North Pacific Fisheries Commission

NPFC-2021-SCsm01-Final Report

1st Special Meeting of the Scientific Committee
REPORT

20-22 January 2021

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North Pacific Fisheries Commission
1st Special Meeting of the Scientific Committee

20-22 January 2021
Video conference

REPORT

Agenda Item 1. Opening of the meeting

1. The 1st Special Meeting of the Scientific Committee (SC) took place in the format of video conferencing via WebEx, and was attended by Members from Canada, China, Japan, the Republic of Korea, the Russian Federation, Chinese Taipei, the United States of America and Vanuatu. Dr. Larry Jacobson attended the meeting as an invited expert. The Organization for Regional and Inter-regional Studies (ORIS) and the Pew Charitable Trusts (Pew) attended as observers.

2. The meeting was opened by Dr. Janelle Curtis (Canada) and Dr. Toshihide Kitakado (Japan), who served as Co-Chairs. 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 (Annex A). The List of Documents and Participants List are attached (Annexes B, C).

Agenda Item 3. Overview of the outcomes of SSC PS06 and intersessional work

4. Dr. Kitakado presented the outcomes and recommendations from the SSC PS06 meeting and the outcomes of the intersessional work.

Agenda Item 4. Member’s fishery status including 2020 fishery

5. China reported that, based on preliminary data up to December 10, the nominal catch-per-unit-effort (CPUE) in its fishery was around 9.5 tons per day per vessel. The total catch in 2020 was around 42,000 tons.

6. Japan presented its fishery status. The total catch in 2020 was about 30,000 tons, the lowest since 1950. Nominal CPUE was 1.0 ton per haul per vessel, the lowest since 1994. Fishing grounds were mainly in the high seas where Japan harvested about 60% of its total catch

through the fishing season.

7. Korea presented its fishery status. In 2020, the start of the fishing season was delayed due to the COVID-19 pandemic. Total catch was around 5,990 tons, the lowest on record. The number of active vessels has been declining over the past 20 years. Vessels declined from 26 in 2001 to 11 in 2019 and 10 in 2020. Estimates of nominal and standardized CPUE in 2020 were the lowest on record. The extent of the fishing ground in 2020 was smaller than in previous years.

8. Russia presented its fishery status (NPFC-2021-SCsm01-IP01). In 2020, there were only two active vessels. The average CPUE in 2020 was around 10 tons per day per vessel compared to 5 tons per day per vessel in the previous year. Total catch was approximately 750 tons compared to around 2,400 tons in 2019. The 2020 catch was the lowest in 30 years. The majority of catch was taken in the high seas.

9. Chinese Taipei presented its fishery status. In 2020, accumulated catch by early December was around 55,000 tons, lower than 2019 and the lowest since 2003. Compared to previous years, fishing vessels arrived at fishing grounds later in 2020. Nominal CPUE was 1.8 tons per haul per vessel, the second lowest since 2001.

10. Vanuatu presented its fishery status. Annual catch in 2020 was 2,670 tons, the lowest since 2015. Nominal CPUE was 9.5 tons per day per vessel in 2020, the lowest on record. Fishing grounds were mainly in the east in the early fishing season, then shifted to the west later in the season.

11. The Science Manager presented Members' cumulative catch of Pacific saury in the Convention Area based on weekly catch reports provided by Members in 2020 and effort data based on Members' annual reports. In 2020, the fishing season started at the end of May and catch accrued slowly until the end of September, before increasing significantly in October and November. Total catch has been on a decreasing trend from 2015. In 2020, total catch in the Convention Area and Members' exclusive economic zones (EEZs) was approximately 138,000 tons, the second lowest since 1950. Total effort has steadily increased from 1995 to 2019. The number of active vessels in 2019 was the highest on record (Annex D).

Agenda Item 5. Data and specification

12. The SC reviewed the updated BSSPM specifications that were agreed on at the SSC PS05 meeting and reconfirmed at the SSC PS06 meeting.

13. The SC reviewed the abundance indices agreed on at the SSC PS06 meeting.

Agenda Item 6. Review of BSSPM results

14. Japan presented an updated stock assessment for Pacific saury in the North Pacific Ocean using BSSPM (NPFC-2021-SCsm01-WP01). The 2019 median depletion level was only 20.1% of the carrying capacity, declining from 30.7% in 2018. B-ratio (B2019/B_{MSY}) and F-ratio (F2019/F_{MSY}) in 2019 were 0.437 and 1.067, respectively. The three-year (2017-2019) average values for B-ratio and F-ratio were 0.503 and 1.428, respectively. The probability of the population being in the green Kobe quadrant in 2019 was estimated to be nearly 0%, while that of being in the red Kobe quadrant was assessed to be greater than 60%. Based on the weight-of-evidence available now, the current Pacific saury stock is determined to be overfished and subject to overfishing. The MSY is estimated to be around 419,000 tons, which is greater than the current catch level. However, the current biomass level is markedly low, and therefore this amount is not an appropriate level of catch. Using the same formula to calculate TAC in 2019, X=B2019*F_{MSY}=374,000*0.480=179,520 tons. However, the information of further decline in 2020 abundance indices and 2020 catches warrants further decrease from X for setting TAC to help prevent further decline in Pacific saury abundance.

15. China presented the results of its Pacific saury stock assessment (NPFC-2021-SCsm01-WP03). The estimated median B2019 from the two base case scenarios was 388,800 and 446,200 tons, respectively. The median B2019/B_{MSY} and F2019/F_{MSY} over the two base case scenarios were 0.46 and 0.99, respectively. Over two base case scenarios, large interannual variability was shown in biomass trajectory during the most recent years. An increase was found in 2018 followed by a decrease in 2019. The harvest rate in 2019 (F2019=0.47) was quite low compared to that in 2018 (F2018=0.71). The scale of exploitable biomass was sensitive to prior assumption. The probability of the population being in the yellow Kobe quadrant in 2019 was estimated to be greater than 50%.

16. Chinese Taipei presented an updated stock assessment for Pacific saury in the North Pacific Ocean using BSSPM (NPFC-2021-SCsm01-WP02). The models estimate an increase in biomass in 2018 (median B_{2018}/B_{MSY} = 0.80, 80 percentile range 0.56-1.20) followed by a slight decrease in 2019 (median B_{2019}/B_{MSY} = 0.56, 80 percentile range 0.39-0.84). A steady increase in fishing mortality is estimated to have occurred from 2004 to 2018, but a substantial decrease in fishing mortality was estimated in 2019 (median F2019/F_{MSY} = 0.82, 80 percentile range 0.45-1.38). The recent average fishing mortality is estimated to be above F_{MSY} (median F2017-2019/F_{MSY} = 1.28, 80 percentile range 0.66-2.49). The 2019 stock status is likely within the yellow quadrant (Prob[B2019<B_{MSY} and F2019<F_{MSY}] = 61.35%).

17. The SC reviewed the stock assessments presented by Members and aggregated the results,

recognizing their similarities (Annex E).

Agenda Item 7. Recommendations to the Commission to improve CMM for Pacific Saury

18. The SC recommends that the Commission:
    (a) Consider summary stock assessment results for Pacific saury (Annex E).
    (b) Take into account the following paragraphs for improving the CMM for Pacific saury:
        (i) All stock indicators (estimated biomass, nominal CPUE, Japan biomass survey) show that the Pacific saury stock has been declining. Results of combined model estimates indicate that the stock declined with an interannual variability from near carrying capacity in the mid-2000's after a period of high productivity to current levels. Exploitation rates were increasing slowly since 2005 except for 2019. The results also indicated that B was below B_{MSY} (median average B/B_{MSY} during 2017-2019 = 0.544, 80%CI=0.376-0.803) and F was above F_{MSY} (average F/F_{MSY} during 2017-2019 = 1.327, 80%CI= 0.845-1.841). The results further indicated that stock biomass fell to the lowest value since 1980 in 2017 (median B/B_{MSY} = 0.434, 80%CI=0.295-0.639) and has been still at a historically low level in recent years (2017-2019). Information of the nominal CPUE series further indicated that Pacific saury stock biomass has likely been near a record low level in 2020. More attention should be paid to understanding the environmental impacts on Pacific saury, which are poorly understood and incompletely included in the stock assessment modeling.
        (ii) The stock assessment has uncertainties that carry into the TAC calculation. Such uncertainties could lead to potential under or over-harvest of Pacific saury, which may be important, particularly if stock size is low.
        (iii) The Commission should consider further measures to ensure the sustainability of the Pacific saury stock, taking into account current stock conditions and nominal CPUEs in 2020.

Agenda Item 8. Future works

19. The SC requested that the SSC PS continue to advance its work in accordance with the 2020-2025 SSC PS 5-Year Rolling Work Plan.

20. The SC requested that the SSC PS continue to refine the BSSPM specifications.

21. The SC recognized the need to further consider environmental conditions in future analyses, including in the CPUE standardization and the current stock assessment method, as well as in new stock assessment methods such as age-structured models.

Agenda Item 9. Other matters

22. The SC appreciated that Japanese scientists have made a great contribution in conducting fishery-independent surveys in the North-western Pacific Ocean over the years. The SC encouraged Members to consider scientific surveys in the area in order to extend the spatial and temporal coverage of this highly migratory species, with additional financial support from the Commission's Special Project Fund, and to establish a joint Pacific saury survey project.

23. No other matters were discussed.

Agenda Item 10. Adoption of Report

24. The SCsm01 Report was adopted by consensus.

Agenda Item 11. Close of the Meeting

25. The meeting closed at 13:30 on 22 January 2021, Tokyo time.

Annexes:

Annex A – Agenda

Annex B – List of documents

Annex C – List of participants

Annex D – Number of active fishing vessels for Pacific saury fisheries operated in the Convention Area in 1995-2020

Annex E – Stock Assessment Report for Pacific Saury

Annex A

Agenda

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Agenda Item 5. Data and specification for BSSPM

Agenda Item 6. Review of BSSPM results

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Agenda Item 9. Other matters

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Annex B

List of Documents

MEETING INFORMATION PAPERS

Document Number	Title
NPFC-2021-SCsm01-MIP01	Details for the Special Meeting of the Scientific Committee
NPFC-2021-SCsm01-MIP02	Provisional Agenda
NPFC-2021-SCsm01-MIP03 (Rev. 1)	Annotated Indicative Schedule

REFERENCE DOCUMENTS

Document Number	Title
NPFC-2020-SSC PS06-Final Report	SSC PS06 Meeting Report

WORKING PAPERS

Document Number	Title
NPFC-2021-SCsm01-WP01	Updates of stock assessment for Pacific saury in the North Pacific Ocean based on indices up to 2019 by using Bayesian state-space production models
NPFC-2021-SCsm01-WP01_Supplementary information	Supplementary information
NPFC-2021-SCsm01-WP02	Updated stock assessment of Pacific saury (*Cololabis saira*) in the Western North Pacific Ocean through 2019
NPFC-2021-SCsm01-WP03	North Pacific Ocean Pacific Saury 2019 Stock Assessment Update Report

INFORMATION PAPERS

Document Number	Title
NPFC-2021-SCsm01-IP01	Saury fishery in the Northwest Pacific by Russian vessels in 2019 and preliminary results of fishery in 2020

Annex C

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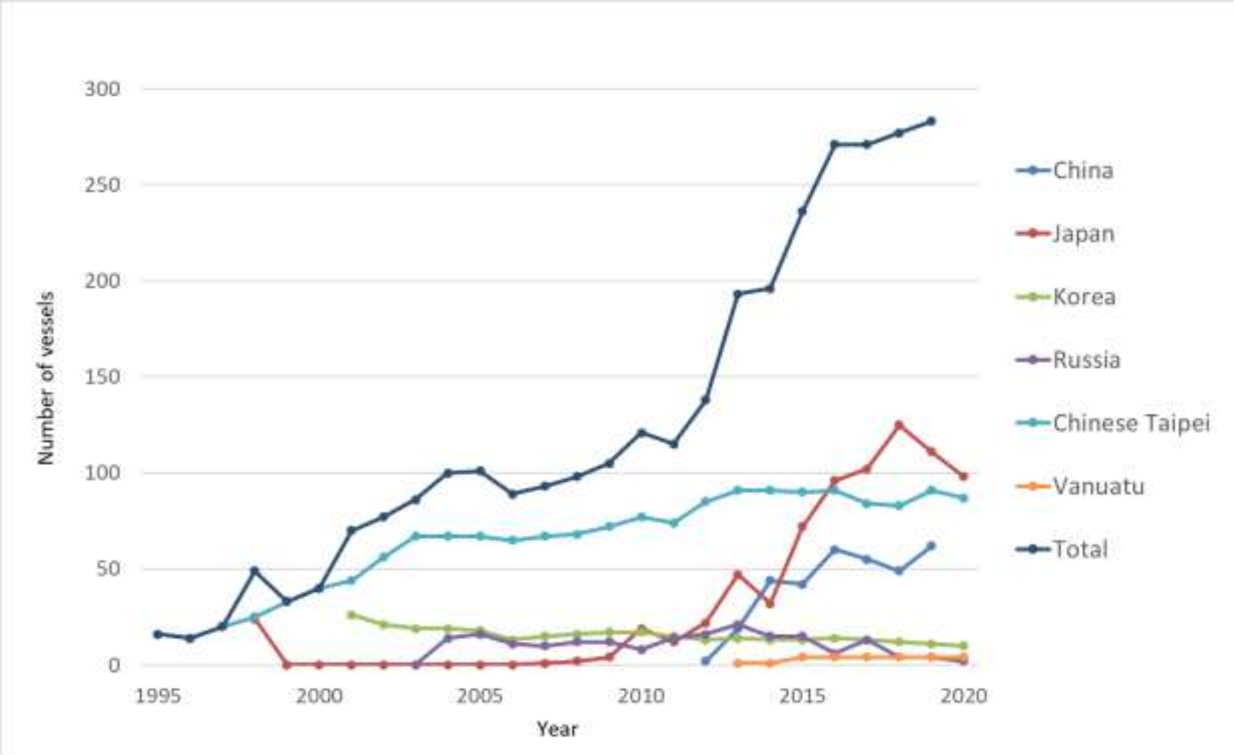
Number of active fishing vessels for Pacific saury fisheries operated in the Convention Area in 1995-2020



Note: Information about the number of Chinese vessels in 2020 is not available.

