Protection On The Move: Applying Dynamic Ocean Management To Address Shark Bycatch In Atlantic Canada

By

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Dedicated to Rob Stewart

Thank you for igniting my passion for sharks and working tirelessly to protect them.
It was an honour to have known you.

Abstract:

The Canadian North Atlantic pelagic longline fishery for swordfish and tuna has unintended bycatch of porbeagle, shortfin mako, and blue sharks. This creates concerns for species-at-risk populations, ecosystem health, harvesters safety and economic security. This study proposes that a Dynamic Ocean Management (DOM) application could mitigate the pelagic shark bycatch associated with this longline fishery. The document reviews published information on the focal shark species, *the fishery*, current marine spatial management tools used in Canada, and theory and applications of DOM. Following this, the study evaluates the attitudes of 14 primary stakeholders towards DOM through stakeholder group governance analysis and semi-structured interviews. The associated stakeholders who participated in the project include one participant from each of the regional RFMOs; NAFO and ICCAT, three participants from DFO, one participant from the Nova Scotia Swordfish Association, four NGO perspectives, two academic perspectives, and two private third-party interest groups. In the interviews, all individuals discussed their views on the bycatch challenge, the desirability and feasibility of applying DOM, and the current efforts undertaken by each group. The results of this study show that a DOM application is seen as a desirable potential solution by most and could be feasible depending on project structure and management style. Therefore, based on the considerations of the governance analyses and interview responses, a management plan is proposed and associated requirements, considerations, and concerns are discussed. Specifically, the plan proposes a management tool in the style of a phone app or website interface. This interface would allow harvesters to geo-tag areas where shark bycatch has impacted their catch in near-real time. When overlaid with other data streams, including historical seasonal data, ocean conditions and species tracking, it allows the whole fleet to strategically plan their next location to set their longlines, with an active consideration to avoid sharks.

Keywords:
Dynamic ocean management, species management, fisheries management, bycatch mitigation, pelagic longline, conservation, Northwest Atlantic, blue shark, porbeagle shark, shortfin mako shark, precautionary approach, adaptive management

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LIST OF ACRONYMS

CBD – Convention on Biological Diversity
CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora
COSEWIC – Committee on the Status of Endangered Wildlife in Canada
CP – Contracting Party
CPC – Cooperating non-Contracting Party
DFO – Fisheries and Oceans Canada
DOM – Dynamic Ocean Management
EAC – Ecology Action Centre
EAF – Ecosystem approach to fisheries
ECCC – Environment and Climate Change Canada
FAO – Food and Agriculture Organization of the United Nations
GDP – Gross domestic product
ICCAT – International Commission for the Conservation of Atlantic Tunas
IPOA – International Plan of Action
ITQ – Individual Transferrable Quota
IUCN – International Union for Conservation of Nature
MPA – Marine Protected Area
MSC – Marine Stewardship Council
MSY – Maximum Sustainable Yield
NAFO – Northwest Atlantic Fisheries Organization
NGO – Non-Governmental Organization
NMCA – National Marine Conservation Area
NOAA – National Oceanic and Atmospheric Administration
NPOA – National Plan of Action
NSSA – Nova Scotia Swordfish Association
NWA – National Wildlife Area
OTN – Ocean Tracking Network
PSAT – Pop-up Satellite Archival Tags
RFMO – Regional Fisheries Management Organization
SARA – Species at Risk Act
SBA – Sensitive Benthic Area
ShARCC – Sharks of the Atlantic Research & Conservation Centre
SPOT – Smart Position and Temperature Tags
SST – Sea surface temperature
TAC – Total allowable catch
UNCLOS – United Nation Convention on the Law of the Sea
VMS – Vessel Monitoring System

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CHAPTER 1: INTRODUCTION

Sharks have lived on this planet for roughly 450 million years and have survived all five natural historical mass extinctions. Many species are the ocean's top predators, playing a crucial role in the ocean ecosystem (Ferretti et al., 2010). However, throughout the past century, shark populations have faced significant declines directly corresponding to negative human interactions (Dulvy et al., 2014). Population declines have been particularly notable for large, pelagic, and migratory sharks, especially for the migratory sharks of the Northwest Atlantic (Baum et al., 2003., Campana et al., 2008). Impacted sharks in the Northwest Atlantic include the porbeagle (*Lamna nasus*), shortfin mako (*Isurus oxyrinchus*), and blue sharks (*Prionace glauca*) (Baum et al., 2003). Considering that these sharks continually enter Canadian waters, effective management needs to be in place to ensure negative human interactions are minimized.

A crucial negative human impact on these species in Canadian waters is commercial fishery bycatch. One Canadian fishery that faces the problem of pelagic shark bycatch is the Canadian North Atlantic pelagic longline fishery targeting swordfish and tuna, hereafter known as *the fishery*. The term bycatch has multiple definitions. For this project, the most appropriate definition is provided by the Oxford English Dictionary as t*he unwanted fish and other marine creatures caught during commercial fishing for a different species* (2017). While *the fishery* intends on catching swordfish and tuna, the design of the longline makes it difficult to be selective of catch. The areas that harvesters hope to find the target species overlaps with areas where porbeagle, shortfin mako, and blue shark may reside. Almost all the shark bycatch occurring in this fishery does not get landed due to quota restrictions and a lack of market for the species (DFO, 2016d). Therefore, this catch is a waste of time and bait for the harvesters, is a risk of mortality for the sharks, and has no benefit to the ecosystem or the industry. Furthermore, high levels of bycatch create a risk of resource depletion, ecosystem impacts, and drives some of these shark species closer to extinction (Baum et al., 2003). Without proper management in place to address this problem, it will continue to occur and be perceived as an unavoidable feature of *the fishery*.

Within Canada, there are management tools designed to protect species and assist in fisheries management. However, shark bycatch in *the fishery* continues to occur under the current management regime and population levels of porbeagle, and shortfin mako sharks are at concerning levels (Gibson & Campana, 2005; ICCAT, 2017b). The challenge in addressing this problem is that *the fishery*, the target species, and the bycatch are all highly dynamic in space and time. Dramatic changes in movement of the target species, result in harvesters covering large spatial areas in a matter of days. Therefore, to address this challenge, management needs to be able to respond quickly to frequent and fast changing movements by the species and *the fishery*.

Given this situation's seasonally wide-ranging and dynamic features, static spatial measures (local area fishery closures) fall short in addressing the problem. Static tools' inability to accommodate large, pelagic, and migratory species, such as the sharks associated with the longline industry, calls for expansion of the management toolbox. To respond to this need, Dynamic Ocean Management (DOM) could be considered a potential means to address this problem. It is described as *management that changes in space and time in response to the shifting nature of the ocean and its users based on the integration of new biological, oceanographic, social and/or economic data in near real-time* (Dunn et al., 2016). DOM's theoretical underpinning considers the dynamic environment of the ocean and requires accurate and precise near real-time data as a core part of the process. This ensures that management and users are operating with the most up to date information possible.

This project proposes a potential DOM-based solution to the issue of pelagic shark bycatch in the Canadian North Atlantic pelagic longline fishery targeting swordfish and tuna. The research for this project was completed through a governance analysis and stakeholder interviews of the four main stakeholder groups: RFMOs, DFO, *the fishery,* and third party organizations. These interviews discussed the challenge of bycatch, the potential of implementing DOM, and current actions each organization was doing to address the bycatch. The results attained from the information provided through the research supported a practical and feasible solution to the bycatch issue. This solution is presented in the form of a phone or computer application used by the harvesters to help mitigate shark bycatch. This application could allow the harvesters to more strategically plot their lines in a way that reduces or eliminates the bycatch, potentially minimizing unwanted species-industry interactions.

There is a serious management challenge within *the fishery* of adequately addressing shark bycatch (Christian et al., 2013; Campana et al., 2009). If addressed, it could improve the relationship between the region's pelagic sharks and the longline harvesters. It stands to protect the species' from becoming unwanted catch and stabilizing populations, but also, assisting the harvesters to catch more of what they want and can profit from, and avoids bycatch costs. *The fishery* and their shark bycatch problem would benefit from a management plan that balances ocean resource use and conservation. This project evaluates how a Dynamic Ocean Management approach could improve pelagic shark bycatch mitigation in the Canadian North Atlantic pelagic longline fishery targeting swordfish and tuna.

The organizational structure of this paper following Chapter 1's Introduction Chapters 2 provides the paper with relevant background and context related to the management challenge. This includes discussions on the focal shark species, *the fishery*, spatial management in Canada, DOM theory and applications, and combining these two approaches. Chapter 3 describes the methodology for this graduate project. Chapter 4 provides an assessment of the governance strategies and the research interview results from each stakeholder group. Chapter 5 explores the preliminary design of the DOM application. Chapter 6 provides discussion and recommendations related to the research findings and application plan. Finally, Chapter 7 summarizes how a DOM application would be beneficial and feasible for the case of shark bycatch in the Canadian North Atlantic pelagic longline fishery targeting swordfish and tuna.

CHAPTER 2: BACKGROUND AND CONTEXT

This chapter provides an overview of all background topics that support the governance analysis, interviews, or application development. The main topics discussed within include the focal species of sharks related to the project, *the fishery* that the research and potential application hope to support, current static spatial management within Canada, and DOM.

2.1: Sharks of The Atlantic

This section analyses the three species of sharks that are the most impacted by *the fishery*; the porbeagle, shortfin mako, and blue shark. When establishing a management plan to mitigate pelagic shark bycatch in *the fishery*, it is valuable to consider varying factors between these sharks to ensure that it can work for all three species.

2.1.a: Porbeagle shark (*Lamna nasus)*

Canada is home to a significant portion of the Northwest Atlantic population of the porbeagle shark (Stevens et al. 2006). Within the region, these migratory sharks are distributed from the northern parts of Newfoundland through to the Gulf of St. Lawrence, the Scotian Shelf, and the Bay of Fundy (DFO, 2016a). DFO's stock assessment for this species indicates that biomass is depleted significantly below MSY and models indicate that the population in 2005 was about 0.1 to 0.24% its size in 1961 (Gibson and Campana, 2005). Given the species low reproductive rate, even with effective management strategies, it would take at least three decades for the species to recover 20% (Gibson and Campana, 2005). Given this and other populations assessments, concern has grown for this species. This is indicated by a variety of conservation listings; the IUCN Red List has them listed as *Endangered*, CITES has listed them under

Appendix II, and an assessment completed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommend that the species be designated as E*ndangered* under SARA (Stevens et al., 2016; CITES, 2017; COSEWIC, 2004). However, the Canadian government decided not to give the species an *Endangered* status or schedule "*due to rigorous conservation measures in the new shark management plan*" (DFO, 2017e). Given current population levels, human interaction risks, and a lack of strength behind the measures of the shark management plan, which will be discussed later, without SARA, the current amount of protection for the species is inadequate. Furthermore, when assessing its movement patterns, the porbeagle spends most its time offshore in pelagic and littoral zones, can dive to depths of 1360 meters, and its temperature preference is between 5 and 12 degrees Celsius.

2.1.b: Shortfin mako shark (*Isurus oxyrinchus*)

The shortfin mako shark is another species occurring in Canadian Atlantic waters. The species' population status has also received attention and is listed as *Vulnerable* on the IUCN Red List, and recommended for *Special Concern* by COSEWIC (Cailliet et al., 2009, Government of Canada, 2017a). However, these listings may be out of date given the latest stock assessment completed in 2017 by ICCAT. This assessment estimated that the stock was depleted and overfishing was occurring. Additionally, it states that based on current catch levels, the North Atlantic population will continue to decline and to prevent further declines, catches would need to be reduced by 72-79% (ICCAT, 2017b). The shortfin mako is a highly migratory species, and while they are not as abundant in Canadian waters compared to other places, they are still found along the continental shelf of Nova Scotia and in the Gulf of St. Lawrence (DFO, 2016b). Shortfin mako differ from the other two sharks focused on in this project is that they have a strong preference for warmer waters. The shortfin mako prefers tropical and temperate offshore waters and occupies from surface to waters as deep as 500 meters. This species will typically not inhabit waters colder than 16 degrees Celsius; they are usually seen in waters that have a temperature range of 17 to 22 degrees Celsius (DFO, 2016b). With the population decreased to concerning levels, and with the mako's slow reproductive rate, there is a need for proper management responses measures to aid this species recovery.

2.1.c: Blue shark (*Prionace glauca)*

While the total North West Atlantic's population of the blue shark is unknown, ICCAT and DFO assessments estimate that the stock has decreased modestly since 1994 (Campana et al., 2015b). The IUCN Red List has blue shark listed as *Near Threatened* (Stevens, 2009). Conversely, COSEWIC's latest assessment for the Canadian range designated the species as *Not at Risk* (COSEWIC, 2016). In Atlantic Canada, blue sharks are the most common pelagic shark species, and are found around Newfoundland, the Gulf of St. Lawrence, the Grand Banks, the Scotian Shelf and the Bay of Fundy (DFO, 2016c). In Canada's temperate waters, this species can be seen in coastal and offshore areas, living in the shallows and at depths greater than 200 meters. The temperature preference for the blue shark is between 10 and 20 degrees (DFO, 2016c). This temperature preference is also a large driver of their migratory patterns; as the waters warm, blue sharks move northward (DFO, 2016c). The blue shark is the most common shark caught by *the fishery*.

