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Status of development of the Management Strategy Evaluation work for Indian Ocean albacore tuna

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Introduction

The current status of the development of a Management Strategy Evaluation (MSE) framework for Indian Ocean albacore tuna (*Tunnus alalunga*) is briefly presented. A first round of simulations of future performance of two Management Procedures has been completed. This initial set was presented to the 3rd session of IOTC Management Procedures Dialogue, held in La Reunion on 20 April 2016.

Future developments will focus on a final agreement on the range of uncertainties covered by the operating models, including possible robustness scenarios of climate and environmental effects on productivity. A wider selection of Management Procedures will be tested, and the tools for exploring simulation inputs and outputs will be further expanded.

Status of development work

Operating Model

The current Operating Model is equivalent to that presented previously (Mosqueira and Sharma 2014), based on the SS3 (Stock Synthesis 3) stock assessment of the albacore stock conducted by the WPTmT in 2014 (Hoyle, Sharma, and Herrera 2014) with one key simplification: the separation of the Taiwanese longline (TWN LL) fleet into two periods of operation, early and late, was not considered in the base OM model. The model is thus greatly simplified and uncertainty in the selectivity curve

is one of the elements of the OM, see below. The differences in selectivity estimated by the base stock assessment model do not appear to be larger than the uncertainty already considered by the OM, so this difference is likely to affect stock assessment point estimates but now the view on uncertainty in stock dynamics presented by the OM.

This iteration of the OM has taken into consideration the recommendations made by WPTmT (IOTC 2014, Table 12) with regards to the scenarios for different model parameters, and the feedback given by the 6th session of th working Party on Methods (WPM), specially that provided by the two invited experts (Dr Owen Hammel and Dr Clay Porch, NOAA, USA).

Dimensions

The model applies a quarterly (three month) time step, and runs over a single region (Figure). Spawning takes place in the fourth quarter, and fish are recruited into the population at the start of the following calendar year, that is they turn into age 1 fish after only three months. The model uses 15 age classes (ages 0 to 14), but age 0 is subsequently dropped from the results (given its effective 3 month life span) and recruitment is assumed to be represented by the abundance of age 1 fish.

The model incorporates catch at length data for a total of seven fleets, as follows

- Japanese longline fleet operating in the North region (`F1_JPN_LL_N`)
- Taiwanese longline fleet operating in the North region (`F2_TWN_LL_N`)
- Purse seine fleet (`F3_PS_N`)
- Other fisheries (`F4_Other_N`)
- Japanese longline fleet operating in the Southern region (`F5_JPN_LL_S`)
- Taiwanese longline fleet operating in the Southern region (`F6_TWN_LL_S`)
- Driftnets (`F7_Drift`)

The separation of longline fleets in Northern and Southern regions (Figure 1) attempts to capture the differences in selectivity due to different main target species for those fleets: tropical tuna in the Northern region and albacore (but also Southern bluefin) in the South.

Indices of abundance

Indices of abundance, derived for CPUE series from four fleets, are used for model conditioning.

- Japanese longline fleet operating in the North region (`S1_JPLL_N`)
- Taiwanese longline fleet operating in the North region (`S2_TWLL_N`)
- Japanese longline fleet operating in the Southern region (`S5_JPLL_S`)
- Taiwanese longline fleet operating in the Southern region (`S6_TWLL_S`)

Natural mortality (M)

Four scenarios for natural mortality at age were considered:

- `0202`: Constant M at 0.2 for all ages.

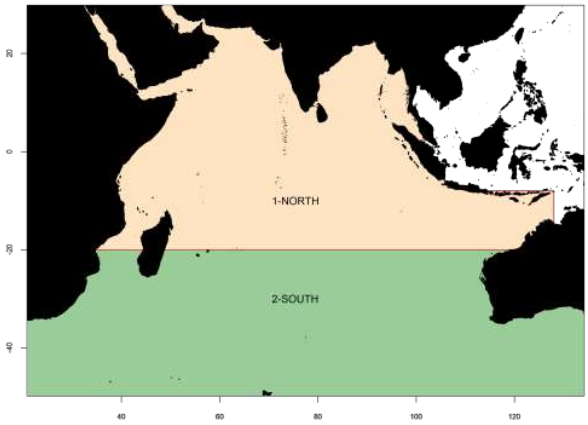

Figure 1: Regions used in albacore OM for separating fleets activity.

