Report of an Independent Peer Review of Three Snow Crab and two Japanese Flying Squid Assessments Conducted by the Japan Fishery Research and Education Agency (FRA) in 2022

By

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1. Summary

Assessments of three snow crab (*Chionoecetes opilio*) and two Japanese flying squid (*Todarodes pacificus*) stocks were conducted by the Japan Fishery Research and Education Agency (FRA) in 2021. These five stock assessments were on the: 1) snow crab - Sea of Japan Area A (SC-SJA) ; 2) snow crab - Sea of Japan Area B (SC-SJB); 3) snow crab – North Pacific stock (SC-NP); 4) Japanese flying squid – winter stock (JFS-WS); and 5) Japanese flying squid – autumn stock (JFS-AS). An independent peer review of these assessments was organized by the Secretariat of Peer Review of the FRA in November 2022. This report is an independent review of the five assessments based on my personal opinions of the submitted documents and clarifications during a meeting. The primary aims for this review were to evaluate the current stock assessments and recommend improvements for future stock assessments.

There were three comments that were relevant to most of the assessments: 1) the stock assessment documents did not provide enough details for a reviewer to understand the data and methods in sufficient detail for a thorough, technical review of the assessment; 2) for several of the stocks in the Sea of Japan, the total catch estimates, especially from non-Japanese fisheries, may be poorly known and biased. It is recommended that closed loop simulations of the populations, fisheries, assessment, and management processes (i.e., MSE-like simulations) be conducted to re-examine the assessment and management processes and to explore alternatives; and 3) the uncertainties in the assessments were generally not incorporated and propagated throughout the methods and reported in the assessment results.

The assessments of the snow crabs in the Sea of Japan Area A (SC-JSA) and Area B (SC-JSB) were closely related. Discussions for these assessments centered on the stock structure, which strongly influenced the findings of this review. All snow crabs in the Sea of Japan are thought to be recruited from a common larval pool in the Sea of Japan, and are considered a single biological stock. However, there are likely minimal post-settlement movements between areas. Due to this and other reasons, SC-JSA and SC-JSB were assessed and managed as two separate management units. Having separate management units for the two areas was considered to be reasonable but it was noted that snow crabs in both areas contribute to and recruit from the same common larval pool. In addition, there are major non-Japanese fisheries that catch snow crabs in other areas of the Sea of Japan that also contribute to and recruit from the same common larval pool. The long term sustainability of the snow crab fisheries in the entire Sea of Japan is therefore likely interdependent, or at the very least not completely independent, as is currently assumed. Therefore, it is important to test this assumption, which is the basis for the current assessment and management system for the stocks. This can be done using closed-loop simulations of the populations, fisheries, assessment, and management processes (i.e., MSE-type simulations).

Notably, the status of the Pacific stock of snow crabs (SC-NP) was particularly concerning. This stock of snow crabs is distributed along the Pacific coast of Honshu Island, from Ibaraki to Aomori Prefectures. Landings in Fukushima Prefecture accounted for most of the fishing effort but fishing effort and catches have declined to very low levels after the 2011 Great East Japan Earthquake. The critical issue for this assessment was that, contrary to expectations, the survey index and estimated stock abundance have continued to decline after the Earthquake, even though the fishing effort and catches have dropped to very low levels. It would be important to monitor this stock closely and study the potential factors affecting the abundance of this declining stock.

Similar to many other squid stocks, the Japanese flying squid stocks (JFS-WS and JFS-AS) have life histories that make a traditional stock assessment approach difficult. Instead, the current Japanese flying squid assessments take a relatively simple approach to estimating recruitment by expanding the standardized CPUE of squid jigging fisheries or surveys. The spawning abundances were then estimated as the number of survivors after removals due to catch and natural mortality. Several issues with the current approach were identified. For JFS-WS, alternative approaches using statistical models with fine temporal scales (i.e., monthly data) appeared to be highly promising and would be strongly recommended. On the other hand, it would be harder to improve the JFS-AS assessment. Major portions of the JFS-AS distribution lie within the EEZs of other countries and the stock is heavily exploited by non-Japanese fisheries. However, the data from these non-Japanese fisheries are highly limited. The catch and abundance index data for the JFS-AS assessment does not appear to encompass the entire stock. Unless this situation changes in the future, this may limit alternative assessment approaches using statistical models with fine temporal scales. For the JFS-AS stock, it is important to explore closed loop simulations (i.e., MSE-type simulations) of the current and alternative assessment and management processes.

2. Background

Assessments of three snow crab (*Chionoecetes opilio*) and two Japanese flying squid (*Todarodes pacificus*) stocks were conducted by the Japan Fishery Research and Education Agency (FRA) in 2021. These five stock assessments were on the: 1) snow crab - Sea of Japan Area A (SC-SJA) ; 2) snow crab - Sea of Japan Area B (SC-SJB); 3) snow crab – North Pacific stock (SC-NP); 4) Japanese flying squid – winter stock (JFS-WS); and 5) Japanese flying squid – autumn stock (JFS-AS). All five stock assessments used a wide variety of models and data.

3. Review System

An independent peer review of these assessments was organized by the Secretariat of Peer Review of the FRA. The review panel consisted of two overseas reviewers from the National Oceanic and Atmospheric Administration (NOAA) of the USA, as well as reviewers from Japan. A hybrid meeting with both online and in-person participation was held during November 8 - 10, 2021 for the overseas reviewers, and included English-Japanese translators to ease language difficulties. A separate meeting was held for the Japanese reviewers.

Assessment documents were translated from Japanese to English, and submitted before the meeting. In order to help FRA scientists prepare, initial questions on the assessments were submitted prior to the meeting, with follow up questions during the meeting.

This report is an independent review of the assessments based on my personal opinions of the submitted documents and clarifications during the meeting. There was no communication between the reviewers after the meeting. The submitted assessment documents were not detailed enough to conduct a thorough technical 'desktop' review. Nevertheless, this review attempts to cover the most important aspects of the assessments.

This report is subdivided into separate sections for each stock and a section summarizing the overall findings. The assessments of snow crab stocks (SC-SJA, SC-SJB, and SC-NP) were reviewed first, followed by the Japanese flying squid stocks (JFS-WS and JFS-AS). If a comment was applicable to multiple stocks, the reader will be referred to earlier sections whenever possible to reduce the report length and repetitiveness. However, the recommendations for each stock were kept separate for the sake of clarity.

4. Overall Comments

Below are several issues that were found to be common for several of the assessments, as well as the corresponding recommendations to alleviate these issues, where appropriate.

1) The stock assessment documents did not provide enough details for a reviewer to understand the data and methods in sufficient detail for a thorough, technical review of the assessment. The Japanese scientists noted that the stock assessment documents were required to be in a specific format and the audience of the documents were primarily non-technical. Given that, it is recommended that documents provided for future peer reviews contain sufficient detailed technical information, and that documents may have to be developed specifically for the peer review or could contain an executive summary for non-technical readers.

2) For several of the stocks, the total catch estimates, especially from non-Japanese fisheries, may be poorly known and biased. It is recommended that for these stocks, some closed loop simulations of the stocks, assessments, and management (i.e., MSE-like simulations) be conducted to examine if these stocks may be prone to biased assessment results and poor management. These simulations may also help to identify appropriate methods to improve the assessment and management of these stocks.

