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Chapter 23: Guiding random acts of kindness: conservation planning for sharks and rays

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Abstract

Significant progress has been made in the past three decades of shark, ray and ghost shark conservation. The first decade saw finning spark globa concern for chondricthhyans as wildlife, leading to fisheries management initiatives and international trade regulations. In the second decade, comprehensive Red List assessments were produced for all species, building on a global status report. This strong science foundation enabled a transition to extensive evidence-based conservation planning that resulted in strong initial signs of action, particularly for sawfishes, devil rays, and angel sharks, in the third decade. This chapter shows how the conservation challenge can be narrowed by resolving taxonomy uncertainties and narrowing down historic and current geographic distributions. Significant challenges remain, particularly in minimizing the fishing mortality of Endangered and Critically Endangered species through catch and trade regulations and the implementation of science-based catch limits for Vulnerable and Near Threatened species. Nevertheless, the initial stages of conservation planning have proven successful in mobilizing the scientific community to find ways of gathering data for incredibly rare species and engaging conservation partners and donors to shift their agendas to support shark and ray conservation. The foundations have been laid for the coming decade of action to ensure significant progress toward systematically recovering sharks and rays by 2030.

23.1 Problem, what problem?

In the beginning, we did not know that sharks needed saving. That is probably because at some point they did not. But somewhere along the line, the human use of the ocean started to have an effect and species began declining to levels where conservation was required. Initially, this was identified as a fisheries management issue, with Mike Holden asking the question as to whether shark populations could be sustainably fished (Holden 1974; Holden 1976). He presented evidence to suggest that the answer may be no, a conclusion that would be revisited many times subsequently (e.g., Simpfendorfer and Dulvy 2017; Walker 1998). The focus on fished species continued until the 1990s when it became clear that not only were sharks overfished, but some had declined to the point where they were in one of the three threatened categories of the IUCN Red List Criteria (see Chapter 22). The requirements for shark conservation are complex, and there are many different pathways to evaluate and implement. Marine conservation mainly comes from the 'small population paradigm' of terrestrial conservation whereas many exploited fish populations suffer from the 'declining population' paradigm that are not readily solved by many of the techniques used in terrestrial conservation. Here, we offer our thoughts on shark conservation based on our time as Co-chairs of the IUCN Shark Specialist Group over the past decade or more.

23.1.1. Why haven't we saved sharks yet?

The earliest serious concerns about the long-term viability of elasmobranch populations and species were for skates. Keith Brander documented the disappearance of the Common Skate from the Irish Sea in 1981 (Brander 1981). This 'species' is now known to be a complex of two species: the Flapper Skate (*Dipturus intermedius*) and the Common Blue Skate (*D. batis*) (Iglésias *et al.* 2010; Last *et al.* 2016a). The serial depletion of larger species of skate was documented for both the Irish Sea (Dulvy *et al.* 2000, Dulvy, 2002 #1775) and the North Sea (Walker 1995; Walker

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1996; Walker and Heessen 1996) around the time that concerns were raised for the fate of the largest skate in the Northwest Atlantic – the Barndoor Skate (*Dipturus laevis*) (Casey and Myers 1998). More generally, these skates exhibited traits – large body size and relatively small geographic ranges – that were shared by other species that might also be at risk in other parts of the world (Dulvy and Reynolds 2002).

The 1999 FAO International Plan of Action for the Conservation and Management of Sharks (IPOA Sharks) called upon governments to develop national and regional plans for the conservation and management of chondrichthyan fishes based on a suite of goals and principles (FAO 1999). In 2005, an Expert Consultation reviewing the exceptionally slow uptake of the process found nine areas of concern:

1. Lack of appropriate taxonomic guides to identify species;
2. Lack or insufficient information on the population biology of elasmobranch species;
3. Lack of funds for management;
4. Lack of human resources;
5. Competition from other management imperatives;
6. Lack of effective policy and institutional practices;
7. Scarce or lacking data, particularly for catch and fishing effort, to inform management decision-making;
8. Weak or non-existent capacity of many developing countries; and
9. Low political priority accorded to elasmobranch fisheries (FAO 2006).

Things improved by 2012, two decades after National Plans of Action (NPOAs) for sharks (defined to include skates, rays, and chimaeras) were due; they had been completed by 17 of the 26 top shark fishing nations. Together, these countries were reportedly responsible for 84% of global shark catch from 2000–2009 (Fischer *et al.* 2012), but significant gaps remained in the completed NPOAs. Based on country surveys, FAO narrowed the reasons for lack of progress to three fisheries management problems, specifically: (1) institutional weakness, (2) lack of trained personnel, (3) deficits in research, monitoring, surveillance, control, and compliance. Half of national survey respondents, particularly those from developing countries, reported data limitations (Fischer *et al.* 2012). China was not mentioned in the report and was not included in the top 26 shark fishing nations. Yet extensive national and international shark fishing by China can be inferred from shifts in landings composition toward smaller individuals and species, consistent with prey release from removing the larger predatory teleosts and sharks (Lam and Sadovy de Mitcheson 2011; Szuwalski *et al.* 2017). Further, China has one of the largest distant-water fishing fleets and it is likely that these catches are substantially underreported (Pauly *et al.* 2013).

While the skate declines spurred a rapid rise in scientific interest in the status of sharks and rays, they had only a tiny impact on the scientific and public consciousness compared to early estimates of shark declines (Baum *et al.* 2003; Dudley and Simpfendorfer 2006; Simpfendorfer and Kyne 2009) and indications of ecosystem impact (Carlson 2007; Heithaus *et al.* 2008; Polovina *et al.* 2009; Stevens *et al.* 2000). These and similar papers published around the same time, particularly those associated with targeted media campaigns, raised the public profile of the need for shark conservation.

Shark finning began being recognised as a conservation issue in the early 1990s, with the participants of the 1991 landmark 'Sharks Down Under' conference ending with a statement of concern and call to stop it (Pepperell 1992). At the time, with virtually no shark fishing limits and a booming demand for shark fin soup, the ability to kill sharks solely for their fins, restrained only by the size of a vessel's hold, gave rise to concerns about shark overfishing. The public's concerns over cruelty and governments' concerns over the associated waste of protein were however bigger drivers of a global wave of shark finning bans adopted over the next few decades. Finning bans are now in place in dozens of countries and are increasingly recognized as a cornerstone for shark fisheries management rather than a panacea (Chapter 26). Finning bans can (1) maximize the use of an animal by avoiding waste and realizing the value of the fins (Shiffman and Hueter 2017), and (2) if implemented with a requirement that fins stay naturally attached to carcasses through landing, can facilitate the species-specific landings data needed for population assessment (Fowler and Séret 2010).

While many studies identified the problems facing sharks generally, they did not provide an understanding of which of the ~1200 species of sharks and their relatives needed to be the focus of protections. Given the diversity of sharks and their relatives, and the limited resources available to conservation efforts, there was a need to better understand the group, those species, and places most in need (Fowler *et al.* 2005; Musick *et al.* 1999).

23.1.2. The first global assessment of all chondrichthyans (1996–2007)

The Shark Specialist Group was formed under the auspices of the International Union for the Conservation of Nature's Species Survival Commission in 1991, led by Chair and Founder Samuel H. Gruber and Deputy Chair Sarah Fowler. The group initially focused on the creation of a substantial newsletter – *Shark News* – which published informal but authoritative articles that revealed a vast wealth of knowledge that was largely untapped because it was not being of sufficient depth to publish as journal articles. The SSG produced a global status report as a first step toward synthesizing this knowledge (Fowler *et al.* 2005). The development of a sufficient base of knowledge and the scientific capacity through these activities quantified significant conservation concerns that had only previously been alluded to (Manire and Gruber 1990). This knowledge, capacity and momentum initiated the first global assessment of the Red List Status of all 1,041 known species. This global assessment spanned 10 years (1996–2007) involving 17 workshops and 302 participants from 64 countries with the Red List Assessments published online between 2003–2008 (Dulvy *et al.* 2014a). As part of this assessment, the geographic distributions of all species were mapped for the first time, with the support of the Global Marine Species Assessment (https://sites.wp.odu.edu/GMSA/initiatives/gmsa/). Overall, 17.4% (181) of the 1,041 shark, ray, and chimaera species were listed as threatened in one of the IUCN categories of Vulnerable, Endangered or Critically Endangered. Just 23% of species were of Least Concern. Trait-based models were applied to the 487 Data Deficient species to estimate that one-quarter of all sharks, rays, and chimaeras were threatened (Dulvy *et al.* 2014a).

