Stock assessment and evaluation for Sea of Japan Area B stock of snow crab (fiscal year 2021)

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Summary

The stock status in Area B for this stock (north of Niigata Prefecture) was evaluated based on pot surveys and the stock density indices of offshore bottom-trawling and small bottom-trawling fisheries that have been conducted since 1999. In snow crab fisheries along the Japan Sea coast of Honshu, different fishing regulations are in place for Area A west of Toyama Prefecture and Area B north of Niigata Prefecture, and there are separate TACs for each area. In Area B, many snow crabs are caught by bottom-trawling and gillnetting. The catch in weight for this area peaked at about 1,000 tons in the 1960s and about 800 tons in the 1980s. Subsequently, it decreased due to the decrease in the number of fishing vessels and nets, and has remained at 200 to 400 tons since the 1990s. The average catch in weight for the 2016-2020 fishing seasons (July to June of the following year) was 213 tons. The stock abundance since 1998 estimated by pot survey has remained between 2,300 to 5,100 tons, with a flat trend for the past 5 years (2016-2020). In addition, the stock density index (average of the past 5 years) based on the catch performance report of offshore bottom-trawling and small bottom-trawling fisheries, which was used as a reference for the stock abundance index value for a long period of time, was at its lowest in 1992, rose in the mid-1990s, and reached its highest in 2013. It has been declining since then but is still high.

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 target reference point was defined as the SSB achieved by a fishing pressure of F30%SPR, which is an alternative value to the fishing pressure that achieves MSY (Fmsy). 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. The SSB of this stock in the 2020 fishing season exceeds the target reference point. In addition, the SSB in the last 5 years (2016-2020 fishing seasons) has been increasing. The fishing pressure of this stock in the 2020 fishing season is below F30%SPR. The ABC for the 2022 fishing season, calculated based on the projected stock abundance for the 2022 fishing season and the Harvest Control Rule, is 500 tons.

	SSB (tons)	Description
A target reference point	—*	Level of SSB is the level of fishing pressure at which the spawning per recruit is 30% of the value when the fishing pressure is 0.
Current value (2020)	1,792	Stock abundance of females after the fishing season estimated based on pot surveys

* The target reference points are not set until the estimated value based on future forecasts is obtained.

Year	Stock abundance (tons)	SSB (tons)	Catch in weight (tons)	F/F30%SPR	Exploitation rate (%)
2017	4,018	1,164	233	0.28	5.8
2018	2,661	1,141	214	0.40	8.0
2019	2,852	921	180	0.31	6.3
2020	3,193	1,792	199	0.30	6.2
2021	3,210	1,096	213	0.33	6.6
2022	3,210	—	—	—	—

- The year indicates the fishing year (July to June of the following year).
- The stock abundance is the value at the beginning of the fishing season (January 1 during the fishing season), and the catch in weight is the value in the fishing year (July to June of the following year). SSB is the value of females after the fishing season.
- The stock abundance and catch in weight are the sum of males (total of male crabs with hard shell and male crabs with soft shell) and females (total of akako and kuroko crabs). The 2021 SSB is the value estimated after the fishing season when the 2021 female catch in weight is assumed to be the average of the 2016-2020 catch in weight.
- The stock abundance in 2021 and 2022 is assumed to be the average of the 2016-2020 stock abundance, and the catch in weight in 2021 is assumed to be the average of the 2016-2020 catch in weight.
- The exploitation rate is the catch in weight for each fishing year / the stock abundance of catch targets at the beginning of each fishing season.

ABC for 2022 (tons)	Forecast stock abundance in 2022 (tons)	Ratio to current fishing pressure (F/F2016-2020)	Exploitation rate in 2022 (%)
500*	3,200*	3.03	6.7

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 target reference point was defined as the SSB achieved by a fishing pressure of F30%SPR, which is an alternative value to the fishing pressure that achieves MSY (Fmsy). This SSB will not be set until the estimated value based on future forecasts is obtained. 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. The ABC for the 2022 fishing season, calculated based on the projected stock abundance for the 2022 fishing season and the Harvest Control Rule, is 500 tons.

*The ABC and stock abundance values are rounded to the nearest ten tons and hundred tons, respectively.

1. Data Sets

The data sets used for this stock assessment are as follows:

Data Sets	Basic Information & Related Surveys
Catch in weight	Landings by prefecture, fishing method, month, and sex (Annual report by MAFF) Prefectural agriculture and forestry statistics (by month and sex)
Fishing Effort CPUE Stock density index (abundance index value)	Catch Performance Report for Bottom-Trawl Fishing in Offshore Waters (Japan Fisheries Research and Education Agency) Catch performance report of small bottom-trawling fisheries (Akita, Yamagata and Niigata Prefectures and Japan Fisheries Research and Education Agency)
Stock abundance / Recruitment volume	Pot survey (Simultaneous survey before snow crab fishing season, Akita Prefecture (June), Yamagata Prefecture (July), Niigata Prefecture (July)) Beam-trawl survey (July, demersal fish stock survey in the northern Sea of Japan, water depth of 190 m to 500 m, Japan Fisheries Research and Education Agency)
Natural mortality coefficient (M) (per year)	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

2. Ecology

(1) Distribution / Migration

The distribution range of the snow crab in the Sea of Japan Area B is the continental shelf slope and its margins north of Niigata Prefecture, most commonly at depths of 200 m to 500 m (Fig. 2-1). It is known that the terminal molt and subsequent primiparous brooding of females is concentrated in a limited area of relatively shallow water (Kon 1980). In addition, mature males and females are distributed at different depths, with a division seen at depths of 260 to 300 m, with males mainly distributed in deeper waters, and females mainly distributed in shallower waters. After hatching, this stock advances through drifting larvae stages for 2 to 3 months (prezoea stage, first zoea stage, second zoea stage, megalop stage) before metamorphosing into juvenile crabs and settling on the seabed (Kon 1980, Yamamoto et al. 2014). Based on the results of tagged releases, it is known that cases of significant horizontal migration are uncommon (Ogata 1974).

(2) Age / Growth

Individuals molt multiple times in the first year from hatching until the 6th instar (Ito 1970), but only molt once per year afterwards. In addition, based on the results of breeding experiments at 1 °C, which is the water temperature in the main distribution area of this stock in the Sea of Japan

(Yamamoto et al. 2015), the period from hatching until recruitment (11th instar) is considered to be 7 to 8 years, with a life span of more than 10 years.

The molt-age of snow crabs can be estimated according from data like carapace width composition (Kon et al. 1968, Yamasaki and Kuwahara 1991, Yamasaki et al. 1992). In juvenile and immature crabs, there is no difference in growth between males and females, and carapace width reaches 60 mm or more in the 10th instar (Fig. 2-2). Individual males that completed their terminal molt usually start to appear in the 11th instar, and the proportion of individuals that completed their terminal molt is 5%, 20%, and 100% in the 11th, 12th, and 13th instars, respectively. After the terminal molt, the propodus (claw) grows larger relative to body size (Fig. 2-2). All individual females are pre-terminal molt up to the 10th instar, and all females complete their terminal molts by the 11th instar. After the terminal molt, the abdominal flap becomes wider to carry eggs. Because body growth ceases after the terminal molt, the group of females in the 11th instar and males in the 11th instar or higher contains multiple cohorts.

(3) Maturation / Spawning

Females complete their terminal molt in the summer or fall of their 10th instar, then mate and spawn their primiparous brood (carry eggs) immediately after reaching the 11th instar (Fig. 2-3). After their first spawning, females incubate the eggs for 18 months, and the larvae hatch in February or March of the following year. Shortly after hatching, the second spawning (multiparous spawning) occurs. The multiparous incubation period is 12 months, and they will spawn every year in February or March. The color of the egg clutch is orange after spawning, then transitions to brown or blackish purple as the larvae develop inside before hatching.

Immediately after their first spawning, females with orange egg clutches at the beginning of the fishing season (November) are called “akako” (red). When the eggs change to brown or blackish purple by the following fishing season 1 year later, the females are called “kuroko” (black).

Snow crab categories are nicknamed by development and by sex: soft shells, hard shells, akako, and kuroko. These nicknames may vary from region to region. In this report, individual males that molted less than 1 year prior are called soft shells, and individual males that molted more than 1 year prior are called hard shells.

(4) Predator-Prey Relationships

This stock feeds year-round except during molting, on crustaceans, fish, squids, polychaetes, shellfish, echinoderms, and other benthic organisms (Ogata 1974). Smaller individuals are preyed upon by eelpouts (Ito 1968, Konishi et al. 2012) and Pacific cod (Ota 2018, Ueda 2018).

3. Fishery Status

(1) Fishery Overview

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 type 1 (hereinafter referred to as “small trawlers”) is high (Fig. 3-1, Table 3-1). In recent years, the ratio of gillnetting, etc. has been relatively increasing due to a decrease in the catch in weight of bottom-trawl nets. In this area, Niigata, Yamagata and Akita Prefectures catch this species, with Niigata Prefecture accounting for about 80% of the catch each year. According to the ordinances of the Ministry of Agriculture, Forestry and Fisheries, the fishing season in this area is set from October 1 to May 31 of the following year. The catch targets for males are hard shell and soft shell crabs with a carapace width of 90 mm or more (mostly 12th and 13th instars), and for females, akako crabs in addition to kuroko crabs (both 11th instar) are also caught.

(2) Trends in Catch in Weight

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, Table 3-1).

Since 1998, the catch in weight of males, aggregated by fishing year (July to June of the following year), declined until 2004 and then remained stable at 150 to 180 tons until 2008, while the catch in weight of females remained stable at 60 to 90 tons until 2010. The catch in weight of males then increased and remained above 250 tons after 2011, but declined after falling below 250 tons in 2014, and was 121 tons in 2020. The catch in weight of females exceeded 100 tons in 2011 and 2012, but has remained at 60 to 80 tons since 2013, and was 78 tons in 2020. The total female and male catch in weight in 2020 was 199 tons, compared to an average of 213 tons for 2016-2020 (Fig. 3-2, Appendix 4, Supplementary Table 4-1).

(3) Fishing Effort

The number of vessels operating offshore and small trawlers (Danish seine), which are the main types of fisheries, has been decreasing year by year, and in the 2000s, the number was around 170, about a quarter of the peak. The number has not been aggregated since 2007, but it is believed to be stable or decreasing. The number of net hauls per fishing year since 1979, when the count could be traced, decreased to about 1/4 of 1979 (22,000 times) by 1998, and then increased slightly to around 67,000 times from 2000-2007. Since 2009, the number of net hauls has 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).

4. Stock Status

(1) Stock Assessment Methods

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

Furthermore, the stock density index of males and females since 1978, which was obtained from the catch performance report of offshore trawlers and small trawlers, was used as a long-term abundance index value rather than the stock abundance based on pot surveys (Appendix 6). The yearly indices are based on the average of the past 5 years because the fluctuations are very large, and because the same vessels switched from small trawler to offshore trawler around 1988, the results of offshore trawler and small trawler fishing were not separated.

In the remainder of this report, mentions of years refer to fishing years (July to June of the following year) unless otherwise noted.

