FINAL

ISC/19/ANNEX/06

ANNEX 6

19th Meeting of the
International Scientific Committee for Tuna
and Tuna-Like Species in the North Pacific Ocean
Taipei, Taiwan
July 11-15, 2019

REPORT OF THE ALBWG WORKING GROUP WORKSHOP

July 2019

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Annex 06

REPORT OF THE ALBACORE WORKING GROUP WORKSHOP

International Scientific Committee for Tuna and Tuna-like Species
in the North Pacific Ocean

February 26 – March 4 2019
NRIFSF/FRA
Shimizu, Shizuoka, JAPAN

1. OPENING OF THE WORKSHOP

1.1 Welcome and introduction

An intersessional workshop of the Albacore Working Group (ALBWG or WG) of the International Science Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) was convened at the National Research Institute of Far Seas Fisheries (NRIFSF/FRA), Shimizu, Shizuoka JAPAN, 26 February – 4 March 2019.

Ogura, M., deputy director of the National Research Institute of Far Seas Fisheries/Fisheries Research Institute, welcomed 8 participants (**Attachment 1**) to the NRIFSF/FRA, and wished them a productive meeting.

The ALBWG Chair briefly described the objectives of the meeting and the expected outcomes. The objectives of this workshop were to: (1) Review progress of MSE development; (2) Review preliminary MSE results; (3) Prepare draft executive summary of the MSE progress for the 4th MSE WS in Yokohama and ISC19 plenary, (4) Review progress on model improvements for 2020 assessment and (5) Review timeline and work plan for MSE and 2020 assessment.

1.2 Adoption of Agenda and Assignment of Rapporteurs

Rapporteur duties were assigned to Steven Teo and Akiko Aoki. The draft agenda was circulated prior to the meeting, reviewed and adopted at the workshop (**Attachment 2**).

1.3 Distribution of documents and working paper availability

Three working papers were submitted and assigned numbers for the workshop (**Attachment 3**). All of the working papers will be publicly available through the ISC website (http://isc.fra.go.jp/) and author contact details will be provided for the other related materials.

1.4 Meeting protocol

The ALBWG Chair noted that the efforts of the WG at this meeting would be collegial and follow the scientific method with an emphasis on empirical testing, open debate, documentation and reproducibility, reporting uncertainty, peer review, and constructive feedback to authors and presenters.

2. PROGRESS OF MSE DEVELOPMENT

The WG reviewed the progress of model development and conditioning for the NPALB MSE.

Summary of results for the North Pacific albacore tuna (Thunnus alalunga) management strategy evaluation. D. Tommasi and S. Teo (ISC/19/ALBWG-01/01)

A management strategy evaluation framework was developed for North Pacific albacore tuna (NPALB, *Thunnus alalunga*) to assess the performance of alternative candidate alternative management strategies and reference points for NPALB given uncertainty. Harvest strategies with Total Allowable Effort (TAE) control performed better than ones with Total Allowable Catch (TAC) control across all performance metrics because they could quickly adjust catches in response to changes in biomass between assessment periods. HS3 showed more variability than HS1 in catch between years because of the steeper changes in catch required once the threshold reference point was crossed. For the same target reference point (TRP), harvest control rules (HCRs) with a higher limit reference point (LRP) performed poorer. They showed a higher probability of the LRP being breached, lower odds of catches being higher than the historical period, and a higher probability of decreases in catch from one year to the next being higher than 30%. Across TRPs, there was no single best-performing HCR for all performance metrics (PMs). Trade-offs were evident between conservation and economic indicators. With a lower fishing intensity TRP, the population was maintained at a higher level, requiring less management intervention and resulting in lower catch variability between years. However, this stability came at a cost to overall catch.

<u>Discussion</u>

After thanking D. Tommasi for the tremendous amount of work put into the MSE modeling, the ALBWG reviewed the various component models and results of the MSE. **The ALBWG agreed with the recommendations of the authors and supported the following as the main results of the MSE to be communicated to managers and stakeholders**:

1. *A lower fishing intensity TRP (i.e. F50), maintains the population at a higher level than F40 and F30, requiring less management intervention and resulting in lower catch variability between years. However, lower fishing intensity results in lower overall catch.*
2. *HCRs with a TRP of F40 have less closures and higher catch stability as compared to a TRP of F30, resulting in comparable or higher catch despite lower fishing intensity.*
3. *An LRP and threshold reference point closer to the TRP results in a higher frequency of*

management interventions, fishery closures and lower catch stability.

4. *HS3 showed lower catch stability than HS1, but had less fishery closures.*
5. *Harvest strategies with Total Allowable Effort (TAE) control performed better than ones with Total Allowable Catch (TAC) control across all performance metrics.*

In the course of the review process, **the ALBWG listed the following limitations of the current MSE, and recommended that the limitations be communicated to the managers and stakeholders at the 4th ISC ALB MSE workshop in Yokohama** during 5-7 March, 2019.

These limitations of the current NPALB MSE framework were:

- Effort is modeled as fishing intensity rather than being modeled explicitly as the number of fishing days or number of hooks. However, in the real world, managers would manage effort as the number of hooks or the number of fishing days rather than fishing intensity. If TAE control was to be implemented, more work would be needed to quantify how fishing intensity would be translated into effort in terms of number of fishing days and number of hooks.
- Given the uncertainty in the relationship between fishing intensity in the MSE and real world effort in number of fishing days and number of hooks, effort control may be more effective in the simulation than in the real world and is assumed to be as effective as TAC control, which may not be realistic.
- It is assumed that effort or catch control is implemented equally effectively across all fisheries, including both NPALB targeting and non-targeting (e.g. surface fleets vs. longline).
- Allocation is assumed to be constant at the average of 1999-2015 levels throughout the simulation. This formulation prevents an assessment of management objective 3, *maintain harvest ratios by fishery*, as the harvest ratios are kept constant by design. Testing of different allocation schemes would require input from managers as to what those allocation rules might be.
- In the simulations for HS1 and HS3, if the fishing intensity is lower than the target reference point, the simulated fishing intensity is increased to the target level when setting the TAC or TAE. This assumes no limitations in the capacity of the NPALB fleets.
- Given the lack of computer and personnel resources, only one rebuilding plan (fishery is closed) was tested. Further work could examine other rebuilding measures proposed by managers and stakeholders at the 3rd MSE workshop in Vancouver during 2017.
- Given the lack of computer and personnel resources, when determining stock status, only the probability of SSB being higher than the LRP or threshold reference point at a 50% level was tested. Further work could examine other probabilities proposed at the 3rd MSE workshop in Vancouver during 2017.
- NPALB is a highly migratory species whose movement rates to given areas in the North Pacific are highly variable. This affects availability to the fisheries operating in those areas.

However, the simulations do not explicitly model these movement processes and instead only approximate the availability to various fleets. Further work could include the development of an area specific model to better capture uncertainty in migration rates, and their relationship to availability.

- The simulations are conditioned on data from 1993 onwards, although available data dates back to 1966. Therefore, the simulations may not include the full range of uncertainty in the population dynamics of NPALB. Thus, the MSE results are most applicable to recent conditions. Nevertheless, inclusion of the lowest productivity scenario (Scenario 6) was an attempt to accommodate some of this uncertainty.

The ALBWG noted that the information from the MSE was highly complex and can be difficult to understand, especially for stakeholders. Therefore, **the ALBWG recommended that a document summarizing the MSE results in less technical language be provided at the 4th ISC ALB MSE workshop in Yokohama**. Subsequently, the ALB WG reviewed a non-technical summary of the ISC ALB MSE developed by the authors and approved the non-technical summary for dissemination to managers and stakeholders (**See Appendix 5c**).

The Chair reminded the ALBWG that a **preliminary executive summary of the ISC ALB MSE is to be completed approximately one month before the IATTC SAC meeting** during May 13 – 17, 2019, in order for the **preliminary results of the ISC ALB MSE to be presented at the IATTC SAC meeting by D. Tommasi. Presentations on the ISC ALB MSE are also to be presented to the ISC Plenary (July 2019), WCPFC NC (September 2019), and possibly the WCPFC SC (August 2019) meetings.**

Given that this is the first round of the ISC ALB MSE, the ALBWG discussed the structure of the executive summary and report. **For the executive summary, the ALBWG recommended the inclusion of subsections on the five main results and the limitations of the MSE using non-technical language, as well as any recommendations from the 4th ISC ALB MSE workshop in Yokohama**. Although the executive summary should communicate brief descriptions of the models to other scientists, it is probably more useful for the executive summary to focus on communications with non-technical audiences. Technical audiences can be directed to sections of the main report, where the technical details can be described. The ALBWG also recommended that the results from all the models runs be presented in the main report of the MSE. However, if the volume of model results are too large, it may be possible to provide the detailed model results in electronic form.

3. PROGRESS ON MODEL IMPROVEMENTS FOR 2020 ASSESSMENT

Plan for updates to the future projection program. H. Ijima; presented by H. Kiyofuji (ISC/19/ALBWG-01/02)

This paper reports on the update plan of future projection program that was used in previous ISC albacore stock assessment. Significant work is to improve the calculation method of F at age. Specifically, it needs to perform the calculation in C++ and obtain F at Age in the fleet base. Next, MCMC result will use as the initial number at age, but as in the case of Bootstrap, the posterior distribution might be asymmetrical. Thus, careful comparison with the base case is necessary.

Discussion

The ALBWG thanked the author for providing an update on the future projections software. The Chair noted that the author is aiming to provide more detailed updates on the future projection software during the upcoming data preparatory workshop in November 2019.

Potential improvements to the stock assessment model for North Pacific albacore tuna. Teo, S., Minte-Vera, C. and D. Tommasi (ISC/19/ALBWG-01/03)

In preparation for the upcoming stock assessment of North Pacific albacore tuna scheduled for 2020 by the Albacore Working Group, the 2017 base case model was re-examined and several potential improvements were identified. These improvements could be classified into two main groups: 1) **Group #1** improvements would maintain a relatively similar model structure to the 2017 base case model, with a start year of 1993; and 2) **Group #2** improvements are focused on extending the start year back to 1966, which is the start year used in the 2014 assessment. The suggested improvements can be summarized as: 1) Correcting catch errors; 2) updating to Stock Synthesis v3.30; 3) fitting to alternative abundance indices; 4) improving abundance indices; 5) reducing misfit to size composition data of major juvenile fisheries; 6) area-specific fleet definitions; 7) sex-specific size composition data from Japanese training and research vessels; 8) size composition data from China and Vanuatu longline fleets; and 9) extending model back to 1966. Based on the analyses of these suggested improvements, a non-exhaustive list of recommendations was developed for the Albacore Working Group to consider, in preparation for the 2020 assessment.

Discussion

The ALBWG thanked the authors for their analyses and presentation. The ALBWG noted the minor catch errors discovered by the authors in the 2017 NPALB assessment and **recommended that the Chair communicate the catch errors to the ISC Plenary**. However, the impact of the error was relatively minor and did not affect the conclusions of the 2017 NPALB assessment. Nevertheless, it was **recommended that the following differences between the 2017 base case model and the model with corrected catch should be presented to the ISC Plenary**.

