 doi:10.20944/preprints202102.0145.v4

Shark conservation: Analysis and synthesis

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Abstract

In this review of the factors relevant to the current status of sharks, we present the general background, the ecological importance of the cartilaginous fishes, the reasons why shark depletion is poorly known, and why commercial shark fishing cannot be sustainable. We conclude with a synopsis of the changes necessary to cope with the current crisis of overfishing. Detailed analyses of fishing records show that the shark species accessible to global fisheries have been systematically depleted since industrial fishing began in the 1950s. By 2003 they had sunk to about 10% of their former levels. Industrial fisheries originally targeted teleost fish, so sharks were mostly discarded with no record being kept. But, with the rise in value of shark fins due to the shark fin trade, at the same time as many teleost fish stocks were depleted, sharks (along with tuna) became the most valuable catches and are now being targeted by fisheries around the world. The shark fin trade is driven by enormous profits and there is no interest in sustainability in either the shark fin industry or consumer countries. Neither the will nor the resources to manage the trade exist. With the global demand for shark fins rising while the large predators supplying that demand are at a tiny fraction of their former numbers, and increasingly threatened with extinction, commercial fishing for sharks is unsustainable. Therefore, all sharks, chimaeras, manta rays, devil rays, and rhino rays should receive immediate protection from international trade. The scale of the global take for the shark fin trade and the state of shark depletion amply documented in the literature merits an Appendix I CITES listing. But a binding international agreement for protection, not only of sharks, but of threatened ecosystems and the loss of biodiversity in general, is what is most needed.

Keywords

biodiversity conservation, sharks, sustainable shark fishing, fisheries, shark fin trade

Acknowledgments: We thank Iris Ziegler for providing much information about the shark fishing industry, and for Table 1. Many thanks to Alex Hofford and Keith DP Wilson for reading an early draft and making helpful suggestions. We are grateful to Randall Arauz, Mary O'Malley, and Stefanie Brendl for their insightful input on a variety of the political aspects of shark conservation.

1 Introduction

Shark conservation has been the subject of numerous reports over many years, with arguments for and against action to limit the fishery. In the absence of a clear conclusion or consensus, we present a detailed and comprehensive data-driven analysis of the various aspects of the matter.

The growth of the market for shark fin soup, a fashionable, high-end Chinese dish, has resulted in intensive shark fishing across all oceans, but most of the slaughter is neither recorded nor managed (Clarke *et al*. 2006a, b; Dulvy *et al*. 2008; Worm *et al*. 2013; Dulvy *et al.* 2014; Fields *et al.* 2017). With their low productivity, sharks have poor capacity to withstand fishing mortality (Myers & Worm 2003) so their numbers are plummeting. In a rigorous global study in 2014, Dulvy *et al*. found one quarter of shark and ray species to be threatened with extinction as a result of overfishing in what could be called "a chronic accumulation of global marine extinction risk." In 2019 the UN Biodiversity Council (IPBES 2019) warned that more than one third of all known shark and ray species are facing the risk of extinction within the next few decades and explicitly named industrial fishing as the main reason for the loss of marine biodiversity. The latest report (Pacoureau *et al*. 2021) found that more than three quarters of oceanic sharks are now threatened with extinction.

At the same time as the rise of the shark fin trade, some 90% of teleost fish stocks have become over-exploited (World Bank 2017), making sharks the most lucrative target. Consequently, fisheries that have not previously hunted them are now doing so (Clarke *et al*. 2007; Hareide *et al.* 2007; Dulvy *et al.* 2008). Pelagic sharks have been hardest hit (Dulvy *et* *al.* 2008; Oliver *et al.* 2015, Pacoureau *et al.* 2021) and they provide most of the fins on the market (Clarke *et al.* 2006a, b; Fields *et al.* 2017), but sharks in a wide variety of ecosystems are targeted. In 2020, MacNeil *et al*. found that reef sharks are functionally extinct on 19% of coral reefs. In Southeast Asia, where large numbers of shark species evolved in its diverse, coral ecosystems, elasmobranchs are particularly threatened and overfished, yet no records have been kept, so the true extent of elasmobranch losses is unknown (Lam & Sadovy de Mitcheson 2011).

In 2013 Worm *et al.* estimated that between 63 and 273 million sharks were killed each year, depending on whether the tonnage is made up of larger or smaller sharks. Since reports for various regions in the world indicate that most sharks caught are immature (Ward & Myers 2005, Lam & Sadovy de Mitcheson 2011, Doherty *et al.* 2014, ICCAT 2019), it is likely that the true number was closer to the higher estimate. Currently, about 600,000 metric tonnes (t) of sharks and rays are caught each year by just the world's top 20 shark fishing nations (Okes & Sant 2019). These figures do not account for bycatch, dead discards, illegal, and unrecorded catches, or the high post-release mortality resulting from poor or inadequate handling procedures (Hutchison *et al*. 2015) in the case of threatened species on which there is a retention ban.

Further, jurisdictional issues, along with the difficulties of obtaining relevant data, have long obscured understanding of sharks' diversity and true numbers (Stevens *et al*. 2000). They range far from land and migrate across oceans, outside countries' Exclusive Economic Zones (EEZs), so their status is difficult for Regional Fisheries Management Organizations (RFMOs) to assess. IUCN (2019) listed 198 data deficient shark species out of the 494 assessed. RFMOs have placed higher priority on species with greater economic importance so shark management in general has been low priority, poor, or entirely lacking (Stevens *et al.* 2000; Dulvy *et al.* 2008; Davidson *et al.* 2016; Cashion *et al.* 2019).

In consumer countries shark fin is a luxury item and there is little interest in sustainability or legal trade. Rich consumers are willing to pay high prices while the will, oversight, and enforcement resources necessary to manage the trade is generally absent. Thus market demand will continue to fuel the intensive search for more sharks, and the problem is likely to become greater as scarcity forces prices up (Sadovy de Mitcheson *et al*. 2018). In 2016 Campana estimated the shark fin market to be worth approximately US$350 million.

Although the idea that sharks are being fished sustainably around the world is still put forward (Simpfendorfer & Dulvy 2017; Shiffman & Hueter 2017), in reality very few of today's commercial shark fishing operations are managed sustainably. In 2020 Ferretti *et al*. found that 91.3% of shark catches are biologically unsustainable and only 16 shark fisheries, globally, were well managed (Feretti *et al.* (2020). But even in well-managed shark fisheries, ecosystem impacts are both almost impossible to detect and difficult to evaluate, and therefore ignored in stock assessments (Ferretti *et al.* 2010; Travis *et al*. 2014). Most shark species are impossible to catch selectively (Walker 1998), especially when using longline gear, and therefore other shark species will be caught as bycatch, including those that are overfished or threatened (Campana 2016, Pacoureau *et al*. 2021).

Increasing numbers of shark and ray species are found to be critically endangered or endangered, including 16 of the 31 species of oceanic sharks and rays (Pacoureau *et al.* 2021). Given the nature of the shark fin trade, without intervention the situation will continue to decline. In the interests of averting a catastrophic collapse across the planet's diverse marine, riverine and estuarine ecosystems, sharks and their habitats must be given effective protection (IPBES 2019, Pacoureau *et al*. 2021).

2 The impact of industrial fishing

With approximately 2.9 million motorized fishing vessels hunting the global ocean, the footprint of industrial fishing exceeds other forms of food production (Kroodsma *et al.* 2018). Modern longliners, sea bottom and deep sea trawling, and drifting fish aggregating devices (dFADs) are particularly lethal (Jones 1992; Sumaila *et al.* 2010; Norse *et al.* 2011; Filmalter *et al.* 2013; Hanich *et al*. 2019). However, wild fisheries provide only 1.2% of global caloric production for human food consumption (Kroodsma *et al.* 2018).

Industrial fishing began throughout the world's tropical and temperate oceans after WWII, although some areas were being fished intensively prior to that (Myers & Worm 2003; Ward & Myers 2005; Ferretti *et al.* 2010). Fishing pressure has escalated (Kroogsma *et al.* 2018) an estimated 18-fold since 1970 (Pacoureau *et al*. 2021).

By 2003, the global ocean had lost an estimated 90% of its predators, 80% within the first 15 years of industrial exploitation (Myers & Worm 2003; Ward & Myers 2005). This suggests that by 1970, the baseline used by Pacoureau *et* *al.* (2021) for their calculations of shark depletion, sharks were already severely depleted, but the abundance of oceanic sharks was reported to have further decreased by some 71% since 1970. Tropical sharks have declined by an average of 87% despite their more resilient life history (Pacoureau *et al.* 2021). This means that overall only about 6% remain of the numbers present in 1950, and only about 3% in the case of tropical sharks.

Sharks were always a substantial bycatch taken by longliners, drift nets, purse seine nets and bottom trawlers. In the Atlantic Ocean, longliners caught two or three sharks for every swordfish, and in the Gulf of Mexico and Pacific Ocean one shark was caught for every two yellowfin tuna (Ferretti *et al.* 2010). They were mostly discarded as trash while official fisheries statistics recorded only landed catches (Campana 2016; Fordham *et al.* 2016).

Industrial fishing resulted in rapid and extreme declines in shark catches (Myers & Worm 2003; Ward & Myers 2005). In the Pacific, for example, the catch of silky shark (*Carcharhinus falciformis*) decreased by some 92%, while in the Gulf of Mexico catches of the oceanic whitetip (*Carcharhinus longimanus*) fell by more than 99% (Ferretti *et al*. 2010). Along the eastern shore of the United States of America (USA) huge declines were recorded: 87% for sandbar sharks (*Carcharhinus plumbeus*), 93% for the oceanic blacktip (*Carcharhinus limbatus*), 97% for tiger sharks (*Galeocerdo cuvier*), 98% for scalloped hammerheads (*Sphyrna lewini*), and more than 99% for bull (*Carcharhinus leucas*), dusky (*Carcharhinus obscurus*) and smooth hammerhead (*Sphyrna zygaena*) sharks (Myers *et al.* 2007). Ecologically, they were functionally removed (Heithaus *et al.* 2008).

Over-exploitation and collapse of the porbeagle (*Lamna nasus*) population in the Northeast Atlantic in the 1960s led to intensive directed fishing in the Northwest Atlantic, where most of the virgin biomass was removed in just six years (Dulvy *et al*. 2008). A similar situation is ongoing for the spiny dogfish (*Squalus acanthias*) (Fordham *et al.* 2016).

