North Pacific Fisheries Commission

NPFC-2020-SSC PS06-Final Report

6th Meeting of the Small Scientific Committee on Pacific Saury REPORT

19-23 November 2020

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North Pacific Fisheries Commission
6th Meeting of the Small Scientific Committee on Pacific Saury

19-23 November 2020
Video conference

REPORT

Agenda Item 1. Opening of the Meeting

1. The 6th Meeting of the Small Scientific Committee on Pacific Saury (SSC PS06) 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, and Vanuatu. Dr. Larry Jacobson participated as an invited expert. The North Pacific Anadromous Fish Commission (NPAFC) attended as an observer.

2. The meeting was opened by Dr. Toshihide Kitakado (Japan), the SSC PS Chair, who welcomed the SSC PS. 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 Participants List are attached (Annexes B, C).

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

3.1 SSC PS05 meeting

3.2 SSC PSint01 virtual meeting

4. The Chair presented the outcomes and recommendations from the SSC PS05 and SSC PSint01 meetings.

3.3 COM05 meeting and CMM 2019-08

5. The Science Manager, Dr. Aleksandr Zavolokin, presented the outcomes from the fifth Commission meeting and an overview of Conservation and Management Measure (CMM) 2019-08 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 recommended that the SC endorse the Terms of Reference for the SSC PS proposed at the SSC PS05 meeting (Annex D).

4.2 CPUE Standardization Protocol

7. The SSC PS recommended that the SC endorse the CPUE Standardization Protocol revised at the SSC PS05 meeting (Annex E).

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 2020 fishery

9. China presented its fisheries activities. Total catch fluctuated from 2013 to 2019. The catch in 2019 was over 50,000 tons. In 2019, there were 62 active vessels in the Convention Area. Comparing the mean weekly catch value in 2020 and that from 2015-2019, the main fishing season in 2020 has been two weeks later than previous years. The 2020 fishing season for Pacific saury had not been finished yet and the reported catch showed an increasing trend recently. China mentioned that the outbreak of COVID-19 was likely to reduce the Pacific saury fishing efforts, which may consequently affect the total catch.

10. Chinese Taipei presented its fisheries activities. Historical catch was at its highest in 2014. The catch in 2019 was 83,941 tons, the lowest since 2007. In 2020, fishing vessels began operations in fishing grounds later than in previous years. The distribution of fishing activities in 2020 has been limited in the area west of 170^{o} East and more southerly than in 2019. Nominal CPUE has been about 8 tons/day in 2020 compared to 12 tons/day in 2019 and 28 tons/day in 2018.

11. Vanuatu presented its fisheries activities. Annual catch in 2019 was 3,465 tons. Nominal CPUE in 2020 has been a historical low at 7.06 tons/day, compared to 10.76 in 2019. Fishing grounds have mainly been in the east in the early fishing season, then shifting to the west.

12. Japan presented its fisheries activities (NPFC-2020-SSC PS06-WP11). Annual catch has continued to decrease since 2008. Annual catch in 2019 was 42,790 tons, the lowest since 1950, but the fishing condition in 2020 has been even worse so far. The accumulated catch from August to October in Japan was about 13000 metric tons, about 64% of 2019 (20,300 MT). Nominal CPUE from August to October in 2020 dropped to the historical lowest at 0.86 tons/hauls, which was 64% of that in 2019 (1.38 tons/hauls). The fishing grounds in late August

and September 2020 were between 156°E and 165° E longitude, which is farther east than those in 2019.

13. Korea presented its fisheries activities. The general trend in annual catch has been one of decline. Annual catch in 2019 was 8,375 tons, a historical low. The annual catch in 2020 is expected to be even lower. Accumulated catch by month has been historically low for every month in 2020. Nominal CPUE is expected to be a historical low in 2020. The fishing distribution in 2020 has been spread over a smaller area than in 2019.

14. Russia presented its fisheries activities (NPFC-2020-SSC PS06-WP19). The highest catch by Russian vessels was in 2007 and amounted to 109,000 tons. However, there has been a significant decrease in catch in the last 5 years. The number of fishing vessels has also significantly decreased in recent years. In 2019, catch was 2,402 tons, the lowest level since 1985.

15. The Science Manager presented Members' cumulative catch of Pacific saury in the Convention Area based on weekly catch reports provided by Members in 2020. As of 14 November, the cumulative total in 2020 is slightly more than 100,000 tons, and the Pacific saury fisheries are still ongoing.

16. The SSC PS compiled a table of Members' Pacific saury catches up to 2020, with preliminary catch statistics as of 14 November (Annex F). The SSC PS noted the decline in catch in 2019 and low catch in the 2020 fishing season.

Agenda Item 6. Fishery-independent abundance indices

6.1 Review of results of abundance estimation based on 2020 Japanese biomass survey

17. Japan explained that, due to COVID-19, it had to use a different research vessel for its 2020 biomass survey. The survey period was shorter than previous years and therefore the surveyed area was reduced to the west of 175° E. The survey was conducted over a narrower sea surface temperature (SST) range of 8-13°C, compared to 7 or 8-17°C in previous years. The survey was conducted over 64 stations. 1,118 fish were caught. Age-1 fish were mainly distributed west of 167° E and age-0 fish west of 175° E. The density of Pacific saury was remarkably lower in this year than the previous year (2019; a reduction of approximately 90%).

18. Japan presented a study exploring the effect of sea surface temperature in spatio-temporal modeling of Pacific saury distribution using Japanese fishery-independent survey data through the VAST model (NPFC-2020-SSC PS06-WP13). Abundance indices for age-0 and age-1 fish

were predicted through this modeling. Incorporating not only spatio-temporal variation but also SST effects on fish density resulted in a biologically plausible prediction of annual distribution patterns. Age-specific standardized abundance indices indicated similar year trends to nominal abundance indices, except for some years.

19. Japan presented the estimation of the Japanese survey biomass index of Pacific saury for 2020 using VAST model (NPFC-2020-SSC PS06-WP14). The estimated biomass index from the developed VAST model indicated similar year trends with the index from the swept-area method since 2011 and the estimate in 2020 dropped to the historical lowest since 2003.

20. Japan presented a supplementary study applying delta-GLM models to the 2020 survey data. The study showed a similar trend to the VAST model for the biomass index estimate.

21. The SSC PS expressed its appreciation to Japan for conducting the biomass survey in 2020 despite the difficult circumstances caused by COVID-19.

22. The SSC PS noted the declining trend of the fishery-independent index through 2020.

6.2 Review of plans of future biomass surveys

23. Japan reported that it is planning to conduct a biomass survey with full area coverage for 2021. In light of the probable continued impact of COVID-19, Japan will prioritize carrying out the survey for the conventional survey area, from the Japanese EEZ to 165°W longitude. Japan suggested that it may be fruitful to conduct additional surveys in the northern and eastern sides of the conventional survey area and encouraged other Members to conduct such surveys if possible.

24. Russia explained that it has a long history of conducting research surveys in the northern side of the Japanese survey area. Russia suggested that it may be able to provide data from such surveys.

25. Canada explained that it conducts pelagic surface trawls in the northeastern Pacific Ocean and may be able to provide data from such surveys.

26. Science Manager reported that NPFC has been discussing plans to participate in NPAFC's pan-Pacific survey as part of the International Year of the Salmon initiative, which may provide useful information on the distribution of Pacific saury.

27. The SSC PS encouraged 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.

6.3 Recommendations for future work

28. Recommendations for future work are given in paragraph 27 and the SSC PS Work Plan.

Agenda Item 7. Fishery-dependent abundance indices

7.1 Review of any updates and progress

29. China presented a standardization of CPUE data for Pacific saury from 2013 to 2019 using a generalized linear model (GLM) and a generalized additive model (GAM) on the assumption of lognormal distribution of errors (NPFC-2020-SSC PS06-WP07). China recommended using the standardized CPUE derived from GAM as the input for the stock assessment.

30. The SSC PS agreed to use China's standardized CPUE derived from GAM as the input for the stock assessment.

31. Japan presented a standardization of CPUE data for Pacific saury from 1994 to 2019 using GLM (NPFC-2020-SSC PS06-WP12). Japan recommended using the standardized CPUE derived from GLM as input for the stock assessment.

32. The SSC PS agreed to use Japan's standardized CPUE derived from GLM as input for the stock assessment.

33. Korea presented a standardization of CPUE data for Pacific saury from 2001 to 2019 using GLM (NPFC- 2020-SSC PS06-WP03). Korea recommended using the standardized CPUE derived from GLM as input for the stock assessment.

34. The SSC PS agreed to use Korea's standardized CPUE derived from GLM as the input for the stock assessment.

35. Russia presented a standardization of CPUE data for Pacific saury from 1994 to 2019 using GLM (NPFC-2020-SSC PS06-WP04). Russia recommended using the standardized CPUE derived from GLM as input for the stock assessment.

36. The SSC PS agreed to use Russia's standardized CPUE derived from GLM as the input for the

stock assessment.

37. Chinese Taipei presented a standardization of CPUE data for Pacific saury from 2001 to 2019 using GLM and GAM on the assumption of lognormal distribution of errors (NPFC-2020-SSC PS06-WP05). Chinese Taipei recommended using the standardized CPUE derived from GAM as input for the stock assessment.

38. The SSC PS agreed to use Chinese Taipei's standardized CPUE derived from GAM as the input for the stock assessment.

39. The finalized table of abundance indices is attached to the report as Annex G.

40. The Chair reminded Members to follow the most up-to-date CPUE standardization protocol when conducting future CPUE standardizations.

41. The SSC PS discussed the impact of COVID-19 on Members' fishing operations in 2020. The SSC PS noted that the start of some Members' fishing operations was slightly delayed due to COVID-19, which might have contributed partially to their low catch through early November.

42. The SSC PS agreed that updated CPUE standardization up to 2020 will be submitted by Members to the next SSC PS meeting.

7.2 Review of progress on collaborative work for development of joint CPUE

43. Chinese Taipei presented research on the standardization of joint CPUE data for Pacific saury from 2001 to 2019 using conventional and geostatistical approaches (NPFC-2020-SSC PS06-WP06). The results of relative density from VAST and GLM showed similar trends but VAST performs better than GLM in terms of higher R^2 value, fewer residuals departing from zero, and smaller residual variance. Correlation analysis indicated that the joint CPUE index could resolve the inconsistencies among Members' individual indices. Chinese Taipei recommended using VAST for deriving the standardized joint index as improved input data in the stock assessment and that its analysis be considered as a standard tool in the CPUE standardization.

44. The SSC PS recognized the value of the work done by Chinese Taipei and the contributions of all collaborating Members. The SSC PS agreed to use the standardized joint CPUE index derived from VAST as input for sensitivity analyses to supplement the stock assessment (Annex G).

45. The SSC PS agreed to update the shared data for a single joint CPUE index for future stock assessment by a date to be decided intersessionally depending on the meeting schedule for 2021, which is to be set by the Commission in February 2021.

46. The invited expert advised the SSC PS that procedures for calculating joint CPUE using the VAST or other model are suitable for consideration as data used in stock assessment models.

7.3 Recommendations for future work

47. Recommendations for future work are given in paragraphs 40, 42, 44, 45, 46 and the SSC PS Work Plan.

Agenda Item 8. Stock assessment using "provisional base models" (BSSPM)

8.1 Review and update of the existing specification

48. The SSC PS reviewed the updated BSSPM specification that was agreed on at the SSC PS05 meeting.

8.2 Review of BSSPM results

49. China presented its results of Pacific saury stock assessment (NPFC-2020-SSC PS06-WP08). The estimated median B_{2019} from the two base case scenarios was 596,100 and 2,311,000 metric tons, respectively. The median B_{2019}/B_{MSY} and F_{2018}/F_{MSY} over the two base case scenarios were 0.69 and 1.13, respectively. The probability of the population being in the green Kobe quadrant in 2018 was estimated to be greater than 32%.

50. Japan presented an updated stock assessment for Pacific saury in the North Pacific Ocean using BSSPM (NPFC-2020-SSC PS06-WP10). The 2019 median depletion level was only 26% of the carrying capacity, declining from 33.9% in 2018. B-ratio (B/B_{MSY}) in 2019 and F-ratio (F/F_{MSY}) in 2018 were 0.574 and 1.382, respectively. The probability of the population being in the green Kobe quadrant in 2018 was estimated to be less than 10%, while that of being in the red Kobe quadrant was assessed to be greater than 80%, which indicated that the population was overfished and subject to overfishing in 2018. For population outlook, population dynamics were projected for some scenarios and showed that continuation of the current level of catch may cause a further decline in the population size. However, as shown in the retrospective/hindcasting analyses, the estimation for the recent population size tended to depend on the recent data set. Therefore, for providing better management advice, Japan strongly suggested that the analysis should be updated using the most recent abundance indices (including 2020 fishery-independent abundance index and 2019 CPUE indices).

51. Chinese Taipei presented an updated stock assessment for Pacific saury in the North Pacific Ocean using BSSPM (NPFC-2020-SSC PS06-WP17). The models estimate an increase in biomass in 2018 (median B_{2018}/B_{MSY} = 0.87, 80 percentile range 0.61-1.30) followed by a slight decrease in 2019 (median B_{2019}/B_{MSY} = 0.70, 80 percentile range 0.48-1.05). A steady increase in fishing mortality is estimated to have occurred from 2004 to 2018 and the recent average fishing mortality is estimated to be above F_{MSY} (median $F_{2016\text{-}2018}/F_{MSY}$ = 1.26, 80 percentile range 0.65-2.35).

52. The SSC PS agreed that Members will share the code from each other's stock assessment models by the end of November 2020 and finish the check by the end of December 2020. In future, the code and data files should be shared when assessment reports are submitted for greater transparency and reproducibility.

8.3 Advice on the stock status

53. See section "Summary of stock assessment results" of the stock assessment report for the condition of the stock (Annex H).

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

54. The SSC PS recognized that the current stock assessment uses a CPUE series of up to 2018, thereby producing assessment results with a 3-year time lag between the data and the report to the Commission meeting planned to be held in early 2021. Noting that the CPUE data for 2019 have become available and recognizing the importance of using all available scientific information for the stock assessment, subject to approval from Members' governments, it is suggested to hold a special session for conducting an updated Pacific saury stock assessment in January 2021 using the 2019 CPUE data after cross-checking the computer code of Members' stock assessment analyses. This would reduce the time lag between data availability and report to the Commission and also enhance the transparency and reproducibility of the analyses.

55. The SSC PS noted that Vanuatu is a small island developing state which still needs to develop its fishery, and that the Vanuatu urges the SSC PS to consider its aspiration when making recommendations to the Commission.

8.5 Recommendations for future work

56. Recommendations for future work are given in paragraph 52 and the SSC PS Work Plan.

Agenda Item 9. Biological information on Pacific saury

9.1 Review of any updates and progress

9.2 Distribution and migration patterns of juvenile Pacific saury

57. Japan presented a description of the longitudinal distribution of Pacific saury juveniles (NPFC-2020-SSC PS07-WP15). Japan calculated cumulative percentages of age-0 abundance from west to east for all years from 2003 to 2019. Two major patterns in annual longitudinal distributions were observed. Age-0 fish showed a multi-peak longitudinal distribution pattern in some years. On the contrary, most age-0 fish were found only in the waters east of 180°E longitude in the rest of those years. The present western boundary at 170°E longitude is highly likely to fail to protect a large part of age-0 fish under the situations in some years. In light of the precautionary approach, Japan proposed to expand the area by setting the western boundary at 160°E longitude to prevent exposure to fishing pressure for age-0 fish not only in the eastern part but also the western part of distributions.

58. Chinese Taipei noted that age composition in scientific surveys may differ from age composition in fisheries due to the selectivity of the sampling/fishing gears. The Chinese Taipei research results for the age composition of catch in 2017 showed that on average less than 20% saury was age-0 fish in the catch from May to July, in which the fishing locations were mainly east of 160°E.

59. The SSC PS encouraged Members to conduct further analyses, including refining the method of calculating annual longitudinal distributions.

60. The SSC PS recognized the need to engage in further research and discussions to further refine the definition of juvenile Pacific saury described in paragraph 20 of the SSC PS04 report.

9.3 Recommendations for future work

61. Recommendations for future work are given in paragraphs 59, 60 and the SSC PS Work Plan.

Agenda Item 10. Exploration of stock assessment models other than existing "provisional base models"

10.1 Review of proposals for developing new stock assessment models

62. China presented a trial study of stock assessment for North Pacific Ocean Pacific saury using Age-Structured Assessment Program (ASAP; NPFC-2020-SSC PS06-WP09). The trial was successful and the ASAP model may be useful in future stock assessments for Pacific saury, particularly if non-linear CPUE models can be accommodated.

63. The SSC PS requested the NPFC Secretariat to inquire with the developer of the model about incorporating hyperstability parameters into ASAP.

64. The SSC PS encouraged Members to conduct research towards the development and evaluation of age/size-structured production models.

10.2 Invention and refinement of data

65. Japan presented its age-determination and age-length keys for Pacific saury, from 2000 to 2018 (NPFC-2020-SSC PS06-WP16).

66. Chinese Taipei presented body length distributions and age compositions of the Pacific saury caught by the Chinese Taipei saury fishery in 2007-2018 (NPFC-2020-SSC PS06-WP18).

10.3 Finalization of initial data set and assumptions for initial trials of conditioning new stock assessment models

10.4 Discussion on simulation setting

10.5 Data sharing protocol for age/size/stage-structured models

67. The SSC agreed to hold further discussions intersessionally through a Small Working Group (SWG) regarding age-determination techniques and the development of a standardized approach to determining, collecting and sharing age and size data. The SWG will be co-led by Dr. Satoshi Suyama (Japan) and Dr. Wen-Bin Huang (Chinese Taipei). The SWG will provide an update to the next SSC PS meeting.

