

Stock assessment for Tsushima Warm Current Stock of Round Herring (Fiscal Year 2024)



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General introduction for stock assessments of small pelagic fish in the Japan Sea & East China Sea

- Pelagic Fish Group 4 in Nagasaki field station (9 researchers)
- 20 species including commercially important species: jack mackerel, chub mackerel and sardine
- main fishery: purse seine and set net



	TAC introduction	data availability (fishery and science)	abundance estimation	peer review (Fiscal Year)
Japanese jack mackerel	1997	rich	Yes	2021
Japanese sardine	1997	rich	Yes	2021
Chub mackerel	1997	rich	Yes	2020
Spotted mackerel	1997	moderate	Yes	2020
Japanese anchovy	2024	moderate	Yes	2023
Round herring	2024	moderate	Yes	2025
Japanese Spanish mackerel	-	limited	No (index only)	-
Mackerel scads	-	limited	No (index only)	-

Characteristics of round herring fishery and management

- Commercially important, but not a major target species compared with mackerels
- Moderate catch volume, smaller than that of major pelagic species
- Moderate fishery data availability and scientific knowledge
 - Existing data are informative, but not sufficient for a fully comprehensive assessment
- Recently introduced into the TAC management framework (since 2024)
 - Also important as a bycatch species in mackerel and sardine fisheries
- Through this peer review, we aim to explore efficient ways to improve the assessment of this species.

Ecology of Round herring

Distribution



- ✓ Distributed along the coast of Japan; common from central Honshu southwards (Ochiai & Tanaka, 1986)
- ✓ Sexual maturity reached at age 1
- ✓ Length at age: 150 mm (age 1), 230 mm (age 2)
- ✓ Feed on copepods, decapod larvae, and amphipods (Tanaka et al., 2006)
- ✓ Preyed upon by large fish, marine mammals, seabirds, and cephalopods



Ecology of Round herring

Comments

- Is this a semelparous species? If not, how does the VPA account for possible older ages? Does it use a plus group at age 3? If this is not a semelparous species, then cutting off the age at 3 without a plus group in the VPA model could cause bias in estimation of management reference points. If the VPA methodology includes a plus group, how does the VPA compute abundance and F in the plus group and how informative are the data about abundance in the plus group by year?
- If F was set to zero for many years, could fish older than 3 years be observed? Have any four or five year olds ever been observed?

As with other herring species, round herring is an iteroparous species and not semelparous (Nyuji and Takasuka, 2017). In this study, we assumed a maximum longevity of two years and therefore did not assume a plus group in the VPA.

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Ecology of Round herring

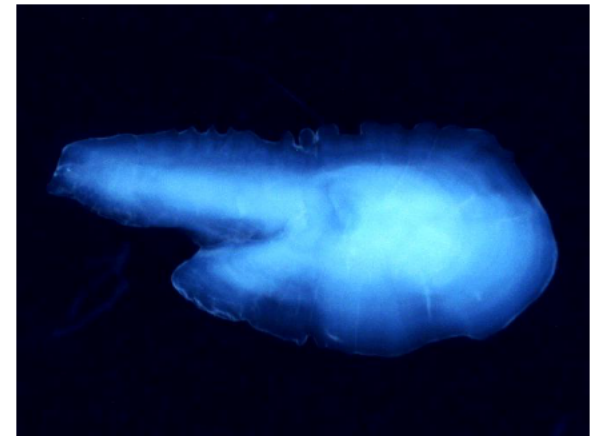
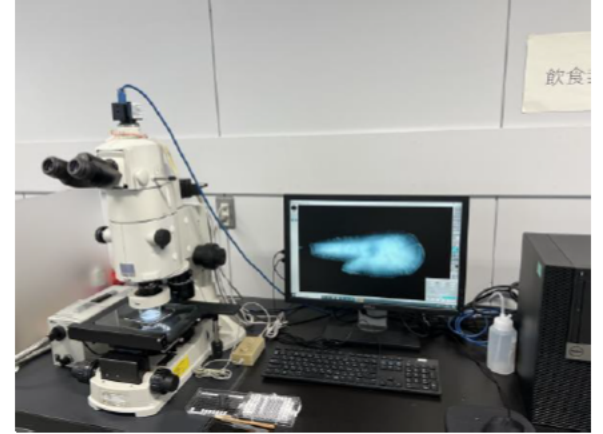
This assumption is supported by our age-determination data collected in 2024 ($n = 111$), in which no individuals older than two years were observed, as well as by Ohshimo et al. (2011), who similarly reported no individuals aged three years or older. Although Chullasorn et al. (1977) reported individuals up to six years old, these age estimates have been regarded as unreliable in later studies.

Based on the current evidence, we consider the exclusion of a plus group to be appropriate. However, continued age-determination surveys are important, and if many older individuals are detected in the future, the VPA age structure, including the introduction of a plus group, will be reconsidered.

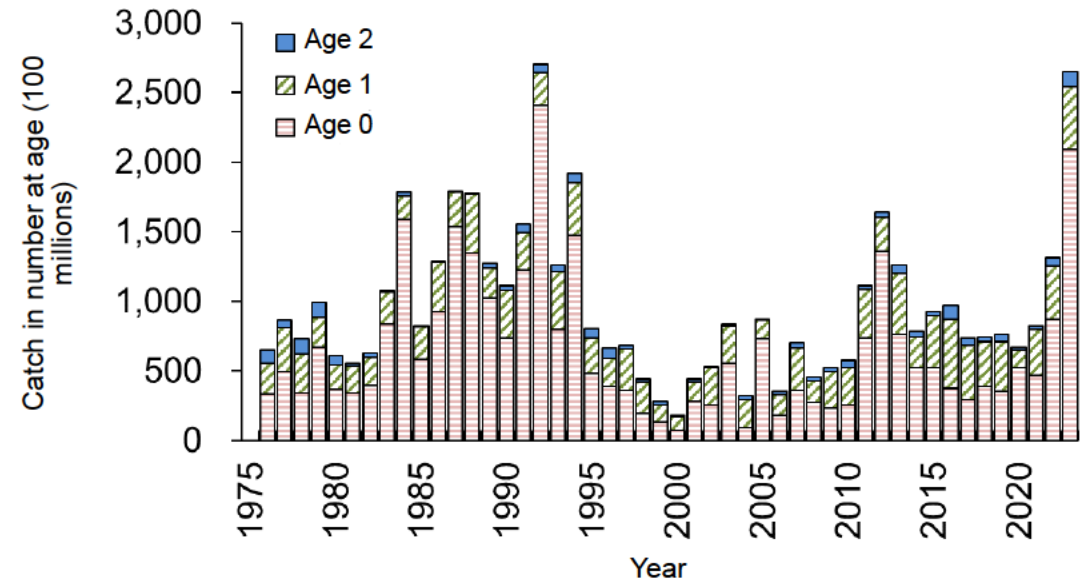
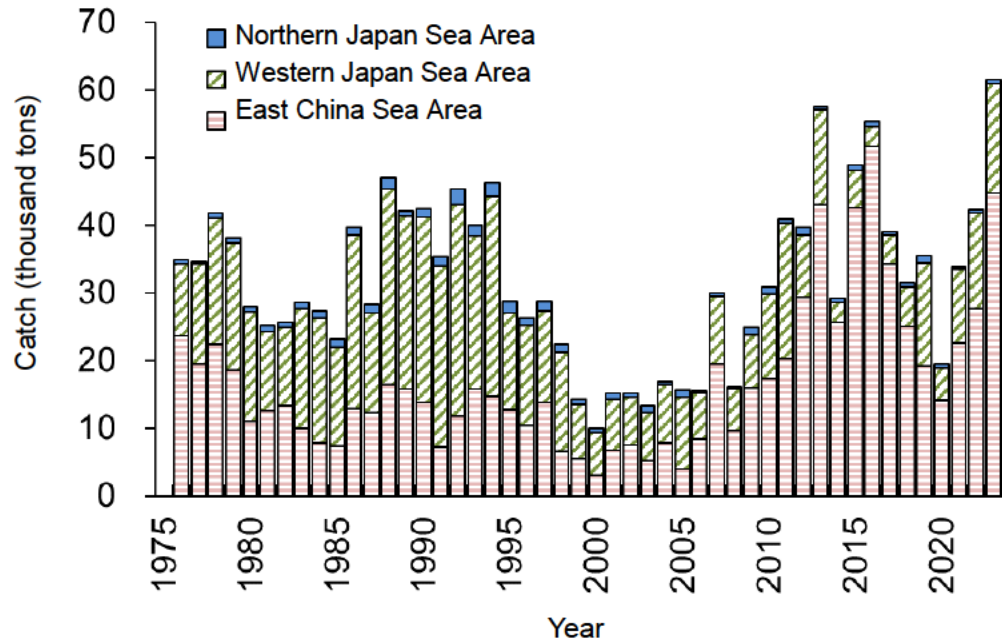
Comment

How has abundance of different predators changed over the years?

This species were prey upon by large fish, mammals, seabirds, and cephalopods. However, quantitative information on temporal changes in the abundance of these predators is limited and therefore changes in overall predation pressure through time remain largely unknown.



Fishery Status



- ✓ Total catch in 2023 was 59,236 mt (historical high)
- ✓ Catch amount in East China Sea were high in 2023
- ✓ Catch number at age 0 were high in 2023



How to calculate CAA?



Data collection and processing

- Participating organizations from 17 prefectures collected monthly length compositions and catch weights at major fishing ports.
- Monthly length compositions and catch weights were aggregated into two areas: the East China Sea and the Sea of Japan.
- Length compositions were converted to body weight for each 5-mm length bin using a length–weight relationship.

Estimation of monthly catch at age

- Monthly catch at age was calculated as follows:

$$C_{t,i} = \left[\frac{n_i \times BW_i}{\sum_0^{260} n_i \times BW_i} \times CW \times ALK_{t,i} \right] / BW_i$$

Total weight of length composition

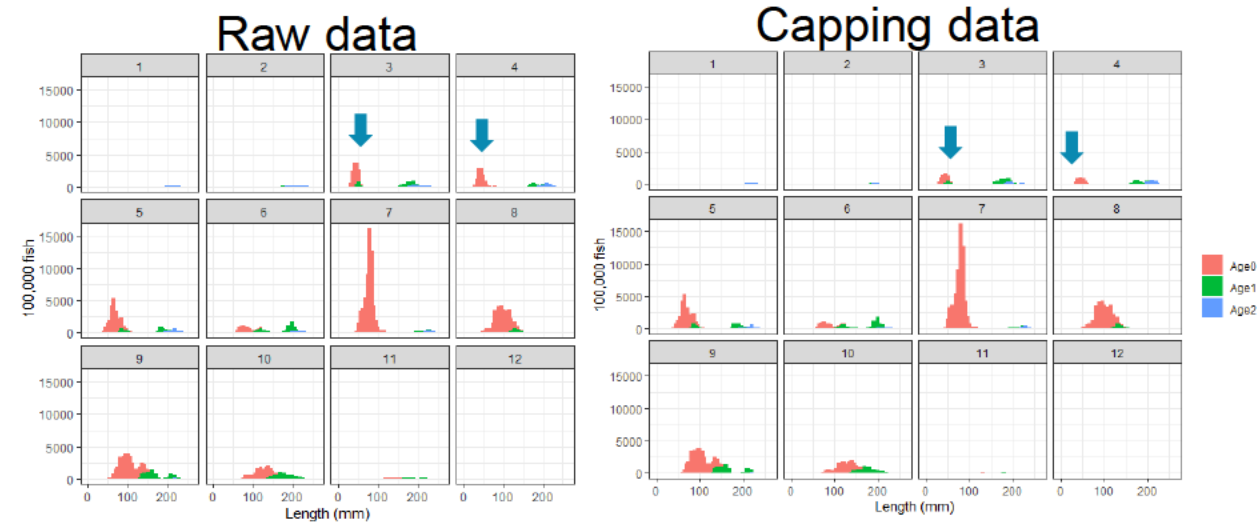
- where $C_{t,i}$, n_i , BW_i and $ALK_{t,i}$ denote the catch number, number of fish measured, body weight, and age–length key at length (i mm bin) and age t , respectively.
- CW represents the monthly catch weight, estimated from official prefectural catch reports.

Fishery status: Calculation Methods

Comment

- How does capping the number of fish at 100 reduce bias due to sampling?

In March and April, large numbers of small individuals were repeatedly caught and measured from the same fishing vessels. If the catch-at-age (CAA) was estimated using the raw data, these repeated measurements would disproportionately inflate the estimated abundance of age-0 fish. By capping the number of fish per sampling event at 100 individuals, we reduced the influence of such highly clustered samples and limited the dominance of a small number of fishing operations. As a result, the estimated number of age-0 fish was 134 million higher when using the raw data compared to the capped data, indicating that capping effectively reduced upward bias in the age-0 estimates.