- `0303`: Constant M at 0.3 for all ages.
- `0404`: Constant M at 0.4 for all ages.
- `0402`: M=0.4 at age 0, decreasing to 0.2 at age 5 and older.
- `0403`: M=0.4 at age 0, decreasing to 0.3 at age 5 and older.

Variability in recruitment deviations (σ_R)

Two values were considered for the true variability of recruitment in the population (`sigmaR`), 0.4 and 0.6.

Steepness of the stock-recruitment relationship (h)

Three values for the steepness (h) of the stock-recruitment relationship were considered: 0.7, 0.8, and 0.9. The Beverton and Holt stock-recruit model implemented in SS3 (Methot and Taylor 2011) is as follows:

$$R_y = \frac{4hR_0B_y}{B_0(1-h) + B_y(5h-1)} \tag{1}$$

where R_y is the estimated recruitment for year y, h is steepness, R_0 is the virgin recruitment, B_y is the biomass in year y, and B_0 is virgin biomass, the spawning biomass before fishing started.

There is little or no information in stock assessment data sets to estimate steepness (Pepin), so most tuna stock assessment choose to set it at a fixed value. (Simon 2012) showed that steepness in tuna stocks is likely to be at the high end of the range while (Szuwalski et al. 2014) showed that SSB is more likely to be driven by recruitment than recruitment by SSB.

Coefficient of variation in the CPUE series (c_v)

Four values for the coefficient of variation in the CPUE series were included: 20, 30, 40 and 50%.

Weight in final likelihood of trends in length composition (S_{len})

Three values were applied to the relative weight of length sampling data in the total likelihood, through changes in the effective sampling size parameter, of 20, 50 and 100. This alters the relative weighting of length samples and CPUE series in informing the model about stock dynamics and the effects of fishing at length.

Effective catchability trend over time for CPUE series (q_{LL})

Two scenarios were considered for the effective catchability of the CPUE fleet. On the first one it was assumed that the fleet had not improved its ability to fish for albacore over time, or that any increase had been captured by the CPUE standardization process. An alternative scenario considered a 2.5% increase in catchability by correcting the CPUE index to reflect this.

Selectivity function of CPUE fleet (s_{LL})

Two possible functional forms for the selectivity of the CPUE LL fleet were considered: a logistic function (Log), where selectivity stays at the maximum level, or double normal (DoNorm), where selectivity drops at some point in the age range.

Data

The datasets employed are those used in the WPTmT stock assessment (Hoyle, Sharma, and Herrera 2014; IOTC 2014). Figure ?? shows the data availability for each type and fleet.

Results and diagnostics

The aggregated population model obtained from the complete grid of model runs included a high proportion of unrealistic estimates. The virgin recruitment (LN(R0)) estimate obtained in some runs was at the higher limit specified in the model control ($ln(R_0) < 15$). This gives indication of a mismatch between the information content of the data and a particular set of fixed parameters, or of conflicts between the various data sources.

An strategy for filtering unfeasible stock trajectories was devised, based on the relationship between the area of the ocean considered as suitable habitat for albacore and the estimates of carrying capacity (K) obtained in stocks assessments of albacore in all oceans (Arrizabalaga et al. 2015; Mosqueira and Scott 2016). By selecting SS3 runs monly if the estimate of B_0 was no higher than the 95% confidence interval of the model fit $K = 878127$, a total of 516 runs were kept.

The final conditioned OM for albacore, 1950-2012, can be summarised by a plot of the recruitment, biomass and fishing mortality time series (Figure 3, with their estimated uncertainties.)

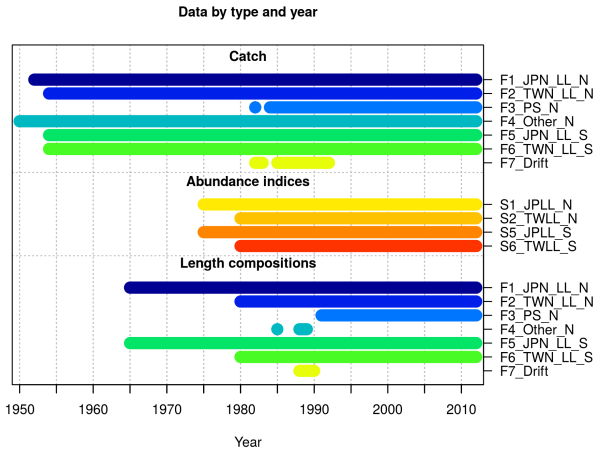

Figure 2: Data coverage by year for each fleet and source: catch, abundance indices and length composition.

