



A global overview of shark sanctuary regulations and their impact on shark fisheries



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ABSTRACT

Due to rapid declines of shark populations across many species and regions of the world, the need for large-scale conservation measures has become widely recognized. Some coastal states have opted to implement ‘Shark Sanctuaries’, which prohibit commercial shark fishing and the export of shark products across large areas, typically their entire Exclusive Economic Zones. Although shark sanctuaries cover almost as much area globally as marine protected areas (MPAs), their success has yet to be evaluated. Here, key features and regulatory details for eleven shark sanctuaries (covering 3% of global ocean area) are summarized, highlighting their commonalities and differences. Catch data are then used to shed light on the impact current shark sanctuaries could have on shark catch, foreign fleets, trade and abundance. Based on this comparative analysis, recommendations are made to implement program evaluation measures within existing and future shark sanctuaries that would explicitly outline goals and measures of success or failure. In summary, although shark sanctuaries may have the intended effect of reducing shark mortality, there appears a need to address bycatch within shark sanctuary regulations, and to collect baseline data that can be used to monitor sanctuary effectiveness.

1. Introduction

Many shark populations have undergone rapid declines [1–3], leaving numerous species threatened with extinction [4] and large areas depleted of sharks despite former abundance [5–7]. The primary cause of these declines is overexploitation [4] – both targeted and incidental, i.e. via unintended bycatch, such that present rates exceed population rebound rates in many regions [8,9]. Other substantial drivers of decline include habitat degradation, persecution and climate change [4]. Slow life history characteristics also mean that recovery can be slow, even where strong conservation strategies exist, and few depleted populations show signs of recovery [10]. Although the type and degree of threat differs by region and species, the primary driver behind targeted shark fishing has been for fins, which fetch a relatively high price [11]. Because fins are more valuable than carcasses, there is economic incentive to keep only the fins and discard the rest, called ‘shark finning’. In this way, even small boats catch and land a large number of shark fins before having to offload their catch, which exacerbates overexploitation. Although fins remain highly valued, expanding markets for shark meat have also contributed to an increase in targeted shark fishing [12].

In response to this myriad of issues, a number of conservation strategies have been implemented to curb overexploitation. For exam-

ple, shark finning prohibitions are widely used, but often lack enforcement, or contain loopholes [13–15]. Shark fin bans make it unlawful to possess, sell, trade, or distribute shark fins (e.g., in Hawaii, Oregon, California; regulations available at <http://www.sharkdefenders.com/p/shark-conservation-laws.html>) but have limited spatial extent and do not address shark bycatch or transshipment. More multifaceted rules, such as quotas, trip limits and size restrictions, aim to protect sharks for long-term sustainable use, but these are generally part of more complex rules, and compliance can be a challenge (http://www.fisheries.noaa.gov/sfa/hms/compliance/guides/documents/rec_sharks.pdf). Protected areas (e.g., marine protected areas) that protect many species, including the special case of shark reserves (e.g., Fiji's Shark Reef Marine Reserve and the Raja Ampat Shark Sanctuary) provide ecosystem-based approaches to conservation that can protect sharks [5,16], but are not typically large enough to cover the movement of many shark species through their lifetimes [17]. And, very recently, the Port State Measures Agreement went into force, which aims to tackle all forms of illegal, undocumented and unreported (IUU) fishing, including for sharks (<http://www.fao.org/port-state-measures/background/en/>).

To be effective, conservation strategies such as those mentioned above, require dedicated resources. At a minimum, educational programming (e.g., of the regulations, spatial boundaries, and species identification), monitoring for compliance on- and offshore, and

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enforcement, including the time to follow through with penalties in the case of non-compliance are essential [18,19]. As well, to enable sustainable shark fishing, adequate in-situ species-specific population data, scientific expertise, and complete and accurate reporting amongst fishers are needed to set science-based sustainable catch limits. Establishing each of these can be a challenge for many states, especially for those with expansive and remote ocean territories, small human populations, or significant fishing by foreign fleets.

Additionally, some individuals in the commercial shark fin business have been found to be persistent in their search for unexploited and unprotected shark populations to meet demands and will exploit policy loopholes, as well as fish illegally [8,13]. Some fin distributors have readily acknowledged their role in the diminished status of shark populations, admitting that these declines increase profit margins – stating that they still hold on to basking shark fins despite their current value because “they’ll be worth more when they are extinct” (CWP personal observation). As such, global exploitation and threat risk to sharks remains high [4,8] and IUU shark fishing remains a global threat [12].

In light of these challenges, alternative shark conservation tactics may be needed to match local threats and needs, as well as available data and resources. The details of these policies may also encompass community values and traditions, which can determine whether more or less severe rules and penalties are implemented. As a prominent example, a number of jurisdictions have implemented bans that specifically prohibit the targeting and retention of sharks and shark parts within entire Economic Exclusive Zones (EEZ). These so-called ‘Shark Sanctuaries’ vary in detail (Table 1, 2), but all prohibit targeted commercial shark fishing at a minimum, and intend to make it unlawful to possess, sell, or trade sharks or their parts (<http://www.pewtrusts.org/en/research-and-analysis/fact-sheets/2016/03/shark-sanctuaries-around-the-world>).

Although the first shark sanctuary was only established in 2009 in Palau, shark sanctuaries have already been criticized as a conservation tactic. These concerns include being limited to states with certain socioeconomic features (e.g., dependence on dive tourism), insufficient enforcement, overexploitation and degradation of other resources not included in the shark sanctuary regulations, and diversion of resources from other fisheries management and conservation measures [20–22]. In response to these criticisms, it has been argued that this type of moratorium can in fact be more easily be enforced than other conservation tactics through trade export monitoring, and effectively prevents overexploitation [23].

Here, the key features of eleven current shark sanctuaries and the regulations that comprise them are summarized, highlighting commonalities and differences. The impact these sanctuaries may have on shark catch, foreign fleets, trade and abundance are then investigated using historical reconstructed catch data obtained from the Sea Around Us Project [24], which include officially reported catch data with best estimates of both landed and discarded catch. Finally, recommendations are made for improved program evaluation within existing and future shark sanctuaries.