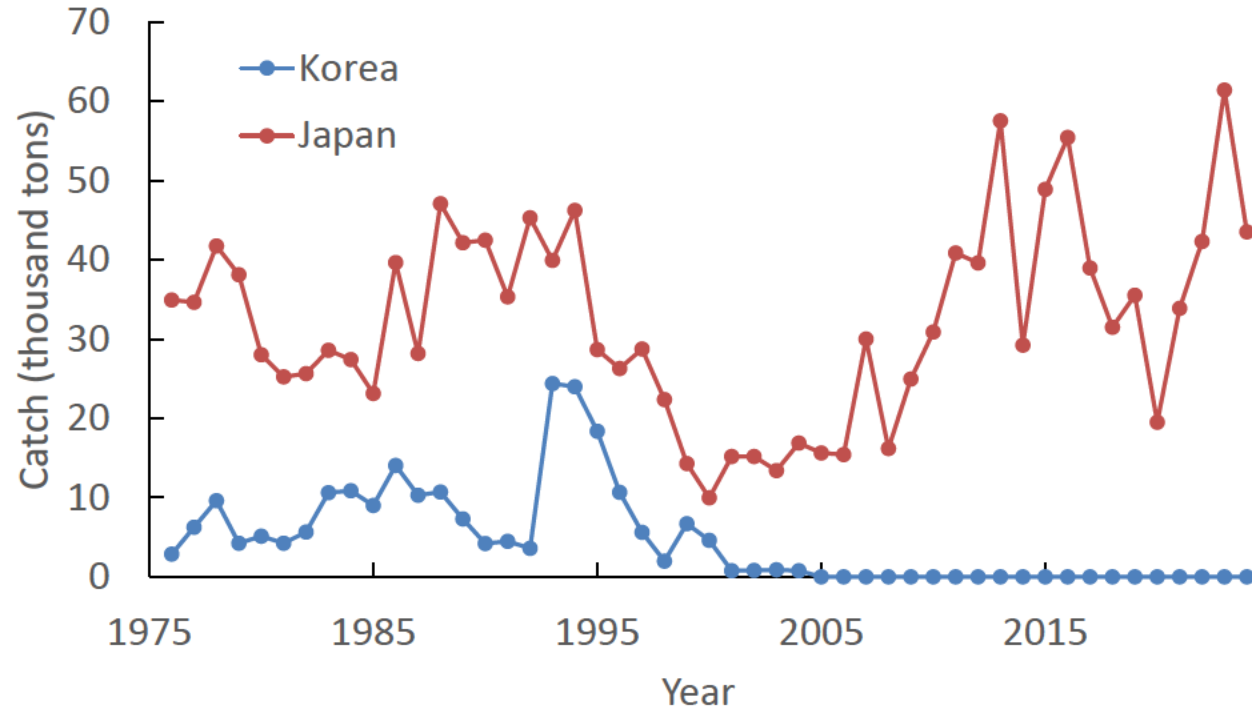


Monthly length compositions weighted by catch amount in 2023

Estimated CAA in 2023 (x million fish)

	Raw data	Capping data
Age0	2095	1961
Age1	447	441
Age2	106	106

Fishery Status



Comments

- Have there been any attempts to impute the unknown catches from S. Korea since 1990 and from China? There should be a statement of the anticipated bias that could result in stock assessment results with the missing catch records from these two countries. Please see my next comment on this.

No, we have not estimated.



Fishery Status

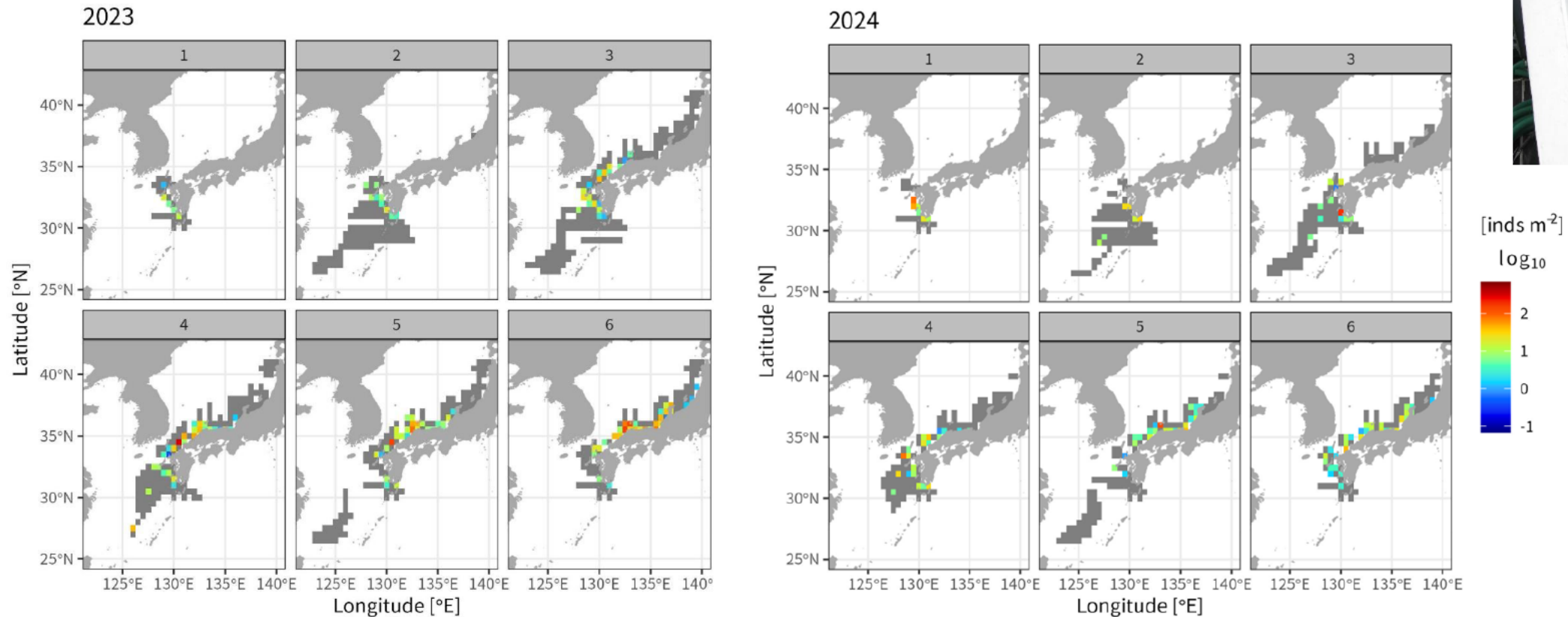
Comment

- It should be mentioned that if true catches were larger than the ones used from Japan, the abundance estimates may be too low and the F estimates may be too high. A sensitivity analysis should be applied in which potential catches per year from S. Korea were added to the catch-at-age data, perhaps assuming the same weight at age, and proportion catch biomass by age as in Japanese waters as seen in the most recent available historic catch biomass values for S. Korea.

First, it is necessary to consider whether round herring caught by South Korea and China belong to the same stock as that assessed for Japanese waters. Given that round herring is a coastal species with limited large-scale migration, and that reported catches from South Korea and China have not exceeded those from Japan, we consider that the influence of catches from these two countries on our stock assessment results is likely to be limited.



Stock status: Abundance indices (1)



Comments

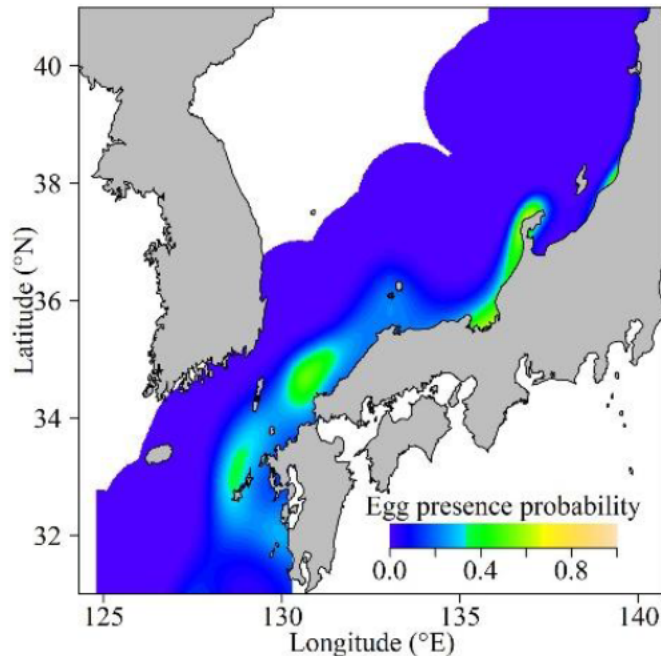
1. Do these surveys cover the entire area where eggs and larvae are present?
2. How accurate is species and egg and larval stage identification for Round Herring?



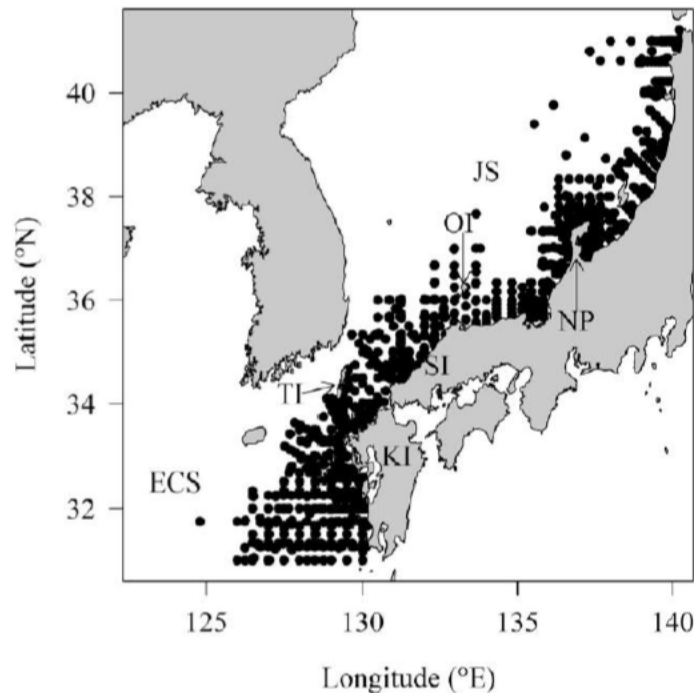
Stock status: Abundance indices (1)

Comments

1. Do these surveys cover the entire area where eggs and larvae are present?



Egg presence probability estimated using GAM (Suzuki et al. 2018)



Egg survey sites during the study period, 1997-2013 (Suzuki et al. 2018)

Yes, the survey cover the entire known distribution area of eggs and larvae. According to Suzuki et al. (2018), the main spawning grounds have gradually shifted northward from the waters off western Kyushu to the Sea of Japan and the survey covered these area. The present study uses the same survey data and includes updated information.

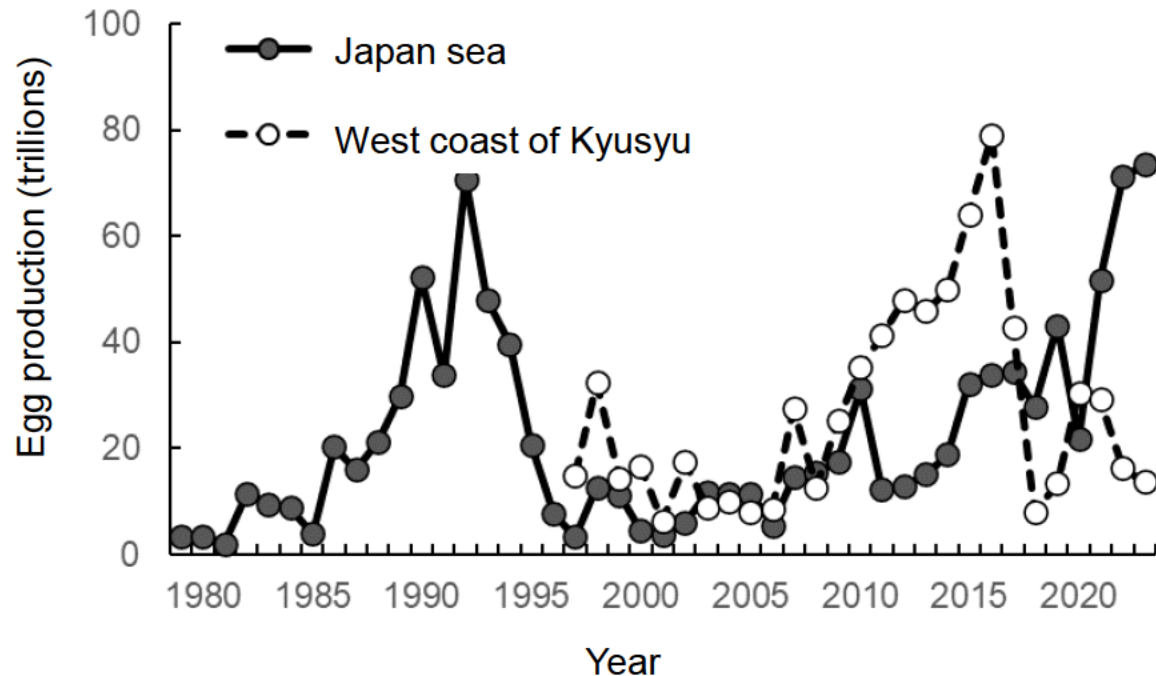


Stock status: Abundance indices (1)

Comments

2. How accurate is species and egg and larval stage identification for Round Herring?

Based on **key morphological characters**, the eggs and larvae can be unequivocally identified as round herring following the criteria described in *Larvae of Fishes in Japan*, 2nd edition.



