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A limit reference point to prevent recruitment overfishing of Pacific bluefin tuna

Shuya Nakatsuka[a,*], Yukimasa Ishida[a], Hiromu Fukuda[a], Tetsuya Akita[b]

[a] National Research Institute of Far Seas Fisheries, Orido 5-7-1, Shimizu, Shizuoka 424-8633, Japan
[b] National Research Institute of Far Seas Fisheries, Fukuura 2-12-4, Kanazawa, Yokohama, Kanagawa 236-8648, Japan

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ABSTRACT

Pacific bluefin tuna (PBF) (*Thunnus orientalis*) is commercially important in the North Pacific Ocean. Although its stock has been relatively low for decades, international discussions on a long-term management framework, including the definition of a limit reference point (LRP), have only recently started. This paper argues that an LRP for PBF could be developed by determining a biomass level that would prevent recruitment overfishing. First, it reviews the development of LRPs for various tuna species and demonstrates that most of these limits are not necessarily based on biological information on the respective species. Then, the current management of PBF is also reviewed as background information for considering an LRP for PBF. Finally, a variety of simple analyses of the stock–recruitment relationship of PBF are conducted to find a biomass level that would prevent recruitment overfishing—i.e. an LRP below which stocks should not fall. It is concluded that, for the first time to our knowledge, defining such an LRP for a tuna species is possible (about 30 thousand tonnes or 5% of estimated unfished spawning stock biomass in our calculation). Not only is the LRP based on actual experience, but also the logic behind it would be easier for stakeholders to understand than the theoretical LRPs used elsewhere. This LRP should be useful in future in more comprehensive management framework, such as one through management strategy evaluations, in which stakeholder involvement in decision-making is crucial.

1. Introduction

Frameworks using limit reference points (LRPs) are becoming increasingly common in fisheries management. An LRP is a point below which it is considered undesirable for a stock to fall. It is typically expressed as a percentage of the unfished spawning stock biomass (SSB_0), or as the biomass required to produce the maximum sustainable yield (B_{MSY}), or its fraction. After an LRP is set, an appropriate management framework is considered on the basis of risk assessments of the stock declining below the LRP. In international discussions, this approach was firmly established after the adoption of the United Nations Fish Stocks Agreement (UNFSA) [1], including its Annex, which stipulates guidelines for the application of precautionary reference points, and the United Nations' Food and Agricultural Organization's Code of Conduct for Responsible Fisheries [2].

Because tunas are highly migratory, their management requires international cooperation through inter-governmental organizations commonly referred to as regional fisheries management organizations (RFMOs). International Seafood Sustainability Foundation (ISSF) reported that, as of March 2015, LRPs (including interim LRPs) had been adopted by various RFMOs for 10 tuna stocks [3]. However, discussions on an LRP for Pacific bluefin tuna (PBF) (*Thunnus orientalis*) started only recently [4].

Management of PBF attracts a lot of attention from fishermen, consumers, environmental non-governmental organizations, and the media. Because of its high commercial value and relatively coastal nature, PBF has been caught by variety of fisheries and has been at generally low stock levels for a long time. Therefore, any PBF management measures, including the setting of an LRP, might affect a large number of stakeholders.

Here, first, LRPs for various tuna species are reviewed and it is demonstrated that most of the existing LRPs for tunas are not based on biological information on the respective species. Second, the current management of PBF is reviewed as background information for determining LRPs for the species. Third, on the basis of the results of a current stock assessment of PBF [5], a variety of simple analyses of stock–recruitment relationships are conducted with the aim of determining a suitable biomass that would prevent recruitment overfishing (i.e. prevent reduction of the biomass to a level at which recruitment would be negatively affected)—namely, an LRP below which stocks

* Corresponding author.
E-mail address: Snakatsuka@affrc.go.jp (S. Nakatsuka).

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should not fall. Setting such an LRP for PBF is possible because good recruitment estimates are available and necessary in order to balance PBF conservation and societal needs.

2. Review of development of LRPs for various tuna species and their possible application to PBF

An LRP has traditionally been viewed as an indicator of the status of a fishery and of the resource level that is biologically undesirable and best avoided through management action [6]. In practice, LRPs were set to avoid irreversible, slowly reversible, or long-term impacts on stocks, with an emphasis on preventing recruitment overfishing [7,8]. The LRP is sometimes called a "biological reference point" [6]—a term that suggests it should be developed on the basis of biological information.

The approaches being taken by the tuna RFMOs to develop LRPs vary widely. Around the world there are five tuna RFMOs,[1] which in effect collectively manage the tuna fisheries globally. ISSF [3] used a single unit of measurement, the ratio of depletion compared with B_0[2] (the unfished total biomass), to compare the LRPs adopted by the five tuna RFMOs (Table 1). These ratios vary from a low of 7.7% of B_0 to a high of 20% of B_0. Note also that CCSBT decided that the limit below which the stock size of Southern bluefin tuna (*Thunnus maccoyii*) should not be allowed to fall (which might be considered effectively to be an LRP) was the SSB in 2010, which was about 5% of SSB_0 [9].

Apparently, there is no single globally agreed approach among the tuna RFMOs for the development of LRPs. Note also that a similar management goal may be achieved by different responses when the LRP is breached, for example by implementing stricter measures if the LRP level is relatively low.

The above-mentioned differences in LRPs could have substantial management implications. International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) is responsible for the assessment of PBF stocks and the current estimated SSB_0 for PBF is about 650 thousand tonnes [5]. If the LRPs of other stocks were applied to PBF, depending on whether the lowest percentage (5%) or the highest percentage (20%) was used, the LRP for PBF could vary from 32 thousand to 129 thousand tonnes.

