Defining stock status against conservation and management reference points: a global review for informing the process of status determination for key IOTC stocks

Discussion working document produced by the Ad-Hoc Reference Point Working Group

ABSTRACT

The Kobe Plot has been widely used as a practical, user-friendly method for presenting stock status information and to characterize the status of stocks as "overfished" ($B < B_{MSY}$) and "subject to overfishing" ($F > F_{MSY}$). When providing advice on stock status relative to MSY-based reference points, IOTC stocks are currently considered to be overfished and subject to overfishing when the target MSY-based reference points are breached (i.e., $SSB < SSB_{MSY}$ and $F > F_{MSY}$). However, there is no further change to stock status when the limit reference points are breached; which may not consistent with the intended application of target and limit reference points. For example, when managing stocks to MSY-based target reference points (the agreed/desired state of the stock) it is expected that the stock will fluctuate around that target, sometimes above and sometimes below, due to natural fluctuation in recruitment, stock abundance or other sources of variability.

The adoption of new target and limit reference points (IOTC Res. 15/10), requires a review of the approach used to determine stock status relative to these new reference points. As suchm, the IOTC Scientific Committee recommended to consider alternative formulations of the Kobe plot to indicate an appropriate buffer zone below B_{MSY} to account for natural variations in biomass. In 2019, the TCMP recommended that discussions on potential refinements to the Kobe plots and definitions of "overfished" and "overfishing" in relation to target and limit reference points to be conducted in collaboration with other t-RFMOs. This document discusses and provides possible alternative approaches for evaluating stock status (i.e. "overfished" and "overfishing") and communicating scientific management advice considering limit and target reference points.

KEYWORDS

Tuna, Stock Status, Overfished, Overfishing, Kobe plot, Majuro plot

1. Introduction

The first joint meeting of the tuna Regional Fisheries Management Organizations (tRFMOs), held in Kobe, Japan, in January 2007, recommended standardizing the presentation of stock assessment outcomes. At that meeting, tRFMOs agreed, for consistency, to use the Kobe plot, a "four quadrant" colored plot, to represent stock status against Maximum Sustainable Yield (MSY) related reference points. The Kobe Plot has been widely used as a practical, user-friendly method for presenting stock status information (tRFMO, 2009). In the Kobe plot, stock abundance (Biomass –B or Spawning Stock Biomass - SSB) is represented on the X-axis and fishing mortality on the Y-axis and it is usually divided into four quadrants in relation to the reference points at B_{MSY} and F_{MSY}.

The Kobe plot was developed prior to target and limit reference points being explicitly adopted by most of the tRFMOs, and at a time when some of the tuna stock assessments were deterministic, assuming perfect knowledge, and without quantification of associated sources of uncertainty. Therefore, it was reasonable to characterize stock status relative to B_{MSY} and F_{MSY} because "optimum yield" or MSY was the implicit or explicit management objective of tRFMO mandates (ISSF, 2018). As

such, the Kobe plot has been used to characterize the status of stocks as "overfished" ($B < B_{MSY}$) and "subject to overfishing" ($F > F_{MSY}$).

When providing advice on stock status relative to MSY-based reference points, IOTC stocks are currently considered to be overfished and subject to overfishing when the target MSY-based reference points are breached (i.e., $SSB < SSB_{MSY}$ and $F > F_{MSY}$). However, there is no further change to stock status when the limit reference points are breached. This approach is not consistent with the intended application of target and limit reference points. For example, when managing stocks to MSY-based target reference points (the agreed/desired state of the stock) it is expected that the stock will fluctuate around that target, sometimes above and sometimes below, due to natural fluctuation in recruitment, stock abundance or other sources of variability. A small decrease in SSB below the target reference point could result in the stock being assessed as overfished generating a false perception of its status.

Since the development of the Kobe plot, most of the tRFMOs have adopted or are in the process of adopting explicit target and limit reference points (ISSF, 2015) either under a Harvest Control Rule (HCR) framework or independently. The adoption of new target and limit reference points, as it was the case of IOTC (Res. 15/10), requires a review of the approach used to determine stock status relative to these new reference points. This need was recognized by the IOTC Scientific Committee which recommended a review of the approach used to provide management advice, particularly in relation to how the outcomes from stock assessments are reported against target and limit reference points.

Considering that several International Organizations consider a stock "overfished" when biomass falls below the limit reference point (e.g. below 50% of SSB_{MSY} or below 20% B_0), which characterize an undesirable situation and biological risk or point of recrutiment impairment (limit reference points) instead of a desired situation of the stock (target reference points), the IOTC Scientific Committee recommended to consider alternative formulations of the Kobe plot to indicate an appropriate buffer zone below B_{MSY} to account for natural variations in biomass and provided three examples of modified Kobe plot for presentation to the TCMP in 2019. The SC recognized that such an approach does not imply that no management action should take place until after a stock breaches the biomass limit reference point. For example, when management procedures are adopted, they will be used to manage fishing mortality to maintain the stock at the desired target reference points.

