# Chapter 41. Tunas and Billfishes

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## 1. Introduction

Tunas and billfishes are epipelagic marine fishes that live primarily in the upper 200 metres of the ocean and are widely distributed throughout the tropical, subtropical and temperate waters of the world's oceans (Collette and Nauen 1983; Nakamura 1985). Tunas (Tribe Thunnini, family Scombridae) include five genera (*Thunnus, Katsuwonus, Euthynnus, Auxis* and *Allothunnus*) with 15 species altogether (Collette et al., 2001). Seven of the 15 species of tunas are commonly known as "principal market tunas" due to their economic importance in the global markets (Majkowski 2007). These include albacore (*Thunnus alalunga*), bigeye tuna (*T. obesus*), Atlantic bluefin tuna (*T. thynnus*), Pacific bluefin tuna (*T. orientalis*), southern bluefin tuna (*T. maccoyii*), yellowfin tuna (*T. albacares*) and skipjack tuna (*Katsuwonus pelamis*). The principal market tunas have extensive oceanic distributions and are highly migratory. They sustain diverse fisheries worldwide, from highly industrialized commercial fisheries, to small and medium scale artisanal fisheries, and also lucrative recreational fisheries. The non-principal market tuna species including longtail tuna (*Thunnus tonggol*), blackfin tuna (*Thunnus atlanticus*), kawakawa (*Euthynnus affinis*), little tunny (*E .alletteratus*), black skipjack (*E. lineatus*), bullet tuna (*Auxis rochei*), frigate tuna (*A. thazard)* and slender tuna (*Allothunnus fallai*) have in general more coastal distributions, except for the slender tuna which is found worldwide in the Southern Ocean. These species also sustain important small to medium industrial and artisanal fisheries throughout their distributions (Collette and Nauen, 1983; Majkowski, 2007).

Billfishes are highly migratory fishes that live also primarily in the upper 200 metres of the ocean and have widespread oceanic distributions. They are distinguished by their elongate spears or swords on their snouts. Some billfish species are targeted by commercial and recreational fisheries world-wide, but generally billfish species are caught as a by-product of the tuna fisheries (Kitchell et al., 2006). Billfishes include ten species in two families (Xiphiidae and Istiophoridae); the monotypic Xiphiidae (swordfish, *Xiphias gladius*) and Istiophoridae containing five genera and nine species: blue marlin (*Makaira nigricans*), sailfish (*Istiophorus platypterus*), black marlin (*Istiompax indica*), striped marlin (*Kajikia audax*), white marlin (*Kajikia albida*), and four spearfishes, shortbill spearfish (*Tetrapturus angustirostris*), roundscale spearfish (*Tetrapturus georgii*), longbill spearfish (*Tetrapturus pfluegeri*), and Mediterranean spearfish (*Tetrapturus belone*) (Collette et al., 2006)

Due to the highly migratory nature, widespread distributions, and global economic importance of tunas and billfishes, five Regional Fisheries Management Organizations (RFMOs) are in charge of their management and conservation (hereinafter referred to as tuna RFMOs). The five tuna RFMOs are the International Commission for the Conservation of Atlantic Tunas (ICCAT, Atlantic Ocean), the Indian Ocean Tuna Commission (IOTC, Indian Ocean), the Inter-American Tropical Tuna Commission (IATTC, Eastern Pacific Ocean), the Western and Central Pacific Fisheries Commission (WCPFC, Western Pacific Ocean), and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT, Southern Ocean).

## 2. Population trends or conservation status

### *2.1 Aggregated at global scale*

Annual catches of tunas and billfishes have risen continuously since the 1950s, reaching at least 6 million tons in 2012 (Figure 1A). In 2012, the total catches of tunas and billfish species combined contributed up to 9.3 per cent of the annual total marine fish catch (FAO, 2014). Although the global increase in catches of all marine fishes reached a peak at the end of the 1980s and has since then stabilized, tuna and billfish catches have not reached a plateau yet. However, a plateau will likely be reached in the short term as many of the world's most important tuna and billfish fisheries are considered fully exploited now with limited room for sustainable growth (Miyake et al., 2010; Juan-Jordá et al., 2011; ISSF, 2013a). The current exploitation status of principal-market tuna and billfish populations is summarized according to the latest fisheries stock assessments and biological reference points[1] carried out by the five tuna RFMOs. Currently the tuna RFMOS have formally assessed a total of 44 stocks (13 species) of tuna and billfish species, including 23 principal market tuna stocks (7 species) and 21 billfish stocks (6 species) (Appendix 1). Hereinafter, the term "population" is used instead of "stock¨. Each tuna RFMO has its own convention objectives ranging from ensuring the long term conservation and sustainable use of tuna and tuna-like species to, in some cases, ensuring the optimum utilization of stocks.[2] Scientific advisory groups or science providers within these tuna RFMOs routinely carry out stock assessments and estimate two common standard biological reference points, $B/B_{MSY}$ and $F/F_{MSY}$, which are used to determine the current exploitation status of the populations. $B/B_{MSY}$ is the ratio of the

[1] Definitions of the term "reference points" are available at the FAO Term Portal (http://www.fao.org/faoterm/en/) and in ISSF (2013b).

