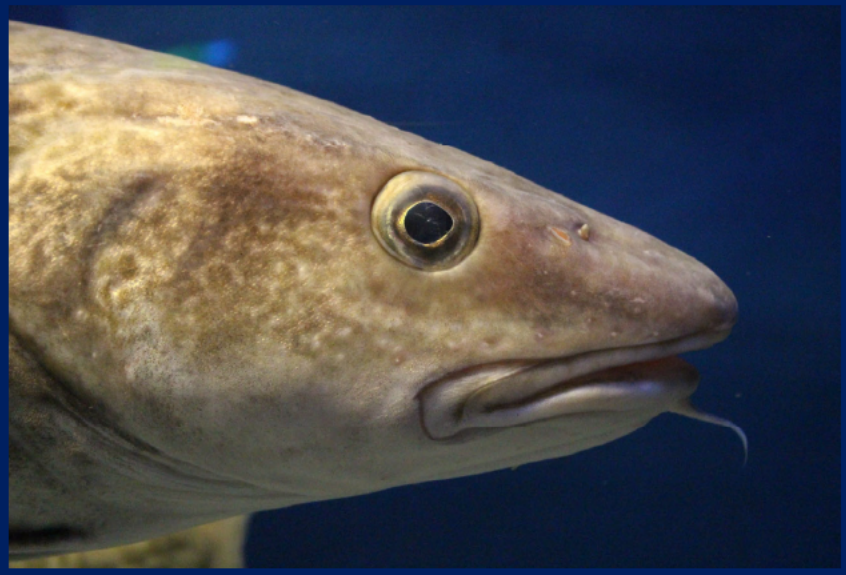
Peer review 2024 – Pacific Cod

Stock Assessment for Honshu Northern Pacific Stock of Pacific Cod (Fiscal Year 2023)

Participating Organizations:
Aomori Prefectural Industrial Technology Research Center Fisheries Institute, Iwate Prefectural Fisheries Technology Center, Miyagi Prefecture Fisheries Technology Institute, Fukushima Prefectural Fisheries and Marine Science Research Center, Fukushima Prefectural Research Institute of Fisheries Resources, Ibaraki Prefectural Fisheries Research Institute, and Marine Ecology Research Institute



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Contents

- Biology
  - Distribution, spawning ground,
  - Growth, Mature

- Stock assessment
  - Fisheries, Catch,
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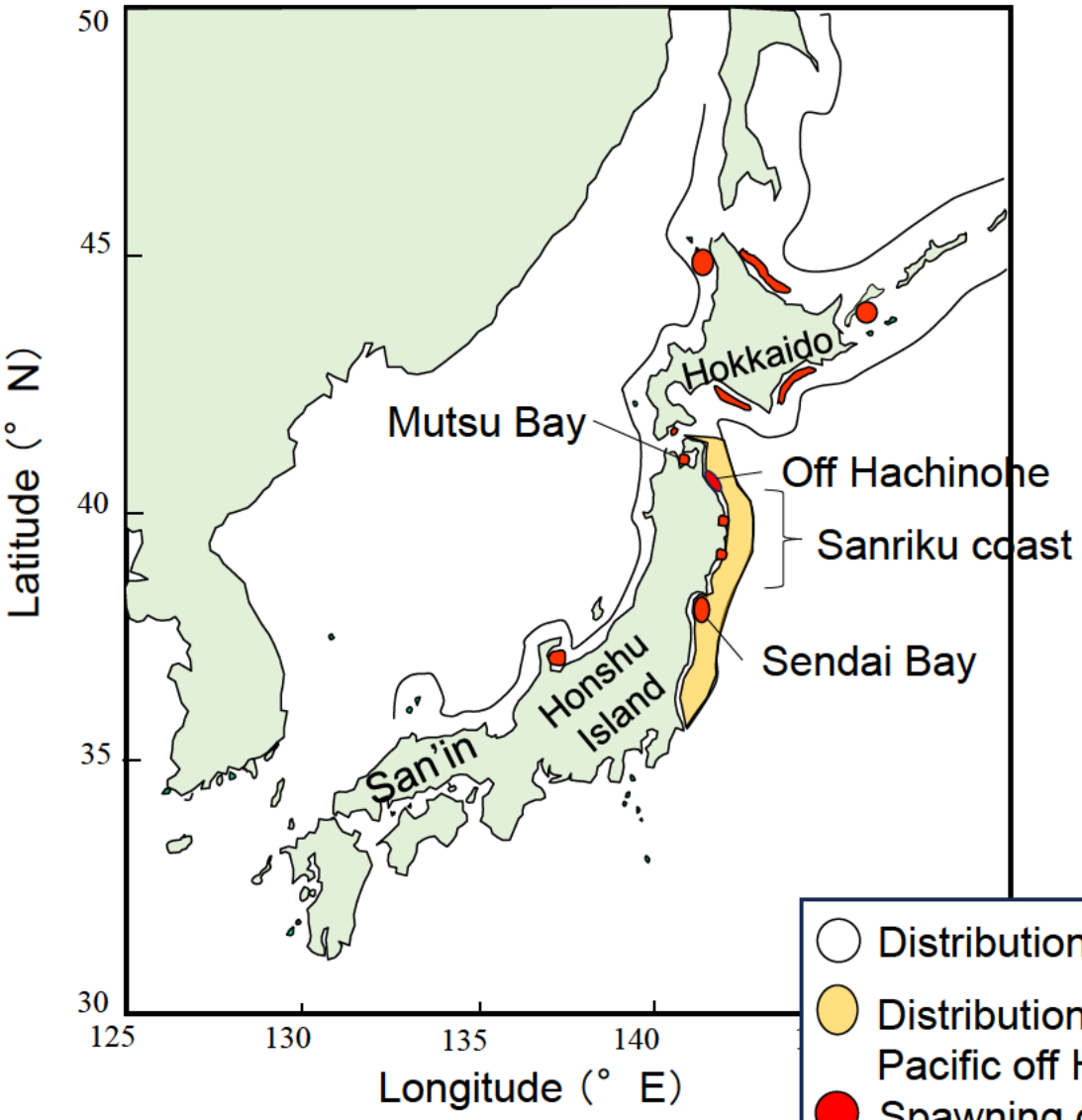
  - Estimation of stock abundance , F and M
  - Stock-Recruitment Relationship
  - Backward resampling of Recruitment
  - Future projection

- Issue in the Future

Distribution and Spawning ground



The range of travel for individual subpopulations is limited and there is little interaction between them (Bakkala et al. 1984).

However, mitochondrial DNA analysis of Pacific cod distributed in Japan shows no clear genetic differences, except for schools distributed in the San'in region (Suda et al. 2017).

Tagged and released in Mutsu Bay (Miura et al. 2019)

Release sites in Mutsu Bay (Area A)

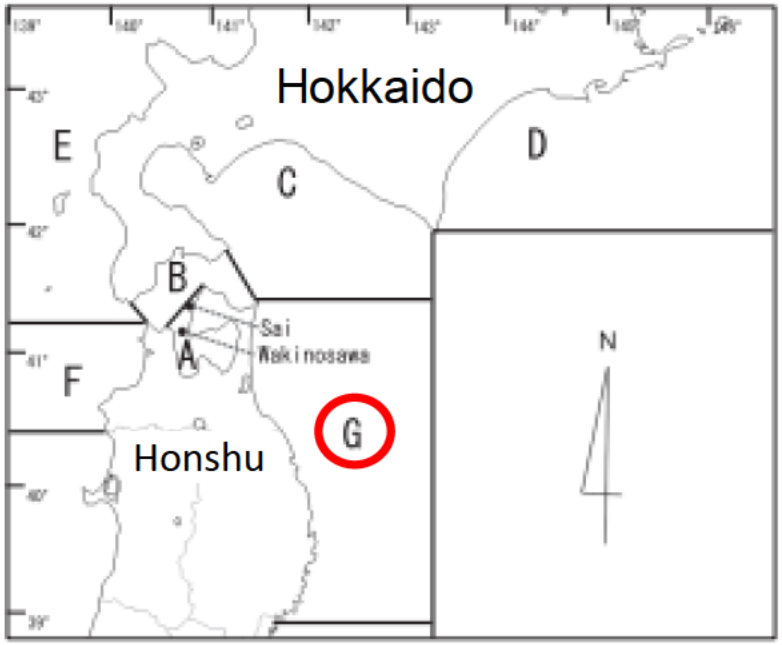


Fig. 1. Map showing release sites (●) and areas of recaptures for Pacific cod *Gadus macrocephalus* in the present study; A: Mutsu Bay, B: Tsugaru Strait, C: Off Southwest Hokkaido, D: Off Southeast Hokkaido, E: Northern Sea of Japan, F: Southern Sea of Japan, and G: Off Northwestern Honshu.

Survey period :1979-2017
Release: 3,226 ind.
Recapture: 398 ind.*
*Off the pacific of Honshu(Area G): 4 ind.

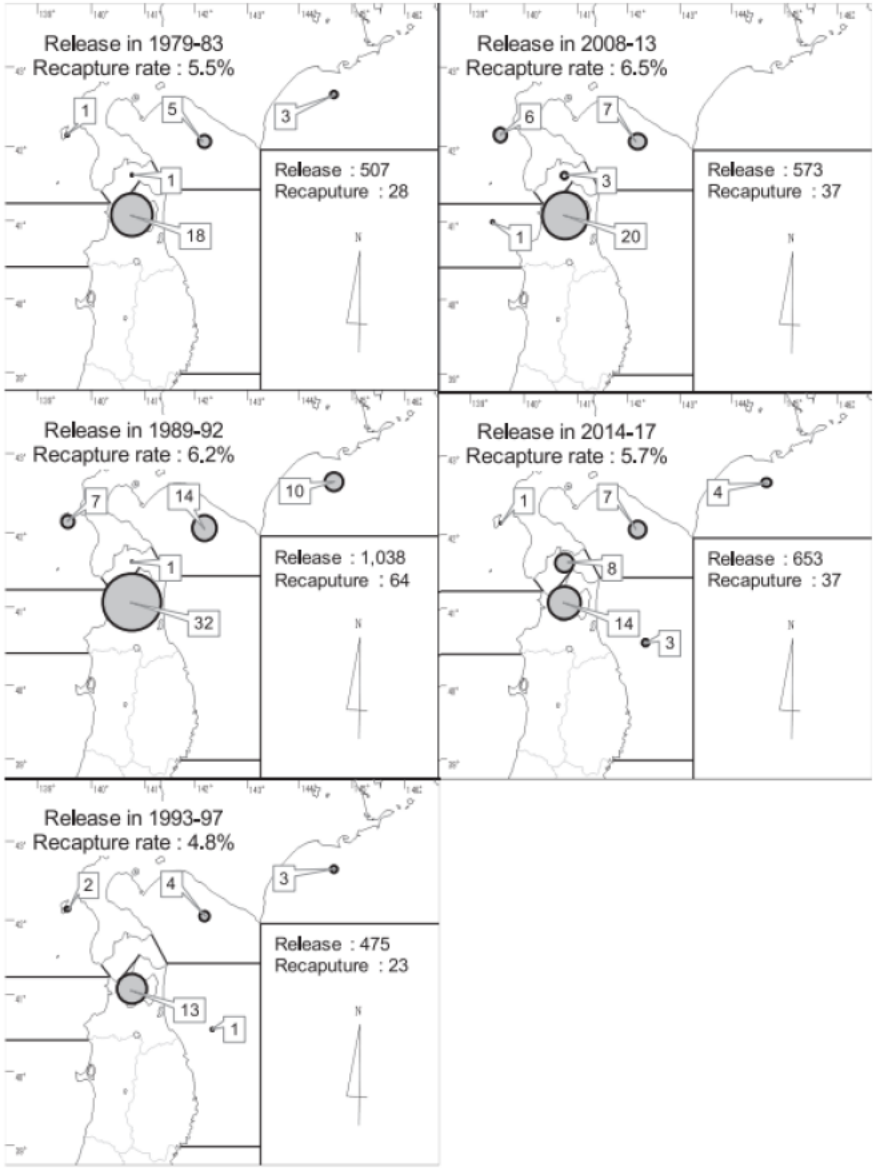


Fig. 2. Number of released fish from Sai and Wakinosawa (mouth of Mutsu Bay) phase I (1979–1983) to V (2014–2017). Balloons show the number of recaptured fish.

Age and growth

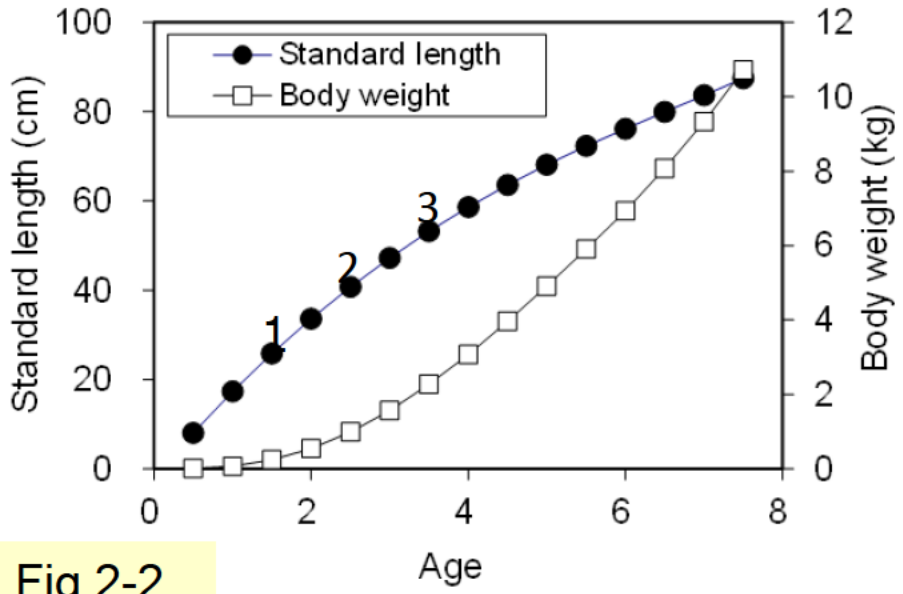
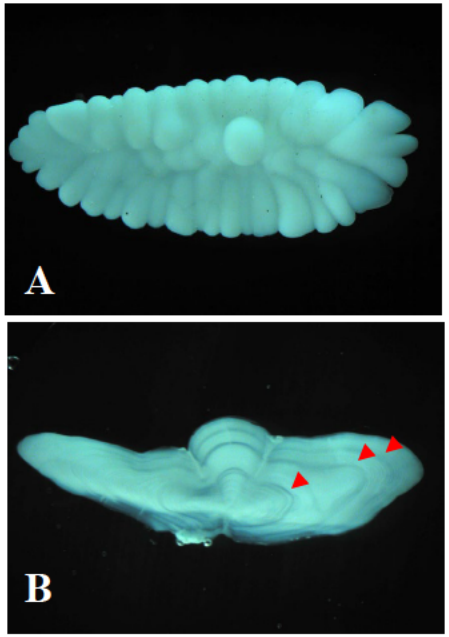


Fig.2-2

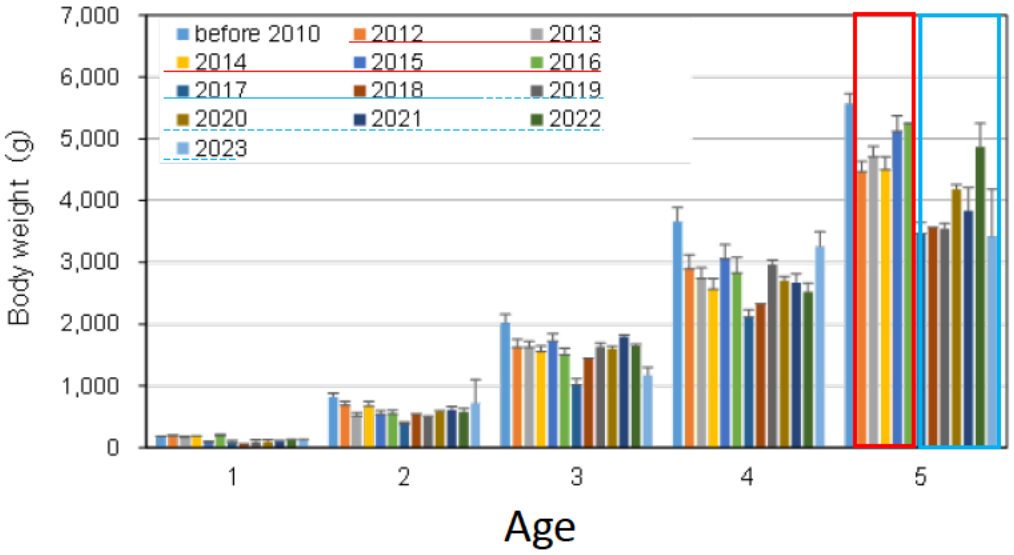
Age1 :19cm、0.09kg
Age2 :34cm、0.5kg
Age3 :48cm、1.7kg
Age8 :90cm、10kg