In 2019, the TCMP noted that redefining the term "overfished" using the limit rather than the target could create conflicts with the usage of the term in other international fora and that further discussion is required on this issue before any agreement is adopted by the IOTC Commission. Moreover, the TCMP recommended that discussions on potential refinements to the Kobe plots and definitions of "overfished" and "overfishing" in relation to target and limit reference points to be conducted in collaboration with other t-RFMOs, ideally through the KOBE process. The TCMP agreed that progress on this issue should continue intersessionally within a small working group presenting their deliberations to the Scientific Committee, which should provide its recommendation to the TCMP in 2020[1]. The TCMP also developed the Terms of References for this group (Annex 1).

The objective of this document is to discuss and provide possible alternative approaches for evaluating stock status (i.e. "overfished" and "overfishing") and communicating scientific management advice considering limit and target reference points . To inform this discussion, we provide a review of the approach used in other international organizations, including tRFMOs, to determine stock status and provide scientific management advice.

[1] TCMP was cancelled in 2020 and SC recommendations should be presented in 2021

2. The Precautionary Approach and Reference Points

The UN Fish Stocks Agreement (UN, 1995) and the FAO Code of Conduct for Responsible Fisheries (FAO, 1995) provide the foundations of the Precautionary Approach (PA) to fisheries management, which aims to apply a precautionary approach for the future sustainable management of fish resources to avoid unacceptable or undesirable situations (FAO, 1996). The PA seeks to protect fish stocks from fishing practices that may put their long-term viability in jeopardy despite uncertainties in stock biology, response to fishing, or exact state of exploitation, taking into account that changes in fisheries systems are not well understood and are only slowly reversible (Garcia, 1996). A key element of operationalizing the PA involves the notion that, all other things being equal, fishing pressure should decrease as the stock status uncertainty increases.

Annex II of the UN Fish Stocks Agreement provides guidelines for the application of reference points and the precautionary approach. It requests the use of two types of precautionary reference points: conservation or limit reference points and management or target reference points. And it states that management strategies shall ensure that there is very low risk of breaching limit reference points while target reference points should not be exceeded on average. Moreover, UNFSA considers that the fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points while its objective is to maintain fish stocks at the biomass that can produce the MSY.

In practical terms, the precautionary approach calls for fishery management to determine the status of the stock(s) relative to limit and, target (and in some cases including threshold) reference points (RPs), to predict outcomes of management alternatives for reaching the targets while avoiding with high probability the limits, and to characterise the uncertainty in both of the cases (de Bruyn et al., 2013). Limit Reference Points (LRP) indicate a “biological” limit beyond which the state of a fishery and/or a resource is undesirable, the stock is considered to be beyond safe biological limits, and should be avoided with high probability according to a given set of management objectives (ISSF, 2013). In term of biomass, this indicates a level below which stock productivity (recruitment) is likely to be seriously impaired. In contrast, a Target Reference Point (TRP) defines the desired level of harvest and biomass that would achieve fishery objectives and allow optimal harvest on average. The PA also recommends that LRPs and TRPs might be used in combination with precautionary or threshold RPs to trigger actions as soon as targets are breached to avoid reaching the LRPs (ICES, 2019). This threshold is a level of biomass or fishing mortality rate between the LRP and TRP that can serve as a “red flag”to trigger specific management actions designed to reduce fishing mortality to below the target fishing reference point (Figure 1). These reference points, ideally, should be included in a Management Procedure framework (along with Harvest Control Rules) when stock status (or any other indicator such as CPUE) triggers pre-agreed management actions to maintain the stock at the target levels while avoiding with high probability the limits reference points. As such, the need of threshold reference points might not be needed when robust Management Procedures are adopted. The development and selection of Management Procedures (MPs) should involve the evaluation of expected MP performance with respect to agreed target and limit reference points (and other management objectives). Thus reference points are essential for evaluating MPs, but should not constrain how MPs are constructed.