2.2. Canadian North Atlantic Pelagic Longline Fishery Targeting Swordfish and Tuna

The Canadian North Atlantic pelagic longline fishery targeting swordfish and tuna extends from Georges Bank to the Flemish Cap, and a majority of the activity occurs along the continental shelf *(Figure 1).* This fishing area is connected to the movement of the intended species, the swordfish, as well as seasonal warming trends of surface water temperature, and northward movements of the Gulf Stream edge (DFO, 2016d). This project and review focuses solely on the longline portion of *the fishery* as the small harpoon industry does not have an issue of shark bycatch and the longline makes up for 81% of the total swordfish landings (DFO, 2016d).

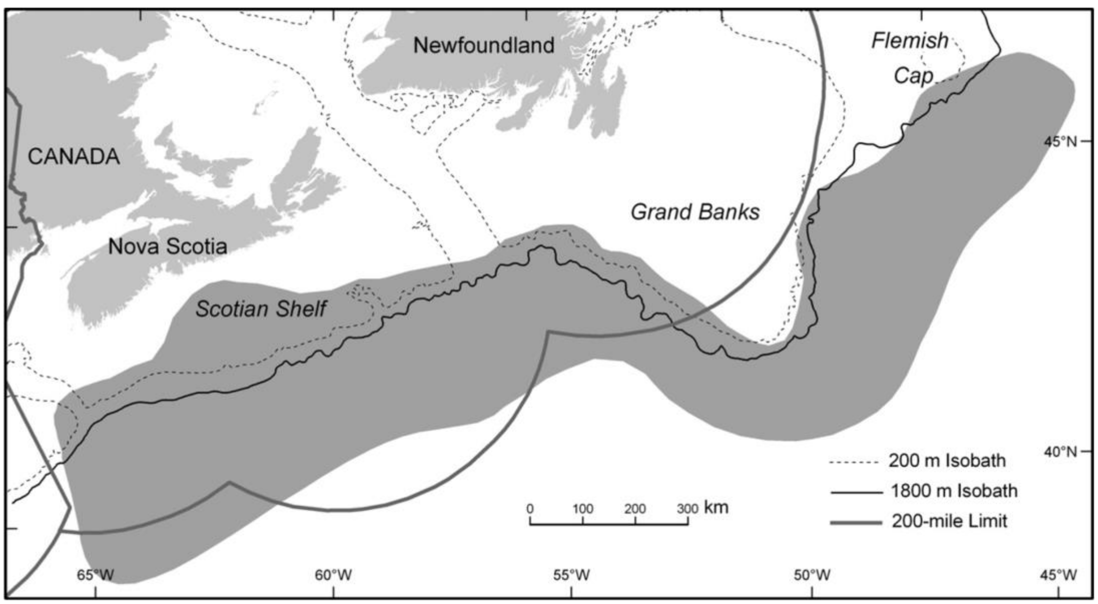

Figure 1: the Canadian North Atlantic pelagic longline fishery targeting swordfish and tuna geographic location (Carruthers and Neis, 2011).

When assessing *the fishery's* operations, each vessel deploys longlines of an average length of 30 to 50 miles, with each line having roughly 600 to 1,100 hooks (IMM, 2011). Catch consists of a multitude of pelagic species and so it has become a multi-species fishery. To manage this, the harvester's licence conditions control their authorized catch. These licence conditions identify the authorized, directed species and permitted bycatch species, which includ sharks, marlins and "other tunas" (DFO, 2016d). Furthermore, access to *the fishery* is limited to the current existing licences, and has been since 1992 (DFO, 2016d). There is a total of 77 licences under this fishery, with approximately 50 to 55 active and authorized to operate Atlantic-wide in the most recent years (DFO, 2016d). The Nova Scotia Swordfish Association (NSSA) represents all longline licence holders, and *the fishery* operates from April through December; however, the season has the potential to extend year-round, quota permitting.

A notable factor for *the fishery* is their Marine Stewardship Council (MSC) Certification. The Canadian North Atlantic pelagic longline fishery targeting swordfish and tuna received their sustainable certification in April 2012 (MSC, 2017). While the MSC Certification pushes the industry to continue to improve their management practices, *the fishery* still faces a variety of fisheries management issues. Two of their most significant challenges, which are also the focal point of this project, is *the fishery's* challenges with bycatch and depleted species concerns. While *the fishery* targets swordfish and certain tunas (bigeye, yellowfin, and albacore), they also have a wide variety of incidental bycatch including sharks, turtles, seabirds, and other fishes. One of the most striking statistics of this fishery is that to reach an annual targeted catch of 20,000 swordfish there is a bycatch estimate of 100,000 sharks (Christian et al., 2013; Campana et al., 2009). This statistic is a reason for great concern as the shark bycatch significantly outpaces the targeted catch for *the fishery*, and as previously mentioned, the most common sharks caught in these lines are the three-focal species of this project (Fitzgerald, 2000). While the permitting landing of these sharks are limited by quotas (porbeagle 50t; blue shark 250t; and shortfin mako 100t), actual catch probably far exceeds the landings with most sharks being discarded at sea without being counted. Therefore, these allowances only help restrict the landings, not species avoidance (DFO, 2016d). It is also undesirable for *the fishery*, particularly with blue sharks, as they fill up their lines, meaning less potential catch of swordfish, monetary loss in bait, hooks, lost revenue, and increased time use of detaching sharks from the lines.

Another notable concern regarding *the fishery* is the severe interactions with blue sharks. Blue sharks are the most commonly caught large shark in Canadian fisheries waters (DFO, 2016d). However, a lot of this catch goes unreported as landings are extremely low due to a lack of market and value. Currently, ICCAT reports state that current harvest levels are sustainable (Lopez, 2015). However, the blue shark population in Canadian waters has been declining, and mortality has been increasing. Catch rates in both longline fisheries and recreational tournaments have fallen, and the median size of the sharks has decreased (DFO, 2016d). Precautionary action benefits both the ecosystem and the future of *the fishery*.

Regarding monitoring *the fishery*, at this time, *the fishery* only has ~5 to 10% observer coverage; with minimal data, estimates of bycatch numbers, and how significant the impacts are on the species, remains relatively unknown (Hanke et al., 2012; Christian et al., 2013; IMM, 2011). There are also uncertainties regarding post-release bycatch mortality rates. Specifically, estimates have shown blue shark's having a lower post-release mortality rate (23.1%), in comparison with porbeagle (59.1%) and shortfin mako (49.3%) (Campana et al., 2015). However, this does not consider realities of *the fishery* such as having gangion line, which is the part of the fishing line closest to the hook, cut free by harvesters and left attached to the shark upon their release. This is an unknown mortality risk to the impacted sharks in the water.

Overall, the standards put in place to assist with *the fishery's* bycatch needs to be continually reassessed and improved where possible.

2.3: Spatial Management Tools Currently Used in Canada

The Government of Canada has a variety of tools which it currently applies to ocean ecosystem and fisheries management. While many of the tools overlap with each other, they all have distinctive factors to consider when deciding how to address an area or management issue. This section gives a brief synopsis on the capabilities of each approach.

2.3.a: Marine Protected Areas (MPAs)

MPAs have received a lot of attention at an international level and within Canada. Internationally, the Convention on Biological Diversity (CBD) established the *Aichi Biodiversity Targets*. Within this, Target 11 has a goal of 10% protection of coastal and marine area protection by 2020 (CBD, n.d.). From this, Canada has agreed to meet this target by having 5% protection by 2017 and 10% by 2020 (DFO, 2017a). An MPA must meet five criteria. These include a clearly defined geographic location; stock management or conservation objectives directly related to an important species or habitat; the area must contain an important species or habitat; the measures must be long term; and the measures need to protect the species or habitat from existing and foreseeable pressures (Government of Canada, 2017b). The *Oceans Act* MPAs, marine National Wildlife Areas (marine NWAs), and National Marine Conservation Areas (NMCAs) are all accepted contributions towards the Canadian targets.

Oceans Act MPAs are designated through DFO and follow the protected area definition set out by the International Union for Conservation of Nation (IUCN). The IUCN defines it as *a clearly defined geographical space, recognized, dedicated, and managed through legal or other effective means, to achieve long-term conservation of nature with associated ecosystem services and cultural values* (IUCN, 2017). These MPAs have a permanent placement and are fixed static areas that can vary in size. The *Oceans Act* MPA structure ensures that there is a core conservation area, but MPAs can have varying intensities and types of activities within. Their protection measures include considerations for both the seabed and the water column and have the potential to cover areas such as wetlands and estuaries. Overall, the areas provide conservation for fishery resources, their habitats, endangered or threatened species and their habitats, unique habitats, and areas of high biodiversity or biological productivity (DFO, 2016f). While the creation of *Oceans Act* MPAs within Atlantic Canada are poised to grow, at present there are only two off-shore MPAs in the Maritime region; The Gully and St. Ann's Bank. This lack of area covered jeopardizes the populations of pelagic species in this area.

Environment and Climate Change Canada (ECCC) contributes to the Aichi Target 11 through marine NWAs. These MPAs are legislated through the *Canada Wildlife Act* and focus on wildlife and habitat conservation. Marine NWAs are chosen based on their potential for conservation, research, and interpretation (ECCC, 2017). The criteria the ECCC considers in the site selection process includes migratory birds, species at risk, critical habitat for species at risk, and rare habitat. Similar to *Oceans Act* MPAs, these protected areas consider the seabed as well as the water column and have the potential to include wetlands, estuaries, islands, and other coastal lands (ECCC, 2017). Marine NWAs impose site regulations through prohibitions such as disturbing, damaging, destroying, or removing wildlife or habitat; dumping or discharging waste material; and flying over the area below certain height restrictions (ECCC, 2017). Marine NWAs can be a valuable tool to enable the conservation of seabirds and marine species through minimizing disturbance through human impact, as well as fostering monitoring, research, and surveillance. However, in Canada only one marine NWA has been proposed, off the Pacific coast, and there are no formal designations. This means that a valuable tool that could be applied in the Maritime region by ECCC is not occurring.

The third and final tool classified as a Canadian MPA are NMCAs. The Parks Canada Agency completes this under the *National Marine Conservation Areas Act*. Similar to the two tools mentioned above, NMCAs have a temporally permanent placement, are a fixed static area that varies in size depending on the NMCA, consider both the seabed and water column in their design and include other areas such as wetlands, estuaries, islands, and coastal land. NMCAs aim to maintain the structure and function of marine ecosystems in balance with sustainable use (PC, 2017). NMCAs operate by providing ecosystem protection from activities such as ocean dumping, undersea mining, oil and gas exploration and development, and commercial fishing. These MPAs are established to provide areas representing Canada's marine diversity, maintain ecological processes, support the sustainable use of marine species and ecosystems, develop marine research and ecological monitoring, protect depleted, vulnerable, threatened, or endangered marine species and their habitats, establish areas for marine recreation, and support the development of MPA networks (PC, 2017). While similar to the other MPA initiatives, NMCAs put more emphasis on public enjoyment and education opportunities, alongside the primary focus of environmental reasons. However, like the marine NWAs, there are no NMCAs in Canada's Maritime Region. This lack of application of a valuable static tool again shows that other means need to be considered if the ones in place are not effectively applied to address management challenges in the Maritime's inter-sectoral offshore areas.

While there has been much hype about these tools as a means of achieving the Aichi target, Canada has fallen short on the international stage due to factors such as multiple gaps in legal provisions, overwhelmingly long designation timelines for MPAs, and weakness due to a lack of minimum protection standards (WCEL, 2017). These issues, and the current total lack of offshore protected areas, creates concern and indicates that management and conservation in off-shore regions and for pelagic species is lacking.

2.3.b: Critical Habitat

There are species-specific tools that can improve Canada's ocean ecosystems. Designation of aquatic critical habitat occurs through the *Species at Risk Act* (SARA), and is implemented by DFO or Parks Canada. The purpose of establishing an aquatic critical habitat is for the survival and recovery of a listed aquatic species. Critical habitat by definition, is *the habitat necessary for the survival or recovery of wildlife species listed under SARA, and that is identified as the species' critical habitat in the recovery strategy or within an action plan for the species* (ECCC, 2007). For aquatic species, critical habitat may include areas related to spawning, rearing young, migration, or feeding. While SARA does not prohibit certain activities outright, it prohibits destruction within the critical habitat. Therefore, there must be an assessment of every proposed activity within the habitat on a case-by-case basis, followed by site-specific mitigation planning (ECCC, 2007). While critical habitat may be a species-specific measure, depending on the species, it could additionally have massive impacts on the health of the ecosystem. While the legislation behind endangered species designations presents a potential means for valuable protection, results from its implementation have been mixed. Reviews have shown that the chance of marine species, in general, receiving a protection listing is significantly lower in comparison to other species classifications. Only 12 of the 62 (~19%) marine fishes proposed for listing have been approved by the Govrnment of Canada under SARA, post COSEWIC review (McDevitt-Irwin, 2015). In the case of sharks residing in the Atlantic Ocean, only the white shark (*Carcharodon carcharias*) is listed under SARA, (under schedule 1). This reflects that terrestrial species are far better addressed and even within this challenging marine context, shark species are further disregarded.

2.3.c: Sensitive Benthic Areas

Sensitive Benthic Areas focus strictly on benthic ecosystem conservation. They are policy based action occurring through *The Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas*. Their aim is to protect fundamental conservation features within the ocean's benthic environment, while minimizing the socioeconomic impacts of restrictions (DFO, 2012). SBAs can apply to all commercial, recreational, and Aboriginal marine fishing activities that are licensed or managed by DFO. Once an area has been selected, the SBA is created through a fisheries closure. The closures prohibit or restrict some levels of bottom-contact fishing, minimizing bottom disturbance. Prohibitions could potentially include bottom trawls, traps, dredges, or bottom longlines. SBA designations are used in a case-specific approach to both its temporal and spatial scope reasoning. However, a notable concern for SBAs and the *Fisheries Act* tools stated in section 2.3.d below, is the supporting legislation. While the Policy is guided by the *Fisheries Act, the* Act itself is severely out of date and needs to be modernized (Coté et al., 2012). It is unable to reflect on sustainability principles including ecosystem and precautionary approaches, due to a lack of guidance regarding management objectives, principles, and procedures (Coté et al., 2012). Therefore, the legislative strength of SBAs is weak and further legislative measures that effectively consider marine biodiversity need to be developed.

