

Response to the Request from the Committee of Stock Management Policy (1st session) on Walleye Pollock Japanese Pacific Stock

The first Conference of Stock Management Policy (Stakeholder meeting) on this stock (held on August 20 and 21, 2020) requested four items on Walleye Pollock Japanese Pacific stock and Northern Sea of Japan stock in response to the information presented by the Scientific Meeting on Reference Points (held on April 19, 2019). Response to the requested items regarding the Pacific stock (A, C and D below) is as follows.

Requested 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 based on the latest stock assessment.

1. Introduction

In response to the request, firstly we revised results for the parameter estimation of the hockey stick (HS) model of the stock-recruitment (S-R) relationships based on the stock assessment results of 2020. Secondly, we showed the revised proposal for the reference points, fishing ban level, and HCRs based on the revised HS model by using the same method as presented at the previous Scientific Meeting. Finally, we also revised future projection results based on the updated conditions.

The proposal at the Scientific Meeting held in April 2019 was based on the 2018 stock assessment results (i.e. results of the latest stock assessment at that time). The revised proposal in this document is based on the 2020 stock assessment, which is the latest assessment result now. The latest stock assessment includes two more assessment years of abundance, etc. compared with the 2018 stock assessment. The plus group of cohort analysis has been expanded from age 8+ to age 10+ since the stock assessment of the last year (the 2019 stock assessment).

2. S-R relationship

As the S-R relationship of this stock, the Scientific Meeting has proposed the HS model for S-R relationship. The least squares method was used for parameter estimation of the relationship. A model that considers autocorrelation in residuals of observation values of recruitment against the predicted values was not used. We updated the parameters of this HS model using the recruitment and spawning stock biomass (SSB) of the 1981-2016 fishing years (FYs) based on the latest stock assessment results. Compared to the previous model, we found a slight change in the slope of the updated HS model (Parameter a in the table below and Figure A-1). The breakpoint of the HS model is at 151 thousand tons of SSB also in the updated relationship (Parameter b in the table below). The expected recruitment on average with the SSB at this level or higher is about 1.8 billion in number (previous value was 1.9 billion). As is the case with the proposal at the Scientific Meeting in 2019, we did not use the data of the

recent three years (2017-2019 FYs) for the estimation of the parameters of HS model, because the recruitment was not directly estimated from cohort analysis for these years.

Proposal	S-R relationship	Optimization method	Autocorrelation	<i>a</i>	<i>b</i>	S.D.
Proposal by the Scientific Meeting (2019)	Hockey stick (HS)	Least squares method	No	12.455	150,944	0.532
Updated value	Hockey stick (HS)	Least squares method	No	11.795	150,944	0.580

Here, *a* represents the slope of the S-R curve to the break point, while *b* represents the SSB (tons) at the break point.

Regarding this stock, we have no historical information of decrease in recruitment associated with the depletion of SSB. Compared with the HS model, Beverton-Holt (BH) and Ricker (RI) models have a milder decrease of the projected recruitment associated with a decrease of SSB (Figure A-2). The 2019 Science Meeting concluded that, if SSB fell below the recorded low level, a non-conservative extrapolation number as recruitment would pose a risk, in the context of the fisheries management based on future projection result. Therefore, the HS model which can produce more conservative recruitment was approved to apply the S-R relationship. The updated data of recruitment and SSB has not changed this conclusion. We compared the least squares method and the least absolute value method for optimization of parameter estimation using the updated data, then the difference of the small-sample-size-corrected version of Akaike information criterion (AICc) between the two methods was very small, at 0.16. Therefore, there is no need to change the optimization method in this revision (Table A-1). There is also no need to consider autocorrelation for the HS model because a diagnostic did not show any autocorrelation in the residuals between the predicted value and observed value (Figure A-3). For these reasons, in this revision based on the 2020 stock assessment, we did not change the model of the S-R relationship, optimization method, and treatment of autocorrelation from those of the 2019 Scientific Meeting (Figure A-4).

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

The 2019 Scientific Meeting proposed as following: SB_{msy}, which is the SSB corresponding to maximum sustainable yield (MSY), as the target reference point (SB_{target}); SB_{min}, which is the lowest SSB that has ever been observed in history, as the limit reference point (SB_{limit}); and the SSB will recover to the SB_{target} in 10 years with a probability of 50% or higher under fishing based on the proposed HCRs, as the fishing ban level (SB_{ban}). The revised results using the 2020 stock assessment are shown in the table below and Table A-2.

Proposal	Item	Value	Remarks
Proposal by the Scientific Meeting (2019)	SBtarget	220 thousand tons	SSB corresponding to MSY (SBmsy)
	SBlimit	151 thousand tons	The smallest SSB ever observed (SBmin)
	SBban	70 thousand tons	The threshold for SSB to recover to the proposed SBtarget with a probability of 50% under fishing based on the proposed HCRs ($\beta = 0.8$) for 10 years
Updated value	SBtarget	228 thousand tons	SSB corresponding to MSY (SBmsy)
	SBlimit	151 thousand tons	The smallest SSB ever observed (SBmin)
	SBban	60 thousand tons	The threshold of for SSB to recover to the updated SBtarget with a probability of 50% under fishing based on the proposed HCRs ($\beta = 0.8$) for 10 years

We updated SBmsy as the SBtarget in the same way as used for the 2019 Scientific Meeting: i.e. the equilibrium situation is defined after the simulation period that is 20 times the average generation time (8.46 years); Fmsy is defined as the F value which can maximize the average catch at equilibrium situation; SBmsy is defined as the average SSB at equilibrium situation under fishing by Fmsy. For the simulation, we used the HS model 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 2015-2019 FYs. The settings of other biological parameters used for the simulation are shown in Table A-3 Average SSB at equilibrium situation when we used various F and the corresponding average catch at age are shown in Figure A-5. Here, the ratio of older fish in expected catch were increase on average with higher SSB level. Updated SBmsy that maximizes the average catch was increased by 8 thousand to 228 thousand tons compared to the proposal at the 2019 Scientific Meeting.

SBmin, which is the proposed SBlimit, was 151 thousand tons based on the 2020 stock assessment as well. This is the same level as “the minimal SSB that may produce strong year class (SSB of 151 thousand tons that produced 1982 year class)” which was empirically used as Blimit in the past.

We searched candidate values of SBban in the range of 5 thousand to 150 thousand tons. From these candidate values, the minimal values for recovery to the SBtarget after 10 years with a probability of 50% was chosen based on the simulation assuming the catch control by the HCRs which was also depended on the candidates of SBban. The starting condition of simulation (e.g. age composition, average body weight at age, and selectivity) were randomly chosen from the observed value of the 1981-2019 FYs, while the fishing mortality during the recovery period was given from the HCRs according to the SSB of each year. Simulation was made 10,000 times for each SSB candidate values at the starting point. As is the case with the

proposal at the 2019 Scientific Meeting, the coefficient β is set to 0.8. As a result, we updated the proposed SBban to 60 thousand tons (Tables A-2 and A-4). The threshold for SSB to recover to the SBlimit in 10 years with a probability of 50% or higher when β is set to 0.8 was 30 thousand tons (Tables A-2 and A-5).

4. Kobe plot

The revised Kobe plot based on the updated SBmsy and corresponding exploitation rate (Umsy) or fishing mortality (Fmsy) are shown in Figure A-6. Fishing mortality (F) of this stock was judged to have been below the Fmsy since the 2001 FY, excluding the 2004 and 2008 FYs. Exploitation rate (U) was judged to have been below the Umsy since the 2001 FY, excluding the 2004 and 2008 FYs. SSB has been over the SBmsy (proposed SBtarget) since the 2009 FY.

5. Proposed HCRs

The HCRs are rules to specify the fishing mortality (F) corresponding to the SSB, considering the probability of maintaining or recovering the SSB above the proposed SBtarget. The HCRs are described in the “Basic Guidelines for the Harvest Control Rules and the Estimation of the Allowable Biological Catch (ABC)” as the Type-I rule. In this rule, the F is controlled to directly reduced according to the SSB level, when the SSB falls below the SBlimit. The SBban is the SSB level which catches should be prohibited. Multiplying the Fmsy by the coefficient β is the upper limit of F. Based on the updated SBlimit and SBban, because the SBban is updated to 60 thousand tons from 70 thousand tons, the slope to reduce F when SSB falls below the SBlimit is slightly gentler. The proposed HCR that used 0.8 for the coefficient β is shown in Figure A-7.

6. Future projection

(1) Setting of future projection

We updated the future projection based on the updated S-R relationship and HCRs. For future projection, we made forward cohort calculation from the abundance of the 2019 FY estimated by the 2020 stock assessment to the 2051 FYs. Recruitment for the future projection was given from the HS model and projected SSB of the respective year. We assumed errors in logarithmic normal distribution as the uncertainty of recruitment in 10,000 stochastic simulation. The catch in the 2020 FY was assumed from the projected biomass and the current F (F2015-2019*). The current F is average F value at age of the 2015-2019 FYs and the selectivity is used update of SBmsy. Settings of other biological parameters that are used for the future projection are shown in Table A-2. As fishing mortality in the 2021 FY and after, we used the F provided by the updated HCRs according to the SSB projected for the respective fishing year. For mathematical equations used for the calculation, see Appendix 9 of the report of 2020 stock assessment.

(2) Prediction for the 2021 FY

Based on the future projection that uses the updated proposed HCRs, we projected the SSB and catch of the 2021 FY. The projected SSB in the 2021 FY was 350 thousand tons on average, which was above the SBlimit in all simulations. For this reason, the fishing mortality of the 2021 FY, which was provided by the updated HCRs, is F_{msy} multiplied by the coefficient β . The average catch of the 2021 FY was 189 thousand tons when β is set to 0.8.

SSB in the 2021 FY (average projection value): 350 thousand tons			
Item	Catch in the 2021 FY (thousand tons)	Ratio to the current fishing mortality (F/F2015-2019*)	Exploitation rate in the 2021 FY (%)
$\beta=1.0$	226	2.08	22
$\beta=0.9$	208	1.88	20
$\beta=0.8$	189	1.67	18
$\beta=0.7$	169	1.46	16
$\beta=0.6$	148	1.25	14
$\beta=0.5$	127	1.04	12
$\beta=0$	0	0	0
F2015-2019*	122	1.00	12

Selectivity of F2015-2019* is different from the selectivity in the report of the 2020 Stock Assessment (i.e. F2015-2019). Selectivity of F2015-2019 is the same as that used for the calculation of MSY reference points at the 2019 Scientific Meeting. F2015-2019 is obtained by %SPR-conversion of the average F value of the 2015-2019 FYs under this selectivity. F2015-2019* is simply averaged value of F at age for the 2015-2019 FYs. Both have the same %SPR.

(3) Projection for the 2022 FY onward

Results of the medium- to long-term future projection based on the updated HCRs are shown in Figure A-8, Tables A-6, and A-7. When catch control based on the updated HCRs is continued for 10 years, predicted SSB in the 2031 FY will be 284 thousand tons on average with β set to 0.8 (80% confidence interval: 190 thousand to 398 thousand tons). The probability of the predicted SSB being above the updated SBtarget, SBlimit, and SBban is 72%, 98%, and 100%, respectively. As presented in the report of the 2020 stock assessment, most recently, the 2016 year-class of this stock is estimated to be relatively abundant and the abundance of the 2017 year-class is also estimated to be high. For this reason, it is projected that the SSB and abundance will stop declining in the short-term but we need to pay attention to the information that strength of the 2018-2019 year-classes seems to be weak. If we have the average recruitment that is projected from the HS model, it is expected that the SSB will be maintained above the updated SBtarget with a high probability in the medium- to long- term, but there is

also a possibility that the SSB will fall below the updated SBtarget in the short-term. As presented in the report of the 2020 stock assessment, in order to prevent the SSB falling below the updated SBtarget with a probability of over 50% in the short-term, it should be considered to set β to 0.7 and under. In order to avoid the risk that the SSB will fall below the SBlimit, it is not recommended to set β to 0.9 or higher.

Uncertainty considered: recruitment					
Item	SSB in the 2031 FY (thousand tons)	80% Confidence interval (thousand tons)	Probability of the SSB in the 2031 FY being above the following reference points (%)		
			Proposed SBtarget	Proposed SBlimit	Proposed SBban
$\beta=1.0$ (Fmsy)	232	153-327	44	91	100
$\beta=0.9$	256	170-359	58	96	100
$\beta=0.8$	284	190-398	72	98	100
$\beta=0.7$	318	215-441	85	99	100
$\beta=0.6$	359	246-494	94	100	100
$\beta=0.5$	411	286-559	98	100	100
$\beta=0$	1,063	808-1355	100	100	100
F2015-2019*	423	295-573	99	100	100

Requested Item C

Calculate the specific value of the coefficient β , with which the probability that the spawning biomass of the walleye pollock Japanese Pacific stock will exceed the target reference point in the 2031 fishing season is exactly 50%.

