Food and Agriculture Organization of the United Nations

NPFC

North Pacific Fisheries Commission

Pacific saury stock assessment and management in the NPFC

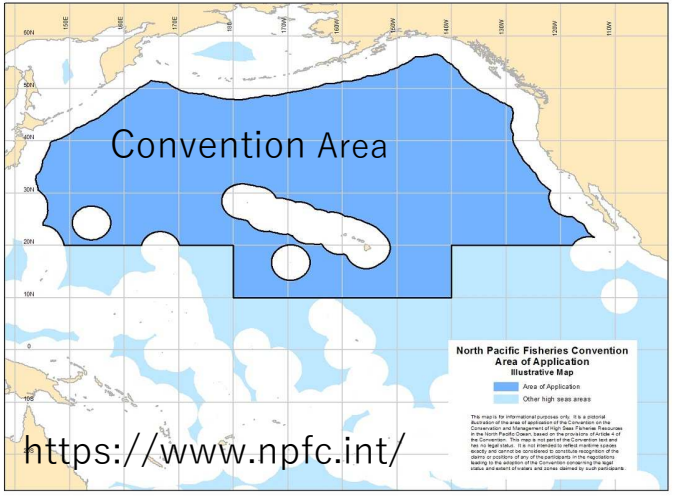
Toshihide Kitakado (Tokyo University of Marine Science and Technology)

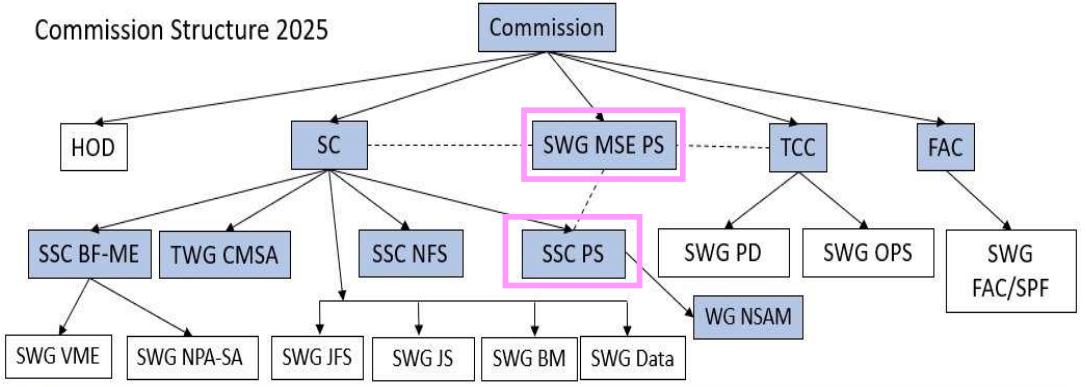
Chair of the Small Scientific Committee on Pacific Saury

Co-chair of the Small Working Group on MSE for Pacific Saury

NPFC/FAO informal workshop on science-based management options available for operationalizing the precautionary approach (Dec 10, 2025)

Background: North Pacific Fisheries Commission (NPFC)





Current members (9): Canada, China, EU, Japan, Korea, Russia, Chinese Taipei, US, Vanuatu

Current list of priority species in NPFC

- North Pacific *armorhead Pentaceros wheeleri*,
- Splendid alfonsino *Beryx splendens,*
- Sablefish *Anoplopoma fimbria*
- Skilfish *Erilepis zonifer*
- Pacific saury *Cololabis saira,*
- Neon flying squid *Ommastrephes bartramii,*
- Japanese flying squid *Todarodes pacificus,*
- Chub mackerel *Scomber japonicus,*
- Blue (spotted) mackerel *Scomber australasicus,*
- Japanese sardine *Sardinops melanostictus*.

Contents of my talk on Pacific saury

- Backgrounds on biology and fisheries of Pacific saury
- Provisional and currently developing modelling approaches for stock assessment
- Development of an interim Harvest Control Rule and its development processes
- My private answers to “Questions” addressed

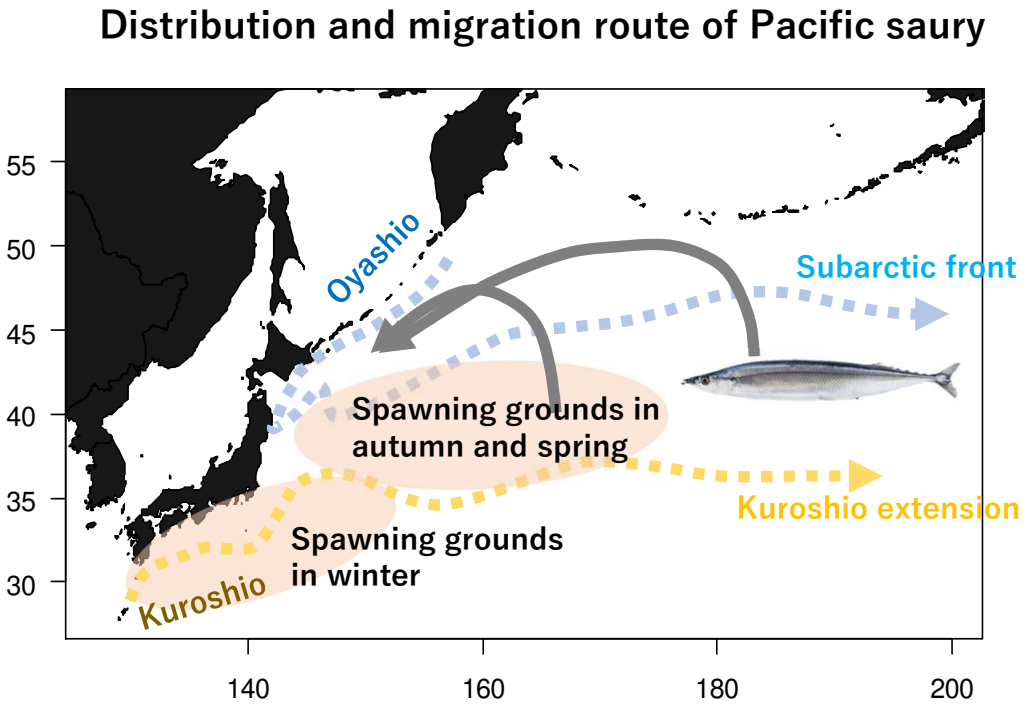
Food and Agriculture Organization of the United Nations

NPFC
North Pacific Fisheries Commission

BACKGROUNDS ON BIOLOGY AND FISHERIES OF PACIFIC SAURY

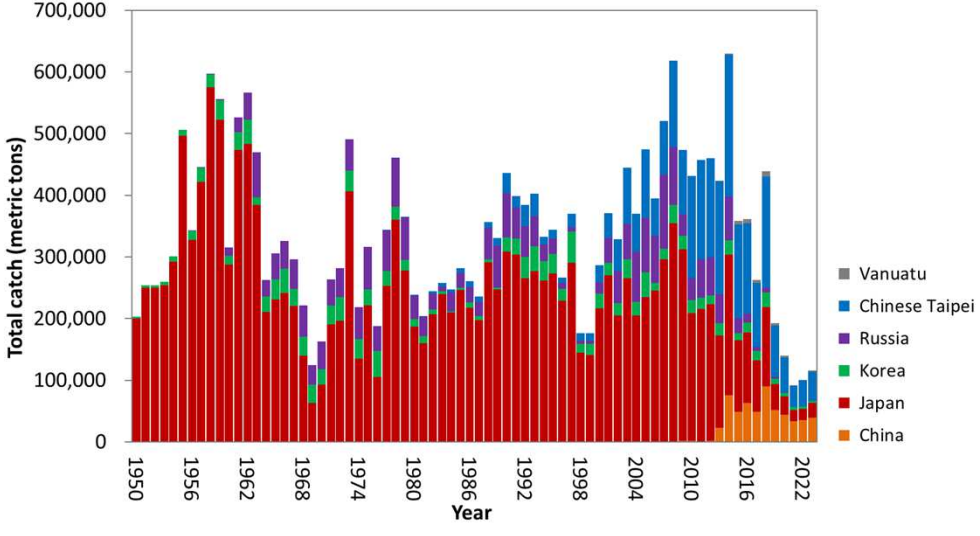
Background: biology of Pacific saury

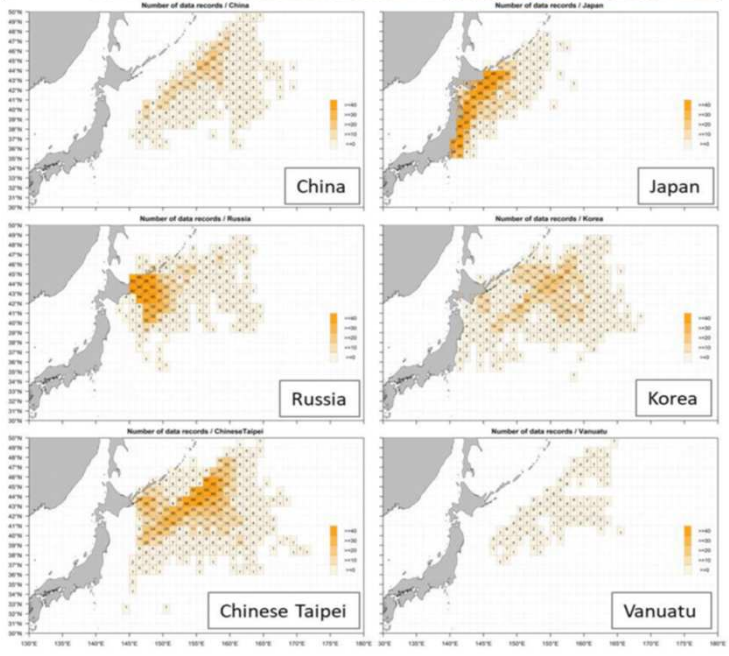
- Highly migratory species
- During summer and autumn, migrating from high seas to coastal areas for feeding zooplankton
- 2 years life span
- Some age-0 fish can contribute as spawners



