FINAL

ISC/18/ANNEX/04

ANNEX 4

18th Meeting of the
International Scientific Committee for Tuna
and Tuna-Like Species in the North Pacific Ocean
Yeosu, Republic of Korea
July 11-16, 2018

REPORT OF THE ALBACORE WORKING GROUP WORKSHOP

October 2017

July 2018

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Annex 04

REPORT OF THE ALBACORE WORKING GROUP WORKSHOP

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

19-20 October 2017
Pinnacle Hotel
Vancouver, British Columbia, Canada

1. OPENING OF THE WORKSHOP

1.1 Welcome and Introduction

An intersessional workshop of the Albacore Working Group (ALBWG or WG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) was convened at the Pinnacle Hotel, Vancouver, British Columbia, Canada, from 19-20 October 2017. Scientists from Canada, China, Chinese Taipei, Japan, the United States of America (USA), and the Inter-American Tropical Tuna Commission participated in the meeting (**Attachment 1**).

1.2 Review and Approval of Agenda

The draft agenda was reviewed and adopted at the meeting (**Attachment 2**). S. Teo (SWFSC/NOAA) and H. Ijima. (NRIFSF/FRA) were assigned as lead and support rapporteur, respectively.

2. OVERVIEW OF MEETING OBJECTIVES AND CONFIRMATION OF GOALS

The ALBWG Chair briefly described the objectives of the meeting and the expected outcomes. The objectives of this workshop were to: (1) discuss the Management Strategy Evaluation (MSE) framework, including the MSE Operating Model (OM), to be applied in the testing of the harvest strategies developed at the 3rd ISC MSE Workshop, and (2) identify key uncertainties and scenarios to be considered for initial MSE testing.

This report is a record of discussions on the development of the MSE OM, MSE framework, and uncertainties to be considered in the MSE.

3. MANAGEMENT STRATEGY EVALUATION PROCESS UPDATE

Prior to this workshop, a 2.5 day MSE workshop (3rd ISC MSE Workshop; **Attachment 3**) with fishery managers, stakeholders, and scientists, was convened in Vancouver, Canada, 17-19 October, to review and update management objectives, performance indicators and harvest control rules (HCRs) to be tested by the ALBWG.

D. Tommasi presented the current state of the MSE software/model development, and led a discussion on the structure and parameterization of the various software modules, and on the uncertainties to be considered. The main software modules in the MSE are the OM, the estimation model (EM), and management model. The OM is a mathematical representation of the “true” population dynamics of the stock. From the OM output, data is generated with observation error and inputted into the EM. The EM is the North Pacific Albacore stock assessment model and is used to generate the estimates of stock status and reference points that inform the management model. The management model consists of the HCR that sets the total allowable catch (TAC) or total allowable effort (TAE). The TAC or TAE is then applied to the operating model, with some implementation error.

The WG discussed the structure and parameterization of the OM. The WG agreed to use Stock Synthesis as the modelling platform for the OM for initial MSE testing. The WG suggested the potential use of time-varying age-selectivity to represent the age-specific availability in an area, with fleets in the same area sharing the same age selectivity. Variability in age-selectivity would be a way to account for age-specific movement. After some discussion, the WG agreed that the areas in the MSE will be the same as those defined in the 2017 stock assessment, for the first round of MSE. It was also proposed that the OM could be conditioned on information and data that was not used in the assessment. For example, there may be area-specific indices that were not available to the assessment but that could be used to condition the OM. **The WG therefore requested that Japan provide historical (1966-2015) area-specific longline standardized indices to condition the OM, if possible. The WG also requested that the US provide historical (1966-2015) area-specific standardized indices from the US troll and pole-and- line fishery, if possible**.

During the discussion on the assessment and management modules, the WG noted that the current projection software used in the assessment and the MSE does not include parameter uncertainty. **The WG therefore requested that Japan improve the projection software to include parameter uncertainty**. Part of the candidate harvest strategies being evaluated in the MSE include probabilistic statements on the probability of breaching a reference point.

However, there are several ways of calculating the probability of breaching a reference point in the assessment module. After some discussion, **the WG agreed to use the uncertainty of the SSB and fishing intensity estimated in the assessment module as the probability of breaching reference points**.

The WG discussed the uncertainties in a range of biological and fisheries processes to be included in the MSE. It was agreed that to account for parameter uncertainty, a suite of different OMs be built to reflect discrete levels of influential parameters such as steepness, natural mortality, and growth. As these uncertainties in the OM include uncertainties in the sex-specific parameters (growth and mortality), **the WG requested Japan provide sex-specific size composition from different areas to help condition the OM.** Another uncertainty in the OM is the potential for a changing relationship between effort and catch (i.e., catchability) for different fleets. This will impact the implementation effectiveness of the HCRs, especially those using TAE, as well as the catchability associated with specific abundance indices. The WG suggested that one potential way of implementing this uncertainty is to use trends in the implementation error, and time-varying catchability of specific indices in the OMs. Time-varying growth was identified as an additional uncertainty to be included in the OM. The possibility of conditioning the OM on the earlier period (i.e., 1966-2015) when a change in growth was observed and of imposing a similar trend in the MSE simulations was also discussed.