1. Introduction

In response to this request, we made an additional future projection using the HS model, reference points, fishing ban level, and HCRs, which were updated in Item A. In order to explore the specific value of the coefficient β with which the probability that the SSB will exceed the SBtarget in the 2031 FY is exactly 50%, we examined β with intervals of 0.01 within the range between 0.9 and 1.0 in the future projection.

2. β with which the probability that the spawning biomass will exceed the target reference point after 10 years is 50%

The probability that the SSB of the 2031 FY will exceed the SBtarget was nearly 50% when the coefficient β was set to 0.95 (Tables C-1 and C-2). When we searched β more finely around 0.95, the probability that the SSB in the 2031 FY will exceed the SBtarget was exactly 50% when β was set in the range of 0.952 to 0.948, and 51% when β was set in the range of 0.945 to 0.951. In these ranges of β (0.945 to 0.958), the differences between the maximum and the minimum value of the average catch was from 1 thousand to 2.3 thousand tons for the 2021-2022 FYs, while it was several hundred tons after the 2023 FY.

As mentioned in the report of the 2019 Scientific Meeting, it has not been recommended to use a high β value such as over 0.9. The updated result of future projection doesn't change this conclusion; the probability that the SSB will fall below the updated SBtarget and SBlimit in the short-term became higher, when higher β value is used. For example, when β was set to 0.95, it was projected that SSB will decrease in the short term and will fall below the updated SBtarget in the 2024 FY with a high probability. The probability of falling below the proposed SBlimit in the 2025 and 2026 FYs was projected to be 10% or higher (Table C-1). If higher fishing mortality was applied for the catch control using the high β value, we would have to be faced the higher risk of biomass depletion. It is considered that we need to avoid such a risk whenever possible.

Requested 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

1. Introduction

This is the request for the evaluation of the upper limit of carry-over rule if it is introduced to the TAC control. In the carry-over rule, some amount of unused catch remains is able to use in the next year. Prior the establishment of the rule, it should be evaluated the risk of excessive fishing mortality and negative influence for stock due to the carry-over including the most extreme situations.

A possible most extreme situation would be that all the unused remains will be caught in next year with all of the allowable catch together (this means extreme catch is repeatedly happen biennially). In this document, we conducted simulations assuming this extreme situation to evaluate the effects of upper-limit of carrying-over of various unused catch. The unused catch was determined by the ratio to the available catch (total of the initial TAC and the carried-over catch) of the year, and the upper-limit of carrying-over was determined by the ratio to the initial TAC in the simulation of future projection (FigureD-1). For the condition of future projection, we used the updated HS model of S-R relationships, reference points, fishing ban level, and HCRs which was described in Request Item A.

2. Evaluation of the influence of unused remains and carrying over in extreme situation

[Method]

Assuming the most extreme situation for remain and carrying over, we made the future projection assuming that the unused remains is occurring every two years, and these remains are caught with all allowable catch in the subsequent year of these years. The future projection assumed that the unused remains and carrying over begins from the 2021 FY. For instance, the remains is occurred in the 2021 FY, then there is no remains in the 2022 FY. The following 2023 FY has the unused remains again and in the 2024 FY there is no remains. In this case, all allowable catch including the unused remains which carried over from the previous year is caught together in even years. For the F in even years, the probability of exceedance of the F_{msy} were calculated (for the years of all-fishing in this case). In addition, we showed the average catch expected in the 2021-2031FY, and the probability that the SSB will exceed the SBtarget (SB $_{msy}$ in this case) and SBlimit (151 thousand tons as SB $_{min}$) at 10 years after starting catch control by the HCRs (i.e. in the 2031 FY). Because the unused remains are occurred in odd years in this future projection, the biomass (spawning biomass) in even years are naturally larger than that in odd years. Thus, we also examined the probability that the SSB in the 2030 FY will exceed the proposed SBtarget and SBlimit for reference.

As the projection scenario, the unused remains are set at the 5% interval within the range of 0 to 30% of the available catch projected in odd years (defined as “reserve rate”). We also set

the upper limit of carry-over at the 5% interval within the range of 5 to 30% of the initial TAC (ABC), which was assumed by the projected catch from the HCRs (defined as “carry over limit”). We made the projection scenarios by combinations of the reserve rate and carrying over limit with various β for the HCRs from 0.7 to 1.0 in 0.05 intervals. The projection is made 10,000 times for each combination.

[Mathematical equation]

When the catch projected in year t based on the proposed HCRs at the k th 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-1}^k and the “reserve rate” of year t as RR_t , thus the unused remains in year t is expressed as follows:

$$RR_t \times ABC_t^k + ABC_{t-1}^k$$

When the gross catch in year t is GC_t ;

$$GC_t^k = (1 - RR_t) \times ABC_t^k + ABC_{t-1}^k$$

Here, the F of year t at age s is $xF_{s,msy}$, where x that satisfies the following equation 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} is the age at recruitment and S_{max} is the age of plus group: these are 0 and 10, respectively. M_s is natural mortality at the age of s , $N_{s,t}^k$ is the number of age s fish in year t of the k th trial, and v_s is body weight per fish of age s . $F_{s,msy}$ is fishing mortality at age, which can produce MSY (F_{msy}). Therefore the selectivity of $xF_{s,msy}$ is same as that of F_{msy} .

Unused remains that can be carried over to the next 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 gross catch is smaller than the catch projected by HCRs, the difference is carried over to the following year. Unused remains cannot be carried over two years later.

$ABC_t^k \times CR_t$: Carry over is capped by the “carry over limit” (CR_t) which is the ratio to the projected catch by the HCRs.

[Result]

We made future projection for the period from the 2020 to 2031 FYs under the scenarios which were conditioned by the combinations of reserve rate (0 to 30%), carry-over limit (5 to 30%), and the coefficient β (0.7 to 1.0) for HCRs (Figure D-2). The unused remains and carrying-over was assumed to be happen since the 2021 FY in in odd years (2021, 2023, 2025, 2027 and 2029 FYs). The catch of the even years (2022, 2024, 2026, 2028 and the 2030 FYs) increases with additional carried-over catch. The average of the probability that the F for the even years will exceed F_{msy} is shown for each carry-over limit in Table D-1. Depending on the value of the coefficient β of the HCRs, F will exceed F_{msy} for some case of carry-over

limit. In order to prevent F from exceeding F_{msy} , it is considered to be necessary to keep the carry-over limit under 15% of the initial allowable catch projected by HCRs (“initial value”) even when β is not over 0.8. F will exceed F_{msy} when the carry-over limit is over 10% even with β not exceeding 0.85, and when the carry-over limit is over 5% even with β not exceeding 0.9. No F will exceed F_{msy} when the carry-over limit is not exceeding 20% with β not exceeding 0.75, and when the carry-over limit is not exceeding 25% with β not exceeding 0.7.

Tables D-2 and D-3 show the probability that SSB will exceed the SBtarget (SB_{msy}) and the SBlimit (151 thousand tons that is the lowest observed value for this stock) in the 2031 FY under the future projections. In comparison with the scenario without any unused remains, when the carry-over limit is 15% with β not exceeding 0.8, the probabilities of exceedance for the SSB in the 2031 over the SBtarget and SBlimit is lower by up to 6% and lower by up to 1%, respectively. Similarly, when the carry-over limit is 10% with β not exceeding 0.85, those probabilities of exceedance are lower by up to 4% and lower by up to 1%, respectively. When the carry-over limit is 5% with β not exceeding 0.90, those probabilities of exceedance are lower by up to 2% and not negatively affected, respectively. In all cases, the lower the carry-over limit, the smaller the influence on the probabilities of exceedance over the reference points are. Basically, carrying-over of unused remains has the negative influence for the adaptability of catch control to the stock status, and therefore, it is desirable to set a lower value for carry-over limit. With lower adaptability of harvest control, there are also negative influence for the future average catch compared with the scenario without any unused remains (Table D-4). For example, when the reserve rate is 15% with 0.8 for β , the average catch expected in the 2021-2031 FYs is smaller by 1 thousand to 7 thousand tons compared to the scenario without any unused remains (when the reserve rate is 0%; 163 thousand tons) under the condition of 5 to 30% carrying-over limit. It should be noted that the carrying-over of unused remains can provide flexibility for catch, however the eventual total catch may be slightly smaller.

In this future projection, the unused remains in odd years has the effect of increasing the biomass (and SSB) in even years. Actually, the probability that the SSB of the 2030 FY will exceed the SBtarget and expected catch is equal to or greater than that of the scenario without any unused remains (Table D-5).

Both in 2030 and 2031 FYs, with a higher reserve rate and lower carry-over limit, the probabilities of exceedance for the SSB over the SBtarget and SBlimit are higher compared to the scenario without any unused remains. This is interpreted that the effect of unused remains exceeds the negative influence of carry-over.

3. Evaluation of the influence of reserve rate is randomly changed

[Method]

Naturally, actual reserve rate will vary depending on the year. For this reason, we examined the impact of carry-over limit in the condition that the reserve rate will randomly change in uniform distribution within the range of 0 to 50% from the 2021 FY. We set the carry-over

limit in 5% intervals within the range of 5 to 30%, and compared the probability that the F of each year will exceed F_{msy} . For reference, we also compared the probability that SSB will exceed the SB_{target} and SB_{limit} , and future average catch which was projected each year.

[Result]

Table D-5 shows the result of the future projection of the probability that F will exceed F_{msy} for the 2021-2031 FY under the catch control based on the HCRs. Based on the result of the carry-over limit in above section (Figure D-3), focusing on the scenario using 15% for the carry-over limit, the probability that F will exceed F_{msy} was extremely low when β is not exceeding 0.8 (Table D-6-c). This mean that the carry-over limit, which can prevent excessive fishing mortality even with the extreme situation, would work adequately to prevent excessive fishing in the actual fishing situation.

The probability that SSB will exceed the SB_{target} and SB_{limit} is shown in Tables D-7 and D-8, and the average catch is shown in Table D-9. For comparison, we show again the results of the scenario without any unused remains in Table D-10 (repost of Table A-6 and Table A-7 (b) of the Requested Item A). From these results, it is considered that there is positive effect for future SSB by unused remains and carrying over if the carry-over limit was not over 15% and the reserve rate within the range between 0 and 50%, which is similar effect to the cutdown the β for 0.1-0.2. In this case, the positive effect of unused remains would be stronger than the negative effect of carrying-over for the biomass. The future average catch is also similar to the result when β of the HCRs was cutdown. Therefore, it is suggested that if unused remains and carrying over are allowed, the flexibility of fishing may increase but the eventual total catch can be slightly smaller.

These simulation results were based on an assumptive condition which have big influence. Thus we need pay attention to the reasonability of scenarios for the reserve rate (random change within the range between 0% and 50%) to translate the simulation results for the implementation the carrying-over rule .

4. Conclusion

For introduction of a rule to catch the unused remains of the allowable catch of a certain year during the succeeding year, it should be considered necessary to set a carrying-over limit to prevent F from exceeding the F_{msy} , even when fishing is conducted with the most extreme unused remains and carrying over under the rule. We examined the limitation that satisfies the above: when 0.8 is used for the coefficient β of the HCRs (0.8 has been recommended by the Scientific Meeting), it is considered to be desirable to set the carrying over limit up to 15% of the initial allowable catch. It is considered that the desirable carry-over limit depends on the β value. The larger the β value, the lower the necessary carry-over limit.

Stock assessment generally have uncertainty in biomass estimates of the latest year. For this reason, also in order to avoid a negative influence on biomass due to excessive fishing caused by assessment uncertainty, it would be necessary to set the upper limit for determination of

carrying-over amount not only based on the initial allowable catch at the assessment year, but also based on the re-calculated allowable catch based on the “latest” stock assessment result at all times.

Remarks

The Report of the 2020 Stock Assessment Report of walleye pollock Pacific stock already includes future projection results based on the previous S-R relationships, reference points, etc. which were proposed at the 2019 Scientific Meeting. In order to avoid confusion, we wish to add the contents of Requested Items A and C to the appendix of the Stock Assessment Report.

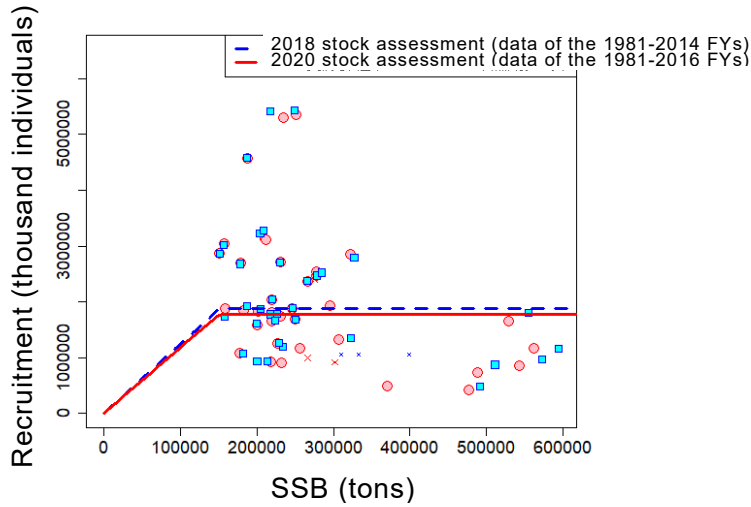


Figure A-1. Comparison of estimation results of HS model of S-R relationship

The blue squares represent the SSB and recruitments of the 2019 stock assessment, while the red circles represent the SSB and recruitments based on the 2020 stock assessment. For the estimation of HS model parameter, we didn't use the last three years' data (cross marks) which were not based on the direct estimation from cohort analysis. The blue dashed line is the HS model proposed at the 2019 Scientific Meeting, while the red solid line is updated one based on the 2020 stock assessment.

