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Are we ready for elasmobranch conservation success?

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Conservation challenges facing elasmobranchs (sharks and rays) due to large population declines of many species are now widely recognized (Dulvy et al. 2017). Consequently, numerous conservation and management actions have been implemented (Davidson et al. 2016), and growing evidence suggests some species are showing signs of recovery (e.g., Peterson et al. 2017). While recovery is the intent of conservation policy and management actions, population increases can produce unforeseen challenges, particularly related to human social responses.

Recovery of some terrestrial species, particularly carnivorous predators (e.g., wolves), has produced negative reactions from a portion of the public. Opposition to predator recovery has even led to intentional killing of animals, producing an additional threat to species and hampering conservation efforts (e.g., Treves & Karanth 2003). It is clear that recovery efforts for some species will lead to inevitable increases in human–wildlife conflicts. Treves and Karanth (2003) suggest successful conservation of carnivores requires not only favourable ecological conditions, but also a tolerant socio-political landscape.

Given efforts towards conserving elasmobranchs, it is important to consider potential negative consequences of increased human–wildlife conflicts as recovery occurs. By identifying potential points of conflict and solutions to these challenges, chances of successful coexistence increase. We identify three forms of human–wildlife conflict related to the conservation of elasmobranchs: shark bites on humans; management conflicts involving threatened species; and depredation in fisheries. We then propose pathways critical for the development of solutions to these conflicts.

Real or perceived recovery of shark species that are potentially dangerous to humans (e.g., white sharks, *Carcharodon carcharias*) can result in conflict over conservation efforts. White sharks were protected in many countries during the 1990s, with some populations showing theoretical (Braccini et al. 2017) or actual signs of population increase (Curtis et al. 2014). The real and perceived threats to humans from species such as white sharks drive fear, which fuels controversy over conservation policies (McPhee 2012). This was illustrated in the case of the white shark, a federally protected species in Australia, following a cluster of fatal attacks; the Government of Western Australia introduced a range of initiatives to mitigate shark hazards, including setting drum lines, aerial patrols and using telemetry to determine when tagged white sharks were near beaches (McAuley et al. 2016). Public outcry over the setting of drum lines fuelled by several conservation organizations (e.g., Australian Marine Conservation Society 2014) and scientific input led to discontinuation of the programme. Gibbs and Warren (2015) found most 'ocean-users' opposed kill-based shark hazard management. However, in coastal regions where tourism and ocean use represent important sources of leisure and revenue, culling policies for managing human–shark encounters are prevalent (e.g., Australia, South Africa, Egypt, Russia, Seychelles and Mexico; Neff & Yang 2013), despite uncertain effectiveness in reducing risk (e.g., McPhee 2012). Non-lethal alternatives to managing human–shark conflict such as unmanned vehicles to monitor swimming areas of high use may be a strategy in managing these situations (Gallagher 2016).

Government-supported shark culling is not limited to protecting bathers from shark attacks. The Hawaiian monk seal (*Monachus schauinslandi*) is one of the world's rarest marine mammals and is listed under the US Endangered Species Act (Lowry et al. 2011). At French Frigate Shoals in the Northwestern Hawaiian Islands, up to 30% of monk seal pups are lost annually to predation by Galapagos sharks (*Carcharhinus galapagensis*) (Gobush 2010). In response, a shark culling programme was implemented to remove sharks targeting monk seals (Antonelis et al. 2006) based on the hypothesis that a small number of sharks exhibited this unusual predatory behaviour, and their removal would have minimal impact on the local shark population (Dale et al. 2011). This produced conflict between those concerned about monk seal pup survival and those concerned about the shark population. Members of the public also expressed concern that the programme ran counter to natural processes in wild areas (Lowry et al. 2011). Consequently, experiments to deter sharks from areas associated with monk seal pup mortality were conducted in lieu of lethal removals (Gobush & Farry 2012). This programme was designed to remove sharks from a population considered to be healthy at the time (Bennett et al. 2003); as such, it is plausible that recovery of other shark species could result in similar scenarios in other areas.

