Animal Conservation

ZSL LET'S WORK FOR WILDLIFE

Animal Conservation. Print ISSN 1367-9430

REVIEW

Shark conservation and management policy: a review and primer for non-specialists

D. S. Shiffman[1] & N. Hammerschlag[1,2]

1 Leonard and Jayne Abess Center for Ecosystem Science and Policy, University of Miami, Coral Gables, FL, USA
2 Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL, USA

Keywords
sharks; elasmobranchs; overfishing; marine reserves; protected areas; fisheries; threatened species; conservation policy.

Correspondence
David Shiffman, Leonard and Jayne Abess Center for Ecosystem Science and Policy, University of Miami,1365 Memorial Dr #230, Coral Gables, FL 33146, USA.
Email: David.Shiffman@gmail.com

Editor: Nathalie Pettorelli
Associate Editor: Rob Williams

Received 05 October 2015; revised 08 December 2015; accepted 13 January 2016

doi:10.1111/acv.12265

Abstract

There is increasing concern for the conservation of sharks among scientists, environmental conservation advocates, and the interested public, but misunderstanding among policy non-specialists about which conservation and management policies are available, and which might work best for certain situations, persists. Here we present a review of fisheries management and conservation literature relating to sharks. Policies are broadly divided into target-based policies that aim for sustainable fisheries exploitation (e.g. fisheries quotas) and limit-based policies that aim to prevent all fisheries exploitation of entire taxa (e.g. marine reserves). A list of the pros and cons of each policy is included, as is a decision tree to aid in selection of the most appropriate policy. Our goal is that this paper will allow policy non-specialists, including scientists without policy training, environmental activists, and concerned citizens, to make informed decisions when advocating for shark conservation.

Introduction

Twenty-four percent of shark, skate and ray species are considered Threatened with extinction by the IUCN Red List's Shark Specialist Group (Dulvy *et al.*, 2014).The late age-at-maturity and low fecundity of sharks means that populations cannot recover from fishing pressure as quickly as commercially exploited teleost fishes (Hoenig & Gruber, 1990; Smith, Au & Show, 1998; Simpfendorfer & Kyne, 2009). Shark populations have decreased due to both targeted overfishing (Baum *et al.*, 2003; Dulvy *et al.*, 2008; Camhi, Valenti & Fordham, 2009) and bycatch (both discarded catch and incidental catch that is also sold, Molina & Cooke, 2012; Oliver *et al.*, 2015).

By one estimate, between 63 and 273 million sharks were killed in 2010 alone, which significantly exceeds the estimated population rebound rate (Worm *et al.*, 2013). Though markets exist for meat (for consumption), jaws (as tourist curios), and/or cartilage and liver oil (as alternative medicine), among the largest driving forces for shark fishing is to obtain fins for shark fin soup (Cunningham-Day, 2001; Speigel, 2001, Clarke, Milner-Gulland & Bjorndal, 2007). Shark fin soup is a traditional delicacy associated with royalty and wealth that is primarily consumed in China, but can be found in other Asian countries and their diaspora communities worldwide (Speigel, 2001; Clarke *et al.*, 2007). At least 126 countries catch sharks (Davidson, Krawchuk & Dulvy, 2015) with the top 20 responsible for approximately 80% of the global annual catch (Lack & Sant, 2011). The global annual value of trade in shark parts is approximately US$1 billion [Fisheries and Aquaculture Department (FAO), 2010], not counting illegal fisheries (e.g. Carr *et al.*, 2013).

As awareness of shark population declines increases, there has been increased public and professional interest in enacting legal protections for sharks (Simpfendorfer *et al.*, 2011; Lack & Sant, 2011; Techera & Klein, 2011; Hammerschlag & Gallagher, 2014). Many elasmobranch researchers report a desire to participate in the management process (Shiffman & Hammerschlag, 2015). However, some researchers are not sufficiently familiar with technical aspects of environmental policymaking needed to perform policy relevant research (Singh *et al.,* 2014). In some nations (including the United States), the concerned public is frequently presented with opportunities to influence fisheries management decisions as part of the policy implementation process (Simpfendorfer *et al.*, 2011), but many are misinformed about available shark conservation policies. Such a situation can lead to lost, misguided and/or wasted opportunities to affect shark conservation policy.

While there are numerous thorough environmental NGO reports (e.g. Lack & Sant, 2011) and a recent advanced textbook (Techera & Klein, 2014) that detail current advances in

shark conservation policy, there are few thorough primers available. Accordingly, here we provide a literature review and an introductory guide to the different available shark conservation and management policies and regulations, developed through our experience in performing conservation-relevant research and our extensive discussions with policy experts. For each policy, specific examples are provided, along with their advantages and disadvantages. These policies can be set by natural resources managers at a variety of geographic scales (Table 1), and examples of each are listed in Table 2. Though some examples are broadly applicable, the majority come from the United States, Australia and Canada, (three nations with a highly regulated shark fishery and a great deal of associated scientific research; Momigliano & Harcourt, 2014), and it is important to note that developing nations may not have these resources (therefore policies that work in the U.S., Australia or Canada may not be as effective in these countries). It is our goal that this paper will aid researchers without sufficient policy knowledge or training, as well as environmental advocates and the interested public, in making informed decisions when advocating for management.

Following Caddy & McGarvey (1996), in this review we broadly divide policy tools into target-based fisheries management policies that aim for the sustainable exploitation of some species and newer limit-based conservation policies that ban some kind of exploitation entirely without a species-specific focus (Table 3). 'Shark' is defined herein as extant members of subclass Elasmobranchii (class Chondrichthyes), not including the closely related rays and skates of the family Rajiformes (following Ebert, Fowler & Compagno, 2014). It should be noted that skates and rays are also in need of conservation (Dulvy *et al.*, 2014), and that many of the same tools described here could benefit them. It should also be noted that while these policies largely focus on commercial fisheries, recreational fisheries can pose a significant threat to some shark species and some of the same policies would work to regulate them (Shiffman & Hammerschlag, 2014).

Table 1 Organizations that can set conservation and management policy on different spatial scales

Organization	Authorities
State-level natural resource management agencies (U.S.) Ex: Florida Fish and Wildlife Conservation Commission (FWC).	Sets regulations governing fish exploitation in state waters (up to 3 miles from shore) Employ researchers who conduct scientific stock assessments of commercially exploited species, law enforcement officers
Interstate Fisheries Management Councils (U.S.) Ex: Pacific Fishery Management Council, (includes Oregon, Washington, California, Idaho)	Sets regulations governing exploitation of fish stocks that straddle state boundaries Set rules governing exploitation of fish stocks throughout U.S. exclusive economic zone (up to 200 miles from shore) Advisory councils include fishermen, conservation agencies, scientists
National-level natural resources management agencies Ex: National Marine Fisheries Service (U.S.)	Manages exploitation of fish stocks within U.S. exclusive economic zone in cooperation with Fisheries Management councils Employs scientists who conduct scientific stock assessments of commercially exploited species Create rebuilding plan for depleted species Enforce national-level ocean conservation laws
National governments (legislature or executive)	Create legislation or executive level marine conservation and management policies Ex: Magnusson-Stevens Fisheries Conservation Act (U.S.)
Regional Fisheries Management Organizations/RFMOs (International) Ex: International Commission for the Conservation of Atlantic Tunas (ICCAT)	International treaty agreements between nations that share a fish stock or between nations that all fish in the same geographic area Resolutions often non-binding Member nations must adjust their own national regulations to comply with RFMO agreements
Wildlife management and conservation treaties (international) Ex: Convention on International Trade of Endangered Species (CITES)	Regulates, restricts or bans international trade in threatened and endangered species Requires infrastructure and enforcement by member states.

