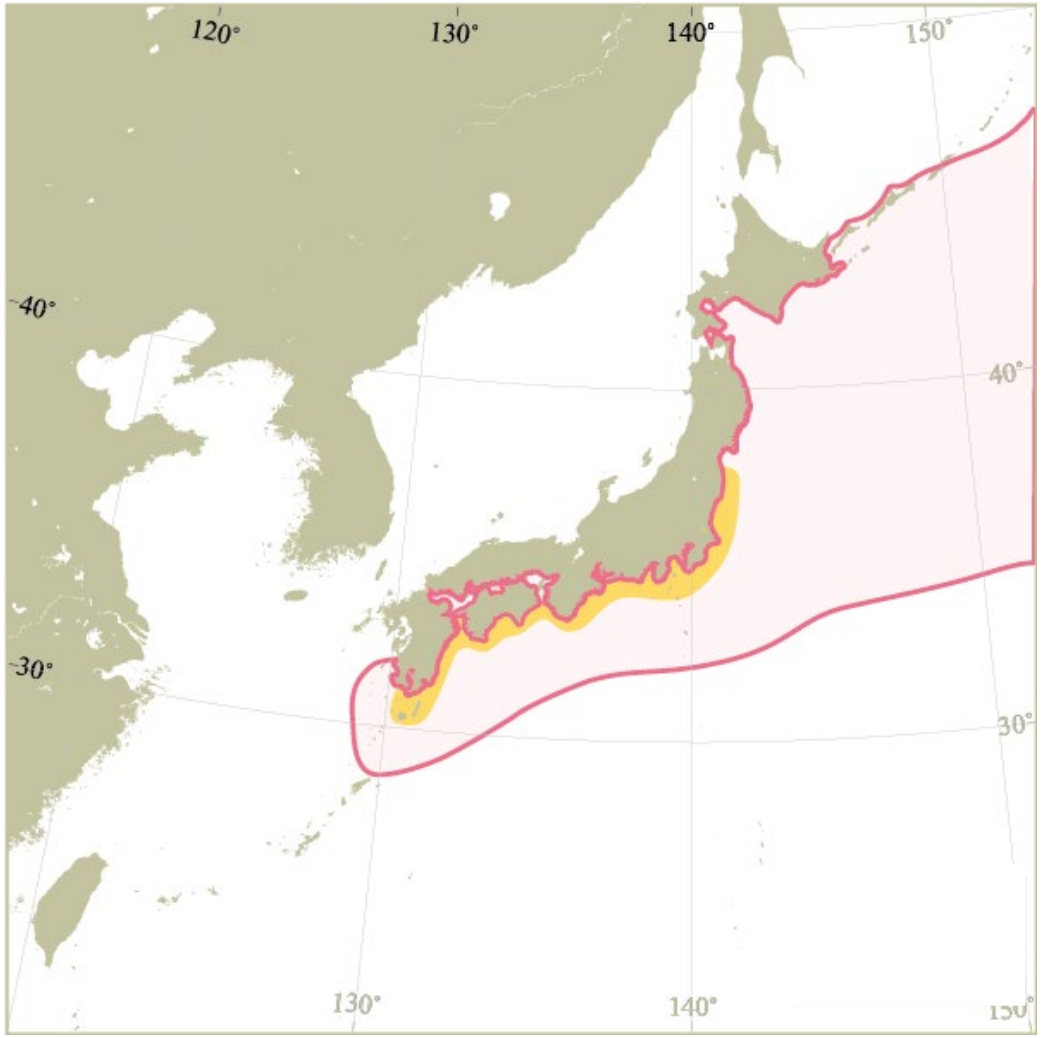
Pacific stock of Japanese sardine

Contents

- Biology and Stock assessment
  Distribution, Maturation, Natural mortality, Catch at age, Stock abundance indices, VPA
- Stock-Recruitment Relationships
- Reference points, Kobe-plot
- Harvest Control Rule, Future projection

Distribution



Distribution range

Spawning grounds

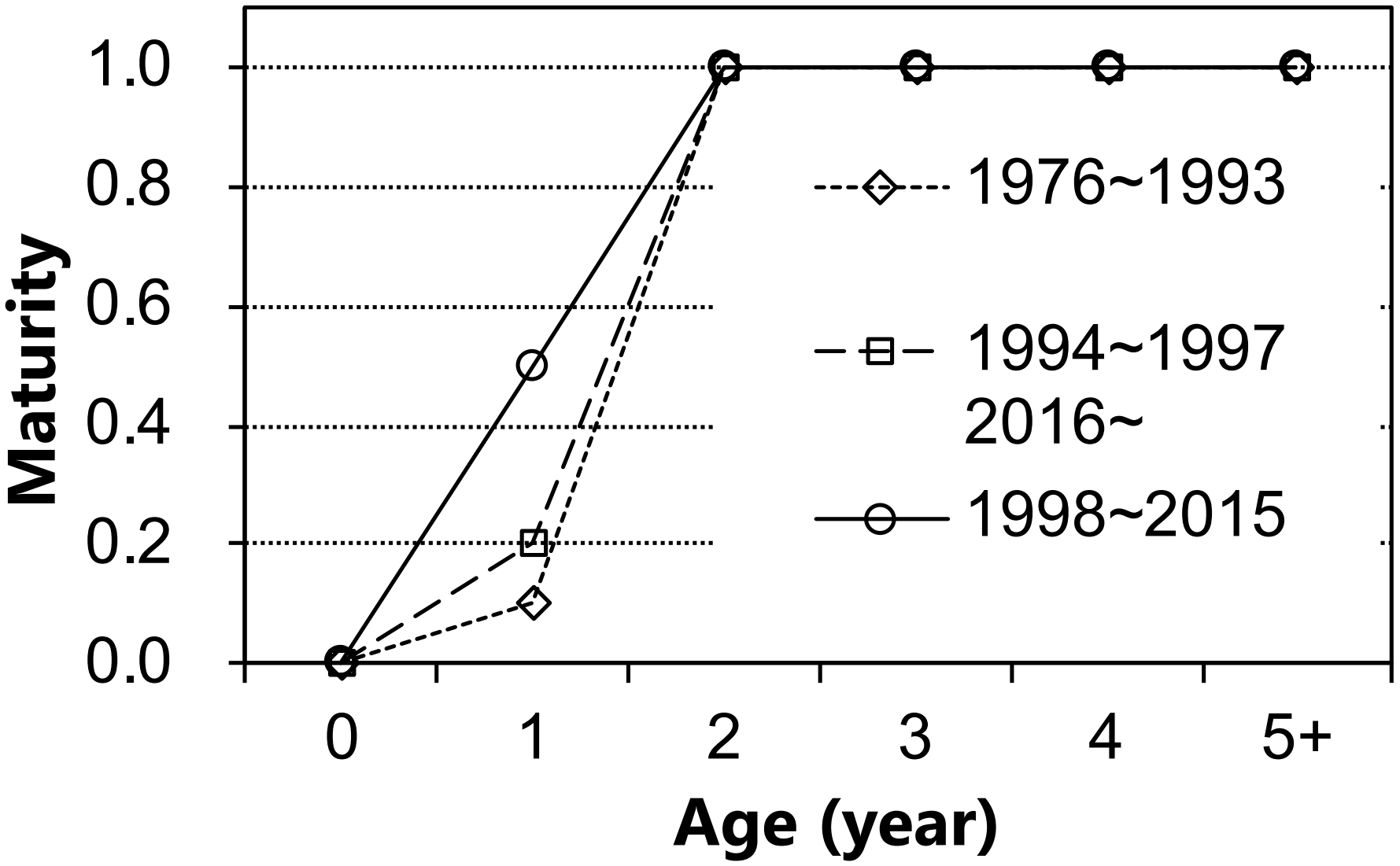
Reviewer's Comments

- Q 1: Conceptually, the offshore and coastal group are from the same spawning grounds in the Kuroshio Current, and the proportion of each cohort that goes to each group is highly variable and depends on oceanic conditions, with certain months favouring one group or the other. Is that a reasonable summary?

Response

- Yes, it is correct. Thank you for summarizing.

Maturity



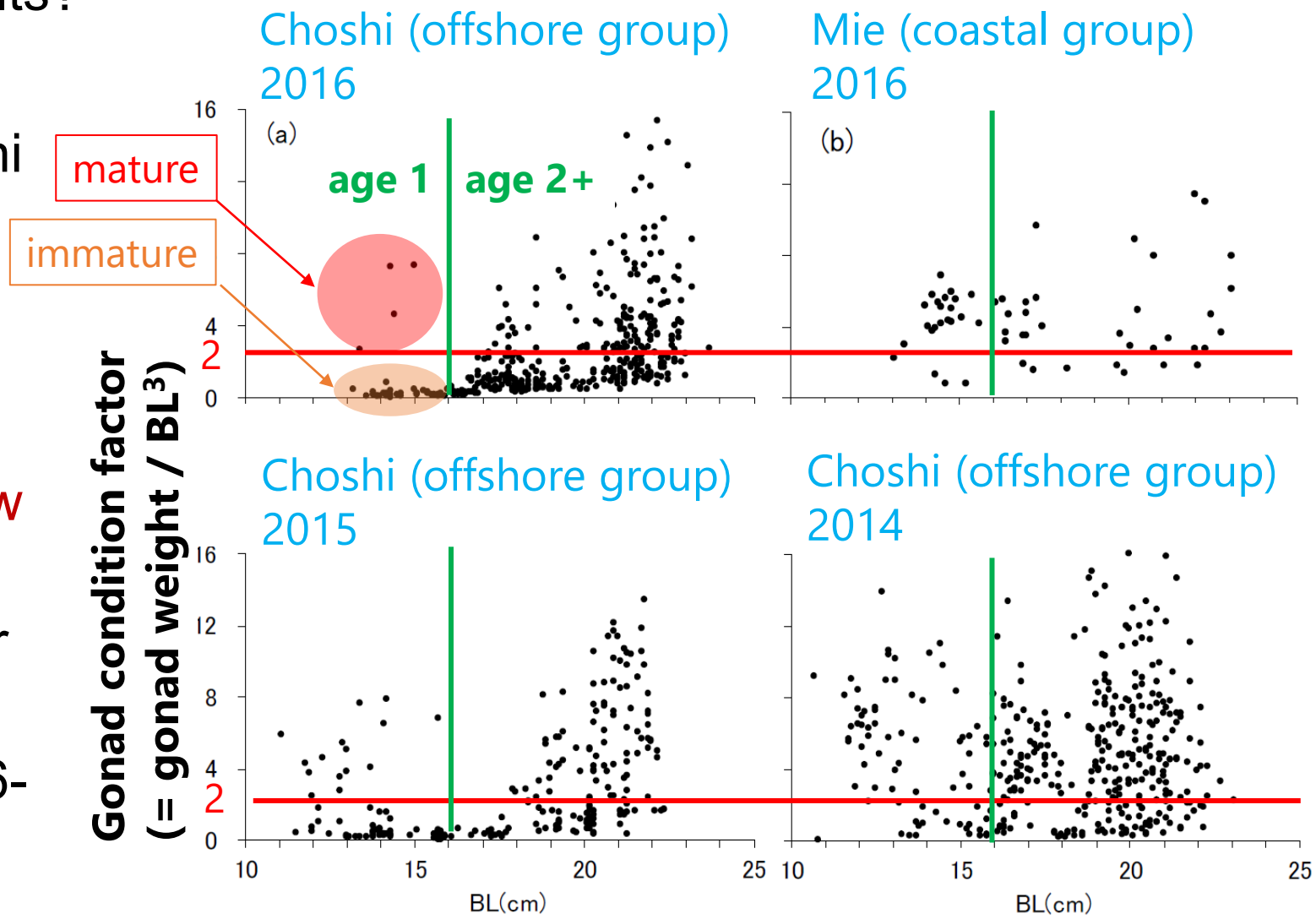
Stock size affects maturity at age 1

Reviewers Comments

- Q 10: Curious about the assumed changes in maturity during 1994-1997 and 2016-present. What is the evidence to support that assumption and what is the effect of that assumption on assessment results?

Response

- Age-1 maturity was low at Choshi (offshore group) in 2016
  - high in 2015 and 2014.
- Age-1 maturity remained high at Mie (coastal group) in 2016
- Age-1 maturity continue to be low in 2016 and after for offshore
- Age-1 maturity remained high for coastal group
- We assume that maturity in 2016- was the same as in 1994-1997.