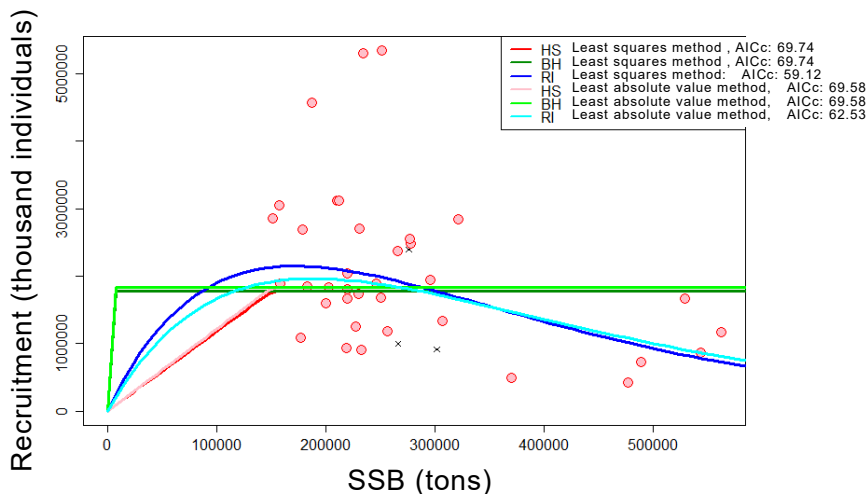


Figure A-2. Comparison of the models of S-R relationships

HS, RI and BH models are applied for S-R relationships using the least squares method and the least absolute value method. The upper-right numbers in the figure are values of the small-sample-size-corrected version of AIC (AICc). The red circles represent the SSB and recruitments (1981-2016 FYs) used for the analysis, the data for latest three years (2017-2019 FYs) are not used for analysis because these are not based on the direct estimation from cohort analysis (cross mark).

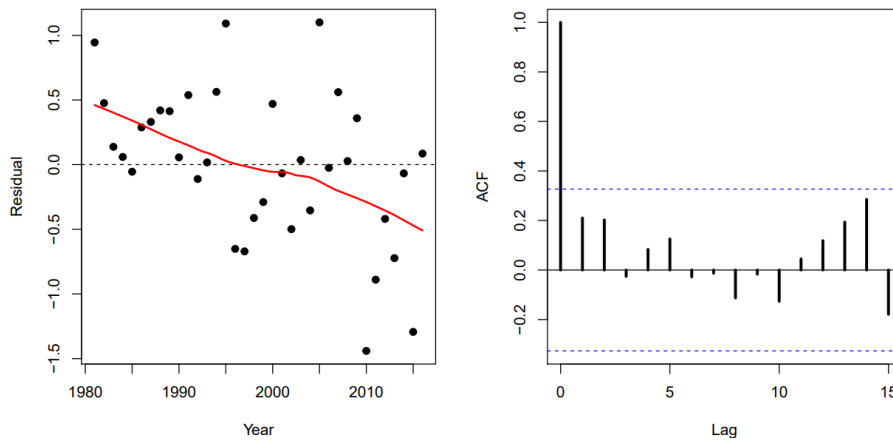


Figure A-3. Residual trend in the HS model of S-R relationship and autocorrelation plot
 Based on the results when the HS model is applied for S-R relationship using the least squares method. The blue dashed lines in the right figure of autocorrelation plot express the 95% confidence interval.

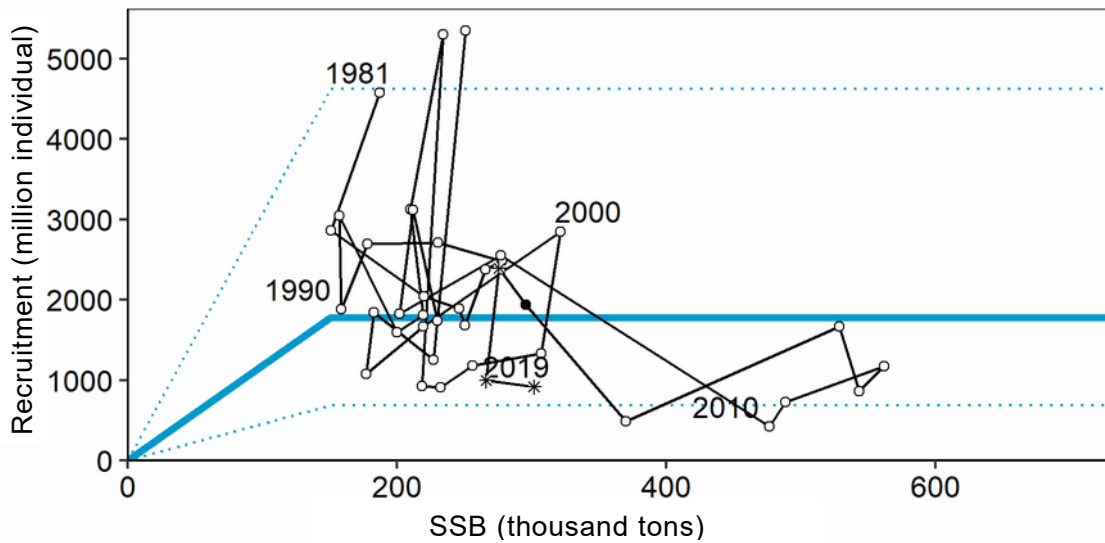


Figure A-4. Updated HS model of S-R relationships (relationship between SSB and recruitment)

The blue line indicates the HS model of S-R relationship based on the recruitment and SSB of the 1981-2016 FYs, which are estimated in the 2020 stock assessment. We didn't use the data of the 2017-2019 FYs (with asterisk (*) mark) for the estimation of the HS model parameters, because the recruitment values of these data were estimates from the survey data. Filled circle (●) indicates the 2016 year-class, which was newly estimated in the cohort analysis from this stock assessment. The dotted lines show the 90% interval of SSB and recruitment.

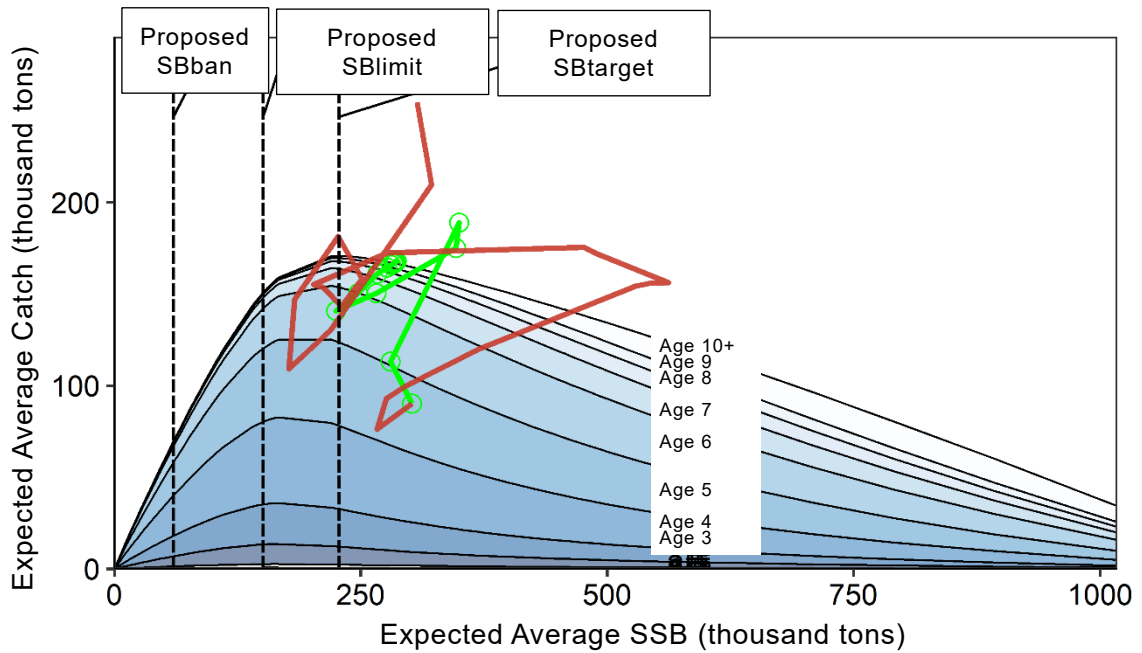
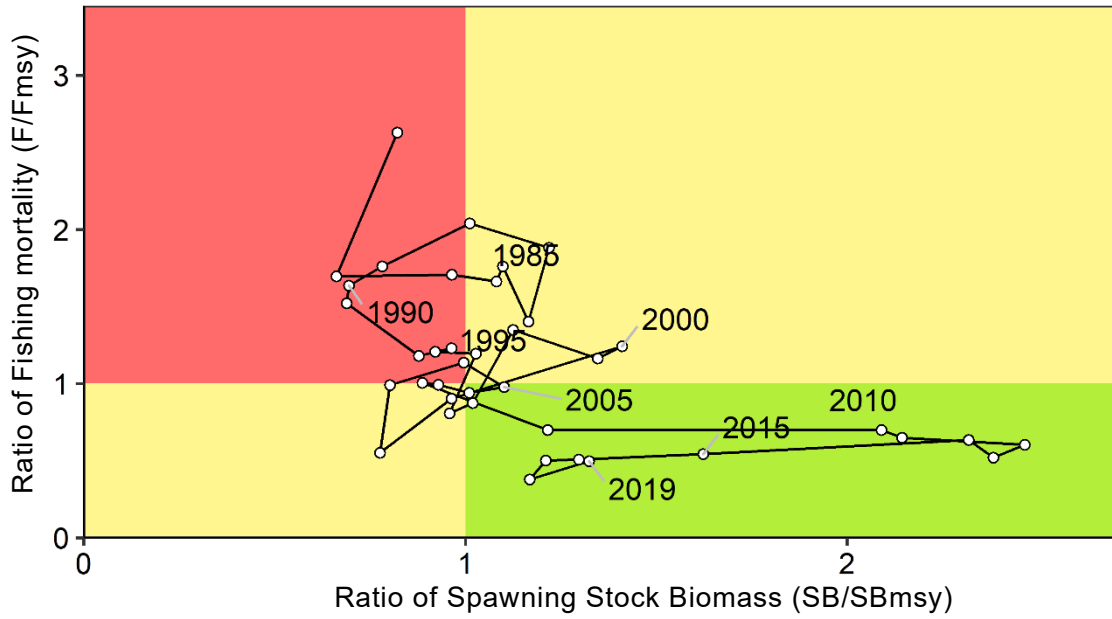


Figure A-5. Relationship between the proposed reference points and yield curves at age

The figure shows the average catch weight at age corresponding to the SSB, and the relationship between each of the proposed reference points at equilibrium situation based on the future projection simulation. The red line represents the relationship between the SSB and catch, which were estimated by the 2020 stock assessment, while the green line represents yearly changes in the average SSB and average catch in the future projection when fishing is conducted based on the proposed HCR ($\beta = 0.8$) under the proposed reference point. The unfished SSB (SB0) is estimated to be 1.179 million tons.

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

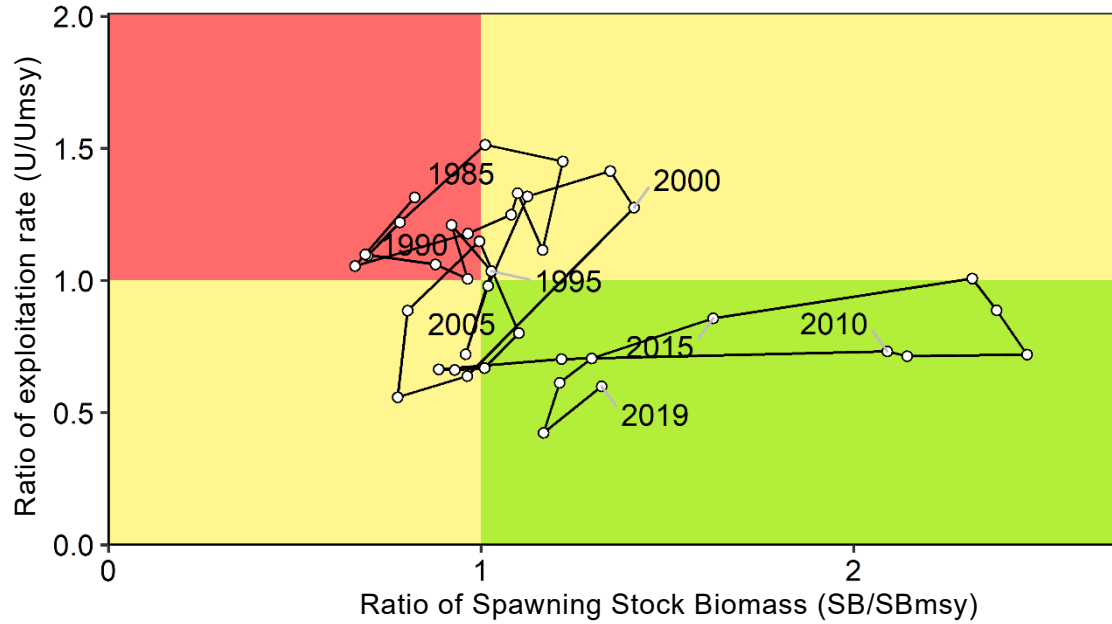


Figure A-6. Kobe plot based on the updated MSY reference points

The upper chart (a) shows the relationship of Spawning Stock Biomass (SSB) ratio to SBmsy and fishing mortality (F) ratio to Fmsy. The lower chart (b) shows the relationship of SSB ratio to SBmsy and exploitation rate (U) ratio to Umsy.