Target-based fisheries management policy tools focusing on sustainable exploitation of sharks

Sustainable fisheries management aims to allow commercial fisheries exploitation but at a level that does not significantly negatively affect populations (FAO code of conduct for responsible fisheries; Techera, 2014). Both models and practical experience show that sustainable fisheries exploitation of sharks is possible (Walker, 1998; Klein, 2014; Worm, Cosandey-Godin & Davis, 2014), but there are few real-world examples, and most are small-bodied, fast-growing sharks exploited in developed nations with significant fisheries management infrastructure (e.g. a relatively atypical shark fishery). These include the Australian gummy shark (*Mustelus antarcticus*) fishery (Walker, 1998), the U.S. Atlantic blacktip (*Carcharhinus limbatus*) fishery (Fishwatch 2014, http://www.fishwatch.gov/profiles/atlantic-blacktip-shark) and the first shark fishery to obtain a marine stewardship council certification as sustainable [the Canadian Pacific spiny dogfish (*Squalus acanthias*) fishery; Lawrence, 2014]. Relatively few examples of sustainable shark fisheries targeting larger-bodied, slower growing sharks or occur in developing nations without significant fisheries management infrastructure.

Table 2 examples of different types of shark conservation and management policies

Policy type	Policy type	Law name	Sample text
Fin ratio	RFMO resolution	IATTC resolution C-05-03, 'Resolution on the conservation of sharks caught in association with the tuna fisheries of the Eastern Tropical Pacific' (2005)	*Participating members of IATTC* 'shall require their vessels to have onboard fins that total no more than 5% of the weight of sharks onboard, up to the first point of landing'
Naturally Attached *	National legislation (USA)	S 850, 'Shark Conservation Act' (2010)	*Amended the Magnuson-Stevens Fishery Conservation and Management Act to state that it is prohibited** 'to land any such fin that is not naturally attached to the corresponding carcass, or to land any shark carcass without such fins naturally attached'
Fin ban	State-level legislation (California, USA)	AB 376, 'An act to add Section 2021 to the Fish and Game Code, relating to sharks.' (2011)	*Adds the following to the California Fish and Game code:* 'Shark fin means the raw, dried, or otherwise processed detached fin or the raw, dried, or otherwise detached tail of an elasmobranch... it shall be unlawful for any person to possess, sell, offer for sale, trade, or distribute a shark fin'
Shark Sanctuaries	National legislation (Palau)	Senate Bill 8-105, 'Shark Haven Act' (2011)	'It is unlawful within the Republic of Palau's territorial waters, 6 contiguous zone, or exclusive economic zone for any person to catch, capture, or intentionally fish for... any shark, or any part of any such'
Species-specific catch and bycatch protection	RFMO resolution	IATTC resolution C-11-10, 'Resolution on the conservation of Oceanic whitetip sharks' (2011)	*Participating members of IATTC* 'shall prohibit retaining onboard, transhipping, landing, storing, selling, or offering for sale any part or whole carcass of oceanic whitetip sharks in the fisheries... [and] promptly release unharmed, to the extent practicable, whitetip sharks when brought alongside the vessel.'
Catch ban	Natural resource management agency (state level) rule	Florida Fish and Wildlife Conservation Commission (FWC) rule 68B-44, Florida administrative code 'Prohibited Species; Prohibition of Harvest, Landing, and Sale' (2012)	'No person shall harvest, possess, land, purchase, sell, or exchange any [*LIST OF PROHIBITED SPECIES*], or any part of any of these species.'

*The US Shark Conservation Act prohibits landed sharks without fins naturally attached with the exception of the smooth dogfish.

Sections (Limited entry, total catch, and gear restrictions, Species-specific area management, Shark finning policies, Species-specific catch and trade restrictions, National plans of action for sharks) review the most common target-based policies used for sharks.

Limited entry, total catch, and gear restrictions

Permits

A government permit is often required in order to fish for sharks (or to sell sharks caught as bycatch). For example, the United States Atlantic Highly Migratory fisheries management plan for sharks requires that fishermen obtain (and renew annually) a permit for directed or incidental take of sharks (National Marine Fisheries Service, 2006). For example, in 2011, there were 217 'directed shark' and 262 'incidental shark' permits issued for the U.S. Atlantic shark fishery (numbers which provide some sense of the scale, if not the total impact, of one shark fishery). Some fisheries are 'limited entry,' i.e., not everyone who wishes to participate in the fishery is granted a government permit to participate, which can allow regulators to better monitor and control the scale of a fishery. However, overcapacity of fishing fleets is a problem facing global fisheries in general (Pauly, 2009), and simply limiting the number of fishing vessels participating in a fishery does not necessarily limit total catch without the inclusion of

Table 3 Delineations of different policies between target-based and limit-based

Policy	Reason for categorization
Target-based	Allows sustainable exploitation for species which can withstand it
Permits	Helps limit catch to sustainable levels, but does not ban catch
Quotas/Trip Limits	Limits catch to sustainable levels, but does not ban catch
Gear restrictions	Reduces bycatch but does not ban all exploitation
Time/Area closures	Protects important aggregations but doesn't ban all exploitation
Finning ban: Fin to carcass ratio	Limits waste and cruelty associated with the fin trade, don't ban the fin trade
Finning ban: fins naturally attached	Limits waste and cruelty associated with the fin trade, don't ban the fin trade
Species-specific catch/trade restrictions	Protects threatened species but allows for exploitation of others
National Plan of Action (NPOA) Sharks	Overall plan for sustainable fisheries management
Limit based	Bans all exploitation of sharks, not species-specific
Fin bans	Bans a major use of shark products to stop a reason for exploitation
Marine reserves	Bans all fisheries exploitation of sharks and other species
Shark Sanctuaries	Bans all fisheries exploitation of sharks

quotas, because new technology and increasingly efficient fishing methods can lead to increased catch per vessel, i.e., 'effort creep' (Kompas & Gooday, 2007).

Quotas and trip limits

The fishery for an individual shark species or species group can be regulated by a quota or total allowable catch, a maximum quantity (usually expressed in weight, not number of sharks) that can be exploited in a year. For example, the U.S. Atlantic Highly Migratory Species shark fishery has a trip limit of 36 large coastal sharks (several species of sharks managed together in a single quota by the U.S. National Marine fisheries service including bull *Carcharhinus leucas*, lemon *Negaprion brevirostris*, nurse *Ginglymostoma cirratum*, silky *C. falciformis*, spinner *C. brevipinna* and tiger sharks *Galeocerdo cuvier*) (Stone *et al.*, 1998). At the state, national, and international level, most natural resource agencies and Regional Fisheries Management Organizations (RFMOs) have scientific committees which recommend measures that would allow for sustainable exploitation, which may or may not be followed (Crosson, 2013). Additionally, minimum size limits designed to restrict exploitation before they reach reproductive maturity, or maximum size limits designed to protect the largest breeding females, are sometimes established. A potential problem with this policy is that quotas can lead to 'high-grading,' discarding less valuable catch and switching it for more valuable catch while keeping total landings within the quota.

