Peer Review of Four Japanese Blue and Chub Mackerel Stock Assessments in 2020

By

Steven L. H. Teo
Research Fishery Biologist
Southwest Fishery Science Center
National Marine Fisheries Service

Contents

Background

Assessments of two blue mackerel (*Scomber australasicus*) and two chub mackerel (*Scomber japonicus*) stocks were conducted by Japan's Fishery Research and Education Agency (FRA) in 2020. These four stock assessments were on the: 1) blue mackerel - East China Sea (BM-ECS) ; 2) chub mackerel - Tsushima (CM-T); 3) blue mackerel - Pacific (BM-P; and 4) chub mackerel - Pacific (CM-P) stocks. The assessments of the BM-ECS and CM-T stocks were conducted jointly by the National Research Institute of Fisheries Science (NRIFS) and the Seikai National Fisheries Research Institute (SNFRI), while the assessments of the BM-P and CM-P stocks were conducted by the NRIFS.

An independent peer review of these assessments was organized by the Secretariat of Peer Review of the FRA under the specified Terms of Reference (ToR, Appendix 1). The review panel consisted of two reviewers from Japan and myself as the overseas reviewer (Dr. Steven L. H. Teo). A face-to-face review panel meeting was planned but the COVID-19 situation forced the change to a short web meeting. This web meeting was held during October 20 and 21, 2020 for approximately four hours each day, 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 web meeting. In order to help NRIFS and SNFRI scientists prepare for the web meeting, initial questions on the assessments were submitted prior to the web meeting, with follow up questions during the web meeting. The documentation for each assessment consisted of a main assessment document, several appendices, and a meeting report for determining reference points for each stock.

This report is an independent review of the four assessments based on my personal opinions of the submitted documents and clarifications during the web meeting. There was no communication between the Japanese reviewers and I. The submitted assessment documents were not detailed enough to conduct a thorough technical review. Overall, the lack of time, lack of detailed documentation, online format, and language difficulties made it difficult to thoroughly review all aspects of the assessments as specified in the ToRs. Nevertheless, this review attempts to cover the important points of the assessments. One recommendation would be to provide more detailed documentation and reduce the number of stocks being reviewed at the same time. In my experience, it would have taken about several full days of a workshop to thoroughly review a single stock assessment, especially for an initial review. It would also be useful for the non-Japanese reviewer to receive a document on the current Japanese fisheries management system for these stocks to better focus the review on the most important aspects of the assessments.

This report is subdivided into five sections with one section for each stock and a section summarizing the overall findings. The assessments of the BM-ECS and CM-T stocks are based on similar data and modelling approaches, with similar fisheries and management, and are reviewed in Sections 1 and 2, respectively. The assessments of the BM-P and CM-P stocks are also relatively similar and reviewed in Sections 3 and 4 respectively. If a comment is applicable to multiple stocks, the reader will be referred to earlier sections whenever possible to reduce the report length and repetitiveness.

All four assessments were broadly similar and consisted of five phases. First, time series of catch-at-age and abundance indices were developed for each stock and a virtual population analysis (VPA) model was used to estimate the historical population dynamics. Importantly, the VPA estimated the recruitment, spawning stock biomass (SSB), population structure (N-at-age), and fishing mortality at age (F-at-age) over the historical period. Second, the estimated recruitment and spawning biomass were used to develop the stock-recruitment relationship (SRR) and biological reference points for each stock. Third, a short-term (two-year) projection was used to bring forward the estimated N-at-age in the terminal year of the VPA (e.g., 2018) to the current year (e.g., 2020). This short-term projection was performed using the abovementioned SRR and the estimated F-at-age from the average of several terminal years of the VPA. Fourth, the projected SSB was used to determine the current stock status and, in combination with the harvest control rules (HCRs), used to determine the allowable biological catch (ABC). Lastly, long-term (e.g., 10 year) projections were used to test the robustness of the HCRs to reach management objectives.

1. Blue Mackerel - East China Sea Stock (BM-ECS Stock)

The stock assessment, as well as fisheries and management, of the BM-ECS stock is closely related to the CM-T stock, which is discussed subsequently in Section 2.

1.1 Data

A VPA model was used to estimate the population dynamics of the BM-ECS stock during the historical period. A VPA model 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 used as tuning indices for the VPA model were also examined.

1.1.1 Catch-at-age

Developing the catch-at-age time series depends largely on two components: 1) the total catch in numbers; and 2) robustly sampling the age composition of the catch. The assessment documents did not provide enough detail on how the catch-at-age time series was developed and much of the discussion during the web meeting was focused on this part of the assessment. Overall, this review found that the assumption that the catch-at-age was known without error was severely violated, which likely led to large errors and may have biased the results of the VPA model and assessment.

The time series of total catch used in this assessment did not include catch by important non-Japanese fisheries fishing on the same stock. The total catch in this assessment was based on reported catches of the BM-ECS stock by Japanese and South Korean fisheries. However, the assessment did not include the BM-ECS catch by Chinese vessels, which were likely substantial. The BM-ECS catch by Chinese vessels is unknown but there were reported to be hundreds of Chinese fishing vessels fishing within the BM-ECS stock range and the reported annual total mackerel catch by China was approximately 500,000 t. In comparison, the combined BM-ECS catch by Japanese and Korean fisheries ranged from about 30,000 to 120,000 t annually. The BM-ECS stock is likely to be an important component of total mackerel catch by China and the amount of BM-ECS catch that is missing from the assessment is therefore likely to be at least on the same order of magnitude as the catch from Japanese and South Korean fisheries. In addition, there may also be smaller amounts of catch by other fleets (e.g., Taiwan) that are currently not included.

Prior to 2008, South Korea only reported total mackerel catch, which is a combination of both blue and hub mackerel, and the BM-ECS catch had to be extracted from that using the species ratios from similar Japanese fisheries. This would be a reasonable approximation based on the assumption that the two stocks have similar distributions relative to the fishing grounds. It would nevertheless be useful to show that this assumption is valid under different environmental conditions.

It is unclear if the units of catch of the Japanese and Korean fisheries needed to be converted from weight to numbers of fish. A VPA model requires that the catch units be in numbers but landings statistics are often in tons. If this was the case, the landings data would have to be converted into numbers using the weight-at-age and age compositions of the catch. However, this process was not considered to be a critical issue and there was no discussion of this during the web meeting.

After substantial discussion during the web meeting, this review concluded that the process used to estimate the age composition of the catch for the BM-ECS stock assessment was heavily flawed. Best practises for obtaining age composition data for a VPA would entail a robust sampling program of the catch, with aging of sampled hard parts (e.g., otoliths) to provide direct observations of age compositions or at least the development of age-length keys to convert lengths to ages. However, there was little to no sampling of hard parts of the catch of the BM-ECS stock, which did not allow for direct observations of age compositions nor development of age-length keys. Instead, size (length and weight) observations were converted to age compositions using cohort slicing with an arbitrary process.

Several lines of evidence suggest that the cohort slicing process for the BM-ECS was not appropriate. First, the assessment document stated that the growth of the BM-ECS stock was unknown, which indicates that the fundamental basis for assigning age from size is quite weak. Second, size observations for the large purse seine fishery, which is the largest source of catch in this assessment, were not based on sampling the catch but were instead based on the recorded number of fish in a box (large fish; each box was assumed to be 18 kg so if there were 20 fish in the box, the size of fish in the box was assumed to be 0.9 kg), and the recorded average weight of the fish (small fish; age-0 to age-1). Third, size bins were assigned to ages based on arbitrary categories like 'mini', 'small', and 'large', without supporting evidence. Fourth, an examination of the available length histograms of the BM-ECS stock showed that the assumed age classes did not align well with observed length modes. Fifth, the other blue mackerel stock assessment in this review (i.e., BM-P stock) showed evidence of highly variable growth and substantial overlap of age classes within length bins, especially the larger lengths. Given the above problems, the estimated age compositions of the BM-ECS stock likely had substantial errors.

In general, the biology of mackerel stocks, with the majority of growth in the first year and variable growth through space and time, makes it likely that a single size bin can contain several age classes and the age compositions within size bins can change over time. It is therefore important to have a robust sampling program for the hard parts of the catch for mackerel stocks.

The catch-at-age time series for the BM-ECS likely had substantial errors in both the total catch and the age compositions. Hence, it is likely that the catch-at-age time series used for the BM-ECS stock assessment had substantial errors. The assumption that the catch-at-age was known without error was therefore severely violated and may have led to large errors and biased the results of the BM-ECS assessment.

1.1.2 Relative abundance indices

In VPA models, one or more abundance indices are often used to tune the results of the model. Ideally, these indices are based on surveys with a sampling design appropriate for the stock. Otherwise, a standardization procedure is used to standardize commercial catch-per-unit-effort (CPUE) data to minimize the effect of changes in fishing operations (e.g., gear, fishing location, technology) on catchability.