(2) Trends in Stock Abundance and Fishing Pressure

The stock abundance of catch targets at the beginning of the fishing season was estimated using the standing stock and the catch in number by sex based on the results of a pot survey conducted at a depth of 200 m to500 m in Sea of Japan Area B (Appendix 2, 3, and 4). The number of males in the stock population ranged from 1.7 million to 6.7 million, with 2.5 million in 2020. Females ranged from 2.3 million to 14.7 million, with 10.6 million in 2020 (Fig. 4-1, Supplementary Table 4-1). The total stock abundance of males and females has remained between 2,300 and 5,100 tons since 1998. After exceeding 5,000 tons in 2010, it declined in 2013 and reached a record low of 2,300 tons in 2014. It ranged from 2,700 to 4,000 tons in 2016-2019 and 3,193 tons in 2020 (Fig. 4-2, Supplementary Table 4-1). The stock abundance trend was judged to be flat based on the trends over the past 5 years (2016-2020). In addition, the amount of SSB after the fishing season remained between 1,200 and 2,500 tons until 2009, decreased during 2010-2015, but increased in 2017 and was 1,792 tons in 2020 (Fig. 4-3, Supplementary Table 4-1). The trend in SSB was determined to be an increase based on the trend in SSB over the past 5 years (2016-2020).

The exploitation rate and F were estimated from the stock abundance and catch in weight (Fig. 4-4, Fig. 4-5, Supplementary Table 4-1). Both values were slightly higher in males in 2013 and 2014, but have remained stable at lower values since 2003. Females, on the other hand, had been on the rise since 2010, but declined in 2017. F values in 2020 were 0.10 for males and 0.04 for females (Supplementary Table 4-1).

(3) Yield Per Recruit (YPR), Spawning Per Recruit (SPR), and Current Fishing Pressure

An instar composition model incorporating the terminal molt of snow crab (Ueda et al. 2009) was used to calculate %SPR and YPR for each sex. The calculation method is the same as that used in Area A. However, the calculation results for females in Area B differ from those in Area A in terms of both %SPR and YPR because akako crabs are also subject to landing in Area B. At this time, biological lifespan is not taken into account. 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.

Survival rates after release of by-catch not eligible for landing are strongly influenced by season, time spent on board, and carapace condition. Survival rates are low when air and surface water temperatures are high, or when the carapace is soft immediately after molting. The survival rate after release, examined by sex and maturity off the coast of Kyoto Prefecture, is as low as 0 to 0.15 in October, when air and surface water temperatures are high and some individuals are just after molt, but in March, April, May, and December, the survival rate is reported to be 0.87 to 1.00, except for a rate of 0.71 for mature females in March (Yamasaki 1994). The average survival rate after release, excluding October, was about 0.8. However, in actual fisheries, released individuals are left on board for a longer period of time after landing the nets than in the survey, and it is assumed that they are not handled carefully, so 0.5 was used as the survival rate after release in this analysis.

The F30%SPR of males was 0.20. The Fcurrent (average for 2016-2020) for males is 0.08, which is below the F30%SPR (Fig. 4-6). The F30%SPR of females was 0.22. The Fcurrent for females is 0.07, which is below the F30%SPR (Fig. 4-6).

The F0.1 for males is 0.16 and the Fcurrent (0.08) is below F0.1 (Fig. 4-7). The F0.1 for females is 0.19 and the Fcurrent (0.07) is below F0.1 (Fig. 4-7).

The current F values for both males and females are below F30%SPR and F0.1.

(4) Reference Point

After the Stock Management Policy Commission and the Fishery Policy Council held in March 2021, the target reference point was set as the amount of SSB to be achieved by a fishing pressure of F30%SPR, which is an alternative to the level of fishing pressure (Fmsy) to achieve MSY. However, it will not be set until forecasts based on future projections are obtained.

(5) Stock Levels/Trends and Fishing Pressure Levels

The SSB of this stock in 2020 is above the target reference point. The SSB in 2020 was 4.27 times the target reference point. The current fishing pressure is below the F30%SPR, which is defined as the alternative value of Fmsy, for both sexes (Fig. 4-6). The SSB of this stock has been increasing in the last 5 years (2016-2020) (Fig. 4-3, Supplementary Table 4-1).

(6) Trends in Abundance Indices

The stock density index (kg/net) first peaked in 1985 for males and 1983 for females, and then declined for both, increasing from 1993 for males and 1992 for females (Fig. 4-8, Table 4-1). Since the 2000s, both males and females have been highly variable. The stock density index for 2020 (provisional until March 2021) was at the average level since 2000 for males and the highest ever for females.

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. 4-9, Table 4-1). Since 2010, it has been at its highest level to date, at 10.6 in 2020. The average for the past 5 years was 3.4 at its lowest in 1992, but rose to 7.1 in 2005. It then declined slightly, but rose again to 9.3 in 2013. Although it has declined slightly since 2014, the average for the past 5 years in 2020 was 7.7, which is still high. When a cumulative normal distribution was fitted to this abundance index value (1982-2020), the level in 2020 was 83.5% (Appendix 7).

The stock density index in Area B shows large annual variation for both males and females. This is because in Area B, where there is a lot of steep terrain, it is possible to change the target species and fish even within a single fishing area of 10 minutes of latitude by 10 minutes of longitude, which is the aggregation unit of the catch performance report, and the CPUE of each fishing area is easily affected by the use of the fishing grounds. The increase in the stock density index around 2010 is also presumed to be an effect of changes in the use of this fishing ground.

5. Calculation of ABC in 2022

(1) Harvest Control Rules

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.

(2) Calculation of Allowable Biological Catch (ABC)

Since the stock-recruitment relationship is unknown in this area, the ABC for the 2022 fishing season was calculated based on the projected stock abundance value for the 2022 fishing season and Harvest Control Rules (Appendix 4).

Since it is more difficult to collect small individuals in pot surveys than in trawl surveys, it is difficult to grasp the standing stock population of crabs before they are recruited into the fishery, and although beam-trawl surveys, which can also collect small individuals, have been conducted since 2016, sufficient data has not yet been accumulated (Appendix 5). Therefore, the average stock abundance for the past 5 years (2016-2020) based on the pot survey was used to calculate the catch in weight. The 2022 stock abundance was estimated to be 3,210 tons based on the 2016-2020 average. The ABC for 2022 was then calculated to be 500 tons, which is the expected catch at the level of fishing pressure (F30%SPR multiplied by 0.8) in the Harvest Control Rule.

6. Additional Comments

It is important to continue to comply with stock conservation under the Ministry of Agriculture, Forestry and Fisheries regulations and voluntary regulations. In addition, since akako crabs, the fishing of which is prohibited by voluntary regulations in Area A, are caught in Area B, it is preferable to prohibit fishing of akako crabs in terms of securing the SSB. Even in the cases of by-catch of akako crabs, the stock conservation effect of the release is considered to be high after December when the survival rate of release is high.

The stock density index for bottom-trawl fisheries, which is used to calculate abundance index values, shows large annual fluctuations in single-year values in Area B. This is because in Area B, where there is a lot of steep terrain, it is possible to change the target species and fish even within a single fishing area of 10 minutes of latitude by 10 minutes of longitude, which is the aggregation unit of the catch performance report, and the CPUE (kg/net) of each fishing area is easily affected by the use of the fishing grounds. In the future, it will be essential to monitor the stock abundance through research vessel surveys and to analyze the operation of small bottom trawl and gill nets in order to obtain a highly accurate understanding of population trends.

In March 2021, the Stock Management Policy Commission and the Fishery Policy Council decided to replace the fishing pressure (Fmsy) at the level to achieve MSY in the stock assessment of Area B with the biological reference point (F30%SPR), while stating that "When a decrease in stock becomes apparent, a more precautionary catch strategy should be reconsidered." Although the F30%SPR is a biological reference point that was adopted as a catch strategy to secure the SSB in the stock assessments of this stock before the fiscal year 2019, it is essential to verify the robustness of this management measure based on future projections. At this time, reference points based on future resource projections have not yet been presented. It is important to search for alternative values for recruitment and to construct an instar composition model in parallel with the accumulation of data from the beam-trawl survey (Appendix 5).

7. References

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Fig. 2-1. Distribution of Sea of Japan Area A stock of snow crab

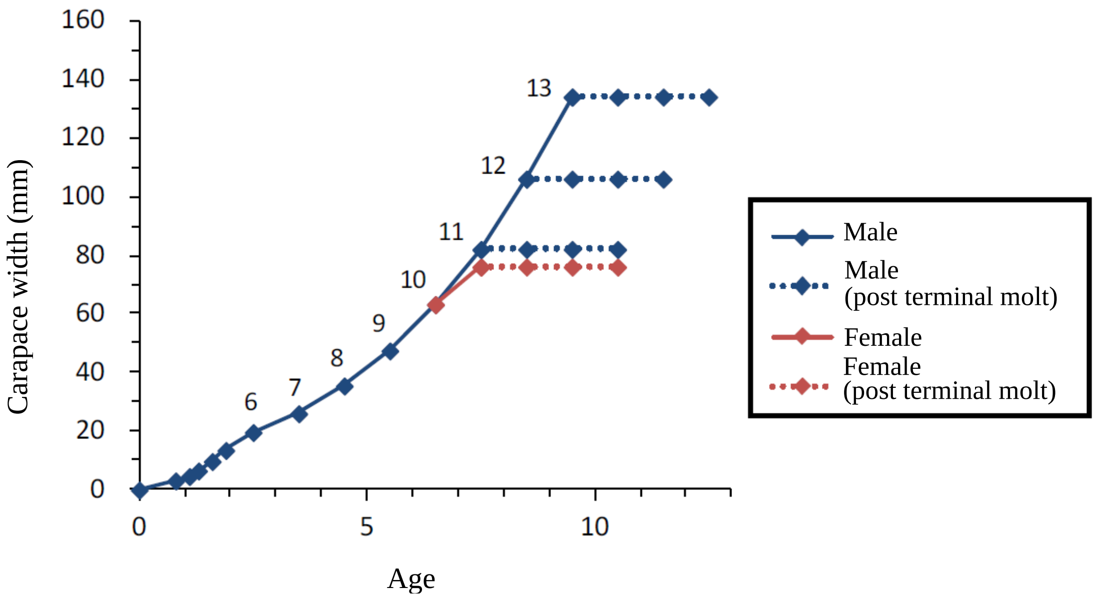


Fig. 2-2. Relationship between age, molt-age, and carapace width of snow crabs

・Numbers indicate molt-age.

・The two sexes are the same until the 10th instar.

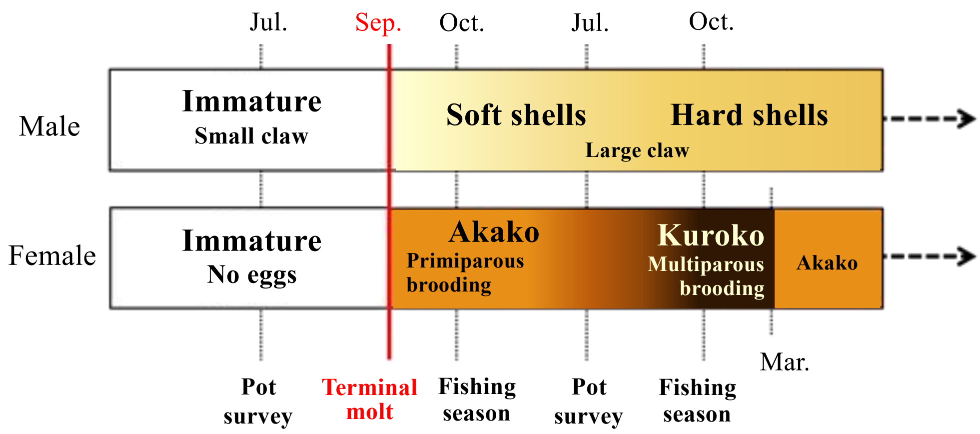


Fig. 2-3. Diagram of snow crab life history and catch categories

- Soft shells: Males that molted within the past year.
- Hard shells: Males that completed their terminal molt more than 1 year prior.
- Akako: Females carrying orange-colored eggs on their abdomen.
- Kuroko: Females carrying brownish to blackish-purple eggs.