68. The SSC PS agreed to hold further discussions on the specifications for age-structured models at the next SSC PS meeting.

10.6 Recommendations for future work

69. Recommendations for future work are given in paragraphs 64, 67, 68 and the SSC PS Work Plan.

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

11.1 Review of RPs report

11.2 Investigation of reasonable actions

11.3 Discussion on MSE

11.4 Recommendations for future work

70. The SSC PS agreed to continue to advance discussions and work toward the setting of biological RPs and development of the timeframe for the MSE process as described in the SSC PS Work Plan.

71. The SSC-PS agreed to evaluate the performance of the $B_{current}$ * F_{MSY} approach used to calculate the 2020 TAC through historical TAC calculations in comparison to observed catches and stock trends, by simulation and by any other means available.

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

72. The SSC PS reviewed the 2020-2024 SSC PS 5-Year Rolling Work Plan and updated it as detailed in NPFC-2020-SSC PS06-WP01 (Rev. 1).

Agenda Item 13. Other matters

13.1 Draft agenda and priority issues for next meeting

73. The Chair will develop the agenda and priorities for the next meeting based on the SSC PS Work Plan.

13.2 Date of SSC PS meetings in 2021

74. The SSC PS suggested to hold two four-day meetings in 2021, the first in October (preparation of data (fisheries data up to 2020, survey index up to 2021, nominal CPUE data up to September 2021), model specifications, and stock assessment output format) and the second in December (stock assessment).

13.3 Invited experts

75. The SSC PS expressed its appreciation for the continued valuable contributions of the invited expert, Dr. Larry Jacobson.

76. As Dr. Jacobson will no longer be able to participate in the meetings of the SSC PS, the SSC PS recommended that an expert with similar qualifications and experience be invited to the next SSC PS meetings.

13.4 Other matters

77. No other matters were discussed.

Agenda Item 14. Recommendations to the Scientific Committee

78. The SSC PS06 recommends the following to the SC:
    (a) Endorse the Terms of Reference for the SSC PS proposed at the SSC PS05 meeting (Annex D).
    (b) Endorse the CPUE Standardization Protocol revised at the SSC PS05 meeting (Annex E).
    (c) Endorse the stock assessment report (Annex H).

(d) Further measures should be taken effectively to avoid the decreasing trend identified by:
    (i) Stock assessments conducted by China, Japan and Chinese Taipei (Annex H)
    (ii) Members' and joint standardized CPUEs up to 2019 (Annex G)
    (iii) Japan's fishery-independent biomass index up to 2020 (Annex I)
    (iv) Members' catch up to 2019 and preliminary catch as of 14 November 2020 (Annex F)
    (v) Members' preliminary estimates of nominal CPUEs up to 2020

(e) Endorse the SSC PS Work Plan (NPFC-2020-SSC PS06-WP01 (Rev. 1)).

(f) Allocate funds for the participation of an invited expert in the next SSC PS meetings.

(g) Hold two four-day meetings in 2021, in October and December.

Agenda Item 15. Adoption of the Report

79. The SSC PS06 Report was adopted by consensus.

Agenda Item 16. Close of the Meeting

80. The meeting closed at 16:37 on 23 November 2020, Tokyo time.

Annexes:

Annex A – Agenda

Annex B – List of Documents

Annex C – List of Participants

Annex D – Terms of Reference for the SSC PS

Annex E – CPUE Standardization Protocol for Pacific Saury

Annex F – Members' Pacific saury catches up to 2020, with preliminary catch statistics as of 14 November 2020

Annex G – Updated total catch, CPUE standardizations and survey biomass indices for the stock assessment of Pacific saury

Annex H – Stock Assessment Report for Pacific Saury

Annex I – Japan's fishery-independent biomass index from 2003 to 2020

Annex A

Agenda

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- 3.1 SSC PS05 meeting
- 3.2 SSC PSint01 virtual meeting
- 3.3 COM05 meeting and CMM 2019-08

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
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Agenda Item 9. Biological information on Pacific saury
- 9.1 Review of any updates and progress
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Agenda Item 10. Exploration of stock assessment models other than existing "provisional base models"
- 10.1 Review of proposals for developing new stock assessment models
- 10.2 Invention and refinement of data

10.3 Finalization of initial data set and assumptions for initial trials of conditioning of new stock assessment models
10.4 Discussion on simulation setting
10.5 Data sharing protocol for age/size/stage-structured models
10.6 Recommendations for future work

Agenda Item 11. Toward setting of biological reference points (RPs) and development of Management Strategy Evaluation (MSE)
11.1 Review of RPs report
11.2 Investigation of reasonable actions
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Agenda Item 12. Review of the Work Plan of the SSC PS

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Annex B

List of documents

MEETING INFORMATION PAPERS

Symbol	Title
NPFC-2020-SC05-MIP01 (Rev. 1)	Details for the virtual meetings of the Scientific Committee and its subsidiary bodies
NPFC-2020-SSC PS06-MIP02	Provisional Agenda
NPFC-2020-SSC PS06-MIP03 (Rev. 1)	Annotated Indicative Schedule

REFERENCE DOCUMENTS

Symbol	Title
NPFC-2020-SSC PSint01-Summary	Summary of the 1st Intersessional Meeting of the Small Scientific Committee on Pacific Saury
NPFC-2019-SSC PS05-Final Report	Report of SSC PS05 Meeting
	Review of Target and Limit Reference Points (Consultancy Report by Laurence T. Kell)
NPFC-2019-COM05-Final Report	Report of the 5th Commission Meeting
CMM 2019-08	CMM 2019-08 for Pacific Saury
	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

WORKING PAPERS

Symbol	Title
NPFC-2020-SSC PS06-WP01 (Rev. 1)	SSC PS Work Plan for 2020-2025
NPFC-2020-SSC PS06-WP02	Compiled data on Pacific saury catches in the northwestern Pacific Ocean
NPFC-2020-SSC PS06-WP03	Standardized CPUE of Pacific saury (*Cololabis saira*) caught by the Korean's stick-held dip net fishery up to 2019
NPFC-2020-SSC PS06-WP04	CPUE standardization for the Pacific saury Russian catches in the Northwest Pacific Ocean
NPFC-2020-SSC PS06-WP05	Standardized CPUE of Pacific saury (*Cololabis*

	saira) caught by the Chinese Taipei stick-held dip net fishery up to 2019
NPFC-2020-SSC PS06-WP06	Joint CPUE standardization of the Pacific saury in the Northwest Pacific Ocean during 2001-2019 by using the conventional and geostatistical approaches
NPFC-2020-SSC PS06-WP07	Standardized CPUE of Pacific saury (*Cololabis saira*) caught by the China's stick-held dip net fishery up to 2019
NPFC-2020-SSC PS06-WP08	North Pacific Ocean Pacific Saury (*Cololabis saira*) 2020 Stock Assessment Update Report
NPFC-2020-SSC PS06-WP09	A trial study of stock assessment for North Pacific Ocean Pacific Saury (*Cololabis saira*) using Age-Structured Assessment Program
NPFC-2020-SSC PS06-WP10 (Rev. 1)	2019 updates of stock assessment for Pacific saury in the North Pacific Ocean by using Bayesian state-space production models
NPFC-2020-SSC PS06-WP11	Pacific saury fishing condition in Japan
NPFC-2020-SSC PS06-WP12	Standardized CPUE of Pacific saury (*Cololabis saira*) caught by the Japanese stick-held dip net fishery up to 2019
NPFC-2020-SSC PS06-WP13	Updated outcomes on application of VAST model to fishery-independent survey data for Pacific saury
NPFC-2020-SSC PS06-WP14	Estimation of Japanese survey biomass index of Pacific saury for 2020 using VAST model
NPFC-2020-SSC PS06-WP15	Description of longitudinal distribution of Pacific saury juvenile in response to NPFC CMM 2019-08
NPFC-2020-SSC PS06-WP16	Age-determination and age-length keys for Pacific saury, *Cololabisa saira*, from 2000 to 2018
NPFC-2020-SSC PS06-WP17	Stock assessment of Pacific saury (*Cololabis saira*) in the Western North Pacific Ocean through 2019
NPFC-2020-SSC PS06-WP18	Body length distributions and age compositions of the Pacific saury caught by the Chinese Taipei saury fishery in 2007-2018
NPFC-2020-SSC PS06-WP19	Saury fishery in the Northwest Pacific by Russian vessels in 2019 and preliminary results of fishery in 2020

Annex C

List of participants

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Annex D

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

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 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
5. 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
6. To facilitate data- and code- sharing processes
7. To review/improve the presentation of stock assessment results (including stock status summary reports in a format to be determined by the Working Group)
8. To explore the design of the Management Strategy Evaluation framework.

Annex E

CPUE Standardization Protocol for Pacific Saury

The use of CPUE in a stock assessment implicitly assumes that CPUE is proportional to stock abundance/biomass. However, many factors other than stock abundance/biomass may influence CPUE. Thus, any other factors, other than stock abundance/biomass, that may influence CPUE should be removed from the CPUE index. The process of reducing/removing the impacts of these factors on CPUE is referred to as CPUE standardization.

<u>The following protocol is proposed for the CPUE standardization:</u>

(1) Conduct a thorough literature review to identify key factors (i.e., spatial, temporal, environmental, and fisheries variables) that may influence CPUE values;

(2) Determine temporal and spatial scales for data grouping for CPUE standardization;

(3) Plot spatio-temporal distributions of fishing efforts and catch to evaluate spatio-temporal patterns of fishing effort and catch;

(4) Calculate correlation matrix to evaluate correlations between each pair of those variables;

(5) Identify potential explanatory variables based on (1)-(4) as well as interaction terms to develop full model for the CPUE standardization;

(6) Fit candidate statistical models to the data (e.g., GLM, GAM, Delta-lognormal GLM, Neural Networks, Regression Trees, Habitat based models, and Statistical habitat based models);

(7) Evaluate the models using methods such as likelihood ratio, AIC/BIC and cross validation;

(8) Evaluate if distributional assumptions are satisfied and if there is a significant spatial/temporal pattern of residuals in CPUE standardization modeling;

(9) Extract yearly standardized CPUE and standard error by a method that is able to account for spatial heterogeneity of effort, such as least squares mean or expanded grid. If the model includes area and the size of spatial strata differs or the model includes interactions between time and area, then standardized CPUE should be calculated with area weighting for each time step. Model with interactions between area and season or month requires careful consideration on a case by case basis;

(10) Recommend a time series of yearly standardized CPUE and associated uncertainty;

(11) Plot nominal and standardized CPUEs over time;

(12) This protocol can be used for joint CPUE standardization.

DOCUMENT TEMPLATE FOR PRESENTING STANDARDIZED CPUE OF PACIFIC SAURY

Title: Standardized CPUE of Pacific saury (*Cololabis saira*) caught by the MEMBER's stick-held dip net fishery up to 20XX

Author's Name(s)

Affiliation(s)

Background of the Pacific saury fishery

- Description of the Pacific saury fishery of corresponding member.

METHOD

The data

- Spatial and temporal patterns of catch and effort (Fig. 1)
- Available covariates with explanation on resolution and coverage (Table 1)
- Correlations among the variables (Fig. 2)
- If there are any candidate environmental covariates, describe explanations and the reason for including them.

Full model description and model selection

- Type and assumptions of the model
- Response and explanatory variables and interactions
- Assumed error distribution
- Formulation of full model
- Model selection method

Yearly trend extraction

- How to extract yearly trend from the selected model

- How to evaluate uncertainty of the extracted trend, if necessary

RESULT and DISCUSSION

- Result of the model selection, at least for the full, null and best models (Table 2)
- Interpretation of the selected model
- Model diagnosis: Analysis of deviance table (Table 3), tendencies of the residuals (Fig. 3) and percentage of the deviance explained
- The extracted yearly trend (Table 4), comparing with the nominal CPUE (Fig. 4)
- Further discussion

REFERENCES

APPENDICES

- **Appendix I:** Checklist for the CPUE standardization protocol
- Further information in forms of description, figures, or table

Table 1 Summary of explanatory variables used in GLM*.

Variables		Number of categories	Detail	Note
Year	*Year*	25	1994–2018	
Month	*Month*	5	August–December	
Fishing area	*Area*	5	I–V	*see* Fig. 1
Vessel size	*Grt1*	10	$Grt<20$, $20 \leqq Grt<40$, ..., $180 \leqq Grt<200$ tons	at intervals of 20 tons
	Grt2	5	$Grt<40$, $40 \leqq Grt<80$, ..., $160 \leqq Grt<200$ tons	at intervals of 40 tons
Sea surface	*Sst1*	12	$Sst<10$, $10 \leqq Sst<11$, ..., $20\,^{o}\mathrm{C} \leqq Sst$	at intervals of 1°C
temperature	*Sst2*	5	$Sst<10$, $10 \leqq Sst<13$, ..., $19\,^{o}\mathrm{C} \leqq Sst$	at intervals of 3°C

**All of the tables and figures in this document template are presented as an example.*

Table 2 Result of model selection

No	$\eta(t_i)$	ϕ	Adj. R^2	Dev. expl. %	BIC	*d*
1	$\beta_0 + \beta^{Y}_{year_i}$	0.84	0.122	13.9	211201	26
2	$\beta_0 + \beta^{Y}_{year_i} + \beta^{M}_{month_i}$	0.83	0.132	15.1	210828	29
3	$\beta_0 + \beta^{Y}_{year_i} + \beta^{M}_{month_i} \vert \beta^{Y}_{year_i}$	0.79	0.155	18.7	210330	97
4	$\beta_0 + \beta^{Y}_{year_i} + \beta^{M}_{month_i} \vert \beta^{Y}_{year_i} + \beta^{V}_{Idves_i}$	0.73	0.194	23.0	**209391**	148
5	$\beta_0 + \beta^{Y}_{year_i} + \beta^{M}_{month_i} + \beta^{V}_{Idves_i}$	0.76	0.171	19.3	209958	80

β_0 – intercept, $\beta^{Y}_{year_i}$ – coefficient of *i*-th year ($year_i$), $\beta^{M}_{month_i}$ – coefficient of *i*-th month ($month_i$), $\beta^{V}_{Idves_i}$ – coefficient of *i*-th unique ID of a vessel ($Idves_i$).

Table 3 Analysis of deviance table

	SS	Df	F	Pr(>F)	Signif. codes
Year	453.8	24	39.35	< 2.2e-16	***
Month	117.3	1	244.06	< 2.2e-16	***
Grt1	265.9	7	79.03	< 2.2e-16	***
Sst2	51.1	4	26.60	< 2.2e-16	***
Year:Month.int	1067.4	72	30.85	< 2.2e-16	***
Year:Area.int	296.3	48	12.85	< 2.2e-16	***
Year:Grt.int	258.6	48	11.21	< 2.2e-16	***
Month.int:Area.int	45.4	6	15.734	< 2.2e-16	***
Month.int:Grt.int	33.5	6	11.624	4.74E-13	***
Area.int:Grt.int	39.4	6	13.651	1.50E-15	***
Residuals	19277.7	40113			

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Table 4 Nominal and standardized CPUEs of Japanese stick-held dip net fishery for Pacific saury from 1994 to 2018.