The abundance indices for the BM-ECS assessment requires substantial improvement. Four age-disaggregated abundance indices from the large purse seine fishery (age-0, age-1, age-2, and age-3+) and two semi-disaggregated abundance indices from the medium purse seine fishery (age-0-1, and age-2+) were used for tuning the VPA model. All six indices were nominal indices, which assumes that the catchability of the fisheries have not changed over the entire period (2003-2018). The assessment document stated that the 2003-2018 period was chosen for the indices because operational status and fishing efficiency were relatively constant during this period. However, no evidence was shown to support the assumption that catchability for these fisheries and various age classes were constant over this period. Upon further discussion, NRIFS scientists indicated that there have been prior attempts to standardize these indices but none have been successful so far. Furthermore, the units of CPUE were tons/set, with an unit of effort being a single set. Using a single set as the unit of effort excludes important variables of effort, like search time and technology. Therefore, the CPUE here is an indicator of school size, which when used as an abundance index, assumes that school size is closely related to stock size. However, there is no evidence that this was the case for the BM-ECS stock. This may have resulted in abundance indices that are hyperstable, which may in turn cause biased VPA model results. It was also noted that the abundance indices from the large purse seine do not appear to be consistent with the indices from the medium purse seine. Having multiple inconsistent indices is detrimental to the modelling. Instead, it would have been better to base it on the indices that are considered more representative of the BM-ECS stock as a whole.

1.1.3 Recommendations on data

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

1) Most importantly, it is critical to have good estimates of the BM-ECS catch by non-Japanese fisheries. If the total catch is poorly known, most models are not expected to perform well, especially data-rich models like the VPA. In some cases, missing catch can be estimated if there are good proxies for the missing catch (e.g., effort, constant proportion of bycatch) and/or good surveys of the stock. However, this does not appear to be the case.
2) If the BM-ECS catch of non-Japanese fisheries remains poorly known in the future, it may be more appropriate to use alternative assessment and management methods for this stock. For example, an observation-based management procedure that sets the catch limits based on a survey of the stock biomass in Japanese waters before the fishing season starts, could be used to manage the stock for Japanese fisheries. However, it would be important to use simulations (e.g., an MSE-type process) to evaluate if such a procedure would meet management objectives and be robust for

this stock, including both Japanese and non-Japanese fisheries that are not under the management procedure. Alternatively, data-poor methods can be used to assess the stock but the associated uncertainty would be relatively high and may not be appropriate for the management of this stock.

3) It is important to establish a robust sampling and aging program for the catch to improve the age compositions used for the assessment, especially for the fisheries with large catches. The design of such a sampling program is beyond the scope of this review and would be dependent on fishery operations. For example, the landings of the large purse seine fishery appear to be sorted by approximate size classes (e.g., mini, small, large). Therefore, the sampling program could sample from each size classe (e.g., one otolith every N boxes of small fish) and raise the age compositions of each size class to the total catch subsequently. A subset of the samples could also be set aside to construct age-length keys for fisheries that can only sample lengths.
4) In terms of abundance indices, it is recommended that a survey for the BM-ECS stock be developed. Given the overlap in spatial range and fisheries, it may be desirable to design a joint survey with the CM-T stock. The design of such a survey would be beyond the scope of this review but would likely entail a combination of acoustics to estimate biomass and trawling to identify species and age.
5) While the survey is being developed, it is recommended that more research efforts be put into standardizing the current abundance indices or investigate alternative indices. In addition, it would be important to investigate how to improve the abundance indices so that it is more closely related stock size rather than school size.
6) Instead of fitting multiple inconsistent indices from different fisheries, it is recommended to fit only to the indices considered to be the most representative of the stock as a whole.

1.2 Biology

1.2.1 Stock structure and distribution

The stock structure for this stock assessment appears to be appropriate. However, given the lack of time and importance of other issues, there was relatively little discussion on this topic. Given more time, it would have been useful to go over the evidence for the stock structure. The distribution of the stock covers the fishing grounds of several nations. The catch from some important non-Japanese fisheries were not included and may have resulted in substantial errors in the assessment (Section 1.1.1).

1.2.2 Natural mortality

The natural mortality (M) of the BM-ECS stock was assumed to be 0.4 y^{-1} based on a reported maximum age (A_{max}) of 6 years, using the relationship of $M=2.5/A_{max}$ from Tanaka (1960). However, a recent reanalysis of the $M=a/A_{max}$ relationship (i.e., a is the fitted parameter) with substantially more data, suggested that a is ~5 (Then et al. 2014), which would in turn suggest a higher M for this stock. In addition, the commonly-used empirical relationship by Hoenig (1983) that relates maximum age with M would also suggest a substantially higher M for this stock. In comparison to this assessment, a recent assessment of a *Scomber japonicus* stock in the eastern Pacific Ocean (Crone et al. 2019)had an estimated posterior of 0.81 ± 0.13 y^{-1} for M. These lines of evidence suggest that the M used for this assessment can be improved. However, it would be difficult to improve the M parameter until more research and sampling is done on this stock (Section 1.1.3). A meta-analysis for M using empirical relationships (e.g., Hoenig, Pauly) would be dependent on a good understanding of the biological parameters for the stock (e.g., maximum age, growth). Nevertheless, it may be worth exploring using M parameter values from closely related stocks with better biological studies and sampling.

It is noted that a presentation during the web meeting included results of a preliminary study of a reanalysis of M using various empirical relationships. However, the biological parameters used in that preliminary study were in conflict with those in the assessment documents. For example, the maximum age in the preliminary study was 10 to 11 years but was stated as 6 years in the assessment documents. It was also unclear whether the preliminary study was based on the BM-ECS stock. It would nevertheless have been useful if the results of the preliminary study were cited in the assessment documents.

1.2.3 Growth

The assessment document states that the growth of the BM-ECS stock is unknown. It is critical to improve the research and sampling program for the BM-ECS stock. A good first step would be to establish a robust sampling and aging program for the BM-ECS stock (Section 1.1.3). A subset of the samples could be used to develop growth models for the stock and examine the variability and influences on the growth.

1.2.4 Recommendations on biology

Based on the above findings, there are several recommendations for improving the biology used for the BM-ECS assessment:

1) It is strongly recommended that the research and sampling program for the BM-ECS stock be improved. Doing so will improve the biological parameters like growth and natural mortality, as well as the data used for the assessment.
2) It is recommended that the natural mortality parameter be subject to a reanalysis. A meta-analysis using empirical relationships like the Hoenig and/or Pauly

relationships would be dependent on a good understanding of the biological parameters for the stock (e.g., maximum age, growth). It may be worth exploring using values from closely related stocks with better biological studies and sampling. Over the long run, it may be possible to estimate natural mortality within the assessment model using a reasonable prior. However, substantial improvements in the data and biological understanding for this stock would be necessary before doing so.

1.3 Estimation Model

1.3.1 VPA model

A ridge VPA model (Okamura et al. 2017) was used in the BM-ECS stock assessment to estimate the historical population dynamics of the stock. The ridge VPA reduces the retrospective bias in model results by including a penalty term for fishing mortality (F) in the terminal years that is weighted by the size of the retrospective bias. A weighting coefficient (λ, between 0 and 1) sets the relative weighting between the likelihood of model fit ($\lambda \rightarrow 0$) and the F penalty ($\lambda \rightarrow 1$). As λ approaches 0, the model is similar to a traditional VPA, but as λ approaches 1, the model prioritizes reducing the F penalty over model fit. The λ is estimated from minimizing the retrospective bias of biomass over a number of terminal years. Essentially, there is a tradeoff between reducing the retrospective bias (and terminal F penalty) versus improving model fit to the tuning indices.

There was a change in how the F penalty and retrospective bias was calculated for this year's assessment. In previous assessments, the penalty on terminal F was based on "F square" and the retrospective bias of biomass was calculated over a five year period. It is unclear what "F square'' meant but I assumed it meant that the F penalty was calculated as the square of F in the terminal year (i.e., the F penalty gets smaller as terminal F gets smaller). For this assessment, the F penalty was instead calculated as the residual sum of squares over the terminal five years, and the retrospective bias was based on the terminal seven years. The λ was estimated as 0.76, which meant that the model had major retrospective bias and was heavily weighted towards the F penalty. This would in turn result in a terminal F that tended towards the average of the terminal five years, even if the data indicated otherwise. Interestingly, if a retrospective period of five years was used, as in previous assessments, the λ would have been estimated as 0.10 and the terminal F would have been exceedingly high.

The exceedingly high terminal F and major retrospective pattern suggested that there may be fundamental problems with the model and data. There was not enough time during the web meeting to examine these problems in depth but the ridge VPA was an attempt by the modellers to mitigate the obvious symptoms of very high terminal F and retrospective pattern. The changes in the model settings for this assessment substantially increased the F penalty so that the terminal F was reduced to more reasonable values. However, there are likely to be fundamental problems with the data (e.g., missing catch, unrepresentative indices; Section 1.1) and biological parameters (Section 1.2) for the BM-ECS stock. It was also not clear if the problems with the high terminal F were related to the much higher reported catch in 2018 by Korea. Simply changing the model settings likely only alleviated the symptoms for this assessment but did not cure the fundamental problems with the assessment. A VPA makes strict assumptions about the data, which have been severely violated in this assessment (Section 1.1). The priority would be to solve the problems with the data first. Although improving the data for this assessment is critical, it may also be beneficial to explore the use of statistical catch-at-age models, which can be more flexible and able to model the data as it is collected. It would also be easier to develop models with alternative hypotheses.