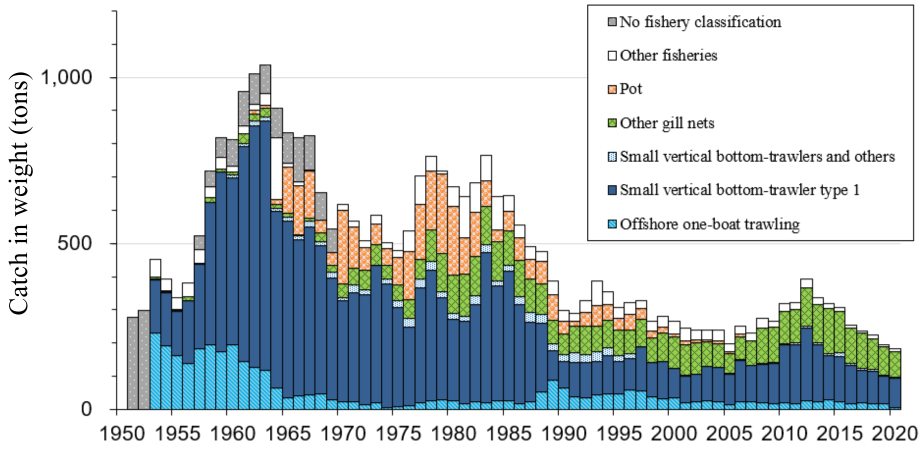


Fig. 3-1. Catch in weight of snow crab by fishery type (calendar year)

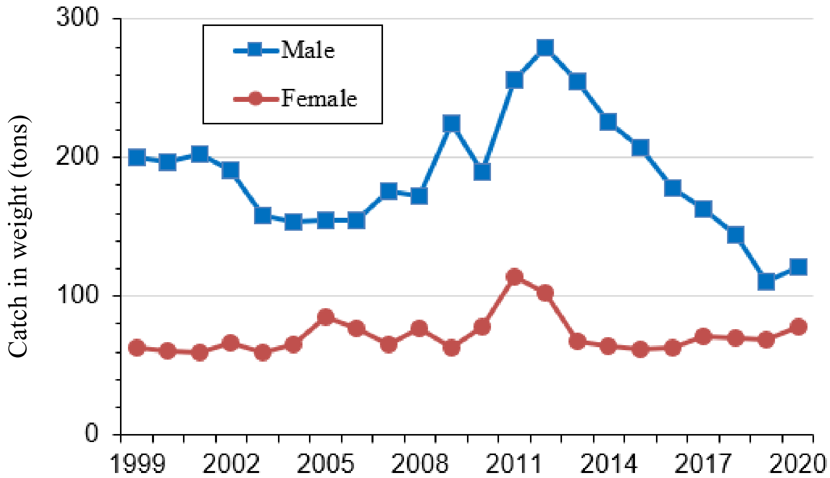


Fig. 3-2. Catch in weight of snow crab by sex (fishing year)

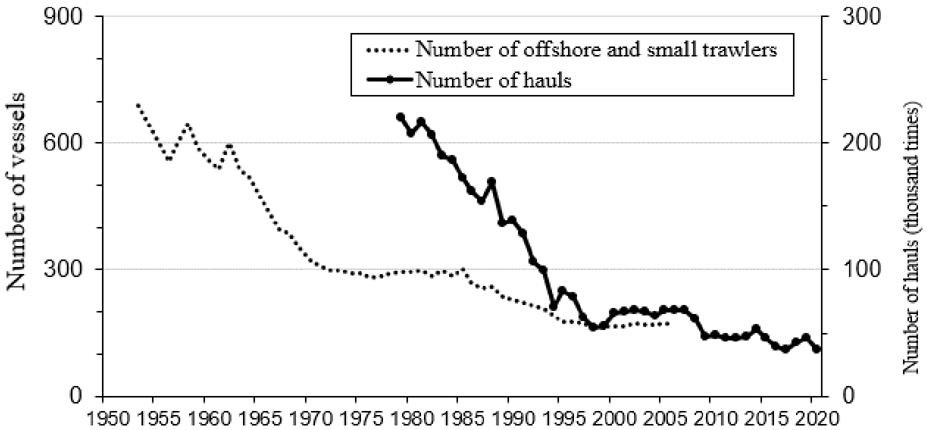


Fig. 3-3. The number of offshore and small trawlers and hauls. The number of vessels has not been counted since 2007.

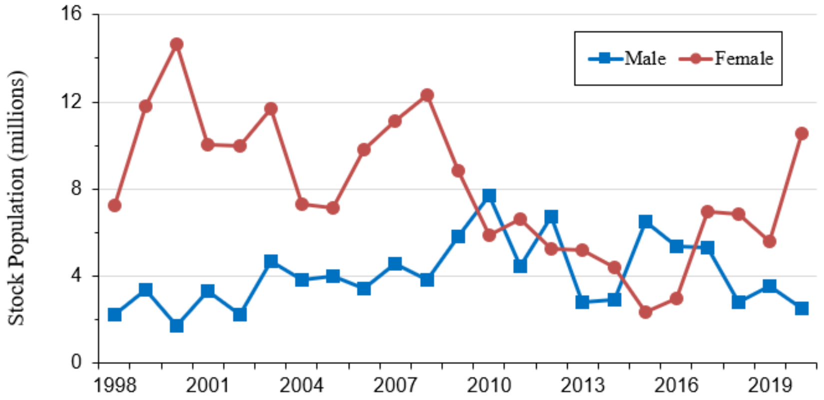


Fig. 4-1. Stock population at the beginning of the fishing season as estimated by pot survey
Values for males are for carapace width of 90 mm or more, and values for females are the sum of akako and kuroko crabs.

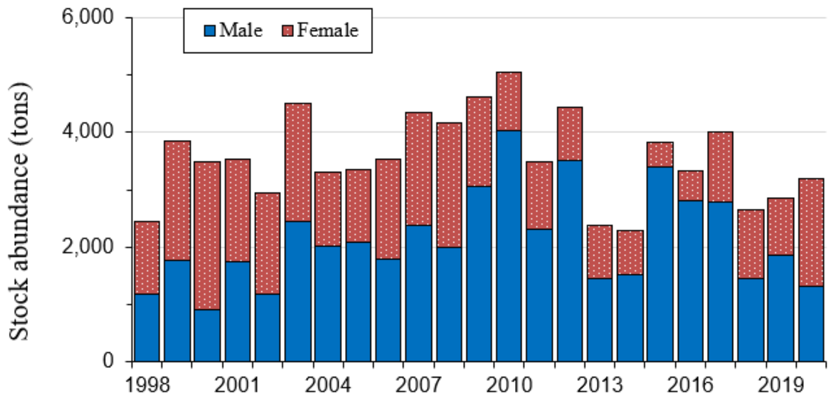


Fig. 4-2. Stock abundance at the beginning of the fishing season and SSB after the fishing season estimated by pot survey
Values for males are for carapace width of 90 mm or more, and values for females are the sum of akako and kuroko crabs.

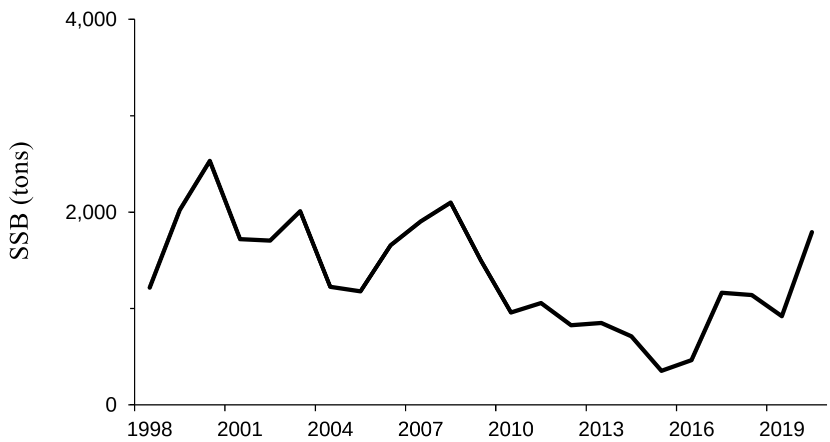


Fig. 4-3. SSB after the fishing season estimated by pot survey
Values for akako and kuroko crabs are included.

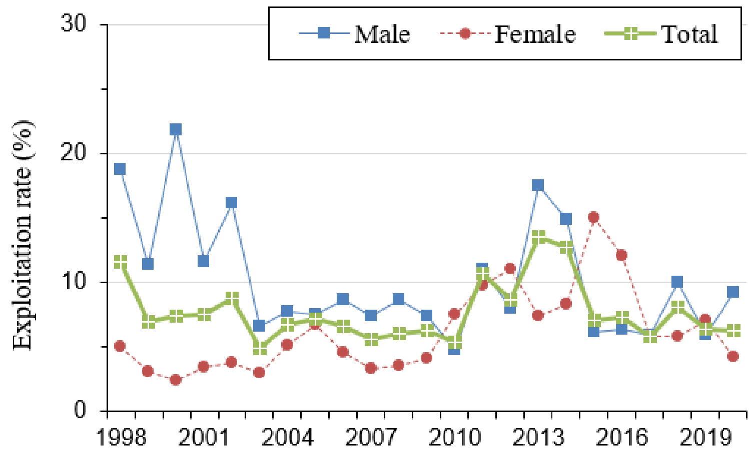


Fig. 4-4. Exploitation rate

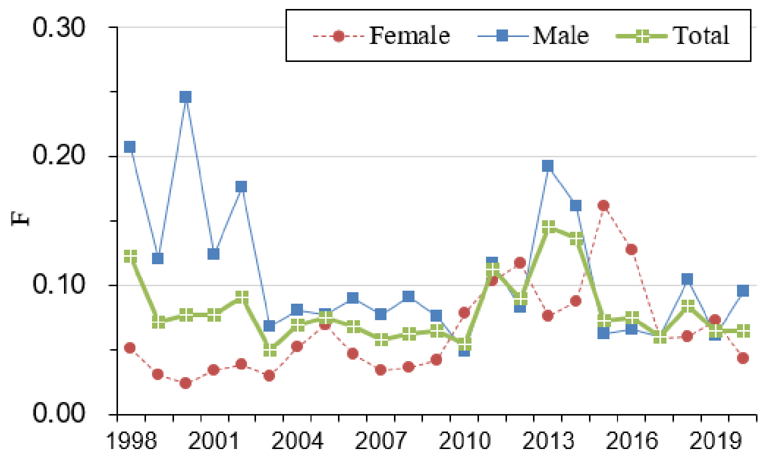


Fig. 4-5. Fishing coefficient (F)

