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International management of tuna fisheries

Arrangements, challenges and a way forward

Cover photograph:

A tuna seiner fishing in the eastern Pacific Ocean in the process of retrieving its net (courtesy of Wayne Perryman, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, United States of America).

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by

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The Marine and Inland Fisheries Service (FIRF) is responsible for all programmes and activities of the Food and Agriculture Organization of the United Nations (FAO) that relate to the management and conservation of fisheries resources. This technical paper was prepared as part of the work programme of FIRF to enhance the understanding of arrangements, challenges and a way forward for the management of tuna fisheries on a global scale, particularly in the light of international standards and modern expectations for fisheries management. The key international standards considered include: (i) the 1982 United Nations Convention on the Law of the Sea; (ii) the 1992 United Nations Conference on Environment and Development; (iii) the 1995 FAO Code of Conduct for Responsible Fisheries; and (iv) the 1995 United Nations Fish Stocks Agreement.

This technical paper was prepared under the direction of Jacek Majkowski, FIRF. The author is Dr Robin Allen, a tuna expert based in New Zealand. He is a former Director of the Inter-American Tropical Tuna Commission in La Jolla, California, United States of America.

Abstract

This paper reviews the current management of tuna fisheries by the five tuna regional fisheries management organizations (RFMOs), focusing on the management of target species in the light of international standards and modern expectations for fisheries management. The key international standards used flow from the 1982 United Nations Convention on the Law of the Sea via the 1992 United Nations Conference on Environment and Development to the 1995 FAO Code of Conduct for Responsible Fisheries and the 1995 United Nations Fish Stocks Agreement. Subsequent to those instruments, other expectations of best practices have been gathered into the expectation that RFMOs undergo performance reviews.

The paper discusses the status of the stocks of the major species of tuna for each of five tuna RFMOs and examines the management response of each RFMO. According to the recommendations of the scientific bodies of the RFMOs, 14 of the major market species are in need of management action. Of those 14 species, the commissions of the RFMOs took action commensurate with the scientific advice in only five cases, and in three of the five cases, the actions only reflected other circumstances.

Conditions that provide incentives for participating governments to take (or not to take) cooperative actions to conserve resources are discussed. Apart from complying with global obligations and expectations, the major necessary condition for successful negotiation is that all participants in a negotiation should benefit from agreement to cooperate rather than from unrestrained competition. The fishery in the eastern Pacific Ocean is used as an example to show that this condition generally cannot be expected to be met.

The use of rights-based management systems is discussed and these systems are advanced as a means to facilitate the addressing of shortcomings in the current conservation and management of tuna fisheries. The elimination of the need to compete for a share of the available catch allows individuals to optimize their investment in fishing effort to match their share of the catch, providing them with the incentive to avoid overcapacity. Secure, exclusive and long-term rights provide fishers with a collective interest in the conservation of the fisheries and the efficient use of the resources. Transferability of rights allows fishing opportunities to be used by those fishers who produce the greatest economic benefits and can provide a means of reaching an agreement among different sectors of the industry via a transfer of fishing rights.

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The author is also grateful for the assistance provided by Guillermo Compeán, Bob Kennedy, Driss Meski, Peter Miyake and Andrew Wright, who reviewed various sections of the paper and made helpful comments.

Acronyms and abbreviations

B_{MSY}	biomass for maximum sustainable yield
CCRF	FAO Code of Conduct for Responsible Fisheries
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CPC	Party, cooperating non-party, fishing entity or regional economic integration organization (collectively IATTC)
CPUE	catch per unit effort
FAD	fish aggregating device
F_{MSY}	fishing effort for maximum sustainable yield
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tuna
IOTC	Indian Ocean Tuna Commission
IUCN	International Union for Conservation of Nature
MSY	maximum sustainable yield
NGO	non-governmental organization
RFMO	regional fisheries management organization
RMO	regional management organization
SCRS	Standing Committee for Research and Statistics (ICCAT)
TAC	total allowable catch
TBAP	Tuna and Billfish Assessment Programme
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNFSA	United Nations Fish Stocks Agreement
VPA	virtual population analysis
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	Western and Central Pacific Ocean

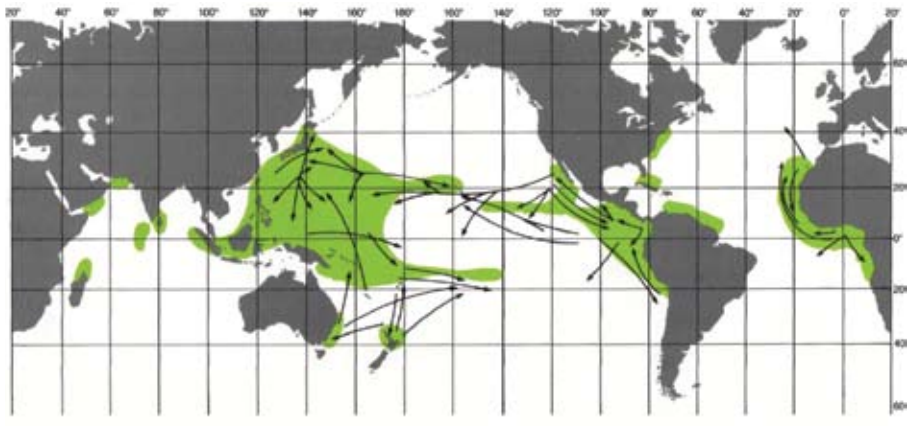
1. Introduction

This technical paper reviews the current management of tuna fisheries by the five tuna regional fisheries management organizations (RFMOs) in the light of international standards and modern expectations for fisheries management. It discusses conditions that provide incentives for participating states to take (or not to take) cooperative actions to conserve resources. Shortcomings of traditional negotiations among states to allocate access to shared fisheries are identified and finally the use of rights-based systems is advanced for the conservation and management of tuna fisheries as a means of addressing those shortcomings.

It has been understood for many years that tuna fisheries and other fisheries for highly migratory species need international cooperation for their conservation and management. This was recognized during the negotiation for the 1982 United Nations Convention on the Law of the Sea (UNCLOS or the 1982 Convention) when they were singled out with other highly migratory species in an article providing special treatment for the management of their fisheries.

What is it about tunas and tuna-like fisheries that require this special attention? The answer to this question comes from their distribution and movement. Figure 1 illustrates this for skipjack tuna, showing the distribution and movements of the species as it was known during the negotiations for the UNCLOS. It was clear that these fish ranged across the jurisdictions of many countries and that much of the stock was found on the high seas. All of the major market species of tunas make extensive movements and of those species at least albacore and bluefin

FIGURE 1
Distribution of a skipjack tuna fishery and fishery movements



Note: Colour green indicates fishery distribution and arrows indicate fishery movements.
Source: Joseph, Klawe and Murphy, 1988.

tunas undertake regular migrations. If one state tried to conserve the stock within its own area of jurisdiction, or tried to regulate its own fishing fleet to ensure the stock is kept at high levels, other states would be able to capture the benefits of that restraint as free riders. Free riding states would be able to enjoy the benefits of the investment in conservation made by responsible states and might entirely undo the conservation efforts of responsible states. Recognizing this, UNCLOS required that states cooperate to ensure conservation and the promotion of the objective of optimum use of highly migratory fish.

In reality, the states participating in the fisheries for tunas have demonstrated an inability to cooperate effectively to achieve those management goals. The result has been that tuna fleets and their catches have been growing, often unsustainably. Consequently, there are too many tuna fishing vessels for the amount of fish available and many stocks are either at risk of being, or are, overexploited. Increasingly, restrictive measures are necessary to control the potential fishing effort.

Section 2 of this paper discusses modern standards for fisheries management. Section 3 introduces the five tuna RFMOs and reviews the management and status of the major stocks for which they are responsible. Section 4 discusses incentives and disincentives for members of organizations to cooperate within the RFMOs. Section 5 describes recent work that contemplates the use of rights-based management systems to improve the management of tuna fisheries and Section 6 concludes with indications of the most promising way forward.

2. Modern standards of management for tuna fisheries

Article 64 of the 1982 UNCLOS requires cooperation of coastal states and other fishing states, either directly or via international organizations, to ensure the conservation and promotion of optimum utilization of highly migratory species within and beyond the exclusive economic zones.

UNCLOS provided only very basic standards for the management of highly migratory species. As a consequence of increasing international concern about the lack of regulation of high seas fishing fleets, the 1992 United Nations Conference on Environment and Development (UNCED) addressed the need to spell out more detailed requirements to achieve the cooperation envisaged by UNCLOS by recommending in Chapter 17 of the Agenda 21[1] that:

> *17.49(e) States should convene, as soon as possible, an intergovernmental conference under United Nations auspices, taking into account relevant activities at the subregional, regional and global levels, with a view to promoting effective implementation of the provisions of the United Nations Convention on the Law of the Sea on straddling fish stocks and highly migratory fish stocks. The conference, drawing, inter alia, on scientific and technical studies by FAO….*

Subsequently, two international instruments that provided a global reference for standards for fisheries management were adopted in 1995, namely the FAO Code of Conduct for Responsible Fisheries (FAO CCRF) and the United Nations Fish Stocks Agreement (UNFSA or the Agreement).

The UNFSA enumerated a number of general principles to be followed for the conservation and management of highly migratory fishing stocks, including:

- ensuring the long-term sustainability of stocks and promotion of their optimum utilization;
- ensuring that management measures are based on the best scientific information and are designed to maintain or restore stocks at levels capable of producing the maximum sustainable yield qualified by appropriate factors;
- promoting application of the precautionary approach;

[1] United Nations Conference on Environment and Development (UNCED). 1992. Agenda 21. Rio de Janeiro. Available at www.un.org/esa/sustdev/documents/agenda21/english/Agenda21.pdf

- adopting measures for the conservation and management of species belonging to the same ecosystem or associated with or dependent upon the target species and protecting biodiversity; and
- taking measures to prevent or eliminate overfishing and excess fishing capacity.

Similar principles were described in the FAO CCRF.

The precautionary approach to fisheries management was elaborated with the requirement to be more cautious when information is uncertain, unreliable or inadequate and to use the best scientific information and improved techniques for dealing with risk and uncertainty, and with the adoption of target and limit reference points to support management objectives and to constrain harvesting within safe biological limits. The fishing mortality rate that generates maximum sustainable yield and the biomass that would produce maximum sustainable yield were specified as minimum standards for limit reference points.

Further, the FAO CCRF and the UNFSA established the role of the RFMOs as the primary vehicle for cooperation among states to conserve not only the fish that are the object of the fisheries but also other parts of the ecosystems that are affected by fishing. In an ad hoc way, most RFMOs were developed by treaties among states that shared the objective of conserving fish stocks before these global agreements were adopted.

The five tuna RFMOs include the West and Central Pacific Fisheries Commission (WCPFC), the Inter-American Tropical Tuna Commission (IATTC), the International Commission for the Conservation of Atlantic Tuna (ICCAT), the Indian Ocean Tuna Commission (IOTC) and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT). Of these five commissions, only the WCPFC was formed after 1995, with the result that its convention drew heavily on the new global instruments. The first tuna body, the IATTC, began its work in 1950 and the ICCAT, the IOTC, and the CCSBT were formed between 1969 and 1994. In the absence of detailed global standards, the early RFMOs were obliged to develop their own standards.

In recent years, there has been a great deal of discussion and criticism about efforts to conserve and manage fisheries, both national and international. RFMO performance has been examined in a number of reviews published by non-governmental organizations (NGOs) or prepared as background papers for UN consultations. An independent panel based at Chatham House, United Kingdom (Lodge *et al.*, 2007), compared practices of RFMOs with international standards and recommended best practices for RFMOs, including practices for conservation and management.

A new widely accepted standard practice that has emerged from these reviews is that RFMOs should undergo regular independent performance reviews. Three of the tuna RFMOs (CCSBT, ICCAT and IOTC) have completed their first reviews, the WCPFC has scheduled a review in 2010 and the IATTC is considering a review process.

Many of the external reviews mentioned previously have been relatively optimistic in the sense that the changes deemed necessary to improve the performance of RFMOs were addressed to behavioural changes rather than fundamental changes that would require major changes to the conventions of the RFMOs. However, an alternative view is expressed by Hilborn (2007): "The existing governance regimes for high seas fisheries have failed totally. Despite the existence of numerous regional management organizations (RMOs) as mandated by the UN fishing agreements, none of them regulates high seas fisheries to any effect". Governance, particularly decision-making by consensus or super majorities, and the reliance on national governments to monitor and to carry out enforcement of their own fleets is seen by Hilborn as the particular weakness of RFMOs. He goes on to say that fundamental changes to the existing legal framework for governance of the high seas are necessary to achieve conservation goals and implies the need for governments to pass their role in regulating high seas fisheries to a single organization that would set the rules for high seas fisheries with the intention of maximizing their value for all people. In some respects, this followed on from Joseph and Greenough (1979), who explored the idea of a global organization for all tuna fisheries.