Natural mortality

M：0.4

Tanaka’s equation (1960): M = 2.5 / maximum age

(the same equation for chub mackerel)

Maximum age of Japanese sardine: 7 years old

(2.5/7 = 0.357 ≈ 0.4)

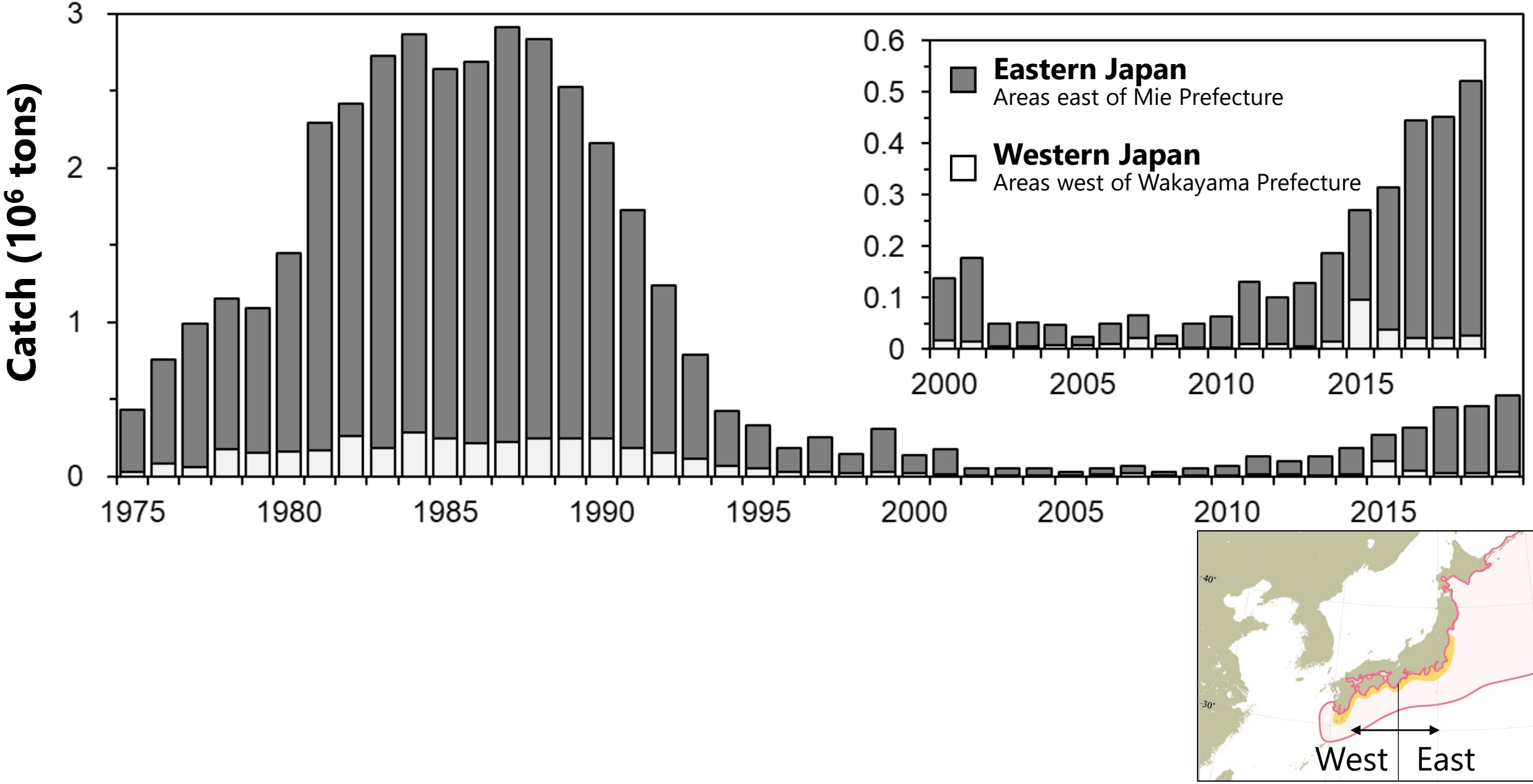
Reviewer's Comments

- Q 12: Based on predator-prey relationships, M may change with abundance and environmental conditions as well. Was there consideration of this? If so, any previous studies on this?
- Q 14: The M (0.4) seems a little low compared to the EPO sardine posterior (0.585). Where did the 0.4 come from?

Response

- We agree that M can change. However, we do not assume a temporal change of M and use a constant M.
- We do not have any information about the previous study on M of post-recruitment Pacific stock of Japanese sardines.
- We used the Tanaka's equation which is the same as chub mackerel assessment, based on the maximum age 7 year.

Catch


Catch (10^6 tons)
3
2
1
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
0.6
0.5
0.4
0.3
0.2
0.1
0
2000
2005
2010
2015
Eastern Japan
Areas east of Mie Prefecture
Western Japan
Areas west of Wakayama Prefecture
40°
30°
West
East

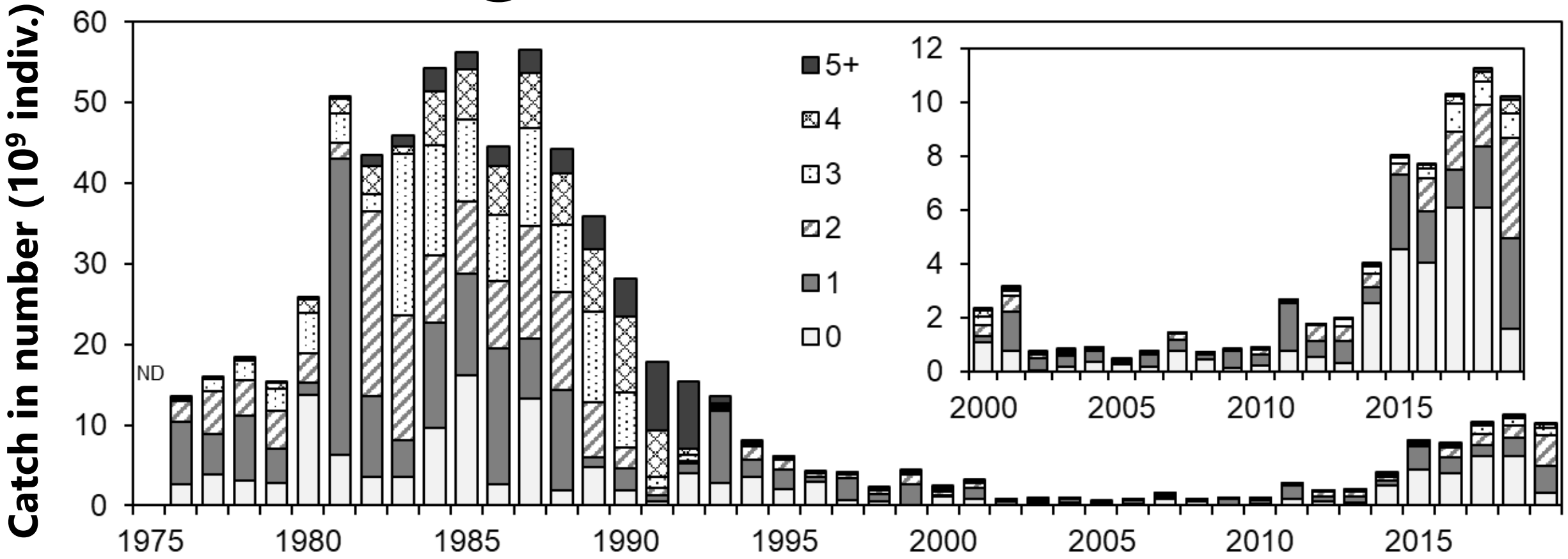
Reviewer's Comments

- Q 2: Russia and China catches substantial amounts of sardines (>175,000 t). How about other countries?
- Q 3: Please explain why non-Japanese catches were not included for the base case scenario.

Response

- No country other than these countries catch the Pacific stock of Japanese sardine.
- There was a very small abundance and catches outside of Japanese EEZ before 2016.
- In recent years, catches by foreign fleets have increased outside of Japanese EEZ and fishing mortality for the stock has also increased.
- Japanese sardine expands their distribution outside of Japanese EEZ at a high abundance level.
- But we cannot forecast that catches by foreign fleets may continue to be large in the future because we do not judge the present is in the high abundance regime.
- Thus, we did not use high fishing mortality considering foreign catches in future projection.

Catch-at-age


Catch in number (10^9 indiv.)
60
50
40
30
20
10
0
ND
1975
1980
1985
1990
1995
2000
2005
2010
2015
5+
4
3
2
1
0
12
10
8
6
4
2
0
2000
2005
2010
2015

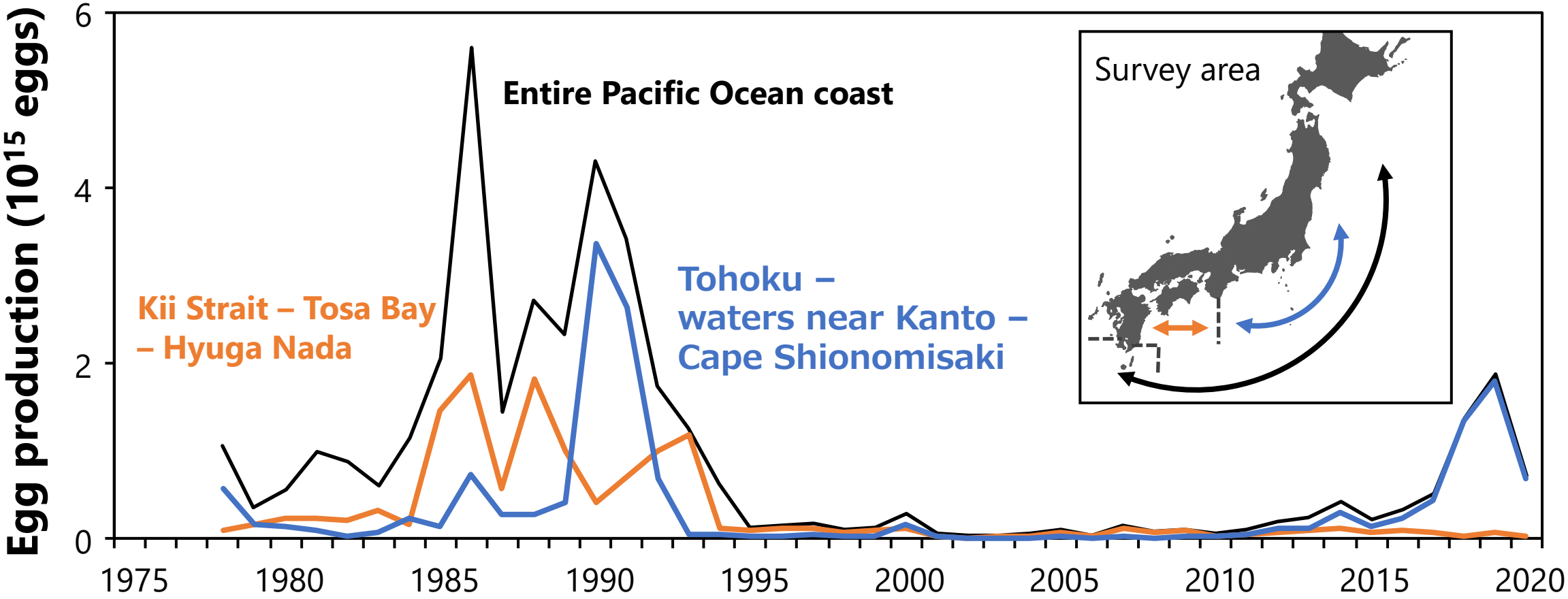
Reviewer's Comments

- Q 4: Just checking my understanding. It looks like the ALKs and length-weight relationships are developed for each area and moth and year? Is that correct?
- Q 5: Is there a study on aging error?

Response

- We developed the ALKs for each NE and SW Japan, month, and year, but the length-weight relationships for each prefecture and year.
- Nakai (1962) reported that six scientists fully agreed about their scale readings on age 0-2 Japanese sardines, but five scientists differed in their scale readings for 5 of 20 fish (25%) on age 3+ fishes.
- Mitani (1983) read the same scale from each fish three times and reported that 81.8-89.0% consistency for the first-third annuli and 69.4-75.4% consistency for the fourth-seventh annuli.

