SIOTI Briefing Paper and Position Statement on Harvest Strategies and Control Rules for Target Species in the Indian Ocean Purse Seine Tuna Fishery

Task 1: Review of progress in development of harvest strategies and control rules by IOTC, and the implications for the relevant SIOTI Action Plan activities (specifically critical IPGs 2) of any progress or changes or changes to plans that have occurred since May 2017

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Introduction and background

The main objective of this task is to review the progress in the development of harvest strategies (HS) and control rules (HCR) for the tropical tuna stocks of the Indian Ocean Tuna Commission (IOTC). This review includes (i) the relevant concepts of the Precautionary Approach (PA) and Management Strategy Evaluation, (ii) a summary of the IOTC plan towards a robust management of tuna stocks, (iii) an update of the technical work developed to evaluate alternative HS for the tropical stocks in the IOTC, (iv) a description of the interaction between managers and scientists within the IOTC in relation to MSE and, (v) the implications for the SIOTI Action Plan activities.

The IOTC has committed to a path of adopting Harvest Strategies (HS) or Management Procedures (MP) to achieve its management objectives of high long-term yields whilst maintaining stocks within sustainable limits with high probability, consistent with the PA. The PA seeks to protect fish stocks from fishing practices that may put their long-term viability in jeopardy despite the many unknowns on stocks biology, response to fishing or exact state of exploitation (Garcia 1996). In practice, the PA requires fisheries management bodies to determine the status of fish stocks relative to target reference points (TRP) and limit reference points (LRP), to predict outcomes of management alternatives for reaching the targets while avoiding the limits, and to characterize the uncertainty in both cases. The current management framework of IOTC's tropical tuna stocks is based on Resolutions 12/01 and 15/10. These establish management actions for the different states of exploitation of the stocks, expressed in biomass and harvest rates relative to their corresponding Maximum Sustainable Yield RPs. The implicit target of this recommendation is to maintain the stocks in the green area ($B>B_{MSY}$ and $F<F_{MSY}$) of the Kobe plot with high probability, which adds to the traditional objective of achieving the maximum sustainable catch (MSY). However, this recommendation relies on the interpretation of what is considered 'high probability' and in particular to 'as short a period as possible' when stocks are estimated to be outside the green area of the Kobe plot.

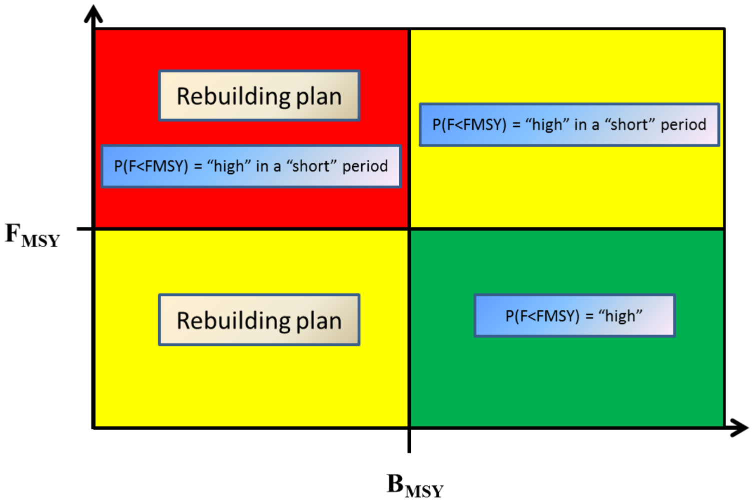

Figure 1. IOTC's management framework based on Resolutions 12/01 and 15/10.

IOTC's Technical Committee on Management Procedures (TCMP) and Commission recommended ways to further define the current management framework building on Resolutions 12/01 and 15/10, in particular in relation to management objectives, associated probabilities, timelines and acceptable levels of risk (IOTC 2017b; IOTC 2017a). Also, one of the main goals of IOTC's workplan for the development of HS for key species (2017-2020) is to undertake MSE to evaluate candidate HS that are robust to the many uncertainties inherent to tropical tuna fisheries (IOTC 2017b). In this context, IOTC also aims at adopting Harvest Strategies to ensure the robust management of the stocks under its purview. Therefore, IOTC is moving towards a scientifically sound and specific decision-making scheme that needs to be evaluated before adoption.

Precautionary Approach, Reference Points, Harvest Control Rules, Harvest Strategies and Management Strategy Evaluation

The sustainability of fisheries is determined by the balance between the amount of biomass harvested and the capacity of fish stocks to respond to harvesting. The Indian Ocean Tuna Commission (IOTC) is responsible for the conservation of tuna species in the Indian Ocean and, on the basis of scientific evidence, makes recommendations with the aim of maintaining the populations of tuna at levels that will permit the maximum sustainable catch. Therefore, a foundational management objective of IOTC is achieving the Maximum Sustainable Yield (MSY), an equilibrium state at which the capacity of the fish stocks to replace the removed biomass is maximised, and therefore, the long-term catch from fish stocks is maximised too (Schaefer, 1954).

