North Pacific Fisheries Commission

NPFC-2021-SSC PS08-Final Report

8th Meeting of the Small Scientific Committee on Pacific Saury REPORT

10-14 December 2021

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North Pacific Fisheries Commission
8th Meeting of the Small Scientific Committee on Pacific Saury

10-14 December 2021
WebEx

REPORT

Agenda Item 1. Opening of the Meeting

1. The 8th Meeting of the Small Scientific Committee on Pacific Saury (SSC PS08) took place in the format of video conferencing via WebEx, and was attended by Members from Canada, China, Japan, the Republic of Korea, the Russian Federation, Chinese Taipei, the United States of America, and Vanuatu. Dr. Larry Jacobson participated as an invited expert.

2. The meeting was opened by Dr. Toshihide Kitakado (Japan), the SSC PS Chair, who welcomed the participants. The Science Manager, Dr. Aleksandr Zavolokin, outlined the procedures for the meeting. Mr. Alex Meyer was selected as rapporteur.

Agenda Item 2. Adoption of Agenda

3. The agenda was adopted without revision (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 PS07 meeting

4. The Chair presented the outcomes and recommendations from the SSC PS07 meeting.

3.2 COM06 meeting and CMM 2021-08

5. The Science Manager presented the outcomes from the sixth Commission meeting and an overview of Conservation and Management Measure (CMM) 2021-08 For Pacific Saury.

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

6. The SSC PS reviewed the Terms of References of the SSC PS and determined that no revisions are currently necessary.

4.2 CPUE Standardization Protocol

7. The SSC PS reviewed the CPUE Standardization Protocol and determined that no revisions are currently necessary.

4.3 Stock Assessment Protocol

8. The SSC PS reviewed the Stock Assessment Protocol and determined that no revisions are currently necessary.

Agenda Item 5. Member's fishery status including 2021 fishery

9. The Science Manager presented the cumulative catch of Pacific saury as of 27 November in 2020 and 2021. In 2021, the total catch in the Convention Area was 89,494 tons. Preliminary catches in the exclusive economic zones (EEZs) of Russia and Japan were 36 tons and 902 tons respectively. In 2020, Members' total catch in the Convention Area over the same period was 122, 595 tons.

10. China presented its fisheries activities until 13 November in 2021 (NPFC-2021-SSC PS08-IP05). The preliminary reported catch was 31,859 tons, a decrease of 64.7% from the total reported catch in 2018. The nominal CPUE of the Chinese fishery was 7.22 tons/vessel/day. The number of vessels was 66.

11. Japan presented its fisheries status in 2021 (NPFC-2021-SSC PS08-IP04). 124 fishing vessels have been registered, 4 fewer than the previous year. The Japanese total catch by November 30 was 17,899 tons (37,715 and 27,197 in 2019 and 2020, respectively). Nominal CPUE by November 30 showed a continuous decrease since 2018. It has decreased 16.5% from the previous year, and was the lowest since 2000. Because Pacific saury have hardly been found in the EEZ in 2021, 95.0% of the catch occurred in the high seas. This proportion is extraordinarily high compared with recent years (49.0% and 59.0% in 2019 and 2020, respectively). Japanese annual catch in 2021 will be the lowest historically since 1950.

12. Korea presented its fisheries activities (NPFC-2021-SSC PS08-IP06). The Korean fishing vessels caught 4,346 tons of Pacific saury as of November 2021, which was a historical low. There has been a gradual decrease in the number of Korean vessels operating in the Convention Area, and just 10 vessels operated in 2020 and 2021 respectively. Typically, the Pacific saury catch of Korean fisheries has shown two modes, in spring and autumn, but in 2021, there appeared to be a faint mode in autumn. The nominal CPUE from June to November 2021 was 2.67 tons/haul, which was the lowest level since 2001. The main fishing ground of the Korean vessels was at 43ºN, 159ºE, indicating that the vessels have shifted further to the northeast in

2021 compared to 2020.

13. Russia presented its fisheries activities (NPFC-2021-SSC PS08-IP01). Russian annual catch for Pacific saury was 753 tons in 2020, and 608 tons in 2021, the lowest since 1991. Two fishing vessels participated in fishery for Pacific saury in 2020 and three vessels in 2021, and those were the lowest numbers of active vessels in the last 30 years. Commercial concentrations of Pacific saury were of lower density in summer and early autumn 2020 compared to 2021. In 2020, catches increased substantially in autumn, and in 2021, the seasonal increase in catches was lower. Fishing grounds were located further east in 2020 compared to previous years, and were distributed even further to the east in 2021. Average CPUE values (catch per day per vessel) were 9.9 tons in 2020 and (preliminarily) 4.2 tons in 2021, which is the lowest in the last 30 years.

14. Chinese Taipei presented its fisheries activities (NPFC-2021-SSC PS08-IP02). The catch was 104,405 tons in 2017 and increased to around 180,000 tons in 2018 then declined to 56,662 tons in 2020. In 2021, fishing vessels began operations in fishing grounds earlier than previous years. The preliminary catch in 2021 was 33,258 tons and fishing occurred more northerly than in 2020, and the nominal CPUE from June to November was about 1 tons/haul in 2021.

15. Vanuatu presented its fisheries activities (NPFC-2021-SSC PS08-IP03). The Pacific saury fishery was first developed in 2004 with 16 authorized fishing vessels during 2004 through 2021. The active fishing vessel has remained the same at 4 since 2015. The estimated catch and nominal CPUE in 2021 were 1,270 tons and 5.3 tons/vessel/day, which were the lowest records in recent years. The fishing grounds in 2021 were mainly to the west of 165°E longitude.

16. The SSC PS noted common results in the 2021 fisheries among the six members as follows: i) there has been a sharp decline in catch and nominal CPUE from 2020 to 2021, continuing the declining trend in recent years; ii) the spatial distribution of the fishing grounds has also shifted, with fishing grounds shifting to the east and a higher proportion of catch occurring in the Convention Area compared to previous years; iii) there was a reduced proportion of catch in autumn, which has been the main fishing season, compared to past years; and iv) an increased proportion of catch in early summer was observed.

17. The SSC PS noted unusual fishing activity by some Members east of 170°E in June and July 2021. According to CMM 2021-08 for Pacific Saury, Members of the Commission are encouraged to take measures for fishing vessels flying their flags to refrain from fishing for Pacific saury in the areas east of 170°E from June to July. The SSC PS requested those

Members to provide information on the catch and size of Pacific saury from that area.

18. The SSC PS noted that some Members' fisheries might have been affected by COVID-19 in 2021.

19. The SSC PS agreed to update the template for the submission of each Member's fisheries status information by adding new charts showing relative accumulated catch and relative seasonal catch (available on the website).

Agenda Item 6. Fishery-independent abundance indices

6.1 Review of any updates and progress

20. No updates were provided.

6.2 Review of plans of future biomass surveys

21. Japan presented the plans for its 2022 biomass survey (NPFC-2021-SSC PS08-IP07). Japan plans to conduct its biomass survey with the usual area coverage in 2022. There has been an eastward shift of the center of the distribution of age-0 fish in the survey area in recent years. However, restrictions on the mobility of Japan's research vessels and the need to continue to survey the western part of the survey area make it difficult for Japan to survey the area east of 165°W. In light of this, additional surveys by other Members for the eastern area would be fruitful.

22. Japan presented information about a biomass survey it conducted in 2012 covering the area from 165°W to 145°W. The survey was conducted with the *Hokuho-maru*, the research vessel used to conduct the annual Japanese biomass survey, in the area west of 165°W and the *Kaiyo-maru*, a special research vessel which conducted a survey in the area from 165°W to 145°W. The *Kaiyo-maru* is approximately four times the size of the *Hokuho-maru* and uses nets that are about twice as large. The biomass of Pacific saury in the area east of 165°W was estimated to be 2.4% of the area west of 165°W during 2012 and the proportion of age-0 fish was very high. Japan therefore had considered the importance of surveys east of 165°W to be low in 2012.

23. The SSC PS noted that observed fishing effort east of 170°E during 2021 indicates that the distribution patterns may have shifted. Japan noted that it is difficult to conduct the same survey in the area east of 165°W in the future due to logistical issues.

6.3 Recommendations for future work

24. The SSC PS suggested that Japan consider increasing the distance between transects so as to expand the area covered by its biomass survey eastward, while recognizing that fuel and other mobility restrictions may make this unfeasible.

25. The SSC PS suggested that conducting a biomass survey later during the fishing season may yield useful information about Pacific saury on the eastern side of the survey area that may be able to better inform the stock assessment.

26. The SSC PS suggested that, as an experimental analysis, Japan explore using the VAST model, if possible, to extrapolate the results of the biomass survey beyond the easternmost survey boundary i) to examine the sensitivity of biomass estimates and trend to the area definition (questioning the appropriateness that the current east boundary is the same as the longitude of the easternmost track line) and ii) to investigate if the amount of Pacific saury might have increased recently. Japan replied that it was not positive about conducting such analysis for the following reason: an extrapolated estimation current VAST setting might lead to misleading results because fish distribution is not determined only by the environment that is currently considered but also by the oceanographic structures and mobility of the fish.

27. The SSC PS encouraged Japan to continue to conduct its biomass survey and Members to conduct research surveys or share data from existing research surveys that could complement the Japanese biomass survey and provide useful information for understanding the abundance, spatio-temporal distribution, and migration patterns of Pacific saury.

Agenda Item 7. Fishery-dependent abundance indices

7.1 Review of any updates and progress

28. Japan informed the SSC PS that Members have held intersessional discussions on the method of extracting the CPUE in the CPUE standardization.

29. Korea informed the SSC PS that it would reflect the intersessional discussion on CPUE standardization, including spatial heterogeneity, and submit the results at the next meeting.

7.2 Recommendations for future work

30. The SSC PS encouraged Members to continue engaging in communication on the CPUE standardization process to share each other’s skills and views.

Agenda Item 8. Biological and environmental information relevant to Pacific saury

8.1 Review of any updates and progress

31. Japan presented information on the geographic variation in feeding of Pacific saury in June and July in the North Pacific Ocean (NPFC-2021-SSC PS08-IP08). The main prey of Pacific saury were *Neocalanus plumchrus*, *N. cristatus*, *Calanus* and Euphausiids. Analysis of gut content showed that Pacific saury gut fullness is high when they feed on *Neocalanus* copepods. Prey availability might be higher in relatively cold water since *Neocalanus* copepods were mainly distributed in cold water in the northern part of the surveyed area. May to August is an important season for Pacific saury to rapidly increase their size by feeding on abundant *Neocalanus* copepods. This information might be useful for developing a more efficient and appropriate exploitation/management strategy of Pacific saury.

8.2 Recommendations for future work

32. The SSC PS encouraged Japan and other Members to conduct further analyses of the spatial distribution and abundance of Pacific saury and environmental conditions and to make any relevant information available to other Members.

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

9.1 Review of results and implications to management

33. Chinese Taipei presented an updated stock assessment for Pacific saury in the North Pacific Ocean using BSSPM (NPFC-2021-SSC PS08-WP01). The models estimate the lowest biomass level in 2020 (median B_{2020}/B_{MSY} = 0.43, 80 percentile range 0.27 – 0.66), followed by a slight increase in 2021 (median B_{2021}/B_{MSY} = 0.55, 80 percentile range 0.35 – 0.85). An increasing trend in the fishing mortality is estimated from 2004 to 2018 and the recent average fishing mortality is estimated to be below F_{MSY} (median F2018-2020/F_{MSY} = 0.94, 80 percentile range 0.48 – 1.90). It should be noted that the models estimate a slight decrease in the fishing mortality in 2020 (median F2020/F_{MSY} = 0.75, 80 percentile range 0.40 – 1.42). The ensemble MCMC results from the two base cases indicated that the 2020 stock status is likely within the yellow quadrant on the Kobe plot (Prob [B2020<B_{MSY} and F2020<F_{MSY}] = 71.56%).

34. China presented its Pacific saury stock assessment results (NPFC-2021-SSC PS08-WP02 (Rev. 1)). The estimated median B_{2020} from the two base case scenarios was 390,700 and 404,050 metric tons, respectively. The median B_{2020}/B_{MSY} and F_{2020}/F_{MSY} over the two base case scenarios were 0.33 and 0.99, respectively. Over two base case scenarios, large interannual variability was shown in biomass trajectory during the most recent years. A decreasing biomass trend was found in 2019 and 2020, followed by an increase in 2021. The probability of the population being in the red Kobe quadrant in 2020 was estimated to be around 48%.

35. Japan presented an updated stock assessment for Pacific saury in the North Pacific Ocean using

BSSPM (NPFC-2021-SSC PS08-WP03). The 2021 median depletion level was only 19.5% of the carrying capacity. B-ratio (B/B_{MSY}) and F-ratio (F/F_{MSY}) in 2020 were 0.339 and 1.033, respectively. B-ratio over 2019-2021 and F-ratio over 2018-2020 were 0.378 and 1.480 respectively. The probability of the population being in the green Kobe quadrant in 2020 was estimated to be nearly 0%, while that of being in the red Kobe quadrant was assessed to be around 54%. For population outlook, the projection results showed that increased catch compared to the current level may cause a severe decline in the population size.

36. The SSC PS reviewed the stock assessments presented by Members and aggregated the results, recognizing their similarities (Annex D).

9.2 Development of recommendations to the Commission to improve conservation and management

37. The SSC PS recommends that the SC consider and endorse the following rationale and approach in its scientific advice to the Commission:
   (a) The current annual TAC for 2021-2022 specified in CMM 2021-08 for Pacific saury (333,750 tons) is much larger than the TAC would be based on the F_{MSY} catch approach (B_{2021}*F_{MSY} = 192,804 tons) and the current biomass is much lower than B_{MSY}. Reducing F in the short term may increase the probability of achieving long-term sustainable use of Pacific saury (i.e. higher long-term catch closer to MSY of around 419,000 tons).
   (b) A harvest control rule (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.

9.3 Recommendations for future work

38. The SSC PS agreed that it may be useful to examine the temporal patterns of the process errors in the stock assessment models to investigate the potential link with environmental factors.

39. The SSC PS agreed to develop a Figure (or two) showing a map of the extent of the general distribution of the Pacific saury stock, the extent of the Japanese biomass survey, the general life history migration pattern of the species as it is currently understood, and the boundaries of Members' EEZs and the Convention Area.

Agenda Item 10. New stock assessment models

10.1 Review of any updates and progress

40. No updates were provided.

10.2 Data sharing protocol for new models

41. Discussion of the data sharing protocol for new models was deferred.

10.3 Recommendations for future work

42. The SSC PS agreed to continue the work to develop age-structured stock assessment models, and encouraged Members to prepare and submit specifications with preliminary results at the next SSC PS meeting.

