Understanding the impacts of anti-finning regulations on global shark mortality

By

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Abstract

Increasing fishing pressure coupled with regulatory failures impede biological conservation of sharks worldwide, resulting in population declines for many species. Much of the demand for shark products has been fuelled by a burgeoning market for their fins, historically harvested by a wasteful practise called shark finning. National and international policy has aimed to eliminate this practise by mandating sharks be landed whole with fins naturally attached (FNA), or even by banning shark fishing altogether in so-called shark sanctuaries. This study maps the global regulatory landscape explicitly on anti-finning legislations across 280 exclusive economic zones (EEZs) and 4 Regional Fishery Management Organizations (RFMOs) and examines trends in shark mortality related to such legislation. Results show that only 25% (n=70) of EEZs adopted a FNA ban category and only around 6% (n=19) of EEZs were protected as shark sanctuaries. Some of the largest shark fishing countries (e.g., Pakistan, Iran, Indonesia) had no or weak finning legislation. Total shark mortality as calculated in this study showed an increasing trend for coastal sharks and a decreasing trend for open-ocean sharks between 2010 and 2018, suggesting diverging trends in national and RFMO-regulated fisheries. In order to contextualize and cross-reference these analyses, 10 expert interviews were conducted. Interview results showed that coastal gillnet fisheries were considered to be a significant and unobserved source of shark bycatch; also, all the respondents reported either a decreasing trend (n=8) or stable trend (n=2) in shark finning over the last two decades, with increased utilisation of whole sharks and growing markets for shark meat and other products. Overall, these results highlight priority areas for strengthening existing measures and improving the effectiveness of current legislation in controlling shark finning and shark mortality at both RFMO and national levels.

Keywords: anti-finning, mortality, bycatch fate, sharks, RFMOs

Chapter 1: Introduction

1.1 Context

Sharks and their relatives (Class Chondrichthyes, herein “sharks”) are one of the most ancient and ecologically varied vertebrate lineages, having evolved at least 420 million years ago and spread swiftly to occupy the top tiers of aquatic food webs (Compagno, 1990; Kriwet et al., 2008; Dulvy et al., 2014). This group of marine vertebrates are described as one of the most diverse predatory lineages on the planet, with important functional roles in top-down control of coastal and oceanic ecosystem structure and function (Ferretti et al., 2010; Heithaus et al., 2012; Stevens et al., 2000). However, many shark species feature slow life histories, resulting in low population growth rates and reproduction, making them intrinsically vulnerable to increased fishing mortality (Musick, 1999; Cortés, 2002; Garcia et al., 2008; Dulvy and Forrest, 2010). Shark population declines are especially concerning because they may influence marine communities via 'top-down' control, though the degree of influence may vary depending on habitat (Worm et al., 2009; Ferretti et al. 2010). Several studies have demonstrated this top-down control and the ecological consequences of its removal. For example, a long-term study of tiger sharks (*Galeocerdo cuvier*) and their prey in the Shark Bay seagrass system in Western Australia discovered that the presence of tiger sharks and the risk of predation influenced prey species' behaviour, with prey species avoiding high-risk predation areas (Heithaus et al. 2012). Similarly, in the northwest Atlantic, Myers et al. (2007) found that overfishing and population decrease of apex sharks resulted in the release of their meso-predator elasmobranch prey species. These mid-trophic level prey sharks and rays increased rapidly in some situations, no longer subject to apex shark predation, and this had cascade effects. According to the study, the population of the cownose ray (*Rhinoptera bonasus*) has increased by an order of magnitude during the 1970s. Cownose rays, which predominantly eat bivalves, have been connected to the collapse of the North Carolina Bay scallop fishery because the rays eat the bivalves before they breed (Myers et al., 2007).

Sharks, like all marine animals, suffer from the effects of habitat loss, climate change, and ecosystem alterations (Techera & Klein, 2011). In addition, a majority of species is affected by unregulated overfishing, finning, and bycatch mortality (Worm et al., 2013). Sharks and rays are mostly caught as non-target catch, but they are frequently kept as valuable bycatch in fisheries that target more productive teleost fish species like tunas or groundfishes (Stevens et al., 2005). The high value of their meat, fins, livers, and/or gill rakers is increasing fishing pressure on these vulnerable species, as teleost target species become less accessible (due to depletion or management restrictions) (Fowler et al., 2002; Clarke et al., 2006; Lack and Sant, 2009). Fins, in particular, have become one of the most valuable seafood commodities: it is estimated that in te early 2000s between 26 and 73 million individuals' fins were traded each year, worth US$400-550 million at the time (Clarke et al., 2007). The international trade to supply Asian demand for shark fin soup, a popular and usually pricey Chinese dish, has been a major driver of shark fishing for decades. This very profitable trade in shark fins (which includes fins of sharklike rays like wedgefishes and sawfishes) is mainly unregulated in the 86 countries and territories that exported more than 9,500 mt of fins to Hong Kong (a major fin trade centre) in 2010 (Clarke et al., 2006). This global demand for shark products exponentially increased shark and ray landings worldwide, as reported to the UN's Food and Agriculture Organization (FAO), which valued $1 billion at their height in 2003, but have since fallen to $800 million as the catch has decreased (Dulvy et al., 2014; Musick and Musick, 2011). However, the true total catch is likely to be 3–4 times higher than recorded (Clarke et al., 2006; Dulvy et al., 2014; Worm et al., 2013). The majority of chondrichthyan catches are unregulated, unreported, or illegal (IUU), resulting in a dearth of species-specific landings data (Barker and Schluessel, 2005; Clarke et al., 2006; Iglésias et al., 2010; Bornatowski et al., 2013). Moreover, a previous study by Worm et al. (2013), estimated that the total shark mortality was 1,455,000t in 2000, or the equivalent of 100 million sharks per year, with similar levels predicted for 2010. However, since then new finning and shark fishing regulations have been introduced to halt or reverse shark population declines globally. Therefore, this research primarily focuses to evaluate the effectiveness of anti-finning regulations in curbing global shark mortality at recent times.

1.2 Management Problem

Sharks play an important role in global fisheries as both a target species and a by-product species (incidentally caught but retained). Because of their life history characteristics, some exploited shark species can support higher levels of mortality and thus are likely to be at lower risk from fishing mortality (e.g., blue sharks) (Kirby, 2006; Oldfield et al. 2012). Other shark species are unable to sustain even moderate levels of mortality and are subject to overexploitation. As a result, many shark populations that have been examined recently are declining (e.g., Baum et al. 2003; Dulvy et al. 2008; Ferretti et al. 2008; Worm et al. 2013; Dulvy et al. 2014), and one quarter of shark and ray species are threatened, according to the International Union for Conservation of Nature's Red List criteria (Dulvy et al. 2014). This high mortality rate has been fuelled in part by the growing market for shark fins (Clarke et al. 2006; Clarke et al., 2007), and it is often poorly regulated, with few shark capture restrictions in place, putting certain species at risk of overfishing due to poor regulation, enforcement, or management (Lack et al. 2014).

Shark finning is the practice of removing any of a shark's fins (including the tail) while at sea and discarding the rest of the shark (MOU, 2010). This may occur while the animal is still alive. Only the fins are kept because the rest of the animal is deemed low-value and is therefore discarded to save space, weight, and fuel. The primary issues associated with this practise are as follows (Ziegler, 2019; MSC Programme Improvements Database, 2019) : (i) Animal

Welfare concerns occur where live sharks are finned, thrown back into the sea, where they bleed to death, suffocate because they cannot swim or breathe, or are eaten alive by other predators or scavengers; (ii) Wasteful practises are incurred when shark bodies are finned and discarded, protein and other potential goods are wasted and only 2-5 percent of a shark's body is used, (iii) Management weaknesses are involved where finning activity is largely unregulated, poorly managed, and underreported, and (iv) Enforcement problem occur when it is extremely difficult to identify the shark species from the mainly dried fins upon landing, species-specific shark catch information is frequently lost (Zeigler, 2019; MSC Programme Improvements Database, n.d.). This makes it difficult to determine whether shark fins have been extracted from endangered, threatened, or protected shark species, or whether forbidden species, which are not allowed to be kept under regional or national law, have been taken (Zeigler, 2019). As a result, it is challenging to estimate stock status, jeopardising proper shark management. It is also impossible to quantify the initial live weight and the number of sharks finned because fins are frequently held at sea for several weeks and are typically partially dried when landing (Zeigler, 2019; MSC Programme Improvements Database, n.d.; MSC Consultation Document on Shark Finning, n.d). With the growing concern on highly valued shark fin trade in many parts of the world, some jurisdictions such as Canada, the United States, Australia, and European countries have sanctioned anti-finning legislation for decades (Worm et al., 2013), yet such practices continue elsewhere, for example in many South Asian countries (Arai and Azri, 2019; Dulvy et al., 2014). In a recent study by Brautigam (2020), it has been reported that nine out of the 43 nations with highest levels of shark fishing had no anti-finning legislations at all and bans could not be verified for additional nine countries. In some fisheries, sharks are still targeted for their fins (Dharmadi et al., 2015; Arai and Azri, 2019) which is often determined by size of the fin and demand for the product in the local or international market (Jaiteh et al., 2017). Moreover, despite the high incidence of shark bycatch in pelagic longline fisheries and suggestions to build shark mitigation techniques, progress in research and implementation has lagged behind that of other bycatch of marine species, such as seabirds (Patterson et al., 2014).

Currently, international law requires nation-states to collaborate in the management of resources found on the high seas (Fisheries and Oceans, 2011). Regional Fisheries Management Organizations, or RFMOs, are entities in charge of controlling fish stocks on the high seas and serve as a platform for nation-states to collaborate. RFMOs were formed to address a lack of collaboration among nation-states fishing highly migratory transboundary species (EU, 2015). They have evolved since then. There are RFMOs for tuna and tuna-like species, groundfish, salmon, and other species, for example. Furthermore, each RFMO has its own convention area, which may or may not overlap with the EEZs of numerous nations or with the convention area of another RFMO. A nation-state can become a contracting party (CP) to an RFMO based on its historical presence in the RFMO's convention area or its proximity to the RFMO's convention area. Quotas, fishing closures, bycatch limits, gear restrictions, and other rules are all aided by the CPs. Furthermore, certain councils and groups within RFMOs are dedicated to carrying out specific responsibilities (e.g., a Scientific Council or a Bycatch Reduction Committee) (Lodge, 2008). Tuna RFMOs, for example, have established legally enforceable best-practice measures to reduce seabird bycatch, such as the deployment of bird scaring lines and/or weighted lines to keep seabirds away from baited hooks as they are deployed (Patterson et al., 2014). However, corresponding best-practice measures for sharks have yet to be agreed upon in these RFMOs.

One challenge is that shark stock assessments have been difficult to obtain for many populations due to a paucity of information on species biology and insufficient fisheries data (including on catch levels and hence catch per unit effort) (Patterson et al., 2014). Most shark species caught as a result of incidental fishing have not been subjected to such thorough quantitative analysis (Patterson et al., 2014). A lack of reliable data on which to base stock assessments and total mortality estimates from bycatch, discards, and landing records frequently impedes effective shark management (Stevens et al., 2000).

1.3 Current management approaches

1.3.1 Species by-catch and mortality measures

Oceanic or pelagic sharks and rays may make up a significant portion of the catch in pelagic longline fisheries as a target, by-product, or incidental bycatch (Mandelman et al., 2008), and they may be vulnerable to high levels of mortality from fishing (Dulvy et al. 2008). As a result, numerous pelagic shark species regularly caught on pelagic longlines targeting tuna have been overfished. The Western and Central Pacific Fisheries Commission (WCPFC) conducted stock assessments of the oceanic whitetip and silky sharks, which revealed that both species were overfished and subject to overfishing. The predicted fishing mortality for oceanic whitetip shark (FCURRENT / FMSY = 6.5; Rice & Harley 2012) and silky shark (FCURRENT / FMSY = 4.3; Rice & Harley 2013) was several-fold higher than the levels associated with maximum sustainable production. The WCPFC Scientific Committee concluded that, in addition to any limits on retaining catch, bycatch mitigation (i.e. capture prevention) measures were required to adequately reduce fishing death bycatch (Patterson et al., 2014). Concerns have been expressed about a greater range of sharks in the western and central Pacific Ocean (WCPO; Kirby 2006), and the WCPFC has classified 14 priority shark species (Clarke, 2011; Harley et al. 2013).

Moreover, some of the tuna RFMOs' member countries have implemented shark-specific measures in some circumstances. Wire leaders, for example, are forbidden in Australian-managed longline tuna fisheries because they are frequently related with shark targeting and retention and have been shown to boost shark catch rates (Ward et al., 2008). Several countries, notably Cook Island, New Caledonia, Palau, the Maldives, the Marshall Islands, and French

Polynesia, have established shark sanctuaries where commercial shark fishing is prohibited altogether (Patterson et al., 2014; Ward et al., 2008).

Furthermore, the Appendices to the Convention on the Conservation of Migratory Species (UNEP/CMS) and its specific daughter agreement, the Memorandum of Understanding on the Conservation of Migratory Sharks, identify several shark species taken in longline fishing in the WCPFC (CMS Shark MOU) (MOU, 2010). Because of the high mortality of sharks due to a variety of impacts and threats, including bycatch, signatories to this MOU have agreed to a global conservation plan for migratory sharks (Patterson et al., 2014):

- to create programmes to track shark bycatch
- to encourage the development of capability for the safe handling and release of sharks
- to create and employ selective fishing gear, systems, and techniques to ensure that shark capture in fisheries is sustainable and well-managed, and that shark mortality is kept to a minimum.

1.3.2 Spatial risk assessment measures

Changes in fishing gear and methods, acoustic deterrents, and temporal and spatial management measures such as closed marine protected zones have all been used to reduce bycatch (Hazen et al., 2018; Welch et al. 2020). However, despite the fact that the fluidity of interactions between marine predators and their surroundings has long been known, spatial management techniques are still primarily based on static borders and narrow temporal scales (Hazen et al., 2018; Welch et al. 2020). As a result, fixed time-area restrictions may not always include the main habitat of species of concern, restricting fishing activity needlessly when the danger of bycatch is low (Hazen et al., 2018; Welch et al. 2020). While many of these strategies have worked for single species, managers are frequently forced to choose between protecting numerous species and maintaining commercially sustainable fisheries (Hazen et al., 2018; Welch et al. 2020). One strategy for better preserving sharks from both targeted and bycatch is to implement Marine Protected Areas (MPAs) and shark sanctuaries (MacKeracher 2019). However, because huge, highly mobile pelagic sharks regularly migrate enormous distances and are largely circum-global, it is still unknown how efficient these borders are for their protection (MacKeracher 2019). As a result, observing their movements and behaviour can help conserve their key habitat usage areas (Queiroz et al. 2019).

However, because to recent technological advances and monitoring systems, it is now able to examine satellite-collected data on vessel activity (Long, 2020). Global Fishing Watch (GFW) was established to analyse and make publicly available all trackable fishing activity in the ocean (Merten et al. 2016; Tickler et al. 2018; Nugent 2019), providing fresh light on fishing's geographical footprint and related repercussions. For example, Queiroz et al. 2019 used satellite data to track the movement of pelagic sharks and global fishing fleets from GFW to estimate the global risk to pelagic sharks. On a worldwide scale, the study assessed the amount of overlap in space utilisation by sharks and commercial fisheries. This estimate was derived from a combination of global data on fishing vessels monitored by the AIS (Automatic Identification System), which was developed as a vessel safety and anti-collision system, and an analysis of pelagic shark movements tracked by satellite transmitters in the Atlantic, Indian, and Pacific Oceans. The research looked at 23 different species of big pelagic sharks that reside in oceanic and/or neritic environments spanning from tropical to cold temperate zones. Sharks consume 24 percent of the space that pelagic longline fisheries use, according to the study's results. It was revealed that hotspots of space occupied by commercially valuable sharks and globally protected species had the largest overlap with longlines, with up to 76 percent and 64 percent overlap, respectively, and were likewise linked to considerable increases in fishing effort.

