TUNA TODAY, TAKING FROM TOMORROW: AN ECONOMIC ASSESSMENT AND POLICY ANALYSIS OF INDIAN OCEAN TUNA COMMISSION MANAGEMENT OF YELLOWFIN TUNA (*THUNNUS ALBACARES*)

By

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Abstract

In 2015, the Indian Ocean Tuna Commission (IOTC) assessed that the yellowfin tuna (YFT) stock was overfished and subject to overfishing, meaning the population would decline without effective management. Since then, the recommended maximum sustainable yield (MSY) of YFT in the Indian Ocean has decreased by 17%, while catches have remained the same. This is despite IOTC Resolutions instituting catch limits. As States prioritize short-term economic benefits, I looked to understand how this influences the economic outlook of the fishery from 2014-2022 by valuing actual catches versus catch at the recommended MSY using import price data for fresh, frozen, and canned markets. Additionally, I looked to understand actions taken and level of compliance with YFT measures taken over this period. These analyses occur in 3-year increments coinciding with the IOTC's YFT stock assessments in 2015/2016, 2018, and 2021. As time has progressed, the gap between economic outputs of actual catch and catch at recommended MSY continues to grow, with varying levels of compliance to new management measures. As this occurs, IOTC decision-making has become more complex as Member States attempt to maximize their portion of a decreasing catch and enact measures which do not reach the scientifically advised threshold necessary for YFT recovery. The lack of an allocation regime, uncertainties surrounding stock assessments and catch reporting, and the potential socioeconomic impacts from recovery efforts exacerbate these issues. As the IOTC continues to debate the best course, they may risk a stock crash that causes economic devastation, particularly for Coastal States.

Keywords: Tuna economics; Compliance; Regional fisheries management organizations; Transboundary fisheries; Policy analysis

List of Abbreviations Used

CMM:	Conservation and Management Measure
CSSBT:	Commission for the Conservation of Southern Bluefin Tuna
dFAD:	Drifting Fish Aggregating Device
DWFN:	Distant Water Fishing Nation
EEZ:	Exclusive Economic Zone
FAD:	Fish Aggregating Device
IATTC:	Inter-American Tropical Tuna Commission
ICCAT:	International Commission for the Conservation of Atlantic Tunas
IOTC:	Indian Ocean Tuna Commission
MSY:	Maximum Sustainable Yield
RFMO:	Regional Fisheries Management Organization
SIDS:	Small Island Developing States
TAC:	Total Allowable Catch
TCAC:	Technical Committee on Allocation Criteria
tRFMO:	Tuna Regional Fisheries Management Organization
UNCLOS:	United Nations Convention on the Law of the Sea
UNFSA:	United Nations Fish Stocks Agreement
WCPFC:	Western and Central Pacific Fisheries Commission
WGFAD:	Working Group on Fish Aggregating Devices
WPSE:	Working Party on Socioeconomics
WPTT:	Working Party on Tropical Tunas
YFT:	Yellowfin Tuna

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Chapter 1: Introduction

The Indian Ocean is home to more than two billion people who rely on its resources for food security, nutrition and employment opportunities, while it is also the world's second-largest tuna contributor with 1.2 million tonnes and $8.6 billion (2018 USD) supplied to global tuna markets (PEW Charitable Trusts, 2020). Indian Ocean tuna catches are almost equally shared between industrial and artisanal fisheries, which differs from most other oceans, and the fisheries are under pressure with development aspirations for Coastal States and the need for increased food supply globally (Mullon et al., 2017). One of the key species fished is yellowfin tuna (YFT; *Thunnus albacares*), which was first evaluated as overfished and subject to overfishing by the Indian Ocean Tuna Commission (IOTC) in 2015. Despite numerous conservation and management measures and negotiations in international forums, the population has continued to decline, likely due to maintained high catch levels and a lack of meaningful management measures to rebuild the population. Thus, ten years following that first assessment, the population remains overfished and subject to overfishing as stock projections continue to decline.

The IOTC is tasked with "ensuring, through appropriate management, the conservation and optimum utilisation of stocks… and encouraging sustainable development of fisheries" (IOTC, n.d.). While scientific data evaluates YFT as overfished (spawning biomass below biomass producing the maximum sustainable yield; MSY) and subject to overfishing (mortality higher than mortality producing MSY), political motivations can and do disrupt the connectivity between scientific advice and conservation and management measures (CMMs), resulting in measures that fail to promote the longevity of stocks (McDorman, 2005). Member State priorities in these negotiations result from differences in social, economic, political, and management motivations (Sinan et al., 2021), which can disrupt the link between scientific advice and management. Through negotiations between States, the Commission adopts the lowest common denominator to reach a consensus, which can permit status quo management (Schatz, 2024b), or in cases where the Commission votes on management measures, objections from Member States can lower the efficacy of the measure.

While the IOTC has negotiated towards effective CMMs that promote YFT recovery (Figure 1), including 16/01, 17/01, 18/01, 19/01, and 21/01, the population has continued to decrease. In response to the declining population, the IOTC Working Party on Tropical Tunas (WPTT) recommends a 20% catch decrease as it will place the YFT stock in the "green" zone of the KOBE II plot by 2030 (IOTC-WPTT, 2022). This advice puts increased pressure on Member States to find a solution while also making it more challenging to negotiate shares of a dwindling resource. At the IOTC's 28th Session in 2024, an updated YFT proposal that was more in line with scientific advice saw heated debate; however, in the end, the Commission could not agree to the measure.

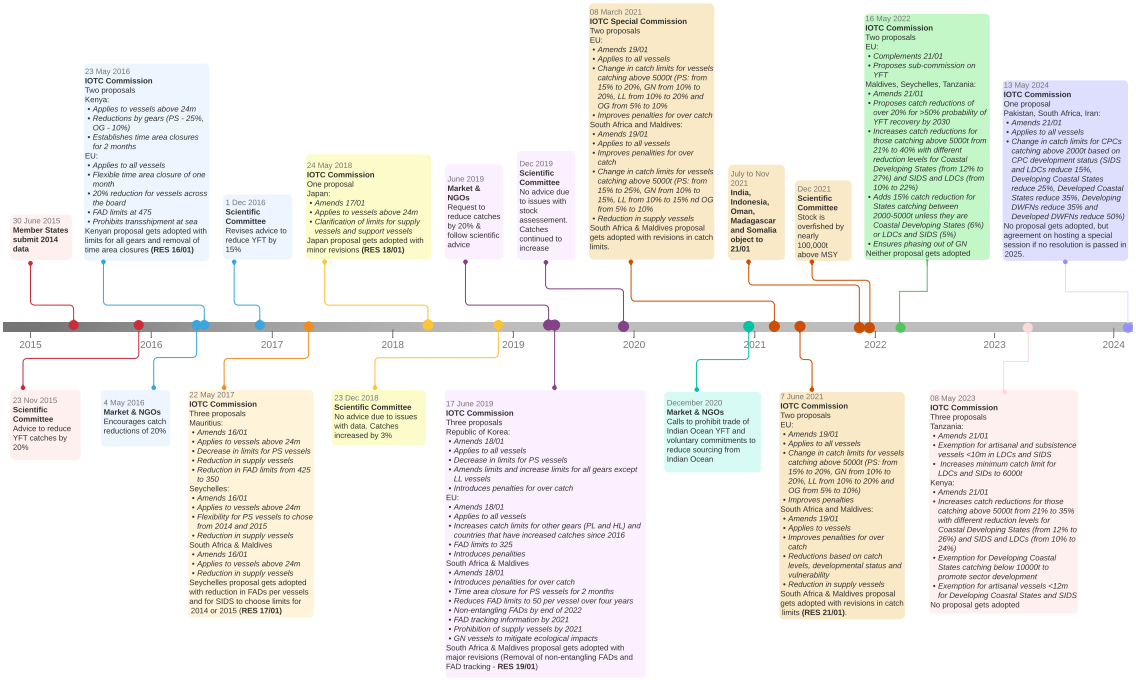

Figure 1. *IOTC timeline of YFT management decisions.*

Note. The information from this figure comes from governance documents and meeting minutes from the IOTC website (www.iotc.org). Acronyms used in the figure include: YFT (yellowfin tuna), NGO (non-governmental organization), SIDS (small island developing state), LDC (least developed countries), DWFN (distant water fishing nations), MSY (maximum sustainable yield), PS (purse seine), OG (other gears), HL (handline), PL (pole and line), LL (longline), GN (gillnet), FAD (fish aggregating device).

At the same time, the IOTC has focused on mitigating the impacts of drifting fish aggregating devices (dFADs) as a potential path toward population recovery due to the high catch levels of juvenile yellowfin and bigeye tunas (Artetxe-Arrate et al., 2021; Davies et al., 2014). Drifting FADs attract high levels of tuna biomass regardless of population size, which threatens overexploitation and unsustainable catch levels of already overfished species, like yellowfin and bigeye tuna (Ehrhardt et al., 2017). IOTC took this concern on through establishing the FAD Working Group, hosting a special Commission session on FADs in 2023, and adopting CMMs 23/02 (now void due to 1/3 of Member States rejecting it) and 24/02. Additionally, the IOTC has debated and adopted CMMs on fisheries closures, both for dFADs (23/02) and voluntarily for the entire Indian Ocean (23/03). While Correa et al. (2023) estimate that a three-month full fishery closure would recover the YFT stock to sustainable levels by 2030, there is also potential recovery through a three-month dFAD closure. In looking at these measures with more depth, there are also questions of whether the adopted measures could have promoted positive change or whether non-compliance and implementation resulted in lowered efficacy.

The contribution of this paper is twofold. First, I look to value the Indian Ocean YFT fishery at actual catches and recommended MSY under the assumption that continued inaction comes with sustained present-day benefits but long-term costs to Member States. This valuation aims to determine the economic output gap between current and scientifically recommended catch levels. Second, I look to better understand the IOTC's management actions over the last ten years in the context of the decreasing tuna populations to examine the lack of implementation of comprehensive management measures in combination with noncompliance of IOTC Member States. These two factors undermine IOTC's objectives for YFT stock recovery while making it more difficult for the States to agree to new and improved management efforts. Overall, I aim to quantify the impact of inaction on economic outcomes from the fishery and better understand why management has been ineffective.

Management Problem:

While estimates of the YFT population have continued to decrease over the past decade, catch levels in the Indian Ocean continue to remain relatively unchanged. As

countries prioritize short-term economic gains, they risk the fishery's long-term health and economic benefits. This prioritization makes achieving consensus on effective conservation and management action difficult as Member States prioritize their own socioeconomic goals over the collective. Ironically, the decreasing population puts increased pressure on the fishery and a greater need for management action. As the IOTC delays action, the future economic cost of implementing meaningful management measures and the threat of a complete population collapse continue to increase. In this case, States attempt to hold onto their portion of a shrinking resource, which delays management action until it may be too late for full population recovery, or the economic cost of catch reductions to support population recovery becomes unfeasible.

Nevertheless, while it is undoubtedly costly to implement management measures today, it is likely more costly to delay action. To break this cycle within the IOTC, I aim to outline how much States might be losing due to a lack of meaningful action. Additionally, I look toward potential management paths that the IOTC can take to promote population recovery.

Graduate Project Structure

The paper proceeds as follows: after a background description of the tuna industry, international fisheries management through regional fisheries management organizations, and fisheries management tools and stock assessments, I will outline the method used for this project, including data sources and assumptions. Then, I will discuss the last ten years of IOTC yellowfin tuna management and the associated potential cost of implementing effective management efforts while looking at what these mean for stock recovery and potential future management options. I conclude with a summary of the study and provide future management recommendations based on the study findings. I draw the reader's attention to the list of acronyms on page vii, as the tuna fisheries world has been called "alphabet soup" for a reason.