Agenda Item 11. Toward setting of biological reference points (RPs) and development of Management Strategy Evaluation (MSE)

11.1 Joint SC-TCC-COM Small Working Group on MSE for Pacific saury

43. The Science Manager presented an update on the progress with setting up a joint SC-TCC-COM Small Working Group on Management Strategy Evaluation for Pacific saury (SWG MSE PS). The Commission endorsed the Terms of Reference of the SWG MSE PS and selected Dr. Toshihide Kitakado (Japan) and Mr. Justin Turple (Canada) as the co-Chairs of the SWG MSE PS. The 1st SWG MSE PS meeting will take place on 21-22 February 2022. The meeting agenda is available on the website.

11.2 Recommendations for future work

44. The SSC PS held initial discussions on possible approaches to developing harvest control rules. The SSC PS agreed to hold further discussions and develop recommendations for future work at its next meeting based on the outcomes of the 1st SWG MSE PS meeting.

Agenda Item 12. Review of the Work Plan of the SSC PS

45. The SSC PS reviewed the 2021-2025 SSC PS 5-Year Rolling Work Plan (NPFC-2021-SSC PS08-WP04).

Agenda Item 13. Other matters

13.1 Draft agenda and priority issues for next meeting

46. The Chair presented the agenda and priorities for the next meetings based on the SSC PS Work Plan. The priorities are to:
    (a) Review standardized CPUE up to 2021.
    (b) Review the Japanese fishery-independent survey results up to 2022.
    (c) Update BSSPM analyses and provide recommendations to the SC/Commission.
    (d) Review progress on new assessment models and finalize a set of models and specification.
    (e) Start discussion on development and evaluation of HCR as a short-term task.

47. The SSC PS recommends holding two 4-day formal SSC PS meetings in 2022 (30 August to 2

September and November or December) and intersessional SSC PS meetings. The SSC PS also recommends that the SWG MSE PS hold an intersessional meeting in 2022 to review the outcomes of the SSC PS09 meeting.

48. The SSC PS agreed to extend the deadline for the submission of working papers related to Members' CPUE standardization and the Japanese biomass survey estimates to the SSC PS09 meeting. The abovementioned papers must be submitted, at the latest, 10 days prior to the SSC PS09 meeting.

13.2 Invited expert

49. The SSC PS expressed its appreciation for the continued valuable contributions of the invited expert, Dr. Larry Jacobson. The SSC PS recommends that Dr. Jacobson be invited to the next SSC PS meetings.

13.3 Election of SSC PS Chair

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

13.4 Other matters

51. No other matters were discussed.

Agenda Item 14. Recommendations to the Scientific Committee

52. The SSC PS recommends the following to the SC:
    (a) Endorse the stock assessment report (Annex D).
    (b) Endorse the SSC PS Work Plan (NPFC-2021-SSC PS08-WP04).
    (c) Allocate funds for the participation of an invited expert in the next SSC PS meetings.
    (d) Select Dr. Toshihide Kitakado (Japan) to serve as Chair of the SSC PS.
    (e) Hold two 4-day formal meetings (30 August to 2 September and November or December), and intersessional meetings of the SSC PS in 2022.
    (f) Consider and endorse the rationale and approach described in paragraph 37 in its scientific advice to the Commission.

53. The SSC PS recommends that the SWG MSE PS hold an intersessional meeting in 2022 to review the outcomes of the SSC PS09 meeting.

Agenda Item 15. Adoption of the Report

54. The SSC PS08 Report was adopted by consensus.

Agenda Item 16. Close of the Meeting

55. The meeting closed at 13:55 on 14 December 2021, Tokyo time.

Annexes:

Annex A – Agenda

Annex B – List of Documents

Annex C – List of Participants

Annex D – Stock Assessment Report for Pacific Saury

Annex A

Agenda

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- 3.1 SSC PS07 meeting
- 3.2 COM06 meeting and CMM 2021-08

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

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Agenda Item 6. Fishery-independent abundance indices
- 6.1 Review of any updates and progress
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Agenda Item 10. New stock assessment models
- 10.1 Review of any updates and progress
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Annex B

List of Documents

MEETING INFORMATION PAPERS

Symbol	Title
NPFC-2021-SC06-MIP01	Meeting Information
NPFC-2021-SSC PS08-MIP02	Provisional Agenda
NPFC-2021-SSC PS08-MIP03	Annotated Indicative Schedule

REFERENCE DOCUMENTS

Symbol	Title
	COM06 Report
	Terms of Reference for the Small Scientific Committee on Pacific Saury (SSC PS)
	CPUE Standardization Protocol for Pacific Saury
	Stock assessment protocol for Pacific Saury
	SSC PS07 Report

WORKING PAPERS

Symbol	Title
NPFC-2021-SSC PS08-WP01	Updated stock assessment of Pacific saury (*Cololabis saira*) in the Western North Pacific Ocean through 2021
NPFC-2021-SSC PS08-WP02 (Rev. 1)	Updates of stock assessment for Pacific saury in the North Pacific Ocean up to 2020
NPFC-2021-SSC PS08-WP03	2021 updates on Pacific saury stock assessment in the North Pacific Ocean using Bayesian state-space production models
NPFC-2021-SSC PS08-WP04	Five-Year Work Plan of the Small Scientific Committee on Pacific Saury (SSC PS)

INFORMATION PAPERS

Symbol	Title
NPFC-2021-SSC PS08-IP01	Fishery for Pacific saury by Russian vessels in 2020
NPFC-2021-SSC PS08-IP02	Fishery status for Pacific saury, Chinese Taipei
NPFC-2021-SSC PS08-IP03	Fishery Status for Pacific saury, Vanuatu

NPFC-2021-SSC PS08-IP04	Pacific saury fishing condition in Japan in 2021 (until November)
NPFC-2021-SSC PS08-IP05	Fishery status including 2021 fishery, China
NPFC-2021-SSC PS08-IP06	Korean Stick-held dip net Fishery Status up to 2021
NPFC-2021-SSC PS08-IP07	Plans for biomass survey by Japan in 2022 and future
NPFC-2021-SSC PS08-IP08	Geographic variation in feeding of Pacific saury *Cololabis saira* in June and July in the North Pacific Ocean

Annex C

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Annex D

Stock Assessment Report for Pacific Saury

Abstract:
This report presents the results of stock assessment of Pacific saury updated at the 8th Small Scientific Committee on Pacific saury held virtually during December 10-14, 2021.

EXECUTIVE SUMMARY

Data

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 180º 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.

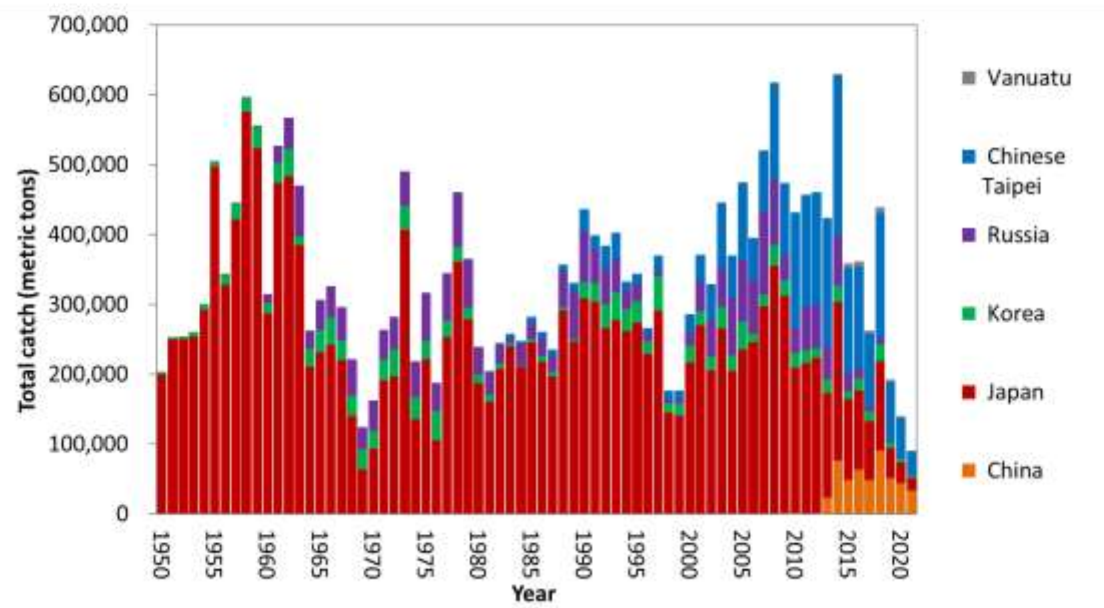


Figure 1. Time series of catch by Member during 1950-2021. The catch data for 1950-1979 are shown but not used in stock assessment modeling. 2021 catch data are preliminary (as of 27 November 2021).

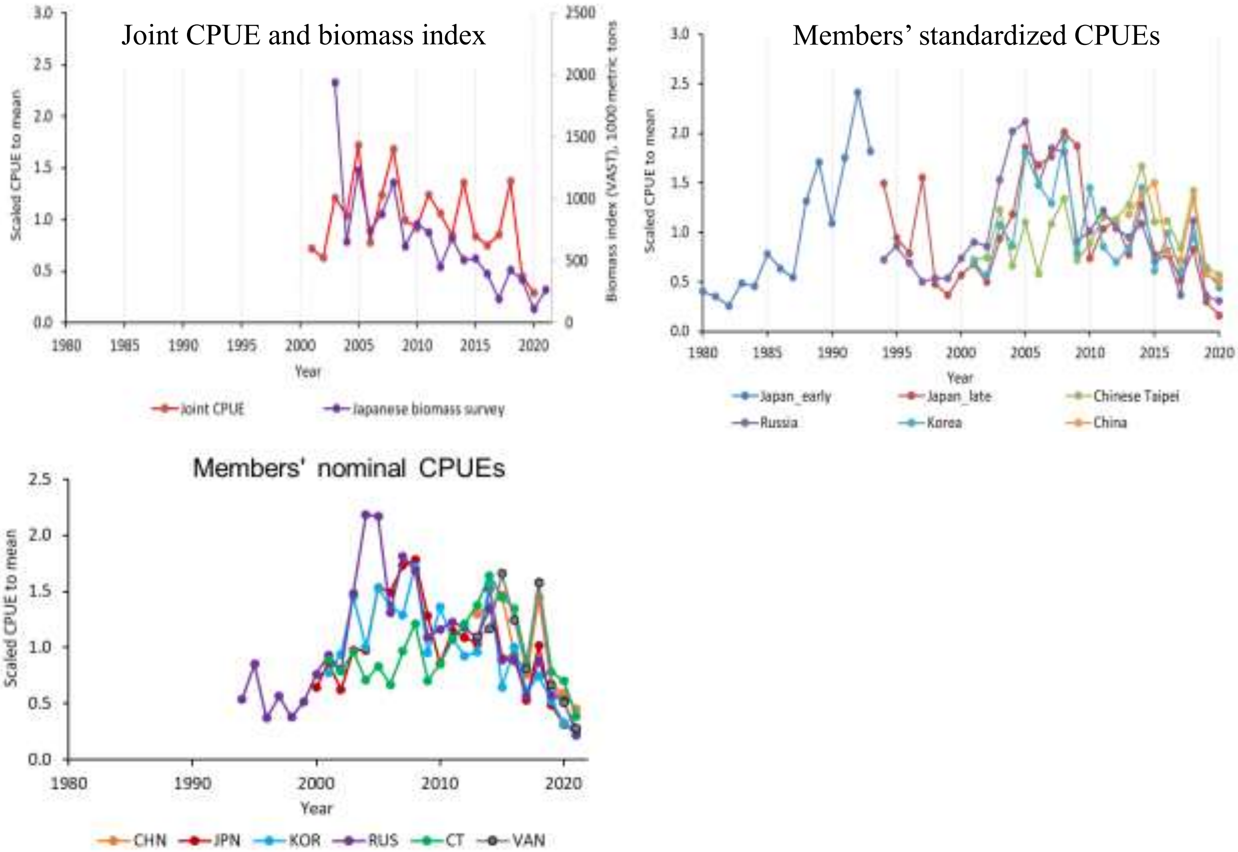


Figure 2. Time series of Japanese survey biomass index and joint, standardized and nominal CPUE indices. The nominal CPUE data are shown but not used in stock assessment modeling. 2021 nominal CPUEs are preliminary (as of November 2021).

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 1980-2021. 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 G, SSC PS07 report for more details). The two base case scenarios differ in using Japanese early CPUE (base case B1) or not (base case B2). Time-varying catchability for Japanese CPUE was assumed in B1 to account for potential increases in catchability between 1980 and 1994. A higher weight was given to the Japanese biomass survey estimates than to Members' CPUEs. 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 similarity among Members' results. Therefore, outcomes of MCMC runs were aggregated over the 6 models (2 base case models x 3 Members). 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) exploitation 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 values are presented.

	Median	Lower10%	Upper10%	Median_CHN	Median_JPN	Median_CT
C_2020 (10000 t)	13.968	13.968	13.968	13.968	13.968	13.968
AveC_2018_2020 (10000 t)	25.704	25.704	25.704	25.704	25.704	25.704
AveF_2018_2020	0.435	0.180	0.743	0.482	0.515	0.298
F_2020	0.322	0.144	0.590	0.353	0.355	0.253
FMSY	0.352	0.185	0.559	0.370	0.357	0.334
MSY	41.901	33.956	56.291	43.358	40.529	42.145
F_2020/FMSY	0.938	0.523	1.529	0.986	1.033	0.794
AveF_2018_2020/FMSY	1.247	0.647	1.967	1.334	1.480	0.936
K (10000 t)	255.121	157.185	517.839	253.100	242.055	268.400
B_2020 (10000 t)	43.415	23.680	96.706	39.625	39.345	55.200
B_2021 (10000 t)	54.774	30.260	122.400	51.790	47.993	70.355
AveB_2019_2021 (10000 t)	50.173	28.629	115.984	46.317	43.323	67.935
BMSY (10000 t)	120.784	76.740	236.751	119.600	114.410	127.700
BMSY/K	0.465	0.389	0.577	0.461	0.463	0.471
B_2020/K	0.175	0.099	0.275	0.159	0.161	0.208
B_2021/K	0.223	0.123	0.353	0.209	0.195	0.265
AveB_2019_2021/K	0.207	0.120	0.319	0.191	0.179	0.255
B_2020/BMSY	0.361	0.218	0.587	0.327	0.339	0.428
B_2021/BMSY	0.463	0.264	0.765	0.432	0.412	0.550
AveB_2019_2021/BMSY	0.427	0.260	0.693	0.390	0.378	0.528