In the South China Sea, 109 species of sharks were recorded as being fished in the 1970s but only 18 are present in current market surveys. The market is now dominated by smaller species, of which 65% are under the age of sexual maturity (Lam & Sadovy de Mitcheson 2011). Indonesia is the largest shark fishing country in the world and its annual catch exceeds 100,000 t per year from its 17,000 islands (Sadovy de Mitcheson *et al.* 2018), yet fishery management is virtually absent. Japan has operated some of the largest elasmobranch fisheries in the Northwest Pacific and was already trading shark fins with China more than 200 years ago. Japan's large trawl fisheries showed signs of being over-exploited before World War II, so in the Northwest Pacific shark exploitation may have peaked before the 1950s (Ferretti *et al.* 2010). In the Mediterranean, trawl fishing led to the loss of 16 out of 31 species in the Tyrrhenian Sea, 6 out of 33 species in the Adriatic Sea, and half of the species in the Gulf of Lion since the 1950s. Nine of the 16 shark species still landed in the Mediterranean are more threatened regionally than at the global level and between 53 and 71% are at risk of extinction (Cashion *et al*. 2019). Pelagic fisheries landings in Brazil recorded the disappearance of 14 species of carcharhinids between 1977 and 1994 (Amorim *et al*. 1998). Devil ray abundance has declined by at least 85% in the past 15 years in the Southwest Indian Ocean (Pacoureau *et al*. 2021).

Since the 1980s, the tuna industry has increasingly made use of dFADs, and half of all tuna are now caught using them (Balderson & Martin 2015). These consist of floating platforms trailing lengths of netting to ensure that they move with the ocean currents, rather than being swept along by the wind. They maximize their catch by taking advantage of the tendency of tuna to shelter beneath floating objects. However, a variety of other marine animals, including the juveniles of oceanic whitetip and silky sharks, also use that shelter, and are therefore a major bycatch in those fisheries. Drifting FADs are left to drift, usually for several months between visits by the fishing fleet, which then uses purse seines to net the entire shoal of fish that has accumulated beneath them. In the Indian Ocean over 80% of the purse seine catch is now made using dFADs (Hanich *et al.* 2019), and between 480,000 and 960,000 silky sharks, most of which are juveniles, are killed each year through entanglement in those trailing nets (Filmalter *et al*. 2013). This mortality, from the Indian Ocean alone, is comparable in scale to the entire reported world fishing catch of 400,000 to 2,000,000 animals, the silky shark being second only to the blue shark for use in the fin trade (Fields *et al.* 2017). Although some RFMOs are beginning to demand that dFADs must be non-entangling, the criteria for a non-entangling dFAD are still very weak. Many dFADs constructed to be non-entangling become entangling with the passage of time (Wang *et al*. 2020).

3 The ecological consequences

In pristine, unfished regions sharks are abundant and diverse (Ferretti *et al.* 2010). As highly successful top and middle predators, they survived the several mass extinctions and, through radial evolution, adapted to new ecological niches (Kriwet & Benton 2004; Kriwet *et al.* 2009; Guinot & Calvin 2016). Thus, over the past 500 million years, they became deeply woven into the aquatic ecosystems of the planet. But industrial fishing resulted in a large-scale ecological transformation, not only in terms of the size of individuals and the relative abundance of species, but also community biomass (Stevens *et al.* 2000; Ward & Myers 2005; Myers *et al*. 2007; Ferretti *et al.* 2010; Travis *et al.* 2014). The removal of top predators causes alternating increases and declines in the abundance of lower levels on the food chain, an effect called a *trophic cascade* (Ward & Myers 2005). However, due to the difficulties in studying marine ecosystems, particularly in deep waters, few such cases have been identified and little is known about the complex ecological roles played by sharks (Stevens *et al.* 2000; Mumby *et al*. 2006; Myers *et al*. 2007; Heithaus *et al.* 2008, Pacoureau *et al*. 2021).

Food-web models suggest that large sharks are among the most strongly interacting species (Freire *et al*. 2008), and that their overfishing may have contributed to the degradation of the coral ecosystems in the Caribbean (Bascompte *et al*. 2005). A 'removal' computer simulation conducted for the reef ecosystem of Floreana Island in the Galápagos Islands found that sharks were at the top of the trophic scale and that their removal caused a four-level trophic cascade (Okey *et al.* 2004). Toothed cetaceans, sea lions, marine iguanas, and other mid-level predators were predicted to increase, which led directly to intensified predation on reef fish and a decline in their numbers. This in turn led to an increase in small benthic invertebrates. Other trophic cascades were also apparent. The removal of the sharks caused a rebalancing of the entire ecosystem.

The presence of large sharks has a marked effect on the behaviour of prey species. The removal of tiger sharks so affected the evasion behaviour of dugongs and green sea turtles in Shark Bay, Australia, that the sea floor patterns of sea grass and its nutrient composition were significantly changed (Heithaus *et al*. 2007, 2008). The removal of the great sharks is likely to have allowed smaller species to move into the sunlit upper layers of the ocean during the daylight hours, whereas formerly they only migrated upwards at night (Ward & Myers 2005).

Some elasmobranchs, including reef and tiger sharks, leave their ranges for a period of weeks when fishing begins (Porcher 2010, 2017), putting their communities (Mourier *et al.* 2012, Papastamatiou *et al*. 2020) into disarray. This tendency to flee when some of their number are killed was independently seen in reef sharks in French Polynesia and tiger sharks in the Bahamas, suggesting that it is a widespread reaction to fishing pressure.

The depletion of top predators, therefore, causes deep disruption in ecological communities that is widespread and long-lived (Heithaus *et al.* 2008; Ferretti *et al.* 2010). Over more than seven decades, industrial shark removal has resulted in major shifts in biomass and size composition in all oceans (Ward & Myers 2005; Myers *et al.* 2007; Ferretti *et al.* 2010). For example, the mean weight of blue sharks (*Prionace glauca*) caught was 52 kg in the 1950s, but just 22 kg in the 1990s, while the species abundance fell to only 13% of that of the 1950s (Ward & Myers 2005). Along the Eastern coast of the USA, 11 species of large shark declined between 1970 and 2005, while catch rates for 14 small elasmobranch species increased from about 1% to some 26% per year (Myers *et al.* 2007; Heithaus *et al.* 2008). Ten-fold declines in 12 large pelagic predators between 1950 and 2000 were noted in the Pacific Ocean at the same time that pelagic stingrays (*Dasyatis violacea*) and other smaller elasmobranchs increased some 10- to 100-fold (Heithaus *et al.* 2008). In the North Sea, a rich ecosystem of elasmobranchs was changed to one consisting of a few small, productive species such as small spotted cat sharks (*Scyliorhinus canicula*) and small skates (Ferretti *et al.* 2010).

But, RFMOs have not and do not take the ecological consequences of shark removal into account (Travis *et al*. 2014).

4 The uncertainties

Although staggering numbers of sharks are being killed in all oceans, it is impossible to determine their precise status because much of this mortality is not recorded. For example, by studying the shark fin market in Hong Kong between 1999 and 2001, Clarke *et al.* (2006a b) found that, at that time, the shark mortality necessary to support the shark fin trade was four times what had been reported to the Food and Agriculture Organization of the United Nations (FAO), which is the only organization that keeps global fishing records. Clarke *et al*. found that about 1.7 million tonnes of sharks a year were being sacrificed for the vanity soup but cautioned that these estimates were low and did not include shark mortality that did not produce fins (such as hooking mortality, post-release mortality, predatorial mortality during longlining, and the killing of sharks by fishermen to reduce bait loss on future sets, as well as incidental, artisanal, and recreational catches and discards). Thus, all estimates based on recorded catches underestimate the mortality that sharks are actually facing by approximately a factor of four.

Global studies have emphasized the problems inherent in assessing the status of sharks, providing detailed descriptions of the difficulties on every level (Clarke *et al.* 2006a, b; Worm *et al.* 2013; Dulvy *et al*. 2014; Dent & Clarke 2015). For a shark fishery to be sustainable it must be possible to determine not only what the shark fishing mortality is, but also the mortality that will produce maximum sustainable yield, yet in the case of sharks those reference points are often not known or are extremely uncertain (Worm *et al*. 2013; Dulvy *et al*. 2014; Campana 2016; ICCAT 2019; Queiroz *et al*. 2019). Most shark hunting nations still do not keep species-specific catch records (Clarke *et al*. 2006a, b; Musick & Musick 2011; Dent & Clarke 2015; Fields *et al*. 2017), and recorded catches from industrial fisheries are known to be inaccurate. Catch data from artisanal fisheries are generally ignored, but in many regions they are significant (IOTC 2020). In the Indian Ocean, for example, such fisheries are not required to report shark catch data, contributing to the underestimation of shark mortality (IOTC 2020).

In 2015, for example, the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) analyzed shortfin mako (*Isurus oxyrinchus*) stocks using the most complete data available. It found that due to missing information, untested indicators, and conflicts in the available data, the assessment was impossible to make at all (NOAA 2017).

Such uncertainties are amplified by the vagueness and secrecy involved in the trade in shark products (Dent & Clarke 2015).

4.1 Illegal, unreported, and unregulated fishing

Illegal, unreported, and unregulated (IUU) fishing takes about 20% of the world's fishing catch, and as much as 50% in some fisheries. It is valued at between $10 billion and $23.5 billion annually from 11 to 26 million tonnes of fish (Agnew *et al.* 2009). These losses contribute to the unreliability of stock assessments, and to the danger of their collapse (Widjaja *et al.* 2020). As top-valued animals, sharks are especially vulnerable.

IUU fishing includes not only fishing which directly contravenes laws, but also fishing conducted under the area of management of a RFMO in a manner that contravenes the conservation and management rules of that organization, as well as fishing done outside of management areas in a manner that is not consistent with state responsibilities for the conservation of marine resources under international laws (Widjaja *et al.* 2020). It has been correlated with poor governance, resulting in a lack of management of fishing capacity and consequent overfishing (Meere & Lack 2008). With seafood in high demand, and the difficulties of enforcing fisheries management, particularly on the high seas, IUU fishing is profitable and globally there has been a lack of political will to take the actions required to address it (Meere & Lack 2008).

