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APPLICATION OF HARVEST CONTROL RULES FOR TROPICAL TUNAS IN THE EASTERN PACIFIC OCEAN

Mark N. Maunder and Richard B. Deriso

CONTENTS

ABSTRACT

The IATTC has used seasonal closures to manage the purse-seine fishery for tropical tunas in the eastern Pacific Ocean since 2002. Interim target and limit reference points based on maximum sustainable yield (MSY) and reductions in recruitment, respectively, have been adopted for these tunas. We evaluate the use of the harvest control rule (HCR) used by the IATTC, which is based simply on limiting fishing mortality (*F*) to levels that do not exceed the level corresponding to the MSY.

Until 2010, the implemented closures were shorter than indicated by the stock assessments and recommended by the IATTC staff; however, since then they have been consistent with both. The stock assessments, which cover the 1975-2014 period, estimate that for most of that period the fishing mortality of yellowfin and bigeye tuna has been below the level corresponding to MSY. No assessment is available for skipjack tuna, but the fishing mortality increased starting in the early 1990s and leveled out in the late 2000s.

It is currently not possible to evaluate the appropriateness of the limit reference points unless some assumptions are made about the population dynamics of tuna (*e.g.* steepness of the stock-recruitment relationship). Extensive meta-analysis shows no evidence for depensation, and when fishing pressure is reduced, stocks almost always increase in abundance, indicating that hard biomass-based limit reference points can be set at low levels of abundance. (A 'hard' reference point demands strict and prompt management action if a stock falls below that point; a 'soft' reference point requires only that appropriate action be taken within a reasonable time.) The appropriateness of the HCR with respect to the limit reference points has not been thoroughly tested. A preliminary management strategy evaluation (MSE) for bigeye tuna indicated that the HCR based on F_{MSY} is appropriate and will result in a low probability of exceeding the limit reference point. A more comprehensive MSE is needed to evaluate the HCR. Alternative HCRs that include soft and hard limit reference points, use biomass-based

reference points, and establish well-defined management actions when reference points are exceeded, should be considered.

1. INTRODUCTION

Target (TRP) and limit (LRP) reference points and harvest control rules (HCRs) are essential components of the guidelines for adopting the precautionary approach to fisheries management outlined in Annex II of the United Nations Straddling Fish Stocks Agreement (UNFSA 1995), and there is mounting pressure from a variety of organizations and certification bodies to adopt such reference points and HCRs. At its 87th meeting in July 2014, the Inter-American Tropical Tuna Commission (IATTC) adopted interim TRPs and LRPs for managing tuna in the EPO, and applies an operational HCR for tropical tunas (yellowfin, skipjack, and bigeye) in the eastern Pacific Ocean (EPO). We provide the available evidence for the validity of this HCR.

2. REFERENCE POINTS

The objective of LRPs is to protect a stock from serious, slowly reversible, or irreversible fishing impacts. In general, avoiding these impacts is interpreted as ensuring that recruitment is not substantially impacted.

The TRPs adopted formally by the IATTC in 2014, and used informally in prior years, are the biomass (B) and fishing mortality rate (F) corresponding to the maximum sustainable yield (B_{MSY} and F_{MSY}, respectively). The LRPs, which are based on biological grounds, are those associated with a 50% reduction in recruitment based on a conservative assumption of the steepness (h) of the stock-recruitment relationship (h = 0.75; see Maunder and Deriso 2014), .

The LRPs have not been tested to determine if they are appropriate to protect a stock from such impacts. This is not a trivial task, since the answer is dependent on depensation (a decrease in the breeding population leads to a reduction in recruits per spawner) caused by factors such as the Allee effect (the reduced likelihood of finding a mate), the number killed by predators being independent of the abundance of the prey, and niche invasion by other species. Meta-analyses of stock-recruitment relationships find little evidence for depensation (Myers *et al*. 1995; Liermann and Hilborn 1997, 2001). Extensive meta-analysis shows no evidence for depensation: when fishing pressure is reduced, stocks almost always increase in abundance, and productivity is most impacted by changes in régime (Hilborn *et al*. 2014; Vert-pre *et al*. 2013). Most, if not all, LRPs, including those used by the IATTC, are arbitrary and have not been tested. The difference with the IATTC reference points is that they are more directly related to the requirement of ensuring that recruitment is not substantially impacted and to common assumptions about the stock-recruitment relationship. Alternative reference points could be based on the distribution of historical values, as recommended for skipjack tuna (Maunder and Deriso 2007). It is unlikely that future analyses or research will develop less arbitrary LRPs.

