North Pacific Fisheries Commission

NPFC-2019-SSC PS04-Final Report

4th Meeting of the Small Scientific Committee on Pacific Saury REPORT

19, 20, 22 April 2019

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North Pacific Fisheries Commission
4th Meeting of the Small Scientific Committee on Pacific Saury

19-22 April 2019
Jeju, Republic of Korea

REPORT

Agenda Item 1. Opening of the meeting

1. The 4th Meeting of the Small Scientific Committee on Pacific Saury (SSC PS04) took place in Jeju, Republic of Korea on 19, 20, 22 April 2019, 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. The meeting was opened by Dr. Toshihide Iwasaki (Japan) who served as the SSC PS Chair.

2. Dr. Seok-Gwan Choi welcomed the participants to Jeju on behalf of the host Member. He highlighted the important role of the SSC PS and commended the valuable efforts it has made to date to complete the Pacific saury stock assessment. Lastly, Dr. Choi expressed his hope that the meeting would facilitate further progress for the sustainable management of fisheries.

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. Review of the CMM 2018-08 for Pacific saury

4. The Chair presented CMM 2018-08 for Pacific saury adopted by the Commission in July 2018. The Chair highlighted tasks from the Commission for the SC and SSC PS specified in the CMM.

Agenda Item 4. Review of Members' fisheries and research activities

5. China presented its fisheries and research activities. There were 49 active fishing vessels in the Convention Area in 2018, a decrease from 2017. Total catch was approximately 90,000 tons. Every vessel reports its position via VMS to China Overseas Fishing Association, as well as weekly catch. Logbook information is reported to Shanghai Ocean University, under the authorization of the Chinese government. In 2018, China implemented two study fleets to collect biological information on Pacific saury.

6. Russia presented its fisheries activities. Russia explained that the 2017 catch information it had initially reported in the 2017 annual report (6,315 tons) was correct and the information reported to the Technical Working Group on Pacific Saury Stock Assessment (TWG PSSA) incorrect. In 2018, nominal catch-per-unit-effort (CPUE) increased from 2017. There were four active vessels in the Convention Area and ten active vessels in the Russian EEZ, only seven of which fished for a long period.

7. Korea presented its fisheries activities. In 2018, there were 12 active vessels in the Convention Area. Total catch was approximately 23,000 tons. The total number of fishing days was 811. The fishing months are from May to December. In 2018, the set of months with the highest catch differed from that for 2001-2017. Korea is preparing fine-scale spatial distribution data and will submit them to the next meeting.

8. Japan presented its fisheries and research activities. In 2018, total catch was approximately 129,000 tons. Almost all fish were caught by stick-held dip nets. Less than 1% was caught by set nets and drift gill nets. 140 vessels, divided into two size groups (>100 tons; <50 tons), were licensed by the national government to fish for Pacific saury. 51 vessels (size: <10 tons) were licensed by prefectural governments to fish for Pacific saury. The majority of the catch was of age-1 fish (73%). From June to July 2018, Japan conducted its annual fisheries-independent survey for Pacific saury in two areas: 151 degrees east longitude to 161 degrees east longitude, and east of 170 degrees east longitude. The estimated biomass is 2,346,000 metric tons. Japan will conduct its 2019 fisheries independent survey in June and July, which should contribute to the next stock assessment. The survey will be conducted from the near coast of Japan to 165 degrees west longitude, in areas where the sea surface temperature (SST) is 9-17 degrees Celsius. Two research vessels will be used. Three types of gears will be used: sea surface trawl nets, frame nets and Neuston nets. Japan will also conduct oceanographic observations, sampling of phytoplankton, and sampling of zooplankton. Scientists from China and Russia will participate in the survey.

9. Chinese Taipei presented its fisheries and research activities. In 2018, the preliminary catch estimate is approximately 180,000 tons. The number of active vessels in the Convention Area was 83. Fishing effort was approximately 6,000 fishing days. Chinese Taipei has been conducting Pacific saury-related research on the effects of environmental factors and climate change on abundance, the spatial distribution of fishing patterns, CPUE standardizations, stock assessments, and biology.

10. Vanuatu presented its fisheries activities. In 2018, there were four active vessels in the Convention Area. Fishing effort was 277 days, a decrease from 2017. The fishing months were

July to November. Total catch was approximately 8,000 tons.

Agenda Item 5. Report and recommendations from the 3rd and 4th TWG PSSA meetings, BRP/HCR/MSE Workshop and intersessional work of the TWG PSSA

11. On behalf of the Chair of the Biological Reference Point/Harvest Control Rule/Management Strategy Evaluation (BRP/HCR/MSE) Workshop, Dr. Jie Cao (China) summarized the outputs of the workshop and presented recommendations for consideration by the SSC PS.

12. The SSC PS thanked the United States for providing a voluntary contribution for facilitating the attendance of the three invited experts at the workshop.

13. The Science Manager, Dr. Aleksandr Zavolokin, informed the SSC PS that the consultant, Dr. Laurence Kell, had updated his report on the review of target and limit reference points based on the discussions at the workshop. The report is available on the NPFC website.

14. The Chair of the TWG PSSA, Dr. Toshihide Kitakado (Japan), summarized the outputs of the 3rd and 4th TWG PSSA meetings, and the intersessional work of the TWG PSSA, and presented recommendations and stock assessment results (Annex D) for consideration by the SSC PS.

15. The SSC PS commended the TWG PSSA for the significant amount of work it has done and great progress it has made, as well as the TWG PSSA Chair for his dedicated work and leadership.

16. The SSC PS thanked the United States for providing a voluntary contribution for facilitating the attendance of an invited expert at the 3rd and 4th TWG PSSA meetings.

17. The SSC PS adopted the reports of the 3rd and 4th TWG PSSA meetings and endorsed the recommendations from the meetings. The endorsed recommendations are listed under paragraph 41.

18. The SSC PS endorsed the estimates of reference quantities based on the stock assessment results (Annex D) provided by the TWG PSSA04: Based on combined model estimates, B was below Bmsy (B/Bmsy during 2016-2018 = 0.82) and F was below Fmsy (F/Fmsy during 2015-2017 = 0.82). Results indicate that the stock declined from near carrying capacity in the mid-2000's after a period of high productivity to current levels. Exploitation rates were increasing slowly during this period but remained lower than Fmsy. Point estimates indicate that stock biomass fell to the lowest value since 1980 (B/Bmsy = 0.63) in 2017, then increased to Bmsy in 2018. Biomass estimates show long-term fluctuations and interannual variability.

Agenda Item 6. Spatial distribution of juvenile Pacific saury in the Convention Area

19. Japan presented a summary of available biological and ecological information on age-0 Pacific saury relevant to CMM 2018-08, including relevant literature, differences in distribution and migration between ages, and length at maturity (NPFC-2019-SSC PS04-IP01 and 02). Based on a review of this information, Japan suggested that age-0 fish are abundant east of 165 degrees east longitude during June to July and it is unlikely that a large proportion of age-0 fish will migrate into fishing grounds in the main fishing season (August to November) of the same year.

20. SSC PS recognized the importance of the definition of juvenile as it pertains to Pacific saury. Juvenile Pacific saury was defined as immature fish according to the following definitions of juvenile given by some organizations:
    (a) A young fish or animal that has not reached sexual maturity[1].
    (b) One of several marked phases or periods in the development and growth of many animals. The life history stage of an animal that comes between the egg or larval stage and the adult stage; juveniles are considered immature in the sense that they are not yet capable of reproducing, yet they differ from the larval stage because they look like smaller versions of the adults[2].
    (c) An immature fish, i.e. one that has not reached sexual maturity (but could still be larger than the minimum landing size – MLS)[3].
    (d) Larva are defined as 0-30 days old. Juveniles are from 1 month to 3 months. Young fish are defined as 3 – 6 months old. Immature fish are 6 – 9 months old. Adult Pacific saury are defined as fish older than 9 months[4,5].

21. The SSC PS concluded that the spawning season of Pacific saury ranges from autumn to spring[6].

22. The SSC PS noted the seasonal observed differences in minimum length at maturity are as follows:

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[1] Roberts K.J. et al., 1995. Defining fisheries: a user's glossary. Louisiana State University, Louisiana, USA, 22 p. (Rev.)
[2] New England Fishery Management Council. https://www.nefmc.org/files/Glossary.pdf.
[3] Joint Nature Conservation Committee. http://jncc.defra.gov.uk/pdf/glossary.pdf.
[4] Tian Y., Akamine T., Suda M. 2004. Modeling the influence of oceanic–climatic changes on the dynamics of Pacific saury in the northwestern Pacific using a life cycle model[J]. Fisheries Oceanography, 13(S1): 125-137.
[5] Ito S., Kishi J. M., Kurita Y., et al. 2004. Initial design for a fish bioenergetics model of Pacific saury coupled to a lower trophic ecosystem model[J]. Fisheries Oceanography, 13(S1): 111-124.
[6] Fuji T., Suyama S., Vijai D., Kidokoro H. and Iwasaki T. 2017. Stock identity, spawning ground, maturation, and migration of Pacific saury, *Cololabis saira*. NPFC-2017-TWG PSSA02-WP07.

(a) Autumn: 26.0-28.7 cm[7,8]
(b) Winter (main spawning season): 25.4 cm[9]
(c) Spring: 27.0-29.4 cm[10]
(d) August-November: 25 cm[6,11]

23. Under experimental conditions, which differ in terms of feeding condition and water temperature, etc., from the natural condition described in paragraph 22, the minimum length of male and female fish that had matured was 23.5 and 22.4 cm, respectively.[12]

24. Considering the annual variation in survey results, the SSC PS concluded that age-0 Pacific saury are abundant east of 165-170 degrees east during June to July, when age-0 fish have not reached sexual maturity, and most of them are unlikely to migrate into fishing grounds in the main fishing season (August to November) of the same year. Both immature fish and adults are under fishing pressure[13,14,15,16].

25. The SSC PS recognized that further analyses on length at maturity and age composition over time and space may be beneficial for management and stock assessment. The SSC PS agreed to examine the amount of data available for maturity and length, and fit a logistic curve to maturity data considering all spatial or temporal combinations that are relevant and possible.

Agenda Item 7. Data collection and management

7.1 Observer Program

26. The Science Manager presented a draft template for identification of scientific data which can be collected and/or validated by at-sea observers, fishermen, electronic reporting systems and other means for Pacific saury (NPFC-2019-SSC PS04-WP02). The SSC PS reviewed and

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7 Suyama S. 2002. Study on the age, growth, and maturation process of Pacific saury *Cololabis saira* (Brevoort) in the North Pacific. Bull Fish Res Agen 5: 68-113.
8 Huang W.-B. and Huang Y.-C. 2015. Maturity characteristics of Pacific saury during fishing season in the northwest Pacific. J Mar Sci Tech 23: 819-826.
9 Hatanaka M., Watanabe T., Sekino K., Kosaka M., Kimura K. 1953. Studies on the reproduction of the saury, *Cololabis saira* (Brevoort), of the Pacific coast of Japan. Tohoku J Agric Res 3: 293-302.
10 Kurita Y. 2006. Regional and interannual variations in spawning activity of Pacific saury *Cololabis saira* during northward migration in spring in the north-western Pacific. Biol Fish 69: 846-859.
11 Fuji T., Suyama S. and Oshima K. 2019. Available information of growth, maturation and mortality for future stock assessment and management of Pacific saury, *Cololabis saira*. NPFC-2019-TWG PSSA04-WP02.
12 Nakaya M., Morioka T., Fukunaga K., Murakami N., Ichikawa T., Sekiya S., Suyama S. (2010) Growth and maturation of Pacific saury *Cololabis saira* under laboratory conditions. Fisheries Science 76: 45-53
13 Fuji T., Suyama S., Kidokoro H., Abo J., Miyamoto H. and Vijai D. 2018. Consideration of precautionary approach to sustain the Pacific saury stock and fishery based on spatial distribution of immature age-0 fish. NPFC-2018-SSC PS03-WP01.
14 Suyama S., Miyamoto H., Naya M., Fuji T., Hashimoto M., Oshima K., Nakayama S. and Iwasaki T. 2018. Update of biomass estimate through Japanese fishery independent survey for Pacific saury in 2018. NPFC-2018-TWG PSSA03-WP09 (Rev. 1).
15 Suyama S., Nakagami M., Naya M. and Ueno Y. 2012. Migration route of Pacific saury *Cololabis saira* inferred from the otolith hyaline zone. Fisheries Science, 78: 1179–1186.
16 Suyama S., Ozawa H., Shibata Y., Fuji T., Nakagami M. and Shimizu A. 2019. Geographical variation in spawning histories of age-1 Pacific saury *Cololabis saira* in the North Pacific Ocean during June and July. Fisheries Science DOI: 10.1007/s12562-019-01308-0.

updated the template (Annex E).

7.2 Data sharing

27. The Science Manager updated the SSC PS on progress in data sharing.

28. The SSC PS reviewed the shared data and noted the need to share biological data, such as catch-at-size and catch-at-age data, for work towards the use of age-structured stock assessment models. The SSC PS reviewed a table of the availability of such data.