2. Current shark sanctuaries

At the time of writing, eleven EEZs were considered ‘Shark Sanctuaries’ (Tables 1, 2, Fig. 1). These large-scale regulations have been enacted as independent laws, amendments to national fisheries acts, or as declarations – herein called ‘regulations’. The first national shark sanctuary was declared in 2009 by Palau. Since then, ten others have followed, with the most recent being enacted by the Federated States of Micronesia in 2015. Although St. Maarten, the Cayman Islands, Curacao, and Grenada have also recently (June 2016) declared that they will close their EEZs to commercial shark fishing, details have not yet been made public. The total area covered by existing shark sanctuaries is 15,610,219 km², which equates to about 3% of the

world’s ocean area. The total shelf area is 345,466 km², representing about 2% of the total shark sanctuary area. The vast majority (88%) of shark sanctuary area is in the tropical Pacific, covering a total of 13,742,401 km² including the Republic of Palau, the Marshall Islands, French Polynesia, the Cook Islands, New Caledonia, and the Federated States of Micronesia. The Caribbean has the second largest area including Honduras, the Bahamas and the British Virgin Islands, covering 951,807 km². The Indian Ocean has a total of 916,011 km² sanctuary area, all within the Maldives.

Current shark sanctuaries occur across a wide range of geographic, social and economic settings (Table 1). For example, two sanctuaries were declared by sparsely populated island nations – with < 25,000 people in the Cook Islands and Palau – while Honduras has more than 8 million people, and the Maldives have one of the highest population densities in the world [25]. The number of people per square kilometre of ocean territory ranges from fewer than 0.1 in half the sanctuaries to almost 40 in Honduras [25]. Although diverse in many aspects, sanctuaries have so far been enacted in coastal states with medium to high inequality-adjusted human development indices [IHD; [26]] and developing economies [27]. These states tend to have relatively high life expectancy, education, and income per capita, but often have only limited resources for science, monitoring, and enforcement.

Important industries across shark sanctuaries include fishing, fish processing, transshipment, and tourism, and shark meat is listed as a top commodity in French Polynesia (as of 2013, Table 1). Tourism ranks among the most profitable industries for most shark sanctuaries, except for Honduras and New Caledonia. The type of tourism is not specified; however, an Internet search showed that there are dive shops in all sanctuaries, but that there are fewer than 10 in most (Table 1). Although shark dive tourism is economically valuable [see [28]], the prevalence of dive tourism does not appear to be a strong common thread, suggesting that each state has unique motivations for implementing a shark sanctuary.

3. Details of shark sanctuary amendments

The details of shark sanctuary policies importantly determine the extent to which a shark sanctuary may protect, or rebuild shark populations. With the exception of making commercial shark fishing illegal and banning the sale of shark products, the details vary widely (Table 2). Some of the regulatory documents are extensive (47-pages in the Marshall Islands), while others are short 2-page summaries (French Polynesia and New Caledonia). There are differences in the reasons provided for implementing a shark sanctuary, specification or severity of penalties, exemptions for some species or some fishers, inclusion of rays and chimaeras, treatment of bycatch or transshipment, among others. Differences in the details of the regulations may be due to the government’s priorities, individuals within the government organization, existing fishing regulatory structure, political realities (e.g., corruption, stakeholder influence), difference in perceived regional need, social and cultural considerations, among others. Ideally, the language and details also evolved to incorporate knowledge of lessons learned from previous sanctuary designations.

Table 2 summarizes details of the regulatory documents, highlighting some of the commonalities and differences. Below, is summary of each descriptor listed in Table 2, with a few excerpts to provide context to what may or may not be included. Note that these comments and quotes are not exhaustive and readers are referred to the original sources for details (found at <http://www.sharkdefenders.com/p/shark-conservation-laws.html>).

3.1. Reasoning

Reasons for choosing a shark sanctuary as a conservation strategy are outlined in five of the regulatory documents, and these vary from general terms regarding global concern for sharks, to local concerns for

Table 1
Key features of present Shark Sanctuaries. Included are states that have amendments to national fisheries acts that prohibit targeted commercial shark fishing at a minimum, and have language aiming to make it unlawful to possess, sell or trade sharks or their parts. EEZ - Exclusive Economic Zone covers a band from shore up to 200 nm, where each has rights to explore and exploit, conserve and manage resources.

Country	EEZ area (km ²)	Shelf area (km ²)	Human Population	Urbanization (%)	Ocean Density (per km ²)	GDP (PPP; million)	GDP (per capita PPP)	Exports (million)	Dive tourism (number of dive shops)	Exports (commodities)	Industries
Bahamas	628,026	117,344	324,597	83	0.517	\$9166	\$25,200	\$976	15	Crawfish	Tourism, maritime industries, transshipment
British Virgin Islands (UK)	80,111	3093	33,454	46	0.418	\$500	\$42,300	\$25	7	Fresh fish	Tourism
Caribbean Netherlands	24,866	437									
Cook Islands	1,960,027	1213	9838	75	0.005	\$244	\$12,300	\$3	4	Fish, pearls and pearl shells	Tourism, fishing
French Polynesia	4,771,088	27,653	282,703	56	0.059	\$7150	\$26,100	\$230	7	Cultured pearls, mother-of-pearl, shark meat	Tourism, pearls
Honduras	218,804	61,050	8,746,673	55	39.975	\$41,060	\$4900	\$7759	25	Shrimp, lobster	NA
Maldives	916,011	31,488	393,253	46	0.429	\$5191	\$14,900	\$301	26	Fish	Tourism, fish processing, shipping, coral and sand mining
Marshall Islands	1,992,022	20,891	72,191	73	0.036	\$175	\$3200	\$54	6	Fish	Tuna processing, tourism, seashells, pearls
Micronesia (Federated States of)	2,992,415	26,076	105,216	22	0.035	\$306	\$3000	\$88	4	Fish	Tourism, specialized aquaculture, craft items (shell)
New Caledonia (France)	1,422,596	52,754	271,615	70	0.191	\$11,100	\$38,800	\$1565	6	Fish	NA
Palau	604,253	3467	21,265	87	0.035	\$272	\$15,100	\$19	9	Shellfish, tuna	tourism, craft items (shell, pearls)

EEZ and shelf area from Sea Around Us project – from Pauly and Zeller [24].
Human population, Urbanization, GDP, Exports, Industries – from Central Intelligence Agency Worldfact Book (CIA [25]).
Dive tourism – derived from Google Searches for “Dive Shop”, “Scuba”, “Diving” in each country or region.
Ocean density – calculated as human population per EEZ area.

Table 2
Summary of amendments defining 'shark sanctuaries'.

