Northern Hokkaido Stock of the Arabesque Greenling

Pleurogrammus azonus

For Peer Review in 2021

Reviewer's Comments

- Model selection and reference points (16)

There was no discussion of alternative stock-recruitment relationships or model selection procedure for this stock. Alternative stock recruitment models may produce very different management reference points, and an exploration of alternative models seems warranted to better characterize uncertainty in stock projections and reference points.

In 2020 and 2021 stock assessment, we used selected SR model and reference points proposed temporarily by the Research Institute Meeting on Reference points (2019). Model selection and reference points proposed Meeting (2019) are shown in this presentation.

- Indices weighted (17)

In the WP-NJS assessment, unequal weights (W_k) 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?

In 2020 stock assessment, we used one standardized CPUE for tuning(0-4+), so weighting of index is not considered. Model fittings are shown in this presentation.

- Plot of abundance indices (18)

Similar to the other assessments, penalty term (the square of F) was weighted by λ, but I was unable to find the final λ value in the report. Fits to 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 caused a degradation of fit to the abundance indices approaches a value of 1.

We used λ=0.09 in SA 2020 (I'm sorry to show the value of λ in Appendix2 and Appendix 8). Fitting of Abundance indices are shown in this presentation. In SA 2021, we showed the plots of abundance indices and residual.

Reviewer's Comments

- Diagnostics of standardized (GLM) CPUE (19)

Are uncertenly estimates available for the annual abundance indices? Standard errors of the annual survey estimates could potentially be used as relative weights for individual years in the tuning process, and otherwise help with interpretation of trends over time and/ or interannual variability. The offshore bottom trawl CPUE was standardized using a generalized liner model (GLM), so estimates of uncertainly for year effects can be calculated from the GLM outputs. These could be used when calculating the negative log-likelihood in the tuning procedure, but it was not clear whether the authors took this approach or not. Diagnostics for the linear model (e.g. selection of covariates, residual plot, etc.) would be helpful to better understand the quality of the fit.

We did not use the information of standard errors of estimates GLM CPUE in SA2020. We would like to try to conduct by the next full stock assessment.

- Natural mortality rate (20)

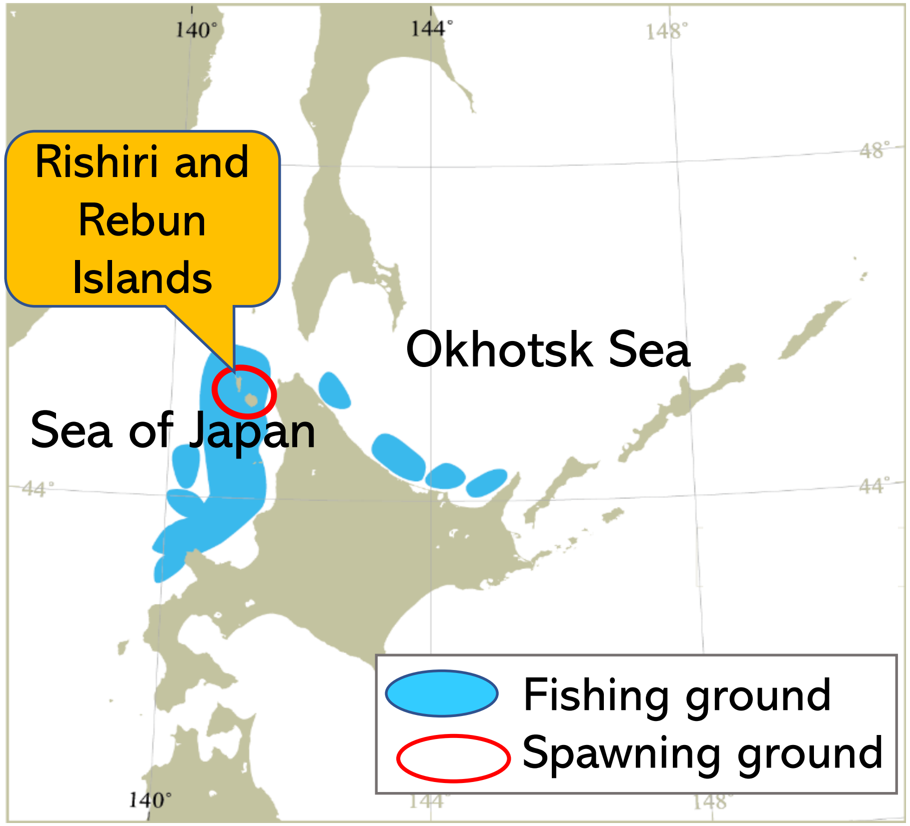
The natural mortality rate (M) is assumed to be 0.295 per year for all ages. Based on the reported longevity (8 or 9 years), M estimates based on ~5/ A_{max} would be closer to 0.5 per year. However, since M is not known with precision and affects estimates of F (and therefore abundance), model runs with alternative values for M would help managers understand risk associated with uncertainty in M

We have conducted the sensitivity test about the natural mortality (0.5M, M,1.5M, 2M) for Biomass and SSB, these results are shown in this presentation.

Contents

- Biology and Stock Assessment
  Distribution, Growth, Estimation of Catch Number at Age, Stock abundance indices, VPA
  responces to comments (17) , (18) , (19) and (20)
- Stock-Recruitment Relationships
  responces to comment (16)
- Proposed “Reference points”, Kobe-plot
- Harvest Control Rule and Future projection

Distribution

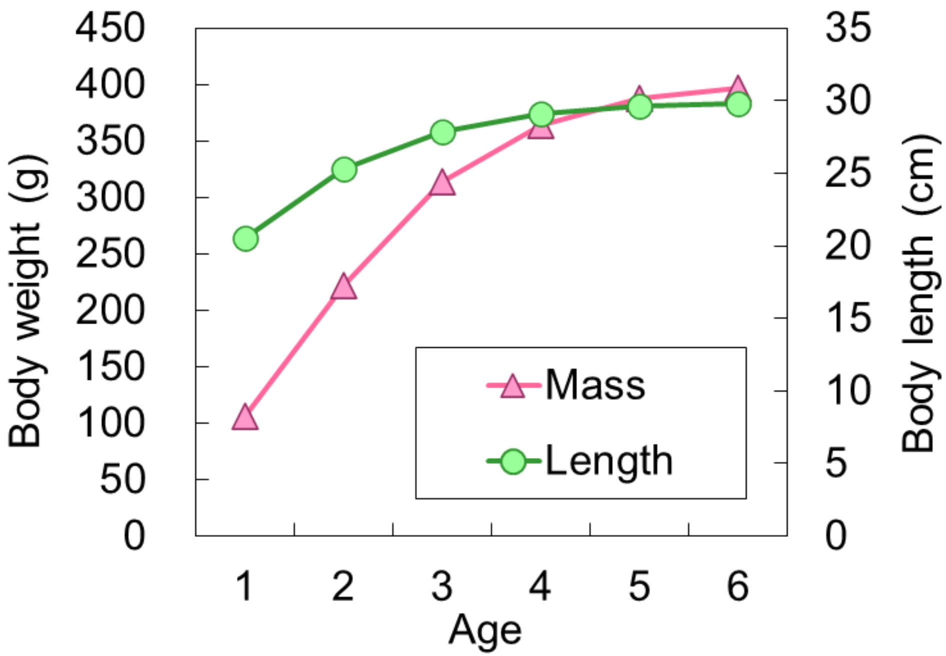


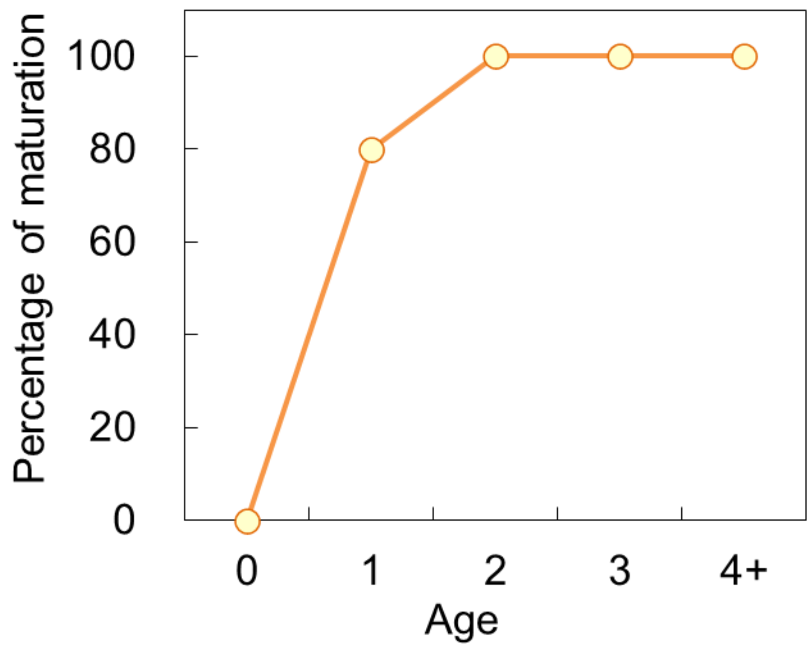
<u>Distribution</u>
Main distribution areas of Arabesque greenling are the Sea of Japan, the Okhotsk Sea and southwest coast of Sakhalin (Arabesque greenling research group 1983).

<u>Spawning</u>
The spawning grounds are the coastal areas of Rishiri and Rebun Islands and the shallowest area of Musashi bank.

Mature fish stay around their spawning ground.

Growth and Maturation





Male

$$L_t = 292.2 / \{1 + 1.086 \times \exp(-0.955 \times t)\}$$

$$W = 0.469 \times L^{3.612} \times 10^{-6}$$

Female

$$L_t = 307.0 / \{1 + 1.191 \times \exp(-0.876 \times t)\}$$

$$W = 0.884 \times L^{3.493} \times 10^{-6}$$

(Takashima et al. 2013)

(Takashima and Mitsuhashi 2009)

Maturation (recent study)

Table 3 Maturation rates of 1-year-old female *Pleurogrammus azonus* collected in the Sea of Japan off northern Hokkaido from September 1st to October 15th

Year	Sep 1–15	Sep. 16–30	Oct. 1–15	Mean
2004			0.54	0.54
2005			0.98, 0.89	0.94
2006			0.94	0.94
2007		0.87	0.71, 0.86, 0.54	0.75
2008		0.50, 0.63, 0.67	0.79, 0.85	0.69
2009	0.97		0.73	0.85
2010		0.91	0.98, 0.99, 0.98	0.96
2011		0.99	1.00	1.00
2012	0.96	0.99	0.98, 0.98	0.98
2013	0.99	0.97		0.98
2014		0.97	0.99, 0.99	0.98
2015	0.97	1.00	0.99	0.99
2016	1.00	0.97, 1.00	0.98	0.99

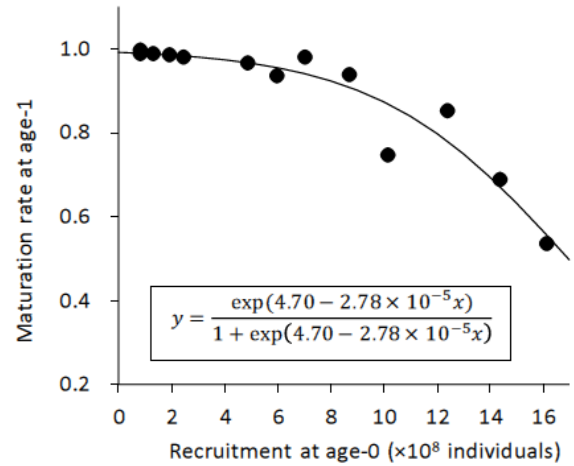


Fig. 7 Relationship between recruitment of 0-year-old individuals and maturation rate of 1-year-old *Pleurogrammus azonus* of each year-class in seas off northern Hokkaido. The line indicates the fitted logistic curve.

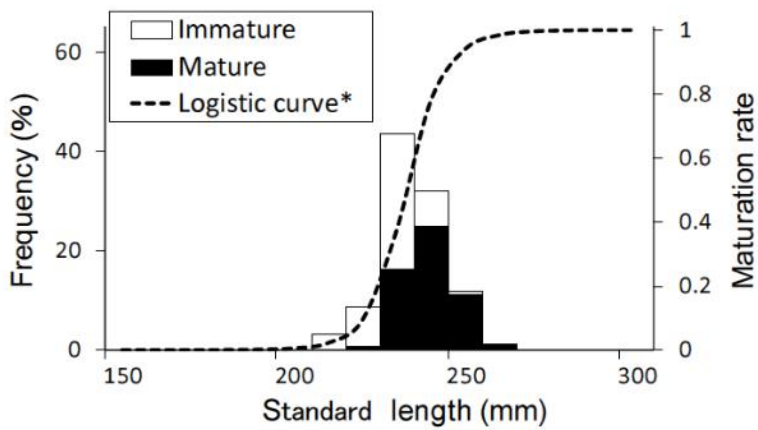
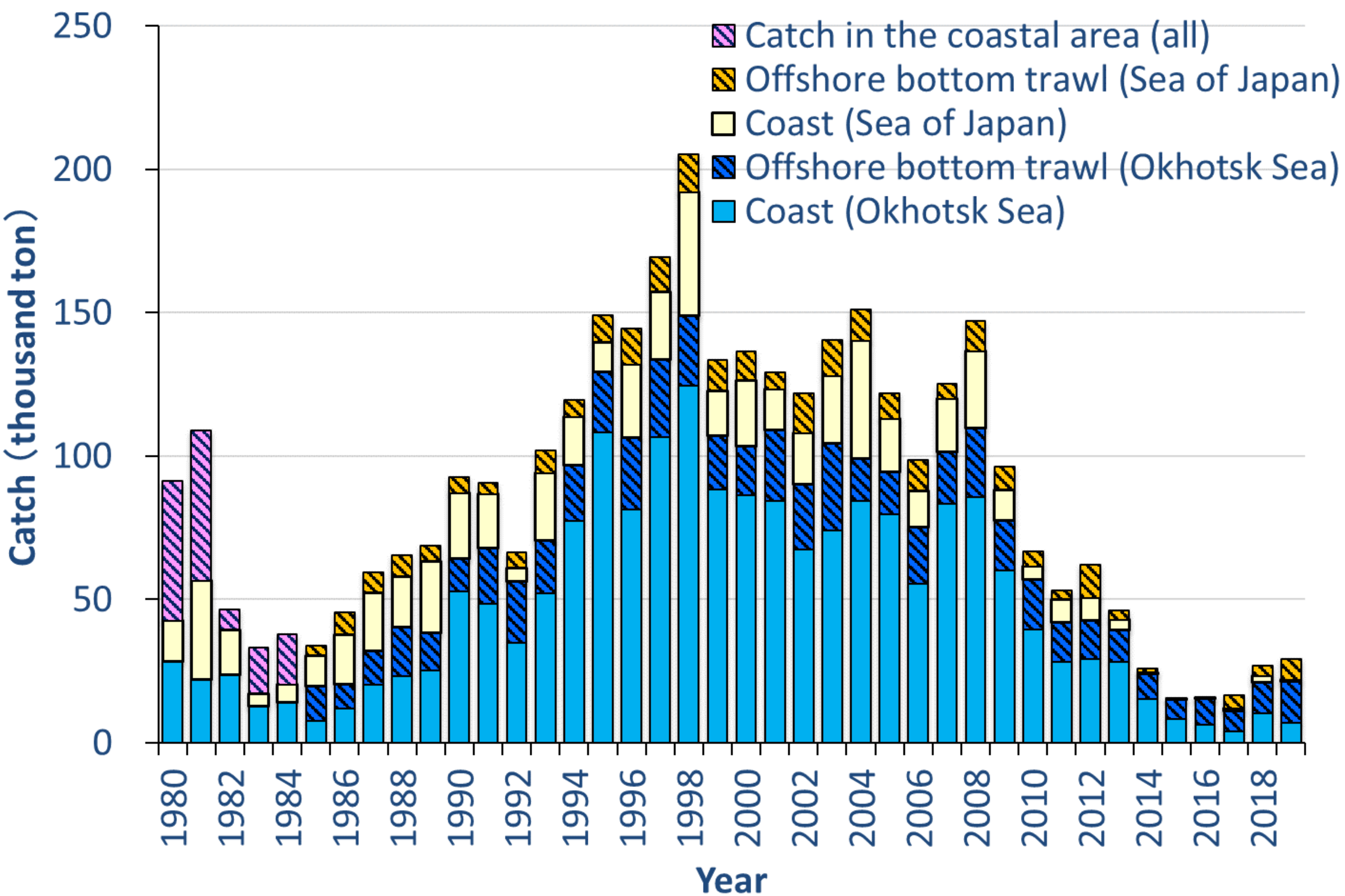