1.3.2 Model diagnostics

The assessment documents did not provide model diagnostics like retrospective patterns and model fit. However, these model diagnostics for both the base case model were shown during the web meeting, after being requested. The model diagnostics indicated that the indices for this assessment were not well fit and there were large retrospective patterns, especially if the model settings for the previous assessments were used. The use of the ridge VPA reduced the retrospective bias and high terminal F but resulted in a tradeoff with poor model fit to the indices (see Section 1.3.1). It is unclear if such a tradeoff is a good idea. The poor model diagnostics are likely an indicator of fundamental problems with the assessment.

1.3.3 Uncertainty

The treatment of uncertainty in the BM-ECS assessment was inadequate. As discussed in the above sections, there were large uncertainties throughout the assessment. However, there was minimal consideration of uncertainty in the data, modelling, and results of the assessment. For example, the estimated population structure (N-at-age) and F-at-age in the terminal years were assumed to be known without error. This is an assumption that is severely violated for this assessment and not recommended for any assessment. Therefore, when the N-at-age and F-at-age are used in the projections without uncertainty, 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 a VPA model, especially when the data were not developed according to the assumptions made (e.g., catch-at-age is known without error). One possibility is to use a bootstrap process to simulate the uncertainty in the data, if possible. However, it may also be beneficial to explore the use of statistical catch-at-age models, which can more easily include the uncertainty in the data and biological processes throughout the model.

1.3.4 Recommendations on estimation model

Based on the above findings, there are several recommendations for improving the estimation model used for the BM-ECS assessment:

1) It is strongly recommended that model diagnostics be included in the assessment documents.
2) 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.
3) It would be beneficial to explore the use of statistical catch-at-age models, which can be more flexible and more easily include the uncertainty in the data and biological processes throughout the model. It would also be easier to develop models with alternative hypotheses.

1.4 Projections

1.4.1 Stock-recruitment relationship (SRR)

Several candidate SRRs (e.g., Beverton-Holt, Ricker, and Hockey-Stick) were fitted to the estimated historical recruitment and spawning biomass from the VPA model. The Hockey-Stick SRR estimated by the least absolute value method (HS-L1) was selected during a prior meeting to be the SRR for calculating the biological reference points and future projections. The selected HS-L1 SRR was then used to estimate biological reference points and compute future projections.

The choice of SRR appeared to be somewhat arbitrary, with management considerations being highly influential. For example, it was noted that the HS-L1 SRR had the lowest expected recruitment for the lowest historical spawning biomass, which would reduce the risk of overfishing at low biomass. In addition, although the SB_{MSY} estimated using the HS-L1 SRR was higher than all historical SB (i.e., the stock has been overfished throughout the entire modeling period), it was lower than that estimated using the Beverton-Holt or Ricker models. Therefore, it was considered that “stock management using HS-L1 for the stock-recruitment relationship had a good balance between the viewpoint of stock protection and the reality of the management objectives”. The selected SRR resulted in SB_{MSY} and F_{MSY} estimates that were somewhat in the middle of the choices. Given that management considerations were clearly important in the choice of SRR, it may not be appropriate for this review to comment on the choice of SRR. Nevertheless, it is noted that there is substantial uncertainty inherent in the selection of the SRR that is not reflected in the biological reference points and future projections based on the SRR. It is noted that the HS-L1 SRR was not the best model in terms of Akaike's Information Criteria (AIC). It is also inappropriate to consider the estimates of recruitment and spawning biomass from the VPA model as known without error (Section 1.3.3). The estimated historical recruitment and spawning biomass also made it difficult to distinguish whether the historical period was on the slope or flat part of the Hockey-Stick. Overall, it may be useful to consider incorporating the uncertainty in the form of SRR into the future projections, calculations of the reference points, and management decisions. This could take the form of a model ensemble approach and allow managers to better understand and incorporate the whole range of risks into their decision making.

In addition to the use of the SRR in this assessment, the observed cross-correlation lags between the recruitment and spawning biomass was discussed during the web meeting. This is important because the observed cross-correlation lag indicates the relative influence of environmental drivers and spawning biomass on recruitment (Szuwalski et al. 2015) and small pelagic species are commonly heavily influenced by environmental drivers (Zwolinski and Demer 2014). Given the lack of time, there was limited discussion during the web meeting but it was noted that a recent study has analyzed this for several Japanese stocks, including the mackerel stocks being reviewed (Kurota et al. 2020). Based on this analysis, the recruitment of the BM-ECS stock (spotted mackerel in Kurota et al. 2020) was identified as being significantly environmentally driven. Therefore, it would be advisable to take this into account when assessing and managing the BM-ECS stock.

1.4.2 Short-term projections

The terminal year of the estimation model is 2018 but the allowable catch for the current fishing year is based on the spawning biomass in 2020. Therefore two years of projections are required to bring forward the estimated N-at-age in 2018 to estimate the projected spawning biomass in 2020. One of the problems is that these short-term projections are highly sensitive to the estimates of age-0 and age-1 fish in the terminal year but these estimates are highly uncertain due to the lack of observations. In addition, the F in 2019 is assumed to be the average of 2016-2018. In addition, catches by non-Japanese fisheries are not limited by Japanese management, Therefore, the projected spawning biomass in 2020, on which the allowable catch is calculated from, is highly uncertain. It should be noted that this uncertainty is currently under-estimated because the N-at-age in the terminal year of the estimation model is assumed to be known without error, which is considered inappropriate (Section 1.3.3). It is therefore important to incorporate that uncertainty in the N-at-age in the terminal year into the short term projections. The uncertainty in the projected recruitment is also likely under-estimated (Section 1.4.2) but this is less important in the short term projections because these recruits do not reach maturity in the two years.

One way to improve the short-term projections is to develop scientific surveys of the age-0 and age-1 fish of this stock in Japanese waters, prior to the start of the fishing season (Section 1.1.3). Having such a survey would greatly improve the estimates of age-0 and age-1 throughout the historical period, and improve the short-term projections. It should be noted that the catch of the BM-ECS stock is predominantly age-0 and age-1 fish and the recruitment of this stock is likely heavily environmentally driven. Basing the allowable catch of age-0 and age-1 on the two-year projections of spawning biomass may lead to large mismatches between expectations and observations of catch. Such mismatches have led other countries to use management procedures based on observations from surveys before the fishing season. For example, this management procedure could set the allowable catch based on a survey of the age-0 and age-1 fish in Japanese waters before the fishing season starts. This survey would alleviate the problems of knowing and managing a stock with highly variable recruitment driven largely by environmental conditions, as well as the catch by non-Japanese fisheries. However, it would be important to use simulations (e.g., an MSE-type process) to evaluate if such a procedure would meet management objectives and be robust for this stock, including both Japanese and non-Japanese fisheries that are not under the management procedure.

1.4.3 Long-term projections

The assessment documents did not clearly state the purpose of the long-term projections. During the web meeting, it was clarified that one of the management objectives was the probability of exceeding the target reference point (MSY) over the next 10 years should not exceed 50%. In addition, there were probabilities associated with the limit and ban reference points as well. Therefore, the long-term projections were used to estimate the appropriate F-multiplier (relative to F_{MSY}) to achieve that management objective. The models used for the long-term projections were similar to the short -term projections. Similarly, the uncertainty for the long-term projections are currently under-estimated because the N-at-age in the terminal year of the estimation model is assumed to be known without error, which is considered inappropriate (Section 1.3.3). It is therefore important to incorporate that uncertainty in the N-at-age in the terminal year into both the short term and long-term projections. 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, catches by non-Japanese fisheries are not limited by Japanese management. Therefore, it may not be reasonable to assume that the F-multiplier applies to non-Japanese fisheries as well.

1.4.5 Recommendations on projections

Based on the above findings, there are several recommendations for improving the SRR and projections used for the BM-ECS assessment:

1) Consider incorporating the uncertainty in the form of SRR into the future projections, calculations of the reference points, and management decisions.
2) It is advisable to consider the influence of environmental drivers on recruitment, when assessing and managing the BM-ECS stock.
3) It is recommended to incorporate that uncertainty in the N-at-age in the terminal year into the short term and long-term projections.
4) It recommended to develop scientific surveys of the age-0 and age-1 fish of this stock in Japanese waters, prior to the start of the fishing season.
5) It is recommended not to assume that the F of non-Japanese fisheries are subject to the F-multiplier for the long-term projections.

2. Chub Mackerel - Tsushima Stock (CM-T Stock)

The stock assessment, as well as fisheries and management, of the CM-T stock was closely related to the BM-ECS stock. Therefore this review found similar problems and provided similar recommendations. In order to reduce the repetitiveness and lengthiness of the report, references are made to earlier sections when appropriate. However, the recommendations for the CM-T stock are kept separate for the sake of clarity.

2.1 Data

A VPA was used to estimate the population dynamics of the CM-T stock during the historical period. Therefore, the assessment of the CM-T stock had similar assumptions on data as the BM-ECS stock (see Section 1.1).

