2022/10/28

The Sea of Japan Area B of snow crab

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- Biology

  Distribution, Growth

  * Fishing regulations

- Stock assessment

  Fisheries, Catch, fishing effort, Density index(by catch performance report)

  Pot survey

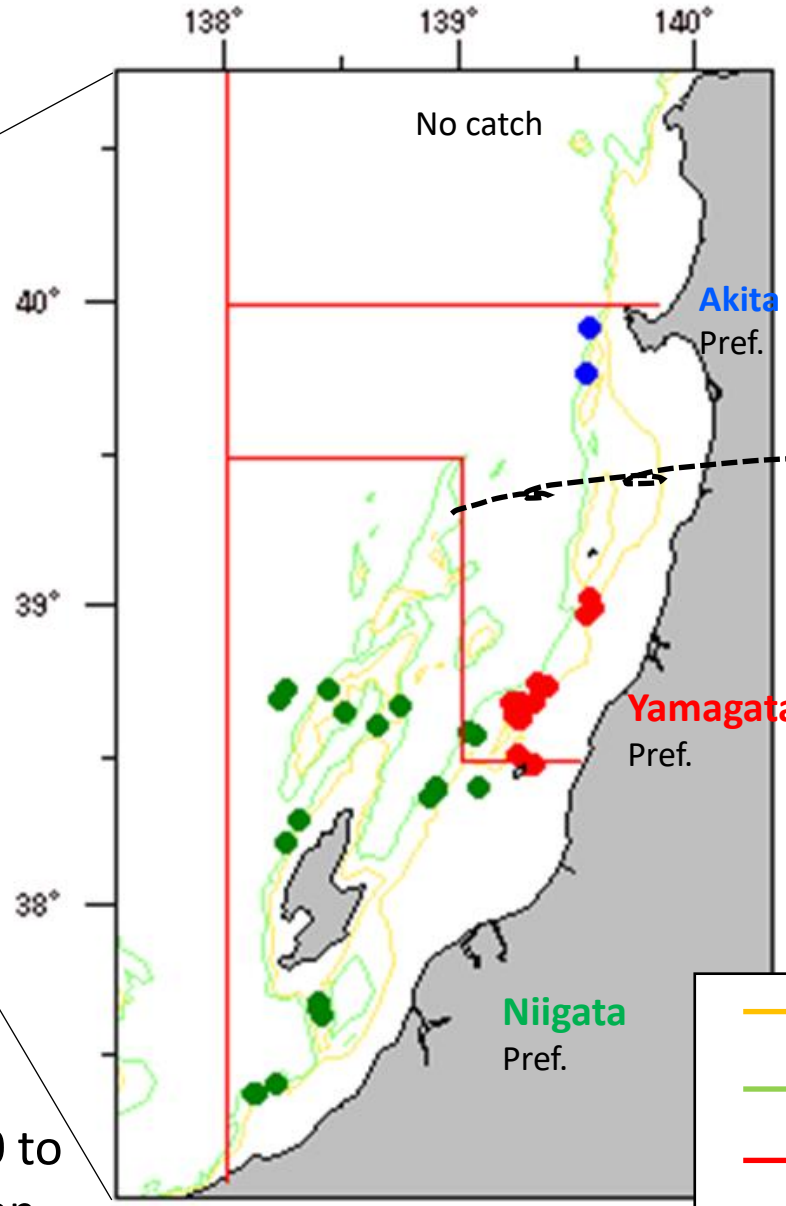
  Estimation of stock abundance and Natural mortality

- Future projection

  Beam trawl survey

Distribution Area B

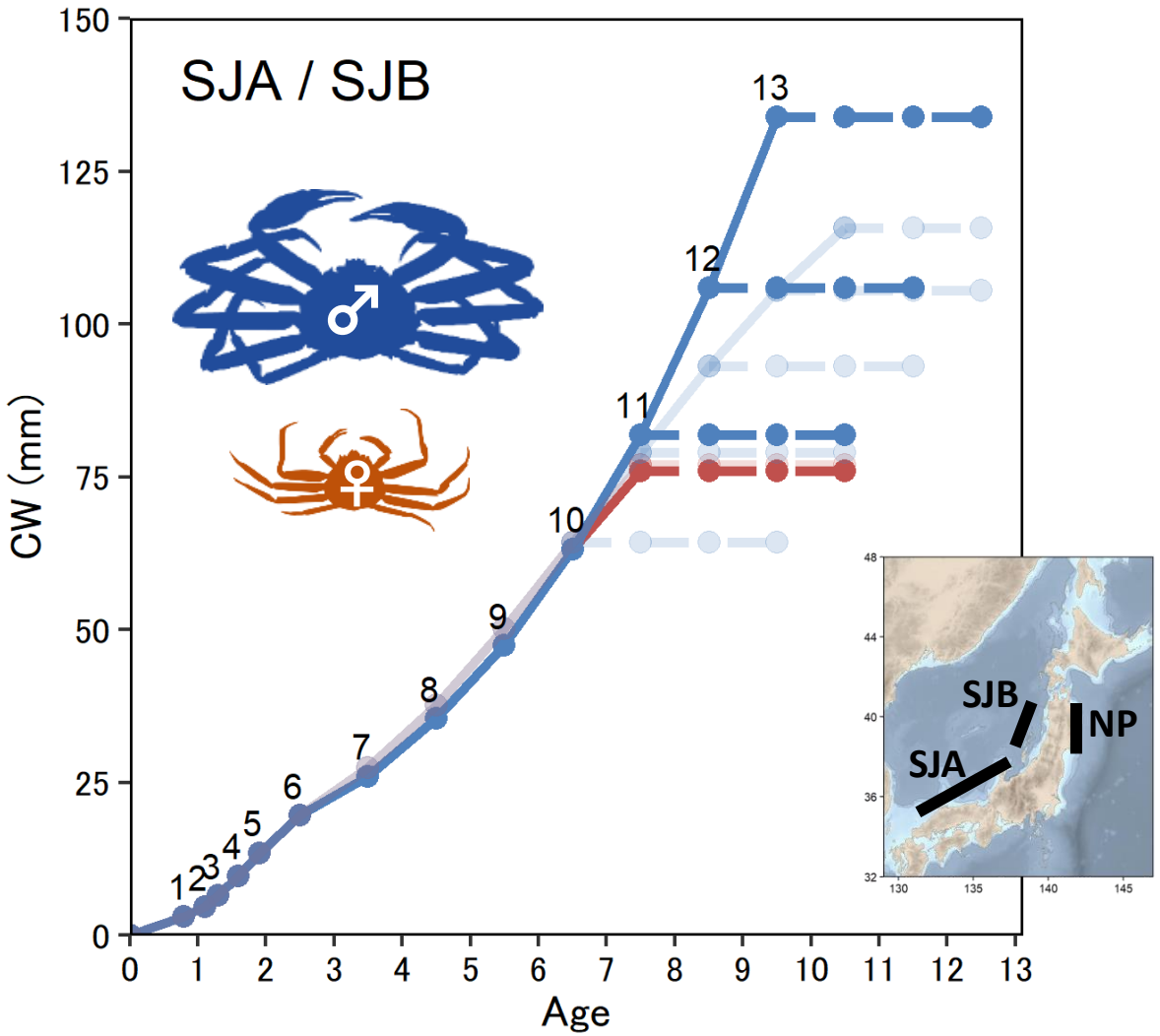
Distribution area



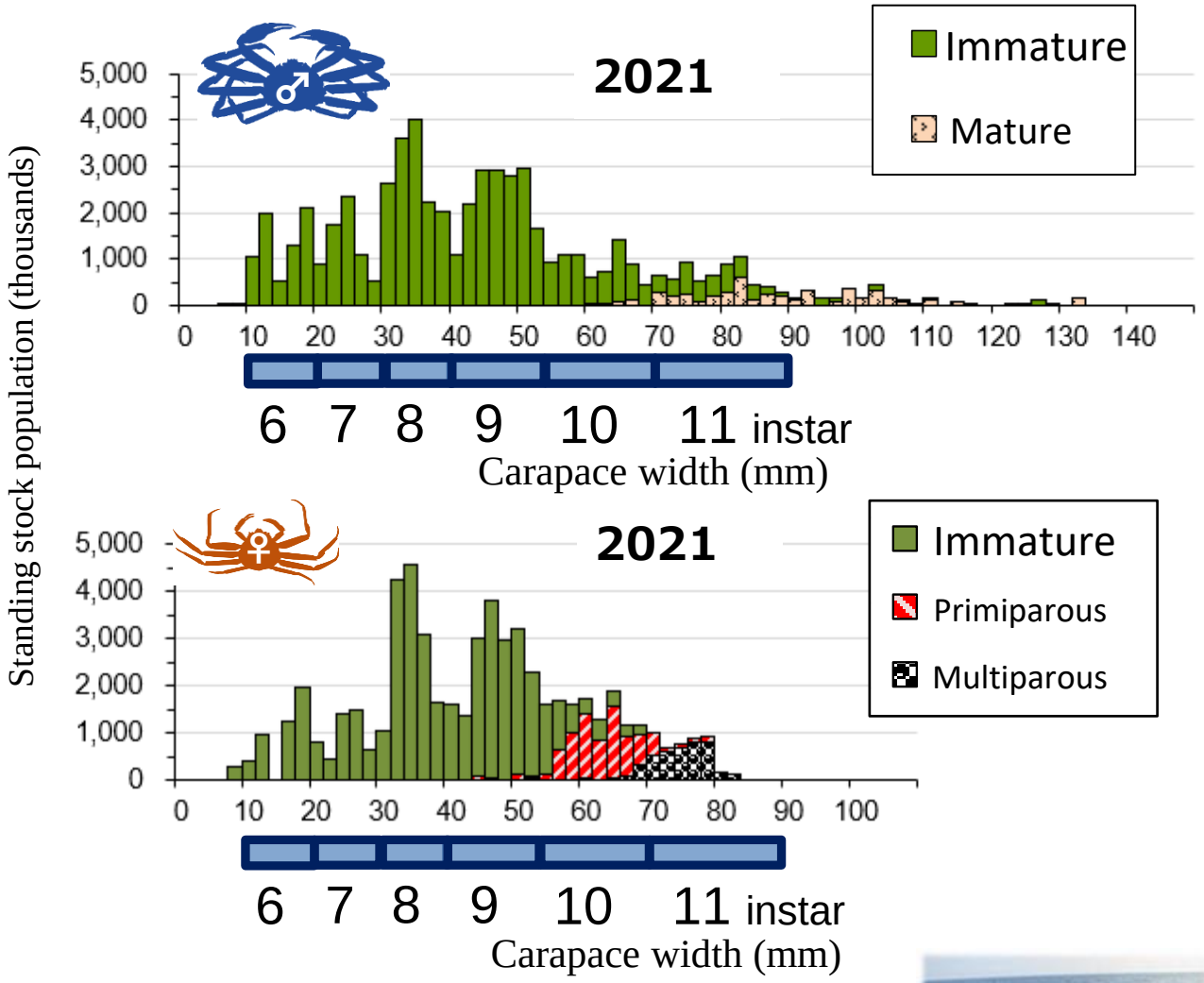
Trawl operation is challenging in Area B because of rocky reefs and islands, and also, steep and rough sea floor.

Snow crab Area B is distributed on the continental shelves and slopes from 200 to 500 m depth in the northern Sea of Japan.