Background: Fishery for Pacific saury

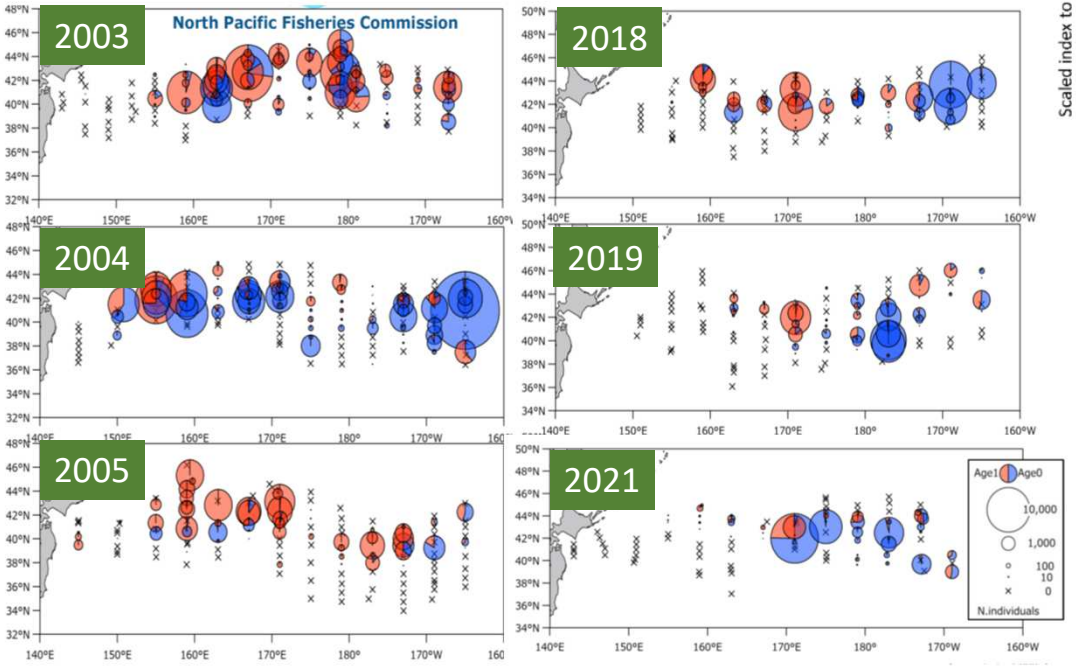
- Stick-held dip net (with fishing lamp)
- Historically, utilized mainly by Japan in its EEZ
- Recently fishery in high seas, too
- Catch has been declining recently

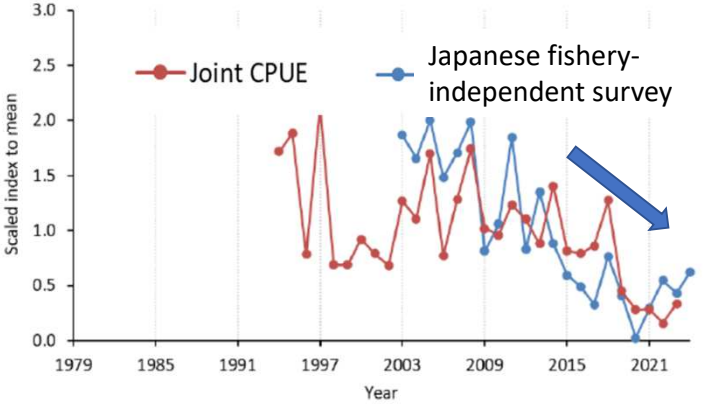


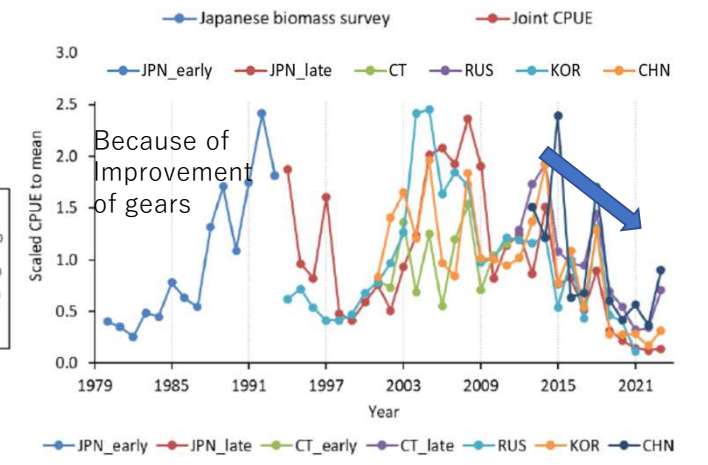


Background: Fishery for Pacific saury

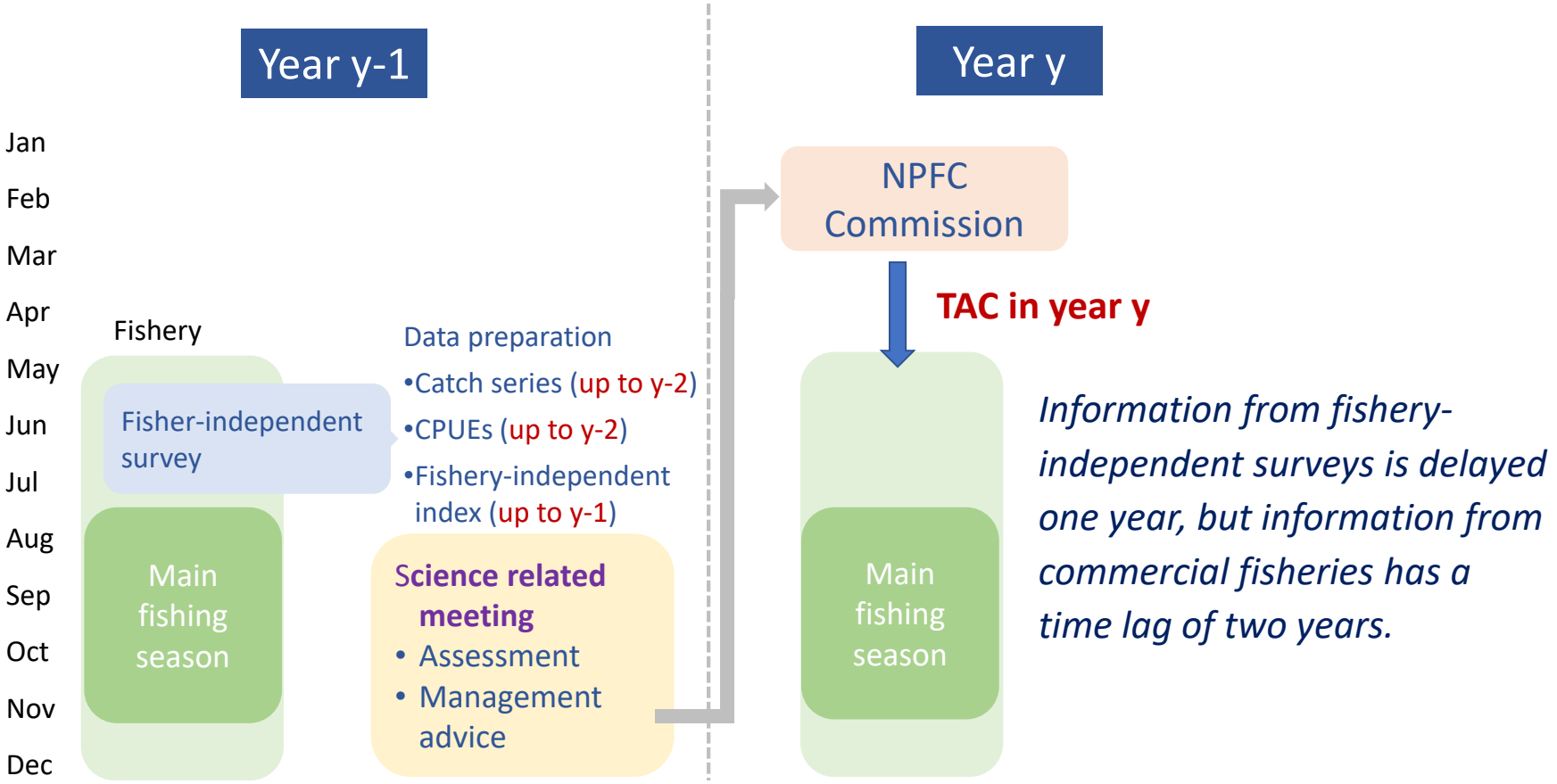
Japan's pre-fishery survey from June to July since 2003







Background: Annual schedule of the NPFC



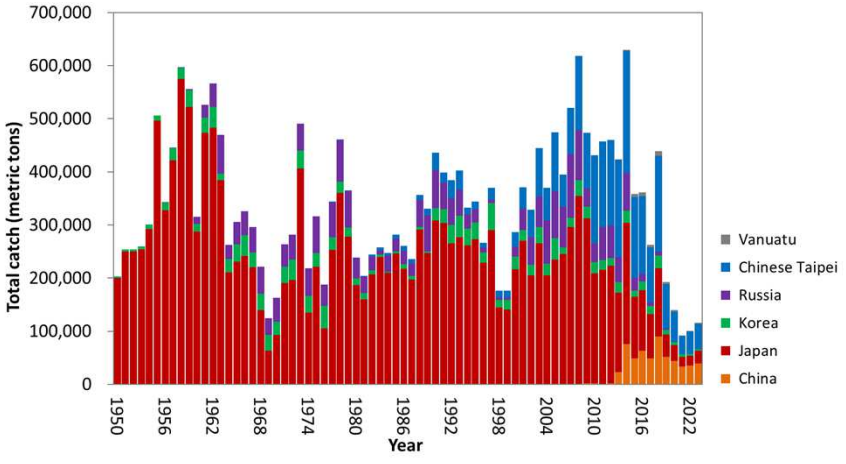
Food and Agriculture Organization of the United Nations

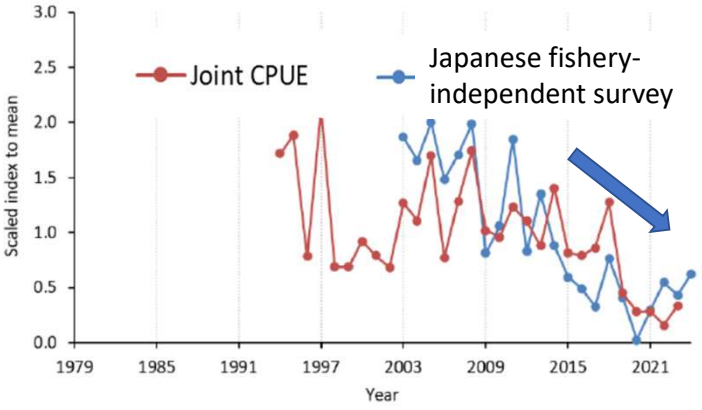
NPFC
North Pacific Fisheries Commission

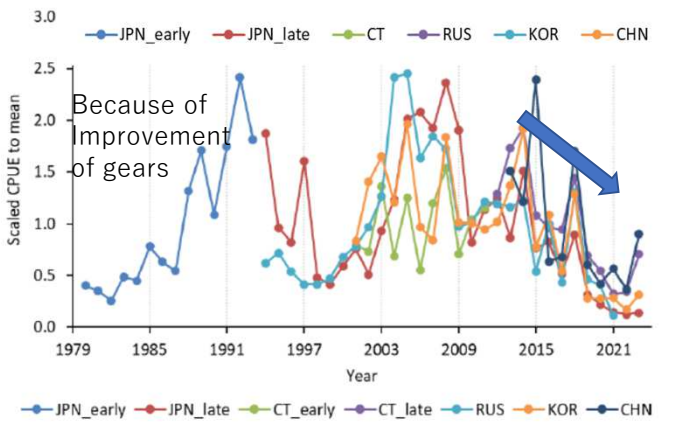
PROVISIONAL AND CURRENTLY DEVELOPING MODELLING APPROACHES FOR STOCK ASSESSMENT

Background: Fishery-independent and dependent indices for Pacific saury

- Time series of total catch
- Time series of fishery-independent abundance index
- Time series of fishery-dependent abundance indices
  - Each member's CPUE
  - Joint CPUE