Crothers and Nelson (2007) also argue that existing governance arrangements are inadequate and that overfishing in the high seas is a result of the lack of incentives for states or RFMOs to act responsibly in dealing with the effects of an overcapitalized fisheries sector. They offer an alternative of a governance structure with sole owners (High Seas Fisheries Corporations), which would be owned collectively by states and have explicit and exclusive authority to manage the high seas fisheries within their portfolio.

As well as the standards for management provided by international instruments, there have been a number of commentaries on other improvements that could be made in fisheries management, particularly related to failures of management systems to provide the maximum benefits that should be available from a well managed fishery. These improvements relate closely to the UNFSA principles of optimum utilization and the avoidance of overcapitalization.

Tuna RFMOs have given little attention to economic criteria in determining management standards. The reluctance to do this is understandable given the diversity of economies and different economic objectives of their members. Nevertheless, studies have demonstrated that modern fisheries are often extremely wasteful. For example, a World Bank and FAO report[2] concluded that the difference between actual and potential benefits from world fisheries (including tuna fisheries) was in the order of US$50 billion per year. The waste (difference between actual and potential benefits) may be caused in several ways. The most obvious waste is the result of overexploitation of fisheries, which is the case in some of the tuna fisheries discussed in Section 3 below. In addition, a fishery

[2] World Bank and FAO. 2008. The Sunken Billions: The Economic Justification for Fisheries Reform. Agriculture and Rural Development Department. Washington DC, World Bank.

that is managed to produce the maximum sustainable yield can be wasteful for several reasons. Waste can occur as a result of management that restricts the use of available fishing capacity to achieve a target, for example, with the use of closed seasons because capacity is not fully utilized for other operational reasons or because, as is normally the case, the economically optimal catch is less than the maximum sustained catch.

For example, for each year between 2003 and 2007, the eastern Pacific Ocean tuna purse-seine fishery was closed for six weeks to maintain the catch at the maximum sustainable yield for yellowfin and bigeye tunas (see Table 2 in the following section), indicating that the fishing capacity was at least 12 percent too large over the period. Further, Joseph (2003) showed that there was significant overcapacity in the eastern Pacific Ocean purse-seine fishery during the period from 1971 to 2000. For part of that period (1980–1997), there were no restrictive management measures that constrained catches, suggesting that the overcapacity in the more recent period was even greater than 12 percent. Joseph also suggested that purse-seine fleets in other regions were also not fully utilized, based on comparisons of catch rates from various areas.

Globally, Reid *et al.* (2005) and Miyake (2005), respectively, reviewed capacity of fleets using two of the most important fishing methods for tuna, the purse-seine and the longline methods. Reid *et al.* showed that there is excess purse-seine fishing capacity in the Pacific Ocean, the Atlantic Ocean and the Indian Ocean and Miyake concluded that the same level of global catches could be achieved with a smaller longline fleet size.

Overcapacity leads to pressures on representatives of states, who negotiate in tuna RFMOs, to seek to maintain or improve fishing opportunities for their own fleets on stocks already at, or approaching full exploitation. This pressure has arguably been a significant cause for the lack of, or poor, decision-making by tuna RFMOs.

The performance of the tuna RFMOs, discussed below, seems to show that their members often do not seem to be able to improve their or their industries' return from the fishery by cooperating with other governments. The international standards that they have agreed to in global forums are being trumped by national interests in the fisheries managed by the tuna RFMOs.

3. The tuna RFMOs and the stocks for which they are responsible

Five RFMOs have been established with mandates that include ensuring the sustainable use, conservation and management of tuna stocks. Some of them also have responsibilities for harvested species other than tunas and all of them address issues of associated and dependent species taken incidentally during tuna fishing operations. All the tuna RFMOs recognize their obligation to ensure the conservation of associated and dependant species. The obligation is addressed either through the application of measures designed to minimize the impact of fishing on species such as marine turtles and seabirds or by measures to constrain catches of other species such a sharks to optimum levels. Nevertheless, for reasons of brevity, this paper will only deal with their role with respect to conservation and management of the major market species of tunas such as albacore tuna, bigeye tuna, bluefin tuna, skipjack tuna and yellowfin tuna.

Earlier it was noted that the highly mobile and in some cases migratory nature of tunas makes international cooperation essential for the management of fisheries for these stocks. Modern tuna vessels, particularly large-scale longline and purse-seine vessels, have the capability to move rapidly to any part of the world. Thus, the tuna RFMOs not only have to deal with migratory fish, but migratory fishing fleets as well. The markets for tuna are global (Jeon, Reid and Squires, 2008; Catarci, 2005). Surpluses and shortages in any one region quickly lead to catches or products flowing to other regions. Surpluses seldom lead to less pressure on stocks, whereas shortages almost always tend to reduce stocks. The global nature of markets aggravates any problems of overfishing.

The CCSBT was established in 1994 and is the only tuna RFMO whose principal mandate is for a single tuna species (southern bluefin tuna) throughout its range. The objective of its governing convention[3] is to "ensure, through appropriate management, the conservation and optimum utilisation of southern bluefin tuna". The CCSBT since its formation in 1994 has had to grapple with trying to rebuild an overfished stock.

The IATTC was founded in 1950 and has responsibility for the conservation and management of tuna species and other species taken by tuna fishing vessels in the eastern Pacific Ocean. The conservation and management objective for the commission[4] is "to keep the populations of fishes covered by the convention at

[3] Article 3, Convention for the Conservation of Southern Bluefin Tuna.

[4] Article II, Convention for the Establishment of an Inter-American Tropical Tuna Commission.

those levels of abundance which will permit the maximum sustained catch". The IATTC adopted a new convention in 2003 that will come into effect in August 2010 with an objective of *ensuring the long-term conservation and sustainable use of the fish stocks covered by this convention, in accordance with the relevant rules of international law*.

The ICCAT was established in 1969 to be responsible for the conservation of tunas and tuna-like species in the Atlantic Ocean and its adjacent seas. The conservation and management objective for the commission[5] is to "maintain the populations of tuna and tuna-like fishes that may be taken in the convention area at levels which will permit the maximum sustainable catch".

The IOTC was established under Article XIV of the FAO constitution and is mandated to manage tuna and tuna-like species in the Indian Ocean and adjacent seas. The IOTC began its work in 1996, following preliminary work of the Indo-Pacific Tuna Development and Management Programme. Its objective[6] is "to promote cooperation among its Members with a view to ensuring, through appropriate management, the conservation and optimum utilisation of stocks and encouraging sustainable development of fisheries based on such stocks".

Most recently, the WCPFC was created in 2004. The objective of the WCPFC is "to ensure, through effective management, the long-term conservation and sustainable use of highly migratory fish stocks in the western and central Pacific Ocean in accordance with the 1982 Convention and the Agreement".[7]

The tuna RFMOs use similar processes to develop and agree on conservation and management measures. They collect or assemble data about the fisheries, carry out a scientific assessment of the state of the stocks, using either dedicated scientific experts or a committee of scientists drawn from members and cooperating participants, or some combination of those arrangements. The best scientific advice is presented to their governing commission, which then develops any management measures it believes necessary in the light of the scientific advice and other relevant factors. The commissions generally strive to make such decisions by consensus of their members. For the CCSBT and the IATTC, decisions require unanimity, while the ICCAT, the IOTC and the WCPFC may take conservation and management decisions upon a vote by a qualified majority but then provide the possibility for parties to either opt out or to seek a review of the decision. These rather unwieldy decision-making processes tend to result in lowest common denominator decisions rather than producing forward-looking and precautionary conservation and management measures.

MANAGEMENT AND STATUS OF MAJOR TUNA STOCKS

This section will focus on each of the major market species of tunas for each of the commissions in turn. Majkowski (2007) provides a general review of the development of the fisheries and of the state of the stocks for these species.

[5] Article VIII, International Convention for the Conservation of Atlantic Tunas.

[6] Article V: Agreement for the establishment of the Indian Ocean Tuna Commission.

[7] Article II: Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean.

Skipjack tuna provide about half of all tuna catches and are important in the areas covered by each of the tuna RFMOs except for CCSBT but are not the object of any management measures because the stocks have generally demonstrated a capacity to support current levels of fishing. Although skipjack do not have any major conservation and management issues of their own, fisheries targeting skipjack, particularly by purse seiners using fish aggregating devices (FADs), have a significant impact on stocks of yellowfin and bigeye and so the management issues for those species, which are also targeted by other gear types, are complicated by the desire to maximize skipjack catches. Accordingly, skipjack tuna fisheries will not be discussed further in the paper, except as they impinge on the management of other stocks.

In all cases, the discussion of the management by the tuna RFMOs below is based on the stock assessments carried out by the scientific bodies of each commission. The RFMOs' own assessments are used here because they are the basis for management decisions. There are other assessments of tuna stocks and, in particular, there has been a high profile and pessimistic interpretation of the state of the stocks of pelagic fisheries by Myers and Worm (2003) that is markedly different from the RFMO assessments. However, the techniques relied on by Myers and Worm have been shown to be unreliable (Sibert *et al.*, 2006: Kleiber and Maunder, 2008).

The reports from the scientific bodies give far more detail than is possible to give in this paper, which deals with all the tuna RFMOs. This paper endeavours to present the main thrust of those assessments, but inevitably does not include all of the nuances in the detailed assessments. Readers who wish to have more detailed information should consult the original reports of the scientific bodies. Stock assessments should always be appreciated with the understanding that hindsight in assessment is more accurate than forecasts. Thus, what might clearly be recognized now as overfishing in past years may not have been detectable with the data that were available at the time.

Discussions of management objectives for fisheries often involve the use of terms that may be used with different meanings in other places. Here a common objective for tuna RFMOs is to maintain a catch at the maximum level that can, on average, be sustained over time, referred to as the "maximum sustainable yield" (MSY). "Overfishing" is a term used to denote fishing with a level of effort that is greater than that required to produce the MSY (F_{MSY}) and the term "overfished" means a stock that has been reduced to a size less than that which would provide the MSY (B_{MSY}).

The Commission for the Conservation of the Southern Bluefin Tuna

The Japanese longline fishery for southern bluefin tuna started in the early 1950s and within ten years its catch increased to between 70 000 and 80 000 tonnes per year. An Australian purse-seine fishery began about the same time and in the 1980s its catches exceeded 20 000 tonnes per year. The longline fishery takes mostly large fish. In the early years of the fishery, the Australian purse-seine fishery

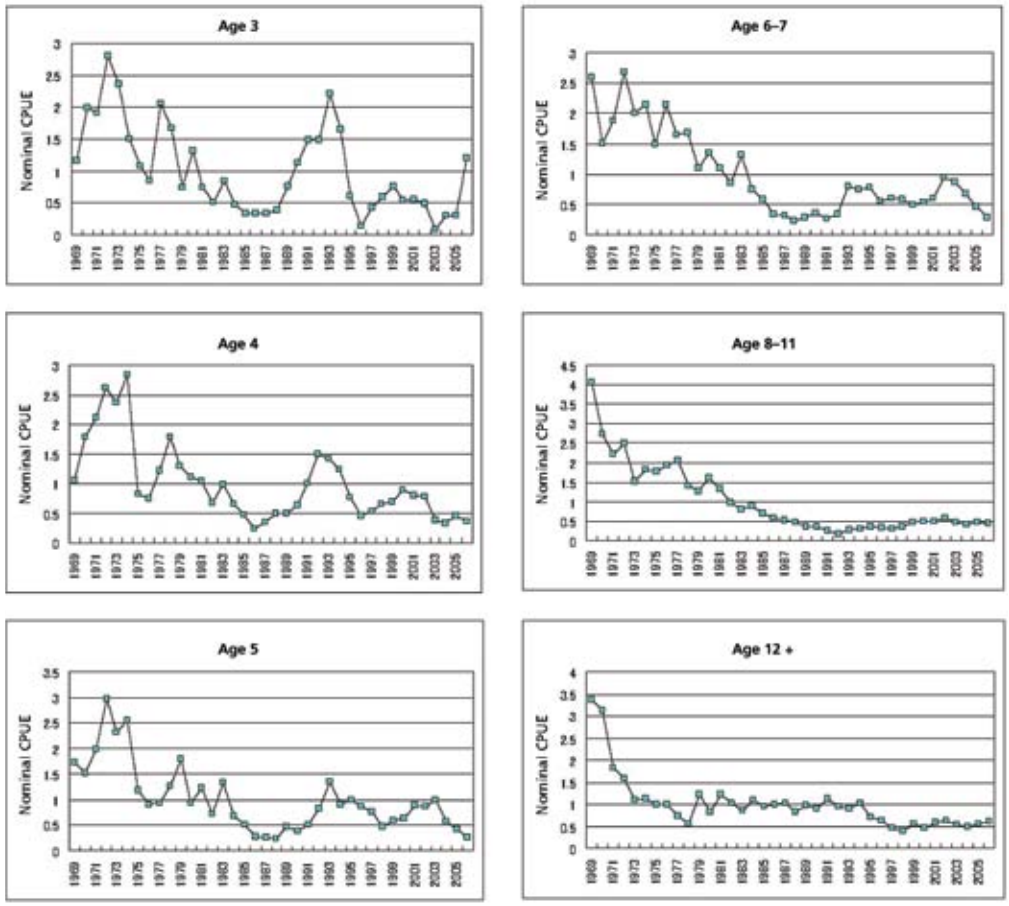
took very large numbers of juvenile fish, which were moving away from the spawning grounds to the northwest of Australia. After 1991, the Australian fishers transferred their attention to somewhat larger fish that could be held in cages and grown on to sizes suitable for the sashimi market.