Year	Nominal CPUE (metric ton / hauls)	Standardized CPUE	CV (%)	95% CI	
				Lower	Upper
1994	5.38	2.93	3.53	2.74	3.14
1995	4.41	2.16	6.53	1.90	2.44
1996	2.40	1.62	4.69	1.48	1.77
1997	4.77	3.58	12.93	2.79	4.63
1998	1.44	1.02	3.86	0.94	1.09
1999	1.45	0.75	3.97	0.70	0.81
2000	2.18	1.37	4.38	1.26	1.49
2001	3.18	2.06	5.64	1.84	2.32
2002	1.93	1.15	5.66	1.02	1.29
2003	3.21	2.17	4.27	2.01	2.37
2004	3.65	2.51	3.95	2.33	2.71
2005	6.63	4.38	4.05	4.03	4.72
2006	6.03	3.93	4.30	3.61	4.28
2007	7.81	4.05	4.31	3.73	4.40
2008	7.81	4.93	4.06	4.56	5.31
2009	4.60	3.58	4.43	3.29	3.92
2010	2.73	1.49	3.66	1.37	1.59
2011	4.45	2.36	4.01	2.19	2.55
2012	3.65	2.31	4.31	2.12	2.52
2013	3.04	1.43	3.88	1.33	1.55
2014	5.42	2.49	3.64	2.32	2.67
2015	2.65	1.34	4.43	1.23	1.46
2016	2.82	1.50	5.94	1.33	1.68
2017	1.40	1.08	4.23	1.00	1.17
2018	2.96	1.40	3.91	1.30	1.52

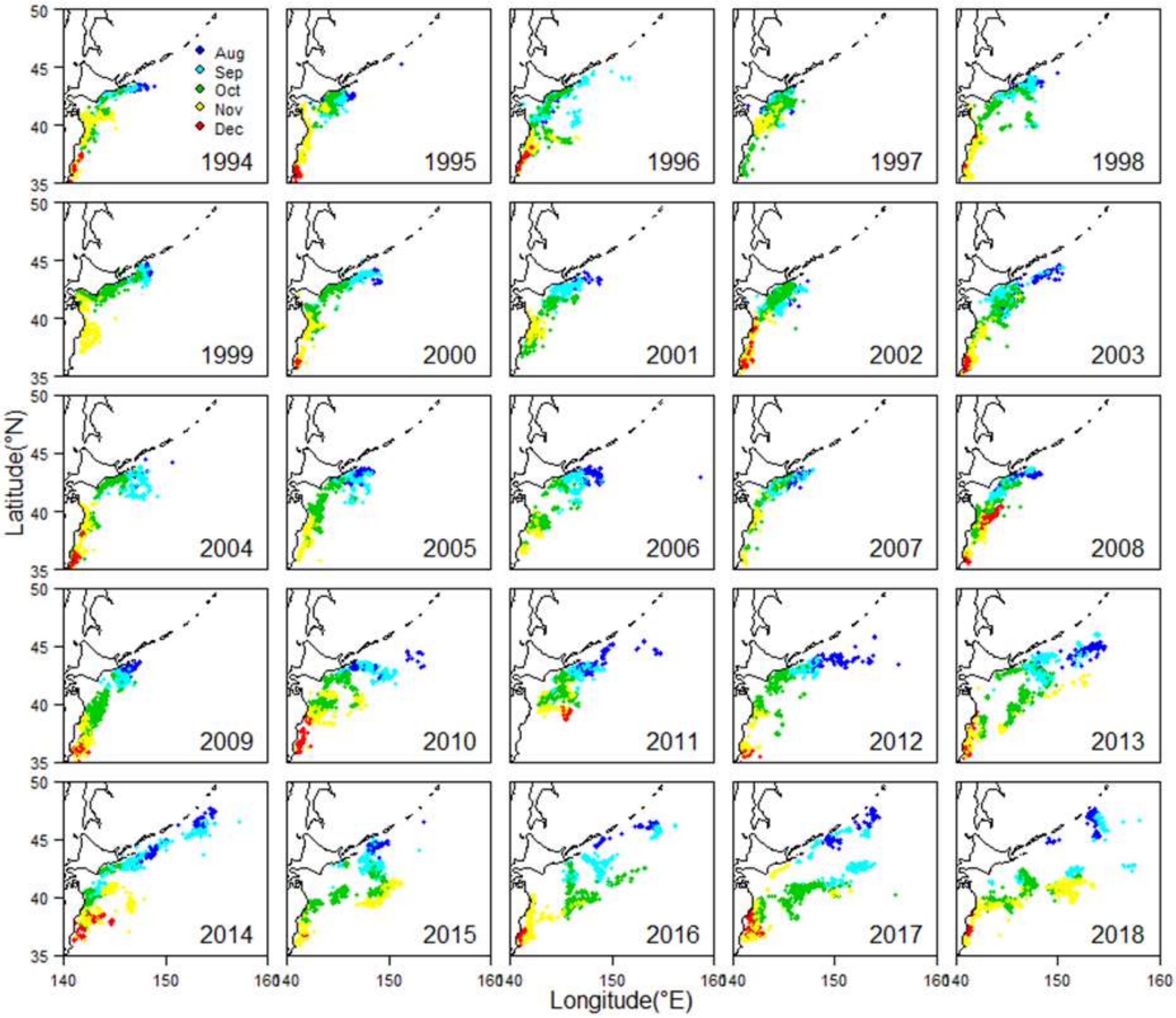


Fig. 1 Inter-annual variation of monthly fishing ground of Japanese stick-held dip net fishery for Pacific saury from 1994 to 2018.

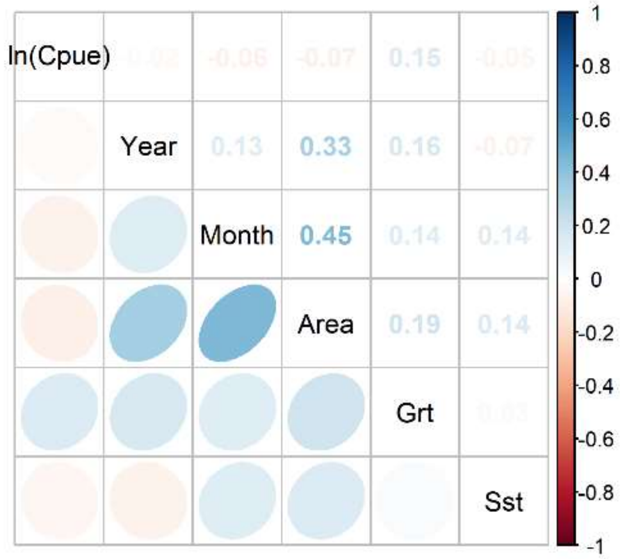


Fig. 2 Correlation matrix of explanatory variables used in the analysis.

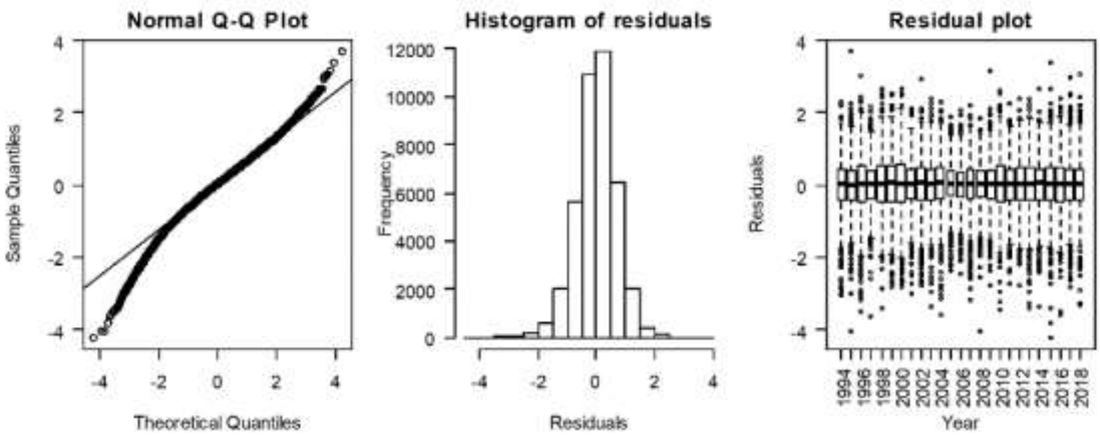


Fig. 3 Q-Q plot, histogram of residuals and residual plots across years for the best GLM.

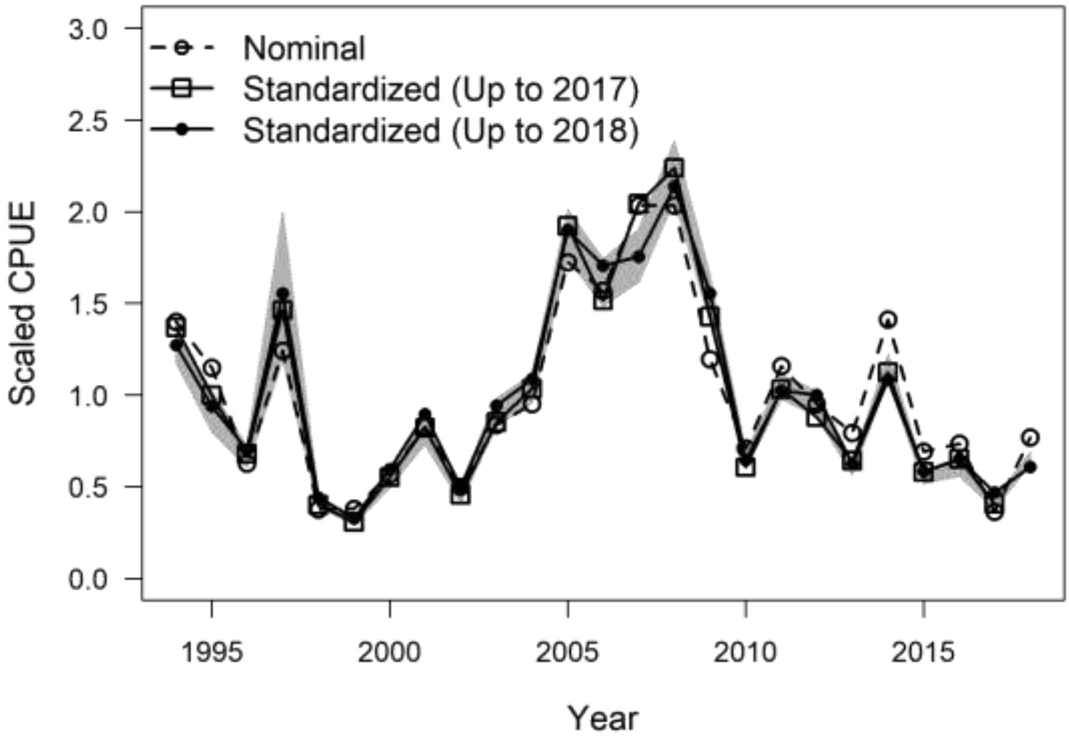
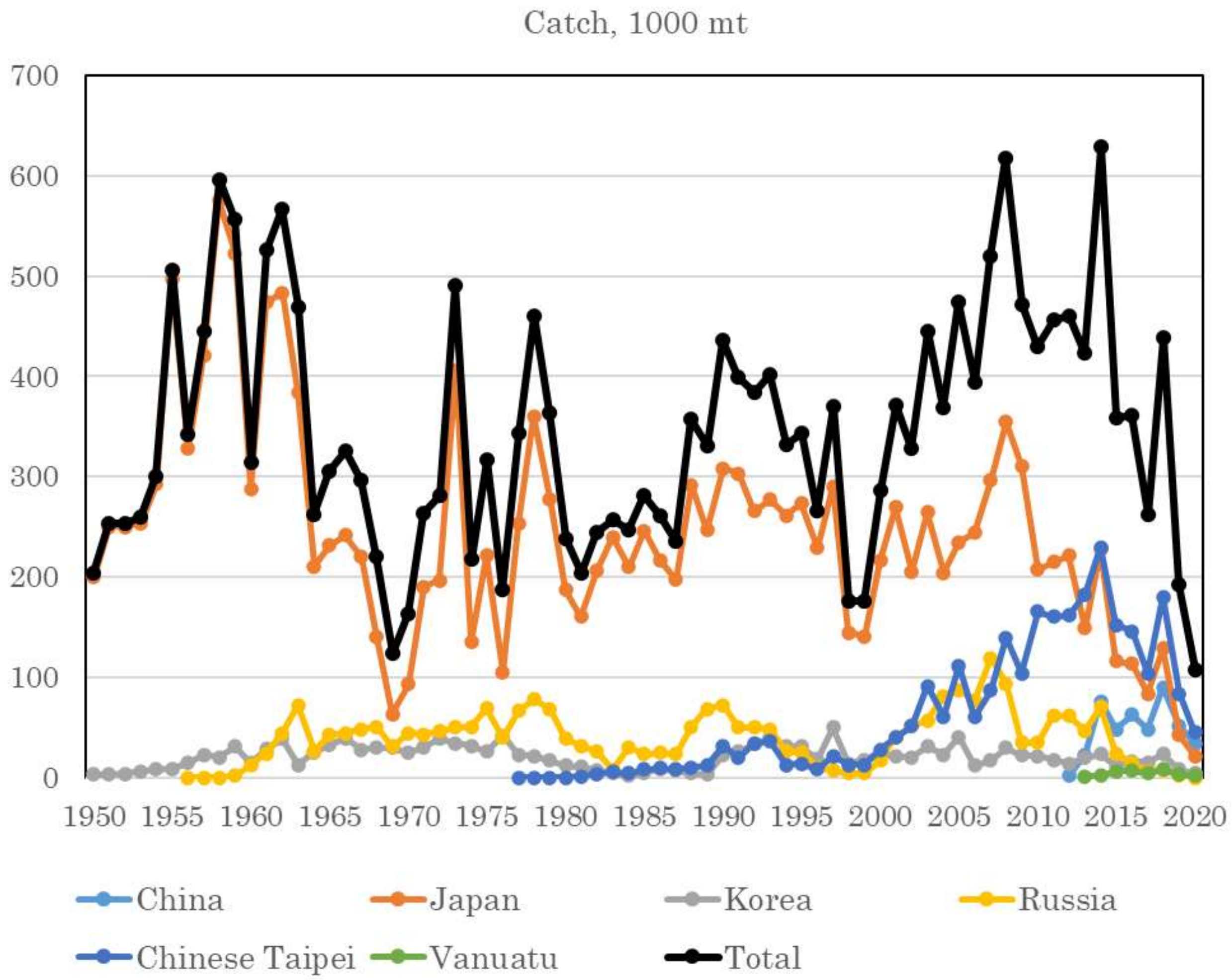


Fig. 4 A scaled nominal CPUE series and two scaled standardized CPUE series with catch and effort data up to 2017 and 2018. Gray zone indicates 95% confidence band for the standardized CPUE up to 2018.

Annex F

Members' Pacific saury catches up to 2020, with preliminary catch statistics as of 14 November 2020



2020 catch of Pacific saury, as of 14 November:						
China	Japan	Korea	Russia	Chinese Taipei	Vanuatu	TOTAL
34,386	21,618	4,313	249*	45,433	2,160	108,158

* Only in the Convention Area and does not include the catch in the Russia's EEZ.

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

Year	Total catch (metric tons)	Biomass JPN (Observed biomass)*	CPUE_ CHN (metric tons per day)	CPUE JPN_early (metric tons per net haul)	CPUE JPN_late (metric tons per net haul)	CPUE KOR (metric tons per day)	CPUE RUS (metric tons per day)	CPUE CT (metric tons per net haul)	Joint CPUE
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				3.07		17.7		
1995	343743				2.16		20.4		
1996	266424				1.67		15.0		
1997	370017				3.74		11.3		
1998	176364				1.07		12.4		
1999	176498				0.80		11.2		
2000	286186				1.43		16.1		
2001	370823				2.12	7.29	20.9	1.58	0.73
2002	328362				1.17	8.43	19.6	1.63	0.58
2003	444642	1,068.6			2.19	12.75	28.5	2.68	1.11
2004	369400	965.4			2.61	9.05	43.9	1.46	1.25
2005	473907	905.9			4.47	14.27	46.4	2.40	1.67
2006	394093	764.0			4.09	13.23	32.3	1.27	0.70

2007	520207	647.1			3.89	12.50	40.7	2.36	1.10
2008	617509	871.8			5.02	16.54	41.0	2.92	1.52
2009	472177	651.7			3.73	8.63	20.6	1.58	0.82
2010	429808	471.0			1.55	12.88	22.3	1.94	0.85
2011	456263	648.6			2.40	9.40	26.1	2.51	1.17
2012	460544	421.6			2.39	8.21	23.2	2.47	1.04
2013	423790.3	654.1	13.96		1.44	8.89	20.9	2.80	0.87
2014	629576.4	505.5	16.22		2.52	15.01	23.8	3.64	1.39
2015	358882.7	422.0	17.74		1.34	6.86	15.3	2.44	0.89
2016	361687.6	357.5	9.31		1.52	9.47	15.9	2.45	0.75
2017	262639.4	176.6	8.53		1.08	6.16	8.3	1.85	0.85
2018	439079.0	420.0	15.90		1.45	8.12	21.0	3.10	1.26
2019	192377.0	294.7	6.91		0.68	5.30	6.6	1.41	0.45

* Observed biomass corresponds to $\sum_i^N (d_i \cdot A_i)$, where d_i and A_i denote mean density and area in stratum i.

Annex H

Stock Assessment Report for Pacific Saury

Abstract:
This report presents results of stock assessment work at the 6th meeting of the Small Scientific Committee on Pacific Saury (SSC-PS), held virtually during November 19-23, 2020.

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 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.

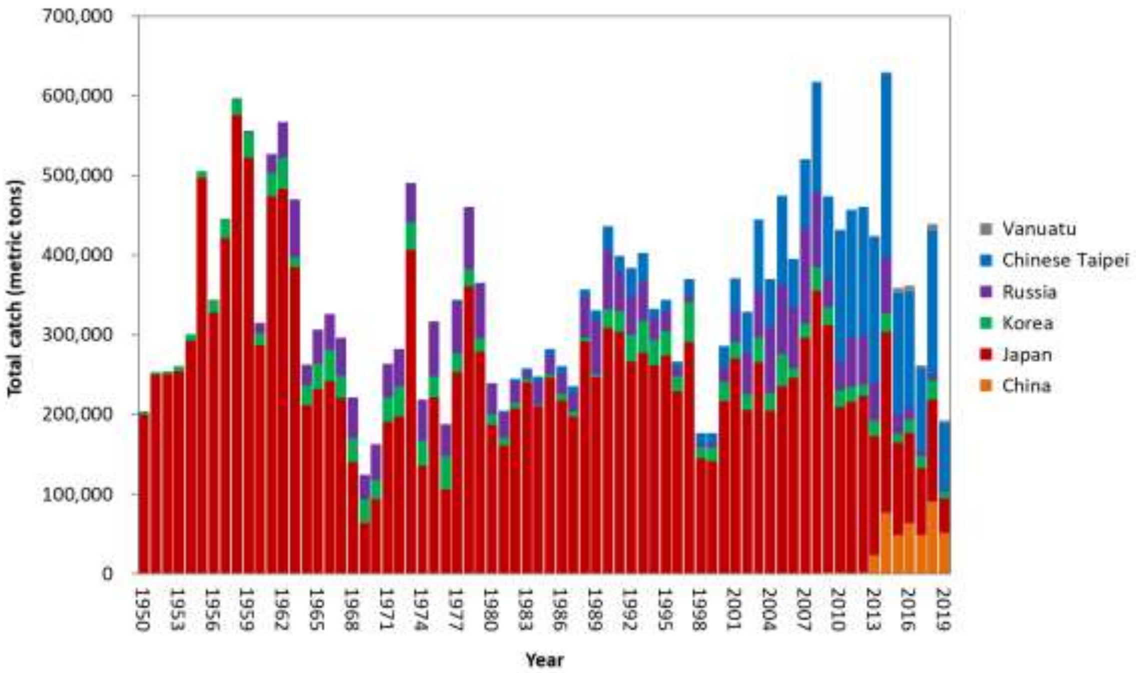


Figure 1. Time series of catch by Member during 1950-2019. The catch data for 1950-1979 and 2019 are shown but not used in stock assessment modeling.