Egg abundance

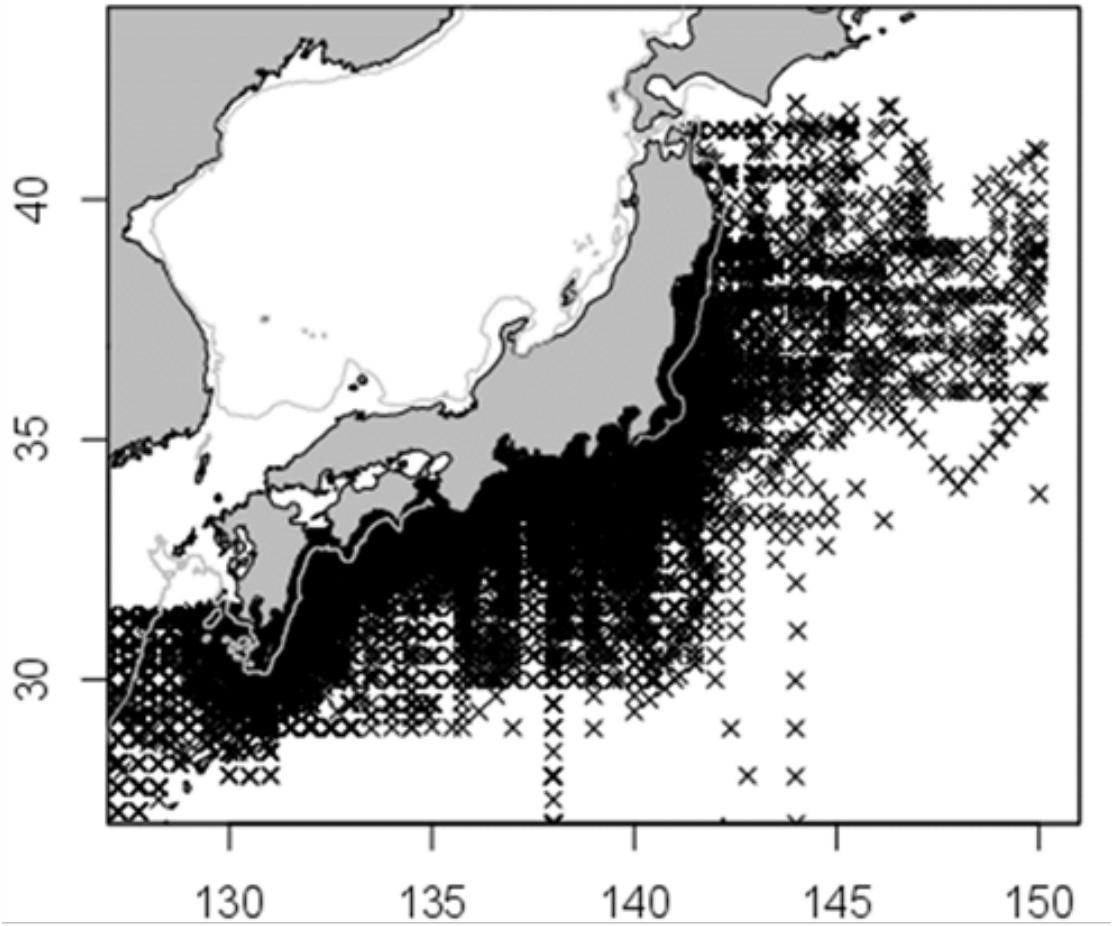


Reviewer's Comments

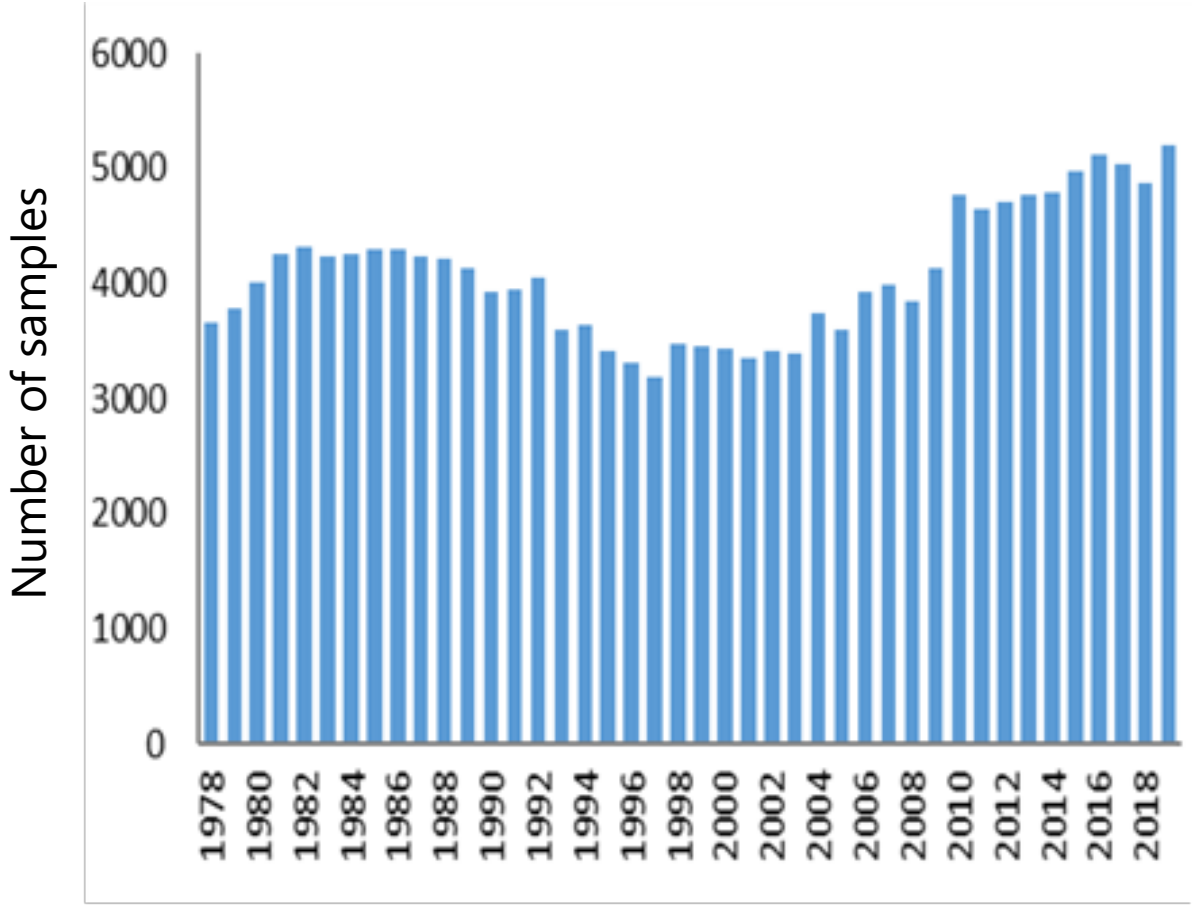
- Q 7: The EPI is likely the most important index because it represents the SSB. Unfortunately, there is not enough details in Appendix 3 to understand the index. Please provide more details. For example, what are the stations and areas covered by the egg and larval survey, especially compared with the distribution of the SSB? Noting that the reproductive biology of sardines vary by area, time, and environmental conditions, were the fecundity and maturity of the stock sampled during the survey or assumed based on other info? If sampled, how were they sampled? If assumed, what was assumed and based on what info?

Response

- The Egg and Larval survey is conducted by 19 prefectural fisheries institutes and JFREA in every month along the Pacific coast of Japan using NORPAC net. Number of samples per year is c.a. 5 thousands.



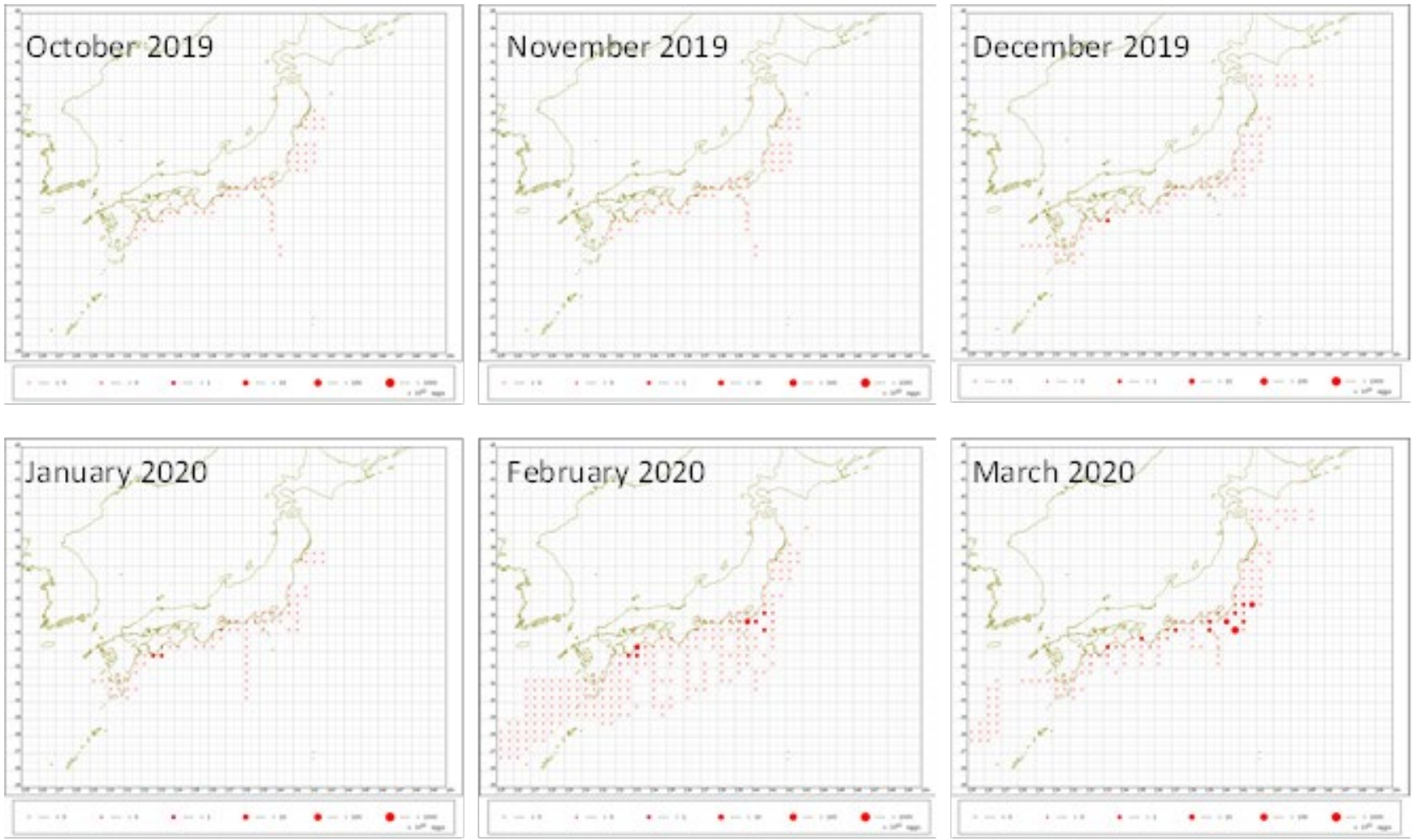
Sampling stations of Egg and Larval Survey along the Pacific coast



Number of samples of Egg and Larval Survey along the Pacific coast

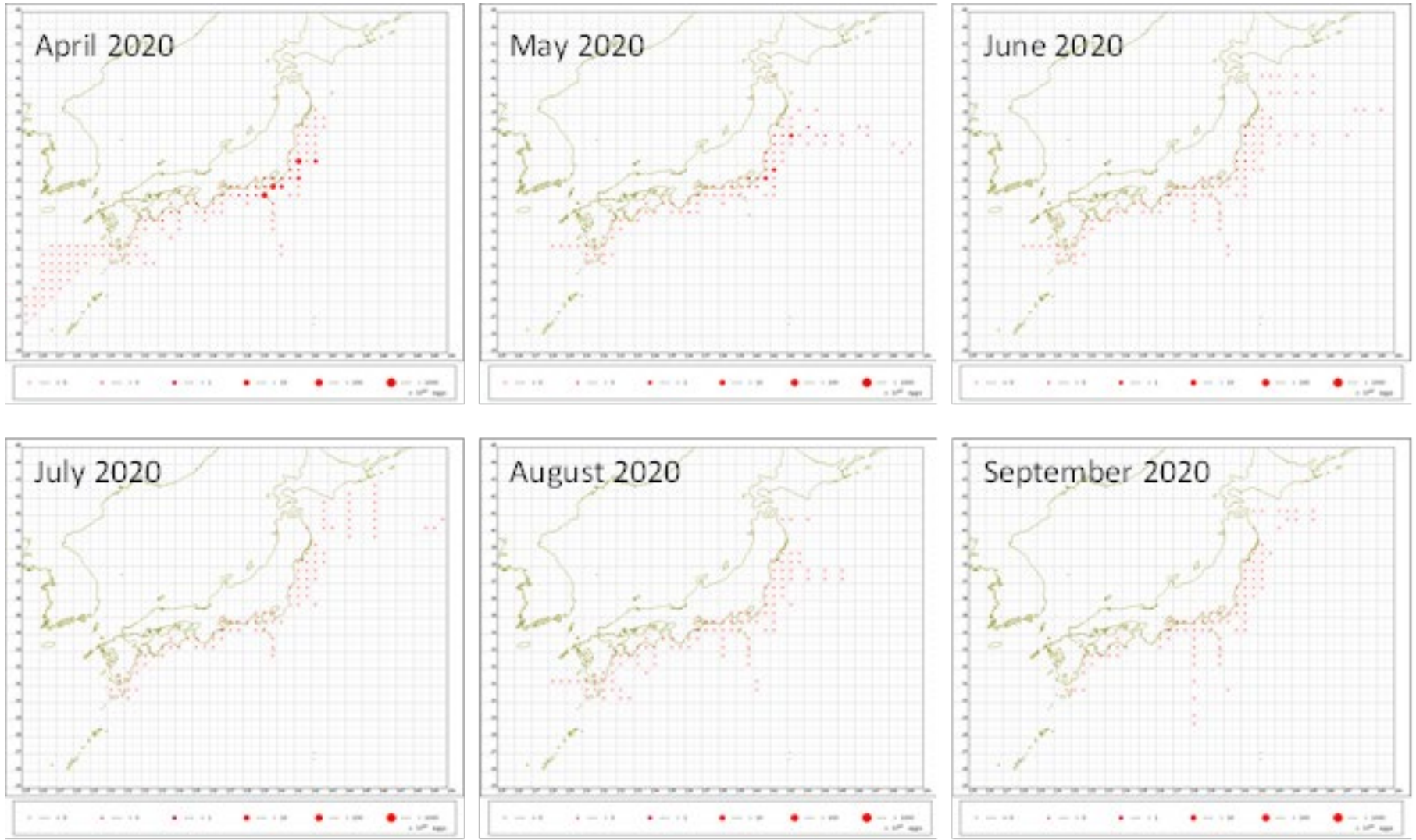
Response

- Monthly Egg and Larval Survey covers the spawning ground and season of the Pacific stock of Japanese sardine. The spawning area of sardine was at the western part of the survey area from November to January, then expanded to the eastern part in February and March.



Response

- Monthly Egg and Larval Survey covers the spawning ground and season of the Pacific stock of Japanese sardine. The spawning area moved to the eastern part of the survey area from April to June.