Agenda Item 8. Review/update of the 2017-2021 Work Plan

8.1 Ongoing/planned projects

8.1.1 Stock assessment meeting

29. The SSC PS agreed to hold stock assessment meetings twice a year in 2019-2020. The SSC PS suggested that the next two stock assessment meetings should be four days each, subject to possible change based on intersessional discussions.

8.1.2 Spatial/temporal map of Members' catch and effort

30. The Data Coordinator, Mr. Mervin Ogawa, reported on the progress of an ongoing project for the development of the spatial/temporal map of Members' Pacific saury catch and effort (NPFC-2019-SSC VME04-WP07).

31. The SSC PS reviewed the spatial/temporal map of Members' Pacific saury catch and effort and suggested holding further discussions intersessionally.

8.1.3 Expert to review Pacific saury stock assessment

32. The SSC PS recognized the significant contributions made by Dr. Larry Jacobson to the work of the TWG PSSA and recommended that the SC recommend that the Commission fund the participation of Dr. Jacobson (or an expert with similar qualifications and experience) in the next Pacific saury meetings.

8.2 New projects

33. No new projects were proposed.

8.3 2017-2021 Work Plan

34. The SSC PS drafted a two-year workplan for the stock assessment and management of Pacific saury (NPFC-2019-SSC04-IP03).

35. The SSC PS reviewed the 2017-2021 Work Plan and updated it as detailed in NPFC-2019-SSC

PS04-WP03 (Rev. 1).

Agenda Item 9. Other matters

9.1 Selection of SSC PS Chair

36. The participants from the SSC PS proposed that the SSC PS and the TWG PSSA be combined into one group, given the overlap in the scope, objectives and membership of the two groups, to facilitate more efficient discussions and work.

37. The SSC PS endorsed the proposal and recommended that the SC combine the SSC PS and the TWG PSSA into one new SSC.

38. The SSC PS recommended that the SC select Dr. Toshihide Kitakado (Japan) to serve as the Chair of the new SSC.

39. The SSC PS recommended that the SC recommend that the Commission consider allowing more flexibility (i.e. multiple extensions) in the terms for the Chairs of the SC's subsidiary bodies.

9.2 Other issues

40. No other matters were discussed.

Agenda Item 10. Recommendations to the Scientific Committee

41. The SSC PS informs the SC that it endorses the following recommendations made by the TWG PSSA:

    TWG PSSA03 meeting

    (a) Continue developing a single joint CPUE index to resolve different patterns in standardized indices among Members and to enable the calculation of the CPUE with higher spatial and temporal coverage;
    (b) Update the shared data for a single joint CPUE index for future stock assessment; and
    (c) Provide the TWG PSSA with a secure space for collaborative work, such as GitHub.

    TWG PSSA04 meeting

    (a) The participants recommended that the SC draft rules to address submission, revision and treatment of scientific papers before and during meetings, and submit the rules to the Commission for consideration.
    (b) The participants recommended that the SSC PS endorse the stock assessment report.
    (c) The participants recommended considering sharing more data for improving the current stock assessment and developing future ones.
    (d) The participants recognized the contribution by the invited expert in facilitating the work

of the TWG PSSA and recommended inviting Dr. Larry Jacobson (or an expert with similar qualifications and experience) to also attend the next TWG PSSA meetings.

42. The SSC PS recommends the following to the SC:
    (a) The SSC PS recommends that the SC endorse the stock assessment report from the TWG PSSA04 (Annex D).
    (b) According to the stock assessment results by TWG PSSA04, the SSC PS recommends that further measures should be taken effectively to avoid the increasing trend in the exploitation rate to sustain biomass.
    (c) The SSC PS recommends that Members share more data (e.g. size-at-maturity measurements, catch-at-size data and catch-at-age data, etc.) for improving the current stock assessment and developing future stock assessments.
    (d) The SSC PS recommends that the SC endorse the updated table for identification of scientific data which can be collected and/or validated by at-sea observers, fishermen, electronic reporting systems and other means for Pacific saury (Annex E).
    (e) The SSC PS recommends that the SC recommend that the Commission fund the participation of Dr. Larry Jacobson (or an expert with similar qualifications and experience) in the next Pacific saury meetings.
    (f) The SSC PS recommends that the SC endorse the updated 2017-2021 SSC PS Work Plan (NPFC-2019-SSC PS04-WP03 (Rev. 1)).
    (g) The SSC PS recommends that the SC combine the SSC PS and the TWG PSSA into one new SSC.
    (h) The SSC PS recommends that the SC select Dr. Toshihide Kitakado (Japan) to serve as the Chair of the new SSC.
    (i) The SSC PS recommends that the SC determine the Terms of Reference (TORs) for the new SSC which should include the TORs of the TWG PSSA.
    (j) The SSC PS recommends that the SC recommend that the Commission consider allowing more flexibility (i.e. multiple extensions) in the terms for the Chairs of the SC's subsidiary bodies.
    (k) The SSC PS noted the definitions of juvenile as it pertains to Pacific saury, its spawning season, its seasonal change in minimum length at maturity and areas where age-0 Pacific saury are abundant (paragraphs 20-24).
    (l) The SSC PS agreed to examine the amount of data available for maturity and length of Pacific saury, and fit a logistic curve to available maturity data considering all spatial or temporal combinations that are relevant and possible.

Agenda Item 11. Next meeting

43. The SSC PS suggested that its next meeting should be held in fall 2019. The SSC PS suggested

it to be four days long, subject to possible change based on intersessional discussions.

Agenda Item 12. Adoption of the Report

44. The SSC PS04 Report was adopted by consensus.

Agenda Item 13. Close of the Meeting

45. The SSC PS thanked the Chair for his hard work and excellent chairing over the past four years.

46. The meeting closed at 12:19 on 22 April 2019.

Annexes:

Annex A – Agenda

Annex B – List of Documents

Annex C – List of Participants

Annex D – Stock Assessment Report for Pacific Saury

Annex E – Scientific data which can be collected and/or validated by at-sea observers, fishermen, electronic reporting systems and other means for Pacific saury

Annex A

Agenda

Agenda Item 1. Opening of the meeting

Agenda Item 2. Adoption of Agenda

Agenda Item 3. Review of the CMM 2018-08 for Pacific saury

Agenda Item 4. Review of Member's fisheries and research activities

Agenda Item 5. Reports and recommendations from the 3rd and 4th TWG PSSA meetings, BRP/HCR/MSE Workshop and intersessional work of the TWG PSSA

Agenda Item 6. Spatial distribution of juvenile Pacific saury in the Convention Area

Agenda Item 7. Data collection and management

- 7.1 Observer Program
- 7.2 Data sharing

Agenda Item 8. Review/update of scientific projects and the 2017-2021 Work Plan

- 8.1 Ongoing/planned projects
  - 8.1.1 Stock assessment meeting
  - 8.1.2 Spatial/temporal map of Members' catch and effort
  - 8.1.3 Expert to review Pacific saury stock assessment
- 8.2 New projects
- 8.3 2017-2021 Work Plan

Agenda Item 9. Other matters

- 9.1 Selection of SSC PS Chair
- 9.2 Other issues

Agenda Item 10. Recommendations to the Scientific Committee

Agenda Item 11. Next meeting

Agenda Item 12. Adoption of the Report

Agenda Item 13. Close of the Meeting

Annex B

List of documents

MEETING INFORMATION PAPERS

Document number	Title
NPFC-2019-SC04-MIP01 (Rev. 3)	Details for the Meetings of the Scientific Committee and Small Scientific Committees
NPFC-2019-SSC PS04-MIP02	Provisional Agenda
NPFC-2019-SSC PS04-MIP03	Provisional Annotated Agenda
NPFC-2019-SSC PS04-MIP04	Indicative Schedule

REFERENCE DOCUMENTS

Document number	Title
CMM 2018-08	CMM For Pacific Saury
NPFC-2019-AR-Annual Summary Footprint - Pacific saury	2018 – Annual summary footprint for Pacific saury in the NPFC Area of Competence

WORKING PAPERS

Document number	Title
NPFC-2019-SSC PS04-WP01 (Rev. 1)	Compiled data on Pacific saury catches in the northwestern Pacific Ocean
NPFC-2019-SSC PS04-WP02	Template for identification of scientific data which can be collected and/or validated by at-sea observers, fishermen, electronic reporting systems and other means - Pacific saury
NPFC-2019-SSC PS04-WP03 (Rev. 1)	SSC PS Work Plan, 2017-2021
NPFC-2019-SSC VME04-WP07	Spatial management of VMEs and bottom fisheries, spatial/temporal map of Members' Pacific saury catch and effort

INFORMATION PAPERS

Document number	Title
NPFC-2019-SSC PS04-IP01	Migration route of Pacific saury Cololabis saira inferred from the otolith hyaline zone
NPFC-2019-SSC PS04-IP02	Biological and ecological information on age-0 PS relevant to CMM 2018-08
NPFC-2019-SSC PS04-IP03	Strawman's proposal of 2-years workplan for the stock assessment and management on PS
NPFC-2019-SC04-IP01 (Rev. 2)	Status of Members' Annual Reports for 2018

MEETING REPORTS

Document number	Title
NPFC-2018-TWG PSSA03-Final Report	Report of the 3rd TWG PSSA meeting
NPFC-2019-TWG PSSA04-Final Report	Report of the 4th TWG PSSA meeting
NPFC-2019-WS BRP_HCR_MSE01-Final Report	Report of the BRP/HCR/MSE workshop

Annex C

List of Participants

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Annex D

Stock Assessment Report for Pacific Saury

Abstract:
This document reports the results of the stock assessments conducted at the 4th meeting of the Technical Working Group on Pacific saury stock assessment (TWG PSSA), held at Yokohama during March 6-9, 2019.

EXECUTIVE SUMMARY

Data

Pacific saury (*Cololabis saira*) is widely distributed from the subarctic to the subtropical regions of the North Pacific Ocean. While their fishing grounds are limited to west of 180E, the main fishing grounds 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.

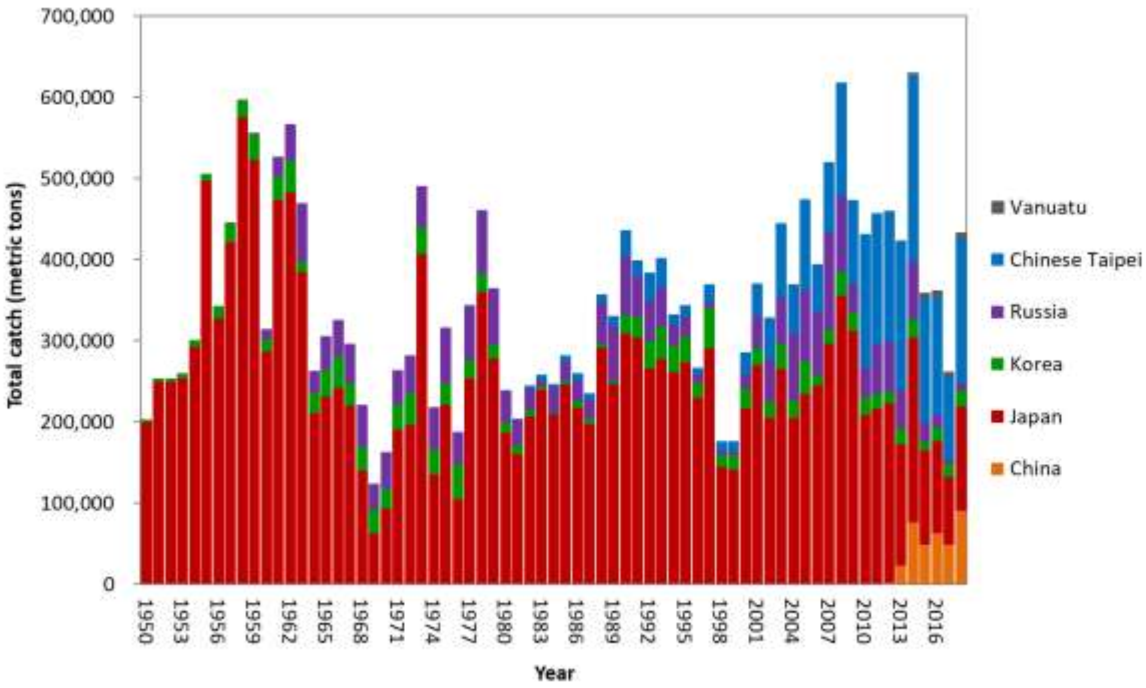


Figure 1. Time series of catch by Member. The catch data for 1950-1979 and 2018 are shown in the figure but were not used in stock assessment modeling.

