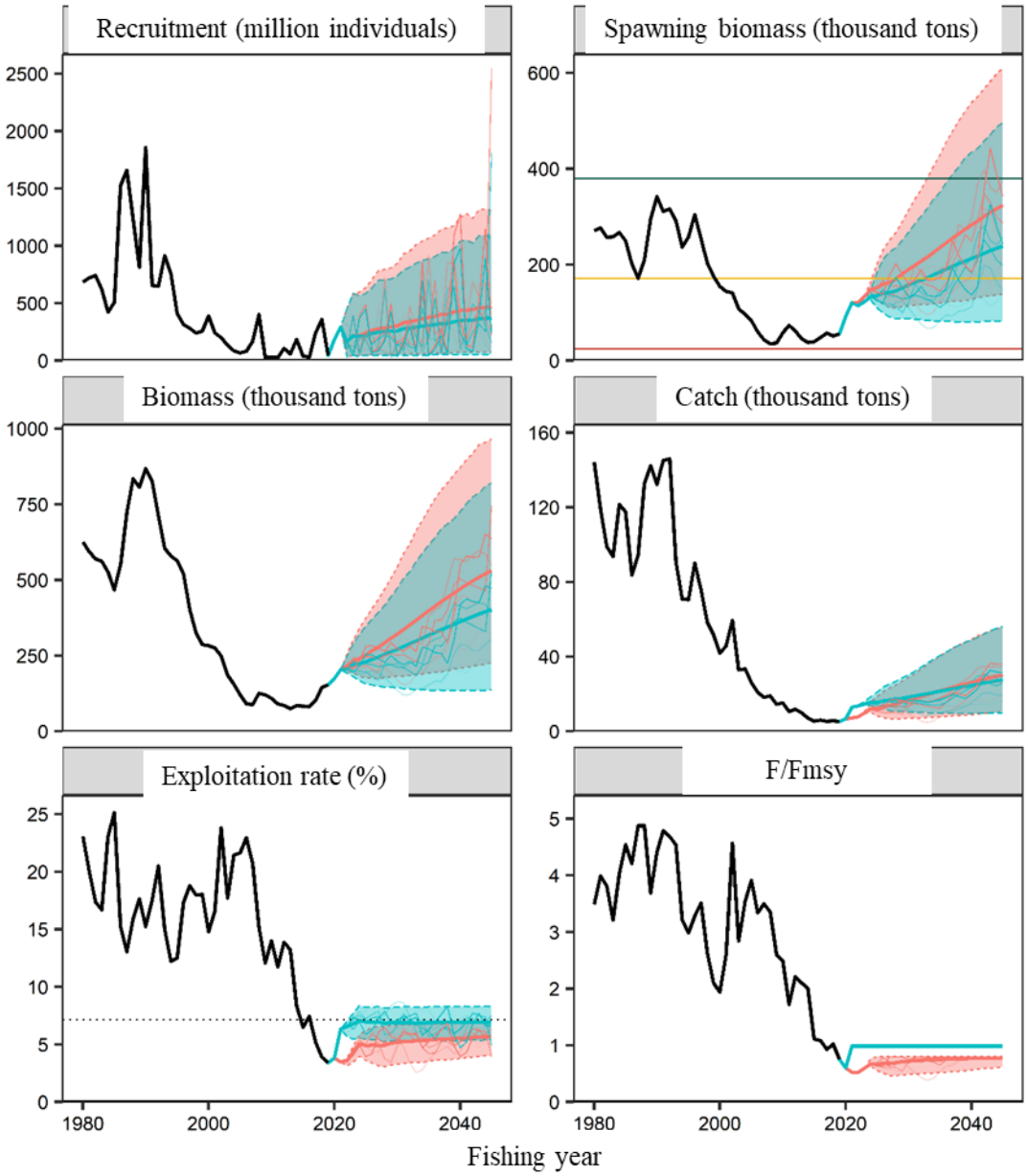


Figure A-7. Future projection based on the proposed HCRs (in red) and the future projection that assumes continued fishing at the current fishing mortality level (in blue)

The thick solid line, shaded area and thin lines represent average value, the 90% prediction interval that includes 90% of the simulation results, and three future projection examples, respectively. In the figure of spawning biomass, the green dashed line represents the proposed target reference point, the yellow dotted line represents the proposed limit reference point and the red line shows the proposed fishing ban level. The dashed line in the figure of exploitation rate shows Umsy. The figure shows the results of the proposed HCRs with β set to 0.8. The recruitment of the 2020 fishing season is set to the value of the recruitment of the 2014 fishing season. The recruitment of the 2021 fishing season is set to the average of the recruitments of the 2008 fishing season and the 2014 fishing season. The catch of the 2020 fishing season is set to TAC (6.7 thousand tons).

Table A-1. Examination results of S-R relationships

S-R relationship	Optimization method	Auto correlation	a	b	S.D.	AICc	Data quantity
Hockey stick	**Least squares method**	**None**	**1.797**	**341,743**	**0.799**	**97.5**	**38**
Ricker	Least squares method	None	1.797	1.58×10^{-13}	0.799	97.5	38
Beverton-Holt	Least squares method	None	1.797	2.77×10^{-13}	0.799	97.5	38
Hockey stick	Least absolute value method	None	1.661	341,743	0.803	104.7	38
Ricker	Least absolute value method	None	1.715	5.90×10^{-23}	0.801	104.7	38
Beverton-Holt	Least absolute value method	None	1.826	1.09×10^{-22}	0.799	104.7	38

The recommended S-R relationship is indicated in bold face. S.D. is an index expressing magnitude of dispersion of recruitment, which is the standard deviation of log residuals (square root of mean square error).

Table A-2. Average spawning biomass at equilibrium of the respective proposed reference points; ratio to the initial spawning biomass assuming no catch (SB0); average catch; %SPR-converted fishing mortality; exploitation rate; proportional connection of fishing effort to F2015-2019* (Note 1); and fishing mortality at age at the fishing mortality that produces MSY (Fmsy)

Item	Explanation	Spawning biomass (thousand tons)	Ratio to SB0	Catch (thousand tons)	Fishing mortality (%SPR)	Exploitation rate	Ratio of the fishing effort
Proposed target reference point	Spawning biomass that produces MSY (SBmsy)	380	0.53	44	60	0.07	1.01
Proposed limit reference point	Spawning biomass that produces 60% of MSY (SB0.6msy)	171	0.24	27	52	0.09	1.36
Proposed fishing ban level	Spawning biomass that produces 10% of MSY (SB0.1msy)	25	0.03	4	48	0.10	1.58
Fishing mortality that produces MSY (Fmsy)	(Ages 2, 3, 4, 5, 6, 7, 8, 9 and 10+) = (0.02, 0.03, 0.07, 0.11, 0.13, 0.14, 0.15, 0.13, 0.13)						

Note 1: Value obtained by %SPR-conversion of the F value that gives the same fishing mortality as the average F value at age of the 2015-2019 fishing seasons under the selectivity of the average F of the 2013-2019 fishing seasons based on the 2020 stock assessment

Table A-3. Selectivity

Age	Average of the 2013-2019 fishing seasons (Note 1)	Average of the 2015-2019 fishing seasons	Average of the 2013-2017 fishing seasons (Note 2)
2	0.14	0.12	0.18
3	0.26	0.24	0.36
4	0.51	0.50	0.60
5	0.81	0.75	0.81
6	0.99	0.63	1.15
7	1.05	0.48	1.24
8	1.18	1.13	1.31
9	1.00	1.00	1.00
10	1.00	1.00	1.00

Note 1: Selectivity used for this update of MSY reference points and future projection

Note 2: Selectivity used for calculation of MSY reference points in the proposal by the Research Institute Meeting in 2019

Table A-4. Parameters used for MSY reference point calculation and future projection

Age	Natural mortality	Maturity rate	Average weight of stock (g)	Average weight of catch (g) (Note 1)	Selectivity (Note 2)	F2015-2019* (Note 3)
2	0.30	0.00	134	98	0.14	0.02
3	0.25	0.00	229	187	0.26	0.03
4	0.25	0.31	326	284	0.51	0.07
5	0.25	0.89	425	380	0.81	0.10
6	0.25	0.99	485	455	0.99	0.13
7	0.25	1.00	545	505	1.05	0.14
8	0.25	1.00	570	574	1.18	0.15
9	0.25	1.00	578	605	1.00	0.13
10+	0.25	1.00	688	680	1.00	0.13

Note 1: Average body weight of catch of the 2015-2019 fishing seasons

Note 2: Selectivity of the average F of the 2013-2019 fishing seasons based on the 2020 stock assessment

Note 3: Value obtained by %SPR-conversion of the F value that gives the same fishing mortality as the average F value at age of the 2015-2019 fishing seasons under the selectivity of Note 2

Table A-5. Probability for spawning biomass to exceed the proposed target reference point (a) and the proposed limit reference point (b)

The catch of the 2020 fishing season is TAC (6.7 thousand tons) while the catch of the 2021 fishing season and after is based on the proposed HCRs.

(a) Probability for spawning biomass to exceed the proposed target reference point

(%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	0	1	1	2	12	24
0.9	0	0	0	0	0	0	0	0	0	0	1	1	2	16	31
0.8	0	0	0	0	0	0	0	0	0	1	1	2	3	21	39
0.7	0	0	0	0	0	0	0	0	0	1	1	2	3	27	49
0.6	0	0	0	0	0	0	0	0	0	1	2	3	4	35	59
0.5	0	0	0	0	0	0	0	0	1	1	2	4	6	43	69
0.4	0	0	0	0	0	0	0	0	1	1	3	5	7	53	78
0.3	0	0	0	0	0	0	0	0	1	2	3	6	10	61	86
0.2	0	0	0	0	0	0	0	0	1	2	4	8	12	70	91
0.1	0	0	0	0	0	0	0	1	1	3	6	10	16	78	96
0	0	0	0	0	0	0	0	1	2	3	7	13	20	86	98

(b) Probability for spawning biomass to exceed the proposed limit reference point

(%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	2	12	22	25	31	37	43	46	70	82
0.9	0	0	0	0	0	2	14	24	28	35	42	48	51	76	87
0.8	0	0	0	0	0	3	16	28	32	39	48	53	57	82	92
0.7	0	0	0	0	0	3	18	31	36	44	53	59	63	87	95
0.6	0	0	0	0	0	4	21	35	41	49	59	65	69	91	97
0.5	0	0	0	0	0	6	25	39	46	55	65	71	75	94	99
0.4	0	0	0	0	0	7	29	45	52	61	71	76	81	97	99
0.3	0	0	0	0	0	10	35	50	57	67	77	82	86	98	100
0.2	0	0	0	0	0	14	42	58	64	73	82	87	90	99	100
0.1	0	0	0	0	0	21	50	66	70	79	87	91	93	100	100
0	0	0	0	0	0	32	60	73	78	85	91	94	96	100	100

Table A-6. Changes in future average spawning biomass (a) and future average catch (b)
The catch of the 2020 fishing season is TAC (6.7 thousand tons) while the catch of the 2021 fishing season and after is based on the proposed HCRs.

(a) Average spawning biomass

(Thousand tons)
(千トン)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	56	92	121	119	131	144	146	152	154	160	168	175	182	246	299
0.9	56	92	121	120	132	146	149	156	158	165	174	182	190	267	330
0.8	56	92	121	120	134	149	152	159	163	170	181	190	199	291	364
0.7	56	92	121	121	135	151	155	163	168	176	188	198	209	318	399
0.6	56	92	121	122	137	154	159	168	173	182	196	208	219	347	437
0.5	56	92	121	123	139	156	162	172	178	189	204	217	231	380	477
0.4	56	92	121	124	140	159	166	177	184	197	213	228	244	415	518
0.3	56	92	121	125	142	162	170	182	191	204	223	240	258	454	560
0.2	56	92	121	126	144	165	174	188	198	213	233	253	273	496	603
0.1	56	92	121	127	146	168	179	194	205	222	245	267	290	541	648
0	56	92	121	127	148	171	184	200	213	232	257	282	309	589	695

(b) Average catch

(Thousand tons)
(千トン)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	8.8	9.3	11.5	13.9	14.1	15.0	15.6	16.4	17.7	18.6	19.5	28.0	34.4
0.9	5.2	6.7	7.9	8.5	10.7	13.0	13.2	14.2	14.8	15.6	16.9	17.8	18.7	27.7	34.5
0.8	5.2	6.7	7.1	7.7	9.8	12.0	12.2	13.2	13.8	14.6	15.9	16.8	17.8	27.1	34.0
0.7	5.2	6.7	6.2	6.9	8.8	10.9	11.2	12.1	12.7	13.5	14.7	15.7	16.6	26.1	32.9
0.6	5.2	6.7	5.3	6.0	7.8	9.7	10.0	10.9	11.5	12.2	13.4	14.3	15.2	24.7	31.0
0.5	5.2	6.7	4.5	5.1	6.7	8.4	8.7	9.5	10.1	10.8	11.8	12.7	13.5	22.6	28.3
0.4	5.2	6.7	3.6	4.2	5.5	7.0	7.3	8.0	8.5	9.1	10.0	10.8	11.6	19.9	24.7
0.3	5.2	6.7	2.7	3.2	4.3	5.5	5.7	6.3	6.7	7.2	7.9	8.6	9.3	16.4	20.1
0.2	5.2	6.7	1.8	2.2	2.9	3.8	4.0	4.4	4.7	5.1	5.6	6.1	6.6	12.0	14.5
0.1	5.2	6.7	0.9	1.1	1.5	2.0	2.1	2.3	2.5	2.7	3.0	3.2	3.5	6.5	7.8
0	5.2	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0

Examination Item B

Regarding walleye pollock Northern Sea of Japan stock, do trial calculations of the probability of exceeding the proposed reference points for each of the five years from the 2021 fishing season, where catch is fixed at 7,000 tons, 8,000 tons, 9,000 tons or 10,000 tons, with varying β in 0.1 intervals within the range of 0 to 1.0.

