

CHAPTER 3

GLOBAL CATCHES OF LARGE PELAGIC FISHES, WITH EMPHASIS ON THE HIGH SEAS¹

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For many of the world's coastal regions, the exploitation of large pelagic fishes, particularly for tuna, has a long and significant history (Majkowski 2007). In the North Pacific, Japanese and Native Americans hunted Pacific bluefin tuna (*Thunnus orientalis*) more than five millennia ago (Anonymous 2013b), and people living in the Pacific Islands have fished for tuna at the subsistence level for centuries (SPC 2013). Similarly, in the Atlantic Ocean, especially in the Mediterranean Sea, the exploitation of various tuna species dates back to ancient times. Drawings of tuna have been discovered in the Grotta del Uzzo (c. 9000 BCE) and Genovese caves on Levanzo Island, near Sicily (c. 3000 BCE; Longo and Clarke 2012), and both the Phoenicians and the Romans used a variety of netting methods to capture these fish (Fromentin and Powers 2005; Di Natale 2010). Some of the earliest currencies of these societies depicted Atlantic bluefin tuna (*Thunnus thynnus*) on their coins (Di Natale 2011), and

literature and artwork from ancient Greece attempted to portray the importance of these fish and the associated fisheries (Longo and Clarke 2012). Over time, fishing methods diversified, and by the eleventh century traditional trap fishing (*la tonnera*) in the Mediterranean had been established (Longo and Clarke 2012).

THE EXPANSION OF LARGE-SCALE TUNA FISHERIES

For centuries, tuna continued to be targeted by small, localized fisheries using traps and other artisanal methods. Commercial tuna fishing by longline and pole-and-line began around the Pacific Islands in the 1910s and 1920s. However, it was not until after World War II that industrial efforts began to intensify (Miyake 2005; Gillett 2007). Initially, smaller species (e.g., skipjack *Katsuwonus pelamis* and albacore tuna *Thunnus alalunga*) were sought for canning purposes and dried export by locally based but foreign-owned fleets (mainly from the United States and Japan). However, improvements in fishing vessel technology and shipping methods—as well as the development of flash freezing capabilities—precipitated a rapid expansion in the industry, not only in terms of the gears used but also with regard to the species targeted and the regions fished (Gillett 2007; Majkowski 2007).

Around the world, purse-seine catches quickly surpassed those of smaller pole-and-line operations, and a substantial shift in gear occurred in the 1970s. By the early 1980s the

European purse-seine fleet had expanded into the Indian Ocean (Stequert and Marsac 1983, 1989; Fonteneau 1996; Bayliff et al. 2005; Marsac et al. 2014), while purse-seine fleets in the western Pacific, which had simultaneously expanded outward from the Pacific islands and South American countries, began fishing in the eastern Pacific (Majkowski 2007). The next decade saw an even greater increase in purse-seine effort, often in combination with fish aggregating devices (FADs), by these fleets in all three oceans (Bromhead et al. 2003; Miyake 2005; Davies et al. 2014).

FADs exploit the propensity of tunas and other pelagic fishes to gather under floating objects (e.g., rafts formed by uprooted trees after typhoons) and follow them as they drift with the currents. The first stage for fisheries was to search for these “natural FADs”; this was quickly replaced by the use of artificial FADs, made of palm fronds and other natural products, which are either allowed to drift (d-FADs) until sufficient fish had gathered under them (at which point they are harvested) or are anchored (a-FADs) and harvested at set intervals (Floyd and Pauly 1984). The current stage of FAD development involves large concrete or metal contraptions, with electronics that monitor the biomass of fish under them and communicate the results via satellite to purse-seiners who harvest the FADs when the aggregated fish biomass is deemed sufficient (Dagorn et al. 2013).

In tandem with increasing management measures (primarily with regard to the implementation of regional fisheries management organizations [RFMOs]; United Nations 1995), the 1990s saw an increased prevalence of illegal fishing (Majkowski 2007). It was during this time that the use of flags of convenience intensified; also, many smaller coastal countries began chartering vessels from foreign fleets of longliners and purse-seiners (Majkowski 2007).