3) The uncertainties in the assessments were generally not propagated throughout the methods and results of the assessments. For example, the assessment results included probabilistic

statements based on forward projections but the uncertainties in the estimates of N-at-age, recruitment, and SSB were not propagated into the forward projection calculations. It was unclear how important these uncertainties were in the management of these stocks but the uncertainties were clearly not well characterized nor propagated in these assessments. It is recommended that the uncertainties in each step of the assessment be estimated and propagated to the next step in a consistent manner so that the probabilistic statements are inclusive of all sources of uncertainty in the assessment.

5. Snow crab – Sea of Japan Stock Area A (SC-SJA)

Discussions on the stock structure for the snow crabs in the Sea of Japan Area A (SC-SJA) and Area B (SC-SJB) strongly influenced the findings of this review (see Section 5.2.1). All snow crabs in the Sea of Japan, including SC-JSA and SC-JSB, are thought to be recruited from a common larval pool in the Sea of Japan, and are considered a single biological stock. However, there are likely minimal post-settlement movements between Areas A and B, as well as between other areas in the Sea of Japan. Due to this and other reasons (Section 5.2.1), the SC-JSA and SC-JSB stocks are assessed and managed as two separate management units. Having separate management units for the two areas was considered to be reasonable but it was noted that snow crabs in both areas contribute to and recruit from the same common larval pool. In addition, there are major non-Japanese fisheries that catch snow crabs in other areas of the Sea of Japan that also contribute to and recruit from the same common larval pool. The long term sustainability of the snow crab fisheries in the entire Sea of Japan is therefore likely interdependent, or at the very least not completely independent, as is currently assumed. Therefore, it is important to test this assumption, which is the basis for the assessment and management system for the SC-JSA and SC-JSB stocks. The most important recommendation for Sections 5 and 6 is that the assessment and management system for SC-JSA and SC-JSB be re-examined using closed-loop simulations of the populations, fisheries, and management (i.e., MSE-type simulations) (see Section 5.2.1 for details). Ideally, this would include non-Japanese fisheries catching snow crabs in the Sea of Japan as well. For example, the stock assessment report stated that it is “necessary to hold constructive talks between the two countries based on the Japan– Korea Fisheries Agreement to develop appropriate stock management measures for areas like the provisional waters between Japan and Korea”, which would be a step in the right direction.

5.1 Data

Cohort analysis was used to estimate the population dynamics of the SC-SJA stock during the historical period. Cohort analysis assumes that the catch-at-age is known without error. Therefore, it was critical to examine the data preparation and determine if this assumption was severely violated. In addition, the relative abundance indices were also examined. It was noted that development of data for stock assessments was also dependent on the stock structure for the assessment.

5.1.1 Catch-at-age

Developing the catch-at-age time series for a stock depends largely on two components: 1) the total catch in numbers; and 2) robustly sampling the age composition of the catch. Overall, this review was concerned about the assumption that the SC-JSA stock could be assessed and managed independently from the SC-JSB and non-Japanese stocks. This assumption resulted in the total catch, and hence catch-at-age data, missing substantial catches from the SC-JSB and non-Japanese fisheries fishing on the same biological stock. , which were available but not included in the assessment. Given the limited post-settlement movements, this missing catch is not likely to substantially affect the historical estimates of the snow crab population dynamics within Area A but will likely affect the estimated level of sustainable fishing and future projections.

The assessment of SC-JSA included catches from Japanese fisheries in Area A. However, there were other sources of fishing mortality that were not completely accounted for. Most important were catches by South Korean fisheries, which operate within the South Korean EEZ and an area called 'provisional waters between Japan and Korea'. Estimates of the South Korean catches suggest a level of catches similar to the Japanese catches. However, South Korean fisheries only target male snow crabs while females are discarded. In addition, there have been reported catches by a Russian fishery. Currently, the South Korean catches in the 'provisional waters between Japan and Korea' have been implicitly included by assuming an unknown, constant mortality in the transition parameters (see Section 5.3.1). However, South Korean catch estimates appear to vary substantially with respect to the Japanese catches. It is recommended to continue working on obtaining or estimating the catch and catch-at-age by non-Japanese fisheries.

The age or instar compositions of SC-JSA were estimated from length composition or commercial size category (CSC) data because snow crabs currently cannot be aged using external hard parts. For fishery-relevant sizes, the SC-JSA exhibit instars stages corresponding to ages. The size compositions from surveys exhibited clear modes that correspond well to instars and ages. Mixed Gaussian models were used to estimate the age compositions from the survey size compositions. However, the catches from commercial fisheries were not well-sampled. Instead, cohort slicing or CSC keys (CSC keys were 1:1 keys akin to cohort slicing) were used to slice these size compositions into ages. Such methods can result in biased estimates of age classes. For example, the model estimated very low transition rates for males in instar 11-13. This may be the result of an overestimated catch-at-age for males in instar 11-13 due to cohort slicing. It is recommended that age-length keys (or instar-length keys in this case) be constructed from the mixed Gaussian models, and that the keys be used to estimate the proportion of ages at each length class within the estimation model. It is also recommended that the uncertainty in the mixed Gaussian models be included and propagated into the estimated catch-at-age data and estimation models.

Given the difficulties of aging snow crabs, assessments of snow crabs in other parts of the world often use length-structured models instead of age-structured models. It is recommended to explore the use of length-structured models in future assessments.

5.1.2 Relative abundance indices

A trawl survey was used to develop N-at-instar observations that were fitted in the cohort analysis. The review panel examined the survey design and found that the survey design adequately covered the spatial and depth range of the SC-JSA stock. However, some concern was expressed with the use of a constant catch efficiency for all instars and years. It was assumed that differences in catch efficiency would be captured by the estimates in the transition parameters. It is recommended that the size and/or instar selectivity of the trawl survey be estimated directly in the estimation model and/or from gear efficiency experiments. This can be easily done if a state-space or statistical catch-at age or catch-at length model is used instead of a cohort analysis.

5.1.3 Recommendations on data

Based on the above findings, there are several recommendations for improving the data used for the SC-JSA assessment:

1) It is recommended to continue working on obtaining or estimating the catch and catch-at-age by non-Japanese fisheries.

2) It is recommended that age-length keys (or instar-length keys in this case) be constructed from the mixed Gaussian models, and that the keys be used to estimate the proportion of ages at each length class within the model.

3) It is recommended that the uncertainty in the mixed Gaussian models be included and propagated into the estimated catch-at-age data and estimation models.

4) It is recommended that the size and/or instar selectivity of the trawl survey be estimated directly in the estimation model and/or from gear efficiency experiments.

5.2 Biology

5.2.1 Stock structure and distribution

There was substantial discussion on the stock structure for the snow crab stocks in the Sea of Japan Area A (SC-SJA) and Area B (SC-SJB). During the discussion, it was clarified that all snow crabs in the Sea of Japan, including the SC-JSA and SC-JSB stocks, were considered a single biological stock but SC-JSA and SC-JSB were the two management units for Japan. Both SC-JSA and

SC-JSB are recruited from a common larval pool in the Sea of Japan but there is thought to be minimal post-settlement movements between Areas A and B. The populations, habitats, and fisheries in the two areas are also quite different. Area A has a substantially larger snow crab population and includes the main spawning area. The fisheries in Area A are dominated by large vessels with higher catches and market prices. The population in Area B is smaller and the steep, rocky habitat makes trawling more difficult. The fisheries in Area B consisted largely of smaller vessels using a mix of gears.

