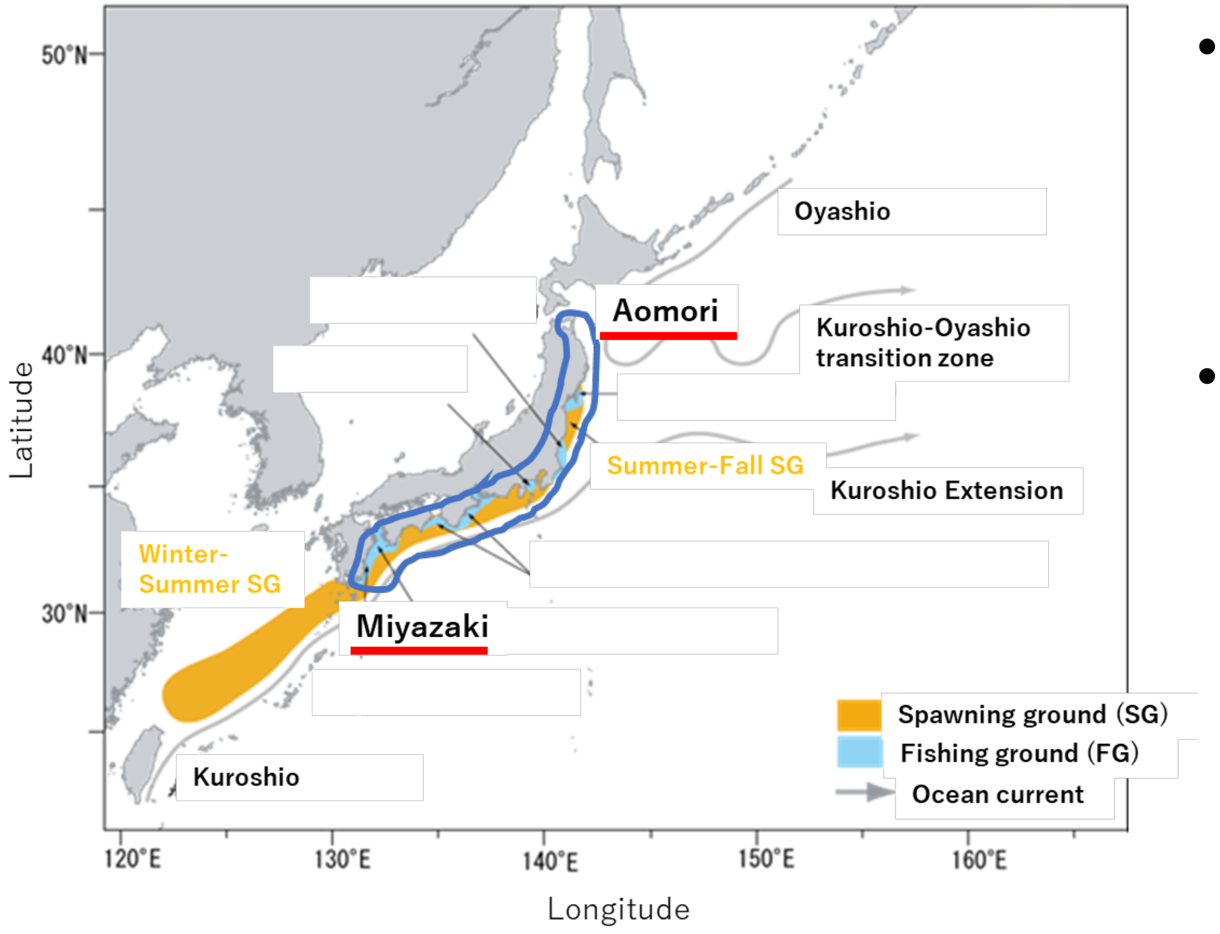
Pacific stock of Jack Mackerel

Contents

- Biology and Stock assessment
- Stock-Recruitment Relationships
- Reference points and Kobe-plot
- Harvest Control Rule and Future projection

Distribution



- The Pacific stock distributes along the Pacific coastal waters of the Japanese archipelago.

- The spawning grounds are southern East China Sea area and coastal areas on the Pacific side of Japan.

Reviewers Comments

- 1) The figs of spawning grounds for the Pacific and Tsushima stocks suggest that there is substantial overlap in their spawning grounds in the East China Sea. In addition, the text explaining the stock distributions do not provide evidence of stock structure for the two stocks. Therefore, it is not clear that the assumed stock structure is appropriate. It may be that both the Pacific and Tsushima stocks are the same stock and a portion of the stock goes to the Pacific side. Please provide evidence that the stock structures for the Jack Mackerel stocks (Pacific & Tsushima) is appropriate and how the distributions were derived.

(Responses)

Currently, Jack mackerel in the Pacific could be consisted of East China Sea (main spawning grounds) and Pacific (local spawning grounds).

However, juvenile and adult fish cannot move from Pacific to East China Sea probably due to Kuroshio current, but its unclear.

The magnitude of recruitment from East China Sea to Pacific is also unclear.

Some research surveys and analyses have been conducted.

- 2) If there are indeed two stocks, the special notes also suggest that the stock origin of fish caught on fishing grounds are not clear and may be a mixture of the two stocks. Therefore, there is a need to detail how the catch-at-age data is separated for the two stocks on the fishing grounds.
- 9) The calculation of the total catch is a bit complex with adding and subtracting from multiple sources, and I got a little confused. Please explain the logic of how total catch was calculated.

(Responses)

The total catch is calculated as the sum of the catch records from prefectures along the Pacific coast (between Aomori and Miyazaki).

The catch by fleets operated in the East China Sea is removed from the total catch because it is treated as the TWC stock.

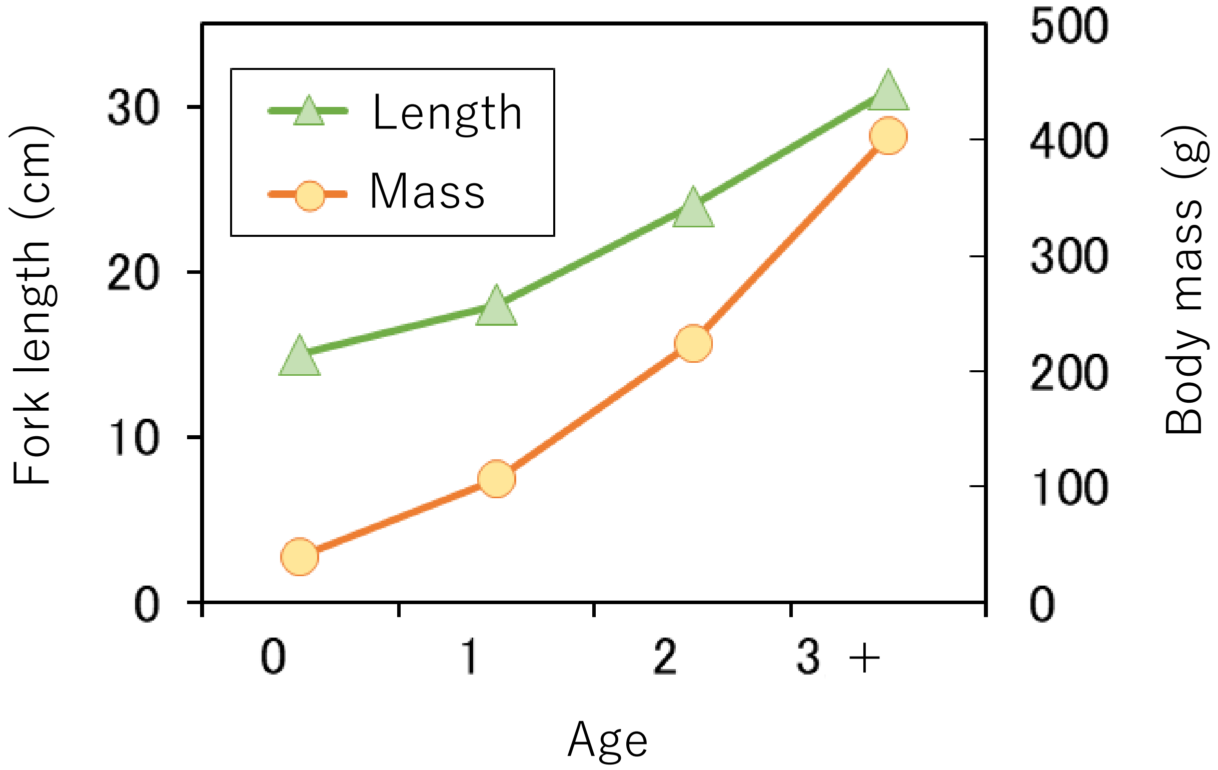
Reviewers Comments

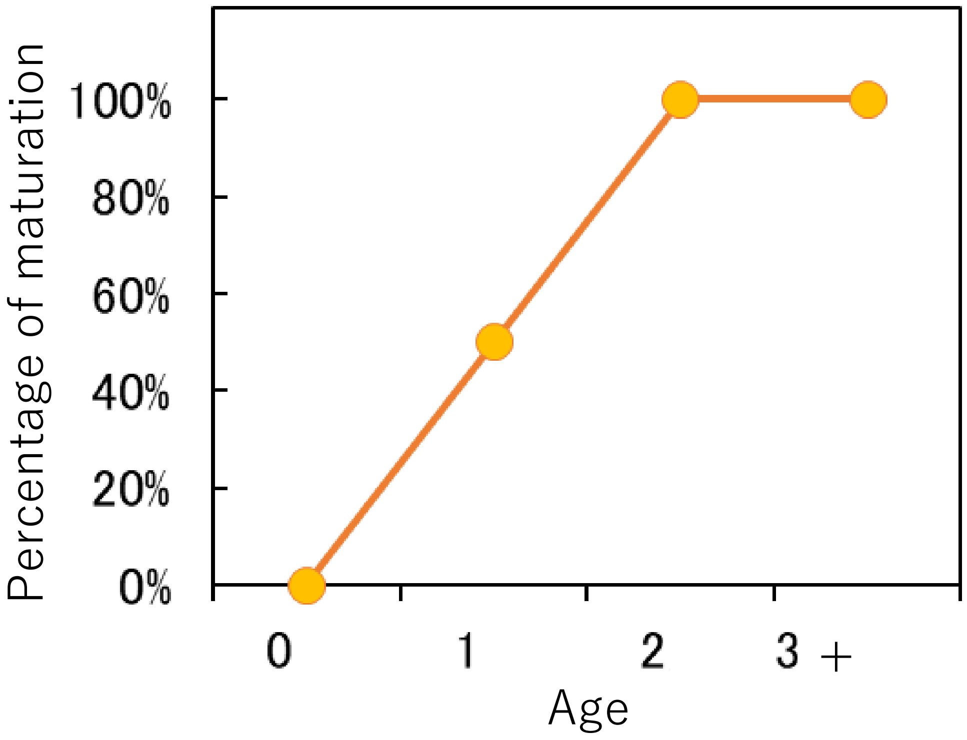
- 10) The distribution of this stock appears to extend into the East China Sea (Fig. 2-1). Therefore, it may also caught by non-Japanese fleets. However, I do not see the catch of non-Japanese fleets. Has the catch by non-Japanese fleets been included? If not, why not? If yes, please explain and document. Also, Fig 2-1 shows that the stock does not extend into the pelagic waters of the Pacific. Is that correct?

(Responses)

We assume that the stock does not extend into the pelagic waters of the Pacific and that there is no catch of non-Japanese fleets.

Growth and Maturity





Natural Mortality

$M = 0.5$ (Tanaka 1960, $M = 2.5/A_{max}$)

Reviewers Comments

- 18) Using Hoenig, the assumed maximum age of 5 years is inconsistent with an M of 0.5 per year (you would need a max age of about 10 or 11 years to get M of 0.5 per year). I am unfamiliar with Tanaka 1960.

(Responses)

The formula of Tanaka 1960 is based on the idea that M is inversely proportional to the longevity, like Hoenig (1982).