Furthermore, in a 2016 study by Pfleger et al. (2017), shark researchers from Beneath the Waves and the University of Miami affixed satellite transmitters to the dorsal fins of 10 blue sharks in the northwest Atlantic and gathered data on their whereabouts during a 110-day period. The researchers then linked shark movements to GFW's location data on fishing vessel movements throughout the same time period. This found that 30% of the sharks they tagged were captured during the study, confirming that the number of sharks caught each year is likely to be substantially underestimated.

1.3.3 Anti-finning measures

The majority of RFMOs have banned shark finning, although their current ban status various across different jurisdictions (Zeigler et al., 2020). Shark finning is illegal in certain fisheries, and sharks must be landed with their fins naturally attached at the first place of landing; there are also trip limits that limit the number of sharks that can be taken. Similarly, the European Union banned shark finning in 2013, requiring all EU ships to dock sharks with their fins attached naturally (FNA), with few exceptions, such as Spain and Portugal which issued special permits to adopt a fin-to-carcass ratio (FCR) regulatory policy (Zeigler, 2019; Fowler et al., 2010). In addition, multiple United Nations General Assembly (UNGA) Resolutions have called for a ban on shark finning. The MSC stated in 2011 that they were looking to review, possibly revise, and clarify the requirements with respect to shark finning, as part of their normal process of reviewing their standards and requirements in relation to current scientific understanding and global best practices in fisheries management (MSC, 2020; Zeigler et al., 2020). Shark conservation measures were also recognised by tuna RFMOs, and in 2010, the WCPFC adopted Conservation and Management Measures (CMM) 2010-07, which states that contracting parties must take the necessary measures to require their fishers to fully utilise any retained shark catches, with all parts of the shark except the head, guts, and skins to be retained to the point of first landing or transhipment. In 2011, the WCPFC passed CMM 2011-04, which stated that no oceanic whitetip sharks (*Carcharhinus longimanus*) must be kept in whole or in part. CMM 2013-08 was issued in 2013, stating that no silky sharks (*Carcharhinus falciformis*) must be kept in whole or in part (Zeigler et al., 2020). However, demand for shark fins has also recently declined, owing in part to new spending restrictions imposed by the Chinese government, as well as increased public awareness (Clarke & Dent 2014).

1.4 Research goals and objectives

The primary objective of this research is to identify the existing finning legislations over different shark fisheries and major tuna RFMOs (tRFMOs) and thus, investigate whether the presence of such measures had any mitigating effect on the global shark mortality in recent years. Therefore, the research question can be stated as, "How finning regulations in major shark fishing nations and RFMOS have affected the global shark catch and mortality during recent times?" Hence, this research aims to evaluate: (i) global shark catch and finning regulations across various fishing entities and 4 major tuna RFMOs, (ii) shark by-catch fate and global mortality estimates over the period for which data was available, and (iii) discrepancies between regulatory measures and estimates of shark mortality. In addition to the literature review, this research also conducted several semi-structured interviews with potential informants to help: (i) provide supporting context to the main analysis and (ii) cross-referencing the already existing/published data with additional perspectives, context, and possibly unpublished background information from the interviewees.

Chapter 2: Methodological Approaches

The research methods included three approaches: (i) exploratory analysis of global reconstructed shark catch data from the Sea Around Us Project (SAUP) database, (ii) comprehensive desktop review on global shark regulations and mortality and (iii) semi-structured interviews to add supporting context to the published data.

2.1 Catch data analysis

2.1.1 Global shark landings and major shark fishing nations

To investigate global shark catch and fisheries, global catch data for sharks were gathered from the Sea Around Us Project database (SAU, 2021). An exploratory analysis was carried out to compile and visualise data on shark landings, catch types, and the identification of significant shark fishing nations, as well as the frequency of their catches and the gear they used between 2010 to 2018. The raw dataset consisted of 12 variables in total and out of this, 8 were categorical variables. These eight variables and the categories (n) per non-numeric variable are as follows: (i) fishing-entity (n=176), (ii) year (n=9; between 2010-2018), (iii) scientific name (n=173; including sharks, rays, and skates), (iv) common names (n=173), (v) sector type (n=4; includes artisanal, industrial, recreational and subsistence), (vi) catch type (n=2; landings vs discards), (vii) reporting status (n=2; reported vs unreported), and (viii) gear (n=40). Moreover, species-specific data and top ten fishing nations were filtered out to perform quantitative analysis comprising of only true shark species (i.e. 57% of the species listed in the SAU dataset were sharks). An additional column named “order” was included to the shark species dataset (i.e. sharks listed separately from rays and skates) (Appendix I) to group the number of individual species according to a single category and thus, exclude any redundancies from the dataset. Similarly, the 40 unique gears listed in the database were aggregated into 11 gear groups using the following classifications (Appendix II): (i) trawlers, (ii) small-scale gears, (iii) subsistence/recreational/artisanal gears, (iv) nets, (v) lines, (vi) longlines, (vii) purse-seines, (viii) mixed gear, (ix) pots and traps, (x) hand and tools, and (xi) unknow/other gears. These species and gear classifications are used throughout the paper for consistency and simplicity.

2.2 Literature review

2.2.1 Regulatory landscape of finning bans

A thorough review analysis was performed to visualize and analyse the regulatory landscape of global shark finning bans. Data were gathered from online published literatures and reports on shark specific finning regulations to display a landscape for 280 Exclusive Economic Zones (EEZs) and four major tuna RFMOs, namely: WCPFC (Western Central Pacific Fisheries Commission), IATTC (Inter-American Tropical Tuna Commission), ICCAT (International Commission for the Conservation of Atlantic Tunas), and IOTC (Indian Ocean Tuna Commission). Finning bans were sorted and grouped into six categories, which are as follows (Table 1): (i) fins-naturally-attached (FNA), (ii) fins-to-carcass ratio (FCR), (iii) finning-various-bans (FVB), (iv) finning-ban-unspecified (FBU), (v) shark sanctuaries (SS), and (vi) other bans (OB). To display the relative strength of regulations across all EEZs a global map was generated using ArcGis Desktop. Moreover, graphs were generated using Microsoft Excel based on these six regulatory categories. The categorical values for each ban type were given a rank based on their varied strengths (z), with SS having the highest strength (z=5) and OB having the lowest (z=0) (Table 1). Then minimum-maximum normalization was applied to scale the values from 0 to 1 respectively. The equation is as follows:

$$Weighted\ ban\ strength,\ z = \frac{strenth\ of\ each\ category\ of\ ban,\ \ x}{Maximum\ strength\ of\ ban}$$

Table 1: Types of finning bans and their descriptions and weight of strength for each category.

Acronyms	Ban category	Ban descriptions	z
FNA	Fins naturally attached	fins-naturally-attached (e.g. no finning in territorial/international waters by a particular fleet/flag/ country; sharks must be landed whole; sharks must be landed, transported, sold, or disposed of whole)	0.8
FCR	Fins to carcass ratio	fins-carcass-ratio (e.g. no fins on board without corresponding carcasses)	0.6
SS	Shark sanctuary	prohibit the commercial fishing of all sharks, the retention of sharks caught as bycatch, and the possession, trade, and sale of sharks and shark products within a country's full exclusive economic zone (EEZ)	1
FBU	Finning ban unspecified	this includes countries that have explicitly mentioned about finning measures but did not identify the specific ban status/category	0.2
FVB	Finning various bans	this includes countries that have more than one category of bans in place (such as FNA/ FCR for some species or fins-artificially attached (FAA) for others). FAA refers to fins being artificially tied to carcasses with a rope or other methods, even after being separated from the body.	0.4
OB	Other bans	this includes countries that have not mentioned any finning prohibition measures, or no information located on which to assess existence of finning measure; also, includes, any knowledge or available information, indicates that the finning measure is not in place although they might have other fishing or trade regulations in place for sharks or other elasmobranch species.	0

2.2.2. Fate and mortality of sharks

The information on shark bycatch fate and mortality rates were acquired from a variety of published sources. In total, data from 11 sources including two RFMO (WCPFC and IOTC) datasets and nine research publications were compiled for the bycatch fate (BF) dataset. Moreover, information from 60 peer-reviewed articles were gathered for the post-release mortality (PRM) dataset. The attributes of the two datasets are separately discussed below:

(i) Bycatch fate (BF): The raw BF dataset has 368 observations and 25 variables in total and out of these, 21 are non-numeric variables. Few of the non-numeric variables were grouped for data homogeneity, which includes gear, species by habitat and by-catch fate classifications. In addition, the methods used in the 11 identified data sources for the BF dataset are as follows:

(i) observer (n=8), (ii) researcher (n=2) and (iii) logbook (n=1). The fate bycatch dataset was filtered to remove all species belonging to non-shark families such as, "Dasyatidae", "Mobulidae", "Myliobatidae", "Rajidae" and "Torpedinidae". All missing values for categorical variables were filled in with the value “unknown”. All values in figure 6 are in log(tonnes).

(ii) Post-release mortality (PRM): There are 22 variables in the raw data from the post-release mortality (PRM) dataset, 18 of which are non-numerical. The PRM data contains 327 observations. In addition, the methods used in the 60 identified data sources for PRM dataset are as follows: (i) acceleration data loggers (n=1), (ii) blood chemistry (n=5), (iii) captivity after fishing (n=4), (iv) PRM model (n=1), (v) satellite tag (n=27), and (vi) visual (n=30). It is to be noted that some of the studies used more than one methodology and thus the count for total methods is higher than the number of studies included in the paper. The PRM dataset was filtered to remove all species belonging to non-shark families such as, “Aetobatidae”, “Dasyatidae”, “Gymnuridae”, “Mobulidae”, “Myliobatidae”, “Rajidae”, “Rhinidae”, “Rhinobatidae”, and “Torpedinidae”.

2.2.3. Total Mortality calculations

Total mortality was calculated for coastal and offshore species separately. The species that were caught using long line and purse seine gears were considered offshore species while species caught using other gears were considered to be coastal species. Total mortality is calculated using the following equation:

$$total\ mortality = \sum (n_{catch} \times p_{fate} \times m_{fate})$$

Three different fate types were used, which are: “discard_alive”, “discard_dead”, and “retained”. For each fate type, the product of the following three components were computed: n_{catch} which is the number of individual shark specimen caught, p_{fate} which is the probability of the given fate type and m_{fate}which is the probability of mortality for the given fate type. The products of these components for each of the three fate types were then summed to compute the total mortality. The total coastal and offshore mortalities were computed by each year to gain a better understanding of the mortality trends across time for these two species groups.

Before calculating mortality estimates, the mortality dataset was filtered to keep only the data related to shark species. The bycatch fate dataset was processed in the following ways: All missing values in the RFMO column were considered as "Non-RFMO", For the fate type all finned (fins kept, carcass discarded) values were replaced with "discarded_dead", and fate type values having "discard_unknown" were randomly given a category among "discard_alive" and "discard_dead" with a ratio of 50:50. The SAUP dataset was separated into "coastal sharks" and "offshore sharks" based on gear usage. Specimen caught with longline, or purse seine gear types were designated as offshore while those caught with other gears were designated as coastal species.

Coastal mortality:

Coastal mortality was calculated as follows:

$$coastal\ mortality = \sum(n_{coastal\_catch} \times p_{fate} \times m_{fate})$$

As mentioned previously the product of n_{catch}, p_{fate} and m_{fate} are calculated for all three fate types then summed to get the total coastal mortality. The data was grouped by year and coastal mortality was then computed separately for each year's data using the equation above.

❖ **Fate 1: Mortality of sharks discarded alive**

$n_{coastal\_catch}$: the number of individual sharks caught. The SAUP data was filtered to keep only **discard** data for coastal species. The values in the "sum" (catch tonnage) column were summed to get the total catch weight. This was then divided by the median average weight of coastal shark species (i.e. both large and small), which is 20.75 kgs according to Worm et al., 2013.

$p_{discarded\_alive}$: probability of being discarded alive. The bycatch fate data was filtered to exclude data about non-shark families and to keep only RFMO related data. We calculate the sum of the "sample size" column for each fate type which gives us the total number of individuals that suffered each "fate type". We divide these numbers with the total sum of sample sizes to get the individual probabilities for each fate type. We use the probability of being discarded alive for this part.

$m_{discarded\_alive}$: probability of mortality when being discarded alive. The mortality data was filtered to exclude data about non-shark families. We calculate the sum of "sample size" for each "estimate type". We then divide it with the total sum of samples sizes to get the individual probabilities.

This gives us,

$$coastal\ mortality_{discarded\_alive} = n_{coastal\_catch} \times p_{discarded\_alive} \times m_{discarded\_alive}$$

❖ **Fate 2: Mortality of sharks discarded dead**

$n_{coastal\_catch}$: we use the same process as before (or reuse the previous value).

$p_{discarded\_dead}$: same process as before. We just use the probability of being discarded dead for this part.

$m_{discarded\_dead}$ is 1 since the specimen is already dead when it was discarded.

Now,

$$coastal\ mortality_{discarded\_dead} = n_{coastal\_catch} \times p_{discarded\_dead} \times m_{discarded\_dead}$$

❖ **Fate 3: Mortality of sharks retained**

$n_{coastal\_catch}$: since we are considering the sharks retained, we filter the SAUP data to keep only **landing** data for coastal species. We then sum all the values in the "sum" (catch tonnage) column and divide it by the median weight of coastal species (20.75 kgs).

$p_{retained}$: same process as before. We just use the sum of retained unknown and retained whole probabilities for this part.

$m_{retained}$ is 1 since fish don't survive once retained.

Now,

$$coastal\ mortality_{retained} = n_{coastal\_catch} \times p_{retained} \times m_{retained}$$

Finally,

$$total\ coastal\ mortality = \sum(coastal\ mortality_{fate})$$

<u>Offshore mortality</u>:

Offshore mortality was calculated as follows:

$$offshore\ mortality = \sum(n_{offshore\_catch} \times p_{fate} \times m_{fate})$$

As with coastal mortality the product of n_{catch}, p_{fate} and m_{fate} are calculated for all three fate types then summed to get the total offshore mortality. The data was grouped by year and offshore mortality was then computed separately for each year's data.

❖ **Fate 1: Mortality of sharks discarded alive**

$n_{offshore\_catch}$: the number of individual sharks caught. The SAUP data was filtered to keep only **discard** data for offshore species. The values in the "sum" (catch tonnage) column were summed to get the total catch weight. This was then divided by the median weight of pelagic shark species which is 36 kgs according to Worm et al., 2013.

$p_{discarded\_alive}$: probability of being discarded alive. We filter the bycatch fate data to exclude data about non-shark families and keep only RFMO data. We then divide the sum of sample sizes for each fate type by the total sum of sample sizes to get individual probabilities for each fate type. We use the probability of being discarded alive for this part.

$m_{discarded\_alive}$: probability of mortality after being discarded alive. We exclude all data about non-shark families and calculate the sum of sample size for each estimate type. Then we divide it with the total sum of samples sizes to get the individual probabilities. Now,

$$offshore\ mortality_{discarded\_alive} = n_{coastal\_catch} \times p_{discarded\_alive} \times m_{discarded\_alive}$$

- **Fate 2: Mortality of sharks discarded dead**

$n_{offshore\_catch}$: same process as before.

$p_{discarded\_dead}$: same process as before. We use the probability of being discarded dead for this part.