Given the minimal post-settlement movements between Areas A and B, and differences in fishery operations, having separate management units for the two areas is reasonable. However, it is important to note that the snow crabs in both areas, as well as non-Japanese waters in the Sea of Japan, contribute to and recruit from the same common larval pool. The long term sustainability of the snow crab fisheries in the Sea of Japan are therefore likely interdependent, or at the very least not completely independent, as is currently assumed. It is recommended that research be conducted to understand the reproductive contributions from different areas in the Sea of Japan, as well as the connectivity between the areas.

The current assumption that SC-SJA and SC-SJB can be assessed and managed independently may not be appropriate. It is strongly recommended that the assessment and management system for SC-JSA and SC-JSB be re-examined using closed-loop simulations of the populations, fisheries, and management (i.e., MSE-type simulations). For example, one possible scenario may be to assume that all snow crabs in the Sea of Japan, including those in non-Japanese waters, belong to the same stock and contribute to a common larval pool. The stock then settles and recruits into area-specific meta-populations that are linked by post-settlement movements rates. The total recruitment and area-specific proportions in the Sea of Japan each year would also be important variables. These rates and variables can be estimated from experimental data, borrowed from other snow crab stocks, or simply assumed based on expert knowledge. Furthermore, the recommended closed-loop simulations may also be used to re-examine the current assumption (noted to be inappropriate in previous sections) that non-Japanese fisheries have negligible impacts on SC-SJA and SC-SJB. For example, some scenarios could include various levels of recruitment and catches by fisheries in non-Japanese areas to examine the potential impacts of these fisheries on SC-JSA and SC-JSB, and test potential assessment and management processes.

5.2.2 Natural mortality

The natural mortality (M) of SC-JSA is subsumed into the instar transition rates ($S_{i,a}$) for the cohort analysis. The $S_{i,a}$ is estimated separately for immature and mature instars but is assumed to be time-invariant. Unknown impacts from bycatch and South Korean catches are also subsumed into the $S_{i,a}$ parameters. Interestingly, the forecast model includes explicit, fixed M parameters that were estimated from lab experiments.

It was noted that future stock assessments may be based on state-space models. If that is the case, it is recommended that future stock assessments explore estimation of age-specific and/or time-varying M within the estimation model.

5.2.3 Maturity

There was no discussion on the maturity of SC-JSA.

5.2.4 Growth

Aging using external hard parts is thought to be impossible due to molting. However, there are some studies exploring the possibility of aging internal hard parts. Size data were presented that appeared to be consistent with instars or cohorts. Mixed Gaussian models were used to separate the catch-at-size into catch-at-instars and appeared to fit the size data well. It is recommended that the work on using mixed Gaussian models be continued and be incorporated into the future state-space models (Section 5.3). If aging or use of mixed Gaussian models to separate instars from size data is done consistently, growth models may not be necessary in the future except to help with interpolating data gaps in instar-length keys in this or the SC-JSB stock.

5.2.5 Recommendations on biology

Based on the above findings, there are several recommendations for improving the biological assumptions and parameters used for the SC-JSA assessment:

1) It is recommended that research be conducted to understand the reproductive contributions from different areas in the Sea of Japan, as well as the connectivity between the areas.

2) It is strongly recommended that the assessment and management system for SC-JSA and SC-JSB be re-examined using closed-loop simulations of the populations, fisheries, and management (i.e., MSE-type simulations).

3) It is recommended to use closed-loop simulations to re-examine the impacts of non-Japanese fisheries on SC-SJA and SC-SJB.

4) It is recommended that future stock assessments explore estimation of age-specific and/or time-varying M within the estimation model.

5) It is recommended that the work on using mixed Gaussian models be continued and be incorporated into the future assessments.

5.3 Estimation Model

Previous SC-JSA stock assessments have used cohort analysis as the estimation model. During discussions of the model, the Japanese stock assessment scientists clearly understood the limitations of this approach and expressed an interest in developing a state-space model approach similar to the SC-NP stock assessment model. It is recommended that a state-space model approach be explored for future SC-JSA stock assessments.

5.3.1 Cohort analysis model

A modified cohort analysis (i.e., VPA) model was used in the SC-JSA stock assessment to estimate the historical population dynamics of the stock. One key difference from standard cohort analysis was the use of transition probabilities from one instar to the next. These transition probabilities were assumed to be constant through time, and were estimated within the model. One concern was that these transition probabilities subsumed various unrelated processes, including natural mortality, part of the South Korean catches, bycatch mortality, and instar catch efficiency. Another concern was that these processes were clearly not constant through time but allowing annually changing transition probabilities led to over-fitting.

It is recommended that a state-space model approach be explored for future SC-JSA stock assessments. In addition, it is recommended to explore using a length-structured model (state-space or otherwise) instead of an age-structured model because the observations from snow crabs are naturally length-structured.

5.3.2 Model diagnostics

The assessment documents did not provide model diagnostics like retrospective patterns and model fit. However, these model diagnostics for the base case model were shown during the meeting. The model diagnostics indicated that the survey N-at-instar observations were reasonably well fit and there were no obvious patterns in the residuals. There were also negligible retrospective patterns in the biomass and transition rate estimates.

5.3.3 Uncertainty

The treatment of uncertainty in the SC-JSA assessment was inadequate. Uncertainties in the data (catch-at age and survey abundance estimates), and model parameters (biological and other processes) were not considered and propagated into the model and into other aspects of the assessment. Importantly, the estimated population structure (N-at-age) and F-at-age in the terminal years were assumed to be known without error to estimate the stock-recruitment relationship (SRR) and projections. Given that the estimated N-at-age and F-at-age have uncertainties that were unaccounted for, the estimated probability distributions from the projections will likely be erroneous. Along with the N-at-age and F-at-age, the uncertainty in the estimated recruitment and spawning biomass also appeared to be neglected. It is understood that it is more difficult to work with uncertainty in cohort analysis, especially when the data were not developed according to the assumptions made (e.g., catch-at-age is known without error). It is recommended to explore using state-space models, which can more easily include the uncertainty in the data and biological processes throughout the model and projections. It was reported that current Japanese regulations (e.g., TAC) are based on deterministic calculations and consideration of uncertainty in the assessment results are not mandatory. Nevertheless, the stock assessment scientists reported that there has been recent work on better incorporating the sources of uncertainty into the assessment results.

5.3.4 Recommendations on estimation modeling

Based on the above findings, there are several recommendations for improving the estimation models used for the SC-JSA assessment:

1) It is strongly recommended that model diagnostics be included in the assessment documents.

2) It is recommended that a state-space model approach be explored for future SC-JSA stock assessments.

3) It is recommended to explore using a length-structured model (state-space or otherwise) instead of an age-structured model.

4) It is critical that the uncertainty be treated appropriately in the stock assessment. It is therefore strongly recommended that future assessments do not assume that estimated quantities (e.g., N-at-age, F-at-age, recruitment, spawning biomass) are known without error and, where appropriate, uncertainty in the data collection and biological processes be included and propagated through the estimation model and projections.

