NPFC

North Pacific Fisheries Commission

Stock assessment report for Pacific saury

EXECUTIVE SUMMARY

Data used in the assessment modeling

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

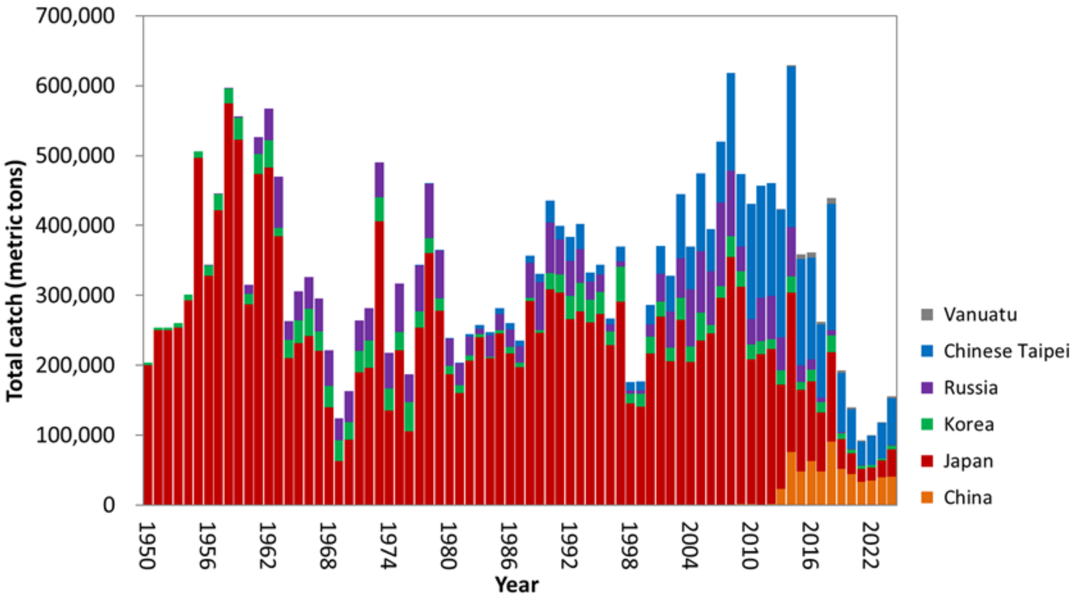

Figure 1. Time series of catch by Member during 1950-2024. The catch data for 1950-1979 are shown but not used in stock assessment modeling. Catch data in 2024 are preliminary (as of 29 November 2024) and not used in the assessment.

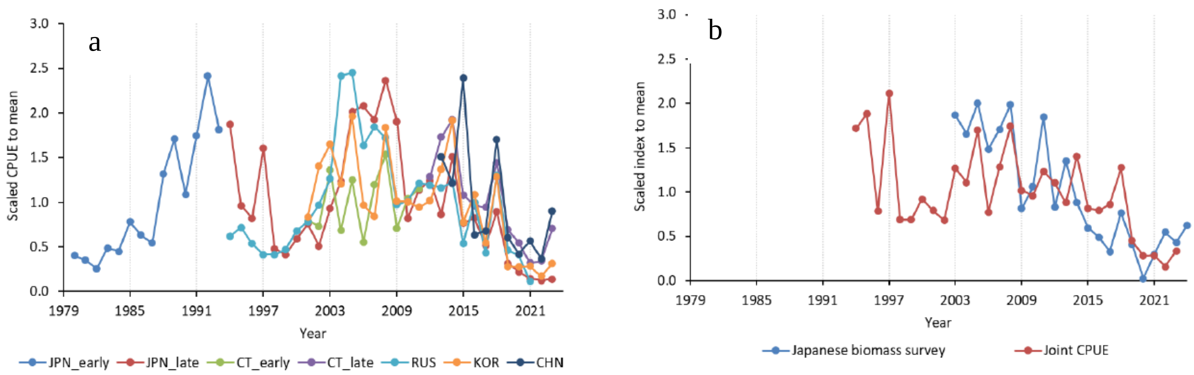

Figure 2. Time series of (a) Japanese survey biomass index and joint CPUE and (b) Member's standardized CPUE indices used in the assessment modeling.

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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 1980-2024. Scientists from three Members (China, Japan and Chinese Taipei) each conducted analyses following the agreed specification which called for two base case scenarios and two sensitivity scenarios (see Annex F, SSC PS13 report for more details). The two base case scenarios differ in using each Member's standardized CPUEs (base case B1) or standardized joint CPUEs (base case B2). For the two sensitivity cases with Japanese early CPUE (1980-1994), time-varying catchability was assumed to account for potential increases in catchability. A higher weight was given to the Japanese biomass survey estimates than to Members' CPUEs in B1 while comparable weights were given to the Japanese biomass survey estimates and the joint CPUEs in B2. The CPUE data were modeled as nonlinear indices of biomass. Members used similar approaches with some differences in the assumption of the time-varying catchability and prior distributions for the free parameters in the model.

Summary of stock assessment results

The SSC PS considered the BSSPM results and noted the agreement in trends among Members' results for each base case model. However, there was a marked difference in the biomass level between B1 and B2 due to the different CPUE trends used. The SSC PS discussed and recognized that the results covered a wide range of uncertainties in data, model and estimation, and it therefore concluded the outcomes of MCMC runs could be aggregated over the 6 models (2 base case models x 3 Members) as in the previous assessments. The aggregated results for assessing the overall median values and their associated 80% credible intervals are shown in Table 1a (The aggregated results for 2023 are shown in Table 1b). The graphical presentations for times series of a) biomass (B), b) B-ratio (=B/B_{MSY}), c) harvest rate (F), d) F-ratio (F/F_{MSY}) and e) B/K are shown in Figure 3. The Kobe plot with time trajectory using aggregated model outcomes is shown in Figure 4. Time series of median estimated values for biomass, harvest rate, B-ratio, F-ratio and depletion level relative to K are shown in Table 2.

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

a. 2024 assessment

	Median	Lower10%	Upper10%	Median_CHN	Median_JPN	Median_CT
C_2023 (10000 t)	11.836	11.836	11.836	11.836	11.836	11.836
AveC_2021_2023	10.352	10.352	10.352	10.352	10.352	10.352
AveF_2021_2023	0.328	0.158	0.528	0.352	0.339	0.302
F_2023	0.297	0.155	0.469	0.313	0.307	0.277
FMSY	0.330	0.139	0.543	0.357	0.336	0.310
MSY (10000 t)	39.440	32.021	47.010	40.155	39.284	39.010
F_2023/FMSY	0.920	0.656	1.411	0.915	0.942	0.903
AveF_2021_2023/FMSY	1.008	0.755	1.435	1.013	1.026	0.988
K (10000 t)	248.067	151.766	565.726	234.100	253.396	254.500
B_2023 (10000 t)	39.875	25.214	76.394	37.830	38.599	42.720
B_2024 (10000 t)	52.763	35.130	91.631	50.920	52.120	55.155
AveB_2022_2024	41.563	27.387	77.406	39.705	40.555	44.165
BMSY (10000 t)	120.100	78.060	253.481	113.800	119.008	125.100
BMSY/K	0.485	0.392	0.604	0.480	0.471	0.505
B_2023/K	0.161	0.101	0.228	0.158	0.154	0.169
B_2024/K	0.212	0.122	0.315	0.212	0.206	0.219
AveB_2022_2024/K	0.169	0.106	0.236	0.168	0.163	0.175
B_2023/BMSY	0.328	0.225	0.452	0.323	0.322	0.339
B_2024/BMSY	0.435	0.270	0.628	0.433	0.431	0.440
AveB_2022_2024/BMSY	0.345	0.235	0.470	0.341	0.341	0.352