Descriptor	Bahamas	British Virgin Islands	Caribbean Netherlands	Cook Islands	French Polynesia	Honduras	Maldives	Marshall Islands	Micronesia	New Caledonia	Palau
Year	2011	2014	2015	2012	2012	2011	2010	2011	2015	2013	2009
Document title	S.I. No.64 of 2011	Virgin Islands Fisheries (Protected Species) Order, 2014	Declaration*	Marine Resources (Shark Conservation) Regulations 2012	Order no. 396 CM (2006); no. 1784 CM (2012)	Agreement No. 002–2010	(1) NO: FA_D2/29/2009/212; (2) NO:30-D2/29/2010/32; (3) NO: (JUL)138/1/2011/42	Bill No: 100ND1	No. 18–134, C.D.1, C.D.2; C.B. 19–86	No. 2013–1007/ GNC	Senate Bill No. 8–105
Reason provided?	No	No	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes
Local reason?	NA	NA	Yes	No	NA	No	Yes	Yes	No	NA	No
EEZ?	Yes	Yes	Yes	Yes	Not stated	Yes	Yes	Yes	Yes	Yes	Yes
Sharks defined?	No	Yes	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Rays included?	NA	Yes	Yes	Yes	No	NA	Yes	NA	Yes	Yes	NA
Fines?	Yes	Yes	No	Yes	No	No	No	Yes	Yes	No	Yes
Other penalties?	No	No	No	Yes	No	Yes	Yes	Yes	No	No	Yes
Research permit exemptions?	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	No
Fishing exemptions? If exemptions, species exceptions?	No	Yes	No	No	No	No	No	Yes	No*	No	Yes
Fishing ban on sharks?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Finning specified?	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Possession ban?	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes
Trade ban?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Sale ban?	Yes	Yes	Yes	Yes	Yes	Yes	Yes*	Yes	Yes	Yes	Yes
Transshipment specified?	No	No	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes
Provisioning (chumming) ban?	No	Yes	No*	Yes	Yes	No	No	No	No	Yes	Yes
Bycatch release clarity?	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Gear restriction?	No	No	Yes	Yes	No	No	No	Yes	Yes	No*	No
Status/monitoring reports required?	No	No	Yes	No	No	No	No	No*	No	No	Yes

*Maldives – presumed 'sale' ban as it is "illegal to catch, keep in captivity, trade or harm any of the animals listed".

*Marshall Islands – there is mention of 'monitoring and surveillance of the vessels and fleets', but not in monitoring of sharks or their population status.

*New Caledonia – there is mention of "net cutters to be used to free accidentally caught animals" – not reduce catch.

*Federated States of Micronesia – no exceptions for subsistence or other shark fishing, but the law says "It shall be unlawful to purchase, offer for sale or sell sharks or shark parts, including shark fins which have been removed on board a vessel, transhipped or landed in contravention of this section", where this section refers to a "fishing vessel originated from FSM", not necessarily by those originating from elsewhere (imports). Note: Fishing vessel is defined as "any vessel, boat, ship, canoe, or other craft, which is used for, equipped to be used for or of a type that is normally used for fishing..."

*Caribbean Netherlands – Not the entire EEZ of the Netherlands, but the entire EEZ of Bonaire, Saba and Sint Eustatius. "Declaration for the establishment of a Marine Mammal and Shark Sanctuary in the Caribbean Netherlands".

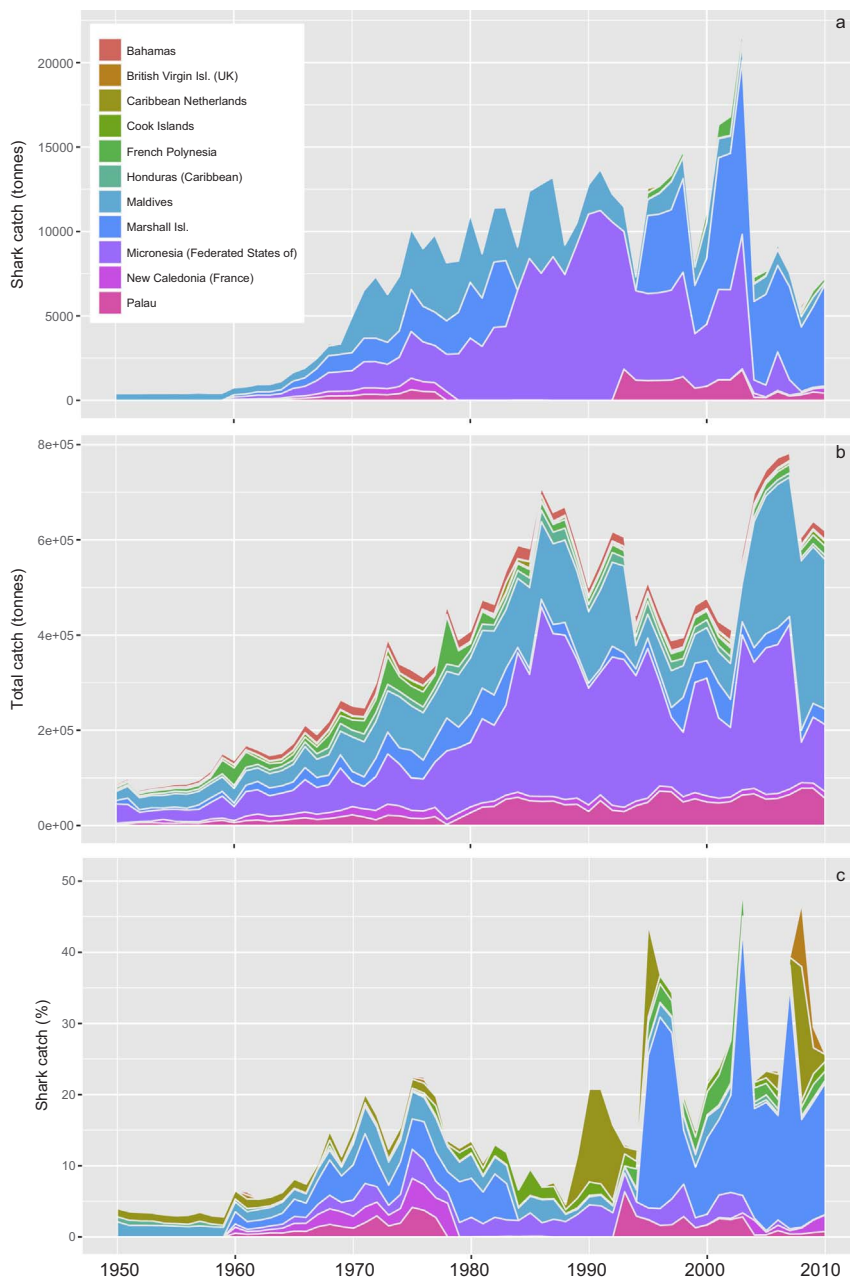


Fig. 1. Shark catch (a), total fish catch (b) and percent shark in total catch (c) from each Shark Sanctuary country. Data from Sea Around Us (Pauly and Zeller [24]). EEZ boundaries from [29].