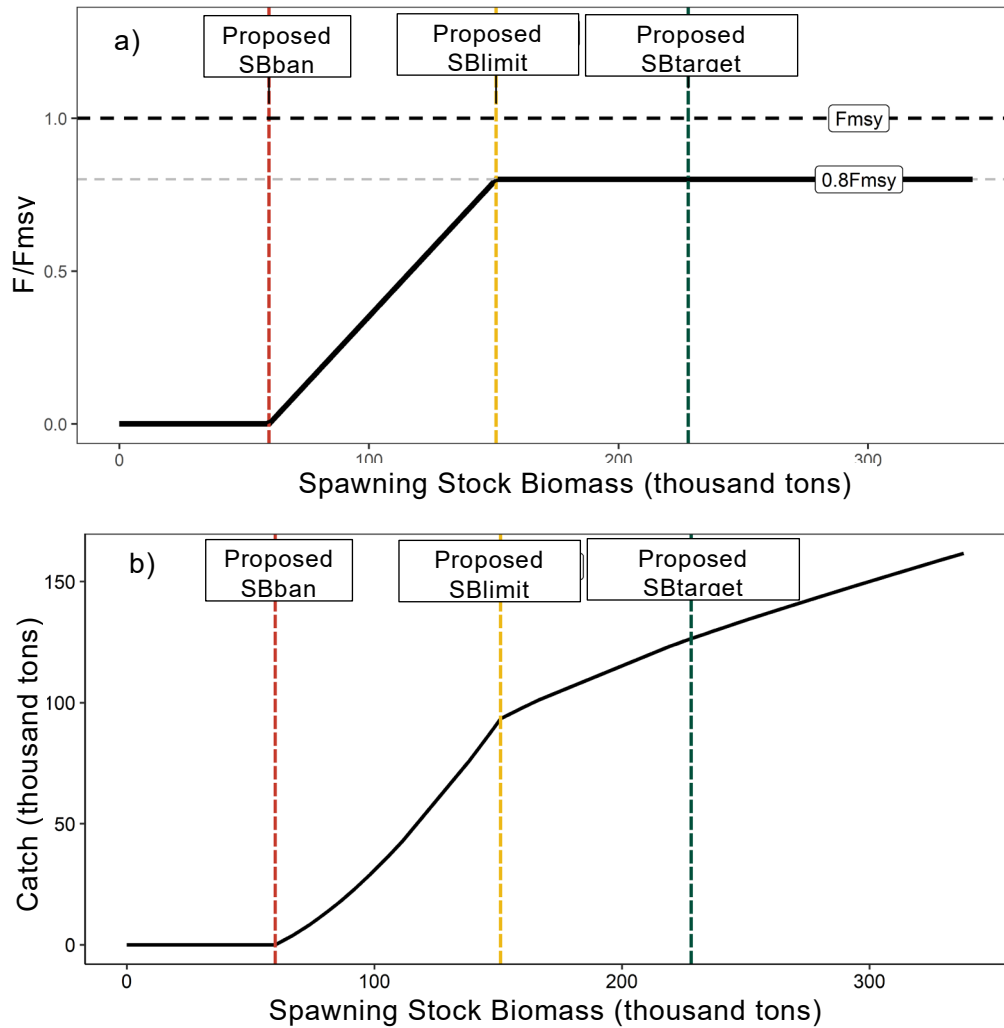
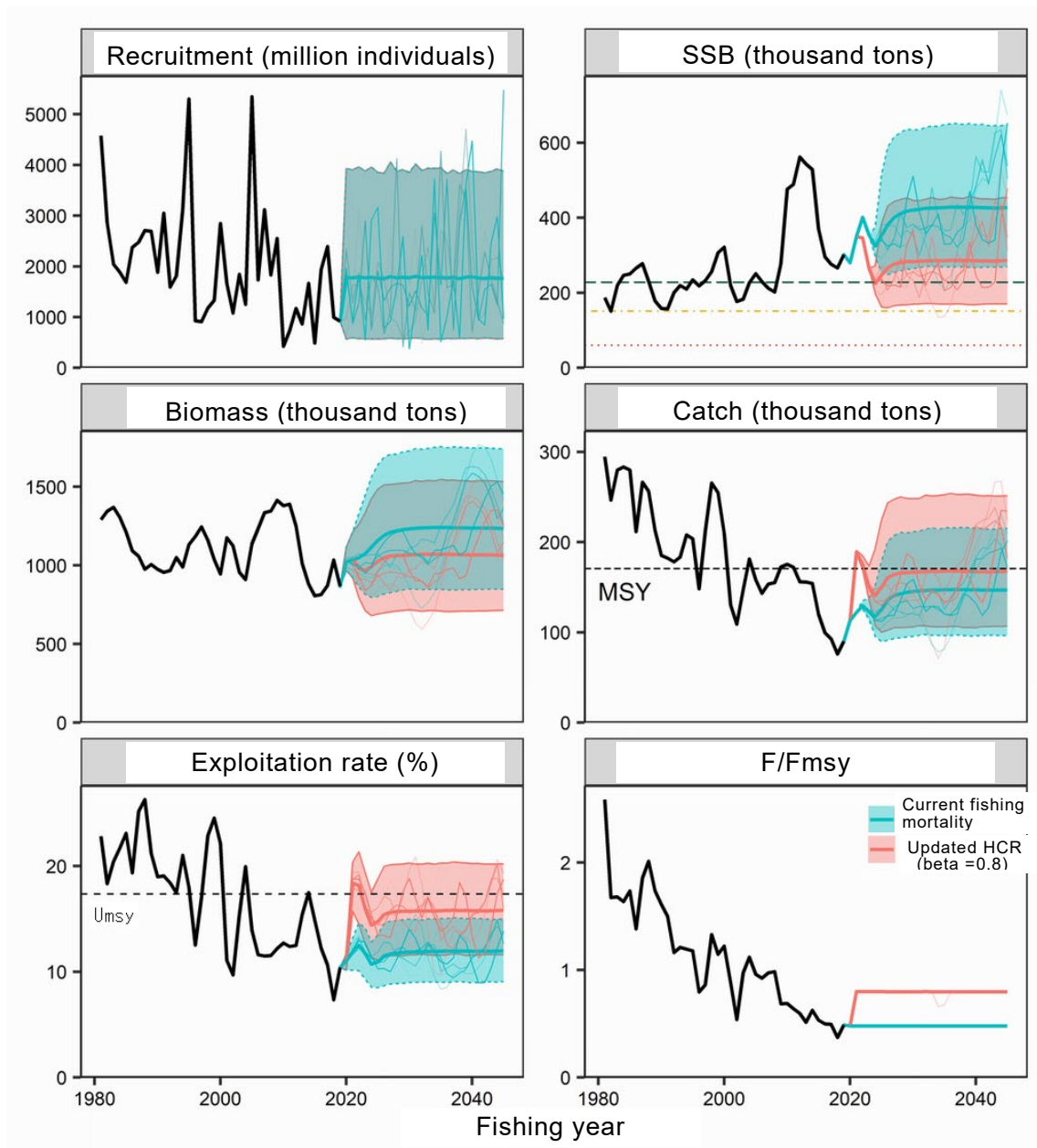


Figure A-7. Proposed HCRs (when β is 0.8)

The proposed target reference point (SB_{target}) is SB_{msy} , which is calculated based on the updated HS model. As the proposed limit reference point (SB_{limit}), we used the lowest SSB that has ever been observed in assessment periods. As the proposed fishing ban level (SB_{ban}), we updated the threshold value for SSB to recover to the SB_{target} in 10 years with a probability of 50% under fishing based on the updated HCRs with the coefficient β set to 0.8. The black dashed line represents F_{msy} ; the grey dashed line represents $0.8F_{msy}$; the black thick line represents the updated HCR; the red dashed line represents the updated SB_{ban} ; the yellow dashed line represents the proposed SB_{limit} ; and the green dashed line represents the updated SB_{target} . The upper chart a) expresses a schematic diagram of the updated HCR where the vertical axis is fishing mortality. The lower chart b) where the vertical axis is the expected catch based on the updated HCRs under the respective SSB. Whereas the actual catch volume slightly different depending on the age composition, b) shows the catch volume in the case of average age composition in an equilibrium state.



(Shaded: 5-95% prediction interval; thick solid line: average value; thin solid line: simulation example)

Figure A-8. Comparison of the future projection based on the updated HCRs ($\beta = 0.8$) with the future projection that assumes continued fishing at the current fishing mortality (F2015-2019*)

The thick solid line, shaded area and thin lines represent average value, the 90% prediction interval, and three future projection examples, respectively. In the figure of SSB, the green dashed line represents the proposed SBtarget, the yellow dotted line represents the proposed SBlimit, and the red line shows the proposed SBban. The catch of the 2020 FY was assumed based on the projected total biomass and the current fishing mortality (F2015-2019*: average F value at age of the 2015-2019 FYs). The coefficient β in the proposed HCR used as an example is set to 0.8.

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

Model of S-R relationship	Optimization method	Autocorrelation	a	b	S.D.	AICc	n
Hockey stick	Least squares method	No	11.795	150,944	0.580	69.74	36
Ricker	Least squares method	No	33.988	5.82x10 ⁻⁶	0.501	59.12	36
Beverton-Holt	Least squares method	No	1.18x10 ⁷	6.636	0.580	69.74	36
Hockey stick	Least absolute value method	No	12.172	150,944	0.581	69.58	36
Ricker	Least absolute value method	No	28.275	5.30x10 ⁻⁶	0.506	62.53	36
Beverton-Holt	Least absolute value method	No	4.44x10 ¹⁹	2.42x10 ¹³	0.581	69.58	36

The recommended model of 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 SSB at equilibrium of the respective proposed reference points; ratio to the unfished SSB (SB0); average catch; %SPR-converted fishing mortality; exploitation rate; proportional connection of fishing effort to the current fishing mortality (F2015-2019*); and fishing mortality at age that can produces MSY (Fmsy)

Proposed reference points etc.	Explanation	SSB (thousand tons)	Depletion ratio (Ratio to SB0)	Catch (thousand tons)	Fishing pressure (%SPR)	Exploitation rate	Ratio of the fishing effort
SBtarget	SSB corresponding to MSY (SBmsy)	228	0.193	171	19.7	0.17	2.08
SBlimit	Smallest SSB ever observed (SBmin)	151	0.128	151	15.2	0.19	2.71
SBban	The threshold of SSB at which it can recover to the SBtarget in 10 years with 50% probability under fishing based on the HCRs (β set to 0.8)	60	0.051	70	13.2	0.20	3.10
--	The threshold of SSB at which it can recover to the SBlimit in 10 years with 50% probability under fishing based on the HCRs (β set to 0.8)	30	0.025	36	12.6	0.21	3.22
Fmsy	Fishing mortality that can produce MSY (Age 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10+) = (0.009, 0.017, 0.067, 0.124, 0.326, 0.565, 0.805, 0.670, 0.637, 0.717, 0.717)						

F2015-2019* is the average F value at age of the 2015-2019 FYs.

Table A-3. Parameters used for MSY reference point calculation and future projection

Age	Natural mortality	Maturity rate	Average body weight (g)	Selectivity	Current fishing mortality (F2015-2019*)
0	0.40	0.0	44	0.010	0.004
1	0.35	0.0	107	0.020	0.008
2	0.30	0.0	218	0.083	0.032
3	0.25	0.0	360	0.154	0.059
4	0.25	0.2	475	0.404	0.156
5	0.25	0.8	563	0.701	0.271
6	0.25	0.9	642	1.000	0.386
7	0.25	1.0	698	0.832	0.321
8	0.25	1.0	726	0.791	0.306
9	0.25	1.0	756	0.891	0.344
10+	0.25	1.0	819	0.891	0.344

F2015-2019* is the average F value at age of the 2015-2019 FYs.

Table A-4. Probability for SSB to exceed the target reference point (SBtarget) after 10 years – by candidate value for the fishing ban level (SBban)

If the SBban is low, it is necessary to lower the fishing mortality of the recovery period (by setting β lower). β value is changed in the range between 0.1 and 1 in 0.1 intervals.

