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Scientific Research and Its Influence in Decision-Making of Tuna Regional Fisheries Management Organizations: Case Studies in the Atlantic Ocean and Indian Ocean

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Abstract: Scientific research has played an important role in the conservation and management of high seas fisheries resources since the adoption and entry into the force of the 1982 United Nations Convention on the Law of the Sea (UNCLOS). In addition, regional fisheries management organizations (RFMOs) have become the most important platform in addressing fisheries-related issues under the contemporary international fisheries legal regime, which also includes the responsibility to ensure that their decisions have to properly incorporate recommendations of scientific research into their decisions. This paper aims to analyze, from a legal aspect, how scientific research plays its role in the formation and adoption of conservation and management measures (CMMs) in RFMOs and finds that scientific research has become an essential and integral part of both International Commission on the Conservation of Atlantic Tunas (ICCAT) and the Indian Ocean Tuna Commission (IOTC). Although, on some occasions, these recommendations will not be totally accepted and adopted by the Commission due to social, economic, and political considerations, the results from scientific research have become the basis for issues related to conservation and management measures discussed in RFMOs and will be more influential if the Scientific Committee provides a more concrete recommendation to the Commission.

Keywords: scientific research; international fisheries legal regime; high seas fisheries management; conservation and management measures (CMMs); regional fisheries management organizations (RFMOs); Scientific Committees; International Commission on the Conservation of Atlantic Tunas (ICCAT); Indian Ocean Tuna Commission (IOTC)

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1. Introduction

The conservation and management of high seas fisheries has been highly concerned since fishing technologies have been significantly improved, which resulted in the tremendous increase in terms of fishing capacity, fishing effort and spatial extent worldwide, and the emergence of distant water fishing nations (DWFNs) [1]. Increasing the fishing capacity of those DWFNs has resulted in a tremendous decrease or even depletion of those fisheries resources [2]. It has been recently indicated by many international organizations, including the United Nations Food and Agriculture Organizations (FAO), that almost 90 percent of global marine fish stocks are now fully exploited or overfished [3,4]. Therefore, how to conserve and manage marine fisheries resources, particularly those on the high seas, has become an important issue in the international community [5].

To this end, scientific research has been expected to be an important element to facilitate better the conservation and management of high seas fisheries resources since the last quarter of the 20th century, particularly after the adoption and entry into the force of the 1982 United Nations on the Law of the Sea (UNCLOS) [6]. Scientific research provides

better information of the current status of fisheries resources in the oceans and thus assists the States and regional fisheries management organizations (RFMOs) to determine more accurate effective conservation and management measures (CMMs) to meet the goals of sustainable development, such as total allowable catch (TAC), quotas of a specific fish species allocated to the States, and restrictions of fishing seasons and areas, as well as the limitations of fishing gear and the number of fishing vessels [7]. All of these are the major agendas discussed in each of the international fisheries forums today.

Meanwhile, RFMOs have become the primary cooperative mechanism addressing the conservation and management of fisheries resources and fishing activities on the high seas, particularly tuna RFMOs [8]. As of today, many RFMOs have established their own Scientific Committees or relevant subsidiary bodies to conduct in-house scientific research for fisheries resources under their authority. Details of the scientific research and stock assessments of a certain species, such as the status quo of a fish species, TAC, and the probability of the biomass to be recovered in a specific year, will be provided by the Scientific Committee and relevant Working Groups to the RFMO [9]. The organization will mostly make decisions for its CMMs according to the recommendations made by the Scientific Committee. Despite this, however, on some occasions, there will be exceptions, meaning that the recommendations from the Scientific Committee will not be totally accepted by the organization [10].

This paper aims to analyze scientific research in international fisheries management through the analysis of current practices in RFMOs, with special reference to tuna RFMOs in the Atlantic Ocean and Indian Ocean. This paper firstly discusses scientific research-stipulated international fisheries legal instruments. Secondly, this paper analyzes the current practice of scientific research in tuna RFMOs in the Atlantic Ocean and the Indian Ocean, namely the International Commission on the Conservation of Atlantic Tunas (ICCAT) and the Indian Ocean Tuna Commission (IOTC), of which the authors have some close observations for the practice of scientific research in these two organizations by attending their relevant meetings. Further, this paper analyzes how scientific research is conducted in these two RFMOs and provides examples on how the Scientific Committee operates to address issues related to scientific research, particularly the determination of TAC. Lastly, this paper provides discussions on the differences of both RFMOs and conclusions based on the research findings.

2. Regulations and Importance of Scientific Research under International Fisheries Laws

International efforts to maintain and rebuild marine fisheries resources began in 1970s, and later, these actions were further incorporated into UNCLOS [11]. As mentioned earlier, UNCLOS was the first international convention to mention the concept of scientific research in the conservation and management of marine fisheries. For example, in Article 61 "Conservation of the living resources", paragraph 2 states that "[t]he coastal State, taking into account the best scientific evidence available to it, shall ensure through proper conservation and management measures that the maintenance of the living resources in the exclusive economic zone is not endangered by over-exploitation". In this paragraph, UNCLOS requires that coastal States must consider and incorporate scientific evidence when they endeavor to maintain fisheries resources not endangered or overfished in their EEZs [12]. Similar regulations also exist in Part VII, Section 2 of UNCLOS for the conservation and management of the living resources of the high seas. In Article 119 "Conservation of the living resources of the high seas", paragraph 1 stipulates that, in deciding the TAC and establishing CMMs for marine living resources in the high seas, States shall "take measures which are designed, on the best scientific evidence available to the States concerned". Paragraph 2 of the same article also stipulates that "[a]vailable scientific information, catch and fishing effort statistics, and other data . . . shall be contributed and exchanged on a regular basis . . . " Thus, in many aspects, UNCLOS "obligates states to

conserve wide-ranging and valuable species" [13], particularly the straddling and highly migratory species.

