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Shark Conservation – Analysis and Synthesis

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Abstract

A detailed analysis of fishing records has shown that the shark species accessible to global fisheries have been systematically depleted for decades. They were already fished to about 10 percent of their former levels by 2003. Now one species after another is being listed on the IUCN Red List of Threatened Species as their numbers drop towards extinction. Shark depletion has not been well documented and a large proportion of shark mortality has been bycatch, the target species being teleost fish. But with the rise in value of shark fins due to the shark fin trade, at the same time as teleost fish stocks have become severely overfished, sharks, along with tuna, have become the most valuable catches. Fishing on the high seas is scarcely profitable, and so is heavily supported by subsidies. But the shark fin trade, in which organized crime is heavily involved, is driven by enormous profits and provides a powerful demand for the fins of all sharks. Thus it is now being supplied by fisheries around the world. There is no interest in sustainability in consumer countries, and neither the will nor the resources to manage the trade exist. Although some shark fisheries might have been managed sustainably in some regions for certain species for meat, such fisheries are increasingly dependent on the shark fin trade.. The rising global demand for shark fins, coupled with the increasing depletion of the animals supplying that demand, makes commercial fishing for sharks unsustainable. Given their high ecological value across the aquatic ecosystems they inhabit, it is important that they receive more effective measures of protection going far beyond the currently existing ones. In particular, protection of all sharks, manta rays, devil rays and rhino rays through an Appendix I CITES listing should be effected immediately due to the scale of the global take of the shark fin trade and the state of shark depletion amply documented in the literature.

Keywords

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

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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 here a detailed and comprehensive data-driven analysis of the various aspects of the matter.

The growing 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). However, sharks have low productivity, and thus a low capacity to withstand fishing mortality (Myers & Worm 2003). As a result, 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 decades and explicitly named commercial fishing over the last 50 years as the main reason for the loss of marine biodiversity.

As a result of the shark fin trade, and because some 90% of teleost fish stocks are over-exploited (World Bank 2017), sharks have become 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) and they provide most of the fins on the market (Clarke *et al.* 2006a, b; Fields *et al.* 2017). However, sharks in a wide variety of ecosystems are being 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 (the uncertainty is due to whether the tonnage is made up of larger or smaller sharks). Given that 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 dead discards, 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 Because sharks range far from land and migrate across oceans, outside countries' Exclusive Economic Zones (EEZs), their status is difficult for Regional Fisheries Management Organizations (RFMOs) to assess. IUCN (2019) lists 198 data deficient shark species out of 494 assessed species. Jurisdictional issues, along with the difficulties of obtaining relevant data, have long obscured understanding of their diversity and true numbers (Stevens *et al*. 2000). RFMOs have placed higher priority on species with greater economic importance so that 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 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 (Campana 2016).

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. Simpfendorfer & Dulvy (2017) found that only a few smaller and highly productive shark species are managed sustainably, while 91.3% of shark catches are biologically unsustainable. Feretti *et al* (2020) found that only 16 shark fisheries globally, were well managed. Further, even in well managed shark fisheries, ecosystem impacts are almost impossible to detect, 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).

The evidence shows that high fishing mortality has caused increasing shark depletion since industrial fishing began, and that now, with the added pressure of the shark fin trade, a large fraction of the species accessible to commercial fishing are approaching extinction. Without intervention, given the nature of the trade, the situation will continue to decline. Therefore, 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).

Background

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). This pressure has only escalated (Kroogsma *et al.* 2018).

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). Though RFMOs have considered it acceptable to fish regional stocks to a low level, this was the first time that it was found that the planetary ocean as a whole had been fished to such a drastic extent: severe depletion of entire communities had occurred throughout its ecosystems.

Today, 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 fish aggregating devices (FADs) 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).

Major shifts in biomass and size composition have occurred, and large predatory fish, such as tuna and sharks, are most affected (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). 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 now ongoing for the spiny dogfish (*Squalus acanthias*) (Fordham *et al.* 2016).

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).

As a result of such intensive industrial fishing, rapid and extreme declines in shark catches occurred (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). 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. However, 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).

Since the 1980s, the tuna industry has increasingly made use of dFADs (Balderson & Martin 2015) In the Indian Ocean, over 80% per cent of the purse seine catch is now made on sets around dFADs (Hanich *et al.* 2019). These take advantage of the tendency of tuna to shelter beneath floating objects to maximize their catch. A variety of other marine animals, including the juveniles of oceanic whitetip and silky sharks, also use that shelter.