The United Nations Convention on the Law of the Sea, the FAO Code of Conduct, and the UN Fish Stocks Agreement, as well as a variety of other international codes of conduct, agreements and regulations, have been put in place for the purpose of ensuring that fishing activities are conducted responsibly. Their objectives include taking the precautionary approach to fisheries management, ensuring that bycatch and waste are minimized, that the marine environment is conserved to sustainable levels, and that the economic interests of coastal communities are taken into account. RFMOs, as well as the large seafood companies, are those in a position to ensure that these principles are respected (Greenpeace 2020). However, compliance with these measures is poor. Many vessels intentionally violate laws on the virtually unmonitored high seas (Meere & Lack 2008). Without a strong, internationally binding High Seas Treaty there is almost no prosecution to be feared by fishing fleets for violations, even if detected.

For example, Taiwan has over 1,100 flagged vessels fishing across all the oceans, and hundreds more Taiwanese-owned vessels are flagged to other countries. It is one of the world's largest distant-water fishing powers. It is a party to several RFMOs, including the Inter-American Tropical Tuna Commission (IATTC), the International Commission for the Conservation of Atlantic Tunas (ICCAT), the Indian Ocean Tuna Commission (IOTC), and the Western and Central Pacific Fisheries Commission (WCPFC). Yet Greenpeace (2020) found that 50% of its ships practised shark finning. Thirteen percent killed toothed cetaceans, such as dolphins and false killer whales, to use as shark bait or to sell. (The meat of dolphins is extremely attractive to sharks and stays on the hook better than fish meat.) Further, 92% of ships in the Taiwanese fleet committed human rights abuses. These included the withholding of wages, excessive overtime (20 h/day shifts), deception, physical violence, and passport confiscation with no recourse to apply for justice. In spite of some improvements and efforts to legalize the Taiwanese fleet, continued violations are reported.

Taiwan is home to one of the top three tuna traders in the world, Fong Chun Formosa Fishery Company, Ltd., which recently purchased the American canned tuna company 'Bumble Bee', making it a major supplier of tuna to consumers in the USA (Greenpeace 2020). It is a telling illustration of how successful and insidious is IUU fishing in today's market.

In all four tuna RFMOs, fishing vessels regularly retain valuable shark species, including oceanic whitetip, scalloped hammerhead, and silky sharks, in spite of retention bans (IOTC 2020).

4.2 Other markets

As well as the shark fin market, the increasing demand for a component of shark liver oil, squalene, is a prominent cause of shark mortality. Squalene fishermen often extract the animal's liver and throw the body back into the ocean, which is called "shark livering." The scale of the shark liver oil market requires more than three million deep-sea sharks annually and targets species with large livers such as the Greenland shark (*Somniosus microcephalus*), the whale shark (*Rhincodon typus*), and deep-sea sharks including the gulper shark (*Centrophorus granulosus*), the leafscale gulper shark (*Centrophorus squamosus*) and the Portugese dogfish (*Centroscymnus coelolepis*). Even when they are caught in low numbers, deep-sea sharks are extremely vulnerable to fishing.

However, except in South Korea, there is no standard code designating shark liver oil or squalene, and countries do not declare their catches to the FAO. It is therefore impossible to analyse the global market in any detail (Chabrol 2012).

Shark meat and oil are now being used in everything from make-up to dogfood, particularly from blue, shortfin mako and scalloped hammerhead (*Sphyrna lewini*) sharks (Cardeñosa 2019). Given the success of IUU fishing, threatened species easily find their way into the market.

4.3 Replacing depleted species

The high diversity of shark species in the Hong Kong shark fin market indicates the likelihood that species more sensitive to fishing pressure are being replaced by others as their numbers become depleted. Such substitution could mask losses of declining species (Fields *et al*. 2017).

When landings of species complexes appear to remain stable, or even increase, in spite of intensive fishing, the declines or disappearance of the more sensitive members can go unnoticed while removal continues because overall yields are sustained by the more productive species in an unperceived target replacement (Davidson *et al*. 2016). Continued fishing pressure on such populations has often resulted in their total collapse (Stevens *et al.* 2000; Ferretti *et al.* 2010). Species replacement contributes to the uncertainties inherent in shark fisheries data (Ferretti *et al*. 2010).

Examples include the disappearance of three of the largest skate species from British waters, and steep declines in others, all while fishery reports on "skates and rays" claimed that the populations were stable (Davidson *et al*. 2016).

The angel shark (*Squatina squatina*) was nearly fished to extinction in Europe. It was recorded and sold under the name "*monkfish*", but as the catch dwindled, fishermen substituted anglerfish (*Lophius spp*.) which was then sold under the same name (Davidson *et al*. 2016).

Similarly, as many popular fish species have become critically depleted and scarce, sharks have been substituted, using a false label to sell them. For example in 2019 Hobbs *et al*. used DNA Barcoding to identify species sold in the UK. Out of 79 tested samples of "fish and chips" sold as takeaways, 71 were spiny dogfish—almost 90% of the tested samples. They were labelled as 'Rock Eel', 'Rock Salmon', 'Rock' or 'Huss', thereby making it almost impossible for consumers to know that they were eating shark meat, and possibly the meat of a threatened species; the spiny dogfish is critically endangered in the Eastern North Atlantic (Hobbs et al. 2019). Hobbs *et al*. (2019) also found that cheap fast-food outlets were the best places to disguise shark meat and sell it under a false name.

In Australia 'flake' is the name used for the meat of a wide variety of sharks, including the endangered school shark (*Galeorhinus galeus*), the endangered scalloped hammerhead, and the critically endangered whitefin swellshark *(Cephaloscyllium albipinnum).* According to the Australian Marine Conservation Society (AMCS), 'flake' is widely used for fish and chips (AMCS), but less than 30% of fish and chips shops label the species being used correctly (Guida 2021). In their report, AMCS highlighted the fact that the most popular seafood in Australia exploits these endangered sharks, yet half of the consumers are not aware that they are eating shark when they buy flake (Guida 2021).

5 Shark conservation measures

The regulations intended to protect and manage sharks in recent decades have been ineffective in stopping the decline in their numbers (Ward-Paige *et al*. 2012; Davidson *et al*. 2016; Pacoureau *et al*. 2021). Listings by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) are proving inadequate in the face of the secretive shark fin trade (Fields *et al.* 2017; Cardeñosa *et al.* 2019; Booth *et al.* 2020). To date, only 5 species of ray (sawfish) and not one species of shark has been listed under CITES' Appendix I in spite of their ongoing depletion, though 14 species of shark and 27 species of ray, including the IUCN critically-endangered rhino rays, have been included under Appendix II.

Listings are opposed by shark hunting nations because of the high commercial value of the fins (Worm *et al.* 2013). Protection can only be gained one species at a time, while the shark fin market is indiscriminate, taking fins from essentially any species of shark or ray. Once separated from the animal, it is time consuming to determine from which species a fin has been taken, so enforcement is weak (Clarke *et al*. 2006a). Further, an Appendix II CITES listing only requires a "Non-detrimental" finding to export fins from the listed species—it grants no protection from being fished in the first place. Since fins can be stockpiled until a "Non-detrimental" finding can be arranged, the loophole undermines the protection that was intended by the original CITES listing (CREMA 2018). Countries also avoid granting protection to endangered sharks by claiming that they are not wildlife but species of commercial interest to fisheries (pers. comm. Arauz 2021).

For example, the whale shark continues to decline in both abundance and size in spite of being protected by the Bonn Convention on Migratory Species of Wild Animals 2010 (CMS), CITES, and the Commonwealth Environment Protection and Biodiversity Conservation Act (EPBC) (Ward-Paige *et al.* 2012). In 1999 it was listed on Appendix II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS) and on Appendix I in 2017 (CMS 2020). The sand tiger shark *(Carcharias taurus*) in southern Australia has been protected from fishing since 1984, but due to the high rate of incidental hooking the population continues to decline (Ward-Paige *et al.* 2012).

In 2015, 52% of fins (by weight) analysed in the Hong Kong market were CITES-listed sharks (Cardeñosa *et al.* 2019). In a later study, fins from 76 species of elasmobranchs were found being traded in Hong Kong, and one third of those species were considered to be threatened with extinction (Fields *et al.* 2017). In 2017, a shipment of shark fins intercepted in Germany, en route between Mexico and Hong Kong, was found to include four species of CITES-listed sharks out of eleven (Villate-Moreno *et al*. 2021).

5.1Finning bans and Fins Naturally Attached policies

Finning bans were thought to be a viable means to combat shark finning in the belief that they would result in a decline in shark mortality (Clarke *et al*. 2007, 2013). A fins-to-carcass ratio of 5% has generally been adopted (calculated as fins being 5% of the weight of the sharks on board the fishing vessel). This was intended to indicate that no sharks had been finned and discarded at sea. However, these ratios are almost impossible to verify, especially when fins have been dried or are frozen, and the legislation has not helped to improve data availability with respect to the true numbers and species of sharks being caught.

As a result, several jurisdictions have introduced a *fins naturally attached* (FNA) regulation that requires that fins cannot be cut off at sea but must be landed naturally attached to the body of the animal. This is now considered to be the only way to guarantee that finning did not occur (Cortés *et al.* 2006), and to permit the true numbers, species, and size of the sharks caught to be reported accurately for the analysis of fishing-induced mortality.

The FNA policy has been an important improvement and is globally acknowledged as being the best practice (Cortés *et al.* 2006; Fischer *et al.* 2012, Biery *et al*. 2012). It has been implemented in many countries and RFMOs including Costa Rica (2008), US (2011), EU (2013), Canada (2019), North East Atlantic Fisheries Commission (NEAFC) (2015), Northwest Atlantic Fisheries Organization (NAFO) (2017), and General Fisheries Commission for the Mediterranean (GFCM) (2018).

However, there is no strict FNA policy for vast regions of the high seas, including the Indian Ocean (IOTC), the Western Central Pacific (WCPFC) the Atlantic Ocean and adjacent seas (ICCAT) and the Eastern Pacific Ocean (IATTC). These authorities continue to allow the 5% rule, or other fins-to-carcass ratios, as sufficient proof that finning does not occur. Therefore, for most regions globally, finning bans are still the only form of control on shark catches that have been implemented.

