Gadus chalcogrammus

Japanese Pacific stock Walleye Pollock

Osamu Sakai
Japan Fisheries Research and Education Agency

For Peer Review in 2021

Timeline and materials

Meeting	Contents	For review
Apr. 2019, Scientific meeting	Proposal of the candidates of MSY reference points and HCR using 2018 assessment data	
Sep. 2019, Assessment meeting	Update and improving of assessment (extending the plus group, using ridge VPA)	
Aug. 2020, Stakeholder meeting (1)	Explaining the proposal from scientific meeting of 2019. Stakeholders requested the update of the reference points using 2020 assessment data.	
Sep. 2020, Assessment meeting	Update and improving of assessment (change the assumption of latest recruitment)	X
Sep. 2020, Scientific meeting	Update the proposal of MSY reference points and HCR using 2020 assessment data	X
Nov. 2020, Stakeholder meeting (2)	Explaining the proposal from scientific meeting of 2020. Stakeholders requested the evaluation for constant catch rule.	
Dec. 2020, Scientific meeting	Evaluation of constant catch rule based on the scenario modeling of projection.	
Dec. 2020, Stakeholder meeting (3)	Explaining the results of constant catch projection. Stakeholders adopted the harvest scenario.	
Jan. 2021, Deliberation Council of fisheries policy	Consultation of the harvest scenario and TAC	

Contents

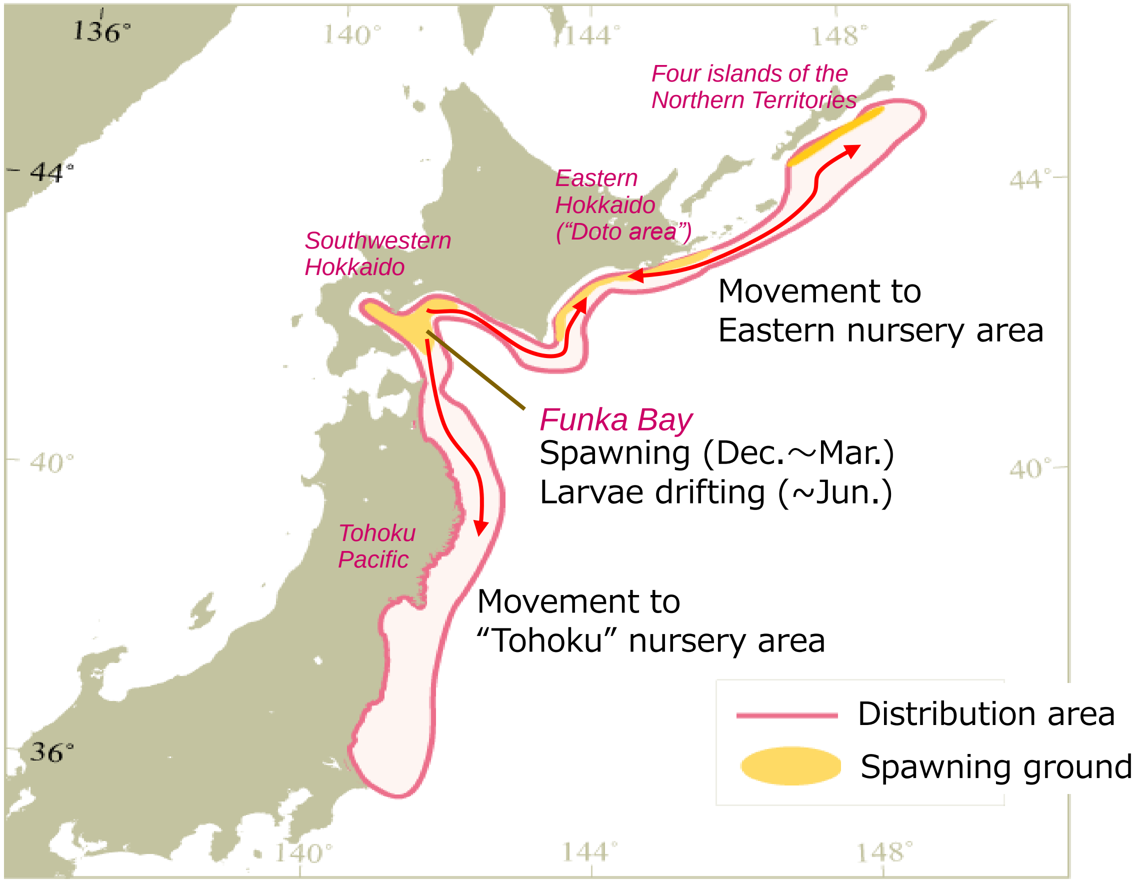
- Biology and Stock assessment
  Distribution, Movement, Growth, Catch, Estimation of catch at age (CAA), Abundance indices, Natural Mortality, ridge VPA

- Stock-Recruitment Relationships

- Reference points, Kobe-plot

- Harvest Control Rule, Future projection

Distribution



(From Honda et al. 2004)

Walleye pollock (Japanese Pacific stock) distributes along the Japanese Pacific coast.

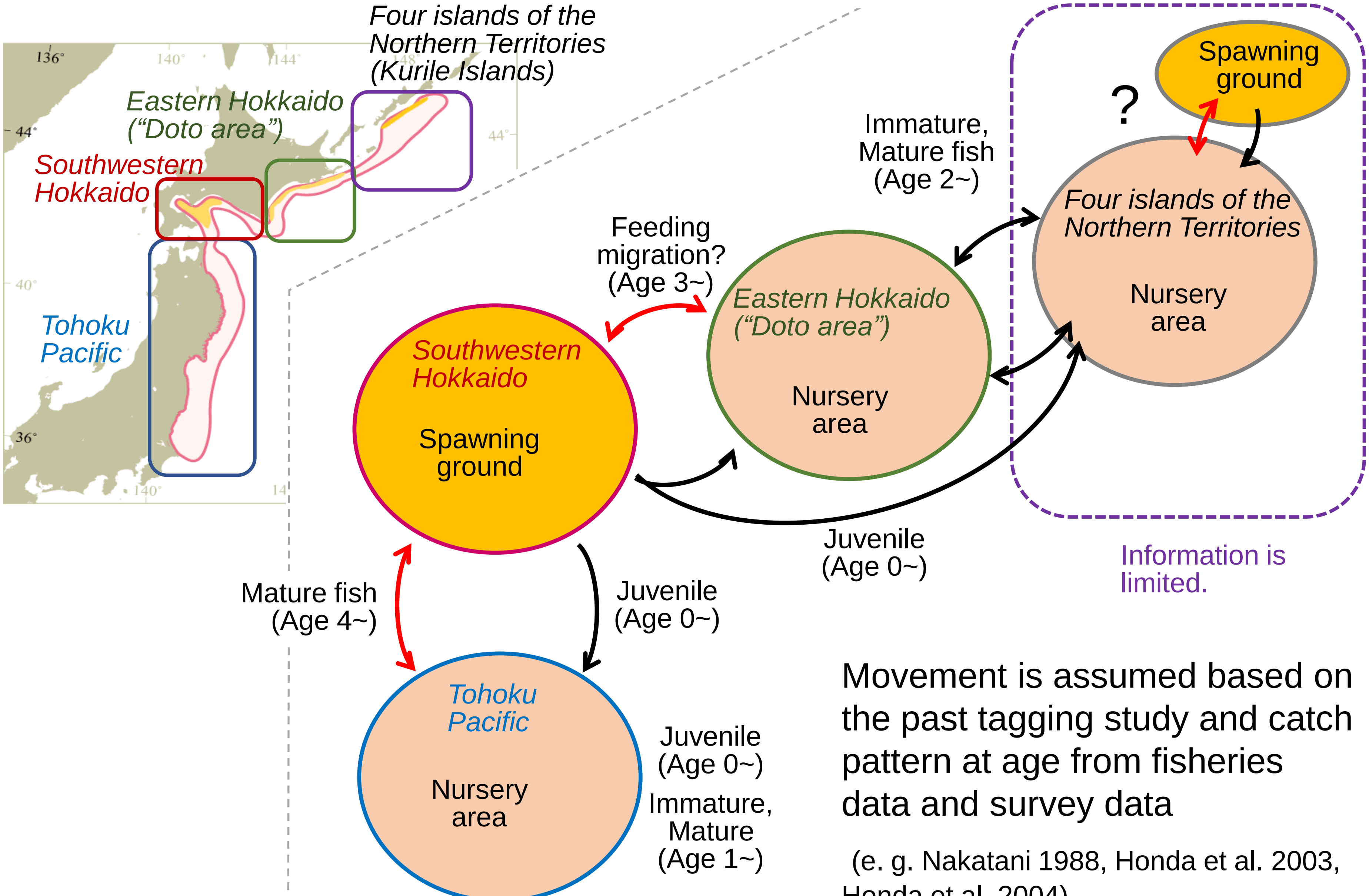
There are several spawning areas. The main spawning ground is around Funka Bay.

The continental shelf region is considered the important nursery area for larvae and Juvenile pollock (Tohoku, Eastern Hokkaido, and Northern Territories).

[Northern Territories Issue]
From Japan's basic standpoint, the Northern Territories are inherent territories of Japan which continue to be illegally occupied by Russia.

(Ministry of Foreign Affairs of Japan 2011)

Movement

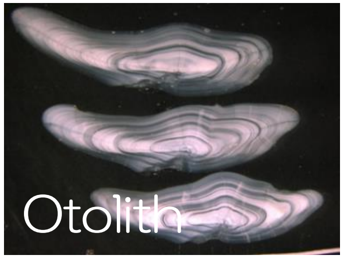


Movement is assumed based on the past tagging study and catch pattern at age from fisheries data and survey data

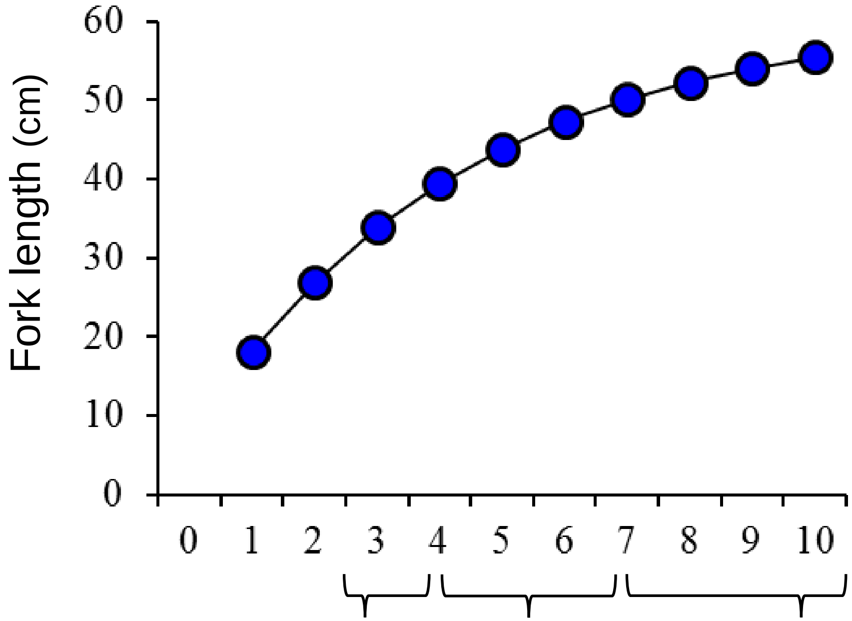
(e. g. Nakatani 1988, Honda et al. 2003, Honda et al. 2004).

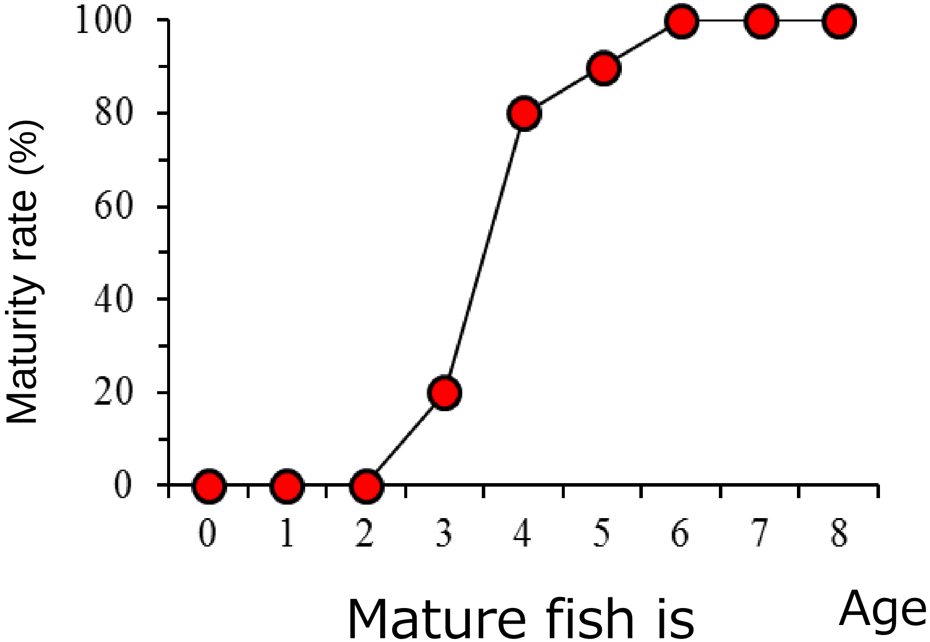
Growth

Fork length



Maturity





Age 3~4
30~40cm

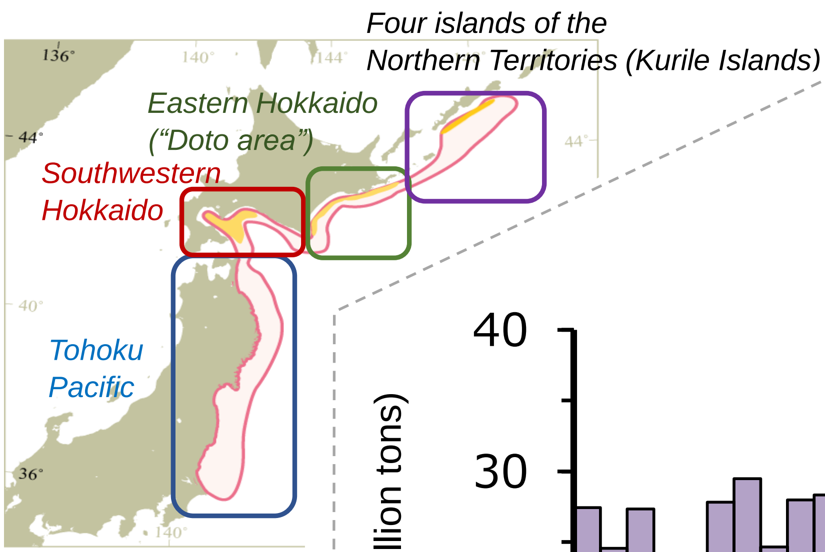
Age 4~7
40~50cm

Age 7~8
50cm~

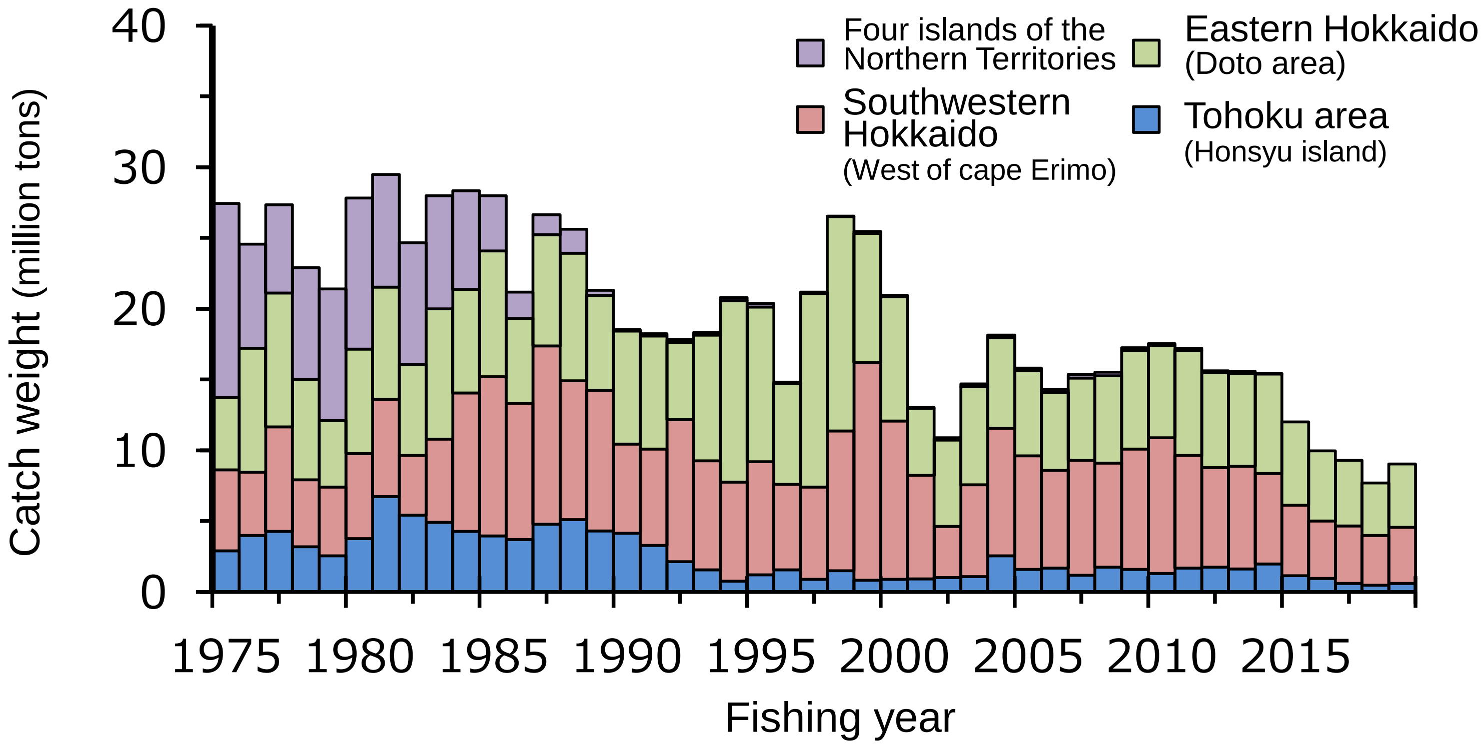
Mature fish is mainly age 4+.
(40cm~)

e. g. Hamatsu and Yabuki (2007)

Catch

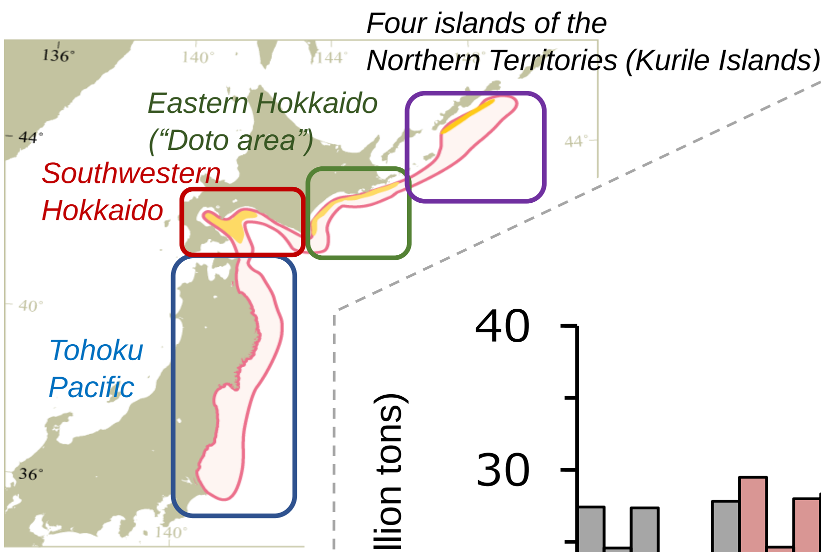


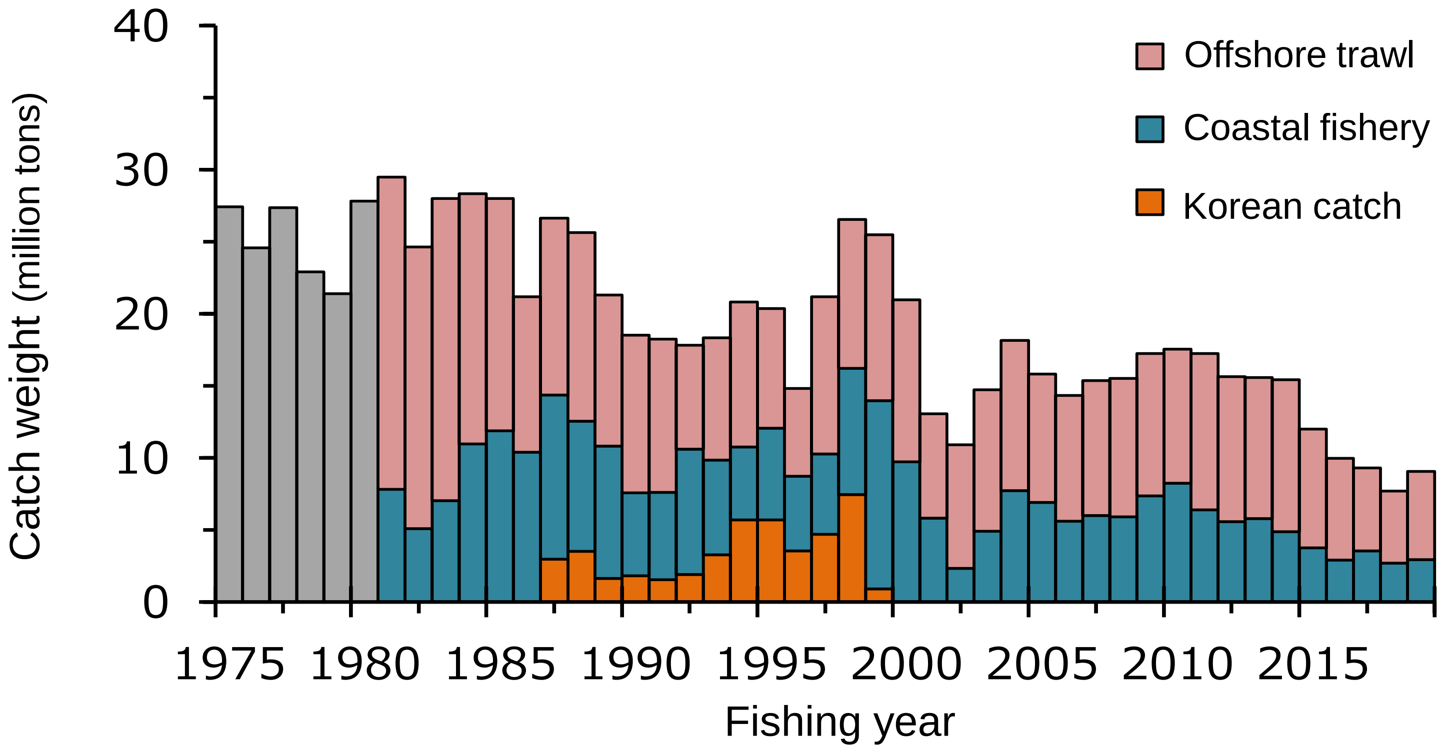
Fishing year: April~March



The dominant catch comprises southwestern Hokkaido and Eastern Hokkaido areas. Japanese Catch of Northern Territories is included (but excluding Russian catch).

Catch





There are two types of fisheries; offshore bottom trawl and coastal fishery.
The catch by Korean trawl vessels in Japanese EEZ are included.

Reviewer's Comment #01

- Clarify whether catches used in each assessment represent all sources of catch taken from the assessed area. Are catches by all foreign fisheries accounted for, or are there other sources of mortality (e.g., discarded catch), that could bias the total catch estimates? The VPA model assumes that catches are known exactly, so sources of bias in the catch estimates should be minimized to avoid bias in derived reference points and projections.

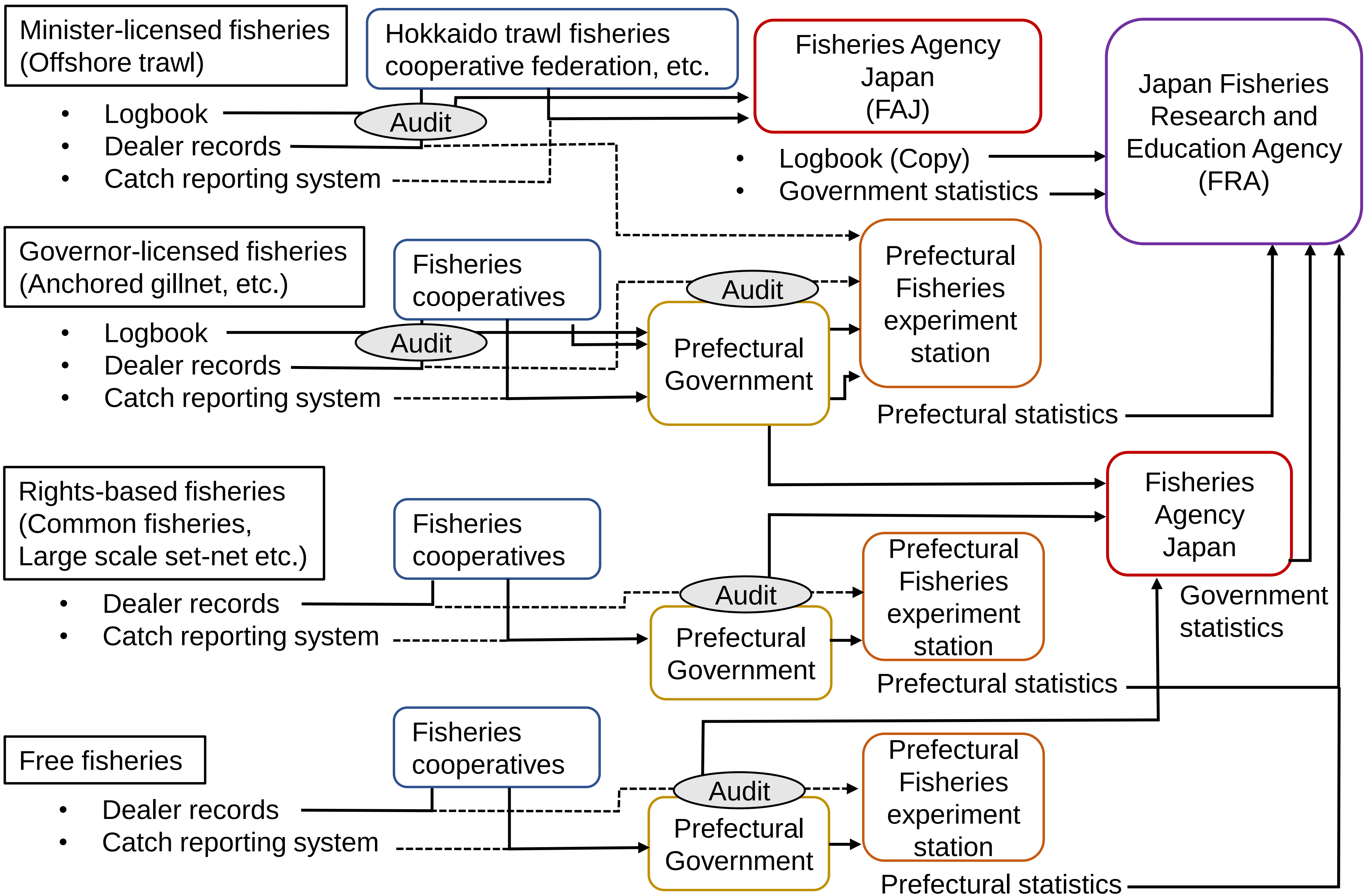
Response

Regarding the catch of foreign fishing vessels, the Russian catch around the four islands of northern territories is not taken into consideration. There is a territorial dispute between Japan and Russia in this area, thus it is required to handle carefully the Russian information in this area based on the government's position.

From scientific point of view, Japanese scientists and Russian scientists have opportunities for information exchange routinely under the Japan-Russia Reciprocal Fishery Agreement. But we have judged that Russian information is not available for our stock assessment at present, because detailed catch statistics (i. e. catch at age) have not been provided from Russia.

Regarding the Japanese catch, we considered that the catch statistics is correct especially in recent years. The catch has not reached the TAC in recent years, thus there is no incentive to discard and/or under-report for fishermen.

Japanese catch reporting scheme



Official statistics are open to the public…

Offshore bottom trawl

Minister-licensed fisheries

- "Catch statistics of offshore bottom trawl fisheries in Hokkaido"
- "Catch statistics of offshore bottom trawl fisheries in the Northern Pacific"

✓ Statistical information based on the logbook.
✓ Published as yearbook from FAJ and FRA.

Coastal fishery

Governor-licensed fisheries (Anchored gillnet, etc.)

Rights-based fisheries (Common fisheries, Large scale set-net etc.)

Free fisheries

- Statistics are published on the internet and/or are distributed as a booklet by each prefectural government.

e. g.

