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INTERIM LIMIT AND TARGET REFERENCE POINTS FOR TUNA, BILLFISH AND OTHER HIGHLY PRODUCTIVE FISHES IN THE EASTERN PACIFIC OCEAN

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SUMMARY

Although MSY-based reference points are established for the tropical tuna stocks in the eastern Pacific Ocean (EPO) under Resolution C-16-02, they are currently only defined for yellowfin and bigeye tuna, and a proposal has been recently made for skipjack tuna. Reference points are considered a standard component of contemporary fisheries management and are an integral component of most, if not all, ecolabeling and consumer-based certification programs. In addition, according to the FAO Code of Conduct for Responsible Fishing, Regional Fisheries Management Organizations (RFMOs) should adopt, on the basis of the best scientific information available, stock-specific target and limit reference points, and corresponding management actions. Therefore, reference points are needed for all species associated with the EPO tuna fisheries. Unfortunately, the relevant information may not be available to reliably estimate reference points for all species and the formal adoption of reference points can be time consuming. Therefore, the IATTC staff proposes *interim* limit and target reference points that can be used for tuna, billfish and other highly productive fishes in the EPO. These reference points are based on the *interim* reference points currently used for bigeye and yellowfin and the assumption of a conservative value for the steepness (h = 0.75) of the Beverton-Holt stock-recruitment relationship.

Limit Reference Point: defined as the spawning biomass that produces 50% of the virgin recruitment (R_0) when the spawner-recruitment relationship follows the Beverton-Holt function with an assumed steepness (h) of 0.75. The spawning biomass at the limit reference point is equal to 0.077 of the equilibrium unfished spawning biomass (S_0 or B_0). The fishing mortality (F) limit reference point is the value of F that, under equilibrium conditions, maintains the spawning biomass at the biomass limit reference point.

Target Reference Point: defined as 0.3 of the dynamic unfished spawning biomass (S_0 or B_0) or the spawning biomass that maximizes yield under current relative age specific fishing mortality when the spawner-recruitment relationship follows the Beverton-Holt function with an assumed steepness (h) of 0.75, whichever is largest. The fishing mortality (F) target reference point is the value of F that, under equilibrium conditions, maintains the spawning biomass at the biomass target reference point.

These *interim* limit and target reference points would be adopted for species for which there are no reference points, interim or otherwise, until sufficient information is available (i.e., there is sufficient knowledge about the stock-recruitment relationship or the tradeoffs related to the age-specific selectivities to the fisheries) for a stock to produce species-specific reference points.

1. INTRODUCTION

Reference points are considered a standard component of contemporary fisheries management and are an integral component of most, if not all, ecolabeling and consumer-based fishery certification programs. MSY (Maximum Sustainable Yield) based target and recruitment-based limit reference points were adopted for the tropical tuna in the EPO at the 87th Meeting of the IATTC in 2014. When adopted, the Commission noted these reference points as *interim* and *"considered that work on this item should continue to test their robustness".* Although these reference points have become well established for yellowfin and bigeye in the EPO, recent work has shown challenges in defining the same MSY-based reference points for skipjack, and the staff proposed *proxy* reference points based on the *interim* reference points for yellowfin and bigeye (SAC-13-07). Reference points are also needed for effective conservation and management of other species associated with the EPO tuna fisheries. Unfortunately, it is not uncommon that the relevant information needed to estimate and adopt reference points (e.g., knowledge about the stock-recruitment relationship) is not available for many of these species. Finally, adopting reference points through individual resolutions for each species could be a very time-consuming process. Under these circumstances, it may be convenient to establish an *interim* definition of reference points at IATTC, appliable to a wider range of highly productive fishes.

Although it could be interpreted that, by default, the Antigua Convention establishes MSY-based target reference points for the tuna fisheries in the EPO, this interpretation is not straightforward to implement. MSY is defined as the maximum yield that can be sustained from the stock on a long-term basis and is typically calculated using equilibrium conditions. MSY is a function of the stock's biology (growth, natural mortality, and the stock-recruitment relationship) and size/age of the fish caught (selectivity). One complicating factor is that because MSY is dependent on the size/age of the fish caught, MSY can change depending on the allocation of effort among the different fisheries (e.g., between the longline and purse-seine tuna fisheries in the EPO). Some studies (e.g., Maunder, 2002) have calculated the highest MSY that can be obtained (i.e., by optimizing the age at entry into the fishery and assuming a knife edged selectivity), but due to practical issues of implementing such a harvest strategy, many MSY calculations are based on the current allocation of effort among the different fisheries acting on the stock (Maunder, 2002). Furthermore, MSY is highly dependent on the stock-recruitment relationship, which is essentially unknown for tuna stocks. MSY can be viewed as the product of yield-per-recruit (YPR) and the stock-recruitment relationship. If recruitment is assumed to be independent of spawning stock biomass, MSY calculations are identical to YPR calculations. Yield-per-recruit analyses sometimes determine that maximum yield occurs at very high or infinite exploitation rates due to the combination of natural mortality and growth used in the assessment and the estimated selectivities (e.g., skipjack tuna in the EPO, SAC-13-07). These results, in combination with the assumption that recruitment is independent from spawning stock biomass (steepness = 1), make defining MSY based reference points problematic for some stocks. For this reason, conservative reference points are often proposed on a stock by stock basis as it was the case of skipjack (e.g., SAC-13-07).

