Reference Points for skipjack tuna on the IATTC management scheme

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Juan-Carlos Quiroz, Guillermo Morán

Tuna Conservation Group

Nobis Building, Office 707, Guayaquil. Ecuador.

jcquiroz@facilevisual.com

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Abstract

The C-16-02 resolution mandates the use of F_{MSY}, B_{MSY}, and an associated B_{LIM} and F_{LIM} as the primary reference points for fishery management of tropical tunas in the IATTC area. This paper aimed to define proxies reference points (RP) used to reach or approximate the maximum sustainable yield (MSY) for spikjack tuna, commenting on the technical standards and available methods for calculating these management quantities.

***K*eywords** Tropical tunas · Biomass reference points · Tier system · Harvest control rules.

1 Introduction

The focus of IATTC tropical tuna management has been on meeting biological and economic objectives based on maximum sustainable yield (MSY) reference points (RP). In the context of this scheme, harvest strategies developed by IATTC for principal tropical tunas — bigeye (*Thunnus obesus*), yellowfin (*Thunnus albacares*), and skipjack (*Katsuwonus pelamis*) — in 2014 required the adoption of management objectives and applicable limits and targets MSY-based RP, as generally understood, expressed in terms of spawning biomass (SB) and fishing mortality (F).

These objectives, together with a detailed rule (i.e. Harvest Control Rule) on how to define allowable exploitation (C-16-02), are already used to allocate global fishing efforts for the principal three tropical tunas. Management objectives include sustainability, safety, production, employment and stability, while RP aims to guide fisheries towards achieving these objectives. However, the used approach to estimating MSY-based RP differs across tropical tunas, each offering strengths and shortcomings.

In 2020, the IATTC scientific staff reported comprehensive outcomes from integrated stock assessment models for yellowfin and bigeye (SAC-11-07, SAC-11-06), leaving the skipjack stock without quantitative assessment. Nevertheless, inferences about stock status arose from a productivity and susceptibility analysis (PSA), indicating that the skipjack exploitation condition should be more optimistic than bigeye and providing a qualitative stock status for skipjack (SAC-11-15). This year, during the 13th Meeting of the Scientific Advisory Committee (SCA), an interim stock assessment framework was presented (SAC-13-07), enabling the estimate of spawning biomass ratios to define confident and reliable depletion levels.

As opposed to the robustness of stock assessment models for yellowfin and bigeye, the ability of the skipjack models to estimate MSY-based quantities relevant to the management is insufficient. Indeed, analyses made by IATTC scientific staff were unattainable to provide robust MSY estimates, mainly because of the fishing selectivity and the population growth that make the yield calculations implausible (SAC-13-07). As still skipjack shares some management links with the other tropical tunas (e.g, bigeye), the objective of this document was to propose technical standards for adopting MSY-based RP for skipjack in the Eastern Pacific Ocean (EPO) and considerations in amending the C-16-02 resolution.

2 Reference points used by IATTC

MSY is defined as the most significant long-term average yield captured from a stock under existing environmental conditions and a constant fishing mortality rate, and its shape depends on the kind of model, stock biology, and fishing selectivity. Recognising that MSY has become the cornerstone to defining a threshold upon which could determine the sustainable fishing effort (also any catch surplus), the harvest control rule adopted by IATTC (C-16-02) in 2014 defined the target MSY-based RP as:

(i) SB_{MSY}: the biomass of spawners that would result on average if F_{MSY} is constantly applied year after year, and

(ii) F_{MSY}: the fishing mortality rate that, if applied constantly, would result in SB_{MSY} and MSY on average over the long term.

Likewise, the limit RP (Note that limits RP are independent of MSY) were defined as:

(iii) SB_{limit}: the spawning biomass that produces 50% of the virgin recruitment with the stock-recruitment relationship ($h = 0.75$) follows the Beverton-Holt function, and

(iv) F_{limit}: the fishing mortality rate corresponding to SB_{limit}. Note that limit RP are not based on MSY quantities.