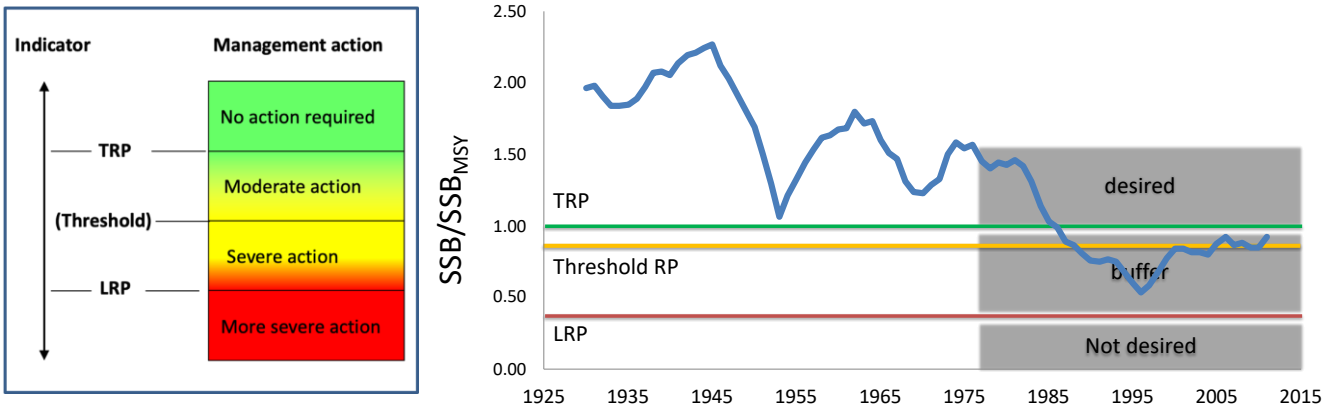


Figure 1.- A generalization illustration of target, threshold and limit reference points embraced in the Precautionary Approach to guide fishery management. Management actions should be adopted, ideally through a Management Procedure, to achieve target reference points while avoiding limit reference points.

3. Consideration of different types of reference points in tuna RFMOs

It is important to recognize that the concept of MSY and MSY-based reference points represent theoretical concepts that are easy to understand and communicate, but there are technical complications and simplifying assumptions that are often ignored (IATTC, 2011).

MSY-based reference points are difficult to estimate accurately, because they depend on biological attributes that are difficult to estimate. Notably, the degree of density-dependent compensation in the stock recruit relationship (steepness), is difficult to estimate reliably, particularly if there is not informative contrast in the spawner-recruit time series (that can only be achieved by severely depleting the population). The stock recruit relationship uncertainty has a direct impact on uncertainty in MSY-based reference points. In contrast, depletion-based estimates are largely independent of the stock-recruit relationship and historical exploitation history as they are closely linked to relative abundance estimates. Moreover, there is also a mathematical quirk that can arise in relation to MSY calculations for some particular stocks when only mature individuals are selected to the fishery (i.e. skipjack in the Indian Ocean), in which MSY is only approached asymptotically as F approaches infinity because of an invulnerable component of the spawning population.

MSY-based reference points also depend on stationary biological and fishery characteristics. When fishery selectivity changes noticeably (e.g. the introduction and expansion of the purse seine fleet), it will affect the MSY-based reference points because a different combination of fishing gears will result in a different MSY. Thus, how MSY reference points are reported (MSY based on historical, dynamic, or future fishery selectivity) should be decided while a depletion-based reference point remains the same regardless of fishery selectivity.

Non-stationary biological attributes of the system are potentially more problematic. For some tuna stocks there is a suggestion that the stock-recruitment relationship might have fundamentally changed, or could experience periodic regime shifts that may remain in place for decades. And climate change may introduce long-term trends in population productivity. Thus, these conditions will affect the calculation and interpretation of MSY-based reference points. The concept of non-stationary carrying capacity can be described with “dynamic B_0“ - the biomass that would have been observed in the absence of fishing. Depletion relative to dynamic B_0 provides a reference point that partitions biomass changes due to natural processes and fishing mortality.

4. Review of how stock status is characterized in relation to reference points

4.1. Non-tuna International and National bodies

Food and Agriculture Organization (FAO)

FAO publishes every two years the State of World Fisheries and Aquaculture (SOFIA) report which presented a global view of capture fisheries and aquaculture, status of fish stock including associated policy issues. FAO assessments considers a stock is overfished when its biomass is below 80% of MSY (40% of B0 based on Schaefer surplus production model) (FAO, 2011).

Australia's Harvest Strategy Policy

Australia's Commonwealth Harvest Strategy Policy (HSP; DAWR, 2018a) and associated implementation guidelines (DAWR, 2018b) provide a framework and guidance for the development and implementation of harvest strategies. The HSP defines biological and economic objectives and identifies reference points to be used in harvest strategies to achieve these objectives. The HSP defines a harvest strategy as a decision framework consisting of processes for monitoring and assessing the biological and economic conditions of the stock against reference points, and pre-agreed rules (e.g HCR) for controlling fishing activity. Ideally, these HCRs should be simulation-tested to ensure that they are appropriate for the individual fisheries, but, particularly for small stocks, this is not always practical.

The HSP defines TRPs as the desired status of stocks and LRPs as situations to be avoided because they represent a point beyond which the risk to the stock is regarded as unacceptably high. The default TRP for key commercial stocks is the biomass at Maximum Economic Yield (B_{MEY}). If B_{MEY} cannot be estimated, the HSP defines a proxy of 48% B_0, or 120% B_{MSY} (noting that where B_{MSY} is poorly estimated, a proxy of 40% B_0 is used). The policy prescribes a minimum value for the LRP of 20% B_0, and requires that harvest strategies maintain the biomass above this LRP at least 90% of the time. Although the HSP specifies biomass-based reference points, the requirements of the HSP can be met through the use of reference points based on fishing mortality that give the same or similar outcomes in terms of the policy's objectives.