Chapter 2: Background

Regional Fisheries Management Organizations (RFMOs)

The United Nations Convention on the Law of the Sea (UNCLOS; 1982) was the first piece of international legislation outlining coastal State sovereign rights to natural resources up to 200 nautical miles off that State's coast, called an exclusive economic zone (EEZ). Included in this, Coastal States have jurisdiction over fisheries management within their EEZ. Additionally, UNCLOS outlines that for highly migratory species, Coastal States and other States fishing for species outlined in ANNEX I (incl. tropical, neritic, and bluefin tuna species, marlins, swordfish, dolphins, oceanic sharks, and cetaceans) shall "cooperate directly through appropriate international organizations with a view to ensuring conservation and promoting the objective of optimum utilization of such species throughout the region" (UNCLOS, 1982, art. 64). While UNCLOS set the legal framework for fisheries management for transboundary and straddling fish populations (fish whose dispersal crosses multiple EEZs or one States' EEZs and the high seas), problems remained regarding the management of these fisheries. Prior to UNCLOS, 90% of fishing activities occurred within newly established coastal State EEZs and with increasing high seas fishing activities, there was a need for delineation of jurisdiction over straddling fish stocks both within coastal State EEZs and the high seas (Kaitala & Munro, 1993).

The United Nations Fish Stocks Agreement (Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UNFSA), 1995) aimed to build on UNCLOS to promote the "long-term conservation and sustainable use of straddling… and highly migratory fish stocks" and the "cooperation of States to that end." This agreement sets out guidelines for the creation of RFMOs to oversee the conservation and management of these fish stocks and requires cooperation among Coastal States in the region and Distant Water Fishing Nations (DWFNs), or States fishing in Coastal State EEZs and/or the high seas. It should be noted that not all RFMO members are parties to UNFSA and, therefore, are not required to abide by its legislation. Additionally, RFMOs represent a subset of

regional fishery bodies, through which UNFSA requires Member States to agree on and comply with CMMs and catch allocation (FAO, 2004).

There are approximately 17 RMFOs around the world overseeing various fish stocks, including five tuna Regional Fisheries Management Organizations (tRFMOs; Figure 2). These five include the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), the Inter-American Tropical Tuna Commission (IATTC), the International Commission for the Conservation of Atlantic Tunas (ICCAT), the Indian Ocean Tuna Commission (IOTC), and the Western and Central Pacific Fisheries Commission (WCPFC). RFMOs have similar operating structures overall, with a central Commission made up of Member States, a Committee on Finance, a Compliance Committee, and a Scientific Committee (Cullis-Suzuki & Pauly, 2010), but there are several differences in their management and governance based on their establishing agreements, rules of procedure, and fishery composition. These differences may be a product of different adoption years, with the oldest to youngest being IATTC (1949)[1], ICCAT (1969), CCSBT (1994), IOTC (1996), and WCPFC (2004) (ISSF, 2024). This might be a factor of international legal regimes, such as UNCLOS and UNFSA, helping to shape more recent RFMOs. In comparison, tRFMOs face similar problems associated with conflicts between resource users (Sinan et al., 2021), including Coastal States versus DWFNs and associated histories of colonization; equity in resource allocation (Abolhassani, 2018; Seto et al., 2021); and finding consensus on CMM implementation (McDorman, 2005). Additionally, despite the stated objective of conserving species, RFMOs face complexities associated with managing multiple species and gears, accounting for species biology and migration, and navigating the geopolitics of international governance. This paper will focus on IOTC management outcomes, and therefore, this background section will explore examples of these in an IOTC context.

[1] IATTC revised its Convention text in 2010

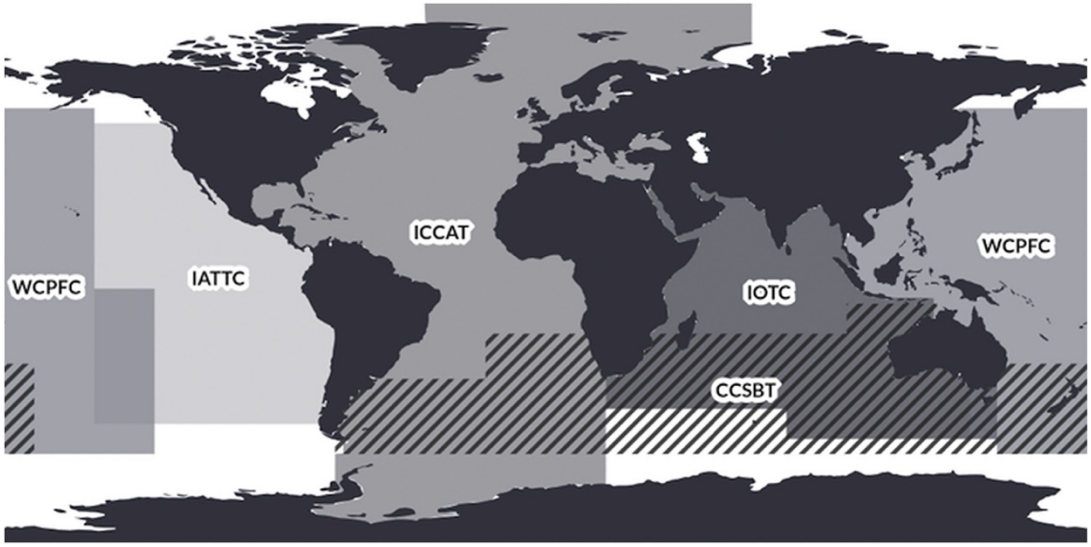

Figure 2. *The five tRFMOs and their respective areas of competence (Coulter et al., 2020).*

Conflict Between Users; Coastal States versus DWFNs

Historically, DWFNs, primarily developed States, have dominated global industrial tuna catches (Haas, Azmi, Sinan, et al., 2024; Mapping Distant-Water Fisheries Access Arrangement, 2022). With the implementation of UNCLOS and the establishment of coastal State EEZs, DWFNs were required to buy access from Coastal States to fish in their waters through access agreements (Swartz et al., 2010). Additionally, under UNCLOS (1982, art. 62(2)), countries not optimally utilizing their resources, or who do not have the fishing capacity to do so, may give other States access to their waters. This article has entrenched de facto distant water fishing access within international law and serves as a contentious issue in catch allocation negotiations today through historical catch attributions. In the Western Indian Ocean, the European Union hold formal access agreements with Mauritius and Seychelles and has an agreement with Madagascar in limbo, however, they also flag European vessels under Coastal States to increase their reach (Mapping Distant-Water Fisheries Access Arrangement, 2022). Through these agreements, DWFNs also provide economic benefits through development aid, port usage and production (Sinan et al., 2022). Over time, fisheries access agreements have entwined the economies of Coastal States with DWFNs (Andriamahefazafy et al., 2019), such that the Coastal States rely on them to source their production sector. While these agreements benefit Coastal States, there are questions surrounding the power balance between

Coastal States and DWFNs, as well as the fairness and sustainability of these agreements (Andriamahefazafy & Kull, 2019). In essence, with the implementation of UNCLOS, DWFNs became resource seekers and Coastal States became resource holders with fishing efforts aggregating in coastal State EEZs over time (Campling et al., 2024; Pauly & Zeller, 2016).

Due to the concentration of fishing within lower-income Coastal States, there is competition between the needs of DWFNs and Coastal States. For some Coastal States, tuna fisheries are necessary factors for food sustenance, nutrition, culture, and employment (Coro et al., 2016; Sinan et al., 2021), meaning that these countries rely on tuna for basic human needs, especially in rural areas (Mohan Dey et al., 2005). Alternatively, some Coastal States are looking to develop their fisheries (Sinan et al., 2021), however, there are challenges to making room for new States in the fishery due to maximal exploitation. In comparison, DWFNs are significant resource users and importers of tuna products (Sinan et al., 2021). However, their tuna fishery is only a small percentage of overall employment, meaning that while they may rely on seafood as a source of food, these States do not necessarily rely on the fishery as a source of income and employment for their populations (Barange et al., 2014). With the globalization of tuna fisheries, there is competition between export-oriented DWFN and the artisanal and small-scale fleets of Coastal States, with a higher proportion of the resource going to Global North markets than towards sustaining coastal State populations (Pauly & Zeller, 2016). This conflict is considered in UNFSA, where management of fisheries must consider the disproportionate burden on developing States (UNFSA, 1995); however, there is no definition of what a disproportionate burden is, nor how to prevent it. Additionally, the rights of Coastal States are enshrined in Article XVI of the IOTC Agreement which states, “This Agreement shall not prejudice the exercise of sovereign rights of a coastal state in accordance with the international law of the sea for the purposes of exploring and exploiting, conserving and managing the living resources” (IOTC, 1993). Both UNFSA and the IOTC Agreement highlight the importance of considering coastal State needs in management, however, DWFNs have historically dominated the governance decisions of IOTC (Sinan et al., 2022).

DWFNs typically have higher international geopolitical power, which increases their power relations within the RFMO decision-making processes and allows them to dominate catches. More recently, however, Coastal States in the Indian Ocean have begun to argue for the social and economic importance of tuna fisheries to their populations, with a growing understanding that they have the most to gain and lose from IOTC decisions (Sinan et al., 2022). With declining landings in the late 2010s, Coastal States began to realize that they needed to improve their involvement in IOTC decision-making and have a collective voice in lobbying for the rights of Coastal States, so they came together to form the G16 (*Our Story*, n.d.), a regional sub-coalition of like-minded Coastal States. The G16 has provided Coastal States with a backbone to improve their voice in IOTC decision-making and CMM propositions while advocating on issues relevant to improving the benefits they receive from IOTC fisheries (Sinan et al., 2022). While the G16 has built a network among Coastal States and improved coastal State involvement, there are disagreements among Coastal States due to their socioeconomic contexts and some State's alignment with DWFNs (Andriamahefazafy et al., 2019; Sinan et al., 2022). As Coastal States look to improve their capacities within IOTC decision-making, forums like the G16 allow for improved ability to negotiate and improve their power.

Resource Allocation

One of the key responsibilities of tRFMOs is deciding who gets access to these economically important resources, while accounting for social, economic and environmental factors. The majority of tRFMOs (CSSBT, IATTC, ICCAT, WCPFC) have either a process or principles in place that oversee resource allocation; however, many lag behind in creating a systematic process and rely on negotiations (Seto et al., 2021). Additionally, through their allocation process, many lack inclusion of equity-based principles or the tRFMOs ignore these principles in practice. In comparison, the IOTC has been negotiating on an allocation regime since 2011 (IOTC, 2010) and has yet to institute a systematic process due to institutional, political, and scientific barriers (Sinan & Bailey, 2020). Particularly, Coastal States and DWFNs disagree over the allocation of historical catches within a coastal State's EEZ and whether IOTC should allocate those catches to the flag state of the vessel (which has been the predominant

assumption of DWFNs) or the coastal State (Andriamahefazafy et al., 2024; Sinan & Bailey, 2020), with a 2018 DWFN proposal suggesting that the IOTC should allocate 85% of quota based on historical catch (Mapping Distant-Water Fisheries Access Arrangement, 2022). While the IOTC lacks an allocation regime, they do have total allowable catches (TAC) set for YFT and skipjack tuna (Seto et al., 2021); however, without a quota allocation process, there is an inequitable distribution of fishery benefits. Additionally, in a declining YFT population, there are increasing debates on who should take on the conservation burden (Sinan & Bailey, 2020). Without a formalized algorithm for deciding allocation amounts, Member States renegotiate the TAC every few years, but the agreed TAC does not necessarily follow the IOTC Scientific Committee's advice for decreasing catch levels and, more recently, States have not found consensus, with some objecting to the YFT TAC measure.