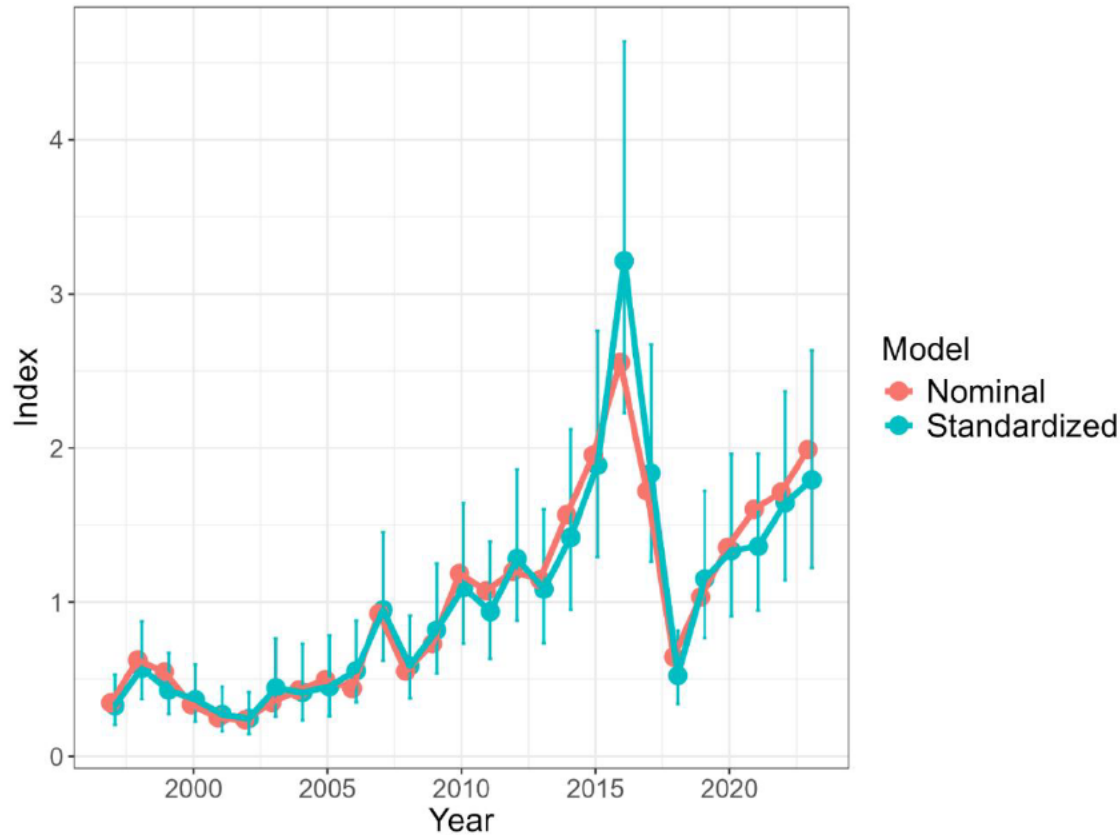
- Please provide confidence intervals for each estimates index point in each year.

We did not estimate confidence intervals for these survey results because the indices were calculated as simple sums of egg production within each area. These data were subsequently standardized by the VAST model, where uncertainty is explicitly accounted for.

Changes in egg production over time



VAST : Vector Autoregressive Spatio-Temporal model



Trends in abundance indices with (standardized) and without (nominal) standardization (error bars representing the 95% confidence interval)

Comment

- What was the standard error or coefficient of variation per year in the index values obtained?

Confidence intervals were estimated using a simulation-based approach **within the VAST framework** (Thorson et al., 2015; Thorson, 2019), in which uncertainty in spatio-temporal random effects and temporal autocorrelation was propagated to derived abundance indices.

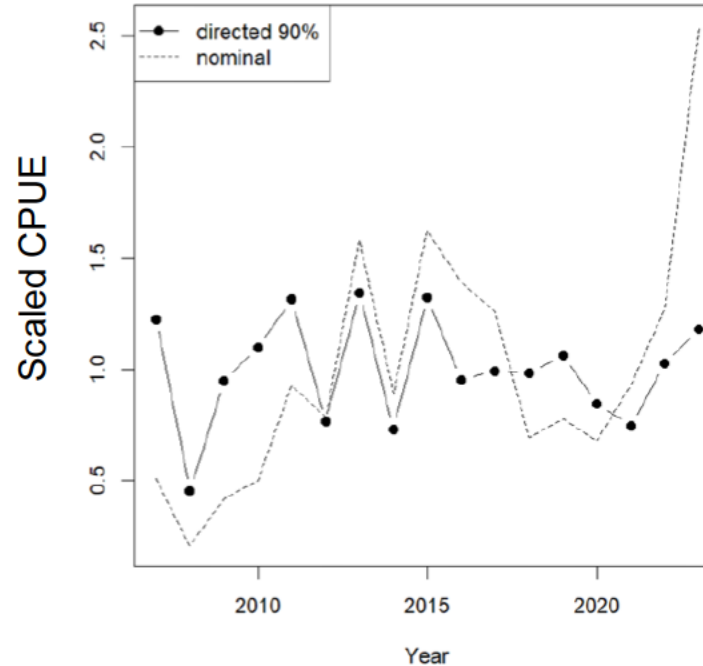
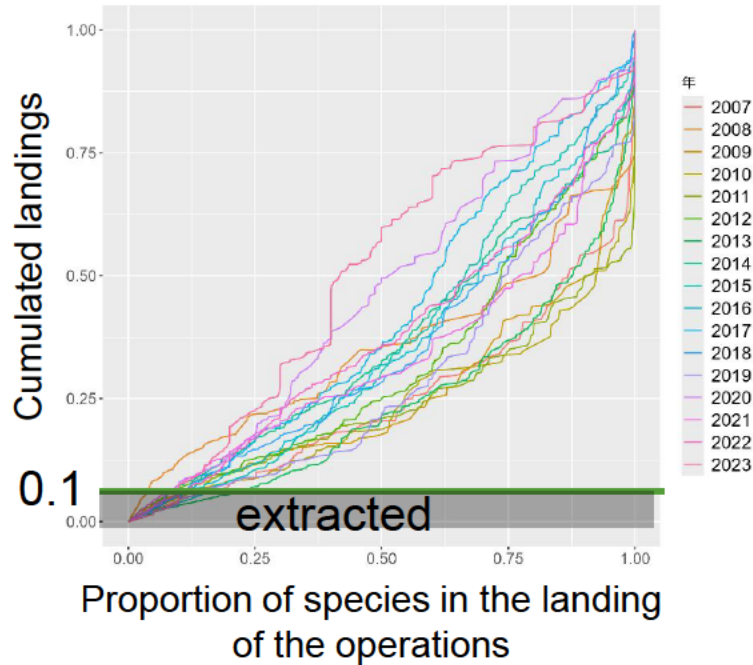
- Were the CVs in annual estimates used in the tuning of the VPA to the abundance indices?

No. The CVs of the annual estimates were not directly used in tuning the VPA

Stock status: Abundance indices (2)



Lage and medium-sized purse seine fisheries data



All data (nominal)

Directed data
extracted by 90%
explain levels
(Biseau 1998)

Turning index
in 2024

Comment

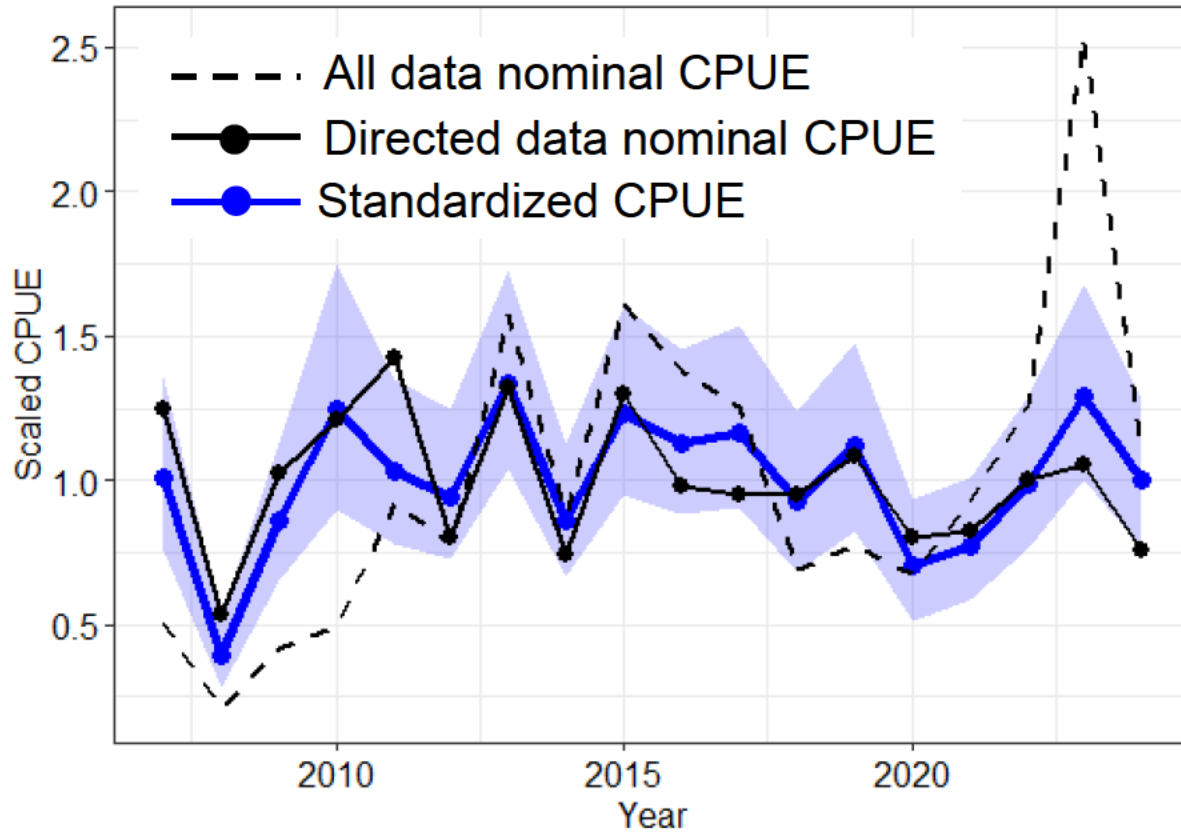
- Could confidence intervals be provided for the abundance index in each year?

At present, confidence intervals could not be provided. However, we estimated standardized CPUE with confidence intervals using directed data for stock assessment in 2025.