Growth

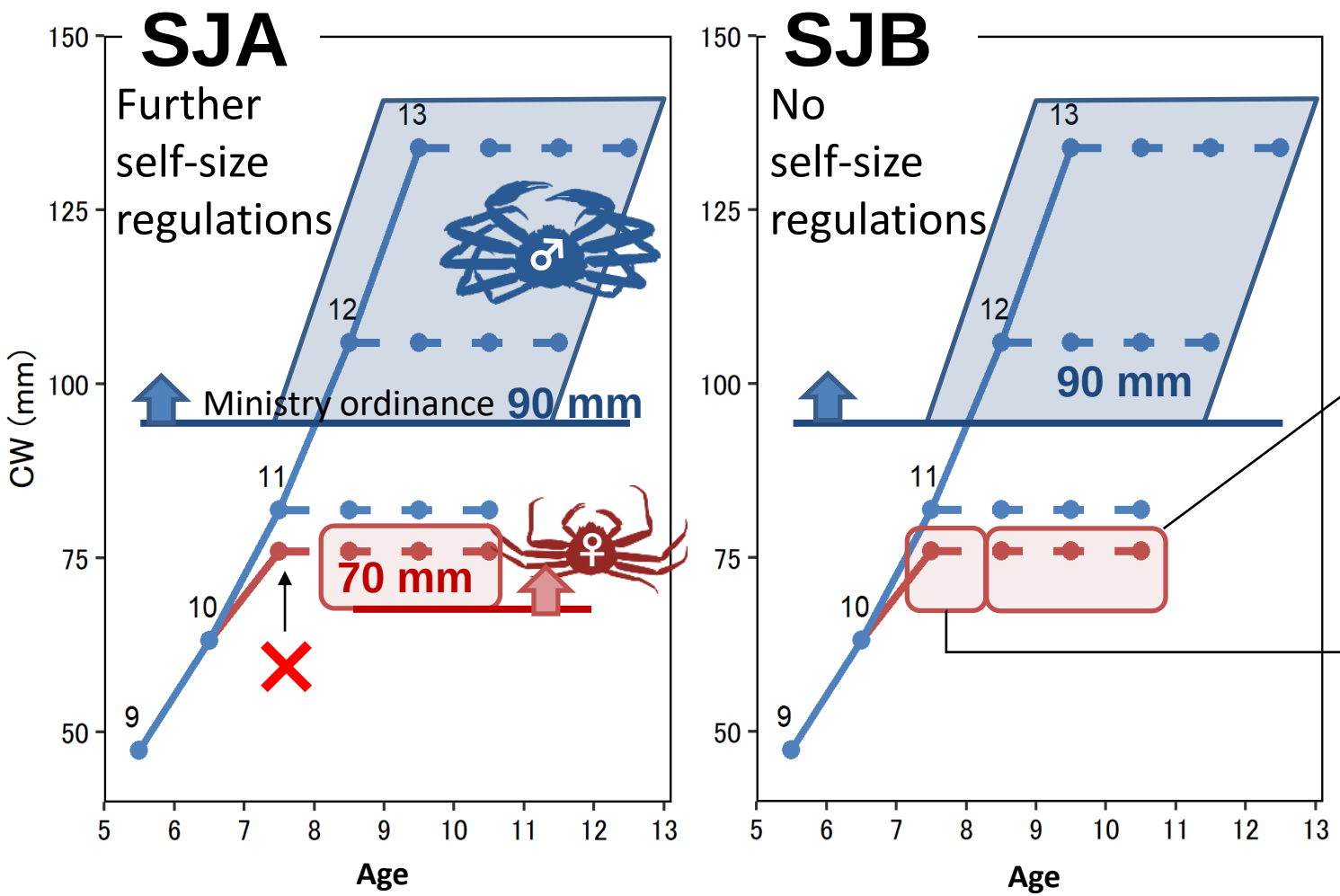


Limited growth information is available in Area B, and we assume the same growth as in Area A.



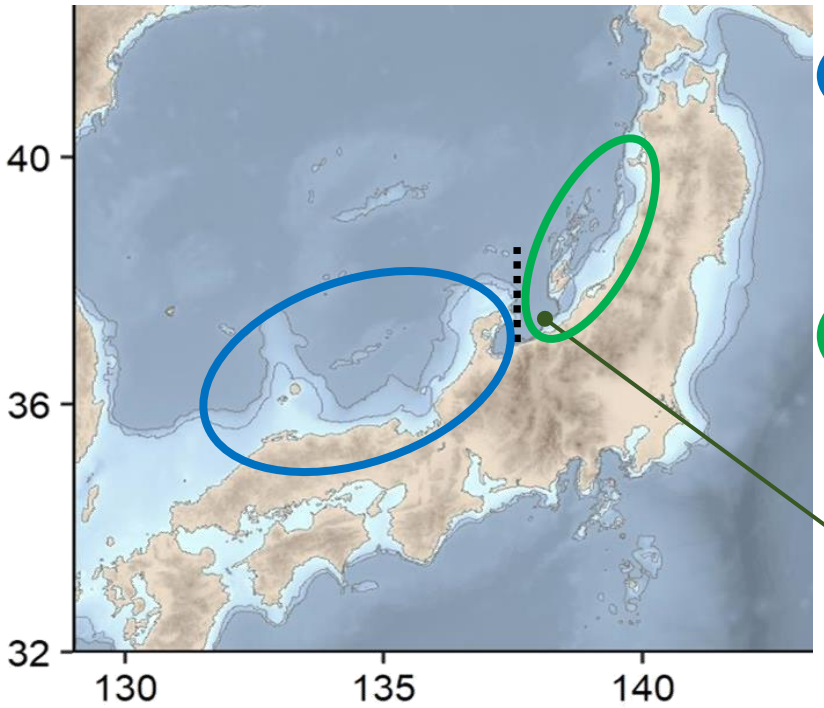
Supplementary Figure 5-2.
Carapace width composition by sex based on beam-trawl surveys (2016-)

Fishing regulations (size, mature)



- Males>90 mm CW is catchable in both areas and further self-size regulations only in Area A.
- Mature females are catchable in both areas, but primiparous females with orange to red colored embryos (before eye pigmentation) are retained in the Area A stock (primiparous and multiparous females are not distinguished in Area B).

Fishing regulations (season)



Fishing season (Ministry ordinance)

		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
SJA	♂			6				20					
	♀			6	31								
SJB	♂		1							31			
	♀		1							31			
*	♂			6						10			
	♀			6			28						

＊ In the southern edge of Area **B (Self regulation)**

Fishing season by the ministry ordinance is longer in Area B than A, because fishing opportunity is limited for smaller vessels in area B due to the severe weather in winter season.

Fisheries and catch

- In this area, the ratio of offshore trawl fisheries (hereinafter referred to as “offshore trawlers”) to the snow crab catch is low, and the ratio of small vertical bottom-trawl (hereinafter referred to as “small trawlers”) is high (Fig. 3-1). The ratio of gillnet is getting higher in recently.
- The catch in weight (calendar year) peaked at about 1,000 tons in the 1960s and about 800 tons in the 1980s. After that, it decreased and has stayed at 200 to 400 tons since the 1990s (Fig. 3-1).

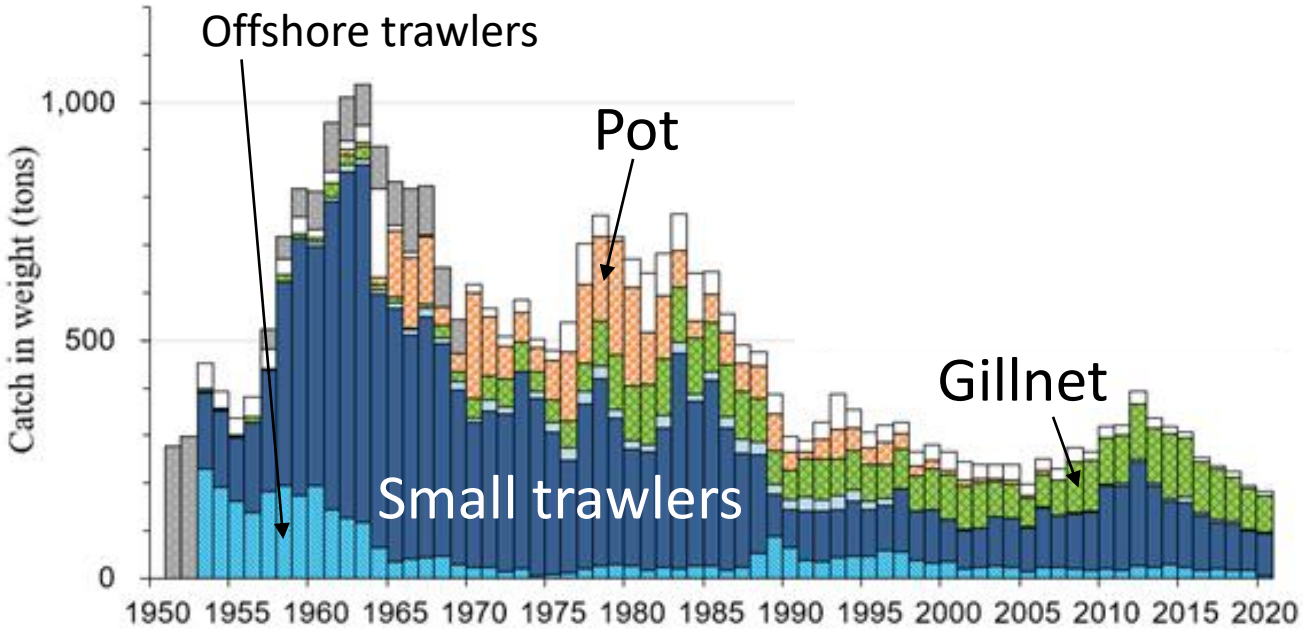
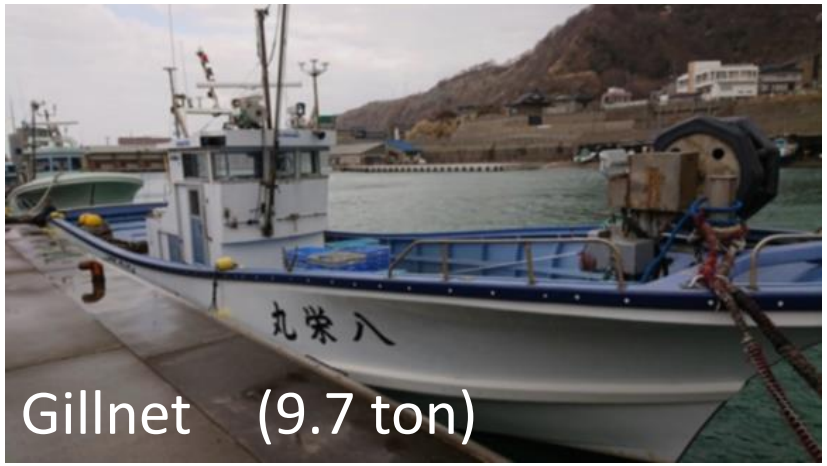


Fig. 3-1. Catch in weight of snow crab by fishery type (calendar year)



Fishing Effort and Density index

- The number of net hauls per fishing year since 1979, when the count could be traced, decreased to about 1/4 of 1979 by 1998. Since 2009, the number of net hauls had generally leveled off at around 48,000 times, but has been on a downward trend since 2015, and was 36,000 times in 2020 (Fig. 3-3).
- The total stock density index of males and females generally ranged from 3 to 6 until 1992, but from 5 to 9 during 1993-2009 (Fig. 4-10). Since 2010, it has been at its highest level to date, at 10.6 in 2020. The average for the past 5 years is high too.
- When a cumulative normal distribution was fitted to this abundance index value (1982-2020), the level in 2020 was 83.5%.

