NPFC-2025-TWG CMSA11 WP09
July 15th-18th, 2025
@Shanghai, China

Biological reference points and future projections in the 2025 stock assessment for the Northwestern Pacific chub mackerel

Shota Nishijima[1], Momoko Ichinokawa[1], Kazuhiro Oshima[1], and Joel Rice[2]

1: Japan Fisheries Research and Education Agency

2: NPFC consultant

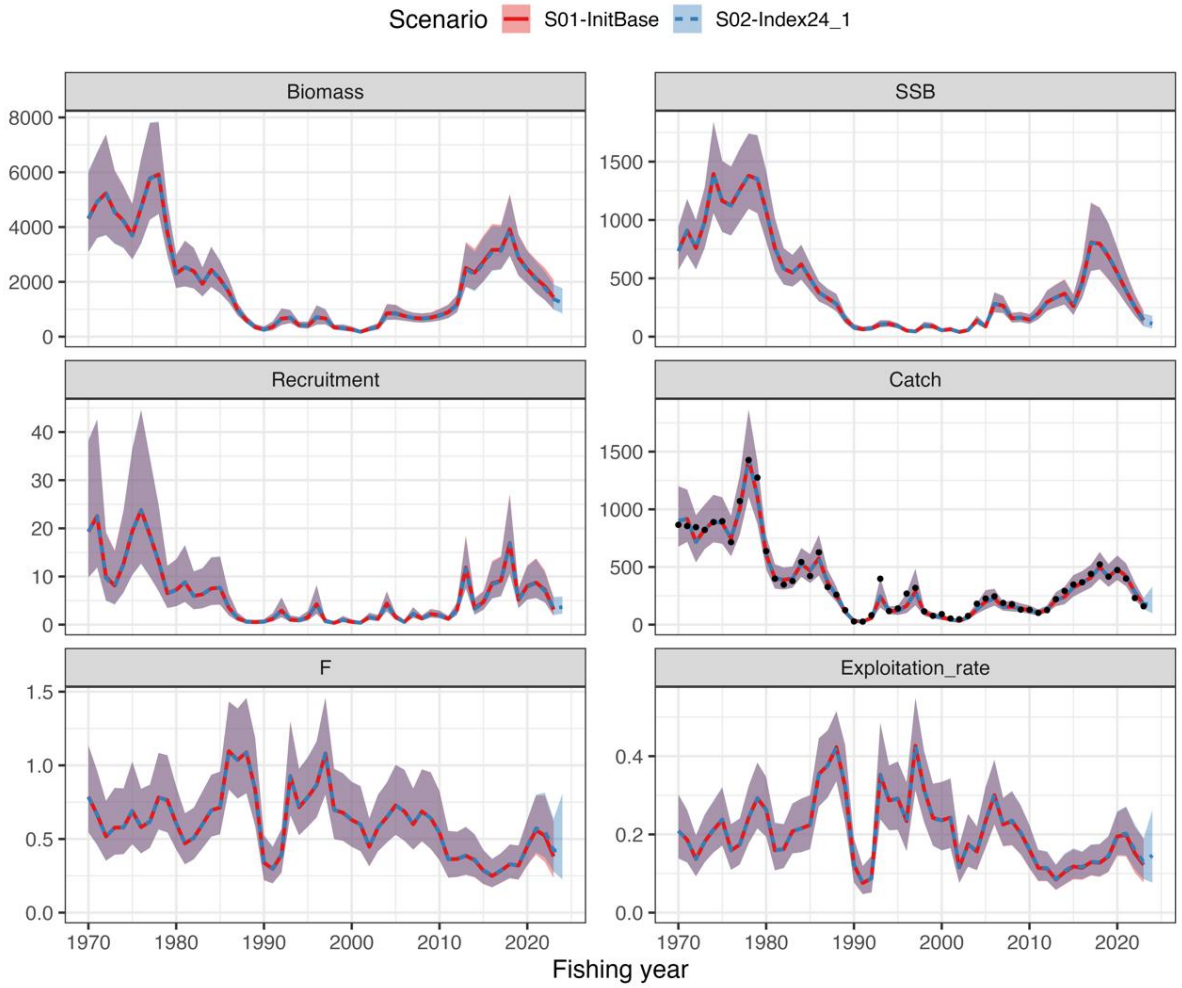
Summary

- Conducted stochastic future projections with candidate base-case stock assessment results to provide scientific information that could be used to draft management advice on the Northwestern Pacific stock of chub mackerel
- The estimated spawning stock biomass at maximum sustainable yield (SSB_{MSY}) was highly sensitive to input data and model configurations, estimated values were consistently higher than the current stock abundance.
- Propose using the first to third quartiles of historical SSB as interim reference points which might be used for short- or long-term target and limit, and with future probabilities calculated over these empirical reference points as well as the MSY-based ones.
- Under constant-catch scenarios, unless the annual total catch is kept below 60,000–70,000 tons, there is less than a 90% probability of maintaining SSB above the first quartile, and less than 60% probability of reaching the median five years later (in the 2031 fishing year).
- Under constant-F scenarios, fishing pressure must be F50%SPR (correspond to about 70,000 tons catch in the 2026 fishing year) or lower to achieve the median SSB with a probability exceeding 50% after five years.
- Considering the projection results that the stock continues to decline under the current fishing pressure (16-17% SPR) as long as the body weight and maturity rate are kept at a current low level, it is necessary to substantially reduce fishing pressure in order to avoid further decline and facilitate stock recovery.
- We also argue that development of harvest control rule and target and limit reference points are urgently needed for the long-term sustainable management of this stock.

Introduction

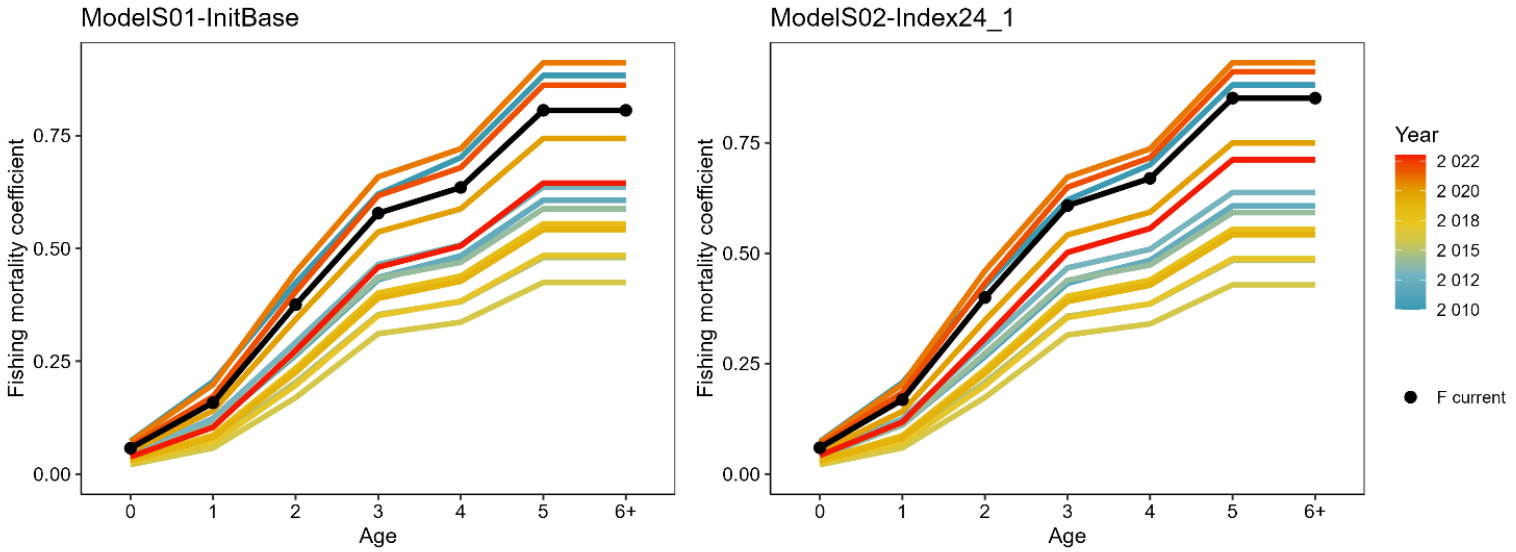
- This document provides useful information for future management of this stock by presenting the methods and results of biological reference points and future projections using the estimated population dynamics of this stock under candidate base case scenarios of SAM (NPFC-2025-TWG CMSA11-WP06).
- In the last Commission, the TWG CMSA was asked to provide projections and associated probabilities, based on constant catch scenarios (e.g. increments of 5.000 mt) or constant F scenarios, aiming at reaching an appropriate MSY proxy (SSB and F) within 5 to 10 years [with a probability higher than 50%.]
- The estimated SSB_{MSY} was highly sensitive to a variety of assumptions including input data, biological parameters, and stock-recruitment relationships and was unrealistically higher than the observed ranges of historical SSB (NPFC-2025-TWG CMSA11-WP07).
- We therefore calculated percentiles of historical SSB (e.g. 1st, 2nd, 3rd quartiles) between FY1970-2023 and propose using these quartiles as interim and empirical reference points for short- and long-term management objectives.
- In the future projections, simulations based on forward calculations of population dynamics with stochastic uncertainty in process errors were conducted under the assumption of constant catches or constant F.
- We computed the statistics of catch and SSB and probabilities that the stock exceeds the empirical and MSY-based reference points in any year until FY2036 (ten years after management implementation in FY2026) under constant-catch and constant-F scenarios.
- Output values from this analysis will be useful to make scientific advice for the international management of this stock.