Table ES1. Estimates of maximum sustainable yield (MSY), female spawning biomass (SSB) quantities, and fishing intensity (F) based reference point ratios for north Pacific albacore tuna for the 2017 base case model and the same model with the corrected catch. SSB0 and SSBMSY are the unfished biomass of mature female fish and at MSY, respectively. The Fs in this table are not based on instantaneous fishing mortality. Instead, the Fs are indicators of fishing intensity based on SPR and calculated as 1-SPR so that the Fs reflects changes in fishing mortality. SPR is the equilibrium SSB per recruit that would result from the current year's pattern and intensity of fishing mortality. Current fishing intensity is based on the average fishing intensity during 2012-2014 (F2012-2014).

Quantity	2017 Base Case	2017 Base Case with Corrected Catch
MSY (t) [A]	132,072	129,524
SSB_{MSY} (t) [B]	24,770	23,795
SSB_0 (t) [B]	171,869	168,656
SSB_{2015} (t) [B]	80,618	78,240
$SSB_{2015}/20\%SSB_{current,\ F=0}$ [B]	2.47	2.44
$F_{2012\text{-}2014}$	0.51	0.51
$F_{2012\text{-}2014}/F_{MSY}$	0.61	0.61
$F_{2012\text{-}2014}/F_{0.1}$	0.58	0.58
$F_{2012\text{-}2014}/F_{10\%}$	0.56	0.57
$F_{2012\text{-}2014}/F_{20\%}$	0.63	0.64
$F_{2012\text{-}2014}/F_{30\%}$	0.72	0.73
$F_{2012\text{-}2014}/F_{40\%}$	0.85	0.85
$F_{2012\text{-}2014}/F_{50\%}$	1.01	1.02

A – MSY includes male and female juvenile and adult fish

B – Spawning stock biomass (SSB) in this assessment refers to mature female biomass only.

Based on the authors' analyses, **the ALBWG recommended the following research in preparation for the 2020 assessment**. Higher priority was given to research that are likely to have bigger impacts on assessment results and could be completed in the short time window. Lead scientists for various research topics were identified (in parentheses).

High priority

1) Update all data to 1966 - 2018 (all ALBWG members);
2) Correct any catch errors (S. Teo);
3) Update modelling platform to v3.30 of Stock Synthesis (S. Teo);

4) Develop a single stock-wide adult NPALB index using a length dis-aggregated, spatiotemporal, delta-GLMM model (K. Fujioka & H. Ijima);
5) Determine the appropriate seasonality for the current adult (JPLL in A2) and juvenile/subadult (JPLL in A1&3) indices (K. Fujioka & Ijima);
6) Develop adult and juvenile/subadult indices that are consistent with the appropriate seasonality, and for 1993 – 2018 (K. Fujioka & H. Ijima);
7) Develop an index representing adults in area A4 (K. Fujioka & H. Ijima);
8) Re-examine the representativeness of the size composition data from the Japan pole-and-line and EPO surface fleets (Y. Aoki & S. Teo);

Medium priority

1) Update future projections software (H. Ijima)
2) Develop area-specific fleets for Taiwan and EPO fisheries (C.Y. Chen & S. Teo);
3) Develop and document area- and sex-specific size compositions from Japan research and training vessels (TBD);
4) Develop and examine models that fit to the sex-specific size compositions from Japan research and training vessels to estimate sex-specific differences in biology (S. Teo);
5) Re-examine parameterization of important biological parameters like steepness, natural mortality, and growth (S. Teo & H. Ijima);
6) Develop and document area-specific size composition and other fishery data for China and Vanuatu longline fleets (H. Kiyofuji, S. Teo & C. Minte-Vera);
7) Re-examine the representativeness of the size composition data from the Japan longline vessels during 1975 – 1992 period (H. Ijima);

Low priority

1) Examine information on NPALB biology and fishery operations during the 1975 – 1992 period (H. Ijima);
2) Develop a combined fleets longline abundance index using spatiotemporal models.

4. TIME AND PLACE OF NEXT MEETING

The WG developed a work plan for the completion of the first round of the NPALB MSE, data preparatory meeting and the stock assessment scheduled for 2020 (**Attachment 4**). **The WG agreed with the proposed work plan.**

5. OTHER MATTERS

Two presentations were provided to the working group on sex discrimination method using DNA makers and key points to understand spatio-tempoeal model.

Sex discrimination method in Albacore using DNA markers. S. Chiba, presented by H. Kiyofuji (Oral presentation)

We tried to apply three sex-specific DNA markers to sex discrimination of Albacore. First of all, known sex samples (10 males and 12 females) of ALB were used for the discrimination test. The results agreed with known sex except a false-negative signal shown in sex-specific marker 1. Second, 185 unknown sex samples were used for trial test with the sex-specific marker 2. The test showed that the samples consist of 137 males and 48 females. Although future tests need to ensure, these results suggest that sex-specific marker 2 may have applicability to NPALB.

Discussion

The ALBWG thanked the Chair for presenting this exciting, new research. Further tests are required but these results suggest that it may be plausible to collect sex-specific fisheries data in the near future in a cost-effective way, which is a high priority for albacore research.

Key points to understand spatio-temporal model – Modelling of random effects. M. Kai (Oral presentation)

The contents of spatial temporal models for pelagic sharks published in the international journals (Kai et al. 2017a, b) was explained concisely.

References

Kai, M., Thorson, J.T., Piner, K.R., Maunder, M.N., 2017a. Predicting the spatio-temporal distributions of pelagic sharks in the western and central North Pacific. *Fish. Oceanogra.* **26**, 569−582. doi:10.1111/fog-12217.

Kai, M., Thorson, J.T., Piner, K.R., Maunder, M.N., 2017b. Spatio-temporal variation in size-structured populations using fishery data: an application to shortfin mako (*Isurus oxyrinchus*) in the Pacific Ocean. *Can. J. Fish Aquat. Sci.* **74**, 1765−1780. doi:10.1139/cjfas-2016-0327.

Discussion

The ALBWG thanked the author for presenting this important research. The ALBWG discussed how these class of models may be applied to Japanese longline data to help improve the adult abundance indices for NPALB. In particular, there was a lot of interest in developing a length-disaggregated, spatiotemporal, delta-GLMM model for albacore tuna.

6. CLEARING OF THE REPORT

The WG Chair prepared a draft of the report, which was reviewed by the WG prior to adjournment of the workshop. After the workshop, the WG Chair evaluated and incorporated suggested revisions, made final decisions on content and style and distributed a second draft via email for approval by WG members. The final report will be forwarded to the Office of the ISC Chair for review and approval by the ISC19 Plenary.

7. ADJOURNMENT

The ALBWG meeting was adjourned at 11:05 on 4 March 2019. The WG Chair and WG members expressed their appreciation to Dr. D. Tommasi (primary MSE modeler) for her enormous efforts to develop the MSE framework for North Pacific albacore. He also thanked the scientists participating in the workshop for their attendance and contributions on albacore matters.

Attachment 1 - List of Participants

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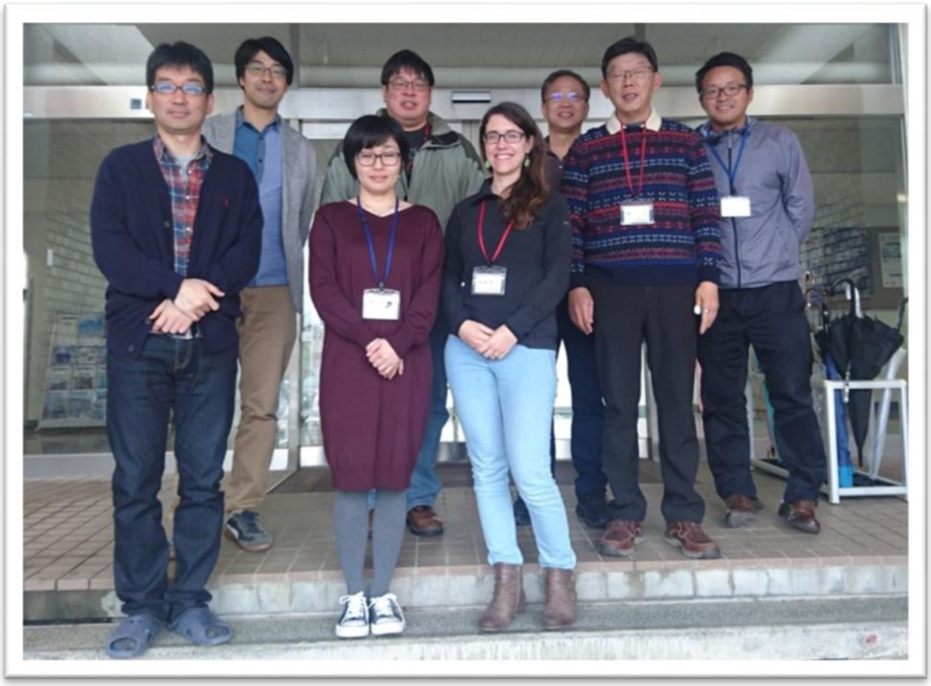

The Albcore Working Group - Back (left to right) – Hidetada Kiyofuji, Ko Fujioka, Akiko Aoki, Steve Teo, Desiree Tommasi, Zane Zhang, Chiee-Young Chen and Yoshinori Aoki.

Attachment 2 - Meeting Agenda

ALBACORE WORKING GROUP (ALBWG)

INTERNATIONAL SCIENTIFIC COMMITTEE FOR TUNA AND TUNA-LIKE SPECIES IN THE NORTH PACIFIC OCEAN

INTERSESSIONAL DATA PREPARATION WORKSHOP

26 February – 4 March 2019

NRIFSF/FRA, Shimizu, Shizuoka, JAPAN

Agenda

1. Opening of the Workshop
    - Welcome
    - Opening Remarks
    - Workshop Goals and Outputs
    - Introductions
2. Meeting Logistics
    - Meeting Protocol
    - Review and Adoption of the Agenda
    - Assignment of Rapporteurs
3. Review outcomes of ALBWG WS in April 2018
4. Progress of MSE development
    - Review of Operating Model (OM) structure
    - Review of Operating Model conditioning
    - Overview of MSE framework and modeling structure and workflow
    - Uncertainties considered and fishing scenarios tested
    - Overview of harvest strategies
5. Review preliminary MSE results
    - Presentation and discussion of MSE results
    - Summary of main key points for managers and stakeholders
    - Future research recommendations
6. Progress on model improvements for 2020 assessment
7. Review timeline and work plan for MSE and 2020 assessment
8. Draft executive summary of MSE report for ISC19 plenary
9. Other matters
10. Clearing of Report
11. Closing remarks and adjournment

Attachment 3 - Meeting Documents

Number	Title and Authors	Availability
ISC/19/ALBWG-01/01	Summary of results for the North Pacific albacore tuna (Thunnus alalunga) management strategy evaluation. D. Tommasi and S. Teo	Available from the ISC website
ISC/19/ALBWG-01/02	Plan for updates to the future projection program. H. Ijima	Available from the ISC website
ISC/19/ALBWG-01/03	Potential improvements to the stock assessment model for North Pacific albacore tuna. S. Teo, C. Minte-Vera and D. Tommasi	Available from the ISC website
Presentation	Sex discrimination method in Albacore using DNA markers. Satoru Chiba	Contact the author
Presentation	Key points to understand spatio-temporal model -Modeling of random effects – Mikihiko Kai	Contact the author

Attachment 4 - Work plan

Date	Location	Task/Event
March 5-7, 2019	Yokohama, Japan	4th ISC MSE workshop
May 13-17, 2019	La Jolla, USA	10th IATTC SAC
July 11-15, 2019	Chinese Taipei	ISC19 Plenary
Aug 12-20, 2019	Pohnpei, Federated States of Micronesia	15th WCPFC-SC
Sep 2-6, 2019	Portland, OR, USA	15th WCPFC-NC
Nov 12-18, 2019	Shimizu, Japan	ALBWG: data preparatory
March 16-23, 2020	La Jolla, CA, USA	ALBWG: stock assessment
Late 2020	To be determined	ALBWG: review results from 2nd round of MSE 5th ISC MSE workshop

Data submission: earlier than Dec. 25 2019.