(%)

SSB at the start of recovery (candidate value for the fishing ban level: 1 thousand tons)																														
β	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150
1.0	0	0	1	2	5	8	11	15	20	23	27	30	34	36	38	41	42	44	46	47	49	50	51	52	53	55	55	56	57	57
0.9	0	0	1	3	7	11	17	22	27	32	36	40	44	47	49	51	54	56	58	60	61	63	64	65	66	67	67	69	69	70
0.8	0	0	2	5	10	17	24	30	36	42	47	51	55	58	61	64	66	69	71	72	74	75	77	77	78	79	80	81	81	81
0.7	0	0	3	7	15	23	32	40	47	53	58	63	66	70	73	76	78	80	82	84	85	86	87	88	89	89	89	90	90	91
0.6	0	1	4	11	21	32	42	50	58	64	69	74	77	81	83	86	88	90	91	92	93	94	94	95	95	96	96	96	96	96
0.5	0	1	6	16	30	42	52	61	69	74	79	83	86	89	91	93	95	96	96	97	97	97	98	98	98	98	99	99	99	99
0.4	0	2	9	24	39	52	63	71	78	83	87	90	93	95	96	97	98	98	99	99	99	99	99	100	100	100	100	100	100	100
0.3	0	3	14	33	49	63	73	80	86	90	93	95	97	98	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100
0.2	0	4	20	42	60	73	81	87	92	95	97	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.1	0	6	30	54	70	81	88	93	96	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.0	0	10	40	64	79	87	93	96	98	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table A-5. Probability of SSB to exceed the limit reference point (SB_{limit}) after 10 years – by candidate value for the fishing ban level (SB_{ban})

If the SB_{ban} is low, it is necessary to lower the fishing mortality of the recovery period (by setting β lower). β value is changed in the range between 0.1 and 1 in 0.1 intervals.

(%)

SSB at the start of recovery (candidate value for the fishing ban level: 1 thousand tons)																														
β	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150
1.0	0	2	10	20	31	41	49	56	62	67	72	76	79	82	84	87	88	89	91	92	93	94	94	95	95	96	96	96	97	97
0.9	0	3	13	26	38	49	57	64	70	76	80	83	86	88	90	92	93	94	95	96	96	97	97	97	98	98	98	98	98	99
0.8	0	4	17	32	46	57	65	73	78	83	86	89	91	93	95	96	96	97	98	98	98	99	99	99	99	99	99	99	99	99
0.7	0	6	22	39	54	65	74	80	85	88	91	94	95	96	97	98	98	99	99	99	99	100	100	100	100	100	100	100	100	100
0.6	0	8	28	47	62	73	80	86	90	93	95	97	98	98	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100
0.5	0	11	35	55	70	79	86	91	94	96	98	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.4	1	15	43	63	77	85	91	95	97	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.3	1	20	50	71	83	90	95	97	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.2	1	26	59	77	88	94	97	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.1	2	33	66	83	92	97	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.0	2	40	73	88	95	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table A-6. Probability for SSB to exceed the proposed target reference point (SBtarget) (a) and the proposed limit reference point (SBlimit) (b)

The following tables shows the results of the future projection when β is changed between 0 and 1.0 under the catch control by HCRs, or when the current fishing mortality is continued, after the 2021 FY. The catch of the 2020 FY is assumed based on the projected biomass of the 2020 FY and the current fishing mortality (F2015-2019*). F2015-2019* is the average F value at age of the 2015-2019 FYs.

(a) Probability for SSB 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	100	100	100	100	0	5	28	38	43	45	45	44	44	45	45
0.9	100	100	100	100	100	13	38	50	55	57	58	58	58	59	58
0.8	100	100	100	100	100	33	52	63	68	70	71	72	72	72	73
0.7	100	100	100	100	100	88	70	76	80	83	84	84	85	85	86
0.6	100	100	100	100	100	100	88	89	91	92	93	94	94	94	95
0.5	100	100	100	100	100	100	99	97	98	98	98	98	98	98	99
0.4	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
F2015-2019*	100	100	100	100	100	100	100	98	98	99	99	99	99	99	99

(b) Probability for SSB 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	100	100	100	100	100	100	81	88	90	91	90	91	91	91	91
0.9	100	100	100	100	100	100	91	93	95	95	95	95	96	96	96
0.8	100	100	100	100	100	100	98	97	98	98	98	98	98	98	98
0.7	100	100	100	100	100	100	100	99	99	100	99	99	99	100	100
0.6	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.4	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
F2015-2019*	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table A-7. Predicted average values of future SSB (a) and catch (b)

The following tables show the results of the future projection when β is changed between 0 and 1.0 under the catch control by HCRs, or when the current fishing mortality is continued, after the 2021 FY. The catch of the 2020 FY is assumed based on the projected biomass and the current fishing mortality (F2015-2019*). F2015-2019* is the average F value at age of the 2015-2019 FYs.

(a) Future average SSB (thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	302	280	350	317	224	183	205	223	231	233	234	232	232	233	234
0.9	302	280	350	331	244	202	224	243	252	255	256	255	256	257	258
0.8	302	280	350	346	266	225	247	267	277	281	284	284	284	285	286
0.7	302	280	350	362	290	251	274	296	308	313	316	317	318	319	320
0.6	302	280	350	379	317	281	306	330	345	352	357	358	359	362	362
0.5	302	280	350	397	348	317	345	372	390	400	406	409	411	414	415
0.4	302	280	350	416	381	358	391	423	447	460	469	473	476	483	483
0.3	302	280	350	436	419	407	446	486	517	536	549	556	562	573	573
0.2	302	280	350	457	461	464	515	565	607	634	654	667	677	699	699
0.1	302	280	350	479	508	532	598	665	723	763	795	818	835	884	884
0.0	302	280	350	502	560	613	702	792	876	938	989	1030	1063	1174	1180
F2015-2019*	302	280	350	401	354	324	353	382	401	411	418	421	423	427	427

*Yellow shading expresses that the value is below the proposed target reference point.

(b) Future average catch (thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	90	113	226	193	158	148	156	168	172	172	172	171	172	172	173
0.9	90	113	208	185	155	145	154	165	168	170	170	170	170	170	171
0.8	90	113	189	175	151	141	150	161	164	166	166	167	167	167	168
0.7	90	113	169	163	145	136	145	155	159	161	162	162	163	163	163
0.6	90	113	148	150	136	129	137	148	152	154	155	156	156	157	157
0.5	90	113	127	133	126	120	128	139	143	145	147	147	148	149	149
0.4	90	113	104	114	111	108	115	126	130	133	135	136	137	138	138
0.3	90	113	80	92	93	91	98	108	113	116	118	119	120	122	122
0.2	90	113	54	66	69	69	75	84	88	91	93	95	96	99	99
0.1	90	113	28	35	39	40	44	49	53	55	57	58	59	62	62
0.0	90	113	0	0	0	0	0	0	0	0	0	0	0	0	0
F2015-2019*	90	113	122	130	123	117	125	136	141	143	144	145	146	147	147

Table C-1. Probability for SSB to exceed the proposed target reference point (SB_{target}) (a) and the proposed limit reference point (SB_{limit}) (b)

The following tables show the results of the future projection when β is changed in the range of 0.91 to 0.99 with intervals of 0.01 under the catch control by HCRs, after the 2021 FY. The catch of the 2020 FY is assumed based on the projected biomass of the 2020 FY and the current fishing mortality (F_{2015-2019*}). F_{2015-2019*} is the average F value at age of the 2015-2019 fishing seasons.

(a) Probability for SSB to exceed the proposed target reference point (%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
0.99	100	100	100	100	0	5	29	39	44	46	47	46	46	47	47
0.98	100	100	100	100	0	6	30	40	45	47	48	47	47	48	48
0.97	100	100	100	100	100	6	31	41	47	48	49	49	48	49	49
0.96	100	100	100	100	100	7	32	43	48	49	50	50	49	50	50
0.95	100	100	100	100	100	8	33	44	49	50	51	51	51	51	52
0.94	100	100	100	100	100	9	34	45	50	51	52	52	52	53	53
0.93	100	100	100	100	100	9	35	46	51	53	54	54	54	54	55
0.92	100	100	100	100	100	10	36	47	52	54	55	55	55	55	56
0.91	100	100	100	100	100	11	37	48	53	55	56	57	57	57	57

(b) Probability for SSB to exceed the proposed limit reference point (%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
0.99	100	100	100	100	100	100	82	88	91	91	91	91	92	91	92
0.98	100	100	100	100	100	100	83	89	91	92	92	92	92	92	92
0.97	100	100	100	100	100	100	84	89	92	92	92	92	93	92	93
0.96	100	100	100	100	100	100	85	90	92	92	93	93	93	93	93
0.95	100	100	100	100	100	100	86	90	93	93	93	93	94	93	94
0.94	100	100	100	100	100	100	87	91	93	93	93	94	94	94	94
0.93	100	100	100	100	100	100	88	92	94	94	94	94	95	94	95
0.92	100	100	100	100	100	100	89	92	94	94	94	95	95	95	95
0.91	100	100	100	100	100	100	90	93	95	95	95	95	95	95	96

Table C-2. Projected average values of future SSB (a) and catch (b)

The following tables show the results of the future projection when β is changed between 0 and 1.0 under the catch control by HCRs after the 2021 FY. The catch of the 2020 FY is assumed based on the projected biomass and the current fishing mortality (F2015-2019*). F2015-2019* is the average F value at age of the 2015-2019 fishing seasons.

(a) Future average SSB (thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
0.99	302	280	350	318	226	185	207	225	233	235	236	234	234	235	236
0.98	302	280	350	319	228	187	209	227	235	237	238	236	236	237	238
0.97	302	280	350	321	230	189	210	229	237	239	240	238	238	240	241
0.96	302	280	350	322	232	190	212	231	239	241	242	241	241	242	243
0.95	302	280	350	324	234	192	214	233	241	244	245	243	243	244	245
0.94	302	280	350	325	236	194	216	234	243	246	247	245	245	247	248
0.93	302	280	350	327	238	196	218	236	245	248	249	248	248	249	250
0.92	302	280	350	328	240	198	220	239	247	250	251	250	250	252	253
0.91	302	280	350	330	242	200	222	241	249	253	254	253	253	254	255

*Yellow shading expresses that the value is below the proposed target reference point.

(b) Future average catch (thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
0.99	90	113	224	192	158	148	156	168	171	172	172	171	172	172	173
0.98	90	113	222	192	157	147	155	168	171	172	171	171	171	172	172
0.97	90	113	220	191	157	147	155	168	171	172	171	171	171	172	172
0.96	90	113	219	190	157	147	155	167	170	171	171	171	171	171	172
0.95	90	113	217	189	156	146	155	167	170	171	171	171	171	171	172
0.94	90	113	215	188	156	146	155	167	170	171	171	170	171	171	172
0.93	90	113	213	188	156	146	155	166	169	170	170	170	171	171	172
0.92	90	113	211	187	156	145	155	166	169	170	170	170	170	171	171
0.91	90	113	210	186	155	145	154	165	169	170	170	170	170	170	171