The high demand for sashimi-grade tuna also led to the onset of tuna “ranching,” a capture-based husbandry practice whereby tuna (primarily bluefin but also yellowfin) are

taken from wild schools and fattened in large ocean pens before being killed and exported, overwhelmingly to Japan (Miyake et al. 2010). These operations originated in the 1990s in the Mediterranean, where Croatia, Italy, Malta, and Spain are the main countries ranching Atlantic bluefin tuna, and southern Australia, where southern bluefin tuna (*Thunnus maccoyii*) is ranched. They later expanded to the Pacific coast of Mexico, where yellowfin tuna are fattened with locally caught sardine. By the end of the 2000s, around 12,000 t of tuna were ranched annually (FAO 2013b).

Despite tuna fisheries being among the most valuable in the world (FAO 2012), and despite the considerable interest by civil society in the management of large pelagic fishes, to date there are no global and comprehensive spatial datasets or atlases presenting the historical industrial catches of all the tuna and billfish species.

MATERIAL AND METHODS

The aim of this chapter is to present the methods used to produce this comprehensive atlas of the fisheries for large pelagic fishes and to discuss its output and implications.² To produce this atlas, we assembled various existing tuna datasets (table 3.1) and harmonized them using a rule-based approach.

For each ocean, the nominal catch data were spatialized according to reported proportions in the spatial data. For example, if France reported 100 t of yellowfin tuna in 1983 using longlines in the nominal dataset, but there were 85 t of yellowfin tuna reported spatially in 1983 by France using longlines, in four separate statistical cells (potentially of varying spatial size), the nominal 100 t for France were split up into those four spatial cells according to their reported proportion of total catch in the spatial dataset. This matching of the nominal and spatial records was done over a series of successive refinements, with the first being the best-case scenario, in which there were matching records for year, country, gear, and species. The last refinement was the worst-case scenario, in which there were no

Table 3.1. Overview of the various data sources used to create global catch maps of industrially caught tuna and other large pelagic fishes.

Ocean	RFMO	Sources		Spatial resolution	Countries/ gear/species
		Nominal catch	Spatialized catch		
Atlantic	ICCAT	ICCAT website	ICCAT website	1° × 1°, 5° × 5°, 5° × 10°, 10° × 10°, 10° × 20°, 20° × 20°	114/48/142
Indian	IOTC	IOTC website	IOTC website	1° × 1°, 5° × 5°, 10° × 10°, 10° × 20°, 20° × 20°	57/35/45
Eastern Pacific	IATTC	IATTC website	FAO Atlas of Tuna and Billfish Catches	5° × 5° ^a	28/11/19
Western Pacific	WCPFC	WCPFC website	WCPFC website	5° × 5°	41/9/9
Southern ^b	CCSBT ^b	Provided by CCSBT staff	CCSBT website	5° × 5°	11/8/1

^aA number of these cells were straddling the Pacific and Atlantic Oceans. Their total catch was split into these two ocean basins, proportionately to the surface of the cell included in each ocean. This step was then corrected for biological distributions (based on www.fishbase.org); catches of both Atlantic bluefin tuna and Atlantic white marlin that were obviously wrongly allocated to the Pacific Ocean were reallocated back to the Atlantic Ocean.

^bThis RFMO covers all three oceans but deals only with southern bluefin tuna. Note that the other RFMOs also sometimes report this species (which we account for to avoid double-counting).

Acronyms: CCSBT, Commission for the Conservation of Southern Bluefin Tuna; FAO, Food and Agriculture Organization; IATTC, Inter-American Tropical Tuna Commission; ICCAT, International Commission for the Conservation of Atlantic Tunas; IOTC, Indian Ocean Tuna Commission; RFMO, regional fisheries management organization; WCPFC, Western and Central Pacific Fisheries Commission.

matching records except for the year of catch. For example, if France reported 100 t of yellowfin tuna caught in 1983 using longlines, but there were no spatial records for any country catching yellowfin tuna in 1983, the nominal 100 t for France was split up into spatial cells according to their reported proportion of total catch of any species and gear in 1983. After each successive refinement, the matched and nonmatched records were stored separately, so that at each new refinement, only the previous step's nonmatched records were used. The matched database was added to at the end of each step. The end result was a catch baseline database containing all matched and spatialized catches records, which sum up to the original nominal catch.