Annex E

Stock Assessment Report for Pacific Saury

Abstract:
This report presents the results of stock assessment of Pacific saury updated at the 1st Special meeting of the Scientific Committee held virtually during January 20-22, 2021.

EXECUTIVE SUMMARY

Data

Pacific saury (*Cololabis saira*) is widely distributed from the subarctic to the subtropical regions of the North Pacific Ocean. The fishing grounds are west of 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.

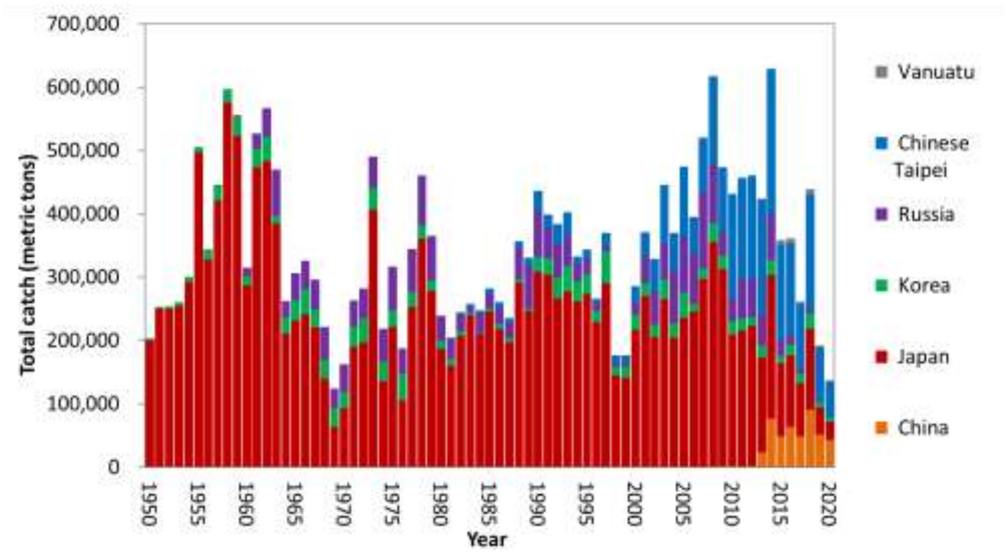


Figure 1. Time series of catch by Member during 1950-2020. The catch data for 1950-1979 are shown but not used in stock assessment modeling. 2020 catch data are preliminary.

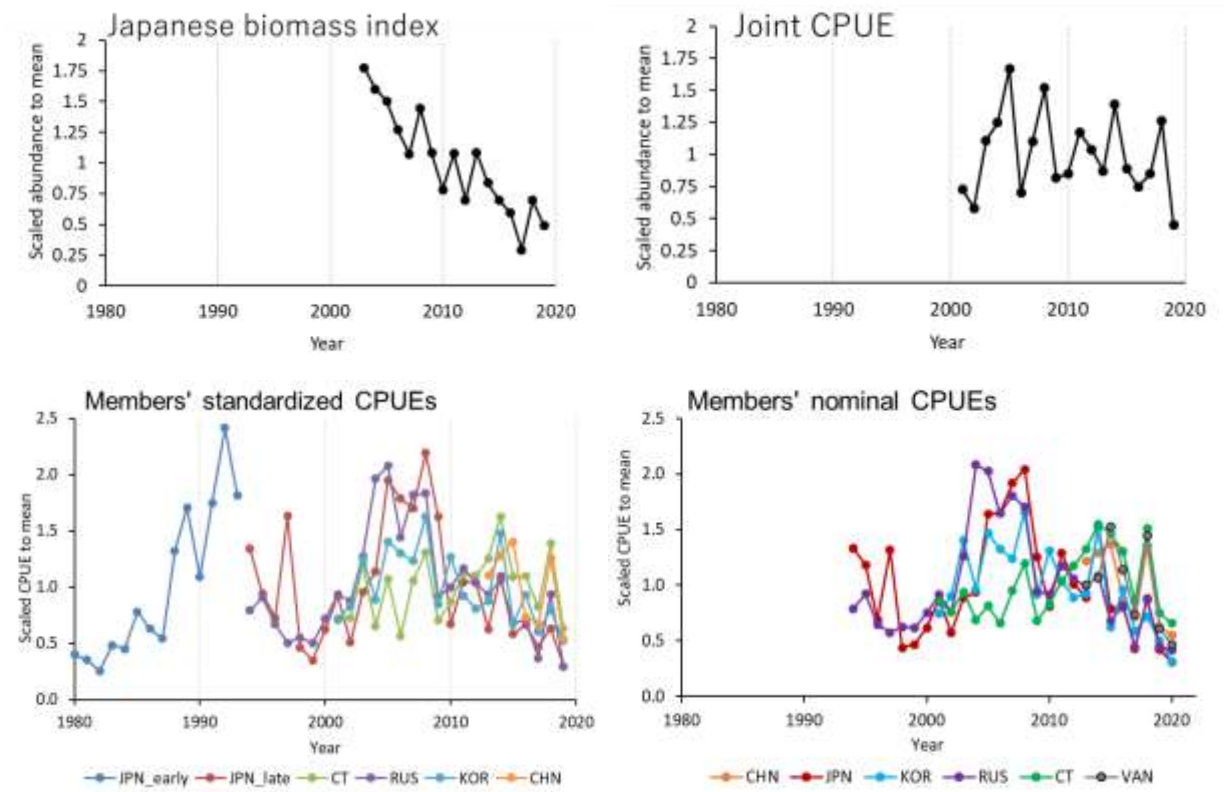


Figure 2. Time series of Japanese survey biomass index and joint, standardized and nominal CPUE indices. 2020 nominal CPUEs are preliminary.

Brief description of specification of analysis and models

A Bayesian state-space production model (BSSPM) used in previous stock assessments was employed as an agreed provisional stock assessment model for Pacific saury during 1980-2019. 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.

Summary of stock assessment results

The SC considered the BSSPM results and noted similarity among Members' results. Therefore, outcomes of MCMC runs were aggregated over the 6 models (2 base case models x 3 Members). The aggregated results for assessing the overall median values and their associated 80% credible intervals are shown in Table 1. The graphical presentations for times series of a) biomass (B), b) B-ratio (=B/B_{MSY}), c) exploitation rate (F), d) F-ratio (F/F_{MSY}) and e) B/K are shown in Figure 3. The Kobe plot with time trajectory using aggregated model outcomes is shown in Figure 4.

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

	Median	Lower10%	Upper10%	Median_CHN	Median_JPN	Median_CT
C_2019 (10000 t)	19.238	19.238	19.238	19.238	19.238	19.238
AveC_2017_2019 (10000 t)	29.803	29.803	29.803	29.803	29.803	29.803
AveF_2017_2019	0.582	0.255	0.891	0.637	0.691	0.400
F_2019	0.428	0.183	0.681	0.467	0.515	0.292
FMSY	0.431	0.235	0.643	0.472	0.480	0.353
MSY	41.852	35.069	52.220	42.559	41.866	41.110
F_2019/FMSY	0.979	0.605	1.419	0.991	1.067	0.859
AveF_2017_2019/FMSY	1.327	0.845	1.841	1.349	1.428	1.175
K (10000 t)	213.851	140.075	412.510	200.000	192.763	252.150
B_2018 (10000 t)	66.810	43.279	152.200	61.710	57.249	93.055
B_2019 (10000 t)	44.937	28.256	105.116	41.180	37.379	65.855
AveB_2017_2019 (10000 t)	50.783	32.999	115.754	46.517	42.822	73.385
BMSY (10000 t)	97.116	65.530	185.400	90.195	87.318	116.900
BMSY/K	0.445	0.391	0.552	0.440	0.443	0.455
B_2018/K	0.332	0.216	0.481	0.321	0.307	0.376
B_2019/K	0.224	0.143	0.330	0.214	0.201	0.266
AveB_2017_2019/K	0.254	0.167	0.363	0.244	0.232	0.296
B_2018/BMSY	0.712	0.486	1.068	0.693	0.667	0.798
B_2019/BMSY	0.480	0.321	0.728	0.464	0.437	0.563
AveB_2017_2019/BMSY	0.544	0.376	0.803	0.525	0.503	0.625

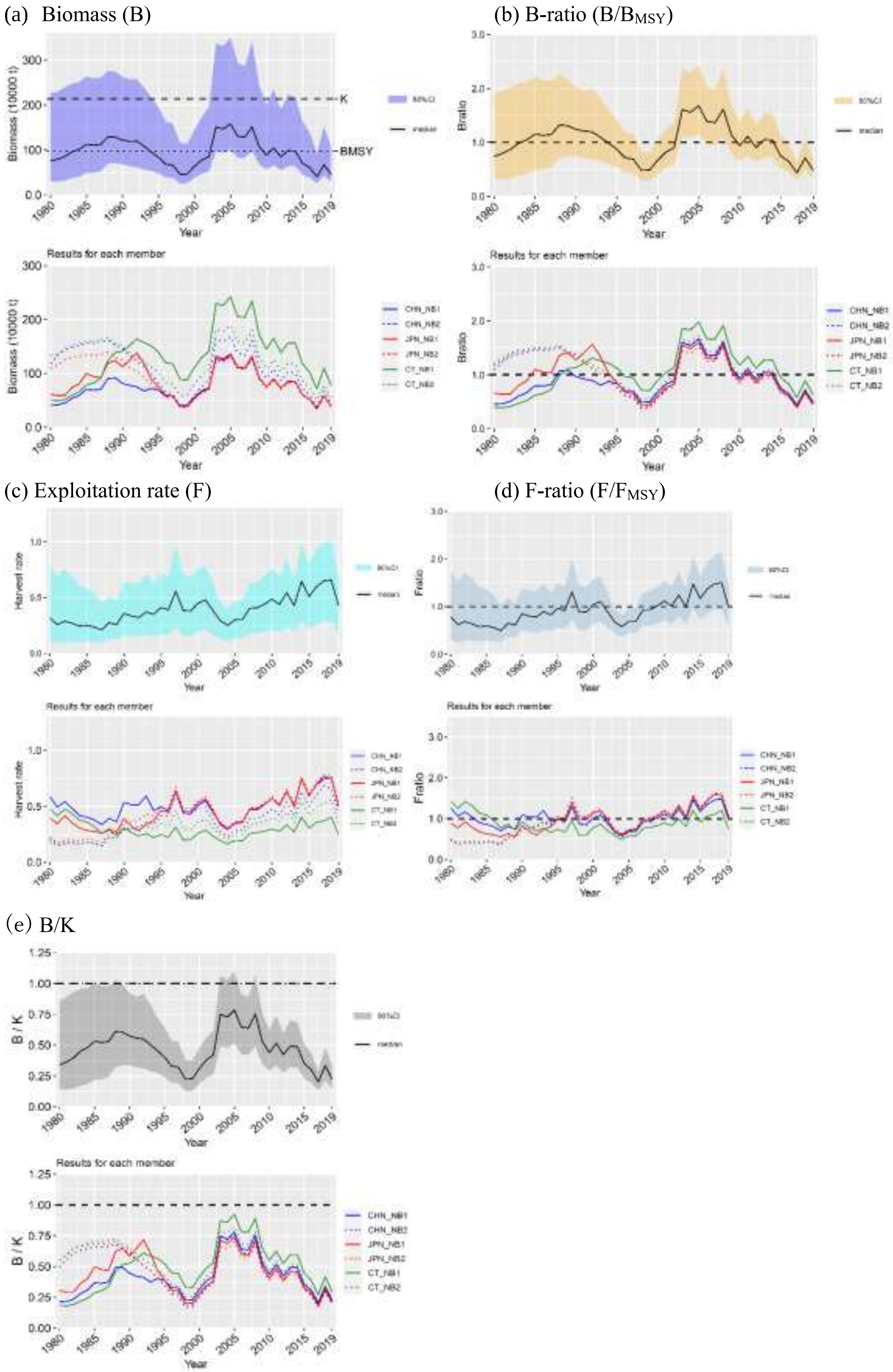


Figure 3. Time series of median estimated values of six runs for biomass, harvest rate, B-ratio, F-ratio and depletion level relative to K. The solid and shaded lines correspond to NB1 and NB2, respectively.

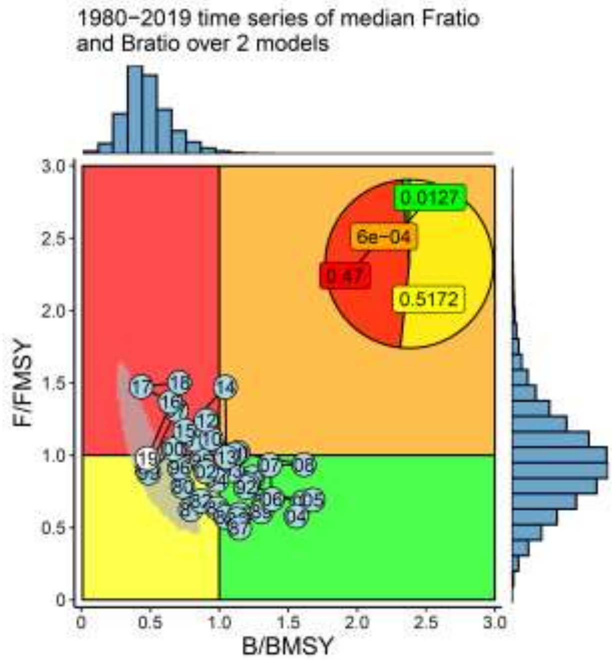


Figure 4. Kobe plot with time trajectory. The data are aggregated across 6 model results (2 base-case models by 3 Members).