One of the scenarios to be analyzed by the MSE is a partial shift of fishing effort on south Pacific albacore to the north Pacific. Therefore, **the WG requested that the WG chair obtain catch data of south Pacific albacore through the ISC DATAWG**.

One major point of discussion was the historical and potential future changes in the gear (size) selectivity of the longline fleets. The gear selectivity of the Japanese longline fleets were likely affected by changes in the hooks per basket. Therefore, **the WG requested that Japan provide the estimated change in hooks per basket over time (annually from 1966 - 2015)** to D. Tommasi to help with structuring the potential changes in gear (size) selectivity of the Japanese longlines.

During the discussion of the range of uncertainties and scenarios to be considered, the WG prioritized developments to the OM model to capture uncertainties as specified below. This prioritization reflects an assessment of which uncertainties are most consequential and the need to provide an initial set of results in summer of 2019 (**work plan in Attachment 3**).

High priority

1. Recruitment – autocorrelation and various values of steepness
2. Natural mortality – various values of M
3. Growth – various values of growth parameters

Medium priority

4. Age selectivity – time-varying age selectivity
5. Recruitment – linked to environmental indices
6. Natural mortality – sex-specificity
7. Catchability – time varying implementation error

Low priority

8. Growth – time-varying growth
9. Catchability – time varying catchability of indices
10. Size selectivity – time varying selectivity

In addition to the uncertainties listed above, the WG also prioritized the development of potential future fishing effort scenarios proposed during the 3rd MSE Workshop.

High priority

1. Shift of south Pacific fishing effort to the north Pacific – new entrant to fishery but catch is known to the assessment and under HCR – ramp in catch
2. Shift of south Pacific fishing effort to the north Pacific – new entrant to fishery but catch is known to the assessment and under HCR – step change in catch

Medium priority

3. Shift of south Pacific fishing effort to the north Pacific – new entrant to fishery but catch is not known to the assessment and is not under HCR – ramp in catch.
4. Shift of south Pacific fishing effort to the north Pacific – new entrant to fishery but catch

is not known to the assessment and is not under HCR – step change in catch.

Finally, as requested by participants in the 3rd MSE workshop (Attachment 3), the ALBWG discussed and clarified performance indicators to reflect the updated management objectives identified during the 3rd MSE workshop (Table 3 in Attachment 3).

4. ADJOURNMENT

The ALBWG meeting was adjourned at 12:30 on 20 October 2017. The WG Chair thanked the hosts (Dr. J. Holmes, ISC chair and T. Sullivan) for their hospitality and overall meeting arrangements, which served as the foundation for a productive meeting. He also thanked the scientists participating in the workshop for their attendance and contributions.

Attachment 1 - List of Participants

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Attachment 2 – Draft Agenda

Albacore Working Group (ALBWG)
THE INTERNATIONAL SCIENTIFIC COMMITTEE FOR TUNA AND TUNA-LIKE SPECIES IN THE NORTH PACIFIC

Intersessional Workshop on Management Strategy Evaluation

19-20 October 2017
Vancouver, BC, Canada

October 19, 2017 (1:30 pm – 5:00 pm)

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 of MSE base-case operating model
    - Presentation by D. Tommasi on NPALB MSE framework and current base-case OM

October 20, 2017 (9:00 am – 5:00 pm)

4. Review of uncertainties to be considered
5. Identification of MSE scenarios and OM model structure/parametrizations to be developed to account for uncertainty
6. Recommendations
7. MSE timeline and work plan
8. Other Matters
9. Closing remarks

Attachment 3

3rd ISC Management Strategy Evaluation (MSE) Workshop

17-19 October 2017
Vancouver, BC, Canada

ALBWG Chairman's Report on Outcomes for North Pacific Albacore

Management Strategy Evaluation (MSE) is a structured process used to compare the relative effectiveness of alternative management measures in achieving specific management objectives. Each of the Tuna RFMOs have started working towards the development and implementation of an MSE. The Albacore Working Group (ALBWG) of the International Scientific Committee of Tuna and Tuna-like Species in the North Pacific Ocean (ISC) was endorsed by the Western and Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC) to develop an MSE for the North Pacific Albacore stock. To support this MSE work, two MSE workshops were previously sponsored by the (ISC) and held in 2015 and 2016. Candidate management objectives and performance indicators were proposed at the 2nd ISC MSE Workshop for North Pacific Albacore (Attachment 5 in the report of the ALBWG workshop; http://isc.fra.go.jp/pdf/ISC16/ISC16_Annex_08_Report_of_the_ALBWG (Apr2016).pdf).