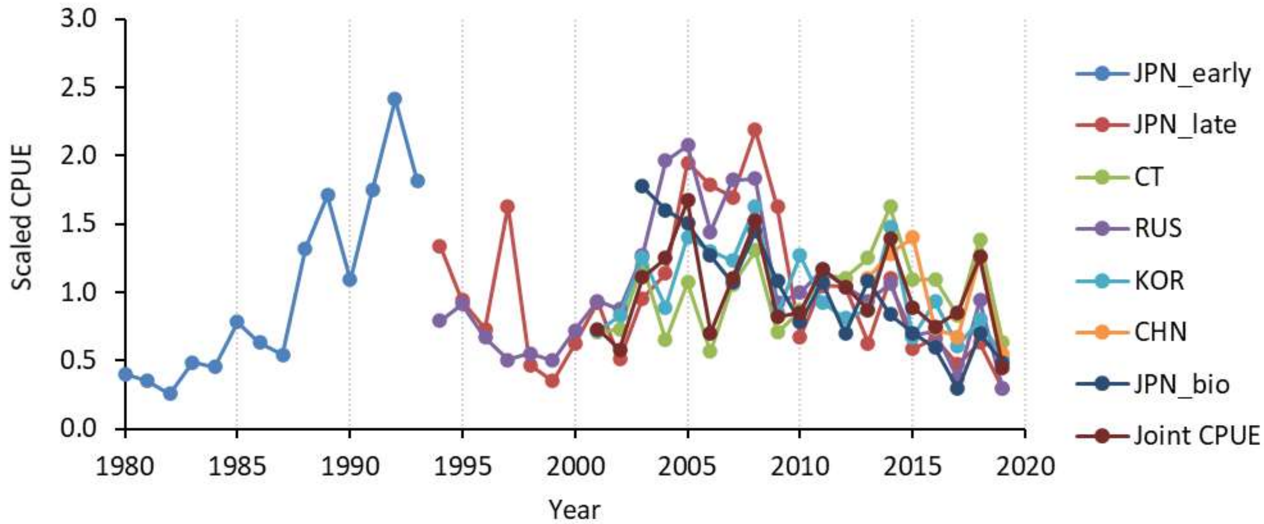


Figure 2. Time series of standardized CPUE and Japanese survey biomass indices (JPN_bio) during 1980-2019. Survey data for 2019 were used in assessment modeling but CPUE data for 2019 were not.

Brief description of specification of analysis and models

A Bayesian state-space production model used in previous stock assessments was employed as an agreed provisional stock assessment model for Pacific saury during 1980-2019. Scientists from three Members (China, Japan and Chinese Taipei) each conducted analyses following the agreed specification which called for two base case scenarios and four sensitivity scenarios (see Annex G, SSC PS05 report for more details). The two base case scenarios differ in using Japanese early CPUE (base case NB1) or not (base case NB2). Time-varying catchability for Japanese CPUE was assumed in NB1 to account for potential increases in catchability between 1980 and 1994. A higher weight was given to the Japanese survey biomass indices 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 dissimilarities among Members' results for base case 2. The SSC PS was unable to clarify the reason for the dissimilarities and agreed that it would not be advisable to aggregate Members' stock results.

All six base case model runs (two scenarios from each of three members) indicate that recent Pacific saury stock size was less than Bmsy (Figure 3). In particular, median estimates from five out of six runs indicate that 2019 Pacific saury biomass was less than Bmsy. Results from all six model runs indicate that average 2017-2019 biomass was less than Bmsy (see also Figure 4).

A majority of base case model comparisons indicate that recent harvest rates for Pacific saury were higher than Fmsy (Figure 3). In particular, median estimates from five runs indicate that the harvest rate during 2019 and average rates during 2017-2019 were higher than Fmsy (see Figures 3 and 4).

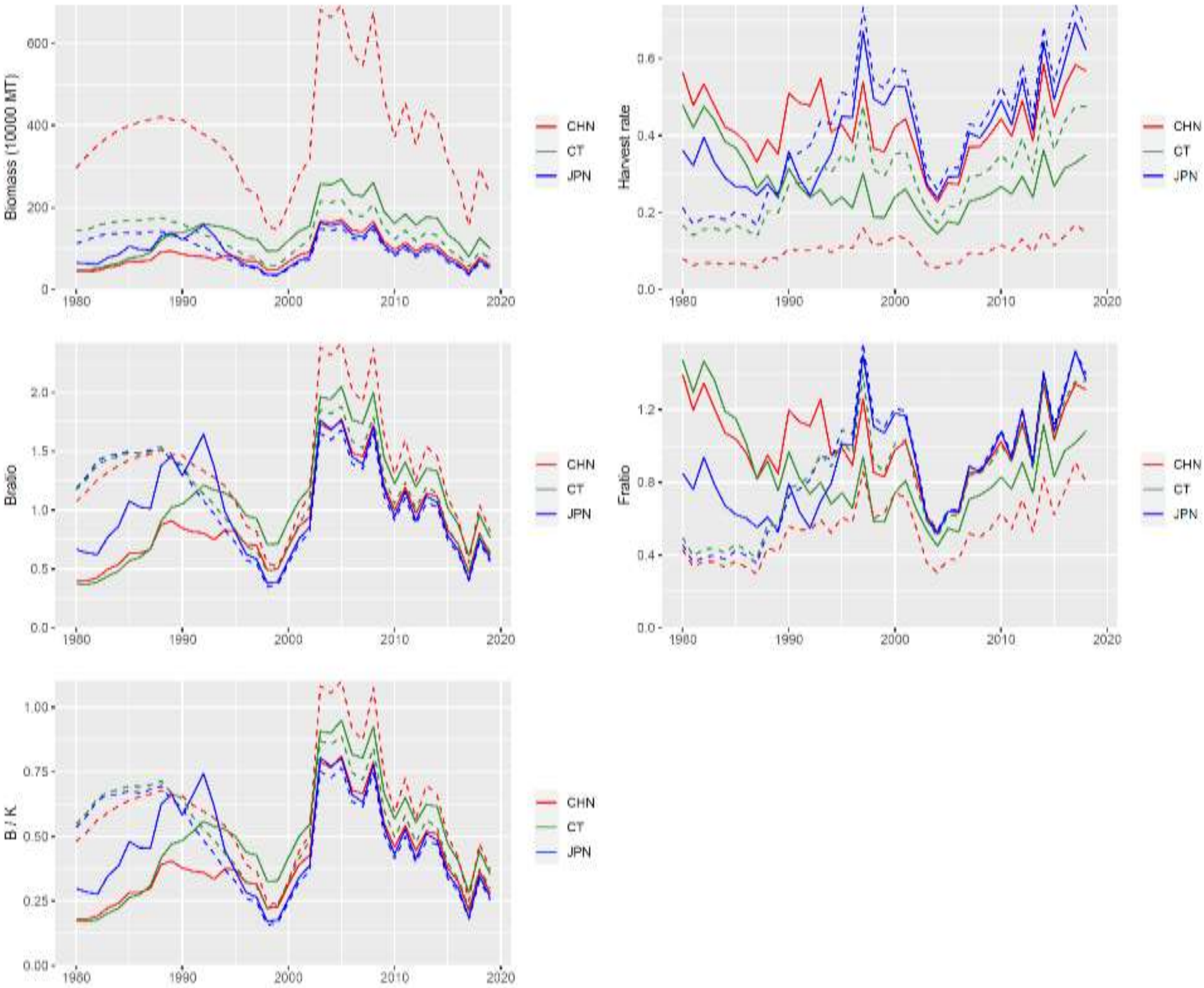


Figure 3. Time series of median estimated values of six runs for biomass, harvest rate, B-ratio, F-ratio, and depletion level relative to the carrying capacity. The solid and shaded lines correspond to NB1 and NB2, respectively.

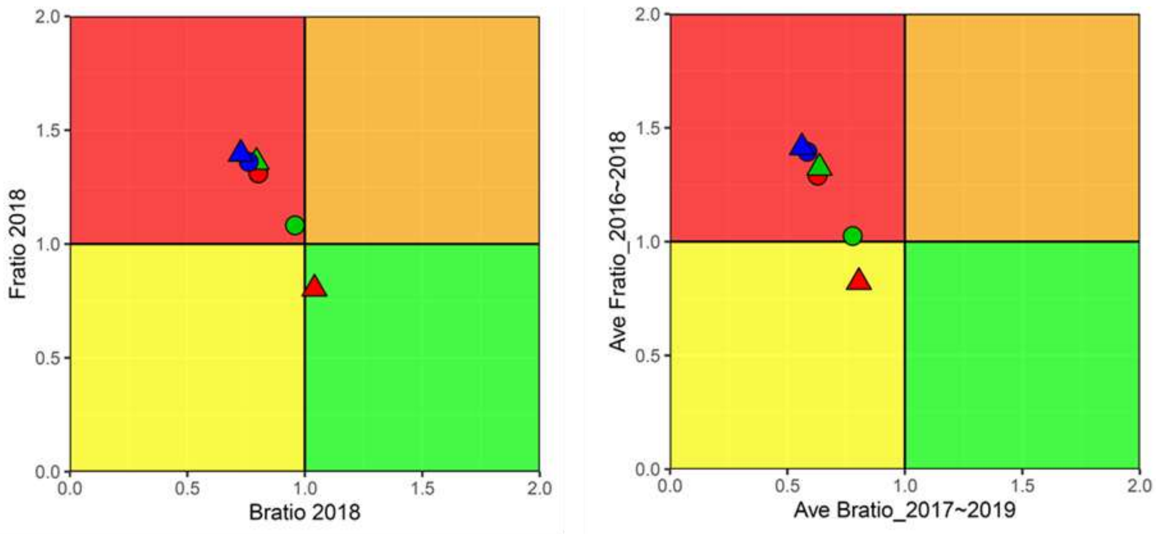


Figure 4. Kobe plots for six runs for NB1 (circle) and NB2 (triangle) by three members' scientists (red for China, blue for Japan and green for Chinese Taipei).

Additional data for 2019-2020 indicate Pacific saury biomass continued to decline after 2019 to a relatively low level in 2020. In particular, CPUE and catch data for 2019, preliminary fishery data through October 2020 and Japanese survey data for 2020 were presented and discussed but could not be included in BSSPM analysis (there were also concerns about the plausibility of the very low biomass estimate, see below). The additional fishery data for 2019 has no additional uncertainty but the 2020 fishery and survey data include increased uncertainty due to effects of Covid-19 which delayed the start of the commercial fishery for some members, may have affected commercial operations and reduced the Japanese survey to a smaller area and narrower SST range than usual. The additional uncertainty for 2020 must be clearly described and considered carefully.

SSC PS members indicate that Covid-19 effects on catches were likely stronger than effects on CPUE. Nominal CPUE for 2020 calculated by Members using data through October were not comparable to data for previous years based on the entire fishing season. For the sake of comparability, nominal CPUE was recalculated for all years based on fishing through October. Trends in the seasonally truncated data through were similar to original CPUE trends and to standardized CPUE used in assessment modeling. The adjusted data show that 2020 CPUE for each Member was at historical low levels. 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.

Preliminary catch data for 2020 through the end of October totaled only about 67 thousand mt. Fishing continues but most Members do not expect catch to increase substantially based on seasonal trends and low CPUE (Figure B=seasonal cumulative catch by Member). Thus, 2020 catches are expected to be low.

The Japanese fishery-independent survey is important in Pacific saury stock assessments. Survey catches during 2020 were very low and the original swept-area biomass estimate was only about 10 thousand mt. However, sampling did not cover the traditional survey area outside the 13° isotherm where one-year-old Pacific saury may be encountered in large numbers and east of 170° W where zero-year-old fish are most common (about 50% of total biomass is typically in the area not sampled based on historical records). The SSC PS reviewed a 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 in 2002 was only 51 thousand MT (CV 98%, 95% CI 7-180 thousand mt) compared to the average swept-area biomass of 383 thousand mt during 2015-2019. The SSC PS did not endorse the VAST point estimate in 2020 due to high uncertainty and some doubt about plausibility of the very low estimates. However, they agreed that the VAST estimates as a whole captured the declining trend in the stock during recent years.

Table 1. Summary of estimates of reference quantities. Median values are reported.

	China		Japan		Chinese Taipei	
	Base case 1	Base case 2	Base case 1	Base case 2	Base case 1	Base case 2
C2018 (10,000tons)	43.91	43.91	43.91	43.91	43.91	43.91
AveC2016-2018 (10,000tons)	35.45	35.45	35.45	35.45	35.45	35.45
AveF2016-2018	0.56	0.15	0.64	0.69	0.40	0.63
F2018	0.57	0.15	0.62	0.68	0.43	0.65
FMSY	0.44	0.21	0.46	0.48	0.40	0.45
MSY(10,000tons)	43.18	54.81	42.9	44.1	43.04	41.56
F2018/FMSY	1.31	0.80	1.36	1.40	1.11	1.55

AveF2016-2018/FMSY	1.30	0.83	1.40	1.42	1.04	1.52
K (10,000tons)	221.10	689.00	207.6	206.0	287.80	251.30
B2018 (10,000tons)	77.27	295.85	70.5	65.0	125.50	92.25
B2019 (10,000tons)	59.61	231.10	54.0	50.2	100.30	74.19
AveB2017-2019 (10,000tons)	60.81	228.73	55.9	51.8	102.29	74.07
BMSY (10,000tons)	98.05	305.70	92.9	91.7	131.60	116.35
BMSY/K	0.43	0.43	0.44	0.44	0.46	0.46
B2018/K	0.37	0.47	0.35	0.33	0.44	0.37
B2019/K	0.28	0.37	0.27	0.25	0.35	0.30
B2017-2019/K	0.29	0.37	0.28	0.27	0.36	0.30
B2018/BMSY	0.80	1.04	0.76	0.73	0.96	0.79
B2019/BMSY	0.62	0.82	0.58	0.56	0.77	0.64
B2017-2019/BMSY	0.63	0.81	0.61	0.58	0.78	0.64

Current stock condition

All six base case model runs (two scenarios from each of three members) indicate that recent Pacific saury stock size was less than Bmsy. In particular, median estimates from five out of six runs indicate that 2019 Pacific saury biomass was less than Bmsy. Results from all six model runs indicate that average 2017-2019 biomass was less than Bmsy. Relative abundance indices indicated that Pacific saury stock biomass may have been near record low levels during 2019 and 2020. The 2020 biomass index from the Japanese survey has large uncertainties but dropped to the historical lowest level.

A majority of base case model comparisons indicate that recent harvest rates for Pacific saury were higher than Fmsy. In particular, median estimates from five runs indicate that the harvest rate during 2019 and average rates during 2017-2019 were higher than Fmsy.

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) 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 showed that BSSPM model projections for Pacific saury were less useful than expected and the SSC-PS agreed results were likely to be misinterpreted. The issue was discussed and further explained in the report. Additional research or age-structured assessment modelling may be required to provide projection results for use by managers, to enhance projection capability and support potential MSE (Management Strategy Evaluation) work.
3) The SSC-PS noted that an internal computation of q for the Japanese survey used in calculating predicted survey values and prior probability might improve model performance. However, there was no evidence of a problem in the current model formulation.
4) The SSC PS reviewed promising approach for spatial/temporal model-based survey biomass estimation using Japanese survey data and the VAST model. The SSC-PS agreed that the approach was useful and decided to

continue work on the topic.