Wakataka-maru trawl Survey

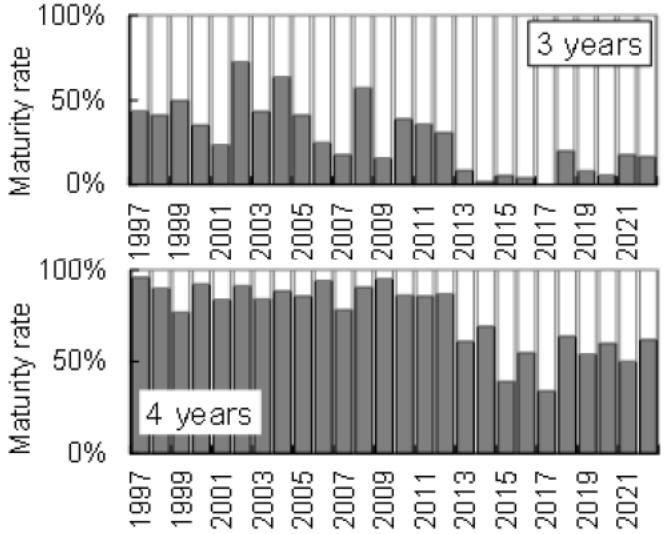


A:Sagittal otolith of Pacific cod
B:The section(0.3mm)

Since the Earthquake, Growth and Maturity



Supplementary Fig. 8-1

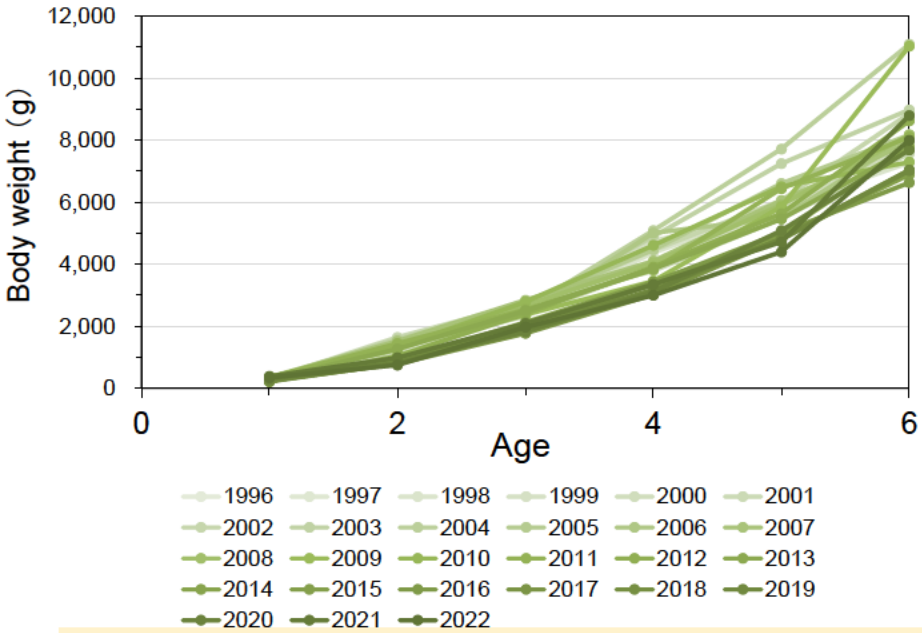


Supplementary Fig. 8-2

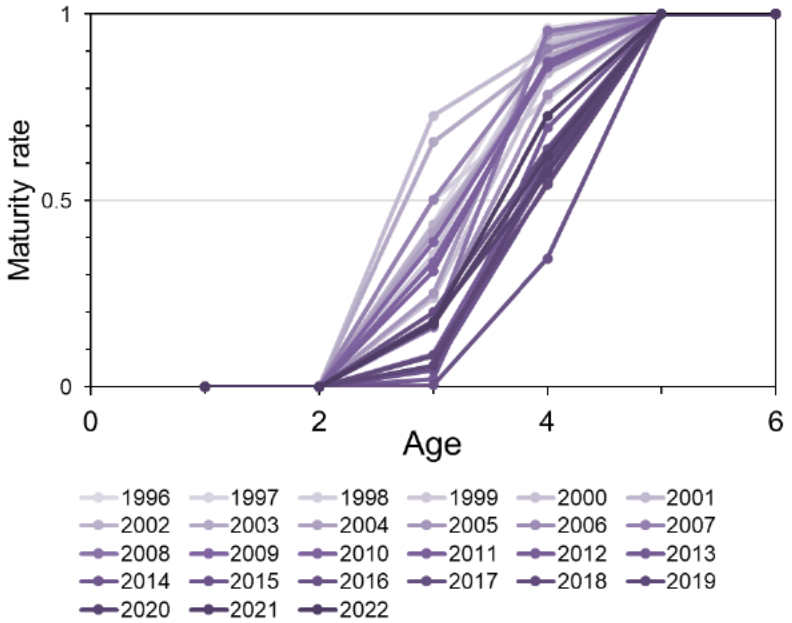
- Pacific cod growth was shown to be negatively correlated with recruitment even before the Earthquake (Narimatsu et al. 2010)
- Growth slowed down in tandem with the rapid increase in stock following the Earthquake from 2012 to 2016.
- Pacific cod caught in surveys conducted in 2017 and April 2018 tended to be significantly lighter in body weight.
- Following the slowdown in growth, the maturity rate by age also declined, particularly in the age 3 and age 4 groups.

Age and growth

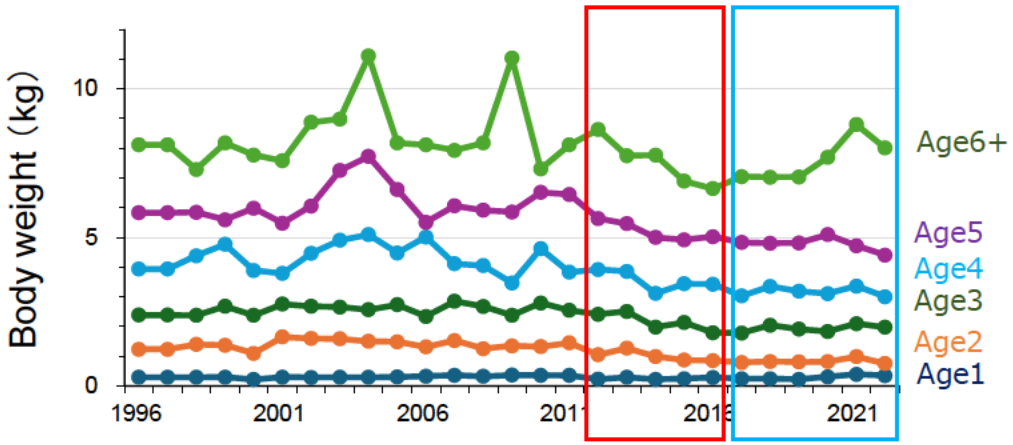
Supplementary Table 2-1 （reorganization）

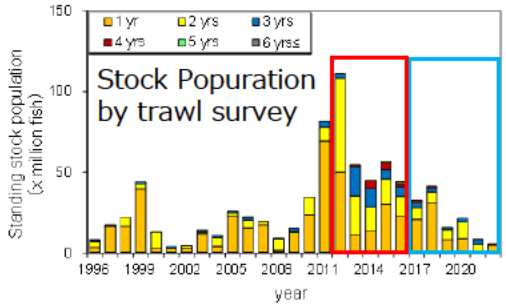


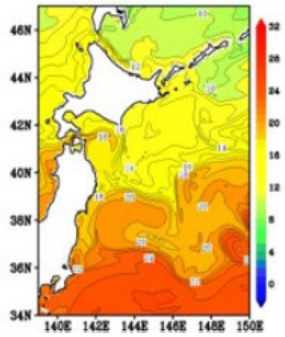
Supplementary Table 2-1 （reorganization）



Supplementary Fig. 8-2 (reorganization)







Temperature（℃）of Sea surface Nov.-2018

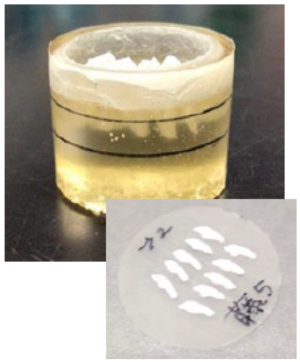
FRA-ROMS Ⅱ

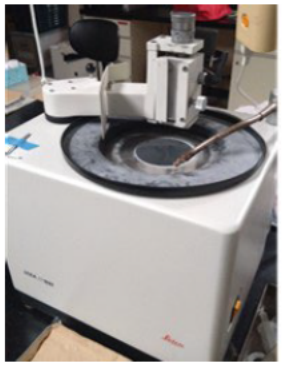
Age and growth

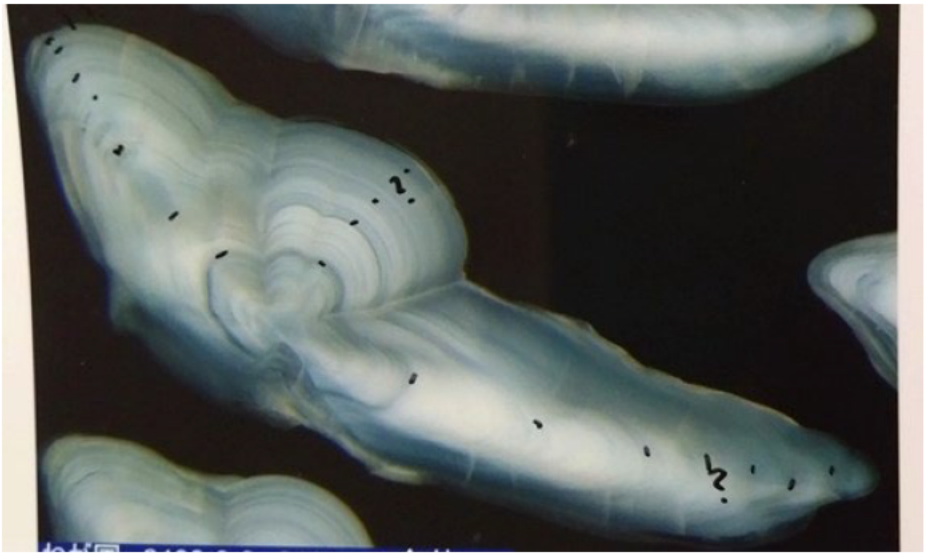
・Since 1996, we has been observing around 1,000 otoliths per year, including individuals collected through trawl surveys and individuals purchased at the market.

・The method is resin embedding, creating thin sections, taking pictures with a stereo microscope, and observing on photographs in the process of this slide.

＊The thickness of the section is 0.3 mm.







Annual rings observed otolith sections of the cod

・Although the uncertainty of the observation results is not taken into account in the VPA, the observation of otoliths is cross-checked and the two directions of otoliths are counted even in the case of one person.

Fishery and Catch

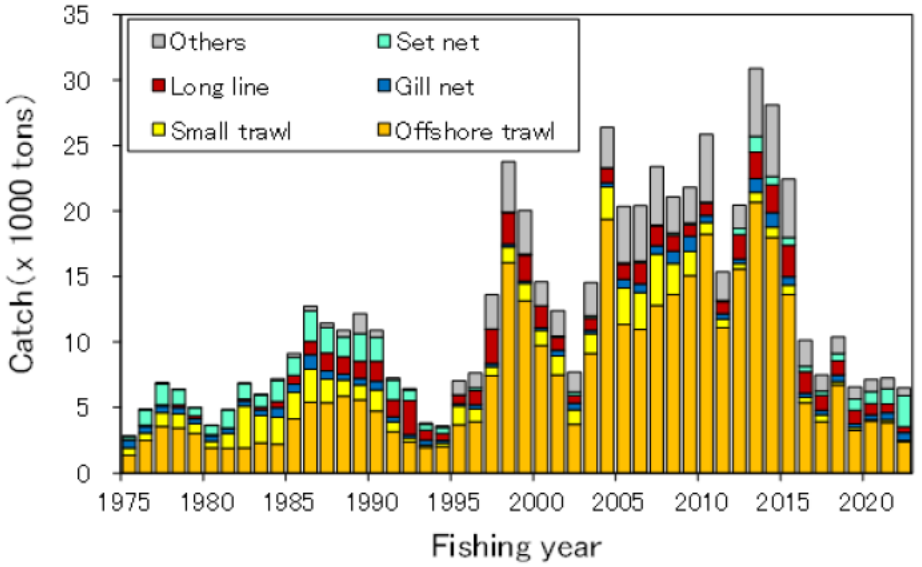


Fig. 3-1 Catches of Pacific Cod by Fishery Type.

- Fishery: Offshore trawl, Set net, Long line and Gill net

- Catch:
  1993 : 3,000tons
  2010 : 26,000tons
  2013 : 31,000tons
  2022 : 6,500tons

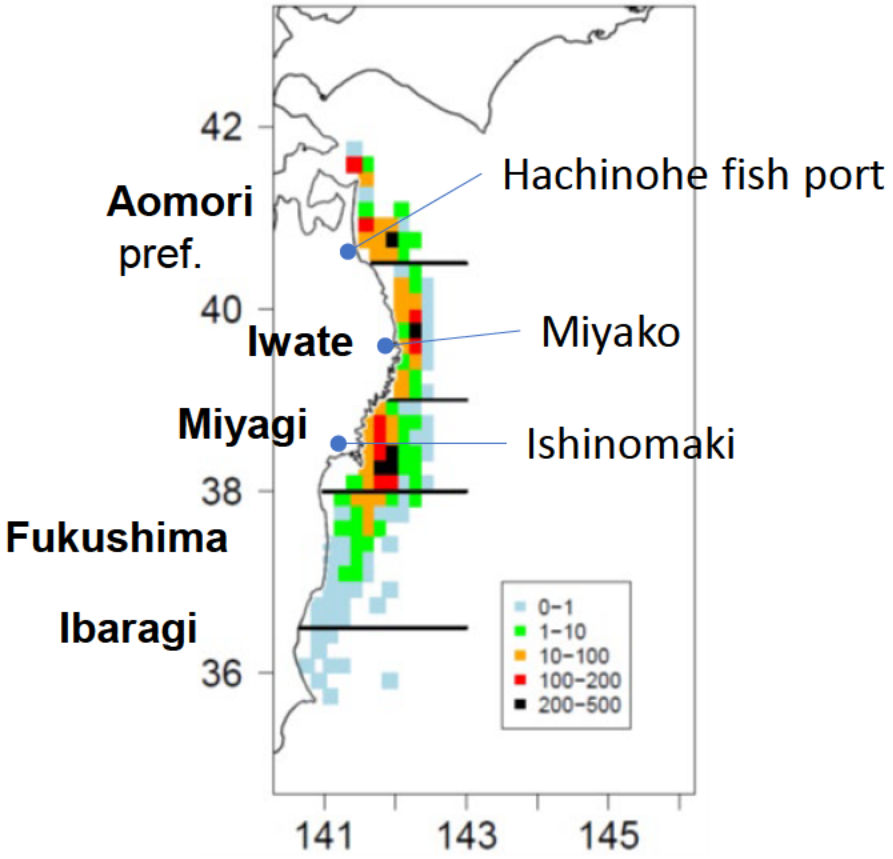
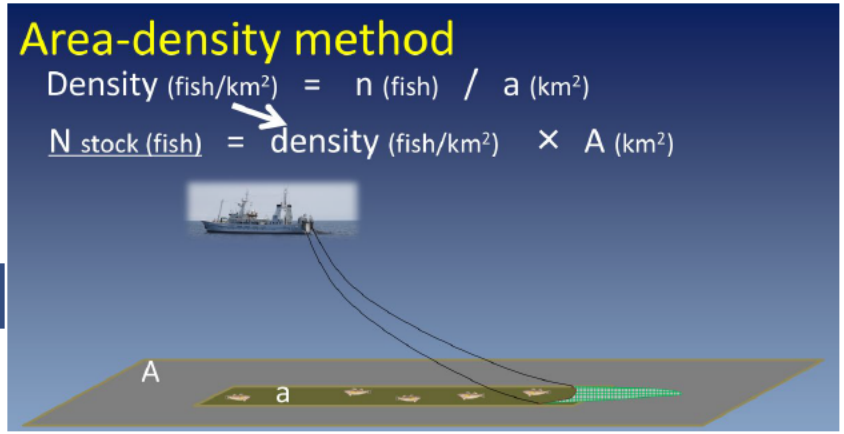