2.1.1 Catch-at-age

The process used to develop the catch-at-age time series for the CM-T stock was highly similar to the BM-ECS stock. Therefore, the CM-T stock assessment likely had substantial errors in both the total catch and the age compositions (see Section 1.1.1 for details). Hence, it is likely that the catch-at-age time series used for the CM-T stock assessment had substantial errors. The critical assumption for VPA models that the catch-at-age was known without error was therefore severely violated and may have led to large errors and biased the results of the CM-T assessment. It should be noted that the age and growth for the CM-T stock has been previously studied (Shiraishi et al. 2008) and may be considered better known than the BM-ECS stock. However, the results from Shiraishi et al. (2008) indicates that there are likely multiple cohorts within length bins. Therefore, similar to the BM-ECS stock, it is recommended to have a robust sampling program for the hard parts of the catch for the CM-T stock.

2.1.2 Relative abundance indices

The abundance indices for the CM-T assessment were developed from the same process and data sources as the BM-ECS assessment. Therefore, the same findings for the BM-ECS assessment largely apply to the CM-T assessment as well (see Section 1.1.2 for details). All six indices used for the CM-T assessment were nominal indices but no evidence was shown to support the assumption that catchability for these fisheries and various age classes were constant. Furthermore, the units of CPUE were tons/set and is likely an indicator of school size rather than stock size. This may have resulted in abundance indices that are hyperstable, which may in turn cause biased VPA model results. It was also noted that the abundance indices from the large purse seine do not appear to be consistent with the indices from the medium purse seine. It would have been better to base it on the indices that are considered more representative of the CM-T stock as a whole.

2.1.3 Recommendations on data

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

1) Most importantly, it is critical to have good estimates of the CM-T catch by non-Japanese fisheries. If the total catch is poorly known, most models are not expected to perform well, especially data-rich models like the VPA. In some cases, missing catch can be estimated if there are good proxies for the missing catch (e.g., effort, constant proportion of bycatch) and/or good surveys of the stock. However, this does not appear to be the case.
2) If the CM-T catch of non-Japanese fisheries remains poorly known in the future, it may be more appropriate to use alternative assessment and management methods for this stock. For example, an observation-based management procedure that sets the catch limits based on a survey of the stock biomass in Japanese waters before the fishing season starts, could be used to manage the stock for Japanese fisheries. However, it would be important to use simulations (e.g., an MSE-type process) to evaluate if such a procedure would meet management objectives and be robust for this stock, including both Japanese and non-Japanese fisheries that are not under the management procedure. Alternatively, data-poor methods can be used to assess the stock but the associated uncertainty would be relatively high and may not be appropriate for the management of this stock.
3) It is important to establish a robust sampling and aging program for the catch to improve the age compositions used for the assessment, especially for the fisheries with large catches. The design of such a sampling program is beyond the scope of this review and would be dependent on fishery operations. For example, the landings of the large purse seine fishery appear to be sorted by approximate size

classes (e.g., mini, small, large). Therefore, the sampling program could sample from each size classe (e.g., one otolith every N boxes of small fish) and raise the age compositions of each size class to the total catch subsequently. A subset of the samples could also be set aside to construct age-length keys for fisheries that can only sample lengths.

4) In terms of abundance indices, it is recommended that a survey for the CM-T stock be developed. Given the overlap in spatial range and fisheries, it may be desirable to design a joint survey with the BM-ECS stock. The design of such a survey would be beyond the scope of this review but would likely entail a combination of acoustics to estimate biomass and trawling to identify species and age.
5) While the survey is being developed, it is recommended that more research efforts be put into standardizing the current abundance indices or investigate alternative indices. In addition, it would be important to investigate how to improve the abundance indices so that it is more closely related stock size rather than school size.
6) Instead of fitting multiple inconsistent indices from different fisheries, it is recommended to fit only to the indices considered to be the most representative of the stock as a whole.

2.2 Biology

2.2.1 Stock structure and distribution

The stock structure for this stock assessment appears to be appropriate. However, given the lack of time and importance of other issues, there was relatively little discussion on this topic.

2.2.2 Natural mortality

Similar to the BM-ECS stock, the M of the CM-T stock was assumed to be 0.4 y^{-1} based on a reported maximum age (A_{max}) of 6 years. The M used for this assessment can be improved but more research and sampling is needed on this stock (see Section 2.2.2 for details).

2.2.3 Growth

The growth of the CM-T stock is better known than the BM-ECS stock due to a previous study (Shiraishi et al. 2008). However, it is important to establish a robust sampling and aging program for the CM-T stock, perhaps in conjunction with the BM-ECS stock.

2.2.4 Recommendations on biology

Based on the above findings, there are several recommendations for improving the biology used for the CM-T assessment:

1) It is strongly recommended that the research and sampling program for the CM-T stock be improved. Doing so will improve the biological parameters like growth and natural mortality, as well as the data used for the assessment.
2) It is recommended that the natural mortality parameter be subject to a reanalysis. A meta-analysis using empirical relationships like the Hoenig and/or Pauly relationships would be dependent on a good understanding of the biological parameters for the stock (e.g., maximum age, growth). It may be worth exploring using values from closely related stocks with better biological studies and sampling. Over the long run, it may be possible to estimate natural mortality within the assessment model using a reasonable prior. However, substantial improvements in the data and biological understanding for this stock would be necessary before doing so.

2.3 Estimation Model

2.3.1 VPA model

The estimation model was a VPA model but unlike the BM-ECS which used a ridge VPA model (Okamura et al. 2017), the VPA model appeared to be a standard VPA model with tuning indices. This suggests that the retrospective pattern was not as severe as for the BM-ECS stock (Section 1.3.1). Nevertheless, a VPA makes strict assumptions about the data, which have been severely violated in this assessment (Section 2.1). Similar to the recommendations for the BM-ECS stock, the priority would be to solve the problems with the data first. However, it may also be beneficial to explore the use of statistical catch-at-age models, which can be more flexible and able to model the data as it is collected. It would also be easier to develop models with alternative hypotheses.

2.3.2 Model diagnostics

The assessment documents for the CM-T stock did not provide model diagnostics like retrospective patterns and model fit. However, these model diagnostics for both the base case model were shown during the web meeting, after being requested. The model diagnostics indicated that the medium purse seine indices for this assessment were poorly fit and there was some retrospective bias. The poorly fit medium purse seine indices indicate that these indices are not consistent with the other data sources. It is recommended that future assessments do not include these indices.

2.3.3 Uncertainty

Similar to the BM-ECS stock, the treatment of uncertainty in the CM-T assessment was inadequate. There were large uncertainties throughout the assessment but there was minimal consideration of uncertainty in the data, modelling, and results of the assessment (see Section 1.3.3 for details).

2.3.4 Recommendations on estimation model

Based on the above findings, there are several recommendations for improving the estimation model used for the CM-T assessment:

1) It is strongly recommended that model diagnostics be included in the assessment documents.
2) 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.
3) It would be beneficial to explore the use of statistical catch-at-age models, which can be more flexible and more easily include the uncertainty in the data and biological processes throughout the model. It would also be easier to develop models with alternative hypotheses.

2.4 Projections

2.4.1 Stock-recruitment relationship (SRR)

The process to select the SRR for the CM-T stock was similar to the BM-ECS stock (see Section 1.4.1 for details). However, unlike the BM-ECS stock, the Hockey-Stick SRR estimated by the least squares method (HS-L2) was selected for the CM-T stock.

Similar to the BM-ECS assessment, the choice of SRR for the CM-T stock appeared to be somewhat arbitrary, with management considerations being highly influential. Given that management considerations were clearly important in the choice of SRR, it may not be appropriate for a scientific peer review to comment on the choice of SRR. However, it is noted that the HS-L2 SRR was the poorest model in terms of AIC. Nevertheless, it is also noted that the SRR for the CM-T stock appeared to be more robust than for the BM-ECS stock. There is substantial uncertainty inherent in the selection of the SRR that is not reflected in the biological reference points and future projections based on the SRR. Overall, it may be useful to consider incorporating the uncertainty in the form of SRR into the future projections, calculations of the reference points, and management decisions. This could take the form of a model ensemble approach and allow managers to better understand and incorporate the whole range of risks into their decision making. It is also important to include the uncertainty in the recruitment and spawning biomass estimates from the VPA model rather than assuming they are known without error.

Unlike the BM-ECS stock, the recruitment of the CM-T stock was identified to be influenced by both the spawning biomass and environmental drivers (Kurota et al. 2020). Therefore, it would be advisable to take this into account when assessing and managing the CM-T stock.

2.4.2 Short-term projections

The short-term projections for the CM-T stock were similar to the BM-ECS stock and had similar problems (see Section 1.4.2 for details). The projected spawning biomass in the current fishing year (i.e., 2020), on which the allowable catch is calculated from, is highly uncertain because the projections are highly sensitive to the uncertain and unobserved estimates of age-0 and age-1 fish in the terminal year (i.e., 2018) and catches by non-Japanese fisheries are not limited by Japanese management. It should also be noted that this uncertainty is currently under-estimated because the N-at-age in the terminal year of the estimation model is assumed to be known without error, which is considered inappropriate (Section 2.3.3).

Similar to the recommendations for the BM-ECS stock, one way to improve the short-term projections of the CM-T stock is to develop scientific surveys of the age-0 and age-1 fish of this stock in Japanese waters, prior to the start of the fishing season (Section 2.1.3). This survey could be a joint survey of the CM-T and BM-ECS stocks. The survey results could then be the basis for managing the stocks in Japanese waters. It would be important to use simulations (e.g., an MSE-type process) to evaluate if such a procedure would meet management objectives and be robust for this stock, including both Japanese and non-Japanese fisheries that are not under the management procedure.