$m_{discarded\_dead}$ is 1 since the specimen is already dead when it was discarded. Now,

$$offshore\ mortality_{discarded\_dead} = n_{coastal\_catch} \times p_{discarded\_dead} \times m_{discarded\_dead}$$

- **Fate 3: Mortality of sharks retained**

$n_{offshore\_catch}$: for sharks retained we first filter and keep only **landing** data for offshore species. Then we sum all the values in the "sum" (catch tonnage) column and divide it by the median weight of coastal species (36 kgs) according to Worm et al. 2013.

$p_{retained}$: same as before (use the sum of retained unknown and retained whole probabilities for this part).

$m_{retained}$ is 1 (since fish don't survive on land).

Now,

$$offshore\ mortality_{retained} = n_{coastal\_catch} \times p_{retained} \times m_{retained}$$

Finally,

$$total\ offshore\ mortality = \sum (offshore\ mortality_{fate})$$

2.3 Semi-structured interviews

In addition to desktop review, this study conducted 10 semi-structured interviews with selected experts to contextualize, ground-truth and cross reference the published data. This helped the study to obtain an informed perspective on the current trends in shark finning and shark mortality at different geographical scales (global, regional, and national). Moreover, experts' knowledge on how the management problem could be addressed at RFMO (regional fisheries management organizations) and country levels were also gathered from the interviews.

2.3.1. Sampling strategy

Interviews were conducted with selected fisheries and shark experts from regional management fisheries organization (RFMOs), international organizations (e.g., Worldwide Fund for Nature), academia, non-governmental organizations (NGOs) and other institutions or companies, who have ample experience and knowledge on shark trade, bycatch, and mortality rates. The experts were first gathered in phases using a non-probabilistic purposive sampling method based on publications. In addition, a snowballing approach was used if the researcher/supervisor had any personal ties to experts with extensive knowledge (technical, process, and interpretive in nature) on the research topic (Bogner et al., 2018; Myers, 2008; Collins, 2010). Furthermore, certain experts were chosen based on previous interview respondents' remarks, which included names and contact information for people who may provide more information about the research under inquiry. In summary, there are three techniques to selecting experts for purposive sampling:

- Identifying authors from research articles on the subject under examination.

- The researcher's and her supervisor's personal relationships with possible experts.
- Recruiting specialists who have been suggested by potential interviewers

2.3.2. Interview design

The problem-centered interview (PCI), created by Witzel in 2000, was used as the interview approach in this study (Doringer, 2020). PCI demands the use of a specific research design and interview instruments, this is the case and in general, an interview guide is used, which begins with a narration and finishes with precise follow-up questions (Döringer, 2020). As a consequence, PCI is particularly suitable for this study since it offers sufficient methods for reconstructing the implicit aspects of expert knowledge while keeping the research goal in mind (Döringer, 2020).

The interview questionnaire (Appendix III) has three main sections which include: (1) Respondents' personal information, (2) Perception and observations of the respondents, and (3) Management recommendations. Each section has a combination of open- and close-ended questions, which are basically qualitative in nature as it is mostly based on participants' observations on the particular topic. Each section is particularly designed to address the research question and three main objectives. Particularly, the 'Perception and Observations' section has seven questions, which include: (i) observed changes in finning incidences, (ii) observed changes in shark trade, (iii) observed any transition in species composition in shark fin trade, (iv) observations on the trend of shark mortality in light of emerging finning and other legislations, (v) perceptions on top areas most prone to shark by-catch and shark finning, and (vi) perceptions on type of gears most likely to incur shark bycatch. The last section of the questionnaire had a single question on management initiatives to address the current legislative gaps to reduce: (i) shark bycatch, and (ii) shark finning.

2.3.3. Analytical strategy

The interviews yielded a large data collection with diverse perspectives and personal narratives. A combination of deductive and inductive analysis was performed on the qualitative data gathered from the 10 semi-structured expert interviews. The intended analytical strategy for this particular research includes the following steps:

Data processing

All the recorded interviews were transcribed in a world file. All the transcriptions were cleaned and formatted to remove any grammatical or spelling redundancies. After transcribing the interviews, the researcher imported the data in an Excel spreadsheet to collect all the core information and attributes in a single file and thus, identify elements which could be analysed both deductively and inductively. For instance, the research expects the following three types of responses for deductive coding from the investigation on shark finning treads over the recent years: (i) shark finning is increasing, (ii) shark finning is decreasing, (ii) no change or cannot answer specifically. Similarly, the researcher also anticipated a perceived understanding of the respondents on trends in shark mortality which can be deductively coded for the purpose of the study.

Data importation and analysis

All the data gathered in the Excel spreadsheet was then imported into NVivo 12 for a hybrid content analysis to distinguish attributes deductively, as well as identify emerging themes and concepts inductively without pre-existing coding structure or guide. To develop fundamental observations/themes on shark trade and mortality, each rationale was read and re-read for iterative inductive coding. Initially, the researcher attempted to inductively code and categorize the respondents based on their demographic attributes. Each respondent was asked to give a little background about themselves and all these information in each of the transcription were coded in NVivo under the grandparent node “research focus”. Then a word cloud query was used to visualize the following categories/parent nodes: (i) shark experts and (ii) fisheries experts. Next, the respondents were further classified according to the organization that they represent under their parent nodes, which includes the following types: (i) International or regional organizations/NGOs (e.g. WWF, RFMOs), (ii) Local organization/NGOs, (iii) others (e.g. academics, self-employed, etc) (Appendix IV). Similarly, responses for management recommendations were inductively coded under two parent nodes: (i) shark finning and (ii) shark by-catch. This resulted in the identifying three themes or categories of management recommendation for sharks qualitatively and they are as follows: (i) precautionary measures, (ii) institutional measures and (iii) scientific measures (Appendix V). Other than the aforementioned inductive coding, all other elements were deductively coded for quantitative comparisons. These includes the following elements: number of responses on the trends in shark finning and mortality, regions of the global ocean that experience most shark by-catch and mortality and gears/fleets incurring most shark by-catch, respectively.

Chapter 3: Results

3.1 Global hotspots for shark catch

3.1.1 Global shark catches by fishing entities (2010 to 2018)

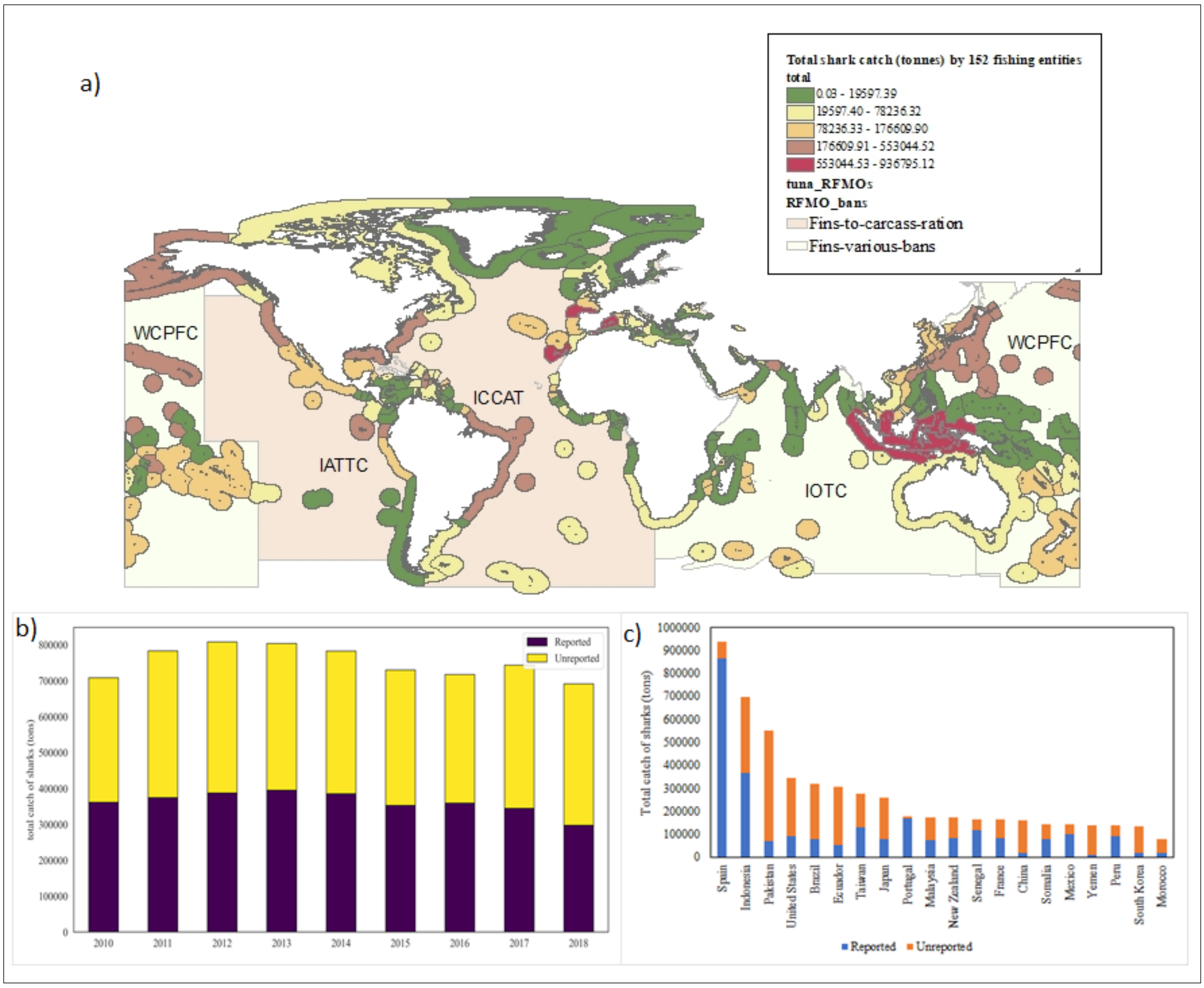

Figure 1: (a) Map of total catch of true shark species (reported and unreported) in tonnage by 152 fishing entities; (b) Total catch (tons) of true sharks between 2010 and 2018 by the 152 fishing nations; (c) Reported and unreported catch of true sharks (tons) by top 20 shark fishing entities as reported in the SAU data.

The reconstructed catch statistics that the SAUP (Sea Around Us Project) database presents include official reported catch data as well as reconstructed estimates of undocumented catches (including major discards), all with references to specific EEZs. FishStat, a database maintained by the Food and Agriculture Organization of the United Nations (FAO), is the primary source of officially reported catch data. According to reconstructed catch data from

SAUP, there were in total 152 fishing entities that reported shark catch (species exclusively belonging to true shark species) between 2010 and 2018. The map (figure 1a) illustrates the total catch (i.e., sum of landings and discards in tons) for all those 152 fishing entities. According to (Figure 1a), regions surrounding the Indian ocean (e.g., Pakistan, China, Malaysia, Indonesia), North Atlantic (e.g., Spain, France, USA, Mexico), South Atlantic (e.g., Brazil, Argentina, Uruguay) and South Pacific (e.g., Peru, Ecuador) had the highest catch. The map (figure 1) also shows four major Tuna RFMOs which are colour coded according to the strengths of their current finning ban status. The types of finning bans and their adoption by various EEZs and RFMOs are discussed in detail in the next section.

The SAUP database was also analysed to visualize the total shark catches (reported and unreported) over the eight years period (2010-2018) (Fig. 1b). During this period, the highest catch was reported in 2012 and 2013, catching around 800000tons of sharks for each year and the lowest catch was around ≃690000tons in 2018 (figure 1b). The proportions of reported and unreported catch were almost equal (≃400000tons) for these two years. A decreasing trend can be observed after 2013 for the next three consecutive years (i.e. 2013 to 2016) (Fig. 1b). However, in 2017 a sudden increase in catch amount was observed at ≃750000tons of sharks. More specifically, the graph in (figure 1c) shows the amount of reported and unreported catch in tonnage for top 20 shark fishing entities. Here Spain, Indonesia, and Pakistan lead in terms of total catch, but note that Pakistan is identified as the country with the highest unreported shark catch (Fig. 1c).

3.1.2 Shark catches by top 10 fishing entities (2010 to 2018)

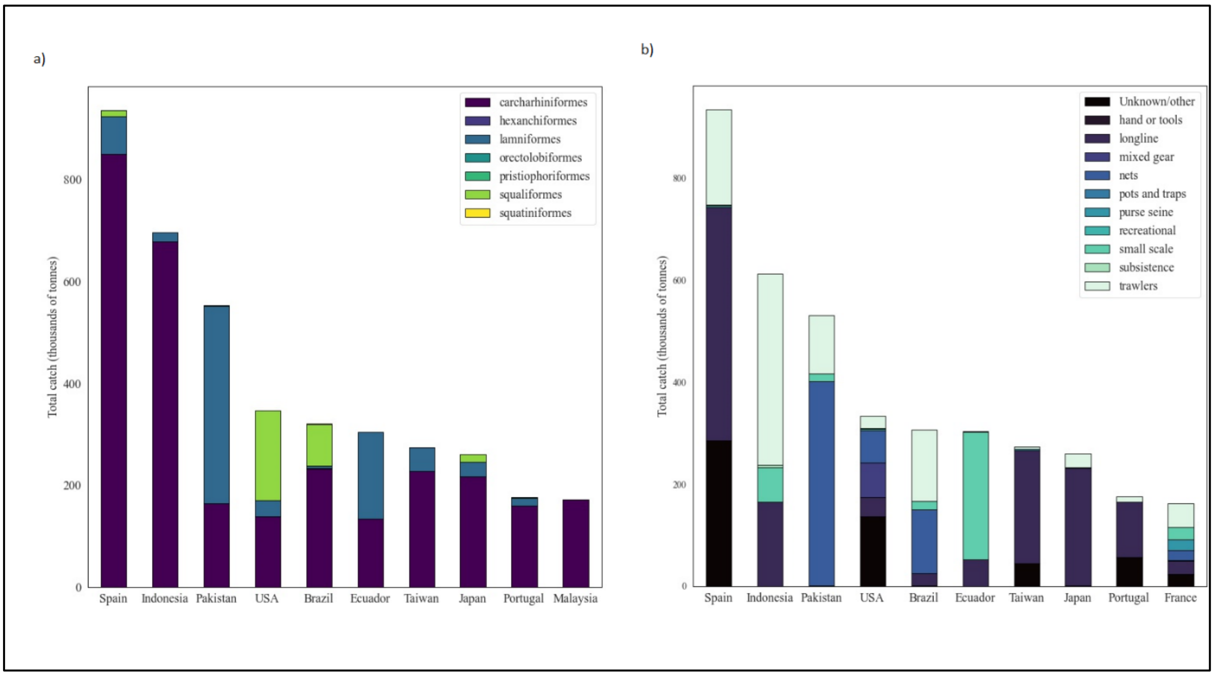

Figure 2 *(a) Total catch (tonnage) composition of sharks according to species order and top 10 shark fishing nations; (b)Total catch (tonnage) of sharks according to gear class and top 10 shark fishing nations (SAUP, 2020).*

Catch composition of the top 10 shark fishing entities according to their species order (Fig. 2a) revealed that 73% of the total catch among these countries were species belonging to the order Carcharhiniformes, followed by Lamniformes (19%) and Squaliformes (7%) (see Appendix I for detailed species list). Similarly, (figure 2b) illustrates gear use by the top 10 shark fishing countries. Results show that long-lines had the highest percentage of catch (33%), followed by trawlers (24%), nets (16%) and small-scale fishing gears (9.6%) (see Appendix II for detailed list of gears according to each group). Among these 10 countries, the catch composition for Brazil and Portugal is most diverse and for both cases the highest catch was in the Carcharhiniformes order as shown in (Fig. 2a and 2b). On the other hand, USA and France use various types of gears and catch was highest for unknown and trawler gear classes, followed by longlines respectively (Fig. 2b).