3. HARVEST CONTROL RULE

For bigeye and yellowfin, the IATTC has applied the informal HCR of fishing at F_{MSY} or, more accurately, reducing the fishing mortality to F_{MSY} if the fishing mortality of either stock exceeds its respective F_{MSY}, as estimated by the base case stock assessments. The HCR is based on the general management goal outlined 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 probability of exceeding the LRP was not explicitly considered when the HCR was developed, and the action to be taken if the LRP is exceeded has not been defined.

3.1. Evidence that the harvest control rule is appropriate

HCRs should be extensively evaluated to determine if they meet management goals. For example, MSE should be used to determine if the HCR ensures that there is a low probability that the LRP is exceeded. The HCR used by the IATTC has not been extensively tested.

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 LRP. They found that the probability of recruitments dropping below half of the virgin recruitment ($R_{0.5}$) in a particular year is lower than 10% for the projected 9 years, except for one particular year when the stock-recruitment steepness (*h*) in the stock assessment model was over-assumed. They also found that there was only one or (depending on the scenario) two years during the 1975-2014 period in which the recruitments were lower than $R_{0.5}$. However, it should be noted that, for some species, the annual variation in recruitment due to environmental conditions can reduce recruitment below $R_{0.5}$ even when the spawning stock biomass (SSB) is relatively high.

Maunder *et al*. (2015) found that the probability of the fishing mortality exceeding that corresponding to a recruitment level of $R_{0.5}$ ($F_{0.5R0}$) is zero for the projected years when the average length of the oldest fish (L_2), natural mortality (*M*), and *h* are perfectly specified in the stock assessment model. $F_{0.5R0}$ is also not exceeded when L_2 is under-assumed. Both over-assumed *h* and over-assumed *M* result in $F_{0.5R0}$ being exceeded for a few years in the 9-year projection period, but the probability of exceeding $F_{0.5R0}$ is very low (lower than 5% in any particular year). The probability of the level of depletion (*d*) of the SSB being below the biomass corresponding to $R_{0.5}$ ($d_{0.5R0}$) is zero for all the scenarios.

3.2. Implementation of the harvest control rule

The HCR is implemented in the EPO by the IATTC using limited entry and a time closure for purse-seine vessels. The closure can be in one of two periods, July to September or November to January, and can also be adjusted to take into account increases or decreases in fleet capacity (see http://www.iattc.org/PDFFiles2/IATTC-75-07b-Conservation-recommendations-and-AnnexREV.pdf). The duration of the closure is calculated as follows:

Duration of closure = 365-*F* multiplier * (365-current closure)/(capacity at end of previous year/previous 3-year average capacity).

There is also a smaller spatial closure for purse-seine vessels from 29 September to 29 October within the area from 96° to 110°W between 4°N and 3°S. An evaluation of this closure (see Appendix I of https://www.iattc.org/Meetings/Meetings2014/MAYSAC/PDFs/SAC-05-16-Conservation-recommendations.pdf) found that it was equivalent to 3 days of closure for the entire EPO, and therefore the closure calculation above is adjusted for this.

The longline fishery is managed using annual catch quotas for bigeye tuna divided among the major longline fishing nations. The quotas are adjusted appropriately based on any conservation measures that are adopted for purse-seine vessels.

3.3. Evidence that the harvest control rule has been applied

The operational IATTC HCR has been in action for a number of years, and this historical period can be used to determine if the HCR has been implemented. There are two ways of doing this: first, the estimate of the annual fishing mortality can be compared to the fishing mortality corresponding to maximum sustainable yield (i.e. $F/F_{MSY} \leq 1$); and second, the official closure length set in a particular year can be compared to the closure length calculated based on F_{MSY} using the assessment for the previous year.