The catches thus assigned to the various sized tuna cells (1° × 1° to 20° × 20°; table 3.1) were then spatially reallocated to the standard 0.5° × 0.5° cells used by the *Sea Around Us* following the procedure described in chapter 5. All artisanal catches (i.e., any gear other than industrial-scale longlines, purse-seines, and pole-and-lines,³ as well as offshore gillnets) were reallocated to the EEZs of origin of the fleet, as the *Sea Around Us* defines artisanal

fleets as being restricted to domestic inshore areas (chapter 2). Here, only the industrial catches are presented.

Finally, a review of the literature was performed for each ocean to collect estimates of discards. Because of the limited amount of country- and fleet-specific data that this search yielded, it was decided that discard percentages should be averaged across the entire time period and applied to the region of origin of the fleet (e.g., East Asia or Western Europe), rather than the country of origin of the fleet. Similarly to the spatialization step described above, successive refinements were then performed to add discards to all reported catch.

For the Atlantic Ocean, we identified the lowest discard rate as 1.1% (longlines, North America; ICCAT 2009), the highest as 100% (longlines targeting swordfish; European Commission 2011), and the median discard rate as 10.7% (purse-seine, western and northern Europe; Amandè et al. 2011). For the Indian Ocean, we identified the lowest discard rate as 1.5% (gillnet, Asia; Shahifar 2012), the highest as 113% (longline; Alverson et al. 1994), and the median discard rate as 7.2% (longline, Asia; IOTC 2000). For the Pacific Ocean, we

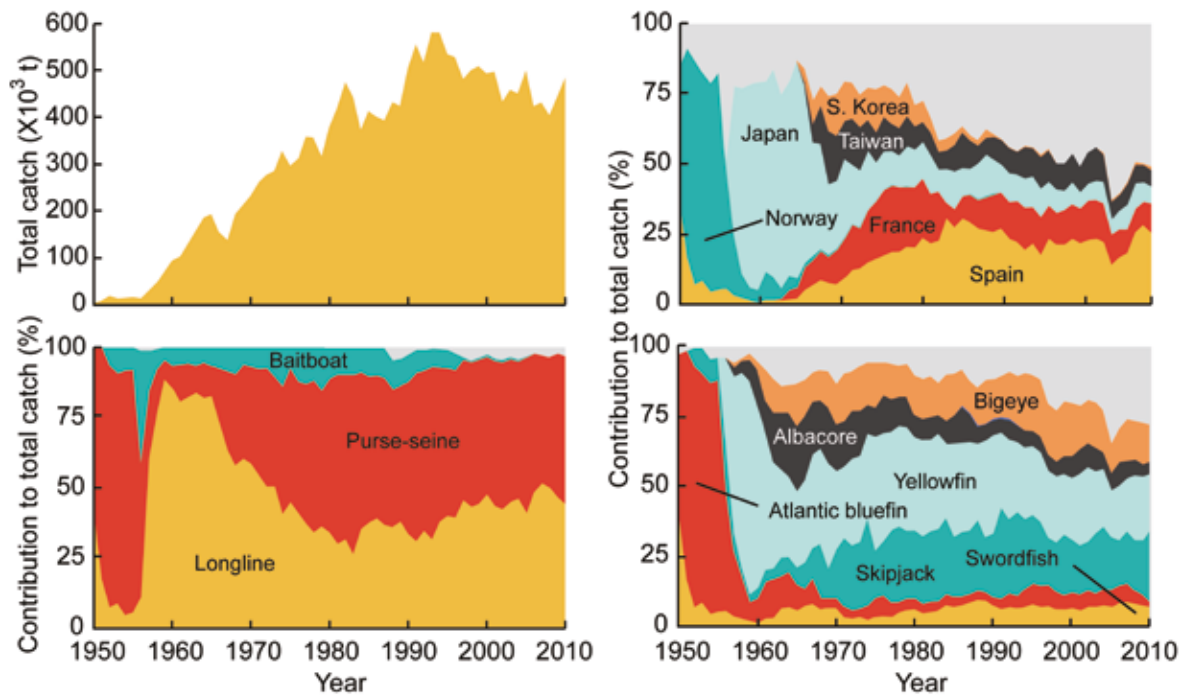


Figure 3.1. Industrial catch of large pelagic species in the Atlantic Ocean, 1950–2010. The top left panel shows nominal catches (without bycatch), whereas the top right, bottom left, and bottom right panels show this total catch as percentage contributions disaggregated by country, gear, and species, respectively. Gray areas are “other.”

identified the lowest discard rate as 0.4% (pole-and-line; Kelleher 2005), the highest as 75% (longline, Federated States of Micronesia; Bailey et al. 1996), and the median discard rate as 20.5% (longline, Fiji, Hawaii; Lawson 1997; Kelleher 2005; WPRFMC 2013).