Drifting FADs 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 are left to drift, usually for several months between visits by the fishing fleet, which uses purse seines to net the entire shoal of fish that has accumulated beneath them. The sharks are then either retained as bycatch or discarded depending on regional conservation measures. Overall survival rates are low (Poisson *et al.* 2014, Eddy *et al.* 2016). Hutchison et al. (2015) found that overall mortality in discarded juvenile silky sharks exceeded 84% (Hutchison *et al*. 2015). Half of all tuna are now caught using dFADs (Balderson & Martin 2015) and in the Indian Ocean alone, between 480,000 and 960,000 juvenile silky sharks are killed per year through entanglement in the trailing nets (Filmalter *et al*. 2013). This mortality is comparable in scale to the entire reported world fishing catch of 400,000 to 2,000,000 animals; the silky shark is second only to the blue shark in the fin trade (Fields *et al.* 2017). Though some RFMOs are beginning to demand that dFADs must be non-entangling, the criteria for a non-entangling dFAD are weak. Many dFADs constructed to be non-entangling become entangling with the passage of time (Wang *et al*. 2020).

As well as the shark fin market, the increasing demand for 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 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*), 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 this product, countries do not declare their exchanges to FAO, and it is therefore not possible to analyse the global shark liver oil market (Chabrol 2012).

Global studies of shark depletion have emphasized the problems inherent in assessing the true situation, 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).

For example, in 2015 the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean analysed shortfin mako 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).

Clarke *et al*. (2006a, b) found that the shark biomass required to support the shark fin trade annually exceeds the total catch reported to the Food and Agriculture Organization of the United Nations (FAO) (which is the only organization keeping track of catches globally) by three or four times. The inconsistent recording of shark catches and the secrecy involved in the trade in shark products makes it difficult if not outright impossible to produce proper assessments of mortality. Most shark hunting nations do not keep species-specific catch statistics (Clarke *et al*., 2006a, b; Musick & Musick 2011; Dent & Clarke 2015; Fields *et al*. 2017).

Shark Protection Measures

The regulations passed to protect and manage sharks in the past decades have been ineffective in stopping the decline (Ward-Paige *et al*. 2012; Davidson *et al*. 2016), and 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 granted listings on Appendix II. Listings are opposed by shark hunting nations because of the high commercial value of the fins (Worm *et al.* 2013). Protection must 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 difficult 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, under the influence of the shark fin trade the loophole undermines the protection that was intended by the original CITES listing (CREMA 2018).

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 this species 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).

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% is usually adopted (calculated as fins being 5% of the weight of the sharks on board the fishing vessel), which supposedly indicates that no sharks have been finned and discarded at sea. However, these ratios are almost impossible to verify, especially when fins have been dried or are frozen. In addition, the legislation has not helped to improve data availability with respect to the true numbers and the species of sharks caught. Therefore, several jurisdictions, such as the European Union (EU), USA and Canada, as well as some RFMOs, 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, which is the only guaranteed method to avoid shark finning (Cortés *et al.* 2006). Only then can the true numbers, species, and size of the sharks caught be reported accurately for the analysis of fishing-induced mortality. An FNA policy 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). 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).

However, there is no strict FNA policy for vast regions of the high seas, including the Indian Ocean (Indian Ocean Tuna Commission, (IOTC)), the Western Central Pacific (The Western and Central Pacific Fisheries Commission) (WCPFC)) the Atlantic Ocean and adjacent seas (The International Commission for the Conservation of Atlantic Tunas (ICCAT)) and the Eastern Pacific Ocean (Inter-American Tropical Tuna Commission (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.

The Marine Stewardship Council (MSC), which awards its label to presumably sustainable fisheries, admits that finning still occurs in these certified fisheries. Its Fisheries Certification Standard still accepts the fins-to-carcass ratio with some degree of external validation as sufficient proof. It has therefore been criticized widely by environmental organizations and civil society for its lack of implementation of a FNA policy as this is the globally acknowledged best practice to demonstrate compliance and facilitates the enforcement of finning bans (Ziegler 2019).

For the industry, fins-to-carcass ratios are easy to implement compared with 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) but an FNA policy is globally considered to be much easier to monitor and control (Fischer *et al.* 2012).