The Scientific Committee of the CCSBT is responsible for the assessment and analysis of the status and trends of southern bluefin tuna and the information provided in this section is drawn from its reports.[8]

In the years leading up to international management, the stock suffered a serious decline. The catch rates for the largest fish (ages 12 plus) declined steeply

FIGURE 2

Trends in nominal catch rates (numbers per 1 000 hooks) of southern bluefin tuna by age group



Note: Figures show ages 3, 4, 5, 6 and 7, 8–11 and 12+ caught by Japanese longliners operating in CCSBT statistical areas 4–9 in months 4–9.

Source: CCSBT (Attachment 8), 2007.

[8] Reports of the Scientific Committee can be found on the CCSBT web site at www.ccsbt.org/docs/meeting_r.html

during 1969–1974[9] and the catch rates for younger fish declined more slowly (Figure 2).

Before the convention governing the CCSBT entered into force in 1994, Australia, Japan and New Zealand cooperated in a trilateral arrangement that carried out stock assessments and made agreements on quotas for each country. By the early 1980s, it was clear that the stock was declining seriously and scientists warned that, while it was not possible to determine a stock size that would provide the MSY, the stock should be rebuilt to levels at least as great as those in 1980. This advice was reiterated throughout the period leading up to the establishment of the commission (Caton and Majkowski, 1987). The species was listed by the International Union for Conservation of Nature (IUCN) in 1996[10] as critically endangered.

The CCSBT was unable until 2006 to adopt management measures that might be expected to have the stock rebuild. The report of the commission's performance review working group[11] provides a concise history of events relating to conservation and management of the stock. The commission set quotas for the then members (Australia, Japan and New Zealand) totalling 11 750 tonnes for each year from 1994–1995 to 1996–1997. It was understood in addition to theses quotas that other fishing countries were also taking southern bluefin tuna. No total allowable catch (TAC) was agreed in the years 1997–2002, but in 2003 the commission agreed to an aggregate quota of 14 030 tonnes for its five members for 2003–2004 (the quotas for the original three members were set at the same levels as the quotas in 1994–1996). This was repeated for 2004–2005 and together with allocations for non-members amounted to a TAC of 14 300 tonnes. For 2005–2006, it was agreed that catch limits would not exceed the limits of the previous year. Essentially, there was no management response that usefully addressed the declining stock during the 1997–2007 decade. However, during the later part of this period, from 2002 to 2005, the commission devoted considerable effort to developing a management procedure for the fishery that would be able to set global TACs to achieve specified targets. In September 2005, the Scientific Committee completed its development work and selected a preferred management procedure.

Unfortunately, reviews of southern bluefin tuna farming and market data presented to a special meeting of the commission in 2006[12] suggested that the catches may have been substantially underreported over the previous 10 to 20 years. This underreporting undermined the previous stock assessments and left the current status of the stock unclear. The impact of unreported catches on the

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[9] Report on Biology, Stock Status and Management of Southern Bluefin Tuna: 2007. In Report of the Twelfth Meeting of the Scientific Committee. (Attachment 8.) CCSBT.

[10] www.iucnredlist.org/details/21858

[11] Report of the Performance Review Working Group. Canberra, Australia, 3–4 July 2008. Available at www.ccsbt.org/docs/pdf/meeting_reports/ccsbt_15/report_of_PRWG.pdf

[12] Report of the Special Meeting of the Commission. Canberra, Australia, 18–19 July 2006. Available at www.ccsbt.org/docs/pdf/meeting_reports/ccsbt_13/report_of_special_meeting_2006.pdf

estimates of past total catch meant that it was not possible to proceed with the preferred management procedure.

The stock assessment in 2006[13] suggested that the southern bluefin tuna stock was at a very low level, well below the 1980 level, and as well was below the level that would support the MSY. The ratio between the estimated 2006 spawning biomass and the unexploited spawning biomass was estimated to be in the range of 10 to 13 percent. The Scientific Committee advised that an immediate reduction in the catch below current levels was required and said that it would be necessary to reduce the total catch to less than 14 925 tonnes to decrease the probability of further stock declines. Following the 2006 assessment, the commission reduced the TAC for members and non-members to 11 810 tonnes without providing a rational for the quantity. At the same time, significant changes were made in management of the southern bluefin tuna fishery by one of the CCSBT members, with the aim of significantly reducing the opportunity for underreporting of catches.

The Inter-American Tropical Tuna Commission

During the 1950s, tuna fishing in the eastern Pacific Ocean increased significantly with the United States pole-and-line fishing vessels fishing for yellowfin and skipjack off Mexico and Central America and with the Japanese longline fleet expanding eastwards from the western Pacific. After 1961, the pole-and-line vessels were for the most part converted to purse seining and the technique for catching large yellowfin associated with dolphin schools was developed. In the early 1990s, fishing with FADs became the most effective way for purse-seine vessels to catch skipjack, along with significant quantities of small bigeye and yellowfin.

Unlike for the Atlantic and Indian Oceans, for the Pacific Ocean there is a commission for each of its eastern and central and western basins. On the one hand, there are single trans-Pacific stocks for Pacific bluefin and northern albacore and individual fish migrate to and from the east and west. Southern albacore also form a single Pacific stock but there is little fishing of this stock on the eastern Pacific Ocean. On the other hand, bigeye, yellowfin and skipjack do not make extensive movements (on a Pacific-wide scale) and the question of whether their stocks are more effectively assessed as a number of stocks with some mixing, or as independent east and central-west stocks has not been resolved. In this paper, the bigeye, yellowfin and skipjack stocks are treated as separate eastern and central-western stocks.

The IATTC employs a dedicated research staff to carry out research into and assessment of the state of tuna stocks. The assessment information reported below is taken from the IATTC Fishery Status Reports.[14] Recently, the IATTC staff's assessments of the northern albacore and Pacific bluefin have been based on

[13] Report of the Eleventh Meeting of the Scientific Committee.

[14] Electronic versions of the Fishery Status Reports are available at www.iattc.org/FisheryStatusReportsENG.htm

cooperative work carried out within the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean.[15]

Northern albacore tuna

In 2005, the advice to the commission was that estimated spawning stock biomass is at or below the MSY level and that a modest reduction in fishing mortality was necessary to ensure that the biomass is maintained above the lowest levels recently observed. However, because successful management would require complementary action by both the IATTC in the east and WCPFC in the west, the IATTC staff recommended that, pending action by both commissions, the fishing mortality in the eastern Pacific Ocean not be increased. The IATTC resolved (Resolution C-05-02[16]) that fishing mortality for northern albacore in the eastern Pacific should not be increased and required IATTC parties, cooperating non-parties, fishing entities or regional economic integration organizations (collectively CPCs) to take measures to ensure their fishing mortality for the stock did not increase. As noted below, the WCPFC took the same action in the central and western Pacific Ocean.

Bigeye tuna

Before 1994, most bigeye in the eastern Pacific Ocean were taken by longline with lesser amounts taken by purse seine. The growth of purse-seine catches after the introduction of FADs in the early 1990s was followed by declining longline catch rates and catches, and purse-seine catches have been greater than longline catches since 2004. The bigeye catches for 2000–2007 are shown in Table 1. The total catch peaked in 2000 and has subsequently declined.

The most recent assessment of the state of the stock is illustrated in Figure 3. Up to 1994, the stock was maintained well above the size associated with the MSY, with a fishing mortality rate below the rate that would produce the MSY. Since then, the fishing mortality rates have increased and the stock has declined and has been overfished for about the last five years.

TABLE 1
Annual catches of bigeye tuna in the eastern Pacific Ocean (tonnes)

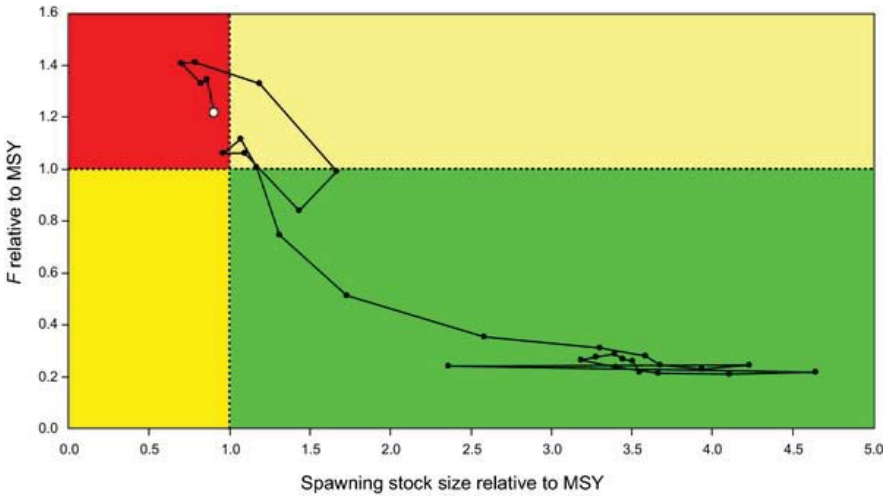
Year	Purse-seine (retained) method tonnes	Longline method tonnes	Total including other methods tonnes
2000	94 960	47 605	148 148
2001	61 156	68 754	131 223
2002	57 440	74 424	132 813
2003	54 174	59 776	116 231
2004	67 592	43 478	112 852
2005	69 826	41 720	113 544
2006	83 978	35 363	121 263
2007	61 434	25 560	88 280

Source: IATTC (based on Table A-2a), 2008b.

[15] http://isc.ac.affrc.go.jp/

[16] IATTC Resolutions are held on the Web site www.iattc/ResolutionsActiveENG.htm

FIGURE 3
Phase plot of the time series of estimates of stock size and fishing mortality of eastern Pacific bigeye tuna relative to their MSY reference points



Note: Each dot is based on the average exploitation rate over three years. The larger dot indicates the most recent estimate (2005–2007).
Source: IATTC (Figure D-9), 2008b.

In 2002, the scientific advice provided to the IATTC was that the stock was declining and was currently at or below the level that would support the MSY. It recommended that fishing mortality should be reduced by 16 percent. The recommendation was not fully implemented and in subsequent years the scientific advice has been that more drastic reductions are necessary to conserve the stock. The advice in 2004 was that the catch of bigeye tuna should be reduced by 50 percent through a variety of mechanisms. The conservation resolution for 2004–2006, which was extended to 2007 (Resolution C-06-02), required a six week closure of purse-seine fishing and placed limits on longline catches for each country, falling far short of the recommended reduction of 50 percent.

Recruitment to the stock has not been measurably affected by the overfishing and, as the purse-seine fishery predominantly takes young fish, those catches have not been seriously affected by the reduced stock. However, the longline fishery depends on older fish whose numbers have been reduced by several years of overfishing and accordingly, longline catches have been declining. None of the major longline fishing countries was able to reach its catch limit because of the declining stock of larger fish, while purse-seine catches increased during 2004–2007 compared with 2002.