INDUSTRIAL TUNA FISHERIES OF THE ATLANTIC OCEAN

Industrial catches in the Atlantic Ocean steadily increased from very low values in 1950 to a high of almost 600,000 t/year in the mid-1990s (figure 3.1). They subsequently declined to around 400,000 t/year by the mid-2000s before rebounding beyond 500,000 t by 2012 (figure 3.1).

Longline catches became prevalent in the 1960s with the arrival of Japanese vessels in the Atlantic, but their contribution to the total catch decreased over time (figure 3.1). In the early 1980s, their contribution began to increase again to reach about 50% of the total catch by the mid-2000s. However, this relative increase was essentially caused by the migration of European purse-seiners to the Indian Ocean (Stequert and Marsac 1983, 1989;

Fonteneau 1996; Bayliff et al. 2005; Marsac et al. 2014), as well as the overall decline of the EU fleet and number of fishing access agreements (Anonymous 2005, 2013a).

Purse-seiners (targeting skipjack and yellowfin tunas) are the second major gear in terms of catch (figure 3.1). Apart from a high contribution in the early 1950s (mostly from Norway), the purse-seine fleet only truly began expanding in the late 1960s and 1970s with the development of the French and Spanish fleets off West Africa, following the decreasing catches of albacore tuna in the Bay of Biscay (Chauveau 1989; Fonteneau et al. 1993; Sahastume 2002). It is noteworthy that the fleet of purse-seiners in the Atlantic Ocean has been increasing again since the late 2000s, with some vessels coming back from the Indian Ocean to avoid Somali piracy (Anonymous 2013a).

INDUSTRIAL TUNA FISHERIES OF THE INDIAN OCEAN

Industrial fisheries started in 1952 with the arrival of Japanese longliners (figure 3.2). By the mid-1950s, with Taiwan joining in,