the region or its citizens. In the Marshall Islands, the reason provided is to “address certain gaps, and to modernize such laws in light of recent development in international, regional, and sub-regional fisheries law”. For Honduras, the reason is that the country is a signatory of international conventions for the protection of the environment and marine species, emphasizing among other species, the shark. For the Maldives, the reason is local, stating that shark populations show stock decline, and that some populations are under threat of extinction locally. For Palau, the reason is also local, but cites an ecosystem context, stating that “Palau’s economic and cultural fate is inextricably tied to the ocean, and sharks play an integral role in maintaining the ocean’s complex ecological balance. Their diminishing numbers have already had wide ranging negative impacts... These continued negative impacts, if unabated, will be disastrous for Palau”.

3.2. Sharks defined

Explicit definition of what is included in the commercial fishing ban on ‘sharks’ (e.g., sharks in a strict sense, or both sharks and rays) may influence the extent and enforcement of the regulations, especially in navigating loopholes. Sharks are explicitly defined by seven of the eleven sanctuaries – some to include rays, and others to exclude them. For Honduras, the Bahamas, Palau and the Marshall Islands, the bans only refer to “shark”, “sharks” or “all shark species”, and do not explicitly state what species or species groups are included. In French Polynesia, the ban applies to all fish belonging to the taxon Elasmobranchii, with the exception of rays. The Maldives defines sharks (Miyaru) as Elasmobranchii, to include rays, skates and sawfish. The same is true for New Caledonia and the Federated States of Micronesia where the ban applies to all fish belonging to the Elasmobranchii. The British Virgin Islands and the Cook Islands define sharks to include rays. Only the Cook Islands includes Chimaeras.

However, those that do not define sharks in the sanctuary regulations, may define them in other fisheries-related acts.

3.3. Penalties

Specifying penalties within the regulations provides context on the severity of breaches. Most shark sanctuary documents specify penalties, with clarification on the expected fines per incident. For example, the British Virgin Islands states fines “not exceeding \$1000”, the Bahamas is \$5000 (~\$5000 USD), Cook Islands is \$NZ100,000 to \$250,000 (\$71,000 to \$179,000 USD) and the Federated States of Micronesia is \$50,000 to \$250,000. While these do not specify if fines are the same for each offence, others do. The Marshall Islands states that fines are “\$5000 to \$100,000, added to an amount equivalent to the current retail value of the fish, fish product or other marine resources obtained in contravention of the measure, and/or be imprisoned up to six months”. Palau states that violations are “punishable by a fine of not more than \$250,000. If the fins or tail of a shark have been removed, or if a shark has otherwise been cut up, separated, or dismembered... each piece of the shark shall be considered a separate criminal violation”. Others, such as French Polynesia, simply point to other regulations such that violations ... are punishable by the sanctions stated in the provisions in Book 1, Title 3 of the present code.

Other penalties for non-compliance are included as well. For example, Honduras states that penalties include suspension of fishing and marketing licenses until the end of the fishing season. The Marshall Islands states that there will be “seizure, and [persons] may be imprisoned up to six months”. The Cook Islands states that with “second or subsequent occurrence, any license to conduct commercial fishing or transshipment of fish or fish products must be revoked and cancelled, and prohibited from operating in waters within the Cook Islands”.

3.4. Scientific permits

Making scientific permits available allows for data collection, and may promote scientific observation that would increase knowledge and awareness of the conservation needs of local shark populations. Exemptions for scientific permits are permitted in half of the sanctuaries. In the Bahamas, the minister responsible can provide “permits to fish for, possess or export any shark or shark parts for educational, scientific or research purposes”. The Marshall Islands will grant “permits for research on sharks”. In New Caledonia, exemptions to the bans can be granted ... for the harvesting of sharks or shark parts to scientific ends (marking, biological sampling, or work on carcasses of dead animals) or with the goal of stock restoration or breeding. In the British Virgin Islands, “a person may fish for shark, or have in his or her possession, or export any shark, or shark parts for educational, scientific or research purposes if he or she is the holder of a marine scientific research permit”. And, in the Federated States of Micronesia, “any person who holds a license or permit from the Authority to conduct scientific research on sharks and carries out activities in accordance with that license or permit shall not be held in contravention of this section”.

3.5. Exemptions

Consideration of traditional cultural activities has important management and policy implications, and shark fishing is part of many people's heritage. Therefore, in addition to scientific permits, other exemptions to the ban are in effect in three of the eleven shark sanctuaries. Palau exempts vessels “wholly owned by Palauan citizens or a business entity wholly owned by Palauan citizens” to “catch, incidental to other fishing activities, not more than one shark in any given calendar day, so long as the shark is landed whole, reported to the Bureau of Marine Resources and the Division of Marine Law

Enforcement on the day it is caught, and the shark is used for a non-commercial purpose that is either personal or traditional”. The Marshall Islands allows “fishing for shark for subsistence use... provided that no person shall harvest shark that have been declared as protected species”. In the British Virgin Islands a “person may fish for shark for private subsistence except for those sharks listed as endangered (EN) or critically endangered (CR) under the IUCN Red List of Threatened Species if he or she is a licensed local fisherman”.