Primary objectives of the 3rd ISC MSE Workshop were to (1) review management objectives and performance metrics previously proposed during the 2nd ISC MSE Workshop (Yokohama, May 2016), (2) identify acceptable level of risk for each objective to be used in evaluating performance of management strategies, (3) develop a preliminary set of candidate reference points and harvest control rules for testing and review the work plan and timeline for conducting the MSE.

The purpose of this report is to document the updated proposed objectives and performance indicators to be tested in the MSE for North Pacific Albacore. This report also documents candidate Reference Points (RPs) and Harvest Control Rules (HCRs) for the initial round of MSE by the ALBWG. The agenda for this meeting is in **Table 1**.

There were 23 participants (**Table 2**) attending the 3rd ISC MSE Workshop, including fishery managers, non-governmental organizations, scientists, and stakeholders. H. Kiyofuji, the ALBWG Chair, briefly overviewed the purpose of the workshop and explained basic terminologies used in the MSE. D. Tommasi reviewed and led a discussion on the MSE process, purpose, management objectives, and performance indicators. S. Teo, the ALBWG vice-Chair, was the lead rapporteur for the workshop and led a discussion to identify the harvest strategies to be tested in the initial MSE for North Pacific Albacore.

Update Management Objectives from 2nd ISC MSE Workshop

Six candidate management objectives developed at the 2nd ISC MSE Workshop were reviewed and clarified through discussion during the 3rd ISC MSE Workshop (**Table 3**). Management objectives are a key component of the MSE process. Management objectives are statements describing things that are important to decision-makers and stakeholders (e.g., ecological, socio-economic, cultural aspects) and expected achievements for a stock/fishery. Objectives are important because they guide the development of specific benchmarks used to evaluate the performance of management strategies. The objectives need to be translated into measurable quantities (performance indicators) that can be computed. Management objectives themselves cannot be evaluated directly through MSE but performance indicators corresponding to each objective can be evaluated to identify trade-offs between objectives. During the MSE process, conflicts among objectives may become apparent. For example, when increasing catch to achieve objective #4 (**Table 3**), spawning stock biomass may decline, leading to lower performance in objective #1 (i.e., there is a trade-off between catch and biomass). These conflicts are quantified using performance indicators. **The workshop participants requested that during the following ALBWG science workshop, the ALBWG develop performance indicators and expected outputs consistent with the updated management objectives.**

Harvest strategies for initial MSE testing

A harvest strategy is a framework that specifies the pre-agreed management actions necessary to achieve management objectives and consists of several components such as management objectives, reference points, harvest control rules, and acceptable levels of risk.

Reference points are benchmarks used to determine stock status in fisheries management. There are two types of reference points traditionally used in fisheries management: 1) target reference points (TRPs), and 2) limit reference points (LRPs). TRPs are benchmarks that should be achieved according to the management objectives, and indicates that the stock and/or fishery is in a desirable condition (e.g. B_{TARGET} and F_{TARGET}). LRPs are benchmarks that should not be breached with any substantial probability according to the management objectives, and indicates that the stock is likely in an undesirable condition and management action is likely required to help the stock and/or fishery recover (e.g. B_{LIMIT} and F_{LIMIT}). Trigger or threshold reference points are used to specify a change in management actions, and act as a buffer between TRPs and LRPs. These reference points can be parameters of harvest control rules, specifying control points when management actions (measures) should be taken.

A Harvest Control Rule (HCR) is a pre-agreed rule for fisheries management, whereby the management action (e.g. allowable catch and/or effort limitation) is determined in response to changes in stock status and/or other indicators. There are two basic types of rules, empirical and model-based. An empirical rule is when the decision rule is based on trends in scientific research data and/or commercial fishery observations (e.g. catch- per-unit-effort; CPUE). A model-based rule is a decision rule that is based on the stock status estimates from a stock assessment model. **Although the first round of the MSE will be focused on model-based rules, the ALBWG was requested to study the feasibility of using empirical rules in future rounds of the MSE for this stock**.

Discussions on candidate RPs and HCRs were initiated using proposals from WCPFC members

(WCPFC-NC12-2016/WP-01). After substantial discussion, two harvest strategies (see below) were proposed for the initial round of MSE. An additional harvest strategy was proposed after the workshop due to inconsistencies between the proposed HCRs and figures used to describe Harvest Strategy 1. In addition, Table 4 specifies both harvest strategies, together with corresponding lists of candidate RPs and HCRs. Table 4 also specifies additional assumptions for both strategies on catch and/or effort allocation among fleets, if the HCRs should be applied only on albacore targeting or also non-targeting fleets, and on the frequency of the stock assessments.

Harvest Strategy 1

Harvest Strategy 1 based changes in management actions on changes in spawning stock biomass (SSB), as described below and outlined in **Figure 1**.

