ANNEX 1

TECHNICAL MITIGATION TECHNIQUES TO REDUCE BYCATCH OF SHARKS: THERE IS NO SILVER BULLET

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2. Introduction

Sharks have been experiencing massive population declines worldwide over the past 50 years, with some oceanic species decreasing by up to 71% over that period (Pacoureau et al. 2021). Sharks have k-selected life histories (Holden 1973) which includes slow growth, delayed maturity and low fecundity. These characteristics make them particularly vulnerable to significant long-term population impacts from any form of increased unnatural mortality (Dulvy et al. 2008, Gilman 2011, Dulvy et al. 2014).

Fisheries are the single biggest driver of declines in marine ecosystem biodiversity worldwide (Dayton et al. 1995). Sharks are taken in fisheries globally on a massive scale, with an estimate of total shark take of around 1.4 million tons in 2010 alone (Worm et al. 2013). A major component of take in fisheries is from bycatch, where non-target species are taken incidentally when fishing for other, more valuable species. These non-target individuals are sometimes retained if there is a market for the product, however many are discarded and unreported (Clarke et al. 2006, Morgan et al. 2009, Worm et al. 2013, Campana et al. 2016), likley resulting in underestimates of total take. The lack of accurate harvest data for sharks means that quantitative stock assessment is difficult at best (Clarke et al. 2006). This situation presents not only an issue of uncertain population stocks and species decline, but also of a perverse waste of resources in a world where millions of people rely on small scale fishing to survive.

Fisheries bycatch and finding solutions to the problem has received increasing attention in recent times. Most bycatch research to date has focused on charismatic species such as seabirds (Løkkeborg 2011), cetaceans (Leaper and Calderan 2018) and pinnipeds (Hamilton and Baker 2019). Shark bycatch has only recently become an active area of research, with most studies occurring over the past 15-20 years. Mitigation reviews generated from these studies have focused on particular aspects of mitigation or gear type (e.g., Gilman et al. 2008, Waugh et al. 2013, Favaro and Cote 2015, Howard 2015, Gilman et al. 2016); sensory biology (e.g., Hart and Collin 2015, Lucas and Berggren 2022); geographical areas (e.g., Stobutzki et al. 2006, Ardill et al. 2011, Molina and Cooke 2012, Sacchi 2021); certain species or species groups (e.g. Dagorn et al. 2013); or for particular fisheries (e.g., Clarke et al. 2014, Poisson et al. 2016, Restrepo et al. 2017). This paper presents the first comprehensive global review of technical mitigation measures (i.e., gear modifications and mitigation devices) designed to reduce shark bycatch in commercial fishing gear, building on the work of Fowler (2016). It includes assessments of mitigation testing, effectiveness and a synthesis of best practice mitigation, identifying areas requiring greater attention and covers all shark and ray species and fishing techniques.

3. Methods

Although there has been considerable progress in some fisheries regarding the development, testing and implementation of mitigation measures to reduce shark bycatch in commercial fishing gear, much of this information is not easily accessible. Literature searches were conducted using various search databases (EBSCO, Google Scholar, Bycatch.org, Regional Fisheries Management Organisation (RFMO) websites) using search terms such as "*shark + bycatch + mitigation*", "*shark + repellent*", "*bycatch + mitigation*". Opportunistic searches were conducted when reviewing papers, and when colleagues alerted the authors to papers that may have been missed in structured searches. Non-published or 'grey literature' was sought out through the websites of RFMOs, fishing industry, and commercial bycatch mitigation technology manufacturers, as well as by contacting key researchers via email or ResearchGate (https://www.researchgate.net/) to access relevant unpublished reports. This resulted in 271 papers, reports & promotional material being identified for further evaluation. Studies were not considered further if they did not contain empirical evidence relating to a technique. The final list for inclusion comprised 184 papers.

In reporting the results of this review, we follow Patterson et al. (2014), in dividing bycatch mitigation techniques into a hierarchical structure of three sections from the most to least desirable approach: preventing capture, enabling escape, and decreasing at-vessel mortality/increasing post-release survival.

Following Hamilton and Baker (2019) we restricted this review to technical mitigation measures. Effective bycatch mitigation strategies for sharks often comprise a suite of management measures in conjunction with technical mitigation. These include traditional input and output controls, operational adjustments through ‘codes of practice’ protocols (e.g., ‘move-on’ provisions, handling and release protocols) and implementation of appropriately designated spatial and/or temporal closures (Dunn et al. 2011, Kaplan et al. 2014, Hazen et al. 2018). These approaches are important and will be reviewed separately (D. Drynan and GB Baker, unpublished). Development and implementation of multi-jurisdictional agreements, regulations and/or legislation to facilitate mitigation uptake are also likely to be important, e.g., through Multilateral Environmental Agreements (MEAs) such as CMS (2016), or RFMOs (IOTC 2017, WCPFC 2019) but are also outside the scope of this review.

4. Results

A synopsis of the technical mitigation assessment is provided below. A summary of the assessment and effectiveness of each technical measure identified is provided in Table 1.
While this provides an overview of technical mitigation measures, caution should be exercised before extending proven measures to other fisheries. Fishery-specific characteristics such size of target species and operational elements may mean that the evaluation responses reported as effective in one area or fishery may not be effective elsewhere with other target and bycatch taxa and under different operational conditions.

***Table 1** – Summary of whether a technical mitigation measure for reducing shark bycatch in commercial trawl, purse-seine, longline, gillnet, and pot/trap operations has been assessed and if there is evidence that it is effective in reducing bycatch.* ("-" = measure is not considered applicable for relevant fishing gear; "?" in 'Assessed' category = unclear if this measure has been assessed; "?" in 'Effective' category = lack of knowledge of the measure's effectives, or there have been conflicting/inconclusive results, and/or more trials are required)