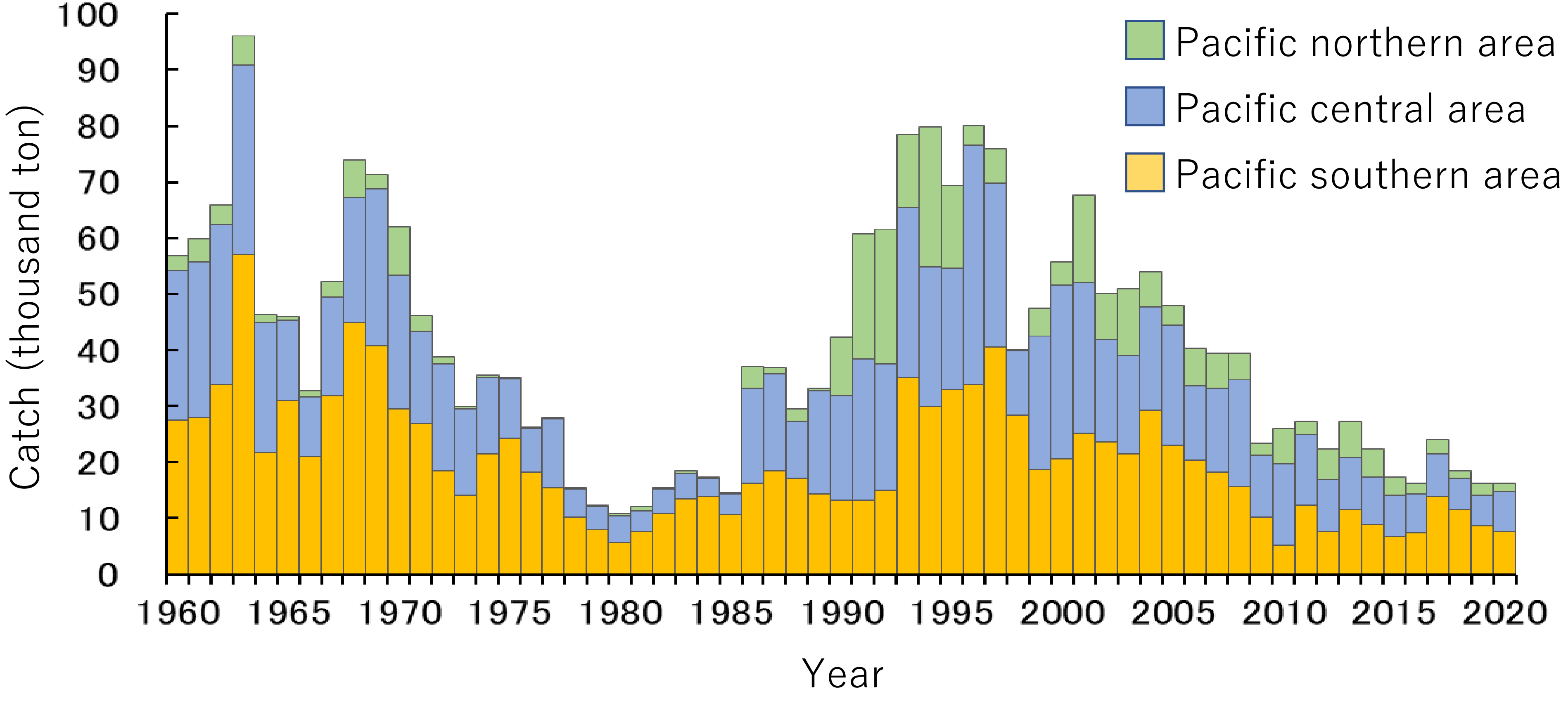
- 19) Given that there has been more recent and more appropriate meta-analysis of natural mortality relationships (i.e., Hamel 2015) than Tanaka 1960, there is a need to explain why using the relationship in Tanaka 1960 is the best scientific information available.
- 20) Even if using Tanaka 1960 is appropriate, the range of sensitivity for M (0.4 to 0.6) does not likely cover the uncertainty in the Tanaka 1960 meta-analysis. If using Tanaka 1960, it would be important to calculate the prediction interval for the relationship (Hamel 2015).

(Responses)

The formula of Tanaka 1960 is a simple and convenient method, but some problems have been pointed out, such as the definition of longevity and the amount of data that supports it.

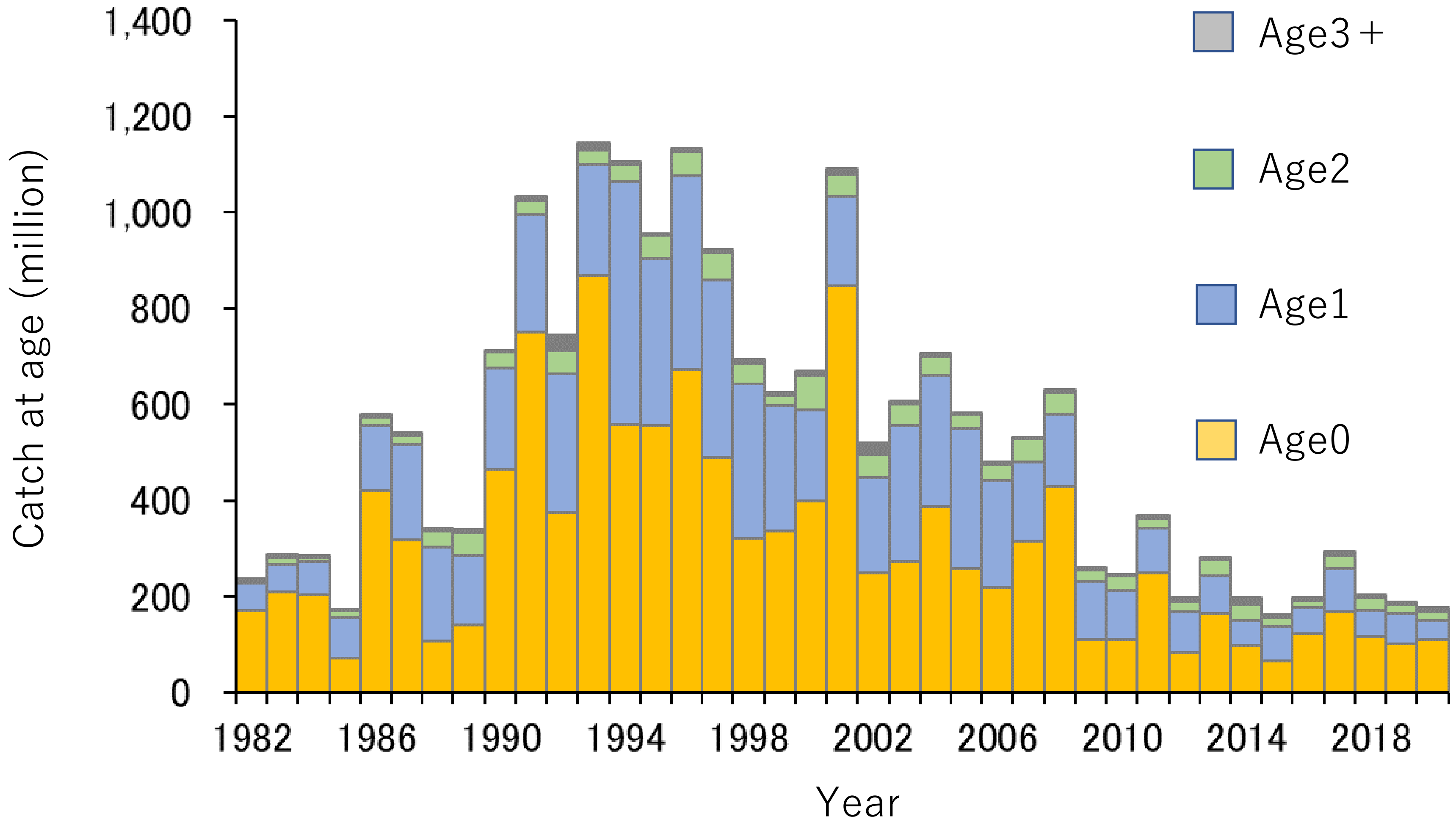
With Hamel (2015) as a reference, we will continue to investigate M and the interval of sensitivity analysis.

Catch



Pacific northern area
Pacific central area
Pacific southern area
Catch (thousand ton)
100
90
80
70
60
50
40
30
20
10
0
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

Catch at age (CAA)



Reviewers Comments

- 11) The length-weight relationship used to convert catch in weight to catch in numbers appears to be fixed (BW (g) = 0.013 × FL3 (cm)). This assumes that this does not vary by space and time. If so, please show the data used to develop this relationship and evidence to support this assumption.
- 12) Was any aging done to develop the ALKs or were these based on growth models? If there was aging done, please show the aging data relative to the ALKs.
- 13) If the ALKs were based on growth models, please show the growth models and the uncertainty and variability in the growth models (and the data if possible). In Section 2.2, the age and growth section states that growth varies by space and time. Therefore, there should be growth models by space and time.
- 14) If the ALKs were based on aging, please show the aging data and the estimated aging error.
- 15) Cohort slicing assumes that a single length can only be assigned to a single age. This is likely inappropriate. Instead, the ALK should be used to assign a single length into multiple ages with different probabilities, based on the aging data or growth model. Based on aging done in the EPO, small pelagic fish like sardine and mackerels with the same length often have different ages, especially after age-0. Please show the aging data to support that assumption. Based on the examples in Fig. 3, this assumption does not appear to be well supported for some years and ages.
- 16) For each region and month, the same ALK appears to be used for all years. As stated in the documents, this is likely inappropriate due to variability in growth. Based on aging done in the EPO, the ALK can vary greatly between years. It is good that studies are being done to deal with this issue.
- 17) In addition, the age selectivity of each fishery also affects the ALK. Therefore, it is common for each fishery to have separate ALKs. Therefore, it would be useful to have studies comparing the ALKs between fisheries in the future, especially for different gears.

(Responses)

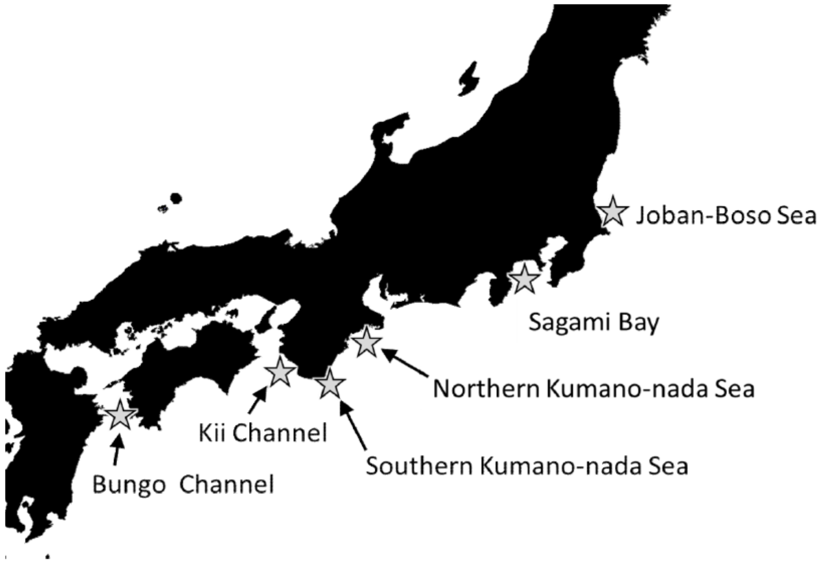
To develop CAA, a fixed FL-BW relationship and a fixed ALK is used for all years.

We use an ALK developed by cohort slicing.

As the reviewer stated, we also think that this method needs improvement.

Catch at age (CAA) – Recent progress

- We have recently found spatial and temporal difference in the FL-BW and the FL-Age relationships.
- We are improving how to develop CAA.