The recovery of shark populations and their interactions with threatened prey species can also lead to conflicts over both species. One example is interactions between white sharks and grey seals (*Halichoerus grypus*) in the northeast USA. Both populations were significantly depleted, but recent studies show increases for both species (Curtis et al. 2014, Wood LaFond 2009, respectively). Skomal et al. (2012) hypothesized that growing sightings of white sharks off Cape Cod (Massachusetts) combined with concurrent increases in attacks on grey seals were indicative of a change in white shark predatory behaviour. Grey seals frequent many areas along the coast of Massachusetts, some near popular swimming areas on Cape Cod. Consequently, Massachusetts Division of Marine Fisheries made efforts to increase public awareness in order to reduce risk of human–shark interactions that could negatively affect tourism in the region. This included erecting signs, printing brochures with shark safety tips and flying 'white shark flags' to notify bathers when sharks are present. A Nantucket-based group (Seal Abatement Coalition) even called for a seal cull and is lobbying Congress to remove grey seals from the list of species protected by the Marine Mammal Protection Act (Starobin 2013). This issue intensified recently as Massachusetts experienced its first fatal shark attack since 1936 (Mervosh 2018), and local authorities made calls for both seal culls (Anon 2018) and a 'shark hazard mitigation strategy' (Eustachewich 2017). The white shark population increase has thus led to issues for conservation of both white sharks and grey seals that will require ongoing conflict management for long-term conservation success for both species. Similarly, unmanned vehicles or human shark-spotters to monitor swimming areas of high use may be strategies in managing these situations (Gallagher 2016).

The third form of human–wildlife conflict is increased depredation in fisheries (i.e., sharks taking fish caught on or in fishing gear). A review of studies that quantified shark depredation in commercial and recreational fisheries shows increasing levels across some studies (Mitchell et al. 2018a). These increases in depredation rates, despite potential declines in many pelagic shark populations (Dulvy et al. 2008), suggest changing behaviour patterns in sharks that may intensify conflict with humans and hamper conservation efforts. In the waters off north-western Australia, where shark populations have recovered following the cessation of intensive foreign fishing in the 1980s and the closure of some domestic shark fisheries in the 2000s, recreational fishers report high depredation rates (Mitchell et al. 2018b), leading to calls for the reintroduction of shark fishing (Simpfendorfer unpublished data 2019). Reports from Pacific Island nations suggest recent increases in depredation are due to shark-specific or marine protected area legislation combined with decreased prey abundance as a result of increased industrial fishing efforts. Perceived increases in shark populations are attributed to increased depredation, with several communities intentionally killing sharks to reduce interactions (Cramp unpublished data 2019). Additionally, reports of great hammerhead sharks (*Sphyrna mokarran*) depredating Atlantic tarpon (*Megalops atlanticus*) in Florida recreational fisheries are increasing, particularly at popular tarpon fishing spots. Some anglers perceive sharks as increasing in abundance and therefore posing a threat to their catch (Drymon & Scyphers 2017). Whether increased shark depredation is due to a learned behaviour, decreased prey abundance, increased shark abundance, or all three factors, it has substantial economic and sociocultural impacts in commercial, recreational and subsistence fisheries (Mitchell et al. 2018a) and so must be considered as a source of conflict that may affect conservation efforts, especially where it leads to fishers killing sharks and/or lobbying against management measures. Increased stakeholder engagement, quantifying depredation rates and understanding socioeconomic drivers of when and where fishers choose to engage in retaliatory killing of sharks may help mitigate depredation.

Conservation and recovery of threatened elasmobranch species are clearly complicated by a number of factors (Dulvy et al. 2017). Many of these are well known and have been addressed many times before as conservationists and managers work to mitigate detrimental impacts on species. However, as the capacity to mitigate threats and to recover populations increases, the potential consequences of success must be considered. While widespread success in recovering elasmobranch populations is some time away, scientists, advocates and managers need to be prepared for societal conflicts that may arise when and where it does occur. In particular, implications for current and future conservation management need to be considered as part of conservation strategies in the context of how humans will interact and potentially compete with recovering species. This will require, from the outset, increased public education and outreach regarding the potential future implications of conservation success and strategies to reduce conflict in order to avoid negative responses to successful conservation outcomes or the thwarting of future conservation endeavours.

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