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	92.275	0.258	0.738	0.777	0.353
1981	98.031	0.208	0.803	0.617	0.384
1982	108.000	0.227	0.899	0.663	0.431
1983	116.000	0.222	0.982	0.640	0.468
1984	121.499	0.203	1.036	0.580	0.494
1985	130.400	0.216	1.113	0.616	0.530
1986	131.400	0.198	1.122	0.565	0.537
1987	135.851	0.173	1.160	0.492	0.555
1988	151.300	0.236	1.285	0.672	0.616
1989	150.201	0.220	1.266	0.632	0.610
1990	148.400	0.294	1.242	0.847	0.597
1991	141.800	0.281	1.186	0.817	0.570
1992	139.400	0.275	1.157	0.809	0.555
1993	131.900	0.305	1.093	0.899	0.525
1994	122.000	0.273	1.020	0.803	0.490
1995	113.191	0.304	0.934	0.906	0.448
1996	100.900	0.264	0.823	0.797	0.395
1997	98.680	0.375	0.794	1.146	0.381
1998	78.871	0.224	0.631	0.681	0.302
1999	83.925	0.210	0.669	0.638	0.319
2000	103.363	0.277	0.830	0.835	0.395
2001	116.200	0.319	0.949	0.945	0.454
2002	129.649	0.253	1.078	0.740	0.517
2003	209.600	0.212	1.820	0.596	0.889
2004	150.700	0.245	1.265	0.713	0.618
2005	197.277	0.240	1.690	0.686	0.822
2006	162.100	0.243	1.356	0.709	0.666
2007	178.800	0.291	1.519	0.835	0.743
2008	190.100	0.325	1.641	0.918	0.797
2009	133.642	0.353	1.116	1.035	0.547
2010	137.200	0.313	1.157	0.909	0.565
2011	130.517	0.350	1.102	1.013	0.538
2012	108.700	0.424	0.915	1.229	0.448
2013	116.996	0.362	0.993	1.043	0.487
2014	112.233	0.561	0.964	1.589	0.473
2015	89.430	0.401	0.760	1.153	0.372
2016	76.115	0.475	0.641	1.378	0.314
2017	56.540	0.464	0.473	1.352	0.231
2018	73.870	0.594	0.631	1.690	0.308
2019	52.106	0.369	0.438	1.072	0.213
2020	43.415	0.322	0.361	0.938	0.175
2021	54.774		0.463		0.223

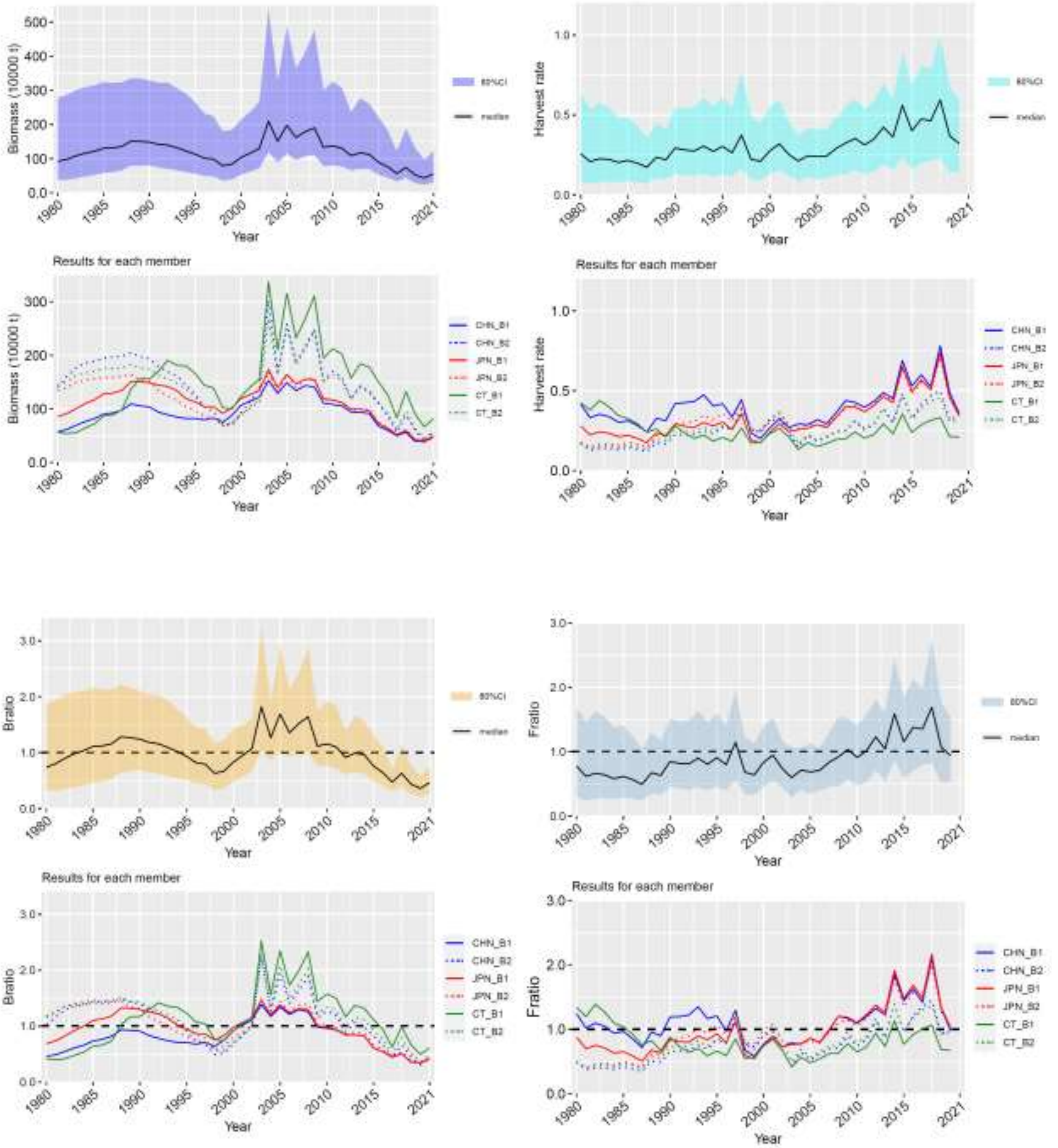


Figure 3. Time series of median estimated values of six runs for biomass, harvest rate, B-ratio, F-ratio and depletion level relative to K. The solid and shaded lines correspond to B1 and B2, respectively.

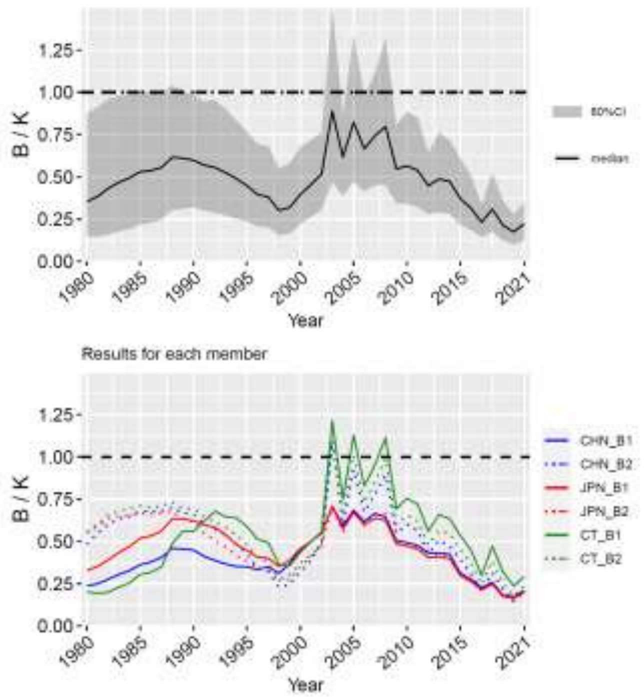


Figure 3 (Continued).

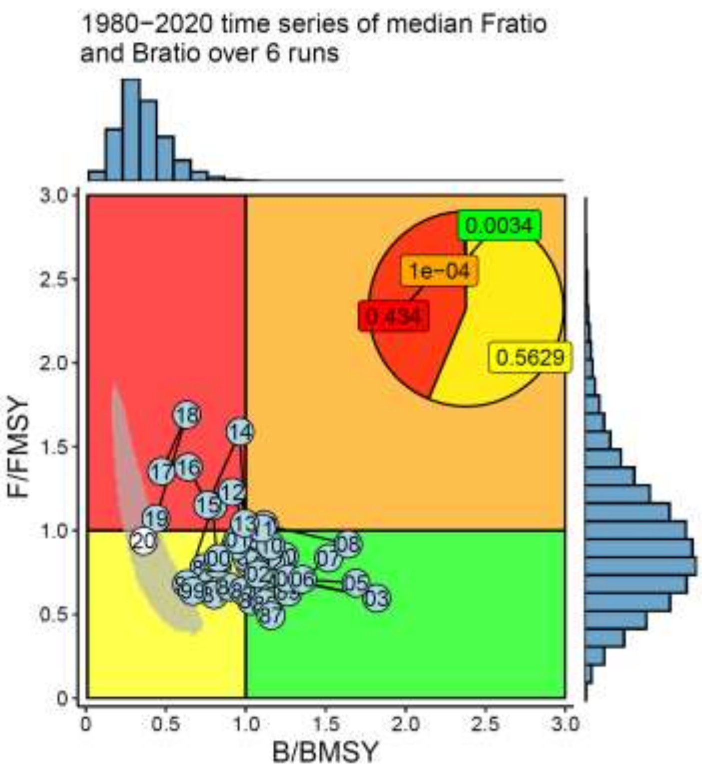


Figure 4. Kobe plot with time trajectory. The data are aggregated across 6 model results (2 base-case models by 3 Members).

Nominal CPUE trends and standardized CPUEs used in assessment modeling were similar (Figure 2). Preliminary catch (around 90,000 mt as of 27 November) and preliminary nominal CPUE in 2021 for each Member were at the lowest levels historically. CPUE declines more slowly than stock biomass as demonstrated in all BSSPM results for Pacific saury. Thus, the decline in stock biomass was probably greater than the decline in CPUE.

The Japanese fishery-independent survey is important in Pacific saury stock assessments. However, sampling did not cover the traditional survey area outside the 13ºC isotherm and east of 170º W in 2020, and the area in the easternmost and a part of the second easternmost lines in 2021. The SSC PS07 reviewed the result from VAST model to extrapolate over the unsampled area. VAST model estimates were similar to survey swept-area-biomass in recent years but appeared less accurate for early years when stock biomass was highest. The VAST model estimate for Pacific saury biomass index was 110 thousand mt (CV 158%, 95% CI 20-942 thousand mt) in 2020 and 266 thousand mt (CV 33%, 95% CI 151-518 thousand mt) in 2021. The SSC PS07 endorsed the use of the VAST point estimates with their uncertainty in the BSSPM stock assessment instead of the original swept-area biomass index.

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.

Current stock condition

Results of 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. Exploitation rates were increasing slowly since 2005 except for 2019. The results also indicated that B was below B_{MSY} (median average B/B_{MSY} during 2019-2021 = 0.427, 80%CI=0.260-0.693) and F was above F_{MSY} (average F/F_{MSY} during 2018-2020 = 1.247, 80%CI= 0.647-1.967). The results further indicated that stock biomass fell to the lowest value since 1980 in 2020 (median B/B_{MSY} = 0.361, 80%CI=0.218-0.587) and has been still at a historically low level in recent years (2019-2021). Information of the nominal CPUE series further indicated that Pacific saury stock biomass has likely been near a record low level in 2021.

HCR and reference points have not yet been established for Pacific saury although an HCR is needed and research is expected to begin this year. The Commission used F_{MSY} catch in place of an HCR to set the TAC for 2020 (TAC = F_{MSY} x Biomass). According to special comment #4 in the 2020 stock assessment "the Fmsy catch approach resulted in a TAC for 2020 that was substantially larger than the actual catch" and "TAC values could be calculated using the F_{MSY} estimate and historical biomass estimates from the BSSPM for comparison to actual catches".

Results from the suggested calculations for 2020 based on updated estimates differ because the 2020 F_{MSY} catch is only slightly larger than the observed catch (Figure 5). The difference is probably due to uncertainty in the scale of estimated biomass and trend for terminal years.

Based on the updated figures, F_{MSY} catch levels were higher than actual catch during 1980-2010, lower during 2011-2017 and 2021 and nearly the same during 2018-2019. In 2014 and 2018 catch was substantially higher than the F_{MSY} catch level. Thus, biomass was relatively high prior to 2011 while catches were less than F_{MSY} catch and biomass declined to a historical low during 2011-2021 while catches were usually greater than or equal to F_{MSY} catch. Based on these results, catches generally exceeded the F_{MSY} catch level and contributed to the recent decline in biomass.

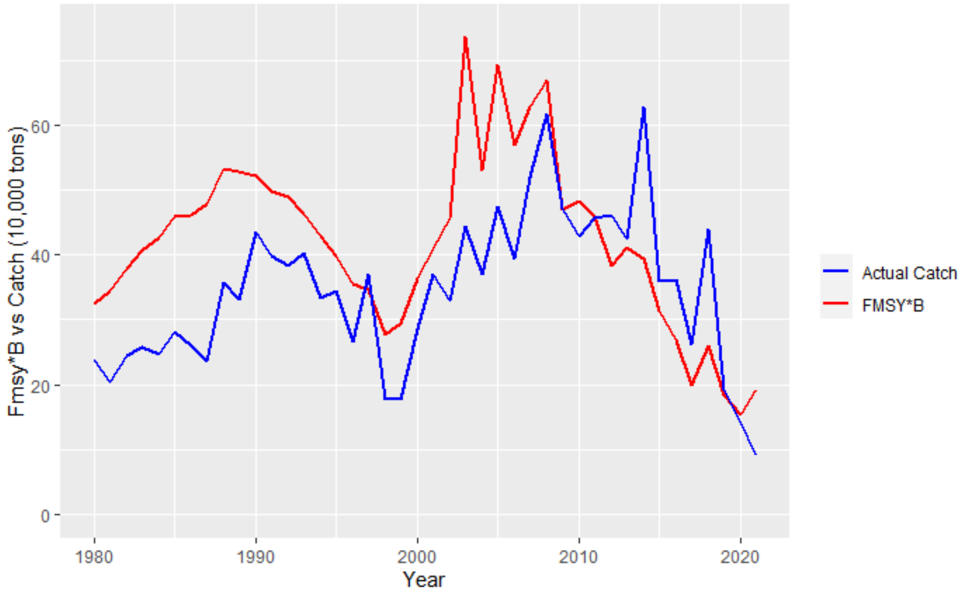


Figure 5. Median time series of F_{MSY}*B and the actual catch. Note that the catch in 2021 is a preliminary number as of Nov 27, 2021.

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. The estimates of a nonlinear parameter in the assessment model support this modeling decision.
2) Retrospective analyses have shown that BSSPM model projections are not suitable for use by managers and they have therefore been omitted (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. However, the Japanese assessment used projections to illustrate the response of a hypothetical stock to various levels of harvest during 2022-2026. The results indicate that substantial changes in stock size may occur over five years if harvest levels are held steady at levels higher or lower than recent levels but should be interpreted carefully. They illustrate potential effects of various harvest levels for a hypothetical stock similar to Pacific saury under idealized and constant conditions but little or no information about actual stock conditions that may develop in coming years. Importantly, they ignore unfavorable recent environmental conditions and random variation in surplus production that is common in the actual stock.
3) The 2020 biomass index from the Japanese survey has large uncertainties due to incomplete survey coverage.
4) 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. However 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.
5) Any new HCR for Pacific saury should include concrete definitions of overfishing (F too high) and

overfished stock status (biomass too low) based on clearly defined reference points (targets and limits). The Commission may consider what actions it will take if overfishing or overfished stock status occur.