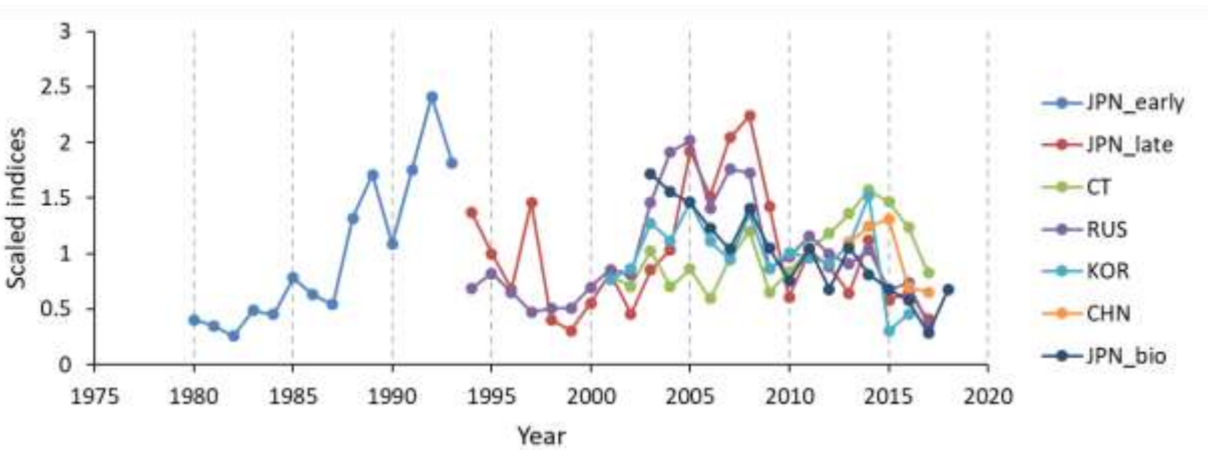


Figure 2. Time series of CPUE and Japanese survey biomass indices (JPN_bio). Survey data for 2018 were used in assessment modeling but CPUE data for 2018 were not.

Brief description of specification of analysis and models

A Bayesian state-space production model which was used in the previous stock assessments was employed for 1980-2018 as an agreed provisional stock assessment model to assess Pacific saury. Scientists from three Members (China, Japan and Chinese Taipei) each conducted analyses following the agreed specification for six base case models as well as six sensitivity case models (see Annex F, TWG PSSA03 report for more details). The six base case models covered three different assumptions of prior distribution for catchability (q) of the Japanese biomass survey index 1) q from 0.1 to 1; 2) q fixed at 1; and 3) q from 0.1 to 3[17] and two scenarios where the Japanese early CPUE was either used or not used. For the three base case scenarios that used the Japanese early CPUE, time-varying catchability was assumed because of the stated increase of catchability between 1980 and 1994. A higher weight was given for the Japanese biomass survey estimates compared to that for the 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

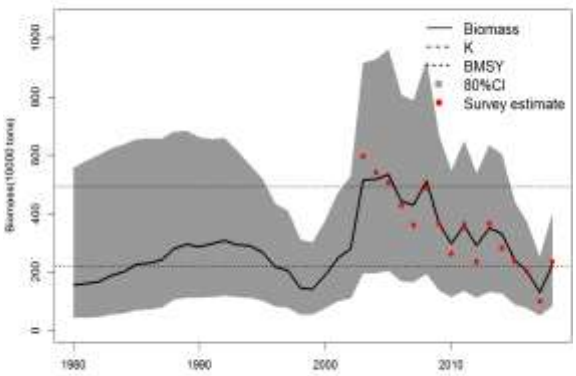
The results of the six base case models by the three stock assessment groups were averaged with equal weight to account for uncertainty in time-varying catchability in the models and differences in assumptions of prior distributions. The stock assessment results for each Member were similar, so outcomes of MCMC runs were aggregated over for the 18 models (6 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/Bmsy), c) exploitation rate (F), d) F-ratio (F/Fmsy) and e) B/K are shown in Figure 3. The Kobe plot with time trajectory using aggregated model outcomes is shown in Figure 4.

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

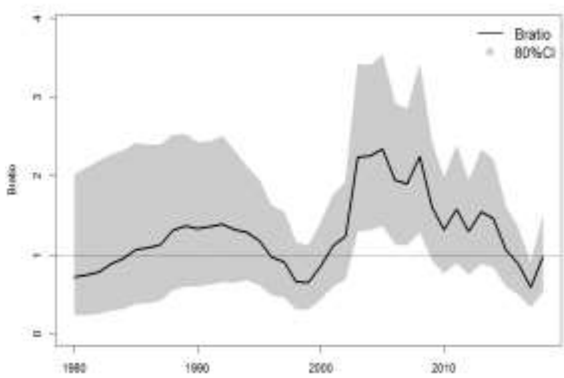
	Aggregated	Lower 10%	Upper 10%	China	Japan	Chinese Taipei
C2017 (10,000tons)	26.2			26.2	26.2	26.2
Ave C2015-2017 (10,000tons)	32.8			32.8	32.8	32.8
Ave F2015-2017	0.18	0.10	0.49	0.18	0.19	0.15
F2017	0.20	0.11	0.54	0.21	0.23	0.16
FMSY	0.25	0.11	0.45	0.27	0.26	0.24
MSY (10,000tons)	49.3	32.4	81.2	54.9	49.4	44.8
F2017 / FMSY	0.81	0.42	1.77	0.84	1.09	0.61
Ave F2015-2017 / FMSY	0.82	0.41	1.78	0.74	0.94	0.78
K (10,000tons)	490.3	244.2	930.1	497.3	468.1	504.4
B2017 (10,000tons)	129.7	51.0	249.4	126.6	114.4	175.1
B2018 (10,000tons)	222.5	82.6	395.6	221.8	209.0	246.6
Ave B2016-2018 (10,000tons)	184.8	70.1	334.8	181.8	172.3	223.3
BMSY (10,000tons)	219.7	111.1	419.4	218.5	206.6	232.6
BMSY / K	0.44	0.39	0.53	0.42	0.43	0.46
B2017 / K	0.27	0.15	0.40	0.25	0.23	0.33
B2018 / K	0.44	0.24	0.64	0.44	0.41	0.47
B2016-2018 / K	0.38	0.21	0.53	0.37	0.34	0.42
B2017 / BMSY	0.63	0.34	0.95	0.57	0.51	0.80
B2018 / BMSY	1.04	0.58	1.55	1.00	0.91	1.16
B2016-2018 / BMSY	0.82	0.47	1.22	0.83	0.75	0.90

[17] The third assumption on prior distribution catchability used in Chinese Taipei's report was q > 1.

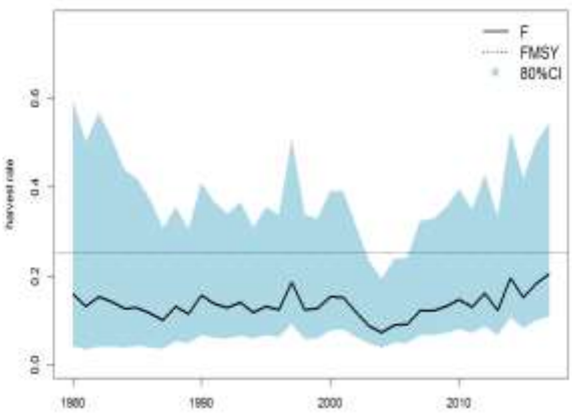
(a) Biomass (B)



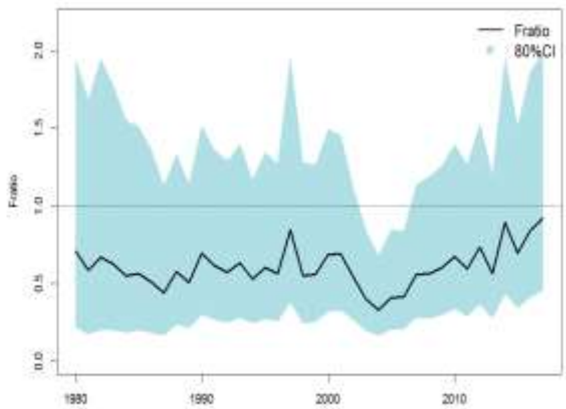
(b) B-ratio (B/Bmsy)



(c) Exploitation rate (F)



(d) F-ratio (F/Fmsy)



(e) B/K

Figure 3. Time series plots for five key reference quantities: a) biomass (B), b) B-ratio (=B/Bmsy), c) exploitation rate (F), d) F-ratio (F/Fmsy), and e) B/K. The red dots in figure (a) show the survey biomass index by Japan, which was used in the model for the estimation of biomass. The data are aggregated across 18 model results (6 base-case models by 3 Members).

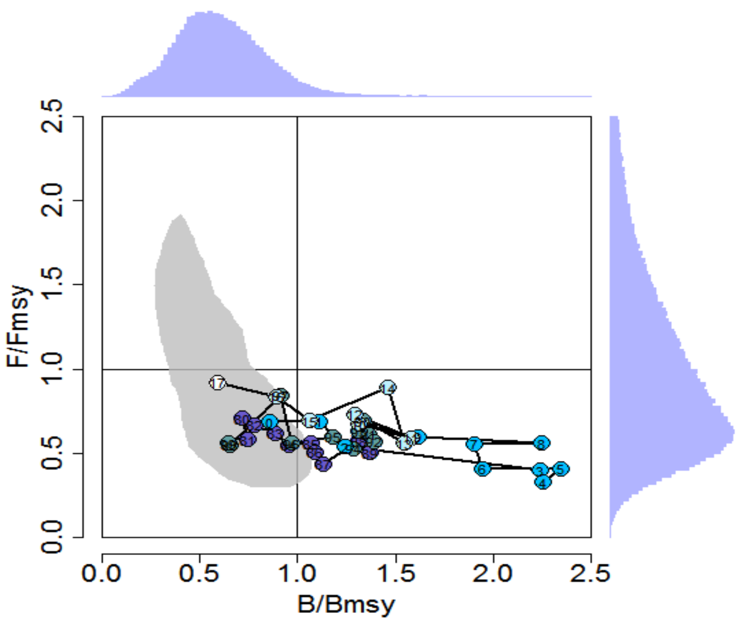


Figure 4. Kobe plot with time trajectory. The data are aggregated across 18 model results (6 base-case models by 3 Members).

Current stock condition

Based on combined model estimates, B was below Bmsy (average B/Bmsy during 2016-2018 = 0.82) and F was below Fmsy (average F/Fmsy during 2015-2017 = 0.82). Results indicate that the stock declined from near carrying capacity in the mid-2000's after a period of high productivity to current levels. Exploitation rates were increasing slowly during this period but remained lower than Fmsy. Point estimates indicate that stock biomass fell to the lowest value since 1980 (B/Bmsy = 0.63) in 2017, then increased to Bmsy in 2018. Biomass estimates show long-term fluctuations and interannual variability.

Special comments regarding the procedures and stock assessment results

The TWG PSSA 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.
2) Retrospective analyses showed that BSSPM model projections for Pacific saury were less useful than expected and the TWG 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) Several issues related to prior distributions for catchability in the Japanese survey used in modeling merit attention. Additional field studies to estimate catchability would be useful. The TWG noted that the upper bound in base case models 3 and 6 may not constrain the BSSPM sufficiently and result in biomass estimates that are too low. The TWG was pleased to learn of tentative plans for participation of scientists from other Members in the Japanese survey.
4) The TWG plans to review any progress on spatial/temporal model-based survey biomass estimation and variance of the current survey catchability estimate prior to the next assessment. Japan agreed to internally discuss the possibility of making survey data available to the Members and associated conditions.

5) Certain other key parameter estimates (i.e. intrinsic growth rate and shape) reach the upper bound of their prior ranges in some models indicating that these parameters and suitable priors in stock assessment modelling should be investigated before the next assessment.
6) It may be possible to increase efficiency of stock assessment work by reducing duplicate work by Members. For example, CPUE standardization 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.
7) Three independent assessment model computer programs were used in this assessment to fit the same model. 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-structured models are introduced.
8) 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 the format of the executive summary with respect to information requirements and effective communication.
9) Because of the similarity in outcomes, the TWG agreed to aggregate Members' stock assessments for communicating results in 2019. This may not be advisable in future years.
10) 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.

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. More than 97% of Japan's total catch is caught by the stick-held dip net. Since 1995, the annual catch of Pacific saury for stick-held dip net fishery has varied. Maximum and minimum catches of 347 thousand tons and 84 thousand tons were recorded in 2008 and 2017, respectively. The 2018 annual catch of this fishery was 128,457 tons in the national waters and in the NPFC Convention Area.

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 8 thousand tons in 2018.

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 2013. Currently there are four vessels operating in the Northwest Pacific targeting saury. 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).

