North Pacific Fisheries Commission

NPFC-2023-SSC PS12-Final Report

12th Meeting of the Small Scientific Committee on Pacific Saury REPORT

11–14 December 2023

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North Pacific Fisheries Commission
12th Meeting of the Small Scientific Committee on Pacific Saury

11–14 December 2023
Nanaimo, British Columbia, Canada (Hybrid)

FINAL REPORT

Agenda Item 1. Opening of the Meeting

1. The 12th Meeting of the Small Scientific Committee on Pacific Saury (SSC PS12) was held in a hybrid format, with participants attending in-person in Nanaimo, British Columbia, Canada, or online via WebEx, on 11–14 December. The meeting was attended by Members from Canada, China, Japan, the Republic of Korea, the Russian Federation, Chinese Taipei, the United States of America, and the Republic of Vanuatu. The Pew Charitable Trusts (Pew) attended as an observer. Dr. Larry Jacobson participated as an invited expert.

2. The meeting was opened by Dr. Toshihide Kitakado (Japan), the SSC PS Chair. He expressed his gratitude to Canada for hosting the meeting and everyone who helped to arrange the meeting. The Chair highlighted the importance of Pacific saury as part of the marine ecosystem in the North Pacific and its value as a food resource, and looked forward to productive discussions on this important species.

3. Canada welcomed the participants and thanked them for coming to Nanaimo. Canada also introduced the history and characteristics of Nanaimo.

4. The Science Manager, Dr. Aleksandr Zavolokin, outlined the procedures for the meeting.

5. Mr. Alex Meyer was selected as rapporteur.

Agenda Item 2. Adoption of Agenda

6. The SSC PS agreed to add an item on new information on parameters as agenda item 10.2.1. As a result of the addition, the agenda items that were previously 10.2.1–10.2.3 on the provisional agenda were renumbered as agenda items 10.2.2–10.2.4 on the revised agenda.

7. The revised agenda was adopted (Annex A). The List of Documents and List of Participants

are attached (Annexes B, C).

Agenda Item 3. Overview of the outcomes of previous NPFC meetings

3.1 SSC PS11

8. The Chair presented the outcomes and recommendations from the 11th SSC PS meeting.

3.2 SWG MSE PS04

9. The Chair presented the outcomes and recommendations from the 4th meeting of the joint SC-TCC-COM Small Working Group on Management Strategy Evaluation for Pacific saury (SWG MSE PS04).

3.3 COM07

10. The Science Manager reminded the SSC PS that the 7th Commission meeting adopted Conservation and Management Measure (CMM) 2023-08 for Pacific Saury, adopted a Resolution on Climate Change, and tasked the Secretariat with developing a matrix for the recommendations of the Performance Review Panel that include each recommendation and responses from the responsible subsidiary body.

11. Recommendations from the Performance Review report that concern Pacific saury were reviewed under agenda item 13.2.

Agenda Item 4. Review of the Terms of References of the SSC PS and existing protocols

4.1 Terms of References of the SSC PS

12. The SSC PS reviewed and recommended revising the Terms of References (ToR) of the SSC PS to add "stock assessment data inputs with respect to shifting species and fisheries distribution" as an item for which the impacts of climate change should be explored (Annex D).

4.2 CPUE Standardization Protocol

13. The SSC PS reviewed the catch-per-unit-effort (CPUE) Standardization Protocol and determined that no revisions are currently necessary.

4.3 Stock Assessment Protocol

14. The SSC PS reviewed and recommended revising the Stock Assessment Protocol to include non-stationary population and fisheries processes as a relevant ecosystem consideration regarding the stock in future assessment documents (Annex E).

Agenda Item 5. Member’s fishery status including 2023 fishery

15. Chinese Taipei presented its fisheries status (NPFC-2023-SSC PS12-IP01). The catch returned to around 180,000 tons in 2018 after a 3-years consecutive decline, but a further decline since then has been observed. In 2023, fishing vessels began operations in fishing grounds later than the previous years, and the catch distribution was noted to be further north than in the same period of 2022. The accumulated catch, 45,171 tons, by the end of October of 2023 is higher than that of the same period of 2022, and it is noted that the nominal CPUE is 1.53 tons/haul of 2023 which is higher than 1.01 tons/haul of 2022. Regarding the size box composition (S: less than 6 pcs/kg; 1: 7~9 pcs/kg; 2: 10~12 pcs/kg; 3: 13~15 pcs/kg; 4: 16~18 pcs/kg; 5: more than 19 pcs/kg), the mode size boxes for Pacific saury caught in each month from June to October were 3, 5, 4, 4, and 5, respectively. Overall, the size of Pacific saury caught in 2023 was smaller than in 2022.

16. Chinese Taipei further informed the SSC PS that, during the 2023 fishing season, 29 of 66 vessels fishing for Pacific saury temporarily returned to port for safety inspections from the end of July until the middle of September, before resuming fishing afterwards.

17. China presented its fisheries status (NPFC-2023-SSC PS12-IP02). Total catch in 2022 was 35,477 MT. In 2023, China reached its catch limit stipulated in CMM 2023-08 at the end of September and stopped fishing after 28 September, which was earlier than in previous years. The total catch was 39,252 MT. A total of 57 vessels have been operating, a decrease of 6 from 2022. The trend in relative seasonal catch in 2023 and 2022 were similar, but with higher overall catch in 2023. As of 28 September, the nominal CPUE has been 10.06 MT/vessel/day, the highest since 2020. Standardized effort was 8,367 vessel days in 2022. The fishing grounds in 2023 shifted slightly to the north and to the west, perhaps due to the adoption of a spatial closure east of 170^{o}E longitude, and no fishing occurred from October onwards. A yearly comparison of body length compositions has been conducted up to 2019, using a size-length key provided by Japan. The size compositions in 2019 and 2016 were similar. The catch in 2018, which was the highest historically, was dominated by age-1 fish.

18. The SSC PS encouraged China to accelerate its efforts to calculate body length compositions for 2020 onwards. China said that it would endeavor to present the data ahead of SSC PS13.

19. Vanuatu presented its fisheries status (NPFC-2023-SSC PS12-IP03). Total annual catch peaked at 8,231 MT in 2018, after which it declined to a historical low in 2022. Total catch in 2023 was 1,108 MT. Vanuatu’s Pacific saury fishery began in 2004. In total, it has authorized 16 vessels. The number of operating vessels was 4 from 2015 to 2021 and was 3 in 2022. Only 2

vessels are currently active in 2023. Annual comparison of accumulated catch shows a trend of abundance increasing from September. Annual comparison of the relative seasonal catch shows that there are usually two peaks in the fishing season. Nominal CPUE in 2023 was 9.8 MT/day. The main fishing grounds began in the east early in the season, before shifting to the west. Fishing grounds did not cross 165ºE longitude in 2021–2023. Looking at the monthly size box compositions in 2023 (S: less than 6 pcs/kg; 1: 7~9 pcs/kg; 2: 10~12 pcs/kg; 3: 13~15 pcs/kg; 4: 16~18 pcs/kg; 5: more than 19 pcs/kg). There were no size box S catches and the percentage of size box 1 catches was very low.

20. Korea presented its fisheries status (NPFC-2023-SSC PS12-IP04). In 2023, total catch was 3,107 MT and annual catch has continued to decrease since 2018. The number of vessels operating has gradually decreased each year from 2015 to 2022, and has decreased from 10 in 2022 to 6 in 2023 due to the continued low level of Pacific saury catch. Nominal CPUE was 4.65 MT/vessel/day in 2023, almost double that in 2022. Standardized effort was 928 days in 2023, less than half of that in 2022. In 2023, fishing grounds were east of 150ºE (150–170ºE) longitude. In July, fishing moved northward. In 2023, the overall body length range was 20–32 cm, with a mean value of 27.7 cm. The monthly mean body length was lowest in November and highest in June. There was no significant difference in size compositions between 2022 and 2023, but fish seemed to be smaller in 2023. By size box composition (S: 18–30 cm; M: 23–33 cm; L: 27–34 cm; 2L: 29–34 cm (fork length)), the ratio of S was dominant for most of the fishing season, except May to July. The size composition appears to be smaller in 2023 compared to 2022.

21. Japan presented its fisheries status (NPFC-2023-SSC PS11-IP05). In 2023, the annual catch until the end of November was 24,046 MT, compared to 17,868 MT in 2022. The annual catch as of the end of 10 December was 24,432 MT, compared to 17,910 in 2022. 109 vessels were registered in 2023, a decrease of 3 from the previous year. Total landings until the end of November in 2023 exceeded the annual catches in 2021 and 2022 and was the third highest in the last five years. In 2023, as of the end of November, the peak in 10-day catch was in mid-October. This was earlier than the 2022 peak, which was in early November. 2023 nominal CPUE was 0.62, which was higher than that of 2021 and 2022, and the third lowest since 2000. In 2023, the fishing grounds in August and September were mainly in the high seas, but after October, the main fishing grounds moved into Japan's exclusive economic zone (EEZ). In addition to the Pacific Ocean side of the EEZ, the Sea of Okhotsk has also been a major fishing ground. The percentage of age-0 fish seems to have been high throughout the fishing season.

22. The SSC PS noted a shift in 2023 in the primary fishing grounds of Japanese fleets to coastal

areas earlier than in 2022, with an increase in fishing activities within the Japanese EEZ compared to 2019–2022. These timing differences in fishing ground transitions and the swift responses from fishing fleets suggest nonstationary fleet dynamics, potentially influencing key model parameters like catchability and selectivity in the stock assessment, and should be considered in future work, particularly as the SSC PS transitions to an age-structured model.

23. Russia presented its fisheries status (NPFC-2023-SSC PS12-IP07). The annual catch has continued to decrease since 2007. Total catch in 2021 was 609 MT (the lowest after 1991) and Russian vessels did not fish for Pacific saury in 2022. Since 2014, there has been an annual decrease in the number of Pacific saury fishing vessels. In 2020, the number of fishing vessels was at its lowest since 1991. 3 vessels operated in 2021 and 0 in 2022. 2021 seasonal catch and accumulated catch were at their lowest since 1991. Nominal CPUE in 2021 was 4.2, the lowest since 2000. Fishing grounds have shifted eastward between 2020 and 2021. In 2023, one Russian vessel fished for Pacific saury in the Convention Area beginning from late October. Total catch of Pacific saury was approximately 50 MT.

24. The Science Manager presented the cumulative catch of Pacific saury for 2020, 2021, 2022 and 2023. The cumulative catch in 2023 as of 2 December is approximately 102,006 MT, which is approximately 68% of the total allowable catch (TAC) in the Convention Area as stipulated in CMM 2023-08, compared to 94,623 MT in 2022, 89,492 MT in 2021, and 122,595 MT in 2020.

25. China noted that its fishing activities ceased at the end of September in accordance with relevant paragraphs in CMM 2023-08. China also noted a significant reduction in Chinese Taipei's fishing efforts, attributed to special circumstances such as vessels' safety inspections, resulting in a significantly lower catch. Without those two constraints mentioned above, the total catch of Pacific saury in 2023 could have been much higher.

26. The SSC PS noted that recent data indicate at least some improvement in stock condition. The SSC PS noted that the catch for almost all Members who fished for Pacific saury in 2023 increased compared to 2022. The SSC PS also noted that nominal CPUE for these Members increased from 2022 to 2023, apart from in the case of Russia, whose nominal CPUE data were not yet available. The SSC PS also noted that the average size of fish caught in 2023 for most Members was smaller than in 2022. In the case of the Japanese fishery, this was due to the increased proportion of age-0 fish in the catch.

27. The SSC PS noted that the distribution of fishing grounds in 2023 had shifted northward and, for most Members, westward compared to 2022.

28. The SSC PS noted that having Pacific saury bycatch data from other fisheries would ensure more reliable catch information and thus improve the Pacific saury stock assessment. The SSC PS encouraged Members to provide this information to the next SSC PS meeting.

29. The SSC PS noted that regular reporting of species-specific bycatch information from Members' fisheries, such as Pacific saury bycatch from chub mackerel fisheries, would be useful going forward. Conversely, if bycatch data were available from the Pacific saury fisheries, this may be useful for other stock assessments (e.g. chub mackerel) undertaken by the NPFC.

Agenda Item 6. Fishery-independent abundance indices

30. Japan informed the SSC PS that it plans to conduct its biomass survey with the usual method in 2024. Japan further explained that it plans to cover at least the usual survey area and to possibly extend the survey coverage northward to ensure greater coverage of the distribution of Pacific saury if a northward expansion is logistically possible.

31. The SSC PS welcomed Japan's plans to possibly expand the survey area and the additional information this would provide. At the same time, the SSC PS noted that care should be taken when incorporating additional data into the existing survey design.

32. Russia reminded the SSC PS that it has conducted research surveys in the North Pacific focusing on Pacific salmon since the 1980s. Russia explained that Pacific saury is also caught in these surveys and that the surveys overlap with some of the northern parts of the Japanese biomass survey. Russia suggested that the data from its surveys could potentially be integrated with the Japanese biomass survey data in the vector autoregressive spatio-temporal (VAST) model.

33. The SSC PS welcomed the suggestion from Russia and encouraged Russia and Japan to share information with each other and explore the potential for collaboration in the intersessional period.

Agenda Item 7. Fishery-dependent abundance indices

34. The SSC PS agreed to continue to prepare standardized CPUE indices as inputs for the Pacific saury stock assessment.

35. The SSC PS agreed on the importance of resolving the discrepancy between the stock assessment model results and Chinese Taipei's standardized CPUE index ahead of the next

Pacific saury stock assessment.

36. Chinese Taipei informed the SSC PS that it plans to analyze possible causes of this issue and present potential ways to resolve it at the next SSC PS meeting.

37. The SSC PS noted the value of reporting effective effort data (catch divided by standardized CPUE) by individual Members and encouraged Members to continue to do so.

38. The SSC PS noted the value of the joint CPUE standardization, thanked Chinese Taipei for contributing this work, and encouraged Chinese Taipei to continue.

Agenda Item 8. Biological information on Pacific saury

39. Dr. Jihwan Kim, a postdoctoral researcher under the NPFC Internship Program, presented a study on the interannual to decadal relationship between total catch variability of Pacific saury and basin-scale ocean environmental variability in the North Pacific (NPFC-2023-SSC PS12-IP06). The fluctuating total annual catch and significant decline of Pacific saury over the past decade underscore the importance of understanding the factors affecting its abundance, including its relationship to long-term ocean environmental variability. The study examined the relationship between annual Pacific saury catch and the North Pacific basin-scale ocean environment. The results show a significant correlation between increased catches and the intensification of the Kuroshio Extension Jet. A 2-year lead-lag relationship between the North Pacific Gyre Oscillation (NPGO) and saury catches suggests its potential as a predictor of annual catches of Pacific saury. These results constitute a major contribution and may lead to improved stock assessment models for Pacific saury stocks.

40. The SSC PS noted that the catch of Pacific saury exhibits some synchronicity with climatically-induced environmental variability. This is evidenced by the correlation between the decrease in the total catch of Pacific saury in recent years and the NPGO. Caution is required because correlation does not prove causality and catch is not abundance. However, it seems likely, based on this analysis, that environmental information could be used to improve stock assessments and management advice. This is a key area of future research and should be considered at the next stock assessment.

41. The SSC PS welcomed the study and suggested conducting further analyses, such as by including Members' CPUE data and biomass estimates from the stock assessment results in the study. Members agreed that monthly 1 x 1 degree CPUE data and time series of biomass estimates will be shared with the intern for analyses on the relationship between Pacific saury

abundance indices and basin-scale ocean environmental variability in the North Pacific.

Agenda Item 9. Stock assessment using "provisional base models" (BSSPM)

9.1 Retrospective patterns and scaling issue

9.2 Model validation (model runs and retrospective analyses by Members using the same data and priors)

9.3 Process error assumptions

42. China presented the results of a study to cross-check Members' code by testing the sensitivity of BSSPM results to different prior assumptions of key model parameters (NPFC-2023-SSC PS12-WP05 (Rev. 1)). The study tested two types of prior assumptions, as extracted from the BSSPM assessment reports of China (NPFC-2023-SSC PS11-WP15), which, like Japan, employed a flat prior distribution for free parameters, and Chinese Taipei (NPFC-2023-SSC PS11-WP16), which employed less informative priors for key parameters such as carrying capacity (K) and intrinsic growth rate (r). China compared reference points and parameter estimates from two prior scenarios and successfully reproduced the results of Chinese Taipei's BSSPM. China found that, generally, Base case 1 is more robust to prior assumptions than Base case 2. Notably, key reference points (e.g., F_{MSY}, K, and B_{MSY}) in both Base case scenarios differed significantly between the two types of priors. Lognormal priors resulted in shorter tails in the posterior distributions of r and K in Base case 1 and Base case 2, respectively. In Base case 1, lognormal priors shifted the posterior distributions of q to the left. Time series plots confirmed scale differences among Members' assessment results due to different prior assumptions. Base case 2 showed sensitivity of absolute estimated biomass and harvest rate to prior assumptions, while relative quantities (B/B_{MSY} and F/F_{MSY}) remained robust. The use of lognormal (less informative) priors alleviated scale difference between the two base case scenarios. In conclusion, the BSSPM code from China and Chinese Taipei have been cross-validated, and their assessments are reproducible. Scale differences among Members' analyses stem from differing prior assumptions.

