Chapter 40. Sharks and Other Elasmobranchs

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Sharks and rays are among the most endangered group of marine animals and include many species for which there is little information on abundance and distribution. There are no global abundance trends for elasmobranchs as a group, and very few robust regional trend indicators. Population-level stock assessments, which provide the most reliable index of abundance, are available for only about 10 per cent of 1,088 chondrichthyan species (FAO 2012; Worm et al., 2013; Dulvy et al., 2014; Cortés et al. 2012). Almost all of these assessments report a depleted and/or over-exploited population. In light of the scarcity of time series of absolute abundance indicators, the conservation status of elasmobranchs as a group is most commonly based on trends in reported landings, trajectories of standardized catch rates or indices of current status.

1. Global catches and trends

Global landings of sharks, rays and chimaeras (chondrichthyans) as reported to the Food and Agriculture Organization of the United Nations (FAO) have increased steadily since the 1950s, peaking at about 888,000 mt in 2000 before declining (Figure 1). In 2012, landings were 14 per cent lower than in 2000. The increasing trend in global catches reflected a combination of fisheries expansions into previously-unexploited regions, changes in the species composition of catches, and changes in the way countries reported landed catch for sharks and rays (e.g. changes in the taxonomic resolution of the reported landings; Ferretti et al. 2010). Historically, many species of sharks and rays had low commercial value, and were not regularly recorded in fisheries statistics. Since the 1980s, sharks became an alternative resource for some fisheries as many fish stocks collapsed and demand for shark fins in Asian markets strongly increased. The resulting increased fishing pressure on elasmobranchs and reports of severely depleted populations attracted the attention of management agencies, which increasingly reported shark statistics.

Although it has been assumed that the recent decline in reported landings may reflect better management for the species (FAO 2010), a recent analysis of the FAO chondrichthyan landings disaggregated by countries (Davidson et al. 2015) evaluated the importance of direct and indirect indices of fishing exploitation and measures of fisheries management performance, revealing that the decline is more closely related to fishing pressure and population declines (Eriksson and Clarke 2015, Davidson et al. 2015). Yet reported landings continue to be a gross underestimation of actual catches (Dulvy et al. 2014). Catches estimated from the volume of the shark-fin trade suggest global shark catches are on the order of 1.7 million mt in recent years (Clarke et al., 2006). More recently, Worm et al. (2013), using various assumptions about reporting rate, discarding and post-release mortality, derived a similar global estimate of 1.41 million mt in 2010, which is twice the figure reported from FAO statistics. Not included in that value would be any post-release mortality of discarded, unfinned catch. Thus, actual trends in shark catch and landings are unknown. Similar reporting issues confound shark catch statistics reported by other regional fisheries management organizations (RFMOs), such as is the case with blue sharks reported by International Commission for the Conservation of Atlantic Tunas (Campana et al., 2006).

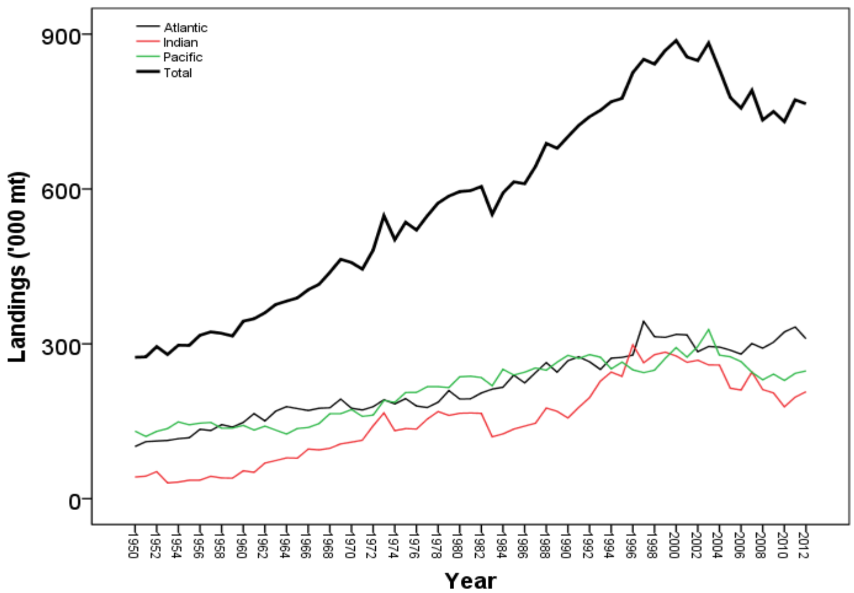

Figure 1. Trends in reported landings of elasmobranchs as reported to FAO. The trend line for the Atlantic includes the Mediterranean.