The adoption of the United Nations Fish Stocks agreement (UNFSA) achieves a major step forward in the development of a comprehensive legal regime for the long-term conservation and sustainable use of straddling and highly migratory fish stocks, which were contently mentioned but not clearly practically stipulated in the provisions of UNCLOS. UNFSA significantly amends and improves the relevant regulations related to those fish stocks in UNCLOS and, further, provides detailed measures related to scientific research in its provisions. For examples, Article 5, "General Principles", requires States to "ensure that such measures are based on the best scientific evidence available" and "apply the precautionary approach in accordance with Article 6". In addition, the article stipulates that States shall "promote and conduct scientific research and develop appropriate technologies in support of fishery conservation and management". Furthermore, Article 6, "Application of the precautionary approach", stipulates that "the absence of adequate scientific information shall not be used as a reason for postponing or failing to take conservation and management measures". In addition, it also states that "States shall take measures to ensure that, when reference points are approached, they will not be exceeded". Therefore, UNFSA not only establishes a more comprehensive legal regime for the conservation and management of straddling and highly migratory species but also requires those measures to be adopted "based on the best scientific evidence available and for States to be more cautious when information is uncertain, unreliable or inadequate [14]".

In addition to these two international, legally binding documents, other international fisheries instruments also provide regulations related to scientific research in their provisions, including "soft laws" that are non-legally binding to States. Hard laws, usually entitled "Convention" or "Agreement", mean that they are established and regulated by legally binding instruments. States are compelled to comply with the regulations stipulated in those legally binding instruments and are also subjected to enforcement and punishment (if any exists in their articles) if they do not fulfill their legal obligations. On the other hand, the contents in soft laws, usually entitled "Declaration", "Code of Conduct", or "International Plan of Action", are not compulsory, and there are usually no enforcement or punishment provisions. Thus, States are, in fact, in a voluntary spirit and address the subjects called upon in the instrument based on their goodwill [15]. For examples, Article 6.4 of the 1995 FAO Code of Conduct for Responsible Fisheries (CCRF) states that "conservation and management decisions for fisheries should be based on the best scientific evidence available", and States should "assign priority to undertake research and data collection in order to improve scientific and technical knowledge". Meanwhile, the regulations in Article 6.5 are very similar to those in UNFSA, which establishes that States and RFMOs "should apply a precautionary approach widely . . . , taking account of the best scientific evidence available". More importantly, "the absence of adequate scientific information should not be used as a reason for postponing or failing to take measures [16]". Further, the regulations related to scientific research also exist in the International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA-IUU), adopted by FAO in 2001. In the section of "Internationally Agreed Market-Related Measures", it states that "States should ensure that measures on international trade in fish and fishery products are transparent, based on scientific evidence . . . " Additionally, in the section of Research, it provides that "States should encourage scientific research on methods of identifying fish species from samples of processed products [17]". Therefore, these soft laws not only apply scientific research to the conservation and management of fish stocks but also extend to processing and trading measures or postharvest stages.

3. Regional Fisheries Management Organizations in High Seas Fisheries Management

Since the adoption of UNFSA, RFMOs have become the major platform for the States to address the cooperation and negotiation of high seas fisheries management. As mentioned above, there are already plenty of RFMOs established as of today, but different

terminologies have been used to describe these kinds of organizations in international fisheries communities [18]. For example, FAO, the leading and the only global organization responsible for fisheries-related issues, uses the term "Regional Fishery Bodies" (RFBs) for these fisheries organizations. In addition, the types and mandates of these RFBs differ tremendously because of their constitutional agreements. Not all of them have the authority to regulate activities related to fishing operations in their area of competence. Those RFBs that have mandates to regulate fisheries operations and resources in their area of competence are named "RFMOs". For the purpose of this manuscript, the term "RFMOs" is selected to describe those regional organizations. In addition, using the term "RFMO" is also consistent with that used in modern international fisheries instruments, such as UNFSA and IPOA-IUU.

The establishment of RFMOs is primarily because of the common interests among States concerns. Through RFMOs, States can cooperate with each other to overcome conflicts regarding the utilization of marine fisheries resources and then are able to share the revenues from fisheries activities, as well as establish principles, regulations, and procedures for further cooperation among them [3]. Despite this, however, the performance and effectiveness of each RFMO heavily depend upon the political will of its members, particularly relevant regulations in its constitutional agreement, and funding provided by its member States. Based on FAO, as shown in Figure 1, there are already over 50 RFMOs around the global oceans [19].

Figure 1. Illustrative Map of the Regional Fisheries Bodies. Reproduced from [19], with permission from Food and Agriculture Organization of the United Nations, 2022.

RFMOs can be generally categorized by different criteria into different types. The first criterion is their connections with FAO. RFMOs that are established within the framework of the FAO Constitution or a specific provision in their constitutive agreements clearly states the linkage with either Article VI or Article XIV of the FAO Constitution are "FAO statutory bodies", such as the Indian Ocean Tuna Commission (IOTC) and the General Fisheries Commission for the Mediterranean (GFCM). Other RFMOs outside the FAO framework are "autonomous RFMOs", which usually obtain greater self-ruling power than those under the FAO framework (e.g., Inter-American Tropic Tuna Commission, IATTC). Secondly, RFMOs can be categorized by the target species under their authority. For examples, ICCAT is responsible for highly migratory stocks (HMS), such as tunas. Thirdly, the classification of RFMOs is regarding their missions or mandates. For examples, IATTC is with the

mandate to conserve and manage fisheries resources within its area of competence, but the International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC) is without such a mandate, which is only for purely scientific research and advice purposes for other RFMOs [20].

4. International Commission for the Conservation of Atlantic Tunas and Scientific Research

ICCAT was established by the International Convention for the Conservation of Atlantic Tunas (ICCAT Convention) [21], which was adopted at a Conference of Plenipotentiaries convened by the FAO Director General in Rio de Janeiro, Brazil in 1966. The ICCAT Convention entered into the force on 1 April 1969. Although FAO initiated the negotiation of the ICCAT Convention, ICCAT did not become a FAO statutory body, as mentioned above. In other words, the ICCAT Convention eventually has no specific provision stating a link with any provision of the FAO Constitution. However, the Director General of FAO continues to exercise the depositary function for the ICCAT Convention, meaning that there are still connections between ICCAT and FAO and greater than other autonomous RFMOs [22]. Currently, the ICCAT has 52 Contracting Parties and 5 Cooperating Non-Contracting Parties, Entities, or Fishing Entities [23]. The Convention Area of ICCAT, as stated in Article 2 of the ICCAT Convention, "shall be all waters of the Atlantic Ocean, including the adjacent Seas". In other words, seas adjacent to the Atlantic Ocean, such as the Mediterranean Sea, the Black Sea, and the Caribbean Sea, also belong to the ICCAT Convention Area, as shown in Figure 2.