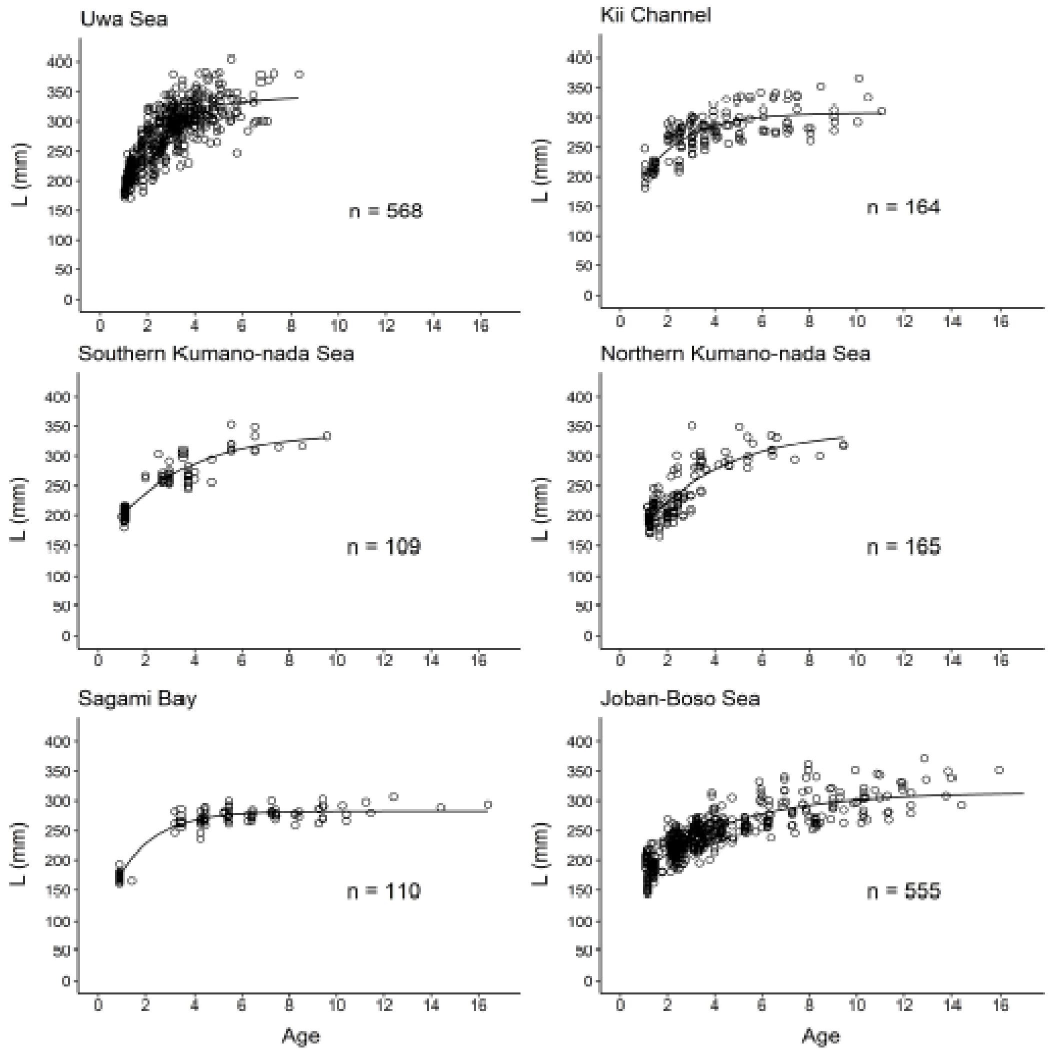
FL-BW relationships in 6 different areas

Table 6. Fork length(L mm) - body weight(W g) relationships and calcurated W-at-ages of adult jack mackerel by Sea areas

Area	L-W relationship	W-at-ages 1	2	3	4	5	6
Uwa Sea	$W = 2.62 \times 10^{-5} L^{2.88}$	95	229	342	421	470	500
Kii Channel	as avobe	117	206	275	321	351	369
Southern Kumano-nada Sea	as avobe	111	188	261	324	375	416
Northern Kumano-nada Sea	as avobe	86	157	229	295	351	398
Sagami Bay	$W = 2.08 \times 10^{-4} L^{2.49}$	85	155	203	232	248	257
Joban-Boso Sea	$W = 1.42 \times 10^{-5} L^{2.98}$	75	121	167	209	246	276

Watanabe et al. unpublished data

Catch at age (CAA) – Recent progress



Growth equations and L-at-ages in 6 different areas

Table 5. Fork length (L mm) growth equations and calcurations L-at-ages of adult jack mackerel by Sea areas

Area	von Bertalanffy growth equations	L- at- ages					
		1	2	3	4	5	6
Uwa Sea	$L_t = 343(1 - e^{-0.56(t+0.41)})$	187	254	292	314	326	333
Kii Channel	$L_t = 307(1 - e^{-0.53(t+1.00)})$	201	245	271	286	295	300
Southern Kumano-nada Sea	$L_t = 341(1 - e^{-0.32(t+1.70)})$	198	237	266	287	302	312
Northern Kumano-nada Sea	$L_t = 347(1 - e^{-0.29(t+1.55)})$	181	223	254	277	295	308
Sagami Bay	$L_t = 283(1 - e^{-0.63(t+0.57)})$	178	227	253	267	275	279
Joban-Boso Sea	$L_t = 313(1 - e^{-0.27(t+2.18)})$	180	211	235	253	268	278

Watanabe et al. unpublished data

Procedures of tuned VPA

Fundamental part

$$N_{a,y} = N_{a+1,y+1}\exp(M) + C_{a,y}\exp(M/2)$$

$$N_{2,y} = \frac{C_{2,y}}{C_{2,y}+C_{3+,y}} N_{3+,y+1}\exp(M) + C_{2,y}\exp(M/2)$$

$$N_{3+,y} = \frac{C_{3+,y}}{C_{2,y}+C_{3+,y}} N_{3+,y+1}\exp(M) + C_{3+,y}\exp(M/2)$$

$$N_{a,Y} = \frac{C_{a,Y}}{1-\exp(-F_{a,Y})}\exp(M/2)$$

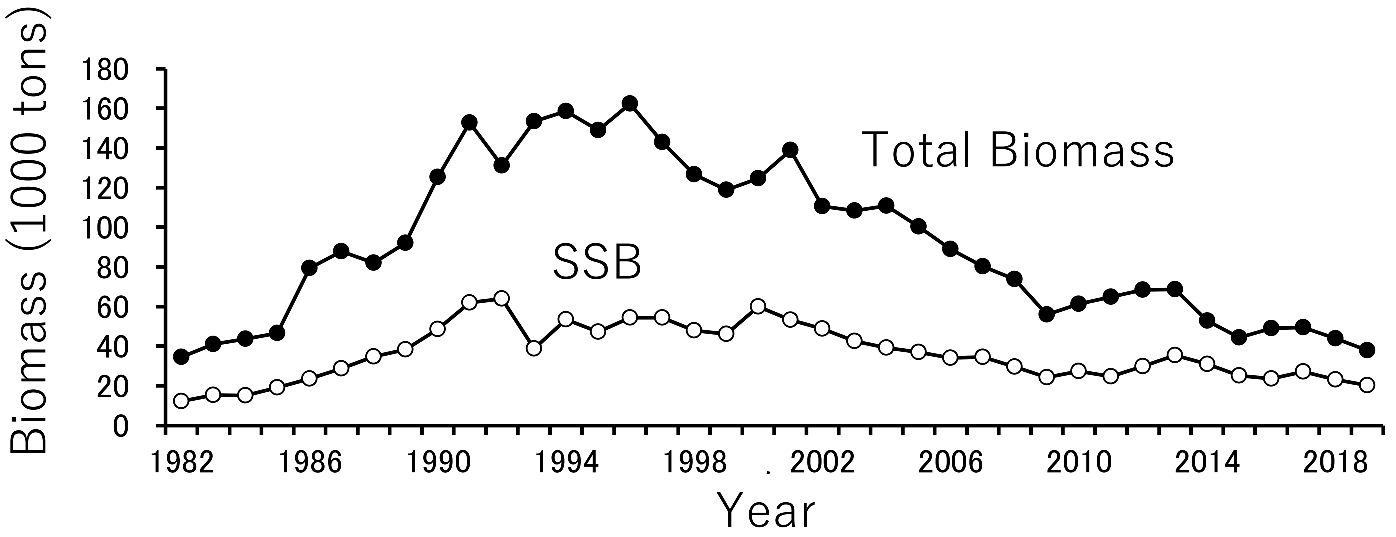
$$F_{a,y} = -\ln\left(1 - \frac{C_{a,y}\exp(M/2)}{N_{a,y}}\right)$$