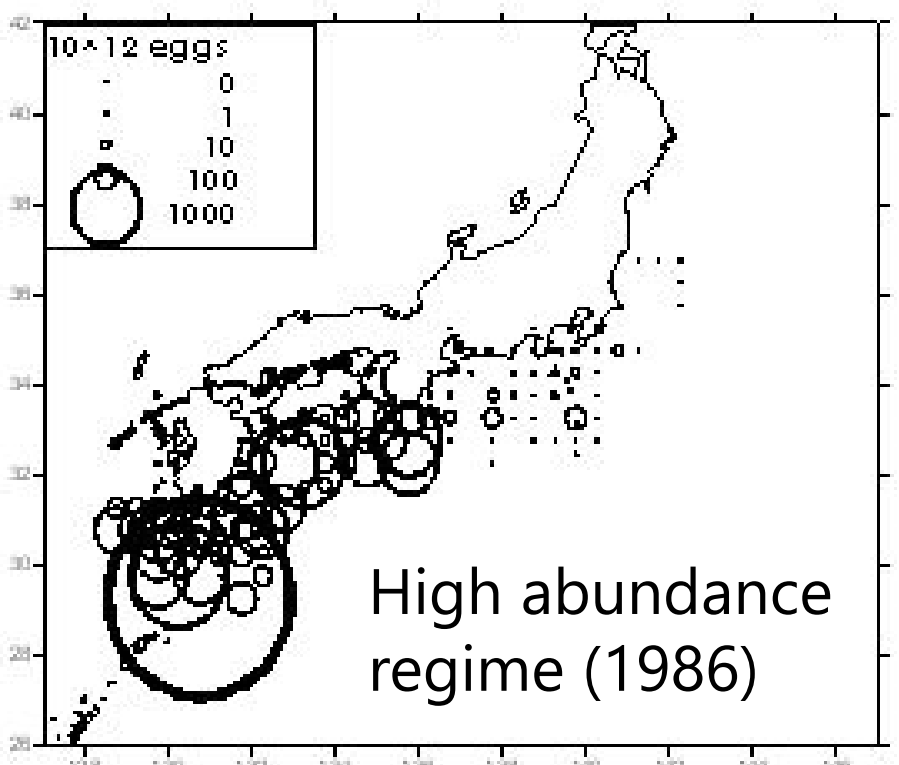


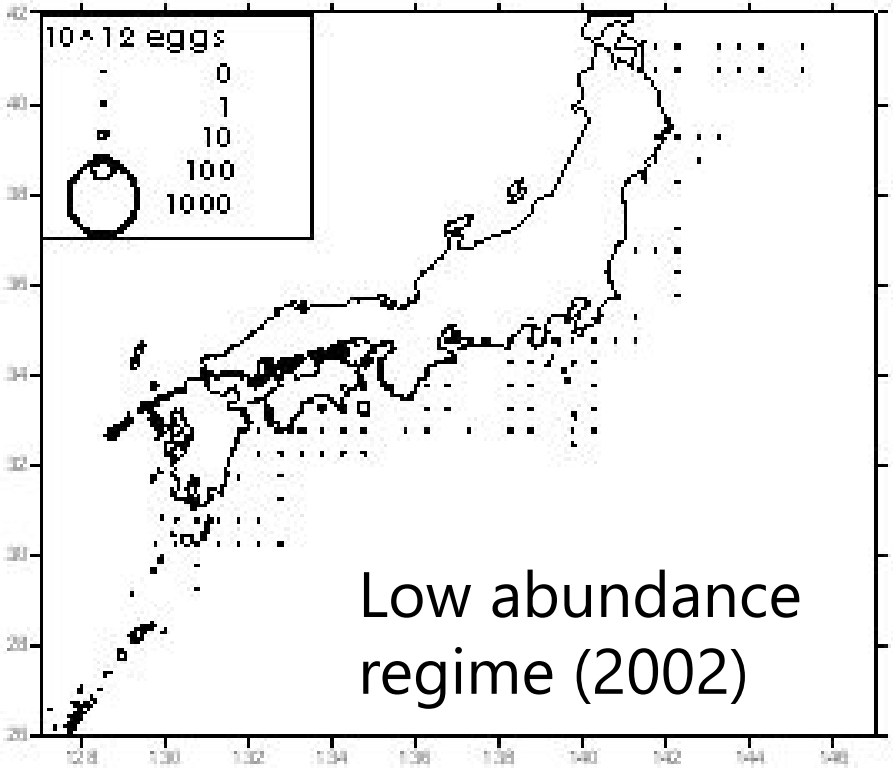
Reviewer's Comments

- Q 11: Spawning areas appear to change with regime. Does the survey designs change with it to ensure coverage of the SSB?

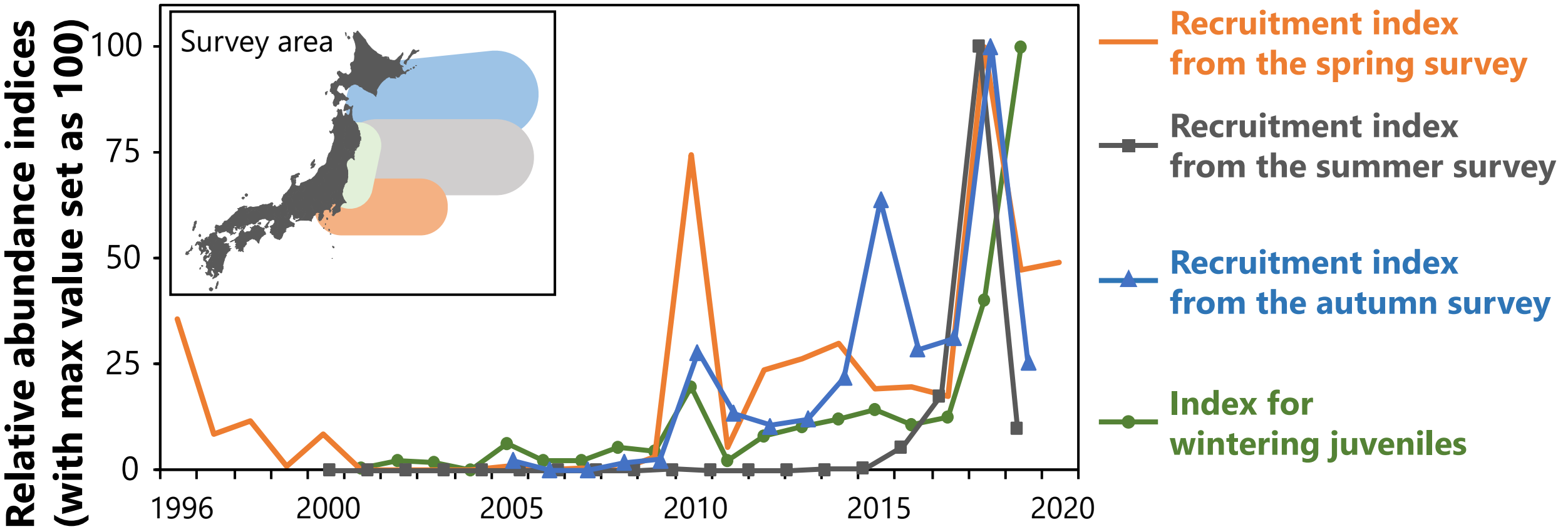
Response

- The Egg and Larval Survey covers the spawning ground in the high abundance regime as well as that in the low abundance regime of sardine.





Abundance indices



As the index for wintering juveniles corresponds to the recruitment in the previous year,
the value is shown for the corresponding previous year, and values for 2002 onward are shown.

Reviewer's Comments

- Just making sure I got this right. Spawning biomass index is a egg production index (EPI) from a egg and larval survey. There are several recruitment indices but indices only cover the coastal or offshore areas and none cover the entire area. Therefore, some indices can be conflicting because recruitment to the offshore vs coastal areas can be very different.
- Q 6: It appears there were 3 indices fit in the model: 1) the EPI representing the SSB; 2) an age-0 index based on a pelagic fish survey in the Northwestern Pacific (NWPI); and 3) an age-1 index for wintering juveniles (WJI) in Chiba. Is that correct?

Response

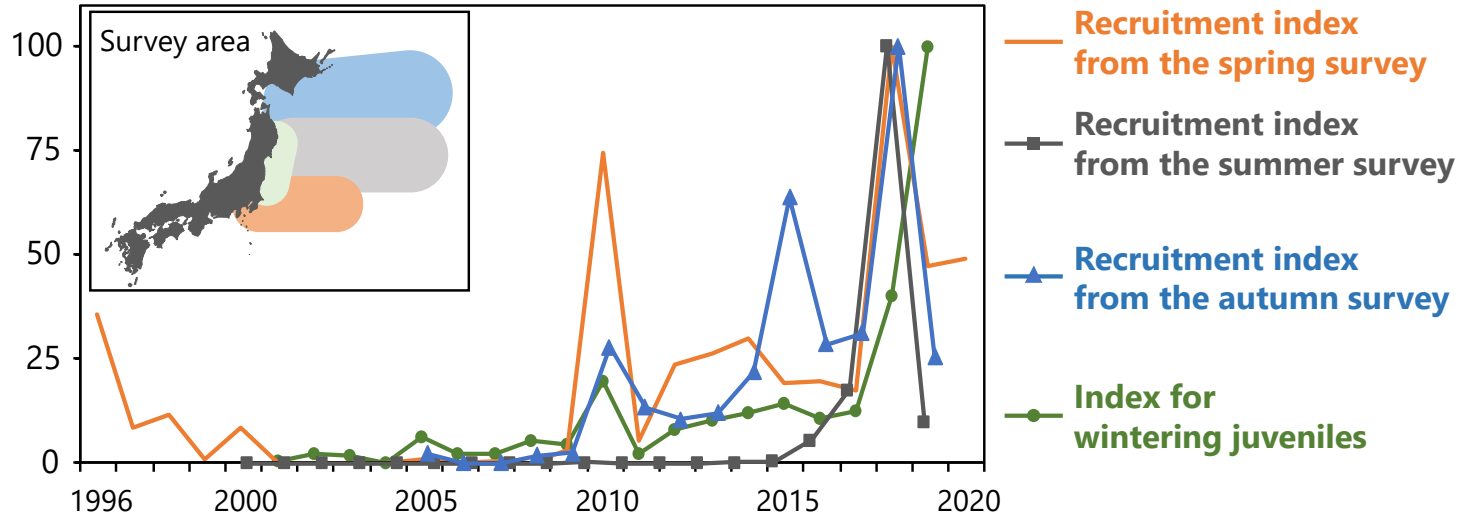
- Yes, correct.

Reviewer's Comments

- Q 8: The NWPI appears to be one out of several candidate age-0 indices. Please explain the reasoning behind using this index rather than the others. Why is this index considered the most representative for age-0? What are the areas and times covered by this survey, especially compared with the distribution of the recruitment?

Response

- Recruits are caught by commercial vessels in fall and after. Thus, we use the results of the fall survey as the index of recruitment. The survey covers a broad area including off the Eastern Hokkaido to Joban for the Japanese EEZ and 39-50 N, 145-180 E in the high seas area.
- The survey area covers most of the distribution of the recruitment.



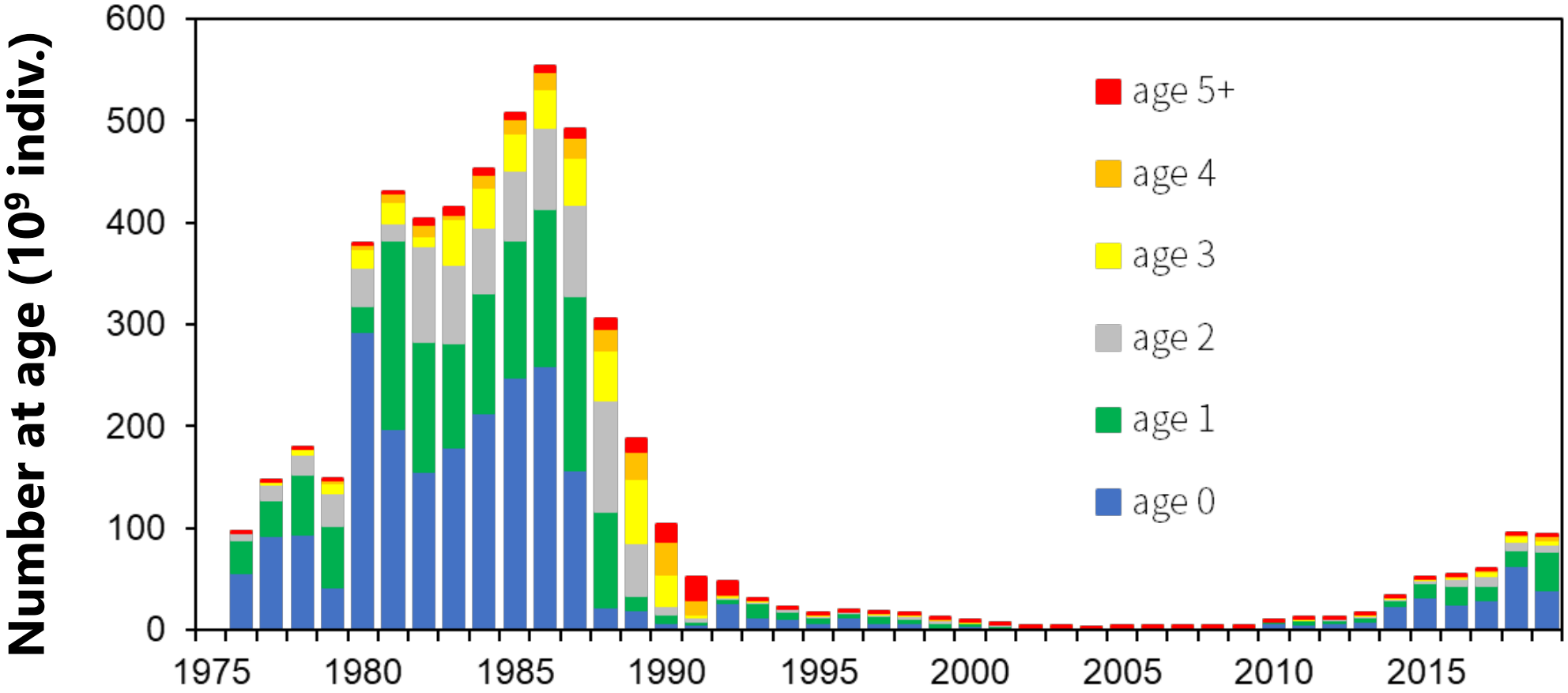
Reviewers Comments

- Q 9: Based on Appendix 3, it is not clear on whether the WJI is based on a scientific survey or some sort CPUE from a commercial purse seine fishery. Please provide the details of this index. For example, spatial and temporal coverage. What is the source of the data? If it is based on a commercial fishery, what is the standardization model? And if a survey, what is the survey design?