Gear restrictions and modifications

Restricting specific types fishing gear can affect the species of sharks captured, as well as the quantity. Following a coastal gillnet ban in California in 1994, populations of local shark species that had suffered high gillnet bycatch mortality increased (e.g. soupfin shark *Galeus galeus* and leopard shark *Triakis semifasciata;* Pondella & Allen, 2008). Simple changes such as altering the material of longline leaders can allow sharks to bite through and escape if captured, and changing the type of bait used can result in differences in species attracted to the hook in the first place (Gilman *et al.*, 2007; Ward *et al.*, 2008). Adding 'escape grates' to trawl nets resulted in 88% of spiny dogfish caught as bycatch being released, (Chosid *et al.*, 2012). Putting electromagnetic materials on longline hooks reduced bycatch of juvenile sandbar shark *Carcharhinus plumbeus* by 2/3 (Brill *et al.*, 2009). Other gear modifications (e.g. fishing depth of gear, hook type, net size), can also lead to reductions in shark bycatch (Kerstetter & Graves, 2006; Gilman *et al.*, 2007; Ward *et al.*, 2008). Using circle hooks instead of J-hooks may reduce bycatch mortality, as the shape of the circle hook reduces the chance of a hook causing internal injury if swallowed (Kerstetter & Graves, 2006), and other hook designs are intentionally weak so a hooked shark can break free. Research on technology to reduce bycatch is still in an early phase (Oliver *et al.*, 2015), and many gear modifications are voluntary.

Species-specific area management

Time-area closures are specific geographic areas closed to fishing during specific periods of time to temporarily protect certain species during vulnerable periods. Many time-area closures are associated with nursery areas (Heupel & Carlson, 2007), migratory routes, or aggregations for feeding and mating (Hoyt, 2014). Australia, for example, enacts time-area closures to protect gummy sharks from fishing mortality on their way to pupping grounds, which successfully reduced pup mortality. A disadvantage is that this tool can shift fishing pressure on animals outside the time-area closure, because restricting fishing in some areas does not restrict total effort (O'Keefe, Cadrin & Stokesbury, 2013). Time-area closure may also disproportionately affect certain life-history stages outside of the closed area (Wiegand, Hunter & Dulvy, 2011).

Shark finning policies

Finning

Many shark fins are obtained through 'finning', in which fishers catch sharks, cut the fins off the often still alive animals, and dump the carcasses back overboard (Speigel, 2001). The term finning is commonly (but erroneously) used as a synonym for shark fishing of any kind, for removing fins on land, or for the international trade in shark fins, but

the term finning only refers to removing fins at sea and discarding the carcass at sea. Though prohibited in many developed nations, finning still occurs both legally and illegally. For example, in the year 2000, out of 1.6 million tons of sharks caught, Worm *et al.* (2013) estimated that 900 thousand tons of shark were discarded after being finned. Finning complicates other management regulations, as species identity (as well as age, sex and reproductive status) is not easily determined from detached fins (however, see Doukakis *et al.*, 2011 for a genetic guide and SharkFinID.com for a training program for Customs personnel). Many early shark conservation campaigns focused on finning rather than unsustainable fisheries overexploitation in general (Lawrence, 2014).

Finning bans: fin to carcass ratios

Some nations attempt to ban shark finning through 'fin to carcass ratios,' which allow fishers to remove fins at sea if the total weight of fins landed does not exceed a certain ratio (typically 5%) of the total weight of shark carcasses landed concurrently (Biery & Pauly, 2012). This restricts finning while allowing some processing flexibility to the fishing industry. The actual ratio of fin weight to carcass weight varies widely by shark species and by fin removal procedure, which is rarely reflected in fisheries policies (Biery & Pauly, 2012; Santana-Garcon, Fordham & Fowler, 2012). This allows fishermen to land more fins than should be permitted according to the spirit of these policies (Clarke *et al.*, 2013). Only one commercially exploited shark species in U.S., the smooth dogfish *Mustelus canis* is governed by a fin ratio policy, an unusually high 12%.

Fin ratios do not restrict fishing pressure or total catch; complementary regulations are required (Clarke *et al.*, 2013). Additionally, fishers can potentially capture prohibited species and retain their fins through 'high grading,' switching the fins of prohibited but more valuable species for those of the species they legally land the carcasses of.

Finning bans: fins naturally attached

Regulations requiring sharks to be landed with 'fins naturally attached' make removal of fins at sea illegal even if the carcass is retained, which allows natural resource managers to better identify species-specific catch rates. (Lack & Sant, 2011). This is considered preferable relative to fin ratios or allowing finning (Fowler, Seret & Clarke, 2010; Biery & Pauly, 2012). However, these regulations govern how a shark is killed, not how many are killed, and therefore require complementary management tools if the goal is restricting total catch (Clarke *et al.*, 2013).

Species-specific catch and trade restrictions

Some species of sharks are protected from exploitation entirely within a given political boundary, or by any fishers associated with a country or RFMO that made the rule. Additional protection for particularly threatened species has long been considered a part of sustainable fisheries management. Species with local catch bans in place in multiple countries include the great white *Carcharodon carcharias*, the whale shark *Rhincodon typus*, the basking Shark (*Cetorhinus maximus* Gunnerus 1765), and several species of sawfishes (Camhi *et al.*, 2009). In U.S. Atlantic waters, while many species of sharks can be exploited by fishers, 19 threatened species are protected from exploitation. Individual U.S. states can implement additional rules, such as Florida adding tiger sharks and three species of hammerhead sharks (*Sphyrna* sp.) to their list of prohibited species in 2012, but these protections do not extend to adjacent Federal waters (Gallagher *et al.*, 2014*a*).

In addition to prohibited species lists, there are national-level conservation laws which protect threatened species while allowing exploitation of co-occurring species, such as the Endangered Species Act (ESA) in the United States. The National Marine Fisheries Service (NMFS) can list a species as Endangered or Threatened, which provides strong legal protections for that species, due to any of a variety of factors including overexploitation by humans and inadequacy of existing regulatory mechanisms (Daves & Nammack, 1998). To date, the Smalltooth *Pristis pectinata* and Largetooth *Pristis microdon* sawfish and some populations of the scalloped hammerhead *Sphyrna lewini* are the only elasmobranchs to have received ESA protection (Lack & Sant, 2011). ESA protection and the associated recovery plan for smalltooth sawfish resulted in a ban on the use of gill nets in their critical habitat area. Some protections focus on requiring release when caught rather than avoiding capture, these may be less effective if capture is likely to result in mortality (Gallagher *et al.*, 2014*a*). The NMFS recently denied a petition to list great white sharks due to evidence that the species is recovering and thus was not threatened with imminent extinction (Burgess *et al.*, 2014; Curtis *et al.* 2014).

Threatened species can be protected via the Convention on International Trade in Endangered Species (CITES) Appendix I, which means a general ban on commercial international trade, and Appendix II, which require that trade be monitored and regulated (Daves & Nammack, 1998). Eight species of sharks are currently listed on CITES Appendix II (great white shark, whale shark, basking shark, oceanic whitetip shark *Carcharhinus longimanus*, porbeagle shark *Lamna nasus*, and scalloped, smooth and great hammerhead sharks), in addition to both species of manta rays (*Manta* sp.) and all seven species of sawfishes. A listing on Appendix I of the Convention on Migratory Species (CMS) obligates parties to strictly protect species, while an Appendix II listing obligates some level of international cooperation in the management of that species (Edwards, 2008; Lack & Sant, 2011). In 2010, 36 nations signed a CMS 'memorandum of understanding' which stressed the need for international cooperation and called for stronger management policies for migratory sharks whose movements pass between several national political boundaries, but this memorandum included few specifics and was non-binding (Klein, 2014). CMS Appendix II listings have cur-

rently not led to any binding international agreements to protect migratory sharks (Edwards, 2008).