Attachment 5
4th ISC Management Strategy Evaluation (MSE) Workshop
5 – 7 March 2019
Yokohama, Kanagawa, JAPAN

ALBWG Chairman's Report on Outcomes for North Pacific Albacore

Management strategy evaluation (MSE) is a process that, given the management objectives that stakeholders and managers have conveyed, uses computer simulations to assess the performance of candidate harvest strategies. The two Regional Fisheries Management Organizations (RFMOs) tasked with managing north Pacific albacore (NPALB), namely the Northern Committee of the Western and Central Pacific Fisheries Commission (WCPFC NC) and the Inter American Tropical Tuna Commission (IATTC), requested the Albacore Working Group (ALBWG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) to start developing an MSE for NPALB. The WCPFC NC established a limit reference point (LRP) of $20\%SSB_{CURRENT,\ F=0}$ (SSB: Spawning Stock Biomass) for NPALB, but no formal harvest strategy or target reference point (TRP).

The 3rd MSE Workshop in Vancouver, Canada during 2017, focused on updating management objectives, and developing candidate reference points and harvest control rules for testing. There were two main outputs from the workshop, which were 1) updated management objectives and 2) proposed candidate harvest strategies and associated reference points and harvest control rules. The ISC ALBWG was requested to develop performance indicators and expected outputs consistent with the updated management objectives.

Primary objectives of the 4th ISC MSE WS were to: (1) examine the preliminary results of the initial round of MSE for NPALB with managers and stakeholders; (2) collate feedback from managers and stakeholders on future MSE improvements; and (3) develop recommendations for the WCPFC NC and IATTC. Expected outputs from the workshop are: (1) a list of improvements for future rounds of MSE for the ISC ALBWG; and (2) a list of recommendations for the WCPFC NC and IATTC.

The purpose of this report is to document the feedback from managers and stakeholders after examining the preliminary results of the initial round of MSE for NPALB. This report also documents the candidate Reference Points (RPs) and Harvest Control Rules (HCRs) proposed by managers and stakeholders for future evaluation in a 2nd round of MSE by the ALBWG, pending approval by the ISC Plenary. The agenda for this meeting is in **Appendix 5a**.

There were 26 participants (**Appendix 5b**) attending the 4th ISC MSE Workshop, including fishery managers, non-governmental organizations, scientists and stakeholders. Dr. Tokio Wada, executive director of the Fisheries Research Agency, welcomed the 26 participants to Japan and wished them a productive meeting.

The ALBWG vice-Chair, S. Teo (NOAA/SWFSC), was the lead rapporteur and A. Akiko (NRIFSF), C. Barroso (NOAA/WCRO) and R. Wysocki (DFO) were the support rapporteurs for the workshop.

The ALBWG Chair, H. Kiyofuji (NRIFSF/FRA), briefly overviewed the purposes and goals of the workshop. The ALBWG vice-Chair, S. Teo briefly reviewed the basic concepts of the MSE process and outcomes from the 3rd MSE Workshop in Vancouver, Canada. The lead MSE scientist, D. Tommasi (NOAA/SWFSC), reviewed and led a discussion on the preliminary results from first round of the MSE process. The ISC ALB WG provided a summary of preliminary results to the MSE WS participants after thorough discussion at the ALB WG meeting prior to the MSE WS (**Appendix 5c**).

During and after the above presentations, there was substantial discussion on the results of the initial round of MSE. **The workshop participants recommended that the ISC ALBWG should continue working on the MSE process for a 2nd round because the results presented at the 4th ISC ALB MSE Workshop were useful for understanding the tradeoffs and potential performance of candidate reference points and harvest control rules.** However, some candidate reference points and harvest control rules developed at the 3rd MSE Workshop were not evaluated in time due to computer resource limitations. However, some candidate reference points and harvest control rules developed at the 3rd MSE Workshop were not evaluated in time due to computer resource limitations. Therefore, **no management recommendations for the WCPFC NC and IATTC were developed by the workshop participants.** Instead, the **workshop participants developed a focused list of candidate reference points and harvest control rules to be examined for the 2nd round of MSE (Figure 1, and Tables 1- 5).** The workshop participants also raised several points regarding clarity of presentation of results, modification of management objectives, and technical aspects of the MSE. **A list of recommendations and future improvements were developed by the workshop participants.**

Given the recommendation to continue with the MSE process, the workshop participants discussed the MSE workplan with the ALBWG and expressed a desire to examine the results from the 2nd round of MSE by early 2020. However, the ALBWG noted that the next full stock assessment has been scheduled for March 2020 and it will be highly difficult for the ALBWG to review the MSE results and perform a full stock assessment during the same period. In addition, there are also not enough computer resources to complete all model runs by early 2020. Some workshop participants volunteered to check with their organizations on the availability of additional computer resources that could be brought to bear but would require some follow up after the workshop.

Subsequent to the workshop, the ISC Chair, J. Holmes (DFO), reminded the ALBWG that the workplan has to be approved by the ISC Plenary and that he was not supportive of delaying the assessment, noting that the final year of data in the last assessment in 2017 was from 2015. Based on this discussion, **the ALBWG recommended a workplan to present the results of the 2nd round of MSE at the 5th MSE Workshop by late 2020, if the model runs are completed by that time.**

Recommendations and future improvements suggested by the participants during the 4th ISC MSE workshop.

Presentation of MSE Results

1. ‘The ALBWG should be more explicit in the labelling of performance indicators and specify if an indicator is based on a probability. For example, for Management Objective #2, the performance indicator labelled “Relative total biomass” was actually the probability of the depletion of total biomass being over the minimum historical depletion and could instead be labelled “probability of total biomass > minimum historical”.
2. Performance indicators using relative total or spawning biomass are likely to be better understood than indicators using probabilities. Separate plots of the mean or median of the relative biomasses coupled with plots of the variability of those relative biomasses may be preferable to a single plot of probabilities. Comparison with historical levels could be done by including indications of the historical levels to be compared.
3. The ALBWG should provide guidance on how to interpret fishing intensity in terms of implications to fleet management. For example, it would be useful for managers to be shown the changes in fishing intensity relative to current fishing intensity.

Management Objectives

4. Managers and stakeholders should prioritize, rank, or weight the management objectives to assist decision making and help resolve tradeoffs in management objectives.
5. Management Objective #6 was considered of relatively low priority by managers and stakeholders in evaluating candidate reference points and harvest control rules.
6. The ALBWG should try to obtain the necessary expertise to evaluate the Management Objective of “Maximizing the economic returns of existing fisheries”. However, this would be a longer-term goal beyond the 2nd round of MSE.
7. As the MSE process continues, it should be emphasized that the overarching objective running through all the management objectives of the MSE is to maintain the viability and sustainability of the current NPALB stock and fisheries.

Candidate harvest strategies, reference points and harvest control rules (Figure 1, Table 1 and Table 2)

8. The 2nd round of MSE should focus on Harvest Strategy 3 (Fig. 1) using the specific reference points and harvest control rules listed in Table 2.
9. Harvest Strategy 1 should be removed from further consideration because it performed poorer in terms of Management Objective #1 relative to Harvest Strategy 3, and it was considered undesirable to have a discontinuity in fishing intensity once the limit reference point was breached. In addition, participants of the 3rd MSE Workshop intended to evaluate Harvest Strategy 3 rather

than Harvest Strategy 1.

10. Harvest Strategy 2 should be removed from further consideration because the absence of a threshold reference point required a large drop in fishing intensity once the limit reference point was breached and it performed poorer than Harvest Strategy 3 with F50 or F40 in terms of Management Objective #2.
11. The candidate target reference point of F30 should be removed from further consideration because it was the worst performing in terms of Management Objectives #1, 2, and 5, and had a similar performance to F40 for Management Objective #4.
12. The candidate target reference point of F0204 should be removed from further consideration because the actual fishing intensity of this reference point varied substantially between productivity scenarios. It also performed poorer than TRP40 and TRP50 for Management Objectives #1, 2, and 5.
13. A stricter risk level of 90% (rather than 50%) should be used when evaluating the risk of breaching the candidate limit reference points of SSB7.7% and SSB14% (i.e., the LRP is breached if the probability of being above the limit reference point drops below 90%). Given that the candidate limit reference point of SSB20% is relatively conservative, a risk level of 80% was considered appropriate for that reference point. This risk level should be calculated in the same way as is currently done in NPALB stock assessments, by using future projection software over a period of 10 years and calculating the probability of breaching the limit reference point.
14. In addition to harvest control rules where all fisheries are managed by total allowable effort (TAE) or total allowable catch (TAC), there should be an evaluation of harvest control rules where surface fisheries (i.e., Japan pole-and-line and EPO surface) are managed by TAE and all other fisheries are managed by TAC.
15. The levels of fishing intensity should be limited by the historical (1997 – 2015) levels (or distributions of historical fishing intensity levels) achieved by the NPALB fisheries. However, if these levels of fishing intensity are not high enough to compare performance of threshold and limit reference points, low productivity scenario should be used in the operating models to evaluate these reference points, where appropriate.
16. A future fishing effort scenario where an unmanaged new fishery is removing an increasing amount of unreported catch should be evaluated to understand how large amounts of unreported catch may affect the performance of the harvest control rules.
17. Implementation error distribution should include both positive and negative errors.

<u>MSE Workplan</u>

18. The ISC ALBWG should continue working on the MSE process for a 2nd round because the results presented at the 4th ISC ALB MSE Workshop were useful for understanding the tradeoffs and potential performance of candidate reference points and harvest control rules. However, some candidate reference points and harvest control rules developed at the 3rd MSE Workshop were not evaluated in time due to computer resource limitations. Therefore, the workshop participants developed a focused list of candidate reference points and harvest control rules to be examined for the 2nd round of MSE.