Hokkaido: "Hokkaido Suisan-Gensei"

https://www.pref.hokkaido.lg.jp/sr/sum/03kanrig/sui-toukei/suitoukei.html

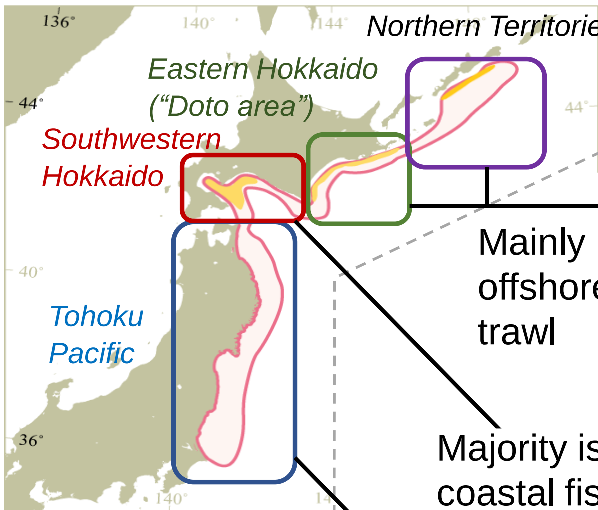
Aomoriken: "Aomoriken Gyokaku Toukei"

https://www.pref.aomori.lg.jp/soshiki/nourin/sshinko/suisan_top.html

Iwateken: "Iwate no Toukei"

http://www3.pref.iwate.jp/webdb/view/outside/s14Tokei/top.html

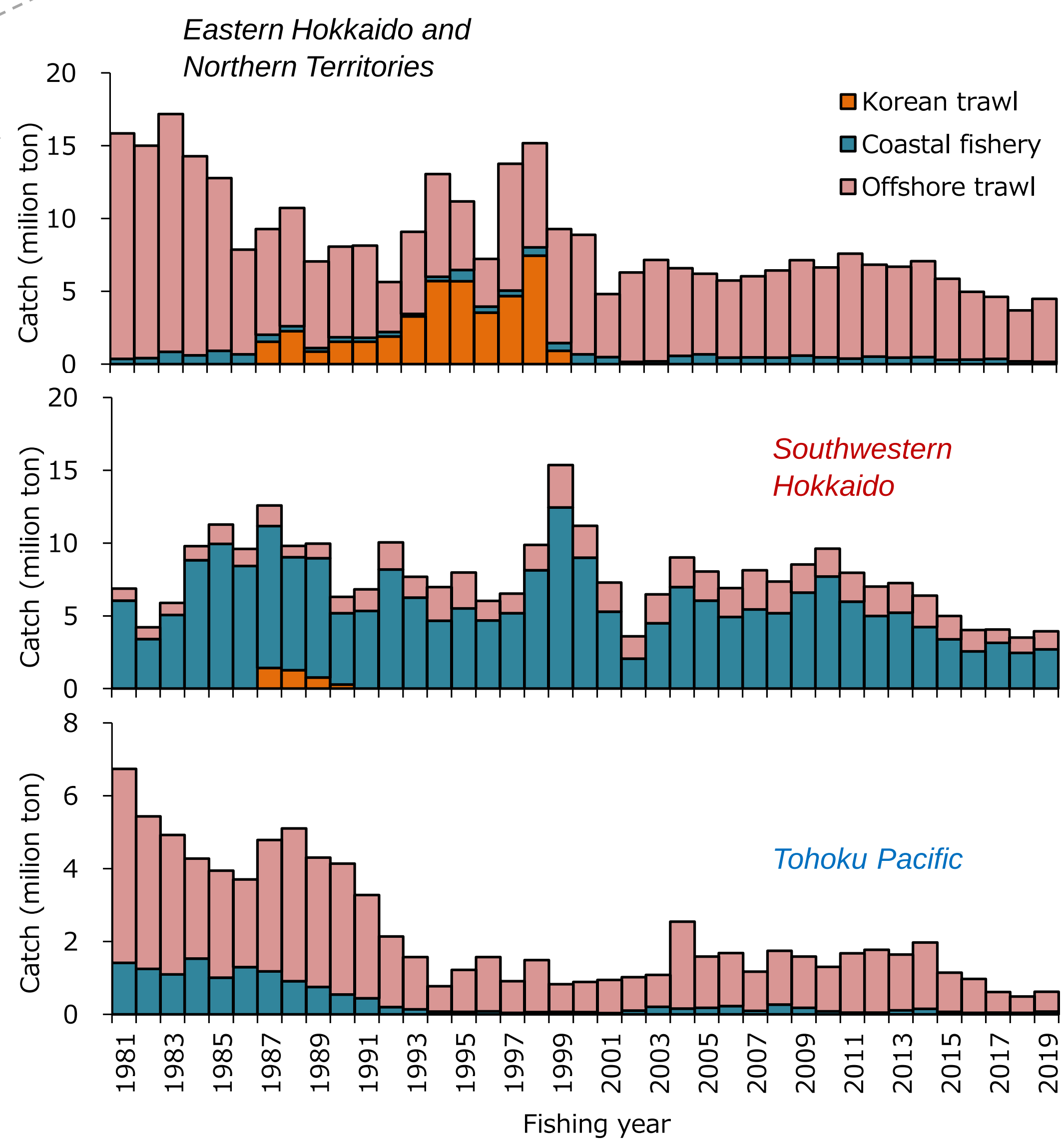
Catch



Mainly offshore bottom trawl

Majority is coastal fishery

Mainly offshore bottom trawl



In this assessment,
catch at age (CAA) is estimated
in each area by each relevant institute.

Eastern Hokkaido:
Kushiro field station (FRA)

Southwestern Hokkaido:
Hokkaido Research Organization (HRO) &
Kushiro field station (FRA)

Tohoku Pacific:
Hachinohe field station (FRA)

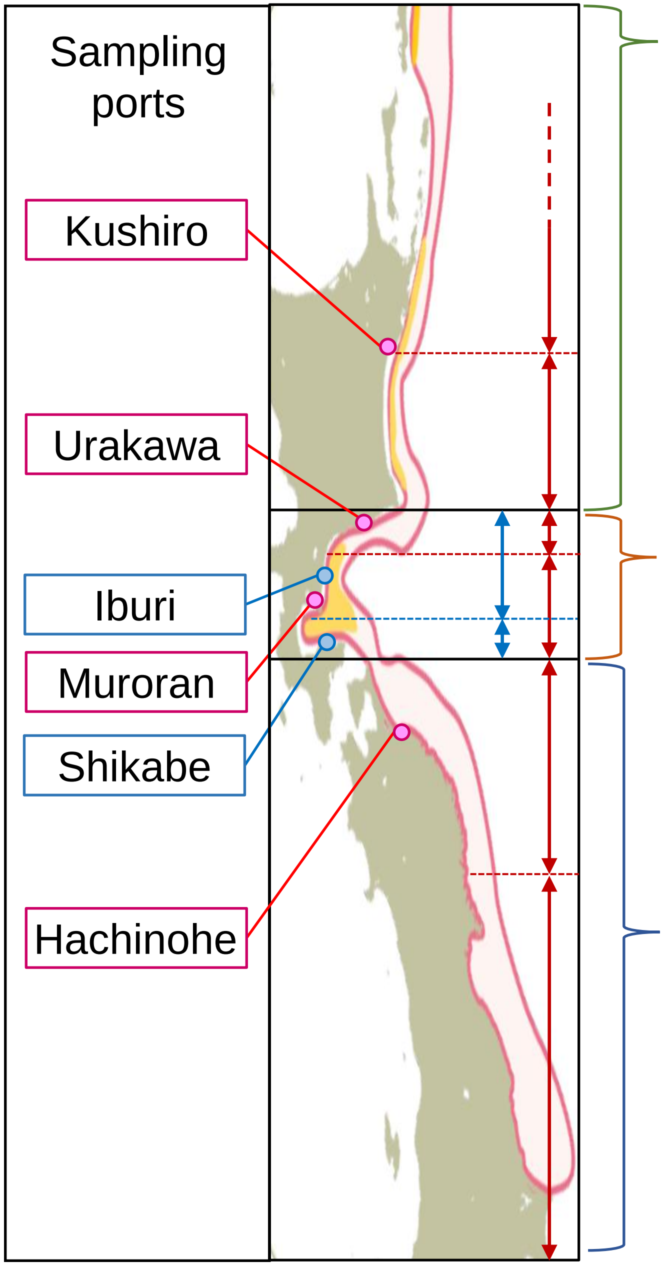
Reviewer's Comment #02

- Provide additional details regarding the sampling programs that were used to estimate catch at age. In addition to the total catch (question #1, above), the method used to allocate catches to individual age classes in a given year should be documented in the assessment or in an appendix to the assessment. Sample sizes and average age by major fleet, year, and area would be useful.

Response

We would like to explain detailed information from next slides.

Estimation of Catch at Age (CAA)



Eastern Hokkaido

The area was divided into two sub-areas.
Age compositions for both sub-areas were obtained by monthly sampling at Kusiro port, which is main port of offshore bottom trawl in the eastern Hokkaido.

Southwestern Hokkaido

There was a lot of catch by coastal fishery in this area. Their age compositions were obtained based on two sampling ports (Iburi, Shikabe) at each of two divided sub-areas.

For the age composition of offshore bottom trawl, The area was divided into two sub-areas. Sampling ports were Urawaka and Muroran for each sub-area.

Tohoku Pacific

The area was divided between North and South sub-areas. Their age compositions were calculated from length frequency data from prefecture's institute using Age-Length-Key (ALK). The ALK is estimated from port sampling at Hachinohe (Jan., Feb.) and Research vessel's sample (Apr., Oct.).

Ageing and calculation of CAA

Example of CAA estimation for Eastern Hokkaido area;

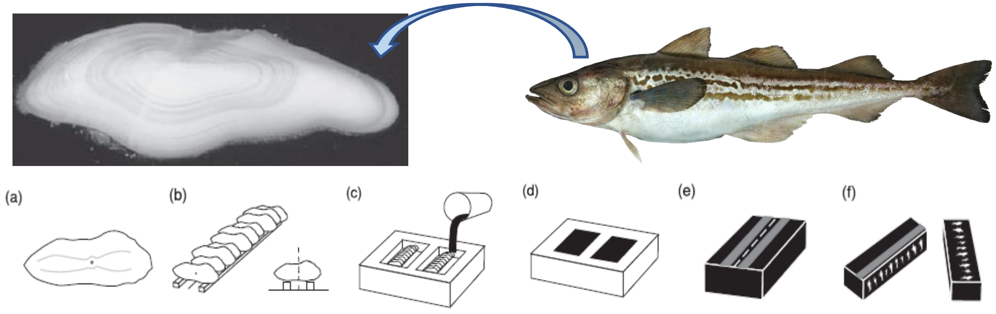
Monthly port sampling for each sub-area and fishery (gear).

Measurement of length and weight, extraction of otoliths

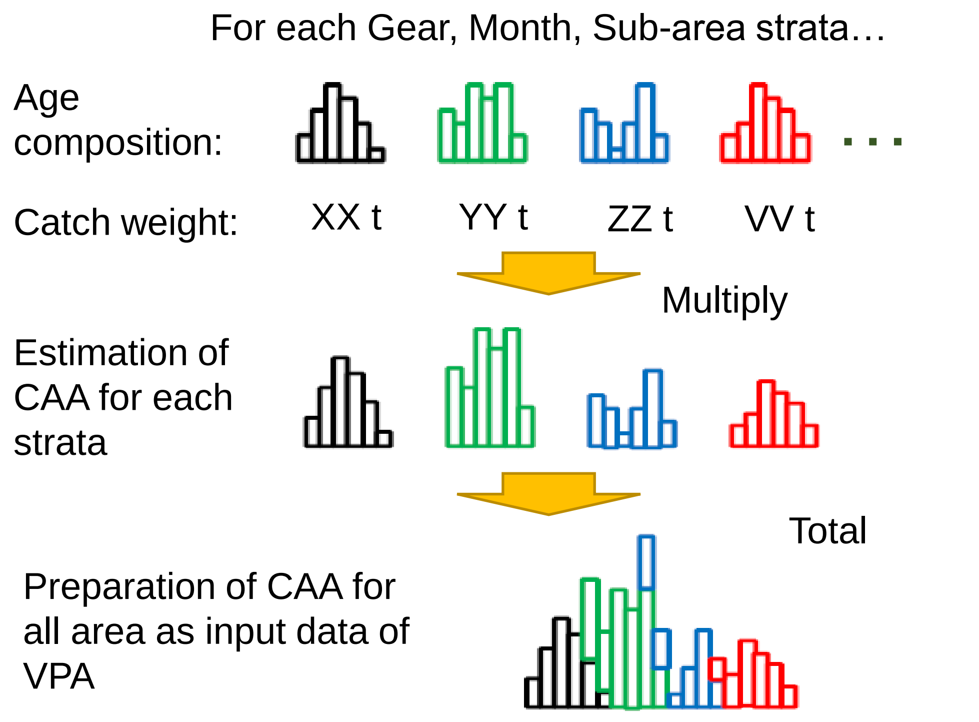
Ageing otoliths using black-resin method with 2-3 readers

Calculation of age composition of each sample (based on ageing data of about 100 fishes in each sample)

Estimation of CAA for each sub-area and fishery based on the catch weight and corresponding age composition data



Black resin method (Kooka and Yabuki 2008)



Example of sampling in Eastern Hokkaido

The CAA was calculated based on the catch weight and age composition of each stratum (fishing gear, sub-area, and month). For the strata without sample, substitute age composition data from adjacent strata was used to calculate the CAA.

	Month	Apr.		May		Sep.		Oct.		Nov.		Dec		Jan.		Feb		Mar.		Coastal
2016	Sub-area	West	East	West	East	West	East	West	East	West	East	West	East	West	East	West	East	West	East	fishery
	Catch of Otter trawl (t)	26	785	10	13	1,565	1,565	744	941	259	584	227	220	1,023	57	617	285	643	372	3,141
	Sample from Otter trawl	substitution	X	X	X	X	X	X	substitution	X	substitution	X	X	X	substitution	X	X	substitution	X	substitute
	Catch of Danish seine (t)	426	2,604	557	796	7,843	1,790	1,587	1,821	2,066	655	3,392	716	3,406	247	2,116	1,580	1,682	3,380	
	Sample from Danish seine	substitution	substitution	substitution	substitution	X	X	X	substitution	X	X	X	X	X	X	X	X	X	X	

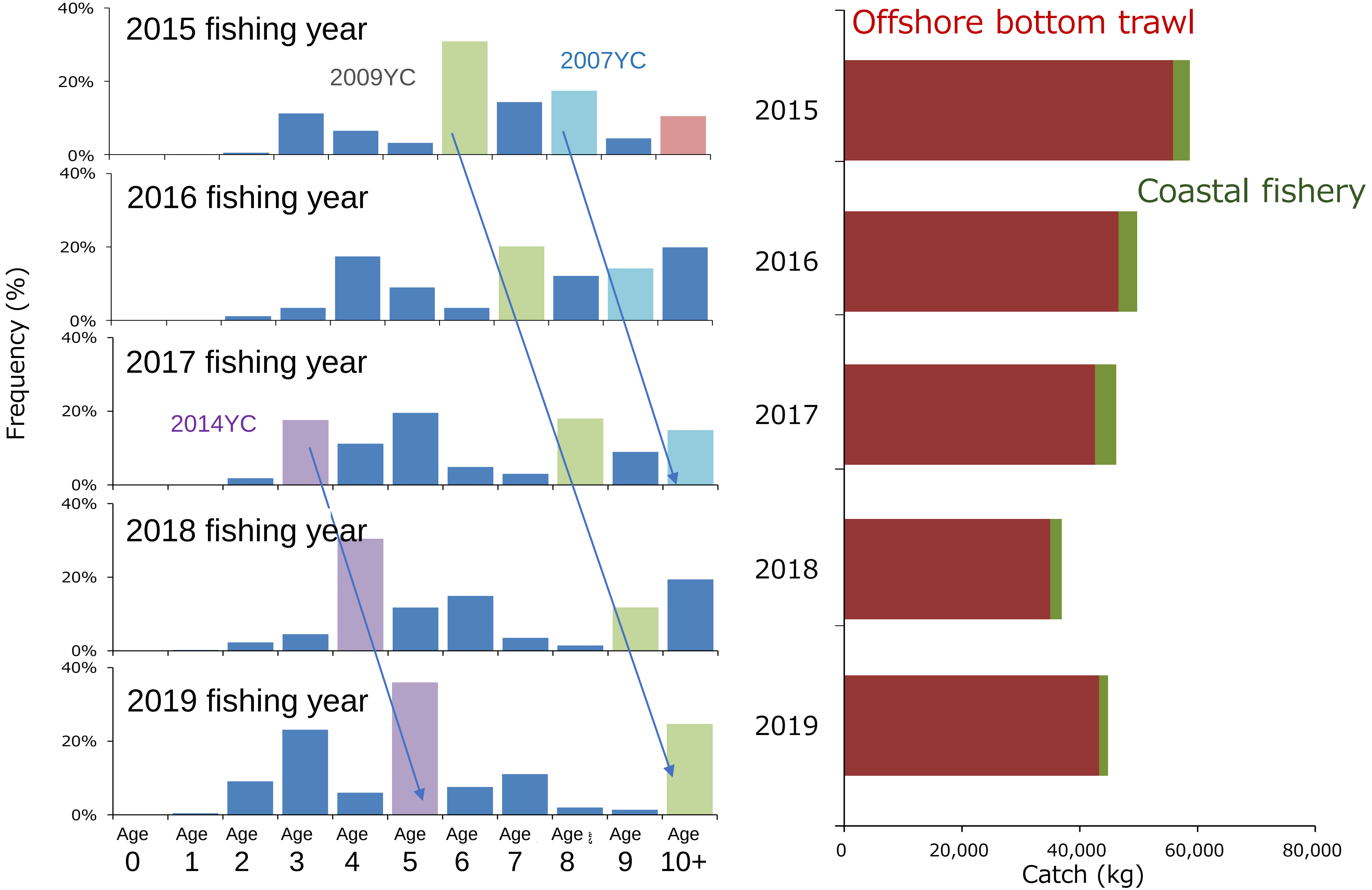
	Month	Apr.		May		Sep.		Oct.		Nov.		Dec		Jan.		Feb		Mar.		Coastal
2017	Sub-area	West	East	West	East	West	East	West	East	West	East	West	East	West	East	West	East	West	East	fishery
	Catch of Otter trawl (t)	549	59	86	181	1,401	1,148	959	1,031	306	574	395	392	518	321	586	263	290	463	3,607
	Sample from Otter trawl	substitution	X	X	X	X	X	X	substitution	X	substitution	X	X	X	substitution	X	X	substitution	X	substitute
	Catch of Danish seine (t)	663	1,044	424	1,669	5,344	6,262	4,161	1,310	1,533	823	2,193	317	2,456	191	1,130	877	960	1,685	
	Sample from Danish seine	substitution	X	substitution	X	X	X	X	X	X	substitution	X	X	X	X	substitution	X	substitution	X	

	Month	Apr.		May		Sep.		Oct.		Nov.		Dec		Jan.		Feb		Mar.		Coastal
2018	Sub-area	West	East	West	East	West	East	West	East	West	East	West	East	West	East	West	East	West	East	fishery
	Catch of Otter trawl (t)	132	140	295	441	1,742	273	939	848	88	917	325	56	405	174	378	360	489	274	1,919
	Sample from Otter trawl	X	X	X	X	X	substitution	X	X	substitution	X	X	substitution	X	X	X	X	X	X	substitute
	Catch of Danish seine (t)	127	678	471	3,151	5,472	1,973	3,419	1,654	1,625	880	1,789	62	1,154	109	1,345	511	634	1,637	
	Sample from Danish seine	substitution	X	substitution	substitution	X	X	substitution	X	X	substitution	X	substitution	X	X	X	X	substitution	X	

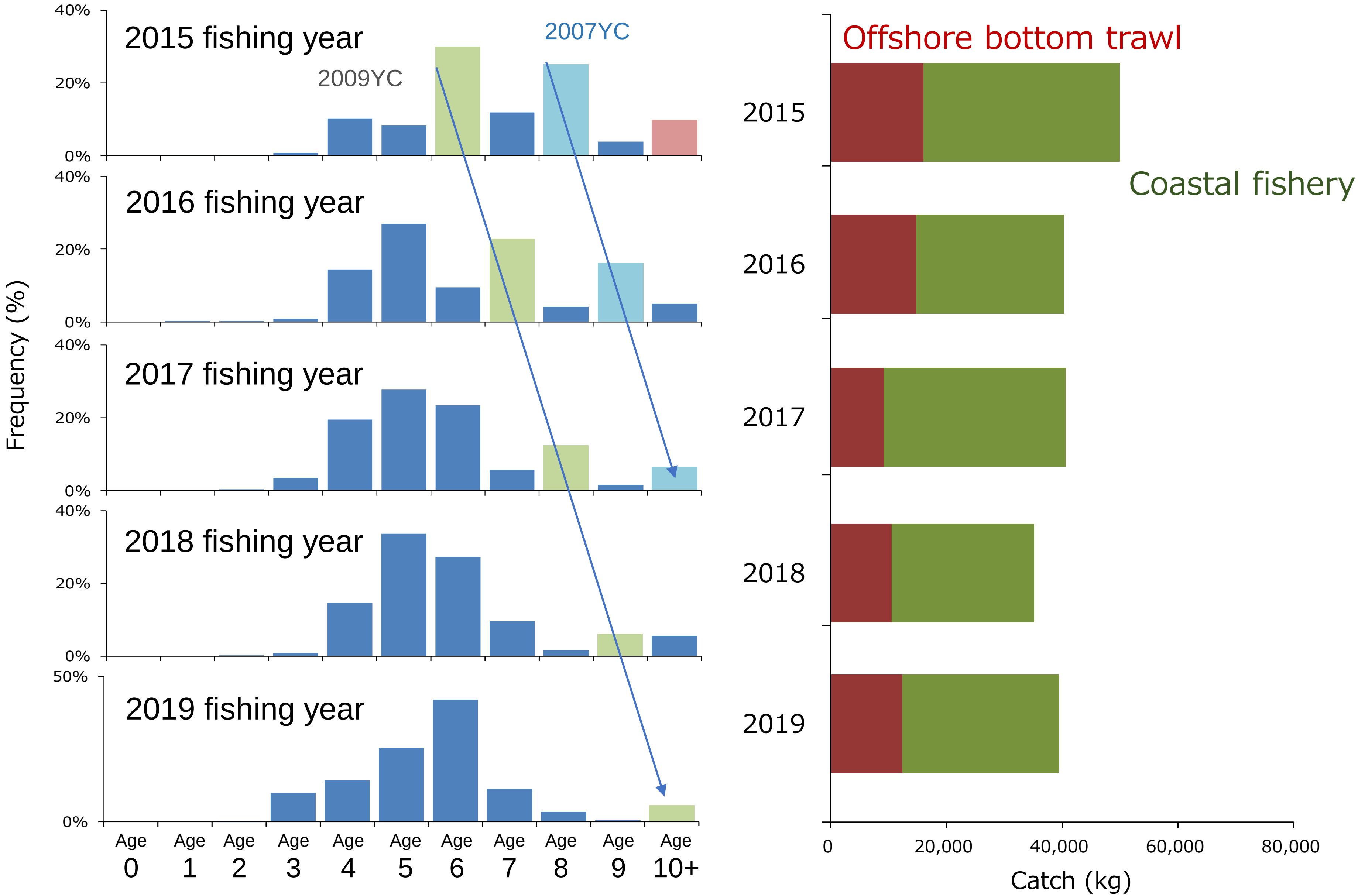
	Month	Apr.		May		Sep.		Oct.		Nov.		Dec		Jan.		Feb		Mar.		Coastal
2019	Sub-area	West	East	West	East	West	East	West	East	West	East	West	East	West	East	West	East	West	East	fishery
	Catch of Otter trawl (t)	276	180	144	294	1,975	673	1,353	409	665	166	185	377	83	997	632	421	394	462	1,485
	Sample from Otter trawl	X	X	X	X	X	X	X	X	X	X	X	X	substitution	X	X	X	X	X	substitute
	Catch of Danish seine (t)	184	1,733	595	2,422	7,909	1,139	2,683	1,139	1,763	470	1,216	547	375	2,623	877	3,590	883	3,467	
	Sample from Danish seine	substitution	X	X	X	X	X	X	X	X	X	X	substitution	substitution	X	X	X	substitution	X	

June-August: Closed season of offshore bottom trawl fishery

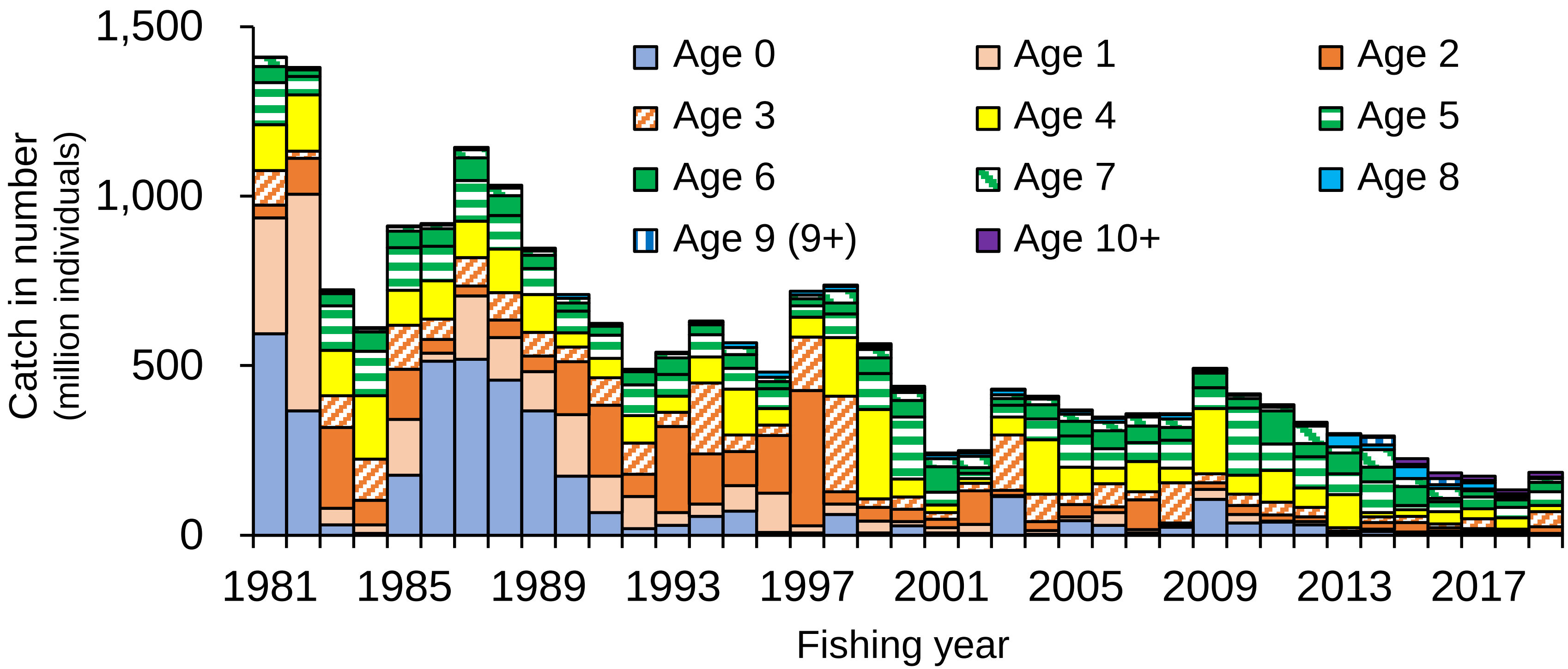
Recent 5yrs CAA for Eastern Hokkaido



Recent 5yrs CAA for Southwestern Hokkaido



CAA for assessment



- Plus-group was extended from age 8+ to 10+ in 1997-1999.
  - By 1997, plus group had been age 8+.
  - In 1998, plus group was age 9+.
  - Since 1999, plus group was age 10+.