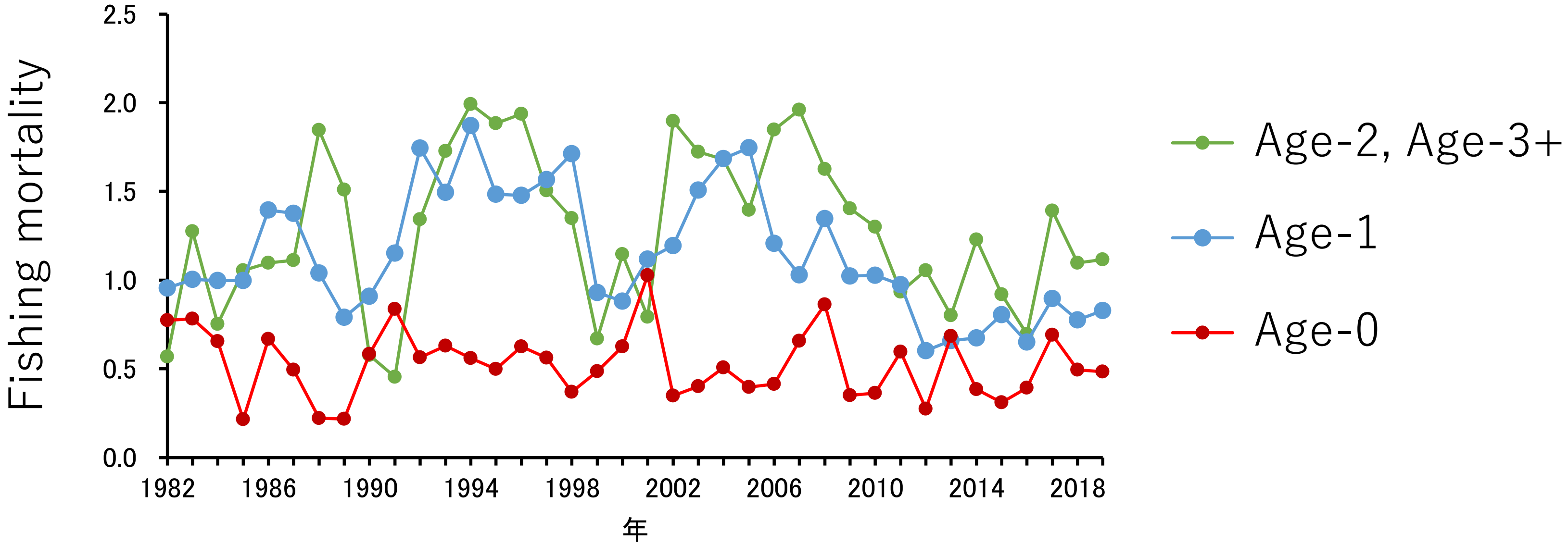
Tuning part

$$RSS = \sum_{j=1}^{6}\sum_{y=2005}^{Y}(\ln(\hat{I}_{j,y}) - \ln(I_{j,y}))^2$$

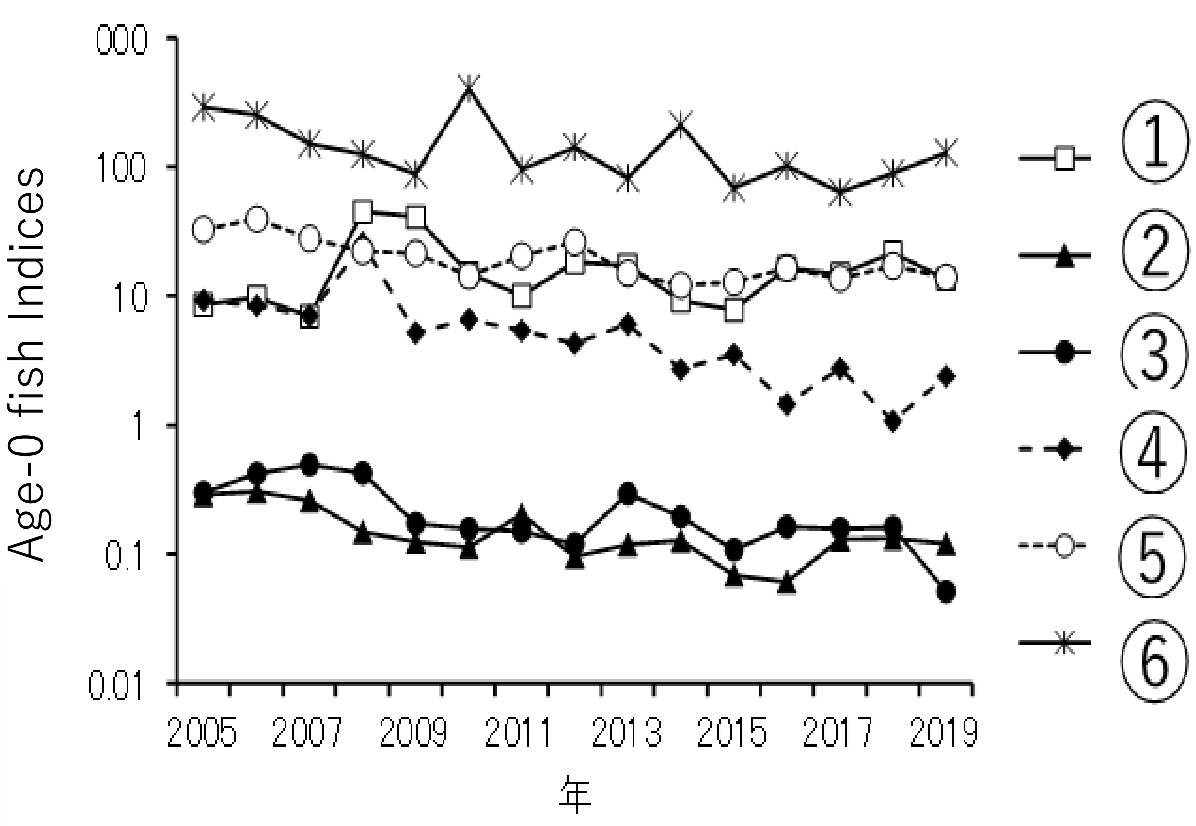
$$\ln(\hat{I}_{j,y}) = \ln q_j N_{0,y}$$

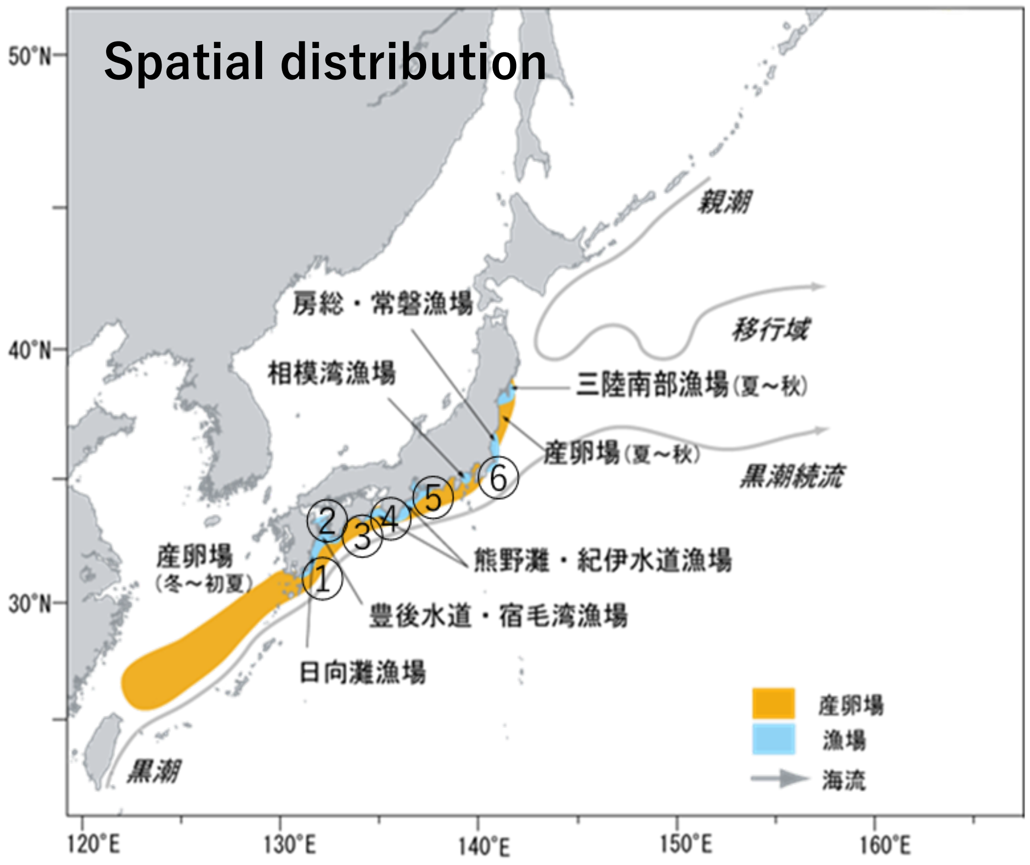
Summary of the VPA model results





Tuning indices





Reviewers Comments

- 3) Detailed description of the tuning indices are lacking (i.e., need more details of the 6 tuning indices). Please describe the process and thinking behind why these indices were used to represent the stock as a whole.

(Responses)

The fishery targeting the Pacific stock is mainly operated in the coastal areas of each region.

As a result, we have not been able to obtain a single index that would represent the stock as a whole.

So, we chose to use the 6 tuning indices in the different coastal regions and treated them equally in the VPA to represent the age-0 fish biomass as a whole.

- 5) It appears that all indices were for age-0 fish. There is catch from age-1-3 fish, so why not have other indices as well?

(Responses)

We are investigating the usefulness of the fisheries data as an index for age-1-3 fish.

- 6) What is the spatial distribution of each index relative to the stock? What were the catches relative to the total catch?

(Responses)

The indices are widely scattered across the central and western area of the distribution.

The catch of all indices represents about 32% of the total catch in 2019.

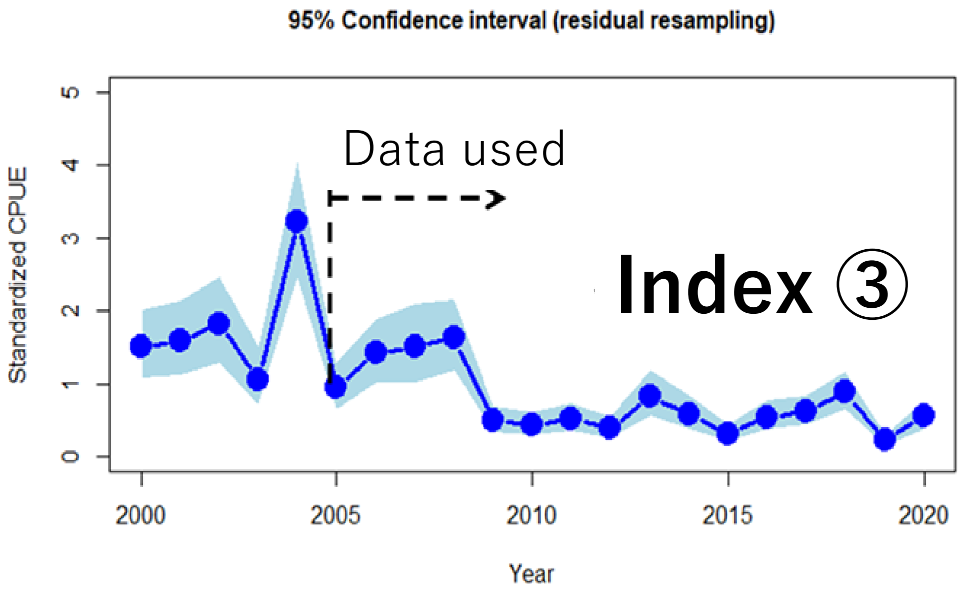
Reviewers Comments

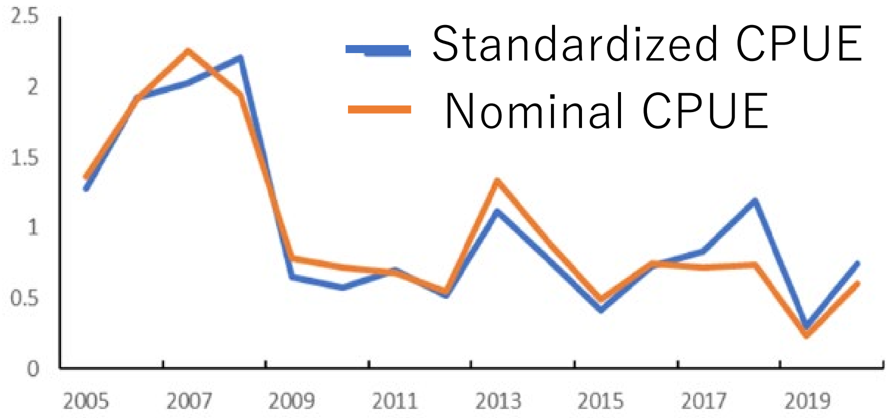
- 4) Were the indices standardized or nominal? If not, this assumes that catchability is constant for all indices for all years. Please support this assumption.

(Responses)

The indices used in the VPA model are not standardized.

However, we have tried standardizing CPUE, and a progress report was shared among all parties involved this year.





Reviewers Comments

- 7) It is generally not considered good practice to just try and fit multiple indices representing the same age class without considering how representative each is. This is because any conflicts will be resolved in the model by just going through the middle. Please explain the thought process behind doing so.
- 8) Were the indices weighted during the model fitting? If not, there is an implicit assumption that all indices were equally representative of the stock as a whole. Given that there were indices from different gears and fisheries and different likely spatial coverages, is that a good idea? Please support this assumption.

(Responses)

Conflicts among indices can be resolved in the model by counteracting each other, however we chose to use these indices for the abovementioned reasons.