2.4.3 Long-term projections

The long-term projections for the CM-T stock were similar to the BM-ECS stock and had similar problems (see Section 1.4.3 for details). The uncertainty for the long-term projections are currently under-estimated because the 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, catches by non-Japanese fisheries are not limited by Japanese management. Therefore, it may not be reasonable to assume that the F-multiplier applies to non-Japanese fisheries as well.

2.4.4 Recommendations on projections

Based on the above findings, there are several recommendations for improving the SRR and projections used for the CM-T assessment:

1) Consider incorporating the uncertainty in the form of SRR into the future projections, calculations of the reference points, and management decisions.
2) It is advisable to consider the influence of both environmental drivers and the spawning biomass on recruitment, when assessing and managing the CM-T stock.

3) It is recommended to incorporate that uncertainty in the N-at-age in the terminal year into the short term and long-term projections.
4) It recommended to develop scientific surveys of the age-0 and age-1 fish of this stock in Japanese waters, prior to the start of the fishing season.
5) It is recommended not to assume that the F of non-Japanese fisheries are subject to the F-multiplier for the long-term projections.

3. Blue Mackerel - Pacific Stock (BM-P Stock)

The stock assessment, as well as fisheries and management, of the BM-P stock is closely related to the CM-P stock, which is discussed subsequently in Section 4. There are also some similarities, albeit less, with the BM-ECS and CM-T stocks. Therefore, if similar comments or discussions were made for the BM-P stock, the reader will be referred to earlier sections to reduce the repetitiveness and lengthiness of the report. However, the recommendations for the BM-P stock are kept separate for the sake of clarity.

3.1 Data

Like all four assessments, a VPA was used to estimate the population dynamics of the BM-T stock during the historical period. A VPA 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 used as tuning indices for the VPA model were also examined.

3.1.1 Catch-at-age

Similar to the BM-ECS and CM-T assessments, the assessment documents did not provide enough detail on how the catch-at-age time series was developed. However, after much discussion during the web meeting, this review found that the processes used to develop the catch-at-age time series for the BM-P stock were more appropriate and the assumption that the catch-at-age was known without error was not severely violated. Nevertheless, this review found aspects with potential room for improvement.

Importantly, the total catch of the BM-P stock was predominantly from Japanese fisheries, and included catch from all major non-Japanese fisheries fishing on the same stock. The total catch in this assessment was based on reported catches of the BM-P stock by Japanese, Chinese, and Russian fisheries. The catch by Chinese and Russian fisheries were based on reported total mackerel (combined blue and chub mackerel) catch reported to the North Pacific Fisheries Commission, and split into blue and chub mackerel catch based on stock ratios from similar Japanese fisheries. The proportions of blue mackerel in those ratios were relatively low, and the catch of the BM-P stock by Chinese and Russian fisheries were also low. During the web meeting, it was reported that there were no known major fisheries for the BM-P stock by other non-Japanese fisheries. Similar to the BM-ECS and CM-T assessments, it is unclear if the units of catch needed to be converted from weight to numbers of fish but this process was not considered to be a critical issue and there was no discussion of this during the web meeting (see Section 1.1.1).

Although not documented in the assessment documents, presentations during the web meeting showed that seasonal age-length keys were developed to estimate the age composition of the catch for the BM-P stock assessment. Using age-length keys are more appropriate than cohort slicing. Due to the lack of time, there was no discussion on the sampling used to develop the age-length keys. It is assumed here that the sampling was robust and appropriate but should be reviewed in the future. However, it was noted that the aging was based on reading scale samples and meetings are held to standardize reads. Reading scales are more likely to lead to biased ages as compared to reading otoliths. Therefore, it would be useful to perform experiments to compare different hard parts for aging and to validate the ages. If validation experiments are not possible, it would nevertheless be useful to obtain reader-specific estimates of bias and error (Punt et al. 2008). In addition, the age-length keys have some bins with missing data, likely due to insufficient sampling, which may cause some bias and error in the age compositions. If increasing sampling is not possible, it may be useful to experiment with interpolating those gaps with fitted seasonal growth models. Although cost-prohibitive, operational sampling and aging of the catch is commonly thought to result in improved age compositions compared to using age-length keys.

The age-length keys were used to convert lengths to ages but it was unclear how the length compositions were developed. Due to the lack of time, there was no discussion of this matter. It is assumed here that the length sampling for the BM-P assessment was robust and appropriate but should be reviewed in the future. If the process and data used here were similar to the BM-ECS and CM-T stocks (Section 1.1.1), it may lead to bias and errors in the catch-at-age data used for the assessment and hence the results.

3.1.2 Relative abundance indices

Two tuning indices were used for the BM-P assessment: 1) a dip-net index from Shizuoka prefecture; and 2) egg abundance index from samples along the Pacific coast of Japan. The main assessment document stated other tuning indices were used as well (e.g., mid-water trawl survey) but this conflicts with the appendices detailing the VPA model. Based on discussions during the web meeting, the main assessment document was found to be inaccurate and the dip-net and egg abundance indices are the two tuning indices used for the BM-P assessment.

There was very limited information on the data and methods used to develop the dip-net index. However, it appears that the dip-net index was based on the CPUE of a dip-net fishery around Shizuoka prefecture. The index is a nominal index (i.e., unstandardized) used to represent the abundance of age-0 year class. It appears to be particularly important for estimating the abundance and F of age-0 fish in the terminal year, which are then used in the short-term projections. However, the likely small area of the fishery compared to the stock's distribution, lack of standardization, and poor model fit (Section 3.3.2) would suggest that the dip-net index is a poor indicator of the abundance of age-0 fish and is inconsistent with the other pieces of data. Therefore, it is not recommended to continue using this index. It is unclear why the midwater trawl surveys used for age-0 indices of the CM-P stock could not be used to develop similar indices for this stock. It would be useful to explore alternative methods to estimate the abundance and F of age-0 fish in the terminal year, and reduce reliance on the short-term projections (Section 3.4.2).

There was limited information on the data sources used to derive the egg abundance index for the BM-P stock. It is assumed in this review that the egg samples were from a survey using a Continuous Underway Fish Egg Sampler (CUFES) system or plankton nets. However, there was detailed information on the method used to standardize the egg abundance index. A Vector Autoregressive Spatio-Temporal (VAST) model was used to standardize the egg abundance index. The VAST standardization model looks reasonable although there was no time to examine the model in detail during the web meeting. One minor quibble would be whether to consider using an additional submodel to model the species composition (blue vs chub) of the eggs instead of using fixed effects based on the chub egg density. This is not expected to change the results substantially. Nevertheless, this review agrees that the inclusion of the chub effect was necessary in the standardization of the egg abundance index. The egg abundance index was used to represent the relative spawner abundance of the BM-P stock, which has been used in other assessments (e.g., Lo et al. 2005). The coverage of the egg samples, standardization model, and reasonable model fit (Section 3.3.2) would suggest that this is an appropriate index of the spawning biomass. However, it should be noted that egg abundance indices are generally thought to be less reliable indicators of spawning abundance than a direct survey of the spawning biomass. It is strongly recommended to maintain this index as the primary index, unless a direct survey of spawning biomass is developed, and continue research and development of this index.

3.1.3 Recommendations on data

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

1) It is recommended to perform experiments to compare different hard parts for aging and to validate the aging.
2) It would also be recommended to obtain reader-specific estimates of bias and error in the aging.
3) If possible, it would be useful to increase sampling to minimize the gaps in the age-length keys. Otherwise, it would be recommended to experiment with interpolating those gaps with fitted seasonal growth models.
4) It was not possible to review the robustness of the length and age sampling program but it would be recommended to examine it at the next review.
5) It is recommended to keep using the standardized egg abundance index as the primary index unless a survey of the spawning biomass is developed. However, it is recommended that the data sources and standardization be documented better and reviewed thoroughly in the future. Continued research and development of this index is encouraged.
6) It is not recommended to continue using the dip-net index and instead explore alternative methods to estimate the abundance and F of age-0 fish in the terminal year, and reduce reliance on the short-term projections.
7) Although not as critical as the BM-ECS and CM-T stocks, it may be useful to explore alternative assessment and management methods for this stock. For example, an observation-based management procedure that sets the catch limits based on a survey of the stock biomass in Japanese waters before the fishing season starts, could be used to manage the stock for Japanese fisheries. However, it would be important to use simulations (e.g., an MSE-type process) to evaluate if such a procedure would meet management objectives and be robust for this stock, including both Japanese and non-Japanese fisheries that are not under the management procedure. Alternatively, data-poor methods can be used to assess the stock but the associated uncertainty would be relatively high and may not be appropriate for the management of this stock.

3.2 Biology

3.2.1 Stock structure and distribution

The stock structure for this stock assessment appears to be appropriate. However, given the lack of time and importance of other issues, there was relatively little discussion on this topic. Given more time, it would have been useful to go over the evidence for the stock structure.