In 2007 and 2008, the scientific advice was that the fishing mortality rate should be reduced by about 20 percent of the recent fishing mortality. The IATTC was not able to agree on new conservation measures at meetings held in June 2007, October 2007, March 2008, June 2008 and October 2008. However, during 2008, most of the IATTC members undertook to close their purse-seine fisheries on

a voluntary basis for six weeks in their entirety or on a vessel-by-vessel basis, apparently in recognition that while the commission was unable to agree on conservation measures, the individual members understood the need for action. In 2009, the IATTC staff estimated[17] the effect of the voluntary closures to be between 50 percent and 58 percent of the recommended closure and recommended that purse-seine fishing in the eastern Pacific Ocean be closed for 12 weeks and that an offshore area be closed from 12 September to 31 December each year. At its 2009 annual meeting, the IATTC agreed (ad referendum Colombia) to conservation Resolution C-09-01 that would: close the purse-seine fishery for 59, 62 and 73 days in 2009, 2010 and 2011, respectively; close an offshore area that was about 60 percent of the size of that recommended for one month; and imposed limits on longline catches of bigeye tuna. The 14 members of the commission who had agreed to the resolution at the meeting also agreed to a recommendation to apply the conservation and management measures in Resolution C-09-01, whether or not Colombia agreed to withdraw its reservation to the resolution.[18] Thus, after three years, the IATTC members managed to agree on measures that after a further two years would approach the scientific advice.

Pacific bluefin tuna

Unlike the other bluefin species, Pacific bluefin have not shown the effects of serious overfishing. In the last 30 years, catches have fluctuated around 20 000 tonnes per year without any trend. The most recent stock assessment reported to the IATTC indicated that the stock has fluctuated, with peaks in the spawning biomass in the early 1960s, late 1970s and late 1990s. There has been no scientific advice provided to the IATTC suggesting the need for management measures, nor have any been adopted.

Yellowfin tuna

The yellowfin tuna fishery in the eastern Pacific Ocean has the longest history of stock assessments and management of any tuna fishery. The first stock assessment was provided to the IATTC in 1962. In the early 1960s, the surface fishery (initially pole-and-line, which was subsequently converted to purse seine), was confined to coastal waters but rapidly started to expand offshore. Since 1962, the fishery has been through two cycles of being overfished, followed by a stock recovery. The first overfishing episode[19], which occurred in the 1960s, was followed by the first imposition of a TAC and eventually allocation of quotas to some countries.

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[17] Unilateral management actions taken in 2008. Paper for the 10th Stock Assessment Review Meeting, Del Mar, California, USA, 12–15 May 2009. Document SARM-10-04a. Available at www.iattc.org/PDFFiles2/SARM-10-04a-Unilateral-management-actions.pdf

[18] Colombia subsequently withdrew its reservation to the resolution.

[19] In the light of current understanding of the distribution of yellowfin tuna in the eastern Pacific Ocean, this overfishing episode would be seen as one of local depletion of part of the stock. However, at the time it appeared to be a matter affecting the entire stock and the IATTC reacted on that understanding.

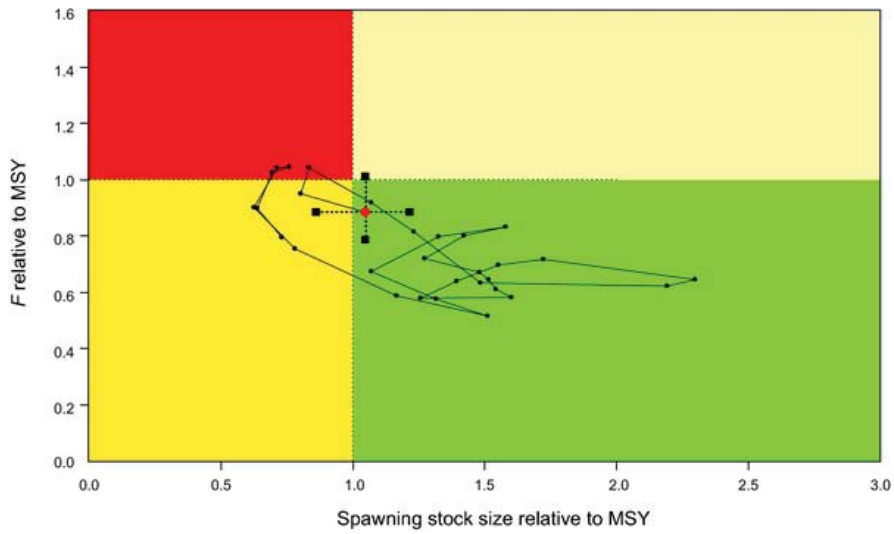
The second overfishing episode occurred during 1980–1986 after negotiations on country quotas failed. Fortunately for the yellowfin stock, other factors lead substantial parts of the fleet to tie up or to move to other areas. The fleet size declined after 1981 and the stock again recovered. Until 1988, the yellowfin stock stayed above the level that would provide the MSY and remained so until 1997. However, the purse-seine fleet grew rapidly after 1992 and by 1998 management measures once again became necessary.

In 1998, the IATTC began its efforts to control the growth of the purse-seine fleet by freezing at existing levels the capacity[20] for each state with purse-seine vessels in the fishery, including an allowance for vessels that had previously participated in the fishery. The commission also recognized the aspirations of other coastal states to develop their fisheries and provided for them to establish or enlarge their fleets. This measure was extended until June 2000 and then lapsed. In 2002, the commission adopted Resolution C-02-03, which abandoned the idea of country capacity quotas, except in the sense of specific provisions for some coastal countries, and instead used a regional register of vessels as a control mechanism. However, the total capacity allowed by the 1998 and 2002 resolutions was more than the capacity actually fished in 1998. The controls were not sufficient on their own to resolve the growing conservation needs of the fishery but probably have prevented even greater capacity increases.

The most recent assessment of the state of the stock is illustrated in Figure 4.

FIGURE 4

Phase plot of the time series of estimates of stock size and fishing mortality of eastern Pacific yellowfin tuna relative to their MSY reference points



Note: Each dot is based on the average exploitation rate over three years. The large dot indicates the most recent estimate (2005–2007). The squares represent approximate 95 percent confidence intervals.
Source: IATTC (Figure B-8), 2008b.

[20] In this paper "capacity" refers to the carrying capacity of purse-seine vessels measured by the volume of the spaces for storing frozen tuna.

Since 2002, the stock has been maintained near the level that provides the MSY by closing the fishery to purse-seine fishing for periods of time ranging from one month to six weeks each year. Table 2 compares the scientific recommendations for closure and the closures adopted by the IATTC from 2003 to 2007.

While the stock has remained about the level that produces the MSY over the period despite the management measures being less restrictive than those recommended, the catch has fallen from 413 000 tonnes in 2003 to 173 413 tonnes in 2007. Among the factors causing the decline in annual catches was a decline in the average size of fish in the catch from 12.4 kg to 8.3 kg.[21] For many years the commission has been advised that the average size of the yellowfin in the catch has been less than the size that would maximize the MSY and evidently this disparity has increased over the period.

TABLE 2
Comparison of scientific advice for eastern Pacific purse-seine closures (period of time) and the closures adopted

Year	Scientific advice	Actual closure
2003	2 months	42 days
2004	2 months	42 days
2005	No recommendation	42 days
2006	69 days	42 days
2007	74 days	42 days
2008	12 weeks	Voluntary 42 days

Source: The scientific advice is reported in the minutes of commission meetings and in staff conservation recommendations and the actual closures are from the conservation resolutions of the commission.

The stock size that produces the MSY is calculated using the current size composition of the catch and that stock size, and the associated MSY declines as the average size of fish in the catch declines. Thus, Figure 4 should be interpreted with the understanding that the yellowfin stock has been maintained near levels that produced successively less optimal MSYs as the average size of fish in the catch declined.

The International Commission for the Conservation of Atlantic Tuna

Substantial quantities of bluefin and albacore tunas have been taken in the Atlantic Ocean and the Mediterranean Sea since 1950. The longline fishery developed in the late 1950s, initially taking mostly albacore and purse seining mostly for yellowfin and skipjack, grew in importance during the mid-1960s. Similar to the situation in the eastern Pacific Ocean, though to a lesser extent, the proportion of bigeye tuna in purse-seine catches increased after 1991. Pole-and-line fishing for albacore and yellowfin tunas has been a significant fishing method since the late 1950s.

Stock assessment for ICCAT is provided by the Standing Committee for Research and Statistics (SCRS)[22] and the information on the stocks presented in this paper is drawn from the SCRS reports.

[21] IATTC. 2008. Tunas and Billfishes in the eastern Pacific Ocean in 2007. Fishery Status Report No. 6. Available at www.iattc.org/FisheryStatusReportsENG.htm

[22] The most recent SCRS report is available on the ICCAT Web site at www.iccat.int/Documents/Meetings/Docs/2009-SCRS_ENG.pdf

Albacore tuna

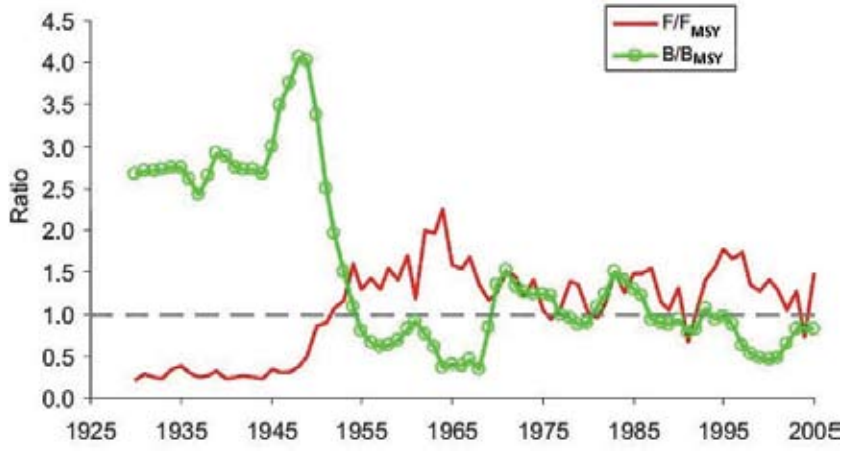
ICCAT treats albacore as three stocks (northern Atlantic Ocean, southern Atlantic Ocean and the Mediterranean Sea) within its area of jurisdiction, although the Mediterranean Sea stock has never been assessed.

Northern Atlantic albacore tuna. The estimated fishing mortality rate for northern albacore has been at or above F_{MSY} for most of the last 50 years. The estimated stock size has fluctuated above and below the size that would provide the MSY during the same period (Figure 5).

The biomass of the stock has been near or below B_{MSY} since 1999. The SCRS provided estimates of MSY of 32 600 tonnes in 2002 and 30 600 in 2006. In 1998, ICCAT recommended (Recommendation[23] 7-02) that fishing capacity should not increase over the level of 1993–1995, imposed a TAC of 34 500 tonnes in 2001 and reduced the TAC to the estimated MSY of 30 200 tonnes for each of the years 2008 and 2009. In 2006, the SCRS warned that the stock would not recover from the overfished conditions if catch levels remained over 30 000 tonnes and advised that Recommendation 7-02 would allow the potential catch to exceed the TAC. In fact, the catches for 2002, 2003 and 2007 were less than the TACs and the stock has recovered towards B_{MSY}, despite weaker than recommended management measures.

FIGURE 5

Estimates of the stock status of northern Atlantic albacore tuna by relative biomass (B/B_{MSY}) and relative fishing mortality rate (F/F_{MSY})



Source: ICCAT (ALB-Figure 6), 2008.

Southern Atlantic albacore tuna. Catches of southern albacore exceeded the level that the stock could replace for most years between 1970 and 2005. ICCAT set a TAC of 29 900 tonnes for the year 2004 and subsequently a TAC of

[23] ICCAT management measures are available on the ICCAT Web site at www.iccat.int/en/RecsRegs.asp

30 915 tonnes per year for the years 2005–2007, based on the MSY estimated by the SCRS in 2003 and 2004, respectively. The estimated biomass fell fairly steadily from 1965 until it reached levels of about B_{MSY} in the mid-1990s. In recent years, catches have remained well below the MSY and the TAC. In 2007, the SCRS recommended that the catch be limited to 29 200 tonnes per year and the ICCAT subsequently set a TAC of 29 900 tonnes per year for the years 2008–2011.