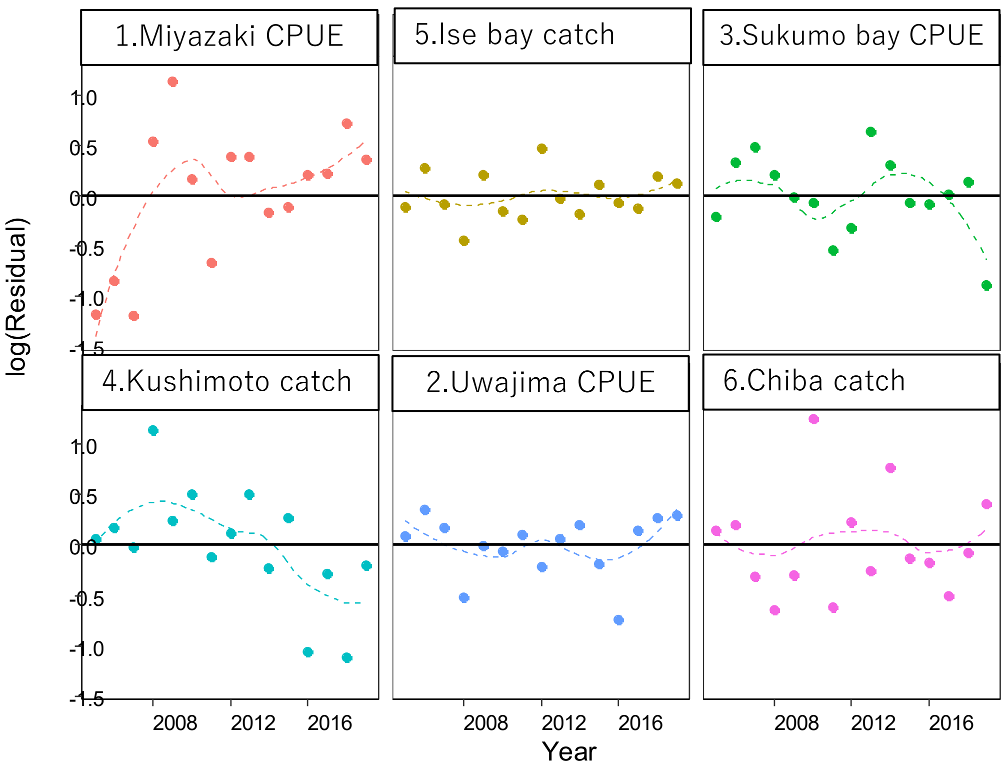
Recently, we have tried the fitting method used by the TWC stock.

Reviewers Comments

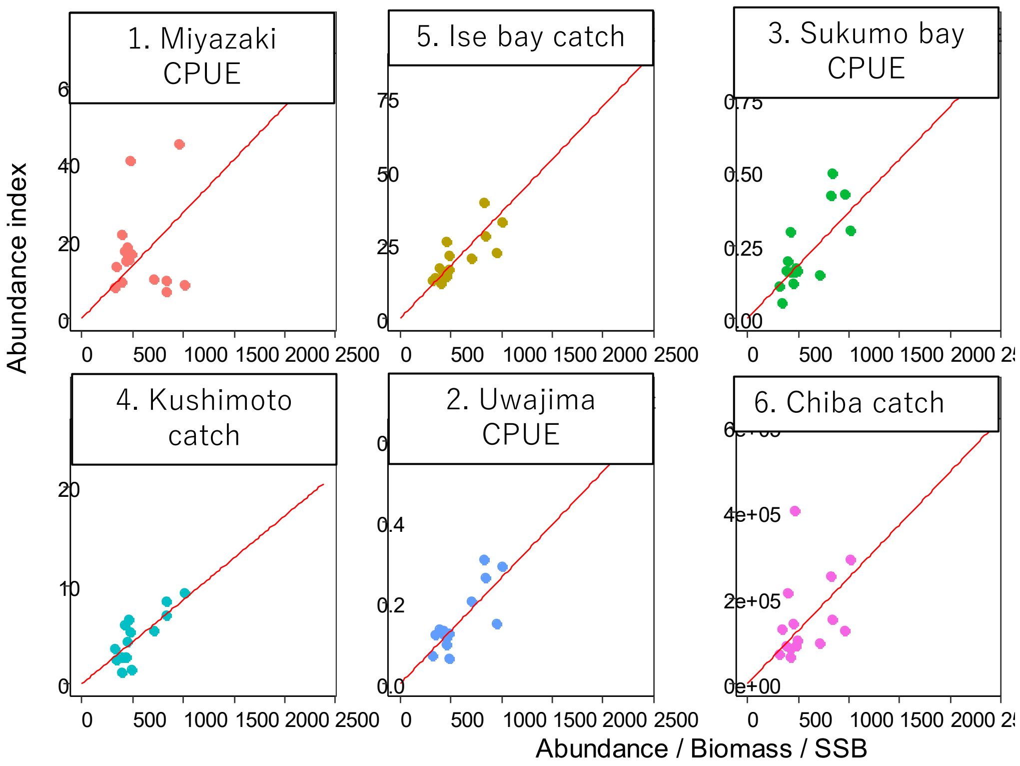
- 21) Please show the model diagnostics for the VPA model. Retrospective pattern and fit to the indices. Also please show model results when not fitting to the indices, and fitting to each index in turn (this is to look at the influence of each index).

Responses (The model diagnostics)

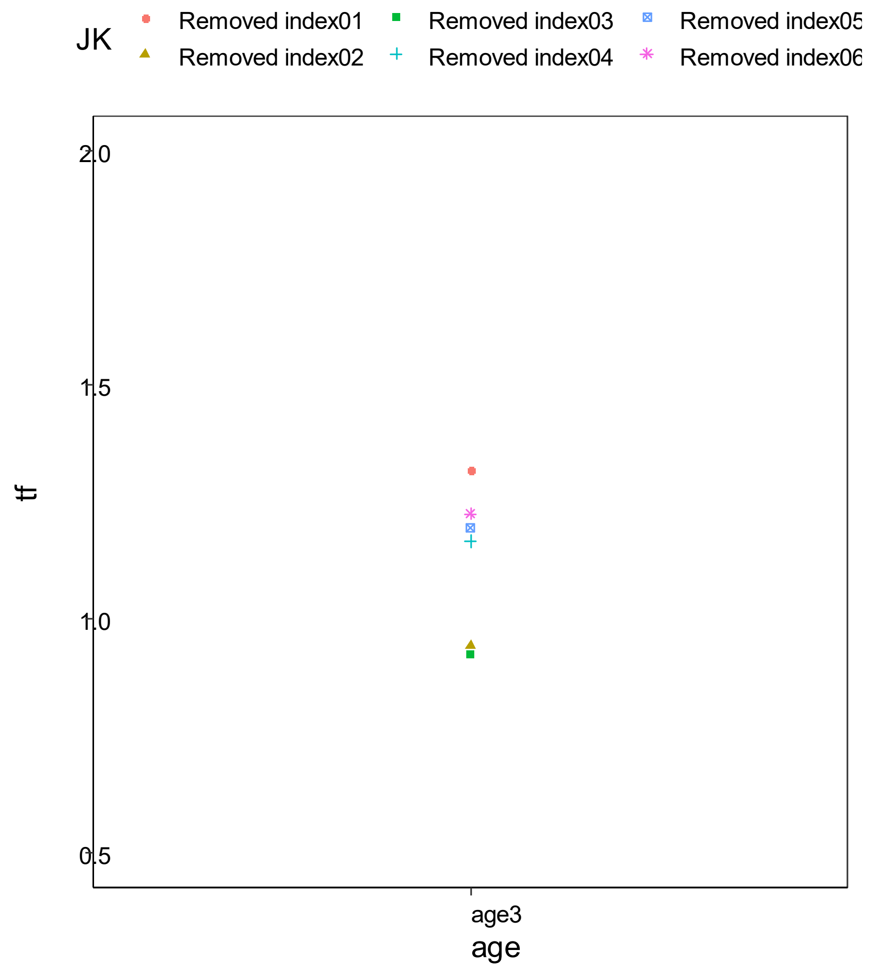
Residuals

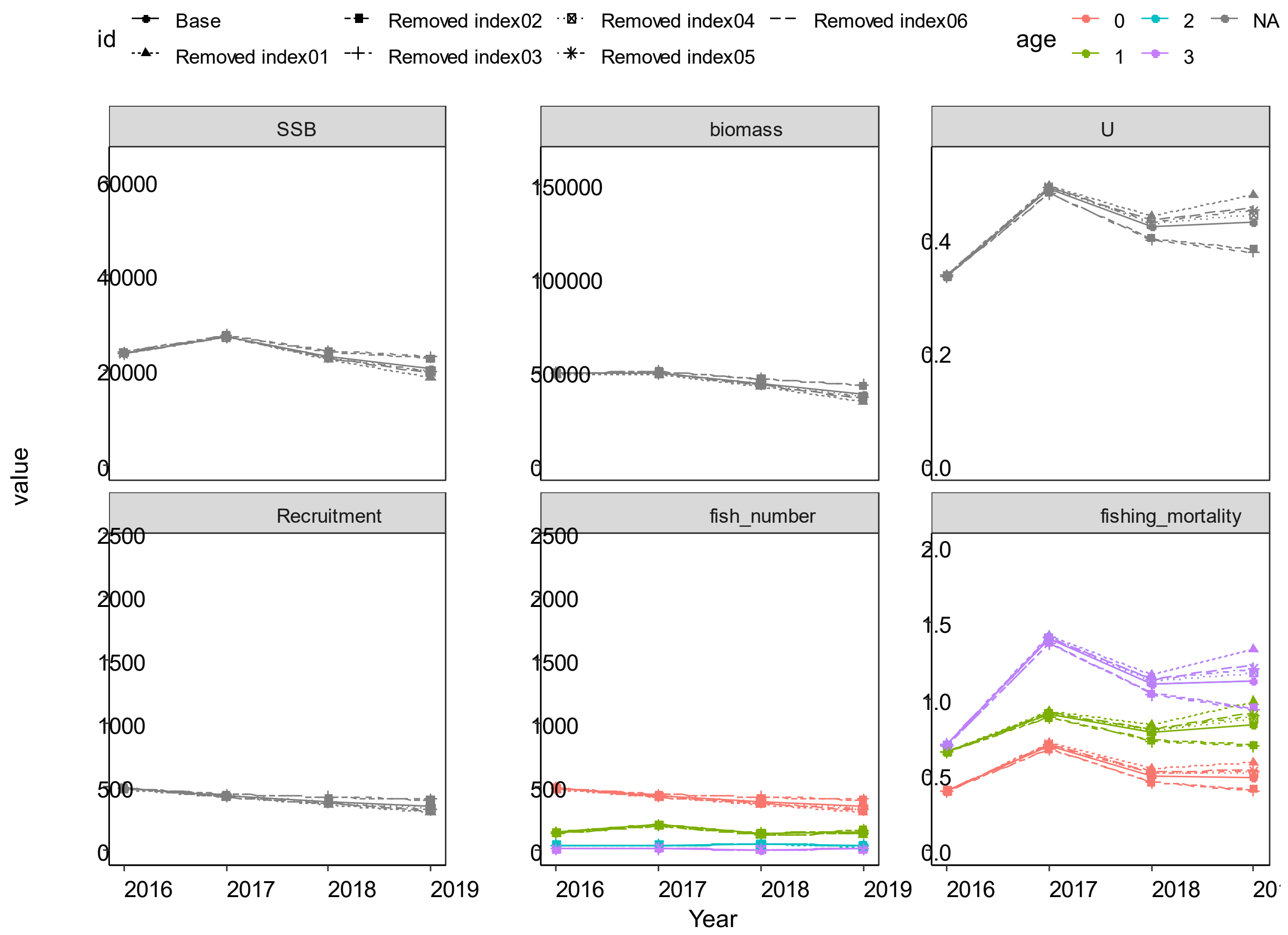


Estimates vs observations



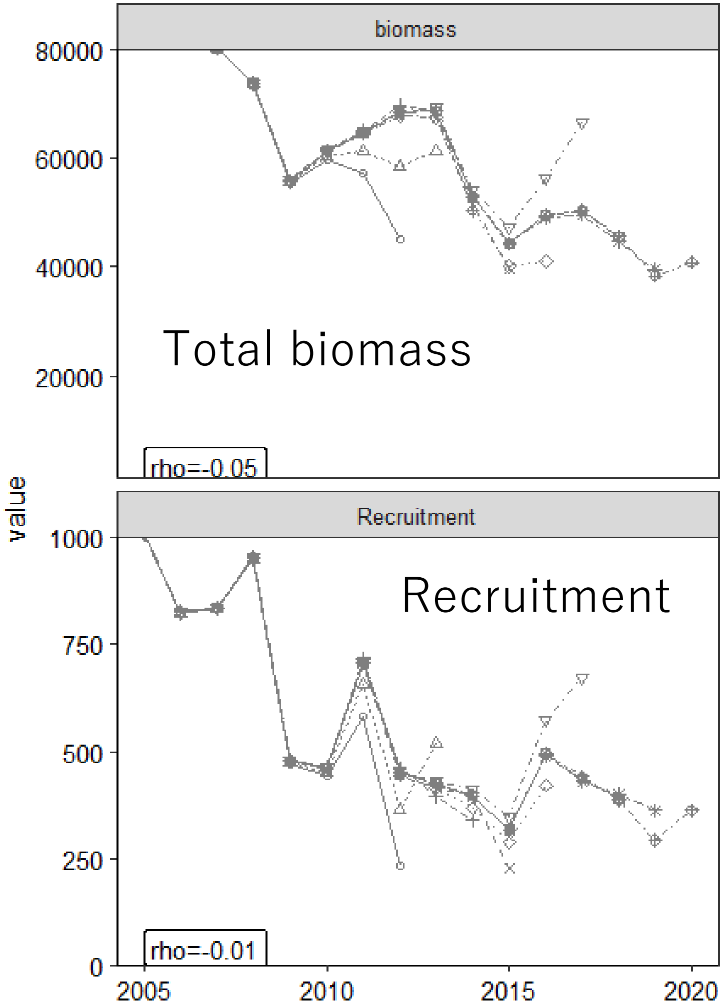
Responses (Jackknife analysis)