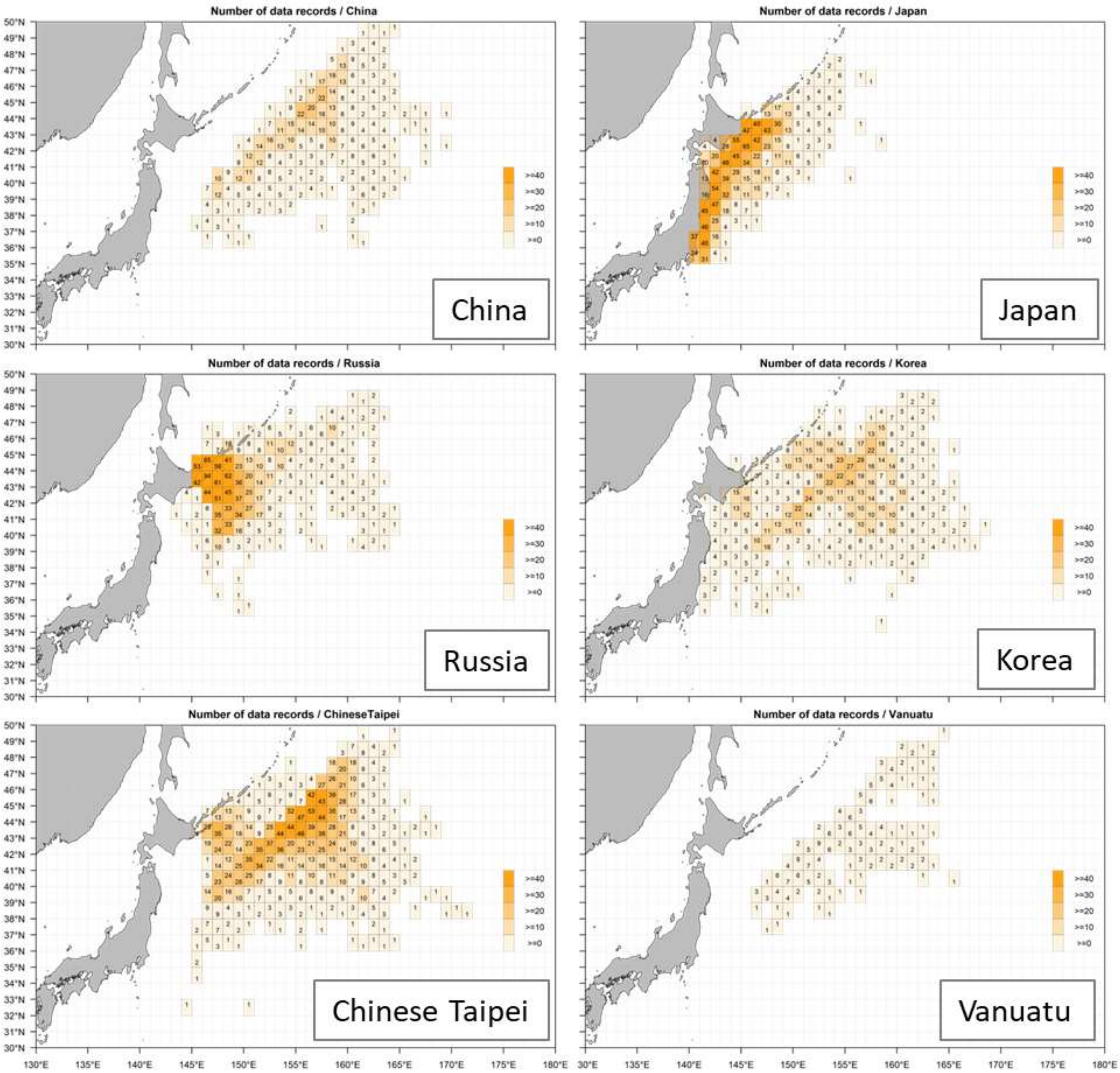


Figure 1. Main fishing grounds for Pacific saury by fishing members in the Western North Pacific Ocean. The legend shows the number of data records. This figure is based on the data shared by the Members for the development of a joint CPUE index (NPFC-2018-TWG PSSA03-WP02, NPFC-2018-TWG PSSA03-WP03,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

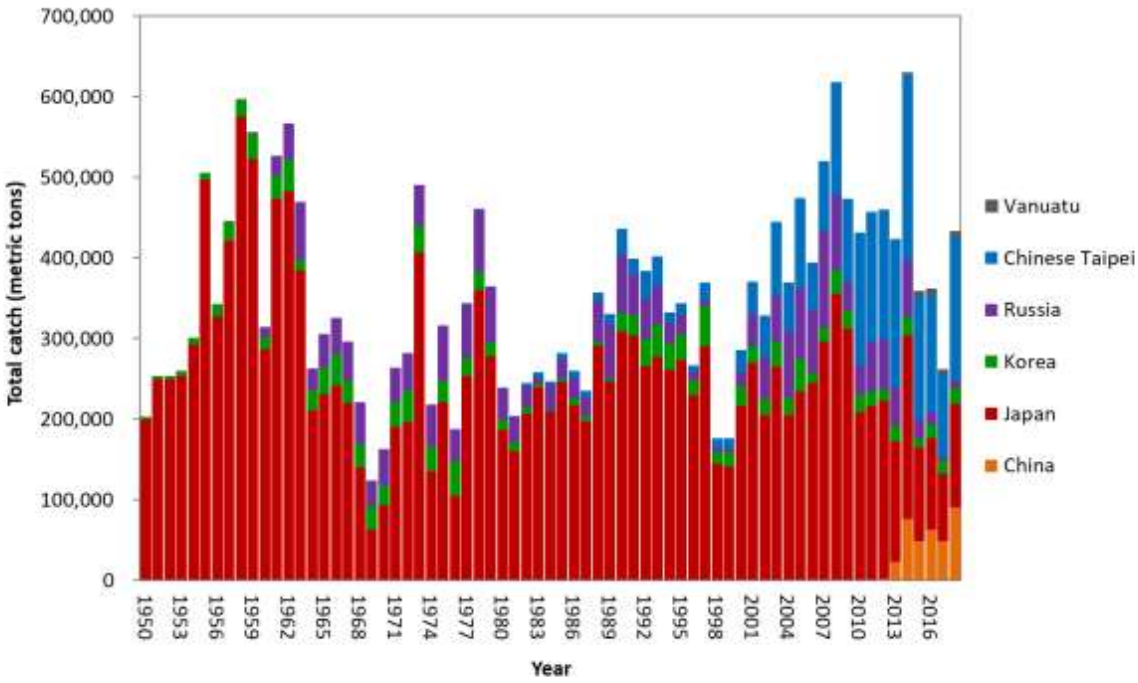


Figure 2. Time series of catch by Member.

3. SPECIFICATION OF STOCK ASSESSMENT

A Bayesian state-space production model which was used in the previous stock assessments was employed for 1980-2018 as an agreed provisional stock assessment model to assess Pacific saury. Scientists from three Members (China, Japan and Chinese Taipei) each conducted analyses following the agreed specification for six base case models as well as six sensitivity case models (see Annex F, TWG PSSA03 report for more details). The six base case models covered three different assumptions of prior distribution for catchability (q) of the Japanese biomass survey index 1) q from 0.1 to 1; 2) q fixed at 1; and 3) q from 0.1 to 3[18] and two scenarios where the Japanese early CPUE was either used or not used. For the three base case scenarios that used the Japanese early CPUE, time-varying catchability was assumed because of the stated increase of catchability between 1980 and 1994. A higher weight was given for the Japanese biomass survey estimates compared to that for the Members' CPUE. 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. Details are given in the following sections.

3.1 Bayesian state-space production model

The population dynamics is modelled by the following equations:

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

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

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

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[18] The third assumption on prior distribution catchability used in Chinese Taipei's report was q > 1.

$f(B)$: 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 estimate

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

where

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

CPUE series

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

where

$I_{t,f}$: the biomass index in year *t* for biomass index *f*

q_f : the catchability coefficient for biomass index *f*

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

For the estimation of parameters, Bayesian methods were used with 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-2019-TWG PSSA04-WP10 (Rev. 1) and NPFC-2019-TWG PSSA04-WP08 (Rev. 1); for the non-uniform priors used in Chinese Taipei, see document NPFC-2019-TWG PSSA04-WP09 (Rev. 1).

3.2 Agreed scenarios

Table 1. Definition of scenarios

Case	Relative bias in biomass estimate	Fishery dependent index	Variance component	Hyper-stability
Base case 1 (B1)	U~(0.1, 1)	A1	V1	H1
Base case 2 (B2)	1 (unbiased)	A1	V1	H1
Base case 3 (B3)	U~(0.1, 3)	A1	V1	H1
Base case 4 (B4)	U~(0.1, 1)	A2	V2	H2
Base case 5 (B5)	1 (unbiased)	A2	V2	H2
Base case 6 (B6)	U~(0.1, 3)	A2	V2	H2
Sensitivity case 1 (S1)	U~(0.1, 1)	A1	V3	H3
Sensitivity case 2 (S2)	1 (unbiased)	A1	V3	H3
Sensitivity case 3 (S3)	U~(0.1, 3)	A1	V3	H3
Sensitivity case 4 (S5)	U~(0.1, 1)	A2	V3	H3
Sensitivity case 5 (S5)	1 (unbiased)	A2	V3	H3
Sensitivity case 6 (S6)	U~(0.1, 3)	A2	V3	H3

A1: With JPN early CPUE (1980-1993) with assumptions of time-varying *q*

A2: Without JPN early CPUE (1980-1993)

V1: Variances of CPUEs are assumed to be common and 6 times of that of biomass

V2: Variances of CPUEs are assumed to be common and 5 times of that of biomass

V3: Variances of CPUEs are assumed to be separate free parameters

H1: b is a common parameter for all fisheries but JPN_early, with a prior distribution, *b* ~ U(0, 1) [*b*_JPN_early=1]

H2: *b* is a common parameter for all fisheries, with a prior distribution, *b* ~ U(0, 1)

H3: *b*=1

Table 2. Description of symbols used in the stock assessment

Symbol	Description
C_{2017}	Catch in 2017
$AveC_{2015\text{-}2017}$	Average catch for a recent period (2015–2017)
$AveF_{2015\text{-}2017}$	Average harvest rate for a recent period (2015–2017)
F_{2017}	Harvest rate in 2017
F_{MSY}	Annual harvest rate producing the maximum sustainable yield (MSY)
MSY	Equilibrium yield at FMSY
F_{2017}/F_{MSY}	Average harvest rate in 2017 relative to FMSY
$AveF_{2015\text{-}2017}/F_{MSY}$	Average harvest rate for a recent period (2015–2017) relative to FMSY
K	Equilibrium unexploited biomass (carrying capacity)
B_{2017}	Stock biomass in 2017 estimated in the model
B_{2018}	Stock biomass in 2018 estimated in the model[b]
$AveB_{2016\text{-}2018}$	Stock biomass for a recent period (2016–2018) 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_{2017}/K	Stock biomass in 2017 relative to K[a]
B_{2018}/K	Stock biomass in 2018 relative to K[a,b]
$B_{2016\text{-}2018}/K$	Stock biomass in the latest time period (2016-2018) relative to the equilibrium unexploited stock biomass[a,b]
B_{2017}/B_{MSY}	Stock biomass in 2017 relative to BMSY[a]
B_{2018}/B_{MSY}	Stock biomass in 2018 relative to BMSY[a,b]
$B_{2016\text{-}2018}/B_{MSY}$	Stock biomass for a recent period (2016–2018) relative to the stock biomass that produces maximum sustainable yield (MSY) [a,b]

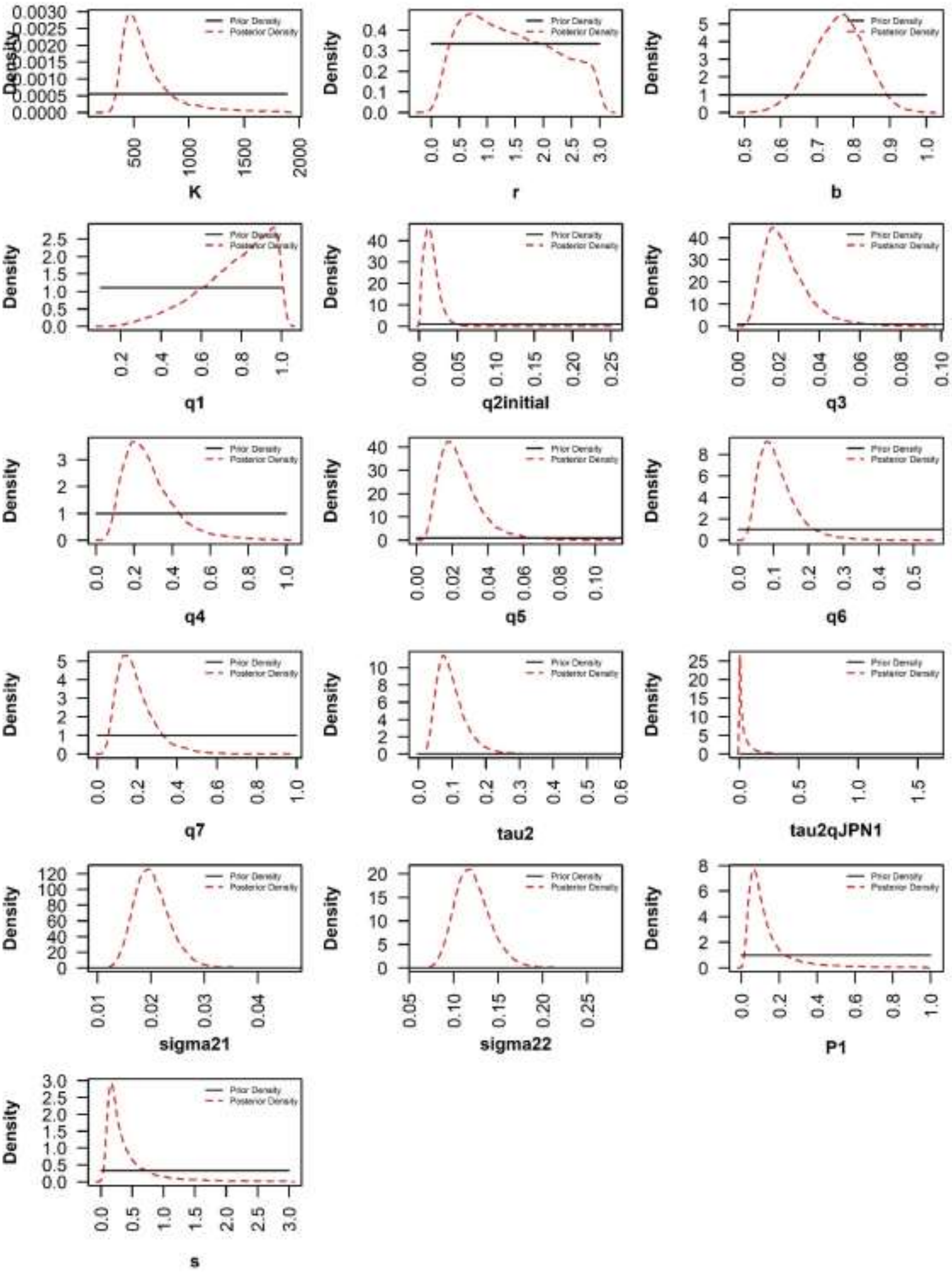
[a]calculated as the average of the ratios,

[b]Japanese biomass survey available but no CPUE available in 2018.