Abundance indices

Offshore bottom trawl (Eastern - Southwestern Hokkaido)

- Standardized CPUE at age
  - ✓ Tuning index for age 3, 4, 5, 6, and 7
  - ✓ 1999-2019 fishing year

Anchored gillnet for walleye pollock (Southwestern Hokkaido)

- Standardized CPUE based on skipper's note
  - ✓ Tuning index for SSB
  - ✓ 2010-2019 fishing year
- Abundance index based on prefectural statistics (logbook)
  - ✓ Tuning index for SSB
  - ✓ 2003-2019 fishing year

Tuning indices For VPA

These indices are provided by Hokkaido Research Organization (HRO)

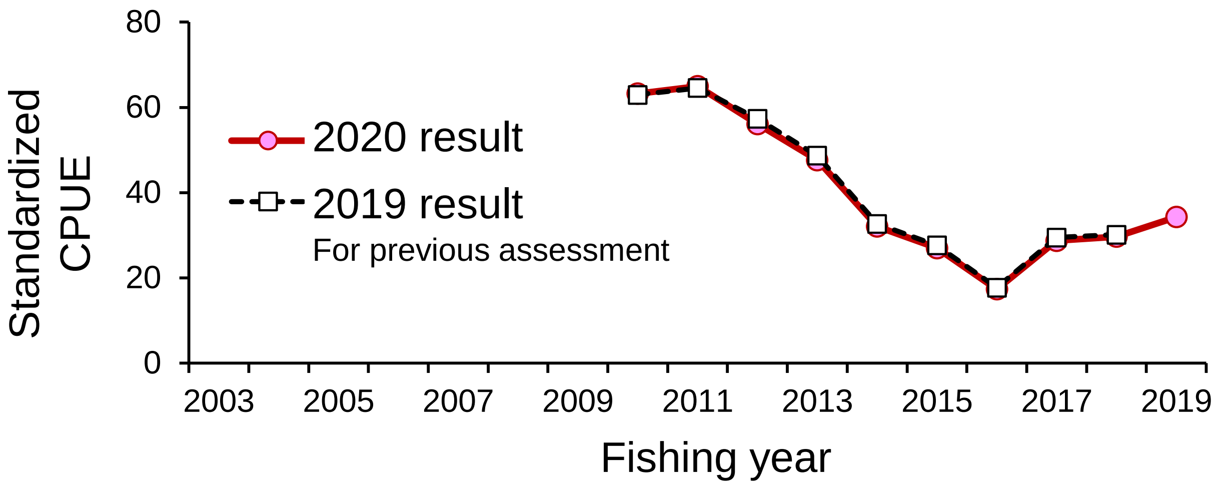
Survey data (Eastern - Southwestern Hokkaido)

- Acoustic and trawl survey (Jun.-Jul.)
  - ✓ Abundance estimation for age 1 and 2.
  - ✓ 2005-2019

Recruitment index to assume latest 3 years' recruitment

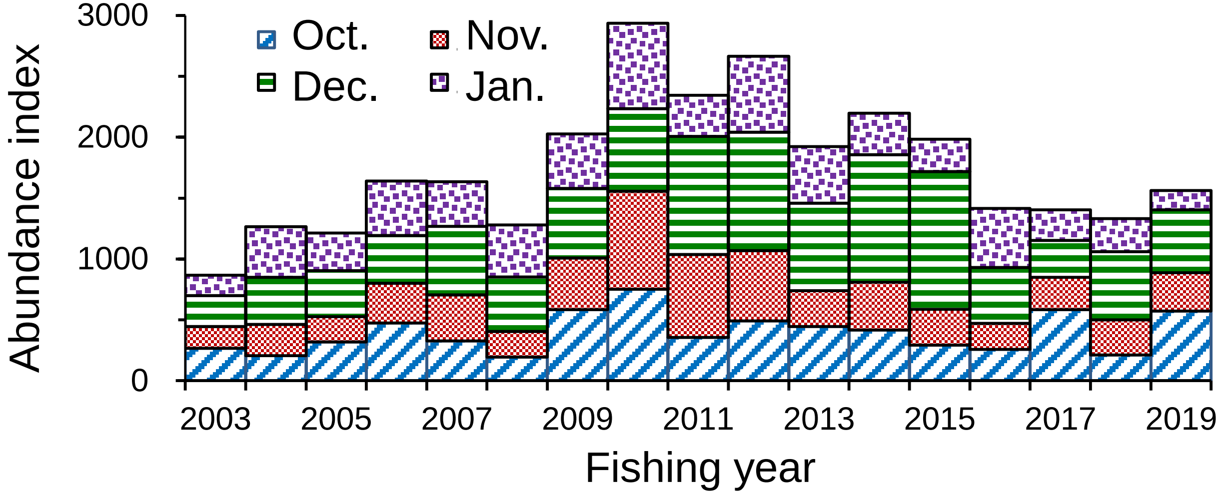
Indices of Anchored gillnet

Standardized CPUE based on skipper's note



- ✓ 18-19 fishing boats /year
- ✓ Approx. 800 op. /year
- ✓ CPUE (Catch/number of net) was standardized using GLM

Abundance index based on prefectural statistics (logbook)

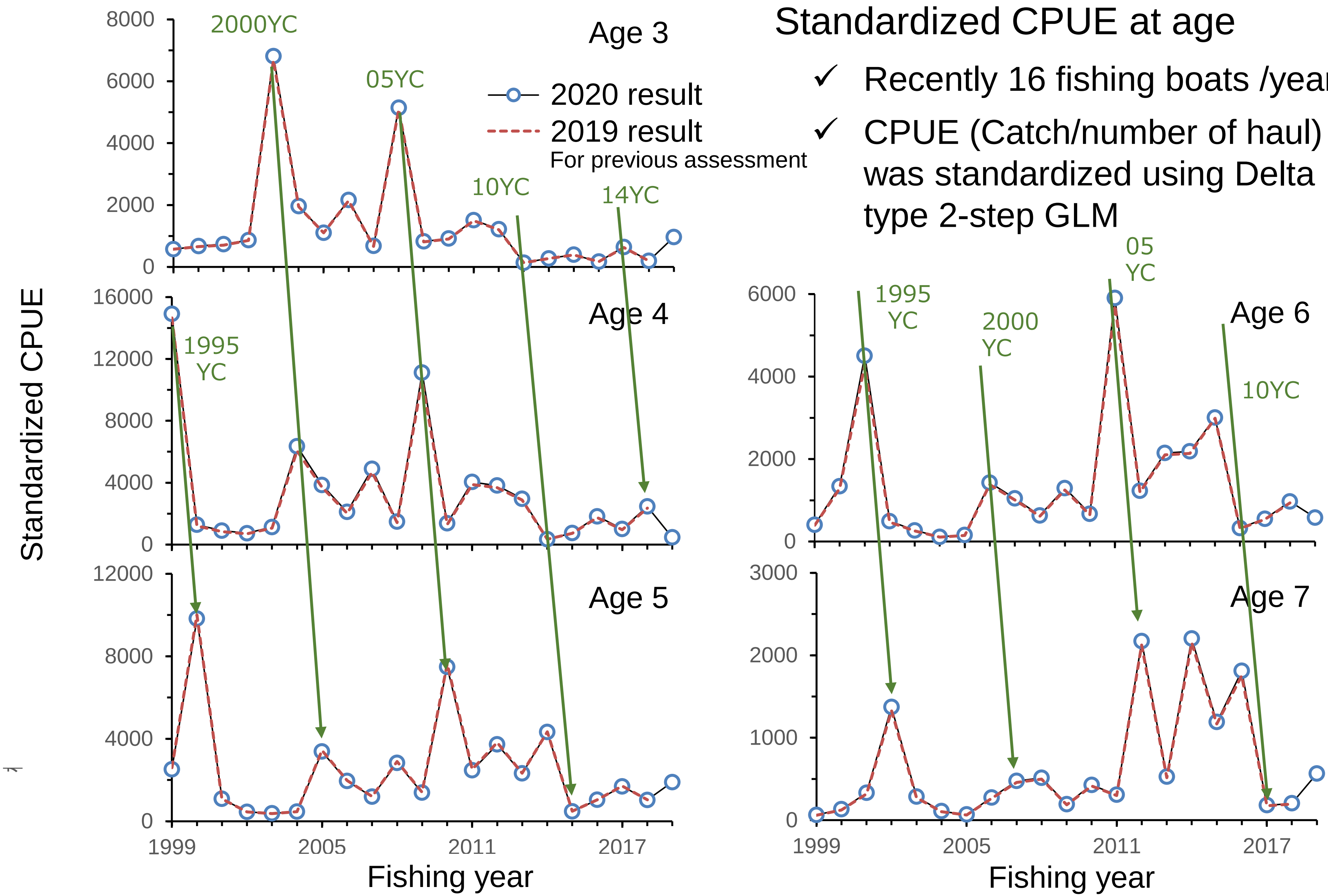


- ✓ Approx. 500 fishing boats were licensed, but not all of them operated every year (268 boats operated in 2019 fishing year).
- ✓ Based on Catch/number of net.

Indices of Offshore Bottom Trawl

Standardized CPUE at age

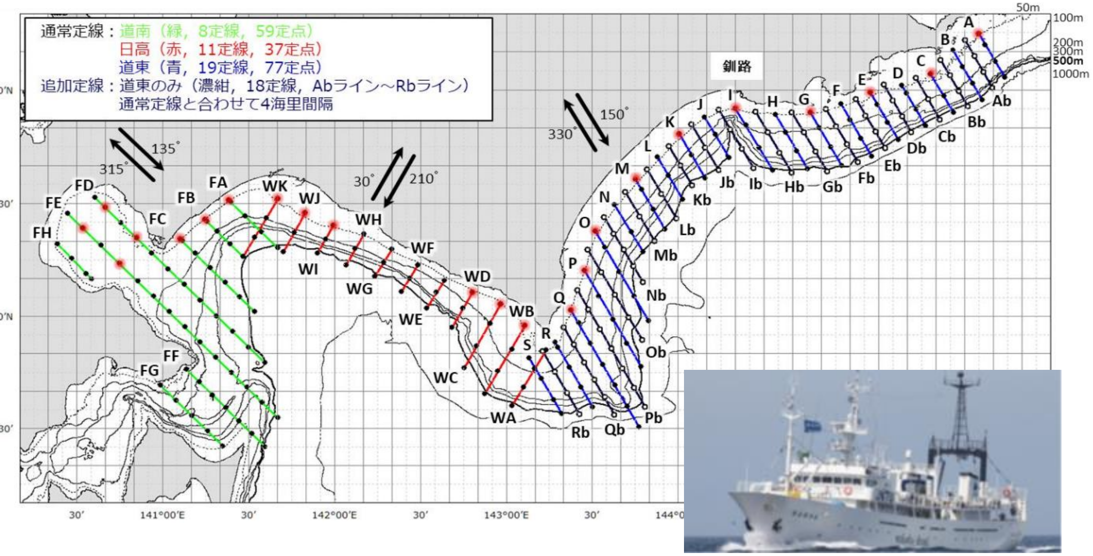
- ✓ Recently 16 fishing boats /year
- ✓ CPUE (Catch/number of haul) was standardized using Delta type 2-step GLM

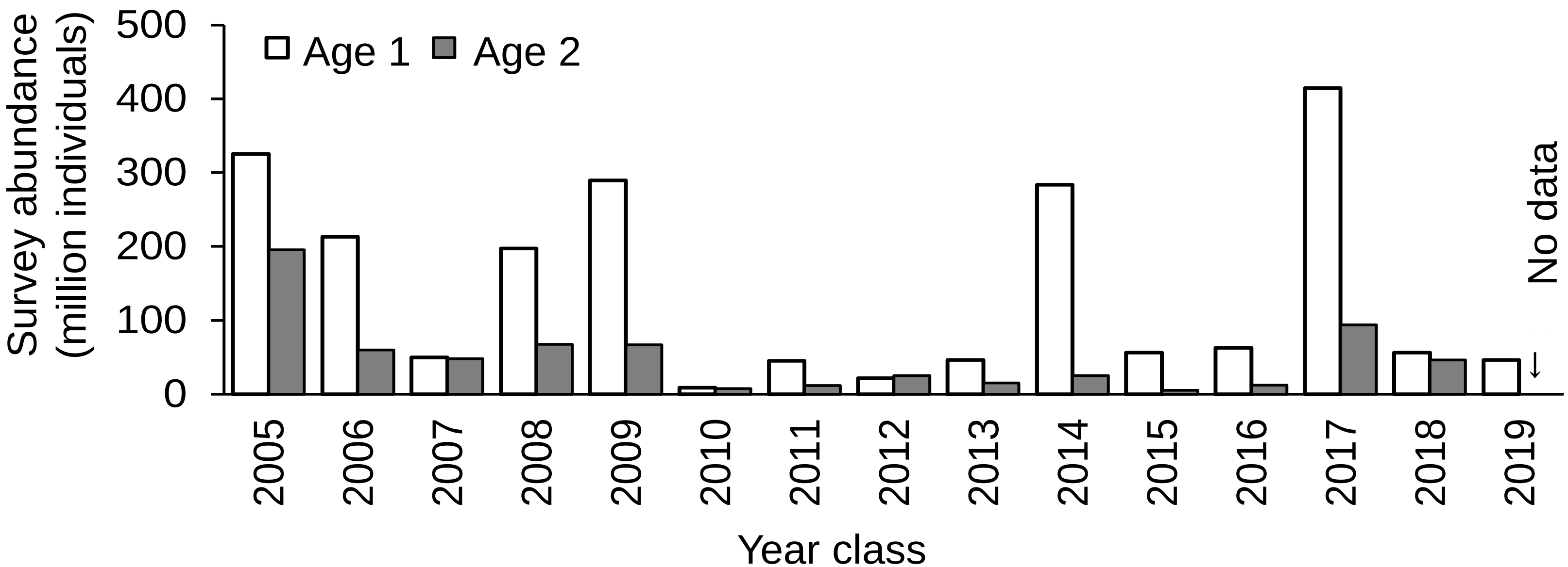


Survey data

Acoustic and trawl survey (Jun.~Jul.)

- ✓ Using quantitative echo sounders
- ✓ Trawling for species and size identification





Reviewer’s Comments #03 and #13

- Describe how indices of abundance are calculated, and provide tables of sample size (number of hauls, trips, etc.) by year and area for each index. Are survey indices derived from design-based estimators, or are model-based methods (e.g., generalized linear models) used to derive annual estimates? If model-based methods are used, describe the model selection procedure and diagnostics for the final model.
- Are uncertainty estimates available for the annual abundance indices? Standard errors of the annual survey estimates could potentially be used as relative weights in the tuning process, and otherwise help with interpretation of trends over time and/or interannual variability.

Response

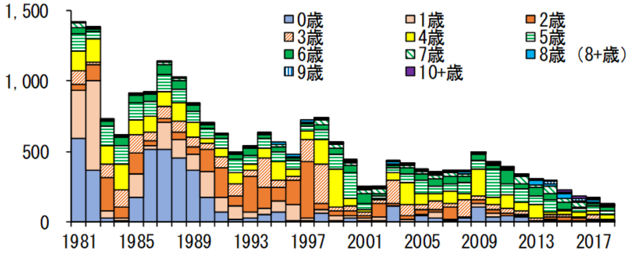
Indices of Anchored gillnet and offshore bottom trawl are based on commercial fishery data, which are calculated by Hokkaido Research Organization (HRO) and FRA, respectively. For the index of skipper’s note from Anchored gillnet and CPUE at age from offshore bottom trawl were standardized using GLM. Detailed information is not provided for the indices of Anchored gillnet by HRO, thus we documented for the offshore bottom trawl standardized CPUE at age additionally to describe detailed information.

Acoustic and trawl survey is design-based index. Detailed information of survey design was described in Honda et al. (2004). Uncertainty of the index has not been provided at this stage.

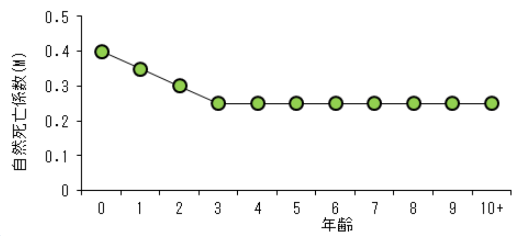
Uncertainties of the standardized CPUE on offshore bottom trawl are shown in provided document. In current VPA analysis, uncertainties (e. g. confidence interval) of tuning indices were not used for stock estimation. We understand that those information are important when we will use integrated stock assessment model (i. e. Stock Synthesis).

Stock assessment method

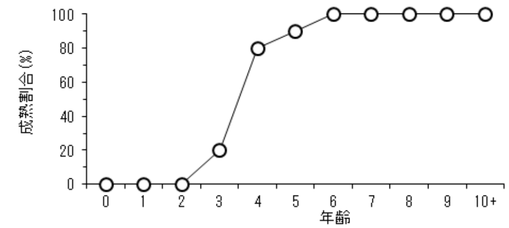
Catch at Age（CAA）



Natural mortality（M）

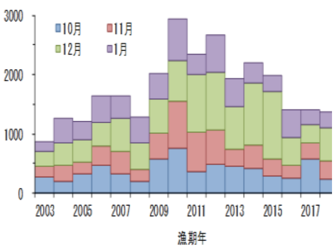


Maturity ratio

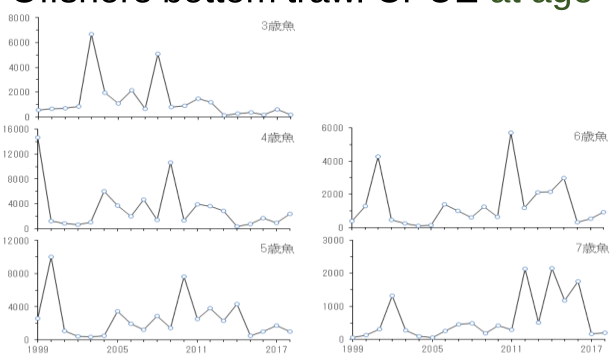


Tuning indices

Anchored gillnet indices



Offshore bottom trawl CPUE at age



Cohort analysis

- ✓ Pope’s method
- ✓ Recruitment of latest 3 years are assumed from survey data.

Tuning

- ✓ F at age in terminal year is estimated (age 3-9)
- ✓ Using ridge VPA

Result of analysis

- Biomass
- Recruitment
- SSB
- F

Future projection & Calculation of ABC

Reviewer's Comment #14

- The natural mortality rate (M) is assumed to be 0.25 per year for ages 3 and above, with larger values for younger ages. Please describe any ageing studies done for the assessment or from the literature, and comparisons with similar stocks. I am not very familiar with Widrig (1954), but the authors indicate that individuals of age 20 are caught, although infrequently. Based on recent meta-analyses (e.g. Then 2014, Hamel 2015) M estimates based on ~5/Amax are in common use, which is roughly consistent with the assumed value for age 3+ fish.
- However, since M is not known with precision and affects estimates of F (and therefore abundance), model runs with alternative values for M would help managers understand risks associated with uncertainty in M.

Response

We would like to explain detailed information in next slides.

Natural mortality (M)

- In our assessment, natural mortality (M) has been assumed according to Widrig (1954) since 1995 (1st assessment in Japan).
- Widrig (1954) method;

Total mortality (Z) can be expressed by fishing mortality (F) and natural mortality (M).

Fishing mortality (F) may be considered as directly proportional to fishing effort (X).

If a series of pairs of values of fishing effort (X) and total mortality (Z) is known, following equations give a linear relation between them.

$$Z = F + M$$

$F = q \cdot X$ where q is the constant factor of proportionality (i.e. catchability).

$$Z = q \cdot X + M$$

By application of the method, natural mortality (M) and catchability (q) can be obtained by simple linear regression.

- In 1995 assessment, total mortality (Z) was probably calculated from offshore bottom trawl CPUE by age according to Ricker (1975).

$$Z = \frac{1}{y_{t+1} - y_t} ln \frac{CPUE_{a,t}}{CPUE_{a+1,t+1}}$$

Where, CPUE is catch number per trawl operation, y is fishing year, a is age.

M estimation according to Widrig (1954)

- This is recreation because detailed documents at the time are apparently not on file.
- Data are the catch number at age and fishing effort of offshore bottom trawl fishery in 1986-1993;

Effort	1986	1987	1988	1989	1990	1991	1992	1993
	41768	46783	43119	35472	53346	37700	24841	27251

CAA	1986	1987	1988	1989	1990	1991	1992	1993
Age0	53355	51942	46567	37475	17767	6810	2008	2867
Age1	2502	16639	11030	10163	18161	10563	7455	3168
Age2	4207	2660	4592	4170	12078	17310	5025	16751
Age3	6215	7431	7077	6058	3412	6673	6074	2994
Age4	11665	9649	11185	10204	3744	5557	7391	3686
Age5	10613	10651	8777	7289	6145	6691	9246	6054
Age6	5354	5944	5156	3551	2423	2663	3937	4523
Age7	1242	2078	1912	1273	1323	583	436	2373
Age8	381	677	796	743	1024	227	261	365

(From assessment report in 1995)

1. CPUE is calculated by fishing effort (number of operation) and catch number at age.
2. Based on the CPUE, Z at age is calculated.
3. Average value of Z (age1-age7) is calculated.
4. M value is estimated.

M estimation according to Widrig (1954)

- This is recreation because detailed documents at the time are apparently not on file.
- Data are the catch number at age and fishing effort of offshore bottom trawl fishery in 1986-1993;

CPUE	1986	1987	1988	1989	1990	1991	1992	1993
Age0	1.277	1.110	1.080	1.056	0.333	0.181	0.081	0.105
Age1	0.060	0.356	0.256	0.287	0.340	0.280	0.300	0.116
Age2	0.101	0.057	0.106	0.118	0.226	0.459	0.202	0.615
Age3	0.149	0.159	0.164	0.171	0.064	0.177	0.245	0.110
Age4	0.279	0.206	0.259	0.288	0.070	0.147	0.298	0.135
Age5	0.254	0.228	0.204	0.205	0.115	0.177	0.372	0.222
Age6	0.128	0.127	0.120	0.100	0.045	0.071	0.158	0.166
Age7	0.030	0.044	0.044	0.036	0.025	0.015	0.018	0.087
Age8	0.009	0.014	0.018	0.021	0.019	0.006	0.011	0.013

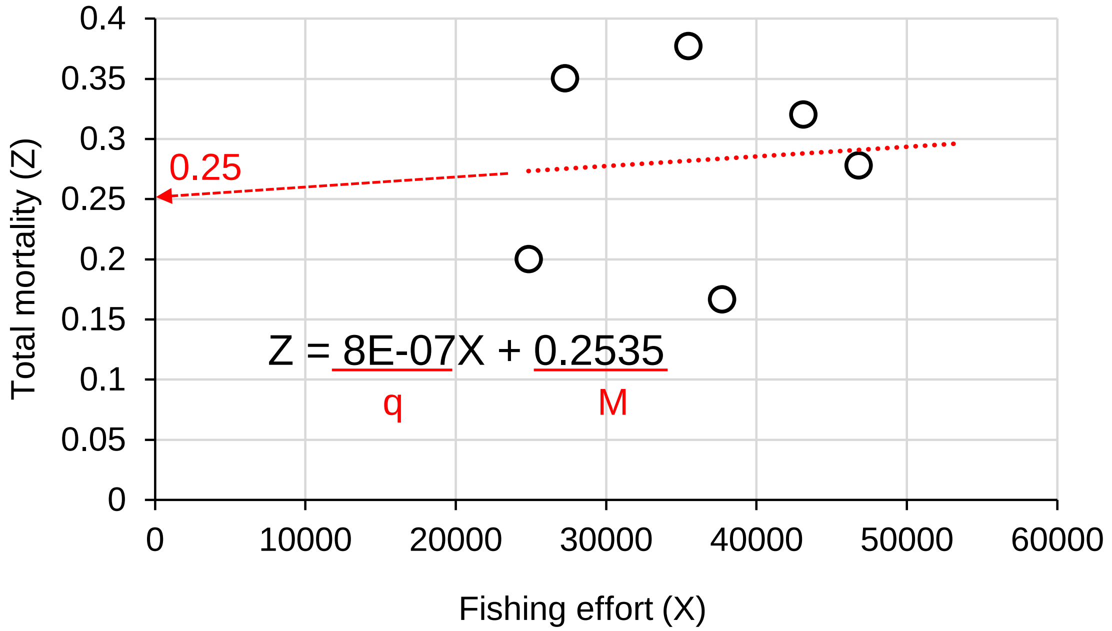
Z	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93
Age0-1	1.279	1.468	1.327	1.132	0.173	-0.508	-0.363
Age1-2	0.052	1.206	0.777	0.235	-0.299	0.326	-0.717
Age2-3	-0.456	-1.060	-0.472	0.609	0.246	0.630	0.610
Age3-4	-0.326	-0.490	-0.561	0.889	-0.835	-0.519	0.592
Age4-5	0.204	0.013	0.233	0.915	-0.928	-0.926	0.292
Age5-6	0.693	0.644	0.710	1.509	0.489	0.113	0.808
Age6-7	1.060	1.053	1.204	1.395	1.077	1.392	0.599
Age7-8	0.720	0.878	0.750	0.626	1.416	0.387	0.270

1. CPUE is calculated by fishing effort (number of operation) and catch number at age.
2. Based on the CPUE, Z at age is calculated.
3. Average value of Z (age1-age7) is calculated.
4. M value is estimated.

M estimation according to Widrig (1954)

- This is recreation because detailed documents at the time are apparently not on file.
- Data are the catch number at age and fishing effort of offshore bottom trawl fishery in 1986-1993;

Average Z	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93
Age1-	0.278	0.320	0.377	0.883	0.167	0.200	0.351



* The value of 1989-90 was dropped as the outlier.

1. CPUE is calculated by fishing effort (number of operation) and catch number at age.
2. Based on the CPUE, Z at age is calculated.
3. Average value of Z (age1-) is calculated.
4. M value is estimated.
5. M=0.25

Assumption of M under age 3

- Higher M values have been assumed for age 0-2 based on general reasons since 1997 assessment (3rd assessment in Japan).
- Detailed documents at the time are apparently not on file.
- This assumption would be determined using examples from the assessments of similar stock in US (i.e. Eastern Bering Sea stock).

Age	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Japanese Pacific Stock (This assessment)	0.40	0.35	0.30	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25						
Eastern Bering sea (Wespestad and Terry 1984) *		0.85	0.45	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.40	0.50	0.50	0.60
Eastern Bering sea (current assessment: Ianelli et al. 2020)		0.90	0.45	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	

* Originally, the value from Bakkala et al. 1980 (INPFC doc. 2337) was referred.

The other method to estimate M

- We have been used same M assumption since 1997 in terms of consistency.
- If we use the other method to estimate M…?

	Source	Formula	Note
1)	Pauly (1980)	$log_{10}(M) = -0.0066 - 0.279log_{10} + 0.6543log_{10}(k) + 0.4634log_{10}\ (Temp)$	Constant M
2)	Hoenig (1983)	$lnM = 1.46 - 1.01\ln(t_{max})$	Constant M
3)	Chen and Watanabe (1989)	$M(t) = \begin{cases} k/\left(1-e^{-k(t-t_0)}\right), & t \le t_M \\ k/(a_0 + a_1(t-t_M) + a_2(t-t_M)^2), & t > t_M \end{cases}$ $t_M = -\frac{1}{k}(\ln\left\|1-e^{kt_0}\right\| + t_0)$ $\begin{cases} a_0 = 1 - e^{-k(t_M-t_0)} \\ a_1 = ke^{-k(t_M-t_0)} \\ a_2 = -\frac{1}{2}(k^2e^{-k(t_M-t_0)}) \end{cases}$	Age specific M
4)	Gislason et al. (2010)	$lnM(t) = 0.55 - 1.61\ln\left(L(t)\right) + 1.44\ln(L\infty) + \ln(k)$	Age specific M

Parameters;

	Parameter		Source
a)	Growth (Von Bertalanffy)	$L\infty = 57.3,\quad k = 0.23,\quad t_0 = -0.49$	Yabuki (unpubl. data)
b)	Maximum age	$t_{max} = 22$	Yabuki et al. (1993)
c)	Water temperature	2~6℃	Shida (2011)

The other method to estimate M

- The M values which we have been used are not substantially different between the other estimation especially for age 3+;

Age	0	1	2	3	4	5	6	7	8	9	10+
Assumption for the assessment	0.40	0.35	0.30	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
[The other method]											
1) Pauly (1980) : 2-6℃						0.17 ~ 0.28					
2) Hoenig (1983)						0.19					
3) Chen and Watanabe (1989)	-	0.79	0.53	0.42	0.36	0.32	0.30	0.28	0.27	0.26	0.21
4) Gislason et al. (2010)	-	1.47	0.76	0.52	0.41	0.34	0.30	0.27	0.26	0.24	0.23

- As you indicated, “M is not known with precision and affects estimates of F (and therefore abundance)”, thus we would like to continue working to improve.
- Especially for younger age’s M, our staff have a plan to directly estimate based on the acoustic-trawl method which was used for Pacific sardine in the California Current Ecosystem (Zwolinski and Demer 2013).

Equations of VPA for plus group

- As mentioned above, plus group has been age 8+ by 1997, age 9+ in 1998, age 10+ since 1999 (extended from age 8+ to 10+ in 1998-1999).
- The equations of plus group calculation are as following;

Estimation of N

Age	1994	1995	1996	1997	1998	1999	2000	2001
0								
1								
2								
3								
4								
5								
6								
7								
8(+)								
9(+)	No data	No data	No data	No data				
10+	No data	No data	No data	No data	No data			

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

$$N_{7,y} = \left(\frac{C_{7,y}}{C_{8+,y}+C_{7,y}}\right) N_{8+,y+1}\exp(M) + C_{7,y}exp\left(\frac{M}{2}\right)$$

$$N_{8+,y} = \left(\frac{C_{8+,y}}{C_{8+,y}+C_{7,y}}\right) N_{8+,y+1}\exp(M) + C_{8+,y}exp\left(\frac{M}{2}\right)$$

$$N_{9,y} = \left(\frac{C_{9,y}}{C_{10+,y}+C_{9,y}}\right) N_{10+,y+1}\exp(M) + C_{9,y}exp\left(\frac{M}{2}\right)$$

$$N_{10+,y} = \left(\frac{C_{10+,y}}{C_{10+,y}+C_{9,y}}\right) N_{10+,y+1}\exp(M) + C_{10+,y}exp\left(\frac{M}{2}\right)$$

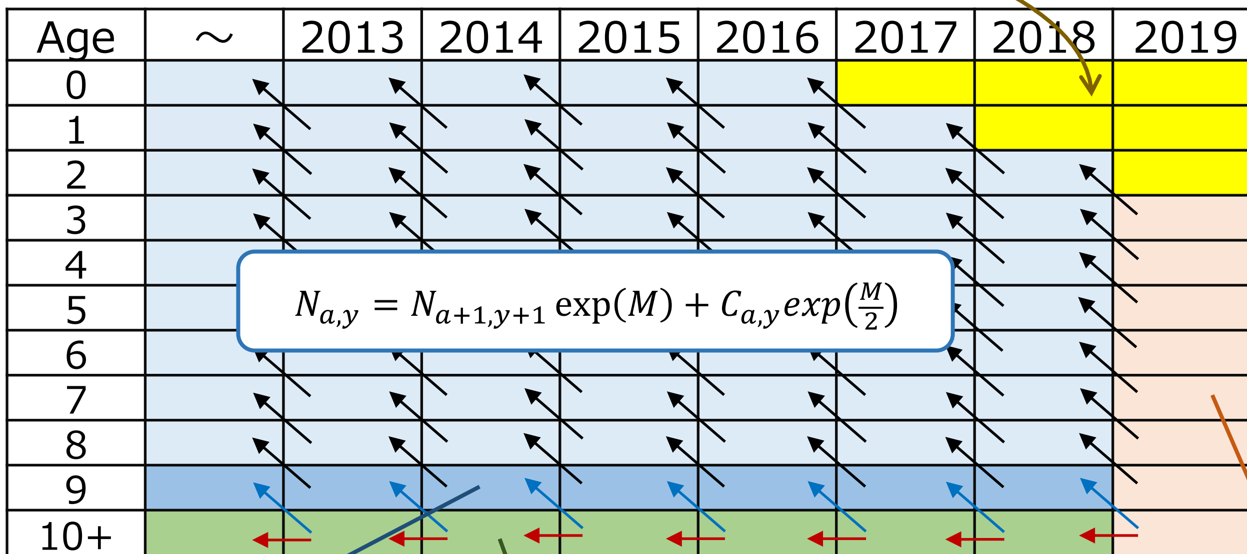
$$F_{a,y} = -ln\left(1 - \frac{C_{a,y}\,exp\left(\frac{M_a}{2}\right)}{N_{a,y}}\right)$$

F of plus group and previous age are assumed to be equal, except for 1997 and 1998.

Equations of VPA for the terminal year

- The terminal year of this assessment is 2019 fishing year.
- Recruitments of recent 3 year-classes are assumed from survey data.

Estimation of N



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

$$N_{9,y} = \left(\frac{C_{9,y}}{C_{10+,y}+C_{9,y}}\right) N_{10+,y+1}\exp(M) + C_{9,y}exp\left(\frac{M}{2}\right)$$

$$N_{10+,y} = \left(\frac{C_{10+,y}}{C_{10+,y}+C_{9,y}}\right) N_{10+,y+1}\exp(M) + C_{10+,y}exp\left(\frac{M}{2}\right)$$

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

F of plus group and that of previous age are assumed to be equal.