Additional data for 2020 indicate Pacific saury biomass continued to decline after 2019 to a relatively low level in 2020. In particular, preliminary fishery data in 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 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, which 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.

SC members indicate that Covid-19 effects on catches were likely stronger than effects on CPUE. Nominal CPUE trends and standardized CPUEs used in assessment modeling were similar (Figure 2). The nominal CPUE in 2020 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 totaled only about 137 thousand mt (Figure 1).

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 index was only about 10 thousand mt. However, sampling did not cover the traditional survey area outside the 13ºC isotherm where one-year-old Pacific saury may be encountered in large numbers and east of 170º 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 PS06 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 index in 2020 was only 50 thousand mt (CV 100%, 95% CI 7-180 thousand mt) compared to the average swept-area biomass index of 334 thousand mt during 2015-2019. The SSC PS06 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. The figures quoted in this paragraph reflect improvements made during the intersessional period.

Current stock condition

Results of combined model estimates indicate that the stock declined with an interannual variability from near carrying capacity in the mid-2000's after a period of high productivity to current levels. Exploitation rates were increasing slowly since 2005 except for 2019. The results also indicated that B was below B_{MSY} (median average B/B_{MSY} during 2017-2019 = 0.544, 80%CI=0.376-0.803) and F was above F_{MSY} (average F/F_{MSY} during 2017-2019 = 1.327, 80%CI= 0.845-1.841). The results further indicated that stock biomass fell to the lowest value since 1980 in 2017 (median B/B_{MSY} = 0.434, 80%CI=0.295-0.639) and has been still at a historically low level in recent years (2017-2019). Information of the nominal CPUE series further indicated that Pacific saury stock biomass has likely been near a record low level in 2020.

Special comments regarding the procedures and stock assessment results

The SC 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 were not suitable for use by managers and they were therefore omitted. (See discussion in last assessment (NPFC-2019-SSC PS04-Final Report).)
3) Transparency and reproducibility were enhanced by submitting computer programs, code and input data files used for assessment modeling during the intersessional period.
4) An F_{MSY} approach was used in the Commission meeting in 2019 to calculate a TAC for 2020. However, it can be difficult to estimate current F_{MSY} from historical data when the environment is changing. It is therefore important to further evaluate the F_{MSY} approach for Pacific saury. For example, as shown in Agenda Item 7, the F_{MSY} catch approach resulted in a TAC for 2020 that was substantially larger than the actual catch. TAC values could be calculated using the F_{MSY} 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.
5) The 2020 biomass index from the Japanese survey has large uncertainties due to incomplete survey coverage but Members noted it had dropped to the lowest historical level.
6) The updated and 2019 assessments show the same trends in relative fishing mortality (Fratio) and relative biomass (Bratio) but there were substantial differences from the 2017 assessment in the magnitude of absolute biomass and fishing mortality as well as B_{MSY} and F_{MSY} due to a change in how catchability of the Japanese survey was modeled. Changes in MSY and *F_{MSY} catch = F_{MSY} x biomass* tend to be modest relative to the changes in absolute stock size and fishing mortality because stock size and fishing mortality estimates like F_{MSY} tend to change in opposite directions. For example, MSY=B_{MSY} x F_{MSY} was 49.3 (10,000t) in the previous assessment (NPFC-2019-SSC PS04-Final Report) and 41.9 (-15% change) in this assessment, despite changes in B_{MSY} from 219.7 to 97.1 (-56%) and changes in F_{MSY} from 0.25 to 0.43 (+72%). These changes were due to the model differences especially the prior specification of the catchability in the Japanese survey. Sensitivity to assumptions about survey catchability is a common problem in stock assessments with limited data.
7) Both environmental conditions and fishing impacts might have contributed to current low stock size for Pacific saury. Process errors in the BSSPM partially account for environmental and other effects that appear to increase or decrease stock productivity, while the harvest rate measures changes in fishing pressure. The oceanographic or biological factors responsible for changes in productivity have not yet been determined. Development of modeling procedures to incorporate environmental change is an important area for current research.
8) The nominal CPUE in 2020 shows a decline in catch for all Members to the lowest recorded level. When viewed by month, the decline in nominal CPUE was primarily experienced in the early months of the fishery (May through September). However, the later months of the fishery (October to December) showed a mixed pattern, with nominal CPUE from some members increasing in 2020 over 2019 levels, while for others the nominal CPUE declined in the later months as well (Figure 5).
9) After a decade of decline the time is right to start talking about environmental effects on the assessment and Pacific saury. Such information might support managers' long-term planning and capitalization of the fishery. The work discussed should include refinements to stock assessment models to better reflect and estimate

environmental effects in addition to environmental effects on recruitment and biology. This work could be folded into the development of age-structured and improved BSSPM models. These efforts should be begun immediately, carried out intersessionally, and discussed at the next SSC PS meeting. Some coordination among Members may be required.

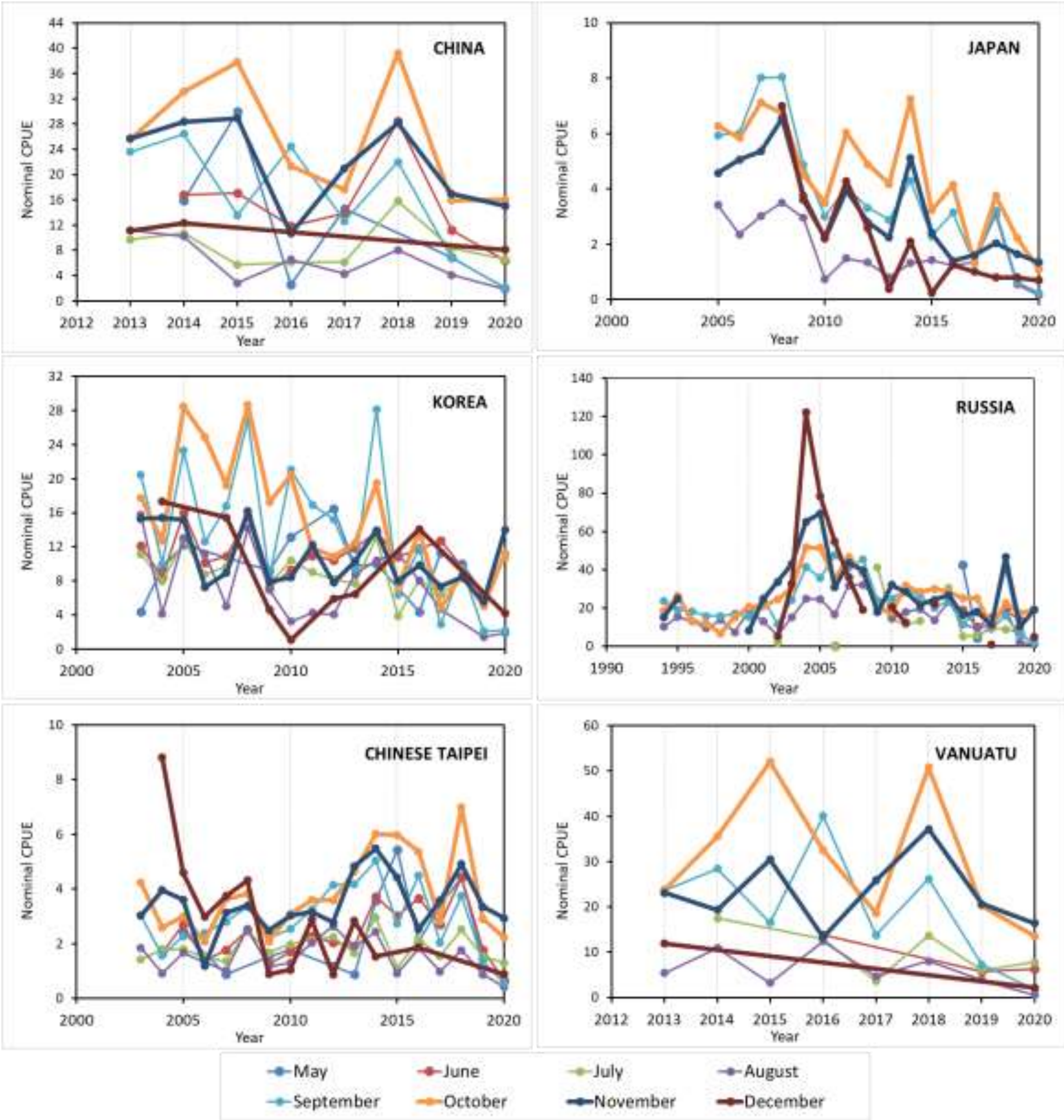


Figure 5. Time series of monthly nominal CPUEs of Members. 2020 nominal CPUEs are preliminary.

1. INTRODUCTION

1.1 Distribution

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

1.2 Migration

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

1.3 Population structure

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

1.4 Spawning season and grounds

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

1.5 Food and feeding

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

1.6 Age and growth

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

1.7 Reproduction

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

2. FISHERY

2.1 Overview of fisheries

Western North Pacific

In Japan, the stick-held dip net fishery for Pacific saury was developed in the 1940s. Since then, the stick-held dip net gears have become the dominant fishing technique to catch Pacific saury in the northwest Pacific Ocean. Since 1995, more than 97% of Japan's total catch is caught by the stick-held dip net. The annual catch of Pacific saury for stick-held dip net fishery has fluctuated. Maximum and minimum catches of 355 thousand tons and 30 thousand tons were recorded in 2008 and 2020, respectively.

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

Russian fishery for Pacific saury has been conducted using stick-held dip nets in the northwest Pacific Ocean in the area that includes national waters (mainly within the Russian EEZ) and adjacent NPFC Convention Areas. Russian catch statistics for saury fishery exists, beginning from 1956, and standardized CPUE indices from that fishery were calculated since 1994. Saury fishery traditionally occurred from August to November; however, in recent years, the onset of fishing for saury shifted to the early summer period. Peak catch of saury of over 100 thousand tons was in 2007. Since then, the annual catch has been decreasing, and was about 2.4 thousand tons in 2019 and about 750 tons in 2020.

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

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

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

Eastern North Pacific

Although Pacific saury occur in the Canada EEZ, there is no targeted fishery for the species. There is no historical record of Canadian participation in international fisheries for saury. Domestic fisheries sometimes capture saury as bycatch in pelagic and bottom trawls and there are a handful of records from other gear types including commercial longlines. The most recently compiled estimates indicate only 224 kg of saury were captured by Canadian commercial fisheries over 17 years from 1997-2013 (Wade and Curtis 2015). There are also records of saury catches from research trawls (surface, pelagic and bottom trawls) in Canadian waters, but the catches have been minimal.

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

Historically, Japanese and Russian vessels operated mainly within their own EEZs, but they have shifted into the

Convention Area in recent years. Chinese, Korean and Chinese Taipei vessels operate mainly in the high seas of the North Pacific (Figure 1).

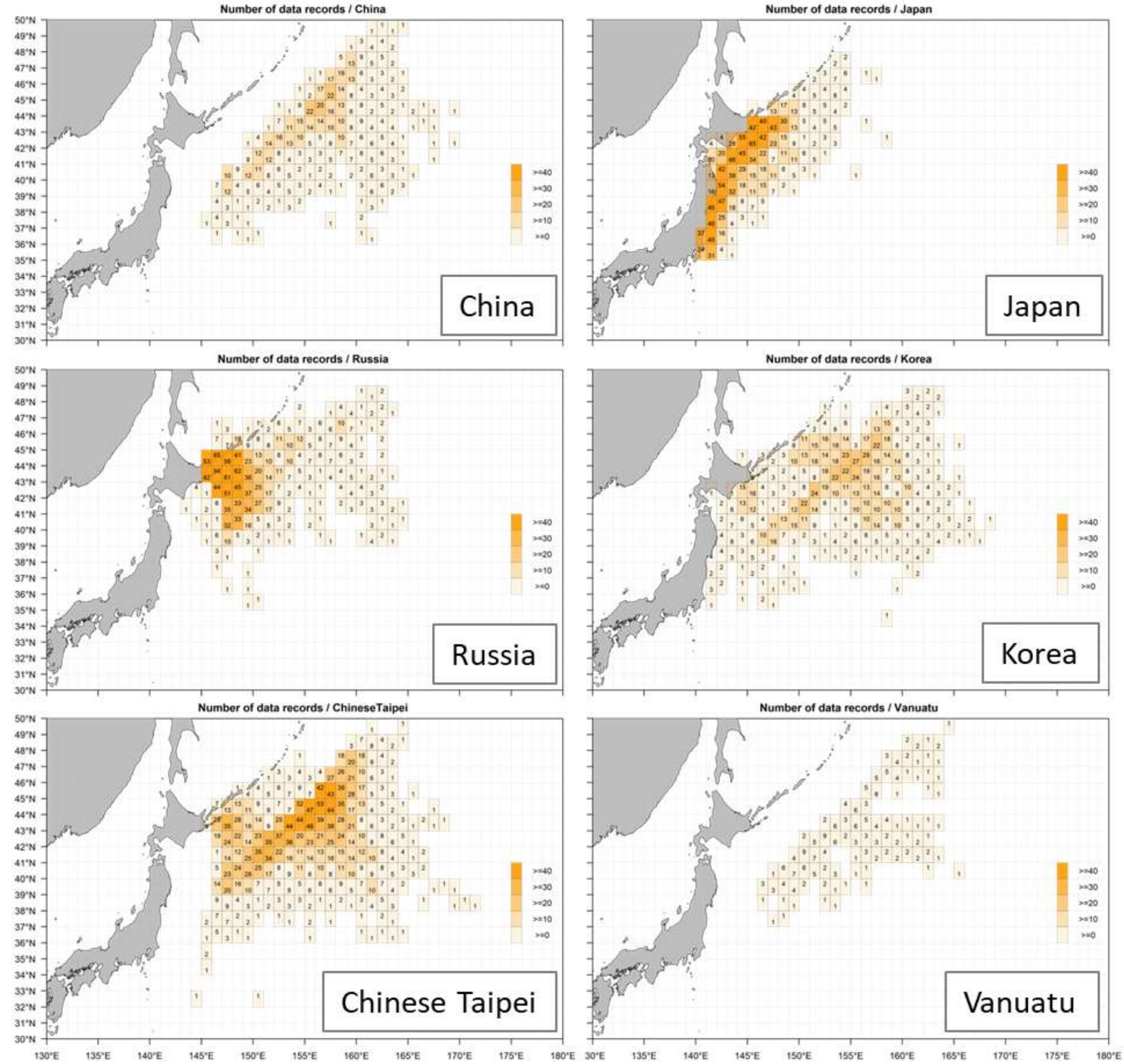


Figure 1. Main fishing grounds for Pacific saury by fishing members in the western North Pacific Ocean during 1994-2017. The legend shows the number of data records. This figure is based on the data shared by the Members for the development of a joint CPUE index (NPFC-2018-TWG PSSA03-WP02, NPFC-2018-TWG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