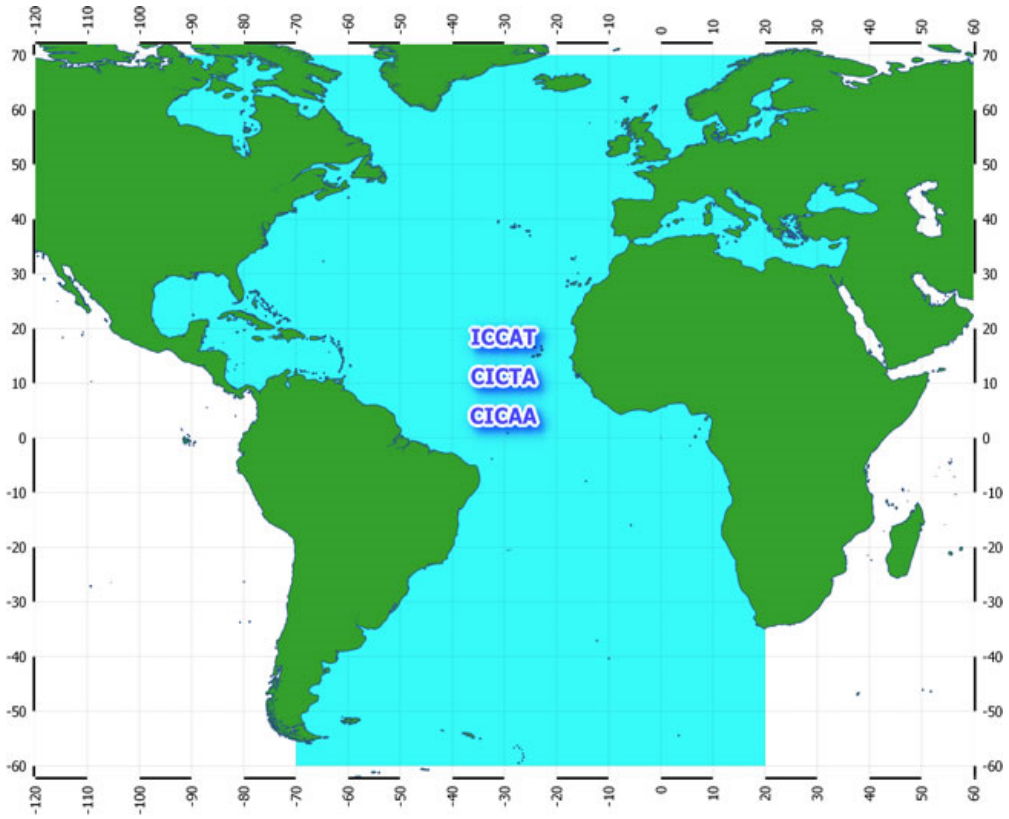

Figure 2. Convention Area of the ICCAT. Reproduced from [24], with permission from International Commission for the Conservation of Atlantic Tunas, 2022.

As regards the scientific research, several provisions in the ICCAT Convention provide relevant regulations to this end. For examples, Article IV, paragraph 1 states that "[t]he Commission, in carrying out these responsibilities shall, insofar as feasible, utilise the technical and scientific services of, and information from, official agencies of the Contracting

Parties". Article VI, paragraph 1 also stipulates that each Panel "shall be responsible . . . for collecting scientific and other information relating thereto". Furthermore, Article VIII requires that the "Commission may, on the basis of scientific evidence, make recommendations designed to maintain the populations of tuna and tuna-like fishes". All of these contents indicate that scientific research has been an essential part for the operation of ICCAT regarding the conservation and management of ICCAT species.

To fulfill those requirements, a Standing Committee on Research and Statistics (SCRS) has been established in charge of matters relevant to scientific research, data collections, and statistics in ICCAT, the purpose of which is to "develop and recommend to the Commission such policies and procedures in the collection, compilation, analysis and dissemination of fishery statistics as may be necessary to ensure that the Commission has available at all times complete, current and equivalent statistics on fishery activities in the Convention area" [25]. However, it is worth noting that the establishment of SCRS was not stipulated in any provisions of the ICCAT Convention. Rather, details of the establishment of SCRS were in the ICCAT Rules of Procedure, Rule 13 of which stipulates that "there shall be a Standing Committee on Research and Statistics on which each member country of the Commission may be represented" [26]. In addition to SCRS, some Working Groups (WGs) related to scientific research were also established and convene every year if necessary. In 2018, the WG meetings related to scientific research included:

- λ Blue marlin data preparatory and stock assessment meetings;
- λ MSE Bluefin Tuna (BFT) intersessional meeting;
- λ MSE Northern swordfish intersessional meeting;
- λ Small Tuna Species Group intersessional meeting;
- λ Meeting of the ICCAT Working Group on Stock Assessment Methods;
- λ Sharks Species Group intersessional meeting [27].

As regards how scientific research procedures are conducted in the ICCAT, following this study, the Bigeye Tuna (BET) stock assessment in 2018 is an example to illustrate. BET is a strictly managed fisheries resource in the ICCAT, including the TAC and national quota of each fleet. Generally, the Commission of the ICCAT decides the TAC and subsequent national quota of BET for a term of three (3) years. In 2018, it was time to decide the TAC and national quota of BET for the following 2019–2021 based on the stock assessment that examines the current status of BET in the Atlantic Ocean.

At the beginning, the Secretariat of ICCAT initialed a process to conduct an assessment that included a data preparatory meeting to collect biology information and fisheries indicators from Contracting Parties and Cooperating non-Contracting Parties, Entities, or Fishing Entities (hereinafter, CPCs) during the meeting. Following, the BET data preparatory meeting serves as a first step to review the reported catch data, indices of abundance, and other relevant biological and fisheries information aiming for BET stock assessment. The participants of the working group that were from different CPCs reviewed and discussed all the information provided and, while appropriate, revised or provided additional comments [28].