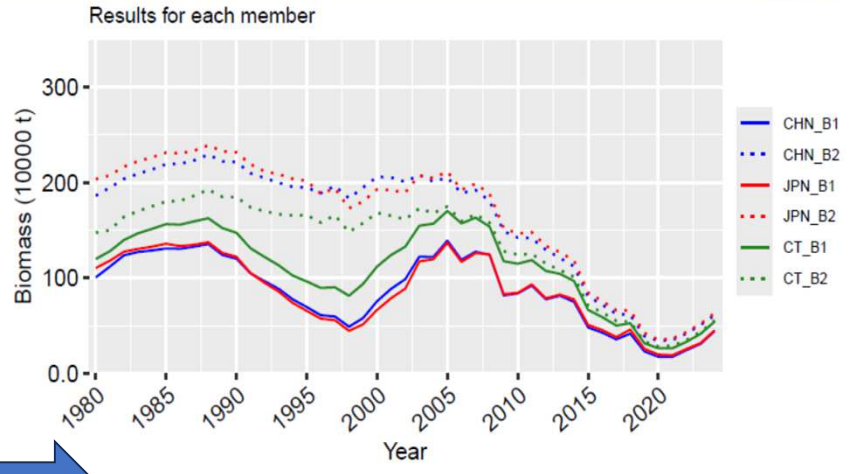


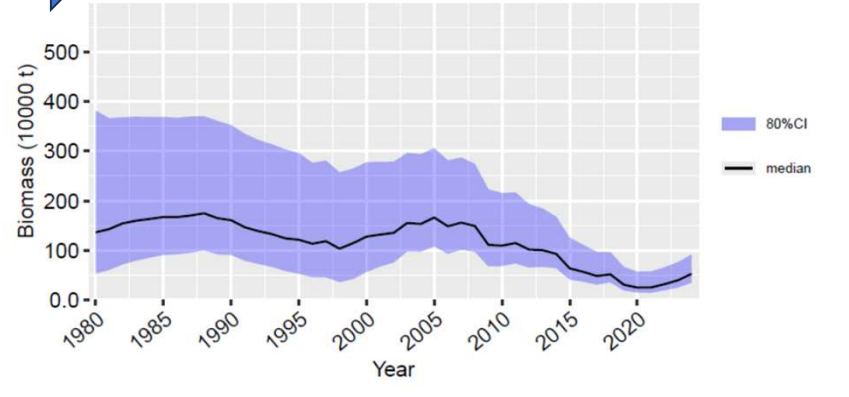
Specification of an interim stock assessment model

Bayesian state-space surplus production model

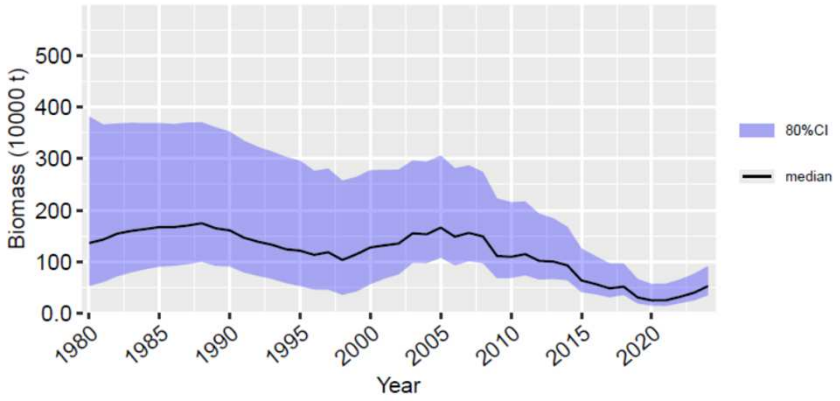
$$B_{t+1} = \left[B_t + r \cdot B_t \cdot \left[1 - \left(\frac{B_t}{K}\right)^z\right] - C_t\right] \cdot e^{u_t}, \qquad u_t \sim N(0, \tau^2$$

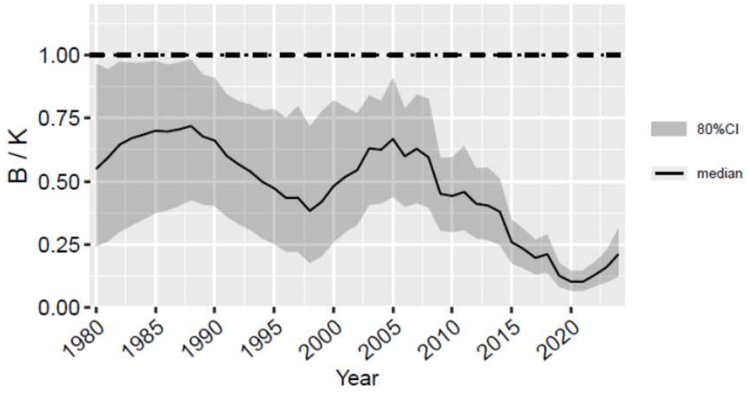
	Base case (B1)	Base case (B2)
Initial year	1980	1980
Biomass survey	$I_{t,bio} = q_{bio}\, B_t e^{v_{t,bio}}$ $v_{t,bio} \sim N\left(0, cv_{t,bio}^2 + \sigma^2\right)$ $q_{bio} \sim U(0,1)$ (2003-2024)	Same as left
CPUE	CHN(2013-2023) JPN_late(1994-2023) KOR(2001-2023) RUS(1994-2021) CT(2001-2011, 2012-2023) $I_{t,f} = q_f B_t^b e^{v_{t,f}}, \quad v_{t,f} \sim N(0, \sigma_f^2)$ $\sigma_f^2 = c \cdot \left(ave\left(cv_{t,bio}^2\right) + \sigma^2\right)$ c=5 $ave\left(cv_{t,bio}^2\right)$ is computed except for 2020 survey	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)
Prior for other than q_{bio}	Own preferred options	Own preferred options