[2] See Agreement for the Establishment of the Indian Ocean Tuna Commission (United Nations, *Treaty Series*, vol. 1927, No 32888); Convention between the United States of America and the Republic of Costa Rica for the establishment of an Inter-American Tropical Tuna Commission (United Nations, *Treaty Series*, vol. 80, No. 1041); Convention for the Conservation of Southern Bluefin Tuna (United Nations, *Treaty Series*, vol. 1819, No. 31155); Convention for the strengthening of the Inter-American Tropical Tuna Commission established by the 1949 Convention between the United States of America and the Republic of Costa Rica; Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean (United Nations, *Treaty Series*, vol. 2275, No. 40532); International Convention for the Conservation of Atlantic Tunas (United Nations, *Treaty Series*, vol. 673, No. 9587).

current biomass (often measured only for the spawning fraction of the population) relative to the biomass that would provide the maximum sustainable yield (MSY). A population whose biomass has fallen below $B_{MSY}$ (i.e., $B/B_{MSY} < 1$) is considered to be "overfished" with regards to this target. $F/F_{MSY}$ is the ratio of current fishing mortality relative to the fishing mortality rate that produces MSY. Overfishing is occurring for a population whose fishing mortality exceeds $F_{MSY}$ (i.e., $F/F_{MSY} > 1$).

According to the most recent fisheries stock assessments (2010-2014, Appendix 1), 51.2 per cent of the tuna and billfish populations are not overfished and are not experiencing overfishing (21 populations), 14.6 per cent of populations are not overfished but are experiencing overfishing (6 populations), 22 per cent of populations are overfished and are experiencing overfishing (9 populations), and 12.2 per cent of populations are overfished but are not experiencing overfishing anymore (5 populations) (Figure 2A). However, the total catches and abundance differ markedly among tuna and billfish species and populations, around 3 orders of magnitude between the population with the smallest catches (eastern Pacific sailfish ~300 tons/annually) and the population with the largest catches (western and central Pacific skipjack ~1,700,000 tons annually). When accounting for their relative contributions to their total global catches, a different global picture of the status of these species emerges (Figure 2B). In terms of their relative contributions to the total catches, 86.2 per cent of the global catch of tuna and billfish comes from healthy populations, for which the biomass is not overfished and whose populations are not experiencing overfishing, 4.5 per cent of the catch comes from populations that are not overfished but are experiencing overfishing, 1.4 per cent of the catch comes from populations that are overfished and are experiencing overfishing, and 8 per cent of the catch comes from populations that are overfished and are not experiencing overfishing anymore (Figure 2B). This distinct pattern of global exploitation status is mostly driven in part by the fact that tropical skipjack and yellowfin tuna populations contribute 68 per cent of the global tuna catches and their populations are largely at healthy levels and not experiencing overfishing. In contrast, most of the populations that are overfished and experiencing overfishing are mostly temperate bluefin tuna and billfish populations, whose combined catches make up a relatively small fraction of the total catch.

Although the current exploitation status for the principal market tunas is relatively well known globally, knowledge of the exploitation status for the non-principal market tuna and billfish populations and species is fragmentary and uncertain. Currently, all the populations for all seven species of principal market tunas are formally assessed on a regular basis (every 2-4 years depending on the population) by the scientific staff or scientific committees in the five tuna RFMOs, and have management and conservation measures in place. Not all billfish populations and species have been formally assessed yet, therefore the global picture of their current exploitation status may be biased towards the most commercially productive and resilient species of billfish. Furthermore, tuna RFMOs have not yet conducted formal fisheries stock assessments or adopted management and conservation measures for any of the eight non-principal market tuna species. Therefore their current exploitation status is unknown or highly uncertain throughout their neritic distributions.  There are some exceptions and some species of non-principal market tunas have been assessed locally by national government fisheries agencies or recently by IOTC. For the South Atlantic Ocean off the coast of Brazil, *Thunnus atlanticus* was assessed in the year 2000, concluding the population was as at healthy levels and not experiencing overfishing (Freire, 2009). In the Indian Ocean, *Thunnus tonggol* was assessed for the first time in the year 2013 and 2014 by the IOTC Working Party on neritic tunas. The assessments concluded that *Thunnus tonggol* was likely subject to overfishing in recent years while not being in an overfished state (IOTC-SC17, 2014). Therefore the exploitation status for the majority of non-principal market tuna populations and species is mostly unknown throughout their ranges, despite the importance of their commercial fisheries for many coastal fishing communities in many developed and developing countries around the world.

### *2.2 Four major taxonomic and/or geographic subdivisions*

Since the 1950s, principal market tunas have made up the majority of the global catches of tunas and billfish combined (Figure 1A). In 2012, the catch of principal market tunas accounted for 80 per cent of the total catch, the catch of non-principal market tunas accounted for 16 per cent and billfish catch accounted for 4 per cent. Among principal market tunas, skipjack tuna and yellowfin tuna make up 46 per cent and 22 per cent of the global catch in 2012, followed by bigeye tuna (7 per cent), albacore tuna (4 per cent) and the three bluefin tuna species (1 per cent). The increasing trend in the total catch of principal market tunas is mainly due to the increase in catches in tropical tuna species since the 1950s until today, a trend driven by skipjack tuna, followed by yellowfin tuna and then bigeye tuna. By contrast, temperate principal market tuna species, including albacore tuna and the three bluefin tuna species, show an increasing trend in catch up to the 1970s, and since then the trend has stabilized or shown a decrease. Over two-thirds of the world's tunas and billfishes catches currently come from the Pacific Ocean (69 per cent), 22 per cent come from the Indian Ocean and 9 per cent from the Atlantic Ocean (Figure 1B). Although catches in the Atlantic Ocean have increased only until the early 1980s and since then have declined slightly, in the Pacific and Indian Oceans catches have increased continuously since the 1950s.