The area managed by WCPFC, the western and central Pacific Ocean, is where the vast majority of the PBF catch (recently about 80% [5]) is taken. As noted above, WCPFC has adopted the most stringent LRP (20% of SSB_0) for tropical tunas among the five tuna RFMOs. WCPFC is the newest of the five tuna RFMOs; the WCPFC Convention refers to UNFSA in many of its Articles, as the negotiations for establishment of WCPFC started immediately after the completion of the UNFSA negotiation. As a result, B_{MSY} is considered the default option for an LRP in the discussions of WCPFC [10,11]. However, B_{MSY} values are usually highly sensitive to assumptions in the parameters required for their estimation such as steepness[3] and selectivity [12,13]. As a result, 20% of SSB_0 was chosen by WCPFC as an LRP as a proxy for B_{MSY} for tropical tunas and southern albacore [11]. In contrast, B_{MSY} is treated as a target reference point rather than an LRP by IATTC [14], ICCAT [15], IOTC [16], and CCSBT [17], meaning that the management frameworks for these regions and species are aimed at B_{MSY}.

The study by Preece et al. [12] was the basis for the WCPFC discussions aimed at developing LRPs [10]; it recommended LRPs of 20% of SSB_0 by referring to several past studies, including those of Myers et al. [18] and Beddington and Cooke [19], which provided generally qualitative support for that level. None of the cited studies, however, demonstrated that a decline in recruitment, or any other undesirable outcome, would in fact occur if the SSB were to decrease below 20% of SSB_0 for tuna species based on biological information. IATTC, which manages the tuna fisheries in the other side of the Pacific Ocean, took a different approach from WCPFC; In IATTC, 7.7% of SSB_0 was proposed as an LRP for the tropical tunas as a point of 50% R_{max} (the biomass level at which recruitment is expected to be one half of that of the stock's unfished status) under a conservative assumption of the productivity [21]; this was adopted as an interim LRP [14].

Another interesting point is that most of the tuna stocks in Table 1 have almost never been reduced to the biomass levels of their LRPs. Therefore, in these cases there is no empirical information available for use in developing appropriate LRPs based on stock–recruitment relationships.[4] As a general rule, the higher the LRP, the higher the stock level would be maintained, and this would also result in more efficient fishing operations. Consequently, managers and stakeholders might choose to set LRPs higher than the levels at which undesirable events would actually occur to maintain high stock levels and/or keep fishing operations efficient.

PBF has a long history of exploitation[5]; the stock is estimated to have remained relatively low, fluctuating at around 2–25% of the estimated SSB_0 for the entire period over which it has been assessed (Fig. 1 [5]). In other words, for almost all of the past over 60 years the PBF stock has remained below the LRP levels set by WCPFC for tropical tunas and southern albacore. However, the decreases and increases in the PBF stock during that period indicate that the stock has maintained its capacity to recover within these past fluctuations. Also, ISC [5] estimates that PBF is capable of increasing to almost 300 thousand tonnes in SSB if current management measures by relevant RFMOs continue under historical levels of recruitment. Stock sustainability is obviously crucial when an LRP is considered, but given the importance of PBF fisheries to stakeholders and local communities (see also Section 3.2) it is not desirable either to overly restrict fishing operations, as this could cause unnecessary socioeconomic disruption [23].

Table 1
Limit reference points (LRPs) adopted by the tuna regional fisheries management organizations (RFMOs) and their values as ratios of unfished total biomass (B_0) [3].

RFMO	Stocks	Adopted biomass LRP	LRP relative to B0
CCSBT	SBT	None	N/A
IATTC	BET	$B_{0.5R0}$	0.077
	YFT	$B_{0.5R0}$	0.077
ICCAT	SWO-N	0.4 B_{MSY}	0.20
IOTC	BET	0.5 B_{MSY}	0.14
	YFT	0.4 B_{MSY}	0.14
	SKJ	0.4 B_{MSY}	0.14
WCPFC	BET	0.2 $SB_{F=0}$	0.20
	SKJ	0.2 $SB_{F=0}$	0.20
	YFT	0.2 $SB_{F=0}$	0.20
	ALB-S	0.2 $SB_{F=0}$	0.20

SBT: southern bluefin tuna, BET: bigeye (*Thunnus obesus*), YFT: yellowfin (*Thunnus albacares*), SWO: swordfish (*Xiphias gladius*), SKJ: skipjack (*Katsuwonus pelamis*), ALB: albacore (*Thunnus alalunga*), N: north, S: south; B_{MSY}, biomass required to produce the maximum sustainable yield, $B_{0.5R0}$: biomass where recruitment is expected to reduce to the one half of that of B_0, $SB_{F=0}$: spawning biomass expected when no fishing is conducted. See footnote 1 for abbreviations of RFMOs.

[1] Western and Central Pacific Fisheries Commission (WCPFC) covers the western and central Pacific Ocean; Inter-American Tropical Tuna Commission (IATTC) covers the eastern Pacific Ocean; International Commission for the Conservation of Atlantic Tunas (ICCAT) covers the Atlantic Ocean; Indian Ocean Tuna Commission (IOTC) covers the Indian O0cean; and Commission for the Conservation of Southern Bluefin Tuna (CCSBT) specifically covers Southern bluefin tuna.

[2] ISSF used the term B_0. For simplicity's sake, B_0 and SSB_0 are treated interchangeably here.

[3] The ratio of recruitment when the stock is at 20% of SSB_0 against that expected at SSB_0 in the Beverton–Holt stock–recruitment relationship [20].

[4] The latest bigeye tuna stock assessment in the western Pacific Ocean reported that, in 2012, the SSB was slightly below the LRP (20% of SSB_0), but a decrease in recruitment was not reported [22].

[5] PBF bones have been found in shell mounds in Japan dating back several thousand years.