1. Introduction

In response to the request, we made future projection by using the S-R relationships, the proposed reference points, the proposed fishing ban level and the proposed HCRs, which were updated in response to Examination Item A.

2. Results of the calculation

Results of the trial calculation are shown in Tables B-1 to B-4. When the amount of catch that is fixed for the five years from the 2021 fishing season is increased, the probability that the spawning biomass will exceed the proposed target reference point and limit reference point decrease.

The probability that the estimated spawning biomass of the 2031 fishing season will exceed the proposed target reference point is 9 to 12% when β is set to 0. The probability of exceeding the proposed limit reference point is 48 to 55% when β is set to 1.0, and 56-62% when β is set to 0.8. The probability of exceeding the fishing ban level is 100% for all values of catch fixed for the five years and all proposed HCRs.

Remarks

The 2020 Stock Assessment Report of walleye pollock Northern Sea of Japan stock includes future projection results based on the S-R relationships, reference points, etc. which were proposed at the 2019 Research Institute Meeting. In order to avoid confusion, we wish to add the content of Examination Items A and B to the appendix of the said Stock Assessment Report.

Table B-1. Probability for spawning biomass to exceed the proposed reference points when the catch of the five years from the 2021 fishing season is fixed at 7,000 tons and β is changed in 0.1 intervals within the range of 0 to 1.0

The catch of the 2020 fishing season is TAC (6.7 thousand tons) while the catch of the 2026 fishing season and after is based on the proposed HCRs.

(a) Probability for spawning biomass to exceed the proposed target reference point

(%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	1	1	2	3	15	26
0.9	0	0	0	0	0	0	0	0	0	1	1	2	3	19	33
0.8	0	0	0	0	0	0	0	0	0	1	1	2	3	23	41
0.7	0	0	0	0	0	0	0	0	1	1	1	3	4	29	50
0.6	0	0	0	0	0	0	0	0	1	1	2	3	5	36	59
0.5	0	0	0	0	0	0	0	0	1	1	2	4	6	43	69
0.4	0	0	0	0	0	0	0	0	1	1	2	4	6	50	77
0.3	0	0	0	0	0	0	0	0	1	1	2	5	8	57	84
0.2	0	0	0	0	0	0	0	0	1	1	3	5	9	65	90
0.1	0	0	0	0	0	0	0	0	1	2	3	6	11	72	94
0	0	0	0	0	0	0	0	0	1	2	4	7	12	78	97

(b) Probability for spawning biomass to exceed the proposed limit reference point

(%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	4	23	39	38	40	47	51	55	74	84
0.9	0	0	0	0	0	4	23	39	39	43	50	55	59	79	89
0.8	0	0	0	0	0	4	23	39	40	45	53	59	62	84	92
0.7	0	0	0	0	0	4	23	39	42	48	56	62	66	88	95
0.6	0	0	0	0	0	4	23	39	44	50	60	65	70	91	97
0.5	0	0	0	0	0	4	23	39	45	53	63	69	73	94	99
0.4	0	0	0	0	0	4	23	39	47	56	67	72	77	96	99
0.3	0	0	0	0	0	4	23	39	48	59	70	76	81	98	100
0.2	0	0	0	0	0	4	23	39	50	62	73	79	84	99	100
0.1	0	0	0	0	0	4	23	39	52	64	76	82	86	99	100
0	0	0	0	0	0	4	23	39	53	67	79	85	89	100	100

Table B-1 (continued). Changes in the average of future spawning biomass (c) and catch (d) when the catch of the five years from the 2021 fishing season is fixed at 7,000 tons and β is changed in 0.1 intervals within the range of 0 to 1.0

The catch of the 2020 fishing season is TAC (6.7 thousand tons) while the catch of the 2026 fishing season and after is based on the proposed HCRs.

Average spawning biomass

(Thousand tons)

(千トン)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	56	92	121	121	135	152	160	172	169	172	179	188	197	260	310
0.9	56	92	121	121	135	152	160	172	171	175	183	193	202	280	339
0.8	56	92	121	121	135	152	160	172	172	178	188	198	208	301	370
0.7	56	92	121	121	135	152	160	172	174	181	192	203	215	324	403
0.6	56	92	121	121	135	152	160	172	176	184	196	209	222	349	438
0.5	56	92	121	121	135	152	160	172	178	187	201	215	229	377	475
0.4	56	92	121	121	135	152	160	172	179	191	206	221	236	406	513
0.3	56	92	121	121	135	152	160	172	181	194	211	227	244	438	553
0.2	56	92	121	121	135	152	160	172	183	198	216	234	253	473	595
0.1	56	92	121	121	135	152	160	172	185	201	222	241	262	510	639
0	56	92	121	121	135	152	160	172	187	205	227	249	271	550	685

(c) Average catch

(Thousand tons)

(千トン)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	7.0	7.0	7.0	7.0	7.0	18.3	18.1	18.4	19.5	20.5	21.6	29.7	35.7
0.9	5.2	6.7	7.0	7.0	7.0	7.0	7.0	16.6	16.6	17.0	18.2	19.2	20.3	29.1	35.4
0.8	5.2	6.7	7.0	7.0	7.0	7.0	7.0	14.8	15.0	15.6	16.8	17.8	18.8	28.1	34.6
0.7	5.2	6.7	7.0	7.0	7.0	7.0	7.0	13.0	13.4	14.0	15.2	16.1	17.2	26.7	33.2
0.6	5.2	6.7	7.0	7.0	7.0	7.0	7.0	11.2	11.7	12.4	13.5	14.4	15.4	24.8	31.1
0.5	5.2	6.7	7.0	7.0	7.0	7.0	7.0	9.4	10.0	10.6	11.6	12.5	13.4	22.4	28.2
0.4	5.2	6.7	7.0	7.0	7.0	7.0	7.0	7.6	8.1	8.7	9.6	10.4	11.2	19.5	24.4
0.3	5.2	6.7	7.0	7.0	7.0	7.0	7.0	5.7	6.2	6.7	7.5	8.1	8.7	15.8	19.8
0.2	5.2	6.7	7.0	7.0	7.0	7.0	7.0	3.8	4.2	4.6	5.1	5.6	6.1	11.4	14.3
0.1	5.2	6.7	7.0	7.0	7.0	7.0	7.0	1.9	2.2	2.4	2.7	2.9	3.2	6.2	7.7
0	5.2	6.7	7.0	7.0	7.0	7.0	7.0	0	0	0	0	0	0	0	0

Table B-2. Probability for spawning biomass to exceed the proposed reference points when the catch of the five years from the 2021 fishing season is fixed at 8,000 tons and β is changed in 0.1 intervals within the range of 0 to 1.0

The catch of the 2020 fishing season is TAC (6.7 thousand tons) while the catch of the 2026 fishing season and after is based on the proposed HCRs.

(a) Probability for spawning biomass to exceed the proposed target reference point

(%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	1	1	2	3	14	26
0.9	0	0	0	0	0	0	0	0	0	1	1	2	3	18	33
0.8	0	0	0	0	0	0	0	0	0	1	1	2	3	23	40
0.7	0	0	0	0	0	0	0	0	0	1	1	2	4	28	49
0.6	0	0	0	0	0	0	0	0	0	1	1	3	4	34	58
0.5	0	0	0	0	0	0	0	0	1	1	2	3	5	41	68
0.4	0	0	0	0	0	0	0	0	1	1	2	4	6	49	77
0.3	0	0	0	0	0	0	0	0	1	1	2	4	7	56	84
0.2	0	0	0	0	0	0	0	0	1	1	3	5	8	63	90
0.1	0	0	0	0	0	0	0	0	1	1	3	6	10	71	94
0	0	0	0	0	0	0	0	0	1	2	4	7	11	77	97

(b) Probability for spawning biomass to exceed the proposed limit reference point

(%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	3	20	35	35	38	44	49	53	73	84
0.9	0	0	0	0	0	3	20	35	36	40	48	52	57	78	88
0.8	0	0	0	0	0	3	20	35	38	43	51	56	60	83	92
0.7	0	0	0	0	0	3	20	35	39	45	54	60	64	87	95
0.6	0	0	0	0	0	3	20	35	40	48	57	63	68	91	97
0.5	0	0	0	0	0	3	20	35	42	50	61	67	71	93	98
0.4	0	0	0	0	0	3	20	35	44	53	64	70	75	96	99
0.3	0	0	0	0	0	3	20	35	45	56	67	74	79	97	100
0.2	0	0	0	0	0	3	20	35	47	59	71	77	82	98	100
0.1	0	0	0	0	0	3	20	35	48	62	74	80	85	99	100
0	0	0	0	0	0	3	20	35	50	64	77	83	87	100	100

Table B-2 (continued). Changes in the average of future spawning biomass (c) and catch (d) when the catch of the five years from the 2021 fishing season is fixed at 8,000 tons and β is changed in 0.1 intervals within the range of 0 to 1.0

The catch of the 2020 fishing season is TAC (6.7 thousand tons) while the catch of the 2026 fishing season and after is based on the proposed HCRs.

(c) Average spawning biomass

(Thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	56	92	121	120	133	149	157	168	166	169	177	185	193	257	307
0.9	56	92	121	120	133	149	157	168	167	172	180	190	199	276	336
0.8	56	92	121	120	133	149	157	168	169	175	184	194	205	297	367
0.7	56	92	121	120	133	149	157	168	171	178	189	200	211	320	400
0.6	56	92	121	120	133	149	157	168	172	181	193	205	217	344	435
0.5	56	92	121	120	133	149	157	168	174	184	198	211	224	371	472
0.4	56	92	121	120	133	149	157	168	176	187	202	217	232	401	511
0.3	56	92	121	120	133	149	157	168	177	191	207	223	240	433	551
0.2	56	92	121	120	133	149	157	168	179	194	212	230	248	467	593
0.1	56	92	121	120	133	149	157	168	181	198	218	237	257	504	636
0	56	92	121	120	133	149	157	168	183	201	223	244	266	543	683

(d) Average catch

(Thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	8.0	8.0	8.0	8.0	8.0	17.6	17.5	17.9	19.1	20.1	21.1	29.3	35.4
0.9	5.2	6.7	8.0	8.0	8.0	8.0	8.0	15.9	16.1	16.6	17.8	18.8	19.8	28.7	35.2
0.8	5.2	6.7	8.0	8.0	8.0	8.0	8.0	14.2	14.6	15.2	16.4	17.4	18.4	27.7	34.4
0.7	5.2	6.7	8.0	8.0	8.0	8.0	8.0	12.5	13.0	13.7	14.8	15.8	16.8	26.3	33.0
0.6	5.2	6.7	8.0	8.0	8.0	8.0	8.0	10.8	11.4	12.1	13.2	14.1	15.0	24.5	30.9
0.5	5.2	6.7	8.0	8.0	8.0	8.0	8.0	9.0	9.7	10.4	11.3	12.2	13.1	22.1	28.0
0.4	5.2	6.7	8.0	8.0	8.0	8.0	8.0	7.3	7.9	8.5	9.4	10.1	10.9	19.2	24.3
0.3	5.2	6.7	8.0	8.0	8.0	8.0	8.0	5.5	6.0	6.6	7.3	7.9	8.6	15.6	19.7
0.2	5.2	6.7	8.0	8.0	8.0	8.0	8.0	3.7	4.1	4.5	5.0	5.5	6.0	11.3	14.2
0.1	5.2	6.7	8.0	8.0	8.0	8.0	8.0	1.8	2.1	2.3	2.6	2.8	3.1	6.1	7.7
0	5.2	6.7	8.0	8.0	8.0	8.0	8.0	0	0	0	0	0	0	0	0

Table B-3. Probability for spawning biomass to exceed the proposed reference points when the catch of the five years from the 2021 fishing season is fixed at 9,000 tons and β is changed in 0.1 intervals within the range of 0 to 1.0

The catch of the 2020 fishing season is TAC (6.7 thousand tons) while the catch of the 2026 fishing season and after is based on the proposed HCRs.