Used SAM results (candidate base cases)



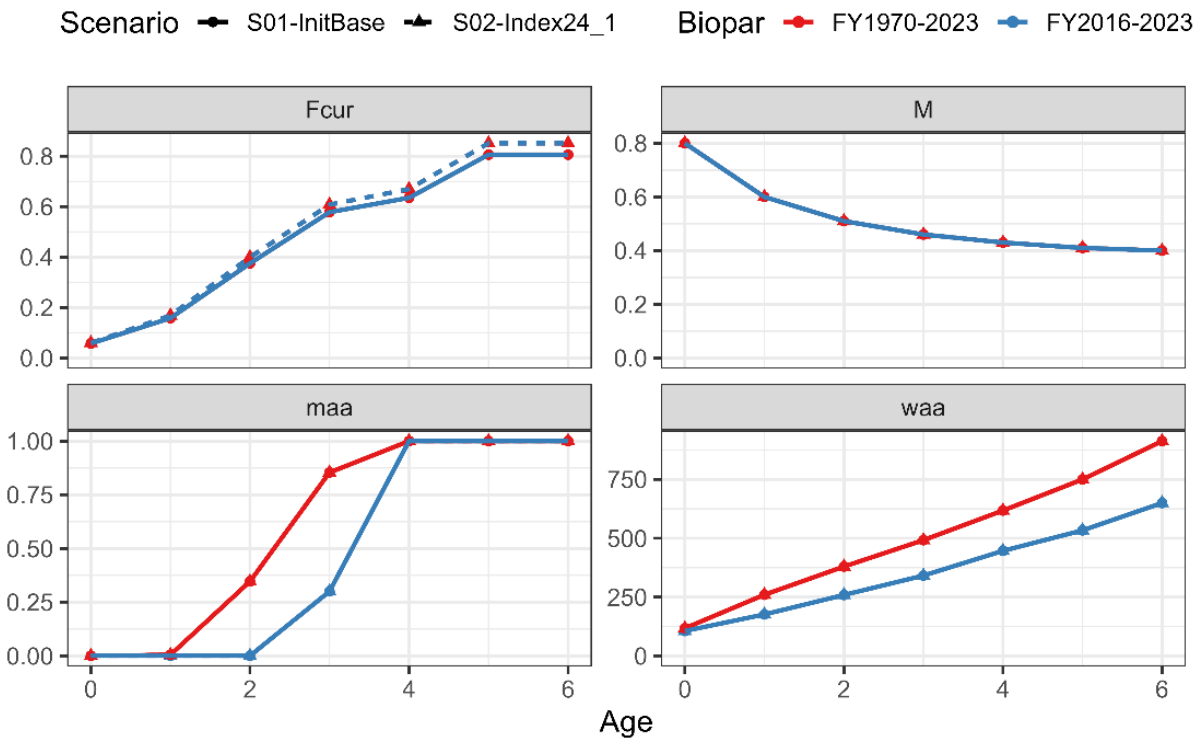
- Used parameter estimates of candidate base case scenarios of SAM: S01-InitBase and S02-Index24_1 (NPFC-2025-TWG CMSA11-WP06).
- The only difference between these two scenarios is exclusion or inclusion of FY2024 abundance indices (Table 1) and the abundance estimates were fairly similar between the scenarios (Fig. 1).

Current F and F reference points



- Calculated commonly used biological reference points such as F%SPR (30%, 40%, 50%, 60%, and 70%), F0.1, F_{MSY}, and SSB_{MSY}.
- The most recent three-year average of F at age (F2021-2023), estimated by the two candidate base cases, was defined as current F (F_{CUR}) and its selectivity at age was used to calculate the biological reference points (Fig. 2).

Biological parameters



- Used the most recent 8 years (FY2016-2023) average of weight at age and maturity at age
- Also analyzed the case using the all-year average (FY1970-2023) to inform the effects of time-varying biological parameters (future projection results are shown in Appendix)

Population dynamics in future projection

- Follow the population dynamics of SAM
- Used the point estimates for simplicity

$$N_{y,a}^{i} = \begin{cases} \dfrac{\hat{\alpha} S_y^i}{1 + \hat{\beta} S_y^i} \exp\left(\varepsilon_{y,a}^{i}\right) & (a = 0) \\ N_{y-1,a-1}^{i} \exp\left(-M_{a-1} - F_{y-1,a-1}^{i}\right) \exp\left(\varepsilon_{y,a}^{i}\right) & (0 < a < 6) \\ \left[N_{y-1,a-1}^{i} \exp\left(-M_{a-1} - F_{y-1,a-1}^{i}\right) + N_{y,a}^{i} \exp\left(-M_a - F_{y,a}^{i}\right)\right] \exp\left(\varepsilon_{y,a}^{i}\right) & (a = 6+) \end{cases}$$

- Initial condition of number at age is N2023 for S01 and N2024 for S02
- Estimated F2023 was used
- Management implementation starts from 2026 (constant catch or constant F)
- F2024 and F2025 are assumed to be the same as F2023 (projected catch in FY2024-2025 is 170,000 – 180,000 tons)
- If assuming F2024-2025 = F2021-2023 (3-year average), the projected catch in FY2024 exceeds 200,000 tons (seems unrealistically high considering current fishing situation)
- Replicate was 3,000 runs by each scenario

Constant-catch and constant-F scenarios

Model settings	S01-InitBase (S01): Initial base case with no FY2024 abundance indices S02-Index24_1: Another candidate base case with FY2024 abundance indices
Biological parameters (weight and maturity)	Recent8YRave: Average during FY2016-2023 AllYRave: rAverage during FY1970-2023
Constant-catch scenarios	Catch a fixed amount (ranging from 0 to 200,000 tons in increments of 10,000 tons) each year since FY2026.
Constant-F scenarios	Catch by fixed fishing pressure (ranging from F30%SPR to F70%SPR in increments of 5%SPR) each year since FY2026.

Catch numbers $$C^i_{y,a} = \frac{F^i_{y,a}}{F^i_{y,a} + M_a}\left(1 - \exp\left(-F^i_{y,a} - M_a\right)\right)N^i_{y,a}\,, \qquad \left(F^i_{y,a} = x^i_y F_{cur,a}\right)$$

- In constant-catch scenarios, the adjustment factor x^i_y is determined to satisfy $\sum_{a=0}^{6+} w_a C^i_{y,a} = CC$
- In constant-F scenarios, the adjustment factor x^i_y is the ratio of Fref to Fcur
- Projected population dynamics until FY2026 (ten years later since first management implementation)

Results

Stock-recruitment relationship and SSB_{MSY}

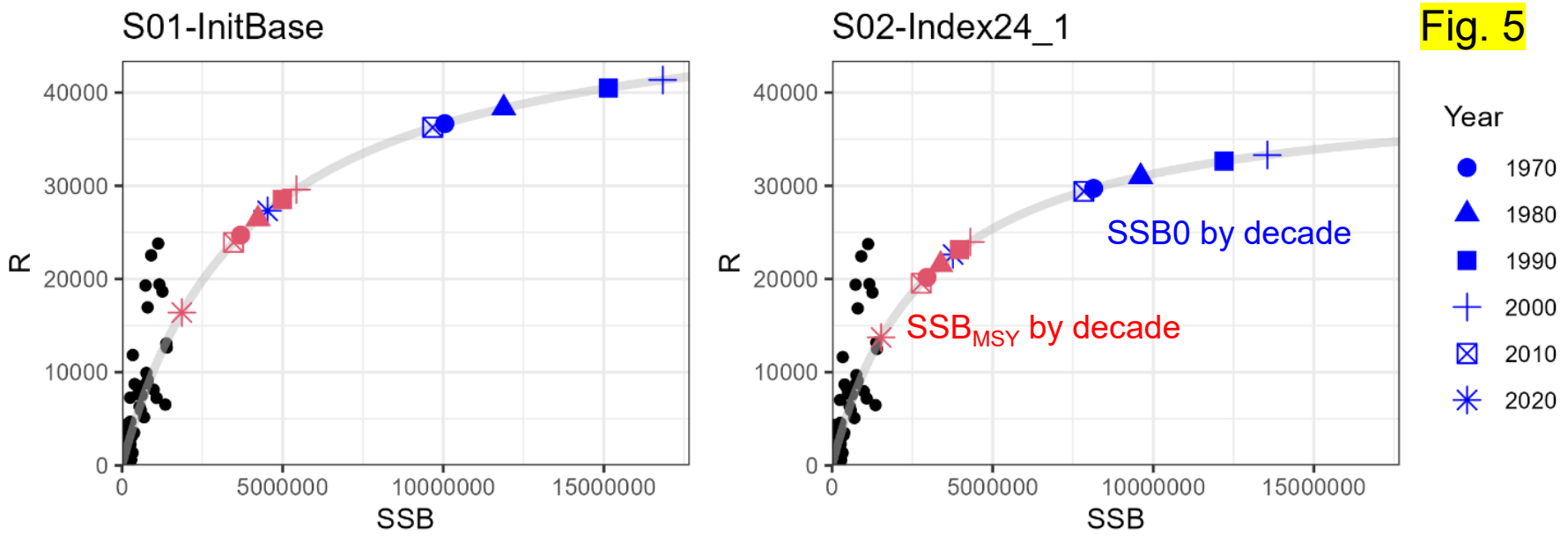


Fig. 5

- The SSB0 and SSB_{MSY} calculated based on this stock-recruitment relationship are extrapolated values that exceed the past recruitment and spawning stock biomass
- The estimated values of SSB0 and SSB_{MSY} (even under the single stock-recruitment relationship) varied greatly depending on which year's biological parameters were used.
- SSB0 using the biological parameters of the 2020s, when growth and maturation were heavily delayed, was equivalent to SSB_{MSY} in other decades.
- Even between the two models, the MSY reference points differed greatly probably because the influence of a slight difference of estimated stock-recruitment relationships became larger by the extrapolation of estimating MSY

Biological reference points

Scenario	S01-InitBase		S02-Index24_1	
Biological parameter	Ave2016-2023	Ave1970-2023	Ave2016-2023	Ave1970-2023
currentSPR/SPR0	0.174	0.291	0.162	0.278
SSBmedian	289	289	289	289
deple_median_last3	0.912	0.912	0.892	0.892
SSB_Q1	107	107	107	107
deple_Q1_last3	2.463	2.463	2.404	2.404
SSB_Q3	721	721	724	724
deple_Q3_last3	0.365	0.365	0.356	0.356
Fmed/Fcur	0.312	1.091	0.310	1.067
F0.1/Fcur	0.902	0.902	0.838	0.838
FpSPR.30.SPR/Fcur	0.613	0.964	0.580	0.911
FpSPR.40.SPR/Fcur	0.435	0.644	0.412	0.609
FpSPR.50.SPR/Fcur	0.311	0.440	0.295	0.416
FpSPR.60.SPR/Fcur	0.219	0.299	0.207	0.282
FpSPR.70.SPR/Fcur	0.147	0.194	0.139	0.184
Fmsy/Fcur	0.160	0.422	0.161	0.415
Bmsy	6,551	11,882	5,417	9,597
SBmsy	1,915	4,158	1,561	3,317
h	0.354	0.501	0.364	0.512
SB0	4,680	11,892	3,863	9,613
SBmsy/SB0	0.409	0.350	0.404	0.345
FmsySPR	0.679	0.511	0.665	0.501
B/Bmsy	0.219	0.121	0.254	0.143
SB/SBmsy	0.074	0.034	0.084	0.040
SBmsy/SBmax	1.373	2.982	1.116	2.371