Stock status: Abundance indices (2)



Lage and medium-sized purse seine fisheries data



All data (nominal)

Directed data
extracted by 90%
explain levels

Turning index
in 2024

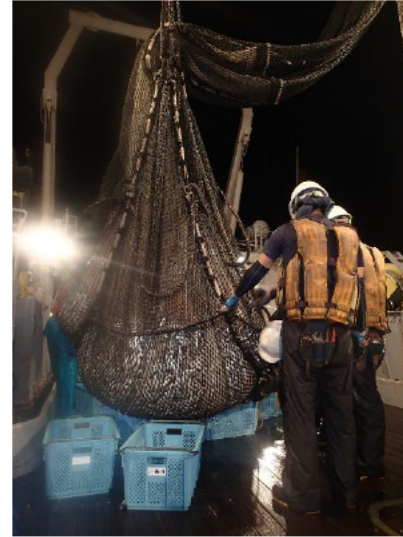
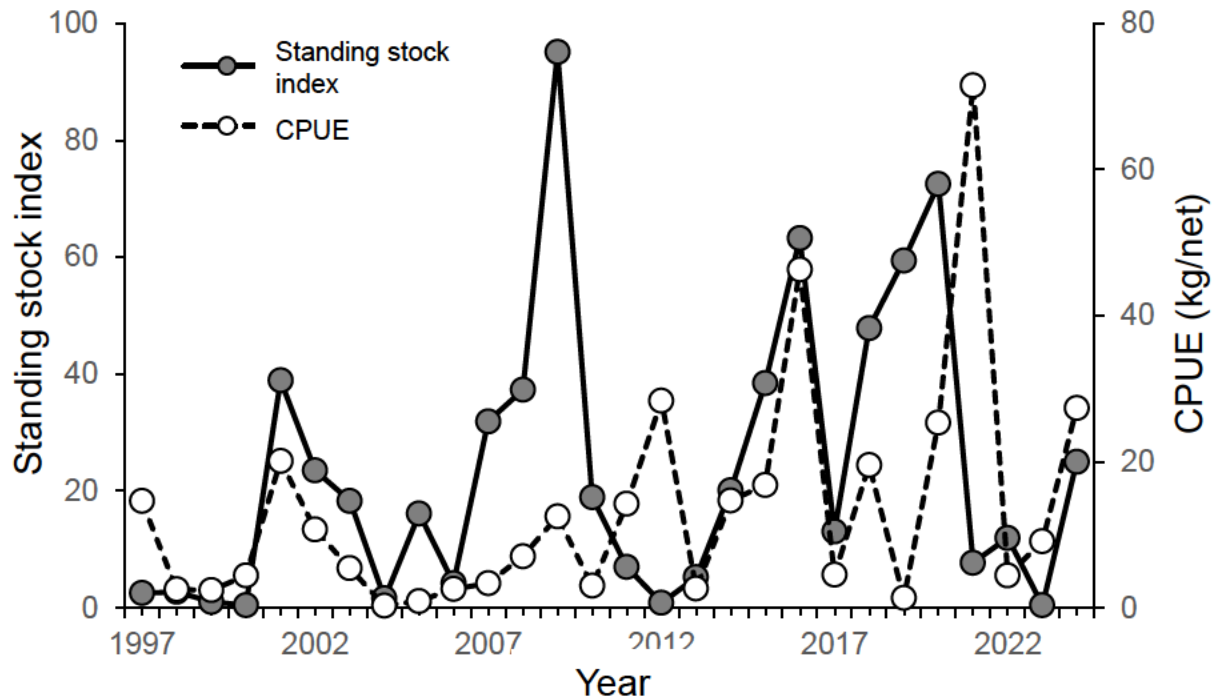
Standardized CPUE
with confidence interval

Turning index
in 2025

$\text{Log}(\text{CPUE}) \sim \text{factor}(\text{Year}) + \text{factor}(\text{Area}) + \text{factor}(\text{Month}) + \text{s}(\text{SST})$

Stock status: Summary of Survey Results

Pelagic Fish Abundance Survey Using Quantitative Echo Sounders



Comment

- How is information from this survey used to produce the spawning stock index?

We did not use this information in the stock assessment model due to highly fluctuation. However, the survey information is important for understanding stock condition, particularly in the most recent years, because it is fishery-independent.

Turned VPA



Step 1: Calculation of stock population using Pope's approximation formula

Data (1976-2023)

Catch at Age
Weight at Age
Maturity at Age
M = 0.7

Assumption

Lifespan : 3 years (death at the end of age2)
F@age1 = F@age2
Terminal F (2023) = Average of each age group
in previous 3-year period (2020 -2022)



Stock population
Fishing mortality
at age and by year

Adjustment F in 2023

Step 2: Adjustment of F in the most recent year

Abundance indices

- (1) Standardized egg density = SSB (Age 1-2)
- (2) Large and medium sized purse seine CPUE = Biomass (Age 0-2)



Based on each abundance index, the negative log likelihood function to be minimized was defined as shown below (Hashimoto et al. 2018).

$$-\ln L = \sum_k \sum_y \left[\frac{[\ln I_{k,y} - (b_k \ln B_{k,y} + \ln q_k)]^2}{2\sigma_k^2} - \ln \left(\frac{1}{\sqrt{2\pi}\sigma_k} \right) \right]$$

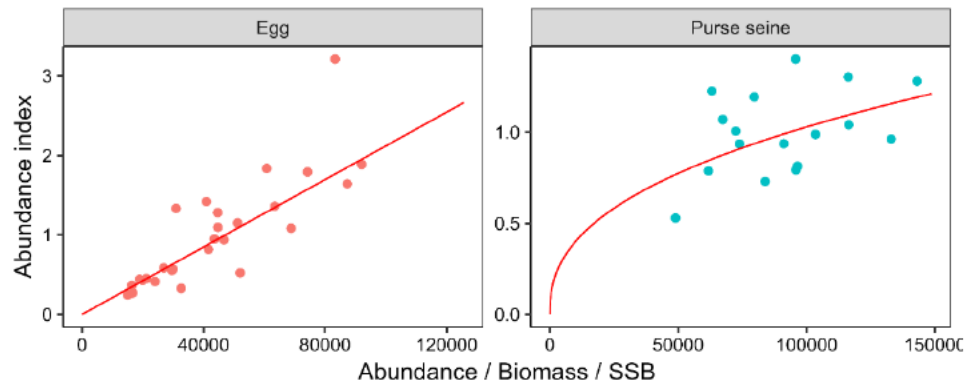
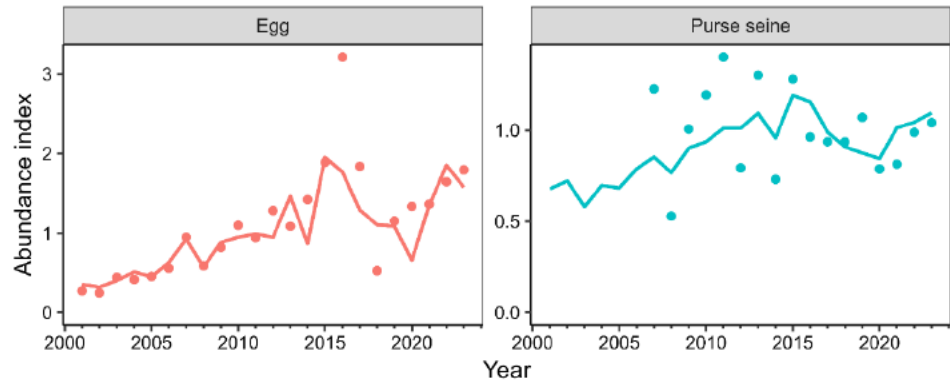
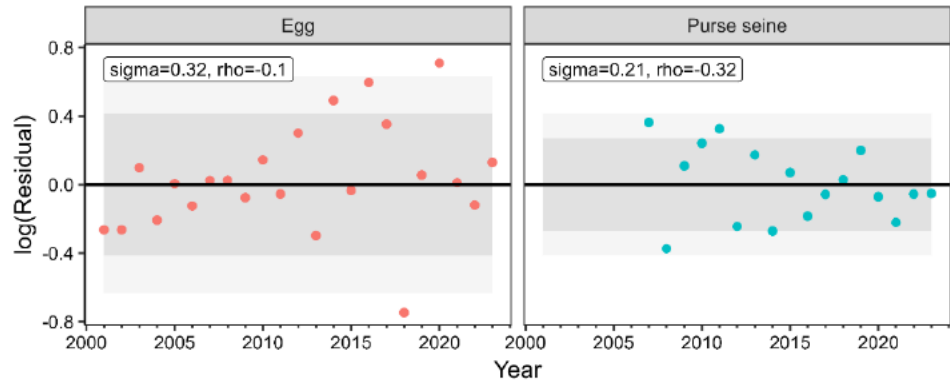
minimize

Weight for each index
Index with smaller σ_k have higher weights

$$I_{k,y} = q_k B_{k,y}^{b_k}$$

In this equation, $I_{k,y}$ is the observed value of index k in year y (1: spawning volume, 2: large and medium-sized purse seine CPUE), $B_{k,y}$ is the biomass that fits index k in year y (1. SSB, 2. biomass), and q_k , b_k and σ_k are estimated parameters (estimated at the same time as terminal F).

Stock status: Model diagnostics



Comment

- This ($b_2 \neq 1$) appears to be a very good modeling decision!

Thank you!

- The trends in the abundance indices are similar prior to about 2014 but differ quite a bit after 2014 between the pelagic egg and purse seine cpue indices. Could this be due to the purse seine index having a non-linear relationship to stock biomass and the egg and larval index having a linear relationship with stock biomass?

After 2014, the egg index shows large residuals with several outliers, whereas the purse seine index exhibits smaller residuals and a better model fit. When a linear relationship with stock biomass is assumed for PS indices, the estimated biomass is relatively high around 2015 and then declines sharply toward 2020. This pattern is more consistent with the trend observed in the egg index (SSB). Therefore, **our results support the reviewer's interpretation** that the differing post-2014 trends may be related to differences in the assumed relationship between each index and stock biomass.