Species-specific regulations may reduce or prohibit exploitation of threatened species while still allowing for sustainable exploitation of co-occurring species with healthier populations. The disadvantages are that they do not alleviate other stressors, including the use of fishing gears that can cause bycatch mortality of prohibited species. Many international resource treaties, such as CITES, CMS and some RFMOs, are voluntary for nations to join, and some allow for participating nations to opt out. Negotiations incorporate politics in addition to the biology of exploited species, potentially resulting in conservation plans that are weaker than necessary to protect threatened species (Lack, 2014).

National plans of action for sharks

In 1999, the UN FAO Committee on Fisheries (COFI) adopted the International Plan of Action for Sharks (IPOA), which suggests content for shark fishing nations to include in their National Plans of Action for sharks (NPOA). NPOAs should strive to accomplish ten general goals related to sustainable fisheries, and include basic information about a nation's shark fauna, fisheries and management capabilities. It was recommended that by 2001, all shark fishing nations should create draft NPOAs, but as of 2011, only thirteen of the top twenty fishing shark fishing nations (and only fourteen total nations) had completed draft NPOA (Lack & Sant, 2011).

Limit-based conservation policies focusing on banning all exploitation of sharks

Many historical shark fisheries collapsed within decades (Cunningham-Day, 2001; Campana, Joyce & Marks, 2008) and have still not recovered despite decades of target-based management. For example, more than 50 years after the poorly managed soupfin shark fishery in California collapsed due to overexploitation during the 1940s, populations still have not recovered (Camhi *et al.*, 2009). Accordingly, newer management policies that ban some kind of exploitation entirely to promote healthy sharks populations without a species-specific focus, termed here as 'limit-based conservation' policies following Caddy & McGarvey (1996) are gaining support.

Fin bans

Fin bans make it illegal to buy, sell, possess or trade shark fins regardless of species, nation of origin or whether they came from finning. Fin bans are relatively easy to enforce compared to other types of fin restrictions; if a shark fin is sold, it is illegal, and therefore there is no need to determine how and where it was caught or whether the shark is a prohibited species (http://agendaminutes.calgary.ca/sirepub/item.aspx?itemid=24053). These policies also attract high levels of public engagement (online petitions for these policies regularly get thousands of signatures) and the resulting media coverage can raise public awareness of shark conservation in general.

Fin bans' inherent limitations mean that they cannot accomplish what many supporters claim in public statements advocating for these policies. They do not prevent sharks from being caught, killed and sold as long as the fins are not sold. The U.S. states and Canadian cities which have enacted fin bans are not the largest consumers or suppliers of shark fin soup, raising questions about whether these policies significantly reduce global supply or demand while removing fins obtained from well-managed shark fisheries from the marketplace (Lawrence, 2014). This may result in fins from less sustainably managed fisheries filling the demand. Additionally, many U.S. fin bans have an exception for smooth and/or spiny dogfish that is rarely mentioned in advocacy or media coverage. The terms 'fin bans' and 'finning bans' are often incorrectly used interchangeably, and are also incorrectly treated as synonymous with bans on killing sharks entirely.

Fin bans can show that shark fin soup is incompatible with local values, which may discourage use elsewhere by associating consumption with social stigma (Lawrence, 2014). However, this may also be perceived as culture-based discrimination (e.g. the moratorium on commercial whaling, which has been perceived as cultural discrimination by some Japanese groups, increasing resistance to change; Ackerman, 2002).

No-take marine protected areas ('reserves')

No-take marine protected areas (MPAs), often termed marine reserves, are defined here as regions where all fishing is banned. Most marine protected areas do not protect against all fishing despite a widespread belief that they do, and no-take reserves are a comparatively rare type of marine protected area. Shark Sanctuaries, described later, are essentially a subset of reserves that only apply to commercial shark fishing. No-take marine reserves are just one type of marine protected area, and terminology delineating different types can be inconsistent and confusing. The IUCN categories of protected area, which range from IA 'strict nature reserve' to VI 'protected area allowing sustainable use of natural resources,' provide a good general framework (Dudley, 2008). Many protected areas, regardless of IUCN category, can be broadly characterized as 'paper parks' (i.e. protections on paper that are not actually enforced in the real world; Rodriguez & Rodriguez-Clark, 2001), and it is important that protected area regulations be enforced (which requires enforcement resources) so that they can effectively accomplish their goals. These areas can also prevent other types of stressors that can affect sharks. However, some can increase recreational use of these areas, potentially increasing stressors such as boat traffic and noise (Codarin *et al.*, 2009).

Populations of relatively small fishes within strongly protected reserves have been shown to rapidly recover from fisheries exploitation (Norse, 2010). Studies showing benefits for larger, more migratory species like sharks are more rare (e.g. Howey-Jordan *et al.,* 2013; Graham *et al.,* 2016), but sometimes show that protecting part of a migratory corridor

is effective even if the entire habitat range isn't protected (e.g. Pichegru *et al.*, 2010; Young *et al.*, 2015). Reserves can benefit the habitat itself as well non-target species, unlike target-based policies which only manage the species targeted by fisheries. When resources are available, reserves may be relatively easy to enforce; there is no need to determine whether observed fishers are following specific regulations, if a boat is fishing, it is illegal. However, effectiveness varies, with highest effectiveness found with large, well-enforced and isolated reserves that have been in existence for at least a decade (Edgar *et al.*, 2014).

Reserves do not allow for sustainable fishing within their boundaries. Sustainable exploitation of fishes immediately outside reserve boundaries may occur through 'spillover effects,' but there is no evidence yet supporting this for sharks. Although many species may move out of the borders of the reserves, a well-designed reserve can protect areas used during critical life history phases (Knip, Heupel & Simpfendorfer, 2012; Hoyt, 2014) or areas with relatively high shark populations. There is no issue of at-vessel or post-release bycatch mortality for sharks, problems that can be associated with other management tools.

Unfortunately, the boundaries of reserves are often based on political, not biological, factors, which can complicate their effectiveness (Halpern, 2014). Enforcement can also be an issue; for example, although most of the Galapagos is a reserve, illegal shark fishing is still occurring (Carr *et al.*, 2013). Illegal fishing in a reserve may be lower than legal levels of fishing outside, which would mean that the reserve is still successfully reducing exploitation, but is not yet quantified.

Shark sanctuaries

Nationwide bans on all commercial shark fishing, termed 'Shark Sanctuaries' in advocacy campaigns, are a new policy tool, particularly popular for island nations (Pew Environment Group, 2012, Chapman *et al.*, 2013). Due to their size, they are comparable to Very Large Marine Protected Areas (Maxwell, Ban & Morgan, 2014), but with a taxa-specific focus. Some Shark Sanctuaries allow artisanal or recreational fishing, or small-scale fishing by locals, with variable definitions between Sanctuaries. Though Israel and Congo banned shark fishing many years earlier, the first country to be referred to as a Shark Sanctuary in advocacy campaigns was Palau in 2009.

Shark Sanctuaries can protect key life-history phases of vulnerable shark species. They also can protect lesser known shark species that may not get protection in target-based fisheries due to lower public support. Sanctuaries may be supported by local cultural values (i.e. traditional respect for sharks among some Pacific island cultures). Sanctuaries can reduce or prevent the removal of threatened species (though bycatch can remain a problem), which can occur even in well-regulated fisheries that use indiscriminate fishing gear. In one respect, Shark Sanctuaries are relatively easy to enforce if resources are available, because managers can quickly identify any captured shark as illegal without having to identify the species, capture location or fishing gear in question.