F_{CUR} = F2021-2023 was equivalent to 16-17%SPR

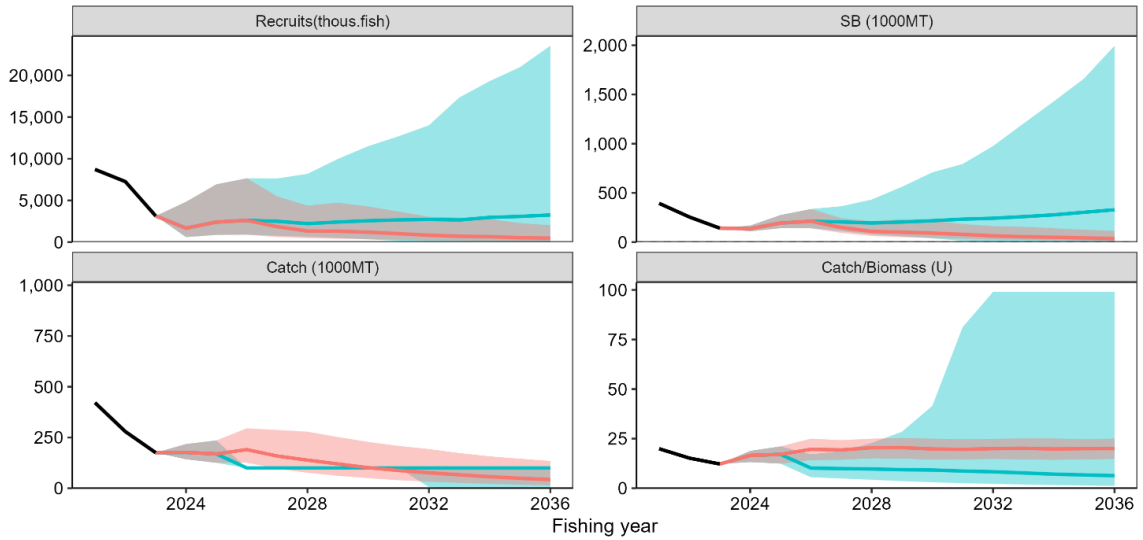
F_{CUR} is much higher than commonly used F reference points including F_{MSY} = F67-68%SPR

If using the all-year average of biological parameters, the ratios of F reference points to F_{CUR} became lower

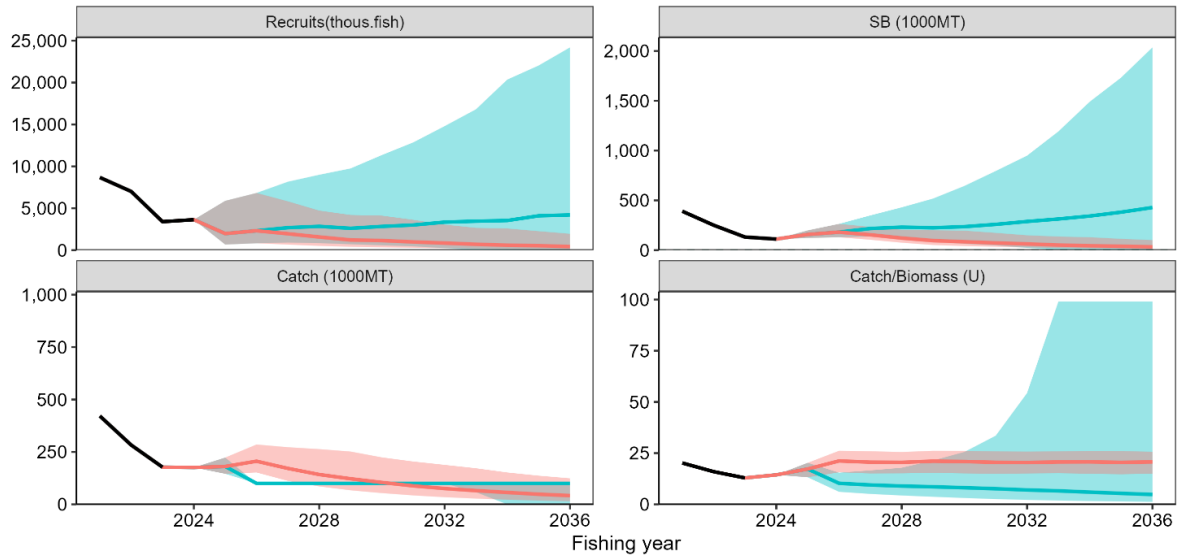
Example of constant-catch scenarios

Projection under current F (red) and constant catch of 100,000 tons (blue)

S01-InitBase

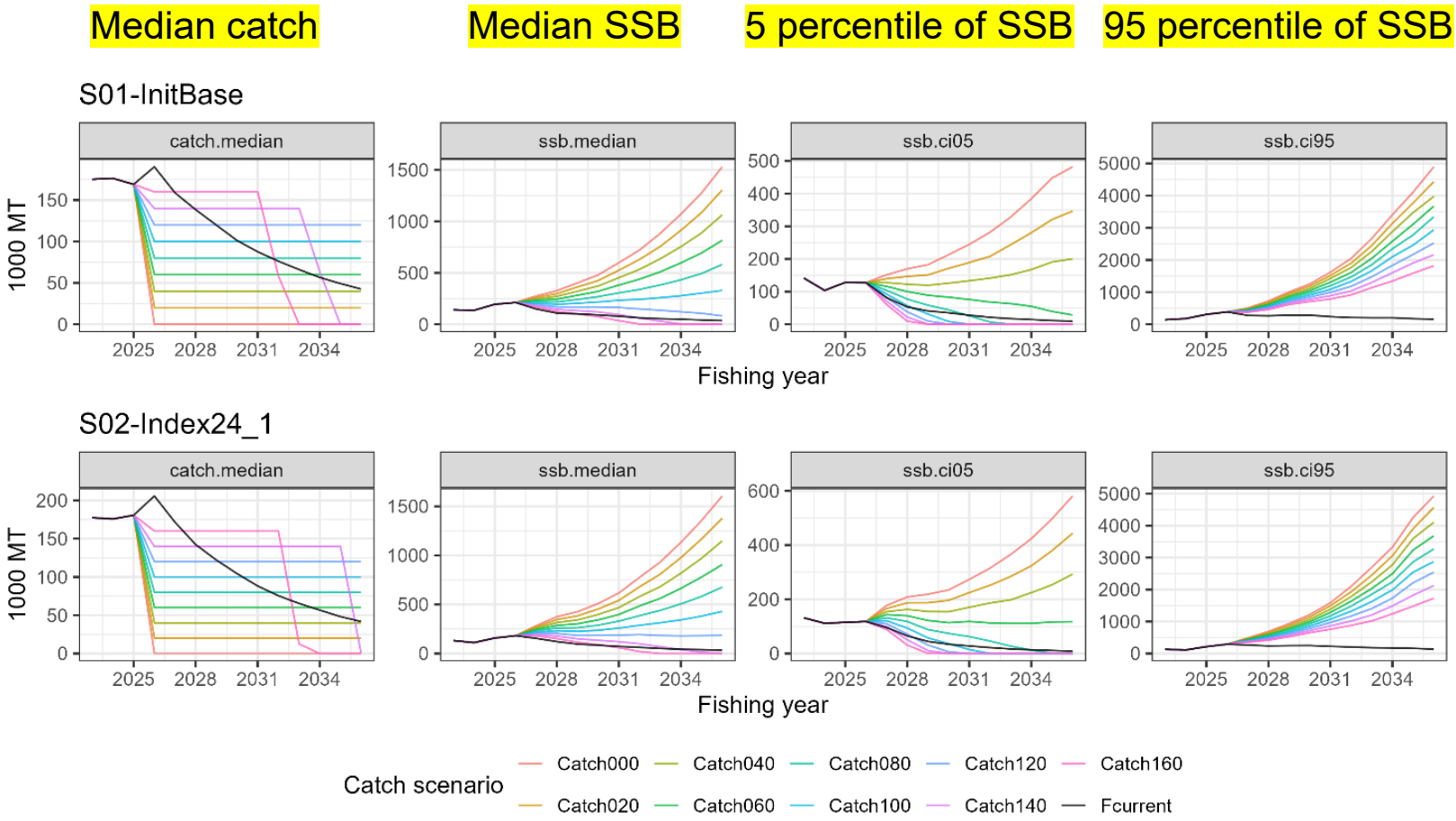


S02-Index24_1



- If current fishing pressure continues, SSB will continue to decline
- Under constant-catch scenario of 100,000 tons, the exploitation rate becomes higher when stock biomass is low and lower when stock biomass is high, resulting in wider prediction intervals for SSB than those under the current-F scenario.
- Maintaining catches at 100,000 tons would lead to a gradual increase in the median SSB, but there is also a possibility that the stock could collapse, and catches become unsustainable within ten years.
- This result is worse than last year's base-case assessment (NPFC-2024-SC09-WP20 (Rev. 1)), likely reflecting a decrease in estimated stock biomass in this year's update.