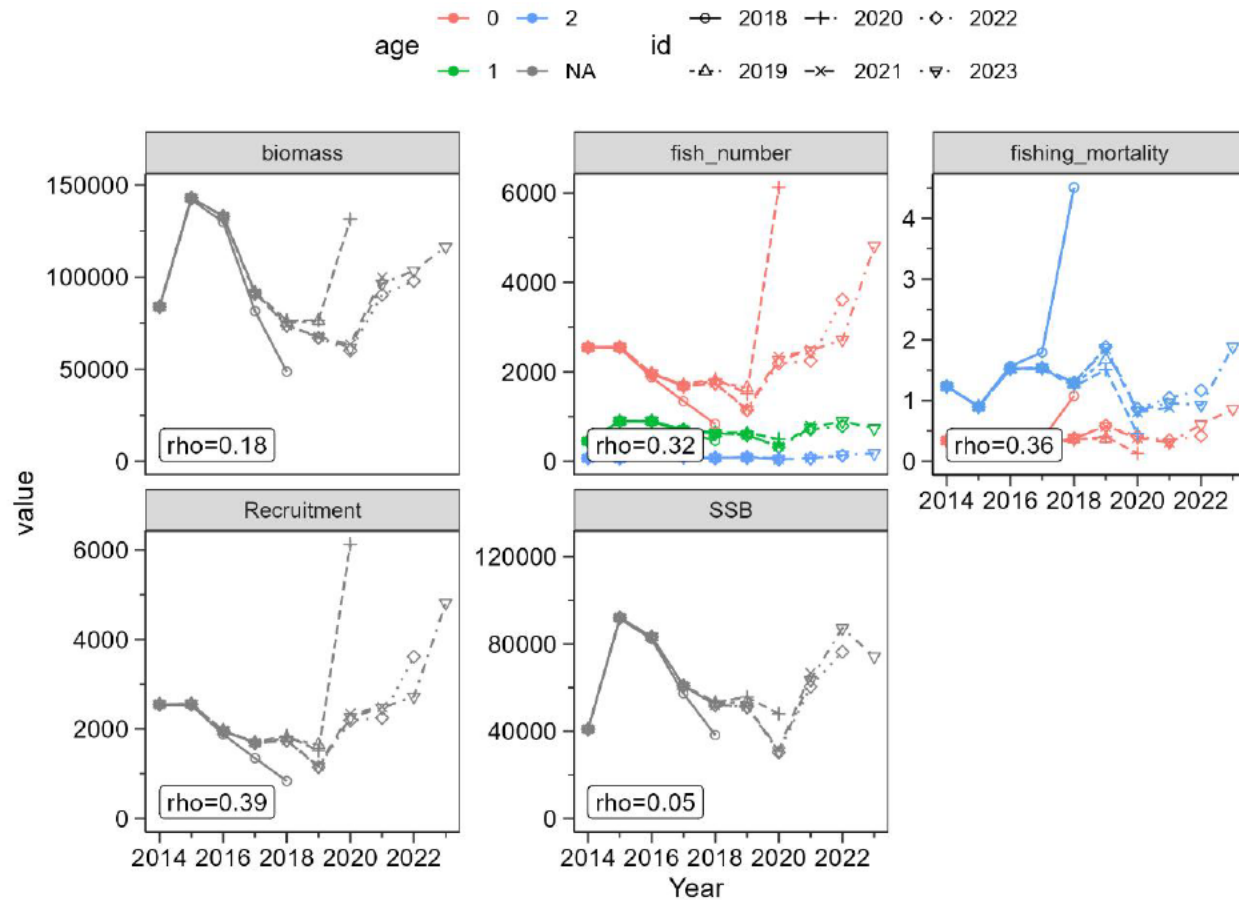
Stock status: Model diagnostics



Comment

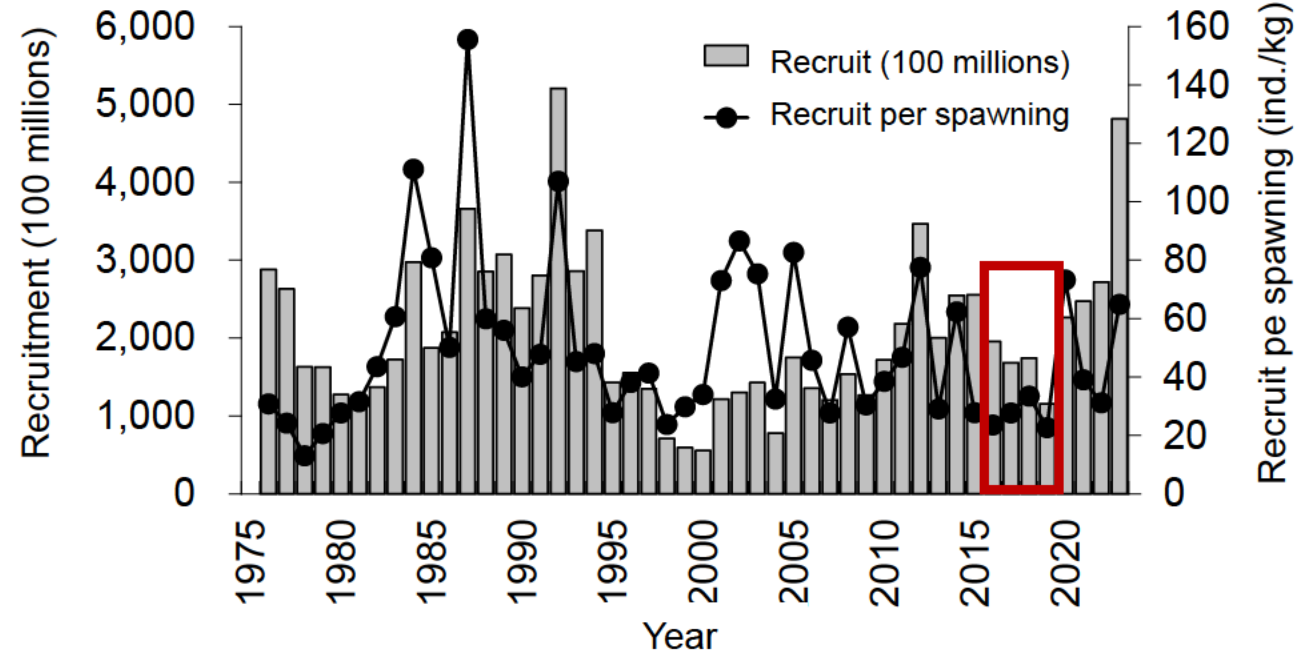
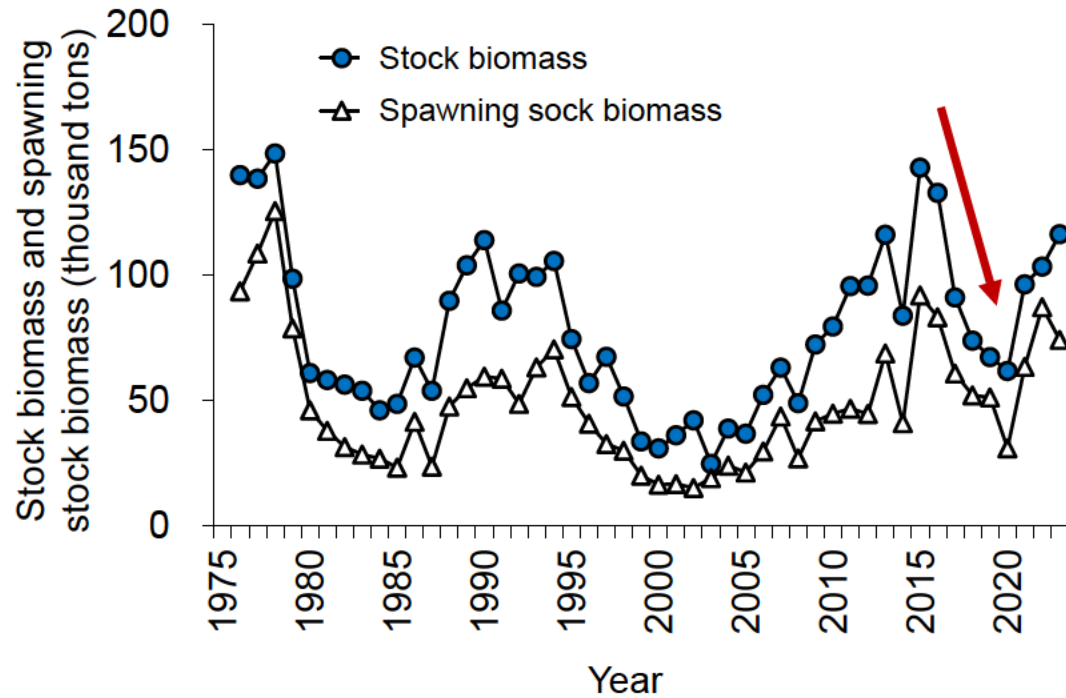
- How large does rho need to be before retrospective bias is judged to be large?

Hurtado-Ferro et al. (2015) suggested that Mohn's ρ values exceeding 0.30 or below -0.22 for short-lived species may indicate notable retrospective bias. We considered these values as general guidance when interpreting our results, but did not apply them as strict thresholds, recognizing that retrospective patterns should be evaluated in the broader context of model behavior.



Results of retrospective analysis

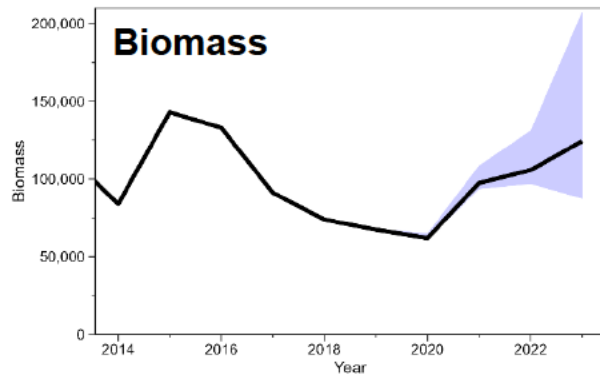
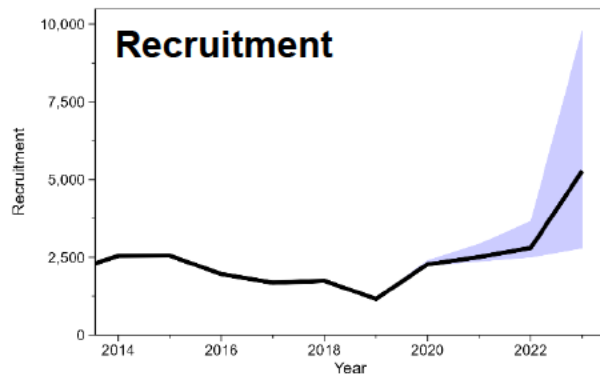
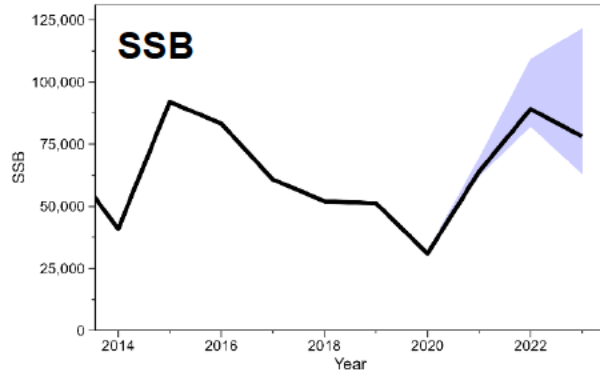
Stock status: Trends in Stock Biomass and Fishing Pressure



- What is hypothesized to have caused this sharp decline in SSB after the peak in 2016?

The sharp decline in SSB after the peak in 2016 is hypothesized to have been caused by low recruitment and reduced recruitment per spawner during the period from 2016 to 2019.

Stock status: Trends in Stock Biomass and Fishing Pressure



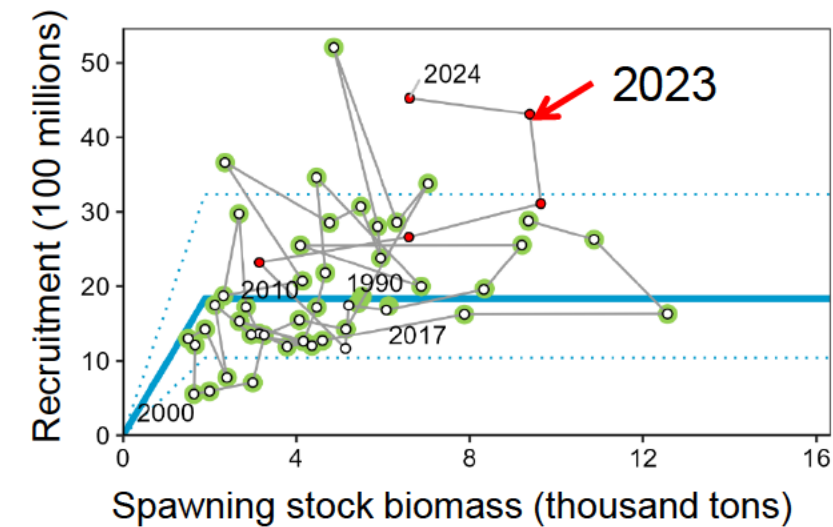
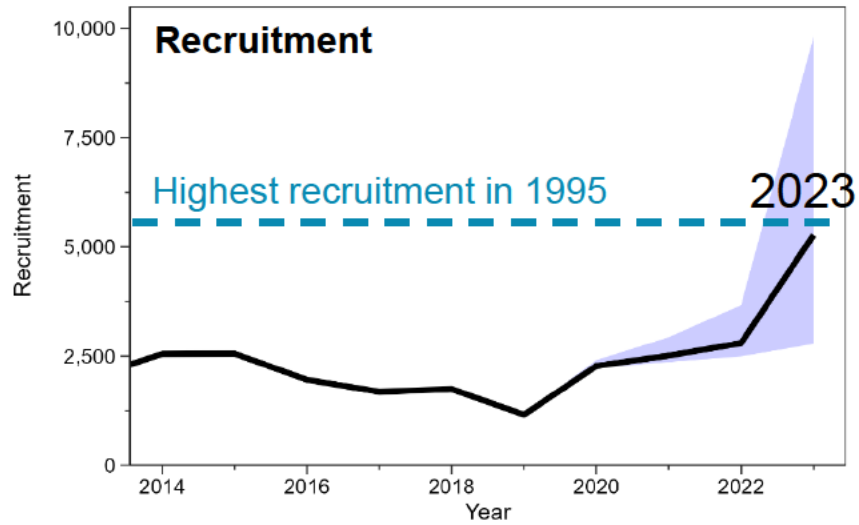
Comment

- Bootstrapping methodology should be applied to generate confidence intervals in these abundance estimates as is commonly done in other stock assessments that use VPA (e.g., ADAPT VPA and VPA 2 Box used at ICCAT). Bootstrapping of each abundance index time series that the VPA model is fitted to needs to be done to characterize the uncertainty in abundance and fishing mortality rate estimates in each historical and projected future year.

As suggested, we estimated confidence intervals using a residual-based bootstrap method, in which residuals of the abundance indices were resampled.



Stock status: Trends in Stock Biomass and Fishing Pressure



Comment

- When bootstrapping is done, there will likely be uncertainty over whether the 2023 recruitment was second highest since, the most recent recruitment estimates in VPA are typically the most uncertain compared to recruitment estimates earlier in the time series.

Bootstrapping indicated relatively high uncertainty in the 2023 recruitment estimates; however, even the lower bound of the 95% confidence interval remained higher than those of most previous years.

In addition, an updated stock assessment conducted in fiscal year 2025 indicated that recruitment in 2023 was the second highest over the period 1996–2023.



Stock status: Trends in Stock Biomass and Fishing Pressure

Comment

- Bootstrapping of the abundance index data used in tuning the VPA should be done to determine confidence intervals for F, N, and stock biomass estimates from the VPA.

Following table shows the 5th, 50th, and 95th percentile values for F at age, N at age, and SSB.