Under the Australian Policy, a stock is considered "overfished" when its biomass falls below the LRP. A stock is considered to be "subject to overfishing" when fishing mortality is at a level likely to result in the stock becoming overfished. For a stock that is already overfished, overfishing is defined as the fishing mortality that will prevent the stock recovering in accordance with its rebuilding strategy.

United State Magnuson–Stevens Fishery Conservation and Management Act (MSFCMA)

In the United States, a science-based system is used to manage stocks. Scientific and Statistical Committees (SSCs) initiate the process by calculating a risk neutral Overfishing Limit (OFL) which in essence corresponds to the catch at F_{MSY}. Then, with a requirement to take uncertainty into account, the SSCs calculate an Allowable Biological Catch (ABC) which is lower than the OFL. In some cases this buffer between ABC and OFL is calculated statistically and in other cases it is by simpler ad hoc methods such as ABC=0.75OFL. Then, Fishery Management Councils set Annual Catch Limits (ACLs) which must be less than or equal to the ABC. Finally, the Councils set an Annual Catch Target (ACT) that may be lower than the ACL, taking management uncertainty into account. Thus, the system is inherently precautionary, part of which is in the hands of a scientific process (Methot et al 2014).

In terms of status determinations, overfishing generally occurs when $F>F_{MSY}$, or some proxy. The overfished limit is calculated for each stock taking into account uncertainties, but it cannot be lower than 0.5 B_{MSY}. In some cases, ad hoc methods such as $B_{limit}=(1-M)* B_{MSY}$ are used (Restrepo et al. 1998).

It should be noted that stocks that are subject to international agreements such as the tuna RFMOs are not required to have ACLs.

4.2. tunaRFMOs

Most tuna RFMOs have used the Kobe plot to represent stock status relative to MSY (previously considered as a management target) and characterize stock status (ISSF, 2015) as agreed in the Kobe meeting (Kobe, 2007). Since then, most tRFMOs have adopted TRPs and LRPs (Table 1), however, there is yet no standard way of representing stock status relative to both target and limit reference points levels (ISSF, 2015).

Table 1.- Summary of current management framework in tuna RFMOs (modified from ISSF, 2013)

Element	IATTC	ICCAT	IOTC	WCPFC	CCSBT
Management objectives (convention)	Population level that can produce the MSY. Apply the Precautionary Approach.	Maintain population at level that can permit maximum sustainable catch.	Conservation and optimum utilization of stocks.	Long-term conservation and sustainable use of HMS. Maintain stocks at levels capable of producing MSY, as qualified by environmental, economic and SIDs considerations.	Ensure, through appropriate management, the conservation and optimum utilization of SBT.
Target Reference Points	Interim target reference points for BET, SKJ and YFT = F_{MSY} and B_{MSY} are an implied TRP.	F_{MSY} and B_{MSY} are an implied TRP. For Northern Albacore 60% probability to be in Kobe green quadrant	Interim target reference points for ALB, BET, YFT and SWO (B_{MSY}, F_{MSY}), and SKJ (40% B_0, E_{TARG})	Interim target reference points for: SKJ: 50% SBcurrent, F=0 Southern ALB[2]: 56% SBcurrent, F=0	Rebuilding objective: 30% SSB0 by 2035 (50% probability).
Limit reference Points	Interim Limit Reference Points for BET and YFT = 7.7 % of SSB_0	None yet. For Northern Albacore Blim = $0.4*B_{MSY}$ and Flim =	Interim limit reference points for ALB, SWO and YFT (0.4 B_{MSY}, 1.4 F_{MSY}), BET (0.5 B_{MSY}, 1.3 F_{MSY}), and SKJ (0.4 B_{MSY}, 1.5 F_{MSY})	ALB, BET, SKJ and YFT: 20%SBcurrent, F=0 (defines overfished) F_{MSY} (defines overfishing)	

[2] The actual target is an 8 percent increase in catch per unit of effort (CPUE) for the southern longline fishery as compared to 2013 levels. This currently equates to 56 percent of spawning stock biomass in the absence of fishing but this depeltion level is updated every 3 years following each SP albacore assessment.

UNFSA provides guidance for the application of PA in fishery management and states that the “fishing mortality rate (F) which generates Maximum Sustainable Yield (MSY) should be regarded as a minimum standard for Limit Reference Points (LRPs)” and “that management strategies should ensure that the risk of exceeding LRPs is very low”. Moreover, a general target in UNFSA relates to “maintain or restore stocks at levels capable of producing maximum sustainable yield” which is recognized as a management or target reference point. The latter has been translated by many of the tuna RFMOs to MSY, or a stock size that can produce MSY, as their management objective (Table 1).