Different constant-catch scenarios



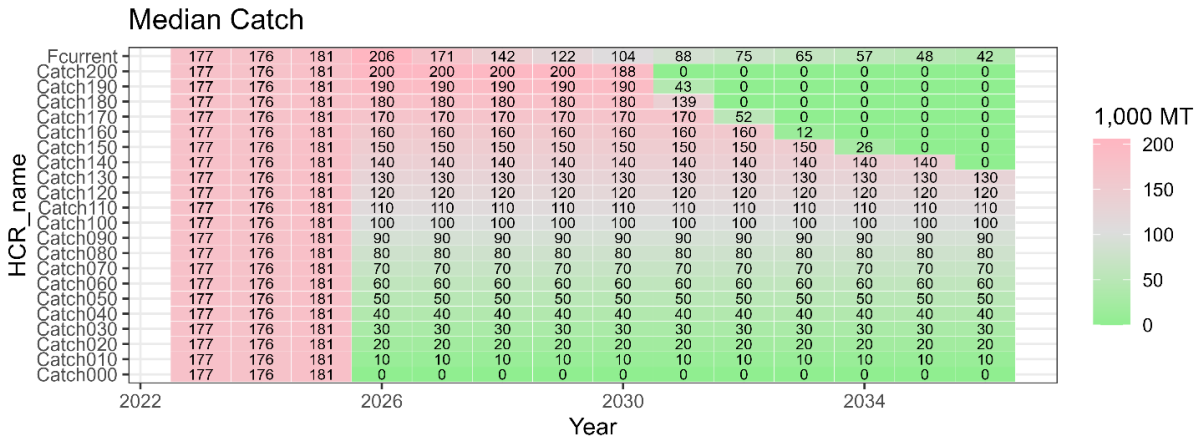
When using S01-InitBase, even a catch of 60,000 tons results in a decrease in the 5th percentile of SSB

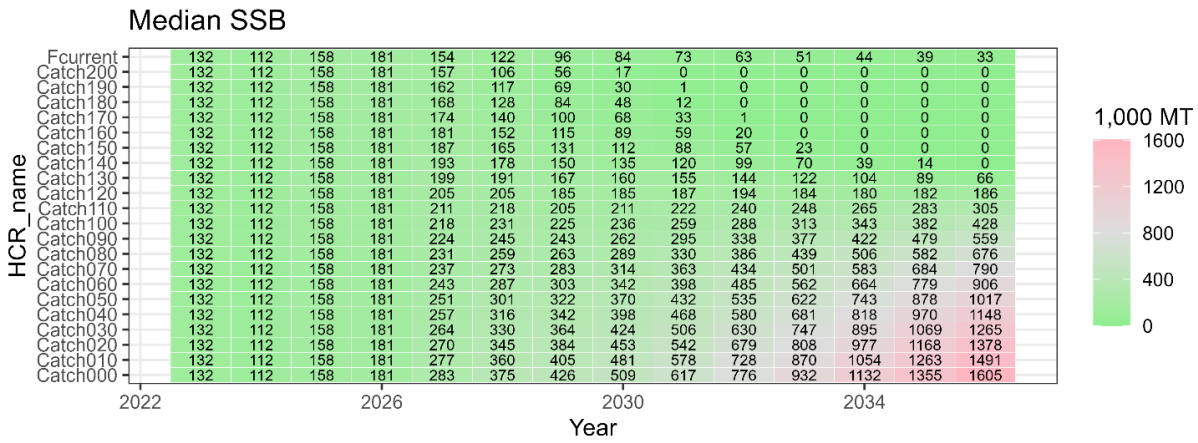
Under S02-Index24_1, catches below 60,000 tons maintain the 5th percentile of SSB at about the current level

This is likely because steepness of the stock-recruitment relationship was slightly higher in S02

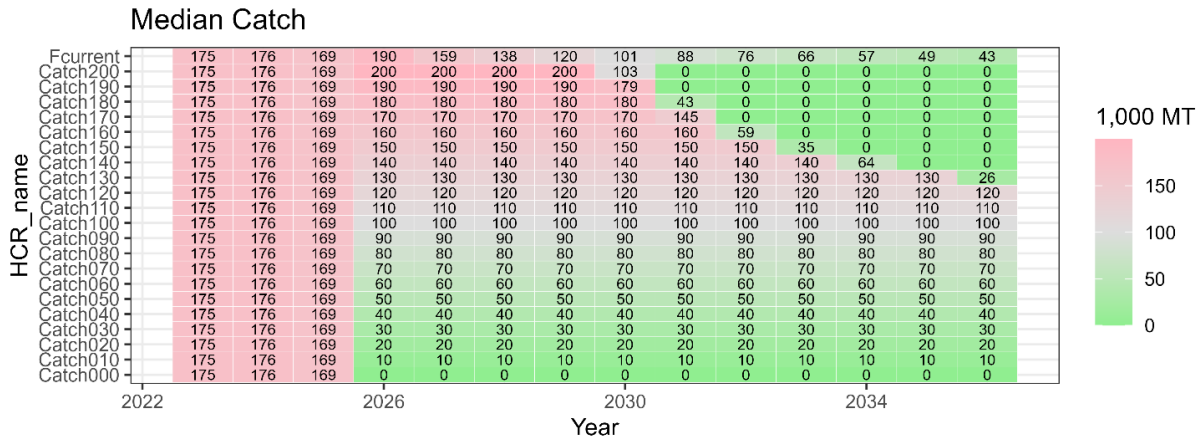
Future catch and SSB under constant-catch

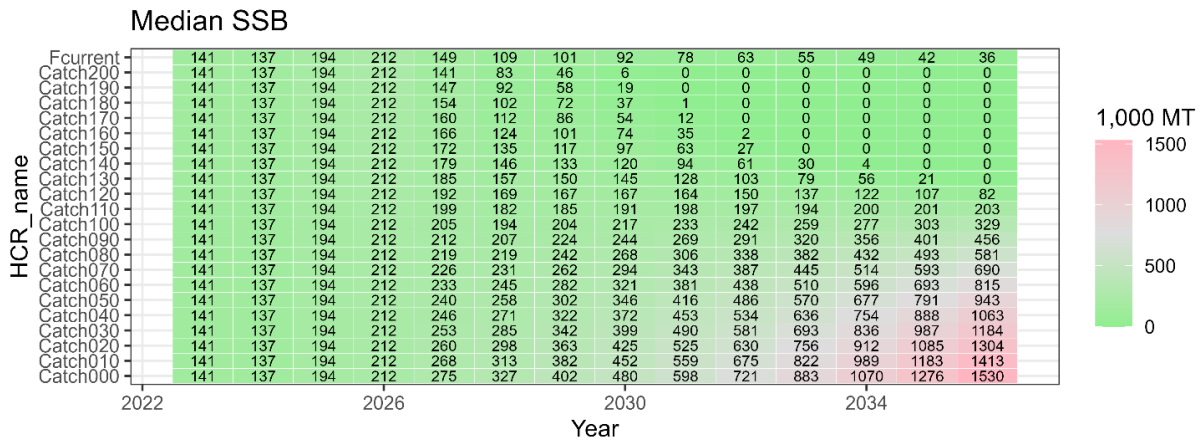
S01-InitBase





S02-Index24_1

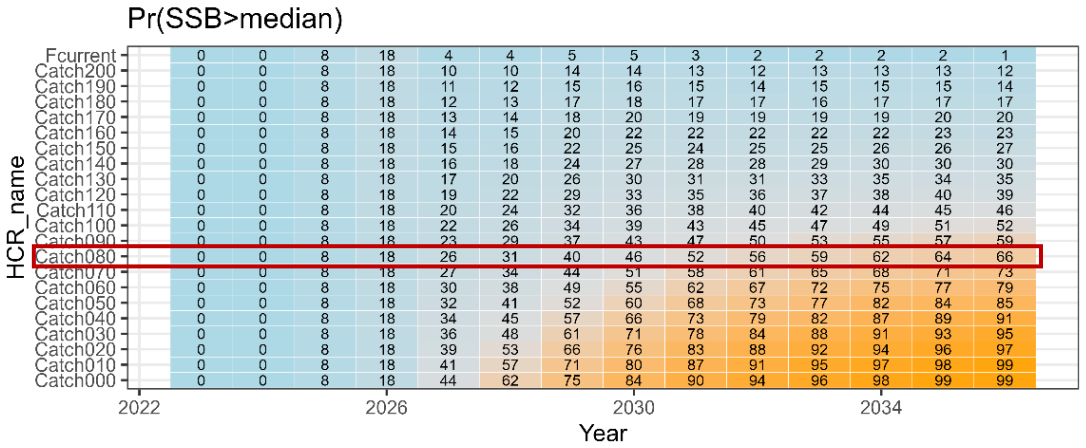


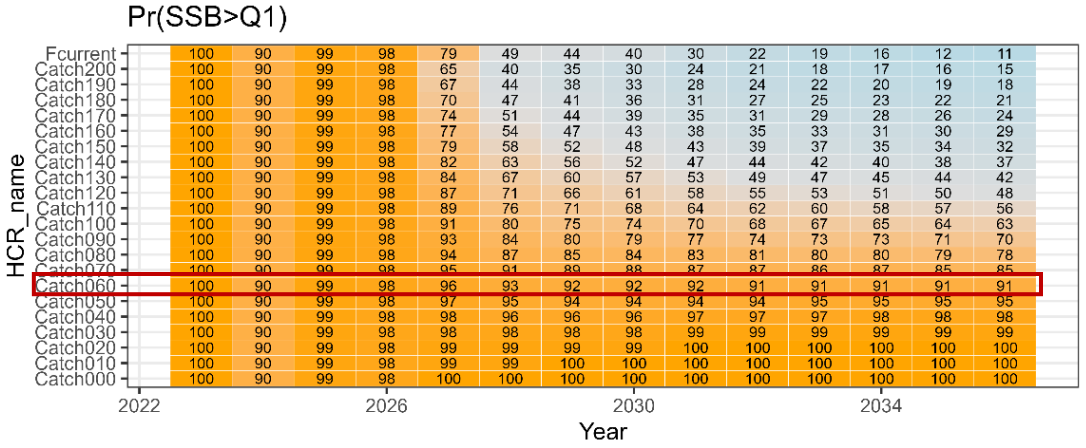


Annual catch of 130,000 tons or larger can not be maintained and SSB will collapse in 10 years