Technical Measure	Trawl		Purse Seine		Longline		Gillnet		Pot/Trap	
	Assessed	Effective	Assessed	Effective	Assessed	Effective	Assessed	Effective	Assessed	Effective
3.1.2 Chemical Repellents	-	-	-	-	Yes	?	No	?	No	?
3.1.4 Active Electrical Repellents	No	?	Yes	?	No	?	No	?	No	?
3.1.5 Electropositive Metal Repellents	-	-	-	-	Yes	?	-	-	-	-
3.1.6 Magnet Repellents	No	?	-	-	Yes	?	Yes	?	Yes	Yes
3.1.7 Visual	Yes	No	-	-	No	?	No	?	No	?
3.1.8 Removal of Light Sticks	-	-	-	-	Yes	?	Yes	?	No	?
3.1.9 Auditory	No	?	No	?	No	?	No	?	No	?
3.2.1 Bait Type	-	-	-	-	Yes	Yes	-	-	-	-
3.2.2 Bait Size	-	-	-	-	No	?	-	-	-	-
3.2.3 Removal of Bait	-	-	-	-	No	?	-	-	-	-
3.2.4 Artificial Baits	-	-	-	-	Yes	?	-	-	-	-
3.2.5 Removal of Tickler Chains	Yes	Yes	-	-	-	-	-	-	-	-
3.2.6 Gillnet Mesh Size	-	-	-	-	-	-	Yes	Yes	-	-
3.2.7 Gillnet Tension	-	-	-	-	-	-	Yes	?	-	-
3.2.8 FADs (Fish Aggregation Devices) – Construction and Deployment	-	-	Yes	Yes	-	-	-	-	-	-

Technical Measure	Trawl		Purse Seine		Longline		Gillnet		Pot/Trap	
	Assessed	Effective	Assessed	Effective	Assessed	Effective	Assessed	Effective	Assessed	Effective
3.2.9 FADs – Change Fishing Strategy	-	-	Yes	Yes	-	-	-	-	-	-
3.2.10 Change Capture Method	No	?	No	?	Yes	Yes	No	?	Yes	Yes
3.3.1 Leader Material	-	-	-	-	Yes	Yes	-	-	-	-
3.3.2 Leader Construction	-	-	-	-	Yes	?	-	-	-	-
3.3.3 Escape Panels/Hatches in Purse Seine Gear	-	-	Yes	No	-	-	-	-	-	-
3.3.4 Excluders	Yes	Yes	-	-	-	-	-	-	-	-
3.4.1 Reduce Soak Time	No	?	-	-	Yes	Yes	Yes	?	No	?
3.4.2 Water Temperature	No	?	No	?	Yes	?	No	?	No	?
3.4.3 Hook Type	-	-	-	-	Yes	Yes	-	-	-	-
3.4.4 Modified Hooks	-	-	-	-	Yes	?	-	-	-	-
3.4.5 Release before Haulback	No	?	Yes	Yes	Yes	Yes	No	?	No	?
3.4.6 Handling Techniques	Yes	Yes	Yes	Yes	Yes	Yes	No	?	No	?
3.4.7 Water Tables and Release Chutes	No	?	No	?	No	?	-	-	-	-

3.1 Prevent Capture Using Sensory Techniques

3.1.1 Repellents Overview

Repellents act on the sensory systems that sharks use to locate prey or use to avoid being predated themselves (Swimmer et al. 2008, Jordan et al. 2013, O'Connell et al. 2014a, Hart and Collin 2015) and their application to mitigation of bycatch has been recently comprehensively reviewed by Lucas and Berggren (2023). These mechanisms have been thought to have potential to encourage avoidance of fishing gear, thus reducing shark bycatch (Jordan et al. 2013). Techniques including chemical, active electrical, electropositive metals, and visual repellents have all shown promise, however there is a lack of empirical evidence that demonstrates they are effective in reducing shark bycatch in fisheries. In addition, there are large logistical, cost, and environmental impact issues that need to be overcome before any of these techniques could be deployed in fisheries. As olfactory, electrical and visual sensory systems are the most important senses used by sharks for prey location, they are thus more likely to be useful for reducing bycatch, whereas auditory and taste systems appear to be less important (Swimmer et al. 2008, Jordan et al. 2013, O'Connell et al. 2014a, Hart and Collin 2015). We refer readers to Hart and Collin 2015 and Lucas and Berggren 2023 for detailed overviews of sensory systems in sharks.

3.1.2 Chemical (Rating: Requires Further Development)

Semiochemicals are ‘signal’ producing chemicals, usually in the form of an odor produced from decaying conspecifics or predator pheromones. It is thought the ‘signal’ of dead conspecifics triggers a ‘fright’ behavioural response, where sharks stop feeding and leave the area immediately as a survival tactic, which could be exploited to discourage shark interactions with fishing gear (O'Connell et al. 2014, Stroud et al. 2014). This class of semiochemicals are termed ‘necromones’.

Evasion reactions have been observed in multiple species when exposed to necromones, including Port Jackson Sharks (*Heterodontus portusjacksoni*) under laboratory conditions (Gervais and Brown 2021), and in Caribbean Reef Sharks (*Carcharhinus perezi*) and Blacknose Sharks (*Carcharhinus acronotus*) in a field experiment on wild individuals, without any apparent impact on teleost fish behaviour (Stroud et al. 2014). However there have been contradictory results from studies that have tested the application of necromones in fishing gears. The catch rate of Tiger Sharks (*Galeocerdo cuvier*) on benthic longlines was not affected by the presence of canisters containing decaying heterospecific shark species (Broadhurst and Tolhurst 2021), with set depth and soak time more important factors affecting catch rate.

Despite this, there is clear potential for further research into the application of the repellent qualities of necromones, especially in fisheries that utilise baits as the primary attractant for target species. There have been promising results from a preliminary trial of a commercially available shark repellent canister (‘SuperPolyShark’, Shark Defense Technologies, Oak Ridge NJ, USA). This product is manufactured from the rotting carcasses of sharks and was inserted into squid bait (*Decabrachia sp.*) in a longline trial in the South-east Atlantic. Trials of various repellent concentrations showed an overall 39% reduction in shark catch rate without impacting target species catch rates (Rice et al. 2014), however this effect diminished with increasing soak time. Broader application of this promising approach requires further research on other target and non-target species in a range of fisheries.

Despite the promising results described above, the issues of density-dependent feeding (O'Connell et al. 2014a) and species-specific responses (Noatch and Suski 2012, Hart and Collin 2015) need to be overcome before chemical repellents could be applied more broadly to mitigate shark bycatch. Both of these issues require detailed knowledge of the biology of non-target shark species to assist in resolving them.

3.1.3 Electrical & Magnetic Overview

Electrical and magnetic repellents rely on interference with the electroreceptor system in sharks to deter interactions with fishing gear (Kalmijn 1966). This system is highly developed in most sharks but appears to be mostly used by species that inhabit high turbidity and/or low light areas, where visual cues for prey are not easily detected (Hutchinson et al. 2012, Jordan et al. 2013). Perhaps of most importance to the context of shark bycatch mitigation, teleost fish do not possess an electroreception system, so are not impacted by the presence of weak electric fields (Jordan et al. 2013).