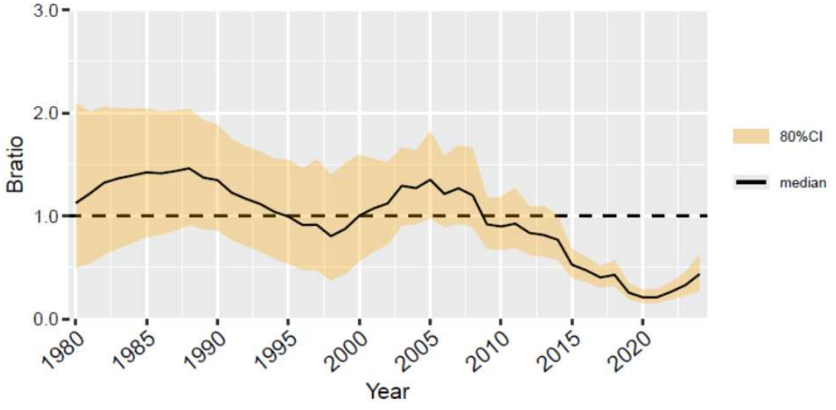


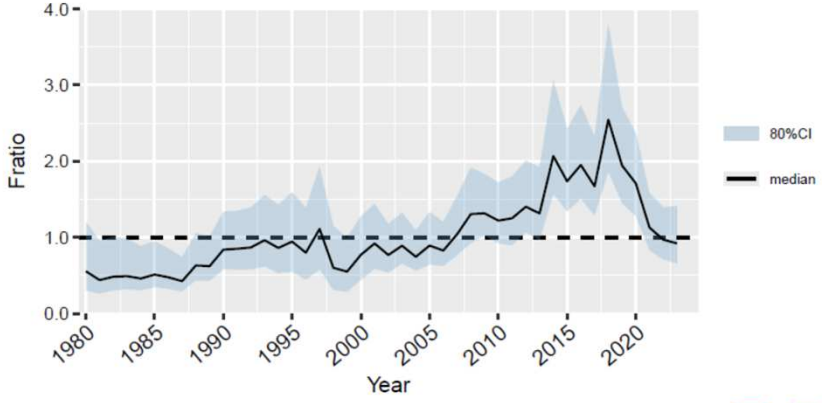


Combined and separate results of 2024 assessments



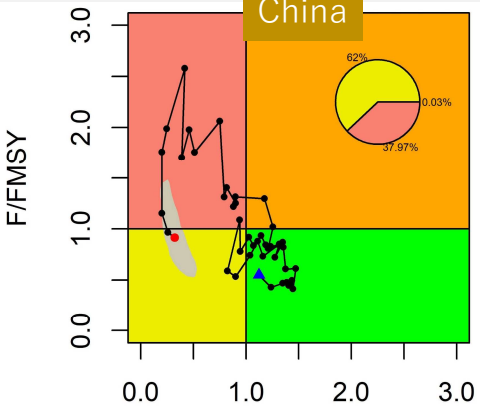




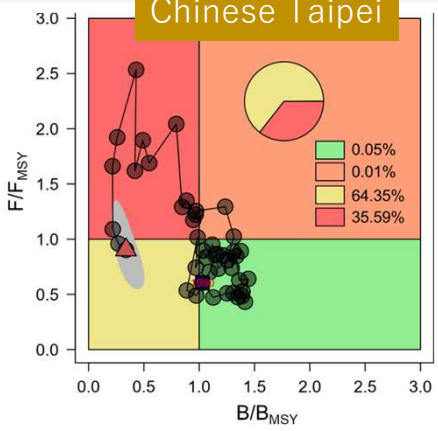


Separate and combined Kobe plots of 2024 assessments

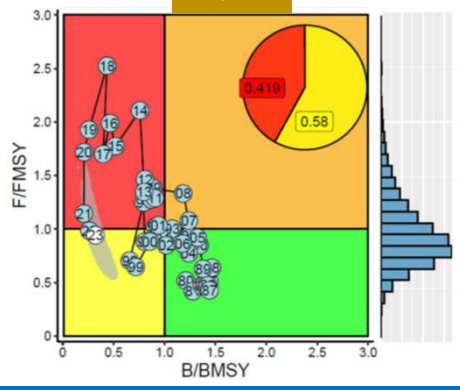
China



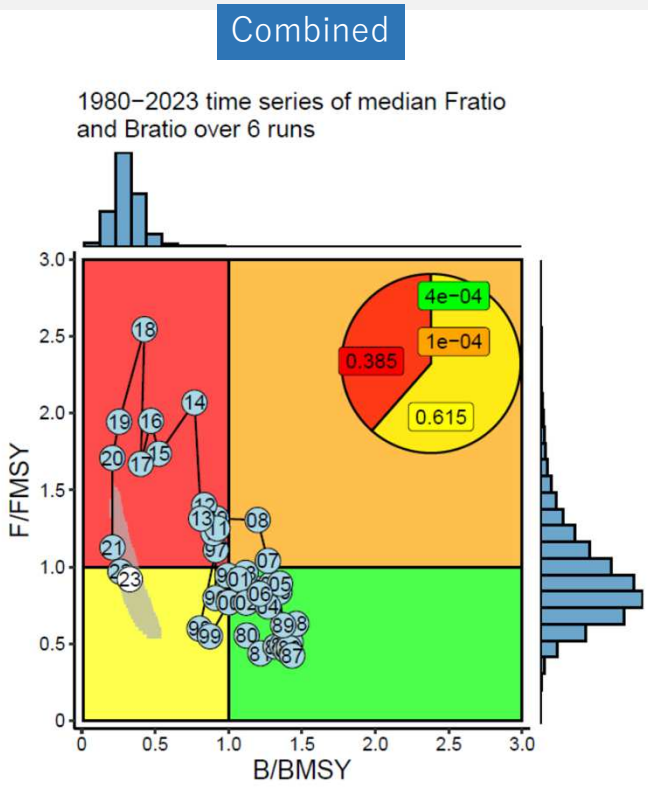
Chinese Taipei



Japan



Combined



New stock assessment models

- Age-structured models (Ages 0 and 1)
- Consideration of different fisheries impact over Members' fisheries
- Consideration of continuous spawning seasons over 9 months
- Stochastic stock-recruitment relationship
- Stock Synthesis 3 (SS3)

- No geographical configuration including migration patterns

Food and Agriculture Organization of the United Nations

North Pacific Fisheries Commission

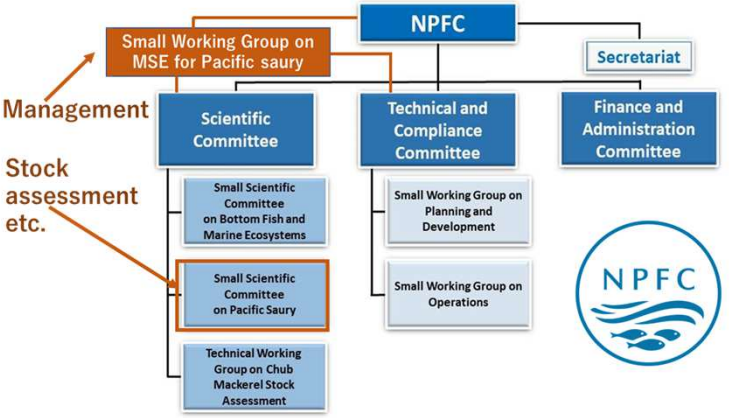
DEVELOPMENT OF AN INTERIM HARVEST CONTROL RULE AND ITS DEVELOPMENT PROCESSES

Objectives stipulated in ToR of SWG MSE PS

Short-Term Objectives: within one to two years (completed in April 2024) :

a) **develop draft interim management objectives** and a **draft interim harvest control rule (HCR)** that meets such objectives to report to the Commission (preferably before the 8th Commission annual meeting); and

b) **evaluate the robustness of the draft interim harvest control rule** with consideration of possible uncertainties including effects of climate changes.



Mid-Term Objectives: within three to five years:

a) develop **draft mid- to long-term management objectives** by setting the **target and limit reference points** for the population status as well as by defining “overfishing” and “overfished” for the sustainable use of the Pacific saury stock;

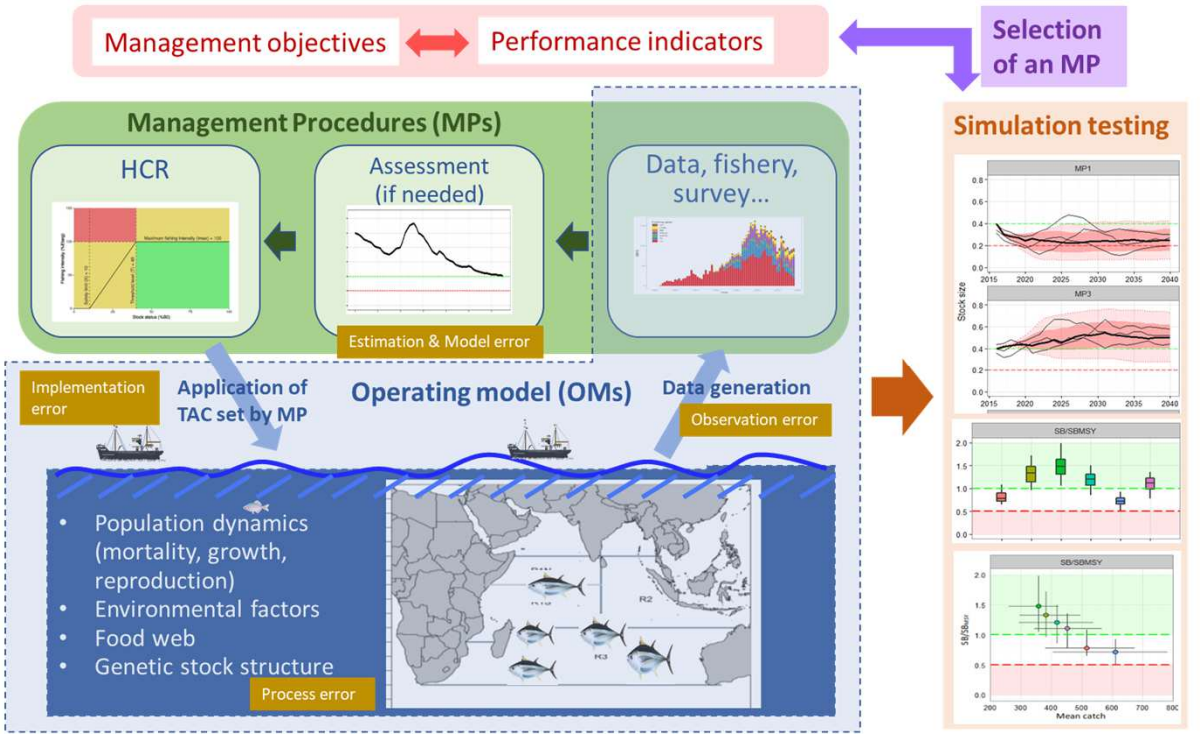
b) assess the feasibility of establishing a **management procedure through an MSE**

MSE (Management Strategy Evaluation) in nutshell

"an evaluation process of candidate management procedures for achieving stated management objectives through stochastic simulations" (DS Butterworth)

MSE Process

1. Identification of **Management objectives** and **performance indicators**
2. Development of **Management Procedures (MPs)**
3. Development of **Operating Models (OMs)**
4. **Simulation testing** of MPs with the OMs
5. **Selection of an MP** based on simulation performance
6. **Implementation of the MP**



Management objectives

(a) Recovery of the stock (prioritized objective):

i. The stock status is recovered above B_{tar} within 5 years with 50% probability;

ii. The stock status is maintained above the B_{tar} level in each of years 6-10 with 50% probability.

(b) Avoiding unsustainable state of the stock (secondary objective):

i. The annual probability in each of years 6-10 that the stock drops below B_{lim} should not exceed 10%;

ii. The annual probability in each of years 6-10 that fishing mortality is above F_{lim} should not exceed 10%.

(c) Achieving high and stable catch (tertiary objective):

i. Average catch over years 6-10 is as high as possible;

ii. Catch in each of years 6-10 is as stable as possible.

Reference point	Default value	Potential range
$B_{tar} = c*B_{MSY}$	c = 1	c = 0.8 – 1.2
$B_{lim} = c*B_{MSY}$	c = 0.35	c = 0.2 – 0.5
$F_{tar} = c*F_{MSY}$	c = 1	c = 0.8 – 1.2
$F_{lim} = c*F_{MSY}$	c = 1.35	c = 1.2 – 1.5

Note: Any numerical specification such as probabilities and target years stated in the objectives above may require adjustment after the simulation is carried out if none of the evaluated HCRs can meet the management objectives.

2. Operating models (OMs)

- **Short-Term Objectives: within 1-2 years:** develop a **draft interim MP**

[Option A] Use the **current interim stock assessment model (BSSPM)** with consideration of uncertainties in estimated parameters and process errors as the basis.
The model can be extended through accounting for some changes in environmental conditions and/or auto-correlation in the process error terms or incorporating stochastic variation into key parameters (r and/or K).

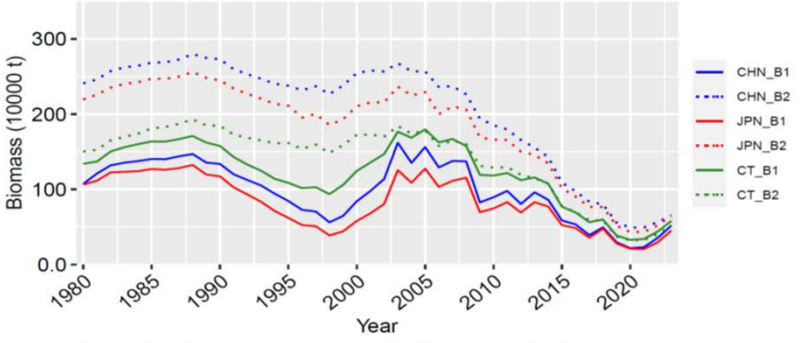
- **Mid-Term Objectives: within 3-5 years:** Establish a **MP through an MSE**

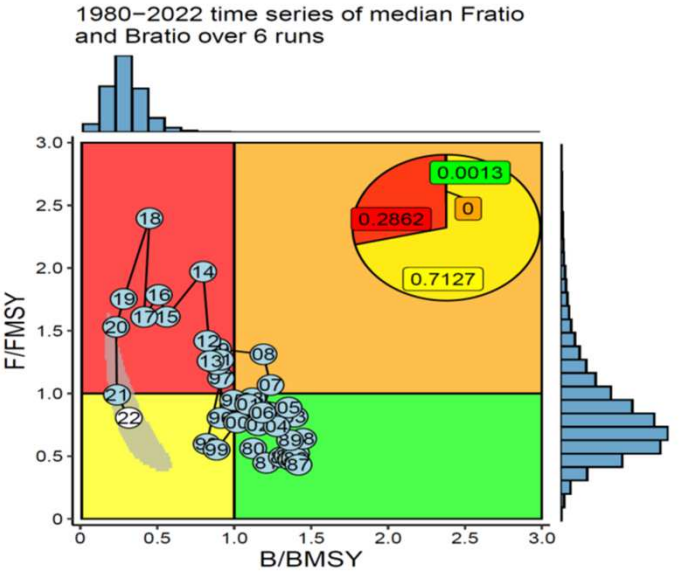
[Option B] Use an **age-structured model** with consideration of uncertainties in estimated and key input parameters (natural mortality and steepness) as well as recruitment process errors.

