

Report of an Independent Peer Review of Japanese Anchovy, Japanese Seabream, and Bastard Halibut Stock Assessments Conducted by the Japan Fishery Research and Education Agency (FRA) in 2023

By

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December 28th, 2023

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1. Summary

Assessments of two Japanese anchovy (*Engraulis japonicus*), two Japanese seabream (*Pagrus major*) and one Bastard halibut (*Paralichthys olivaceus*) stocks were conducted by the Japan Fishery Research and Education Agency (FRA) in 2023. These five stock assessments were on the: 1) Japanese anchovy - Pacific (JA-P) ; 2) Japanese anchovy - Tsushima (JA-T); 3) Japanese seabream – western Sea of Japan and East China Sea (JS-ECS); 4) Japanese seabream – central and western Seto Inland Sea (JS-SIS); and 5) Bastard halibut - Seto Inland Sea (BH-SIS) stocks. An independent peer review meeting of these assessments was organized by the Secretariat of Peer Review of the FRA in November 2023. This report is an independent review of the five assessments based on my personal opinions of the submitted documents and clarifications during the meeting. The primary aims for this review were to evaluate if the current stock assessments were based on the best scientific information available (BSIA) and recommend improvements for future stock assessments.

All five assessments used virtual population analysis (VPA) models (i.e., cohort analysis) to estimate the population dynamics of the stocks during the historical period. Critically, a VPA model assumes that the catch-at-age is known without error. Therefore, this review focused on examining the data preparation and determining if this assumption was violated. Developing the catch-at-age time series depends largely on two components: 1) the total catch; and 2) the age composition of the catch. Based on the assessment documents and the meeting, this review concluded that all five stock assessments violated the assumption that the catch-at-age was known without error, to various degrees, which likely led to large errors and biased results of the VPA models and assessments. Therefore, all five stock assessments did not meet the criteria of being BSIA. For future assessments, it was recommended to consider if the quality of the catch-at-age data will be substantially improved to meet the requirements of a VPA model. If the quality of the catch-at-age data will likely remain similar in the future, it is strongly recommended to explore the use of integrated models to allow modeling of the appropriate processes for the population and observations (i.e., bringing the model to the data), rather than having to make strong but invalid assumptions about the data to fit a VPA model.

Importantly, the total catch used for two stock assessments (JA-T, JS-ECS, and JS-SIS) were considered inappropriate because non-negligible amounts of catch of the stocks by non-Japanese or recreational fisheries were excluded. The reasons for excluding these catches were that catch data from these fisheries were often more uncertain and untimely compared to Japanese commercial fisheries, and did not have corresponding age compositions. In addition, the non-Japanese fisheries are not subject to Japanese domestic fishery management and it is unclear what the catch and/or effort level of these non-Japanese fisheries would be in the future. This review concluded that these were not appropriate reasons to exclude catches from non-Japanese fisheries because there was enough information to develop catch-at-age time series using available data from a combination of Japanese and non-Japanese sources. Even if uncertain, it is inappropriate to assume the catch by these non-Japanese or recreational fisheries is zero, which is what is currently assumed. It is critical that all catches on a stock be included

in an assessment model because the primary objective of an assessment model is to assess the impact of fishing (i.e., the input signal on the system) on the population dynamics of the stock (i.e., the response of the system to the input signal). Neglecting these sources of catch would have biased the model results, including estimates of spawning stock biomass (SSB), recruitment and fishing mortality (F). In some cases, it may be useful to develop model ensembles that cover a range of reasonable scenarios for these non-Japanese and recreational fisheries to help inform decision making. If the decision making process requires focusing only on Japanese fisheries, it would be important to reconsider the current model-based assessment approach, and instead consider an observation-based management procedure that sets the stock's fisheries management (e.g., catch limits) based on a survey of the stock's biomass in Japanese waters.

It should be highlighted that the age compositions for one stock (JS-SIS) in this review were considered to be BSIA. The JS-SIS stock was the only stock with year-, month- and area-specific ALKs that were developed from age-length data gathered through regular sampling of the fishery, and used to convert the length compositions into age compositions. All the other four stocks did not have regular sampling and aging of hard parts of the catch, and instead made strong assumptions about invariant age-length relationships. However, upon closer examination, these assumptions were found to be violated and the age compositions from these four stocks were not considered to be BSIA. In addition, the availability and/or quality of the abundance indices were highly variable and exhibited substantial room for improvements.

Interestingly, the Japanese anchovy stocks (JA-P and JA-T) have shirasu fisheries with substantial amounts of catch. Given the very small size of individuals captured by the shirasu fishery, the population removals by the shirasu fishery, in terms of numbers of fish, are likely to be substantially larger than the fisheries included in the assessment. However, it is currently unclear how to include these removals in stock assessment models. These pre-recruitment fish are still subject to density-dependent processes and very high mortality. Preliminary VPA models were developed that included these shirasu removals but the results were considered to be unreasonable because of extremely high recruitment estimates. These unreasonably high recruitment estimates were likely due to the assumed natural mortality rates and the assumption that these removals were post-recruitment. This review recommends including these shirasu removals in future assessments but substantial research is required to develop models that can include pre-recruitment fisheries.

An unusual feature of the other three stock assessments (JS-ECS, JS-SIS, and BH-SIS) was the supplementation of natural recruitment by hatchery releases (i.e., stock enhancement) and the integration of these hatchery releases into the wild SSB, stock assessments, and fishery management. An overview of the stock enhancement program for all three stocks was presented at the review meeting to the review panel. The aims of the stock enhancement program were to contribute to the enlargement of future SSB and catch by releasing hatchery-reared recruits to supplement wild-origin recruitment. Subsequently, a transition from stock enhancement to stock management is to be promoted for stocks that had completed the goal of stock enhancement or is able to sustain the stock level with

reduced levels of hatchery releases. The stock enhancement program collects and rears wild fish as spawning stock in hatcheries. These hatchery releases were considered to be biologically similar to natural recruits and after maturity, considered to be part of the wild SSB. Importantly, hatchery releases have morphological characteristics that allow hatchery releases to be identified. The hatcheries are managed by the prefectural governments and there are currently no regulatory limitations on the number of hatchery releases for these stocks. Overall, the aim of the stock assessment and management of these three stocks was to assess and manage the fishery and fish stocks, including both wild and hatchery-released fish. At the same time, it was important for the assessment to assess the source of recruits (wild or hatchery) into the fishery. Therefore, the assessment had to estimate the contributions of wild versus hatchery-released recruits into the population, while disregarding the source when estimating the F-at-age and SSB. This approach was considered to be unusual by this review and there was much discussion on the impact of this. Discussions centered on the conceptual use of SRRs and MSY reference points for the assessment and management of these stocks. In addition, the importance of considering the hatchery releases as mark and recapture experiments was highlighted. For example, it was considered important to obtain data on the marking rates, mark loss rates, and identification rates of 'recaptured' fish for each batch of releases. These data could then be used in integrated assessment models as mark-recapture data. It was recommended that sampling and aging programs for these stocks include protocols to identify and age hatchery releases, as well as collect data on the marking rates, mark loss rates, and identification rates for hatchery releases.

The biological information and parameters used for all the assessments had substantial room for improvement. The stock structures for most, but not all, stocks appeared to be appropriate, given the current available information. More work on the stock structure is recommended, especially for the JA-T, JS-ECS and BH-SIS stocks. In addition, there was also a clear need to re-evaluate and improve the natural mortality (M) parameters for all the stocks, using up-to-date scientific information.

Given that the primary data inputs for all five assessments were not considered to be BSIA, this review concluded that the results of the VPA models were also not BSIA. This review did not spend much time on the VPA methodology because it was clear that the data issues identified precluded the model results from being considered as BSIA. One concern was that the treatment of uncertainty in all five assessments were considered inadequate. All five assessments did not consider uncertainty in the VPA model at all. Importantly, all five assessments assumed that the estimated population structure (N-at-age) and F-at-age in the terminal years of the VPA models were known without error, and these were in turn used to estimate the stock-recruitment relationships (SRRs) and in the projections. Given that the estimated N-at-age and F-at-age have uncertainties, the probability distributions from the projections will likely be erroneous if these uncertainties were not included. 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 working with uncertainties in VPA models is more difficult, especially when the data were not developed according to the assumptions made. However, incorporating and propagating uncertainty from the data and estimation models through to the projections is important because the

probability distributions from the projections appeared to be important for decision making. For all five stocks, it was recommended to explore the use of integrated models to allow modeling of the appropriate processes for the population and data (i.e., bring the model to data), rather than having to make strong, unsubstantiated assumptions about the data to fit a model with stringent data requirements. These integrated models can be more flexible and more easily include and propagate the uncertainty in the data and biological processes throughout the model. It would also be easier to develop models with alternative hypotheses. For the stocks with hatchery releases, it was recommended to integrate mark and recapture data from hatchery releases into the assessment model, which will help improve the model results.

All five assessments used the VPA model outputs to estimate the SRRs and in the short- and long-term projections. Given that the data inputs and results from the VPA models were not considered to be BSIA, the short- and long-term projections were also considered to be not BSIA. All five assessments required short-term projections to bring forward the estimated N-at-age in the terminal year of the VPA model to the current fishing year and set the allowable catch based on the projected SSB. In terms of methodology, the projection models were relatively straightforward and appropriate, given the information available. However, it is important to note that the projected SSB in the projected year, on which the allowable catch is calculated from, is highly uncertain and the uncertainties in these projections are currently under-estimated. Basing the allowable catch on the short-term projections may lead to large mismatches between expectations and observations. Multi-decadal long-term projections were used to estimate the appropriate F-multiplier (e.g., relative to F_{MSY}) to achieve the management objectives. The models used for the long-term projections were similar to the short-term projections, and were relatively straightforward and appropriate. However, similar to the short-term projections, the uncertainties for the long-term projections are currently under-estimated.

2. Background

Assessments of two Japanese anchovy (*Engraulis japonicus*), two Japanese seabream (*Pagrus major*) and one Bastard halibut (*Paralichthys olivaceus*) stocks were conducted by the Japan Fishery Research and Education Agency (FRA) in 2023. These five stock assessments were on the: 1) Japanese anchovy - Pacific (JA-P) ; 2) Japanese anchovy - Tsushima (JA-T); 3) Japanese seabream – western Sea of Japan and East China Sea (JS-ECS); 4) Japanese seabream – central and western Seto Inland Sea (JS-SIS); and 5) Bastard halibut - Seto Inland Sea (BH-SIS) stocks. All five assessments were led by the Fisheries Stock Assessment Center, Fisheries Resources Institute of the FRA, in collaboration with other scientific organizations.

All five assessments were broadly similar and consisted of five phases. First, time series of catch-at-age and abundance indices (if available) were developed for each stock and a virtual population analysis (VPA) model was used to estimate the historical population dynamics. Importantly, the VPA model 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, short-term (two or three year) projections were used to bring forward the estimated N-at-age in the terminal year of the VPA model (e.g., 2019) to the current year (e.g., 2021). 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 model. 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 – 20 year) projections were used to test the robustness of the HCRs to reach management objectives.

3. Review Process

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 one reviewer from Japan, who was appointed by the Japanese Society of Fisheries Science, and two overseas reviewers from the National Oceanic and Atmospheric Administration of the USA, including myself. The in-person meeting was held during November 7-9, 2023, and included English-Japanese translators to ease language difficulties.