Fig. 2 Example of estimation of maturation rate of 1-year-old female *Pleurogrammus azonus* using standard length frequency composition of sample and logistic curve.
* Modified from Takashima et al. (2016)

- Maturation rate 1 year-old fish may change by amount of recruitment

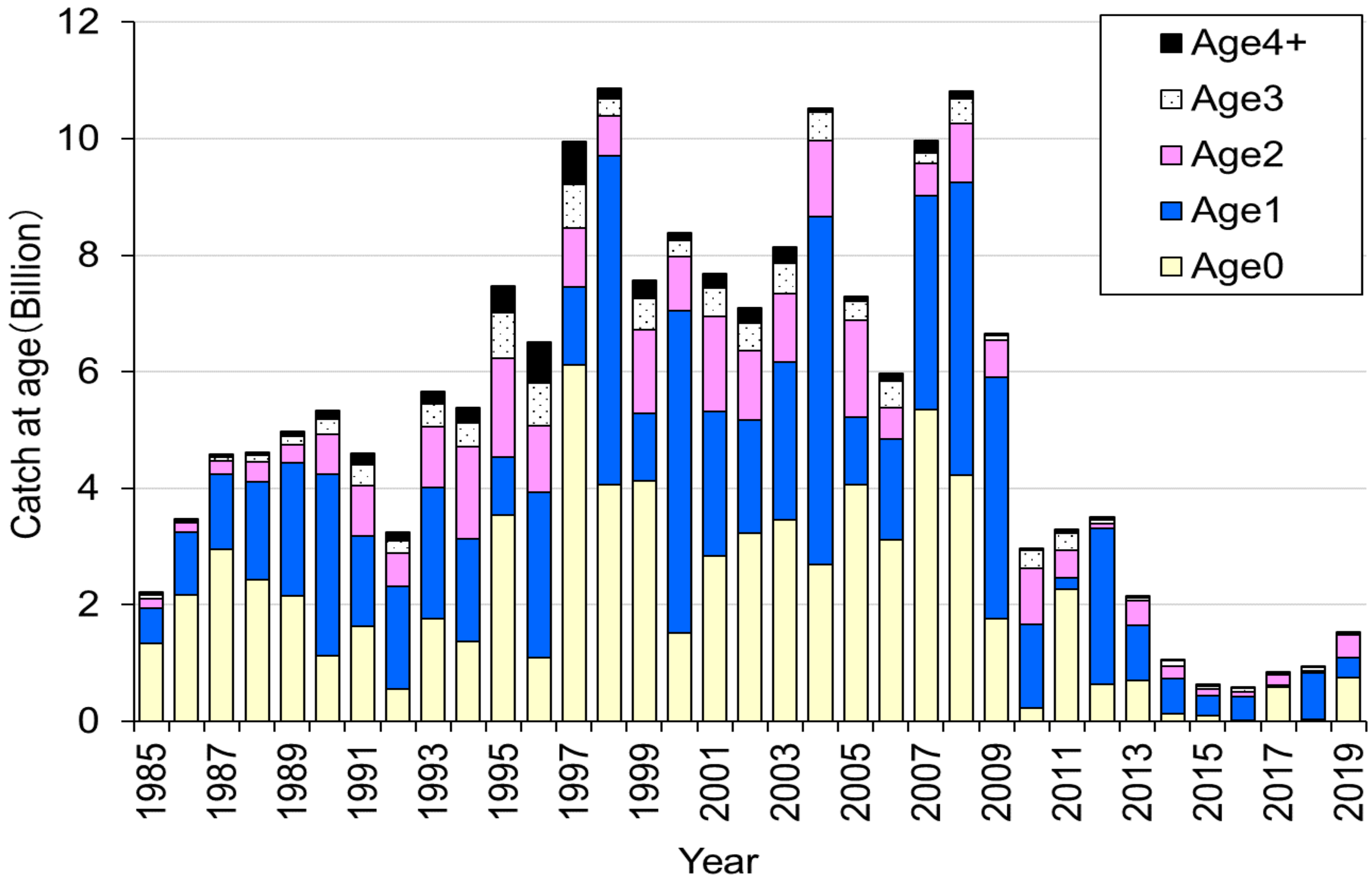
(Sakaguchi et al. 2018)

Catch



Catch in the coastal area (all)
Offshore bottom trawl (Sea of Japan)
Coast (Sea of Japan)
Offshore bottom trawl (Okhotsk Sea)
Coast (Okhotsk Sea)
Catch（thousand ton）
250
200
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year

Catch at age (CAA)



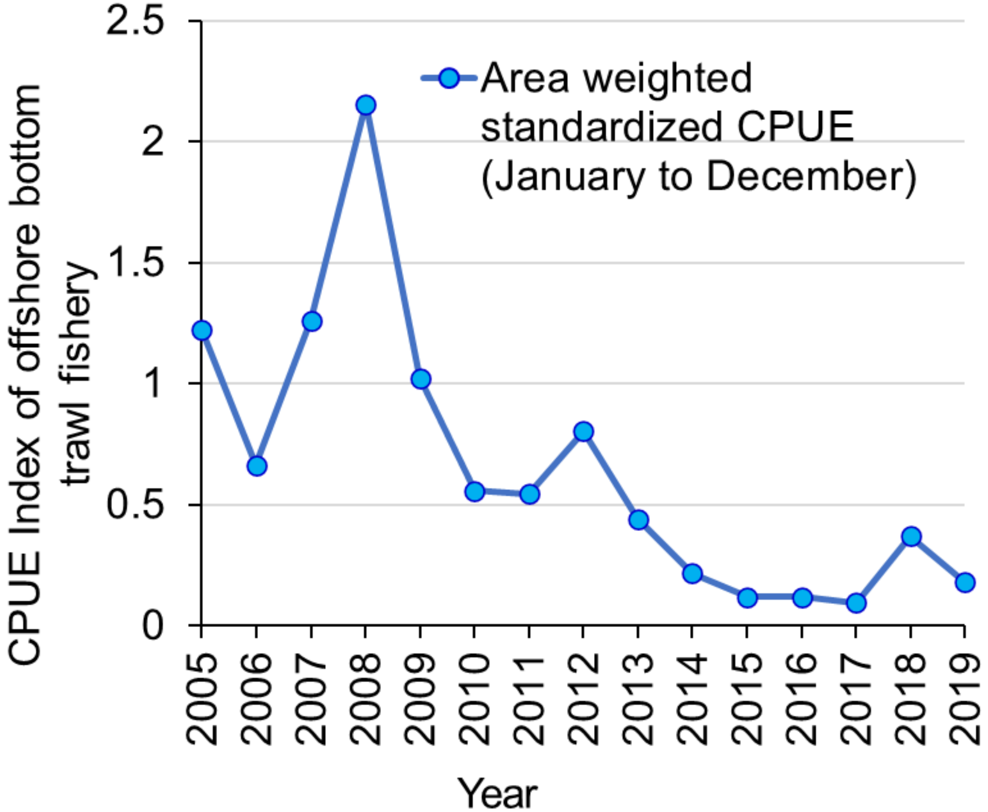
Reviewer's Comment (17)

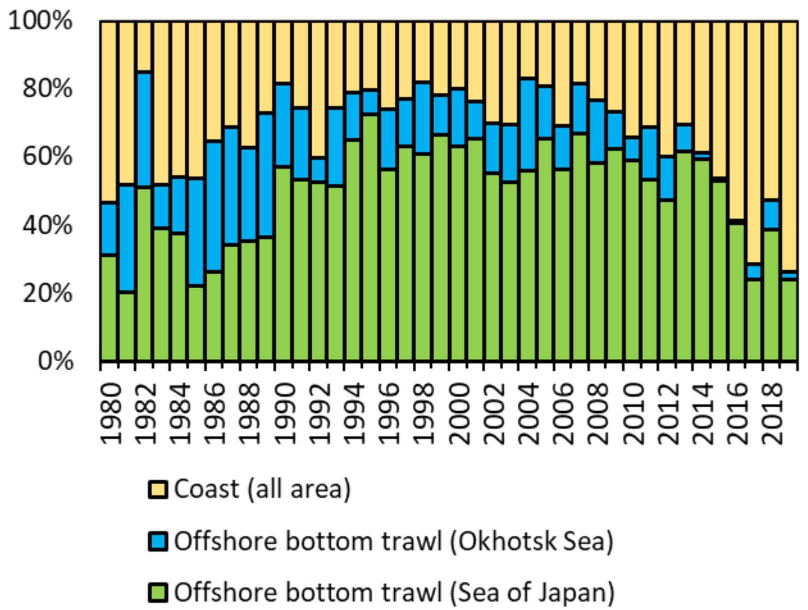
In the WP-NJS assessment, unequal weights (W_k) given to each index of abundance.

This assessment did not describe any weighting of different indices in the negative log-likelihood.

Were all of the abundance indices equally weighted?

Responses: (17)/ Tuning indices (abundance) age 0-4+





We used one standardized CPUE index for bottom trawl fishery as tuning index (age 0-4+). ･･･(17)

Reviewer's Comment (18)

・ Similar to the other assessments, penalty term (the square of F) was weighted by λ, but I was unable to find the final λ value in the report.

・ Fits to 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 caused a degradation of fit to the abundance indices approaches a value of 1.

Procedures of tuning VPA

Responses: (18)/penalty

Fundamental part

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

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

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

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

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

$$F_{3,y} = F_{4+,y}$$

N:Stock number a: age y: year F: fishing mortality
M: natural mortality 0.295/year p: plus groop (4+)

Tuning part

$$\boldsymbol{Obj} = (1-\lambda)\times\sum_{y}\left[\log(CPUE_y) - \log\left(q\left\{\sum_{a=0}^{4+}\Omega_{a,y}S_{a,y}B_{a,y}\Big/\sum_{a=0}^{4+}\Omega_{a,y}S_{a,y}\right\}^{b}\right)\right]^2 + \lambda\times\sum_{a=1}^{4+}\left(F_{a,Y}\right)^2$$

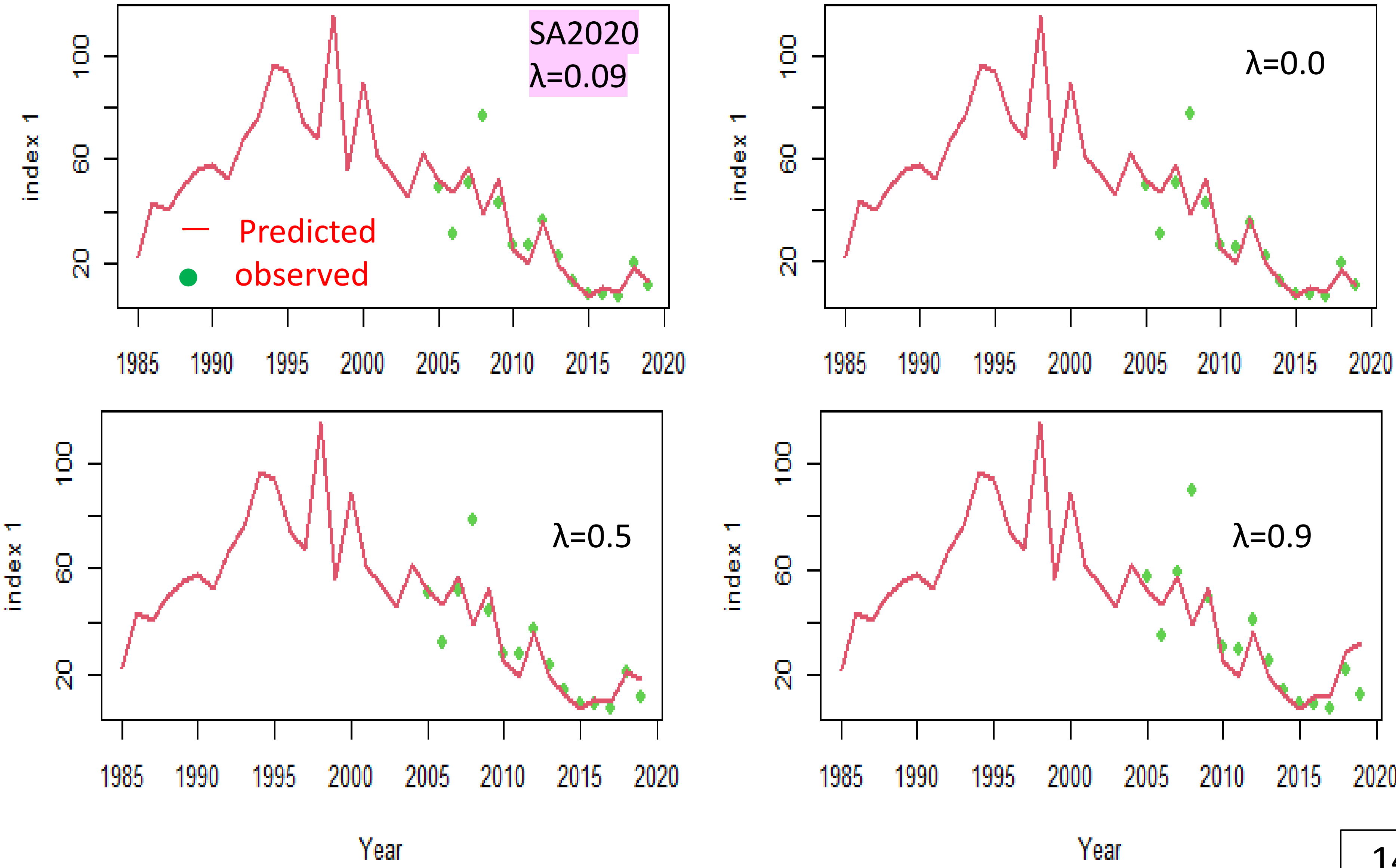
$$S_{a,y} = F_{a,y}/\max(F_{4+,y})$$

λ: weight of penalty (0.09)
$CPUE$: offshore fishery CPUE
$S_{a,y}$: selectivity at age
$\Omega_{a,y}$: ratio of Offshore fishery to total catch

Used λ value was 0.09 (p28 (Appendix 2), p54 (Appendix 8) in the report)・・・(18)

Response: (18) / Fitting of indices ($0 \leqq \lambda \leqq 1,$)

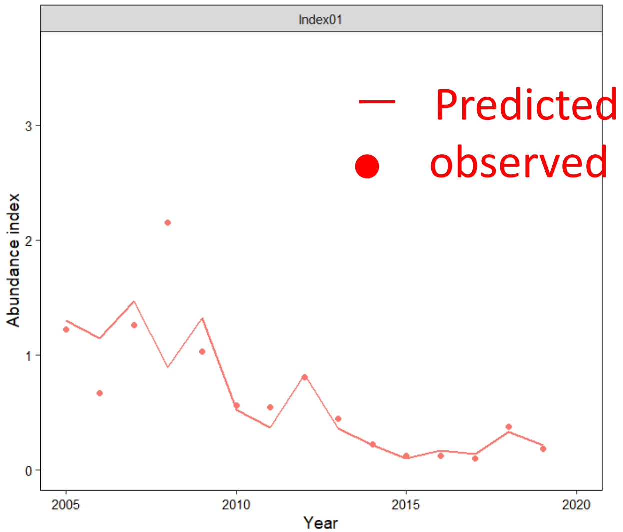
Tuning indices (abundance): Age 0-4^{+}

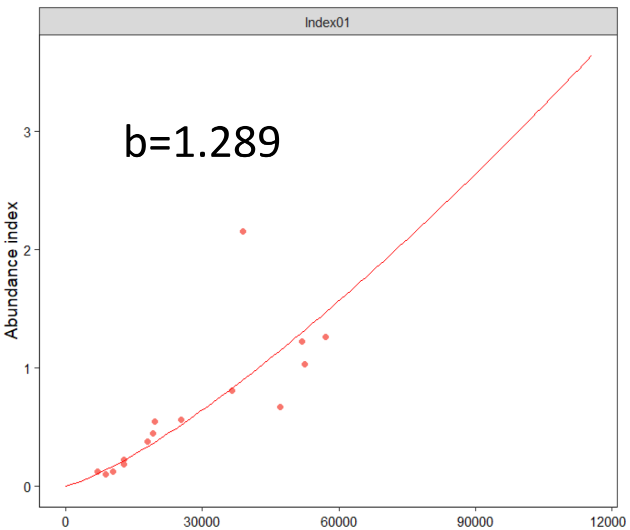


Response: (18) / Fitting of indices (λ0.09)