In a long term sense, B_{MSY} is the average biomass that results from fishing constantly at F_{MSY}. But, given that there is considerable variability in the stock-recruitment relationship, in practice stock biomass will fluctuate above and below the equilibrium B_{MSY} level when fished at a F target (at or close to F_{MSY}). Therefore, an equilibrium B_{MSY} target will be exceeded in some years due to natural variability and it seems problematic to consider B_{MSY} as a desired management target while it is also used as the level to characterize “overfished” stock status. This apparent contradiction between UNFSA guidelines, as well as the tuna RFMO Conventions, has caused considerable confusion when providing the management advice and characterizing stock status.

In situations where there is little or no quantitative analysis of uncertainty, and particularly where F_{MSY} is determined assuming perfect knowledge, the estimate of F_{MSY} should be used as a fishing mortality limit reference point as suggested in the UNFSA Annex II Guidelines. Consequently, the target F should be less than F_{MSY} so as to provide the precautionary buffer which is expected to be cautious because F_{MSY} is not usually associated with bringing the biomass below biologically safe limits, though a wide range of biomass outcomes for some stocks can be experienced at F_{MSY} because of variability in productivity (e.g. recruitment) (ISSF, 2013).

Where uncertainty has been robustly considered under a MP-HCR framework tested through MSE that has both a low probability of breaching safe biological limits (LRP) and achieving a biomass TRP while providing the higher average long-term catch, then the F resulting from the HCR could be treated as a target. Similarly the limit reference point can be defined from such considerations so as to recognise and maintain the stock within biologically safe limits (i.e. the limit RP can also be defined so as to have a low chance of breaching the actual biological limit despite uncertainties in assessing current status). Thus, it would be better to establish Biomass limit reference points at a lower level than B_{MSY} by an amount that depends primarily on recruitment variability and estimation error (Restrepo 2008).

There is no standardized way to characterize stock status (i.e. “overfished” and “overfishing”) among tRFMOs. The terms "overfished" (or "overexploited") refers to the biomass of the population and indicates that the abundance is too low in comparison to biologically safe thresholds. The term "overfishing" relates to fishing mortality levels and indicates that the F is too high relative to some benchmarks, explicit or implicit. Current practice in the tuna RFMOs is summarized in Table 2. In line with UNFSA guidelines, overfishing is generally considered when fishing mortality is above F_{MSY}. However, there is no consensus on how to characterize an “overfished" stock as IATTC/ICCAT/IOTC use this term when the spawning biomass is below SSB_{MSY} (or in the case of SKJ below $0.4*SSB_0$) while WCPFC (and ISC) considers a stock to be overfished when it is below the LRP. CCSBT does not have formal definitions for “overfished” or “overfishing”.

Table 2.- Current practice for stock status determination by the tuna RFMOs. Note: The LRP for tuna stocks managed by WCPFC is 20% of the unfished SSB" (modified from ISSF, 2018).

TunaRFMO	OVERFISHED	OVERFISHING
IATTC	$SSB<SSB_{MSY}$	$F>F_{MSY}$
ICCAT	$SSB<SSB_{MSY}$	$F>F_{MSY}$
IOTC	$SSB<SSB_{MSY}$	$F>F_{MSY}$
WCPFC	$SSB<SSB_{LRP}$	$F>F_{MSY}$
CCSBT	None	None

Based on those differences on how to define overfished stock status, different plots have been developed to characterize the stock status and provide management advice. The Kobe Plot (Figure 1 left), a four-quadrant plot, is used to represent status relative to the MSY-based reference points which are considered the implicit targets for IATTC, ICCAT and IOTC. In the Kobe plot, the stock status is represented in two dimensions: Fishing mortality and biomass (or SSB), both relative to their MSY target values. This allows reporting of stock status in four categories: 1) Green: Not-overfished ($B> B_{MSY}$) and not undergoing overfishing ($F< F_{MSY}$), 2) Orange: Not-overfished ($B> B_{MSY}$) but undergoing overfishing ($F> F_{MSY}$), 3) Yellow (lower-left): Overfished ($B< B_{MSY}$) but not undergoing overfishing ($F< F_{MSY}$) and, 4) Red: Overfished ($B< B_{MSY}$) and undergoing overfishing ($F> F_{MSY}$). The Kobe plot was formulated on the basis that tuna RFMO Conventions desired objective for fishery management is to maintain stocks at abundance levels that produce MSY. In many cases, these characterizations are presented in a manner that permits expressing the quantified uncertainties in the status evaluations, which acknowledge the degree of certainty in status outcome that can be estimated by the methods used in each assessment, providing estimates of probability of stock status within each of the areas shown.