Tuna Industry

There are seven commercially important species across all ocean basins, including skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), bigeye (*Thunnus obesus*), albacore (*Thunnus alalunga*), and three species of bluefin (*Thunnus maccoyii, T. orientalis, and T. thynnus*). Industrial or large-scale fisheries for these species have significantly expanded since the 1950s, moving from 450,000 t in 1950 (Coulter et al., 2020) to 5.2 million t in 2022 (ISSF, 2024), which includes significant expansions in the tropical tuna fisheries (skipjack, bigeye, yellowfin), mainly due to increases in purse seine catches (ISSF, 2024; PEW Charitable Trusts, 2020). Of the seven most valuable tuna species, the tropical tuna species account for the majority of catches and generate the most revenue (PEW Charitable Trusts, 2020). The economic output from these fisheries varies based on the species and the gear vessels used, as these factors influence the size of the fish and the market that the fish enter (Table 1). The main gear types are, from most to least, purse seine, longline, pole and line, handline, gillnets, and trolls, with several other gears used mainly in artisanal fisheries (PEW Charitable Trusts, 2020). The primary markets for Indian Ocean tropical tunas are steaks/sashimi and cannery products; however, artisanal catches also enter local markets. There are also other coastal neritic tuna species mainly fished by Coastal States for local consumption.

Table 1. *Main gear types and markets for tropical tuna species globally in 2018 (skipjack, yellowfin, bigeye tunas), with catch percentages from (PEW Charitable Trusts, 2020).*

Species (catch)	Gear Type	% of catch	Market
Skipjack tuna	Purse seine	79%	Canned
(2.9 million t)	Pole and line		Canned
	Gillnet		Canned
	Other		Mixed
Yellowfin tuna	Purse seine	58%	Canned
(1.5 million t)	Longline		Sashimi
	Handline		Sashimi
	Gillnet		Canned
	Other		Mixed
Bigeye Tuna	Purse seine	>50%	Canned
(406,257 t)	Longline		Sashimi

Note. This table only includes the most prevalent gears for each fish, with the source only showing percentages for the most utilized gear.

Before entering global markets, catches go through processing depending on size and species, with the highest value and volumes coming, in order, from canned tunas, sashimi/steaks, and local consumption (Lecomte et al., 2017). Production through canning and loining (for steaks and sashimi) occurs internationally (Figure 3); however, select global markets dictate import and ex-vessel prices for commercially produced tuna (Guillotreau et al., 2017; Miyake et al., 2010). The two leading markets which dictate international trade are Bangkok, Thailand, for cannery-grade tuna products (skipjack and yellowfin tunas) and Tokyo, Japan, for sashimi-grade tuna products (fresh and frozen bluefin, bigeye and yellowfin tunas) (Guillotreau et al., 2017). Other important international landing destinations are Pago-Pago (American Samoa), Manta (Ecuador), Philippines, and Spain (García-del-Hoyo et al., 2017; Guillotreau et al., 2017; Squires et al., 2023). There is also cannery production capacity within the Indian Ocean, which contributes to coastal State economies (Andriamahefazafy et al., 2020). Mauritian, Seychellois, and Malagasy canneries process purse seine catches, Iranian canneries process gillnet catches, and Maldivian canneries process pole and line catches (Lecomte

et al., 2017). Mauritian, Maldivian, and Malagasy production facilities also export tuna loins to global destinations for canning (Guillotreau et al., 2017; Miyake et al., 2010; *Products*, n.d.). Despite the global nature of tuna production, production capacity has an increasingly important influence on Indian Ocean coastal State economies, especially about conversations of potential management measures, such as closures (Guillotreau, Dissou, et al., 2024).

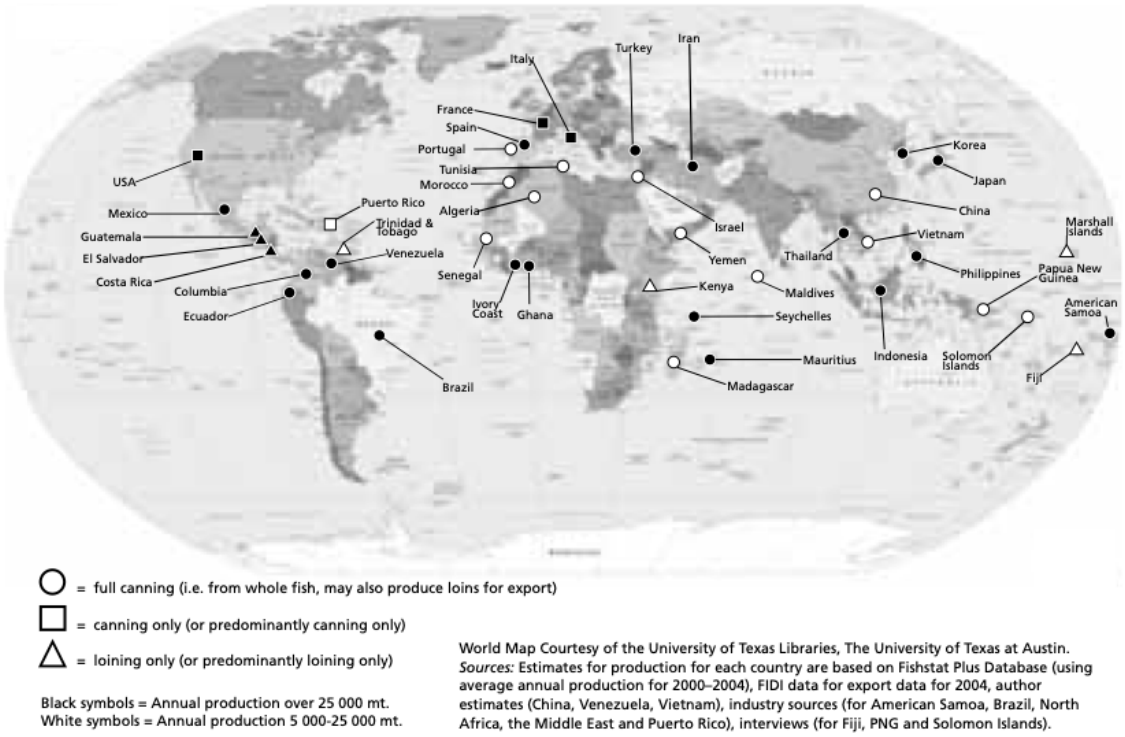

Figure 3. *Locations of global tuna processing capacity as of 2006 (Miyake et al., 2010).*

As mentioned, increases in purse seiners have primarily driven the expansion of tropical tuna fisheries over the last 75 years, and more recently, purse seiners have increasingly relied on the use of drifting fish aggregating devices (dFADs) (Davies et al., 2014; Maufroy et al., 2017). While dFAD use has revolutionized tropical tuna fisheries due to increased efficiency (Davies et al., 2014), there are increasing environmental impacts associated with unregulated growth, resulting in an increased management focus across all tRFMOs. The major impacts of dFADs include habitat degradation, marine pollution, bycatch, net entanglements, overexploitation, and juvenile catch. Approximately 40% of dFADs end up outside fishing grounds (Imzilen et al., 2022) and become abandoned, lost, or discarded (ALD) gear. The high number of ALD dFADs has

spurred questions surrounding whether dFAD abandonment is illegal under international law (Schatz, 2024a). Once ALD, dFADs have the potential to enter and damage coastal habitats (Maufroy et al., 2015; Moreno et al., 2018; Uyarra et al., 2023) and break down into microplastics that can impact food webs (Simmonds & Nunny, 2022) and human health (Smith et al., 2018).

Purse seine fishing around dFADs also results in high bycatch levels due to the large congregation of species around these objects (Dagorn et al., 2012; Murua et al., 2021), especially compared to purse seine fishing on free schools (Filmalter et al., 2013). It should be noted that the bycatch to target species catch ratio is low relative to other gears, but due to large catch volumes using dFADs, their use may still impact overall biodiversity if caught at unsustainable levels or through selective removal (Dagorn et al., 2012). Net entanglements also negatively impact marine species diversity through ghost fishing; however, all tRFMOs have outlawed dFADs with entangling designs (Simmonds & Nunny, 2022; Zudaire et al., 2021). Lastly, there is potential for overexploitation due to large fish aggregations around dFADs, especially for YFT and bigeye tuna, as almost all YFT and bigeye tuna caught around dFADs are juveniles (Pearce et al., 2023). While the Indian Ocean purse seine fleet is a smaller proportion of the total fishery compared to other ocean basins, the IOTC still considers dFAD use as a significant threat to stock health and the environment and has a Working Party on Fish Aggregating Devices to help determine management actions.

Stock Assessments and Management Tools

UNFSA outlines principles for RFMO management including adoption of CMMs (UNFSA, 1995, art. 1), use of the precautionary approach (UNFSA, 1995, art. 6), management procedures and limit reference points (UNFSA, 1995, ANNEX II), and data collection and stock assessments (UNFSA, 1995, art. 14) that all aim to ensure fish populations remain at a level producing MSY while considering other species in the ecosystem (UNFSA, 1995, art. 5). RFMOs still utilize these tools, among others, for promoting the conservation and sustainable use of fish species, however, across RFMOs their implementation in practice is quite varied. Of note, while managing for MSY has been criticized due to its inability to deliver sustainable fisheries (Mace, 2001), recommended MSY was used in this analysis due to its widespread use within

international fisheries management as well as its adoption within UNCLOS and UNFSA. More specifically, in IOTC, stock assessments produce a recommended MSY, which is used to provide management advice based on target and limit reference points and determine the TAC.

To achieve their management goals, RFMOs provision their scientific committees to oversee and develop research programs based on the Commission agendas, with a central feature being stock assessments. Stock assessments estimate fishery population levels through modelling based on biological indicators (e.g., catch-per-unit-effort, size-at-age, spawning biomass, age, length, etc.) (Maunder & Punt, 2013). Over time, stock assessment methodologies have evolved, with a movement towards integrated methods such as Stock Synthesis modelling, which allow scientists to analyze multiple data sources and assumptions simultaneously. These assessments allow scientists to estimate biological aspects of the fishery, which helps estimate a TAC (Hilborn, 2003) and provide management advice (Punt et al., 2020).

Scientific Committees associated with tRFMOs use stock assessments to estimate the overall health of the fish populations under their jurisdictions and provide management advice (Kell et al., 2015). Additionally, they plot fishing mortality (F) relative to mortality at MSY (Fmsy) and spawning stock biomass (SSB) relative to SSB at MSY (SSBmsy) on KOBE II matrices to show whether the stock is overfished, subject to overfishing, both, or neither (Figure 4). In the IOTC, overfished and subject to overfishing statuses are based on target and limit reference points established through CMM 15/10. These calculations include a degree of uncertainty, and models provide a percent likelihood of where the stock is on the plot, with a higher percentage indicating greater likelihood.

Target and limit reference points provide managers with checkpoints to further evaluate population health and compare it to a desired state (PEW Charitable Trusts, 2016). Target reference points represent what managers strive for, whereas limit reference points are the “danger zone” for sustainable resource use (PEW Charitable Trusts, 2016). When combined with KOBE II quadrants, reference points can outline when tRFMOs require management action to return population levels to the desired state. The IOTC has agreed to target and limit reference points for all species, with their targets

being biomass at MSY and mortality at MSY and limits being 0.4*biomass at MSY and 1.4*mortality at MSY (IOTC, 2015d). Despite criticism onThe IOTC Scientific Committee provides management advice and recommendations based on these reference points and the KOBE II plot quadrant. Additionally, reference points represent a key step towards establishing a management procedure, or harvest strategy, for a fishery.