Age	F		NAA (x million fish)			SSB (t)
	0	1-2	0	1	2	1-2
5%	0.35	0.75	278	63	15	62,991
50%	0.86	1.88	482	74	18	74,245
95%	17.46	38.18	954	118	28	117,434



Stock status: Trends in Stock Biomass and Fishing Pressure

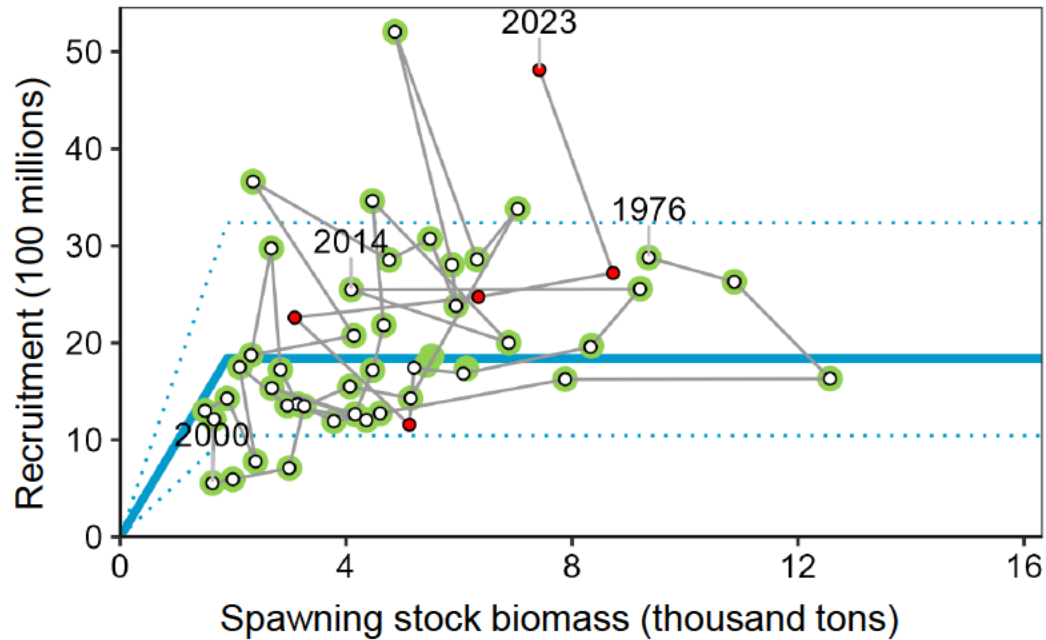
Comment

- A bootstrapping framework would allow a statement on the probability that there is an increasing trend in SSB.
- A measure of the uncertainty in estimates of the quantities in this table should also be provided, e.g., in the form of coefficients of variation (CVs) shown in parentheses
- With bootstrapping of the abundance indices, confidence intervals could be provided for the estimated quantities.
- Probability statements should be provided for each of these quantities.

These comments were related to the text format of the assessment report. As response to general questions, the uncertainty of stock assessment would be the same problem for all stocks in Japan. We intend to address the treatment of uncertainty as a common issue for all species.



Stock status: Stock-recruitment Relationship

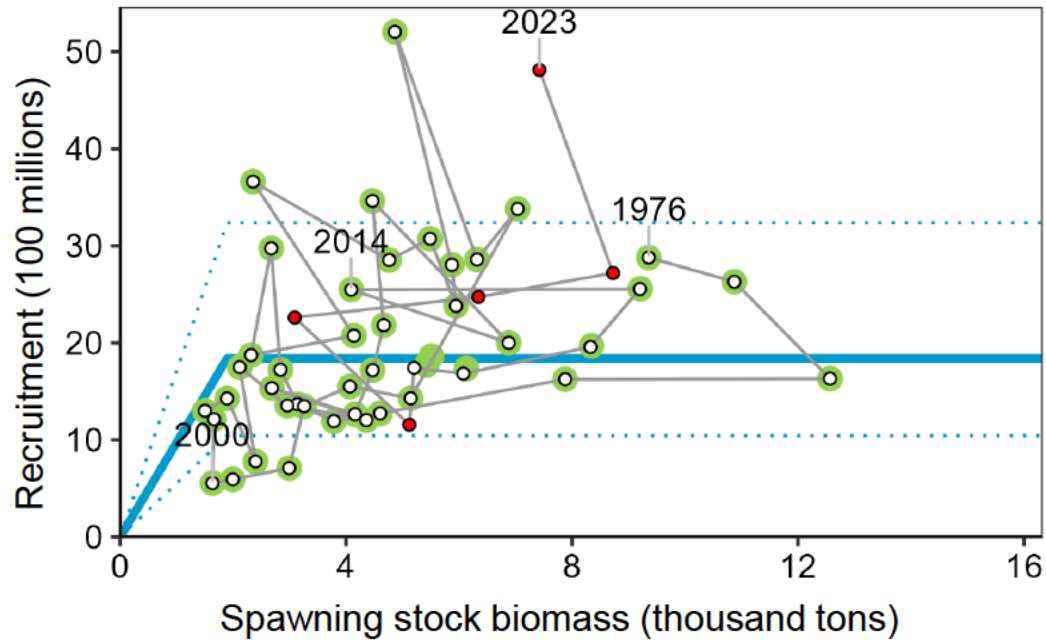


Comment

- The Ricker or Beverton-Holt have numerous superior properties for representing stock-recruit dynamics to the hockey stick model. I would recommend that the stock assessment group consider replacing the hockey-stick model with either the Beverton-Holt or Ricker models. There should be technical justification which is ecologically, empirically and statistically based.

As explained in the general comments, we follow [the Guidelines for determining the stock–recruitment relationship](#). In a previous analysis conducted in 2021, three stock–recruitment relationships were examined in accordance with these guidelines. Based on AIC, the hockey-stick model provided the best fit among the three models; however, the differences in AIC were less than 4. Results from the Management Strategy Evaluation (MSE) suggested that [the hockey-stick model was preferable because it implied a lower risk to stock status](#), even in cases where the assumed SR relationship was misspecified.

Stock status: Stock-recruitment Relationship

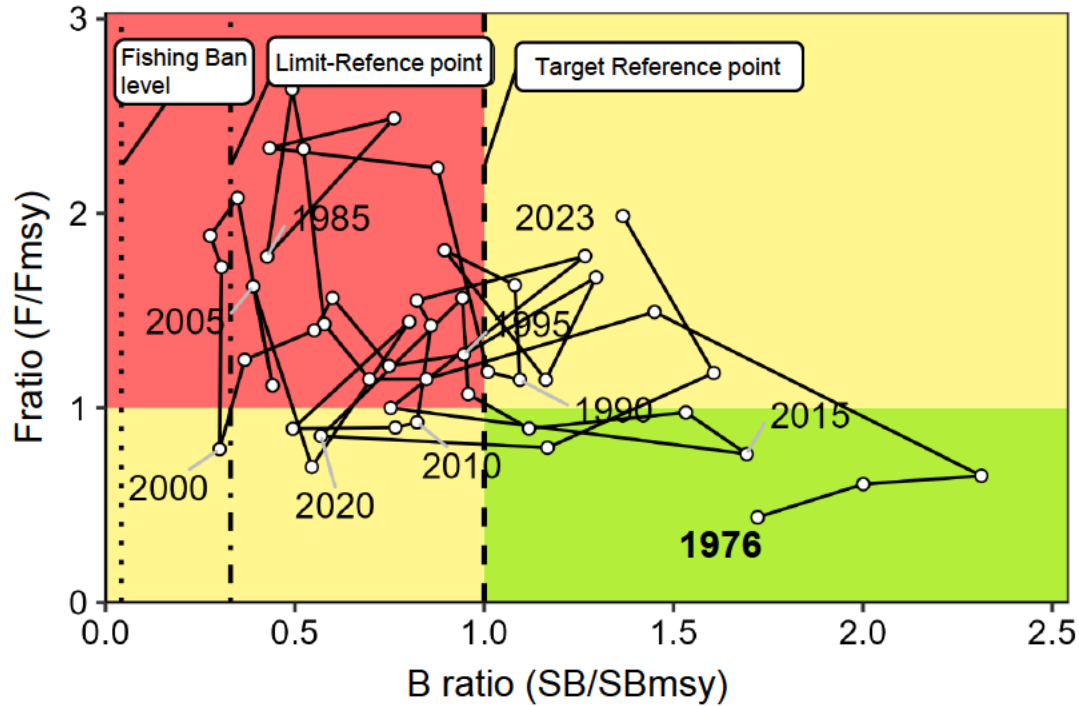


In the case of round herring, we consider that the main reason for the observed variability is the **inherently high interannual variability in recruitment**, as noted in reviewer's comment.

Additional comment

- Why are the time trajectories for estimated recruitment for shotted halibut (Fig. 4-4) and splendid alfonsino (Sup. Fig. 2-4) so remarkably smooth while those for Japanese Anchovy (Fig. 4-6) and round herring (Figure 4-5) far more variable between years (See these assessment document plots copied in Figure 2 below)? **Is the main reason for smooth versus highly variable time series of recruitment estimates driven mainly by fish biology and ecology (actual low versus high interannual variability in recruitment processes), or could it be related to the interaction between the structure of the catch-age data (e.g., smearing of catch-at-age due to imperfect length-to-age assignment) and the VPA assessment methodology applied?**

Stock status: Stock Levels, Trends and Fishing pressure Levels



Comment

- It would be appropriate to provide a probability statement for the probability that the stock biomass in 2023 was greater than the SBmsy level.

According to the bootstrap results, there was a **99.6% probability** that the stock biomass in 2023 exceeded SBmsy.

- The initial year in the lower right-side quadrant should have a label for year also.

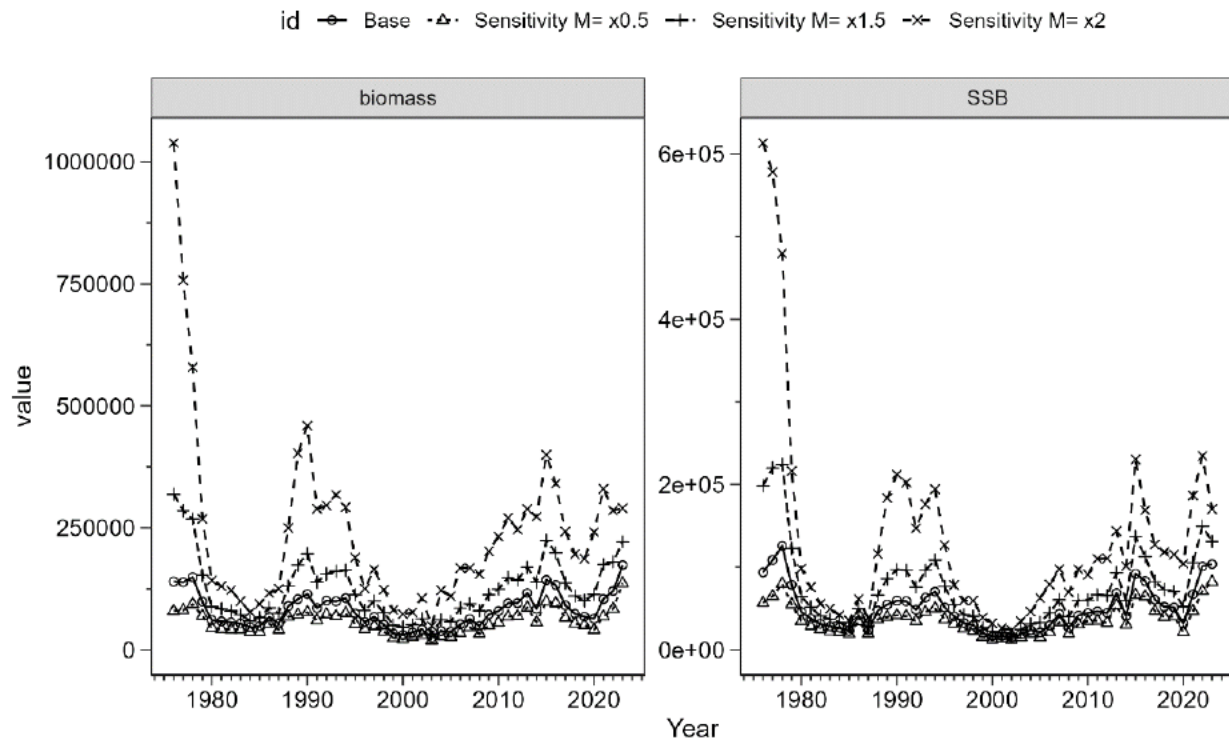
OK



Stock status: Stock Levels, Trends and Fishing pressure Levels

Comment

- Could M be changing systematically over time, e.g., due to changes in predation rates on recruited fish in this stock?
- Some bootstrapping algorithms for VPA also introduce uncertainty in M , e.g., by taking draws of M from an uncertainty distribution (or prior distribution for M).



We do not have information on temporal changes in M for round herring. However, our institute is conducting cross-species research on M .

To evaluate the sensitivity of our results to uncertainty in M , we conducted a sensitivity analysis by varying M to 0.5, 1.5, and 2.0 times the base value and examined the resulting effects on biomass and spawning stock biomass (SSB).

Stock status: Stock Levels, Trends and Fishing pressure Levels

Comment

- How was Fmsy calculated?

Fmsy was defined as fishing pressure required to maintain SBmsy.

The reference points, MSY and Fmsy were determined at the FY 2021 Research Institute Meeting. Fmsy was estimated through forward projection using age-specific selectivity and mean body weight (g) by age from the stock assessment results at that meeting.