Among the non-principal market tuna species, frigate and bullet tunas combined (*Auxis rochei* and *A. thazard*) make up 40 per cent of the catch and kawakawa (*Euthynnus affinis*) makes up 33 per cent of the catch. Among billfishes, swordfish (*Xiphias gladius*) makes up 51 per cent of the catch and Atlantic blue marlin (*Makaira nigricans*) makes up 17 per cent of the catch. Global catches for non-principal market tunas and billfish have also shown a continuous increase since the 1950s, accelerating in the 1980s, a result that is likely to be derived from better reporting of the catch for these species. However, it is generally agreed that catch estimates for non-principal market tunas and billfish have been and still are underestimated as the majority of these species are caught by small scale fisheries or as a by-catch[3] of principal market tuna fisheries. Small-scale coastal fisheries targeting both principal market tunas and the smaller non-principal market tunas are poorly reported. Similarly, billfish catches, of which the majority come from industrial tuna fisheries as bycatch, have also been commonly poorly reported and monitored (Miyake et al., 2010).

According to the latest tuna RFMO fisheries stock assessments (Appendix 1), the global picture of the exploitation status of tunas and billfishes indicates that principal market tuna populations are relatively better managed than billfish populations (Figure 2C). Although 37 per cent of billfish populations (7 of 19 populations) are currently overfished and experiencing overfishing, 9 per cent of the principal market tunas (2 of 22 populations) are considered to be overfished and experiencing overfishing. The majority of principal market tunas are at healthy levels with 64 per cent of the populations not overfished and not experiencing overfishing, and 18 per cent of the populations, although overfished, are no longer experiencing overfishing and therefore are on the path to recovery, if fishing mortality continues to be controlled. The exploitation status of tunas and billfishes also differs among the three major oceans (Figure 2C). In the Atlantic Ocean, the status of only 47 per cent of the populations is currently healthy (not overfished and not experiencing overfishing), in the Indian Ocean the status of half of the populations (50 per cent) is healthy, and in the Pacific Ocean over half of the populations (~56 per cent) is currently healthy and within sustainable levels.

When accounting for the relative contributions of their catches, principal market tuna populations provide the majority of the catches from healthy populations when compared with billfish species. Although 87 per cent of the total catches of principal market tunas come from healthy populations (not overfished and not experiencing overfishing) and only 0.9 per cent come from unhealthy populations (overfished and experiencing overfishing), 60.8 per cent of the total catches of billfish populations come from healthy populations and 16.1 per cent come from unhealthy populations. Healthy populations of skipjack in every ocean make up a large portion of the total tuna catches, whereas healthy swordfish populations make up the largest portion of the total billfish catches. As previously mentioned, the exploitation status remains unknown for some billfish species and populations, and therefore this global picture might be biased towards the most commercially data-rich billfish species. Among the three oceans, the large majority of tuna and billfish catches in the Indian and Pacific Oceans come from healthy populations (92.3 and 87.5 per cent, respectively), and in the Atlantic Ocean 66.4 per cent of the catches come from healthy populations. In the Atlantic, currently 7.9 per cent of the tuna and billfish catches come from unhealthy populations (overfished and experiencing overfishing) and 25.7 per cent of catches come from overfished populations for which overfishing is no longer occurring and therefore might be on their path to recovery.

[3] Definitions of the term “by-catch” are available at the FAO Term Portal and in Gilman et al. (2014).

## 3. Special conservation status issues (CITES, national listing or priority for Marine Protected Area)

In 2011, the International Union for Conservation of Nature (IUCN) assessed for the first time the global conservation status for all tuna and billfish species using the IUCN criteria (Collette et al. 2011). The IUCN conservation assessments provide a complementary tool to existing fisheries stock assessment for setting conservation priorities at the global levels for this group of species and a platform for identifying species with long-term sustainability issues. The IUCN assessments utilize the IUCN Red List Criteria and all the available species information, including their global distribution, ecology, landing trends, biomass trends (mostly derived from fisheries stock assessments), and impacts of major threats, in order to classify species into the IUCN Red List categories. These categories range from Least Concern and Near Threatened, to the three threatened categories (Vulnerable, Endangered, Critically Endangered), providing a species ranking in terms of their relative risk of global extinction and conservation needs.

There is also a Data Deficient category where species with insufficient information to be evaluated are placed. Nonetheless, the information used to categorize tuna and billfishes in the IUCN Red List categories vary greatly among species; whereas some species such as *Allothunnus fallai* and *Tetrapturus angustirostris* are data poor due to scarce and incomplete landing and biological data against which to apply the IUCN criteria, some species such as the majority of the principal market tuna species are data rich with relatively extensive and highly detailed biological studies and fisheries stock assessment models for multiple populations throughout their distribution, which makes applying the IUCN criteria relatively easy. The IUCN Red List evaluation for the 25 species of tunas and billfishes resulted in 48 per cent (12 of 25 spp.) of species being listed under the Least Concern category, 12 per cent of tunas and billfishes listed in the Near Threatened category (*Thunnus alalunga*, *T. albacares* and *Kajikia audax*), and 24 per cent (6 spp.) had declined sufficiently in biomass to trigger listing under the Threatened categories. *Thunnus maccoyii* is listed as Critically Endangered, *T. thynnus* is Endangered, and *T. obesus, T. orientalis, Kajikia albida* and *Makaira nigricans* are Vulnerable. Lastly, 16 per cent (4 spp.) of tunas and billfish were listed as Data Deficient (Collette et al., 2011; Collette et al., 2014).