Tuning index (abundance): Age 0-4+

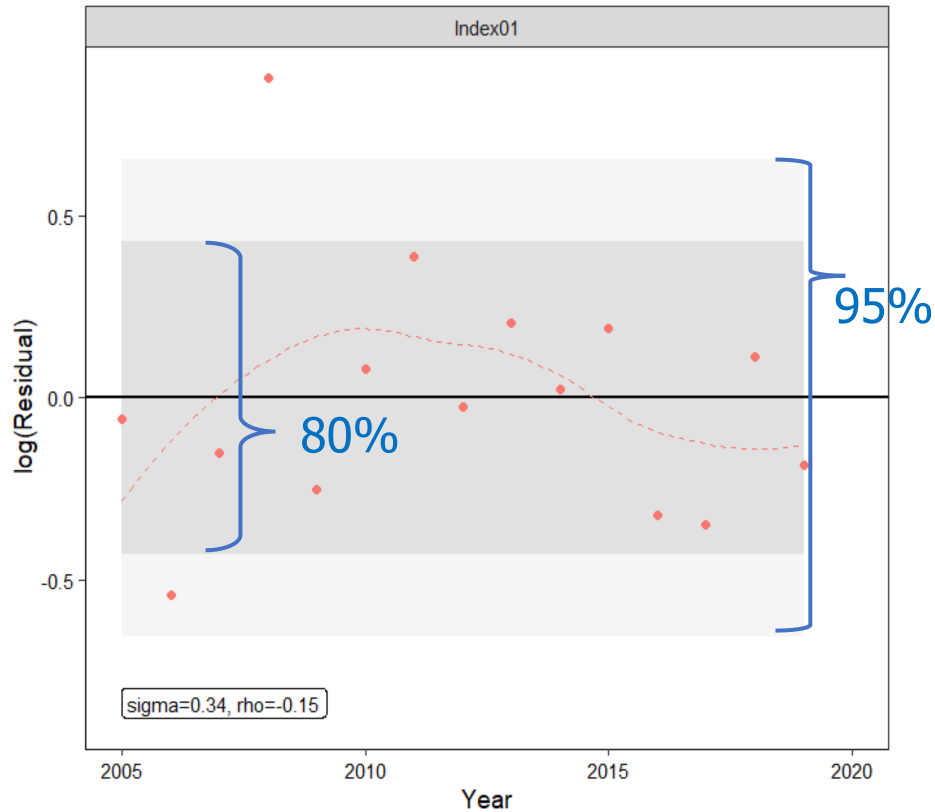
Estimates vs observations





Biomass

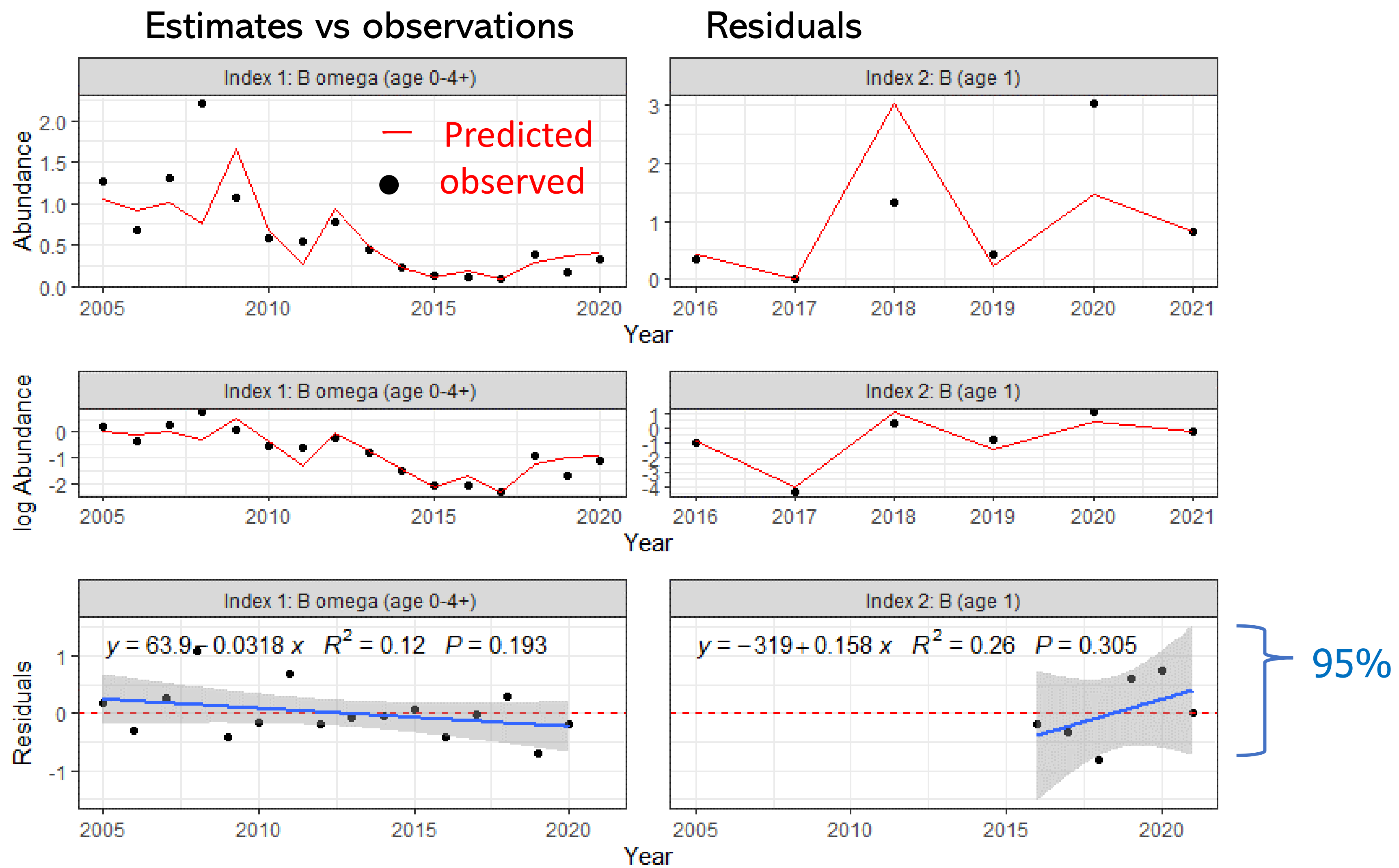
Residuals



Used λ value was 0.09

Response: (18) / Fitting of indices in SA2021

Tuning indices (abundance) Age 0-4^{+} and index for Age1(added)



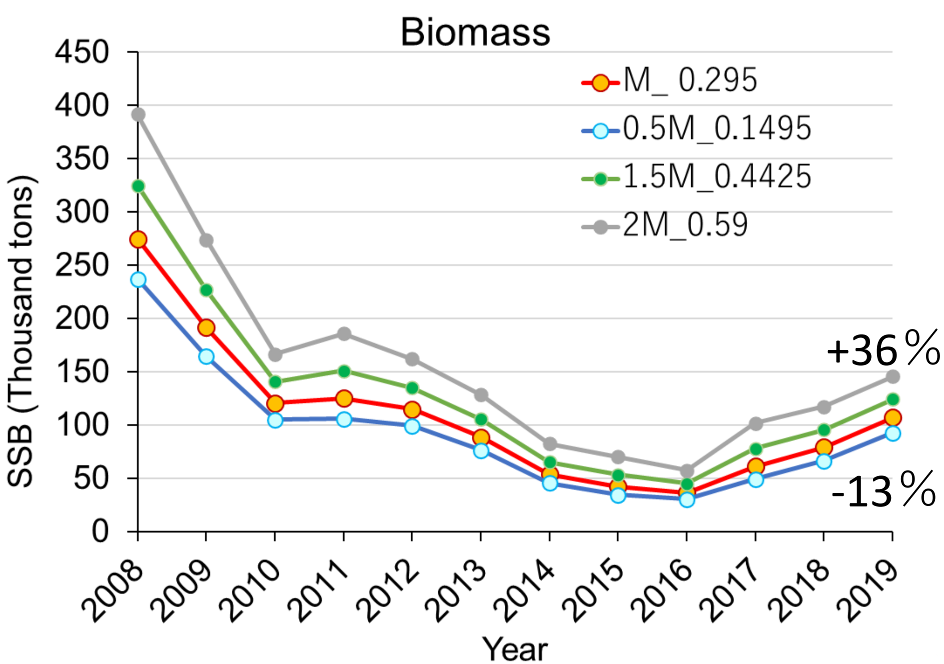
Reviewer's Comment (19)

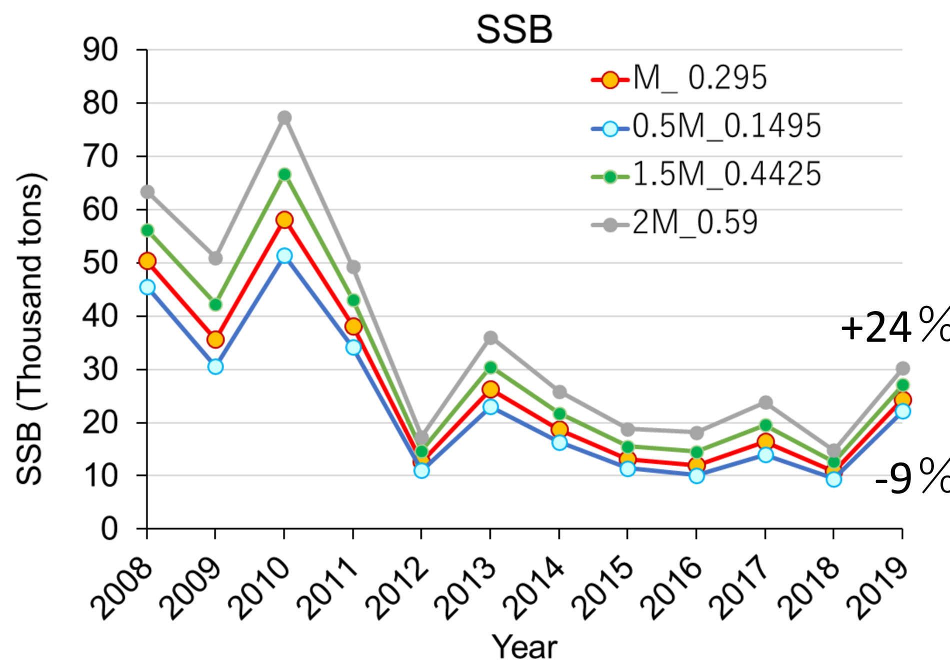
Are uncertainly estimates available for the annual abundance indices? Standard errors of the annual survey estimates could potentially be used as relative weights for individual years in the tuning process, and otherwise help with interpretation of trends over time and/ or interannual variability. The offshore bottom trawl CPUE was standardized using a generalized liner model (GLM), so estimates of uncertainly for year effects can be calculated from the GLM outputs. These could be used when calculating the negative log-likelihood in the tuning procedure, but it was not clear whether the authors took this approach or not. Diagnostics for the linear model (e.g. selection of covariates, residual plot, etc.) would be helpful to better understand the quality of the fit.

Response(19)：We did not use the information of standard errors of estimates GLM CPUE in SA2020. We would like to try to conduct by the next full stock assessment.

Response: (20)/ Sensitivity test (M) for this stock

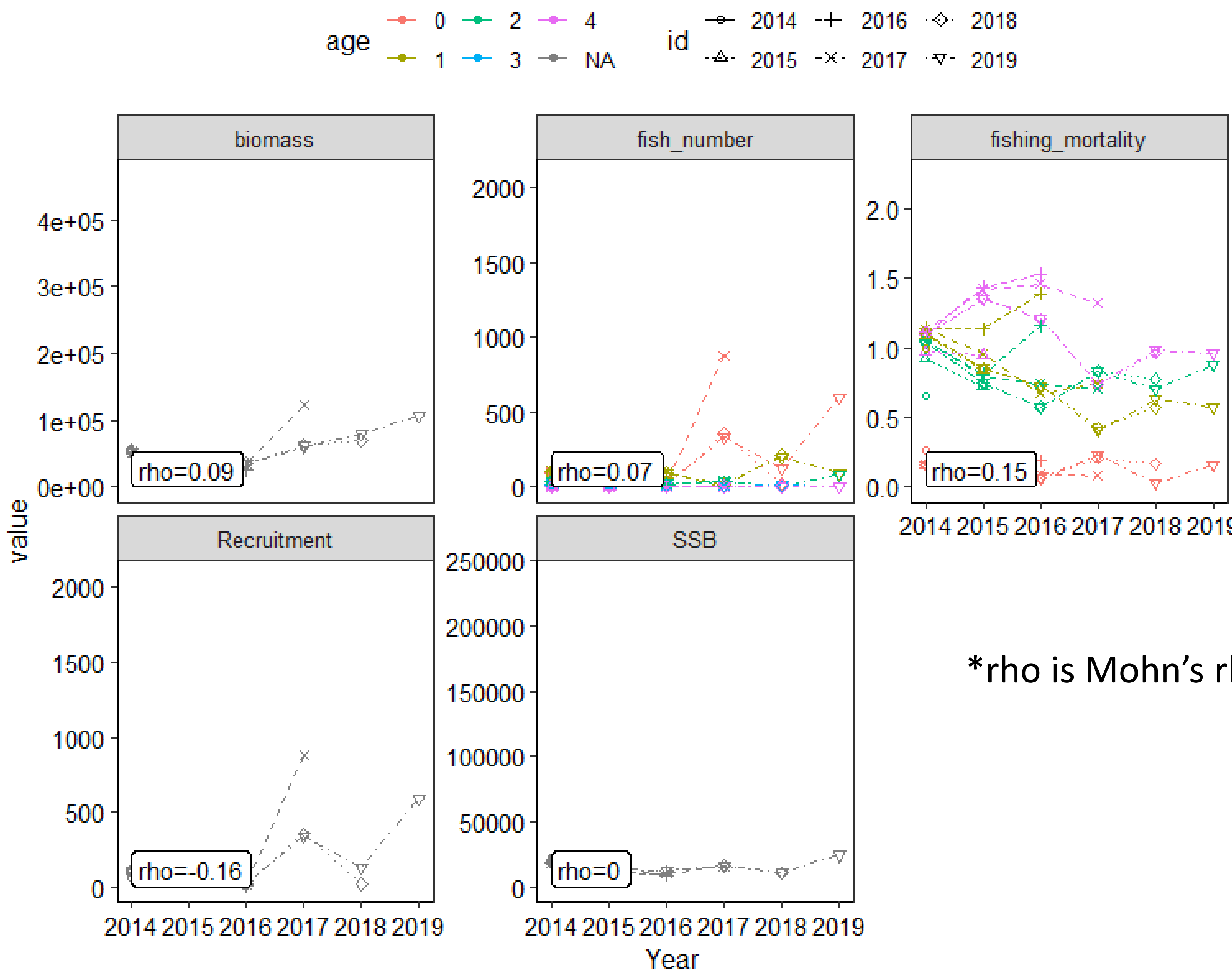
The natural mortality rate (M) is assumed to be 0.295 per year for all ages. Based on the reported longevity (8 or 9 years), M estimates based on ~5/ A_{max} would be closer to 0.5 per year. However, since M is not known with precision and affects estimates of F (and therefore abundance), model runs with alternative values for M would help managers understand risk associated with uncertainty in M