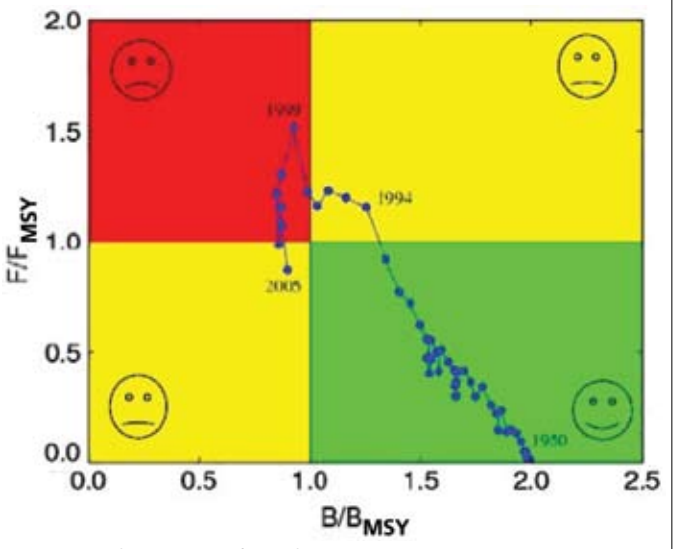
Bigeye tuna

In the Atlantic Ocean, bigeye tuna were initially taken in a pole-and-line fishery that still continues to provide significant quantities. The longline fishery started taking bigeye tuna after 1960 and very quickly provided the major part of the catch. In the 1990s, purse-seine catches of small bigeye tuna in association with FADs increased significantly. The total catch peaked in 1994 at 134 000 tonnes and since then the catches by all three methods have declined with a combined catch of 67 000 tonnes in 2006.

Bigeye tuna were last assessed by the SCRS in 2007 using data up to 2005 and Figure 6 shows the characterization that the SCRS felt best represented the state of the stock. Up to 1993, the fishing mortality rate was lower than the rate that would produce the MSY and the stock remained above the level that could produce the MSY (estimated in 2007 to be from 90 000 to 93 000 tonnes). However, increasing effort eventually reduced the stock below the level that could produce the MSY and the stock suffered both overfishing and being overfished between 1998 and 2004. While the current estimates show that relative biomass was never much lower than relative biomass in 2006 (B_{2006}/B_{MSY}=0.92), the estimates in earlier years were much lower; for example, in the SCRS 2002 report, the relative biomass for 1998 was estimated to be in the range of 0.57–0.63, suggesting at that time the need for even more urgent responses by the commission.

FIGURE 6

Time series of B/B_{MSY} and F/F_{MSY} showing the progression of the stock status of bigeye tuna as the Atlantic tuna fisheries evolved, 1950–2005



Source: ICCAT (BET-Figure 7, left panel), 2008.

ICCAT adopted recommendations addressing management of fisheries for bigeye in 1998 and in each year from 2000 to 2005. The 1998 recommendation limited the number of fishing vessels longer than 24 m to the average of the

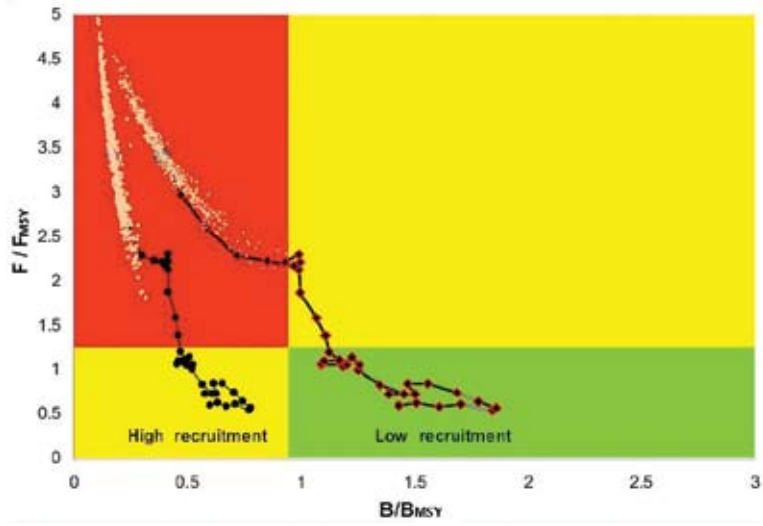
number of those vessels fishing in 1991 and 1992 and requested that Chinese Taipei limit its catches to 16 500 tonnes per year. In 2000, ICCAT limited the catch of contracting parties and cooperating non-contracting parties to the average of their catch in 1991 and 1992 and requested that China, Chinese Taipei and the Philippines observe certain limits. These measures were continued in 2003, and in 2004 a multiannual (now extended to 2009) TAC of 90 000 tonnes with quotas for all major participants in the fishery was adopted. In fact, catches fell faster than the catches required by the recommendations. These reductions in catch were related to declines in purse-seine and longline fishing fleet sizes and to declines in longline and pole-and-line catch per unit effort (CPUE). The average catch between 2002 and 2007 was 77 000 tonnes per year. While ICCAT did take measures in response to the scientific advice, it appears that other factors were responsible for reducing catches towards sustainable levels.

Bluefin tuna

Bluefin tuna, along with southern bluefin tuna and Pacific bluefin tuna, are the most valuable and most sought after of the tunas. The effect of high levels of exploitation is aggravated by their relatively slow growth and slower reproduction. Two stocks (East Atlantic and West Atlantic), with an uncertain amount of mixing, are recognized by ICCAT.

Bluefin tuna in the East Atlantic. The estimated status of the eastern stock under two assumed recruitment levels is shown in Figure 7.

FIGURE 7
Stock status of the eastern Atlantic bluefin tuna



Note: Estimated from virtual population analysis (VPA) run 14 considering either high recruitment or low recruitment levels. The terminal year is highlighted by a larger dot. White dots represent the distribution of the terminal year obtained through boot strapping.
Source: ICCAT (BFTE-Figure 4), 2008.

Scientific advice has highlighted chronic overfishing of the eastern stock of bluefin tuna over a long period. Reported catches peaked at 50 000 tonnes in 1996. Eventually the ICCAT addressed the scientific advice with programmes of reductions of catches to 32 000 tonnes per year for the years 2003–2006 (Recommendation 02-08) and to 29 500 tonnes and 28 500 tonnes for 2007 and 2008, respectively (Recommendation 06-05). In 2008, the SCRS estimated that the current fishing mortality was still three times the rate that would produce the MSY and reported that even its most optimistic evaluation indicated that substantial overfishing was occurring and the spawning biomass was well below the level needed to produce the MSY. The SCRS recommended that the reduction of catches to 15 000 tonnes per year or less would be more likely than the existing measures to allow the stock to rebuild. The ICCAT agreed to reduce the catch to 22 000 tonnes in 2009 and further to 19 950 tonnes in 2010.

The management of this stock is further threatened by other management failures, including non-reporting of catches. In 2008, the SCRS estimated total catches of 50 000 tonnes for 2006 and 61 000 tonnes for 2007 compared with reported catches of 30 647 tonnes for 2006 and 32 398 tonnes for 2007. In its comment on the effect of management regulations, the SCRS concluded its advice with "Based on the Committee's analysis, it is apparent that the TAC is not respected and is largely ineffective in controlling overall catch although enforced control seems to have been deployed in 2008 in the Mediterranean Sea" and provided the view that continuing with the current management scheme would most probably lead to further reduction in spawning stock biomass with high risk of fisheries and stock collapse. Poor data quality and missing data have a significant impact on the effectiveness of RFMOs and this instance is one of the most significant.

Bluefin tuna in the West Atlantic. In 1998, ICCAT adopted a 20 year rebuilding plan designed to restore the biomass of the bluefin tuna to B_{MSY} with a TAC of 2 500 tonnes later reduced to 2 100 tonnes from 2007. In 2008, the SCRS reported that, rather than rebuilding, the stock was below the level of the plan's first year and recommended a TAC of 2 000 tonnes under an optimistic scenario or 1 500 tonnes under other scenarios, to be 75 percent certain that the stock would rebuild according to the plan.

No additional management action was taken by ICCAT in response to the 2008 SCRS recommendations.

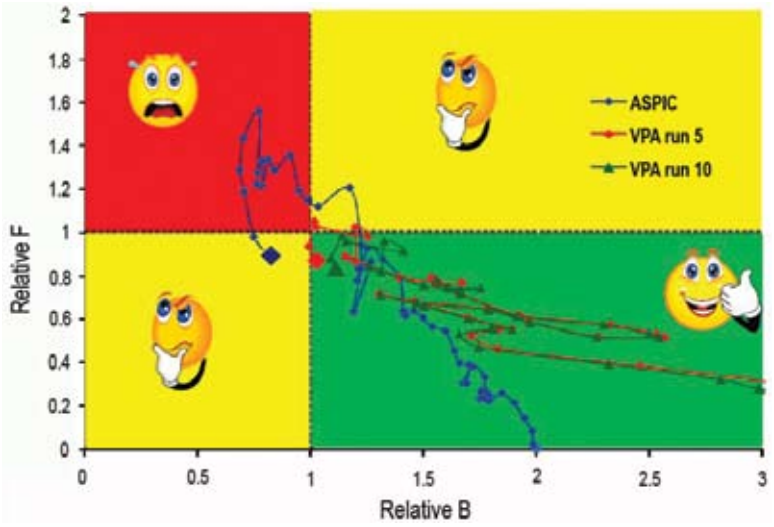
Yellowfin tuna

The state of the stock of yellowfin tuna in the Atlantic Ocean was assessed in 2008 using both age-structured and production modelling. An overview of the results is illustrated in Figure 8. The age structured modelling results reported by the SCRS indicated that the stock was near the level that would provide the MSY and that the fishing mortality rate was near or below the rate associated with the MSY. However, the estimates of MSYs themselves have declined 30 percent from

the levels in the mid-1970s because of the decline in the average size of fish in the catch. In that sense and similar to the situation with yellowfin tuna in the eastern Pacific Ocean, the fishery is operating near a MSY that is suboptimal compared with the MSY of previous years. The SCRS recommended, as it had previously, that effective measures be found to reduce fishing mortality of small yellowfin if the commission wished to increase the long-term sustainable yield.

FIGURE 8

Stock status trajectories of Atlantic yellowfin tuna B/B_{MSY} and F/F_{MSY} from age-structured and production model analyses



Note: The age-structured analysis started in 1970 and the production model analysis started in 1950. Current status is indicated by the large point at the end of each time-series.
Source: ICCAT (YFT-Figure 9), 2008.

The Indian Ocean Tuna Commission

Industrial longline fishing began in the Indian Ocean in the early 1950s. Longline catches of bigeye peaked at 112 000 tonnes in 1998 and yellowfin peaked at 196 000 tonnes in 1993. Longlining has been the principal method of taking albacore, with catches reaching 39 000 tonnes in 2001 and thereafter declining to 22 000 tonnes by 2006. Purse seining began in the Indian Ocean in the late 1970s and by 2003 purse-seine catches of yellowfin tuna had increased to 233 000 tonnes and the most recently reported catch of skipjack of 258 000 tonnes was the greatest recorded. Artisanal fisheries take a greater proportion of tunas in the Indian Ocean than in other areas. While they focus on neritic tunas, they also take significant quantities of bigeye, yellowfin and skipjack.

The Scientific Committee advises the commission on the status of stocks and on management issues and the information below concerning the status of stocks is drawn from its reports.[24]

[24] Reports of the Scientific Committee can be found on the IOTC Web site at www.iotc.org/English/meetings.php

Albacore tuna

Preliminary analysis by the Scientific Committee in 2008 indicated that the current biomass was greater than B_{MSY} and that it was unlikely that the fishing mortality rate was greater than F_{MSY}.

Given the scientific advice, the IOTC has not taken any management action directed at the management of albacore fisheries.

Bigeye tuna

The 2005 and 2006 catches of bigeye tuna were around the level of the MSY, currently estimated to be 111 000 tonnes, but the catches from 1996 to 2004 exceeded the MSY. The results of the 2006 stock assessment for bigeye tuna were broadly similar to the results of earlier assessments and indicated that the spawning stock declined over the course of the fishery but was probably still above the level that would provide the MSY and would remain so with current levels of catches. However, the outlook provided by the Scientific Committee suggested that the lower purse-seine catches of small bigeye in 2003 and 2004 were influenced by high catch rates of yellowfin, and that it was possible that previous catch patterns with large numbers of small bigeye tuna would return in future, with detrimental effects on the stock.