It should be noted that the IUCN criteria sometimes conflict with fisheries management objectives (Davies and Baum, 2012). For example, a species whose abundance declines from the unfished level by one-half in a given period of time may be classified in a threatened category in the IUCN Red List, but it might be well managed (i.e., not overfished and not experiencing overfishing) from an RFMO perspective. Conversely, a species that remains severely overfished for a period of time may be of grave concern to an RFMO but not classified in a threatened category in the IUCN Red List. Nevertheless, from a global conservation perspective, the latest IUCN assessments and derived conservation status were largely consistent with the current knowledge about the exploitation status of tuna and billfish populations derived from the RFMO fisheries stock assessments, in that the three longer-lived bluefin tuna species with geographically restricted spawning sites are more vulnerable to overfishing and are in need of more stringent management and conservation measures than the shorter-lived and more resilient tropical tuna species such as skipjack tuna for which spawning occurs in multiple broad spawning grounds throughout the tropics (Reglero et al., 2014).

More importantly, the IUCN conservation assessments are a useful tool particularly for those tuna and billfish species which are commercially exploited but lack formal fisheries population assessment, whose exploitation status is unknown and highly uncertain, and which do not have any management and conservation measures in place to ensure their long-term sustainability. According to the latest IUCN assessments, the following four IUCN Data Deficient species, *Thunnus tonggol, Tetrapturus angustirostris, Tetrapturus georgii* and *Istiompax indica*, should be the focus of future management and conservation efforts to ensure that their current fishing exploitation, and absence of fishery population assessments and management plans, do not jeopardize the long-term sustainability of these species.

A proposal to list Atlantic bluefin tuna on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was introduced at the fifteenth meeting of the Conference of the Parties in March 2010 by Monaco and supported by the United States and several European countries, but the proposal failed. There have also been several attempts to list several tuna and billfish species under National Listings. In the United States, the Center for Biological Diversity petitioned the United States Department of Commerce National Marine Fisheries Service to list both the eastern and western Atlantic populations of the bluefin tuna as endangered under the United States Endangered Species Act (ESA) (Center for Biological Diversity, 2010) but the Department rejected the petition, although declaring the Atlantic bluefin to be "a species of interest" after a review (Atlantic Bluefin Tuna Status Review Team, 2011). A petition from the Biodiversity Legal Foundation requesting listing of the Atlantic white marlin (*Kajikia albida*) as a threatened or endangered species under the ESA was found to be not warranted at that time by the National Marine Fisheries Service (White Marlin Biological Review Team, 2007). In Canada, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determined in 2011 that the western Atlantic bluefin tuna was Endangered (Maguire, 2012). In Brazil, a number of specialists, coordinated by the Brazilian Ministry of Environment (MMA) through the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBIO), evaluated the risk of extinction of marine species following IUCN Red list of Threatened Species. Most species have been listed in the same category as the global list, however *Xiphias gladius* was categorized as Near Threatened, *Makaira nigricans* as Endangered, *Thunnus alalunga* and *T. albacares* as Least Concern and *Auxis rochei* and *A. thazard* as Data Deficient, differently from the global list (ICMBIO. In press).

 

Marine protected areas (MPAs), or time-area closures, a term mostly used by fisheries managers, are one of the many tools available to fishery managers to reduce fishing mortality or redistribute fishing effort to protect a segment of a fish population (e.g. spawning adults) or vulnerable fish habitats, among many other applications. Marine protected areas or time-area closures can vary from complete prohibition on fishing or other forms of exploitation “no-take zone” to a continuum of spatial, temporal and user restrictions allowing numerous options and applications. Currently, the role of pelagic MPAs or time-area closures for the conservation and management of tunas and billfishes is a major topic of discussion, given their high mobility, their wide distributions, the dynamic physical nature of pelagic habitats, as well as the small number of empirical and theoretical studies showing their effectiveness (Davies et al., 2012; Dueri and Maury 2012). In the last decade, tuna RFMOs have tested and implemented several types of time-area closures, always in combination with other tools to control catch and effort, to reduce fishing effort and reduce by-catch of non-target species (Sibert et al. 2012). Past experiences indicate that time-area closures, if used alone, might be ineffective and inefficient to manage tuna species (ISSF, 2012). However, if time-area closures are used in combination with other fishery management tools, closures could have substantial benefits when the objectives are clearly defined and their implementation is accompanied by close evaluation, monitoring and enforcement (ISSF, 2012).

The future success of pelagic MPAs or time-area closures as a fisheries, conservation and management tool for tuna and billfish species relies on more theoretical modelling and long-term empirical studies to compare and contrast their effectiveness with other fishery management tools and in combination with these tools.