This paper proposes limit and target reference points for tuna, billfish, and other highly productive fishes in the EPO. There are two key precautionary concepts behind the proposed reference points: 1) precautionary reference points are defined by explicitly making a conservative assumption about the steepness of the Beverton-Holt stock-recruitment relationship (h = 0.75); and 2) until more detailed analyses are conducted, low target biomass reference points, possibly due to the current selectivity patterns, should be avoided. In the absence of adopted reference points for any particular highly productive fish stock, these *interim* reference points would be used until information (e.g., knowledge about the stock-recruitment relationship or the tradeoffs related to the age-specific selectivities to the fisheries) is available from which stock-specific reference points could be derived.

2. LIMIT REFERENCE POINTS

Limit reference points are related to stock levels or fishing mortality levels that should be avoided because further stock depletion or higher fishing mortalities could endanger the biological sustainability of the stock. The IATTC adopted an *interim* biomass limit reference point in 2014 for tropical tunas (IATTC Resolution C-16-02). This reference point is defined as the spawning biomass that produces 50% of the virgin recruitment (R_0) when the spawner-recruitment relationship follows the Beverton-Holt function with an assumed conservative steepness (h) of 0.75 (SAC-05-14). The spawning biomass at the limit reference point is equal to 0.077 of the equilibrium unfished spawning biomass (S_0 or B_0) and is independent of the stock for which the reference point is applied. The fishing mortality (F) limit reference point is the value of F that, under equilibrium conditions, maintains the spawning biomass at the biomass limit reference point. Since, the corresponding F will depend on the biology and selectivity, the F will differ among stocks.

3. TARGET REFERENCE POINTS

Target reference points are related to the management objectives. Article VII 1(c) of the IATTC's Antigua Convention states that *"[The Commission shall perform the following functions…] to maintain or restore the populations of harvested species at levels of abundance which can produce the maximum sustainable yield".* In conjunction with IATTC Resolution C-16-02, the target reference points are interpreted to be those corresponding to MSY.

SAC-13-07 proposed a conservative *proxy* target biomass reference point for skipjack tuna of $S_{MSY}/S_0 = 0.3$ based on the range of S_{MSY}/S_0 estimated for yellowfin and bigeye tuna in the EPO under different assumptions (Table 1). The definition of this reference point was based on the same productivity-susceptibility argument that has been used previously to manage skipjack tuna based on the assessments of yellowfin and bigeye tuna (i.e., skipjack is more productive than the other two species and has similar susceptibility to bigeye). Given the higher productivity of skipjack, $S_{MSY}/S_0 = 0.3$ is therefore considered a conservative reference point. Other more arbitrary *proxy* reference points such as the value advocated by the Marine Stewardship Council (MSC) for stocks that do not have explicitly calculated reference points, SPR[1] = 0.4, could also be used. SPR is equivalent to S/S_0 when steepness = 1. However, these reference points do not take into consideration the characteristics of most species caught in the EPO tuna fisheries.

Most teleosts commonly caught in EPO tuna fisheries are highly productive fishes. They are highly fecund pelagic spawners, exhibit rapid growth rates and are often short lived. Typically, these species have highly variable recruitment, show no evidence of a stock-recruitment relationship, and have ample favorable habitat for larval development in the tropical areas of the EPO. There are examples of highly depleted stocks capable of producing recruitment levels like those achieved at much higher spawning biomass levels. For example, north Pacific bluefin tuna was depleted to around 3% of its unfished value and rebuilt rapidly when exploitation rates were reduced (International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean, 2022, Figure 5-11). There is no evidence of higher recruitment levels before the stock became highly depleted or when the stock rebuilt back to higher spawning biomass. Maunder (2022) refers to these species as having a saturating life history strategy where the number of

[1] SPR spawning potential ratio defined as spawning stock biomass (S) /recruits (R) over spawning stock biomass in an unfished condition (dynamic S_0)/recruits in an unfished condition (dynamic R_0).

eggs produced is far more than is needed to saturate the available habitat even at low adult population sizes. Maunder and Deriso (2013) argue that the spatial-temporal extent of spawning is more important than the number of spawners. Based on these arguments, the staff reiterates that the IATTC *interim* limit reference points for tropical tunas calculated with h = 0.75 value for steepness of the Beverton-Holt stock-recruitment relationship are conservative. In the absence of any adopted target reference points (e.g., from conventional stock assessments), this same conservative assumption could be used to define target reference points for highly productive species caught in the EPO tuna fisheries.