3.2.2 Natural mortality

Similar to the other stocks here, the M of the CM-T stock was assumed to be 0.4 y^{-1} based on a reported A_{max} of 6 years. However, as discussed previously (Section 1.2.2), there appears to be some inconsistencies with this, and more research on M is recommended. Given that there has been more biological research done on this stock than the BM-ECS and CM-T stocks, it would be useful to develop a prior for M, based on a meta-analysis of the biological parameters of the stock (Hamel 2015) or some other approach (e.g., Liu et al. 2020). This prior could in turn be used to estimate M within the assessment model using an integrated assessment model, which could be a better approach if done well (Punt et al. 2021).

3.2.3 Growth

The growth of the BM-P stock is better known than the BM-ECS and CM-T stocks. Growth appears to vary by season and area but the amount of variability was not examined in this review. Seasonal age-length keys for every year are used in this assessment but it may be useful to explore the development and use of area-season-specific age-length keys, especially if the variability of growth by area is large.

3.2.4 Recommendations on biology

Based on the above findings, there are several recommendations for improving the biology used for the BM-P assessment:

1) It is recommended that the natural mortality parameter be subject to a reanalysis. Given that the biological parameters for the BM-P stock are better known than the BM-ECS and CM-T stocks, it would be reasonable to expect quick progress on a meta-analysis using empirical relationships like the Hoenig and/or Pauly relationships. Over the long run, it may be possible to estimate natural mortality within the assessment model using a reasonable prior.
2) It would be recommended to examine the variability of growth by area and season, and if large, it would be recommended to use area and season-specific age length keys.

3.3 Estimation Model

3.3.1 VPA model

The estimation model for the BM-P stock appeared to be a standard VPA model with tuning indices. A VPA makes strict assumptions about the data, which did not appear to be severely violated in this assessment (Section 3.1). However, it may also be beneficial to explore the use of statistical catch-at-age models, which can be more flexible and able to model the data as it is collected. It would also be easier to develop models with alternative hypotheses.

3.3.2 Model diagnostics

The assessment documents did not provide model diagnostics like retrospective patterns and model fit. However, these model diagnostics for both the base case model were shown during the web meeting, after being requested. The egg abundance index was well fit but the dip-net index was poorly fit. This suggested that the dip-net index was inconsistent with the other data sources of this assessment, and its use for future assessments is not recommended or should at least be re-evaluated (Section 3.1.2). The VPA model exhibited minor amounts of retrospective pattern that did not appear to be an important concern.

3.3.3 Uncertainty

Similar to the other stocks here, the treatment of uncertainty in the BM-P assessment was inadequate (see Section 1.3.3 for details). The results and estimates from the VPA model (e.g., spawning biomass, recruitment, N-at-age, F-at-age) were assumed to be known without error. This is not recommended for any assessment. Bootstrapping analyses indicated substantial uncertainty especially near the terminal years. It is known to be more difficult to work with uncertainty in a VPA model. One possibility is to use a bootstrap process to simulate the uncertainty in the data, if possible. However, it may also be beneficial to explore the use of statistical catch-at-age models, which can more easily include the uncertainty in the data and biological processes throughout the model.

3.3.4 Recommendations on estimation model

Based on the above findings, there are several recommendations for improving the estimation model used for the BM-P assessment:

1) It is strongly recommended that model diagnostics be included in the assessment documents.
2) 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.
3) It would be beneficial to explore the use of statistical catch-at-age models, which can be more flexible and more easily include the uncertainty in the data and biological processes throughout the model. It would also be easier to develop models with alternative hypotheses.

3.4 Projections

3.4.1 Stock-recruitment relationship (SRR)

Several candidate SRRs (e.g., Beverton-Holt, Ricker, and Hockey-Stick) were fitted to the estimated historical recruitment and spawning biomass from the VPA model. The Ricker

SRR estimated by the least absolute value method (RI-L1) was selected during a prior meeting to be the SRR for calculating the biological reference points and future projections. The selected RI-L1 SRR was then used to estimate biological reference points and compute future projections.

The choice of SRR appeared to be somewhat arbitrary, with management considerations being highly influential. A Ricker SRR is typically used for species with population dynamics subject to overcompensation (e.g., salmon), rather than for mackerel, and the AIC for the RI-L1 was inferior to the AICs for the HS-L1 and BH-L1 SRRs. However, the reasoning behind using a Ricker SRR was based at least in part that "the recruitment slope for a SSB of 38,000 tons or less was gentle". In addition, a sensitivity analysis on the management performance under a mis-specified SRR suggested that the tradeoff between the risk of lower catches and breaching the historically low SSB level was more conservative for the RI-L1 SRR.

Given that management considerations were clearly important in the choice of SRR, it may not be appropriate for this review to comment on the choice of SRR. Nevertheless, it is noted that there is substantial uncertainty inherent in the SRR that is not reflected in the biological reference points and future projections based on the SRR. For example, the estimated recruitment and spawning biomass used to estimate the SRR was assumed to be known without error. Therefore, the re-sampling of the recruitment and spawning biomass used to estimate the variability of the SRR would have underestimated the variability of the SRR. In addition, the estimated historical recruitment and spawning biomass was relatively flat, which makes it difficult to distinguish between the Ricker, Beverton-Holt and Hockey-Stick. Overall, it may be useful to consider incorporating the uncertainty in the form of SRR into the future projections, calculations of the reference points, and management decisions. This could take the form of a model ensemble approach and allow managers to better understand and incorporate the whole range of risks into their decision making.

Similar to the BM-ECS stock (see Section 1.4.1 for details), an analysis of the SRRs of multiple Japanese stocks (Kurota et al. 2020) indicated that the recruitment of the BM-P stock (spotted mackerel in Kurota et al. 2020) was identified as being significantly environmentally driven. Therefore, it would be advisable to take this into account when assessing and managing the BM-P stock.

3.4.2 Short-term projections

Similar to the BM-ECS and other stocks in this review (see Section 1.4.2 for details), two years of projections are required to bring forward the estimated N-at-age in 2018 to estimate the projected spawning biomass in 2020. The problems for doing so are similar (see Section 1.4.2) although non-Japanese fisheries are less important for the BM-P stock.

Similar to the BM-ECS stock, one way to improve the short-term projections is to develop scientific surveys of the age-0 and age-1 fish of this stock, prior to the start of the fishing season (Section 3.1.3). However, one complication for the BM-P stock is that the spatial range of this stock extends much further than the BM-ECS stock.

3.4.3 Long-term projections

The long-term projections for the BM-P stock were similar to the BM-ECS stock and had similar problems (see Section 1.4.3 for details). The uncertainty for the long-term projections are currently under-estimated because the 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, catches by non-Japanese fisheries are not limited by Japanese management. However, the historical impact of non-Japanese fisheries on this stock appears to be smaller than the other stocks.

3.4.4 Recommendations on projections

Based on the above findings, there are several recommendations for improving the SRR and projections used for the BM-P assessment:

1) Consider incorporating the uncertainty in the estimates or recruitment and spawning biomass, and the form of SRR into the future projections, calculations of the reference points, and management decisions.
2) It is advisable to consider the influence of environmental drivers on recruitment, when assessing and managing the BM-P stock.
3) It is recommended to incorporate that uncertainty in the N-at-age in the terminal year into the short term and long-term projections.
4) It recommended to develop scientific surveys of the age-0 and age-1 fish of this stock, prior to the start of the fishing season.
5) It is recommended not to assume that the F of non-Japanese fisheries are subject to the F-multiplier for the long-term projections.

4. Chub Mackerel - Pacific Stock (CM-P Stock)

The stock assessment, as well as fisheries and management, of the CM-P stock was closely related to the BM-P stock. Therefore this review found similar strengths and weaknesses , and provided similar recommendations. In order to reduce the repetitiveness and lengthiness of the report, references are made to earlier sections when appropriate. However, the recommendations for the CM-P stock are kept separate for the sake of clarity.

4.1 Data

A VPA was used to estimate the population dynamics of the CM-P stock during the historical period. Therefore, the assessment of the CM-T stock had similar assumptions on data as the other stocks (e.g., Section 1.1 and 3.1).

4.1.1 Catch-at-age

The process used to develop the catch-at-age time series for the CM-P stock was highly similar to the BM-P stock (Section 3.1.1). The assessment documents did not provide enough detail on how the catch-at-age time series was developed. However, this review found that the processes used to develop the catch-at-age time series for the CM-P stock were reasonably appropriate and the assumption that the catch-at-age was known without error was not severely violated. Nevertheless, this review found aspects with potential room for improvement.

One key difference between the catch of the CM-P and BM-P stocks is that the catch of Chinese and Russian fisheries constitute a substantial proportion of the total catch of the CM-P stock. Therefore, it is more important to develop accurate information on the catch-at-age of the Chinese and Russian fisheries for this stock. There were thought to be no other major non-Japanese fisheries for this stock. The catch by Chinese and Russian fisheries were based on reported total mackerel (combined blue and chub mackerel) catch reported to the North Pacific Fisheries Commission, and split into blue and chub mackerel catch-at-age. The species/length/age compositions of the Chinese and Russian fisheries is assumed to be the same as similar Japanese fisheries. Although this assumption is reasonable given the current lack of detailed information, it would nevertheless be important to test his assumption in the future, if possible.

Similar to the BM-P stock, seasonal age-length keys for every year were developed and used to convert length compositions to age compositions for the CM-P stock. This is considered to be more appropriate than cohort slicing. However, there were also similar aspects with potential room for improvement and similar recommendations (see Section 3.1.1 for details).