3.2 Global shark finning regulations

3.2.1 Regulatory categories and strength

The six ban categories considered in the study are listed in Table 1 and were each given a weight (z) between 0 and 1 according to the magnitude of its ban strength from 0 to 5 (Table 1). Shark sanctuaries are the most powerful in protecting sharks and were included as one of the ban types because they prohibit all shark commercial fishing, the retention of sharks caught as bycatch, and the ownership, trading, and sale of sharks and shark products throughout a country's entire exclusive economic zone (EEZ), implying that no finning is allowed within the sanctuaries' geographical boundaries. The five additional criteria in (Table 1) were then applied to all other EEZs and RFMOs to determine which locations had stronger finning prohibitions. Results showed that, there are eight regional fisheries and management organisations (RFMOs) that have approved legally enforceable measures to ban shark finning (named Recommendations or Resolutions depending on the RFMO). The International Commission for the Conservation of Atlantic Tunas (ICCAT), the General Fisheries Commission of the Mediterranean (GFCM), the Indian Ocean Tuna Commission (IOTC), the Inter-American Tropical Tuna Commission (IATTC), the North Atlantic Fisheries Organization (NAFO), the Southeast Atlantic Fisheries Organization (SEAFO), the Western Central Pacific Fisheries Commission (WCPFC), and the Northeast Atlantic Fisheries Commission (NEAFC) are the eight regional fisheries management organisations. However, the scope of this study is limited to the four major tuna RFMOs (ICCAT, IATTC, WCPFC and IOTC) as displayed in the map in (figure 1) (see also Table 4 in the next chapter).

3.2.2 Finning regulations by major fishing entities and EEZs.

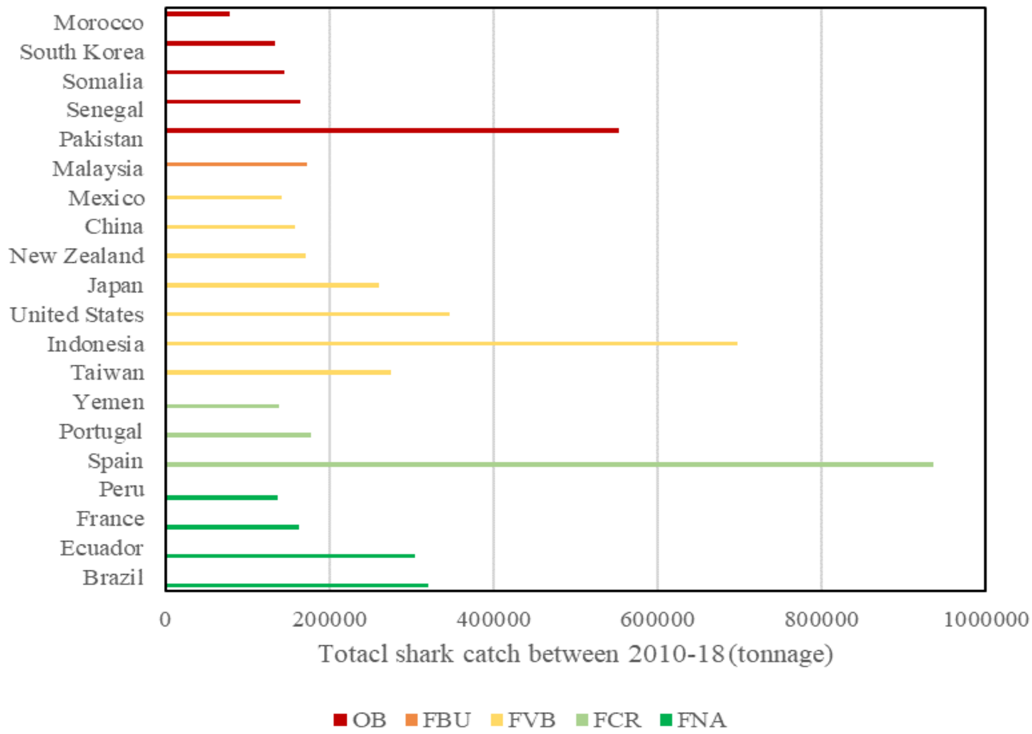

Figure 3: *Type of finning regulations for the top 20 shark fishing countries.*

The graph in (Fig. 3) shows the top 20 shark fishing countries according to their total catch (in tonnes) and ban categories. Among them, 30% (n=6) have various finning bans (FVB) followed by FNA (25%, n=5), FCR (15%, n= 3) and FBU (5%, n=1). The highest catch was reported by Spain having an FCR ban; in contrast to other EU countries which follow the FNA rule. It is illegal to have shark fins onboard without the corresponding carcasses. Compliance is verified through the use of a conversion system of fins to carcass weight. After Spain, two other countries surrounding the Indian Ocean had the highest shark catch, that is Indonesia and Pakistan. Indonesia has an FVB ban status because it prohibits the finning of sharks and rays that are young or pregnant. Only thresher sharks (*Alopias spp*) must be returned at sea whether alive or dead and must be noted in the logbook and all carcasses of sharks and rays accidentally caught during operations must be landed in whole (all fins connected to its body). Pakistan on the other hand has no such finning regulations in place and thus, falls under OB ban category. However, for countries such as the USA, which stands in the fourth position among the top 20, all sharks must be landed with their fins fully or partially attached in the natural way in all federal waters (with an exemption for smooth dogfish). Therefore, USA falls under the FVB ban category. Moreover, Brazil (4.7%) and Ecuador (4.5%) are ranked in the 5th and 6th position, despite having a stronger FNA ban category.

Similar to Indonesia, Taiwan (7th) and Japan (8th) surrounding the Indian Ocean are among the top 20 shark fishing countries and have adopted an FVB ban status. For example, in Taiwan, all sharks must be landed with their fins naturally attached. This policy took effect on January 1, 2013, for freezer vessels, and was changed in October 2013 to allow small-scale longline fisheries to land sharks with fins naturally attached or fastened to carcasses (fins-artificially-attached) (Zeigler, 2020). FAA, FNA, and FCR for Taiwanese fleets operating in varying conditions, such as national (NW) vs. distant waters (DW); RFMO CMMs are implemented. Malaysia on the other hand, being the 10th in position, is the only country surrounding the Indian ocean that has an unspecified finning ban (FBU) according to Section 8(b) Fisheries Act of 1985 since 2014 (NPOA Sharks, 2014; Zeigler, 2020).

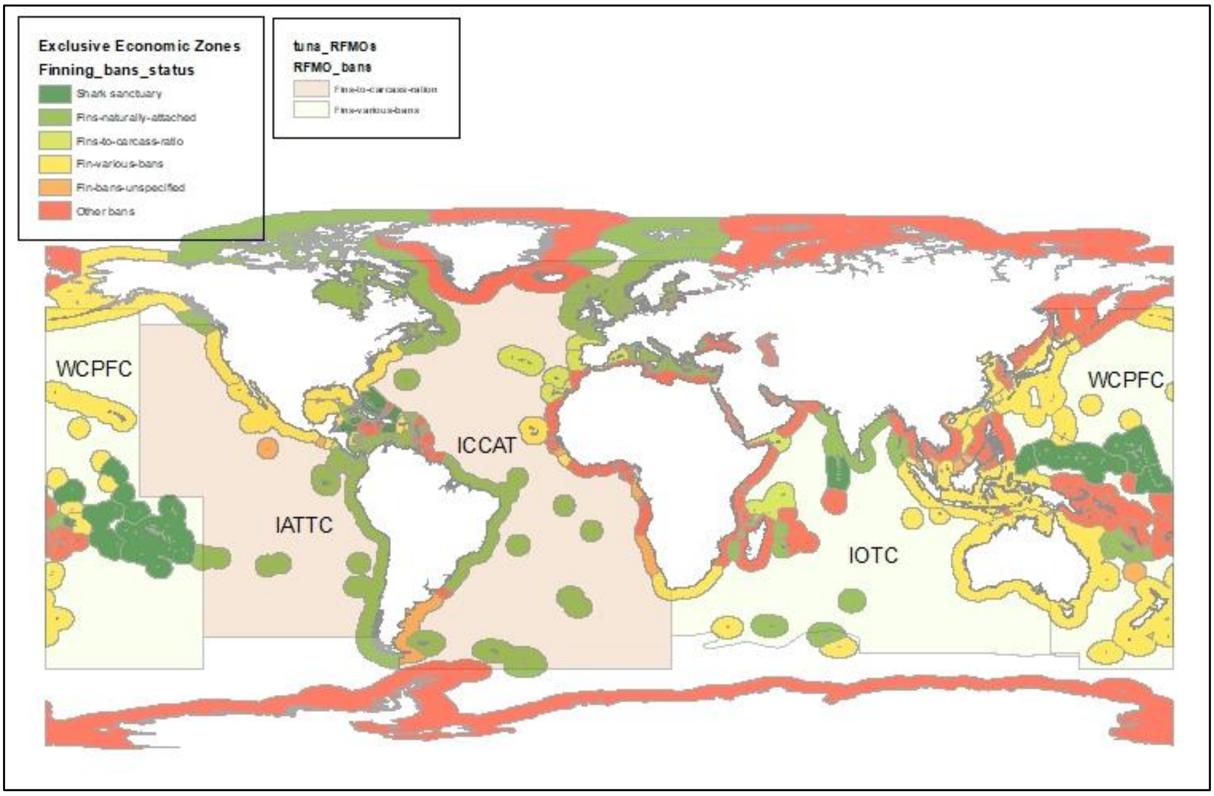

Figure 4*: The map shows the global regulatory landscape of all EEZs and four major tuna RFMOs.*

The map (Fig. 4) shows the global regulatory landscape of 280 exclusive economic zones, out of which 50%, (n=140) had no finning-specific bans (OB) in place, although they might have other fishing or trade regulations in place. However, a significant number of countries (25%, n=70) (including 24 EU countries, except Spain and Portugal) adopted fins-naturally attached (FNA) policy (sheen green), followed by FVB (10.7%, n=30) (yellow), SS (6%, n=19) (dark green), FCR (3.9%, n=11) (lawn green) and FBU (3.5%, n=10) (orange). The 19 shark sanctuaries, many of which are located within the Caribbean and WCPFC convention area are: Bahamas, Bonaire, British Virgin Islands, Cayman Islands, Dominican Republic, French Polynesia, Honduras, Kiribati, Maldives, Marshall Islands, Micronesia, New Caledonia, Palau, Saba, Samoa, Sint-Maarten, Gilbert Islands and Phoenix Group.

Moreover, the map shows five major tuna RFMOs and their finning ban status accordingly: IATTC (FCR), ICCAT (FCR), WCPFC (FVB), IOTC (FVB) and CCSBT (OB) (see Table 3). Both IATTC and ICCAT recommends that all shark catches be fully utilised (defined as the fishing vessel keeping all components of the shark save the head, guts, and skins until the first landing) (Brautigam, 2020). Fins should not account for more than 5% of the sharks' total weight. However, it is not specified whether the weight refers to whole or dressed sharks (Brautigam, 2020). Contrarily, IOTC and WCPFC have a mixed ban status (FVB), which mostly adopted FNA policy with few exceptions (Brautigam, 2020). For example, IOTC implements an FNA policy for fresh sharks (MSC Report, 2020) but an FCR policy for frozen sharks (Brautigam, 2020). Similarly, WCPFC also has alternative measures to FNA (e.g. FAA) that have been adopted as exceptions to FNA requirements in certain jurisdictions, such as New Zealand (Brautigam, 2020). Here, shark finning is prohibited as of October 2014 for some species, October 2015 for most others, but not until October 2016 for blue sharks, but there is no prohibition on the removal of fins at sea. Moreover, in New Zealand, FAA or FCR applies to 9 shark and chimaera species caught in separate fisheries under different management regimes (Brautigam, 2020).

3.2.3 Regulatory timeline by country and landscape by ocean areas

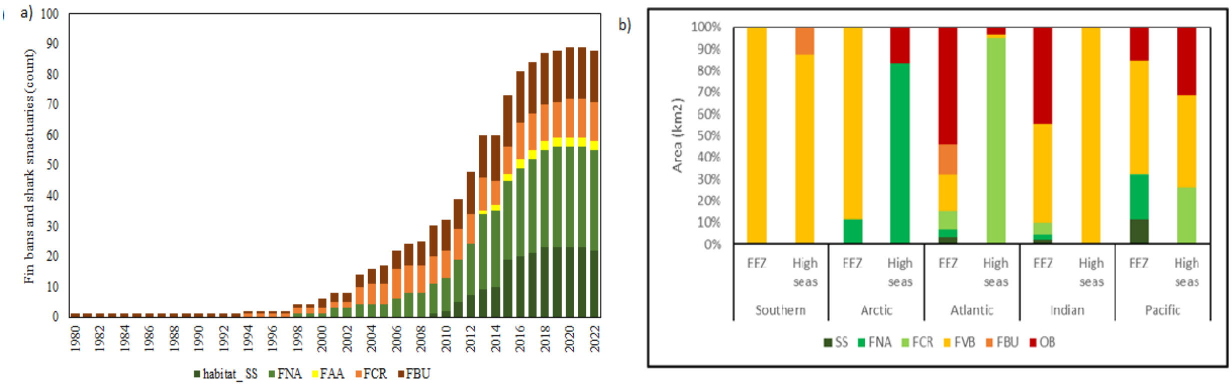

Figure 5: (a) Cumulative count of active and amended finning regulations by EEZs from 1980 to 2022; (b) Finning regulations according to the total area covered by the EEZs and high seas within different RFMO boundaries.

The cumulative count of finning bans (both active and amended) by EEZs over the years (1980 to 2022) is shown in Figure 5b. Results show that Israel was the first country to adopt a finning ban although it was unspecified (FBU). After Israel, Canada was the second country to adopt a FCR type of ban in 1994 (HSI, 2019, 2019), which was later amended in 2018 to adopt FNA ban status, for all sharks landed in Canada (Fisheries and Oceans Canada, 2019). Moreover, in 1998 FNA ban category was introduced by South Africa. Although, the country adopted two categories (FNA and FCR) of bans simultaneously, however, it was the first time that FNA was adopted for all domestic vessels operating in the national waters of South Africa (HSI, 2019). FCR was also applied for both domestic and foreign vessels operating in international waters which stated: “However, fins from sharks caught in international waters may be landed in South Africa with fins detached from carcasses with an 8% ratio for domestic vessels and a 5% ratio for foreign vessels” (HSI, 2019). Recently, in 2017, FNA ban was implemented for specific fisheries via permit conditions in the country and also, FCR may apply in some cases with special permits. Furthermore, the first country to establish a shark sanctuary in 2009 was Palau which, “prohibit the commercial fishing of all sharks, the retention of sharks caught as bycatch, and the possession, trade, and sale of sharks and shark products within a country’s full exclusive economic zone (EEZ)” (HSI, 2019). Apart from this, another distinct category of finning ban evolved as FAA (fins-artificially attached) and was introduced by Taiwan in 2013 which either required fins to be artificially tied to the carcasses (FAA) or fins naturally attached by small-scale longline fisheries. Later, in 2016 Taiwan amended the ban status to a combination of finning regulations, according to the following statement: “FAA, FNA, FCR for fleets operating under differing conditions, including fleeting operating in national (NW) and distant waters (DW)” (HSI, 2019). Apart from Taiwan, New Zealand also explicitly adopted FFA with a combination of FCR in 2014, which states: “FAA applies to most species; FAA or FCR applies to 9 shark and chimaera species taken in fisheries under different management regimes” (Brautigam, 2020). Similarly, many EEZs have amended previously adopted weaker finning regulations to stronger ones and thus, an incremental increase is observed in (Fig. 5a) for FNA regulations and shark sanctuaries adopted by several nations over the years.