The IATTC staff proposes taking the biological assumptions and the fishery selectivities estimated in the stock assessment and use these to calculate a target reference point assuming a conservative value for the steepness of the stock-recruitment relationship[2]. We use steepness of h = 0.75 to be consistent with the assumption used in calculating the limit reference points. However, to add additional precaution and to avoid low levels of S_{MSY}/S_0 due to the selectivity of the fisheries, we also apply a minimum of $S_{MSY}/S_0 \geq 0.3$ based on bigeye and yellowfin tunas. The target fishing mortality reference point is the F that produces the target biomass reference point under average conditions.

These reference points are illustrated here using skipjack tuna (see SAC-14-09) and south EPO swordfish (SAC-14-15). The reference model for skipjack tuna results in S_{MSY}/S_0 = 0.15. This value occurs at a more depleted level than $0.3S_0$ and therefore $0.3S_0$ is used as the target reference point. The stock assessment of south EPO swordfish uses five models as a reference set, which encompasses different stock structure hypotheses, and hypotheses that explain the simultaneous increase in catches and indices of abundance observed in the last 20 years. Due to the uncertainty on the process that generated this peculiar pattern, it is considered that the MSY estimated with h = 1 is not appropriate. The S_{MSY}/S_0 for South EPO swordfish computed using the mix of fisheries in the last three years of the assessment (2017-2019) and steepness of 0.75 is on average 0.25 (Table 2, the average is done considering equal weight for all models as suggested in WSRSK-02). Therefore, for the South EPO stock a target reference point of 0.3 S_0 would be more precautionary and should be used.

The proposed protocol for defining *interim* reference points for tuna, billfish and other highly fecund species caught by EPO fisheries is as follows:

1. A formal stock assessment exists:

    1.1. MSY-based RPs are definable. Adopt these. Example of YFT and BET (see Table 1).

    1.2. MSY-based RPs are not definable. Apply the proposed *interim* RPs (apply the minimum of 0.3 and the value from the assessment parameters with h = 0.75) (example with skipjack, see SAC-14-09).

This protocol is similar to the tier system described by Quiroz and Morán (2023), except that our proposed level 1 has two subcomponents which relate to their first and second “tiers” and we do not define a reference point for stocks that are not assessed.

4. DISCUSSION

The proposed value of the steepness of the Beverton-Holt stock-recruitment relationship (h = 0.75) is an arbitrary value that is assumed to be conservative for highly-fecund, pelagic spawners that have high recruitment variability. There are various meta-analyses that attempt to provide general information about the value of steepness for species groups (e.g., Myers, 2001), but the estimates for tunas and other species are highly dubious due to model misspecification and regime shifts (e.g., Szuwalski, 2015). Due to the lack of evidence suggesting recruitment is reduced when $S_{MSY}/S_0 \geq 0.3$ for highly fecund pelagic

[2] Stock Synthesis is run starting from the parameter file estimated from the stock assessment, with the steepness value replaced with the desired value, estimation is turned off by making the maximum phase zero.

spawning teleost species, we believe that the proposed reference points are conservative for these species.

5. REFERENCES

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TABLE 1. Ranges of S_{MSY}/S_0 estimated in the bigeye (SAC-11-06, Table 7) and yellowfin (SAC-11-07, table 8) stock assessments.
TABLA 1. Rangos de S_{RMS}/S_0 estimados en las evaluaciones de las poblaciones de patudo (SAC-11-06, Tabla 7) y aleta amarilla (SAC-11-07, Tabla 8).

Steepness (*h*)	Bigeye	Yellowfin
1.0	0.20 – 0.24	0.23 – 0.32
0.9	0.25 – 0.27	0.28 – 0.35
0.8	0.28 – 0.30	0.32 – 0.37
0.7	0.31 – 0.32	0.35 – 0.40

TABLE 2. Potential target reference points for the reference set of models that compose the south EPO swordfish stock assessment (SAC-14-15) computed with steepness assumption = 0.75.
TABLA 2. Puntos de referencia objetivo potenciales para el conjunto de referencia de los modelos que conforman la evaluación de la población de pez espada del OPO sur (SAC-14-15) calculados con el supuesto de inclinación = 0.75.

Model	SMSY/S0
H1	0.263
1	0.244
2	0.242
3	0.244
4	0.244
Average	**0.247**