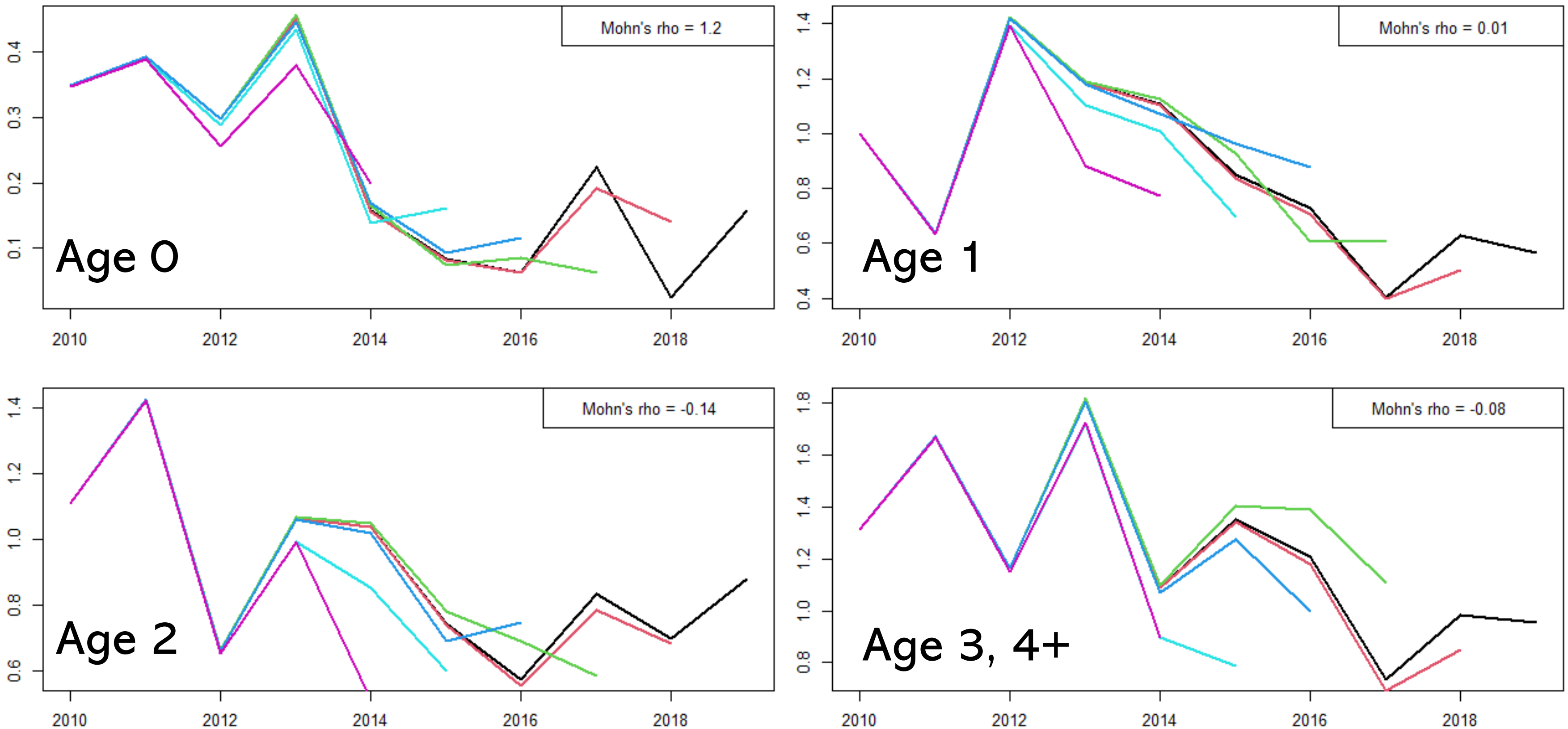
- Our institute just starts the discussion about the natural mortality.
- We have conducted the sensitivity test about the natural mortality. When the natural mortality changes (0.5×M~2×M), the Biomass and SSB in 2019 differ from-13%～36%,-9%~24% respectively.

Retrospective analysis

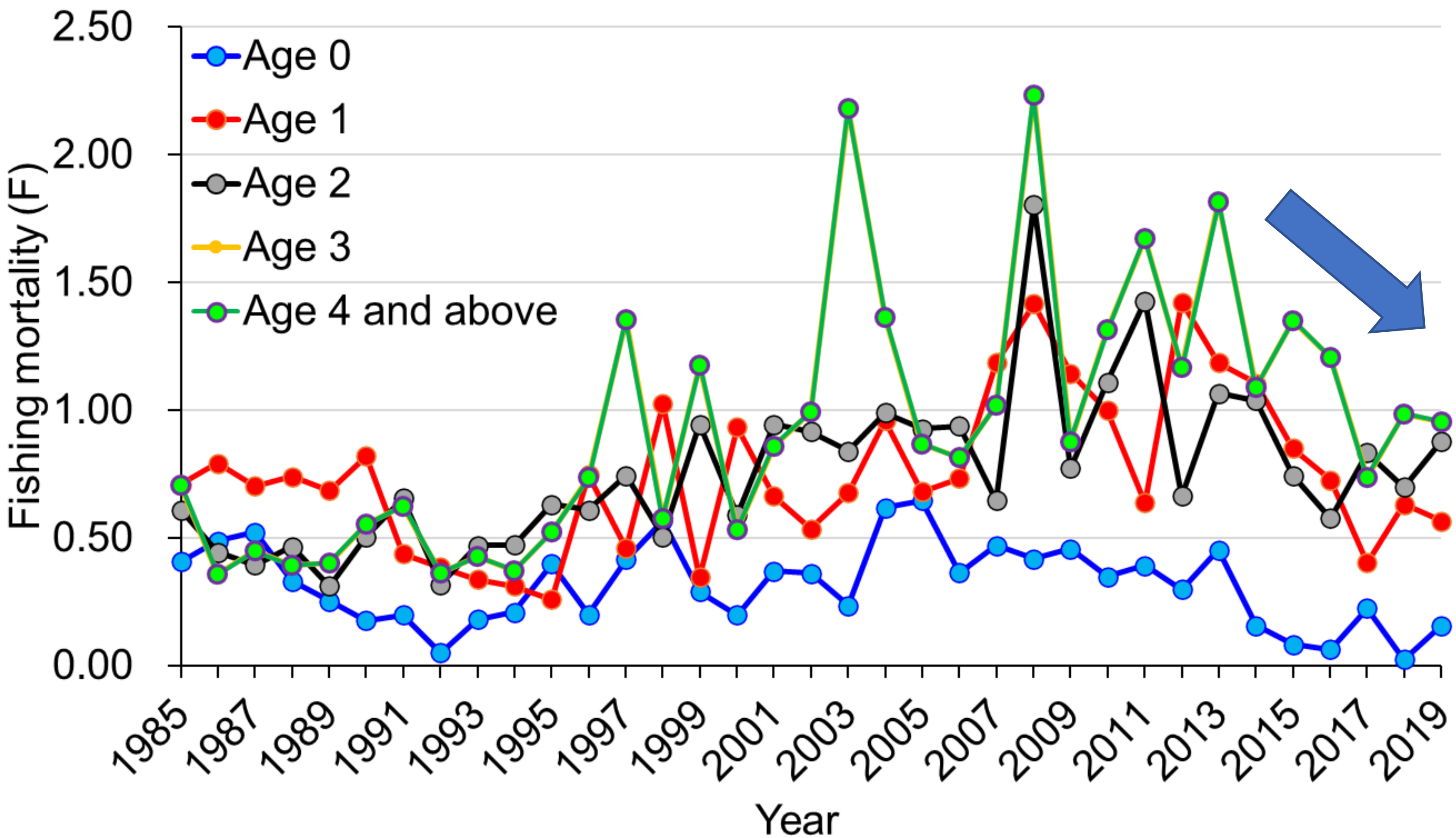


*rho is Mohn's rho

Retrospective analysis
(Fishing mortality at age)

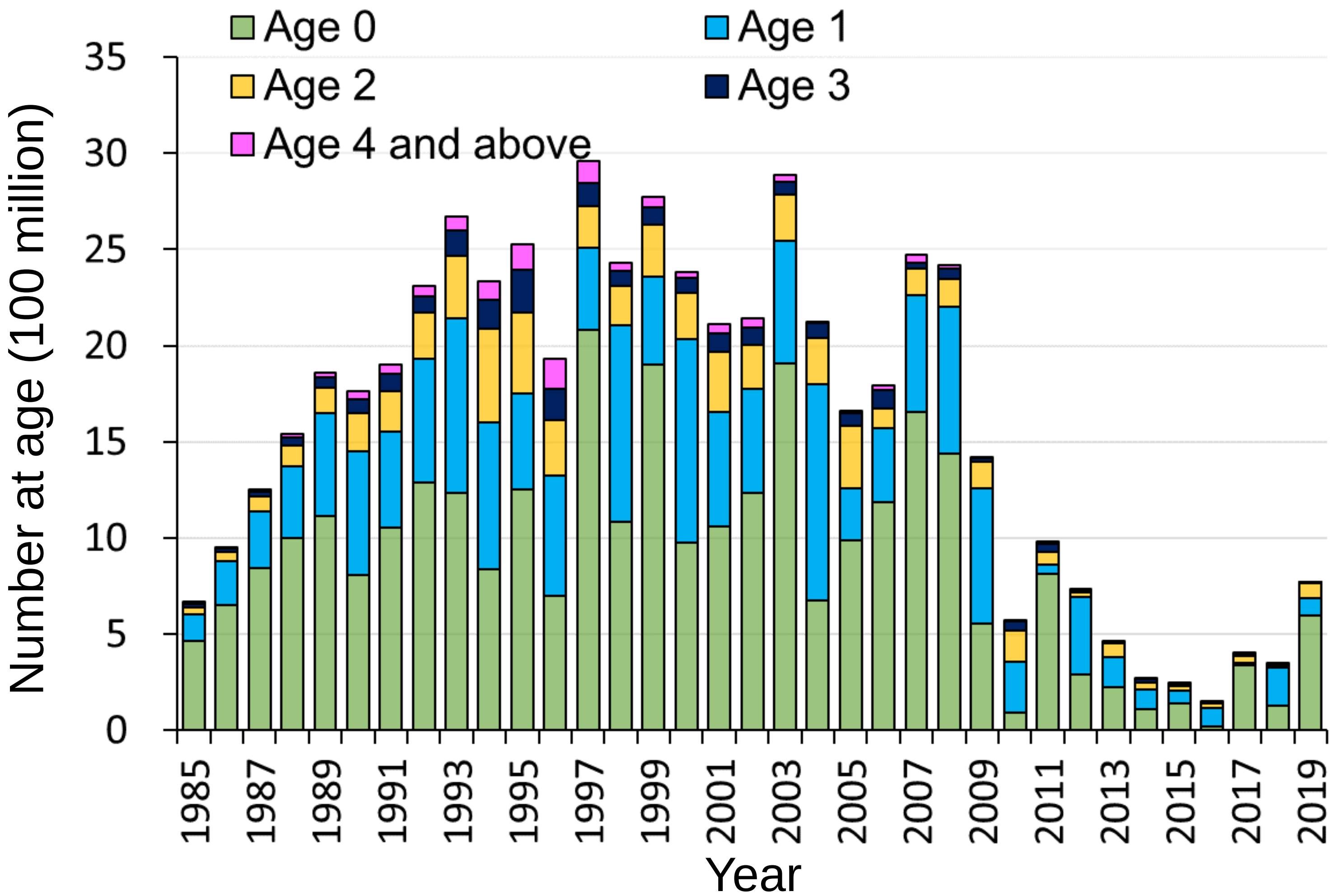


Fishing mortality at age

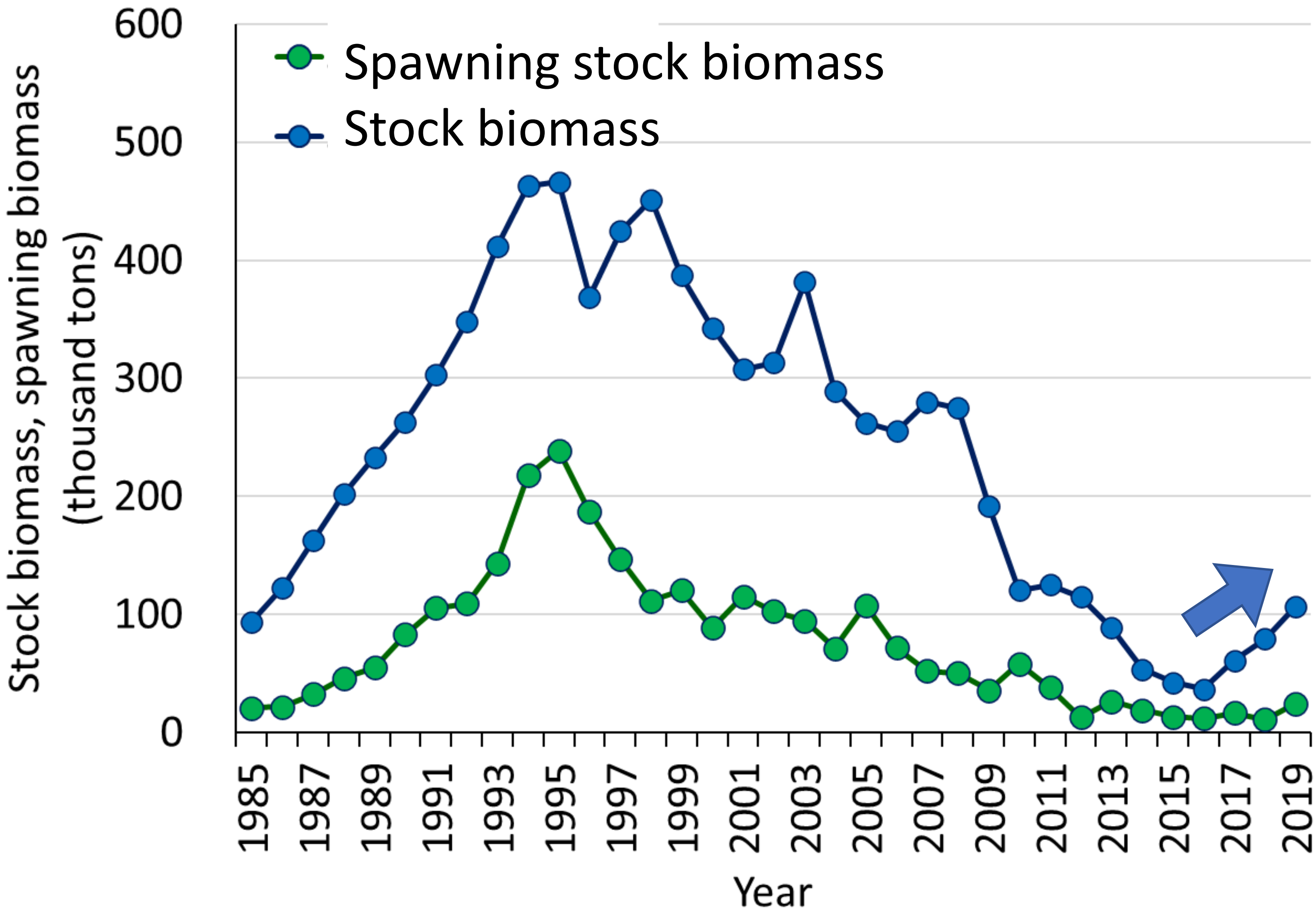


Fishing mortality is highest in 2008, then decreased since 2013
Voluntary restraints on fishing started in 2012 (continued)

Number at age



Stock biomass and SSB



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Reviewer's Comment (16)

There was no discussion of alternative stock-recruitment relationships or model selection procedure for this stock.

Alternative stock recruitment models may produce very different management reference points,

and an exploration of alternative models seems warranted to better characterize uncertainty in stock projections and reference points.

Response (16) : model selection and reference points

・We discussed stock- recruitment relationships and model selection for this stock in the Research Institute Meeting on Reference points (Apr. 2019).

Stock-Recruitment Relationship

(proposed temporarily by the Research Institute Meeting in Apr. 2019)

◆Dataset for S-R relationship

SSB & Recruitment values (1985 - 2017)

◆Estimate parameters

1) Stock-Recruitment Relationship

→ Hockey-stick (HS), Ricker (RI), Beverton-Holt (BH)

2) Optimization methods

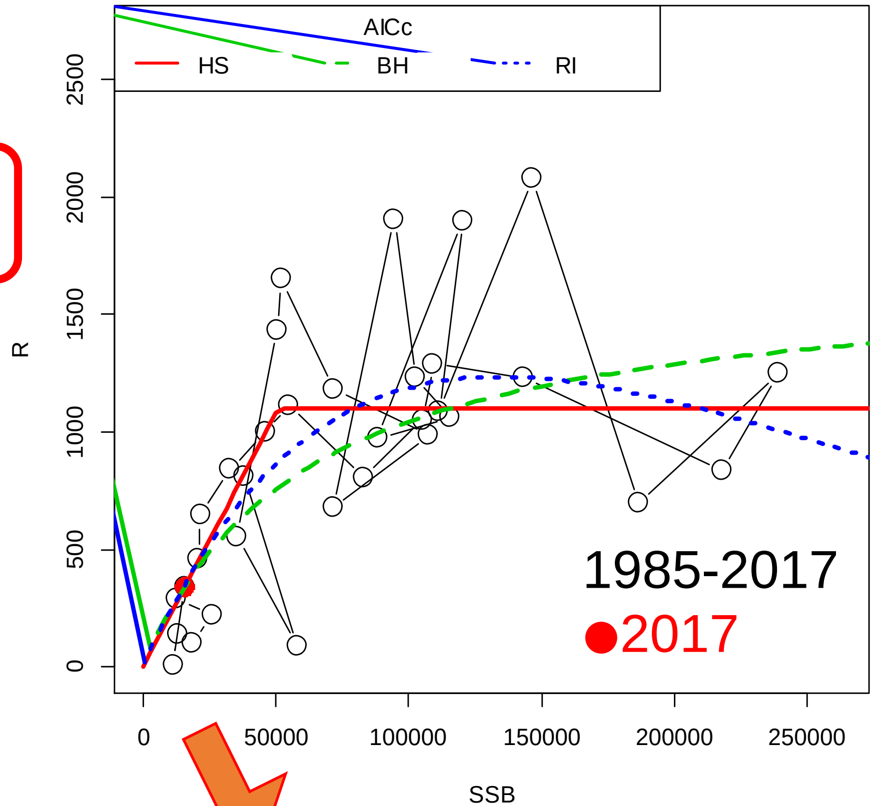
least absolute value method (L1), least square method (L2)

Response (16) : model selection and reference points

Stock-Recruitment Relationships

S-R rel.	Optimization method	AICc	ΔAIC	Lank ΔAIC	S.D.
HS	L1	64.2	0	1	0.620
RI	L1	67.8	3.6	2	0.655
BH	L1	69.5	5.4	3	0.673
HS	L2	81.0	16.8	4	0.744
RI	L2	82.4	18.2	5	0.760
BH	L2	83.0	18.9	6	0.768

- We selected HS least absolute value method (L1).