2.2 Catch records

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

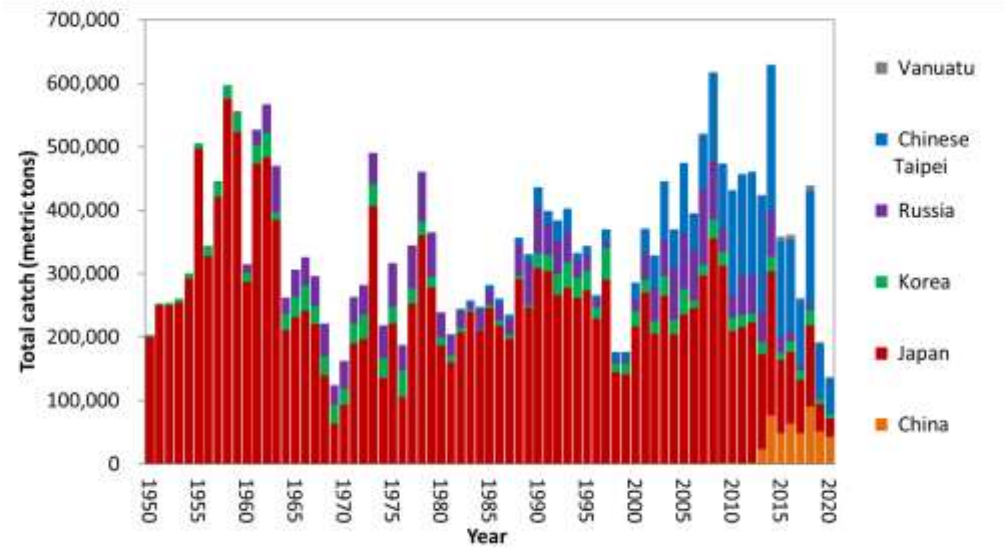


Figure 2. Time series of catch by Member during 1950-2020. The catch data for 1950-1979 are shown but not used in stock assessment modeling. 2020 catch data are preliminary.

3. SPECIFICATION OF STOCK ASSESSMENT

A Bayesian state-space production model (BSSPM) used in previous stock assessments was employed as an agreed provisional stock assessment model for Pacific saury during 1980-2019. 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:

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

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*

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

r : the intrinsic rate of natural increase

K : the carrying capacity

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

The multiple biomass indices are modelled as follows:

Survey biomass estimate

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

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

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

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-2020-SSC PS06-WP08 and NPFC-2020-SSC PS06-WP10; for the non-uniform priors used in Chinese Taipei, see document NPFC-2020-SSC PS06-WP17.

3.2 Agreed scenarios

Table 1. Definition of scenarios

	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(2013-2019) JPN_early(1980-1993) (with time-varying q) JPN_late(1994-2019) KOR(2001-2019) RUS(1994-2019) CT(2001-2019)	CHN(2013-2019) JPN_late(1994-2019) KOR(2001-2019) RUS(1994-2019) CT(2001-2019)	Two sets as on the left for NS1 and NS2 respectively	NS3: Joint CPUE 2001-2019 (no JPN_early) NS4: Joint CPUE 2001-2019 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

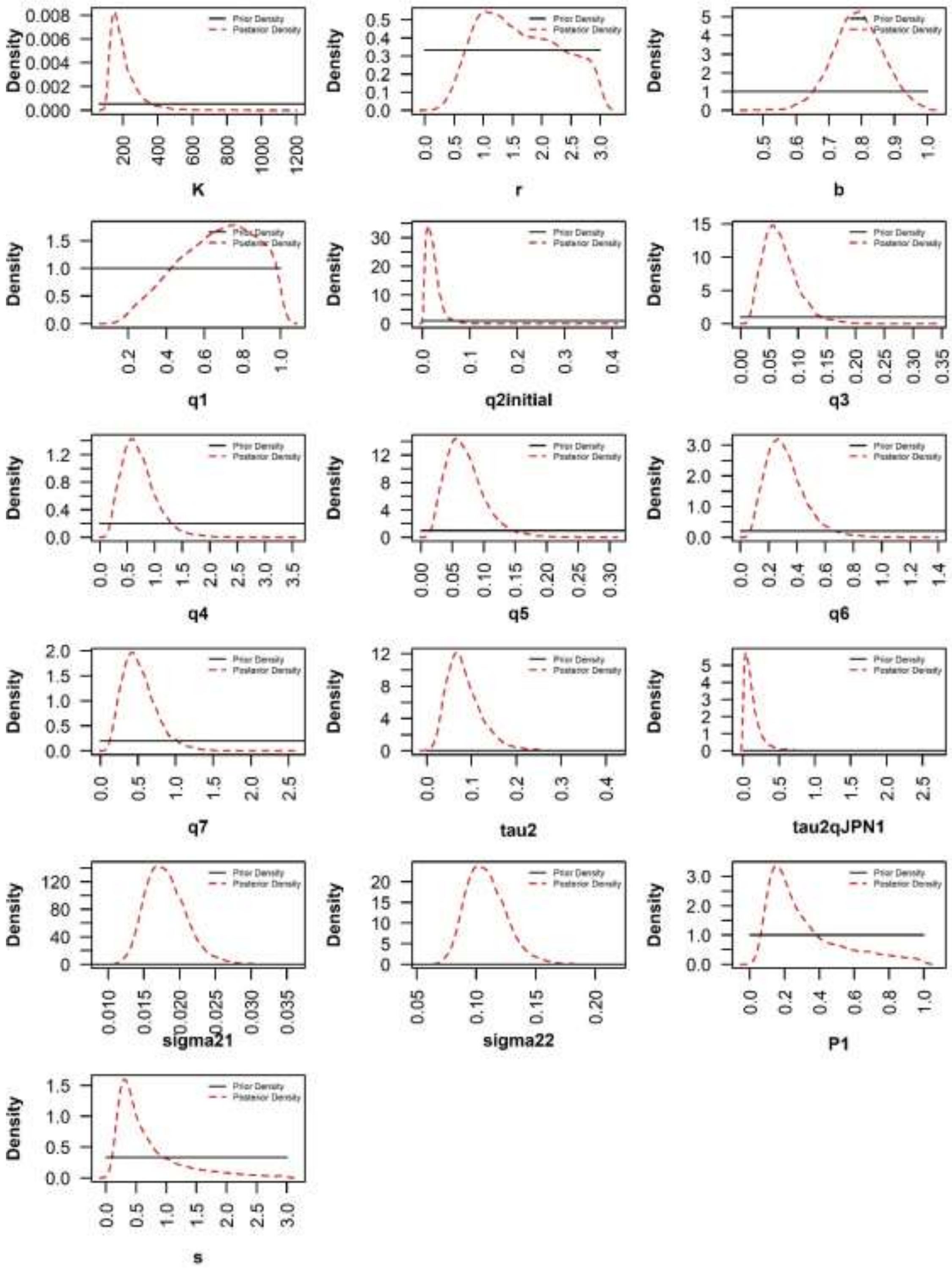
Symbol	Description
C_{2018}	Catch in 2019
$AveC_{2017\text{-}2019}$	Average catch for a recent period (2017–2019)
$AveF_{2017\text{-}2019}$	Average harvest rate for a recent period (2017–2019)
F_{2019}	Harvest rate in 2019
F_{MSY}	Annual harvest rate producing the maximum sustainable yield (MSY)
MSY	Equilibrium yield at F_{MSY}
F_{2019}/F_{MSY}	Average harvest rate in 2019 relative to F_{MSY}
$AveF_{2017\text{-}2019}/F_{MSY}$	Average harvest rate for a recent period (2017–2019) relative to F_{MSY}
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
$AveB_{2017\text{-}2019}$	Stock biomass for a recent period (2017–2019) estimated in the model
B_{MSY}	Stock biomass that will produce the maximum sustainable yield (MSY)
B_{MSY}/K	Stock biomass that produces the maximum sustainable yield (MSY) relative to the equilibrium unexploited biomass[a]
B_{2018}/K	Stock biomass in 2018 relative to K[a]
B_{2019}/K	Stock biomass in 2019 relative to K[a]
$B_{2017\text{-}2019}/K$	Stock biomass in the latest time period (2017-2019) relative to the equilibrium unexploited stock biomass[a]
B_{2018}/B_{MSY}	Stock biomass in 2018 relative to B_{MSY}[a]
B_{2019}/B_{MSY}	Stock biomass in 2019 relative to B_{MSY}[a]
$B_{2017\text{-}2019}/B_{MSY}$	Stock biomass for a recent period (2017–2019) relative to the stock biomass that produces maximum sustainable yield (MSY) [a]

[a]calculated as the average of the ratios.

4. RESULTS by CHINA, JAPAN and CHINESE TAIPEI

4.1 CHINA

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

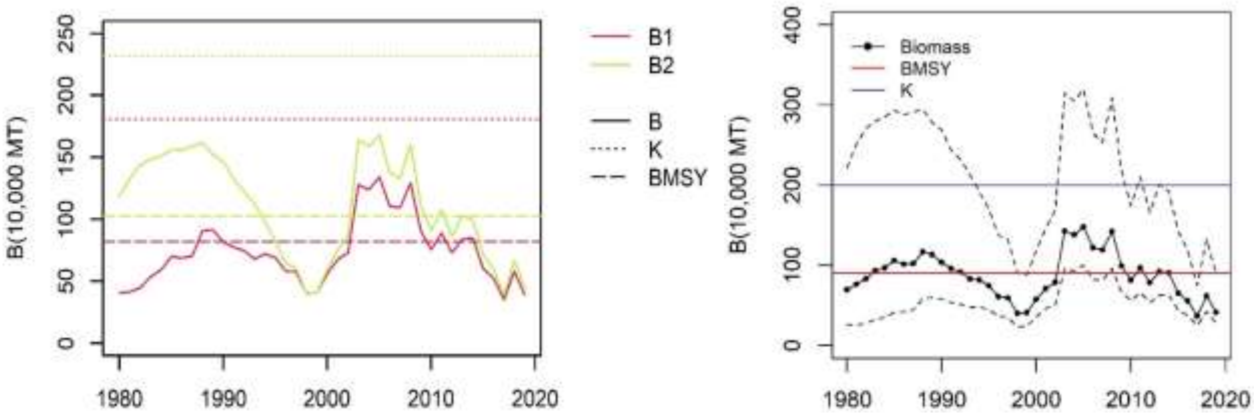


4.1.2 Summary of estimates of parameters and reference points

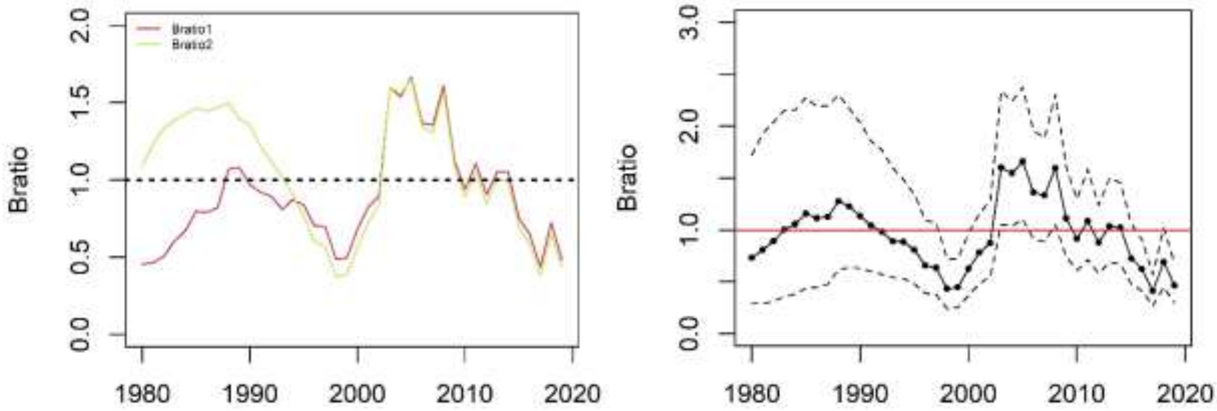
	Base case 1	Base case 2	Over all 2
C2019	19.24	19.24	19.24
AveC2017-2019	29.80	29.80	29.80
AveF2017-2019	0.67	0.59	0.64
F2019	0.49	0.43	0.47
F_{MSY}	0.51	0.42	0.47
MSY	41.71	43.86	42.56
F2019/F_{MSY}	0.97	1.02	0.99
AveF2017-2019/F_{MSY}	1.31	1.40	1.35
K	180.60	231.90	200.00
B2018	58.04	66.98	61.71
B2019	38.88	44.62	41.18
AveB2017-2019	44.00	50.19	46.52
B_{MSY}	82.16	102.90	90.20
B_{MSY}/K	0.44	0.44	0.44
B2018/K	0.34	0.30	0.32
B2019/K	0.23	0.20	0.21
B2017-2019/K	0.26	0.23	0.24
B2018/B_{MSY}	0.72	0.66	0.69
B2019/B_{MSY}	0.48	0.44	0.46
B2017-2019/B_{MSY}	0.55	0.49	0.53