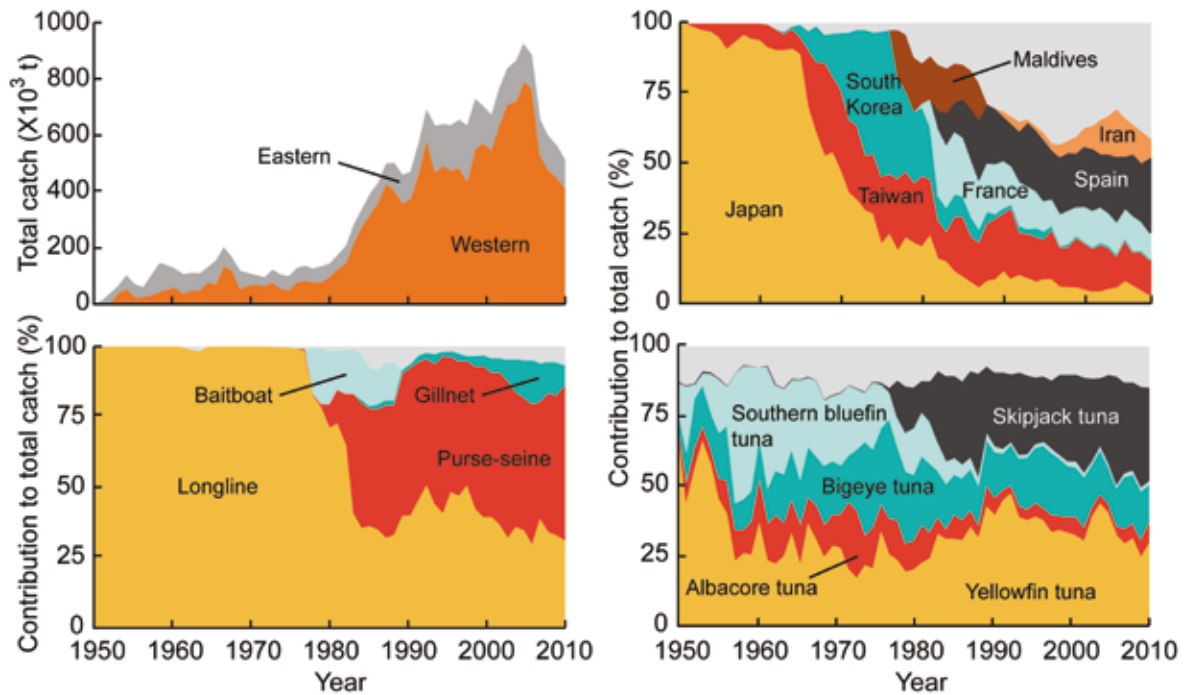


Figure 3.2. Industrial catch of large pelagic species in the Indian Ocean, 1950–2010. The top left panel shows nominal catches (without bycatch) by FAO area (51: western Indian Ocean; 57: eastern Indian Ocean), whereas the top right, bottom left, and bottom right panels show this total catch as percentage contributions disaggregated by country, gear, and species, respectively. Gray areas are “other.”

catches reached 100,000 t/year. Until the migration of the European purse-seiners in the early 1980s, catches slightly fluctuated, but they always remained below 200,000 t/year (figure 3.2). Thereafter, catches increased to 600,000 t/year by the mid-1990s, and then again to more than 900,000 t/year by the mid-2000s (mostly because of the expansion of the Iranian gillnet fleet). Since then, industrial catches have steadily declined, at least in part because of the effects of Somali piracy in the region (Chassot et al. 2010; Martín 2011; Anonymous 2014).

With the expansion of the Japanese fleet in the 1950s through the 1970s, followed by the arrival of European purse-seiners, the contribution of the western Indian Ocean has consistently increased over time, from zero in 1950 to a stable level of about 80% after 1990 (figure 3.2). Focusing on the purse-seine fleets, FADs have been used since the beginning of this fishery in the Indian Ocean (Stequert and Marsac 1983, 1989; Davies et al. 2014). Drifting FADs, developed in the early 1990s (Bayliff et al. 2005), are now used predominantly in the

northern area in the second half of the year but less in the Mozambique Channel because of the high occurrences of natural rafts (Davies et al. 2014).⁴ About 55% of the total purse-seine catch was taken under d-FADs in the early 1980s, increasing to 74% in the late 2000s and early 2010s.

INDUSTRIAL TUNA FISHERIES OF THE PACIFIC OCEAN

The industrial tuna fisheries of the Pacific Ocean are currently among the most profitable fisheries in the world. Their main targets are skipjack, yellowfin, bigeye, and albacore tunas, but two species, yellowfin and skipjack, have contributed more than 79% of the catch by weight from 1950 to 2010 (figure 3.3). However, on a per-kilogram basis, the most valuable species caught in the Pacific are bigeye and bluefin (Majkowski 2007; Williams and Terawasi 2011).

At present, the majority of the catch is acquired through the use of purse-seines targeting yellowfin and skipjack for canning (Lehodey et al. 2011; Hall and Roman 2013;