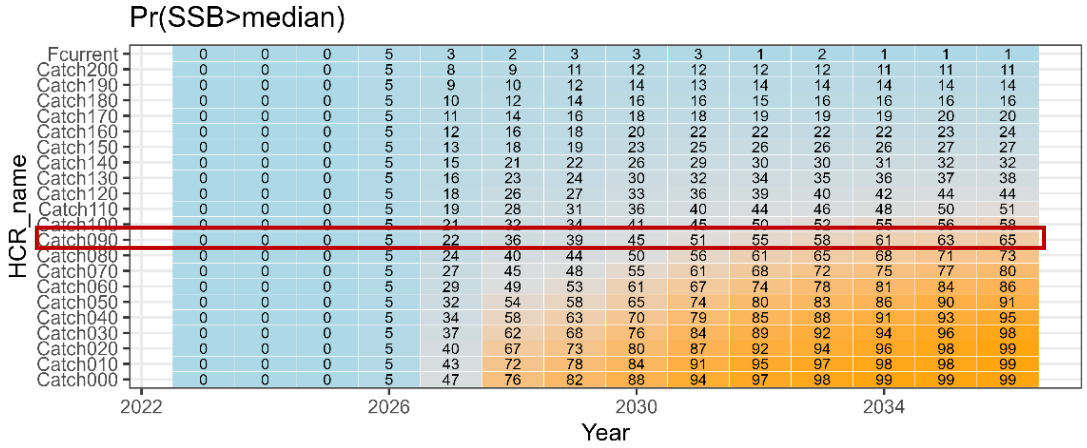
Probabilities over the first quartile and median of SSB

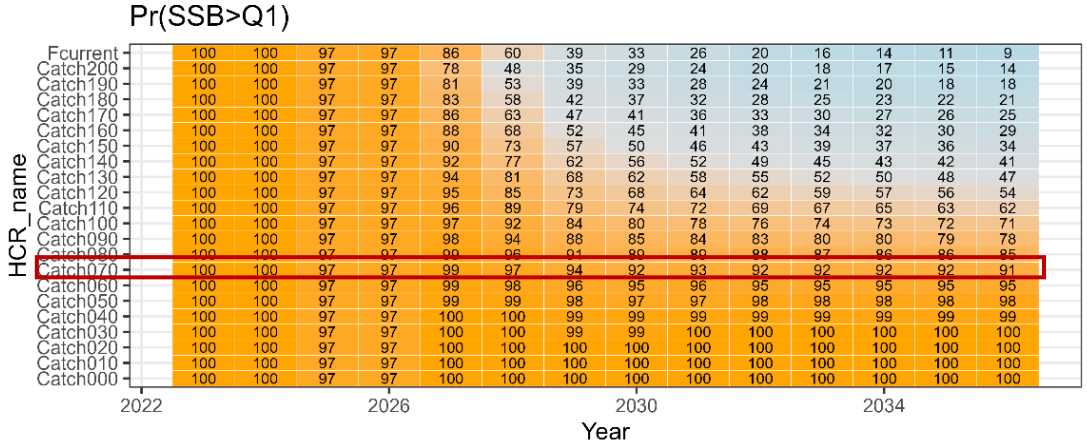
S01-InitBase





S02-Index24_1



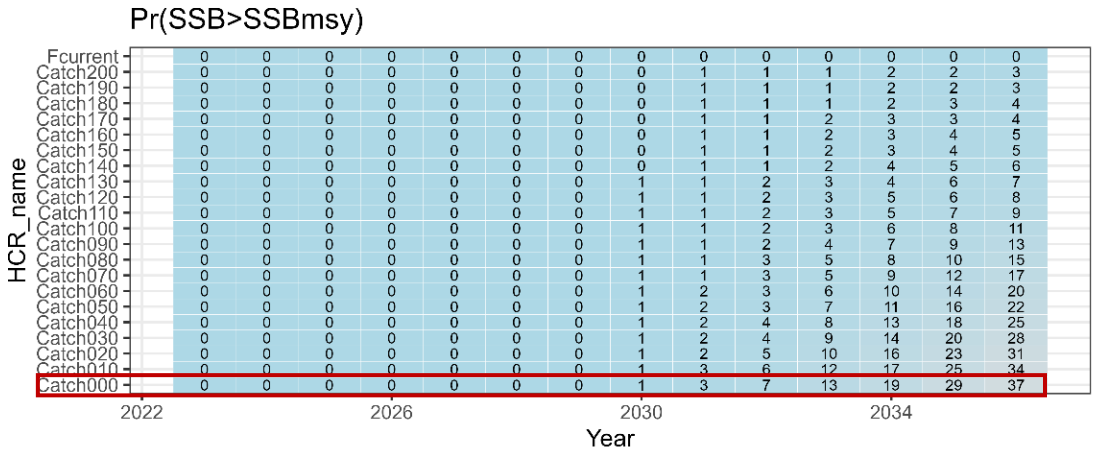


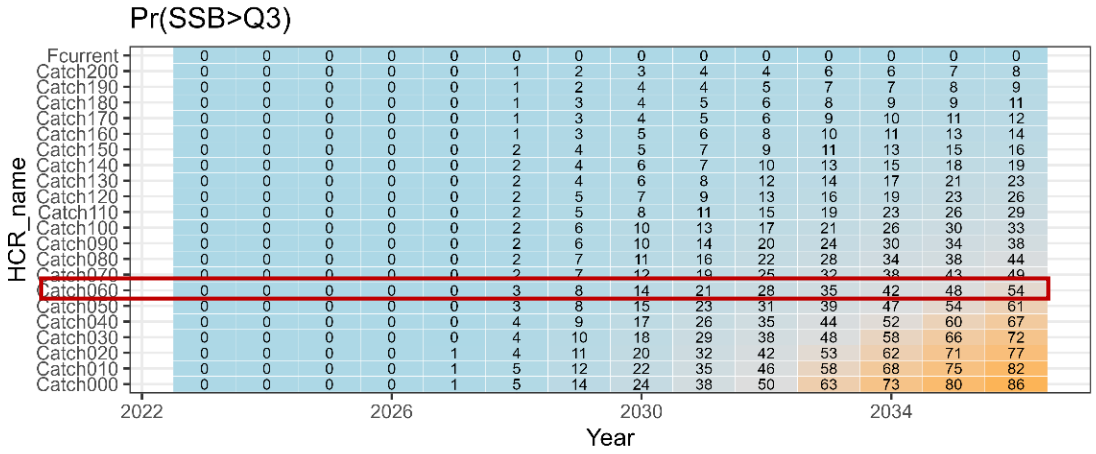
The catch amount needs to be lower than 80 to 90 thousand tons (depending on the base-case scenario) to achieve a probability higher than 50% that SSB will exceed historical median in FY2031 (five years after management implementation).

The catch amount needs to be lower than 60 to 70 thousand tons to achieve a probability higher than 90% that SSB will exceed its first quartile thorough FY2036.

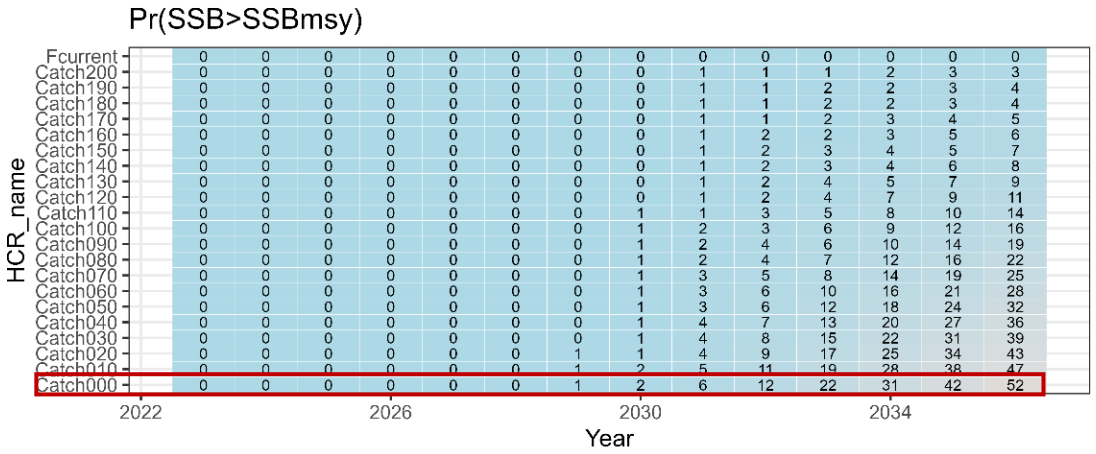
Probabilities over the third quartile of SSB and SSB_{MSY}

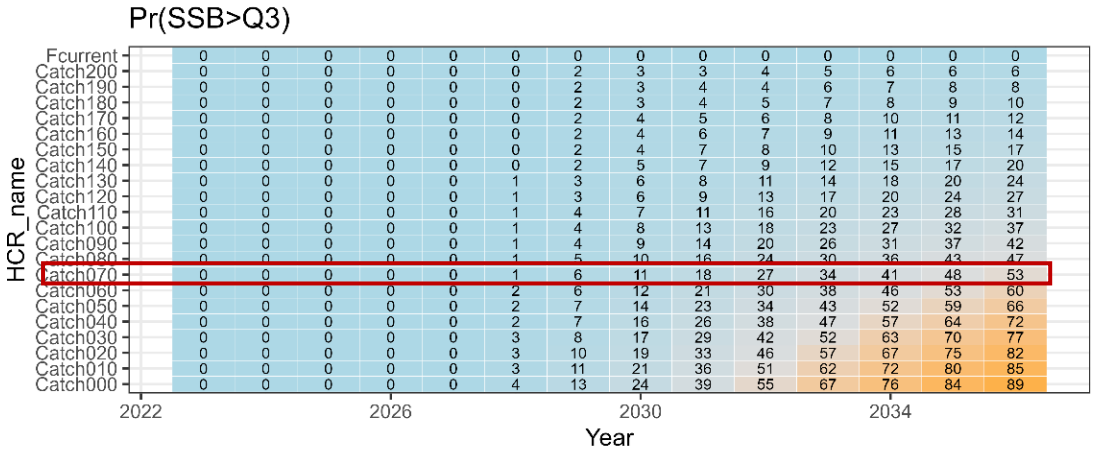
S01-InitBase





S02-Index24_1





The catch amount needs to be lower than 60 to 70 thousand tons to achieve a probability higher than 50% that SSB will exceed its third quartile in FY2036 (ten years after management implementation)

Even with no fishing, the probability of reaching SSB_{MSY} by 2036 was 37% in S01-InitBase and 52% in S02-Index24_1.