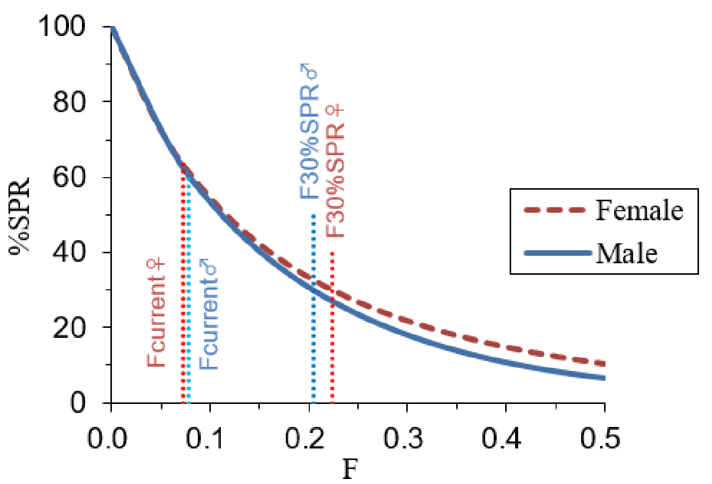


Fig. 4-6. Relationship between F and %SPR

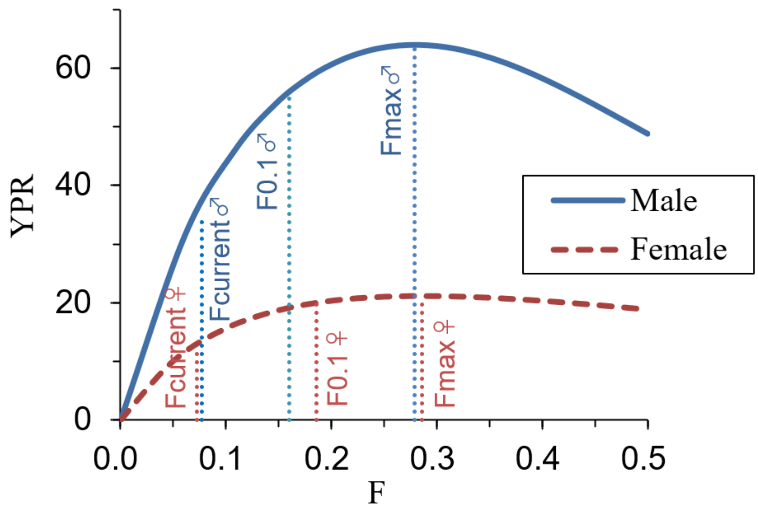


Fig. 4-7. Relationship between F and YPR

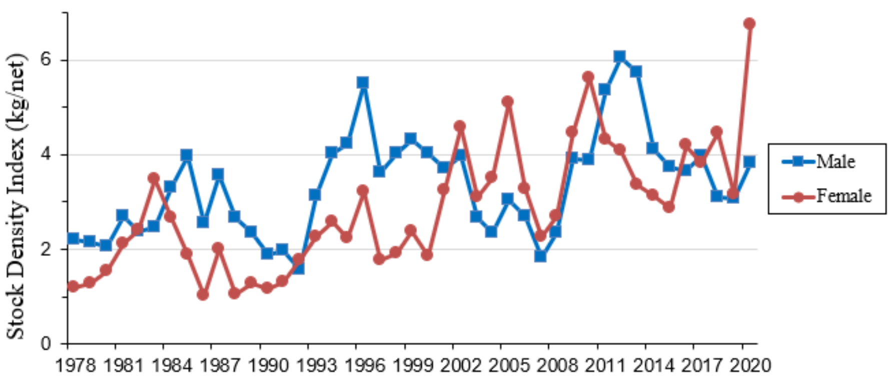


Fig. 4-8. Stock density index by sex and by offshore and small trawlers (Danish seine)

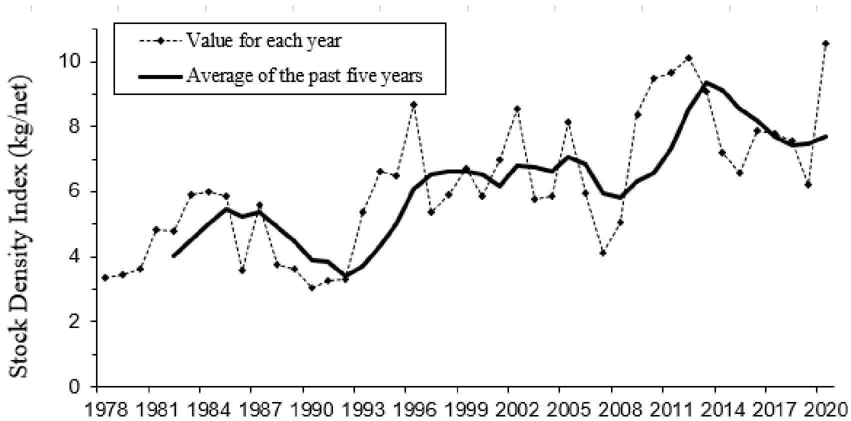


Fig. 4-9. Stock density index (dotted line indicates the total of males and females each year, bold solid line indicates the average of the past 5 years)

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

Year	Catch in weight by fishery type (tons)							
	Offshore one-boat trawling	Small vertical bottom-trawler type 1	Small vertical bottom-trawlers and others	Other gill nets	Pot	Other fisheries	No fishery classification	Total
1950								
1951							278	278
1952							298	298
1953	231	160	2	7		53		452
1954	192	158	4	5		36		394
1955	163	134	2	3		35		336
1956	138	191	1	11		40		380
1957	182	255	3	2		42	41	524
1958	195	429	0	15		33	47	719
1959	175	539	0	10		34	61	819
1960	195	501	10	9		17	79	811
1961	144	648	10	29		24	104	958
1962	126	727	16	20	13	19	90	1010
1963	117	751	12	27	10	34	86	1,036
1964	65	532	9	11	16	186	90	909
1965	35	533	13	9	141	10	91	832
1966	40	472	11	2	148	11	133	817
1967	43	508	16	10	142	2	104	824
1968	48	446	12	28	37	0	84	654
1969	29	366	18	22	39	0	69	543
1970	24	303	9	41	221	19		618
1971	24	327	23	51	124	18		567
1972	13	333	14	59	68	20		508
1973	20	413	2	61	63	26		585
1974	6	372	15	41	50	17		501
1975	10	297	22	46	82	21		478
1976	11	238	27	54	147	61		538
1977	20	346	28	57	167	86		704
1978	26	394	26	94	178	43		761
1979	28	308	19	115	238	11		719
1980	26	247	15	116	209	58		671
1981	17	248	17	125	109	124		640
1982	22	294	26	118	133	91		684
1983	21	451	25	115	77	77		766
1984	26	346	16	118	35	101		642
1985	27	389	19	102	59	49		645
1986	16	300	23	110	67	38		554
1987	23	239	31	99	60	37		489
1988	53	206	26	92	70	28		475
1989	89	89	21	69	77	42		387
1990	66	78	21	62	39	31		297
1991	39	103	29	79	16	23		289
1992	34	108	22	87	41	35		327
1993	45	100	30	77	61	73		386
1994	47	114	25	83	48	37		354
1995	47	98	17	76	36	32		306
1996	58	95	15	71	48	35		322
1997	55	134	1	81	33	23		327
1998	38	104	1	73	19	32		267
1999	33	111	1	84	18	34		281
2000	34	89	1	93	11	38		266
2001	20	81	1	93	13	37		245
2002	24	83		93	10	30		240
2003	26	103		75	5	29		238
2004	24	102	1	71	9	32		239
2005	14	93	1	59	7	24		198
2006	23	124	2	68	10	23		250
2007	24	109		73		25		231
2008	21	114		107		33		275
2009	17	123	3	104		20		267
2010	19	175	3	98		25		320
2011	18	177	5	100		22		322
2012	26	219	5	115		28		393
2013	23	172	7	115		20		337
2014	28	135	6	134		17		320
2015	22	137	13	122		13		307
2016	18	115	7	105		8		253
2017	19	100	5	105		7		236
2018	18	97	5	94		11		225
2019	16	84	4	85		7		196
2020	7	87	4	77		7		182

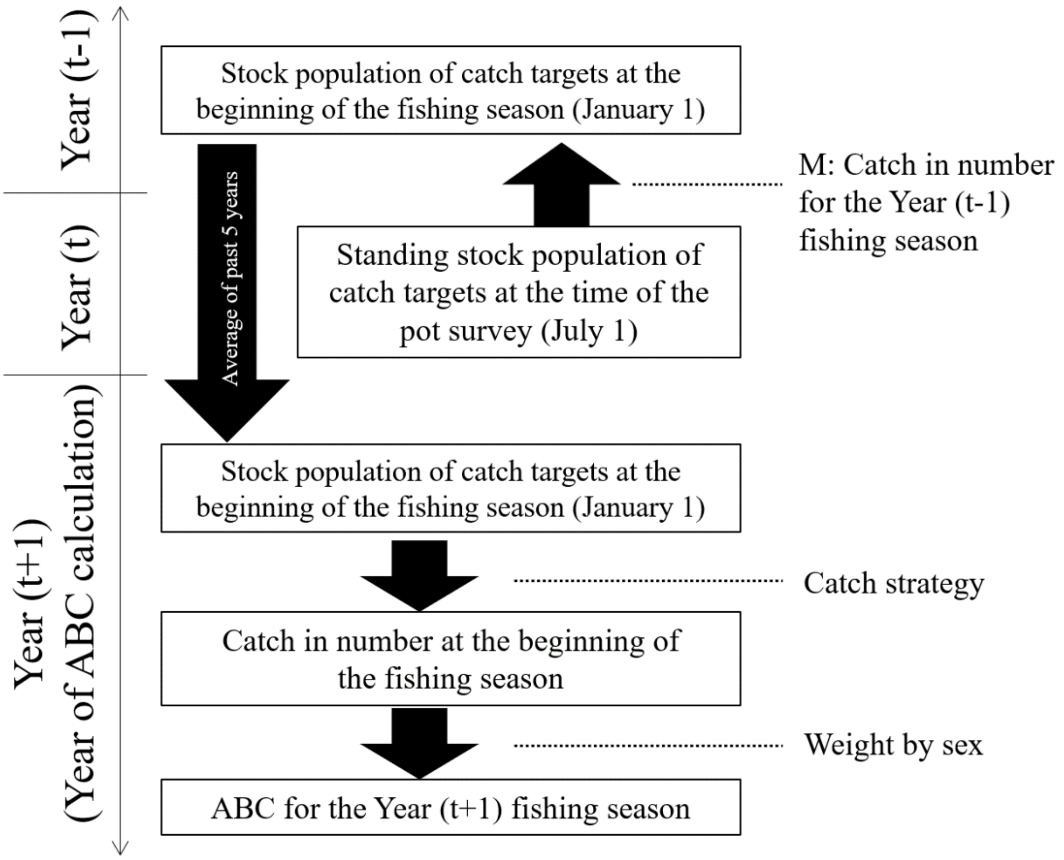
According to the Annual Report on Fishery and Aquaculture Production Statistics, Ministry of Agriculture, Forestry and Fisheries (including data from some prefectures). Provisional values for 2020.