Nevertheless, finning bans and an FNA policy are difficult to enforce and their use appears to divert 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). A surplus of low-value shark meat has been forced onto markets around the world (Clarke *et al*. 2007; Dent & Clarke 2015). Though only the fins are valuable, the rest of the shark has to be used. 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).

Another problem with the dumping of shark meat into local fish markets is that it is potentially poisonous. 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. The large species, such as hammerhead, lemon and tiger sharks that are targeted in Florida are apparently being killed simply for the value of their fins.

In parallel, the spiny dogfish fishery 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 a potential risk to human health and globally threatened.

Markets

Shark meat and oil are now being used in everything from make-up to dogfood, particularly from blue, shortfin mako (*Isurus oxyrinchus*) and scalloped hammerhead (*Sphyrna lewini*) sharks (Cardeñosa 2019). This indicates how widespread but hidden is the use of shark products once the animal has been killed for the fin trade.

Studies of the species supplying the markets in Hong Kong between 1999 and 2001 indicated that, at that time, elasmobranchs accessible to fisheries were facing four times the mortality that had been reported to the Food and Agriculture Organization of the United Nations (FAO) (Clarke *et al.* 2006a, b). This is the same trend that has been found in fisheries generally (Pauly & Zeller 2016). Clarke *et al.* found that about 1.7 million tonnes of sharks a year were being sacrificed for the vanity soup and 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). 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).

The high diversity of 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 other, more productive species in an unperceived, yet effective, target replacement (Davidson *et al*. 2016). These factors impede the assessment of shark abundance and contribute to the uncertainties inherent in fisheries data (Ferretti *et al*. 2010). Increased pressure on such populations has often resulted in their total collapse (Stevens *et al.* 2000; 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 population was 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 "fish and chips" and other fish products 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*. (2109) also found that cheap fast food outlets seemed to be the best place to disguise shark meat and sell it under a false name.

Ecology

In pristine, unfished regions sharks are abundant and diverse (Ferretti *et al.* 2010). As top and middle predators, they were deeply woven into the aquatic temperate and tropical ecosystems of the planet through radial evolution into new ecological niches following several planet-wide extinctions (Kriwet & Benton 2004; Kriwet *et al.* 2009; Guinot & Calvin 2016).

The beginning of 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).

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).

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 behaviour was independently seen in reef sharks in French Polynesia and tiger sharks in the Bahamas, suggesting that it is widespread.

Ecological communities respond strongly to the depletion of top predators and the resulting changes are widespread and long-lived (Heithaus *et al.* 2008; Ferretti *et al.* 2010). The extreme disruption wrought by more than seven decades of shark removal through trawling and longlining has caused major, cascading biodiversity shifts throughout the originally complex and diverse aquatic ecosystems that evolved over the past 500 million years, and these changes have been ignored by RFMOs (Travis *et al*. 2014).

Shark Fishery Sustainability

The global markets for shark meat and fins have been separate in the past, and relied on different species (Dent & Clarke 2015). Only about 9% of elasmobranch fisheries are managed and considered sustainable (Simpfendorfer & Dulvy 2017) and they 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).

In the USA, for example, the fishery for spiny dogfish is one of those considered 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 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 competed with cod for others. Thus, when the stocks of cod were depleted, dogfish had less competition, which supported an increase in their numbers. 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). However, this increase 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 their numbers to recover, not to eliminate the meso-predators and increase the damage and imbalance. Dogfish are fished in part by trawlers (NOAA 2020), which is highly destructive to the sea floor. Raising the level of this activity cannot be beneficial in any way.

In spite of the fact that dogfish meat is considered a danger to human health (Taylor *et al.* 2014; St. Gelais & Costa-Pierce 2016), it 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). In 2018, commercial dogfish landings were estimated at 16.7 million pounds, while annual discards from commercial and recreational sources combined have remained at around 11 million pounds over the past decade. In 2014 recreational discards alone totalled 8 million pounds of shark (Atlantic States Marine Fisheries Commission 2018). Not only is the fishery itself destructive, but there is wastage on a similar scale.

Dulvy *et al.* (2008) found that the scale of 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. Though 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 (Myers & Worm 2003; Ferretti *et al.* 2010). The boom and bust pattern of the exploitation of this stock is typical of such 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 this stock have been relatively 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 mostly with gillnets and bottom longlines in the North West Atlantic, has been certified as sustainable since 2012 by MSC (MSC 2020).