Regional differences in the status of shark and ray populations might reflect different histories of fishing exploitation (Figure 1). The North-West Pacific, North-East Atlantic and Mediterranean were the areas where industrial fisheries began before the 1950s. These three areas, in decreasing order, recorded the highest initial catches per unit shelf area. The North Atlantic, Mediterranean, around Australia and New Zealand, and the North Pacific are the regions with the longest history of intensive fishing, but are also among the best-monitored sectors of the world's oceans, with stock assessments available for some species. The analysis of International Union for the Conservation of Nature (IUCN) Red List species indicated that these regions (as a group) were somewhat less likely to have a higher proportion of threatened species (<20 per cent) than were the less populated Indian, central Pacific and south and central Atlantic Oceans (>20 per cent) (Dulvy et al., 2014). Unassessed fisheries in the central Pacific and central and southern Atlantic were also likeliest to be characterized by low relative biomass on the basis of time series of catch and fisheries development, and species life histories traits (Costello et al., 2012); this is indicative of overfishing.

1.1 Conservation status

A comprehensive analysis of 1,041 chondrichthyan species on the IUCN Red List (www.redlist.org) reported that 17 per cent of the species were considered threatened with extinction (Critically Endangered, Endangered or Vulnerable, Dulvy et al., 2014). Moreover, just 241 species (23 per cent of the total) were considered to be safe from extinction threats (categorized as Least Concern according to IUCN criteria), which is the lowest fraction of safe species among all vertebrate groups studied by IUCN to date. Assessed shark and ray species with large body sizes were considered to be in the most danger, especially those living in shallow waters that were accessible to fisheries. Almost half of the examined species (47 per cent) were considered data-deficient, meaning that their conservation could not be assessed for lack of adequate data on abundance and distribution. However, in an independent study, Costello et al. (2012) used a multivariate regression analysis of assessed finfish species to estimate the current population biomass relative to maximum sustainable yield (MSY) in 1,793 unassessed marine fisheries around the world. Chondrichthyans had the lowest relative biomass values (40 per cent of the MSY (optimal) level) of any fish species or group; this was considered indicative of considerable over-exploitation (Costello et al., 2012).

2. Drivers of shark decline

2.1 Sharks are intrinsically vulnerable

Most sharks and rays are characterized as having low productivity associated with low fecundity, a slow growth rate, and a late age at sexual maturation (Musick, 1999). These life history characteristics are more similar to those of marine mammals than of the more productive bony fishes (Myers and Worm, 2005), which make them particularly susceptible to fishing pressure (Walker, 1998). Deep-sea sharks appear to be particularly susceptible, due to their very low productivity (Clarke et al., 2003; Forrest and Walters, 2009).

However, the similarity of their environmental preferences to several commercially valuable teleost species can also increase the likelihood of their capture in some fisheries. For example, blue shark catch rates and seasonal distributions tend to co-vary with those of swordfish, making the blue sharks difficult to avoid in a swordfish fishery (Bigelow et al., 1999). Similarly, many skates and rays are captured in bottom trawling for groundfishes such as flounders, and subsequently discarded dead (Enever et al., 2009; Damalas and Vassilopoulou 2011; Graham et al., 2001).

2.2 Fishing

Mortality due to fishing is almost entirely responsible for the world-wide declines in shark and ray abundance. Although directed shark fishing is still practised in some countries, a much larger proportion of overall shark mortality is associated with by-catch in non-shark fisheries (Lewison et al., 2004).

2.2.1 By-catch

Sharks have typically been exploited as a by-catch of commercial fisheries targeting more valuable bony fishes, especially tuna and billfish (ICCAT, 2005) and in trawl fisheries exploiting groundfishes and shrimps (Shepherd and Myers, 2005). In many countries, shark by-catch is partially or primarily retained for the fin and/or food trade. But even where living sharks are released at sea because they are considered unwanted catch, post-release mortality rates can exceed 18 per cent for some species (Campana et al., 2009; Musyl et al., 2011). In the North-West Atlantic, blue shark by-catch from an international pelagic longline fleet outnumbers the target swordfish catch by about 3:1, resulting in an annual post-release blue shark mortality of ~20,000 mt (Campana et al., 2009). Similar calculations of capture and post-release mortality of released sharks, using conservative mortality estimates for all shark species, suggest total shark mortalities of non-landed sharks of about 34,000 mt per year (Worm et al., 2013). Discarded skate and ray by-catch of bottom trawl fisheries are ubiquitous and poorly documented, but appear to be responsible for steep declines in abundance, and even risk of extinction, in some areas (Shepherd and Myers, 2005; McPhie and Campana, 2009).