Realized F2026 under constant-catch scenarios

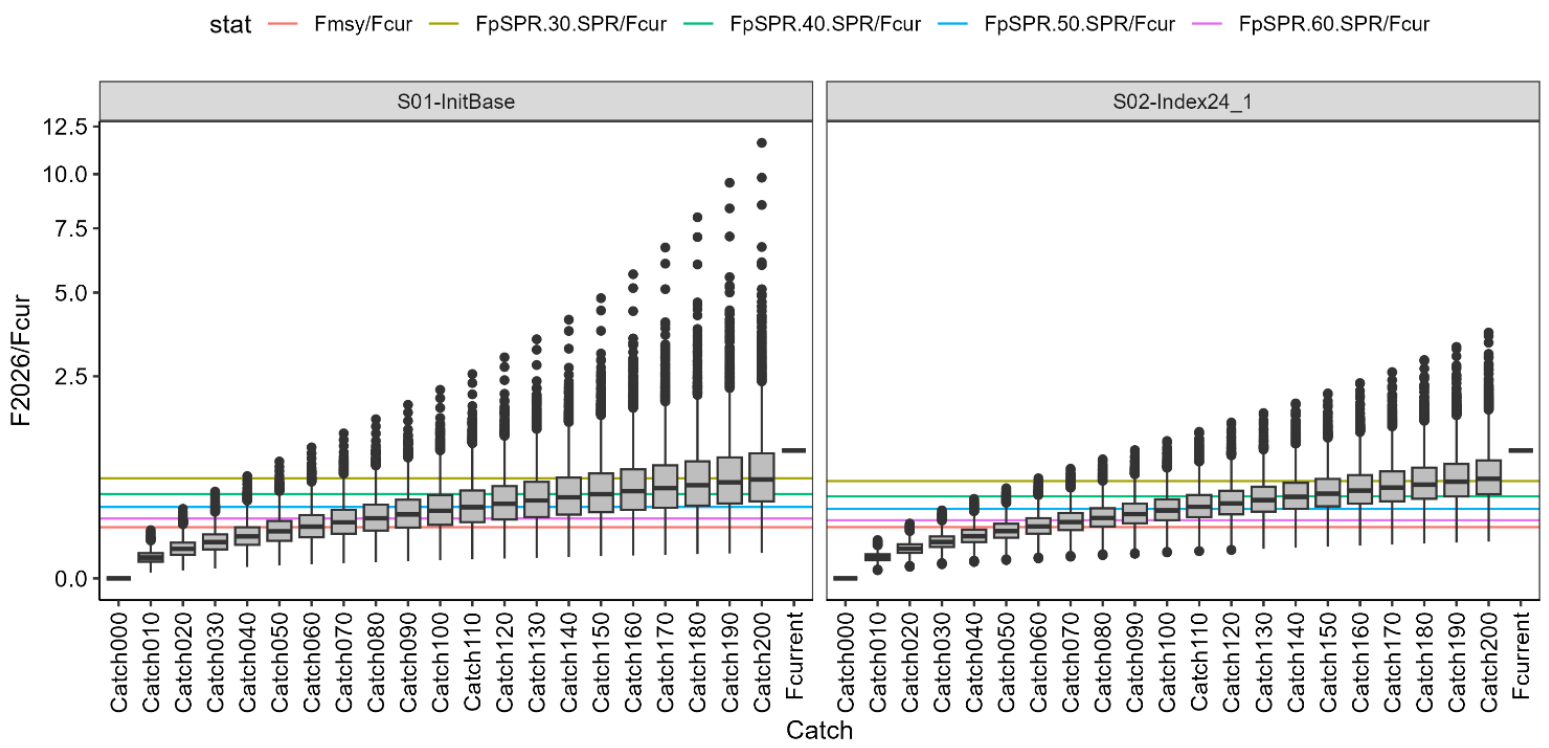
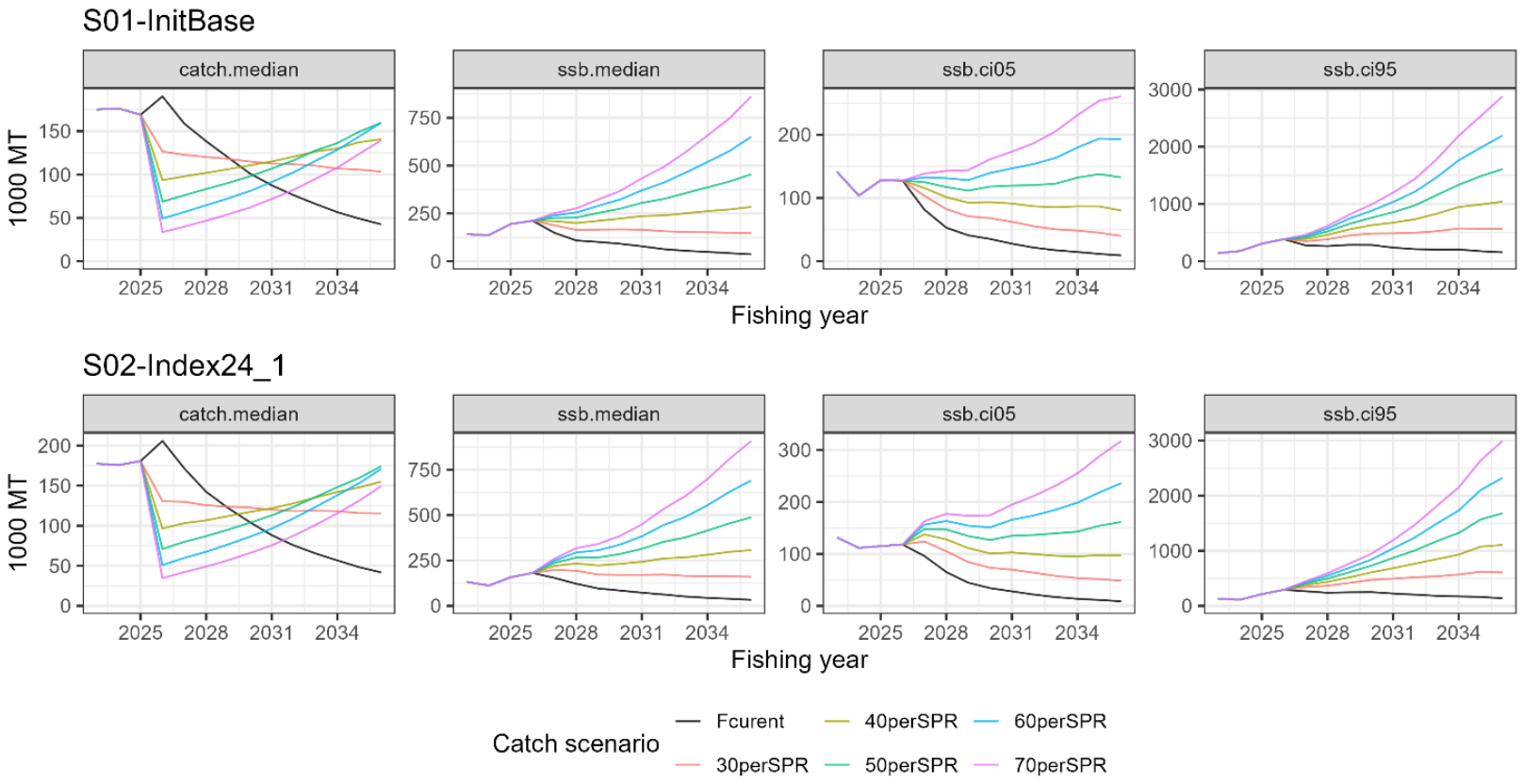


Fig. 9

- Catches below 50,000 tons corresponded to F < F_{MSY},
- Catches below 100,000 tons corresponded to F < F50%SPR.
- Compared to S01-InitBase, the uncertainty in the projected F in S02-Index24_1 was smaller because stock biomass up to FY2024 was estimated in S02, reducing the influence of process error.