4.1.2 Relative abundance indices

The abundance indices for the CM-P assessment were different from the BM-P assessment. For the CM-P stock. Four tuning indices were fitted to the VPA model: 1) CPUE of age-0 fish from a midwater trawl survey in spring; 2) CPUE of age-0 fish from a midwater trawl survey in fall; 3) a dip-net index from the Izu Islands; and 4) an egg abundance index from samples along the Pacific coast of Japan. The two midwater trawl surveys indices were standardized and used to indicate relative trends in age-0 abundance. Both survey indices appear to be consistent with each other. The dip-net index is used here to represent the spawning biomass abundance trends and is standardized, unlike the BM-P assessment where the dip-net index was used to represent age-0 abundance and was not standardized. It is unclear if this was the same fishery for both the CM-P and BM-P assessments, and why the methods and usage were different. The egg abundance index for the CM-P stock was used to represent the spawning biomass but was not standardized. It was not clear why this index was nominal but the egg abundance index for the BM-P stock was standardized. It is assumed that the data for both egg abundance indices were from the same egg survey. During the web meeting, development of a standardized egg abundance index was shown. It is recommended to use the standardized egg abundance index in the future.

Unfortunately, there was no time to discuss and review these indices in detail during the web meeting and the documentation on them were relatively limited. It is therefore recommended to review the abundance indices in more detail in the future. Nevertheless, some considerations for future development of these indices are included here. Overall, the indices for the CM-P stock followed an increasing trend since about 2005 and were visually similar to the expected trends of the VPA model. However, the estimated residuals between the VPA model and the tuning indices were relatively poor (Section 4.3.2). Therefore, research and development on the abundance indices for the CM-P stock needs to be continued. For the midwater trawl surveys, the inclusion of SST and water temperature at depth may not be appropriate for the standardization model because these variables likely affect the growth, survival, and abundance of age-0 fish, and including these variables may not just standardize the catchability of the trawl (i.e., the objective of standardization). For the dip-net index, it is not clear if the spatial coverage of the fishery covers enough of the spawning biomass to be representative of the stock. For the egg abundance index, it is unclear if the use of a nominal index is appropriate, especially when standardization was clearly important for the BM-P stock.

4.1.3 Recommendations on data

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

1) It is recommended to test the assumption that the species/length/age compositions of the Chinese and Russian fisheries are similar to Japanese fisheries, if possible.
2) It is recommended to perform experiments to compare different hard parts for aging and to validate the aging.
3) It would also be recommended to obtain reader-specific estimates of bias and error in the aging.

4) If possible, it would be useful to increase sampling to minimize the gaps in the age-length keys. Otherwise, it would be recommended to experiment with interpolating those gaps with fitted seasonal growth models.
5) It was not possible to review the robustness of the length and age sampling program but it would be recommended to examine it at the next review.
6) It is recommended to continue research and development on the abundance indices and examine them in more detail at the next review.
7) It is recommended to use a standardized egg abundance index instead of a nominal index.
8) It may be useful to explore alternative assessment and management methods for this stock. For example, an observation-based management procedure that sets the catch limits based on a survey of the stock biomass in Japanese waters before the fishing season starts, could be used to manage the stock for Japanese fisheries. However, it would be important to use simulations (e.g., an MSE-type process) to evaluate if such a procedure would meet management objectives and be robust for this stock, including both Japanese and non-Japanese fisheries that are not under the management procedure. Alternatively, data-poor methods can be used to assess the stock but the associated uncertainty would be relatively high and may not be appropriate for the management of this stock.

4.2 Biology

4.2.1 Stock structure and distribution

The stock structure for this stock assessment appears to be appropriate. However, given the lack of time and importance of other issues, there was relatively little discussion on this topic. Given more time, it would have been useful to go over the evidence for the stock structure.

4.2.2 Natural mortality

Similar to the other stocks, the M of the CM-P stock was assumed to be 0.4 y^{-1}. However, as discussed previously (Section 1.2.2), there appears to be some inconsistencies with this, and more research on M is recommended, especially because there has been more biological research done on this stock than the BM-ECS and CM-T stocks (see Section 3.2.2 for details).

4.2.3 Growth

Similar to the BM-P stock, the growth of the CM-P stock is better known than the BM-ECS and CM-T stocks. The considerations and recommendations for this stock are the same as for the BM-P stock (see Section 3.2.3 for details).

4.2.4 Recommendations on biology

Based on the above findings, there are several recommendations for improving the biology used for the CM-P assessment:

1) It is recommended that the natural mortality parameter be subject to a reanalysis. Given that the biological parameters for the BM-P stock are better known than the BM-ECS and CM-T stocks, it would be reasonable to expect quick progress on a meta-analysis using empirical relationships like the Hoenig and/or Pauly relationships. Over the long run, it may be possible to estimate natural mortality within the assessment model using a reasonable prior.
2) It would be recommended to examine the variability of growth by area and season, and if large, it would be recommended to use area and season-specific age length keys.

4.3 Estimation Model

4.3.1 VPA model

The estimation model was a ridge VPA model (Okamura et al. 2017) due to the large retrospective patterns observed and the large increase in terminal recruitment. See Section 1.3.1 for details on the ridge VPA model. There was not enough time to examine these model problems in depth but the change in method this year was an attempt by the modellers to mitigate the problems. However, it is not clear if the new method is a reasonable solution or simply reducing the symptoms for a short time. Unfortunately, there was not enough time to examine the model and diagnostics in detail. It is therefore not possible to propose potential solutions to the observed problems. It may nevertheless be beneficial to explore the use of statistical catch-at-age models, which can be more flexible and able to model the data as it is collected. It would also be easier to develop models with alternative hypotheses.

4.3.2 Model diagnostics

The assessment documents for the CM-P stock did not provide model diagnostics like retrospective patterns and model fit. However, these model diagnostics for both the base case model were shown during the web meeting, after being requested. The model diagnostics indicated that the indices for this assessment were not well fit and there were large retrospective patterns. The use of the ridge VPA reduced the retrospective bias somewhat but likely resulted in a tradeoff with poor model fit to the indices (see Section 1.3.1). It is unclear if such a tradeoff is a good idea.

4.3.3 Uncertainty

Similar to the other stocks here, the treatment of uncertainty in the CM-P assessment was inadequate (see Section 1.3.3 and 3.3.3 for details). There were large uncertainties throughout the assessment but there was minimal consideration of uncertainty in the data, modelling, and results of the assessment.

4.3.4 Recommendations on estimation model

Based on the above findings, there are several recommendations for improving the estimation model used for the CM-P assessment:

1) It is strongly recommended that model diagnostics be included in the assessment documents.
2) 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.
3) It would be beneficial to explore the use of statistical catch-at-age models, which can be more flexible and more easily include the uncertainty in the data and biological processes throughout the model. It would also be easier to develop models with alternative hypotheses.

4.4 Projections

4.4.1 Stock-recruitment relationship (SRR)

The process to select the SRR for the CM-P stock was similar to the other stocks (see Section 1.4.1 for details). The Hockey-Stick SRR estimated by the least squares method (HS-L2) was selected for the CM-P stock. However, unlike the other stocks, significant autocorrelation was detected and included in the relationship.

Similar to the other assessments, management considerations appeared to be highly influential in the choice of SRR for the CM-P stock. There was also no time during the web meeting to discuss the SRR. Given those considerations, it may not be appropriate for this review to comment on the choice of SRR. Nevertheless, it is noted that there is substantial uncertainty inherent in the SRR that is not reflected in the biological reference points and future projections based on the SRR. For example, the estimated recruitment and spawning biomass used to estimate the SRR was assumed to be known without error. Therefore, the re-sampling of the recruitment and spawning biomass used to estimate the variability of the SRR would have underestimated the variability of the SRR. In addition, the estimated historical recruitment appeared to be strongly influenced by two regimes. Overall, it may also be useful to consider incorporating the uncertainty in the form of SRR into the future projections, calculations of the reference points, and management decisions. This could take the form of a model ensemble approach and allow managers to better understand and incorporate the whole range of risks into their decision making.

Similar to the CM-T stock (see Section 2.4.1 for details), an analysis of the SRRs of multiple Japanese stocks (Kurota et al. 2020) indicated that the recruitment of the CM-P stock was identified to be influenced by both spawning biomass and environmental drivers. Therefore, it would be advisable to take this into account when assessing and managing the CM-P stock.

4.4.2 Short-term projections

Similar to the other stocks in this review (see Section 1.4.2 for details), two years of projections are required to bring forward the estimated N-at-age in 2018 to estimate the projected spawning biomass in 2020. The problems for doing so are similar (see Section 1.4.2). Similar to the BM-ECS stock, one way to improve the short-term projections is to develop scientific surveys of the age-0 and age-1 fish of this stock, prior to the start of the fishing season (Section 4.1.3). However, one complication for the CM-P stock is that the spatial range of this stock extends much further than the BM-ECS stock.

4.4.3 Long-term projections

The long-term projections for the CM-P stock were similar to the other stocks, with similar problems (see Section 1.4.3 for details). The uncertainty for the long-term projections are currently under-estimated because the 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, catches by non-Japanese fisheries are not limited by Japanese management. Therefore, it may not be reasonable to assume that the F-multiplier applies to non-Japanese fisheries as well.