2.3.d: Fisheries Closures and Management

There are also non-SBA fisheries closures that can occur through the *Fisheries Act* which DFO also manages to help improve the management of Canadian fisheries. These closures can be applied to commercial, recreational, Aboriginal, and food fisheries for conservation, safety, contamination, seasonal, or other reasons (DFO, 2017b).

Aside from formal fisheries closures, there are variation orders that specify closed times, fishing quotas, or limits on the size and weight of the individuals that are caught (DFO, 2017b). Additionally, each commercial fishery is subject to requirements that can be updated to ensure management is operating at an adequate capacity. These conditions include licensing, logbooks to record information on catch and effort, at-sea monitoring, and standards for gear, tags, and tabs. Furthermore, gear modifications can be imposed to help improve targeted catch, mitigate bycatch, decrease bycatch mortality rates, or for other reasons.

Canada has a variety of tools it can apply to manage the oceanic ecosystem and the range of fisheries that occur within it. However, all the strategies listed above, except the fisheries closures and management requirements, are geographically static areas that cannot entirely capture the needs of an ecosystem or dynamic species on their own. Static spatial measures are valid tools that help improve ocean ecosystems and fisheries, and they have a wide variety of benefits and positive outcomes (Gell and Roberts, 2003; Börger et al., 2014). However, most of these approaches are derived from terrestrial management planning experiences and cannot always respond to the complexity associated with the ocean ecosystem and the issues that occur in and on the waters. Additionally, it is clear that the use of these tools are not widely used or being used effectively. Therefore, it would be valuable to consider other management tools that can respond to concerns when static spatial management cannot adequately address it alone.

2.4: Dynamic Ocean Management

To address current failures in static spatial management, other tools should be considered to supplement management. DOM ocean-specific approach provides management with a means of filling this gap. Reflecting on international law and policy, DOM's theoretical underpinnings, and examples of current applications provides the information needed to understand the value that DOM can contribute to this case study, or other similar situations.

2.4.a: DOM and International Law

To start, DOM has great potential to meet legal requirements and policy agendas at the international level, particularly with regards to the ecosystem approach to fisheries (EAF), and precautionary approach.

EAF "*recognizes explicitly the complexity of ecosystems and the interconnections among its component parts*" (Garcia et al., 2003). The approach requires: (1) the ecosystem's definition and scientific description; including its scale, extent, structure, functioning; (2) an environmental assessment for its health or integrity in the context of societal acceptance; (3) a threat analysis; and (4) its maintenance, protection, mitigation, rehabilitation, etc., using (5) adaptive management strategies (Garcia et al., 2003). EAF's origins started with the 1972 UN Conference on Human Environment in and the 1982 adoption of UNCLOS. EAF is already widely endorsed on an international level including by the FAO in their Code of Conduct for Responsible Fisheries, and the United Nations Sustainable Fisheries Resolutions (Garcia et al., 2003; United Nations General Assembly, 2017). Under FAO, EAF is the main reference framework for implementing the principles of sustainable development and fisheries management. Within their Code of Conduct, they have 20 operational objectives and measures associated to EAF. This includes points such as reducing bycatch and discards, improving ecosystem well-being, rebuilding ecosystems, and maintaining biological diversity (Garcia et al., 2003).

Furthermore, the precautionary approach to fisheries plays an integral role in the development of DOM and as international legal underpinnings. Binding legal requirements for the approach began with the formal action at the 1995 UN Fish Stocks Agreement. The FAO defines the precautionary approach as "*A set of agreed cost-effective measures and actions, including future courses of action, which ensures prudent foresight, reduces or avoids risk to the resources, the environment, and the people, to the extent possible, taking explicitly into account existing uncertainties and the potential consequences of being wrong*" (Garcia, 1995). This approach is essential in acknowledging the uncertainty connected to the available understanding that managers have on the bio-ecological, social, and economic processes related to fisheries. Internationally, the acceptance of this concept began with its recognition in international instruments including UNCLOS' discussions of straddling and highly migratory fish stocks, as well as the FAO Code of Conduct for Responsible Fisheries (Garcia, 1995). This approach forces governance bodies to think proactively, before severe risks or irreversible damage becomes apparent. Through agreements, the UN and FAO have applied the approach requiring the use of "*best scientific evidence available*" and making strong recommendations to have active participation by industry in advisory and decision-making systems (Garcia, 1995). Connecting DOM to the precautionary approach system is valuable for both the related policies and the tool. DOM continuously provides new data about a given ecosystem and/or species, which improves management's knowledge of the best scientific evidence available. In turn this helps create a better understanding of the current situation, any related risks increased detriment to the ecosystem or species.

Most recently, under the December 2016 United Nations Sustainable Fisheries Resolutions, Resolution 71/123 discussed multiple factors on EAF and the precautionary approach. It recognized the importance of data collection and monitoring of catches, including bycatch and discards as fundamental for ecosystem approaches (United Nations General Assembly, 2017). Additionally, it calls upon States, directly or through RFMOs, to apply precautionary and ecosystem approaches to conservation, management, and exploited fish stocks (United Nations General Assembly, 2017). It also encourages States to implement and adopt these two approaches to address bycatch and overfishing, among other concerns (United Nations General Assembly, 2017). These resolutions provide support in the development of DOM as a tool for use by States. However, the resolutions also receive benefit from DOM as it can be a tool to address the requests and encouragements made. DOM inherently uses the interconnections of the ecosystem's components through the data required to adapt to the management's directive consistently (Maxwell et al., 2015). It considers the target ecosystem's full description in the management plan, reflects on needs based on the ecosystem's health, considers the threats involved, and addresses required management through an adaptive lens (Maxwell et al., 2015). Presenting DOM as a tool under EAF and the precautionary approach promotes the values and needs of sustainable fisheries and fosters an increase applications of DOM around the world, perhaps even in international jurisdictions.

2.4.b: DOM Theory

DOM aims to balance ocean resource use against conservation, and improves management through a constant intake of relevant new data (Lewison et al., 2015). The DOM theory is comprised of seven elements *(Figure 2)*. Each element of a DOM practice plays a crucial role in creating an efficient system and feedback loop (Hobday & Hartog, 2014). Elements one through four are all comprised of the data portion of the management plan. This includes data collection, data upload, data processing, and data delivery. Elements five through seven are action elements for managers. This includes managerial decision making, implementation considerations, and enforcement (Hobday & Hartog, 2014).

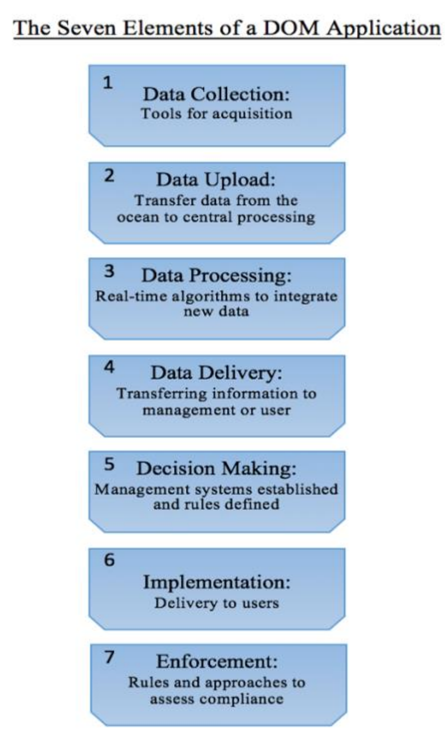

Figure 2: The seven elements of a DOM application, modified from Hobday et al., 2014.

DOM theory has four different Types of processing protocols to address a scale of management intensity and requirements *(Figure 3).* DOM applications have varying amounts factors required throughout their processing, therefore Types I – IV were established (Lewison et al., 2015). All Types start with data input, consider trade-off analysis, and produce a data product. However, Types III and IV can have multiple data inputs, incorporate statistical analysis, and dynamic modeling. Then, all four reach a stage of a completed data product, and Type IV may also include stakeholder adjustments before releasing a final product (Lewison et al., 2015).

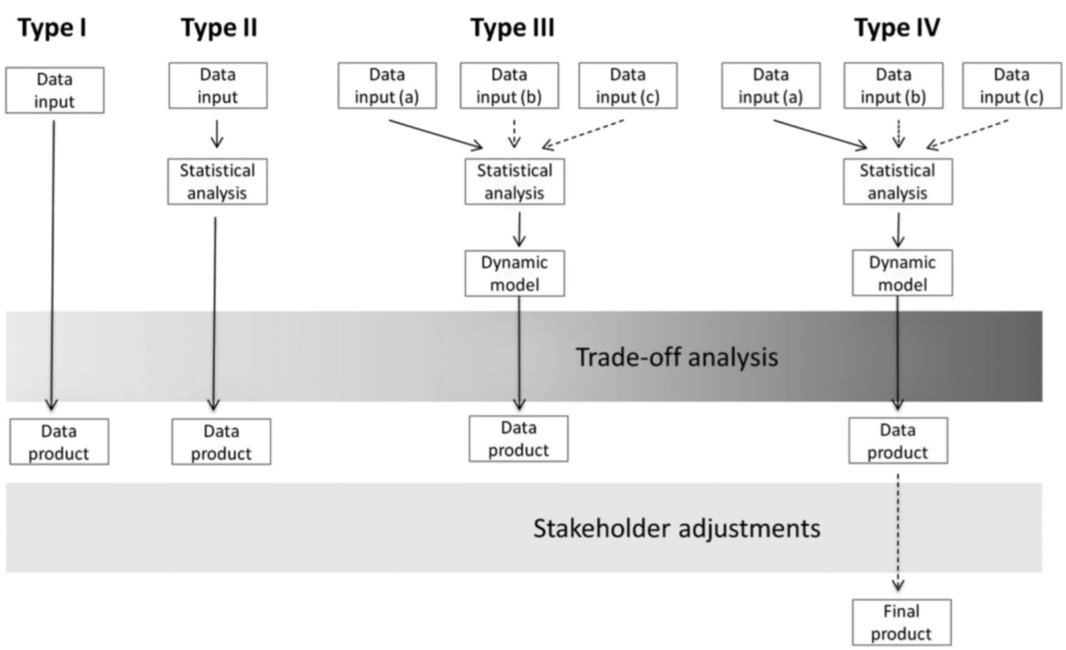

Figure 3: *The four types of DOM processing protocols (Lewison et al., 2015).*

2.4.c: DOM Applications

There are a variety of DOM applications currently in place (Lewison et al., 2015). DOM applications are typically applied to one of three different management challenges: target quota management, bycatch management, and avoiding protected species (Lewison et al., 2015). This discussion will focus on the latter two as it relates to the case study of this project. Throughout current applications of DOM, there is a lot of variabilities regarding the time it takes for management to complete one feedback loop. The timeframe from data received to product release ranges from hourly extending to weekly. Additionally, the frequency of product update can vary from within hours to monthly (Lewison et al., 2015). Overall, all aspects of a DOM plan (e.g., compliance, type of data, management type, data to release time, and product update) depend on the management challenge at hand.

Two examples where Dynamic Ocean Management is used to help avoid bycatch are the Eastern Australia's longline fishery and Turtle Watch in the Northern Pacific (Hobday et al. 2011; Howell et al. 2008; O'Keefe and DeCelles 2013). There are many parallels between the Eastern Australian longline fishery and the case study of this project. It is a multi-species longline fishery which includes quota-limited management of southern Bluefin tuna. A challenge of concern for both users and managers was minimizing non-quota holder southern Bluefin capture (Hobday et al. 2011). Here, a DOM Type IV management plan was developed. Managers implemented spatial zoning to regulate access to areas that changed over time in response to the species' movements. This involved understanding the tuna's habitat preferences and combining that with data in near real-time sea surface temperature (SST) readings and altimeter-based estimates of subsurface ocean temperatures (Hobday et al. 2011). With these data, managers mapped the distribution of tuna habitat in real time. Following this, managers converted the map into a zoning map, which was more user-friendly for the harvesters. This map has three zones, an "OK habitat" where fishing is unrestricted and few southern Bluefin tuna are found, a "core habitat" where most of the tuna were expected to be, and an intermediate buffer habitat as a precautionary measure (Hobday et al. 2011). This map was then updated every fortnight for the harvesters where those zones are and where they were permitted to fish and not fish. The factors and data involved in this example are valuable to consider. Similar to this project's case study, it focuses on a longline fleet that deals with interactions of highly mobile pelagic species.

The next example, TurtleWatch is a Type III example of DOM. While it required an intensive level of data processing its mapping conversion needs are not at the same level as the previous example. The TurtleWatch DOM example is a voluntary management effort from the National Oceanic and Atmospheric Association (NOAA) in the United States intended to help the Hawaii-based longline fishery avoid loggerhead turtle bycatch. Although it is a voluntary approach, if harvesters catch too many turtles the fishery closes. Therefore, there is incentive for them to use the program as it also protects their ability to continue to fish (Howell et al. 2008). The data required for this project includes the characteristics of the fishery, bycatch information, satellite tags for tracking of the loggerhead turtle and SST data (Howell et al. 2008). By amalgamating all this data, the TurtleWatch map shows SST, ocean current conditions, and the predicted locations of current loggerhead turtle habitat (PIFSC, 2017). Considering harvesters catch data and fishing patterns proved to be valuable in this context as it informed managers about what time of year and location for when bycatching loggerheads occurred.