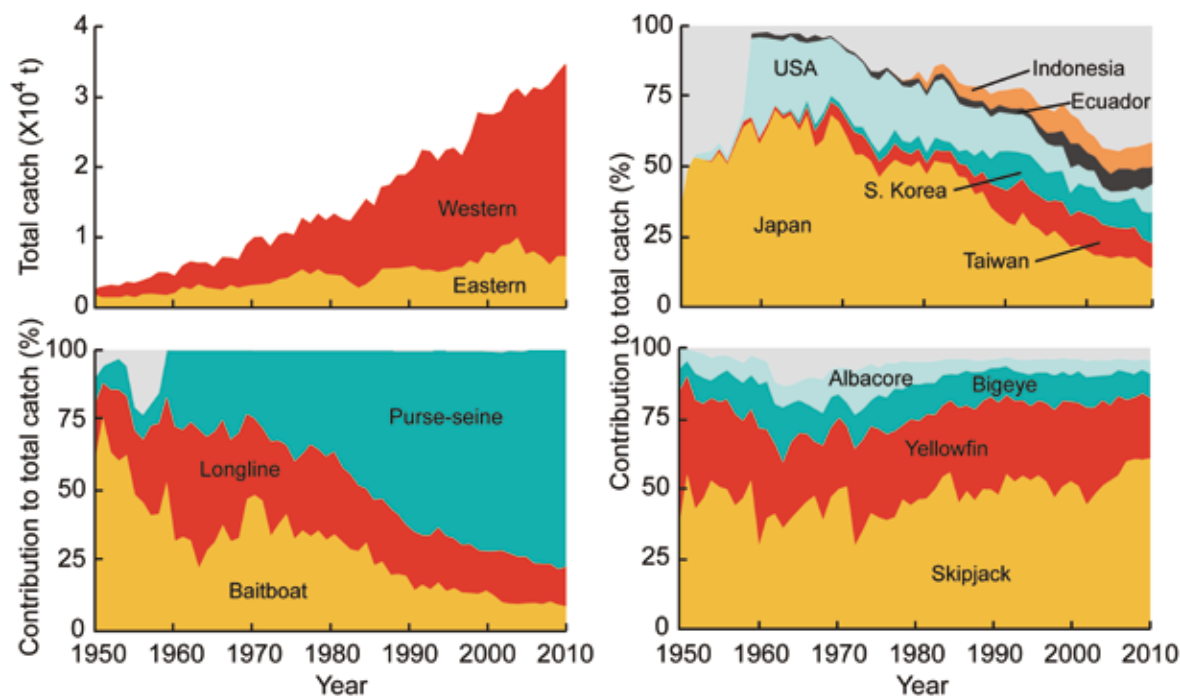


Figure 3.3. Industrial catch of large pelagic species in the Pacific Ocean, 1950–2010. The top left panel shows nominal catches (without bycatch) by area (“Western,” WCPFC; “Eastern,” IATTC), whereas the top right, bottom left, and bottom right panels show this total catch as percentage contributions disaggregated by country, gear, and species, respectively. Gray areas are “other.”

Sumaila et al. 2014). Specifically, purse-seiners are responsible for more than 70% of the tuna caught in the Pacific Ocean (figure 3.3), and purse-seining with the use of d-FADs massively increased (Hall and Roman 2013; IATTC 2013b). Historically, distant-water fleets from Japan, Korea, Taiwan, and the United States were the main purse-seining operations in the Pacific Ocean, with fleets from, for example, China, Ecuador, El Salvador, New Zealand, and Spain becoming more prevalent in the region since the 2000s. In addition, since the late 1980s, Pacific island-based purse-seine fleets have steadily increased in number, and in 2010 there were seventy-eight locally based purse-seine vessels in the western part of the Pacific Ocean (Williams and Terawasi 2011).

Longlines are the second most common gear in the Pacific Ocean, contributing about 20% of the catch (figure 3.3). All longline fleets target primarily mature bigeye and yellowfin (which are flash frozen, then thawed for sale as fresh sashimi), as well as some albacore for canning (WCPFC 2011; Sumaila et al. 2014). Fleets from Asia, South America, and Spain

have also targeted swordfish in the eastern part of the Pacific Ocean since the 1950s. Between 2000 and 2010, the total annual catch of this species averaged more than 800 t (1.8% of the total catch).

The prevalence of pole-and-line fishing (i.e., baitboat, figure 3.3) has decreased significantly over the last three decades (from more than 70% of the total catch in the early 1950s to about 10% in the 2000s), largely as a result of the expansion of purse-seining (Williams and Terawasi 2011). Nonetheless, this type of surface fishing remains a seasonal venture for Australia, Fiji, and Hawaii (domestic fleets), as well as Japan (both distant-water and domestic fleets) and a year-round fishery for domestic vessels from Indonesia, the Solomon Islands, and French Polynesia (Amoe 2005; Langley et al. 2010; WPRFMC 2013). Skipjack is the primary species landed by pole-and-line (81.4% of the catch).