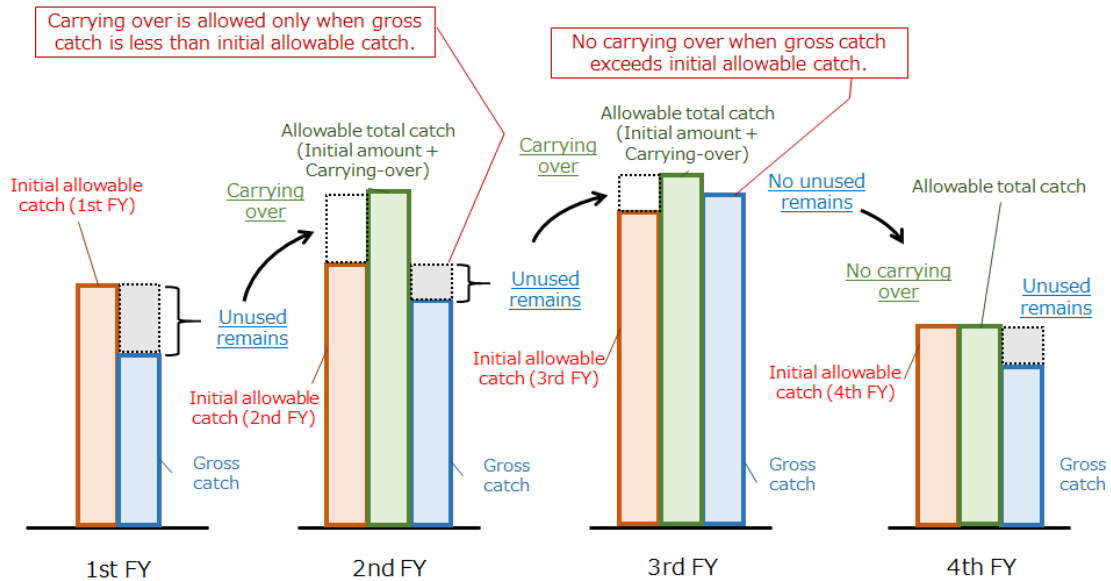
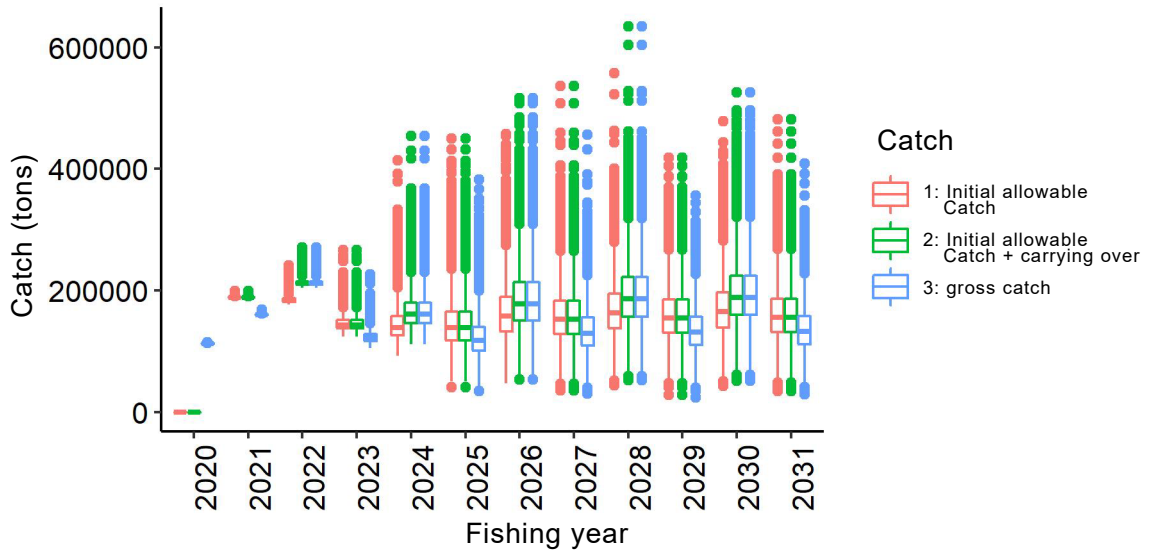


Figure D-1. Example of carrying over of unused catch remains

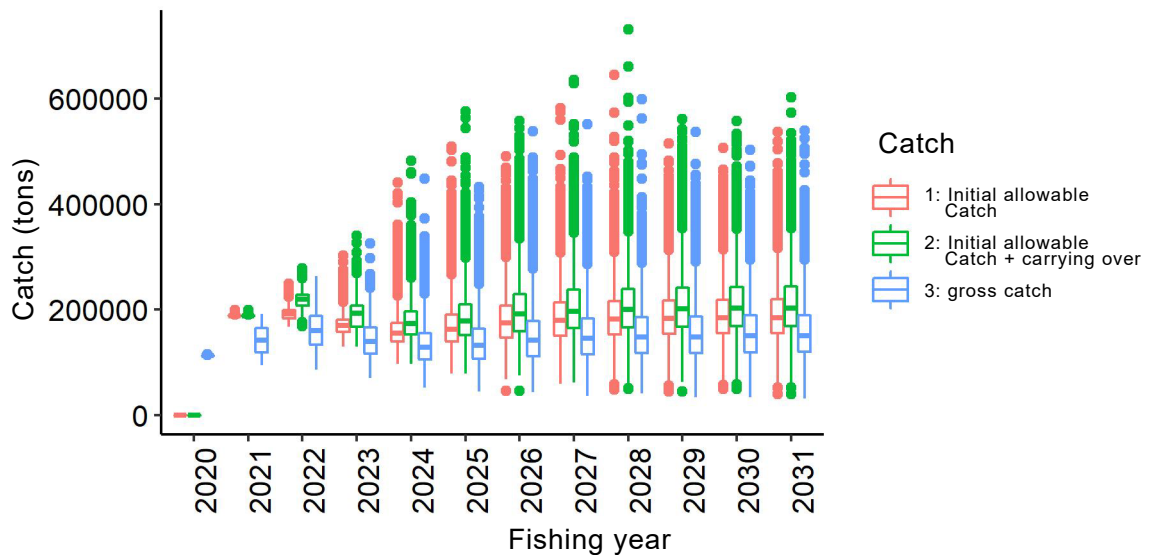
The “unused remain” is the unused portion of the initial allowable catch (e.g. TAC) set by the HCR, which is occurred when the gross catch is less than the initial allowable catch. This unused remains is carried over to increase the allowable total catch of the following year. This carried-over portion is not able to carry two years later; only the unused portion of the initial allowable catch can be carried over to the succeeding year even if the gross catch is less than allowable total catch (initial allowable catch + carrying-over amount). The “Upper limit of carry-over” is defined as the ratio to the initial allowable catch in this document.



In the case when the “reserve rate” is 0 or 0.15 and the “carry-over limit” is 0.15 of the initial value.

Figure D-2. Example of projected catch in the simulation assuming extreme situation for carrying-over of unused remains (In the case when the coefficient β used for the HCR is 0.8)

After the 2021 FY, unused portion is assumed to be 15% of the allowable total catch in odd years, and all allowable total catch including the carried over remains is caught in even years. The carry-over limit is assumed to be 15% of the initial allowable catch.



In the case when the “reserve rate” is 0 to 0.5 and the “carry-over limit” is 0.15 of the initial value.

Figure D-3. Example of projected catch in the simulation assuming random change for reserve rate (In the case when the coefficient β used for the proposed HCR is 0.8)

After the 2021 FY, random change of reserve rate is assumed in the range of 0 to 50% of the allowable total catch. The carry-over limit is assumed to be 15% of the initial allowable catch.

Table D-1. Average probability that the F will exceed the Fmsy for even-years in the future projection with extreme situation for carrying over of unused remains (until the 2031 FY).

Results of combinations of reserve rate (0 to 30%) and the coefficient β (0.7 to 1.0) for HCRs are shown for each carry-over limit setting. The higher the probability of exceeding Fmsy, the darker the shade is.

(Unit: %)

a) carry-over limit: 5% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	46	96	97	97	98	99	99
0.95	0	85	85	86	85	85	84
0.9	0	0	0	0	0	0	0
0.85	0	0	0	0	0	0	0
0.8	0	0	0	0	0	0	0
0.75	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0

b) carry-over limit: 10% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	46	96	97	98	98	99	99
0.95	0	85	97	98	98	99	99
0.9	0	0	78	77	76	75	74
0.85	0	0	0	0	0	0	0
0.8	0	0	0	0	0	0	0
0.75	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0

c) carry-over limit: 15% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	46	96	97	98	99	99	99
0.95	0	85	97	98	99	99	99
0.9	0	0	78	97	98	98	99
0.85	0	0	0	65	63	61	59
0.8	0	0	0	0	0	0	0
0.75	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0

d) carry-over limit: 20% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	46	96	97	98	99	99	99
0.95	0	85	97	98	99	99	99
0.9	0	0	78	97	99	99	99
0.85	0	0	0	65	96	97	97
0.8	0	0	0	0	47	45	42
0.75	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0

e) carry-over limit: 25% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	46	96	97	98	99	99	99
0.95	0	85	97	98	99	99	99
0.9	0	0	78	97	99	99	99
0.85	0	0	0	65	96	98	99
0.8	0	0	0	0	47	89	89
0.75	0	0	0	0	0	14	11
0.7	0	0	0	0	0	0	0

f) carry-over limit: 30% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	46	96	97	98	99	99	99
0.95	0	85	97	98	99	99	99
0.9	0	0	78	97	99	99	99
0.85	0	0	0	65	96	98	99
0.8	0	0	0	0	47	89	98
0.75	0	0	0	0	0	14	69
0.7	0	0	0	0	0	0	3

Table D-2. Probability that SSB will exceed the SBtarget (SBmsy) in the 2031 FY (left tables) and the difference with the scenario without unuse remains and carrying over (right tables), in the future projection with extreme situation for carrying over of unused remains.

Results of combinations of reserve rate (0 to 30%) and the coefficient β (0.7 to 1.0) are shown for each carry-over limit setting.

a) carry-over limit: 5% of the initial allowable catch

(Unit: %)

β	0%	5%	10%	15%	20%	25%	30%
1	45	43	46	49	51	54	58
0.95	51	49	52	55	58	61	64
0.9	58	56	59	62	65	68	71
0.85	65	63	66	69	72	74	77
0.8	73	71	74	76	78	80	83
0.75	79	78	80	82	84	86	87
0.7	85	84	86	87	89	90	92

β	0%	5%	10%	15%	20%	25%	30%
1	0	-2	1	4	6	9	13
0.95	0	-2	1	4	7	10	13
0.9	0	-2	1	4	7	10	13
0.85	0	-2	1	4	7	9	12
0.8	0	-2	1	3	5	7	10
0.75	0	-1	1	3	5	7	8
0.7	0	-1	1	2	4	5	7

b) carry-over limit: 10% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	45	43	40	43	46	49	52
0.95	51	49	47	50	53	56	59
0.9	58	56	54	57	60	62	65
0.85	65	63	61	64	67	70	72
0.8	73	71	69	72	74	76	79
0.75	79	78	76	78	80	83	85
0.7	85	84	83	84	86	88	89

β	0%	5%	10%	15%	20%	25%	30%
1	0	-2	-5	-2	1	4	7
0.95	0	-2	-4	-1	2	5	8
0.9	0	-2	-4	-1	2	4	7
0.85	0	-2	-4	-1	2	5	7
0.8	0	-2	-4	-1	1	3	6
0.75	0	-1	-3	-1	1	4	6
0.7	0	-1	-2	-1	1	3	4

c) carry-over limit: 15% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	45	43	40	38	41	44	47
0.95	51	49	47	45	48	51	53
0.9	58	56	54	52	55	58	60
0.85	65	63	61	59	62	65	68
0.8	73	71	69	67	70	72	75
0.75	79	78	76	75	77	79	81
0.7	85	84	83	81	83	85	87

β	0%	5%	10%	15%	20%	25%	30%
1	0	-2	-5	-7	-4	-1	2
0.95	0	-2	-4	-6	-3	0	2
0.9	0	-2	-4	-6	-3	0	2
0.85	0	-2	-4	-6	-3	0	3
0.8	0	-2	-4	-6	-3	-1	2
0.75	0	-1	-3	-4	-2	0	2
0.7	0	-1	-2	-4	-2	0	2

d) carry-over limit: 20% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	45	43	40	38	36	39	42
0.95	51	49	47	45	43	46	48
0.9	58	56	54	52	50	53	56
0.85	65	63	61	59	58	60	63
0.8	73	71	69	67	65	68	70
0.75	79	78	76	75	73	76	77
0.7	85	84	83	81	80	82	84

β	0%	5%	10%	15%	20%	25%	30%
1	0	-2	-5	-7	-9	-6	-3
0.95	0	-2	-4	-6	-8	-5	-3
0.9	0	-2	-4	-6	-8	-5	-2
0.85	0	-2	-4	-6	-7	-5	-2
0.8	0	-2	-4	-6	-8	-5	-3
0.75	0	-1	-3	-4	-6	-3	-2
0.7	0	-1	-2	-4	-5	-3	-1

e) carry-over limit: 25% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	45	43	40	38	36	34	37
0.95	51	49	47	45	43	41	44
0.9	58	56	54	52	50	48	51
0.85	65	63	61	59	58	56	59
0.8	73	71	69	67	65	63	66
0.75	79	78	76	75	73	71	74
0.7	85	84	83	81	80	79	81

β	0%	5%	10%	15%	20%	25%	30%
1	0	-2	-5	-7	-9	-11	-8
0.95	0	-2	-4	-6	-8	-10	-7
0.9	0	-2	-4	-6	-8	-10	-7
0.85	0	-2	-4	-6	-7	-9	-6
0.8	0	-2	-4	-6	-8	-10	-7
0.75	0	-1	-3	-4	-6	-8	-5
0.7	0	-1	-2	-4	-5	-6	-4

f) carry-over limit: 30% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	45	43	40	38	36	34	32
0.95	51	49	47	45	43	41	39
0.9	58	56	54	52	50	48	46
0.85	65	63	61	59	58	56	54
0.8	73	71	69	67	65	63	61
0.75	79	78	76	75	73	71	70
0.7	85	84	83	81	80	79	77

β	0%	5%	10%	15%	20%	25%	30%
1	0	-2	-5	-7	-9	-11	-13
0.95	0	-2	-4	-6	-8	-10	-12
0.9	0	-2	-4	-6	-8	-10	-12
0.85	0	-2	-4	-6	-7	-9	-11
0.8	0	-2	-4	-6	-8	-10	-12
0.75	0	-1	-3	-4	-6	-8	-9
0.7	0	-1	-2	-4	-5	-6	-8

Table D-3. Probability that SSB will exceed SBlimit (151 thousand tons) in the 2031 FY (left tables) and the difference with the scenario without remains and carrying over (right tables), in the future projection with extreme situation for carrying over of unused remains.