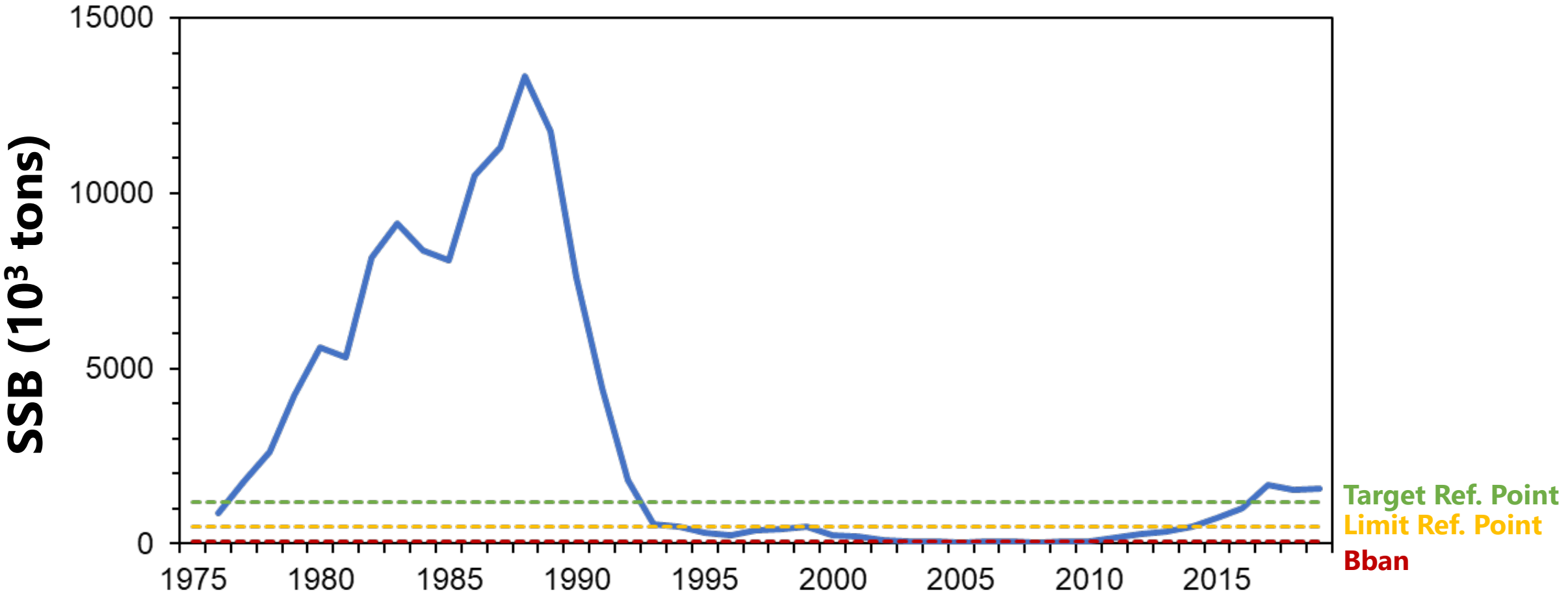
Response

- In winter, immature sardines (c.a. 12-15 cm BL) concentrate on the continental shelf (40-140 m deep) off Boso and Joban and stay there for c.a. three months.
- The WJI is a cumulative CPUE of the commercial large-scale purse seine fishery for two size classes (8-12 cm and 12-16 cm BL) of sardine during winter (December to April) off Boso and Joban (34-37° N, 139° 45'-143° 00'E).

Number-at-age



SSB


SSB (10³ tons)
15000
10000
5000
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
Target Ref. Point
Limit Ref. Point
Bban

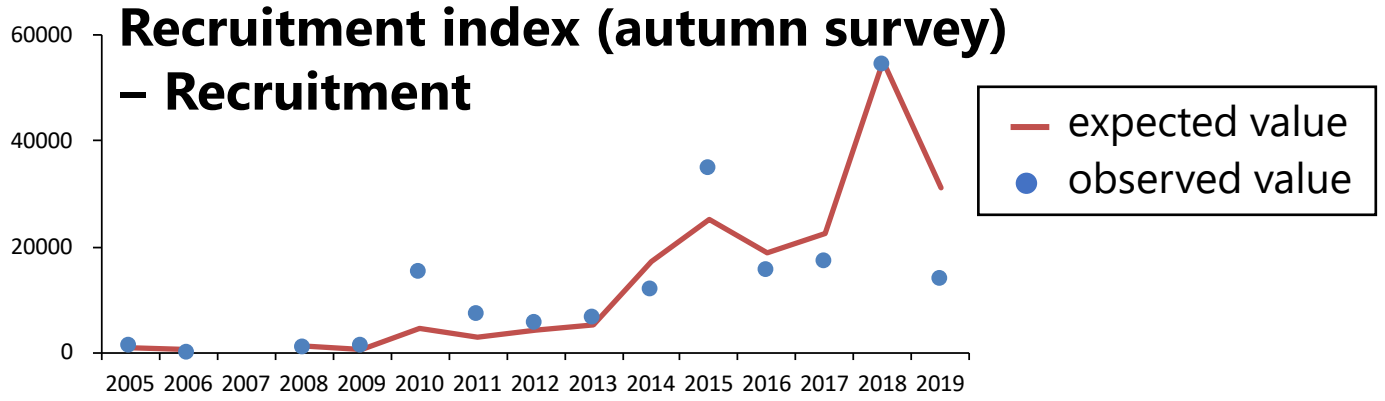
Reviewer's Comments

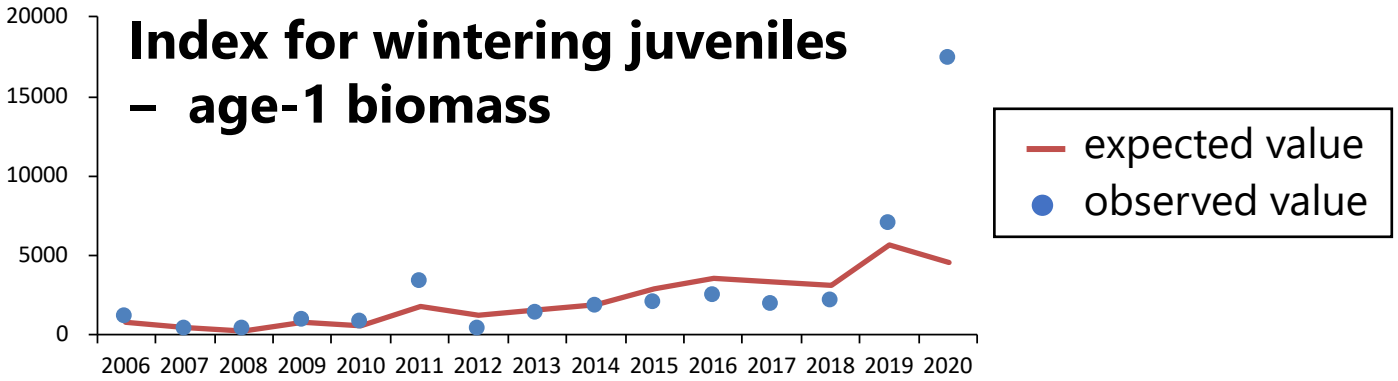
- Q 15: Please show the model diagnostics for the base case and the Appendix 9 (A9) models. Retrospective, fits to the indices, and the various model params (e.g., λ, η, q, b, F).

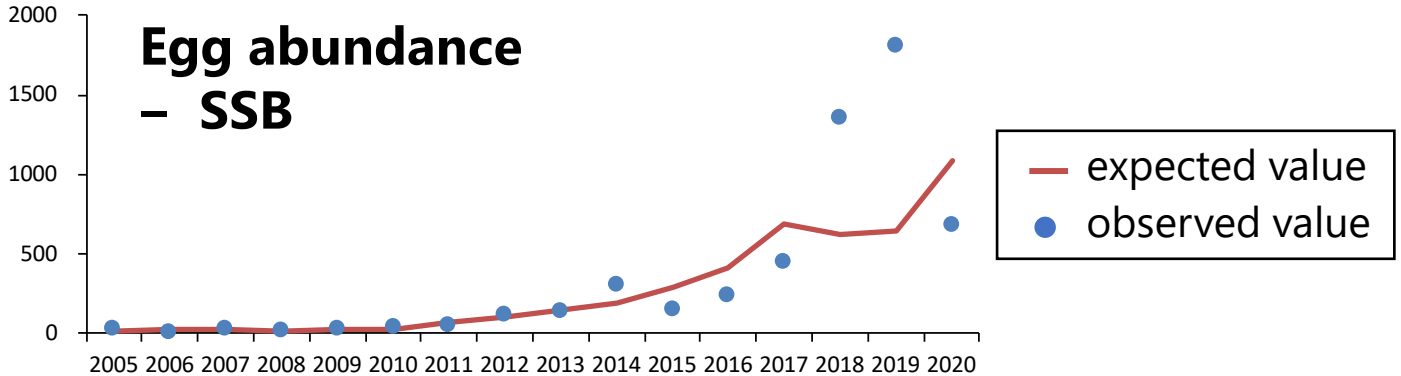
Response

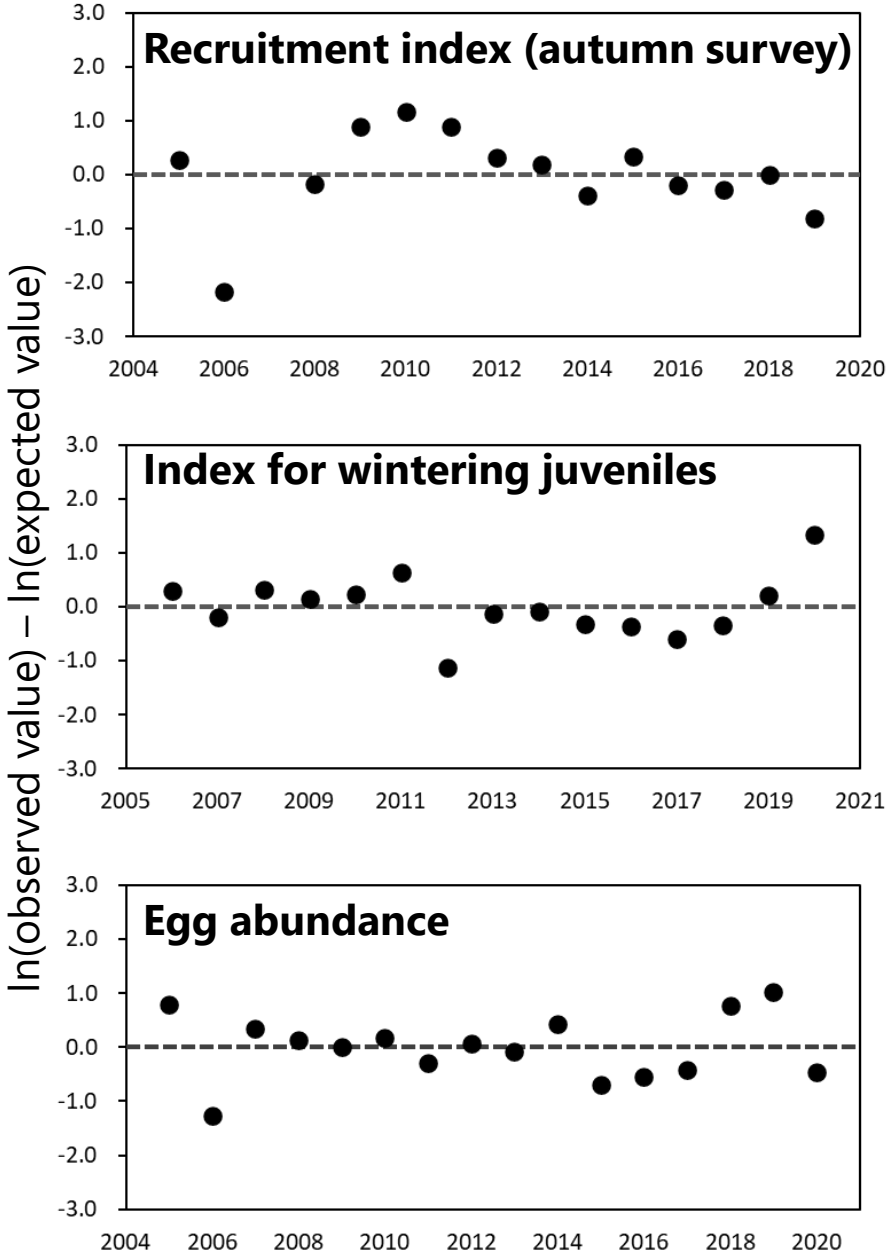
- I will show the model diagnostics for the base case.

Data Fit

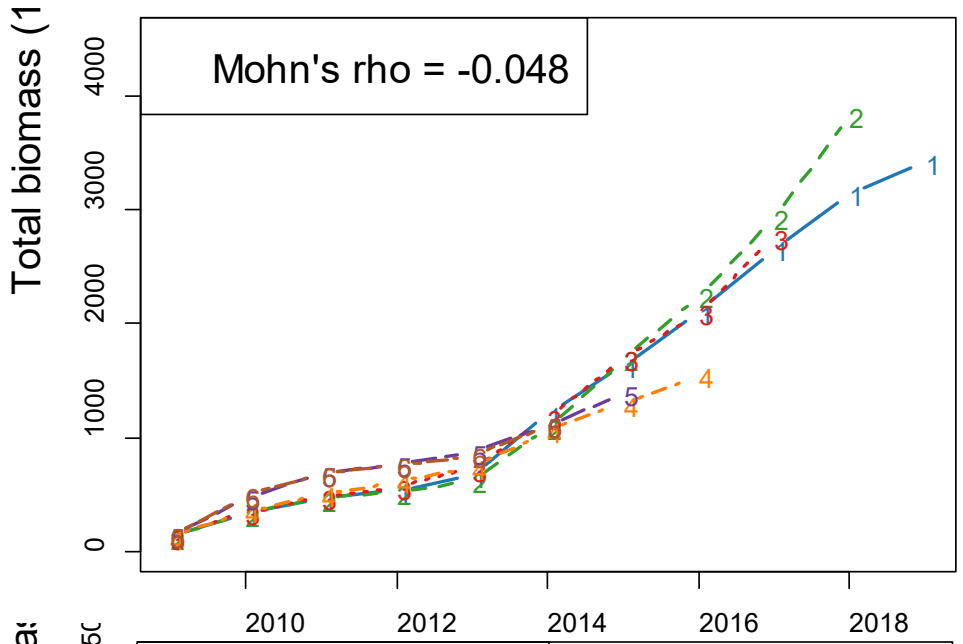

Recruitment index (autumn survey)
– Recruitment
60000
40000
20000
0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
expected value
observed value