5.4 Projections

5.4.1 Stock-recruitment relationship (SRR)

The recruitment and SSB estimates from the cohort analysis were used to develop the appropriate SRR to use for calculating biological reference points (BRPs) and for the future projections. It was reported that the assessment scientists follow guidelines from FRA to estimate the SRR in a stock assessment. These guidelines appear to be used across all FRA stock assessments and are beyond the ToRs for this review.

The Ricker SRR was chosen for the SC-JSA SRR because of evidence for density-dependent cannibalism and lower AICc compared to the Beverton-Holt or Hockey-stick SRRs. This review thought that available evidence supports the use of the Ricker SRR. However, there was some concern that the SRR estimates excluded the reproductive production from snow crabs in other areas of the Sea of Japan to the common larval pool (Section 5.2.1). If other areas in the Sea of Japan make important contributions to the reproductive potential, the use of only the SC-JSA estimates of SSB and recruitment would likely result in a biased SRR. On the other hand, if the other areas of the Sea of Japan are not important sources of reproductive production, it can then be argued that these other areas are sink populations and can be managed as such, resulting in very high fishing mortality in those areas. It is recommended that research be conducted to understand the reproductive contributions from different areas and the connectivity between the areas (Section 5.2.1). It is also recommended to explore how best to represent the SRR of the stocks based on the reproductive contributions and the connectivity of the different areas.

5.4.2 Short-term projections

The terminal year of the estimation model is 2020 but the allowable catch for 2022 - 2023 were based on short-term projections. These short-term projections used the 2021 trawl survey results and estimated transition probabilities to project the recruitment and SSB for 2022 and 2023. In terms of the methodology, the projection models are relatively straightforward and appropriate, given the biology of the stock and the information available. However, it is recommended to better incorporate the uncertainty in the various estimates (e.g., N-at-age, transition rates) from the stock assessment into the results of these projections.

5.4.3 Long-term projections

One of the objectives for the SC-SJA stock assessment is to examine the probability of exceeding the target and limit reference points, over the next 10 years (up to 2030). The models used for the long-term projections were similar to the short-term projections, and were relatively straightforward and appropriate. However, the uncertainty for the long-term projections are currently under-estimated because the uncertainties from the assessment are not fully incorporated into the projections. For example, N-at-age in the terminal year of the estimation model is assumed to be known without error, which is considered inappropriate. This would be especially important for calculating the probabilities of exceeding the limit and ban reference points, which are based on the tail of the probabilities. In addition, these projections did not consider the likely interdependence of the long term sustainability of the SC-JSA stock on the snow crab fisheries in other areas of the Sea of Japan.

5.4.4 Recommendations on projections

Based on the above findings, there are several recommendations for improving the SRRs and projections used for the SC-JSA assessment:

1) It is recommended to conduct research on the relative reproductive contributions from different areas in the Sea of Japan, including non-Japanese areas, and the connectivity between the areas.

2) It is recommended to conduct research on how best to represent the SRR of the stocks based on the reproductive contributions and connectivity of the different areas.

3) It is recommended that the recruitment and SSB estimates used to develop the SRRs have uncertainty associated with them.

4) It is recommended to incorporate uncertainties from the stock assessment (e.g., N-at-age, transition probabilities) into the short term and long-term projections.

6. Snow crab – Sea of Japan Stock Area B (SC-SJB)

The SC-JSB stock assessment has substantially more data and knowledge gaps than the SC-JSA assessment, and may be considered a data moderate assessment. Substantial amounts of work is needed to improve this assessment. Similar to the previous section, discussions on stock structure for SC-SJA and SC-JSB strongly influenced the findings of this review, and it is recommended to re-examine the assessment and management system for SC-JSA and SC-JSB using closed-loop simulations of the populations, fisheries, and management (i.e., MSE-type simulations). See Section 5.2.1 for details.

6.1 Data

The data for the SC-JSB assessment is relatively poor compared to the SC-JSA stock assessment, and may be considered a data moderate assessment.

The SC-JSB stock abundance was largely estimated by multiplying the estimated population density (individuals per area) from a pot survey by the area in Area B. Each pot in the survey is assumed to cover 0.005 km^2, based on literature. The estimated stock abundance was then split by sex and instars using the size and sex composition from the pot survey, as well as assumed gear selectivity. This review therefore focused on the abundance index from the pot survey and its use in the assessment.

6.1.1 Abundance indices

The most important data in the SC-JSB assessment was the stock abundance estimates from the pot survey. The pot survey may be adequate to develop a relative abundance index for Area B but should not be used to directly derive an absolute abundance. There was strong concern about the assumption that each pot in the survey covers 0.005 km^2 and then simply multiplying the estimated population density from the pot survey by the total area to estimate stock abundance. This assumption is very likely invalid and should not be used in the assessment. It is critical that the pot survey not be used to directly derive an absolute abundance estimate. Instead, it is recommended that the pot survey be used to develop a relative abundance index.

There were also problems with splitting the estimated stock abundance into instars and sex due to potential size and sex selectivity of the gear or area-specific availability. In addition, the catch-at-age or catch-at-size of the fishery is largely unknown. It is recommended to begin a program to collect data from the commercial fishery and to compare the catch-at-size with the Area A fishery.

6.1.2 Recommendations on data

Based on the above findings, there are several recommendations for improving the data used for the SC-JSB assessment:

1) It is critical that the pot survey not be used to directly derive an absolute abundance estimate.

2) It is recommended that the pot survey be used to develop a relative abundance index.

3) It is recommended to improve data collection for the SC-JSB stock, especially from the commercial fishery.

4) It is recommended to compare the data between the SC-JSA and SC-JSB stocks, and explore the relationships between the two stocks.

6.2 Biology

The biology of the SC-JSB stock was relatively poorly known compared to the SC-JSA stock. It is strongly recommended to explore if the biological parameters from the SC-JSA stock are reasonable for the SC-JSB stock.

6.2.1 Stock structure and distribution

There was substantial discussion on the stock structure for snow crabs in the Sea of Japan. The findings and recommendations for the SC-JSB stock were similar to the SC-JSA stock. See Section 5.2.1 for details.

6.2.2 Natural mortality

There was little discussion on the M used for the SC-JSB stock. Given the lack of information on the SC-JSB stock, it is recommended to explore using parameters from the SC-JSA stock.

6.2.3 Maturity

There was no discussion on the maturity of SC-JSB.

6.2.4 Growth

There was little discussion and information on the growth parameters for the SC-JSB stock. Given the lack of information on the SC-JSB stock, it is recommended to explore using parameters from the SC-JSA stock.

6.2.5 Recommendations on biology

Based on the above findings, there were several recommendations for improving the biological assumptions and parameters used for the SC-JSB assessment:

1) It is recommended to improve the understanding of SC-JSB biology.

2) It is strongly recommended to explore if the biological parameters from the SC-JSA stock are reasonable for the SC-JSB stock.

3) It is recommended that research be conducted to understand the reproductive contributions from different areas in the Sea of Japan, as well as the connectivity between the areas.

4) It is strongly recommended that the assessment and management system for SC-JSA and SC-JSB be re-examined using closed-loop simulations of the populations, fisheries, and management (i.e., MSE-type simulations).

5) It is recommended to use closed-loop simulations to re-examine the impacts of non-Japanese fisheries on SC-SJA and SC-SJB.