b. 2023 assessment

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

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

Year	Biomass	HarvestRate	Bratio	Fratio	Depletion
1980	136.290	0.175	1.123	0.554	0.549
1981	143.000	0.143	1.217	0.438	0.594
1982	154.500	0.158	1.321	0.482	0.646
1983	159.818	0.161	1.364	0.490	0.671
1984	163.400	0.151	1.391	0.459	0.685
1985	167.300	0.168	1.422	0.511	0.701
1986	167.100	0.156	1.413	0.475	0.697
1987	170.216	0.138	1.434	0.424	0.706
1988	174.700	0.204	1.461	0.630	0.719
1989	164.800	0.201	1.372	0.621	0.677
1990	160.800	0.271	1.346	0.838	0.661
1991	146.700	0.272	1.225	0.849	0.601
1992	138.900	0.276	1.166	0.867	0.567
1993	132.866	0.303	1.115	0.962	0.539
1994	124.225	0.268	1.040	0.860	0.498
1995	121.400	0.283	0.993	0.944	0.473
1996	113.402	0.235	0.911	0.798	0.434
1997	118.500	0.312	0.913	1.110	0.435
1998	103.500	0.170	0.802	0.600	0.383
1999	114.500	0.154	0.873	0.549	0.419
2000	127.800	0.224	1.002	0.769	0.481
2001	131.800	0.281	1.071	0.920	0.518
2002	135.296	0.243	1.120	0.768	0.545
2003	155.200	0.286	1.292	0.890	0.631
2004	153.300	0.241	1.269	0.744	0.625
2005	166.208	0.285	1.350	0.892	0.668
2006	148.600	0.265	1.213	0.826	0.599
2007	155.978	0.334	1.268	1.040	0.629
2008	149.101	0.414	1.198	1.305	0.595
2009	111.116	0.425	0.917	1.315	0.451
2010	109.500	0.393	0.897	1.220	0.442
2011	114.800	0.397	0.924	1.250	0.458
2012	101.700	0.453	0.834	1.402	0.411
2013	100.373	0.422	0.814	1.314	0.404
2014	93.029	0.677	0.768	2.068	0.380
2015	63.708	0.563	0.525	1.736	0.259
2016	56.762	0.637	0.471	1.950	0.232
2017	48.322	0.543	0.402	1.670	0.197
2018	51.780	0.842	0.427	2.545	0.212
2019	30.715	0.636	0.255	1.944	0.126
2020	25.040	0.558	0.209	1.709	0.103
2021	25.250	0.365	0.209	1.127	0.103
2022	31.970	0.313	0.264	0.969	0.130
2023	39.875	0.297	0.328	0.920	0.161
2024	52.763		0.435		0.212

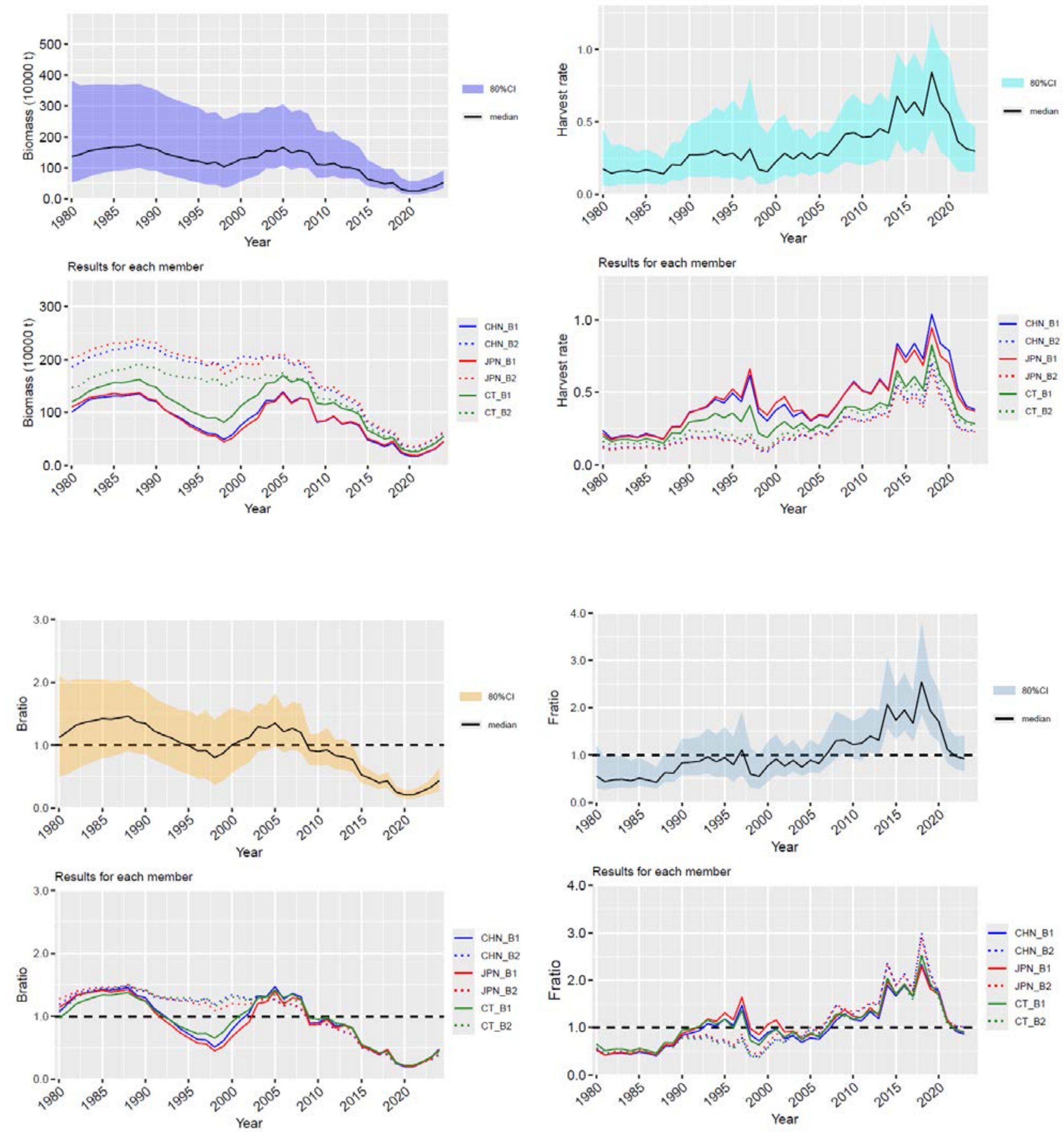


Figure 3. Time series of median estimated values of six runs for biomass, harvest rate, B-ratio, F-ratio and depletion level relative to K. The solid and shaded lines correspond to B1 and B2, respectively.

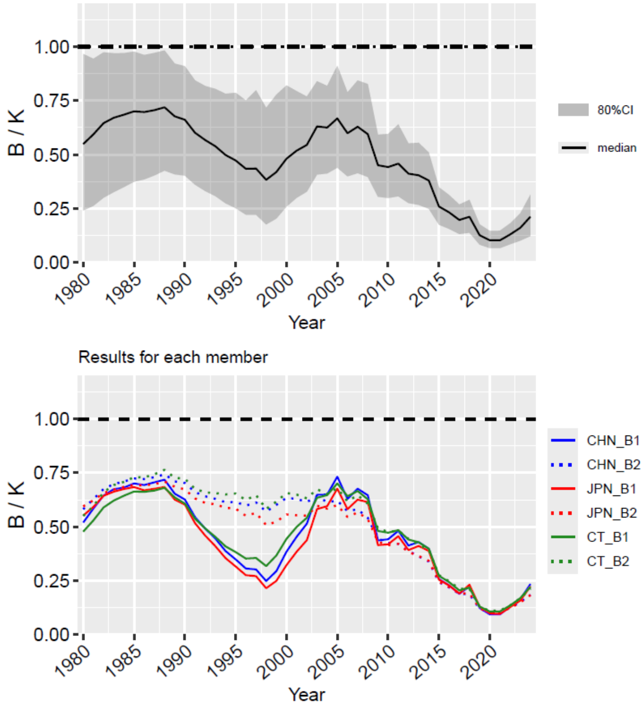
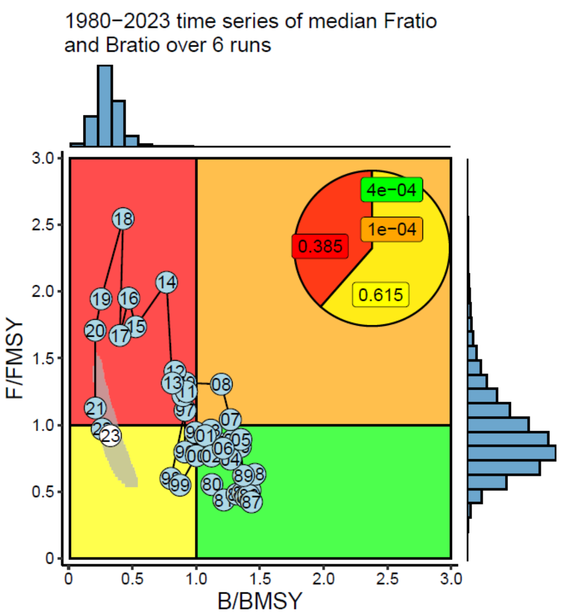


Figure 3 (Continued).