5) Certain key BSSPM parameter estimates (i.e. intrinsic growth rate and shape) reached the upper bound of their prior ranges in some models indicating that their priors should be refined before the next assessment.
6) Results for scenario NB2 in one Member's analysis were significantly higher than from results of other runs but the reason could not be determined given the time constraint and meeting format. The SSC PS noted that the scales of estimated biomass among previous base case scenarios from the three Members have shown some discrepancies.
7) The Invited Expert and some Members pointed out scale instability in the NB2 model run may have been due to or exacerbated by specification of prior distributions, computer code or other correctable problem in addition to lack of information about scale in the available data. All of these potential causes are very common and should be expected to occur from time to time in practical fishery work with statistically or computationally complex models and fishery data. In any case, it seems premature to conclude that the BSSPM is inherently or unusually unstable given that such pathological patterns were not observed in other base case models used in this assessment or previous assessments.
8) Member scientists agreed to exchange the code and input data files and work collaboratively to explain the differences.
9) Nominal and standardized CPUE data were available for 2019 but not used in assessment models because they were not included in the terms of reference. However, the data for 2019 indicate that Pacific saury biomass for all Members declined by an average of about 50% during 2018-2019. For example, the decline based on GLM standardized joint CPUE was 59%.
10) It would be easier to maintain computer code and ensure correct calculations if one program were used by all Members, particularly as more complicated age/size-structured models are introduced.
11) It may be possible to increase efficiency of stock assessment work by reducing duplicate work by Members. For example, CPUE standardization, model development and assessment modeling might be done by single subgroups. The time saved could be used to develop harvest control rules and implement age-structured models, for example.
12) Transparency and reproducibility could be enhanced by submitting computer programs, code and input data files used for assessment modeling and standardizing CPUE data by each Member.
13) This executive summary for Pacific saury stock assessment results is an attempt to enhance communication with managers, other scientists and interested persons who may not want to read the full assessment report with complete technical details. Such reports are typically short and include agreed sets of tables and figures in standard formats. The NPFC should discuss a common format of the executive summary over species with respect to information requirements and effective communication.
14) Members report that the fishing grounds have shifted further offshore over the last decade. Japanese survey results indicate possible changes in spatial distribution of Pacific saury habitat. Potential effects on productivity are unknown.
15) Pacific saury stock size has declined over the last two decades due to climatic and human factors acting together in a manner that is not understood. There is an urgent need to determine if ongoing environmental changes are likely to be reducing productivity of the fishery. The SSC-PS should routinely devote time to investigating the biological and ecological mechanisms linking population dynamics and the environment. The recent paper by Members (Hsu, J., Chang, Y.J., Kitakado, T., Kai, M., Li, B., Hashimoto, M., Hsieh, C.H, Kulik, V., Park, K. J. (2020). Evaluating the spatiotemporal dynamics of Pacific saury in the Northwestern Pacific Ocean by using a geostatistical modelling approach. Fisheries Research (accepted)) demonstrates the success and importance of working on this topic.
16) An Fmsy approach was used to calculate a TAC for 2020 and the SSC-PS recognizes this as an important step in management. However, it can be difficult to estimate current Fmsy from historical data when the environment is changing. It is therefore important to further evaluate the Fmsy approach for Pacific saury. For example, historical TAC values could be calculated using the Fmsy estimate and historical biomass estimates from the BSSPM for comparison to actual catches after 2000 while the stock was declining. Calculations of this sort could be completed this year as a prelude to a more extensive MSE effort

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 Kuril Islands to eastward to 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

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 160E) 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 technic 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 43 thousand tons were recorded in 2008 and 2019, 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 thousand tons in 2019.

China commenced its exploratory saury fishing using stick-held dip net 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.

The Pacific saury fishery of Chinese Taipei was first developed in 1975 by a research vessel, thereafter two commercial fishing vessels started operating in the Northwest Pacific Ocean in the next year. Between the 1980s and the early 1990s, the Pacific saury caught by some fishing fleets including trawlers, drift net fishing vessels, squid jiggers and tuna longliners. The number of fishing vessels reached 43 in 1985, 1986, and 1989. However, only the squid jiggers harvest the Pacific saury after 1996. Since the Pacific saury fishing season is mainly in the second half of the year, most fishing vessels typically fish for Atlantic shortfin squid (*Illex argentinus*) in the Southwest Atlantic Ocean for the first 4 or 5 months of the year. After the end of squid fishing season, the fishing vessels return to homeport to change fishing gear and then proceed to harvest Pacific saury in the Northwest Pacific Ocean. Before 2005, most of the fishing vessels engaged in the Pacific saury fishery also conducted neon flying squid jigging operations in the Northwest Pacific Ocean. After then, as the catch of Pacific saury exceeded that of neon flying squid, the fishing vessels changed their fishing practices to target Pacific saury only.

Vanuatu commenced its development of Pacific saury fishery by using stick-held dip net at 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 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)

While Japanese and Russian vessels operate mainly within their EEZ, Chinese, Korean and Chinese Taipei vessels operate mainly in the high seas of the North Pacific (Figure 1).

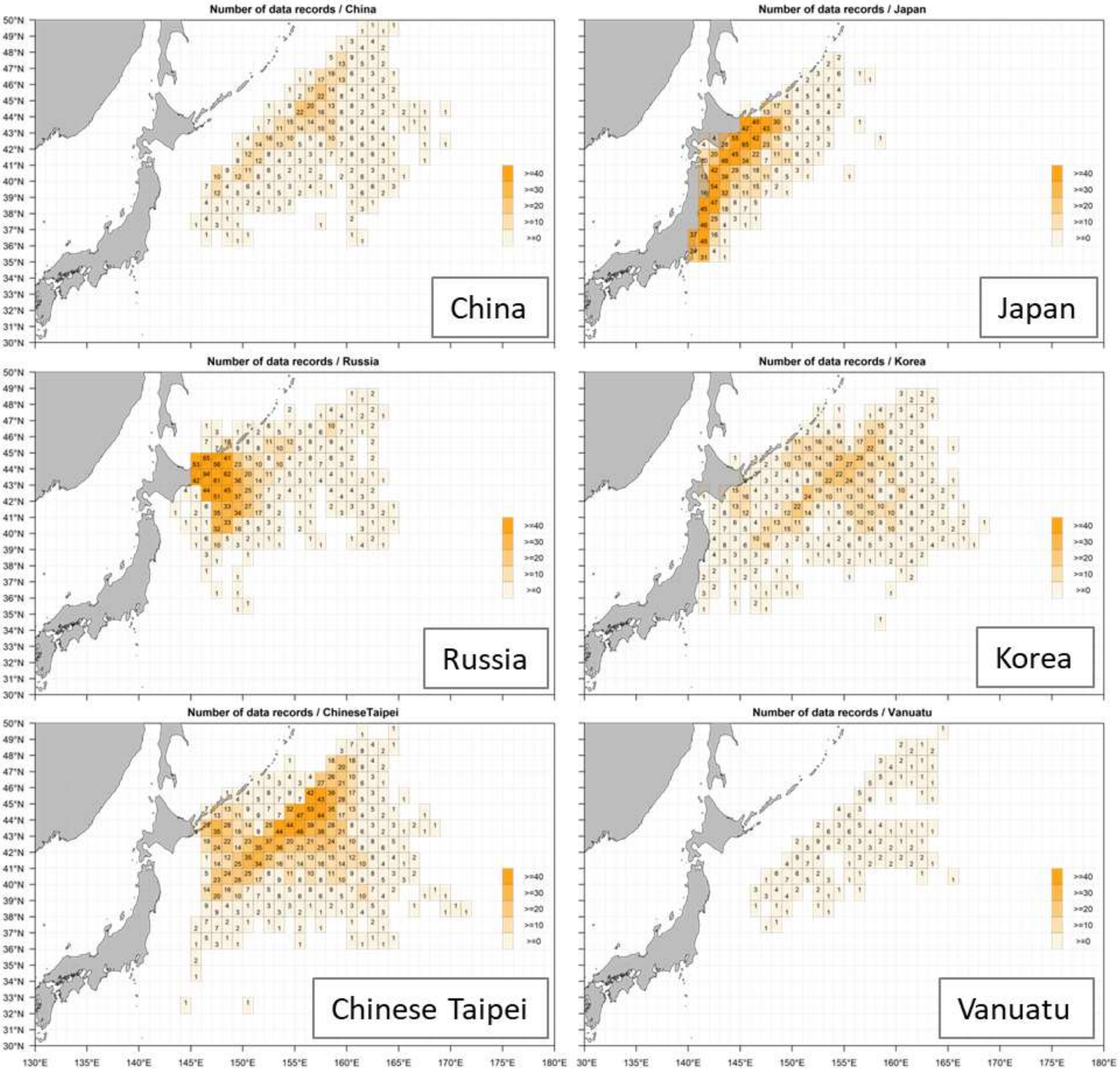


Figure 1. Main fishing grounds for Pacific saury by fishing members in the Western North Pacific Ocean. The legend shows the number of data records. This figure is based on the data shared by the Members for the development of a joint CPUE index (NPFC-2018-TWG PSSA03-WP02, NPFC-2018-TWG PSSA03-WP03, 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 by Member.

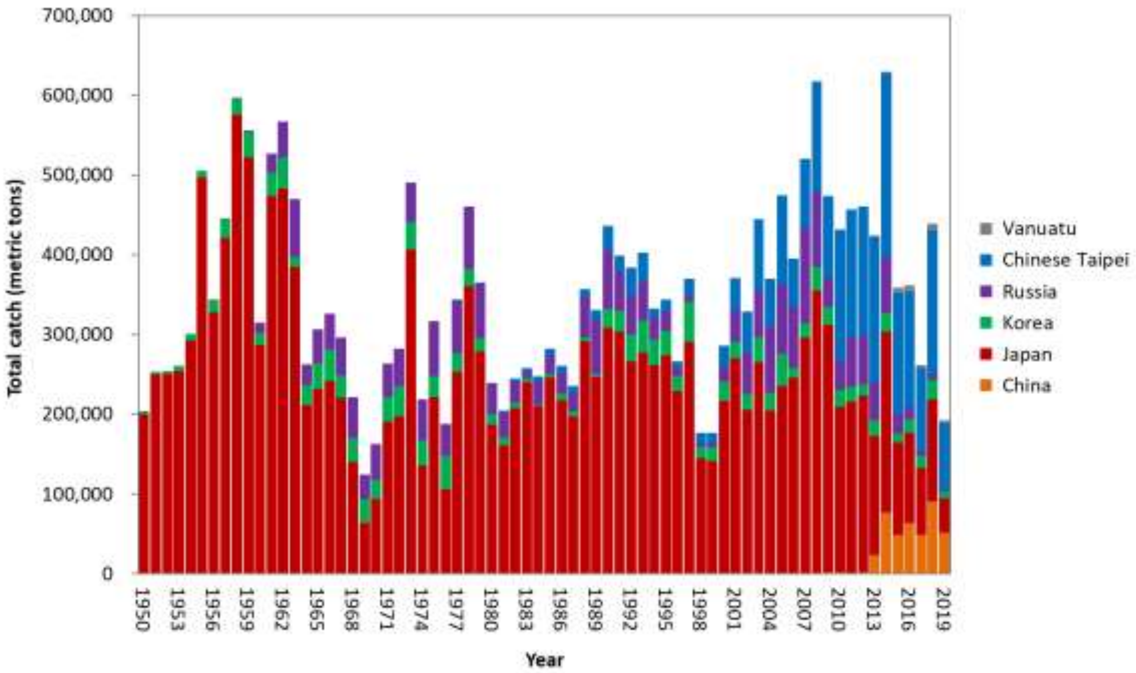


Figure 2. Time series of catch by Member during 1950-2019. The catch data for 1950-1979 and 2019 are shown but not used in stock assessment modeling.

3. SPECIFICATION OF STOCK ASSESSMENT

A Bayesian state-space production model used in previous stock assessments was employed as an agreed provisional stock assessment model for Pacific saury during 1980-2019. Scientists from three Members (China, Japan and Chinese Taipei) each conducted analyses following the agreed specification which called for two base case scenarios and four sensitivity scenarios (see Annex G, SSC PS05 report for more details). The two base case scenarios differ in using Japanese early CPUE (base case NB1) or not (base case NB2). Time-varying catchability for Japanese CPUE was assumed in NB1 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 3 members)

The multiple biomass indices are modelled as follows:

Survey biomass index

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

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 survey 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 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 PS-WP08 and NPFC-2020-SSC PS-WP10; for the non-uniform priors used in Chinese Taipei, see document NPFC-2020-SSC PS-WP17.

3.2 Agreed scenarios

Table 1. Definition of scenarios

	New base case (NB1)	**New base case (NB2)**	**Sensitivity case (NS1, NS2)**	**Sensitivity case (NS3, NS4)**
Initial year	1980	1980	1980	1980/2001
Biomass survey	B_obs = B_est*q1 ~ LN(log(q*B), s^2) q~U(0, 1)	Same as left	q~U(0, 2)	q~U(0, 1) 2003-2019

CPUE	CHN(2013-2018) JPN_early(1980-1993) (with time-varying q) JPN_late(1994-2018) KOR(2001-2018) RUS(1994-2018) CT(2001-2018)	CHN(2013-2018) JPN_late(1994-2018) KOR(2001-2018) RUS(1994-2018) CT(2001-2018)	Two sets as on the left for NS1 and NS2 respectively	NS3: Joint CPUE 2001-2017 (no JPN_early) NS4: Joint CPUE 2001-2017 and JPN_early
Variance component	Variances of logCPUEs are assumed to be common and 6 times of that of logbiomass	Variances of logCPUEs are assumed to be common and 5 times of that of logbiomass	Same as base cases 1 and 2, respectively	Same weight between biomass and joint CPUE
Hyper-depletion/ stability	A common parameter for all fisheries but JPN_early, with a prior distribution, b ~ U(0, 1) but [b_JPN_early=1]	A common parameter for all fisheries with a prior distribution, b ~ U(0, 1)	Same as base cases 1 and 2, respectively	b ~ U(0, 1)
Prior for other than q_biomass	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_{2018}	Catch in 2018
$AveC_{2016\text{-}2018}$	Average catch for a recent period (2016–2018)
$AveF_{2016\text{-}2018}$	Average harvest rate for a recent period (2016–2018)
F_{2018}	Harvest rate in 2018
F_{MSY}	Annual harvest rate producing the maximum sustainable yield (MSY)
MSY	Equilibrium yield at FMSY
F_{2018}/F_{MSY}	Average harvest rate in 2018 relative to FMSY
$AveF_{2016\text{-}2018}/F_{MSY}$	Average harvest rate for a recent period (2016–2018) relative to FMSY
K	Equilibrium unexploited biomass (carrying capacity)
B_{2018}	Stock biomass in 2018 estimated in the model
B_{2019}	Stock biomass in 2019 estimated in the model[b]
$AveB_{2017\text{-}2019}$	Stock biomass for a recent period (2017–2019) estimated in the model[b]
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_{2018}/K	Stock biomass in 2018 relative to K[a]
B_{2019}/K	Stock biomass in 2019 relative to K[a,b]
$B_{2017\text{-}2019}/K$	Stock biomass in the latest time period (2017-2019) relative to the equilibrium unexploited stock biomass[a,b]
B_{2018}/B_{MSY}	Stock biomass in 2018 relative to BMSY[a]
B_{2019}/B_{MSY}	Stock biomass in 2019 relative to BMSY[a,b]
$B_{2017\text{-}2019}/B_{MSY}$	Stock biomass for a recent period (2017–2019) relative to the stock biomass that produces maximum sustainable yield (MSY) [a,b]

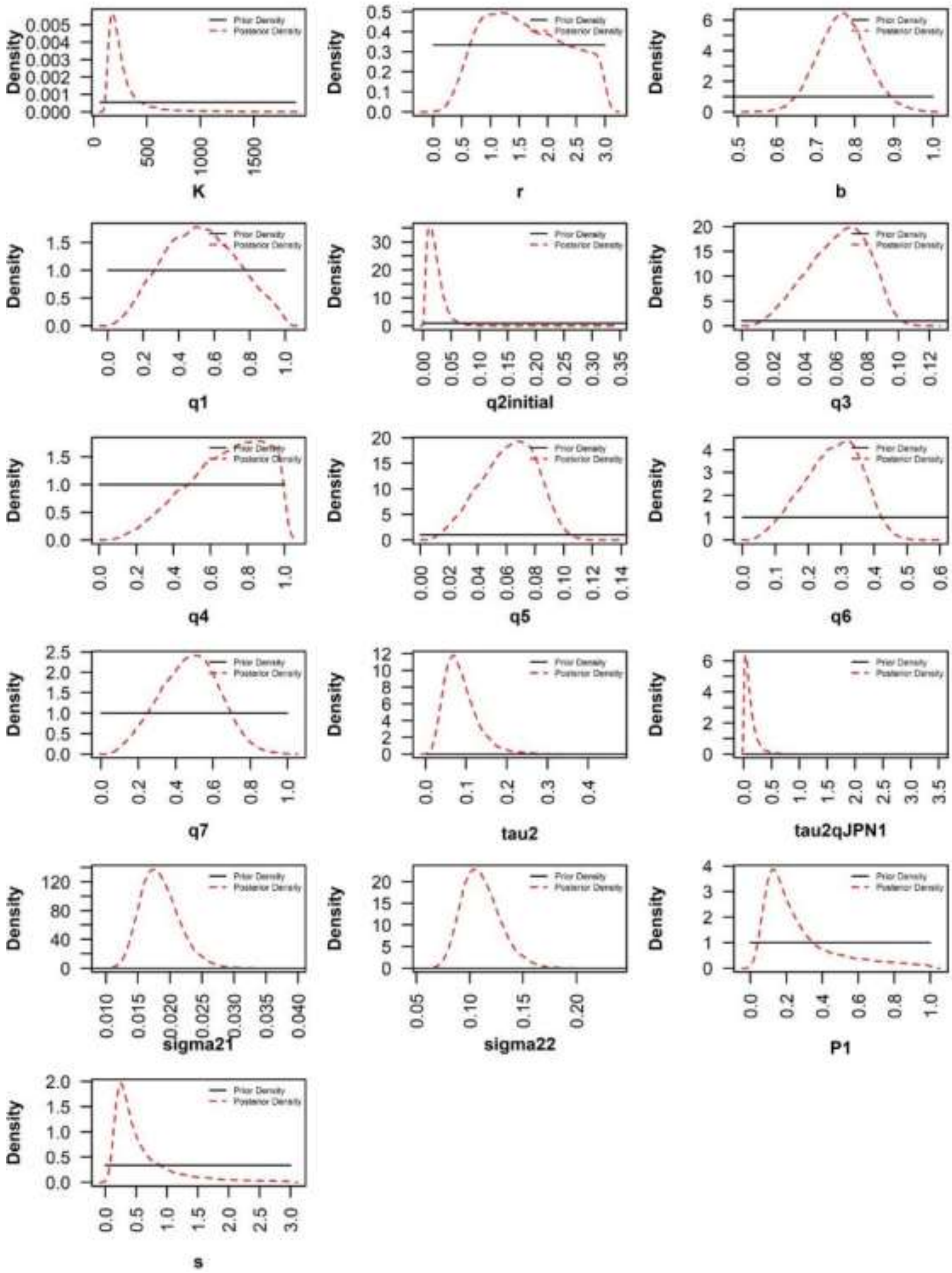
[a]calculated as the average of the ratios,

[b]Japanese biomass survey available but no CPUE available in 2019.