THE SOUTHERN BLUEFIN TUNA FISHERY

Unlike the other tuna species, which form distinct populations in each ocean, southern

bluefin tuna (*Thunnus maccoyii*) has a circum-polar distribution range between 8°S and 60°S, although it occurs mainly between 30°S and 50°S (www.fishbase.org). Initially, Australia began fishing for southern bluefin in the southern Pacific Ocean with the use of surface gears in the early 1950s, and in 1965 Japan entered the fishery with a longline fleet (CCSBT 2011; Polacheck 2012). Currently, nine countries (including the EU as a single entity) target southern bluefin; however, Japan and Australia are responsible for most of the catch of southern bluefin. Despite the use of other gears in the past and a large surface gear component targeting southern bluefin for ranching, longlines are currently the primary gear used to catch southern bluefin tuna (CCSBT 2011).

THE INDUSTRIAL CATCH OF LARGE PELAGIC FISHES: GLOBAL MAPS

The database described above allows mapping of the global catch of pelagic fishes (mainly tuna, as well as billfishes, and including bycatch and discards) by industrial fisheries, by year, from 1950 to 2010. As an example, we present a catch map representing this catch,

averaged for the 11 years from 2000 to 2010 (figure 3.4).

CONCLUSION

This contribution introduced the first harmonized and spatially complete database of global large pelagic fisheries for all large pelagic taxa, including an estimate of discards. Until now, only regional (RFMO) or incomplete (e.g., the FAO Atlas of Tuna and Billfish Catches) databases existed, thus providing a truncated picture of these highly interconnected and global fisheries. Therefore, the interest of this new database lies in its ability to show the development of the various fisheries within and between each ocean basin (i.e., a clear advantage of scaling up), despite its preliminary nature. Notably, figures 3.1, 3.2, and 3.3, pertaining to the Atlantic, Indian, and Pacific Oceans, respectively, show an ominous progression, with catches peaking in the Atlantic in 1994 and in the mid-2000s in the Indian Ocean, but still increasing—until when?—in the Pacific Ocean.

Several points are perfectible, and the total catch is still thought to be incomplete and will have to be fixed in future iterations:

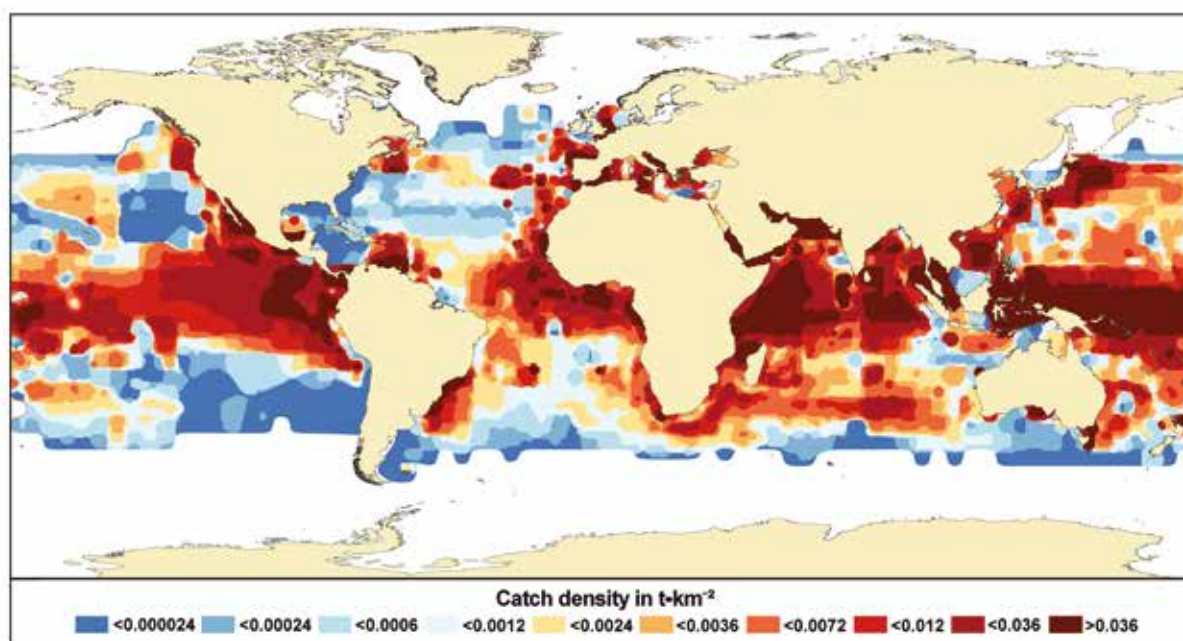


Figure 3.4. Average annual catches (t/km²) of large pelagic species (tuna and billfishes, as well as associated bycatch and discards) for 2000–2010 as derived for the present database and spatially assigned to the Sea Around Us 0.5° × 0.5° cells.