Elasmobranch species living in the high seas appear to be particularly susceptible to undocumented and/or illegal catches.

2.2.2 Historical shark fisheries

At local scales, targeted shark fisheries have developed in multiple regions of the world. In the Mediterranean Sea, for example, fishing for sharks constituted an important off-season activity for fishing communities relying on harvests of tuna or small pelagic species, such as sardines and anchovies (Ferretti et al., 2008). In the Adriatic Sea, at the beginning of the last century, there were elasmobranch fisheries for angel sharks, skates and dogfishes; some have persisted into recent times (Ferretti et al., 2013; Costantini et al., 2000). In Monterey Bay, United States, between the 1930s and the 1940s, large numbers of basking sharks stimulated the development of a directed fishery used for the production of liver oil and other pharmaceutical products (Castro et al., 1999). Similar fisheries developed in the northeast Atlantic for basking and porbeagle sharks (Fowler et al., 2004; Sims, 2008). Directed fisheries for the meat of porbeagle shark and/or spiny dogfish still persist in both the North-West Atlantic and the North-East Pacific Oceans (Campana et al., 2008; Rago and Sosebee, 2009).

2.2.3 Shark fishing for fins

In recent decades, an increasing demand for shark fins from the Asian market stimulated the conversion of many industrial fisheries from bony fishes to sharks (Amorim et al., 1998; Aires-da-Silva et al., 2008). For countries in central America and in southeastern Asia, shark finning has become an important source of income (Dell'Apa et al., 2014).

The commercial trade in shark fins has been a primary driver of shark mortality. With prices of up to 2,000 United States dollars per kg, and a total estimated market value of about 350 million dollars, the fin trade is a strong motivator for retaining shark by-catch (Worm et al., 2013). The fin trade (which also includes fins of landed sharks) has been linked to a median annual estimate of 38 (CI: 26 – 73) million sharks landed, resulting in fishing mortality rates which are unsustainable for some species (Clarke et al., 2006, 2013).

Some elasmobranch species are also the target of a lucrative international trade of body parts, above and beyond that of shark fins, leading to unsustainable mortality rates for some species. The jaws and teeth of white sharks have been sold for as much as 50,000 US dollars (Fergusson et al. 2009), resulting in the intentional killing of many accidentally caught sharks that might otherwise be released. Sawfishes are critically endangered in most parts of the world, in part because of the high value of their toothed rostra (Harrison and Dulvy, 2014, Dulvy et al. 2014).

2.2.4 Recreational fisheries

Recreational shark fisheries provide an economic value to local communities greatly exceeding the value of commercial fisheries for the same species (Babcock, 2008). Although some recreational shark fisheries have been converted to no-kill, catch-and-release fisheries, recreational shark fishing remains a significant source of fishing mortality in regions such as the southeastern United States. Shark tournaments (a specific type of recreational shark fishing) have been conducted for decades in several countries (Campana et al., 2006; Pradervand et al., 2007), but even shark tournaments have converted to catch-and-release in some regions, with rewards given for sharks that are tagged and released (NOAA, 2013).

2.3 Habitat destruction

Population declines have been linked to habitat destruction in some regions and for some species, but the linkage is often indirect. Habitat destruction is considered an issue for elasmobranch species living in estuarine or mangrove habitats and in demersal communities exploited by trawl fisheries. For example, in the Adriatic Sea, elasmobranch catch rates in an aggregate of five trawl surveys declined by 94 per cent between 1948 and 2005. Exploitation history and spatial gradients in trawl fishing pressure, one of the most destructive forms of fishing in use (Walting and Norse, 1998), explained most of the declining patterns in abundance and diversity (Ferretti et al., 2013).

2.4 Pollution

Persistent bioaccumulation of toxins and heavy metals have been documented in sharks feeding at high trophic levels, at concentrations which can be toxic to human consumers, but their effect on the host shark remains unclear (Storelli and Marcotrigiano, 2001; Mull et al., 2012).