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)

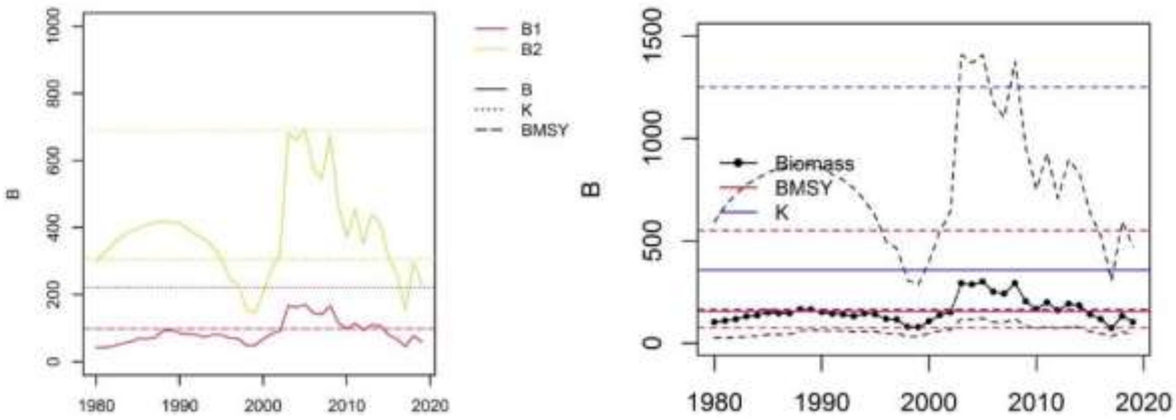


4.1.2 Summary of estimates of parameters and reference points

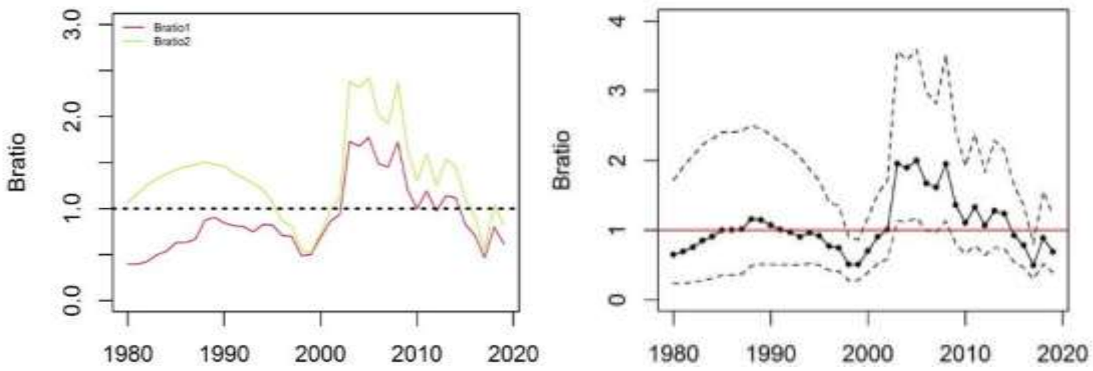
	Base case 1	Base case 2	Over all 2
C2018	43.91	43.91	43.91
AveC2016-2018	35.45	35.45	35.45
AveF2016-2018	0.56	0.15	0.33
F2018	0.57	0.15	0.33
FMSY	0.44	0.21	0.32
MSY	43.18	54.81	45.93
F2018/FMSY	1.31	0.80	1.13
AveF2016-2018/FMSY	1.30	0.83	1.13
K	221.10	689.00	357.10
B2018	77.27	295.85	132.90
B2019	59.61	231.10	103.00
AveB2017-2019	60.81	228.73	103.47
BMSY	98.05	305.70	155.95
BMSY/K	0.43	0.43	0.43
B2018/K	0.37	0.47	0.40
B2019/K	0.28	0.37	0.31
B2017-2019/K	0.29	0.37	0.32
B2018/BMSY	0.80	1.04	0.89
B2019/BMSY	0.62	0.82	0.69
B2017-2019/BMSY	0.63	0.81	0.69

4.1.3 Time series plots for base case models and aggregated results

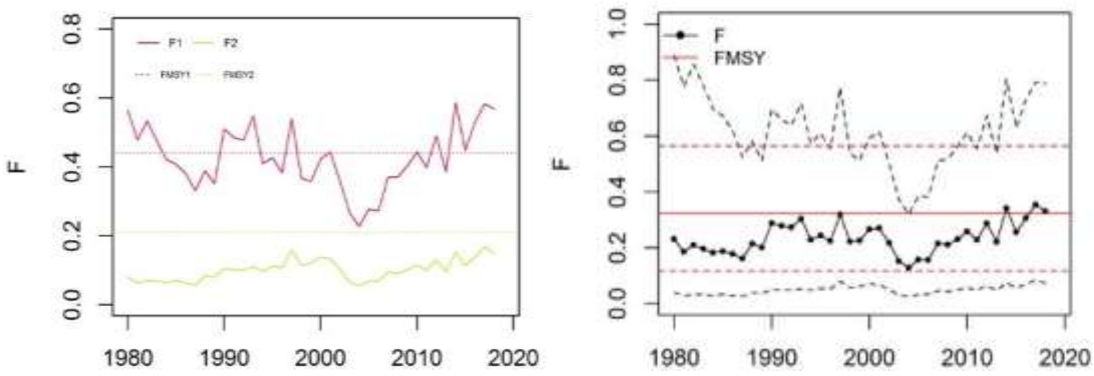
(a) Biomass



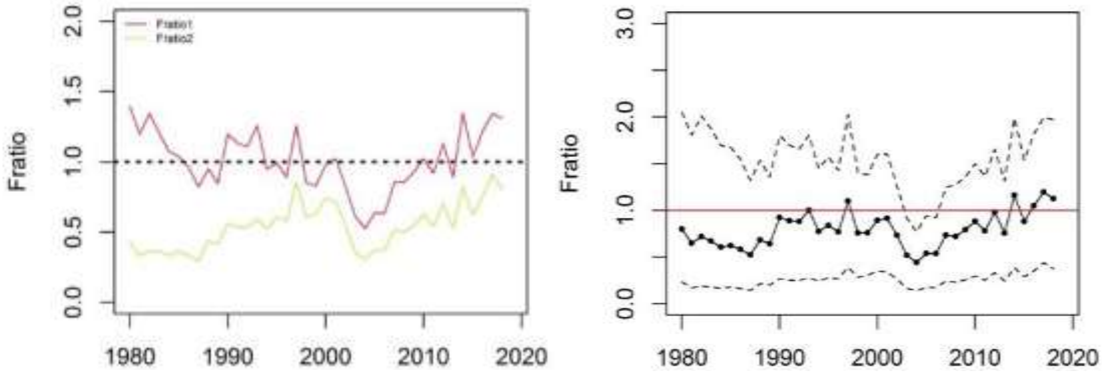
(b) B-ratio (B/Bmsy)



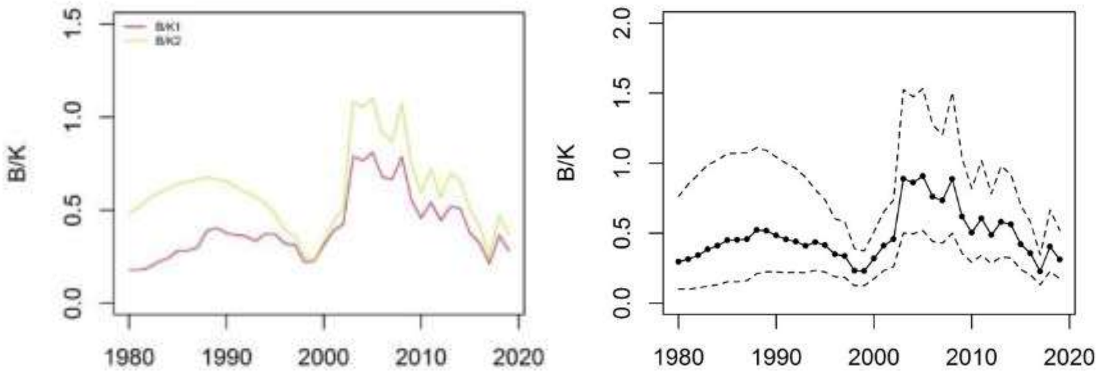
(c) Exploitation rate (F)



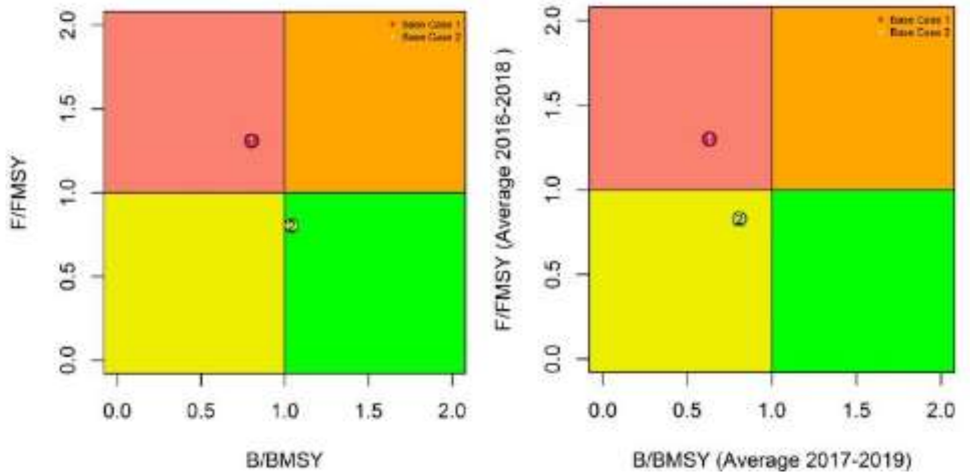
(d) F-ratio (F/Fmsy)

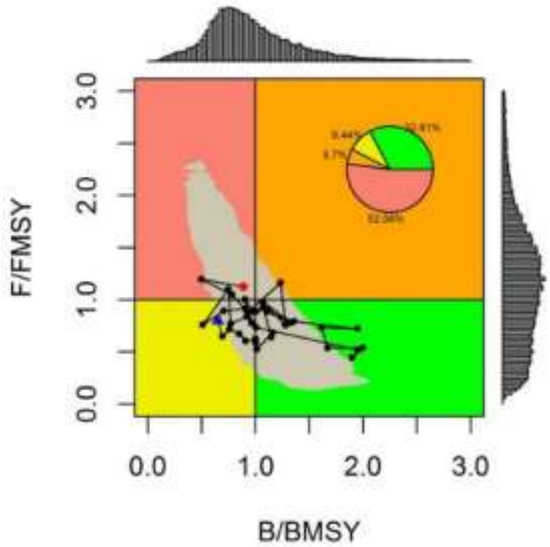


(d) B/K



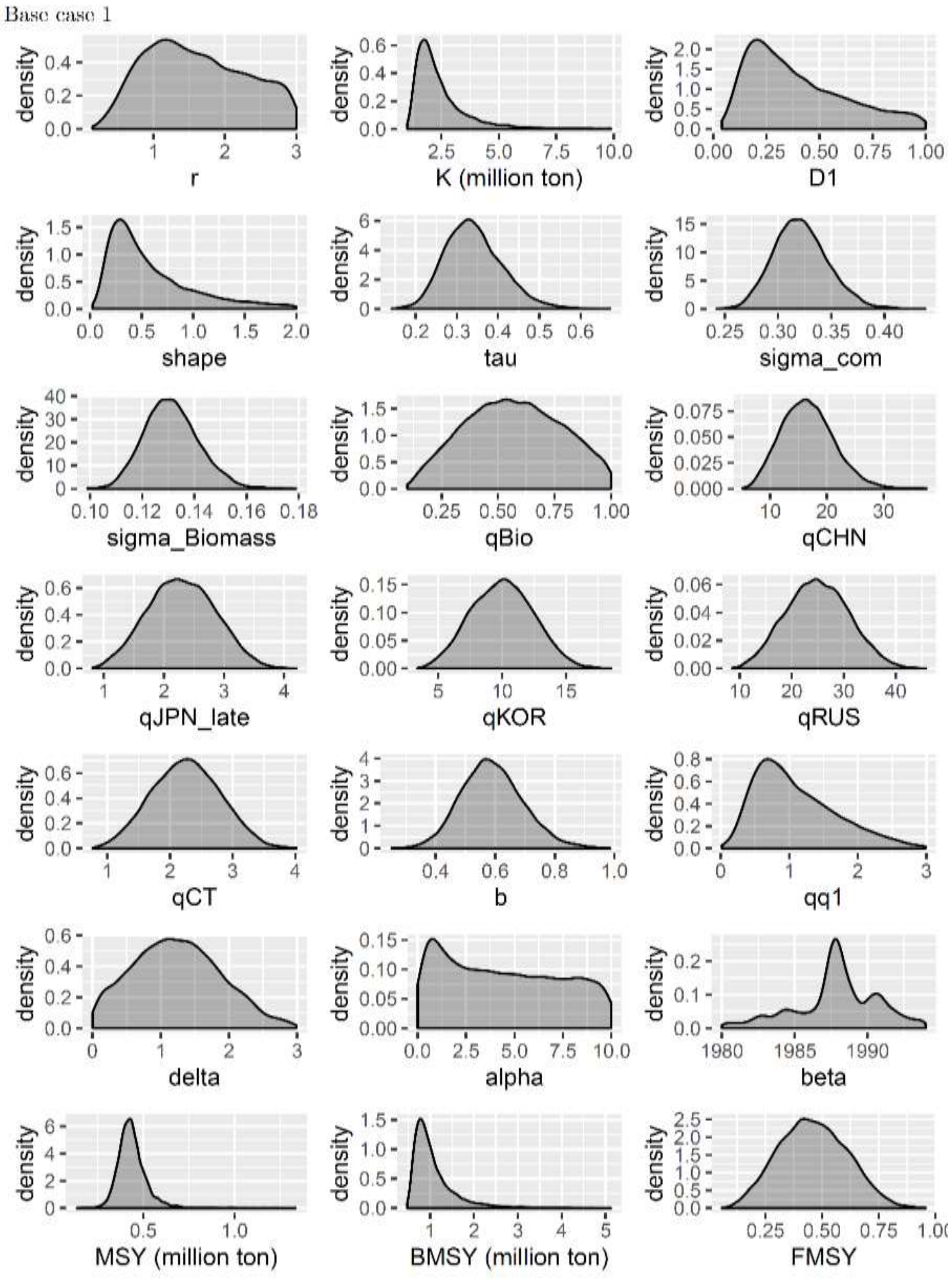
4.1.4 Kobe plots





4.2 JAPAN

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



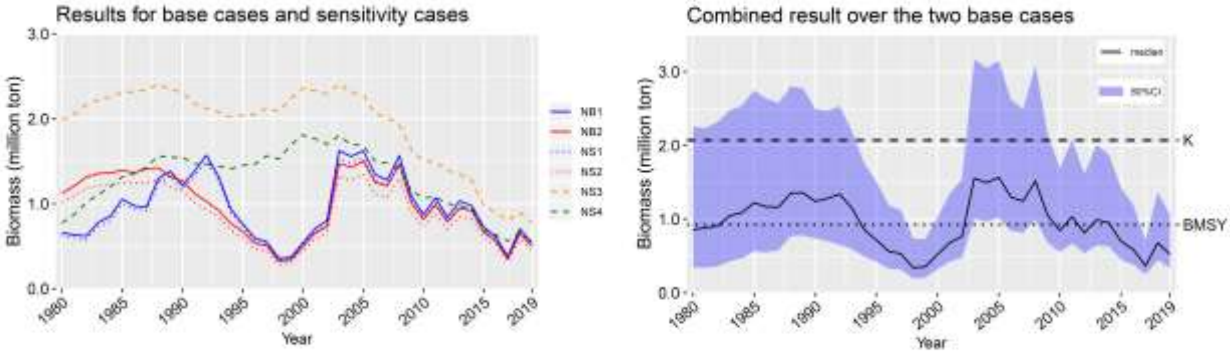
Note: Prior for each free parameter is assumed to be uniform over the shown horizontal range.