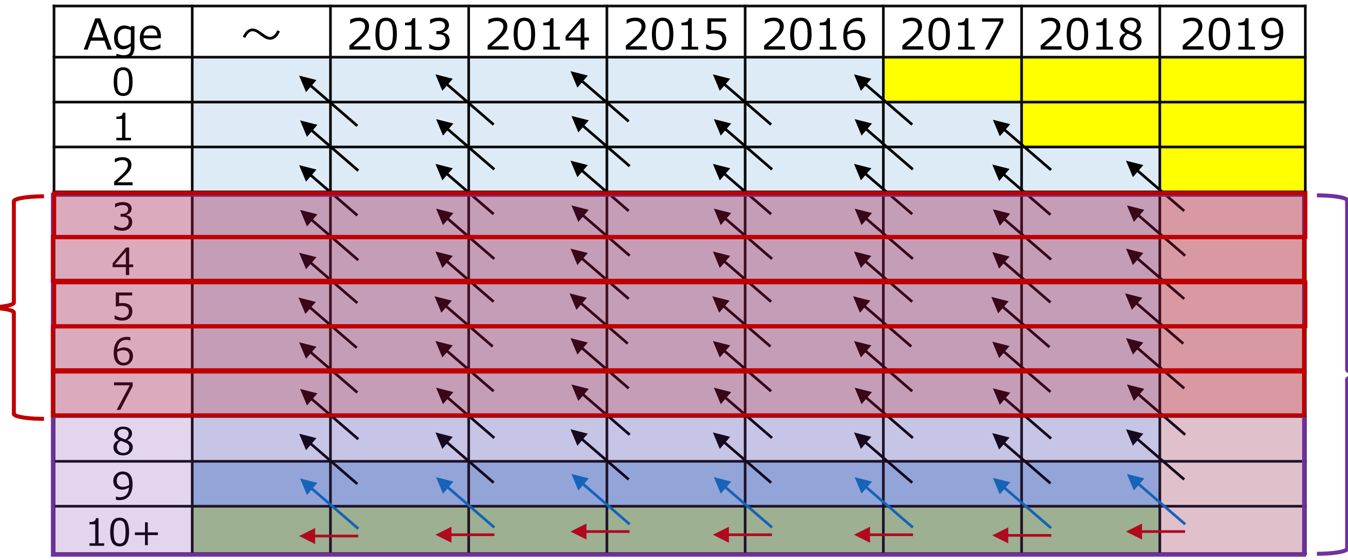
$$N_{a,Y} = \frac{C_{a,Y}\exp\left(\frac{M_a}{2}\right)}{\left(1-\exp\left(-F_{a,Y}\right)\right)}$$

The terminal F of age 3-9 is obtained from maximum likelihood estimation under the tuning process. The terminal F of plus group (10+) and previous age (9) are assumed to be equal.

Equations of VPA for tuning part

- The terminal F (age 3-9) is estimated by minimizing the difference between the predicted abundances or SSB and the observed tuning indices.

Estimation of N



Negative log likelihood

$$-\ln L = \sum_a \sum_y \left[\frac{[\ln I_{a,y} - (b_a \ln D_{a,y} + \ln q_a)]^2}{2\sigma_a^2} - \ln\left(\frac{1}{\sqrt{2\pi}\sigma_a}\right)\right]$$

$$+ \sum_y \left[\frac{[\ln J_y - (b' \ln S_y + \ln q')]^2}{2\sigma'^2} - \ln\left(\frac{1}{\sqrt{2\pi}\sigma'}\right)\right]$$

$$+ \sum_y \left[\frac{[\ln K_y - (b'' \ln S_y + \ln q'')]^2}{2\sigma''^2} - \ln\left(\frac{1}{\sqrt{2\pi}\sigma''}\right)\right]$$

Offshore trawl CPUE (I_a) are fitted to predicted abundance (D_a) for each age 3~7.

Abundance index of anchored gillnet from logbook (J) and its CPUE from skipper's note (K) are fitted to predicted SSB (S).

Power relation is assumed between the index and the abundance or SSB (nonlinearity parameter b).

Reviewer's Comment #11

- In the WP-NJS assessment, unequal weights (Wk) given to each index of abundance. This assessment did not describe any weighting of different indices in the negative log-likelihood. Were all of the abundance indices equally weighted?

Response

In the maximum likelihood estimation, σ^2 of following equation is the variance between the tuning indices and the relative abundance or SSB. The weight for each index is expressed by the magnitude of σ. Indices with smaller (bigger) σ values have higher (lower) weights. For more information, please see Hashimoto et al. (2018).

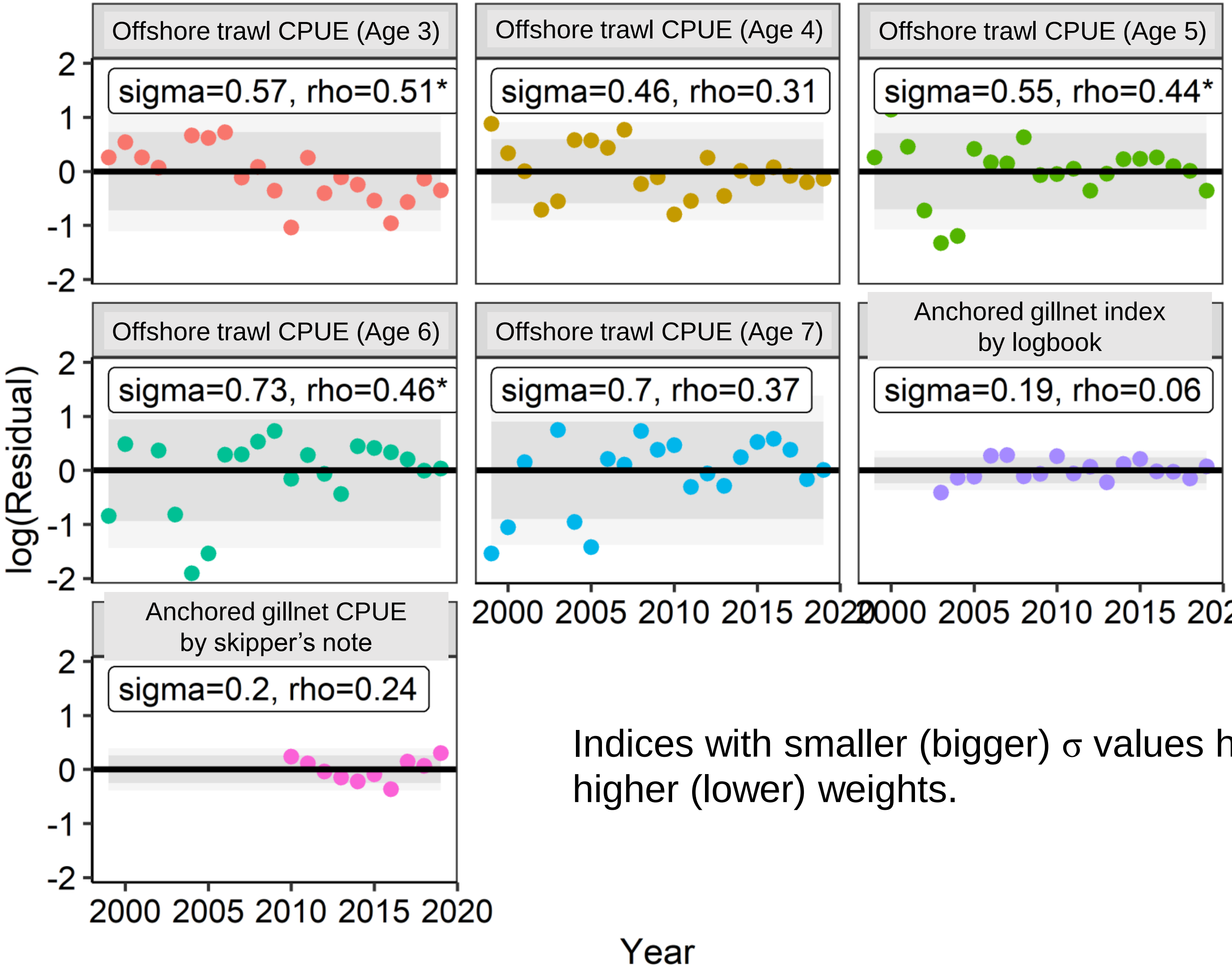
Negative log likelihood

$$-\ln L = \sum_a \sum_y \left[\frac{\left[\ln I_{a,y} - (b_a \ln D_{a,y} + \ln q_a)\right]^2}{2\sigma_a^2} - \ln\left(\frac{1}{\sqrt{2\pi}\sigma_a}\right) \right] + \sum_y \left[\frac{\left[\ln J_y - (b' \ln S_y + \ln q')\right]^2}{2\sigma'^2} - \ln\left(\frac{1}{\sqrt{2\pi}\sigma'}\right) \right] + \sum_y \left[\frac{\left[\ln K_y - (b'' \ln S_y + \ln q'')\right]^2}{2\sigma''^2} - \ln\left(\frac{1}{\sqrt{2\pi}\sigma''}\right) \right]$$

Offshore bottom trawl CPUE (I_a) are fitted to predicted abundance (D_a) for each age 3~7.

Abundance index of anchored gillnet from logbook (J) and its CPUE from skipper's note (K) are fitted to predicted SSB (S).

Results of sigma values

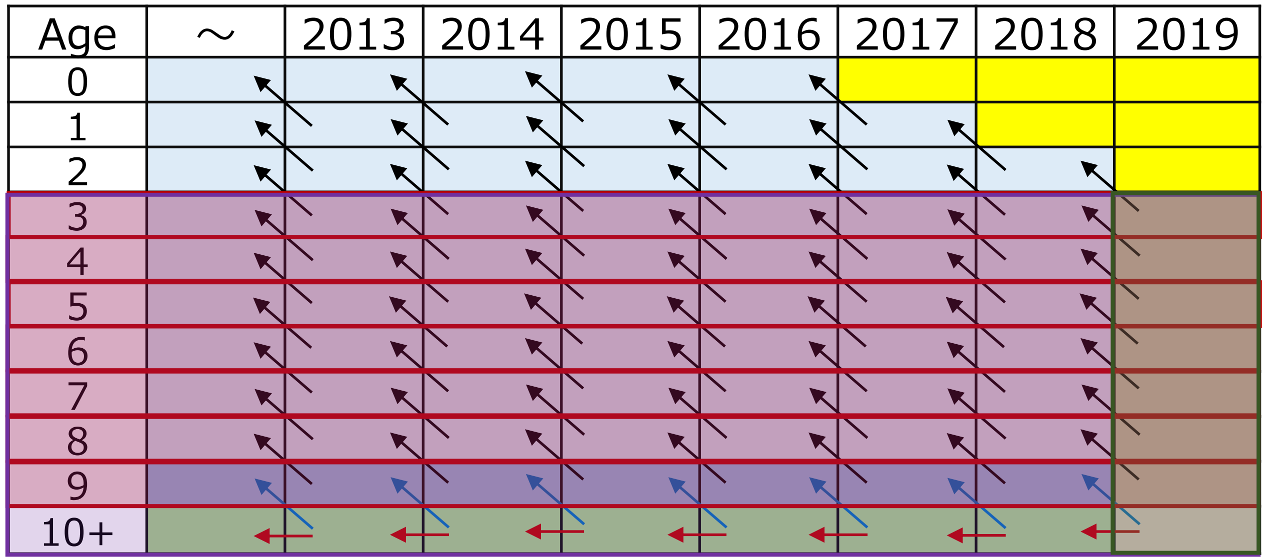


Indices with smaller (bigger) σ values have higher (lower) weights.

Equations of VPA for ridge penalty

- To avoid overfitting problem, ridge penalty is used to obtain a stable estimation of terminal F. The penalty parameters (λ, η) are selected by minimizing the RMSPE of F at age 3-9 and SSB in retrospective analysis.

Estimation of N



RMSPE (Root Mean Square Percentage Error)

$$RMSPE_{F_a'} = \sqrt{\frac{1}{n}\sum_{k=Y-i}^{n}\left(\frac{{F_a}'^{R_i}_k - {F_a}'_k}{{F_a}'_k}\right)^2}$$

$$RMSPE_{SSB'} = \sqrt{\frac{1}{n}\sum_{k=Y-i}^{n}\left(\frac{SSB'^{R_i}_k - SSB'_k}{SSB'_k}\right)^2}$$

Here, n is the range of comparison of difference in estimates. In this analysis, n is set to 11 to compare the number of cohort-ages. Retrospective calculation is 5 years

Objective function

$$-\underbrace{(1-\lambda)\ln L}_{\text{Negative log likelihood}} + \alpha\lambda\left[\underbrace{(1-\eta)\sum_{a=4}^{9} F_{a,Y}^2 + \eta F_{3,Y}^2}_{\text{Penalty weighted square of F}}\right]$$

Negative log likelihood

Penalty weighted square of F

Appropriate penalty coefficients λ and η is searched.

α is a weighting factor that was given for convenience to the penalty term (20).

Searching of ridge penalty coefficients

We obtained the combination of λ (0≦λ<1) and η (0≦η≦1) by grid searching for the value at which the average RMSPE of SSB and F value of each age for the retrospective years is smallest in intervals of 0.05, then further searching in intervals of 0.005 around the resulting combination with the smallest value.

Average RMSPE of SSB and F value at age when penalties λ and η are changed with intervals of 0.05. When λ is 0.55 and η is 0.95, the RMSPE is minimum.

RMSPE		Lambda																			
		0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
Eta	0	0.309	0.227	0.213	0.228	0.236	0.252	0.270	0.258	0.296	0.300	0.337	0.329	0.374	0.442	0.672	0.960	1.120	1.244	6.363	10.123
	0.05	0.309	0.225	0.219	0.226	0.237	0.257	0.251	0.267	0.277	0.282	0.308	0.331	0.392	0.385	0.631	0.889	1.179	1.442	3.456	1.2E+08
	0.1	0.309	0.226	0.218	0.234	0.236	0.268	0.250	0.285	0.283	0.333	0.301	0.347	0.367	0.418	0.415	0.876	0.996	1.531	3.356	1.1E+08
	0.15	0.309	0.228	0.220	0.229	0.231	0.244	0.236	0.270	0.268	0.307	0.302	0.380	0.442	0.392	0.402	0.752	0.947	1.255	3.233	5E+08
	0.2	0.309	0.227	0.225	0.225	0.228	0.241	0.257	0.289	0.302	0.277	0.306	0.302	0.342	0.379	0.467	0.658	0.847	1.109	1.437	1.9E+09
	0.25	0.309	0.228	0.220	0.220	0.252	0.243	0.256	0.260	0.283	0.266	0.304	0.292	0.339	0.352	0.377	0.624	0.797	1.264	1.362	2.3E+08
	0.3	0.309	0.220	0.228	0.233	0.223	0.235	0.247	0.279	0.257	0.263	0.297	0.289	0.365	0.337	0.403	0.589	0.779	1.035	1.288	Inf
	0.35	0.309	0.222	0.222	0.229	0.233	0.225	0.249	0.245	0.273	0.257	0.284	0.282	0.331	0.394	0.344	0.459	0.723	0.955	1.213	8.216
	0.4	0.309	0.224	0.229	0.220	0.235	0.246	0.256	0.257	0.255	0.268	0.267	0.303	0.294	0.320	0.326	0.522	0.719	0.970	1.136	7.699
	0.45	0.309	0.226	0.229	0.224	0.238	0.225	0.257	0.276	0.257	0.253	0.284	0.279	0.294	0.331	0.333	0.417	0.606	0.846	1.354	7.190
	0.5	0.309	0.225	0.224	0.216	0.227	0.228	0.236	0.233	0.245	0.273	0.269	0.272	0.287	0.309	0.364	0.389	0.403	0.753	1.123	6.676
	0.55	0.309	0.306	0.224	0.221	0.237	0.226	0.230	0.239	0.254	0.248	0.275	0.260	0.283	0.286	0.317	0.325	0.424	0.706	1.042	6.145
	0.6	0.309	0.293	0.227	0.217	0.222	0.230	0.233	0.228	0.233	0.241	0.263	0.256	0.270	0.281	0.310	0.333	0.411	0.639	0.949	3.521
	0.65	0.309	0.307	0.228	0.223	0.211	0.221	0.226	0.229	0.240	0.241	0.240	0.250	0.282	0.291	0.300	0.322	0.432	0.574	0.826	1.355
	0.7	0.309	0.321	0.232	0.218	0.217	0.218	0.234	0.225	0.219	0.225	0.236	0.256	0.283	0.263	0.288	0.305	0.348	0.384	0.821	1.183
	0.75	0.309	0.309	0.222	0.218	0.226	0.220	0.226	0.225	0.225	0.234	0.229	0.223	0.253	0.242	0.267	0.311	0.312	0.468	2.591	3.893
	0.8	0.309	0.304	0.231	0.221	0.224	0.228	0.214	0.221	0.222	0.230	0.232	0.231	0.240	0.238	0.244	0.308	0.281	0.314	2.339	3.417
	0.85	0.309	0.323	0.234	0.223	0.230	0.225	0.215	0.221	0.216	0.221	0.234	0.229	0.234	0.230	0.239	0.258	0.268	0.381	0.354	3.050
	0.9	0.309	0.315	0.240	0.231	0.230	0.237	0.225	0.227	0.220	0.215	0.219	0.218	0.224	0.227	0.229	0.238	0.239	0.248	0.306	2.379
	0.95	0.309	0.335	0.250	0.232	0.228	0.235	0.233	0.230	0.219	0.223	0.229	**0.207**	0.211	0.209	0.218	0.213	0.210	0.223	0.254	0.302
	1	0.309	0.370	0.292	0.287	0.294	0.288	0.291	0.282	0.281	0.281	0.296	0.290	0.279	0.285	0.293	0.275	0.282	0.274	0.270	0.273

Searching of ridge penalty coefficients

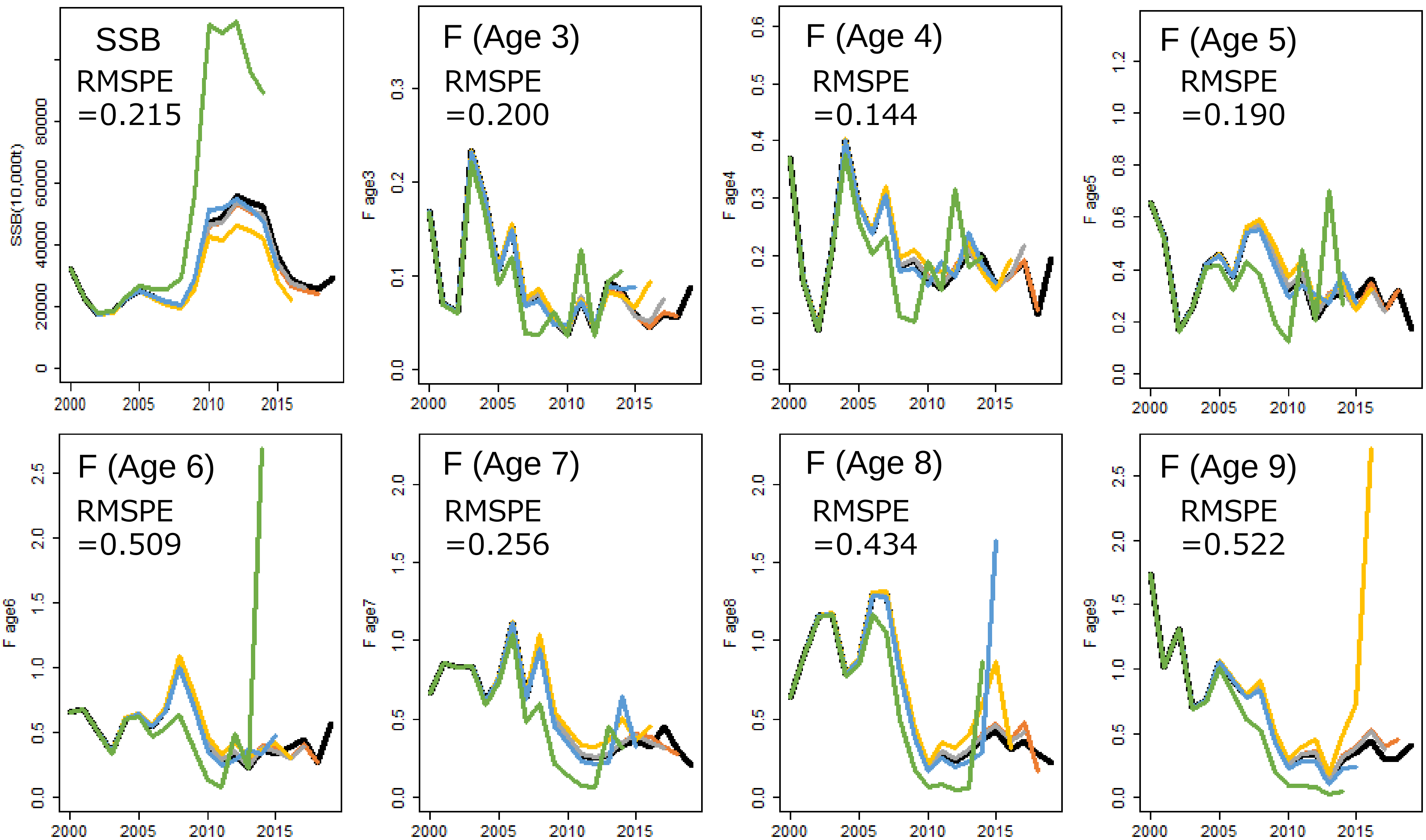
We obtained the combination of λ (0≦λ<1) and η (0≦η≦1) by grid searching for the value at which the average RMSPE of SSB and F value of each age for the retrospective years is smallest in intervals of 0.05, then further searching in intervals of 0.005 around the resulting combination with the smallest value.

Average RMSPE of SSB and F value at age when penalties λ and η are changed with intervals of 0.005. When λ is 0.540 and η is 0.945, the RMSPE is minimum.

RMSPE		Lambda																				
		0.500	0.505	0.510	0.515	0.520	0.525	0.530	0.535	0.540	0.545	0.550	0.555	0.560	0.565	0.570	0.575	0.580	0.585	0.590	0.595	0.600
Eta	0.905	0.214	0.213	0.212	0.215	0.213	0.214	0.213	0.219	0.214	0.214	0.216	0.221	0.224	0.218	0.227	0.228	0.219	0.238	0.225	0.224	0.221
	0.910	0.211	0.211	0.213	0.213	0.217	0.216	0.216	0.220	0.217	0.215	0.215	0.215	0.216	0.219	0.217	0.217	0.221	0.217	0.228	0.233	0.221
	0.915	0.210	0.217	0.223	0.217	0.218	0.219	0.224	0.216	0.225	0.218	0.217	0.219	0.220	0.219	0.218	0.217	0.220	0.219	0.225	0.225	0.213
	0.920	0.211	0.216	0.208	0.208	0.216	0.217	0.219	0.220	0.220	0.220	0.219	0.219	0.220	0.220	0.221	0.216	0.218	0.218	0.216	0.220	0.232
	0.925	0.212	0.209	0.218	0.219	0.215	0.218	0.217	0.211	0.224	0.223	0.222	0.222	0.222	0.220	0.218	0.222	0.218	0.218	0.221	0.216	0.220
	0.930	0.208	0.202	0.209	0.215	0.209	0.211	0.215	0.213	0.214	0.214	0.215	0.224	0.224	0.224	0.223	0.219	0.219	0.222	0.222	0.226	0.217
	0.935	0.207	0.207	0.211	0.207	0.209	0.207	0.216	0.216	0.215	0.221	0.217	0.214	0.214	0.218	0.224	0.224	0.223	0.216	0.225	0.220	0.227
	0.940	0.207	0.208	0.210	0.208	0.208	0.209	0.206	0.211	0.212	0.213	0.213	0.213	0.213	0.213	0.214	0.217	0.213	0.209	0.211	0.213	0.210
	0.945	0.227	0.218	0.209	0.209	0.209	0.208	0.210	0.209	**0.199**	0.210	0.210	0.212	0.213	0.215	0.215	0.215	0.215	0.211	0.207	0.211	0.207
	0.950	0.229	0.220	0.221	0.211	0.209	0.209	0.207	0.210	0.213	0.210	0.207	0.202	0.212	0.211	0.214	0.215	0.209	0.214	0.208	0.205	0.211
	0.955	0.222	0.229	0.225	0.220	0.216	0.213	0.209	0.209	0.208	0.210	0.208	0.211	0.211	0.212	0.213	0.214	0.215	0.213	0.214	0.206	0.204
	0.960	0.223	0.226	0.224	0.231	0.229	0.216	0.218	0.210	0.209	0.208	0.219	0.214	0.210	0.211	0.213	0.214	0.214	0.214	0.213	0.215	0.205
	0.965	0.231	0.226	0.226	0.226	0.225	0.223	0.221	0.219	0.215	0.211	0.209	0.209	0.214	0.207	0.207	0.210	0.213	0.214	0.214	0.214	0.214
	0.970	0.228	0.231	0.232	0.229	0.225	0.223	0.234	0.226	0.221	0.218	0.214	0.211	0.212	0.210	0.208	0.208	0.208	0.207	0.207	0.214	0.216
	0.975	0.239	0.228	0.232	0.233	0.226	0.226	0.225	0.230	0.233	0.224	0.220	0.215	0.215	0.212	0.220	0.209	0.209	0.209	0.209	0.209	0.209
	0.980	0.238	0.242	0.234	0.232	0.235	0.234	0.230	0.228	0.226	0.238	0.223	0.231	0.221	0.217	0.218	0.213	0.212	0.212	0.211	0.211	0.211
	0.985	0.233	0.232	0.234	0.241	0.235	0.248	0.230	0.232	0.231	0.228	0.229	0.229	0.227	0.229	0.221	0.226	0.217	0.214	0.214	0.214	0.215
	0.990	0.238	0.238	0.248	0.238	0.247	0.247	0.243	0.242	0.237	0.238	0.234	0.233	0.233	0.233	0.227	0.219	0.224	0.223	0.221	0.217	0.220
	0.995	0.242	0.259	0.253	0.259	0.260	0.255	0.260	0.250	0.252	0.246	0.247	0.244	0.241	0.243	0.240	0.233	0.241	0.233	0.231	0.230	0.229

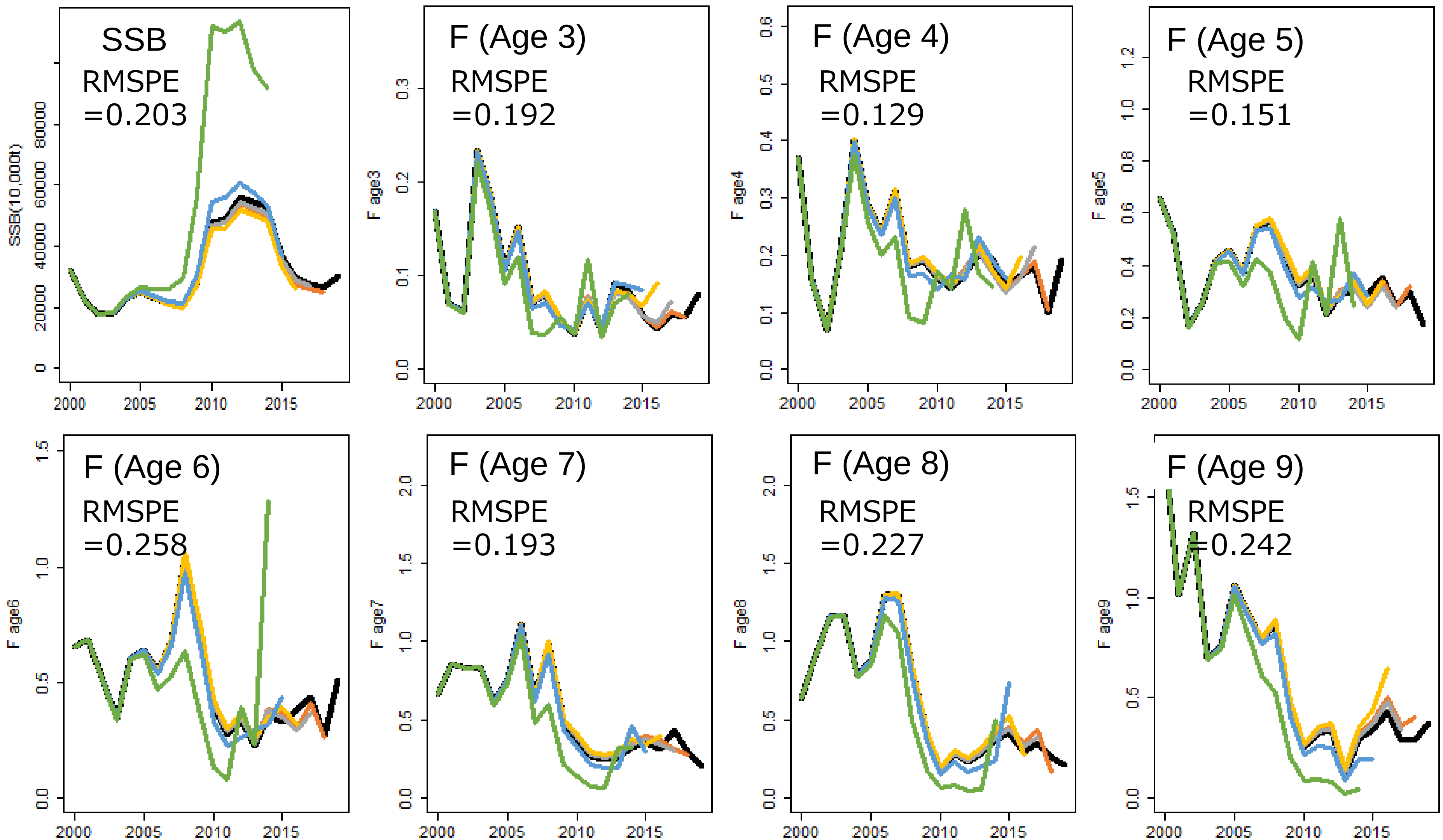
Retrospective analysis

Without any ridge penalty



Retrospective analysis

When λ is 0.540 and η is 0.945, the RMSPE is minimum.