Assessment documents were translated from Japanese to English, and submitted to reviewers before the meeting. In order to help FRA scientists prepare for the meeting, initial questions on the assessments were submitted prior to the meeting, with follow up questions during the meeting. The documentation for each assessment consisted of a main assessment document, and depending on the assessment, several appendices.

This report is an independent review of the five assessments based on my personal opinions of the submitted documents and clarifications during the meeting. There was no communication between the other reviewers and I, with regards to this report. The submitted assessment documents were not detailed enough to conduct a thorough technical ‘desktop’ review. The lack of detailed documentation and time, made it difficult to thoroughly review all aspects of the assessments. Nevertheless, this review attempts to cover the specified ToRs. It should be noted that there was no opportunity to review and recommend alternative model configurations for the models. Instead, the primary aims for this review were to evaluate if the current data and stock assessments were based on the best scientific information available (BSIA), and recommend improvements for future stock assessments.

This report is subdivided into separate sections for each stock and a section summarizing the overall findings. As specified in the ToRs, the data, biology (i.e., information and parameters), methodology, and results from the assessment and projection models of each stock were reviewed and evaluated. The assessments of Japanese anchovy stocks (JA-P and JA-T) were reviewed first, followed by the Japanese seabream stocks (JS-ECS and JS-SIS), and the Bastard halibut (BH-SIS) stock. If a comment was applicable to multiple stocks, the reader will be referred to earlier sections whenever possible to reduce

the report length and repetitiveness. However, the recommendations for each stock were kept separate for the sake of clarity.

4. Japanese Anchovy – Pacific Stock (JA-P Stock)

4.1 Data

A VPA model (i.e., cohort analysis) was used to estimate the population dynamics of the JA-P 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 substantially violated. In addition, the abundance indices used as tuning indices for the VPA model were also examined.

4.1.1 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. Substantial discussion during the meeting was focused on this part of the assessment. Overall, this review found that the catch-at-age data used for the JA-P stock assessment were not likely to be BSIA because the same age-length key (ALK) was used for all areas and all years. Using the same ALK assumes that the age-length relationship (i.e., growth) of this stock was invariant for all areas and years, which was not supported by the available evidence and did not reflect the changes in growth. In addition, using a single ALK also assumes that age-related processes, like age-based movements and selectivities, were negligible or constant for this stock. Overall, the assumption that the catch-at-age was known without error appeared to have been violated, and likely led to errors and may have biased the results of the VPA model and assessment.

The time series of total catch used in this assessment only included catches from Japanese fisheries on post-recruitment anchovy. It did not include catch by the Japanese shirasu fishery, which capture 20,000 – 25,000 mt of post-larval anchovy annually. There was substantial discussion of the shirasu fishery during the meeting. Given the very small size of individuals captured by the shirasu fishery, the population removals by the shirasu fishery, in terms of numbers of fish, are likely to be substantially larger than the fisheries included in the assessment. However, it is currently unclear how to include these removals fish in stock assessment models. These pre-recruitment fish are still subject to density-dependent processes and very high mortality. Preliminary VPA models were developed that included these shirasu removals but the results were considered to be unreasonable because of extremely high recruitment estimates. These unreasonably high recruitment estimates were likely due to the assumed natural mortality rates and the assumption that these removals were post-recruitment. This review recommends including these shirasu removals in future assessments but substantial research is required to develop models that can include pre-recruitment fisheries. The distribution of this stock is largely within the EEZ of Japan and catches by non-Japanese fisheries were assumed to be negligible. This

review considered this assumption to be reasonable. However, this review recommends that more work be done to document the activities of non-Japanese fisheries operating within the range of this stock, especially during 'high' regimes.

Monthly ALKs were developed to convert length distributions into age distributions. However, the same ALK was used for all years and areas. Since 2008, the same length-weight relationship was used for all areas and years to convert total catch in weight to total catch in numbers. The total catch in numbers were combined with the age distributions to obtain the catch-at-age data used in the VPA model. The ALKs were based on length measurements (1978 – present) and age readings of scales from sampled anchovies (2000 – 2017). Age readings were done for four areas (Hokkaido, Ibaraki, Chiba, and Kochi) from 2000 to the present, with variable coverage by area but the age data during 2018 to the present is currently being reorganized and not used for the assessment. Using the same ALK for all areas and years assumes that the age-length relationship (i.e., growth) of this stock was the same for all areas and years. No evidence was presented to support this assumption. Data from other similar species (Kuriyama et al. 2021) suggest that this assumption is not valid and does not reflect the likely variability in growth. In addition, using a single ALK also assumes that age-related processes, like age-based movements and selectivities, were negligible or constant for this stock. It was unclear if these assumptions were supported. Using the same length-weight relationship since 2008 assumes that weight-at-length is constant since 2008. An analysis of the length-weight relationships by year during 1998-2007 suggest non-negligible interannual variability in the length-weight relationships. This suggests that the assumption of a constant weight-at-length for all years is not valid and will likely result in biased estimates of total catch in numbers. There was no discussion of the sampling designs for the length distributions and scale samples due to lack of time. It is assumed here that the sampling designs were robust and appropriate but should be reviewed in the future. It was noted that reading scales are more likely to lead to biased ages as compared to reading otoliths. Therefore, it was recommended to perform experiments to compare different hard parts for aging and to validate the ages. If validation experiments are not feasible, it would nevertheless be useful to obtain reader-specific estimates of bias and error (Punt et al. 2008).

In general, it was recommended to develop year- and area-specific ALKs and length-weight relationships. It was unclear if the data to do so was already being collected but required reorganizing, or sampling programs need to be improved. If some ALKs have some bins with missing data, likely due to insufficient sampling, it may be useful to experiment with interpolating those gaps with fitted seasonal growth models.

4.1.2 Relative abundance indices

Two tuning indices were used in the JA-P assessment: 1) an egg production index (EPI) was used to represent trends in the SSB; and 2) the Northward Survey index (NSI) is an age-0 index based on a midwater trawl survey. Based on the discussions during the meeting, this review considered the EPI index to be BSIA, albeit with room for improvements, but the NSI index was not considered BSIA.

The EPI is based on the aggregated catch of eggs and larvae in 30-minute squares during large-scale monthly egg and larval surveys conducted by prefectural fisheries institutes and the FRA during 1982 to the present. The egg and larval surveys extend along the Pacific Coast of Japan, from Kyushu to the south of Tohoku, and covers the spatial extent of the spawning ground during both low and high abundance periods. Currently, the EPI is an aggregate of the eggs and larvae sampled per unit effort of the surveys. However, the egg production of individual fish is variable and is affected by various biological parameters like batch fecundity, spawning fraction, sex ratio, and average fish weight. If adult fish are sampled in conjunction with the egg samples, the daily egg production method (DEPM) may be used to estimate SSB from the egg surveys (Lo et al. 2005). In surveys of other small pelagic stocks around the world, egg production is often used with spatial-temporal models to provide spatially and temporally explicit estimates of egg production, daily fecundity, and SSB (Stratoudakis et al. 2006). In addition, continuous underway fish egg sampler (CUFES) systems are often used to improve spatial coverage and lower survey costs. It was recommended that the DEPM approach be considered for future assessments.

The NSI is based on the age-0 CPUE of a midwater trawl survey conducted by the FRA in the Kuroshio-Oyashio transition zone and the Oyashio region during June-July since 2001. The spatial extent of the midwater trawl survey does not match the spatial distribution of age-0 fish of this stock. During the meeting, maps of the survey CPUE (Fig. 1) showed that the CPUEs were highly patchy and the highest CPUE areas were often at the southern edge of the survey. In addition, it was reported that anchovies are predominantly distributed along the coast during 'normal' recruitment regimes but become widely distributed in the Kuroshio-Oyashio regions during 'high' recruitment periods. It was clear that the survey only covers a portion of the spatial range of the age-0 fish of this stock, and areas with high CPUE may be outside of the survey area. Moreover, the survey area does not correspond to the coastal distribution of this stock during 'normal' recruitment regimes. This was reflected in the relatively abrupt drops in the index during the recent 'normal' period compared to the EPI index, and the catchability of the NSI was likely not constant over time. Therefore, the age-0 CPUE from this survey was likely not representative of the age-0 abundance of this stock, especially during 'normal' recruitment regimes in recent years. It was also reported that the definition of age-0 fish from this survey was not based on aging samples but rather assuming that fish <10.5 cm SL are age-0 fish. However, the ALK used to develop the catch-at-age in Section 4.1.1 suggests that the majority of 9-10.5 cm fish in June-July are likely to be age-1 fish. It was recommended to expand the survey area to cover the entire spatial range of the age-0 fish of this stock, and perform aging of the samples.

There were limited details in the documentation and not enough time during the meeting to review the indices in detail. Nevertheless, it was noted that both indices were nominal indices (i.e., unstandardized), with an implicit assumption that catchability was constant for these indices. However, given that both indices were based on surveys, this assumption may be reasonable if both surveys are well-designed. However, the NSI survey was not well designed for this stock and the NSI likely did not have constant catchability. It was also reported during the meeting that these surveys were multi-

species surveys and therefore had multiple objectives. It was strongly recommended to review the design of these surveys with respect to the objectives of a stock assessment before using the survey data for an assessment. It was noted that uncertainties for both indices were not estimated because standardization was not performed. It was strongly recommended to estimate the uncertainty of the indices, even if standardization was not performed.

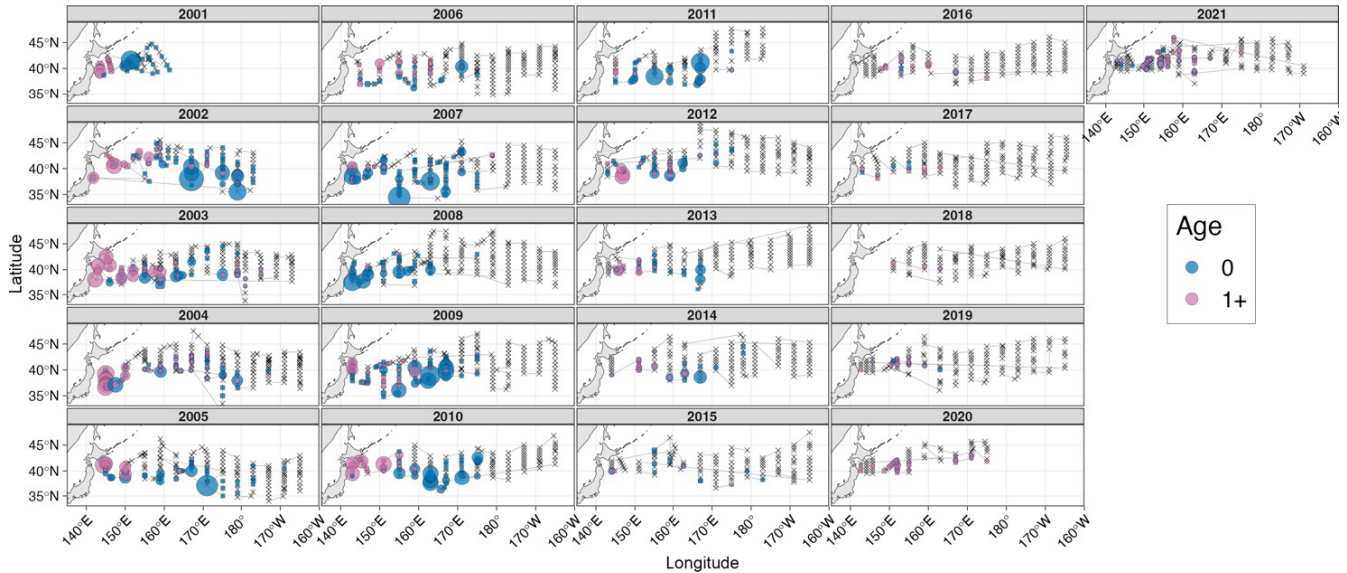


Figure 1. Annual maps of age-0 and age-1+ CPUE of the Northward Survey.