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23.1.3. The Global Shark Trends Project (2013–2021)

The Class Chondrichthyes is the first marine lineage, apart from hard corals (Family Scleractinia) and groupers (subfamily Epinephelinae), to undergo reassessment allowing the production of Red List Indices to track progress toward international Biodiversity and Sustainable Development targets (Carpenter *et al.* 2008; Pacoureau *et al.* 2021; Sadovy de Mitcheson *et al.* 2020). In the intervening decade since the first global assessment there was a massive growth in chondrichthyan species descriptions, and the resolution of synonyms and many species complexes (see Chapter 2). Most of these taxonomic issues were resolved by the revision of the global field guide for sharks (Ebert *et al.* 2013a) – the first update since the 1980s (Compagno 1984a; Compagno 1984b) – the development of regional guides (Ebert and Stehmann 2013) and the completion of the first guide to the Rays of the World (Last *et al.* 2016a). This latter volume, in particular, overhauled the taxonomy of rays, breaking up and naming three very large radiations, notably the Rajiformes (Skates), the Rhinopristiformes (Sawfishes, Wedgefishes, Giant Guitarfishes, Guitarfishes and Fiddler Rays) and the Myliobatiformes (Stingrays), and in particular the revision of massive genera *Himantura* and *Dasyatis* (Last *et al.* 2016c). With this improved understanding of taxonomy, and with more than 10 years since the completion of many of the original Red List assessments the process of a global reassessment began with an *ad hoc* series of projects:

- the reassessment of sawfishes in 2013/2014 (Dulvy *et al.* 2016b; Harrison and Dulvy 2014),
- the 2014 NE Atlantic and Mediterranean Sea reassessment (Dulvy *et al.* 2016a; Fernandes *et al.* 2017; Nieto *et al.* 2015; Walls and Dulvy 2020),
- the 2015 NE Pacific workshops in Seattle & Reno, USA (Ebert *et al.* 2017),
- the 2015 Australian 'Shark Report Card' (Simpfendorfer *et al.* 2019).
- The 2017 Arabian Seas reassessment (Jabado *et al.* 2018; Jabado *et al.* 2017).

The Global Shark Trends Project (2017–2020), supported by the Shark Conservation Fund, completed the assessment of 1,199 mostly marine species through a total of 17 workshops and 46+ hours of Zoom conference call workshops (for SE Asia and West Africa) that together involved at least 255 participants from 82 countries and territories. The project did not assess the 36 species of the freshwater stingray radiation of Potamotrygonidae in South America. The results will soon be tallied and published but it is already clear that at least one-third (37.5%) of chondrichthyans are now threatened (Chapter 22; https://www.iucnredlist.org; 2021-01 update). These results will guide the next decade of shark conservation, and also underpin broader ocean conservation efforts (Mann *et al.* 2021).

23.2. What are the conservation challenges?

23.2.1. It's not all about sharks (#raysneedlove2)

Since Brander (1981) documented the depletion of the Common Skate from the Irish Sea it should have been obvious that there were serious overfishing issues facing the rays. For too long, however, conservation efforts and messaging focused almost exclusively on sharks, particularly large charismatic species bringing tourism opportunities, such as Basking, White Shark and Whale Sharks. This started to change with the realization that sawfishes were disappearing from many parts of their former range (Anonymous 2000; Simpfendorfer 2002). But it was not until the publication of the results from the first global IUCN SSG assessment that the extent of the conservation crisis faced by rays became clear (Dulvy *et al.* 2014a). There were more threatened ray species than shark species, and five of the seven most threatened families were rays (see Section 23.2.4). Clearly, the focus needed to rapidly broaden from solely sharks to include the many threatened rays. With growing recognition of the international trade in gill plates of manta rays – the Giant Manta Ray (*Mobula birostris*) and Reef Manta Ray (*M. alfredi*) – came a greater appreciation in the public and conservation groups that rays also had conservation needs (Couturier *et al.* 2012; Heinrichs *et al.* 2011; O'Malley *et al.* 2016). Much of the initial focus on the two manta species stemmed from their value to tourism (O'Malley *et al.* 2013). By comparison, much less attention was paid to the other devil rays and to some degree this selective attention was enabled by the older taxonomy which incorrectly separated out the two larger species in the genus *Manta*. It is now widely recognised that all species belong in the same genus *Mobula* (Hosegood *et al.* 2020; White *et al.* 2018). Over time, and in part prompted by the consistent treatment of all devil ray species, the common threat from the international gill plate trade and the common life history feature of having extremely low fecundity of one pup per year and potentially one pup every few years (Lawson *et al.* 2017; Pardo *et al.* 2016).

23.2.2. It's not all about shark fin trade – sharks are killed for their meat, skin, and oil too!

The Convention on the International Trade in Endangered Species of Wild Flora and Fauna (CITES) is an international conservation agreement with a membership of 183 Parties (countries) that agree to adhere to the agreements made at Conventions of the Parties. The aim of CITES is to ensure that the international trade in wild plants and animals is not detrimental to the survival of these species. Species can be proposed for listing one of the three appendices. Until recently, there was resistance to listing any commercially valuable fishes on the appendices of CITES because they are not considered to be 'wildlife' (Vincent *et al.* 2014). Over the past two decades, significant progress has been made in ensuring fin trade is regulated through both fins-attached policies and the listing of officially 48 shark and ray species on Appendix II of CITES. Still, there are at least five other issues to consider.

(1) There has been considerable interest in international trade regulation of sharks that contribute to a greater fraction of the fin trade, such as Silky Shark, Shortfin Mako, hammerheads, and Thresher sharks. (Clarke *et al.* 2006a; Clarke *et al.* 2006b). There are other wide ranging and heavily traded pelagic species that have yet to be stock assessed properly, e.g., Blue Shark (*Prionace glauca*). But most importantly there is increasing recognition that many other species of sharks, rays and even ghost sharks (Chimaeriformes) enter the fin trade. The use of DNA-based identification of small fins and fin trimmings has revealed a much greater diversity of coastal species in the international trade, such as Weasel Sharks (*Hemigaleus*, *Hemipristis*), and Smooth-hounds (*Mustelus* spp.), than previously appreciated (Cardeñosa *et al.* 2019; Fields *et al.* 2018)

(2) The international trade in fins and gill plates is a major driver of unsustainable fishing – half of the 69 high-volume or high-value sharks and rays in the global fin trade are threatened (53.6%, n = 37) (Bräutigam *et al.* 2015; Dulvy *et al.* 2014a). Yet, very few of the most Endangered and Critically Endangered species are targeted for the luxury product trade, except for the five sawfishes (Pristidae) and two species of hammerhead shark (*Sphyrna lewini* and *S. mokarran*),

which have highly valued fins, and the Giant Devil Ray (*Mobula mobular*), which has large valuable gill plates.

(3) The issue remains that sharks are killed primarily for their meat as food, but the magnitude of many fisheries is poorly recognized. This is because many species are captured for subsistence use and do not enter local markets where they might be recorded by traditional forms of economic accounting analysis used by decision-makers (Da Silva and Bürgener 2007). When species are sold in markets there is widespread aggregation of products and sale under vague product names, such as 'cação' or 'viola' in Peru and Brazil (Bornatowski *et al.* 2013; Cruz *et al.* 2021; López de la Lama *et al.* 2018). We know from studies of skates and angel sharks that such product aggregation leads to a 'portfolio effect' where the decline in the larger more sensitive species can be masked by product substitution using other species (Dulvy *et al.* 2000; Lawson *et al.* 2020).

(4) There is substantial trade in liver oil from many deepwater and coastal chondrichthyans for their liver oil used in dietary supplements, [pharmaceuticals,] vaccines, and biodiesel (Al Hatrooshi *et al.* 2020; Spanova and Daum 2011).

(5) International trade in elasmobranch skins, particularly in SE Asia deserves greater attention (Vannuccini 1999). Of particular concern is the understudied use of stingray skins (mainly *Dasyatis, Pastinachus, Pateobatis,* and *Brevitrygon*) for luxury items (shoes, handbags, belts, wallets and purses) (Grey *et al.* 2006).

When all these issues are considered, a focus only on shark fins and finning will not deliver on the conservation needs of chondrichthyans generally or even sharks specifically. There are multiple drivers of demand and focusing only on single product issues will not solve the wider issue of reducing unsustainably fishing mortality.

23.2.3. It's all about the F (bycatch is bad too)!

There are few analyses of the causes of the crisis facing sharks and rays, and part of the problem is that the effects of fishing are difficult to observe. Unlike the striking maps of temperature, pH, or plastic density in the ocean (Eriksen *et al.* 2014; Hoegh-Guldberg *et al.* 2008) there is no map of fishing mortality for any group of fishes. One could counter that there are maps of fishing activity based on data from Vessel Monitoring System (VMS) or Automatic Identification System (AIS) (Amoroso *et al.* 2018; Kroodsma *et al.* 2018). VMS is used mainly on industrial trawl vessels in adjacent to 24 continental shelf areas in North America, Europe, South Africa, Namibia, Australia, New Zealand, Chile, and Argentina (Amoroso *et al.* 2018). AIS is recovered from industrial fleets mainly operating in the high seas beyond continental shelves. Both methods are promising but have not yet been applied widely enough to be useful. AIS data have been overlaid on satellite tagging data to develop a spatial risk assessment based on the overlap of fishing vessels with tagged sharks (Queiroz *et al.* 2019). There are also maps of the size and number of fishing vessels in tropical coastal zones (Stewart *et al.* 2010). While powerful and unique, these hard-won maps of boat numbers or activity are not the same as a map of fishing mortality – the death rate of fishes due to fishing.

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This lack of an ability to visualize the impact of fishing mortality is compounded by the fact there are few living laboratories within which to see fishing effects, aside from comparisons inside versus outside a few longstanding MPAs or along spatial gradients of fishing pressure or human populations size, trade gravity, and governance (Dulvy *et al.* 2002; Jennings *et al.* 2000; Jensen *et al.* 2012; MacNeil *et al.* 2020). While many scientists and conservationists based at non-governmental organizations (NGOs) understand and support the goal of fisheries sustainability (Shiffman and Hammerschlag 2016). There is a significant fraction of NGOs, however, that argue that sustainable shark fisheries are not possible based on past failures (Shiffman *et al.* In Press).