3.1.4 Active Electrical (Rating: Requires Further Development)

Several laboratory and field trials have shown potential for the application of active electrical repellents in fishing gears, but these have yet to be demonstrated to be effective in commercial fisheries. Active electrical repellents use an external power source to generate an electrical field to interfere with the electroreception system, and all devices commercially available are primarily designed as personal protection for divers and surfers (e.g. Huveneers et al. 2013, Kempster et al. 2016, Huveneers et al. 2018, Egeberg et al. 2019, Thiele et al. 2020). Several trials have shown that baits and gear can be made unattractive to sharks through the use of active electrical repellents, including in purse-seine nets (Hart and Collin 2015). Laboratory experiments have also demonstrated reduced feeding rates in several species when exposed to active electrical stimuli at the bait location (Howard et al. 2018, Polpetta et al. 2021).

Clearly, active electrical systems can repel sharks. However, issues surrounding the practicality of deployment in a fisheries context have yet to be thoroughly researched and resolved, including initial set up cost, maintenance frequency and costs, minaturisation and safety (Jordan et al. 2013).

3.1.5 Electropositive Metals (EPM) (Rating: Not Recommended)

EPMs do not require an external power source, and work by reacting (oxidizing) with water which creates electrical potentials that interfere with the sharks' electrosensory system (Swimmer et al. 2008, Hart and Collin 2015). Most research into EPMs has been conducted in longline fisheries due to the practicality of adding them to baited hooks and the short range in which they can be effective (Stoner and Kaimmer 2008, Brill et al. 2009). It is not clear whether it would be possible to apply them in other gear types.

EPMs have shown potential in laboratory and subsequent field trials in fishing gears where shark feeding behaviour is impacted by their presence (Jordan et al. 2011). However, results have been contradictory between and within species, with effects of habituation, level of satiation, conspecific density, age, and prey detection strategy all been found to impact their effectiveness making general application in fisheries difficult (Tallack and Mandelman 2009, McCutcheon and Kajiura 2013, Stoner and Kaimmer 2008, Kaimmer and Stoner 2008, O'Connell et al. 2014a, Godin et al. 2013, Robbins et al. 2011, Grant et al. 2018).

EPMs can be shaped for application on fisheries gear as has been done in trials of SMART (Selective Magnetic and Repellent) hooks (O'Connell et al. 2014b, Grant et al. 2018). However, they dissolve very quickly and would require replacement after only a few deployments (Grant et al. 2018), potentially making them uneconomical and impractical for fisheries deployment (Stoner and Kaimmer 2008, O'Connell et al. 2014b, Grant et al. 2018). In addition, EPMs are also expensive and hazardous to machine due to their highly flammable filings (Tallack and Mandelman 2009) and are also potentially toxic (Stoner and Kaimmer

2008, Hutchinson et al. 2012, but see Brill et al. 2009). Favaro and Cote (2015) concluded that EPMs were not effective overall and questioned the value of further research into their application in fisheries.

3.1.6 Magnets (Rating: Requires Further Development)

Permanent magnets are thought to work via electromagnetic induction and interfere with the ability of many species to navigate (Hart and Collin 2015). Laboratory and subsequent field trials have shown permanent magnets can reduce shark capture rates where shark feeding behaviour is impacted by their presence without impacting target species behaviour (Rigg et al. 2009, O'Connell et al. 2011a, Smith and O'Connell 2014, Richards et al. 2018). However, as with EPMs, results have been contradictory between and within species (e.g., Stoner and Kaimmer 2008, Porsmoguer et al. 2015, Grant et al. 2018, Westlake et al. 2018, Polpetta et al. 2021) with effects of habituation (O'Connell et al. 2011a), magnet material (O'Connell et al. 2011b), water temperature (Smith and O'Connell 2014) and gear type (O'Connell et al. 2010, O'Connell et al. 2011b, O'Connell et al. 2014a, Richards et al. 2018, Westlake et al. 2018) all found to impact their effectiveness. When coupled with their expense, high maintenance requirements and entanglement issues (Cosandey-Godin and Morgan 2011, O'Connell et al. 2014a), magnets cannot be recommended as a shark bycatch reduction measure at present in longline and purse-seines but may be useful in static gear applications such as gillnets, traps, and pots.

3.1.7 Visual (Rating: Requires Further Development)

Most sharks have poor colour vision or are colour blind (Nguyen and Winger 2019), relying on contrast between an object and background for visual location. If gears can be made to be more visible to sharks this could have a positive impact on bycatch rates (Stone and Dixon 2001). A study into the impact of excluder grate colour showed no effect on bycatch rates (Chosid et al. 2012), however artificial lighting (strobe lights) was shown to repel some sharks or delay time to interaction in a study investing protection for beachgoers (Ryan et al. 2018). Strobe lights may warrant further investigation for application in fisheries, however the difficulties and cost in deploying lights in gears may make this technique unviable.

3.1.8 Lights and Light Sticks (Rating: Requires Further Development)

Many fishers use light sticks and/or lights to increase catch rates of target species (Gilman et al. 2007a). This technique can increase the catch rate of sharks (Poisson et al. 2010, Nguyen and Winger 2019), particularly when green light is used (Afonso et al. 2021); have no effect (Bielli et al. 2020, Darquea et al. 2020); or even decrease catch rates (Senko et al. 2022), demonstrating there is no clear and consistent effect of light sticks on shark catch rates. However, modelling suggests that removing light sticks from longlines in areas that have high catch rates of Shortfin Mako (*Isurus oxyrinchus*) could reduce bycatch by 18% (O'Farrell and Babcock 2021). Despite the contrasting results above, simply removing light sticks in longline fisheries may be a practical and easily implemented bycatch reduction measure. This approach has an additional benefit of reducing marine pollution from fewer discards of potentially toxic light sticks (Afonso et al. 2021). Given the contrasting results, application of light repellents/attractants in fisheries would require local trials on the species of concern to confirm efficacy prior to wider implementation.

3.1.9 Auditory (Rating: Not Recommended)

There have been no studies found specifically investigating the effectiveness of auditory repellents to sharks in fisheries, so this technique cannot be recommended. Experimental and field studies have shown some species react to the presence of artificial and natural sounds, which can reduce interactions with bait (Chapuis et al. 2019), however other species have been found to only react when sounds are delivered in combination with visual repellents (Ryan et al. 2018). Deployment of auditory repellents seems impractical for sharks due to the lack of empirical evidence in a fisheries context, the size and cost of transducers necessary to create the sound, possible effects of habituation (Hart and Collin 2015, but see Chapuis et al. 2019), and other possible unintended environmental impacts.