3.6. Shark finning

Shark finning is a wasteful and largely unaccepted practice, and has been prohibited in many regions long before shark sanctuary regulations came into effect. Finning prohibition, therefore, may be part of pre-existing fisheries regulations or replaced by more encompassing shark sanctuary regulations. However, anti-finning policies are similar amongst the amendments. A few do not specify ‘fins’ but rather ‘any shark part’. For instance, Honduras states that parts and derivatives of shark species cannot be fished, sold or exported. The Maldives states that it is “illegal to harm any of the animals listed”. The Bahamas states that “it is prohibited to fish sharks, and they must be released unharmed”. In French Polynesia, the amendment defines shark fins (“nageoires de requins”) to be all shark fins, and states that it is prohibited to fish for or detain sharks or shark parts, but does not explicitly define fins to be banned. Each of these infers that finning is unlawful; other amendments, however, are more explicit. In Palau, it is “unlawful... for any person to intentionally remove the fins or the tail of, or otherwise mutilate or injure, any shark”. In the Marshall Islands “no person shall... intentionally remove the fins or tail of any shark, or otherwise mutilate or injure any shark within the land or fisheries waters”. In the Cook Islands “no person may remove the fins of, or otherwise mutilate or injure, any shark”. In New Caledonia the mutilation by removal of the fins, or parts of the fins (‘shark-finning’) is prohibited. In the British Virgin Islands “no person shall intentionally remove the fins, tail or mutilate any shark”. In the Federated States of Micronesia, it is “unlawful to remove shark fins from sharks on board fishing vessels, and to retain on board, transship or land sharks or shark fins” (however, see caveat to this rule in the bycatch section below).

3.7. Possession, sale, and trade bans

Enforcement, especially across large EEZs is a challenge for many coastal states, and therefore bans regarding the possession, sale and trade of sharks and shark parts may help identify breaches to regulations. In terms of possession, sale, and trade bans, not all are equally explicit. For example, in New Caledonia, the fishing, capture, or detention of sharks or shark parts is prohibited. As well, in the Maldives it is “illegal to catch, keep in captivity, trade, or harm any of the animals”. In most jurisdictions, a possession ban is implicit. Others, however, are more explicit. In the Bahamas there is “prohibition on possessing, fishing for or landing sharks or shark parts”. In the Marshall Islands there is “prohibition of taking of sharks, possession, sale, and trade”. In the Cook Islands “no person may possess, sale, offer for sale, take, purchase, barter, transport, export, import, trade or distribute shark, shark fins or any part of a shark in the Cook Islands”. In the British Virgin Islands no person shall “sell, purchase or have in his or her possession any shark, shark parts or shark products”. Others are more lenient due to (above listed) ‘exemptions’. For example, in Palau, there is a possession ban “except for vessels and businesses wholly owned by Palauans”.

3.8. Transshipment

Transshipment refers to the transfer of catch to a secondary holding or shipping vessel. Although a normal and legal part of global trade, this practice is often used for illegal and grey-market goods that are

then transferred outside of the jurisdiction where they were caught, and not landed there. Four sanctuary documents have specific language addressing transshipment. In the Marshall Islands “no person shall possess, receive, sell, transfer, store or have on board or transship any shark, shark fins or any other part of a shark”. In the Cook Islands, the ban “includes the transshipment of fish or fish products”. In New Caledonia the butchering, transport, commercialization, placement for sale, sale, purchase, and export of sharks or any part of the animal, including jewelry articles, is prohibited. However, the Federated States of Micronesia are the exception from the others in that dead bycatch is required to be landed at transshipment ports – however, this contradicts the above mentioned ‘anti-finning’ policy where it is “unlawful to remove shark fins from sharks on board fishing vessels, and to retain on board, transship or land sharks or shark fins”.

3.9. Provisioning

Provisioning, or berleying or chumming, is a common activity associated with shark diving tourism operations, and is affected by some of the shark sanctuary regulations. In Palau, it is “unlawful... for any person to intentionally chum for, or otherwise add substances to the water to attract any shark”. In French Polynesia, in lagoons, channels, and within a 1 km radius centred upon the axis of a channel, all activities based on the observation of attracting sharks with food, commonly called shark feeding, is prohibited. In the Cook Islands, “no person may chum for, or otherwise add substances to the water to attract any shark”. In the British Virgin Islands, “no person shall feed, attempt to feed, provide or use food to attract any shark in the fishery waters”.

3.10. Gear modifications and bycatch

Bycatch is a significant (and often dominant) source of shark mortality across many fisheries and should be considered a critical factor that could impair shark conservation efforts [8,9]. Bycatch may be addressed through other aspects of these fisheries acts, however, only four shark sanctuaries include regulations that could reduce incidental shark mortality through gear restrictions. In the Marshall Islands “no person, operator, or fishing vessel, licensed to fish in the Fishery waters of the Marshall Islands shall possess, use or cause to use a trace wire. The authority may make regulations and fishing license condition including restrictions on type of fishing gear in order to further reduce the mortality of sharks”. In the Cook Islands “no vessel may possess, use or cause to be used as part of any fishing gear a wire leader or a trace wire for fishing”. In the Federated States of Micronesia it is “unlawful for fishing vessels to possess wire leaders, steel trace, or wire trace”. In New Caledonia, although it does not restrict the gear used to fish, it requires that net cutters be used to free accidentally caught animals.

Since commercial fishing is still permitted in all shark sanctuaries, except perhaps for Palau which only allows small-scale commercial fishing in some areas, bycatch remains an issue. With only two exceptions (Honduras, Maldives), all of the regulatory documents require that incidentally caught sharks be returned to sea regardless of being dead or alive. In Palau “any shark inadvertently caught or captured, shall be immediately released, whether dead or alive; if caught or captured alive, it shall be released in the manner that affords it the greatest opportunity for survival”. In the Bahamas, “a person who hooks or catches a shark while fishing shall promptly release the shark into the sea unharmed”. In the Marshall Islands “any shark that is inadvertently caught or captured shall be immediately released, whether the shark is dead or alive. No shark shall be retained even if caught as bycatch”. In French Polynesia accidental captures, restricted to fishing and detention, will be immediately returned to the sea. In the Cook Islands “if any shark is caught or captured, it must be immediately released, dead or alive, whole with fins naturally attached. If the shark

is caught or captured alive, it must be released in the manner that affords it the greatest opportunity for survival. No shark, or any part of a shark may be retained even if caught as bycatch”. In the British Virgin Islands “where a shark is inadvertently caught or captured dead or alive, it shall immediately be released into the fishery waters”.