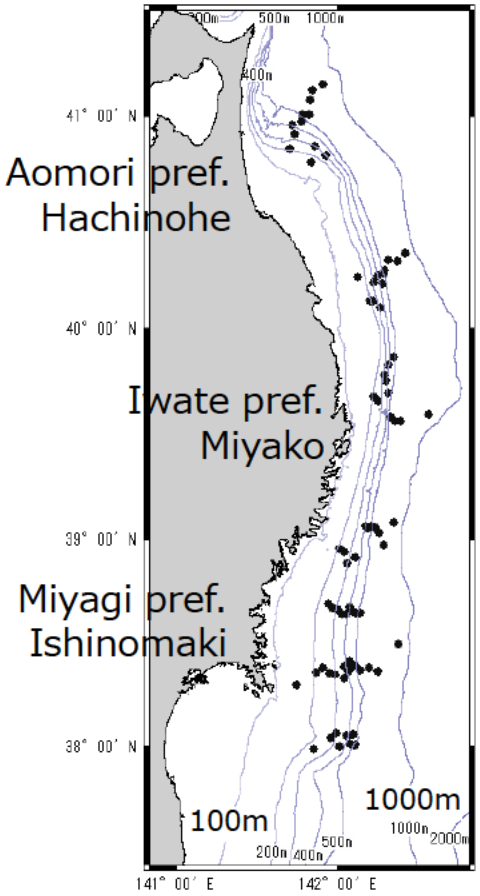
Fig. 3-2 Distribution of Catches (Tons) in 2021 by Offshore Bottom Trawl

- Catch amount was higher from off Aomori prefecture to off Miyagi prefecture

Bottom trawl Survey and Stock abundance index

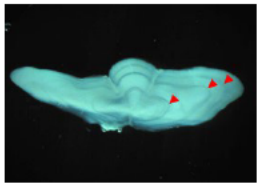
Wakataka maru (692ton)





Survey Area

- Since 1996, every year, the bottom trawl survey has been conducted from October to November.
- The Survey area is off Aomori, Iwate and Miyagi, which is the main distribution area of cods.
- The area-density method uses 8 layers: 0-200, 200-, 300-, 400-, 500-, 600-, 700- and 800-1000m.
- On board, the number and weight of the individuals in the net, the body length and weight are measured. In addition, individuals over 30cm are harvested otoliths, and individuals over 40 cm are harvested from gonads.



- The age of all otolith is assessed and the stock abundance at age of the entire marine area is calculated. It is used for the tuning index value of VPA.

Stock index estimated by Trawl Surveys

Stock Population

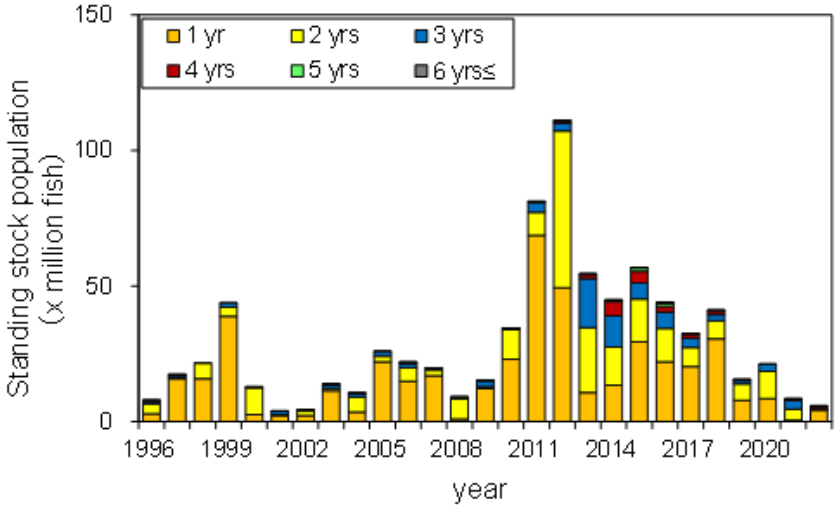


Fig. 4-1 Trends in Standing Stock Population by Age Estimated by Trawl Surveys

Stock Abundance (stock index)

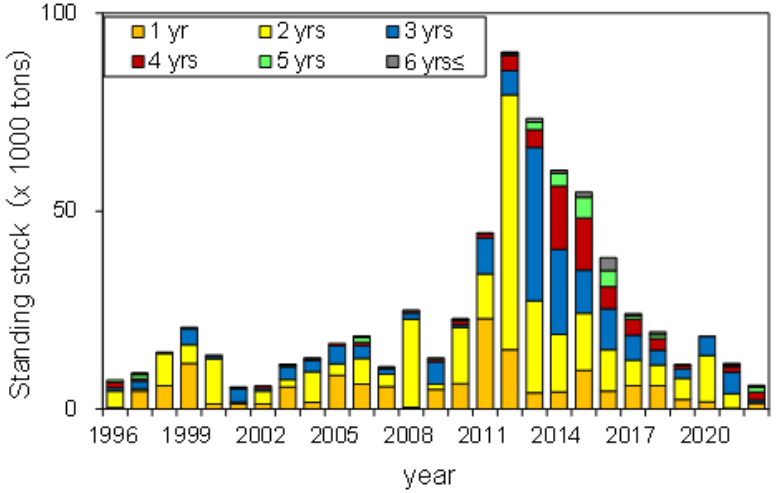


Fig. 4-2 Trends in Standing Stock by Age (Abundance Indices) Estimated by Trawl Surveys

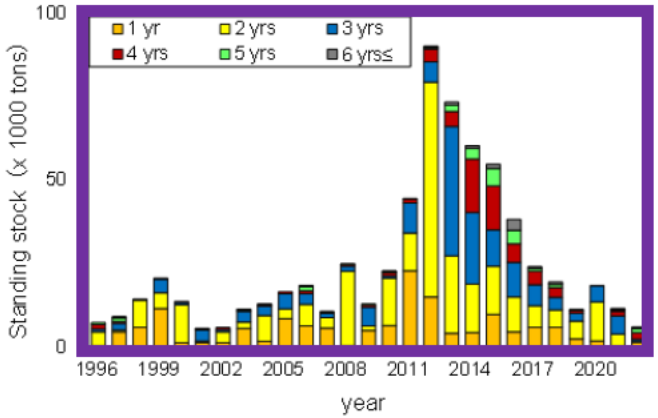
- On the research vessel, a lot of age 1 and 2 fishes are collected. Relatively few age 3+ fishes.
- In recent years, the number of age 1 fish has been decreasing.

- High variability
- In 2013, there were quite a lot of them
- Since then, it has continued to decline, and since 2017 it has been less

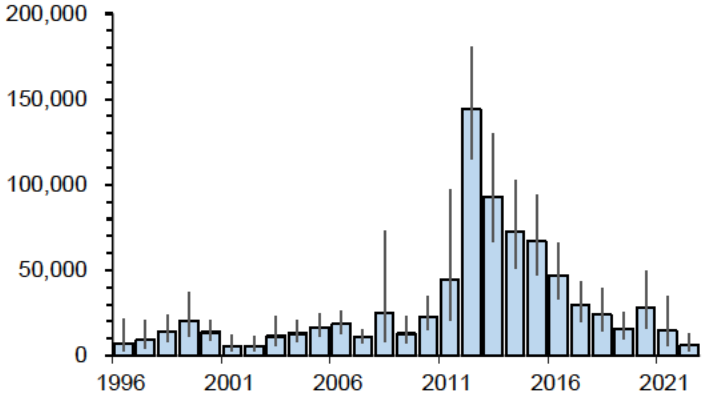
➡ The stock abundance index was used as an index to tune the VPA

Stock index by RV and CPUE by offshore bottom trawl

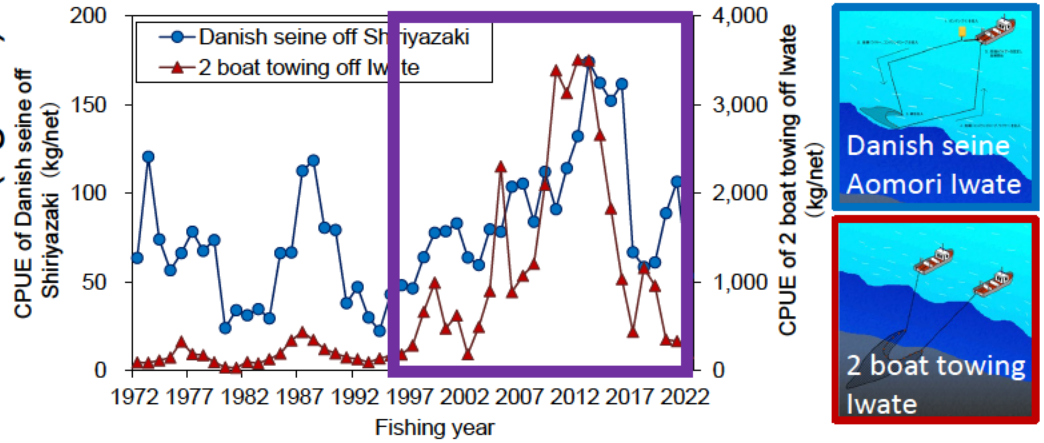
Stock abundance



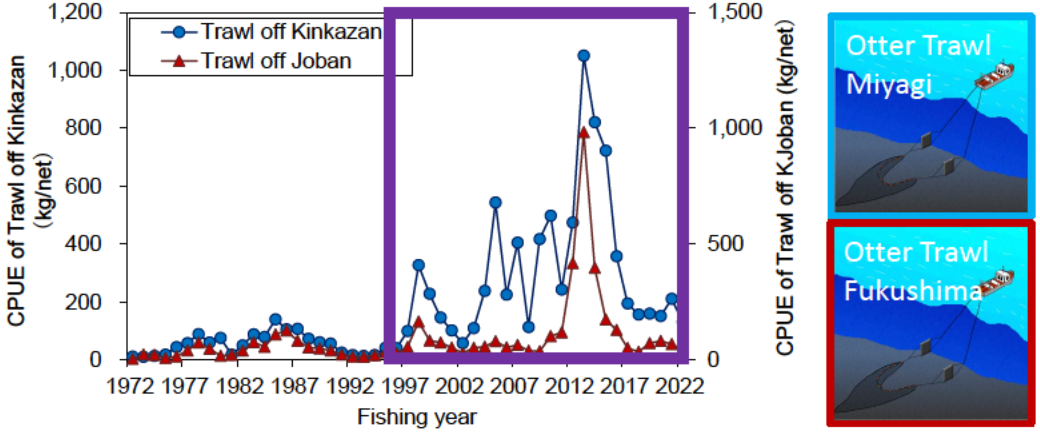
Wakataka maru
*Otter trawl



CPUE (kg/net)



CPUE (kg/net)

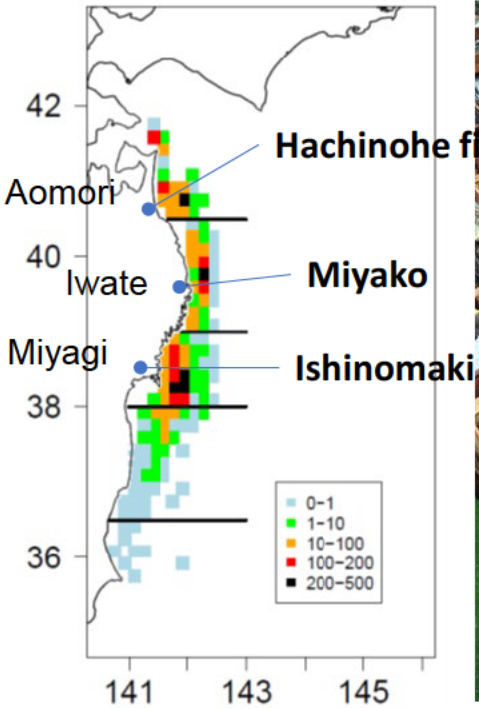


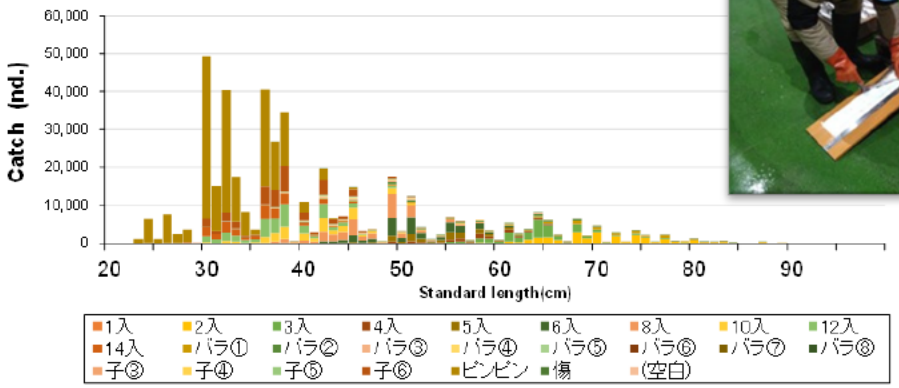
* Stratification area and age-specific collection efficiency are not taken into account.
* Bars are 95% confidence intervals

- In recent years, it has been extremely high around 2013, then decreased significantly, and has been less since 2017.
- In addition, in the data of research vessels, it was the highest in 2012, and it is the highest in the CPUE of fishing vessels, a few years later.

http://www.zensokoren.or.jp/trawl/trawl_fisheries.html

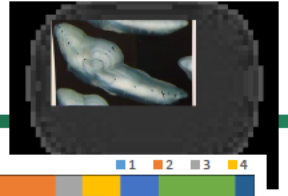
Landing size composition

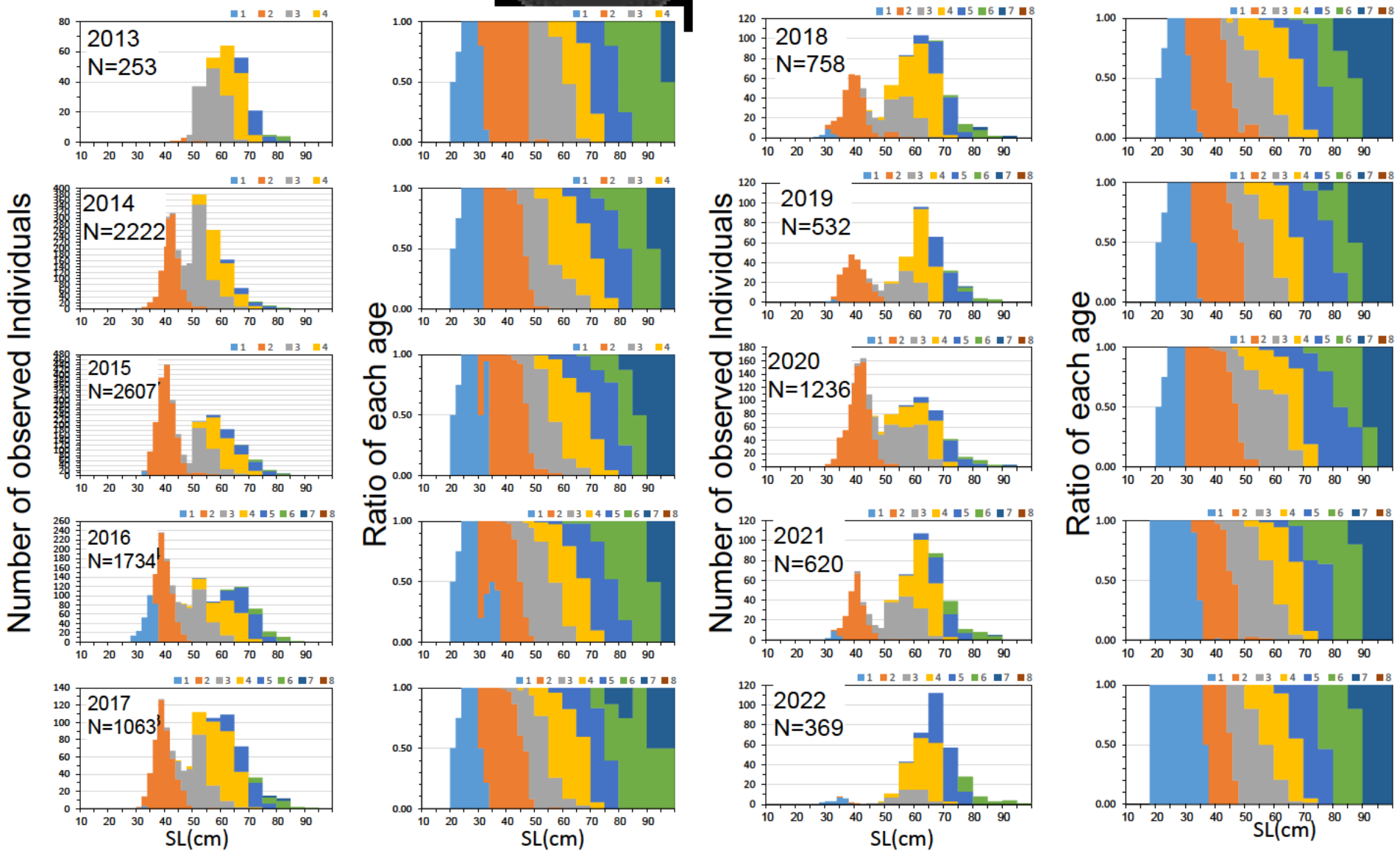




- Since 1996, 40,000 inds./yr have been measured at fish markets in Hachinohe, Miyako and Ishinomaki.
- We measure 5~15% per year for each type of packaging and standard at the time of landing.
- ALK has been created every half year (April-Sep., Oct.-March).
- Number of otoilths observed were 1,000 inds./yr.
- The weight used for VPA is calculated based on this market research data and ALK. Specifically, the average body length of each age is calculated based on the size composition of each age, and it is converted to body weight by the body length-weight relationship equation.