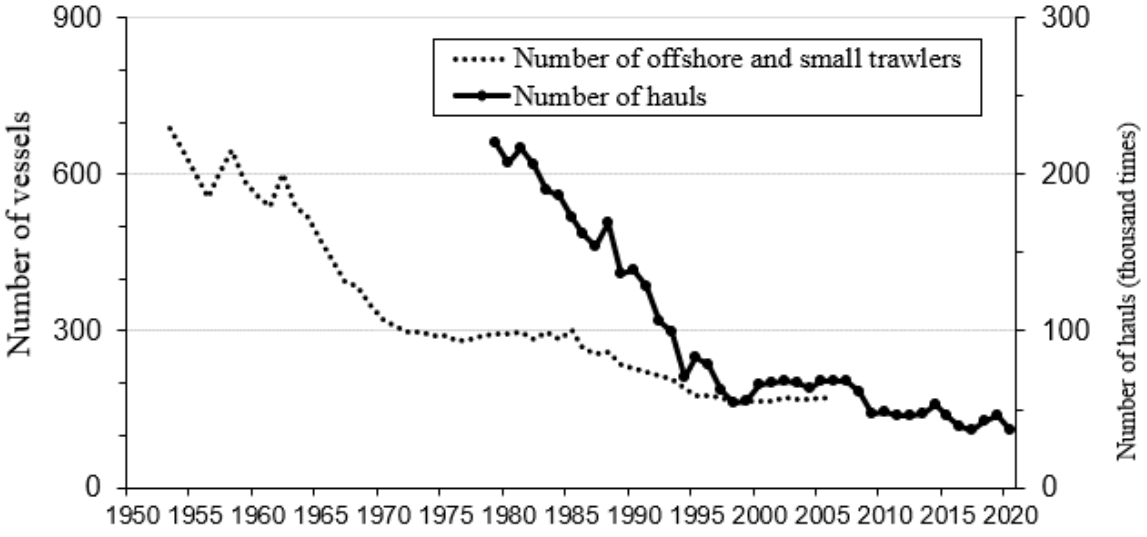


Fig. 3-3. The number of offshore and small trawlers and hauls. The number of vessels has not been counted since 2007.

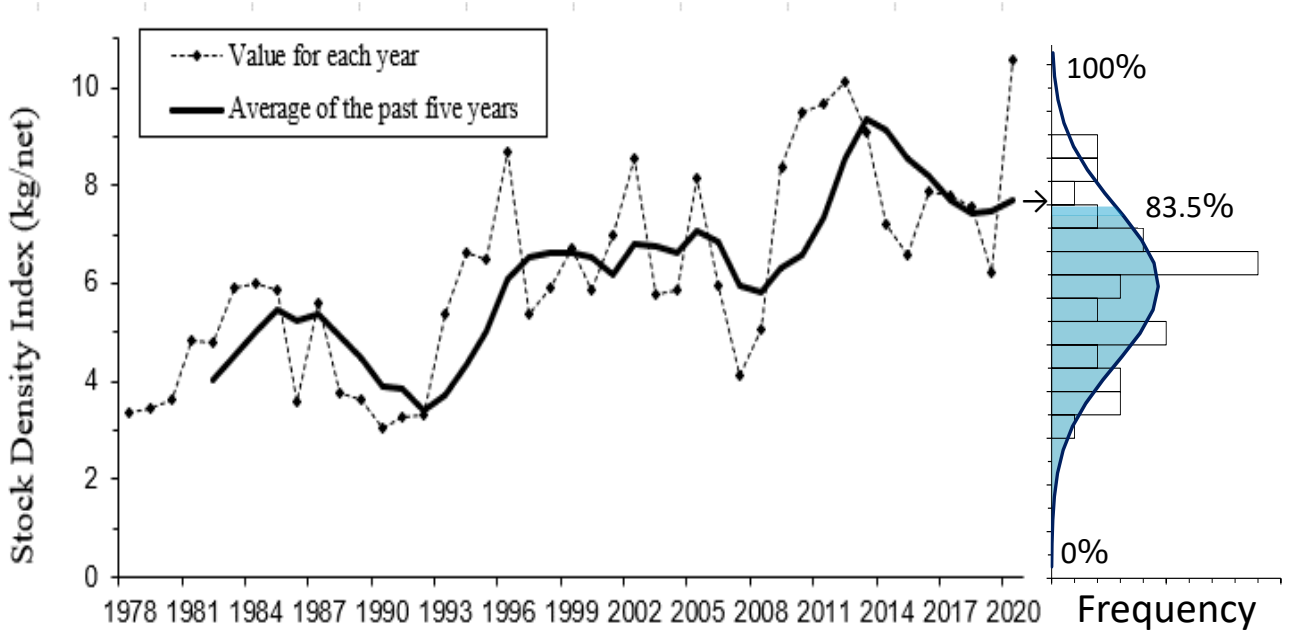
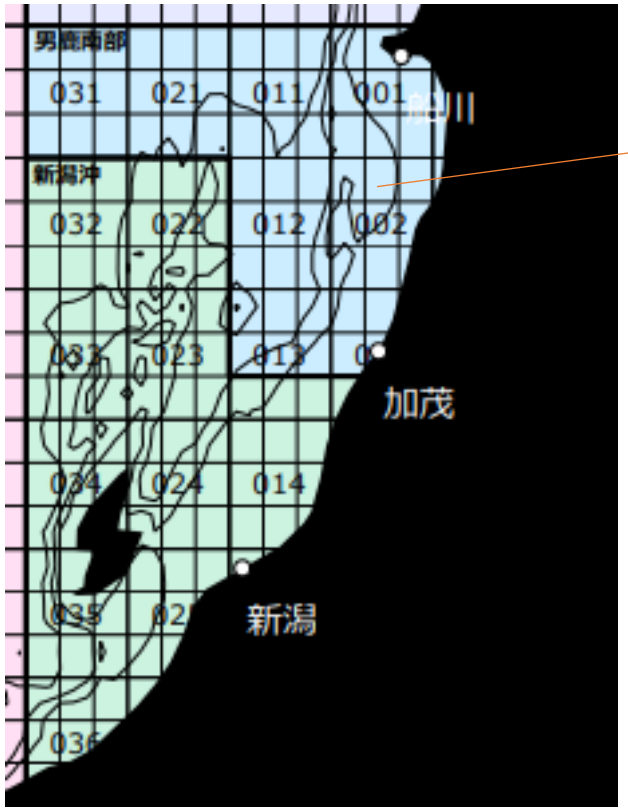
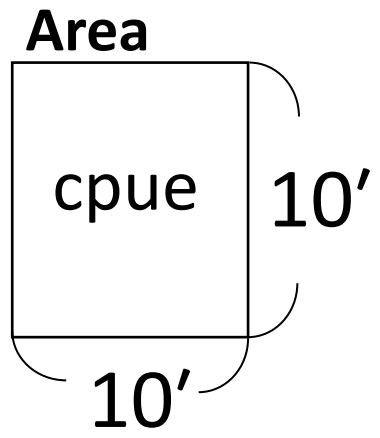


Fig. 4-9. Stock density index (dotted line indicates the total of males and females each year, bold solid line indicates the average of the past 5 years)

Density index（by trawl logbooks）

- The Stock density index in area B is calculated based on official trawl logbooks (large offshore and small vessels), summarizing catch-only CPUE in each month and area and averaged for each year.





One month and **one area** (Catch-only)

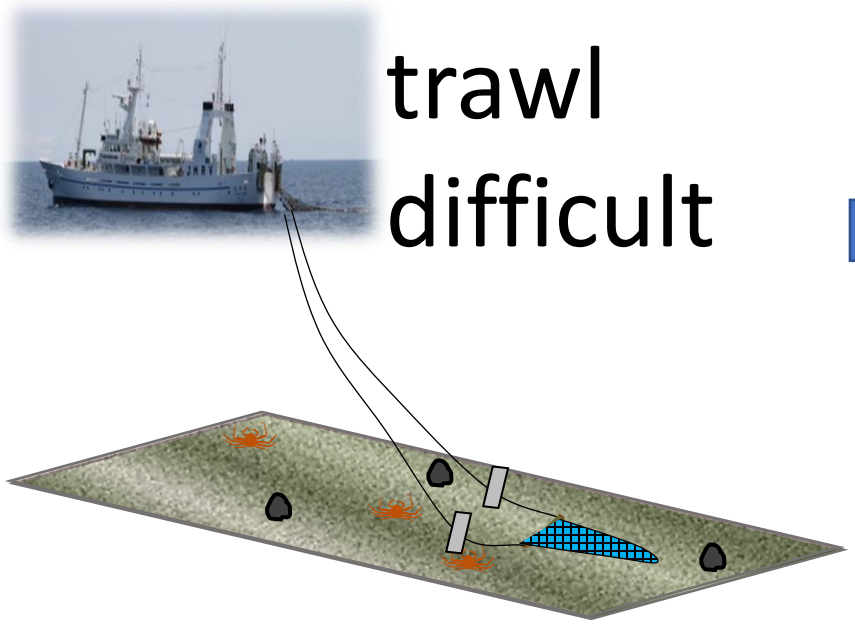
$$\text{cpue (kg/haul)} = \frac{\Sigma \text{ catch}}{\Sigma \text{ haul}}$$

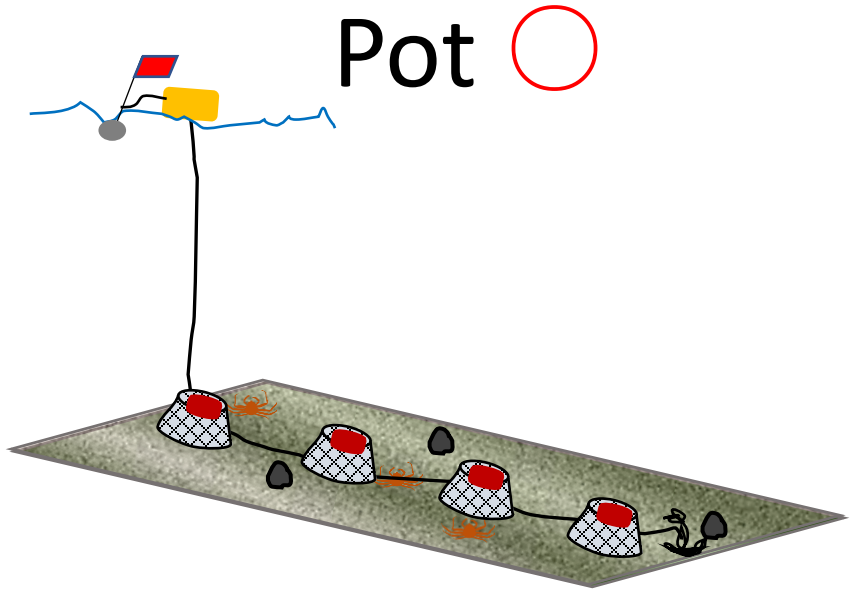
One year

$$\text{Density index (kg/haul)} = \frac{\Sigma \text{cpue}}{\text{Number of area}}$$

Stock Assessment Methods

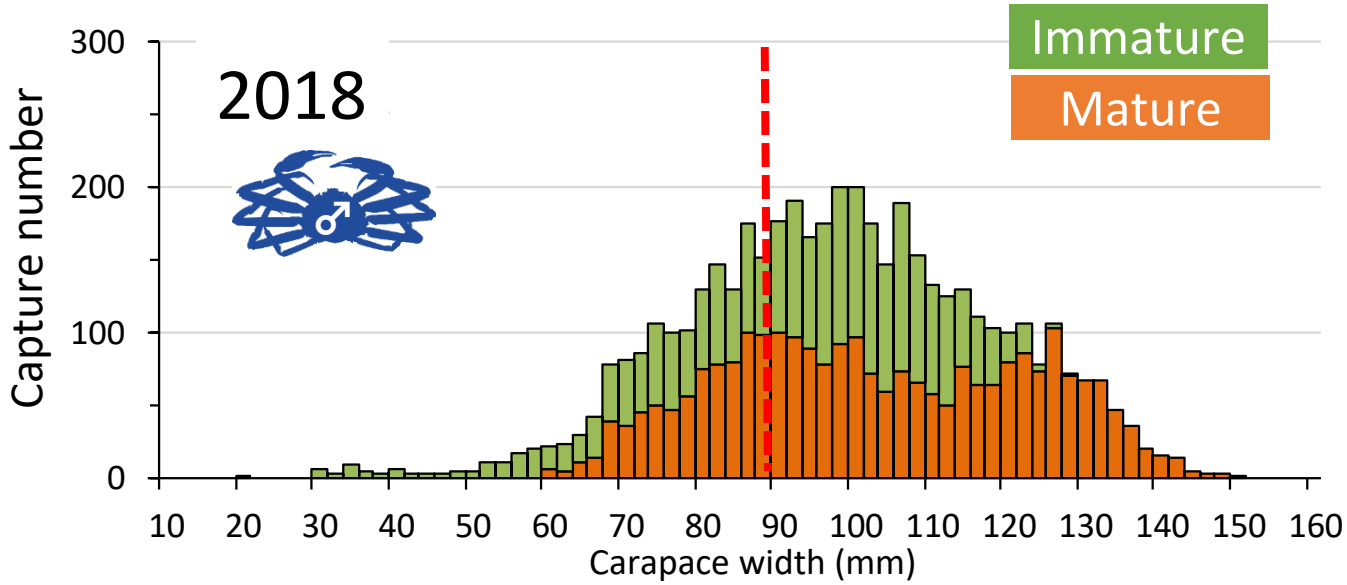
- In order to understand population trends and the current fishing pressure, since 1999 the total stock abundance at the beginning of the fishing season in the previous year has been estimated by a **pot survey** before the snow crab fishing season (Appendix 2, 3, and 4).