6) New HCRs should be evaluated in future work. For example, TAC calculations such as F_{MSY} catch ($C=F_{MSY} \times B$) may be sensitive to uncertainty in the scale of the biomass estimates from models with process errors, prior assumptions and other features such as those in the BSSPM. They are sensitive to uncertainty in trend during the terminal years. It will be useful to consider index based HCR approaches for Pacific saury such as those that use biomass trend information from a survey or model and catch data (e.g. the AIM index method, see https://nmfs-fish-tools.github.io/AIM/).

7) In the next assessment, the geographic area to which data and assessment estimates apply (Convention Area, Members' EEZ or both) should be described.

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 30 thousand tons were recorded in 2008 and 2020, 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 2.4 thousand tons in 2019 and about 750 tons in 2020.

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 only 224 kg of saury were captured by Canadian commercial fisheries over 17 years from 1997-2013 (Wade and Curtis 2015). 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).

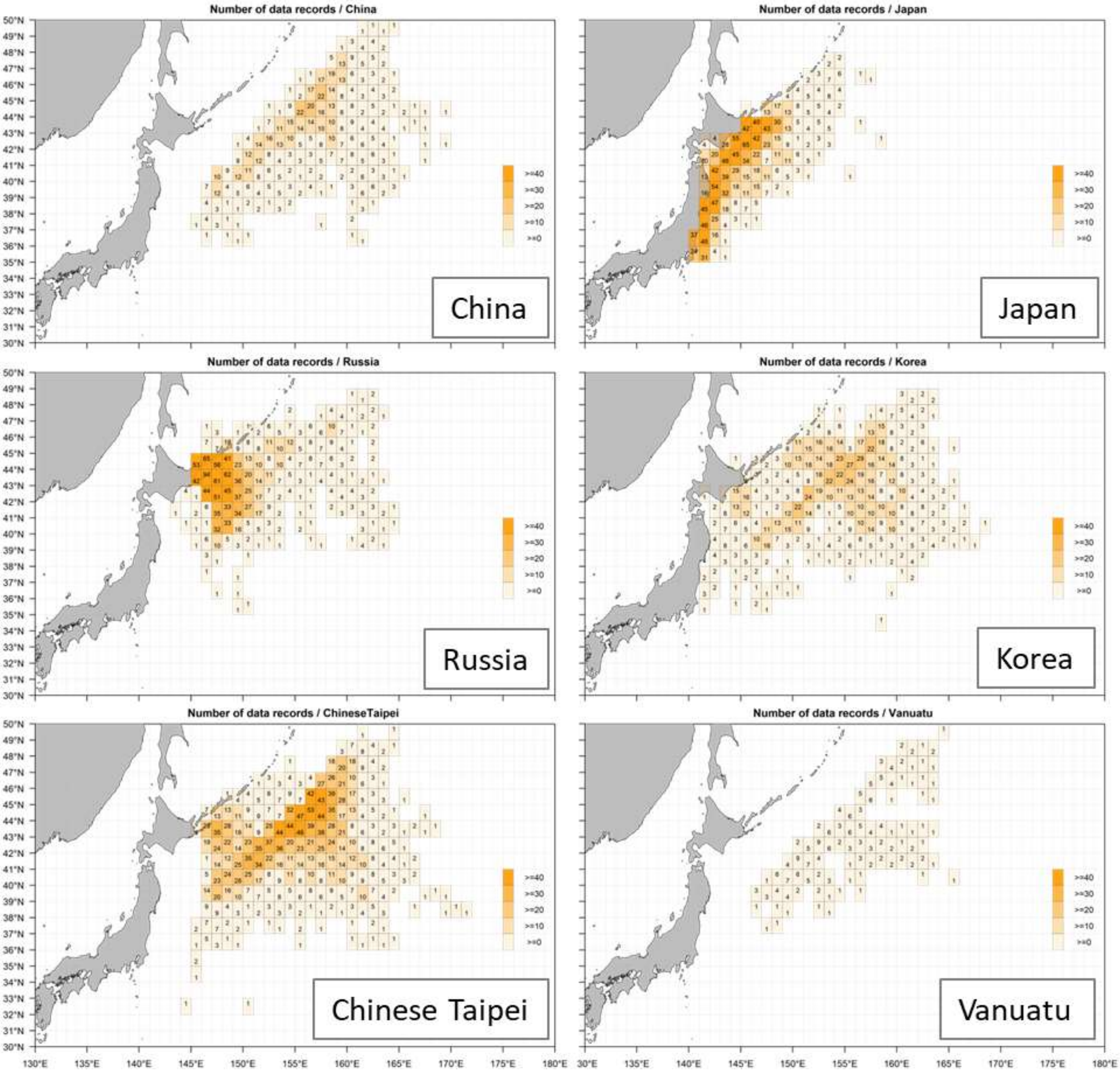


Figure 1. Main fishing grounds for Pacific saury by fishing members in the western North Pacific Ocean during 1994-2017. The legend shows the number of data records. This figure is based on the data shared by the Members for the development of a joint CPUE index (NPFC-2018-TWG PSSA03-WP02, NPFC-2018-TWG PSSA03-WP03, NPFC-2018-TWG PSSA03-WP04, NPFC-2018-TWG PSSA03-WP06b, NPFC-2018-TWG PSSA03-WP08, and NPFC-2018-TWG PSSA03-WP12; available at www.npfc.int).

2.2 Catch records

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

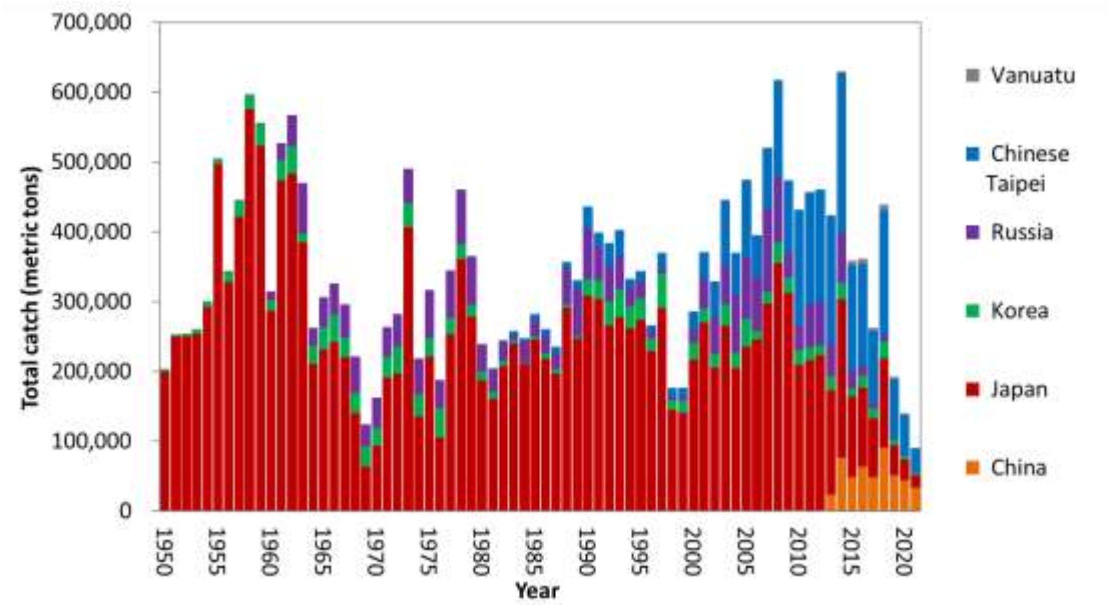


Figure 2. Time series of catch by Member during 1950-2021. The catch data for 1950-1979 are shown but not used in stock assessment modeling. 2021 catch data are preliminary (as of 27 November 2021).

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 1980-2021. 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 G, SSC PS07 report for more details). The two base case scenarios differ in using Japanese early CPUE (base case B1) or not (base case B2). Time-varying catchability for Japanese CPUE was assumed in B1 to account for potential increases in catchability between 1980 and 1994. A higher weight was given to the Japanese biomass survey estimates than to Members' CPUEs. 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

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

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^2_f: the observation error in year *t* for biomass index *f*

For the estimation of parameters, Bayesian methods were used with different own preferred assumption 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-2020-SSC PS06-WP08 and NPFC-2020-SSC PS06-WP10; for the non-uniform priors used in Chinese Taipei, see document NPFC-2020-SSC PS06-WP17.

3.2 Agreed scenarios

Table 1. Definition of scenarios

	Base case (B1)	**Base case (B2)**	**Sensitivity case (S1)**	**Sensitivity case (S2)**
Initial year	1980	Same as left	Same as left	Same as left
Biomass survey	$I_{t,bio} = q_{bio}\, B_t e^{v_{t,bio}}$ $v_{t,bio} \sim N(0, cv_t^2 + \sigma_{bio}^2)$ q_{bio} ~ U(0,1) (2003-2021)	Same as left	Same as left	Same as left
CPUE	CHN(2013-2020) JPN_early(1980-1993, time-varying q) JPN_late(1994-2020) KOR(2001-2020) RUS(1994-2020) CT(2001-2020) $I_{t,f} = q_f B_t^b e^{v_{t,f}}$ $v_{t,f} \sim N(0, \sigma_f^2)$ $\sigma_f^2 = c \cdot (ave(cv_t^2) + \sigma_{bio}^2)$, where $ave(cv_t^2)$ is computed except for 2020 survey	CHN(2013-2020) JPN_late(1994-2020) KOR(2001-2020) RUS(1994-2020) CT(2001-2020)	JPN_early(1980-1993, time-varying q) Joint CPUE (2001-2020) $I_{t,joint} = q_{joint} B_t^b e^{v_{t,joint}}$ $v_{t,joint} \sim N(0, \sigma_{joint}^2)$ $\sigma_{joint}^2 = c \cdot (ave(cv_t^2) + \sigma_{bio}^2)$, where $ave(cv_t^2)$ is computed except for 2020 survey	Joint CPUE (2001-2020)
Variance component	Variances of logCPUEs are assumed to be common and 6 times of that of log biomass (c = 6)	Variances of logCPUEs are assumed to be common and 5 times of that of log biomass (c =5)	Same weight between biomass and joint CPUE	Same as left
Hyper-depletion/ stability	A common parameter for all fisheries but JPN_early, with a prior distribution, $b \sim U(0, 1)$ [b for JPN_early is fixed at 1]	A common parameter for all fisheries with a prior distribution, $b \sim U(0, 1)$	$b \sim U(0, 1)$	$b \sim U(0, 1)$
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

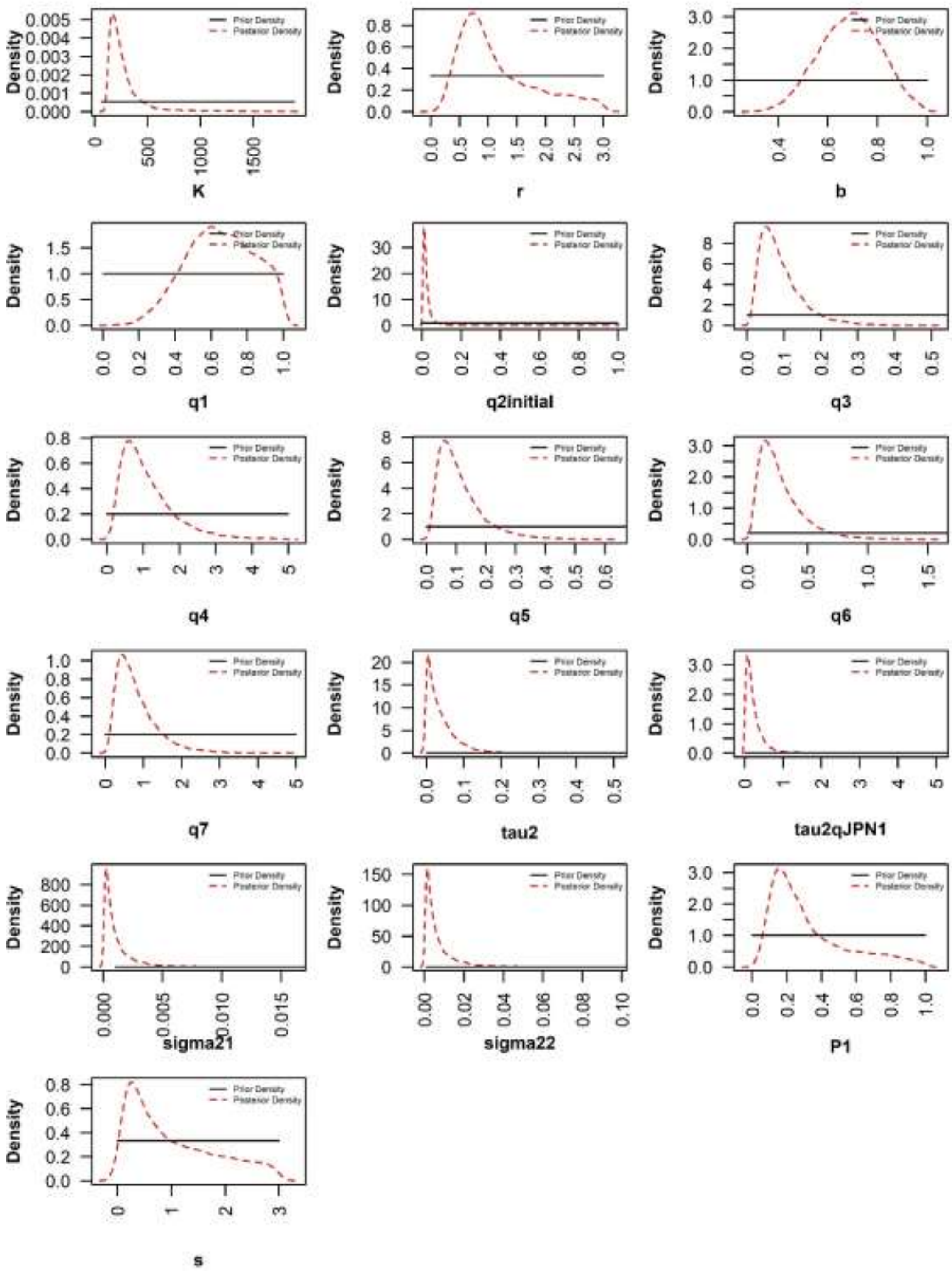
Symbol	Description
C_{2020}	Catch in 2020
$AveC_{2018\text{-}2020}$	Average catch for a recent period (2018–2020)
$AveF_{2018\text{-}2020}$	Average harvest rate for a recent period (2018–2020)
F_{2020}	Harvest rate in 2020
F_{MSY}	Annual harvest rate producing the maximum sustainable yield (MSY)
MSY	Equilibrium yield at F_{MSY}
F_{2020}/F_{MSY}	Average harvest rate in 2020 relative to F_{MSY}
$AveF_{2018\text{-}2020}/F_{MSY}$	Average harvest rate for a recent period (2018–2020) relative to F_{MSY}
K	Equilibrium unexploited biomass (carrying capacity)
B_{2020}	Stock biomass in 2020 estimated in the model
B_{2021}	Stock biomass in 2021 estimated in the model
$AveB_{2019\text{-}2021}$	Stock biomass for a recent period (2019–2021) 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_{2020}/K	Stock biomass in 2020 relative to K[a]
B_{2021}/K	Stock biomass in 2021 relative to K[a]
$B_{2019\text{-}2021}/K$	Stock biomass in the latest time period (2019-2021) relative to the equilibrium unexploited stock biomass[a]
B_{2020}/B_{MSY}	Stock biomass in 2020 relative to B_{MSY}[a]
B_{2021}/B_{MSY}	Stock biomass in 2021 relative to B_{MSY}[a]
$B_{2019\text{-}2021}/B_{MSY}$	Stock biomass for a recent period (2019–2021) relative to the stock biomass that produces maximum sustainable yield (MSY) [a]

[a]calculated as the average of the ratios.