- For stocks at or above $SSB_{THRESHOLD}$ an annual Total Allowable Catch (TAC) or Total Allowable Effort (TAE) is set to allow the stock biomass to fluctuate around SSB_{TARGET} and the fishery to have a fishing impact around F_{TARGET} (**Table 4**).
- For stocks below $SSB_{THRESHOLD}$ with a given probability (see Table 4 for the range of probabilities to be tested) but above SSB_{LIMIT}, an annual TAC or TAE is set based on a proportional reduction from F_{TARGET}, using the fraction SSB_{LATEST}
- / $SSB_{THRESHOLD}$ (**Figure 1 and Table 4**)
- For stocks below SSB_{LIMIT}, a stock rebuilding plan is implemented such that SSB will be rebuilt to SSB_{TARGET} within two generations. More specifically, if the spawning biomass is below the limit reference point (SSB_{LIMIT}) with a given probability (see Table 4 for the range of probabilities to be tested), management measures are established to ensure a probability of at least 50% of restoring SSB to the target level (SSB_{TARGET}).

It was suggested that for Harvest Strategy 1, when SSB falls below SSB_{LIMIT}, alternative management actions be tested in addition to the rebuilding plan outlined above. These are listed in **Table 4**.

Reference points

A candidate set of reference points (SSB_{TARGET}, $SSB_{THRESHOLD}$, SSB_{LIMIT} and F_{TARGET}) to be tested with this HCR were discussed and are listed in **Table 4**. F_{LIMIT} was not included at this stage because no F-based limit reference points have been discussed at the WCPFC Northern Committee. Given the potential different combinations of proposed reference points, a large number of different HCRs based on Harvest Strategy 1 will likely have to be evaluated.

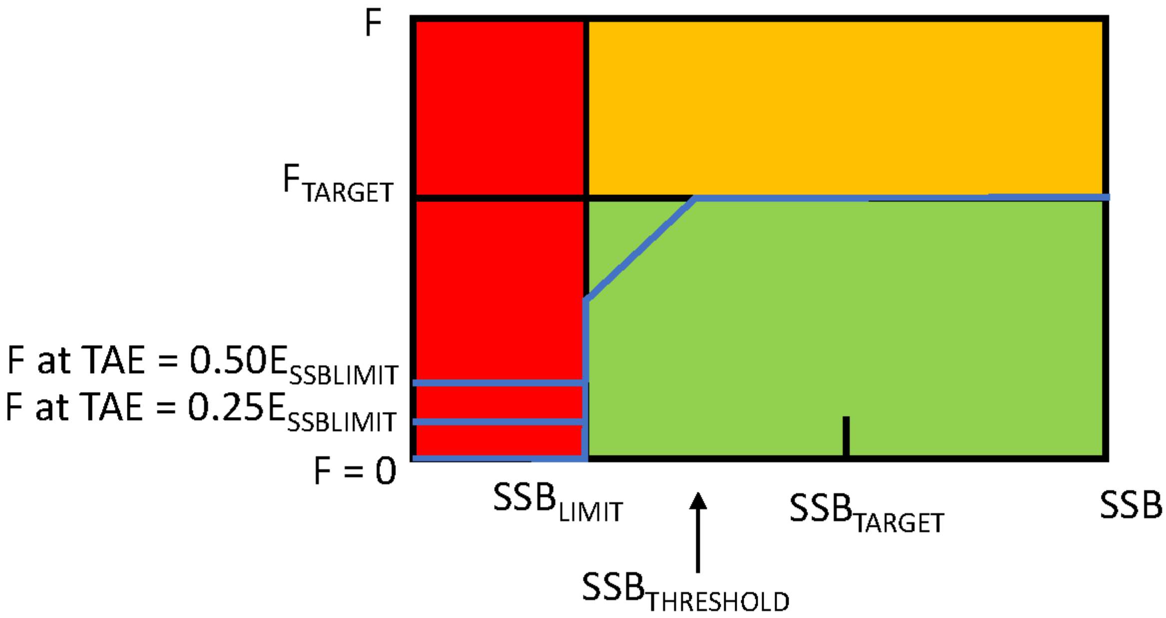

Figure 1. Schematic overview of Harvest Strategy 1.

Harvest Strategy 2 (based on IATTC-Resolution C-16-02)
Harvest Strategy 2 is based on the IATTC HCR for tropical tunas. In summary, changes in management actions occur when SSB drops below a biomass-based LRP or fishing intensity is higher than an F-based LRP, as described below and in **Table 4**.

- If the probability that F will exceed F_{LIMIT} is greater than 10%, management measures shall be established that have a probability of at least 50% of reducing F to F_{TARGET} or less, and a probability of less than 10% that F will exceed F_{LIMIT} (**Table 4**).
- If the probability that SSB is below SSB_{LIMIT} is greater than 10%, management measures shall be established that have a probability of at least 50% of restoring SSB to SSB_{TARGET} or greater, and a probability of less than 10% that SSB will descend to below SSB_{LIMIT} in a period of two generations of the stock or five years, whichever is greater (**Table 4**).