Table 4-1. Stock density index of offshore trawler and small trawler fisheries as a whole in Stock Area B

Fishing year	Male	Female	Male and female	Average of past 5 years
1978	2.2	1.2	3.4	
1979	2.2	1.3	3.5	
1980	2.1	1.6	3.6	
1981	2.7	2.1	4.8	
1982	2.4	2.4	4.8	4.0
1983	2.5	3.5	5.9	4.5
1984	3.3	2.7	6.0	5.0
1985	4.0	1.9	5.8	5.5
1986	2.5	1.0	3.6	5.2
1987	3.6	2.0	5.6	5.4
1988	2.7	1.1	3.7	4.9
1989	2.3	1.3	3.6	4.5
1990	1.9	1.2	3.1	3.9
1991	2.0	1.3	3.3	3.9
1992	1.6	1.8	3.3	3.4
1993	3.1	2.3	5.4	3.7
1994	4.0	2.6	6.6	4.3
1995	4.2	2.2	6.5	5.0
1996	5.5	3.2	8.7	6.1
1997	3.6	1.8	5.4	6.5
1998	4.0	1.9	5.9	6.6
1999	4.3	2.4	6.7	6.6
2000	4.0	1.9	5.9	6.5
2001	3.7	3.3	7.0	6.2
2002	4.0	4.6	8.5	6.8
2003	2.7	3.1	5.8	6.8
2004	2.4	3.5	5.9	6.6
2005	3.0	5.1	8.1	7.1
2006	2.7	3.3	6.0	6.9
2007	1.8	2.3	4.1	6.0
2008	2.4	2.7	5.1	5.8
2009	3.9	4.4	8.4	6.3
2010	3.9	5.6	9.5	6.6
2011	5.3	4.3	9.7	7.3
2012	6.0	4.1	10.1	8.5
2013	5.7	3.4	9.1	9.3
2014	4.1	3.1	7.2	9.1
2015	3.7	2.9	6.6	8.5
2016	3.6	4.2	7.9	8.2
2017	4.0	3.8	7.8	7.7
2018	3.1	4.5	7.6	7.4
2019	3.1	3.1	6.2	7.5
2020	3.8	6.7	10.6	7.7

Values for 2020 are provisional until March 2021.

Appendix 1 Flow of Stock Assessment



*Catch strategy is a Harvest Control Rule established through the Stock Management Policy Commission and the Fishery Policy Council held in March 2021, and is calculated by multiplying the F30%SPR by 0.8.

Appendix 2 Direct Estimation Method for Standing Stock

In June and July 2021, pot surveys were conducted in the northern Sea of Japan by Niigata Prefecture (Koshiji Maru), Yamagata Prefecture (fishing boat) and Akita Prefecture (Chiaki Maru). Each ship in each prefecture used crab pots of the same specifications, and a set was defined as 20 pots mounted at 100-m intervals. The number of survey sites has been based on 38 sites since 2016. In 2021, the survey was conducted at 32 points, excluding the preliminary points off Niigata Prefecture. The total number of survey sites up to 2013 was 23, and there were 32 in 2014 and 2015, including 9 sites conducted independently by Niigata Prefecture. One set was used per survey site, and the immersion time of the pot was at least 8 hours. Frozen mackerels were used as bait, with 4 individuals of about 30 cm in length per pot.

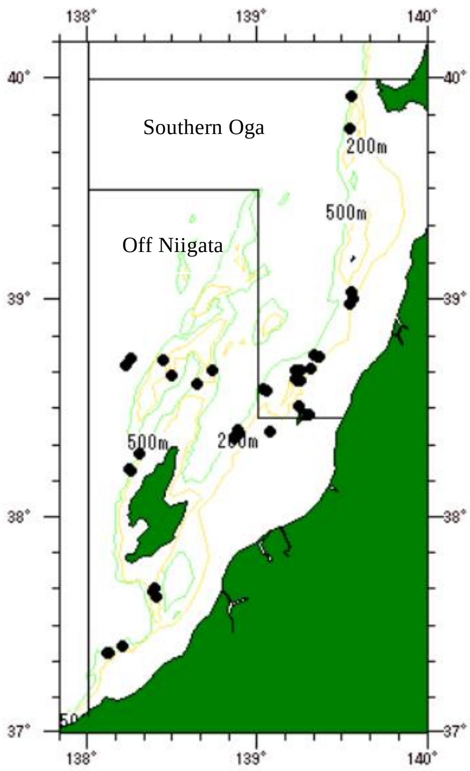
The standing stock was estimated using the area-density method in 6 layers, which were divided into two offshore trawl zones, southern Oga and off Niigata (Supplementary Figure 2-1), and 3 depth zones of 200 m to 500 m at 100-m intervals. The capture efficiency per pot, per day, and per km^2 was set at 0.005 for males (Hoenigetal. 1992, Daweetal. 1993) and 0.0016 for females (see Appendix 5). For weight conversion, the weight of females and males were assumed to be 177 g and 522 g, respectively.

The estimated total standing stock of males and females in 2021 was 2,709 tons (Supplementary Table 2-1). Since 2016, the number of survey sites has been increased and the coefficient of variation (CV) of the stock abundance estimate has been reduced. However, the mean CVs in 2021 were 0.17 and 0.38 for males and females, respectively, with females being slightly higher. In order to further improve the accuracy of stock abundance estimation, the current number of survey sites should be secured in the future, and research and study on the phenomenon of high density and concentrated distribution of females is necessary.

References

Dawe, E., G., J. M. Hoenig and X. Xu (1993) Change-in-ratio and index-removal methods for population assessment and their application to snow crab (*Chionoecetes opilio*). Can. J. Fish. Aquat. Sci., **50**, 1467-1476.

Hoenig, J. M., E. G. Dawe, D. M. Taylor, M. Eagles and J. Tremblay (1992) Leslie analyses of commercial trap data: comparative study of catch ability coefficient for male snow crab (*Chionoecetes opilio*). Int. Coun. Explor. Sea C. M. 1992/K, **34**, 1-8.



Supplementary Figure 2-1. Pot survey sites (basic fixed points since 2016)
In 2021, 32 sites will be implemented, excluding the preliminary sites in the northern Sado and Joetsu areas.

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.

Appendix 3 Corrections to Female Capture Efficiency in Pot Surveys

In Sea of Japan Area B, the standing stock was estimated by pot surveys, and the same capture efficiency was conventionally used for males and females (Appendix 4). On the other hand, it has been pointed out in recent years that the number of females caught with a carapace width of 70 mm to 80 mm, which are estimated to be in the 11th instar, the target for stock assessment, is smaller than that of males caught with a carapace width of 90 mm or more (Supplementary Figure 3-1). Therefore, the capture efficiency of females in the 11th instar was re-estimated using the standing stock population by instar of males.

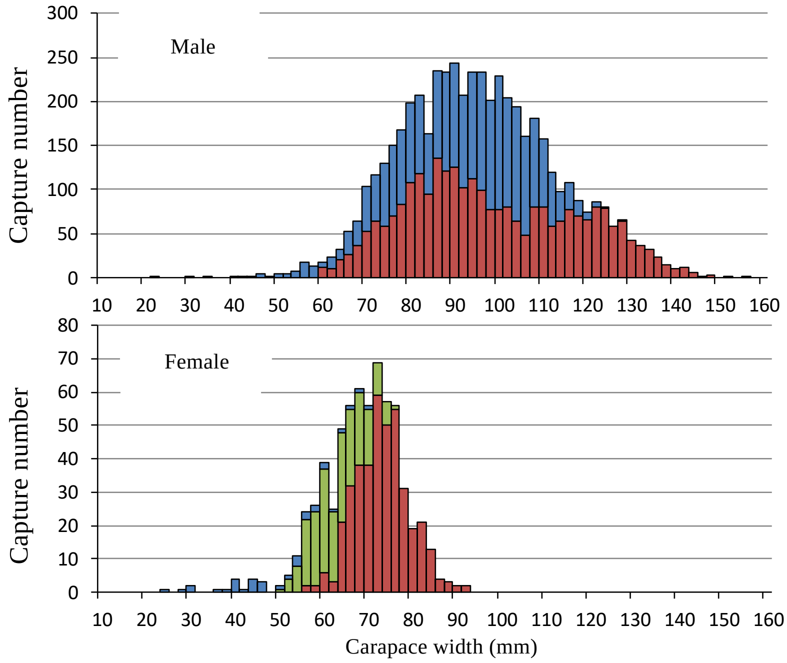
In order to determine the standing stock population of males by instar in the pot survey, instar stratification was performed by fitting a compound normal distribution to the carapace width composition for 2003-2016 for both immature and adult males (Supplementary Figure 3-2). The carapace width composition for each year was stratified into the standing stock population for the 9-13th instars, but since there was no trend to track cohorts, the years were pooled to obtain the average standing stock population by instar for 2003-2016.

In order to compare with the standing stock population by instar from the pot survey, we used the standing stock population by instar in the Sea of Japan Area A from 2003 to 2016, where the catch in number was estimated by a trawl survey, which can collect juveniles. Of these, data for provisional waters between Japan and Korea, which have been shown to have extremely low survival rates, were excluded and the totals were aggregated. The F of males in Area A was above 0.2 around 2000, but has been around 0.14 since 2005, which is not a large deviation from the 0.10 of Area B. Therefore, it was determined that the ratio of the number of 12-13th instar males to 11th instar males stocked in both areas could be regarded as constant.

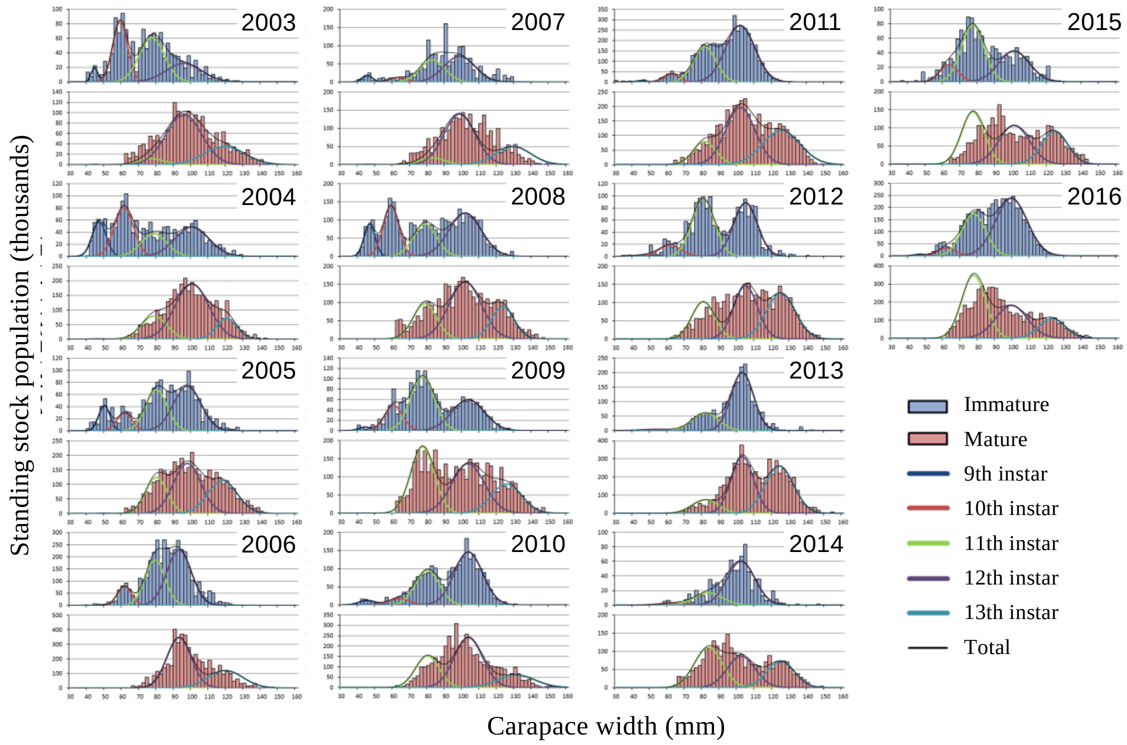
The number of 11th instar (1,707,000) is lower than the number of 12-13th instar (4,130,000) in the pot survey in Area B, while the number of 11th instar (17,204,000) is higher than the number of 12-13th instar (12,983,000) in the trawl survey in Area A (Supplementary Table 3-1).