4.1.3 Time series plots for base case models and aggregated results

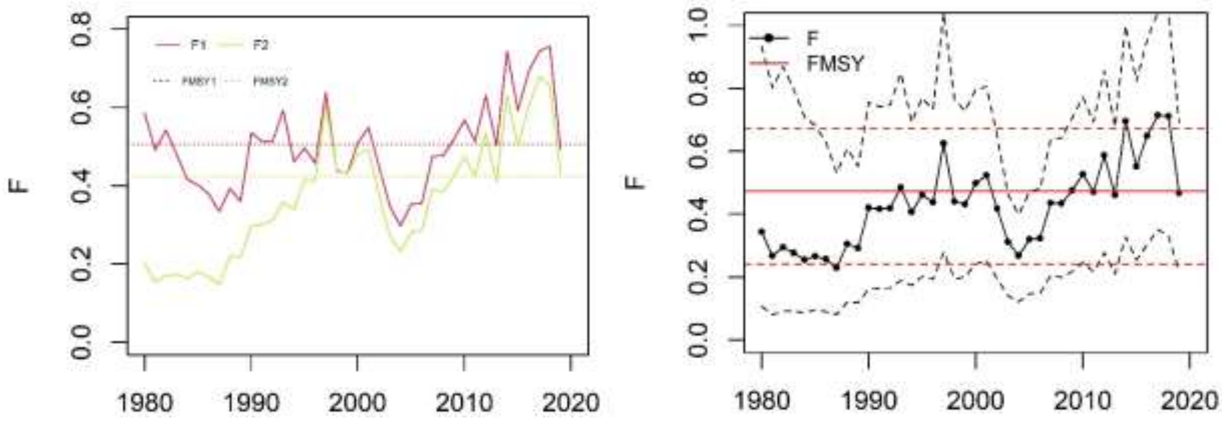
(a) Biomass



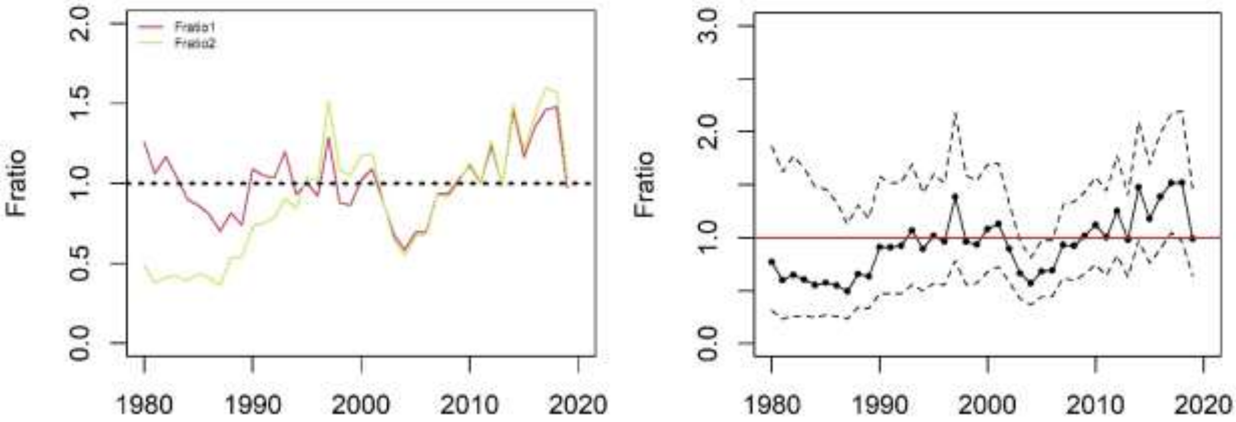
(b) B-ratio (B/B_{MSY})



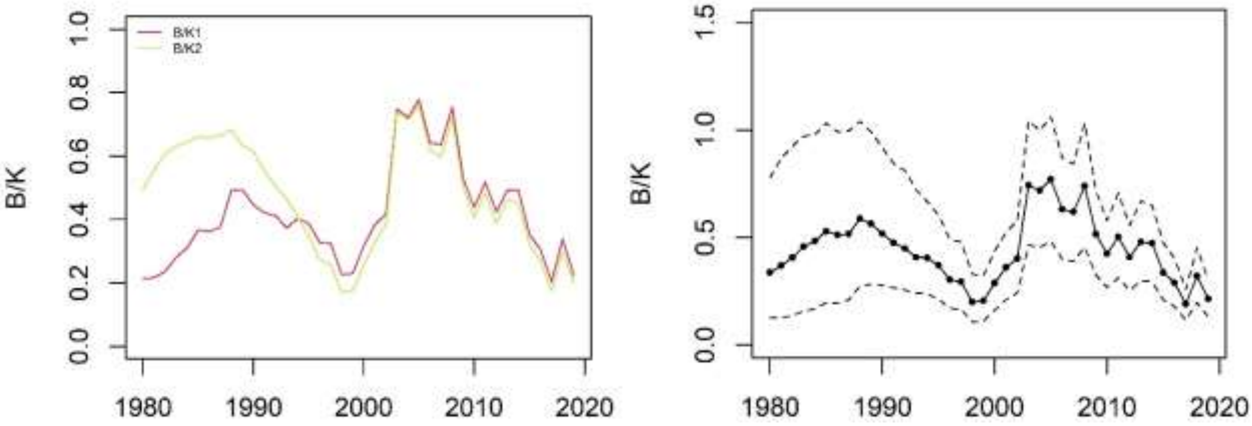
(c) Exploitation rate (F)



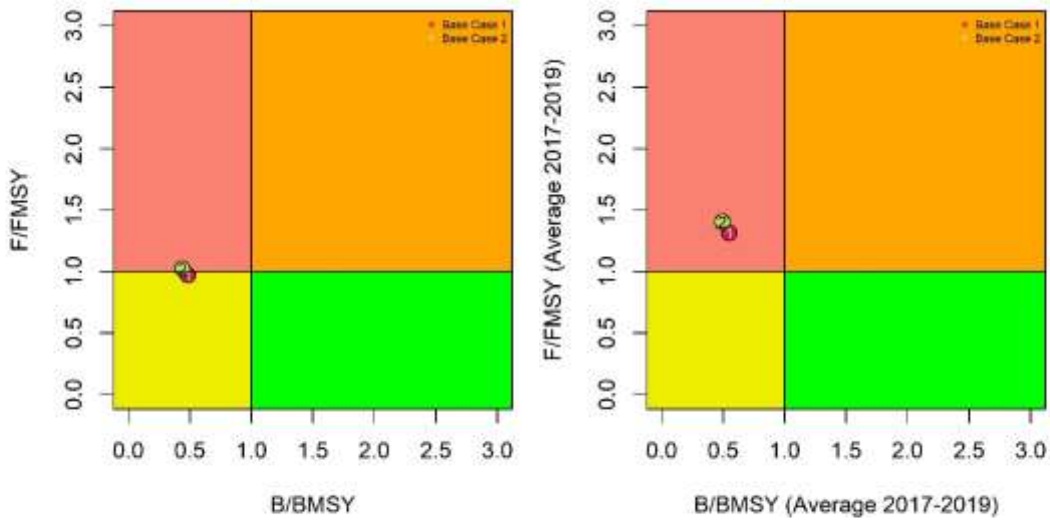
(d) F-ratio (F/F_{MSY})

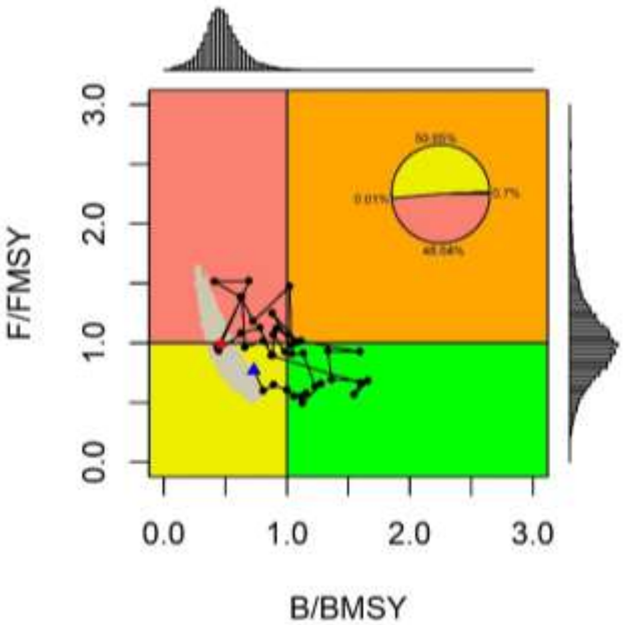


(d) B/K



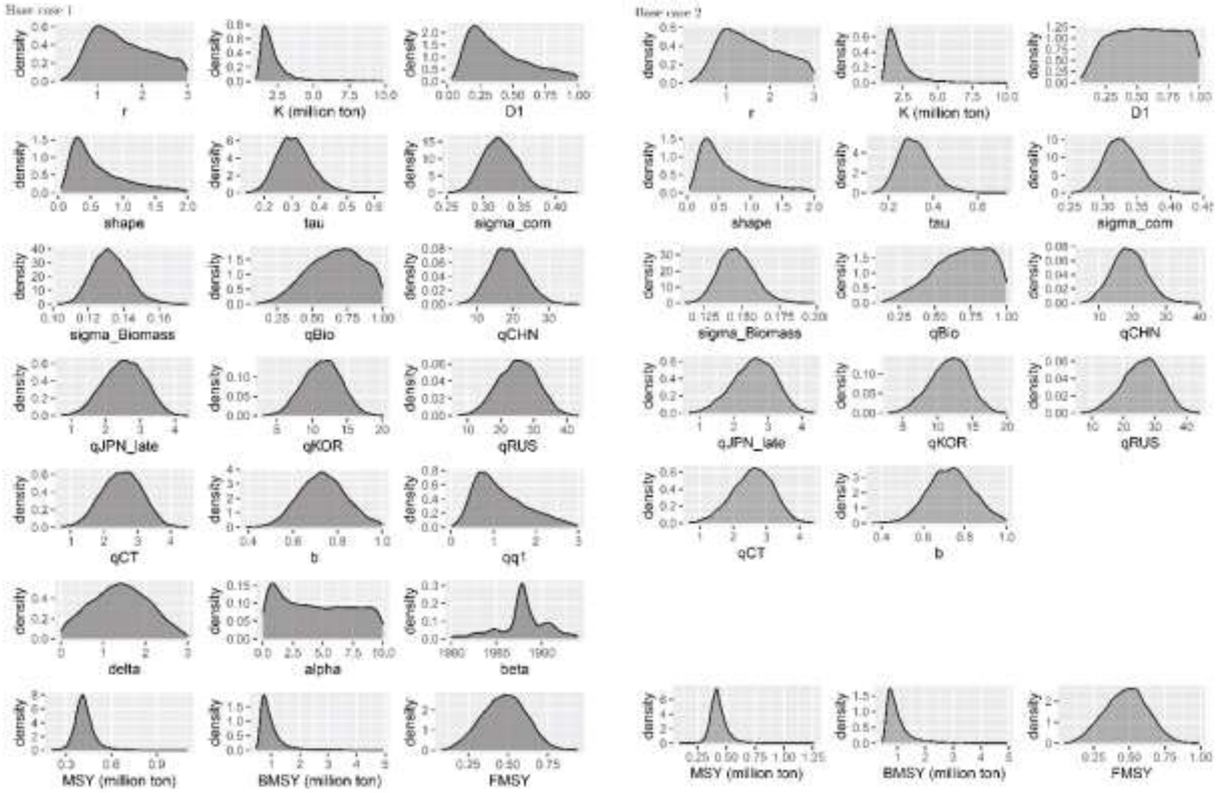
4.1.4 Kobe plots





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

Base case 1

	Mean	Median	Lower10th	Upper10th
C_2019	0.192	0.192	0.192	0.192
AveC_2017_2019	0.298	0.298	0.298	0.298
AveF_2017_2019	0.731	0.742	0.449	1.000
F_2019	0.498	0.502	0.294	0.701
FMSY	0.475	0.478	0.294	0.650
MSY (million ton)	0.422	0.414	0.351	0.497
F_2019/FMSY	1.080	1.045	0.748	1.448
AveF_2017_2019/FMSY	1.451	1.411	1.052	1.887
K (million ton)	2.196	1.909	1.379	3.269
B_2018 (million ton)	0.664	0.584	0.426	0.978
B_2019 (million ton)	0.438	0.383	0.274	0.653
AveB_2017_2019	0.496	0.436	0.323	0.725
BMSY (million ton)	0.982	0.863	0.642	1.419
BMSY/K	0.454	0.442	0.403	0.527
B_2018/K	0.318	0.316	0.212	0.424
B_2019/K	0.209	0.208	0.138	0.281
AveB_2017_2019/K	0.237	0.238	0.161	0.311
B_2018/BMSY	0.702	0.686	0.483	0.941
B_2019/BMSY	0.462	0.452	0.315	0.620
AveB_2017_2019/BMSY	0.523	0.515	0.369	0.685