Unless great discrepancies are found between the 2014 and 2016 SS3 stock assessments, and the population trajectories estimated this year do not fall within the range of trajectories included in the OM, or do so at the extremes of the distributions, I suggest that the current OM does not need to be reconditioned using the most recent stock assessment, except for the procedure applied to the intermediate years.

The conditioning of the OM is based on data up to 2012, as available at WPTmT 2014, but more recent statistics of total catches were already available. The OM has been projected forward deterministically for the intermediate years of 2013-2016 period, so that the application of the MP was considered to start at the first year for which IOTC could still decide on, 2017. The population was projected as follows:

- 2013-2014: Total catch taken equal to be reported catch in the IOTC database, as of 01 April 2016. This projection assumes no changes in aggregated selectivity.
- 2015-2016: Fishing mortality to be at the same level as 2014. Without any other information on the activities of the fleet for that period, the assumption is that levels of effort have been maintained by all fleets.

Either of those two assumptions, most probably the second one, could be deemed erroneous, and a different procedure for extending the OM until the current year could de decided. Known changes in fleet activity and effort levels, for example, could be incorporated and their effect evaluated.

Management Procedure runs

At the moment, some initial runs have been carried out for two contrasting management procedures, based on trends in the CPUE series (*IRate*) and on a biomass dynamics stock assessment (*BRule*). These two procedures have also been applied to Indian Ocean skipjack tuna (Bentley and Adam 2015),

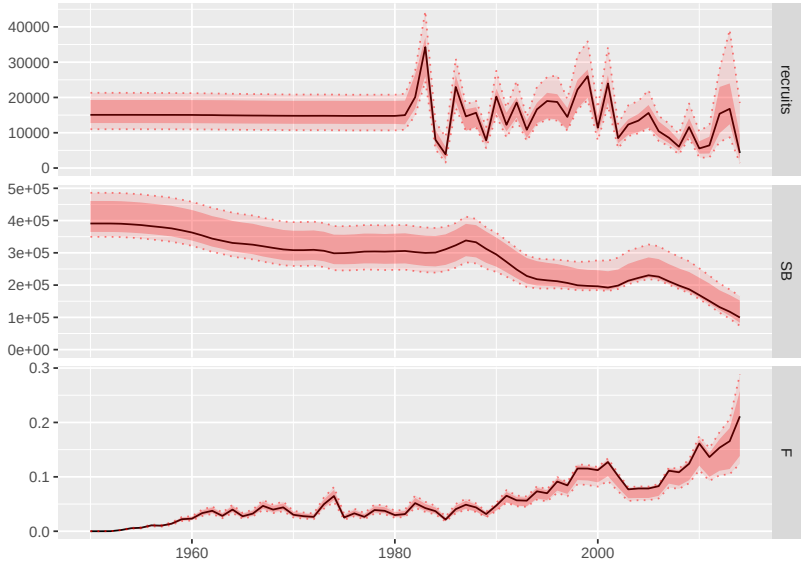

Figure 3: Time series of recruitment, spawning biomass and fishing mortality of the conditioned OM for IOTC albacore. Black line is the median, while coloured ribbons show the 25-75 and 10-90 percentiles.

and one of the them forms the basis for the recently adopted IOTC resolution. There is currently no limits on what type of Management Procedure could be evaluated and eventually adopted for albacore, but unless dicated by data limitations or other reasons, there is a great advantage in considering a common set of MPs across IOTC stocks: that of building on previous experience of scientists and managers when presenting results. For a fuller explanation of these two MPs, please refer to the relevant WPM documents (Bentley and Adam 2015; Bentley and Adam 2016).

A consolidated set of runs for either MP is still to be carried out, pending development of the new forecasting *FLR* package, soon to be released.