Noteworthy is that the FVB and OB ban categories were not applicable for regulatory timeline for the following two reasons:

- As shown in Table 1 in Chapter 2, OB refers that there is no evidence or knowledge of any existing finning ban, including countries having either other trade or catch bans for sharks or there is lack of regulatory measures for protecting elasmobranch species. Therefore, to generate a homogeneous plot explicitly on finning regulations over time, OB was not considered.
- Similarly, FVB ban category was also not displayed in Figure 5b because timeline for individual finning bans were considered separately rather than aggregating a combination of bans under FVB. This suggests FVB was considered for cases, such as the regulatory map for simplicity in displaying countries adopting more than one finning ban such as Taiwan, South Africa and New Zealand as discussed previously.

Other than that, Figure 5b shows finning regulations according to the total area covered by the EEZs and high seas within different RFMO boundaries. Proportions covered by each ban in each ocean are discussed below.

Atlantic Ocean: Overall, (Fig. 5b) shows that more than 55% of the total area of Atlantic EEZs have no finning bans in place (OB), with almost 30% of them implementing unspecified (FBU) and various finning ban (FVB) categories. A small portion (5%) of the Atlantic EEZs is designated as shark sanctuaries (SS), with less than 3% adopting FNA and more than 7% implementing FCR policy. Moreover, the majority (95%) of the high seas in the Atlantic Ocean follows FCR policy as implemented by ICCAT.

Pacific Ocean: Most of the Pacific EEZs (60%) adopted more than one type of finning bans (FVB) and almost 20% agreed to implement FNA policy. Also, a significant portion (10%) of the EEZs in the Pacific are designated as shark sanctuaries. The high seas in the Pacific fall under three categories of bans; almost 30% of the total high sea areas adopted FCR and 40% FVB, as recommended by IATTC and WCPFC respectively (Fig. 5b).

Indian Ocean: Altogether, 5% of the Indian EEZs have SS (2.5%) and adopted an FNA ban policy (2.5%); also, around 10% of them implement an FCR ban policy. However, the majority (45%) of the EEZs in the Indian Ocean follow various finning regulations (FVB) and the other 35% are categorized as OB for having no available information on ban status. All the high seas in the Indian Ocean have FVB ban status as recommended by the Indian RFMO, IOTC (Fig. 5b).

Arctic and Southern Ocean (Antarctic): A small portion (10%) of the EEZs in the Arctic have FNA ban and the remaining 90% have FVB regulatory status. Contrarily, the EEZ of sub-Antarctic Island called, the "Heard and Mcdonald Islands" has an FVB ban category similar to Australia as the islands encompass the most remote territory of Australia. The majority of the high seas area (85%) under the NEAFC RFMO in the Arctic applies an FNA policy since 2015; whereas the high sea in the Southern Ocean has both FVB and FBU regulations in place because of the policies applied by the two RFMOs, CCAMLR and CCSBT respectively (Fig. 5b).

3.3 Bycatch fate and mortality estimates

3.3.1 Shark bycatch fate by species

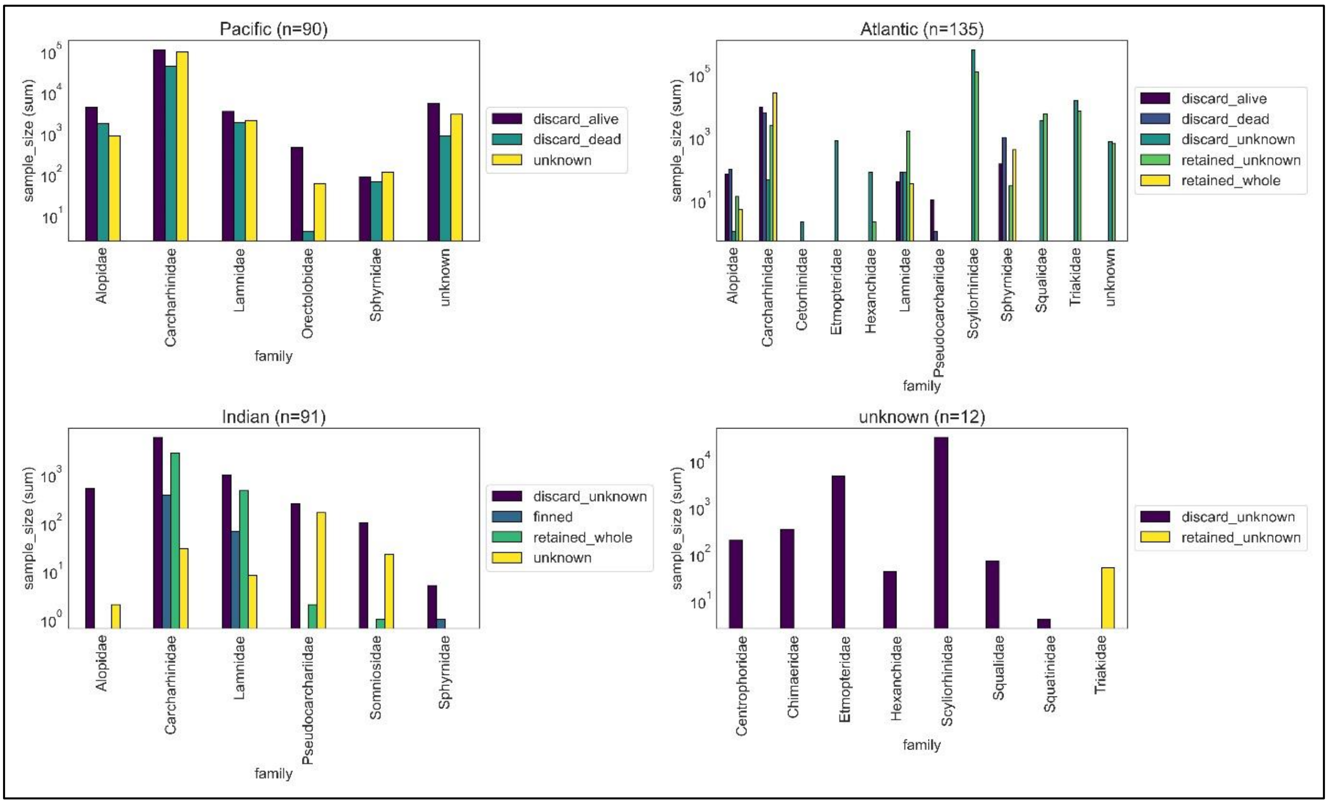

Figure 6: The total number of shark specimens caught in observed sets in (a) Pacific, (b) Atlantic, (c) Indian and (d) unknown oceans and their bycatch fate proportions (count) according to species family from total sample size reported in two RFMO (WCPFC and IOTC) datasets and nine research publications.

<u>Pacific</u>: According to RFMO observer daya, a majority of specimens among all families were discarded alive. 62.16% of specimen in Alopidae, 44.16% of Carcharhinidae, 46.42% of Lamnidae, 87.45% of Orectolobidae and 31.94% of Sphyrnidae families were discarded alive. Dead discards were common for Alopidae (25.21%), Carcharhinidae (17.49%), Lamnidae (25.13%) and Sphyrnidae (24.71%) families. For all families except Alopidae unknown fate had the second highest frequency.

<u>Atlantic</u>: In the Atlantic the fate had more variation. For Alopidae the most common fate was being discarded dead (51.67%) followed by being discarded alive (37.78%). The fate of being retained either whole (2.78%) or unknown (7.22%) was also relatively high. For Carcharhinidae the most common fate was being retained whole (59.81%). Being discarded

alive (21.02%) and being discarded dead (13.82%) also had high sample sizes. Cetorhindae and Etmopteridae were all discarded but their mortality (dead or alive) was unknown (100%). Hexanchidae were most commonly discarded with mortality (dead or alive) unknown (97.47%). Lamnidae were most commonly retained with mortality (dead or alive) unknown (87.33%). Specimens being discarded alive (2.19%), dead (4.43%) or unknown (4.2%) as well as being retained whole (1.85%) had similar amounts. Most Pseudocarchariidae were being discarded alive (90.91%) with a smaller number being discarded dead (9.09%). Scyiiorhinidae were either discarded with mortality (dead or alive) unknown or slightly less likely retained with mortality (dead or alive) unknown. Sphyrnidae were most commonly discarded dead (63.48%), followed by being retained whole (25.74%), then discarded alive (8.97%) and retained with mortality (dead or alive) unknown (1.81%). Among Squalidae most were retained with fate unknown (61.67%) and the rest being discarded with fate unknown (38.33%). Triakidae specimens were commonly being discarded with fate unknown at 68.35% and retained with mortality (dead or alive) unknown at 31.65%.

Indian: In the Indian Ocean most specimens in the Alopidae 99.61%, Carcharhinidae 64.94%, Lamnidae 64.26%, Pseudocarchariidae 60.34%, Somniosidae 81.15% and Sphyrnidae 83.33% were discarded with mortality unknown. Some families such as Carcharhinidae and Lamnidae were also retained whole and finned (then carcass discarded) in significantly numbers (both around 30%) with this fate having the second and third highest amounts respectively among these two families. A small number of Sphyrnidae (16.67%) were also finned (carcass discarded).

Unknown: There were a small sample of 12 observations with the ocean unknown. Here the only fate among all families (100%) except Triakidae was being discarded and mortality being unknown. However, Triakidae were exclusively retained with mortality unknown (100%).

3.3.2 Total mortality estimates

Mortality was calculated separately for coastal and offshore species. For each category the total mortality was calculated as:

$$total\ mortality = \sum(n_{catch} \times p_{fate} \times m_{fate})$$

Here, $n_{catch}$is the number of individual shark specimen caught. This is obtained by dividing the bycatch weight (tonnes) by the average weight of species (coastal or offshore). The $p_{bycatch\ fate}$ is the probability of a particular bycatch fate and $m_{fate}$is the post release mortality for that fate. We calculate the mortality for each bycatch fate: discarded alive, discarded, dead and retained, then sum their resultant values, which gives the total mortality for either coastal or offshore species.

➢ **Coastal Mortality**

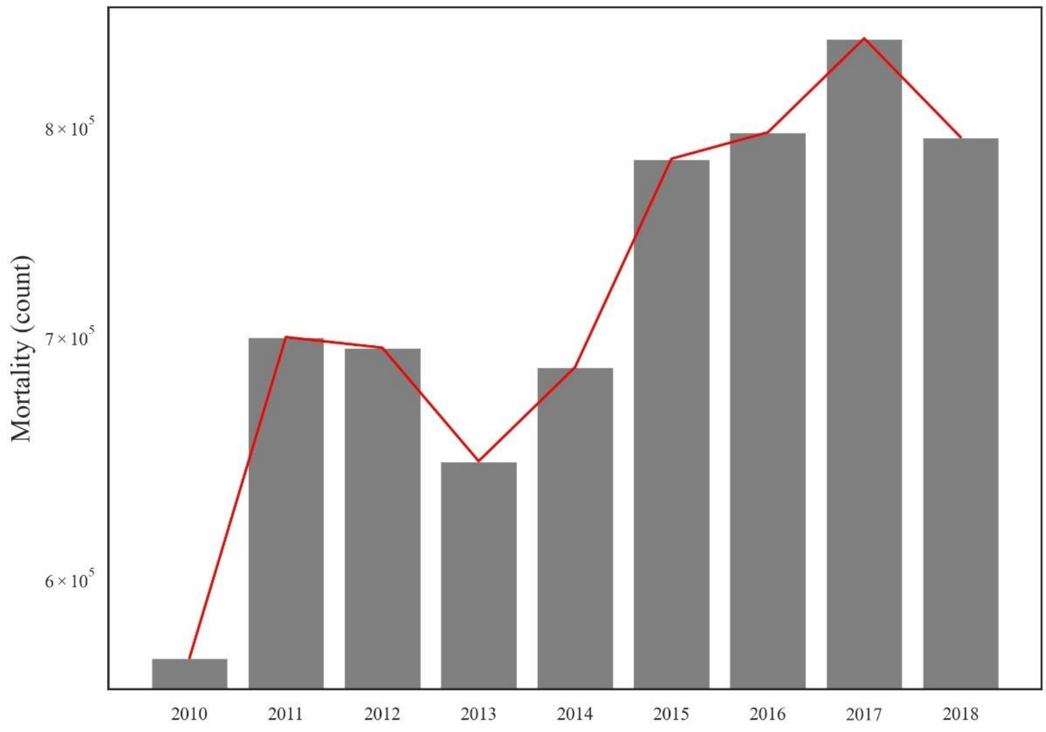

Figure 7: *Coastal mortalities for shark species (2010-2018).*

Figure 7 shows the total coastal mortalities calculated for the years from 2010 to 2018. It is apparent that over the years mortalities for shark species in coastal regions has increased. Mortalities in 2010 were as low as ≃570354 coastal sharks, which increased to ≃699610 the following year. Throughout the next decade mortalities remained relatively stable only declining slightly in 2013 (≃646519 sharks) and then increasing again in 2015 to ≃783679 sharks. Afterwards mortalities increased reaching its peak in 2017 at ≃846075 and then declining slightly in 2018 to ≃794497 individual of sharks.

➢ Offshore Mortality

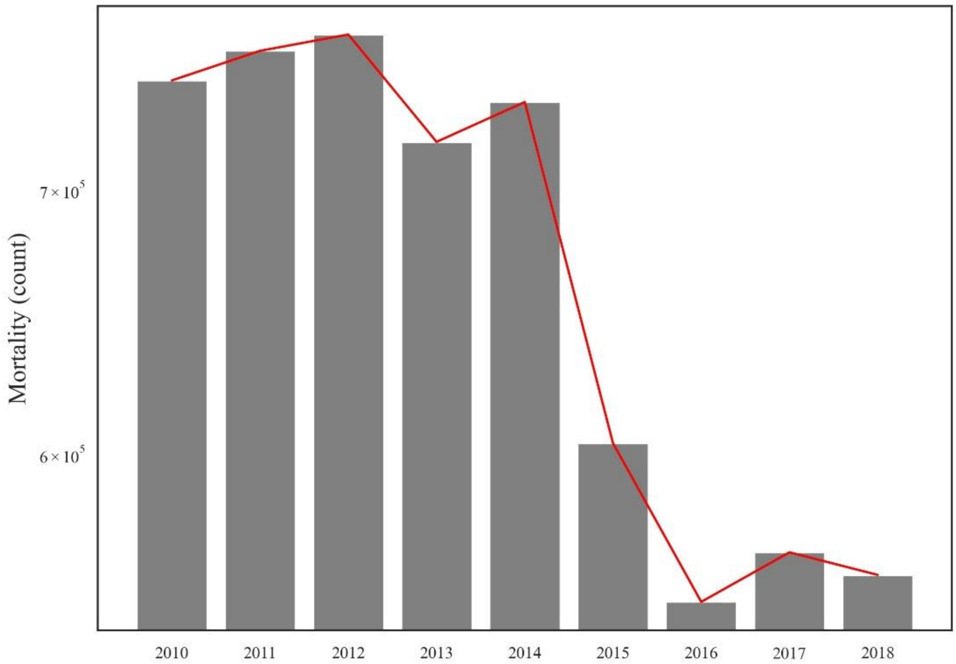

Figure 8: *Offshore mortalities for shark species (2010-2018).*

Figure 8 shows the total offshore mortalities calculated for the years from 2010 to 2018. As we can see over this 8 years timeline, the mortalities for offshore shark species have declined. In 2010 offshore mortalities were around ≃746257 sharks which steadily increased until 2012 up to 766513.08 sharks in two years, then declining in 2013 to ≃720008 individuals. The following year in 2014 mortalities increased slightly then falling drastically in 2015 to ≃604007 and reaching its lowest value in 2016 at ≃550646 individual species of sharks. Since then, mortalities have increased slightly but never exceeding ≃566778 as estimated for 2017.