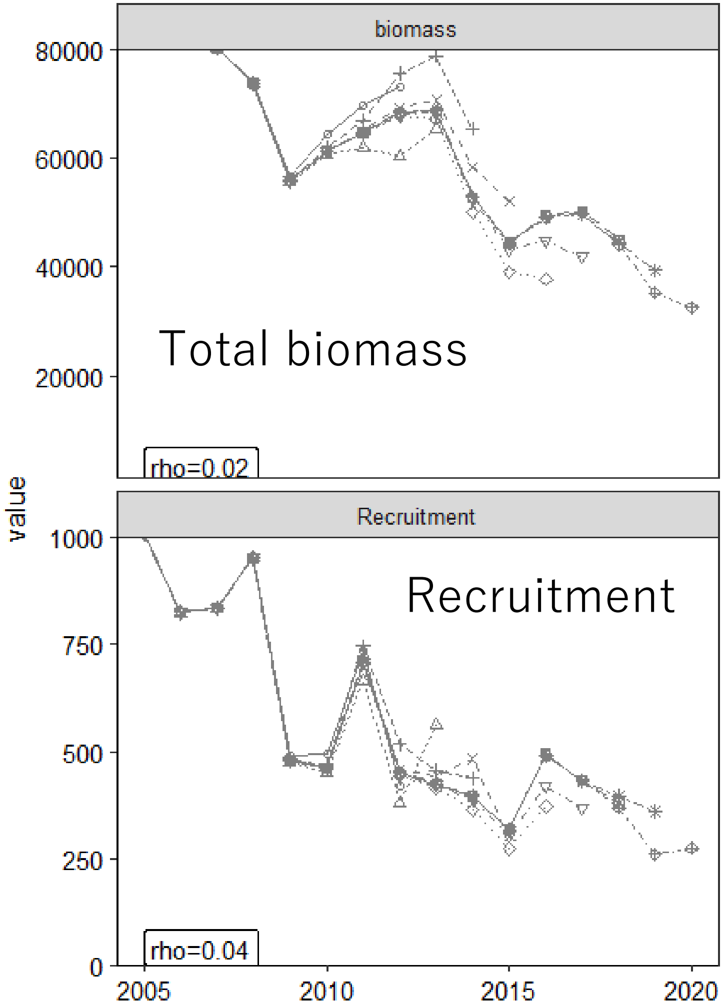


Responses (Retrospective analysis)

VPA



Tuned VPA



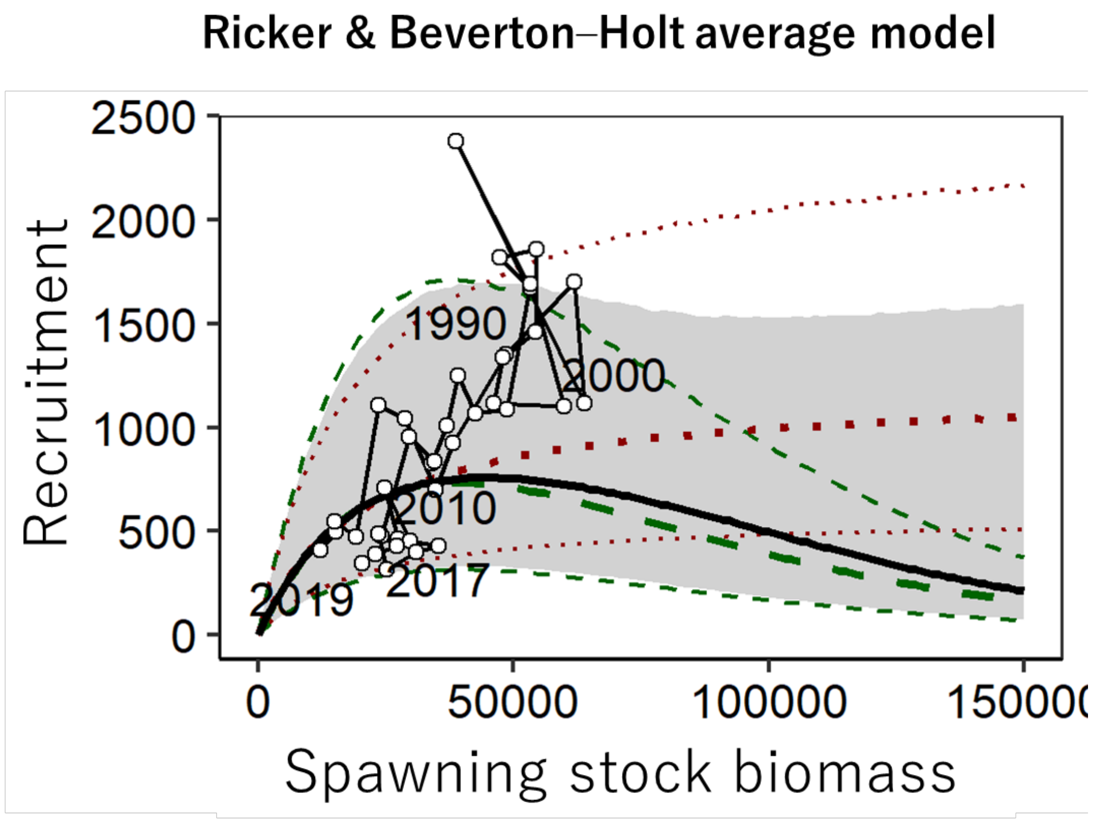
Contents

- Biology and Stock assessment
- Stock-Recruitment Relationships
- Reference points and Kobe-plot
- Harvest Control Rule and Future projection

Stock-Recruitment Relationships

SR model	AICc	SBmsy (1000 tons)	MSY (1000 tons)	%SPR
Ricker	27.18	44	34	17
Beverton –Holt	28.98	132	53	34

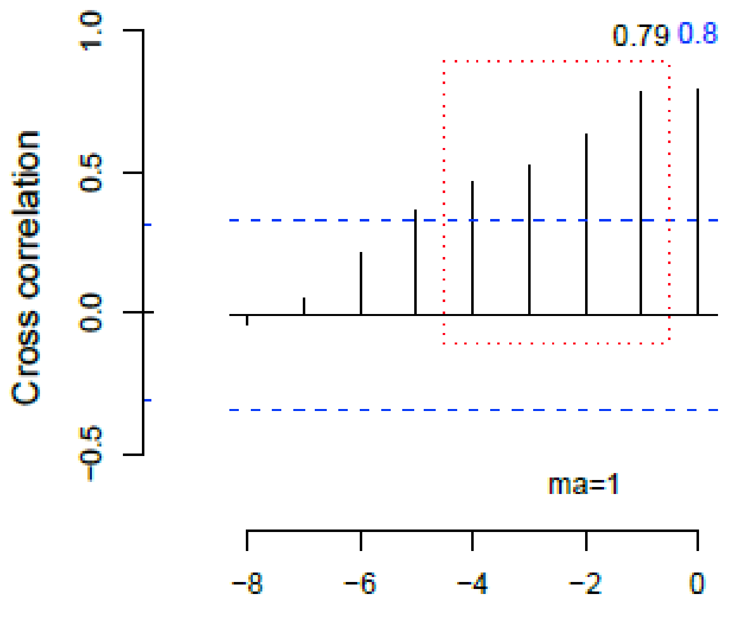
- Small difference in AICc
- Large difference in reference points
- Model averaging to reflect an uncertainty of the estimation of a management reference point in a model selection



Reviewers Comments

- 22) The estimated SSBs and recruitments exhibited an unusual strong linear trend in the S-R curve. This may be indicative of strong maternal effects, which would be surprising for this species, or problems in the estimated time series. Please perform a cross-correlation lag analysis (Szuwalski et al. 2015) to investigate if the SSB was indeed the main influence on the recruitment or vice versa.

Responses (Kurota et al. 2020)



Kurota et al. 2020 Fish. Res.
(Modified)

- Results of cross-correlation lag analysis from Kurota et al. 2020 showed that SSB influenced on the recruitment or vice versa.

Reviewers Comments

- 23) It appears that the SSB and recruitment estimates from the VPA were assumed to be known without error. This may not be a reasonable assumption. Please explain this assumption.
- 24) Given the estimated SSB and recruitment, using the autocorrelated SRR is appropriate. However, the high autocorrelation does suggest that there may be problems with the estimated SSB and recruitment time series.

(Responses)

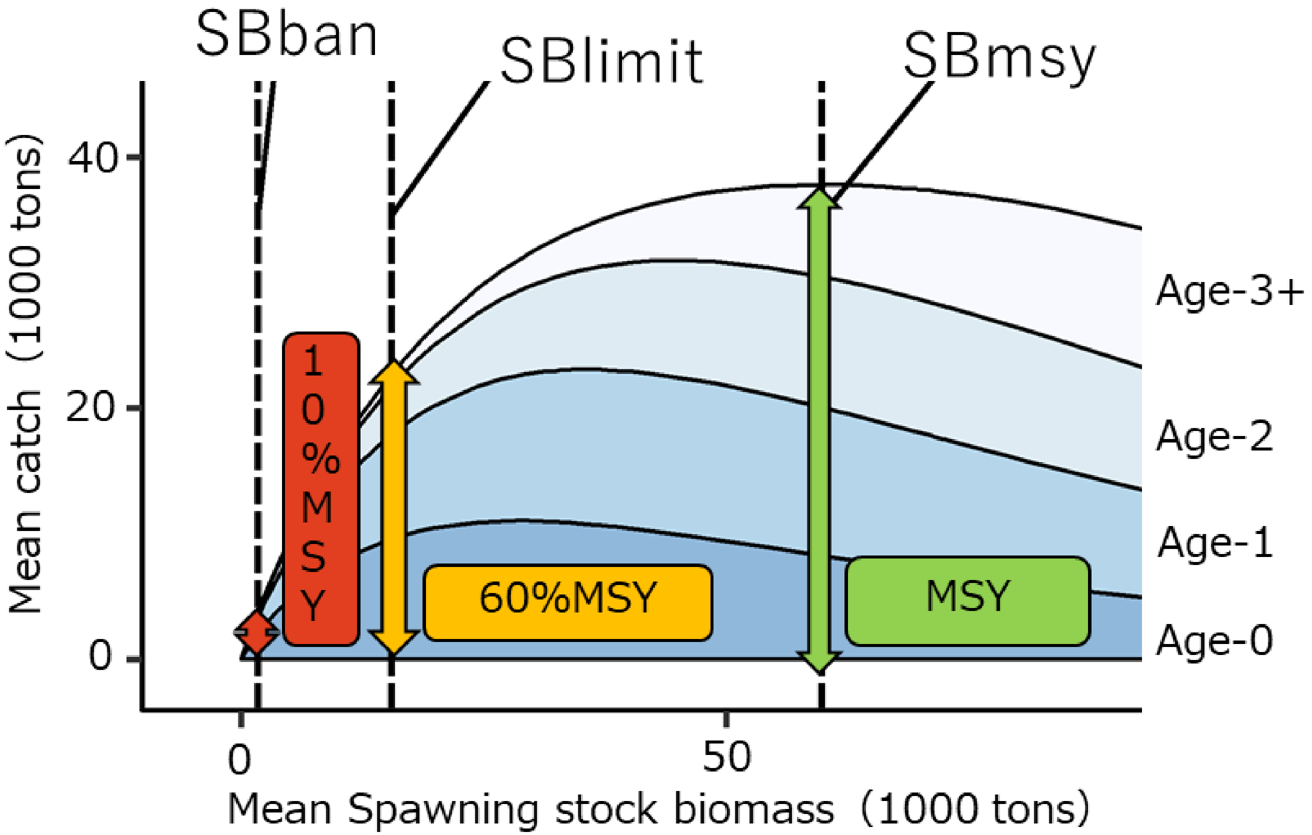
Yes, SSB and recruitment from VPA were assumed to be without error.