Age-length key





- ALK has been created every half year (April-Sep., Oct.-March).
- Number of otoilths observed were 1,000 inds./yr.

Reviewer's comment

Label	Q	A	Slide
T-11	11) The catch data in the annual statistics yearbook is typically in tons. Please describe the method used to convert catch in tons into catch-at-age in numbers?	First, we calculate a tentative CAA. If this CAA is multiplied by BW, it should be the catch, but it does not exactly match the statistical value, so the CAA is adjusted slightly without changing the age ratio.	13,14
T-14	14) Are the same ALKs used to convert index into index-at-age the same as for catch?	No. All fish caught by the trawl surveys have been directly aged, so ALK is not necessary for the index.	10,13, 14
K-1c	c. Were the age records from the fishery or the survey? Or were they pooled together?	We used both otoliths of the fish caught from the fishery and the survey for aging.	10,14
Y-3	I recommend to add a graph of interannual variation of age composition in commercially caught fish, such as histograms of every year	Recent ones are shown.We will consider publishing it next year.Trawl surveys conducted by research vessels in the fall have suggested that one-year-old fish are getting smaller, and we are paying attention to them.	13,14, 16

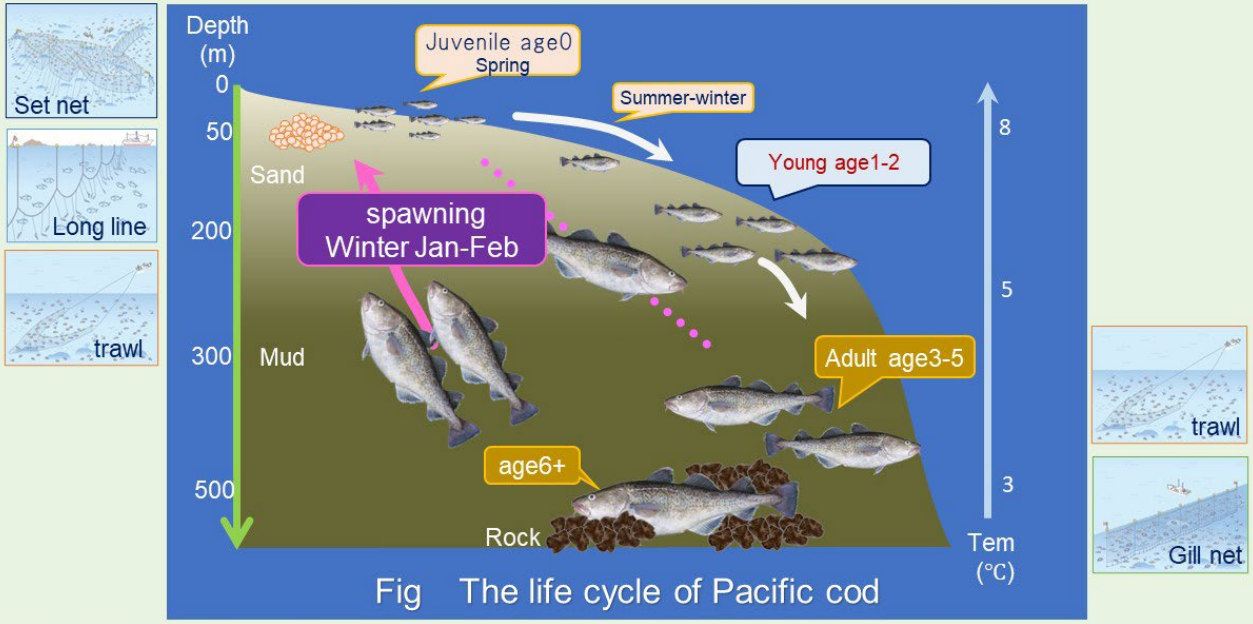
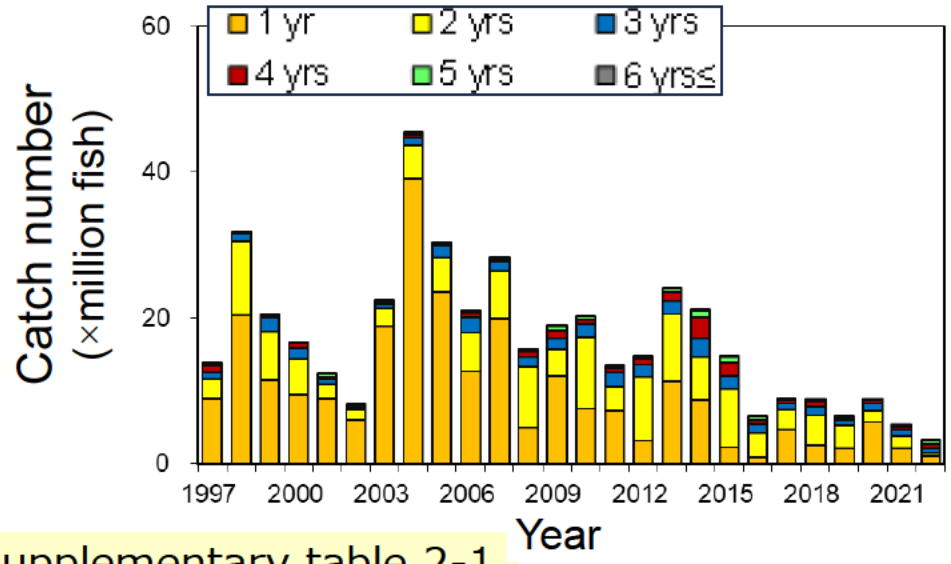


Fig The life cycle of Pacific cod

Illust of Fishing https://www.maff.go.jp/j/tokei/census/gyocen_illust2.html

Trawl surveys by RV Wakataka-maru are carried out twice a year, in spring and autumn. Emphasis is placed on large-scale autumn survey to calculate stock index.
However, since information such as the winter spawning season cannot be obtained from trawl survey, fishes purchased on the market are also used for ALK and CAA.

Catch at Age and Tuning VPA



- In 2013-15, there were many elderly fish.
- In recent years, the ratio of Aeg 1 fish caught has been decreasing.

Supplementary table 2-1

Step1

Age 1-4 $N_{a,y} = N_{a+1,y+1}\, exp(M) + C_{a,y}\, exp(M/2)$

$\boldsymbol{M}$ = 2.5/7 = 0.357 (Tanaka 1960)

the most recent year $N_{a,2022} = C_{a,2022}\, exp(M/2)/(1 - exp(-F_{a,2022}))$

Age 6+ $N_{6+,y} = C_{6+,y}/(C_{6+,y} + C_{5,y}) \times N_{6+,y+1} \times exp(M) + C_{6+,y} \times exp(M/2)$

Age 5 $N_{5,y} = C_{5,y}/(C_{6+,y} + C_{5,y}) \times N_{6+,y+1} \times exp(M) + C_{5,y} \times exp(M/2)$

Age 1-5 $F_{a,y} = -ln(1 - C_{a,y}\, exp(M/2)/N_{a,y}))$

$F_{5,y} = \alpha F_{6+,y}$ $\alpha = 1.0$

Step2

$\sum_a \sum_y (I_{a,y} - q_a B_{a,y})^2$

$\boldsymbol{I}$: stock abundace index by **trawl survey**
$\boldsymbol{B}$: stock abundance by VPA

Based on Hiramatsu (2001), q and Ft for the most recent year which minimize equation were determined analytically and exploratively, respectively.

Stock and Fishing Mortality estimated by T-VPA

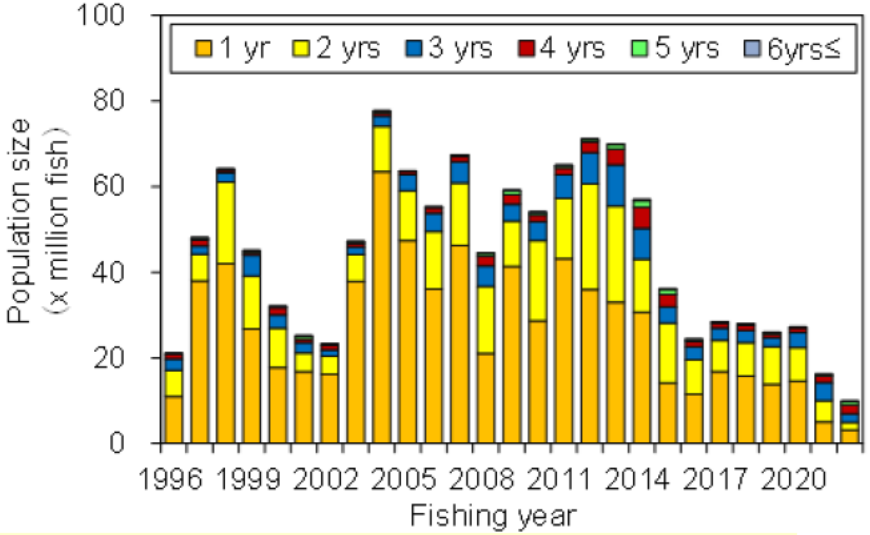


Fig. 4-4 Stock Population at age

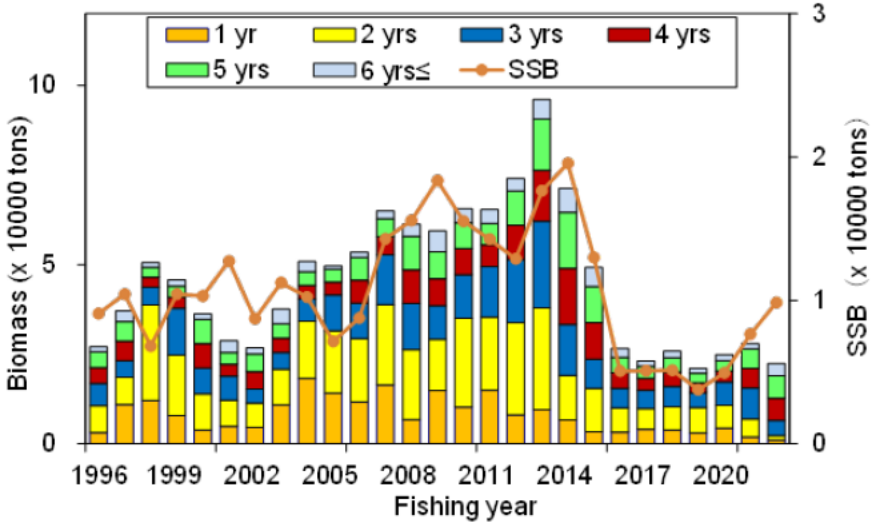


Fig. 4-5 Biomass at age and SSB

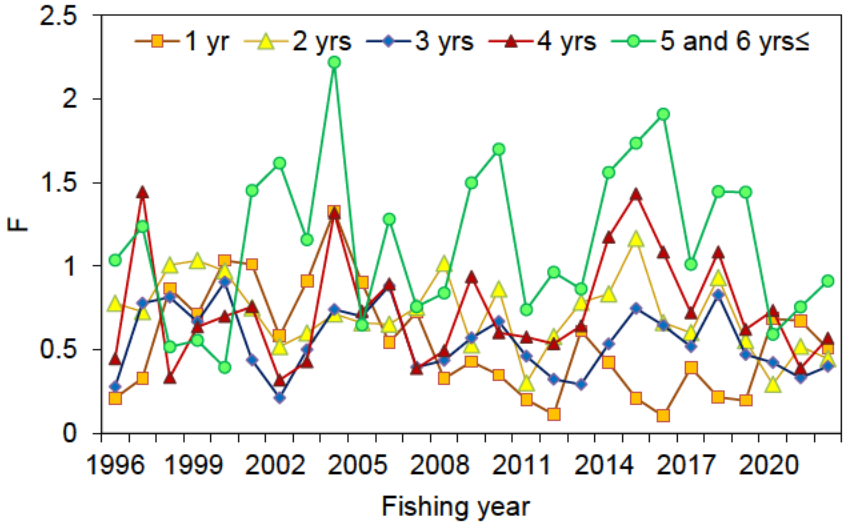


Fig. 4-7 Fishing mortality at age

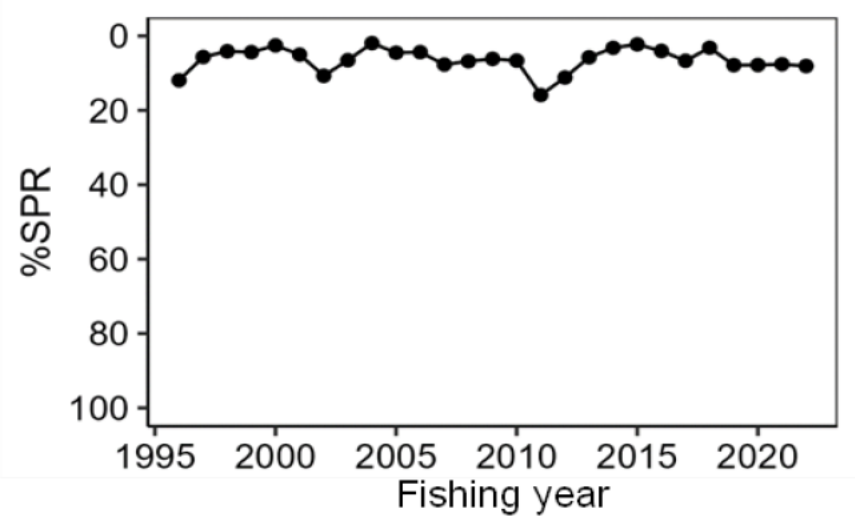
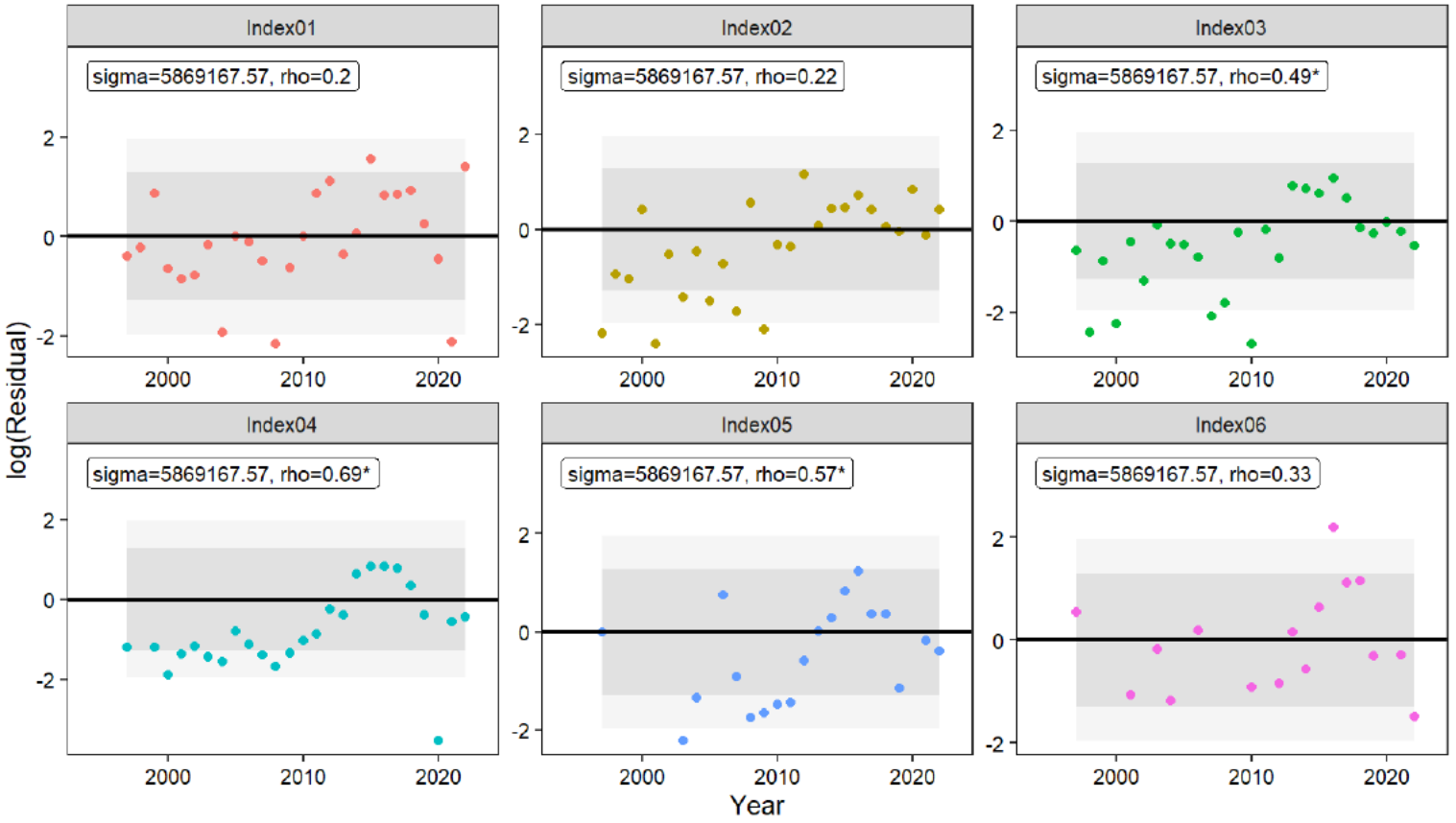