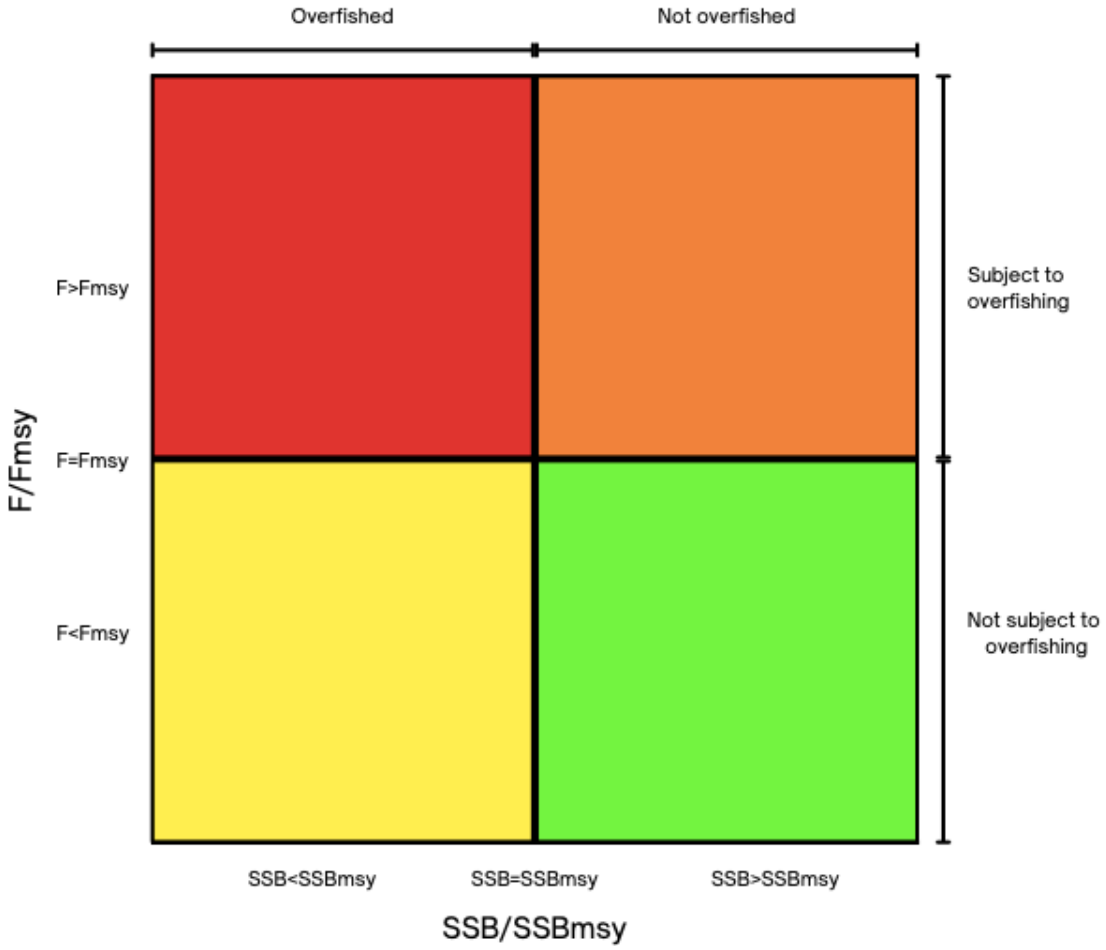

Figure 4. *Overview of KOBE II plot designations.*

Harvest strategies, or management procedures, represent a proactive and systematic approach to fisheries management. First developed in the 1980s, harvest strategies can help manage trade-offs between maximizing catches, minimizing catch variability, and promoting resource longevity (Butterworth, 2007). Harvest strategies are composed of management objectives, reference points, population monitoring and indicator assessment, and harvest control rules that set and modify fishing opportunities (Holmes & Miller, 2022). These elements are all interrelated and provide a management

process that allows for long-term catch sustainability based on fishery status (Galland, 2023). After setting a harvest strategy, researchers can test their effectiveness through management strategy evaluation (Galland, 2024). While they require lengthy development times that are subject to Member State negotiations, once they are adopted, they can reduce negotiation times for initiating management action (Butterworth, 2007). CCSBT was the first tRFMO to adopt a harvest strategy for tuna species in 2011 with great success, and other tRFMOs have since adopted them to promote population growth and TAC increases (Holmes & Miller, 2022). IOTC Member States have yet to agree to a harvest strategy that dictates actions promoting YFT recovery into the green zone of the KOBE II plot (ISSF, 2024); however, they do have harvest strategies for bigeye (IOTC, 2022) and skipjack tunas (IOTC, 2024d). With the scientific committee completing YFT stock assessments every three years, IOTC Member States must renegotiate YFT TAC to reflect the estimated MSY, leaving it vulnerable to short-term economic goals.

Chapter 3: Method

Economic Assessment

To examine the potential future cost of ineffective management efforts, the economic values of reported (nominal) catches (IOTC, 2024a) and potential catches at projected MSY were compared over an eight-year span (2015-2022). In the MSY valuation, catch proportions between gear types were assumed to be the same as for nominal catch data, representing equivalent proportions going towards fresh, frozen and canned markets across the two catch levels. Although a simplification, this assumption is based on the idea that under an allocation framework, States would receive the same relative proportion of overall catches under a lower catch level. This means that in a reduced catch scenario, it is assumed that catches would not be redistributed between fleets or States. With no information to suggest otherwise, this seemed the most parsimonious assumption to make.

Catch proportions for each market were calculated using nominal catch for each year based on catch levels across gear types (Table 2), with the general assumption that longline-caught fish went into frozen markets, handline-caught fish went into fresh markets, and all other gears went into canned markets, although these are simplifications. Each year, proportions were calculated for nominal catch, recommended MSY, and high and low MSY estimations (from stock assessment). As stock assessments for YFT are calculated every three years, I used the same MSY estimations in three-year periods (2016 MSY for 2014-2016, 2018 MSY for 2017-2019, and 2021 MSY for 2020-2022). While the WPTT completed a stock assessment in 2015, I used the 2016 assessment as the stock was reassessed using a new longline cost-per-unit-effort series and updated catch estimates for 2014, which resulted in a more optimistic stock status.

Catch proportions were then multiplied by their annual market price and added together to get a total landed value for the fishery each year under nominal catch and suggested MSY catches. To estimate an annual market price, I used the IOTC import price data from the Fisheries Development Division of the Pacific Islands Forum Fisheries Agency (FFA) for Thai (canned; USD/t) and Japanese (fresh and frozen; Yen/kg) imports (FFA, 2023). As this dataset is in months, I averaged across months to create one annual value for each market (fresh, frozen, canned) and then converted to

USD (using: https://www.exchange-rates.org/) and metric tonnes before adjusting for inflation (using: https://www.usinflationcalculator.com) so that all market prices were in 2022 USD/t. Once multiplied by each catch proportion (canned, fresh, and frozen), the values were summed together for each year and catch scenario (nominal catch vs MSY) to get an overall value for each year and scenario (Figure 5).

Table 2. *Outlines which gear types fed into fresh versus frozen international markets in the catch proportion calculations. All gears not listed were included in the canned tuna market.*

Gear	Gear Group	Market
Longline targeting swordfish	Longline	Frozen
Longline (fresh)	Longline	Fresh
Handline	Line	Fresh
Handline + troll line	Line	Fresh
Handline (offshore)	Line	Fresh
Longline	Longline	Frozen
Coastal longline	Longline	Frozen
Exploratory longline	Longline	Frozen
Coastal longline + troll line	Longline	Frozen

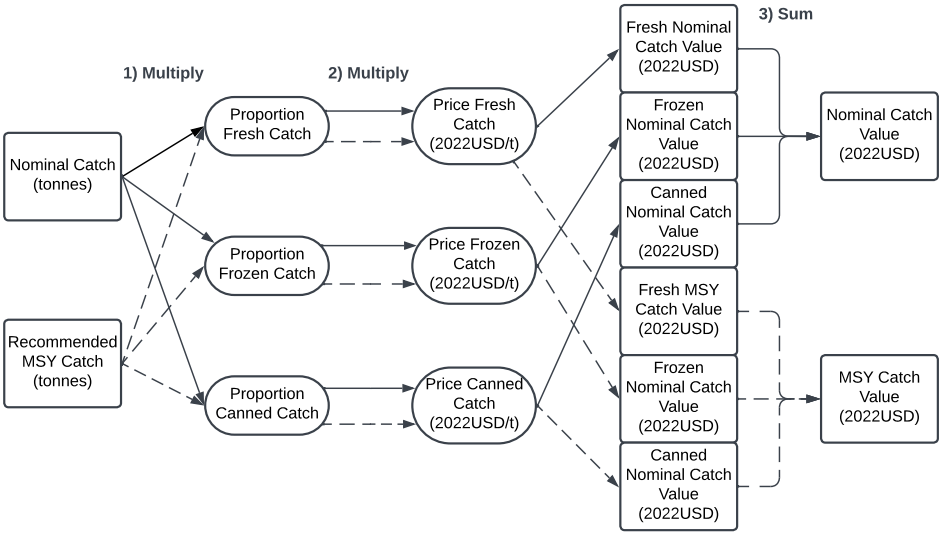

Figure 5. *Flowchart of annual value calculations for nominal catches (solid lines) and recommended MSY catches (dashed lines).*

Note. Squares indicate values that are unique to each stream of calculations (nominal catch versus recommended MSY). Ovals indicate values that are the same for both streams.

Datasets

All data used in these analyses were taken from IOTC stock assessments, datasets, and compliance reports (Table 3). For consistency, I used Stock Synthesis 3 model data from the stock assessments for our MSY-based calculations, as they were used for providing management advice to the IOTC Scientific Committee.

Table 3. *Outline of data used in analyses.*

Data	Source	Last Updated
Nominal catch for all species, including bycatch	https://iotc.org/data/datasets	Jun 17, 2024
Import prices for tuna	https://iotc.org/data/datasets	Oct 20, 2023
2015 Stock Assessment	WPTT17 Report	
2016 Stock Assessment	WPTT18 Report	
2018 Stock Assessment	SC21 Report	
2021 Stock assessment	WPTT24 Report	

Assumptions

In the analysis, I assumed that the Indian Ocean YFT population is one stock for management purposes. In the catch data, all catches classified as "NEI" were removed from calculations as these were not attributed to specific IOTC Member States. Lastly, it is noted that the valuation of the Indian Ocean YFT stock is likely an overestimation of actual gross value, as some YFT go into local markets and not international ones. While this may indicate inaccuracy, I believe that the differences between nominal catch and MSY values would remain the same due to a lack of redistributed catches under the estimated MSY catch scenario.

Literature Review and Policy Analysis

To understand IOTC YFT management action, a literature review was conducted using IOTC governance documents and meeting reports, YFT stock assessments and CMMs relating to YFT and dFADs from 2015-2024. Additionally, to understand IOTC governance and management, I used participant observations at the 25th and 26th Sessions of WPTT, 6th Session of the Working Group on FADs (WGFAD), and 1st Session of the Working Party on Socioeconomics (WPSE), and non-participant observations at the 28th

Session of the IOTC and 13th Meeting of the Technical Committee on Allocation Criteria (TCAC). The difference between these meetings is that in Working Party/Group meetings, official observers can participate in and contribute to the meeting proceedings as equals to Member State delegates. In contrast, they do not have this status at Commission and TCAC meetings, which require credentials.

To estimate the compliance with and effectiveness of YFT-associated CMMs, I compared nominal catch levels by country to 2014 catches. 2014 was used as the reference year because it is the final year before the YFT designation as overfished and subject to overfishing and CMM 16/01 uses 2014 catches as the reference for catch reductions (IOTC, 2016). This reference year changes across YFT CMMs, however, we used 2014 as a standard for comparison across all years. Catch data came from the IOTC nominal catch dataset (Table 3).