2024 assessment



2023 assessment

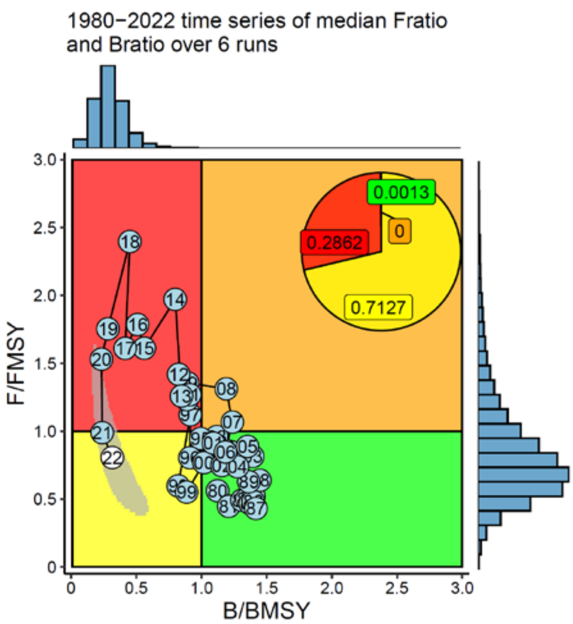


Figure 4. Kobe plot with time trajectory in 2024 (left) and 2023 (right) assessments. The data are aggregated across 6 model results (2 base-case models by 3 Members).

Current stock condition and management advice

Summary of stock status

Results of all Members' and combined model estimates indicate the stock declined with high interannual variability from a high biomass level in the mid-2000's after a period of high productivity to the current low biomass levels. Combined results show that average B was below B_{MSY} during 2022–2024 (median average B/B_{MSY} during 2022–2024 = 0.345, 80%CI = 0.235–0.470) and average F was above F_{MSY} (average F/F_{MSY} during 2021–2023 = 1.008, 80%CI = 0.755–1.435). Thus, stock biomass remained at low levels in recent years. Biomass may have increased modestly during 2022–2024 based on the abundance indices and higher recruitment that may be evident in the Japanese fishery size composition. Based on CPUE, survey data, and model results, the condition of the Pacific saury stock and fishery improved in recent years although biomass remains below B_{MSY}. Harvest rates decreased while biomass and catch increased during 2020–2024. The improvement could be due at least in part to reductions in catch since 2020 and potentially due to unidentified environmental variability.

Uncertainty in assessment

Uncertainty in estimated biomass for the terminal year for Pacific saury translates into uncertainty about unconstrained TAC recommendations for the next fishing season. The estimated biomass for Pacific saury during 2023 in the 2023 assessment (549,400 mt) was substantially higher than the updated estimate (398,750 mt) for 2023 in 2024 assessment. As a result, the recommended 2024 TAC without restriction was 73,490 mt based on the 2023 assessment results, but would have been 75,741 mt based on the 2024 assessment results. Such changes occur because new data bring additional information about recent conditions. Ideally, positive and negative changes are equally likely, and the changes are small. Retrospective patterns in some runs for Pacific saury may have affected the HCR calculations. This is an important topic for work in the next assessment (see "Research Recommendations").

The average ensemble 2024 biomass estimate from all three Members and both base case runs was similar (527,630 mt) to estimates from the Member with no retrospective patterns (Chinese Taipei's average of two base case runs 551.450 mt). The agreement suggests that the ensemble average is precise enough for use in 2025 management.

Management advice

An interim harvest control rule (HCR) for Pacific saury was adopted under CMM 2024-08 For Pacific Saury by the NPFC in April 2024 (Figure 5). The HCR states that the unconstrained Total Annual Catch (TAC) in the following year ($year_{t+1}$) is a function of the biomass, fishing mortality, and B_{MSY} calculated in the current year (t): $TAC_{t+1} = B_t{*}F_{MSY,}{*}(B_t/B_{MSY})$. In addition, the HCR constrains changes in TAC to no more than 10% from one year to the next. The unconstrained 2025 TAC based on the results of the 2024 stock assessment is $B_{2024}{*}F_{MSY}{*}(B_{2024}/B_{MSY})$ = 75,741 tons, which is smaller than the 90% of the 2024 TAC of 225,000 mt. Following the application of the maximum 10% change aspect of the HCR, the final TAC for 2025 is 202,500 tons.

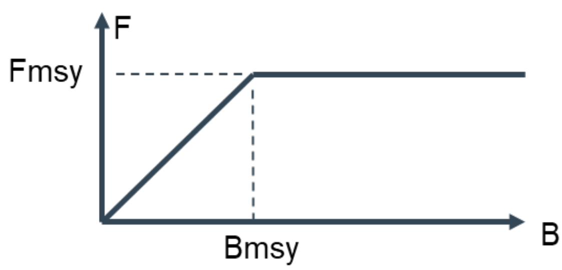


Figure 5. Shapes of the function used in the harvest control rule adopted in 2024 Commission meeting.

Special comments regarding the procedures and stock assessment results

The SSC PS worked collaboratively to produce this consensus stock assessment, which includes significant technical improvements. This section highlights several important aspects of the stock assessment procedure and results.

1) Standardized CPUE data were assumed to be hyperstable and thus less likely to react to changes in biomass. Thus, standardized CPUE were down-weighted relative to the Japanese survey in the first base case (B1), which used CPUE from individual Members. In B1, a single non-linear parameter was used for the CPUEs for each Member. Model results support this decision.

2) Estimated trends in relative stock size measures and reference points from Chinese Taipei (CT), Japan (JPN), China (CHN) and combined models were similar to one another. CPUE, survey trends and model results suggest that stock size is still low but increased since 2020. The F_{MSY} * B * Bratio for 2024 based on the combined models in this assessment is similar to the F_{MSY} * B *Bratio calculated for 2023 in the last assessment despite the recent increasing trend in biomass. The two F_{MSY} * B *Bratio values are similar because recent biomass estimates are lower in the 2024 assessment.

3) Biomass estimates from the 2023 and 2024 assessments are similar in spite of suggestion from the data that stock size increased. This is because the estimated scale of recent biomass is lower in this assessment than in the last assessment. Such uncertainties and shifts in scale can occur because results for most recent years are relatively uncertain and because of retrospective patterns. Retrospective patterns (estimated biomass declined with additional years of data) were noted in results for two Members. Changes were also made in the handling of some CPUE time series in the current model that improved model fit. These changes and the retrospective patterns may have contributed to lower estimated biomass in this assessment for Pacific saury in 2023.

4) Oceanographic or biological factors responsible for changes in Pacific saury productivity have not yet been determined. Development of modeling procedures to incorporate environmental change is an important area for future research. The work should include refinements to stock assessment models to better reflect and estimate environmental effects on recruitment and biology. This work should be coordinated among Members and folded into the development of age-structured and improved BSSPM models.