The small island nations which have created Sanctuaries to date rarely have the natural resource management agency resources (such as boats) to adequately patrol such large areas of ocean (Davidson, 2012). Ports can still be regulated, but this does not restrict transshipment at sea, and the lack of enforcement at sea can lead to 'paper parks' that may not accomplish their goals (Dulvy, 2013). Several cases of illegal fishing in Shark Sanctuaries have been detected and properly enforced (http://www.pewtrusts.org/en/about/news-room/news/2013/02/05/enforcing-laws-of-the-worlds-shark-sanctuaries), though it is unknown how much illegal fishing is not detected or enforced (also true of other fisheries management techniques). Concerns about small island nations' ability to enforce Shark Sanctuaries may also apply to their ability to enforce traditional fisheries management policies and regulations.

Unlike reserves, Shark Sanctuaries are a relatively new and understudied policy. There are currently no systematic scientific evaluations of their effectiveness (Hoyt, 2014). However, an early analysis shows that the Sanctuary in the Maldives has not been well implemented due to lack of stakeholder involvement in planning, and is not accomplishing all of its shark consumption reduction goals (Ali & Sinan, 2014). As with quotas focusing only on sharks, Shark Sanctuaries do not necessarily restrict other types of fishing, which may result in overexploitation of sharks' natural prey, or even accidental shark mortality due to bycatch. For example, hammerhead shark have a pronounced stress response when fighting on a fishing line (even for short periods of time), which results in at-vessel or post-release mortality (Gallagher *et al.*, 2014*a*,*b*). Cumulative impacts including pollution and habitat degradation, which may be permitted in Shark Sanctuaries, can also indirectly affect sharks.

While the long-term effectiveness of Sanctuaries is relatively unexplored, many of the countries that have established Sanctuaries to date have not been major fishing nations—the British Virgin Islands, for example, have reported exporting just 3 tons of shark since 1950 (Davidson *et al.*, 2015). The establishment of a Shark Sanctuary is reported to have stopped the establishment of commercial shark fisheries in the Bahamas (Hepp & Wilson, 2014) and in Palau (http://www.mvariety.com/regional-news/20660-senate-kills-bill-eyeing-repeal-of-anti-shark-fishing-law), however.

In 2011, the Bahamas declared their exclusive economic zone a Sanctuary. However, the Bahamas had already banned longline fishing, the primary gear type used for commercial shark fishing, more than 20 years earlier. This longline ban led to a relatively healthy population of sharks in Bahamian waters, compared to the rest of the Caribbean (Ward-Paige & Lotze, 2011), but it is currently unclear what additional advantage is obtained by the 2011 Shark Sanctuary designation beyond ensuring that a proposed new fishery will not be established. This could affect future advocacy if the health of the Bahamian shark populations is attributed to the Sanctuary and not the earlier longline ban; though the effect is functionally the same, one occurred decades earlier which could lead to advocates incorrectly believing that a Shark Sanctuary can rapidly rebuild shark populations.

Conclusions: priorities for management and advocacy

Numerous policies and regulations exist for the conservation and management of sharks. Current management is relatively effective in some countries, but overall management plans remain fragmented and patchy, with numerous gaps as well as areas of overlapping (and conflicting) protection (Techera & Klein, 2011). The wide distribution and highly migratory nature of many shark species means that a fragmented management regime can have negative consequences. A comprehensive, well-managed and sustainable fishery for sharks is a challenge, but is a commonly stated goal in shark fisheries management and conservation literature (Table 4). To date, fisheries with certain characteristics are much more sustainable than others, but fisheries with these characteristics are relatively rare.

To avoid overfishing, a well-managed shark fishery requires scientific research on the life history, population status and habitat usage of target species. Indeed, one of the biggest hurdles to well-managed shark fisheries besides political will and enforcement resources is the lack of basic biological data on the target species. Some developed countries have performed extensive research of this kind, but fewer studies have occurred in developing nations which may have higher shark biodiversity and fewer management resources (Lack & Sant, 2011). For example, in the past 20 years, 261 papers focusing on life history and population status have been published focusing on the U.S. and Australia, but only 9 focusing on Indonesia, the world's top shark fishing nation by biomass exploited (Momigliano & Harcourt, 2014). Equivalent data from the same species in a better-studied region may or may not be an effective substitute, as life history characteristics can vary between populations. Such data can be difficult to obtain for reasons either logistical or ethical in the case of rare or threatened sharks (Hammerschlag & Sulikowski, 2011).

A sustainable fishery also requires significant enforcement resources, which can take the form of vessel patrols at sea, mandatory onboard observers, inspections in ports, or a variety of electronic vessel monitor systems. The top 20 shark fishing nations vary widely in the availability of this kind of fisheries management infrastructure (Lack & Sant, 2011; Momigliano & Harcourt, 2014). When selecting an appropriate management policy or regulation (Fig. 1), local availability of fisheries management infrastructure, including but not limited to scientific research and enforcement capability, should be considered.

Sustainable exploitation is not possible for all species of sharks or in all circumstances, and such a determination should use a precautionary approach. Creating and enforcing science-based quotas requires infrastructure that may not be available in developing countries. Similarly, some policies like large-scale marine reserves may not be politically possible in areas with economically important fisheries. Therefore, it is important that these tools be used to complement existing conservation and management policy rather than attempt to replace it all (Hoyt, 2014).

One policy tool alone is not going to be a 'silver bullet' for all species (Fig. 2). The most effective conservation practice will be species, stock, location and fishery specific. Effective global shark conservation will require a variety of different and complementary policy tools to succeed.

Table 4 General priorities for the conservation and management of sharks, synthesized from fisheries and conservation literature as well as IUCN Shark Specialist Group and TRAFFIC reports

Priority	Reference
All shark fishing nations should be required to complete a thorough National Plan of Action, which should be publicly accessible, and reviewed and revised as appropriate	Lack & Sant (2011)
Only species whose populations and life history can support a fishery should be targeted.	Stone *et al.* (1998)
Shark fishing quotas should be set for every species targeted by a fishery, and quotas should be based on scientific advice. In the absence of reliable data, a precautionary approach should be taken.	Stone *et al.* (1998)
Scientific monitoring and evaluation (fishery independent as well as logbook and port sampling) of shark populations, particularly those species which are a major component of fisheries and those species which are currently evaluated as Threatened, or Data Deficient by the IUCN Shark Specialist Group, should be a priority.	Simpfendorfer *et al.* (2011)
Appropriate steps should be taken to reduce bycatch, including (but not limited to) seasonal or regional bans on certain types of fishing gear	Oliver *et al.* (2015)
All sharks should be landed with fins naturally attached. Fins should not be landed without carcasses or according to a fin : carcass weight ratio. Full use of carcasses should be encouraged over wasteful use of fins only.	Biery & Pauly (2012).
Shark species which are particularly threatened should be granted special protections throughout their ranges, including (but not limited to) reduced quotas or catch and trade bans	Lack & Sant (2011)
All shark fisheries should be required to report the species composition of their catch	Lack & Sant (2011)
Marine protected areas or time/area closures should be created in appropriate areas	Heupel & Simpfendorfer (2005)
For migratory species, international cooperation combined with analogous domestic management plans throughout their range is required	Techera & Klein (2011)