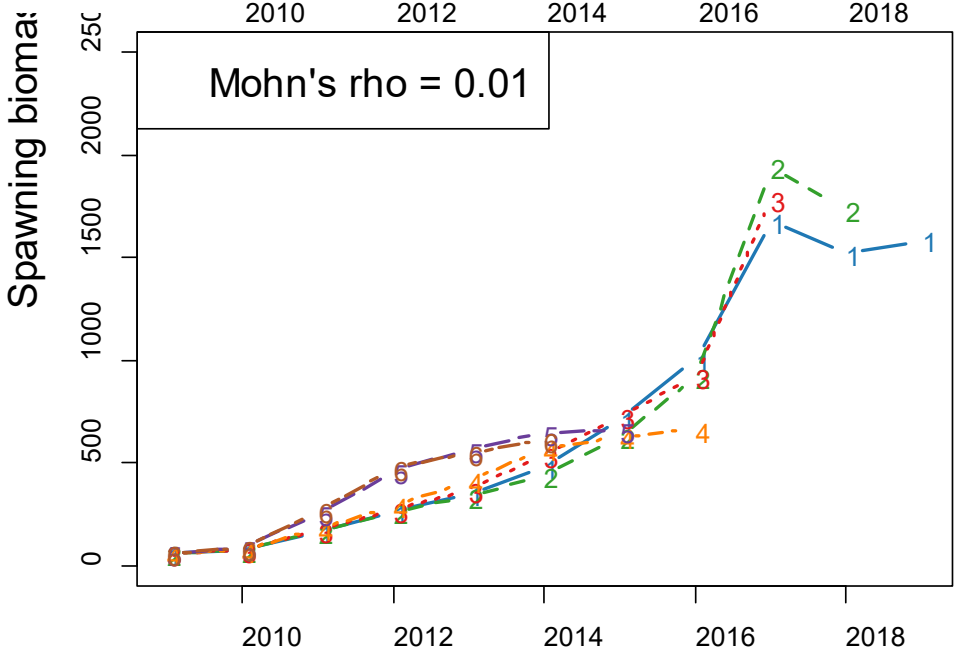

Index for wintering juveniles
– age-1 biomass
20000
15000
10000
5000
0
2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
expected value
observed value

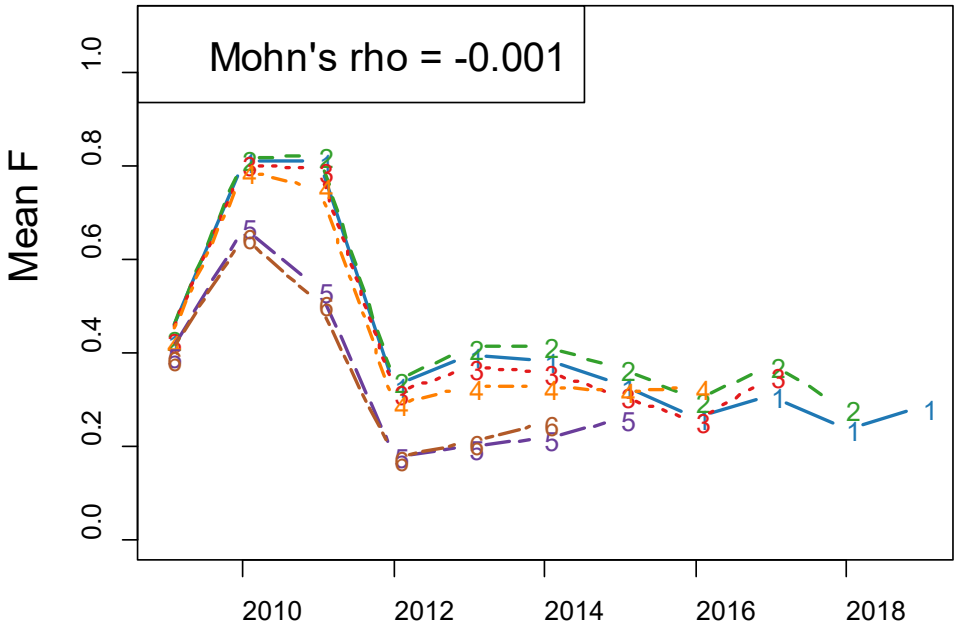

Egg abundance
– SSB
2000
1500
1000
500
0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
expected value
observed value


ln(observed value) – ln(expected value)
Recruitment index (autumn survey)
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Index for wintering juveniles
2005 2007 2009 2011 2013 2015 2017 2019 2021
Egg abundance
2004 2006 2008 2010 2012 2014 2016 2018 2020

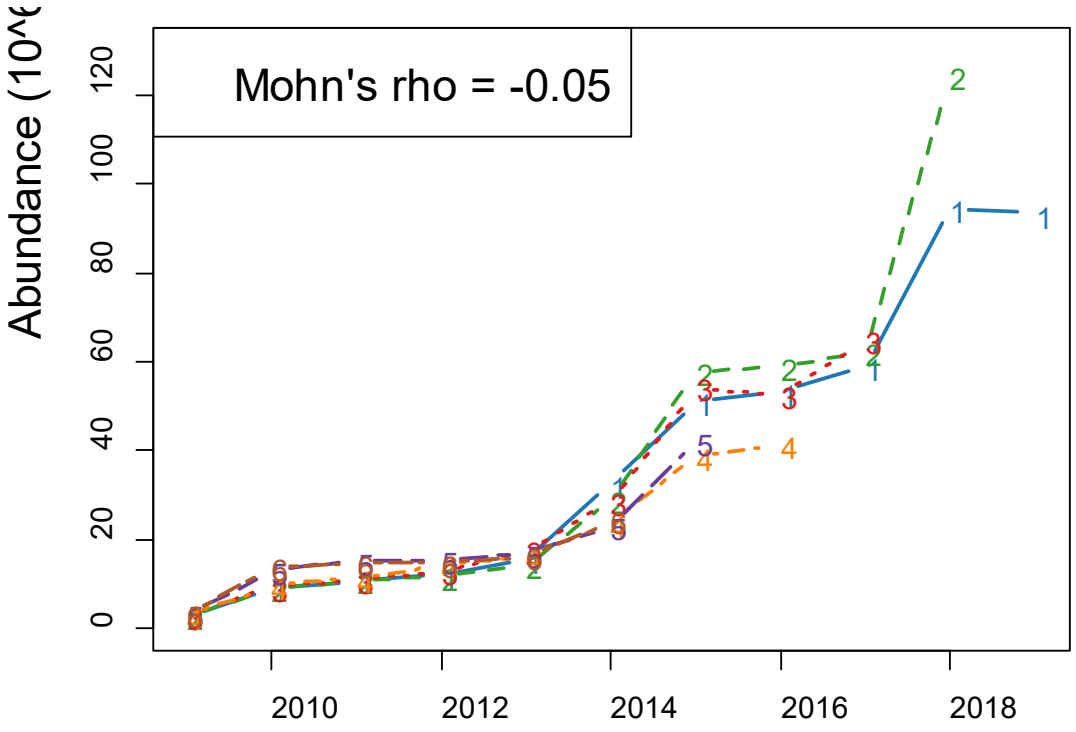
Retrospective pattern

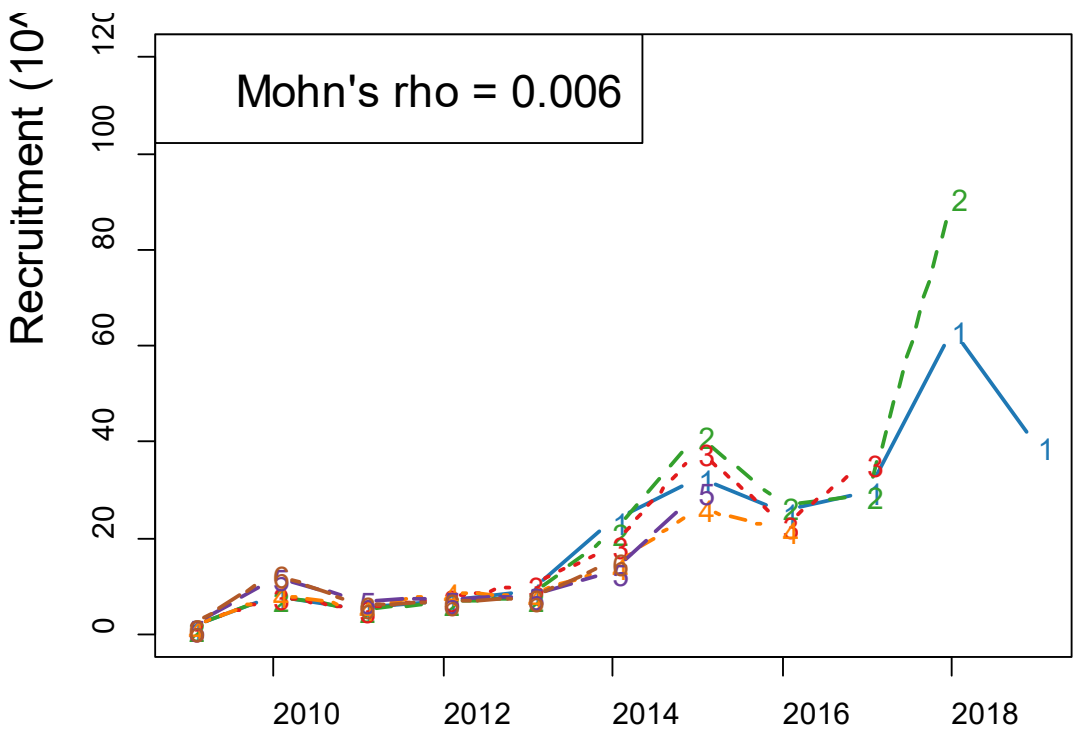






Retrospective pattern





Reviewer's Comments

- Comment 20: It is likely that the current base model would not be considered BSIA (Best Scientific Information Available) because of the missing catch from non-Japanese fisheries. Unless there is a compelling reason that the A9 (Appendix) model is not appropriate, I think it would be useful to explore the following models as potential BSIA models. Let's discuss and explore during the meeting.

  Model A9-a: A9 with no tuning indices

  Model A9-b: A9 + EPI only

  Model A9-c: A9 + EPI + NWPI

  Model A9-d: A9 + EPI + WJI

  Model A9-e: A9 + EPI + WJI + NWPI (this should be the same as the A9 model?)

- Please show the abovementioned model diagnostics for these models.

Reviewers Comments

Response

- The domestic stock assessment aims to assess the stock available for the Japanese fleet.
- There was very small abundance and catches outside of the Japanese EEZ before 2016.
- We have no information on the size or age composition of catches by foreign fleets.
- We estimated the MSY level from the past data-rich Japanese information, catch, age and size composition, etc.
- We have been trying to collect information on size or age composition of catches by foreign fleets.
- As for the additional calculations, we apologize that we cannot provide them since the corresponding researcher headed off for research cruise.

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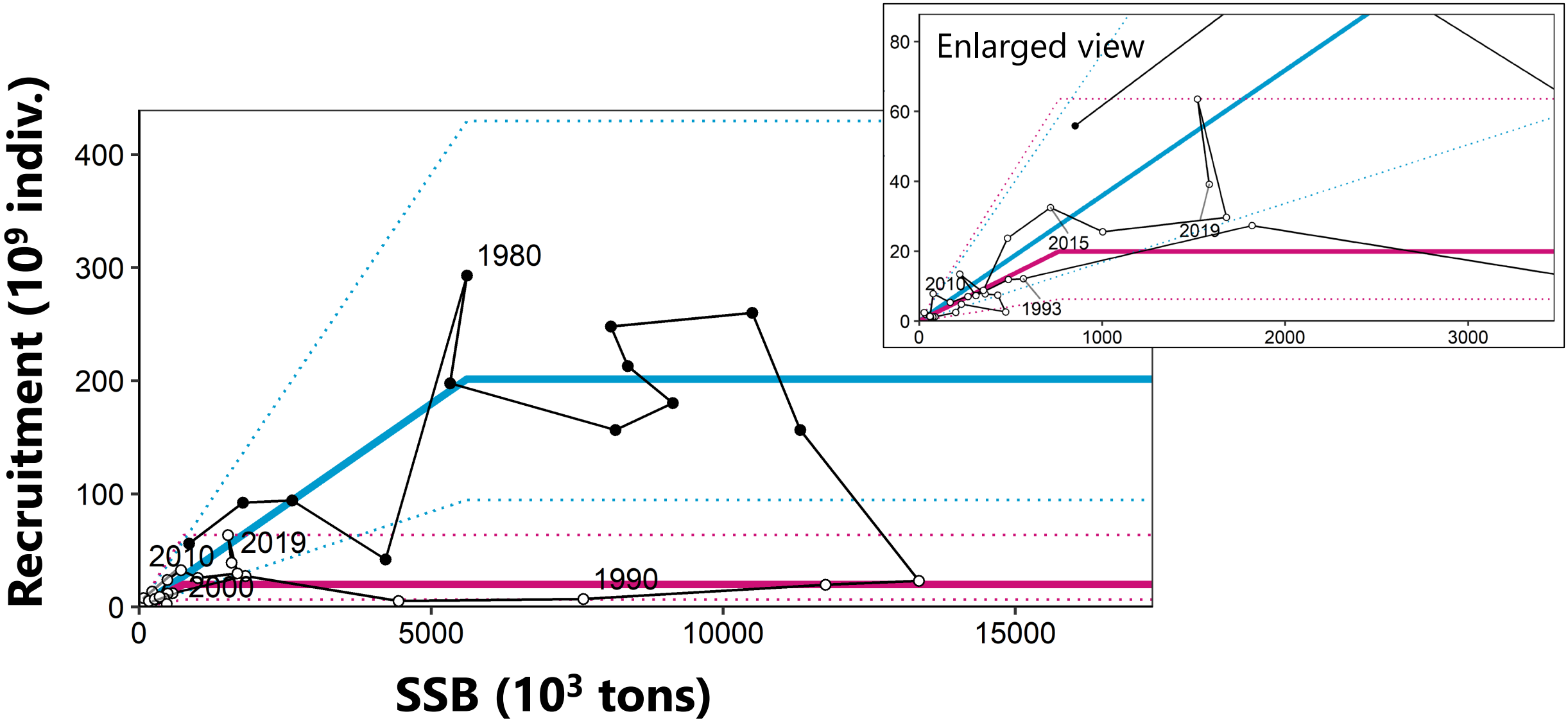
Stock-Recruitment Relationships



Reviewer's Comments

- Comment 16: Key issue is whether to use high or low period SRR to estimate stock status and projections. So probably let's discuss during the meeting.
- Likely that stock is trending towards a high period but may not be fully in the high regime. May be reasonable to use the 'normal' period SRR to calculate current stock status but may not be reasonable to do so for the projections. Let's discuss during the meeting.
- Please tell me during the meeting whether the choice of SRR is considered a management or science decision.