5) Experience with the HCR rule this year suggests that the use of more current data might improve management advice. Currently, the HCR for 2025 is based on CPUE and catch data through 2023 and survey data through 2024. However, catch data are nearly complete for the most recent year when the assessment for that year is completed and reasonably precise CPUE standardization could probably be completed early as well. It would be advisable for the SSC PS to consider approaches to using the most recent data in the assessment. One approach to demonstrating potential benefits would be to do a retrospective analysis of HCR calculations based on the actual terminal year and the year before.

STOCK ASSESSMENT REPORT FOR PACIFIC SAURY

1. INTRODUCTION

1.1 Distribution

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

1.2 Migration

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

1.3 Population structure

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

1.4 Spawning season and grounds

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

1.5 Food and feeding

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

1.6 Age and growth

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

1.7 Reproduction

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

2. FISHERY

2.1 Overview of fisheries

Western North Pacific

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

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

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

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

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

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

Eastern North Pacific

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

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

Report Database System, https://www.st.nmfs.noaa.gov/, accessed March 8, 2019)

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

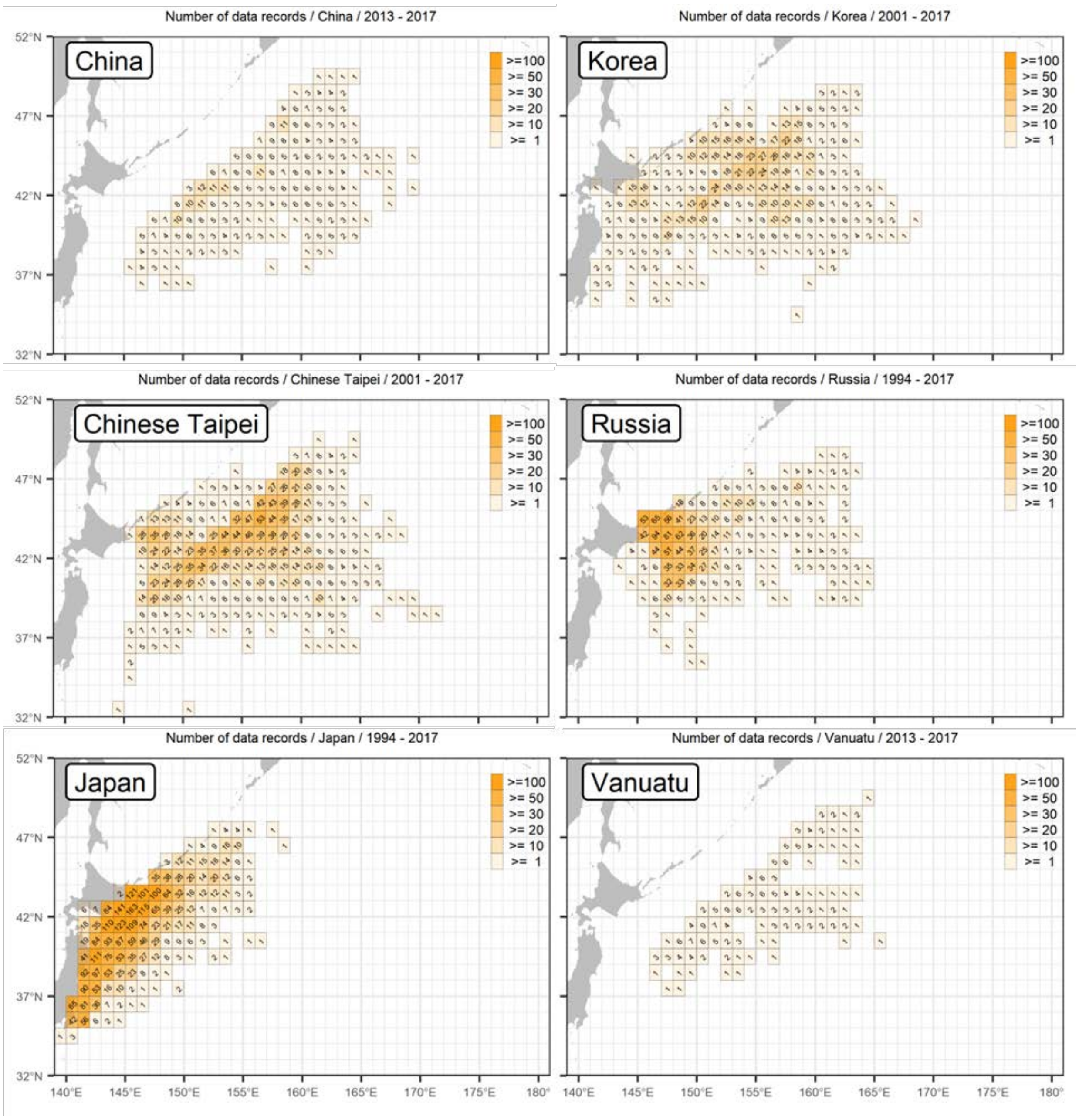


Figure 1 (a). Main fishing grounds for Pacific saury by fishing members in the western North Pacific Ocean during 1994-2017. The legend shows the number of data records. This figure is based on the data shared by the Members for the development of a joint CPUE index