There are numerous narrative analyses of the problems faced by sharks (Dent and Clarke 2015; Vannuccini 1999). But we are not aware of any quantification of the relative importance of threatening process prior to the global summary of the first Red List Assessments of all species (Dulvy *et al.* 2014a). The IUCN Red List process requires a description of threats and the coding of threats against a standard classification (Salafsky *et al.* 2008). This study found that the primary threat to chondrichthyans was overexploitation, followed by habitat loss, persecution, and climate change (Dulvy *et al.* 2014a). One-third of threatened sharks and rays were subject to target fisheries, while the remainder were threatened due to incidental capture in fisheries targeting other species. Some of the most at-risk species were threatened by incidental capture (including sawfishes and large-bodied skates), this dispelling the myth that bycatch deserves lower priority. Overfishing through target and bycatch fisheries is the ultimate cause of population decline, spatial contraction, and rising extinction risk. This primarily is likely to be compounded by habitat degradation, and increasingly climate change in many cases (Chin *et al.* 2010; Sguotti *et al.* 2016; Yan *et al.* 2021). To a first approximation the best adaptation to climate change (and habitat loss and degradation) is to maintain populations that are large enough to cope with these additional threats. This can be achieved by managing species to be at, or ideally above, levels that will produce long-term sustainable yields (Allison *et al.* 2009a; Allison *et al.* 2009b).

23.2.4. What do we need to save?

The first IUCN SSG global assessment provided the first opportunity to develop a data driven approach to conservation prioritisation for all sharks and their relatives. There are as many perceived conservation priorities as there are people in the room, including: population status, ecological role, and evolutionary uniqueness. Unfortunately, there is less time to save Critically Endangered species than Near Threatened species. This narrowing window of conservation opportunity drove our focus on threat status as a primary focus of prioritisation. A key concern was that families with a disproportionately high level of threat risked the loss of whole lineages of evolutionary diversity. This analysis revealed seven priority families, comprised of 5 ray families (*) and two shark families in rank order:

Sawfishes (Pristidae, with all 7 species threatened)*,
Angel sharks (Squatinidae 12 of 15 threatened),
Wedgefishes (Rhynchobatidae 6/6 threatened)*,
Sleeper rays (Narkidae 4/4 threatened)*,
Stingrays (Dasyatidae 21/42 threatened)*
Guitarfishes (Rhinobatidae 15/28 threatened)*
Thresher sharks (3/3 threatened)

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While the taxonomy has changed since 2014, the above list provided the foundation for the IUCN SSG's priority list for conservation planning, starting with sawfishes and angel sharks. The devil and manta rays were added to the priority list for planning because of the rapid emergence of the international trade in gill plates (O'Malley *et al.* 2016). Soon after devil rays were listing on Appendix II at the 17th CITES Convention of the Parties in Johannesburg in 2016 (Chapter 23).

These priorities were extended considerably with the creation of a seven-partner coalition called the Global Shark and Ray Initiative (GSRI) formed by the SSG, involving Wildlife Conservation Society, World Wildlife Fund, TRAFFIC, Shark Advocates International, and the Shark Trust (www.globalsharksraysinitiative.org). This group undertook an intensive 18-month strategic planning process culminating in a 10-year plan composed of four sub-strategies, each with an extensive 'white paper' laying out the theory of change and priority countries. This 150-page document and four extensive underlying 'white papers' remain unpublished but the overview was summarised in Brautigam *et al.* (2015) and the Species and Fisheries sub-strategies are summarised in Dulvy *et al.* (2017). The GSRI Species sub-strategy identified 6 priority groups: Sawfishes, Angel Sharks, Guitarfishes & Wedgefishes, freshwater elasmobranchs, Data Deficient species and Evolutionary Distinct and Global Endangered taxa (EDGE, www.edgeofexistence.org/sharks-and-rays) (Bräutigam *et al.* 2015; Dulvy *et al.* 2017; Stein *et al.* 2018).

Freshwater sharks and rays are overlooked and face a multitude of threats, including exploitation and international trade for use in private and public aquaria (see Chapter 18). There are at least 43 obligate freshwater rays, including the South American radiation of Potamotrygonidae (36 spp), all three *Fluvitrygon* species, the Smooth Whipray (*Fontitrygon garouaensis*), Mekong Stingray (*Hemitrygon laosensis*) and Chindwin Cowtail Ray (*Makararaja chindwinensis*) (Grant *et al.* 2019). With at least 11 euryhaline generalist species entering freshwaters for all or part of their lifecycle (Grant *et al.* 2019; Last *et al.* 2016a; Lucifora *et al.* 2015). For example, the Critically Endangered Largetooth Sawfish (*Pristis pristis*) lives in freshwater for the first five years of life (Thorburn *et al.* 2007) and the Thorny Whipray (*Fontitrygon ukpam*) is found both far upstream in west Africa and in shallow coastal waters (Last *et al.* 2016a). Freshwater sharks and rays occur in heavily fished and heavily modified waterways, their threat status is exacerbated by high habitat–specificity and very small geographic ranges. The principal threats come from: residential and commercial development of riparian and estuarine habitats, mangrove destruction for shrimp farming (particularly in SE Asia), dam construction and water control, and pollution (Dulvy *et al.* 2014a). Furthermore there is a poorly understood international aquarium trade in South American freshwater stingrays (Araújo *et al.* 2004).

Almost half (46.8%, n = 487) of all chondrichthyan species were found to be Data Deficient by the first assessment (Dulvy *et al.* 2014a). Many species were listed as Data Deficient both due to a lack of knowledge, but also because there was the perception that listing a species as Data Deficient would also mobilize funding for new research (N.K. Dulvy unpubl. obs.). The guidance is now much clearer that one should not consider 'downstream' consequences of a listing, such as this case or the case of a species being listed in one of the threatened categories which might lead to strict protection (section 3.2.3, p. 23 IUCN Standards and Petitions Subcommittee 2019).

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23.3 Preparation and conservation planning

Is more knowledge is needed to save a species? As scientists we naturally want more data. But knowledge gaps should not be an excuse for policy inaction, especially when dealing with endangered or inherently vulnerable species. The responsible course is to seek basic regulatory safeguards for all exploited species and strict protections for those considered endangered, (i.e., in the Critically Endangered or Endangered categories of IUCN Red List) while additional information is gathered. For elasmobranchs, this means minimizing fishing mortality and preventing habitat degradation, as climate changes and other lesser threats are evaluated. Such action should be followed up with research to determine if the local status gets better or worse over times and how spatial and temporal factors intersect with the threatening process and can be mitigated (McClenachan *et al.* 2012). Science and other forms of knowledge are needed to minimize conflict, build capacity, and engender support for conservation action. There is, however, surprisingly little knowledge of, or science being generated for, endangered fishes (Guy *et al.* 2021). Many scientists inevitably study the more common and readily available species rather than the rarer harder to find endangered species (Shiffman *et al.* 2020).

Our approach has been to delimit the taxonomic ('what to conserve') and geographic ('where to conserve') scope of the Conservation Plan (Davidson 2014). Both forms of knowledge are particularly important for understanding status, and also for developing a broader consensus among a wider community by building technical capacity and donor interest (Groves *et al.* 2002). We need (i) a stable resolved taxonomy and nomenclature, and (ii) detailed information on species' distributions. These are scientific technical endeavors requiring an engaged and funded cadre of systematists and natural historians who can develop and evaluate both forms of knowledge (Rocha *et al.* 2014; Simpfendorfer *et al.* 2011; White and Last 2012). The collation of distributional information requires the development of funded networks of field scientists as well as processes for capturing and eliciting distributional information (Guy *et al.* 2021; Yan *et al.* 2021). Here, we have found that species assessment and conservation proceed apace when taxonomy yields a stable and defensible nomenclature (see Chapter 2) and thus enable the geographic distributions to be defined. As we show later, this process has brought many new contributors into sharks and ray conservation, some from marine mammal and turtle science, and we are seeing sawfish searches piggybacked onto marine mammal surveys (Braulik *et al.* 2020) and marine mammal conservation planning being undertaken by shark scientists (Hoyt and di Sciara 2021).

23.3.1 What are we saving?

Humanity may be altering genetic diversity and shifting the composition of ecosystems but the defining feature of the Anthropocene will be the loss of species (Díaz *et al.* 2019; Rockstrom *et al.* 2009). Consequently, the taxonomic rank of 'species' is the fundamental unit of evolution and the primary focus of conservation for IUCN Species Survival Commission Specialist Groups.