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)

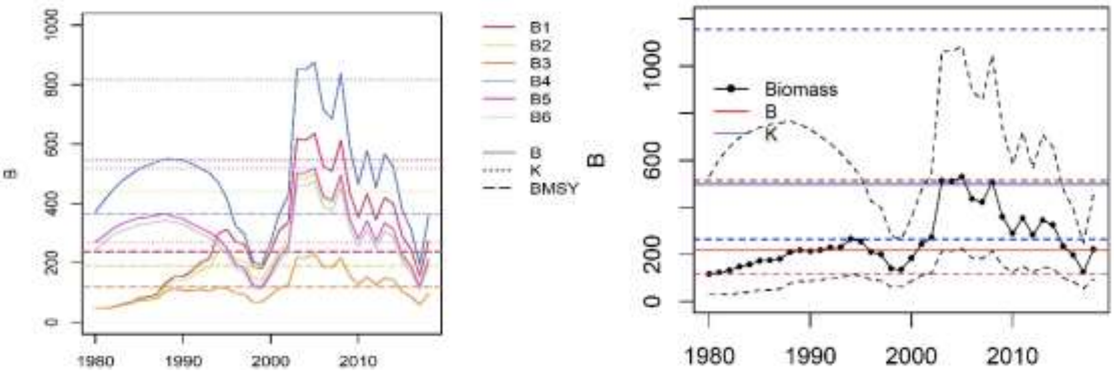


4.1.2 Summary of estimates of parameters and reference points

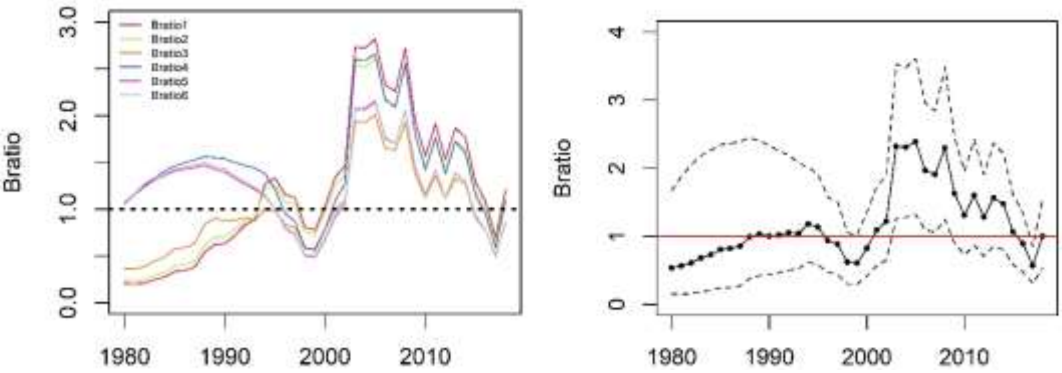
	Base case 1	Base case 2	Base case 3	Base case 4	Base case 5	Base case 6	Overall
C2017	26.18	26.18	26.18	26.18	26.18	26.18	26.18
AveC2015-2017	32.75	32.75	32.75	32.75	32.75	32.75	32.75
AveF2015-2017	0.15	0.18	0.41	0.12	0.19	0.21	0.18
F2017	0.17	0.21	0.45	0.13	0.22	0.24	0.21
FMSY	0.27	0.30	0.37	0.19	0.21	0.24	0.27
MSY	64.65	57.06	44.80	66.50	52.78	51.92	54.86
F2017/FMSY	0.59	0.71	1.17	0.69	1.04	1.07	0.84
AveF2015-2017/FMSY	0.52	0.63	1.06	0.59	0.91	0.94	0.74
K	547.70	441.50	268.10	816.70	517.10	539.00	497.30
B2017	157.00	125.00	58.38	195.00	118.40	109.20	126.60
B2018	272.70	214.60	96.15	357.50	211.40	193.20	221.80
AveB2016-2018	223.38	178.70	80.23	288.30	173.30	158.67	181.83
BMSY	234.50	190.10	119.20	365.40	239.40	240.40	218.50
BMSY/K	0.41	0.41	0.43	0.43	0.43	0.43	0.42
B2017/K	0.30	0.28	0.23	0.27	0.23	0.23	0.25
B2018/K	0.52	0.48	0.38	0.49	0.40	0.40	0.44
B2016-2018/K	0.43	0.40	0.32	0.40	0.33	0.33	0.37
B2017/BMSY	0.69	0.65	0.51	0.59	0.49	0.50	0.57
B2018/BMSY	1.20	1.12	0.85	1.09	0.88	0.88	1.00
B2016-2018/BMSY	1.00	0.94	0.72	0.89	0.72	0.72	0.83

4.1.3 Time series plots for base case models and aggregated results

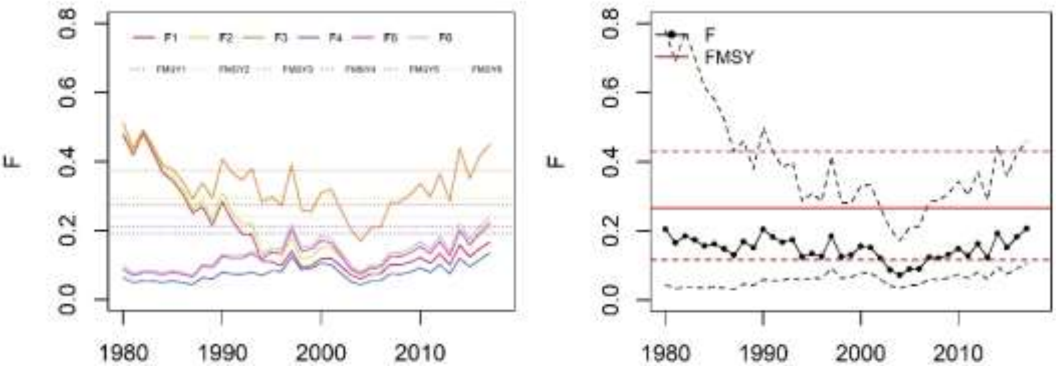
(a) Biomass



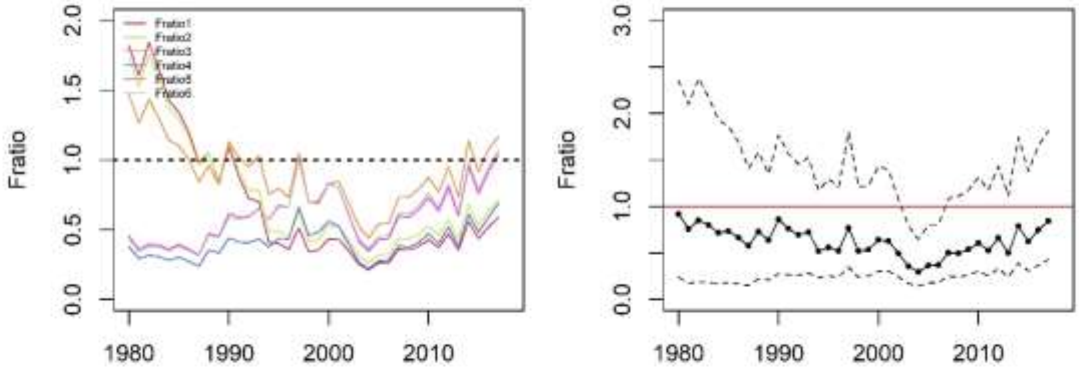
(b) B-ratio (B/Bmsy)



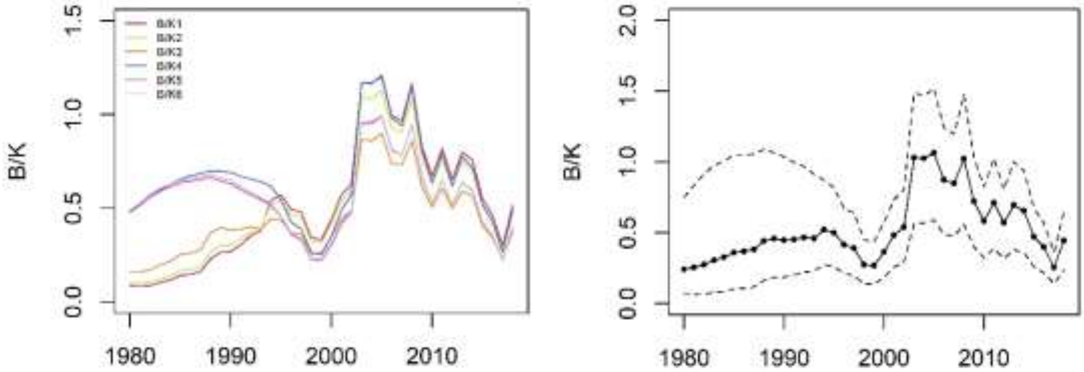
(c) Exploitation rate (F)



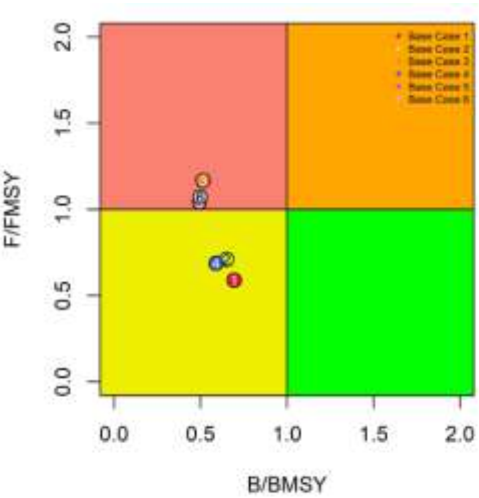
(d) F-ratio (F/Fmsy)