6.3 Estimation Model

Given that the abundance estimates were based on a direct estimate from the pot survey (Section 6.1.1), this review did not examine the estimation model in the traditional sense. As mentioned in Section 6.1.1, there was strong concern about the assumptions used to make the abundance estimates. These assumptions were very likely invalid and should not be used in the assessment.

Several ideas on alternative assessment and management methods were discussed. One idea was brought up to explore the possibility of the snow crabs in Area B as a metapopulation within the Sea of Japan, and therefore could be assessed and managed as such. Another idea was to use the relative abundance index from the pot survey (or some other survey) as part of a management procedure. Such a management procedure could adjust the ABC and/or allowable fishing effort, based on the index trends and historical catches and/or effort. It is recommended to explore these alternative assessment and management methods as part of the closed loop simulations for snow crabs in the Sea of Japan.

The treatment of uncertainty in the SC-JSB assessment was inadequate. Even though the abundance estimates were highly uncertain, there appeared to be minimal consideration and reporting of these uncertainties in the assessment results. During the process to calculate an ABC, a 0.8 multiplier on the 30%SPR target reference point was used to account for the uncertainty in the assessment but this multiplier appeared to be arbitrary and may not have adequately accounted for the high uncertainty in the assessment. It is strongly recommended to incorporate and propagate uncertainty throughout the assessment and report the uncertainty as part of the assessment results.

6.3.1 Recommendations on estimation modeling

Based on the above findings, there were several recommendations for for the SC-JSB assessment:

1) It is recommended to explore alternative assessment and management methods for the SC-JSB stock as part of the closed loop simulations for snow crabs in the Sea of Japan.

2) It is strongly recommended to incorporate and propagate uncertainty throughout the assessment and report the uncertainty as part of the assessment results.

6.4 Projections

Given the limitations of the assessment, no projections were performed for the SC-JSB stock.

7. Snow crab– North Pacific Stock (SC-NP Stock)

The SC-NP stock is distributed along the Pacific coast of Honshu Island, from Ibaraki to Aomori Prefectures. Landings in Fukushima Prefecture accounted for most of the fishing effort on SC-NP but fishing effort and catches have declined to very low levels after the 2011 Great East Japan Earthquake (hereinafter referred to as the Earthquake). The critical issue for the SC-NP assessment was that, contrary to expectations, the survey index and estimated stock abundance have continued to decline after the Earthquake, even though the fishing effort and catches have dropped to very low levels. The review therefore focused on the survey index and other evidence supporting continued abundance decline, as well as the effects from the Earthquake versus other potential factors affecting stock abundance.

7.1 Data

Given the importance of the survey, the review focused on the survey design and corresponding data.

7.1.1 Survey abundance

The bottom trawl survey was the most important source of data for the SC-NP assessment. Based on the swept-area and gear selectivity of the survey, the N-at-instar of the stock was estimated from the catch-at-instar of the survey, and used as inputs into the estimation model.

There were substantial discussions on the survey design, and whether the survey adequately covered the range of the stock in both horizontal and vertical dimensions. Based on those discussions, this review agreed that the survey adequately covered the horizontal and vertical ranges of the stock. There were enough survey stations with zero catches at the edges of the survey that it would be reasonable to conclude that the range of the stock had been largely covered by the survey. There were also discussions on the potential for the stock to be moving deeper and/or northward, as well as the connectivity to snow crabs in Hokkaido waters. Although highly uncertain, the SC-NP stock did not seem to be moving substantially northward or deeper.

The connectivity between the SC-NP stock and the snow crabs in Hokkaido waters is currently unknown.

The catch in number by the survey was converted into N-at-instar based on the size composition and catch efficiency estimates of the trawl gear. The size composition was converted into instar composition by cohort slicing because the number of snow crabs caught were relatively low and modes in the data were not clear nor consistent enough to allow for the use of Gaussian mixture models like the SC-SJA survey. The cohort slicing may not have matched the modes well for all years, and may have resulted in biased estimates, especially for crabs with sizes near the size boundaries between instars. In addition, cohort slicing also did not incorporate the uncertainty in the size-instar relationship. It is recommended to explore using a length-structured estimation model and keep the data as catch-at-size. If an age-structured model is used in the future, it is recommended that size-to-instar keys be developed so that size could be appropriately converted to instar. The keys could be based on the known biology of the SC-NP stock and/or other similar stocks, or estimated from data. Catch efficiency experiments of the trawl gear allowed for direct estimates of the size selectivity or catch efficiency of the fishing gear. These estimates were then used as fixed parameters to estimate the N-at-instar of the population. It is recommended that instead of assuming these parameters as known as fixed, these could be used as priors and estimated within the estimation model.

7.1.2 Catch

Catch by the commercial fishery is recorded as catch in weight, which is converted to catch in number by instar by using the size composition and the average weight by instar of the catch from samples. However, this sampling was only conducted in 1999, 2003, and 2007, and has not been conducted after the 2011 Earthquake. Prior to 2011, size compositions for years without size sampling were assumed to be based on adjacent years, while after 2011, size compositions were assumed to be the same as the bottom trawl survey. Given the very low catches after 2011, the catch is not expected to be influential in the estimated population dynamics in recent years. Nevertheless, it is recommended to assume a constant size selectivity over the time period (i.e., assuming a constant process through time because of lack of temporal information), rather than 'borrow' size data to fill in gaps (i.e., using the same piece of data multiple times but assuming each piece is a new sample), which is statistically inappropriate. Similar to the survey data, it is also recommended to explore using a length-structured estimation model and keep the data as catch-at-size. If an age-structured model is used in the future, it is recommended that size-to-instar keys be developed so that size could be appropriately converted to instar.

7.1.3 Recommendations on data

Based on the above findings, there are several recommendations for improving the data used for the SC-NP assessment:

1) It is recommended to explore using a length-structured estimation model and keep the survey and catch data as catch-at-size.

2)If an age-structured model is used in the future, it is recommended that size-to-instar keys be developed so that size could be appropriately converted to instar.

3) When there are gaps in the catch-at-size data, it is recommended to assume a constant size selectivity over the time period, rather than 'borrow' size data to fill in gaps.

7.2 Biology

7.2.1 Stock structure and distribution

As mentioned above in Section 7.1.1, there were discussions on the potential for the SC-NP stock to be moving deeper and/or northward, as well as the connectivity to snow crabs in Hokkaido waters. Based on those discussions, the stock structure for the assessment appeared to be appropriate. However, it was recommended to explore the connectivity between this stock and the snow crabs in Hokkaido waters, which is currently not well understood. Although highly uncertain, the SC-NP stock did not seem to be moving substantially northward or deeper. However, it was also recommended to continue monitoring the horizontal and vertical distributions of the SC-NP stock. There were also questions on whether climate change was potentially influencing changes in distribution. Given the changes to snow crab populations in other parts of the world, it would be recommended to continue monitoring potential effects of climate change and the distribution of the SC-NP stock.

7.2.2 Natural mortality

The M of the stock was estimated within the model, and assumed to change over time as a first-order random walk. This approach was found to be reasonable. During the review, alternative models that modeled M as a second-order random walk were also examined. That approach appeared to be promising and it is recommended that future assessments explore estimating M as a second-order random walk.