For the industry, fins-to-carcass ratios are easier to implement than an FNA policy or catch reductions, and thus many fisheries still strongly oppose the adoption of an FNA policy. RFMOs have perceived the monitoring, assessment, and enforcement capacity required to manage shark fisheries as being prohibitively costly (Worm *et al*. 2013).

5.2 Shark sanctuaries and fishing bans

The cultural idea that the maximum sustainable yield should be taken for every possible species is by no means universal, even in maritime nations. French Polynesia, for example, wanted its sharks neither fished nor disturbed, and when companies from Asia began intensive shark removal throughout the vast archipelago of that island nation, the government responded by turning its entire EEZ, which is the size of Europe, into a shark sanctuary (Porcher 2010; Ward-Paige 2017). Other nations too, have become shark sanctuaries in response to the nature of the shark fin trade (Ward-Paige 2017; Animal Welfare Institute 2019).

However, polities that have taken the bold step of banning shark fishing in their territories are still limited to a few island nations that have understood that the lifetime value of sharks is substantially better for their economies than the one-time revenues from shark fishing and the shark fin trade (Table 1).

Year	Nation	Comments
1980	Israel	No shark fishing (sharks are not kosher)
2001	Congo-Brazzaville	No shark fishing
2004	Ecuador	Only enforced around Galapagos; sharks caught elsewhere can be landed in Ecuador
2006	French Polynesia	No shark fishing
2006	Egypt	No shark fishing up to 12 NM from shore but only in the Red Sea
2008	Kuwait	Some species are exempt
2009	Palau	EEZ is a shark sanctuary with no shark fishing
2010	Maldives	No fishing for rays and skates in EEZ since 2014.
2011	Tokelau	
2011	Marshall Islands	No commercial shark fishing; no retention of shark bycatch; ban on shark trade
2011	Bahamas	No commercial shark fishing; ban on trade of all shark products
2011	Honduras	No shark fishing
2012	Cook Islands	
2013	Brunei	In EEZ; ban on trade of shark products
2013	New Caledonia (French)	In EEZ
2014	United Arab Emirates	Temporary shark fishing ban in place; no export of any shark products
2015	Federated States of Micronesia	Sharks protected in EEZ
2015	Cayman Islands (UK)	In EEZ
2015	Kiribati	In EEZ; ban on trade of shark products
2015	Bonaire	Sharks protected in marine sanctuary around islands
2015	Sabah	Sharks protected in marine sanctuary around islands
2015	British Virgin Islands	No commercial shark fishing
2015	Madagascar	
2015	Turks and Caicos	Ban on export of sharks
2016	St Maarten	In EEZ
2017	Dominican Republic	
2018	American Samoa	No shark fishing within 3 NM of coast

Table 1: Nations that have banned shark fishing.

Unfortunately, enforcement is often poor due to a lack of sufficient surveillance and monitoring at sea and in the ports. Further, in many cases, the laws are not strong enough to provide complete protection for sharks. Some states, such as Egypt, have only banned shark fishing in part of their territory, while others, such as the Maldives, have not imposed strong enough measures to prohibit the retention of sharks caught as bycatch in other fisheries. While, in addition to the ban on shark fishing, the Bahamas enforces a trade ban on shark products, other nations have not done so.

For these reasons, illegal shark catches and shark finning continue in some shark havens, while the prosecution and conviction of offences can also be difficult. National bans cannot be considered to be a guarantee of safety for sharks since they can be lifted again.

To date, no major shark fishing nation has taken effective steps to protect its sharks from being fished, with the exception of a few half-hearted attempts to define Marine Protected Areas (MPAs), which provide some protection. However, such MPAs are usually too small, and often do not provide the required degree of protection. Fishing for pelagic sharks is often still allowed, as, for example, in most of the MPAs in the Azores.

5.3 The Fisheries Certification Standard for sustainable seafood

The Marine Stewardship Council (MSC), which awards its label to presumed sustainable fisheries, admits that finning still occurs in certified fisheries in spite of having been banned in certified fisheries since 2012. Its Fisheries Certification Standard accepts the fins-to-carcass ratio with some degree of external validation as sufficient proof that finning is unlikely to have occurred. Conformity Assessment Bodies (CABs), which perform the assessment and certification of fisheries, are advised by MSC to consider only systematic finning or successful convictions as evidence for non-compliance with MSC's proclaimed zero-tolerance policy on finning (Arauz 2018; Ziegler 2019; Ziegler *et al.* 2021). Neither has ever deemed a fishery non-eligible for certification. The MSC has therefore been criticized widely for many years, by environmental organizations and civil society, for its failure to implement the globally acknowledged, most effective measure against finning, and to require that an FNA policy is in place as a prerequisite for certification.

The level of monitoring and surveillance that is accepted by certification agents is also insufficient. An observer level of only 5% is often considered a sufficient degree of external validation to prove that finning is not taking place in a fishery. Environmental organizations, retailers, and even other fisheries, have therefore requested that both an FNA policy and a risk-based level of monitoring and surveillance of compliance must be introduced as essential, as part of the Fishery Standard Review that the MSC is currently conducting (Ziegler 2019; Ziegler *et al.* 2021).

The risk that shark finning has taken place is different in different fisheries. That risk, whether for target or bycatch species, may be categorized as low, medium or high. Objectively-verifiable risk criteria, such as the target species, gear used, and geographic area, are used to determine the level of risk. The risk in a swordfish long-line fishery in the Indian Ocean, for example, is much higher than for a pole-and-line fishery in the same area, or in a salmon fishery in Alaska using nets. The long-line fishery would therefore require a higher degree of external surveillance to provide the same assurance of compliance. Risk-based monitoring requires that there be a greater level of surveillance and better external validation of compliance for those fisheries that have a higher risk of shark finning, while for lower-risk fisheries the burden of demonstrating compliance is reduced. (Ziegler *et al.* 2021).

6 The shark meat problem

The use of finning bans and FNA policies have diverted attention from the unsustainability of shark catches. The resulting trend has been towards less detaching of the fins but without a concomitant lessening of mortality (Clarke *et al.* 2013), while a surplus of low-value shark meat has been forced onto markets around the world (Clarke *et al.* 2007; Dent & Clarke 2015). Although only the fins are valuable, the whole shark has to be used. Thus, to a large extent, the shark fin market drives the market for shark meat.

In Costa Rica and other South and Central American countries, for example, sharks were considered undesirable and not used for food prior to the 1980s. Then the inflated price of shark fins resulted in sharks of many species, from a wide variety of habitats, being targeted for their fins alone. The subsequent FNA policies obligated fishermen to land fins attached to the bodies, and the shark fin industry put the surplus meat on the market for domestic consumption. Merchants pushed the meat onto local consumers, relying on the use of various other names to sell it. Now Costa Ricans alone are consuming about 2000 tons of shark meat a year, and the situation is similar in many other countries (Porcher *et al.* 2019).

However, sharks are long-lived top and middle predators and their meat has high levels of accumulated toxins. For example, the Florida Fish and Wildlife Conservation Commission's (FWC) (2020) fishing rules specify a *minimum* size of 54 inches for about half of the shark species caught. At the same time, the Florida Advisory on Fish Consumption (2019) advises that no species of coastal shark longer than 43 inches should ever be eaten by anyone due to its high mercury content. Thus fishermen are specifically advised to catch large sharks, which are the breeding females—mature female sharks of the species targeted are significantly larger than the males—yet at the same time they are considered too toxic to eat.

In parallel, the spiny dogfish fishery in the Northwest Atlantic is being expanded in spite of the finding that 32% of spiny dogfish exceed the United States Environmental Protection Agency (US EPA) recommended threshold level of 0.3 ppm of mercury (US EPA, 2000), and concerns that the meat could have an adverse effect on consumers (Taylor *et al.* 2014). The Maine Seafood Guide (2020) warns that dogfish meat "may contain amounts of mercury in excess of the recommendation of the USA Food and Drug Administration's (FDA) recommended limit". It advises that "pregnant and nursing women, women who may get pregnant, and children under 8 years of age" should not eat any shark, and others should eat no more than two such meals a month.

Shark fins, especially the commonly traded species, are also found to contain high levels of toxins, including mercury and arsenic (Barcia *et al.* 2020).

Shark fisheries are therefore targeting an animal that is both a potential risk to human health and globally threatened.

7 Sustainability in shark fisheries

The global markets for shark meat and fins have been separate in the past, and relied on different species (Dent & Clarke 2015). Those considered sustainable are those few in the USA, New Zealand, Australia, and Canada that have fished sharks and skates for meat (Simpfendorfer & Dulvy 2017). However, since these fisheries are now being propped up economically by the value of the sharks' fins (Shiffman & Hueter 2017, Wiersma & Carroll 2018) their long-term viability is questionable (Porcher *et al*. 2019).

7.1 The spiny dogfish

In the USA, the fishery for spiny dogfish is one of those advertised to be sustainable (Simpfendorfer & Dulvy 2017). It supplies more than 90% of the global trade in the species, the meat being sent to Europe while the fins go to Asia (Wiersma & Carroll 2018). When decades of overfishing in the Northeast Atlantic caused a 95% decline, and finally the closure, of the European spiny dogfish fishery, the USA expanded its take in the Northwest Atlantic in the 1990s to fill the demand (Wiersma & Carroll 2018). More than 95% of the sharks landed were mature females, the largest (and usually pregnant) dogfish (Rago *et al.* 1998). The biomass of the female spawning stock declined by 75% as a result (Wiersma & Carroll 2018), and the fishery collapsed. However, the US Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) declared the fishery rebuilt in 2010 (meaning that dogfish numbers had increased) and since then has been working to expand it, considering it to be underutilized (Witkin *et al.* 2015; NOAA 2016; St. Gelais & Costa-Pierce 2016). Spiny dogfish consume some of the same fishes that were depleted by fisheries on the eastern seaboard of the USA, and compete with cod for others. So when cod stocks were severely depleted, dogfish had less competition, and their numbers increased. The expansion of the dogfish fishery was therefore driven in part by the hope of eradicating this competition for fishermen, with the claim that getting rid of spiny dogfish would help restore balance to the ecosystem (St. Gelais & Costa-Pierce 2016).

As a result, dogfish meat has been marketed in the Atlantic states as a replacement for teleost fish whose stocks have been badly depleted, including cod (Goldfarb 2016; New York Post 2016; Kowacki 2018), even though it is known to be a potential danger to human health (Taylor *et al.* 2014; St. Gelais & Costa-Pierce 2016).