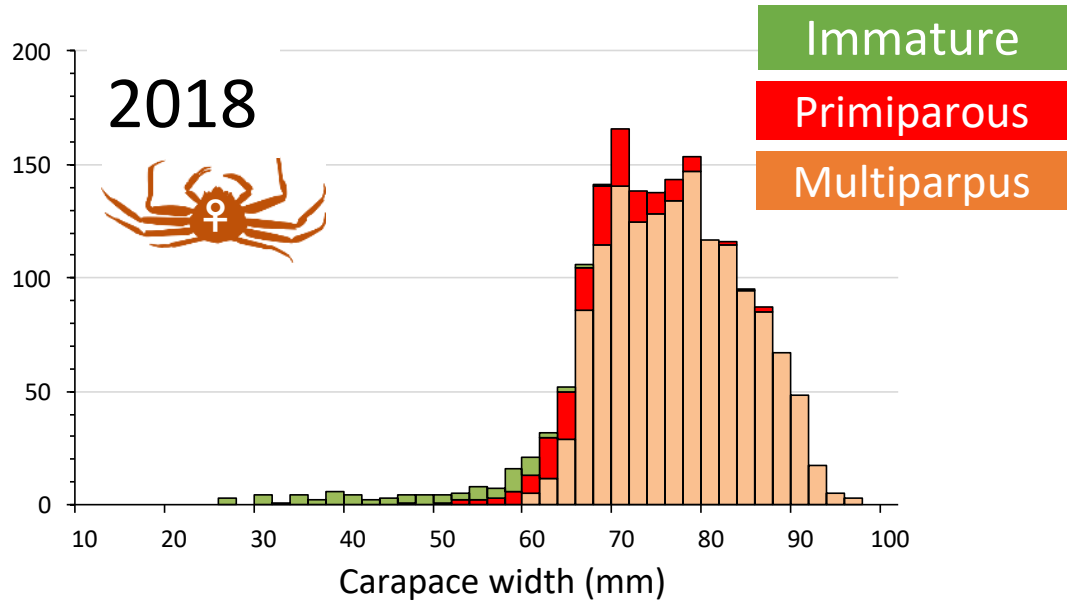




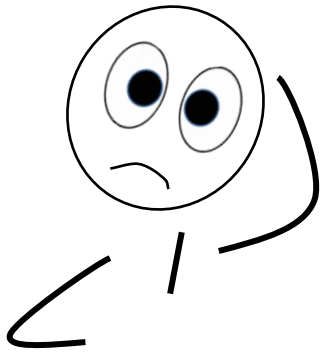
Crab pot has been used because sea floor is steep, rough and rocky in Area B

Stock Assessment Methods (Problem of pot survey)





Carapace width composition in 2018 from **pot survey** in Sea of Japan Area B.

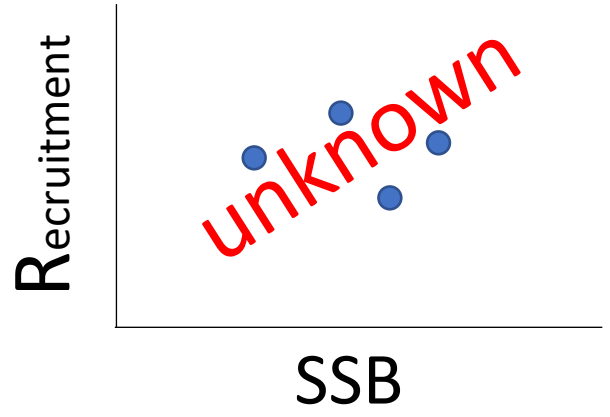


Male

- Mode of small crabs is unclear
- Age decomposition is uncertain

Female

- It is difficult to collect small crabs



Reviewer's comment

Same as for the Sea of Japan A stock, it would be a good idea to discuss stock structure of the Sea of Japan A and B stocks at the same time. However, the approach used to estimate stock abundance appears to be very different from the A and Japan Sea stocks, and Please explain the approach in detail at the meeting. I think there is a need to explain the approach. I am confused by the approach. h and why this approach was taken, so that I can understand it.

Stock structure and distribution (Same questions as for the Sea of Japan A stock.)

1) Given the geography of the Sea of Japan and the biology of snow crabs, one would expect a single snow crab stock around the whole Sea of Japan. What is the evidence for having two snow crab stocks in the Sea of Japan (Area A ad B)? Or is the separation due to management units?

2) Are there snow crabs along the Korean peninsula and Russian sides of the Sea of Japan? If so, are these crabs included in this or the Area B assessment?

3) Are there snow crabs in deeper areas that are harder to fish?

4) Are any parts of the Sea of Japan considered international waters?

Data – total catch

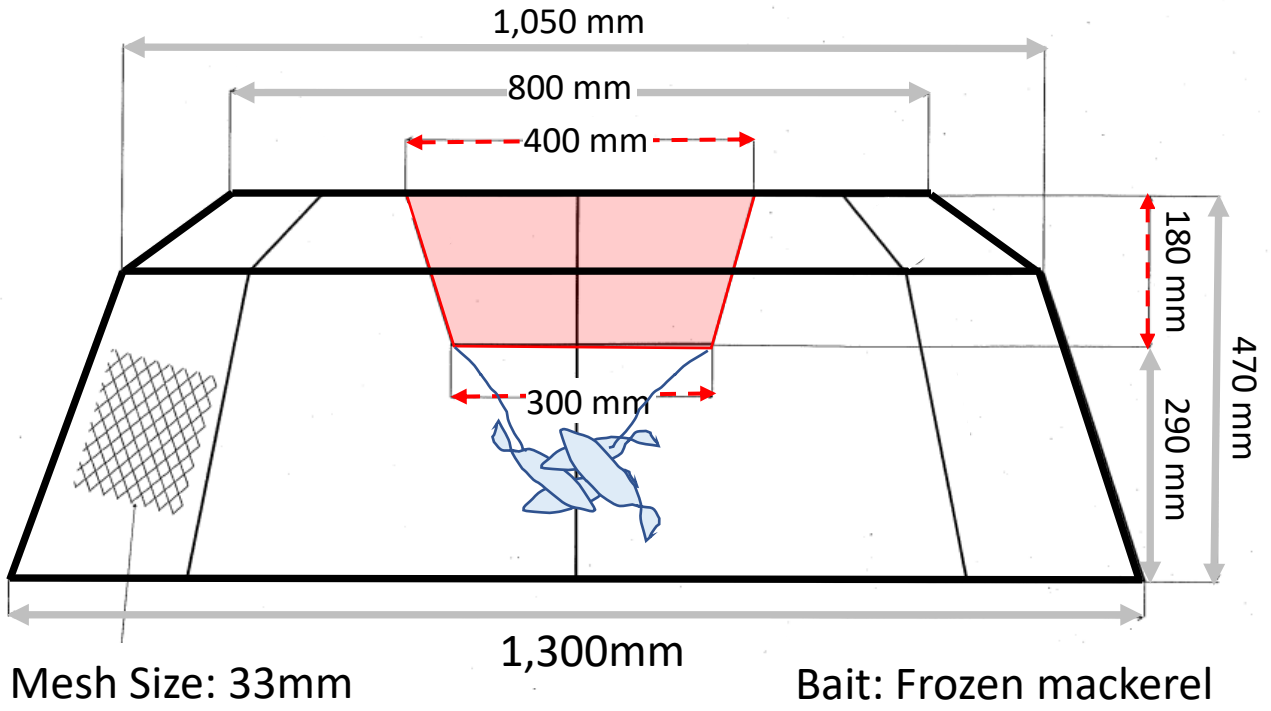
2) Is there likely to be catch along the Russia or Hokkaido coast?

Reviewer's comment

Data – Abundance indices

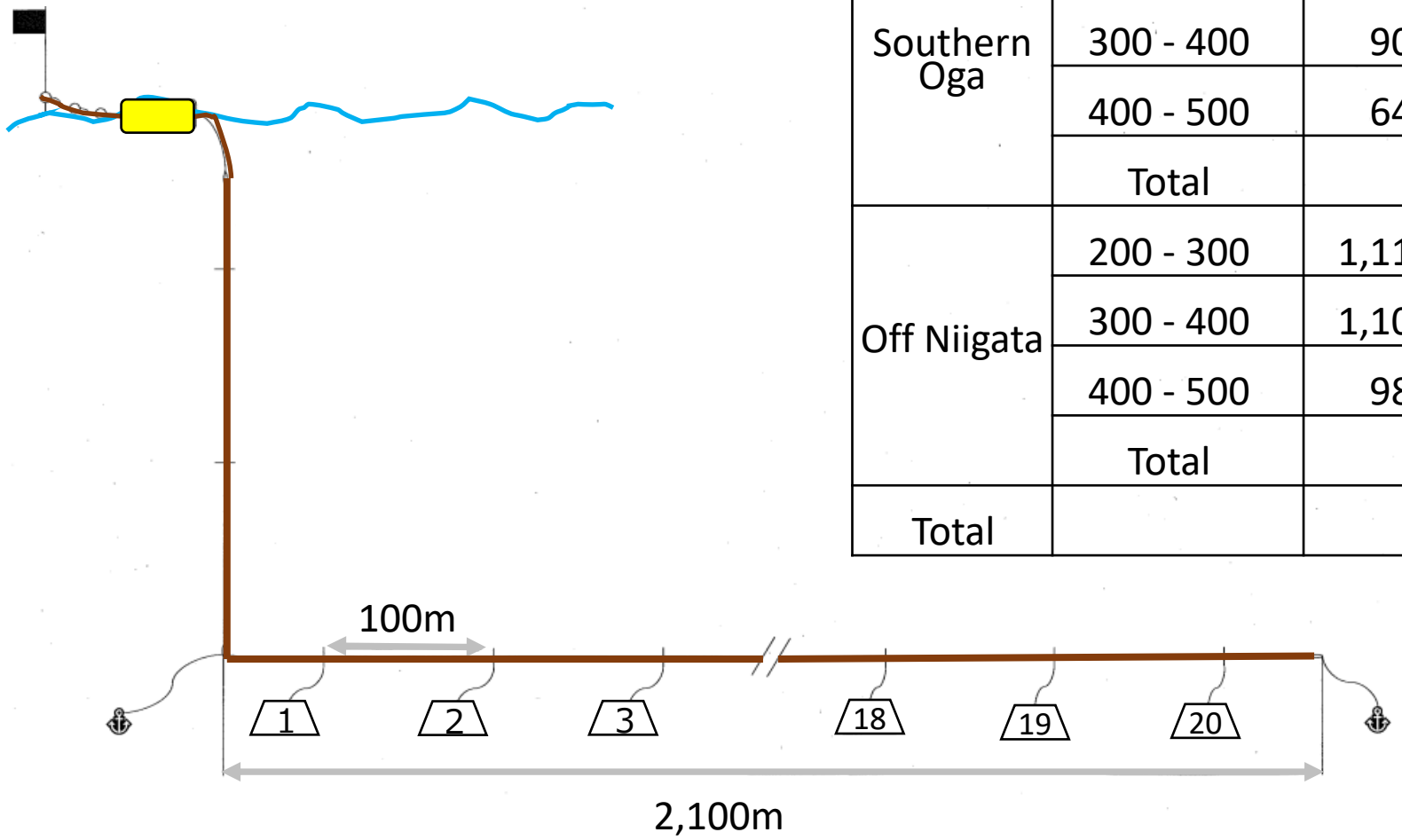
7) I am a little confused about which abundance index or indices was used to estimate the stock density. It looks like there was a commercial trawl, a pot survey, and a beam trawl survey. Were all three used? Which is the most important for estimating current stock status?