43. Chinese Taipei presented updates (NPFC-2023-SSC PS12-WP06) to the stock assessment for Pacific saury in the North Pacific Ocean using BSSPM that it submitted to SSC PS11 (NPFC-2023-SSC PS11-WP16). Chinese Taipei has conducted the diagnostics of retrospective analyses and posterior predictive model checks for the two base cases. No retrospective pattern was identified. However, a discrepancy between real and simulated data under the fitted models has been found.

44. The SSC PS agreed to study the methodologies and use the results to investigate further refining the index weighting configuration.

45. Japan presented updates (NPFC-2023-SSC PS12-WP09) to its stock assessment result submitted to SSC PS11 (NPFC-2023-SSC PS11-WP14). As for the combined base case stock assessment result, the 2023 median depletion level was only 21.0% (80%CI=10.7-34.8%) of the carrying capacity. Furthermore, B-ratio (=B/B_{MSY}) and F-ratio (=F/F_{MSY}) in 2022 were 0.337 (80%CI=0.229-0.474) and 0.799 (80%CI=0.517-1.384), respectively. The probability of the stock being in the green Kobe quadrant in 2022 was estimated to be nearly 0%, while the probabilities of being in the yellow and red Kobe quadrants were assessed as 72% and 28%, respectively. It should be noted that there is a large difference in the biomass series between the two base cases, while there is little difference in relative quantities such as the B- and F-ratios and depletion level. Based on the updated results, if the same formula used in TAC calculation in the 2019 Commission meeting is applied, it would be $F_{MSY}*B_{2023}$=183,000 (tons). However, considering the current overfished population level and applying a simple discount exploitation rate depending on the current B-ratio, an appropriate catch would be $(B_{2023}/B_{MSY})*F_{MSY}*B_{2023}$=80,000 (tons).

46. The SSC PS reviewed the stock assessments conducted by Members and aggregated the results, recognizing the agreement in trends among them (Annex F).

47. The SSC PS agreed that this year's stock assessment is of a comparable quality to its previous Pacific saury stock assessments and that it represents the best available understanding of the Pacific saury biomass and population dynamics. The SSC PS recognized that there remain sources of uncertainty that should be further investigated, including the prior assumptions, scaling issues, and retrospective patterns. The SSC PS also noted the need to investigate further refinements to the stock assessment model or the input data to improve predictive performance.

48. The invited expert suggested considering additional hyperdepletion parameters for Members' CPUE indices.

Agenda Item 10. New stock assessment models

10.1 Data available

49. Japan offered to provide Members with its age-length key (ALK) by around March or April 2024. The SSC PS requested Members to use the ALK to prepare catch-at-age and catch-at-size data and to share these on the collaboration site.

10.2 Review of progress on new stock assessment models

10.2.1 New information on parameters

50. Japan presented a summary of the possible ranges of the key parameters in the age-structured stock assessment models for Pacific saury and the possible ranges to be considered, based on the best biological knowledge available and discussion so far (NPFC-2023-SSC PS12-WP02 (Rev. 2)). Japan focused on 1. natural mortalities for age 0 and age 1 fish (*M0* and *M1*, respectively), 2. the treatment of age 0 fish spawning, and 3. the steepness of the Beverton-Holt stock recruitment relationship (*h*). Japan recommended considering (1.71, 2.75) and (0.5, 1) as the possible range of *M0* and *M1*/*M0*, respectively. It also recommended considering (0.05, 0.2) as a possible range for a degree of relative contribution of age 0 to age 1 egg production, interpreted as the product of maturation rate, relative fecundity per weight, and relative times of spawning in a spawning season. Japan also created a prior distribution of steepness parameter based on the best knowledge available on Pacific saury biology to present a possible range of the steepness to be considered. The 0.025, 0.5, 0.975 percentiles of the distribution of *h* were 0.26, 0.96, and 0.99, respectively, indicating that the steepness of Pacific saury might be smaller than is estimated from phylogeny. Japan recommended checking model sensitivities inside these ranges when the parameters are fixed, or, if they are estimated, to check whether the estimated values are inside the ranges or not.

10.2.2 Stock Synthesis 3

51. Chinese Taipei presented the methodology for a preliminary age-structured assessment with the Stock Synthesis 3 (SS3) framework, including information on input data, model structure, and parametrization (NPFC-2023-SSC PS12-IP08). Chinese Taipei noted, however, that there is still uncertainty in life history parameters and input length composition data, such as maturation, growth, and natural mortality. Chinese Taipei recommended continuing model development work, reducing data conflicts and modeling uncertainties, and examining and improving input assessment data.

52. Chinese Taipei shared the latest version of developed SS3 files with the SSC PS group. The data and control files are designated for use within the Working Group on New Stock Assessment Models (WG NSAM). The SSC PS thanked Chinese Taipei for sharing these valuable resources.

53. Japan offered to provide the SSC PS with size composition data from its biomass survey. The SSC PS requested that Japan initially prepare and provide yearly data aggregated over space.

54. 4The SSC PS agreed to task the WG NSAM to use these conditional age-at-length data to estimate the growth function internally in the SS3 model.

55. The SSC PS agreed to switch from using non-age-specific natural mortality to age-specific natural mortality in the SS3 model.

56. The SSC PS agreed to conduct further updates on the biological parameters and a comprehensive review of input data required for the age-structure model through a thorough data preparation process.

10.2.3 State-space age-structured model

57. Japan presented a progress report on its development of a state-space age-structured stock assessment model for Pacific saury up to 2023 (NPFC-2023-SSC PS12-WP07 (Rev. 1)). The key assumptions for the next-generation stock assessment of Pacific saury are 1. the steepness (*h*) of the Beverton-Holt stock recruitment relationship, 2. the natural mortalities for age 0 and age 1 fish, and 3. the treatment of age 0 fish spawning. Japan narrowed down the candidate hypotheses on these assumptions based on biological perspectives, and then observed the sensitivity of the model behaviors against these assumptions. The model with estimated *h* and gamma (contribution of age-0 fish to the spawning activity relative to age-1 fish) and age-dependent *M* showed the maximum likelihood. Estimated *h* (0.47) was small but was inside the 95% confidence interval of the prior distribution. Estimated gamma (0.13) was plausible. Estimated gamma was very small when *h* was fixed at 0.86. *F* was unnaturally small, under *h*=0.86 and gamma = 0.2 or 0.1. One of small *h*, small gamma, and small *F* must be chosen. The model had predictability to some extent. The assumptions of *h* and gamma might have large effects.

58. Japan offered to share its code with the SSC PS.

10.2.4 Other models (if any)

59. The SSC PS invited other Members to also present any new stock assessment models at future meetings.

10.3 Preparation of the specification for new stock assessment models

60. The SSC PS compiled a table with updated initial specifications of the SS3 model and the state-space age-structured model presented by Chinese Taipei and Japan (Annex G). The SSC PS agreed to continue to discuss and refine these specifications.

10.4 Recommendations for future work

61. The SSC PS agreed to task the WG NSAM to continue to develop the SS3 model and the state-

space age-structured model and to hold regular virtual meetings and, if necessary, in-person meetings. The SSC PS agreed to appoint Dr. Libin Dai (China) to lead the WG NSAM.

62. The SSC PS agreed to continue to develop a new age-structured model, review results at the 2024 or 2025 stock assessment meeting, and use it to provide management advice subsequently.

63. The SSC PS agreed that the new age-structured model is expected to be very useful for Pacific saury but that it may not necessarily replace the current relatively simple BSSPM model, nor should use of the current BSSPM model necessarily stop entirely. The SSC PS agreed to address the question of how to use the two models alone or in combination at a later stage. The SSC PS agreed that an age-structured model will provide a wealth of detailed information about the stock, serve as a basis for MSE, and improve projection capability. However, biomass, fishing mortality estimates, and quota calculations used to provide management advice might be variable and sensitive to modest changes in model configuration and data. In contrast, MSY and relative estimates such B/B_{MSY} and F/F_{MSY} from the BSSPM model used to provide management advice are stable and robust. It is possible that the best approach will be to use both the new age-structured model and the current BSSPM model, if only to check results.

Agenda Item 11. Progress on development and evaluation of an interim harvest control rule (HCR) as a short-term task

11.1 Review of conditioning of operating models (OMs)

64. The invited expert presented considerations for managing uncertainty about Pacific saury population dynamics in HCR analyses, including possible ways to manage the volume of calculations and possible key parameters for simulation analyses (NPFC-2023-SSC PS12-WP08). The invited expert recommended focusing simulations on MCMC results with relatively high posterior probability by eliminating cases with low probability or, as a more extreme but possibly acceptable alternative, to use the single MCMC run with the highest posterior probability.

65. The Chair presented a comparison of possible screening approaches using combined constraints with the highest density intervals over key parameters (r, K, z, and D_{2023}) for ensuring the representativeness of samples from MCMC outcomes. The SSC PS agreed to use that approach in the final simulation.

66. Canada presented joint work by Canada and China simulating climate indices for process error in Pacific Saury assessment (NPFC-2023-SSC PS12-WP03). Canada and China sought to build out a function that could simulate future conditions for environmental indices by calculating

the autocorrelation function and variance (here standard deviation) of some common environmental covariates that could then be used as an alternative to sampling from the historical distribution of process errors from the stock assessment. Canada and China suggested that process errors could be chosen from a distribution that “looked like” environmental variables thought to be controlling stock productivity. Canada and China explored six large scale environmental covariates that have been linked to fish productivity in the North Pacific Ocean through a number of studies: Pacific Decadal Oscillation, Kuroshio Current Extension, the NPGO Index, the North Pacific Index (NPI), the Aleutian Low Pressure Index and the Arctic Oscillation Index.

67. The SSC PS agreed to adopt an additional base case scenario for simulating the process error with autocorrelation and assumed values of sigma = 0.182 (median over 6 runs) and *rho* = 0.2 (*rho* estimated from NPI).

68. The SSC PS reviewed and further refined the draft specification of simulation for testing HCRs (Annex H). The SSC PS agreed to conduct the simulation work to test the HCRs based on the updated specification and understands that the analyst may need to make some relatively minor modifications to the specifications as the work proceeds.

11.2 Review of candidate harvest control rules (HCRs)

69. The SSC PS reviewed and agreed to retain the current set of candidate HCRs.

11.3 Recommendations to the SWG MSE PS05

70. The SSC PS noted that the simulation work to test the candidate HCRs endorsed by SWG MSE PS04 is ongoing and that it therefore has no recommendations for the SWG MSE PS05 at this time.

Agenda Item 12. Development of recommendations to improve conservation and management of Pacific saury stock

71. The SSC PS recommended that the SC consider and endorse the following rationale and approach in its scientific advice to the Commission:
    (a) The current biomass is much lower than B_{MSY} and the TAC for 2023-2024 may not reduce fishing mortality (F) in those years. An HCR that reduces F when biomass is low may increase the probability of achieving long-term sustainable use of Pacific saury (i.e. higher long-term catch closer to MSY of around 396,570 tons). A reduction to the TAC for 2023-2024 would increase the probability of higher long-term biomass and catch levels in the Pacific saury stock.

(b) The SSC PS recommended that the SC recommend that the Commission, at its 8th meeting, in accordance with its schedule, adopt an interim HCR from the list to be provided by the SWG MSE PS. In case the Commission cannot adopt an interim HCR, the following management recommendation is provided.

(c) An HCR that reduces the target harvest rate and TAC when biomass falls below its target level may be appropriate for Pacific saury. This type of HCR is used in managing many fisheries around the world. For example, if an HCR that reduces F linearly when biomass is below B_{MSY} is applied, the TAC calculated based on such an HCR (B_{2023}*F_{MSY}*(B_{2023}/B_{MSY}) = 73,490 tons could be smaller than the current catch. Note, the above HCR is currently being evaluated for management.

(d) The SSC PS noted that a possible TAC catch limit in 2024 calculated by B_{2023}*F_{MSY}*(B_{2023}/B_{MSY}) based on the 2023 assessment would be lower relative to that based on the 2022 assessment, even though biomass in 2023 itself is higher than that in 2022. The SSC PS discussed why this was the case and agreed that the main reason is an overall reduction of scales in biomass estimates in the 2023 assessment relative to that in 2022 because of slight changes in model configurations, use of new abundance indices, and time lag between fishery-independent and dependent abundance indices, particularly that the most recent CPUE data (2023) are not included in the model used to set the current limit in 2024.

(e) There is a two-year lag between the collection of fishery data and stock assessment work. There is a one-year lag between the survey and stock assessment work. The condition of the stock may change substantially between collection of data and management so that management measures are less effective or less appropriate. Approaches to reducing the delay should be considered. Such approaches were considered in HCR analysis but were dropped due to time constraints.

Agenda Item 13. Review of the Work Plan of the SSC PS

13.1 Work Plan of the SSC PS

72. The SSC PS reviewed, revised and endorsed the 2023-2027 SSC PS 5-Year Rolling Work Plan (NPFC-2023-SSC PS12-WP01 (Rev. 1)).

13.2 NPFC Performance Review recommendations

73. The Chair presented the proposed responses, drafted with the SC Chair and the Secretariat, to the recommendations from the Performance Review report that concern Pacific saury.

74. The SSC PS reviewed the Performance Review panel’s recommendations and the draft responses presented by the Chair, and developed a table with its comments on each

recommendation (NPFC-2023-SSC PS12-WP10).

Agenda Item 14. Other matters

14.1 Observer Program

75. The Science Manager reminded the SSC PS of previous discussions regarding the establishment of a regional NPFC observer program and the data gaps and needs that could be filled by such a program as identified by the SSC PS. He further informed the SSC PS that the TCC is discussing the development of a regional observer program for compliance and that the Compliance Manager, Ms. Judy Dwyer, will provide an update at SC08 and seek input from the SC regarding potential ways to combine this program with a program for collecting scientific observer data.

76. The SSC PS reaffirmed the importance of having the opportunity to provide direct input on its data needs during the regional observer program development process.

14.2 Draft agenda, priority issues and timeline for next meeting

77. The SSC PS agreed to hold a 5-day meeting in the virtual format on 26-30 August 2024 and a 3-and-a-half-day in-person meeting on 12-16 December 2024. In addition, the SSC PS will hold regular virtual intersessional meetings. The WG NSAM will hold regular virtual intersessional meetings and may meet in person in June (TBD) for a 3-day workshop.

78. The SSC PS agreed on the following priorities for the next meeting:
    (a) Review standardized CPUE up to 2023.
    (b) Review the Japanese fishery-independent survey results up to 2024.
    (c) Update BSSPM analyses.
    (d) Review progress on new assessment models, review required data, finalize a set of models and specification, and evaluate key uncertainties.
    (e) Investigate environmental impact on productivity.
    (f) Review progress on development and evaluation of management procedure as a medium-term task.
    (g) Review Pacific saury bycatch data from Members.

14.3 Invited expert

79. The SSC PS expressed its appreciation for the continued valuable contributions of the invited expert, Dr. Larry Jacobson. The SSC PS recommended that Dr. Jacobson be invited to the next SSC PS and WG NSAM meetings.

14.4 Selection of Chair and vice-Chair for SSC PS

80. The SSC PS re-elected Dr. Toshihide Kitakado to serve as its Chair.

81. The SSC PS elected Dr. Libin Dai to serve as its vice-Chair.

14.5 Other

82. No other issues were discussed.

Agenda Item 15. Consolidated recommendations to the Scientific Committee

83. The SSC PS recommended that the SC:
    (a) Endorse the revised ToR of the SSC PS (Annex D).
    (b) Endorse the revised Stock Assessment Protocol (Annex E).
    (c) Endorse the stock assessment report (Annex F).
    (d) Endorse the SSC PS Work Plan (NPFC-2023-SSC PS12-WP01 (Rev. 1)).
    (e) Allocate funds for the participation of an invited expert in the next SSC PS and WG NSAM meetings.
    (f) Consider the SSC PS's comments on the NPFC Performance Review recommendations that concern Pacific saury (NPFC-2023-SSC PS12-WP10).

Agenda Item 16. Adoption of the Report

84. The SSC PS12 Report was adopted by consensus.

Agenda Item 17. Close of the Meeting

85. The SSC PS thanked the Chair for his effective leadership and guidance.

86. The Chair thanked the participants for their dedicated and constructive discussions, Canada for hosting the meeting and its hospitality, the Secretariat for helping the host to organize the meeting, the invited expert for his technical guidance, and the rapporteur for his support.