3.4. Interview Results

3.4.1. Interviewee Demographics

The 10 respondents who took part in the semi-structured interviews are experts coming from different fields in the marine sector with ample experience on sharks (n=6) and marine fisheries (n=4). The average years of experience for shark experts was 11±5.66 years and for fisheries experts was 22±10.8 years respectively (Appendix IV). Moreover, the current research focus of the respondents include: (i) sharks and rays in the Mediterranean, (ii) tuna gillnet fisheries, (iii) live release/ post release mortality in Reunion Island, (iv) stock assessment of *Mobula* rays and other endangered species of elasmobranch, (v) sharks and rays conservation, (vi) tuna fisheries, (vii) bycatch discard issues and (viii) spatial resolution of species specific pelagic and coastal sharks, (ix) sharks and rays stock assessment and (x) diversity and distribution of marine megafauna like manta rays and whale sharks.

3.4.2. Perceptions and Observations

Expert responses on the frequency of finning practices showed that majority of shark (n=5) and fisheries (n=3) experts observed decreasing finning incidences as shown in Table 2. However, only two responses were coded as “arbitrary” because these respondents could not provide an explicit answer to the problem. Table 2 summarizes all the key responses and the driving factors accompanying such observations.

Table 2: Perceived observations by shark and fisheries experts on the trends of shark finning (2000-2020), the corresponding driving factors and relevant quotes to support their perceptions.

Expert categories	**Organization type (N)**	**Trends in shark finning (2000-20)**	**Driving factors**	**Respondent quotes**
Shark experts	International NGOs /organizations (RFMOs) (1)	arbitrary	No proof of systematic FI by EU fleets	*“Several finning incidences here and there but couldn’t see any proof of finning on a systematic basis. Now the question arises, how systemic it (particularly EU finning) actually has been before the anti-finning legislations?”*
	Local NGO (4)	decreasing	transition of fisheries	*“Following the finning bans-a big change-since then (2000.) The fishery transitioned from target shark fishery to target tuna fishery-which aimed at decreasing shark mortality in Sri Lankan waters. But this wouldn’t be necessarily correlated with the shark finning bans-more correlated to the transition of fisheries that took place.”*
		decreasing	EU 2013 regulations adopting FNA ban status without any exceptions	*“Since 2013 when the EU regulations came in place we see a major improvement in finning, I mean they are not openly going on. However, I think there are few incidences illegally and this has been proven by all the reports that come out reporting illegal incidences again and again. But overall, the majority in big part of the world and I think it is like almost half of the major fishing nations that have the FNA or at least finning meshes in place. This has gone down.”*
		decreasing	value of fins decreasing	*“For Brazilian companies, it's decreasing. Because in this WWF report, I interviewed some fishermen and interpreters, and the value of the fin with exceptions hammerheads and mackerel sharks are decreasing.”*
		decreasing	high demand for shark meat	*“I think is there's a decrease, but because there's a heavy demand for the shark meat itself. Sharks are being landed, like as a whole family, of course, the fins are exported.”*

	Academic (1)	decreasing	increased finning enforcements and regulations	*"Finning decreased-most countries land sharks whole for meat demand. So, finning is limited to industrial fleets-continuing at a lower scale (finning is going down 1980s and 1990s)-due to increased finning enforcements and regulations."*
Fisheries experts	International NGOs/ Organizations (RFMOs) (2)	decreasing	improved measures and monitoring	*"Finning has decreased since 2000, there are no directed shark finning in the Indian Ocean at the moment either from IOTC or WWF network."*
		decreasing	Non-retention and landing whole specimen rules	*"The act of finning is limited to some industrial long-liners or purse seiners maybe, but the overall value has declined. So I don't think there are many because if the meat is valuable or meat with other more valuable fishes (like mackerel), you eat a burrito or taco for instance, in central America or Mexico, then there is a high chance that you're going to be eating some shark species."*
	Local NGO/ Institution (1)	decreasing	RFMO (IOTC) regulations	*"Finning has over all decreased and it was even not a problem for French territories, as France had its own regulations for finning. However, due to the regulation of IOTC, it has declined I assume; however, IUU fishing, except rumours in Madagascar, cannot estimate IUU fishing for shark finning"*
	Others (1)	arbitrary	outlawed finning practices that still continue under the radar	*"Well, I'm not sure I've noticed any change. So, there's a big push to reduce finning, but my impression is that it goes on, under the radar. In the Maldives, for example, shark catching is banned, as well as shark finning. You know, it goes on. Just recently, customs and customs service in Maldives had a big-undisclosed link of buying shark fins."*

Similar to Table 2, another table was generated to display respondents' perceptions on shark mortality (Table 3). Majority of fisheries experts (n=3) claimed that shark mortality was relatively low over the last two decades, with the exception of one expert who claimed that shark mortality was relatively high. On the other hand, there were diverse responses from shark experts which includes the following mortality scales: (i) relatively low (n=2), (ii) relatively high (n=3) and (iii) no change (n=1). Table 3 summarizes the collective responses on trend and driving factors on shark mortality.

Table 3: Perceived observations by shark and fisheries experts on the trends of shark mortality over last two decades, the corresponding driving factors and relevant quotes to support their perceptions.

Expert categories	**Organization type (n)**	**Trends in shark mortality (2000-20)**	**Driving factors**	**Respondent Quotes**
Shark experts	International NGOs/ organizations (1)	relatively high	food-security	*"Increased landing is suspected of species once discarded that serve as substitutes for food security-often considered as relatively cheaper seafood option. For some countries, there are market data for other there are not (e.g Croatia)."*
	Local NGOs (4)	relatively low	shark sanctuary	*"Mortality is increasing. From all the data that I gathered from FAO, SAU and Latino bulletins and also from few monitoring programs that are happening in Brazil. For example, there is a monitoring program funded by Norweigh and looking into their data base for Brazil, I can see that shark catches is going up. We observed reductions. Species that was seen 20 years ago are now rare. So shark mortality is increasing a lot."*
		Relatively high	shark meat trade	*"Shark finning legislation particularly didn't have an impact on reducing overall shark mortality. But countries that used to undertake shark finning, after the prohibitions they landed the sharks whole. And it basically resulted in new markets for shark meat, oil and other products for countries that didn't consume shark meat previously. The major issue probably existing and emerging shark fisheries resulting in increasing shark mortality. For instance, in a hypothetical scenario, if there were no finning taking place anywhere in the world, yet the rate of shark mortality would be high resulting in declining populations."*
		no change	big interest by Spain and Portugal fleets	*"But if you look into data for thirty years for EU fleets, especially for Spain and Portugal, you can really see that the sharks were big interest something like 30 years ago and since then it has gone up! Up! UP! So the catches of blue sharks, they increased by more than 10-fold. We are now looking at figure about 60000 tonnes a year just in the Atlantic. And the majority of that is caught actually by Spain*

				and Portugal. So it has not really improved in the number of sharks caught but at least we have more data."
		relatively low	full protection bans for some shark species	*"Yeah, since that of 2000 in the last two decades, with the enforced enforcement from both national and international levels. It definitely has helped, especially if it's fully protected. If it's fully protected, there's less grey area. I definitely agree on that, like, for example, the manta rays and whale sharks. If it's something like hammerheads, where you're not allowed to export it, but you're allowed to kind of have it for local consumption, then that's where it gets a little bit tricky."*
	Academic (1)	relatively high	massive shark by-catch	*"In the USA, it has decreased and in Bahamas it's nearly zero. Mostly, as a result of Shark Sanctuaries. Landing in Belize stabilized and decreased. So I think most of the shark sanctuaries are doing well for the coastal species."*
Fisheries experts	International NGOs/ organizations (2)	relatively low	decreased population size	*"Shark (elasmobranch) catches are definitely decreasing- guitarfishes, mobulids and wedgefishes are very rare. Shortfin mako can sometimes be observed in large number but in different class size (juveniles, pups, sub-adult). However, didn't observe a fully grown scalloped hammerhead for four years. Sawfishes are almost completely gone-last reporting in 2015 and 2016 in Pakistan maybe. Silky sharks are more consistent in number-maintaining class sizes. Oceanic whitetips are rare from 2015- 2018 sampling. So assumption is that high population decreased or migration to high seas."*
		relatively high	Purse seine and artisanal fisheries	*"The bycatch of sharks in purse seine fisheries are really more than longlines in comparison by a factor of 100 or more over four years, but in recent years, we have seen a terrific decline of the oceanic whitetip shark which for me is a political thing in the South Pacific. A huge decline in the silky sharks which is a major bycatch in purse seine fleets. It maybe 80% decline according to the data of our measurements and then comparing with Shelly Clarke's review for longline fisheries and we are no way near that estimate."*

	Local NGO /Institutions (1)	relatively low	live release mandates	*"Legislations of IOTC ban such shark finning practices-encourage live release practice. After oceanic whitetips, IOTC banned on threshers. However, populations of some sharks in the Reunion Island are in decline, such as thresher sharks."*
	Others (1)	relatively low	outlawed product practices	*"There is a low level of shark mortality and possibly finning happening due to essentially outlawed product practices that still continue under the radar, but it will be a relatively low level of mortality. Although, of course, if shark numbers are low, then even a relatively low level of mortality in terms of absolute numbers, again, would have a big impact."*

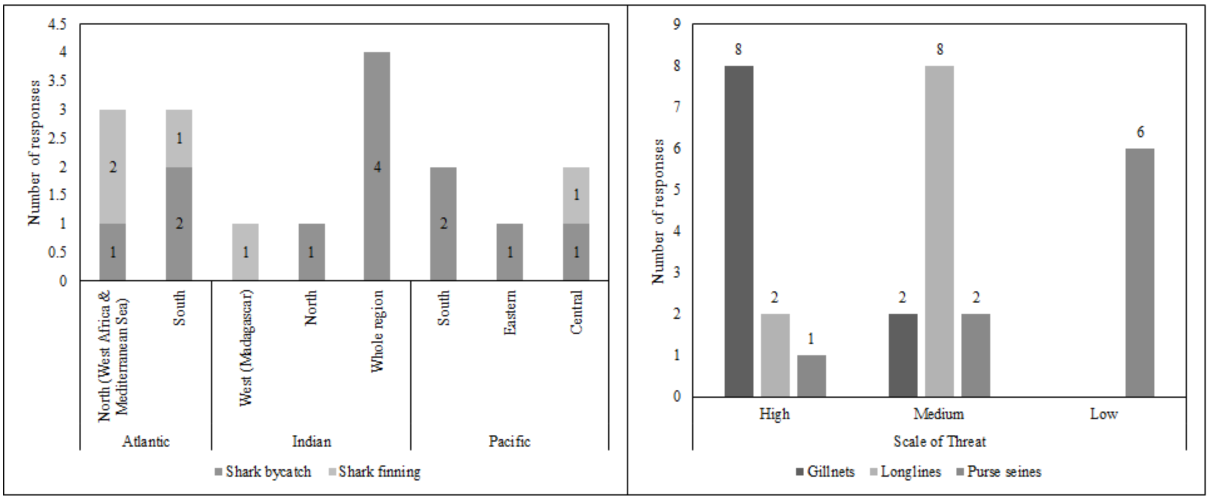

Figure 9: Perceptions on (a) hotspot regions and (b) fishing gears most likely to incur shark by-catch.

Furthermore, multiple responses (n=18) were obtained for identifying the following top 3 regions of the global ocean most prone to shark-bycatch (figure 9a): Indian Ocean (n=4), South Atlantic (n=2) and South Pacific (n=2) as shown in (figure 9a) respectively. On the other hand, there were fewer responses (n=5) for identifying regions that incur most shark finning and these regions include: North Atlantic (Mediterranean and West Africa) (n=2), South Atlantic (n=1), West Indian Ocean (Madagascar) (n=1) and central Pacific (n=1) respectively (Fig. 9a). Around 50% interviewees could not specify exact locations on shark finning as they occur discretely by IUU fishing. So they answered, either "cannot be answered in volume," or "cannot specifically/directly indicate" out of total responses (n=18) on identifying shark-bycatch and finning hotspots (Fig. 9a). In addition, perception of the interviewees on gears/fleet types most likely to incur shark bycatch were gathered (figure 9b). The degree of threat was ranked according to 'high', 'medium' and 'low'. Most of the respondents (n=8) reported gillnets (GN) to incur most shark by-catch, and few (n=2) reported longlines (LL) and one reported purse-seines/FADs (fish aggregating devices) to have higher scale of threat (Fig. 9b). Noteworthy is that 100% of the respondents' ranked gillnets and longlines as having high or medium degree of threat for shark by-catch. Apart from this, purse seines (PS) were least reported (n=6) or seen to have less impact on shark by-catch compared to GN and LL for majority of the respondents (Fig. 9b).

Chapter 4: Discussion

4.1. **Regulatory landscape**

This study evaluates trends in shark mortality as a result of anti-finning laws in 280 EEZs and four tRFMOs. Only 25% (n=70) of EEZs adopted a FNA prohibition category, and roughly 6% (n=19) of EEZs were designated as shark sanctuaries, according to the findings. Between 2010 and 2018, total shark mortality in this analysis indicated contrasting trends in national and RFMO-regulated fisheries. Overall, the correlations and discrepancies between the global finning regulatory framework and shark mortality is discussed in this Chapter.

4.1.1 Management discrepancies in major tuna RFMOs

Various RFMOs have developed and adopted shark-specific management and conservation measures that have been criticised by marine professionals (Dent and Clarke, 2015). Lack of cooperation and participation by nation-states and foreign vessels, as well as a lack of research to make sound decisions, have impeded the ability of RFMOs to conduct their tasks effectively (Cullis-Suzuki and Pauly, 2010; Mooney-Seus and Rosenberg, 2007; Szigeti and Lugten, 2015).

The main problem is that RFMOs are resistant to change. The United Nations General Assembly (UNGA), for example, has issued a number of proclamations and resolutions encouraging RFMOs to call on CPs to adopt their own NPOA-Sharks (Worm et al., 2013), although it appears that RFMOs have a mixed track record in attaining these objectives. For example, shortfin mako sharks (*Isurus oxyrinchus*) are particularly vulnerable to ICCAT fisheries, according to a 2008 Ecological Risk Assessment for sharks (COFI, 2018). ICCAT has barred the retention of numerous other shark species during the previous decade but has neglected to impose even the most basic restrictions on makos. ICCAT made merely a first step toward mitigating additional reductions in the North Atlantic Shortfin Makos population in response to a 2017 assessment (COFI, 2018). Instead of the suggested restriction on mako retention, an ICCAT policy passed in 2017 ordered that Shortfin Makos brought to the boat alive be gently released, unless the Party has a minimum size limit or a discard rule that limits profit (COFI, 2018). Dead makos can still be landed by boats under 12 metres, as well as bigger vessels in specific circumstances, for the purposes of monitoring catch and reporting statistics. Hence, the domestic implementation of these already minimal measures is far from complete (COFI, 2018).

The second issue with shark measures in RFMOs is that when relevant data is not available, a precautionary approach must be used to preserve the survival of shark species. There is currently a scarcity of information about shark populations and shark capture. Many of the existing quotas and catch measures lack the necessary foundation to allow for sound management decisions. For example, because shark discards are not included in the published FAO data on world shark catch, real mortality is greatly understated (Anderson, 2011; Levesque, 2008). Furthermore, shark catches are rarely documented by species, making it impossible to identify the right shark species (Lack and Sant, 2009). As a result, ICCAT and other RFMOs struggle to establish how each shark species should be maintained due to a lack of reporting and scientific data (Schleit, 2015).