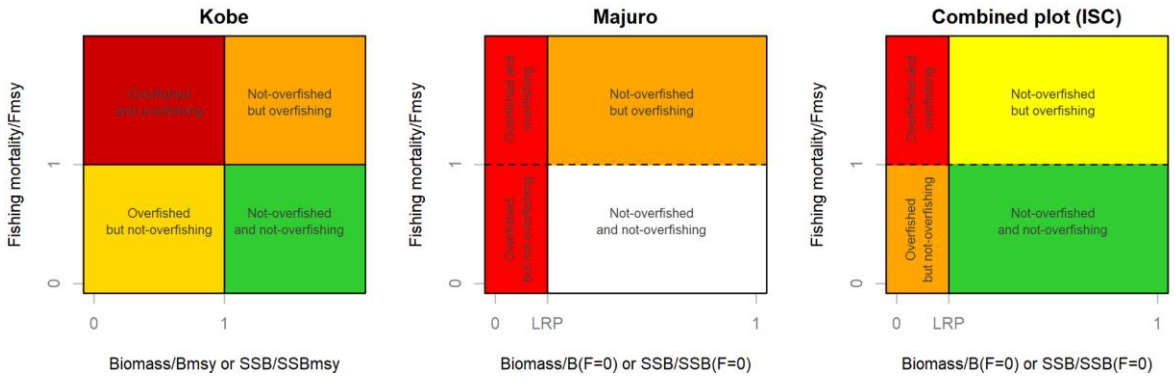


Figure 2.- User-friendly plot to characterize stock status and provide management advice: (left) Kobe plot, (center) Majuro plot, and (right) ISC plot (from Merino et al., 2020).

More recently, WCPFC proposed an alternative to the Kobe plot called the Majuro plot (Figure 2, center) where stock status is characterized in two dimensions but in terms of spawning potential's depletion (relative to virgin or unfished biomass $B_{F=0}$ or spawning stock biomss $SSB_{F=0}$) and fishing mortality (relative to F_{MSY}). In this case, three quadrants are identified: (1) White: not overfished ($B>B_{LRP}$ - Biomass Limit Reference Point) and not undergoing overfishing ($F<F_{MSY}$), 2) Orange (or upper-right) area: Not-overfished ($B>B_{MSY}$) but undergoing overfishing ($F>F_{MSY}$), and, 3) Red: Overfished (B<BLRP) and either undergoing overfishing ($F> F_{MSY}$) or not undergoing overfishing ($F<F_{MSY}$). The red zone represents an "overfished" state of the stock when spawning potential level is lower than the agreed LRP, a point at which the stock is considered outside biological safe limits as impaired recruitment becomes increasingly likely. In the Majuro plot, there is no change in stock status when the Target Reference Point is breached (e.g. 50% of B0 for skipjack – Figure 3). Although WCPFC SC

uses Majuro plots based on depletion levels to characterize stock status, both Majuro and Kobe plots are presented to inform managers.

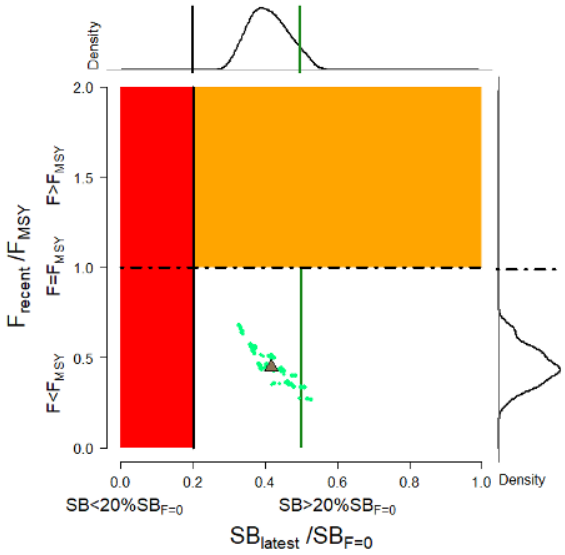


Figure 3.- Majuro plot from last stock assessment of skipjack. Majuro plot for the latest spawning potential (2018) summarizing the results for each of the models in the structural uncertainty grid with weighting. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality, and marginal distributions of each are presented. Vertical green line denotes the interim TRP for skipjack. Brown triangle indicates the median of the estimates (source: WCPFC 2019).

In addition, the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC), which is responsible of providing the scientific advice for north Pacific stocks to the WCPFC and IATTC, uses an adapted representation that combines the four-quadrant color scale of the Kobe plot with the stock status definition of the Majuro framework (Figure 1, right). The difference of this combined plot from Majuro is that overfished (SSB<SSBLRP) category is separated between fishing mortality below F_{MSY} (orange) and fishing mortality above F_{MSY} (red). Moreover, in this case, all the area above the LRP and below F_{MSY} is colored in green.