4.4.4 Recommendations on projections

Based on the above findings, there are several recommendations for improving the SRR and projections used for the CM-P assessment:

1) Consider incorporating the uncertainty in the form of SRR into the future projections, calculations of the reference points, and management decisions.
2) It is advisable to consider the influence of both environmental drivers and the spawning biomass on recruitment, when assessing and managing the stock.
3) It is recommended to incorporate that uncertainty in the N-at-age in the terminal year into the short term and long-term projections.
4) It recommended to develop scientific surveys of the age-0 and age-1 fish of this stock in Japanese waters, prior to the start of the fishing season.

5) It is recommended not to assume that the F of non-Japanese fisheries are subject to the F-multiplier for the long-term projections.

5. Conclusions

Detailed reviews and recommendations of each assessment can be found in their specific section. However, there appeared to be broad patterns that could be discerned.

Most importantly, the estimated population dynamics of the BM-ECS and CM-T stocks during the historical period (i.e., results from the VPA models), as well as the downstream analyses, likely have large errors and biases. A substantial amount of work is required to improve the data sources for the BM-ECS and CM-T stocks. The most critical, and likely difficult, task is to obtain accurate catch-at-age time series for non-Japanese fisheries. Even for the Japanese fisheries, there does not appear to be a robust biological sampling program for the BM-ECS and CM-T stocks. In addition, the abundance indices also require substantial work. Given the large amount of work needed for improving the assessments of the BM-ECS and CM-T stocks, it would be important to provide enough resources for the work to be done.

It may be useful to consider alternative assessment and/or management methods for the BM-ECS and CM-T stocks. For example, an observation-based management procedure that sets the catch limits based on a survey of the stocks in Japanese waters before the fishing season starts, could be used to manage the stocks for Japanese fisheries. However, it would be important to use simulations (e.g., an MSE-type process) to evaluate if such a procedure would meet management objectives and be robust for the stocks, including both Japanese and non-Japanese fisheries that are not under the management procedure.

The data sources for the BM-P and CM-P stocks were substantially better because: 1) all major sources of catch were included; 2) seasonal age-length keys were developed each year through biological sampling and used to convert length to age compositions; and 3) surveys were available as abundance indices. However, there remains room for improvement in the assessments, especially in how hard parts are sampled and aged, as well as the development of standardized abundance indices.

For all four stock assessments, the natural mortality was assumed to be 0.4 y^{-1} based on a reported maximum age of 6 years, which is inconsistent with other research. Given the importance of this parameter, more research on natural mortality is recommended. It would be useful to develop a prior for natural mortality. This prior could in turn be used within an integrated assessment model, which could be a better approach if done well.

The treatments of uncertainty in all four assessments were inadequate. Uncertainties are inherent throughout the assessments but there was not enough consideration of uncertainty in the data, modelling, and results of the assessments. For example, the estimated population and fishery dynamics (N-at-age, recruitment, spawning biomass, and F-at-age) in the terminal years were assumed to be known without error, which is not recommended for any assessment. When the N-at-age and F-at-age are used in the projections without uncertainty, the estimated probability distributions from the projections will likely be erroneous. Similarly, the use of estimated recruitment and spawning biomass without uncertainty in the stock-recruitment relationships will likely result in an underestimate of the uncertainty in these relationships. It would likely be beneficial to explore the use of statistical catch-at-age models, which can more easily include the uncertainty in the data and biological processes throughout the model.

All four stocks required two years of projections to bring forward the estimated N-at-age in 2018 to estimate the projected spawning biomass in 2020. These short-term projections are highly sensitive to the estimates of age-0 and age-1 fish in the terminal year but are highly uncertain due to the lack of repeated observations on those age classes. For some stocks, this is compounded by substantial non-Japanese catches that are not limited by Japanese managemen. In addition, the N-at-age and F-at-age used for the projections were assumed to be known without error. Therefore, the projected spawning biomass in 2020, on which the allowable catch is calculated from, is more uncertain than is currently assumed. Similar issues are also apparent for the long-term projections.

References

Crone, P. R., K. T. Hill, J. P. Zwolinski, and M. J. Kinney. 2019. Pacific Mackerel (*Scomber japonicus*) Stock Assessment for U.S. Management in the 2019-20 and 2020-21 fishing years. Page 112 p. Pacific Fishery Management Council, Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, OR 97220.

Hamel, O. S. 2015. A method for calculating a meta-analytical prior for the natural mortality rate using multiple life history correlates. ICES Journal of Marine Science 72(1):62–69.

Kurota, H., C. S. Szuwalski, and M. Ichinokawa. 2020. Drivers of recruitment dynamics in Japanese major fisheries resources: Effects of environmental conditions and spawner abundance. Fisheries Research 221:105353.

Liu, C., S. Zhou, Y.-G. Wang, and Z. Hu. 2020. Natural mortality estimation using tree-based ensemble learning models. ICES Journal of Marine Science 77(4):1414–1426. Oxford Academic.

Lo, N. C. H., B. J. Macewicz, and D. A. Griffith. 2005. Spawning biomass of Pacific sardine (Sardinops sagax), from 1994-2004 off California. Pages 93–112 California Cooperative Oceanic Fisheries Investigations Reports.

Okamura, H., Y. Yamashita, and M. Ichinokawa. 2017. Ridge virtual population analysis to reduce the instability of fishing mortalities in the terminal year. ICES Journal of Marine Science 74(9):2427–2436.

Punt, A. E., C. Castillo-Jordán, O. S. Hamel, J. M. Cope, M. N. Maunder, and J. N. Ianelli. 2021. Consequences of error in natural mortality and its estimation in stock assessment models. Fisheries Research 233:105759.

Punt, A. E., D. C. Smith, K. KrusicGolub, and S. Robertson. 2008. Quantifying age-reading error for use in fisheries stock assessments, with application to species in Australia's southern and eastern scalefish and shark fishery. Canadian Journal of Fisheries and Aquatic Sciences 65(9):1991–2005.

Shiraishi, T., K. Okamoto, M. Yoneda, T. Sakai, S. Ohshimo, S. Onoe, A. Yamaguchi, and M. Matsuyama. 2008. Age validation, growth and annual reproductive cycle of chub mackerel Scomber japonicus off the waters of northern Kyushu and in the East China Sea. Fisheries Science 74(5):947–954.

Szuwalski, C. S., K. A. Vert-Pre, A. E. Punt, T. A. Branch, and R. Hilborn. 2015. Examining common assumptions about recruitment: A meta-analysis of recruitment dynamics for worldwide marine fisheries. Fish and Fisheries 16(4):633–648.

Zwolinski, J. P., and D. A. Demer. 2014. Environmental and parental control of Pacific sardine (Sardinops sagax) recruitment. ICES Journal of Marine Science: Journal du Conseil 71(8):2198–2207.

Appendix 1 - Terms of Reference

Terms of reference for the Peer Review of Japanese domestic fishery stock assessment

Independent peer review is conducted by external experts on Japanese domestic fishery stock assessment reported by Fishery Research and Education Agency (hereafter, FRA) to evaluate the scientific appropriateness of its assessments. External experts review the appropriateness of the stock assessment and provide recommendation and suggestions for future improvements. FRA either reflects the recommendations to future stock assessment process or provides valid explanation in a document if the suggested proposal is not applicable. The peer review process is performed in accordance with the following tasks:

1. Peer review process is organized by the Secretariat of Peer Review and requires three independent reviewers for each stock: two Japanese reviewers and one overseas reviewer.
2. Japanese reviewers are appointed by the Japanese Society of Fisheries Science (JSFS). Overseas reviewer is appointed from the experts recommended by the National Ocean and Atmospheric Administration (NOAA).
3. In principle, the peer review process is conducted by peer review of the stock assessment report and panel meeting. FRA is required to send stock assessment report to Japanese reviewers few months prior to the panel meeting. For an overseas reviewer, FRA is required to prepare and send English-translated stock assessment report few months prior to the panel meeting. Panel meeting is organized by three independent reviewers, stock assessment team, the Secretariat of Peer Review, and other FRA personnel. In the panel meeting, explanation on stock assessment report is provided by the stock assessment team and question-and-answer session is provided by the independent reviewers.
4. Each independent reviewer prepares a peer review report and submits the document to FRA after peer-reviewing the stock assessment report and attending the panel meeting. A peer review report is roughly 10 pages long and contains the following 7 elements A)-G). After the submission, the Secretariat of Peer Review creates the report of the panel meeting.

    A) Determine whether the data used for stock assessment are adequate to understand the stock dynamics of the target species and represent the best scientific information available (BSIA).
    B) Discuss whether the biological parameters used for stock assessment are appropriate.
    C) Discuss whether the basic biological information such as distribution, migration pattern, and population are appropriate.
    D) Evaluate whether the stock assessment methodology is based on the most appropriate available study and performed analytically.

E) Evaluate whether the data are treated statistically correctly.

F) Evaluate whether the stock assessment result obtained from the input data and methodology used is appropriate.

G) Evaluate the validity of methodology and result used for the future projection.

5. The Secretariat of Peer Review publishes the peer review report on web page in Japanese and English. Each peer review report is followed by the document of countermeasure that FRA shall take. The proceeding of the panel meeting is also published along with the reports.