3.11. Monitoring and reporting shark status

Scientific monitoring of a stock's status and mortality rate is commonly used in fisheries when considering conservation needs. However, only two of the eleven examined regulatory documents specifically requires monitoring as part of the shark sanctuary implementation. In Palau, the regulations “directs the Ministers of State, Justice, and Natural Resources, Environment and Tourism to report at least biannually to the President of the Republic and Olbiil Era Kelulau on the current status of Palau's anti-shark fishing laws”. As well, to report on “the state of knowledge on the status of the shark populations within the Republic of Palau's waters,” as well as those sharks subject to treaties of agreements to which the Republic of Palau is a party” (e.g., sharks listed as depleted, endangered or threatened by any national, international or other authority). The Caribbean Netherlands also includes this monitoring, stating that “non-detrimental scientific research on marine mammals and sharks will be encouraged in the Sanctuary and in the Caribbean in general, and resources will be sought for the periodic evaluation of the status of marine mammal and shark populations and of existing or potential threats to these animals within the Reserve”. Otherwise, there appear to be no requirements for defining sanctuary goals or guidelines to evaluate effectiveness.

4. Impacts on fisheries

Given that these policies prohibit landing sharks, including bycatch, and compliance breaches are also not typically documented in publicly accessible datasets – two ways in which shark populations are often assessed – there are challenges to monitoring the effectiveness of shark sanctuaries. However, historical catch data may provide some insight into the impact that shark sanctuaries may have. Below, reconstructed catches from officially reported catch data combined with best estimates of landed and discarded catches [extracted from the Sea Around Us Project; [24]] are used to explore the impact shark sanctuaries may have in terms of shark mortality, fishing, and trade.

4.1. Within shark sanctuaries

Prior to the implementation of shark sanctuaries, i.e. between 1950 and 2010, a total of 450,936 t of shark was reportedly caught across all shark sanctuary EEZs (Table 3) – an average of 7515 t per year. This is a relatively small amount compared to the global mortality, which was estimated at 1,445,000 t per year [year 2000; [8]]. Although shark catch was low in the 1950's and 1960's, it steadily rose in the 1970's and remained above 7500 t per year, with peaks in the early 2000's, until the mid- to late-2000's when there is an observed decline in catch (Fig. 1a), pre-dating shark sanctuary legislations.

Throughout this time period, there was variable shark catch within and between sanctuaries [Figs. 1a and 2a - EEZ v8 downloaded from [29]]. Those with the lowest shark catch, < 5000 t total from 1950 to 2010, were the British Virgin Islands, the Bahamas, the Cook Islands, Caribbean Netherlands, and Honduras. Those with the highest cumulative shark catch, close to or exceeding 200,000 t, were the Maldives, the Marshall Islands and the Federated States of Micronesia. The Maldives had the highest shark catch per kilometre squared. Catches were not directly proportional to EEZ area. The Maldives and Palau, for example, had 20 and 99 times more shark catch than the Bahamas, respectively, despite having similarly sized EEZs (Table 3). French Polynesia, had considerably lower shark catch than the Federated States of Micronesia and the Marshall Islands, despite having an EEZ almost

Table 3
Total reconstructed catch in each of the eleven shark sanctuaries, covering the period of 1950–2010. Shark catch is the functional group ‘sharks (≥ 90 cm)’ and shark and ray catch is an undifferentiated group. Data from Sea Around Us (Pauly and Zeller [24]).

Country	Total catch (tonnes)	Shark catch (tonnes)	Shark & ray catch (tonnes)
Bahamas	1,019,896	1067	2370
British Virgin Islands	81,600	386	386
Caribbean	122,718	1375	1394
Netherlands			
Cook Islands	290,080	1769	1769
French Polynesia	1,182,847	7704	7704
Honduras (Caribbean)	777,318	1660	1660
Maldives	6,523,894	99,269	99,518
Marshall Islands	1,666,746	123,979	125,530
Micronesia (Federated States of)	9,225,346	186,565	190,963
New Caledonia	656,281	6566	6946
Palau	1,940,975	20,597	20,771
Total	23,487,701	450,936	459,011

two times their size, and listing shark meat as a top export (Table 1).

One problematic issue with these catch statistics and in relating them to the current policies, which prohibit targeted shark fishing and not other fishing, is that it is not clear what portion of those caught sharks were targeted and what were incidentally caught and landed. If

most of the sharks were caught incidentally in other fisheries, this would likely continue after declaration of the sanctuary, reducing its effectiveness. From 1950–2010 the total fisheries catch within the shark sanctuaries was 23,487,701 t (Figs. 1b, 2b, Table 3). With few exceptions (those with gear restrictions) these fisheries remain unaffected by current shark sanctuary measures. The proportion of shark catch to total catch may, however, provide some insight on the prevalence of targeted shark fisheries – higher ratio may infer higher prevalence for targeted shark fishing. Figs. 1c and 2c show the percentage of catch that comprised sharks, which indicates increased proportions of shark to overall catch in the mid-1990’s to mid-2000’s, reaching up to 50% shark catch, with the highest ratio in the Marshall Islands – the country with the second largest shark catch (15% of total catch; Table 3). Therefore, a large part of the catch may have been targeted. In this case, a policy that prohibits the targeting and retention of sharks or shark parts may have the intended effect of reducing shark mortality significantly.

Another limitation is that a few amendments – Palau, the Marshall Islands and the British Virgin Islands – allow subsistence or personal shark catches. However, the vast majority (86%) of shark catches have come from the industrial sector (Table 4), suggesting that bans to commercial shark fishing would have the most significant impact. Artisanal fishing also had a sizeable secondary catch, but this was almost entirely in the Maldives where amendments no longer permit shark landings, including for artisanal purposes.