Reference points

- SSB_{LIMIT} is $SSB_{0.5r0}$ and F_{LIMIT} is $F_{0.5r0}$. This is the spawning biomass or fishing intensity corresponding to a spawning biomass that leads to a 50% reduction in the virgin recruitment level given a steepness value of 0.75.
- SSB_{TARGET} is SSB_{MSY} and F_{TARGET} is F_{MSY}. These refer to the spawning biomass or fishing mortality corresponding to the maximum sustainable yield (MSY). For North Pacific albacore, SSB_{MSY} corresponds to approximately 14% of the virgin spawning biomass in the latest stock assessment but is considered difficult to estimate reliably for this stock.

Harvest Strategy 3 (based on Harvest Strategy 1)
It was discovered after the workshop, that the diagram used (**Figure 2**) to describe the HCRs for

harvest strategy 1 during the MSE workshop was not consistent with the actual HCRs (cf. Figure 1). Therefore, Harvest Strategy 3 was developed, after the workshop, to have HCRs that were consistent with Figure 2. Harvest Strategy 3 based changes in management actions on changes in spawning stock biomass (SSB), as described below and outlined in **Figure 2**.

- For stocks at or above $SSB_{THRESHOLD}$, the HCRs are the same as harvest strategy 1 (**Table 4**).
- For stocks below $SSB_{THRESHOLD}$, the annual TAC or TAE decreases linearly until the TAC_{LIM} or TAE_{LIM} is reached. The TAC_{LIM} or TAE_{LIM} are the TAC and TAE when SSB < SSB_{LIMIT}, and a stock rebuilding plan is not implemented (**Table 4**).
- For stocks below SSB_{LIMIT}, the stock rebuilding plan is the same as harvest strategy 1 but alternative actions only include constant TAE or TACs (**Table 4**).

Reference points

The candidate set of reference points (SSB_{TARGET}, $SSB_{THRESHOLD}$, SSB_{LIMIT} and F_{TARGET}) to be tested are the same as harvest strategy 1 and are listed in **Table 4**

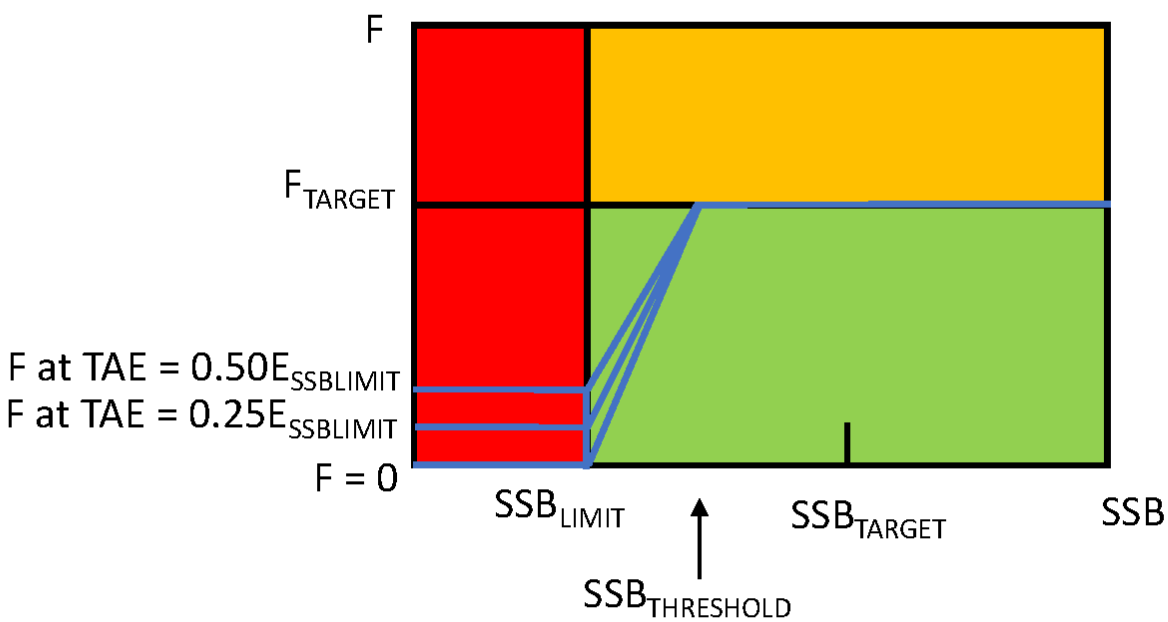

Figure 2. Schematic overview of Harvest Strategy 3.

Work Plan

The ALBWG presented the following schedule for the initial MSE process for North Pacific Albacore. It was noted that the results will be presented at a future date to receive feedback from the managers and stakeholders. Participants of the workshop agreed with the schedule and encouraged the ISC to convene a 4th ISC MSE Workshop to discuss the initial MSE results in detail.