In 2006, the Scientific Committee recommended that catches should not exceed the MSY and that fishing effort should not increase further from 2004 levels. In fact, the Scientific Committee first recommended reductions of catches of bigeye to the MSY in 2001, then estimated to be 90 000 tonnes. In 2003, the commission agreed[25] to hold a working group in 2005 to consider conservation and management options that may be applicable to the highly migratory fish stocks of the Indian Ocean. In 2005, the commission agreed that catches of contracting and cooperating non-contracting parties should be limited to the catches of recent levels.[26] As all the annual catches since 1996 had been greater than the estimated MSY, albeit only slightly in 2001, this was unlikely to have been sufficient to limit catches to the MSY. Recognizing this, perhaps and that since its fourth session in 2001 the Scientific Committee had recommended a reduction in catches of bigeye tuna, the commission also agreed to establish[27] a working party on management options, with responsibilities to provide the commission with management options that would, *inter alia*, take account of recent assessments and best advice.

Yellowfin tuna

In 2003, the Scientific Committee reported its view that catches under current fishing patterns were close to, or possibly above, the MSY and that any further increase in both effective fishing effort and catch above the levels in 2000 should be avoided.

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[25] IOTC Recommendation 03/06. IOTC Resolutions and Recommendations are available on the IOTC Web site at www.iotc.org/files/proceedings/misc/ComReportsTexts/resolutions_E.pdf

[26] IOTC Resolution 05/01.

[27] IOTC Recommendation 05/06.

During 2003–2006, the catches of yellowfin tuna in the Indian Ocean averaged 456 000 tonnes per year compared with the previous greatest catch of 395 000 tonnes in 1993. In its 2007 report, the Scientific Committee considered two possible reasons for the increase, each of which would have different consequences for the state of the stock. The first explanation was the possibility that environmental conditions may have favoured large recruitment during the late 1990s and early 2000s. The second explanation was that during the years of high catches, yellowfin were more catchable than previously. In the first case, there would be no serious consequences of the high catches, which simply would have been a proportion of a larger stock. However, if the second explanation were correct, a greater quantity than normal of yellowfin would have been taken from the stock, leading to a reduced stock size at the end of the period. While the evidence is mixed, the Scientific Committee considered increased catchability the more likely alternative. It recommended that catch levels be reduced to pre-2003 levels and that fishing capacity should not exceed the current level.

The only action taken by the IOTC in response to the recommendations of the Scientific Committee was in 2003[28] to limit the number of large-scale vessels of parties with more than 50 such vessels to the number they had in 2003. Evidently this measure was not effective in limiting catches to the levels in 2000 as recommended by the Scientific Committee in 2003.

The Western and Central Pacific Fisheries Commission

While the WCPFC has only been in existence since 2004, it has been able to rely on an outstanding research programme carried out by of the Oceanic Fisheries Programme of the Secretariat of the Pacific Community, formerly known as the Tuna and Billfish Assessment Programme (TBAP), which in turn succeeded a large-scale skipjack tuna tagging project.

Langley, Williams and Hampton (2008) provide an overview of the fisheries and state of the stocks. The longline fisheries have been well established since World War II and currently take a little more than 200 000 tonnes. There are several fleets involved in the fishery, each of which fishes in different ways. The overall catch composition is roughly one-third for each of albacore, bigeye and yellowfin tunas; some components of the fleet target albacore and other components target the tropical tunas. The purse-seine fisheries, which catch mostly skipjack tuna but also important quantities of yellowfin and bigeye tunas, did not develop significantly until 1979 and in succeeding years the fishery has grown to take more than 1.5 million tonnes, by far the largest of the tuna fisheries. There is also an important pole-and-line fishery, which though declining in recent years, takes about 200 000 tonnes, catching mostly skipjack.

The Scientific Committee is responsible for reviewing analysis, assessments and recommendations of scientific experts and also for making recommendations on its own initiative on matters concerning conservation and management of stocks, for the consideration of the WCPFC.

[28] IOTC Resolution 03/01.

Albacore tuna

Albacore tuna in the North Pacific. The Scientific Committee did not provide advice about northern albacore tuna; however, the WCPFC Northern Committee drew the commission's attention to the IATTC 2005 resolution on northern albacore tuna. The WCPFC apparently acted upon information in that resolution and adopted CMM-2005-03[29], which echoed the terms of the IATTC resolution and required members and cooperating non-members to take measures to not allow their fishing effort to be increased beyond current levels.

Both the WCPFC and IATTC decisions recognized the need to cooperate with one another to achieve conservation and management of this stock. The realization of that intention is discussed below.

Albacore tuna in the South Pacific. In 2005, the Scientific Committee advised that current catch levels appeared to be sustainable and suggested that increases in fishing mortality and yields were possible. However, it was likely that any significant increase in effort would reduce catch rates with only moderate increases in yields and that there may be severe catch-rate reductions in some areas. In its 2005 decision (CMM-2005-02) to restrain fishing effort to current levels, albeit sacrificing potential yield, the commission took account of the likelihood of catch rates being reduced in areas with locally concentrated fishing effort (near small island states) and the likelihood of economic consequences of increased fishing effort. This is the only example of international management measures in tuna fisheries where optimum catches have been explicitly identified as less than the MSY and that could be seen as being the result of a precautionary approach.

Bigeye tuna

Through the late 1990s, the WCPFC Scientific Committee's predecessor, the Standing Committee on Tuna and Billfish, cautioned against increased levels of fishing mortality of bigeye and yellowfin. At its first meeting in 2005, the Scientific Committee concluded that bigeye in the western and central Pacific Ocean (WCPO) was likely experiencing overfishing. The commission adopted CMM-2005-1 to limit fishing effort for bigeye and yellowfin tunas to current levels.

In 2006, the Scientific Committee's assessment was that, while the stock was still above B_{MSY}, the estimate of the ratio of current fishing mortality and F_{MSY} was greater than in 2005 and it recommended a 25 percent reduction in fishing mortality from the average levels for 2001–2004 to maintain the bigeye stock at a level capable of producing the MSY.

The results of the Scientific Committee's 2008 assessment are illustrated in Figure 9. It recommended a minimum 30 percent reduction in fishing mortality from the average levels in 2003–2006, with the goal of returning the fishing mortality rate to F_{MSY}. It noted that the estimate of the ratio of current fishing

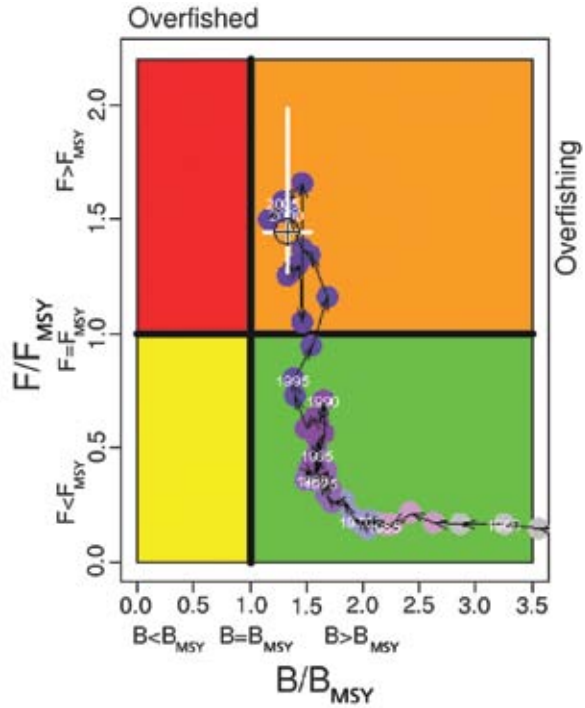
[29] WCPFC conservation and management measures are available on the WCPFC Web site at www.wcpfc.int/

mortality to F_{MSY} was greater than the corresponding estimate in 2006 and that the recommendation was consistent with its advice at that time.

The WCPFC adopted a further measure in 2006 requiring the members, participating territories and cooperating non-members not to increase their fishing effort over 2001–2004 levels. However, the overfishing continued as shown by the increase in the ratio of current fishing mortality to F_{MSY}. In 2008, the WCPFC agreed on a measure CMM 2008-1 that aimed to reduce fishing mortality by 30 percent over a three-year period. CMM 2008-1 is very complex and its effectiveness will be hard to assess until the end of the three-year period. The measure does not apply to small island developing state members and participating territories in the convention area that are seeking to develop their own fisheries; to the extent they are successful in so doing, the conservation goals of the measure will be compromised unless further measures are taken. Other longline fishing states that took an average of more than 2 000 tonnes per year during the years 2001–2004 are required to reduce their catches from that average by 10, 20 and 30 percent in 2009, 2010 and 2011, respectively. The measure restricts purse-seine fishing with FADs at certain times, notes the Third Implementing Arrangement of the Nauru Agreement (Attachment A of CMM 2008-1) and relies heavily on its restrictions on purse-seine fishing to achieve the objective of reduced fishing mortality. It seems that the WCPFC's contribution to conservation was the restriction on the use of FADs and the longline reductions; the purse-seine restrictions of the Nauru Agreement would have occurred anyway. Reliance on the Third Implementing Arrangement, which has different objectives for conservation and management, is likely to be problematic for the WCPFC. However, this

FIGURE 9

The temporal trend in the annual stock status of western Pacific bigeye tuna



Note: Temporal trend in annual stock status for western Pacific bigeye tuna, relative to B_{MSY} (x-axis) and F_{MSY} (y-axis) reference points, for the model period (1952–2006) from the base-case model (run 4). The colour of the points is graduated from mauve (1952) to dark purple (2006) and the points are labelled at five-year intervals. White lines represent the confidence interval associated with F/F_{MSY} and B/B_{MSY}. The last year of the model (2007) is excluded because it is highly uncertain.
Source: WCPFC (Figure 3), 2008.

novel feature of the measure should be seen in the light of the fact that only 18 percent of the WCPO tuna fisheries occur in the high seas. Further, the incorporation of the text of the Third Implementing Arrangement within the measure means that the substance of the Third Implementing Arrangement can be reviewed within the WCPFC.

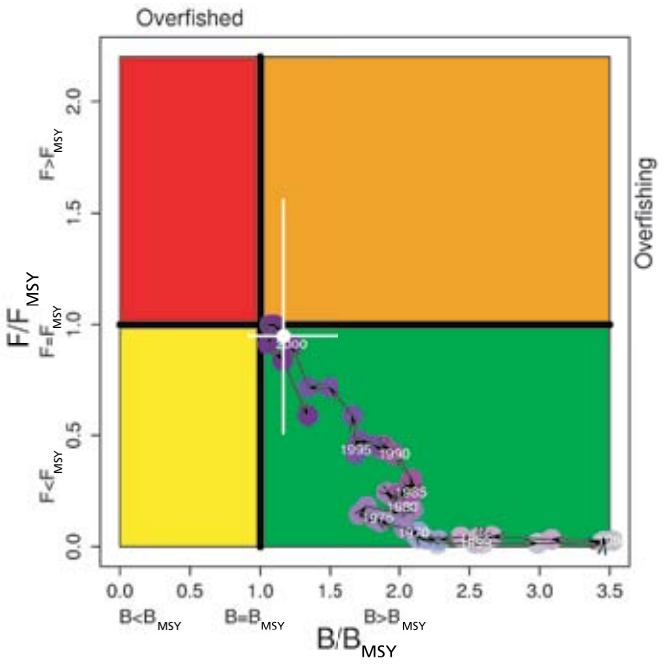
Pacific bluefin tuna

Pacific bluefin tuna comprise a single stock in the Pacific Ocean. Catches have fluctuated without a trend in the last 30 years and to date there has been little concern about the sustainability of the stock. The scientific advice to the commission in 2008 was that with the current level of fishing mortality and average recruitment the current yields should be maintained, that current fishing mortality should not be increased but that reductions in fishing mortality should, after a period, provide greater yields.

The commission has not taken any actions specifically aimed at Pacific bluefin tuna.

FIGURE 10

The temporal trend in the annual stock status of western Pacific yellowfin tuna



Note: Temporal trend in annual stock status of western Pacific yellowfin, relative to B_{MSY} (x-axis) and F_{MSY} (y-axis) reference points, for the model period (1952–2006). Temporal trend in annual stock status, relative to B_{MSY} (x-axis) and F_{MSY} (y-axis) reference points, for the model period (1952–2006). The colour of the points is graduated from mauve (1952) to dark purple (2006) and the points are labelled at five-year intervals. The white point represents the reference points computed for the "current" period (2002–2005) and the white lines represent the associated 95 percent confidence intervals.
Source: WCPFC (Figure 4), 2007.

Yellowfin tuna

The management measures CMM 2005-1 and CMM 2006-01 were intended to stop growth in fishing effort for yellowfin tuna as well as for bigeye tuna. Nevertheless, in 2006, the Scientific Committee recommended that there be a 10 percent reduction in fishing mortality and in 2007 it advised the commission that fishing mortality should be reduced if the commission wished to reduce the likelihood of overfishing. The 2007 advice is the most recent provided to the commission and presented a slightly more optimistic assessment than the assessment of 2006, with a probability of more than 50 percent that the fishing mortality is less than the MSY level. Figure 10 shows the temporal trend in the estimated stock status from 1952 to 2006 as estimated in 2007.