Fishing mortality on yellowfin tuna is estimated to be below F_{MSY} throughout the assessment period (1975-2014), except the early 1980s and the mid-2000s (Figure 1). Fishing mortality on bigeye is estimated to be below F_{MSY} for all of the assessment period (Figure 2). No estimate of F_{MSY} is available for skipjack, but the fishing mortality started to increase in the early 1990s, and leveled off in the late 2000s (Figure 3). F/F_{MSY} is uncertain for yellowfin and bigeye because of uncertainties in the stock assessment. In particular, the steepness of the stock-recruitment relationship is uncertain, and lower values can produce estimates of F that are above F_{MSY}.

The IATTC has used seasonal closures to manage the purse-seine fishery for tropical tunas in the EPO since 2002. Initially the closures were not as long as indicated by the stock assessments and/or recommended by the IATTC staff (Table 1). The longer closure was mainly needed for bigeye, but was also needed for yellowfin in some years. In 2012 the closure was set at the lower end of the staff's recommendation, which was in turn shorter than indicated by the stock assessment. Since then the stock assessment has indicated that the closure could be shortened slightly, but due to increases in fleet capacity and uncertainty in the results of the assessment, the staff has recommended maintaining the existing closure, and this recommendation has been adopted by the Commission. In 2013 and 2015 the closure length indicated by the stock assessments was slightly longer for yellowfin than for bigeye.

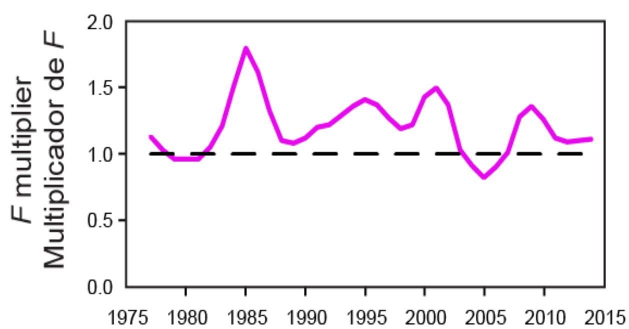

FIGURE 1. Change in current fishing mortality on yellowfin required to correspond to MSY (Fmultiplier = F_{MSY}/F) (Minte-Vera *et al*. in press).

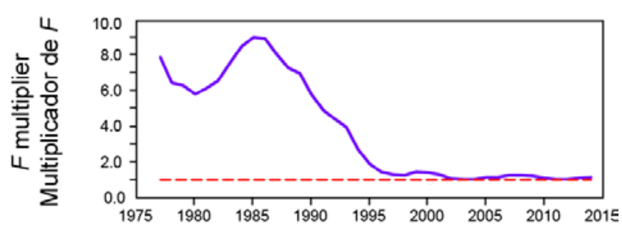

FIGURE 2. Change in current fishing mortality on bigeye required to correspond to MSY (*F*multiplier = F_{MSY}/F) (Aires-da-Silva and Maunder in press)

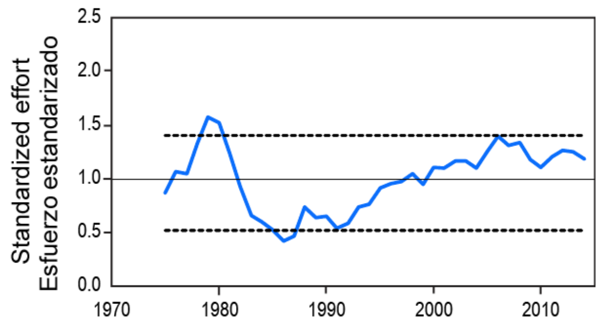

FIGURE 3. Standardized fishing effort indicator for skipjack (Maunder in press).