Next, the Secretariat presented up-to-date fisheries statistics available to the meeting participants, including Task I (nominal catches) data and Task II (catch and effort, size frequencies, and catch-at-size) of BET. It was to review fisheries indicators, particularly catch per unit effort (CPUE) for BET and, primarily, catch data from CPCs such as those provided by Brazil and Spain Governments, as well as available indices of relative abundances by fleet and estimations of combined indices. Lastly, possible models for stock assessment were proposed and discussed regarding the feasibility of the use in modeling the population dynamics. At this time, the scientists in the meeting agreed to conduct assessments based on surplus production models, stock synthesis, and a virtual population analysis. However, the fleet structure, model setup, and specifications mostly remained the same as in the last assessment in 2015 [28].

After the preparatory meeting, the Secretariat then convened the stock assessment meeting one to three months later to complete the task of BET stock assessment, and the

results of this evaluation will be considered and presented for the subsequent plenary meetings convened later this year. Based on all available data adopted during the data preparatory meeting, such as the aforementioned biology information, catch, efforts, and size estimates, the stock assessment models and their specifications were developed after a comprehensive discussion; in this case, that includes Stock Synthesis III (SS3), Just Another Bayesian Biomass Assessment (JABBA, a new and open-source modeling software), and MPB. After several sensitivity runs of adjustments, the current status of the BET stock was concluded (shown in Figure 3 and Table 1) for the reference of SCRS and other meetings [29].

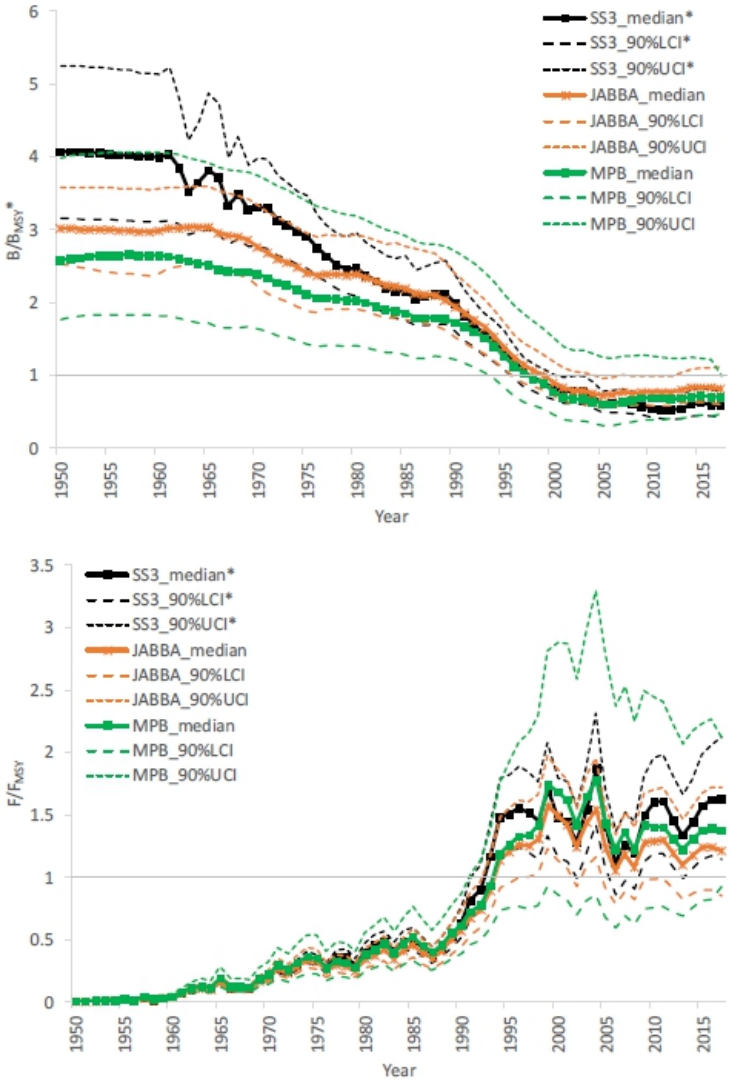

Figure 3. Comparison of the results from different models between 1950 and 2017 for Atlantic BET with 90% confidence intervals. * indicates the results from SS3 are distinguished from the other two models and decided as the stock assessment recommendations to the Commission. Reproduced from [29], with permission from International Commission for the Conservation of Atlantic Tunas, 2022.

Table 1. Statistics summary of the stock status, benchmarks, and key parameters from the three stock assessment models for Atlantic BET. Reproduced from [29], with permission from International Commission for the Conservation of Atlantic Tunas, 2022.

Assessment Method Estimates	Median	SS3 90%LCI	90%UCI	Median	JABBA 90%LCI	90%UCI	Median	Mpb 90%LCI	90%UCI
F_{2017}/F_{MSY}	1.629	1.143	2.123	1.210	0.851	1.723	1.373	0.926	2.121
B_{2017}/B_{MSY} *	0.590	0.426	0.797	0.824	0.601	1.115	0.707	0.468	0.989
B_{MSY} *	425,601	427,979	444,593	408,041	290,355	665,500	411,499	278,845	628,778
F_{MSY}	0.193	0.150	0.238	0.191	0.105	0.283	0.194	0.110	0.317
MSY	76,232	72,664	79,700	77,636	66,601	86,575	80,359	69,340	88,348
K **	1,404,845	1,010,578	1,831,922	1,342,195	941,998	2,183,037	1,123,463	1,118,011	757,601
r	-	-	-	0.133	0.072	0.212	0.195	0.110	0.317

* SBB (SS3) or exploitable biomass (production models); ** Virgin SSB (SS3) or carrying capacity (production models).

5. Indian Ocean Tuna Commission and Scientific Research

The IOTC was established by the Agreement for the Establishment of the Indian Ocean Tuna Commission (IOTC Agreement), which was adopted by the FAO Council at its 105th Session in Rome on 25 November 1993 and later entered into the force on 27 March 1996 [30]. Since IOTC is established under Article XIV of the FAO constitution, it is a "FAO statutory body" within the FAO framework. The establishment of the IOTC was to replace the former Indian Ocean Fishery Commission (IOFC), which entered into effect in the 1970s but was not able to effectively manage the increasing fishing activities in the Indian Ocean due to a lack of necessary mandates [31]. Currently the IOTC has 30 member States and two Cooperating non-Contracting Parties (CNCPs) [32]. The area of competence of the IOTC, as stated in Article 2 of the IOTC Agreement, is the Indian Ocean (FAO statistical areas 51 and 57) and adjacent seas, as shown in Figure 4 [33].