The ratio of 11th instar to 12-13th instar on the standing stock population in Area A is 1.325 (= 17,204/12,983). Assuming that the survival rate, i.e., the carapace width composition of the stock, was the same in Area B and Area A, the actual 11th instar in Area B was calculated to be 5,472,000 (= 4,130 × 1.325). Therefore, the ratio of the capture efficiency of the 11th instar to the 12-13th instars in the pot survey in Area B was calculated to be 0.312 (= 1,707/5,472).

The capture efficiency of males in the pot survey in Area B is 0.005. Based on the above, the capture efficiency of females was set at 0.0016 (= 0.005 × 0.312, rounded to the nearest four decimal place). As a result of this change, the standing stock population of females in the 11th instar determined from the pot survey results averaged 2.3 times the standing stock of males in the 12-13th instars. The results of the trawl survey in Area A showed that the value was almost twice as high, which was judged to be reasonable.



Supplementary Figure 3-1.
Carapace width composition in 2016 from pot survey in Sea of Japan Area B.
For males, blue indicates immature and red indicates mature, and for females, red indicates 11th instar, green indicates 10th instar, and blue indicates 9th instar or younger.



Supplementary Figure 3-2. Carapace width composition and estimated instar composition during 2003-2016 by pot surveys in Sea of Japan Area B

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

Appendix 4 A Method for Estimating Stock Abundance Based on Crab Pot Surveys

For the purpose of the calculations, it was assumed that the catch (January 1) and the survey (July 1) would take place within a short period of time. January 1 was assumed to be the middle of the fishing season, and the survey was assumed to represent the stock status after the fishing season. Molting occurs mainly before the catch or after the survey, i.e. in autumn, so it does not occur between the catch date and the survey date, and individual body sizes do not change during this period.

It is difficult to determine the standing stock population of 10th instar females and males with carapace widths of less than 90 mm prior to recruitment because it is difficult to collect smaller individuals in pots compared to trawls. Therefore, the stock abundance of catch targets (N'_{t-1}) at the beginning of the fishing season (January 1) of year t-1 was obtained by using the standing stock population after the fishing season of year t-1 (Nt) and the catch in number of the fishing season of year t-1 (Ct-1) estimated in the 2021 (t) survey, and using the regression method (Supplementary Table 4-1).

$$N'_{t-1} = N_t \exp\left(\frac{M}{2}\right) + C_{t-1} \qquad (1)$$

In the above equation, M is the natural mortality coefficient (0.2). The catch in number was determined by dividing the catch in weight by sex by the average weight (522 g for males and 177 g for females). Since akako crabs are caught in Area B, the 11th instar individuals sampled in the survey were already the catch target at the beginning of the fishing season (January 1), and F values for both sexes were calculated using the equation below:

$$F_{t-1} = -\ln(1 - E_{t-1}) = -\ln(1 - \frac{C_{t-1}}{N'_{t-1}}) \qquad (2)$$

In the above equation, E is the catch rate.
The catch in number in year t+1 with a given fishing pressure is then calculated using the following equation:

$$C_{t+1} = N'_{t+1}\left[1 - \exp(-F)\right] \qquad (3)$$

In the above equation, N'_{t+1} is the stock population at the beginning of the fishing season in year t+1, which is the average of the stock population for the last 5 years (2016-2020), assuming that the current stock status will continue. The current fishing pressure (Fcurrent) uses the average value of F for the last 5 years (2016-2020), and the catch in number (Ct+1) obtained by substituting it for F in the above equation is multiplied by the average weight (w) to estimate the catch in year t+1 at the current fishing pressure.

Supplementary Table 4-1.

Standing stock population, stock population, stock abundance, catch in number (fishing year), catch in weight (fishing year), exploitation rate, and fishing coefficient (F) in Area B

Standing stock population at the time of survey (thousands)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Male	1,653	2,703	1,223	2,673	1,715	3,950	3,212	3,358	2,856	3,815	3,145	4,906
Female	6,223	10,335	12,945	8,785	8,715	10,267	6,260	6,025	8,465	9,723	10,735	7,657

Catch in number (thousands)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Male	421	384	376	388	365	304	295	297	296	337	330	430	364
Female	361	358	346	338	373	335	366	479	438	369	435	356	439

Catch in weight (tons)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Male	220	200	196	202	191	159	154	155	154	176	172	224	190
Female	64	63	61	60	66	59	65	85	77	65	77	63	78
Total	283	264	258	262	257	218	219	240	232	241	249	288	268

Stock population at the beginning of the fishing season (thousands)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Male	2,248	3,371	1,728	3,342	2,261	4,669	3,845	4,009	3,452	4,554	3,806	5,852	7,703
Female	7,238	11,780	14,652	10,047	10,004	11,681	7,285	7,137	9,793	11,114	12,298	8,818	5,860

Stock abundance at the beginning of the fishing season (tons)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Male	1,173	1,760	902	1,744	1,180	2,437	2,007	2,093	1,802	2,377	1,987	3,055	4,021
Female	1,281	2,085	2,593	1,778	1,771	2,068	1,289	1,263	1,733	1,967	2,177	1,561	1,037
Total	2,455	3,845	3,495	3,523	2,951	4,505	3,297	3,356	3,536	4,344	4,163	4,616	5,058
SSB	1,217	2,022	2,532	1,718	1,705	2,008	1,225	1,178	1,656	1,902	2,100	1,498	960

Exploitation rate (%)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Male	18.7	11.4	21.8	11.6	16.2	6.5	7.7	7.4	8.6	7.4	8.7	7.3	4.7
Female	5.0	3.0	2.4	3.4	3.7	2.9	5.0	6.7	4.5	3.3	3.5	4.0	7.5
All	11.5	6.9	7.4	7.4	8.7	4.8	6.6	7.2	6.6	5.6	6.0	6.2	5.3

Fishing coefficient (F)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Male	0.21	0.12	0.25	0.12	0.18	0.07	0.08	0.08	0.09	0.08	0.09	0.08	0.05
Female	0.05	0.03	0.02	0.03	0.04	0.03	0.05	0.07	0.05	0.03	0.04	0.04	0.08
All	0.12	0.07	0.08	0.08	0.09	0.05	0.07	0.07	0.07	0.06	0.06	0.06	0.05

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

The catch in number and catch in weight for 2020 are provisional values.

The catch in number and catch in weight for 2021 are forecast values (average values for 2016-2020).

The stock populations at the beginning of the fishing season in 2021 and 2022 are forecast values (average of 2016-2020).

F16-20 is the average value for 2016-2020.

Italic values are forecasts.

Supplementary Table 4-1.

Standing stock population, stock population, stock abundance, catch in number (fishing year), catch in weight (fishing year), exploitation rate, and fishing coefficient (F) in Area B (Continued)

Standing stock population at the time of survey (thousands)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Male	6,641	3,581	5,608	2,084	2,237	5,541	4,543	4,544	2,265	3,035	2,083
Female	4,906	5,407	4,229	4,351	3,636	1,804	2,374	5,949	5,832	4,709	9,162

Catch in number (thousands)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Male	491	534	488	434	396	341	312	276	212	231	*274*
Female	648	579	380	364	350	357	399	394	390	440	*396*

Catch in weight (tons)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Male	256	279	255	226	207	178	163	144	110	121	*143*
Female	115	103	67	64	62	63	71	70	69	78	*70*
Total	371	381	322	291	269	241	233	214	180	199	*213*

Stock population at the beginning of the fishing season (thousands)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Male	4,449	6,733	2,791	2,906	6,520	5,361	5,334	2,779	3,566	2,534	*3,915*	*3,915*
Female	6,624	5,253	5,188	4,382	2,344	2,980	6,974	6,839	5,595	10,566	*6,591*	*6,591*

Stock abundance at the beginning of the fishing season (tons)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Male	2,322	3,514	1,457	1,517	3,403	2,798	2,784	1,451	1,861	1,323	*2,043*	*2,043*
Female	1,172	930	918	776	415	528	1,234	1,211	990	1,870	*1,167*	*1,167*
Total	3,495	4,444	2,375	2,293	3,818	3,326	4,018	2,661	2,852	3,193	*3,210*	*3,210*
SSB	1,058	827	851	711	353	464	1,164	1,141	921	1,792	*1,096*	

Exploitation rate (%)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Male	11.0	7.9	17.5	14.9	6.1	6.4	5.8	9.9	5.9	9.1	*7.0*
Female	9.8	11.0	7.3	8.3	14.9	12.0	5.7	5.8	7.0	4.2	*6.0*
All	10.6	8.6	13.6	12.7	7.0	7.2	5.8	8.0	6.3	6.2	*6.6*

Fishing coefficient (F)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	F16-20
Male	0.12	0.08	0.19	0.16	0.06	0.07	0.06	0.10	0.06	0.10	*0.07*	0.08
Female	0.10	0.12	0.08	0.09	0.16	0.13	0.06	0.06	0.07	0.04	*0.06*	0.07
All	0.11	0.09	0.15	0.14	0.07	0.08	0.06	0.08	0.07	0.06	0.07	

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

The catch in number and catch in weight for 2020 are provisional values.

The catch in number and catch in weight for 2021 are forecast values (average values for 2016-2020).

The stock populations at the beginning of the fishing season in 2021 and 2022 are forecast values (average of 2016-2020).

F16-20 is the average value for 2016-2020.

Italic values are forecasts.

Appendix 5 An Attempt to Estimate Stock Abundance and Recruitment Volume by Beam-Trawl Survey

In Sea of Japan Area B, the standing stock was estimated by pot surveys, but due to the nature of the fishing gear, the number of small-sized individuals collected was low, and the recruitment (for Area A, 10th instar in the population dynamics model, and 8th instar in the model for YPR/SPR analysis) was unknown. Therefore, a survey of demersal fish resources in the northern part of the Sea of Japan using a large beam-trawl (hereinafter referred to as "beam-trawl survey") was conducted since 2016 by Mizuho Maru (156 tons) (Tenyo Maru (995 tons) since 2018), with the aim of collecting small individuals as well. The survey area was the continental shelf slope area off the west of Oga (Akita), off the mouth of the Omono-gawa, around Tobi-shima, off Kamo (Yamagata), around Awa-shima, off Himesaki (Sado-shi), off Joetsu-shi (Niigata), Mogami Tai, and Hyoutan-Guri, and at a depth of 170 m to 500 m, where snow crabs are collected, and 30-40 sites are hauled each year (Supplementary Figure 5-1). The hauled nets were set at 2 knots for 20 minutes during the day. The number of individuals collected in each haul was converted to distribution density by multiplying the haul distance by the net mouth width of the beam trawl (6.8 m). The capture efficiency was assumed to be 0.3 (Watanabe and Kitagawa 2004). Then, for each sub-sea area in the agriculture and forestry statistics (south of Oga and off Niigata), depth zones of 200 m to 300 m, 300 m to 400 m, and 400 m to 500 m were established, stratified into six in total, and the standing stock population was estimated by the area-density method. For the sake of convenience, the size of each age group was tabulated by considering 10 mm to 20 mm carapace width as the 6th instar, 20 mm to 30 mm as the 7th instar, 30 mm to 40 mm as the 8th instar, and 40 mm to 54 mm as the 9th instar for both sexes. For larger sizes, males of 54 mm to 70 mm were considered to be the 10th instar, 70 mm to 90 mm to be the 11th instar, 90 mm to 120 mm to be the 12th instar, and 120 mm or larger to be the 13th instar. In the case of females, immature individuals with internal egg masses at the time of the survey were considered to be the 10th instar (called “akako crabs” during that year's fishing season), and mature individuals were considered to be the 11th instar (called “kuroko crabs” during that year's fishing season).