23.3.2. Solving the sawfish taxonomy

Prior to 2013, there were seven extant species of sawfishes in two genera *Anoxypristis* and *Pristis* (Faria *et al.* 2013). While the genus *Anoxypristis* only ever had one extant species (Narrow Sawfish, *A. cuspidata*) the genus *Pristis* originally had six species, including *P. microdon, P. perotteti and P. pristis*. These three species are now known to form a single pan-global species –

the Largetooth Sawfish (*Pristis pristis*) (Faria *et al.* 2013). The resolution of the taxonomy enabled the reassessment of the Red List status of these species in 2013 (Harrison and Dulvy 2014). A species listed on the CITES Appendices cannot have their name changed without a proposal going "to the floor" of the convention to be voted on by the member countries. In 1997, a proposal to list all sawfish species on CITES Appendix I failed by a large margin. A full decade later, six of the seven species of sawfish (i.e., all except *Pristis microdon*) were listed on CITES Appendix I (Lawson and Fordham 2018; Vincent *et al.* 2014). Australia successfully led the effort to except "*P. microdon*" to allow for aquarium trade, but in 2011, the Australian government reported that it could not be certain that such exports were not detrimental to species recovery. A subsequent Australian proposal to 'up list' "*Pristis microdon"* to CITES Appendix I was adopted by consensus by the Parties in March 2013, thereby completing a global ban on commercial international trade in all sawfishes (Fordham *et al.* 2018). There remain seven sawfish 'species' listed on Appendix I of CITES, which means trade in specimens of these species is only permitted in exceptional circumstances.

23.3.3. The taxonomic rise of devil rays and fall of manta rays

Three things led to a shift in the taxonomy of the Mobulidae: the development of a photographic sightings database, cheap international travel, and the availability of digital underwater cameras (Marshall *et al.* 2011; Marshall and Pierce 2012). This resulted in the discovery that there were two species of manta ray: the Reef Manta Ray *Manta alfredi* (Krefft 1868) and the Oceanic Manta Ray *M. birostris* (Walbaum 1792). This prompted the revision of Red List Assessments, changing the status of Oceanic Manta Ray from Near Threatened to Vulnerable and the listing of Reef Manta Ray as Vulnerable in November 2011. All mobulid species were threatened by the emerging demand for, and international trade in, their gill plates (known as Peng Yu Sai, "Fish Gill of Mobulid Ray") which first appeared in the Philippines in 1970 and expanded internationally in the early 1990s. The gill plates are used to make a tonic, purportedly for its health benefits (Acebes 2013, O'Malley et al. 2016). While the larger gill plates are most valuable reaching USD $150–$419 per kilogram, smaller gill plates appeared in the trade suggesting that other smaller devil rays species were being incorporated due to the rising demand and expanding fisheries (Croll *et al.* 2016). Data on the consequences of fisheries and trade are exceedingly hard to find or do not exist because the population declines happened prior to the advent of scientific monitoring except in places where fisheries development was hindered by civil war (see the supplementary informationn in Pacoureau *et al.* 2021). There is a unique dataset collected in Mozambique which shows that these smaller devil rays were declining just as steeply as the larger manta species (Pacoureau *et al.* 2021; Rohner *et al.* 2017). Later in 2011, the Oceanic Manta Ray was the first ray to be listed on Appendix I and II of the Convention of Migratory Species (CMS) (Couturier *et al.* 2012; Lawson and Fordham 2018; Lawson *et al.* 2017). The Oceanic and Reef Manta Ray were listed on Appendix II of CITES in 2013 followed by the listing of the remaining devil rays in 2016 (Lawson and Fordham 2018; Lawson *et al.* 2017).

Though there was greatest interest in regulating fisheries for and protecting the iconic manta rays, there was increasing recognition within the IUCN SSG that while these larger species court much tourism value and scientific interest, their smaller relatives were receiving much less scientific and conservation attention. The IUCN SSG sought to guide the energy, capacity, and funding devoted to the larger Manta Rays to the rest of devil rays through two workshops in Durban, South Africa

(9–12 June 2014) and Plymouth, United Kingdom, during the 2015 Fisheries Society for the British Isles (FSBI) symposium (27–31 July 2015) (Lawson *et al.* 2017). This process resulted in the development of a Global Devil Ray and Manta Ray Conservation Strategy, which was purposefully named to extend the priority to the less well-known devil rays. These and other processes lead to three important sources of information. First, there was a systematic review of the target and bycatch fisheries for these species (Croll *et al.* 2016). Second, the development of comparative analyses of maximum intrinsic population growth, r_{max}, which provided compelling evidence that these species had incredibly low productivity and capacity to withstand fishing pressure (Dulvy *et al.* 2014b; Pardo *et al.* 2016). Third, was the broadening of the evidence base and the consensus that the smaller devils rays were a non-trivial component of the international trade in gill plates and that regulation was needed to ensure sustainability of these species(Haque *et al.* 2020a). Subsequently, the devil rays joined the 'manta rays' on CITES Appendix II in 2016 (Lawson *et al.* 2017).

It has taken a global collaboration of scientists' time to gather the genetic samples, and the evidence suggests both devil and manta rays belong in a single genus *Mobula* (White *et al.* 2018). While the community originally focused on the manta rays, the reality was that all species were threatened and deserving of attention, and this is now being increasingly recognised by molecular geneticists (Hosegood *et al.* 2020). However, the taxonomic story isn't over yet as this new study clearly identifies a third large 'manta' ray species in the Gulf of Mexico (Hosegood *et al.* 2020) and raises the concern that placing the enigmatic *M. rochebrunei* as a junior synonym of *M. hypostoma* might overlook the true risk of extinction in West African waters. The search for more specimens of devil rays from West Africa continues (G. Stevens, G. Notarbartolo di Sciara, and D. Fernando pers. comm. 24th November 2020).

23.3.4. Uncertainty in South American *Squatina* taxonomy

The taxonomy of South American angel sharks remains confusing despite the increasing availability of identification guides and sightings databases, particularly in particularly in Europe and North Africa (https://angelsharksmap.zsl.org).

A key challenge is that it is not at all clear where the northern border of Chilean Angel shark (*Squatina armata*) ends and where the southern border of Pacific Angel Shark (*Squatina californica*) begins and the degree of overlap of both species (Cañedo-Apolaya *et al.* 2021). Both species have previously been considered conspecific and are not well-differentiated in the literature or in landings data with all data for this species attributed to Pacific Angel Shark (Ellis *et al.* 2020). Some literature on the elasmobranch fauna of Peru, Ecuador, and Colombia lists the presence of Pacific Angel Shark while other papers mention only Chilean Angel Shark, and some country checklists include both species and these sympatric records are likely incorrect (Cornejo *et al.* 2015; Dulvy *et al.* 2020). These taxonomic problems lead to problems in understanding the distribution (see section 23.5). Resolving these problems is challenging because the type specimen (holotype) of the Chilean Angel Shark was lost in a fire at the Austral University of Chile in 2003 (F. Concha pers. comm. 28th February 2021). The first task is to reassign a new holotype (neotype) and develop identification guides and undertake surveys (see section 23.5). New molecular sampling reveals that *S. armata* and *S. californica* are sympatric in Peru, along with a possible new undescribed species (Cañedo-Apolaya *et al.* 2021).

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There has been a high degree of confusion on the Atlantic coast of South America with the resolution of three long-known species (*S. argentina*, *S. guggenheim*, and *S. occulta*) as well as the recent description of two new species (*S. david* and *S. varii*). Similar taxonomic uncertainty surrounds these new species. David's Angel shark (*S. david*) was described in 2016 and occurs in the southern Caribbean from Panama to Suriname (Acero *et al.* 2016), but may have occurred down to northwest Brazil (Acero *et al.* 2019). Prior to the description of this species, angel sharks caught in the southern Caribbean were thought to be *Squatina dumeril* (Acero *et al.* 2019).

23.3.5. The rise of rhino rays

What are the rhino rays? At a Global Shark and Ray Initiative meeting in London February 2019, the order Rhinopristiformes was colloquially dubbed as 'rhino rays' and the name is beginning to stick, intentionally propagated in social media and increasingly in scientific articles (e.g., Haque *et al.* 2021). The name was chosen purposefully for three reasons: (1) to acknowledge their iconic snouts, (2) to underscore that many of these species are as close to extinction as rhinoceroses, and (3) create a memorable name that would resonate with the public.

There has been a radical change in the taxonomy of 'guitarfishes'. Prior to the publication of Rays of the World, the 'guitarfishes' comprised three families with most species in the genus *Rhinobatos*:

> Rhinidae (1 species),
> Rhinobatidae (45 species in 5 genera [*Aptychotrema n*=3, *Glaucostegus n*=4, *Rhinobatos n*=33 species, *Trygonorrhina n*=2, and *Zapteryx n*=2]), and
> Rhynchobatidae comprised of 5 described and one undescribed species (Dulvy et al. 2014).

Now, there is one order or 'rhino rays' – the Rhinopristiformes comprising 60 species in five families, and:

> Sawfishes (Pristidae; Anoxypristis *n*=1, *Pristis n*=4),
> Wedgefishes (Rhinidae; *Rhina n*=1, *Rhynchobatus n*=8, *Rhynchorhina n*=1),
> Guitarfishes (Rhinobatidae; *Acroteriobatus n*=8, *Rhinobatos n*=15, and *Pseudobatos n*=8),
> Giant Guitarfishes (Glaucostegidae; Glaucostegus *n*=6), and the
> Banjo rays (Trygonorrhinidae; *Aptychotrema n*=3, *Trygonorrhina n*=2, and *Zapteryx n*=3).