As regards the legal regulations related to scientific research, Article V of the IOTC Agreement clearly states that the Commission shall "encourage, recommend, and coordinate research and development activities in respect of the stocks and fisheries" covered by the IOTC Agreement. To this end, the Commission, the highest decision-making body in the IOTC, established the Scientific Committee as an advisory body to the Commission. The Scientific Committee includes scientists from IOTC member States, as well as experts from non-Member States, intergovernmental organizations (IGOs), and nongovernmental organizations (NGOs). In order to facilitate the work of the Scientific Committee, several Working Parties (WPs) have been established to this end. The objective of WPs is to analyze technical issues related to the management goals of the Commission. For example, WPs related to different species (i.e., neritic tunas) aim to analyze the status of the stock and provide options to the Scientific Committee for management recommendations to the Commission. Currently, the active WPs include:

- λ WP on Billfish (WPB);
- λ WP on Data Collection and Statistics (WPDCS);
- λ WP on Methods (WPM);
- λ WP on Neritic Tunas (WPNT);
- λ WP on Temperate Tunas (WPTmT);
- λ WP on Tropical Tunas (WPTT);
- λ WP on Ecosystems and Bycatch (WPEB).

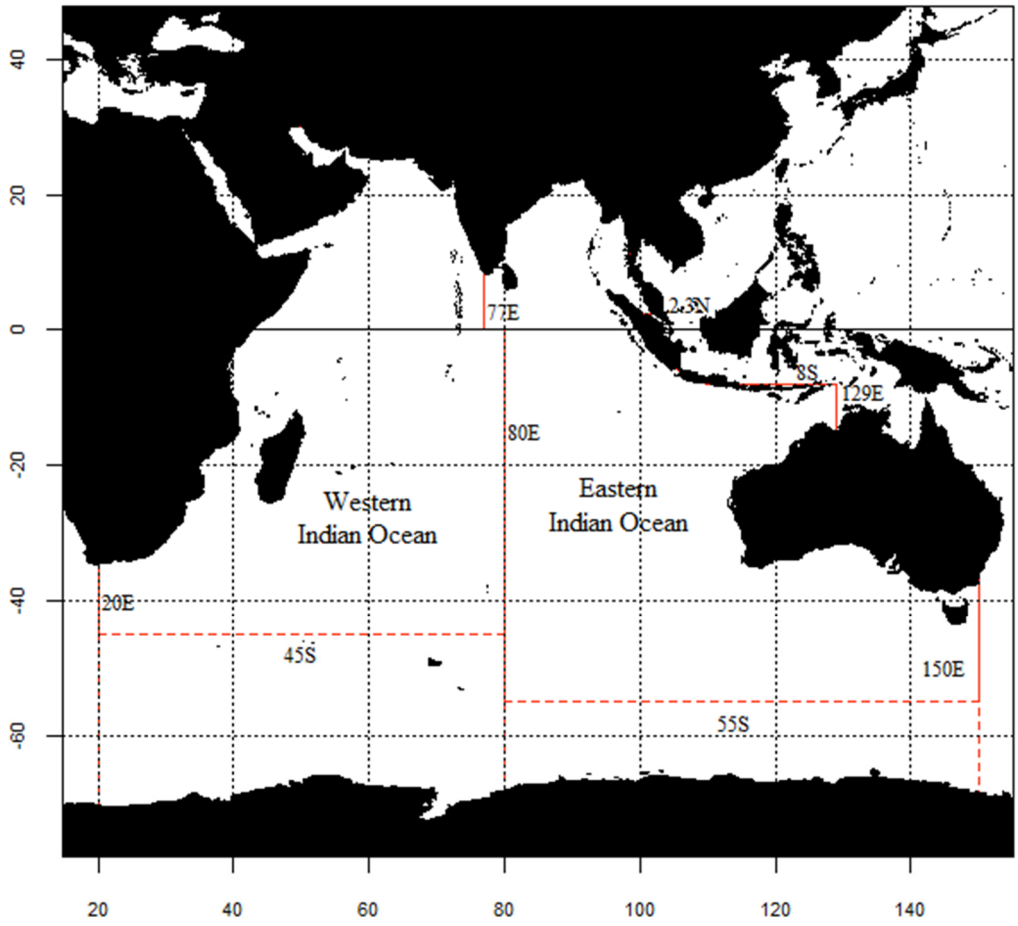

Figure 4. IOTC area of competence. Source: IOTC website. Reproduced from [33], with permission from Indian Ocean Tuna Commission, 2022.

The scientific research procedures in the IOTC are very similar to those of the ICCAT. Again, when taking BET as an example, in 2016, the Commission of the IOTC decided to conduct a stock assessment for BET in the Indian Ocean and requested the Working Party for Tropic Tunas (WPTT) in charge of this assessment. Firstly, the Secretariat developed a series of maps, figures, and tables that highlight the historical and emerging trends in the fisheries data held by the Secretariat and summaries any important reviews to the series of historical catches for BET: a range of fishery indicators (catch and effort trends) for fisheries catching BET in the IOTC area of competence [34]. This document was submitted to the WPTT for discussions and considerations of the member States. In fact, the fisheries information considered in the BET stock assessment in the IOTC was almost the same was that conducted by the ICCAT, such as catch data, fisheries indicators, length frequency data, tagging release/recovery locations, and relevant biological parameters. Further, potential population dynamics models were discussed, including structure and initial conditions, recruitments, movements, fisheries dynamics, and a statistical framework. Following, the models for stock assessment and factors were decided, as well as estimation of the parameters for the final model options [35].

Among these models, the results based on the SS3 model were selected as the management advice for BET, because a more comprehensive range of model options was investigated, and a range of diagnostics indicated that the model represented a reasonable fit to the data from fisheries and their biology. Finally, the assessment was concluded by producing projections from assessment models (shown in Figure 5 and Table 2) to indicate scientifically an optimal, sustainable level of exploitation for the BET resource for the references of the Scientific Committee, as well as the Commission [36].