Results of combinations of reserve rate (0 to 30%) and the coefficient β (0.7 to 1.0) are shown for each carry-over limit setting.

a) carry-over limit: 5% of the initial allowable catch

(Unit: %)

β	0%	5%	10%	15%	20%	25%	30%
1	91	89	91	92	93	94	95
0.95	93	92	93	94	95	96	97
0.9	95	95	96	96	97	98	98
0.85	97	97	97	98	98	99	99
0.8	98	98	99	99	99	99	99
0.75	99	99	99	99	100	100	100
0.7	100	100	100	100	100	100	100

β	0%	5%	10%	15%	20%	25%	30%
1	0	-2	0	1	2	3	4
0.95	0	-1	0	1	2	3	4
0.9	0	0	1	1	2	3	3
0.85	0	0	0	1	1	2	2
0.8	0	0	1	1	1	1	1
0.75	0	0	0	0	1	1	1
0.7	0	0	0	0	0	0	0

b) carry-over limit: 10% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	91	89	88	89	91	92	93
0.95	93	92	91	92	93	94	95
0.9	95	95	94	95	96	96	97
0.85	97	97	96	97	97	98	98
0.8	98	98	98	98	99	99	99
0.75	99	99	99	99	99	99	100
0.7	100	100	99	100	100	100	100

β	0%	5%	10%	15%	20%	25%	30%
1	0	-2	-3	-2	0	1	2
0.95	0	-1	-2	-1	0	1	2
0.9	0	0	-1	0	1	1	2
0.85	0	0	-1	0	0	1	1
0.8	0	0	0	0	1	1	1
0.75	0	0	0	0	0	0	1
0.7	0	0	-1	0	0	0	0

c) carry-over limit: 15% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	91	89	88	86	88	89	91
0.95	93	92	91	90	91	93	94
0.9	95	95	94	93	94	95	96
0.85	97	97	96	96	96	97	98
0.8	98	98	98	97	98	98	99
0.75	99	99	99	99	99	99	99
0.7	100	100	99	99	99	100	100

β	0%	5%	10%	15%	20%	25%	30%
1	0	-2	-3	-5	-3	-2	0
0.95	0	-1	-2	-3	-2	0	1
0.9	0	0	-1	-2	-1	0	1
0.85	0	0	-1	-1	-1	0	1
0.8	0	0	0	-1	0	0	1
0.75	0	0	0	0	0	0	0
0.7	0	0	-1	-1	-1	0	0

d) carry-over limit: 20% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	91	89	88	86	84	86	88
0.95	93	92	91	90	89	90	91
0.9	95	95	94	93	92	93	94
0.85	97	97	96	96	95	96	96
0.8	98	98	98	97	97	98	98
0.75	99	99	99	99	98	99	99
0.7	100	100	99	99	99	99	99

β	0%	5%	10%	15%	20%	25%	30%
1	0	-2	-3	-5	-7	-5	-3
0.95	0	-1	-2	-3	-4	-3	-2
0.9	0	0	-1	-2	-3	-2	-1
0.85	0	0	-1	-1	-2	-1	-1
0.8	0	0	0	-1	-1	0	0
0.75	0	0	0	0	-1	0	0
0.7	0	0	-1	-1	-1	-1	-1

e) carry-over limit: 25% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	91	89	88	86	84	83	85
0.95	93	92	91	90	89	87	89
0.9	95	95	94	93	92	91	92
0.85	97	97	96	96	95	94	95
0.8	98	98	98	97	97	97	97
0.75	99	99	99	99	98	98	98
0.7	100	100	99	99	99	99	99

β	0%	5%	10%	15%	20%	25%	30%
1	0	-2	-3	-5	-7	-8	-6
0.95	0	-1	-2	-3	-4	-6	-4
0.9	0	0	-1	-2	-3	-4	-3
0.85	0	0	-1	-1	-2	-3	-2
0.8	0	0	0	-1	-1	-1	-1
0.75	0	0	0	0	-1	-1	-1
0.7	0	0	-1	-1	-1	-1	-1

f) carry-over limit: 30% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	91	89	88	86	84	83	81
0.95	93	92	91	90	89	87	86
0.9	95	95	94	93	92	91	90
0.85	97	97	96	96	95	94	93
0.8	98	98	98	97	97	97	96
0.75	99	99	99	99	98	98	98
0.7	100	100	99	99	99	99	99

β	0%	5%	10%	15%	20%	25%	30%
1	0	-2	-3	-5	-7	-8	-10
0.95	0	-1	-2	-3	-4	-6	-7
0.9	0	0	-1	-2	-3	-4	-5
0.85	0	0	-1	-1	-2	-3	-4
0.8	0	0	0	-1	-1	-1	-2
0.75	0	0	0	0	-1	-1	-1
0.7	0	0	-1	-1	-1	-1	-1

Table D-4. Annual average of catch projected in the 2021-2031 FYs, in the future projection with extreme situation for carrying over of unused remains.

Results of combinations of reserve rate (0 to 30%) and the coefficient β (0.7 to 1.0) are shown for each carry-over limit setting. The higher the average catch, the darker the shade is.

(Unit: thousand tons)

a) carry-over limit: 5% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	173	172	171	169	168	166	164
0.95	171	170	169	167	165	163	161
0.9	169	168	166	165	163	161	159
0.85	166	165	164	162	160	158	156
0.8	163	163	161	159	157	155	153
0.75	160	159	157	155	153	151	149
0.7	156	155	154	152	149	147	145

b) carry-over limit: 10% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	173	172	172	170	169	167	165
0.95	171	170	170	168	166	165	163
0.9	169	168	168	166	164	162	160
0.85	166	165	165	163	161	159	157
0.8	163	163	162	160	158	156	154
0.75	160	159	159	157	155	153	151
0.7	156	155	155	153	151	149	147

c) carry-over limit: 15% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	173	172	172	171	170	168	166
0.95	171	170	170	169	168	166	164
0.9	169	168	168	167	165	163	162
0.85	166	165	165	164	163	161	159
0.8	163	163	162	161	160	158	156
0.75	160	159	159	158	156	154	152
0.7	156	155	155	154	152	150	148

d) carry-over limit: 20% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	173	172	172	171	170	169	167
0.95	171	170	170	169	169	167	165
0.9	169	168	168	167	166	165	163
0.85	166	165	165	164	164	162	160
0.8	163	163	162	161	161	159	157
0.75	160	159	159	158	158	156	154
0.7	156	155	155	154	154	152	150

e) carry-over limit: 25% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	173	172	172	171	170	170	168
0.95	171	170	170	169	169	168	166
0.9	169	168	168	167	166	166	164
0.85	166	165	165	164	164	163	161
0.8	163	163	162	161	161	160	159
0.75	160	159	159	158	158	157	155
0.7	156	155	155	154	154	153	151

f) carry-over limit: 30% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	173	172	172	171	170	170	169
0.95	171	170	170	169	169	168	167
0.9	169	168	168	167	166	166	165
0.85	166	165	165	164	164	163	163
0.8	163	163	162	161	161	160	160
0.75	160	159	159	158	158	157	157
0.7	156	155	155	154	154	153	153

Table D-5. Probability that SSB will exceed the SBtarget (SBmsy) and the SBlimit (151 thousand tons) in the 2030 FY (left and right tables, respectively)

Results of combinations of reserve rate (0 to 30%) and the coefficient β (0.7 to 1.0) are shown for each carry-over limit setting.

a) carry-over limit: 5% of the initial allowable catch

(Unit: %)

β	0%	5%	10%	15%	20%	25%	30%
1	44	46	51	56	61	67	72
0.95	51	53	58	63	68	73	77
0.9	57	59	64	69	74	78	81
0.85	65	67	71	75	79	82	86
0.8	72	74	77	81	84	87	90
0.75	79	80	83	86	89	91	93
0.7	84	85	88	90	92	94	95

β	0%	5%	10%	15%	20%	25%	30%
1	91	92	94	95	97	98	98
0.95	93	94	96	97	98	98	99
0.9	95	96	97	98	99	99	99
0.85	97	98	98	99	99	99	100
0.8	98	99	99	99	100	100	100
0.75	99	99	99	100	100	100	100
0.7	100	100	100	100	100	100	100

b) carry-over limit: 10% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	44	46	48	53	58	63	68
0.95	51	53	55	59	64	70	74
0.9	57	59	61	66	71	75	79
0.85	65	67	68	73	77	80	83
0.8	72	74	75	79	82	85	88
0.75	79	80	81	84	87	89	91
0.7	84	85	86	89	91	93	94

β	0%	5%	10%	15%	20%	25%	30%
1	92	92	92	94	96	97	98
0.95	94	94	95	96	97	98	99
0.9	96	96	97	97	98	99	99
0.85	98	98	98	98	99	99	100
0.8	99	99	99	99	99	100	100
0.75	99	99	99	100	100	100	100
0.7	100	100	100	100	100	100	100

c) carry-over limit: 15% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	44	46	48	50	55	60	65
0.95	51	53	55	56	61	66	71
0.9	57	59	61	63	68	73	76
0.85	65	67	68	70	74	78	81
0.8	72	74	75	76	80	83	86
0.75	79	80	81	82	85	87	90
0.7	84	85	86	87	89	91	93

β	0%	5%	10%	15%	20%	25%	30%
1	92	92	92	93	95	96	98
0.95	94	94	95	95	97	98	98
0.9	96	96	97	97	98	98	99
0.85	98	98	98	98	99	99	99
0.8	99	99	99	99	99	99	100
0.75	99	99	99	99	100	100	100
0.7	100	100	100	100	100	100	100

d) carry-over limit: 20% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	44	46	48	50	51	57	61
0.95	51	53	55	56	58	63	68
0.9	57	59	61	63	65	69	74
0.85	65	67	68	70	72	75	79
0.8	72	74	75	76	77	81	84
0.75	79	80	81	82	83	86	88
0.7	84	85	86	87	88	90	92

β	0%	5%	10%	15%	20%	25%	30%
1	92	92	92	93	94	96	97
0.95	94	94	95	95	96	97	98
0.9	96	96	97	97	97	98	99
0.85	98	98	98	98	98	99	99
0.8	99	99	99	99	99	99	100
0.75	99	99	99	99	99	100	100
0.7	100	100	100	100	100	100	100

e) carry-over limit: 25% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	44	46	48	50	51	53	58
0.95	51	53	55	56	58	60	64
0.9	57	59	61	63	65	66	71
0.85	65	67	68	70	72	73	76
0.8	72	74	75	76	77	79	82
0.75	79	80	81	82	83	84	86
0.7	84	85	86	87	88	88	90

β	0%	5%	10%	15%	20%	25%	30%
1	92	92	92	93	94	95	96
0.95	94	94	95	95	96	96	97
0.9	96	96	97	97	97	98	98
0.85	98	98	98	98	98	98	99
0.8	99	99	99	99	99	99	99
0.75	99	99	99	99	99	100	100
0.7	100	100	100	100	100	100	100

f) carry-over limit: 30% of the initial allowable catch

β	0%	5%	10%	15%	20%	25%	30%
1	44	46	48	50	51	53	55
0.95	51	53	55	56	58	60	61
0.9	57	59	61	63	65	66	68
0.85	65	67	68	70	72	73	74
0.8	72	74	75	76	77	79	80
0.75	79	80	81	82	83	84	84
0.7	84	85	86	87	88	88	89

β	0%	5%	10%	15%	20%	25%	30%
1	92	92	92	93	94	95	95
0.95	94	94	95	95	96	96	97
0.9	96	96	97	97	97	98	98
0.85	98	98	98	98	98	98	99
0.8	99	99	99	99	99	99	99
0.75	99	99	99	99	99	100	100
0.7	100	100	100	100	100	100	100

Table D-6. Probability that F of each year will exceed the Fmsy in the future projection where reserve rate is randomly changed within the range of 0 to 50%

The table shows the results of each setting of carry-over limit for the scenario where the coefficient β for HCRs is changed from 0.7 to 1.0 in 0.05 intervals. The higher the probability of exceeding Fmsy, the darker the shade is.