The commission took no action in 2007 but, as reported above in the section on bigeye, adopted measure CMM-2008-1 in 2008 to reduce purse-seine catches, including those of yellowfin.

Cooperation between the Inter-American Tropical Tuna Commission and the Western and Central Pacific Fisheries Commission

In the Pacific Ocean, intercommission cooperation between the IATTC and the WCPFC is necessary for the conservation and management of stocks that have significant movements to and from the eastern and western Pacific Ocean and that are exploited by fleets that move between the two convention areas. In their 2005 decisions concerning management of the northern albacore fishery, both commissions recognized the need for cooperation with each other to effectively manage the fishery. The measures of each commission included not allowing increases in fishing effort and were adopted recognizing that firmer action should be taken jointly by the two commissions.

The two commissions, under a memorandum of understanding, have agreed that the two secretariats should consult regularly to consider issues of common interest. Such meetings, which are usually held in the margins of the annual sessions of each commission, have been held each year since 2006. Despite the recognition of the need for cooperation to develop firmer actions for the management of northern albacore, there has been no substantive discussion of the matter. Similarly, cooperation that will be required for effective management of the fishery for Pacific bluefin and other species has not yet been addressed substantively at the consultative meetings.

Summary of the management responses of the RFMO commissions

The stock status and need for management actions by the tuna commissions is closely related to the market value of each species and its productivity. Skipjack tuna are the most abundant and productive of the major market species; they are also the least valuable and their stocks do not appear to have been affected sufficiently by fishing to require management action, at least for conservation purposes. Bluefin tunas are the most valuable and highly sought after; generally their productivity is less than the market demand and all stocks except the stock

for Pacific bluefin are overexploited. The stocks of the other species are in an intermediate situation, with some requiring management and others not.

The history of the fisheries for tuna since 1950 has been one of a relentless increase in demand and fishing capacity in all areas. Table 3 shows that the result of that development has, according to the assessments of the appropriate scientific bodies, been that of the 22 stocks of the major market species, 14 are now in need of management to restrict fishing effort.

TABLE 3
The state of the stocks of the major market species of tunas

RFMO	Albacore tuna		Bigeye tuna	Bluefin tuna	Skipjack tuna	Yellowfin tuna
	Northern	Southern				
CCSBT				■		
IATTC	■		■	■	■	■
ICCAT	■	■	■	■ ■	■	■
IOTC	■		■		■	■
WCPFC	■	■	■	■	■	■

Note: ■ indicates stocks for which scientific advice has recommended management action to keep them at target levels. ■ indicates stocks for which scientific advice does not contemplate management action to conserve them.

Source: Author, based on assessments of the Scientific Committees of the CCSBT, the IATTC, the ICCAT, the IOTC and the WCPFC.

The cells of the table are blank when the relevant commission does not exercise a management role. Note that northern albacore for the IATTC and WCPFC is the same stock. For ICCAT, bluefin tuna has an eastern stock and a western stock. The scientific advice for southern albacore to the WCPFC contemplates management action for the purpose of maintaining high catch rates in some areas and keeping the stock level well above B_{MSY}.

Of the 14 stocks in need of management action, the only ones for which recent actions commensurate with the scientific advice have been taken by the commission are the southern albacore and bigeye in the Atlantic Ocean, and the southern albacore and bigeye (and possibly yellowfin) in the western and central Pacific Ocean. However, the measures for bigeye in the Atlantic Ocean did not result in declines in fishing (declines took place for other reasons) and the measure for bigeye and yellowfin in the western and central Pacific Ocean relied on and endorsed actions that had already been taken by another arrangement for most of the reduction in purse-seine fishing.

The survey of advice and management actions has illustrated some particular problems. The most important problem is the use of restrictive measures to try to deal with overcapacity in the fisheries.

The Second Meeting of the Regional Fishery Body Secretariats Network[30] in 2009 recognized that IATTC is the only RFMO that has a strict capacity limitation regime in place. Even so, the limit provided by the IATTC for the purse-seine fleet capacity is far above the optimum fleet size set in its 2002 Resolution on Capacity (C-02-03) and restrictions on fishing time are necessary. Unless an effective means

is found for dealing with the overcapacity of tuna fleets, the tuna RFMOs will always be struggling to find reasonable means of restraining fishing effort and conserving the stocks.

Overcapacity of fleets has been exacerbated by weak fulfilment of the aspirations of developing countries to participate in fisheries. The Rio Declaration put sustainable development and the special situation and needs of developing countries squarely onto the international agenda. Sharing of resources that are at or near full exploitation can only be done by reallocation of fishing opportunities from developed to developing countries. This has been recognized by tuna commissions. However, the two provisions for members that are developing countries cited in this paper, the IATTC Resolution C-02-03 and the WCPFC management measure CMM-2008-01, do not reallocate fishing opportunities from members of developed countries. These provisions are examples of what could be known as unsustainable development.

The use of MSY calculated using the current size composition of the fish stock as a target or limit reference point is of dubious value. Figures 4 and 10 showing the phase plot of fishing effort and biomass for yellowfin in the eastern Pacific and Atlantic Oceans, respectively, suggest that stocks are being fished at near the optimum level, when in fact the MSY itself has fallen substantially as the fishery has reduced the average size of fish in the stock. The use of the phase diagrams as a common tool for the tuna commissions to communicate the condition of stocks was agreed at the joint tuna commission in Kobe in 2007. The two diagrams illustrate that, on their own, these plots may be misleading.

Two of the important standards for management from UNFSA and CCRF, the precautionary approach and the setting of limit points, seem to have had little effect on management by the tuna RFMOs. The limiting of fishing effort in the southern albacore fishery by the WCPFC is the only action that might reasonably be described as precautionary. The only claim to setting target or limit reference points that could be made is that most of the tuna RFMOs use the B_{MSY} or the F_{MSY} as either a limit or target reference point.

[30] www.fao.org/fishery/rsn/en

4. Incentives and disincentives for cooperation in international tuna fisheries management

The general recognition that mankind needs to conserve the resources it depends upon, including fisheries, provides a strong incentive for states to cooperate in the conservation and management of particular resources such as tuna fisheries. However, states may also perceive that cooperation will either enhance or diminish their use of a resource and this will provide either an incentive or disincentive to cooperate with others.

Achieving agreement among members of a RFMO has been considered from the perspective of the discipline of game theory (Lodge *et al.*, 2007; Chapter 2). A rather simple conclusion of this type of analysis is that for a successful management agreement, each member must expect that the benefit of cooperation is greater than the benefit of competing outside of an agreement. In a simple situation with two players sharing a single resource, this condition can easily be satisfied. However, in most cases of international tuna fisheries, the situation is considerably more complex as illustrated below with a simplified analysis of the situation with members of the IATTC.

The IATTC has 16 members, including Colombia, Costa Rica, El Salvador, Ecuador, France, Guatemala, Japan, the Republic of Korea, Mexico, Nicaragua, Peru, Panama, Spain, the United States, Vanuatu and Venezuela, and as well there are an additional 9 countries or fishing entities involved in the fishery, among which 5 cooperate formally with the IATTC and 4 cooperate informally.

Figure 11 shows the tuna catches in the eastern Pacific Ocean from 1988 to 2008. During those years, the catches ranged between 500 000 and 900 000 tonnes and comprised between 10 and 20 percent of the world's total catch of tunas. For most years, yellowfin tuna comprised the largest component of the catch, followed by skipjack tuna and then bigeye tuna.

Figure 12 shows the catches of yellowfin tuna by fishing method. The colours brown, green and blue represent purse-seine catches and are partitioned according to the way in which schools of tuna are located. The brown colour represents schools that are associated with flotsam or FADs deployed by fishers to attract fish. FADs have been used in the eastern Pacific Ocean since 1993 and are particularly effective at attracting skipjack and small bigeye tunas.

The blue colour represents catches from schools that are associated with dolphins. Most of the catches of yellowfin in the eastern Pacific Ocean are from schools associated with dolphins. In most respects, this is the best way of catching

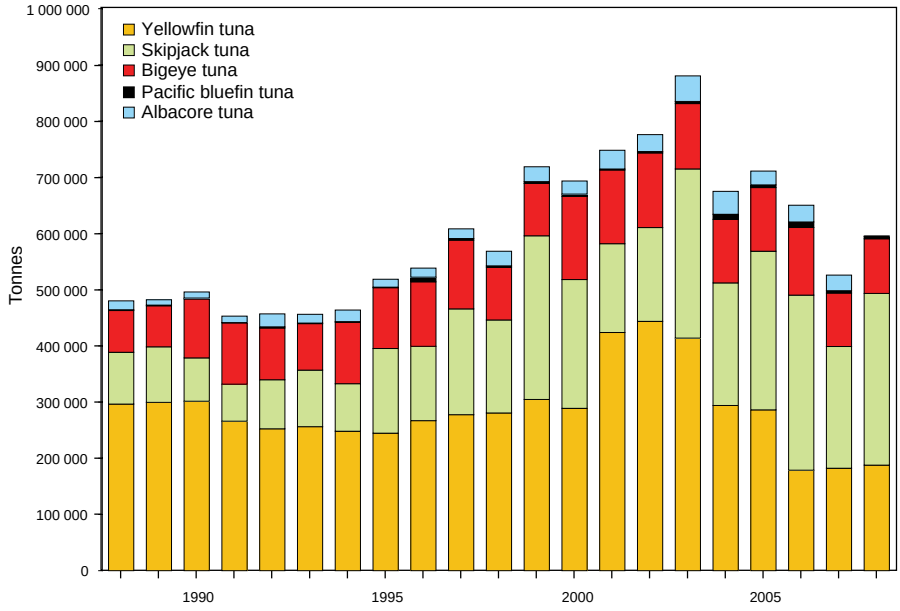
yellowfin tuna in the eastern Pacific Ocean as it produces medium to large fish with very little bycatch. Of course, the involvement of dolphins makes this a very complicated fishery; issues relating to management of the bycatches of dolphins are described by Joseph (1994). Similarly, the fishery using floating objects is also associated with a number of difficult bycatch issues described by Hall (1996).

The green colour in Figure 12 represents yellowfin tuna that are found near the surface without being aggregated either by a floating object or a school of dolphins (unassociated schools). Most purse-seine vessels are specialized with different equipment to make them suitable to fish for either schools associated with dolphins or schools associated by FADs, but not both. However, any vessel will take advantage of an unassociated school that it comes across.

The orange colour represents yellowfin tuna taken by longline. Longline vessels generally fish for bigeye tuna and take smaller amounts of yellowfin tuna. The longline method catches the largest fish and has the smallest impact on the populations. The graph also shows the catches by pole-and-line (yellow). This used to be the predominant form of fishing, which has now practically disappeared from the eastern Pacific Ocean.

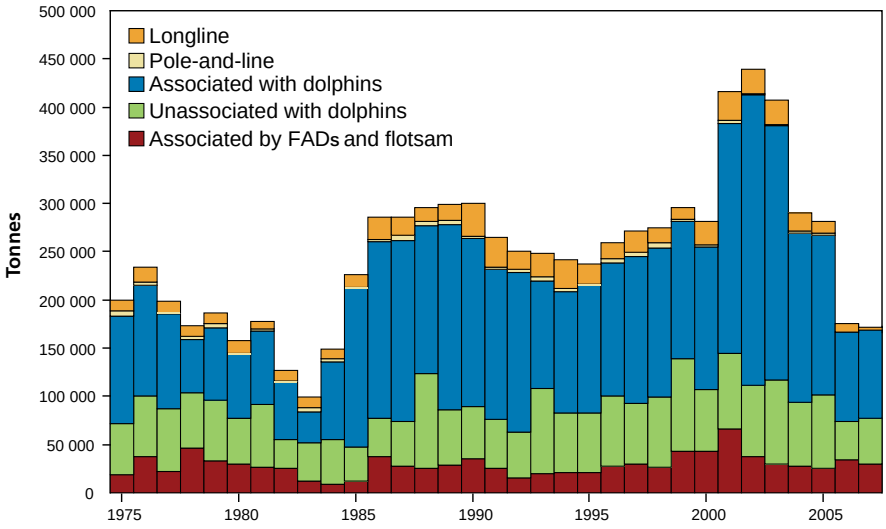
FIGURE 11

Catches of yellowfin, skipjack, bigeye, Pacific bluefin and albacore tunas in the eastern Pacific Ocean by fishing method, 1988–2008 (tonnes)



Source: Courtesy of the IATTC (Dr G. Compeán, personal communication). 2007 data are provisional.