8) It appears that the trawl index and the pot survey were the two most important indices. If that is correct, please explain both in more detail.

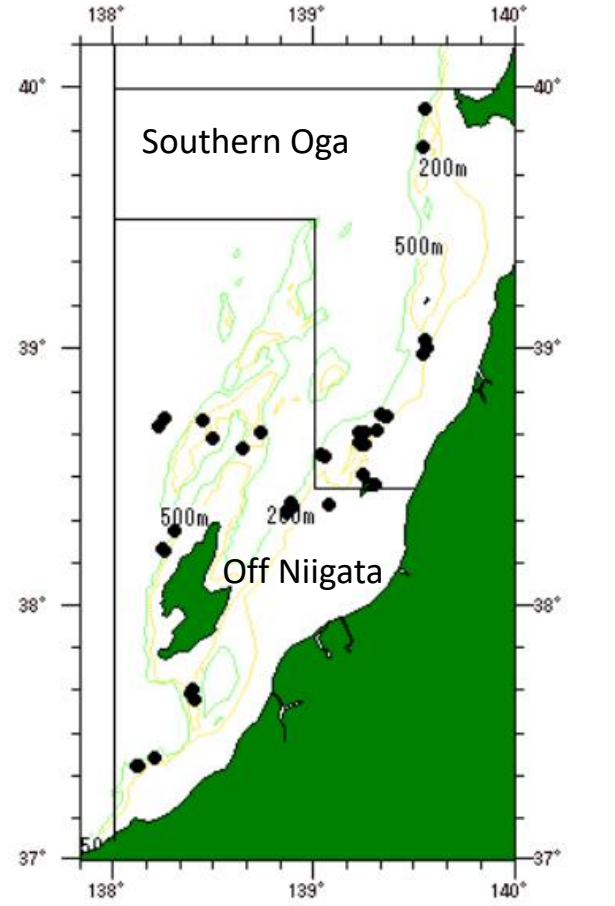


- Stock assessment is mostly based on crab pot surveys and ABC is estimated using the survey-based standing stock biomass.
- Indices from commercial trawlers and beam trawl survey are used as supporting information.

Pots survey



Area	Depth zone (m)	Area (km^2)	Number of survey **sites**
Southern Oga	200 - 300	1,029	6
	300 - 400	900	8
	400 - 500	647	6
	Total		20
Off Niigata	200 - 300	1,116	4
	300 - 400	1,102	6
	400 - 500	980	2
	Total		12
Total			32

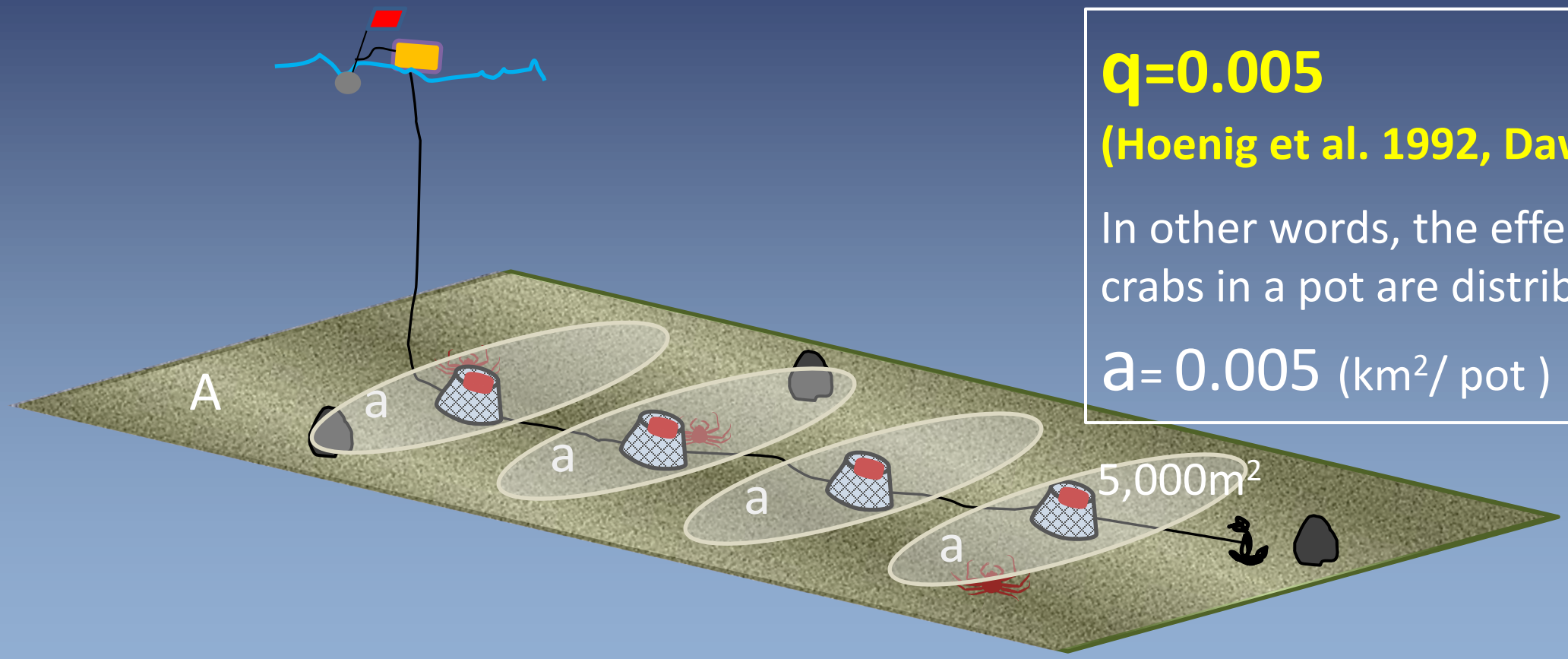


A total of 20 pots are arranged with 100 m spacing in a line of 2100 m

Method for estimating abundance

density (ind./km^2) = $\sum_{i=1}^{pot} n_i$(ind.) / pot / a(km^2/pot)

N stock (ind.) = density (ind./km^2) × A (km^2)



q=0.005

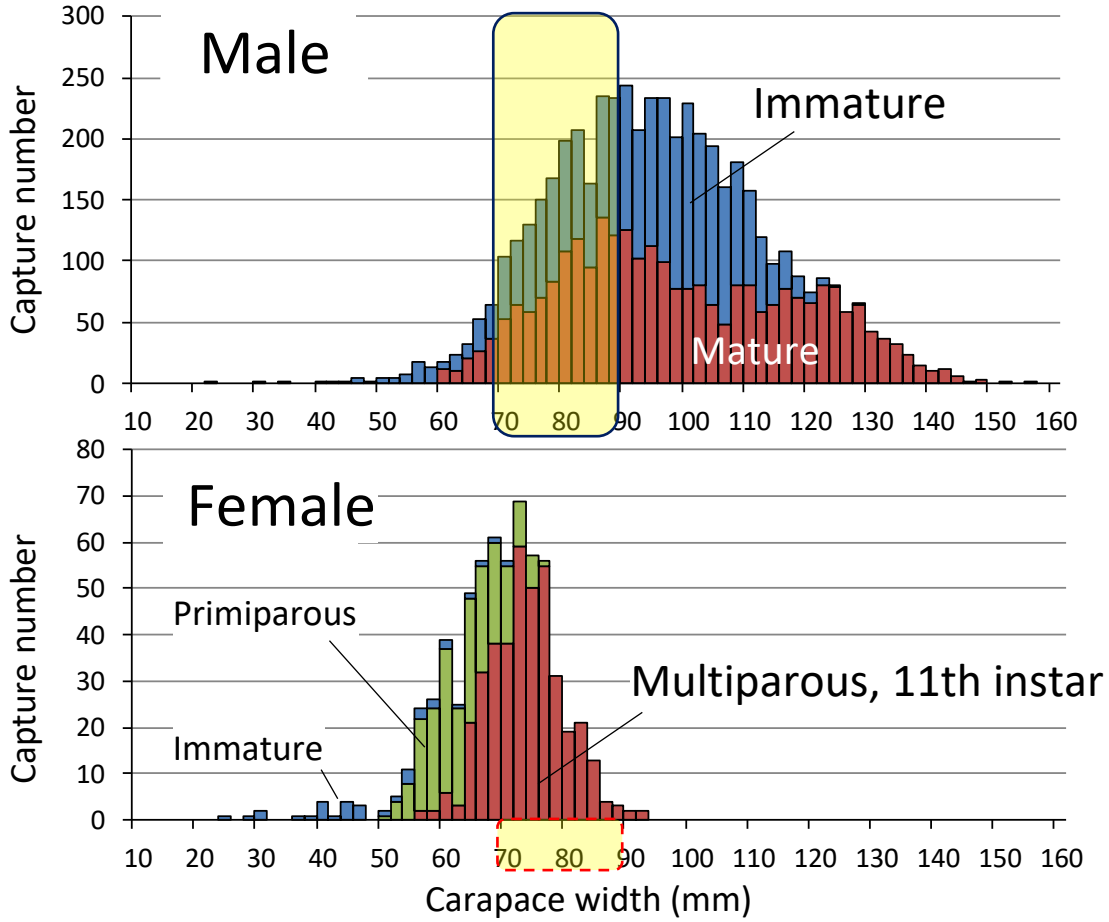
(Hoenig et al. 1992, Dawe et al. 1993)

In other words, the effective area where crabs in a pot are distributed in 1km^2

a= 0.005 (km^2/ pot)

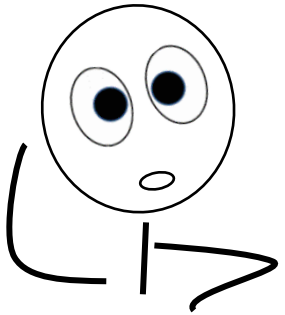
Standing stock biomass is estimated by the crab-pot surveys assuming gear efficiency of 0.005 for male and 0.0016 for female

Appendix 3 Corrections to Female Capture Efficiency in Pot Surveys



Supplementary Figure 3-1.
Carapace width composition in 2016 from **pot survey** in Sea of Japan Area B.

Number of CW70-90mm (11th instar) < Number of CW90mm- (12,13th instar)



Is this size selectivity of pot ?

・No female gear efficiency was available and used 0.005 also for females.
・Catch of male 11th instar is fewer than larger (older) group probably due to lower catch efficiency, therefore it may be also the case for female 11th instar.
・Male per female gear efficiency ratio of crab pots was estimated based on the standing stock population in the Sea of Japan Area A stock.