87. The meeting closed at 16:45 on 14 December 2023, Nanaimo time.

Annexes:

Annex A – Agenda
Annex B – List of Documents
Annex C – List of Participants
Annex D – Revised Terms of Reference of the SSC PS
Annex E – Revised Stock Assessment Protocol for Pacific Saury

Annex F – Stock Assessment Report for Pacific Saury

Annex G – Specifications of the Stock Synthesis 3 model and the state-space age-structured model

Annex H – Specification of simulation for testing HCRs

Annex A

Agenda

Agenda Item 1. Opening of the Meeting

Agenda Item 2. Adoption of Agenda

Agenda Item 3. Overview of the outcomes of previous NPFC meetings
- 3.1 SSC PS11
- 3.2 SWG MSE PS04
- 3.3 COM07

Agenda Item 4. Review of the Terms of References of the SSC PS and existing protocols
- 4.1 Terms of References of the SSC PS
- 4.2 CPUE Standardization Protocol
- 4.3 Stock Assessment Protocol

Agenda Item 5. Member's fishery status including 2023 fishery

Agenda Item 6. Fishery-independent abundance indices

Agenda Item 7. Fishery-dependent abundance indices

Agenda Item 8. Biological information on Pacific saury

Agenda Item 9. Stock assessment using "provisional base models" (BSSPM)
- 9.1 Retrospective patterns and scaling issue
- 9.2 Model validation (model runs and retrospective analyses by Members using the same data and priors)
- 9.3 Process error assumptions

Agenda Item 10. New stock assessment models
- 10.1 Data available
- 10.2 Review of progress on new stock assessment models
  - 10.2.1 New information on parameters for stock assessment models
  - 10.2.2 Stock Synthesis 3
  - 10.2.3 State-space age-structured model
  - 10.2.4 Other models (if any)
- 10.3 Finalization of specification for new stock assessment models
- 10.4 Recommendations for future work

Agenda Item 11. Progress on development and evaluation of an interim harvest control rule (HCR) as a short-term task
- 11.1 Review of conditioning of operating models (OMs)
- 11.2 Review of candidate harvest control rules (HCRs)
- 11.3 Recommendations to the SWG MSE PS05

Agenda Item 12. Development of recommendations to improve conservation and management of

Pacific saury stock

Agenda Item 13. Review of the Work Plan of the SSC PS

13.1 Work Plan of the SSC PS
13.2 NPFC Performance Review recommendations

Agenda Item 14. Other matters

14.1 Observer Program
14.2 Draft agenda, priority issues and timeline for next meeting
14.3 Invited expert
14.4 Selection of Chair and vice-Chair for SSC PS
14.5 Other

Agenda Item 15. Consolidated recommendations to the Scientific Committee

Agenda Item 16. Adoption of Report

Agenda Item 17. Close of the Meeting

Annex B

List of Documents

MEETING INFORMATION PAPERS

Document Number	Title
NPFC-2023-SC08-MIP01 (Rev. 2)	Meeting Information
NPFC-2023-SSC PS12-MIP02 (Rev. 1)	Provisional Agenda
NPFC-2023-SSC PS12-MIP03 (Rev. 1)	Annotated Indicative Schedule

WORKING PAPERS

Document Number	Title
NPFC-2023-SSC PS12-WP01 (Rev. 1)	Five-Year Work Plan of the SSC PS
NPFC-2023-SSC PS12-WP02 (Rev. 2)	Summary of the possible ranges of the key parameters in the age-structured stock assessment models for Pacific saury
NPFC-2023-SSC PS12-WP03	Simulation of climate indices for process error in Pacific Saury assessment
NPFC-2023-SSC PS12-WP04	SSC PSint 2023-04 Meeting Summary
NPFC-2023-SSC PS12-WP05 (Rev. 1)	Testing the sensitivity of BSSPM results to different prior assumptions of key model parameters
NPFC-2023-SSC PS12-WP06	Updates of stock assessment of Pacific saury (*Cololabis saira*) in the Western North Pacific Ocean through 2022
NPFC-2023-SSC PS12-WP07 (Rev. 1)	Progress report of the development of the state-space age-structured stock assessment model for Pacific saury up to 2023
NPFC-2023-SSC PS12-WP08 (Rev. 1)	Managing uncertainty about Pacific saury population dynamics in HCR analyses
NPFC-2023-SSC PS12-WP09	2023 updates on Pacific saury stock assessment in the North Pacific Ocean using Bayesian state-space production models (rev)
NPFC-2023-SSC PS12-WP10	NPFC Performance Review recommendations

INFORMATION PAPERS

Document Number	Title
NPFC-2023-SSC PS12-IP01	Fishery status for Pacific saury up to Oct 2023
NPFC-2023-SSC PS12-IP02	Fishery Status of PS in China

NPFC-2023-SSC PS12-IP03	Fishery Status for Pacific saury in Vanuatu
NPFC-2023-SSC PS12-IP04	Korean Stick-held dip net (SHDN) Fishery Status up to 2023
NPFC-2023-SSC PS12-IP05	Pacific saury fishing condition in Japan in 2023
NPFC-2023-SSC PS12-IP06	The interannual to decadal relationship between total catch variability of Pacific saury (*Cololabis saira*) and basin-scale ocean environmental variability in the North Pacific
NPFC-2023-SSC PS12-IP07	Fishery for Pacific saury by Russian vessels in 2023
NPFC-2023-SSC PS12-IP08	Updated saury's SS3 model for SSC PS 12

REFERENCE DOCUMENTS

Document Number	Stock assessment protocol for Pacific Saury
NPFC-2023-SSC PS11-Final Report	11th Meeting of the Small Scientific Committee on Pacific Saury
NPFC-2023-SWG MSE PS04-Final Report	4th Meeting of the Joint SC-TCC-COM Small Working Group on Management Strategy Evaluation for Pacific Saury (SWG MSE PS)

Annex C

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Annex D

Revised Terms of Reference of the SSC PS

Terms of Reference for the Small Scientific Committee on Pacific Saury (SSC PS)

(revised in December 2023)

1. To review fishery data
    - Catch series
    - Age/size composition data
    - Others
2. To review fishery-dependent and fishery-independent indices
    - Review/update the existing CPUE Standardization Protocol
    - Review/update the indices
    - Evaluate the quality of the indices
    - Recommendation for future work
3. To review and update biological information/data
    - Stock structure
    - Growth
    - Reproduction and maturity schedule
    - Natural mortality
    - Migration pattern
    - Others
4. To explore the impact of climate change on Pacific saury stock assessment and fishery performance, including stock assessment data inputs with respect to shifting species and fisheries distribution, life history characteristics, phenology, biological reference points and relevant parameters
5. To update the stock assessment using "provisional base models" (i.e. Bayesian state-space production models)
    - Review the existing Stock Assessment Protocol
    - Simple update (including projection and evaluation of reference points as well as diagnosis)
    - Consideration of scenarios (for base and sensitivity)
    - Assessment of uncertainties and the implications for management
    - Evaluation/improvement (if necessary) of the models
    - Recommendation of the research for future work
6. To explore stock assessment models other than existing "provisional base models"
    - Data invention/availability (including the identification of potential covariates)
    - Initial (and continued) discussion on age-/size/stage-structure models
    - Identification of lack of information/data gaps and limitations
    - Recommendation of the research for future work

7. To facilitate data- and code- sharing processes
8. To review/improve the presentation of stock assessment results (including stock status summary reports in a format to be determined by the Working Group)
9. To support the technical work related to the Management Strategy Evaluation.

Annex E

Revised Stock Assessment Protocol for Pacific Saury

Stock assessment protocol for Pacific Saury

(revised in December 2023)

(1) Identify the data that will be available to the stock assessment;

(2) Evaluate data quality and quantity and potential error sources (e.g., sampling errors, measurement errors, and associated statistical property (e.g., biased or random errors, statistical distribution) to ensure that the best available information is used in the assessment;

(3) Select population models describing the dynamics of PS stock and observational models linking population variables with the observed variables;

(4) Develop base case scenarios and alternative scenarios for sensitivity analyses;

(5) Compile input data and prior distributions for the model parameterization for the base case and alternative scenarios;

(6) For each scenario, fit the model to the data, diagnostics of model convergence, plot and evaluate residual patterns, compare prior and posterior distributions for key model parameters, and evaluate biological implications of the estimated parameters;

(7) Develop retrospective analysis to verify whether any possible systematic inconsistencies exist among model estimates of biomass and fishing mortality;

(8) Identify final model configuration and model runs for each scenario;

(9) For each scenario, estimate and plot exploitable stock biomass and fishing mortality (and their relevant credibility distributions) over time;

(10) For each scenario, estimate biological reference points (e.g., MSY, Bmsy, Fmsy) and its associated uncertainty;

(11) Identify target and limit reference points for stock biomass and fishing mortality;

(12) Have the Kobe plot for each scenario;

(13) Determine if the stock is “overfished” and “overfishing” occurs for the base and sensitivity scenarios;

(14) Finalize the base-case scenario;

(15) Develop alternative ABCs for the projection (e.g., 5-year projection);

(16) Conduct risk analysis for each level of ABC defined in Step (15) for the base-case scenario;

(17) Develop decision tables with alternative state of nature;

(18) Determine optimal ABCs based on decision tables developed in Step (17);

(19) Provide scientific advice on stock status and appropriate catch level to SC through SSC PS;

(20) Include relevant ecosystem considerations regarding the stock in future assessment documents, including data and results from other scientific studies regarding potential impacts on the stock [assessment] due to climate change, non-stationary population and fisheries processes, predator-prey dynamics, or impacts of distribution and phenological changes on assessment data.

Stock Assessment Report for Pacific Saury

EXECUTIVE SUMMARY

Data used in the assessment modeling

Data are included from the NPFC Convention Area and Members' Exclusive Economic Zones (EEZs). Pacific saury (*Cololabis saira*) is widely distributed from the subarctic to the subtropical regions of the North Pacific Ocean. The fishing grounds are west of 180° E but differ among Members (China, Japan, Korea, Russia, Chinese Taipei, and Vanuatu). Figure 1 shows the historical catches of Pacific saury by Member. Figure 2 shows CPUE and Japanese survey biomass indices used in the stock assessment. Appendix 1 shows data used for the updated stock assessment.

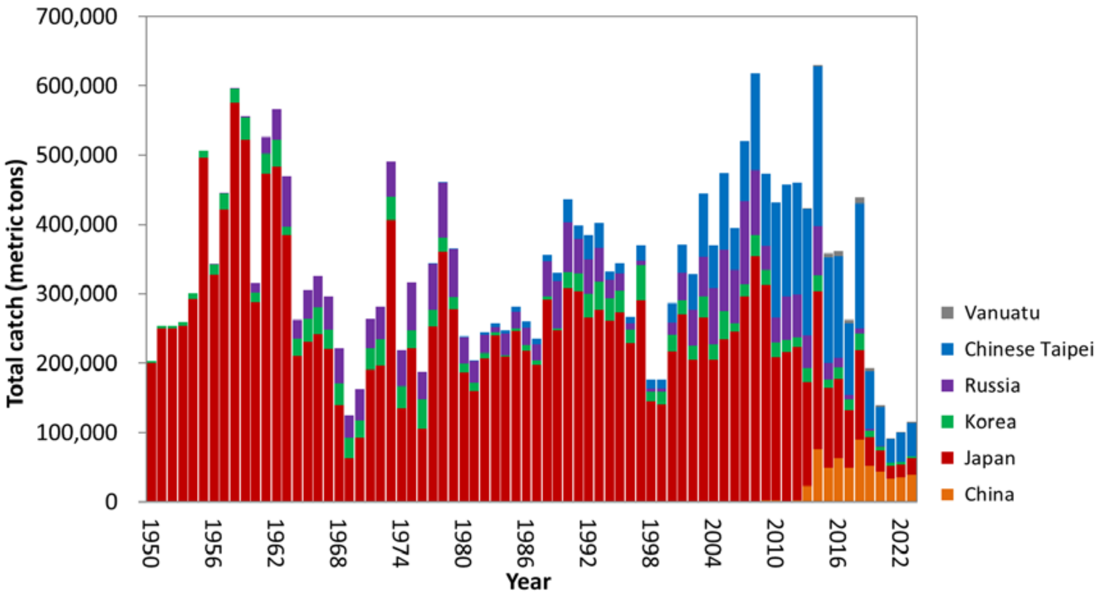


Figure 1. Time series of catch by Member during 1950-2023. The catch data for 1950-1979 are shown but not used in stock assessment modeling. Catch data in 2023 are preliminary (as of 2 December 2023) and not used in the assessment.

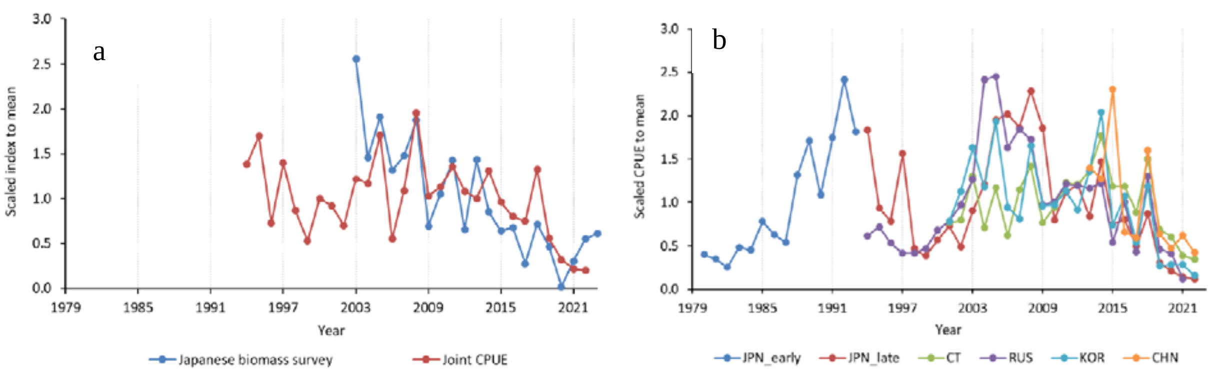


Figure 2. Time series of (a) Japanese survey biomass index and joint CPUE and (b) Member's standardized CPUE indices used in the assessment modeling.

Brief description of specification of analysis and models

A Bayesian state-space production model (BSSPM) used in previous stock assessments was employed as an agreed provisional stock assessment model for Pacific saury during 1980-2023. Scientists from three Members (China, Japan and Chinese Taipei) each conducted analyses following the agreed specification which called for two base case scenarios and two sensitivity scenarios (see Annex F, SSC PS09 report for more details). The two base case scenarios differ in using each Member's standardized CPUEs (base case B1) or standardized joint CPUEs (base case B2). For the two sensitivity cases with Japanese early CPUE (1980-1994), time-varying catchability was assumed to account for potential increases in catchability. A higher weight was given to the Japanese biomass survey estimates than to Members' CPUEs in B1 while comparable weights were given to the Japanese biomass survey estimates and the joint CPUEs in B2. The CPUE data were modeled as nonlinear indices of biomass. Members used similar approaches with some differences in the assumption of the time-varying catchability and prior distributions for the free parameters in the model.

Summary of stock assessment results

The SSC PS considered the BSSPM results and noted the agreement in trends among Members' results for each base case model. However, there was a marked difference in the biomass level between B1 and B2 due to the different CPUE trends used. The SSC PS discussed and recognized that the results covered a wide range of uncertainties in data, model and estimation, and it therefore concluded the outcomes of MCMC runs could be aggregated over the 6 models (2 base case models x 3 Members) as in the previous assessments. The aggregated results for assessing the overall median values and their associated 80% credible intervals are shown in Table 1. The graphical presentations for times series of a) biomass (B), b) B-ratio (=B/B_{MSY}), c) harvest rate (F), d) F-ratio (F/F_{MSY}) and e) B/K are shown in Figure 3. The Kobe plot with time trajectory using aggregated model outcomes is shown in Figure 4. Time series of median estimated values for biomass, harvest rate, B-ratio, F-ratio and depletion level relative to K are shown in Table 2.

Table 1. Summary of estimates of reference quantities. Median and credible intervals for the aggregated results are presented. In addition, median values of Member's combined results (over B1 and B2) are shown.

	Median	Lower10%	Upper10%	Median_CHN	Median_JPN	Median_CT
C_2022 (10000 t)	10.009	10.009	10.009	10.009	10.009	10.009
AveC_2020_2022	11.066	11.066	11.066	11.066	11.066	11.066
AveF_2020_2022	0.337	0.141	0.621	0.328	0.376	0.316
F_2022	0.245	0.113	0.426	0.231	0.270	0.237
FMSY	0.314	0.108	0.576	0.305	0.350	0.297
MSY (10000 t)	39.657	30.473	48.874	40.434	39.856	38.940
F_2022/FMSY	0.806	0.519	1.436	0.810	0.799	0.809
AveF_2020_2022/FMSY	1.111	0.770	1.748	1.159	1.106	1.079
K (10000 t)	264.054	147.520	702.181	285.000	251.768	260.100
B_2022 (10000 t)	40.820	23.503	88.382	43.290	37.073	42.300
B_2023 (10000 t)	54.940	33.227	108.300	57.340	52.284	55.320
AveB_2021_2023	42.410	25.270	90.015	44.623	39.042	43.883
BMSY (10000 t)	128.100	74.289	317.407	136.900	118.580	130.150
BMSY/K	0.481	0.389	0.604	0.469	0.469	0.506
B_2022/K	0.155	0.089	0.233	0.150	0.151	0.163
B_2023/K	0.209	0.105	0.341	0.200	0.210	0.214
AveB_2021_2023/K	0.163	0.092	0.244	0.156	0.160	0.170
B_2022/BMSY	0.316	0.195	0.474	0.306	0.316	0.323
B_2023/BMSY	0.426	0.227	0.698	0.412	0.441	0.424
AveB_2021_2023/BMSY	0.331	0.201	0.496	0.320	0.336	0.337

Table 2. Time series of median estimated values for biomass, harvest rate, B-ratio, F-ratio and depletion level relative to K. The unit of biomass is 10,000 tons.