Fig. 4-9 %SPR

The robustness of Model (Residual Plots)



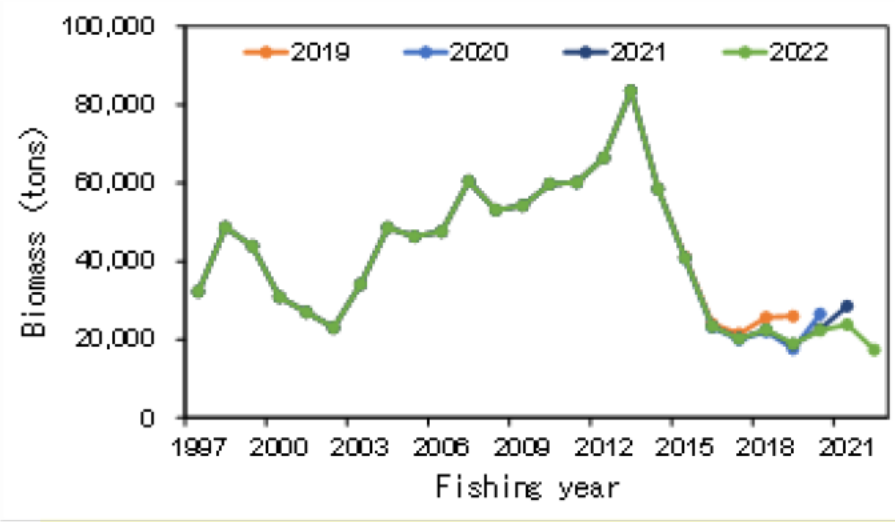
Supplementary Fig. 2-1. **Residual Plots** Showing the Difference Between Observed Abundance Indices and Projections in the Model

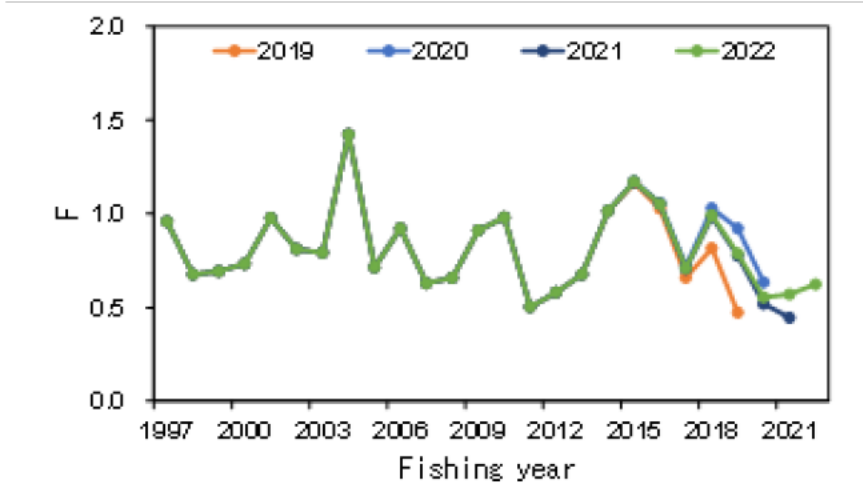
＊Light shading is 95% confidence interval, and dark shading is 80% confidence interval.

・Before 2010, the residuals were somewhat skewed.

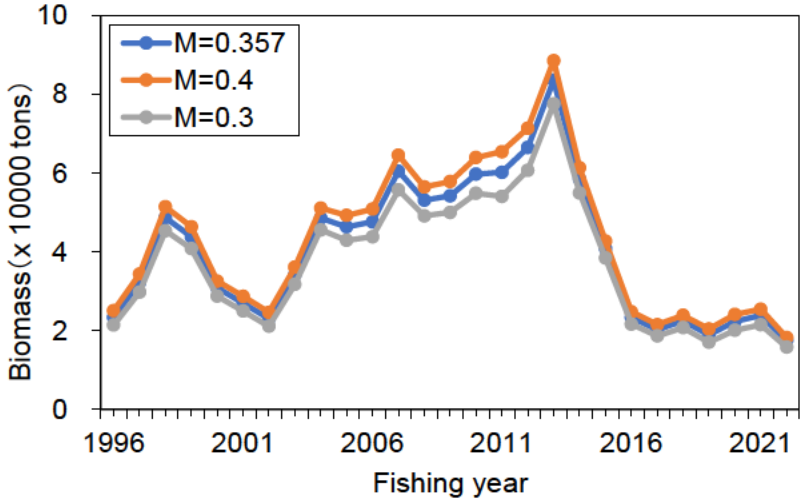
・Although the area of operation of the survey has not changed before and after the earthquake, it is considered to be related to the fact that the area where fishing vessels operate has changed significantly.

Retrospective Analysis and Changes in Biomass when M is Adjusted





Supplementary Fig. 2-2. Results of Retrospective Analysis of Biomass (Left) and F (Right)



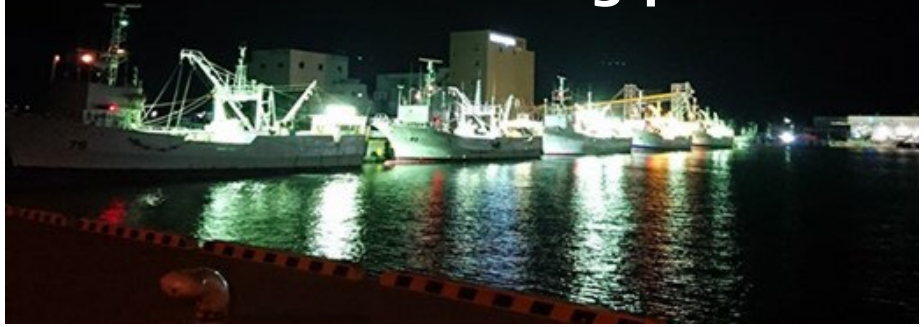
- Biomass has been revised slightly downward
- F is unstable, but the residuals are not biased
- The difference in the estimation results by M is small

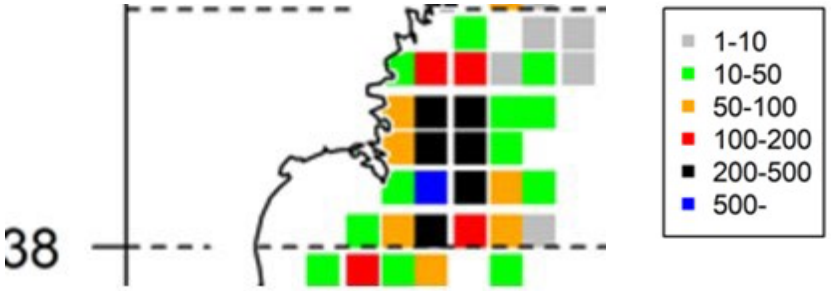
Fig. 4-8. Changes in Biomass when M is Adjusted

Reviewer's comment

Label	Q	A	Slide
T-11	11) The catch data in the annual statistics yearbook is typically in tons. Please describe the method used to convert catch in tons into catch-at-age in numbers?	First, we calculate a tentative CAA. If this CAA is multiplied by BW, it should be the catch, but it does not exactly match the statistical value, so the CAA is adjusted slightly without changing the age ratio.	13,14
T-14	14) Are the same ALKs used to convert index into index-at-age the same as for catch?	No. All fish caught by the trawl surveys have been directly aged, so ALK is not necessary for the index.	10,13, 14
K-1c	c. Were the age records from the fishery or the survey? Or were they pooled together?	We used both otoliths of the fish caught from the fishery and the survey for aging.	10,14
Y-3	I recommend to add a graph of interannual variation of age composition in commercially caught fish, such as histograms of every year	Recent ones are shown.We will consider publishing it next year.Trawl surveys conducted by research vessels in the fall have suggested that one-year-old fish are getting smaller, and we are paying attention to them.	13,14, 16

Offshore commercial bottom trawlers at Ishinomaki fishing port





The Map of fishing ground of offshore trawlers in April-June 2022

Since the earthquake, trawlers at Ishinomaki Fishing Port have been returning to the port in the evening instead of operating at night. The fishing grounds are now limited to the coast of Miyagi Prefecture.

Stock-Recruitment Relationship

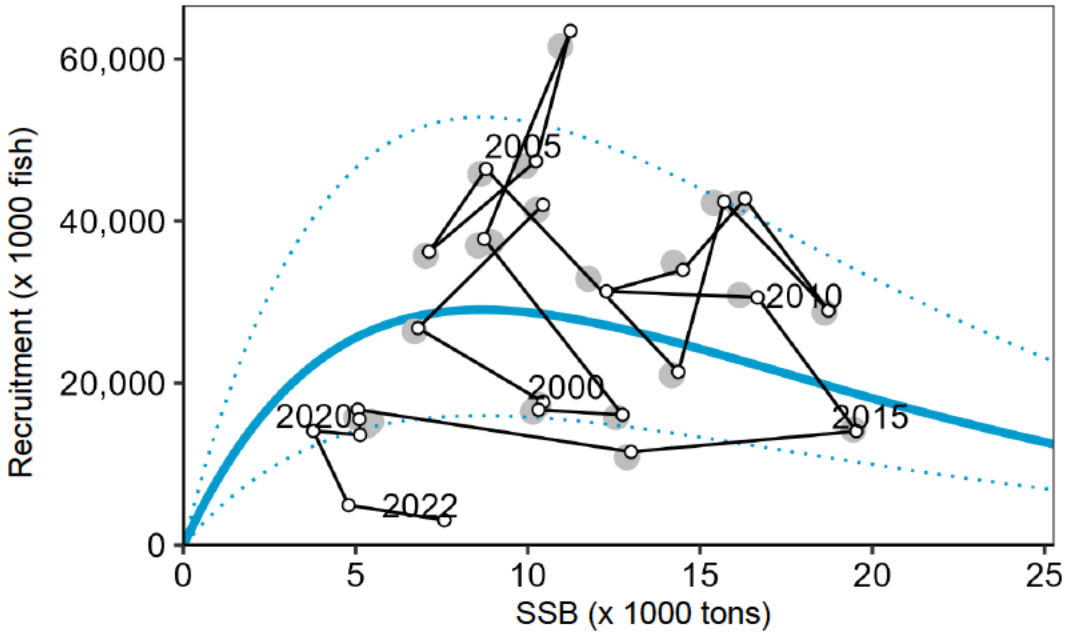
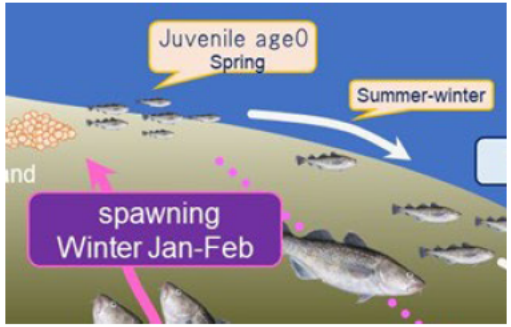


Fig. 4-11. Relationship between SSB and Recruitment Size (Number of Age 1 Fish)

The gray circles and blue line are the stock-recruitment relationship model proposed at the Research Institute Meeting held in August 2021 (Narimatsu et al. 2021). The dotted line indicates the range estimated to contain 90% of the observed data. White circles indicate biomass and recruitment size data in the FY2023 stock assessment.

- Smaller individuals have also been shown to be preyed upon by large Pacific cod (Hashimoto 1974).
- Recruitment continues to be lower than projected from stock-recruitment relationships



Estimated MSY (Stock-Recruitment Relationship Catch in weight curve)

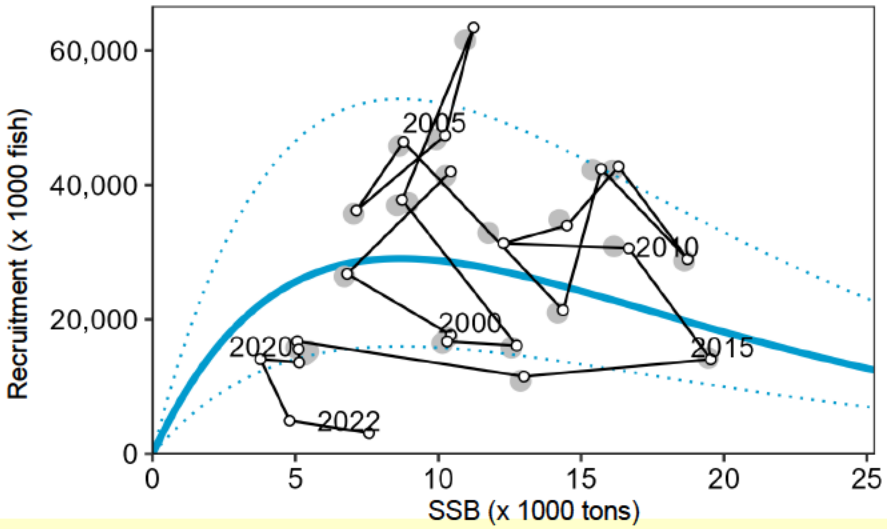
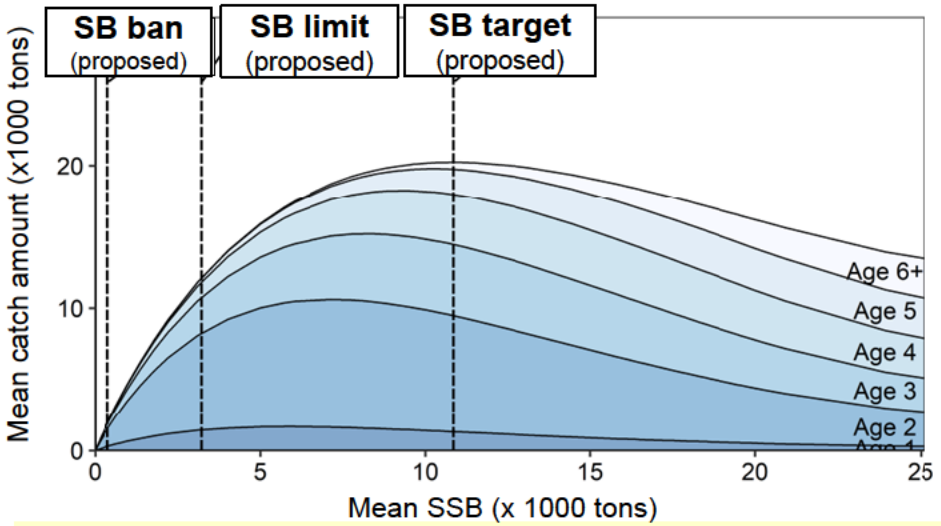
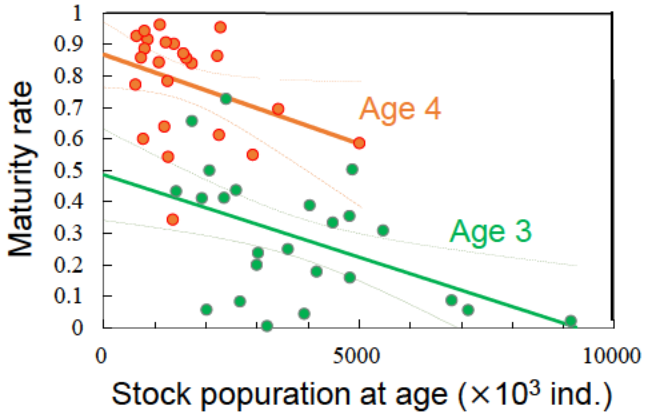


