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REFERENCE POINTS AND HARVEST RATE CONTROL RULES

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International agreements (*e.g*. the United Nations Straddling Stocks Agreement) mandate the use of reference points, harvest control rules, and the precautionary approach. Tuna Regional Fisheries Management Organizations, which follow these agreements, have started the process of developing and implementing reference points and harvest control rules. In particular, in 2012 the Indian Ocean Tuna Commission (IOTC) approved limit and target reference points for the major tuna stocks.

1. REFERENCE POINTS

Target (TRP) and limit (LRP) reference points are the two main types of reference points traditionally used in fisheries management, and they are generally developed in terms of fishing mortality (F) or stock biomass (B). A limit reference point is used to indicate a state of a fish stock or fishery that is considered undesirable, and a target reference point is used to indicate a state that is considered desirable (Punt and Smith 2001; Sainsbury 2008). A fish stock or fishery is expected to approach or fluctuate around a target reference point, and to have a very high probability (*e.g*. at least 90%) of not exceeding a limit reference point (Sainsbury 2008). Limit reference points have been traditionally set on biological grounds to protect a stock from serious, slowly reversible or irreversible fishing impacts, which include recruitment overfishing and genetic modification (Sainsbury 2008). Target reference points have traditionally been set with the aim of maximizing yield (*e.g*. maximum sustainable yield; MSY), economic benefits (*e.g*. maximum economic yield; MEY), or some other measure of benefits (*e.g*. optimal yield; OY).

LRPs are often associated with management action, perhaps as part of a harvest control rule, and in this context are often referred to as trigger reference points. Care needs to be taken when using LRPs as trigger points. “Use of reference points should recognize that risk will not abruptly change at a reference point. This is especially important when identifying trigger reference points and the resulting management response, and when considering the consequences of uncertainty in the estimation of where a fishery currently is in relation to its reference points.” (Sainsbury 2008). To paraphrase Punt and Smith (2001): if a limit reference point is triggered, this does not mean that the species has a high risk of biological extinction. An appropriate response to a limit reference point being triggered would be a reduction in fishing mortality rather than the closure of the whole fishery. If appropriately set, the probability of triggering a limit reference point should be low, but clearly not zero. There is also a difference between exceeding a limit and knowing you exceeded it, or a probability that you will versus the probability that you have. Any harvest control rule recommended by the IATTC staff should prevent fishing mortality from getting near the IOTC recommended limit reference points for fishing mortality, commented on below.

Fish population abundance fluctuates for many reasons, but more generally due to either changes in the ecosystem, whether that means abundance of the various species or environmental changes, or to changes in fishing mortality. Changes in the recruitment of cohorts to the population are thought to be the primary driving cause for fluctuations in population abundance. There is scant evidence for tuna populations that the cause of fluctuations in recruitment is change in the amount of spawning, except at the extreme level of low spawning. As a consequence, changes in fishing mortality are not likely to filter through to changes in survival of the young via their impact on adults.

The IATTC staff's base case assessment of yellowfin and bigeye tuna in the eastern Pacific Ocean assumes that there is no direct relationship between the level of spawning and the level of recruitment to a stock. The relationship between the level of spawning and the level of recruitment is often expressed in terms of the 'steepness' of the stock-recruitment relationship: the fraction of the virgin recruitment realised when the spawning biomass is 20% of the virgin spawning biomass. A steepness of 1.0 corresponds to the assumption that there is no such relationship. Under the assumption that there is no such relationship, altering fishing mortality affects the total yield from a given cohort of fish but does not affect future recruitment. For that reason, fishing mortality in excess of F_{MSY} would not drive the population to collapse, but rather adversely impact the yield that can be harvested from a given cohort. The IATTC staff also show results corresponding to a steepness of 0.75 and in this case changes in fishing mortality do filter through to changes in recruitment to some extent. That effect is one reason IATTC staff encourage a precautionary view of F_{MSY}.