4. DISCUSSION

Between 2002 and 2010, the seasonal closures of the purse-seine fishery for tropical tunas in the EPO were shorter than indicated by the stock assessments and recommended by the IATTC staff; however, since then they have been consistent with both. The stock assessments, which cover the 1975-2014 period, estimate that for most of that period the fishing mortality of yellowfin and bigeye tuna has been below the level corresponding to MSY. The fishing mortality rate for yellowfin tuna was estimated to be above MSY during the mid-1990s, which indicates that in recent years the HCR has been implemented appropriately. However, these conclusions are uncertain due to uncertainty in the results of the stock assessment. This uncertainty explains why the current assessment estimates that fishing mortality has been below F_{MSY} historically, while the earlier assessment on which the management action was based indicated that stricter management was needed.

It is currently not possible to evaluate the appropriateness of the LRPs used by the IATTC. However, they appear to be based on reasonable assumptions and are directly related to the purpose of LRPs; therefore, although they are still arbitrary, they are somewhat less so than most LRPs used by other management organizations. Extensive meta-analysis shows no evidence for depensation, and when fishing pressure is reduced, stocks almost always increase in abundance (Hilborn *et al*. 2014), indicating that hard biomass-based LRPs can be set at low levels of abundance.

The appropriateness of the HCR with respect to the LRPs has not been thoroughly tested. A preliminary MSE for bigeye indicated that the HCR based on F_{MSY} is appropriate and will result in a low probability of exceeding the LRP. The MSE analysis added uncertainty in the operating model to the uncertainty in the stock assessment parameters by conducting multiple MSEs with different model assumptions. However, these assumptions were chosen arbitrarily, and a more quantitative method is needed to determine the assumptions and their weight in the analysis. A simplified stock assessment model was used as part of the management procedure to reduce computational demands, and future work may need to evaluate more complex assessment models.

The HCR used by the IATTC is simplistic, and the action to be taken when the LRP is exceeded has not been defined in detail. A more fully defined HCR might be required when comprehensive MSE is carried out. For example, several management organizations use two LRPs, a 'soft' limit to trigger precautionary management action and a 'hard' limit to trigger severe management action (*e.g.* closure of a fishery). The current IATTC HCR uses F_{MSY} as both a target and a soft limit, in the sense that, if it is exceeded, then management action is taken to reduce the fishing mortality to F_{MSY}. No detailed action has been defined for when the IATTC hard limit ($F_{0.5R}$) is exceeded. Biomass-based reference points are not used in the HCR. Alternative HCRs that include soft and hard LRPs, use biomass-based reference points, and have well-defined management actions for when reference points are exceeded, should be considered.

TABLE 1. Closures of the purse-seine (PS) fishery recommended by the IATTC staff and implemented by the IATTC, 2002-2015. YFT: yellowfin; BET: bigeye.

Year	Resolution	*F* multiplier		Closure (days)	
		YFT	BET	Recommended	Implemented
2002	C-02-04	1.12	1.85	31	31
2003	C-03-12	1.20	0.79	61, plus additional measures[1]	42
2004	C-04-09	1.12	0.62	61[2], plus additional measures[3]	42
2005	C-04-09	0.83	0.57	61, plus additional measures	42
2006	C-04-09	1.02	0.68	69, plus additional measures[4]	42
2007	C-06-02	0.88	0.77	74	42
2008	None	1.13	0.82	84	49
2009	C-09-01	1.09	0.81	84	59
2010	C-10-01	1.33	1.13	62	62
2011	C-11-01	1.13	0.93	62	62
2012	C-12-01	1.15	0.95	62-74[5]	62
2013	C-13-01	1.01	1.05	62	62
2014	C-13-01	1.21	1.04	62	62
2015	C-13-01	1.11	1.14	62	62

[1] Additional 61 days between 90°W and 150°W from 5°N to 10°S
[2] 2-month closure, which is 61 days for most combinations
[3] One of three options: (1) 6-month PS closure west of 95°W between 8°N and 10°S; (2) 6-month closure of PS fishery on floating objects west of 95°W; (3) Limit annual catch of bigeye by each PS vessel with an observer to 500 t
[4] Additional 95 days for PS fishery for bigeye on floating objects
[5] 74 days after adjusting for capacity