For the stock assessment carried out in 2020 for yellowfin and bigeye tunas (SAC-11-07, SAC-11-06), target (i and ii) and limit (ii and iv) RP were estimated considering changes in natural mortality (M), growth rate, and fishing selectivity (fixed steepness, h, on several levels). Similarly, the current interim stock assessment framework for skipjack (SAC-13-07) was able to estimate limit RP. However, target MSY-based RP have neither been estimated because of infeasible fishing mortality levels triggered by the trade-off between growth, natural mortality, and independent stock-size recruitment assumption ($h = 1$). Therefore, the IATTC scientific staff to cope with this difficulty used a conventional MSY-proxy RP for the target MSY of skipjack.

3 Tier system

The C-16-02 resolution mandates the use of F_{MSY} and the associated SB_{MSY} as primary RP for tropical tunas fisheries managed by IATTC. However, other reference points, such as MSY-based proxies, must also have a guaranteed place in this resolution to formalising alternative technical standards and methods for approaching the MSY. An example is the low exploitation rate estimated for skipjack from the interim stock assessment (SAC-13-07), where it is unclear, or at least debatable, how are calculated and which are the MSY-proxy quantities relevant to define stock status.

Given the outcomes from the tropical tunas stock assessment (SAC-11-07, SAC-11-06, SAC-13-07), it is reasonably developed a tier system to categorise tropical tuna stocks according to what type of assessment (e.g., absolute or relative quantitative model, data-poor models) could be performed and what kind of RP could be estimated (F_{MSY}, SB_{MSY} or MSY-proxies), set out several methods (e.g., base o interim case model) by which RP could be computed, and recommended methods of computing RP for each tropical tuna stocks in the IATTC area.

3.1 Proxy reference points

Following the "Antigua Convention" (2003) and the independence management scheme among bigeye and skipjack after the recent vessel-based measures (see C-21-4, C-20-06), it may be more convenient to set a tier system for stocks not based on the kind of data available (an approach used by several fishing agencies and RFMO), but based instead on the type of RP determination possible in each tropical tuna specie.

In most cases, MSY-proxies are based on quantities like $F_{x\%}$ and $SB_{x\%}$, where the $x\%$ is normally expressed in relation to spawning biomass per recruit (SPR), in the case of F, and concerning an unfished spawning biomass SB_0, static or dynamic, in the case of SB (SBR). This is the case for skipjack under the umbrella of the recent stock assessment (SAC-13-07), where proxies are extrapolated from SBR values for bigeye and yellowfin. In fact, given that the range of SPR ratio for bigeye is $SB_{MSY}/SB_0 = 0.20 - 0.24$, and the range for yellowfin is $SB_{MSY}/SB_0 = 0.23 - 0.32$, when the steepness of $h = 1$, the stock status of skipjack was defined using a conservative reference proxy $SB_{MSY}/SB_0 = SBR = 0.30$, under which it is assumed that skipjack is more vulnerable to fishing mortalities that bigeye and yellowfin, which is the opposite according the life history parameters.

Usually, a phase diagram (Figure 1) is used to represent the historical development of stock SB versus SB_{MSY} (or proxy); therefore, an absolute value for SB_{MSY} (or proxy) is needed. Most proxy methods provide a value of the SB_{MSY} proxy as a proportion of the unfished spawning biomass SB_0. Therefore some estimate of SB_0 is needed to obtain an absolute value of the SB_{MSY} proxy. This estimate can come from current or historical recruitment levels; however, in many cases, the resulting SB_0 estimate cannot be interpreted as unfished spawning biomass. The choice of recruitment level can be difficult because of the possibility of regime shifts and the difficulty in disentangling the effects of fishing and other processes on recruitment.