There was also some discussion on the viability of using a combination of acoustics and midwater trawl data (i.e., acoustic-trawl method) to obtain length- or age-specific abundance, as in surveys conducted by NOAA in the California Current System (Zwolinski et al. 2016). However, it was reported that there were many more species caught in the Japanese surveys than the California surveys, and it was currently impractical to use the acoustic-trawl method for Japanese waters. It was nevertheless recommended to conduct research on using a combination of acoustics and trawl data to provide synoptic estimates of biomass of this and other small pelagic stocks.

4.1.3 Recommendations on data

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

- 1) It was recommended that more work be done to document the activities of non-Japanese fisheries operating within the range of this stock, especially during ‘high’ regimes.
- 2) It was recommended to include shirasu removals in future assessments but substantial research is required to develop models that can include pre-recruitment fisheries.

- 3) It was recommended to develop year- and area-specific age-length keys and length-weight relationships unless there is strong evidence that these do not vary by year and area.
- 4) It was recommended to compare different hard parts, validate the aging, and/or provide estimates of reader-specific aging bias and error.
- 5) It was recommended that the daily egg production method approach and spatial-temporal models be considered for the Egg Production Index.
- 6) It was recommended to not fit to the Northward Survey Index unless the survey is expanded to cover the entire spatial range of the age-0 fish of this stock, including the coastal areas, and perform aging of the sampled fish.
- 7) It was strongly recommended to review the design of these surveys for the Egg Production Index and Northward Survey Index with respect to the objectives of using the indices for a stock assessment.
- 8) It was strongly recommended to estimate the uncertainty of the indices, even if standardization was not performed.
- 9) It was recommended to conduct research on using a combination of acoustics and trawl data to provide synoptic estimates of stock biomass.

4.2 Biology

4.2.1 Stock structure and distribution

The stock structure for this assessment was considered BSIA, given the current available information. However, it was encouraged to continue research on this topic.

4.2.2 Natural mortality

The natural mortality (M) of the JA-P stock was assumed to have an average value of 1.4 y^{-1} based on the empirical relationships developed by Pauly (1980) and Quinn and Deriso (1999). This average M value was assumed to be further distributed into age-specific M values ranging from 1.0 y^{-1} for age-0 to 1.9 y^{-1} for age-3+. There was substantial discussion at the meeting on the assumptions and reasoning behind the age-specific M values. Overall, the age-specific M values appeared to be not well supported by evidence and based at least in part on whether assessment results with these M values were reasonable. It was noted that in 2021, the anchovy assessment in the Eastern Pacific Ocean (Kuriyama et al. 2021) had estimated an average M of $0.41 \pm 0.13 \text{ y}^{-1}$, although Kuriyama et al. (2021) also noted that previous assessments had assumed higher fixed values for M . In light of this discussion, this review considered the average M value to be BSIA but the further distribution of the average M value into age-specific M values was not. It was strongly recommended that the M values for this stock to be re-evaluated and improved. It was recommended that future assessments consider estimating M within the assessment model. If estimating M within the assessment model is not possible, it was

recommended to perform a series of sensitivity runs that represent the estimated uncertainty of the M values (e.g., Hamel 2015), and reasonable, alternative M patterns (e.g., average M for all ages; Lorenzen size-specific M). It would be recommended to perform a meta-analysis (Hamel 2015) using more recent empirical relationships.

4.2.3 Maturity

The maturity of the JA-P stock was assumed to be 0 % at age-0 and 100 % at age-1+. However, it was reported that some age-0 fish were found to be mature. During the discussion of this issue at the meeting, it was reported that the assumed 0 % maturity at age-0 was used to reflect the likely low contribution of age-0 fish to recruitment but it was unclear how low that contribution was. The effect of this assumption on assessment results is unclear. It was recommended that research be conducted on the maturity of this stock: 1) continue data collection on maturity by area and year; and 2) examine the effects of this maturity variability on the population dynamics and assessments of this stock.

4.2.4 Growth

The sampling program for this stock included sampling of hard parts for aging. Therefore, growth was not important for this assessment. Given that, there was no review of the growth for this stock. Nevertheless, it was recommended to include growth studies in the future to help with interpolating data gaps in the ALKs (see Section 4.1.3).

4.2.5 Recommendations on biology

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

- 1) It was strongly recommended that the natural mortality for this stock to be re-evaluated and improved.
- 2) It was recommended that future assessments consider estimating natural mortality within the assessment model.
- 3) If estimating natural mortality within the assessment model was not possible, it was recommended to perform a series of sensitivity runs that represent the estimated uncertainty of the natural mortality, and alternative natural mortality patterns.
- 4) It was recommended that the natural mortality for this stock be re-examined by performing a meta-analysis using empirical relationships that are more recent and richer in data.
- 5) It is recommended that data on maturity by area and year continue to be collected and the effects on population dynamics be examined.

4.3 Estimation Model

In Section 4.1, this review found that the primary data inputs (i.e., catch-at-age and abundance indices) for the assessment of the JA-P stock were not BSIA. Given that the estimation model was a VPA, which makes the critical assumption that the catch-at-age is known without error, this review also found that the results of the VPA were not BSIA. This review did not spend much time on the VPA methodology during the meeting because it was clear that the data issues identified precluded the VPA results from being considered as BSIA. Nevertheless, this review briefly examined the methodology of the VPA model.

4.3.1 VPA model

A ridge VPA model (Okamura et al. 2017) modified with a non-linear coefficient on the tuning index (Hashimoto et al. 2018), was used in the JA-P 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 fit to the indices ($\lambda \rightarrow 0$) and the F penalty ($\lambda \rightarrow 1$). As λ approaches 0, the model is similar to a traditional tuned 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. This assessment modified the ridge VPA by including an additional coefficient (b) that estimates the non-linearity of the relationship between the index and the population (i.e., catchability). This b coefficient was included to minimize an observed tradeoff between lowering the bias in spawning biomass estimates and a higher negative bias in recruitment.

A large number of models were run with various scenarios, parameters, and initial values (see Supplementary Table 2-4 of assessment report). Based on these models, a model λ of 0.66 was chosen as the base case model. However, it was not clear why only that model was chosen instead of other plausible models. For example, in Supplementary Table 2-4, as the λ decreased from 0.70 to 0.66, the Mohn's rho was similar but model fit improved. However, the model with λ of 0.65 used very different initial values, which likely resulted in a poorly converged model. It was not clear why initial values that improved model convergence were not used in models very close to the base case model. The decision to use a λ of 0.66 appeared to be, at least in part, based on an incomplete exploration of the model space and poor model convergence.

The poor model diagnostics for the NSI index also suggested that the base case model was inappropriate. The estimated b and σ parameters for the NSI index were approximately 6.7 and 0.97, which were extremely high, and suggested that this index may not be representative of the population. This was not surprising given the fundamental flaws of this index (see Section 4.1.2). In comparison, the estimated b and σ parameters for the EPI index were approximately 0.62 and 0.22, which would

suggest that the EPI index was more representative of the population than the NSI index. Therefore, similar to the recommendation on data, it was recommended that the base case model should be fit only to the EPI, unless the NSI survey is substantially improved (Section 4.1.3). However, it should be noted that the EPI is an index of SSB and the terminal recruitment would be relatively uninformed without an age-0 recruitment index. This was evident in a preliminary model run shown during the meeting, which showed that the estimated recruits in the terminal year of a model fit only to the EPI was unreasonably high. It was noted that if the uncertainty of the recruitment estimates were estimated, it would be clear that the terminal recruitment estimates were uninformed and highly uncertain, and therefore not useful for projections.

The tuning indices were only fit from 2010 – 2021 to represent the ‘normal’ recruitment regime that is currently evident. However, it was not clear that such a truncated tuning was appropriate. The assessment model should be able to handle both ‘high’ and ‘normal’ recruitment regimes if the indices used were representative of the stock dynamics. Based on a visual comparison, the results from the VPA appeared to be consistent with the trends suggested by the EPI index. Therefore, it was recommended to fit to the EPI for the entire time series rather than 2010 – 2021, unless there were problems with the EPI survey design prior to 2010.

Simply changing the model settings likely only alleviated the symptoms for this assessment but did not solve the fundamental problems with the assessment. A VPA makes strict assumptions about the data, which have been violated in this assessment (Section 4.1). The priority would be to solve the problems with the data first. Although improving the data for this assessment is critical, it is also recommended 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 and examine conflicts in the data and parameters.

4.3.2 Model diagnostics

As mentioned in Section 4.3.1, the model diagnostics indicated that the NSI index was not well fit. There were a moderate level of retrospective patterns but this was not surprising given the use of the modified ridge VPA (see Section 4.3.1). The retrospective patterns may have been due to the previously discussed data problems.

4.3.3 Uncertainty

The treatment of uncertainty in the JA-P assessment was poor. No uncertainties in the data and parameters were considered. The estimated population structure (N-at-age) and F-at-age in the terminal years were assumed to be known without error to estimate the stock-recruitment relationship (SRR) and projections. Given that the estimated N-at-age and F-at-age have uncertainties that were unaccounted for, the estimated probability distributions from the projections will likely be erroneous. Along with the N-at-age and F-at-age, the uncertainty in the estimated recruitment and spawning biomass also appeared to be neglected. It is understood that it is more difficult to work with uncertainty in a VPA

model, especially when the data were not developed according to the assumptions made (e.g., catch-at-age is known without error). It may be beneficial to explore the use of statistical catch-at-age or integrated models, which can more easily include the uncertainty in the data and biological processes throughout the model.

4.3.4 Recommendations on estimation modeling

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

- 1) It was recommended that only the Egg Production Index be fitted, unless the Northward Survey design is substantially improved (see Section 4.1.3).
- 2) It was recommended to fit to the Egg Production Index for the entire time series rather than 2010 – 2021, unless there were problems with the survey design prior to 2010. If so, it is important to describe the problems.
- 3) 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.
- 4) It would be beneficial to explore the use of statistical catch-at-age or integrated 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.
- 5) It was recommended to develop models that can include pre-recruitment fisheries, like the shirasu fishery.

4.4 Projections

The outputs from the VPA model were used to estimate the stock-recruitment relationship (SRR) and used in the short- and long-term projections. Given that the results from the VPA model were not considered to be BSIA (Section 4.3), this review also concluded that the results of the projections were not BSIA. Nevertheless, this review briefly examined the methodology of the projections.

4.4.1 Stock-recruitment relationship (SRR)

The estimated recruitment and SSB from the VPA model was used to develop the appropriate SRR to use for calculating biological reference points (BRPs) and for the future projections. It was reported during the meeting that the assessment scientists follow guidelines from FRA to estimate the SRR in a stock assessment. These guidelines appear to be used across all FRA stock assessments and is beyond the ToRs for this review. Therefore, this section does not consider whether the SRR was BSIA.