(a) Probability for spawning biomass to exceed the proposed target reference point

(%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	0	1	1	2	13	25
0.9	0	0	0	0	0	0	0	0	0	1	1	2	3	17	32
0.8	0	0	0	0	0	0	0	0	0	1	1	2	3	22	39
0.7	0	0	0	0	0	0	0	0	0	1	1	2	3	27	48
0.6	0	0	0	0	0	0	0	0	0	1	1	2	4	33	57
0.5	0	0	0	0	0	0	0	0	0	1	2	3	5	40	67
0.4	0	0	0	0	0	0	0	0	1	1	2	3	5	47	76
0.3	0	0	0	0	0	0	0	0	1	1	2	4	6	55	83
0.2	0	0	0	0	0	0	0	0	1	1	2	4	7	62	89
0.1	0	0	0	0	0	0	0	0	1	1	3	5	9	69	94
0	0	0	0	0	0	0	0	0	1	1	3	6	10	76	97

(b) Probability for spawning biomass to exceed the proposed limit reference point

(%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	3	18	32	32	36	42	47	51	72	83
0.9	0	0	0	0	0	3	18	32	33	38	45	50	54	77	88
0.8	0	0	0	0	0	3	18	32	35	41	48	54	58	82	92
0.7	0	0	0	0	0	3	18	32	36	43	51	57	62	86	95
0.6	0	0	0	0	0	3	18	32	38	45	55	61	66	90	97
0.5	0	0	0	0	0	3	18	32	39	48	58	65	69	93	98
0.4	0	0	0	0	0	3	18	32	40	50	61	68	73	95	99
0.3	0	0	0	0	0	3	18	32	42	53	64	71	76	97	100
0.2	0	0	0	0	0	3	18	32	44	56	68	75	80	98	100
0.1	0	0	0	0	0	3	18	32	45	58	71	78	83	99	100
0	0	0	0	0	0	3	18	32	46	61	74	81	86	99	100

Table B-3 (continued). Changes in the average of future spawning biomass (c) and catch (d) when the catch of the five years from the 2021 fishing season is fixed at 9,000 tons and β is changed in 0.1 intervals within the range of 0 to 1.0

The catch of the 2020 fishing season is TAC (6.7 thousand tons) while the catch of the 2026 fishing season and after is based on the proposed HCRs.

(c) Average spawning biomass

(Thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	56	92	121	119	131	147	153	164	163	166	174	182	190	254	305
0.9	56	92	121	119	131	147	153	164	164	169	177	186	195	272	333
0.8	56	92	121	119	131	147	153	164	166	172	181	191	201	293	364
0.7	56	92	121	119	131	147	153	164	167	175	185	196	207	315	398
0.6	56	92	121	119	131	147	153	164	169	178	190	201	213	340	433
0.5	56	92	121	119	131	147	153	164	171	181	194	207	220	366	469
0.4	56	92	121	119	131	147	153	164	172	184	199	213	227	395	508
0.3	56	92	121	119	131	147	153	164	174	187	203	219	235	427	548
0.2	56	92	121	119	131	147	153	164	175	190	208	225	243	461	590
0.1	56	92	121	119	131	147	153	164	177	194	214	232	252	497	634
0	56	92	121	119	131	147	153	164	179	197	219	239	261	536	681

(d) Average catch

(Thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	9.0	9.0	9.0	9.0	9.0	16.9	17.0	17.4	18.6	19.6	20.6	28.9	35.1
0.9	5.2	6.7	9.0	9.0	9.0	9.0	9.0	15.3	15.6	16.2	17.4	18.3	19.3	28.2	34.9
0.8	5.2	6.7	9.0	9.0	9.0	9.0	9.0	13.6	14.1	14.8	16.0	16.9	17.9	27.3	34.1
0.7	5.2	6.7	9.0	9.0	9.0	9.0	9.0	12.0	12.6	13.3	14.5	15.4	16.4	25.9	32.8
0.6	5.2	6.7	9.0	9.0	9.0	9.0	9.0	10.3	11.0	11.8	12.8	13.7	14.7	24.1	30.7
0.5	5.2	6.7	9.0	9.0	9.0	9.0	9.0	8.7	9.3	10.1	11.1	11.9	12.8	21.8	27.9
0.4	5.2	6.7	9.0	9.0	9.0	9.0	9.0	7.0	7.6	8.3	9.2	9.9	10.7	18.9	24.2
0.3	5.2	6.7	9.0	9.0	9.0	9.0	9.0	5.3	5.8	6.4	7.1	7.7	8.4	15.4	19.6
0.2	5.2	6.7	9.0	9.0	9.0	9.0	9.0	3.5	4.0	4.4	4.9	5.4	5.8	11.1	14.1
0.1	5.2	6.7	9.0	9.0	9.0	9.0	9.0	1.8	2.0	2.3	2.5	2.8	3.0	6.0	7.6
0	5.2	6.7	9.0	9.0	9.0	9.0	9.0	0	0	0	0	0	0	0	0

Table B-4. Probability for spawning biomass to exceed the proposed reference points when the catch of the five years from the 2021 fishing season is fixed at 10,000 tons and β is changed in 0.1 intervals within the range of 0 to 1.0

The catch of the 2020 fishing season is TAC (6.7 thousand tons) while the catch of the 2026 fishing season and after is based on the proposed HCRs.

(a) Probability for spawning biomass to exceed the proposed target reference point

(%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	0	1	1	2	13	25
0.9	0	0	0	0	0	0	0	0	0	1	1	2	2	16	31
0.8	0	0	0	0	0	0	0	0	0	1	1	2	3	21	39
0.7	0	0	0	0	0	0	0	0	0	1	1	2	3	26	48
0.6	0	0	0	0	0	0	0	0	0	1	1	2	4	32	56
0.5	0	0	0	0	0	0	0	0	0	1	1	3	4	38	66
0.4	0	0	0	0	0	0	0	0	0	1	2	3	5	46	75
0.3	0	0	0	0	0	0	0	0	1	1	2	4	6	53	83
0.2	0	0	0	0	0	0	0	0	1	1	2	4	7	61	89
0.1	0	0	0	0	0	0	0	0	1	1	2	5	8	68	93
0	0	0	0	0	0	0	0	0	1	1	3	5	9	75	96

(b) Probability for spawning biomass to exceed the proposed limit reference point

(%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	2	16	29	30	34	39	45	48	71	83
0.9	0	0	0	0	0	2	16	29	31	36	43	48	52	76	87
0.8	0	0	0	0	0	2	16	29	32	38	46	51	56	81	91
0.7	0	0	0	0	0	2	16	29	34	40	49	55	59	85	94
0.6	0	0	0	0	0	2	16	29	35	43	52	59	63	89	97
0.5	0	0	0	0	0	2	16	29	36	45	55	62	67	92	98
0.4	0	0	0	0	0	2	16	29	37	48	59	66	70	95	99
0.3	0	0	0	0	0	2	16	29	39	50	62	69	74	97	100
0.2	0	0	0	0	0	2	16	29	40	52	65	72	78	98	100
0.1	0	0	0	0	0	2	16	29	42	55	68	75	81	99	100
0	0	0	0	0	0	2	16	29	43	58	72	78	84	99	100

Table B-4 (continued). Changes in the average of future spawning biomass (c) and catch (d) when the catch of the five years from the 2021 fishing season is fixed at 10,000 tons and β is changed in 0.1 intervals within the range of 0 to 1.0

The catch of the 2020 fishing season is TAC (6.7 thousand tons) while the catch of the 2026 fishing season and after is based on the proposed HCRs.

(c) Average spawning biomass

(Thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	56	92	121	118	129	144	150	160	159	163	171	179	186	250	302
0.9	56	92	121	118	129	144	150	160	161	166	175	183	191	269	331
0.8	56	92	121	118	129	144	150	160	162	169	178	188	197	289	362
0.7	56	92	121	118	129	144	150	160	164	171	182	193	203	311	395
0.6	56	92	121	118	129	144	150	160	165	174	186	198	209	335	430
0.5	56	92	121	118	129	144	150	160	167	177	191	203	216	361	466
0.4	56	92	121	118	129	144	150	160	169	180	195	209	223	390	505
0.3	56	92	121	118	129	144	150	160	170	183	200	215	230	421	545
0.2	56	92	121	118	129	144	150	160	172	187	204	221	238	454	588
0.1	56	92	121	118	129	144	150	160	173	190	209	228	246	491	632
0	56	92	121	118	129	144	150	160	175	193	215	235	255	529	679

(d) Average catch

(Thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	10.0	10.0	10.0	10.0	10.0	16.2	16.4	17.0	18.2	19.1	20.1	28.4	34.8
0.9	5.2	6.7	10.0	10.0	10.0	10.0	10.0	14.6	15.1	15.7	16.9	17.9	18.9	27.8	34.6
0.8	5.2	6.7	10.0	10.0	10.0	10.0	10.0	13.1	13.6	14.4	15.6	16.5	17.5	26.9	33.8
0.7	5.2	6.7	10.0	10.0	10.0	10.0	10.0	11.5	12.2	12.9	14.1	15.0	16.0	25.5	32.5
0.6	5.2	6.7	10.0	10.0	10.0	10.0	10.0	9.9	10.6	11.4	12.5	13.4	14.3	23.8	30.5
0.5	5.2	6.7	10.0	10.0	10.0	10.0	10.0	8.3	9.0	9.8	10.8	11.6	12.5	21.5	27.7
0.4	5.2	6.7	10.0	10.0	10.0	10.0	10.0	6.7	7.4	8.1	8.9	9.7	10.4	18.7	24.1
0.3	5.2	6.7	10.0	10.0	10.0	10.0	10.0	5.0	5.6	6.2	6.9	7.5	8.2	15.2	19.6
0.2	5.2	6.7	10.0	10.0	10.0	10.0	10.0	3.4	3.8	4.3	4.8	5.2	5.7	11.0	14.1
0.1	5.2	6.7	10.0	10.0	10.0	10.0	10.0	1.7	2.0	2.2	2.5	2.7	3.0	5.9	7.6
0	5.2	6.7	10.0	10.0	10.0	10.0	10.0	0	0	0	0	0	0	0	0

Examination Item D

Calculate and evaluate methods for carrying over (possible percentage of carrying-over amount to the initial TAC) after examination of methods by the Fisheries Agency of Japan and the Hokkaido Federation of Fisheries Cooperative Associations

3. Introduction

This is the request for study of the upper limit of carry-over if a system is introduced to catch the remainder of the allowable catch of the preceding year. Considering the possibility of introduction of the system, it is considered necessary to assess the possibility of excessive fishing mortality when the most extreme fishing is conducted under the system, and its negative influence on maintenance and recovery of the stock.

Fishing of the most extreme remainder and carrying over is thought to catch all the remainder of the allowable catch of a certain year during the succeeding year (this is repeated biennially). In this material, we set the ratio of remainder of catch (ratio to the total of the initial TAC and the carrying-over catch of the year) and the upper limit of allowed carrying over (ratio to the initial TAC) in the calculation of future projection and conducted simulations with varying remainder ratio and carrying-over limit (FigureD-1). For the future projection, we used the S-R relationships updated in Examination Item A and the proposed reference points, fishing ban level and HCRs based on the relationships.

4. Assessment of the influence of extreme remainder and carrying over

[Method]

Assuming the most extreme remainder and carrying over, we made the future projection based on the alternation of a year with remainder and the succeeding year where all allowable catch including the remainder of the previous year is caught. The future projection assumed that remainder and carrying over begins from the 2021 fishing season when fishing based on the proposed HCRs starts. Namely, it is assumed that there is remainder in the 2021 fishing season, but there is no remainder in the 2022 fishing season and all allowable catch including the remainder from the previous year is caught. The succeeding 2023 fishing season has remainder again and in the 2024 fishing season the remainder is caught together with the initial estimated catch of the year. We calculated probability that the fishing mortality of the year of all-fishing (even-numbered years in this case) will exceed the fishing mortality that produces MSY (Fmsy) when this extreme fishing is repeated. We also compared this scenario's probability that the spawning biomass will exceed the proposed target reference point (SBmsy; 380 thousand tons) and the proposed limit reference point (SB0.6msy; 171 thousand tons) 10 years after starting operation of the proposed HCRs (in the 2031 fishing season) with the scenario without a remainder carrying over. We also showed the average catch expected in the 2021-2031 fishing seasons.

The remainder in the future projection is examined at the 5% interval within the range of 5 to 30% of the catch projected for odd-number years. We examined the upper limit of carry-over of remainder catch at the 5% interval within the range of 0 to 30% of the catch projected in the respective year based

on the proposed HCRs. We made trials of combinations of the fishing scenarios of remainder and carrying over by changing safety coefficient β of the proposed HCRs from 0.1 to 1.0 in 0.1 intervals. A trial is made 10,000 times for each combination.