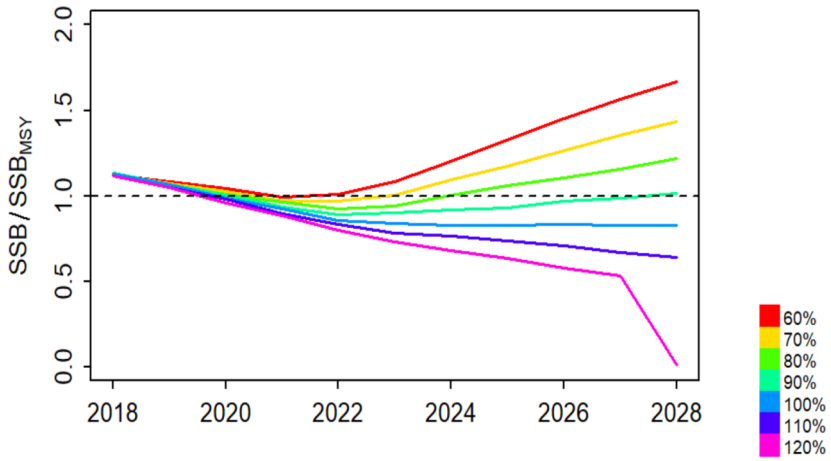

Figure 5. Trajectories of the median stock status between 2019 and 2028. Reproduced from [37], with permission from Indian Ocean Tuna Commission, 2022.

Table 2. Key management quantities from the 2016 SS3 assessment. Reproduced from [36], with permission from Indian Ocean Tuna Commission, 2022.

Management Quantity	Aggregate Indian Ocean
Most recent catch estimate (t) (2015)	93,040
Mean catch over last 5 years (t) (2011–2015)	101,483
h (steepness)	0.7, 0.8, 0.9
MSY (1000 t) (80% CI)	104 (87–121)
Data period (catch)	1975–2015
CPUE series/period	1979–2015
F_{MSY} (80% CI)	0.17 (0.14–0.20)
SB_{MSY} or * B_{MSY} (1000 t) (80% CI)	525 (364–718)
F_{2015}/F_{MSY} (80% CI)	0.76 (0.49–1.03)
B_{2015}/B_{MSY} (80% CI)	n.a.
SB_{2015}/SB_{MSY} (80% CI)	1.29 (1.07–1.51)
B_{2015}/B_{1950} (80% CI)	n.a.
SB_{2015}/SB_{1950} (80% CI)	0.38 (n.a.–n.a.)
$SB_{2015}/SB_{current, F=0}$ (80% CI)	n.a.

* The Management Quantities refer to the data used in the last assessment, conducted in 2016.

6. Case Studies on the Influence of Scientific Research in Decision-Making of ICCAT and IOTC

In RFMOs, the connection between scientific research and organization decision-making is mostly related to the determination of the TAC for a specific species in a given year, which will subsequently form the basis for the national quota determined based on the relevant criteria for that specific species to each CPC of that RFMO [38]. In addition, the results of scientific research form the foundation of certain CMMs, such as the coverage rates of observers onboard fishing vessels and the number of fish aggregation devices (FADs) allowed onboard a purse seine fishing vessel. In light of the fact that obtaining a national quota as much as possible is usually the first priority for almost every State in the RFMOs and impacts to the fishing fleet of CPCs may vary significantly due to different regulations in CMMs, it is crucial to understand the role and influence of scientific research in decision-making procedures in RFMOs [39].

In the ICCAT, the determination of the TAC and national quota for BET are the responsibility of Panel 1. After the stock assessment meeting, Panel 1 convened an intersessional meeting of Panel 1, the objective of which was to provide a forum for discussion on the current and possible future management measures related to tropical tunas, including modifications of the current CMMs or adoption of new measures and development of Management Strategy Evaluation (MSE) and Harvest Control Rules (HCRs). Due to the fact that the latest stock assessment results indicated that the status of BET is overfished and subject to overfishing, CPCs expressed a willingness to develop a comprehensive suite of measures to stop overfishing and support the rebuilding of the Atlantic BET stock for two overarching goals, including reducing the catch of BET with scientific advice and reducing the mortality of juvenile BET (<100 cm) [40].

Later, in the 21st Special Meeting held in Dubrovnik, Croatia, several CPCs tabled proposals for revising the current management plan of BET. Despite the fact that these proposals were primarily based on the scientific information provided by SCRS, the limits set in each proposal were different significantly. This was because the scientific data provided by SCRS were not fixed numbers. Taking the TAC of BET as an example, SCRS only provided the projected outcomes subject to different years for recovery (i.e., 10 years or 15 years) and different percentage of success (i.e., 50% or 60%) that the population of BET stock will be restored and recovered to a heathy status (i.e., biomass that enables a fish stock to deliver the maximum sustainable yield or Bmsy). Therefore, the TAC has to be lower if we want the recovery of BET stock in shorter years and a higher successful percentage and vice versa. However, different CPCs have different opinions on how many years for recovery, as well as the favorite percentage for success, and thus, they have different proposed TACs. For example, in the proposal of South Africa, the TAC was 55,000 tons for 2019 [41], but in the proposal of Guatemala, the TAC was 65,000 tons [42]. Panel 1 tried to merge different proposals into one and additionally convened many informal meetings in the margin of the Special Meeting to reach a consensus TAC among the CPCs. Unfortunately, Panel 1 was eventually unable to reach a consensus on a revised management plan for tropical tunas [43].

The determination of the TAC for BET continued in 2019. A 2-day intersessional Panel 1 meeting was held before and in conjunction with the 27th Regular Meeting of ICCAT in November. In the Panel 1 meeting, the opinions for the TAC of BET stock still widely varied, from 65,000 tons to 55,000 tons. Led by Guatemala, Latin American CPCs insisted that the TAC should be 65,000 tons in order to support their development needs, and the United States proposed to have a lower TAC at 55,000 tons to ensure the successful recovery of BET. More importantly, most CPCs agreed and accepted the TAC to be between 60,000 and 62,500 tons, which was a great improvement for CPCs to reach a consensus on this issue. In the 27th Regular Meeting, the Chair of Panel 1 tried to narrow down the gap between CPCs and then proposed 61,500 tons as a middle ground. After several rounds of informal meetings, a revised management plan for BET was finally adopted by all CPCs, including setting a recovery period for 15 years with the goal of achieving Bmsy with a probability of more than 50%. In addition, the TAC for 2019 and 2020 were 62,500 tons and 61,500 tons, respectively, and the TAC for 2021 will be determined based on the results of the stock assessment completed in 2021 [44].