Reviewer's Comments

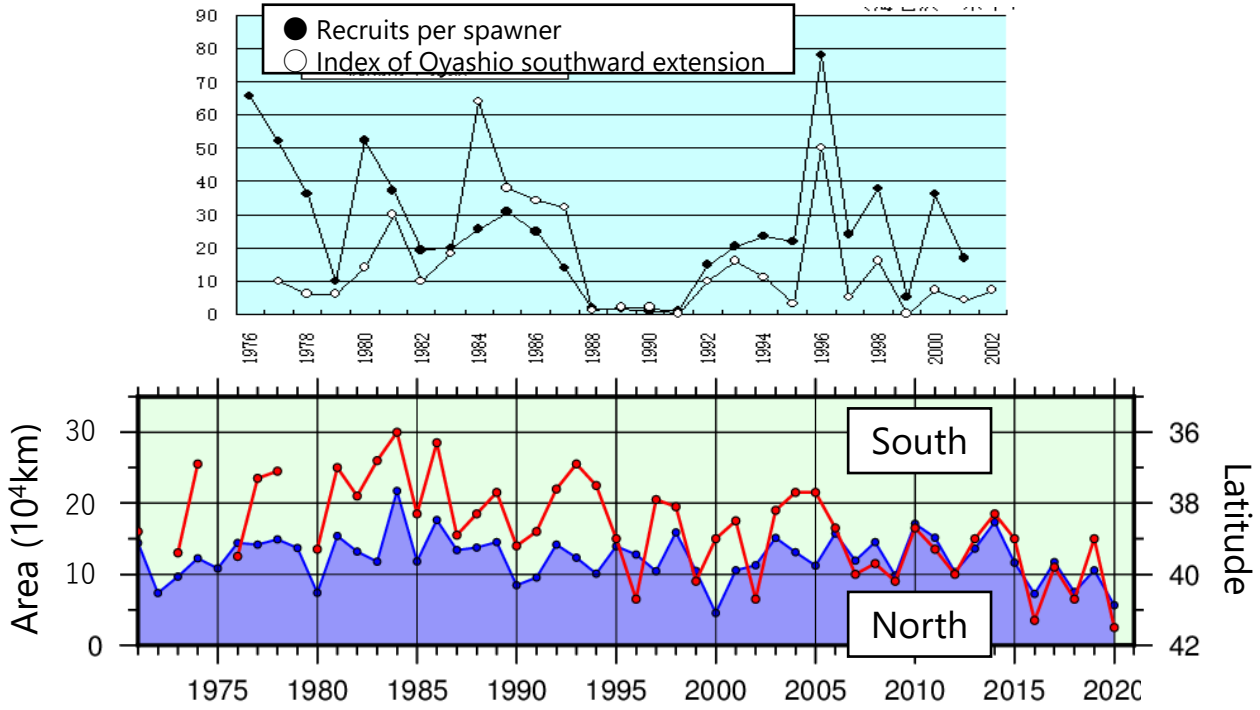
Response

- Recent recruitment was greater than the normal period SRR but stays within the range of 90% of the data.
- The recent spawning ground remains off Shikoku Island to Kanto where was the spawning ground at the low abundance regime, not the south of Kyushu at the high abundance regime.

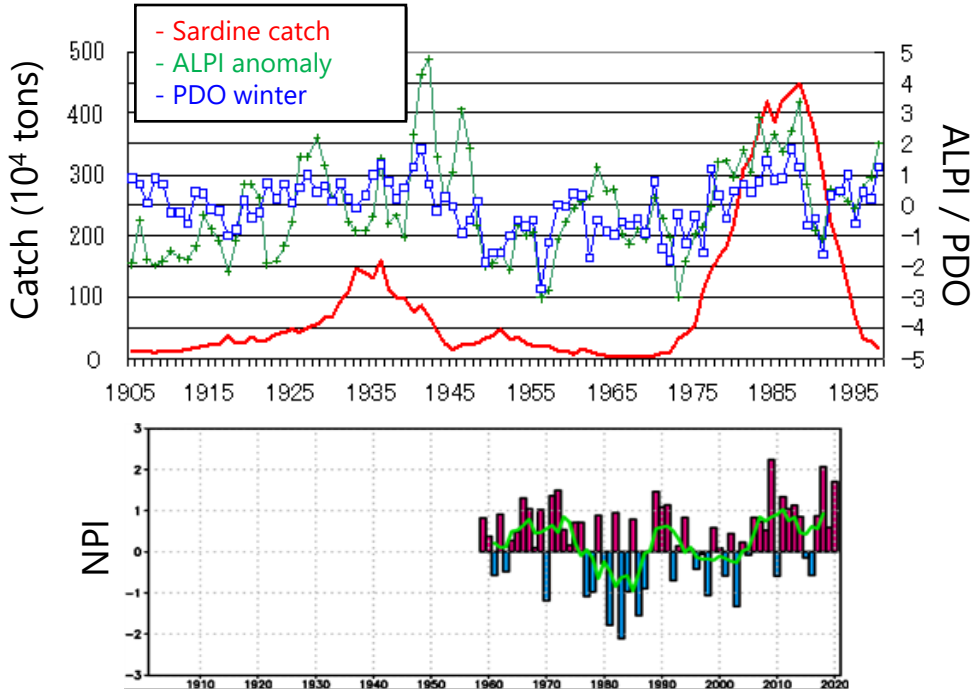
Reviewer's Comments

Response

- In the 1980s, the Oyashio cold current was strong and the North Pacific Index of winter was negative. But in the present, the Oyashio cold current is weak and the NPI was positive.
- We cannot forecast the stock may increase as the level at the 1980s.
- Thus, we decided to use the normal period SRR as a science decision.



https://www.jma.go.jp/jma/index.html



https://www.jma.go.jp/jma/index.html

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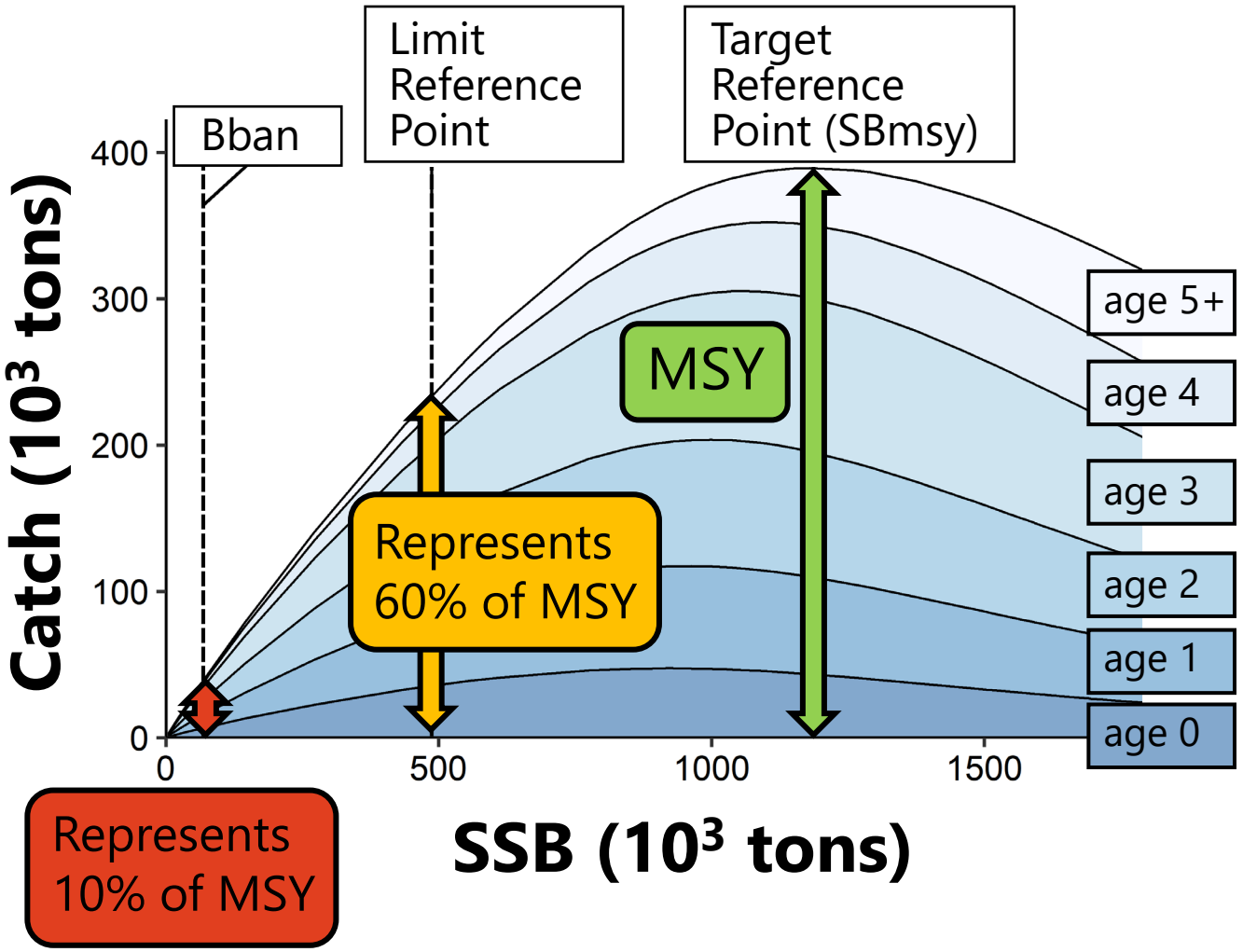
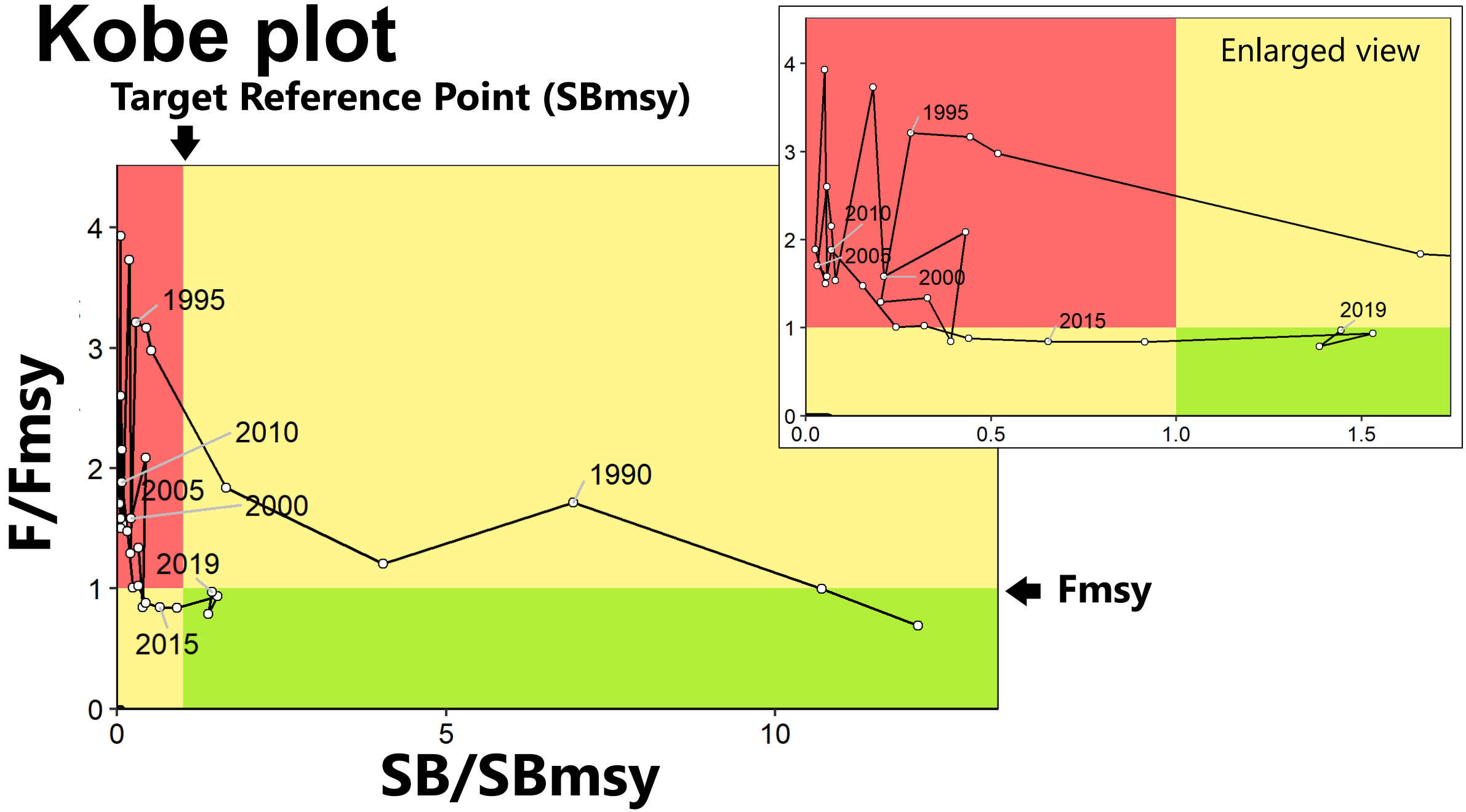
Reference Points



Reference Points	Catch (10^3 tons)	SSB (10^3 tons)
Target (SBmsy)	**389**	**1187**
Limit	**234**	**487**
Bban	**39**	**69**

Kobe plot


Target Reference Point (SBmsy)
Enlarged view
F/Fmsy
SB/SBmsy
Fmsy
1995
2010
2005
2000
1990
2019
2015
0
1
2
3
4
5
10
0.0
0.5
1.0
1.5

