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CURRENT AND FUTURE RESEARCH ON MANAGEMENT STRATEGY EVALUATION (MSE) FOR TUNAS AND RELATED SPECIES IN THE EASTERN PACIFIC OCEAN

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1. INTRODUCTION

Management of many fish stocks is moving away from traditional stock assessment towards the use of harvest control rules (HCRs) based on reference points (RPs) and tested using management strategy evaluation (MSE). This change is partly due to the realization that many stock assessments are highly uncertain, and that the uncertainty should be taken into consideration when implementing management. Another important reason is to have pre-agreed management procedures in place to avoid arbitrary changes in management when stock assessment results are controversial. The goal of MSE is to identify assessment methods and HCRs that are robust to uncertainty while attaining management objectives.

MSE involves using simulation analysis to test alternative management procedures under different possible states of nature (de la Mare 1986; Butterworth *et al.* 1997; De Oliveira *et al.* 1998; Butterworth and Punt 1999; Smith *et al.* 1999). These procedures comprise a number of components, including a) the data collected, b) the assessment method used to analyze the data (*e.g.* the stock assessment), and c) the HCR (Schnute *et al.* 2007). The MSE requires one or more operating models that represent the alternative states of nature used to test the management procedure. The MSE also needs evaluation criteria (*e.g.* average catch and depletion levels) to evaluate the performance of the management procedure. The combination of assessment method and HCR can be anything from a simple scaling of catch-per-unit-effort (CPUE) data to a complicated RP-based HCR applied to results of an integrated stock assessment model.

The MSE process leading to actual implementation of a management procedure, as opposed to theoretical research, is very time-consuming, and each component is complicated in its own way. Scientific studies often focus on the development of operating models, assessment methods, and HCRs, but developing evaluation criteria and ensuring that the HCRs are practical require that political, economic, and social factors be taken into account.

At its 87th meeting in October 2014, the IATTC adopted interim target and limit RPs for two species of tropical tunas, bigeye (*Thunnus obesus*) and yellowfin (*T. albacares*). The target reference points are the biomass (B) and fishing mortality rate (F) corresponding to the maximum sustainable yield (MSY; thus B_{MSY} and F_{MSY}, respectively) which have been the *de facto* target reference points used in managing tuna in the eastern Pacific Ocean (EPO). The limit reference points are based on biological grounds to protect a stock from "serious, slowly reversible, or irreversible" fishing impacts, which is generally interpreted as meaning that recruitment is not substantially impacted. Staying within these limits ensures that, even in

a pessimistic scenario, recruitment will not fall to a very low level. The limit RPs are those associated with a 50% reduction in recruitment under a conservative assumption (h = 0.75) about the relationship between stock size and recruitment, expressed as steepness (h; see Maunder and Deriso 2014). The IATTC has operated under the informal HCR of fishing at F_{MSY}, or more accurately, reducing the fishing mortality to F_{MSY} if fishing mortality on bigeye or yellowfin exceeds F_{MSY} for that species, as estimated by the base case stock assessments. This HCR does not take uncertainty into consideration, nor the probability of exceeding the limit RP, and the action to be taken if the limit RP is exceeded has not been defined. The HCR and RPs have not been tested to determine whether they meet the management goals, and the management goals have not been explicitly defined, except in broad terms in the Antigua Convention (*i.e.* "maintain or restore the populations of harvested species at levels of abundance which can produce the maximum sustainable yield").

The IATTC staff has conducted several research projects related to MSE and plans to pursue these investigations, in collaboration with other organizations. This document outlines past and future research by IATTC staff on MSE.