But using sharks as a replacement for depleted fish stocks is not a viable solution, for not only are sharks high on the food chain and of incalculable ecological importance, but shark productivity is comparatively very low. The increase in these meso-predators was known to have resulted from the elimination of the large sharks (Heithaus *et al.* 2008), so the only way to restore the ecosystem is to permit the overfished stocks of sharks and cod to recover (World Bank 2017). Dogfish are fished mostly by bottom gillnets and trawlers (NOAA 2020), which is highly destructive to the sea floor and could in no way benefit the marine habitat.

The dogfish fishery is not only destructive, but extremely wasteful. In 2018 commercial dogfish landings were estimated at 16.7 million pounds, while discards from commercial and recreational sources combined have remained at around 11 million pounds each year over the last decade. In 2014 recreational discards alone totalled 8 million pounds of shark (Atlantic States Marine Fisheries Commission 2018).

Dulvy *et al.* (2008) found that the threat to sharks is greater than that predicted by fisheries' assessments and that local analyses may underestimate the risk of the collapse of global stocks. Although spiny dogfish numbers increased due to the removal of their predators and competitors, such increases can be quickly reversed if intensive fishing continues because of the high sensitivity of elasmobranchs to any changes in survival rate (Myers & Worm 2003; Ferretti *et al.* 2010). Collapse is particularly likely when vulnerable stocks from just one region are expected to supply 90% of the world's demand (Wiersma & Carroll 2018).

The boom and bust pattern of spiny dogfish exploitation is typical of targeted elasmobranch fisheries. Rapidly increasing yields are followed by sudden and extreme declines in catch, which signify not only the fragility of the fishery but also poor management (Cashion *et al.* 2019). USA Federal efforts to manage spiny dogfish have been ineffective, hampered by high bycatch and the defiance of scientific advice by the Atlantic states. The stock is currently assessed as 'Endangered' by IUCN (with a declining population trend) on the basis of past and continuing declines, persistent market demand, targeted fishing, increasing discards, and growing pressure to reopen fisheries (Fordham *et al.* 2016). Nevertheless, US Atlantic spiny dogfish meat, fished by trawlers, bottom gillnets, and bottom longlines in the North West Atlantic, has been certified as sustainable since 2012 (MSC 2020). But the history of the fishery suggests that it is not, and will not remain productive for long.

7.2 Sustainability in the shark fin trade

Most species taken in the shark fin trade have never been known to support sustainably-managed fisheries (Fields *et al.* 2017). However, Simpfendorfer & Dulvy (2017) claimed that fisheries serving the shark fin market could, with management, be made sustainable for two species: the shortfin mako and blue sharks in the North and South Atlantic, and the blue shark in the North Pacific.

While the Northwest Atlantic Fisheries Organization (NAFO) and ICCAT are responsible for the management of fisheries in the Northwest Atlantic, ICCAT is responsible for the longline fisheries that catch most of the pelagic shark species (Campana 2016). ICCAT represents 48 contracting nations and groups, including the EU, that between them fish more than 127 million hooks each year in the North Atlantic. Their priority is tuna, swordfish, and billfish; sharks are of lesser concern. Member nations provide data of highly variable quality for their fisheries and there are also several major fishing nations fishing the North Atlantic that provide no shark catch data to anyone, and are not party to ICCAT.

ICCAT has applied different standards for sharks than for tuna, swordfish, and billfish, which Campana (2016) concluded meant that sharks were considered as a nuisance, not a concern. Until recently, there was no effort to measure or compensate for discards, discard mortality, or hooking mortality. Although it is now required that discards be reported, most contracting parties report very limited data on shark discards, if any.

7.3 The shortfin mako

In a parallel with many other species, and as a result of industrial overfishing, the mean weight of the shortfin mako taken by longliners fell from 74 kg in the 1950s to just 38 kg in the 1990s (Ward & Myers 2005). This indicates how seriously the species has been affected by human predation. Like other cold water sharks, shortfin makos are slow growing and have a low reproductive rate, so they are especially vulnerable to overfishing. They are killed for sport as well as for their meat and fins, are fished by many nations worldwide, and have suffered high mortality throughout their range (Ferretti *et al.* 2010; Rigby *et al.* 2019). Shortfin mako have a greater landed value than blue sharks, and are retained after capture for use as meat (ICCAT 2020).

The shortfin mako was assessed on the IUCN Red List in 2000 as being 'Near Threatened'. It was reclassified as 'Vulnerable' in 2009, and in 2019 as 'Endangered' worldwide, with a decreasing population trend. In 2017, NOAA Fisheries stated that it was being overfished in the North Atlantic (NOAA 2017). An ICCAT stock assessment that same year showed a 90% probability that the stock was overfished and that overfishing was occurring (ICCAT 2017), advising as a result that there must be a ban on all retention of shortfin mako sharks in the North Atlantic. This was reconfirmed in an update in 2019 (ICCAT 2019), which stated that the status of the species was so dire that even if all fishing was stopped immediately, their numbers would continue to decline for the next fifteen years, with a probability of only about 50% that the stock would be rebuilt by 2045. The probability that it would be rebuilt would not exceed 70% until 2070, some 50 years from now (ICCAT 2019). The ICCAT considers that shortfin mako stocks are on a similar trajectory in the South Atlantic, and therefore requested a Total Allowable Catch limit (TAC) for the species (ICCAT 2019).

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But the implementation of a retention ban was blocked by both the USA and the European Union (EU) (ICCAT 2019), which chose to put short-term fishing interests before the need to protect the species. The USA boasts the biggest recreational shark fishery in the world (Walker 1998), and they insisted that the recreational fishery continue to be allowed to land adult animals as trophies, even when the animal is alive when brought to the boat. (The commercial fishery would only be allowed to retain animals already dead (ICCAT 2020)). For this reason, the USA rejected the retention ban on the endangered shortfin mako in the North Atlantic. But the shortfin mako shark is one of the few shark species that has a high chance of survival, exceeding 77%, when it is released alive, if best-release handling practices are in place and applied (ICCAT 2019). The EU is responsible, globally, for more recorded shark catches than any other polity because of the large catches of Spain, Portugal and France, while the USA is the fifth most prolific shark hunting nation (TRAFFIC 2019). Regardless, the USA claims to be the best nation in the world in terms of shark conservation (Shiffman & Hueter 2017).

The depletion of shortfin mako sharks in the North Atlantic is the result of intensive fishing since the early 1990s. While the reporting of shark catches has probably improved (FAO 2020) during the last 30 years, recorded catches have been slowly decreasing since 2013. Historically, landings from the North were always higher than those from the South, but this has changed recently and for the last two years landings from the South have exceeded those from the North (Figure 1).

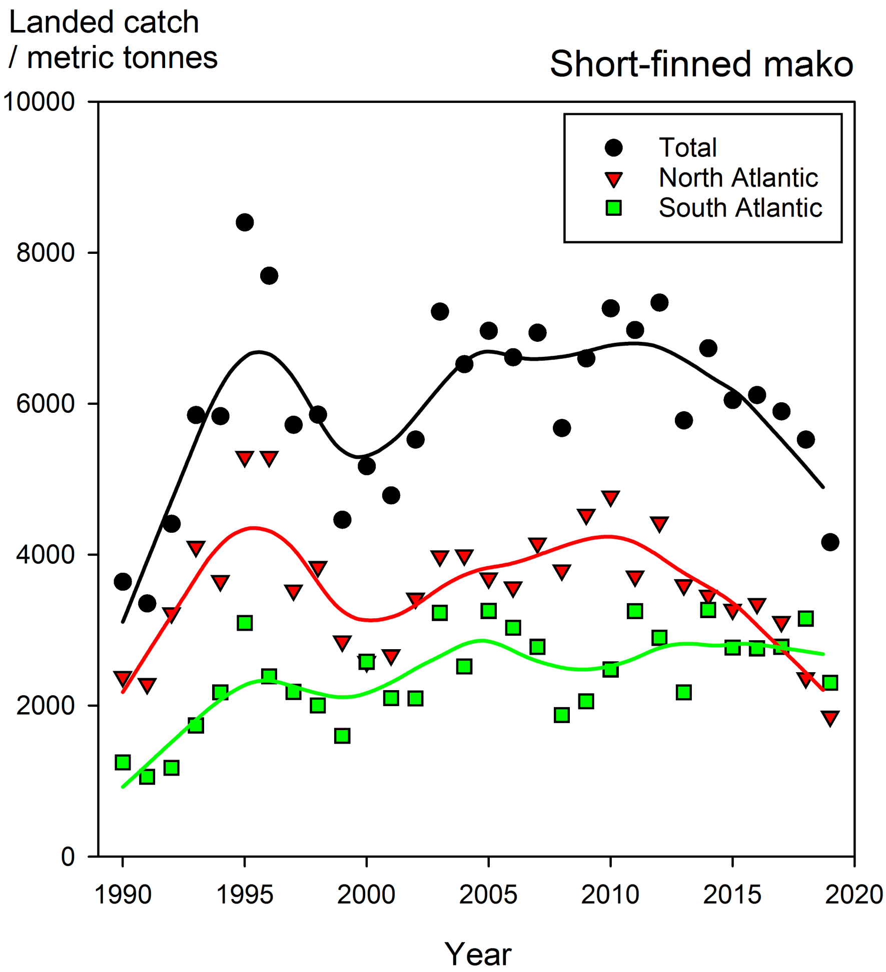

Figure 1: Landings of shortfin mako sharks as reported to the ICCAT, showing the North and South Atlantic catches.

Although the EU supported the CITES Appendix II listing of the shortfin mako in 2019, it still refuses to follow clear scientific advice to bring about effective conservation measures. There are plenty of examples (Tolotti 2015) in the history of RFMOs showing the effectiveness of retention bans, which remove the economic incentive perceived from the bycatch of endangered species when the animals have to be released, dead or alive, and cannot be retained and sold. The EU delegation's proposed TAC limits (ICCAT 2020) during the 2020 negotiations lacked scientific justification and denied the effectiveness of a retention ban as a conservation measure for endangered mako sharks. But the EU fishing industry, especially that of Spain and Portugal, has an economic interest in continuing to land shortfin mako sharks as a valuable bycatch, and they can still be landed if the animals are dead when hauled on board.