Reviewer's Comment #04

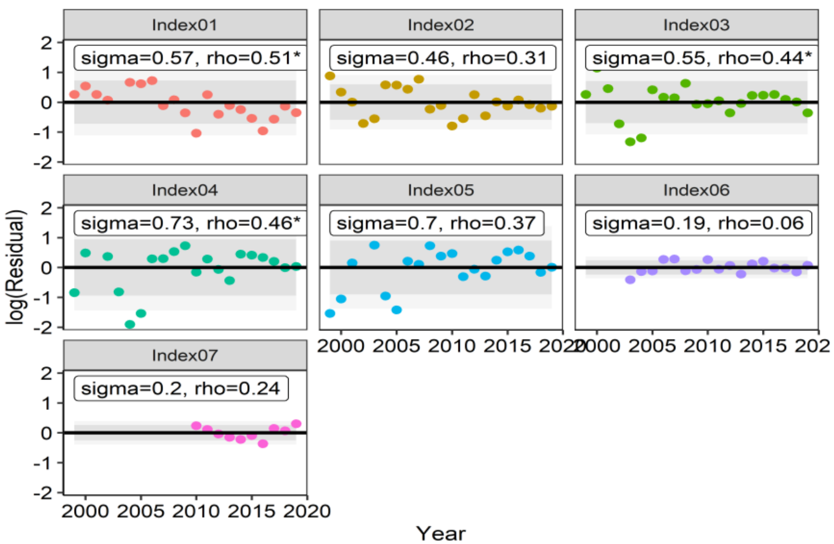
- The Ridge VPA defines a penalty term (the square of F) with a weight (λ) that is chosen to minimize retrospective bias. The assessments provide plots showing the retrospective bias given the chosen weight (e.g., Appendix Figure 2-2 on page 32 of the WP-NSJ assessment). However, it would be helpful to see how fits to each abundance index change for alternative values of λ. I suggest plotting fits to each index using three values of λ: 1) the λ that minimizes the retrospective bias (this is already done), 2) λ=0, and 3) λ=0.99. The purpose of this is to show how fits to the abundance indices are affected by minimization of the retrospective bias.

Response

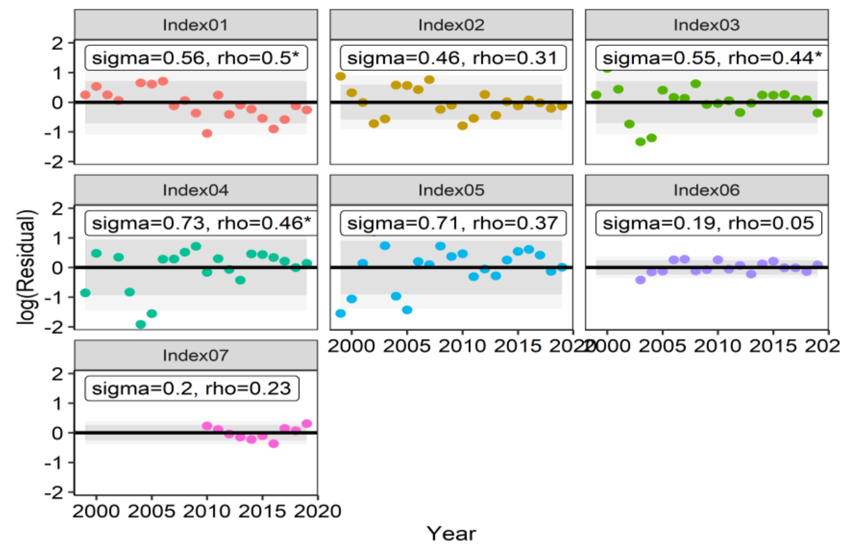
The fits to the tuning indices using different penalty coefficients are showed in next slide.

Sensitivity test using alternative λ

Base case (Lambda=0.540, Eta=0.945)

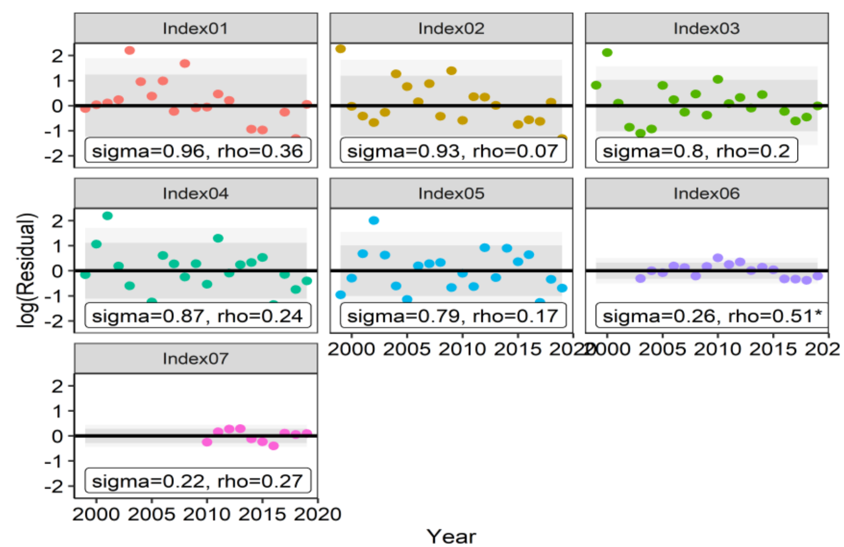


Lambda=0



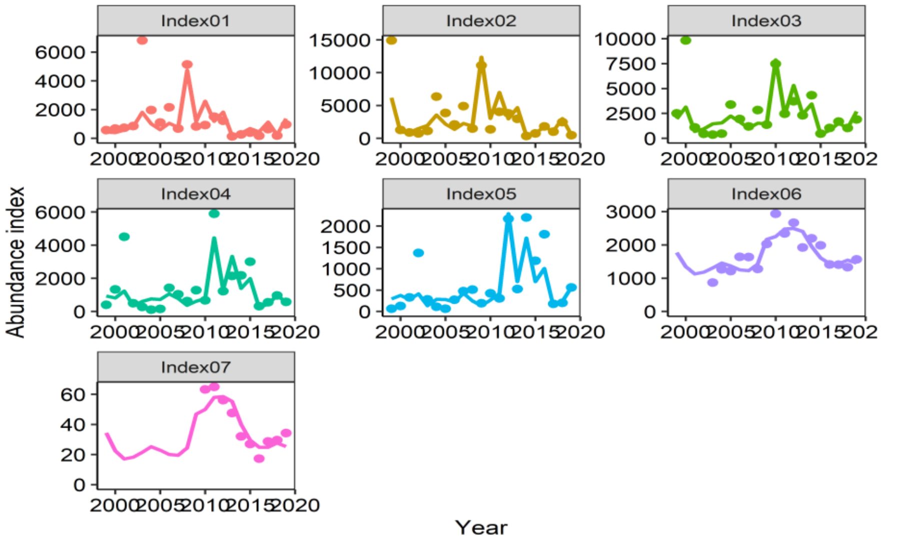
Sigma	Base case	λ=0	λ=0.999
Offshore trawl CPUE (Age 3)	0.5662	0.5564	0.9641
Offshore trawl CPUE (Age 4)	0.4631	0.4611	0.9321
Offshore trawl CPUE (Age 5)	0.5498	0.5513	0.8005
Offshore trawl CPUE (Age 6)	0.7319	0.7348	0.8687
Offshore trawl CPUE (Age 7)	0.7044	0.7075	0.7901
Anchored gillnet Logbook index	0.1857	0.1856	0.2554
Anchored gillnet Skipper’s note	0.1994	0.2010	0.2227

Lambda=0.999, Eta=0.945

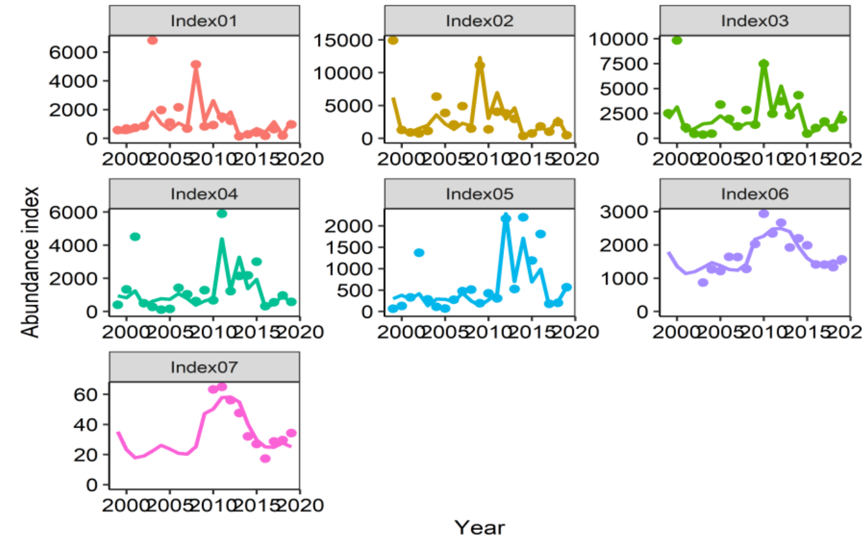


Sensitivity test using alternative λ

Base case (Lambda=0.540, Eta=0.945)

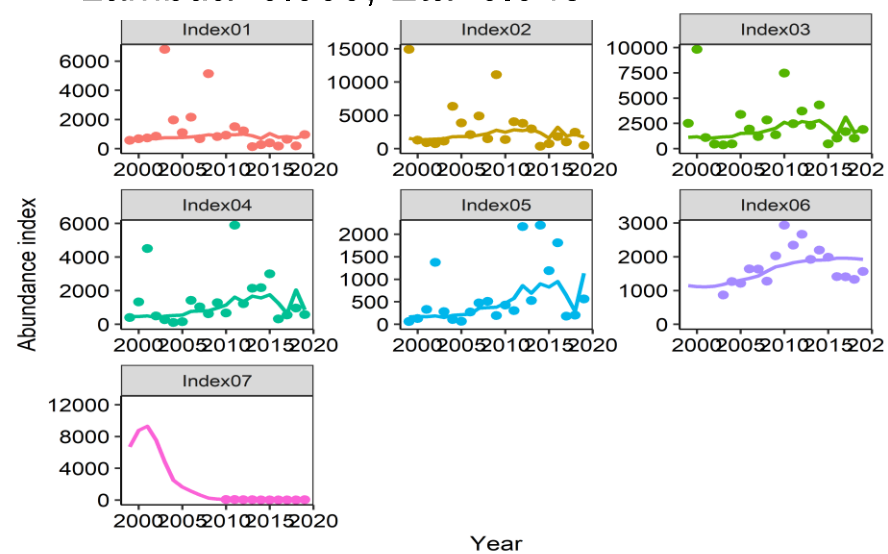


Lambda=0



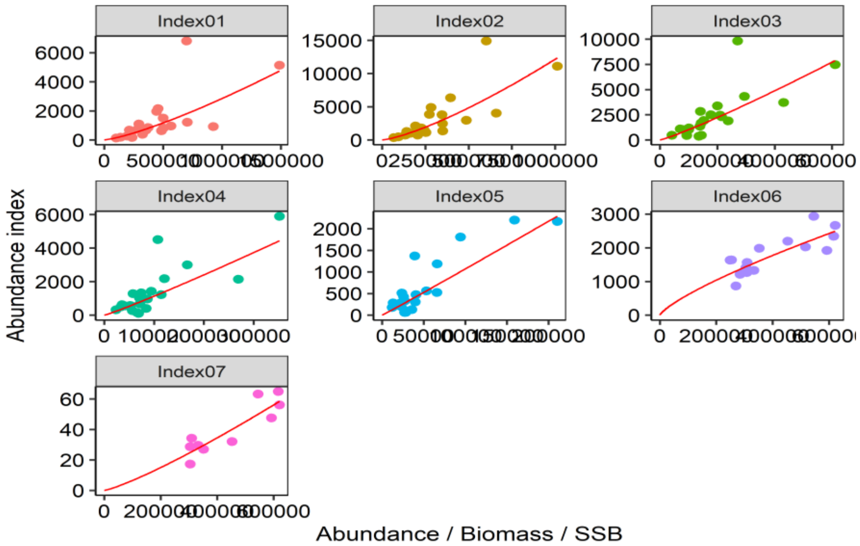
Sigma	Base case	λ=0	λ=0.999
Offshore trawl CPUE (Age 3)	0.5662	0.5564	0.9641
Offshore trawl CPUE (Age 4)	0.4631	0.4611	0.9321
Offshore trawl CPUE (Age 5)	0.5498	0.5513	0.8005
Offshore trawl CPUE (Age 6)	0.7319	0.7348	0.8687
Offshore trawl CPUE (Age 7)	0.7044	0.7075	0.7901
Anchored gillnet Logbook index	0.1857	0.1856	0.2554
Anchored gillnet Skipper's note	0.1994	0.2010	0.2227

Lambda=0.999, Eta=0.945

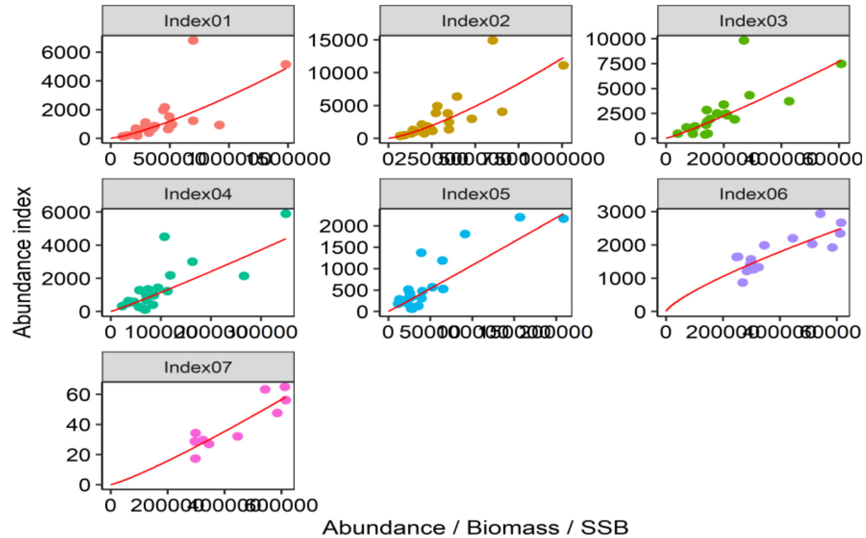


Sensitivity test using alternative λ

Base case (Lambda=0.540, Eta=0.945)

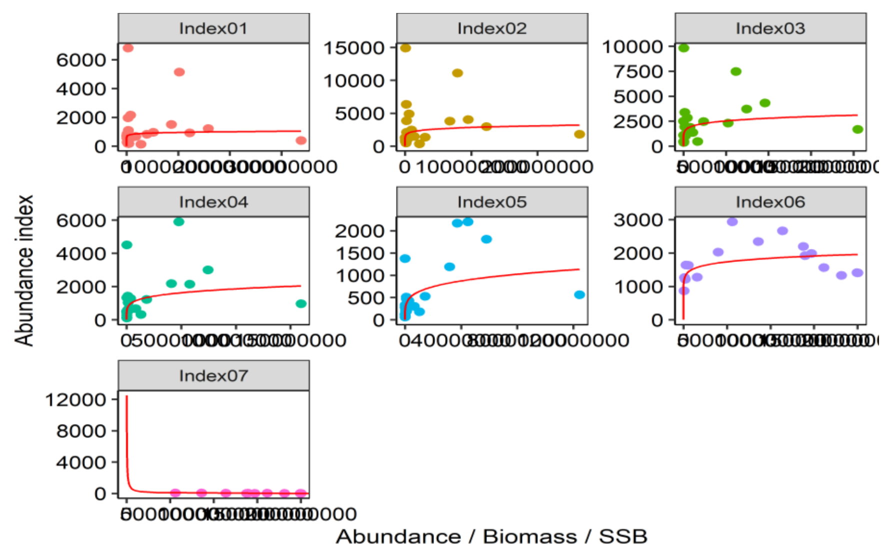


Lambda=0



b	Base case	λ=0	λ=0.999
Offshore trawl CPUE (Age 3)	1.281	1.290	0.068
Offshore trawl CPUE (Age 4)	1.329	1.323	0.120
Offshore trawl CPUE (Age 5)	1.132	1.123	0.147
Offshore trawl CPUE (Age 6)	1.084	1.072	0.194
Offshore trawl CPUE (Age 7)	1.022	1.019	0.229
Anchored gillnet Logbook index	0.771	0.768	0.087
Anchored gillnet Skipper's note	1.198	1.161	-0.897

Lambda=0.999, Eta=0.945



Reviewer's Comment #12

- Does the weighting factor (α) in equation 8 retain a value of 20 in the final model? It seems that the chosen value will affect the influence of the penalty term. Fits to the abundance indices should be plotted for alternative weightings on the penalty term (see question #4). Minimizing the retrospective pattern by emphasizing the penalty term may cause a significant degradation of fit to the abundance indices.

Response

Because the log-likelihood term and the penalty term have different scales, the size of the two terms was adjusted by multiplying the penalty term by using α, only making it easier to search for λ. Even if different α value was used, relative weight of the log-likelihood term and penalty term would be the same with different adjusted λ value. For example, if α=1 was used, then λ would be selected 0.9591474.

Objective function

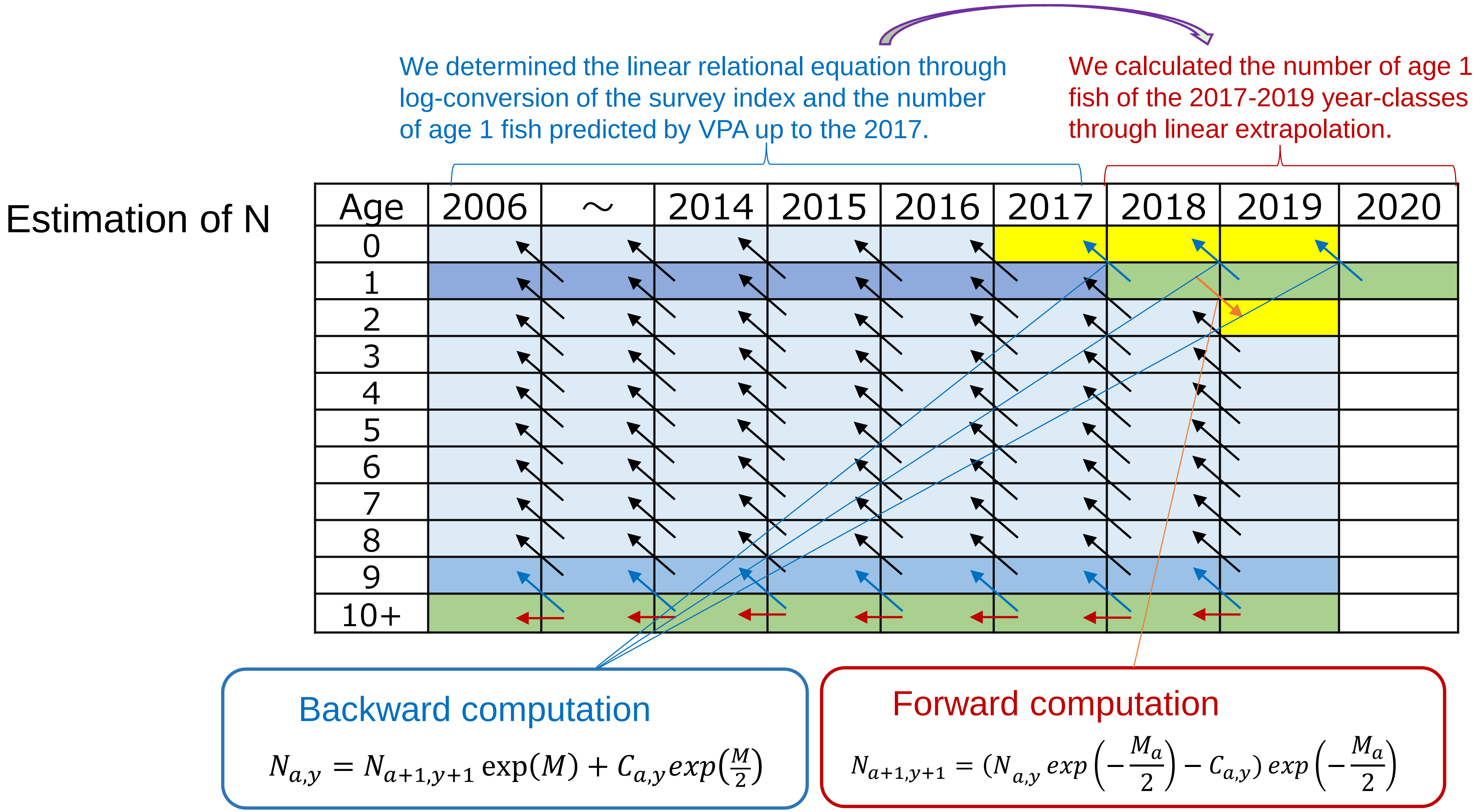
$$\underbrace{-(1-\lambda)lnL}_{\text{Log likelihood term}} + \alpha\lambda\left[\underbrace{(1-\eta)\sum_{a=4}^{9} F_{a,Y}^2 + \eta F_{3,Y}^2}_{\text{Penalty term}}\right]$$

Appropriate penalty coefficients λ and η is searched.

α is a weighting factor that was given for convenience to the penalty term (20).

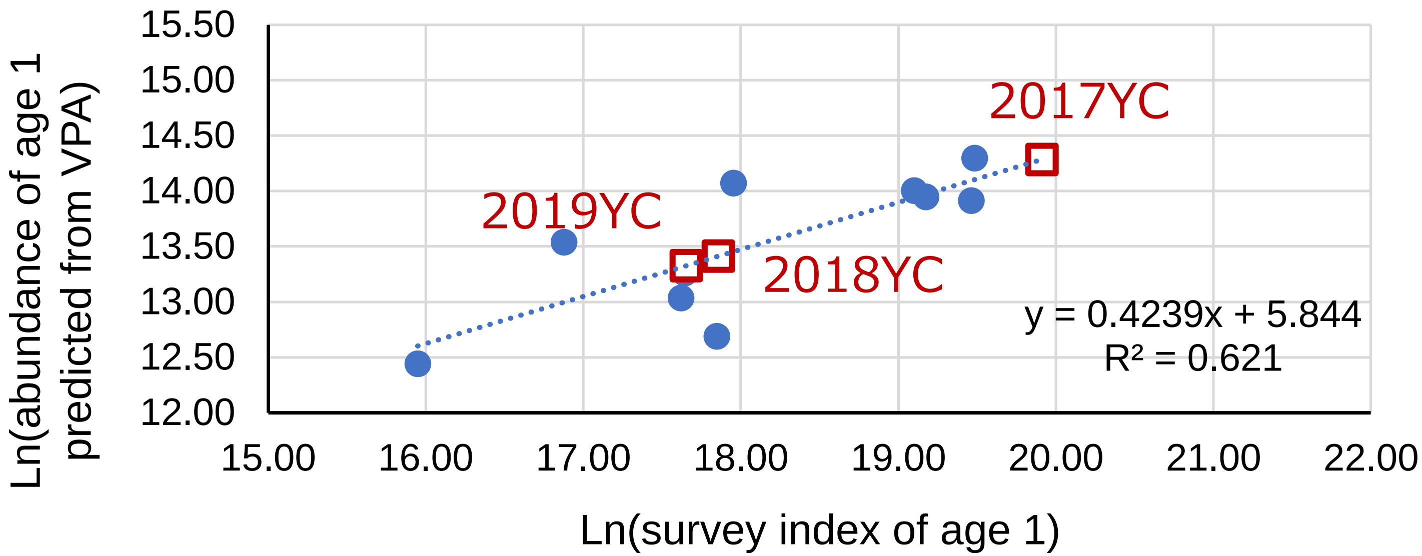
Recruitment of the latest 3 years

- Recruitment of the latest 3 year-classes is estimated by linear extrapolation using the relationship between predicted abundance from VPA and survey abundance of age 1 based on the acoustic trawl survey from June to July.



Recruitment of the latest 3 years

The relationship between the survey index and the abundance from cohort analysis



Age	2017YC	2018YC	2019YC
0(recruitment)	2,391 million indv.	997 million indv.	918 million indv.
1	1,597 million indv.	668 million indv.	613 million indv.

Reviewer's Comment #15

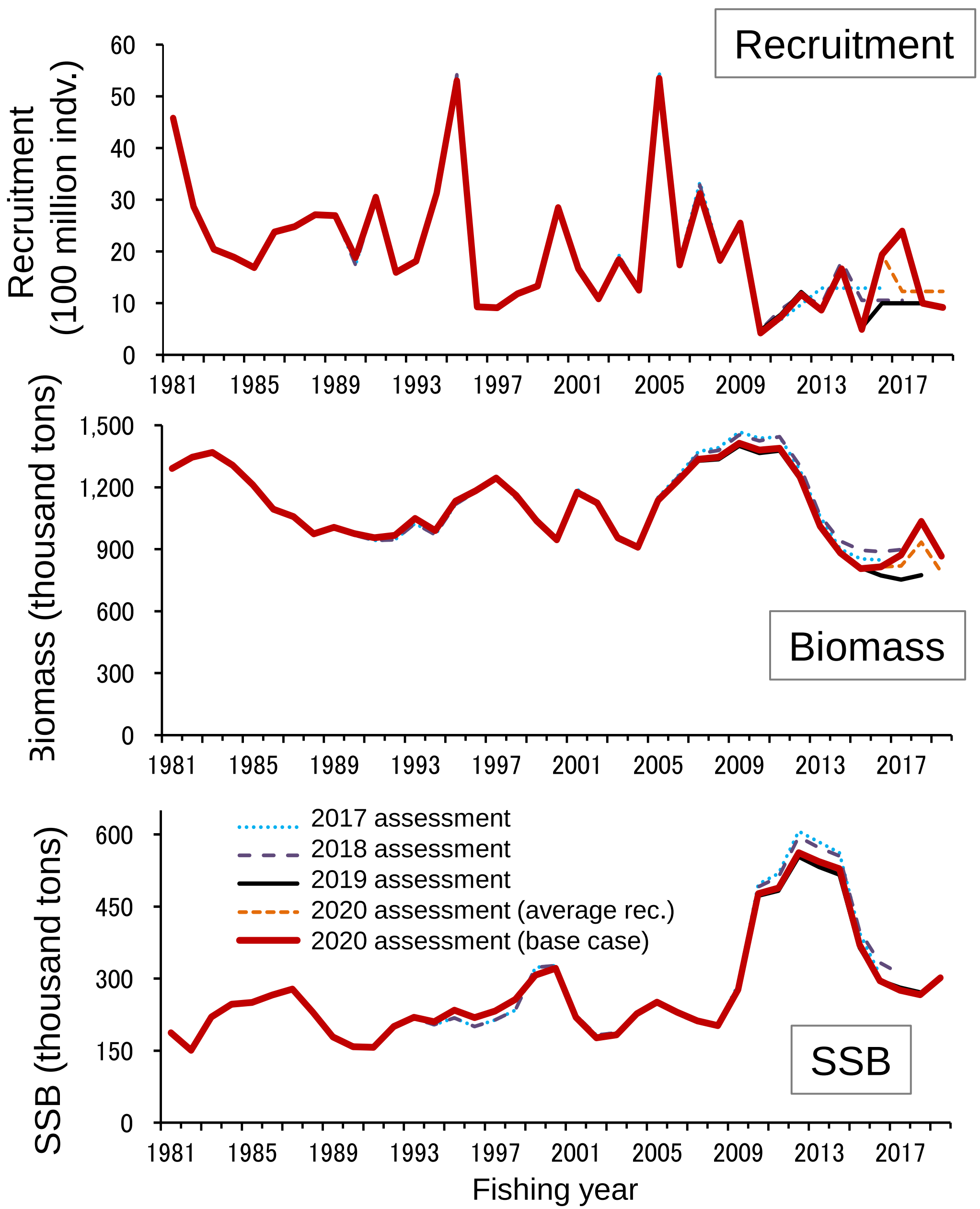
- In this assessment, recent recruitments are informed by an age-1 survey, whereas previous assessments used an average of recent recruitments. A comparison of the two approaches would be welcome, given the recent change. Another alternative would be to assume recruitments were equal to the expected value from the assumed stock-recruitment relationship. The authors note that the survey did not detect the 2005 and 2007 year-classes, but that they were considered 'dominant' cohorts. A brief discussion of this inconsistency would be appreciated.

Response

We would like to explain alternative result using previous recruitment assumption in next slide.