2. PREVIOUS MSE WORK

Maunder (2014) developed a procedure to conduct management strategy evaluations (MSEs) using the Stock Synthesis (SS; Methot and Wetzel, 2013) general stock assessment program as the operating model. Samples from the posterior distribution of a Bayesian application of SS using Markov Chain Monte Carlo (MCMC) are used to represent the possible states of nature, allowing for uncertainty in parameters used in typical stock assessment models. The bootstrap procedure built into SS for generating random observations is used to include observation uncertainty in the future data used in the HCR. Process error is included by extending the "estimation" period of the stock assessment used to create the operating model to include the period over which the MSE will be conducted. Priors can be put on model parameters that are usually fixed (*e.g.* natural mortality), and the parameters estimated to more accurately represent uncertainty. R code was developed to communicate between the SS-based operating model and the management procedure that is being evaluated. The advantage of using SS is that assessments based on SS are already available for many stocks, including the tuna assessments in the EPO, and these can easily be converted into SS-based operating models to conduct an MSE. The procedure was applied to Pacific bluefin tuna, based on the stock assessment carried out in SS by the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC). The management procedure, comprised of simple harvest rates applied to two CPUE-based indices of abundance, one for spawners and one for recruits, was compared to a simple catch-based management procedure similar to that evaluated by the ISC's working group on Pacific bluefin. The result of this research, initially developed in collaboration with John Walter of the US National Marine Fisheries Service, is not a final MSE to be used for managing this stock. It is only the first step in the process, and will hopefully prompt a collaborative effort among all the interested parties to develop a full MSE which, if found to be appropriate, can be used to provide management advice.

Maunder *et al.* (2015) conducted a preliminary MSE on bigeye tuna to investigate the appropriateness of the operational F_{MSY}-based HCR, given the new interim limit RP. The approach followed that developed by Maunder (2014) and was based on using the SS-based stock assessment model for bigeye as the operating model. The assessment method was a simplified version of the SS-based model. This academic exercise, conducted in collaboration with Jiangfeng Zhu, a visiting scientist from the College of Marine Sciences at Shanghai Ocean University, China, is also not a final MSE to be used for validating the reference points or HCR, or for managing the stock.

As part of the FAO *Common Oceans* project, during 2015 the IATTC staff, in conjunction with FAO and World Wildlife Fund, conducted a workshop in Panama where the MSE concepts were discussed. The

main objective of the workshop was "to accelerate the development of tuna harvest strategies within the Eastern Pacific Ocean by assisting IATTC Commissioners and technical advisors to become familiar with the MSE process and the way that scientists and decision makers should work together towards selecting and implementing robust [harvest strategies]."

IATTC staff also participated in the 2015 ISSF Stock Assessment Workshop on Characterizing Uncertainty in Stock Assessment and Management Advice. A presentation was given that reviewed he IATTC's progress towards the formal adoption of harvest strategies for the management of the stocks under its jurisdiction, with a special focus on the treatment of uncertainty and the estimation of risk.

Research on MSE for dorado (*Coryphaena hippurus*) in the EPO is ongoing. Following very successful data and modelling workshops with colleagues from coastal EPO countries in 2014 and 2015, the IATTC staff secured funds to expand on a preliminary SS model for dorado and conduct the first integrated stock assessment for this species, along with initiating research on MSE. A simplified version of the SS model used for the assessment (Aires-da-Silva *et al.* 2016) was used as the operating model for the MSE. The MSE approach is based on work done previously by Maunder (2014) and Maunder *et al.* (2015) for MSE research on Pacific bluefin and bigeye tunas. At this stage the work has focused on testing the current management strategy, which is based on seasonal closures. We used five alternatives: the current closure, and closures starting in either January, February, March, or April. Ongoing work will focus on alternative strategies, including: no seasonal closure; fixed seasonal closure but later in the year; dynamic seasonal closure based on a minimum size limit, recruitment timing, and growth; seasonal closures based on impacts of sea-surface temperatures on CPUE; and preserving a percentage of the initial CPUE. The objective of this research, partially funded by WWF and conducted in collaboration with Juan Valero, of the Center for the Advancement of Population Assessment Methodology in San Diego, USA, is not to develop a final MSE for managing dorado, but to provide a tool for formally evaluating alternative management strategies that, if found to be useful, could be used to inform management decisions. Work on the MSE for dorado will continue after this meeting of the Scientific Advisory Committee (SAC), and the results will be presented and discussed with interested parties at future IATTC Technical Meetings on dorado.