Since the retention-ban motion for shortfin mako was not adopted in 2019 (ICCAT 2019) nor 2020 (ICCAT 2020d), overfishing continues in 2021 (ICCAT 2020d). No changes to the existing agreement have been made and the next Commission Meeting at which a ban could be adopted will not take place before the end of 2021. Catches of more than 1800 t, as are expected based on 2019 data for the North Atlantic (ICCAT SCRS 2020), reduces the probability that the stock will rebuild by 2070 to less than 10%. Canada, which, with Senegal, proposed the retention ban in both 2019 and 2020, has prohibited the retention of mako, dead or alive, on its fleets since the beginning of the 2020-21 fishing season (Fisheries and Oceans Canada 2020). In 2021, Spain and Portugal announced national bans on the landing of shortfin mako sharks from the North Atlantic after the Scientific Review Group (SRG) of the EU for CITES denied a "Non-detrimental finding" for mako sharks from the North Atlantic (SRG 2020). However, it remains uncertain whether those national bans will stop overfishing since they apply only to landings in Spanish and Portuguese harbours. In the case of Portugal, they exclude catches taken in domestic waters such as the Azores, which is a mega-fauna hotspot. Without a retention ban at the RFMO level they could be revised unilaterally at any time. Further, Morocco, the second biggest catch nation for mako in the North Atlantic, has not announced any prohibition, so achieving a binding retention ban at the ICCAT remains a priority to prevent the collapse of the Atlantic stocks. However, this would not be in the interest of the EU's shark fishing industry, which continues to try to maximize its short term profits, instead of working towards rebuilding stocks and long term sustainability.

In the Indian Ocean, the state of shortfin mako stocks may be on a similar track. In a 2020 stock assessment, the 16th Session of the IOTC Working Party on Ecosystems and Bycatch (IOTC 2020) defined the stock status as 'unknown' because the data that was used for the stock assessment, which came from different fisheries, was too inconsistent. Despite the situation in the Atlantic and the overall poor reporting of shark bycatch, the advice in the Working Party's report to the Commission did not include specific conservation measures except for the general recommendation of improved data reporting on shark bycatch. The reported nominal catch data for shortfin mako sharks was only 1087 t in 2019, but this appears to represent gross under-reporting since 37,773 t of unspecified shark catches were also recorded. This has to be considered in conjunction with the generally poor compliance with reporting requirements for shark data in the IOTC. Only 36% of member states provided the data required for reporting shark bycatch, indicating very low compliance with the requirement in 2020 (IOTC 2020).

7.4 The blue shark

The blue shark is the source of more fins for the shark fin trade than any other species (Clarke *et al*. 2006b). It is one of the most heavily targeted shark species in all oceans. Fields *et al*. (2017) estimated that between 34 and 64% of shark fins traded in Hong Kong are from the blue shark, although the chairman of the Hong Kong Marine Products Association, Ricky Leung Lak-kee, has stated that blue shark fins make up 60 to 80% of those consumed in Hong Kong (Kao 2017).

The species dominates the bycatch of longline fisheries (Oliver *et al*. 2015) and is considered to be at high risk due to its distribution, which overlaps heavily fished regions (Queiroz *et al.* 2019). Further, as oxygen minimum zones (OMZs) expand due to global warming, blue sharks may be shifting their distribution patterns into surface waters to avoid deeper, oxygen depleted waters (Vedor *et al.* 2021). Therefore they are at even higher risk of being caught by surface longliners, who operate mostly above those OMZ depths (Vedor *et al.* 2021).

Clarke *et al.* (2007) found that blue sharks were already being taken at rates possibly exceeding the maximum sustainable yield (MSY) between October 1999 and March 2001. Since then, catch rates in the North Pacific have been estimated to be declining at 5% per year (Clarke *et al.* 2013), which also suggested that the slaughter was unsustainable. Further, most blue sharks caught in the Atlantic are juveniles (ICCAT 2019), a strong sign of over-exploitation. Killed before reproducing, their numbers will not be sustained. Similarly, in Peru, of 11,166 blue and mako sharks caught in a longline fishery, 83.7% were sexually immature and under the legal minimum landing size (Doherty *et al.* 2014).

In the USA and Canadian swordfish and tuna fisheries in the North Atlantic, blue shark discards approach 100% because blue shark meat has no commercial value in North America. Yet blue shark catches often exceed catches of the target species. Canada's North West Atlantic pelagic longline swordfish fishery, for example, reports catches of 20,000 swordfish and 100,000 blue sharks annually (Make Stewardship Count 2018), indicating extreme wastage. In the North Atlantic some 3 million blue sharks (~100,000 t) have been estimated to be discarded each year (Campana 2016).

In the Atlantic Ocean, blue shark catches have steadily increased since the 1990s, from roughly 3,000 t in 1990 to more than 73,000 t in 2011 (Figure 2), an almost 25-fold increase over 30 years. Although the species is relatively productive, there is no evidence that such a take could be sustainable. Indeed, landings have begun to decline in the North.

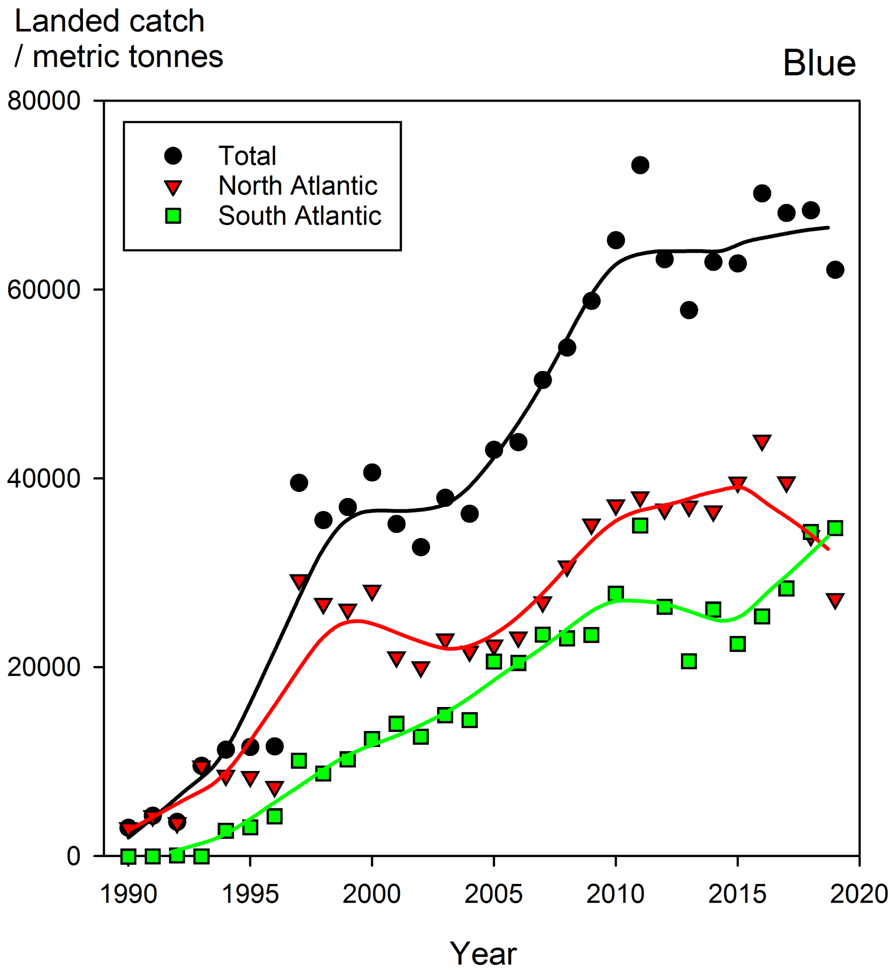

Figure 2: Landings of blue shark as reported to the ICCAT, showing the North and South Atlantic fisheries.

In its 2019 stock assessment, the ICCAT found that there was such a high uncertainty in the data and model structural assumptions that the possibility of the stock being overfished, and overfishing occurring, could not be ruled out. It therefore established TACs for blue sharks in both the North and South Atlantic for the first time, but it has not yet defined a Harvest Control Rule (HCR) though HCRs are in place for most teleost stocks. In the North Atlantic, the TAC was set at 39,102 t (ICCAT 2019), which is somewhat higher than the 2018 catch, so there is no requirement that the catch be reduced.

In 1997 blue shark landings in the North more than tripled within a single year, from less than 10,000 t in 1996 to almost 30,000 t. This marked the targetting of blue sharks by Spain, and the beginning of the massive exploitation of blue sharks in the Atlantic. Since they are targeted for their fins, since 2013, in the EU they have to be landed with fins naturally attached to the carcass. Despite the increased effort and storage capacity required as a result of this measure, landings have continued increasing to an all-time high of about 45,000 t in 2016. Since then, they have declined by about 5,000 t per year.

In the South Atlantic the EU's share has fluctuated between 25% and 70% over the years with a 50% average, making the EU the driver for the increasing tonnage since 1997. In 2019, catches exceeded those in the North for the first time, suggesting that EU fleets compensated for the decreased catch in the North by an almost equal increase in the catch in the South (Fig 2).

Overall, is it the EU fleets that are most heavily engaged in the targeting of blue sharks in the Atlantic, with Spain and Portugal responsible for 80% - 90% of all catches there since 1997. At the same time, the FAO 2015 report lists Spain as the third most important shark fin producer in the world, and states that the country exported 3,409 t of shark fins to Southeast Asia each year between 2000 and 2011 (Dent & Clarke 2015). However, the numbers of fins in Asian markets coming from the North Atlantic greatly exceeds the reported catch (Clarke 2008), indicating that there is substantial unreported finning which is not being taken into account by the ICCAT. The lucrative shark fin market provides strong motivation for such activity. Sharks whose fins have been cut off and then dumped, often still living, back into the sea, are not recorded because most western countries have banned the practice of shark finning. It is estimated that the actual numbers of blue sharks being killed are four times those reported (Campana 2016).

In the absence of any measure to prevent overfishing, and to ensure the rebuilding of overfished stocks, continued depletion appears inevitable. In 2020 the EU approved a proposal from the 2019 ICCAT meeting for an active management of shark stocks (EU Parliament 2020). Since the EU fleets are the main players in this business, it remains to be seen what this will involve for blue sharks.

In 2017, the blue shark was listed on Appendix II of the CMS listings (CMS 2020).