[Option C] Possible to consider further **complicated models to account for migration patterns and difference in space and time** in Member's fishing operations.

Operating Models (OMs)

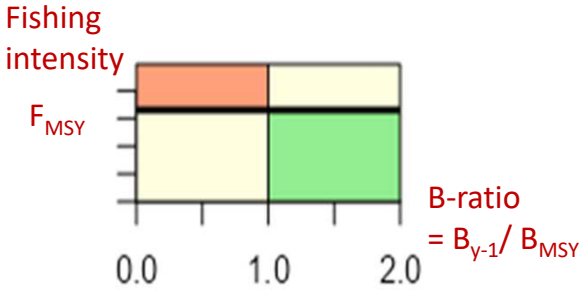
[Option A] Use the **current interim stock assessment model (BSSPM)** with consideration of uncertainties in estimated parameters and process errors as the basis. The model can be extended through accounting for some changes in environmental conditions and/or auto-correlation in the process error terms or incorporating stochastic variation into key parameters





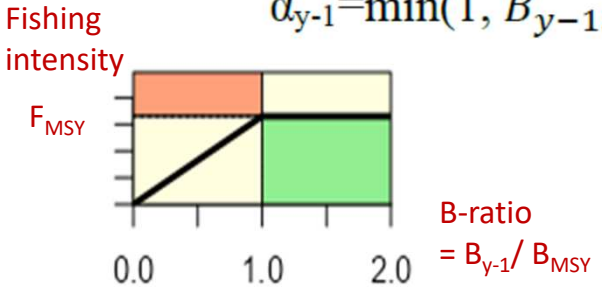
Final 4 selected options

HCR0: $TAC_y = F_{MSY} * B_{y-1}$



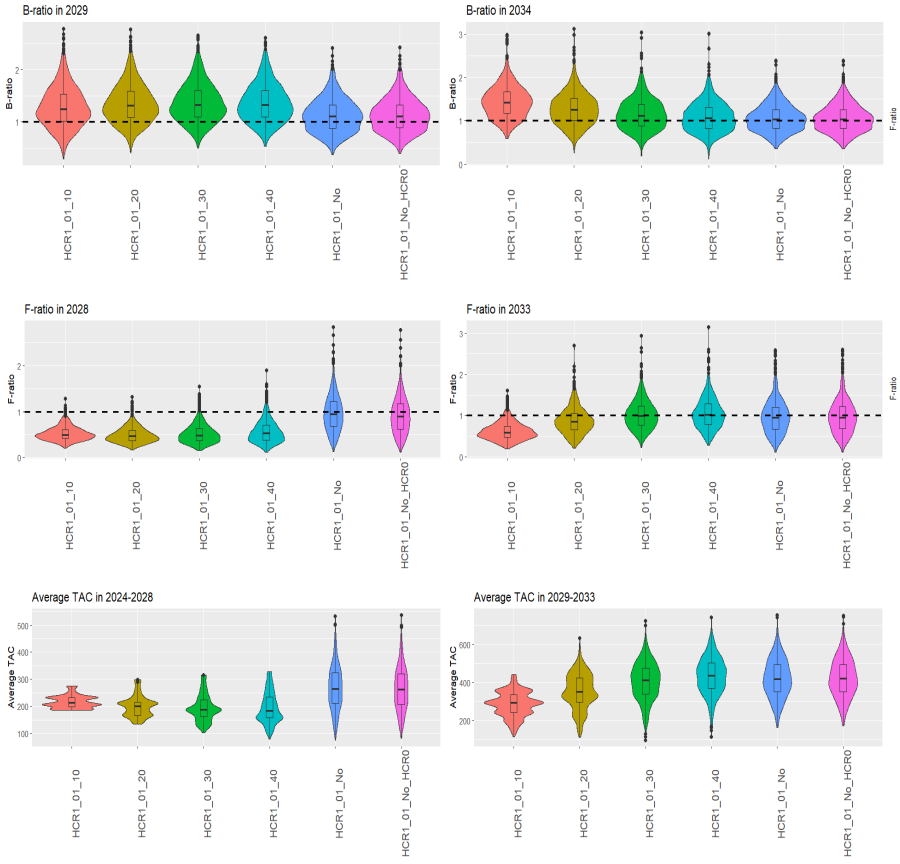
HCR1: $TAC_y = \alpha_{y-1} * F_{MSY} * B_{y-1}$

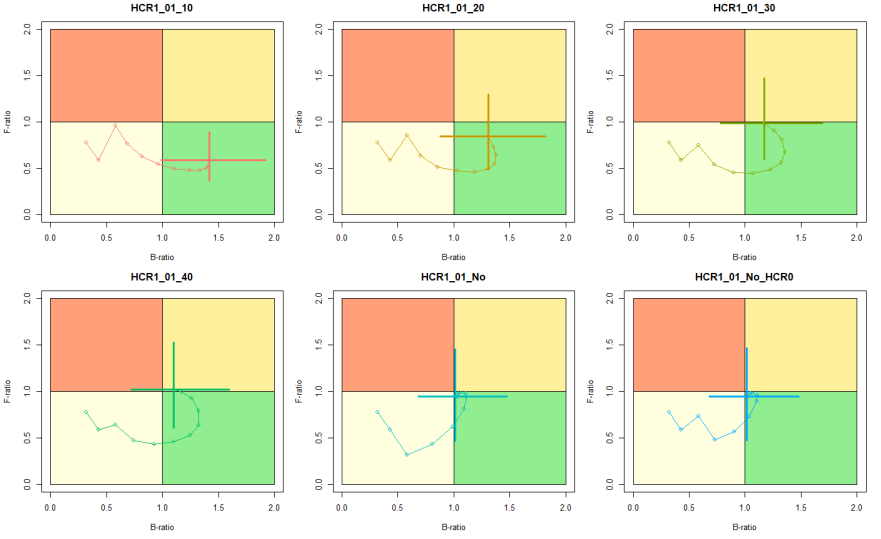
$\alpha_{y-1} = \min(1, B_{y-1}/B_{MSY})$



- **HCR1_10% (MAC=10%)**
- **HCR1_20% (MAC=20%)**
- **HCR1_30% (MAC=30%)**
- **HCR1_40% (MAC=40%)**
- **HCR1_no_HCR0 (no constraint)**
- **HCR1_no_HCR0 (no constraint with HCR0 application in 2024)**

Results of initial runs => Revision of options => Final set of options

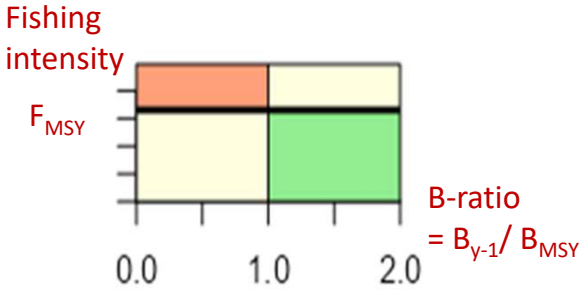




Finally, the SWG selected the 4 different types of HCR.

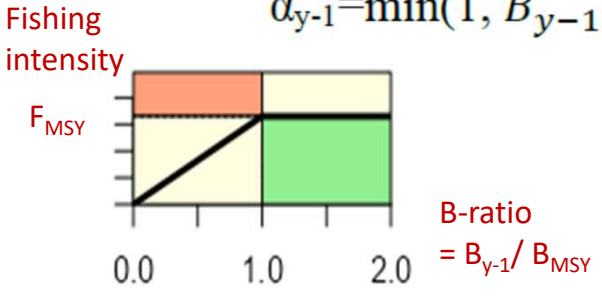
Final 4 selected options

HCR0: $TAC_y = F_{MSY} * B_{y-1}$



HCR1: $TAC_y = \alpha_{y-1} * F_{MSY} * B_{y-1}$

$\alpha_{y-1} = \min(1, B_{y-1}/B_{MSY})$



- HCR1_10% (MAC=10%)
- HCR1_20% (MAC=20%)
- HCR1_30% (MAC=30%)
- HCR1_40% (MAC=40%)
- HCR1_no_HCR0 (no constraint)
- HCR1_no_HCR0 (no constraint with HCR0 application in 2024)

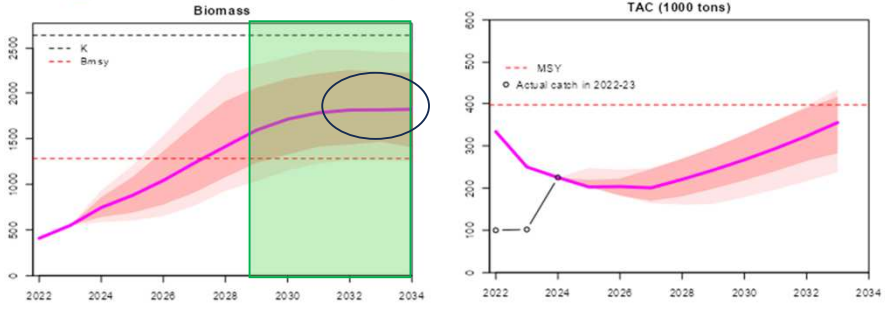
Primary objective

(a) Recovery of the stock (prioritized objective):

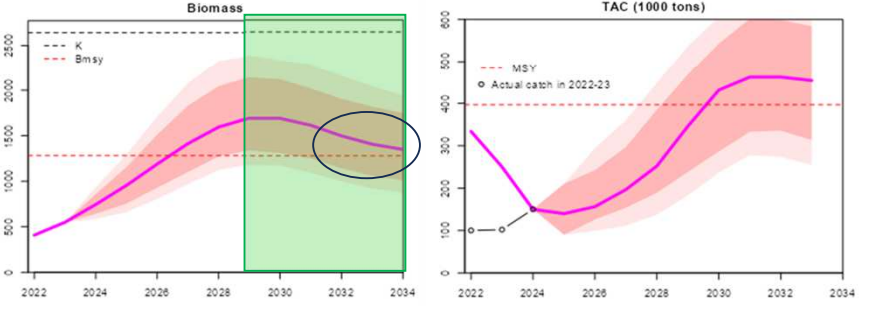
i. The stock status is recovered above B_{tar} within 5 years with 50% probability;

ii. The stock status is maintained above the B_{tar} level in each of years 6-10 with 50% probability.