The main difference between the two approaches of communicating stock status is related to the characterization of an overfished stock (Table 1). In the WCPFC, the idea behind establishing the Majuro diagram is to define "overfished" status related to breaching the Limit Reference Points, which is considered a highly undesirable state that is irreversible or slowly reversible such as impaired recruitment, and to constrain harvesting within safe biological limits rather than relating overfished to a target which is a desired management situation. As fishery management shall ensure that the risk of exceeding limit reference points is very low, and to reach target reference points on average (UNFSA, 1995), when a stock is being overfished ($F>F_{MSY}$) WCPFC takes appropriate action to ensure that the stock does not breach the biological LRP and, that ideally stock fluctuates around the TRP (Davies and Basson, 2009). F_{MSY} is here regarded as a limit. In other words, the fishing mortality should be lower than F_{MSY} and therefore, there will be a very low probability of the stock breaching the LRP.

Indian Ocean skipjack, a paradigmatic example

There are important implications for the alternative definitions of overfished for fish stocks (Figure 2). For example, the 2017 Indian Ocean skipjack stock assessment estimated that, on average, the stock was exactly at the biomass target reference point ($40\%SSB_0$), which was estimated to be 1.61 (between 1.25-2.35) of SSB_{MSY}. However, the IOTC estimated that there was a 49% probability of being

overfished, which cannot be considered a low probability. This was because the overfished status is defined as being above or below the adopted biomass TRP, which is not consistent with the intended application of target (desired state of the stock) reference points as the stock will fluctuate around that target, sometimes above and sometimes below, due to natural fluctuation in recruitment, stock abundance or other sources of variability. In the skipjack case, the stock was estimated to be fluctuating around a precautionary TRP (which was established at a point around 60% larger than the biomass corresponding to the MSY estimated in 2017) with a null probability of being below the adopted LRP, a benchmark that should not be breached with any substantial probability. In this regard, it is incompatible to maintain the stock fluctuating around the biological TRP with high probability while achieving a very low probability of not being estimated as overfished as required by Resolution 15/10).

5. Alternative options for discussion

The Kobe Plot was widely embraced as a practical, user-friendly method for presenting stock status information (tRFMO, 2009). It should be noted that, at that time, none of the tRFMOs had adopted explicit target and limit reference points, and it was reasonable to characterize stock status relative to B_{MSY} and F_{MSY} as a default because MSY or "optimum yield" was the objective of the RFMO Conventions. Today, however, most of the tRFMOs have adopted or are in the processes of adopting explicit target and limit reference points (Table 1). Because of this, it is necessary to review and adapt the approach used to determine stock status and the provision of management advice to current circumstances. If B_{MSY} is the target (the desired outcome of the management) it could not be used to characterize the overfished stock status and, when limit reference points have been adopted for a stock, they could be used, apart from conveying where SSB and F are in relation to the target(s) and limit(s), to characterize “overfished” status; which should be avoided with high probability. Management actions, ideally as part of a MP/HCR, should be established to maintain the stock fluctuating at/around the targets while ensuring avoiding to breac the limits.

- **<u>“Overfished” stock status</u>**

When Target Reference Points and Limit Reference Points are not available, the “overfished” stock status should continue to be characterized based on biomass at MSY, that is, when SSB or B is below SSB_{MSY}/B_{MSY} as currently being used in IOTC management framework. When MSY-based references points cannot be estimated with an acceptable level of precisions, depletion-based references points would be more approapiate.

When precautionary Target Reference Points (as in the case of skipjack) and Limit Reference Points are available, the “overfished” stock status should be characterized based on Limit Reference Points, that is, when SSB or B is below SSB_{LRP}/B_{LRP}. As part of this exercise, current target reference points and limit reference points should be reviewed considering most recent available information as required by the ToR of the ad-hoc reference points group.

Using LRPs to determine “overfished” stock status should not be interpreted as meaning that no management action is needed until breaching LRP. In both cases, when SSB or B departs from target Biomas or SSB_{MSY}/B_{MSY} and the risk of breaching the limits increases, management actions should be adopted to maintain the biomass of the stock fluctuating to the desired target level. Ideally, this should be done through an adopted robust Management Procedure, that will maintain the stock at around the target reference points while avoiding with high probability the limit reference points.

- **<u>"Overfishing" occurring</u>**

Irrespective if TRP/LRP are available or not, overfishing is characterized when $F > F_{MSY}$.