4.2.2 Summary of estimates of parameters and reference points

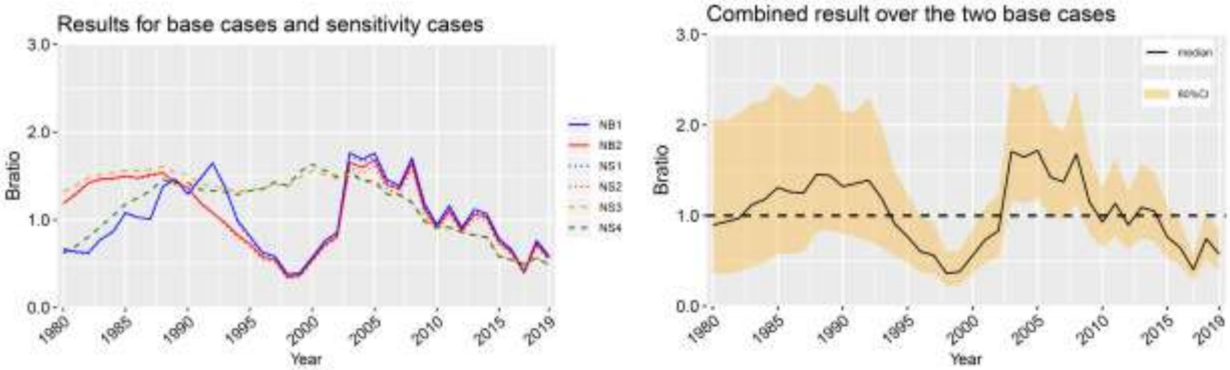
	NB1 Median	NB2 Median	Overall Median
C_2018	0.439	0.439	0.439
AveC_2016_2018	0.354	0.354	0.354
AveF_2016_2018	0.642	0.690	0.664
F_2018	0.623	0.676	0.649
FMSY	0.456	0.484	0.470
MSY	0.429	0.441	0.435
F_2018/FMSY	1.361	1.396	1.377
AveF_2016_2018/FMSY	1.402	1.422	1.412
K	2.076	2.06	2.070
B_2018	0.705	0.650	0.677
B_2019	0.540	0.502	0.521
AveB_2017_2019	0.559	0.518	0.539
BMSY	0.929	0.917	0.924
BMSY/K	0.438	0.439	0.439
B_2018/K	0.347	0.331	0.339
B_2019/K	0.265	0.254	0.26
AveB_2017_2019/K	0.277	0.265	0.271
B_2018/BMSY	0.761	0.727	0.745
B_2019/BMSY	0.584	0.560	0.572
AveB_2017_2019/BMSY	0.606	0.583	0.594

4.2.3 Time series plots for base case models and aggregated results

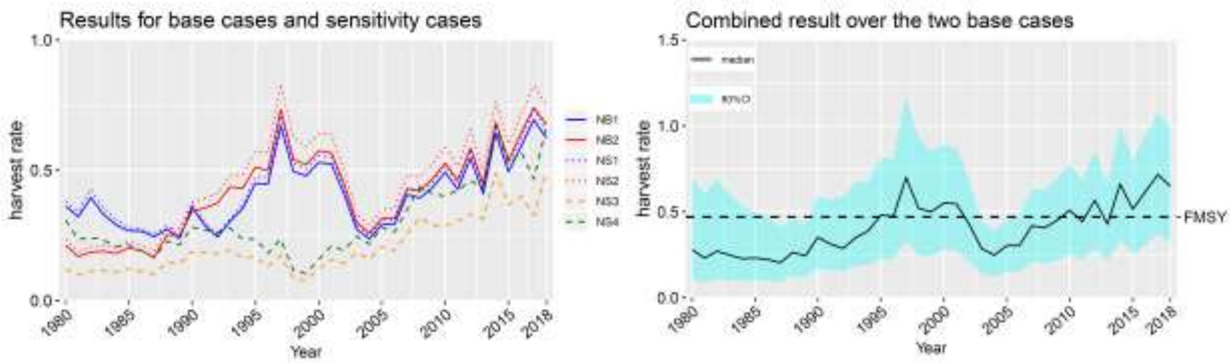
(a) Biomass



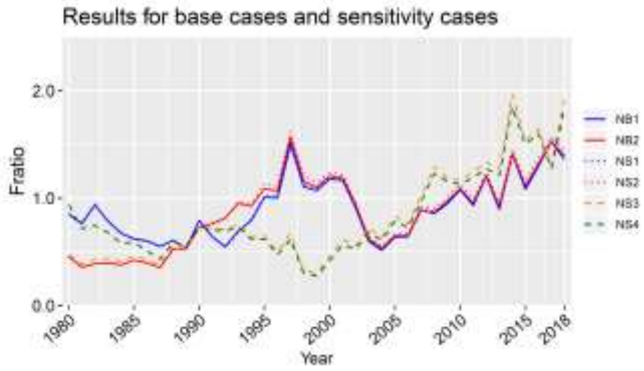
(b) B-ratio (B/Bmsy)

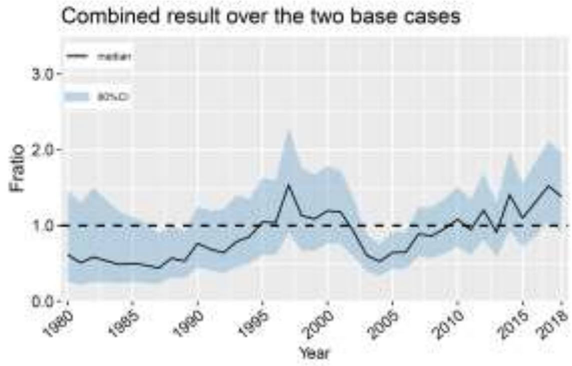


(c) Exploitation rate (F)

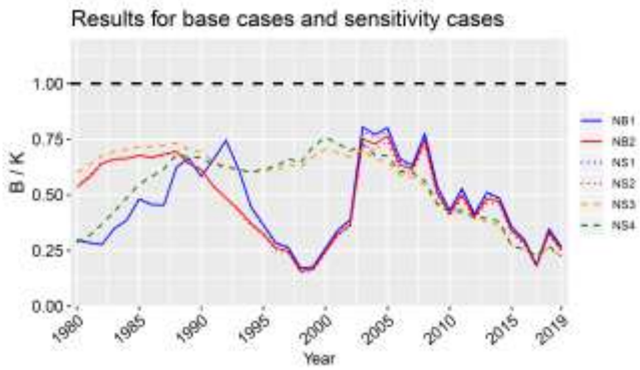


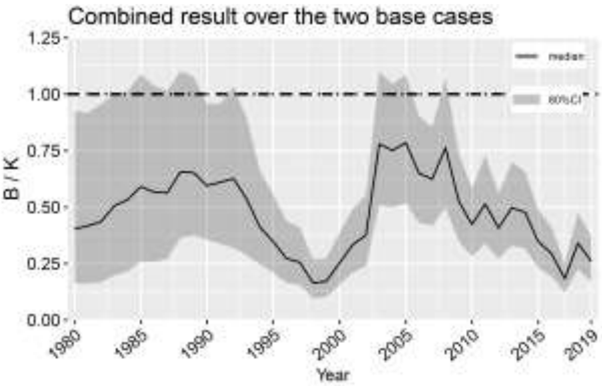
(d) F-ratio (F/Fmsy)



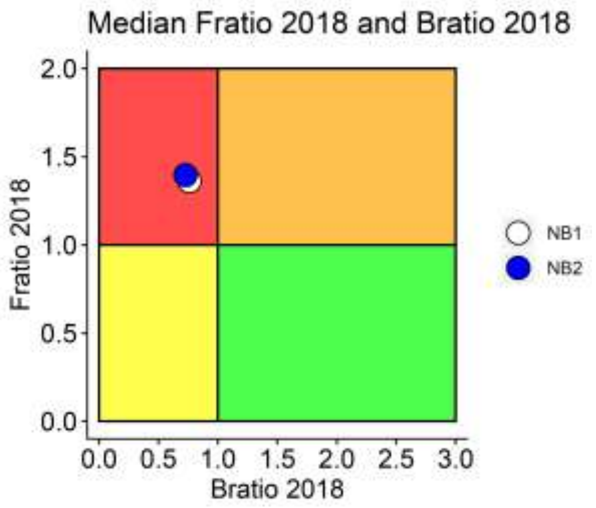


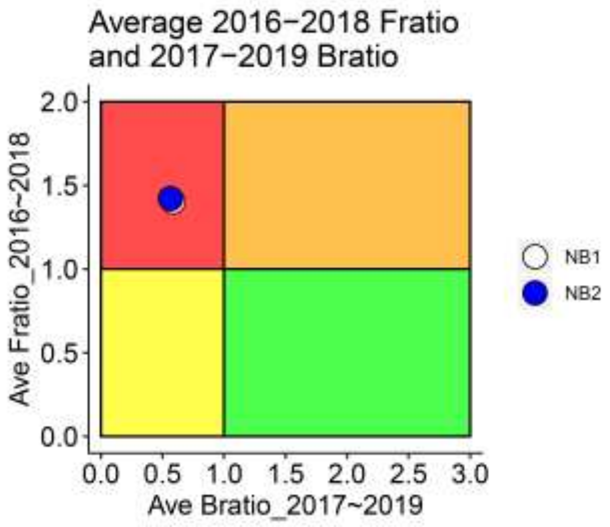
(e) B/K

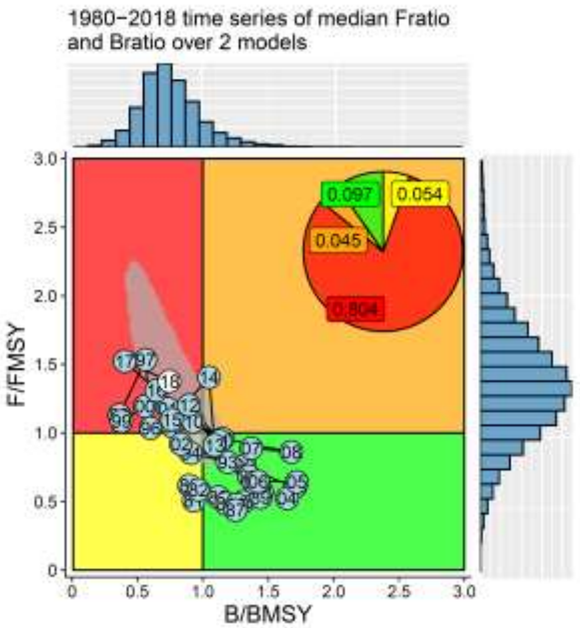




4.2.4 Kobe plots

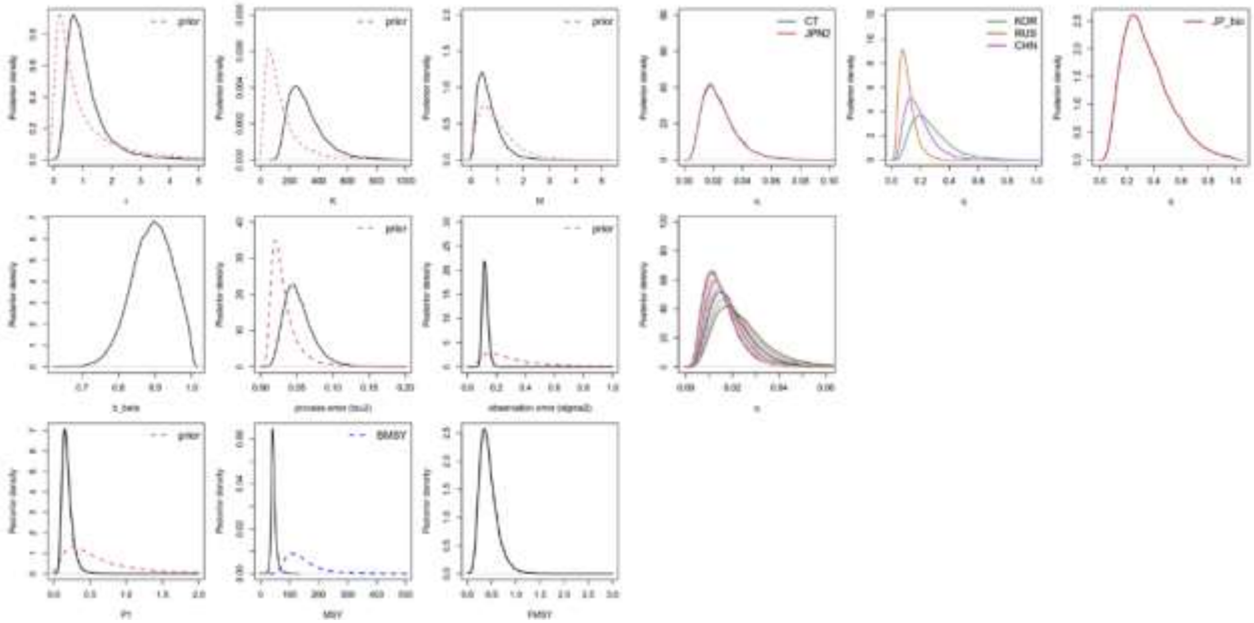






4.3 CHINESE TAIPEI

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

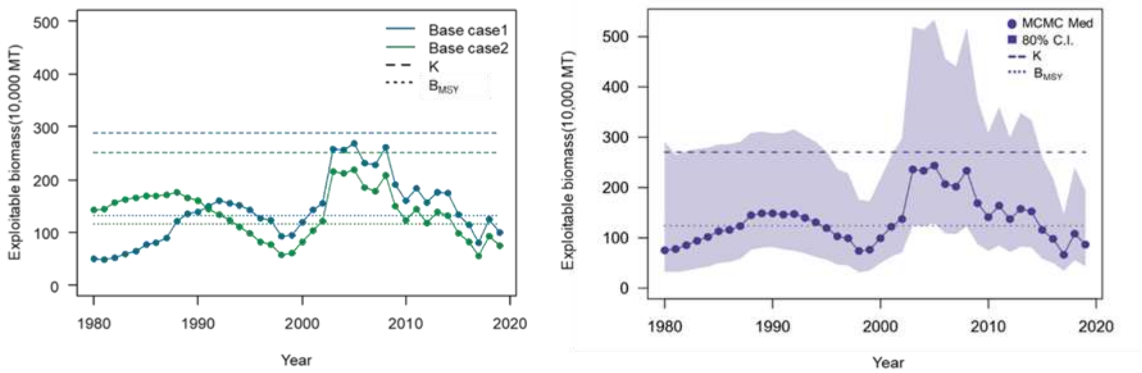


4.3.2 Summary of estimates of parameters and reference points

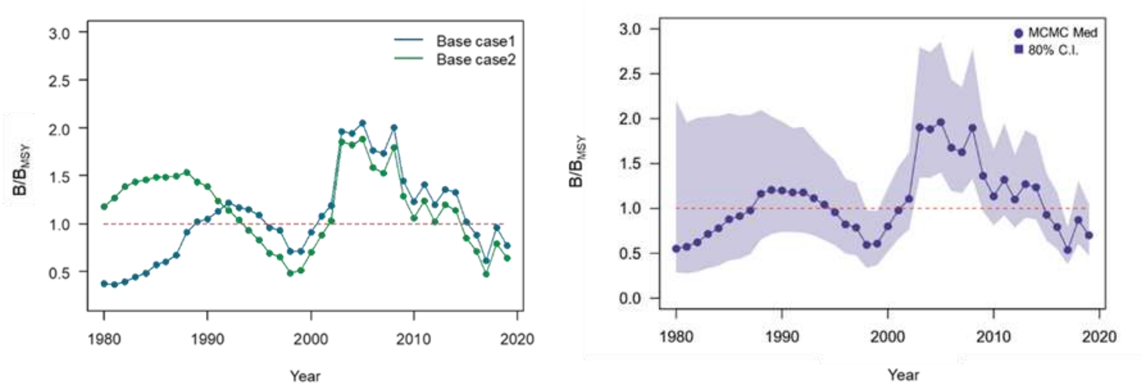
	Base case1	Base case2	Overall
	Median		
C_{2018}	43.91	43.91	43.91
$AveC_{2016\text{-}2018}$	35.45	35.45	35.45
$AveF_{2016\text{-}2018}$	0.40	0.63	0.50
F_{2018}	0.43	0.65	0.52
F_{MSY}	0.40	0.45	0.42
MSY	43.04	41.56	42.32
F_{2018}/F_{MSY}	1.11	1.55	1.31
$AveF_{2016\text{-}2018}/F_{MSY}$	1.04	1.52	1.26
K	287.80	251.30	270.20
B_{2018}	125.50	92.25	108.10
B_{2019}	100.30	74.19	86.96
$AveB_{2017\text{-}2019}$	102.29	74.07	87.57
B_{MSY}	131.60	116.35	124.10
B_{MSY}/K	0.46	0.46	0.46
B_{2018}/K	0.44	0.37	0.41
B_{2019}/K	0.35	0.30	0.35
$B_{2017\text{-}2019}/K$	0.36	0.30	0.33
B_{2017}/B_{MSY}	0.61	0.48	0.54
B_{2018}/B_{MSY}	0.96	0.79	0.87
B_{2019}/B_{MSY}	0.77	0.64	0.70
$B_{2017\text{-}2019}/B_{MSY}$	0.78	0.64	0.71

4.3.3 Time series plots for base case models and aggregated results

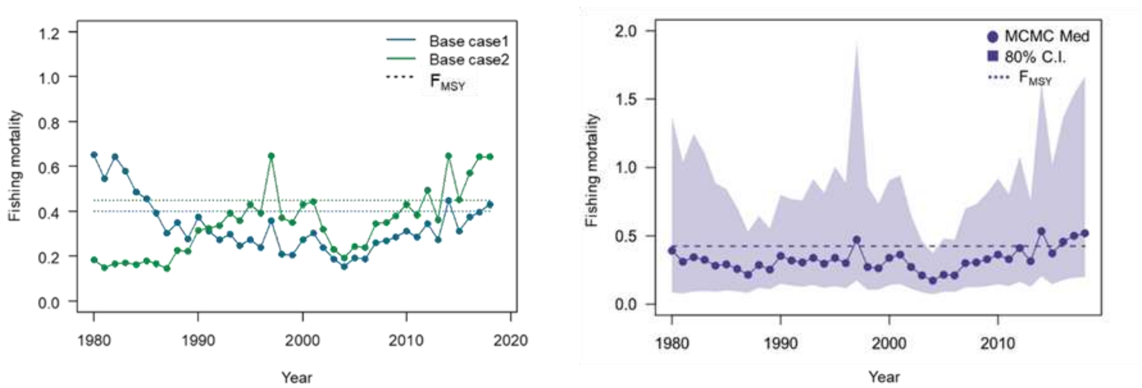
(a) Biomass



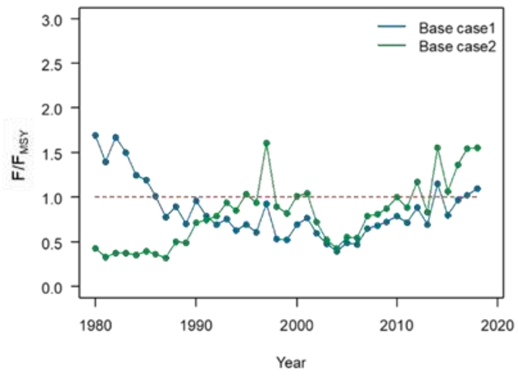
(b) B-ratio (B/Bmsy)