- In addition, two international agreements – the UN Fish Stocks Agreement (UN, 1995), and the FAO Code of Conduct for Responsible Fisheries (FAO, 1995)– provide the foundation of the Precautionary Approach (PA) to fisheries management (Garcia, 1996), which seeks to protect fish stocks from fishing practices that may put their long-term viability in jeopardy despite the many unknowns on stocks biology, response to fishing or exact state of exploitation. Despite not being included explicitly in its convention, in practice IOTC applies the principles of the PA (Resolution 12-02), which requires that undesirable outcomes be anticipated and measures taken to reduce the probability of them occurring (De Bruyn et al., 2013). In addition, as happens with the other tuna Regional Fisheries Management Organisations (RFMOs), IOTC is in the process of incorporating the PA into its specific management framework by developing RPs, HCRs and Harvest Strategies. To help provide consistency of advice across the RFMOs a common management advice framework has been developed to visualize the state of exploitation of fish stocks (De Bruyn et al., 2013) (i.e. the Kobe Framework). Kobe plots and the Kobe Strategy Matrix (K2SM) are the agreed way to report the probability of something happening (e.g. biomass-B falling below BMSY or fishing mortality-F going over FMSY) under alternative management scenarios (ISSF, 2013). The current management framework in IOTC recommend decisions that will maintain fish stocks at levels above that of B_{MSY} and fishing mortality at levels below F_{MSY} with high probability (Figure 1). In particular, IOTC Resolution 15/10 *On target and limit Reference Points and a decision framework* provides the following guidelines:

(i) For a stock where the assessed status places it within the lower right (green) quadrant of the Kobe Plot, aim to maintain the stock with a high probability within this quadrant;
(ii) For a stock where the assessed status places it within the upper right (orange) quadrant of the Kobe Plot, aim to end overfishing with a high probability in as short a period as possible;
(iii) For a stock where the assessed status places it within the lower left (yellow) quadrant of the Kobe plot, aim to rebuild these stocks in as short a period as possible;
(iv) For a stock where the assessed status places it within the upper left quadrant (red), aim to end overfishing with a high probability and to rebuild the biomass of the stock in as short a period as possible.

This management framework does not specify the probability levels and timeframes for the decisions to be adopted. However, IOTC is committed to define these in the short term (IOTC 2017b).

- The practical application of the PA requires fisheries management bodies to determine the status of fish stocks relative to target reference points (TRP) and limit reference points (LRP), to predict outcomes of management alternatives for reaching the targets while avoiding the limits, and to characterise the uncertainty in both cases. In general, LRPs are benchmarks that should not be exceeded with any substantial probability according to a given set of management objectives. They indicate the limit beyond which the state of a fishery and/or a resource is not considered desirable and remedial management action is required to allow the recovery of the stock. In the exceptional case when a stock is at very low abundance, LRPs can also be taken as an interim rebuilding target (ISSF, 2013). In contrast, a TRP is a benchmark that should be achieved on average according to a given set of management objectives. It corresponds to a state of a fishery and/or resource which is considered desirable (ISSF, 2013). The PA also recommends that LRPs and TRPs are used in combination with precautionary RPs (F_{pa}, B_{pa} or $B_{trigger}$) to determine what actions to be taken to avoid reaching the LRPs. A trigger or threshold is a level of biomass or a fishing mortality rate between the limit and target reference points that serves as a "red flag" and may trigger particular management actions designed to reduce fishing mortality.

Three categories of methods for Reference Points estimation, with varying data requirements and strengths and weaknesses are discussed (Preece et al., 2011): 1) MSY-based, 2) Spawning Per Recruit (SPR) based and 3) Depletion based. Each method has its positives and negatives. In brief, the differences of the three types of RPs considered in tuna RFMOs are the following:

1) MSY is most often calculated by finding deterministic equilibrium dynamics of the stock using the selectivity values of the current fisheries. MSY based RPs are built into many of the legal frameworks of highly migratory fisheries (e.g. UNCLOS, 1982; UNFSA, 1995 and ICCAT foundational management objectives). Historically, MSY based RPs (FMSY, BMSY) have been used as a target, but these have been recognised for some time now as limit RPs for fishing mortality and biomass in some areas (Mace, 2001).

   The strength of MSY (and MSY-based RPs) is that it covers productivity directly, maximising yields while maintaining the population level at a safe and productive level. The key weakness is the difficulty in robustly estimating it. This is because MSY based RPs are sensitive to uncertainties in the steepness of the stock-recruitment curve and fisheries selectivity at age.

Several examples have shown that for various levels of steepness, there is a wide range of values for MSY, and therefore, also a wide range of values for the MSY-based reference points. Steepness is one of the parameters of stock-recruitment (SR) relationships and; it reflects the impact that a biomass reduction below a particular level has on recruitment. Note that steepness is a measure of the productivity of a stock, and can be interpreted as a measure of the resilience of the stock to fishing pressure. In tuna RFMOs, there is not enough information on steepness and therefore the SR relationship is weak.

2) The spawning potential per recruit is the potential contribution of spawning stock biomass (SSB) over the lifetime of a single recruit. It can be calculated at any given fishing mortality level. A practical measure of the state of depletion of exploited stocks is the spawning potential ratio (SPR), which represents the ratio of the spawning potential per recruit for a given level of F, and the spawning potential per recruit in the pristine stock (SPR0). The SPR is often used to estimate LRPs (Mace, 2001). Some authors recommend reductions of 35%-40% in SPR0 as LRPs (Preece et al., 2011).

3) Depletion based RPs are based on the depletion level of the total (or SSB) biomass and provide biomass based RPs (e.g. x% of SSB). Depletion estimates provide information on how much the SSB has been reduced since fishing began and therefore, how much SSB remains, and the estimated impact on historic, current and future recruitment and yield. Most common depletion based RPs are defined as % of the initial unfished biomass. An advantage of depletion based RPs is that they are relatively stable between assessments and, in many of the tuna stocks have provided the least variation in the range of results across a range of steepness values used (Kolody et al., 2010).