3.2 Prevent Capture Using Non-Sensory Techniques

3.2.1 Bait Type (Rating: Recommended)

Baits are a primary driver for fishing gear selectivity in hook fisheries, and the type of bait used will impact both target and non-target catch (Løkkeborg et al. 2014). Changing bait from squid to fish is beneficial for protecting some bycatch species groups (e.g., sea-turtles), but may result in higher shark catch rates (Gilman et al. 2020). This presents a conundrum for fisheries managers. Multiple studies have trialed this change in bait type, with the majority focused on reducing sea-turtle bycatch in longline fisheries (e.g., Gilman et al. 2007b, Yokota et al. 2009, Fernandez-Carvalho et al. 2015). Sharks were only a secondary consideration in these studies, but many reported an increased catch rate of sharks, indicating a preference for fish bait (e.g. Watson et al. 2005, Foster et al. 2012, Amorim et al. 2015, Howard 2015, Gilman et al. 2016, Kumar et al. 2016, Gilman et al. 2020). These include Blue Sharks (*Prionace glauca*) (Foster et al. 2012), Shortfin Mako (Amorim et al. 2015) and Sandbar Shark (Driggers III et al. 2017), with some notable and contradictory exceptions where catch rates increased significantly on squid bait, e.g. Scalloped Hammerhead (*Sphyrna lewini*) (Driggers III et al. 2017), Porbeagle (*Lamna nasus*) and Shortfin Mako (Foster et al. 2012). Other studies have found no effect of bait type on shark catch rates, e.g., Blue Shark (Fernandez-Carvalho et al. 2015), Blue Shark and Shortfin Mako (Yokota et al. 2009), while others concluded that fish baits reduce shark bycatch when compared to squid (Watson et al. 2005, Gilman et al. 2007b). Despite some of the contrasting results of individual studies, the results of meta-analyses by Gilman et al. (2020) confirm that overall, fish baits increase shark catch rates when compared to squid. To reduce shark bycatch, squid bait should be used in preference to fish bait, however local trials should be conducted prior to wider implementation. The aims of the individual fisheries' bycatch reduction strategy will need to determine the priority order for species to be protected.

3.2.2 Bait Size (Rating: Requires Further Development)

Bait size can be used to increase selectivity, where large baits tend to catch large sharks, and small baits tend to catch small sharks (Løkkeborg et al. 2014, Kumar et al. 2016, Gilman et al. 2020). If the aim of a shark bycatch reduction strategy is to reduce the impact on certain age/size classes, then changing bait size could be a useful bycatch mitigation technique. Further field trials would be required to establish optimal bait size for local conditions and species.

3.2.3 Removal of Bait (Rating: Requires Further Development)

The removal of baits entirely can be beneficial for reducing shark bycatch, especially when the target species prefers attractants such as lures. Kyne and Feutry (2017) reported that target recreational sportfish Barramundi (*Lates calcarifer*) are caught primarily on lures, and two river shark species of conservation concern, Speartooth Shark (*Glyphis glyphis*), and Northern River Shark (*Glyphis garricki*), are caught primarily on baited hooks. By not allowing baits to be used in this fishery, this will likely have a positive impact on both shark species whilst not impacting the target fishery. This approach is unlikely to be viable in large scale commercial fisheries but could be applied in small-scale or recreational fisheries to benefit threatened species.

3.2.4 Artificial Baits (Rating: Requires Further Development)

Artificial baits are already use in commercial fisheries and are primarily designed to attract target species but could be made to be unattractive to sharks (Erickson et al. 2000, Gilman et al. 2008, Løkkeborg et al. 2014). They can be made from waste products rather than fish that could otherwise be used for human consumption (Ecological Based Artificial Baits (EBAB); (Bach et al. 2012). The manufacturing process of artificial baits provides an opportunity to incorporate olfactory repellents which may reduce shark interactions with baits (Erickson et al. 2000). This approach can have a dual positive impact by reducing shark bycatch and reducing costs to fishers from reduced bait depredation (O'Keefe et al. 2014). Field trials of artificial baits have shown promising initial results in the reduction of bycatch rates (Erickson et al. 2000 and Bach et al. 2012), and an increase in target catch (Erickson et al. 2000). However, species specificity was apparent, where Requiem (*Carcharhinidae*), Mako (*Isurus sp.*) and Hammerheads (*Sphyrnidae sp.*) had no catch on artificial baits, but Blue Shark and Oceanic Whitetip (*Carcharhinus longimanus*) catch rates did not differ from regular bait types (Bach et al. 2012). Local trials would need to be conducted to ascertain shark responses before artificial baits could be used.

3.2.5 Removal of Ticklers (Rating: Recommended)

Tickler chains are an optional piece of gear that sit ahead of demersal trawl nets and disturb benthic species from the seafloor, increasing catch rates of species of target species. Kynoch et al. (2015) found that the catch rate of sharks was significantly reduced when the tickler was removed, without impacting catch rates of most target species.

3.2.6 Gillnet Mesh Size (Rating: Recommended)

The mesh size of gillnets and trammel nets can be used to select for size/age classes of both target and non-target species (Kirkwood and Walker 1986). It is important to note that mesh size cannot select for non-target species unless there is a distinct size difference between target and non-target species. Selectivity is useful when particular age classes need to be protected, e.g., juveniles required to maintain recruitment into populations (Ceyhan et al. 2010). Gillnets have high mortality and injury rates once an individual is caught (Rulifson 2007, Thorpe and Frierson 2009, Baremore et al. 2012), so selecting the optimal mesh size is critical for reducing bycatch whilst maintaining target catch (McAuley et al. 2007, Rulifson 2007, Baremore et al. 2012). Field studies have confirmed that it is possible to determine optimal mesh size ranges for gill and trammel nets that substantially reduce the take of juvenile sharks (Carlson and Cortés 2003, Ceyhan et al. 2010)

A modelling approach is a very useful technique to establish the most appropriate mesh size that maximises target size catch and minimizes non-target size catch. There have been a number of studies that have modelled size selectivity in gillnets for many commonly caught sharks (e.g., Kirkwood and Walker 1986, Carlson and Cortés 2003, McAuley et al. 2007, Rulifson 2007, Ceyhan et al. 2010, Baremore et al. 2012). These modelling procedures are well understood so selecting appropriate mesh sizes for other species where protection of particular size/age classes is needed in gillnet and trammel net fisheries should be straightforward.