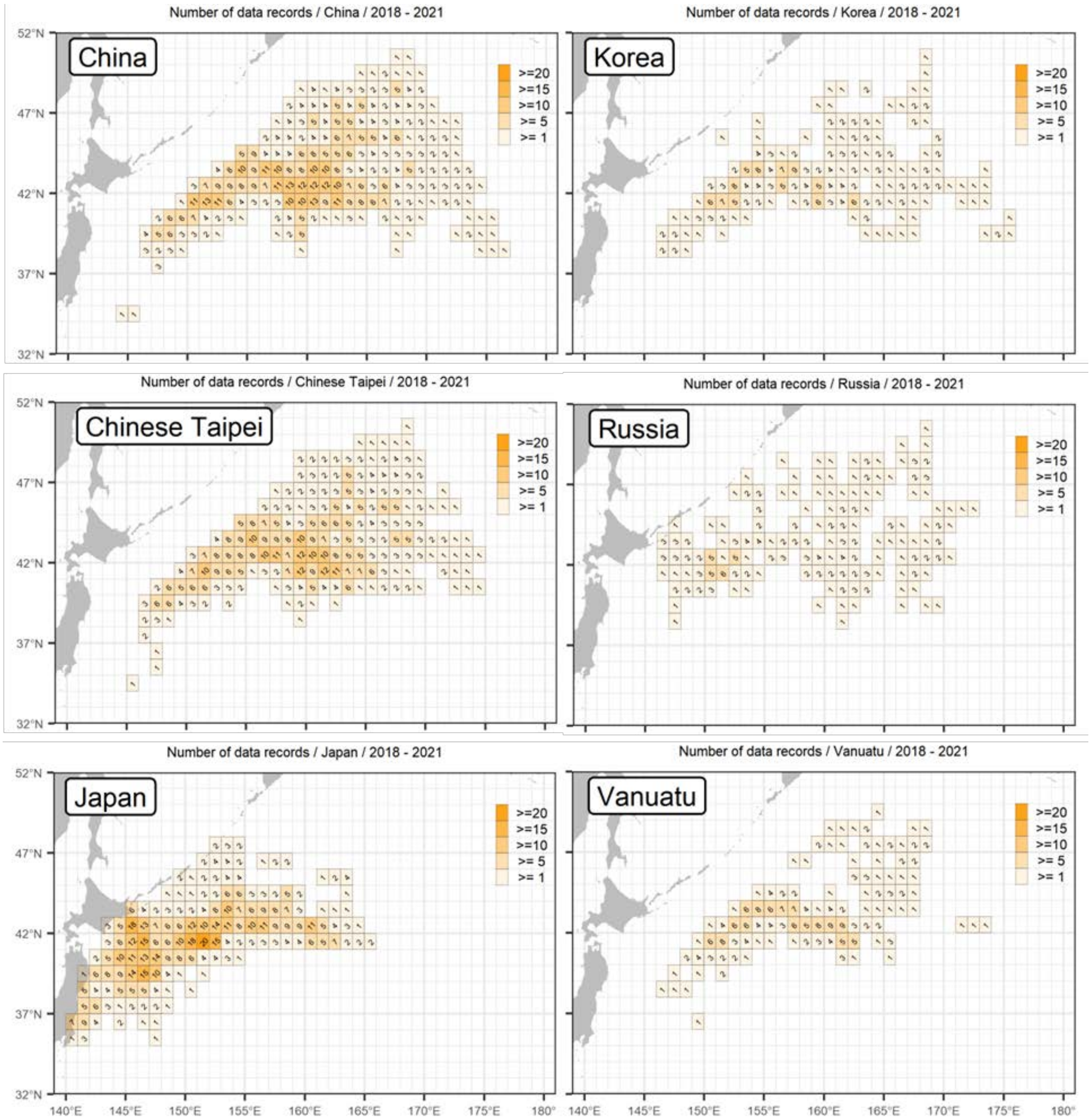


Figure 1 (b). Main fishing grounds for Pacific saury by fishing members in the western North Pacific Ocean during 2018-2021. The legend shows the number of data records. This figure is based on the data shared by the Members for the development of a joint CPUE index

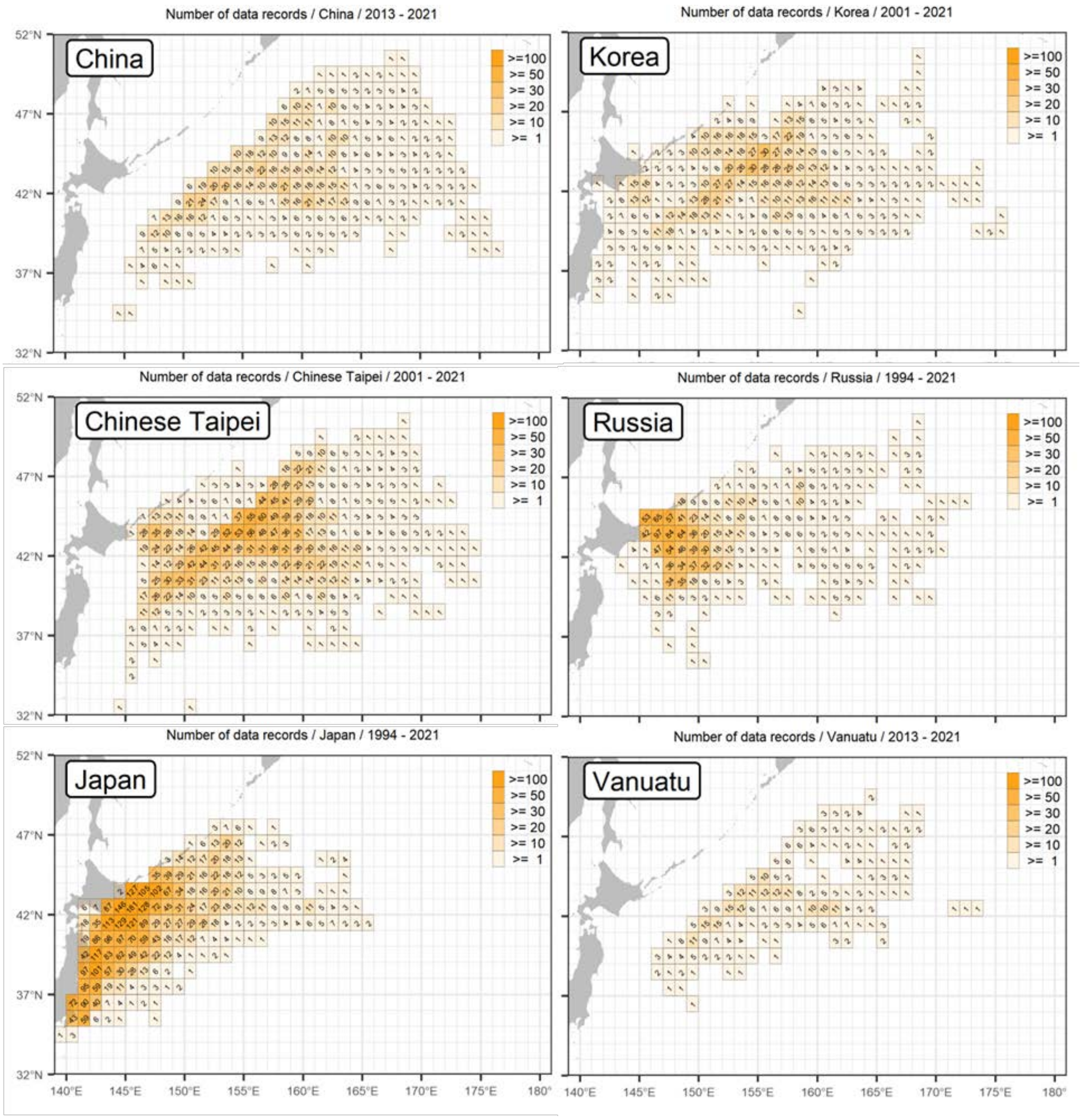


Figure 1 (c). Main fishing grounds for Pacific saury by fishing members in the western North Pacific Ocean during 1994-2021. The legend shows the number of data records. This figure is based on the data shared by the Members for the development of a joint CPUE index