Chapter 4: Ten Years of IOTC Yellowfin Management

In this chapter, I synthesize the science, management measures, catches, and economic output related to Indian Ocean YFT fisheries over the past decade. The synthesis is organized in three-year increments, as new stock assessments are done on this interval.

2014-2016: Initial Red Status

In 2015, the IOTC's WPTT conducted a stock assessment that determined the YFT population was in the red zone of the KOBE II plot (94% probability), meaning it was both overfished and subject to overfishing (IOTC-WPTT, 2015). This designation was primarily due to increased fishing mortality (average catch from 2012-2014 is ~100,000t more than 2009-2011) and a declining longline catch-per-unit-effort. In 2016, WPTT undertook an additional stock assessment and found that YFT was still in the red zone but with a more optimistic probability (67.6%) (IOTC-WPTT, 2016), meaning that there was a lower probability of the stock being both overfished and subject to overfishing. Interestingly, however, in both 2014 and 2015, the catch is below the lower MSY estimate that was determined through the stock assessment (Figure 6). Therefore, Member States were not maximizing the benefits they could have received from the fishery (Figure 7). Despite the red KOBE II plot designation, this demonstrates that the fishery was not maximally exploited until 2016 when the actual catch and MSY are almost equal. It should be noted that the nominal catch values only represent reported catch, and therefore, some catches would not be included (e.g., illegal, unreported, unregulated fishing). Without the inclusion of these catches, the fishing mortality could be higher than MSY despite what is shown here.

In terms of YFT management, the 2015 stock assessment noted that there were no CMMs to regulate YFT overexploitation outside of 15/08 (IOTC, 2015c), which implemented FAD limits, introduced efforts towards biodegradable and non-entangling design of drifting FADs (dFADs), and outlined dFAD management plans (all except FAD limits have yet to be fully implemented). Indirectly, there were other CMMs passed in 2014 and 2015 that would aid YFT management and population recovery, including resolutions establishing an allocation system (14/02 – negotiations still ongoing in 2024) (IOTC, 2014), outlining data requirements for FADs (15/02) (IOTC, 2015a), requiring purse seine vessels to retain YFT on board unless unfit for human consumption (15/06)

(IOTC, 2015b), and describing MSY-based target and limit reference points (15/10) (IOTC, 2015d). In 2016, IOTC Member States adopted their most direct and comprehensive YFT management measure in CMM 16/01, which first went into effect starting in 2017. Resolution 16/01 outlines a YFT rebuilding plan specific to vessels over 24 m and vessels under 24 m fishing outside of their country's EEZ, meaning it targets industrial fishing efforts over artisanal (IOTC, 2016). It also specifies YFT catch reductions (between 5-15%) based on gear type. For purse seine vessels, it also reduces the dFAD limits and outlines that IOTC Member States must limit their number of supply vessels to half of their purse seine fleet. It should be noted that the IOTC Scientific Committee advised for a 20% reduction in YFT catch in 2015, so 16/01 includes a more modest reduction. In 2016, however, the Scientific Committee amended their recommendation to a 15% catch reduction. Despite these CMMs, the estimated MSY through stock assessments decreased moving into the 2017-2019 period.

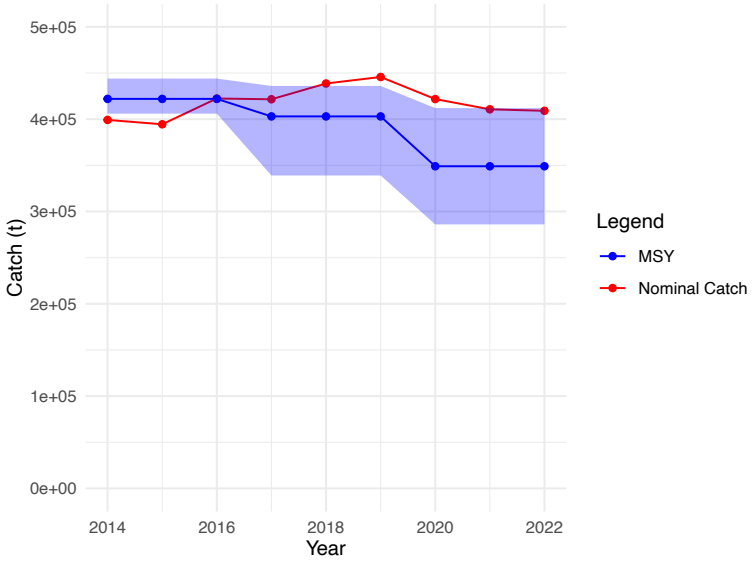

Figure 6. *Catch data for Indian Ocean yellowfin tuna plotted against recommended maximum sustainable yield (MSY).*

Note. Recommended MSY values sourced from WPTT stock assessment reports from SS3 models. The assessments were completed based on data up until 2015, 2017, and 2020 respectively, with reports released in 2016, 2018, and 2021. There was a stock assessment done in 2015, however, it was reassessed in 2016 with more reliable longline catch data. MSY values were used across triannual periods based on assessment completion and the data used. The shaded area do not represent statistical probability, but speak to the accuracy of the stock assessment using the upper and lower MSY estimates from each assessment.

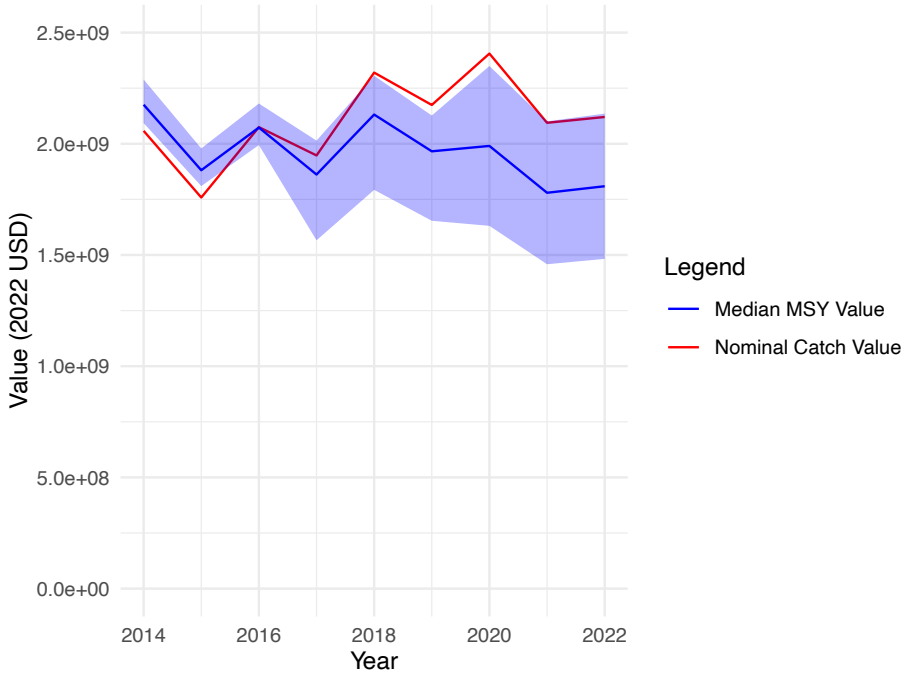

Figure 7. *Value of the yellowfin tuna fishery based on import fish prices from Japan (fresh and frozen) and Thailand (canned) in 2022 USD for actual catch and for catch at recommended MSY.*

Note. The ribbon does not represent uncertainty in the estimated value, but instead demonstrates value calculations for the upper and lower MSY estimations for each stock assessment period.

2017-2019: Attempts at Management and Rise of Oman

In 2018, the WPTT conducted another stock assessment to again find that YFT was in the red zone of the KOBE II plot (94% probability) (IOTC-SC, 2018). While the result is similar to the 2015 stock assessment, it is more pessimistic than the 2016 one. Additionally, this stock assessment had data issues, so the Scientific Committee provided no management advice. Due to a lower MSY estimation from the stock assessment, this period shows nominal catch as higher than the MSY (Figure 6), with the value difference of actual catch and catch at MSY growing from 2017-2019 (Figure 7). In 2019, both nominal catch and the value of the nominal catch fishery lie outside of the upper MSY estimation. This is likely due to an increase in nominal catch over this period, regardless of CMMs designed to improve stock biomass and promote stock recovery.

Despite CMM Resolution 16/01, most IOTC Member States maintained or increased their catch levels, including those that should have reduced under 16/01 (Table

4). Of the countries covered under 16/01, the only ones who reduced their 2017 YFT catch by the amount specified were India, Korea Republic, and Taiwan (China). Additionally, France and Spain reduced their catch (11% and 6 % respectively), but not by 15%. As a result of other Member States' increased catches, the overall YFT catch for IOTC remained the same in 2017 as in 2016. Another problem associated with implementing quotas in 16/01 was that purse seine fishing behaviour moved towards favouring dFAD-associated schools over free-swimming schools. This change represents a shift towards catching and overexploiting juvenile YFT, meaning that while purse seine vessels maintained their catch tonnage, an increased proportion of juveniles were caught. This shift is believed to have occurred because purse seine vessels wanted to avoid using up their YFT quota prior to catching skipjack tuna, the target fish surrounding dFADs.

While this result does not necessarily affect the purse seine economic structure, as their catch goes towards canneries regardless of school type, it may have affected the long-term stability of the YFT population and risk stock recovery. Several countries did reduce their catch levels; however, these reductions were likely offset by other countries increasing their catch. During this period, 16/01 underwent three subsequent revisions (17/01, 18/01, 19/01). In these revisions, the quota calculations largely remained unchanged, with catch reductions ranging between 5-15% and only applying to vessels over 24 m and vessels less than 24 m operating outside a country's EEZ (IOTC, 2017, 2018, 2019). It should be noted that India objected to 19/01, so 18/01 still applies to them. The main differences in 19/01 are that it specifies punishments for catching over quotas, includes a phasing out of gillnets, and outlines a plan for improving the YFT assessment (IOTC, 2019).

Table 4. *State catches relative to 2014 catch levels in the years following the implementation of IOTC Resolutions 16/01 (effective 2017), 17/01 (effective 2018), and 18/01 (effective 2019).*

Fleet	2014 Catch (t)	Catch Relative to 2014		
		2017/2014	2018/2014	2019/2014
Australia	19.39	3.41	1.99	2.34
China	1077.68	2.75	4.31	2.98
Comoros	1399.02	3.44	2.28	3.77
France (EU)	33513.22	0.89	0.90	0.81
Mayotte (EU)	195.25	0.45	0.14	0.57
Reunion (EU)	417.36	1.35	1.49	1.33
Portugal (EU)	149.77	0.35	NA	NA
Spain (EU)	58228.55	0.94	0.80	0.73
India	33427.24	0.42	1.12	1.00
Indonesia	25238.90	1.07	0.90	1.41
Iran	46215.51	1.21	1.27	1.26
Japan	4072.50	0.98	0.83	0.62
Jordan	17.00	0.88	0.82	0.65
Kenya	71.31	2.65	50.26	51.25
Korea (Rep)	10345.00	0.79	0.68	1.04
Madagascar	734.67	0.96	0.95	0.97
Malaysia	77.32	4.96	5.77	5.53
Maldives	49207.95	1.00	0.96	0.91
Mauritius	4908.07	1.63	2.37	2.58
Mozambique	5.39	31.22	28.83	49.88
Oman	7207.70	2.69	4.00	5.14
Pakistan	14452.00	1.76	1.14	0.47
Philippines	69.22	1.05	NA	NA
Seychelles	25079.30	1.84	1.68	1.74
South Africa	83.05	2.98	3.99	4.68
Sri Lanka	37768.60	1.01	1.05	1.19

Fleet	2014 Catch (t)	Catch Relative to 2014		
		2017/2014	2018/2014	2019/2014
Taiwan (China)	12285.28	0.74	0.88	0.77
Tanzania	3441.50	1.13	1.13	1.13
Thailand	186.81	NA	NA	NA
United Kingdom	85.86	0.24	0.10	0.17
Yemen	29180.40	0.62	0.62	0.62

Note. Numbers greater than one indicate catch increases, where numbers lower than one indicate catch decreases. "NA" indicates that there were no YFT catches for that fleet in that year. Removed data for Belize, East Timor, UK Territories, Egypt, Djibouti, and Bangladesh.