3.2.7 Gillnet Tension (Rating: Requires Further Development)

The selectivity of gillnets and trammel nets can be improved by increasing the tension of the net. In general, with increasing net tension, the lower the likelihood of capture and subsequent wrapping and entanglement. Thorpe and Frierson (2009) conducted trials of modified and unmodified anchored gillnets and reported significantly lower catch rates of Blacknose and Blacktip Sharks (*Carcharhinus limbatus*) in modified nets, without impacting the catch rate of the target species. However, catch rates of Bonnethead Sharks (*Sphyrna tiburo*) were uniform across mesh sizes and modified/unmodified nets due to their exaggerated cepholaphoil that resulted in 'hammer wrapping'. Thus, this technique would not be suitable for other species that have similar physiology, e.g., Hammerhead Sharks. Despite the limited evidence available for this technique, this appears to be a relatively simple measure that could be applied using existing equipment, warranting further field trials.

3.2.8 FADs – Construction and Deployment (Rating: Recommended)

Fish Aggregating Devices (FADs) are anchored (AFAD) or drifting (DFAD) floating structures with underwater appendages or tails deployed by fishers to create microhabitat and shelter in the open ocean (Restrepo et al. 2016). They are primarily used in purse-seine fisheries, but also in pole & line fisheries (Miller et al. 2017), and constructed from a range of materials that include many man-made non-biodegradable materials, e.g., fishing nets, plastic bottles, polystyrene, fiberglass that can then become a substantial marine pollution problem (Escalle et al. 2019, Proctor et al., 2019, Churchill 2021, Gillman et al., 2022).

Their use has increased substantially since they were first introduced in the 1990's, leading to an increase in the volume and diversity of bycatch (Watson et al. 2009). FADs are associated with incidental entanglement and drowning, with an estimated two million sharks killed worldwide each year (Dagorn et al. 2012a, Filmalter et al. 2013). Ghost fishing after a Fish Aggregation Device (FAD) is abandoned is another source of undocumented bycatch mortality as many are lost or abandoned and can drift thousands of kms on oceanic currents (Escalle et al. 2019).

Changing designs and construction methods to create non-entangling FADs is possibly the most practical method to reduce capture of sharks (Restrepo et al. 2019b) and possibly eliminate entanglement altogether (Restrepo et al. 2016). Relatively simple changes such as using optimal mesh size, weighting nets to maintain tension, rolling nets into 'sausages' or replacing nets altogether with ropes can reduce bycatch (Dagorn et al. 2012a, Dagorn et al. 2013, Restrepo et al. 2019b). In addition, creating appendages that are longer and placing them deeper in the water column may reduce bycatch of some species (Orue et al. 2019).

To address the issue of marine pollution, the use of biodegradable materials (Ardill et al. 2011, Dagorn et al. 2013, Escalle et al. 2019, Restrepo et al. 2019a, Restrepo et al. 2019b), has already been adopted by some RFMOs (Restrepo et al. 2019a), although a need still exists to agree on definitions of biodegradable materials, and to promote progressive change to these materials where immediate change is not possible (Zudaire et al. 2021). While complete elimination of FADs and hence bycatch around floating devices may not be possible in the short term, these measures can greatly reduce their impact.

3.2.9 FADs – Change Fishing Strategy (Rating: Recommended)

Changing fishing strategy when using FADs can result in improved bycatch rates. In purse-seine fisheries, setting on free schools and not using FADs at all can reduce bycatch by 3-6 times and produce a 'higher value' catch (Ardill et al. 2011, Dagorn et al. 2013, Restrepo et al. 2016). Another strategy is to only set on large schools of tuna, where the ratio of catch to bycatch decreases as catch size increases (Dagorn et al. 2012b). Avoiding sets on small schools of target species appears to be a simple and effective bycatch mitigation measure, especially as most fishers already have equipment such Global Positioning Satellite (GPS) enabled buoys and echo-sounders that can be used to determine the likely catch (Lopez et al. 2017).

Changing the timing of sets to exploit differences in diel behaviour of target and non-target species may not be an effective mitigation strategy. Tagging studies have shown that there are no temporal differences in aggregation of target/non-target species in existing FADs (Dagorn et al. 2012a, Forget et al. 2015), so actions such as conducting night sets may not be effective. However, Lopez et al. (2017) found that this behaviour is highly variable and differs between regions, requiring regional-specific studies to confirm appropriate prescriptions for individual fisheries. In addition, Orue et al. (2019) reported a small two week window immediately after FADs are deployed, where target species aggregate and before non-target species arrive that could be exploited and reduce bycatch. However, most FADs are used most often beyond this initial deployment time window so any reduction in bycatch would be short lived. Finally, a trial to draw sharks away from the FAD by towing bags of bait prior to setting demonstrated the potential of this method but small sample sizes did not permit firm conclusions to be drawn (Dagorn et al. 2012a).

3.2.10 Change Capture Method (Rating: Recommended)

While use of alternative gears may not be practical in all circumstances (Ardill et al. 2011), changing capture method can reduce shark bycatch rates. To address bycatch of Greenland Shark (*Somniosus microcephalus*), trials were conducted to assess if changing from fixed longline and gillnet capture to Norwegian pot traps was feasible. In a paired trial conducted by Grant (2015) with pot traps and longlines, Greenland Shark bycatch was reduced to zero in the traps without reducing target catch, while 15 individuals were caught on longlines. Further refinement of the pot design also recorded zero bycatch of Greenland Sharks, and bycatch rates of other non-target species was significantly lower (Folkins et al. 2021).

3.3 Increase Escape

If sharks can escape or be released whilst still in the water, they have a much greater chance of surviving the encounter (Ardill et al. 2011, Poisson et al. 2014). There are also safety benefits for fishers in releasing sharks in the water through minimizing the potential for bites and physical collisions during unhooking or detangling landed fish (Poisson et al. 2011, Poisson et al. 2012, Zollett and Swimmer 2019).