Fin Trade Sustainability

Most species taken in the shark fin trade have never been known to support sustainably-managed fisheries (Fields *et al*. 2017). 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.

In a parallel with many other species, and as a result of industrial fishing, the mean weight of the shortfin mako taken fell from 74 kg in the 1950s to just 38 kg in the 1990s (Ward & Myers 2005), indicating how seriously the species has been affected by human predation. Like other cold water sharks, shortfin makos are slow growing and so 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). The shortfin mako was assessed on the IUCN Red List in 2000 as being 'Lower risk/Near Threatened', and in 2009 it was reclassified as 'Vulnerable' (IUCN Red List). In 2017, the NOAA Fisheries website stated that it was being overfished in the North Atlantic (NOAA 2017), and in the 2019 IUCN Red List assessment it was re-classified as 'Endangered' worldwide, with a decreasing population trend. ICCAT's scientists therefore advised that there must be a ban on retention of the shortfin mako in the North Atlantic (ICCAT 2019), stating 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 (ICCAT 2019). The situation is considered to show a similar trend in the South Atlantic (ICCAT 2019).

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 this species. The EU fleets made 60% of the mako shark landings in the Atlantic in 2018 (ICCAT 2019) and the EU is responsible globally for more recorded shark catches than any other nation because of the large catches of Spain, Portugal and France, while the USA is the fifth most important shark hunting nation (TRAFFIC 2019). Yet the USA is claimed to be the best nation in the world in terms of shark conservation (Shiffman & Hueter 2017).

The retention-ban motion for shortfin mako was not adopted and the continuing catch will not allow the stock to rebuild, even by 2070. Overfishing of this species continues (ICCAT 2019). Only Canada, which championed the retention ban together with Senegal in 2019, has so far prohibited the retention of mako, dead or alive, on its fleets since the beginning of the 2020/2021 fishing season (Fisheries and Oceans Canada 2020).

Shortfin mako have a greater landed value than blue sharks, and approximately two-thirds of them are retained after capture for use as meat. However, blue shark meat has no commercial value in North America. In both the USA and Canadian swordfish and tuna fisheries blue shark discards approach 100%, and 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 the extreme wastage. In the North Atlantic 3 million blue sharks (~100,000 t) have been estimated to be discarded each year (Campana 2016).

The blue shark is the source of more fins for the shark fin trade than any other species (Clarke *et al*. 2006b). Fields *et al*. (2017) estimated that 34 to 64% of shark fins traded in Hong Kong are from the blue shark, but the chairman of the Hong Kong Marine Products Association, Ricky Leung Lak-kee, stated that blue shark fins make up 60 to 80% of those consumed in Hong Kong (Kao 2017). The species also dominates the bycatch of longline fisheries (Oliver *et al*. 2015). Clarke *et al.* (2007) found that blue sharks were already being taken at levels 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 suggests that the slaughter is unsustainable.

While the Northwest Atlantic Fisheries Organization (NAFO) and ICCAT are responsible for 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 tunas, 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. As a result, ICCAT data for shortfin mako and blue sharks is so uncertain and incomplete as to suggest that these populations are anywhere from lightly-fished to overfished (Campana 2016).

Further, there is no effort to measure or compensate for discards, discard mortality, or hooking mortality. Until recently ICCAT applied different standards for sharks than for tunas, swordfish, and billfish, which Campana (2016) concluded meant that sharks were considered as a nuisance, not as a concern.

In 2018, 33,853 t of blue shark was reported as being taken in the North Atlantic, with Spain responsible for about 64% of this at 21,685 t (ICCAT 2019). 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 ICCAT. The lucrative shark fin market provides strong motivation. Sharks whose fins have been cut off, then were 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 the number reported (Campana 2016).

In 2017, the blue shark was listed on Appendix II of the CMS listings (CMS 2020). In 2019 ICCAT found that there was such a high uncertainty in data inputs and model structural assumptions that the possibility of the stock being overfished, and overfishing occurring, could not be ruled out. It therefore established limits on blue shark takes in both the North and South Atlantic for the first time. In the North Atlantic the limit was set at 39,102 t (ICCAT 2019) – somewhat higher than the 2018 catch, meaning that there is no requirement to reduce the catch. However, in 2020 EU approved a proposal from the 2019 ICCAT meeting for an active management of shark stocks in the future (EU Parliament 2020).