4. RESULTS by CHINA, JAPAN and CHINESE TAIPEI

4.1 CHINA

4.1.1 Prior and posterior distributions for Base case model 1 (as an illustrative example)

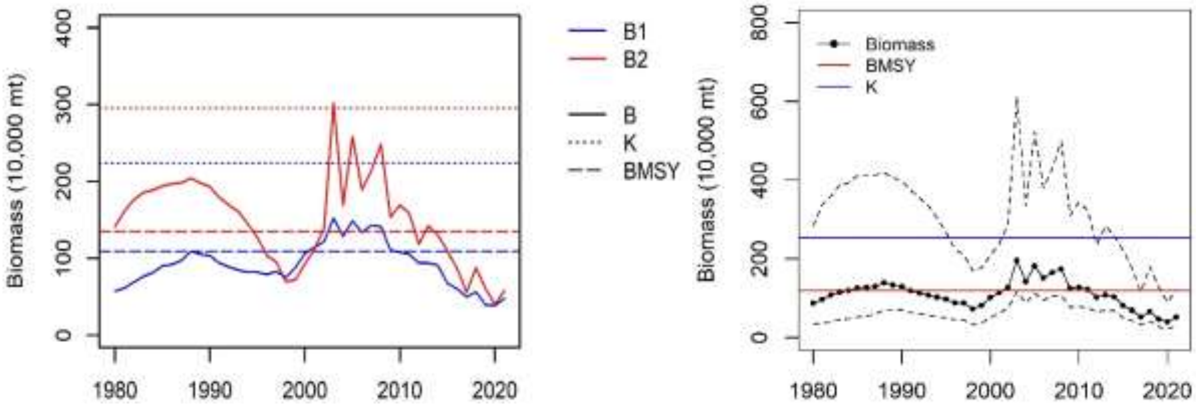


4.1.2 Summary of estimates of parameters and reference points

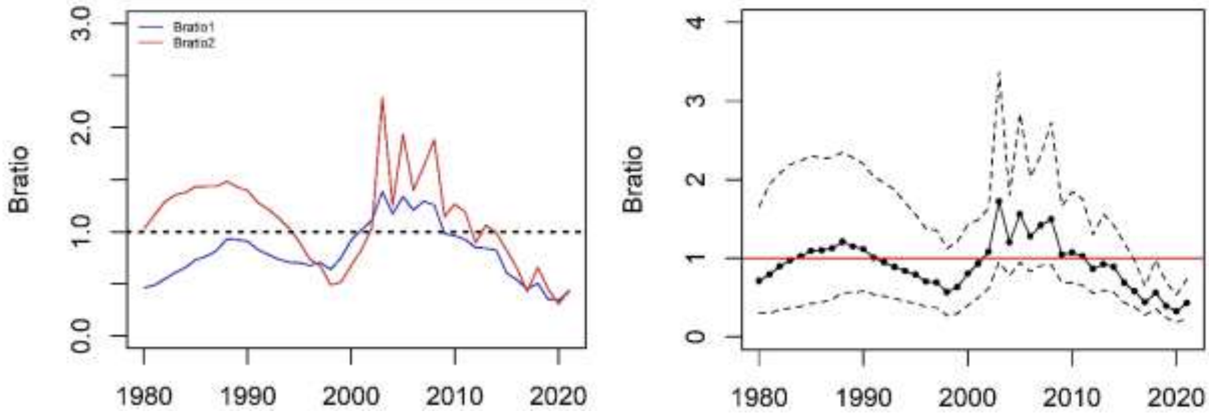
	Base case 1	Base case 2	Over all 2
C2020	13.97	13.97	13.97
AveC2018-2020	25.70	25.70	25.70
AveF2018-2020	0.55	0.40	0.48
F2020	0.36	0.35	0.35
F_{MSY}	0.38	0.36	0.37
MSY	41.78	47.13	43.36
F2020/F_{MSY}	0.98	0.99	0.99
AveF2018-2010/F_{MSY}	1.47	1.14	1.33
K	224.00	295.40	253.10
B2020	39.07	40.41	39.63
B2021	48.06	58.40	51.79
AveB2019-2021	42.37	53.52	46.32
B_{MSY}	108.90	135.00	119.60
B_{MSY}/K	0.48	0.45	0.46
B2020/K	0.17	0.14	0.16
B2021/K	0.21	0.21	0.21
B2019-2021/K	0.19	0.19	0.19
B2020/B_{MSY}	0.35	0.31	0.33
B2021/B_{MSY}	0.42	0.44	0.43
B2019-2021/B_{MSY}	0.38	0.41	0.39

4.1.3 Time series plots for base case models and aggregated results

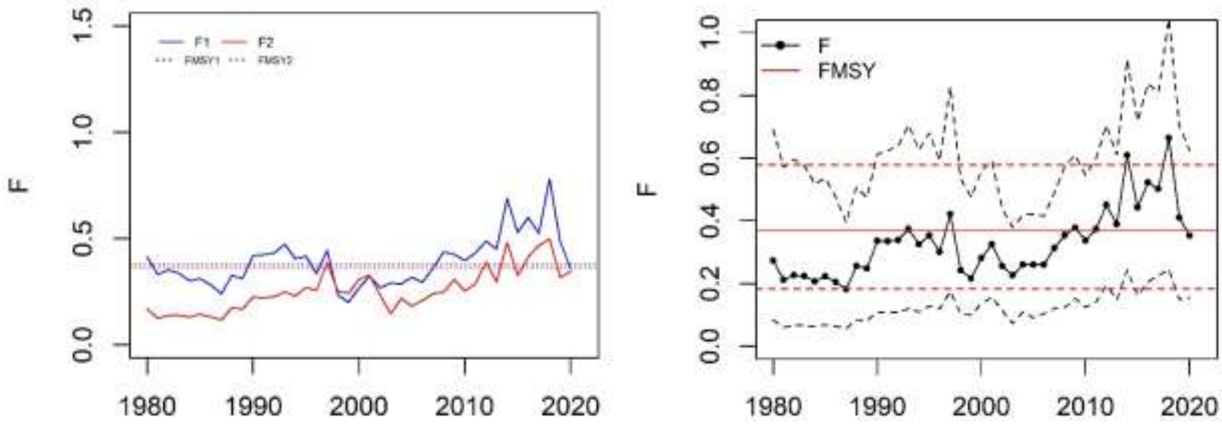
(a) Biomass



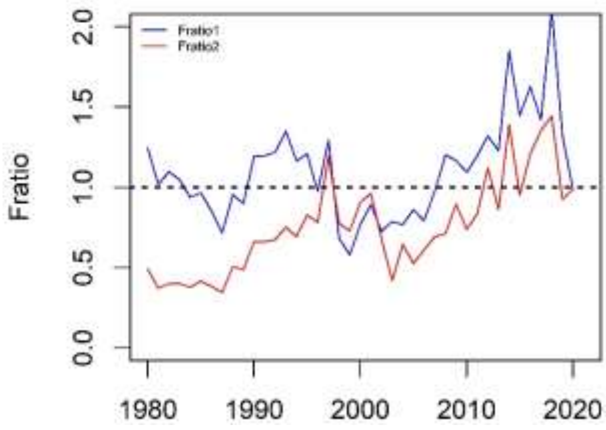
(b) B-ratio (B/B_{MSY})

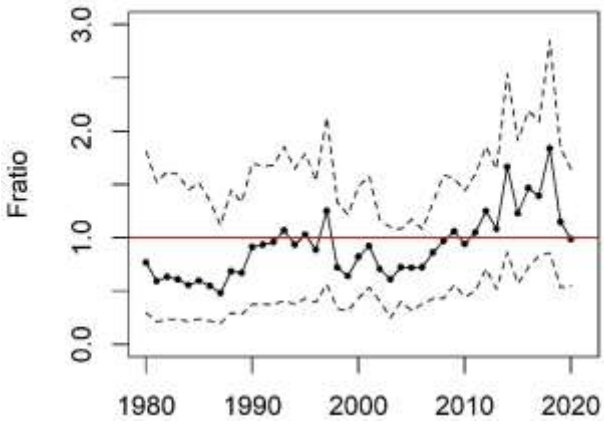


(c) Exploitation rate (F)

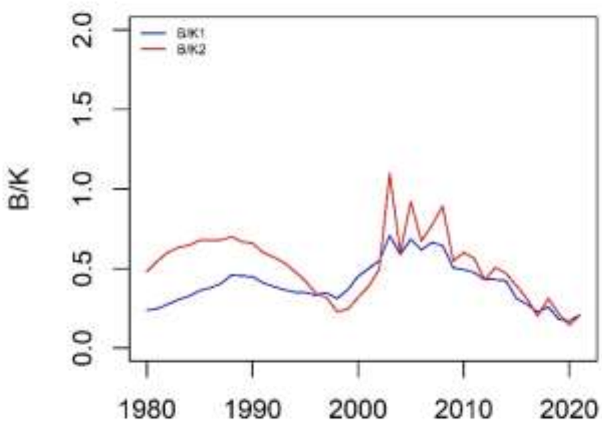


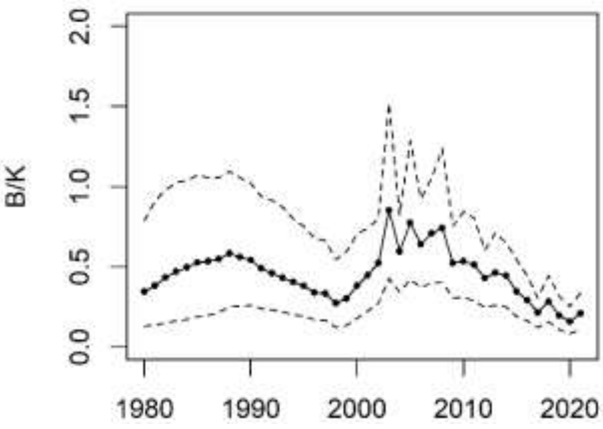
(d) F-ratio (F/F_{MSY})