## 4. Key pressures linked to trends

Commercial fishing has been identified as the primary pressure driving tuna and billfish population declines and causing the overexploitation of some populations (Collette et al., 2011). Over the last century, industrial fisheries targeting tuna and billfish species have sequentially expanded from coastal areas to the high seas and now their fisheries cover the majority of the world’s oceans (Miyake et al., 2004). Globally tuna and billfish catches and fishing effort have risen consistently since the 1950s and may not have yet reached a plateau (Juan-Jordá et al., 2011). Currently the global demand for tuna meat is still increasing, and fishing capacity, with the construction of new fishing vessels, especially purse seiners, and improved technology, is also increasing (Justel-Rubio and Restrepo, 2014). As concluded by Allen (2010), managing capacity and eliminating overcapacity where it exists has been identified as one of the major challenges jeopardizing the long-term sustainability of tuna and billfish species.

Climate change is another potential pressure that needs to be accounted for in the biology, economics and management of tuna and billfish species (McIlgorm, 2010). It is projected that by increasing ocean water temperatures, and altering oceanic circulation patterns and the vertical stratification of the water column, climate change will lead to a decrease in primary productivity in the tropics and a likely increase in higher latitudes (Intergovernmental Panel on Climate Change (IPCC, 2007)). Climate change, and the resultant increase in ocean temperatures, is also increasing the extension of areas with hypoxic waters and oxygen-depleted dead zones (Altieri and Gedan, 2015).

The extension of deep hypoxic bodies of water limits the distribution of tunas and billfishes by compressing their preferred habitat into a narrow surface layer, making this species more vulnerable to over-exploitation by surface gears (Prince and Goodyear, 2006). Thus, climate change might have an effect on tuna and billfish species by changing their physiologies, temporal and spatial horizontal and vertical distributions and abundances within the water column. A growing number of studies are evaluating the current and future impacts of climate change on the physiology, distribution, abundance and reproductive and feeding migrations of these species (Dufour et al., 2010; McIlgorm, 2010; Muhling et al., 2011; Bell et al., 2013; Dueri et al., 2014).

A study modelling the impacts of climate change on skipjack tuna in the tropical world's oceans suggests that the spatial distribution and abundance of skipjack tuna may change substantially with current suitable tropical habitats deteriorating and habitat suitability improving at higher latitudes (Dueri et al., 2014). In the Western and Central Pacific, another modelling study evaluated the effect of climate change on the food webs, habitat and main fish resources of the region, and found that distribution of skipjack tuna, the major tuna resource of the area, may move further east across the region. This eastward movement of skipjack tuna could benefit some nations by increasing their access to tuna resources and adversely affect other nations which would lose access to optimum tuna fishing grounds (Bell et al., 2013).

In the Atlantic Ocean, it has been documented that each year North Atlantic albacore tuna and East Atlantic bluefin tuna have arrived progressively earlier in the Bay of Biscay area, a major feeding ground, indicating that these species may be progressively adapting the timing of their feeding migrations and latitudinal distributions in response to climate change (Dufour et al., 2010). Another modelling study has also suggested that climate change might alter the temporal and spatial spawning and migratory activity of the West Atlantic bluefin tuna in the Gulf of Mexico with subsequent effects on population sizes and fisheries (Muhling et al. 2011). The impacts of climate change on tuna and billfish species are raising increasing concerns and need to be further understood, in order that governments and tuna RFMOs can respond rapidly to climate change by developing mitigation and adaptation programs.

## 5. Major ecosystem services provided by the species group and impacts of pressures on provision of these services

### *5.1 Ecosystem services*

The impacts of fishing on the abundance of fishes and food web dynamics can have consequences on the structure, functioning and resilience of marine ecosystems (Heithaus et al., 2008; Baum and Worm, 2009). Consequently, population declines in tuna and billfish species and changes in their food web dynamics may be impairing the ocean's capacity to generate basic ecosystem processes which are vital to enable the maintenance and delivery of other ecosystem services benefiting human health, welfare and economic activities. To what extent widespread declines in tuna and billfish populations have altered the capacity of the ocean to support vital ecosystem processes, functions and services by altering species interactions and food web dynamics is poorly known (Kitchell et al., 2006; Hunsicker, 2012; IATTC, 2014a).

Tuna and billfish species are large predatory fishes, acting as apex and mesopredators and occupying high trophic levels in the marine food web; their removal could have ecological consequences for predator-prey interactions through trophic cascading effects (Baum and Worm, 2009). To fully understand the effects of removing tunas and billfishes from marine ecosystems, and their value in maintaining key ecosystem processes and services, requires better understanding of their unique role as predators and prey, and their interactions and dynamics using modelling and empirical approaches. This requires the collection of accurate information on trophic links and biomass flows through the food web in open marine ecosystems and accounting for environmental forcing (IATTC, 2014a).

To date, tuna RFMOs have conducted limited research and have a limited track record for incorporating food-web and ecosystem considerations into the management of tuna and billfish fisheries because traditionally their management has focused on achieving MSY for each of their targeted species individually. Consequently, according to de Bruyn et al., (2013), tuna RFMOs have implemented limited conservation measures to address the wide ecological effects of fishing . However, in the last decade tuna RFMOs, and especially IATTC and WCPFC, have increased their research activities to ensure that ecosystem considerations are part of their agendas (IATTC 2014a). These actions have mostly focused on monitoring, quantifying and mitigating incidental by-catch, increasing the coverage of the observing programmes and modifying fishing gear technology (Gilman et al., 2014; IATTC, 2014a).