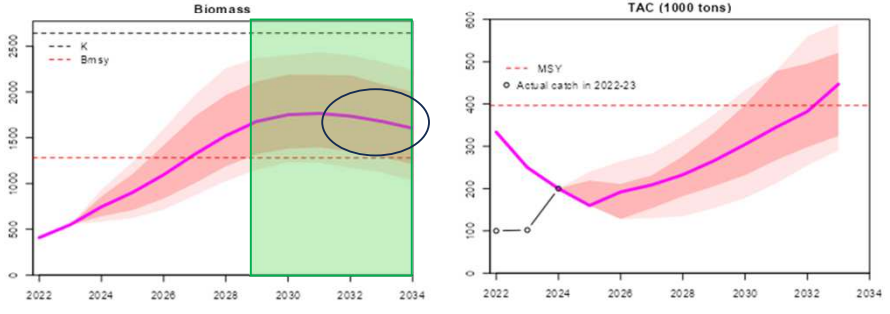
HCR1_10%



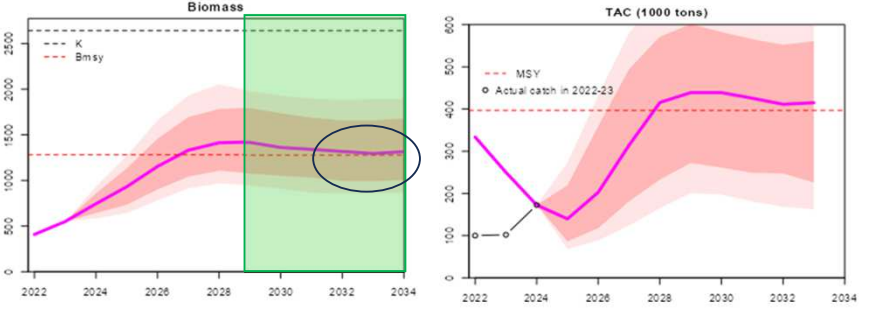
HCR1_40%



HCR1_20%



HCR1_No_HCR0



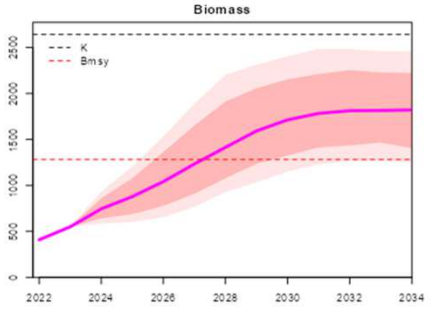
Tertiary objective

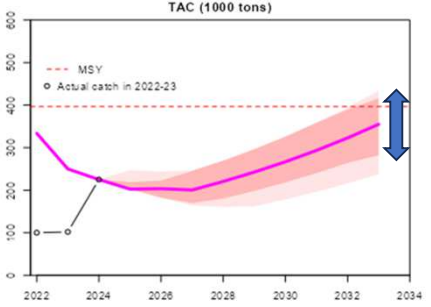
(c) Achieving high and stable catch (tertiary objective):

i. Average catch over years 6-10 is as high as possible;

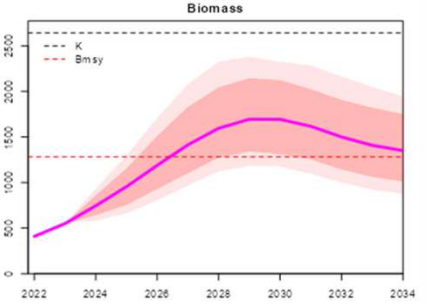
ii. Catch in each of years 6-10 is as stable as possible.

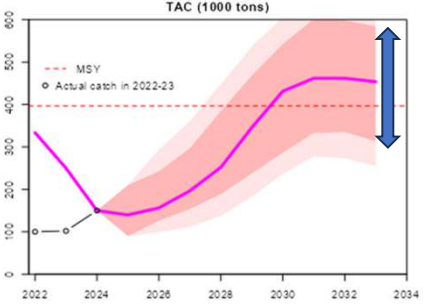
HCR1_10%



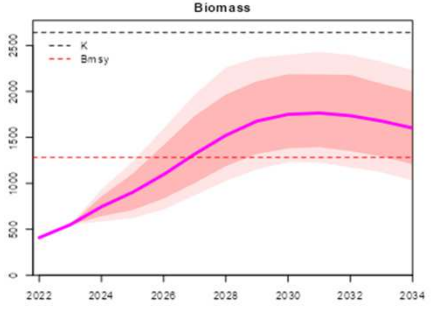


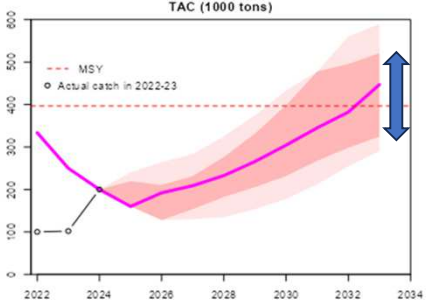
HCR1_40%



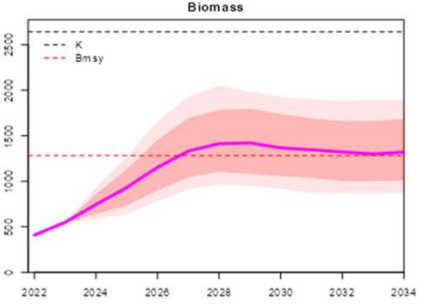


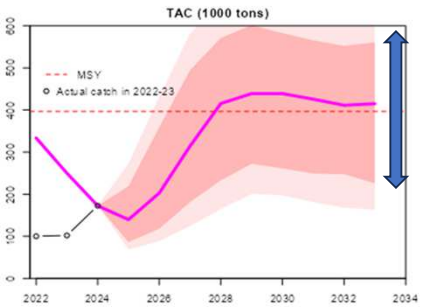
HCR1_20%





HCR1_No_HCR0

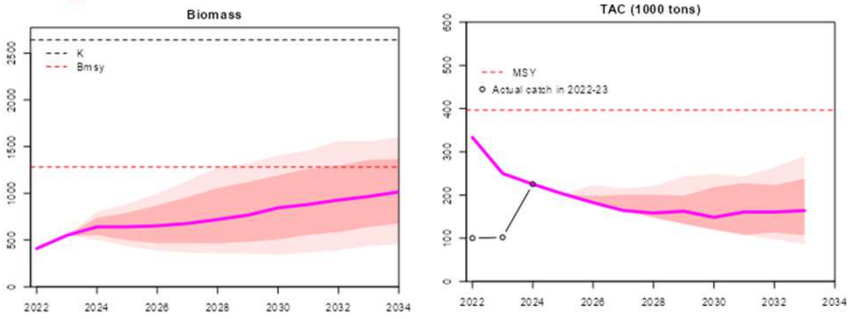




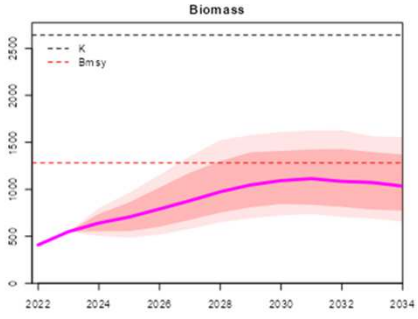
Simulation trajectories of biomass and TAC (robustness case)

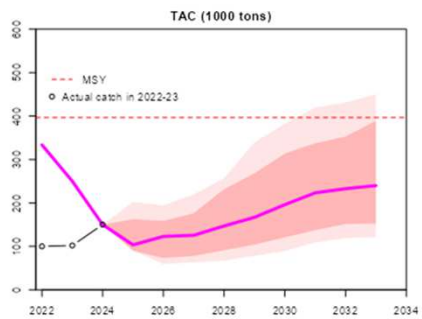
- Climate changes causes **negative** effects on productivity

HCR1_10%

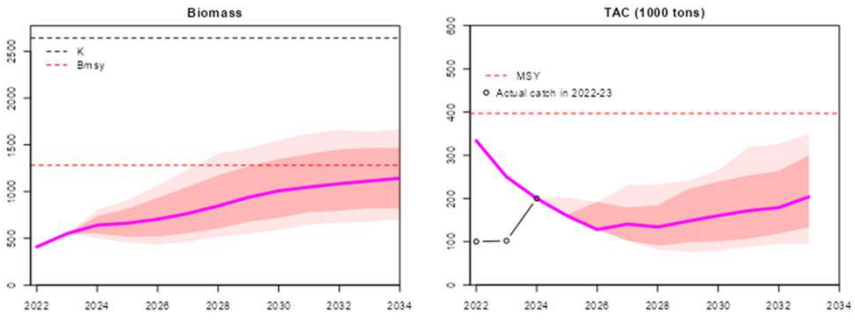


HCR1_40%

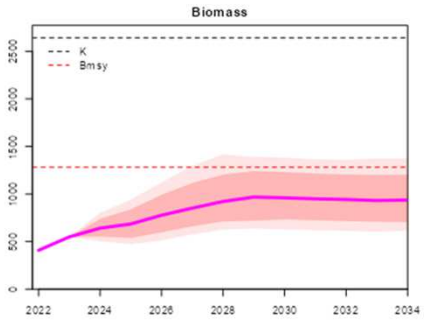


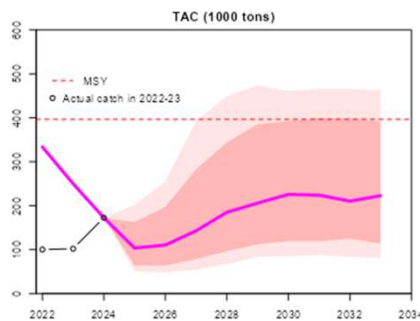


HCR1_20%



HCR1_No_HCR0





Item	HCR1_10%	HCR1_20%	HCR1_40%	HCR1_No_HCR0
(a)-i Stock recovery (> B_{MSY}) in 5 yrs	Achieved [1 year delay in reaching B_{MSY} relative to other options]	Achieved	Achieved	Achieved [Lowest biomass (near B_{MSY}) after stock rebuilds]
(a)-ii Stock maintain after recovery	Achieved [High stock biomass (> B_{MSY})]	Achieved [High stock biomass (> B_{MSY})]	Achieved	Achieved [Lowest biomass (near B_{MSY})]
(b)-i Avoiding B < B_{lim}	Achieved	Achieved	Achieved	Achieved
(b)-ii Avoiding F > F_{lim}	F < F_{lim} in the simulations	F < F_{lim} in the simulations	High risk of F exceeding F_{lim}.[2]	Highest risk of F exceeding F_{lim}.[2]
(c)-i TAC (2024-2033)	Lowest average	Low average	High average	Highest average
(c)-ii TAC stability (2024-2033)	Most stable	Stable		
Responsiveness to lower/higher biomass or environmental change (Robustness)	Lowest ability to reduce/increase quota	Low ability to reduce/increase quota	Improved ability to reduce/increase quota	Greatest ability for reducing/increasing quota
If the underlying stock productivity declines or stays low (robustness)	Slowest rate and lowest probability of recovery	Slow rate and low probability of recovery	Highest probability of achieving B_{tar}	
Other characterization				Nearest F to $F_{MSY.}$