The above are characteristics of alternative RPs and the associated estimation problems. According to them, Preece et al (2011) recommend a three level hierarchical approach to setting LRPs. The first level uses F_{MSY} and B_{MSY} but only where reliable and precise estimates of steepness are available. The second uses F_{SPR} and 20% of SSB0 assuming that steepness is not known well but the key biological estimates are reasonably well estimated. The third level does not provide an F-based LRP if the key variables are not well estimated or understood but suggests that the SSB limit of 20% of SSB0 be used (Preece et al., 2011).

In 2015, on Resolution 15/10, IOTC established interim target and limit RPs for their most important stocks including tropical tunas referenced to MSY (Table 1). In this Resolution it is explicitly noted that *where the IOTC Scientific Committee considers that MSY-based reference points cannot be robustly estimated, biomass limit reference points will be set at a rate of B0*.

This is the case for IOTC skipjack (*) and the Commission re-defined the TRP and LRP as depletion-based RPs for this stock in Resolution 16/02.

Stock	TRP	LRP
Yellowfin (2015, Res 15/10)	$B_{TARGET} = B_{MSY}$; $F_{TARGET} = F_{MSY}$	$B_{LIM} = 0.40\ B_{MSY}$ $F_{LIM} = 1.40\ F_{MSY}$
Bigeye (2015, Res 15/10)	$B_{TARGET} = B_{MSY}$; $F_{TARGET} = F_{MSY}$	$B_{LIM} = 0.50\ B_{MSY}$ $F_{LIM} = 1.30\ F_{MSY}$
Skipjack (2015, Res 15/10)	$B_{TARGET} = B_{MSY}$; $F_{TARGET} = F_{MSY}$	$B_{LIM} = 0.40\ B_{MSY}$ $F_{LIM} = 1.50\ F_{MSY}$
Skipjack (2016, Res 16/02)	$B_{TARGET} = 0.40\ B0$; $F_{TARGET} = F_{0.4B0}$	$B_{LIM} = 0.20\ B_0$

Table 1. Target and limit RPs for the IOTC tropical stocks from Resolutions (15/10) and (16/02, skipjack).

- Harvest Control Rules (HCR) are pre-agreed management decisions that determine how the fishing mortality used to compute the TAC should be set automatically in relation to the state of some indicator of stock status (ISSF, 2013). Harvest Control Rules can be empirical or model-based (Figure 2). Model-based HCRs are attractive because they may be linked to the stock assessment results and generally have a greater capacity to "learn" about stocks' productivities (ISSF, 2013) and empirical based HCRs are generally applied in stocks with limited data availability.

HCRs require specifying threshold, limit and target coordinates (which may not exactly correspond to the established RPs). Model based HCRs are often described using Kobe plots (Figure 1.a). Here, when the stock level is above the precautionary threshold (Bthresh), the fishing mortality applied to the stock will be below FMSY (Ftar). When the stock falls below Bthresh but is above Blim, the fishing mortality will be lower than Ftar. When the stock falls below Blim, the fishing mortality will be reduced to a minimum.

In the empirical HCRs (Figure 1.b) targets and gradients of change need to be defined too. This management procedure uses CPUE as an index of biomass and sets a total allowable catch (TAC) that, over most of the range of CPUE, is proportional to that index. A desired state of one or many indices helps setting the management target and if the index is below that level the recommended TAC will be reduced, if it is above that level this will be increased and should the index be in the targeted value TAC will be maintained. To both empirical and model based HCRs additional restrictions can be applied. For example, the maximum rate of change of TAC or the TAC that will never be exceeded.