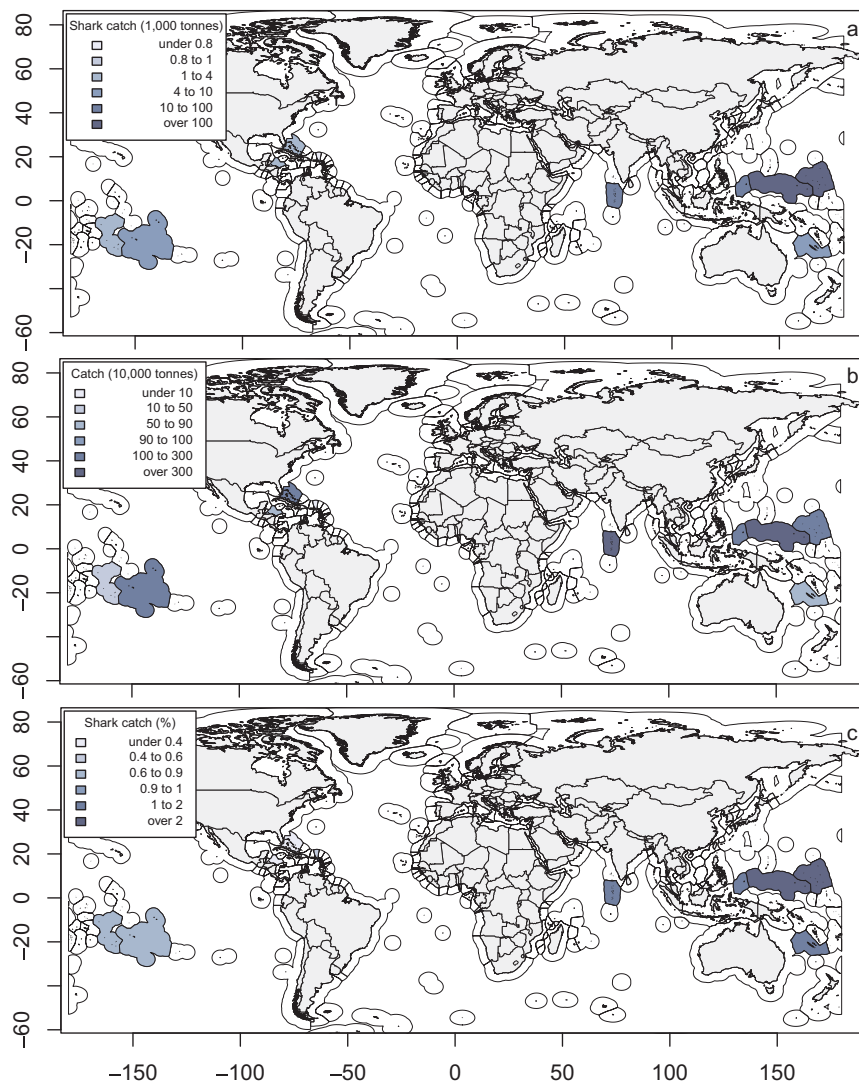


Fig. 2. Shark catch, total catch, and ratio of shark to total catch by country. Data from Sea Around Us (Pauly and Zeller [24]). EEZ boundaries from [29].

Table 4
Reconstructed shark catch in tonnes from Sea Around Us (Pauly and Zeller [24]) by fishing sector.

Country	Industrial	Artisanal	Subsistence	Recreational
Bahamas	355	56		656
^a British Virgin Islands	360	20	5	
Caribbean Netherlands	1096	45	82	152
Cook Islands	752	255	762	
French Polynesia	7704			
Honduras (Caribbean)	249	922	489	
Maldives	40,789	58,479		
^a Marshall Islands	123,979			
Micronesia (Federated States of)	186,565			
New Caledonia	6566			
^a Palau	20,597			
Total	389,013	59,777	1338	808

^a Countries that have exemptions for subsistence shark catch.

4.2. Outside sanctuaries

Fishing is a global economic enterprise and an EEZ is far from being exclusively fished by its own jurisdiction. 102 states have a history of fishing within shark sanctuary EEZs (Fig. 3, Table A1). Many of these (26) have had relatively small total landings of < 10 t of fish (e.g., U.K., Germany, Costa Rica, Sweden, South Africa), while others have had relatively large catches – Japan, Maldives, Taiwan, USA, Indonesia (largest to smallest annual catches exceeding 1 million tonnes of fish catch per year). As well, all of the top 13 shark fishing nations according to the FAO [13] – Indonesia, India, Spain, Taiwan Province of China, Argentina, Mexico, The United States of America, Pakistan, Malaysia, Japan, France, Thailand, Brazil – have a history of fishing in these shark sanctuaries (Table A1). Therefore, prohibiting commercial shark catch and export from these regions would affect other countries' catch and trade.

In terms of interrupting the supply of shark fins to international markets, bans on exports of sharks and their parts from these shark sanctuaries could, if there was full compliance, have a small impact on markets. Using the year 2000 as a reference – before shark sanctuaries were implemented – the total global shark mortality was estimated at 1,445,000 t [8]. In the same year, shark catch across all shark sanctuaries was 11,309 t, or less than 1% of global mortality. Using these numbers to evaluate the impact on shark fin supplies would require the assumption that targeted shark fishing would have remained the same in these regions regardless of the creation of the shark sanctuary. However, at least in the case of the Bahamas and Palau, where commercial shark fishing for fin exports had already been announced [22], this would not have been the case. Therefore, amendments were preventative in these cases, making it a challenge to evaluate the long-term impact of the sanctuary on shark fin supplies.

4.3. Protecting and rebuilding shark populations

Whether shark sanctuaries protect or rebuild depleted shark populations also depends on a variety of biological factors. For example, a sanctuary's success may be determined by its size in relation to the species using the sanctuary, where those with small home ranges like reef sharks may receive adequate protection by both small (e.g., British Virgin Islands) and large (e.g., French Polynesia) sanctuaries, whereas wide-ranging species, like whale sharks, might receive only marginal benefit [17,30]. As well, sanctuary success could be influenced by the habitats used by sharks and their protection (e.g., through other laws or isolation) from human activities, such as habitat destruction, pollution, climate change and tourism-associated behaviour [5,10,31–33]. These additional stresses would also be important in cases where rebuilding of depleted populations was necessary, due to limited rebound potential

which limits recovery [10,34].

5. A call for program evaluation

These combined circumstances, where shark sanctuary regulations lack detail regarding program goals, guidelines for evaluation, and data on shark catch and trade, means that traditional methods of assessing shark populations and human use patterns are not possible. So, how can we evaluate the effectiveness of this conservation strategy? How can we measure the impact of stopping a proposed shark fishery in the Bahamas? And, how could we monitor a population trajectory when there is no baseline and no data being collected? These are challenging questions, but since the future of some shark populations may depend on the success of these strategies, they are important questions to address.

Sharks generally have slow life history characteristics, requiring > 100 years to recover from depletion [10]. Therefore, it is unlikely that shark populations would have increased at any detectable level within a decade in these shark sanctuaries, even if adequate baseline data was maintained and monitored. However, that does not mean that ongoing evaluations to determine theoretical success cannot be made. Since the number of states developing shark sanctuary legislation is growing, it is prudent to initiate various levels of program evaluation [35] – either post hoc in existing sanctuaries, or ideally, with the creation of any new shark sanctuaries – to begin to understand their value and limitations for regional and global shark conservation.