19. Pending approval by the ISC Plenary and resolving potential conflicts with the workload of the ALBWG, results of the 2nd round of MSE should be presented at the 5th ISC ALB MSE Workshop as soon as possible, and no later than late 2020.
20. Given the timeline and previous computer resource limitations, it is important that improved computer resources be available for the 2nd round of ISC ALB MSE.

<u>Others</u>

21. The adequacy of 45 replicates per "run" (i.e., each OM-MP combination) should be examined to a) determine if the rank order of each run for each performance indicator was stable as more replicates are added; and b) determine if and how the value of each performance indicator varied with increasing numbers of replicates.
22. The relationship between how effort is modelled in the MSE operating models (i.e., fishing intensity) and effort in the real world should be examined by the ALBWG and included in the future round of MSE to help managers and stakeholders, if possible.
23. Economic expertise, even though now is not available for the ALBWG, may be needed for future round of MSE since economic aspects are important incentives for the fishery industry.

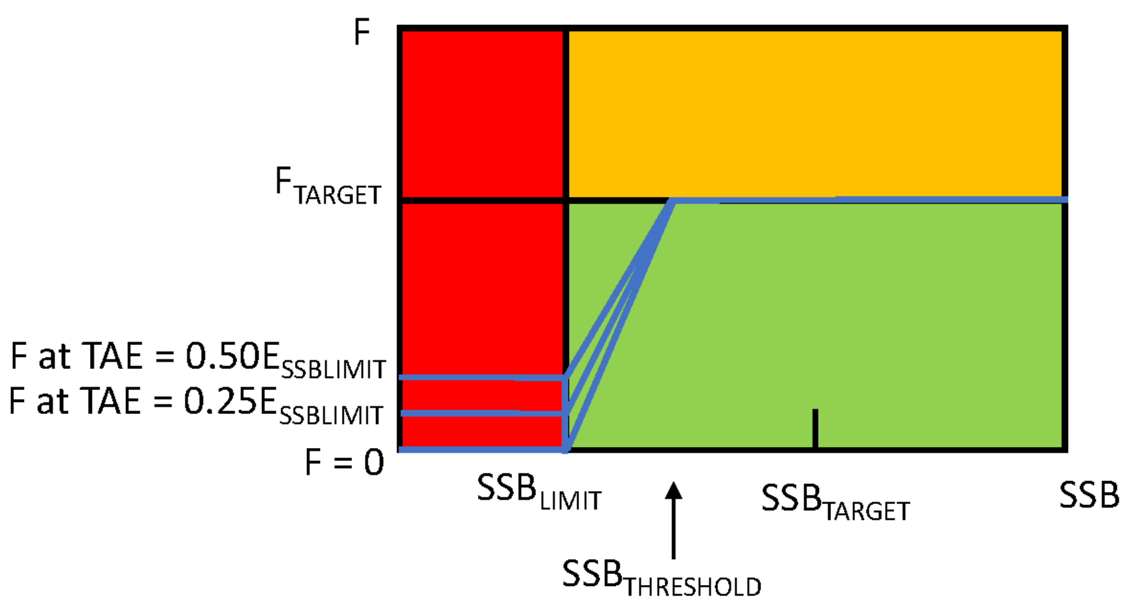

Figure 1. Schematic overview of Harvest strategy 3.

Table 1. Proposed changes to the operating model for the 2nd round of NPALB MSE.

Model Process	**1st MSE Round**	**2nd MSE Round**
Available Fishing Effort	All fleets assumed to fish at the TAE or TAC, with an implementation error. This is assumed to be true even if TAE or TAC is greater than achieved historically by the fleets	Maximum fishing intensity or mortality for each year is based on a random draw from the estimated distribution of historical fishing intensity or mortality for 1997-2015. e.g., Max(F) ~ Normal[$F_{1997\text{-}2015}$, SD($F_{1997\text{-}2015}$)]. The fishing intensity or mortality could be fleet-specific or non-fleet-specific. If TAC or TAE is greater than historical maximum catch or effort, catch/effort are based on Max(F). If Max(F) is greater than TAE or TAC, fleets assumed to fish at TAE or TAC with an implementation error.
Implementation Error	Positive implementation error only (i.e., fleets are assumed to only fish at or more than the TAE or TAC).	Bidirectional implementation error (i.e., fleets can fish at, less or more than the TAE or TAC).
Harvest controls when $SSB \geq SSB_{THRESHOLD}$	Fleets assumed to be under TAE or TAC control, based on F_{TARGET}.	Additional option to be evaluated where fleets are not under harvest control, if $SSB \geq SSB_{THRESHOLD}$.
Harvest controls when $SSB \leq SSB_{LIMIT}$	TAC = 0 or TAE =0	Evaluate additional options listed in Table 3.
Computation of Prob($SSB > SSB_{LIMIT}$)	Computed using the maximum likelihood estimate of SSB and its standard deviation as estimated by the EM (i.e. simulated stock assessment)	Use the current NPALB future projection software to calculate the Prob($SSB > SSB_{LIMIT}$) over the next 10 years using current fishing conditions.

Table 2. List of control-type, candidate target, threshold, and limit reference points to be evaluated for the 2nd round of NPALB MSE. Mixed control-type indicates that surface fleets (i.e., Japan pole-and-line, and EPO surface) are under Total Allowable Effort (TAE) control while all other fleets are under Total Allowable Catch (TAC) control.

	Control-type	F_{TARGET}	$B_{THRESHOLD}$	B_{LIMIT}
1	All Fleets under TAC	$F_{50\%}$	$30\%SSB_{CURRENT, F=0}$	$20\%SSB_{CURRENT, F=0}$
2	All Fleets under TAC	$F_{50\%}$	$30\%SSB_{CURRENT, F=0}$	$14\%SSB_{CURRENT, F=0}$
3	All Fleets under TAC	$F_{50\%}$	$30\%SSB_{CURRENT, F=0}$	$7.7\%SSB_{CURRENT, F=0}$
4	All Fleets under TAC	$F_{50\%}$	$20\%SSB_{CURRENT, F=0}$	$14\%SSB_{CURRENT, F=0}$
5	All Fleets under TAC	$F_{50\%}$	$20\%SSB_{CURRENT, F=0}$	$7.7\%SSB_{CURRENT, F=0}$
6	All Fleets under TAC	$F_{40\%}$	$20\%SSB_{CURRENT, F=0}$	$14\%SSB_{CURRENT, F=0}$
7	All Fleets under TAC	$F_{40\%}$	$20\%SSB_{CURRENT, F=0}$	$7.7\%SSB_{CURRENT, F=0}$
8	All Fleets under TAC	$F_{40\%}$	$14\%SSB_{CURRENT, F=0}$	$7.7\%SSB_{CURRENT, F=0}$
9	All Fleets under TAE	$F_{50\%}$	$30\%SSB_{CURRENT, F=0}$	$20\%SSB_{CURRENT, F=0}$
10	All Fleets under TAE	$F_{50\%}$	$30\%SSB_{CURRENT, F=0}$	$14\%SSB_{CURRENT, F=0}$
11	All Fleets under TAE	$F_{50\%}$	$30\%SSB_{CURRENT, F=0}$	$7.7\%SSB_{CURRENT, F=0}$
12	All Fleets under TAE	$F_{50\%}$	$20\%SSB_{CURRENT, F=0}$	$14\%SSB_{CURRENT, F=0}$
13	All Fleets under TAE	$F_{50\%}$	$20\%SSB_{CURRENT, F=0}$	$7.7\%SSB_{CURRENT, F=0}$
14	All Fleets under TAE	$F_{40\%}$	$20\%SSB_{CURRENT, F=0}$	$14\%SSB_{CURRENT, F=0}$
15	All Fleets under TAE	$F_{40\%}$	$20\%SSB_{CURRENT, F=0}$	$7.7\%SSB_{CURRENT, F=0}$
16	All Fleets under TAE	$F_{40\%}$	$14\%SSB_{CURRENT, F=0}$	$7.7\%SSB_{CURRENT, F=0}$
17	Mixed	$F_{50\%}$	$30\%SSB_{CURRENT, F=0}$	$20\%SSB_{CURRENT, F=0}$

18	Mixed	$F_{50\%}$	$30\%SSB_{CURRENT, F=0}$	$14\%SSB_{CURRENT, F=0}$
19	Mixed	$F_{50\%}$	$30\%SSB_{CURRENT, F=0}$	$7.7\%SSB_{CURRENT, F=0}$
20	Mixed	$F_{50\%}$	$20\%SSB_{CURRENT, F=0}$	$14\%SSB_{CURRENT, F=0}$
21	Mixed	$F_{50\%}$	$20\%SSB_{CURRENT, F=0}$	$7.7\%SSB_{CURRENT, F=0}$
22	Mixed	$F_{40\%}$	$20\%SSB_{CURRENT, F=0}$	$14\%SSB_{CURRENT, F=0}$
23	Mixed	$F_{40\%}$	$20\%SSB_{CURRENT, F=0}$	$7.7\%SSB_{CURRENT, F=0}$
24	Mixed	$F_{40\%}$	$14\%SSB_{CURRENT, F=0}$	$7.7\%SSB_{CURRENT, F=0}$

Table 3. Details of candidate harvest controls at specific SSB relative to SSB reference points to be evaluated for the 2nd round of NPALB MSE.