We have started to incorporate error into the model.

Contents

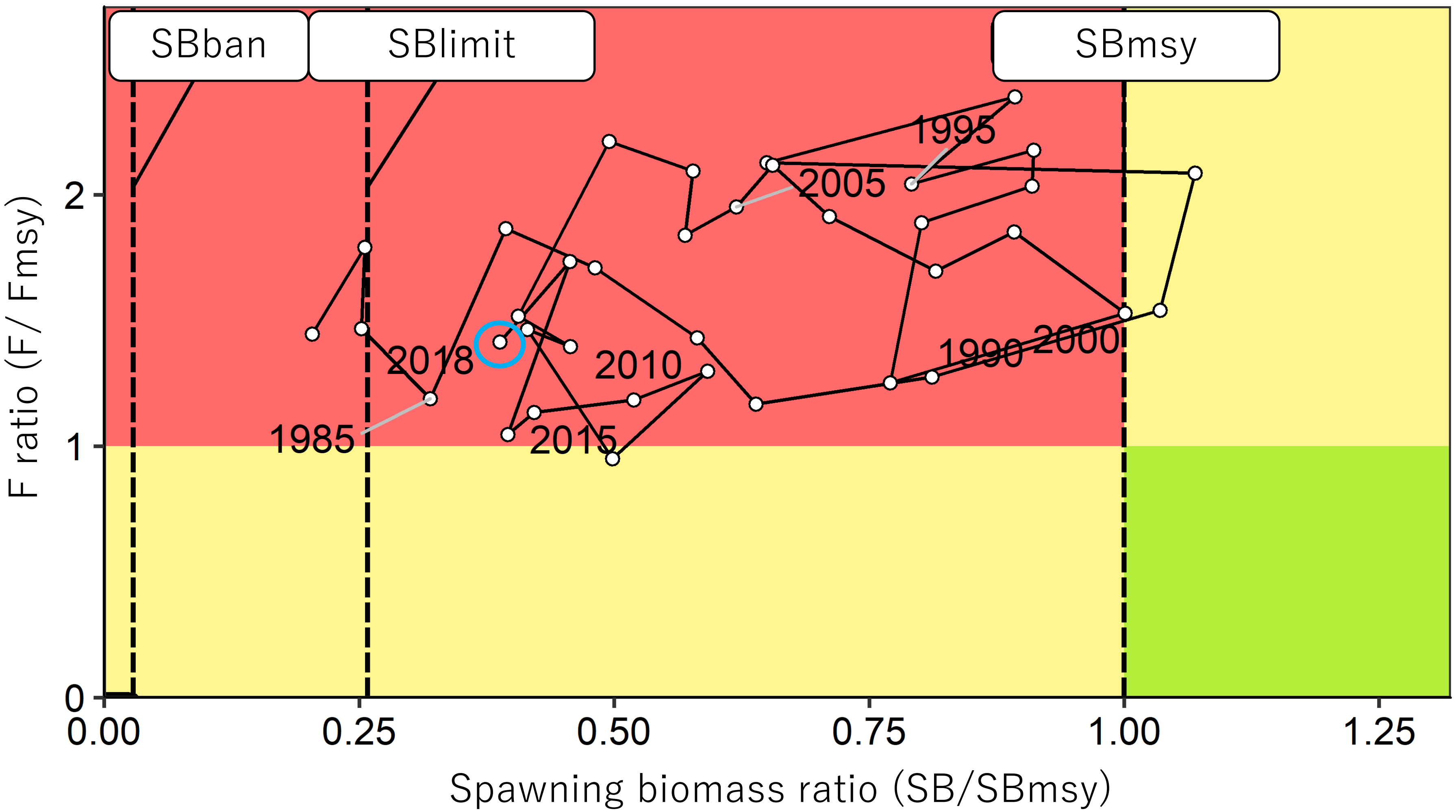
- Biology and Stock assessment
- Stock-Recruitment Relationships
- Reference points and Kobe-plot
- Harvest Control Rule and Future projection

Reference points



Reference point	SSB (1000 tons)
SBmsy	60
SBlimit	15
SBban	1.7

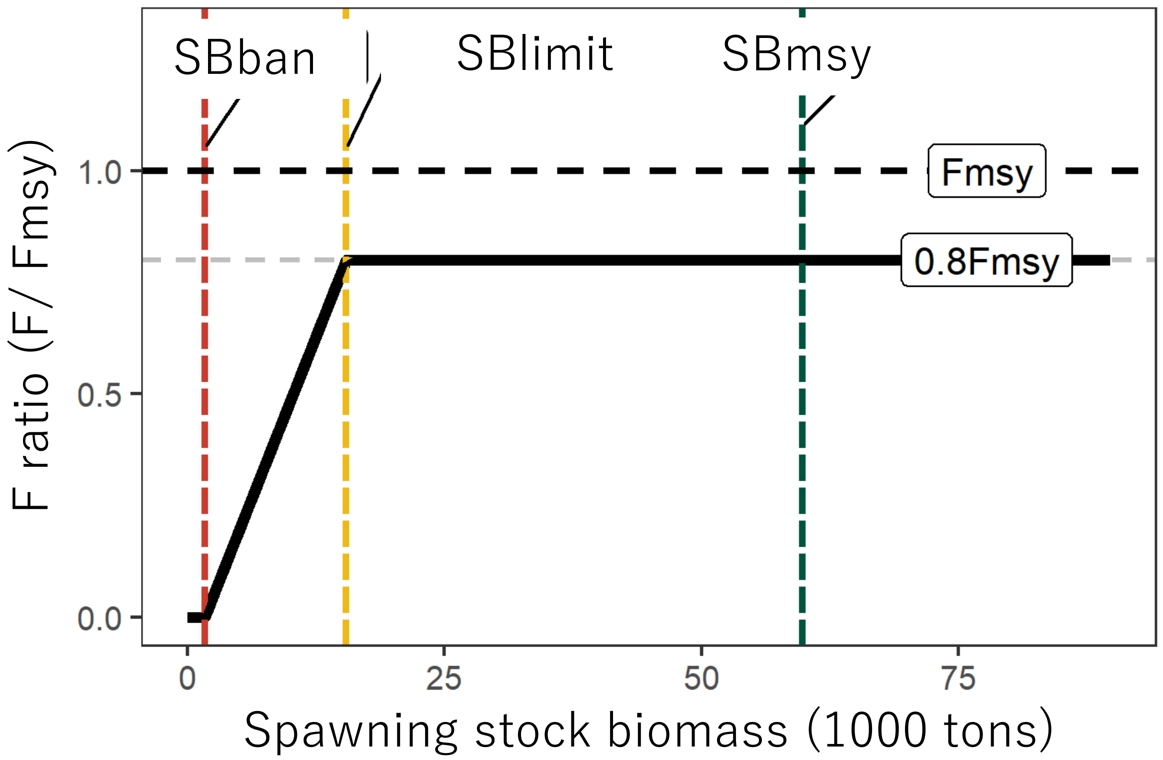
Kobe plot

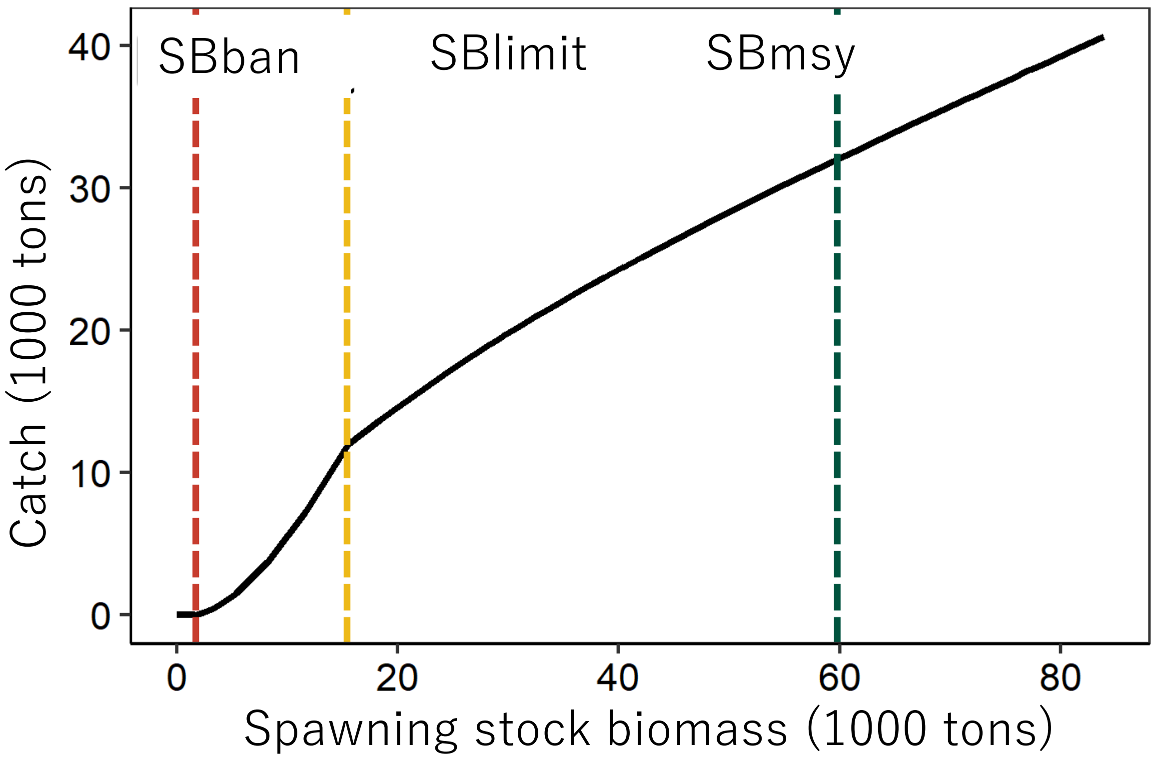


SBban
SBlimit
SBmsy
1995
2005
2018
2010
1990
2000
1985
2015
2
1
0
0.00
0.25
0.50
0.75
1.00
1.25
F ratio (F/ Fmsy)
Spawning biomass ratio (SB/SBmsy)