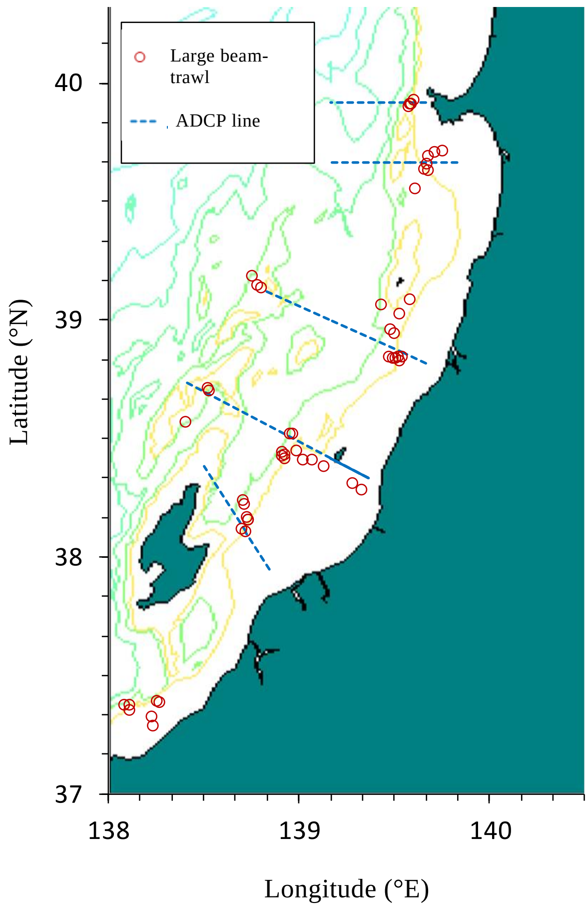
First, the carapace width composition by sex based on the standing stock population in Sea of Japan Area B during 2016-2021 is shown in Supplementary Figure 5-2. In each year, individuals with carapace widths of 10 mm to 90 mm were mainly collected from both sexes. On the other hand, the target size of the stock was collected in small numbers, and the carapace width composition differed greatly from the pot survey. For sizes of less than 90 mm before recruitment, it can be observed that for both sexes, the 8th, 9th, and 10th instar in 2018, 2019 and 2020, respectively, are more common. Next, the standing stock population by instar and maturity stage in Sea of Japan Area B is shown in Supplementary Figure 5-3. The 9th instar, which was more common in 2019, was more common in 2020 as males in the 10th instar and female akako crabs, and in 2021 as males in the 11th instar and female kuroko crabs. If there is a distinct abundance of 8th and 9th instar in this survey, it suggests that the individuals of catch target size will increase in a few years. In addition, the 7-9th instars have increased since 2017, and the individuals of catch target size are expected to increase in the future. The standing stock population since 2016 for the 8th instar, which is assumed to be the recruitment volume in the age composition model of snow crab used for YPR and SPR analysis (Ueda et al. 2009), ranged from 2.6 to 14.5 million for males and from 2.5 to 14.6 million for females. The average for the last 5 years (2017-2020) was 9.0 million males and 8.1 million females.

Thus, while the data from the beam-trawl suggests that recruitment can be roughly ascertained, the data on mature females is also unstable, as in the pot survey, because female maturity states are highly variable. It is necessary to examine the stock calculation that can utilize the advantages of each survey data by comparing it with the pot survey results as well as accumulating the beam-trawl survey data.

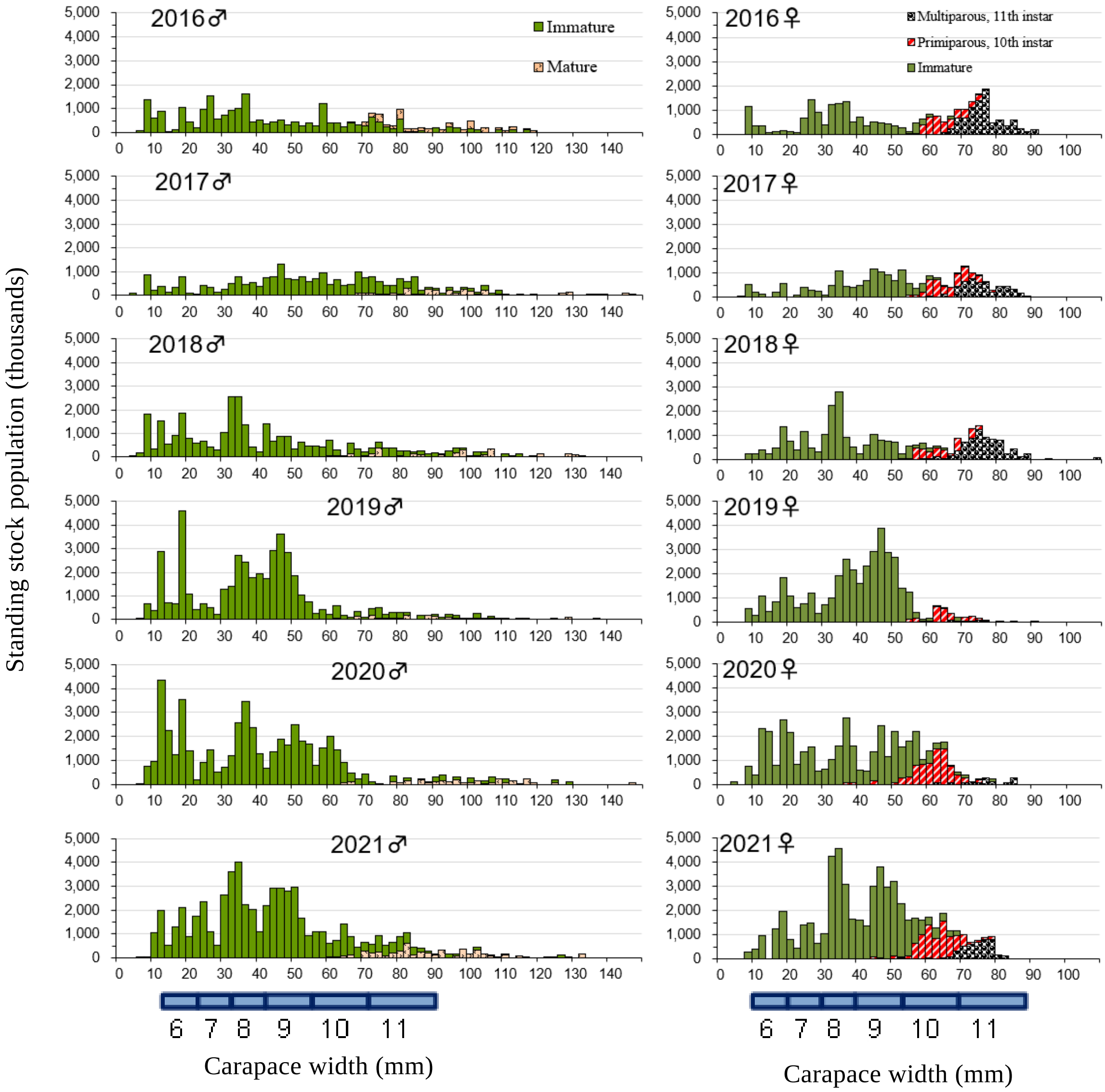
References

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.

T. Watanabe and D. Kitagawa (2004) Estimating net efficiency of a survey trawl for the snow crabs (*Chionoecetes opilio* and *C. japonicus*) using a deep-sea video monitoring system on a towed sledge. Fish. Sci., **70**, 297-303.

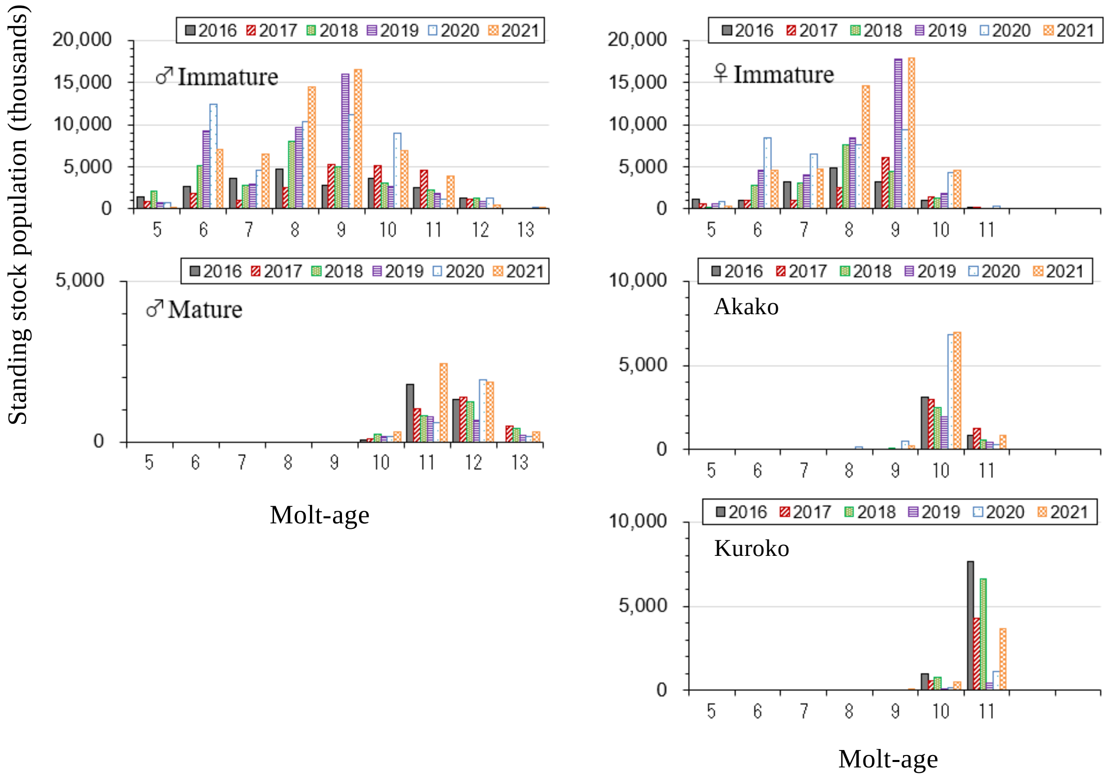


Supplementary Figure 5-1. Survey area map of the beam-trawl survey



Supplementary Figure 5-2. Carapace width composition by sex based on beam-trawl surveys (2016-2021)

The vertical axis is the standing stock population, and the supplementary line is every million crabs.