3.3.1 Leader Material (Rating: Recommended)

Wire leaders have higher catch rates and at-vessel mortality of sharks compared to nylon leaders (Ward et al. 2008, Gilman et al. 2016, Santos et al. 2017, but see Afonso et al. 2012), with some studies also reporting increases in target catch rates when nylon leaders were used (Ward et al. 2008, Afonso et al. 2012). The lower catch rates of sharks in these studies has been attributed to the ability of sharks to bite off the nylon leader and escape at up to four times the rate compared to wire leaders (Afonso et al. 2012, Santos et al. 2017). Afonso et al. (2012) demonstrated that when all shark bite offs were included the Catch Per Unit Effort (CPUE) was the same between leader types, so the picture may not be as clear as first thought. These results indicate that the leader material itself may not impact catch rates; rather nylon facilitates escape prior to haulback. Decreased at-vessel mortality of sharks caught on nylon leaders was almost universal from the studies reviewed, with the exception of Afonso et al. (2012), who reported higher at-vessel mortality on nylon leaders, with Silky Sharks (*Carcharhinus falciformis*), Oceanic Whitetip and Threshers only found alive at haulback on wire leaders. Despite these contradicting results, reviews by Ardill et al. (2011), Patterson et al. (2014) and a meta-analysis conducted by Musyl and Gilman (2019) all agree that nylon leaders are preferable, and that wire leaders should be banned as is already implemented in Australia and South Africa (Gilman et al. 2008). Overall, the change from wire to nylon leader material is an effective means of reducing shark bycatch, but any trailing gear (hooks, leaders and other gear that is foul hooked) needs to be removed, preferably prior to being brought onboard to increase post release survival (Sepulveda et al. 2015, Musyl and Gilman 2019, Grant et al. 2020).

3.3.2 Leader Construction (Rating: Requires Further Development)

Leader construction can influence catch rates of sharks. Stone and Dixon (2001) found that braided and tarred multifilament nylon gangions caught around half the number of sharks and target species compared to monofilament gangions, which they attributed to the higher visibility of multifilament gangions. Grant et al. (2020) also tested the difference between these two types of gangions and reported the opposite, with three times less Greenland Shark caught on monofilament. This was attributed to bite offs, as the hook loss rate was doubled for monofilament, but noted that snagging on the sea floor may have influenced this result. The lack of studies and contrasting results mean this technique would require further work to be done before making an assessment.

3.3.3 Escape Hatches/Panels in Purse Seine Gear (Rating: Requires Further Development)

Escape panels/hatches have been trialed in purse-seine fisheries with limited success (Itano et al. 2012, Restrepo et al. 2016), however with refinements including the position of the hatch and consideration of the sea conditions (e.g., current direction) improvements may be achieved (Itano et al. 2012). Another approach trialed was to draw sharks out of the net by creating a large escape window that allows the FAD to be towed through prior to closing the purse (Dagorn et al. 2012a). Results from this study were inconclusive, as not all sharks followed the FAD out, perhaps due to the close presence of the vessel or thruster noise (Restrepo et al. 2016). Research into the behaviour of target and non-target species whilst inside the net is needed to ascertain if segregation between the two groups at any stage that may be exploited (Poisson et al. 2021). These measures cannot be recommended currently without further field trials.

3.3.4 Excluders in Trawls (Rating: Recommended)

In trawls, excluders are an effective bycatch mitigation measure for large non-target species without impacting on target catch rates and can increase the value of target catch through reduced damage (Brewer et al. 2006, Chosid et al. 2012, Vasapollo et al. 2019). Excluders were primarily developed to exclude sea-turtles (Brewer et al. 1998) and marine mammals (Hamilton and Baker 2019) where there is a large size difference between target and non-target species but have also been used to reduce the catch of sharks (Stobutzki et al. 2002).

Research has focused on testing excluder designs and configuration of escape openings (Brewer et al. 1998, Stephenson et al. 2008), use of a funnel within the net to maintain target catch when an excluder is in use (Fennessy and Isaksen 2007, Zeeberg et al. 2006), size selectivity of excluders and grid spacing (Brčić et al. 2015), the effects of grate colour, grid angle and the location of the escape hatch (i.e., configuration) (Chosid et al. 2012, Wakefield et al. 2017), and evaluation of excluder effectiveness in whole of fishery studies (Raborn et al. 2012), most of which have reported positive impacts on bycatch. Not all trials of excluders have been successful, demonstrating that application of a technique in one area may not translate to other areas without trials and adjustments to suit local conditions (Shepherd and Myers 2005, Brčić et al. 2015). Shepherd and Myers (2005) also reported that despite the mandated use of excluders for over 20 years, the absence of other complimentary mitigation measures has not been sufficient to halt shark population declines. Despite these concerns, it is clear that the use of excluders when properly configured can reduce shark bycatch substantially.

3.4 Decrease At-Vessel Mortality and Increase Post-Release Survival

If the capture of sharks cannot be avoided completely and techniques to allow escape are not effective or practical, the last options for fishers are to reduce at-vessel mortality and to increase post-release survival after capture and handling. As the overall aim of bycatch mitigation is to ensure that non-target individuals remain viable in the population, taking measures to ensure sharks survive unavoidable encounters is crucial. In many situations, in particular developing nations, where moving to different areas, changing gear configurations, or halting fishing entirely are not possible, this may be the only viable option available to fishers (Gupta et al. 2020).

Various studies have shown that many species are particularly susceptible to the capture process, so techniques to increase survival and mandatory release provisions serve little purpose as the shark is likely to die shortly after (Morgan et al. 2009, Marshall et al. 2015). However, some species such as Blue Shark and Tiger Shark are robust and survive the capture process well, making them good candidates for release (Morgan and Burgess 2007, Musyl et al. 2011, Nunes et al. 2019). As part of any bycatch mitigation strategy, it is imperative that data are collected on the species captured and how well these survive handling so informed decisions can be made on appropriate species-specific handling techniques.

3.4.1 Reduce Soak Time/Time On-Line (Rating: Recommended)

Reducing gear soak time and therefore the time a shark is caught up is a simple way to reduce at-vessel mortality and increase post-release survival for most gears (Ward et al. 2004, Diaz and Serafy 2005, Morgan and Burgess 2007, Morgan et al. 2009, Morgan and Carlson 2010, Carruthers et al. 2011, Poisson et al. 2011, Braccini et al. 2012, Gallagher et al. 2014, Marshall et al. 2015, Bell and Lyle 2016, Nunes et al. 2019). The longer a shark is caught up in fishing gears, the more likely it is to suffer injuries, hypoxia, exhaustion, and predation that results in mortality (Cook et al. 2019). An immediate measure to decrease shark mortality is to cease the practice of dragging sharks on longlines until the rest of the catch is processed, which would in practice reduce soak time (Musyl and Gilman 2019).