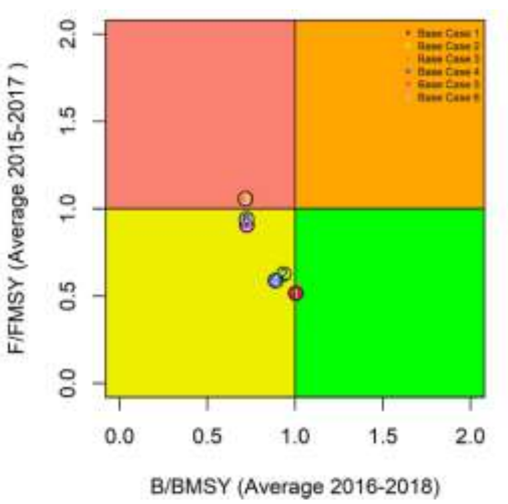


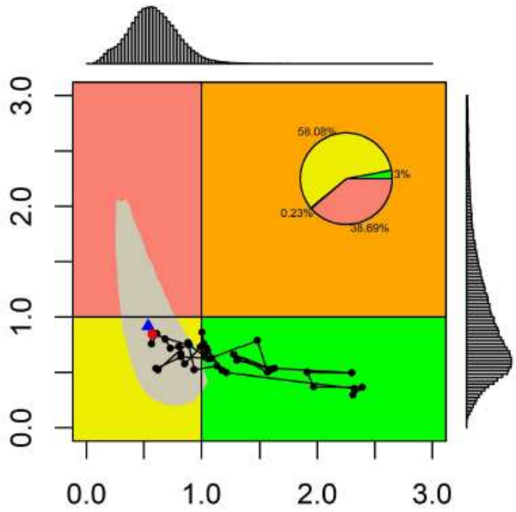
(e) B/K



4.1.4 Kobe plots

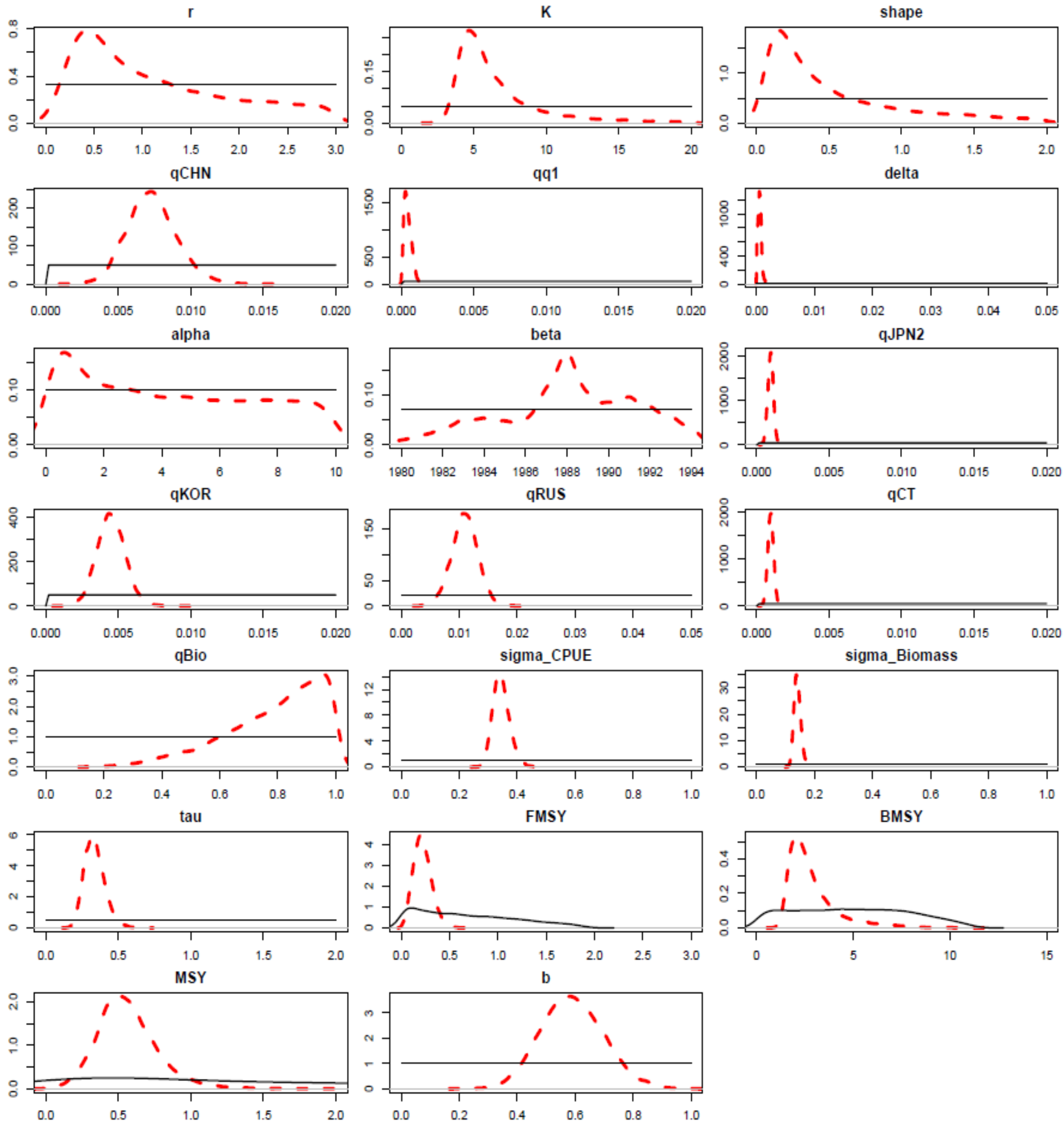






4.2 JAPAN

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

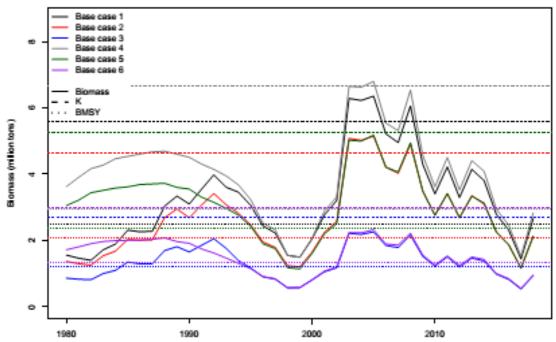


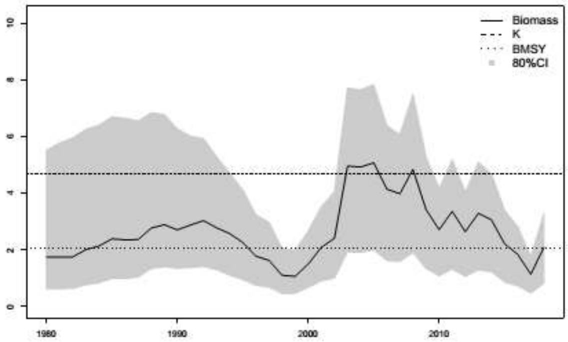
4.2.2 Summary of estimates of parameters and reference points

	Base 1	Base 2	Base 3	Base 4	Base 5	Base 6	Overall
C2017	26.18	26.18	26.18	26.18	26.18	26.18	26.18
Ave C2015-2017	32.75	32.75	32.75	32.75	32.75	32.75	32.75
Ave F2015-2017	0.16	0.19	0.44	0.15	0.19	0.42	0.19
F2017	0.18	0.22	0.49	0.17	0.22	0.47	0.23
FMSY	0.21	0.23	0.35	0.2	0.21	0.34	0.26
MSY	54.29	50.34	43.49	60.15	53.39	45.21	49.4
F2017 / FMSY	0.83	0.96	1.35	0.81	1.06	1.38	1.09
Ave F2015-2017 / FMSY	0.71	0.83	1.19	0.69	0.91	1.23	0.94
K	557.95	464	270.75	665.15	524.1	299.3	468.1
B2017	144.4	117.2	53.58	152.8	116.4	55.68	114.4
B2018	266.25	213.1	94.28	283.05	213.3	96.03	209
Ave B2016-2018	211.93	173.7	76.39	226.05	173.17	78.37	172.27
BMSY	248.6	208.1	121.5	295.7	236.7	132.7	206.6
BMSY / K	0.42	0.42	0.43	0.42	0.43	0.43	0.43
B2017 / K	0.27	0.25	0.2	0.25	0.22	0.2	0.23
B2018 / K	0.49	0.45	0.36	0.46	0.4	0.34	0.41
B2016-2018 / K	0.4	0.37	0.3	0.37	0.33	0.28	0.33
B2017 / BMSY	0.6	0.56	0.45	0.56	0.49	0.43	0.5
B2018 / BMSY	1.11	1.02	0.8	1.03	0.89	0.75	0.91
B2016-2018 / BMSY	0.9	0.83	0.66	0.84	0.73	0.62	0.75

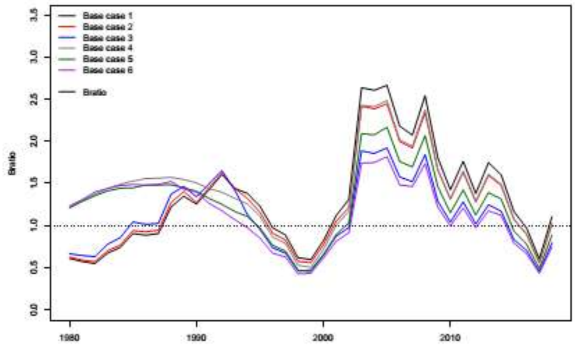
4.2.3 Time series plots for base case models and aggregated results

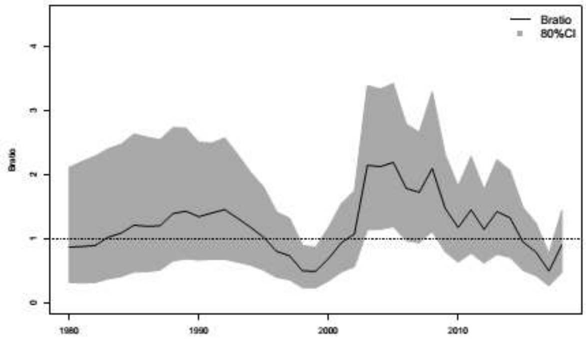
(a) Biomass



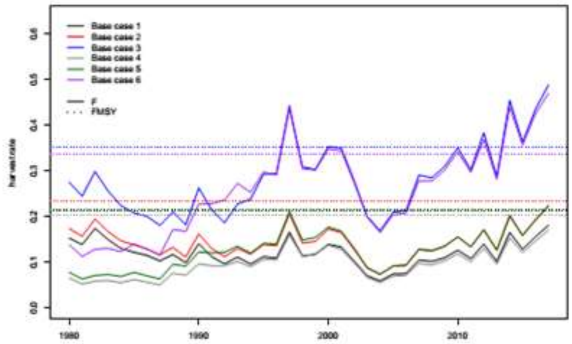


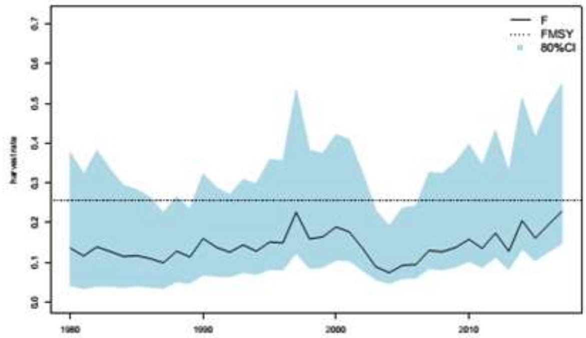
(b) B-ratio (B/Bmsy)



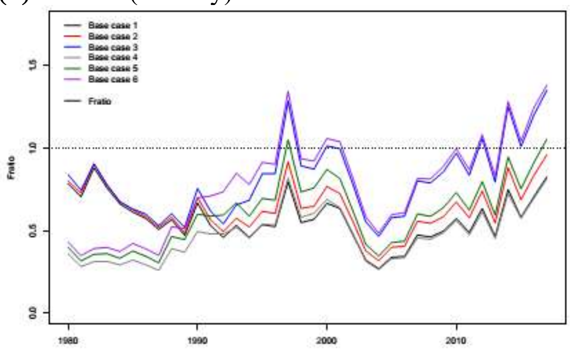


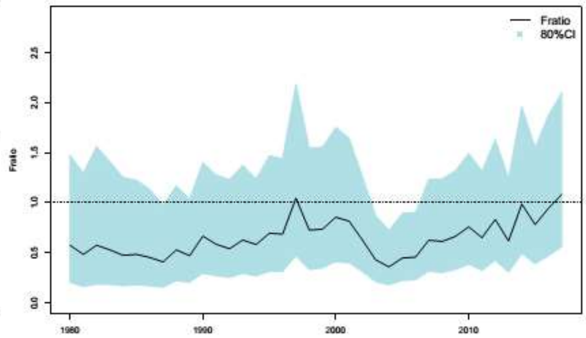
(c) Exploitation rate (F)



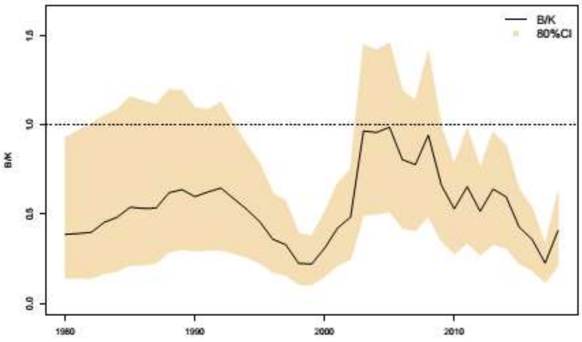


(d) F-ratio (F/Fmsy)