Stock Status	Candidate Harvest Control Rules
$SSB \geq SSB_{THRESHOLD}$	No TAE or TAC control $TAE = E(F_{TARGET})$ $TAC = B_{LATEST} * F_{TARGET}$
$SSB < SSB_{THRESHOLD}$, > SSB_{LIMIT}	$TAE = TAE_{MIN} + [E(F_{TARGET}) – TAE_{MIN}] * (SSB - SSB_{LIMIT}) / (SSB_{THRESHOLD} – SSB_{LIMIT})$, or TAE_{MIN}, whichever is greater $TAC = TAC_{MIN} + [(B_{LATEST} * F_{TARGET}) – TAC_{MIN}] * (SSB – SSB_{LIMIT}) / (SSB_{THRESHOLD} – SSB_{LIMIT})$, or TAC_{MIN}, whichever is greater TAE_{MIN} and TAC_{MIN} are the TAEs and TACs when $SSB \leq SSB_{LIMIT}$, without the rebuilding plan (see below)
$SSB \leq SSB_{LIMIT}$	For LRPs (B_{LIMIT}) with 20%$SSB_{CURRENT, F=0}$, or 14%$SSB_{CURRENT, F=0}$ $TAE=0.25 * E_{SSBLIM}$ $TAE=0.5 * E_{SSBLIM}$ $TAC=0.25 * C_{SSBLIM}$ $TAC=0.5 * C_{SSBLIM}$ For LRPs (B_{LIMIT}) with 7.7%$SSB_{CURRENT, F=0}$ TAE=0 $TAE=0.25 * E_{SSBLIM}$ TAC=0 $TAC=0.25 * C_{SSBLIM}$
$Prob(SSB > SSB_{LIMIT})$	For LRPs (B_{LIMIT}) with 20%$SSB_{CURRENT, F=0}$ $Prob(SSB > SSB_{LIMIT}) = 80\%$ For LRPs (B_{LIMIT}) with 14%$SSB_{CURRENT, F=0}$, or 7.7%$SSB_{CURRENT, F=0}$ $Prob(SSB>SSB_{LIMIT}) = 90\%$
$Prob(SSB > SSB_{THRESHOLD})$	50%
Rebuilding plan when $SSB \leq SSB_{LIMIT}$	To be determined in future MSE rounds. Previously identified candidates for rebuilding plan: $TAE = E(F(Prob. (SSB > SSB_{TARGET}) > 50\%))$ in 2 generations $TAC = B * F(Prob. (SSB > SSB_{TARGET}) > 50\%)$ in 2 generations

Additional Assumptions	
Assessment periodicity	Once every 3 years
Allocation	Average of 1999-2015

Table 4. List of the five operating models (OMs) representing different uncertainty scenarios and their parameter specifications to be evaluated for the 2nd round of NPALB MSE. A value of 1 for a parameter means a base case value, a value of 2 a lower value than base, and a value of 3 a higher value than base. See Table 4 in ISC (2018) for a detailed list of actual steepness, growth, and natural mortality values for each operating model. OM No. 3 here corresponds to OM No. 22 in Table 4 in ISC (2018), OM No. 4 to OM No. 25, OM No. 6 to OM No. 26, and OM 7 to OM No. 27.

OM No.	Steepness	Growth	Natural Mortality	Age Selectivity	Recruitment Autocorrelation
Base/1	1	1	1	Time varying	0.42
3	3	2	1	Time varying	0.42
4	3	3	1	Time varying	0.42
6	3	3	2	Time varying	0.42
7	3	3	3	Time varying	0.42

Table 5. List of potential future fishery effort scenarios to be evaluated for the 2nd round of NPALB MSE. These future fishery effort scenarios are of medium priority and may be evaluated with a subset of model runs if there are time constraints.

Potential future fishery effort scenarios
1) Increased effort & catches in the north Pacific – new entrant to fishery but catch is known to the assessment and under HCR – ramp in catch of 2,400 t per year up to 50,000 t
2) Increased effort & catches in the north Pacific – new entrant to fishery but catch is not known to the assessment and is not under HCR – ramp in catch of 2,400 t per year up to 50,000 t

Appendix 5a. Agenda for 4th ISC MSE meeting.

Albacore Working Group (ALBWG)

International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

4th Management Strategy Evaluation Workshop for Managers and Stakeholders

5-7 March 2019
Yokohama, Japan

Draft Agenda

March 5, 2019 (9:30 – 5:00)

1. Opening of the Workshop
   - Welcoming Remarks
   - Chair's Opening Remarks
   - Overview of Workshop Goals
     - ✓ Examine preliminary results of the North Pacific Albacore (NPALB) MSE
     - ✓ Provide feedback to ALBWG on future improvements
     - ✓ Develop recommendations for the WCPFC NC and IATTC
   - Overview of Workshop Outputs
     - ✓ List of future improvements to ALBWG
     - ✓ List of recommendations for WCPFC NC and IATTC
   - Introductions

2. Meeting Logistics
   - Meeting Protocol
   - Review and Adoption of Agenda
   - Assignment of Rapporteurs
   - Group Photo

3. Review of North Pacific Albacore (NPALB) MSE process and progress
   - Presentation on the NPALB MSE Process
     - ✓ Refresher on "What is an MSE?"
     - ✓ Outcomes from previous NPALB workshops
     - ✓ Review management objectives, performance metrics, and candidate RPs and HCRs developed at previous NPALB MSE workshops
     - ✓ Progress since last workshop in Vancouver, Canada (October 2017)

4. Preliminary results of the first round of the NPALB MSE
   - Presentation on the preliminary results of the NPALB MSE
   - Discussion on the preliminary results
   - Potential discussion points
     - ✓ Are the preliminary results clear and understandable?
     - ✓ Is there sufficient information provided for managers and stakeholders to evaluate the MSE results, and subsequently to propose HCRs and RPs for NPALB?
     - ✓ What are the most important management objectives and performance metrics when evaluating the candidate RPs and HCRs?
     - ✓ Are there management objectives and performance metrics that should be added, removed, and/or changed?
     - ✓ Are there other candidate RPs and HCRs that should be tested?
     - ✓ What are the most promising candidate RPs and HCRs? And why?
     - ✓ Should the NPALB MSE continue for a second round, and if so, what are the objectives for continuing the MSE?

March 6, 2019 (9:00 – 17:00)

5. Review of agenda and status from Day 1

6. Continue discussion of preliminary results and development of workshop outputs
   - Develop a candidate list of recommendations to the NC for overnight consideration
   - Develop a candidate list of future improvements to the ALBWG for overnight consideration

March 7, 2019 (9:00 am – 12:00)

7. Finalize outputs from workshop
   - Identify list of recommendations to the NC
   - Identify list of future improvements to the ALBWG

8. Review MSE timeline and work plan

9. Closing remarks

Appendix 5b. List of Participants at the 4th MSE Workshop, 5-7 March 2019, Queen's Square Yokohama, JAPAN.

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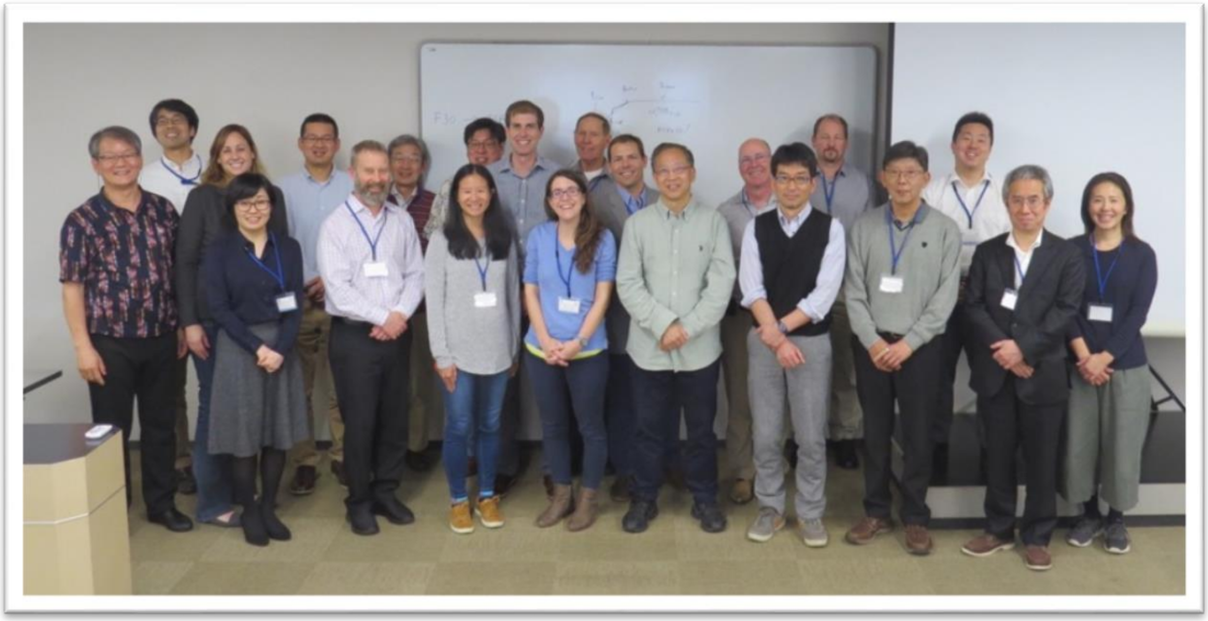

Appendix 5c. Management Strategy Evaluation for North Pacific Albacore (*Thunnus alalunga*) Tuna: A Summary for Managers and Stakeholders.

Introduction

Management strategy evaluation (MSE) is a process that, given the management objectives that stakeholders and managers have conveyed, uses computer simulations to assess the performance of candidate harvest strategies. The two Regional Fisheries Management Organizations (RFMOs) tasked with managing north Pacific albacore (NPALB), namely the Northern Committee of the Western and Central Pacific Fisheries Commission (WCPFC NC) and the Inter American Tropical Tuna Commission (IATTC), requested the Albacore Working Group (ALBWG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) to start developing an MSE for NPALB. The WCPFC NC established a limit reference point (LRP) of 20%SSBCURRENT, F=0 (SSB: Spawning Stock Biomass) for NPALB, but no formal harvest strategy or target reference point (TRP).

Goal

Examine the performance of alternative harvest strategies and associated reference points for NPALB. A harvest strategy is a framework for establishing which fisheries management actions (such as setting a total allowable catch) are appropriate for achieving stated management objectives. It specifies (1) what harvest control rule will be applied, (2) how stock status estimates will be calculated (e.g. via a stock assessment), and (3) how data (such as catch or effort) will be monitored.

A harvest strategy can also include allocation rules. For this MSE, managers and stakeholders at previous workshops specified management actions as the setting of Total Allowable Catch (TAC) or Total Allowable Effort (TAE) but did not develop any fishery-specific allocation rules. The TAC or TAE for the entire NPALB stock was instead assumed to be split between all the fisheries using the average harvest ratios from 1999-2015. As such, this MSE was not designed to test the performance of different allocation schemes or domestic allocation issues.

Note that most fisheries are split by gear (longline vs. surface) and country, except for the EPO surface fishery, which combines harvest from the US and Canada.

How does MSE work?

The MSE tested the effect of changing the total harvest amount on achieving the management objectives. Within each harvest strategy, the different levels of total allowable harvest are set by a harvest control rule that specifies a management action to be taken (or not), based on the condition of the simulated albacore population relative to reference points. These reference points were estimated by a stock assessment using data extracted from the simulated albacore population and fisheries. The results are different levels of total allowable harvest over time, as the simulated albacore population responds to different harvest rules.

The computer simulations allowed for testing the harvest strategies under different “what if” scenarios for stock productivity, availability to the Eastern Pacific Ocean (EPO) fishery, assessment error, or management implementation error to make sure that the proposed harvest strategies could meet management goals in the real world. These "what if" scenarios were based on the ALBWG's best estimate of the uncertainty, or were specified by the managers and stakeholders.

Management Objectives

The performance of each harvest strategy was evaluated based on how well each met the management objectives that managers and stakeholders specified during previous workshops. The management objectives for this MSE were: 1) maintain historical spawning biomass; 2) maintain historical total biomass; 3) maintain historical harvest ratios of each fishery; 4) maintain catches above historical average; 5) minimize changes in management over time; and 6) maintain fishing impact around the target value. It should, however, be noted that management objective #3 (maintain historical harvest ratios of each fishery) was not well evaluated for this round of MSE because there were no allocation rules specific to each fishery. Instead, harvest ratios of each fishery were maintained at the average of 1999 – 2015 into the future.