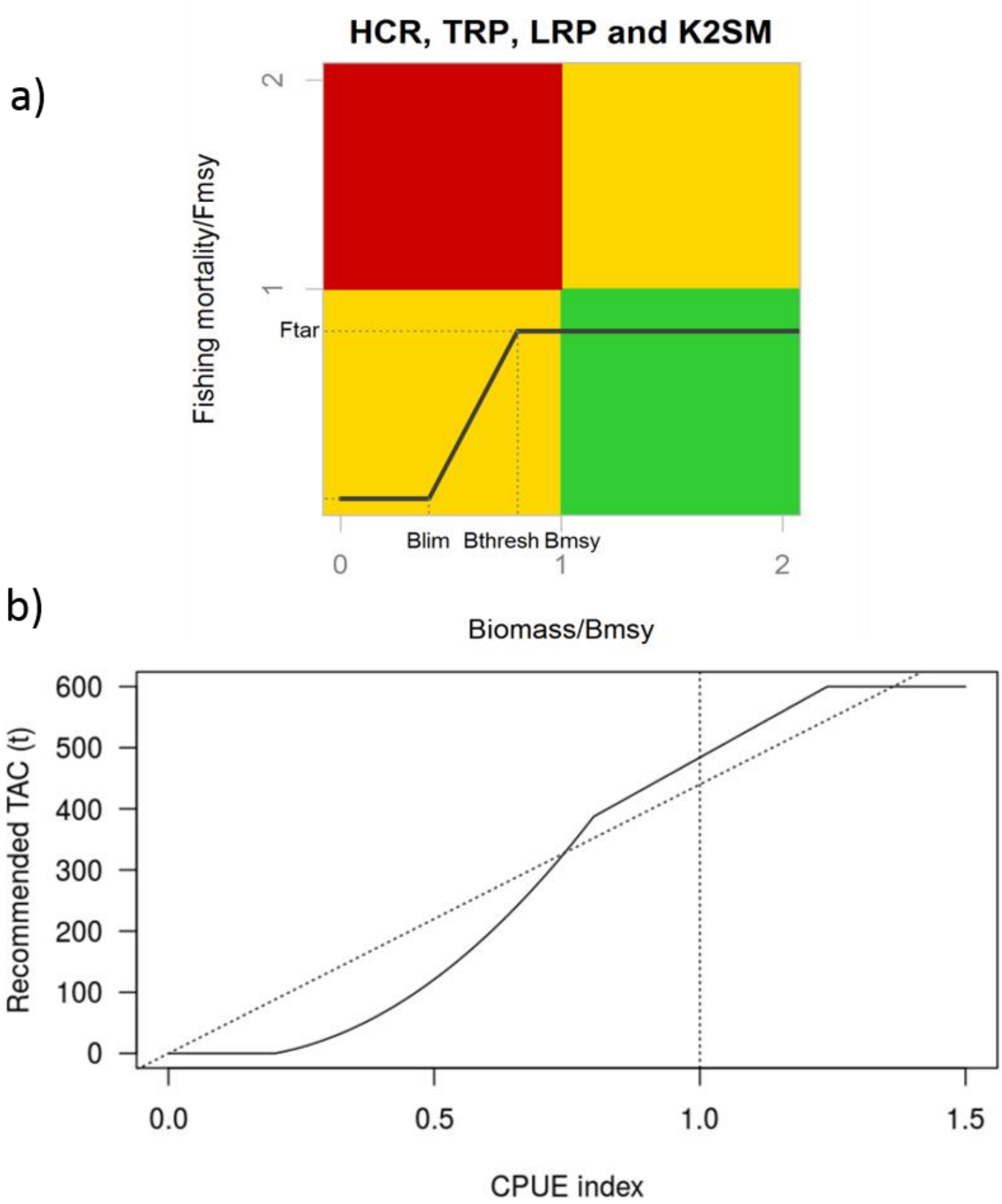

Figure 2. Examples of a) Model based HCR with RPs plotted in a Kobe plot. b) Empirical CPUE-based HCR.

Across tuna RFMOs specific HCRs are used to determine TAC for three stocks: Southern bluefin tuna (CCSBT), North Atlantic albacore (ICCAT) and Indian Ocean skipjack (IOTC).

In 2016, IOTC adopted a Harvest Control Rule for Indian Ocean through Resolution 16/02. This resolution defines management objectives, target and limit RPs. The most relevant aspects of this resolution are summarized below:

- *The Skipjack tuna stock assessment shall be conducted every three (3) years, with the next stock assessment to occur in 2017. Estimates of 7(a–c) shall be taken from a model-based stock assessment that has been reviewed by the Working Party on Tropical Tunas and endorsed by the Scientific Committee via its advice to the Commission.*

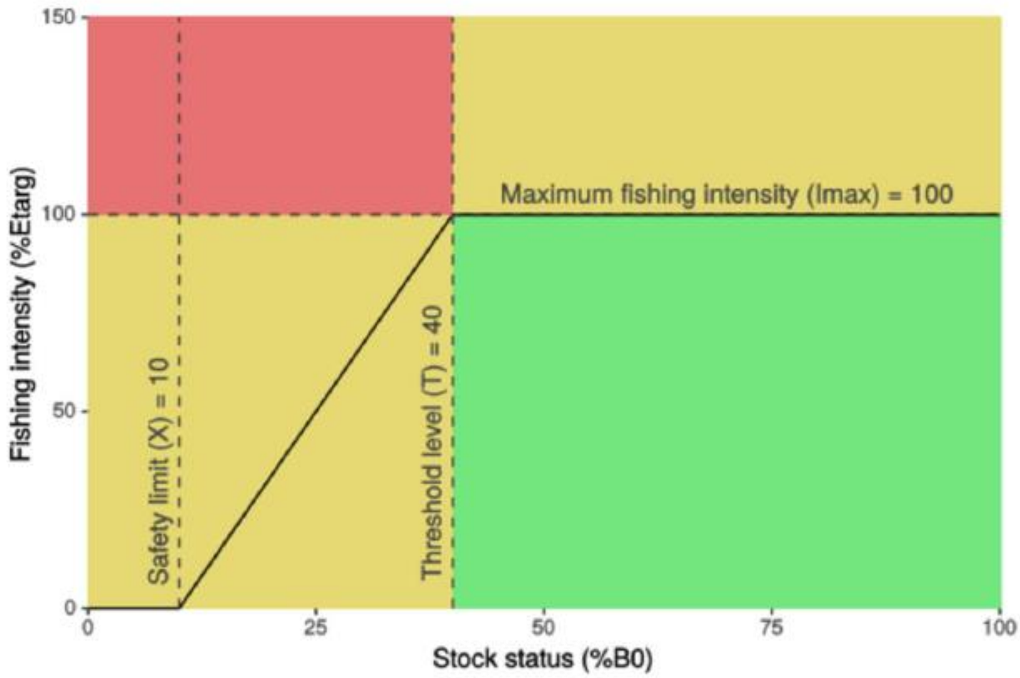

Figure 3. HCR adopted for skipjack in IOTC (Resolution 16/02).