With 90% of teleost stocks overfished (World Bank 2017), blue sharks are caught in increasing numbers around the world for their previously low-valued meat. In Chile, for example, retention of blue sharks increased almost sixty-fold between 1999 and 2009 (Davidson *et al.* 2016). In the ICCAT area alone, reported landings of blue shark have increased by a factor of about six from 11,300 t in 1994 to 70,200 t in 2016 and 68,200 t in 2018.

A further problem with the prediction of sustainability for the blue shark in the Atlantic Ocean (Simpfendorfer & Dulvy 2017) is that it is based on MSY. Sustainability is defined as the "*current biomass being greater than that required to achieve MSY or current fishing mortality being less than that which will yield MSY*" (Simpfendorfer & Dulvy 2017). But MSY is estimated from actual landings, so it is hardly applicable to a largely discarded species (Campana 2016). Further, this method is no longer considered to be applicable to fisheries that are overfished and require stock rebuilding: spawning biomass first has to be restored, then the mortality from fishing must always be lower than mortality to maintain MSY (Hilborn & Walters 1992; Tsikliras & Froese 2019).

Just two years after Simpfendorfer & Dulvy (2017) claimed that the shortfin mako and blue shark fisheries in the North and South Atlantic Ocean were "bright spots of sustainable shark fishing," the unfolding trends indicated that they were wrong.

8 High seas fishing economics

The fishing industry is currently propped up by an estimated US$35.4 billion in subsidies (Sumaila *et al.* 2019). China provides the highest subsidy among nations, at 21% of the total, followed by the USA at 10%, and the Republic of Korea at 9%. These subsidies far exceed the profits from their fishing (Sala *et al*. 2018). The only fishing fleets that are currently profitable are the longliners and purse-seiners which target the highest-valued marine animals: tuna and sharks (Sala *et al*. 2018). Fully 54% are unprofitable, especially the largest fishing fleets. The current scale is enabled only by those large government subsidies (Sala *et al*. 2018; Sumaila *et al.* 2019). The diesel for the long distance fishing fleets of the EU is paid for by subsidies, for example, which allow them to go fishing in the distant Indian Ocean and the Western and Central Pacific. There, with their larger vessels and superior technology, they compete with the local fisheries for the remaining stocks of fish (Sala *et al.* 2018, Sumaila *et al.* 2019). Deep-sea trawling, which is one of the most destructive fishing practices, is especially supported by subsidies, yet 32% of deep-sea trawling is unprofitable (Sumaila *et al.* 2010, 2019; Norse *et al.* 2011; Sala *et al.* 2018).

Evidently, high seas fishing activity would be completely transformed if subsidies were halted. For example, Spain, a top provider of blue shark fins to Asia, has its most profitable fisheries in the Western Indian Ocean, the Southeast Pacific, and the Southwest Pacific, far from its own EEZ. But many of its distant purse-seine fisheries would not be profitable without subsidies, and its high seas bottom trawling would be unprofitable everywhere without subsidies (Sala *et al.* 2018).

8.1 The sunken billions

A global study by the World Bank and FAO, *Sunken Billions* (2008) and *Sunken Billions Revisited* (2017), reported that overfishing has resulted in a loss of about US$83 billion yearly. It found that fishing effort must be reduced to get the best economic result for solving the evolving global fisheries crisis. The fundamental reforms that are required must follow two parallel and simultaneous paths: (a) stock recovery, which would require giving depleted and over-exploited stocks a chance to recover, primarily by reducing fishing effort, and (b) restoring the integrity of the habitats on which the stocks depend (including mangroves, coral reefs, and seagrass beds).

This is the course of action which should be taken. However, the shark fin trade has made these top and middle predators valuable, so global fisheries are targeting them instead, despite their high ecological importance and the toxicity of their fins and meat. They are increasingly threatened.

Clearly, shutting down a large proportion of the world's industrial fishing fleet will be disruptive and social unrest is predicted because millions of fishers will have to switch to other occupations. It has been recommended that the fishing subsidies that have encouraged overfishing in the past be used to help ease the social transition (Arnason *et al.* 2008; World Bank 2017; IPBES 2019).

9 Analysis

It has been known for decades that sharks are vulnerable to overfishing (*e.g.* Travis 1961; Walker 1998; Castro *et al.* 1999), that they are under high fishing pressure (Myers & Worm 2003; Worm *et al.* 2013), are of high ecological value (Stevens *et al.* 2000; Ferretti *et al*. 2010), and that those accessible to commercial fishing fleets are threatened with global extinction (Dulvy *et al*. 2014; Pacoureau *et al.* 2021). One scientist after another has advised over many years that species-specific records are a necessary prelude to the possibility of sustainable management of sharks, and that collecting data, especially in data-poor regions, should be a priority (Stevens *et al.* 2000; Ward-Paige *et al*. 2012; Oliver *et al*. 2015; Pauly & Zeller 2015). Since industrial fishing fleets operate over vast regions, and usually in international waters (Kroodsma *et al.* 2018), the availability of accurate data, and international cooperation in its collection, is necessary on a global scale, for both the monitoring and management of elasmobranch catch and bycatch at the species-specific level (Oliver *et al.* 2015; Davidson *et al.* 2016).

Nevertheless, it was found in 2015 that of the top ten shark fishing nations, only the USA had kept reasonable records, and only half had kept any records at all (Oliver *et al.* 2015). Lam & Sadovy de Mitcheson affirmed in 2011 that at that time Chinese shark catch data were classified as state secrets and such data continue to be unavailable publicly. Thus, although China fishes more intensively than any other nation (Sala *et al.* 2018), its large shark catches have not been included in any fisheries' assessments.

9.1 Fisheries management

With the Atlantic Ocean being situated between the continents of Europe and America, in the heart of what is considered the civilized western world, one would expect it to display the most exceptional management of fish and shark stocks. However, the above examination of the situation there clearly illustrates the failure of RFMO shark management.

The shortfin mako shark went from 'Near Threatened' to 'Endangered' in less than 20 years because effective conservation actions were not taken, despite better knowledge. RFMOs made no attempt to maintain the population of this shark at a healthy level because of the strong lobbying power of fisheries' interests in the delegations. The refusals of the USA and the EU since 2017, to follow the ICCAT's science-based recommendations for an immediate retention ban on shortfin mako in the North Atlantic (ICCAT 2019; ICCAT 2020a) provides an illustration of the way industry interests take precedence over the conservation of valuable, high-priced animals. The same tendency can be seen throughout the history of shark fishing (Ward & Myers 2005; Campana 2016; Fordham *et al.* 2016). The priority of the parties to the RFMOs is to maximize the profits of their own fisheries, and managing sharks can reduce those profits (Campana 2016). Even where possible, with few exceptions, RFMOs have not intervened as sharks have been increasingly overfished (Dulvy *et al.* 2014).

In the USA fishermen are applying powerful political pressure to be allowed to continue to fish sharks and profit from the shark fin trade, in spite of the global danger to sharks, even attempting to scare Americans with the threat of more shark attacks if they cannot kill the animals (Gehan 2019). When Texas passed a law that required that all dead sharks shipped through the state must have their fins naturally attached, meaning that fishermen could no longer sell the fins, the Western Gulf of Mexico shark fishery was effectively shut down in 2019 (Gehan 2019), a telling illustration of how the shark fin market drives shark fisheries.

9.2 The inherent problems establishing global sustainability

The detailed recording and international cooperation that would be necessary to make commercial shark fishing sustainable in the face of the shark fin trade appears prohibitively difficult. Fisheries management schemes are expensive to set up and operate. Expenses range from those for scientific advice and management, to enforcement, including monitoring, control, and surveillance, and they can reach 14% of the value of landings (World Bank 2017). Most of the cost is borne by the public sector, while the benefits are concentrated on the fishers (World Bank 2017; Ferretti *et al.* 2020). Neither the necessary funds, nor an international organization that could create such a cooperative network, exist. It would require that every country keeps politics, financial self-interest, corruption, and criminality out of the process.

The extent of surveillance and monitoring that would be required, as well as its cost, is also prohibitive, but essential to any claim to the sustainable management of all shark fisheries, and not just the official target species. Even 100% human observer coverage on all vessels would be insufficient to ensure that finning or illegal retention does not take place (Human Rights at Sea 2020; McVeigh & Firdaus 2020; Greenpeace 2020). But due to the illegal character of the shark fin trade and the huge profits associated with it, observers have been murdered (Human Rights at Sea 2020). Severe human rights abuses also happen on a regular basis, especially on the long distance fleets of WCPFC, including on MSC certified fisheries vessels, as revealed by Greenpeace (2020) and Human Rights at Sea (2020). It is apparent from the shark fin industry that illegal, unreported, and unregulated activities tend to accompany the abuse of, and crimes against, humans (IPBES 2019). Two of us have been threatened (BWD in Hong Kong, with violence at a public meeting, and IFP by a fisherman with death if he caught her alone at sea, during her ethological study of shark behaviour in French Polynesia.

In Asian consumer nations there is little government interest in regulating the shark fin market and the resources required to do so are simply not in place (Sadovy de Mitcheson *et al*. 2018). Shark fin consumers can afford to pay high prices for them and are quite unconcerned about sustainability.

The involvement of fisheries worldwide and the participation of criminal networks in a trade driven by high prices and rich customers, contrasted with the catastrophic, ongoing depletion of the animals supplying the fins (Fields *et al*. 2017), makes the shark fin trade unsustainable.

Even the pressure from artisanal and subsistence fishing in remote regions, or shark netting programs to 'protect' beaches, can cause serious depletion of large coastal sharks (Ferretti *et al*. 2010). Since the stocks of most elasmobranchs have collapsed, and in view of their low productivity, truly sustainable shark fishing would therefore now require the enforcement of near-zero shark mortality globally to allow both top predators and their small elasmobranch prey to recover (Ward-Paige *et al*. 2012; Davidson *et al*. 2016). Clearly this would not support even a tiny fraction of the shark fin trade.

The current tendency to turn to fishing sharks because the shark fin trade has made them profitable, instead of concentrating on the recovery of the gravely depleted teleost fish stocks and their habitats (with the goal of long-term yields from healthy fish stocks in the future), is a dangerous course which should not be pursued. Sharks will go the way of the teleost fish, and much more quickly, if the current trend continues. No lessons have been learned from the demise of Grand Banks cod (Mason 2002) and North Sea herring (Dickey-Collas 2010) it seems.