[Mathematical equation]

When the catch projected in year t based on the proposed HCRs at the kth trial of the future projection is expressed as ABC_t^k, catch with addition of the carry-over from the previous year as $ABC+_t^k$ and the rate of remainder (reserve rate) of year t as RR_t, the remainder catch in year t is expressed as follows:

$$RR_t \times ABC +_t^k$$

When the actual catch in year t is GC_t;

$$GC_t^k = (1 - RR_t) \times ABC +_t^k$$

Here, the fishing mortality of year t at age s is $xF_{s,msy}$, where x that satisfies the equation below is explored:

$$GC_t^k = \sum_{s=S_{min}}^{S_{max}} (1 - \exp(-xF_{s,msy}))\exp(-\frac{M_s}{2})N_{s,t}^k v_s$$

S_{min} stands for the age at recruitment and S_{max} stands for the age of plus group: these are 2 and 10, respectively. M_s is natural mortality at the age of s, $N_{s,t}^k$ is the number of fish of age s in year t of the kth trial, and v_s stands for body weight per fish of age s. $F_{s,msy}$ is fishing mortality at age, which produces MSY (Fmsy) and the fishing mortality that is estimated as $xF_{s,msy}$ is F under the same selectivity as Fmsy.

Remainder catch that may be carried over to the succeeding year (t + 1) is the smallest value obtained under the following condition. If the value is negative, the amount of carry-over is deemed to be zero.

- $ABC_t^k - GC_t^k$

: When the actual catch is smaller than the catch projected with the proposed HCRs, the difference is carried over to the following year. Carried-over catch from the previous year cannot be carried over further to the following year.

- $ABC_t^k \times CR_t$

: Limit of allowable carrying over is up to a certain rate to the catch projected with the proposed HCRs (Carry rate, CR_t).

[Result]

We made future projection by changing the remainder rate in the range of 5 to 30% starting from the 2021 fishing season for the period from the 2020 fishing season to the 2031 fishing season (Figure D-2). A remainder is generated in odd-number years (2021, 2023, 2025, 2027 and 2029 fishing seasons). The catch of the even-number years (2022, 2024, 2026, 2028 and the 2030 fishing seasons)

increases with additional carried-over catch. The average of the probability that the fishing mortality projected for the even-number years will exceed Fmsy is shown for each upper limit of carry-over in Table D-1. Depending on the value of safety coefficient β of the proposed HCRs, fishing mortality will exceed Fmsy for some upper limit. In order to prevent fishing mortality from exceeding Fmsy, the upper limit of carry-over needs to be not higher than 5% of the prediction value of the initial proposed HCRs ("the initial value") when β is set to 0.9 and under, or not higher than 20% of the initial value when β is set to 0.8 and under.

Table D-2 shows the probability that spawning biomass will exceed the proposed target reference point (SBmsy) in the 2031 fishing season with varying upper limit of carry-over. Under the remainder and carrying-over conditions of this trial calculation, the probability of exceeding the proposed target reference point is almost the same with the scenario without a remainder carrying over.

Table D-3 shows the probability that spawning biomass will exceed the proposed limit reference point (SB0.6msy) in the 2031 fishing season with varying upper limit of carry-over. The probability of exceeding the proposed limit reference point rises with a higher remainder rate, and decreases with a higher upper limit of carry-over.

With lower adaptability of harvest control, the average of catch expected in the future also decreases compared with the scenario without a remainder carrying over (Table D-4). For example, when the remainder rate is 15%, β is set to 0.8 and carrying over is 5 to 15%, the average catch expected in the 2021-2031 fishing seasons is smaller by 0.2 to 0.7 tons compared with the average catch without a remainder carrying over (12.8 thousand tons). While flexible carrying over of catch is allowed, the eventual catch can be slightly smaller.

With a higher remainder rate and lower upper limit of carry-over, the probability that spawning biomass will exceed the proposed reference points is higher compared with the scenario without a remainder carrying over. This is interpreted that the effect of remainder exceeds the negative influence of carry-over and increases the biomass.

5. Impact assessment when remainder rate is randomly changed

[Method]

It is expected that actual remainder rate will vary depending on the year. For this reason, we examined the impact of upper limit setting of carry-over assuming that the remainder rate will randomly change in uniform distribution within the range of 0 to 40% from the 2021 fishing season where fishing based on the proposed HCRs starts (Figure D-3). We set the upper limit of carry-over in 0.5 intervals within the range of 0 to 30% of the initial value and compared the probability that the fishing mortality of each year will exceed Fmsy. For reference, we also compared the probability that spawning biomass will exceed the proposed target reference point and limit reference point, and average of projected catch for each year.

[Result]

Table D-5 shows the result of the future projection of the probability that fishing mortality will exceed Fmsy in the 2021 fishing season and after when fishing is conducted based on the proposed

HCRs. Depending on the value of safety coefficient β of the proposed HCRs and the upper limit of carry-over, fishing mortality will exceed Fmsy. In order to prevent fishing mortality from exceeding Fmsy for the period up to the 2031 fishing season, it is necessary to limit the upper limit of carry-over to 10% with β set to 0.9 and under, and to 25% with β set to 0.8 and under.

The probability that spawning biomass will exceed the proposed target reference point and limit reference point is shown in Tables D-6 and D-7, and the average catch is shown in Table D-8. For comparison, we show the results of the scenario without a remainder carrying over in Table D-9 (repost of Table A-5 and Table A-6 (b) of the Examination Item A). When we compare the two scenarios of future projection, the probability that spawning biomass will exceed the proposed target reference point and limit reference point is higher than that of the scenario without a remainder carrying over regardless of the upper limit of carry-over (the lower the upper limit, the higher the probability). The result is considered to reflect the effect of biomass increase caused by remainder. The projected catch is slightly smaller than the catch of the scenario without remainder carrying over regardless of the upper limit of carry-over. If remainder and carrying over is allowed, the flexibility of fishing will increase but the eventual catch can be slightly smaller. The precondition of the remainder rate (random change within the range of 0 to 40%) is set based on the average remainder rate (unused rate of TAC: about 20%) of the 2015-2019 fishing seasons, but it is necessary to pay attention that this setting is only assumed.

6. Conclusion

For introduction of a system to catch the remainder of the allowable catch of a certain year during the succeeding year, it is considered necessary to set a limit to prevent fishing mortality from exceeding the fishing mortality that produces MSY (Fmsy) even when fishing is conducted with the most extreme remainder and carrying over under the system. The desirable upper limit of carry-over depends on the β value chosen for the fishing scenario. The larger the β value, the lower the necessary limit.

Stock assessment can have gross errors in biomass estimates of the latest year, in particular. For this reason, also in order to avoid a negative influence on biomass due to excessive fishing caused by assessment error, it is necessary to set the upper limit for determination of carrying-over amount not only as ratio to the "initial allowable catch" but also as ratio to the "allowable catch based on the latest stock assessment result" at all times.

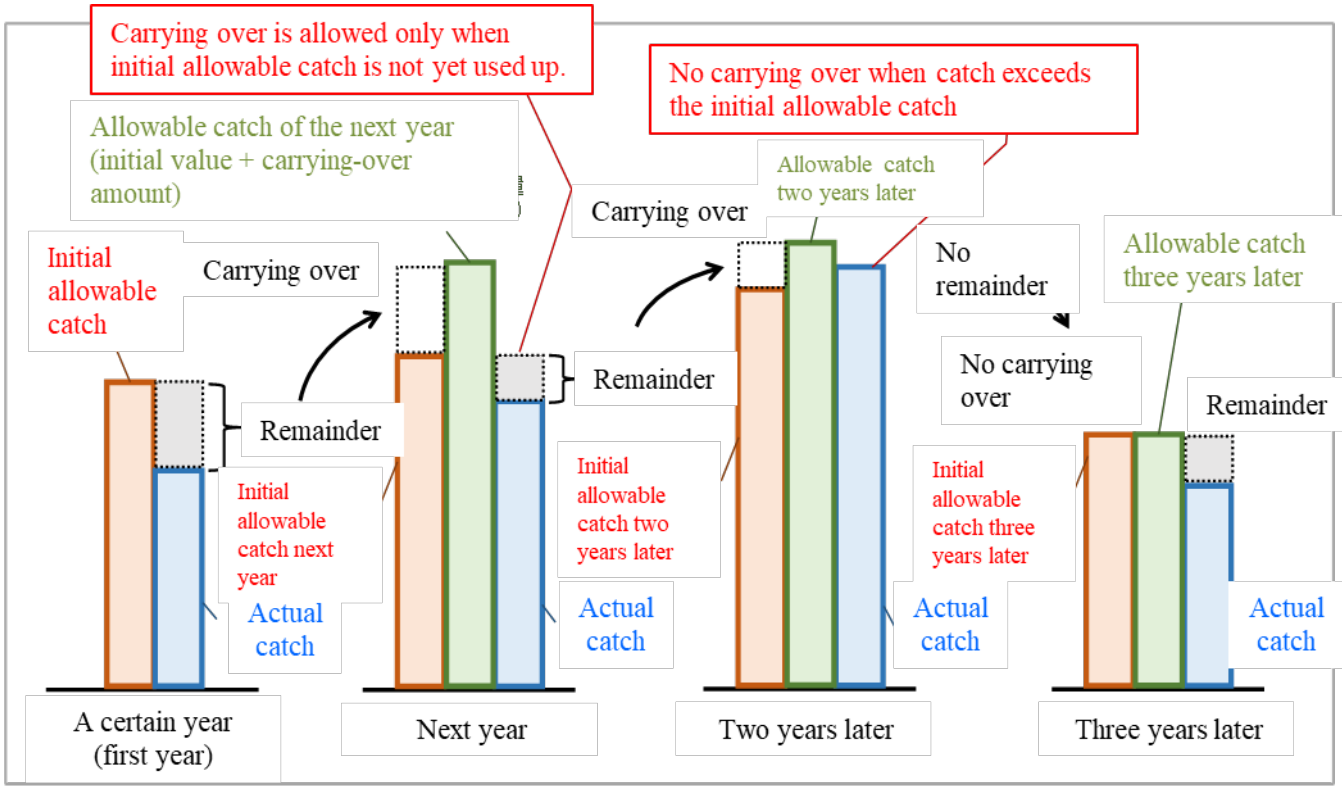


Figure D-1. Conceptual diagram of remainder and carrying over of allowable catch

The assumed "remainder" is the unused part of the initial allowable catch set by the proposed HCRs when the actual catch did not reach the limit. This remainder is added to the initial allowable catch of the following year to make the allowable catch of the year. If there is a remainder of this allowable catch, only the difference with the initial allowable catch of the year can be carried over to the succeeding year. The "Upper limit of carry-over" is determined as the ratio to the initial allowable catch of alternate years.

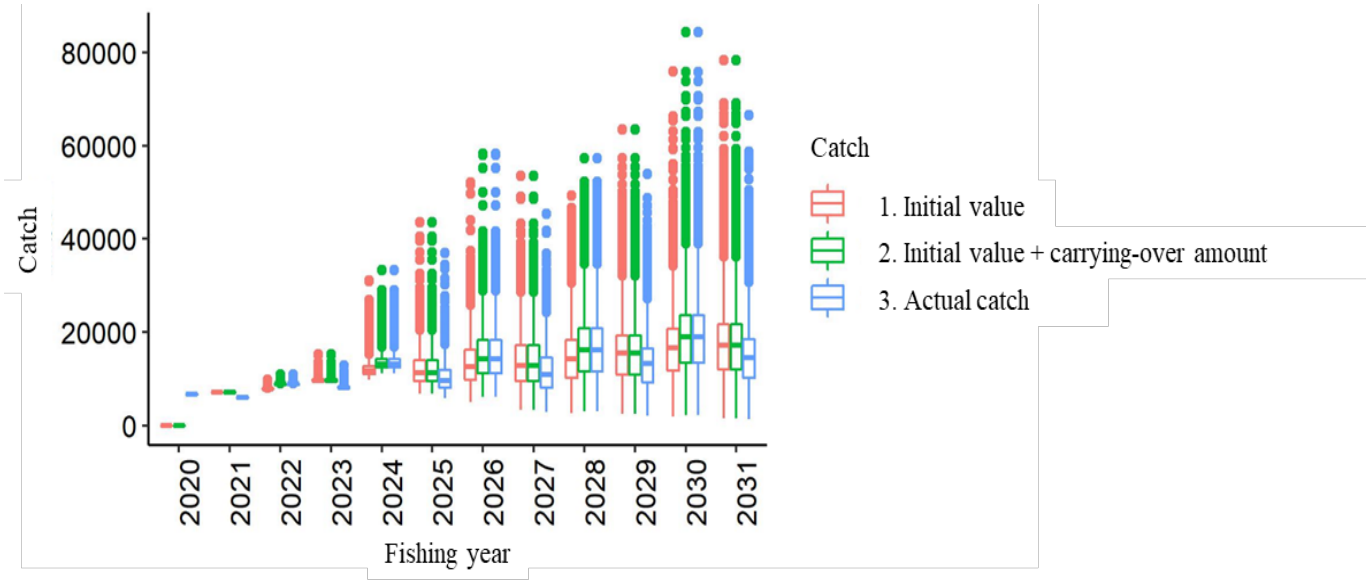


Figure D-2. Example of projected catch in future projection with extreme remainder carrying-over scenario (safety coefficient β used for the proposed HCRs is set to 0.8)

It is assumed that, after the 2021 fishing season, there is a remainder of 15% of the allowable catch in odd-number years and all allowable catch including the remainder of the previous year is caught in even-number years. The upper limit of carry-over is 15% of the initial allowable catch.