DOM plans that are created to address protected species have additional benefits as precautionary and response tools. Considering the current population levels of the porbeagle and shortfin mako sharks, this case study goes beyond the issue of bycatch, but also, is a potential protected species management issue if their population levels continue to decrease. One of the most notable examples of this type of DOM application is WhaleAlert. The phone app is used in a variety of locations across the United States and Canada to help reduce ship collisions with a variety of whale species including blue and North Atlantic right whales. Information provided with this application includes current ship location, seasonal management areas, right whale listening buoys, dynamic management areas, areas to be avoided, mandatory ship reporting areas, and recommended routes (NOAA, 2017). To reduce collisions in "hot spot" whale areas, DOM and spatial planning aids in identifying best possible pathways for the ships to avoid whales. This process also involved gaining stakeholder and government acceptance for proposed routes, verifying mariner compliance, and consistently assessing approaches to improve whale detection and communications (Wiley et al., 2013). For this to be successful, the first steps include understanding the spatial distribution and relative abundance of whales in selected areas such as a sanctuary or adjacent waters, identifying whale high-use areas, modelling various traffic separation schemes, and calculating risk reduction and industry impacts of alternative paths (Wiley et al., 2013).

Dynamic Ocean Management is being used around the world for consideration of a wide variety of management challenges (Lewison et al., 2015). By creating adaptive strategies for bycatch, quota management, and protected species improvements have been made in fisheries management regarding factors such as management efficiency and catch:bycatch ratios (Dunn et al., 2016). Applying a DOM approach also has other potential benefits from a harvesters perspective. This includes small areas of restrictions and a short time duration for those restrictions to be in place, improved mobile species management, improved relationships between management and users, increase in profit, and real-time management able to adapt to the situation's changing needs.

2.5: Combining Static and Dynamic Spatial Approaches

The potential competing needs of ecological and economic objectives within ocean management do not always align, and therefore adaptive management is required. A set of management tools is needed to assist in maintaining balance and be capable of addressing a wide variety of needs. No single tool or approach can tackle all ocean-based management issues. It is beneficial to have both static and dynamic methods being used together to maximize ocean management goals (Maxwell et al., 2015). Static approaches are well embedded in current policy and management structures. However, these tools are based on terrestrial management approaches. Ocean management would benefit from DOM as it considers oceanographic physical, chemical, and biological factors.

When considering how to incorporate DOM into current legislation and management, there are multiple theoretical frameworks and governance strategies that it could be applied. DOM could be approached through the structures of adaptive management, ecosystem-based management, and systematic conservation planning (Maxwell et al., 2015). The former two of these frameworks are already embedded throughout the Government of Canada and DFO. Integration of DOM could promote the further development of adaptive and ecosystem-based management, and their associated frameworks, while fostering its own development simultaneously. DOM would not be replacing these frameworks but be a tool that falls within that could increase the efficiency of implementing framework and policy objectives (Maxwell et al., 2015). For example, there are strong connections between the precautionary approach, adaptive management, and the needs for blue shark management. While the blue shark may not be viewed as having a concerning population level, they remain the most frequent form of bycatch for *the fishery* (DFO, 2016d). Adapting precautionary measures to ensure the population levels do not fall, can help safeguard a future of healthy oceans. Regarding adaptive management, it couples at the implementation stage of adaptive management by updating the related spatial management areas while continuing to use the predefined procedures provided by the adaptive management process. This results in adaptive management moving at a faster pace and with consistently updated information (Maxwell et al., 2013).

Adding DOM to the current toolbox provides managers with an opportunity to be more selective and strategic in addressing management problems. Each problem has a variety factors that may require a different or multiple approaches that might contrast with the ones currently available. To select a tool for management, there needs to be considerations of the underlying factors involved in each situation. Figure 4 *(below)* is a decision tree that reflects on influencers (top row) that should be considered when deciding on the use of static and/or dynamic approaches. This figure was constructed based on the information connected to literature discussions in Sections 2.3 & 2.4. The information within the sections indicates values and concerns of each approach, and the types of issues they are capable of addressing. When overlapping this information with the five influencers, recommended management pathways were developed. The suggested pathways are not the only way management can be done, but instead, provide a considerate recommendation.

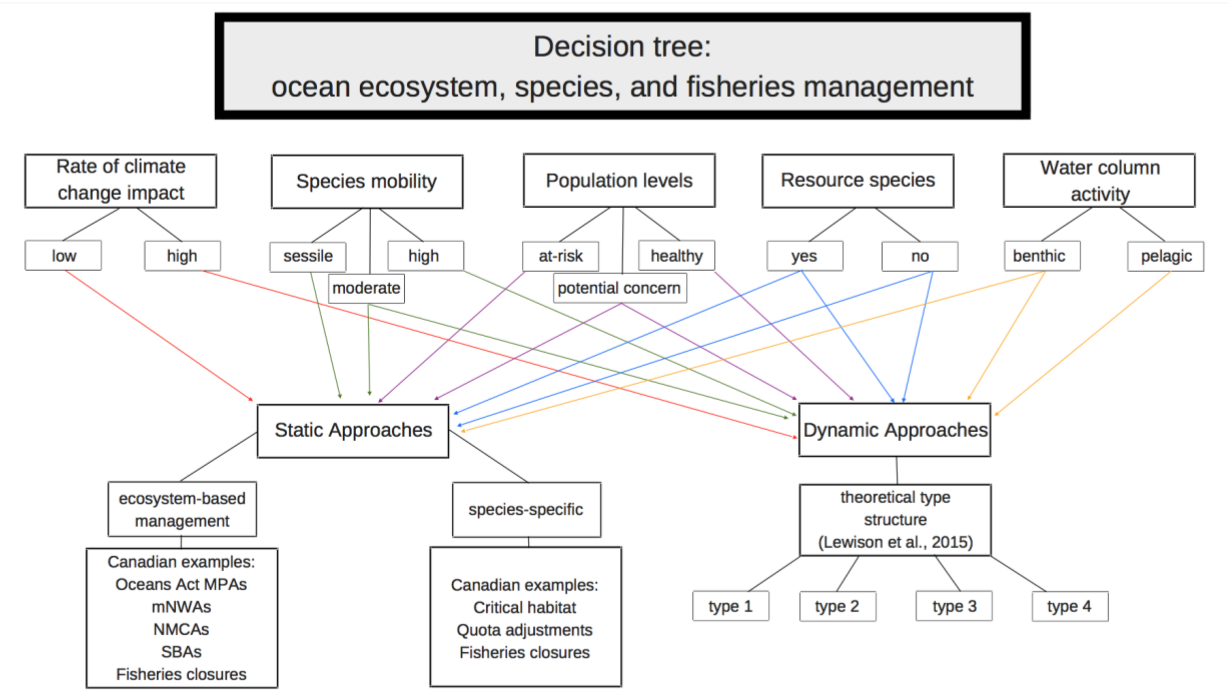

Figure 4: A decision tree for ocean ecosystem and fisheries management tool application with Canadian examples.

CHAPTER 3: CASE STUDY METHODOLOGY

The methodology for this project consisted of an in-depth literature review, governance assessment, stakeholder interviews, and a preliminary application configuration. This chapter lays out the details required in each part of the methodology.

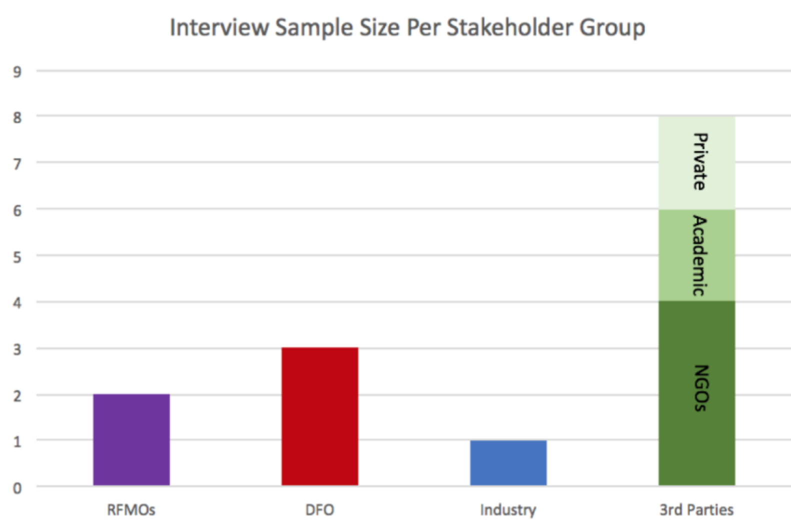

Figure 5: Interview Sample Size Per Stakeholder Group

From the literature review, four main stakeholder groups were identified *(see figure 5)*. These groups are the Regional Fisheries Management Organizations (RFMOs) of the region, NAFO and ICCAT provided an international perspective. Fisheries and Oceans Canada represented the Canadian Federal Government and has management responsibilities for *the fishery*. The Nova Scotia Swordfish Association represented the harvesters. Finally, the fourth group was third-party interest groups including NGOs, private interests, and the recreational shark fishery in the region. For each of the stakeholder groups, I completed a governance assessment to outline the tools each stakeholder was equipped with to address the management challenges associated with this study. This governance review involved collecting and analyzing all relevant governance documents that each stakeholder group used in relation to this project. The analysis highlighted the governance documents that were imperative in addressing the shark bycatch challenge in *the fishery*. Additionally, it notes when stakeholders had established governance tools but were not using them correctly, if at all.

Prior to the interviews, all participants received a presentation on DOM theory and applications from the researcher. All interviews conducted for this project followed a format that consisted of three main topics: bycatch within *the fishery*, and introduction to DOM and applying it to *the fishery*, and management efforts implemented by each participant's organization *(see full list interview questions in Appendix I).* These interviews were approximately an hour long each, and provided the research project with in-depth stakeholder opinions and facilitated a brainstorming session on the potential of applying DOM. The data presented by these interviews was then amalgamated for a qualitative analysis that assessed the content of each discussion and established patterns in the responses within each group and overall. This assessment established emerging themes and grouped ideas for consideration in developing a DOM plan.

The next stage of this project was the preliminary application configuration. A potential strategy for applying a DOM tool was developed based on the information given in the governance analysis and interviews. A mixed-methodology approach provided this project with a holistic view of the bycatch challenge within *the fishery* and how to appropriately respond to the problem, as it considered the core factors involved in a DOM plan.

CHAPTER 4: GOVERNANCE ANALYSIS & STAKEHOLDER INTERVIEW RESULTS

This study used a three-part approach to governance analysis and obtaining stakeholder perspectives. The first part of each stakeholder section evaluated the governance strategies that each group currently possesses to address shark bycatch in *the fishery*. Following this, in each section, there is a discussion of the interview results for each stakeholder group. The results follow the structure of the perspectives on shark bycatch, DOM application development, and organizational actions taken to address the challenge. Next, results are extracted at a group level through consolidated graphs (section 4.5 for all interviews), it needs to be noted that the point of view presented by each participant does not necessarily represent the formal opinion of their organization. The responses are their own professional opinion and perspective within the context of the organization they work for.

4.1 International

While shark bycatch occurs within both the Canadian domestic longline fishery and the international longline swordfish fishery in the North Atlantic, this project strictly focused on the domestic fishery. Therefore, the governance tools being used by the RFMOs do not directly apply to the focal fishery. However, their governance strategies provide insight into a variety of tools that could help support current domestic management. The RFMO's interviewed to obtain their view on management within the domestic fishery, and on parallels with current international management.

4.1.a: Governance

NAFO and ICCAT address separate management issues and have slightly different spatial jurisdictions. However, both RFMOs have both acknowledged shark bycatch in the Northwest Atlantic and have implemented broad shark protection measures. Starting with NAFO, the management documentation that addresses shark bycatch and shark management is the *Annual NAFO Conservation and Enforcement Measures Document*. While NAFO focuses on the Northwest Atlantic international groundfish fishery, shark bycatch remains a challenge. To address shark management, *Article 12* of the 2017 annual document covers *Conservation and Management of Sharks* (NAFO, 2017). When addressing bycatch, section 5 of *Article 12* states: "*In fisheries that are not directed at sharks, each Contracting Party shall encourage every vessel entitled to fly its flag to release sharks alive, and especially juveniles, that are not intended for use as food or subsistence" (NAFO, p.18, 2017).* This measure helps ensure that when catching sharks is undesirable, their release back into the ecosystem is the preferred option over keeping them as additional catch.

Furthermore, NAFO has established other recommendations to help conserve shark species. This includes recommending research into selective fishing gear that has a lesser impact on sharks, conducting research on sharks when possible – including biological, ecological, life-history, behavior, migration, and other factors, and as of the 2017 document, shark finning has been abolished (NAFO, 2017). To monitor success, an annual compliance review is completed which ensures that all contracting parties comply with the standards. This compliance review mandates that harvesters record all catches analysis at a species level and submit daily catch reports which includes shark bycatch (NAFO, 2017). For the compliance review, NAFO compares daily catch reports with landings and observer reports to maintain accuracy. These statistics can assist scientists with future stock assessments.

In contrast, since ICCAT is considered the main shark governance RFMO for the region, their governance approach to shark management is more intensive. Article 4 of the ICCAT Convention states:

> *"the Commission shall be responsible for the study of the population of tuna and tuna-like fishes (the Scombriformes with the exception of Trichiuridae and Gempylidae and the genus Scomber) and such other species of fishes exploited in tuna fishing in the Convention area as are not under investigation by another international fishery organization"* (ICCAT, p.6, 2004).