The greatest issue, and arguably the simplest to address, is the major tuna RFMO's shark 'finning ratio.' Shark finning is a major concern for shark conservationists (Spiegel, 2001). IATTC and ICCAT, the two major tuna RFMOs (Table 4), have the same shark fin limit: not more than 5% of the weight of sharks onboard, up to the first place of landing (COFA TUNAS, 2015; NAFO, 2016). However, the 5% fin-weight ratio has a number of flaws. It is unclear if the fins should be wet or dry in the measure. The weight of anything that is wet vs dry differs significantly (Biery and Pauly, 2012). Furthermore, across species and vessels, the fin ratio, fin set, fin technique, and state of the shark corpse (dressed or round) differ (Godin and Worm, 2010). As a result, because each shark species and fishery are unique, RFMOs cannot have a single overarching metric that is beneficial for all shark species. In addition, shark finning is a wasteful procedure that uses just 2-5 percent of the shark's whole-body weight (Godin and Worm, 2010). Illegal finning, excessive grading (mixing carcasses and fins from various species) and keeping extra fins for every corpse on board are all examples of loopholes that arise from the 5% finning ratio (Godin and Worm, 2010; Schleit, 2015). The remedy to the 5% shark finning ratio is to enact a "fins attached" policy, which states that no shark can be finned until a ship arrives at a port (Biery and Pauly, 2012; Godin and Worm, 2010). Although transporting whole sharks aboard ships would take up a lot of room, there appears to be no other effective alternative for dealing with this problem internationally (Biery and Pauly, 2012).

Table 4: List of five major tuna RFMOs (tRFMOs) and 3 non-tuna RFMOs and their shark finning regulations across the high seas.

RFMO Acronym	Full forms	Ocean regions	Finning Bans Dates	FB w/FCR Measure Date	FB w/FNA Measure Date
IATTC	Inter-American Tropical Tuna Commission	Pacific Ocean	2005	2005	-
ICCAT	International Commission for the Conservation of Atlantic Tunas	Atlantic Ocean	2004	2004	-
IOTC	Indian Ocean Tuna Commission	Indian Ocean	2005	2005	2017; fresh sharks
NAFO	Northwest Atlantic Fisheries Organization	Northwest Atlantic Ocean	2005	2005	2017
NEAFC	North-East Atlantic Fisheries Commission	Northeast Atlantic and Arctic Ocean	2015	-	2015
WCPFC	Western Central Pacific Fisheries Commission	Central Pacific	2006	2010	2019;with exceptions
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources	Southern (Antarctic Ocean)	2006	-	-
CCSBT	Commission for the Conservation of Southern Bluefin Tuna	overlapping-southern Indian, Atlantic, and Pacific oceans	-	-	-

However, since 2017 five RFMOs have adopted the FNA policy (Table 4) which perhaps, explains the steep decline in shark catch between 2017 and 2018 as shown in figure 1. These five RFMOs are: WCPFC, NAFO, IOTC, GFCM and NEAFC. However, both IOTC and WCPFC are tagged as having various finning bans in this study because they adopted FNA policy with certain alternatives and restrictions. For example, alternative measure such as (FAA) is implemented by WCPFC in certain cases, such that a rope or wire is used to bind each shark carcass to its corresponding fins (WCPFC, 2019). Noteworthy is that Commission Members, Cooperating Non-Members, and Participating Territories (CCMs) of WCPFC may allow its fishing vessels to store the carcasses and corresponding fins in different holds as long as the fishing vessel keeps a record or logbook that shows where the tagged fins and correspondingly tagged carcasses are stored in a way that inspectors can easily identify them (WCPFC, 2019). Moreover, IOTC Contracting Parties and Cooperating Non-Contracting Parties (CPCs) separate finning policies for two types of specimens: (i) sharks landed fresh and (ii)shark landed frozen (IOTC, 2021). These exceptions are as follows:

(i) Sharks landed fresh: The removal of shark fins from vessels is prohibited under CPCs. Shark fins that are not naturally attached to the shark corpse until the initial point of landing are prohibited from being landed, retained on-board, transhipped, or carried by CPCs (IOTC, 2021).

(ii) Sharks landed frozen: Fins that equal more than 5% of the weight of sharks on board, up to the initial point of landing, are prohibited for all sharks. CPCs that do not currently mandate fins and carcasses to be offloaded simultaneously at first landing must take the required steps to assure compliance with the 5% ratio, such as certification, observer monitoring, or other acceptable procedures (IOTC, 2021).

Moreover, all the interview data (80%) also suggests that shark finning may have decreased or over the years due to the existence stricter anti-finning legislations; however, most respondents felt this may have had little impact on overall shark mortality. This is also reflected in the statements of the eight interviewees as shown in Table 2 and Table 3 in Chapter 3.

4.1.2 Gaps in country level shark conservation measures

Contrary to earlier evaluations, recent findings by Van Houton (2020), imply that the majority of shark fins harvested come from EEZs rather than high-seas locations. Blue sharks (P. glauca), which are abundant and ubiquitous, continue to be the leading species in fins traded in the Hong Kong market hub. Even yet, genetic barcoding found an extra 40 range-restricted coastal species, whereas research from other markets reveal a higher proportion of coastal sharks (Van Houton, 2020). The Hong Kong, Vancouver, and San Francisco market sources all have comparable geographic patterns, indicating that China is the established aggregating node that receives, processes, and delivers the bulk of fins to worldwide markets. Another study, by Feitosa et al (2018) which was conducted in Brazil, took fin samples from a number of local wet markets, and found that fishing activity is dominated in coastal Brazil and the Caribbean. The Brazilian study specifically shows that despite having a FNA regulatory measure (Fig. 3) within its national jurisdiction, the country stands in the sixth position along with Morocco for having 75% (241920 tons) of their total shark catch (320783 tons) between 2010 and 2018 unreported; also, this country fails to control finning practises and catch as reported by the study (Feitosa et al., 2018). This definitely raises question on the effectiveness of anti-finning bans in reducing illegal finning and overall shark mortality.

Moreover, Figure 1c and Figure 3 in Chapter 3 shows that EEZs surrounding the Indian Ocean and South America have the highest unreported catch and, in some cases, weakest finning legislations. For example, after Yemen, both Pakistan and China have the largest proportions (88%) of unreported catch relative to the country's total shark catch; yet, Pakistan has an OB ban category and China has a weaker FVB ban status. Previous research shows that pelagic sharks are caught in Pakistan by a large and poorly regulated fleet of gillnetters operating in the Pakistani EEZ, the ABNJ (Areas beyond national jurisdictions), and occasionally in the waters of other nations such as Yemen and Somalia (Moazzam and Osmani, 2022). In Pakistan, 12 different species of pelagic sharks are taken as bycatch and landed by tuna gillnet vessels. Although most pelagic shark species are listed on Appendix-II of the CITES, it is illegal to export these fins without valid permission from the national CITES management authority (in Pakistan, the Ministry of Maritime Affairs), pelagic shark fins still find their way into the Hong Kong shark fin market disguised as dried fish (Moazzam and Osmani, 2022). This is also evident from the conversation with one of the interviewees, who stated that, "The catch composition for sharks is less than 5% of the total catch. This is really underestimated because they have got 14000 drift gillnet vessel and Pakistan has 700 vessels targeting tuna. Iran and Pakistan share a border and there is some kind of illegal trade going on between these two countries. Most of the sharks in Pakistan, half of them is speculated to be landed by Iranian vessels because Iran do not consume sharks due to religious reason. Almost 75 fisheries network is concentrated in shark catches which can go between 10000-15000tonnes from 75 fishermen in Pakistan. Pakistan is exporting 26000kgs of shark fins directly to Hong Kong. But Iran is sending it to UAE and repackaged from either Somalia or Sudan and then end up in Hong Kong," (AF02, personal communications, 2021). This suggests that there is an urgent need for Pakistan to adopt a stricter regulatory measure in compliance with IOTC. Another good example of a country which is lacking in effective conservation actions for sharks is Indonesia, which is second to Spain for total shark catch between 2010 to 2018 (Fig. 1c). Although, Indonesia made considerable progress in taxonomic resolution of their landings in the past decade, yet IUU fishing has been identified as a significant issue in Indonesia, particularly for endangered endemic sharks (Fischer et al. 2012; FAO 2016). Without IUU fishing restrictions, it is projected that fisheries management choices would be erroneous, resulting in management goals not being attained and the possibility of population overfishing (Doulman 2000; Daviidson et al., 2016).

4.2. Shark trade

Overfishing for shark fins was one of the primary reasons of shark population decreases (Anderson, 2011; Biery and Pauly, 2012). Shark finning could easily have risen if RFMOs (apart from the NEAFC) had not taken stricter actions to restrict it; thankfully, this has not happened (Travis, 2016). According to surveys and studies done by WildAid in China (the world's largest shark importer) in 2014, shark fin imports have decreased significantly between 2011 and 2013 (Whitcraft et al., 2014; Travis, 2016) (see Table 5). Shanghai, Beijing, Guangzhou, and Chengdu were the sites of the polls. Furthermore, ninety-one percent of respondents agreed that the Chinese government should prohibit all shark fin trading (Whitcraft et al., 2014), indicating that demand for shark items, particularly fins, may be dropping in China. Shark finning has been declining since 2011, as shown in Table 5 (Travis, 2016).

Table 5: Decline of shark fin imports to China from 2011-2013 (Travis, 2016).

Year	Weight of Imports (kg)	Decrease (%)
2011	10,292,421	-
2012	8,254,332	20
2013	5,390,122	35

Moreover, import volumes into Hong Kong decreased overall between 1998 and 2013, with a sharp dip in 2011. Reduced demand in Hong Kong and other related consumer markets, as well as declining shark populations, are two main factors that have contributed to the reduction in imports since 2012 (Shea and To, 2017). The first is that, while not mentioned here, greater shark conservation initiatives and increased public awareness among the general public and the media in recent years may have impacted consumer demand in Hong Kong and mainland China (Shea and To, 2017; Travis, 2016). Another reason for the decline in 2012 could be because shark populations are falling, resulting in lower catch and trade volumes around the world. Reduced shark fishing quotas, as a result of lower capture yield, may result in a drop in trade volume (Shea and To, 2017; Travis, 2016). This is doubtful, however, because the majority of shark-catching fisheries, whether as a primary or secondary capture, are still poorly managed. Taiwan and mainland China have both experienced a comparable reduction in imports since 2012 (Shea and To, 2017). Declines in finning incidences over the last decade is also evident from the interview results as quoted in Table 2.

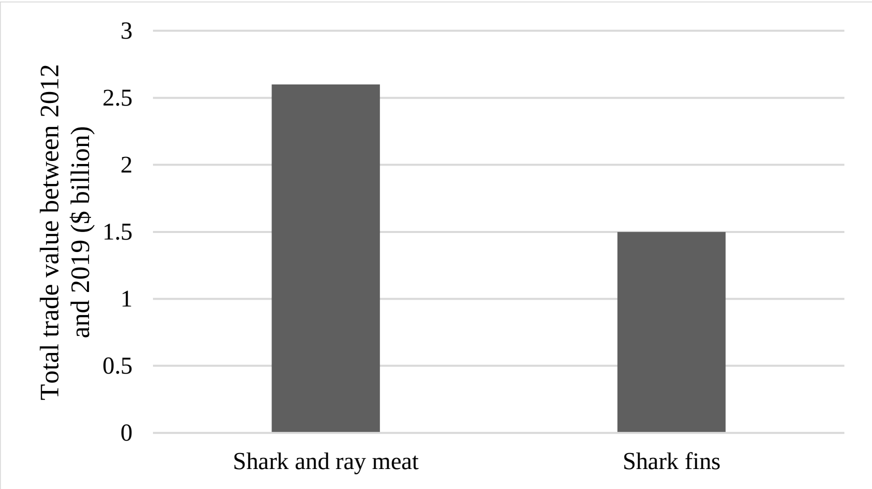

Figure 10: The overall trade value for shark and ray meat and shark fins (WWF, 2021).

Despite the fact that fins are normally far more expensive than meat and the worldwide fin trade has gotten far more attention to date, global traffic in shark and ray meat is now higher in both volume and value than global trade in fins (Fig. 10). This shift in shark trade market has also been observed by many experts who were interviewed as part of this study as presented in Table 2 and Table 3. However, between 2012 and 2019, the overall value of shark and ray commerce exceeded US$4.1 billion (WWF, 2021). The overall value of shark and ray meat (US$2.6 billion) is more than that of shark fins (US$1.5 billion) (Fig. 10) (WWF, 2021). Prices can range from US$0.1/kg for meat to more than US$100/kg for fins, with the latter commanding some of the highest prices in Asia (WWF, 2021). Price varies significantly based on species, product, and seller, among other considerations. Italy pays the highest average price for shark meat imports, at US$4/kg, while Hong Kong pays the highest price for fins, at US$30/kg, among the top merchants (WWF, 2021).

4.3 Global shark mortality

The primary objective of this study was to understand the global regulatory landscape for shark finning and how effective the existing legislations have been in controlling the rate in shark mortality. This lead to a series of investigations in order to provide holistic perceptions on the current trends in shark mortality between 2010 and 2018 (Fig. 7 and Fig. 8). However, the mortality calculations performed in this study are considered conservative for the following assumptions:

(i) The mortality of coastal and pelagic species was separated according to the gear classification in the SAU data. Sharks caught in longlines and purse seines were filtered to calculate the total mortality of offshore shark species. Sharks caught in all other gears were considered for calculating the coastal mortality over the eight years period.

(ii) The average weight used in this study to calculate individual species count is highly conservative. It used the median weight for coastal species and offshore species (deep sea and pelagic) as reported by Worm et al., 2013.

However, despite the complexity and underlying assumptions in estimating mortality, it still provides a global picture on the overall trends in shark mortality in light of the existing legislations. For instance, results of this study show that mortality of coastal species follows an increasing trend (Fig. 7) despite the concurrent increase in stronger finning legislations and shark sanctuaries. Contrarily, the mortality of the offshore species shows a declining trend with increase in regulations. There could be several reasons for this but some of the major driving factors can be evident from few of the respondent's statements during interviews.

Firstly, this could be due to better monitoring infrastructure for offshore fisheries. This could be evident from one of the interviewee's responses, that states: "Transition of fin trade from pelagic (e.g. Blue, Thresher, hammerhead) to coastal species partly because, offshore fisheries are better monitored and for those fleets it is not worth landing the meat so far in distance. For example, in Tunisia, targeted elasmobranch fisheries which are officially bycatch fisheries often target endangered species such as guitarfishes which are regionally prohibited to catch. This supplies the local market with meat. So, we need country-specific data whether they recognize that fins are highly valuable. Moreover, income and food security aspects are extremely crucial for some of the developing countries. Even if you have regional binding legal status yet not implemented at national level (mostly for coastal fisheries)" (AF01, pers. Communications, 2021). Secondly, it could be due to massive levels IUU fishing taking place in some of the major shark fishing hotspots and many time shark products are wrongly labelled or exported in disguise of other fish products. This could be linked with the information provided by the interviewees, which includes the following statements:

Interviewee 2 (AF02)

"…discrepancies in fisheries statistics remain. Shark fins are labelled under frozen products-not labelled accurately. Improvements in gillnet fisheries and non-retaining measures needed-catch bans for threshers, whitetips, silky and hammerheads in Indian for various shark species is there but it's not working because: (i)underreported data, and (ii) Japan and Korea, fishing with longlines hardly report shark catches. They do not agree having finning requirements/regulations and want fins to be removed partially for easy storage. In terms of overall fishing mortality, longline data are probably the most robust other than purse seiner, gillnets."