Appendix 3 Corrections to Female Capture Efficiency in Pot Surveys

Supplementary Table 3-1. Standing stock population by instar during 2003-2016 estimated by pot survey in Sea of Japan Area B and trawl survey in Area A

Instar	Maturity	Standing stock population (thousands)	
		Area B, pot	Area A, trawl
11th instar	Immature	772	15,044
11th instar	Mature	935	2,160
12th instar	Immature	1,221	7,438
12th instar	Mature	1,838	2,589
13th instar	Mature	1,071	2,956
11th instar total		1,707	17,204
12-13th instars total		4,130	12,983

① $\frac{17{,}204}{12{,}983} = 1.325$

② 11th instar : **5,472** × 1.325

③ **Size selectivity of pot in Area B for *male(11th instar)***

$$\frac{1{,}707}{5{,}472} = 0.312$$

④ Capture efficiency of pot

Initially
Male(11th instar) : 0.005
Female(11th instar) : 0.005

× 0.312

Male(11th instar) : 0.0016
Female(11th instar) :0.0016

Stock calculation (Density, Standing stock)

Supplementary Table 2-1. Standing stock in June-July 2021 based on pot survey

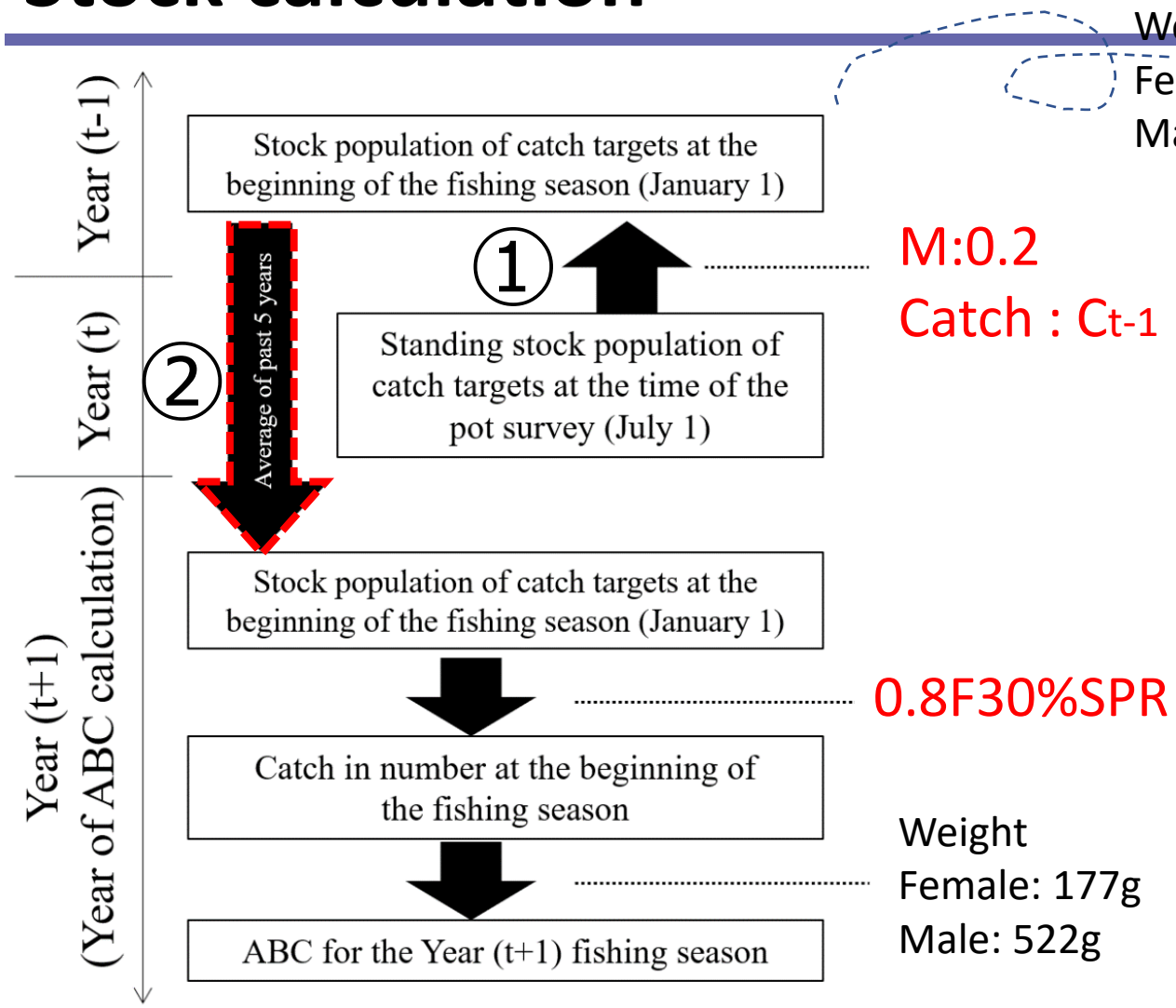
Area	Depth zone (m)	Area (km^2)	Number of survey sites	Average density (ind./pots)		Standing stock population (thousands)		Standing stock (tons)	
				Male	Female	Male	Female	Male	Female
Southern Oga	200-300	1,029	6	1.3	6.9	264	4,427	138	784
	300-400	900	8	2.9	2.3	526	1,294	274	229
	400-500	647	6	0.7	0.0	84	10	44	2
	Total		20			874	5,731	456	1,014
Off Niigata	200-300	1,116	4	1.1	1.9	251	1,299	131	230
	300-400	1,102	6	3.3	3.0	738	2,055	385	364
	400-500	980	2	1.1	0.1	220	77	115	14
	Total		12			1,209	3,431	631	607
Total			**32**			**2,083**	**9,162**	**1,087**	**1,622**

Values for males are for a carapace width of 90 mm or more and values for females are for the 11th instar.

Capture efficiency : male 0.005, female 0.0016 Weight : male 522g, female 177g

＊The estimated number of females much larger than makes in 2021, probably because difference in the size of the year-classes that observed as 11th and 12th instars in 2021.

Stock calculation



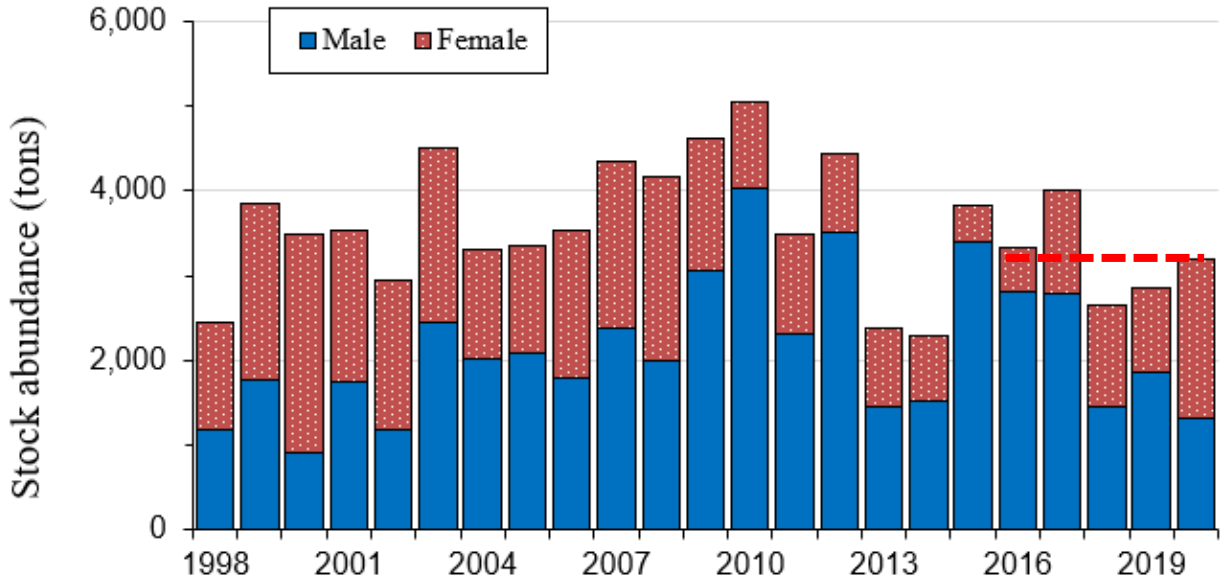
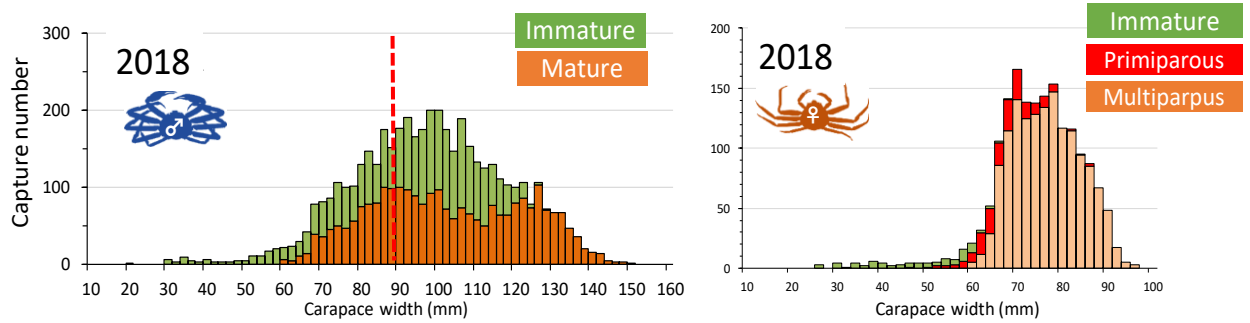


Fig. 4-2. Stock abundance at the beginning of the fishing season

- Molting season is in late summer (Sep to Oct) and back calculation can reduce assumptions.
- Natural mortality of 0.2 for hardshell (Yamasaki 1996) was assumed (though catch includes both hard-and softshells, we assume that catch is mainly consists of hardshell individuals).
- Considering the uncertainty of the estimates, we average stock abundance in the last five years and used as ABC.

Harvest Control Rules (Fmsy proxy : F30%SPR)

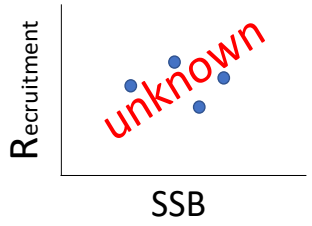
Stock Assessment Methods (Problem of pot survey)



Carapace width composition in 2018 from **pot survey** in Sea of Japan Area B.