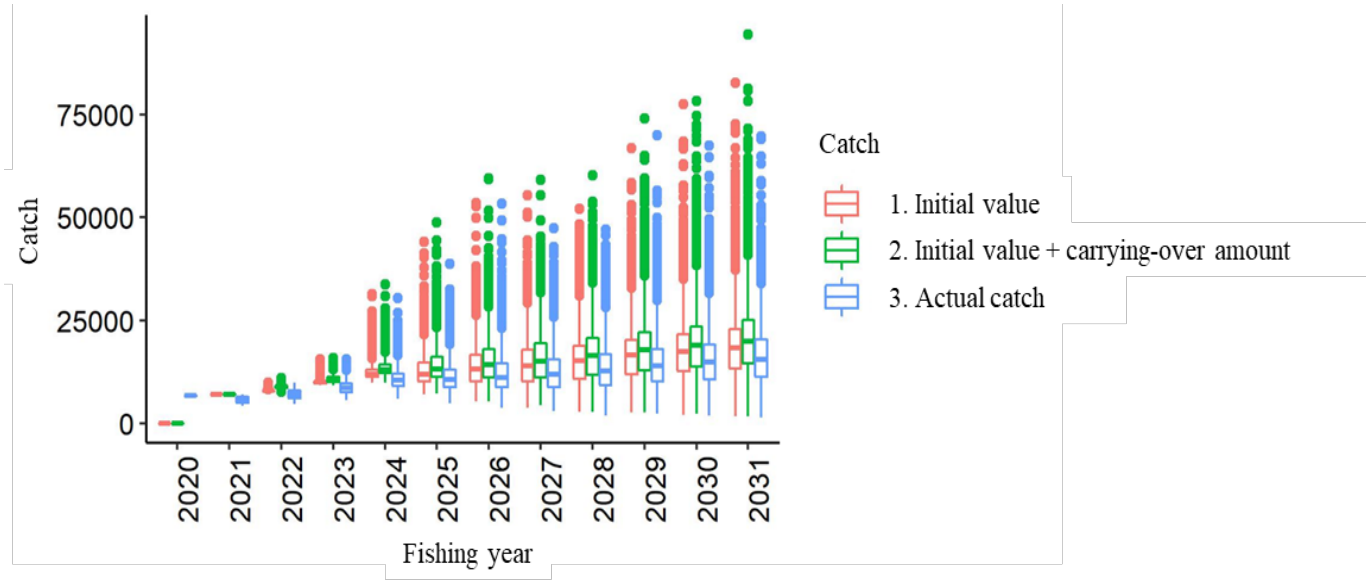


Figure D-3. Example of projected catch in future projection with a random remainder rate (safety coefficient β used for the proposed HCRs is set to 0.8)

It is assumed that, after the 2021 fishing season, there is a remainder of 0 to 40% of the allowable catch. The upper limit of carry-over is set to 15% of the initial allowable catch.

Table D-1. In the future projection with extreme remainder and carrying over (until the 2031 fishing season), average of the probability that the fishing mortality projected for even-number years will exceed the fishing mortality that produces MSY (Fmsy)

Results of different combinations of remainder rate (5 to 30%) and the value of safety coefficient β (0.1 to 1.0) are shown for each upper limit setting. The items at the top of the table show the remainder rate (%) and carrying-over rate (%). Because the result where carrying-over rate exceeds the remainder rate is the same as the result where both have the same value, the former is left out.

（Unit：%）

β	5%-0%	5%-5%	10%-0%	10%-5%	10%-10%	15%-0%	15%-5%	15%-10%	15%-15%	20%-0%	20%-5%	20%-10%	20%-15%	20%-20%
1.0	9	23	10	23	27	10	24	28	31	11	25	28	32	37
0.9	0	0	0	0	1	0	0	1	22	0	0	1	23	28
0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

β	25%-0%	25%-5%	25%-10%	25%-15%	25%-20%	25%-25%	30%-0%	30%-5%	30%-10%	30%-15%	30%-20%	30%-25%	30%-30%
1.0	11	26	29	33	38	45	11	27	30	34	39	46	59
0.9	0	0	1	24	28	32	0	0	1	24	29	32	36
0.8	0	0	0	0	0	9	0	0	0	0	0	9	23
0.7	0	0	0	0	0	0	0	0	0	0	0	0	0
0.6	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
0.4	0	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D-2. In the future projection with extreme remainder and carrying over, the probability that spawning biomass will exceed the proposed target reference point (SBmsy) in the 2031 fishing season (upper table) and the difference with the scenario without remainder (lower table)

Results of different combinations of remainder rate (5 to 30%) and the value of safety coefficient β (0.1 to 1.0) are shown for each upper limit setting. The items at the top of the table show the remainder rate (%) and carrying-over rate (%). Because the result where carrying-over rate exceeds the remainder rate is the same as the result where both have the same value, the former is left out.

(Unit:%)

β	5%-0%	5%-5%	10%-0%	10%-5%	10%-10%	15%-0%	15%-5%	15%-10%	15%-15%	20%-0%	20%-5%	20%-10%	20%-15%	20%-20%
1.0	2	2	2	2	2	2	2	2	2	2	2	2	2	2
0.9	2	2	2	2	2	2	2	2	2	3	2	2	2	2
0.8	3	3	3	3	3	3	3	3	3	3	3	3	3	3
0.7	4	3	4	4	3	4	4	4	3	4	4	4	4	3
0.6	5	4	5	5	4	5	5	5	4	5	5	5	4	4
0.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6
0.4	8	7	8	8	7	8	8	8	8	8	8	8	8	8
0.3	10	10	10	10	10	10	10	10	10	10	10	10	10	10
0.2	12	12	13	12	12	13	13	12	12	13	13	13	12	12
0.1	16	16	16	16	16	16	16	16	16	16	16	16	16	16
0	20	20	20	20	20	20	20	20	20	20	20	20	20	20

β	25%-0%	25%-5%	25%-10%	25%-15%	25%-20%	25%-25%	30%-0%	30%-5%	30%-10%	30%-15%	30%-20%	30%-25%	30%-30%
1.0	2	2	2	2	2	2	2	2	2	2	2	2	2
0.9	3	3	2	2	2	2	3	3	2	2	2	2	2
0.8	3	3	3	3	3	3	4	3	3	3	3	3	3
0.7	4	4	4	4	4	3	4	4	4	4	4	4	3
0.6	5	5	5	5	4	4	5	5	5	5	5	4	4
0.5	6	6	6	6	6	6	7	6	6	6	6	6	6
0.4	8	8	8	8	8	8	8	8	8	8	8	8	8
0.3	10	10	10	10	10	10	11	10	10	10	10	10	10
0.2	13	13	13	13	12	12	13	13	13	13	13	12	12
0.1	16	16	16	16	16	16	16	16	16	16	16	16	16
0	20	20	20	20	20	20	20	20	20	20	20	20	20

β	5%-0%	5%-5%	10%-0%	10%-5%	10%-10%	15%-0%	15%-5%	15%-10%	15%-15%	20%-0%	20%-5%	20%-10%	20%-15%	20%-20%
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.9	0	0	0	0	0	0	0	0	0	1	0	0	0	0
0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.7	1	0	1	1	0	1	1	1	0	1	1	1	1	0
0.6	1	0	1	1	0	1	1	1	0	1	1	1	0	0
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.4	1	0	1	1	0	1	1	1	1	1	1	1	1	1
0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	0	0	1	0	0	1	1	0	0	1	1	1	0	0
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

β	25%-0%	25%-5%	25%-10%	25%-15%	25%-20%	25%-25%	30%-0%	30%-5%	30%-10%	30%-15%	30%-20%	30%-25%	30%-30%
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.9	1	1	0	0	0	0	1	1	0	0	0	0	0
0.8	0	0	0	0	0	0	1	0	0	0	0	0	0
0.7	1	1	1	1	1	0	1	1	1	1	1	1	0
0.6	1	1	1	1	0	0	1	1	1	1	1	0	0
0.5	0	0	0	0	0	0	1	0	0	0	0	0	0
0.4	1	1	1	1	1	1	1	1	1	1	1	1	1
0.3	0	0	0	0	0	0	1	0	0	0	0	0	0
0.2	1	1	1	1	0	0	1	1	1	1	1	0	0
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D-3. In the future projection with extreme remainder and carrying over, the probability that spawning biomass will exceed the proposed limit reference point (SB0.6msy) in the 2031 fishing season (upper table) and the difference with the scenario without remainder (lower table).

Results of different combinations of remainder rate (0 to 30%) and the value of safety coefficient β (0.1 to 1.0) are shown for each upper limit setting. The items at the top of the table show the remainder rate (%) and carrying-over rate (%). Because the result where carrying-over rate exceeds the remainder rate is same as the result where both have the same value, the former is left out.

β	5%-0%	5%-5%	10%-0%	10%-5%	10%-10%	15%-0%	15%-5%	15%-10%	15%-15%	20%-0%	20%-5%	20%-10%	20%-15%	20%-20%
1.0	47	46	48	47	46	50	48	47	45	51	49	48	47	45
0.9	52	51	54	52	51	55	53	52	51	56	55	53	52	50
0.8	58	57	59	58	57	60	59	58	57	61	60	59	58	56
0.7	64	63	65	64	63	66	64	63	62	67	65	64	63	62
0.6	70	69	70	69	68	71	70	69	68	72	71	70	69	68
0.5	75	74	76	75	74	76	76	75	74	77	76	76	75	74
0.4	81	80	81	81	80	81	81	81	80	82	81	81	80	80
0.3	86	86	86	86	86	87	86	86	86	87	87	86	86	85
0.2	90	90	90	90	90	91	90	90	90	91	91	90	90	90
0.1	94	94	94	94	94	94	94	94	94	94	94	94	94	94
0	96	96	96	96	96	96	96	96	96	96	96	96	96	96

β	25%-0%	25%-5%	25%-10%	25%-15%	25%-20%	25%-25%	30%-0%	30%-5%	30%-10%	30%-15%	30%-20%	30%-25%	30%-30%
1.0	52	50	49	48	46	45	53	52	50	49	47	46	45
0.9	57	56	54	53	52	50	58	57	56	54	53	51	50
0.8	62	61	60	59	57	56	63	62	61	60	58	57	56
0.7	68	66	65	64	63	62	69	67	66	65	64	63	62
0.6	73	72	71	70	69	68	74	73	72	71	70	69	68
0.5	78	77	76	75	75	74	78	78	77	76	75	75	74
0.4	83	82	81	81	80	80	83	83	82	81	81	80	80
0.3	87	87	87	86	86	85	88	87	87	86	86	86	85
0.2	91	91	91	90	90	90	91	91	91	91	90	90	90
0.1	94	94	94	94	94	94	94	94	94	94	94	94	94
0	96	96	96	96	96	96	96	96	96	96	96	96	96

β	5%-0%	5%-5%	10%-0%	10%-5%	10%-10%	15%-0%	15%-5%	15%-10%	15%-15%	20%-0%	20%-5%	20%-10%	20%-15%	20%-20%
1.0	1	0	2	1	0	4	2	1	-1	5	3	2	1	-1
0.9	1	0	3	1	0	4	2	1	0	5	4	2	1	-1
0.8	1	0	2	1	0	3	2	1	0	4	3	2	1	-1
0.7	1	0	2	1	0	3	1	0	-1	4	2	1	0	-1
0.6	1	0	1	0	-1	2	1	0	-1	3	2	1	0	-1
0.5	0	-1	1	0	-1	1	1	0	-1	2	1	1	0	-1
0.4	0	-1	0	0	-1	0	0	0	-1	1	0	0	-1	-1
0.3	0	0	0	0	0	1	0	0	0	1	1	0	0	-1
0.2	0	0	0	0	0	1	0	0	0	1	1	0	0	0
0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

β	25%-0%	25%-5%	25%-10%	25%-15%	25%-20%	25%-25%	30%-0%	30%-5%	30%-10%	30%-15%	30%-20%	30%-25%	30%-30%
1.0	6	4	3	2	0	-1	7	6	4	3	1	0	-1
0.9	6	5	3	2	1	-1	7	6	5	3	2	0	-1
0.8	5	4	3	2	0	-1	6	5	4	3	1	0	-1
0.7	5	3	2	1	0	-1	6	4	3	2	1	0	-1
0.6	4	3	2	1	0	-1	5	4	3	2	1	0	-1
0.5	3	2	1	0	0	-1	3	3	2	1	0	0	-1
0.4	2	1	0	0	-1	-1	2	2	1	0	0	-1	-1
0.3	1	1	1	0	0	-1	2	1	1	0	0	0	-1
0.2	1	1	1	0	0	0	1	1	1	1	0	0	0
0.1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D-4. In the future projection with extreme remainder and carrying over, annual average of catch projected in the 2021-2031 fishing seasons (upper table) and the difference with the scenario without remainder (lower table)

Results of different combinations of remainder rate (0 to 30%) and the value of safety coefficient β (0.1 to 1.0) are shown for each upper limit setting. The items at the top of the table show the remainder rate (%) and carrying-over rate (%). Because the result where carrying-over rate exceeds the remainder rate is same as the result where both have the same value, the former is left out.