- *The Skipjack tuna HCR shall recommend a total annual catch limit using the following three (3) values estimated from each Skipjack stock assessment. For each value, the reported median from the reference case adopted by the Scientific Committee for advising the Commission shall be used.*

  a) The estimate of current spawning stock biomass (Bcurr);

  b) The estimate of the unfished spawning stock biomass (B0);

  c) The estimate of the equilibrium exploitation rate (Etarg) associated with sustaining the stock at Btarg.

- *The HCR shall have five control parameters set as follows:*

  a) Threshold level, the percentage of B_0 below which reductions in fishing mortality are required, B_{thresh} = 40%B_0. If biomass is estimated to be below the threshold level, then fishing mortality reductions, as output by the HCR, will occur.

  b) Maximum fishing intensity, the percentage of E_{targ} that will be applied when the stock status is at, or above, the threshold level I_{max} = 100%. When the stock is at or above the threshold level, then fishing intensity (I) = I_{max}

  c) Safety level, the percentage of B_0 below which non-subsistence catches are set to zero i.e. the non-subsistence[6] fishery is closed B_{saftey}= 10%B_0.

  d) Maximum catch limit (C_{max}), the maximum recommended catch limit = 900,000t. To avoid adverse effects of potentially inaccurate stock assessments, the HCR shall not recommend a catch limit greater than C_{max}. This value is based upon the estimated upper limit of the MSY range in the 2014 Skipjack stock assessment.

e) Maximum change in catch limit (D_{max}), the maximum percentage change in the catch limit = 30%. To enhance the stability of management measures the HCR shall not recommend a catch limit that is 30% higher, or 30% lower, than the previous recommended catch limit.

- *The recommended total annual catch limit shall be set as follows:*

  a) If the current spawning biomass (B_{curr}) is estimated to be at or above the threshold spawning biomass i.e., B_{curr} >= 0.4B_0, then the catch limit shall be set at [I_{max}xE_{targ}xB_{curr}].

  b) If the current spawning biomass (B_{curr}) is estimated to be below the threshold biomass i.e, B_{curr} < 0.4B_0, but greater than the safety level i.e., B_{curr} > 0.1B_0, then the catch limit shall be set at [I x E_{targ} x B_{curr}]. See Table 1 in Appendix 1 for values of fishing intensity (I) for specific B_{curr}/B_0.

  c) If the spawning biomass is estimated to be at, or below, the safety level, i.e. B_{curr} <= 0.1B_0 then the catch limit shall be at 0 for all fisheries other than subsistence fisheries.

  d) In the case of (a) or (b), the recommended catch limit shall not exceed the maximum catch limit (C_{max}) and shall not increase by more than 30% or decrease by more than 30% from the previous catch limit.

  e) In the case of (c) the recommended catch limit shall always be 0 regardless of the previous catch limit.

- *The HCR described in produces a relationship between stock status (spawning biomass relative to unfished levels) and fishing intensity (exploitation rate relative to target exploitation rate) as shown below (See Table 1 in **Appendix 1** for specific values):*

Appendix 1

Table 1. Values of fishing intensity for alternative levels of estimated stock status (**B_{curr} /B_0**) produced by the HCR with suggested control parameters (Safety level =10%, Threshold level=40% and Maximum fishing intensity=100%).

Stock status (B_{curr} /B_0)	**Fishing Intensity (I)**		**Stock status (B_{curr} /B_0)**	**Fishing Intensity (I)**
At or above 0.40	100%		0.24	46.7%
0.39	96.7%		0.23	43.3%
0.38	93.3%		0.22	40.0%
0.37	90.0%		0.21	36.7%
0.36	86.7%		0.20	33.3%
0.35	83.3%		0.19	30.0%
0.34	80.0%		0.18	26.7%
0.33	76.7%		0.17	23.3%
0.32	73.3%		0.16	20.0%
0.31	70.0%		0.15	16.7%
0.30	66.7%		0.14	13.3%
0.29	63.3%		0.13	10.0%
0.28	60.0%		0.12	6.7%
0.27	56.7%		0.11	3.3%
0.26	53.3%		0.10 or below	0%
0.25	50.0%			

It is important to note that what is adopted in Resolution 16/02 is a model-based HCR that does not prespecify the data and methods of analysis that will be used to estimate stock status. Note also that the different biomass levels are relative to the unexploited values (depletion based RPs).

- <u>Harvest strategies (HS)</u> also known as Management Procedures (MP) are the series of human actions undertaken to monitor the stock, assess its state, make management decisions and implement the management advice. A HS is a pre-agreed set of rules that can specify changes to the total allowable catch (TAC) based on updated monitoring data and methods of analysis. Adopting a HS requires specifying the management objectives (probabilities, timeframes and risk), RPs (TRP and LRP), performance indicators to monitor how effective the measure is, the data and methods of analysis to determine the current state of the resource and, a decision rule (or HCR) based upon the state of the stock.

Currently, there is one HS in place across tuna RFMOs. The HS, known as 'Bali procedure' allows for adjusting the HCR parameters to set different time horizons for rebuilding, and to constrain the maximum TAC changes allowed every time the TAC is updated. In brief, the CCSBT 'Bali procedure' consists on:

- Achieving a 70% probability of rebuilding the stock to the interim rebuilding target reference point of 20% of the original spawning stock biomass by 2035;
- The minimum TAC change (increase or decrease) is 100 tonnes;
- The maximum TAC change (increase or decrease) is 3,000 tonnes;
- The TAC will be set for three-year periods and;
- A meta-rule process for dealing with exceptional circumstances

The technical specification of the HS detail the data and models that will be used to set the state of the stock and how the TACs will be calculated.