Studies of satellite tagged sharks have confirmed that when a shark is landed in good condition, which is usually a result of shorter time caught in gears, post release survival is much more likely (Moyes et al. 2006, Musyl et al. 2011, Tolotti et al. 2015). The impact of reducing soak time on target catch appears to be minimal but can also result in reduced shark catch rates which is a desirable outcome (Ward et al. 2004). However, the overall finding of reducing soak times having a positive impact on survival does not apply to all species: Morgan et al. (2009) found that increasing soak time had no impact on at-vessel survival for Bull Shark (*Carcharhinus leucas*) and Dusky Sharks (*Carcharhinus obscurus*). Frick et al. (2010) reported Gummy Shark (*Mustelus antarcticus*) suffered high mortality from capture in gillnets in an experimental setting, even with very short soak times. Contrary to expectations, post-encounter survival increased with increased soak times. The same study also reported that the same species had very low mortality rates when captured in long line gear, demonstrating the importance of species-specific knowledge on gear type interactions when designing a mitigation strategy.

Other factors that need to be considered when assessing soak time include increased survival associated with increasing body size (Diaz and Serafy 2005, Gallagher et al. 2014, but see Morgan and Carlson 2010), decreased survival associated with increasing water temperature (see below, Gallagher et al. 2014) and sex-specific mortality where captured males have higher mortality than females (Coelho et al. 2012). These factors are further complicated by species specific responses, for example Morgan and Carlson (2010) found that increasing body size and longer time on-line increased mortality in Sandbar Sharks (*Carcharhinus plumbeus*), whereas Diaz and Serafy (2005) found the opposite for Blue Shark. Despite these species-specific nuances, reducing soak times is an effective and relatively simple shark bycatch mitigation to implement (Cook et al. 2019, Musyl and Gilman 2019, Zollett and Swimmer 2019).

3.4.2 Water Temperature (Rating: Requires Further Development)

Higher water temperatures can result in higher at-vessel mortality for multiple shark species (Morgan and Burgess 2007, Braccini et al. 2012). This is due to the stress response from capture that lowers blood pH and causes acidosis, which increases as water temperature increases (Hyatt et al. 2018). In contrast Dapp et al. (2017) found the opposite for Blue Shark, where mortality was higher in lower water temperatures. A review by Gale et al. (2013) found that 70% of studies concluded that warmer temperatures contributed to an increase in at-vessel mortality. Water temperature could be used to determine time/area closures when water temperatures reach a particular threshold (Morgan and Burgess 2007). This may be particularly useful as water temperatures increase globally due to climate change but will require knowledge of species-specific reactions in local conditions.

3.4.3 Hook Type (Rating: Recommended)

Replacing J-hooks with Circle hooks generally results in less internal or gut hooking, higher rates of jaw hooking and lower at-vessel mortality for sharks. Internal hooking has been found to be consistently higher when J-hooks are used in comparison to circle hooks (Watson et al. 2005, Ward et al. 2009, Al-Qartoubi et al. 2018, Nunes et al. 2019), and circle hooks are more likely to hook in the mouth or jaw, making release easier and faster (Kerstetter and Graves 2006, Al-Qartoubi et al. 2018, Grant et al. 2020). When internally hooked, release is often only possible through cutting through the leader which leaves the hook in place where it can cause internal injuries or leave trailing gear attached, reducing post-release survival (Sepulveda et al. 2015, Nunes et al. 2019). Comparisons of hook types have almost universally reported higher at-vessel mortality when using J-hooks (Kerstetter and Graves 2006, Carruthers et al. 2009, Reinhardt et al. 2018, Nunes et al. 2019, Zollett and Swimmer 2019 but see Afonso et al. 2012).

Whilst the change from J-hooks to circle hooks appears to be an effective bycatch mitigation measure, there is a trade-off against an apparent higher CPUE for multiple species of sharks on circle hooks (e.g., Afonso et al. 2011, Ward et al. 2009, Reinhardt et al. 2018). However, the increase in shark CPUE on circle hooks is not universal (Kim et al. 2006, Yokota et al. 2006) and species-specific responses may play a part in determining catch rates (Fernandez-Carvalho et al. 2015). Different results in shark CPUE studies have also been attributed by some authors to the bait type used (Amorim et al. 2015, Gilman et al. 2007b, Watson et al. 2005, Godin et al. 2012). Knowledge of local species bait preference and how this interacts with hook type is crucial for successful implementation.

Regardless of the variety of responses to hook type reported, there is general agreement that circle hooks appear to increase CPUE for sharks, but internal hooking rates and subsequent injuries are lower compared to J-hooks (Ardill et al. 2011, Graves et al. 2012, Patterson et al. 2014, Favaro and Cote 2015, Gilman et al. 2016, Reinhardt et al. 2018). However, this should be treated with caution as different gears, fishing locations, timing, target species, non-target species, bait type, and size/shape of hooks may confound results (Godin et al. 2012, Graves et al. 2012).

3.4.4 Modified Hooks (Rating: Requires Further Development)

Similar to the effect of bait size, using larger hooks can also impact selectivity, with large hooks catching large fish, and small hooks catching small fish (Morgan et al. 2009). This can provide a useful tool to protect particular size/age classes, e.g., juveniles needed for recruitment. There have been few studies that have investigated the effect of increasing hook size/width on CPUE, with varied results including reduced CPUE for both target and on-target species (Swimmer et al. 2011) and increased CPUE for both (Gilman et al. 2012). Gilman et al. (2018) reported distinct target and non-target species-specific responses in a trial of three different hook sizes, illustrating the need to conduct local trials prior to wider implementation. Modifying hook height and width can influence gear selectivity, but this requires further study to determine optimal sizes to suit local conditions.

3.4.5 Release Before Haulback (Rating: Recommended)

Releasing a captured shark in the water before being hauled onboard can improve post-release survival (Musyl and Gilman 2019, Zollett and Swimmer 2019). Cutting through leaders as close to the hook as possible on longlines at the vessel side, or release prior to brailing in purse-seines (Ardill et al. 2011, Poisson et al. 2014), are two relatively simple techniques that can improve post-release survival. Release at this stage of the capture process almost entirely removes risks of mortality associated with handling, crushing, abrasions and hypoxia, and benefits fishers through reduced risk of injury from landed sharks (Poisson et al. 2011, Poisson et al. 2012, Cook et al. 2019, Zollett and Swimmer 2019).