Table Parameters for future projections

Age	Selectivity	Average body weight (g)
Age 1	0.23	15.9
Age 2	1.00	67.7
Age 3	1.00	134

Table Reference points and MSY

Item	Value	Explanation
SBtarget	54,000 tons	Target reference points. Spawning stock biomass required for the realization of Maximum Sustainable Yield MSY (SBmsy).
SBlimit	18,000 tons	Limit reference point. SSB required for a catch of 60% of MSY (SB0.6msy)
SBban	2,000 tons	Fishing ban level. SSB required for a catch of 10% of MSY (SB0.1msy)
Fmsy		Fishing Pressure (Fishing mortality F) required for the realization of Maximum Sustainable Yield (MSY). (Age 0, Age 1 and Age 2) = (0.33, 1.45, 1.45)
% SPR (Fmsy)	44.7%	%SPR corresponding to Fmsy
Maximum Sustainable Yield (MSY)	35,000 tons	Maximum Sustainable Yield (MSY)

Future Projection

Stock population at age by year
Fishing mortality at age by year

Forward calculation
for 2024 onward

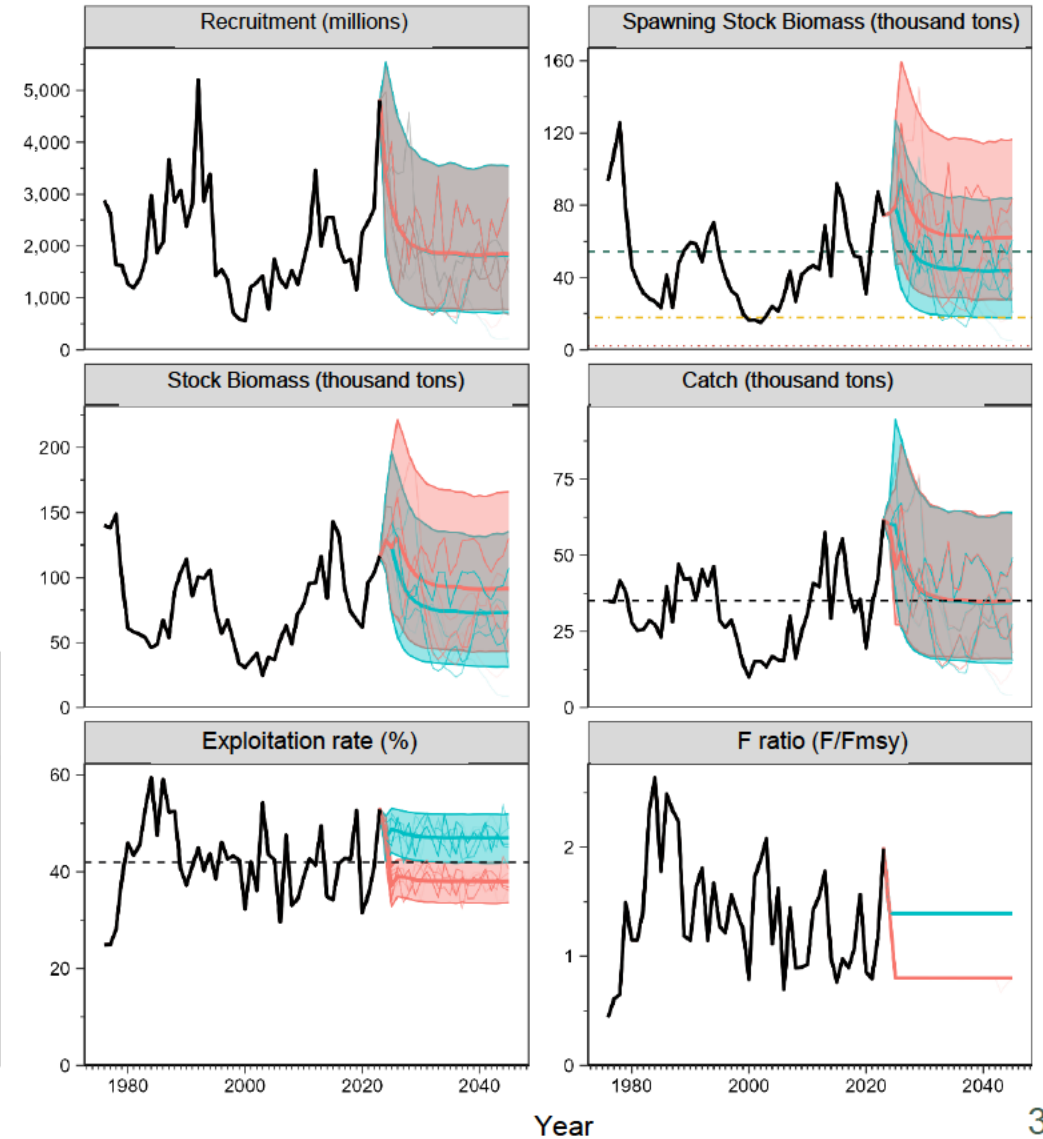
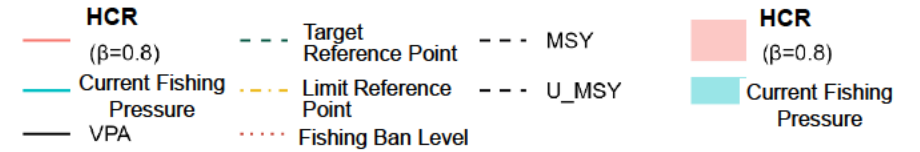
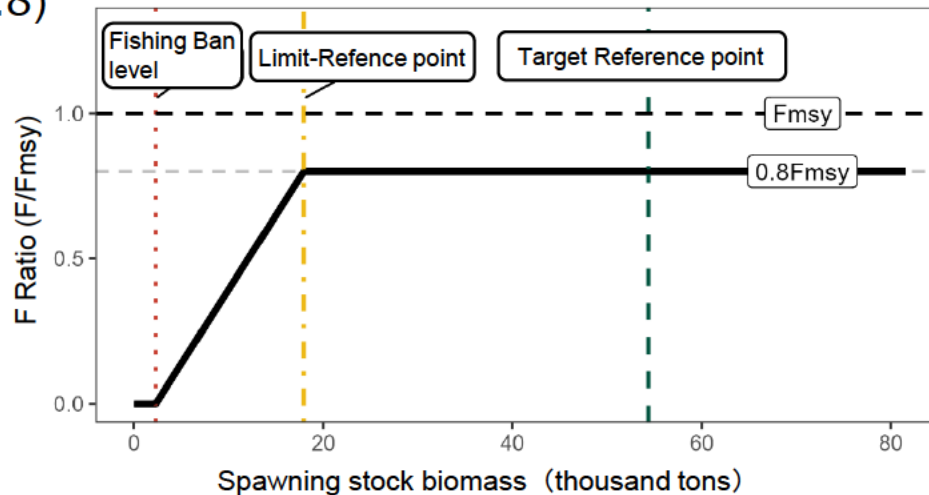
Assumed Recruitment (Calculated from Stock-Recruitment relationship considering recruitment fluctuations)

Stock population in 2024 and onwards

F for 2024 assumed simple average of F from 2021 to 2023

F for 2025 onward assumed based on HCRs ($\beta=0.8$)

Harvest Control Rule



Others



This species has a short life span, and the majority of the catch consists of fish age 0 to 1. In order to ensure stable utilization of this stock, we believe that it will be effective to maintain SSB above a certain level. Therefore, when recruitment is deemed to be low, measures such as refraining from catching age 0 fish are believed to be effective.

Comment

- Technically how might this be achieved?

This issue could be addressed in future studies **by implementing systematic monitoring of age-0 abundance** through routine fishery-dependent sampling, complemented by fishery-independent surveys (e.g., larval, juvenile, or acoustic surveys). In addition, it may be possible to **regulate fishing seasons or specific fisheries** that predominantly catch age-0 fish. Such approaches would improve the ability to track recruitment dynamics and contribute to more effective fisheries management.

Summary



Maximum Sustainable Yield (MSY), Spawning Stock Biomass (SSB) Levels and Trends, and Allowable (or Acceptable) Biological Catch (ABC)	
SSB required for MSY (SBmsy)	54,000 tons
Level of SSB in 2023	Over the level required for MSY
Level of fishing pressure in 2023	Over the level required to maintain SBmsy
Changes in SSB in 2023	Increase
Maximum Sustainable Yield (MSY)	35,000 tons
ABC for 2025	46,000 tons
Comment: - The ABC was calculated using harvest control rules based on the catch strategy for this stock, which was compiled during the “ Stock Management Policy Review Meeting ” and established through the “Fishery Policy Council”. - Adjustment coefficient $\beta = 0.80$ was used.	

Comment

- This should be a probability statement, e.g., giving the probability that SSB for 2023 is above the level required for MSY.
- This could be restated as the probability that SSB in 2023 is increasing.

Thank you for your valuable comment. As response to general questions, we intend to address the treatment of uncertainty as a common issue for all species.



Slides for the Follow-up Discussion

Chullasorn et al. (1977)



- Otolith collected from 564 specimens

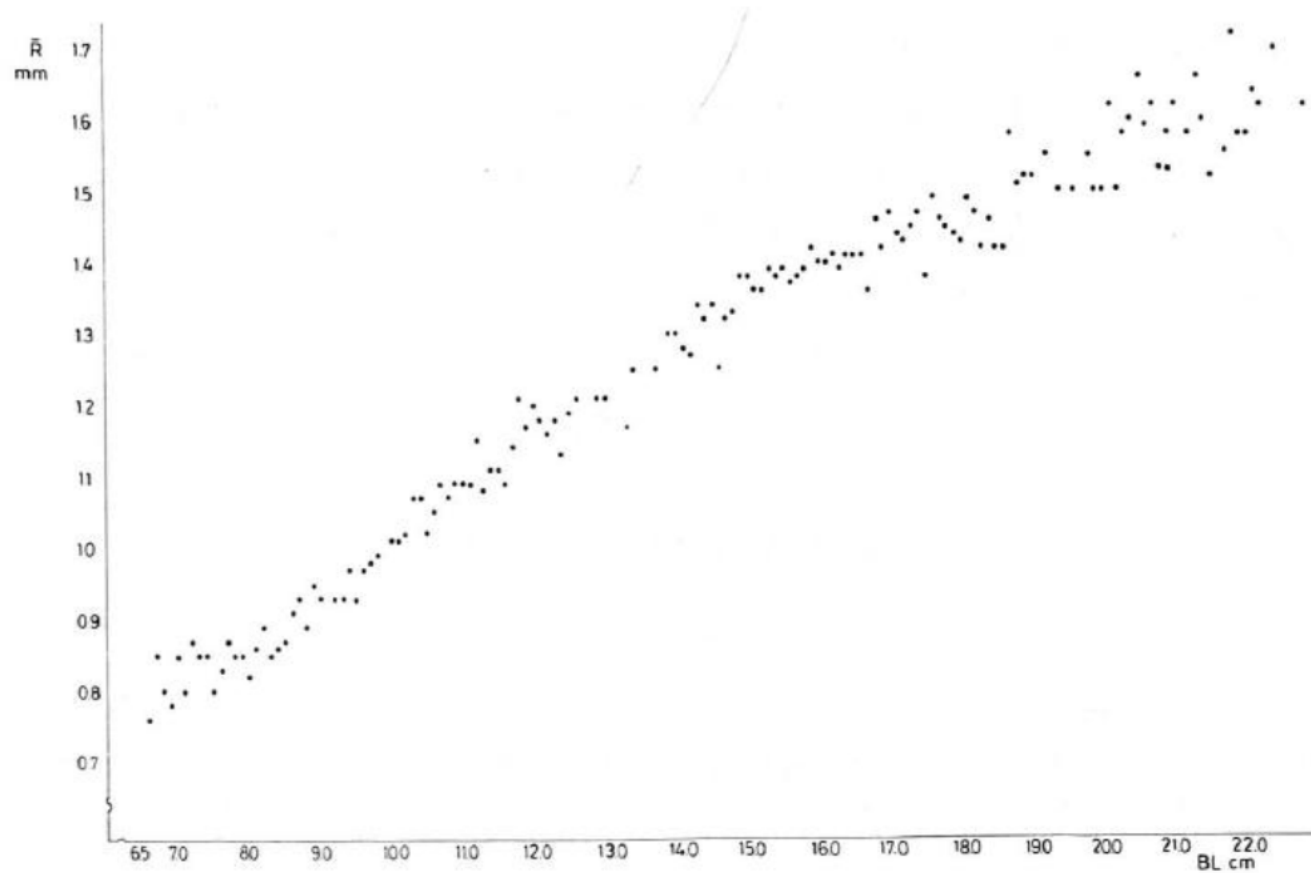


Fig. 1. Relationship between body length and average otolith size.