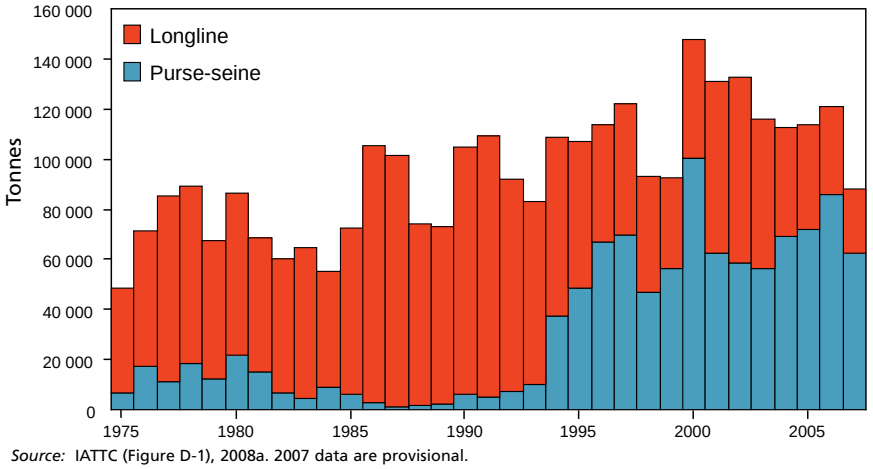
FIGURE 12
Catches of yellowfin tuna in the eastern Pacific Ocean by fishing method, 1975–2007 (tonnes)



Source: IATTC (Figure B-1), 2008b. 2007 data are provisional.

Figure 13 shows the catches of bigeye tuna by fishing method; in this case, there are only two methods of importance, longline and purse-seine. Up to 1993, the catch was mostly taken by longline (shown in red). As with yellowfin, this method takes large individuals. Blue bars represent bigeye catches by purse seine using FADs. Bigeye associated with FADs tend to be quite small and the fishery takes these fish several years before they otherwise would become available to the longline fishery. Evidently, the purse-seine fishery is in the process of replacing

FIGURE 13
Catches of bigeye tuna in the eastern Pacific Ocean by fishing method, 1975–2007 (tonnes)



Source: IATTC (Figure D-1), 2008a. 2007 data are provisional.

longline catches because it takes small fish before they would become available to the longline fishery. At the same time, because it catches small fish, the growth of the purse-seine fishery has reduced the total yield of bigeye tuna from the fishery.

The major management problems in the fishery today are the result of too much fishing effort being exerted for the productive capacities of yellowfin and bigeye tunas. The fact that this is probably not the case for skipjack considerably complicates management because the countries that mostly catch skipjack, but also some of the other species, do not have the same interest in restricting fishing effort as do the other countries.

As well as the overall issue of fishing effort, the yellowfin stock size was relatively low during 2005–2008 and catches comprised relatively smaller yellowfin tuna from sets on FADs or from unassociated schools than catches of medium and large yellowfin associated with dolphins.

The bigeye stock is overfished and this represents the most serious management challenge for tuna fisheries in the eastern Pacific Ocean.

Table 4 illustrates a simplified description of the 2003 catches by six of the countries involved in the fishery, arranged into three what are called in this paper "coalitions", each of which fishes mostly with a particular fishing technique. These countries provide the most extreme examples of national fishing methods and other participants in the fishery take either smaller catches or tend to use a mixture of fishing techniques. The first coalition comprised of Ecuador and Spain caught mostly skipjack using FADs, the second coalition comprised of Mexico and Venezuela caught mostly yellowfin associated with dolphins and the third coalition, comprised of Japan and the Republic of Korea, depended on bigeye tuna taken by longline.

TABLE 4
Catches of bigeye, skipjack and yellowfin tunas by six countries in 2003 (tonnes)

Fishing method	Country	Bigeye tuna tonnes	Skipjack tuna tonnes	Yellowfin tuna tonnes
Purse seine, principally with FADs	Ecuador	25 000	140 000	33 000
	Spain	8 000	29 000	4 000
Purse seine, mainly setting on schools associated with dolphins	Mexico	0	9 000	173 000
	Venezuela	0	8 000	95 000
Longline	Japan	25 000	0	9 000
	Republic of Korea	10 000	0	5 000

Note: Shading used to highlight various coalitions.
Source: IATTC (based on Table A-3a), 2008b.

Longline coalition members take very large bigeye and yellowfin and have little effect on purse-seine catches. However, the purse-seine catches of smaller

bigeye and to a lesser extent yellowfin have a significant effect on longline catches. Because longline catches have little effect on them, the purse-seine FAD coalition does not expect to be better off by cooperating with, rather than competing against, the longline coalition.

The primary targets of FAD sets is skipjack. However, these sets also take small bigeye and yellowfin. Sets on schools associated with dolphin sets take medium- to large-sized yellowfin and no bigeye. Sets on FADs have a negative effect on catches of yellowfin associated with dolphins but sets on dolphins have very little effect on catches of yellowfin from sets on FADs. As a result, the FAD coalition does not expect better results from cooperation with, rather than competing against, the dolphin coalition.

Thus the basic condition for successful cooperation described at the beginning of this section – that each member must expect that the benefit of cooperation is greater than the benefit of competing outside of an agreement – does not seem to be met in the eastern Pacific tuna fisheries. Perhaps the conclusion drawn by Hilborn (2007) that the collective action of states is not adequate to meet the challenges provided by managing these fisheries was right in this case.

5. A way forward – Rights-based management

The FAO has recently carried out a project "Management of tuna fishing capacity: conservation and socio-economics". Under the auspices of the project, the capacity of tuna fishing fleets and trends in tuna catches in the world were described (Miyake, Miyabe and Nakano, 2004), the markets for tuna and the status of tuna stocks of the world have been addressed (Bayliff, de Leiva and Majkowski, 2005), and management options (Bayliff and Majkowski, 2007)[31] for the future were considered. In a statement attached to their report, the workshop participants concluded that effective rights-based management systems will lead to elimination of overcapacity in the tuna fleets.

Following the FAO project, the IATTC and the World Bank sponsored a workshop[32] on rights-based management and buybacks in international tuna fisheries that examined the use of rights-based management systems and possible means of transitioning from the status quo to more effective systems, including the use of buying back existing fleet capacity. The issues discussed in the workshop are presented in more depth in Allen, Joseph and Squires (2010a, b).

The FAO project and the IATTC and World Bank workshop have illustrated the problems associated with the continued growth of tuna fishing fleets in response to market demands for fish. The incentives for international cooperation to manage the fisheries well are weak or even perverse and have led to overfishing in many cases and to poor economic performance in most cases.

Rights-based management systems have been well tested within national jurisdictions and have demonstrated a facility for addressing the perverse incentives that exist in fisheries that have been managed in ways that lead to competition among fishers or sectors of industries to maximize their share of fishing opportunities.

The elimination of the need to compete for a share of the available catch allows individuals to optimize their investment in fishing effort to match their share of the catch. For example, fleet owners who might otherwise maximize the number of vessels they own to maximize their share of the total catch, would, if they had to observe a catch quota, be expected to retire some vessels that were not needed

[31] Report of the Methodological Workshop on the Management of Tuna Fishing Capacity: Stock Status, Data Envelopment Analysis, Industry Surveys and Management Options. La Jolla, California, United States of America, 8–12 May 2006.

[32] Report of a workshop on rights-based management and buybacks in international tuna fisheries. IATTC and World Bank, La Jolla, California, United States of America, 5–9 May 2008. Available at www.iattc.org/PDFFiles2/Rights-based-management-report.pdf

to catch their quota. The situation of owners of single vessels is different. An owner with only one vessel can permanently affect capacity only by withdrawing his vessel. Doing so would benefit the remaining owners, but unless there is some compensation for withdrawing a vessel, owners are unlikely to do so. Transferable quotas can provide a means to reduce the fleet capacity to levels sufficient to take the available catch, either through a fleet-wide buyback programme or by arrangements among groups of owners.

Secure, exclusive and long-term rights provide a collective interest of fishers for the conservation of the fisheries and for the efficient use of the resources. Transferability allows fishing opportunities to be used by those fishers who produce the greatest economic benefits and also can provide the means to address the effects of fishers who take bycatches of what are target species for others. Transferable rights offer a new dimension for negotiations that could provide a means of reaching an agreement among different user groups, such as the FAD and longline coalitions of the previous section, via a transfer of fishing rights. For example, longline fishers could purchase bigeye quota from FAD fishers.

Of course, the implementation of rights-based methods has many challenges and will likely require a significant change in systems of monitoring, control and surveillance. Costs of rights-based management systems are likely to be significantly greater than the costs of other systems, raising the question of who should pay for the management system.

The application of rights-based management in international tuna fisheries will be even more complicated than it is in national fisheries. As with any effective international cooperation in fisheries management, it is essential that all states with an interest in the fishery are included in the allocation of rights and that there be a mechanism for new entrants that wish to exercise their right to fish on the high seas. A number of questions must be addressed in implementing rights-based systems in either a national or international context but the answers to the questions are less clear in the international arena.

The first question is what should be the nature of the rights and who should be the rights holders. In tuna fisheries, because of the mobility of the fish, the most effective and practical right is a catch quota. Quotas for fishing effort can also be used, but are less effective because it is difficult to describe physical measures that directly govern fishing effort. For example, providing a quota for days fishing can be frustrated by employing larger vessels, and limiting vessel size might be overcome by increasing the power of the winch. Nevertheless, there may need to be trade-offs between the most efficient system and other systems that are practical for other reasons, including cost. The choice of a particular rights-based management system should, of course, be informed by careful analysis of its ability to meet the policy objectives of the participants, including expected costs and benefits of the change.

In the international arena, the possibilities for who should be rights holders include states (and other entities), individual fishers and corporations that hold all the rights and allow harvesting on their behalf.

Another important question is who is responsible for recording rights. It is essential that this task be done by an independent and trusted agency. Registration of rights is vital and is usually more complex than it appears at first sight, particularly when the rights are transferable. The agency registering rights must have the confidence of all participating states and it must operate within a legal system that is acceptable to all.

Finally, ensuring compliance with rights or enforcement raises the question of who will provide an international enforcement capability. Enforcement could be shared by participating states, built into an RFMO or might require the establishment of a new agency.

Further detail is provided in Allen, Joseph and Squires (2010a, b), who also describe some current partial approaches to rights-based management in tuna fisheries and the systems that support it.

Serdy (2007) has shown that there is no general legal constraint for the trading of quotas among RFMO members and noted some precedents for trades among members. Of course, member governments can allocate national quotas to individuals as has been done by Australia for southern bluefin tuna.

6. Conclusion

Tuna are highly sought after fish and fisheries for tuna have developed over the last half century to such an extent that most of them are in need of restrictive management and several fisheries are overfished. That development has meant that the world's tuna fleets are larger than those required to provide maximum yields and larger again than those required to produce the maximum economic benefit from the fisheries. The major market species discussed in this paper are all subject to international fisheries requiring multilateral cooperation for management and in all ocean basins fisheries management organizations have been established as the vehicle for cooperation.

The present management system results in the very mixed performance of the management bodies that was described in Section 3. The commissions are often very slow to accept scientific advice that requires significant management action, and conservation measures are often only applied when there is an appearance of an emergency rather than as a measured response to changes in situations.

The management organizations depend on agreements among their members and their decisions are compromised by the mixed incentives of those members, who have to balance their obligations to conserve the resources with the need to support their own industries. The splitting of governments' attention between questions of conservation and allocation often results in more attention being given to securing allocation for their fleets than to overall conservation. As long as this remains the case, the management organizations are not likely to perform well in their primary role of conservation of resources.

The adoption of rights-based management systems is the most promising way forward to overcome those problems. These systems would relieve governments from day-to-day allocation decisions and allow them to focus on their more important role of being responsible for the conservation of the fisheries.

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This paper reviews the current management of tuna fisheries by the five tuna regional fisheries management organizations (RFMOs), which focus on the management of target species in the light of international standards and modern expectations for fisheries management. This paper demonstrates that the scientific advice for the management of tuna stocks is not generally followed, at least not on a timely basis. The underlying issues that account for the failure of RFMOs to meet global standards and expectations are discussed and rights-based management systems are advanced as a means of addressing some of the management shortcomings.

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