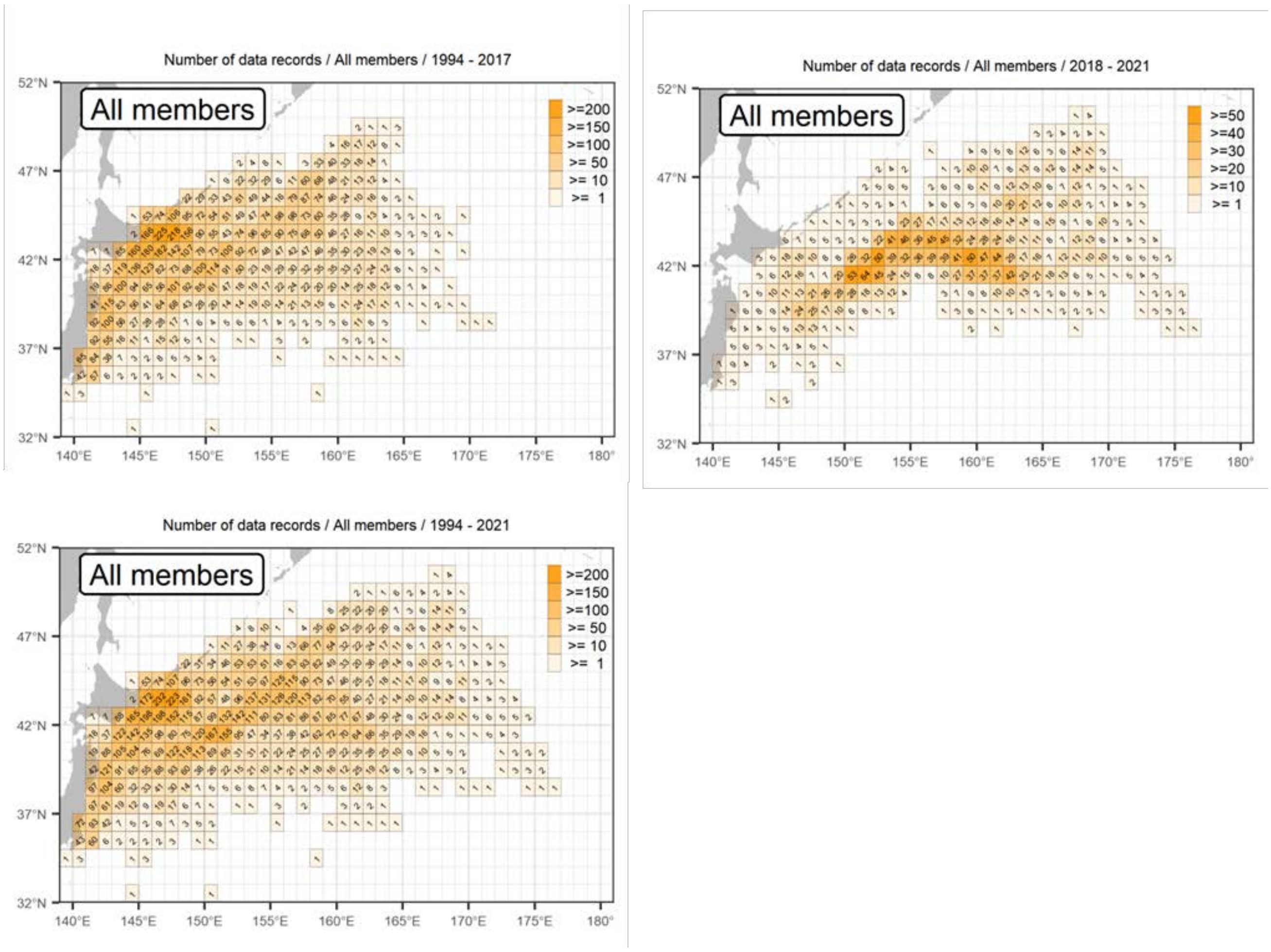


Figure 1 (d). Main fishing grounds for Pacific saury in the western North Pacific Ocean. The legend shows the number of data records. This figure is based on the data shared by the Members for the development of a joint CPUE index

2.2 Catch records

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

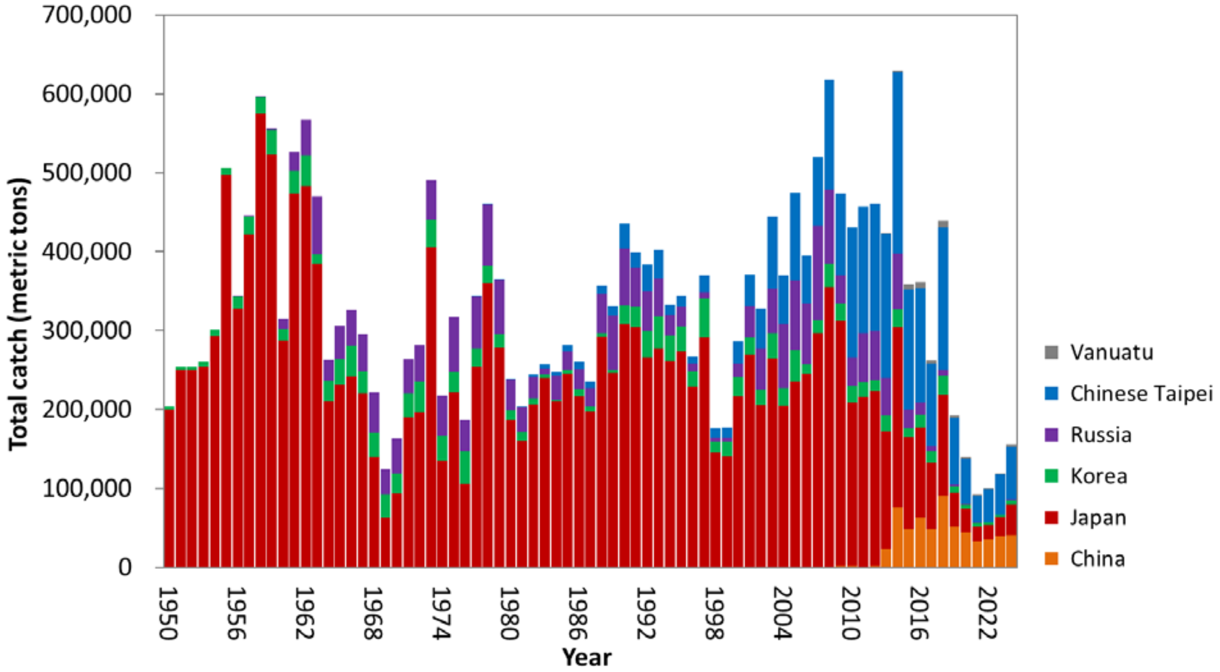


Figure 2. Time series of catch by Member during 1950-2024. The catch data for 1950-1979 are shown but not used in stock assessment modeling. Catch data in 2024 are preliminary (as of 29 November 2024) and not used in the assessment.

3. SPECIFICATION OF STOCK ASSESSMENT

A Bayesian state-space production model (BSSPM) used in previous stock assessments was employed as an agreed provisional stock assessment model for Pacific saury during 1980-2024. Scientists from three Members (China, Japan and Chinese Taipei) each conducted analyses following the agreed specification which called for two base case scenarios and two sensitivity scenarios (see Annex G, SSC PS13 report for more details). The two base case scenarios differ in using each Member's standardized CPUEs (base case B1) or standardized joint CPUEs (base case B2). For the two sensitivity cases with Japanese early CPUE (1980-1994), time-varying catchability was assumed to account for potential increases in catchability. A higher weight was given to the Japanese biomass survey estimates than to Members' CPUEs in B1 while comparable weights were given to the Japanese biomass survey estimates and the joint CPUEs in B2. The CPUE data were modeled as nonlinear indices of biomass. Members used similar approaches with some differences in the assumption of the time-varying catchability and prior distributions for the free parameters in the model.

3.1 Bayesian state-space production model

The population dynamics is modelled by the following equations:

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

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

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

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

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

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

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 Member-specific differences in preferred assumptions for the prior distributions for the free parameters. MCMC methods were employed for simulating the posterior distributions. For the assumptions of uniform priors used in China and Japan, see documents NPFC-2024-SSC PS14-WP10 and NPFC-2024-SSC PS14-WP11; for the non-uniform priors used in Chinese Taipei, see document NPFC-2024-SSC PS14-WP09.

3.2 Agreed scenarios

Table 1. Definition of scenarios

	Base case (NB1)	**Base case (NB2)**	**Sensitivity case (NS1)**	**Sensitivity case (NS2)**
Initial year	1980	1980	1980	1980
Biomass survey	$I_{t,bio} = q_{bio}\ B_t e^{v_{t,bio}}$ $v_{t,bio} \sim N\left(0, cv_{t,bio}^2 + \sigma^2\right)$ q_{bio} ~ U(0,1) (2003-2024)	Same as left	Same as left	Same as left
CPUE	CHN(2013-2023) JPN_late(1994-2023) KOR(2001-2023) RUS(1994-2023) CT(2001-2011, 2012-2023) $I_{t,f} = q_f B_t^b e^{v_{t,f}}$ $v_{t,f} \sim N(0, \sigma_f^2)$ $\sigma_f^2 = c \cdot (ave(cv_{t,bio}^2) + \sigma^2)$, where $ave(cv_{t,bio}^2)$ is computed except for 2020 survey (c = 5)	Joint CPUE (1994-2023) $I_{t,joint} = q_{joint} B_t^b e^{v_{t,joint}}$ $v_{t,joint} \sim N(0, cv_{t,joint}^2 + \sigma^2)$	CHN(2013-2023) JPN_early(1980-1993, time-varying *q*) JPN_late(1994-2023) KOR(2001-2023) RUS(1994-2023) CT(2001-2011, 2012-2023) $I_{t,f} = q_f B_t^b e^{v_{t,f}}$ $v_{t,f} \sim N(0, \sigma_f^2)$ $\sigma_f^2 = c \cdot (ave(cv_{t,bio}^2) + \sigma^2)$, where $ave(cv_{t,bio}^2)$ is computed except for 2020 survey (c = 6)	JPN_early(1980-1993, time-varying *q*) $I_{t,JE} = q_{t,JE} B_t^b e^{v_{t,JE}}$ $v_{t,JE} \sim N(0, \sigma_{JE}^2)$ $\sigma_{JE}^2 = c\ ave(cv_{t,joint}^2 + \sigma^2)$ Joint CPUE (1994-2023) $I_{t,joint} = q_{joint} B_t^b e^{v_{t,joint}}$ $v_{t,joint} \sim N(0, cv_{t,joint}^2 + \sigma^2)$
Hyper-depletion / stability	A common parameter for all fisheries with a prior distribution, *b* ~ *U*(0, 1)	*b* ~ *U* (0, 1)	A common parameter for all fisheries but JPN_early, with a prior distribution, *b* ~ *U*(0, 1) [*b* for JPN_early is fixed at 1]	*b* ~ *U* (0, 1) for joint CPUE. [*b* for JPN_early is fixed at 1]
Prior for other than q_{bio}	Own preferred options	Own preferred options	Own preferred options	Own preferred options