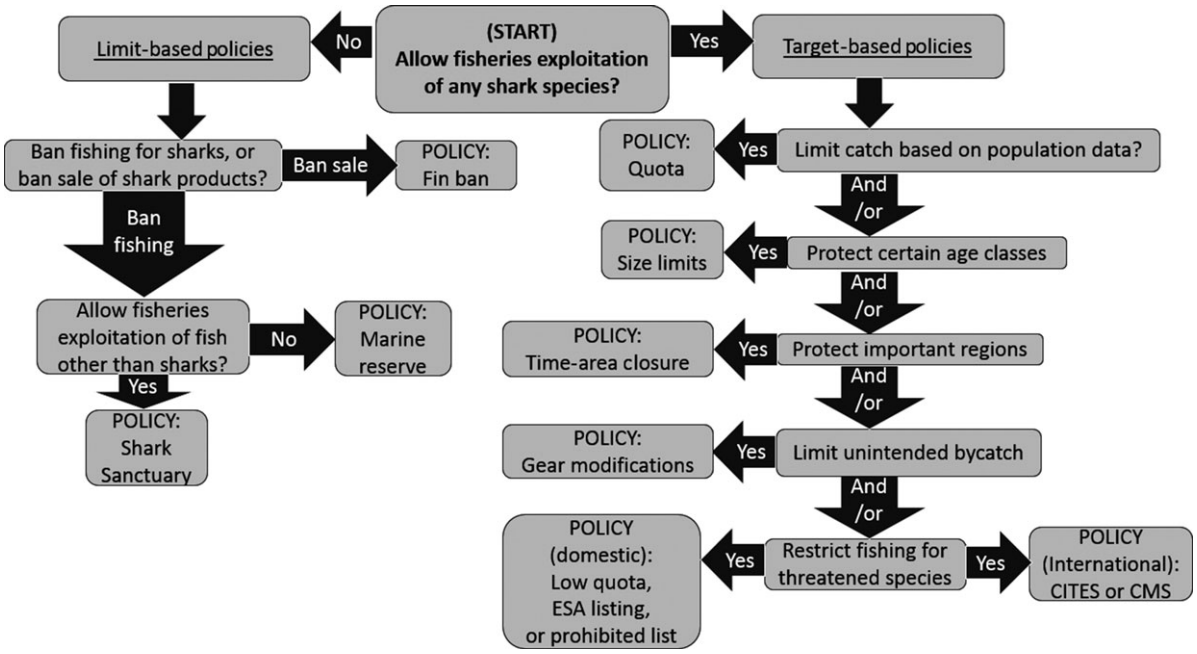

Figure 1 A flowchart demonstrating the primary differences between the goals of the available shark conservation and management policies. To use this chart, begin at the top centre box, answer the questions in each box, and follow the black arrows containing those answers to the appropriate policy.

	Permits	Quotas	Gear restrictions	Time/area closure	Fin:Carcass Ratio	Fins naturally attached	Species harvest ban	CITES Appendix I	CITES Appendix II	Endangered species act	Size limit	Fin bans	Marine reserve	Shark sanctuary
Allows for fisheries exploitation of some species	X	X	X	/	X	X	X	X	X	X	X	/		
Regulates total catch/control scale of fishery	X	X		/			/	/	/		/			
Regulates harvest of particularly threatened species		X							X		/			
Bans all harvest of particularly threatened species		/					X	X						
Bans harvest of all species of sharks				/									X	X
Bans all fishing in an area				/									X	
Reduces unintended bycatch			X	/									X	
Reduces inhumane and wasteful practice of finning					/	X							X	X
Restrict or ban the sale of shark fins												X		
Protects important life history stages/regions			X								X		X	X
Requires detailed scientific data	/	X	X	X			X	X	X	X	X		/	

Figure 2 Characteristics, advantages and disadvantages of different policies. An X means that the characteristic (row) typically applies to that policy (column), a/means that it may or may not apply to that policy or may apply to other species in the region not specifically included in that policy, and no mark means that it typically does not apply. All policies require enforcement and monitoring, though in different forms.

Acknowledgments

The authors thank the other members of author DS's dissertation committee, Dr. Mike Heithaus, Dr. Andy Binder, Dr. Nick Dulvy, and Gina Maranto. The authors also thank Sonja Fordham of Shark Advocates International for her assistance, and thank Dr. Sara Maxwell, one anonymous referee, and the editors of Animal Conservation for their helpful suggestions to strengthen the manuscript during peer review. Funding supporting this research came from The Guy Harvey Ocean Foundation and The Batchelor Foundation.

References

Ackerman, R.B. (2002). Japanese whaling in the Pacific Ocean: Defiance of international whaling norms in the name of scientific research, culture, and tradition. *BC Int'l Comp. L.* **25**, 323–341.

Ali, K. & Sinan, H. (2014). Shark ban in its infancy: successes, challenges and lessons learned. *J. Mar. Biol. Ass. India* **56**, 34–40.

Baum, J.K., Myers, R.A., Kehler, D.G., Worm, B., Harley, S.J. & Doherty, P.A. (2003). Collapse and conservation of shark populations in the Northwest Atlantic. *Science* **5605**, 389–392.

Biery, L. & Pauly, D. (2012). A global review of species-specific shark-fin-to-body-mass ratios and relevant legislation. *J. Fish Biol.* **80**, 1643–1677.

Brill, R., Bushnell, P., Smith, L., Speaks, C., Sundaram, R., Stroud, E. & Wang, J. (2009). The repulsive and feeding-deterrent effects of electropositive metals on juvenile sandbar sharks (Carcharhinus plumbeus). *Fish. Bull.* **107**, 298–307.

Burgess, G.H., Bruce, B.D., Cailliet, G.M., Goldman, K.J., Grubbs, R.D., Lowe, C.G., Macneil, M.A., Mollet, H.F., Weng, K.C. & O'Sullivan, J.B. (2014). A re-evaluation of the size of the white shark (Carcharodon carcharias) population off California, USA. *PLoS ONE* **6**, e98078.

Caddy, J.F. & McGarvey, R. (1996). Targets or limits for management of fisheries? *N. Am. J. Fish Manage.* **16**, 479–487.

Camhi, M., Valenti, S. & Fordham, S. (2009). The conservation status of pelagic sharks and rays. Report of the IUCN Shark Specialist Group, Newbury.

Campana, S., Joyce, W. & Marks, L. (2008). The rise and fall (again) of the porbeagle shark population in the Northwest Atlantic. In *Sharks of the Open Ocean*: 445–461. Pikitch, E., Babcock, E.A. & Camhi, M.D. (Eds). Oxford: Blackwell Publishing.

Carr, L.A., Stier, A.C., Fietz, K., Montero, I., Gallagher, A.J. & Bruno, J.F. (2013). Illegal shark fishing in the Galapagos Marine Reserve. *Mar. Policy* **39**, 317–321.

Chapman, D.D., Frisk, M.J., Abercrombie, D.L., Safina, C., Gruber, S.H., Babcock, E.A. & Feldheim, K.A. (2013). Give shark sanctuaries a chance. *Science* **339**, 757.

Chosid, D.M., Pol, M., Szymanski, M., Mirarchi, F. & Mirarchi, A. (2012). Development and observations of a spiny dogfish Squalus acanthias reduction device in a raised footrope silver hake Merluccius bilinearis trawl. *Fish. Res.* **114**, 66–75.

Clarke, S.C., Milner-Gulland, E.J. & Bjorndal, T. (2007). Social, economic, and regulatory drivers of the shark fin trade. *Mar. Resour. Econ.* **22**, 305–327.

Clarke, S.C., Harley, S.J., Hoyle, S.D. & Rice, J.S. (2013). Population trends in Pacific oceanic sharks and the utility of regulations on shark finning. *Conserv. Biol.* **27**, 197–209.