There was concern and substantial discussions on the estimated trend in M. The estimated Ms were estimated to be increasing 2-3 fold over the past 2 decades, almost in a monotonic fashion. The Ms also exhibited a clear retrospective pattern. There was concern that this may have been a sign of a mis-specified model, or the poorer data quality after 2011 may have driven this trend in M. A series of alternative models were examined to help understand the Ms and how that influenced the estimated population dynamics. These alternative models and corresponding retrospective model runs, included models with constant M, second-order random walk M, model with 2010 terminal year (i.e., pre-Earthquake), and age-specific M. All models exhibited an increasing trend in M, even the models with a pre-Earthquake terminal year. The results of these models suggest that evidence for an increasing M may be inherent in the long-term data from multiple age-classes, even before the Earthquake in 2011.

There were also questions on whether climate change was potentially influencing the estimated increases in M. It was reported that although the trends in M were in the same direction as water temperature (i.e., both increasing), the influence of temperature on M did not appear to be direct and may be acting through secondary, ecosystem level effects. Given that the increasing M was unexpected, it was also recommended to explore estimating M from field experiments.

7.2.3 Maturity

There was no discussion about the maturity of the SC-NP stock.

7.2.4 Growth

Discussions on the growth of SC-NP were included in Section 7.1, where cohort slicing was used to convert size compositions from the survey and commercial catch data into instar compositions. Alternative approaches were recommended in Section 7.1.3.

7.2.5 Recommendations on biology

Based on the above findings, there were several recommendations for improving the biological assumptions and parameters used for the SC-NP assessment:

1) It was recommended to explore the connectivity between the SC-NP stock and snow crabs in Hokkaido waters,

2) It was recommended to continue monitoring the horizontal and vertical distributions of the SC-NP stock.

3) It was recommended to continue monitoring potential effects of climate change on the distribution and M of the SC-NP stock.

4) It was recommended that future assessments explore estimating M as a second-order random walk.

5) It was recommended to explore estimating M from field experiments.

7.3 Estimation Model

A state-space stock assessment model called Just Another state-space Stock Assessment Model (JASAM) (Shibata et al. 2021) was developed for the SC-NP assessment.

7.3.1 JASAM

The JASAM was similar to the state-space Stock Assessment Model (Nielsen and Berg 2014) but included processes and parameters for snow crabs and the SC-NP dataset. There was concern that the increasing trend in M may have been a sign of a mis-specified model but further exploration of this during the meeting was inconclusive (Section 7.2.2).

Overall, this review considered the modeling approach to be appropriate. However, there were some recommendations for potential model improvements. It was recommended to explore using a length-structured model and keep the survey and catch data as catch-at-size. When there are gaps in the catch-at-size data, it is recommended to assume a constant size selectivity over the time period.

7.3.2 Model diagnostics

The assessment documents did not provide model diagnostics like retrospective patterns and model fit. However, these model diagnostics for the base case model were shown during the web meeting. There were large retrospective patterns, especially for the M estimates, which may indicate model mis-specification. However, further exploration of this during the meeting was inconclusive. Model fit to the N-at-age data from the survey was reasonable.

7.3.3 Uncertainty

In principle, JASAM is able to incorporate and propagate uncertainty into the model results. However, such uncertainties were not reported in the documentation but were shown during the meeting. Similar to the SC-JSA assessment, it was reported that current Japanese regulations (e.g., TAC) are based on deterministic calculations and consideration of uncertainty in the assessment results are not mandatory.

7.3.4 Recommendations on estimation modeling

Based on the above findings, there are several recommendations for improving the estimation models used for the SC-NP assessment:

1) It is strongly recommended that model diagnostics be included in the assessment documents.

2) It is recommended to explore using a length-structured model (state-space or otherwise) instead of an age-structured model.

3) When there are gaps in the catch-at-size data, it is recommended to assume a constant size selectivity over the time period rather than 'borrowing' data.

7.4 Projections

There are no fishing operations targeting the SC-NP stock and no proposed target reference points. Therefore, there were no ABCs calculated for this stock using projections. If the M continues to be high, even if the catch is zero, stock abundance is expected to continue to decline. Given that, this review did not consider the projections for this stock.

8. Japanese flying squid - Winter stock (JFS-WS)

Similar to many other squid stocks, the JFS-WS and JFS-AS stocks have life histories that make a traditional stock assessment approach difficult. Instead, the current JFS-WS stock assessment takes a relatively simple approach to estimating recruitment by expanding the standardized CPUE of squid jigging fisheries. The spawning abundance was then estimated as the number of survivors after removals due to catch and natural mortality. This review recognized several issues with the current assessment but also noted that alternative approaches using preliminary statistical models with fine temporal scales (i.e., monthly data) appeared to be highly promising.

8.1 Data

Given the annual life history of the JFS-WS stock, the data for the stock assessment were catch and abundance indices.

8.1.1 Catch

Overall, this review considered the catch data of the JFS-WS stock to be adequate and appropriate for the stock assessment. For this assessment, the catch was important in estimating the spawning abundance from the estimated recruitment.

The JFS-WS stock has large and variable catches, and are caught by both Japanese and international fisheries. There were some concerns and discussions about the catch by international fisheries. It was noted that the catches by these international fisheries are documented and publicly available from various sources - South Korea (official statistics published by South Korea government); and China and Russia (annual catch summaries published by the North Pacific Fisheries Commission). Although catches by China and Russia have only been reported since 2012, it was reported that pre-2012 catches by these two countries are likely to be small and of limited impact to the stock assessment. Russian trawlers have only started to target JFS in the Russian EEZ since 2012. China fisheries do have very large catches of JFS-AS (Section 9.1) but not of JFS-WS. China fisheries do not target JFS-WS on the high seas because JFS-WS do not form large schools in offshore areas. It is recommended that work continue with these international fisheries to ensure that the catches of JFS-WS are reported adequately.

There were discussions about the potential for catches of JFS-AS and JFS-WS being misattributed to each other. The discussions indicated that there was enough differentiation in space and time for the two main stocks of JFS that the catches were well attributed to the correct stock. While there was not 100% separation of the stocks, the stock identification of catches was adequate for the assessment.

Given the annual life history of JFS-WS, there is no need to identify the age in years of the catch. However, some level of aging may be useful to help identify the stock (winter vs autumn), especially when the migration pattern varies from the expected. Daily rings from statoliths have been used to age the squid for age-growth studies. These studies have indicated that approximately one year old JFS-WS return to the spawning ground in winter to spawn. It is recommended to maintain some level of sampling and aging of the catches to identify any shifts in the spawning or distribution of the stock.

8.1.2 Abundance indices

The standardized annual CPUE of the squid jigging fishery was the most critical piece of data for this stock assessment. Critically, this abundance index was assumed to have a fixed and known relationship to recruitment, with a catchability (q) of 18.32 (see Section 8.3 for details). There were substantial discussions on this index and the appropriateness of the assumption of a fixed and known catchability (q).

Overall, this review considered the standardized annual CPUE of the squid jigging fishery was developed in an adequate manner for the stock assessment. However, the assumption of a fixed and known q to estimate recruitment is inappropriate for this assessment. The CPUE was based on the sales slip (i.e., landings) data from 17 ports in 7 regions, with effort as the number of vessels landing squid. The statistical model used was a generalized linear mixed model (GLMM) with the dependent variable being log(CPUE + δ), where δ is a small constant to deal with zero catch strata. Although this review considered the standardization to be adequate, it is recommended to explore using other distributions for the GLMM and other standardization methods as well. Given the standardization of the index was adequate, an assumption of a relatively constant q was reasonable but it was questionable to assume that the q was known, especially known without error (see Section 8.3 for details). In addition, uncertainty in the abundance index can be easily calculated but is currently ignored. It is recommended to include and present the uncertainty of the abundance index and propagate that throughout the assessment process.