The practice of scientific research in the IOTC is similar to that in the ICCAT, with some but important differences. The status of the Yellowfin Tuna (YFT) stock has been the most concerning issue of the IOTC in the past several years. In its 23rd Session Meeting held in Hyderabad, India in 2019, the Scientific Committee explicitly expressed in the meeting that the evidence available in 2018 proved that the YFT stock was determined to be overfished and subject to overfishing, but it was not able to recommend any concrete catch advice to the Commission due to the uncertainty in the projections. Despite this, however, the Scientific Committee still suggested 403,000 tons as the TAC for YFT in the following years as its advice to the Commission. The Scientific Committee also recommended that the

Commission should ensure catches be reduced to end overfishing and allow the spawning stock biomass (SSB) to recover to the level of the maximum sustainable yield (SSBmsy) [45].

To follow the advice from the Scientific Committee, three proposals to revise the current rebuilding plan of YFT were tabled and discussed during the meeting. Unlike the ICCAT, however, there was no argument for the determination of the TAC because of the fact that the Scientific Committee provided a fixed number of the TAC to the Commission. For examples, the proposals of Korea [46] and the European Union [47] both set 403,000 tons as the TAC for YFT in the following years. Therefore, the determination of the TAC was not an issue during the meeting but how to fairly allocate the YFT quota to each fleet fishing in the IOTC area of competence. Finally, the Commission adopted a compromised resolution incorporating all the proposals mentioned above, in which the quotas allocated to the CPCs were reduced according to fishing gears and the amount of historical catch [48].

7. Discussion

Decision-making is important for the effectiveness of RFMOs for the conservation and management of fisheries resources within their areas of competence. Leroy and Morin (2018) indicated that the effectiveness of the decision-making procedure in RFMOs can be evaluated by (1) blocking or opting-out behaviors constrained, (2) transparency in the objection procedure, and (3) conservation and management measures, including the related dispute resolution process, adopted in a timely manner [49]. Pentz and Kelnt (2018) argued that RFMOs requiring consensus for decisions may lack the ability to practice adaptive management against climate change [50]. Further, McDorman (2005) also pointed out that the relationship between RFMO decision-making and scientific information, evidence, advice, and recommendations demonstrates the central challenge for RFMO decision-making to respect state sovereignty while minimizing the scope of states to hinder the adoption and implementation of management and conservation measures that science and the state of the stocks require. It is also worth noting that many of the directions and principles that are to inform management decisions, for example, the precautionary approach, ecosystem management, protection of biodiversity, reduction of over-fishing, etc., are fundamentally scientific matters and are, or are expected to be, dealt with primarily within the science context [38]. This paper is to identify how scientific research influences decision-making processes in the ICCAT and IOTC.

Based on the above analysis, some observations can be learnt from the practices of scientific research in these two RFMOs. Firstly, scientific research has become an existing practice and plays an important role in the operation and decision-making of RFMOs, particularly in the determination of the stock status, TAC, and the following allocated national quota. Secondly, scientific research, generally in the context of stock assessments, is usually initiated and greatly assisted by the Secretariat of a RFMO, which is primarily responsible for data collection and preparation. Thirdly, participants for stock assessments are mostly scientists in the field of marine biology or fisheries rather than managers or officers from governmental fisheries authorities. Therefore, it is easier for scientists to agree on something based on the scientific data provided to the Scientific Committee, and if not, there will be no voting among scientists but defer the decision to the Chair of the Scientific Committee for ruling. Lastly, data preparations in both RFMOs are very similar, including biology, catch, fishing efforts, and CPUE. Models for stock assessments are also similar, particularly the SS3 Model. Projections are for the reference of the Commission when adopting a CMM.

Particularly, in both RFMOs, the determination of the TAC for a specific fish species is generally based on the results of their respective stock assessments [51]. When determining such a TAC, however, how many years for the recovery/rebuilding plan of that fish stock has to be determined in advance. When a TAC is decided, the Commission will determine the quota for each CPC in this organization based on its respective criteria [52]. However, there are still some differences regarding the practice of scientific research in both RFMOs, such as the final outcome of the TAC discussed in the previous section, which greatly

affects the degree and effectiveness of the results from scientific research to be accepted by CPCs. As mentioned previously, despite the fact that scientific research has become an essential part in a RFMO, the results of scientific research are not always observed when a decision is made in a RFMO. In other words, whether suggestions based on scientific research from the Scientific Committee will be accepted by all CPCs accordingly during the decision-making process is still a question to debate. Such a situation may result from two possible reasons: (1) the mandate of the Scientific Committee/SCRS and (2) how the Scientific Committee/SCRS provides its advice regarding scientific research to the Commission.

For the former, the primary question is that, when in a RFMO, the Scientific Committee, which is responsible to conduct scientific research, only has the mandate to "develop and recommend" to the Commission from the scientific aspect rather than the authority to make final decisions, which happens to both the ICCAT and IOTC. The Commission, the highest decision-making body in a RFMO, is the only part that has the right to make final decisions based on those suggestions and recommendations provided by the Scientific Committee. However, during the decision-making process, the Commission considers not only the scientific aspect but also many other aspects, such as political, economic, and social ones. Setting the quota of a specific fish stock for each CPC is usually the best example in which the TAC recommended by the Scientific Committee is not a problem, but the final TAC will exceed the recommended one due to additional requests from some developing CPCs. For example, when the Scientific Committee suggests that the TAC for BET should be 10,000 tons for the next year, such a recommendation has to be submitted to the Commission for final adoption. The TAC is usually adopted by all CPCs without any problems, but when discussing the allocated quota for each CPC, some CPCs will always have different opinions. On the one hand, coastal CPCs always insist that they are eligible to share a certain amount of the quota whether or not they fish in the Convention area of this RFMO based on the right given by the international laws, particularly UNCLOS. On the other hand, CPCs that are DWFNs claim that they want to maintain the same quota as they were to make sure their fishing industry survives. To accommodate all opinions and requirements from CPCs, the final decision of the TAC will inevitably exceed the suggested TAC provided by Scientific Committee. With these additional quotas or "political quotas [5]", this is why the effectiveness of RFMOs for the conservation and management of high seas fisheries is still questionable and not very promising today [6].