Fig. 4-11. Relationship between SSB and Recruitment Size (Number of Age 1 Fish)



Supplementary Fig. 3-2. Relationship of average SSB and average catch in weight at age at equilibrium

- SB over 120 years are estimated by Stock population in 2020 and stock-Recruitment Relationship
- Selection rate of F at age : Average 2016-2019
- Body weight at age : Average 1996-2019
- Maturity rate…
  Age1,2:0.0 Age3,4: Density dependent Age5,6+:1.0



SB target (proposed)	SB limit (proposed)	SB ban (proposed)	SB_{2022}	MSY	Catch 2022
10,900 tons	3,200 tons	400 tons	9,900 tons	20,200 tons	6,500 tons

Kobe plot

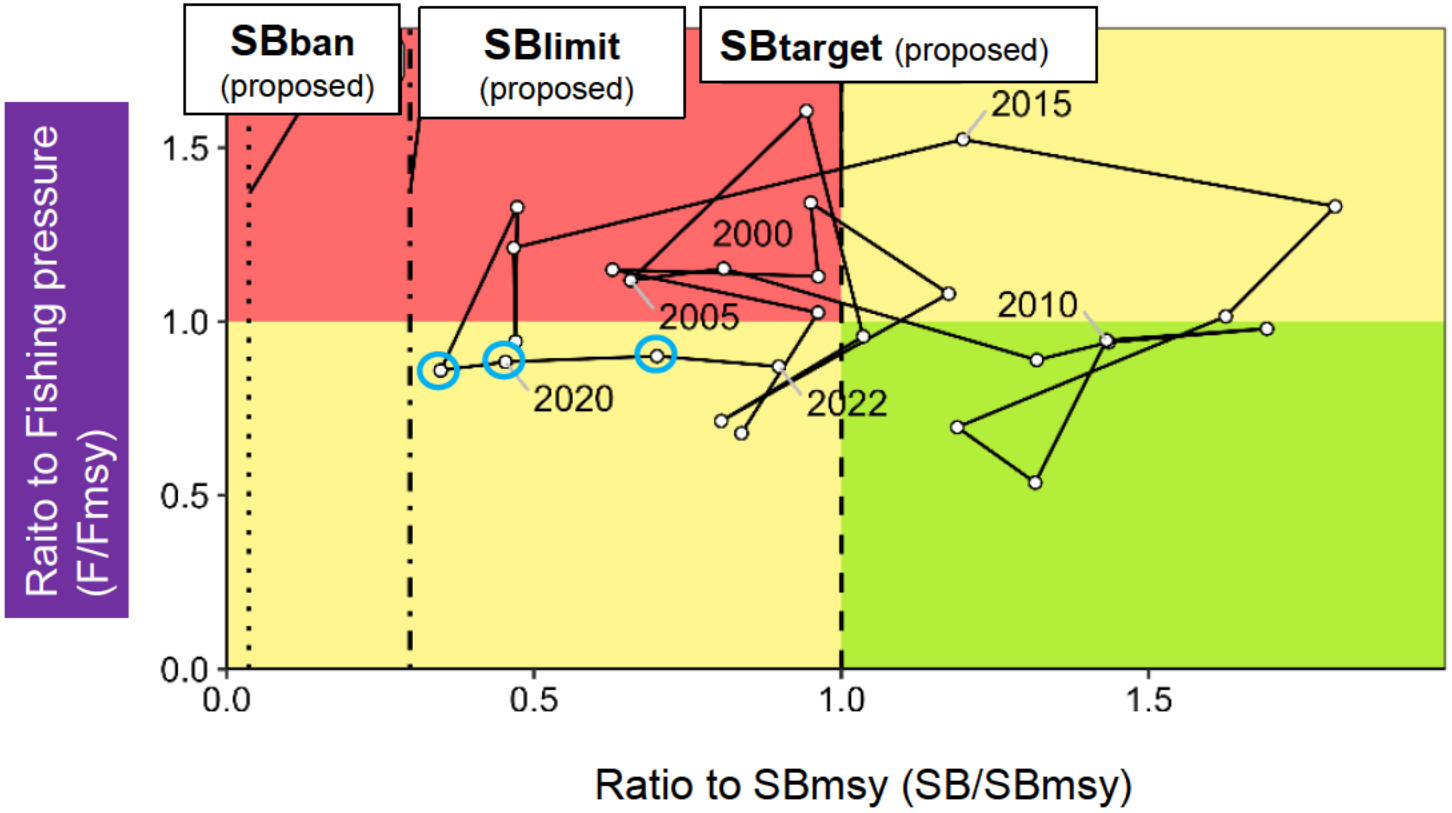


Fig. 4-12. Relationship of SSB required for MSY (SBmsy) and fishing pressure required for MSY (Fmsy) against levels of SSB and fishing pressure (Kobe plot)

- SSB has remained at a level below SBmsy since the 2016 fishing season
- Fishing pressure in the 2019-2021 fishing season was lower than the fishing pressure required for MSY (Fmsy)

Reviewer's comment

Label	Q	A	Slide
T-23	23) Please explain why the Ricker SRR was chosen as the base case. How does the Ricker compare with the Beverton-Holt and hockey-stick?	The reproduction curve confirms the likelihood and other factors and uses a Ricker type. It is also known that large fish eat small fish due to the overlap in the distribution of large fish and small fish due to the increase in density, and we believe that it is ecologically reasonable.	21
K-5	5. Fig. 4-12: I think the y-axis label might be incorrect	It seems that I made a mistake in the English translation file. The correct label is "Ratio to Fishing pressure (F/Fmsy)".	23
Y-11	Negative relationship is presumed between the maturity at age 3 and 4 years and population size. Although the relationship may be incorporated in assessment, in recent years population sizes are decreasing with slow growth and late maturation. In order to solve such contradictions, it is necessary to introduce interannual changes in the parameters related to the productivity of the stock and to change the reference points accordingly.	In future projections, we change the maturation rate as a function of the amount of stock size. Therefore, these results are reflected in MSY and management reference points. We plan to incorporate new data and reflect it when it is reviewed in five years.	22

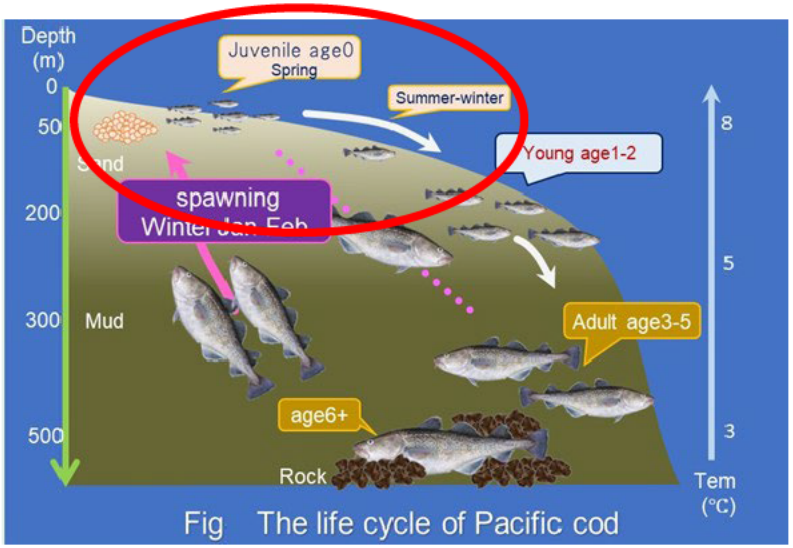
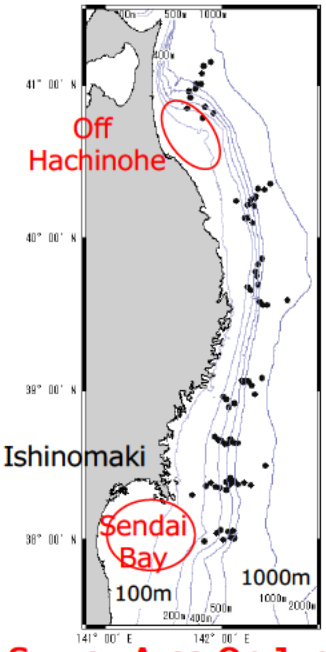


Fig The life cycle of Pacific cod

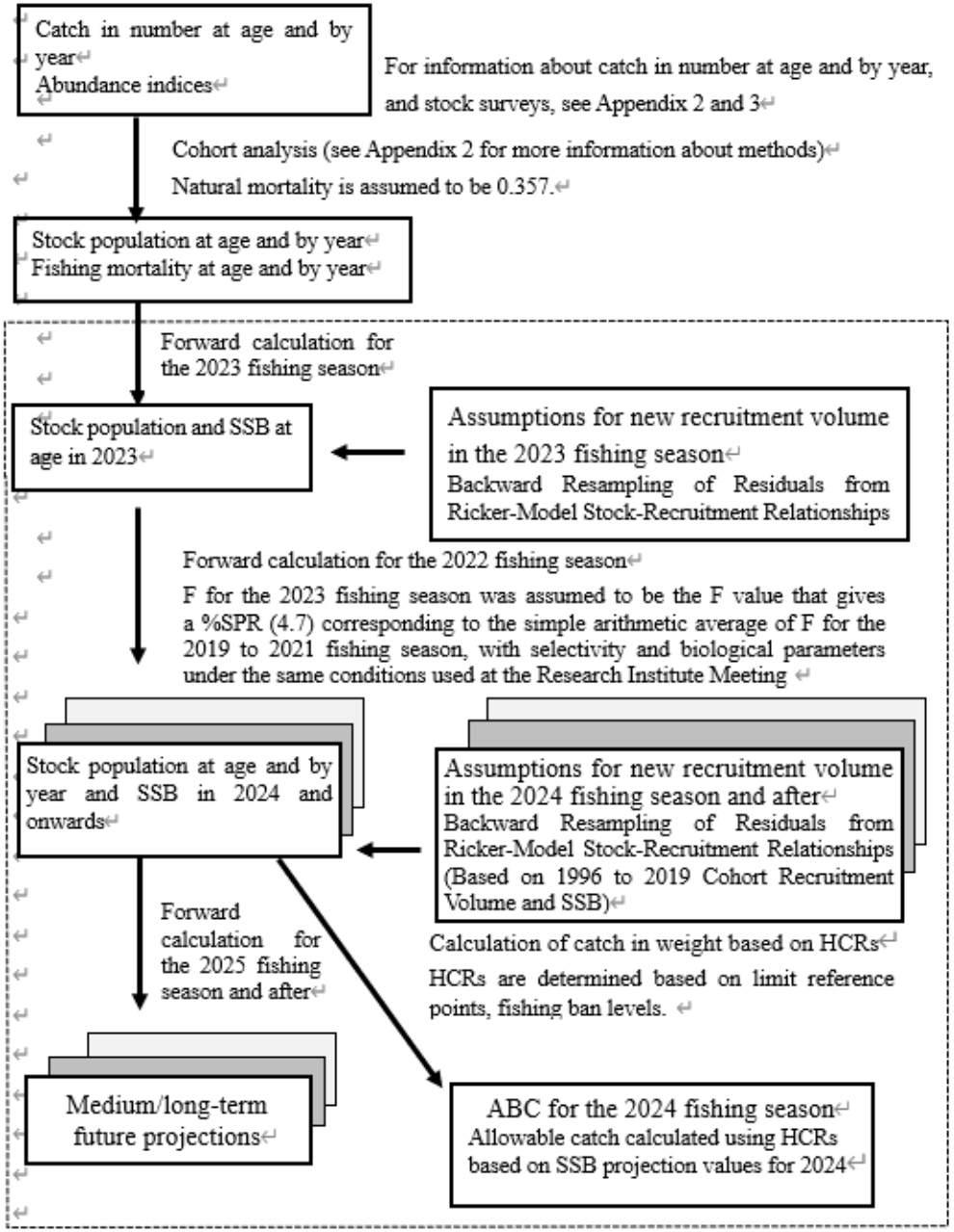


Survey Area On June

・Since 2017, with the exception of 2022, the number of samples has been very low, especially in Sendai Bay.

・We have been analyzing data on water temperature and food environment, focusing on the fact that the warm current Kuroshio Current has been sweeping off the coast of Sendai Bay since around 2016.

Appendix 1 Stock Assessment Flow



Setting Future Projections

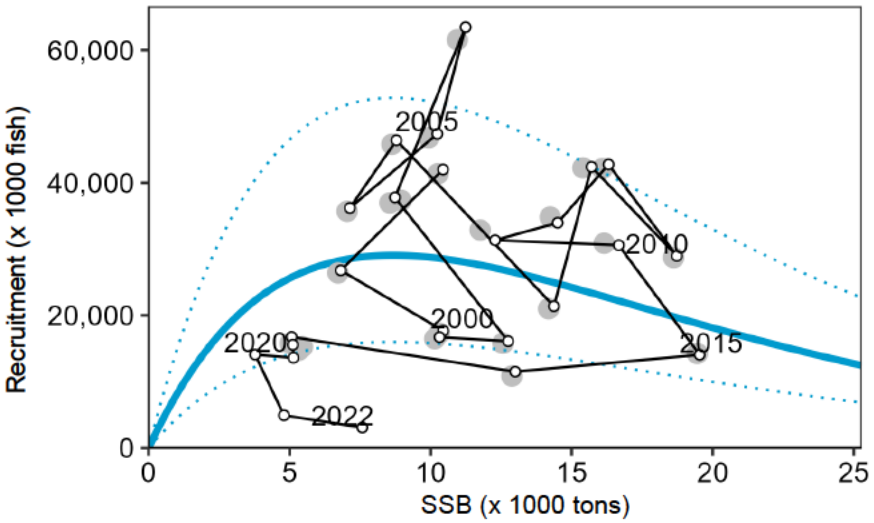
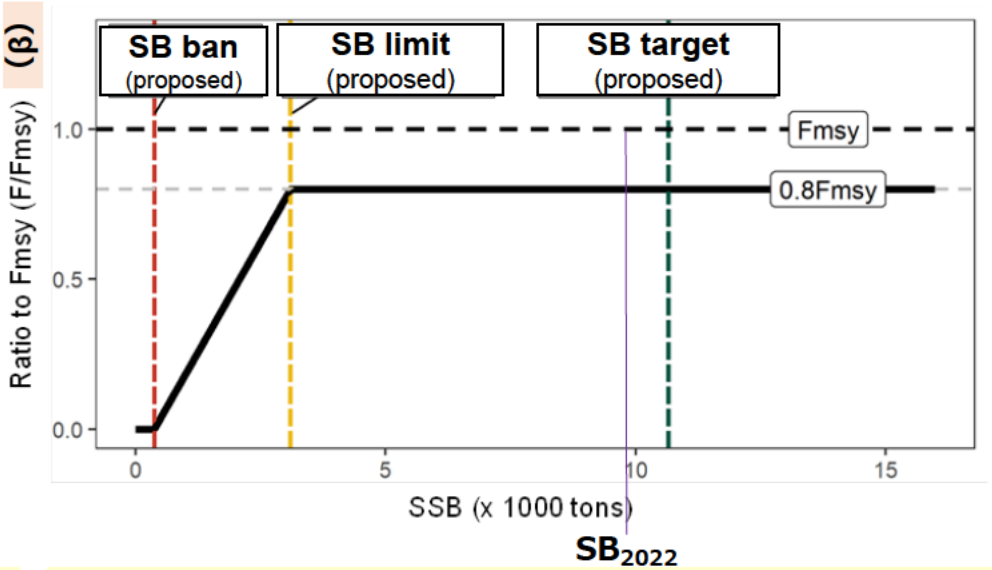
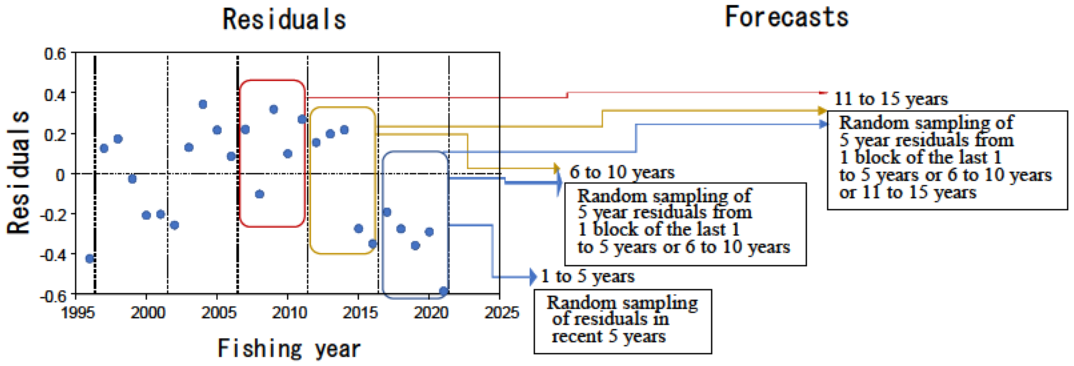