An example output for a single run of the IRate MP can be found in figure ??. This particular MP had these values for some of its input parameters:

- Lag between data collection and assessment: 2 years
- Lag between scientific advice and management action: 2 years
- Frequency of decision: 2 years

A grid of runs across values of the MP parameters leads to a set of performance indicator values from which trade-offs between conflicting objectives can be evaluated. If, for example, making the MP more responsive to perceived changes in abundance (by increasing the value of the responsiveness parameter in *IRate*) brings higher mean catches over the projection time frame, it is likely to do so at the expense of an increase in the risk of F exceeding F_{MSY}. An example plot of these type of trade-off can be found in Figure ??.

Presentation of these trade-offs was welcomed by managers during the last session of the Management Procedures Dialogue (MP032, (MPD 2016)). A request was made, for example, to show a

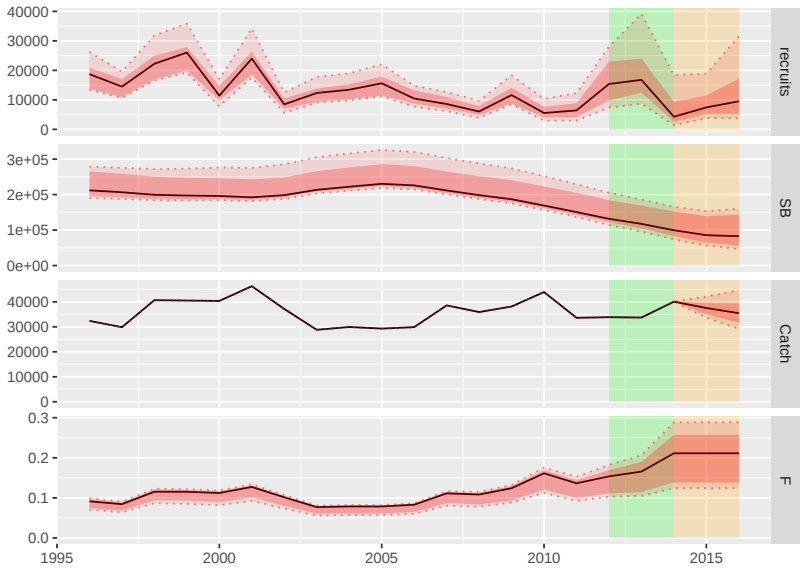

Figure 4: Time series of recruitment, spawning biomass, catch and fishing mortality of the conditioned OM for IOTC albacore in the last decades, including the intermediate years (2013-2016). Black line is the median, while coloured ribbons show the 25-75 and 10-90 percentiles. Green shade shows the catch-based projection period, and orange the F-based one.

similar plot for the Kobe plot-related indicators, SB/SB_{MSY} and F_FMSY, which can be found in Figure ??, again for an initial set of MP runs.

Future dynamics

The future dynamics of both stock and fleets are an essential assumption when evaluating MP performance. The current options considered in the albacore MSE projections are the simplest ones, but other could be explored if the relevant expertise and information can be gathered.

Recruitment

Given our lack of knowledge on the form, strength and variability of the stock-recruitment relationship, simulations are currently considering a range of recruitment variabilities (CV of 30 to 60%) and autocorrelation values (0 to 0.8) so as to incorporate a wide range of scenarios. No MP is likely to perform well under all those circumstances, so narrowing them down, or assigning them different levels of plausibility, would help. This might be a factor where a detailed comparison across albacore stocks in all oceans could be informative, although observations on recruitment are limited for all of them.

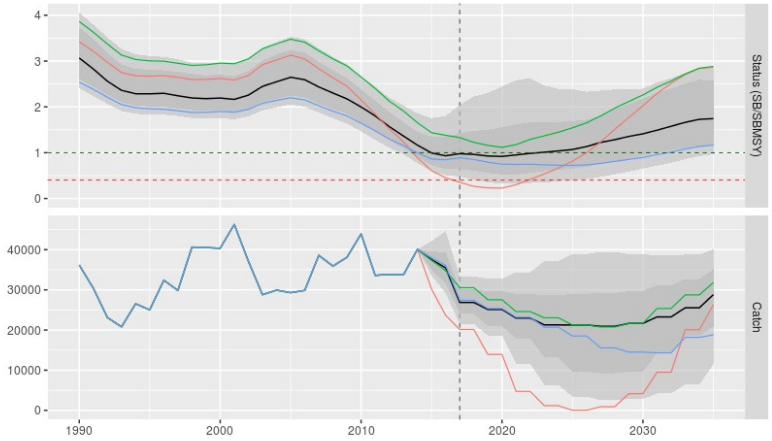

Figure 5: Example run for the IRate MP. Output of two performance indicators: SB_SB_{MSY} and total catch. Ribbons reflect the 20-80 and 25-75 percentiles, black line is the median trajectory, while colour lines show three individual runs.