3.4.6 Handling Techniques (Rating: Recommended)

Satellite tagging studies of multiple shark species have reported that careful handling techniques increases post release survival (e.g., Musyl et al. 2011, Poisson et al. 2011, Poisson et al. 2014). This is one of the few shark bycatch mitigation measures where there is complete agreement about its effectiveness in all studies reviewed. It is simple to implement, at low or no cost to fishers, and results in lower mortality for captured sharks (Gupta et al. 2020). Implementation of this technique relies on the education of fishers. To achieve this, Poisson et al. (2012) produced a simple, informative, and illustrative guide for purse-seine fishers on best practice handling techniques, which provides an excellent model for other fisheries.

3.4.7 Water tables for sorting and release chutes (Rating: Requires Further Development)

Related to the issues of proper handling techniques and reducing the time a shark is on board and out of the water, some studies have advocated for the use of water tables and release chutes on fishing vessels to facilitate rapid sorting and the safer return to the water of bycaught species (Poisson et al. 2012, Cook et al. 2019). Water tables can be simply a table with tall sides where seawater is pumped over so that fish can continue to breathe whilst out of water. Release chutes are installed next to the sorting table and allow for the speedy return of non-target bycatch back to the water without the need to handle it further. Whilst we would assume this would be beneficial for increasing post release survival, we have not been able to locate any studies that have proven efficacy. This technique warrants further investigation.

Conclusions and Future Directions

The synthesis of evidence above demonstrates that there is no single technique that can be applied to all species, fishing gears and regions, with the exception of improving handling practices. Responses to gear modifications vary between regions, depending on local environmental conditions, species composition and other confounding factors, so that techniques that are effective in one area cannot be assumed to work in another. To effectively mitigate bycatch of sharks, most fisheries will require a combination of techniques to be employed but may result in unintended impacts on other species. This will require that each fishery with unintended catches of sharks to assess what species they are catching, what they should not be catching, which of these are most at risk, and what the life history, behavioural and feeding characteristics they have that could be exploited to minimize their catch. There is also a need to address interactive factors of biological, environmental, and technical issues to find a solution for these particular circumstances (Broadhurst et al. 2006, Gallagher et al.

2014). Trials of techniques should be undertaken in relevant areas to ensure efficacy prior to mandating a particular approach to reducing bycatch.

One of the fundamental problems for identifying and assessing mitigation methods is a paucity of detailed data on life history and movement characteristics of many shark species, the factors that contribute to the probability of a species being caught and escaping, and the stressors that increase mortality. Poisson et al. (2021) outline recent advances in technology that could assist greatly in identifying what actually occurs when a shark is captured including the use of autonomous underwater vehicles (UAV) and aerial drones to assist fishers in deciding where and when gears should be set to maximise target catch and minimize bycatch. The cost of using these technologies may be prohibitive for many fisheries and States, requiring technical and financial support to ensure widespread use.

There are multiple approaches to mitigating bycatch that can be split into regulatory (e.g., quotas, bans on take, time/area closures, full retention, etc.) and technical methods (e.g., gear modifications, changes to fishing methods & techniques, etc.), and we have only dealt with technical mitigation techniques in this paper. Whatever approach is taken (including the combination of both regulatory & technical measures), consideration must be given to the level of intended bycatch reduction required, the impact on catch of target species, the impact on non-target species, unintended impacts on other non-target species, and the economic impact for any technique (O'Keefe et al. 2014, Poisson et al. 2021). Balancing these impacts often requires a trade-off approach to maximising bycatch reduction whilst maintaining the economic viability of the fishery (Booth et al. 2020). Any bycatch mitigation technique must be practical and economically viable for fishers to willingly adopt it, requiring close involvement and input by industry and fishery managers (Favaro and Cote 2015).

The priority for bycatch mitigation must be to avoid capture. There are multiple benefits for both fishers and sharks when this is achieved, through higher value landed catch, more opportunity to catch target species, fewer injuries to fishers, less damage to and loss of gears and reduced ecosystem impacts. The most promising technical mitigation measures for reducing shark bycatch mortality are choice of bait type, not using baits at all, constructing non-entangling FADs, change of fishing strategy when using FADs, using effective mesh sizes, removal of tickler chains, or changing capture method. Some techniques can be much more effective if used in concert with each other (Restrepo et al. 2016), but care needs to be taken to ensure that these methods do not conflict with one another or unintentionally impact other species groups. Other pre-capture methods that require more research, development and field trials include the use of artificial baits laced with olfactory repellents such as necromones, optimal bait size, active electrical repellents, strobe lights, removal of light sticks, increasing net tension in gillnets, and drawing sharks away from FADs prior to making sets as currently many do not seem to be a practical option or require more empirical evidence of their efficacy.

If capture cannot be avoided, then efforts need to be made to allow escape prior to haulback. Like avoiding capture, the benefits for fishers include saving time at haulback by not having to untangle and/or unhook sharks on deck, which will also result in fewer injuries to fishers. Allowing escape also eliminates time out of the water for sharks, and reduced damage to target catch. The most effective measures include using monofilament nylon leaders in place of wire leaders or cutting through leaders at the hook in hook and line gear and using excluders in concert with appropriately configured BRDs such as escape panels or hatches in trawls.

Lastly, if haulback after capture is unavoidable, efforts need to be made to reduce at-vessel mortality and increase post-release survival. Careful handling and quick release of sharks, regardless of the gears used, is essential. Changes to fishing practices through reduced soak time, releasing sharks from the net when the gear is still in the water, and the use of circle hooks appear to be the most appropriate techniques currently available. The use of equipment such as water sorting tables and release chutes could also be beneficial for sharks, especially obligate ram ventilators that suffer the highest mortality once out of the water, but this requires further study.

Overall, mitigating shark bycatch is an extremely complex problem that no single technique is going to solve. Solutions need to account for species specificity, tailored to individual fisheries and their management framework and objectives, account for interactions between mitigation strategies and unintended impacts, and make trade-offs between maintaining target catch and minimizing bycatch. The need for fine grained data on shark species' movements and life histories is urgent and should be prioritised. Techniques need to be assessed for the region and species where they will be deployed, and the involvement of the fishing industry must be encouraged and actively sought early in the process. Fishers already hold a huge body of knowledge that must be recognised, respected, and utilised in designing any mitigation strategy. Without their input and support, no bycatch mitigation solution will be effective.

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