- <u>Management Strategy Evaluation (MSE)</u>, the evaluation of HS using simulation, is considered to be the most appropriate way to evaluate the trade-offs achieved by alternative management strategies and to assess the consequences of uncertainty for achieving management goals (Punt et al., 2014). MSE involves using simulation to compare the relative effectiveness for achieving management objectives of different combinations of (i) data collection schemes, (ii) methods of analysis and (iii) subsequent process leading management actions (Punt et al., 2014), i.e. different MPs or HS. MSE requires developing a series of basic steps (Punt et al., 2014; Rademayer et al., 2007):

1. *Identification of management objectives* and representation of these using quantitative performance statistics.

2. *Selection of hypotheses of system dynamics*. A range of hypotheses concerning data, biological information, environmental impact or any other factor that may be considered a source of uncertainty in relation to system dynamics.

3. *Constructing Operating Models (OM):* These provide a mathematical representation of the system that is being managed (fish and fisheries). The impact of the management measures decided through the HCRs in the MP will be evaluated in the OMs. These OMs are considered to be alternative representations of the “true” dynamics of the stock.

4. *Defining Harvest Strategies* or Management Procedures (MP): This includes data used, methods of analysis and decision frameworks (e.g. Harvest Control Rules).

5. *Simulation* of the application of each management strategy or MP.

6. *Summary and interpretation of performance statistics*. This may lead to refinement of the relative weighting of the management objectives as the simulation process develops and continues to provide more refined (tuned) results to inform the quantitative trade-offs among competing goals.

In IOTC, Resolution 13/10 "*On interim target and limit reference points and a decision framework*" identified interim RPs and elaborated on the need to formulate management measures relative to the RPs, using MSE to evaluate HSs in recognition of the various sources of uncertainty in the system. Resolution 15/10 with a renewed mandate for the SC to evaluate the performance of HCRs with respect to the species-specific interim TRP and LRP, for consideration of the Commission and their eventual adoption. A species-specific workplan was re-affirmed at the 2017 Commission Meeting, outlining the steps required to adopt simulation-tested Management Procedures for the highest priority species (including the three tropical tuna stocks) (Kolody and Jumppanen 2017).

The Working Party on Methods (WPM) of the IOTC started a workplan to evaluate MPs for albacore, bigeye, yellowfin and skipjack in 2012. Since then, a small ad-hoc working group has been tasked to develop MSE works and to report the IOTC Commission through MP Dialogue meetings specifically scheduled during IOTC Annual and Scientific Committee meetings.

The technical work carried out by the ad-hoc working group includes with relevance for the adoption of HS for tropical tunas is the following (IOTC 2017):

A. *Progress on OMs and MPs of albacore, skipjack, bigeye and yellowfin:*

a. The grids of OMs for these stocks are based on the latest stock assessments with alternatives for natural mortality, steepness, selectivity and dynamic catchability.

b. The MPs considered for these stocks include model based and empirical HCRs. Overall, the skipjack MSE was used to evaluate only a series of model-based HCRs and did not evaluate a complete MP.

c. The MSEs for albacore, bigeye and yellowfin are scheduled to be completed in two or three years and they are including the current CPUE series and standardization methods used in the assessments of these stocks.

d. The management objectives are relatively generic: i) Maintain the biomass at or above levels required to produce MSY or its proxy, and maintain the fishing mortality rate at or below FMSY or its proxy; and ii) Avoid the biomass being below B_{LIM} and the fishing mortality rate being above F_{LIM} (Resolution 15-10).

e. The performance measures used are aligned with the recommended from IOTC's Scientific Committee (IOTC 2015). These include measures of stock status, safety, yield, abundance and stability (Table 2).

Candidate performance statistics	***Performance measure/s***	***Summary statistic***
Status: maximize probability of maintaining stock in the Kobe green zone		
Mean spawner biomass relative to unfished	SB/SB0	Arithmetic mean over years
Minimum spawner biomass relative to unfished	SB/SB0	Minimum over years
Mean spawner biomass relative to BMSY	SB/SBMSY	Arithmetic mean over years
Mean fishing mortality relative to target	F/Ftarg	Arithmetic mean over years
Mean fishing mortality relative to FMSY	F/FMSY	Arithmetic mean over years
Probability of being in Kobe green quadrant	SB, F	Proportion of years that SB ≥ SBtarg & F ≤ Ftarg
Probability of being in Kobe red quadrant	SB, F	Proportion of years that SB < SBtarg & F > Ftarg
Safety: m*aximize the probability of the stock remaining above the biomass limit*		
Probability that spawner biomass is above 20% of SB0	SB	Proportion of years that SB > 0.2SB0
Yield: maximize catches across regions and gears		
Mean catch	C	Mean over years
Mean catch by region and/or gear	C	Mean over years
Mean proportion of MSY	C/MSY	Mean over years
Abundance: maximize catch rates to enhance fishery profitability		
Mean catch rates by region and gear	A	Arithmetic mean over years
Stability: maximise stability in catches to reduce commercial uncertainty		
Mean absolute proportional change in catch	C	Mean over years of absolute (Ct / Ct−1)
Variance in catch	C	CV over years
Variance in fishing mortality	F	Variance over years
Probability of fishery shutdown	C	Proportion of years that C = 0

Table 2. Candidate perfomance statistics to evaluate HS in IOTC (IOTC 2016).

f. The MPs evaluated for these stocks will take advantage of the recent TCMP meetings to decide on tuning parameters for achieving management objectives.