Most 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). With 90% of teleost stocks overfished (World Bank 2017), blue sharks are increasingly caught globally for their previously low-valued meat. In the ICCAT area alone, reported landings of blue shark have increased by a factor of about six from 11,300 metric tonnes (t) in 1994 to 70,200 t in 2016, and 68,200 t in 2018 (ICCAT 2019). Landings by European fleets in the Atlantic have rocketed, within a period of only twelve years, from a combined catch of less than 5000 mt in 2004 to about 53,000 t in 2016, thereby accounting for almost 75% of all landings in the South and North Atlantic in 2016 (ICCAT 2019). In Chile retention of blue sharks increased almost sixty-fold between 1999 and 2009 (Davidson *et al.* 2016).

Simpfendorfer & Dulvy (2017) based their prediction of sustainability for the blue shark on MSY. They defined sustainability as the "*current biomass being greater than that required to achieve MSY or current fishing mortality being less than that which will yield MSY*". But MSY is estimated from actual landings, so 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 the mortality to maintain MSY (Hilborn & Walters 1992; Tsikliras & Froese 2019).

Just three years after Simpfendorfer & Dulvy (2017) predicted sustainable shortfin mako and blue shark fisheries for the shark fin trade, the unfolding trends indicate that they were wrong.

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). For example, the diesel for the long distance fishing fleets of the EU is paid for by subsidies, which allow them to go fishing in the distant Indian Ocean and in 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, and even then, 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, in the case of Spain, a top provider of blue shark fins to Asia, its most profitable fisheries are longliners in the Western Indian Ocean, the Southeast Pacific, and the Southwest Pacific, far from its own EEZs. But many of its distant purse-seine fisheries would not be profitable without subsidies, and its high seas bottom trawling is unprofitable everywhere without subsidies (Sala *et al.* 2018).

A global study by the World Bank, *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 therefore the course of action which should be taken. However, because the shark fin trade has made the top and middle predators valuable, 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 (World Bank 2017; IPBES 2019).

Discussion

We have 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). 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). Industrial fishing fleets operate over vast regions and usually in international waters (Kroodsma *et al*. 2018). International cooperation in the collection and availability of accurate data is therefore necessary on a global scale, to monitor and manage elasmobranch catch and bycatch at the species-specific level (Oliver *et al.* 2015; Davidson *et al.* 2016). Yet 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. So 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.

Twenty years ago an international plan of action was drafted to address illegal, unreported, and unregulated fishing (Doulman 2000). It was considered vital to gain control of illegal, unreported, and unregulated fishing to establish sustainability in shark fisheries. However, illegal fishing continues unabated and shark fishing pressure has continued to increase (Ferretti *et al.* 2010), even though – or because – official landings have been declining since 2003 due to overfishing (Davidson *et al.* 2016).

The shortfin mako shark went from 'Lower Risk' to 'Endangered' in less than 20 years with no conservation action, indicating that RFMOs did not maintain shark populations at healthy levels. The subsequent refusal of the USA and the EU to follow ICCAT's science-based recommendations (ICCAT 2019) illustrates how industry interests take precedence over the conservation of valuable, high-priced animals, even in such a state of crisis as is apparent for the shortfin mako stocks of the Atlantic. This tendency is seen throughout the history of shark fishing (Ward & Myers 2005; Campana 2016; Fordham *et al.* 2016). RFMO priority is to maximize the profits of their 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).

The cultural idea that catches should be maximized 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, in the USA, which boasts the biggest recreational shark fishery in the world (Walker 1998), 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.

The detailed recording and international cooperation that would be necessary to make commercial shark fishing sustainable in the face of the shark fin trade would seem to be 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). However, 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 keep politics, financial self-interest, corruption, and criminality out of the process.

Further, the extent of surveillance and monitoring that would be required, as well as its cost, is prohibitive. Even 100% human observer coverage on all vessels would be insufficient to ensure that finning or illegal retainment does not take place (Human Rights at Sea 2020; McVeigh & Firdaus 2020; Greenpeace 2020). Due to the illegal character of the shark fin trade and the huge profits associated with it, observers have been murdered.