3. Ecosystem effects of shark depletion

3.1 Community changes through predator or competitor release

Sharks are very abundant and diverse in unperturbed ecosystems (Nadon et al., 2012; Ferretti et al., 2010). However, because of their slow population productivity low levels of fishing mortality may rapidly deplete these communities, with consequent pervasive effects on the structure and functioning of marine ecosystems. The overfishing of sharks can trigger community changes because of changing interspecific interactions among shark species and between sharks and other marine animals. The overfishing of large sharks triggered range expansions of more prolific broad-ranging competitors in coastal and offshore areas (Baum and Myers, 2004; Dudley and Simpfendorfer, 2006; Myers et al., 2007), and increases in small elasmobranchs released from shark predation (van der Elst, 1979; Myers et al., 2007; Ferretti et al., 2010). Sharks are often the sole consumers of small meso-predators, such as small sharks and rays, and of other long-lived marine organisms like turtles, tuna, billfish, and marine mammals, especially during their juvenile stages. Hence when large predatory sharks are removed, a rapid increase in the numbers of dogfishes, skates and rays or the recovery of historically depleted megafauna populations has been observed in some areas (Ferretti et al., 2010).

Changes in community structure due to shark depletion can also have indirect effects on community structure. Green turtles and dugongs affected by the presence of tiger sharks influence the distribution and species composition of seagrass beds through foraging and excavation (Heithaus et al., 2008; Preen, 1995; Aragones, 2000). In the North Atlantic, decades of overfishing on large sharks along the United States east coast coincided with a generalized increase in small shark and ray populations, and a substantial increase in one of these species (the cownose ray) adversely affected the abundance of bay scallops (Myers et al., 2007). Similarly, 50 years of shark netting along the KwaZulu Natal shore in South Africa triggered a trophic cascade involving smaller sharks and bony fishes (Ferretti et al., 2010).

3.2 Effect on stability

In addition to inducing trophic cascades, overfishing of sharks can make communities more prone to perturbations through a reduction in omnivory (Bascompte et al., 2005). In the Caribbean ecosystem, the observed change of many coral reefs from coral- to seaweed-dominated reefs was attributed to the depletion of shark populations and a consequent increase in fish consumers, which ultimately depressed herbivore density. Analyses of long-term time series of cost per unit effort (CPUE) in the Mediterranean Sea demonstrated that the removal of large predatory sharks from coastal ecosystems destabilized the community by reducing resistance, resilience and reactivity (Britten et al., 2014).

4. Shark management

Historically, shark species have been a low management priority for RFMOs and national management bodies (Ferretti et al. 2010; Dulvy et al., 2014). However, this trend is changing as shark and ray species are increasingly representing a larger proportion of protected species relative to other fishes. Regional fisheries management organizations such as the Northwest Atlantic Fisheries Organization (NAFO) and ICCAT now require all countries to report all shark catches, while the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) prohibits directed fishing on any shark species, other than for scientific research. The Bahamas, Maldives and Palau have enacted legislation to prohibit shark fishing within areas under national jurisdiction (Dell'Apa et al., 2014; Techera and Klein, 2014), and the great white shark has become a protected species in all four countries where it is abundant (Australia, New Zealand, South Africa and the United States).

Although sustainable shark fisheries are theoretically possible, most industrial fisheries targeting elasmobranch resources have been characterized by a "boom and bust" trajectory of landings, culminating with a strong depletion of exploited populations (Castro et al., 1999; Campana et al. 2008). A few such fisheries that are apparently sustainable are now in place, but they require more conservative benchmarks and perhaps a higher level of enforcement (Walker, 1998; Gedamke et al., 2007).

4.1 Seafood certification

Certification of the sustainability of a fishery (e.g., the Marine Stewardship Council) is intended to provide an indirect economic incentive towards ensuring that the fished population is not threatened, and certification has been granted for a small number of shark fisheries, such as northwest Atlantic spiny dogfish. However, such certification is usually only possible for directed fisheries; in by-catch fisheries (such as is the case for most elasmobranchs), alternate conservation and/or recovery actions would have to be taken.

4.2 By-catch mitigation options

Reduced by-catch of sharks is usually the preferred option, since it results in both reduced shark mortality and reduced loss of fishing gear and bait (and therefore increased profits) by fishermen.

4.3 Spatial or seasonal closures

In principle, by-catch can be reduced by restricting access to “by-catch hotspots” through spatial or seasonal closures, although this approach is complicated by the similar habitat preferences of the target species and the shark by-catch. To this point, there is still little evidence of the effectiveness of large sanctuaries for sharks (mainly because of the absence of empirical data), although analyses of shark abundance and distribution along spatial gradients suggest that these might be effective management options (Ferretti et al., 2013).