Regime shifts are important to the population dynamics of anchovies and has been clearly shown for this stock. An important discussion during the meeting was how to identify a regime shift in the JA-P stock and which regime to use to estimate stock status and in the projections. It was clear that the recruitment for the JA-P stock has declined substantially over the past few years. Therefore, this review thought that the use of the current ‘normal’ regime was reasonable. However, it is recommended that the criteria for classifying the regime be explained clearly in the assessment documents. It was also recommended that the recruitment and SSB estimates used to develop the SRRs have uncertainty associated with them.

4.4.2 Short-term projections

The terminal year of the estimation model is 2021 but the allowable catch for the current fishing year is based on SSB in 2023. Therefore two years of projections were required to bring forward the estimated N-at-age in 2021 to the projected spawning biomass in 2023. Given that the results from the VPA model were not considered to be BSIA, it follows that the results of these projections were also not considered to be BSIA because the projections relied on the VPA model results for inputs.

In terms of the methodology, the projection models are relatively straightforward and appropriate, given the information available. However, the problems with using short-term projections to estimate SSB in 2023 and set allowable catch should be noted. One of the problems is that the projection results are highly sensitive to the estimates of age-0 and age-1 fish in the terminal year of the VPA model but these estimates are highly uncertain due to the lack of observations, which is common for assessments without well-designed surveys of these age classes in the terminal years. It should also be noted that the uncertainties in these 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. It is therefore important and recommended 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.

Basing the allowable catch on the two-year projections of spawning biomass may also lead to large mismatches between expectations and observations. Such mismatches have led other countries to use management procedures based on observations from surveys before the start of the fishing season. For example, this management procedure could set the allowable catch based on a survey of the stock’s biomass 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.

4.4.3 Long-term projections

One of the management objectives for the JA-P stock was the probability of exceeding the target reference point (MSY) over the next 10 years should not exceed 50%. In addition, there are management objectives and probabilities associated with the limit and ban reference points. Long-term projections out to 2053 were used to estimate the appropriate F-multiplier (e.g., relative to F MSY) to achieve the management objectives. Similar to the short-term projections, the results of these long-term projections were not considered to be BSIA because the inputs for the projections relied on the VPA model results, which were not considered to be BSIA.

The models used for the long-term projections were similar to the short-term projections, and were relatively straightforward and appropriate. However, the uncertainty for the long-term projections are currently under-estimated because the N-at-age in the terminal year of the estimation model is assumed to be known without error, which is considered inappropriate (Section 4.3.3). 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.

Another important consideration is that of potential changes in recruitment regime over the projection period. The projections appeared to only use a 'normal' recruitment regime over the entire projection period, without including the probability of regime switching. Alternative recruitment scenarios incorporating some elements of regime switching may be useful in long-term projections. One recommendation would be to estimate the statistical distribution (potentially bimodal) and the autocorrelation of the estimated recruitment deviates, and use those estimates to represent future recruitment. This allows the projected recruitment to be based on the statistical distribution of the previously observed regimes.

4.4.4 Recommendations on projections

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

- 1) It was recommended that the criteria for classifying the regime be described clearly in the assessment documents so that the criteria can be consistently used in future assessments.
- 2) It was recommended that the recruitment and SSB estimates used to develop the SRRs have uncertainty associated with them.
- 3) It was recommended to incorporate that uncertainty in the N-at-age in the terminal year into the short term and long-term projections.
- 4) It was recommended to estimate the statistical distribution (potentially bimodal) and autocorrelation of the estimated recruitment deviates, and use those statistics to represent future recruitment in the long-term projections.

5. Japanese Anchovy – Tsushima Stock (JA-T)

The stock assessment of the JA-T stock was similar in many aspects to the JA-P stock. In order to reduce the repetitiveness and lengthiness of the report, references are made to earlier sections when appropriate. However, the recommendations for the JA-T stock were kept separate for the sake of clarity.

5.1 Data

A VPA model was used to estimate the population dynamics of the JA-T stock during the historical period. Therefore, the assessment of the JA-T stock made similar assumptions on data as the JS-P stock (see Section 4.1). One key difference between the JA-T and JA-P data was that China and Korea are known to catch large amounts of the JA-T stock.

5.1.1 Catch-at-age

The JA-T stock assessment likely had substantial errors in the total catch and hence catch-at-age data. The critical assumption for VPA models that the catch-at-age was known without error was severely violated and likely led to large errors and biased the results of the VPA model and assessment. Overall, this review found that the total catch and catch-at-age data used for the JS-T stock assessment was not BSIA because substantial amounts of total catch of this stock was not included in the assessment.

Critically, the time series of total catch used in this assessment did not include large amounts of catch by important non-Japanese fisheries fishing on the same stock. The total catch in this assessment was based on reported catches of the JA-T stock by Japanese fisheries but did not include large amounts of catch by vessels from China and Korea. These catches by non-Japanese fisheries were known to be larger than the Japanese fisheries. and neglecting these non-Japanese sources of catch would have resulted in biased results, including estimates of SSB, recruitment and fishing mortality (F). It is critical that future assessments include the catches from non-Japanese fisheries.

Similar to the JA-P stock, this assessment also did not include catch by the Japanese shirasu fishery. This review recommends including these shirasu removals in future assessments but substantial research is required to develop models that can include pre-recruitment fisheries.

The monthly ALKs for the JA-T stock assessment were developed from cohorts in the length data but were not validated with aging data. During the meeting, a request was made to use the JA-T method on JA-P data and compare the results with the JA-P age data. The results suggested that the method using only length data likely over-estimated the proportion of age-0 fish and under-estimated the proportion of age-1 in excess of 20%. It was strongly recommended to develop a sampling and aging program for this stock. Subsequently, similar to the JA-P stock, it was recommended to develop year- and area-specific age-length keys and length-weight relationships. It was recommended to compare different hard parts, validate the aging, and/or provide estimates of reader-specific aging bias and error.

5.1.2 Relative abundance indices

Two tuning indices were used in the JA-T assessment: 1) an egg production index (EPI) was used to represent trends in the SSB; and 2) the Nagasaki CPUE index (NCI) is an age-0 index based on the CPUE of the purse seine fishery operating out of Nagasaki. Based on the discussion during the meeting, this review considered that both the EPI and NCI indices were likely not representative of the trends of the SSB and age-0 fish for the population as a whole. It was noted that juvenile and acoustic surveys of this stock were available but were not used for this assessment.

The EPI for the JA-T stock was based on the same surveys and methodology as the EPI for the JA-P stock, albeit in a different region. See Section 4.1.2 for a discussion of this index. Similar to the JA-P stock, it was recommended that the DEPM approach be considered for future assessments. However, it was noted that the surveys only cover a small part of the entire range of the stock. An unknown but likely large proportion of the spawning area and SSB appeared to be in the EEZs of China and Korea. Therefore, it was likely that the EPI for this stock was not representative of the SSB as a whole. It was recommended that research be performed to answer the question of what proportion of the SSB and spawning area is within the EEZ of Japan, and how variable is that proportion.

The NCI was based on the CPUE (catch in kg per vessel day) of age-0 fish by small and medium purse seine vessels fishing out of Nagasaki prefecture. The zero catch data was removed and the resulting CPUE was standardized with a lognormal GLM. It was noted that the proportion of zero catch data was relatively constant over the time period and a preliminary delta-lognormal standardization including the zero data resulted in a similar index. This index was considered to be important in the assessment because this was the main Japanese fishery on this stock. However, it was clear that the spatial coverage of this fishery was relatively small compared to the spatial range of the age-0 fish. Logbooks were not available for this fishery and the CPUE was based on daily port landings. Therefore, spatial differences in the effort could not be ascertained nor modeled. Given the data were from a purse seine fishery, the CPUEs were likely more related to the catch per set and school size, rather than population size. Overall, this review considered that the NCI may not have been representative of the age-0 fish of this stock.

There were limited details in the documentation and not enough time during the meeting to review the indices in detail. However, the main concern for this review was that the spatial coverage of both indices were not sufficient to cover the stock as a whole. It was likely that a large but variable proportion of the stock was within the EEZs of China and Korea. It was also unclear if the population density was relatively consistent throughout the range and the assumption that the population density within the Japanese EEZ was representative of the stock as a whole but this was considered to be unlikely. It was recommended to conduct research on estimating the proportion of the stock that lies within the EEZs of China and Korea.

Given the difficulties with obtaining data from the stock's entire distribution. It was recommended to develop a survey of the stock in the Japanese EEZ and 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 fisheries 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. Similar to the JA-P stock, it was recommended to perform research on using a combination of acoustics and trawl data to provide synoptic estimates of biomass of this and other small pelagic stocks.

5.1.3 Recommendations on data

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

- 1) If a traditional model-based assessment is used, it is critical to include catches from all fisheries, including non-Japanese fisheries, that capture this stock of anchovy. If the data from outside the Japanese EEZ remains poor 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 fisheries and non-Japanese fisheries that are not under the management procedure.
- 2) It was recommended to include shirasu removals in future assessments but substantial research is required to develop models that can include pre-recruitment fisheries.
- 3) It is recommended 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.
- 4) It was recommended to develop year- and area-specific age-length keys and length-weight relationships from the sampling program.
- 5) It was recommended to compare different hard parts, validate the aging, and/or provide estimates of reader-specific aging bias and error.
- 6) It was strongly recommended to estimate the uncertainty of the indices, even if standardization was not performed.
- 7) It was recommended to conduct research on estimating the proportion of the stock that lies within the EEZs of China and Korea.

8) It was recommended to conduct research on using a combination of acoustics and trawl data to provide synoptic estimates of biomass of this stock.

9) If the acoustic-trawl method is not feasible, it was recommended that the daily egg production method approach and spatial-temporal models be considered for the Egg Production Index.

5.2 Biology

5.2.1 Stock structure and distribution

The stock structure for this stock assessment appeared to be appropriate, given the currently available information. However, the data for this assessment do not cover the entire distribution of the stock. Implicitly, doing so assumes that the fish in the Japanese EEZ acts like a separate stock to the fish in the EEZs of China and Korea, which contradicts the stock structure reported in the assessment.

5.2.2 Natural mortality

The M of the JA-T stock was assumed to be 1.0 y^{-1} for all ages but the basis for this assumption was unclear. It was therefore strongly recommended that the M for this stock be re-evaluated prior to the next assessment. It would be recommended to perform a meta-analysis (Hamel 2015) using more recent empirical relationships.

5.2.3 Maturity

The discussions and recommendations for maturity of the JA-T stock were similar to the JA-P stock. It was recommended that research be conducted on the maturity of this stock: 1) data collection on maturity by area and year; and 2) examine the effects of this maturity variability on the population dynamics and assessments of this stock.

5.2.4 Growth

The growth of this stock is highly uncertain due to the lack of sampling and aging. It is recommended to establish a robust sampling and aging program for this stock (see Section 5.1.3).

5.2.5 Recommendations on biology

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

- 1) It was strongly recommended that the natural mortality for this stock be re-examined by performing a meta-analysis using empirical relationships that are more recent and richer in data.
- 2) It was recommended 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.

- 3) It was recommended that data on maturity by area and year be collected and the effects on population dynamics be examined.
- 4) It was recommended to continue research on the stock structure and distribution of this stock.