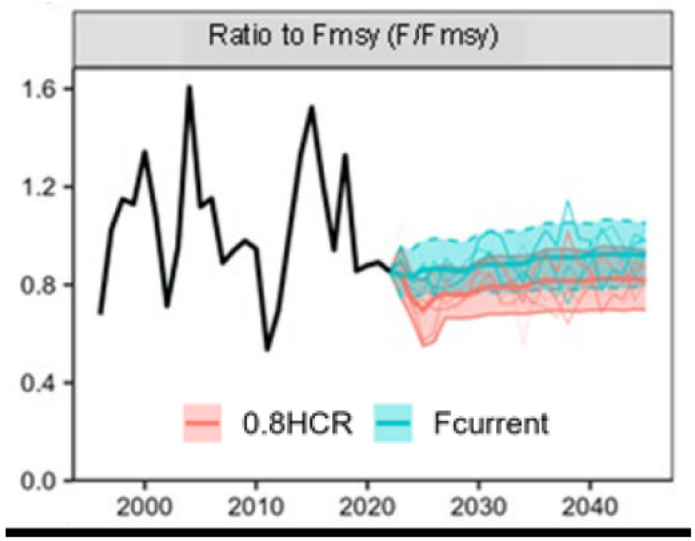
Fig. 4-11. Relationship between SSB and Recruitment Size (Number of Age 1 Fish)



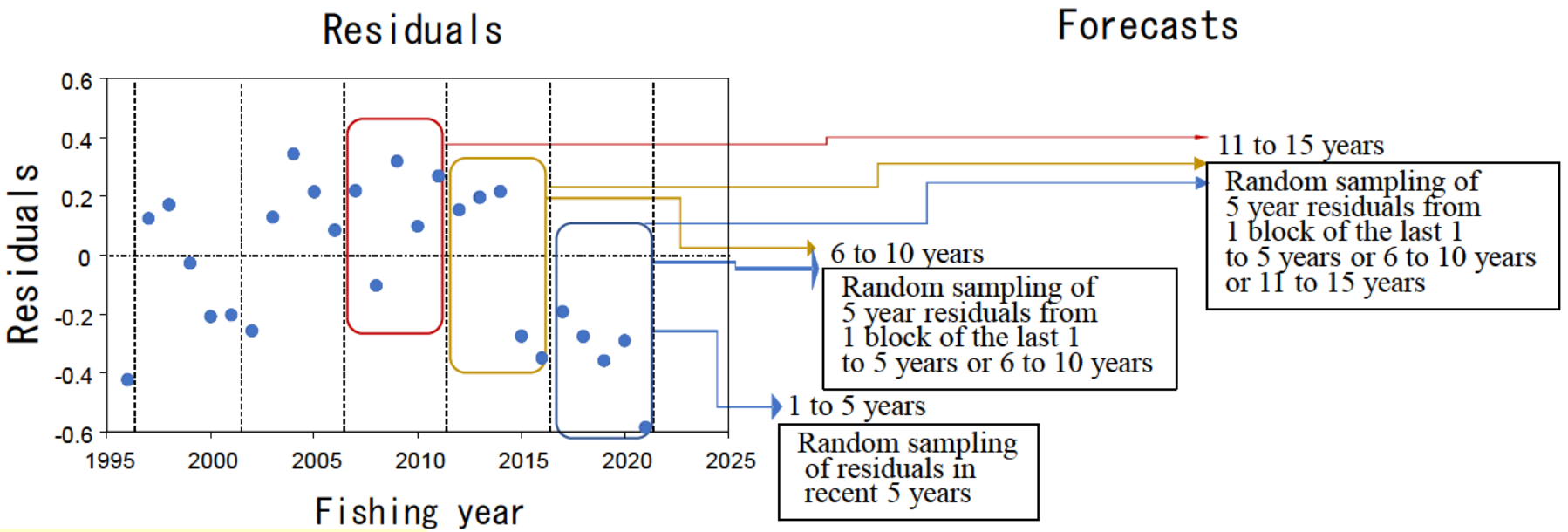
Supplementary Fig. 4-1. Proposed Harvest Control Rules (HCRs)



Supplementary Fig. 5-1. Schematic View of Backward Resampling



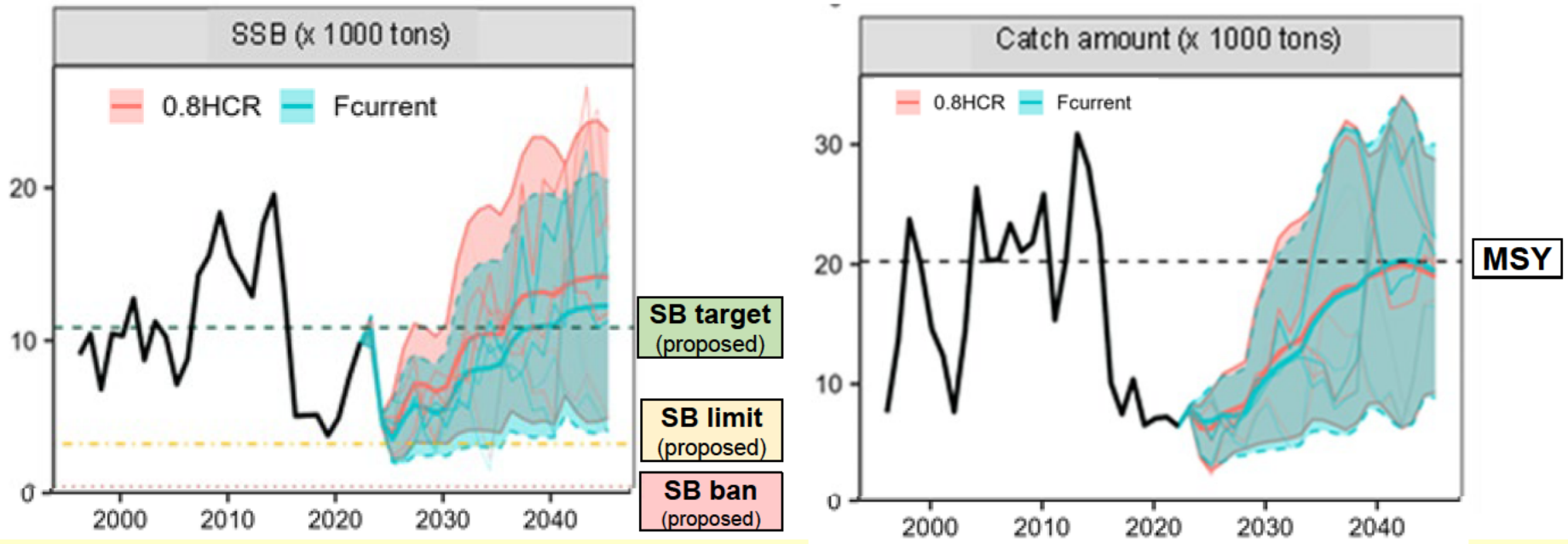
Schematic view of backward resampling



Supplementary Fig. 5-1.

- Since the same trend is projected to continue in the future, we have made future projections incorporating the recent recruitment situation.
- Backward resampling, in which the residuals in the observed values and the stock-recruitment relationship model are resampled retroactively every five years, was employed when projecting recruitment for the 2022 fishing season and onwards.

Future Projections Based on Proposed HCRs (Appendix 4)



Supplementary Fig. 4-2. Future projections based on proposed HCRs (red line), and future projections if the current fishing is continued (blue line). The solid line indicates average values, the shaded area indicates the prediction interval which contains 90% of simulation results, and the thin lines indicate 5 future projections.

・In both cases of fishing pressure, although SSB decreases significantly for a while, it is expected that SSB will recover thereafter.

・ On the other hand, the result was that the future trend of the catch was almost unchanged regardless of the catch pressure.

Future Projections Based on Proposed HCRs (Appendix 4)

Supplementary Table 4-1

a) Trends in average SSB (thousand tons)

Probability (%) that future SSB will exceed proposed target reference points. In the target year, which is 10 years after starting management based on HCRs.

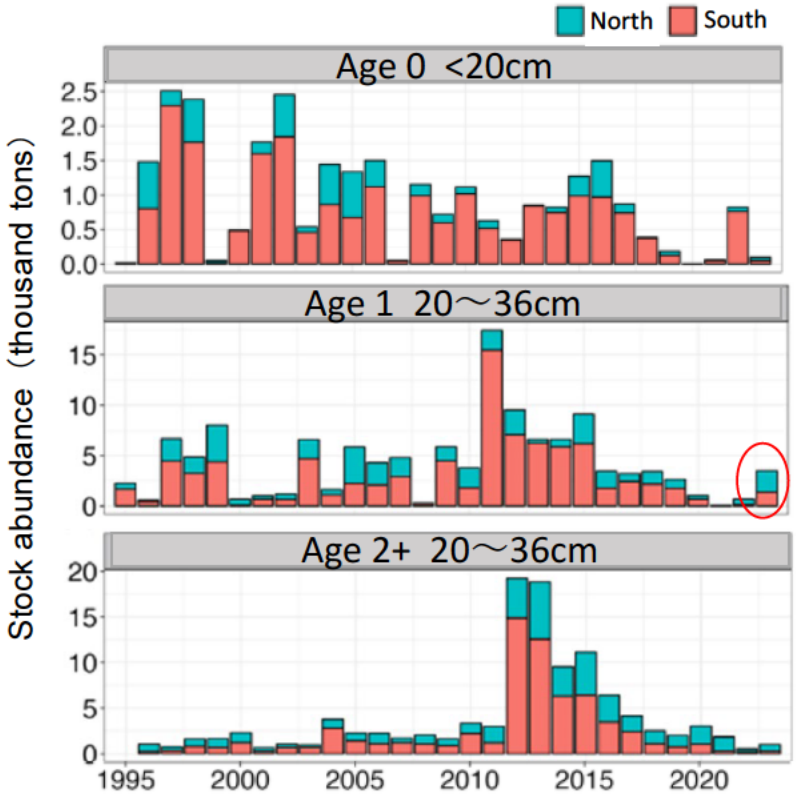
β	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	
1.0	9.9	10.7	4.8	3.3	4.8	5.6	5.2	4.6	5.0	6.4	7.0	6.9	6.9	13%
0.9	9.9	10.7	4.8	3.5	5.2	6.3	6.0	5.5	5.9	7.5	8.4	8.5	8.5	25%
0.8	9.9	10.7	4.8	3.8	5.7	7.1	7.1	6.7	7.0	8.8	10.0	10.4	10.4	41%
0.75	9.9	10.7	4.8	4.0	6.0	7.6	7.8	7.4	7.6	9.6	11.0	11.5	11.6	50%
0.7	9.9	10.7	4.8	4.1	6.3	8.2	8.5	8.2	8.4	10.4	12.1	12.7	12.9	59%
F2019-2021	9.9	10.7	4.8	3.5	4.9	5.8	5.6	5.2	5.6	7.1	8.0	8.1	8.2	24%

b) Trends in average Catch (thousand tons)

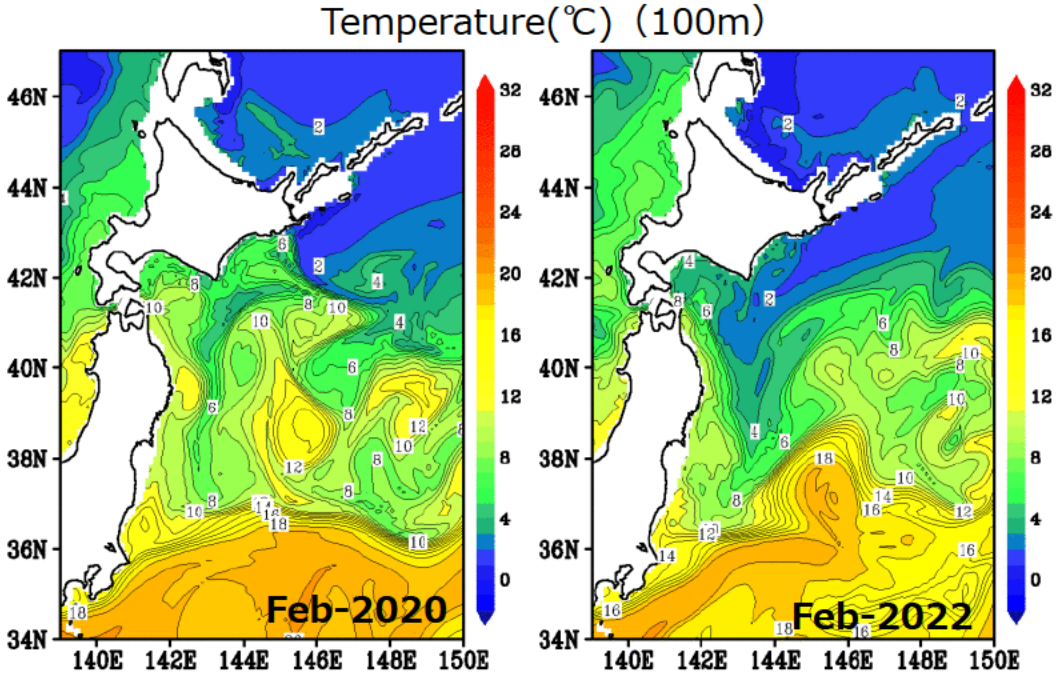
β	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
1.0	6.5	7.9	7.3	6.2	7.7	7.5	7.6	9.2	10.3	11.3	11.7	12.3	14.4
0.9	6.5	7.9	6.8	6.3	7.6	7.7	7.9	9.7	10.9	12.0	12.5	13.1	15.1
0.8	6.5	7.9	6.3	6.3	7.5	7.9	8.3	10.0	11.4	12.6	13.3	13.8	15.5
0.75	6.5	7.9	6.0	6.2	7.4	8.0	8.4	10.2	11.5	12.8	13.6	14.0	15.6
0.7	6.5	7.9	5.8	6.2	7.4	8.0	8.6	10.3	11.6	13.0	13.8	14.2	15.6
F2019-2021	6.5	7.9	6.8	6.9	7.4	7.3	7.6	9.4	10.6	11.5	12.1	12.8	14.9

- The probability of achieving SBmsy after 10 years is 41% at β = 0.8 and 50% at β = 0.75
- The 2024 calculated catch is 6.3 thousand tons at β=0.8 and 6,000 tons at β=0.75