Given the market interplay of supply and demand, wherein the desire for money fuels the targeted hunt for sharks and rich customers supply it, the way to stop the slaughter is to stop the shark fin trade itself. Stopping demand and disrupting international supply chains are key aspects of this.

9.3 Instinct versus science

It has been 'scientifically' argued that fishermen should treat fish as they wish because they are predators and part of the food chain (Diggles *et al.* 2011). In contrast, our civilization prides itself on the idea that humanity uses reason in its decision-making, rather than following its instincts. But Diggles has reminded us of the true situation: the world's fishermen are in the same position as any other predator that is in the process of eliminating its prey. With the human population as over-grown as it is, it has been known for decades that the moment would come in which no wild prey could sustain us.

We have the capacity to recognize the difference between instinctual drive and reasoned thought, yet reason (*i.e.* science) is often rejected in negotiations. Territorial interests supervene and limit international cooperation (Lorenz 1963), which carries over into the management of globally important species. Such barriers must be overcome, otherwise the current pattern of species depletion, extinction, and the unravelling of the planet's ecosystems will continue and accelerate, eventually to the severe detriment of humanity (Barry 2014; IPBES 2019; Dasgupta 2021).

9.4 The ethical aspect

There has been an ethical failure in fisheries, illustrated by the industry's willingness to pillage without regard for the health of the biosphere and the resulting ecological harm (Travis *et al*. 2014), the level of bycatch that has been treated as tolerable (Harrington *et al.* 2005; Ferretti *et al.* 2010; Oliver *et al.* 2015), and the willingness to put short-term financial interests first (Fordham *et al.* 2016; St. Gelais & Costa-Pierce 2016; Shiffman & Hueter 2017: ICCAT 2019, 2020b). Deep-sea trawlers 'mine' ecosystems in the knowledge that they will not recover (Sumaila *et al.* 2010; Norse *et al.* 2011). Although the danger to marine life posed by abandoned ('ghost') fishing nets has long been recognized, for more than three decades the fishing industry has trailed nets to significant depths below dFADs, killing large numbers of sea turtles and sharks, and this mortality from entanglement has been ignored by fisheries scientists and RFMOs alike (Filmalter *et al*. 2013; Stelfox *et al.* 2021). Drifting FADs are regularly abandoned by the fleet that launched them. They are able to drift for as long as two years, can cover distances of more than 10,000 km (Hanich *et al*. 2019), and badly damage the shore, especially delicate environments such as coral reefs and mangroves, when they beach (Balderson & Martin 2015). Depending on their construction materials, dFADs may also contribute to plastic pollution in the oceans (ICCAT 2020).

Yet fish from such fisheries, as well as those practicing shark finning, and other highly wasteful and damaging pursuits, have been certified as "sustainable" by MSC, which claims to use a high standard in recommending only sustainable seafood to a trusting public. However, in practice, it is applying much lower industry standards for certification (MSC 2020b; Kearns 2015; Edwards 2018).

That one soup recipe, in just one of the world's many cultures, could have had such a serious effect on the status of as many species as are represented by the class of Chondrichthyes is a telling indictment of the priorities of humanity. Participation in such a market is an ethical question. The way the industrialized western nations have joined the hunt for sharks to profit from such a market highlights the need to address this facet of the problem.

10 Conclusions

All sharks, manta rays, devil rays, rhino rays, and chimaeras, as well as their parts, require immediate protection from international trade. The illegal character and the high economic incentives associated with the shark fin trade heighten its danger for the increasingly depleted large predators supplying it and the takes of shark liver oil from threatened species, with at-sea processing, is of the same character (Sea Shepherd 2017a, b). The ineffectiveness of the measures taken to date, including CITES Appendix II listings, indicates that the protection afforded to accessible species must be significantly improved (Pacoureau *et al*. 2021). Therefore, a CITES Appendix I listing should immediately be granted to provide the needed protection. The shark fin trade takes all fins, therefore all should be listed. There is already a precedent in listing look-alike species as a counter to deception (Vincent *et al*. 2013).

The claim that there is insufficient data to justify listings on Appendix I does not hold up when it is impossible to assess the status of sharks accurately, a condition that should prompt the use of the precautionary principle. The evidence of over-depletion revealed by a study of the literature provides an alarming warning regarding what is occurring and lays out more than sufficient reason to do so, in multiple contexts. Sharks must be treated internationally as protected wildlife, rather than animals of commercial fisheries interest. Critically, international cooperation is needed. A binding international treaty to protect sharks, as well as threatened biodiversity in general, should be the immediate goal (Dasgupta 2021).

Protection of sharks from international trade would benefit local communities who depend on the sea for their protein. In artisanal fisheries, the elasmobranch catch is generally fully-utilized (Oliver *et al.* 2015). With no shark exports the market would remain local, and prices would not be jacked-up to export levels. Those in industrial nations may choose something else, including plant protein, if fish and shark meat is not on the menu.

Further, a CITES I listing for sharks would greatly simplify management and policing by eliminating the need to identify illegally-caught species, or parts thereof, at border crossings, as well as the continuous demands for more species-specific information in the various regions as required by "Non-detrimental" findings. Such species data is expensive, difficult, and too often impossible to get, while its absence delays action under current rules, and the trade continues.

At the same time, deep sea fishing should be permanently banned and fishing effort must be diminished by a large proportion to permit the damaged ecosystems of oceans, coral reefs and lagoons, mangroves, estuaries, rivers, lakes, and coastlines to recover. All fishing subsidies must end. The money should be used instead to help fishermen switch to other occupations, including, for example, ecotourism or the planting of food crops, and to police the shores and reefs they once fished. Severe sanctions, including heavy fines and vessel seizures, should be levied on violators, and those revenues re-invested in policing and education.

Educating fishers to protect their damaged sea coast is an option that has been found to be highly successful (Alcala 1998). The installation and protection of MPAs helps to increase the abundance of fish in adjacent areas, which will ultimately help to secure income for them. A radical change is needed to ensure that fishers can sell their catch at a fair price to make a living while neither overfishing nor damaging the environment.

Shark bycatch taken by longliners and trawlers should be reduced using available methods (Kaplan et al. 2007; Erickson & Berkeley 2008; Oliver *et al.* 2015; Pacoureau *et al*. 2021). 'Best handling' practices need to be used to ensure that the highest possible number of sharks survive mandatory release. A global shift towards selective fishing methods, and away from today's highly efficient, but also very unselective and destructive methods, should be an objective if we want the remaining biodiversity in our oceans to survive beyond this century (Reid *et al*. 2016; Zhou *et al.* 2019).

However, fishing methods must ultimately be transformed in such a way that bycatch of non-target species is completely avoided. The inevitable reduction in fishing efficiency and the increased costs thereby incurred will mean that consumers will have to pay higher prices to eat fish. But fish provide a high quality protein, and a higher price would reflect more truly the value of such wild prey.

At their own expense, fisheries should be required to keep track of stocks through stock assessments by species and geographic region, update them regularly, and mandate catch limits. Landings should be monitored, and species-specific records kept.

In addition, at least 30% of the ocean should be set aside to recover as MPAs (O'Leary *et al*. 2016). For pelagic species of sharks, large MPAs and no-take zones that include the High Seas are required for effective protection because most are highly migratory. Queiroz *et al*. (2019) concluded that there is a particularly urgent need for conservation and management measures at high-seas hotspots of shark space. Therefore, designation of such MPAs should take the high degree of spatial overlap between sharks and industrial fishing vessels into consideration, especially in those areas that attract fish because of their favourable productivity and temperature profiles (Baum 2019). Coastal MPAs must be managed effectively as no-take zones and large enough to encompass the ranges of the resident sharks, ensuring that they are protected at all times (Dwyer *et al.* 2020).

More scientific observers should be deployed by RFMOs (Campana 2016, Baum 2019). However, given the increasing numbers of human rights violations, disappearances, and murder of observers (Human Rights at Sea 2020), they should not be used for enforcement of regulations nor compliance monitoring. To effect this there are now remote electronic monitoring tools available which are tamper-proof and can cover all activities on board. Monitoring of landings and trans-shipment activities needs to be mandatory, as well as positioning data via the Automatic Identification System (AIS) for all fishing vessels. The equipment should be installed in such a way that it cannot be switched off (Sumaila *et al.* 2020). Implementation of a comprehensive monitoring and surveillance system combining both human observers and remote electronic monitoring should be a priority task for all RFMOs (Ewell *et al*. 2020).

RFMOs should be required to respect human rights, and to address slavery, as well as unsafe and inhumane working conditions. The pervasive problem of IUU fishing should be addressed through all means available.

Change can also come through cultural shifts. Such a change with respect to shark fin soup is already ongoing in China (Sadovy de Mitcheson *et al*. 2018). It needs to be strengthened there and in other shark fin consumer countries. Although demand is decreasing in China and Hong Kong, it is growing in Thailand, Japan, and Malaysia (Dent & Clarke 2015). Removing shark fin from menus and retail markets in consumer countries is of top priority (Sadovy de Mitcheson *et al.* 2018) and shark fin trade bans should be adopted as widely as possible. A trade ban is easier to enforce than fishing regulations on the high seas while taking away the enormous profit, and thereby the incentive, to catch sharks. In the USA, the *Shark Fin Trade Elimination Act* has passed through Congress, and at this writing is awaiting passage in the Senate. Fourteen states have banned shark fins, and Florida has also passed an import ban on fins in 2020. There is a trade ban in Canada, requiring all shark fins to remain naturally-attached to the body of the animal for import and export. Political pressure is being applied to effect a trade ban in Europe (pers. comm. Alex Hofford).

Honest labelling of seafood products should be required for transparency and traceability. There would be a significant decrease in the 'demand' for shark meat if it were actually labelled as shark meat.

There must be a shift in attitude towards the management of the biosphere in the interests of sustainability, not of sharks alone, although they may be taken as key indicators, but to permit our civilization to continue on in good health. The domination by industry must end if the planet's aquatic ecosystems are to be saved from ecological collapse (IPBES 2019; Dasgupta 2021).

If history has taught us anything, no wild animal can withstand targeted industrial-scale hunting long term—not whales, not sea turtles, not fish, and certainly not sharks.

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