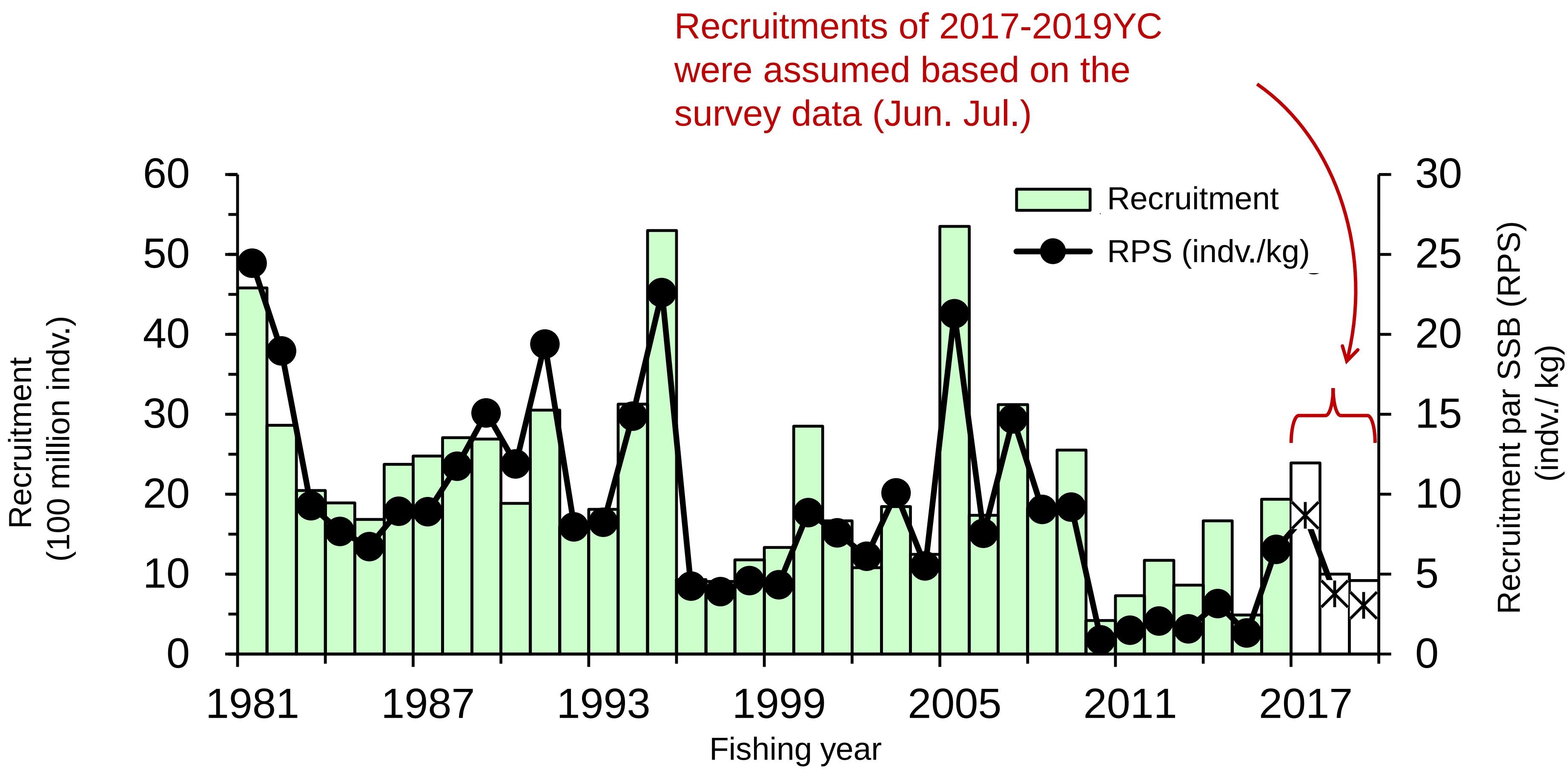
In the acoustic survey, dominant year classes of 2005 and 2007 were not detected. Mechanism of recruitment for dominant year class is remaining under study. In current hypothesis, we suspect that those two dominant year classes were not distributed mainly in survey area, and possibly distributed around the Northern territory area. In addition, immigrant from different spawning ground is suspected to contribute for production of dominant cohorts.

Alternative assumption for the latest recruitment



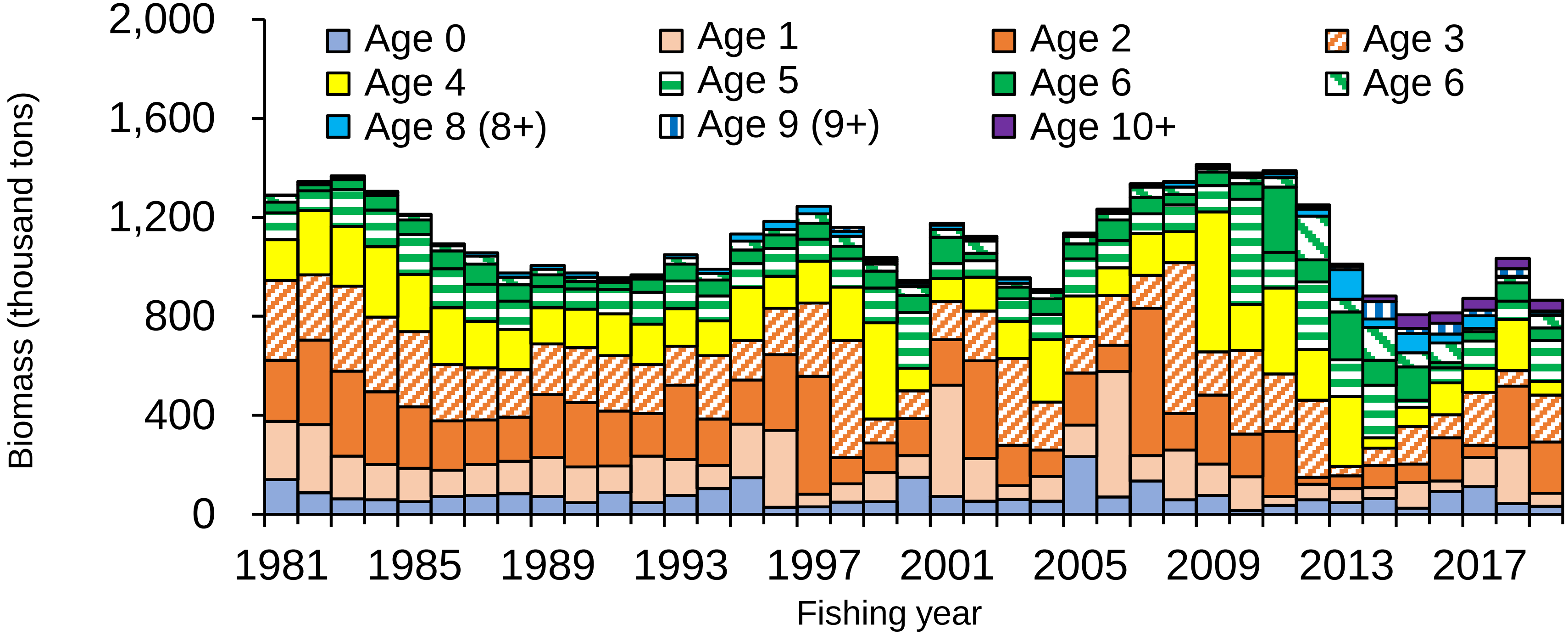
- In previous assessment, the latest 3 years recruitment (2016-2018 YC) was assumed as 998 million indv. based on the average value of 2011-2015 recruitments.
- If we used the same method for 2017-2019 recruitment in this assessment, the value would be 1225 million indv.
- Current assessment used survey data to assume the latest 3 years recruitment. 2017, 2018, and 2019 recruitments were assumed 2391 million, 997 million, and 918 million, respectively.
- We consider that the assumption adequately used the best available scientific data.

Recruitment



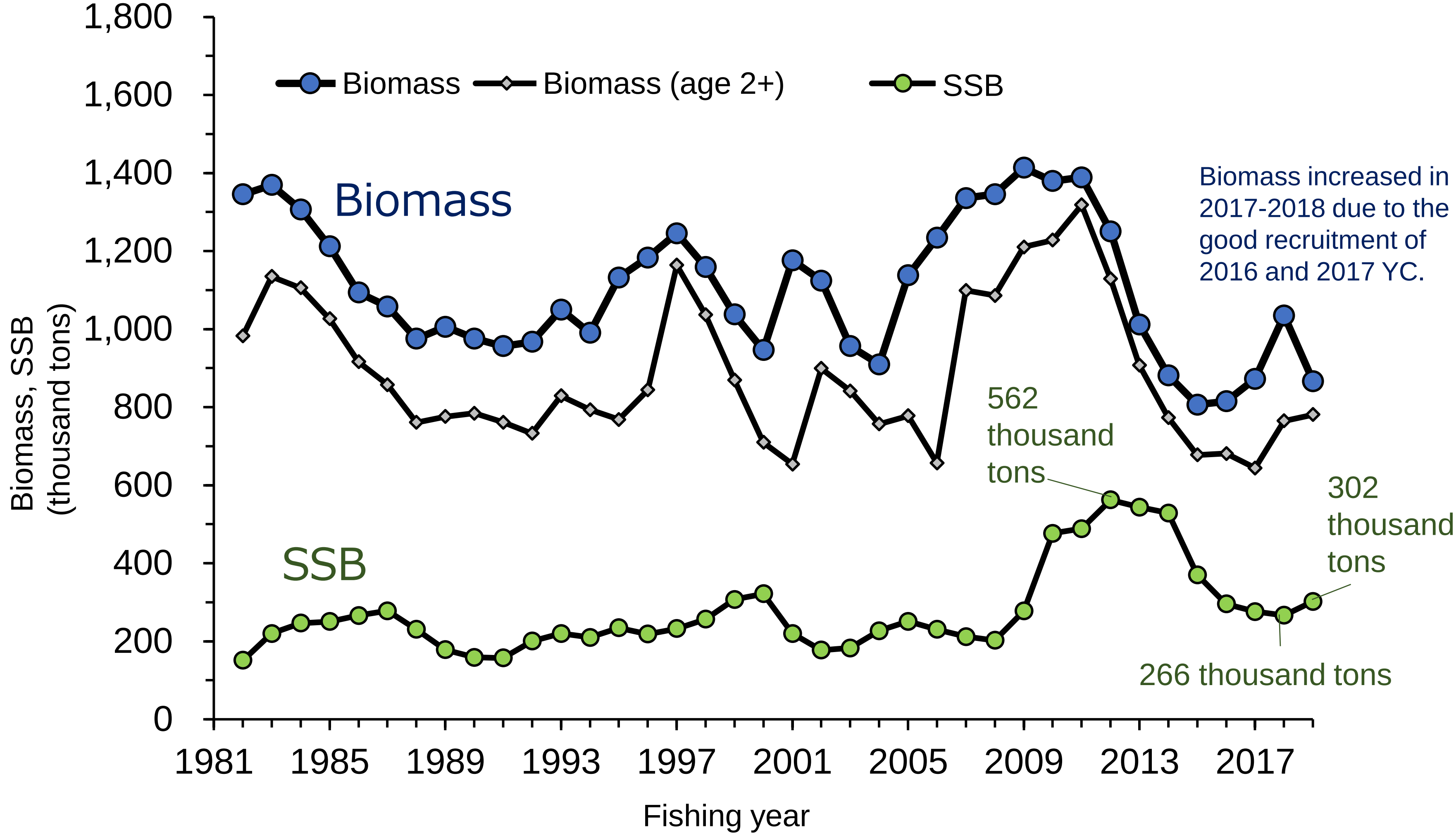
- ✓ Recruitment (from VPA)
  - High: 2014YC (1700 million) , 2016YC (1900 million)
  - Low: 2010YC, 2015YC (<500 million)

Biomass



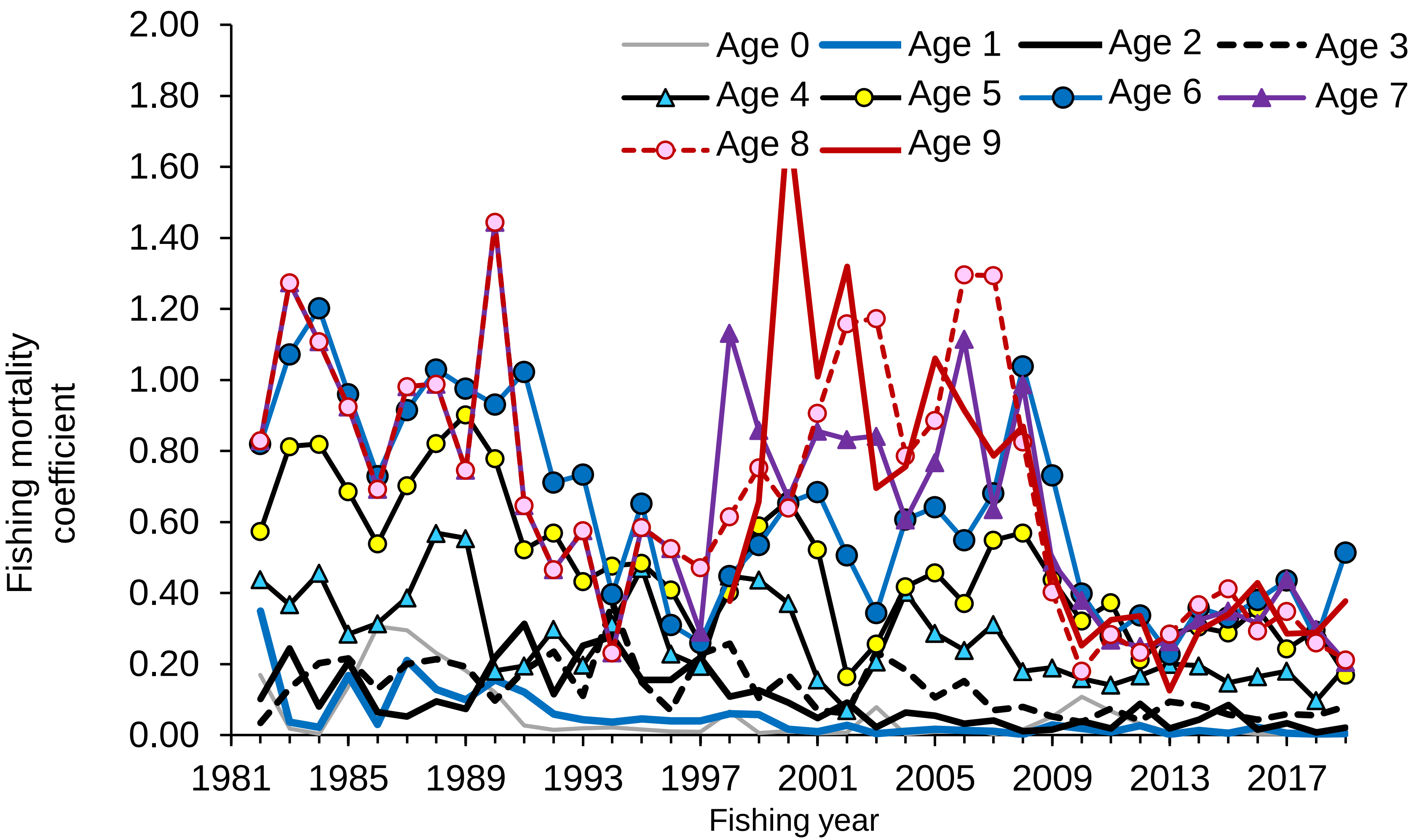
- ✓ The biomass decreased from 2012.
- ✓ After 2014, the biomass remained at around 800 thousand tons.
- ✓ Estimated biomass in 2019 fishing year was 866 thousand tons.

SSB



- ✓ The SSB fell to 266 thousand tons in 2018. In 2019, it recovered a bit to 302 thousand tons.

Fishing mortality



- ✓ F values for all ages decreased after 2010.
- ✓ Those for older fish (> age 6) has remained at lower value stably.

Reviewer's Comment #14

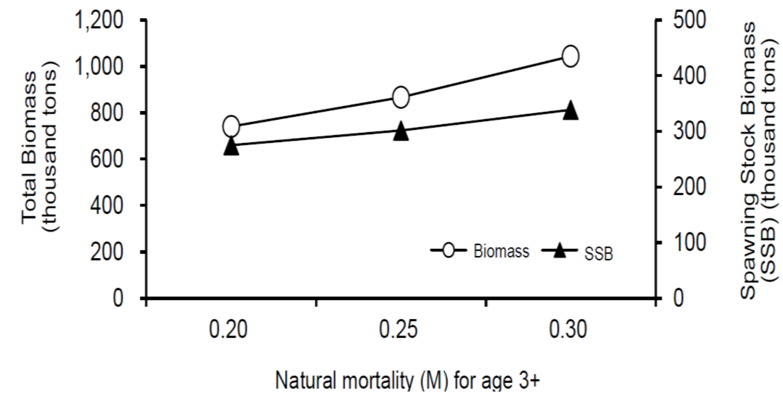
- The natural mortality rate (M) is assumed to be 0.25 per year for ages 3 and above, with larger values for younger ages. Please describe any ageing studies done for the assessment or from the literature, and comparisons with similar stocks. I am not very familiar with Widrig (1954), but the authors indicate that individuals of age 20 are caught, although infrequently. Based on recent meta-analyses (e.g. Then 2014, Hamel 2015) M estimates based on ~5/Amax are in common use, which is roughly consistent with the assumed value for age 3+ fish.
- However, since M is not known with precision and affects estimates of F (and therefore abundance), model runs with alternative values for M would help managers understand risks associated with uncertainty in M.

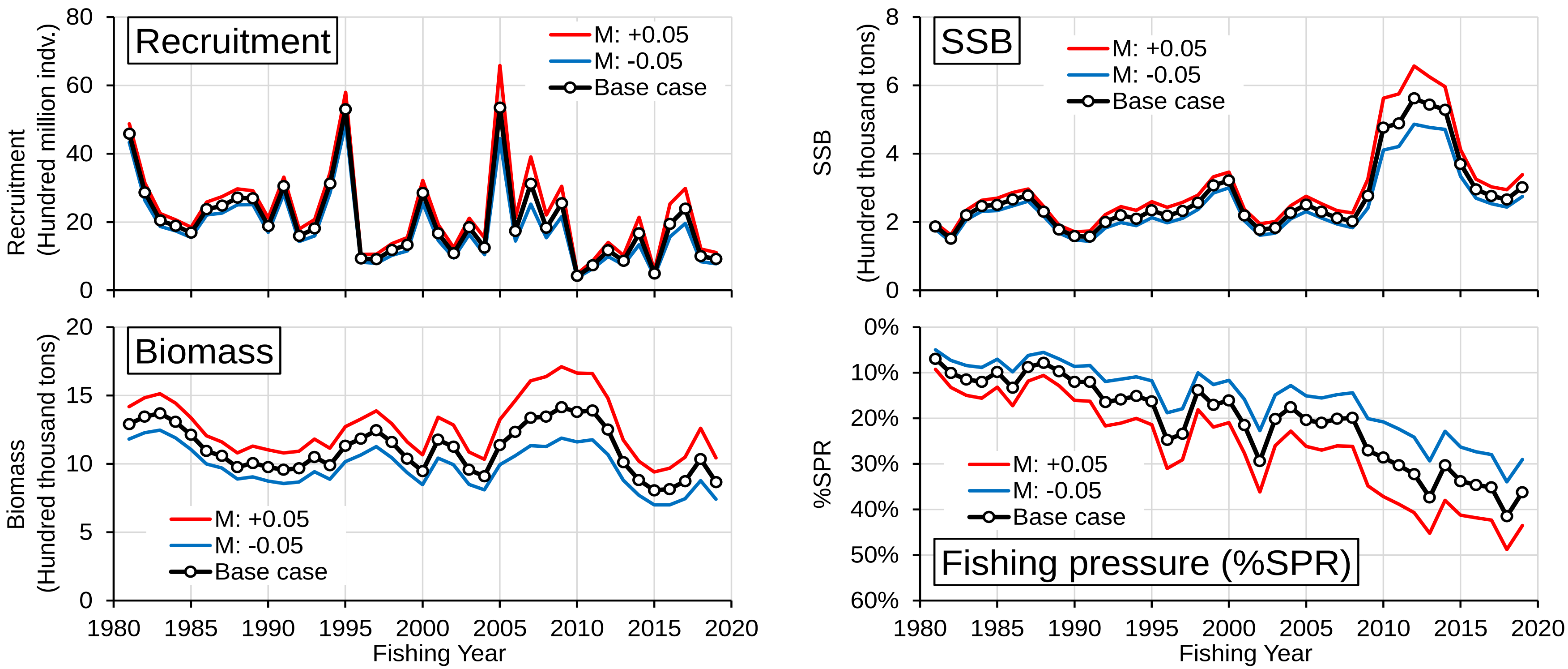
Response

We would like to explain detailed information in next slide.

Alternative M scenario (Sensitivity test)

- In the assessment report, sensitivity test using alternative M (+0.05 or -0.05 for age3 and above) was included. The results showed that both total biomass and SSB in the 2019 increased with a larger value of M and decreased with a smaller value of M (Fig. 4-8).
- Detailed results are shown as following; All scenarios show similar trend, though the alternative M affects the size of stock, and fishing pressure.





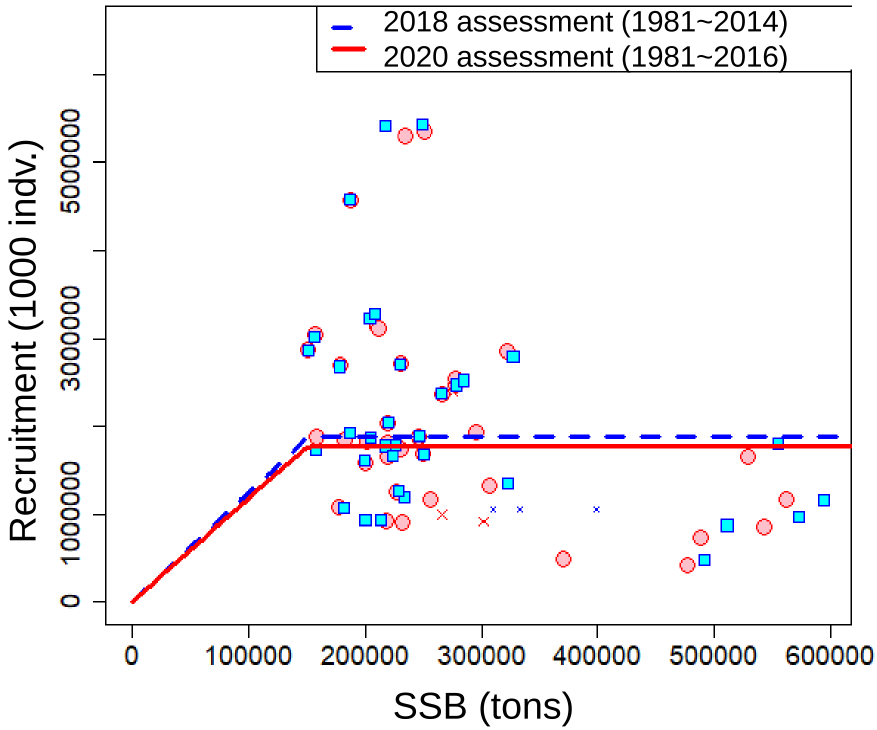
Contents

- Biology and Stock assessment
- Stock-Recruitment Relationships
  SR relationship, Comparison to other candidate models
- Reference points, Kobe-plot
- Harvest Control Rule, Future projection

Stock-Recruitment (SR) Relationship

● Update of the parameters of Hockey stick SR relationship

- Hockey-stick (HS) type
- Estimated by least squares method
- Autocorrelation was not considered
- Latest 3 years values were removed because these recruitment values were assumed by survey.



Blue: Estimated in 2019 meeting
(Based on 2018 assessment)

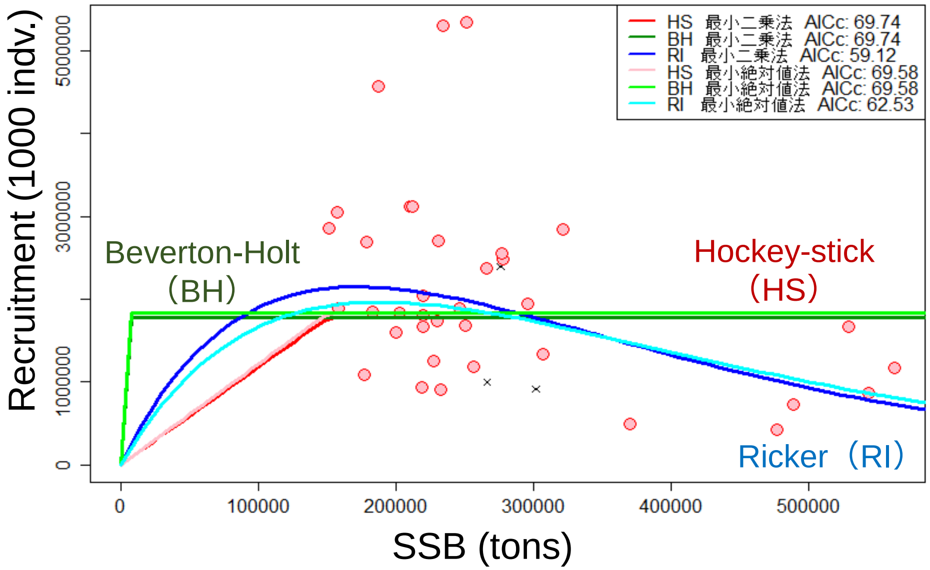
Red: Updated HS relationship
(Based on 2020 assessment)

	Relationship	Optimization	Autocorrelation	a	b	S.D.
Previous	HS	Least squares	No	12.455	150,944	0.532
Updated	HS	Least squares	No	11.795	150,944	0.580

Comparison to other models

● Update of the parameters of SR relationships

Data-set: 1981-2016 fishing year



- Compared with the HS model, BH and RI models have a milder decrease of the projected recruitment associated with a decrease of SSB.
- It is approved that HS model can produce more conservative recruitment.

Model	Optimization	Autocorrelation	a	b	S.D.	AICc
HS	**Least squares**	**No**	**11.795**	**150,944**	**0.532**	**69.74**
RI	Least squares	No	33.988	5.82×10^{-6}	0.501	59.12
BH	Least squares	No	1.18×10^{7}	6.636	0.580	69.74
HS	Least absolute	No	12.172	150,944	0.581	69.58
RI	Least absolute	No	28.275	5.30×10^{-6}	0.506	62.53
BH	Least absolute	No	4.44×10^{19}	2.42×10^{13}	0.581	69.58

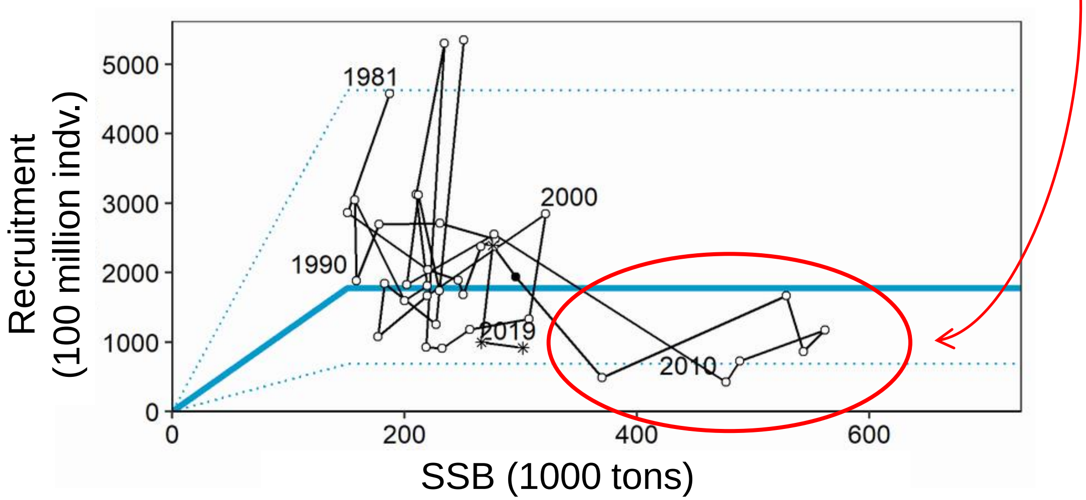
Reviewer's Comment #10

- Model selection based on AICc (Appendix Table 10-1) seemed to favor a Ricker stock-recruitment relationship using both optimization methods. Alternative stock-recruitment models may produce very different management reference points.
- Since the harvest control rule includes a linear reduction in F below the SBlimit, it was not clear why the hockey-stick recruitment model was needed to reduce risks associated with potential future declines in abundance.

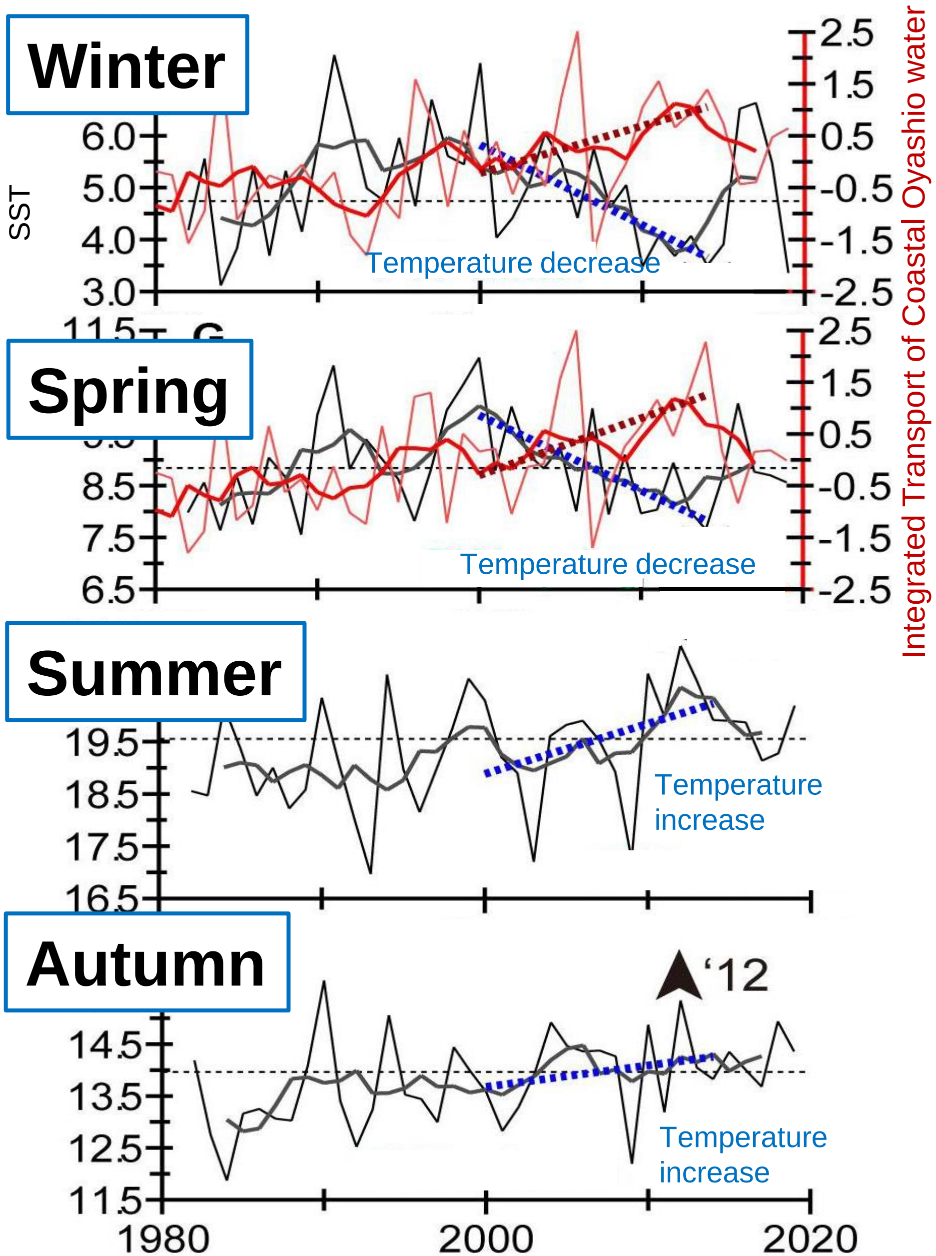
Response

The SR relationship model is selected considering not only the AICc values but also the biological / environmental information. In this case, high-SSB and low-recruitment in 2010s prefers RI relationship from the point of view of fitting, but this period is considered in unfavorable environmental conditions for the reproduction of walleye pollock in this area.