Year	Biomass	HarvestRate	Bratio	Fratio	Depletion
1980	146.700	0.163	1.123	0.562	0.545
1981	153.700	0.133	1.209	0.447	0.588
1982	165.132	0.148	1.311	0.492	0.641
1983	169.033	0.153	1.348	0.501	0.662
1984	172.600	0.143	1.373	0.468	0.675
1985	177.200	0.159	1.402	0.522	0.689
1986	178.100	0.146	1.397	0.484	0.689
1987	181.400	0.130	1.418	0.431	0.699
1988	186.000	0.192	1.448	0.638	0.714
1989	176.079	0.188	1.363	0.628	0.673
1990	173.523	0.251	1.340	0.845	0.660
1991	159.300	0.250	1.228	0.849	0.604
1992	151.500	0.253	1.171	0.867	0.572
1993	145.000	0.277	1.118	0.961	0.544
1994	135.100	0.246	1.044	0.862	0.503
1995	130.900	0.263	0.993	0.947	0.476
1996	121.800	0.219	0.911	0.805	0.436
1997	126.300	0.293	0.915	1.121	0.437
1998	113.500	0.155	0.821	0.598	0.392
1999	124.400	0.142	0.886	0.551	0.423
2000	140.074	0.204	1.018	0.768	0.486
2001	145.600	0.255	1.091	0.912	0.526
2002	151.000	0.218	1.156	0.747	0.563
2003	182.400	0.244	1.392	0.814	0.690
2004	167.100	0.221	1.277	0.738	0.632
2005	179.300	0.264	1.353	0.888	0.672
2006	155.488	0.254	1.184	0.847	0.584
2007	163.168	0.319	1.236	1.067	0.614
2008	159.200	0.388	1.190	1.312	0.594
2009	116.400	0.406	0.894	1.355	0.438
2010	117.900	0.365	0.890	1.232	0.440
2011	122.470	0.373	0.912	1.269	0.453
2012	108.500	0.424	0.825	1.419	0.407
2013	113.500	0.374	0.847	1.259	0.424
2014	104.500	0.602	0.798	1.971	0.398
2015	74.330	0.483	0.561	1.612	0.281
2016	67.220	0.538	0.509	1.786	0.254
2017	53.971	0.487	0.415	1.610	0.205
2018	59.390	0.734	0.450	2.397	0.226
2019	37.252	0.524	0.282	1.754	0.141
2020	30.510	0.458	0.233	1.530	0.115
2021	31.037	0.297	0.238	0.989	0.117
2022	40.820	0.245	0.316	0.806	0.155
2023	54.940		0.426		0.209

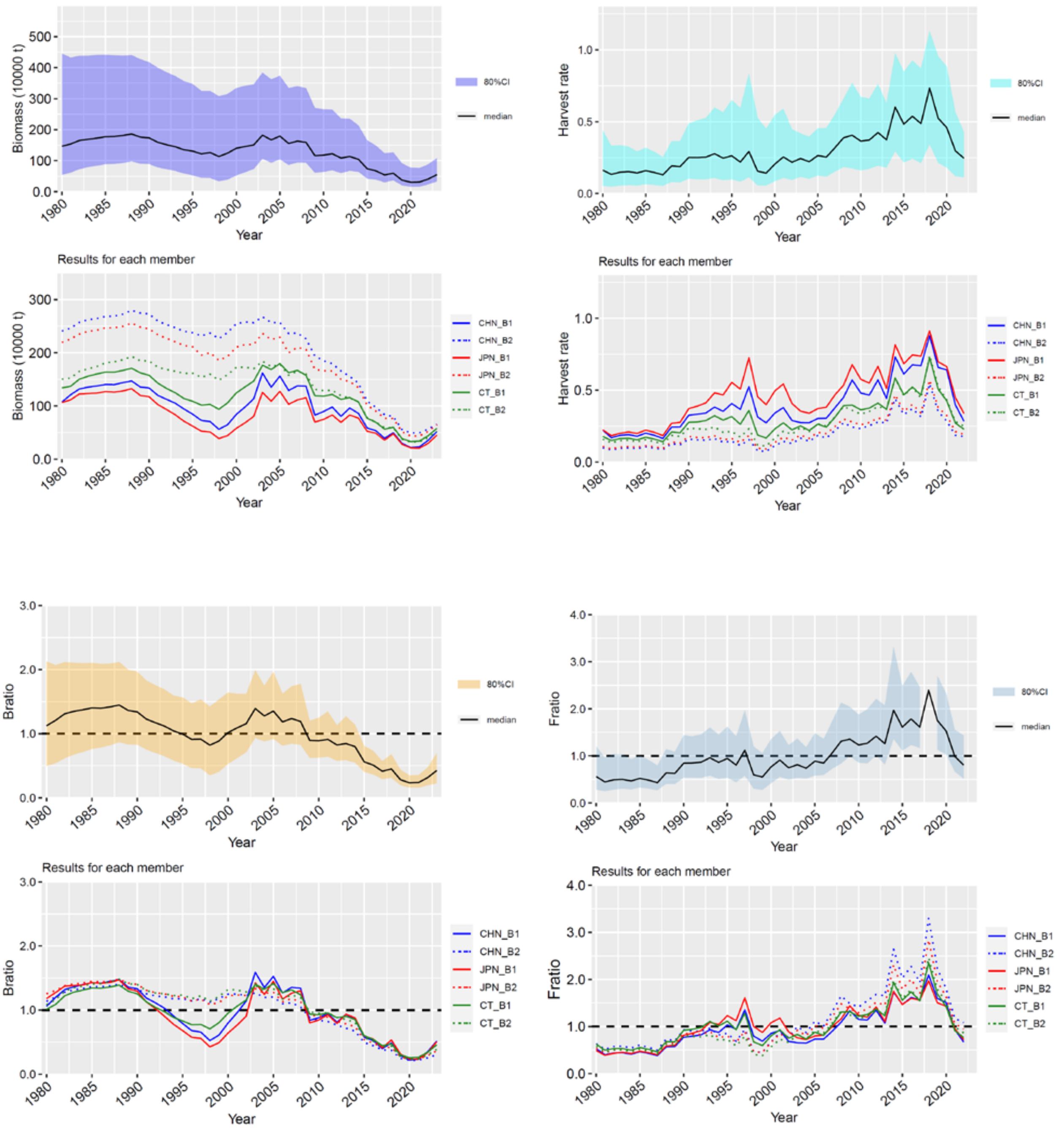


Figure 3. Time series of median estimated values of six runs for biomass, harvest rate, B-ratio, F-ratio and depletion level relative to K. The solid and shaded lines correspond to B1 and B2, respectively.

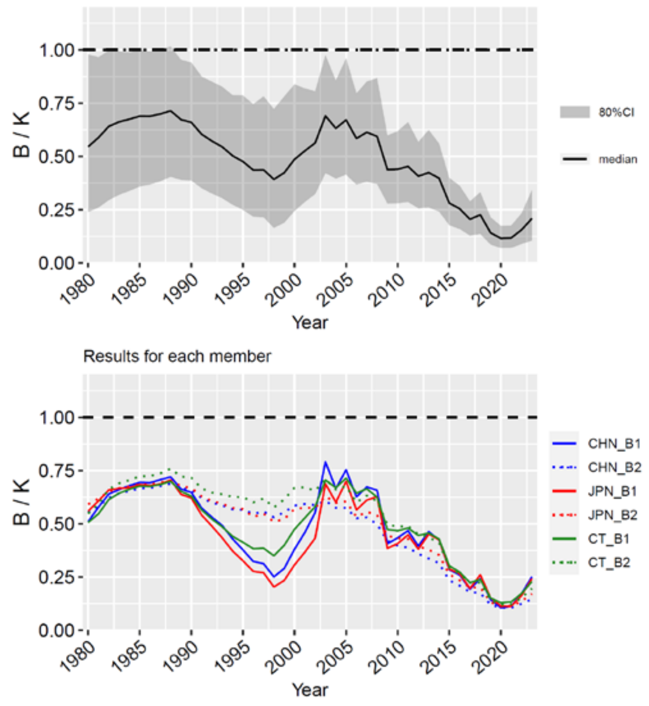


Figure 3 (Continued).

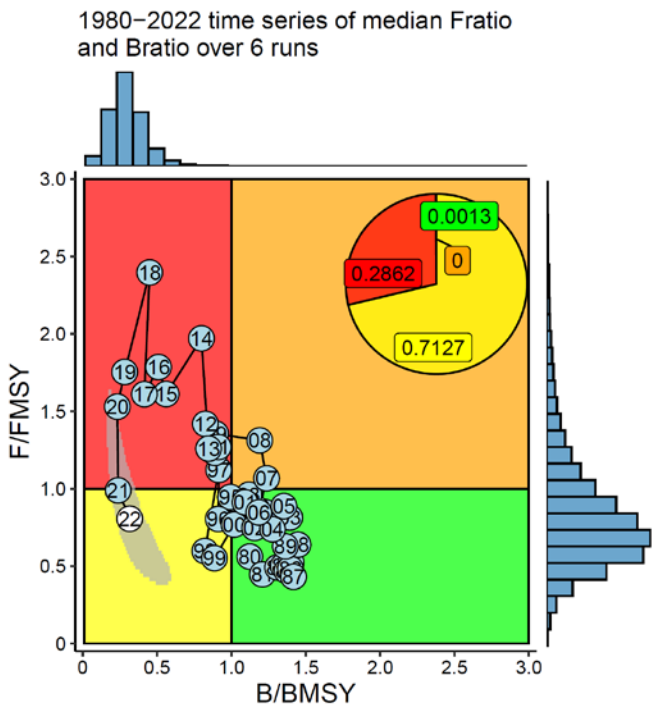


Figure 4. Kobe plot with time trajectory. The data are aggregated across 6 model results (2 base-case models by 3 Members).

Current stock condition and management advice

Summary of stock status

Results of all Members' and combined model estimates indicate that the stock declined with an interannual variability from near carrying capacity in the mid-2000's after a period of high productivity to current low levels. Combined results show that average B was below B_{MSY} during 2021-2023 (median average B/B_{MSY} during 2021-2023 = 0.331, 80%CI=0.201-0.496) and average F was above F_{MSY} (average F/F_{MSY} during 2020-2022 = 1.111, 80%CI= 0.770-1.748). Thus, stock biomass remained at low levels in recent years. The evidence is mixed but biomass may have increased modestly during 2022-2023 based on unstandardized CPUE for 2023 and higher recruitment that may be evident in the Japanese fishery size composition data. There was an increase in the Japanese biomass survey between 2021 and 2023. Ignoring the 2020 survey result (as the 2020 survey was incomplete), the Japanese survey varied without trend at historically low levels during 2015-2023. Standardized CPUE declined to low levels in 2022 but nominal data for 2023 show higher catch rates in 2023 for most Members (Figure 5). Effective fishing effort in the entire fishery remains high with decreases by most Members offset by increases in fishing effort for other Members. Harvest rates declined from a peak in 2018 and were lower but near F_{MSY} during 2021-2022. Reductions in harvest rate and increases in nominal CPUE during 2022-2023 are positive signs but data and recent estimates are variable, CPUE, survey data and biomass are still low, and fishing effort remains high. As described below, management approaches that reduce exploitation at current low biomass levels are more likely to take advantage of any recent increases in stock productivity and help rebuild the fishery and Pacific saury population.

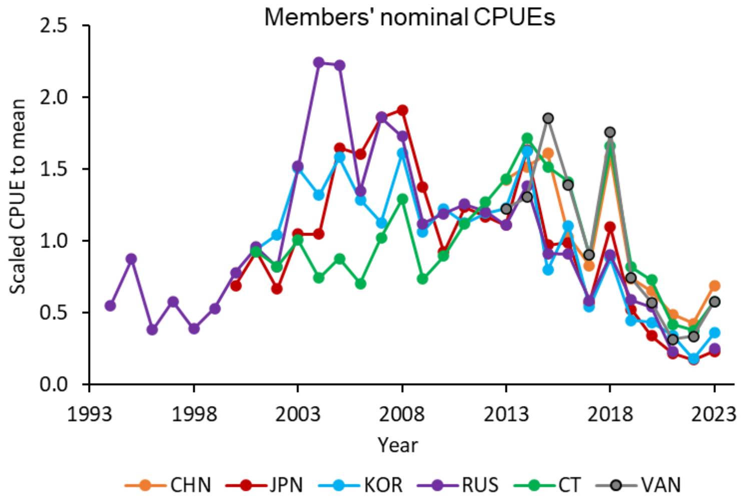


Figure 5. Time series of Member's nominal CPUE indices. Data in 2023 are preliminary (as of November 2023).

The retrospective patterns were modest or not identified and reduced from the previous assessment. There was some scale uncertainty that was examined by Members and determined to be the result of differing prior assumptions. Fortunately, the trends in relative exploitation and relative biomass were robust and consistent.

Management advice

The Commission has responsibility for choosing the TAC and the TAC approach for the Pacific saury fishery. The method used by the Commission in 2019 to set the 2020 TAC for saury was F_{MSY} * B, which is a standard approach used previously in many fisheries. However, it was noted in the previous stock assessment that the original method is seldom used in modern fishery management because it maintains a high (F_{MSY}) fishing mortality level as stock biomass becomes low, as is currently the case for Pacific saury. Simulation studies for many fisheries show better performance (higher average catch and less frequent low biomass conditions) using harvest control rules such as a new standard approach now used in many fisheries. The newer standard reduces fishing mortality in a simple linear fashion when stock size falls below B_{MSY} to help rebuild stocks at low biomass and increase catches (Figure 6). It gives the same F and same TAC for stocks at biomass levels B_{MSY} and higher (the original and new approaches are identical when stock biomass is at least B_{MSY}). The new approach is generally regarded as better on technical grounds at maintaining productive stock levels, avoiding low biomass conditions and obtaining relatively high long-term catch. Both approaches are based on the same underlying reference points (F_{MSY} and B_{MSY}) that are estimable for Pacific saury in the BSSPM and likely future models. Both approaches use robust trend-based stock status measures and reference points.

TAC calculations were carried out in this assessment for illustrative purposes using the original and newer standard approaches (Figure 7). Such calculations may serve as a means for communication between scientists and managers, provide another approach to calculate TAC on an interim manner, or as a basis for further work. Results show that the newer approach results in TAC for 2024 (B_{2023}*F_{MSY}*(B_{2023}/B_{MSY}) = 73,490 tons) that is smaller to the 2023 catch (102,003 tons, preliminary as of 2 December 2023). Results for the original approach yield TAC for 2024 (B_{2023}*F_{MSY} = 172,512 tons), which is substantially higher than recent catches.

The current annual catch limit for 2023-2024 specified in CMM 2023-08 for Pacific saury (250,000 tons) based on historical catch is much larger than a TAC that would be based on the F_{MSY} catch approach 172,512 tons. The current biomass is much lower than B_{MSY} and the TAC for 2023-2024 may not reduce fishing mortality in those years. A harvest control rule that reduces F when biomass is low may increase the probability of achieving long-term sustainable use of Pacific saury (i.e. higher long-term catch closer to MSY of around 396,570 tons). A reduction to the TAC for 2023-2024 would increase the probability of higher biomass and catch levels in the Pacific saury stock.

The HCR used in the second calculation above is a relatively simple approach widely used in many fisheries, but only one example from the range of potential harvest control rules of the same or other types. Note the performance of the above HCRs is in the process of being evaluated.

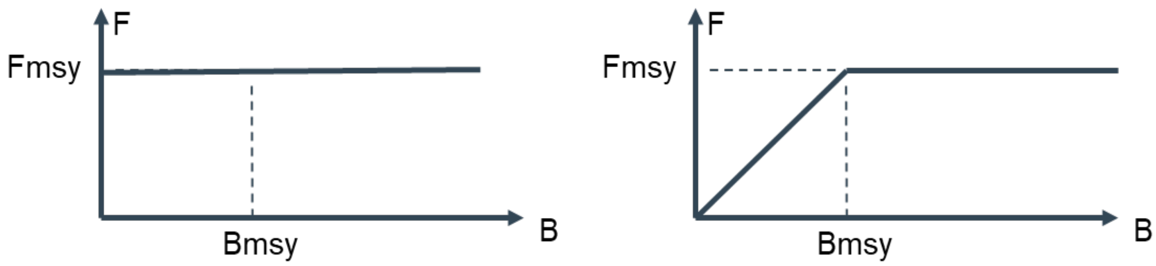


Figure 6. Shapes of harvest rates used in the 2019 Commission meeting for setting the TAC for 2020 (left) and a standard HCR (right).