5.3 Estimation Model

This review found that the results of the VPA model of the JA-T stock were not BSIA because the primary data inputs were not BSIA. This review did not spend much time on the VPA methodology during the meeting because it was clear that the data issues identified in Section 5.1 precluded the VPA results from being considered as BSIA.

5.3.1 VPA model

This review noted that the strict assumptions about the data for a VPA model were severely violated for this assessment (see Section 5.1). The priority for future improvements would therefore be to solve the problems with the data first. It was also recommended to explore the use of statistical catch-at-age or integrated models, which can be more flexible and able to model the data as it is collected. However, given the difficulties of obtaining data from non-Japanese fisheries for this stock, it may not be possible to improve the data in the near future. If the JA-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. This would also reduce the problems with predicting the recruitment regime for future projections. 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.

5.3.2 Model diagnostics

Given the major problems with the input data for the JA-T stock assessment, this review did not consider the model diagnostics to be useful.

5.3.3 Uncertainty

The treatment of uncertainty in the JA-T 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, modeling, 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 was an assumption that was severely violated for this assessment and not recommended for any assessment. Therefore, when the N-at-age and F-at-age were used in the projections without uncertainty, the estimated probability distributions from the projections were 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). It may 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.

5.3.4 Recommendations on estimation modeling

Based on the above findings, there were several recommendations for improving the estimation models used for the JA-T assessment:

- 1) It is critical that the uncertainty be treated appropriately in the stock assessment. It was 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.
- 2) It would be beneficial to explore the use of statistical catch-at-age or integrated 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) It was recommended to develop models that can include pre-recruitment fisheries, like the shirasu fishery.
- 4) If there are continued difficulties in obtaining data from non-Japanese fisheries, it is recommended 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 fisheries 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.

5.4 Projections

The outputs from the VPA model were used to estimate the stock-recruitment relationship (SRR) and in the projections. Given that the results from the VPA model were not BSIA (Section 5.3), this review

also found that the results of the projections were not BSIA. Nevertheless, this review briefly examined the methodology of the projections.

5.4.1 Stock-recruitment relationship (SRR)

It was reported during the meeting that the assessment scientists follow guidelines from FRA to estimate the SRR in a stock assessment. These guidelines appear to be used across all FRA stock assessments and is beyond the ToRs for this review. Therefore, this review did not consider whether the SRR was BSIA.

Overall, discussion for this stock was similar to the JA-P stock (Section 4.4.1), with a focus on identifying the appropriate regimes for the current stock status and projections. However, it was interesting that the differences between regimes for this stock was relatively small compared to other anchovy stocks and other small pelagic species. It was recommended that the criteria for classifying the regime be explained clearly in the assessment documents. It was also recommended that the recruitment and SSB estimates used to develop the SRRs have uncertainty associated with them.

5.4.2 Short-term projections

Given that the results from the VPA model were not considered to be BSIA, it follows that the results of these projections were also not considered to be BSIA because the projections rely on the VPA model results for inputs.

In terms of the methodology, the projection models were relatively straightforward and appropriate, given the information available. However, it should be noted that the projected spawning biomass in the current fishing year (i.e., 2023), on which the allowable catch was calculated from, was highly uncertain because the projections were highly sensitive to the uncertain estimates of young fish in the population in the terminal year and later (i.e., 2021), changes in recruitment, and catches by non-Japanese fisheries are not limited by Japanese management. It should also be noted that this uncertainty was under-estimated because the N-at-age in the terminal year of the estimation model was assumed to be known without error, which was considered inappropriate (Section 4.3.3). One potential way to improve the short-term projections of the JA-T stock is to develop scientific surveys of this stock in Japanese waters and use the survey results as the basis for managing the stocks in Japanese waters.

5.4.3 Long-term projections

The management objectives and long-term projections for the JA-T stock was similar to the JA-P stock (see Section 4.4.3). Similarly, the results of these long-term projections were not considered to be BSIA because the inputs for the projections relied on the VPA model results, which were not BSIA. The models used for the long-term projections were similar to the short-term projections, and were relatively straightforward and appropriate. However, the uncertainty for the long-term projections were under-estimated because the N-at-age in the terminal year of the estimation model was assumed to be known without error, which was considered inappropriate (see Section 4.3.3). This would be especially

important for calculating the probabilities of exceeding the limit and ban reference points, which are based on the tails of the probability distributions. In addition, the treatment of the large catches by non-Japanese fisheries appeared to be neglected. Therefore, these long-term projections do not appear to be based on the reported stock structure in the assessment.

5.4.4 Recommendations on projections

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

- 1) It is recommended that the criteria for classifying the regime be described clearly in the assessment documents so that the criteria can be consistently used in future assessments.
- 2) It is recommended that the recruitment and SSB estimates used to develop the SRRs have uncertainty associated with them.
- 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 is recommended to estimate the statistical distribution and autocorrelation of the estimated recruitment deviates, and use those statistics to represent future recruitment in the long-term projections.

6. Japanese Seabream – Western Sea of Japan and East China Sea (JS-ECS)

The stock assessment of the JS-ECS stock was highly similar to the JS-SIS and BH-SIS assessments. An unusual feature of these three assessments was the supplementation of natural recruitment by hatchery releases (i.e., stock enhancement) and the integration of these hatchery releases into the wild SSBs, stock assessments, and fishery management. An overview of the stock enhancement program for all three stocks was presented to the review panel. The aims of the stock enhancement program were to contribute to the enlargement of future SSB and catch by releasing hatchery-reared recruits to supplement wild-origin recruitment. Subsequently, a transition from stock enhancement to stock management is to be promoted for stocks that had completed the goal of stock enhancement or is able to sustain the stock level with reduced levels of hatchery releases. The stock enhancement program collects and rears wild fish as spawning stock in hatcheries. The progeny of these fish are reared and subsequently released into the wild as hatchery releases at sizes slightly smaller than wild fishery recruits. These hatchery releases were considered to be biologically similar to natural recruits and after maturity, considered to be part of the wild SSB. Importantly, hatchery releases have morphological characteristics (deformity of internostril epidermis for JS-ECS and JS-SIS stocks; and abnormal blind side pigmentation for the BH-SIS stock) that allow hatchery releases to be identified. However, the proportion of hatchery release with identifiable marks varied by hatchery and year, with some releases

being indistinguishable from wild fish. Interestingly, the hatcheries are managed by the prefectural governments and there are currently no regulatory limitations on the number of hatchery releases for these stocks.

Overall, the aim of the stock assessment and management of these three stocks was to assess and manage the fishery and fish stocks, including both wild and hatchery-released fish. At the same time, it was important for the assessment to assess the source of recruits (wild or hatchery) into the fishery. Therefore, the assessment had to estimate the contributions of wild versus hatchery-released recruits into the population, while disregarding the source when estimating the F-at-age and SSB. This approach was considered to be unusual by this review and there was much discussion on the impact of this. Discussions centered on the conceptual use of SRRs and MSY reference points for the assessment and management of these stocks (Section 6.4.1).

6.1 Data

Similar to the other stocks in this review, a VPA model was used to estimate the population dynamics of the JS-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. The relative abundance indices used as tuning indices for the VPA model were also examined. In addition, the data on the contribution of hatchery releases to the population was examined.

6.1.1 Catch-at-age

Much of the discussion for this stock was focused on how the catch-at-age data were developed. Overall, this review found that the catch-at-age data used for the JS-ECS stock assessment was not considered to be BSIA because the total catch and catch-at-age data were likely not BSIA.

There were substantial concerns with the assumed stock structure (Section 6.2.1) and total catches for this assessment. Given the location, it was plausible or even likely that the distribution of this stock overlaps the EEZs of China and Korea. It is known that China and Korea also catch large amounts of Japanese seabream but it was unknown if these catches were from the JS-ECS stock. This assessment assumed that the fisheries of China and Korea caught no JS-ECS fish but no evidence was provided to support this assumption. Japanese seabream is also a popular target of Japanese recreational fisheries and a non-negligible amount of JS-ECS were likely caught by recreational fisheries. However, this assessment assumed that no JS-ECS fish were caught by recreational fisheries. Neglecting non-Japanese and recreational sources of catch would have resulted in biased results, including estimates of SSB, recruitment and fishing mortality (F). If a traditional model-based assessment is used, it is critical that future assessments include the catches from all sources, including recreational and non-Japanese fisheries.

There were substantial concerns with the age compositions and catch-at-age data for this assessment. It was reported that the age compositions and ALKs were provided by each of the eight prefectures. In addition, each of the prefectures used different methods to sample and age the catch, and develop ALKs for their catches. Given the variety of methods used and the lack of detail provided, this review could not perform a review of the methods used to develop the catch-at-age data. It was strongly recommended that the FRA scientists coordinate and review the methods used by the prefectures so that the catch-at-age data would be considered BSIA. For example, the approach taken by the JS-SIS stock assessment to develop annual age compositions would be a good approach (Section 7.1.1).

6.1.2 Relative abundance indices

Only one tuning index, the standardized CPUE of the set net fishery in Shimane (SNI), was available for the JS-ECS assessment. Based on the discussion during the meeting, this review considered the SNI to be BSIA because no other CPUE or survey data were currently available. However, there were substantial concerns that the SNI was likely not representative of the stock abundance trend.

One of the concerns was the relatively small spatial coverage of the SNI compared to the assumed distribution of the stock. The SNI was based only on set nets within Shimane prefecture, which was only a small part of the stock's distribution, and only represented a small portion of the total catch for this stock. While the catch data of the CPUE were likely accurate, there was a lack of effort data. The amount of effort were to a large extent based on assumptions and were poorly defined. For example, the units of effort were assumed to be vessel day but the amount of fishing time (i.e., time between removing fish) was actually unknown but assumed to be one day. In addition, each 'vessel' was actually a 'fishing company' with different number of set nets. and the number of nets actually varied but was assumed to be one net for all fishing companies.

Overall, this review had substantial concerns that the SNI was likely not representative of the stock abundance trend and strongly recommended that alternative data sources be examined for use in the assessment. It was noted that there was relatively little contrast in the catch and CPUE time series during 2007 – 2021 but substantial contrast in the catch during 1969 – 1990. Therefore it was also recommended to focus on the 1969-1990 period for an index because this period was likely to be more informative to the assessment than the recent period.

Although the data quality for this stock is relatively poor, it was important to note that 'mark and recapture' of the hatchery releases can be highly informative in an assessment model. The hatchery releases can be considered to be marked and identified from their morphological differences. Therefore, if the hatchery releases and proportion of 'marked' fish are well recorded, a program to sample the catch, identify 'recaptures' in the catch, and age the 'recaptures' will be highly informative. This data may already be collected by the prefectures. It is therefore strongly recommended to examine the historical data on hatchery releases for mark and recapture data, and develop a program to 'mark' the hatchery releases, sample the catch and identify 'recaptures' of hatchery releases in the catch, and age the 'recaptures'.