### *5.2 Direct services to humans including economic and livelihood services*

Tuna and billfish species provide a wide variety of direct ecosystem services to humans by supporting food production and creating vital coastal livelihoods, economies and recreational opportunities such as sport fisheries (Gilman et al., 2014). At present more than 80 countries have tuna fisheries, thousands of tuna fishing vessels operate in all the oceans, and tuna fishery capacity is still growing in the Indian and Pacific Oceans (ISSF, 2010). The popularity of tuna meat has increased remarkably around the globe and now tuna meat is considered to be a relatively low-cost source of protein, which is traded as a global "commodity" product (i.e. high volume, low value, low margins) (Hamilton et al., 2011). The canning and sashimi industries are the major players in the global trade of tuna, particularly focused on the principal market tuna species.

At the other extreme, in some regions of the world tuna and billfish species still contribute substantially to the subsistence of many fishing communities by providing the great majority of dietary animal protein (Bell et al., 2009). The global economic activity that tuna fisheries can generate directly and indirectly is remarkable. Every year at least 2.5 million tons of the global tuna catch is destined for the canning industry and globally around 256 million cases are consumed (3.2 million tons whole round equivalent), valued at 7.5 billion United States dollars (Hamilton et al., 2011). Therefore, ensuring the long-term sustainability of the world's tuna and billfish fisheries is intrinsically linked with providing food security, vital livelihoods and economic benefits in many regions of the world.

The dependency on healthy and sustainable tuna populations and the direct ecosystem services they provide is particularly strong for countries in the tropical western and central Pacific Ocean which is the most important tuna fishing area in the world. The tuna catch in the West Pacific Ocean is greater than that of the Atlantic, Indian and East Pacific Oceans combined (Miyake et al., 2010). Countries in the tropical west Pacific Ocean depend heavily on tuna resources for their nutrition, food security, economic development, employment, government revenue, livelihoods, culture and recreation (Gillett et al., 2001; Gillett, 2004; Gillett, 2009). Pacific States and territories in the west Pacific Ocean derive a large share of their taxes (up to 40 per cent) and Gross Domestic Product (up to 20 per cent) from fishing licenses sold to distant-water fishing nations and fish processors (Gillett, 2009; Bell et al., 2013).

Tuna and billfish also provide valuable recreational services; these fishes are considered to be valuable sportfishes, which gives them an important status in recreational fisheries in many regions of the world. Although the global picture of the recreational catch, effort and economic data for this industry is very fragmentary or unknown, for those countries with better records, the aggregate impact of the recreational tuna and billfish industry in terms of revenue and employment can be substantial for the local economies. For example, the total annual aggregate value of the recreational billfish industry in Costa Rica, Mexico, the United States Atlantic coast and Puerto Rico (United States) combined ranges between 203 and 340 million United States dollars, creating vital economic development, employment and recreation in the region (Ditton and Stoll, 2003).

## 6. Conservation responses and factors for sustainability

Tuna RFMOs face several challenges to ensure the long-term sustainability of tunas and billfishes and associated ecosystems within their Convention areas. Some of the main challenges have been considered to be:

(a) the existing overcapacity of fishing fleets;

(b) the equitable allocation of fishing rights among fishing nations;

(c) the possible implementation of the precautionary approach[4] and ecosystem approach;

(d) the monitoring of by-catch of vulnerable species; and

(e) the adequacy of financial resources to eliminate illegal, unreported and unregulated fishing and implement effective Monitoring, Control and Surveillance.

Tuna RFMOs have increasingly adopted a series of conservation and management measures to specifically address each of these challenges although their success and implementation have been mixed, and more time is needed to fully evaluate their success.

Tuna RFMOs control the amount of fishing of each stock through a variety of tools including catch limits, time-area closures and other input or output controls. Nevertheless, management of fleet capacity remains an issue of special concern, especially in the long term, because it tends to increase pressure on resources and management. The open access nature of fisheries, particularly in the high seas, has led to overcapacity of fleets in every tuna RFMO convention area (Allen, 2010; Miyake et al., 2010). Once overcapacity develops, it is difficult to reduce it because the fishing industry will continue operating as long as profits exceed costs (ISSF, 2010b). The IATTC has adopted a closed vessel registry for its purse seine fleet, a first and key step in managing overcapacity. However, overcapacity in the region remains well above the target (IATTC, 2014b). ICCAT, IOTC and WCPFC also have measures to limit capacity for some of their fisheries, but the problem of overcapacity has not been addressed in the RFMOs as a whole. It has been proposed that the establishment of exclusive rights to fish can be a formula to prevent overfishing, reduce overcapacity, achieve maximum economic benefits and sustainability in tuna and billfish fisheries, but its application is currently being debated (Allen, 2010; ISSF, 2010b; Squires et al., 2013). Ultimately, the global nature of tuna and billfish fisheries and industries might need cooperation among tuna RFMOs to manage fleet capacity successfully.

The equitable allocation of fishing rights is another challenge, given that allocating

[4] Definitions of the term "precautionary approach" are available at the FAO Term Portal and in ISSF (2013b).

fishing access or catch quotas among the different member countries continues to be one of the most contentious matters in the RFMOs decision-making progress, impeding other more timely relevant conservation and management measures from moving forward, according to the International Seafood Sustainability Foundation (ISSF, 2013c). Nowadays, tuna RFMO allocation negotiations occur in a decision-making climate that is basically consensus-driven, which can result in overall catch levels being higher than scientifically-recommended levels. Identifying solutions requires recognizing the complexity and heterogeneity of tuna fisheries and the diverse objectives of RFMO member countries (ISSF, 2011).