（Unit:%）

β	5%-0%	5%-5%	10%-0%	10%-5%	10%-10%	15%-0%	15%-5%	15%-10%	15%-15%	20%-0%	20%-5%	20%-10%	20%-15%	20%-20%
1.0	14.3	14.5	14.1	14.2	14.4	13.8	14.0	14.2	14.4	13.6	13.8	13.9	14.1	14.3
0.9	13.5	13.6	13.2	13.4	13.6	13.0	13.2	13.3	13.5	12.7	12.9	13.1	13.3	13.5
0.8	12.5	12.7	12.3	12.5	12.6	12.1	12.2	12.4	12.6	11.8	12.0	12.2	12.4	12.5
0.7	11.5	11.7	11.3	11.4	11.6	11.0	11.2	11.4	11.5	10.8	11.0	11.1	11.3	11.5
0.6	10.3	10.5	10.1	10.3	10.4	9.9	10.0	10.2	10.4	9.7	9.8	10.0	10.2	10.3
0.5	9.0	9.2	8.8	9.0	9.1	8.6	8.8	8.9	9.1	8.4	8.6	8.7	8.9	9.0
0.4	7.6	7.7	7.4	7.5	7.7	7.2	7.4	7.5	7.6	7.0	7.2	7.3	7.4	7.6
0.3	6.0	6.1	5.8	5.9	6.0	5.7	5.8	5.9	6.0	5.5	5.6	5.7	5.9	6.0
0.2	4.2	4.3	4.1	4.2	4.2	4.0	4.0	4.1	4.2	3.9	3.9	4.0	4.1	4.2
0.1	2.2	2.2	2.1	2.2	2.2	2.1	2.1	2.2	2.2	2.0	2.1	2.1	2.1	2.2
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

β	25%-0%	25%-5%	25%-10%	25%-15%	25%-20%	25%-25%	30%-0%	30%-5%	30%-10%	30%-15%	30%-20%	30%-25%	30%-30%
1.0	13.3	13.5	13.7	13.9	14.1	14.2	13.0	13.2	13.4	13.6	13.8	14.0	14.2
0.9	12.5	12.7	12.9	13.0	13.2	13.4	12.2	12.4	12.6	12.8	13.0	13.2	13.3
0.8	11.6	11.7	11.9	12.1	12.3	12.5	11.3	11.5	11.7	11.9	12.1	12.2	12.4
0.7	10.5	10.7	10.9	11.1	11.3	11.4	10.3	10.5	10.7	10.8	11.0	11.2	11.4
0.6	9.4	9.6	9.8	9.9	10.1	10.3	9.2	9.4	9.6	9.7	9.9	10.0	10.2
0.5	8.2	8.4	8.5	8.7	8.8	9.0	8.0	8.2	8.3	8.5	8.6	8.8	8.9
0.4	6.9	7.0	7.1	7.3	7.4	7.5	6.7	6.8	7.0	7.1	7.2	7.4	7.5
0.3	5.4	5.5	5.6	5.7	5.8	5.9	5.2	5.3	5.5	5.6	5.7	5.8	5.9
0.2	3.7	3.8	3.9	4.0	4.1	4.1	3.6	3.7	3.8	3.9	4.0	4.0	4.1
0.1	2.0	2.0	2.0	2.1	2.1	2.2	1.9	1.9	2.0	2.0	2.1	2.1	2.2
0	0	0	0	0	0	0	0	0	0	0	0	0	0

β	5%-0%	5%-5%	10%-0%	10%-5%	10%-10%	15%-0%	15%-5%	15%-10%	15%-15%	20%-0%	20%-5%	20%-10%	20%-15%	20%-20%
1.0	-0.2	-0.1	-0.5	-0.3	-0.1	-0.7	-0.5	-0.4	-0.2	-1.0	-0.8	-0.6	-0.4	-0.2
0.9	-0.2	-0.1	-0.5	-0.3	-0.1	-0.7	-0.5	-0.4	-0.2	-1.0	-0.8	-0.6	-0.4	-0.2
0.8	-0.2	-0.1	-0.5	-0.3	-0.1	-0.7	-0.5	-0.3	-0.2	-1.0	-0.8	-0.6	-0.4	-0.2
0.7	-0.2	-0.1	-0.5	-0.3	-0.1	-0.7	-0.5	-0.3	-0.2	-0.9	-0.7	-0.6	-0.4	-0.2
0.6	-0.2	-0.1	-0.4	-0.3	-0.1	-0.6	-0.5	-0.3	-0.2	-0.9	-0.7	-0.5	-0.4	-0.2
0.5	-0.2	-0.1	-0.4	-0.2	-0.1	-0.6	-0.4	-0.3	-0.2	-0.8	-0.6	-0.5	-0.3	-0.2
0.4	-0.2	0.0	-0.4	-0.2	-0.1	-0.5	-0.4	-0.3	-0.1	-0.7	-0.6	-0.4	-0.3	-0.2
0.3	-0.1	0.0	-0.3	-0.2	-0.1	-0.4	-0.3	-0.2	-0.1	-0.6	-0.5	-0.4	-0.3	-0.1
0.2	-0.1	0.0	-0.2	-0.1	-0.1	-0.3	-0.2	-0.2	-0.1	-0.4	-0.3	-0.3	-0.2	-0.1
0.1	-0.1	0.0	-0.1	-0.1	0.0	-0.2	-0.1	-0.1	0.0	-0.2	-0.2	-0.1	-0.1	-0.1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

β	25%-0%	25%-5%	25%-10%	25%-15%	25%-20%	25%-25%	30%-0%	30%-5%	30%-10%	30%-15%	30%-20%	30%-25%	30%-30%
1.0	-1.2	-1.0	-0.8	-0.7	-0.5	-0.3	-1.5	-1.3	-1.1	-0.9	-0.7	-0.5	-0.4
0.9	-1.2	-1.0	-0.8	-0.7	-0.5	-0.3	-1.5	-1.3	-1.1	-0.9	-0.7	-0.5	-0.4
0.8	-1.2	-1.0	-0.8	-0.6	-0.5	-0.3	-1.5	-1.3	-1.1	-0.9	-0.7	-0.5	-0.4
0.7	-1.2	-1.0	-0.8	-0.6	-0.5	-0.3	-1.4	-1.2	-1.0	-0.9	-0.7	-0.5	-0.3
0.6	-1.1	-0.9	-0.8	-0.6	-0.4	-0.3	-1.3	-1.2	-1.0	-0.8	-0.7	-0.5	-0.3
0.5	-1.0	-0.9	-0.7	-0.5	-0.4	-0.3	-1.2	-1.1	-0.9	-0.8	-0.6	-0.5	-0.3
0.4	-0.9	-0.8	-0.6	-0.5	-0.4	-0.2	-1.1	-0.9	-0.8	-0.7	-0.5	-0.4	-0.3
0.3	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.9	-0.8	-0.7	-0.6	-0.4	-0.3	-0.2
0.2	-0.5	-0.5	-0.4	-0.3	-0.2	-0.1	-0.6	-0.6	-0.5	-0.4	-0.3	-0.2	-0.2
0.1	-0.3	-0.3	-0.2	-0.2	-0.1	-0.1	-0.4	-0.3	-0.3	-0.2	-0.2	-0.1	-0.1
0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D-5. In the future projection where remainder rate is randomly changed within the range of 0 to 40%: probability that fishing mortality of each year will exceed the fishing mortality that produces MSY (Fmsy)

The table shows the results of each setting of upper limit of carry-over for the fishing scenario where safety coefficient β is changed from 0.1 to 1.0 in 0.1 intervals. The higher the probability of exceeding Fmsy, the darker the shade is.

(Unit: %)

a) Upper limit of carry-over: 0% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

b) Upper limit of carry-over: 5% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	2	3	3	4	5	5	5	7	10
0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

c) Upper limit of carry-over: 10% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	1	3	5	6	7	8	8	9	13	16
0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

d) Upper limit of carry-over: 15% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	1	5	6	7	9	10	11	12	16	19
0.9	0	0	0	0	0	0	0	1	1	2	2	2	2	4	4
0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

e) Upper limit of carry-over: 20% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	1	6	8	9	11	12	13	14	18	21
0.9	0	0	0	0	0	0	1	2	3	3	4	4	4	7	8
0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

f) Upper limit of carry-over: 25% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	2	7	9	10	12	13	14	15	20	23
0.9	0	0	0	0	0	0	2	3	4	4	5	5	5	8	10
0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

g) Upper limit of carry-over: 30% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	3	7	9	10	12	14	15	16	20	23
0.9	0	0	0	0	0	0	2	3	4	5	6	6	6	9	11
0.8	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2
0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D-6. In the future projection where remainder rate is randomly changed within the range of 0 to 40%: probability that spawning biomass of each year will exceed the proposed target reference point (SBmsy)

The table shows the results of each setting of upper limit of carry-over for the fishing scenario where safety coefficient β is changed from 0.1 to 1.0 in 0.1 intervals.

(Unit: %)

a) Upper limit of carry-over: 0% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	1	1	2	3	22	40
0.9	0	0	0	0	0	0	0	0	0	1	1	2	3	26	48
0.8	0	0	0	0	0	0	0	0	0	1	2	3	4	32	56
0.7	0	0	0	0	0	0	0	0	0	1	2	3	5	38	64
0.6	0	0	0	0	0	0	0	0	1	1	2	4	6	45	72
0.5	0	0	0	0	0	0	0	0	1	1	3	5	7	51	79
0.4	0	0	0	0	0	0	0	0	1	2	3	6	9	59	85
0.3	0	0	0	0	0	0	0	0	1	2	4	7	11	66	90
0.2	0	0	0	0	0	0	0	0	1	2	5	9	13	73	94
0.1	0	0	0	0	0	0	0	1	1	3	6	11	17	80	97
0	0	0	0	0	0	0	0	1	2	4	7	13	20	86	98

b) Upper limit of carry-over: 5% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	1	1	2	2	20	37
0.9	0	0	0	0	0	0	0	0	0	1	1	2	3	24	45
0.8	0	0	0	0	0	0	0	0	0	1	2	2	4	30	53
0.7	0	0	0	0	0	0	0	0	0	1	2	3	5	36	61
0.6	0	0	0	0	0	0	0	0	1	1	2	4	6	43	70
0.5	0	0	0	0	0	0	0	0	1	1	3	5	7	50	78
0.4	0	0	0	0	0	0	0	0	1	2	3	6	9	58	84
0.3	0	0	0	0	0	0	0	0	1	2	4	7	11	66	90
0.2	0	0	0	0	0	0	0	0	1	2	5	8	13	73	94
0.1	0	0	0	0	0	0	0	1	1	3	6	10	16	80	97
0	0	0	0	0	0	0	0	1	2	4	7	13	20	86	98

c) Upper limit of carry-over: 10% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	1	1	2	2	19	35
0.9	0	0	0	0	0	0	0	0	0	1	1	2	3	23	43
0.8	0	0	0	0	0	0	0	0	0	1	2	2	4	28	51
0.7	0	0	0	0	0	0	0	0	0	1	2	3	5	35	60
0.6	0	0	0	0	0	0	0	0	1	1	2	4	5	42	69
0.5	0	0	0	0	0	0	0	0	1	1	3	5	7	49	77
0.4	0	0	0	0	0	0	0	0	1	2	3	6	9	57	84
0.3	0	0	0	0	0	0	0	0	1	2	4	7	11	65	89
0.2	0	0	0	0	0	0	0	0	1	2	5	8	13	72	94
0.1	0	0	0	0	0	0	0	1	1	3	6	10	16	80	96
0	0	0	0	0	0	0	0	1	2	4	7	13	20	86	98