As mentioned, the IOTC catch increased over this period, mainly due to the increased catches of certain Member States while others are reducing their catches in line with YFT quotas. Compared to 2014 catches, several countries increased their catches by more than 1000t by 2019 (Table 4), including China (298%, 2135 t), Comoros (377%, 3880 t), Indonesia (126%, 10314 t), Kenya (5124%, 3583 t), Mauritius (258%, 7773 t), Oman (513%, 29825 t), Seychelles (174%, 18629 t), and Sri Lanka (118%, 6987 t). Resolution 19/01 specifies that the measure now applies to countries now catching greater than the limits outlined, if they were not already above them in 2014 (IOTC, 2019). However, at this point the Resolution still only applies to fleets with certain sized vessels, so it does not necessarily apply to the States with large catch increases.

Notably, this oversight in the resolution allowed for a reallocation of catches from the States that abided by the measure and reduced catches to others, such that the management measures become less effective and benefits towards stock recovery are not seen. There are also questions as to whether some of these States are overreporting catches to get a more favourable allocation of quota when that process is finalized. Specifically, for Oman, while catch has increased substantially, other sectors of the industry have not changed (e.g., local consumption, fleet size, and exports) (Committee on Compliance, 2023). This may indicate they want to expand their sector to provide space for new purse seine vessels. If Member States had reduced their catches in line with

Resolutions 16/01, 17/01, 18/01, and 19/01, the overall economic output of the fishery would also have seen a decrease; however, earlier action to promote stock recovery would have allowed for a faster recovery. This means that the cost of action would have been a shorter-term cost, with the benefit being future catch increases. What you can see here, however, is a growing cost of inaction demonstrated by the increasing gap between the value at nominal catch and the value at recommended MSY. This indicates that the longer the IOTC takes to implement meaningful action towards stock recovery, the higher the economic cost will be.

In this period, the first meeting of the WGFAD occurred in 2017, demonstrating the IOTC's understanding of the importance of FAD management due to their potential impacts on YFT stock health and the environment, especially with the increase in dFAD use in the Indian Ocean. It should be noted that the second WGFAD meeting was not until 2021.

2020-2022: Increasing pressure

In 2021, the WPTT completed a stock assessment finding that YFT was still in the red zone of the KOBE II plot (68% probability), with the MSY having decreased almost 75,000 t since the 2015/16 stock assessments to 349,000 t (286,000-412,000 t) (IOTC-WPTT, 2022). During this period, YFT catch levels averaged over 60000 t more than the median MSY (Figure 6), further increasing fishing pressure on the YFT population. In 2020, the nominal catch is higher than the upper MSY estimate, while in 2021 and 2022, catches are similar to the upper estimate. As such, the difference in economic value between the two catch scenarios continues to grow in this period (Figure 7), such that the value at MSY is reduced by 15-17% compared to the value of the actual catch (Figure 8). This indicates an increasing cost of continued inaction, where if countries were to drop their catch in line with MSY, they would experience a higher economic cost than they would have if the IOTC took meaningful action to increase the stock in the 2014-2016 or 2017-2019 periods.

Over this period, the only CMM the IOTC adopted regarding YFT recovery was Resolution 21/01 (superseded 19/01). This Resolution saw an expansion of the previous iterations such that it now applies to all IOTC Member States, rather than just those with vessels > 24 m and those < 24 m fishing in the high seas (IOTC, 2021). For States that

caught more than 5000 t in 2014 or averaged more than 5000 t between 2017-2019, catch reductions ranged between 10-21%. Those below 5000 t in 2014 were not to exceed either 2000 t or their maximum catch between 2017-2019, depending on their average catch from 2017-2019. The Resolution remained the same as 19/01 for overcatch penalties, supply vessel specifications, and phase-out of gillnets; however, it does specify that the Secretariat prepares allocated catches annually in December for the following year. Following the Commission, India, Indonesia, Oman, Madagascar, and Somalia objected to this Resolution. That being said, Resolution 18/01 still applies to India and Resolution 19/01 still applies to Indonesia, Oman, Madagascar, and Somalia.

In the 2020-2022 period, catches decreased compared to the 2017-2019 period but remained higher than the 2014-2016 average. The 2021 stock assessment showed that if Member States reduced catches to less than 70% of 2020 levels, there was a 67% probability of stock recovery above MSY by 2030 (IOTC-WPTT, 2022), which is a more significant catch reduction than outlined in Resolution 21/01. While several countries reduced their catches throughout this period, the increased catch of other Member States resulted in the average catch for this period remaining over 410,000 t. The top reducers in 2022 compared to 2014 levels, with catches over 1000 t in 2014 and in line with Resolution 21/01, were Spain (27%), France (28%), India (38%), Yemen (38%), Maldives (43%), Republic of Korea (59%), Pakistan (62%), and Japan (64%) (Table 5). Comparatively, the top States who increased their catches compared to 2014, with catch increases over 1000 t, were Kenya (2747%, 1887 t), Oman (1038%, 67593 t), China (341%, 2599 t), Comoros (316%, 3028 t), Mauritius (228%, 6283 t), Indonesia (190%, 22786 t), and Seychelles (143%, 10747 t). Of these, Oman accounts for almost 60% of the increase in catch. Compared to the 2017-2019 period, Oman still saw no changes to other aspects of the YFT industry, with the possibility that they increased their catch to receive a higher proportion of the allocated quota once States agree to an IOTC allocation regime. Of those who increased their catches, Indonesia and Oman were the only ones who objected to 21/01, so this Resolution still applies to the others listed. With the maintained catches overall, it is expected that MSY will continue to decrease upon completion of the new stock assessment in 2024.

Table 5. *State catches relative to 2014 catch levels in the years following the implementation of IOTC Resolutions 19/01 (effective 2020) and 21/01 (effective 2022).*

Fleet	2014 Catch (t)	Catch Relative to 2014		
		2020/2014	2021/2014	2022/2014
Australia	19.39	0.85	1.07	0.87
China	1077.68	3.44	2.51	3.41
Comoros	1399.02	4.82	3.49	3.16
France (EU)	33513.22	0.73	0.85	0.72
Mayotte (EU)	195.25	0.40	0.82	0.94
Reunion (EU)	417.36	1.56	1.57	1.22
Spain (EU)	58228.55	0.76	0.76	0.73
India[a,b]	33427.24	0.62	0.73	0.62
Indonesia[b]	25238.90	1.23	1.55	1.90
Iran	46215.51	1.05	0.96	0.84
Japan	4072.50	0.47	0.24	0.36
Jordan	17.00	0.35	0.59	0.59
Kenya	71.31	4.07	4.70	27.46
Korea (Rep)	10345.00	0.36	0.60	0.41
Madagascar[b]	734.67	0.96	0.96	0.96
Malaysia	77.32	4.84	5.05	4.38
Maldives	49207.95	0.87	0.50	0.57
Mauritius	4908.07	1.99	1.98	2.28
Mozambique	5.39	21.59	48.05	13.95
Oman[b]	7207.70	9.54	10.41	10.38
Pakistan	14452.00	0.36	0.39	0.38
Seychelles	25079.30	1.58	1.36	1.43
South Africa	83.05	2.61	3.70	3.96
Sri Lanka	37768.60	0.98	0.83	0.79
Taiwan (China)	12285.28	0.74	0.80	0.83
Tanzania	3441.50	1.13	1.14	1.01
Thailand	186.81	NA	0.01	0.03

Fleet	2014 Catch (t)	Catch Relative to 2014		
		2020/2014	2021/2014	2022/2014
United Kingdom	85.86	0.07	0.03	0.02
Yemen	29180.40	0.62	0.62	0.62

Note. Numbers greater than one indicate catch increases, where numbers lower than one indicate catch decreases. "NA" indicates that there were no YFT catches for that fleet in that year. Removed data for Belize, East Timor, UK Territories, Egypt, Djibouti, Bangladesh, Portugal (EU), and Philippines due to zero catches during this period.

[a] Objected to 19/01 meaning that this CMM does not apply (18/01 still does)

[b] Objected to 21/01 meaning that this CMM does not apply (19/01 still does)

2023-2024: Issues Remaining

With a continually decreasing stock and no agreed-upon management procedure or allocation regime, difficulties associated with implementing management measures continue. While some States continue to bear the costs of conservation, they have yet to see any benefit as other States have increased their catches, and overall catches have remained the same. As members continue to promote short-term economic interests over long-term YFT stock health, the potential future cost of effective management action continues to grow. As stated, with the MSY continuing to decrease, the catch reductions needed to promote stock recovery increase, meaning that the economic impact on Member States continues to grow. Additionally, as the stock size continues to decrease, there is a higher risk of population collapse, meaning that the economic output of the fishery would collapse for all States. With questions surrounding the potential overestimation of Oman's catches (Committee on Compliance, 2023; Stamatopoulos, 2024), it is unclear whether overall IOTC catches have been maintained over the last ten years. If nominal catches are actually below the reported amounts, it may indicate a lowered fishery output or higher cost-per-unit-effort than IOTC currently estimates. The WPTT should consider these factors in their 2024 YFT stock assessment.

Overall, the decreasing stock size makes it more difficult to agree on measures promoting stock recovery as countries continue to hold onto their portion of the current quota. This difficulty has become evident through the last ten years of allocation regime negotiations and discussions surrounding the 2024 YFT proposal, which would have

updated Resolution 21/01 in line with management advice. As negotiations continue without meaningful action, the YFT population continues to decrease, perpetuating these issues and increasing pressure on the stock. In 2025, there is potential for a Special Session of the Commission focussed solely on YFT, which could provide an opportunity for the Commission to focus on making decisions and progress concerning YFT management.

General Trends:

Over the last 10 years, IOTC estimates of MSY continue to decrease as the catches are maintained (Figure 6). This trend indicates a growing cost of implementing management actions (in line with scientific advice), with an increasing gap between current economic output and output at estimated MSY (Figure 8), as States increasing their catches match those decreasing theirs in line with adopted CMMs. Over this period, tuna prices have largely remained the same, and with estimated increased costs associated with fishing, this indicates a decreased net value in the fishery; however, costs were not included in this study. With Oman's catch accounting for 60% of the increased catches and associated questions surrounding catch accuracy, the actual IOTC catch could be more in line with the estimated MSY than I show here, but still higher than it. Additionally, if Oman's catch is lower than they report, it could indicate that there are fewer fish to catch. With a decreasing population size, the risk of a population collapse and the associated socioeconomic effects continue to increase. As countries prioritize their short-term economic goals over meaningful action toward population recovery, they continue to risk the long-term population stability and the fishery's economic output.