B. *Visualization tools:* The standardised figures and tables for presentation of MSE results that were agreed at WPM07 and SC19 in 2016 were reviewed.

The work of the technical working group has been the cornerstone for the Resolution 15-10 *On target and limit Reference Points and a decision framework*, which defines a series of interim target and limit reference points for albacore, bigeye, yellowfin, skipjack and swordfish (IOTC 2015). The work of the technical working group has also been the basis for the adoption of Resolution 16-02 *on Harvest Control Rules for skipjack tuna in the IOTC area of competence*.

Dialogue between scientists-managers

Management Procedure Dialogue (MPD)

The Indian Ocean Tuna Commission met in Colombo on May 31st, 2014 to start the first Management Procedures Dialogue across the CPC's. Concepts of what the IOTC is trying to develop to insure the long term sustainability of the resource and the fishery were discussed, and put in context with the Precautionary Approach to fisheries. Most of the discussion was targeted to Resolution 13-10, that will need explicit definitions of some key elements to make it workable in the context of a Management Procedure (MP) evaluation. Perspectives from other RFMOs that already have a management procedure in place, CCSBT and the International Whaling Commission (IWC), were presented. A key message extracted from those cases is that in order to make the process more streamlined, explicit guidelines are required, and they will be easier to be put together when the stocks are in a healthy state rather than when the already are severely depleted, as in the case of CCSBT.

The current status of where the IOTC is with regards to MP's was discussed, and perspectives from the coastal and distant water fleets were also presented. Finally, some exercise were developed with the participants to assess their understanding of the issues, and how they would respond to different stock status advice in the context of probability.

Creation of the Technical Committee on Management Procedures (TCMP)

In its 2016 Commission meeting, the IOTC recommended the creation of a TCMP as the formal communication channel between science and management to enhance decision-making response of the Commission in relation to Management Procedures (MPs) (IOTC 2016). The TCMP met in May 2017 for the first time and provided a forum for discussion on the elements of MPs that require a decision by the Commission. The TCMP included the presentation of MSE results to facilitate the exchange of information and views between fishery scientists and managers. It is important to note that currently, despite some agreement on the management objectives, there are no timeframe or probability levels agreed for none of these stocks. Along these lines, IOTC called the TCMP to *define the overarching management objectives to guide the development of management procedures for the IOTC fisheries* (IOTC 2016).

Capacity building workshops in the IOTC

In the tuna RFMOs, and specifically in the IOTC, the MSE process has represented an opportunity to engage scientists and managers view on tuna fisheries stock assessment and management. The adoption of Harvest Strategies has been one condition for the certification of tuna fisheries by the Marine Stewardship Council and this has speeded up the process of setting management objectives, characterizing the uncertainty inherent to fisheries, developing performance measures and evaluating alternative harvest strategies, including harvest control rules.

In general, the MSE process has been led by small team of scientists from the IOTC Scientific Committee. However, one key component of the MSE process is the engagement with third countries within RFMOs, in particular with developing countries. One way to do this have been specific, manager-orientated workshops. The Common Oceans ABNJ Tuna Project (www.commonoceans.org/) has organized a series of workshops to improve the understanding of better management systems for the shared tuna stocks across tuna RFMOs. These workshops have specifically aimed at familiarizing fisheries managers from developing States with the concepts of harvest strategies to participate more fully in the adoption of harvest strategies and the MSE process. Here, we will briefly review the objectives and outcomes of the ABNJ workshops towards building capacity on MSE in the IOTC. Note that the objectives and outcomes of the workshops are very similar.

1) *First Indian Ocean Tuna Management Workshop on Implementation of the Precautionary Approach and Rights-Based Management (22nd – 24th April 2014, Beruwala, Sri Lanka)*

The first tuna RFMO capacity building was held in Sri Lanka in 2014 (ABNJ 2014). The medium-term goal of these workshops was to improve the capacity of developing coastal states to engage in dialogue and negotiations for the implementation of sustainable tuna management through the Indian Ocean Tuna Commission (IOTC). In particular, the first workshop was designed to increase capacity of Indian Ocean developing coastal states to engage in:

i) Development of Harvest Strategies for Conservation Measures;

ii) Evaluation of their performance against management objectives; and

iii) Understanding their sensitivity and robustness to major sources of uncertainty.

2) Indian Ocean Tuna Harvest Strategies Capacity Building (22nd -23rd March, 2017, Colombo, Sri Lanka)

The main goal of this was to create a better understanding among Indian Ocean States of the precautionary approach, Harvest Strategies (HSs) and management strategy evaluation (MSE) for sustainable tuna fisheries (ABNJ 2017a). The workshop featured an agenda of interaction and dialogue among participants, aimed at providing hands on opportunities to learn harvest strategy concepts and run mock simulations of management strategy evaluations of harvest control rules. Attendees gained an increased understanding of the importance of HSs and significantly increased both their knowledge of HS principles and concepts.

Implications for SIOTI Action Plan activities of progress since May 2017

In the 2017 Commission meeting a new calendar was defined for the development of the MSE for the key species in the IOTC (Table 3). This new calendar contains specific tasks that will contribute to the Improved Performance Goals (IPG), 2 and 3.