An Indian Ocean Tuna Commission (IOTC) recommendation made in 2012 (IOTC 12/14) adopted the following interim limit and target reference points for the major tuna species:

IOTC interim target and limit reference points[1]

Stock	Target Reference Point	Limit Reference Point
Albacore tuna	B_{MSY}; F_{MSY}	40% of B_{MSY}; 40% above F_{MSY}
Bigeye tuna	B_{MSY}; F_{MSY}	50% of B_{MSY}; 30% above F_{MSY}
Skipjack tuna	B_{MSY}; F_{MSY}	40% of B_{MSY}; 50% above F_{MSY}
Yellowfin tuna	B_{MSY}; F_{MSY}	40% of B_{MSY}; 40% above F_{MSY}
Swordfish	B_{MSY}; F_{MSY}	40% of B_{MSY}; 40% above F_{MSY}

Of note in the above is that F_{MSY} (the fishing mortality rate corresponding to the maximum sustainable yield) is an interim target reference point for all the tuna species covered. IATTC staff recommendations have also treated F_{MSY} as a target reference point. In addition, IATTC staff recommendations have been based on the harvest control rule that if fishing mortality exceeds F_{MSY}, then reduce it to the level of F_{MSY}. In contrast, F_{MSY} is given as a limit reference point in Annex II of the Straddling Stocks Agreement. The evidence for tunas is that fishing at a level that moderately exceeds F_{MSY} is not unsustainable, and therefore requiring a very low probability (*e.g.* 10%) of exceeding F_{MSY} is unreasonable, particularly in the context of stock assessment uncertainty. Limit reference points should, as originally intended, be developed to protect the stock from serious, slowly reversible, or irreversible fishing impacts, which include recruitment overfishing and genetic modification, and not on some overarching notion that they may in some way protect the ecosystem. The limit reference points recommended by IOTC are not supported by scientific evidence, but as interim levels they would provide protections that limit reference points are intended to provide.

F_{MSY}, which was traditionally treated as a management target, has been transformed into a precautionary limit reference point (LRP) (Mace 2001). This perplexing change has been embraced by many international agreements and is contrary to the traditional management objectives of most management organizations that follow these agreements. The rationale for the change is confusing and vague, and the use of F_{MSY} as a LRP is unreasonable, particularly if the required probability of exceeding the LRP is very low. Certainly there is no disagreement with the goal stated by Sainsbury (2008): "Unacceptable outcomes are strongly based on avoiding irreversible, slowly reversible or long-term impacts of fishing

[1] F_{MSY}: fishing mortality rate corresponding to the maximum sustainable yield; B_{MSY}: biomass corresponding to the maximum sustainable yield

(*e.g*. from UNCED 1992 and UNFSA 1995), and so there is an emphasis on avoiding recruitment overfishing, stock collapse and excessive depletion of very long-lived organisms", but F_{MSY} is not related to any of these. The use of F_{MSY} as a LRP should be re-evaluated in the terms of management objectives, overall consistency, stock assessment accuracy, and practicality.

An alternative limit fishing mortality to that in the IOTC recommendation is F_{LOSS} (see FAO Fish Stock Assessment Manual) which corresponds to the fishing mortality which, if applied over a long time period, would cause the stock biomass to decline to the lowest level observed historically (called B_{LOSS}) during that period. B_{LOSS} has been suggested previously as a biomass level to be avoided for managing tuna in the EPO. In that suggestion, B_{LOSS} could be viewed a limit reference point for biomass. These alternatives and others can best be evaluated within a framework of management strategy evaluation (MSE). There is a current project for MSE on tropical tunas encouraged by the Kobe 3 meeting in July 2012.

2. HARVEST CONTROL RULES

One feature of a management plan that needs to be evaluated is whether a simulation of the plan triggers a limit reference point an undesirable number of times: *i.e.* drastic action has to be taken (Punt and Smith 2001). The *de facto* harvest control rule recommended by IATTC staff is simply that fishing mortality should be reduced to F_{MSY} if it exceeds that level. If followed, this rule would not allow fishing mortality to exceed the IOTC limit reference point unless parameter or model structure uncertainty or operational error is high. A proper evaluation of a harvest control rule is best done as part of an MSE.

A more precautionary harvest control rule was proposed by Restrepo *et al*. (1998), who suggested the following default control rule for data-rich species: Fix maximum fishing mortality at $F = F_{MSY}$ when the stock is healthy, and reduce it in proportion to stock biomass when the stock is "unhealthy". In order to avoid management action due to natural fluctuations, they allow $F = F_{MSY}$ when the stock is somewhat below B_{MSY} because a stock fished at F_{MSY} would fluctuate around B_{MSY} (Restrepo and Powers 1999).

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