6.1.3 Hatchery releases

Hatchery releases are managed by prefectural governments, with the number of hatchery releases varying over the years since the program started in 1977. Five prefectures (Shimane, Yamaguchi, Nagasaki, Kumamoto, and Kagoshima) released a total of 2.73 million fish in 2020. However, the contributions of hatchery releases to the population were only available from three prefectures. There were concerns with the estimation of contribution rates. Details on the sampling and aging protocols by the prefectures were lacking. In addition, the importance of considering the hatchery releases as mark and recapture experiments was highlighted. For example, it was considered important to obtain data on the marking rates, mark loss rates, and identification rates of ‘recaptured’ fish for each batch of releases. These data could then be used in integrated assessment models as mark-recapture data. It was recommended that sampling and aging programs for this stock include protocols to identify and age hatchery releases, as well as collect data on the marking rates, mark loss rates, and identification rates for hatchery releases. It would be important to collect these data from all prefectures and used in future assessments.

6.1.4 Recommendations on data

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

- 1) It is critical that future assessments include the catches from all sources, including recreational and non-Japanese fisheries, especially if traditional assessment models are used.
- 2) It was strongly recommended that the FRA scientists coordinate and review the methods used by the prefectures so that the catch-at-age data would be considered BSIA.
- 3) It was strongly recommended to examine the historical data on hatchery releases for ‘mark’ and ‘recapture’ data, and develop a program to ‘mark’ the hatchery releases, sample the catch and identify ‘recaptures’ of hatchery releases in the catch, and age the ‘recaptures’.
- 4) It was recommended that sampling and aging programs for this stock include protocols to identify and age hatchery releases, as well as collect data on the marking rates, mark loss rates, and identification rates for hatchery releases. It would be important to collect these data from all prefectures and used in future assessments.

6.2 Biology

6.2.1 Stock structure and distribution

The stock structure and distribution for this stock appeared to be poorly understood and the assumed stock structure and distribution for this stock assessment are likely not BSIA. Japanese seabream is also known to be distributed in the EEZs of China and Korea, and are captured by fisheries from these two

countries. However, no evidence was provided to support the assumption that the stock is wholly distributed within the EEZ of Japan. It is strongly recommended to perform studies to better understand the stock structure and distribution of this stock.

6.2.2 Natural mortality

Following a previous study from the Seto Inland Sea (Shimamoto 1999), the M of the JS-ECS stock was assumed to be 0.24 y^{-1} for age-1 and 0.17 y^{-1} for age-2+. A number of previous studies on M were cited by Shimamoto (1999) but the evidence to support those assumptions were unclear. Given the survival rates of hatchery releases to age-1 ranged from 7 to 30 % (Table 4-3 of assessment report), it was unclear if the assumed M rates were reasonable. Sensitivity runs using M that were 30% above and below the assumed rates were performed but these sensitivity runs were arbitrary rather than corresponding to the uncertainty of M . It was noted that mark and recapture data are highly informative on M , which can either be estimated within assessment models or prior to the assessment. It was recommended that the M s assumed for this assessment be re-evaluated and that sensitivity runs be based on the estimated uncertainty of M . It was also recommended that mark and recapture data from hatchery releases be incorporated into the assessment model and used to estimate M .

6.2.3 Maturity

The JS-ECS stock was thought to exhibit 50% maturity at age-3 and be fully mature by age-4. This was considered to be appropriate given the current available information. However, it was recommended to re-examine the maturity of the stock using more recent methods and data, especially focusing on variability between areas and years.

6.2.4 Growth

It was reported that the growth and length-weight relationships for this assessment were based on previous assessments but there was no available evidence to support the growth curves and length-weight relationships. There were plans to perform studies on these relationships in the near future. It was recommended to evaluate the growth and length-weight relationships for this stock, as well as spatial and temporal variability of these relationships.

6.2.5 Recommendations on biology

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

- 1) It was strongly recommended to perform studies to better understand the stock structure and distribution of this stock.
- 2) It was recommended that the natural mortality assumed for this assessment be re-evaluated and that sensitivity runs be based on the estimated uncertainty of natural mortality.

- 3) It was recommended that mark and recapture data from hatchery releases be incorporated into the assessment model and used to estimate natural mortality.
- 4) It was recommended to re-examine the maturity of the stock using more recent methods and data, especially focusing on variability between areas and years.
- 5) It was recommended to evaluate the growth and length-weight relationships for this stock, as well as spatial and temporal variability of these relationships.

6.3 Estimation Model

This review found that the results of the VPA model of the JS-ECS stock could not be considered as BSIA because the primary data inputs for the assessment were not BSIA. This review did not spend much time on the VPA methodology during the meeting because it was clear that the data issues identified precluded the VPA results from being considered as BSIA.

6.3.1 VPA model

A standard tuning VPA model was used in the JS-ECS stock assessment to estimate the historical population dynamics of the stock. This review noted that the strict assumptions about the data for a VPA model were violated in this assessment (Section 6.1). The priority for future improvements would therefore be to improve the data (Section 6.1) and biological understanding (Section 6.2) for this stock. Given the problems with the historical data, it was recommended to explore the use of integrated models for this stock. Doing so will allow modeling of the appropriate processes for the population and data (i.e., bring the model to data), rather than having to make strong, unsubstantiated assumptions about the data to fit a model with stringent data requirements. This will also make it easier to develop multiple scenarios for the historical period with uncertain data, and help estimate and propagate uncertainties in the model. Integrated models are also able to fit mark and recapture data from hatchery releases, which will help improve the model results, even with a relatively short time series.

6.3.2 Model diagnostics

Given the problems with the data, it was difficult to evaluate the model diagnostics because problems identified were likely due to data rather than the model.

6.3.3 Uncertainty

The treatment of uncertainty in the JS-ECS assessment was similar to the other stocks and was similarly inadequate (Sections 4.3.3 and 5.3.3). In addition, the data quality for this stock was especially poor and likely resulted in greater uncertainty that was neglected in the assessment process. It was recommended to explore the use of integrated models, which can more easily include the uncertainty in the data and biological processes throughout the model.

6.3.4 Recommendations on estimation modeling

Based on the above findings, there were several recommendations for improving the estimation models used for the JS-ECS assessment:

- 1) It was recommended to explore the use of integrated models for this stock to allow modeling of the appropriate processes for the population and data (i.e., bring the model to data), rather than having to make strong, unsubstantiated assumptions about the data to fit a model with stringent data requirements.
- 2) It was recommended to integrate mark and recapture data from hatchery releases into the assessment model, which will help improve the model results, even with a relatively short time series.
- 3) 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.

6.4 Projections

The outputs from the VPA model were used to estimate the SRR and in the projections. Given that the results from the VPA model were not considered to be BSIA (Section 6.3), this review also found that the results of the projections were not BSIA.

6.4.1 Stock-recruitment relationship (SRR)

It was reported during the meeting that the assessment scientists follow guidelines from FRA to estimate the SRR in a stock assessment. These guidelines appear to be used across all FRA stock assessments and is beyond the ToRs for this review. Therefore, this review did not consider whether the SRR was BSIA.

Nevertheless, some time was spent discussing how to interpret a SRR with stock enhancement. A SRR typically assumes that the source of recruits is the SSB of the population and the recruits mature into the SSB. Here, the recruits are from both the SSB (wild fish) and hatchery releases, and these recruits mature into the SSB. Conceptually, the situation is similar to a sink population with self-seeded recruits as well as recruits from a source population. The SSB, SRR and MSY of the sink population would be partially dependent on the population dynamics of the source population.

In the case of the JS-ECS stock, the number of hatchery releases are not explicitly managed but are considered part of the wild population after recruitment and fishing on them are managed as such. Therefore, the SSB in the SRR are considered as all the mature fish in the stock, irrespective of source. However, the recruits in the SRR are only the wild recruits, which are identified by removing the reported contribution of hatchery releases from the estimated total recruitment in the VPA model. This

allows the SRR to reflect the contribution of the wild SSB to recruitment. It should be noted that MSY calculations using this SRR may not reflect the sustainability of SSB under fishing, without hatchery releases. The management for this stock is based on the idea that if the wild fish are fished sustainably, the hatchery releases will act as an extra cushion for the population, and would be more conservative than including hatchery releases into the recruitment estimates.

There was some concern with the estimated SRR and MSY-based reference points (SSB_{MSY} and F_{MSY}). Given the small range of estimated SSB and recruitment, the uncertainty in the estimated SRR and MSY-based reference points will be relatively high. However, the uncertainty in the estimated SRR and MSY-based reference points do not appear to be well communicated. Another concern was that the recruitment and SSB estimates were assumed to be known without error. It was therefore recommended that the recruitment and SSB estimates used to develop the SRRs have uncertainty associated with them. If possible, it would be substantially better to estimate the SRR parameters within the estimation model, rather than using a posthoc approach. It was recommended to improve communication of the uncertainties in the assessment and management quantities in the report.

6.4.2 Short-term projections

The terminal year of the estimation model was 2021 but the allowable catch for the current fishing year was based on SSB in 2023. Therefore two years of projections are required to bring forward the estimated N-at-age in 2021 to estimate the projected spawning biomass in 2023. Given that the results from the VPA model were not considered to be BSIA, it follows that the results of these projections were also not BSIA because the projections rely on the VPA model results for inputs.

In terms of the methodology, the projection models were the same as for the other stocks in this review and the comments were similar. One difference was that scenarios with and without hatchery releases were included in the projections. For scenarios including hatchery releases, future recruitment of hatchery releases were assumed to be the average of age-1 recruitment of hatchery releases during 2017 – 2021. The models were relatively straightforward and appropriate, given the information available. However, it should be noted that the uncertainties in these projections were under-estimated because the N-at-age in the terminal year of the estimation model was assumed to be known without error, which was considered inappropriate. It is therefore important and recommended 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.

6.4.3 Long-term projections

Similar to the short term projections, the results of these long-term projections were not considered to be BSIA because the inputs for the projections relied on the VPA model results, which were not BSIA. The models used for the long-term projections were similar to the short-term projections, and were relatively straightforward and appropriate. However, similar to the short-term projections, the uncertainty for the long-term projections were under-estimated.

6.4.4 Recommendations on projections

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

- 1) It was recommended that the uncertainties in the estimated SRR and management quantities be better communicated.
- 2) It was recommended that the recruitment and SSB estimates used to develop the SRRs have uncertainty associated with them.
- 3) It was recommended to incorporate that uncertainty in the N-at-age in the terminal year into the short term and long-term projections.

7. Japanese Seabream – Central and Western Seto Inland Sea (JS-SIS)

The assessment approach of the JS-SIS stock was similar to the JS-ECS stock, albeit with substantially improved data. Therefore, if similar comments or discussions were made for the other stocks, the reader will be referred to earlier sections to reduce the repetitiveness and lengthiness of the report. However, the recommendations for the JS-SIS stock are kept separate for the sake of clarity.

7.1 Data

Similar to the other stocks in this review (see Section 4.1), a VPA model was used to estimate the population dynamics of the JS-SIS stock during the historical period. Therefore, it was critical to examine the data preparation, especially for the catch-at-age data.

7.1.1 Catch-at-age

Overall, this review found that the catch-at-age data used for the JS-SIS stock assessment was not BSIA because non-negligible amounts of catch by the recreational fishery were excluded from the total catch and catch-at-age. However, it was noted that the approach for annual age compositions would be considered as BSIA.