For the latter, how a Scientific Committee/SCRS "advises" the Commission will be the key to whether such a recommendation will be accepted by CPCs without any argument. This is exactly the difference between the ICCAT and IOTC and, thus, results in different outcomes in their decision-making process. In the 26th Regular Meeting of the ICCAT in 2019, the Chair of SCRS reported to all CPCs that SCRS concluded that BET in the Convention area was overfished and was still experiencing overfishing; the latter could be evidenced by the TAC for BET being 65,000 tons in between 2016 and 2018 but the nominal catch for all CPCs was about 72,300 tons in 2016 and about 80,000 tons in 2018, as both were way over the limit of the TAC. Therefore, there was an urgent need for the Commission to renew and adopt its Multi-Annual Conservation and Management Programme for Tropical Tunas to rebuild BET. Thus, as mentioned in the previous section, the Commission should decide the TAC and how long they wish BET to be rebuilt [53].

Generally speaking, in order to successfully rebuild a stock, the probability of not being overfished and not overfishing should be at least greater than 60%. Although a probability of 50% is logically able to rebuild a stock, it will entail a very great risk for the collapse of the stock if an unexpected situation occurs. Based on the calculations of SCRS provided to the Commission, if a 60% probability of not being overfished and not overfishing for BET is reached by 2033, the level of the TAC should be lower than 60,000 tons [53]. However, SCRS did not provide a fixed number for the TAC as its recommendation to the Commission. Rather, it only provided projections with different years of the stock being rebuilt and successful probabilities but deferred the decisions of how many years and successful

probabilities to the Commission. Different years and different successful possibilities will result in different TACs for the following years, which will inevitably become the central questions to be debated in the Commission. For examples, the Chair of Panel 1 and many CPCs, on the one hand, supported that the TAC should be lower than 60,000 tons based on the calculations of SCRS, preferably between 57,500 and 60,000 tons [54]. On the other hand, however, many Latin American CPCs preferred longer years and lower probabilities for the stocks to be rebuilt and insisted that the original TAC of 65,000 tons should be maintained because reducing the TAC in the following years will bring about significant social and economic impacts to their fishing industries and nationals [55]. Furthermore, the European Union proposed a TAC of 62,500 tons as a middle ground, trying to reach a compromise between these two groups [56]. After lengthy debates, the Chair of Panel 1 proposed a gradually reducing formula that was 62,500 tons for the first year and 61,500 tons for the second year and was finally adopted by the Commission [57].

The situation in the IOTC, on the contrary, was not similar to that of the ICCAT. As previously stated, the Scientific Committee of the IOTC did provide a fixed number of TAC for YFT at 403,000 tons, which was agreed on by the participants of the Meeting of Scientific Committee as its recommendation to the Commission. Therefore, despite the fact that several CPCs tabled different proposals for the YFT rebuilding plan, the TAC in these proposals were all 403,000 tons. Although the allocated quota for each CPC remained greatly debated in the following meetings, similar to that of the ICCAT, the TAC for YFT remained unchanged, with the original 403,000 tons agreed on and provided by the Scientific Committee. In other words, the TAC for YFT recommended by the Scientific Committee did not change, and the problems left were how to fairly allocate the quota of YFT to each CPC, which is a social, economic, and political issue rather than scientific one in RFMOs.

In sum, there were many similarities of the ICCAT and IOTC regarding scientific research in their decision-making. The only difference was that the SC of IOTC, in the case of the YFT TAC, provided a fixed number rather than the ICCAT SCRS, which did not provide a fixed number in the BET TAC. Such a difference resulted in significant outcomes when deciding the TACs, including whether significant debates in the negotiation process and "political quota" existed or not.

8. Conclusions

Scientific research has played an important role in the conservation and management of high seas fisheries, particularly after the adoption of UNCLOS. Since then, many international legal instruments have begun to emphasize the importance of scientific research and effective CMMs for the sustainable utilization of high seas fisheries possible, particularly UNFSA. In addition, as the primary cooperative mechanism, RFMOs have been the most important platform in addressing high seas fisheries under the contemporary international fisheries legal regime. In other words, RFMOs are now responsible to ensure the effectiveness of the conservation and management of high seas fisheries, which also includes the responsibility to ensure that scientific research will be properly incorporated into the negotiation and adoption of CMMs.

Based on the practices in the ICCAT and IOTC, scientific research has been part of organizational work without doubt. Similar efforts have been made periodically in the stock assessments for fish species under their mandates in both RFMOs. In most situations, RFMOs adopt decisions on the TAC based on the results of stock assessments conducted and recommended by the Scientific Committee and relevant Working Groups to the Commission, despite the fact that, on some occasions, these recommendations will not be totally accepted and adopted by the Commission. This is, however, not to say that the scientific research does not provide any merit in the work of a RFMO. Rather, the results from scientific research have become the basis for issues related to conservation and management measures discussed in RFMOs, and those occasions are mostly not within the scope of scientific research but social, economic, and political considerations. Along

with that, if the Scientific Committee provides a more explicit and clear recommendation (i.e., a fixed number of the TAC for YFT provided by the IOTC Scientific Committee rather than the range of TACs provided by the ICCAR SCRS) to the Commission and CPCs for determination, it is apparent that these occasions when decision-making is pending or not to be totally accepted and adopted based on scientific research (i.e., political quotas to inflate the final TAC and thus endanger the sustainability of fish stocks) could be less and less in the near future. Therefore, how to enhance the role of scientific research in RFMOs without being affected by political considerations or without a final decision, a key element to ensure the effectiveness of CMMs and sustainable development for fisheries resources, will determine the success of RFMOs for the conservation and management of high seas fisheries resources and is thus worthy of sustained attention.

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