Besides the standardized annual index, an alternative monthly index was also shown that appeared to be highly promising. This monthly index was not used in the assessment but was instead used in a preliminary approach with a statistical catch-at-age model with fine temporal scales (i.e., monthly data). The monthly index showed clear intra-annual declines that could be attributed to removals of the stock by fishing and natural mortality and was fit well by the preliminary model. It is strongly recommended to continue development of this monthly index.

8.1.3 Recommendations on data

Based on the above findings, there were several recommendations for improving the data used for the JFS-WS assessment:

1) It is recommended to continue working with these international fisheries to ensure that the catches of JFS-WS are reported adequately.

2) It is recommended to maintain some level of sampling and aging of the catches to identify any shifts in the spawning or distribution of the stock.

3) It is recommended to explore using other distributions for the GLMM and other standardization methods as well.

4) It is strongly recommended to continue development of this monthly index.

5) It is recommended to include and present the uncertainty of the abundance index and other data sources, and propagate that throughout the assessment process.

8.2 Biology

Given the annual life history of JFS-WS, maturity and growth of the stock was relatively unimportant to the stock assessment. Most of the discussion on the biology of the stock centered around the stock structure and distribution of the stock, and whether the catch could have been mis-identified (see Section 8.1.1).

8.2.1 Stock structure and distribution

The stock structure for this stock assessment appeared to be appropriate, given the current available information. However, as discussed in Section 8.1, it is recommended to continue research on this to identify any shifts in the spawning or distribution of the stock.

8.2.2 Natural mortality

In the current assessment, the M parameter only affects the estimate of spawning abundance because the spawning abundance is estimated as the number of survivors after removals of catch and natural mortality from the estimated recruitment. There was relatively little discussion on M but was generally thought to be in a reasonable range. It was recommended that, if the assessment model changes to a statistical catch-at-age model with fine temporal scales, an attempt be made to estimate M within the model using the current M as a prior.

8.2.3 Recommendations on biology

Based on the above findings, there were several recommendations for improving the biological assumptions and parameters used for the JFS-WS assessment:

1) It is recommended to continue research on the stock structure and distribution of JFS to identify any shifts in the spawning or distribution of the stocks.

2) If the assessment model changes to a statistical catch-at-age model with fine temporal scales, it is recommended to attempt to estimate M within the model with an M prior.

8.3 Abundance estimation

The current JFS-WS stock assessment takes a relatively simple approach to estimating recruitment and spawning abundance. The recruitment abundance was assumed to be equivalent to the product of the standardized CPUE of squid jigging fisheries and the q (18.32) of the CPUE. The spawning abundance for the next year was then estimated as the number of survivors from the current year's recruitment estimate after accounting for removals due to catch and natural mortality. Given this approach, an estimation model in the conventional sense (i.e., cohort analysis or statistical catch-at-age models) was not used for the assessment and was not considered for this review.

Instead, the discussions on abundance estimation focused on how the q was derived, and whether the assumption of a fixed and known q was reasonable for the assessment approach. The critical assumption for deriving the q was that the mean exploitation rate (i.e., catch divided by abundance) for the stock during 1979-2001 was approximately 0.3 (range: 0.2 to 0.4). This mean exploitation rate was related to the mean standardized CPUE for the period to obtain the q of 18.32. It was not clear how the historical exploitation rate of 0.3 was estimated. Overall, this review considered the strong assumption that the q of the CPUE is fixed and known, to be a relatively poor assumption and is not well supported. It would be reasonable to assume that the catchability of the standardized CPUE be relatively consistent over the time period but not to use the q to expand the CPUE to estimate recruitment. This approach may be reasonable for a data poor stock but the data for the JFS-WS stock appears to be suitable for alternative approaches (see below). In many ways, the JFS-WS stock is being managed by a management procedure using the observed CPUE of the squid jigging fishery as the primary information source. Such a management approach is reasonable but would be more appropriate to inform the decision makers that such a procedure is being used.

Several alternative approaches were presented during the meeting that showed great promise. For example, a preliminary statistical catch-at-age model with fine temporal scales (i.e., monthly time steps) was developed that appeared to fit the data well. The monthly index in this alternative approach showed clear intra-annual declines that could be attributed to removals of the stock by fishing and natural mortality. Both the index and size composition data were fitted well by the preliminary model. The estimated abundance trends from the preliminary statistical catch-at-age model were somewhat similar to the current approach. In addition, there were also discussions on a depletion model and a state-space assessment model. It is recommended to continue development of these alternative approaches and use them (or one of them) for future assessments of the JFS-WS stock.

The treatment of uncertainty in the JFS-WS assessment is inadequate and inappropriate. For example, the uncertainties in the standardized CPUE and q were neglected and not propagated into the recruitment and spawning abundance estimates. These uncertainties were likely very large and may have been important in the management of the stock.

8.3.1 Recommendations on abundance estimation

Based on the above findings, there are several recommendations for improving the estimation models used for the JFS-WS assessment:

1) It is recommended to continue development of alternative approaches for this assessment and use them (or one of them) for future assessments of the JFS-WS stock.

8.4 Projections

Given the discussions on the issues with the abundance estimations (Section 8.3), there were minimal discussions and comments on the projections. Given the life history and recruitment variability of this stock, it is difficult to make useful projections. A recommendation was to develop closed loop simulations of the assessment and management process for this stock to evaluate the performance of the current approach with alternative approaches.

8.4.1 Recommendations on projections

Based on the above findings, there were several recommendations for improving the SRRs and projections used for the JFS-WS assessment:

1) It is recommended to develop closed loop simulations (i.e., MSE-type simulations) of the assessment and management process for this stock to evaluate the performance of the current approach with these alternative approaches.

9. Japanese flying squid - Autumn stock (JFS-AS)

The JFS-AS assessment took a similar approach to the JFS-WS assessment because both life histories make a traditional stock assessment approach difficult. However, unlike the JFS-WS assessment, major portions of the JFS-AS distribution lie within the EEZ of other countries and are heavily exploited by non-Japanese fisheries. The catch and abundance index data for the JFS-AS assessment does not appear to encompass the entire stock. Unless this situation changes in the future, this may limit alternative assessment approaches using statistical models with fine temporal scales. It is important to explore closed loop simulations (i.e., MSE-type simulations) of the current and alternative assessment and management processes for the JFS-AS stock.

9.1 Data

The data for the JFS-AS stock assessment were similar to the JFS-WS assessment.

9.1.1 Catch

Overall, this review considered the catch data of the JFS-AS stock to be incomplete and likely to be inadequate for the stock assessment. For this assessment, the catch was important in estimating the spawning abundance from the estimated recruitment. In addition, the incomplete catch data impacts the ability to use alternative assessment approaches like statistical models.