CMM 2024-08

NPFC

North Pacific Fisheries Commission

CMM 2024-08

(Entered into force 15 May 2024)

CONSERVATION AND MANAGEMENT MEASURE FOR PACIFIC SAURY

The North Pacific Fisheries Commission (NPFC),

Reaffirming the General Principles, Article 3 of the Convention, in particular, paragraph (b) stipulating that measures are adopted, based on the best scientific information available, to ensure that fisheries resources are maintained at or restored to levels capable of producing maximum sustainable yield, and paragraph (f) stipulating that preventing or eliminating overfishing and excess fishing capacity and ensuring that levels of fishing effort or harvest levels are based on the best scientific information available and do not exceed those commensurate with the sustainable use of the fisheries resources;

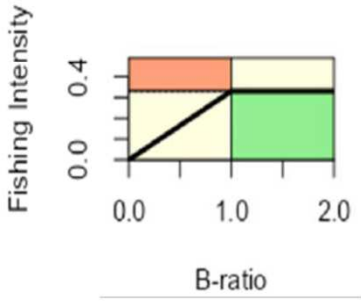


Figure 1. Illustration of the interim HCR.

CATCH MANAGEMENT

5. The interim harvest control rule (HCR) for Pacific saury is as attached in Annex I.

6. The interim HCR is applied until the establishment of a management procedure to be recommended through an MSE process by the Joint SC-TCC-COM Small Working Group on Management Strategy Evaluation for Pacific Saury (SWG MSE PS), or unless otherwise decided by the Commission. The SWG MSE PS and the SC shall review the performance of the interim HCR every year based on the best scientific information available, particularly the latest stock assessment results, and provide a recommendation for the Commission, as necessary.

7. For 2024, Members of the Commission agreed that the annual catch of Pacific saury in the entire area (the Convention Area and the areas under their jurisdiction adjacent to the Convention Area) should not exceed 225,000 metric tons, as calculated using the interim HCR in Annex I.

8. In 2024, the annual total allowable catch (TAC) of Pacific saury in the Convention Area shall be limited to 135,000 metric tons.

Application of HCR in SSC-PS

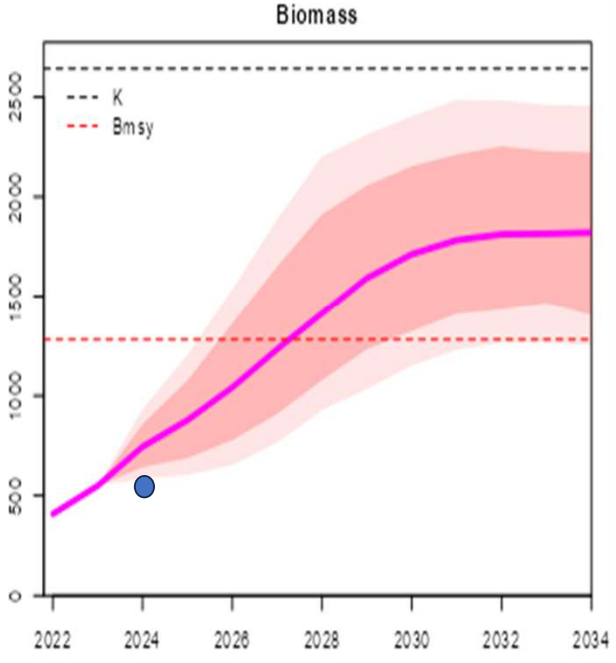
Item 12. Development of recommendations to improve conservation and management of Pacific saury stock

12.1 Application of the adopted HCR to set a TAC in 2025

63. The SSC PS **used the interim harvest control rule (HCR)** for Pacific saury adopted by NPFC in April 2024 under **CMM 2024-08** for Pacific Saury to calculate TAC in the 2025 fishing year. Based on inputs from the assessment, (unconstrained) $TAC_{2025} = (B_{2024} * F_{MSY} * (B_{2024}/B_{MSY}) = 75{,}741$ mt. Based on the adopted HCR, the TAC will be constrained to change by no more than 10% from one year to the next. The constrained 2025 TAC would be 0.9 x 225,000 = 202,500 mt.

Review via 2024 assessments (base case)

HCR1_10%



2023 assessment

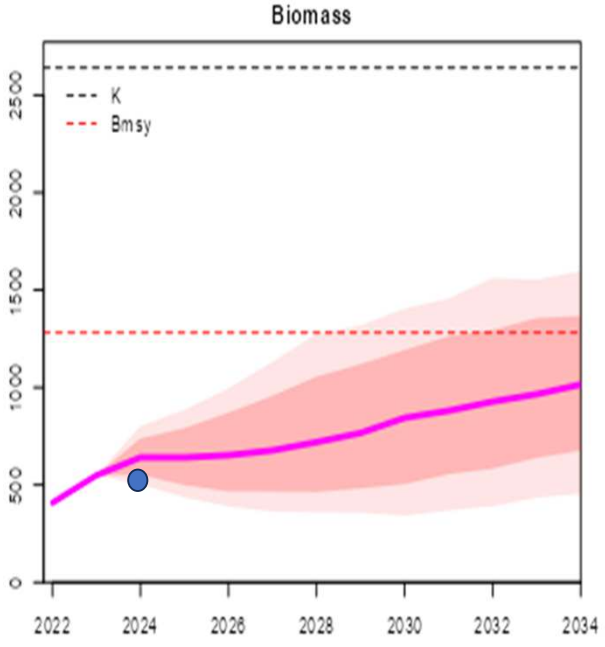
	Median
C_2022 (10000 t)	10.009
AveC_2020_2022	11.066
AveF_2020_2022	0.337
F_2022	0.245
FMSY	0.314
MSY (10000 t)	39.657
F_2022/FMSY	0.806
AveF_2020_2022/FMSY	1.111
K (10000 t)	264.054
B_2022 (10000 t)	40.820
B_2023 (10000 t)	54.940
AveB_2021_2023	42.410
BMSY (10000 t)	128.100
BMSY/K	0.481
B_2022/K	0.155
B_2023/K	0.209
AveB_2021_2023/K	0.163
B_2022/BMSY	0.316
B_2023/BMSY	0.426
AveB_2021_2023/BMSY	0.331

2024 assessment

	Median
C_2023 (10000 t)	11.836
AveC_2021_2023	10.352
AveF_2021_2023	0.328
F_2023	0.297
FMSY	0.330
MSY (10000 t)	39.440
F_2023/FMSY	0.920
AveF_2021_2023/FMSY	1.008
K (10000 t)	248.067
B_2023 (10000 t)	39.875
B_2024 (10000 t)	52.763
AveB_2022_2024	41.563
BMSY (10000 t)	120.100
BMSY/K	0.485
B_2023/K	0.161
B_2024/K	0.212
AveB_2022_2024/K	0.169
B_2023/BMSY	0.328
B_2024/BMSY	0.435
AveB_2022_2024/BMSY	0.345

Review via 2024 assessments (robustness case)

HCR1_10%



2023 assessment

	Median
C_2022 (10000 t)	10.009
AveC_2020_2022	11.066
AveF_2020_2022	0.337
F_2022	0.245
FMSY	0.314
MSY (10000 t)	39.657
F_2022/FMSY	0.806
AveF_2020_2022/FMSY	1.111
K (10000 t)	264.054
B_2022 (10000 t)	40.820
B_2023 (10000 t)	54.940
AveB_2021_2023	42.410
BMSY (10000 t)	128.100
BMSY/K	0.481
B_2022/K	0.155
B_2023/K	0.209
AveB_2021_2023/K	0.163
B_2022/BMSY	0.316
B_2023/BMSY	0.426
AveB_2021_2023/BMSY	0.331

2024 assessment

	Median
C_2023 (10000 t)	11.836
AveC_2021_2023	10.352
AveF_2021_2023	0.328
F_2023	0.297
FMSY	0.330
MSY (10000 t)	39.440
F_2023/FMSY	0.920
AveF_2021_2023/FMSY	1.008
K (10000 t)	248.067
B_2023 (10000 t)	39.875
B_2024 (10000 t)	52.763
AveB_2022_2024	41.563
BMSY (10000 t)	120.100
BMSY/K	0.485
B_2023/K	0.161
B_2024/K	0.212
AveB_2022_2024/K	0.169
B_2023/BMSY	0.328
B_2024/BMSY	0.435
AveB_2022_2024/BMSY	0.345

Future works

Mid-Term Objectives: within three to five years:

a) develop **draft mid- to long-term management objectives** by setting the **target and limit reference points** for the population status as well as by defining “overfishing” and “overfished” for the sustainable use of the Pacific saury stock;

b) assess the feasibility of establishing a **management procedure through an MSE**

- **More realistic operating models based on age-structure models**
- **More evaluation of different typs of management procedures**
  - **Model-based (including different options for parameters + internal assessment)**
  - **Empirical (data-based)**
- **Definition of meta-rules (regular review of “exceptional circumstances”)**
- **Climate scenarios in Operating Models**
- **Quality of input indices**
- **…**

Draft table of elements that could be considered when developing a full MP in the MSE for Pacific saury

Items	Development of interim HCR	Development of full MP
Management objectives	• Primary (recovery) • Secondary (avoid risk) • Tertiary (catch)	The three main objectives will be used as previously agreed. Members may also consider additional objectives relating to the following. • Categories: Stock Status (e.g. B, PGK, Abundance), Safety (Avoiding Blim), Yield (catch) stability, socio-economic (incl. consideration of aspirations of SIDS) and ecological/ecosystem • Achieve robustness under climate changes.
Operating models	BSSMP • Age: aggregated over life • Space: combined over EEZ & CA • Time: annual	Age-structured models (SS3, other state-space models) • Age: 0/1 • Space: so far combined • Time: so far annual (seasonal/monthly) • Include key uncertainties (M, S-R, selectivity…) May consider some spatial elements (i.e. distribution shift) for investigating spatial management (depending on progress on new modelling)