Table 2. Description of symbols used in the stock assessment

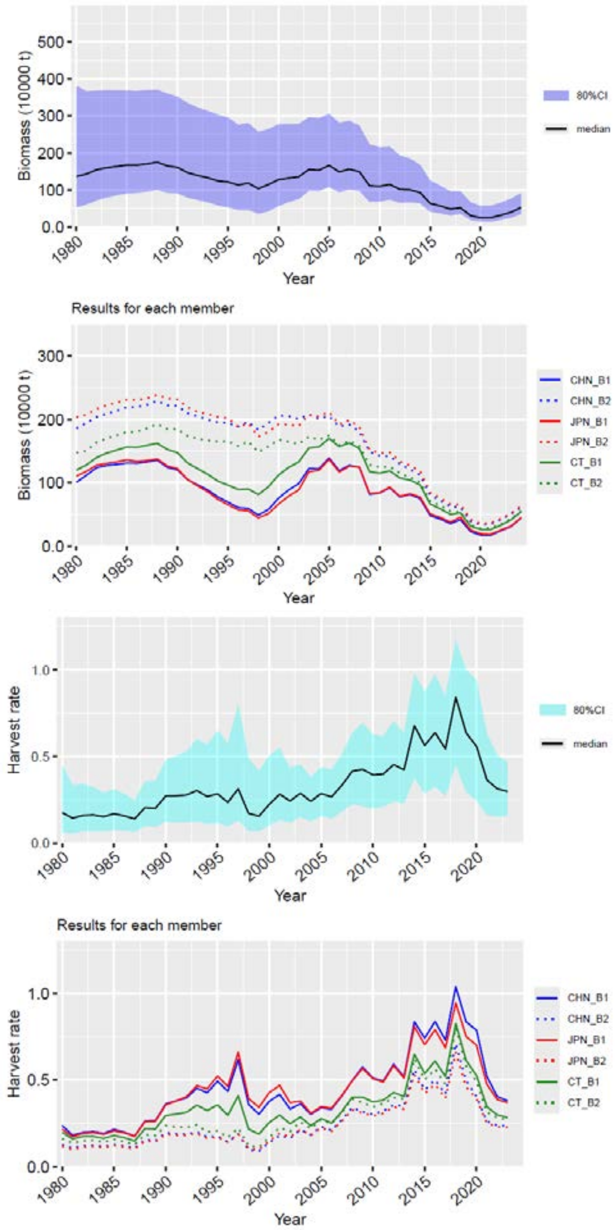
Symbol	Description
C_{2023}	Catch in 2023
$AveC_{2021\text{-}2023}$	Average catch for a recent period (2021–2023)
$AveF_{2021\text{-}2023}$	Average harvest rate for a recent period (2021–2023)
F_{2023}	Harvest rate in 2023
F_{MSY}	Annual harvest rate producing the maximum sustainable yield (MSY)
MSY	Equilibrium yield at F_{MSY}
F_{2023}/F_{MSY}	Average harvest rate in 2023 relative to F_{MSY}
$AveF_{2021\text{-}2023}/F_{MSY}$	Average harvest rate for a recent period (2021–2023) relative to F_{MSY}
K	Equilibrium unexploited biomass (carrying capacity)
B_{2023}	Stock biomass in 2023 estimated in the model
B_{2024}	Stock biomass in 2024 estimated in the model
$AveB_{2022\text{-}2024}$	Stock biomass for a recent period (2022–2024) 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_{2023}/K	Stock biomass in 2023 relative to K[a]
B_{2024}/K	Stock biomass in 2024 relative to K[a]
$B_{2022\text{-}2024}/K$	Stock biomass in the latest time period (2022-2024) relative to the equilibrium unexploited stock biomass[a]
B_{2023}/B_{MSY}	Stock biomass in 2023 relative to B_{MSY} [a]
B_{2024}/B_{MSY}	Stock biomass in 2024 relative to B_{MSY} [a]
$B_{2022\text{-}2024}/B_{MSY}$	Stock biomass for a recent period (2022–2024) relative to the stock biomass that produces maximum sustainable yield (MSY) [a]

[a]calculated as the average of the ratios.

4. SOME AGGREGATED RESULTS FOR VISUALIZATION PURPOSE

4.1 Visual presentation of results

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



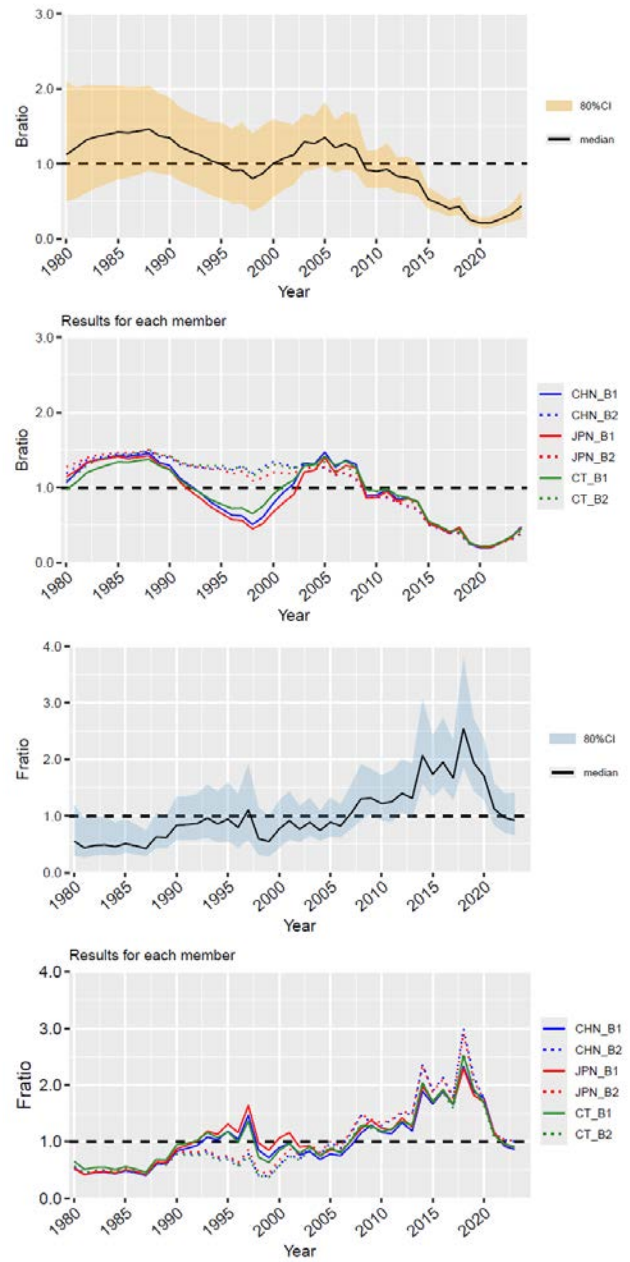


Figure 3. Time series of median estimated values of six runs for biomass, harvest rate, B-ratio, F-ratio and depletion level relative to K. The solid and shaded lines correspond to B1 and B2, respectively.