The JFS-AS stock has large and variable catches, and are caught by both Japanese and international fisheries. There were substantial concerns and discussions about the catch by international fisheries. The catch of this stock by South Korea fisheries were available in official statistics published by the South Korea government. However, there was no available catch data for China fisheries. Based on estimates from scientific studies (e.g., Park et al. 2020) and limited Japanese trading company information, it was assumed in this assessment that the annual catches by China fisheries approximated 150,000 t for 2005 - 2021. Catches for 3 years (2004, 2009, and 2013) were assumed to be zero for the China fleet because of very low effort. It was noted that the catch by China fisheries were likely in excess of the catches by the Japan and Korea fisheries. Therefore, the total catch estimates used in the assessment would likely be incomplete and highly uncertain. It was clear that obtaining better catch data (or estimates) by the China fisheries would be critical for this and future assessments. However, it is currently unclear if ongoing research efforts to better estimate these catches would be successful. It is recommended to continue these research efforts to better estimate or obtain catch and/or effort data on the JFS-AS stock by non-Japanese fisheries. Another major issue was that the catch estimates were used as if known without error and the very large uncertainties in the catches were ignored. It is critical that the assessment and management processes incorporate and consider the very large uncertainties in the catch estimates for the JFS-AS stock. Given that the catch data of the JFS-AS stock may remain poor, alternative approaches using statistical models discussed during the review of the JFS-W assessment are likely not usable. Instead, it is recommended to explore alternative assessment and management processes that are not dependent on accurate catch data from non-Japanese fisheries.

Similar to the JFS-WS stock, there is no need to age the JFS-AS catch in years. However, it is recommended to maintain some level of sampling and aging of the catches to identify any shifts in the spawning or distribution of the stock.

9.1.2 Abundance indices

Similar to the JFS-WS assessment, the abundance index was the most critical piece of data for the JFS-AS stock assessment. However, the recruitment abundance index for the JFS-AS assessment was derived from a squid survey in the Sea of Japan. Similarly, this abundance index was assumed to have a fixed and known relationship to recruitment, with a q of 3.51×10^9 (see Section 9.3 for details). There were substantial discussions on this index and the appropriateness of the assumption of a fixed and known q.

One of the concerns was that the survey only covers part of the distribution of the JFS-AS stock. Some sampling locations have been established in Russian waters for about10 years but large portions of the distribution in the Sea of Japan are not sampled by the survey. Therefore, the proportion of the stock that this survey covers is dependent on the annual variability in the distribution of this stock. Therefore, it is recommended that research be conducted to understand how the distribution of the stock changes over time and with environmental changes. It is also recommended that the assessment does not assume that the proportion of the stock covered by the survey remains constant, unless there is evidence for that.

The concerns with the assumption of a fixed and known q for this assessment are similar to the JFS-WS assessment (Section 8.1.2). In addition, the survey likely did not cover a consistent proportion of the stock over time. Therefore, it is recommended not to assume a fixed and known q for this index. Given the lack of alternative approaches for this stock and the poor catch data, using this index for the management process may be the best currently available approach. However, it is recommended to explore using this index as a relative abundance index, rather than an absolute abundance index, in a management procedure that manages the fishing on this stock in Japanese waters.

9.1.3 Recommendations on data

Based on the above findings, there were several recommendations for improving the data used for the JFS-AS assessment:

1) It is recommended to continue research efforts to better estimate or obtain catch and/or effort data on the JFS-AS stock by non-Japanese fisheries.

2) It is recommended to explore alternative assessment and management processes that are not dependent on accurate catch data from non-Japanese fisheries.

3) It is recommended to maintain some level of sampling and aging of the catches to identify any shifts in the spawning or distribution of the stock.

4) It is recommended to conduct research on how the distribution of the JFS-AS stock changes over time and with environmental changes.

5) It is also recommended that the assessment does not assume that the proportion of the stock covered by the survey remains constant, unless there is evidence for that.

6) It is recommended not to assume a fixed and known q for this index.

7) It is recommended to explore using this index as a relative abundance index, rather than an absolute abundance index, in a management procedure that manages the fishing on this stock in Japanese waters.

9.2 Biology

There were limited concerns and discussions on the biology of the JFS-AS stock.

9.2.1 Stock structure and distribution

The stock structure for this stock assessment appeared to be appropriate, given the current available information. However, as discussed previously, it is recommended to continue research on this to identify any shifts in the spawning or distribution of the stock. It is also recommended to conduct research on how the distribution of the JFS-AS stock changes over time and with environmental changes.

9.2.2 Natural mortality

There was relatively little discussion on M but was generally thought to be in a reasonable range.

9.2.3 Recommendations on biology

Based on the above findings, there were several recommendations for improving the biological assumptions and parameters used for the JFS-AS assessment:

1) It is recommended to continue research on the stock structure and distribution of JFS to identify any shifts in the spawning or distribution of the stocks.

2) It is recommended to conduct research on how the distribution of the JFS-AS stock changes over time and with environmental changes.

9.3 Abundance estimation

The current JFS-AS stock assessment takes the same approach as the JFS-WS assessment except that the source of the abundance index was different. The recruitment abundance was assumed to be equivalent to the product of the standardized CPUE of a squid survey and the q ($3.51x10^{9}$) of the CPUE. The spawning abundance for the next year was then estimated as the number of survivors from the current year's recruitment estimate after accounting for removals due to catch and natural mortality.

Based on similar discussions to the JFS-WS assessment, this review considered the strong assumption that the q of the CPUE is fixed and known, to be a relatively poor assumption and is not well supported. Similarly, the JFS-AS stock is in many ways being managed by a management procedure using the observed survey CPUE as the primary information source. Such a management approach is reasonable but would be more appropriate to inform the decision makers that such a procedure is being used. It is recommended to explore using this index as a relative abundance index, rather than an absolute abundance index, in a management procedure that manages the fishing on this stock in Japanese waters.

Given the poor and incomplete catch data, the alternative modeling approaches discussed for the JFS-WS assessment would be inappropriate. Instead, it is recommended to explore alternative assessment and management processes that are not dependent on accurate catch data from non-Japanese fisheries.

The treatment of uncertainty in the JFS-AS assessment is inadequate and inappropriate. For example, the uncertainties in the catch were neglected and not propagated into the recruitment and spawning abundance estimates. These uncertainties were likely very large and would likely have been important in the management of the stock.

9.3.1 Recommendations on abundance estimation

Based on the above findings, there are several recommendations for improving the estimation models used for the JFS-AS assessment:

1) It is recommended to explore using this index as a relative abundance index, rather than an absolute abundance index, in a management procedure that manages the fishing on this stock in Japanese waters.

2) it is recommended to explore alternative assessment and management processes that are not dependent on accurate catch data from non-Japanese fisheries.

9.4 Projections

Given the discussions on the issues with the abundance estimations, there were minimal discussions and comments on the projections. Given the life history and recruitment variability, as well as the poor catch data of this stock, it is difficult to make useful projections. The most important recommendation from this review was to develop closed loop simulations of the assessment and management process for this stock to evaluate the performance of the current approach with alternative approaches.

9.4.1 Recommendations on projections

Based on the above findings, there were several recommendations for improving the SRRs and projections used for the JFS-AS assessment:

1) It is strongly recommended to develop closed loop simulations (i.e., MSE-type simulations) of the assessment and management process for this stock to evaluate the performance of the current approach with these alternative approaches.

10. References

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