Endorsing the precautionary and ecosystem approach requires the adoption of harvest control rules including limit and target reference points for tunas and billfishes and associated species, a long-standing recommendation of several international FAO Agreements and Guidelines over the past 15 years (Caddy and Mahon, 1995) and part of the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks.[5] This is also part of the more modern RFMO Conventions, such as the WCPFC and IATTC. The CCSBT has adopted a formal management procedure[6] for deciding on Total Allowable Catch levels to rebuild the southern bluefin tuna population to 20 per cent of the unfished abundance level by 2035. The other RFMOs have not adopted such formulaic approaches to decision-making, but all are making progress in adopting population-specific limit and target reference points and discussing the use of harvest control rules. The adoption of harvest control rules and limit and target reference points is also a common requirement of several eco-label certifications, such as the Marine Stewardship Council Management Program.

The fifth aforementioned challenge reflects the paucity of knowledge about the impacts of tuna and billfish fisheries on other less productive species such as sharks, on species interactions and food web dynamics, and on the greater marine ecosystems (Dulvy et al., 2008; Gerrodette et al., 2012; de Bruyn et al. 2013; Gilman et al., 2014; IATTC, 2014a). One issue of concern is the widespread use of Fish Aggregating Devices (FADs) by industrial purse seine tuna fisheries and its potential impacts on tuna populations (especially on very small bigeye), higher levels of bycatch relative to setting nets on free-swimming schools, and possible ecosystem impacts (Dagorn et al., 2012; Fonteneau et al., 2013).

RFMOs have increasingly adopted several measures to monitor and regulate the use of FADs, and to increase data reporting requirements specific to FADs. Moreover, new research initiatives have also been emerging that aim to identify best practices in FAD fishing, as well as modification of gears, and new technology to reduce the catch of non-target species by FAD fisheries. For example, IATTC, IOTC and ICCAT have adopted

[5] United Nations, *Treaty Series*, vol. 2167, No. 37924.
[6] See CCSBT (2011).

measures to require a transition to non-entangling FADs that would reduce unobserved mortality of sharks and other species. Pelagic longline tuna and swordfish fisheries have higher levels of bycatch of sensitive species such as sharks, turtles and seabirds (Gilman, 2011). In addition, mitigation measures in longline fisheries targeting tunas and swordfishes have been developed and adopted by the RFMOs to reduce the by-catch of species like sea birds and sea turtles, although their successful implementation and effectiveness in reducing by-catch levels vary greatly among tuna RFMOs (Small, 2005; Gilman, 2011).

The last challenge encompasses the difficulty of eliminating illegal, unreported and unregulated fishing (IUU) and implementing effective monitoring, control and surveillance (MCS) measures in a context of insufficient financial resources (ISSF, 2013c). Effective MCS is required to successfully implement any conservation and management measure in place and combat IUU fishing. MCS measures can be very diverse, from operating transparent catch documentation schemes, implementing effective at-sea observer programs, requiring vessels to acquire unique vessel identifiers, maintaining comprehensive IUU vessel lists, and operating regular reports of transshipments. The extent to which tuna RFMOs have successfully adopted MCS measures varies greatly (ISSF, 2013c). The compliance mechanisms used by the different tuna RFMOs vary considerably (Koehler, 2013). The identification of best practices, successful measures and incentives to promote best practices is a first step forward, which would require global collaboration among all tuna RFMOs.

