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COMMENTARY

Moving beyond lethal programs for shark hazard mitigation

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Human anxiety about predators is deeply embedded in our evolutionary history and psychology. Sharks, as archetype predators, attract a disproportionate amount of fear because of our poor ability to assess the real threat associated with 'fearsome' risks such as shark bites (Sunstein & Zeckhauser, 2011). This disconnection between reality and human imagination is illustrated by the extreme media attention that surrounds incidents of shark bite (Muter *et al.*, 2012) and the actual numbers of attacks that occur. Fatalities from shark bites remain much lower than in other recreational activities. For instance, in Western Australia, annual fatality rates from shark bite, at their highest, were 1.3 year^{-1} (2008–2013; Australian Shark Attack File, 2013; http://taronga.org.au/animals-conservation/conservation-science/australian-shark-attack-file/annual-australian-shark-attack-report-summary-2013), compared with cycling [average of 5 year^{-1} (2009–2013); www.bitre.gov.au/statistics/safety/fatal_road_crash_database.aspx] and ocean swimming [average of 12.5 year^{-1} (2008–2013); http://surflifesavingwa.com.au/documents/coastal-safety-web.pdf]. Analysis also suggests per capita incidents are declining in some locations such that any absolute increase in numbers of fatalities simply reflects growing human populations using coastal environments (Wetherbee, Lowe & Crow, 1994; West, 2011).

Despite the relatively low risk of fatalities, governments have invested significant economic and human resources in mitigating risk associated with shark bites. Historically, such strategies have largely relied on catch-and-kill programs with the goal of driving localized depletions of animals that are considered a threat to humans. Currently, lethal programs, largely based on nets, which started in the 1930s (New South Wales, Australia) and 1960s (Queensland, Australia and KwaZulu-Natal, South Africa), each catch between 600 and 1500 sharks annually. While the frequency of shark bite incidents has also declined over this period, due either to the nets themselves or broader issues relating to general declines in shark populations or environmental change, there is growing recognition of the high ecological costs of lethal programs, particularly in terms of bycatch of other harmless sharks and nontarget species including cetaceans, turtles and rays.

Irrespective of destructive bycatch, some of the most compelling reasons for moving beyond catch-and-kill programs for shark mitigation lie in our understanding of sharks themselves, their place in marine environments, their increasing economic value as a tourism resource and the fact that, as Hazin & Afonso (2014) show here, alternatives are now available. Sharks are highly susceptible to overexploitation with 15% of the world's species threatened (Dulvy *et al.*, 2014). Species targeted by lethal shark hazard mitigation programs are among some of the most vulnerable. We also know the oceans need sharks: as apex predators, they play critical roles in maintaining ecosystem structure and promoting resilience (Ferretti *et al.*, 2010). Healthy shark populations increasingly generate significant tourism dollars and associated economic benefits for local communities, including species usually considered 'dangerous' (Gallagher & Hammerschlag, 2012). Finally, improvements in our understanding of shark biology derived from, for instance, telemetry and neuroscience can underpin nonlethal mitigation strategies such as warning systems predicated on movements and deterrents (Hammerschlag, Gallagher & Lazarre, 2011; Huveneers *et al.*, 2013).

Hazin & Afonso (2014) demonstrate the practical value of nonlethal strategies as an alternative to the traditional policy of catch and kill. Following an upsurge in incidents with sharks and bathers in north-eastern Brazil, the Metropolitan Region of Recife deployed longlines and drumlines to capture and relocate sharks thought to be a threat. This and a companion paper (Hazin *et al.*, 2013) show that over a 4-year period, once potentially dangerous sharks had been captured and relocated, they tended to move away from protected beaches when released. Furthermore, mortality rates of bycatch not considered to be a threat to humans were generally much lower than in nets, as indeed was also the case for the target species. Importantly, when the program was in place, human interactions with sharks were very low, and increased at times when the program was suspended. Overall,

the nonlethal program reduced shark attacks by 97%, a rate greater than beach netting programs (88–91%; Dudley 1997).

Although the results of Hazin & Afonso's (2014) study are encouraging, they also raise some interesting questions. If simply removing dangerous sharks reduces the risk to beach users dramatically, why did a mitigation program in Hawaii that killed 4500 sharks over 16 years have little effect on incident rates (Wetherbee *et al.*, 1994)? Perhaps this contrasting result is an issue of scale, as the Hawaiian example operated over multiple islands within an archipelago, whereas the Brazilian program protected only a few kilometers of coast. In Recife, intensive capture and relocation over a small area may have driven localized depletions of dangerous sharks, an approach that could be limited by logistics and cost at larger spatial scales. However, the price tag of a nonlethal program does not just involve the funds required to mount a campaign of fishing sufficient to reduce the threat – it must also count the benefits that the presence of sharks can bring to ecosystem health and in some cases also to tourism. As we move to an increasingly wired ocean, the next steps are to build on this experience to improve and integrate surveillance and warning systems into mitigation strategies, but for the moment some gains are clear: Hazin & Afonso (2014) show that there are effective alternatives to a catch-and-kill approach to reduce the threat of sharks in coastal waters.

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