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). As a further example, two of us have been threatened. In Hong Kong, BWD was threatened with violence at a public meeting. In French Polynesia, IFP was threatened during her ethological study of reef sharks. When the local fishermen began finning sharks, they circulated many negative stories about them, including the idea that the animals would be coming out on the beaches to eat babies if they did not kill them. Due to their attitude, IFP had to be extremely secretive on each visit to her study area. Following a television appearance in which she spoke of the need to protect the remaining sharks due to the extreme losses that had occurred, there was an outbreak of extreme hostility against her, including a death threat. There were also attacks on tourists who were concerned about the shark finning openly taking place. The shark fin trade had a very bad effect on the population; the Polynesian culture is traditionally non-violent.

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 depletion of the animals supplying the fins (Fields *et al*. 2017), makes the shark fin trade unsustainable.

Even light fishing pressure by 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 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 are less productive than teleosts but as top and middle predators they are of high ecological importance. They 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.

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 worlds' 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 would be able to 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), and this 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).

There has been an ethical failure in fisheries, illustrated by the industry's willingness to pillage without regard for the health of the biosphere (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). Deep-sea trawlers mine ecosystems in the knowledge that they will not recover (Sumaila *et al.* 2010; Norse *et al.* 2011). Though the danger to marine life posed by abandoned 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). More than 50% of all floating objects are dFADs, many of which were 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 when they beach (Balderson & Martin 2015).

Yet fish from such fisheries 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), as repeated criticism by scientists and NGOs (Make Stewardship Count 2018) also suggests. MSC has even granted sustainable fishing certifications to fisheries in spite of proof that shark finning was occurring. 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). Neither has ever deemed a fishery non-eligible for certification.

This domination by industry must end if the planet's aquatic ecosystems are to be saved from ecological collapse (IPBES 2019).

Conclusions

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. Fishing subsidies must end. The money should be used instead to help fishermen switch to other occupations, including, for example, ecotourism, 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 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 marine protected areas (MPAs) also 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 good price and make a living without overfishing and without damaging the environment. Fishing methods must be transformed in such a way that bycatch 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.

Critically, international cooperation is needed to protect sharks from the shark fin trade. For pelagic species of sharks, large MPAs and no-take zones including the High Seas are required for effective protection, as most are highly migratory. Therefore Queiroz *et al*. (2019), concluded that there is an urgent need for conservation and management measures at high-seas hotspots of shark space. At least 30% of the ocean should be set aside as MPAs to recover (O'Leary *et al*. 2016). 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).

Protection of all sharks, manta rays, devil rays and rhino rays through an Appendix I CITES listing should be effected immediately; the shark fin trade takes all fins, therefore all should be listed. 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. The evidence of over-depletion revealed by a study of the literature provides an alarming warning regarding what is occurring and lays out sufficient reason to do so. The illegal character and the high economic incentives associated with the shark fin trade heighten its danger for the increasingly depleted animals supplying it. The increasing takes of shark liver oil from threatened species, with at-sea processing, is of the same character (Sea Shepherd 2017a, b). The ineffectiveness of Appendix II listings indicates that the level of protection afforded to all accessible sharks must be significantly improved or the current trend towards extinction will continue to its obvious conclusion in the next few decades. There is already a precedent in listing look-alike species (Vincent et al. 2013), and the plight of sharks warrants such a measure.

Such a step would also 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) and with no shark exports, the market would remain local, and prices would not be jacked-up to export levels.

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 sometimes impossible to get, while its absence delays action under current rules, and the trade continues.

Shark bycatch taken by longliners and trawlers should be reduced using available methods (Kaplan et al. 2007; Erickson & Berkeley 2008; Oliver *et al.* 2015) and measures should be taken to reduce shark bycatch and mortality for all fishing gear, by implementing 'best handling' practices for the release of all species in all gear types, so that the highest possible proportion will survive mandatory release. A global shift towards more selective fishing methods, away from today's highly efficient, but also very unselective and destructive fishing methods, should also be an objective if we want the biodiversity in our oceans to survive beyond this century (Reid *et al*. 2016; Zhou *et al.* 2019).

More scientific observers should be deployed by RFMOs (Campana 2016, Baum 2019). However, given the increasing numbers of human rights violations, disappearances, and even murder of observers, 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 Automatic Identification System (AIS) for all fishing vessels. Such 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).

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, and political pressure is being applied to effect a trade ban in Europe.

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, not just a commercial one. 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. 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.

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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