Harvest Strategies and Harvest Control Rules

Figure 1 depicts example harvest control rules (HCRs) that specify management actions for two of the three harvest strategies tested: Harvest Strategy 1 (HS1) and Harvest Strategy 3 (HS3).

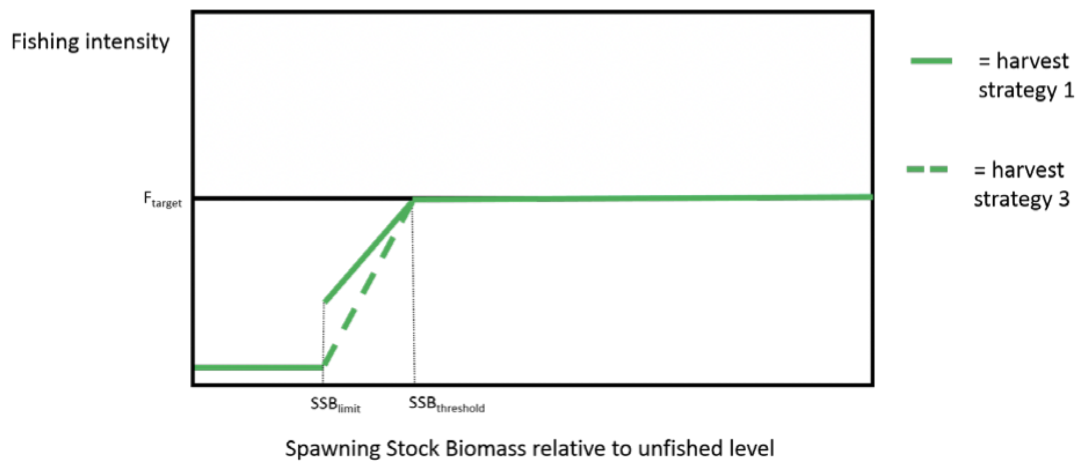

Figure 1. Example harvest control rule (HCR) for harvest strategy 1 and 3.

In this example HCR, if spawning stock biomass (SSB) is above the threshold reference point ($SSB_{threshold}$), then the level of total harvest is set by the target reference point (TRP) (F_{target} in **Figure 1**) for both HS1 and HS3. This situation is like seeing green traffic lights but having to obey a speed limit for the stretch of road.

Reaching the threshold reference point is somewhat like reaching a school zone, where you have to begin reducing speed because the risks are now larger. If SSB is below the threshold reference point but above the limit reference point (LRP; SSB_{limit}), the level of total harvest is reduced to below the TRP, for both HS1 and HS3. However, as shown by the steeper drop in fishing intensity for HS3 (dotted line) in Fig. 1, this reduction is steeper for HS3 than HS1. The reason for an HCR to initiate management action at a threshold rather than a limit reference is to reduce the chances of ever reaching the limit reference point and to avoid severe management actions like closing the fishery that would occur when the limit reference point is breached.

If SSB falls below the LRP, the level of total harvest is drastically reduced for both HS1 and HS3. In this example, harvest goes to 0 and all fisheries that catch NPALB are closed. This is akin to an accident happening ahead and the police having stopped all traffic or only allowing a very slow flow of traffic. For each harvest strategy, different values of TRPs, threshold reference points, LRPs, and rebuilding plans (i.e. management actions when SSB is below the LRP) can be tested.

For HS1 and HS3, 11 harvest control rules with different combinations of TRPs, threshold reference points, and LRPs were tested. These are listed in **Table 1**.

Table 1. List of harvest control rules for harvest strategies 1 and 3. The target reference point (TRP) is an indicator of fishing intensity based on SPR. SPR is the SSB per recruit that would result from the current year's pattern and intensity of fishing mortality relative to the unfished stock. A TRP of F40 would result in the SSB fluctuating around 40% of the unfished SSB. A TRP of F30 implies a higher fishing intensity, and would result in a SSB of around 30% of the unfished SSB. F0204 is a fishing intensity corresponding to the average fishing intensity from 2002 to 2004. The threshold and limit reference points are SSB-based and refer to the specified percentage of unfished SSB. The unfished SSB fluctuates depending on changes in recruitment.

Harvest Strategy	Output Control	Harvest Control Rule	Target reference point (F_{target})	Threshold reference point ($SSB_{threshold}$)	Limit reference point (SSB_{limit})
1 or 3	TAC or TAE	1	F50	30%	20%
1 or 3	TAC or TAE	4	F50	20%	14%
1 or 3	TAC or TAE	6	F50	14%	7.7%
1 or 3	TAC or TAE	7	F40	30%	20%
1 or 3	TAC or TAE	10	F40	20%	14%
1 or 3	TAC or TAE	12	F30	14%	7.7%
1 or 3	TAC or TAE	13	F30	20%	14%
1 or 3	TAC or TAE	15	F30	14%	7.7%
1 or 3	TAE	16	F0204	30%	20%
1 or 3	TAE	17	F0204	20%	14%
1 or 3	TAE	18	F0204	14%	7.7%

Reference Points

A TRP refers to a desired state that management wants to achieve. The level of total harvest given three TRPs: F50, F40, and F30 were evaluated. F40 represents a fishing intensity that leads to a SSB that fluctuates around 40% of the unfished SSB (i.e., removing about 60% of the SSB). In contrast, a TRP of F30 leads to a SSB that is around 30% of unfished SSB (i.e., removing about 70% of the SSB). A TRP of F30 means fishing harder than F40, so the level of biomass desired is lower. In the MSE, the level of total harvest was affected primarily by the TRP.

According to the latest assessment, the average fishing intensity for 2012-2014 was about F50. This is close to the average over the past 20 years, which was F51 **(Fig. 2**). Since 1993, fishing intensity has never reached F30 and only exceeded F40 in 1999 **(Fig. 2**).

Three different threshold reference points, SSB30%, SSB20%, and SSB14% (**Table 1**), were also evaluated. These were associated with three different LRPs: SSB20%, SSB14%, and SSB7.7% (**Table1**). For example, SSB30% roughly means that the reference point is at 30% of unfished SSB. The actual reference point in terms of tons will change depending on the level of estimated recruitment.

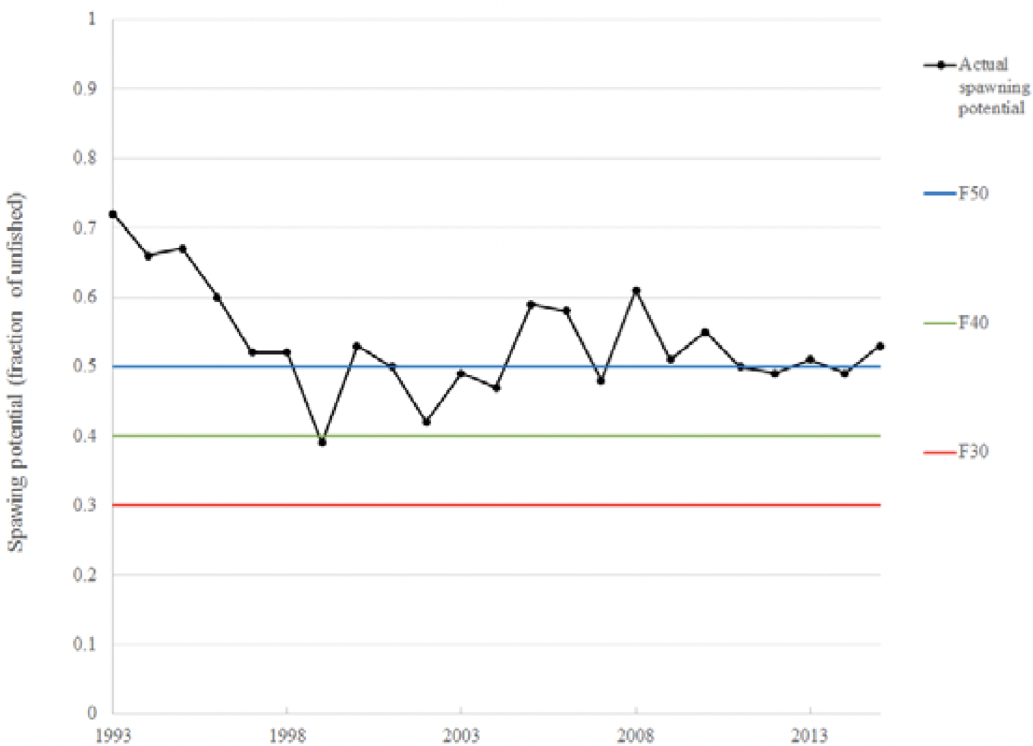

Figure 2. Past trend in spawning potential as fraction of the unfished spawning potential from the 2017 NPALB stock assessment model. The spawning potential one wants to achieve with the three target reference points used in the MSE is also shown. Lower spawning potential is higher fishing intensity.

Results

The results of the MSE analysis can be summarized in five main points:

1. A lower fishing intensity TRP (i.e. F50), maintains the population at a higher level than F40 and F30, requiring less management intervention and resulting in lower catch variability between years. However, lower fishing intensity results in lower overall catch.

There was a clear trade-off between relative total biomass and relative catch. HCRs (HCRs 1, 4, and 6) with F50 had the highest biomass but lowest catch, given the same LRP (**Fig. 3**).

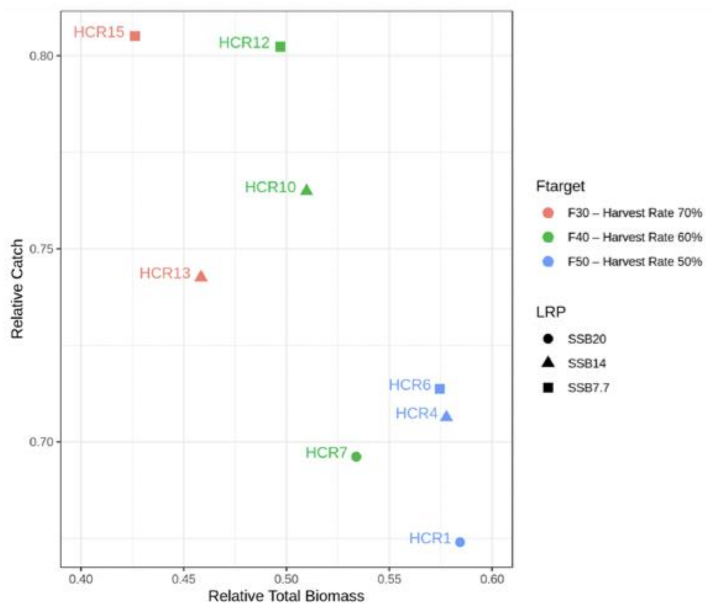

Figure 3. Relative catch and relative total biomass across all runs and reference scenarios for all the HCRs tested in Harvest Strategy 1 with TAC (total allowable catch) control. Here, relative catch is defined as the odds of catch in any given year of the MSE forward simulation being above average historical (1981-2010) catch. Relative total biomass is defined as the odds of depletion in any given year of the MSE forward simulation being above minimum historical (2006-2015) depletion.