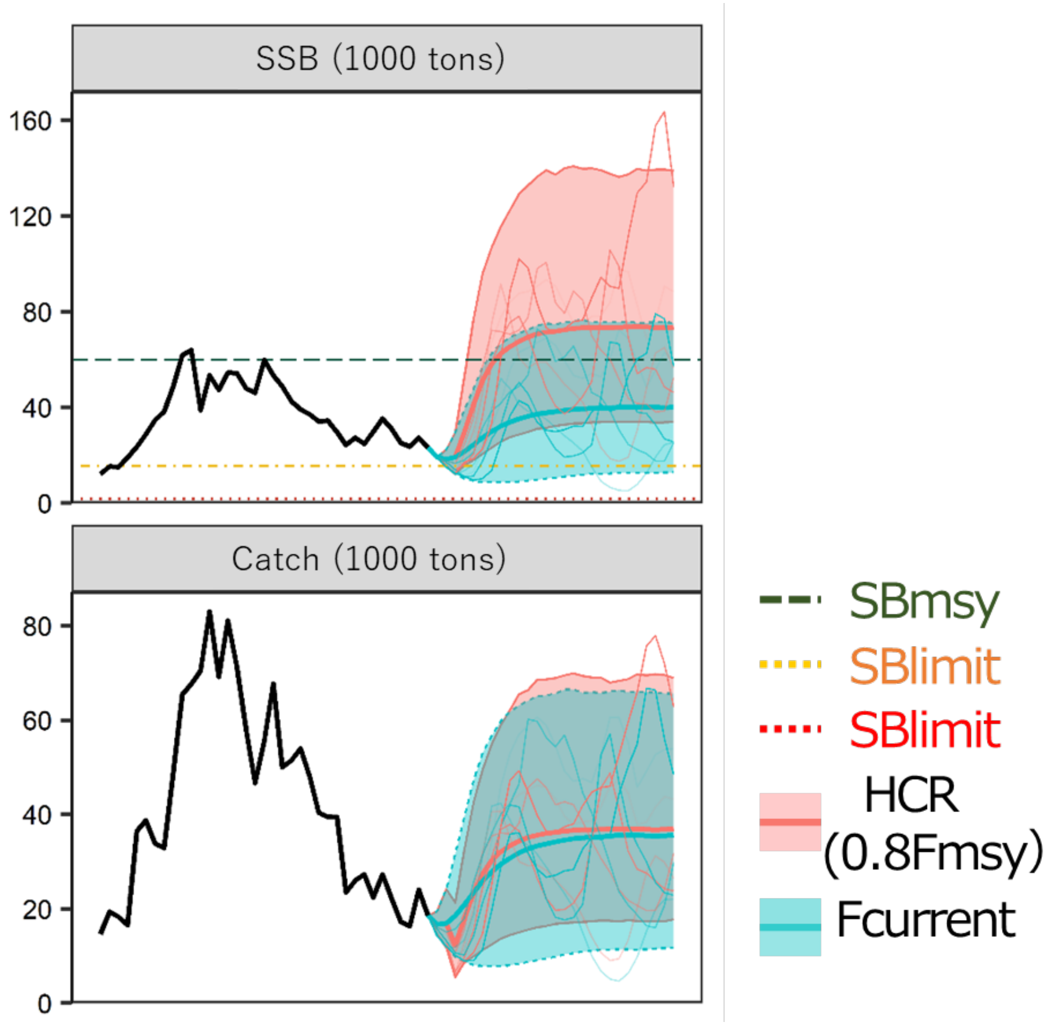
Contents

Harvest control rule





Future projection



β	Probability that the SSB will exceed the SBlimit in 10 years	Probability that the SSB will exceed the SBmsy in 10 years	Catch in 2021 (1000 tons)
1	99%	39%	15
0.9	99%	48%	14
0.8	100%	57%	12
0.7	100%	67%	11
0.6	100%	76%	10
0.5	100%	84%	8
0.4	100%	90%	7
0.3	100%	94%	5
0.2	100%	97%	4
0.1	100%	99%	2

Reviewers Comments

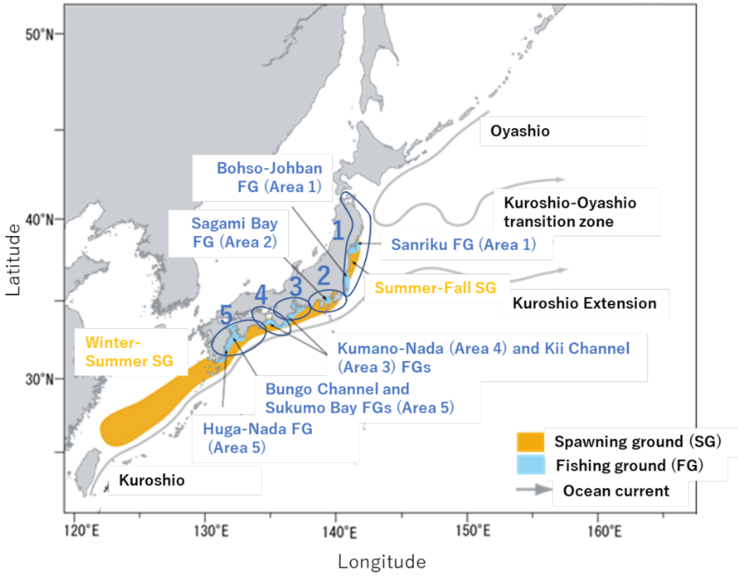
- 25) Was the N-at-age in the terminal year of the VPA model assumed to be known without error? If so, please explain this assumption.

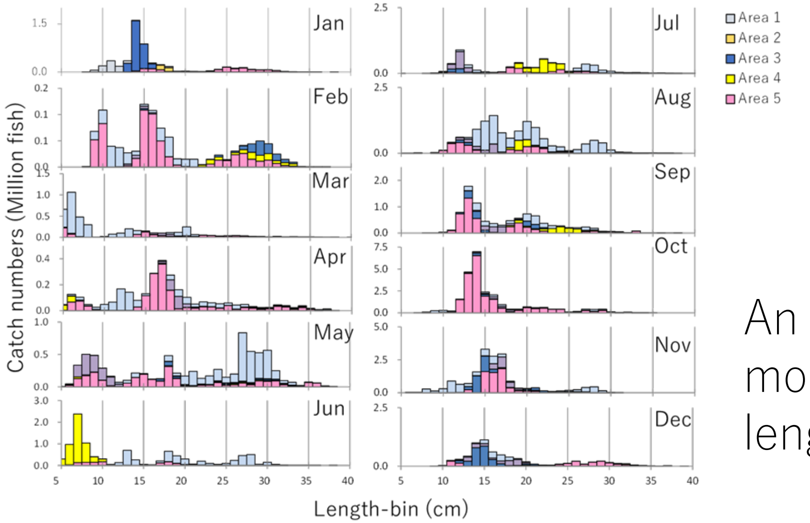
(Responses)

The calculation of terminal year N at age is deterministic, so we will conduct another scenario by next full stock assessment as well as possible.

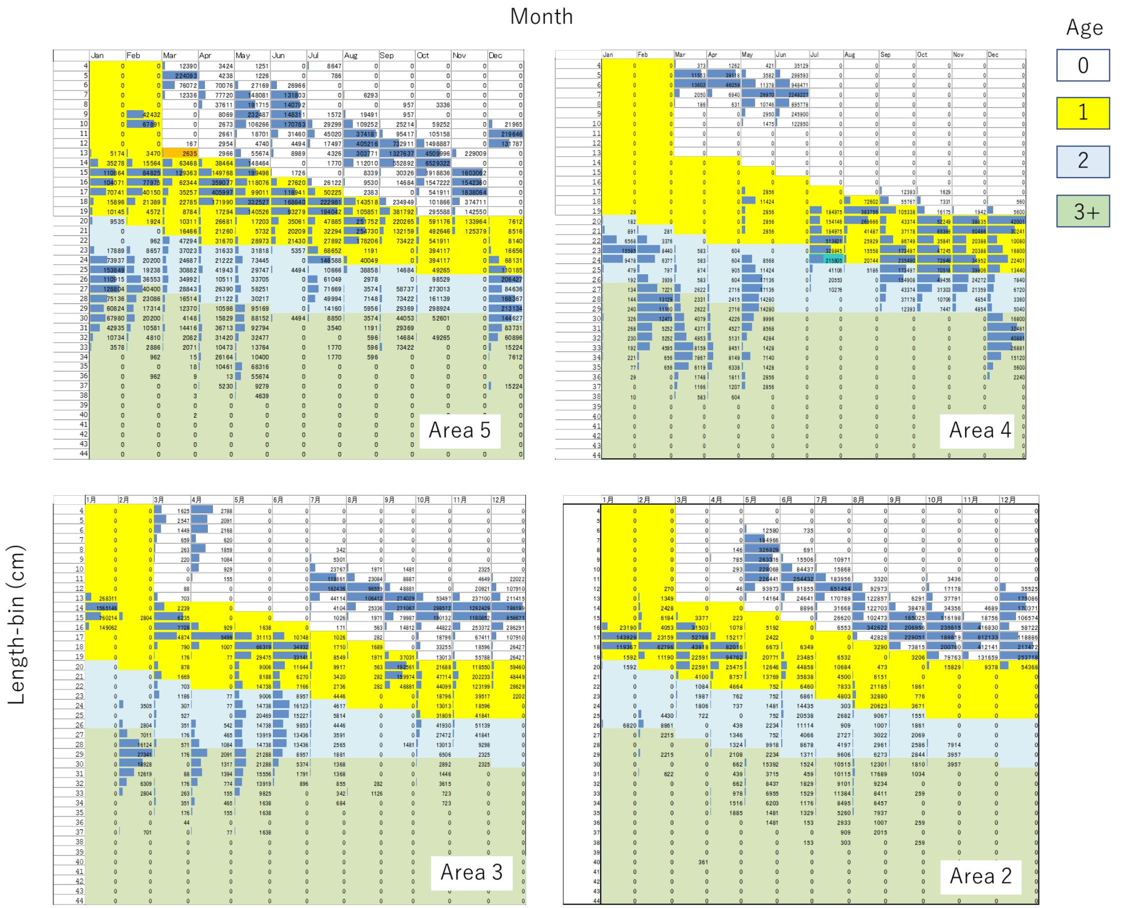
Appendix

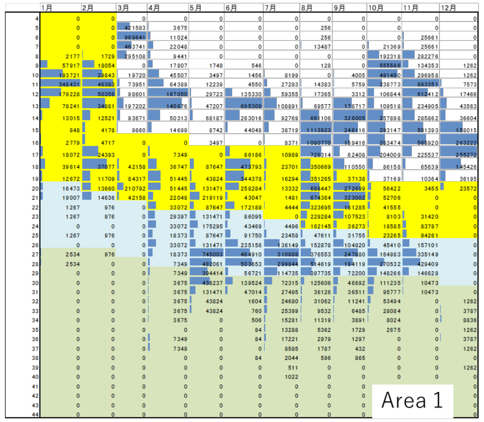
Catch at age (CAA)





An example of monthly catch at length of five areas





An example of monthly catch numbers at length. Different colors represent different age assumed by an ALK for this stock.

Catch at age (CAA)

FL-BW relationship

$$BW\ (\text{g}) = 0.013 \times FL^3\ (\text{cm})$$

ALK

Month

Length-bin

体長階級 (cm)	1	2	3	4	5	6	7	8	9	10	11	12
13以下	1	1	0	0	0	0	0	0	0	0	0	0
14	1	1	1	1	0	0	0	0	0	0	0	0
15	1	1	1	1	1	0	0	0	0	0	0	0
16	1	1	1	1	1	1	0	0	0	0	0	0
17	1	1	1	1	1	1	1	0	0	0	0	0
18	1	1	1	1	1	1	1	1	0	0	0	0
19	1	1	1	1	1	1	1	1	1	0	0	0
20	2	1	1	1	1	1	1	1	1	1	1	1
21	2	2	1	1	1	1	1	1	1	1	1	1
22	2	2	2	1	1	1	1	1	1	1	1	1
23	2	2	2	2	2	2	1	1	1	1	1	1
24	2	2	2	2	2	2	2	1	1	1	1	1
25	2	2	2	2	2	2	2	2	2	1	1	1
26	2	2	2	2	2	2	2	2	2	2	2	2
27	3	3	2	2	2	2	2	2	2	2	2	2
28	3	3	3	2	2	2	2	2	2	2	2	2
29	3	3	3	3	3	2	2	2	2	2	2	2
30	3	3	3	3	3	3	3	3	3	3	3	2
31+	3	3	3	3	3	3	3	3	3	3	3	3