Supplementary Figure 5-3. Standing stock population by instar and maturity stage based on beam-trawl surveys (2016-2021)

The maturation stage of females is the designation when they were landed during the same fishing season as the year of the survey, and the supplementary line is every 5 million crabs.

Appendix 6 A Method for Calculating Abundance Indices Using Catch Performance Reports for Offshore and Small Trawlers (Danish seine)

The abundance index values based on the catch performance reports of offshore and small trawlers (Danish seine) are summarized (Fig. 7 and 8, Table 4-1).

Based on these catch performance reports, the catch in weight and number of hauls by month and area (10 minutes of latitude by 10 minutes of longitude) were aggregated. Based on these, CPUE (U) in month (i), fishing area (j) is expressed in the following equation:

$$U_{i,j} = \frac{C_{i,j}}{X_{i,j}} \qquad (1)$$

In the above equation, C is the catch in weight, X is fishing effort (number of hauls).
The abundance index (P) in the aggregation unit (year, fishing season, etc.) is expressed as the total CPUE in the following equation:

$$P = \sum_{i=1}^{I}\sum_{j=1}^{J} U_{i,j} \qquad (2)$$

The relationship between the effective fishing effort (X'), catch in weight (C), and abundance index (P) in the aggregation unit is expressed in the following equation:

$$P = \frac{CJ}{X'} \quad \text{therefore} \quad X' = \frac{CJ}{P} \qquad (3), (4)$$

In the above equation, J is the actual number of fishing areas with catch, and the stock density index (D) is calculated by dividing the stock abundance index (P) by the number of fishing areas with catch (J).

$$D = \frac{P}{J} = \frac{C}{X'} \qquad (5)$$

The effort in Area B of this stock was calculated by aggregating the total number of all haul nets available during the fishing season (October to May of the following year), excluding the closed season. In Area B, operations mainly targeting this species were not conducted as much as in Area A for the same stock, and although it was possible to examine only the number of hauls with fishing records, it was judged that sufficient accuracy for comparison over time could not be obtained, so the total number of hauls was used. In addition, because the area where operations can take place is limited due to the complexity of the seafloor topography, it is thought that changes such as the expansion or contraction of the distribution area with changes in the amount of resources are small, so the stock density index, which does not take into account the number of fishing areas, is used as a long-term abundance index value.

Appendix 7 Estimation of Catch in Weight Based on Abundance Index Values (when the 2-system rule is applied)

At the Research Agency Forum on Reference Points of Snow Crab (fiscal year 2020) held in April 2020 and the Stock assessment and evaluation for Sea of Japan Area B stock of snow crab (fiscal year 2020), the stock assessment with the 2-system rule based on catch information was presented because the stock-recruitment relationship is unknown in this area. However, at the Stock Management Policy Commission held in August and October 2020 and in March of the following year, it was decided that it was necessary to take into account the characteristics of the fishery and resources in Area B, which has a steep seabed topography and many areas that are not used as fishing grounds even in the depth zone where this species is distributed. It was decided that the catch in weight would be based on the directly estimated stock abundance and F values from the pot survey. In the case of an assessment based on the 2-system rule based on catch information, since long-term data is available, a comparison of stock levels between the 1980s and 1990s and the present can be made, and catch estimates based on current catch conditions can be made. The following is a summary of the results when applied to the 2-system Harvest Control Rules in the "Fiscal 2021 Harvest Control Rules and Basic Guidelines for ABC Calculation."

First, the coefficient (α) for increasing or decreasing the current catch in weight was obtained using a population level of 80% for the target level and a population level of 56% for the limit level. The target level of abundance index value was 7.50 kg/net, the limit level of abundance index value was 6.43 kg/net, and the abundance index value for 2020 was 7.70 kg/net. Based on this, the population level in 2020 is 83.5% above the target reference point (target level) and the limit level, and the coefficient (α) for increasing or decreasing the current catch in weight, calculated from the draft Harvest Control Rules, is 1.018 (Supplementary Figure 7-1 and 7-2). The AAV, an indicator of the magnitude of annual fluctuations in the abundance index value, was 0.072, and the abundance index value increased or decreased by about 7% every year on average.

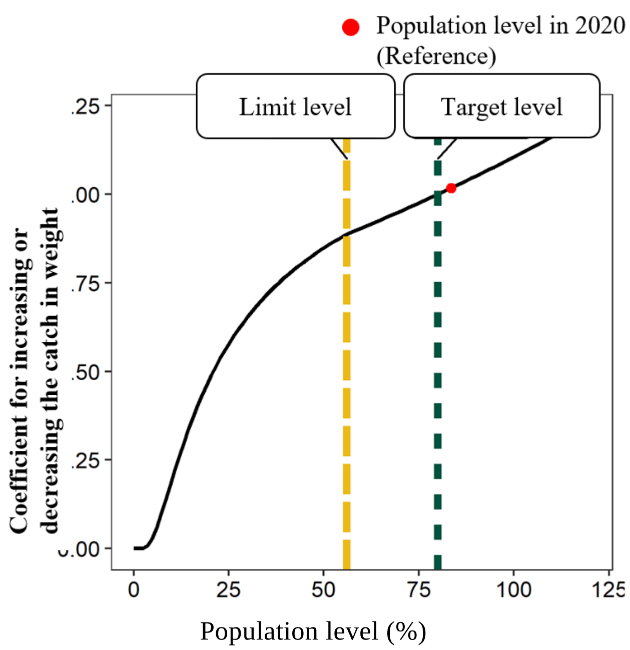
	Abundance index value (kg/net)	Stock abundance Level	Coefficient (α) for increasing or decreasing the catch in weight	Description
General target levels in two-system Harvest Control Rules*	7.50	80%	1.00	A value that corresponds to the 80% level when a time series of abundance index values is fitted to a cumulative normal distribution
General limit levels in two-system Harvest Control Rules*	6.43	56%	0.89	A value that corresponds to the 56% level when a time series of abundance index values is fitted to a cumulative normal distribution
Current value (2020)	7.70	83.5%	1.018	Level obtained by fitting a cumulative normal distribution to the abundance index value.

*This is the value presented in the "Research Agency Forum on Reference Points of Snow Crab in

Fiscal 2020” and the Stock assessment and evaluation for Sea of Japan Area B stock of snow crab (fiscal year 2020).

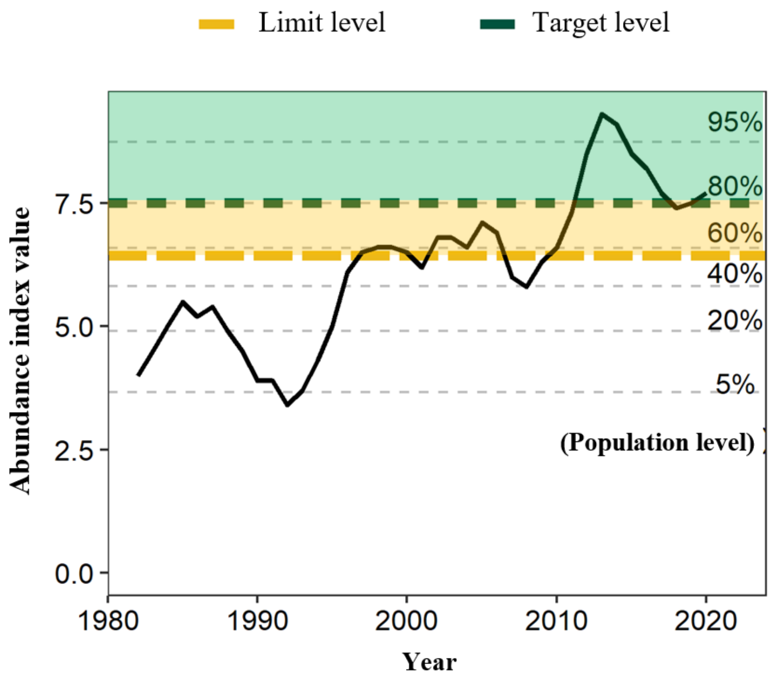
Next, we estimated the catch in weight for 2022 based on the two-system rule. The coefficient (α) for an increase or decrease of the current catch in weight is 1.018, and the average catch in weight (C) for the last 5 years (2016-2020) is 213 tons, according to the “Stock assessment and evaluation for Sea of Japan Area B stock of snow crab (fiscal year 2021).” Based on the 2-system Harvest Control Rules in the “Fiscal 2021 Harvest Control Rules and Basic Guidelines for ABC Calculation,” the 2022 catch of snow crab in the Sea of Japan Stock Area B was estimated to be 217 tons, calculated as α × C (Supplementary Figure 7-3).

	Year	Catch in weight (tons)
Annual changes in catch in weight	2016	241
	2017	233
	2018	214
	2019	180
	2020	199
	Average	213
Catch in weight (estimated value)	2022	217

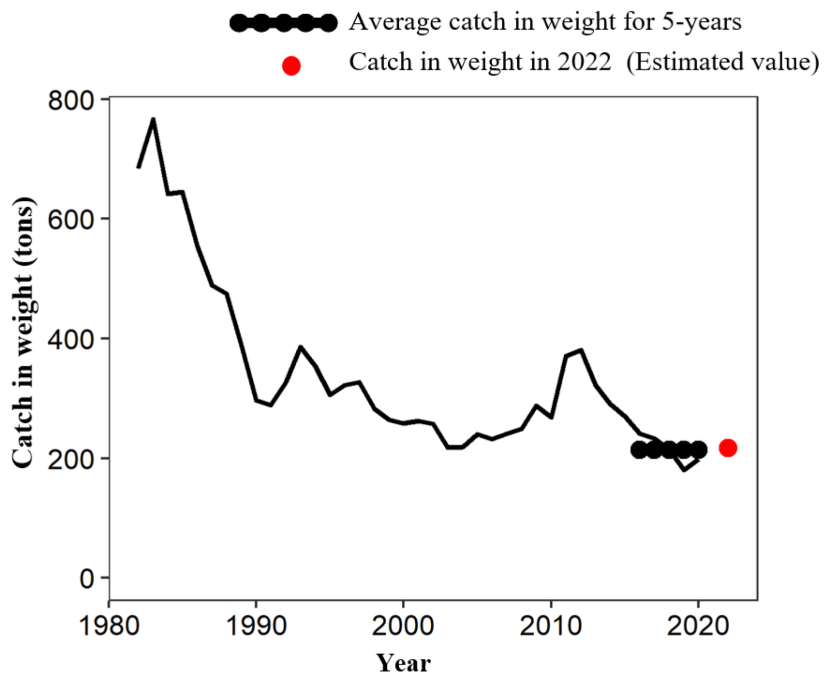


Supplementary Figure 7-1. Target and limit levels for cases based on the two-system rules (Reference)

The red circle indicates that the coefficient for increasing or decreasing the catch in weight at the current (2020) stock level (83.5%) is 1.018 times.



Supplementary Figure 7-2. Trends in abundance index values based on bottom trawl catch information and the population level when a cumulative normal distribution is applied to them (Reference)



Supplementary Figure 7-3. Trends in catch in weight and estimated catch in weight based on the two-system rule (Reference)