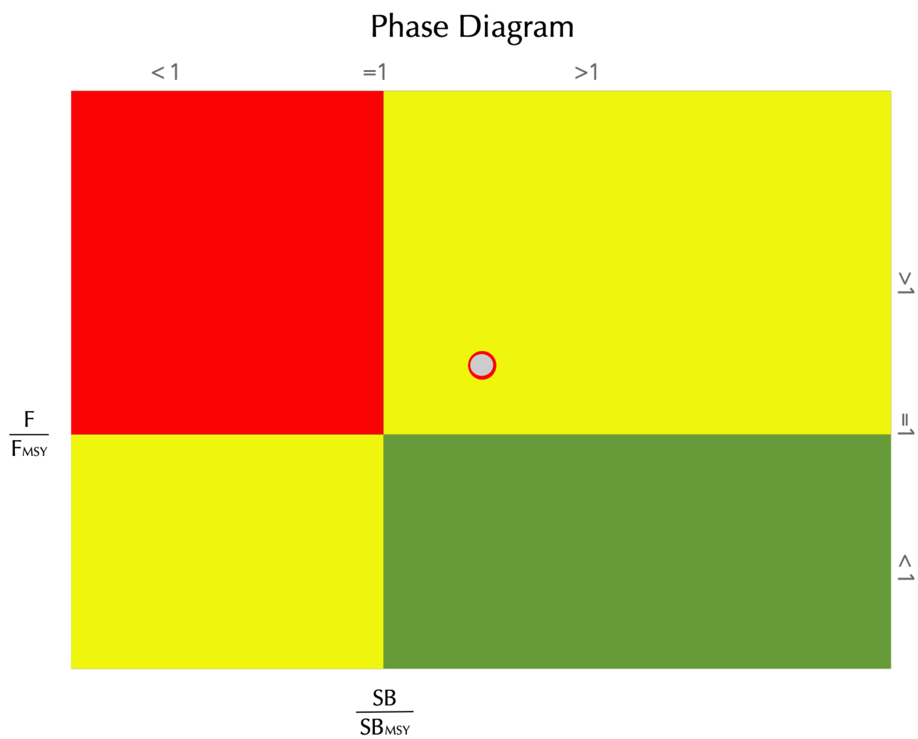

Figure 1: Phase diagram (Kobe plot) showing the exploitation areas (red, yellow, green). Point illustrate a case where SB > SB_{MSY} (fully exploitation), and F > F_{MSY} (overfishing).

3.2 Proposed stock tiers system

Because the level of $SBR = 0.3$ could be considered an interim proxy of SB_{MSY} for skipjack and also differed from absolute MSY-based RPs estimated for bigeye and yellowfin, the technical standards expected to strengthen the C-16-02 resolution also should differ from already adopted technical standards for bigeye and yellowfin. Therefore, Ecuador is interested in proposing a tier system for deriving MSY-based RP for tuna fisheries and tuna fish stocks in the IATTC convention area.

The tier system should assign stocks to tiers according to the amount, types and quality of information available as the basis of advice. Advice based on the higher levels (numbered in descending order with one the highest) is generally considered more reliable (e.g., more precise) than for lower tiers.

The proposed tier system for RP determination has three tiers tailored to data and assessment methods, defined as follows:

- **Tier 1** — Stocks for which there is an integrated age- or length-structured assessment model (e.g., Statistical Catch at Age type models) that provides usable estimates of present abundance. MSY-based RP (F_{MSY} and SB_{MSY}) and the RP SB_{limit} can be reliably estimated (or otherwise specified) from parameters estimated within the assessment model.

- **Tier 2** — Stocks for which there is an integrated age- or length-structured assessment model (e.g., Statistical Catch at Age type models) that provides usable estimates of present abundance. Proxies for the MSY-based RP are chosen. The selection of these proxies should take account of uncertainty in the assessment model and the degree of resilience (or lack thereof) of the species.

- **Tier 3** — Stocks for which insufficient data allows the application of a population dynamics model. Empirical approaches based primarily on catch data (with no relative abundance data), life-history traits, and/or survey data must be used.

3.3 Proxy reference points arguments

3.3.1 Tiers 1 and 2

While the goal of Tier 1 is to be more precise by using stock-specific information and modelling results, the estimates of RP are not necessarily more robust than proxies that are widely used based on analyses that demonstrate their robustness (Clark 1991). Therefore the decision to move from Tier 2 to Tier 1 should be made carefully. The choice between both Tiers is not in itself a basis for applying more or less precaution.

3.3.2 Tier 3

Empirical approaches could be based on historical series of catches. Estimates or proxies for MSY are derived from this series based on judgment (e.g., based on other sources of information such as limited size or age composition data or expert judgment) about the status of the fishery relative to MSY during segments of the time series. The Depletion Corrected Average Catch method (MacCall 2009) is an example of a possible approach. Research in this field is highly emphasised, and several new data-poor methods have been proposed. Depending on the method used, these methods may provide values for F_{MSY} and SB_{MSY}, but the reliability of these values is likely to be low.