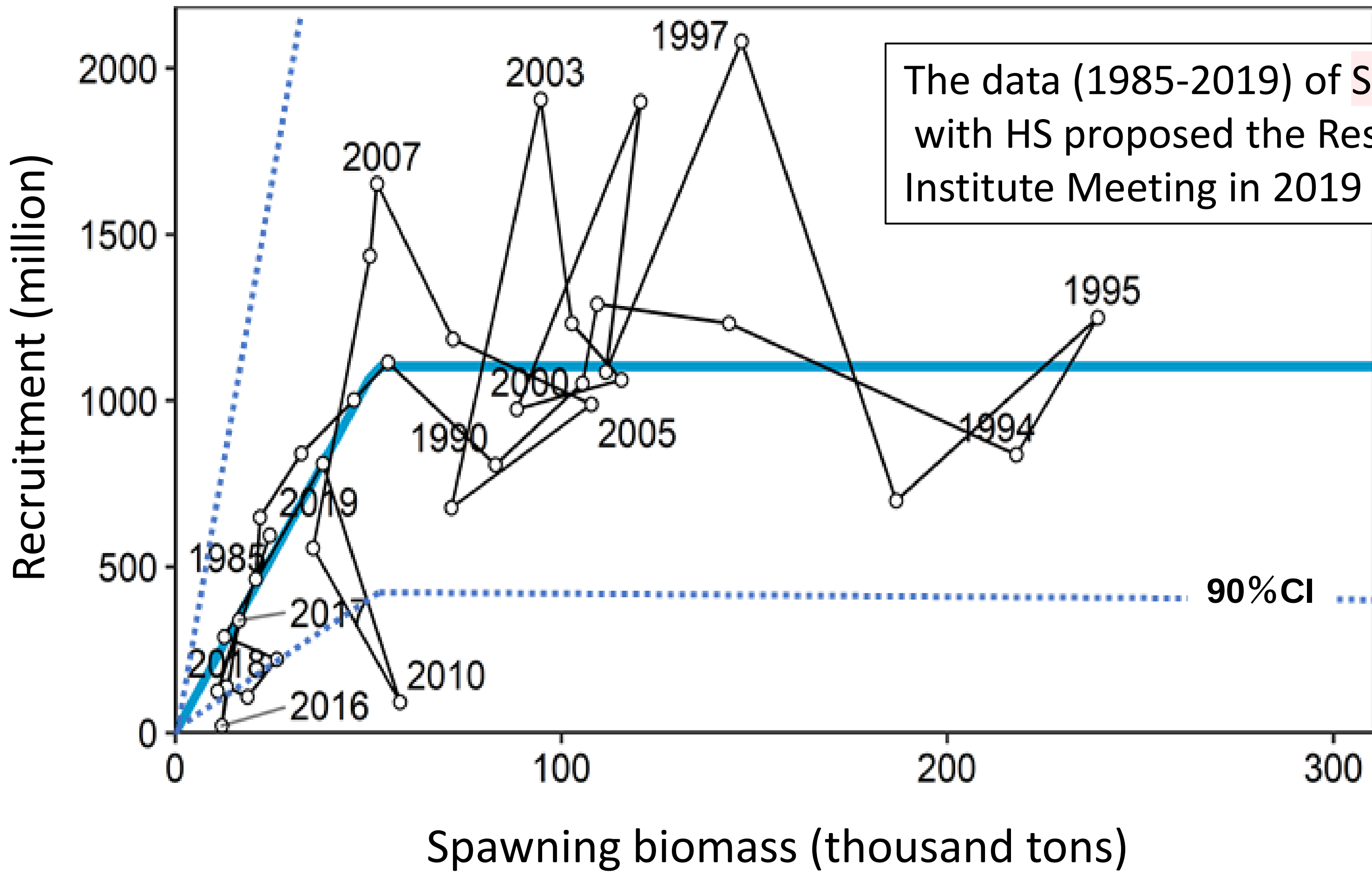
SR.relationship	AR.type	L.type	AICc	delta.AIC	SBmsy	SBlimit	SBban
HS	0	L1*	64.2	0.0	112	34	5
RI	0	L1*	67.8	3.6	136	39	4

*Least absolute value method

(Thousand tons)

Stock-Recruitment Relationship

S-R relationship	Optimization method	Autocorrelation	a	b	S.D.
Hockey Stick	Least absolute value method	No	**0.022**	**51,051**	**0.620**



The data (1985-2019) of SA2020 with HS proposed the Research Institute Meeting in 2019

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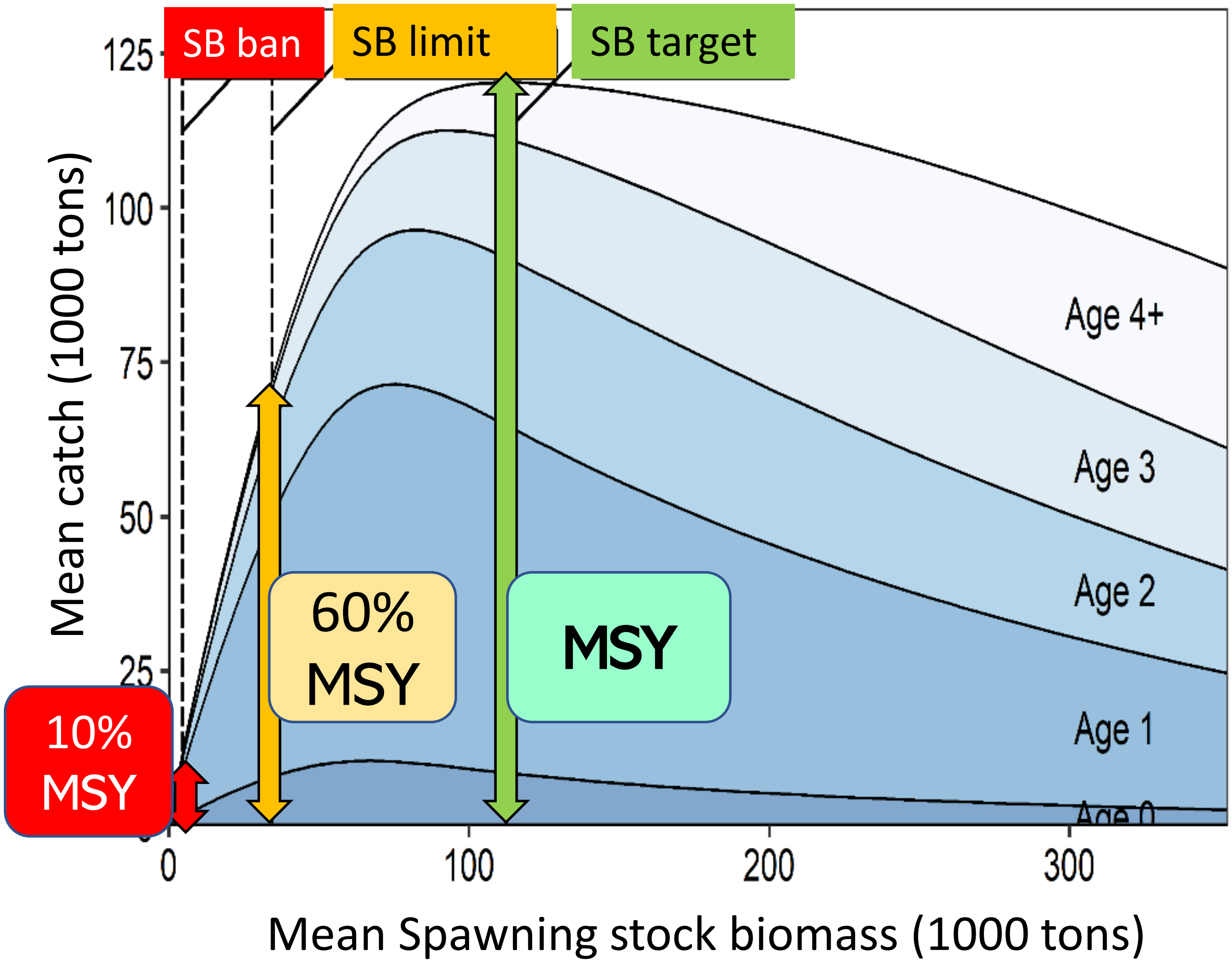
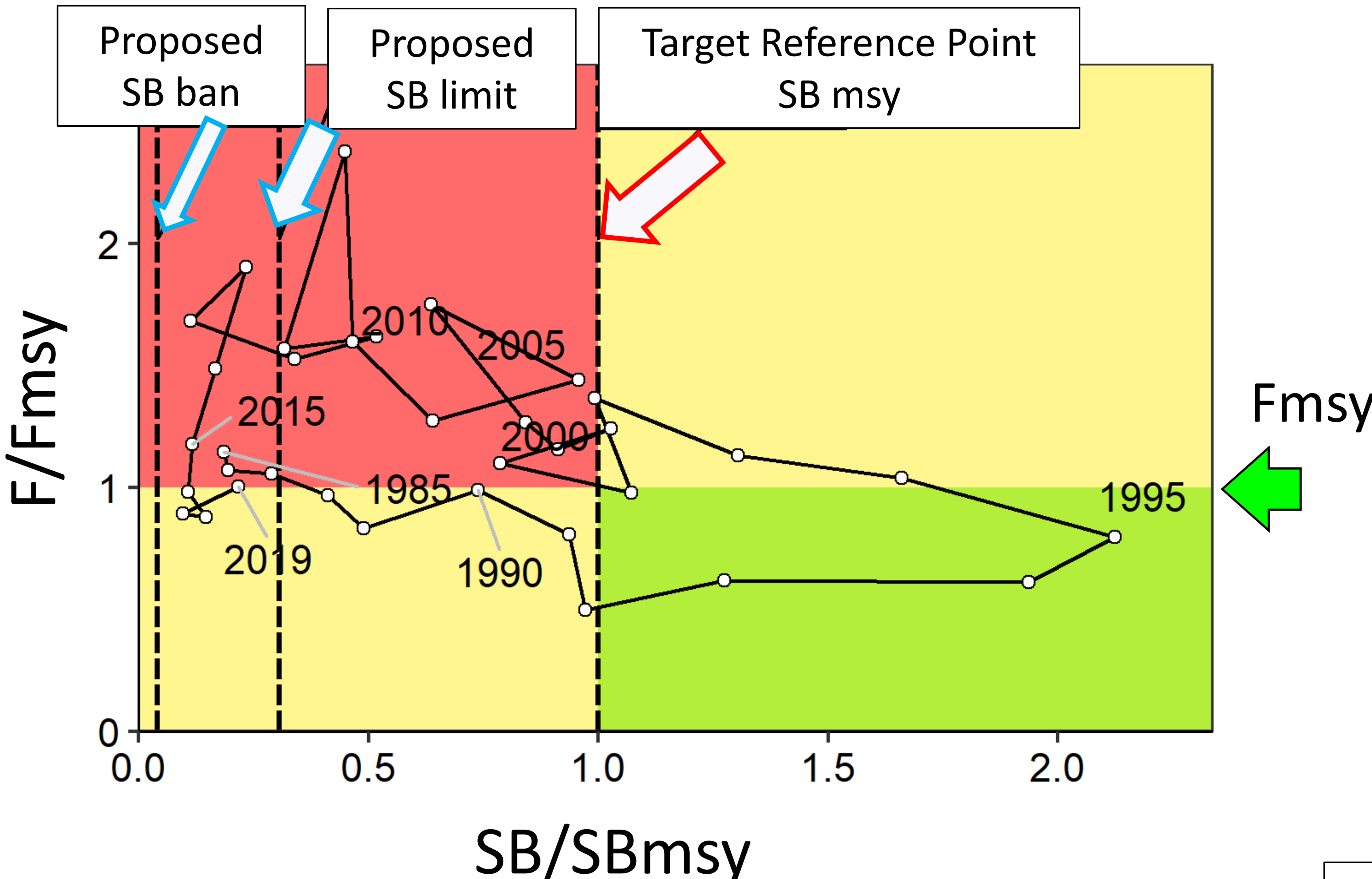
Proposed Reference Points



Reference point	SSB (1000 tons)
SBmsy	112
SBlimit	34
SBban	5

Kobe plot



Proposed
SB ban
Proposed
SB limit
Target Reference Point
SB msy
F/Fmsy
2
1
0
2010
2005
2015
2000
1985
1995
2019
1990
Fmsy
0.0
0.5
1.0
1.5
2.0
SB/SBmsy

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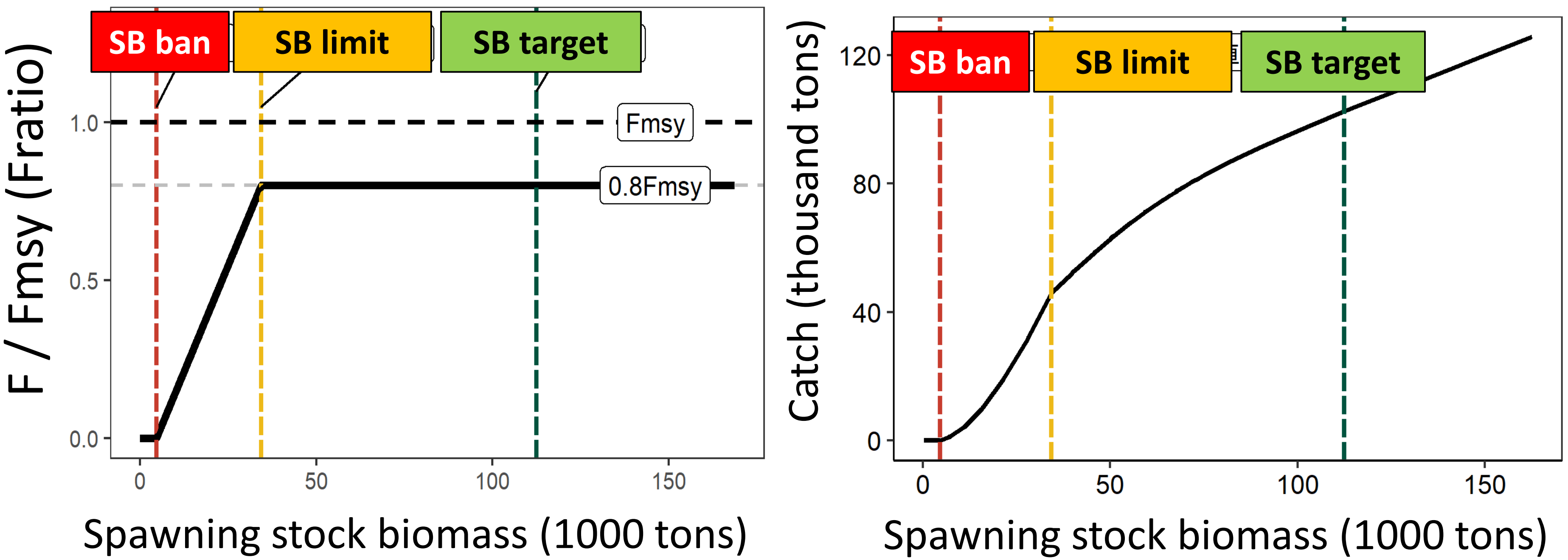
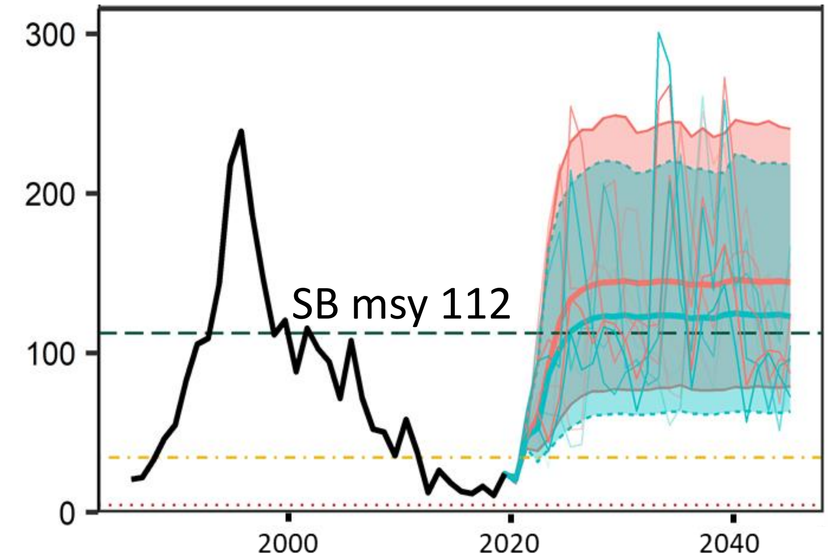
Harvest Control Rule