Dates	Task/Event
19-20 October 2017	ALBWG: to discuss MSE framework and Operating Model for MSE testing
May 2018	ALBWG: discussion and review of preliminary MSE results
28 May 2018	9th SAC of IATTC: review of preliminary MSE results
June 2018	ALBWG: discussion and review results of initial MSE
July 2018	ISC18 Plenary: review results of initial MSE
August 2018	SC14: report initial MSE results
September 2018	NC14: present initial MSE results to managers
Late 2018 – Early 2019	4th ISC MSE workshop (tentative)

Table 1. Agenda for 3rd ISC MSE meeting.

ALBACORE WORKING GROUP (ALBWG)
THE INTERNATIONAL SCIENTIFIC COMMITTEE FOR TUNA AND TUNA-LIKE SPECIES IN THE NORTH PACIFIC

Management Strategy Evaluation Workshop for Managers

17-19 October 2017
Vancouver, Canada

October 17, 2017 (9:30 am – 5:00 pm)

1. Opening of the Workshop
    - Welcoming Remarks
    - Chair's Opening Remarks
        - Overview of Workshop Goals:
            - Finalize performance metrics to be used in the MSE
            - Develop set of candidate harvest control rules (HCRs) and reference points (RPs) to be used in MSE
        - Overview of Workshop Outputs:
            - List of performance metrics and management objectives for MSE
            - Set of candidate HCRs and RPs to be used in MSE
    - Introductions

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

Coffee service 10:15 – 10:30

3. Brief review of MSE structure and process
    - Presentation by D. Tommasi on "What is an MSE" with emphasis to its application to NPALB

Lunch 12:00 – 13:30

4. Review of management objectives and performance metrics discussed during the May 2016 MSE Workshop in Yokohama
    - Presentation by D. Tommasi on translating management objectives into

operational objectives and common risk language

Coffee service 14:15 – 14:30

- Discussion and review of management objectives and performance metrics
- Identification of acceptable level of risk for each objective

Adjourn of the Day 17:00

October 18, 2017 (9:00 am – 5:00 pm)

5. Review of agenda and status from Day 1
6. Development of preliminary set of candidate RPs and HCRs to be tested in MSE framework
    - Presentation by D. Tommasi on RPs and HCRs developed in other tuna RFMOs, and review of the potential RPs and HCRs for NPALB discussed during the May 2016 MSE Workshop in Yokohama
    - Examples from an initial application of potential RPs and HCRs in the NPALB MSE
    - Discussion on the identification of candidate RPs and HCRs
    - Develop list of candidate RPs and HCRs for overnight consideration

Adjourn of the Day 17:00

October 19, 2017 (9:00 am – 12:00 pm)

7. Identify preliminary set of candidate HCRs and RPs to be tested in the MSE
8. Review MSE timeline and work plan
9. Closing remarks

Adjourn Meeting

Table 2. List of Participants at the 3rd MSE Workshop, 17-19 October 2017, Pinnacle Harborfront Hotel, Vancouver, Canada.

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Table 3. Updated management objectives for the North Pacific albacore tuna, October 2017. $SSB_{CURRENT,\ F=0}$ refers to dynamic virgin (unfished) spawning stock biomass and fluctuates depending on changes in recruitment. $SSB_{0.5R0}$ is the spawning biomass that leads to a 50% reduction in the virgin recruitment level given a steepness value of 0.75. 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. For objective 2, depletion refers to the ratio of the latest projected total stock biomass and the unfished total stock biomass.

Objective[A]	**Quantity**	**Proposed Performance Indicators**[B, C, D]	**Example Output**[B]
1. Maintain spawning biomass above the limit reference point	• 20%$SSB_{CURRENT,\ F=0}$ • 14%$SSB_{CURRENT,\ F=0}$ (calculated as (1- M)*SSB20%) • $SSB_{0.5R0}$, where h = 0.75 (IATTC SAC)	• SSB for each projected year / SSB-based LRP	• % of runs in which ratio ≥1 for 29/30, 27/30, 24/30; • Each run = 30 years
2. Maintain total biomass, with reasonable variability, around the historical average depletion of total biomass	• Historical depletion is estimated as the depletion level of total biomass for 2006-2015	• Depletion of projected total biomass over 30 yrs /minimum historical depletion of total biomass (minimum of 2006 - 2015)	• % of runs in which ratio ≥1 for 29/30, 27/30, 24/30; • Each run = 30 years
3. Maintain harvest ratios by fishery (fraction of fishing impact with respect to SSB) at historical average	• Historical harvest ratio by fishery estimated as the average of 2006 – 2015	• Harvest ratio (H) by fishery (i) for each year is calculated as $(1\text{-}SPR_i)/1\text{-}SPR_{total}$	• % of runs within minimum and maximum for 29/30, 27/30, 24/30;