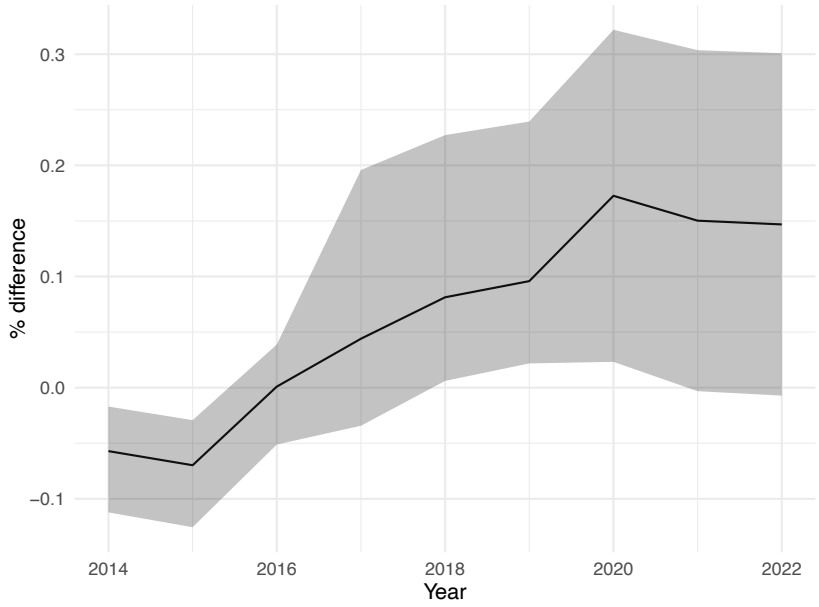

Figure 8. *Percent difference between total value at nominal catch versus at estimated MSY.*

Note. The bands around the black line indicate the % difference between total value at nominal catch versus at the high and low MSY estimates.

Chapter 5: Discussion

Over the past 10 years, the IOTC YFT stock has continually decreased despite several CMMs adopted that implement TACs to avoid further declines. This is potentially due to catches remaining at the same level because while some States have reduced their catches in line with CMMs, others have increased theirs. While the implementation and enforcement of TACs have the best potential for stock recovery (Pons et al., 2017), the IOTC currently lacks compliance across all Member States and adequate enforcement of punishments. Additionally, as time has progressed and proposed management measures attempt to keep up with scientific advice for promoting stock recovery, there have been increased objections to YFT measures and more proposals not being adopted (Figure 1). These factors have an added consequence of reducing the likelihood that Member States who have reduced catches in line with CMMs continue to work towards a new YFT rebuilding plan, potentially because they are carrying the conservation burden without seeing any results for their efforts (personal observation at IOTC's 28th Session). While States agree that there is a need for YFT management, they disagree over who should bear that burden (Augustinis, 2024). Increased objections and lack of new measures may also further indicate a conflict between the economic goals of Member States and stock recovery (Ougier et al., 2024; personal observation at IOTC's 28th Session). As a result of maintained catch levels, the gap between the current economic output of the fishery and the economic output at the estimated MSY continues to grow, demonstrating an increasing potential cost of effective management action. If this path continues, the population will likely continue to decline until States can no longer maintain their catches or the fishery collapses, leading to an economic crash and widespread social impacts among Coastal States.

As this future cost continues to grow, it should be noted that while this study focused on import prices, the consequences and costs of a YFT fishery decline will likely affect all other stages of the value chain within Coastal States, including primary jobs (i.e., fishers), vessels numbers, processing, transport, exports, and other ancillary activities connected to ports and fishing vessels. Therefore, prolonged negotiations on adequate management increase the burden on Small Island Developing States and Least Developed Countries (IPNLF, 2023). This cost would have a reduced impact

internationally, as Indian Ocean tuna catches do not influence global markets (PEW Charitable Trusts, 2020), meaning that prices likely would not change with decreased YFT catches. As a result, States fishing in the Indian Ocean may put greater efforts into maintaining their catches, which would lead to higher costs-per-unit-effort and lower rent. These additional costs would particularly impact the Coastal States that depend on fisheries resources or are looking to develop their fishing capacity (Hanich et al., 2015), which may result in a potential disproportionate burden on SIDS and Least Developed Countries. Considering that UNFSA (1995, art. 24(c)) and the IOTC Establishing Agreement (1993) both recognize the special requirements of developing States, the IOTC must consider disproportionate burdens in future YFT recovery plans. Research into the potential socioeconomic impacts of new management proposals and continued YFT stock declines on value chains may help alleviate concerns and build consensus toward adoption.

Pressure remains on the IOTC to take effective actions to address compliance with and effectiveness of CMMs to promote stock recovery and avoid an increased cost of inaction before the population declines further. However, RFMO conservation and sustainability progress is hampered by their ability to adopt effective CMMs and the implementation and compliance of adopted CMMs (McDorman, 2005). In the IOTC, there are three main topics impeding progress toward adopting effective CMMs or influencing the effectiveness of current CMMs:

- the connection between science and management and the influence of uncertainty
- current management foci and associated challenges (i.e., dFAD regulation and TAC implementation)
- other management actions that IOTC must prioritize (i.e., allocation, harvest strategy, multi-pronged approach).

Additionally, despite not being included in this study, other external issues may influence future management effectiveness, such as the impacts of climate change. These issues will be discussed below.

Science, Management, and Uncertainty

Fisheries science and management contain vast amounts of uncertainty, which can create conditions where consensus is difficult to achieve (Weinstein et al., 2007). This

uncertainty comes out in stock assessments (Edgar et al., 2024) and catch accuracy (Herrera & Báez, 2018). Under stock assessments, there is a paradigm where scientists estimate the number of fish, which allows RFMOs to decide how many fish States can take. However, there is often no real connection between what stock assessments show and what member countries are catching (McDorman, 2005). Additionally, there is uncertainty surrounding how many fish that States take, particularly for small-scale, artisanal fleets, which result in estimated catch levels that may underestimate actual catch without providing uncertainty values in the reported numbers (Pauly & Zeller, 2016; Yuniarta et al., 2017). Additionally, there are cases of overreported catch estimates in declining populations, which may indicate cause for concern (Watson & Pauly, 2001). In the IOTC context, with such significant catch increases for the Omani fleet and potential overexploitation (Stamatopoulos, 2024), actual IOTC catch levels might be lower than reported, meaning a decreased catch-per-unit-effort. Catch accuracy can influence how managers view the stock's outlook, and therefore, improved monitoring and data reporting, with uncertainty values, may enhance management. These uncertainties are a necessary piece of fisheries science and management; however, they influence the IOTC's ability to reach consensus on management measures and the application of the precautionary approach.

In international governance, consensus-based decisions provide the framework for achieving CMMs. While the IOTC has a voting process (IOTC, 1993), decisions are primarily made by consensus to facilitate good relations and compliance among all Member States and to reduce objections. To facilitate consensus, Member States negotiate through prolonged debates that reduce CMM effectiveness as the lowest common denominator is adopted (McDorman, 2005). In conservation decisions, like those revolving around YFT, there is increased importance on finding consensus to improve the CMM's effectiveness towards achieving stock recovery, but negotiations then result in watered-down measures or objections from Member States. Additionally, negotiations to reach a consensus take time. With only five days to negotiate and adopt CMMs at the IOTC Commission meetings and multiple proposals on the table, some do not get the attention they need and end up withdrawn. For example, at IOTC28 in 2024, there were 24 proposals and with a focus on adopting a dFAD measure, the proponents of

the proposal outlining an updated YFT rebuilding plan had to defer the proposal due to a lack of consensus (IOTC, 2024b). Overall, while consensus facilitates more buy in to CMM implementation, it also can hamper effectiveness due to prolonged negotiations that result in decreased effectiveness of measures. These issues may partially explain the continued decrease of YFT CMMs over the past 10 years.

Current Management Foci and Challenges

The IOTC's primary foci for YFT stock recovery are establishing TACs and limiting the impacts of dFADs. This is represented through CMMs 16/01, 17/01, 18/01, 19/01, and 21/01 (TAC-focused), and 19/02, 23/02, 23/09, and 24/02 (dFAD-focused).

While implementing a YFT TAC provides a good opportunity to promote stock recovery (Pons et al., 2016), without an allocation regime in place, there could be increased inequity in who receives fishery benefits (IOTC, 2010). Additionally, while renegotiation is required so that the TAC can reflect stock assessment data, it also renders the decision open to political motivations based on individual State's economic and social situations, which has resulted in less effective measures that do not align with scientific advice. Renegotiation also takes time away from other management issues of importance at Commission meetings for both YFT and other IOTC species.

Drifting FADs are a primary focus in YFT stock recovery due to high levels of juvenile catch (Pearce et al., 2023); however, dFAD management also provides other benefits to Indian Ocean ecosystems. DFAD management has focused on limits, tracking, biodegradability, entanglements, and closures. For YFT, the most critical management options for recovery are dFAD limits to reduce fishing opportunities on dFADs (lower juvenile catch), tracking (to determine the extent of dFAD use), and closures. From a closure perspective, while a 3-month fishery closure offers the best chance for YFT recovery, a 3-month dFAD closure represents the best single-gear approach to recovering YFT. Additionally, it is the only single-gear closure that would recover the stock to the green quadrant of the KOBE II plot by 2030 (Correa et al., 2023). All other tRFMOs overseeing tropical tuna management have implemented dFAD closures (IPNLF, 2023). However, it should be noted that in 2023, the WCPFC reduced their FAD closure period from 3 to 1.5 months in EEZs and from 5 to 2.5 months on the high seas (Haas, Azmi, & Davis, 2024), with States discussing the potential disproportionate burden of FAD

closures and research suggesting that FAD closure removal would not result in effort increases (WCPFC, 2023).

A single gear closure would reduce the overall social and economic impacts on IOTC States from a full fishery closure or a fishery collapse. However, it may damage the economies of the EU, Seychelles, Mauritius and Madagascar (Guillotreau, Salladarré, et al., 2024). This reasoning suggests that the socioeconomic impact on a few States outweighs the ecological, social, and economic benefits for all IOTC Member States under a recovered YFT stock; however, under consensus-based decision-making, the closure will not be effective if these States do not agree to it. Additionally, some argue that the focus on reducing juvenile catches to promote sustainability represents an oversimplification of the problem at hand and may lead to adverse fishery outcomes (Zimmermann et al., 2023). It is correct that reducing juvenile catches will not recover YFT stock alone; however, it does represent a piece of the puzzle that will begin rebuilding the population and will allow further juveniles to reach adulthood and reproduce, one of three rules of fisheries management (Froese et al., 2016). While Resolution 24/02 addresses several environmental concerns associated with dFAD use, a 3-month closure was removed from the final iteration (IOTC, 2024c). The IOTC focus on dFADs represents a focus on how a single gear impacts the YFT stock health, which may provide one path towards stock recovery, but it also may result in further objections that limit effectiveness. Therefore, while important, the IOTC should determine other measures that promote stock recovery while equitably distributing the conservation burden across the fishery.

While these two foci represent pieces of the YFT stock recovery puzzle, the overall IOTC approach is a patchwork of measures that Member States negotiate one at a time, with limited effectiveness in the CMMs adopted. Additionally, the IOTC has focused on single species and gears rather than looking at more comprehensive approaches that consider ecosystem impacts, which can result in adverse consequences. For example, with the adoption of Resolution 16/01 and subsequent implementation of a YFT TAC, purse seine fishing vessels changed fishing behaviours to prioritize dFAD fishing (Tolotti et al., 2023). This behaviour change increased juvenile YFT catches and silky shark bycatch. The consideration of multiple gears in management would also allow

Member States to better understand interactions and trade-offs between gear types when negotiating and making management decisions.

In one such example, the industrial longline and purse seine fleets are in an economic and biological trade-off because they target similar species at different life stages, and the resulting catches enter different markets (Sun (Jenny) et al., 2019). Incorporating socioeconomic indicators would help the IOTC make decisions based on management objectives for ecological health, economic prosperity, and social equity outcomes. Lastly, without systematic components to guide management objectives and actions, these approaches result in the IOTC driving blind and hoping that the new measure they adopt will be good enough. Incorporating systematic frameworks for allocation and a harvest strategy would likely help boost management outcomes.