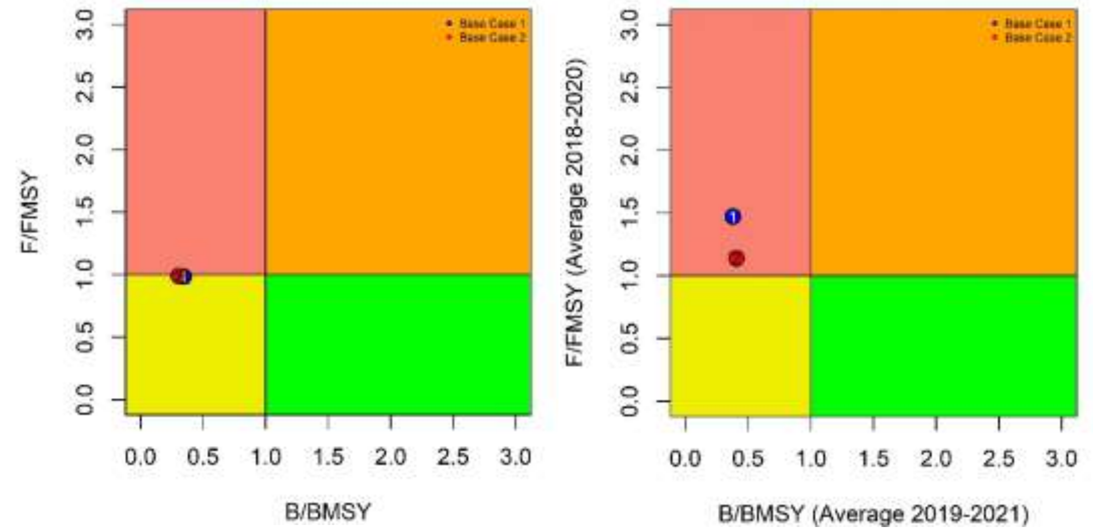


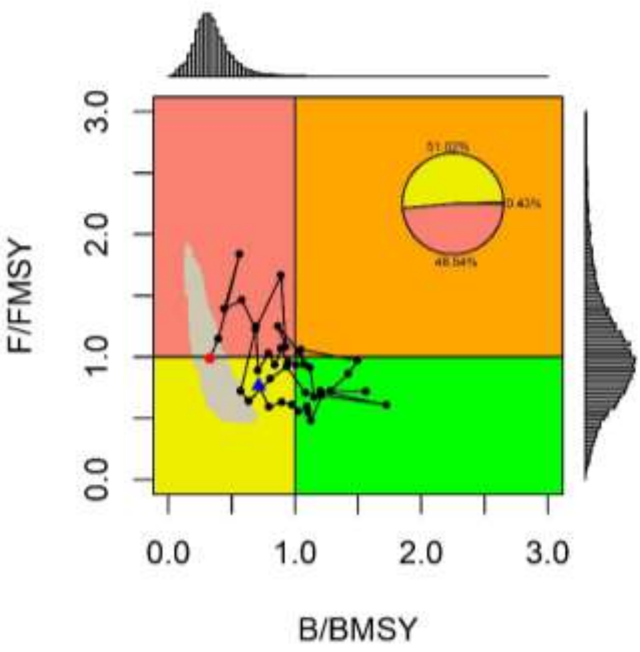
(e) B/K





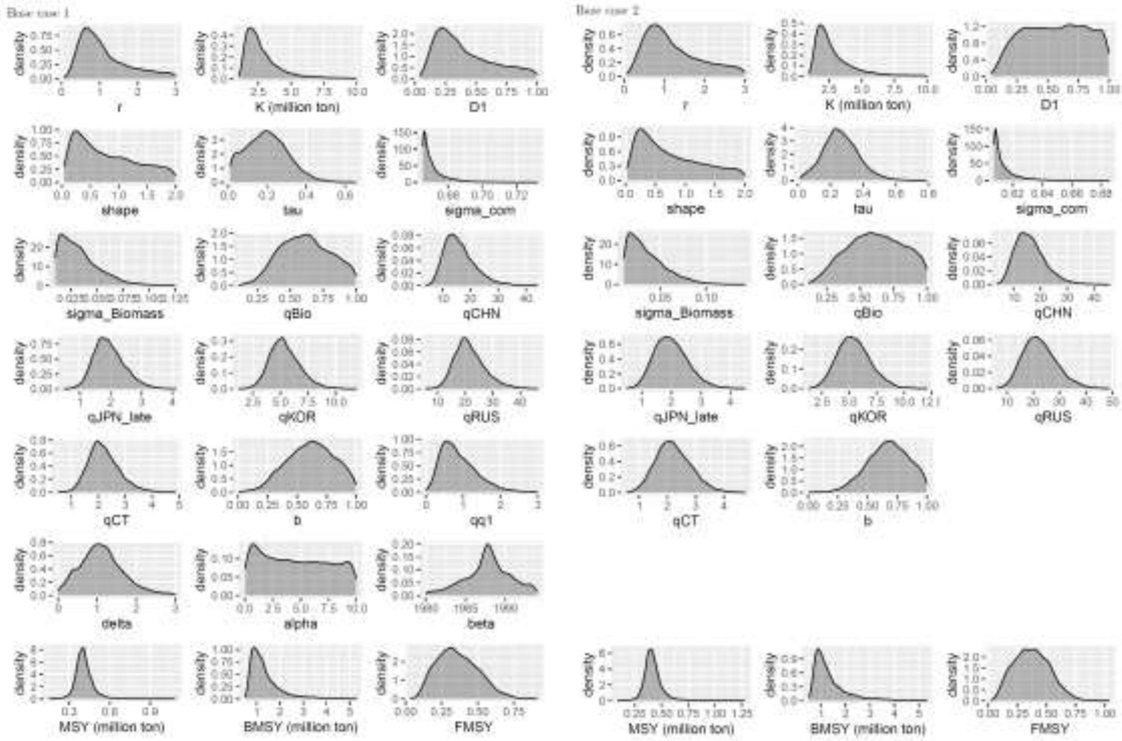
4.1.4 Kobe plots





4.2 JAPAN

4.2.1 Prior and posterior distributions for Base case models



Note: Prior for each free parameter is assumed to be uniform over the shown horizontal range.

4.2.2 Summary of estimates of parameters and reference points

Over the two base cases.

	Mean	Median	Lower10th	Upper10th
C_2020	0.140	0.140	0.140	0.140
AveC_2018_2020	0.257	0.257	0.257	0.257
AveF_2018_2020	0.526	0.515	0.290	0.775
F_2020	0.378	0.355	0.188	0.595
FMSY	0.368	0.357	0.179	0.563
MSY (million ton)	0.415	0.405	0.339	0.498
F_2020/FMSY	1.097	1.033	0.641	1.625
AveF_2018_2020/FMSY	1.543	1.480	0.973	2.187
K (million ton)	2.915	2.421	1.548	4.949
B_2020 (million ton)	0.455	0.393	0.235	0.742
B_2021 (million ton)	0.545	0.480	0.284	0.868
AveB_2019_2021	0.498	0.433	0.274	0.792
BMSY (million ton)	1.336	1.144	0.751	2.189
BMSY/K	0.469	0.463	0.398	0.552
B_2020/K	0.168	0.161	0.094	0.248
B_2021/K	0.205	0.195	0.108	0.314
AveB_2019_2021/K	0.185	0.179	0.106	0.269
B_2020/BMSY	0.358	0.339	0.212	0.526
B_2021/BMSY	0.440	0.412	0.238	0.673
AveB_2019_2021/BMSY	0.396	0.378	0.238	0.574

Base case 1

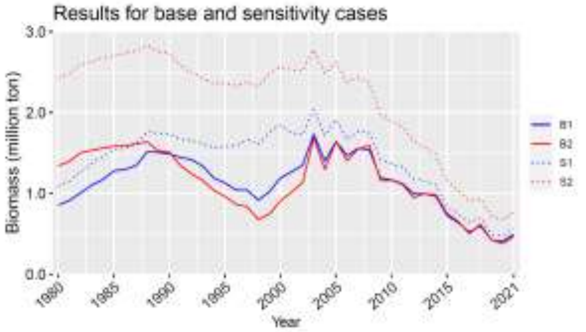
	Mean	Median	Lower10th	Upper10th
C_2020	0.140	0.140	0.140	0.140
AveC_2018_2020	0.257	0.257	0.257	0.257
AveF_2018_2020	0.527	0.516	0.304	0.766
F_2020	0.366	0.344	0.191	0.571
FMSY	0.360	0.346	0.182	0.551
MSY (million ton)	0.411	0.403	0.343	0.483
F_2020/FMSY	1.076	1.019	0.644	1.577
AveF_2018_2020/FMSY	1.567	1.509	1.020	2.191
K (million ton)	2.908	2.439	1.561	4.855
B_2020 (million ton)	0.461	0.406	0.245	0.732
B_2021 (million ton)	0.550	0.493	0.296	0.855
AveB_2019_2021	0.498	0.442	0.281	0.773
BMSY (million ton)	1.339	1.165	0.763	2.150
BMSY/K	0.472	0.467	0.399	0.554
B_2020/K	0.171	0.165	0.098	0.249
B_2021/K	0.208	0.199	0.110	0.316
AveB_2019_2021/K	0.186	0.181	0.108	0.269
B_2020/BMSY	0.363	0.345	0.219	0.529
B_2021/BMSY	0.443	0.417	0.243	0.670
AveB_2019_2021/BMSY	0.396	0.379	0.241	0.569

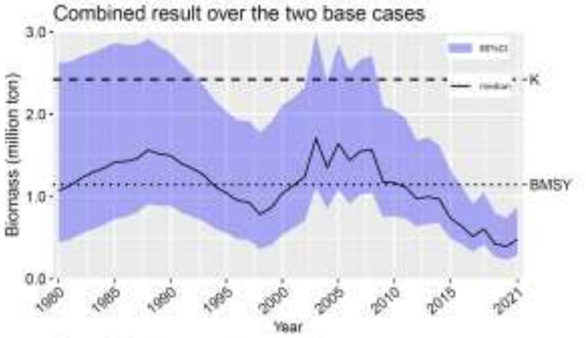
Base case 2

	Mean	Median	Lower10th	Upper10th
C_2020	0.140	0.140	0.140	0.140
AveC_2018_2020	0.257	0.257	0.257	0.257
AveF_2018_2020	0.526	0.515	0.275	0.782
F_2020	0.391	0.370	0.186	0.617
FMSY	0.375	0.370	0.176	0.574
MSY (million ton)	0.418	0.408	0.333	0.514
F_2020/FMSY	1.118	1.050	0.638	1.677
AveF_2018_2020/FMSY	1.519	1.446	0.931	2.185
K (million ton)	2.921	2.395	1.534	5.027
B_2020 (million ton)	0.449	0.377	0.226	0.751
B_2021 (million ton)	0.541	0.466	0.276	0.883
AveB_2019_2021	0.499	0.424	0.267	0.821
BMSY (million ton)	1.333	1.124	0.739	2.245
BMSY/K	0.466	0.459	0.398	0.550
B_2020/K	0.164	0.157	0.091	0.246
B_2021/K	0.203	0.192	0.105	0.311
AveB_2019_2021/K	0.184	0.178	0.105	0.269
B_2020/BMSY	0.354	0.333	0.205	0.523
B_2021/BMSY	0.437	0.406	0.233	0.675
AveB_2019_2021/BMSY	0.397	0.377	0.235	0.579

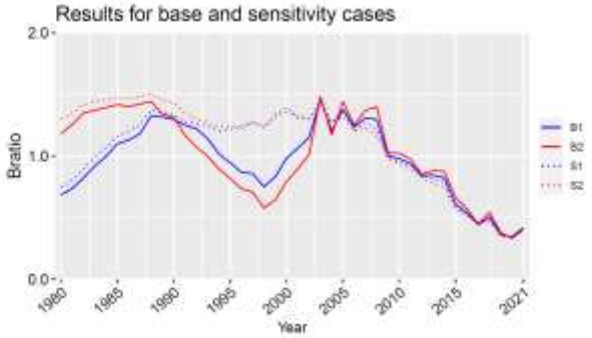
4.2.3 Time series plots for base case models and aggregated results

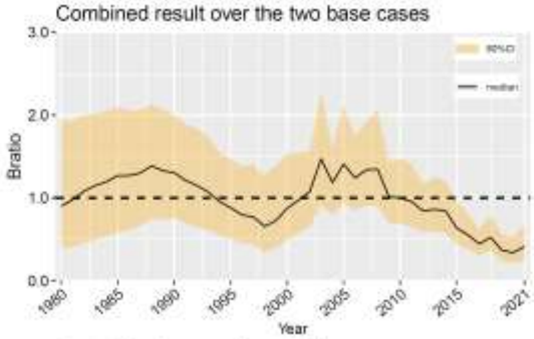
(a) Biomass



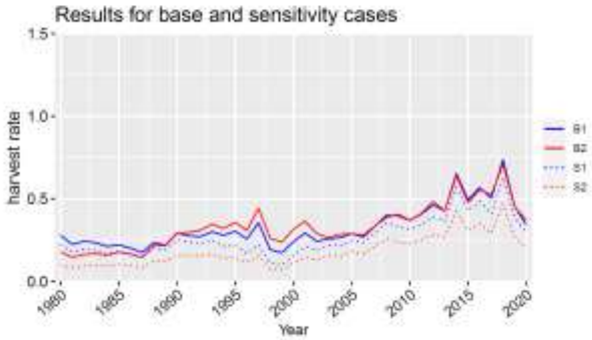


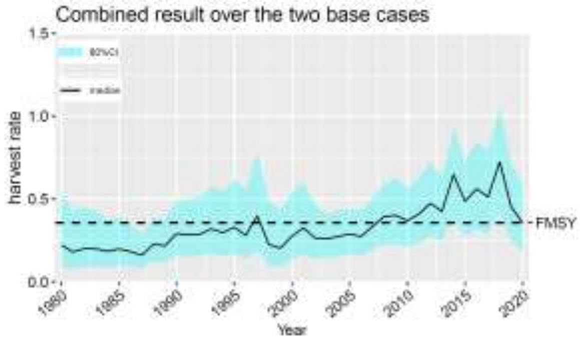
(b) B-ratio (B/B_{MSY})



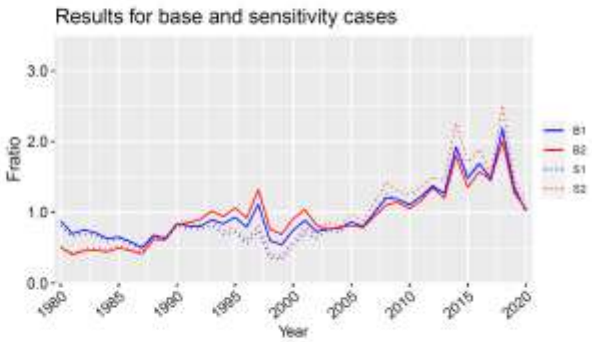


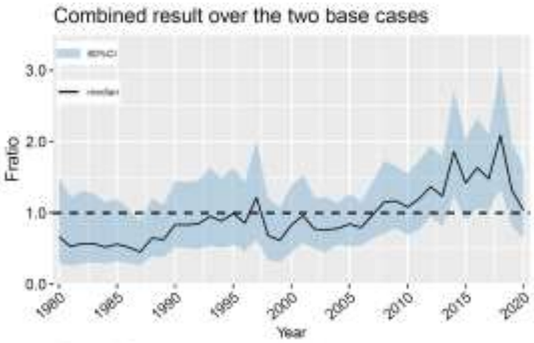
(c) Exploitation rate (F)



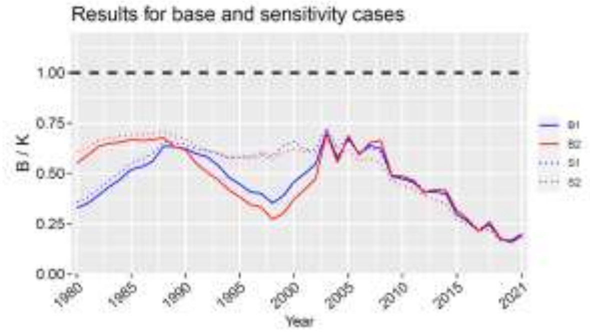


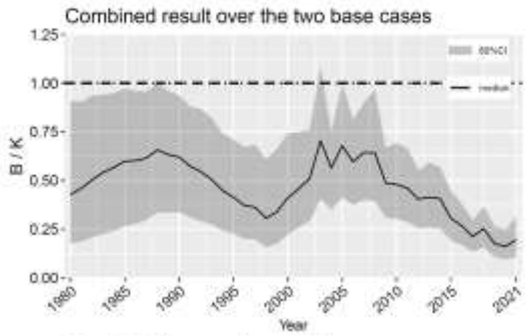
(d) F-ratio (F/F_{MSY})