ICCAT has formally acknowledged all three of the focal sharks of this project as *Bycatch Species of Special Importance* in their governance documents (ICCAT, 2016). To help address bycatch within ICCAT, in 2012, the ICCAT Secretariat hired a By-catch Coordinator to harmonize and analyze fishery datasets in relation to the bycatch species of ICCAT's tuna fishery area (ICCAT, 2017). There are also multiple resolutions put forward by ICCAT to support the conservation and management of sharks. In 2005, Resolution 04-10 –established nine measures to address shark management:

> *"1) CPs and CPCs (contracting parties to the convention), shall annually report Task I and Task II data for catches of sharks, in accordance with ICCAT data report procedures, including available historic data.*
>
> *2) CPCs shall take the necessary measures to require all fisherman fully utilize their entire catches of sharks except for head, guts and skin.*

3) Contracting Parties (CPs) shall require their vessels not to have onboard shark fins that total more than 5% of the weight of sharks onboard, up to the first point of landing. CPs that currently do not require fins and carcasses to be offloaded together at the point of first landing shall take the necessary measures to ensure compliance with the 5% fin-to-body weight ratio through certification, monitoring by an observer, or other appropriate measures.

4) Fin-to-body weight ratio of sharks will be reviewed and reported back to the Commissions in 2005.

5) Fishing vessels are prohibited from retaining on board, transshipping or landing any fins harvested in contravention to this record.

6) In fisheries that are not directed at sharks, CPCs shall encourage the release of live sharks, especially juveniles.

7) CPCs shall, where possible, undertake research to identify ways to make fishing gears more selective.

8) CPCs shall, where possible, conduct research to identify shark nursery areas.

9) The Commission shall consider appropriate assistance to developing CPCs for the collection of data on their shark catches." (ICCAT, 2004b).

This resolution was imperative to empower ICCAT's ability to handle shark management, and paved the way for other Resolutions that addressed the issue of bycatch. This includes RES 15-11's discussions on an ecosystem approach which considered the interdependence of stocks, impacts of fishing on human and natural components, and minimizing negative fishing impacts (ICCAT, 2015a). Additionally, RES 03-10 required Contracting Parties to adopt NPOA-Sharks, while RES 15-02's required Cooperating non-Contracting Parties to use non-entangling FADS[3] (ICCAT, 2003; ICCAT, 2015b).

In addition to these measures, there were also measures adopted for individual shark species. For all three focal species, ICCAT completes stock assessments on an average of once every five years, and has established specific restrictions for shortfin mako and porbeagle sharks. For the shortfin mako, under RES 10-06, all Cooperating non-Contracting Parties have to report catch data on the species, or else they will be prohibited from the species retention (ICCAT, 2010). For the Porbeagle, RES 15-06 officially banned the retention of the species and required live release if caught (COFA TUNAS, 2015; Schleit, 2015; Aten, 2016).

As the public has become more concerned about sharks the governance initiatives by these RFMOs has evolved. Both organizations have altered their requirements, research, and at-sea practices to ensure that management works adequately. Moving forward with governance, both NAFO and ICCAT will continue to be challenged to live up to their agreements in principle on ecosystem approaches. At this time NAFO has adopted amendments related to the ecosystem approach and the precautionary principle, whereas ICCAT is still considering.

4.1.b: Interview Findings

Regarding views on the pelagic shark bycatch in the longline industry, the RFMO's acknowledged that they are aware that the bycatch is occurring but viewed the issue more as a problem for harvesters, and were not sure of the extent it was an ecosystem issue. Still, the RFMO perspective is that management on the subject has improved over the last decade but current measures are not sufficient, and management has not been provided enough resources to succeed. For these organizations, effective management includes adhering to the defined regulatory parameters, a shark fin ban, robust monitoring and enforcement, daily reporting on catch and landings, observer reports, ecosystem management, and ecosystem-based indicators. Finally, regarding ideas for what management tools could potentially improve the pelagic shark bycatch challenge in *the fishery*, recommendations focused on innovation and technology. There was a general theme that the way to find an answer was to keep looking at solutions from a variety of angles. Along with this, other suggestions included increased at-sea monitoring and expanding management tools for shark "hotspots".

A discussion occurred on the potential of using DOM as a potential tool to improve the shark bycatch management in *the fishery*. In their responses, one participant was unaware of DOM before the presentation. However, both believed it had potential to help the issue of shark bycatch in *the fishery*. Regarding feasibility, while both participants thought it was feasible, there was some uncertainty stating that viability is highly dependent on how the industry is approached and the type of data that would be required for success. For the type of DOM application that would be needed, the RFMO group believed that the application required multiple kinds of data and sources; it could not just be a reliance on harvesters communication. Therefore, they both favoured either a Type III (species tags and monitoring) or Type IV (spatial modelling with stakeholder adjustments) approach. However, it was noted by one participant that the application's development hinged on a path of least resistance from the harvesters; the design needs to be one the harvesters would want to participate in. In terms of the application details, both participants believed that the manager role would be best suited to DFO as they are the overarching fisheries manager. Furthermore, data collection should be done by a variety of sources but streamlined into one processing body, and that the application should start out as voluntary, and based on buy-in and success, it could become compulsory if needed.

Currently, these RFMOs have different approaches to address shark bycatch within their organizations (see above). When asked if they thought their organizations were currently doing enough to address their shark bycatch challenges, both respondents said yes. Additionally, the participants believed that their organization would be supportive of a DOM application for pelagic shark bycatch. Moreover, a participant conferred that their organization was establishing further development of precautionary and ecosystem-based management, approaches, and practices, and believed DOM would fit well within this structure. These interview participants exhibited interest in DOM and were intrigued regarding if and how a shark bycatch mitigation application could be developed. Therefore, regardless of their uncertainty towards labeling the bycatch as an issue, they still believed it would be beneficial to have a mitigation tool.

4.2 National

4.2.a: Governance

Management of the Canadian North Atlantic pelagic longline fishery targeting swordfish and tuna, and Canadian shark management, is addressed by the Department of Fisheries and Oceans Canada. They are the overarching manager of Canadian commercial fisheries, and Canadian marine conservation, and have a variety of governance approaches that are used to address *the fishery* and the focal sharks.

DFO's management of the Canadian North Atlantic pelagic longline fishery targeting swordfish and tuna is in coordination with the roles and responsibilities defined in the *Fisheries Act*. Canadian fisheries management decisions are guided by the use of *credible, science-based, affordable and effective practices* (DFO, 2016e). The key priorities for Canadian fisheries management include *environmental sustainability, economic viability, and the inclusion of stakeholders in decision-making processes* (DFO, 2016e). These priorities help ensure that all necessary considerations are made to management's underlying structure. Furthermore, *the fishery* is managed on Individual Transferable Quotas (ITQs) that have been implemented since 2003. This was set in place to ensure that DFO can maintain the Canadian swordfish quota established by ICCAT (DFO, 2016d). However, these regulations address the catch, not the bycatch. Therefore, intentions to achieve precautionary and ecosystem-based management within *the fishery* are not effectively considered in this part of *the fishery's* governance. Additionally, as previously mentioned on in the discussion of SBAs and Fisheries Closures, *the Act* itself is not fully aligned with modern sustainability principles which are considered international "best practices" (Coté et al., 2012). Therefore, from a precautionary and ecosystem-based point of view on the issue and consequence of the shark bycatch *the Act* could be improved.

Currently, most governance action towards the management of sharks in Canada occurs through Integrated Fisheries Management Plans (IFMPs), research and consultation, and fisheries monitoring programs. IFMPs play a highly valuable role as they are one of the main tools the government has in the conservation and sustainable use of marine resources. Throughout the Canadian fisheries, a shark finning ban has been implemented since 1994; diminishing the market for retained shark bycatch (DFO, 2016g). While this approach is valuable, in recent years, these quotas have not been fulfilled given the lack of market to sell them, and therefore the harvesters do not land them. Considering that the bycatch still occurs, this does not address the challenge of mitigation of unintended mortality. For research and consultation, the two standard processes consistently used are the Regional Advisory Process, which provides reports on the status of fisheries, and COSEWIC, which was established as an advisory body for Canada's classifications for wildlife species at risk for the *Species at Risk Act.* Finally, the Fisheries Monitoring Programs in *the fishery* include 100% coverage from the Dockside Monitoring Program, and 5 – 10% coverage from At-Sea Observer Trips (Hanke et al., 2012; Christian et al., 2013; IMM, 2011). This data is imperative for assuring accuracy in fisheries reporting and monitoring patterns of governance.

Aside from the basic structure of fisheries management completed through the *Fisheries Act*, DFO has established *the National Plan of Action for the Conservation and Management of Sharks* (NPOA-Sharks). The NPOA-sharks is in accordance with the principles and provisions of the *International Plan of Action for the Conservation and Management of Sharks* (IPOA-Sharks) which was developed by United Nations Food and Agriculture Organization (FAO). The purpose of this plan is for the "*conservation and management of sharks and their long-term sustainable use"* (DFO, 2016g). The composition of NPOA-Sharks has seven overarching components: (1) Data Collection and Research, (2) Adoption of an Ecosystem Approach and the Precautionary Approach as Key Elements of Fisheries Management Renewal, (3) Standardized Reporting and the Management Plan Process, (4) Bycatch Reduction and Reporting of Discard Mortality, (5) Extend Conservation and Management Measures to the Arctic Coast, (6) Enhance Outreach and Education Efforts in Canada, and (7) National Plan of Action Review (DFO, 2016g). For this project, Sub-section 4 of the NPOA Action section is the most crucial to consider. This subsection acknowledges the need for improved reporting of discarded bycatch and associated mortality rates, raising the awareness among harvesters regarding risks faced by certain sharks, strengthening relations with RFMOs, and conducting a current practice reviews for commercial and recreational fisheries (DFO, 2016g). While this governance initiative could be valuable in improving shark management, there has largely been a failure to address this further. Currently, sharks are still underrepresented in Canadian management, and shark bycatch in *the fishery* remains at notably high levels.

Additionally, the Sustainable Fisheries Framework includes policies on the precautionary approach and bycatch. The precautionary approach policy and policies on managing bycatch can support the development of a strategy that considers the risks and addresses the management of the pelagic shark bycatch. The policy managing bycatch has two objectives: (1) ensuring fisheries are managed to support sustainable harvesting and minimizing risk to bycatch species, and (2) to account for total catch, including retained and non-retained bycatch (DFO, 2013). Clearly, since the non-retained bycatch of blue sharks is not required and typically is not reported, there is a misalignment between *the fishery* and Canada's bycatch and sustainable fisheries policies. Further incorporation of these policies could help provide a greater understanding of the impact *the fishery* is having on these species, and help establish precautionary and proactive action for shark bycatch management.

Considering that a large amount of bycatch still occurs within this and other fisheries in Canada's Atlantic EEZ, it is hard to say that these governance strategies, on their own, are sufficient without the proper support of management tools. Existing approaches provide formal governance support whereas a management tool could be used to help address the challenge. In the case of implementing a DOM strategy through the legislative powers of the *Fisheries Act* and support of other governance tools such as NPOA-Sharks and the Sustainable Fisheries Framework, management could be feasible for the challenge of pelagic shark bycatch in *the fishery*.

4.2.b: Interview Findings

Three participants from DFO agreed to partake in the study. From this, multiple perspectives from within DFO were obtained including from the resource management and science departments. In the discussion of bycatch within *the fishery*, while all agreed they were aware that the bycatch was occurring, only one stated they were aware of shark bycatch being an issue in *the fishery*, and the other two indicated that the classification of it being an issue dependent on which species was being discussed. The view was that the blue shark populations were at a healthy level, and therefore, not a concerning issue but rather a nuisance for harvesters. However, for porbeagle and shortfin mako, there is more reason for concern given their current population level predictions. All participants indicated that in their opinion management addressing bycatch is currently in a good state. However, there was also mention that it could still improve, and they are continuing to do so based on the information they receive. This helps create small incremental changes to make annual management adjustments. Additionally, to improve, the managers are highly reliant on harvesters and observers to provide them with data that enhances understanding of what needs to be done, particularly what is working and what is not. When discussing views on what effective management looked like, a variety of factors were mentioned. This included keeping mortality to a minimum to allow stability or allow increases in stock of populations, acceptable removal limits based on science, improved release methods, catch limits, finning mitigation, and species-specific bycatch mitigation measures. When asked what tools could potentially improve the bycatch challenge within the current management regime, a variety of ideas came up. This included increased monitoring, and possibly new technologies to support higher quality monitoring techniques to gain a better understanding of each of the shark bycatch species, and hotspot identification and mitigation measures.

For the DOM section of the interview, all DFO participants contributed valuable perspectives on the potential development of an application, as well as inherent short-comings which may make it difficult to succeed. Before the DOM presentation, all participants had limited knowledge of DOM, not as the specific term, but conceptually through other similar examples. Additionally, they all thought that DOM, if done correctly, had the potential to help mitigate shark bycatch. However, two out of three did not believe it would be feasible, and the third believed it could, although it would be very challenging to implement. Reasons for apprehension about DOM's applicability were perceptions that DFO does not have the type of data required to support the implementation, *the fishery* is too dynamic, and the thought that the industry would be reluctant as it may impact their livelihood. However, in the brainstorming session where participants were required to consider the potential development of a DOM application, all three participants showed interest in Type I (a ratio map) which could indicate areas where there are high or low areas of bycatch overlap. Additionally, two out of three participants were against Type II (move on rules) as they believed the distances and dynamism would not be adequately represented by this management approach.