Other Management to Prioritize

With respect to current CMM negotiation and adoption, IOTC management is a patchwork approach that requires negotiation at each step, mainly due to the lack of overarching management strategies that would provide a systematic component to management. This approach leaves CMM negotiations open to political interference, which reduces trust, certainty and transparency (Seto et al., 2021) while taking up long periods of time to find consensus on important issues (Holmes & Miller, 2022).

Two current gaps in IOTC YFT management include a systematic allocation regime and a harvest strategy. The IOTC TCAC was first established in 2010 under Resolution 10/01 (IOTC, 2010) with the acknowledgement that the "implementation of a TAC without a quota allocation would result in an inequitable distribution of the catches and fishing opportunities among IOTC Members." Fourteen years later, negotiations surrounding an IOTC allocation regime are still ongoing, with a significant debate among States being attribution of historical catches (Andriamahefazafy et al., 2024; Sinan & Bailey, 2020). The current expected timeline is to have an agreement in 2026 and an adopted allocation framework at the Commission in 2027 (Hanich, 2024). The IOTC has yet to adopt a harvest strategy for YFT, however, focusing on developing one may aid in allocation negotiations (Holmes & Miller, 2022) and promote a systematic management approach that ensures the long-term sustainability of the fishery (Galland, 2023). A harvest strategy would also provide the IOTC with an agreed-upon set of management

actions under various stock scenarios to facilitate quick and comprehensive management responses. Currently, of the components of a harvest strategy, the IOTC conducts population monitoring via stock assessments and has adopted target and limit reference points for YFT. This means that they would still need to set an objective and determine harvest control rules before developing a functional harvest strategy. Addressing issues of allocation and implementing a comprehensive harvest strategy will free up negotiation time at Commission to begin focusing on other issues relating to YFT management (Holmes & Miller, 2022; Wilson et al., 2023), as the IOTC would not have to renegotiate YFT rebuilding plans almost annually, and management would potentially line up better with scientific advice. Notably, this may allow the IOTC to broaden their perspective outside of single species or single gear approaches to consider a multi-pronged management approach that considers varying ecosystem impacts in promoting YFT recovery.

External Influences

Climate change may further influence future management and the economic and ecological output of Indian Ocean YFT. YFT are sensitive to climatic and environmental variations (Lan et al., 2013), with models indicating past poleward shifts in tropical tuna distributions (Erauskin-Extramiana et al., 2019; Monllor-Hurtado et al., 2017), decreased fishery productivity closer to the equator (Barange et al., 2014). Specifically, Indian Ocean YFT may see biomass decreases of up to 43% moving to 2050 (Erauskin-Extramiana et al., 2023). However, some research indicates potential increases of YFT at low latitudes (Erauskin-Extramiana et al., 2019, 2023), demonstrating uncertainty in climate change futures, which could influence management efforts. Regardless, shifting species distributions would impact Coastal States due to changes in species availability in their EEZs, influencing both social and economic conditions. Additionally, with increasing sea surface temperatures, YFT dive deeper, which can lower fishing availability and increase cost-per-unit-effort (Lan et al., 2013), which lowers the fishery's rent. These effects can be seen in the Indian Ocean with decreased catches in some Coastal States (i.e., Pakistan, India, and the Maldives). In the Maldives, the government announced a reopening of their longline fleet (banned in 2019) to maximize marine benefits and use their YFT quota (Ministry of Fisheries, 2024). Reopening longlining

would have allowed the Maldives to target deeper-diving YFT, however, the Maldivian President announced that the Maldives would not be reopening this fishery due to fishers' and non-governmental organizations' environmental concerns (The President's Office, 2024). This decision would have allowed Maldives to diversify their YFT fishery within its allocated catch limits and provided economic benefit. However, it subsequently would have increased the Indian Ocean's overall catches, further widening the gap between actual catch and estimated MSY. Climate change would particularly affect developing Coastal States and SIDS that rely on YFT for food, income, and revenue (Barange et al., 2014; Robinson et al., 2010), and therefore, these States must be considered in discussions on management and climate adaptation. Climate change will impact Indian Ocean YFT, but because the stock is currently overfished and subject to overfishing, fishing pressure currently has a more significant impact (Erauskin-Extramiana et al., 2023), and therefore, the IOTC must first prioritize reducing fishing pressure.

Chapter 6: Recommendations and Conclusion

To successfully recover the Indian Ocean YFT population while addressing the complexity of the problem at hand, the IOTC could consider the following recommendations:

1. Improved Socioeconomic Research Capacity and Integration into Management

While ecological indicators and norms are well established in fisheries management, socioeconomic indicators are largely not understood, incorporated, or established in international tuna management. This means that the IOTC would need to set norms and determine indicators for understanding how socioeconomic indicators reflect social and economic sustainability and State dependence on the fishery. In 2024, the IOTC WPSE hosted their first meeting in Bangkok, Thailand. This working party provides the potential for upholding IOTC commitments for considering the special requirements of developing States (IOTC, 1993, art. 5.2.d) and considering disproportionate burdens of management actions in management (UNFSA, 1995). Because there is no precedence for the systematic inclusion of socioeconomic data at the tRFMO level, it may take years to fully establish and incorporate socioeconomics into IOTC decision-making.

The approach discussed at WPSE in 2024 may prolong this process, with Member States looking to apply their understanding of ecological indicators to socioeconomic ones, however, they may need to define what economic and social sustainability and performance mean before determining what indicators accurately represent these concepts. The data available for consideration that was presented at WPSE revolved around economic output, whereas data surrounding social factors and economic dependence were lacking. Additionally, the focus was on quantitative data, but to consider social data, they must also consider qualitative data. To better understand what data they need, WPSE must first define how they will evaluate socioeconomic outcomes.

While TCAC has discussed socioeconomic indicators in allocation negotiations for years, there is no clear understanding on how to establish, nor incorporate, socioeconomics into management decision-making. WPSE will likely focus on incorporating socioeconomics into the allocation framework, however, they should also begin considering how to incorporate socioeconomics into other forms of management,

such as harvest control rules, and understanding CMM impacts (e.g., effects of closures on value chains) and trade-offs between conservation and economics. Broadening the scope of WPSE will help the working party begin thinking about what data they need to effectively include socioeconomic data in decision-making moving forward. Here, the WPSE can look to previous socioeconomic research to model and better understand what they are trying to accomplish (e.g., (Barclay et al., 2023; Guillotreau, Dissou, et al., 2024; Willis & Bailey, 2020)), as well as look to other tRFMOs to understand how they incorporate socioeconomic considerations in allocation regimes (Seto et al., 2021).

2. Allocation Regime and Harvest Strategy

Adopting a systematic allocation framework would help to remove the politics of negotiation from allocation decisions while freeing up time to focus on other areas of management. Additionally, it would allow the IOTC to promote equity in fishing opportunities and catches. This regime must consider equity principles to promote reparations for past inequities, avoid a disproportionate burden on Coastal States under conservation scenarios, and provide opportunities for fishery development to developing Coastal States. Most importantly, TCAC must ensure that all members agree to the final allocation CMM, without objections, to ensure the effectiveness of the measure. Negotiations on allocation have been ongoing for 14 years, and it is expected that the IOTC will not adopt a final allocation framework until 2027 (Hanich, 2024). With the already prolonged negotiation timeline, it is recommended that Member States work towards finding consensus and compromising to reach a solution.

In addition to an allocation system, the IOTC should consider working toward developing a comprehensive harvest strategy, or management procedure, that can determine a TAC that considers optimal catch levels across fleets and balance trade-offs between ecological, social and economic factors. With the development of a harvest strategy, there is the potential for broadening IOTC YFT management outside of a single-gear and single-species focus through harvest control rules (PEW Charitable Trusts, 2024), which can also consider socioeconomic factors in decision-making (Barclay et al., 2023). A YFT harvest strategy could follow the management procedures for skipjack and bigeye tunas, and by implementing one, the IOTC could reduce the time and effort

required for renegotiating YFT TAC, while potentially improving their ability to recover YFT and allowing for ecosystem considerations in management.

3. New YFT measure in line with scientific advice

Until the IOTC adopts an allocation regime, a focus on adopting an updated version of 21/01 that effectively promotes YFT recovery remains essential, while ensuring compliance across all Member States. In 2023 and 2024, negotiations ultimately resulted in the proponents dropping their YFT proposals due to a lack of consensus. With several negotiations occurring during Commission across a range of issues, it may be challenging to find time to give this issue the attention it requires to ensure that the final measure is comprehensive enough to address YFT stock declines, promote stock recovery, and reduce disproportionate burdens. The IOTC agreed to a Special Session on YFT if they do not pass a new measure at the Commission meeting in 2025. It is vital that Member States begin negotiations prior to and during Commission, however, a Special Session would allow States to focus solely on YFT recovery, which may improve the IOTC's ability to find consensus and compromise among Member States.

Conclusion

Indian Ocean YFT has been under threat for the last ten years, with the estimated MSY declining approximately 25% since 2015. Additionally, over this time, the IOTC has attempted to implement CMMs that support population recovery, yet these measures have not been effective. This study looked to quantify the potential economic impact of introducing management that aligns with the Scientific Committee's MSY recommendation. Additionally, it looked to understand what factors may be impeding the success of CMMs geared towards recovery. As the population continues to decline, there is an increased risk of States not wishing to agree to new measures as they hold onto their current catch amounts. This may cause a continual decrease of YFT and increase the risks of a population collapse and widespread socioeconomic impacts.

In this study, I compared the initial economic output of the YFT fishery at current catch levels against potential catches at the recommended MSY and evaluated CMMs to understand why the population continues to decline. As time has progressed, the gap between the current fishery value and the value at recommended MSY continues to grow. This may make further management actions more challenging to agree to, as States may

prioritize current economic gains over the long-term sustainability of the fishery. While Member States have agreed to CMMs relating to YFT recovery through the implementation of TACs and dFAD regulations, these measures have been ineffective at reducing catches or spurring recovery, potentially because they do not align with scientific advice. This is potentially a result of negotiations, where political interests impact the adopted measure as States look to reach consensus and improve the CMM's impact. As a result, however, the measures become watered-down in that they do not achieve the catch reductions necessary to spur recovery. Additionally, the measures that the IOTC has implemented do not appear to have effective deterrents for overcatch, resulting in several Member States increasing their catches over the time period. This, in turn, puts the conservation burden on States abiding by the CMMs, who have yet to see benefits for their efforts. Instead, the measures perpetuate further decreases in recommended catch levels, which may make it more difficult to agree to future YFT recovery CMMs.

In looking towards addressing this problem, the IOTC should consider the impacts of science and uncertainty, as well as their current management foci (i.e., TAC and dFADs), as they look towards actions that supplement their current approach. Additionally, the IOTC should build upon their socioeconomic work through the WPSE to better understand the social and economic influences that guide Member States' decision-making and promote management actions that consider these factors. Notably, the IOTC could incorporate these data within a systematic allocation framework and harvest strategy, which would reduce the negotiations required for almost annual TAC assessments (i.e., 16/01, 17/01, 18/01, 19/01, 21/01) while allowing for the IOTC to look at other areas that may improve YFT recovery. Additionally, socioeconomic data would enable the IOTC to better understand the impacts of closures on value chains and Member State economies. While these approaches only represent a portion of the potential paths towards recovery, they provide a step that creates a more systematic framework for it and may reduce the political aspects of negotiations, which could result in improved management actions and YFT recovery that accounts for disproportionate burdens in recovery efforts and improves the long-term sustainability of Indian Ocean YFT fisheries.

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