Different constant-F scenarios

Median catch Median SSB 5 percentile of SSB 95 percentile of SSB

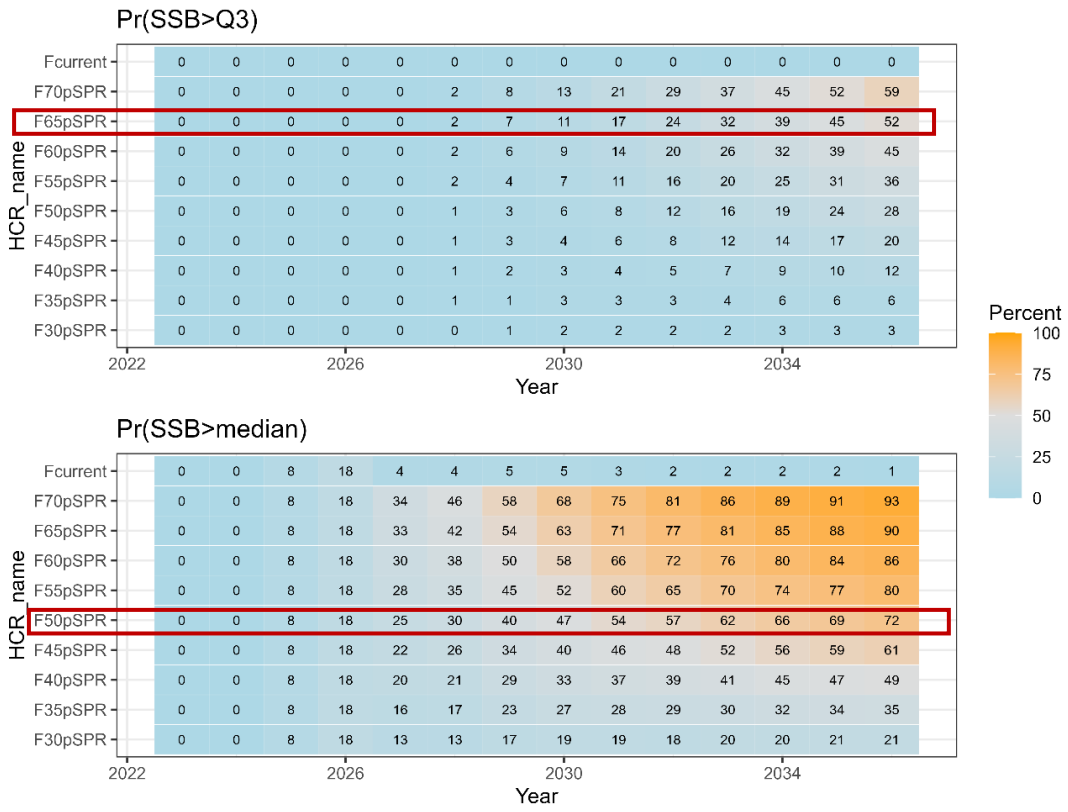


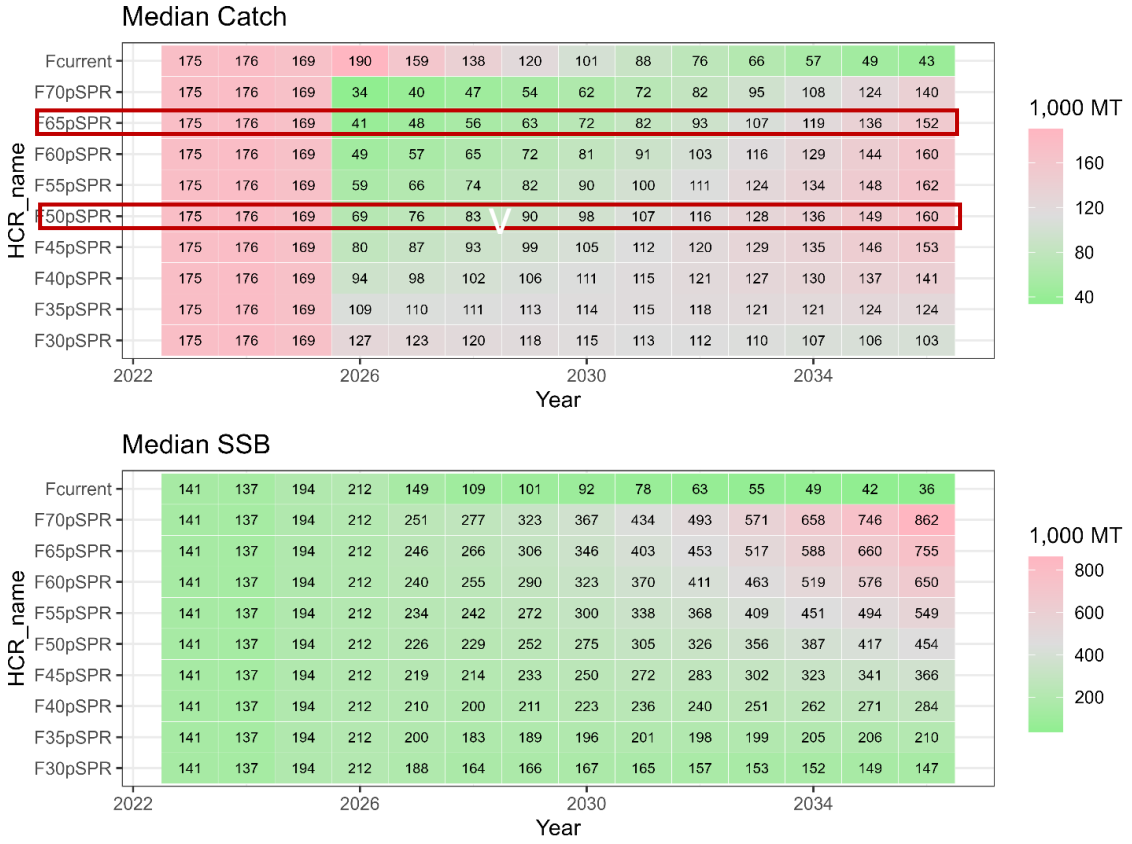
Under F40%SPR, the median projected SSB and catch gradually increase, while the 5th percentile remains at about the current level

If fishing mortality is set lower than F40%, the median SSB is projected to increase

Under F30%, it is projected to be maintained only slightly above the current level

Future projection with S01 under constant F

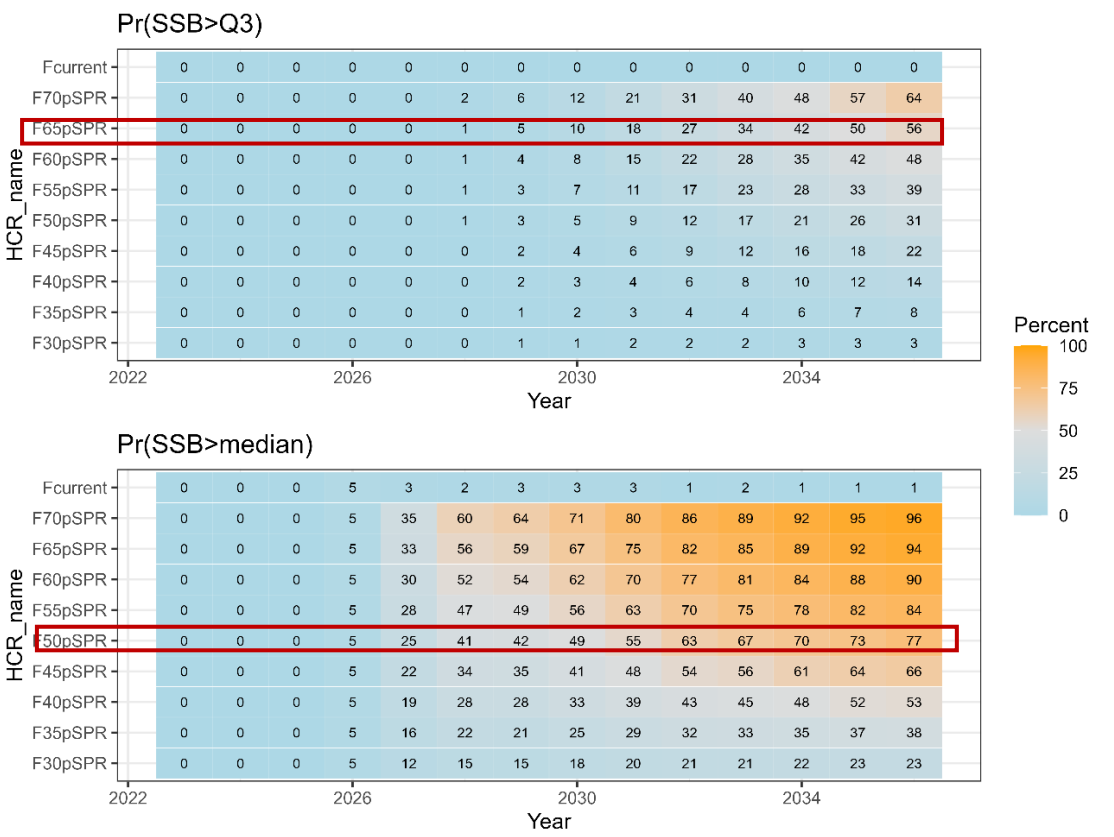


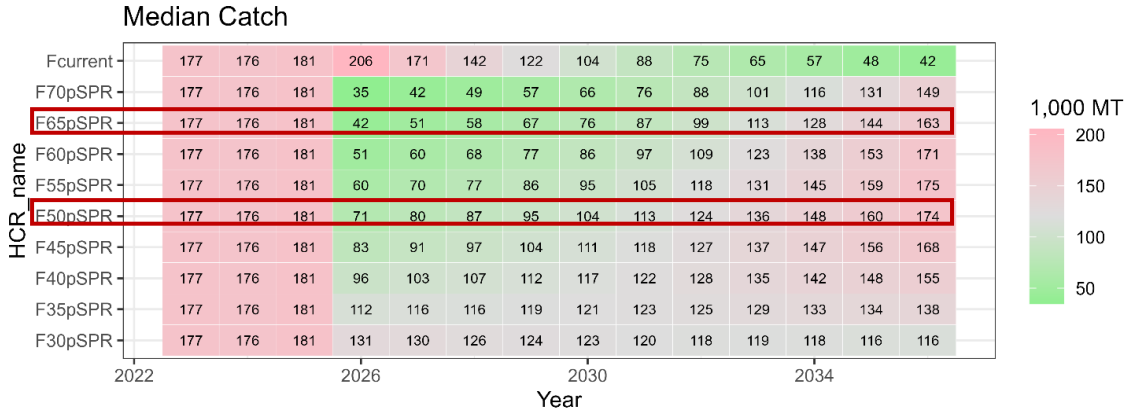


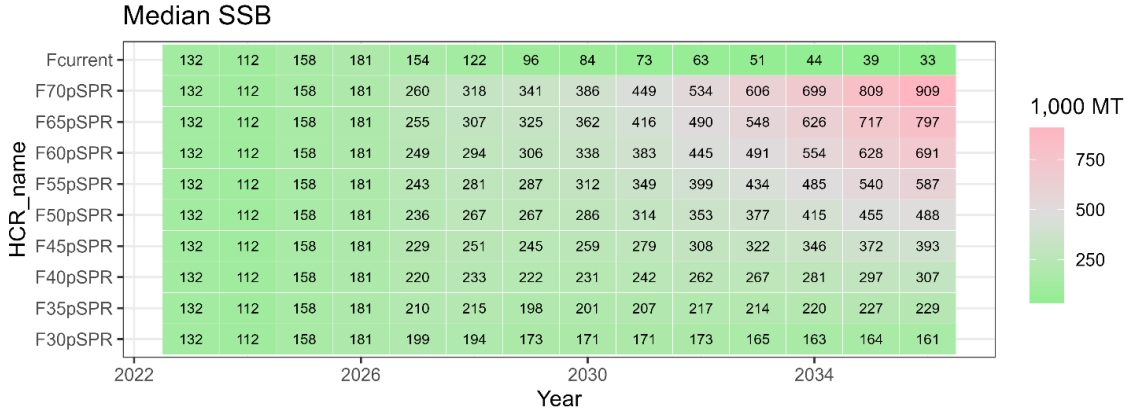
Looking at probabilities with SSB over the historical quartiles, F50%SPR (corresponding to a catch of 69 thousand tons in FY2026) represent the upper fishing mortality levels needed to achieve a probability higher than 50% that SSB will exceed its median in FY2031.