Draft table of elements that could be considered when developing a full MP in the MSE for Pacific saury

Items	Development of interim HCR	Development of full MP
HCRs and MPs	• Set an annual TAC • Just HCR assuming availability of unbiased estimates	• Set an annual TAC • Model-based (incl. assessment) or empirical MPs or combined • May need to consider spatial allocation particularly for juvenile protection • Evaluate advantages and disadvantages of constraints such as existing MAC and a minimum TAC (particularly in light of scale and climate uncertainties)
Main input (incl. assessment)	• Estimates of key reference points from BSSPM analyses	• Estimates of key reference points from BSSPM or others • Address uncertainty in estimates

Draft table of elements that could be considered when developing a full MP in the MSE for Pacific saury

Items	Development of interim HCR	Development of full MP
Time lag btw data & implementation	• 1-yr (survey) • 2-yrs (fisheries CPUE)	• Use the most recent CPUE and survey information from the current fishing year? • Consider the use of an in-season adjustment if possible
Climate impacts	• Considered as robustness case	• Routinely use as part of reference models or robustness testing • Explicitly link climate effects and biological parameters that affect stock size & productivities
Meta rules and others	• No definition of exceptional circumstances	• Develop definition of exceptional circumstances

MY PRIVATE ANSWERS TO "QUESTIONS" ADDRESSED

Questions addressed (1)

- **"How is NPFC currently already applying the PA and where are the gaps?"**
- **"What should be the priority stocks, non-target species and habitats?"**

- Elements of the PA are already reflected in several existing CMMs of the NPFC through data mandatory data collection, VMEs, bottom fisheries, and some species
  - ✓ *CMM 2025-08 "Conservation and management measure for **Pacific saury**" **(priority stocks : e.g. highly variable and fluctuating stocks)***
  - ✓ *CMM 2023-14 "Conservation and management measure on sharks" **(for non-target species)***
  - ✓ *CMM 2025-05 "Conservation and management measure for **bottom fisheries** and protection of **vulnerable marine ecosystems** in the Northwestern Pacific Ocean" **(for habitats)***
  - ✓ *CMM 2024-15 "Conservation and management measure on the prevention, reduction, and elimination of **marine pollution**" **(for habitats)***
- Further work will be useful for developing **reference points** and **management procedures** for priority stocks
- A more structured **risk-based framework**, guided by the precautionary approach, could further support **decision making under uncertainties**

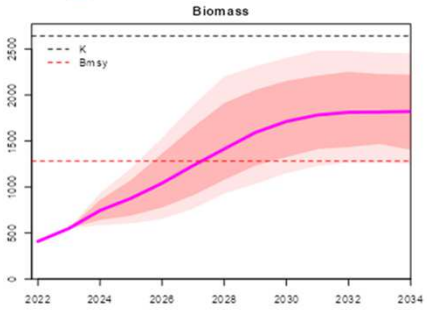
Compendium of NPFC Conservation and Management Measure Handbook-2025
https://www.npfc.int/compendium-npfc-conservation-and-management-measure-handbook-2025

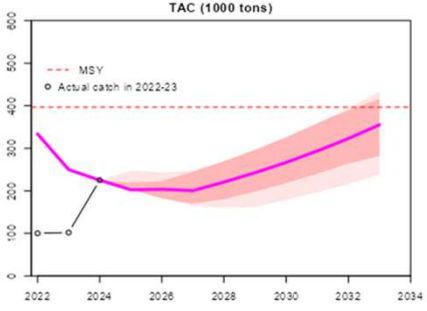
Questions addressed (2)

"Would long-term management plans and impact assessments help?"

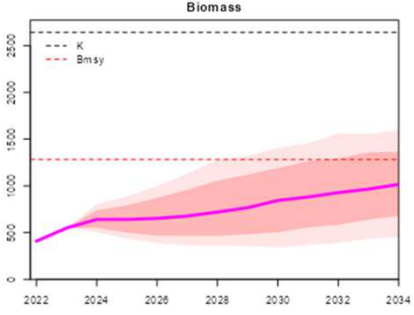
- Long-term management procedures (MPs) evaluated and supported by MSE could help provide stability and transparency in decision making for variable stocks
- MSE is useful to clarify MPs respond to changes in stock status and environmental conditions and provide clearer expectations for managers on

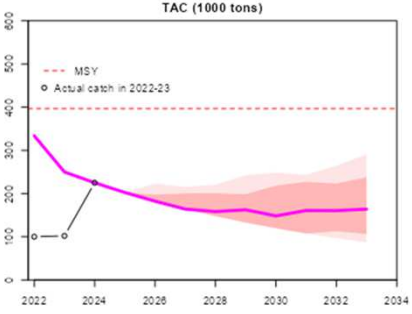
HCR1_10%





HCR1_10%





- Systematic impact assessments can be used when developing a full MSE framework is challenging. They allow us to compare the effects of proposed measures in a consistent way, even in situations where data, time, or agreement are insufficient for a comprehensive MSE.

Questions addressed (3)

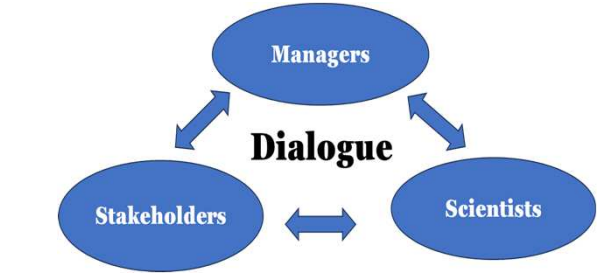
- "What are the responsibilities of the SC & Commission for implementing the PA?"
- "Could the establishment of a joint SC-Commission Working Group on PA help to bring this work forward?"

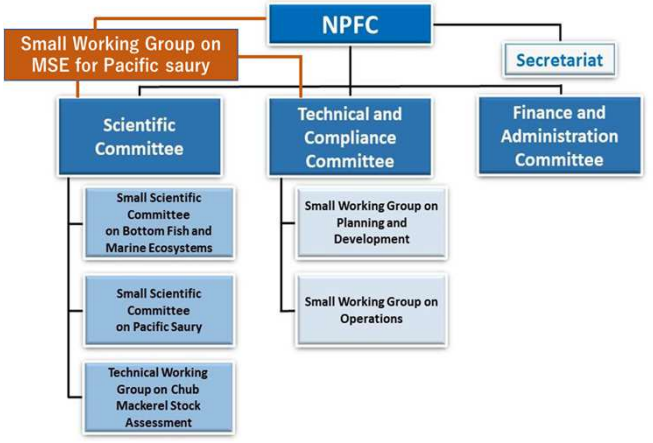
PROS

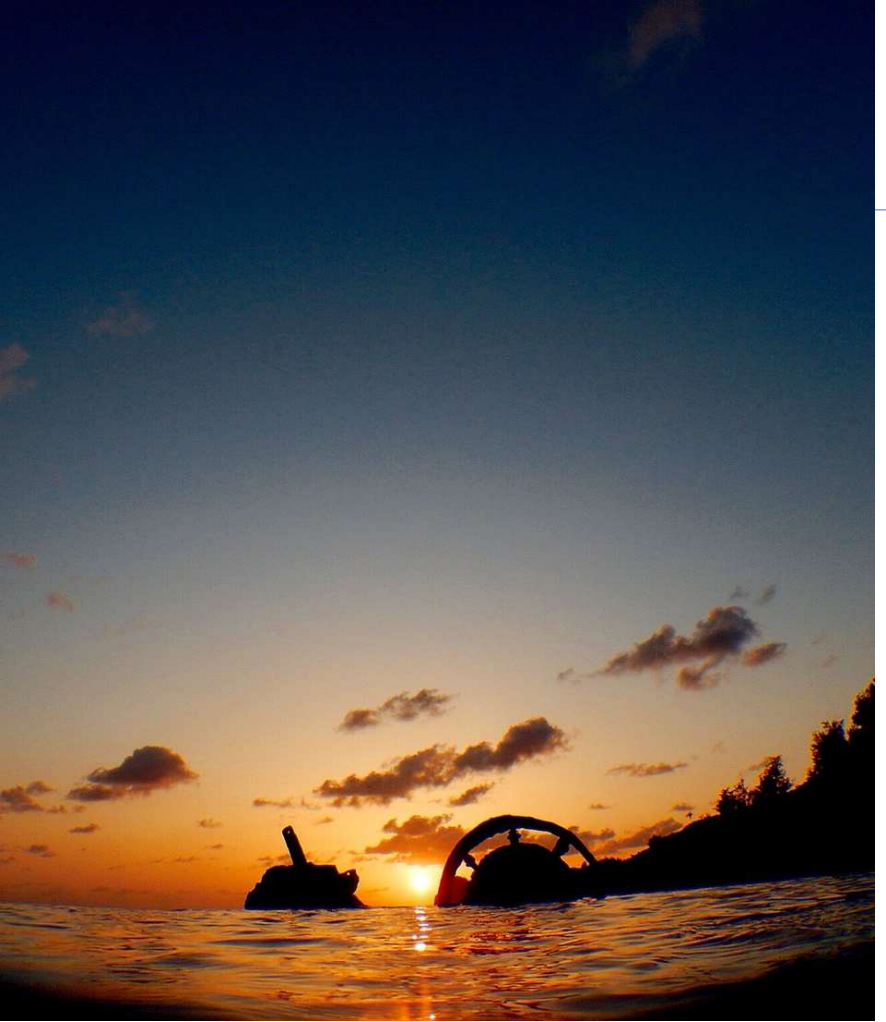
- **Possibly "Yes" as a joint Working Group on MSE** has been useful for improving communication between the SC and the Commission, **developing shared expectations**
- A similar structure could help provide a forum for coordinating priorities and preparing practical steps for advancing the PA

CAVEATS

- **The ToRs (including the timeline)** need to be clearly defined to avoid confusion about roles and responsibilities on both sides
- **If the ToRs are unclear or overly complex**, there is a **risk of slowing** progress rather than facilitating it
- Effectiveness will depend on **stable participation** from both the SC and the Commission (a lesson learned from the joint MSE WG …)







NPFC

North Pacific Fisheries Commission

THANK YOU SO MUCH FOR KIND ATTENTION

Contact:

Toshihide Kitakado

kitakado@kaiyodai.ac.jp