d) Upper limit of carry-over: 15% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	1	1	1	2	18	33
0.9	0	0	0	0	0	0	0	0	0	1	1	2	3	23	41
0.8	0	0	0	0	0	0	0	0	0	1	1	2	4	28	50
0.7	0	0	0	0	0	0	0	0	0	1	2	3	4	34	58
0.6	0	0	0	0	0	0	0	0	1	1	2	3	5	41	68
0.5	0	0	0	0	0	0	0	0	1	1	3	4	7	48	76
0.4	0	0	0	0	0	0	0	0	1	2	3	5	8	56	83
0.3	0	0	0	0	0	0	0	0	1	2	4	7	11	65	89
0.2	0	0	0	0	0	0	0	0	1	2	5	8	13	72	93
0.1	0	0	0	0	0	0	0	1	1	3	6	10	16	80	96
0	0	0	0	0	0	0	0	1	2	4	7	13	20	86	98

e) Upper limit of carry-over: 20% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	1	1	1	2	17	32
0.9	0	0	0	0	0	0	0	0	0	1	1	2	3	22	40
0.8	0	0	0	0	0	0	0	0	0	1	1	2	3	27	49
0.7	0	0	0	0	0	0	0	0	0	1	2	3	4	33	57
0.6	0	0	0	0	0	0	0	0	1	1	2	3	5	40	67
0.5	0	0	0	0	0	0	0	0	1	1	2	4	7	48	75
0.4	0	0	0	0	0	0	0	0	1	2	3	5	8	56	82
0.3	0	0	0	0	0	0	0	0	1	2	4	7	10	64	89
0.2	0	0	0	0	0	0	0	0	1	2	5	8	13	72	93
0.1	0	0	0	0	0	0	0	1	1	3	6	10	16	80	96
0	0	0	0	0	0	0	0	1	2	4	7	13	20	86	98

f) Upper limit of carry-over: 25% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	1	1	1	2	17	32
0.9	0	0	0	0	0	0	0	0	0	1	1	2	3	22	39
0.8	0	0	0	0	0	0	0	0	0	1	1	2	3	26	48
0.7	0	0	0	0	0	0	0	0	0	1	2	3	4	33	57
0.6	0	0	0	0	0	0	0	0	1	1	2	3	5	40	66
0.5	0	0	0	0	0	0	0	0	1	1	2	4	7	47	75
0.4	0	0	0	0	0	0	0	0	1	2	3	5	8	56	82
0.3	0	0	0	0	0	0	0	0	1	2	4	6	10	64	89
0.2	0	0	0	0	0	0	0	0	1	2	5	8	13	72	93
0.1	0	0	0	0	0	0	0	1	1	3	6	10	16	80	96
0	0	0	0	0	0	0	0	1	2	4	7	13	20	86	98

g) Upper limit of carry-over: 30% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	1	1	1	2	17	31
0.9	0	0	0	0	0	0	0	0	0	1	1	2	3	21	39
0.8	0	0	0	0	0	0	0	0	0	1	1	2	3	26	48
0.7	0	0	0	0	0	0	0	0	0	1	2	3	4	32	57
0.6	0	0	0	0	0	0	0	0	1	1	2	3	5	40	66
0.5	0	0	0	0	0	0	0	0	1	1	2	4	6	47	75
0.4	0	0	0	0	0	0	0	0	1	2	3	5	8	55	82
0.3	0	0	0	0	0	0	0	0	1	2	4	6	10	64	88
0.2	0	0	0	0	0	0	0	0	1	2	5	8	13	72	93
0.1	0	0	0	0	0	0	0	1	1	3	6	10	16	80	96
0	0	0	0	0	0	0	0	1	2	4	7	13	20	86	98

Table D-7. In the future projection where remainder rate is randomly changed within the range of 0 to 40%: probability that spawning biomass of each year will exceed the proposed limit reference point (SB0.6msy)

The table shows the results of each setting of upper limit of carry-over for the fishing scenario where safety coefficient β is changed from 0.1 to 1.0 in 0.1 intervals.

(Unit: %)

a) Upper limit of carry-over: 0% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	2	16	26	32	39	48	53	57	82	93
0.9	0	0	0	0	0	3	18	29	35	43	52	58	62	86	95
0.8	0	0	0	0	0	4	20	32	39	47	57	62	66	90	97
0.7	0	0	0	0	0	5	23	36	43	52	62	67	71	93	98
0.6	0	0	0	0	0	6	25	40	47	56	66	72	76	95	99
0.5	0	0	0	0	0	7	29	44	51	61	71	76	80	97	99
0.4	0	0	0	0	0	9	34	49	56	66	76	81	85	98	100
0.3	0	0	0	0	0	12	38	55	61	71	80	85	88	99	100
0.2	0	0	0	0	0	16	45	60	66	76	84	88	92	99	100
0.1	0	0	0	0	0	22	51	66	71	80	88	92	94	100	100
0	0	0	0	0	0	32	59	72	77	85	91	94	96	100	100

b) Upper limit of carry-over: 5% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	2	16	26	31	38	46	51	55	80	91
0.9	0	0	0	0	0	3	17	28	34	42	51	56	60	85	94
0.8	0	0	0	0	0	4	20	31	38	46	56	61	65	89	96
0.7	0	0	0	0	0	5	22	35	41	51	60	66	70	92	98
0.6	0	0	0	0	0	6	25	39	46	55	65	71	75	95	99
0.5	0	0	0	0	0	7	28	44	50	60	70	75	79	97	99
0.4	0	0	0	0	0	9	33	49	56	65	75	80	84	98	100
0.3	0	0	0	0	0	12	38	54	60	70	79	84	88	99	100
0.2	0	0	0	0	0	16	44	60	66	75	84	88	91	99	100
0.1	0	0	0	0	0	22	51	66	71	80	88	92	94	100	100
0	0	0	0	0	0	32	59	72	77	85	91	94	96	100	100

c) Upper limit of carry-over: 10% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	2	15	25	30	37	45	50	54	79	90
0.9	0	0	0	0	0	3	17	28	33	41	50	55	59	84	94
0.8	0	0	0	0	0	3	19	31	37	45	55	60	64	88	96
0.7	0	0	0	0	0	4	22	34	41	50	59	65	69	91	97
0.6	0	0	0	0	0	5	24	38	45	54	64	70	74	94	99
0.5	0	0	0	0	0	7	28	43	50	59	69	75	79	96	99
0.4	0	0	0	0	0	9	32	48	55	64	74	79	84	98	100
0.3	0	0	0	0	0	12	38	54	60	70	79	84	88	99	100
0.2	0	0	0	0	0	16	44	59	65	75	84	88	91	99	100
0.1	0	0	0	0	0	22	51	66	71	80	88	92	94	100	100
0	0	0	0	0	0	32	59	72	77	85	91	94	96	100	100

d) Upper limit of carry-over: 15% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	2	15	24	29	36	44	49	53	78	89
0.9	0	0	0	0	0	3	17	27	33	40	49	54	58	83	93
0.8	0	0	0	0	0	3	19	30	36	44	54	59	63	87	96
0.7	0	0	0	0	0	4	21	34	40	49	59	64	68	91	97
0.6	0	0	0	0	0	5	24	38	44	54	64	69	73	94	99
0.5	0	0	0	0	0	7	28	43	49	58	69	74	78	96	99
0.4	0	0	0	0	0	9	32	48	55	64	74	79	83	98	100
0.3	0	0	0	0	0	12	37	53	60	69	79	84	88	99	100
0.2	0	0	0	0	0	16	44	59	65	75	83	88	91	99	100
0.1	0	0	0	0	0	22	51	66	71	80	88	91	94	100	100
0	0	0	0	0	0	32	59	72	77	85	91	94	96	100	100

e) Upper limit of carry-over: 20% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	2	15	24	29	35	44	49	53	77	89
0.9	0	0	0	0	0	3	16	27	32	40	48	53	58	82	93
0.8	0	0	0	0	0	3	19	30	36	44	53	58	63	87	95
0.7	0	0	0	0	0	4	21	33	40	49	58	64	68	91	97
0.6	0	0	0	0	0	5	24	38	44	54	63	69	73	94	98
0.5	0	0	0	0	0	7	27	42	49	58	69	74	78	96	99
0.4	0	0	0	0	0	9	32	47	54	64	74	79	83	98	100
0.3	0	0	0	0	0	11	37	53	60	69	79	83	87	99	100
0.2	0	0	0	0	0	16	43	59	65	75	83	88	91	99	100
0.1	0	0	0	0	0	22	50	66	71	80	88	91	94	100	100
0	0	0	0	0	0	32	59	72	77	85	91	94	96	100	100

f) Upper limit of carry-over: 25% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	2	14	24	29	35	43	48	52	77	88
0.9	0	0	0	0	0	3	16	27	32	39	48	53	57	82	92
0.8	0	0	0	0	0	3	18	30	36	44	53	58	62	87	95
0.7	0	0	0	0	0	4	21	33	40	48	58	63	68	90	97
0.6	0	0	0	0	0	5	24	37	44	53	63	68	73	94	98
0.5	0	0	0	0	0	7	27	42	49	58	68	74	78	96	99
0.4	0	0	0	0	0	9	32	47	54	63	74	79	83	98	100
0.3	0	0	0	0	0	11	37	53	59	69	79	83	87	99	100
0.2	0	0	0	0	0	15	43	59	65	74	83	88	91	99	100
0.1	0	0	0	0	0	22	50	65	71	80	88	91	94	100	100
0	0	0	0	0	0	32	59	72	77	85	91	94	96	100	100

g) Upper limit of carry-over: 30% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	2	14	24	29	35	43	48	52	77	88
0.9	0	0	0	0	0	3	16	27	32	39	48	53	57	82	92
0.8	0	0	0	0	0	3	18	30	35	44	53	58	62	86	95
0.7	0	0	0	0	0	4	21	33	39	48	58	63	67	90	97
0.6	0	0	0	0	0	5	24	37	44	53	63	68	72	94	98
0.5	0	0	0	0	0	7	27	42	49	58	68	74	78	96	99
0.4	0	0	0	0	0	9	32	47	54	63	73	79	83	98	100
0.3	0	0	0	0	0	11	37	53	59	69	78	83	87	99	100
0.2	0	0	0	0	0	15	43	59	65	74	83	88	91	99	100
0.1	0	0	0	0	0	22	50	65	71	80	88	91	94	100	100
0	0	0	0	0	0	32	59	72	77	85	91	94	96	100	100

Table D-8. In the future projection where remainder rate is randomly changed within the range of 0 to 40%: average value of catch projected for each year

The table shows the results of each setting of upper limit of carry-over for the fishing scenario where safety coefficient β is changed from 0.1 to 1.0 in 0.1 intervals.

(Unit: thousand tons)

a) Upper limit of carry-over: 0% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	7.0	7.7	9.7	11.8	12.1	13.0	13.6	14.5	15.7	16.6	17.6	27.0	34.0
0.9	5.2	6.7	6.3	7.0	8.9	11.0	11.3	12.2	12.8	13.6	14.8	15.7	16.7	26.2	33.1
0.8	5.2	6.7	5.6	6.4	8.1	10.1	10.4	11.3	11.8	12.7	13.8	14.7	15.6	25.2	31.8
0.7	5.2	6.7	4.9	5.7	7.3	9.1	9.4	10.2	10.8	11.6	12.7	13.5	14.4	23.8	30.0
0.6	5.2	6.7	4.3	4.9	6.4	8.1	8.4	9.1	9.7	10.4	11.4	12.2	13.0	22.0	27.6
0.5	5.2	6.7	3.6	4.2	5.5	6.9	7.3	7.9	8.4	9.1	9.9	10.7	11.5	19.8	24.7
0.4	5.2	6.7	2.9	3.4	4.5	5.7	6.0	6.6	7.0	7.6	8.3	9.0	9.7	17.1	21.1
0.3	5.2	6.7	2.2	2.6	3.5	4.5	4.7	5.1	5.5	6.0	6.6	7.1	7.7	13.8	16.8
0.2	5.2	6.7	1.4	1.7	2.4	3.1	3.2	3.6	3.8	4.2	4.6	5.0	5.4	9.9	11.9
0.1	5.2	6.7	0.7	0.9	1.2	1.6	1.7	1.9	2.0	2.2	2.4	2.6	2.9	5.3	6.3
0	5.2	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0