4 Future remarks

In the scheme described by the C-16-02 resolution, the tropical tuna stocks within a specific range around SB_{MSY} should be designated as being fully exploited (provided $SB \geq SB_{MSY}$). Below that range, stocks considered overexploited down to SB_{limit} — limit biomass viewed as something to be avoided. The target fishing mortality is F_{MSY}, and exceeding F_{MSY} should be understood as overfishing. A Tier System, as proposed in this paper, needs to define the management quantities, which should undertake specific and targeted actions and determine explicit stock status.

The tier system described above was designed for consistency in the derivation of RP. Precision and reliability need to be addressed on a stock-by-stock basis, and categories have a wide range of accuracy and reliability. For example, within Tier 2, there are stocks with long time series of data that are informative about stock-recruitment dynamics (S-R, a critical consideration in derivation of RPs) and other stocks with only short time series with essentially no information about S-R dynamics. The amount of precaution in the harvest strategy for these stocks should be based on stock-by-stock considerations, rather than on the tier to which they have been assigned.

In this context, a process is needed to identify and propose methods for deriving MSY-based (and proxies) RP in each tier level. The literature shows several ways of deriving F_{MSY} and SB_{MSY} reference points, or proxies. This process is critical because the F and SB reference points selected should preferably be consistent with each other, in the sense that fishing indefinitely at F_{MSY} (or proxy F_{MSY}) should (theoretically, either in a deterministic or stochastic simulation sense) converge to SB_{MSY} (or proxy SB_{MSY}). However, since proxies are used in situations where the stock-recruit relationship is not known, it won't be easy to ensure the consistency criteria are always met. Also, approaches for calculating SB_0 are crucial because the SB_{MSY} proxy is obtained in relative terms, as a % of SB_0. In order to get a total estimate of the SB_{MSY} proxy, a value of SB_0 must be estimated or selected appropriately. The next step should identify different possibilities to carry out those calculations.

Finally, simulation frameworks are encouraged to explore stock rebuilding when fishing at F_{MSY} or any level of status-quo fishing mortality, F_{quo} (e.g. to examine the probability of SB falling below SB_{limit}). A Precautionary Approach can be implemented by carefully choosing the proxies (e.g. making a more conservative choice within a range of potential proxies when less reliable information is available) or in how the harvest control rules are applied in order to avoid exceeding reference points.

5 Discussion

Tier systems for categorising the information available on stocks and fisheries have become a standard tool (e.g., in parts of the USA, Australia, and Europe). They are used in processes that prepare scientific advice on fisheries management. This system assists in the sustainability of fisheries by helping to identify the balance between the amount of catch and the capacity of fish stocks to respond to harvesting.

The proposed tier system is designed to assign each tropical tuna stock to tiers according to the amount, types and quality of information available as the basis of advice. This kind of tier system can be designed to provide increasingly precautionary management advice for stocks in lower tiers where assessments are less reliable, but a degree of precaution for different tiers should be agreed upon in advance between scientists and managers. Note that the proposed tier system is other from the Data-Rich, Data-Moderate, Data-Poor system used by the US National Marine Fisheries Service (Restrepo and Powers 1999). The tier system described here places emphasis on the type of analyses that are feasible rather than the amount or quality of data.

This tier system has a relatively small number of tiers because, as a practical matter, there is slight variation in information types for tropical tuna fisheries (the kind of fisheries for which the tier system is intended). There is no point in spending time defining tiers that could be theoretically possible but do not occur for these fisheries. Also, having too many levels, each with rules about the derivation of RPs reduces flexibility. In general, the tier system is intended to guide the derivation of RP without inhibiting innovation. However, innovation (i.e., new approaches) should be tempered by critical review and analysis.

The interim assessment model (SAC-13-07) estimates that the spawning biomass of skipjack is currently above the target MSY-proxy of 30% of the unexploited spawning biomass under either the static or the dynamic spawning biomass ratio (SBR). Although several issues remain, such as a misleading initial value for SBR because the model is not fit an initial equilibrium catch, and the initial F is just used as a way to construct the initial age-structure and not estimate absolute F level, the current exploitation is lower than that corresponding to the biomass MSY-proxy RP. Given the importance of MSY-proxies RP, amending the C-16-02 resolution in terms of reference points and harvest control rule would be a natural next step. Harvest control rules are a pre-defined set of management actions to respond to changes in stock status concerning target and limit RP. Harvest control rules can form an essential part of effective management strategy in the IATTC context.

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