Base case 2

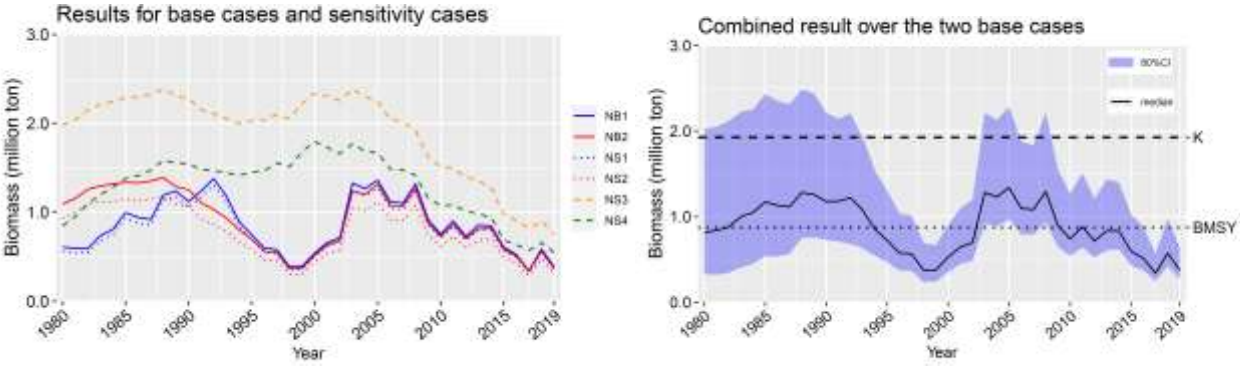
	Mean	Median	Lower10th	Upper10th
C_2019	0.192	0.192	0.192	0.192
AveC_2017_2019	0.298	0.298	0.298	0.298
AveF_2017_2019	0.749	0.768	0.451	1.012
F_2019	0.522	0.527	0.304	0.730
FMSY	0.478	0.482	0.282	0.667
MSY (million ton)	0.435	0.423	0.358	0.523
F_2019/FMSY	1.142	1.093	0.762	1.571
AveF_2017_2019/FMSY	1.504	1.450	1.044	2.012
K (million ton)	2.291	1.948	1.361	3.584
B_2018 (million ton)	0.647	0.562	0.415	0.963
B_2019 (million ton)	0.420	0.365	0.264	0.632
AveB_2017_2019	0.483	0.420	0.316	0.721
BMSY (million ton)	1.024	0.882	0.637	1.563
BMSY/K	0.454	0.443	0.403	0.526
B_2018/K	0.302	0.298	0.191	0.414
B_2019/K	0.196	0.194	0.120	0.269
AveB_2017_2019/K	0.226	0.226	0.143	0.304
B_2018/BMSY	0.666	0.648	0.440	0.914
B_2019/BMSY	0.432	0.423	0.277	0.592
AveB_2017_2019/BMSY	0.497	0.490	0.331	0.666

Over the two base cases.

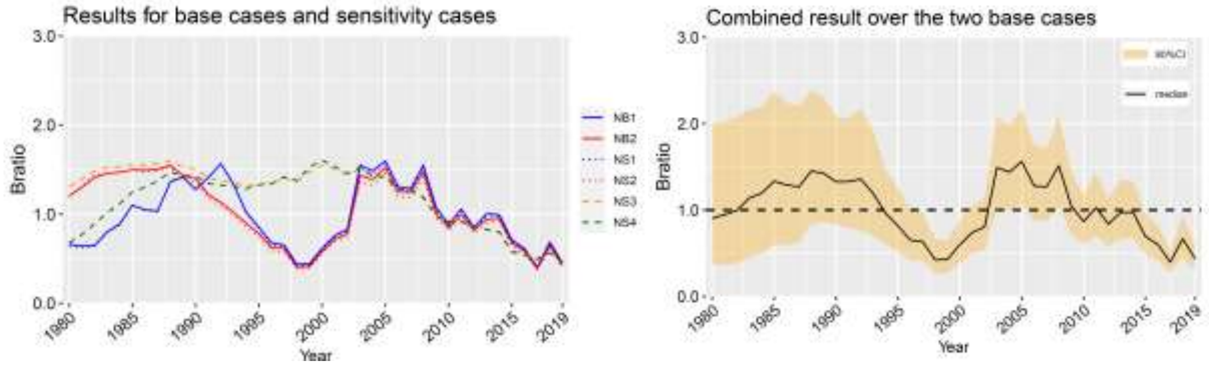
	Mean	Median	Lower10th	Upper10th
C_2019	0.192	0.192	0.192	0.192
AveC_2017_2019	0.298	0.298	0.298	0.298
AveF_2017_2019	0.678	0.691	0.411	0.925
F_2019	0.510	0.515	0.299	0.716
FMSY	0.477	0.480	0.288	0.659
MSY (million ton)	0.428	0.419	0.354	0.510
F_2019/FMSY	1.111	1.067	0.754	1.514
AveF_2017_2019/FMSY	1.477	1.428	1.048	1.948
K (million ton)	2.243	1.928	1.370	3.419
B_2018 (million ton)	0.656	0.572	0.420	0.971
B_2019 (million ton)	0.429	0.374	0.269	0.643
AveB_2017_2019	0.489	0.428	0.319	0.724
BMSY (million ton)	1.003	0.873	0.639	1.485
BMSY/K	0.454	0.443	0.403	0.527
B_2018/K	0.310	0.307	0.200	0.420
B_2019/K	0.203	0.201	0.129	0.275
AveB_2017_2019/K	0.231	0.232	0.151	0.308
B_2018/BMSY	0.684	0.667	0.460	0.929
B_2019/BMSY	0.447	0.437	0.294	0.608
AveB_2017_2019/BMSY	0.510	0.503	0.349	0.677

4.2.3 Time series plots for base case models and aggregated results

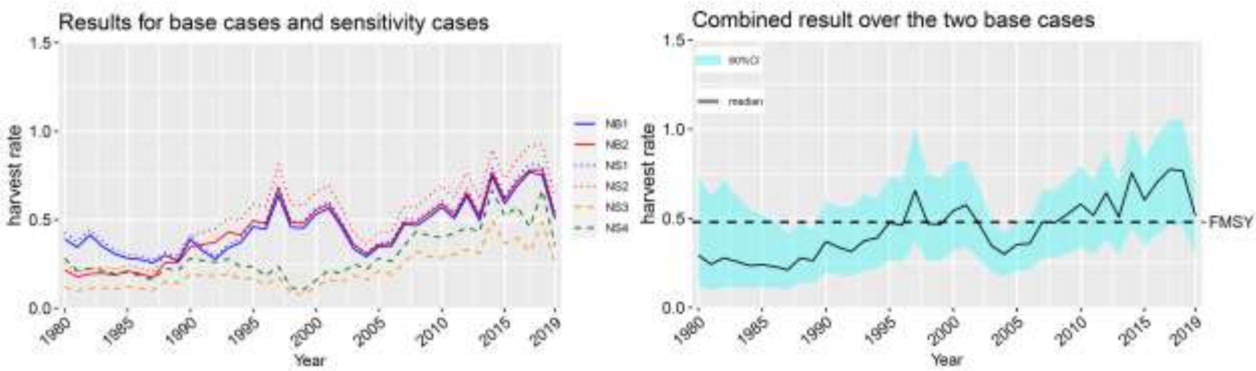
(a) Biomass



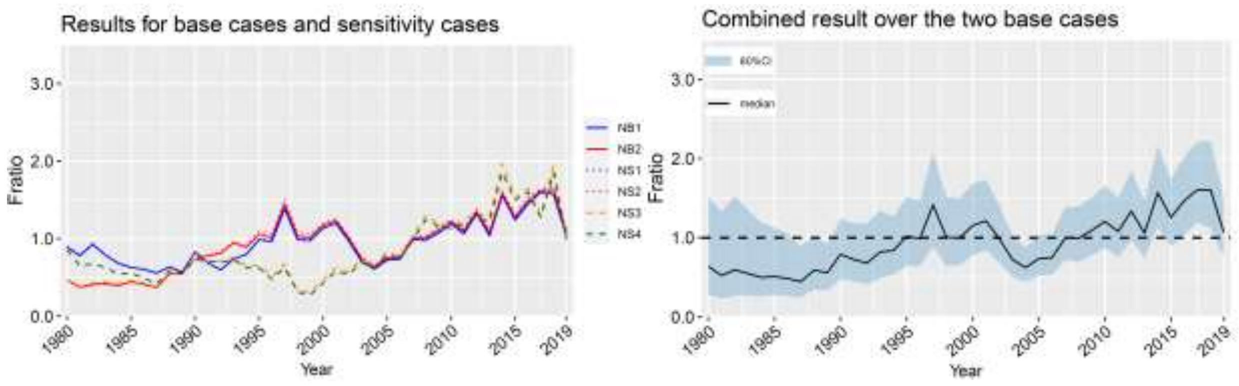
(b) B-ratio (B/B_{MSY})



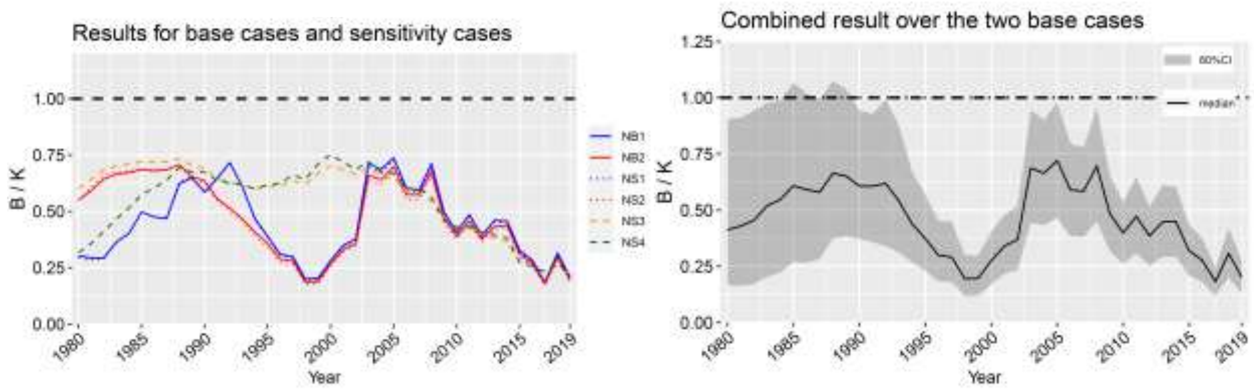
(c) Exploitation rate (F)



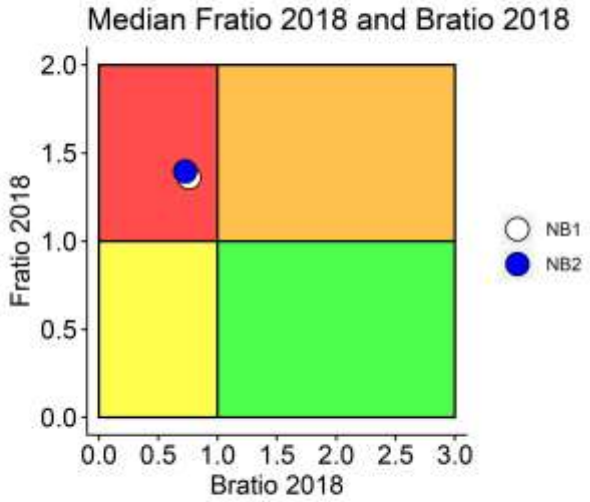
(d) F-ratio (F/F_{MSY})