Fleet responses to changes in abundance or other factors

We have seen changes in some of the fleets capturing Indian Ocean albacore, with changes in areas or target species. Although fleet dynamics are difficult to predict, and even more so in multi-species settings, it would be useful to consider possible changes that could be initiated or accelerated by the adoption of an MP. Reductions in, for example, catch or effort, could lead to certain fleets moving away from albacore, and the loss of a source of information on stock abundance. This type feedback loops can be very difficult for an MP to deal with, so identifying and incorporating them in some robustness test could be an useful exercise, if at all possible.

Data and management lags

Future simulations currently assume that the lags in access to catch and CPUE data, and between scientific advice and management, are likely to stay the same. We have a two-year lag between data and stock assessment, and another two years between stock assessment and any possible IOTC resolution actually being implemented. Even for a relatively long-lived stock like albacore, these lags could seriously impact MP performance. The ability to set management decision for periods longer than two or three years is likely to be severely impacted by the accumulated four years of lag.

The MSE runs being conducted are looking at this factor, but consideration should be given to how realistic is to expect these lags being reduced. Could the data necessary to inform a CPUE-based MP be assembled with a one year lag? Could the detailed catch and effort statistics be obtained from a particular section of a given fleet and a CPUE based on those be used to feed the MP?

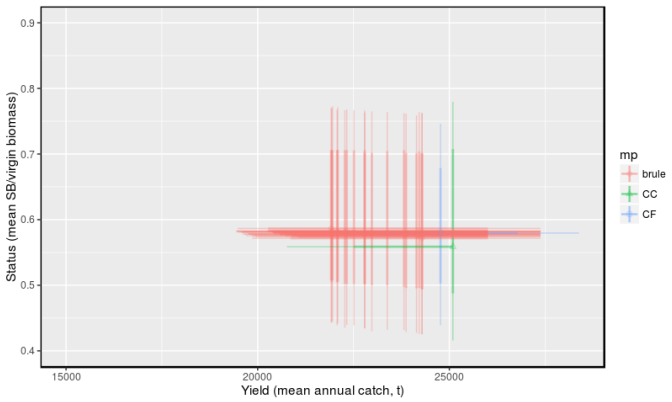

Figure 6: Example trade-off plot for yield vs. status for the *BRule* MP. Crosses reflect the uncertainty in values for those performance indicators at the end of the 20 year projection period. Colours refer to the MP. In this case *BRule* is compared with constant catch (*CC*) and constant fishing mortality (*CF*) scenarios.

Simulation platform and software

Development of this simulation platform has been carried out using the FLR toolset (L. T. Kell et al. 2007), an open source collection of packages in the *R* language (R Core Team 2015) designed for the development and implementation of simulation models of fisheries systems. Development has been carried out in the open, through a publicly-available version control system hosted at http://github.com/iotcwpm/ALB. All inputs and outputs can be generated by installing a single *R* package, called *ioalbmse*, and the corresponding dependencies. Please follow the instructions at the repository above for a local installation. The package contains the SS3 input files used as basis for the OM conditioning. It also contains the OM itself, but not the whole set of 1,200 SS3 runs, given their large. These can be obtained from the author and will be made available online if requested.

A complete technical specification and user manual for the *ioalbmse* package is under development, and will be available for the next session of WPM. The package currently includes an interactive web-based application for exploring the albacore OM, and this is being extended to also allow dynamic exploration of MP evaluation results.

Future developments

The current version of the SS3-conditioned OM has had the support of both WPM and SC, and incorporates the suggestions made by WPTmT in 2014. As suggested above, the need for re-conditioning the OM should be carefully considered, given the amount of effort involved, but could be carried out if deemed necessary.