When $F > F_{MSY}$, management strategies should enable F to remain close to F_{MSY} and not persist above F_{MSY}, to ensure that biomass remains above the LRP with high probability

- **<u>Majuro/Kobe plots re "Overfished/Overfishing"</u>**

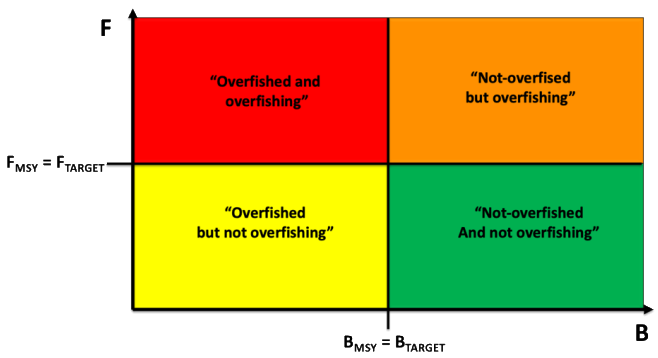
Determining stock status in discrete binary categories is an over-simplification and is not straightforward as some consideration should be given to how they are constructed (e.g. reference points). For example, in a Kobe Plot, if "overfished" is characterized based on TRPs, a minuscule decrease in SSB can move the status from "not-overfished" to "overfished" and may create a false perception of its status. However, due to natural variations the stock (and imperfect stock assessment and management implementation), it is expected to fluctuate around the target. Following the discussion above on reference points and how to characterize stock status, a possible alternative for the graphical representation of stock status is provided as follows:

- If Majuro/Kobe plots are used to define Overfished status, the biomass cross line should represent limit reference points (ISSF, 2013),
- If Majuro/Kobe plots are used to define Overfishing the fishing mortality cross line should represent by F_{MSY} (ISSF, 2013),
- As such, both in the Kobe or Majuro Plot, the "Red" zone should be defined with respect to the LRP rather than target.
- A probabilistic interpretation should be adopted to identify whether the limit is breached, i.e. probabilities to be above/under the LRP should be given,
- It is also recommended that Majuro/Kobe plots are shown for both type of reference points: (i) based on depletion levels (as per WCPFC Majuro original plots) and (ii) based on MSY-based reference points (as per Kobe original plots).

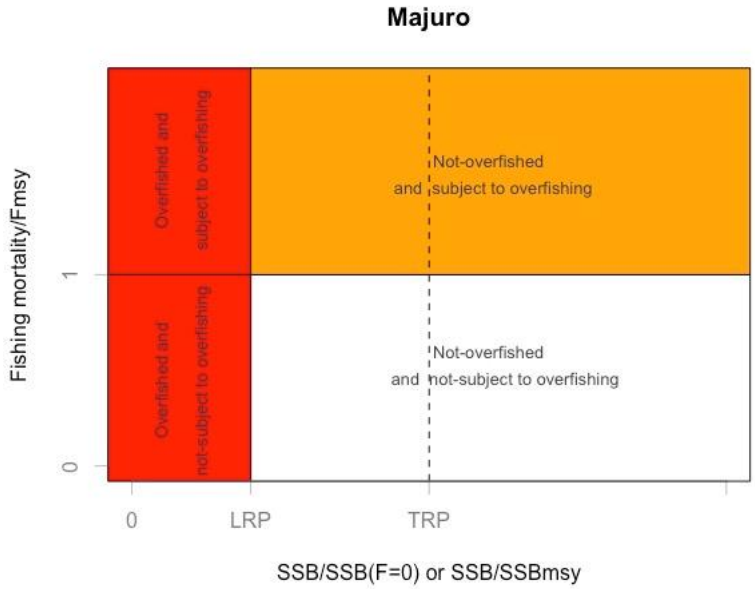
Any of these figures below provide information on the management actions needed to achieve the operational management objectives of the RFMOs over various time frames; which can be obtained from Kobe II strategy matrices or Management Procedures (including Harvest Control Rules).

We do not recommend a particular plot but any plot from below could be used to embrace the recommendations above:

<u>When TRP and LRPs are not established and available, MSY-based references points as currently used in IOTC Kobe plot:</u>



When precautionary TRPs and LRPs are available, modified IOTC Kobe plot (similar to Majuro plot) irrespective of TRP/LRPs being calculated using MSY or depletion levels:



The IOTC Commission should be aware that any change, as discussed above, relating to the definition and presentation of stock status against conservation and management reference points, will require a revision of Resolution 15/10 on target and limit reference points and a management decision framework, including the evaluation of the appropriateness of the reference points, as well as of Recommendation 14/07.

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Annex 1

TERMS OF REFERENCE FOR THE AD HOC REFERENCE POINT WORKING GROUP

An informal working group is established to consider and provide information to the TCMP on issues relating to the definition and presentation of stock status against conservation and management reference points, including but not limited to the following:

- the review of current (interim) reference points
- provide advice on possible revisions to Resolution 15/10 if required
- reporting stock status in relation to limit and target reference points
- suggestions on how to present stock status.

The working group, constituted preferentially by managers, scientists and relevant experts, will be convened by the Scientific Committee Chair and will conduct its work electronically. CPCs and accredited observers will provide focal contacts to the Chair

The matters to be considered by the Working Group will be presented in a draft working paper to be discussed at the relevant species working parties, WPM and SC, who will provide advice to the Working Group. This advice and any further considerations from the Working Group will be reflected in a working paper tabled for discussion at TCMP. Outcomes from TCMP discussions will be reported to the Commission.