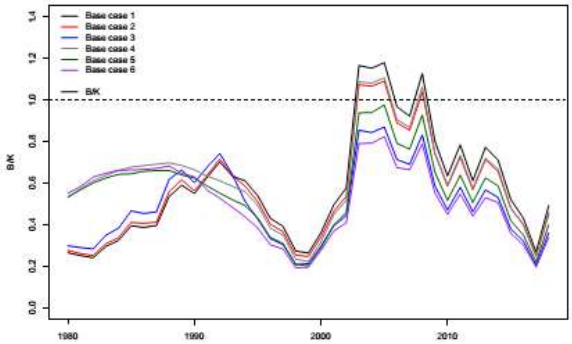




(e) B/K

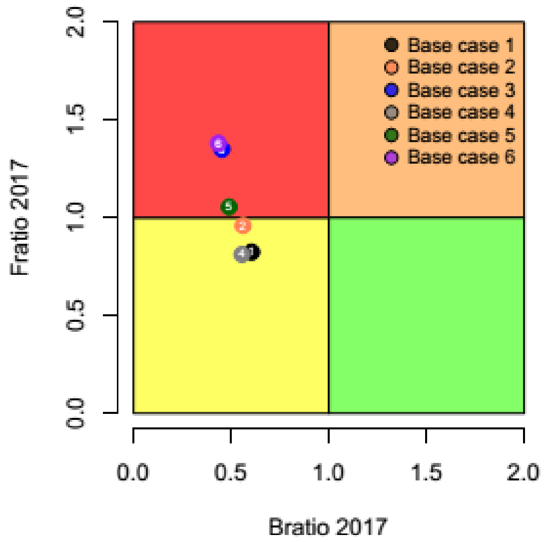


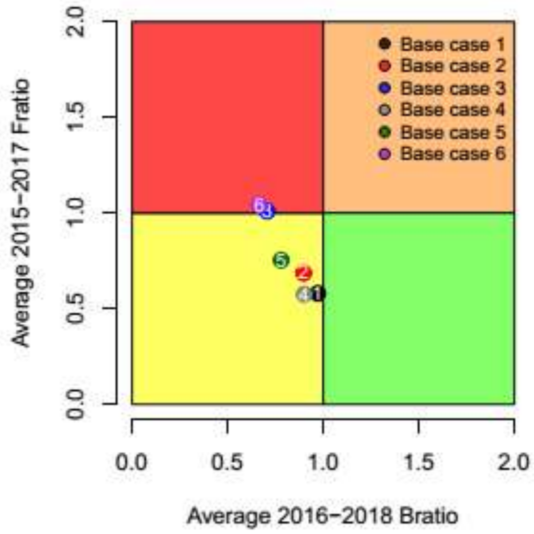
B/K
80%CI
B/K
1980
1990
2000
2010

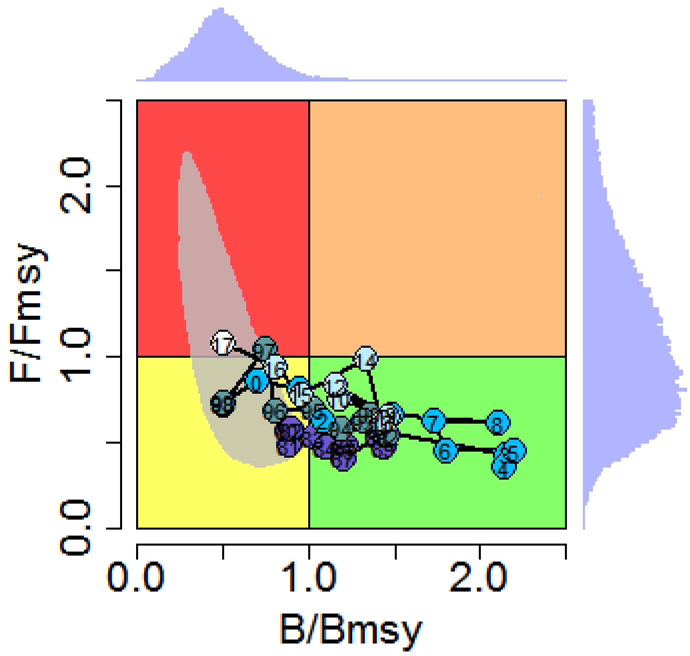


Base case 1
Base case 2
Base case 3
Base case 4
Base case 5
Base case 6
B/K
B/K
1980
1990
2000
2010

4.2.4 Kobe plots

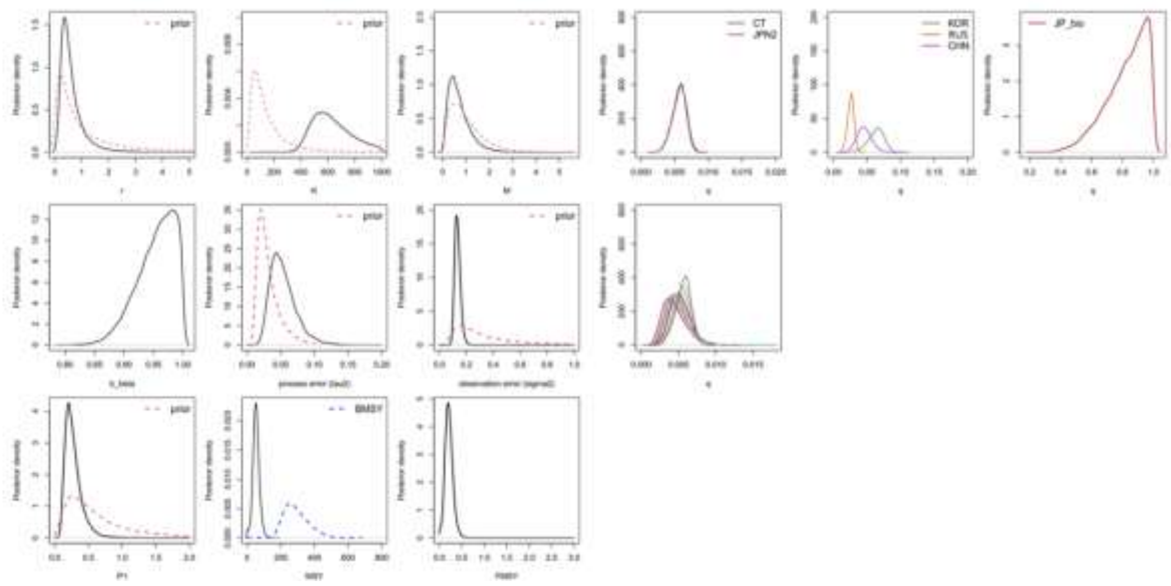






4.3 CHINESE TAIPEI

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

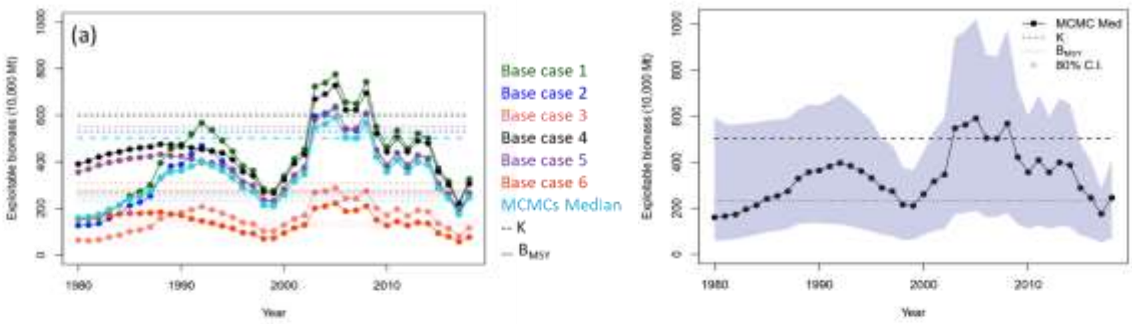


4.3.2 Summary of estimates of parameters and reference points

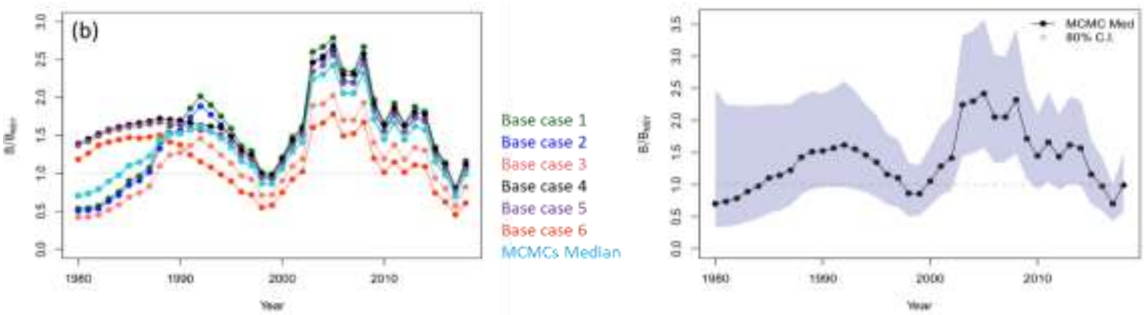
	Base case1	Base case2	Base case3	Base case4	Base case5	Base case6	Overall
				Median			
C_{2017} (mt)	261,789	261,789	261,789	261,789	261,789	261,789	261,789
Ave $C_{2015\text{-}2017}$ (mt)	327,453	327,453	327,453	327,453	327,453	327,453	327,453
Ave F2015-2017	0.12	0.14	0.36	0.12	0.14	0.57	0.15
F_{2017}	0.13	0.15	0.38	0.13	0.15	0.61	0.16
F_{MSY}	0.21	0.23	0.36	0.18	0.19	0.39	0.24
MSY	52.91	50.68	42.72	45.87	44.63	40.19	44.75
F_{2017}/F_{MSY}	0.6	0.67	1.11	0.71	0.77	1.69	0.84
Ave $F_{2015\text{-}2017}/F_{MSY}$	0.56	0.63	0.98	0.67	0.75	1.46	0.78
K	606.7	530.9	308.5	597.4	550.4	266.6	504.4
B_{2017}	222.2	183.1	81.98	220.2	191.5	57.2	175.10
B_{2018}	324.4	266.6	117.3	304.7	264.8	76.18	246.60
Ave $B_{2016\text{-}2018}$	273.3	224.85	99.64	262.45	228.15	66.69	222.13
B_{MSY}	280.3	247.4	143.2	277	256.6	126	231.90
B_{MSY}/K	0.46	0.47	0.46	0.46	0.47	0.47	0.46
B_{2017}/K	0.37	0.35	0.27	0.38	0.36	0.22	0.33
B_{2018}/K	0.54	0.51	0.39	0.52	0.49	0.29	0.47
$B_{2016\text{-}2018}$ /K	0.48	0.45	0.35	0.47	0.45	0.27	0.44
B_{2017}/B_{MSY}	0.8	0.75	0.57	0.81	0.77	0.46	0.70
B_{2018} /B_{MSY}	1.17	1.09	0.82	1.12	1.06	0.61	0.99
Ave $B_{2016\text{-}2018}/B_{MSY}$	1.03	0.97	0.73	1.02	0.96	0.56	0.96

4.3.3 Time series plots for base case models and aggregated results

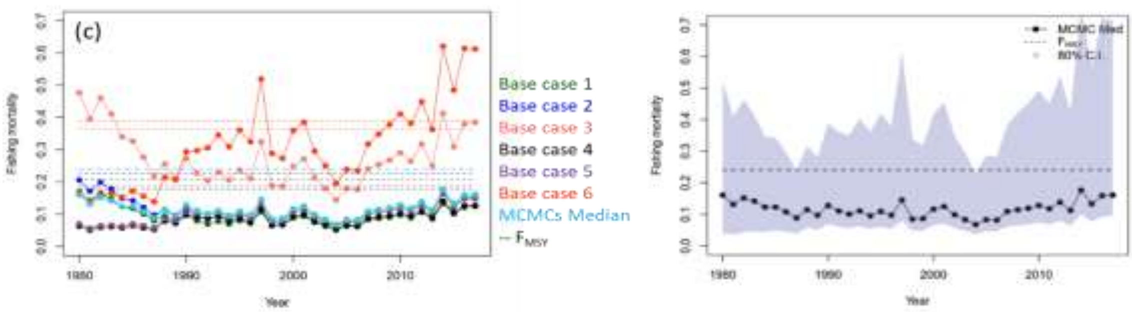
(a) Biomass



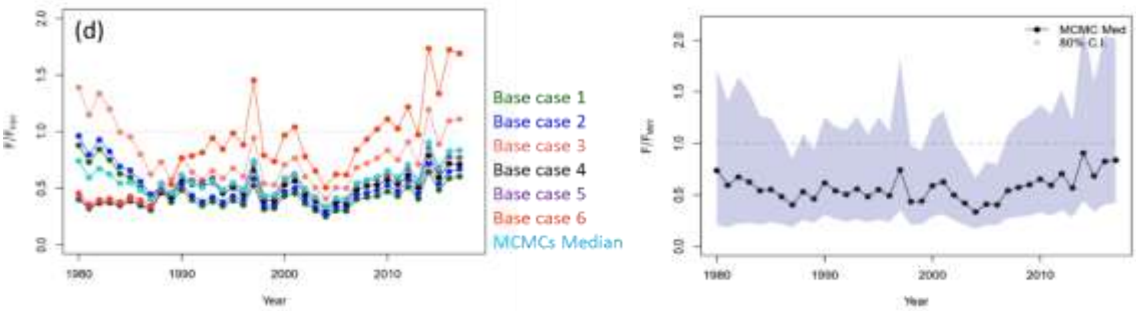
(b) B-ratio (B/Bmsy)