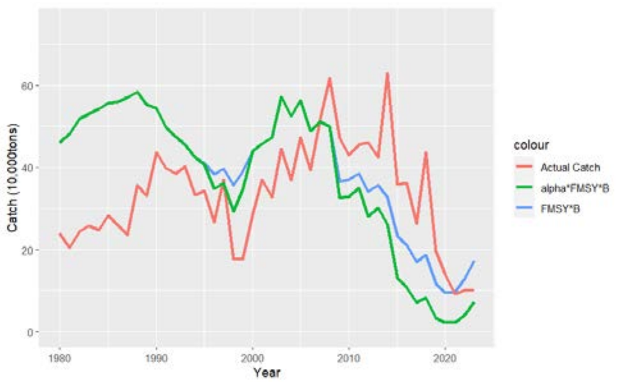


Figure 7. Median time series of F_{MSY}*B, min(1, B/B_{MSY})*F_{MSY}*B, and the actual catch. The first calculation was

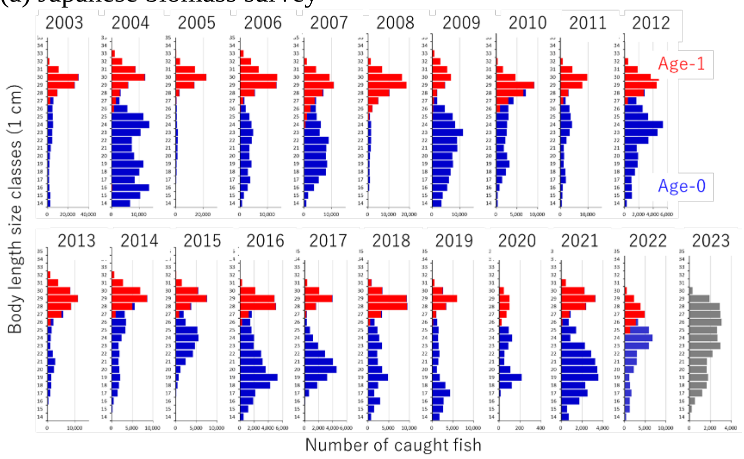
used by the Commission in 2019 and the second calculation is a common HCR used elsewhere that reduces F when biomass falls below B_{MSY}. Note that the catch in 2023 is a preliminary number as of 2 December 2023. Note that these two calculations are the same when $B > B_{MSY}$. Also, the second calculation is shown as an example application of an HCR.

Special comments regarding the procedures and stock assessment results

The SSC PS worked collaboratively to produce this consensus stock assessment, which includes significant technical improvements.

1) Standardized CPUE data were assumed to change more slowly than biomass and were down-weighted relative to the Japanese survey in the first base case (B1), which used CPUE from individual Members. In B1, a single non-linear parameter was used for the CPUEs for each Member. Model results support this decision.
2) Potential Covid-19 effects on CPUE and catches were not considered in this assessment but may be important. Members should consult fishermen regarding possible impacts of COVID-19 on the fishery.
3) Retrospective analyses have shown that BSSPM model projections are not suitable for use by managers and they have therefore been omitted by most Members (see discussion in the 2019 assessment (NPFC-2019-SSC PS04-Final Report)). Projections are problematic because recruits and older Pacific saury are not distinguished in the model, environmental effects are important but not predictable and because the species is short-lived.
4) The 2020 biomass index from the Japanese survey has large uncertainties due to incomplete survey coverage and complicates interpretation of recent trends. It may be better to disregard the 2020 observation when evaluating recent trends visually.
5) The relative importance of fishing and environmental factors on the population dynamics of Pacific saury is unknown and an important area for research. However, changing environmental conditions may have contributed to the decline and current low stock size of Pacific saury. Oceanographic or biological factors responsible for changes in productivity have not yet been determined. Development of modeling procedures to incorporate environmental change is an important area for future research. The work should include refinements to stock assessment models to better reflect and estimate environmental effects on recruitment and biology. This work should be coordinated among Members and folded into the development of age-structured and improved BSSPM models.
6) The Commission should consider defining overfishing and overfished status and identify actions taken when such conditions occur in the future.
7) Time series of size and age composition data from the Japanese survey and fishery (Figures 8 and 9) showed the occurrence of weak year classes (i.e. 2005, 2008) consistently. Such consistency will facilitate application of new age and/or size structured model.

(a) Japanese biomass survey



(b) Japanese commercial fishery between August and November

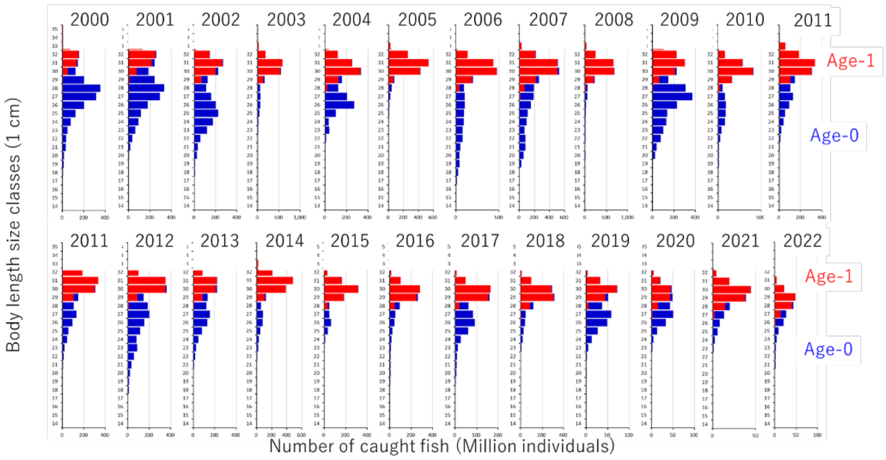


Figure 8. Time series of age and length composition of samples taken from the Japanese survey and commercial fishery (August-November) in Japan.

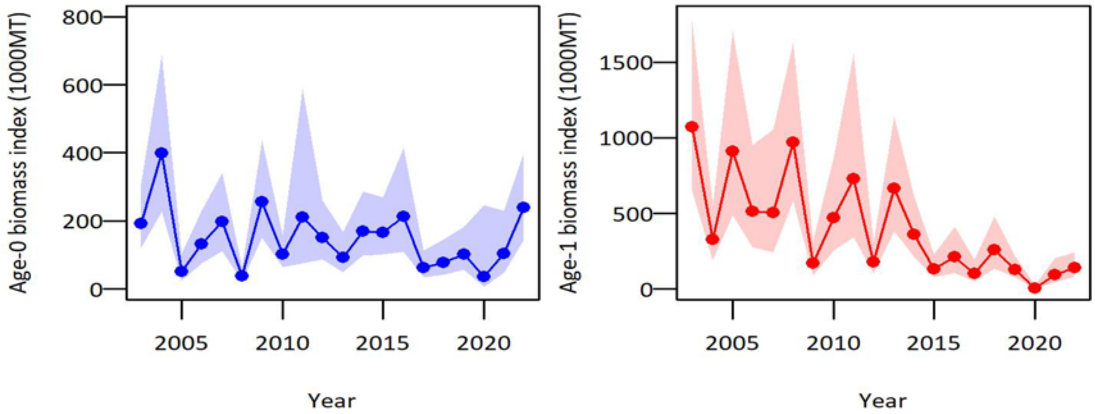


Figure 9. Time series of Japanese survey biomass index by age.

STOCK ASSESSMENT REPORT FOR PACIFIC SAURY

1. INTRODUCTION

1.1 Distribution

Pacific saury (*Cololabis saira* Brevoort, 1856) has a wide distribution extending in the subarctic and subtropical North Pacific Ocean from inshore waters of Japan and the Kuril Islands to eastward to the Gulf of Alaska and southward to Mexico. Pacific saury is a commercially important fish in the western North Pacific Ocean (Parin 1968; Hubbs and Wisner 1980).

1.2 Migration

Pacific saury migrates extensively between the northern feeding grounds in the Oyashio waters around Hokkaido and the Kuril Islands in summer and the spawning areas in the Kuroshio waters off southern Japan in winter (Fukushima 1979; Kosaka 2000). Pacific saury in offshore regions (east of 160°E) also migrate westward toward the coast of Japan after October every year (Suyama et al. 2012).

1.3 Population structure

Genetic evidence suggests there are no distinct stocks in the Pacific saury population based on 141 individuals collected from five distant locales (East China Sea, Sea of Okhotsk, northwest Pacific, central North Pacific, and northeast Pacific) (Chow et al. 2009).

1.4 Spawning season and grounds

The spawning season of Pacific saury is relatively long, beginning in September and ending in June of the following year (Watanabe and Lo 1989). Pacific saury spawns over a vast area from the Japanese coastal waters to eastern offshore waters (Baitaliuk et al. 2013). The main spawning grounds are considered to be located in the Kuroshio-Oyashio transition region in fall and spring and in the Kuroshio waters and the Kuroshio Extension waters in winter (Watanabe and Lo 1989).

1.5 Food and feeding

The Pacific saury larvae prey on the nauplii of copepods and other small-sized zooplankton. As they grow, they begin to prey on larger zooplankton such as krill (Odate 1977). The Pacific saury is preyed on by large fish ranked higher in the food chain, such as *Thunnus alalunga* (Nihira 1988) and coho salmon, *Oncorhynchus kisutsh* (Sato and Hirakawa 1976) as well as by animals such as minke whales *Balaenoptera acutorostrata* (Konishi et al. 2009) and sea birds (Ogi 1984).

1.6 Age and growth

Based on analysis of daily otolith increments, Pacific saury reaches approximately 20 cm in knob length (distance from the tip of lower jaw to the posterior end of the muscular knob at the base of a caudal peduncle; hereafter as body length) in 6 or 7 months after hatching (Watanabe et al. 1988; Suyama et al. 1992). There is some variation in growth rate depending on the hatching month during this long spawning season (Kurita et al. 2004) and geographical differences (Suyama et al. 2012b). The maximum lifespan is 2 years (Suyama et al. 2006). The age 1 fish grow to over 27 cm in body length in June and July when Japanese research surveys are conducted and reach over 29 cm in the fishing season between August and December (Suyama et al. 2006).

1.7 Reproduction

The minimum size of maturity of Pacific saury has been estimated at about 25 cm in the field (Hatanaka 1956) or rearing experiments (Nakaya et al. 2010). In rare cases, saury have been found to mature at 22 cm (Sugama 1957; Hotta 1960). Under rearing experiments, Pacific saury begins spawning 8 months after hatching, and spawning activity continues for about 3 months (Suyama et al. 2016). Batch fecundity is about 1,000 to 3,000 eggs per saury (Kosaka 2000).

2. FISHERY

2.1 Overview of fisheries

Western North Pacific

In Japan, the stick-held dip net fishery for Pacific saury was developed in the 1940s. Since then, the stick-held dip net gears have become the dominant fishing technique to catch Pacific saury in the northwest Pacific Ocean. Since 1995, more than 97% of Japan's total catch is caught by the stick-held dip net. The annual catch of Pacific saury for stick-held dip net fishery has fluctuated. Maximum and minimum catches of 355 thousand tons and 18 thousand tons were recorded in 2008 and 2022, respectively.

Pacific saury fisheries in Korea have been operated with gillnet since the late 1950s in Tsushima Warm Current region. Korean stick-held dip net fishery started from 1985 in the Northwest Pacific Ocean. The largest catch of 50 thousand tons was recorded in 1997 (Gong and Suh 2013).

Russian fishery for Pacific saury has been conducted using stick-held dip nets in the northwest Pacific Ocean in the area that includes national waters (mainly within the Russian EEZ) and adjacent NPFC Convention Areas. Russian catch statistics for saury fishery exists, beginning from 1956, and standardized CPUE indices from that fishery were calculated since 1994. Saury fishery traditionally occurred from August to November; however, in recent years, the onset of fishing for saury shifted to the early summer period. Peak catch of saury of over 100 thousand tons was in 2007. Since then, the annual catch has been decreasing, and was about 610 tons in 2021.

China commenced its exploratory saury fishing using stick-held dip nets in the high seas in 2003, but only started to develop this fishery in 2012. The fishing seasons mainly cover the period from June-November.

Chinese Taipei's Pacific saury fishery can date back to 1975 and had its first commercial catch in 1977. Over the past decade, the number of active Pacific saury fishing vessels has been increasing from 68 to 91 and the catch has fluctuated between 39,750 tons and 229,937 tons since 2001. Aside from Pacific saury fishery, most of the Pacific saury fishing vessels also conduct flying squid jigging operations in the Northwest Pacific Ocean.

Vanuatu commenced its development of Pacific saury fishery by using stick-held dip net in the high seas in 2004. Currently there are four vessels operating in the Northwest Pacific targeting saury, but the total accumulative number of its authorized Pacific saury fishing vessels from 2004 to 2020 is 16. The fishing season mainly covers the period from July to November each year.

Eastern North Pacific

Although Pacific saury occur in the Canada EEZ, there is no targeted fishery for the species. There is no historical record of Canadian participation in international fisheries for saury. Domestic fisheries sometimes capture saury as bycatch in pelagic and bottom trawls and there are a handful of records from other gear types including commercial longlines. The most recently compiled estimates indicate around 300 kg of saury were captured by Canadian commercial fisheries over 17 years from 1997-2013 (Wade and Curtis 2015; NPFC-2022-SSC PS09-IP01). There are also records of saury catches from research trawls (surface, pelagic and bottom trawls) in Canadian waters, but the catches have been minimal.

Management plans developed by the United States' National Marine Fisheries Service currently prohibit targeted fishing on marine forage species including the Pacific saury. In the 1950's to mid-1970's there were sporadic attempts to commercially fish for Pacific saury off of California with limited success using purse seines and light attraction (Kato 1992). Catches from 1969-1972 averaged 450 tons. Currently landings are only "occasionally" reported as bycatch in fisheries on the US west coast. Landings of Pacific saury as bycatch on the US west coast averaged 5.5 kg per year from 2011-2015 (NOAA Fisheries National Bycatch Report Database System, https://www.st.nmfs.noaa.gov/, accessed March 8, 2019)

Historically, Japanese and Russian vessels operated mainly within their own EEZs, but they have shifted into the Convention Area in recent years. Chinese, Korean and Chinese Taipei vessels operate mainly in the high seas of the North Pacific (Figure 1).

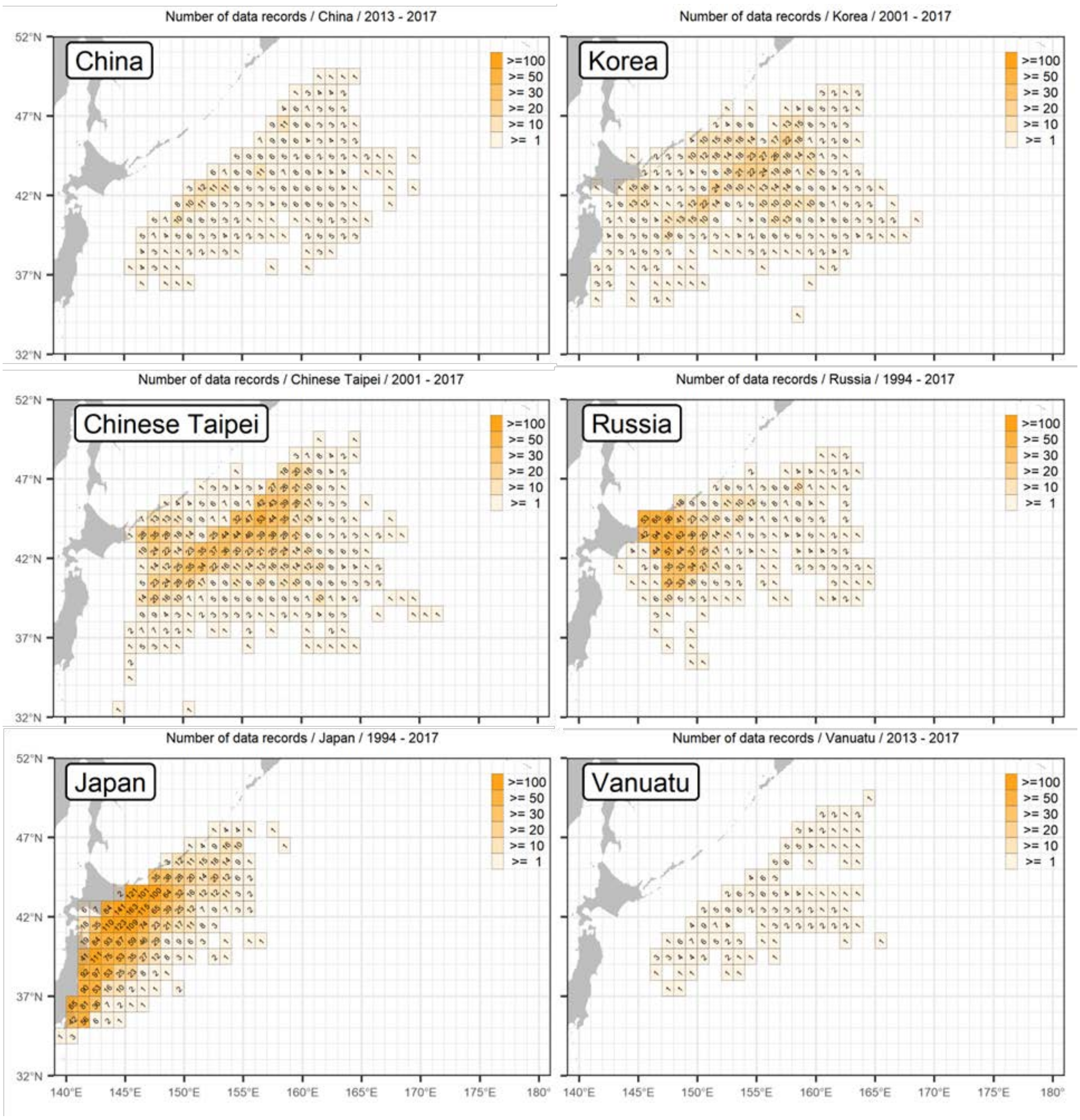


Figure 1 (a). Main fishing grounds for Pacific saury by fishing members in the western North Pacific Ocean during 1994-2017. The legend shows the number of data records. This figure is based on the data shared by the Members for the development of a joint CPUE index