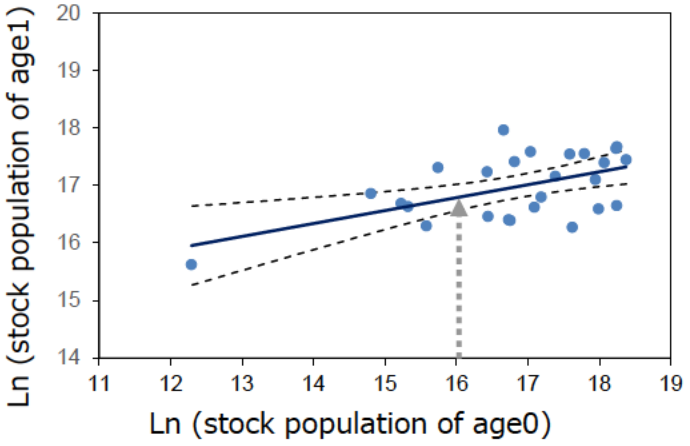
Issue in the future



Trends in Standing Stock abundance by Age Estimated by Trawl Surveys



FRA-ROMS Ⅱ https://fra-roms.fra.go.jp/fra-roms/



Reviewer's comment 1/8

Label	Q	A	Slide
T-1	1) The report states that "fishery catch statistics show no relationship between trends in catches off the Pacific coast of the Tohoku region and those in the Mutsu Bay area". Please show the data to support this statement, especially CPUEs and size compositions by area. This is important because the genetics (i.e., Suda et al. 2017) do not support a separate stock for Hokkaido and Northern Honshu. Also please show the available tagging data.	It is also distributed along the coast of Hokkaido and Mutsu Bay in Aomori Prefecture, and has its own spawning grounds, but based on the tagging-release survey (Fukuda et al. 1985, Miura et al. 2019) and catch trends (Kanno et al. 2001), they are considered different stocks from the northern Pacific Ocean of Honshu. In a survey conducted in 1979-2017, 3,226 individuals were released into Mutsu Bay in Area A, and 398 individuals were recaptured. Most of them were recaptured in Mutsu Bay and the coast of Hokkaido, and only four individuals were recaptured on the Pacific coast of Honshu.	3,4
T-2	2) Are there Pacific cod populations south of Mito?	very few	1,9
T-3	3) There are meta-analytical studies (e.g., Hamel & Cope 2022) relating natural mortality to maximum age that have more species and are more recent than Tanaka (1960). Please discuss the reasons for assuming a fixed M using Tanaka (1960) rather than newer studies with more metadata.	We are using M from Tanaka (1960) continuously. The HCR of this stock is fixed in 2021 and usually uses 5 years in Japanese stock assessment. So, we will reconsider M of this stock in 2026.	16
T-4	4) Was there consideration of the uncertainty in M?	No.	16,19
T-5	5) Were there sensitivity model runs for different M values? A simple and reasonable approach would be to develop a posterior for M using several relationships for M and biological parameters, and use the posterior to develop the uncertainty bounds for M and use these for sensitivity runs. Another approach would be to use the M posterior as part of a model ensemble. This would be important also for model projections.	As with other fish species and groups in Japan, the M value calculated by this formula is empirically used. This M-value is expected to be reconsidered in 2026, when the reference points described below will be updated.	16

Reviewer's comment 2/8

Label	Q	A	Slide
T-6	6) The report states that "growth varies year to year". How much is the year to year variability with respect to the within year uncertainty? Please show the age-size data for several years with good data to show this.	slide7	7
T-7	7) It appears that the maturity -at-age and weight-at-age is estimated every year. What is the source of the data for these? Please show the data.	We directly examined the maturity of fishes by histological observations of gonads and/or GSI values. Fishes were caught by trawl surveys in April and Oct-Nov, and by fish market in every month. The results were shown in Fig. supple 8-2.	6
T-8	8) For a cohort analysis, it is assumed that catch-at-age is known and is typically considered to be an important assumption. Therefore, it is important to understand how the catch-at-age time series was developed. However, it is not clear in the provided documentation how the catch-at-age data was developed. Please explain in detail how the catch-at-age in numbers time series was developed.	Data from Hachinohe in Aomori pref. and Ishinomaki in Miyagi pref. since 1996. The data from Miyako in Iwate pref. has also been used since 2016.	8,13, 14
T-9	9) Appendix 2 states that "Age-length keys were created by year and half-year using the samples caught by bottom-trawl surveys and Pacific cod bought at fish market since 1996". Please describe in detail when, where, and how the ages and lengths were sampled from the surveys and markets, and how the ALKs were generated from these data. Please show the data and ALKs for several years and from different locations.	A total of a few hundred – a few thousand fish were aged in every half a year using section of sagittal otoliths. Both fish caught by trawl surveys and commercial fisheries were aged.Standard lengths about 40 thousand fish caught by commercial fisheries were obtained from fish market in every half a year.	10
T-10	10) Please show the sampled length data and the converted age data.	Every year, a semi-annual ALK is created to age-degrade the body length composition of the catch.	14

Reviewer's comment 3/8

Label	Q	A	Slide
T-11	11) The catch data in the annual statistics yearbook is typically in tons. Please describe the method used to convert catch in tons into catch-at-age in numbers?	First, we calculate a tentative CAA. If this CAA is multiplied by BW, it should be the catch, but it does not exactly match the statistical value, so the CAA is adjusted slightly without changing the age ratio.	13,14
T-12	12) Are there any age-0 fish caught?	Many in trawl surveys and few in commercial fisheries.	5
T-13	13) The VPA model is tuned with age-specific indices based on a bottom trawl survey. Please show the design of the survey with respect to the population distribution, and layers or areas used in the index. Year by year if possible.	The operation area of the trawl survey is off from Aomori to Miyagi Prefs, where is the main distribution area of Pacific cod. The area swept method uses 8 layers: 0-200, 200-, 300-, 400-, 500-, 600-, 700-, 800-1000m.	10
T-14	14) Are the same ALKs used to convert index into index-at-age the same as for catch?	No. All fish caught by the trawl surveys have been directly aged, so ALK is not necessary for the index.	10,13, 14
T-15	15) Please show the indices by area or layer, as well as the relative weightings.	No relative weighting.	10
T-16	16) Please compare the fishery CPUEs with the survey index.	Slide12	12
T-17	17) Please plot the indices with their CVs, as well as the model fits or expectations.	Indices were estimated by age, but CVs were estimated for all ages, so it needs time to show.	12
T-18	18) Why start the model in 1996 when there is data from 1972?	We have the data of annual ALK, body size frequency only from 1996 season year.	13,14
T-19	19) What are the units of the tuning index? It appears that the survey estimates the N-at-age but this is converted into B-at-age for the tuning indices, which were fitted in the model. I do not understand this process because for a VPA, the natural units are numbers so it would be more natural to fit the index as a N-at-age indices.	We tried N at age for index, but that was not adequately fit for the VPA.	11
T-20	20) For the model residual to the indices, Suppl Fig 2-1, it is not clear what the shaded areas mean. Nevertheless, there is an obvious pattern of negative residuals during the early part and positive residuals during the latter part of the time series. Please discuss the potential causes of this.	The wide shaded area shows 95% confidence interval. The narrower one shows 80% confidence interval.	18

Reviewer's comment 4/8

Label	Q	A	Slide
T-21	21) The CV of the indices vary by year. Where these differences considered when tuning the model?	CV was not considered for the tuning.	12
T-22	22) Is there a table of all the estimated parameters and their uncertainty?	We are considering only the uncertainty of future recruitment estimated from SR relationship.	
T-23	23) Please explain why the Ricker SRR was chosen as the base case. How does the Ricker compare with the Beverton-Holt and hockey-stick?	The reproduction curve confirms the likelihood and other factors and uses a Ricker type. It is also known that large fish eat small fish due to the overlap in the distribution of large fish and small fish due to the increase in density, and we believe that it is ecologically reasonable.	21
T-24	24) There are occasionally very large drops in estimated age-1 population. What are the causes of this?	Very poor year classes sometimes occur especially in recent years partly because of reduction of cold current (Oyashio).	30
T-25	25) Please explain the backward resampling in more detail.	Residuals of SR relation were resampled for future recruitment.	27
T-26	26) How were the uncertainties in the data and model results propagated into the projections?	It's a future theme. The uncertainties was adapted only for recruitment.	26,28
T-27	27) How would incorporating the above uncertainties affect the assessment results and projections?	It is used to find the probability of achievement of each reference point.	28,29
T-28	28) What is the purpose of Appendix 9 (monthly catch ratios)?	The administrative management period is July-June, but the stock assessment is April-March, and the tables are used for the compensation.	29
T-29	29) What are the potential improvements for this assessment?	Although it is possible that the recruitment size will continue to be low, it is known that the size varies greatly from year to year. After the analysis we have described today, we know that the 2022 year class is slightly higher. We would like to improve the estimation accuracy of 1-year-old fish (recruitment amount) by using 0-year-old fish data from the research vessel survey.	30

Reviewer's comment 5/8

Label	Q	A	Slide
K-1a	1. Age data are a key component of the cohort analysis. Can the authors please provide more details about the ageing process? a. Specifically, what were the numbers of hard tissues (scales or dorsal fin rays) and sagittal otoliths used for ages?	We used only sagittal otoliths for aging. Otoliths were sliced and aged.	7,10, 13,14
K-1b	b. Are there estimates of ageing uncertainty (also called ageing error) available?	No, but we think aging error is very few because the observation of otoliths is cross-checked and the two directions of otoliths are counted.	7,8
K-1c	c. Were the age records from the fishery or the survey? Or were they pooled together?	We used both otoliths of the fish caught from the fishery and the survey for aging.	10,14
K-1d	d. Which age data are applied to the survey observations?	For the survey observations, we used only otoliths of the fish caught from surveys.	10
K-1e	e. Include figures of the age-length and length-weight relationships described in Section 2 (Age/Growth).	Age-length relationships has been provided in Fig.2-2, So we only provide the SL and BW relationship.	7
K-2a	a. Are there any potential age-0 fish caught in the survey?	We have standing stock biomass of age-0 fish. We are considering to use it for the estimation of age 1 fish one year later.	5,30
K-2b	b. The residuals before and after 2011 seem to show different patterns (Supplementary Fig. 2-1). Before 2011, residuals for nearly all the ages were overall negative. After 2011, most of the residuals were positive for all the ages. The authors explain that this could be due to a decrease in growth (age-weight relationship) after the earthquake in 2011. Are the residuals shown in Fig 2-1 for the numbers of fish or the biomass at age?	The biomass at age.	18
K-3a	3. Distributions of catches (Fig 3-2) a. On the northern end towards Hokkaido there is an area of high catches. Are Pacific Cod found in Hokkaido on the Pacific side?	Yes.	3,4
K-4a	4. Fig. 4-2 a. The biomass of age 2 fish is generally higher than the biomass of age 1 fish in each cohort. Looking at the weight at age tables in Supplementary Table 2-1, age 2 fish can be 4-6x the weight of age-1 fish. Please double check that this is correct and provide more detail of the individual fish measurements in the data to support this.	Pacific cod obtain their weight during age 1 to 2 years, and thus, 2 years fish have 4 times BW of 1 years fish.	5,11, 13,14

Reviewer's comment 6/8

Label	Q	A	Slide
K-5	5. Fig. 4-12: I think the y-axis label might be incorrect	It seems that I made a mistake in the English translation file. The correct label is "Ratio to Fishing pressure (F/Fmsy)".	23
K-6	6. The values for F (shown in Fig. 4-7) are very high particularly for older fish.	Yes. In Japan, testis of Pacific cod have high commercial value. In addition, they migrate to shallower area (<100 m) in spawning season while deep water in the other season. So, older fish are fished by high fishing pressure.	17
K-7	7. Are there any estimates of uncertainty estimates for the hard tissue (scales and dorsal fin rays) samples used to determine ages?	No, but we think aging error is very few because the observation of otoliths is cross-checked and the two directions of otoliths are counted.	8
K-8	8. Appendix 2: Are the survey ages and fishery ages combined in the cohort analysis? That is, were age data from the survey and fishery pooled together and used in the analysis?	Yes.	10
K-9	9. Supplementary Fig. 2-1: The residuals before and after 2011 seem to show different patterns. Before 2011, residuals for nearly all the ages were overall negative. After 2011, most of the residuals were positive. Do the authors have any idea why this might be? Have the surveys changed areas?	Surveys have not changed. But fishing efficiency may be changed in some part of the area in which commercial fisheries had been inhibited after the earthquake (mainly off Fukushima).	18
K-9a	a. Please include the actual fits to the index data (with uncertainties) as a figure	The wide shaded area shows 95% confidence interval. The narrower one shows the standard deviation 80% confidence interval.	12
K-10	10. Supplementary table 2-1: Were there no maturity data for age 1 and 2 fish? Looking at 2001 for example where age-2 maturity is 0 and age-3 is 0.73.	Age 1, 2 years old fish are immature.	5,7
K-11	11. What is the current management of North Pacific Pacific Cod? Does the proposed HCR match the current management?	The management of this stock has started since July 2024.	29

Reviewer's comment 7/8

Label	Q	A	Slide
Y-1	As with other fish stocks, I recommend to add a graph of maturity at age.	Since the change varies greatly from year to year, the maturation rate by year is shown in Supplementary Figure 8-2. It will be added to the detailed version from next year.	6,7
Y-2	Please add graphs of CAA and catch amount at age.	It will be added to the detailed version from next year.	16
Y-3	I recommend to add a graph of interannual variation of age composition in commercially caught fish, such as histograms of every year	Recent ones are shown.We will consider publishing it next year.Trawl surveys conducted by research vessels in the fall have suggested that one-year-old fish are getting smaller, and we are paying attention to them.	13,14, 16
Y-4	What is the factor of slow down growth and late maturation after the Great East Japan Earthquake? Is it affected by changes in the entire ecosystem, including other species?	In the past, the influence of density was large (Narimatsu et al. 2010), but in recent years, a similar trend has been observed in mackerel, etc., and it is thought that the impact of changes in the ecosystem due to the decline of the Oyashio tide is significant. We haven't been able to wrap up the results yet.	6,30
Y-5	What is likely to be the cause of lower recruitment than expected one estimated from the SR curve after 2015?	This group is located in the southern limit of distribution. It is thought that changes in water temperature, changes in the food environment, and changes in the predator environment due to the decrease in the inflow of cold currents have an effect.	21,30
Y-6	Did the rapid decrease in stock size from 2014 to 2016 depend on the increase in F? Or is there the possibility that F has increased as a result of a decrease in stock size?	I think that there is an impact of both.	17
Y-7	Taking into account the slow growth, late maturation, autocorrelation in SR relationship and low recruitment in recent years, I recommend to use model considering annual changes in SR relationship or regime shift. Additionally, change the reference points according to the models.	The SR relationship of this stock have a small number of data and a large amount of variability. It takes 3-4 years for Pacific cod to mature, and their response to the environment from birth to parenthood is complex. I believe that discussions such as regime shifts require more data. However, changes in the maturation rate have already been included in future projections as a function of stock size, and the residuals of the SR relationship have been resampled to reflect the situation in recent years.	21,22, 27

Narimatsu, Y., Y. Ueda, T. Okuda, T. Hattori, K. Fujiwara and M. Ito (2010) The effect of temporal changes in life-history traits on reproductive potential in an exploited population of Pacific cod, Gadus macrocephalus. ICES J. Mar. Sci., 67, 1659-1666.

Reviewer's comment 8/8

Label	Q	A	Slide
Y-8	Why is the F higher in old fish, especially in age 5 and 6 or more? Can you explain in terms of actual situation of fisheries? Or can use of flexible M with age solve the problem?	Basically, the F-number of 1-year-old fish is low, and the older the fish, the higher it tends to be. In particular, the F-number for the oldest is very high. ・During the spawning season, individuals that have moved to shallow water along the coast are caught with longlines, gill nets, and fixed nets, and outside the spawning season, they are caught with bottom trawl nets at depths of 200 m or more offshore. Therefore, it is reasonable that the fishing pressure is higher than that of young immature individuals. However, will it be this high? In light of the fact that there is an ecology such as entering the reef area and making it difficult to be caught, we believe that there is room to consider and adjust the calculation method in the future.	17
Y-9	The estimated %SPR seems very low. Is it possible that M of age 1 year fish is higher?	Possibly. As with the above answer, I would like to verify it as a future issue. On the other hand, it is also possible that it is a population or ecosystem structure that does not allow too many large fish, as is the case with the licker type.	17
Y-10	The residual plots in supplement fig 2-1 have some trends. What happen in the middle of 2010 on the trends.	We are aware that there is a bias. Although the area of operation of the trawl survey has not changed before and after the Earthquake, it is considered to be related to the fact that the area where fishing vessels operate has changed significantly. I think there is such a tendency because it coincides with the period when the southward movement of the cold current weakened.	18, 30
Y-11	Negative relationship is presumed between the maturity at age 3 and 4 years and population size. Although the relationship may be incorporated in assessment, in recent years population sizes are decreasing with slow growth and late maturation. In order to solve such contradictions, it is necessary to introduce interannual changes in the parameters related to the productivity of the stock and to change the reference points accordingly.	In future projections, we change the maturation rate as a function of the amount of stock size. Therefore, these results are reflected in MSY and management reference points. We plan to incorporate new data and reflect it when it is reviewed in five years.	22