Critically, the time series of total catch used in this assessment did not include non-negligible amounts of catch by recreational fisheries fishing on stock. Based on surveys of the recreational fishery, the catch by the recreational fishery was 2 – 8 % of the total catch. While the amounts of catch are not very large, it is critical to include all known sources of removals from the stock. Moreover, a VPA model makes strict assumptions that the catch-at-age of the stock is known without error. Even with integrated models, it is expected to include all known sources of removals and to make reasonable assumptions about the removal processes to interpolate periods with missing data. It is expected that data from recreational fisheries are more difficult to obtain and often of a lower quality. For example, it is

common to associate catches by recreational fisheries with larger uncertainties and to assume the selectivity is similar to commercial fisheries until enough size data is collected from the recreational fisheries to estimate a selectivity function. However, by not including the recreational fishery catch, it was assumed that the recreational fishery caught zero fish, which was clearly not true. It was recommended that catches from the recreational fishery be included in future assessments and reasonable assumptions made to interpolate between years with missing catch data.

In contrast to the total catch time series, the approach to develop annual age compositions was considered as BSIA. Monthly length compositions were collected by fishery for the two main areas of this stock: central Seto Inland Sea and the western Seto Inland Sea. Year-, month- and area-specific ALKs were developed from age-length data from fishery samples, and used to convert the length compositions into age compositions. These age compositions were combined with the catch in numbers to develop the catch-at-age time series. In some cases, fishery-specific ALKs are needed for some assessments because age-specific processes differ between fisheries (e.g., age specific movement to a spawning ground that is fished only by one gear type). It would be recommended to perform experiments to see if year-, month-, area-, and fishery-specific ALKs are necessary for the assessment.

7.1.2 Relative abundance indices

No index was used for tuning the VPA model. Two CPUE time series were developed: 1) small trawl fishery (1968 – 2006); and 2) “Gochi” seine fishery (1996 – 2006) but both were considered to be inadequate to be used as tuning indices. Given the importance of abundance indices for stock assessments, it was strongly recommended to investigate the data from the small trawl fishery and the “Gochi” seine fishery, as well as other fisheries or surveys, to develop an abundance index for this stock.

7.1.3 Hatchery releases

Most of the discussion on hatchery release data were done during the discussion on the JS-ECS stock. As such, see Section 6.1.3 for details. The importance of considering the hatchery releases as mark and recapture experiments was highlighted, especially if abundance indices are unavailable for this stock. It was recommended that sampling and aging programs for this stock include protocols to identify and age hatchery releases, as well as collect data on the marking rates, mark loss rates, and identification rates for hatchery releases. It would be important to collect these data from all prefectures and used in future assessments.

7.1.4 Recommendations on data

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

- 1) It is recommended that catches from the recreational fishery be included in future assessments and reasonable assumptions made to interpolate between years with missing catch data.

- 2) It would be recommended to perform experiments to see if year-, month-, area-, and fishery-specific ALKs are necessary for the assessment.
- 3) It was strongly recommended to investigate the data from the small trawl fishery and the “Gochi” seine fishery, as well as other fisheries or surveys, to develop an abundance index for this stock.
- 4) It was strongly recommended to examine the historical data on hatchery releases for ‘mark’ and ‘recapture’ data, and develop a program to ‘mark’ the hatchery releases, sample the catch and identify ‘recaptures’ of hatchery releases in the catch, and age the ‘recaptures’.
- 5) It was recommended that sampling and aging programs for this stock include protocols to identify and age hatchery releases, as well as collect data on the marking rates, mark loss rates, and identification rates for hatchery releases. It would be important to collect these data from all prefectures and used in future assessments.

7.2 Biology

7.2.1 Stock structure and distribution

The stock structure for this stock assessment appeared to be appropriate and BSIA, given the currently available information. Tagging studies in the 1980s indicated that Japanese seabream in the eastern Seto Inland Sea rarely, if ever, migrate into the western and central Seto Inland Sea. In addition, examination of internal parasites in Japanese seabream from different parts of the Seto Inland Sea suggest that there was little exchange within the different parts of the Seto Inland Sea.

7.2.2 Natural mortality

Similar to the JS-ECS stock, the JS-SIS stock assessment assumed the same M schedule as a previous study of Japanese seabream in the Seto Inland Sea (Shimamoto 1999). The M of the JS-SIS stock was assumed to be 0.39 y^{-1} , 0.24 y^{-1} and 0.17 y^{-1} for age-0, 1 and 2+, respectively. Similar to the JS-ECS stock (Section 6.2.2), it was recommended that the Ms assumed for this assessment be re-evaluated and that sensitivity runs be based on the estimated uncertainty of M. It was also recommended that mark and recapture data from hatchery releases be incorporated into the assessment model and used to estimate M.

7.2.3 Maturity

Similar to the JS-ECS stock, the JS-SIS stock was thought to exhibit 50% maturity at age-3 and be fully mature by age-4. This was considered to be appropriate given the current available information. However, there was some evidence that some fish in the region may exhibit slightly earlier maturity. It was recommended to re-examine the maturity of the stock using more recent methods and data, especially focusing on variability between areas and years.

7.2.4 Growth

Given that there is a robust sampling and aging program for the JS-SIS stock that included sampling of hard parts for aging, growth parameters were not important for the stock assessment. However, it was recommended to evaluate the variability of growth and length-weight relationships between years and areas to improve biological knowledge for the stock.

7.2.5 Recommendations on biology

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

- 1) It was recommended that the natural mortality assumed for this assessment be re-evaluated and that sensitivity runs be based on the estimated uncertainty of natural mortality.
- 2) It was recommended that mark and recapture data from hatchery releases be incorporated into the assessment model and used to estimate natural mortality.
- 3) It was recommended to re-examine the maturity of the stock using more recent methods and data, especially focusing on variability between areas and years.
- 4) While not important for the assessment due to a robust sampling and aging program for this stock, it was recommended to examine the growth and length-weight relationships, as well as spatial and temporal variability of these relationships, to improve biological knowledge for the stock.

7.3 Estimation Model

This review found that the results of the VPA model of the JS-SIS stock were not BSIA because the total catch time series for the assessment were not BSIA.

7.3.1 VPA model

A standard VPA model without tuning indices was used in the JS-SIS stock assessment to estimate the historical population dynamics of the stock. This review noted that the strict assumptions about the data for a VPA model were violated in this assessment (see Section 7.1). The age compositions for this stock was considered to be BSIA but the total catch time series did not include non-negligible catch from the recreational fishery. In addition, no indices were available as tuning indices.

The priority for future improvements would be to develop an index for this stock (Section 7.1.2) and to develop a catch or effort time series for the recreational fishery. Given the otherwise relatively rich data set for this stock, it was also recommended to explore the use of integrated models, especially using an empirical weight-at-age approach (Kuriyama et al. 2015) and mark-recapture data from hatchery releases

7.3.2 Model diagnostics

The model diagnostics indicated a moderate retrospective pattern for the terminal period of the assessment. The cause was likely the lack of information on the recruitment near the end of the historical period, and the lack of a tuning index.

7.3.3 Uncertainty

The treatment of uncertainty in the JS-SIS assessment was similar to the other stocks and was similarly inadequate (see Section 4.3.3 for more details). It was recommended to explore the use of integrated models, which can more easily include and propagate the uncertainty in the data and biological processes throughout the model.

7.3.4 Recommendations on estimation modeling

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

- 1) It was recommended to explore the use of integrated models for this stock to allow modeling of the appropriate processes for the population and data (i.e., bring the model to data), rather than having to make strong, unsubstantiated assumptions about the data to fit a model with stringent data requirements.
- 2) It was recommended to integrate mark and recapture data from hatchery releases into the assessment model, which will help improve the model results, even with a relatively short time series.
- 3) 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.

7.4 Projections

The outputs from the VPA model were used to estimate the SRR and in the projections. Given that the results from the VPA model were not BSIA (Section 7.3), this review also found the results of the projections to not be BSIA. .

7.4.1 Stock-recruitment relationship (SRR)

It was reported during the meeting that the assessment scientists follow guidelines from FRA to estimate the SRR in a stock assessment. These guidelines appear to be used across all FRA stock assessments and is beyond the ToRs for this review. Therefore, this review did not consider whether the SRR was BSIA.

The approach for the SRR of the JS-SIS stock included hatchery releases and was similar to the JS-ECS stock. The comments and recommendations would be therefore be similar as well (see Section 6.4.1 for details). Some time was spent discussing how to interpret a SRR with stock enhancement. It was noted that MSY calculations using this SRR may not reflect the sustainability of SSB under fishing, without hatchery releases. There was also some concern with the estimated SRR and MSY-based reference points (SSB_{MSY} and F_{MSY}). Given the small range of estimated SSB and recruitment, the uncertainty in the estimated SRR and MSY-based reference points will be relatively high. Therefore, it was difficult to distinguish between the different candidate SRRs but the management consequences for the choice of SRR was relatively large. The uncertainty in the estimated SRR and MSY-based reference points do not appear to be well communicated. Another concern was that the recruitment and SSB estimates were assumed to be known without error. It was therefore recommended that the recruitment and SSB estimates used to develop the SRRs have uncertainty associated with them. If possible, it would be substantially better to estimate the SRR parameters within the estimation model, rather than using a posthoc approach. It was recommended to improve communication of the uncertainties in the assessment and management quantities in the report.

7.4.2 Short-term projections

Given that the results from the VPA model were not considered to be BSIA, it follows that the results of these projections for the JS-SIS stock were also not considered to be BSIA because the projections relied on the VPA model results for inputs.

In terms of the methodology, the projection models were the same as for the JS-ECS stock and the comments were similar (see Section 6.4.2 for details). The models were relatively straightforward and appropriate, given the information available. However, it was considered important and recommended 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.

7.4.3 Long-term projections

Similar to the short term projections, the results of these long-term projections were not considered to be BSIA because the inputs for the projections relied on the VPA model results, which were not BSIA. The models used for the long-term projections were similar to the short-term projections, and were relatively straightforward and appropriate. However, similar to the short-term projections, the uncertainty for the long-term projections were under-estimated.

7.4.4 Recommendations on projections

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

- 1) It was recommended that the uncertainties in the estimated SRR and management quantities be better communicated.

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

3) It was recommended to incorporate that uncertainty in the N-at-age in the terminal year into the short term and long-term projections.

8. Bastard Halibut – Seto Inland Sea (BH-SIS)

The stock assessment of the BH-SIS stock had many similarities to other assessments, especially of the JS-ECS and JS-SIS stocks, in this review. Therefore, if similar comments or discussions were made, the reader will be referred to earlier sections to reduce the repetitiveness and lengthiness of the report. However, the recommendations for the BH-SIS stock are kept separate for the sake of clarity.

8.1 Data

Similar to other assessments, a VPA model was used to estimate the population dynamics of the stock during the historical period. Therefore, it was critical to examine the data preparation, especially for the catch-at-age data.

8.1.1 Catch-at-age

Much of the discussion during the meeting was focused on the development of the catch-at-age data. Overall, this review found that the catch-at-age data used for the BH-SIS stock assessment was not BSIA because the total catch in numbers and age composition data were likely not BSIA.

The stock structure for this assessment was uncertain (Section 8.2.1) and this may have led to some small but non-negligible amounts of catch being excluded from the total catch time series. Small amounts of Bastard Halibut were caught outside the Seto Inland Sea but were assumed to be from other stocks and excluded from the assessment. However, based on the discussion of stock structure (Section 8.2.1), this review considered it likely that most, if not all, of the Bastard Halibut caught outside the Seto Inland Sea may be part of the BH-SIS stock. Therefore, it was recommended that future assessments include the small amounts of catch from outside the Seto Inland Sea as a sensitivity run or the base case model. Interestingly, unlike the JS-SIS stock, catch from the recreational fishery appeared to be included in the assessment (Fig 3-1 in the assessment report).