The consequence of taxonomic revision for conservation is clear. It is becoming increasingly apparent that the larger finned species are far more valued than the smaller finned species (Jabado 2018; Moore 2017; Temple 2018). Prior to this taxonomic revision the species were taxonomically jumbled. It is now clear that the larger-finned species are the Sawfishes, Wedgefishes, and Giant Guitarfishes. The smaller-fined species are generally found in the Guitarfishes (Rhinobatidae, *n*=31 species). This taxonomic revision enabled the Shark Specialist Group and the wider conservation community to focus on undertaking Red List Assessment on the 16 species of Wedgefishes and Giant Guitarfishes. This revealed that 15 of the 16 species were Critically Endangered. Only one species is Endangered – the Eyebrow Wedgefish (*Rhynchobatus palpebratus*) – because most of its geographic distribution occurs in northern Australia and SE

Papua New Guinea where fishing pressure is low and there are some management measures in place. It may have had a wider distribution in the Indo-west Pacific Ocean as it is also known from a single record from the Andaman Sea off southwest Thailand (Compagno and Last 2008) and two specimens from Taiwan (Ebert *et al.* 2013b; Kyne *et al.* 2020; Kyne and Rigby 2019).

Taxonomic problems remain mainly because of the issues with separating and identifying members of the 'whitespotted wedgefish' (i.e., *Rhynchobatus djiddensis*) species complex. The name *Rhynchobatus djiddensis* was originally used widely as a catch-all term for any wedgefishes across the Indo-West Pacific (Kyne *et al.* 2020). It is now known that *R. djiddensis* is restricted to the Western Indian Ocean (Last *et al.* 2016a). A new species of wedgefish endemic to southern Japan has been described (*Rhynchobatus mononoke*). Most previous records of this species may have been ascribed to *R. australiae*, which means this species concept may need to be revisited in the subsequent round of IUCN Red List Assessment. Further, two new micro-endemic species have just been described Malagasy Blue-spotted Guitarfish (*Acroteriobatus andysabini*) from Madagascar and Socotra Blue-spotted Guitarfish (*Acroteriobatus stehmanni*) from Socotra Is., with a redescription of *Acroteriobatus leucospilus* (Weigmann *et al.* 2021). The taxonomic status of the Zanzibar Guitarfish (*Acroteriobatus zanzibarensis*) remains uncertain and shares a "characteristic blue-striped snout with the Stripenose Guitarfish" (*Acroteriobatus variegatus*) found off southern India (Last *et al.* 2016a). The taxonomic mystery of rhino rays is far from over and further taxonomic resolution will hopefully help resolve the geographic distributions of these species.

23.3.6 Pinning down the distribution of rare species

A first step to saving species is clarifying taxonomy which helps with resolving geographic distributions (e.g., Weigmann *et al.* 2021). The first IUCN Red List assessments were based on distribution maps derived mostly from FAO species catalogues (Compagno 1984a; Compagno 1984b). These maps in turn helped informed the revision of *Sharks of the World* (Ebert *et al.* 2013a) and the publication of the long-promised *Rays of the World* (Last *et al.* 2016a; Last *et al.* 2016b) and in turn the latest round of reassessment relied heavily upon these comprehensive revisions.

In turn, the most recent Red List Assessments generated by the Global Shark Trends project have taken these maps and modified them with the most recent information from local taxonomists and workshop participants. The verification of type specimens in the taxonomic species description process is a critical part of understanding geographic distributions, as spatial occupancy and distribution is intimately related to abundance (Freckleton *et al.* 2006; Holt *et al.* 1997; MacCall 1990). With a century or more of intense fishing across much of the world (Butcher 1996), distributions have contracted as abundance has been fished down (Fisher and Frank 2004; Frisk *et al.* 2011; Yan *et al.* 2021).

Many endangered species (in the IUCN categories of Endangered or Critically Endangered) are highly catchable and their increasing rarity means their former distribution is more and more difficult to discern as the species are fished down and their range size contracts (Lawson *et al.*

2020; Yan *et al.* 2021). Many populations of these species disappeared long before the advent of scientific monitoring (Dulvy *et al.* 2009; Dulvy *et al.* 2003) requiring the acceptance a of a whole new toolbox of scientific methods, some requiring nascent technologies, such as the use of e-DNA to find sawfishes (Le Port *et al.* 2018; Simpfendorfer *et al.* 2016) and rediscover the existence of Scalloped Hammerhead off Guam (Budd *et al.* 2021). But older DNA techniques such as bar-coding are becoming widely accessible and cheap enough to transform our ability to confirm the identification and presence of hard-to-identify species such as Ganges River Shark (*Glyphis gangeticus*) (Haque and Das 2019). Finally, DNA-barcoding is being used throughout the world to detect the presence of threatened species in supermarket and fish market samples and the passing off of threatened species in bulk product categories, such as 'cação' in South America (Bornatowski *et al.* 2013; Feitosa *et al.* 2018) or the diversity of skate parts lumped and sold as 'skate wings' (Griffiths *et al.* 2013).

For many species there are exceedingly few individuals left, often far too few to base a short-term research program on. This has been a challenge for sawfishes. Setting up a fisheries landings site monitoring program will yield great scientific insights and benefits but might not reveal a single sawfish capture for a decade or more. For such situations asking the fishers about their knowledge of the historical ecology of species to elicit memories of catches is often the only way to rapidly gain an understanding of the status of sawfishes and other rare species (Bom *et al.* 2020; Gerhardt *et al.* 2018; Martínez-Candelas *et al.* 2020; Thurstan *et al.* 2015).

While technological approaches have been natural for many scientists to adopt and for governments and donors to fund, it has been harder to find the expertise and raise funds for historical ecology, traditional ecological knowledge surveys, and other social science approaches. The use of ecological knowledge has risen rapidly as scholars have used this information to reveal the profound insights that fishers have into the ecosystems they fish (Johannes 1981; Johannes *et al.* 2000; Neis *et al.* 1999). Traditional Ecological Knowledge is defined as "a cumulative body of knowledge, practice and belief evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes *et al.* 2000; Drew 2005). Fisheries Ecological Knowledge has provided insights into the status of the Bumphead Parrotfish (*Bolbometopon muricatum*) (Dulvy and Polunin 2004), Chinese Bahaba (*Bahabia taipingensis*) (Sadovy and Cheung 2003) and seahorses (*Hippocampus* spp.) (O'Donnell *et al.* 2010). These methods have been used to understand the historic occurrence and distribution of sawfishes in Brazil (Feitosa *et al.* 2017; Reis-Filho *et al.* 2016), Guinea-Bissau (Leeney and Poncelet 2015), Bangladesh (Hossain *et al.* 2015) Papua New Guinea (Leeney *et al.* 2018), and Tanzania (Braulik *et al.* 2020). These methods are now being expanding to also understand catch and trade of Devil Rays in Bangladesh (Haque *et al.* 2020a).

Shark science has always been very technology driven, with new methods such as electronic tagging and stable isotopes offering tractable research opportunities (Carrier *et al.* 2019). A key technological development has been the development of sightings databases. Sightings databases were first developed for surface swimming, tropical species, that are easily identifiable by the SCUBA diving community (Arzoumanian *et al.* 2005; Speed *et al.* 2007). The earliest databases and programmes were for Whale Shark, manta rays, and Sand Tiger Shark (Town *et al.* 2013; Van

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Tienhoven *et al.* 2007). There is also a longstanding National Sawfish Encounter Database (NSED) in the US which had 5,000 reports since 1782, but this now seems moribund (Waters *et al.* 2014; Wiley and Simpfendorfer 2010). Sawfish sightings can still be reported to https://myfwc.com/research/saltwater/fish/sawfish/contact/. Sightings of Megamouth Shark have been documented on three websites: Florida Museum of Natural History (https://www.floridamuseum.ufl.edu/discover-fish/sharks/megamouths/), Wikipedia (https://en.wikipedia.org/wiki/List_of_megamouth_shark_specimens_and_sightings), and a defunct website (Kyne *et al.* 2019) but neither site has records more recent than 2018. These successes spurred the development of an angel shark sightings database https://angelsharksmap.zsl.org.

The understanding that sawfishes were in trouble has prompted a slew of historical retrospective examinations of a range of data, including beach meshing programs, historical photographs, and museum records. Upon learning of the rarity of sawfishes from the IUCN Shark Specialist Group conservation planning work prompted scientists to conduct a retrospective analysis of the catches of sawfishes in protective beach meshing records in Australia (Wueringer 2017) and KwaZulu-Natal on the western Cape of South Africa (Everett *et al.* 2015). Both analyses suggest steep declines. In South Africa, there was a staggering decline in the catch rate of sawfishes (presumably a mixture of Largetooth Sawfish *Pristis pristis* and Green Sawfish *P. zijsron*). Catches were as high as 0.4 individuals per kilometer of net per year in 1966, declining by 80% to 0.1 within a period of little more than three years, and with the last capture in 1999. Taken together the authors estimated a probability of extinction of 0.9991 for sawfishes (Everett *et al.* 2015). Species are known to contract from the range edges toward the core of the distribution where there is better habitat quality and rescue from migration and dispersal (Yan *et al.* 2021). The speed of sawfish decline is staggering given the extensive wetland breeding habitat available along the KwaZulu-Natal coast and relatively low levels of fishing. These data are the only time-series of the decline and local extinction of sawfishes. Another extensive retrospective analysis relied upon an extensive database of historical sawfish records found in museum collections, newspaper articles, historical photographs, and fishing blogs as accumulated in the National Sawfish Encounter Database (NSED) (Waters *et al.* 2014). This analysis revealed 801 records of Largetooth Sawfish in the Atlantic Ocean between 1830–2009. By tracking the declining frequency of records over the past half century using now from sightings probability models there was a very high probability of that this species was already extinct in US waters (0.99), northern South America (0.99) and southern West Africa (from Cameroon to Namibia, p=0.99) (Fernandez-Carvalho *et al.* 2014).