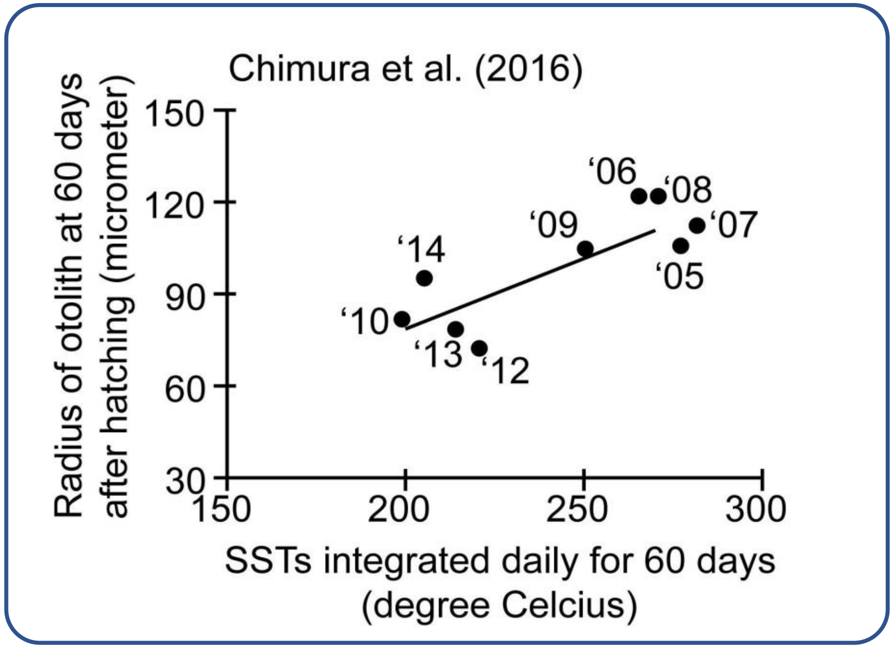
The recruitment was probably decreased not due to the density effect but rather environmental effect in this period. Thus, applying RI relationship here may not always be appropriate.



Suggestion in Kuroda et al. (2020)



- Recruitment hypothesis is "Bigger is better" such that during winters with high SSTs, the survival is enhanced by more successful transport of eggs into the bay and faster larval growth, whereby the faster larval growth is a direct result of higher temperature and larval food availability.
- Decadal cooling of SSTs could slow larval growth and potentially reduce their recruitment.



Reviewer's Comment #10

- Model selection based on AICc (Appendix Table 10-1) seemed to favor a Ricker stock-recruitment relationship using both optimization methods. Alternative stock-recruitment models may produce very different management reference points.
- Since the harvest control rule includes a linear reduction in F below the SBlimit, it was not clear why the hockey-stick recruitment model was needed to reduce risks associated with potential future declines in abundance.

Response

Regarding this stock, we have no historical information of decrease in recruitment associated with the depletion of SSB. Compared with the HS model, BH and RI models have a milder decrease of the projected recruitment associated with a decrease of SSB. The 2019 Scientific Meeting concluded that, if SSB fell below the recorded lowest level, a non-conservative extrapolation number as recruitment would pose a risk, in the context of the fisheries management based on the future projection result.

The default harvest control rule (HCR) which have a linear reduction in F below the SBlimit is just one candidate of the proposal from scientific department to stakeholders. The HCR finalized to use for management is decided based on the discussion in stakeholder meeting. In fact, "constant catch" rule was adopted in this stock. Therefore, for the proposal from scientific department to the stakeholder meeting, SR relationship and HCR should be considered separately.

Contents

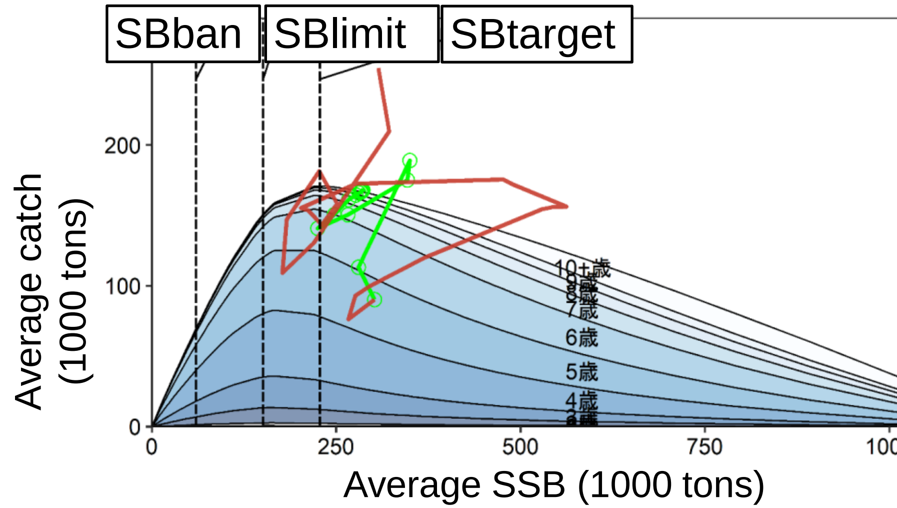
- Biology and Stock assessment
- Stock-Recruitment Relationships
- Reference points, Kobe-plot
  MSY reference points, Fishing ban simulation, Kobe-plot
- Harvest Control Rule, Future projection

MSY Reference points

● Based on updated SR relationship

Calculation of MSY-based reference point

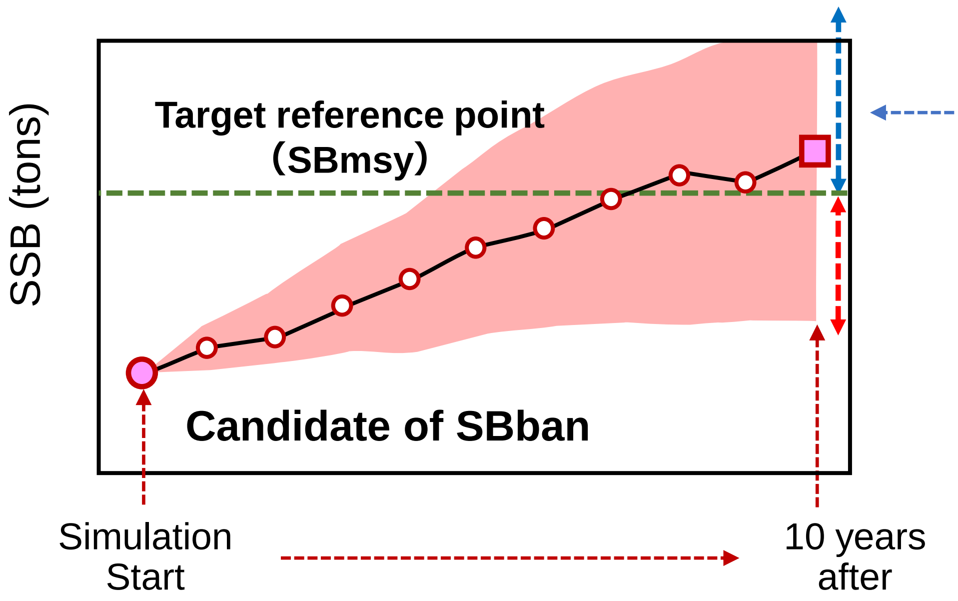
- The equilibrium situation is defined after the simulation period that is 20 times the average generation time (8.46 years)
- Selectivity is average of 2015-2019.
- Biological parameters are based on the average information of 2015-2019.

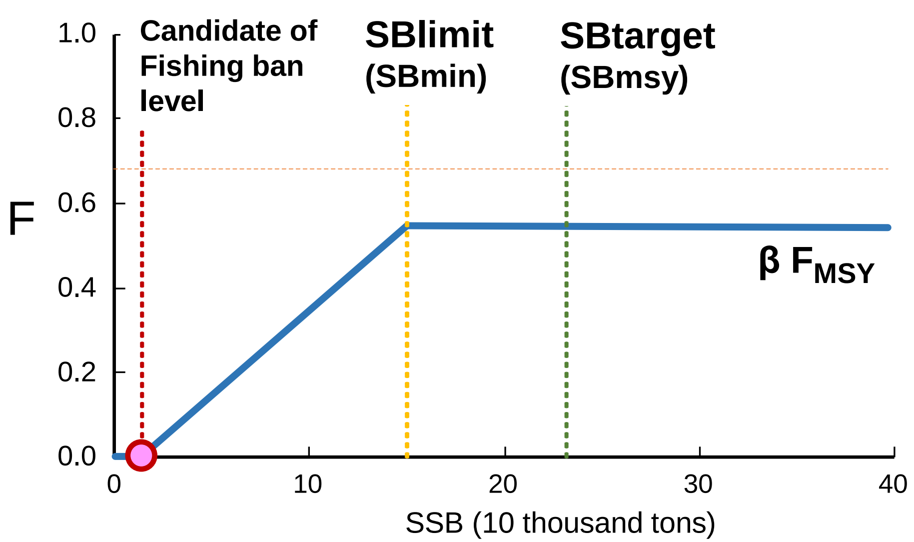


Proposal	Item	Definition	SSB (tons)	SSB/SB0	Expected catch (tons)
Previous	Target reference point	SBmsy (SSB corresponding to MSY)	220 thousand	0.19	176 thousand
Updated			228 thousand	0.19	171 thousand
Previous	Limit reference point	SB min (Historical low level)	151 thousand	0.13	157 thousand
Updated			151 thousand	0.13	151 thousand
Previous	Fishing Ban level	The threshold to recover to the SBtarget (50% probability) for 10 years under fishing based on HCR (β=0.8)	70 thousand	0.06	83 thousand
Updated			60 thousand	0.05	70 thousand

Fishing ban level

● Estimated based on the simulation





From the candidate values of SSB, the minimal values for recovery to the SBtarget after 10 years with a probability of 50% was searched based on the simulation assuming the catch control by the HCRs which was also dependent on the candidates of SBban.

- 10,000 times simulation.
- The initial condition of simulation (e. g. age composition, average body weight at age, and selectivity) were randomly chosen from the observed values of the 1981-2019 FYs.
- The fishing mortality during the recovery period was given from the HCRs according to the SSB of each year.
- Candidate values of SBban were in the range of 5 thousand to 150 thousand tons.

SB ban simulation

Probability for SSB to exceed the target reference point (SBtarget) after 10 years by candidate value for the fishing ban level (SBban)

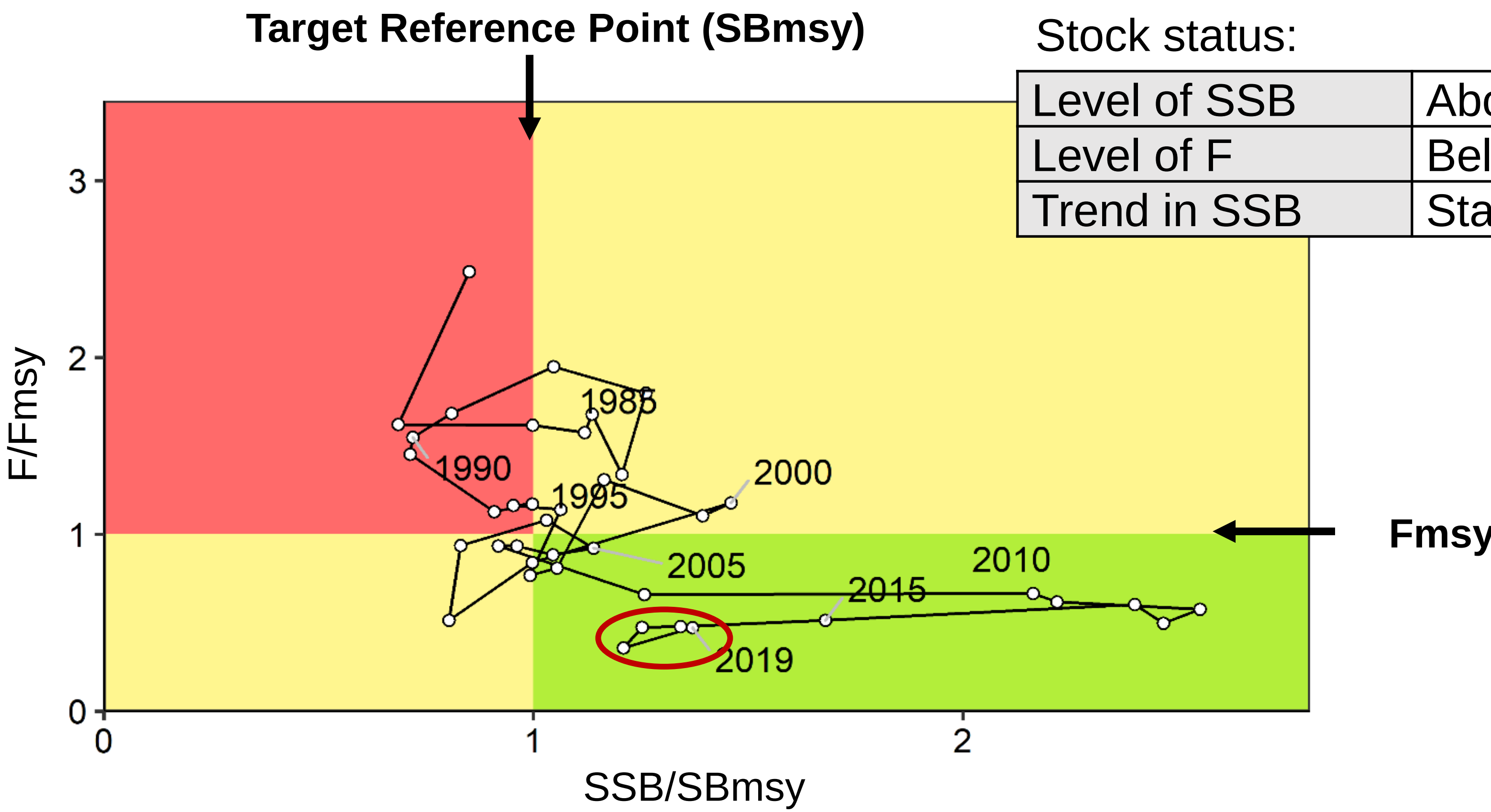
(%)

SSB at the start of recovery (candidate value for the fishing ban level: thousand tons)																														
β	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150
1.0	0	0	1	2	5	8	11	15	20	23	27	30	34	36	38	41	42	44	46	47	49	**50**	51	52	53	55	55	56	57	57
0.9	0	0	1	3	7	11	17	22	27	32	36	40	44	47	49	**51**	54	56	58	60	61	63	64	65	66	67	67	69	69	70
0.8	0	0	2	5	10	17	24	30	36	42	47	**51**	55	58	61	64	66	69	71	72	74	75	77	77	78	79	80	81	81	81
0.7	0	0	3	7	15	23	32	40	47	**53**	58	63	66	70	73	76	78	80	82	84	85	86	87	88	89	89	89	90	90	91
0.6	0	1	4	11	21	32	42	**50**	58	64	69	74	77	81	83	86	88	90	91	92	93	94	94	95	95	96	96	96	96	96
0.5	0	1	6	16	30	42	**52**	61	69	74	79	83	86	89	91	93	95	96	96	97	97	98	98	98	98	99	99	99	99	99
0.4	0	2	9	24	39	**52**	63	71	78	83	87	90	93	95	96	97	98	98	99	99	99	99	100	100	100	100	100	100	100	100
0.3	0	3	14	33	49	**63**	73	80	86	90	93	95	97	98	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100
0.2	0	4	20	42	**60**	73	81	87	92	95	97	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.1	0	6	30	**54**	70	81	88	93	96	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.0	0	10	40	**64**	79	87	93	96	98	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

* Under the grey shaded combination of β and SBban candidates, the SSB cannot recover target level in 10 years.

- Threshold that can recover target level in 10 years with 50% probability under the fishing by HCR (β=0.8) is 60 thousand tons (SBban candidate).

Reference points and Kobe-plot



Stock status:

Level of SSB	Above SBmsy
Level of F	Below Fmsy
Trend in SSB	Stable

Reference points

SB target	SB msy	228 thousand tons
SB limit	SB min	151 thousand tons
SB ban	The threshold to recover to the SBtarget for 10 years under fishing based on HCR (β=0.8)	60 thousand tons

Reviewer's Comment #05

- Plots of spawning biomass versus time and associated reference points for reasonable alternative values of M (e.g., upper and lower bounds) would be useful to help communicate the implications of error in this parameter on management advice. Methods for deriving M are inconsistent among stocks. Standardization of estimation methods is preferred if no specific reasons are given for using a particular method.

Response

Sensitivity test using alternative values of M had been conducted in 2019 meeting using previous data-set (Based on 2018 assessment). We would like to explain detailed information in next slide.

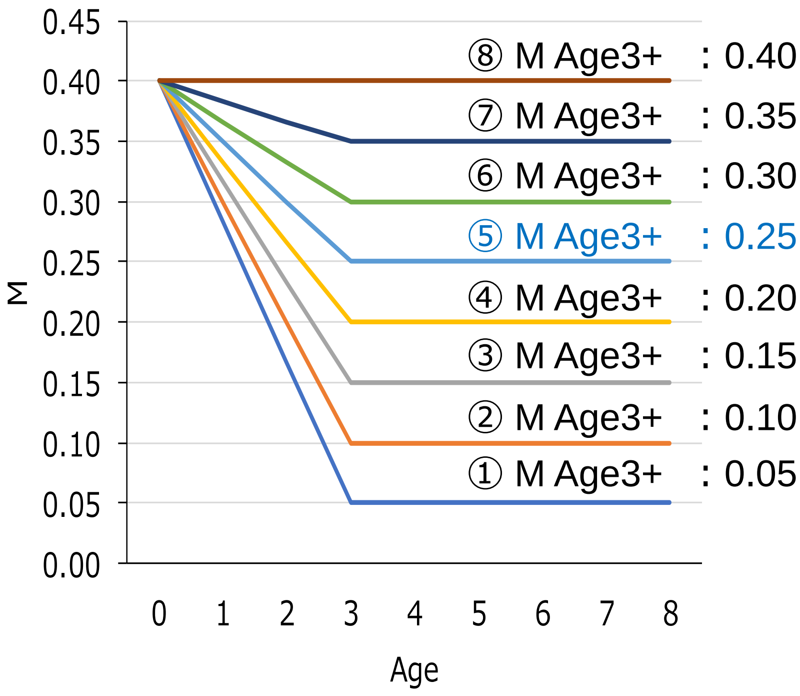
In our view, different assumption of M tends to affect just scale of biomass (and empirical reference point like historical lowest SSB) for VPA, but it has a substantial impact for the calculation of MSY reference points.

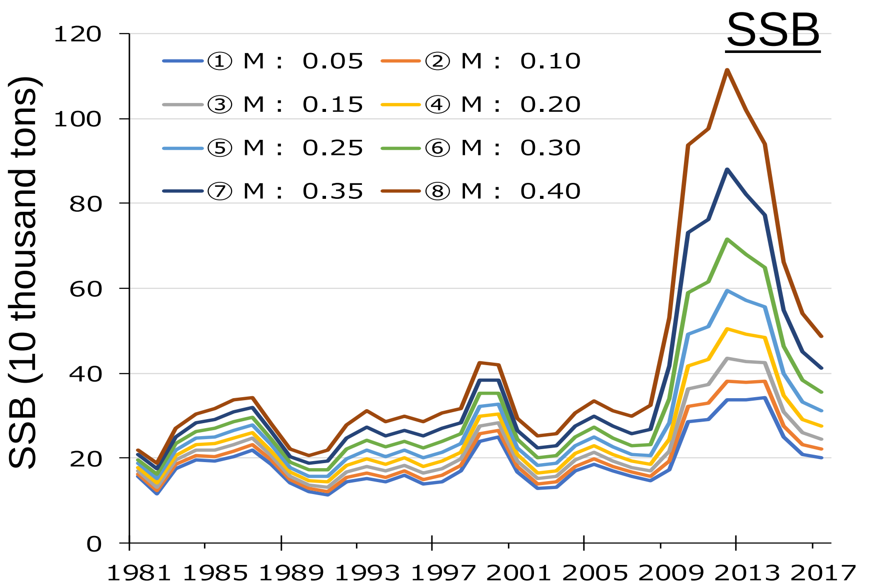
For the methods for deriving M, we would like to continue improving to have consistency across the species and stocks for the assessment.

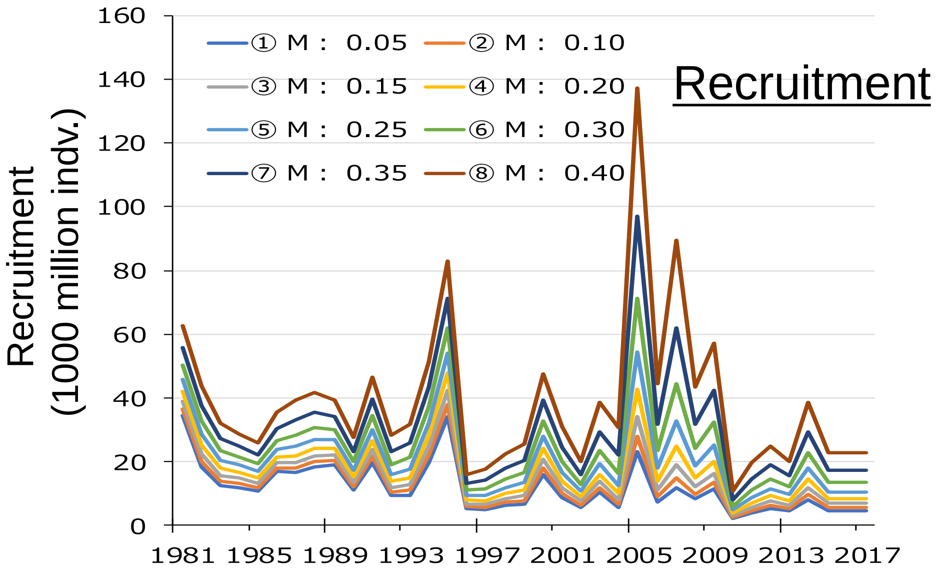
Sensitivity test for alternative M

Alternative 8 scenarios of M

- Age 0: M=0.40
- Age 3+: alternative M from 0.05 to 0.40
- Age 1~2: linear interpolation

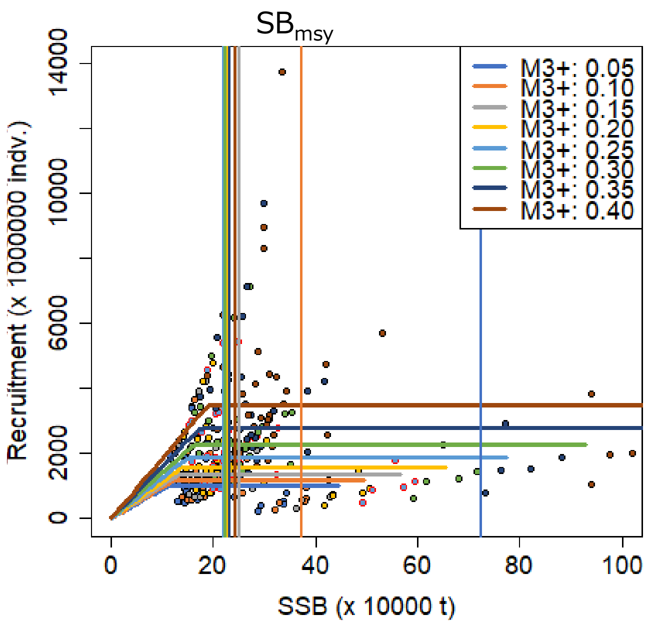




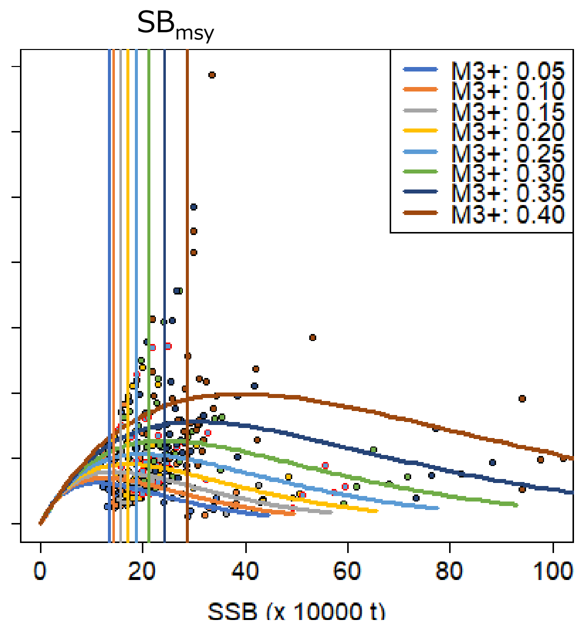


Sensitivity test for alternative M

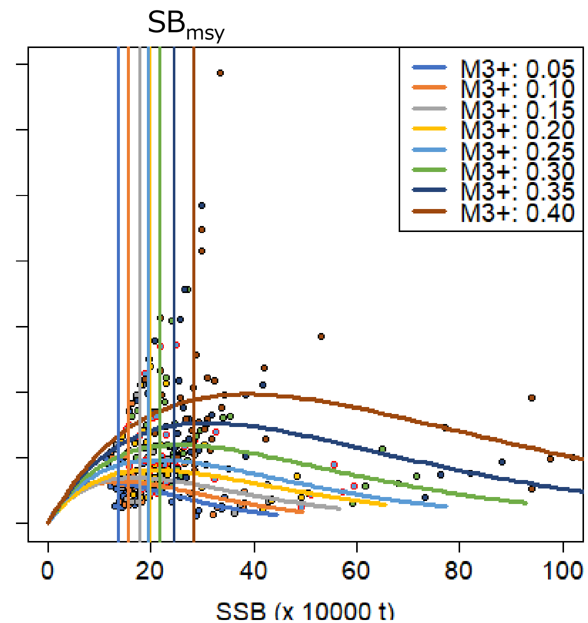
Hockey Stick (HS)
(Least squares)



Ricker (RI)
(Least squares)



Ricker (RI)
(Least absolute)



Alternative M scenarios

Different M provides scale change of absolute value of Biomass and Recruitment.

Hockey stick model : When extremely low M was used, SBmsy was occasionally have high value (over the observational range) .

Ricker model : SBmsy was shifted in response to the change of absolute value of biomass.

Sensitivity test for alternative M

MSY reference points etc. in each alternative M scenario

	HS (Least squares)							
	M3+: 0.05	M3+: 0.10	M3+: 0.15	M3+: 0.20	M3+: 0.25	M3+: 0.30	M3+: 0.35	M3+: 0.40
B_{MSY}	1263426	933858	851170	889615	970497	1087711	1247195	1466047
SB_{MSY}	723997	371822	251305	226231	220251	224551	231121	244052
MSY	201080	182538	176678	175274	175729	180645	188706	203994
U_{MSY}	0.159	0.195	0.208	0.197	0.181	0.166	0.151	0.139
$F_{MSY/}F_{cur}$	0.58	1.08	1.64	2.00	2.32	2.69	3.20	3.90

	RI (Least squares)							
	M3+: 0.05	M3+: 0.10	M3+: 0.15	M3+: 0.20	M3+: 0.25	M3+: 0.30	M3+: 0.35	M3+: 0.40
B_{MSY}	635118	702192	783349	876686	995993	1146917	1352947	1640453
SB_{MSY}	135472	143803	156552	170424	189141	213231	244332	287407
MSY	192696	194405	196881	198861	199903	203819	208842	218994
U_{MSY}	0.303	0.277	0.251	0.227	0.201	0.178	0.154	0.133
$F_{MSY/}F_{cur}$	2.40	2.54	2.67	2.82	2.96	3.13	3.33	3.59

	RI (Least absolute)							
	M3+: 0.05	M3+: 0.10	M3+: 0.15	M3+: 0.20	M3+: 0.25	M3+: 0.30	M3+: 0.35	M3+: 0.40
B_{MSY}	642181	682766	752887	853448	942774	1109619	1326889	1614292
SB_{MSY}	137058	157266	179679	198111	196798	218990	247342	283489
MSY	194942	181671	174896	176414	180831	189062	203137	215338
U_{MSY}	0.304	0.266	0.232	0.207	0.192	0.170	0.153	0.133
$F_{MSY/}F_{cur}$	2.40	2.25	2.16	2.25	2.63	2.86	3.22	3.59

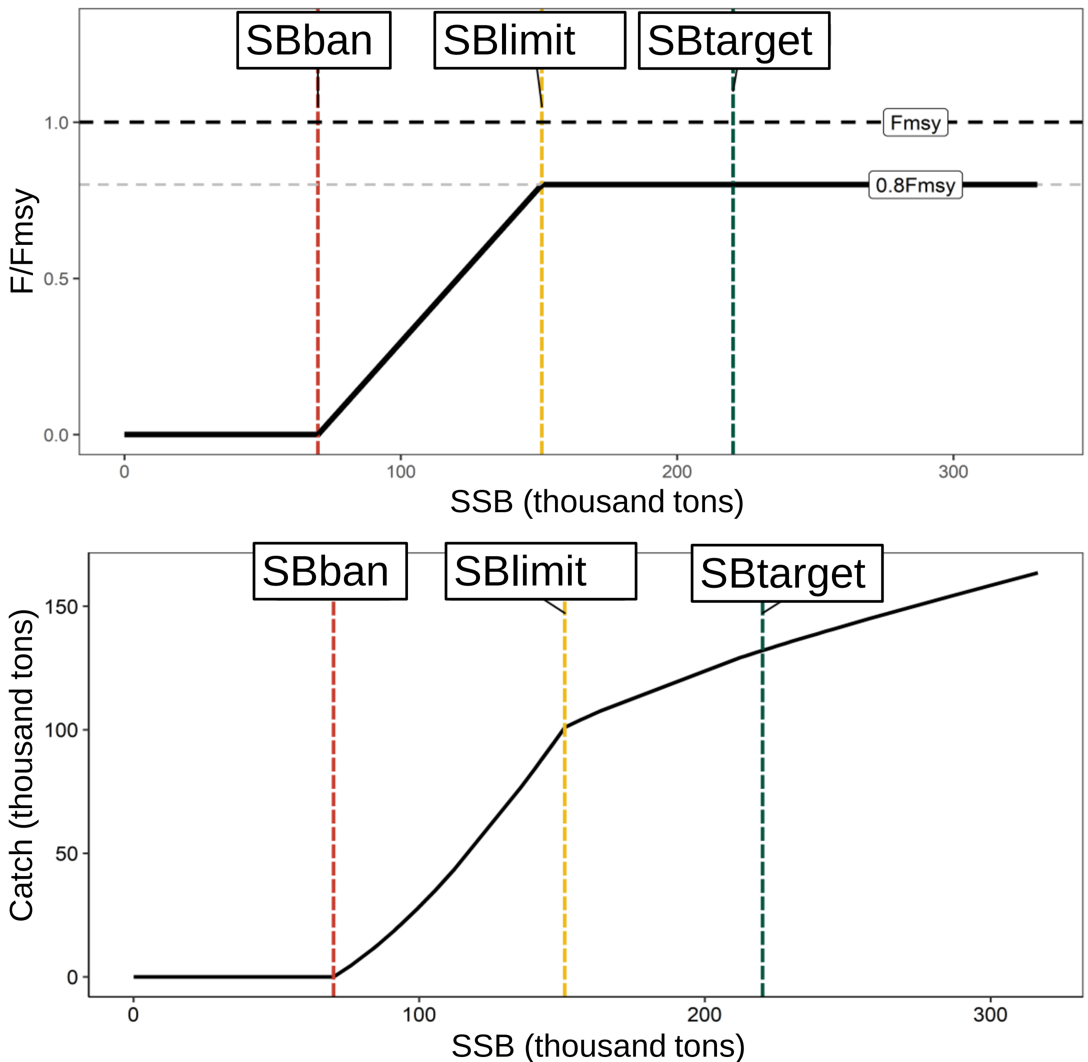
Contents

- Biology and Stock assessment
- Stock-Recruitment Relationships
- Reference points, Kobe-plot
- Harvest Control Rule, Future projection
  Default harvest control rule, Projection using default HCR, Constant catch projection, Adopted rule for management

Harvest Control Rule (HCR)

Default rule:

F is controlled to directly reduced according to the SSB level, when the SSB falls below the SBlimit. Multiplying the Fmsy by the coefficient β is the upper limit of F.