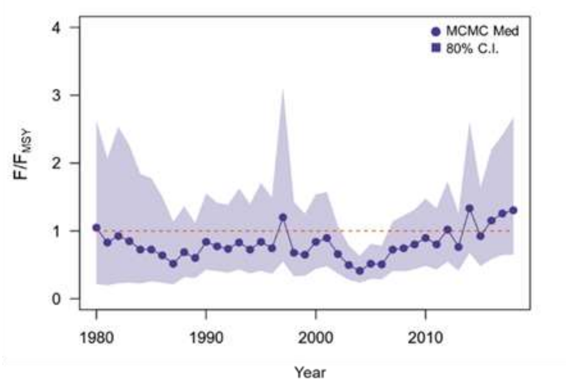


(c) Exploitation rate (F)

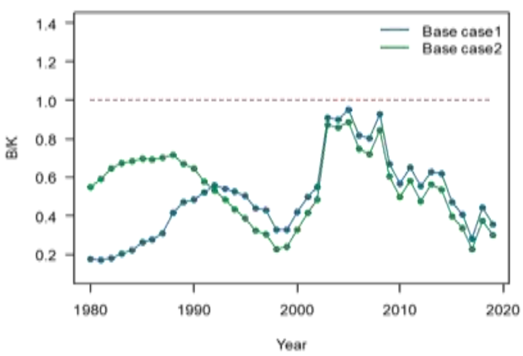


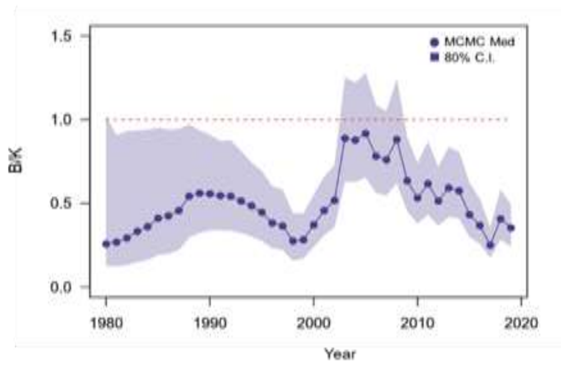
(d) F-ratio (F/Fmsy)



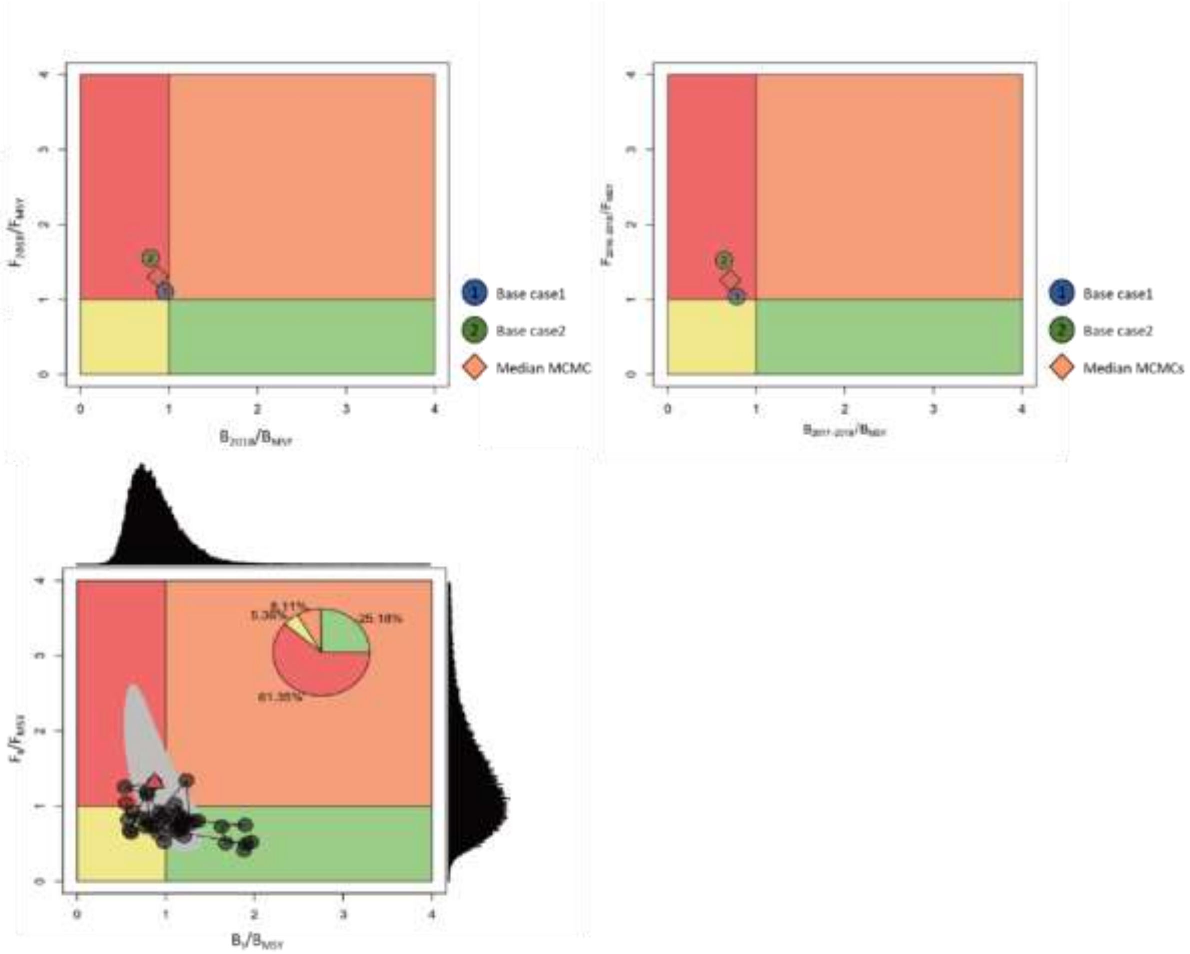


(e) B/K





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/Bmsy), exploitation rate (F), F-ratio (F/Fmsy) and B/K are shown in Figure 3.

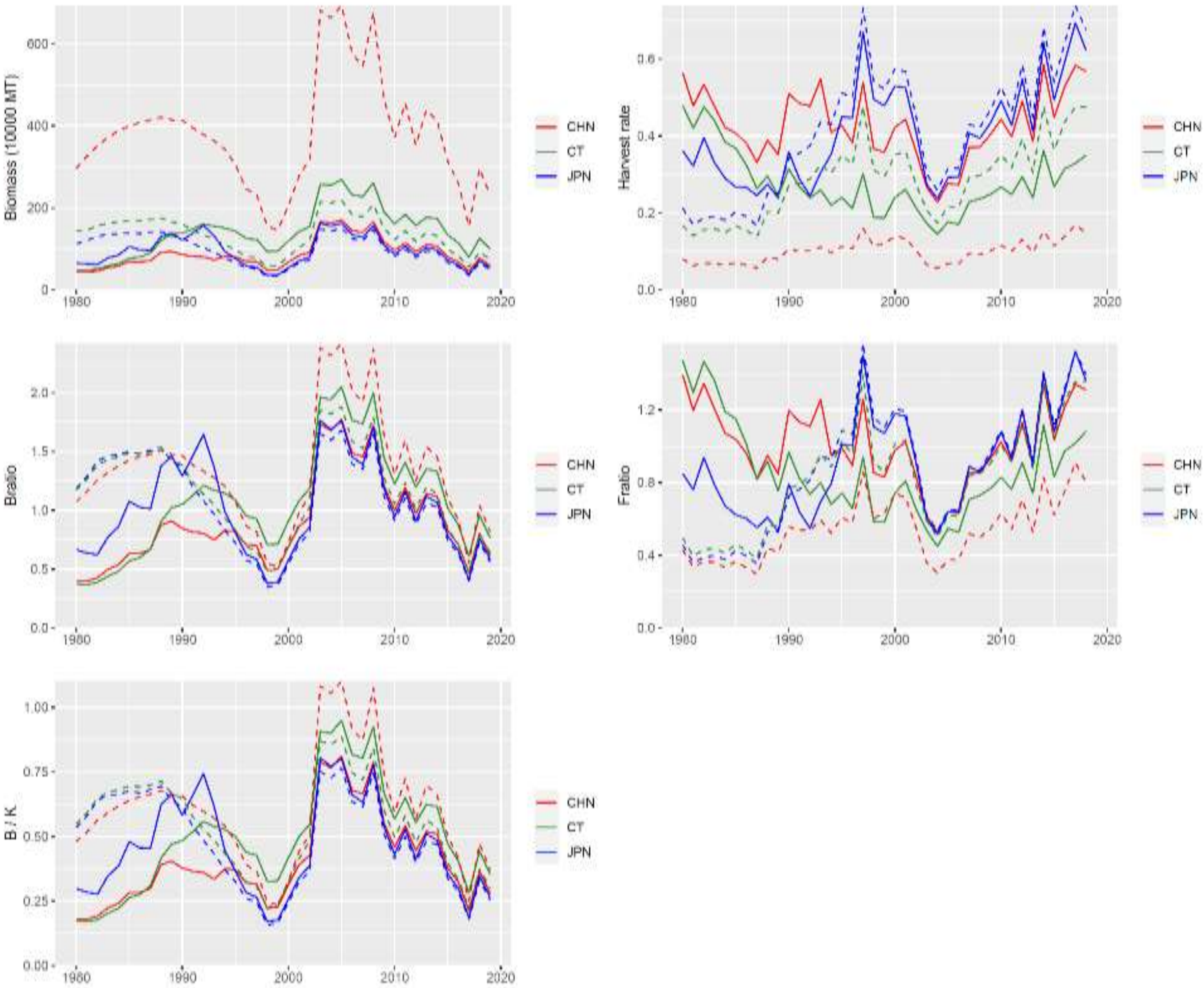


Figure 3. Time series of median estimated values of six runs for biomass, harvest rate, B-ratio, F-ratio, and depletion level relative to the carrying capacity. The solid and shaded lines correspond to NB1 and NB2, respectively.

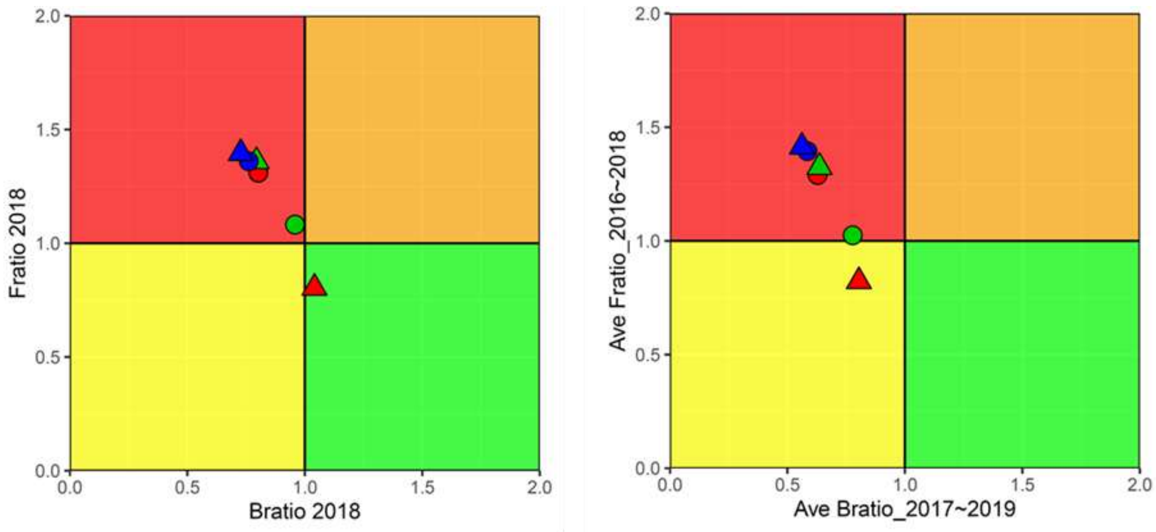


Figure 4. Kobe plots for six runs for NB1 (circle) and NB2 (triangle) by three members' scientists (red for China, blue for Japan and green for Chinese Taipei).

5.2 Summary table

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

	China		Japan		Chinese Taipei	
	Base case 1	Base case 2	Base case 1	Base case 2	Base case 1	Base case 2
C2018 (10,000tons)	43.91	43.91	43.91	43.91	43.91	43.91
AveC2016-2018 (10,000tons)	35.45	35.45	35.45	35.45	35.45	35.45
AveF2016-2018	0.56	0.15	0.64	0.69	0.40	0.63
F2018	0.57	0.15	0.62	0.68	0.43	0.65
FMSY	0.44	0.21	0.46	0.48	0.40	0.45
MSY(10,000tons)	43.18	54.81	42.9	44.1	43.04	41.56
F2018/FMSY	1.31	0.80	1.36	1.40	1.11	1.55
AveF2016-2018/FMSY	1.30	0.83	1.40	1.42	1.04	1.52
K (10,000tons)	221.10	689.00	207.6	206.0	287.80	251.30
B2018 (10,000tons)	77.27	295.85	70.5	65.0	125.50	92.25
B2019 (10,000tons)	59.61	231.10	54.0	50.2	100.30	74.19
AveB2017-2019 (10,000tons)	60.81	228.73	55.9	51.8	102.29	74.07
BMSY (10,000tons)	98.05	305.70	92.9	91.7	131.60	116.35
BMSY/K	0.43	0.43	0.44	0.44	0.46	0.46
B2018/K	0.37	0.47	0.35	0.33	0.44	0.37

B2019/K	0.28	0.37	0.27	0.25	0.35	0.30
B2017-2019/K	0.29	0.37	0.28	0.27	0.36	0.30
B2018/BMSY	0.80	1.04	0.76	0.73	0.96	0.79
B2019/BMSY	0.62	0.82	0.58	0.56	0.77	0.64
B2017-2019/BMSY	0.63	0.81	0.61	0.58	0.78	0.64

6 CONCLUDING REMARKS

The SSC PS considered the BSSPM results and noted dissimilarities among Members' results for base case 2. The SSC PS was unable to clarify the reason for the dissimilarities and agreed that it would not be advisable to aggregate Members' stock results.

All six base case model runs (two scenarios from each of three members) indicate that recent Pacific saury stock size was less than Bmsy. In particular, median estimates from five out of six runs indicate that 2019 Pacific saury biomass was less than Bmsy. Results from all six model runs indicate that average 2017-2019 biomass was less than Bmsy.

A majority of base case model comparisons indicate that recent harvest rates for Pacific saury were higher than Fmsy. In particular, median estimates from five runs indicate that the harvest rate during 2019 and average rates during 2017-2019 were higher than Fmsy.

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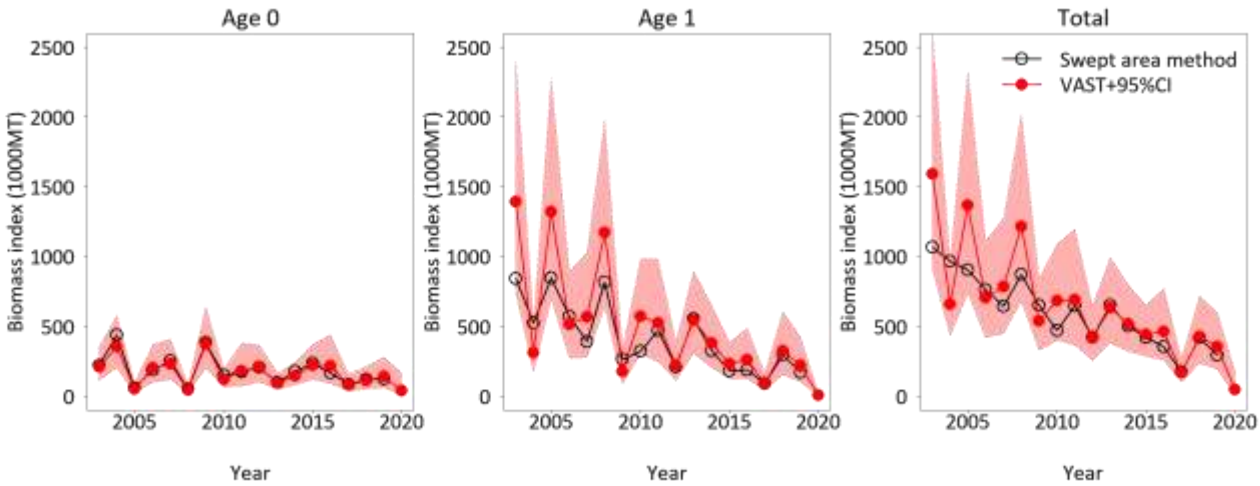
Annex I

Japan's fishery-independent biomass index from 2003 to 2020



Note: red line shows year trends in estimated age 0, age 1 and total biomass index (with 95% confidence intervals shown by red polygons) derived from the VAST model incorporating a quadratic function of SST, compared to those from the swept area method (up to 2019).