Two out of three respondents believed DOM management should be controlled by DFO, and one felt that partnership between government and industry would be more useful. The co-management approach was put forward by a participant to address the crucial factor that industry needs to feel included at a high level to promote buy-in and maintain commitment to send data continually. It was also mentioned that this type of management could help build trust among DFO as fisheries manager and the harvesters. In turn, when it came to the discussion on who should do the data collection, the participants stated that it would be valuable to have the harvesters do so but with verification of observers. Finally, when asked if they believed that this application would be better as a voluntary or compulsory measure, there was a unanimous decision that it would need to be voluntary. Although there was concern about the effectiveness of a voluntary approach. There was also concerns about ensuring that the harvesters would be onboard with the idea, as well as facing the reality that there would be a lack of enforcement capability and funding within DFO if implemented as a compulsory measure.

In reflection on current efforts being done by DFO to mitigate the shark bycatch, all three participants were unsure but with the intention that if it is not enough. DFO will adjust to continually improve the fisheries management to address all challenges to the best of their capabilities. All of the participants believed that DFO could potentially support and develop DOM strategies in the future. However, they also thought that DFO's willingness to consider DOM would most likely be species dependent and would be something for the longer-term.

Other notable comments from these interviews included that DOM could serve well as a *Fisheries Act* tool, instead of something under the *Oceans Act*. This is because the former has more flexibility to respond through variation orders and license conditions. In contrast, *Oceans Act* tools and capabilities are viewed as more fixed measure with limited potential to make adjustments. Additionally, all three participants commented on how the blue shark was by far the most common and prolific of all three shark bycatch species. For these reasons, concerns about mandatory bycatch mitigation for *the fishery* were low, with one participant noting that there were more pressing matters to address first.

4.3 *The Fishery*

4.3.a: Governance

Formally, the governance processes related to the Canadian North Atlantic pelagic longline fishery targeting swordfish and tuna is directed by Fisheries and Oceans Canada. However, this does not mean the participants are without their own initiatives to support DFO's governance capabilities. Aside from the required processes, NSSA has management practices to help mitigate bycatch. For the harvesters, it is beneficial to avoid shark bycatch because they save time when they do not have to cut sharks off the line. It also saves them money as it means fewer hooks and bait are wasted on the unintended catch. Additionally, with fewer sharks on the line, there is a potential increase in profit if other valuable fish are caught instead. At this time, the fleet practices live release to the best of their abilities for all sensitive or non-captured targeted species (DFO, 2016d). To help mitigate the impacts of bycatch, over the past decade *the fishery* implemented gear hauling protocols for turtles, and gear modifications, including longer gangion lines and circle hooks for sharks. While it is now mandated by DFO to use circle hooks, this practice was adopted by the harvesters before the DFO regulation. Additionally, some harvesters within *the fishery* have bought into to multiple pilot projects done by academics and NGOs that set out to mitigate the shark bycatch. These pilot projects included different gear modifications including glow sticks on the longlines and hook timers. While these pilot projects were ultimately unsuccessful, it shows that the industry has an interest in finding solutions to the challenge.

4.3.b: Interview Findings

To assist in gaining a better understanding of the harvester's perspective, an individual from NSSA agreed to participate in this project's interview sessions. Bycatch is seen as an issue for the harvesters. In their perspective, this unwanted and unintentional bycatch wastes harvesters gear and time and is a loss of potential profit from not catching the target species. Furthermore, from an industry perspective, this issue is hard to address because it is not yet known how to target lines to avoid the sharks, if it is indeed possible; they rely on communication between each other to know when and where other harvesters have found a high density of sharks on their lines. From this participant's perspective, the work currently being done by harvesters to address the problem is enough. They remain in compliance with DFO regulations and typically try to avoid all three shark species, with a small exception for shortfin mako as they still have value in the market and the harvesters have a licence to retain them. The participant stated that for *the fishery*, partaking in effective management means abiding by the licence conditions, recording and reporting catch, landing what you can, and releasing of what you will not land.

To achieve effective management, the harvester believed that it is understanding what the removals were from the population, and if they were occurring at a sustainable level. Finally, when asked what additional management tools could improve the bycatch situation, the participant was apprehensive due to the high level of accountability and management *the fishery* already undergoes. Examples of this include the no finning rules, reporting requirements, observer coverage, and dockside monitoring. Additionally, for the captain, this reporting responsibility also comes with duties for crew safety, vessel safety and operation, and catching the fish. Furthermore, the participant mentioned that the harvesters are finding a lot of blue sharks on their lines, and the log book is limited. Therefore, harvesters will use that space to record species that have DFO reporting requirements. Thus, while some harvesters are reporting blue shark in their logbooks, most times they are not acknowledged. The participant then explained that this is where the importance of observers comes in, as their recording of species, such as blue shark, can be extrapolated across the fleet at the end of the season.

Before the presentation on DOM, the participant was aware of DOM as a concept. When the participant was asked if they thought DOM could help mitigate *the fishery's* shark bycatch and if it was feasible their statement was possibly. Regarding intensity, the participant felt that Type IV (spatial modeling with stakeholder adjustments) would be the most valuable. The participant provided valuable insight on applying DOM to *the fishery*. The participant stated that the harvesters know the most about what is occurring in the water. Therefore, it would be best to leave the judgment call up to them. There was also the importance of balancing the considerations of the harvester's income. They will not use a mitigation measure if it significantly impacts their ability to catch the target species. Additionally, if the application was hindering their success, there will not be buy-in and they will not participate in data submission. Overall, harvesters need to see what the benefit is to them to have an ocean full of sharks. Coinciding with these statements, when asked who should oversee management, it came back to the development of harvesters making the judgment call. The participant believes that if it is done through a regulator such as DFO, it must be enforced, which in this case, it would not be successful.

The participant believed that having the manager be the harvesters or a third-party organization co-managing with the harvesters would provide incentive for the industry to participate. In discussions on data collection, the participant firmly believed that most harvesters broadcast their findings truthfully, even more so when discussing the details of shark bycatch. Therefore, if harvesters were to participate, their data would be reliable. For this participant, the ideal model for harvesters to address shark bycatch would be buy-in from the harvesters. Then, the harvesters would provide reliable information. The service provider does the analysis; the harvesters are not going to be involved with that because they do not have the time. After this, the results go directly back to the harvesters. It needs to have a fast turnaround as the harvesters only have hours to decide before the gear goes back in the water. It would need to be an continuous loop of data coming in and information going out. Additionally, regarding technology capability, the participant mentioned that the harvesters have satellite phones and they use their smartphones and computers with internet while at sea. Therefore, the data feedback loop has the capability of continuing at the rate required to be effective.

While the participant believes that from *the fishery* perspective, what they are currently doing to mitigate shark bycatch is enough for conservation, they would still like to improve it for their benefit of time and money. For these reasons, the participant believes NSSA would most likely support a DOM application. The participant thinks it would be most successful if it was sold to the harvesters as a service and started as a pilot project. The participant also stated that if anything starts out as looking like a time area closure or mandatory, they will become resistant.

4.4 Third Party Interests

4.4.a: Governance

While third-party interest groups do not play a direct role in governance, they act as influencers in the establishment of governance and help drive societal narratives. Groups such as NGOs, academics, private third-party organizations, and related fisheries groups can provide research, dialogue, and discussion that can drive, support, disagree with, or critique past, current, or future governance. Some examples of third party influence include academic articles, lobbying, public awareness, consultation, and collaboration.

NGOs that were interviewed for this project include EAC, WWF, and Oceana. Regarding NGOs, each organization has a different approach in how they support governance. NGOs dedicate their time to using science-based research to influence policy decisions, public outreach and education, lobbying to governments, or a mix of these strategies and others. For DOM, the NGOs could employ a variety of these approaches, but they all focus on species conservation and sustainable use. By providing this perspective, the governance controlled by the Federal Government gains perspective to consider in management. Additionally, through their influence in the public sphere, NGO's can influence governance strategies by appealing to public views which governments commonly respond and adapt to.

The academic-based institutions considered in this project included ShARCC and The Ocean Tracking Network (OTN). The research and consultation done by these agencies, as well as others, helps provide valuable information on the dynamics of fisheries, bycatch, and other relatable research points. These institutions support management by providing science-based information, and they are in principle free from upholding certain positions that may occur in government, industry, or NGOs. These organizations and the information they produce can also be valuable in public education initiatives that create awareness on topics such as bycatch management, sustainable fisheries, and general knowledge on marine species.

A private third party organization that plays a crucial role in governance for shark bycatch in *the fishery* that participated in this project is Javitech Atlantic Ltd. They are the institution that DFO hires to run the At-Sea Observer program, a pillar of the current bycatch management governance plan. The data provided by Javitech to DFO is the primary source of reliable data on bycatch (Javitech Atlantic Ltd, 2017). Although the reporting done by the harvesters aims to be as accurate as possible, with the variety of tasks that need to be done on board, it is not always correct. This mainly tends to be the case with species that have high levels of discarded, such as the blue shark. With fewer requirements by DFO to record their information, in comparison to other protected species, data recording is not a priority. The at-sea observers fill this gap by increasing the boat's capabilities of reporting and give DFO more data to ensure management can act with accuracy in their governance and management plans.

Finally, the recreational sport fishing charter *Blue Shark Charters* also provided insight for this project. The recreational fishery helps guide governance for *the fishery* and the shark species through supporting data collection. This fishery collects data on the sharks it catches, the health of the sharks, and any other information they view as valuable before it is released. A primary part of the governance is being aware of the population levels and health status of the sharks to ensure management is appropriately acknowledging the species needs and monitoring patterns over time.

4.4.b: Interview Findings

In total, eight participants participated in the interviews for the third-party interests group. When engaging the participants on the topic of shark bycatch, seven out of eight stated that they are aware of shark bycatch being an issue in *the fishery*, and the other participant reported that they are aware that it happens, but are reluctant to label it an issue. When asked how well the participants thought the problem was being addressed, it was unanimous that the efforts were not enough. Five out of eight led an optimistic view acknowledging progress over the past decade, with more work needing to be done, and the other three participants viewed management's addressing of this issue to be inadequate and of poor quality.

In the brainstorming sessions asking what does effective management on this issue look like to the participants, a variety of factors were mentioned. The ideas mentioned included needing adequate population assessments to create meaningful catch limits, catch limits in line with precautionary science, efforts to minimize encounters with the shark species, a means of measuring the effectiveness of mitigation measures, increased industry engagement, industry education on the importance of sharks, minimizing mortality, and gear modifications. Some mentioned the potential of spatial-temporal closures while others strongly advocated against it. This question had a lot of overlap with the following question about what management tools could potentially improve the bycatch issue? For their answers, contributions included enforceable precautionary catch limits, increased monitoring, gear modifications, a tool to avoid areas of higher risk of bycatch, caps, time-area closures, DOM, spatial time area closures on hotspots, and training harvesters on oceanographic parameters to target their catch more efficiently.

The engagement with third-party perspectives on DOM was reasonably successful due to a high number of participants previously being aware of the management technique. Five out of the eight participants were already aware of DOM, one had known an example but had not heard the technical term prior to the interview, and the two who had not heard of it before both stated they were very interested in learning more. Additionally, one of these latter two mentioned DOM's parallels to adaptive management and adaptive environmental impact assessments. When relating DOM to the shark bycatch five out of eight believed that DOM could help, and the other three saw potential but had hesitations regarding harvesters livelihoods and considerations that it may be more applicable to some of the shark species over others. However, in contrast with the positivity towards DOM being able to help, the perspective on feasibility had a much broader range of responses. Only three participants thought that it would be feasible to use it to address shark bycatch in *the fishery*, one participant stated they did not believe it would be successful, one said that potentially later but currently the data would not be able to support the system, and three participants were unsure and responded with maybe.

When given the chance to analyze the different types of DOM applications, three participants were unsure of which would be best, four participants believed that Type III (species tags and monitoring) or type IV (spatial modelling with stakeholder adjustments) would be the most valuable to address the highly dynamic challenge, and one participant favoured the simplicity of Type I (ratio map), but worried about receiving truthful and accurate data. Another area which received a wide variety of answers and range in certainty was deciding who would be the most appropriate to play the role of the application manager. Four out of the eight respondents believed that DFO would have to be the manager. However, two of the four respondents stated that while they thought DFO would have to be the manager given their role as overarching fisheries manager, they did not believe DFO would do a good job at effectively running the application. The other four respondents were split between two other options. Two stated that the best way forward would be a co-management system between the industry and DFO. The benefits of this strategy included increased buy-in from harvesters as they have some control over implementation and management, and a more holistic process given a wider variety of perspectives. The remaining two participants believed that a third party organization or individual would suit the manager role more appropriately with collaborations from DFO and the harvesters. This last structure was supported by thoughts that DFO implementation may be slow given enduring a formal governmental process, but the harvesters do not have the time to develop this without support of other partners.

In terms of data collection, seven out of eight respondents believed that in order for the application to be successful the data would need to come from a variety of sources. Most mentioned *the fishery* and DFO's observer data as essential sources, however, other sources such as oceanographic, and tagging data could be valuable as well. In contrast, the other participant believed that a more straightforward method of just harvesters providing data applied to Type I (ratio map) might be a more efficient way to get the application started. Finally, the compulsory versus voluntary decision also concluded with a wide variety of answers. Two participants advocated for a compulsory design, both with apprehensions that voluntary would not be effective due to a lack of enforceability. Furthermore, only one participant believed that the structure would permanently be voluntary. For the other four participants, one thought that this answer needs to be species dependent and the other three did not know a specific solution but wanted to see a balance between compulsory and voluntary. Some ideas for this latter group of statements included a voluntary pilot project and then basing a decision on the need for compulsory based on the outcomes as well as voluntary with some aspect of DFO monitoring. While the third-party group does not have direct participation in the bycatch challenge of *the fishery*, their knowledge on the matter provided valuable insight into the application's development.