Initial goals of the evaluation could include a snapshot assessment of contemporary and historic shark populations and their threats. See [5,36,37] for examples where interviews, traditional and local ecological and human use knowledge were combined in a meta-analytic framework with other data sources, such as historic narratives, fisheries catch data and scientific documents, to rebuild understanding of past populations and to put them, and the threats, within a contemporary perspective. This would enable states to gain a better, more explicit and quantitative basis for understanding shark conservation needs in the area.

Next, the evaluation could include a definition of success – at the state and, perhaps, at the global scale. The above described snapshot assessment would be valuable for setting this context. For those states with shark populations that are considered healthy and minimally at risk – the Bahamas, for example, which already had bans on long-line fishing before the shark sanctuary came into effect – a goal for success may be to maintain those populations and minimize forthcoming risks. For other regions, where populations have been depleted, success may need to be defined in incremental steps that allow for detection of success long before population increases could be detected – for example, an increase in compliance and understanding of the regulations (i.e., more social rather than biological cues).

Lastly, the evaluation could monitor for success. Measuring success can take many forms and does not necessarily need to follow a traditional 'stock assessment' approach, which typically involves lethal sampling and would be inappropriate in a shark sanctuary. Today, there are many techniques that offer non-lethal sampling methodologies (e.g., baited remote underwater visual surveys, scuba divers surveys, eDNA) suitable for a shark sanctuary. Other options include increased observer coverage to document the details of what sharks are being caught incidentally in other fisheries, what portion of those are released in good condition, and assessing stakeholder knowledge – for example, do people know they are in a shark sanctuary? As well, legal measures, including the number of breaches of the regulations, prosecutions, fines, permit cancellations could be used to evaluate success. There are many options for program evaluation that have been deployed in other fields that the conservation field could readily deploy.

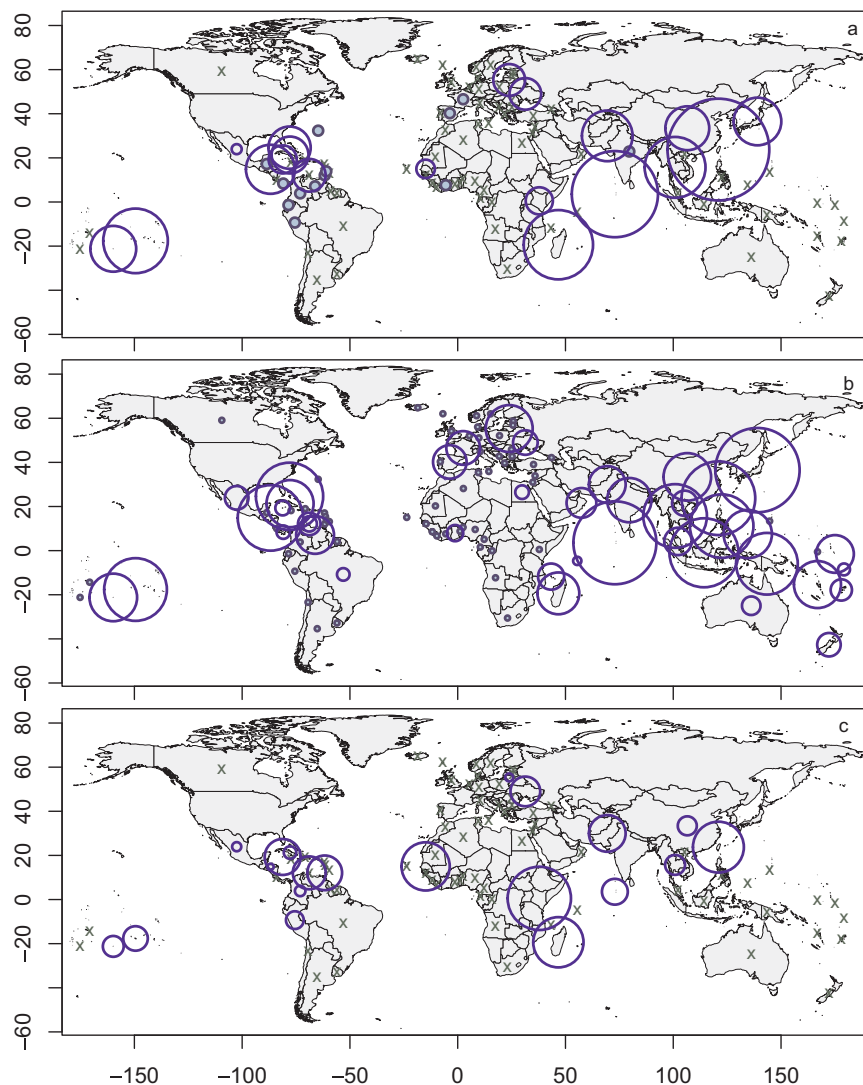


Fig. 3. States fishing within shark sanctuaries. (a) Shark catch (tonnes), (b) total catch (tonnes), (c) percent of shark within total catch (%). Light blue circles show (a) catch < 100 t, (b) shark catch < 10, (c) shark catch < 10%. X's in (a and c) show zeros. Open blue circle size is the log of catch for (a and b), where the highest total catch in (a) was Japan (4,961,291 t) and highest shark catch in (b) was Taiwan (289,688 t). Data from Sea Around Us (Pauly and Zeller [24]). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

6. Conclusion

In response to declining shark populations, continuation of illegal fishing, and the challenges associated with implementing sustainable shark fishing some states have opted to ban commercial shark fishing and the export of shark products altogether. There are currently eleven such Shark Sanctuaries, covering ~3% of the world's oceans. Regulations designating these sanctuaries are highly variable and, importantly, mostly lack details on mitigating shark bycatch, sanctuary goals, and guidelines to evaluate effectiveness. Historical catches provide some insights on their potential as a conservation measure. Available catch data within sanctuaries indicates that their contribution to global shark mortality has been historically small (less than 1%). However, at least two sanctuaries were implemented to prevent incoming commercial shark fishing and as such likely succeeded in having a positive impact. As well, where shark catches were proportionally high compared to total catch, suggesting a preference for sharks, regulations that prohibit the targeting and retention of sharks or shark parts may have the intended effect of reducing shark mortality. Unfortunately, it is difficult to measure the impact of preventative interventions like these, and, where shark landings are prohibited, traditional monitoring is an even bigger challenge. Therefore, there is

urgent need to implement other types of monitoring and data collection, such as through Program Evaluation, to set baselines and measure shark sanctuary efficacy.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.marpol.2017.05.004>.

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