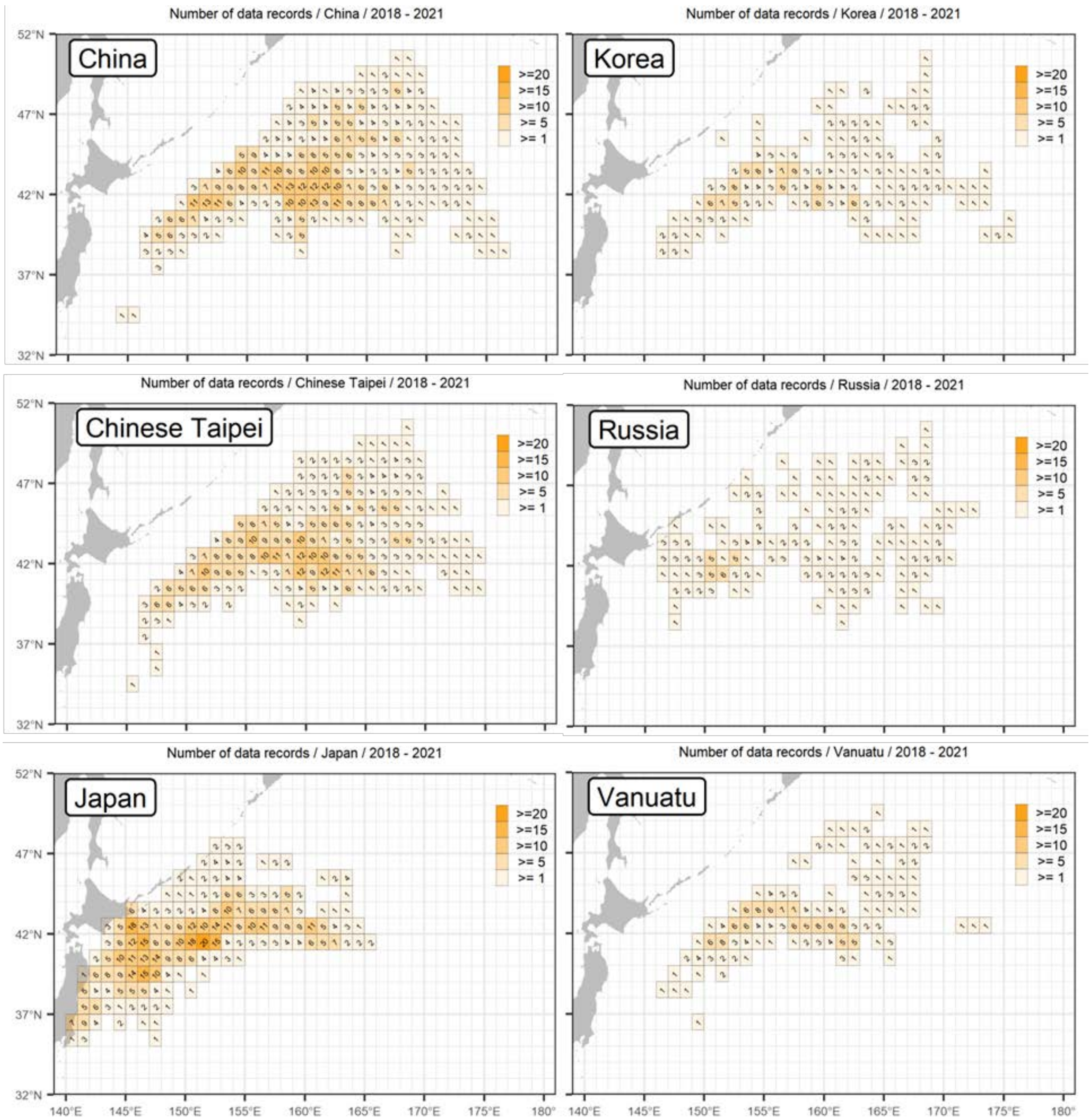


Figure 1 (b). Main fishing grounds for Pacific saury by fishing members in the western North Pacific Ocean during 2018-2021. The legend shows the number of data records. This figure is based on the data shared by the Members for the development of a joint CPUE index

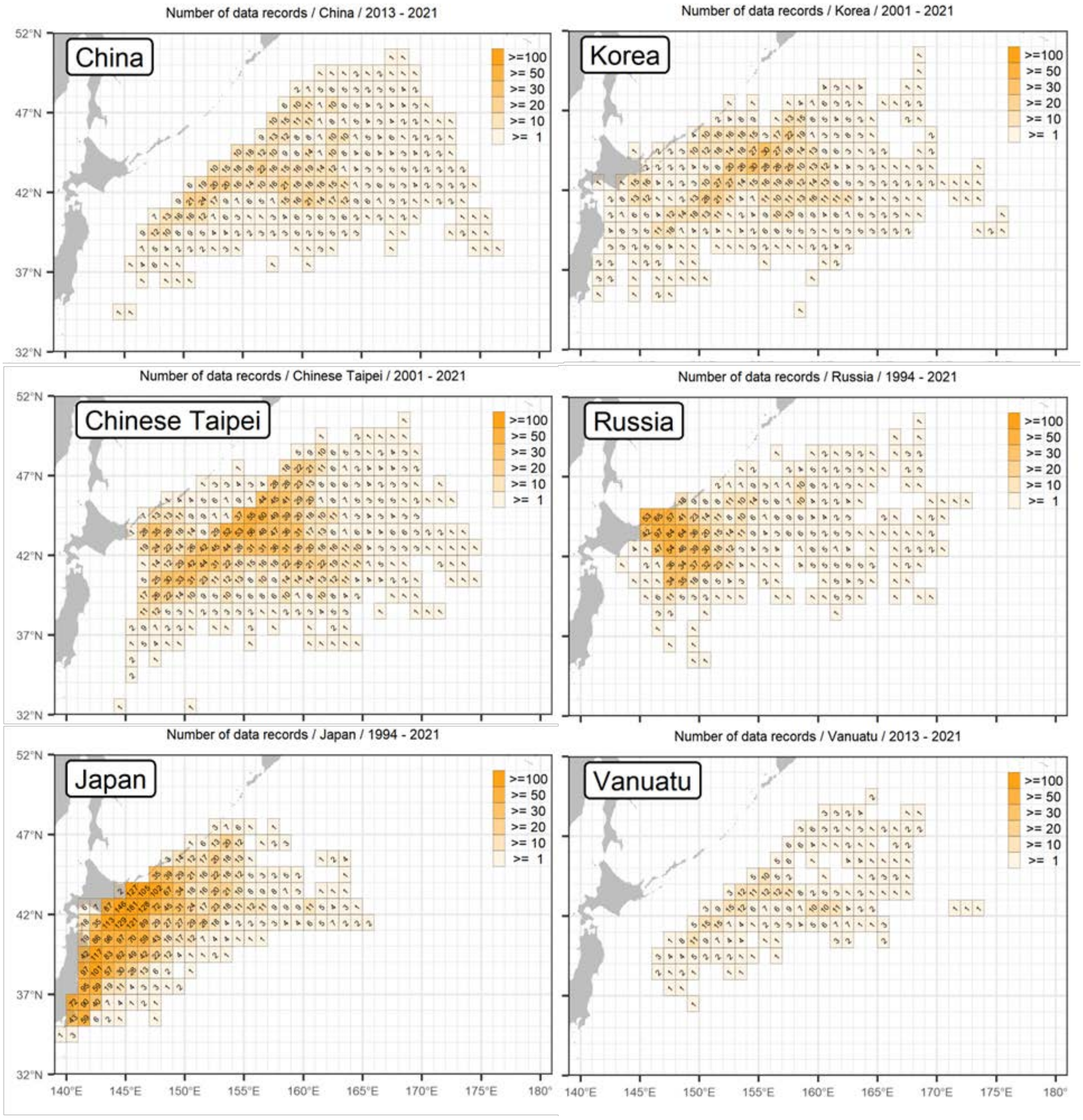


Figure 1 (c). Main fishing grounds for Pacific saury by fishing members in the western North Pacific Ocean during 1994-2021. The legend shows the number of data records. This figure is based on the data shared by the Members for the development of a joint CPUE index

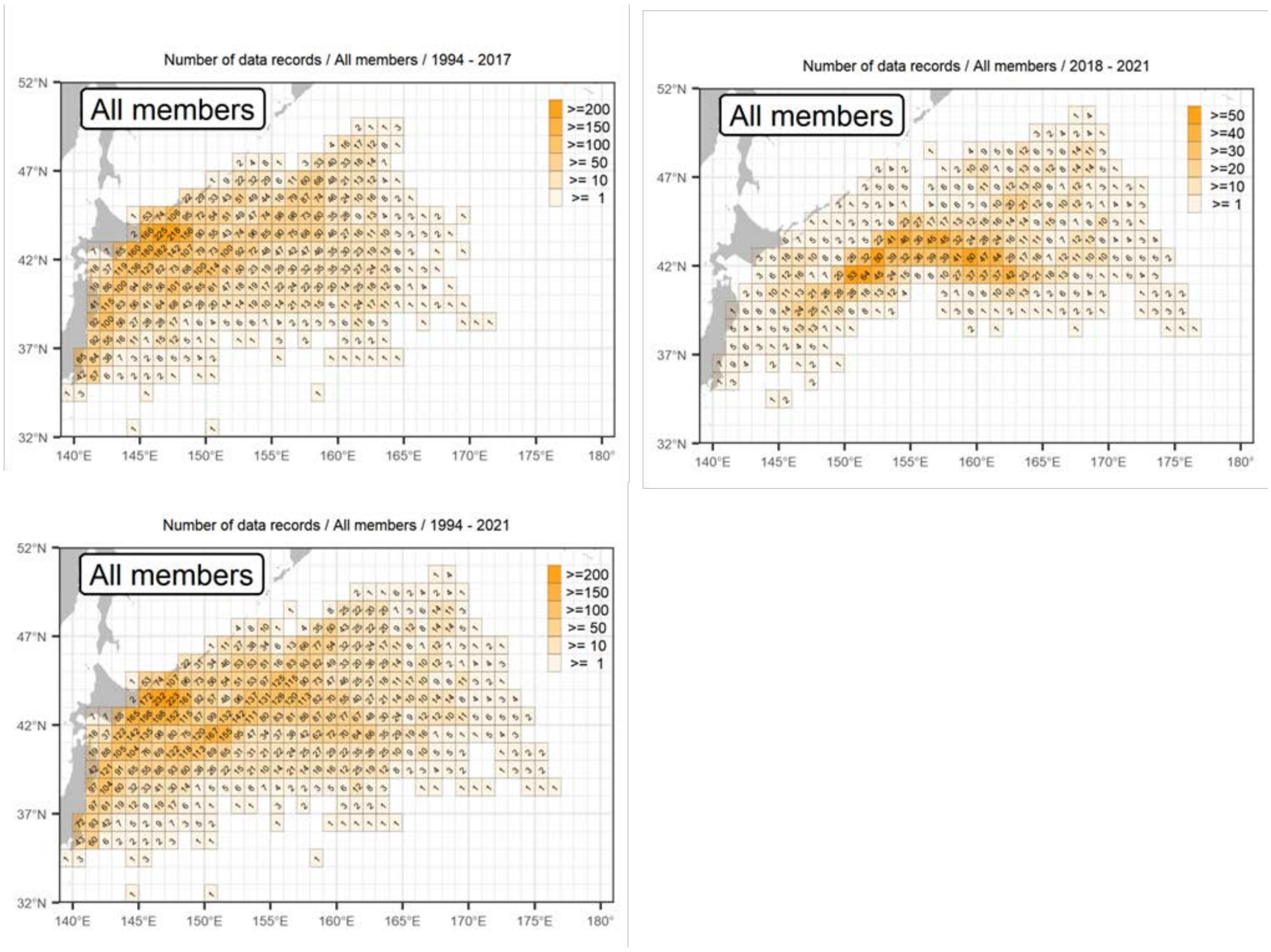


Figure 1 (d). Main fishing grounds for Pacific saury in the western North Pacific Ocean. The legend shows the number of data records. This figure is based on the data shared by the Members for the development of a joint CPUE index

2.2 Catch records

Figure 2 shows the historical catches of Pacific saury in the northwest Pacific Ocean by Member.

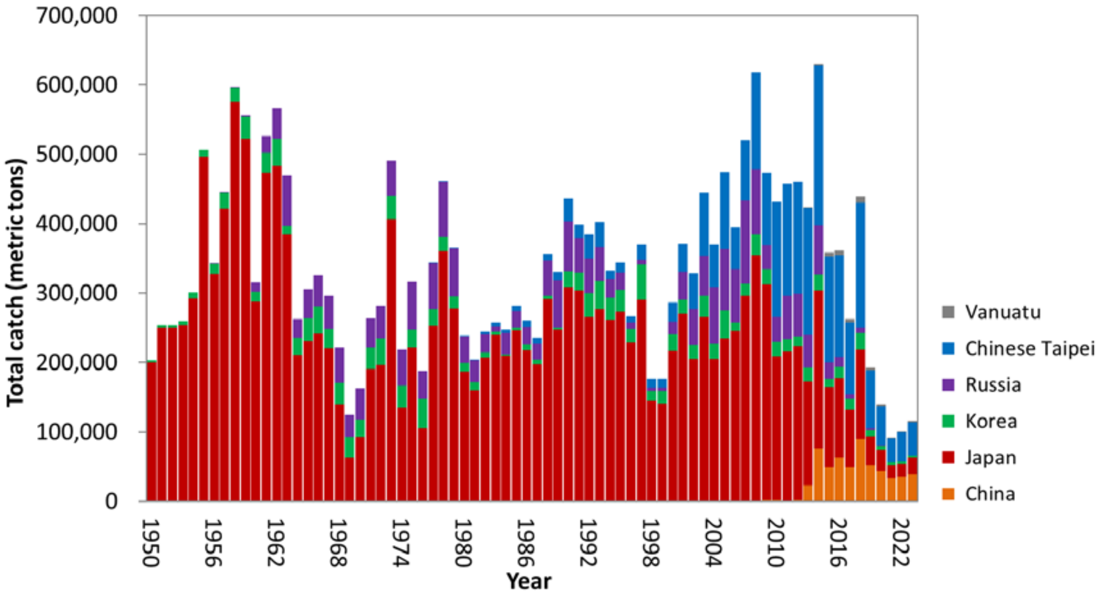


Figure 2. Time series of catch by Member during 1950-2023. The catch data for 1950-1979 are shown but not used in stock assessment modeling. Catch data in 2023 are preliminary (as of 2 December 2023) and not used in the assessment.

3. SPECIFICATION OF STOCK ASSESSMENT

A Bayesian state-space production model (BSSPM) used in previous stock assessments was employed as an agreed provisional stock assessment model for Pacific saury during 1980-2023. Scientists from three Members (China, Japan and Chinese Taipei) each conducted analyses following the agreed specification which called for two base case scenarios and two sensitivity scenarios (see Annex F, SSC PS09 report for more details). The two base case scenarios differ in using each Member's standardized CPUEs (base case B1) or standardized joint CPUEs (base case B2). For the two sensitivity cases with Japanese early CPUE (1980-1994), time-varying catchability was assumed to account for potential increases in catchability. A higher weight was given to the Japanese biomass survey estimates than to Members' CPUEs in B1 while comparable weights were given to the Japanese biomass survey estimates and the joint CPUEs in B2. The CPUE data were modeled as nonlinear indices of biomass. Members used similar approaches with some differences in the assumption of the time-varying catchability and prior distributions for the free parameters in the model.

3.1 Bayesian state-space production model

The population dynamics is modelled by the following equations:

$$B_t = \left\{B_{t-1} + B_{t-1} f(B_{t-1}) - C_{t-1}\right\} e^{u_t}, \quad u_t \sim N(0, \tau^2)$$

$$f(B_t) = r\left[1 - \left(\frac{B_t}{K}\right)^z\right]$$

where

B_t : the biomass at the beginning of year *t*

C_t : the total catch of year *t*

u_t : the process error in year *t*

$f(B)$: the production function (Pella-Tomlinson)

r : the intrinsic rate of natural increase

K : the carrying capacity
z: the degree of compensation (shape parameter; different symbols were used by the 3 members)

The multiple biomass indices are modelled as follows:

Survey biomass estimate

$$I_{t,biomass} = q_{biomass} B_t \, exp(\, v_{t,biomass}), \qquad \text{where} \;\; v_{t,biomass} \sim N\left(0, \sigma^2_{biomass}\right)$$

where

$q_{biomass}$: the relative bias in biomass estimate
$v_{t,biomass}$: the observation error term in year *t* for survey biomass estimate
$\sigma^2_{biomass}$: the observation error variance for survey biomass estimate

CPUE series

$$I_{t,f} = q_f B_t^b \, exp(\, v_{t,f}), \qquad \text{where} \;\; v_{t,f} \sim N\left(0, \sigma_f^2\right)$$

where

$I_{t,f}$: the biomass index in year *t* for biomass index *f*
q_f : the catchability coefficient for biomass index *f*
b: the hyper-stability/depletion parameter
$v_{t,f}$: the observation error term in year *t* for biomass index *f*
σ_f^2: the observation error in year *t* for biomass index *f*

For the estimation of parameters, Bayesian methods were used with Member-specific differences in preferred assumptions for the prior distributions for the free parameters. MCMC methods were employed for simulating the posterior distributions. For the assumptions of uniform priors used in China and Japan, see documents NPFC-2023-SSC PS12-WP05 and NPFC-2023-SSC PS12-WP09; for the non-uniform priors used in Chinese Taipei, see document NPFC-2023-SSC PS12-WP06.