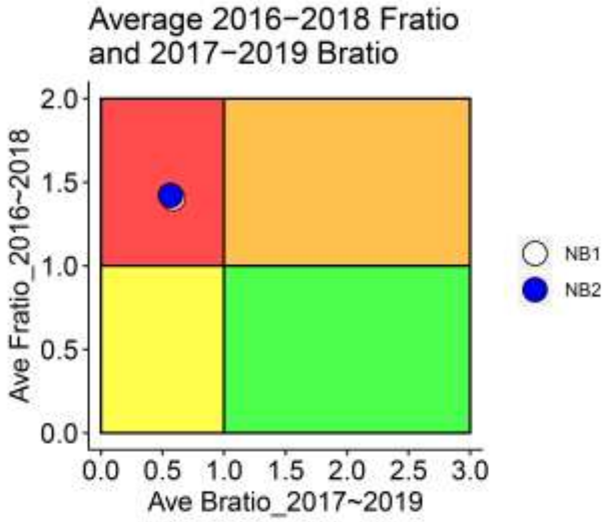


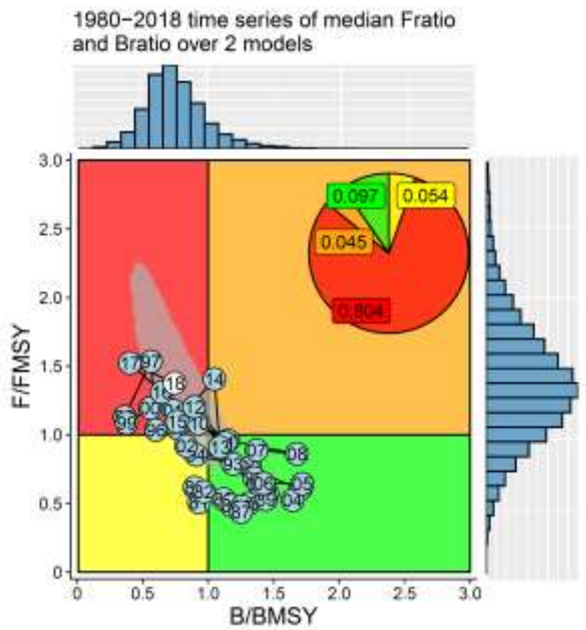
(e) B/K



4.2.4 Kobe plots

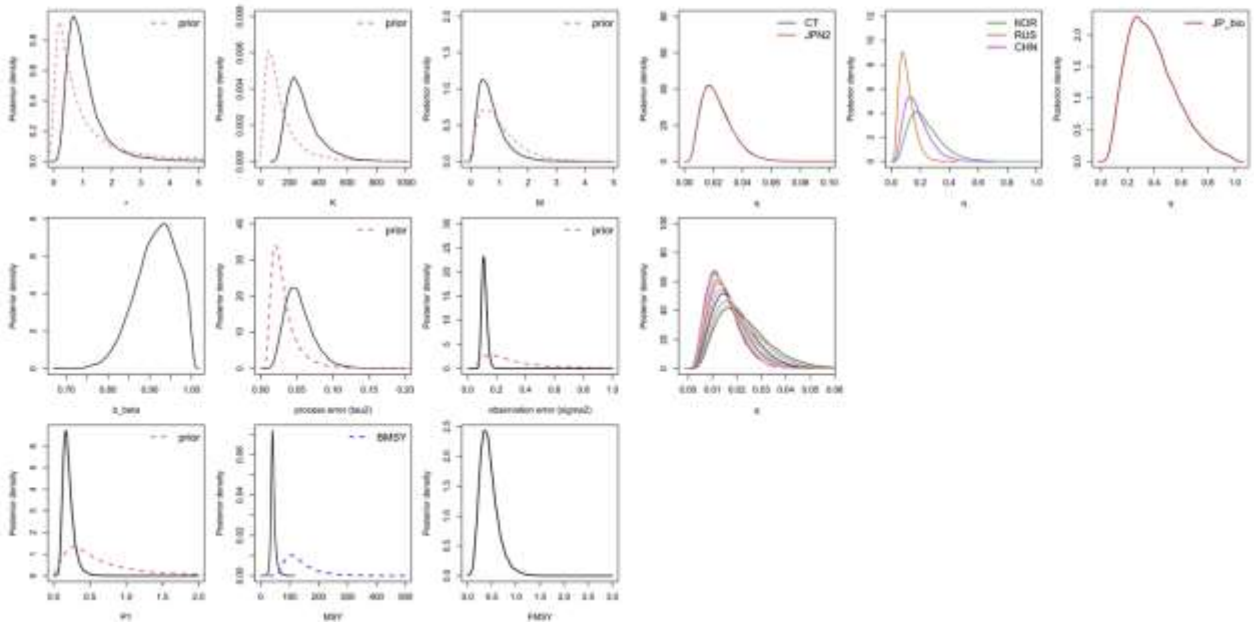






4.3 CHINESE TAIPEI

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



4.3.2 Summary of estimates of parameters and reference points

(a) Base case1

Base case1

	Mean	Median	Lower 10th	Upper 10th
C_{2019}	19.2	19.2	19.2	19.2
Ave_$C_{2017\text{-}2019}$	29.8	29.8	29.8	29.8
Ave_$F_{2017\text{-}2019}$	0.57	0.42	0.18	1.01
F_{2019}	0.34	0.29	0.13	0.61
F_{MSY}	0.45	0.42	0.24	0.70
MSY	43.12	41.84	35.03	52.79
F_{2019}/F_{MSY}	0.75	0.70	0.40	1.15
Ave_$F_{2017\text{-}2019}/F_{MSY}$	1.18	1.05	0.58	1.83
K	297.37	269.80	176.50	455.00
B_{2018}	131.43	109.60	59.84	228.91
B_{2019}	92.42	77.47	42.00	161.10
Ave_$B_{2017\text{-}2019}$	102.91	86.41	47.66	178.53
B_{MSY}	137.58	124.20	82.12	210.00
B_{MSY}/K	0.47	0.46	0.41	0.53
B_{2018}/K	0.43	0.42	0.29	0.58
B_{2019}/K	0.30	0.29	0.21	0.40
$B_{2017\text{-}2019}/K$	0.33	0.33	0.23	0.44
B_{2018}/B_{MSY}	0.93	0.89	0.62	1.29
B_{2019}/B_{MSY}	0.65	0.63	0.44	0.89
$B_{2017\text{-}2019}/B_{MSY}$	0.73	0.70	0.50	0.98

(b) Base case2

Base case2

	Mean	Median	Lower 10th	Upper 10th
C_{2019}	19.20	19.20	19.20	19.20
Ave_$C_{2017\text{-}2019}$	29.80	29.80	29.80	29.80
Ave_$F_{2017\text{-}2019}$	1.22	0.67	0.26	2.87
F_{2019}	0.57	0.43	0.18	0.99
F_{MSY}	0.54	0.46	0.22	0.90
MSY	40.88	40.35	33.04	49.00
F_{2019}/F_{MSY}	1.03	0.96	0.55	1.54
$F_{2017\text{-}2019}/F_{MSY}$	1.94	1.57	0.85	3.42
K	263.33	234.20	149.10	414.41
B_{2018}	97.45	78.72	45.21	168.50
B_{2019}	68.22	55.16	30.65	118.30
Ave_$B_{2017\text{-}2019}$	75.61	61.64	35.43	129.60
B_{MSY}	123.53	109.50	70.50	193.31
B_{MSY}/K	0.47	0.47	0.41	0.54
B_{2018}/K	0.36	0.34	0.25	0.49
B_{2019}/K	0.25	0.24	0.17	0.34
$B_{2017\text{-}2019}/K$	0.28	0.27	0.20	0.37
B_{2018}/B_{MSY}	0.77	0.72	0.53	1.07
B_{2019}/B_{MSY}	0.54	0.50	0.36	0.74
$B_{2017\text{-}2019}/B_{MSY}$	0.60	0.56	0.42	0.81

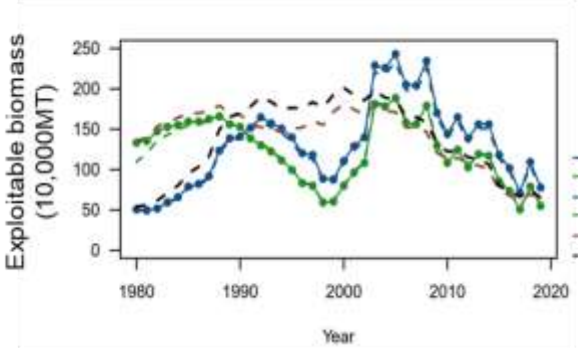
(c) Joint estimates of the base cases 1 and 2

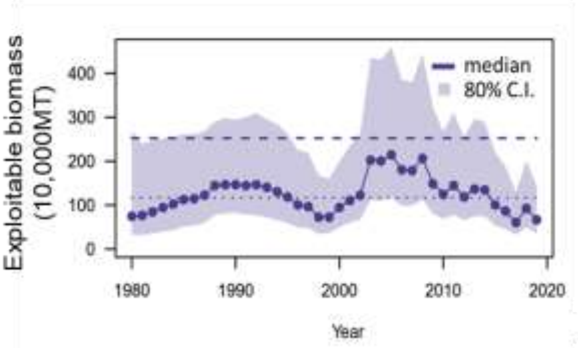
Joint estimates of the base cases 1 and 2

	Mean	Median	Lower 10th	Upper 10th
C_{2019}	19.2	19.2	19.2	19.2
Ave_$C_{2017\text{-}2019}$	29.8	29.8	29.8	29.8
Ave_$F_{2017\text{-}2019}$	0.891	0.523	0.21	1.517
F_{2019}	0.455	0.346	0.145	0.812
F_{MSY}	0.494	0.435	0.231	0.794
MSY	42.00	41.11	34.03	50.98
F_{2019}/F_{MSY}	0.891	0.824	0.45	1.376
Ave_$F_{2017\text{-}2019}/F_{MSY}$	1.56	1.282	0.664	2.491
K	280.352	252.4	160.2	435.51
B_{2018}	114.44	93.24	50.4	202.2
B_{2019}	80.319	65.7	34.6	143
Ave_$B_{2017\text{-}2019}$	89.262	73.258	39.683	156.733
B_{MSY}	130.559	117	75.409	202.1
B_{MSY}/K	0.508	0.46	0.294	0.746
B_{2018}/K	0.393	0.377	0.262	0.543
B_{2019}/K	0.275	0.266	0.182	0.38
Ave_$B_{2017\text{-}2019}/K$	0.307	0.297	0.209	0.416
B_{2018}/B_{MSY}	0.848	0.798	0.558	1.202
B_{2019}/B_{MSY}	0.593	0.563	0.387	0.838
Ave$B_{2017\text{-}2019}/B_{MSY}$	0.661	0.626	0.446	0.921

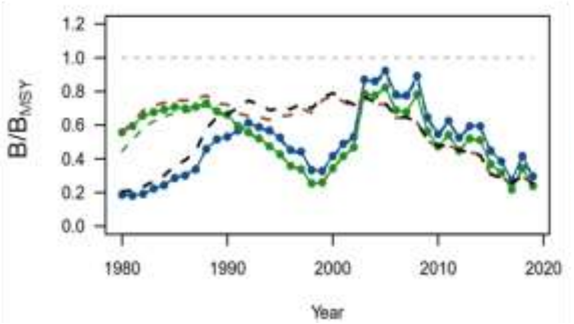
4.3.3 Time series plots for base case models and aggregated results

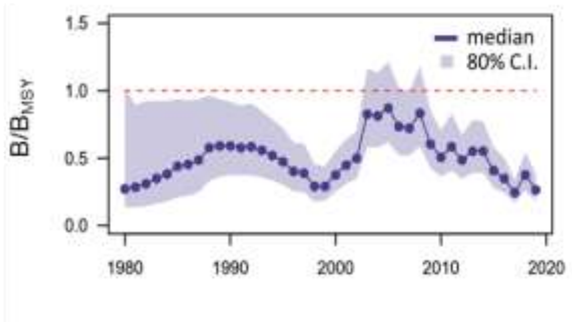
(a) Biomass



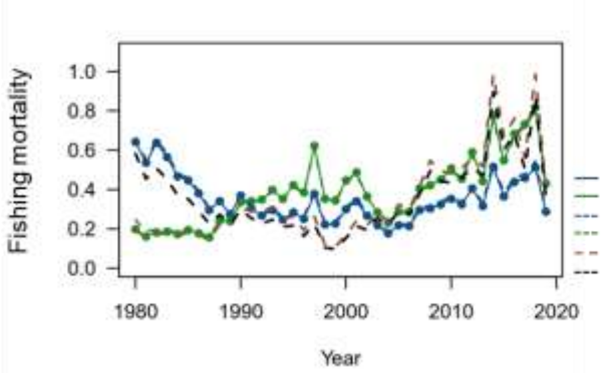


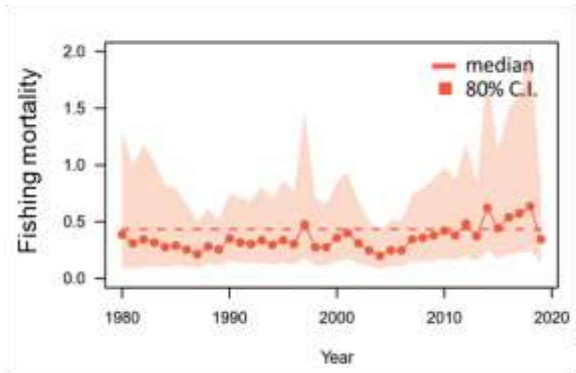
(b) B-ratio (B/B_{MSY})



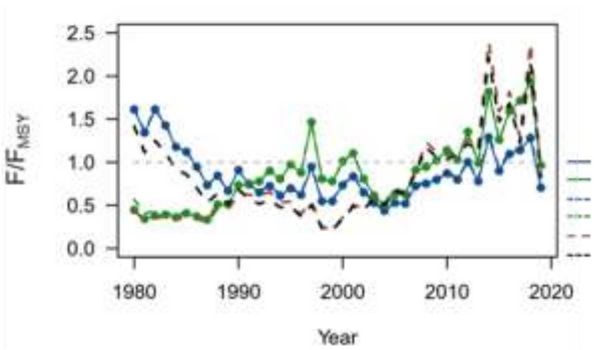


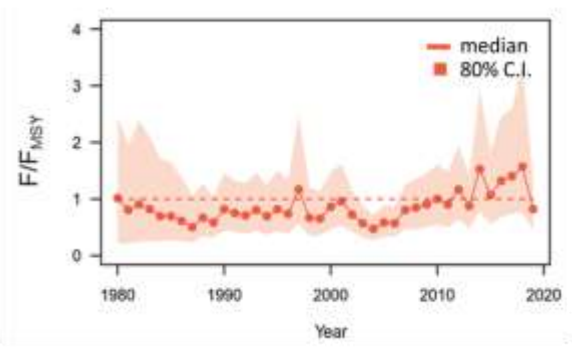
(c) Exploitation rate (F)