3. PROPOSED WORK

The IATTC has received funding from the European Union to conduct a preliminary MSE on tunas in the EPO. This work will start in June 2016, and the results will be presented at the meeting of the SAC in 2017. The main focus of the project is to test the recently-adopted interim target and limit RPs. Reference points cannot be evaluated without considering the associated HCR; in fact, most of them are arbitrary and untested, while HCRs are tested with respect to RPs. Therefore, the first component of the project is to review and evaluate limit RPs qualitatively, and the second is to test HCRs conditional on the RPs. This project will further develop the simulation analyses of Maunder *et al.* (2015) to test the IATTC's informal HCR with respect to the interim target and limit RPs, and alternatives, under different sources of uncertainty. The project will be limited to describing the sources of uncertainty and conducting a simulation analysis to evaluate the informal HCR for bigeye with respect to the interim RPs and alternatives. If there is time, the analyses will be repeated for yellowfin.

A Joint MSE Technical Working Group has been established by the tuna regional fisheries management organizations (RFMOs), as recommended at the Third Joint Meeting of the tuna RFMOs. The intention of the group is to aid the implementation of MSE and the development of tools and methodologies by promoting collaboration, *i.e.* by sharing code and data, working on collaborative papers, and keeping each other updated on the various activities being conducted by the tuna RFMOs, via a webpage

(http://tuna-org.org/mse.htm). An IATTC staff member is on the steering committee of the working group, and several staff members will be involved in the work and in meetings. The first meeting of the working group will take place in the fall of 2016. The future work plan is based on the tasks required when conducting an MSE, with the aim of incorporating them into the Kobe Framework. The tasks are a) identifying management objectives and mapping these into statistical indicators of performance or utility functions; b) selecting hypotheses for consideration in the operating model that represents the simulated versions of reality; c) conditioning the operating model based on data and knowledge, and weighting of model hypotheses depending on their plausibility; d) identifying candidate management strategies and coding these as management procedures; e) projecting the operating model forward in time using the management procedures as a feedback control in order to simulate the long-term impact of management; and f) identifying the management procedures that robustly meet management objectives.

The ISC has a work plan to develop a process for evaluating the performance of alternative management procedures for north Pacific albacore tuna against a range of scenarios that encompass observation (data) and process uncertainty in stock assessments and management, and alternative hypotheses about stock dynamics. This is in response to a proposal by the United States at the 87th Meeting of the IATTC in July 2014 (IATTC-87-PROP-J-1-USA-MSE), that the IATTC scientific staff, in collaboration with the ISC working group, evaluate several candidate target and limit reference points and HCRs for albacore using MSE. The Northern Committee of the Western and Central Pacific Fisheries Commission (WCPFC) recommended the adoption of a management framework for north Pacific albacore that includes reference points and a HCR, and requested evaluation using MSE. The albacore working group concluded that present resources and personnel are not sufficient to develop and conduct an MSE, and an MSE analyst will have to be hired to work on the MSE process. The timeline for that process will depend on when the analyst is hired, but the results will not be reported to the SAC until 2019 at the earliest. IATTC staff will be involved in this research through the working group.

4. DISCUSSION

MSE is a time-consuming process, and includes several diverse components requiring a range of expertise. MSE is well-developed for several fish stocks around the world (*e.g.* southern bluefin tuna), but work on MSE has only recently started at the IATTC and for Pacific Ocean tunas in general. The IATTC can learn from the experience of others and take advantage of existing tools. However, the practicalities of implementing management procedures in the real world and the development of operating models that best represent the tuna populations in the EPO will necessitate detailed research on MSE for those populations.

It is important to realize that the results of MSE will be highly dependent on the choice of operating models used to represent the states of nature. Therefore, these states of nature should be based on the best available scientific information. There is no known management procedure or HCR that automatically works well for all species. Therefore, management procedures and HCRs should be tested using operating models that are consistent with the available data (*i.e.* conditioned on the data) and current scientific knowledge. Essentially, this means that a stock assessment must be conducted to develop the operating model. Therefore, MSE should not be thought of as a replacement for stock assessment; in fact, it means that additional stock assessment research is needed to ensure that the uncertainty about the assessment is accurately represented, and that arbitrarily-chosen operating models do not influence the results of the MSE.

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