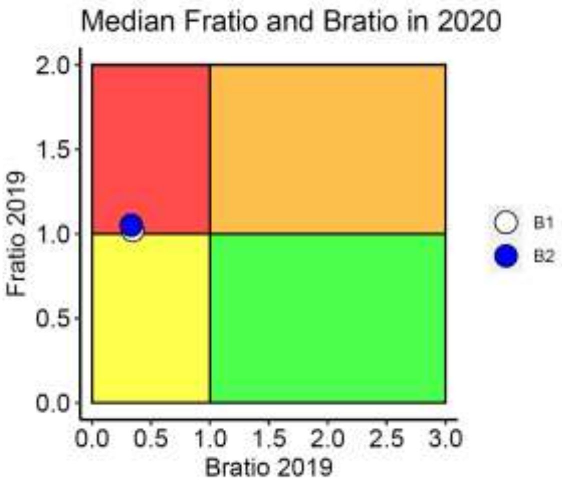


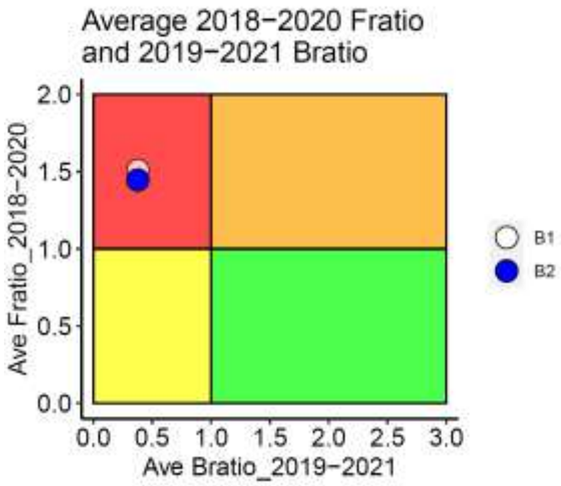
(e) B/K

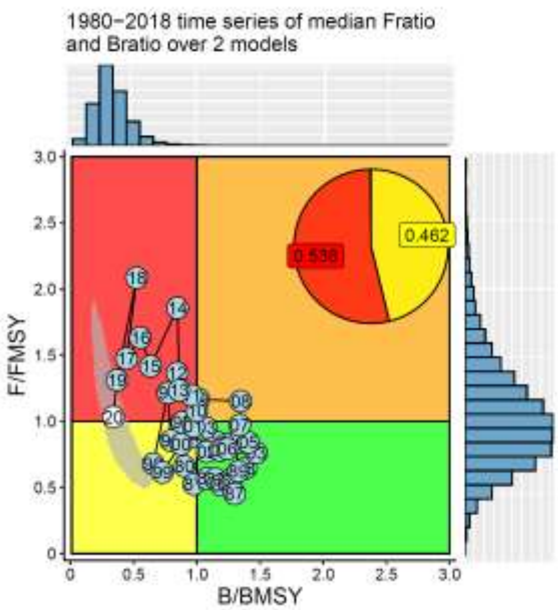




4.2.4 Kobe plots

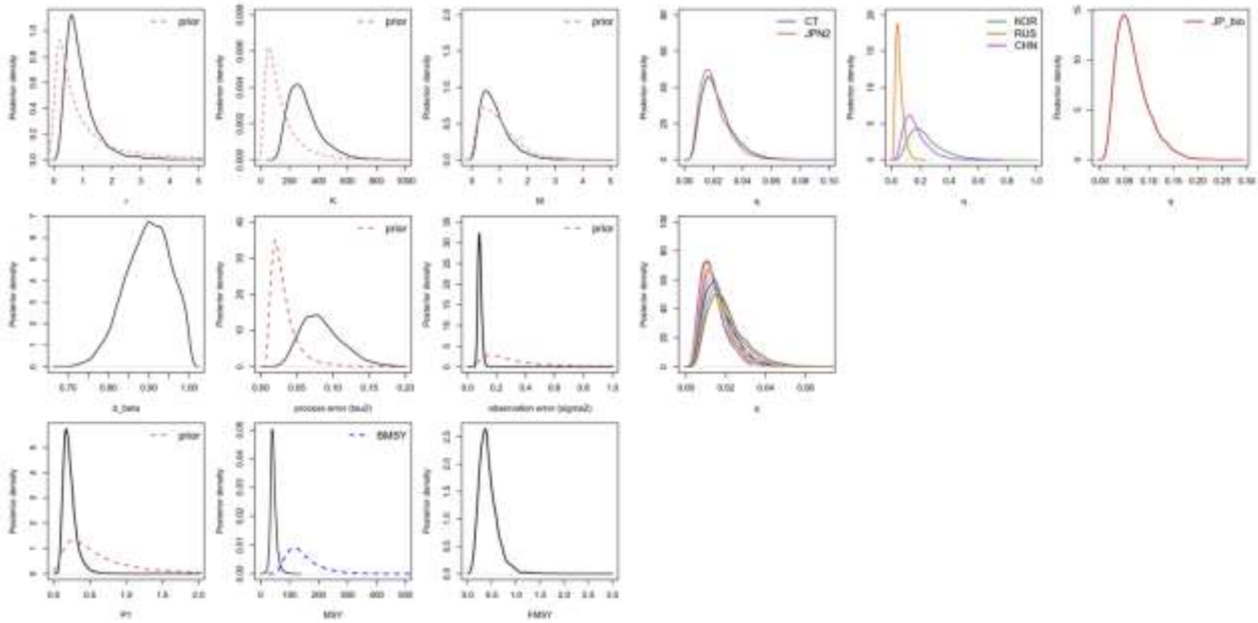






4.3 CHINESE TAIPEI

4.3.1 Prior and posterior distributions for Base case model 1 (as an illustrative example)



4.3.2 Summary of estimates of parameters and reference points

(a) Base case1

	Mean	Median	Lower 10th	Upper 10th
$Catch_{2020}$	13.97	13.97	13.97	13.97
$F_{2018\text{-}2020}$	0.39	0.29	0.14	0.69
F_{2020}	0.29	0.24	0.11	0.51
F_{MSY}	0.43	0.39	0.22	0.67
MSY	44.18	42.65	33.39	56.72
F_{2020}/F_{MSY}	0.67	0.62	0.35	1.04
$F_{2018\text{-}2020}/F_{MSY}$	0.88	0.79	0.44	1.37
K	304.74	281.25	179.61	461.70
B_{2020}	76.34	66.66	34.77	130.09
B_{2021}	93.50	81.73	42.32	159.49
$B_{2019\text{-}2021}$	91.18	79.88	42.12	154.76
B_{MSY}	144.98	132.95	85.58	219.80
B_{MSY}/K	0.48	0.47	0.42	0.55
B_{2020}/K	0.24	0.24	0.17	0.33
B_{2021}/K	0.30	0.29	0.20	0.41
$B_{2019\text{-}2021}/K$	0.29	0.28	0.21	0.38
B_{2020}/B_{MSY}	0.52	0.49	0.34	0.72
B_{2021}/B_{MSY}	0.63	0.61	0.41	0.90
$B_{2019\text{-}2021}/B_{MSY}$	0.62	0.59	0.42	0.84

(b) Base case2

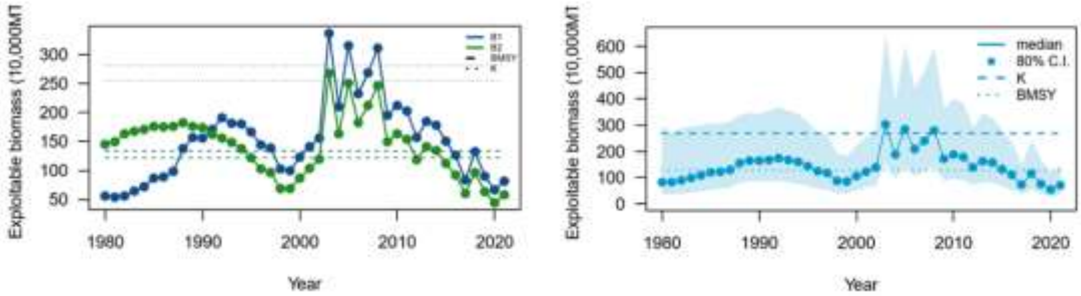
	Mean	Median	Lower 10th	Upper 10th
$Catch_{2020}$	13.97	13.97	13.97	13.97
$F_{2018\text{-}2020}$	0.78	0.46	0.17	1.32
F_{2020}	0.58	0.38	0.15	0.96
F_{MSY}	0.49	0.43	0.21	0.82
MSY	43.11	41.62	31.86	55.61
F_{2020}/F_{MSY}	1.10	0.94	0.49	1.71
$F_{2018\text{-}2020}/F_{MSY}$	1.42	1.16	0.57	2.34
K	287.27	254.50	157.01	465.07
B_{2020}	54.88	44.33	22.68	99.79
B_{2021}	74.02	58.76	30.59	135.89
$B_{2019\text{-}2021}$	69.57	55.68	29.10	127.17
B_{MSY}	137.84	122.25	75.63	221.40
B_{MSY}/K	0.48	0.48	0.42	0.55
B_{2020}/K	0.18	0.18	0.12	0.26
B_{2021}/K	0.25	0.24	0.16	0.36
$B_{2019\text{-}2021}/K$	0.23	0.23	0.15	0.32
B_{2020}/B_{MSY}	0.39	0.36	0.24	0.56
B_{2021}/B_{MSY}	0.52	0.49	0.32	0.77
$B_{2019\text{-}2021}/B_{MSY}$	0.49	0.46	0.31	0.70

(c) Joint estimates of the base cases 1 and 2

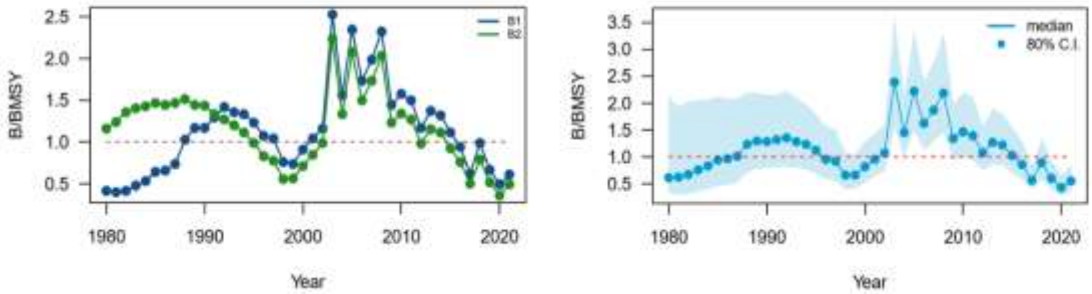
	Mean	Median	Lower 10th	Upper 10th
$Catch_{2020}$	13.97	13.97	13.97	13.97
$F_{2018-2020}$	0.59	0.36	0.15	0.99
F_{2020}	0.43	0.29	0.13	0.75
F_{MSY}	0.46	0.41	0.21	0.75
MSY	43.65	42.14	32.69	56.18
F_{2020}/F_{MSY}	0.88	0.75	0.4	1.42
$F_{2018-2020}/F_{MSY}$	1.15	0.94	0.48	1.9
K	296	268.4	166.6	463.3
B_{2020}	65.61	55.2	26.38	117.67
B_{2021}	83.76	70.37	34.81	149.2
$B_{2019-2021}$	80.37	67.94	33.56	143.16
B_{MSY}	141.41	127.7	79.98	220.2
B_{MSY}/K	0.52	0.47	0.29	0.79
B_{2020}/K	0.21	0.21	0.13	0.3
B_{2021}/K	0.27	0.27	0.17	0.39
$B_{2019-2021}/K$	0.26	0.26	0.17	0.36
B_{2020}/B_{MSY}	0.45	0.43	0.27	0.66
B_{2021}/B_{MSY}	0.58	0.55	0.35	0.85
$B_{2019-2021}/B_{MSY}$	0.55	0.53	0.35	0.79

4.3.3 Time series plots for base case models and aggregated results

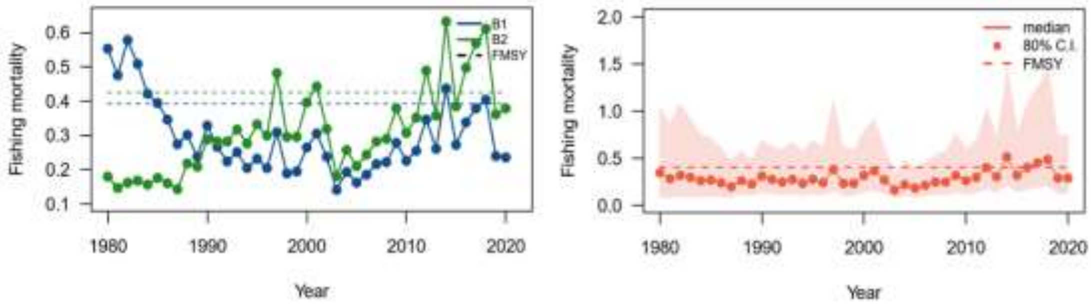
(a) Biomass



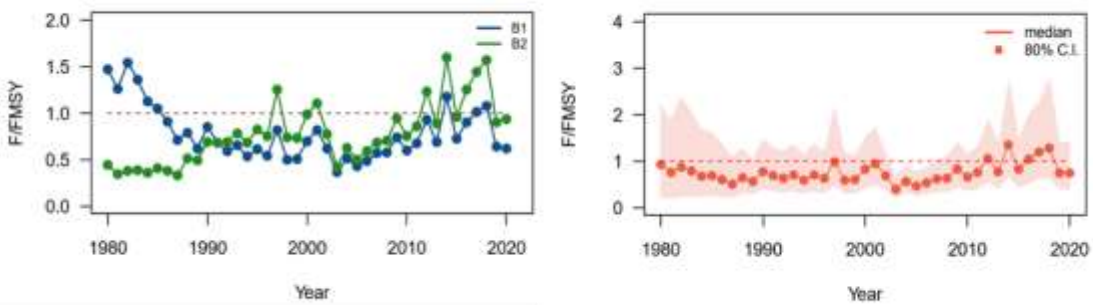
(b) B-ratio (B/B_{MSY})



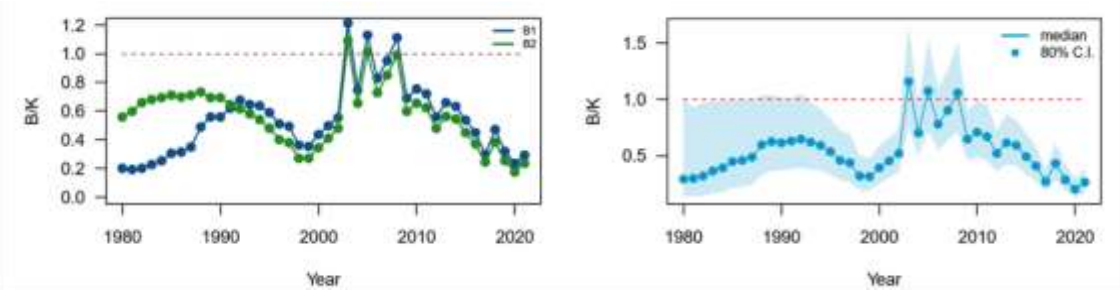
(c) Exploitation rate (F)



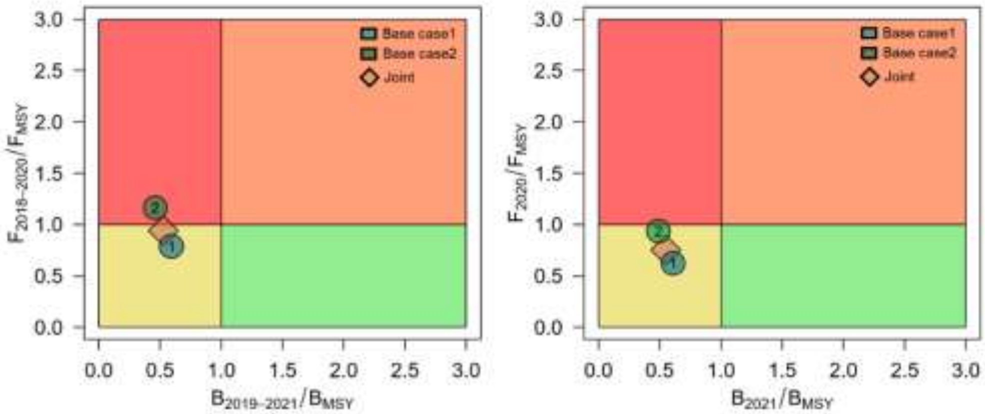
(d) F-ratio (F/F_{MSY})

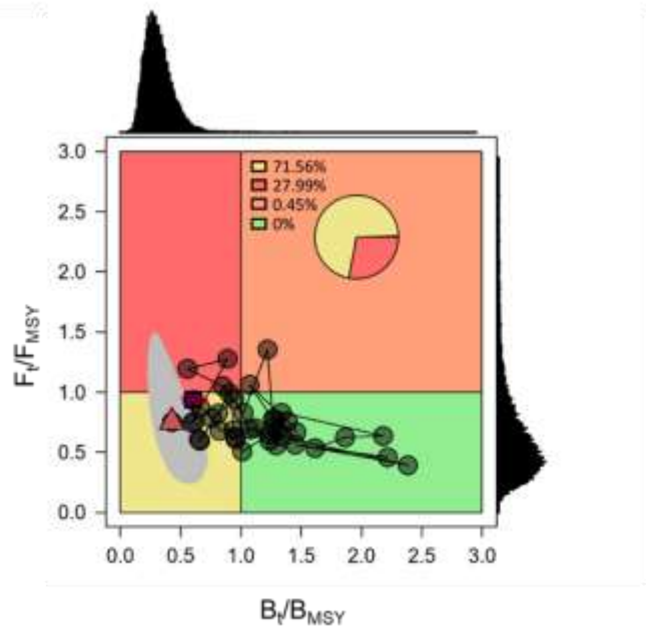


(e) B/K



4.3.4 Kobe plots





5 SOME AGGREGATED RESULTS FOR VISUALIZATION PURPOSE

5.1 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.