Table 1. Mark size, otolith size and calculated body length of round herring.

Age (year)	1	2	3
r'_n (mm)	1.19	1.38	1.53
R' (mm)	1.25	1.45	1.58
l_n (cm)	13.26	17.35	20.50

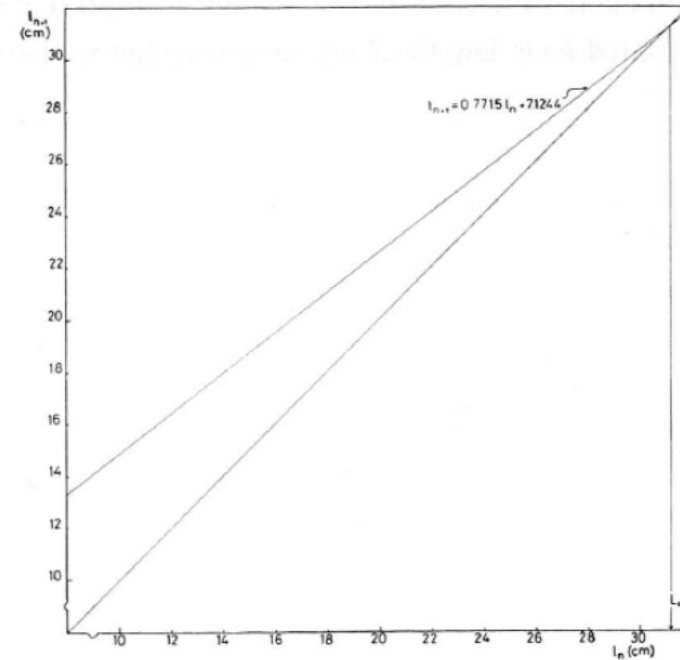


Fig. 6. Walford's growth transformation of body length.

Chullasorn et al. (1977)



The growth of body weight can be derived from the equation (3) and (4) and expressed by the following equation:

$$w_t = 434.54(1 - e^{-0.2594t - 0.2431})^{3.1819}. \quad (5)$$

The calculated body length and body weight at t -years after spawning have been tabulated in Table 2.

Table 2. Body length and body weight at t -years after spawning calculated from the growth equation.

t (years)	1	2	3	4	5	6
l_t (cm)	12.26	16.59	19.92	22.50	24.48	26.01
w_t (g)	22.34	58.48	104.65	154.19	201.65	244.56

- Age-6 values were calculated estimates, not direct observations.
- This manuscript reported that “Age component in the total catch shows the small fish of less than one year old are heavily exploited about 96.5% in term of numbers.”

Growth curve

Ohshimo et al. 2011

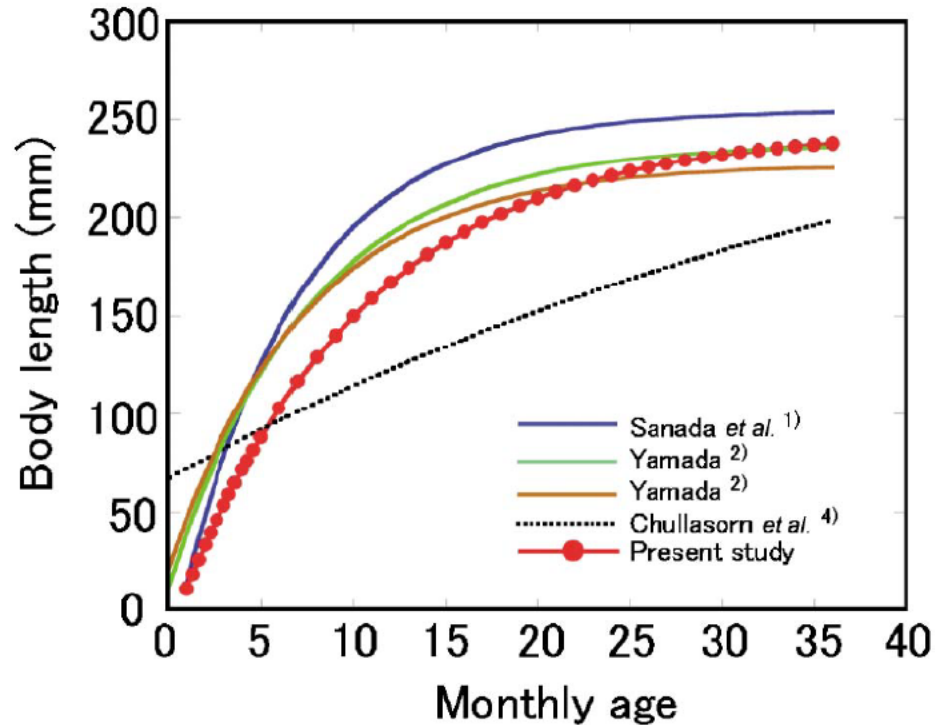
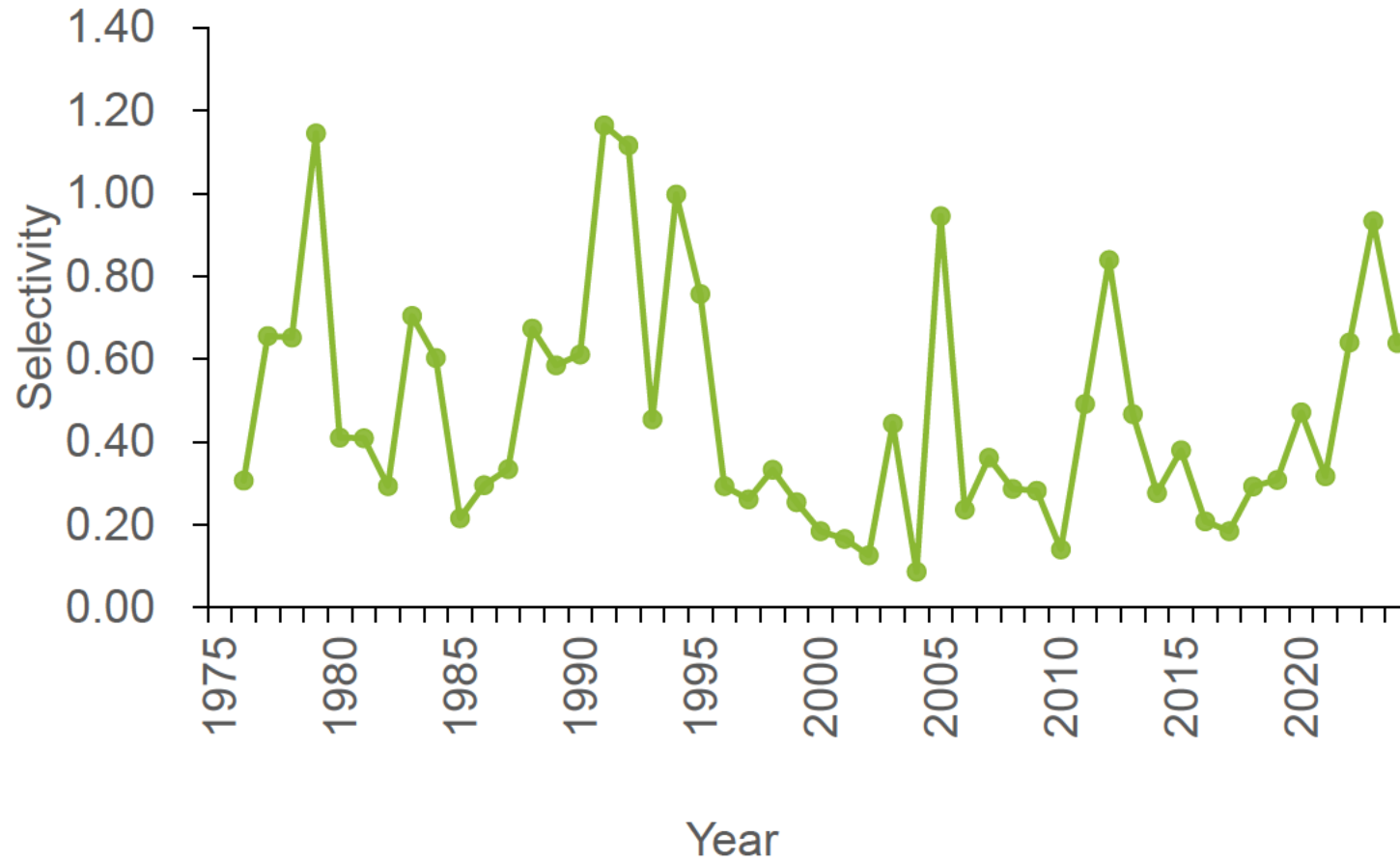


Fig. 5 Comparison between previous studies and the present study. The blue, green and brown solid lines represent the previous growth curves in the Pacific Ocean^{1,2)}, the black dotted line represents the growth curve in the East China Sea⁴⁾ and the red line and closed circles represent our results.

- Age-determination data collected in 2024 (n = 111) tentatively estimated a growth curve that did not differ substantially from that reported by Ohshimo et al. (2011).
- Because our analysis incorporated the relationship between daily and annual otolith rings, growth estimates based on Chullason et al. (1977) are considered unreliable.

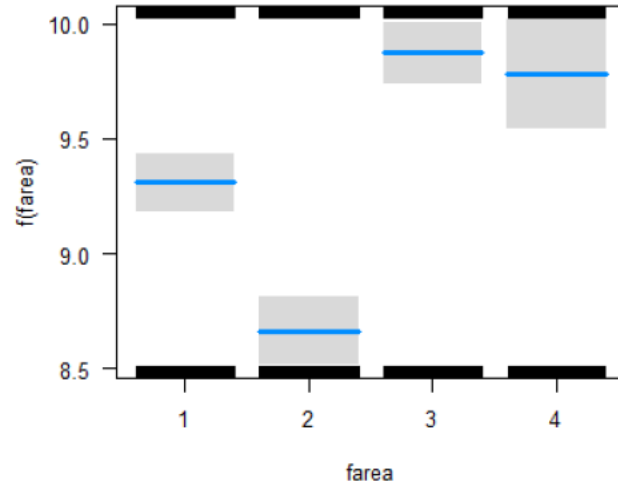
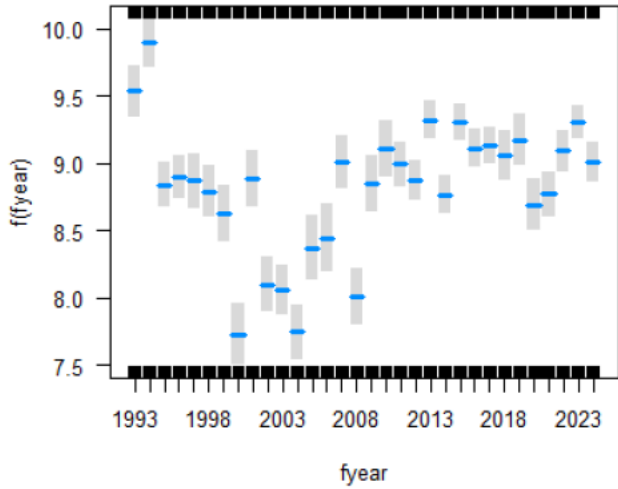


Temporal changes in Selectivity

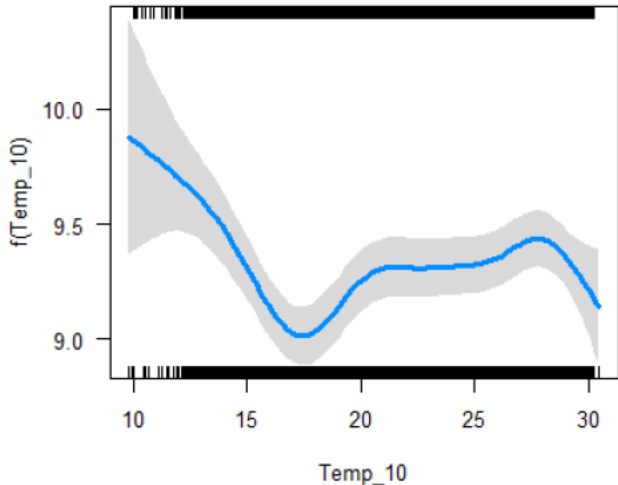


Effect of sea temperature on Purse Seine catch

Log(CPUE)~factor(Year)+factor(Area)+s(Temp10)



- Data collected at low water temperatures showed wider confidence intervals and fewer observations
- A temperature range of approximately 20–28 °C appears to be preferable for round herring



Anova table

Parametric Terms

	df	F	p-value
fyear	31	30.49	<2e-16
farea	3	215.45	<2e-16

Smooth Terms

	edf	Ref.df	F	p-value
s(Temp_10)	7.486	8.454	10.36	<2e-16