Codarin, A., Wysocki, L.E., Ladich, F. & Picciulin, M. (2009). Effects of ambient boat noise on hearing and communication in three fish species living in a marine protected area. *Mar. Poll. Bull.* **58**, 1880–1887.

Crosson, S. (2013). The impact of empowering scientific advisory committees to constrain catch limits in U.S. fisheries. *Sci. Public Policy* **40**, 261–273.

Cunningham-Day, R. (2001). *Sharks in danger: global shark conservation status with reference to management plans and legislation*. Parkland: Universal Publishers.

Curtis, T.H., McCandless, C.T., Carlson, J.K., Skomal, G.B., Kohley, N.E., Natanson, N.J., Burgess, G.H., Hoey, J.J. & Pratt, H.L. (2014). Seasonal distribution and historic trends in abundance of White Sharks, *Carcharodon carcharias,* in the Western North Atlantic Ocean. *PLoS ONE* **9**, e99240.

Daves, N.K. & Nammack, M.F. (1998). U.S. and International mechanisms for protecting and managing shark resources. *Fish. Res.* **39**, 223–228.

Davidson, L.N.K. (2012). Shark sanctuaries: substance or spin? *Science* **338**, 1538.

Davidson, L.N.K., Krawchuk, M.A. & Dulvy, N.K. (2015). Why have global shark and ray landings declined:improved management or overfishing?. *Fish Fish.* (Online DOI: doi: 10.1111/faf.12119).

Doukakis, P., Hanner, R., Shivji, M., Bartholomew, C., Chapman, D., Wong, E.G. & Amato, G. (2011). Applying genetic techniques to study remote shark fisheries in Northeastern Magagascar. *Mitochon. DNA* **22**, 15–20.

Dudley, N. (Ed.) (2008). *Guidelines for applying protected area management categories*. Gland, Switzerland: International Union for the Conservation of Nature.

Dulvy, N.K. (2013). Super-sized MPAs and the marginalization of species conservation. *Aquat. Conserv.* **23**, 357–362.

Dulvy, N.K., Baum, J., Clarke, S., Compagno, L.J., Cortes, E., Domingo, A., Fordham, S., Fowler, S., Francis, M.P., Gibson, C., Martinez, J., Musick, J.A., Soldo, A., Stevens, J.D. & Valenti, S. (2008). You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays. *Aquat. Conserv.* **18**, 459–482.

Dulvy, N.K., Fowler, S.L., Musick, J.A., Cavanaugh, R.D., Kyne, P.M., Harrison, L.R., Carlson, J.K., Davidson, L.N.K., Fordham, S.V., Francis, M.P., Pollock, C.M.,

Simpfendorfer, C.A., Burgess, G.H., Carpenter, K.E., Compagno, L.J.V., Ebert, D.A., Gibson, C., Heupel, M.R., Livingstone, S.R., Sanciangco, J.C., Stevens, J.D., Valenti, S. & White, W.T. (2014). Extinction Risk and Conservation of the world's sharks and rays. *eLife* **3**. (Online DOI: doi: 10.7554/eLife.00590).

Ebert, D.A., Fowler, S. & Compagno, L. (2014). *Sharks of the World*. Plymouth: Wild Nature Press.

Edgar, G.J., Stuart-Smith, R.D., Willis, T.J., Kininmonth, S., Baker, S.C., Banks, S., Barrett, N.S., Becerro, M.A., Bernard, A.T., Berkhout, J., Buxton, C.D., Campbell, S.J., Cooper, A.T., Davey, M., Edgar, S.C., Forsterra, G., Galvan, D.E., Irigoyen, A.J., Kushner, D.J., Moura, R., Parnell, P.E., Shaers, N.T., Soler, G., Strain, E.M. & Thomson, R. (2014). Global conservation outcomes depend on marine protected areas with five key features. *Nature* **506**, 216–220.

Edwards, H. (2008). When predators become prey: the need for International Shark Conservation. *Ocean Coast. Law* **12**, 305.

FAO Fisheries and Aquaculture Department (2010). *The state of world fisheries and aquaculture*. Rome: Food and agriculture organization of the United States.

Fowler, S., Seret, B & Clarke, S. (2010). Shark fins in Europe: implications for reforming the EU finning ban. Report of the IUCN Shark Specialist Group. Available at: https://cmsdata.iucn.org/downloads/sharks_fins_in_europe_implications_for_reforming_the_eu_finning_ban.pdf

Gallagher, A.J., Serafy, J.E., Cooke, S.J. & Hammerschlag, N. (2014a). Physiological stress response, reflex impairment, and survival of five sympatric shark species following experimental capture and release. *Mar. Ecol. Prog. Ser.* **496**, 207–218.

Gallagher, A.J., Orbesen, E.S., Hammerschlag, N. & Serafy, J.E. (2014b). Survival and vulnerability of pelagic shark species to pelagic longline bycatch. *Biol. Conserv.* **1**, 50–59.

Gilman, E., Kobayashi, D., Swenarton, T., Brothers, N., Dalzel, P. & Kinan-Kelly, I. (2007). Reducing sea turtle interactions in the Hawaii-based longline swordfish fishery. *Biol. Conserv.* **129**, 19–28.

Graham, F., Rynne, P., Estevanez, M., Luo, J., Ault, J.S. & Hammerschlag, N. (2016). Use of marine protected areas and exclusive economic zones in the subtropical western North Atlantic Ocean by large highly mobile sharks. *Diversity Distrib*. (Online DOI: doi: 10.1111/ddi.12425).

Halpern, B.S. (2014). Conservation: Making marine protected areas work. *Nature* **506**, 167–168.

Hammerschlag, N. & Sulikowski, J. (2011). Killing for conservation: the need for alternatives to lethal sampling of apex predatory sharks. *End. Spec. Res.* **14**: 135–140.

Hammerschlag, N. & Gallagher, A.J. (2014). Shark declines fuel for a decade of conservation effort. Ocean views. National Geographic online. Available at: http://voices.nationalgeographic.com/2013/11/18/sharkdeclines-fuel-for-a-decade-of-conservation-effort/ (accessed January 2016).

Hepp, J. & Wilson, E.G. (2014). Shark conservation efforts: as diverse as sharks themselves. In *Sharks: conservation, governance and management*: 176–195. Techera, E.J. & Klein, N. (Eds). New York: Earthscan press.

Heupel, M. & Carlson, J. (2007). Shark nursery areas: concepts, definition, characterization and assumptions. *Mar. Ecol. Prog. Ser.* **337**, 287–297.

Heupel, M. & Simpfendorfer, C. (2005). Using acoustic monitoring to evaluate MPAs for shark nursery areas: the importance of long-term data. *Mar. Tech. Soc. J.* **39**, 10–18.

Hoenig, J. & Gruber, S.H. (1990). Life-history patterns in the elasmobranchs: implications for fisheries management. NOAA Technical Report. National Marine Fisheries Service, Silver Spring, MD.

Howey-Jordan, L.A., Brooks, E.J., Abercrombie, D.L., Jordan, L.K., Brooks, A., Williams, S., Gospodarczyk, E. & Chapman, D.D. (2013). Complex movements, philopatry and expanded depth range of a severely threatened pelagic shark, the oceanic whitetip (*Carcharhinus longimanus*) in the western North Atlantic. *PLoS ONE* **8**, e56588. (Online DOI: doi: 10.1371/journal.pone.0056588).