Similarly, for the same LRP, a TRP of F50 had the lowest catch, but the highest catch stability (**Fig. 4**) and lowest odds of a fishery closure (**Fig. 5**). See Table 2 for a description of how the catch, biomass, catch stability and odds of a fishery closure metrics were calculated.

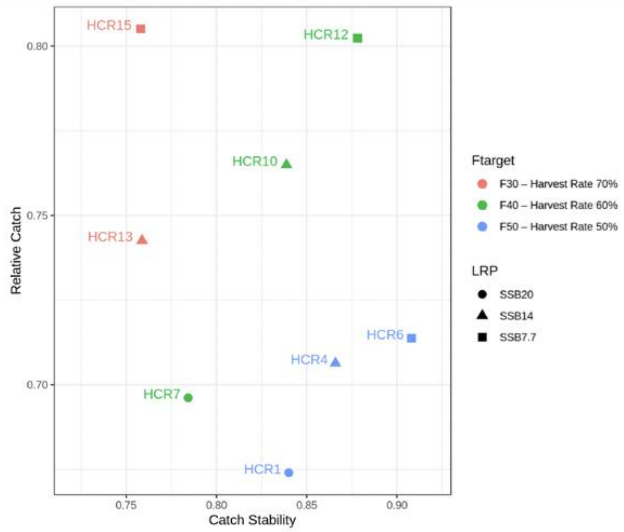

Figure 4. Relative catch and catch stability across all runs and reference scenarios for all the HCRs tested in harvest strategy 1 with TAC (total allowable catch) control. Here relative catch is defined as the odds of catch in any given year of the MSE forward simulation being above average historical (1981-2010) catch. Catch stability is defined as the odds of a decrease in TAC being <30% between consecutive assessment periods (once every 3 years), excluding years where TAC=0.

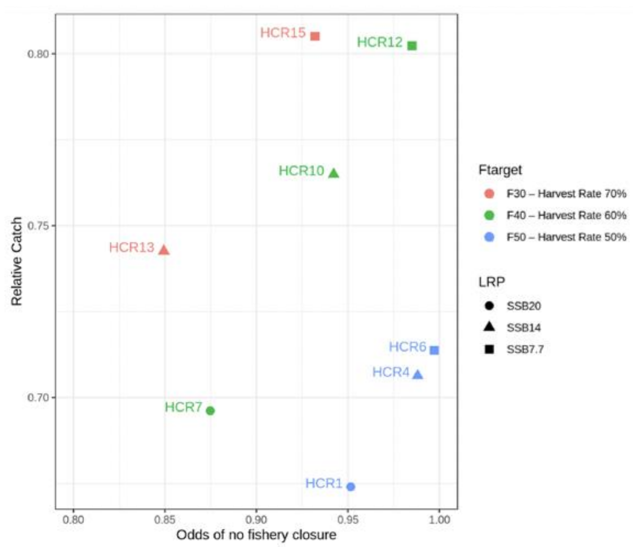

Figure 5. Relative catch and odds of no fishery closures across all runs and reference scenarios for all the HCRs tested in harvest strategy 1 with TAC (total allowable catch) control. Here relative catch is defined as the odds of catch in any given year of the MSE forward simulation being above average historical (1981-2010) catch. Odds of no fishery closure is defined as the odds of spawning stock biomass in any given year of the MSE forward simulation being above the LRP.

Table 2. List of proposed performance indicators. Management objective #3 was not included because it could not be evaluated in this round of MSE.

Management Objective	Label	Performance Indicator
1. Maintain SSB above the limit reference point (LRP)	Odds of no fishery closure	Probability that SSB in any given year of the MSE forward simulation is above the LRP
2. Maintain depletion of total biomass around historical average depletion	Relative Total Biomass	Probability that depletion in any given year of the MSE forward simulation is above minimum historical (2006-2015) depletion
8. Maintain catches above average historical catch	Relative Total Catch	Probability that catch in any given year of the MSE forward simulation is above average historical (1981-2010) catch
9. Change in total allowable catch between years should be relatively gradual	Catch Stability	Probability that a decrease in TAC is <30% between consecutive assessment periods (once every 3 years), excluding years where TAC=0.
10. Maintain fishing intensity (F) at the target value with reasonable variability	F_{TARGET}/F	F_{TARGET}/F

2. HCRs with a TRP of F40 have less closures and higher catch stability as compared to a TRP of F30, resulting in comparable or higher catch despite lower fishing intensity.

The trade-off between more catch and less biomass was not apparent when comparing TRPs of F40 against F30. HCRs with a TRP of F40 performed as well or better than a TRP of F30 not only in terms of relative biomass, catch stability, and fishery closures, but also for relative catch. For the same LRP, relative catch of HCRs with a TRP of F40, was higher or comparable to that of HCRs with a TRP of F30 (**Fig. 3 to 5**). Improved catch stability and lower management intervention led to higher or comparable odds of projected catch being more than average historical catch for a TRP of F40 as compared to F30, even if the fishing intensity was lower.

3. An LRP and threshold reference point closer to the TRP results in a higher frequency of management interventions, fishery closures and lower catch stability.

A LRP closer to the desired target biomass set by the F-based TRP is more likely to be breached. This leads to lower catch stability and higher probability of fishery closures for HCRs with an LRP set at 20% of unfished SSB (SSB20%). **Fig. 6** shows that for HCRs with the same F40 TRP, HCR 7, the one with the highest LRP of SSB20%, had the lowest relative catch, lowest catch stability, and lowest odds of no fishery closure.

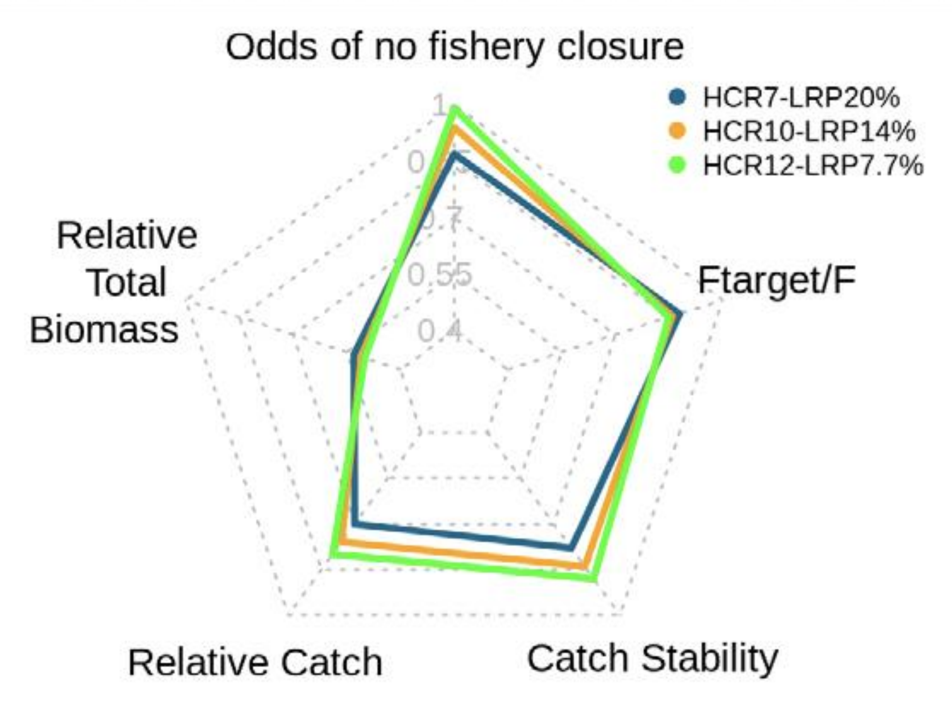

Figure 6. Cobweb plot depicting performance indicators for TAC-based HCR7, HCR10, and HCR12 for HS1 across all runs and reference scenarios. All use a TRP of F40. Values close to the outer web signify a more positive outcome for that performance indicator (i.e., further out is better). Refer to Table 2 for a description of the performance indicators.

4. HS3 showed lower catch stability than HS1, but had less fishery closures.

Harvest Strategy 3 showed less stability in catch between years (Fig. 7) because steeper changes in TAC or TAE were required once the threshold reference point was crossed. However, these steeper reductions in TAC or TAE resulted in a slightly lower frequency of fishery closures (Fig. 7).

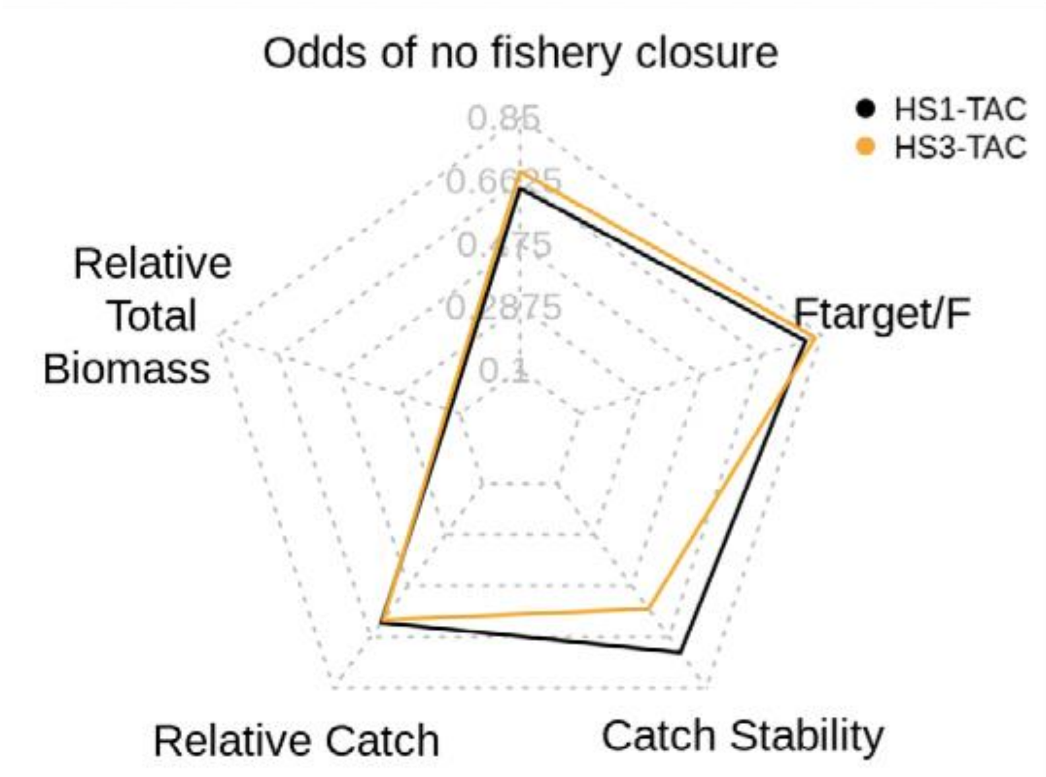

Figure 7. Cobweb plot depicting performance indicators for TAC-based HCR13 for HS1 and HS3 for all runs in the lowest productivity scenario (Scenario 6). Scenario 6 was chosen as it was the scenario with the most fisheries closures and hence best depicted the trade-off between higher catch variability and lower fisheries closures. Values close to the outer web signify a more positive outcome for that performance indicator. Refer to Table 2 for a description of the performance indicators.