Some consideration needs to be given to possible future scenarios involving environmental factors affecting albacore productivity, spatial distribution and catchability. Climate change is likely to have an effect in this stock, and although the exact strength of the link between stock dynamics

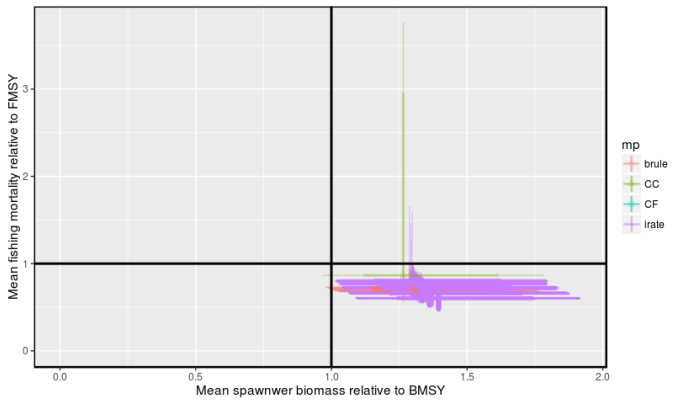

Figure 7: Trade-off plot for the Kobe plot variables, SB/SB_{MSY} and F_FMSY, and for a set of runs of the *IRate* and *BRule* MPS. Crosses reflect the uncertainty in values for those performance indicators at the end of the 20 year projection period. Colours refer to the MP, compared also with constant catch (*CC*) and constant fishing mortality (*CF*) scenarios.

and climate is uncertain, there might be room for constructing certain well-supported scenarios to test the robustness of MPs under those circumstances.

A significant development in the *FLR* platform is taking place that could have a positive impact in the work on albacore tuna. The new version of the package responsible for forecasting and predictions, FLasher, will be able to carry out projections with multiple fleets, each with separate selectivity, and in shorter time steps, e.g. seasonal. This capabilities would open up a new range of possible management scenarios, for example temporal closures, or fleet dynamics, like changes in fishing levels by fleet. The new package is expected to be available in time for simulation runs using it to be presented to the next session of WPM in October 2016.

Some extra MPs need to be considered, and work has started on testing an MP with a HCR loosely based on that currently implemented in CCSBT for Southern bluefin tuna (CCSBT 2016). Although we might soon have the ability to evaluate MPs based on limits on fishing effort, the actual implementation of those might not be feasible, and current indications for IOTC are that catch-based management appears to be the preferred option.

Discussion

The second iteration of the Indian Ocean OM and MSE platform is now nearing completion. Feedback provided by WPTmT in 2014 has already been incorporated into the OM grid. An initial set of MP runs are available, and future developments will add other alternative MPs and HCRs. A complete set of simulation runs will be finalized for presentation and discussion to the next session of WPM and SC. At this moment, feedback from the current session of WPTmt will be most welcome at this point, specially with regards to issues related with productivity of the stock under plausible environmental scenarios, and future changes in the information content of the main index of abundance for this

stock.

All of the MPs evaluated, and those being considered, rely on at least one source of information considered to track the changes in abundance of the stock. For this fishery those sources are limited to the standardized CPUE series for some commercial fleets, typically longliners. Although tremendous effort has gone and still going into the compilation and analysis of data involved in generating these indices, there are enormous problems in estimating how well they give us information on stock status. The results of the recent efforts at better understanding the dynamics of these CPUE series, including document IOTC-2016-WPTmT06-16 in this meeting, could lead to a more robust approach for using the information contained in them, and identifying certain signals of degradation. The later could be used when defining the meta-rules for a possible resolution: when to stop application of the MP given problems with the inputs, in this case the CPUE series.

Some of the future dynamics of the stock might chnage from those estimated (or assumed) by the OM conditioning, and the knowledge on albacore dynamics, both in and outside of the Indfian Ocean, could be used to explore how management and conservation could be impacted. I have outlined above some of the open issues that could be explored now that an MSE simulation platform is available for this stock. Among them, recruitment and productivity links with environmental changes and dynamics, and quality and quantity of information from different fleets, I think deserve some careful consideration.

The final result of this MSE exercise should be the adoption by IOTC of a Management Procedure that has been shown to be robust and performs as required at conserving the albacore stock and ensuring the future of the fisheries operating on it. The work so far has concentrated on the quantitative basis for the selection of an MP and we should be over the next few months in a position to offer IOTC a solid set of MPs and the tools and information for that selection to be based on science. Getting there will also involve a great deal of dialogue among scientists, and of those with managers.

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