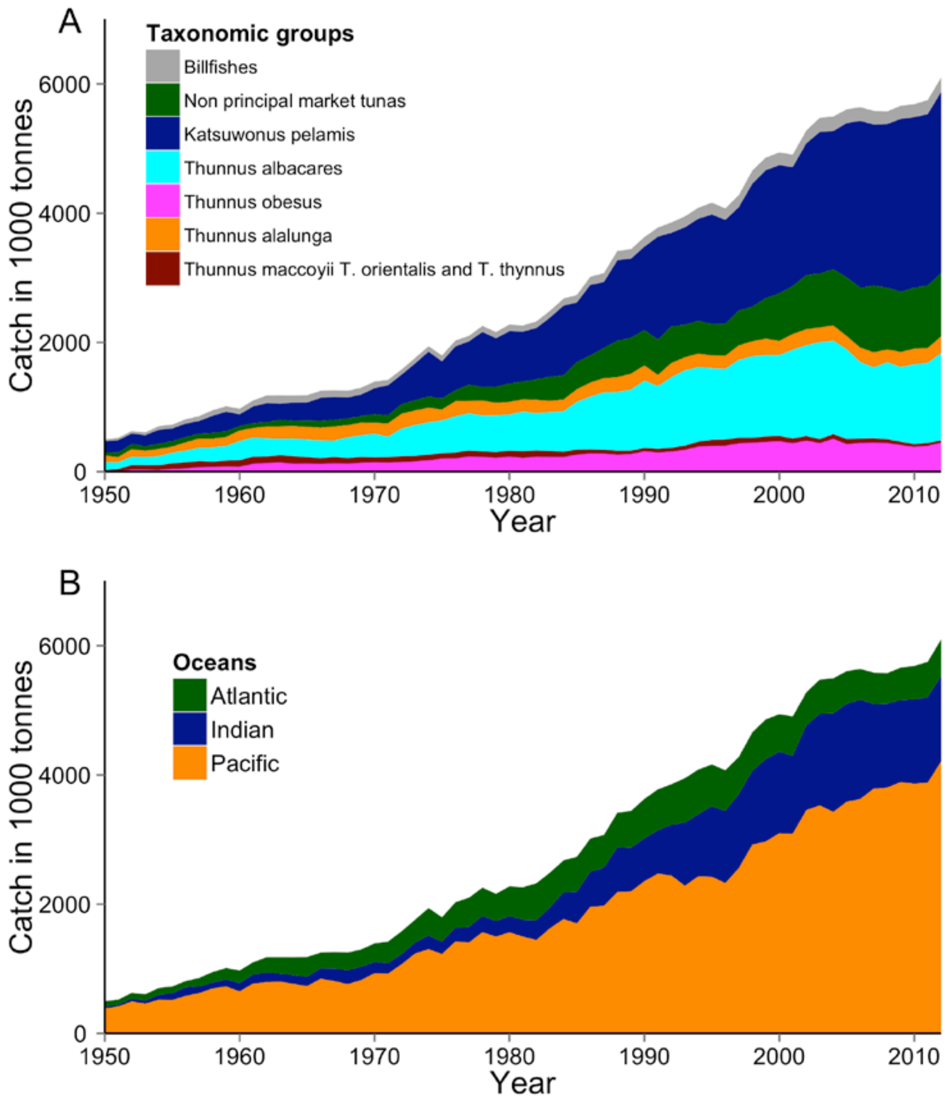


Figure 1. Global catch trends of tuna and billfish species (FAO, 2014). (A) Global aggregated temporal trends of catches by major taxonomic groups. (B) Global aggregated temporal trends of catches by oceans.

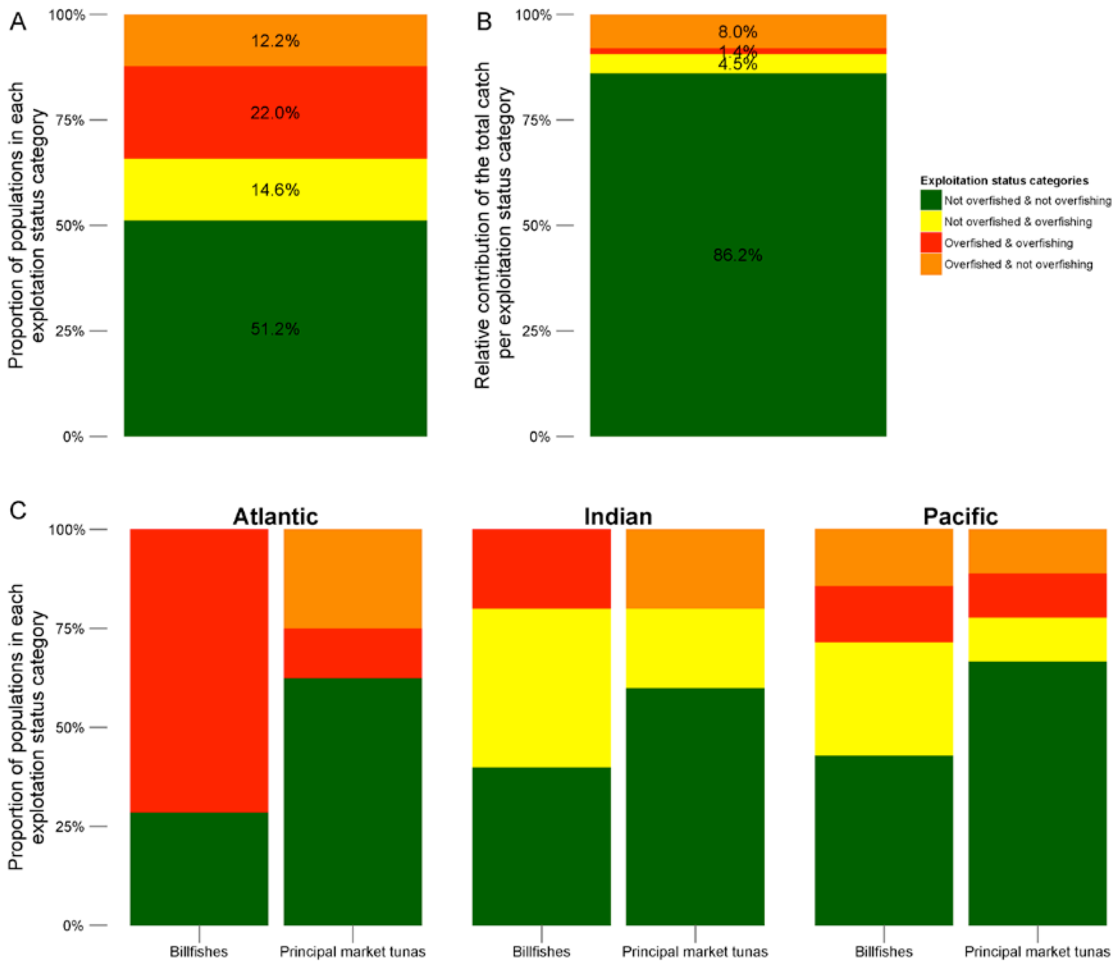


Figure 2. Global exploitation status of principal market tuna and billfish species according to the latest fisheries stock assessments conducted by tuna RFMOs. (A) Proportion of populations by exploitation status. (B) Relative contribution of the total catch by exploitation status. (C) Exploitation status by major taxonomic groups and oceans.

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