3.2 Agreed scenarios

Table 1. Definition of scenarios

	Base case (NB1)	**Base case (NB2)**	**Sensitivity case (NS1)**	**Sensitivity case (NS2)**
Initial year	1980	1980	1980	1980
Biomass survey	$I_{t,bio} = q_{bio}\, B_t e^{v_{t,bio}}$ $v_{t,bio} \sim N(0, cv_{t,bio}^2 + \sigma^2)$ $q_{bio} \sim$ U(0,1) (2003-2023)	Same as left	Same as left	Same as left
CPUE	CHN(2013-2022) JPN_late(1994-2022) KOR(2001-2022) RUS(1994-2022) CT(2001-2022) $I_{t,f} = q_f B_t^b e^{v_{t,f}}$ $v_{t,f} \sim N(0, \sigma_f^2)$ $\sigma_f^2 = c \cdot (ave(cv_{t,bio}^2) + \sigma^2)$, where $ave(cv_{t,bio}^2)$ is computed except for 2020 survey (*c* = 5)	Joint CPUE (1994-2022) $I_{t,joint} = q_{joint} B_t^b e^{v_{t,joint}}$ $v_{t,joint} \sim N(0, cv_{t,joint}^2 + \sigma^2)$	CHN(2013-2022) JPN_early(1980-1993, time-varying *q*) JPN_late(1994-2022) KOR(2001-2022) RUS(1994-2022) CT(2001-2022) $I_{t,f} = q_f B_t^b e^{v_{t,f}}$ $v_{t,f} \sim N(0, \sigma_f^2)$ $\sigma_f^2 = c \cdot (ave(cv_{t,bio}^2) + \sigma^2)$, where $ave(cv_{t,bio}^2)$ is computed except for 2020 survey (*c* = 6)	JPN_early(1980-1993, time-varying *q*) $I_{t,JE} = q_{t,JE} B_t^b e^{v_{t,JE}}$ $v_{t,JE} \sim N(0, \sigma_{JE}^2)$ $\sigma_{JE}^2 = c\ ave(cv_{t,joint}^2 + \sigma^2)$ Joint CPUE (1994-2022) $I_{t,joint} = q_{joint} B_t^b e^{v_{t,joint}}$ $v_{t,joint} \sim N(0, cv_{t,joint}^2 + \sigma^2)$
Hyper-depletion / stability	A common parameter for all fisheries with a prior distribution, *b* ~ *U*(0, 1)	*b* ~ *U* (0, 1)	A common parameter for all fisheries but JPN_early, with a prior distribution, *b* ~ *U*(0, 1) [*b* for JPN_early is fixed at 1]	*b* ~ *U* (0, 1) for joint CPUE. [*b* for JPN_early is fixed at 1]
Prior for other than q_{bio}	Own preferred options	Own preferred options	Own preferred options	Own preferred options

Table 2. Description of symbols used in the stock assessment

Symbol	Description
C_{2022}	Catch in 2022
$AveC_{2020-2022}$	Average catch for a recent period (2020–2022)
$AveF_{2020-2022}$	Average harvest rate for a recent period (2020–2022)
F_{2022}	Harvest rate in 2022
F_{MSY}	Annual harvest rate producing the maximum sustainable yield (MSY)
MSY	Equilibrium yield at F_{MSY}
F_{2022}/F_{MSY}	Average harvest rate in 2022 relative to F_{MSY}
$AveF_{2020-2022}/F_{MSY}$	Average harvest rate for a recent period (2020–2022) relative to F_{MSY}
K	Equilibrium unexploited biomass (carrying capacity)
B_{2022}	Stock biomass in 2022 estimated in the model
B_{2023}	Stock biomass in 2023 estimated in the model
$AveB_{2021-2023}$	Stock biomass for a recent period (2021–2023) estimated in the model
B_{MSY}	Stock biomass that will produce the maximum sustainable yield (MSY)
B_{MSY}/K	Stock biomass that produces the maximum sustainable yield (MSY) relative to the equilibrium unexploited biomass[a]
B_{2022}/K	Stock biomass in 2022 relative to K[a]
B_{2023}/K	Stock biomass in 2023 relative to K[a]
$B_{2021-2023}/K$	Stock biomass in the latest time period (2021-2023) relative to the equilibrium unexploited stock biomass[a]
B_{2022}/B_{MSY}	Stock biomass in 2022 relative to B_{MSY}[a]
B_{2023}/B_{MSY}	Stock biomass in 2023 relative to B_{MSY}[a]
$B_{2021-2023}/B_{MSY}$	Stock biomass for a recent period (2021–2023) relative to the stock biomass that produces maximum sustainable yield (MSY) [a]

[a]calculated as the average of the ratios.

4 SOME AGGREGATED RESULTS FOR VISUALIZATION PURPOSE

4.1 Visual presentation of results

The graphical presentations for times series of biomass (B), B-ratio (B/B_{MSY}), exploitation rate (F), F-ratio (F/F_{MSY}) and B/K are shown in Figure 3.

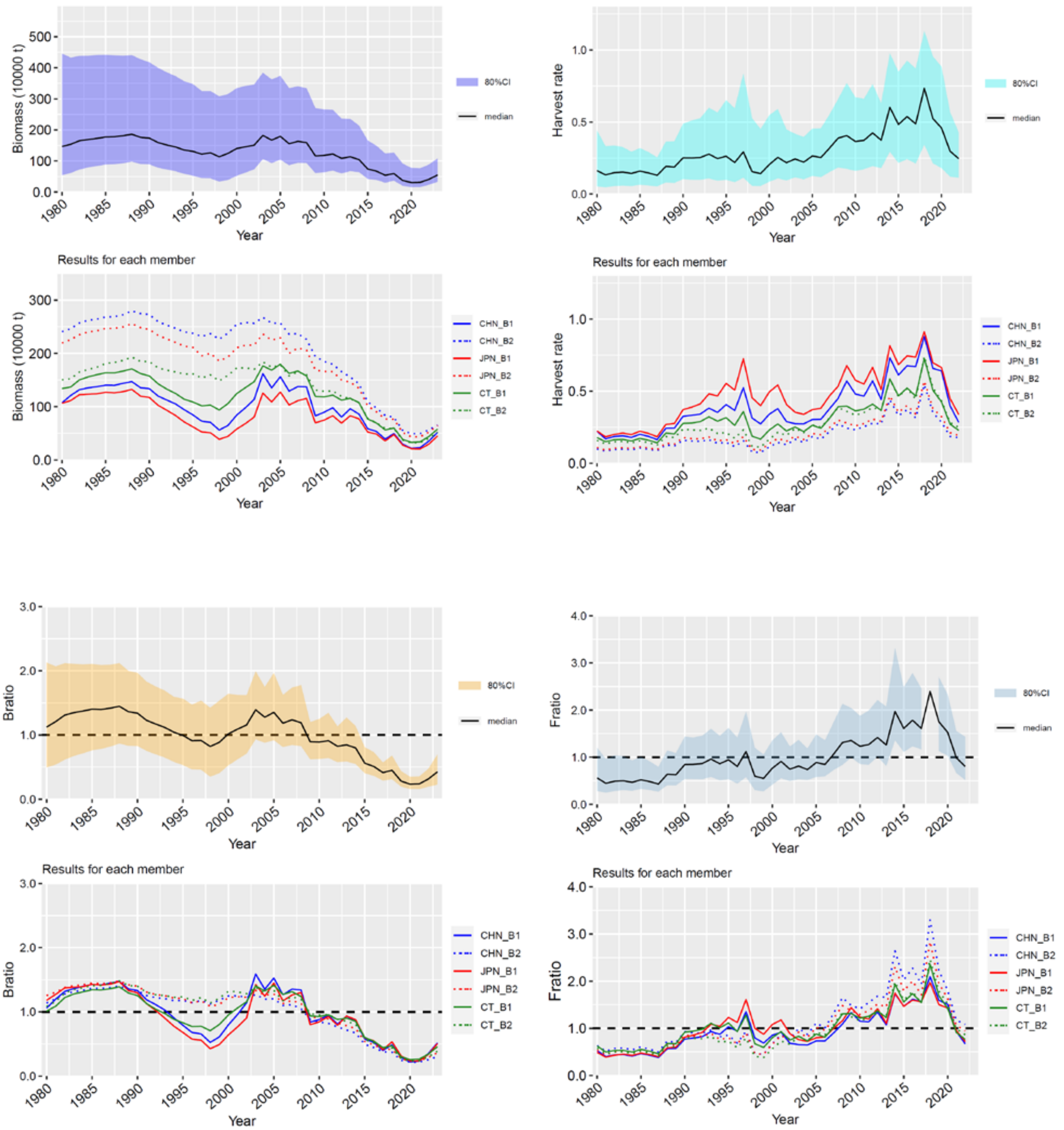


Figure 3. Time series of median estimated values of six runs for biomass, harvest rate, B-ratio, F-ratio and depletion level relative to K. The solid and shaded lines correspond to B1 and B2, respectively.

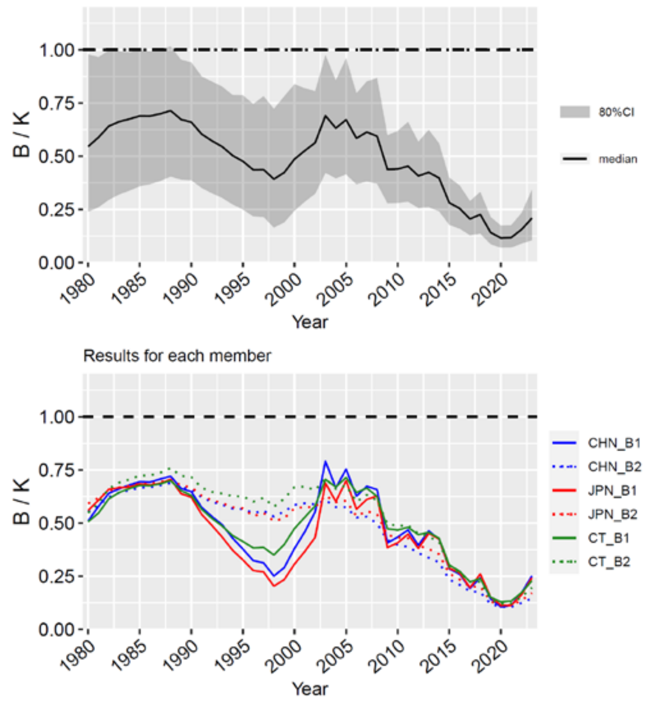


Figure 3 (Continued).

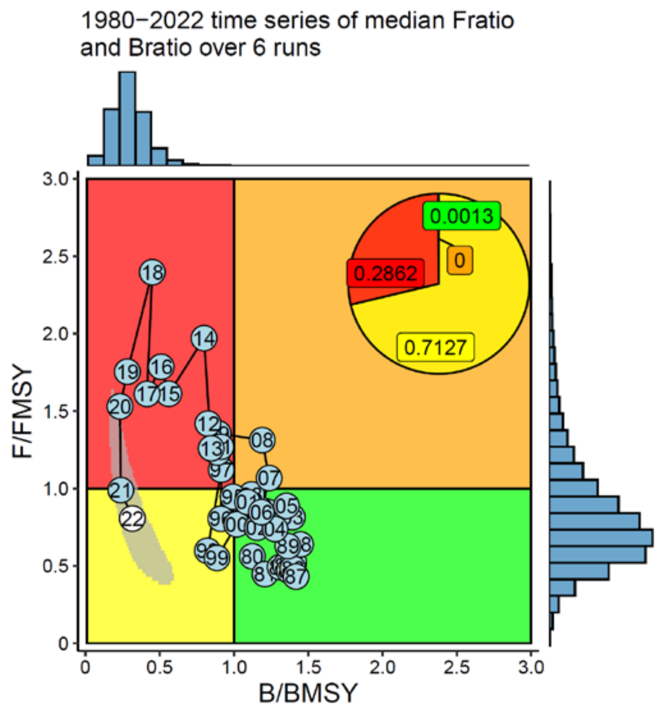


Figure 4. Kobe plot with time trajectory. The data are aggregated across 6 model results (2 base-case models by 3 Members).

4.2 Summary table

Table 3. Summary of estimates of reference quantities. Median and credible interval for the aggregated results are presented. In addition, median values of Member's combined results (over B1 and B2) are shown.

	Median	Lower10%	Upper10%	Median_CHN	Median_JPN	Median_CT
C_2022 (10000 t)	10.009	10.009	10.009	10.009	10.009	10.009
AveC_2020_2022	11.066	11.066	11.066	11.066	11.066	11.066
AveF_2020_2022	0.337	0.141	0.621	0.328	0.376	0.316
F_2022	0.245	0.113	0.426	0.231	0.270	0.237
FMSY	0.314	0.108	0.576	0.305	0.350	0.297
MSY (10000 t)	39.657	30.473	48.874	40.434	39.856	38.940
F_2022/FMSY	0.806	0.519	1.436	0.810	0.799	0.809
AveF_2020_2022/FMSY	1.111	0.770	1.748	1.159	1.106	1.079
K (10000 t)	264.054	147.520	702.181	285.000	251.768	260.100
B_2022 (10000 t)	40.820	23.503	88.382	43.290	37.073	42.300
B_2023 (10000 t)	54.940	33.227	108.300	57.340	52.284	55.320
AveB_2021_2023	42.410	25.270	90.015	44.623	39.042	43.883
BMSY (10000 t)	128.100	74.289	317.407	136.900	118.580	130.150
BMSY/K	0.481	0.389	0.604	0.469	0.469	0.506
B_2022/K	0.155	0.089	0.233	0.150	0.151	0.163
B_2023/K	0.209	0.105	0.341	0.200	0.210	0.214
AveB_2021_2023/K	0.163	0.092	0.244	0.156	0.160	0.170
B_2022/BMSY	0.316	0.195	0.474	0.306	0.316	0.323
B_2023/BMSY	0.426	0.227	0.698	0.412	0.441	0.424
AveB_2021_2023/BMSY	0.331	0.201	0.496	0.320	0.336	0.337

5 CONCLUDING REMARKS

See the Executive Summary.

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Appendix 1

Updated total catch, CPUE standardizations and biomass estimates for the stock assessment of Pacific saury

Year	Total catch (metric tons)	Biomass JPN (VAST, 1000 metric tons)	CV (%)	CPUE CHN (metric tons/ vessel/ day)	CPUE JPN_early (metric tons/ net haul)	CPUE JPN_late (metric tons/ net haul)	CPUE KOR (metric tons/ vessel/ day)	CPUE RUS (metric tons/ vessel/ day)	CPUE CT (metric tons/ net haul)	Joint CPUE (VAST)	CV (%)
1980	238510				0.72						
1981	204263				0.63						
1982	244700				0.46						
1983	257861				0.87						
1984	247044				0.81						
1985	281860				1.4						
1986	260455				1.13						
1987	235510				0.97						
1988	356989				2.36						
1989	330592				3.06						
1990	435869				1.95						
1991	399017				3.13						
1992	383999				4.32						
1993	402185				3.25						
1994	332509					4.13		0.747		1.39	0.29
1995	343743					2.11		0.869		1.70	0.30
1996	266424					1.77		0.646		0.73	0.29
1997	370017					3.52		0.501		1.40	0.30
1998	176364					1.05		0.501		0.87	0.32
1999	176498					0.87		0.568		0.53	0.35
2000	286186					1.28		0.822		1.00	0.32
2001	370823					1.65	7.84	0.947	1.57	0.92	0.19
2002	328362					1.11	11.28	1.172	1.63	0.70	0.18
2003	444642	1348.7	23.9			2.04	16.32	1.526	2.67	1.22	0.18
2004	369400	769.8	20.5			2.72	11.78	2.914	1.45	1.17	0.18
2005	473907	1012.2	30.7			4.40	19.33	2.963	2.39	1.71	0.16
2006	394093	696.6	30.0			4.55	9.45	1.975	1.27	0.55	0.15
2007	520207	782.0	36.9			4.19	8.12	2.231	2.35	1.09	0.17
2008	617509	989.6	26.5			5.15	16.56	2.083	2.90	1.96	0.19
2009	472177	367.4	20.0			4.18	9.60	1.175	1.57	1.03	0.17
2010	429808	554.9	26.4			1.80	9.75	1.224	1.94	1.13	0.17
2011	456263	756.4	35.3			2.52	11.32	1.467	2.51	1.36	0.20
2012	460544	346.4	21.1			2.72	9.19	1.442	2.47	1.08	0.17
2013	423790	758.8	26.6	14.02		1.89	13.61	1.407	2.80	1.00	0.16
2014	629576	448.7	21.7	12.77		3.31	20.42	1.479	3.62	1.31	0.14
2015	358883	337.2	21.4	23.10		1.69	7.41	0.652	2.42	0.96	0.18

2016	361688	358.1	24.4	6.57		1.81	10.76	1.208	2.43	0.80	0.15
2017	262640	145.7	27.3	5.97		1.12	5.40	0.525	1.82	0.75	0.16
2018	435881	378.9	28.7	16.05		1.96	11.89	1.577	3.07	1.33	0.17
2019	195251	247.5	23.4	6.40		0.70	2.75	0.558	1.41	0.56	0.16
2020	139779	12.1	115.7	4.80		0.48	2.85	0.497	1.23	0.32	0.18
2021	92117	161.2	27.0	6.21		0.33	2.83	0.141	0.79	0.22	0.18
2022	100085	290.6	20.4	4.24		0.27	1.62		0.71	0.20	0.16
2023		323.7	26.3								

Annex G

Specifications of the Stock Synthesis 3 model and the state-space age-structured model

Item	SS3	State-space age-structured model
Software	SS3 (NOAA)	Own program coded by TMB
Spatial resolution	Single area (possibly multiple areas from composition perspective?)	Same
Temporal (time-step)	Quarterly	Annual (assuming instantaneous catch in Oct)
Fleet definition	Member-wise + JPN survey	Member-wise + JPN survey
Sex difference	No	No
Catchability	Fleet specific	Fleet specific
Selectivity assumption	Size-based fleet specific	Age-based fleet specific
L-W relationship	Fuji (2019) fixed	Fuji (2019) fixed
Growth (age) / ALK	Refit Suyama et al. (2015) fixed	ALK
Maturity	Size at 50% maturity = 28.7 fixed, Refit Kosaka (2000) and Suyama (2002)	Contribution of age 0 (product of maturity, relative fecundity, and relative times of spawning) is expressed by a single parameter
Fecundity	Fuji et al. (2019) fixed	Contribution of age 0 (product of maturity, relative fecundity, and relative times of spawning) is expressed by a single parameter
Natural mortality	2.18 (/year) common to ages 0 and 1	Age-specific and several options
S-R relationship	B-H (h=0.82 calculate by using Mangle et al. (2010)), sigmaR=0.6	B-H (no assumption for steepness) sigmaR (estimated)
Allocation of Rec over space/time	- No assumption due to single area - Month 7 for age 0	In January instantaneously

Annex H

Specification of simulation for testing HCRs

(as of 13 December 2023)

1. Management Objectives

The SWG MSE PS has **agreed** to continue to base discussions around the three objectives of (a) recovery of the stock, (b) avoiding unsustainable state of the stock, and (c) achieving high and stable catch, with putting a high priority on (a) given the current stock condition.