23.3.7. Conservation planning for sharks and rays

The IUCN Species Survival Commission revisited its conservation planning process through a Task Force convened in 2006. The context was that there had been a long history of production of approximately 60 Action Plans but most were gathering dust on a shelf rather than being acted upon (Harrison and Dulvy 2014; IUCN/SSC 2008). This Task Force found that, while these plans were good sources of biological data and scientific and conservation priorities they had limited conservation success (Fuller *et al.* 2003; Harrison and Dulvy 2014; IUCN/SSC 2008). These reports were often in the form of what IUCN would describe as a *situational analysis* rather than an *action plan*. A situational analysis is a scoping of the broad context or external environment in which IUCN projects operate and is an analysis of trends and pressures, major issues relating to people and ecosystems and an analysis of key stakeholders (e.g., Mallon *et al.* 2015). An action plan would typically identify partners to take the lead on delivering local actions and seek funds to do the work (IUCN/SSC 2008).

The IUCN Shark Specialist Group approach has been to delimit the taxonomic ('what') and geographic ('where') scope of the Conservation Plan and convene a diverse array of participants including species experts and stakeholders ('who') chosen after months of consultation prior to a workshop. We used an online survey to enable respondents to provide information and unpublished knowledge on sawfishes across range states (for survey structure see Annex 5 in Harrison and Dulvy 2014). This survey was sent to 170+ members of the IUCN Shark Specialist Group and to fisheries agencies, non-governmental organizations (NGOs), intergovernmental organizations, and SCUBA diving organizations and shared on social media. A total of 153 respondents from 64 sawfish range states contributed to the first sawfish conservation strategy and formed the IUCN SSG Sawfish Network (see Annex 2 in Harrison and Dulvy 2014). A further 29 experts from eight countries attended the workshop who had knowledge and expertise spanning 49 countries (Dulvy *et al.* 2016b; Harrison and Dulvy 2014). The devil and manta ray strategy workshop was attended by 18 experts with correspondence from another 14 and input from 16 participants during the 2015 Fisheries Society for the British Isles (FSBI) symposium (Lawson *et al.* 2017). Scoping meetings were tacked onto the end of other workshops. For example the one-day scoping meeting for the Eastern Atlantic and Mediterranean angel shark Conservation Strategy (Gordon *et al.* 2017) was added to the Canary Islands workshop for Angelshark Action Plan for the Canary Islands (Barker *et al.* 2016). Workshops were facilitated by a professional facilitator with extensive planning experience in both development and conservation (Martin Clark, https://theadvocacyhub.org/team/martin-clark) and lasted 3–5 days. These meetings would seek to identify threats, typically using the IUCN threat classification typology (Salafsky *et al.* 2008) and constraints that are beyond the sphere of control of the participants (Appendix 1, Harrison and Dulvy 2014; IUCN 2017). The next phase of work would be spent developing first a Vision, then 2–6 Goals each with multiple objectives / sub-objectives and finally actions. Participants were guided to develop actions that were Specific, Measurable, Achievable, Relevant/Realistic, and Time-Bound (SMART) (Lawson *et al.* 2017). Truly SMART actions were only possible for the subnational single species plans, such as the plans for Angelshark (*Squatina squatina*) in the Canary Islands (Spain) and in Wales (UK) and these plans are considerably more detailed than the sawfish and devil and manta ray strategies, with more goals, objectives, and actions (Table 1).

23.4. Future directions in marine species conservation

IUCN Species Survival Commission' strategic plan offers an Assess-Plan-Act cycle, starting with Red Listing (assess) underpinning conservation planning (plan) to guide the necessary actions (act). Thus far the IUCN Species Survival Commission analysis shows that only 9% of the activity of all Specialist Groups falls in the 'Act' zone (Nassar Jafet, IUCN Conservation Leaders presentation 6th October 2019). This could be because actions are conducted by individuals working in NGOs and government agencies rather than by any Specialist Group per se. Nevertheless, there is no doubt that an increase in time spent on conservation action and implementation will be needed to halt and reverse biodiversity loss (Mace *et al.* 2018). Next, we reflect on ways to improve planning and to engage partners to deliver conservation action.

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23.4.1. Advancing conservation with zoos and aquaria

The prevalent terrestrial model for conservation of species that have declined to small numbers of individuals has two sequential parts. First, is to undertake *ex-situ* conservation, which usually takes the form of importing the last remaining individuals into a controlled environment for captive breeding, either in zoos or in cooperation with zoos. Second, while scientists are getting the captive breeding to succeed there is the policy piece to be done, which is to identify sites for reintroduction and ensure threats are minimized to maximize the survival of reintroduced individuals. This process requires considerable financing, public engagement, and policy work and hence has worked best for species local to the zoo. This has been very successful for North American species with the vast support of North American zoos, resulting in 31 species brought back from the brink of extinction including: the recovery and reintroduction of Blackfooted ferret (*Mustela nigripes*) which was Extinct in the Wild in 1996, but was downlisted to Endangered in 2008 (Belant *et al.* 2015). Three other notable successes are the American Bison (*Bison bison*), Grey Wolf (*Canis lupis*), and California Condor (*Gymnogyps californianus*). There have been successes along this model elsewhere, notably Przewalski's Horse (*Equus ferus*) recovered from Extinct in the Wild to Endangered in two decades (King *et al.* 2015), and the recovery of the Arabian Oryx (Islam *et al.* 2011). These terrestrial successes were only possible through extensive engagement with, and leadership from, local zoos.

But will this model work for threatened sharks and rays, which may not be local to the zoos engaged in conservation? This model or a similar version has worked for marine turtle conservation, with hundreds of local aquaria, NGOs, and other actors working their local nesting ground achieving very photogenic results. But it is clearly not working successfully for small cetaceans, which like many sharks are wide-ranging with few site-based conservation opportunities in their life cycle and face near identical threats (Reeves *et al.* 2003). For example, consider the case of the world's smallest porpoise, the Vaquita (*Phocoena sinus*) threatened by incidental capture in monofilament gillnets targeting the Totoaba (*Totoaba macdonaldi*). Despite it being illegal to catch this fish since 1975 there are steep ongoing declines of the Vaquita, which numbered more than 600 individuals in 1997 yet may now number fewer than 10 individuals (Jaramillo-Legorreta *et al.* 2019). Despite a ban the implementation has not been sufficient – in 2018, a total of 400 illegal totoaba gillnets were found. Further, last minute attempts at capturing the remaining individuals failed with the death of an individual due to capture stress (https://www.vaquitacpr.org/rescue-efforts). This example provides two cautionary warning. First the vaquita example underscores the need to focus on the *in-situ* issues of reducing threats to declining species before their populations become too small and enter the extinction vortex of environmental and demographic stochasticity. Second, it is always going to be challenging to develop captive breeding for wide-ranging aquatic organisms when they are depleted to such low levels. Nevertheless, there is one promising example, that of the partnership to breed and reintroduce the Endangered Zebra Shark (*Stegostoma tigrinum*). The approach is for North American zoos to breed eggs that will be transported to West Papua where the plan is to grow the individuals in rearing pens before being tagged and released into the extensive and well managed Marine Protected Areas in the Raja Ampat region (Allchin 2021; Hoopes and Meyer 2020).

Much of the shark conservation supported by North American zoos and aquaria has focused on iconic sharks, notably the White Shark but also Whale Shark or manta rays (B. Firchau pers.

comm.). There is an Association for Zoos and Aquaria program to *Save Animals from Extinction* (AZA SAFE) that has been trying to gain traction since 2015. Individual zoos and aquaria have made significant contributions to raising awareness through #InternationalSawfishDay on 17th October, since 2017 (https://www.fisheries.noaa.gov/feature-story/international-sawfish-day) and supporting Red Listing or conservation planning workshops (National Marine Aquarium, Plymouth, UK; Zoological Society, London; Georgia Aquarium; Audubon Aquarium of the Americas, Bronx Zoo) or through engagement in the Global Shark and Ray Initiative (Wildlife Conservation Society).

The challenge remains that the engagement of zoos and aquaria will depend on finding the intersection (sweet spot) of those sharks and rays that are: (i) amenable to breeding in captivity, (ii) threatened, (iii) present in the waters of the aquarium country, (iv) present in most of the aquaria in the AZA network. Unless present in most aquaria there is little consensus as to which species to focus efforts upon or the genetic diversity to support captive breeding. There are exceedingly few sawfishes in captivity (*n*=77 worldwide) and hence few aquaria to work with. The opportunity offered by the proven power of zoos and aquaria for terrestrial conservation remains unrealized unless we find a new model of species conservation suited to the challenges of marine species.