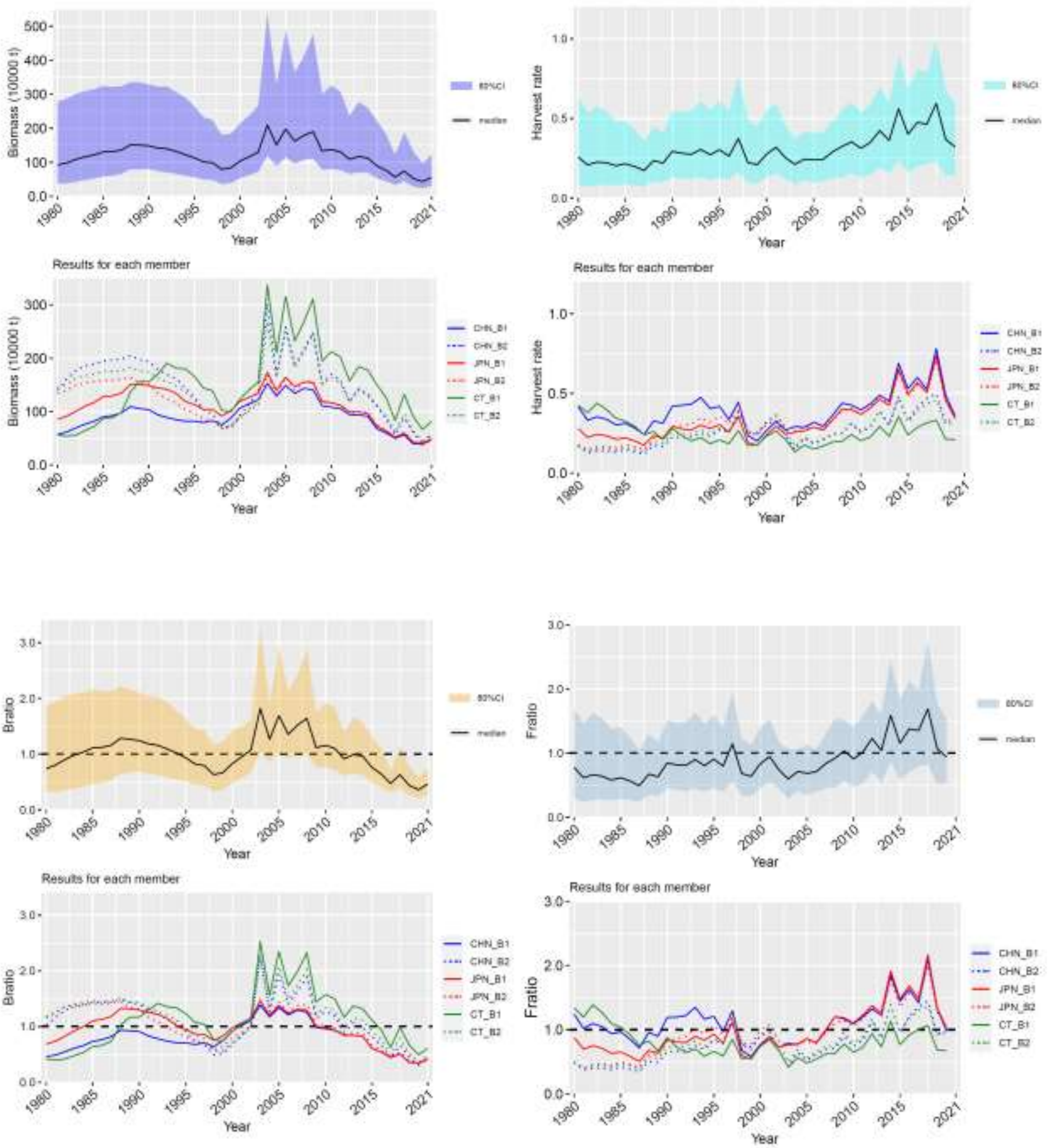


Figure 3. Time series of median estimated values of six runs for biomass, harvest rate, B-ratio, F-ratio and depletion level relative to K. The solid and shaded lines correspond to B1 and B2, respectively.

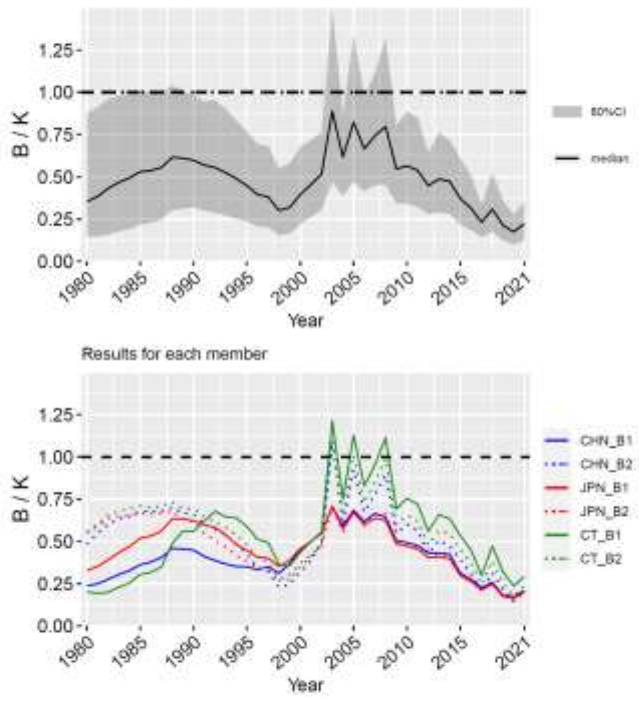


Figure 3 (Continued).

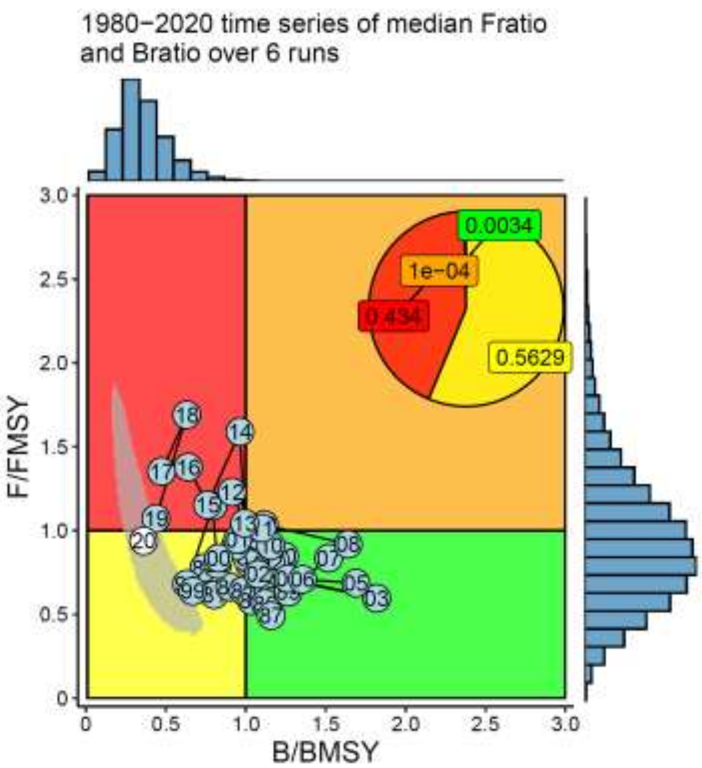


Figure 4. Kobe plot with time trajectory. The data are aggregated across 6 model results (2 base-case models by 3 Members).

5.2 Summary table

Table 3. Summary of estimates of reference quantities. Median values are reported.

	Median	Lower10%	Upper10%	Median_CHN	Median_JPN	Median_CT
C_2020 (10000 t)	13.968	13.968	13.968	13.968	13.968	13.968
AveC_2018_2020 (10000 t)	25.704	25.704	25.704	25.704	25.704	25.704
AveF_2018_2020	0.435	0.180	0.743	0.482	0.515	0.298
F_2020	0.322	0.144	0.590	0.353	0.355	0.253
FMSY	0.352	0.185	0.559	0.370	0.357	0.334
MSY	41.901	33.956	56.291	43.358	40.529	42.145
F_2020/FMSY	0.938	0.523	1.529	0.986	1.033	0.794
AveF_2018_2020/FMSY	1.247	0.647	1.967	1.334	1.480	0.936
K (10000 t)	255.121	157.185	517.839	253.100	242.055	268.400
B_2020 (10000 t)	43.415	23.680	96.706	39.625	39.345	55.200
B_2021 (10000 t)	54.774	30.260	122.400	51.790	47.993	70.355
AveB_2019_2021 (10000 t)	50.173	28.629	115.984	46.317	43.323	67.935
BMSY (10000 t)	120.784	76.740	236.751	119.600	114.410	127.700
BMSY/K	0.465	0.389	0.577	0.461	0.463	0.471
B_2020/K	0.175	0.099	0.275	0.159	0.161	0.208
B_2021/K	0.223	0.123	0.353	0.209	0.195	0.265
AveB_2019_2021/K	0.207	0.120	0.319	0.191	0.179	0.255
B_2020/BMSY	0.361	0.218	0.587	0.327	0.339	0.428
B_2021/BMSY	0.463	0.264	0.765	0.432	0.412	0.550
AveB_2019_2021/BMSY	0.427	0.260	0.693	0.390	0.378	0.528

6 CONCLUDING REMARKS

Results of 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. Exploitation rates were increasing slowly since 2005 except for 2019. The results also indicated that B was below B_{MSY} (median average B/B_{MSY} during 2019-2021 = 0.427, 80%CI=0.260-0.693) and F was above F_{MSY} (average F/F_{MSY} during 2018-2020 = 1.247, 80%CI= 0.647-1.967). The results further indicated that stock biomass fell to the lowest value since 1980 in 2020 (median B/B_{MSY} = 0.361, 80%CI=0.218-0.587) and has been still at a historically low level in recent years (2019-2021). Information of the nominal CPUE series further indicated that Pacific saury stock biomass has likely been near a record low level in 2021.

HCR and reference points have not yet been established for Pacific saury although an HCR is needed and research is expected to begin this year. The Commission used F_{MSY} catch in place of an HCR to set the TAC for 2020 (TAC = F_{MSY} x Biomass). According to special comment #4 in the 2020 stock assessment "the Fmsy catch approach resulted in a TAC for 2020 that was substantially larger than the actual catch" and "TAC values could be calculated using the F_{MSY} estimate and historical biomass estimates from the BSSPM for comparison to actual catches".

Results from the suggested calculations for 2020 based on updated estimates differ because the 2020 F_{MSY} catch is only slightly larger than the observed catch (Figure 5). The difference is probably due to uncertainty in the scale of estimated biomass and trend for terminal years.

Based on the updated figures, F_{MSY} catch levels were higher than actual catch during 1980-2010, lower during 2011-2017 and 2021 and nearly the same during 2018-2019. In 2014 and 2018 catch was substantially higher than the F_{MSY} catch level. Thus, biomass was relatively high prior to 2011 while catches were less than F_{MSY} catch and biomass declined to a historical low during 2011-2021 while catches were usually greater than or equal to F_{MSY} catch. Based on these results, catches generally exceeded the F_{MSY} catch level and contributed to the recent decline in biomass.

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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 per vessel per day)	CPUE JPN_early (metric tons per net haul)	CPUE JPN_late (metric tons per net haul)	CPUE KOR (metric tons per vessel per day)	CPUE RUS (metric tons per vessel per day)	CPUE CT (metric tons per net haul)	Joint CPUE (VAST)
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					3.19		16.89		
1995	343743					2.03		20.15		
1996	266424					1.69		16.15		
1997	370017					3.31		11.74		
1998	176364					1.03		12.49		
1999	176498					0.78		12.61		
2000	286186					1.22		17.31		
2001	370823					1.46	3.82	21.05	1.57	0.72
2002	328362					1.07	3.13	20.01	1.63	0.63
2003	444642	1939.9	29.0			2.00	5.93	35.76	2.67	1.21
2004	369400	652.6	20.7			2.52	4.78	47.10	1.45	1.04
2005	473907	1228.3	30.4			3.96	9.97	49.50	2.39	1.72
2006	394093	744	27.0			3.59	8.22	34.57	1.27	0.78
2007	520207	878.4	27.4			3.77	7.15	43.21	2.37	1.24
2008	617509	1129.2	28.8			4.29	10.69	42.31	2.91	1.68
2009	472177	619.2	24.6			4.00	4.37	21.26	1.57	0.99
2010	429808	797.9	27.5			1.57	8.02	23.68	1.94	0.92
2011	456263	730.2	32.6			2.21	4.74	28.49	2.51	1.24
2012	460544	452.5	23.5			2.38	3.86	24.36	2.47	1.06
2013	423790	680.4	25.7	13.96		1.66	4.67	22.20	2.79	0.85
2014	629576	506.7	23.0	16.24		2.74	8.01	25.37	3.63	1.36

2015	358883	516.2	21.3	17.73		1.66	3.4	16.52	2.42	0.84
2016	361688	396.4	28.1	9.29		1.74	5.47	18.17	2.43	0.75
2017	262639	192.8	27.9	8.5		1.11	3.36	8.59	1.83	0.85
2018	439079	424.9	27.0	15.84		1.76	5.25	26.06	3.09	1.37
2019	192377	347.2	27.3	6.89		0.64	3.37	8.39	1.41	0.45
2020	139676	109.5	158.1	5.95		0.35	2.45	7.19	1.24	0.29
2021		265.8	33.1							