Hoyt, E. (2014). The role of marine protected areas and sanctuaries. In *Sharks: conservation, governance and management*: 236–261. Techera, E.J. & Klein, N. (Eds). New York: Earthscan press.

Kerstetter, D.W. & Graves, J.E. (2006). Effects of circle versus J-style hooks on target and non-target species in a pelagic longline fishery. *Fish. Res.* **80**, 239–250.

Klein, N. (2014). The existing global legal regimes. In *Sharks: conservation, governance and management*: 27–45. Techera, E.J. & Klein, N. (Eds). New York: Earthscan press.

Knip, D.M., Heupel, M.R. & Simpfendorfer, C.A. (2012). Evaluating marine protected areas for the conservation of tropical coastal sharks. *Biol. Conserv.* **148**, 200–209.

Kompas, T. & Gooday, P. (2007). The failure of command and control approaches to fisheries management: lessons from Australia. *J. Glob Env. Issues* **7**, 174–190.

Lack, M. (2014). Challenges for international governance. In *Sharks: conservation, governance and management*: 46–66. Techera, E.J. & Klein, N. (Eds). New York: Earthscan press.

Lack, M. & Sant, G. (2011). The future of sharks: a review of action and inaction. TRAFFIC report. TRAFFIC International and the Pew Environment Group, Cambridge.

Lawrence, A. (2014). Collaborations for conservation. In *Sharks: conservation, governance and management*: 135–156. Techera, E.J. & Klein, N. (Eds). New York: Earthscan press.

Maxwell, S.M., Ban, N. & Morgan, L.E. (2014). Pragmatic approaches for effective pelagic marine protected area management. *End. Spec. Res.* **26**, 59–74.

Molina, J.M. & Cooke, S.J. (2012). Trends in shark bycatch research: current status and research needs. *Rev. Fish Biol. Fish* **22**, 719–737.

Momigliano, P. & Harcourt, R. (2014). Shark conservation, governance and management: the science-law disconnect. In *Sharks: conservation, governance and management*: 89–106. Techera, E.J. & Klein, N. (Eds). New York: Earthscan press.

National Marine Fisheries Service (2006). Final consolidates Atlantic highly Migratory Species Fishery Management Plan. National Marine Fisheries Service, Silver Spring, MD.

Norse, E.A. (2010). Ecosystem-based spatial planning and management of marine fisheries: why and how? *Bull. Mar. Sci.* **86**, 179–195.

O'Keefe, C.E., Cadrin, S.X. & Stokesbury, K.D. (2013). Evaluating effectiveness of time/area closures, quotas/caps, and fleet communications to reduce fisheries bycatch. *ICES J. Mar. Sci.* **71**, 1216–1218.

Oliver, S., Braccini, M., Newman, S.J. & Harvey, E.S. (2015). Global patterns in the bycatch of sharks and rays. *Mar. Pol.* 86–97.

Pauly, D. (2009). Beyond duplicity and ignorance in global fisheries. *Sci. Mar.* **73**, 215–224.

Pew Environment Group. (2012). *Navigating global shark conservation: current measures and gaps*. Washington, DC: Pew Environment Group.

Pichegru, L., Gremillet, D., Crawford, R.J.M. & Ryan, P.G. (2010). Marine no-take zone rapidly benefits endangered penguin. *Biol. Let.* **6**, 498–501.

Pondella, D.J. & Allen, L.G. (2008). The decline and recovery of four predatory fishes from the Southern California Bight. *Mar. Biol.* **154**, 307–313.

Rodriguez, J.P. & Rodriguez-Clark, K.M. (2001). Even paper parks are important. *Trends Ecol. Evol.* **16**, 17.

Santana-Garcon, J., Fordham, S. & Fowler, S. (2012). Blue shark Prionace glauca fin-to-carcass-mass ratios in Spain and implications for finning ban enforcement. *J. Fish Biol.* **80**, 1895–1903.

Singh, G.G., Tam, J., Sisk, T.D., Klain, S.C., Mach, M.E., Martone, R.G. & Chen, K.M.A. 2014. A more social science: barriers and incentives for scientists engaging in policy. *Front. Ecol. Environ.* **12**: 161–166.

Shiffman, D.S. & Hammerschlag, N. (2014). An assessment of the scale, practices, and conservation implications of Florida's charterboat-based recreational shark fishery. *Fish.* **39**, 395–407.

Shiffman, D.S. & Hammerschlag, N. (2015). Preferred conservation policies of shark researchers. *Conserv. Biol*. (online DOI: doi: 10.1111/cobi.12668)

Simpfendorfer, C. & Kyne, P. (2009). Limited potential to recover from overfishing raises concerns for deep-sea sharks, rays and chimaeras. *Env. Conserv.* **36**, 97–103.

Simpfendorfer, C.A., Heupel, M.R., White, W.T. & Dulvy, N.K. (2011). The importance of research and public opinion to conservation management of sharks and rays: a synthesis. *Mar. Fresh. Res.* **62**, 518–527.

Smith, S.E., Au, D.W. & Show, C. (1998). Intrinsic rebound potentials of 26 species of Pacific sharks. *Mar. Fresh. Res.* **49**, 663–678.

Speigel, J. (2001). Even Jaws Deserves to Keep His Fins: Outlawing Shark Finning Throughout Global Waters. *Bos. Coll. Law. Rev.* **24**, 409–437.

Stone, R.B., Bailey, C.M., Mclaughlin, S.A., Mace, P.M. & Schulze, M.B. (1998). Federal management of US Atlantic shark Fisheries. *Fish. Res.* **39**, 215–221.

Techera, E.J. (2014). Approaches to conservation and governance of marine species. In *Sharks: conservation, governance and management*: 9–26. Techera, E.J. & Klein, N. (Eds). New York: Earthscan press.

Techera, E.J. & Klein, N. (2011). Fragmented governance: Reconciling legal strategies for shark conservation and management. *Mar. Pol.* **35**, 73–78.

Techera, E.J. & Klein, N. (Eds) (2014). *Sharks: conservation, governance and management*. New York: Earthscan Press.

Walker, T.I. (1998). Can shark resources be harvested sustainably? A question revisited with a review of shark fisheries. *Mar. Fresh. Res.* **49**, 553–572.

Ward, P., Lawrence, E., Darbyshire, R. & Hindmarsh, S. (2008). Large-scale experiment shows that nylon leaders reduce shark bycatch and benefit pelagic longline fishers. *Fish. Res.* **90**, 100–108.

Ward-Paige, C.A. & Lotze, H.K. (2011). Assessing the value of recreational divers for censusing elasmobranchs. *PLoS ONE* **6**, e25609.

Wiegand, J., Hunter, E. & Dulvy, N.K. (2011). Are spatial closures better than size limits for halting the decline of the North Sea thornback ray? *Mar. Fresh. Res.* **62**, 722–733.

Worm, B., Davis, B., Kettemer, L., Ward-Paige, C.A., Chapman, D., Heithaus, M.R., Kessel, S.T. & Gruber, S.H. (2013). Global catches, exploitation rates, and rebuilding options for sharks. *Mar. Pol.* **40**, 194–204.

Worm, B., Cosandey-Godin, A. & Davis, B. (2014). Fisheries management and regulations. In *Sharks: conservation, governance and management*: 286–308. Techera, E.J. & Klein, N. (Eds). New York: Earthscan press.

Young, H.S., Maxwell, S.M., Conners, M.G. & Shaffer, S.A. (2015). Pelagic Marine Protected Areas Provide Effective Habitat Protection for Multiple Seabird Species. *Biol. Conserv.* **181**, 226–235.