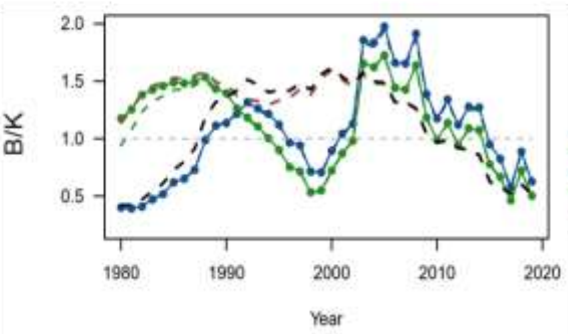


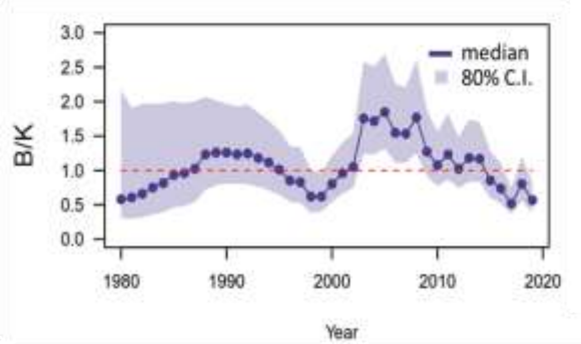
(d) F-ratio (F/F_{MSY})



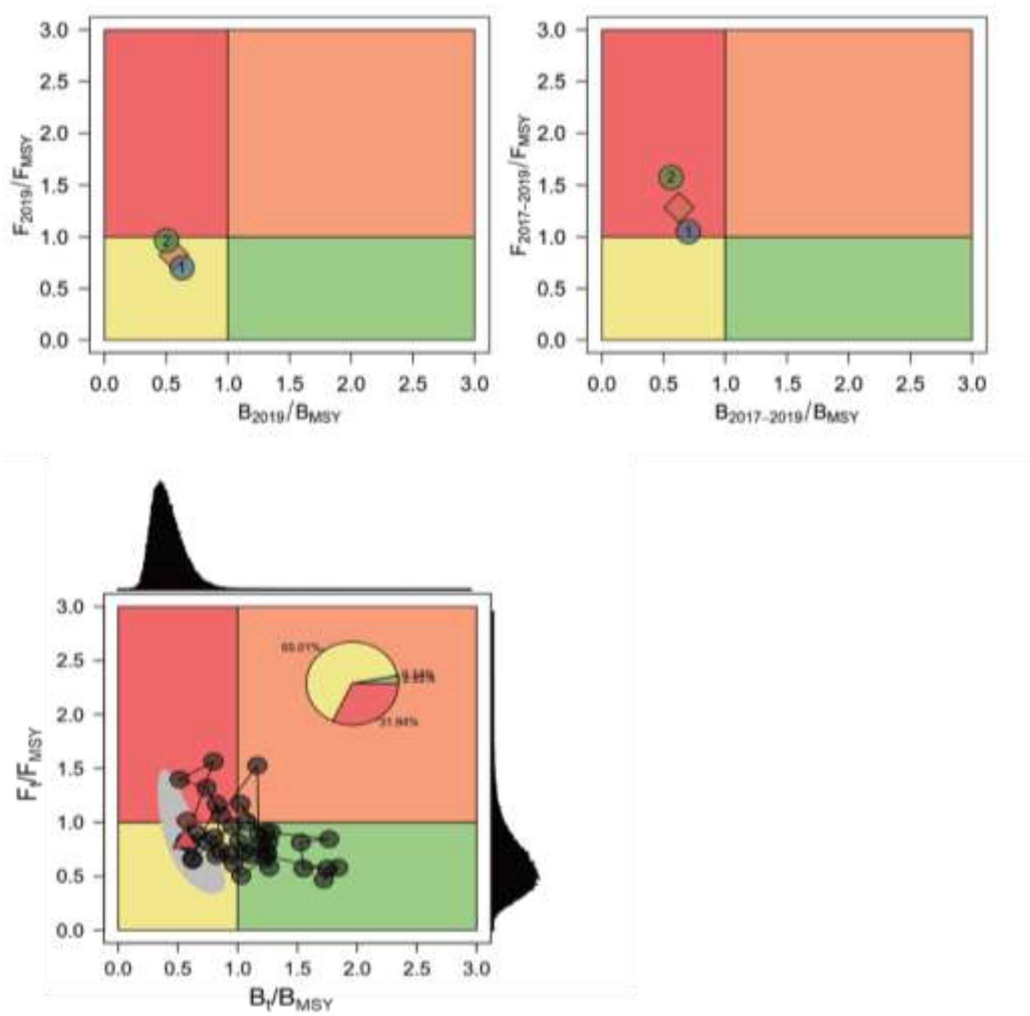


(e) B/K


2.0
1.5
1.0
0.5
B/K
1980
1990
2000
2010
2020
Year
B1
B2
S1
S2
S3
S4


3.0
2.5
2.0
1.5
1.0
0.5
0.0
B/K
median
80% C.I.
1980
1990
2000
2010
2020
Year

4.3.4 Kobe plots

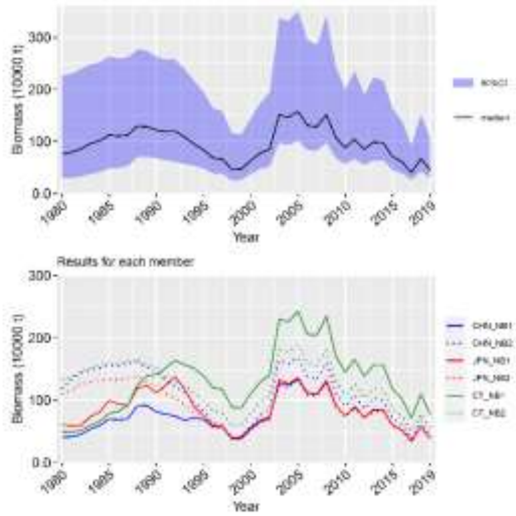


5 SOME AGGREGATED RESULTS FOR VISUALIZATION PURPOSE

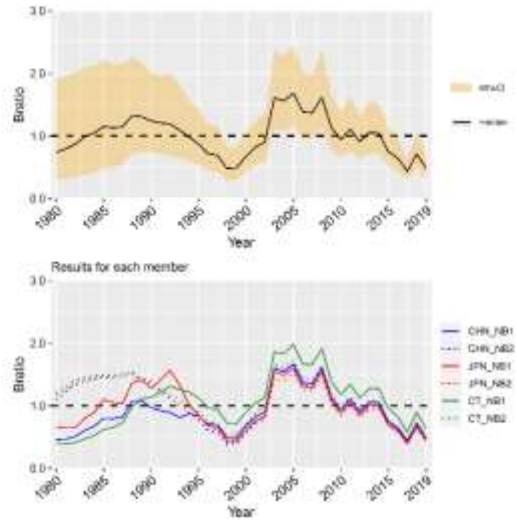
5.1 Visual presentation of results

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

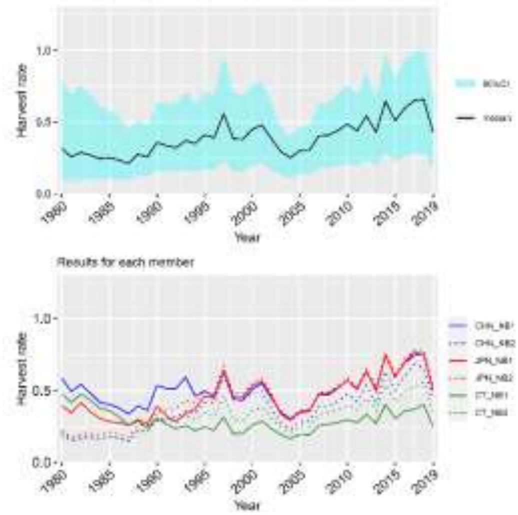
(b) Biomass (B)



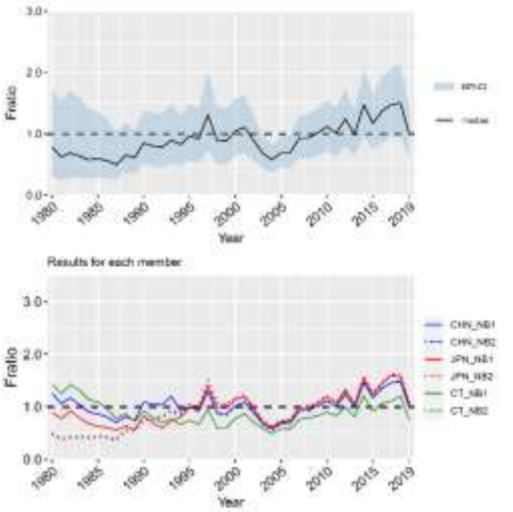
(b) B-ratio (B/B_{MSY})



(c) Exploitation rate (F)



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



(e) B/K

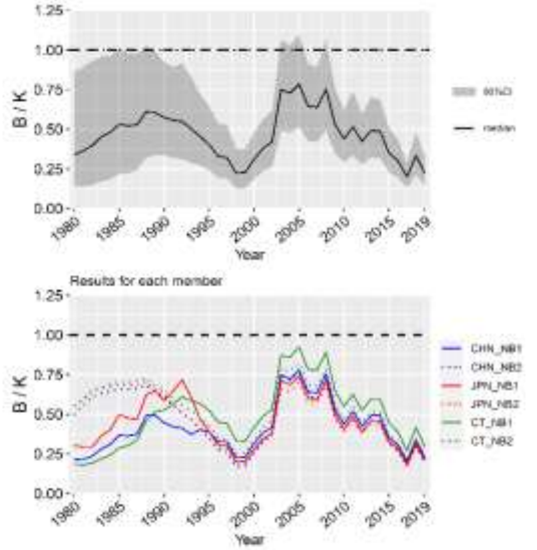


Figure 3. Time series of median estimated values of six runs for biomass, harvest rate, B-ratio, F-ratio, and depletion level relative to the carrying capacity. The solid and shaded lines correspond to NB1 and NB2, respectively.

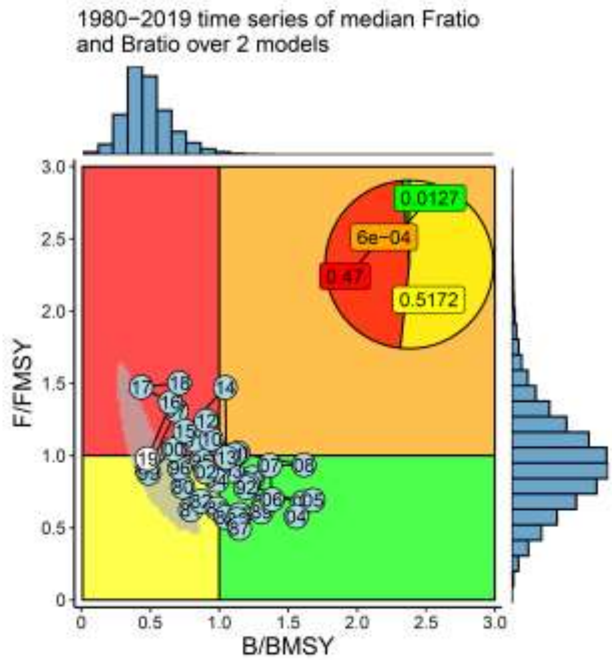


Figure 4. Kobe plot with time trajectory. The data are aggregated across 6 model results (2 base-case models by 3 Members).

5.2 Summary table

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

	Median	Lower10%	Upper10%	Median_CHN	Median_JPN	Median_CT
C_2019 (10000 t)	19.238	19.238	19.238	19.238	19.238	19.238
AveC_2017_2019 (10000 t)	29.803	29.803	29.803	29.803	29.803	29.803
AveF_2017_2019	0.582	0.255	0.891	0.637	0.691	0.400
F_2019	0.428	0.183	0.681	0.467	0.515	0.292
FMSY	0.431	0.235	0.643	0.472	0.48	0.353
MSY	41.852	35.069	52.22	42.559	41.866	41.11
F_2019/FMSY	0.979	0.605	1.419	0.991	1.067	0.859
AveF_2017_2019/FMSY	1.327	0.845	1.841	1.349	1.428	1.175
K (10000 t)	213.851	140.075	412.51	200.00	192.763	252.15
B_2018 (10000 t)	66.81	43.279	152.2	61.71	57.249	93.055
B_2019 (10000 t)	44.937	28.256	105.116	41.18	37.379	65.855
AveB_2017_2019 (10000 t)	50.783	32.999	115.754	46.517	42.822	73.385
BMSY (10000 t)	97.116	65.53	185.4	90.195	87.318	116.9
BMSY/K	0.445	0.391	0.552	0.44	0.443	0.455
B_2018/K	0.332	0.216	0.481	0.321	0.307	0.376
B_2019/K	0.224	0.143	0.33	0.214	0.201	0.266
AveB_2017_2019/K	0.254	0.167	0.363	0.244	0.232	0.296
B_2018/BMSY	0.712	0.486	1.068	0.693	0.667	0.798
B_2019/BMSY	0.48	0.321	0.728	0.464	0.437	0.563
AveB_2017_2019/BMSY	0.544	0.376	0.803	0.525	0.503	0.625

6 CONCLUDING REMARKS

Results of combined model estimates indicate that the stock declined with an interannual variability from near carrying capacity in the mid-2000's after a period of high productivity to current levels. Exploitation rates were increasing slowly since 2005 except for 2019. The results also indicated that B was below B_{MSY} (median average B/B_{MSY} during 2017-2019 = 0.544, 80%CI=0.376-0.803) and F was above F_{MSY} (average F/F_{MSY} during 2017-2019 = 1.327, 80%CI= 0.845-1.841). The results further indicated that stock biomass fell to the lowest value since 1980 in 2017 (median B/B_{MSY} = 0.434, 80%CI=0.295-0.639) and has been still at a historically low level in recent years (2017-2019). Information of the nominal CPUE series further indicated that Pacific saury stock biomass has likely been near a record low level in 2020.

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