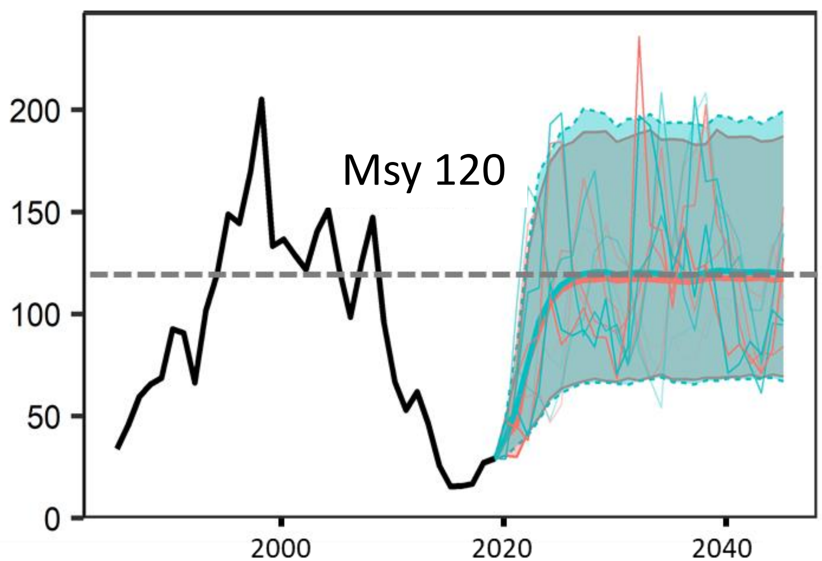


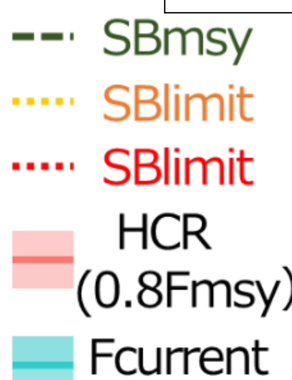
Future Projection

SSB（1000 tons）



Catch（1000 tons）





Probability of spawning biomass in 2031 being above the reference points (%)

β	SB limit	SB target	Catch in 2020
1	100%	39%	55
0.9	100%	55%	51
0.8	100%	70%	46
0.7	100%	84%	42
0.6	100%	93%	37
0.5	100%	98%	32
0.4	100%	100%	26
0.3	100%	100%	20
0.2	100%	100%	14
0.1	100%	100%	7
0	100%	100%	0
Fcur	100%	51%	55

Future Projection: Probability

Probability (%) of future SSB exceeding the SBtarget

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1	0	0	1	12	24	32	35	39	38	39	40	39	40	40
0.9	0	0	1	18	35	46	50	53	53	54	56	55	55	55
0.8	0	0	2	23	48	60	65	68	70	69	70	70	72	70
0.7	0	0	3	31	61	75	80	82	83	83	83	84	85	84
0.6	0	0	4	41	73	86	90	92	93	94	93	93	94	94
0.5	0	0	6	51	83	93	96	98	98	98	98	98	99	99
0.4	0	0	8	62	91	98	99	100	100	100	100	100	100	100
0.3	0	0	10	73	96	100	100	100	100	100	100	100	100	100
0.2	0	0	13	82	99	100	100	100	100	100	100	100	100	100
0.1	0	0	17	90	100	100	100	100	100	100	100	100	100	100
0	0	0	23	95	100	100	100	100	100	100	100	100	100	100
Fcurr	0	0	2	20	32	42	46	49	50	50	51	51	52	51

Probability (%) of future SSB exceeding the SBlimit

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1	0	100	95	97	99	100	100	100	100	100	100	100	100	100
0.9	0	100	98	99	100	100	100	100	100	100	100	100	100	100
0.8	0	100	99	99	100	100	100	100	100	100	100	100	100	100
0.7	0	100	100	100	100	100	100	100	100	100	100	100	100	100
0.6	0	100	100	100	100	100	100	100	100	100	100	100	100	100
0.5	0	100	100	100	100	100	100	100	100	100	100	100	100	100
0.4	0	100	100	100	100	100	100	100	100	100	100	100	100	100
0.3	0	100	100	100	100	100	100	100	100	100	100	100	100	100
0.2	0	100	100	100	100	100	100	100	100	100	100	100	100	100
0.1	0	100	100	100	100	100	100	100	100	100	100	100	100	100
0	0	100	100	100	100	100	100	100	100	100	100	100	100	100
Fcurr	0	100	90	98	99	100	100	100	100	100	100	100	100	100

Future Projection: SSB and Catch

SSB（10³ton）

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1	21	47	52	76	93	101	105	108	110	110	111	110	111	110
0.9	21	47	55	84	105	116	121	124	126	126	127	125	127	126
0.8	21	47	59	92	120	134	139	143	144	145	145	144	145	144
0.7	21	47	63	102	136	153	161	165	166	167	168	166	168	166
0.6	21	47	67	113	154	176	186	191	193	194	195	194	195	194
0.5	21	47	71	125	174	203	215	223	226	228	229	228	230	228
0.4	21	47	76	138	197	234	251	262	268	270	273	271	274	272
0.3	21	47	81	153	224	271	296	311	320	325	329	328	332	330
0.2	21	47	86	170	254	314	350	373	388	397	404	404	412	410
0.1	21	47	92	188	290	367	418	454	478	494	507	511	528	527
0	21	47	98	209	331	431	503	558	599	628	653	666	713	715
Fcurr	21	47	53	86	103	114	118	122	123	123	124	122	124	123

Catch (10³ton)

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1	39	55	84	96	108	113	116	118	118	119	118	119	119	119
0.9	39	51	81	95	107	113	116	118	118	119	117	118	118	119
0.8	39	46	76	92	105	112	115	117	117	118	116	117	117	118
0.7	39	42	71	88	102	109	113	115	115	116	115	115	116	116
0.6	39	37	65	83	97	105	109	111	112	113	112	112	113	113
0.5	39	32	57	75	90	99	104	106	107	108	107	108	108	108
0.4	39	26	49	66	81	91	96	98	100	101	100	101	101	101
0.3	39	20	39	54	68	78	83	87	88	90	90	90	91	91
0.2	39	14	28	40	52	60	66	69	71	72	73	73	74	74
0.1	39	7	15	22	29	35	39	42	44	45	46	46	47	48
0	39	0	0	0	0	0	0	0	0	0	0	0	0	0
Fcur	39	55	76	96	108	114	118	120	121	121	119	120	121	121

Future Projection (low recruitment scenario)

Probability (%) of future SSB exceeding the SBtarget

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1	0	0	0	0	0	0	0	1	4	10	13	15	46	56
0.9	0	0	0	0	0	1	1	4	14	20	23	25	59	73
0.8	0	0	0	0	1	3	3	12	25	31	32	35	67	80
0.7	0	0	0	1	4	8	9	26	38	41	43	45	73	84
0.6	0	0	0	3	12	18	20	42	50	54	55	57	79	88
0.5	0	0	0	8	22	31	35	55	64	66	67	68	85	91
0.4	0	0	0	14	33	47	53	70	77	78	79	79	92	94
0.3	0	0	0	20	46	62	72	83	89	89	90	90	96	98
0.2	0	0	0	26	60	77	86	92	95	96	97	97	99	100
0.1	0	0	0	36	74	89	95	97	98	99	99	99	100	100
0	0	0	1	51	86	96	98	100	100	100	100	100	100	100
Fcurren	0	0	0	0	0	1	1	4	11	16	19	22	55	69

Probability (%) of future SSB exceeding the SBlimit

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1	0	100	71	66	71	68	69	76	82	82	82	83	93	95
0.9	0	100	80	74	80	78	80	84	89	89	89	90	96	97
0.8	0	100	88	81	87	87	88	90	93	93	94	95	98	99
0.7	0	100	92	85	92	94	94	95	96	97	97	97	99	99
0.6	0	100	97	91	95	97	97	98	98	99	99	99	100	100
0.5	0	100	99	95	97	98	99	99	99	100	100	100	100	100
0.4	0	100	100	98	99	99	100	100	100	100	100	100	100	100
0.3	0	100	100	100	99	100	100	100	100	100	100	100	100	100
0.2	0	100	100	100	100	100	100	100	100	100	100	100	100	100
0.1	0	100	100	100	100	100	100	100	100	100	100	100	100	100
0	0	100	100	100	100	100	100	100	100	100	100	100	100	100
Fcurren	0	100	58	68	66	66	65	72	77	77	77	78	92	95

Future Projection (low recruitment scenario)

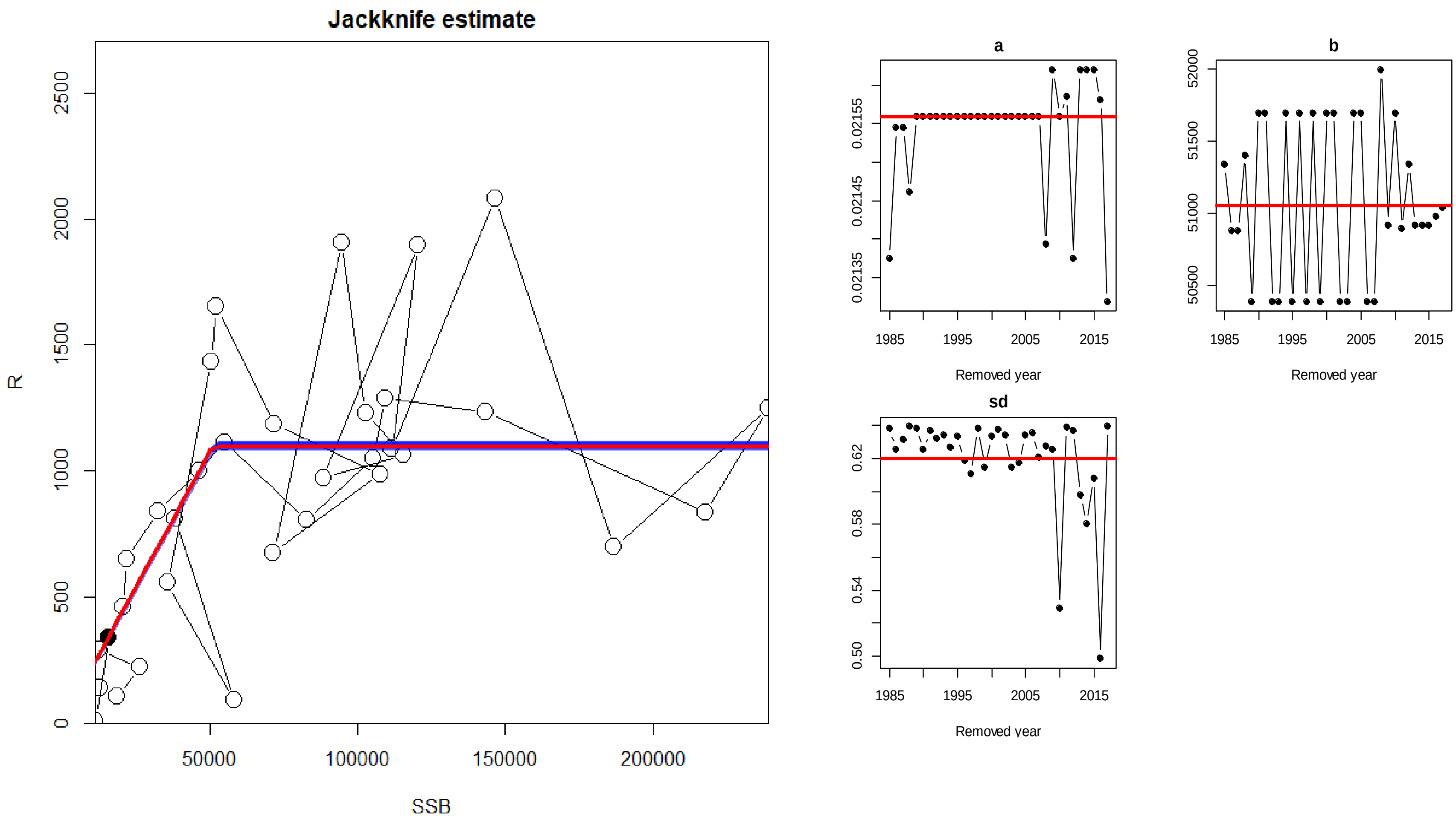
SSB（10^3ton）

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1	21	47	39	42	45	45	45	55	62	65	68	70	102	111
0.9	21	47	42	46	51	52	53	64	73	76	79	81	116	127
0.8	21	47	45	51	58	60	62	75	86	90	92	95	134	146
0.7	21	47	47	56	66	70	73	88	101	106	108	111	155	168
0.6	21	47	50	63	75	82	86	103	118	125	127	130	181	196
0.5	21	47	54	70	86	96	101	121	139	147	150	153	213	231
0.4	21	47	57	78	99	113	120	142	163	174	178	182	253	275
0.3	21	47	61	86	113	132	143	168	193	207	213	219	306	333
0.2	21	47	64	96	130	155	170	201	231	249	259	268	378	413
0.1	21	47	69	108	150	183	205	243	280	305	321	334	481	528
0	21	47	73	120	173	217	248	297	346	381	406	428	639	711
Fcurren	21	47	37	45	45	46	46	57	63	68	71	73	112	123