(Unit: %)

a) carry-over limit: 5% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	0	9	10	8	8	7	8	8	8	8	9
0.95	0	2	3	2	1	1	1	1	1	1	2
0.9	0	0	0	0	0	0	0	0	0	0	0
0.85	0	0	0	0	0	0	0	0	0	0	0
0.8	0	0	0	0	0	0	0	0	0	0	0
0.75	0	0	0	0	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0	0	0	0	0

b) carry-over limit: 10% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	0	17	15	14	14	13	13	14	14	13	14
0.95	0	10	9	8	7	7	7	8	8	8	8
0.9	0	2	3	2	1	1	1	2	1	1	2
0.85	0	0	0	0	0	0	0	0	0	0	0
0.8	0	0	0	0	0	0	0	0	0	0	0
0.75	0	0	0	0	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0	0	0	0	0

c) carry-over limit: 15% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	0	24	19	18	17	16	17	17	18	17	17
0.95	0	16	14	13	12	11	11	12	12	11	12
0.9	0	9	8	7	6	5	6	6	6	6	6
0.85	0	2	3	2	1	1	1	1	1	1	1
0.8	0	0	0	0	0	0	0	0	0	0	0
0.75	0	0	0	0	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0	0	0	0	0

d) carry-over limit: 20% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	0	28	21	21	20	19	20	19	20	20	20
0.95	0	21	16	16	14	14	14	14	15	14	14
0.9	0	14	11	11	9	8	9	9	10	9	10
0.85	0	7	6	6	4	4	4	4	5	4	5
0.8	0	1	2	1	0	0	1	1	1	1	1
0.75	0	0	0	0	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0	0	0	0	0

e) carry-over limit: 25% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	0	32	22	23	21	21	22	21	22	22	22
0.95	0	25	17	18	16	16	17	16	17	17	17
0.9	0	18	13	13	11	11	11	12	12	12	12
0.85	0	11	9	8	6	6	7	7	7	7	7
0.8	0	5	4	4	2	2	2	3	3	3	3
0.75	0	0	1	0	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0	0	0	0	0

f) carry-over limit: 30% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	0	35	22	25	21	23	22	24	23	22	23
0.95	0	28	18	20	16	18	17	19	18	17	18
0.9	0	21	14	15	12	12	12	13	13	13	13
0.85	0	14	10	10	8	8	8	9	8	8	9
0.8	0	7	5	6	4	4	4	4	4	4	5
0.75	0	2	2	2	1	1	1	1	1	1	1
0.7	0	0	0	0	0	0	0	0	0	0	0

Table D-7. Probability that SSB of each year will exceed the SBtarget (SBmsy) in the future projection where reserve rate is randomly changed within the range of 0 to 50%

The table shows the results of each setting of carry-over limit for the scenario where the coefficient β for HCRs is changed from 0.7 to 1.0 in 0.05 intervals. The higher the probability, the darker the shade is.

(Unit: %)

a) carry-over limit: 5% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	98	62	62	70	74	76	78	78	79
0.95	100	100	100	73	69	75	78	80	82	83	83
0.9	100	100	100	83	75	79	83	84	86	86	87
0.85	100	100	100	91	81	84	86	88	89	90	90
0.8	100	100	100	96	87	88	90	91	92	93	93
0.75	100	100	100	99	92	92	93	94	95	95	95
0.7	100	100	100	100	96	95	95	96	96	97	97

b) carry-over limit: 10% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	96	54	58	66	71	72	74	75	75
0.95	100	100	100	65	64	71	75	77	79	79	80
0.9	100	100	100	76	70	76	80	82	83	84	84
0.85	100	100	100	86	77	81	84	86	87	87	88
0.8	100	100	100	94	83	86	88	89	90	91	91
0.75	100	100	100	98	89	90	91	92	93	94	94
0.7	100	100	100	100	94	94	94	95	95	96	96

c) carry-over limit: 15% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	93	47	54	63	68	70	71	72	73
0.95	100	100	99	58	60	68	73	74	76	77	77
0.9	100	100	100	71	66	73	77	79	81	82	82
0.85	100	100	100	82	74	78	82	84	85	86	86
0.8	100	100	100	92	80	83	86	88	89	89	90
0.75	100	100	100	98	87	88	90	91	92	93	93
0.7	100	100	100	100	92	92	93	94	95	95	95

d) carry-over limit: 20% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	90	42	51	61	65	67	69	70	70
0.95	100	100	98	54	57	66	70	73	74	75	75
0.9	100	100	100	66	64	71	75	77	79	80	80
0.85	100	100	100	78	71	77	80	82	83	84	85
0.8	100	100	100	89	78	82	85	86	87	88	88
0.75	100	100	100	96	85	86	89	90	91	92	92
0.7	100	100	100	100	91	91	92	93	94	94	95

e) carry-over limit: 25% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	86	39	49	59	64	66	67	68	68
0.95	100	100	95	50	55	64	69	71	72	73	74
0.9	100	100	100	63	61	69	74	76	77	78	79
0.85	100	100	100	75	69	75	79	81	82	83	83
0.8	100	100	100	87	76	80	83	85	86	87	87
0.75	100	100	100	95	83	85	88	89	90	91	91
0.7	100	100	100	99	90	90	92	92	93	94	94

f) carry-over limit: 30% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	83	37	47	58	62	65	66	66	67
0.95	100	100	93	48	53	63	68	70	71	72	72
0.9	100	100	99	60	60	68	73	75	76	77	77
0.85	100	100	100	73	67	74	78	80	81	82	82
0.8	100	100	100	85	75	79	83	84	86	86	87
0.75	100	100	100	94	82	85	87	88	90	90	91
0.7	100	100	100	99	88	89	91	92	93	94	94

Table D-8. Probability that SSB of each year will exceed the SBlimit (151 thousand tons) in the future projection where reserve rate is randomly changed within the range of 0 to 50%.

The table shows the results of each setting of carry-over limit for the scenario where the coefficient β for HCRs is changed from 0.7 to 1.0 in 0.05 intervals. The higher the probability, the darker the shade is.

(Unit: %)

a) carry-over limit: 5% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	98	98	98	98	99	99	99
0.95	100	100	100	100	99	99	99	99	99	99	99
0.9	100	100	100	100	100	99	99	99	100	100	100
0.85	100	100	100	100	100	100	100	100	100	100	100
0.8	100	100	100	100	100	100	100	100	100	100	100
0.75	100	100	100	100	100	100	100	100	100	100	100
0.7	100	100	100	100	100	100	100	100	100	100	100

b) carry-over limit: 10% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	98	97	97	98	98	98	98
0.95	100	100	100	100	99	98	98	99	99	99	99
0.9	100	100	100	100	99	99	99	99	99	99	99
0.85	100	100	100	100	100	99	99	99	100	100	100
0.8	100	100	100	100	100	100	100	100	100	100	100
0.75	100	100	100	100	100	100	100	100	100	100	100
0.7	100	100	100	100	100	100	100	100	100	100	100

c) carry-over limit: 15% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	97	96	97	97	98	98	98
0.95	100	100	100	100	98	98	98	98	98	98	99
0.9	100	100	100	100	99	98	99	99	99	99	99
0.85	100	100	100	100	100	99	99	99	99	99	100
0.8	100	100	100	100	100	100	100	100	100	100	100
0.75	100	100	100	100	100	100	100	100	100	100	100
0.7	100	100	100	100	100	100	100	100	100	100	100

d) carry-over limit: 20% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	96	96	96	97	97	97	97
0.95	100	100	100	100	97	97	97	98	98	98	98
0.9	100	100	100	100	99	98	98	99	99	99	99
0.85	100	100	100	100	99	99	99	99	99	99	99
0.8	100	100	100	100	100	99	99	100	100	100	100
0.75	100	100	100	100	100	100	100	100	100	100	100
0.7	100	100	100	100	100	100	100	100	100	100	100

e) carry-over limit: 25% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	95	95	96	96	97	97	97
0.95	100	100	100	100	97	97	97	98	98	98	98
0.9	100	100	100	100	98	98	98	98	99	99	99
0.85	100	100	100	100	99	99	99	99	99	99	99
0.8	100	100	100	100	100	99	99	99	100	100	100
0.75	100	100	100	100	100	100	100	100	100	100	100
0.7	100	100	100	100	100	100	100	100	100	100	100

f) carry-over limit: 30% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	94	95	96	96	97	96	97
0.95	100	100	100	100	96	96	97	97	98	98	98
0.9	100	100	100	100	98	98	98	98	99	99	99
0.85	100	100	100	100	99	99	99	99	99	99	99
0.8	100	100	100	100	100	99	99	99	99	99	100
0.75	100	100	100	100	100	100	100	100	100	100	100
0.7	100	100	100	100	100	100	100	100	100	100	100

Table D-9. Future average catch projected for each year in the future projection where reserve rate is randomly changed within the range of 0 to 50%

The table shows the results of each setting of carry-over limit for the scenario where the coefficient β for HCRs is changed from 0.7 to 1.0 in 0.05 intervals. The higher the catch, the darker the shade is.

(Unit: thousand tons)

a) carry-over limit: 5% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	169	171	149	138	147	156	160	162	163	164	164
0.95	162	166	146	136	145	154	158	160	162	162	163
0.9	155	161	144	134	143	152	156	158	160	160	161
0.85	148	156	141	131	140	149	154	155	157	158	159
0.8	141	151	137	129	137	147	151	153	155	156	156
0.75	134	145	134	126	134	144	148	150	152	153	153
0.7	127	139	130	122	130	140	145	147	149	150	150

b) carry-over limit: 10% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	169	178	152	140	148	158	162	163	165	165	166
0.95	162	173	149	138	146	156	160	161	163	164	164
0.9	155	168	147	136	144	153	158	159	161	162	162
0.85	148	162	144	133	141	151	156	157	159	160	160
0.8	141	157	140	131	139	148	153	155	156	157	158
0.75	134	151	137	128	136	145	150	152	154	155	155
0.7	127	144	133	125	132	142	147	149	151	152	152

c) carry-over limit: 15% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	169	184	153	141	149	158	163	164	166	166	167
0.95	162	179	151	139	147	157	161	162	164	165	165
0.9	155	174	148	137	145	154	159	161	162	163	163
0.85	148	168	145	135	143	152	157	158	160	161	161
0.8	141	162	142	132	140	149	154	156	158	158	159
0.75	134	156	138	129	137	146	151	153	155	156	156
0.7	127	149	134	126	133	143	148	150	152	153	153

d) carry-over limit: 20% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	169	190	153	142	150	159	164	165	167	167	167
0.95	162	184	151	140	148	157	162	163	165	165	166
0.9	155	179	149	138	146	155	160	161	163	164	164
0.85	148	173	146	136	143	153	158	159	161	162	162
0.8	141	167	143	133	141	150	155	157	159	159	160
0.75	134	160	139	131	138	147	153	154	156	157	157
0.7	127	153	135	127	134	144	149	151	153	154	154

e) carry-over limit: 25% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	169	194	153	143	150	160	165	166	167	167	168
0.95	162	189	151	141	148	158	163	164	166	166	166
0.9	155	183	149	139	146	156	161	162	164	164	165
0.85	148	177	146	137	144	154	159	160	162	162	163
0.8	141	171	143	134	141	151	156	157	160	160	160
0.75	134	164	140	132	138	148	153	155	157	157	158
0.7	127	157	136	128	135	145	150	152	154	154	155

f) carry-over limit: 30% of the initial allowable catch

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	169	198	153	144	149	161	164	167	167	167	168
0.95	163	192	151	142	148	159	163	165	165	166	167
0.9	156	186	149	140	146	157	161	163	164	164	165
0.85	149	180	146	138	143	155	159	161	162	162	163
0.8	142	174	143	135	141	152	156	159	159	160	161
0.75	134	167	140	133	138	150	153	156	157	157	159
0.7	127	159	136	129	135	146	150	153	154	155	156

Table D-10. Probability for SSB to exceed the proposed SBtarget (a) and SBlimit (b), and the average catch (c) projected in the revised future projections in the scenario without a unused remains and carrying over (repost of Tables A-6 and A-7 (b) of the Examination Item A).

a) Probability for SSB to exceed the proposed SBtarget (%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	100	100	100	100	0	5	28	38	43	45	45	44	44	45	45
0.9	100	100	100	100	100	13	38	50	55	57	58	58	58	59	58
0.8	100	100	100	100	100	33	52	63	68	70	71	72	72	72	73
0.7	100	100	100	100	100	88	70	76	80	83	84	84	85	85	86
0.6	100	100	100	100	100	100	88	89	91	92	93	94	94	94	95
0.5	100	100	100	100	100	100	99	97	98	98	98	98	98	98	99
0.4	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

b) Probability for SSB to exceed the proposed SBlimit (%)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	100	100	100	100	100	100	81	88	90	91	90	91	91	91	91
0.9	100	100	100	100	100	100	91	93	95	95	95	95	96	96	96
0.8	100	100	100	100	100	100	98	97	98	98	98	98	98	98	98
0.7	100	100	100	100	100	100	100	99	99	100	99	99	99	100	100
0.6	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.4	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

c) Future average SSB (thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1.0	90	113	226	193	158	148	156	168	172	172	172	171	172	172	173
0.9	90	113	208	185	155	145	154	165	168	170	170	170	170	170	171
0.8	90	113	189	175	151	141	150	161	164	166	166	167	167	167	168
0.7	90	113	169	163	145	136	145	155	159	161	162	162	163	163	163
0.6	90	113	148	150	136	129	137	148	152	154	155	156	156	157	157
0.5	90	113	127	133	126	120	128	139	143	145	147	147	148	149	149
0.4	90	113	104	114	111	108	115	126	130	133	135	136	137	138	138
0.3	90	113	80	92	93	91	98	108	113	116	118	119	120	122	122
0.2	90	113	54	66	69	69	75	84	88	91	93	95	96	99	99
0.1	90	113	28	35	39	40	44	49	53	55	57	58	59	62	62
0.0	90	113	0	0	0	0	0	0	0	0	0	0	0	0	0