b) Upper limit of carry-over: 5% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	7.0	8.0	10.0	12.1	12.5	13.4	14.0	14.8	16.1	17.0	17.9	27.3	34.3
0.9	5.2	6.7	6.3	7.3	9.2	11.3	11.7	12.5	13.1	14.0	15.2	16.1	17.1	26.6	33.5
0.8	5.2	6.7	5.6	6.6	8.4	10.4	10.7	11.6	12.2	13.0	14.2	15.1	16.0	25.6	32.4
0.7	5.2	6.7	4.9	5.9	7.5	9.4	9.8	10.5	11.1	11.9	13.0	13.9	14.8	24.3	30.6
0.6	5.2	6.7	4.3	5.1	6.6	8.3	8.7	9.4	10.0	10.7	11.7	12.5	13.4	22.5	28.3
0.5	5.2	6.7	3.6	4.3	5.6	7.2	7.5	8.2	8.7	9.3	10.3	11.0	11.8	20.3	25.4
0.4	5.2	6.7	2.9	3.5	4.6	5.9	6.2	6.8	7.3	7.8	8.6	9.3	10.0	17.6	21.8
0.3	5.2	6.7	2.2	2.7	3.6	4.6	4.9	5.3	5.7	6.2	6.8	7.3	7.9	14.2	17.4
0.2	5.2	6.7	1.4	1.8	2.4	3.2	3.4	3.7	4.0	4.3	4.8	5.2	5.6	10.2	12.4
0.1	5.2	6.7	0.7	0.9	1.3	1.6	1.8	1.9	2.1	2.3	2.5	2.7	3.0	5.5	6.6
0	5.2	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0

c) Upper limit of carry-over: 10% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	7.0	8.3	10.1	12.4	12.8	13.6	14.2	15.1	16.4	17.3	18.2	27.4	34.4
0.9	5.2	6.7	6.3	7.6	9.4	11.5	11.9	12.7	13.4	14.2	15.5	16.4	17.3	26.8	33.8
0.8	5.2	6.7	5.6	6.9	8.5	10.6	11.0	11.8	12.4	13.3	14.4	15.3	16.3	25.9	32.7
0.7	5.2	6.7	4.9	6.1	7.6	9.6	10.0	10.8	11.4	12.2	13.3	14.1	15.1	24.6	31.1
0.6	5.2	6.7	4.3	5.3	6.7	8.5	8.9	9.6	10.2	10.9	11.9	12.8	13.7	22.9	28.8
0.5	5.2	6.7	3.6	4.5	5.8	7.3	7.7	8.4	8.9	9.6	10.5	11.2	12.1	20.7	25.9
0.4	5.2	6.7	2.9	3.6	4.7	6.0	6.4	7.0	7.4	8.0	8.8	9.5	10.2	17.9	22.2
0.3	5.2	6.7	2.2	2.8	3.6	4.7	5.0	5.5	5.8	6.3	6.9	7.5	8.1	14.5	17.8
0.2	5.2	6.7	1.4	1.9	2.5	3.2	3.5	3.8	4.1	4.4	4.9	5.3	5.7	10.5	12.7
0.1	5.2	6.7	0.7	1.0	1.3	1.7	1.8	2.0	2.1	2.3	2.6	2.8	3.0	5.7	6.8
0	5.2	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0

d) Upper limit of carry-over: 15% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	7.0	8.6	10.2	12.6	13.0	13.8	14.4	15.3	16.5	17.4	18.4	27.6	34.5
0.9	5.2	6.7	6.3	7.8	9.4	11.7	12.1	12.9	13.5	14.4	15.6	16.6	17.5	27.0	34.0
0.8	5.2	6.7	5.6	7.1	8.6	10.7	11.2	11.9	12.6	13.4	14.6	15.5	16.5	26.1	32.9
0.7	5.2	6.7	4.9	6.3	7.7	9.7	10.2	10.9	11.5	12.3	13.4	14.3	15.3	24.8	31.3
0.6	5.2	6.7	4.3	5.4	6.8	8.6	9.1	9.7	10.3	11.1	12.1	13.0	13.8	23.1	29.1
0.5	5.2	6.7	3.6	4.6	5.8	7.4	7.8	8.5	9.0	9.7	10.6	11.4	12.2	20.9	26.2
0.4	5.2	6.7	2.9	3.7	4.8	6.2	6.5	7.1	7.6	8.1	8.9	9.6	10.4	18.2	22.5
0.3	5.2	6.7	2.2	2.8	3.7	4.8	5.1	5.5	5.9	6.4	7.1	7.6	8.2	14.8	18.1
0.2	5.2	6.7	1.4	1.9	2.5	3.3	3.5	3.9	4.2	4.5	4.9	5.4	5.8	10.7	12.9
0.1	5.2	6.7	0.7	1.0	1.3	1.7	1.8	2.0	2.2	2.4	2.6	2.8	3.1	5.8	6.9
0	5.2	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0

e) Upper limit of carry-over: 20% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	7.0	8.8	10.3	12.7	13.1	13.9	14.5	15.4	16.6	17.6	18.5	27.6	34.5
0.9	5.2	6.7	6.3	8.0	9.5	11.8	12.2	13.0	13.7	14.5	15.7	16.7	17.6	27.1	34.0
0.8	5.2	6.7	5.6	7.2	8.6	10.9	11.3	12.1	12.7	13.5	14.7	15.7	16.6	26.2	33.1
0.7	5.2	6.7	4.9	6.4	7.8	9.8	10.3	11.0	11.6	12.4	13.6	14.5	15.4	24.9	31.5
0.6	5.2	6.7	4.3	5.6	6.8	8.7	9.2	9.8	10.5	11.2	12.2	13.1	14.0	23.3	29.3
0.5	5.2	6.7	3.6	4.7	5.8	7.5	7.9	8.6	9.1	9.8	10.7	11.5	12.3	21.1	26.4
0.4	5.2	6.7	2.9	3.8	4.8	6.2	6.6	7.1	7.7	8.2	9.0	9.7	10.5	18.3	22.8
0.3	5.2	6.7	2.2	2.9	3.7	4.8	5.2	5.6	6.0	6.5	7.1	7.7	8.3	14.9	18.3
0.2	5.2	6.7	1.4	2.0	2.5	3.3	3.6	3.9	4.2	4.5	5.0	5.4	5.9	10.8	13.1
0.1	5.2	6.7	0.7	1.0	1.3	1.7	1.9	2.0	2.2	2.4	2.6	2.9	3.1	5.8	7.0
0	5.2	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0

f) Upper limit of carry-over: 25% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	7.0	8.9	10.3	12.8	13.2	13.9	14.6	15.5	16.7	17.7	18.6	27.7	34.5
0.9	5.2	6.7	6.3	8.2	9.5	11.9	12.3	13.1	13.8	14.6	15.8	16.8	17.7	27.1	34.1
0.8	5.2	6.7	5.6	7.4	8.6	11.0	11.4	12.1	12.8	13.6	14.8	15.7	16.7	26.3	33.2
0.7	5.2	6.7	4.9	6.5	7.8	9.9	10.3	11.1	11.7	12.5	13.6	14.5	15.5	25.0	31.6
0.6	5.2	6.7	4.3	5.7	6.8	8.8	9.2	9.9	10.5	11.3	12.3	13.2	14.0	23.4	29.5
0.5	5.2	6.7	3.6	4.8	5.9	7.6	8.0	8.6	9.2	9.9	10.8	11.6	12.4	21.2	26.6
0.4	5.2	6.7	2.9	3.9	4.8	6.3	6.7	7.2	7.7	8.3	9.1	9.8	10.5	18.4	22.9
0.3	5.2	6.7	2.2	3.0	3.7	4.9	5.2	5.6	6.1	6.5	7.2	7.8	8.4	15.0	18.4
0.2	5.2	6.7	1.4	2.0	2.5	3.4	3.6	3.9	4.2	4.6	5.0	5.5	5.9	10.9	13.2
0.1	5.2	6.7	0.7	1.0	1.3	1.8	1.9	2.0	2.2	2.4	2.7	2.9	3.2	5.9	7.0
0	5.2	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0

g) Upper limit of carry-over: 30% of the initial value

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	7.0	9.1	10.2	12.9	13.2	14.0	14.6	15.5	16.8	17.7	18.6	27.7	34.5
0.9	5.2	6.7	6.3	8.3	9.5	12.0	12.3	13.1	13.8	14.6	15.9	16.8	17.7	27.2	34.1
0.8	5.2	6.7	5.6	7.4	8.6	11.0	11.4	12.2	12.8	13.7	14.8	15.8	16.7	26.3	33.2
0.7	5.2	6.7	4.9	6.6	7.8	10.0	10.4	11.1	11.8	12.6	13.7	14.6	15.5	25.1	31.7
0.6	5.2	6.7	4.3	5.7	6.8	8.9	9.3	9.9	10.6	11.3	12.3	13.2	14.1	23.4	29.5
0.5	5.2	6.7	3.6	4.9	5.8	7.6	8.0	8.7	9.2	9.9	10.8	11.6	12.5	21.3	26.6
0.4	5.2	6.7	2.9	3.9	4.8	6.3	6.7	7.2	7.7	8.3	9.1	9.8	10.6	18.5	23.0
0.3	5.2	6.7	2.2	3.0	3.7	4.9	5.2	5.7	6.1	6.6	7.2	7.8	8.4	15.1	18.5
0.2	5.2	6.7	1.4	2.0	2.5	3.4	3.6	3.9	4.3	4.6	5.1	5.5	6.0	10.9	13.2
0.1	5.2	6.7	0.7	1.0	1.3	1.8	1.9	2.1	2.2	2.4	2.7	2.9	3.2	5.9	7.1
0	5.2	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D-9. In the scenario without a remainder carrying over: probability for spawning biomass to exceed the proposed target reference point (a) and limit reference point (b), and changes in the projected average catch (c) (repost of Tables A-5 and A-6 (b) of the Examination Item A)

(a) Probability for spawning biomass to exceed the proposed target reference point

(%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	0	0	0	0	0	1	1	2	12	24
0.9	0	0	0	0	0	0	0	0	0	0	1	1	2	16	31
0.8	0	0	0	0	0	0	0	0	0	1	1	2	3	21	39
0.7	0	0	0	0	0	0	0	0	0	1	1	2	3	27	49
0.6	0	0	0	0	0	0	0	0	0	1	2	3	4	35	59
0.5	0	0	0	0	0	0	0	0	1	1	2	4	6	43	69
0.4	0	0	0	0	0	0	0	0	1	1	3	5	7	53	78
0.3	0	0	0	0	0	0	0	0	1	2	3	6	10	61	86
0.2	0	0	0	0	0	0	0	0	1	2	4	8	12	70	91
0.1	0	0	0	0	0	0	0	1	1	3	6	10	16	78	96
0	0	0	0	0	0	0	0	1	2	3	7	13	20	86	98

(b) Probability for spawning biomass to exceed the proposed limit reference point

(%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	0	0	0	0	0	2	12	22	25	31	37	43	46	70	82
0.9	0	0	0	0	0	2	14	24	28	35	42	48	51	76	87
0.8	0	0	0	0	0	3	16	28	32	39	48	53	57	82	92
0.7	0	0	0	0	0	3	18	31	36	44	53	59	63	87	95
0.6	0	0	0	0	0	4	21	35	41	49	59	65	69	91	97
0.5	0	0	0	0	0	6	25	39	46	55	65	71	75	94	99
0.4	0	0	0	0	0	7	29	45	52	61	71	76	81	97	99
0.3	0	0	0	0	0	10	35	50	57	67	77	82	86	98	100
0.2	0	0	0	0	0	14	42	58	64	73	82	87	90	99	100
0.1	0	0	0	0	0	21	50	66	70	79	87	91	93	100	100
0	0	0	0	0	0	32	60	73	78	85	91	94	96	100	100

(c) Average catch

(Thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	5.2	6.7	7.0	8.3	10.1	12.4	12.8	13.6	14.2	15.1	16.4	17.3	18.2	27.4	34.4
0.9	5.2	6.7	6.3	7.6	9.4	11.5	11.9	12.7	13.4	14.2	15.5	16.4	17.3	26.8	33.8
0.8	5.2	6.7	5.6	6.9	8.5	10.6	11.0	11.8	12.4	13.3	14.4	15.3	16.3	25.9	32.7
0.7	5.2	6.7	4.9	6.1	7.6	9.6	10.0	10.8	11.4	12.2	13.3	14.1	15.1	24.6	31.1
0.6	5.2	6.7	4.3	5.3	6.7	8.5	8.9	9.6	10.2	10.9	11.9	12.8	13.7	22.9	28.8
0.5	5.2	6.7	3.6	4.5	5.8	7.3	7.7	8.4	8.9	9.6	10.5	11.2	12.1	20.7	25.9
0.4	5.2	6.7	2.9	3.6	4.7	6.0	6.4	7.0	7.4	8.0	8.8	9.5	10.2	17.9	22.2
0.3	5.2	6.7	2.2	2.8	3.6	4.7	5.0	5.5	5.8	6.3	6.9	7.5	8.1	14.5	17.8
0.2	5.2	6.7	1.4	1.9	2.5	3.2	3.5	3.8	4.1	4.4	4.9	5.3	5.7	10.5	12.7
0.1	5.2	6.7	0.7	1.0	1.3	1.7	1.8	2.0	2.1	2.3	2.6	2.8	3.0	5.7	6.8
0	5.2	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0