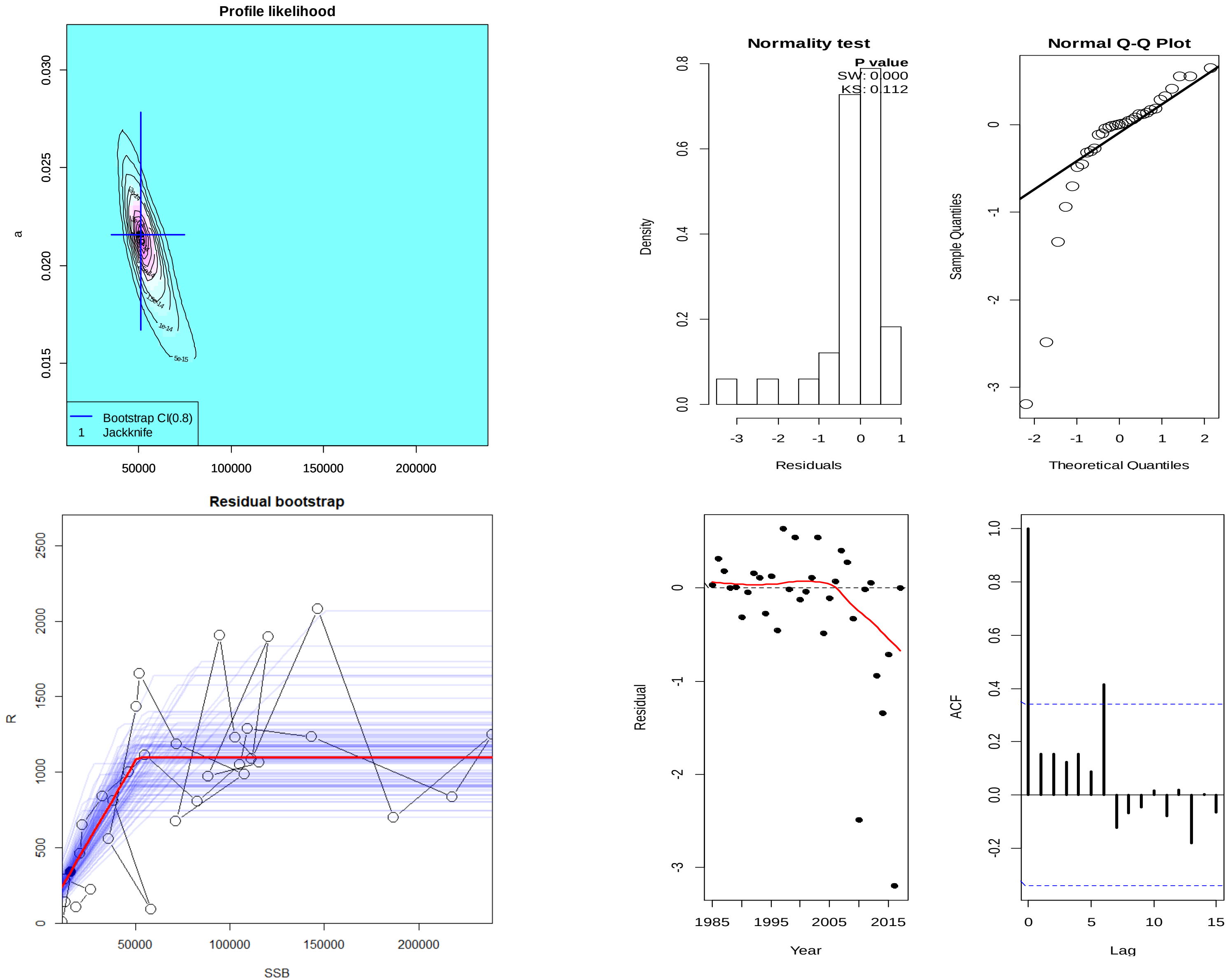
Catch (10^3ton)

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041	2051
1	37	38	47	43	45	47	55	61	68	70	74	82	109	117
0.9	37	35	45	43	47	49	58	64	70	73	76	84	110	118
0.8	37	32	43	43	47	50	60	66	72	74	77	85	110	117
0.7	37	29	41	43	47	51	60	67	72	74	77	85	109	116
0.6	37	26	38	41	46	50	59	66	71	73	76	83	106	113
0.5	37	22	34	38	44	48	57	63	68	70	73	79	102	109
0.4	37	18	29	34	40	44	52	58	63	65	68	73	95	102
0.3	37	14	23	29	34	39	45	50	55	58	60	65	85	91
0.2	37	10	17	21	26	30	35	39	44	46	48	52	69	75
0.1	37	5	9	12	15	18	21	24	26	28	30	32	44	47
0	37	0	0	0	0	0	0	0	0	0	0	0	0	0
Fcurren	37	41	42	44	45	47	54	60	65	69	72	79	110	119

Appendix 2:

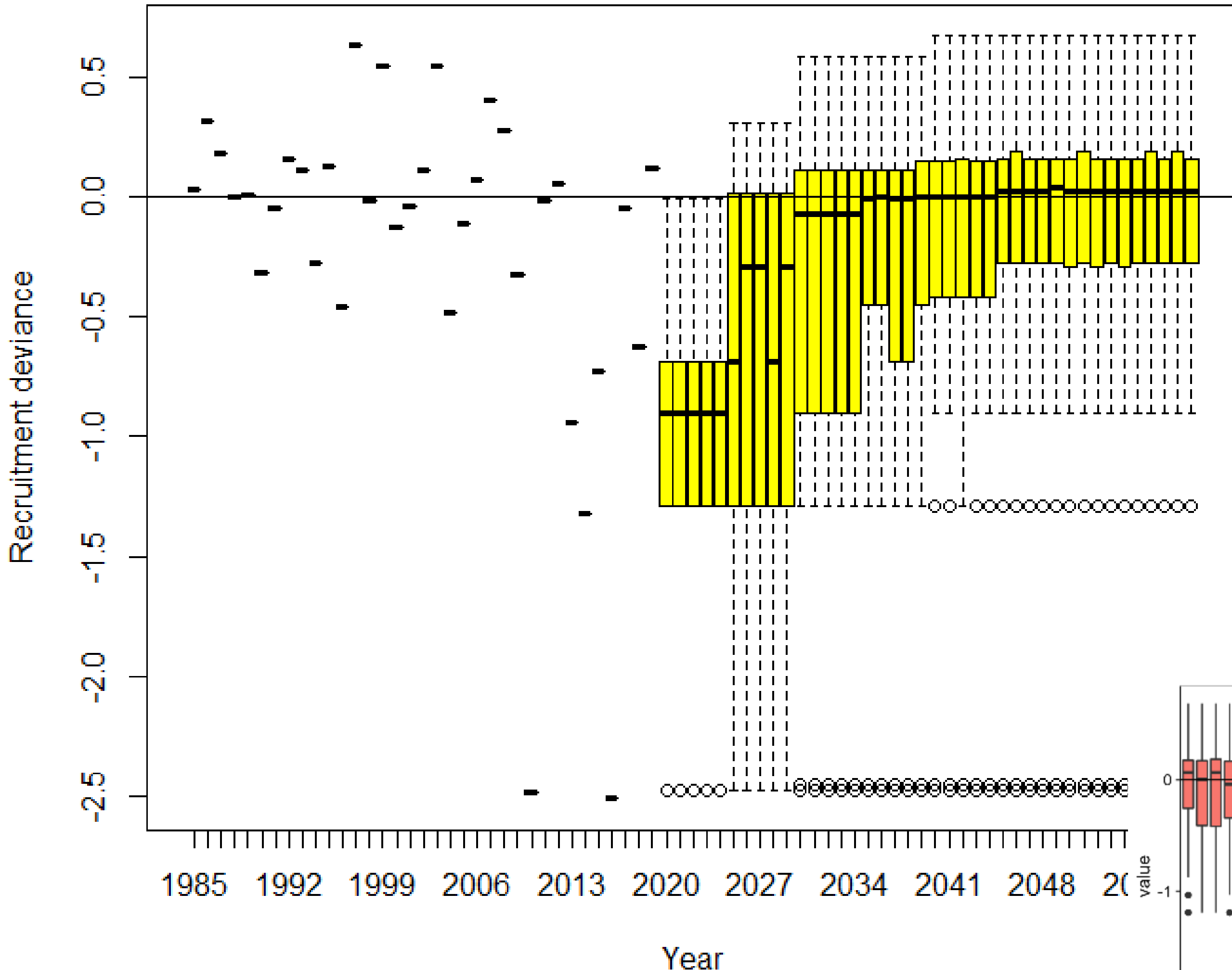

Jackknife estimate
R
SSB
0
500
1000
1500
2000
2500
50000
100000
150000
200000
a
0.02135
0.02145
0.02155
b
50500
51000
51500
52000
sd
0.50
0.54
0.58
0.62
1985
1995
2005
2015
Removed year

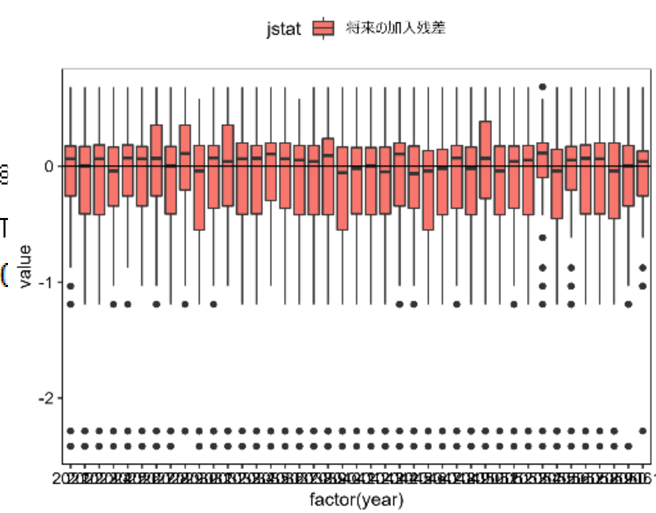
Appendix 3:



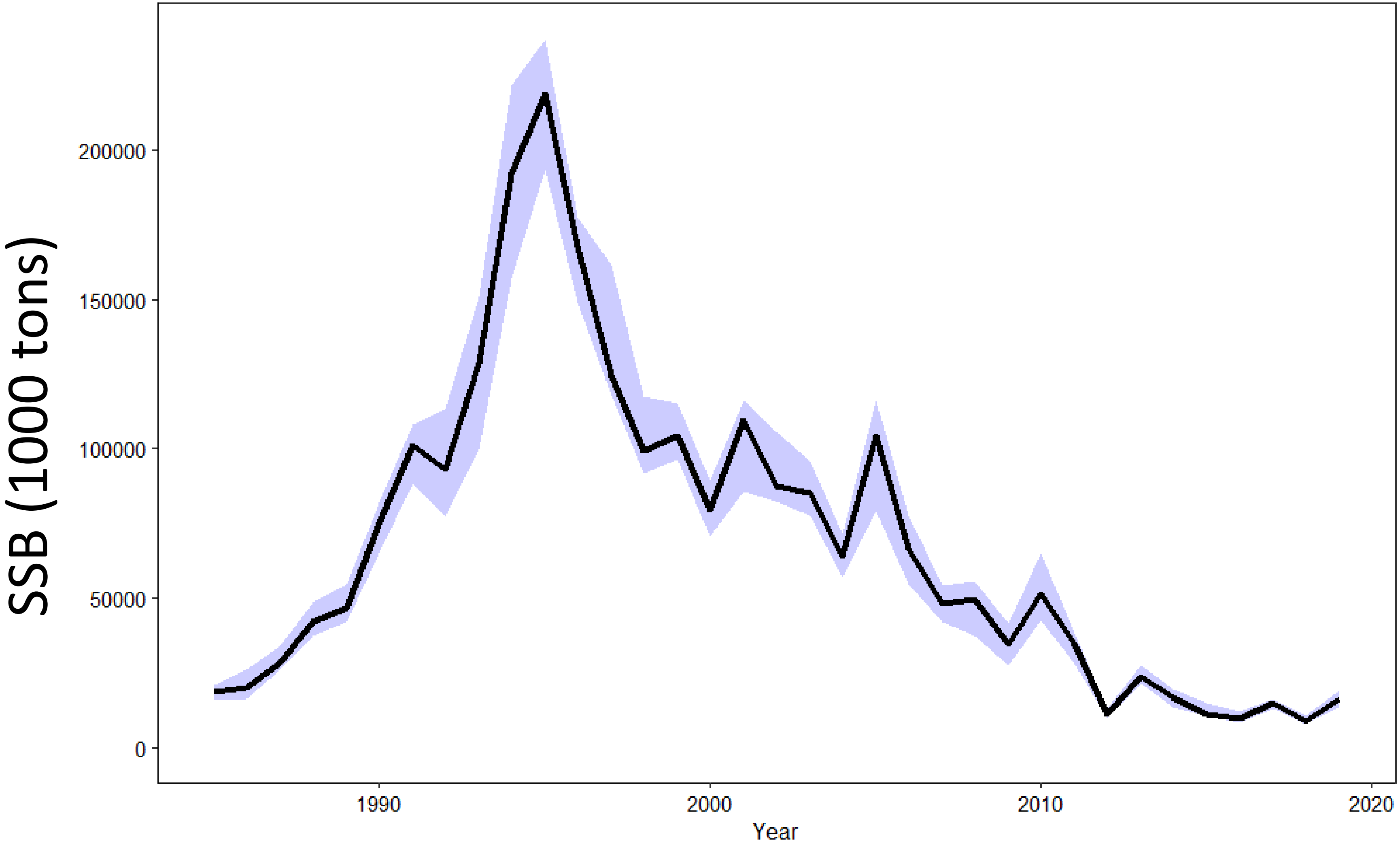
Profile likelihood
a
0.030
0.025
0.020
0.015
50000
100000
150000
200000
Bootstrap CI(0.8)
1 Jackknife
Normality test
P value
SW: 0.000
KS: 0.112
Density
Residuals
Normal Q-Q Plot
Sample Quantiles
Theoretical Quantiles
Residual bootstrap
R
SSB
Residual
Year
1985
1995
2005
2015
ACF
Lag

residuals of recruitment for prediction (low recruitment)



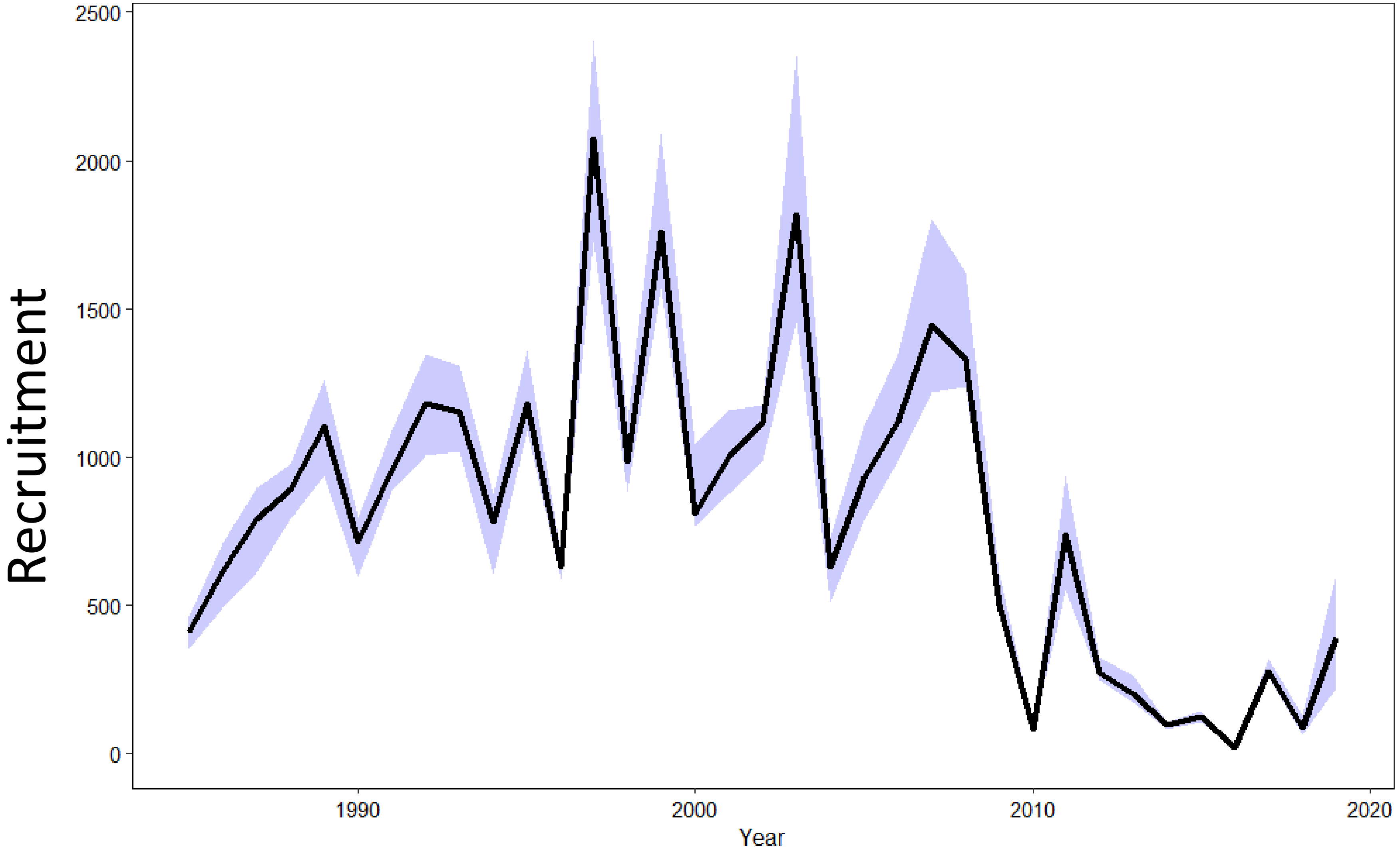


Appendix 4:



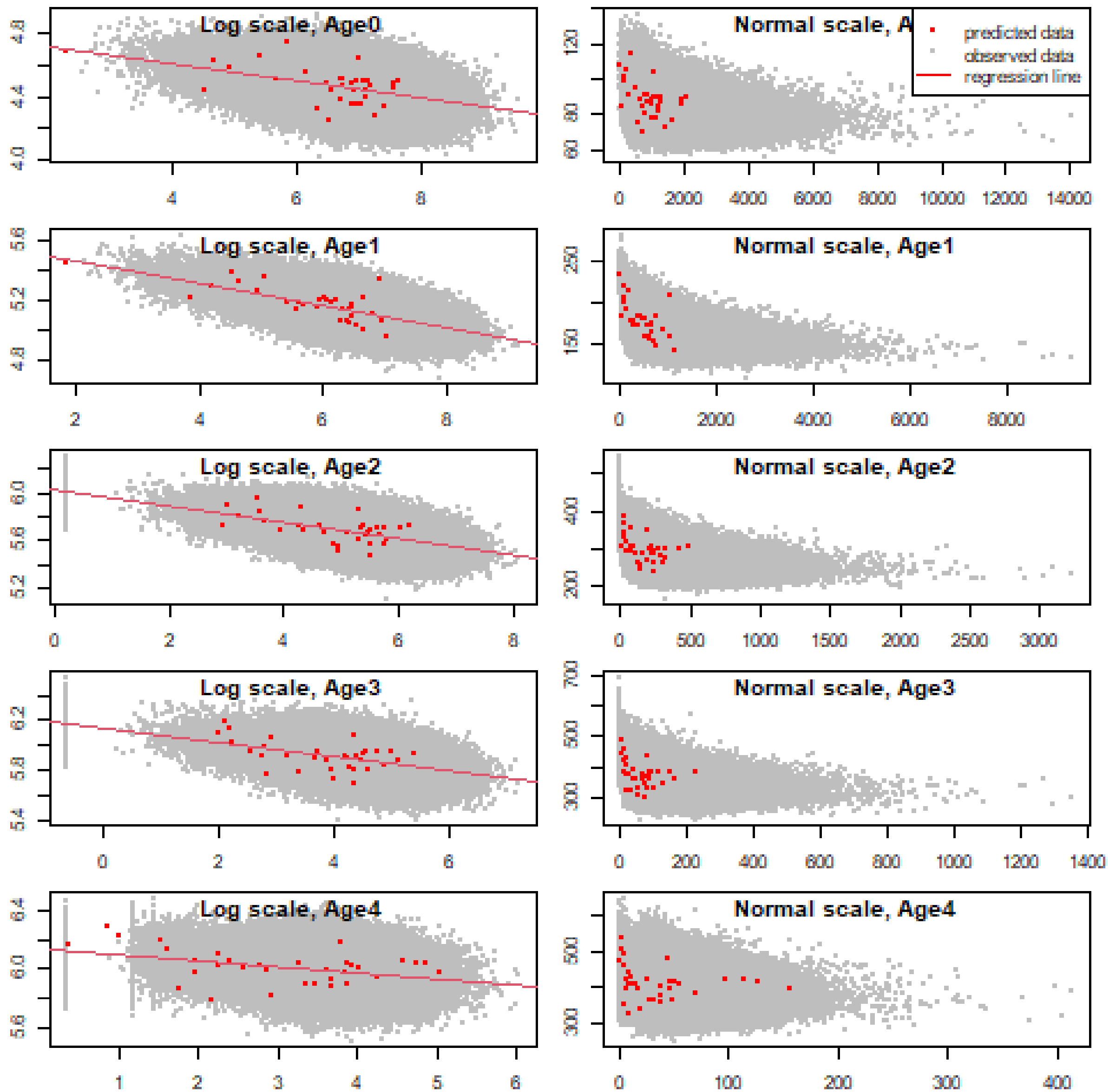
SSB (1000 tons)
200000
150000
100000
50000
0
1990
2000
2010
2020
Year

Appendix 5:



Recruitment
2500
2000
1500
1000
500
0
1990
2000
2010
2020
Year

Relationship between number of fish and body weight



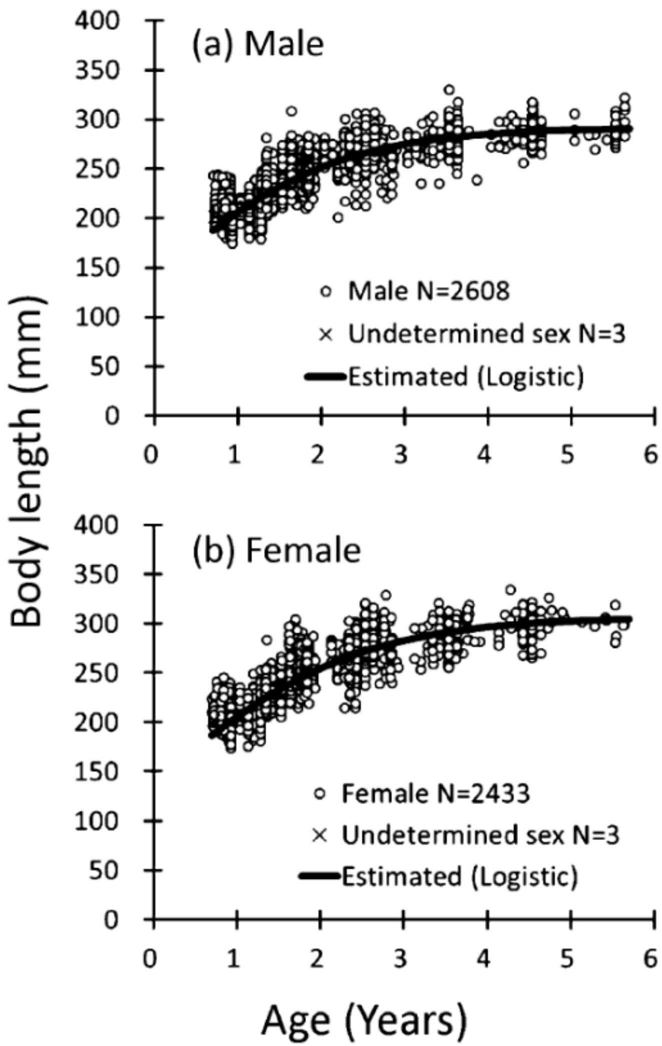
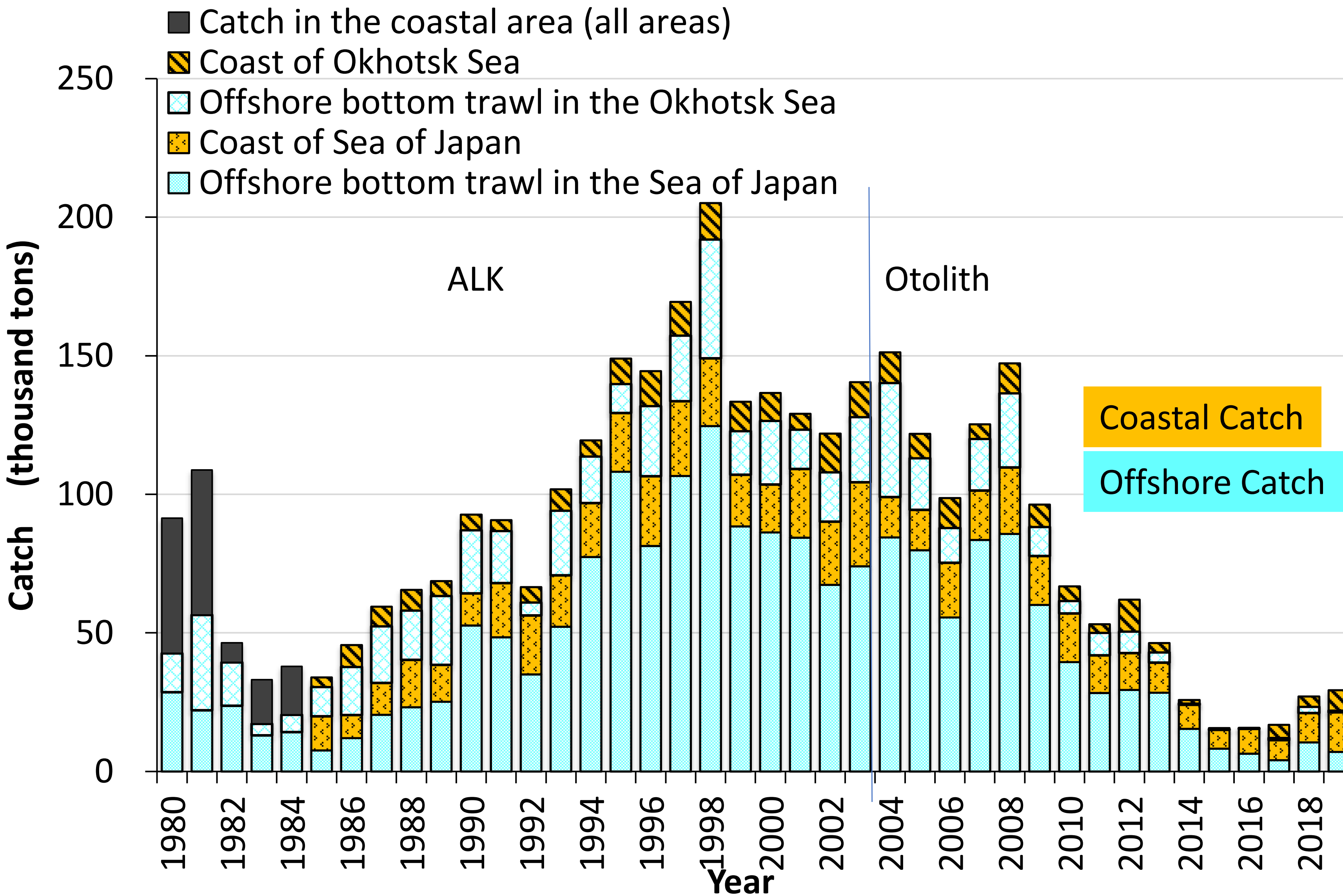


Fig. 7 Age–length relationship with the estimated logistic curves in case 1 for male (a) and female (b).

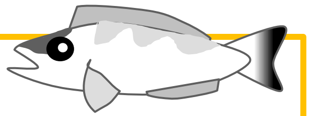
(Takashima et al. 2013)

Calculation for catch at age (CAA) of Arabesque greenling

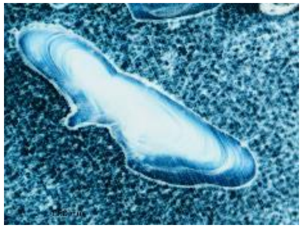


Calculation for catch in number at age (CAA) of Arabesque greenling (Central, Wakkanai and Abashiri Fisheries Research Institute)

①Sampling
for each・・・
- sea area
- fishing season
- fishery type, gear
- box type and size (large, small, mix)



②Measurement of samples
- body length(mm), fork length(mm), body weight(g), sex, etc.
- Age assessment
  observing the cross section of otolith
  (Takashima et al. 2013)



③Estimate the age composition by each box type and size for each fishery gear and fishery type (Offshore, coastal)
(Takashima 2016)

④Estimate the Catch in number at age for each fishery type and area
(Takashima 2016)

Calculation for Catch in number at age (CAA) of Arabesque greenling (Central, Wakkanai and Abashiri Fisheries Research Institute)

③Estimate the age composition by each box type and size

④Estimate the Catch in number at age for each fishery type and area

$$C_{a,k,y} = \frac{L_{0,k,y}}{\sum_t L_{k,t,y}} \sum_i \sum_t \sum_m \frac{W_{k,t,m,y}}{\overline{w}_{k,t,m,y}} n_{i,k,t,m,a,y}$$

a: age, y: year, t: term, i: length class
k: each area and fishery type
m: container type (size type)
ni: measurement number of length class (i)
$L_{0,k,y}$: Total catch in the first or second half season (term) for each K(area), Y(year)
$L_{k,t,y}$: Total catch in each area and fishery type for each K (area), t (term),y(year)
W : weight of catch
$\overline{W}$: average weight of samples

(Takashima 2016)

For example (Offshore trawl fishery for first season in2021)

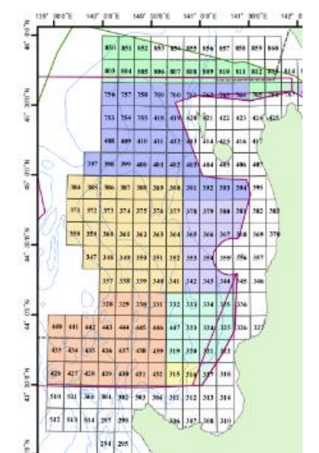
	SA ID	Fishery area	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total Catch
Offshore :Central	19	Shima	5	0	613	82	1,184	**769**			0	0	0	0	**2,653**
	18	Ohuyu	149	218	99	255	95	120			0	0	0	0	935
	17	Shakotan	0	0	0	20	0	0			0	0	0	0	20
	16	Yoichi	16	5	26	**195**	719	41			0	0	0	0	**1,001**
															5,480

ID	M/D	Ship	Mid Area	SA ID	Fishery area	FA no.	Catch(t)	Catch for M		Average weight kg	0	1	2	3	4+
1	4/29	4	Japan Sea	16	Yoichi	316	**1,681**	**195**	36%	0.247	0	0.356	0.614	0.03	4E-04
2	6/2	4	Japan Sea	19	Shima	344	**2,928**	**769**	64%	0.304	0	0.254	0.605	0.131	0.01

- Weight of Sample (each box type) / Catch (each box type) : ratio of sample for each box type
- Number of Sample (each age) for each box type/ratio of samle→Number at age→Ratio of age
- Average weight of sample (each box type) and Number at age→Average weight (weighted by sample)

Calculation of Catch at Age

- Each allocated catch(t) / Average weight (sample) →Total Number of Fish for ID
- Total Number of Fish (each ID) ✕Ratio of age→Catch Number at age



Diagnostics for the liner model

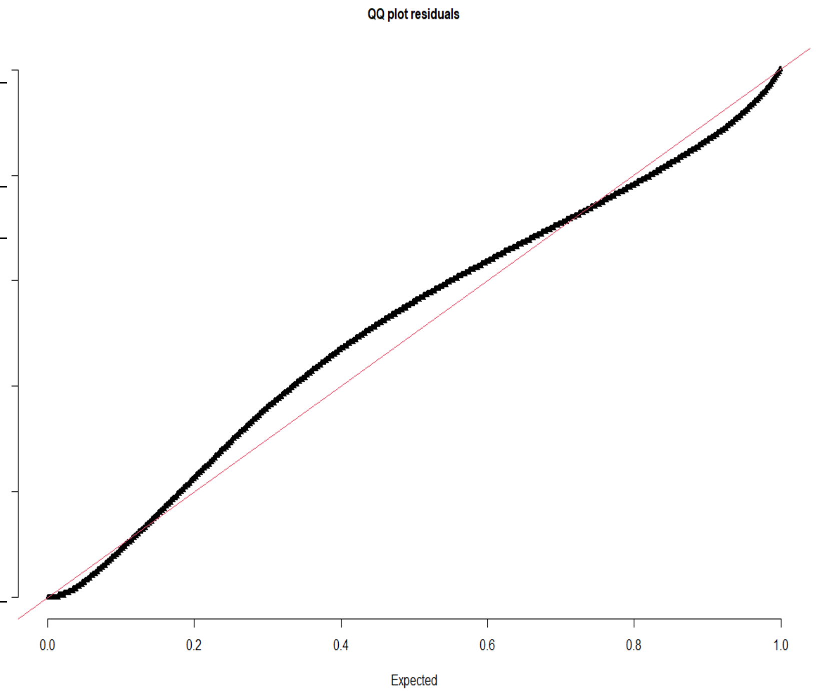
GLM model log(CPUE)=Y+M+SA+Y×M+ Y×SA

Anova Table (Type II tests)

Response: log(hokke/(1000 * num))

Sum	Sq	Df	F value	Pr(>F)
factor(Y)	41012	23	493.04	<0.0001 ***
factor(M)	8686	11	218.34	<0.0001 ***
factor(SA)	104352	12	2404.5	<0.0001 ***
factor(Y):factor(M)	19533	253	21.347	<0.0001 ***
factor(Y):factor(SA)	24361	276	24.405	<0.0001 ***
Residuals	214029	59179		

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1



	Year	Month	SA	Y×M	Y×SA	df	AIC
morel1	○	○	○	○	○	577	246970
morel2	○		○	○	○	577	246970
morel3	○	○		○	○	577	246970
morel4	○	○	○		○	324	251683
morel5	○	○	○	○		301	252860