23.4.2. Learning from terrestrial planning to develop marine conservation plans

Local scale conservation planning, as for Angelshark (*Squatina squatina*) in the Canary Islands and Wales, works well within the context of IUCN Conservation planning and donor funding. Most IUCN conservation plans are at a single country scale. This theory of change was developed for and works well for terrestrial conservation because there are large well-established NGOs and governmental programs of work focused on delivering integrated on-the-ground conservation. Even for wide-ranging species, the sites of conservation need have been identified for decades. Similarly, there are large numbers of well-educated donors and zoos and aquaria well-used to funding parts of such work, which usually takes the form of on-the-ground conservation. Donors are used to funding work that is local in only one country and yields quick photogenic results within a year or two. One recent and welcome example is the National Geographic / IUCN fund for *Recovery of Species on the Brink of Extinction* which offered one-year grants of US $25,000 to "specific and defensible priority actions to avert decline of a species or group of species" (www.iucn.org/commissions/species-survival-commission/get-involved/species-recovery-rfp). There were two successful marine fish grant winners out of the 111 grants awarded in the seven funding rounds from April 2017 to October 2020 (https://www.iucn.org/sites/dev/files/content/documents/ssc_ngs_rfp_grant_awards-abril2021_0.pdf)

Such a planning and funding approach works well for conserving terrestrial species, which are generally data-rich with small ranges and local threats. But it does not translate easily to marine organisms which are generally much more data-poor and wider-ranging, and thus require action and legislative change in many more jurisdictions (Dulvy *et al.* 2016b). Further, most species suffer from a diffuse, wide-ranging, and complex threatening process such as overfishing, (e.g., illegal gillnetting for totoaba), which can often be beyond the 'sphere of control' of workshop participants. Indeed, a Conservation Complexity Index can be calculated as the number of species multiplied the number of range countries. Assuming that all sawfish species will benefit from legislation and

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action in a country then the CCI of sawfishes is 123 (Yan *et al.* 2021). By this measure the Conservation Complexity of both African Elephant species together is 74–111 and the eight species of pangolin is 86 (Dulvy *et al.* 2017). The value of an individual sawfish is around USD$28,000, based mainly on fin value and rostrum at the final point of sale, just over half the value of an elephant around USD$53,000 (McClenachan *et al.* 2016). But the scale of sawfish conservation is much greater than that of African Elephants and requires a global strategic starting point to avoid uncoordinated local conservation potentially in the wrong place (such well-intentioned but undirected activities have been memorably described as "random acts of kindness" by IUCN Species Survival Commission Chair Jon Paul Rodríguez).

A key feature of overfishing is that it is a 'wicked problem' and thus cannot be solved by a small NGO within the timeframe or budget of most donors (Jentoft and Chuenpagdee 2009). For shark conservation, there are few researchers, governments, and donors that know of the conservation crisis faced by sharks or have programmes and the capacity to solve the problem. For example, there are many species listed on protection Appendices, and two examples include the Appendices of the Bern or Barcelona Conventions in Europe or the Appendices of the Convention of Migratory Species (Lawson and Fordham 2018; Walls and Dulvy Submitted). But, in watching our colleagues struggle for funding, it is apparent that there are woefully inadequate funding national and regional frameworks and processes to save these listed sharks and rays. Yet, we are now at a crisis stage where there are as many sharks and rays threatened in Europe as there are threatened birds (Blanchard *et al.* 2017; Walls and Dulvy Submitted). NGOs have been doing as much as possible but, with few exceptions, most shark-focused NGOs are small and the larger NGOs have very few people working on shark policy (Shiffman *et al.* In Press). Like the rest of society, the larger NGOs are prone to economic shocks such as brought about by the 2008 global banking crisis and the COVID-19 pandemic, yet conservation does not attract the bailout that many businesses do (McCleery *et al.* 2020; Roman *et al.* 2009).

By the early 2000s, there was a solid foundation of science on and conservation of sawfishes, with: (1) the addition of the Smalltooth Sawfish (*Pristis pectinata*) to the US Endangered Species list in 2003 and (2) the 2003 American Elasmobranch Society (AES) symposium 'Sawfish: threats, biology, and conservation in the 21st century,' featuring 8 talks (Poulakis and Grubbs 2019). From this basis, the 2013 IUCN SSG sawfish workshop and resultant report galvanised research and conservation of sawfishes prompting a 2014 Symposium at Sharks International (Durban, South Africa, 9 talks), a 2016 AES symposium (New Orleans, USA; 40 presentations), and a second IUCN SSG planning workshop at Georgia Aquarium in 2017 (Fordham *et al.* 2018). This report prompted significant donor engagement, with Save Our Seas Foundation (SaveOurSeas.com) using the findings to prioritize at least $600,000 worth of sawfish searches over the next five years. Also, the GSRI developed an activity to, "Undertake a global sawfish search, deploying a variety of knowledge-gathering techniques by 2018, specifically to: identify target locations and opportunities for conservation action (traditional ecological knowledge surveys); rapidly assess sawfish presence/absence (eDNA techniques); and report sawfish catches (establish catch reporting network)" (Bräutigam *et al.* 2015).

As a further measure of growth in research and conservation activity, two volumes of sawfish papers have been produced: a virtual volume of the journal *Aquatic Conservation* spanning 2015–

2019 consisting of 12 papers (https://onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1099-0755.sawfish) and a 2018 volume of *Endangered Species Research* consisting of 25 papers produced from the 2016 AES workshop (Poulakis and Grubbs 2019). The growth in sawfish science has been near exponential, with 12 citations of the word 'sawfish' in 2000, 110 in 2010 and 615 by 2020 (ISI Web of Science, 22 May 2021). The momentum and donor interest prompted by the 2014 Sawfish report and subsequent activities has led to a massive uptick in searches for sawfishes. A recent review of sawfish research activity documented 251 activities from 64 nations between 2014 and 2019 from personal correspondences, published, and gray literature (Yan *et al.* 2021). This sawfish science has translated into some conservation progress. One of the main findings of the Georgia Aquarium workshop was that sawfishes were specifically protected in 19 of the 36 countries where sawfish populations are known to still occur (Fordham *et al.* 2018). But there are places with promising levels of sawfish abundance that have yet to enact protections, such as Mozambique, Papua New Guinea, and Bangladesh (Haque *et al.* 2020b; Leeney 2017; Leeney *et al.* 2018).

23.4.3. Global downscaling and multispecies regional planning

We made the case for multiscale conservation planning consisting of at least two tiers (Dulvy *et al.* 2016b). First, a global strategic 'situation analysis' to focus research and conservation capacity onto the issue and elevate the issue to the eyeline of donors and funding agencies. Second, identify regional priority locations for conservation. Our theory of change is that his will then unlock the national scale planning and conservation funding opportunities that have served terrestrial conservation well for decades. This approach has been used to identify 58 regional units of 8 species of marine turtle (Wallace *et al.* 2011; Wallace *et al.* 2010). The sawfish approach has followed this model and we are now wondering – what next? How do we bridge from 'lifeboats' and nearby 'beacons of hope' to national planning when there is no funding for planning?

There are tens of thousands of threatened species worldwide (37,480 are listed as Critically Endangered, Endangered, or Vulnerable on the Red List so far). A recommendation of the IUCN Conservation Planning Specialist Group is to move toward multispecies regional planning. In the tropics, we suggest centering on sawfishes, or rhino rays more generally, and incorporating other Critically Endangered and Endangered species. For example, in the Amazon Delta priority sawfish region, Brazil has 51 Endangered or Critically Endangered species, including Stingrays (in the genera *Fontitrygon*, *Dasyatis*, *Hypanus*), Daggernose Shark (*Isogomphodon oxyrhynchus*), Smalltail Shark (*Carcharhinus porosus*). Many of these species face common threats and would benefit from multispecies regional planning (Strongin *et al.* 2020). This is described as the Assess to Plan (A2P) approach by the IUCN Conservation Planning Specialist Group, in which IUCN Red List data is combined with expert knowledge of local partners to identify clusters of co-occurring species with similar conservation needs that can be addressed by the same constituency of actors or agencies (Lees *et al.* 2020). A preliminary examination of the new Red List Assessments reveals that many shallow tropical coastal species of requiem shark (Carcharhinidae) and Whip-tail stingrays (Dasyatidae) are threatened. Since these are the mainstay of many artisanal and industrial target and bycatch fisheries, we cannot escape the conclusion that there might be only one cluster and one systemic problem to be solved. The overwhelming challenge is a drastic reduction in fishing mortality is needed to avert both shark biodiversity and food security crises in countries with low adaptive capacity (Blanchard *et al.* 2017; Davidson and Dulvy 2017).

We also highlight the success of a "stepping-stone" approach which seems to be working for angel sharks in the Northeastern Atlantic and Mediterranean Sea. This planning approach started out from the last remaining stronghold of the Angelshark (*Squatina squatina*) in the Canary Islands (Barker *et al.* 2016). After this 4-day meeting, a fifth day was devoted to expanding the work out to all three species found in the wider region (Gordon *et al.* 2019; Gordon *et al.* 2017; Lawson *et al.* 2020). The greatest opportunities and complexities were in the Mediterranean Sea and there this report explicitly (i) laid out how this work related to a global and regional strategy, (ii) laid out future possible planning exercises at the same regional scale (Northeast Atlantic and west Africa), and (iii) identified SubRegional Action Plans (SubRAPs) spatially delimited by the planning units of the GFCM (General Fisheries Commission for the Mediterranean). This report laid out a process for developing and delivering a SubRAP. This has been highly successful for engaging new partners to fundraise for and lead SubRAP processes in other parts of the Mediterranean.