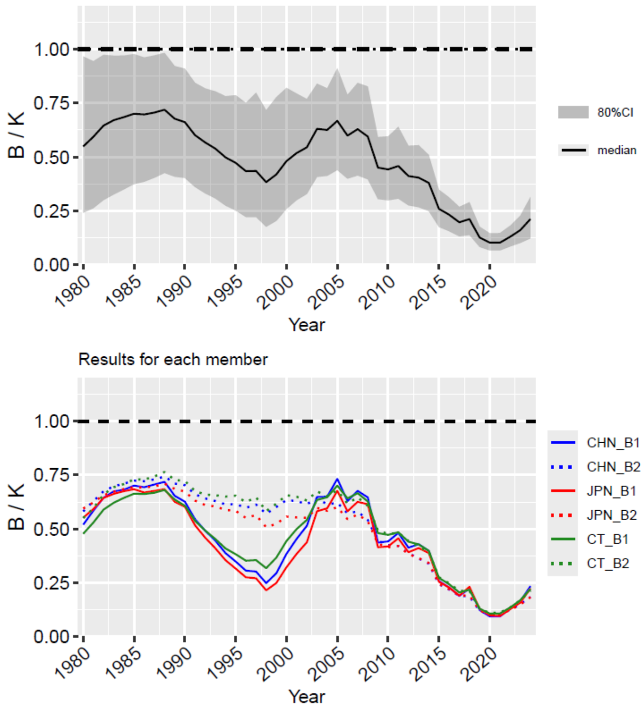


Figure 3 (Continued).

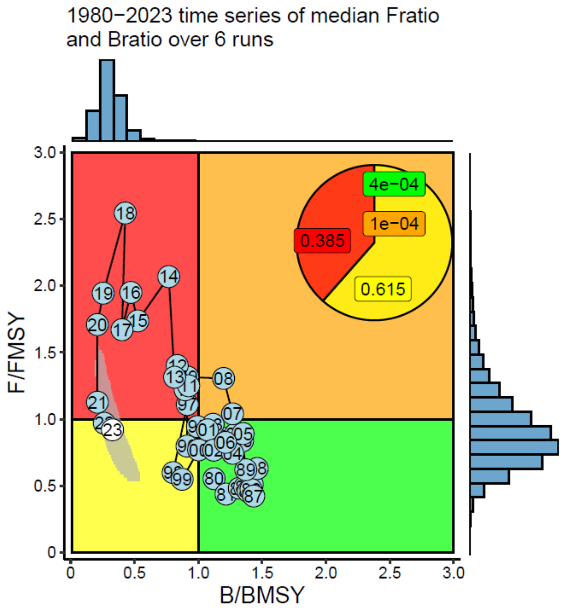


Figure 4. Kobe plot with time trajectory. The data are aggregated across 6 model results (2 base-case models by 3 Members).

4.2 Summary table

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

	Median	Lower10%	Upper10%	Median_CHN	Median_JPN	Median_CT
C_2023 (10000 t)	11.836	11.836	11.836	11.836	11.836	11.836
AveC_2021_2023	10.352	10.352	10.352	10.352	10.352	10.352
AveF_2021_2023	0.328	0.158	0.528	0.352	0.339	0.302
F_2023	0.297	0.155	0.469	0.313	0.307	0.277
FMSY	0.330	0.139	0.543	0.357	0.336	0.310
MSY (10000 t)	39.440	32.021	47.010	40.155	39.284	39.010
F_2023/FMSY	0.920	0.656	1.411	0.915	0.942	0.903
AveF_2021_2023/FMSY	1.008	0.755	1.435	1.013	1.026	0.988
K (10000 t)	248.067	151.766	565.726	234.100	253.396	254.500
B_2023 (10000 t)	39.875	25.214	76.394	37.830	38.599	42.720
B_2024 (10000 t)	52.763	35.130	91.631	50.920	52.120	55.155
AveB_2022_2024	41.563	27.387	77.406	39.705	40.555	44.165
BMSY (10000 t)	120.100	78.060	253.481	113.800	119.008	125.100
BMSY/K	0.485	0.392	0.604	0.480	0.471	0.505
B_2023/K	0.161	0.101	0.228	0.158	0.154	0.169
B_2024/K	0.212	0.122	0.315	0.212	0.206	0.219
AveB_2022_2024/K	0.169	0.106	0.236	0.168	0.163	0.175
B_2023/BMSY	0.328	0.225	0.452	0.323	0.322	0.339
B_2024/BMSY	0.435	0.270	0.628	0.433	0.431	0.440
AveB_2022_2024/BMSY	0.345	0.235	0.470	0.341	0.341	0.352

5. CONCLUDING REMARKS

See the Executive Summary.

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Appendix 1

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

Year	Total catch (metric tons)	Biomass JPN (VAST, 1000 metric tons)	CV (%)	CPUE CHN (metric tons/ vessel/ day)	CPUE JPN_early (metric tons/ net haul)	CPUE JPN_late (metric tons/ net haul)	CPUE KOR (metric tons/ vessel/ day)	CPUE RUS (metric tons/ vessel/ day)	CPUE CT_early (metric tons/ net haul)	CPUE CT_late (metric tons/ net haul)	Joint CPUE (VAST)	CV (%)
1980	238510				0.72							
1981	204263				0.63							
1982	244700				0.46							
1983	257861				0.87							
1984	247044				0.81							
1985	281860				1.4							
1986	260455				1.13							
1987	235510				0.97							
1988	356989				2.36							
1989	330592				3.06							
1990	435869				1.95							
1991	399017				3.13							
1992	383999				4.32							
1993	402185				3.25							
1994	332509					4.08		0.747			1.720	0.37
1995	343743					2.10		0.869			1.882	0.37
1996	266424					1.79		0.646			0.786	0.37
1997	370017					3.49		0.501			2.112	0.37
1998	176364					1.05		0.501			0.688	0.41
1999	176498					0.90		0.568			0.688	0.39
2000	286186					1.28		0.822			0.921	0.36
2001	370823					1.65	8.51	0.947	1.44		0.792	0.31
2002	328362					1.11	14.28	1.172	1.33		0.679	0.30
2003	444642	990.8	25.7			2.03	16.80	1.526	2.47		1.272	0.29
2004	369400	879.4	21.3			2.69	12.23	2.914	1.24		1.109	0.29
2005	473907	1064.5	30.4			4.39	19.94	2.963	2.27		1.700	0.27
2006	394093	786.1	30.1			4.53	9.86	1.975	1.00		0.768	0.25

2007	520207	906.3	32.4			4.19	8.54	2.231	2.17		1.285	0.27
2008	617509	1055.6	29.1			5.15	18.70	2.083	2.79		1.742	0.26
2009	472177	433.2	20.7			4.15	10.27	1.175	1.29		1.019	0.28
2010	429808	561.7	28.3			1.78	10.24	1.224	1.89		0.958	0.27
2011	456263	979.3	32.9			2.48	9.61	1.467	2.09		1.235	0.29
2012	460544	439.6	19.7			2.71	10.36	1.442		2.61	1.103	0.30
2013	423790	716.7	27.8	15.63		1.89	13.90	1.407		3.50	0.883	0.27
2014	629576	466.9	22.6	12.60		3.28	19.50	1.479		3.90	1.405	0.25
2015	358883	316.9	20.6	24.81		1.67	7.90	0.652		2.19	0.817	0.28
2016	361688	261.4	26.4	6.60		1.80	11.08	1.208		1.95	0.791	0.27
2017	262640	173.4	27.6	7.06		1.12	5.54	0.525		1.91	0.862	0.27
2018	435881	406.9	28.2	17.70		1.95	13.06	1.577		2.92	1.276	0.28
2019	195251	217.0	21.3	6.29		0.69	2.86	0.558		1.40	0.451	0.22
2020	139779	11.9	99.2	4.37		0.48	2.81	0.497		1.11	0.279	0.27
2021	92117	158.7	31.1	5.85		0.32	2.89	0.141		0.65	0.283	0.29
2022	100085	290.7	22.4	3.82		0.27	1.77			0.69	0.159	0.28
2023	118355	230.0	29.4	9.37		0.30	3.18			1.43	0.335	0.33
2024		331.8	17.2									