F65%SPR (corresponding to a catch of 41 thousand tons in FY2026) or lower F is needed to achieve a probability higher than 50% that SSB will exceed its third quartile in FY2036.

Future projection with S02 under constant F





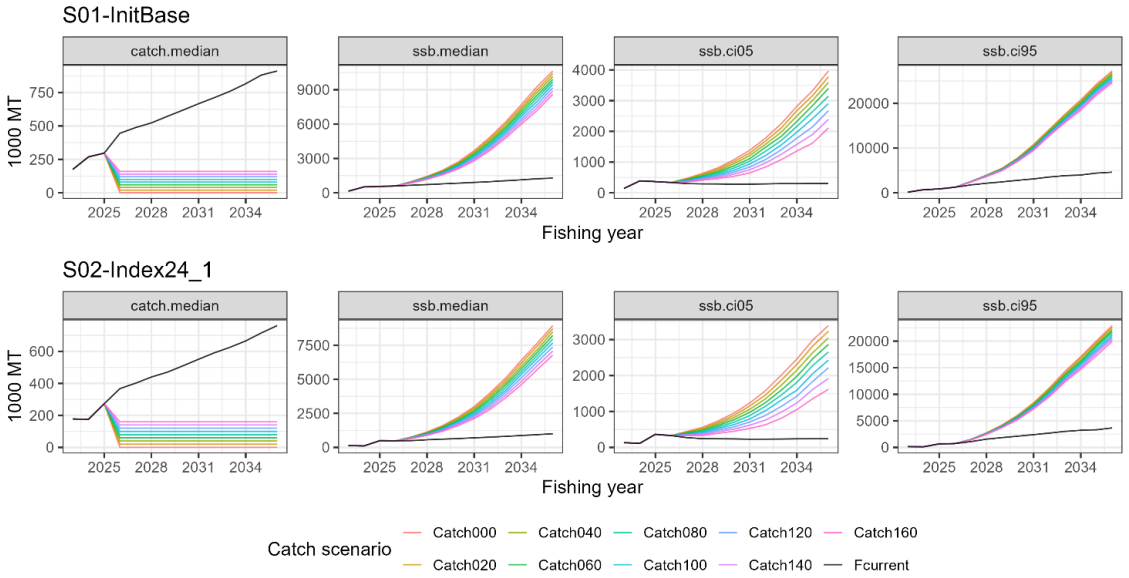


Looking at probabilities with SSB over the historical quartiles, F50%SPR (corresponding to a catch of 71 thousand tons in FY2026) represent the upper fishing mortality levels needed to achieve a probability higher than 50% that SSB will exceed its median in FY2031.

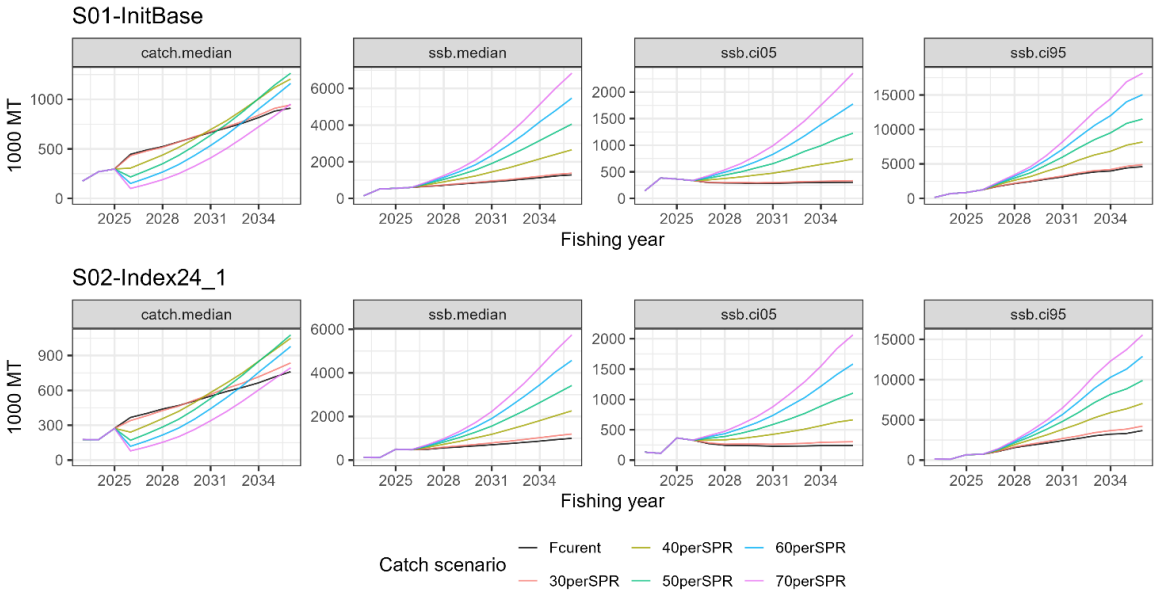
F65%SPR (corresponding to a catch of 42 thousand tons in FY2026) or lower F is needed to achieve a probability higher than 50% that SSB will exceed its third quartile in FY2036.

Future projection using all-year average of biological parameters

Constant catch



Constant F



- Assuming that weight-at-age and maturity-at-age are at their all-year averages, even under F_{CUR}, the stock recovers, and almost all fishing scenarios examined (except F30%SPR), SSB recovers at a rapid pace
- These results suggest that the current slow growth and delayed maturity are hindering stock recovery.
- Tables for SSB, catch, achievement probabilities are available in Appendix of the working paper

Uncertainty of MSY-based reference points

- SSB_{MSY} and SSB0 are still estimated beyond the ranges of historically observed SSB and recruitment, highly sensitive to input data and model settings, and time-varying depending on fluctuating biological parameters.
- Due to such difficulties, we do not recommend explicitly using SSB_{MSY}, SSB0, and related reference points as target biomass-based reference points at this moment.
- We suggest using the first quartile, median, and third quartile of SSB as empirical and provisional reference points, because these reference points are found to be robust to the model settings and input data
- To present uncertainties of MSY reference points to the empirical reference points, we can show potential ranges of these empirical reference points relative to SSB_{MSY}: the first, second (median), and third quartiles of SSB correspond to 3-7%, 7-19% and 16-46% of SSB_{MSY}
- The ranges could be expanded when considering the scenario with alternative stock-recruitment relationship of SHS (Table 4, 5 in NPFC-2025-TWG CMSA11-WP07) to 3-11%, 7-31% and 16-77%.
- Although the exact value of SSB_{MSY} is highly uncertain, it could be possible to provide guidance on how these empirical management reference points could be used (i.e., as target or limit reference points) by presenting such plausible range derived from currently available estimation results.

Importance of development of harvest control rule

- The development and introduction of harvest control rules (HCRs) that can respond quickly to rapidly changing stock status is needed.
- The important uncertainties to be considered in developing HCRs are listed as
    1. temporal variability in biological parameters as discussed above,
    2. uncertainties and biases in parameter estimates by SAM although they are not considered in this document,
    3. uncertainties in stock-recruitment relationship, and
    4. uncertainties in process errors for not only recruitment but also for age-1 and older fish.
- Because development of HCR by management strategy evaluation (MSE) with considering such important uncertainties takes a long time, we can only evaluate provisional management measures based on the results of short- or mid-term future predictions under simple harvesting scenarios such as constant catch and F.
- While the stock is currently declining, in order to avoid further decline and promote recovery, it is necessary to agree, even on a provisional basis, on target and/or limit reference points such as the historical SSB quartiles presented here, and on management objectives based on those references as soon as possible.

Summary of status

Trends of stock abundance and fishing mortality

Compared to last year's stock assessment results, recent estimates of SSB were revised downward, highlighting a more pronounced declining trend since FY2019.

Current fishing pressure (F2021-2023) corresponds to 15–16% of SPR.

Stock abundance level relative to biomass-based reference point

SSB_{MSY} and SSB0 are found to be still unrealistic beyond the ranges of historically observed SSB and recruitment, highly sensitive to input data and model settings, and time-varying depending on fluctuating biological parameters.

Due to such difficulties, we do not recommend explicitly using SSB_{MSY}, SSB0, and related reference points as target biomass-based reference points at this moment.

On the other hand, we propose using empirical reference points such as percentiles of historical SSB as interim management target.

The first quartile (3–11% of potential SB_{MSY}) can be used as a limit reference point below which the future SSB fall, the median (7–31%) as a provisional short-term target (~5 years), and the third quartile (16–77%) as a possible medium-term target (~10 years).

Summary of status

Current fishing mortality relative to F-based reference points

The current fishing mortality (FY2021-2023 = F15-16%SPR) is 6 times higher than F_{MSY} (corresponding to F67-68%SPR).

Although the estimate of F_{MSY} remains uncertain due to the difficulties described above, it would be certain that the current fishing mortality substantially exceeds the level of F_{MSY}.

Future projection

Future SSB is highly dependent on the assumption of future biological parameters.

Under the constant-catch scenarios, the median SSB gradually increases if the annual catch is kept below 110,000 tons, but to ensure an increase in SSB with more than 95% probability, the catch must be limited to below 40,000 tons.

Under the constant-F scenarios, the median SSB gradually increases if fishing mortality is kept at or below F35%SPR, but to ensure an increase in SSB with more than 95% probability, fishing pressure must be kept at or below F50%SPR.

Recommendation

Considering the current situations comprehensively, it is required to reduce current fishing mortality at a certain level to avoid further decrease and facilitate stock recovery in SSB even under such the lowest spawning potential.

The first quartile of historical SSB (3–11% of potential ranges of SSB_{MSY}) may be used as an empirical-based limit reference point.

The median and third quartile of SSB may be used as mid- and long-term empirical-based target reference points, which corresponds to 7–31% and 16–77% of potential $SSB_{MSY,}$ respectively.

We recommend using this kind of historical SSB quantiles as interim and empirical biological reference points for this stock.

A critically important recommendation is to develop a harvest control rule specific to this stock via an MSE process.

This HCR should be dynamic and able to adjust annual total catches depending on the stock abundance as well as the target and limit reference points.

During the process of the development of MSE, uncertainties in parameter estimates, time-varying nature of biological parameters, stock-recruitment assumptions, and process errors should be considered.