In the call to action of what third-party interest groups can do to improve shark bycatch challenges within *the fishery*, examples of their work are mentioned in the governance section. Concerning if they believe their organization's efforts are enough, four thought that they were, two stated that they felt more could be done by all parties involved, and two had no comment. Finally, when asked if the participants believed their organization would support the development of a DOM application to help mitigate pelagic shark bycatch, six out of eight stated they thought their organization would support, one participant was skeptical towards having something this comprehensible being adopted given the current level of management and data available, and the final participant believed that the question was not applicable to their perspective.

4.5 Overall Interview Assessment

This section displays the graphs and lists for the data connected to the interview finding discussions held in the previous interview analysis sections (4.1 – 4.4). The graphs show the amalgamation of responses from all 14 participant's semi-structured interviews. However, given the differences in the number of individuals per group and the small sample, these outcomes are purely meant to show the participant's perspectives and cannot be extrapolated to the populations beyond the sample group.

Section 1: Shark Bycatch

Bycatch questions were explored in order to gain a greater understanding of how the participants perceived shark bycatch within *the fishery*. documented whether the stakeholders believed it was a concern and if there should be improvements in addressing the challenge. Furthermore, these questions provided the research with data regarding how much of an understanding the stakeholders had on the current management tools, if they believed they were enough, and if they thought potential valuable improvements were possible. Having this discussion before introducing the idea of applying DOM allowed the participants to give a genuine response of their perspectives, unbiased from this project's research objective.

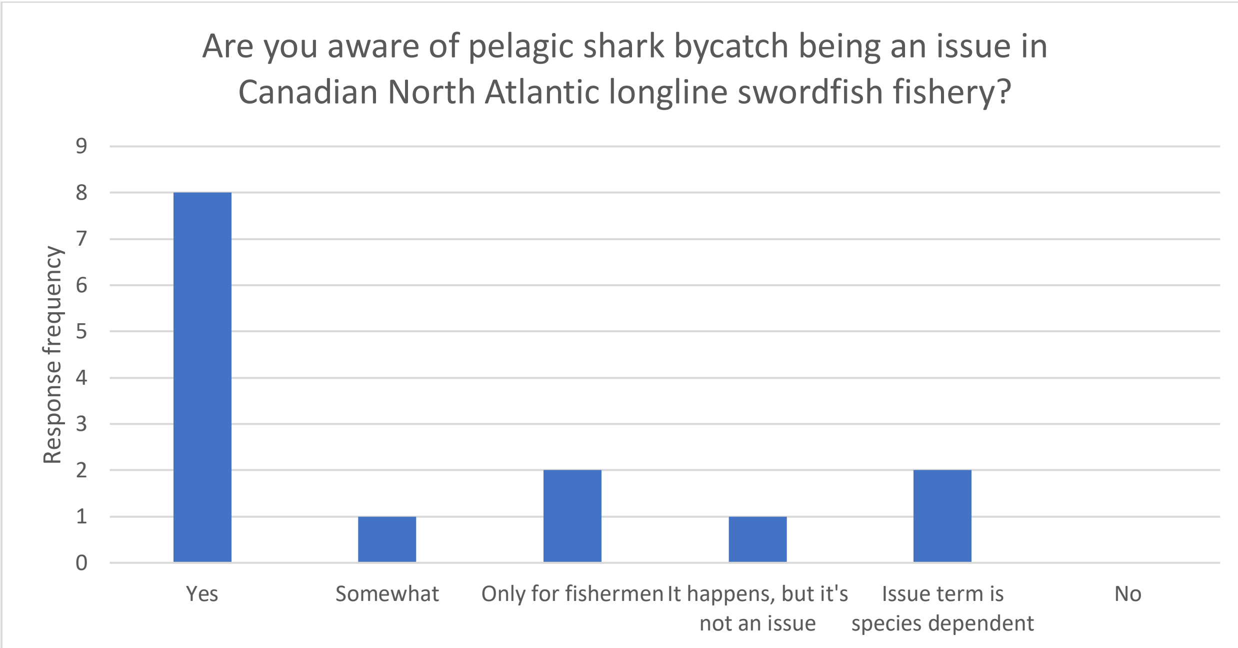

Figure 6: Participant responses to "Are you aware of pelagic shark bycatch being an issue in the Canadian North Atlantic pelagic longline fishery targeting swordfish and tuna?"

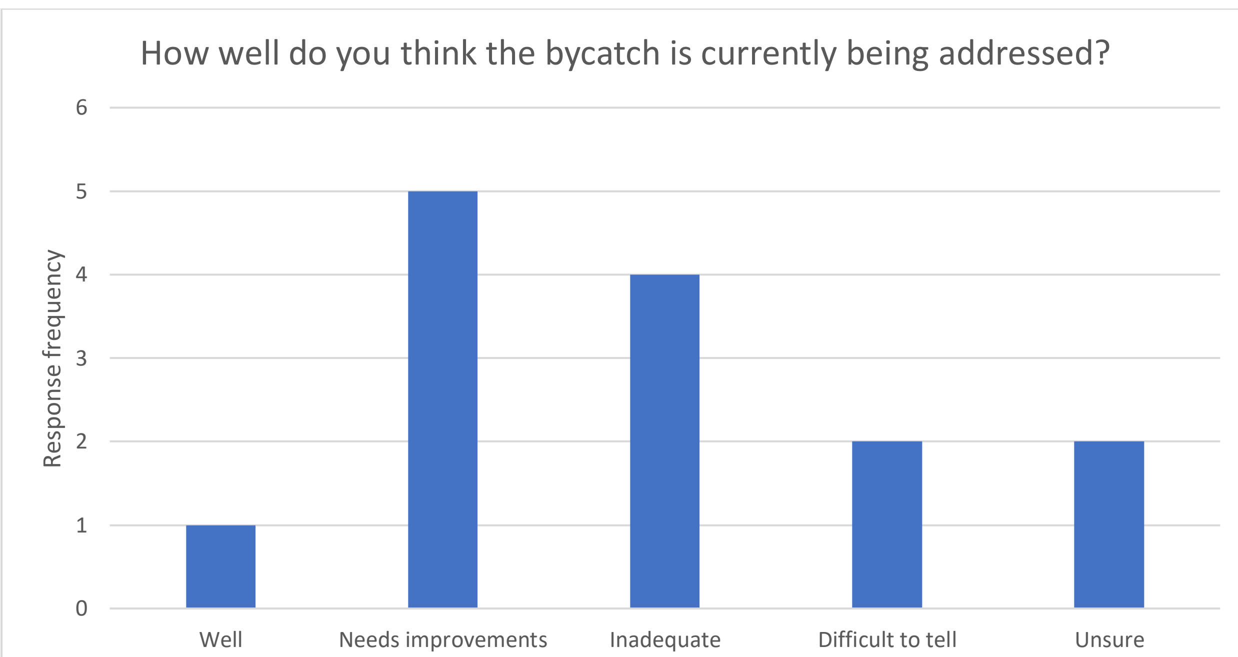

Figure 7: Participant responses to "How well do you think shark bycatch in the fishery is currently being addressed?"

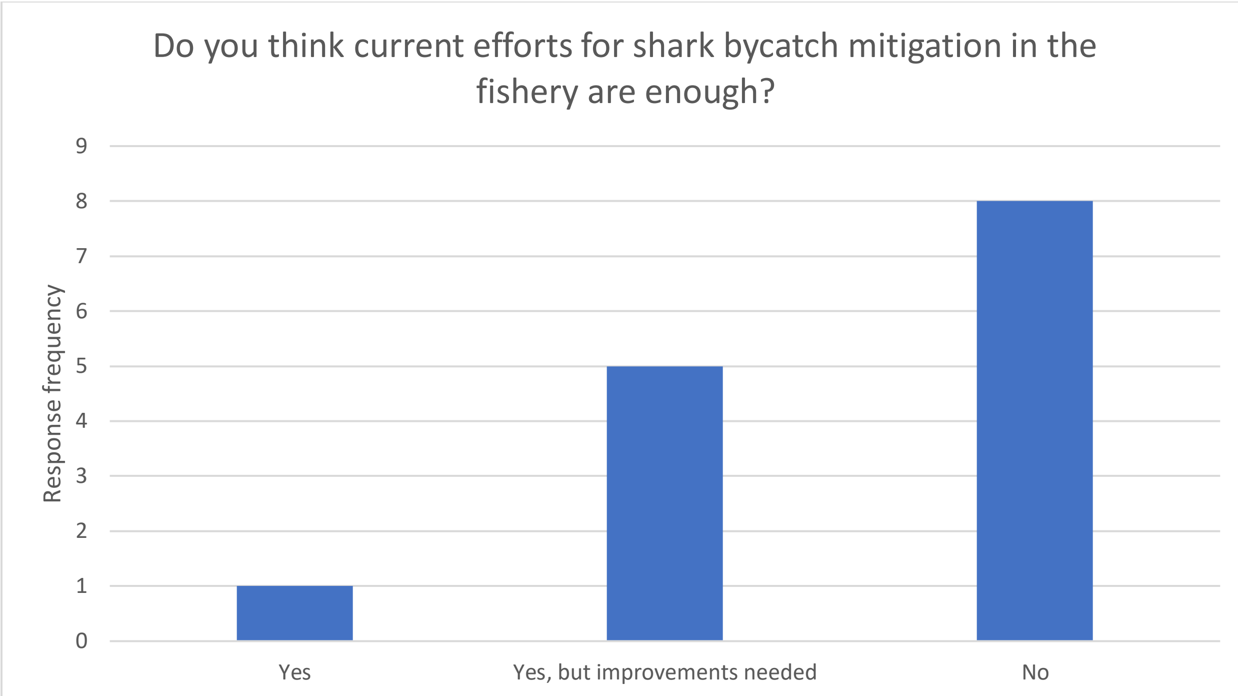

Figure 8: Participant responses to "Do you think current efforts for shark bycatch mitigation in the fishery are enough?"

What does effective shark bycatch management look like to you?

- Defined parameters
- Shark fin ban
- Effective monitoring and enforcement
- Reporting (daily catch, landings, observer reports, bycatch rates and associated mortality)
- Ecosystem-based management (with indicators for various bycatch species)
- Species specific bycatch mitigation measures
- Keeping bycatch mortality to a minimum
- Bycatch removal numbers based on precautionary science
- Counting them and accounting for them in stock assessments
- Ensuring resource practices are sustainable
- Adequate population assessments
- Quotas
- Tools to minimize encounters
- Industry engagement in management
- Education on species importance
- Fewer sharks being caught as bycatch
- Gear modifications
- Spatial-temporal closures

Figure 9: Participant responses to "What does effective shark bycatch management look like to you?"

What management tools do you think would be effective in improving pelagic shark bycatch mitigation for the fishery?
- Increased at-sea monitoring - Innovation in technology to develop bycatch mitigation tools - Greater understanding of species-specific characteristics - Hotspot identification - Improving live release practices - Precautionary catch limits - Electronic video monitoring - Gear modification / less impactful gear - Spatial-temporal management development to avoid high risk bycatch areas - Dynamic Ocean Management

Figure 10: Participant responses to "What management tools do you think would be effective in improving pelagic shark bycatch mitigation for the fishery?"

Section 2: Applying Dynamic Ocean Management

In section 2, the participants were first educated on DOM's theory and applications through a 20-minute presentation on the topic prior to asking the questions. Following this introduction, the participants were asked multiple questions that were related to DOM's capabilities with the shark bycatch challenge *(Figures 11-17).* The main focal areas include DOM awareness, desirability, feasibility, management, and compliance. These responses played an integral role in the application's construction which is discussed in Chapter 5.

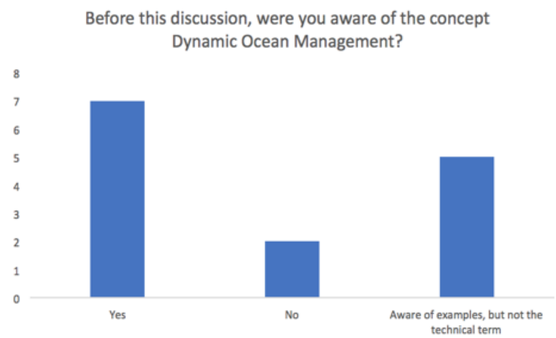

Figure 11: Participant responses to "Before this discussion, were you aware of the concept Dynamic Ocean Management?"

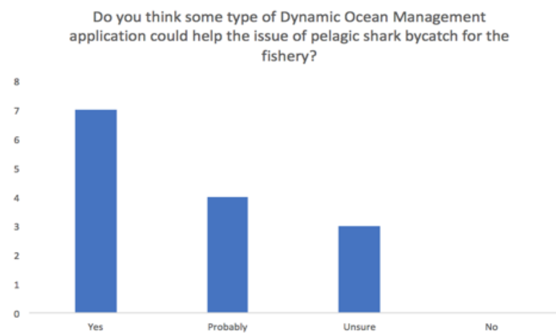

Figure 12: Participant responses to "Do you think some type of Dynamic Ocean Management application could help the issue of pelagic shark bycatch for the fishery?"