(a) Recovery of the stock (prioritized objective):

i. The stock status is recovered above B_{tar} within 5 years with 50% probability;

ii. The stock status is maintained above the B_{tar} level in each of years 6-10 with 50% probability.

(b) Avoiding unsustainable state of the stock (secondary objective):

iii. The annual probability in each of years 6-10 that the stock drops below B_{lim} should not exceed 10%;

iv. The annual probability in each of years 6-10 that fishing mortality is above F_{lim} should not exceed 10%.

(c) Achieving high and stable catch (tertiary objective):

v. Average catch over years 6-10 is as high as possible;

vi. Catch in each of years 6-10 is as stable as possible.

Note: Any numerical specification such as probabilities and target years stated in the objectives above may require adjustment after the simulation is carried out if none of the evaluated HCRs can meet the management objectives.

Table 1. The current list of default value and potential ranges for biological reference points

Reference point	Default value	Potential range
B_{tar} = c*B_{MSY}	c = 1	c = 0.8 – 1.2
B_{lim} = c*B_{MSY}	c = 0.35	c = 0.2 – 0.5
F_{tar} = c*F_{MSY}	c = 1	c = 0.8 – 1.2
F_{lim} = c*F_{MSY}	c = 1.35	c = 1.2 – 1.5

2. Harvest Control Rules (HCRs)

HCR0: TAC_y= Fmsy*$\hat{B}_{y-1}$ (as shown in Figure 1)

HCR1: TAC_y = a_{y-1}*Fmsy*$\hat{B}_{y-1}$, where a_{y-1}=min(1, $\hat{B}_{y-1}/\hat{B}_{msy}$) (as shown in Figure 1)

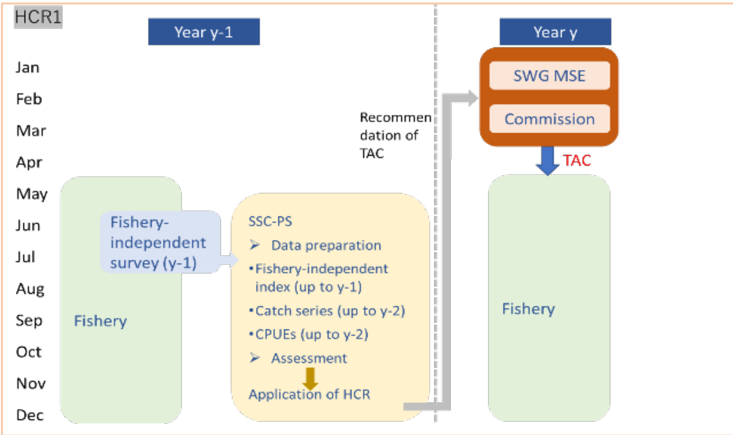


Figure 1. Illustration of the HCR options (HCR0-HCR1).

Table 2. Additional elements for specification of HCRs.

Item	Options
Input of B in HCR	1) previous single year 2) average of previous two years
Maximum allowable change (MAC) in TAC over two consecutive years	A) 20, 30, 40% + no constraint for option 1) above B) 20, 25% and + no constraint for option 2) above
Management cycle	1 year

HCR1 (2 options for inputs of B with different MAC options) [4+3]

HCR0 (single B*single max change for a representative option in HCR) [1]

3. Operating models (OMs)

Basic structure

The SWG MSE PS agreed that Option A (the use of the current interim stock assessment model, BSSPM, as a basis with consideration of uncertainties in estimated parameters and process errors) is to be used as the default option. OMs are to be conditioned based on the most recent BSSPM stock assessment results (aggregated over 6 runs =3 Members for 2 base cases).

For application of HCR0 in year y:

Estimate of biomass in previous year (y-1) as $\log(\hat{B}_{y-1}\hat{F}_{msy}) = \log(B_{y-1}F_{msy}) - 0.5\,\sigma^2 + \varepsilon$

For application of HCR1 in year y:

Estimate of B-ratio (B/Bmsy) in previous year (y-1) as $\log(\frac{\hat{B}_{y-1}}{\hat{B}_{msy}}\hat{B}_{y-1}\hat{F}_{msy}) = \log(\frac{B_{y-1}}{B_{msy}}B_{y-1}F_{msy}) - 0.5\,\sigma^2 + \varepsilon$

The error distribution will be assumed by referring the uncertainty in the actual computation.

Table 3. Specification of OMs for generating future data as input for HCR

Item	Value
Catch in 2023 TAC in 2023	C2023 (actual) TAC2023 = 250,000 (tons)
Terminal year in OM conditioned by the 2023 BSSPM using the actual data (B2023)	Use MCMC samples over 3 Members' 2 base case runs screened by xx% CI constraints over four key parameters (D_{2023}, r, K, z)
Intrinsic rate of increase (r)	Ditto
Carrying capacity (K)	Ditto
Shape parameter (z)	Ditto
Fmsy in future application of HCR	See the formula and figures above.
B (one year time lag)	See the formula and figures above.
B/Bmsy	See the formula and figures above.
Initial year of future simulation	2024
Implementation error	None

Process errors accounting for environmental effects

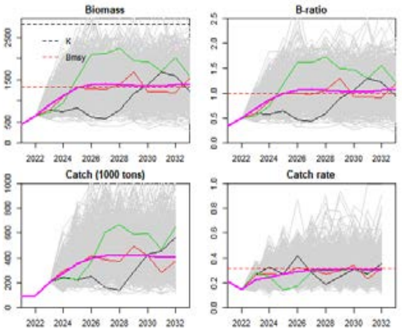
Table 4. Assumptions for process errors

	Model	Value	Note	
R1	IID log-normal assumption	Process error $\sim N(0, \tau^2)$	τ =0.182 is a median process error CV in 2023 BSSPM	Reference scenario (1)
R2	Auto-correlated log-normal assumption	$e_t = \rho\, e_{t-1} + (1- \rho^2)^{1/2}\, u_t$ $u_t \sim N(0, \tau^2)$	τ =0.182 ρ = 0.2	Reference scenario (2)
S3	IID log-normal assumption with a mean adjustment	Process error $\sim N(-0.15, \tau^2)$	τ =0.182	Sensitivity scenario (1) "Climate impacts cause negative productivity" scenario
S4	IID log-normal assumption with a mean adjustment	Process error $\sim N(0.1, \tau^2)$	τ =0.182	Sensitivity scenario (2) "Climate impacts cause positive productivity" scenario

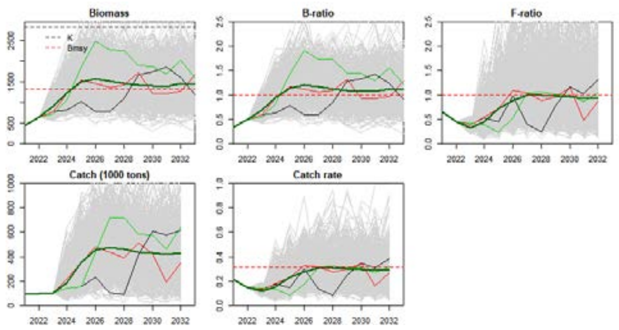
4. Performance measures for evaluating HCRs (tables and figures are only for illustrative purposes)

1) Time series plots for Biomass, Bratio, Fratio, catch and catch rate. Time trajectories of several key performance indicators for HCR0, HCR1. The thick line is the median of 1000 simulations, and the three colored lines in each plot show example trajectories. (add lines for 10% lower bound)

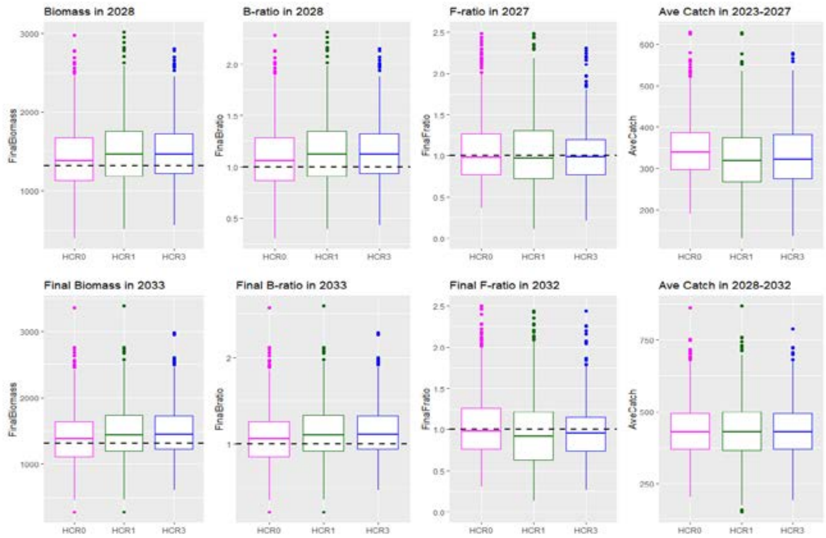
HCR0



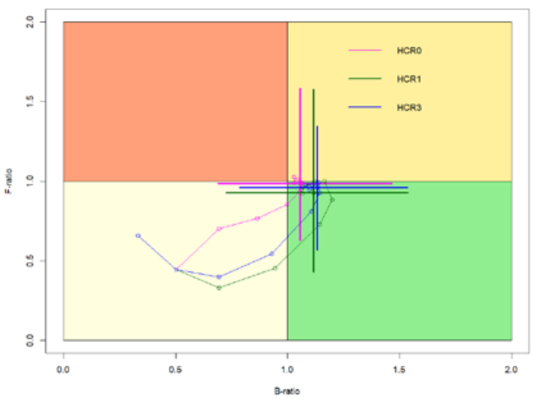
HCR1



2) Box plots of performance indicators for biomass, B-ratio, F-ratio and Average catch. Note that, in this example plot, no restriction was placed on the maximum value of change in consecutive years.



3) Trade-off plots 1: Time trajectories of B- and F-ratios for HCR0 and HCR1 from 2024 to 2033. Each cross refers to the 80% interval for both indices in 2033.



4) Trade-off plots 2: Bratio against the average catch

5) Tables for Pr(B > Btar), Pr(B < Blim) and Pr(F > Flim) relevant to the objectives (a) and (b) with the default reference points (Btar=Bmsy, Blim=0.35, and Flim=1.35Fmsy). Note that all the probabilities related to the biomass is calculated for the biomass at the beginning of year.

(a) Recovery of the stock:

i. Probabilities that the stock status is above B_{tar} at 1, 2,…, 10years after the HCR is implemented;

ii. Probabilities that the stock status is in Kobe green quadrant at 1, 2,…, 10 years after the HCR is implemented.

(b) Avoiding unsustainable state of the stock:

i. Probabilities that the stock status is below B_{lim} at 1, 2, …, 10 years after the HCR is implemented;

ii. Probabilities that the fishing mortality exceeds F_{lim} at 1, 2, …, 10 years after the HCR is implemented.

(c) Achieving high and stable catch:

i. Average catch by 1-5, 6-10 years after the HCR is implemented;

ii. Annual catch variation by 5, 10 years after the HCR is implemented;

iii. Probabilities that the TAC hits the predetermined maximum change by 5, 10 years after the HCR is implemented.

Pr(B > Btar)

Year	HCR0	HCR1
2021	0.000	0.000
2022	0.000	0.000
2023	0.024	0.024
2024	0.282	0.396
2025	0.487	0.665
2026	0.554	0.710
2027	0.573	0.706
2028	0.567	0.633
2029	0.539	0.588
2030	0.518	0.575
2031	0.521	0.578
2032	0.566	0.618
2033	0.563	0.620

P(Kobe green)

Year	HCR0	HCR1
2021	0.000	0.000
2022	0.000	0.000
2023	0.024	0.024
2024	0.267	0.380
2025	0.393	0.539
2026	0.374	0.467
2027	0.343	0.396
2028	0.351	0.365
2029	0.319	0.348
2030	0.295	0.334
2031	0.334	0.372
2032	0.370	0.415

Pr(B < Blim)

Year	HCR0	HCR1
2021	1.000	1.000
2022	0.000	0.000
2023	0.000	0.000
2024	0.000	0.000
2025	0.000	0.000
2026	0.002	0.001
2027	0.001	0.000
2028	0.001	0.000
2029	0.000	0.002
2030	0.003	0.003
2031	0.002	0.001
2032	0.002	0.001
2033	0.003	0.001

Pr(F > Flim)

Year	HCR0	HCR1
2021	0.000	0.000
2022	0.000	0.000
2023	0.000	0.000
2024	0.023	0.008
2025	0.062	0.051
2026	0.109	0.119
2027	0.127	0.163
2028	0.138	0.168
2029	0.135	0.145
2030	0.140	0.142
2031	0.134	0.132
2032	0.127	0.123

TAC

Year	HCR0	HCR1
2021	92	92
2022	98	98
2023	205	103
2024	289	215
2025	368	364
2026	419	454
2027	446	481
2028	444	463
2029	439	438
2030	437	426
2031	428	413
2032	433	423

5. Implementation schedule

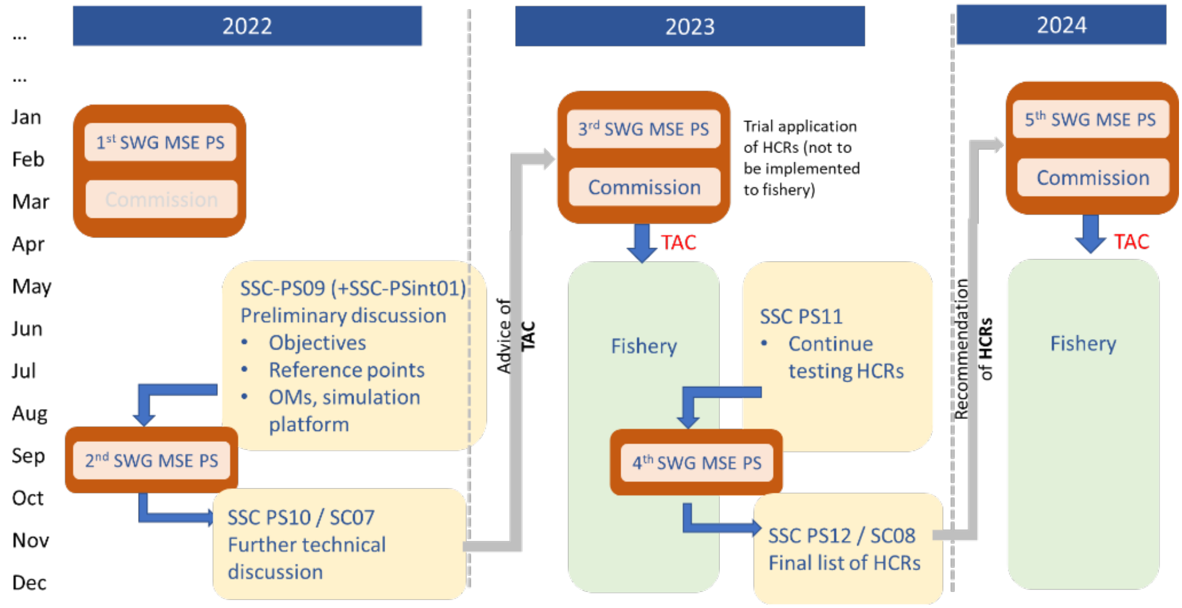


Figure 2. A planned implementation schedule.