Closure of shark mating and pupping grounds to fishing increases the protection of sensitive life-history stages (i.e., Campana et al., 2008). By-catch can also be reduced through modifications to fishing gear; for example, the introduction of the circle hook has reduced shark hooking mortality relative to the traditional J hook (Kaplan et al., 2007). However, other attempts to reduce shark catchability through use of rare earth metals and electrical fields have largely been disappointing (Godin et al., 2013).

4.4 Catch and release

Recreational shark fishing is a relatively small source of fishing mortality, despite its public visibility (Campana et al., 2006). Nevertheless, the introduction of catch-and-release fishing tournaments has reduced the mortality of some species.

4.5 Better monitoring

Ensuring the survival of a shark population is very challenging if the status of the population is unknown. Improved reporting of all catches and discards, the introduction (or expansion) of scientific observer programmes on commercial fishing vessels, and the inclusion of dead discards and estimates of post-release mortality rates in stock assessments, would all lead to improved assessments of population status, and thus simplify recovery efforts.

4.6 Fin trade bans and restrictions on finning

The fin trade has been one of the primary drivers of global shark mortality. Bans on fin sales have been adopted by some cities and in some states of the United States on the presumption that sales would decline in the absence of a legal market. Customer education in some Asian markets is also reducing the demand for wedding soup, and thus fin sales (Eilperin, 2011). Fisheries regulations requiring that the entire shark carcass be landed, and not just the fins, would also reduce shark mortality, as boat capacity is much more limited by the presence of entire sharks than by the much smaller fins. In some countries there is a fin-to-carcass ratio regulation which requires fishers to land no more than a given percentage of fin weight relative to total landings (Davidson et al., 2015).

4.7 Implementation of international policies

In response to the perception that many of the world's elasmobranch species are severely depleted, several international organizations have moved to actively conserve some shark and ray species. The Food and Agriculture Organization of the United Nations (FAO) released an *International Plan of Action for the Conservation and Management of Sharks* urging immediate action to better document and conserve shark and ray species (FAO 1998). The Convention on the Conservation of Migratory Species of Wild Animals[1] (CMS) has listed eight shark species for international conservation and protection (CMS 2014; http://www.cms.int/en/species). Finally, the Shark Specialist Group of the International Union for Conservation of Nature (IUCN) provides information and guidance to governments and non-governmental organizations associated with the conservation of threatened shark species and populations. The SSG released their report on the Global Status of Oceanic Pelagic Sharks and Rays in 2009. As a final step of protection, the international Convention on International Trade in Endangered Species of Wild Fauna and Flora[2] (CITES) attempts to protect endangered species through international trade regulations, such as restrictions on import and export. To this point, CITES has listed 18 shark and ray species under their Appendices I and II trade restrictions (CITES 2014; http://checklist.cites.org), which will remain in place until it can be demonstrated that the population is being managed sustainably. CITES trade restrictions appear to have tangible effects on the trade of listed shark species, and thus reduce the demand (Wells and Barzdo, 1991). However, it is yet to be seen if CITES listings can be implemented in time to protect species, which have already reached the brink of extinction (e.g., sawfish).

5. Ecotourism

Ecotourism in the form of shark diving has become a burgeoning industry generating millions of dollars for local economies worldwide (Musick and Bonfil, 2005; Gallagher and Hammerschlag, 2011). One estimate suggests that shark ecotourism currently generates more than 314 million US dollars per year and supports about 10,000 jobs. Projections suggest that this figure could double in the next 20 years and thus surpass

[1] United Nations *Treaty Series*, vol. 1651, No. 28395.
[2] United Nations *Treaty Series*, vol. 993, No. 14537.

the landed value of global shark fisheries (Cisneros-Montemayor et al., 2013). Indeed, in terms of individual value, sharks in some localities may be worth more alive than if landed and marketed. In the Maldives, it has been estimated that an individual free-swimming grey reef shark is worth 33,500 dollars per year compared to 32 dollars for the same individual sold dead by local fishermen. In the Bahamas, shark diving generates annual revenues of 78 million dollars (Gallagher and Hammerschlag, 2011). In the Maldives (where shark fishing has been banned), ecotourism contributed >30 per cent of the Maldivian GDP (Gallagher and Hammerschlag, 2011).

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