23.4.4. What is the role for MPAs?

As we enter the UN Decade of Ocean Science for Sustainable Development (www.oceandecade.org), there is significant momentum to develop new "30x30" targets for Marine Protected Areas (MPAs) (Jones *et al.* 2020). A challenge and opportunity is to ensure that these initiatives benefit sharks and rays. In sharp contrast to terrestrial vertebrates in which risk is greatest for the species with small ranges, in sharks the species with the largest ranges are often most at risk. This is likely because they span multiple jurisdictions and insufficient protection in any one country and / or on the high seas can undermine safeguards elsewhere (Dulvy *et al.* 2017). Over the past decade one-third of the growth of MPAs was driven by those designated for sharks (Davidson and Dulvy 2017). But these so-called 'shark sanctuaries' were put in locations based on political opportunity and 'pristineness', rather than based on any biodiversity or conservation priorities (Davidson 2012). These 'shark sanctuaries' were not MPAs in any sense of the IUCN classification of Protected Areas, but instead usually took the form of bans on targeting or retention by large-scale commercial fishing operations (Ward-Paige and Worm 2017). Further, they were situated in the 'low-hanging fruit' places of high abundance but relatively low diversity of coral reef sharks, and mostly in the western Pacific Ocean, and in most cases do not cover rays (Veitch *et al.* 2012; Ward-Paige 2017; Ward-Paige and Worm 2017). While it is increasingly clear that these 'shark sanctuaries' have lower fishing pressure and greater abundance of sharks (MacNeil *et al.* 2020; Ward-Paige and Worm 2017), it is also clear there is poaching, waning enforcement, and pressure to roll back regulations (Chapman *et al.* 2021; Cramp *et al.* 2018; Vianna *et al.* 2016). New surveillance technologies do hold promise for improved enforcement (Bradley *et al.* 2019). The challenge is two-fold – to make these existing 'shark sanctuaries' durable, expand their scope to include rays, and to ensure the race for 30% MPA coverage by 2030 protects endangered elasmobranch species.

Generally, larger species need more space and require larger protected area to protect enough of the population to remain viable (Dwyer *et al.* 2020; Newmark 1995; Tamburello *et al.* 2015). While large sharks need large protected areas, many species are small-bodied and have small geographic range sizes and are endemic to the waters of very few countries. Indeed, more than 200 species occur in the waters of only one country (Dulvy *et al.* 2017) and there are at least 99 threatened endemic species found in six hotspots in the waters of only 12 countries: (1) Colombia (2) Brazil-Uruguay-Argentina, (3) South Africa-Mozambique, (4) Australia, (5) Indonesia-Malaysia, and (6) China-Taiwan-Japan (Davidson and Dulvy 2017). These locations also harbor high richness of wide-ranging and the most evolutionary distinct species (Derrick *et al.* 2020). Indeed, focusing on endemic species, particularly in these six hotspot areas, means that only a small fraction of the 30% target is needed to save these sharks. For example, there are 63 endemic sharks and rays in the Western Indian Ocean and that protecting the top 10% priority sites will conserve almost half of the geographic range of each species yet require only 1.16% of the total EEZ (Cheok *et al.* 2021). A key finding of this work and other similar papers is that regional coordination in siting marine protected areas will always work better than uncoordinated 'random acts of kindness' (Cheok *et al.* 2021; Sala *et al.* 2021). Aside from coordinated action, lessons can be learned from marine mammal conservation and there is clear scope to follow the path of International Marine Mammal Areas (Hoyt and di Sciara 2021), though with the caveats that sharks are often more valuable for food and income from exploitation and trade and tackling of bycatch of cetaceans might be less challenging and have greater public support (notwithstanding the Vaquita example. The Key Biodiversity Area approach offers a yet-to-be unexplored opportunity for focussing on key life stages, such as breeding and feeding aggregations or nursery areas of key species (Edgar *et al.* 2008).

23.5 Summary and conclusions

Significant progress has been made in the past three decades of shark and ray conservation. The first decade saw shark finning spark global concern for sharks as wildlife, initiating global initiatives by CITES and FAO. The second decade saw the development of the first IUCN SSG global status report and the first comprehensive assessment of all species. The third decade has seen the transition to extensive evidence-based conservation planning and strong initial signs of action. Significant challenges remain, particularly in minimizing mortality of endangered species through catch and trade regulation and implementation of science-based catch limits for Vulnerable and Near Threatened species. Nevertheless, the initial stages of conservation planning have proven successful in mobilising the scientific community to find ways of gathering data on incredibly rare species and engaging conservation partners and donors to shift their agendas to support shark and ray conservation. The foundations have been laid for the coming decade of action to ensure significant progress toward systematically recovering sharks and rays by 2030.

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Table 1. A decade of conservation strategies, including spatial and taxonomic scale, vision, goal, and objectives.

Strategy	Spatial & Taxonomic scale	Vision	Goal / Objectives	Reference
Sawfish: a global Strategy for Conservation	Global, all five species	a world where all sawfishes are restored through understanding, respect, and conservation to robust populations within thriving aquatic ecosystems	Goal A: Robust sawfish populations where threats are minimised and/or mitigated. 5 Objectives: fisheries management (10 actions), Species Protection (7), Habitat Management (4), trade limitation (3), Strategic research (10). Goal B: Effective sawfish conservation and management achieved through capacity building, research, education, and outreach 4 Objectives: Education & communication (9 actions), Responsible husbandry (3), Sawfish network (3), Fundraising (3)	(Harrison and Dulvy 2014)
Saving Sawfish: Progress and Priorities	Regional, all five species	Same vision, objectives as above	Downscaled to a regional approach focusing on Caribbean, Western Indian Ocean & Australasia, pairing a lifeboat country with and adjacent beacon-of-hope	(Fordham *et al.* 2018)
Eastern Atlantic and Mediterranean Angel Shark Conservation Strategy	Regional, all three species	Angel sharks in the Eastern Atlantic and Mediterranean Sea are restored to robust populations and safeguarded throughout their range.	Goal 1: Minimise fisheries mortality (6 objectives) Goal 2: Identify & protect habitat (4 objectives) Goal 3: Minimise other negative shark-human interactions (4 objectives)	(Gordon *et al.* 2017; Lawson *et al.* 2020)

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Mediterranean Angel Sharks: Regional Action Plan	Regional, all three species	Mediterranean angel sharks are restored to robust populations fulfilling their ecological roles in healthy ecosystems.	Goal 1: Minimise fisheries mortality (4 objectives, 9 actions) Goal 2: Identify & protect habitat (4 objectives, 18 actions) Goal 3: National legislation for angel sharks is established, implemented & enforced (3 objectives, 14 actions)	(Gordon *et al.* 2019)
Angelshark Action Plan for the Canary Islands	Subnational, one species	Angelshark in the Canary Islands are abundant and protected in their unique stronghold.	Goal 1: Minimise fisheries mortality (3 objectives, 24 actions) Goal 2: Minimise threats in critical habitat (2 objectives, 7 actions) Goal 3: Minimise other negative shark-human interactions (2 objectives, 12 actions) Goal 4: Legal protection of species & habitat (7 objectives, 40 actions) Goal 5: Research (7 objectives, 21 actions) Goal 6: Communication (2 objectives, 13 actions)	(Barker *et al.* 2016)
Wales Angelshark Action plan	Subnational, one species	A thriving population of Angelshark in wales	Goal 1: Identify & protect habitat (3 objectives, 13 actions) Goal 2: Minimise fisheries mortality (4 objectives, 13 actions) Goal 3: Communication (8 objectives, 14 actions) Goal 4: Ensure 'connectivity' (4 objectives, 10 actions) Goal 5: Research (8 objectives, 24 actions)	(Barker *et al.* 2020)
Sympathy for the devil: a conservation	Global	Populations of devil and manta rays that flourish in resilient ocean	Goal A: Research (4 objectives, 15 actions) 4 Objectives: Taxonomy, biology, ecology, & strategic	(Lawson *et al.* 2017)

strategy for devil and manta rays		ecosystems, harmoniously with human communities, through knowledge, sustainability, and education.	Goal B: Devil and manta ray populations are maintained at, or recovered to, ecologically relevant levels by managing fisheries, trade, and demand 5 Objectives: fisheries management (15 actions), trade regulation (10), understand markets (8), trade limitation (3), Strategic research (10). Goal C: Goal C: Educated and engaged communities are supporting and benefiting from devil and manta ray conservation and management through improved livelihoods. X Objective: tourism (5), communities (5), livelihoods (4), network (5)	
Global Strategy for the Conservation of Sharks and Rays (2015-2025).	Global	Sharks and rays throughout the world are fulfilling their ecological roles, sustaining well-managed fisheries, and are valued by all for their critical contribution to ecosystem health and human well-being.	4 Strategies Saving species (9 substrategies) Sustainable fisheries (8 substrategies) Responsible trade (4 substrategies) Responsible consumption (6 substrategies)	(Bräutigam *et al.* 2015)