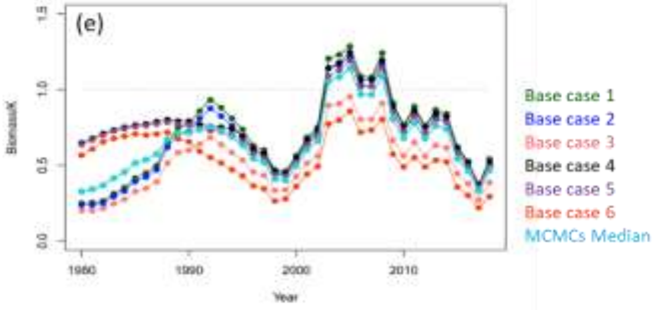
(c) Exploitation rate (F)

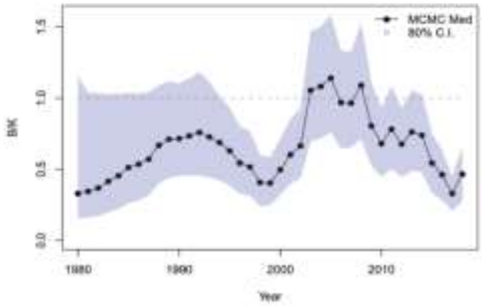


(d) F-ratio (F/Fmsy)

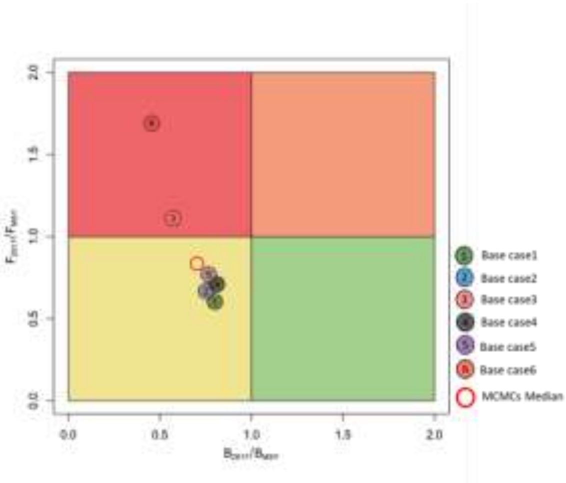


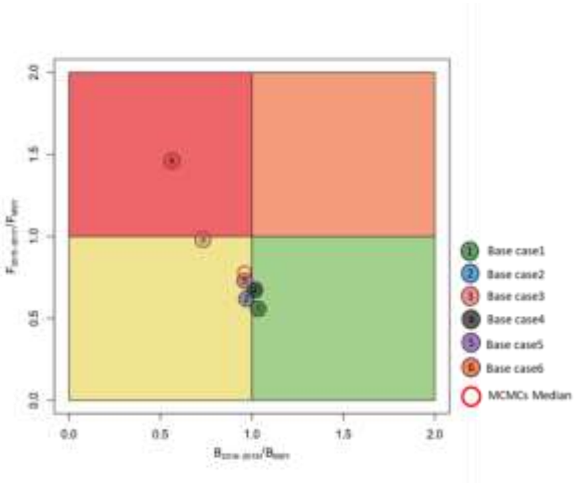
(e) B/K

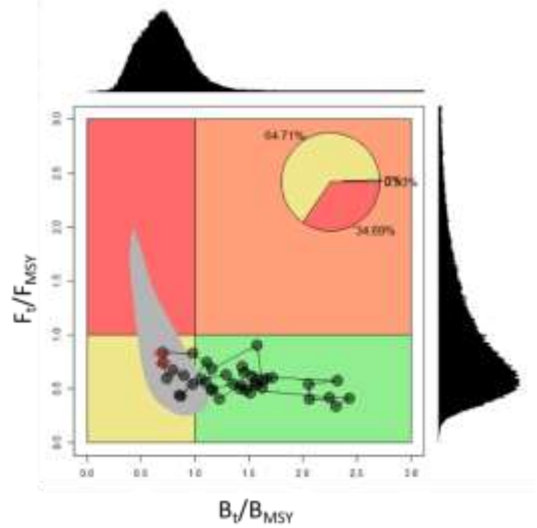

(e)
Base case 1
Base case 2
Base case 3
Base case 4
Base case 5
Base case 6
MCMCs Median
Year


MCMC Med
80% C.I.
B/K
Year

4.3.4 Kobe plots





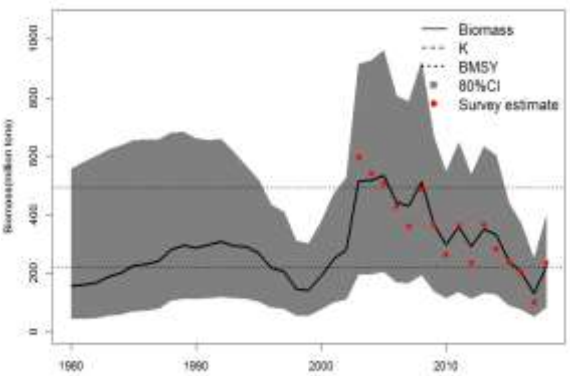


5 AGGREGATED RESULTS

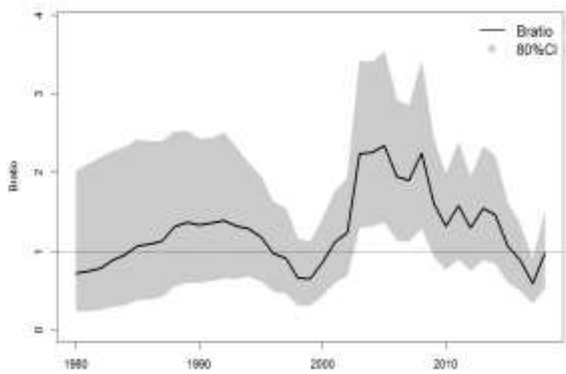
5.1 Visual presentation of results

The graphical presentations for times series of a) biomass (B), b) B-ratio (=B/Bmsy), c) exploitation rate (F), d) F-ratio (F/Fmsy) and e) B/K are shown in Figure 3.

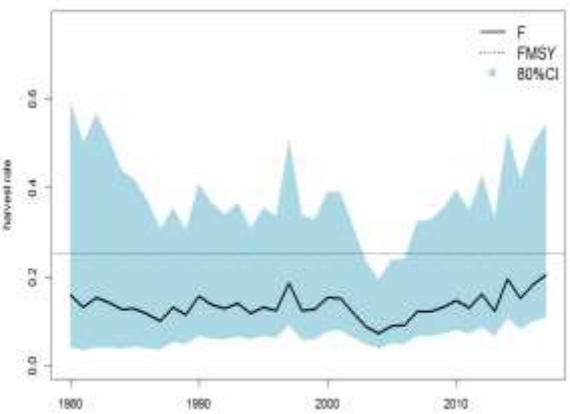
(a) Biomass (B)



(b) B-ratio (B/Bmsy)



(c) Exploitation rate (F)



(d) F-ratio (F/Fmsy)

(e) B/K

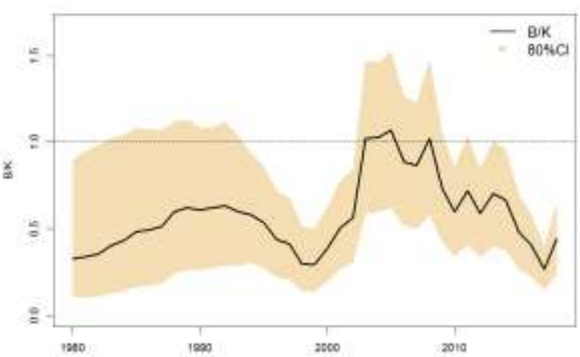


Figure 3. Time series plots for five key reference quantities: a) biomass (B), b) B-ratio (=B/Bmsy), c) exploitation rate (F), d) F-ratio (F/Fmsy) and e) B/K. The red dots in figure (a) are the biomass indices by Japan.

The Kobe plot with time trajectory using aggregated model outcomes is shown in Figure 4.

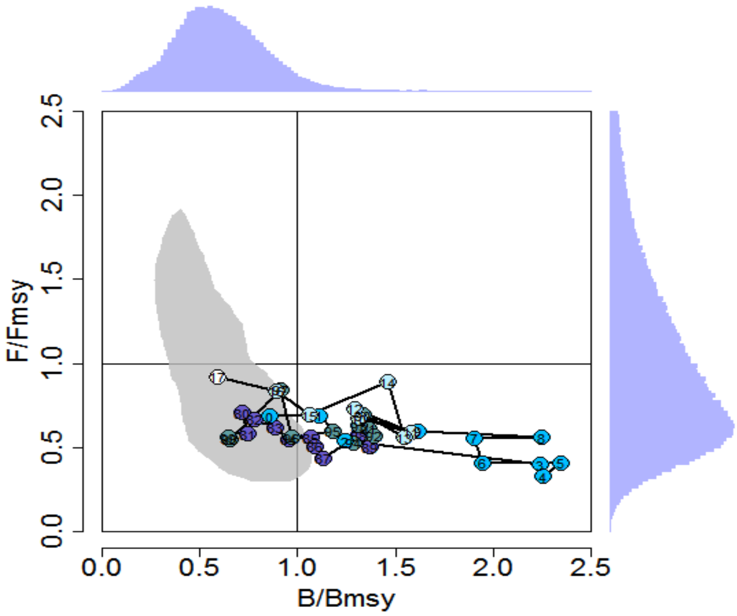


Figure 4. Kobe plots with time trajectory.

5.2 Summary table

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

	Aggregated	Lower 10%	Upper 10%
C2017 (10,000tons)	26.2		
Ave C2015-2017 (10,000tons)	32.8		
Ave F2015-2017	0.18	0.10	0.49
F2017	0.20	0.11	0.54
FMSY	0.25	0.11	0.45
MSY (10,000tons)	49.3	32.4	81.2
F2017 / FMSY	0.81	0.42	1.77
Ave F2015-2017 / FMSY	0.82	0.41	1.78
K (10,000tons)	490.3	244.2	930.1
B2017 (10,000tons)	129.7	51.0	249.4
B2018 (10,000tons)	222.5	82.6	395.6
Ave B2016-2018 (10,000tons)	184.8	70.1	334.8
BMSY (10,000tons)	219.7	111.1	419.4
BMSY / K	0.44	0.39	0.53
B2017 / K	0.27	0.15	0.40
B2018 / K	0.44	0.24	0.64
B2016-2018 / K	0.38	0.21	0.53
B2017 / BMSY	0.63	0.34	0.95
B2018 / BMSY	1.04	0.58	1.55
B2016-2018 / BMSY	0.82	0.47	1.22

6 CONCLUDING REMARKS

Based on combined model estimates, B was below Bmsy (average B/Bmsy during 2016-2018 = 0.82) and F was below Fmsy (average F/Fmsy during 2015-2017 = 0.82). Results indicate that the stock declined from near carrying capacity in the mid-2000's after a period of high productivity to current levels. Exploitation rates were increasing slowly during this period but remained lower than Fmsy. Point estimates indicate that stock biomass fell to the lowest value since 1980 (B/Bmsy = 0.63) in 2017, then increased to Bmsy in 2018. Biomass estimates show long-term fluctuations and interannual variability.

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Annex E

Scientific data which can be collected and/or validated by at-sea observers, fishermen, electronic reporting systems and other means for Pacific saury

Stick-held-dip net fishing information format - Pacific saury				
#	Items	Example	Data collection	Data validation
0	Operational day ID			
1	Vessel flag	KR	*	
2	Vessel name	77Dongnam	*	
3	Vessel call sign (if allocated)	1ABC	*	
4	Vessel Reg No	xxxxxx-xx	*	
5	Lloyd's/ IMO Number (if allocated)	xxxxxxx	*	
6	Light bulb types (traditional/ LED)	traditional	xx	
7	Total light power (kW)	xxx kW	xx	
8	Date of Fishing	14-Apr-18	xx	
9	Fishing position (midnight): latitude (DD,MM.mm)	44, 10.10	xx	X
10	Fishing position (midnight): longitude (DD,MM.mm)	153, 10.10	xx	X
11	Sea Temperature (°C)	15	v	X
12	Number of hauls	3	xx	X
13	Species code (FAO 3-alpha code)	SAP		
14	Retained: Live weight (kg)	3000		X
15	Discarded: Live weight (kg)	0	X	
16	(Bycatch) Species code (FAO 3-alpha code)	OFJ		
17	Retained: Live weight (kg)	0	X	
18	Discarded: Live weight (kg)	10	X	
Biological data - Pacific saury				
0	Operational day ID			
1	Sampled location (fleet/port/lab)	fleet	v	X
2	Fishing Date or Fishing position	14-Apr-18	v	X
3	Length (FL,BL,TL, KL in mm)	FL 15	v	
4	Sex	Male	X	
5	Maturity Stage	Immature	X	
6	Age (if possible)	1	X	

X - data that can ONLY be collected by observers AT SEA; **xx** - data that can be collected by fishermen AT SEA; **v** - data which are preferably collected by observers but a degree of cover can be achieved by other means (in-port collection, EM, ERS etc); ***** - data which can be collected equally well by other means.