- The Inter-American Tropical Tuna Commission (IATTC) posed some data problems by not releasing the spatialized catches that they were supposed to release in 2014. Our temporary solution was to apply the average spatial data of all other gears to the longline fleets, but this was only a stopgap measure. We hope that spatialized IATTC data will become available in the future, which will then improve mapping of tuna catches in the northeast Pacific.
- The ICCAT nominal catch database contains some qualitative geographic information (i.e., “subareas”), which are apparently not geographically defined. Thus, we could not use them to refine our coarse spatialization. If these subareas were to become geographically defined, we could force the allocation of the nominal catch to specific subareas rather than to the entire ICCAT area.
- Our FAD versus free-school breakdown could be improved, using the actual spatial and annual breakdown from the spatialized database rather than applying only the annual breakdown. This gear distinction is made only by the Indian Ocean Tuna Commission (IOTC) and ICCAT. We will later dedicate resources to this issue; in the meantime, our stopgap measure resulted in the same spatial allocation for both FAD and free-school catches.
- Discard rates presented here account for only a subset of the literature, and we encountered some initial difficulties in harmonizing all of them. Feedback from worldwide experts could allow us to refine these rates by integrating a rule-based approach by gear and country to our discard estimation.
- Finally, we also imagine that improved spatial assignment rules and other global databases such as www.fishbase.org could be used to refine our spatial distribution of the catch by, for example, restricting species to certain areas. Thus, this chapter should be seen as version 1.0, and we hope it will trigger some interest in the community, ultimately resulting in the involvement of experts through feedback to improve our set of assumptions.

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NOTES

1. Cite as Le Manach, F., P. Chavance, A. M. Cisneros-Montemayor, A. Lindop, A. Padilla, D. Zeller, L. Schiller, and D. Pauly. 2016. Global catches of large pelagic fishes, with emphasis on the high seas. Pp.34–45 in D. Pauly and D. Zeller (eds.), *Global Atlas of Marine Fisheries: A Critical Appraisal of Catches and Ecosystem Impacts*. Island Press, Washington, DC.

2. The Food and Agriculture Organization of the United Nations (FAO) has published a global, harmonized atlas, but it includes only the catch of twelve species of tuna and billfishes (i.e., albacore, Atlantic bluefin tuna, Atlantic white marlin, bigeye tuna, black marlin, blue marlin, Pacific bluefin tuna, skipjack tuna, southern bluefin tuna, striped marlin, swordfish, and yellowfin tuna; FAO 2013a). This atlas is available at www.fao.org/figis/geoserver/tunaatlas. For reasons of confidentiality of commercial interests, this dataset entirely lacks longline data for the eastern Pacific area after 1962, managed by the IATTC, although some data for the earlier time period have been published in aggregated form (Fonteneau 1997). A recent resolution on confidentiality rules may mean that these spatialized data may eventually become publicly available (IATTC 2013a). Fonteneau (1997) has also published a global atlas but did not estimate discards or scale up the spatialized data to 100% of the nominal catch. Updates were published later but at regional scales and without the Pacific Ocean (Fonteneau 2009, 2010).

3. Except when labeled “nonmechanized,” “coastal,” “small,” or such that nonindustrial fishing can be inferred.

4. Note that the current intense use of d-FADs results in a fishing activity closer to “gathering” than “hunting,” because it greatly reduces searching time and aggregates the fish in traceable locations. However, d-FADs are regularly criticized for generating high bycatch rates of juvenile yellowfin and bigeye tunas, reducing potential catches by the longline fleet (Bromhead et al. 2003; Miyake 2005), and nontarget species including at-risk shark species (Romanov 2002; Dagorn et al. 2013; Filmalter et al. 2013). They also may act as an “ecological trap” by tricking tunas into nonoptimal waters (Hallier and Gaertner 2008).