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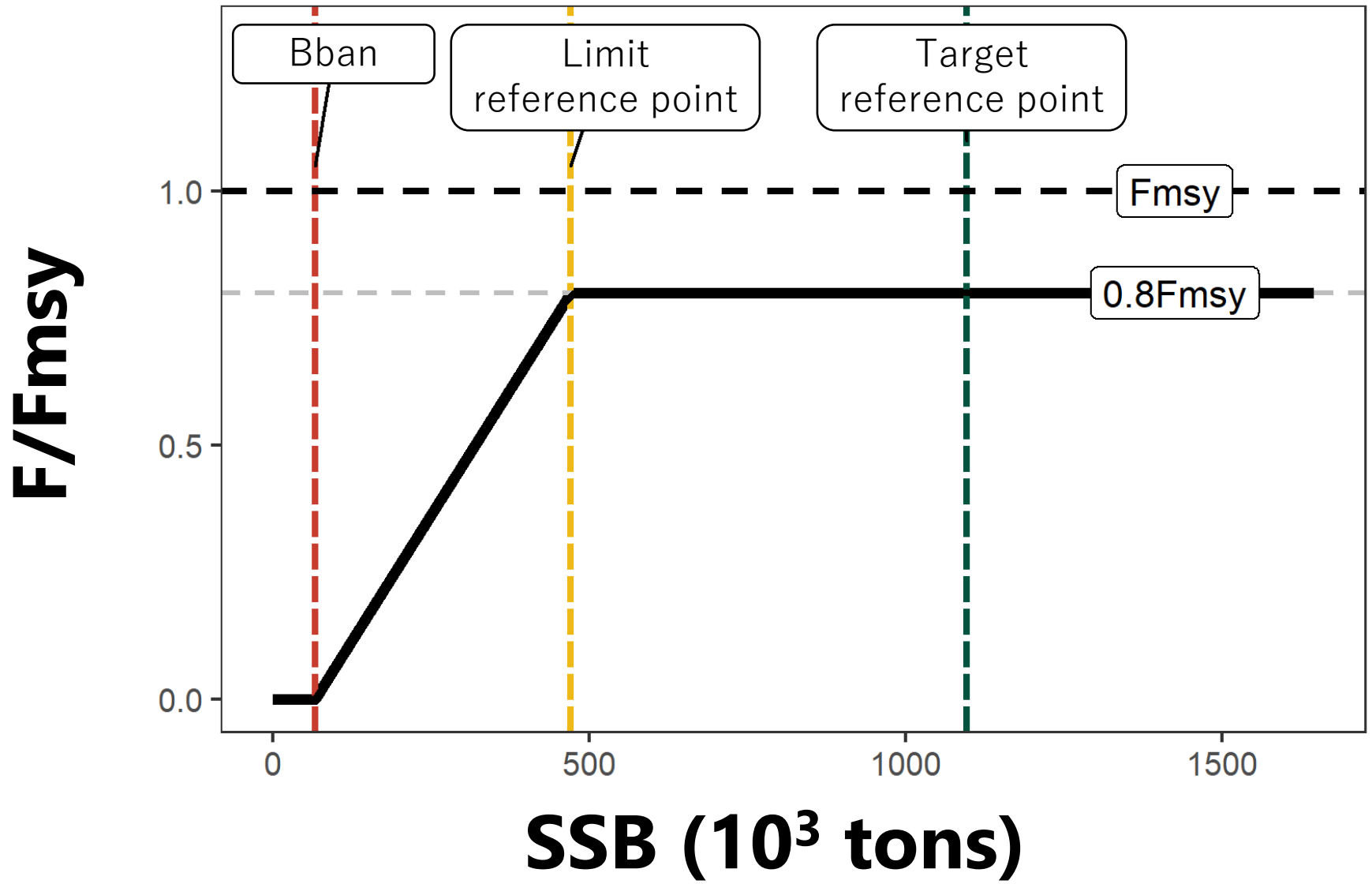
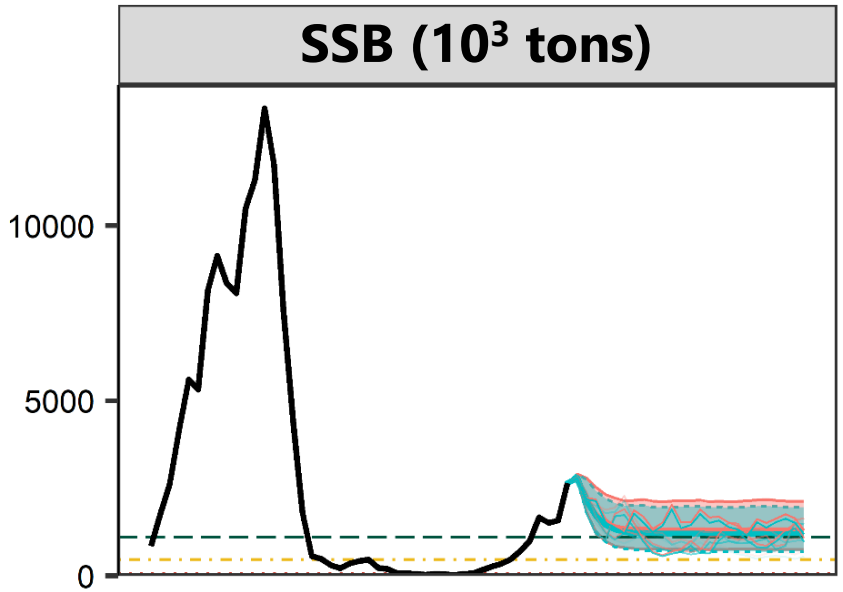
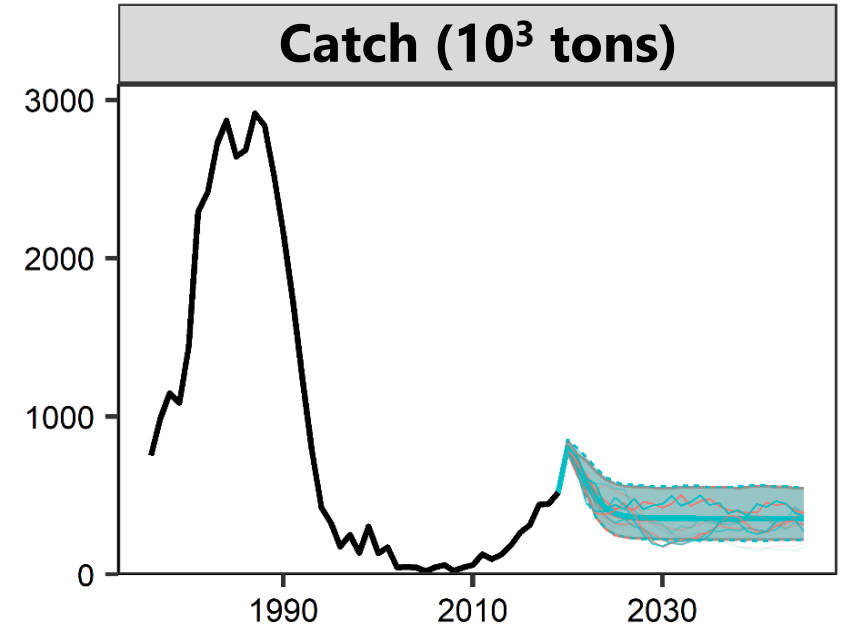
Harvest Control Rule



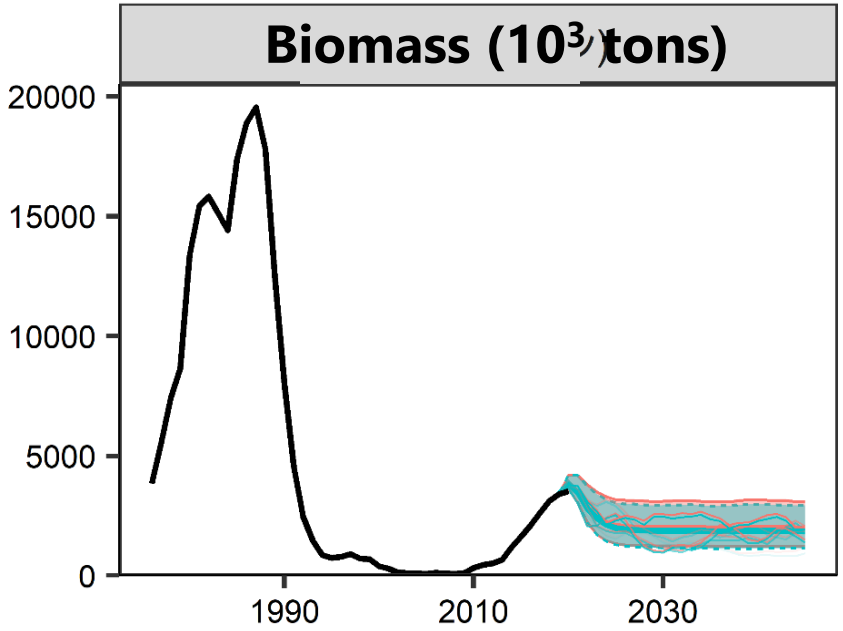
Future Projection 1





Target Ref. Point

Limit Ref. Point



0.8HCR

F2015-2019

average value

simulation example

5-95% prediction interval

Future Projection 2

Probability (%) of being above the proposed target reference point

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041
1.0	100	100	100	89	62	51	47	45	45	44	43	43	43
0.9	100	100	100	95	71	60	55	53	53	52	51	51	51
0.8	100	100	100	98	80	70	64	62	62	61	60	60	60
0.7	100	100	100	100	88	78	74	72	71	70	69	70	69
0.6	100	100	100	100	94	86	82	80	80	79	78	79	78
0.5	100	100	100	100	98	92	90	88	87	86	86	86	85
0.4	100	100	100	100	100	97	95	94	93	93	93	93	92
0.3	100	100	100	100	100	99	98	98	97	97	97	97	96
0.2	100	100	100	100	100	100	100	99	99	99	99	99	99
0.1	100	100	100	100	100	100	100	100	100	100	100	100	100

Probability (%) of being above the proposed limit reference point

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041
1.0	100	100	100	100	100	100	99	99	99	99	98	98	98
0.9	100	100	100	100	100	100	100	100	99	99	99	99	99
0.8	100	100	100	100	100	100	100	100	100	100	100	100	100
0.7	100	100	100	100	100	100	100	100	100	100	100	100	100
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
0.4	100	100	100	100	100	100	100	100	100	100	100	100	100
0.3	100	100	100	100	100	100	100	100	100	100	100	100	100
0.2	100	100	100	100	100	100	100	100	100	100	100	100	100
0.1	100	100	100	100	100	100	100	100	100	100	100	100	100

Future Projection 3

Changes in average values of SSB (10^3 tons)

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041
1.0	2,876	2,882	2,136	1,655	1,416	1,305	1,253	1,237	1,226	1,218	1,210	1,209	1,205
0.9	2,876	2,882	2,205	1,754	1,519	1,403	1,348	1,332	1,321	1,315	1,308	1,309	1,308
0.8	2,876	2,882	2,276	1,861	1,631	1,512	1,454	1,437	1,426	1,421	1,414	1,416	1,418
0.7	2,876	2,882	2,350	1,975	1,755	1,634	1,572	1,553	1,543	1,537	1,531	1,533	1,537
0.6	2,876	2,882	2,427	2,098	1,891	1,771	1,707	1,686	1,674	1,668	1,662	1,664	1,668
0.5	2,876	2,882	2,506	2,230	2,042	1,925	1,860	1,837	1,824	1,818	1,811	1,814	1,818
0.4	2,876	2,882	2,589	2,372	2,209	2,100	2,035	2,013	1,998	1,991	1,984	1,986	1,990
0.3	2,876	2,882	2,676	2,526	2,394	2,298	2,238	2,217	2,202	2,195	2,187	2,189	2,193
0.2	2,876	2,882	2,765	2,691	2,600	2,523	2,473	2,456	2,444	2,438	2,430	2,432	2,436
0.1	2,876	2,882	2,858	2,869	2,829	2,780	2,746	2,739	2,732	2,729	2,723	2,727	2,732

Changes in average values of catch (10^3 tons)

β	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2041
1.0	742	841	693	539	462	427	411	404	401	398	397	396	394
0.9	742	771	656	521	452	418	403	396	394	392	391	391	389
0.8	742	698	613	499	437	405	391	384	382	381	380	380	380
0.7	742	622	564	470	417	389	375	369	367	365	365	365	365
0.6	742	544	509	435	392	366	354	348	346	345	344	344	345
0.5	742	462	446	392	358	337	327	321	319	318	318	318	318
0.4	742	377	376	340	316	300	291	286	285	283	283	283	283
0.3	742	288	298	276	261	250	245	241	240	239	238	238	238
0.2	742	196	209	200	193	187	184	182	181	180	180	180	180
0.1	742	100	110	109	107	105	104	104	103	103	103	103	103

Reviewer's Comments

- Q 17: For Appendix 8, if the idea is to provide projections for the case where the stock is going into a high period, why not use SRR from the high period and resampling of the recruitment residuals of the high period (maybe with some periodicity to switch to the low period at some point in time) rather than the 2000-2014 period? How different would the results be?

Response

- Recent recruitment was greater than the normal period SRR but within the range of 90% of the data.
- The recent spawning ground remains off Shikoku Island to Kanto where was the spawning ground at the low abundance regime, not the south of Kyushu at the high abundance regime.
- We cannot forecast the stock may increase as the level at the 1980s.
- Therefore, we decided to use the normal period SRR.

Reviewer's Comments

- Q 18: It was a little bit difficult to compare the projections from base case vs Appendix 8. Please show a quick comparison?

Response

Projected values for 2021

Item	Base case (Appendix 6)	Favorable recruitment (Appendix 8)
SB in 2021	2.882 million tons	2.935 million tons
Catch in 2021 (β = 0.8)	698 thousand tons	747 thousand tons
Catch in 2021 (β = 1.0)	841 thousand tons	901 thousand tons
Catch in 2021 (F2015-2019)	797 thousand tons	853 thousand tons

Reviewer's Comments

Response

Projection for 2022 onward

Item	Base case (Appendix 6)	Favorable recruitment (Appendix 8)
SB in 2031(80% CI) ($\beta = 0.8$)	1,416 (839-2,118) thousand tons	2,096 (1,460-2,795) thousand tons
Probability of SB in 2031 above target RP ($\beta = 0.8$)	60%	99%
SB in 2031(80% CI) ($\beta = 1.0$)	1,209 (688-1,840) thousand tons	1,819 (1,248-2,459) thousand tons
Probability of SB in 2031 above target RP ($\beta = 1.0$)	43%	93%
SB in 2031(80% CI) (F2015-2019)	1,271 (732-1,930) thousand tons	1,900 (1,310-2,559) thousand tons
Probability of SB in 2031 above target RP (F2015-2019)	48%	95%

Reviewer's Comments

- Q 19: Was uncertainty in the terminal year N-at-age of the VPA considered?

Response

- No, we do not consider the uncertainty of the estimated abundance of terminal year in future projection.