Objective[A]	**Quantity**	**Proposed Performance Indicators**[B, C, D]	**Example Output**[B]
	• Historical variability in harvest ratio estimated from 2006 – 2015	• Projected harvest ratio by fishery over 30 yrs >= minimum historical harvest ratio by fishery (minimum of 2006 - 2015) and <= maximum historical harvest ratio by fishery (maximum of 2006 - 2015)	• Each run = 30 years
4. Maintain catches by fishery above average historical catch	• Average catch by fishery over the 30 year period, 1981-2010.	• Total catch of each projected year / average total historical catch (1981 – 2010) • Catch by fishery of each projected year / average historical catch of the fishery (1981 – 2010) • Projected catch by fisheries over 30 yrs /lower 25% of	• % of runs in which ratio ≥1 for 29/30, 27/30, 22/30, 15/30; • Each run = 30 years;

Objective[A]	Quantity	Proposed Performance Indicators[B, C, D]	Example Output[B]
		historical catch (1981 - 2010) • Projected catch by fisheries over 30 yrs /upper 25% of historical catch (1981 - 2010)	
5. If a change in total allowable effort and/or total allowable catch occurs, the rate of change should be relatively gradual		• % change in TAE and/or TAC between years (separate increases vs decreases)	• Median ± 5 and 95% percentiles of maximum % change in TAE and/or TAC for all years over all runs • Median ± 5 and 95% percentiles of % of projected years where change (0-15%, 15-30%, >30%) in TAE and/or TAC for all years over all runs
6. Maintain F at the target value with reasonable variability	• Various potential target values previously suggested by NC	• F-ratio-target = F-based TRP/ F of each projected year	• Median ± 5 and 95% percentiles of median of F-ratio-target over all runs

<table>
<tr><th>Objective[A]</th><th>Quantity</th><th>Proposed Performance Indicators[B, C, D]</th><th>Example Output[B]</th></tr>
<tr><td></td><td></td><td></td><td>Median ± 5 and 95% percentiles of 10%, 95% of F-ratio-target over all runs</td></tr>
<tr><td colspan="4">The objectives shown below were suggested as ideas requiring further work to implement. They are shown here as an indication of future direction.</td></tr>
<tr><td colspan="4">I. Maximize economic returns of existing fisheries
II. Maintain interests of artisanal, subsistence and small-scale fishers, including limiting the regulatory impact on these fisheries</td></tr>
<tr><td colspan="4">NOTES
A - Objectives 1-6 for the first round of MSE were reviewed and agreed upon by the 3rd MSE Workshop participants, 17-19 October 2017. B - Performance indicators and example output proposed by the Albacore Working Group
C - Performance indicators are configured so that higher estimated values mean better performance and lower estimated values means poorer performance, i.e., they have consistent directionality to reduce confusion in interpreting results. The exception to this practice is the first indicator (% change due to HCR between years) for objective 5 for which there is no directionality.
D - Definition of each fishery for fishery-specific performance indicators should be based on flag and gear.</td></tr>
</table>

Table 4. Candidate harvest strategies, along with corresponding lists of candidate reference points (RPs) and harvest control rules (HCRs), to be evaluated in the initial MSE. $SSB_{CURRENT,\ F=0}$ refers to dynamic virgin (unfished) spawning stock biomass and fluctuates depending on changes in recruitment. $SSB_{0.5r0}$ is the spawning biomass that leads to a 50% reduction in the virgin recruitment level given a steepness value of 0.75. $F_{0.5r0}$ is the fishing intensity corresponding to $SSB_{0.5r0}$. F-based reference points 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 reflect changes in fishing mortality. 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. $E_{2002\text{-}2004}$ refers to the average level of effort from 2002-2004. $E(F_{TARGET})$ refers to the level of effort required to fish at F_{TARGET}.

	Harvest Strategy 1	**Harvest Strategy 2**	**Harvest Strategy 3**
		Reference Points	
B_{TARGET}	$50\%SSB_{CURRENT,\ F=0}$ $40\%SSB_{CURRENT,\ F=0}$ $30\%SSB_{CURRENT,\ F=0}$	$14\%SSB_{CURRENT,\ F=0}$	$50\%SSB_{CURRENT,\ F=0}$ $40\%SSB_{CURRENT,\ F=0}$ $30\%SSB_{CURRENT,\ F=0}$
$B_{THRESHOLD}$	$30\%SSB_{CURRENT,\ F=0}$ $20\%SSB_{CURRENT,\ F=0}$ $14\%SSB_{CURRENT,\ F=0}$		$30\%SSB_{CURRENT,\ F=0}$ $20\%SSB_{CURRENT,\ F=0}$ $14\%SSB_{CURRENT,\ F=0}$
B_{LIMIT}	$20\%SSB_{CURRENT,\ F=0}$ $14\%SSB_{CURRENT,\ F=0}$ $SSB_{0.5r0}$	$SSB_{0.5r0}$	$20\%SSB_{CURRENT,\ F=0}$ $14\%SSB_{CURRENT,\ F=0}$ $SSB_{0.5r0}$
F_{TARGET}	$F_{50\%}$ $F_{40\%}$ $F_{30\%}$ $0.75F_{14\%}$	$F_{14\%}$	$F_{50\%}$ $F_{40\%}$ $F_{30\%}$ $0.75F_{14\%}$
F_{LIMIT}		$F_{0.5r0}$	
	Harvest Control Rules 1		
$SSB \geq SSB_{TARGET}$	$TAE = E_{2002\text{-}2004}$ $TAE = E(F_{TARGET})$ $TAC = B_{LATEST} * F_{TARGET}$		$TAE = E_{2002\text{-}2004}$ $TAE = E(F_{TARGET})$ $TAC = B_{LATEST} * F_{TARGET}$
$SSB \geq SSB_{THRESHOLD}$	$TAE = E_{2002\text{-}2004}$		$TAE = E_{2002\text{-}2004}$