The age compositions for the assessment of the BH-SIS stock also did not appear to be BSIA. Most importantly, a single seasonal ALK was used for all years, which assumed that age-length relationship (i.e., growth) was constant for all years. It was explained that the ALK was based on aging data from otolith samples during 1995 – 2004 but there were not enough samples to develop year-specific ALKs and there were no aging samples after 2004. However, an examination of the year-specific aging data suggested non-negligible variability in the age-length relationships for this stock. Therefore, this review considered that the use of a single seasonal ALK for this stock to be not BSIA. If a VPA model was to

be used for future assessments, it was recommended that an otolith sampling and aging program be developed for this stock so that year-specific seasonal ALKs can be developed. In addition, it was recommended to also examine temporal variability of the length-weight relationship of this stock.

8.1.2 Relative abundance indices

Only one tuning index, the nominal catch-weighted CPUE of the small trawl fishery (STI), was used for the BH-SIS assessment. Several other indices were examined but none were considered useful by the assessment team.

Based on discussions during the meeting, this review considered the STI index to be BSIA because no other CPUE or survey data were currently available. However, there were substantial concerns that the STI was likely not representative of the stock abundance trend. Importantly, the catch and effort data used in the index was relatively coarse, with aggregated catch and numbers of days fished, and the index was a nominal commercial fishery index without standardization. No spatial and temporal catch and effort data (e.g., logbooks) were available for use with CPUE standardization. The assessment team recognized that CPUE standardization was important but did not standardize the index due to the lack of fine scale data on fishery operations. In addition, fishery operations appeared to have changed substantially over the years, with a substantial decline in effort, but a nominal index assumes that the fishing operations have remained the same and covered the same area over time. A catch-weighted index also weights the index towards vessels that catch the most fish, even if they fish only in a small area, but an index should ideally be area-weighted over the entire distribution of the stock. It was strongly recommended that other sources of data, ideally surveys, be developed for use as abundance indices for this stock.

8.1.3 Hatchery releases

Most of the discussion on hatchery release data were done during the discussion on the JS-ECS stock (see Section 6.1.3). The importance of considering the hatchery releases as mark and recapture experiments was highlighted, especially if abundance indices are poor or unavailable for this stock. It was recommended that sampling and aging programs for this stock include protocols to identify and age hatchery releases, as well as collect data on the marking rates, mark loss rates, and identification rates for hatchery releases. It would be important to collect these data from all prefectures and used in future assessments.

8.1.4 Recommendations on data

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

- 1) It was recommended that future assessments include the small amounts of catch from outside the Seto Inland Sea as a sensitivity run or the base case model.

- 2) If a VPA model was to be used for future assessments, it was recommended that an otolith sampling and aging program be developed for this stock so that year-specific seasonal ALKs can be developed.
- 3) It was recommended to also examine temporal variability of the length-weight relationship of this stock.
- 4) It was strongly recommended that other sources of data, ideally surveys, be developed for use as abundance indices for this stock.
- 5) It was strongly recommended to examine the historical data on hatchery releases for 'mark' and 'recapture' data, and develop a program to 'mark' the hatchery releases, sample the catch and identify 'recaptures' of hatchery releases in the catch, and age the 'recaptures'.
- 6) It was recommended that sampling and aging programs for this stock include protocols to identify and age hatchery releases, as well as collect data on the marking rates, mark loss rates, and identification rates for hatchery releases. It would be important to collect these data from all prefectures and used in future assessments.

8.2 Biology

8.2.1 Stock structure and distribution

The stock structure for this stock assessment appeared to be uncertain but this uncertainty was inadequately addressed in the assessment. During the meeting, it was reported that some of the BH-SIS stock was known to migrate out of the Seto Inland Sea after maturity but what happened eventually to these fish was unknown. It was also reported that the line separating the BH-SIS stock from the Pacific stock was largely based on management units rather than biology. For example, spawning habitat for Bastard Halibut is known to occur just outside Seto Inland Sea management area but it was uncertain if these spawning fish were part of the BH-SIS stock. It was therefore strongly recommended to perform studies to better define the stock structure and distribution for the BH-SIS stock. As stated above in the data section, it was recommended that future assessments include the small amounts of catch from outside the Seto Inland Sea as a sensitivity run or the base case model.

8.2.2 Natural mortality

The M for this stock was assumed to be 0.3125 y^{-1} , based on a maximum age of 8 and the empirical relationship from Tanaka (1960). However, the empirical relationship was based on relatively old information and inconsistent with newer studies on M (e.g., Then and Hoenig 2014; Hamel 2015). Similar to the JS-ECS stock (Section 6.2.2), it was recommended that the M for this stock be re-evaluated and that sensitivity runs be based on the estimated uncertainty of M . It was also recommended that mark and recapture data from hatchery releases be incorporated into the assessment model and used to estimate M .

8.2.3 Maturity

The BH-SIS stock was thought to be fully mature by age-4+. This was considered to be appropriate given the current available information. However, it was recommended to re-examine the maturity of the stock periodically using more recent methods and data, especially focusing on variability between areas and years.

8.2.4 Growth

In the data subsection (Section 8.1.4), it was recommended that an otolith sampling and aging program be developed for this stock. This recommended sampling program will also improve the understanding of how growth varies between areas and periods.

8.2.5 Recommendations on biology

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

- 1) It was strongly recommended to perform studies to better define the stock structure and distribution for this stock.
- 2) It was recommended that the natural mortality assumed for this assessment be re-evaluated and that sensitivity runs be based on the estimated uncertainty of natural mortality.
- 3) It was recommended that mark and recapture data from hatchery releases be incorporated into the assessment model and used to estimate natural mortality.
- 4) It was recommended to periodically re-examine the maturity of the stock using more recent methods and data, especially focusing on variability between areas and years.
- 5) It was recommended to use the previously recommended sampling program to improve the understanding of how growth varies between areas and periods.

8.3 Estimation Model

Similar to the other stocks, this review found that the results of the VPA model of the BH-SIS stock were not BSIA because the primary data inputs (i.e., catch-at-age) for the assessment were not BSIA.

8.3.1 VPA model

A standard tuning VPA model was used in the BH-SIS stock assessment to estimate the historical population dynamics of the stock. This review noted that the strict assumptions about the data for a VPA model were violated in this assessment (see Section 8.1).

The priority for future improvements would be to improve the index for this stock (Section 8.1.2) and to develop a catch time series that better encompasses the entire stock (Section 8.1.1). Given the

otherwise relatively rich data set for this stock, it was also recommended to explore the use of integrated models, especially using an empirical weight-at-age approach (Kuriyama et al. 2015) and the mark-recapture data from hatchery releases.

8.3.2 Model diagnostics

The model diagnostics indicated a moderate retrospective pattern for recruitment in the terminal period of the assessment. The cause was likely the lack of information on the recruitment near the end of the historical period, and the lack of a recruitment index. The other important estimated variables (e.g., SSB) exhibited negligible retrospective patterns. The residual patterns of the model fit to the tuning index appeared to be reasonable.

8.3.3 Uncertainty

The treatment of uncertainty in the BH-SIS assessment was similar to the other stocks and was similarly inadequate (see Section 4.3.3 for more details). It was recommended to explore the use of integrated models, which can more easily include and propagate the uncertainty in the data and biological processes throughout the model.

8.3.4 Recommendations on estimation modeling

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

- 1) It was recommended to explore the use of integrated models for this stock to allow modeling of the appropriate processes for the population and data (i.e., bring the model to data), rather than having to make strong, unsubstantiated assumptions about the data to fit a model with stringent data requirements.
- 2) It was recommended to integrate mark and recapture data from hatchery releases into the assessment model, which will help improve the model results, even with a relatively short time series.
- 3) 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.

8.4 Projections

The outputs from the VPA model were used to estimate the SRR and in the projections. Given that the results from the VPA model were not BSIA (Section 8.3), this review also found the results of the projections to not be BSIA. Consequently, there was relatively little time spent on reviewing the projections.

8.4.1 Stock-recruitment relationship (SRR)

It was reported during the meeting that the assessment scientists follow guidelines from FRA to estimate the SRR in a stock assessment. These guidelines appear to be used across all FRA stock assessments and is beyond the ToRs for this review. Therefore, this review did not consider whether the SRR was BSIA.

The approach for the SRR of the BH-SIS stock included hatchery releases and was similar to the JS-ECS and JS-SIS stocks. The comments and recommendations would be therefore be similar as well (see Section 6.4.1 for details). Some time was spent discussing how to interpret a SRR with stock enhancement. It was noted that MSY calculations using this SRR may not reflect the sustainability of SSB under fishing, without hatchery releases. There was also some concern with the estimated SRR and MSY-based reference points (SSB_{MSY} and F_{MSY}). Given the small range of estimated SSB and recruitment, the uncertainty in the estimated SRR and MSY-based reference points will be relatively high. Therefore, it was difficult to distinguish between the different candidate SRRs but the management consequences for the choice of SRR was relatively large. The uncertainty in the estimated SRR and MSY-based reference points do not appear to be well communicated. Another concern was that the recruitment and SSB estimates were assumed to be known without error. It was therefore recommended that the recruitment and SSB estimates used to develop the SRRs have uncertainty associated with them. If possible, it would be substantially better to estimate the SRR parameters within the estimation model, rather than using a posthoc approach. It was recommended to improve communication of the uncertainties in the assessment and management quantities in the report.

8.4.2 Short-term projections

Given that the results from the VPA model were not considered to be BSIA, it follows that the results of these projections for the BH-SIS stock were also not considered to be BSIA because the projections relied on the VPA model results for inputs.

In terms of the methodology, the projection models were the same as for the JS-ECS stock and the comments were similar (see Section 6.4.2 for details). The models were relatively straightforward and appropriate, given the information available. However, it was considered important and recommended 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.

8.4.3 Long-term projections

Similar to the short term projections, the results of these long-term projections were not considered to be BSIA because the inputs for the projections relied on the VPA model results, which were not BSIA. The models used for the long-term projections were similar to the short-term projections, and were relatively straightforward and appropriate. However, similar to the short-term projections, the uncertainty for the long-term projections were under-estimated.

8.4.4 Recommendations on projections

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

- 1) It was recommended that the uncertainties in the estimated SRR and management quantities be better communicated.
- 2) It was recommended that the recruitment and SSB estimates used to develop the SRRs have uncertainty associated with them.
- 3) It was recommended to incorporate that uncertainty in the N-at-age in the terminal year into the short term and long-term projections.

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10. Appendix 1 – Terms of Reference

Independent peer review for Japanese Fish Stock Assessment will be conducted by external experts based on the Stock Assessment Reports provided by Japan Fisheries Research and Education Agency (hereafter, FRA). External experts review the appropriateness of the assessment as mainly for points A to G below and provide recommendation and suggestions for future improvements. The FRA either reflects the recommendations to future stock assessment process or provides valid explanation if the suggested proposal is not applicable.

Points of review

- 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.
- 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.

Review process

At first, the FRA will provide external experts with Stock Assessment Reports and supplemental materials as the subject under the review. After receiving pre-questions from external experts and confirming them by holding specific meeting, the external experts shall prepare and provide a final review report. In response to this, FRA will consider future responses and make a written document. These results shall be made public through the FRA web site.