Year	Skipjack	Yellowfin	Bigeye
2017	**WPs/SC:** Apply HCR using results from 2017 stock assessment to calculate the total annual catch limit. Secretariat to advise CPCs of catch limit.	**WPs/SC:** Undertake MSE and provide advice on the performance of candidate MPs. Identify issues which might need specific guidance from the Commission, including how to interpret objectives, timelines and acceptable levels of risk.	**WPs/SC:** Undertake MSE and provide advice on the performance of candidate MPs. Identify issues which might need specific guidance from the Commission, including how to interpret objectives, timelines and
2018	**TCMP:** Provide advice to the Commission on any outstanding issues resulting from the application of the HCR if required	**TCMP:** Provide advice to Commission on elements of candidate MPs that require a decision by the Commission, including the performance of candidate MPs against Commission objectives	**TCMP:** Provide advice to Commission on elements of candidate MPs that require a decision by the Commission, including the performance of candidate MPs against Commission objectives
	Commission: Provide direction to the WPs/SC on the need to refine	**Commission**: Consider work and advice from subsidiary bodies and provide direction to the WPs/SC on the need to undertake further MSE of candidate or alternative MPs	**Commission:** Consider work and advice from subsidiary bodies and provide direction to the WPs/SC on the need to undertake further MSE of candidate or alternative MPs
	WPs/SC: Consider recommendations from the Commission and further refine the HCR through MSE as directed	**WPs/SC**: Consider recommendations from the Commission and undertake MSE to provide advice on the performance of candidate MPs	**WPs/SC:** Consider recommendations from the Commission and undertake MSE to provide advice on the performance of candidate MPs
2019	**TCMP:** Provide advice to Commission on any outstanding issues resulting from the application of the HCR if required	**TCMP**: Provide advice to Commission on elements of candidate MPs that require a decision by the Commission, including the performance of candidate MPs against Commission objectives	**TCMP:** Provide advice to Commission on elements of candidate MPs that require a decision by the Commission, including the performance of candidate MPs against Commission objectives
	Commission: Consider work and advice from subsidiary bodies and review Resolution 16/02.	**Commission**: Consider work and advice from subsidiary bodies. Decision and adoption of an MP or provide direction to the WPs/SC on the need for further MSE of candidate or alternative MPs	**Commission**: Consider work and advice from subsidiary bodies. Decision and adoption of an MP or provide direction to the WPs/SC on the need for further MSE of candidate or alternative MPs
		WPs/SC: Undertake MSE and provide advice on the performance of candidate MPs	**WPs/SC**: Undertake MSE and provide advice on the performance of candidate MPs
2020		**TCMP**: Provide advice to Commission on elements of candidate MPs that require a decision by the Commission, including the performance of candidate MPs against Commission objectives	**TCMP**: Provide advice to Commission on elements of candidate MPs that require a decision by the Commission, including the performance of candidate MPs against Commission objectives
		Commission: Consider work and advice from subsidiary bodies. Decision and adoption of an MP or provide direction to the WPs/SC on the need for further MSE of candidate or alternative MPs until an MP is adopted.	**Commission**: Consider work and advice from subsidiary bodies. Decision and adoption of an MP or provide direction to the WPs/SC on the need for further MSE of candidate or alternative MPs until an MP is adopted.
	WPs/SC: Apply HCR using results from 2020 stock assessment to calculate the total annual catch limit. Secretariat to advise CPCs of catch limit.		

Table 3. Workplan for MSE development in the IOTC.

In 2017, a HCR was applied to establish catch limits for skipjack in 2018 (IPG3). This HCR will be re-evaluated and reviewed if necessary (IOTC 2017c). With regards to bigeye and yellowfin, the MSE technical work continues its progress and the Commission is scheduled to be in a position to make a decision on the adoption of HS or MPs in 2019 or 2020 (IPG2/IPG3).

The MSE ad-hoc technical working group will again meet in 2018 and review the most recent progress on the bigeye, yellowfin and skipjack MSE. The technical work will also be presented in the IOTC WPM and WPTT.

In 2018, the second edition of the TCMP will take place two days before the Annual Commission meeting. This TCMP is expected to contribute to the process with important points of interest for IPG2 and IPG3 (IOTC 2018). The draft agenda for this meeting includes:

1) Reviewing the decisions of the Commission related to the TCMP
2) Overview of the evaluation of MPs in the IOTC
3) Demonstration with a hands-on workshop

4) Review of the status of the MP/OM in the IOTC with specific slots for bigeye, yellowfin and skipjack
5) Discussion on the actions needed for the adoption of MPs, including budget.
6) Discussion on the future direction of the TCMP

List of References

Garcia, S. 1996. The precautionary approach to fisheries and its implications for fishery research, technology and management: an updated review. FAO Fisheries Technical Paper: 76.

IOTC. 2016. Report of the 19th Session of the IOTC Scientific Committee, Seychelles, 1–5 December 2016.

IOTC. 2017a. Chair report of the 1st IOTC Technical Committee on Management Procedures Yogyakarta, Indonesia, 20 May 2017.

IOTC. 2017b. Report of the 21st Session of the Indian Ocean Tuna Commission. Yogyakarta, Indonesia, 22–26 May 2017.

IOTC. 2017c. Report of the Working Party on Tropical Tunas. Seychelles, October 2017.

IOTC. 2018. Draft Agenda for the 2nd Technical Committee on Management Procedures meeting, 18-19 May, Bangkok (Thailand).

Kolody, D. and P. Jumppanen. 2017. Update on yellowfin tuna management procedure evaluation. IOTC-2017-WPM08-17.