Interviewee 8 (AF08)

"Massive IUU fishing due to weaker monitoring enforcements in Indian and Mediterranean. In case of Atlantic, powerful fleets operate and consumes shark meat as fish and chips. Also, in Australia most of the fish and chips come from sharks."

Thirdly, coastal species are heavily depleted due to rising pressure from gillnet and other coastal fisheries. This could also be evident from the interview results which showed 80% of the respondents' suggested gillnets are most likely gear to incur shark bycatch in coastal fisheries (Figure 9) as stated by one of respondents: "the highest threat comes from the pelagic gill net fisheries, for large pelagic sharks. Iran, Indonesia, Pakistan, Sri Lanka, Oman, Yemen, and India use open ocean drifting gill nets and coastal fisheries. They are mostly small-scale fisheries, are exploiting near shore fisheries and succession going on as fisheries develop. This caused huge depletion in coastal resources which is forcing countries like Sri Lanka, Pakistan, and Iran to move into the high seas" (AF06, pers. Communications, 2021). And lastly, the final reason for such observations could be the fact that shark management and conservation on a global scale has mostly failed in protecting coastal species and resources with rising population and coastal infrastructures (WWF, 2016). There has been considerable success recently in the international domain toward supporting shark populations; nonetheless, the absence of collaboration between nation-states has made achieving some aims and goals challenging (Timms and Williams, 2009).

Chapter 5 Conclusions and Recommendations

The regulatory framework and mortality estimates presented in this study provided a systematic mechanism to assess, compare and understand the effectiveness of current legislations in controlling finning and shark mortality at both RFMO and country levels. Results of this study indicate that anti-finning regulations implemented by RFMOs and various national jurisdictions for sharks have been successful in reducing wasteful practices like finning to some degree. However, discrepancies in these legislations to protect the overall shark population still remain. In particular the emerging markets for shark meat and mortality associated with growing gillnet fisheries in coastal waters, raise potential concerns. Thus, shark specific regulations implemented by RFMOs, and other fishing entities should move beyond finning bans and reflect on the existing and emerging threats to shark populations due to economic, environmental, and social barriers. Therefore, to overcome such barriers, recommendations on shark-bycatch from the expert interviews are summarized in Figure 11.

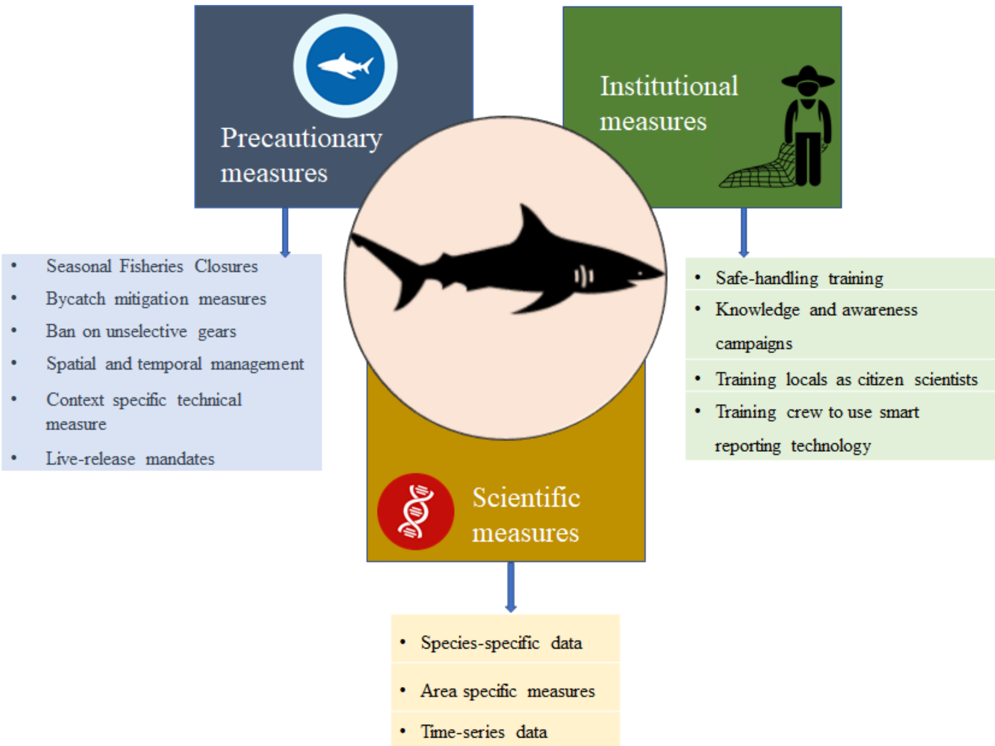

Figure 11: Recommendations by experts on shark by-catch (see all Appendix II).

Apart from the recommendations provided by the expert interviewees, some future directions are suggested with regards the problems in current management initiatives for sharks.

Table 6: General recommendations to promote a sustainable model for conserving sharks.

Problem	Recommendations
Lack of accurate and reliable species-specific data and accessibility	Taxa-specific data should be available to FAO, SAUP and RFMO databases. This would help shark researchers to develop more accurate prediction models for shark bycatch hotspots and mortality.
	Authorities at national scale should ensure that adequate taxonomic specific data recording systems are in place for both fisheries and trade involving species relevant to both CITES and RFMOs (Travis, 2016).
	Intergovernmental bodies such as CITES, CMS, and RFMOs should explore formal collaborations and data-sharing mechanisms for species of mutual concern (Travis, 2016).
	Shark fishermen, dealers, distributors, and retailers who want to sell certified-sustainable shark goods should actively engage in the development of trade monitoring systems that promote traceability and effective management (Dent and Clarke, 2015; Travis, 2016; Haque et al., 2020).
	More study on shark post-release survival should be requested by RFMOs in order to promote the most benign post-release procedures. After sharks are returned to sea, RFMOs and CPs must investigate their condition and fate (Molina and Cooke, 2012; Travis, 2016).
Lack of compliance among nation states, RFMOs, and other stakeholders	Nation-states that are not members of RFMOs but are potential shark fishing nations or may be capturing sharks as bycatch should join the appropriate RFMO (Barker and Schluessel, 2004; Travis, 2016).
	Create good incentives for non-compliant parties to join the RFMO or at the very least become cooperative non-parties who will adhere to the RFMO's objectives (Tarasofsky, 2007; Travis, 2016).
	Educational programmes regarding the relevance of sharks as predators in ecosystems for fishermen and coastal communities. If fishermen who catch sharks as bycatch realise how important they are, they will most likely try to release them unharmed (Travis, 2016; Haque et al; 2020).
Inadequate bycatch mitigation technology	More study on shark bycatch reduction measures is needed. Promote shark-avoidance strategies. The creation of shark repellents may prove to be an effective method for reducing shark bycatch (Travis, 2016).
	Increased usage of bycatch reduction devices (BRDs); nevertheless, RFMOs must emphasise the benefits of these devices, such as reduced catch and gear damage. Observers are used to track the efficiency of by-catch mitigation measures aboard ships (Travis, 2016).
	Continued reductions in FADs or better FAD technology to reduce shark bycatch (Lewison et al., 2004).

Overall, the results of this study identified priority areas for enhancing existing measures and increasing the efficiency of current regulations in preventing shark finning and shark mortality at both the RFMO and national levels. Holistically, the recommendations provided in Figure 11 and Table 8 (see also Appendix II for full reference and response statistics) highlight some critical issues in the management regime that needs immediate conservation attention for protecting taxonomically vulnerable species like sharks. For instance, although certain RFMOs, such as the IOTC and the WCPFC, have enacted tougher anti-finning laws in recent years, they must explicitly define the objectives of their controls and promote uniform regulations for all contracting parties in order to assess their involvement in shark protection on a larger scale. Additionally, area-specific management measures should be used at national scales because effective implementation of conservation plans greatly depends on the socio-economic conditions of coastal communities. Protecting sharks in resource poor communities could be complex without alternatives offered to them. Previously conducted studies and results from the expert interviews in dictate that marginalised, and financially deprived fishers (i.e. opportunistic fisheries) retain almost everything for an extra income (Haque et al., 2021; Haque et al., 2020; Jabado et al., 2015). Therefore, successful marine conservation in underdeveloped nations (e.g. Pakistan, Indonesia, Iran, Sri Lanka, Brazil) necessitates inclusion of local stakeholders in government decision-making and management initiatives (Haque et al., 2021; Haque et al., 2020; Jabado et al., 2015). Otherwise, without adopting a bottom-up decision-making process, implementing conservation policies and management measures in these resource and data poor regions, which are also some of the major hotspots for shark bycatch and trade, would become increasingly challenging. As a result, more evidence-based research on coastal and opportunistic shark and ray fisheries is suggested in order to estimate global risks and capture rates so that realistic conservation objectives may be achieved using sustainable fisheries models.

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Appendices

Appendix I: Shark species classification according to their order with common names as per the SAUP database.

Order	Common names
Carcharhiniformes	Atlantic sharpnose shark, Australian blacktip shark, Blackmouth catshark, Blacktail reef shark, Blacktip reef shark, Blacktip shark, Blue shark, Bonnethead, Brown smooth-hound, Bull shark, Caribbean sharpnose shark, Cat/swell sharks, Catsharks, Copper shark, Draughtsboard shark, Copper shark, Draughtsboard shark, Dusky shark, Galapagos shark, Great hammerhead, Ground sharks, Hammer, bonnet, Scoophead sharks, Hammerhead sharks, Hardnose shark, Houndsharks, Humpback smooth-hound, Lemon shark, Leopard shark, Milk shark, Narrownose smooth-hound, Nursehound, Oceanic whitetip shark, Requiem sharks, Sandbar shark, Sawtail catsharks, Scalloped hammerhead, Sharp-nosed sharks, Sharptooth houndshark, Silky shark, Silvertip shark, Small-spotted catshark, Smooth hammerhead, Smoothhounds, Spinner shark, Spottail shark, Spotted estuary smooth-hound, Starry smooth-hound, Tiger shark, Tope shark, Whitecheek shark, Whitetip reef shark
Hexanchiformes	Bluntnose sixgill shark, Broadnose sevengill shark, Sharpnose sevengill shark
Lamniformes	Basking shark, Bigeye thresher,Great white shark, Longfin mako, Mackerel sharks, Mackerel/white sharks, Mako sharks, Pelagic thresher, Porbeagle, Sand tiger shark,Shortfin mako, Smalltooth sand tiger, Thresher sharks
Orectolobiformes	Arabian carpetshark, Nurse shark, Tawny nurse shark, Whale shark
Pristiophoriformes	Sawsharks
Squaliformes	Angular roughshark, Birdbeak dogfish, Black dogfish, Bramble shark, sleeper, Dogfish sharks, Greenland shark, Gulper shark, Kitefin shark, Knifetooth dogfish, Lantern Sharks, Leafscale gulper shark, Little sleeper shark, Longnose spurdog, Longnose velvet dogfish, Lowfin gulper shark, Pacific spiny dogfish, Picked dogfish, Portuguese dogfish, Sailfin roughshark, Shortspine spurdog, Velvet belly
Squatiniformes	Angel sharks, Argentine angelshark

Appendix II: Gear classification according to SAUP database.

Gear group	Gear types
trawlers	beam trawl, bottom trawl, otter trawl, pelagic trawl, shrimp trawl, dredge, dragged gear
small scale	small scale encircling nets, small scale gillnets, small scale hand lines, small scale lines, small scale longline, small scale other nets, small scale pole lines, small scale pots or traps, small scale purse seine, small scale seine nets, small scale trammel nets
subsistence	subsistence fishing gear
recreational	recreational fishing gear
artisanal	artisanal fishing gear
nets	bagnet, cast nets, encircling nets, gillnet, other nets
longline	longline
purse seine	purse seine
mixed gear	mixed gear
pots and traps	pots or traps
hand or tools	harpoon, hand or tools
Unknown/other	unknown class, unknown by source, unknown by author, other, other industrial

Appendix III: Semi-structured Interview questionnaire

Respondents' Personal Information

Name of interviewee		
Name of organization		
Designation		
Years of Experience	Field	Years
Interview code		
Date		

Perception of the Respondents

i) What changes have you observed in the overall shark trade over the last two decades? ii) What changes have you observed specifically on the trends of shark finning practices over the last two decades? Are they increasing, decreasing, and has remained stable over the years? iii) Could you please elaborate a bit more on this? Why do you think finning practices is increasing/decreasing/no change? iv) Have you observed any transition in fin trade composition from pelagic to coastal species or vice versa? If yes, then what are the reasons for such transitions? v) What would you say, is shark mortality increasing, decreasing, or remained stable with the emergence of finning and other associated legislations over the past decades? vi) Which top three areas in your expertise are more prone to:	
Shark by-catch	Shark finning
vii) Which type of gears/fleets are most likely to incur shark by-catch?	
Gear/Fleet type	Why?
viii) What management approaches could be used to fill in the current legislative and regulation gaps for shark bycatch and finning?	
Shark bycatch	
Shark finning	

Appendix IV: Interviewee demographics

Expert categories	Interview code	Organization name	Country/Region of focus	Experience (years)	Current Research focus
			Shark experts		
Internation NGOs/ organizations (n=1)	AF01	WWF Mediterranean marine initiative	Mediterranean	10	Sharks and Rays in the Mediterranean
Academia (n=1)	AF05	University of Florida	USA	20	Sharks and Rays Conservation
Local NGOs/ institutions (n=4)	AF04	Blue resource Trust	Sri Lanka	10	Stock Assessment of *Mobula* rays and other endangered shark species
	AF08	SharkProject	Germany	6	Spatial resolution-species specific-pelagic or coastal sharks
	AF10	Thrive conservation	Indonesia	5	Manta rays and whale sharks and mainly the marine megafauna
	AF09	National Centre for Research and Conservation of Southern marine biodiversity	Brazil	15	Sharks and rays stock assessment, fisheries statistics and conservation in South America
			Fisheries experts		
International organizations (NGOs, RFMO)	AF02	WWF Mozambique	Indian ocean	13	Tuna gillnet fisheries
	AF07	IATTC	Eastern Pacific	14	Fisheries by catch

Local government/ NGOs/instituitions	AF03	National Centre for Research and Conservation of Southern marine biodiversity	Reunion Island, Indian ocean	25	Live release programs
Others (self-employed)	AF06	Self-employed	Maldives, Indian ocean	36	tuna fisheries

Appendix V: Management recommendation from interviewees on shark by-catch and finning practises.

Category	**Shark finning**	**Responses (%)**
Precautionary measures	Trade-route monitoring	12
	Ban on shark fishing (fisheries management)	12
	Precautionary non-retention measures	6
	Legislations more focused on targeted fishing	6
	Better surveillance-electronic monitoring	12
	Area based management measures (finning hotspots)	6
Institutional measures	Training for finning data collection	6
	Creating consumer awareness	12
	Encouraging independent science	6
Scientific measures	Species-specific trade data	12
	Adequate and accurate product labelling	6
	Catch and trade data transparency & accessibility	6
Category	**Shark bycatch**	**Responses (%)**
Precautionary measures	Seasonal Fisheries Closures	7
	Bycatch mitigation measures	10
	Ban on unselective gears	13
	Spatial and temporal management	10
	Context specific technical measures	7
	Live-release mandates	7
Institutional measures	Safe-handling training	7
	Knowledge and awareness campaigns	7
	Training locals as citizen scientists	3
	Training crew to use smart reporting technology	10
Scientific measures	Species-specific data	10
	Area specific measures	7