5. Harvest strategies with Total Allowable Effort (TAE) control performed better than ones with Total Allowable Catch (TAC) control across all performance metrics.

Fig. 8 provides an overview of results for HCR 13 for HS1 with both a TAC and TAE output control. The TAC based rules underperformed TAE ones across all performance indicators. The largest difference occurred for catch stability. Given the 3 years assessment frequency, in a TAC-based rule the TAC is maintained constant over a 3-year period. Hence, if biomass is reduced because of random, biologically driven variability, fishing intensity can increase and drive the population below the threshold and limit reference points more often, requiring more management intervention. This resulted in TAC-based rules having lower catch stability and being closed more often. However, it should be noted that potential difficulties in measuring and implementing TAEs relative to TACs in the real world were not evaluated for this MSE.

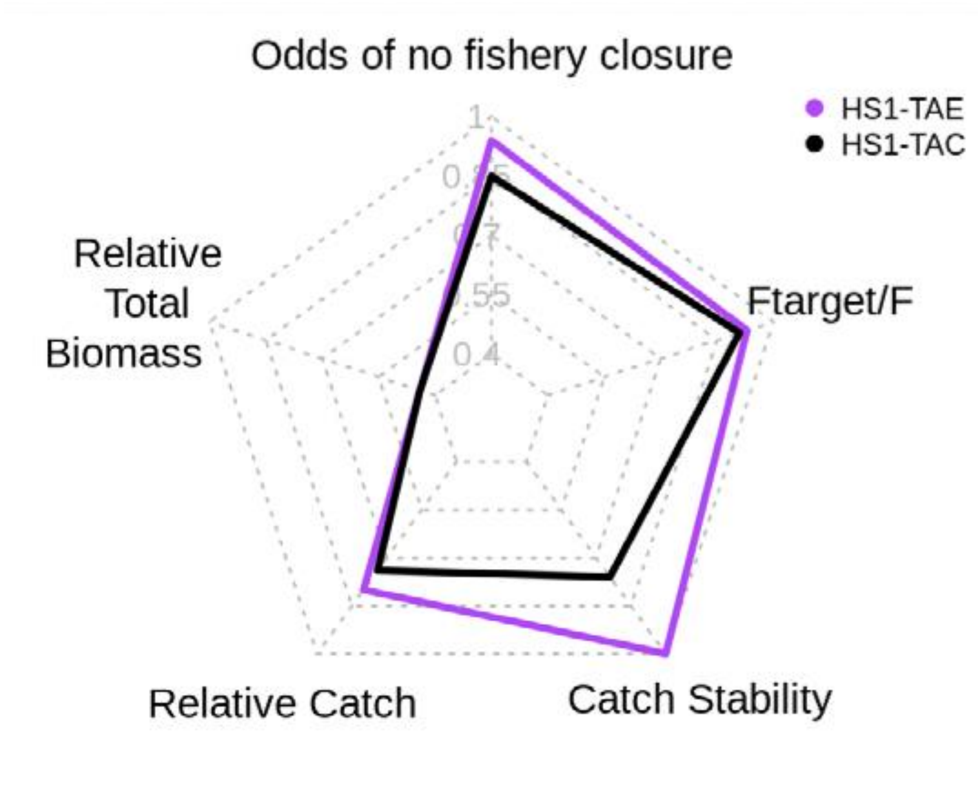

Figure 8. Cobweb plot depicting performance indicators for TAC-based and TAE-based HCR13 for HS1 for all runs and reference scenarios. Values close to the outer web signify a more positive outcome for that performance indicator. Refer to Table 2 for a description of the performance indicators.

Limitations of current NPALB MSE Framework

- Effort is modeled as fishing intensity rather than being modeled explicitly as the number of fishing days or number of hooks. However, in the real world, managers would manage effort as the number of hooks or the number of fishing days rather than fishing intensity. If TAE control was to be implemented, more work would be needed to quantify how fishing intensity would be translated into effort in terms of number of fishing days and number of hooks.
- Given the uncertainty in the relationship between fishing intensity in the MSE and real world effort in number of fishing days and number of hooks, effort control may be more effective in the simulation than in the real world and is assumed to be as effective as TAC control, which may not be realistic.
- It is assumed that effort or catch control is implemented equally effectively across all fisheries, including both NPALB targeting and non-targeting (e.g. surface fleets vs. longline).
- Allocation is assumed to be constant at the average of 1999-2015 levels throughout the simulation. This formulation prevents an assessment of management objective 3, *maintain harvest ratios by fishery*, as the harvest ratios are kept constant by design. Testing of different allocation schemes would require input from managers as to what those allocation rules might be.
- In the simulations for HS1 and HS3, if the fishing intensity is lower than the target reference point, the simulated fishing intensity is increased to the target level when setting the TAC or TAE. This assumes no limitations in the capacity of the NPALB fleets.
- Given the lack of computer and personnel resources, only one rebuilding plan (fishery is closed) was tested. Further work could examine other rebuilding measures proposed by managers and stakeholders at the 3rd MSE workshop in Vancouver during 2017.
- Given the lack of computer and personnel resources, when determining stock status, only the probability of SSB being higher than the LRP or threshold reference point at a 50% level was tested. Further work could examine other probabilities proposed at the 3rd MSE workshop in Vancouver during 2017.
- NPALB is a highly migratory species whose movement rates to given areas in the North Pacific are highly variable. This affects availability to the fisheries operating in those areas. However, the simulations do not explicitly model these movement processes and instead only approximate the availability to various fleets. Further work could include the development of an area specific model to better capture uncertainty in migration rates, and their relationship to availability.
- The simulations are conditioned on data from 1993 onwards, although available data dates back to 1966. Therefore, the simulations may not include the full range of uncertainty in the population dynamics of NPALB. Thus, the MSE results are most applicable to recent conditions. Nevertheless, inclusion of the lowest productivity scenario (Scenario 6) was an attempt to accommodate some of this uncertainty.

Goals of Yokohama MSE Workshop

On March 5th to7th the ISC will host an MSE Workshop for NPALB in Yokohama, Japan. The main goals of the workshop are to 1) examine with managers and stakeholders the preliminary results of the North Pacific Albacore (NPALB) MSE, 2) collate feedback from managers and stakeholders on future MSE improvements, and 3) begin developing recommendations for the WCPFC NC and IATTC.

For example, the ISC ALBWG will be looking for feedback on:

1. the clarity of the presentation of results,
2. the current assumption in the MSE that all fleets (including longline and surface fleets) are managed in the same manner,
3. potential modifications to the HCRs tested (for instance in terms of the level of risk used when comparing the reference points to the current SSB),
4. reducing the current set of HCRs to a smaller set of the most viable candidates if further analyses are deemed necessary.

Frequently Asked Questions

Will the MSE replace the stock assessment?

No. A MSE is a tool that is used in the process of developing new management strategies for a stock. It highlights trade-offs in the performance of candidate harvest control rules under a wide range of potential "what if" scenarios in terms of biology, observation, implementation, and assessment errors. It assesses the effect of a new TAC or TAE on a set of management objectives (e.g. catch, biomass, catch variability) pre-agreed upon with stakeholders. A MSE does not identify a best estimate of current and near term stock status. That remains the role of the assessment and the projection software associated with it.

How does the NPALB MSE determine how much harvest goes to each fishery every year?

Managers and stakeholders at previous workshops did not propose any fishery-specific allocation rules. Instead, the total harvest amount set by the management strategy via a TAC or TAE is split among the participating fisheries using the average historical allocation from 1999-2015. Each fishery receives the same share of the harvest, but the total harvest changes from year to year depending on recruitment trends and the status of the stock relative to the reference points.

Glossary

- **Depletion -** can be defined as spawning biomass depletion or total biomass depletion. It shows what fraction of unfished biomass (spawning or total) the current biomass is. It is calculated as the ratio of the current to unfished biomass (spawning or total).
- **Estimation Model (EM)** – An analytical model that takes data generated with error by the operating model (e.g. catch, abundance index) and produces an estimate of stock status. This often mirrors a stock assessment model.
- **Fishing intensity** – a harvest rate based on SPR. SPR is the SSB per recruit that would result from the current year's pattern and intensity of fishing mortality relative to the unfished stock. A fishing intensity of F30 would result in 30% of the SSB per recruit relative to the unfished state. This is approximately equivalent to a harvest rate of 70%.
- **Harvest control rule (HCR)** - Pre-agreed upon set of rules that specify a management action (e.g. setting the total allowable catch or location/timing of closures) based on a comparison of the status of the system to specific reference points.
- **Harvest strategy (or management strategy)** - a framework for deciding which fisheries management actions (such as setting a TAC) will achieve stated management objectives. It specifies (1) what harvest control rule will be applied, (2) how stock status estimates will be calculated (e.g. via a stock assessment), and (3) how catch or effort will be monitored.
- **Limit reference point (LRP)** – A benchmark current stock status is compared to and that should not be exceeded with a high probability. It can be biomass-based (e.g. SSB_{LIMIT}) or fishing intensity-based (e.g. F_{LIMIT}).
- **Management Objectives** – High-level goals of a management plan (e.g. prevent overfishing or promote profitability of the fishery).
- **Management Strategy Evaluation (MSE)** – a simulation-based analysis to evaluate trade-offs achieved by alternative harvest (or management) strategies and to asses the consequences of uncertainty in achieving management objectives
- **Operating Model (OM)** – Mathematical representation of plausible versions of the true dynamics of the system under consideration. These are conditioned on historical data. Generally, multiple OMs are required to represent the range of uncertainty in different factors. OMs can range in complexity (e.g. from single species to ecosystems models) depending on the management objectives and management strategies being evaluated.
- **Performance metrics** - Quantitative indicators that are used to evaluate each HCR and serve as a quantitative representation of the management objectives.
- **Spawning potential ratio (SPR)** – the ratio of female spawning stock biomass per recruit under fishing to female spawning stock biomass per recruit under unfished conditions.
- **SSB** – female spawning stock biomass.
- **$SSB_{CURRENT,F=0}$ or SSBX%** – unfished spawning stock biomass that fluctuates with changes in recruitment. Also referred to as dynamic unfished spawning stock biomass.

- **Target reference point (TRP)** - A benchmark which a current stock levels is compared to. It represents a desired state that management intends to achieve. It can be biomass-based (e.g. SSB_{TARGET}) or fishing intensity-based (e.g. F_{TARGET}).
- **Threshold reference point** – A benchmark current stock status is compared to. Its value is between that of a target and limit reference point. It represents a control point below which a management action is undertaken to bring the stock back to a target state.