Male
- Mode of small crabs is unclear
- Age decomposition is uncertain

Female
- It is difficult to collect small crabs

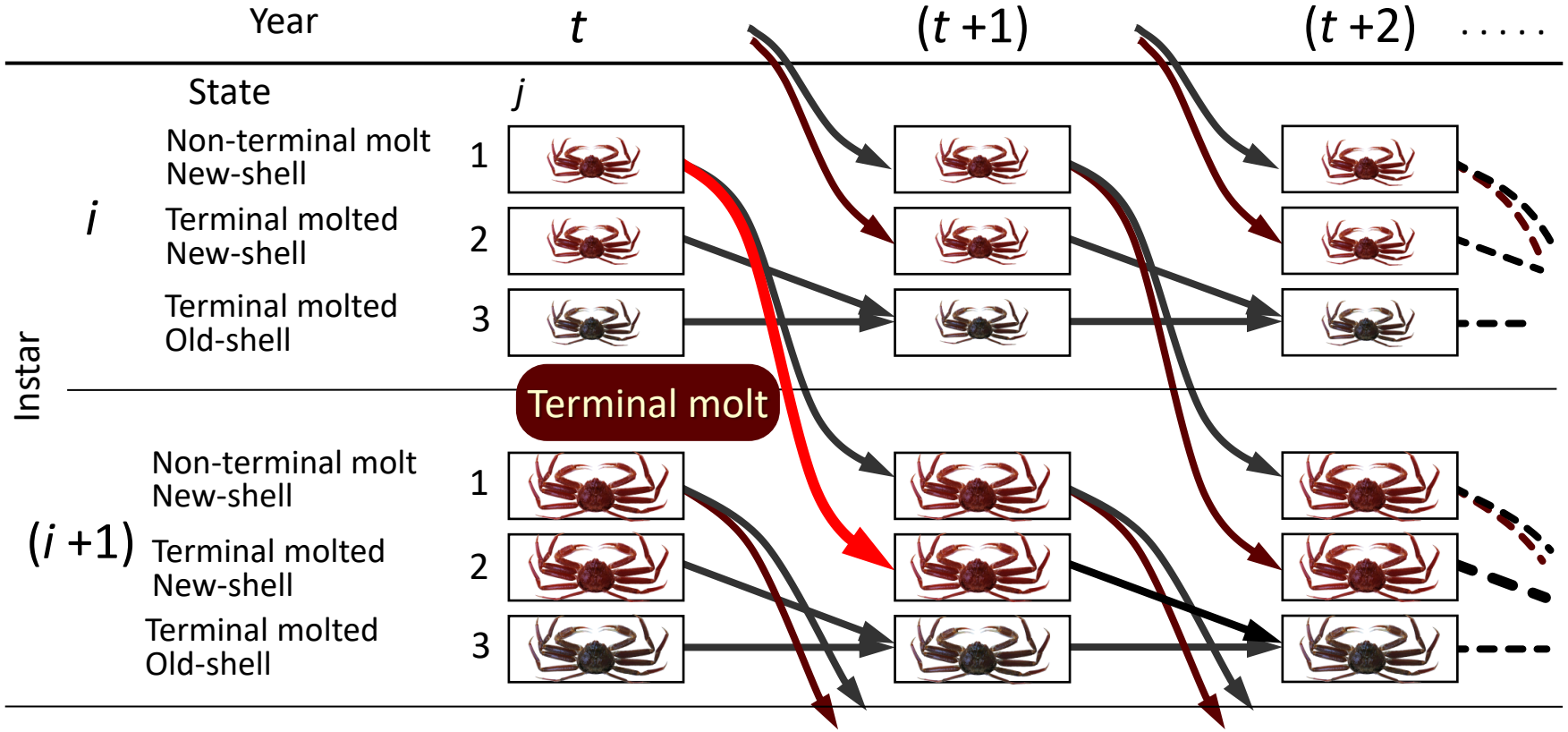


Ueda Y., M. Ito, T. Hattori, Y. Narimatsu and D. Kitagawa (2009) Estimation of terminal molting probability of snow crab *Chionoecetes opilio* using instar- and state-structured model in the waters off the Pacific coast of northern Japan. Fish. Sci., 75, 47-54.

- After the Stock Management Policy Commission and the Fishery Policy Council held in March 2021, it was determined that since the stock-recruitment relationship of this stock is unknown, the fishing pressure (Fmsy) at the level to achieve MSY should be replaced by the fishing pressure at which the amount of spawning per recruit is 30% of the value when the fishing pressure is 0 (F30%SPR).

- The Harvest Control Rule was set as a constant fishing pressure measure using the F30%SPR multiplied by 0.8 to account for uncertainty and to provide a safety margin.

YPR・%SPR



(Ueda et al. 2009)

- M = 0.2 for individuals who completed their terminal molt 1 or more years prior
- M = 0.35 for individuals who did not complete terminal molt or completed terminal molt less than 1 year prior
- Males up to the 11th instar and females up to the 10th instar were by-catch and released at the same F as the target individuals to be landed (males: 12-13th instar, females: 11th instar (akako and kuroko), and the calculation was made assuming a post-release survival rate of 0.5.

%SPR YPR and Fcurrent

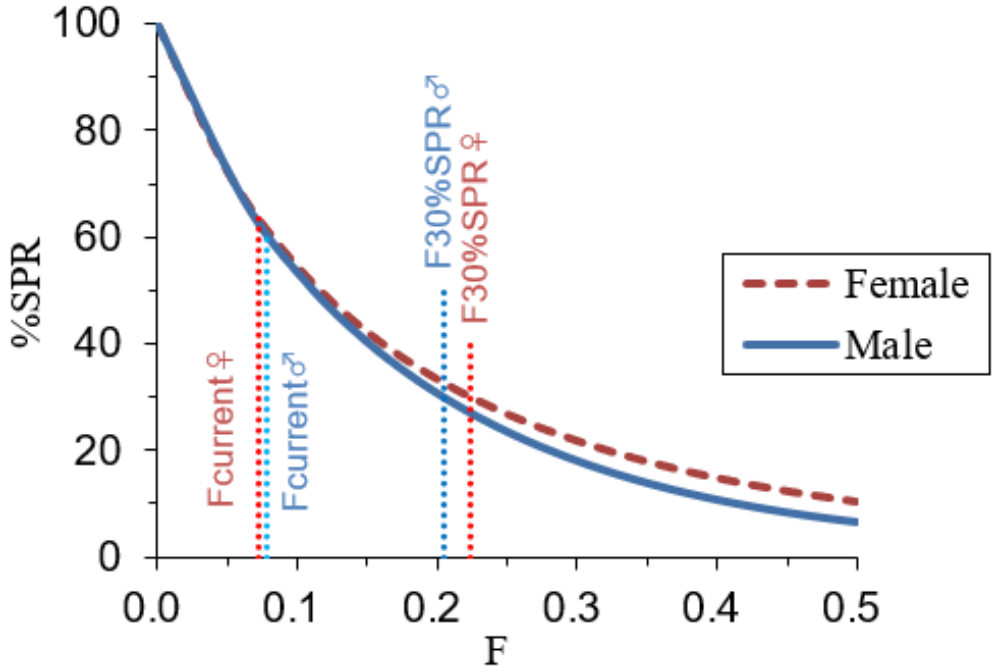


Fig. 4-6. Relationship between F and %SPR

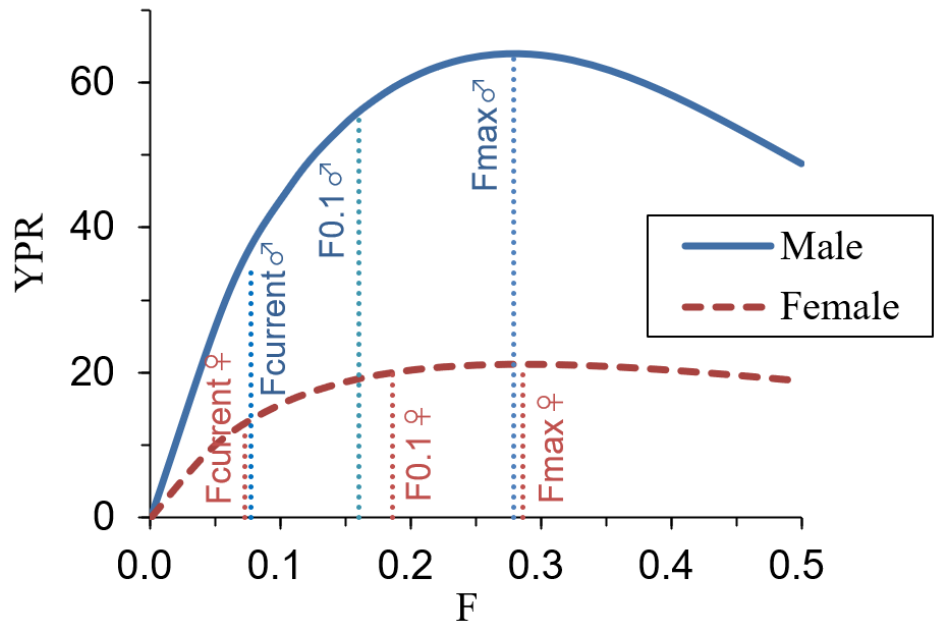
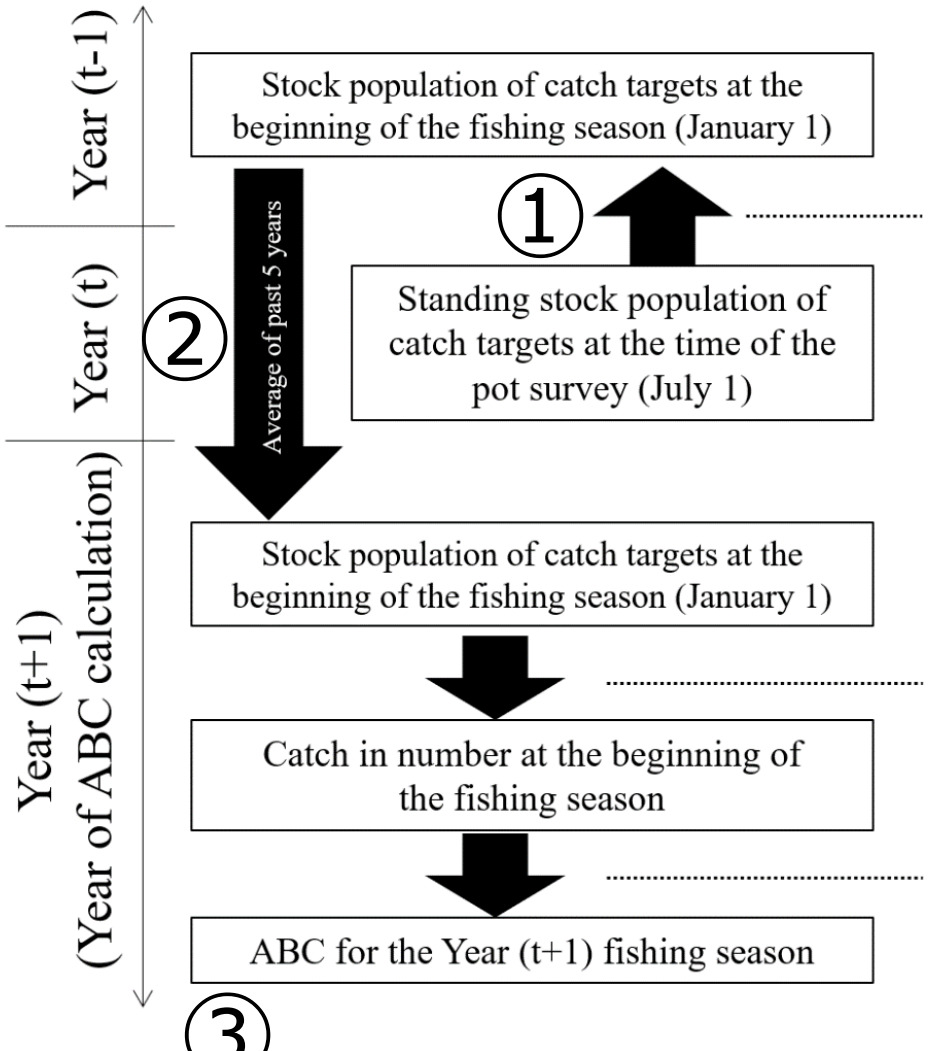


Fig. 4-7. Relationship between F and YPR

F	Male	Female
Fcurrent*	0.08	0.07
Fmax	0.28	0.29
F0.1	0.16	0.19
F30%SPR	0.20	0.22

*Fcurrent : average for 2016-2020

Calculation of Allowable Biological Catch (ABC)



M:0.2

Catch : C_{t-1}

0.8F30%SPR

Weight

Female: 177g

Male: 522g

ABC for 2022 (tons)	Forecast stock abundance in 2022 (tons)	Ratio to current fishing pressure (F/F2016-2020)
500	3,200	3.03

・The ABC of 500 tons is considerably larger than the current catch in the stock but we assume it is concordant with that available fishing areas in the Area B is much narrower than potential snow crab distribution because of rough and steep bottoms in the northern Sea of Japan.

Reviewer's comment

Data – total catch

3) Are there sources of bycatch and dead discards? Has it been included in the assessment?

・We consider bycatch death in SPR/YPR analysis. We assume bycatch mortality of 0.5×F for Juveniles and young individuals that is not targeted in area B fishery (the same assumption of that in Area A).

4) The unit of commercial effort seems to be number of sets. Is that correct? Is there any sort of adjustment for trawl timing? Is there any sort of differentiation in the effort of offshore trawling vs Danish seine or is it assumed that they are the same?

・Fishing effort is based on the number of cast recorded in Japanese official logbooks of bottom trawlers.

・Both offshore large and small local trawlers are Danish seiners. Because only the vessel sizes but fishing depth, size of the nets for the two fisheries are different, we used logbook data from these fisheries without discrimination.

Reviewer's comment

Data – size/instar

5) Is there any uncertainty with regards to the sizes associated with each instar?