	Harvest Strategy 1	Harvest Strategy 2	Harvest Strategy 3
	TAE = E(F_{TARGET}) TAC = B_{LATEST} * F_{TARGET}		TAE = E(F_{TARGET}) TAC = B_{LATEST} * F_{TARGET}
SSB < $SSB_{THRESHOLD}$, > SSB_{LIMIT}	TAE = E(F_{TARGET}) * SSB / $SSB_{THRESHOLD}$ TAC = B_{LATEST} * F_{TARGET} * SSB / $SSB_{THRESHOLD}$		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 ≤ SSB_{LIMIT}, without the rebuilding plan (see below)
SSB ≤ SSB_{LIMIT}	Trigger rebuilding plan TAE = 0 TAE = 0.25 * E_{SSBLIM} TAE = 0.5 * E_{SSBLIM} TAE = E(F_{TARGET}) * SSB / $SSB_{THRESHOLD}$ TAC = 0 TAC = 0.25 * C_{SSBLIM} TAC = 0.5 * C_{SSBLIM} TAC= B_{LATEST} * F_{TARGET} * SSB / $SSB_{THRESHOLD}$ E_{SSBLIM} = E(F_{TARGET}) * SSB_{LIMIT} / $SSB_{THRESHOLD}$ C_{SSBLIM} = B_{LATEST} * F_{TARGET} * SSB_{LIMIT} / $SSB_{THRESHOLD}$	Trigger rebuilding plan	Trigger rebuilding plan TAE = 0 TAE = 0.25 * E_{SSBLIM} TAE = 0.5 * E_{SSBLIM} TAC = 0 TAC = 0.25 * C_{SSBLIM} TAC = 0.5 * C_{SSBLIM} E_{SSBLIM} and C_{SSBLIM} for this harvest strategy are the same as the E_{SSBLIM} and C_{SSBLIM} for harvest strategy 1 E_{SSBLIM} = E(F_{TARGET}) * SSB_{LIMIT} / $SSB_{THRESHOLD}$ C_{SSBLIM} = B_{LATEST} * F_{TARGET} * SSB_{LIMIT} / $SSB_{THRESHOLD}$

	Harvest Strategy 1	Harvest Strategy 2	Harvest Strategy 3
$F > F_{LIMIT}$		TAE = E(F(Prob. ($F < F_{TARGET}$) > 50%) & Prob. ($F > F_{LIMIT}$) < 10%))	
F > Ftarget		TAE = E(F_{TARGET})	
Harvest Control Rules 2			
Prob($SSB > SSB_{LIMIT}$)	90%, 75%, 50%	90%	90%, 75%, 50%
Prob($SSB > SSB_{THRESHOLD}$)	75%, 50%		75%, 50%
Prob($F < F_{LIMIT}$)		90%	
Rebuilding plan	TAE = E(F(Prob. ($SSB > SSB_{TARGET}$) > 50%)) in 2 generations TAC = B * F(Prob. ($SSB > SSB_{TARGET}$) > 50%) in 2 generations	TAE = E(F(Prob. ($SSB > SSB_{TARGET}$) > 50%) & Prob. ($SSB < SSB_{LIMIT}$) < 10%))) in 2 generations TAC = B * F(Prob. ($SSB > SSB_{TARGET}$) > 50%) & Prob. ($SSB < SSB_{LIMIT}$) < 10%)) in 2 generations	TAE = E(F(Prob. ($SSB > SSB_{TARGET}$) > 50%)) in 2 generations TAC = B * F(Prob. ($SSB > SSB_{TARGET}$) > 50%) in 2 generations
Additional Assumptions			
Allocation	Average of 1999-2015	Average of 1999-2015	Average of 1999-2015
HCRs controls on albacore targeting and/or non-targeting	Both targeting and non-targeting Targeting only	Both targeting and non-targeting Targeting only	Both targeting and non-targeting Targeting only
Assessment periodicity	Once every 3 years	Once every 3 years	Once every 3 years
Comments			