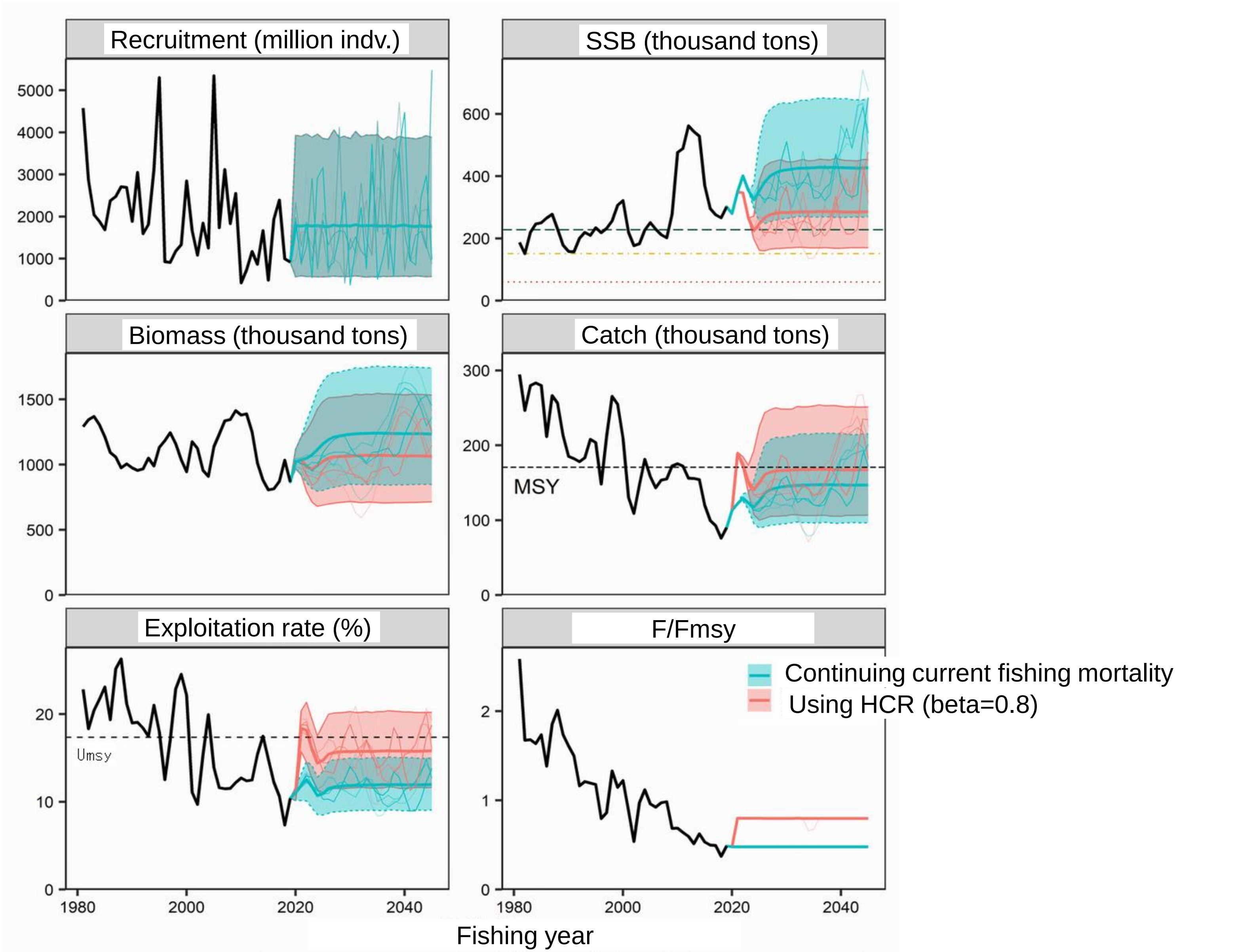
The stakeholders requested alternative rule (constant catch rule) instead of the default rule in the stakeholder meeting.

In alternative scenario, we provided projections using constant catch rule during 2021-2023 (3 years) or 2021-2025 (5 years).

The constant catch amount was tested from 140 thousand to 190 thousand tons.

Through the stakeholder meeting, constant catch rule (170 thousand tons) for next 3 years was adopted and implemented in the fisheries management from 2021.

Projection using default HCR



(Shaded: 5-95% prediction interval; thick solid line: average value; thin solid line: simulated example)

Projection using default HCR

Probability (%) of future SSB exceeding the **target** reference point

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1.0	100	100	100	100	0	5	28	38	43	45	45	44	44
0.9	100	100	100	100	100	13	38	50	55	57	58	58	58
0.8	100	100	100	100	100	33	52	63	68	70	71	72	72
0.7	100	100	100	100	100	88	70	76	80	83	84	84	85
0.6	100	100	100	100	100	100	88	89	91	92	93	94	94
0.5	100	100	100	100	100	100	99	97	98	98	98	98	98

Probability (%) of future SSB exceeding the **limit** reference point

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1.0	100	100	100	100	100	100	81	88	90	91	90	91	91
0.9	100	100	100	100	100	100	91	93	95	95	95	95	96
0.8	100	100	100	100	100	100	98	97	98	98	98	98	98
0.7	100	100	100	100	100	100	100	99	99	100	99	99	99
0.6	100	100	100	100	100	100	100	100	100	100	100	100	100
0.5	100	100	100	100	100	100	100	100	100	100	100	100	100

Expected average **SSB** (thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1.0	302	280	350	317	224	183	205	223	231	233	234	232	232
0.9	302	280	350	331	244	202	224	243	252	255	256	255	256
0.8	302	280	350	346	266	225	247	267	277	281	284	284	284
0.7	302	280	350	362	290	251	274	296	308	313	316	317	318
0.6	302	280	350	379	317	281	306	330	345	352	357	358	359
0.5	302	280	350	397	348	317	345	372	390	400	406	409	411

Expected average **Catch** (thousand tons)

β	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1.0	90	113	226	193	158	148	156	168	172	172	172	171	172
0.9	90	113	208	185	155	145	154	165	168	170	170	170	170
0.8	90	113	189	175	151	141	150	161	164	166	166	167	167
0.7	90	113	169	163	145	136	145	155	159	161	162	162	163
0.6	90	113	148	150	136	129	137	148	152	154	155	156	156
0.5	90	113	127	133	126	120	128	139	143	145	147	147	148

Constant catch projection (constant catch for next 3 years)

Probability (%) of future SSB exceeding the target reference point

(%)

140 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	100	60	53	50	47	47	46	45
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	63	61	60	59	59	59
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	72	73	72	72	72	73
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81	83	84	84	85	86
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	89	91	92	93	94	94
0.5	100	100	100	100	100	93	94	97	97	98	98	98

The larger the catch amount is,
the greater the direct impact on the SSB will be.

150 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	53	51	49	46	47	46	45
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	60	60	60	59	59	59	59
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	67	69	71	72	72	72	73
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	74	78	81	83	84	84	86
0.6	100	100	100	100	96	80	86	90	92	93	94	94
0.5	100	100	100	100	96	86	92	96	97	98	98	98

When SSB is decreased, its recovery speed
will depend on the β value.

160 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	65	46	48	47	46	46	45	45
0.9	100	100	100	100	65	52	56	58	58	58	59	59
0.8	100	100	100	100	65	59	65	69	71	71	72	73
0.7	100	100	100	100	65	65	74	79	82	83	84	85
0.6	100	100	100	100	65	72	82	89	91	93	93	94
0.5	100	100	100	100	65	78	89	95	97	97	98	98

170 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	36	40	44	46	45	46	45	45
0.9	100	100	100	100	36	45	53	56	57	58	58	58
0.8	100	100	100	100	36	51	62	67	70	71	72	72
0.7	100	100	100	100	36	57	70	78	82	83	84	85
0.6	100	100	100	100	36	63	78	87	90	92	93	94
0.5	100	100	100	100	36	70	86	93	96	97	98	98

180 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	20	34	41	44	45	46	44	44
0.9	100	100	100	100	20	39	49	55	57	57	58	58
0.8	100	100	100	100	20	44	58	65	69	70	71	72
0.7	100	100	100	100	20	49	66	76	80	83	84	85
0.6	100	100	100	100	20	55	74	85	90	92	93	94
0.5	100	100	100	100	20	61	82	92	96	97	98	98

190 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	12	29	38	43	45	45	43	44
0.9	100	100	100	100	12	33	46	53	56	56	57	57
0.8	100	100	100	100	12	37	54	64	68	70	70	72
0.7	100	100	100	100	12	42	62	74	79	82	83	85
0.6	100	100	100	100	12	47	70	83	89	91	92	93
0.5	100	100	100	100	12	52	78	91	95	97	97	98

Constant catch (2021–2023) — Direct impact on SSB (2022–2024) — Small impact on future (2031)

Constant catch projection (constant catch for next 3 years)

Expected average SSB (thousand tons)

(thousand tons)

140 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	280	350	386	332	291	261	250	242	238	236	234	234
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	291	273	268	263	260	259	257	257
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	291	285	288	288	286	286	285	284
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	291	299	310	315	317	318	318	318
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	291	313	334	347	353	357	358	359
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	291	327	361	384	396	404	408	410

The larger the catch amount is,
the smaller the average SSB will be.

150 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	280	350	378	316	269	250	244	240	237	236	234	233
0.9	280	350	378	316	269	261	262	260	259	258	257	256
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	281	284	285	285	284	284
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	302	311	315	317	317	318
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	325	342	351	356	357	359
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	351	377	392	402	406	409

After the constant catch, the recovery speed
will depend on the β value.

160 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	280	350	370	300	247	239	239	237	236	235	234	233
0.9	280	350	370	300	247	249	256	258	257	258	256	256
0.8	280	350	370	300	247	260	274	281	283	284	284	284
0.7	280	350	370	300	247	272	294	307	313	316	317	318
0.6	280	350	370	300	247	284	316	337	348	354	357	358
0.5	280	350	370	300	247	297	341	371	389	400	405	409

170 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	280	350	362	284	225	228	234	235	235	235	233	232
0.9	280	350	362	284	225	237	249	255	256	257	256	256
0.8	280	350	362	284	225	248	267	277	281	283	283	284
0.7	280	350	362	284	225	259	286	302	310	315	316	317
0.6	280	350	362	284	225	270	307	331	345	353	356	358
0.5	280	350	362	284	225	282	331	365	385	398	404	408

180 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	280	350	354	268	204	216	229	233	234	234	232	232
0.9	280	350	354	268	204	225	244	252	255	256	255	255
0.8	280	350	354	268	204	235	260	273	279	282	282	283
0.7	280	350	354	268	204	245	278	298	308	314	315	317
0.6	280	350	354	268	204	256	298	326	342	351	355	357
0.5	280	350	354	268	204	267	320	358	381	395	402	407

190 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	280	350	345	253	184	206	224	231	233	233	230	231
0.9	280	350	345	253	184	214	238	249	254	255	253	254
0.8	280	350	345	253	184	223	253	270	278	281	281	282
0.7	280	350	345	253	184	232	270	294	305	311	313	316
0.6	280	350	345	253	184	242	289	321	338	348	353	356
0.5	280	350	345	253	184	252	310	352	377	392	400	406

Constant catch　Direct impact on SSB　Small impact on future

Constant catch projection (constant catch for next 3 years)

Expected average Catch (thousand tons)

(thousand tons)

140 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	113	140	140	140	201	186	182	[illegible]	[illegible]	[illegible]	173	173
0.9	113				185	176	177	[illegible]	[illegible]	[illegible]	171	171
0.8	113				168	166	170	[illegible]	[illegible]	[illegible]	167	167
0.7	113				150	153	161	[illegible]	[illegible]	[illegible]	162	163
0.6	113				132	139	149	[illegible]	[illegible]	[illegible]	156	156
0.5	113				112	123	136	[illegible]	[illegible]	[illegible]	147	148

150 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	113	150	150	150	190	180	179	176	174	173	173	173
0.9	113				175	171	174	172	171	171	170	171
0.8	113				159	161	167	167	167	167	167	167
0.7	113				142	148	158	160	161	162	162	163
0.6	113				125	135	147	151	154	155	156	156
0.5	113				106	119	133	139	143	145	147	148

160 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	113	160	160	160	179	175	176	175	174	173	172	173
0.9	113				165	166	171	171	171	170	170	170
0.8	113				150	155	164	[illegible]	[illegible]	[illegible]	167	167
0.7	113				134	144	155	[illegible]	[illegible]	[illegible]	162	162
0.6	113				117	130	144	[illegible]	[illegible]	[illegible]	155	156
0.5	113				100	115	130	[illegible]	[illegible]	[illegible]	146	148

170 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	113	170	170	170	169	168	[illegible]	[illegible]	[illegible]	[illegible]	172	172
0.9	113				155	160	168	[illegible]	[illegible]	[illegible]	170	170
0.8	113				141	150	161	[illegible]	[illegible]	[illegible]	167	167
0.7	113				126	139	152	[illegible]	[illegible]	[illegible]	162	162
0.6	113				110	125	141	[illegible]	[illegible]	[illegible]	155	156
0.5	113				94	111	127	136	141	144	146	147

180 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	113	180	180	180	158	161	171	173	173	172	171	172
0.9	113				145	153	165	169	170	169	169	170
0.8	113				132	144	158	163	165	166	166	167
0.7	113				118	133	149	156	159	161	161	162
0.6	113				103	121	138	146	151	153	155	156
0.5	113				88	106	124	134	140	144	146	147

190 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	113	190	190	190	147	155	169	172	172	171	171	171
0.9	113				135	147	163	167	169	169	169	169
0.8	113				122	138	155	161	164	165	165	166
0.7	113				109	128	146	154	158	160	161	162
0.6	113				95	116	135	144	150	152	154	155
0.5	113				81	102	121	132	139	143	145	147

Ave. catch by HCR will increase after constant catch.

Ave. catch by HCR will decrease after constant catch

When constant catch is >170 thousand tons, the catch will decrease in any β value.

Constant catch

Small impact on future

Constant catch projection (constant catch for next 5 years)

Probability (%) of future SSB exceeding the target reference point

(%)

The larger the catch amount is,
the greater the direct impact on the SSB will be.

140 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	100	76	74	66	58	52	48	46
							74	71	68	63	61	60
							74	75	76	75	74	73
							74	79	83	85	85	85
							74	83	89	92	93	94
0.5	100	100	100	100	100	76	74	86	93	96	97	98

When SSB is decreased, its recovery speed will depend on the β value.

150 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
					96	63	64	59	54	50	47	45
					96	63	64	64	63	61	60	58
					96	63	64	68	71	73	72	72
					96	63	64	72	79	82	84	84
0.6	100	100	100	100	96	63	64	76	85	90	92	93
0.5	100	100	100	100	96	63	64	80	90	95	96	97

160 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	65	51	53	52	50	48	45	43
0.9	100	100	100	100	65	51	53	56	59	59	57	56
0.8	100	100	100	100	65	51	53	60	67	70	70	69
0.7	100	100	100	100	65	51	53	65	75	80	81	82
0.6	100	100	100	100	65	51	53	69	81	88	90	91
0.5	100	100	100	100	65	51	53	73	87	94	95	96

170 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	36	40	43	46	47	46	42	39
0.9	100	100	100	100	36	40	43	49	54	57	54	51
0.8	100	100	100	100	36	40	43	54	63	67	66	65
0.7	100	100	100	100	36	40	43	57	70	77	78	77
0.6	100	100	100	100	36	40	43	61	77	86	87	88
0.5	100	100	100	100	36	40	43	65	83	92	93	94

180 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	20	31	34	39	44	44	39	35
0.9	100	100	100	100	20	31	34	43	51	54	49	46
0.8	100	100	100	100	20	31	34	46	58	64	61	59
0.7	100	100	100	100	20	31	34	50	66	74	73	71
0.6	100	100	100	100	20	31	34	54	72	82	83	82
0.5	100	100	100	100	20	31	34	57	78	89	90	90

190 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	100	100	100	100	12	23	27	34	40	41	34	31
0.9	100	100	100	100	12	23	27	37	47	50	44	41
0.8	100	100	100	100	12	23	27	40	53	60	55	52
0.7	100	100	100	100	12	23	27	43	60	69	66	64
0.6	100	100	100	100	12	23	27	46	67	78	77	75
0.5	100	100	100	100	12	23	27	49	72	85	85	83

Constant catch   Direct impact on SSB

Impact depending on constant catch amount

Constant catch projection (constant catch for next 5 years)

Expected average SSB (thousand tons)

(thousand tons)

The larger the catch amount is, the smaller the average SSB will be.

After the constant catch, the recovery speed will depend on the β value.

140 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	280	350	386	332	291	306	329	285	259	246	238	235
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	291	306	329	298	278	268	261	258
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	291	306	329	313	300	293	288	285
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	291	306	329	328	324	322	320	318
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	291	306	329	344	351	356	357	358
0.5	280	350	386	332	291	306	329	360	380	394	401	405

150 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	279	297	270	252	243	236	233
0.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	279	297	282	270	264	258	255
0.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	279	297	295	291	288	285	282
0.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	279	297	309	313	316	316	315
0.6	280	350	378	316	269	279	297	323	338	348	352	353
0.5	280	350	378	316	269	279	297	338	366	385	395	400

160 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	280	350	370	300	247	253	266	255	245	239	233	229
0.9	280	350	370	300	247	253	266	266	262	260	254	251
0.8	280	350	370	300	247	253	266	278	282	283	280	277
0.7	280	350	370	300	247	253	266	290	303	310	310	309
0.6	280	350	370	300	247	253	266	303	326	341	345	346
0.5	280	350	370	300	247	253	266	317	352	376	387	392

170 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	280	350	362	284	225	227	235	241	239	236	227	222
0.9	280	350	362	284	225	227	235	250	255	255	248	244
0.8	280	350	362	284	225	227	235	261	273	278	273	269
0.7	280	350	362	284	225	227	235	271	292	303	302	300
0.6	280	350	362	284	225	227	235	283	313	332	336	336
0.5	280	350	362	284	225	227	235	295	337	366	376	380

180 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	280	350	354	268	204	202	206	226	233	232	220	214
0.9	280	350	354	268	204	202	206	235	247	250	240	234
0.8	280	350	354	268	204	202	206	243	263	272	264	258
0.7	280	350	354	268	204	202	206	253	281	296	292	287
0.6	280	350	354	268	204	202	206	262	301	323	324	322
0.5	280	350	354	268	204	202	206	273	322	354	362	364

190 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	280	350	345	253	184	178	178	211	226	226	210	203
0.9	280	350	345	253	184	178	178	218	239	244	229	221
0.8	280	350	345	253	184	178	178	225	253	264	251	244
0.7	280	350	345	253	184	178	178	233	269	286	278	271
0.6	280	350	345	253	184	178	178	242	287	312	308	304
0.5	280	350	345	253	184	178	178	250	306	341	344	344

Constant catch

Direct impact on SSB

Impact depending on constant catch amount

Constant catch projection (constant catch for next 5 years)

Expected average Catch (thousand tons)

(thousand tons)

140 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	113	140	140	140	140	140	223	199	185	178	175	174
0.9	113						205	190	[illegible]	[illegible]	[illegible]	171
0.8	113						187	179	[illegible]	[illegible]	[illegible]	168
0.7	113						167	166	[illegible]	[illegible]	[illegible]	163
0.6	113						147	151	[illegible]	[illegible]	[illegible]	156
0.5	113						125	134	[illegible]	[illegible]	[illegible]	147

150 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	113	150	150	150	150	150	204	191	182	176	173	172
0.9	113						188	182	176	173	170	170
0.8	113						171	171	169	168	166	166
0.7	113						153	159	160	161	161	161
0.6	113						134	145	149	152	154	154
0.5	113						115	128	136	141	143	145

160 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	113	160	160	160	160	160	184	183	178	174	170	170
0.9	113						170	174	172	170	168	167
0.8	113						154	163	[illegible]	[illegible]	[illegible]	164
0.7	113						138	151	[illegible]	[illegible]	[illegible]	159
0.6	113						121	137	[illegible]	[illegible]	[illegible]	152
0.5	113						103	121	[illegible]	[illegible]	[illegible]	143

170 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	113	170	170	170	170	170	163	[illegible]	[illegible]	[illegible]	[illegible]	166
0.9	113						150	[illegible]	[illegible]	[illegible]	[illegible]	163
0.8	113						136	155	[illegible]	[illegible]	[illegible]	160
0.7	113						122	143	[illegible]	[illegible]	[illegible]	155
0.6	113						107	130	[illegible]	[illegible]	[illegible]	149
0.5	113						91	114	127	134	137	139

180 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	113	180	180	180	180	180	141	164	169	165	160	159
0.9	113						130	156	163	162	158	157
0.8	113						118	145	155	157	154	154
0.7	113						105	134	146	150	149	150
0.6	113						92	121	135	141	142	143
0.5	113						79	106	122	129	132	134

190 thousand tons

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
1	113	190	190	190	190	190	119	153	163	159	151	150
0.9	113						110	144	157	155	149	149
0.8	113						100	134	149	150	146	146
0.7	113						89	123	140	143	142	142
0.6	113						78	111	129	135	135	136
0.5	113						66	98	116	124	126	128

Ave. catch by HCR will increase after constant catch.

Ave. catch by HCR will decrease after constant catch

When constant catch is >170 thousand tons, the catch will decrease in any β value.

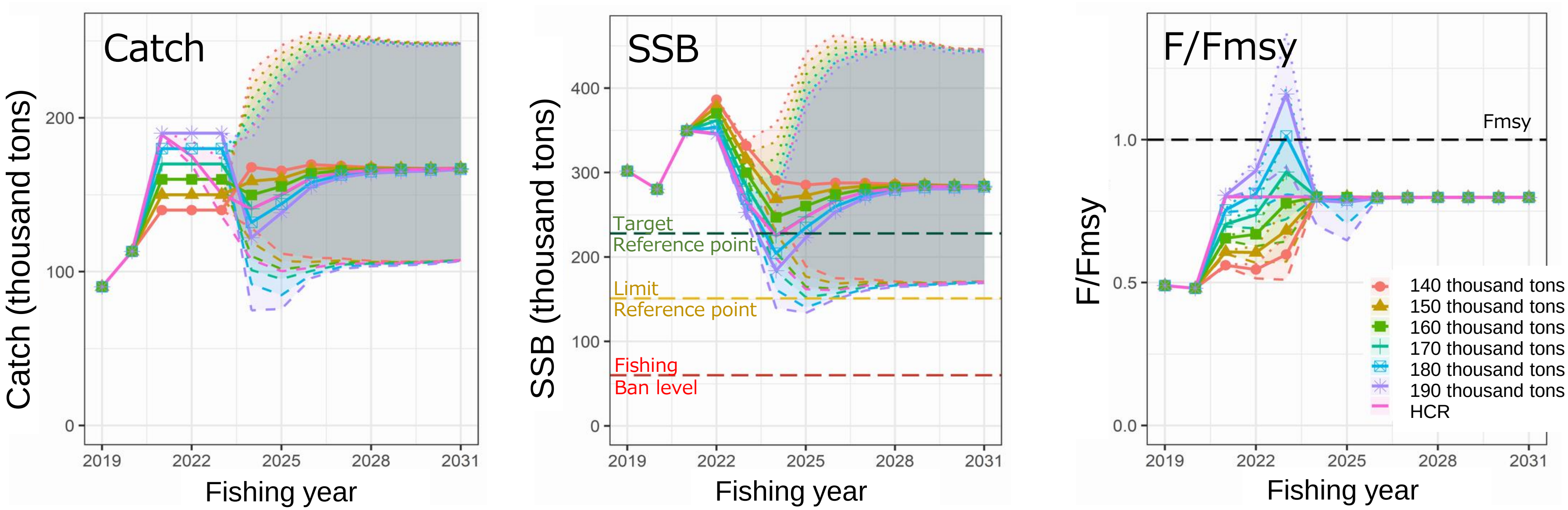
Constant catch

Impact depending on constant catch amount

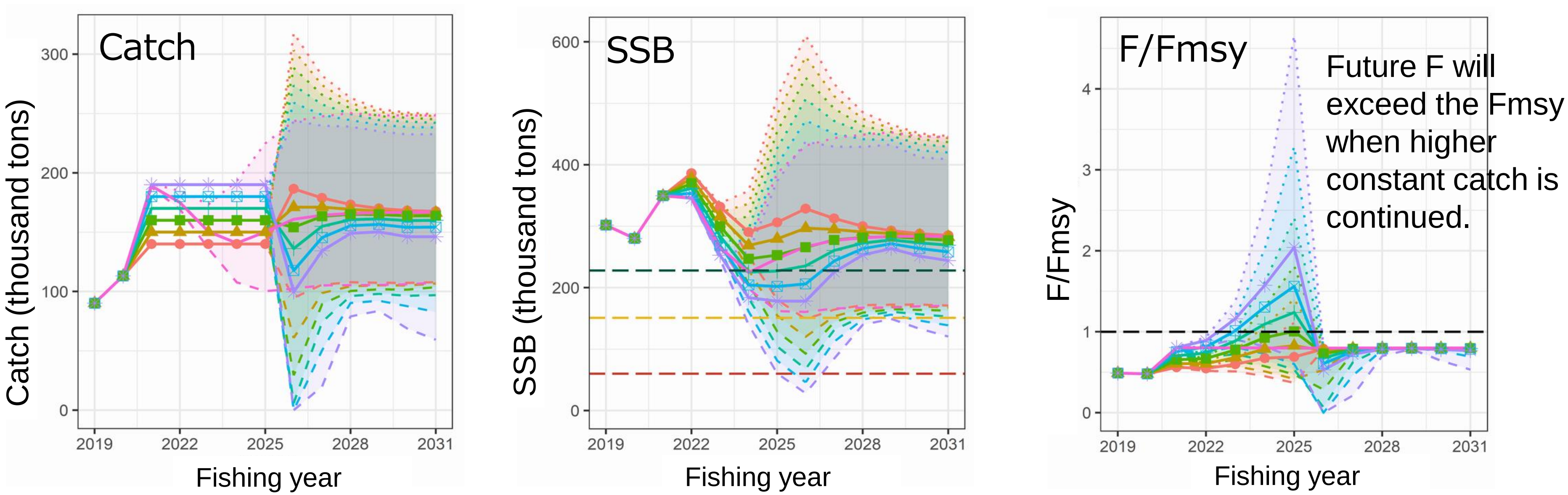
Constant catch projection

constant catch for next 5 years

* Average and 90%ile



Constant catch for next 5 years



Adopted rule for management

Following rule was adopted through the stakeholder meeting;

- Adjust the fishing intensity so that the SSB exceeds the Target reference point with at least 50% probability at 2031 fishing year.
- TAC (≤ABC) during 2021-2023 fishing year will be 170 thousand tons.
- ABC during 2024-2031 fishing year will be calculated using default HCR (β=0.9) .
- During constant catch period (170 thousand tons), if its fishing intensity will be considered to exceed Fmsy, the scenario should be conducted review.

Projection for 2021 | Future projection (2022-)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Expected Catch (thousand tons)	**170 ABC**	**170**	**170**	155	160	168	170	170	170	170	170
Expected SSB (thousand tons)	350	362	284	225	237	249	255	256	257	256	256
Probability(%) SSB>SBtarget	100	100	100	36	45	53	56	57	58	58	**58**
Probability (%) SSB>SBlimit	100	100	100	100	93	94	95	95	95	95	96
Probability (%) F>Fmsy	**0**	**0**	**8**	0	0	0	0	0	0	0	0