6) How was the catch and indices assigned to instars?

・Almost no information regarding age and growth of snow crab in Area B is available. We are now trying to integrate data from crab pot and beam-trawl surveys for providing more accurate stock abundance estimates by applying age-structured models.

Data – Abundance indices

9) It looks like the stock abundance was based directly on the abundance index that is scaled up to the population abundance. A portion of the population is then removed based on the catch and M. Please explain how the population abundance was obtained.

10) I am not sure I understand how the female capture efficiency was calculated in Appendix 3.

・See the answer above

Reviewer's comment

Natural mortality

11) The M used in Appendix 4 was 0.2 y-1?

・We use natural mortality of 0.2 for hardshell individuals in calculating stock abundance at the middle of fishing season from survey-based standing stock biomass estimates.

・We consider bycatch death in SPR/YPR analysis. We assume bycatch mortality of 0.5×F for Juveniles and young individuals that is not targeted in area B fishery (the same assumption of that in Area A).

12) Where did the M value come from?

・M is from Ueda et al. 2009 but originally estimated by Yamasaki (1994).

13) How sensitive are the results to M?

14) What is a reasonable range for M?

・Sensitivity test has not been done for M but now carrying out by using surplus production model along with the other parameters like survey efficiency.

Reviewer's comment

Model

15) It appears that the model described in Appendix 4 is simply to remove crabs from the population estimate (i.e., from the index or survey) due to catch and M. Is that correct?

- See the answer above

16) In addition, the model is used to estimate F, which is used to compare with the F30 reference point. Is that correct?

- We use 0.8 F30%SPR for harvest controlling instead of Fmsy.

17) What is the most important estimate from the model? This is to help the review focus on the most important thing.

- It is stock abundance based on crab pot survey.

18) Has there been any thought about using a population model like the Pacific stock to estimate population abundance?

- We cannot estimate standing stock biomass for juveniles and small individuals by crab pot survey.

19) How were uncertainties in the assessment presented and used in the assessment?

- We are sure that there is considerable uncertainty in crab pot surveys which stems mainly from the assumption of the survey catch efficiency. We are now testing those uncertainties in the surveys by using the surplus production model.

Reviewer's comment

23. This assessment uses a proxy for FMSY (FSPR30%) and an estimate of stock biomass derived from a pot survey to inform catch estimates. Density is calculated per set, representing 20 baited pots mounted at 100-m intervals. It's not clear from the assessment report how catch from baited pot gear (which attracts nearby crabs) is converted to a density.

・See the answer above

24. Explain later

25. Underwater visual survey transects (e.g. ROV or perhaps AUV due to the depth) could be used to estimate crab densities, with pot or other gear types used to verify size, sex, and maturity. Has this approach been considered for estimation of snow crab abundance?

・As pointed, video observation has been carried out with beam-trawl surveys for future analyses on survey catch efficiency.

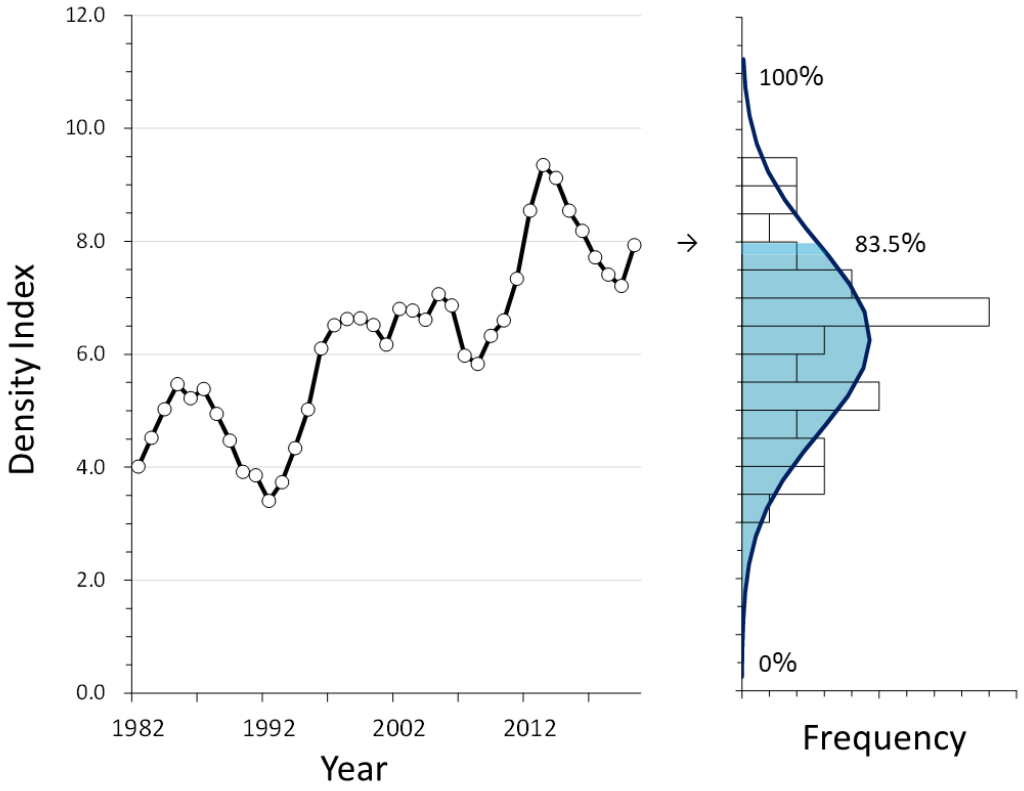
26. An F30% SPR value is reported for males (0.20). Typically, SPR is a function of lifetime egg production and represents the ratio of egg production under fished conditions to egg production in unfished conditions. How is the spawning potential ratio calculated for the males?

・SPR here means spawning-per-recruits (not spawning potential ratio). We assume spawning by mature males and females after terminal molting, and recruitment of 8th instar juveniles (both males and females).

Reviewer's comment

27. The method for determining the population level and current stock status is not clear. For example, Supp. Fig. 7-2 shows population level in percent. What is the basis for 100% of the population level? The reference appears to have been left out of the caption, and I could not determine the method from the text in the report.

・We applied cumulative normal gaussian distribution for the past whole fisheries index data and evaluate present stock level as a quantile.

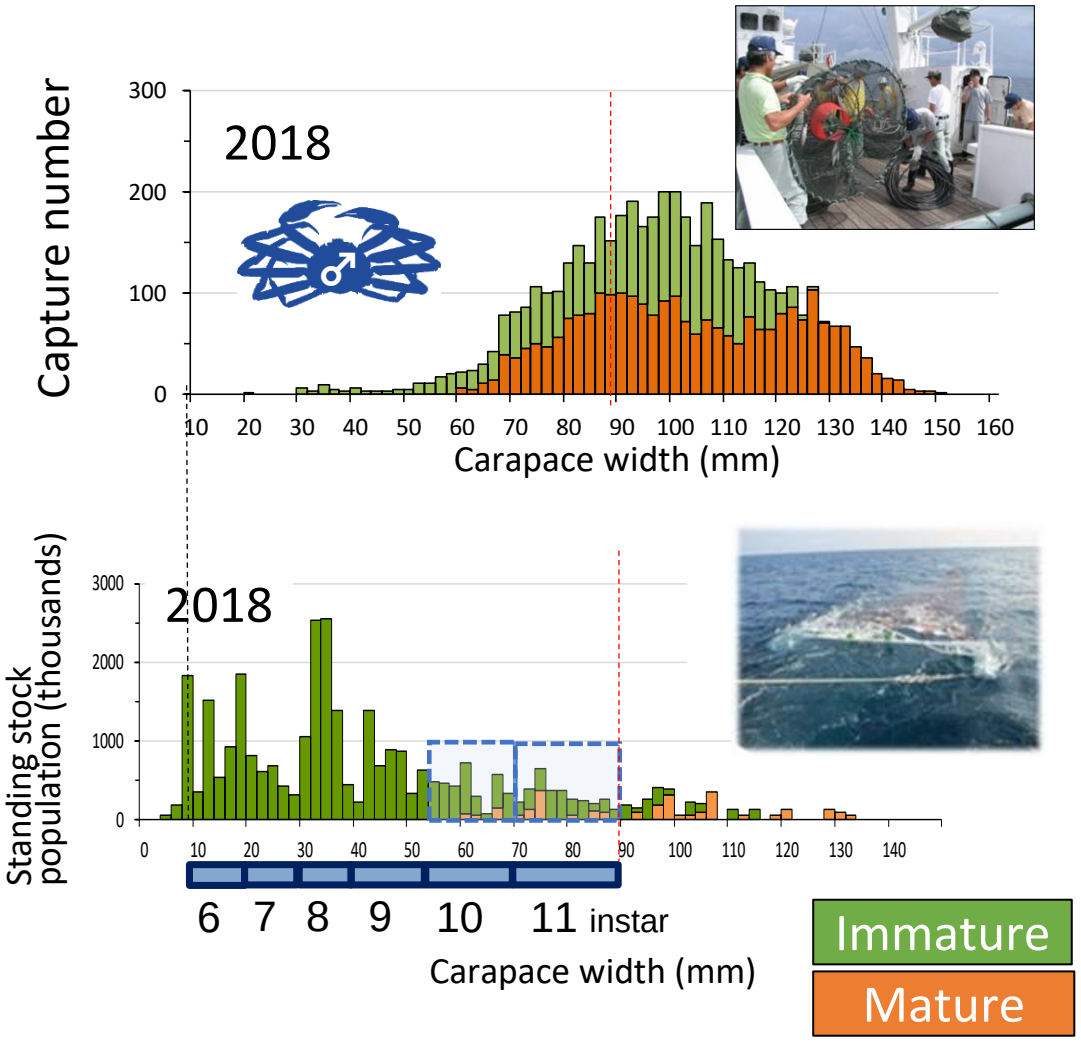


28. How likely is it that Sea of Japan areas A & B are a single biological stock? The reports indicate that regulations differ between the areas, but the dynamics may be strongly linked by dispersal of larvae. Are there data on prevailing currents during pelagic larval stages, genetic testing, or other information to help understand the degree of connectivity between these two stocks?

・We think that biologically two areas belong to the same stock. We are currently exploring the relationships of the two management units by physical modelling (particle tracking) and genetic methods (GRAS-Di and WGS).

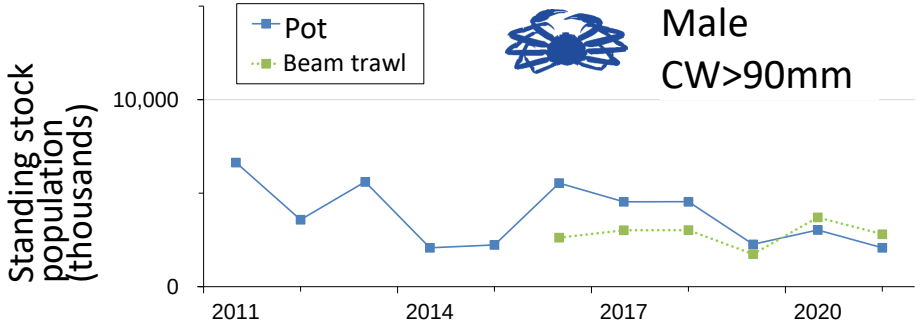
Future projection

24. Since 2016, a beam trawl survey has been conducted to estimate stock abundance, and notably recruitment, which is not well estimated by pot survey data. How do the estimates of stock abundance compare for instars that are well-sampled by both gears?



・One of the potential problems is that the number of large individuals like fisheries targeted males is unexpectedly small, probably due to low density and low catch efficiency of the large crabs.

・The trends in the number of fisheries targeted size groups are persistent in the beam-trawl survey.



・We are now trying to integrate crab pot and beam-trawl survey data by catch efficiency estimates for both surveys.
Currently, we are thinking about the model that weighing data from small and large individuals in beam-trawl and crab pot surveys, respectively.

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