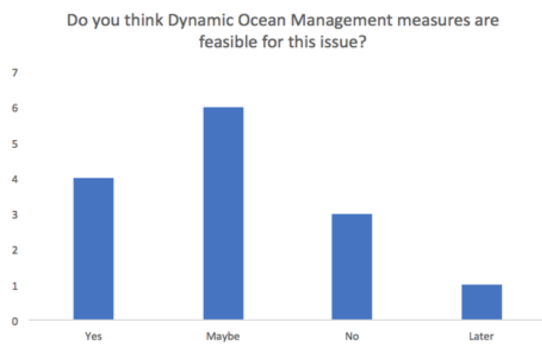

Figure 13: Participant responses to "Do you think Dynamic Ocean Management measures are feasible for this issue?"

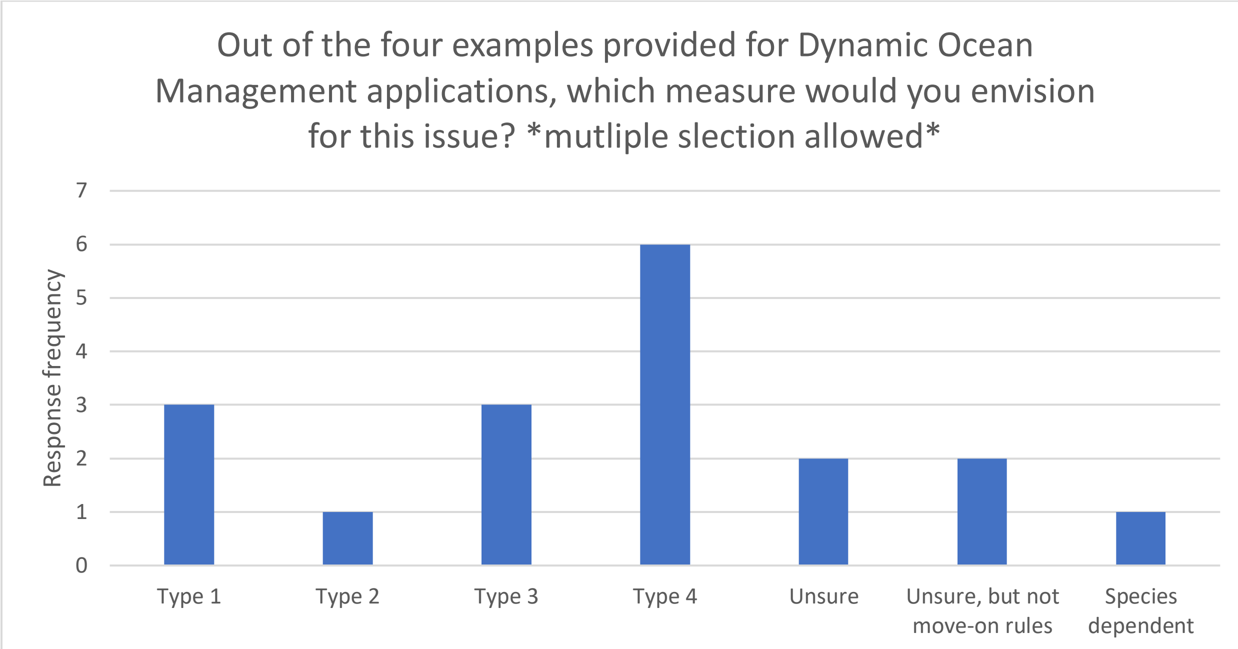

Figure 14: Participant responses to "Out of the four examples provided for Dynamic Ocean Management applications, which measure would you envision for this issue?"

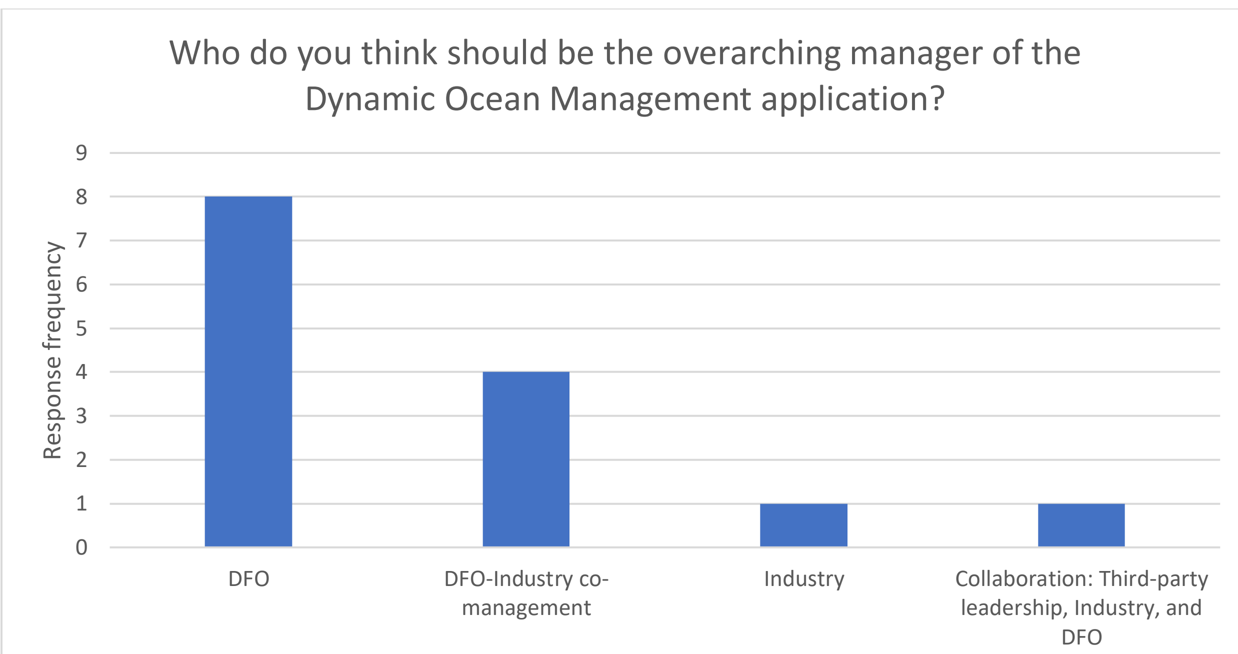

Figure 15: Participant responses to "Who do you think should be the overarching manager of the Dynamic Ocean Management application?"

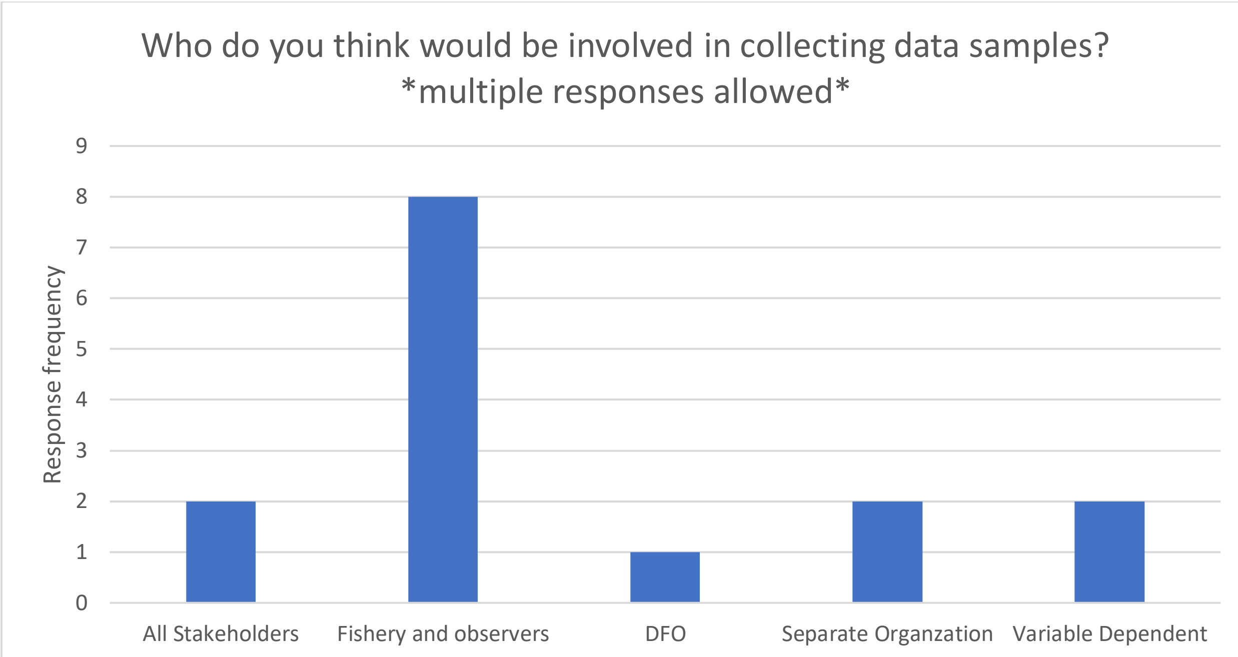

*Figure 16: Participant responses to "Who do you think should be responsible for collecting data samples? *multiple responses allowed*"*

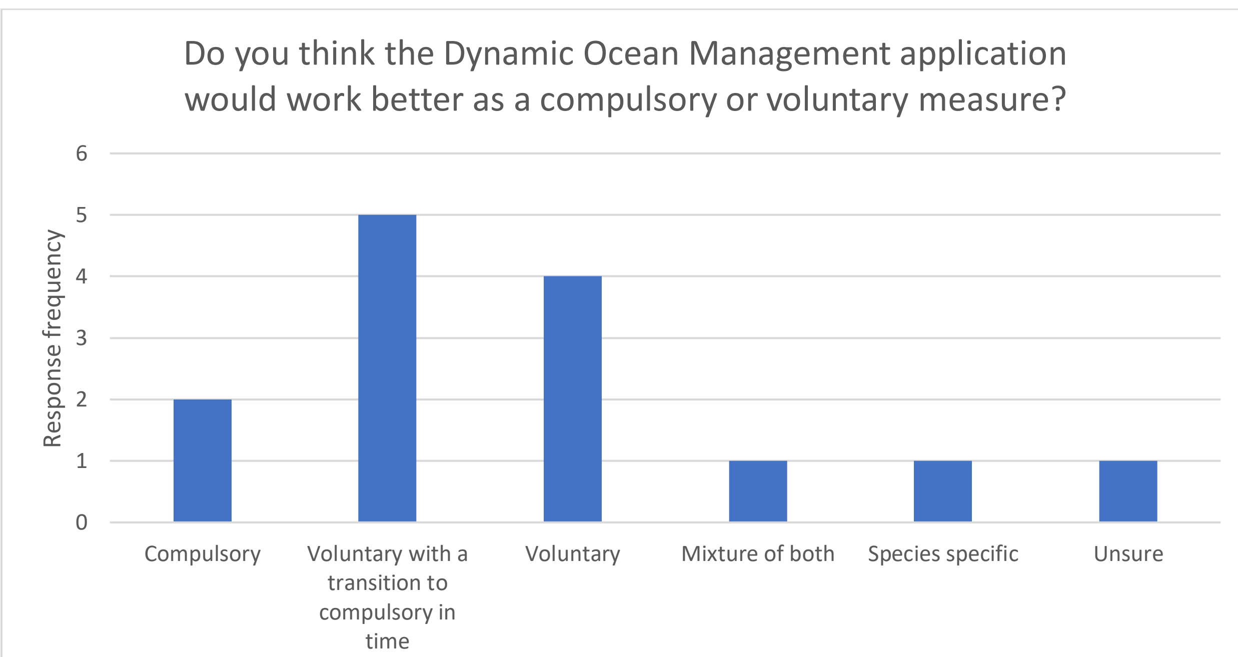

Figure 17: Participant responses to "Do you think the Dynamic Ocean Management application would work better as a compulsory or voluntary measure?"

Section 3: Organization specific questions

The questions in section three, pertaining to an integrated analysis, discussed if the stakeholders thought that what their organization was doing to mitigate bycatch was enough and if they believed their organization would support a DOM application for *the fishery*. While the first question received a variety of responses, the large amount of enthusiasm for DOM in the latter question suggests that the method has a promising future.

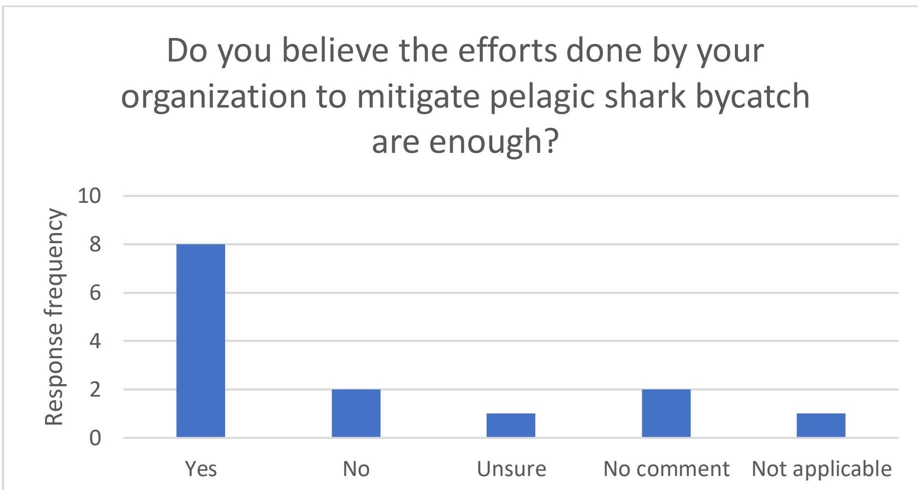

Figure 18: Participant responses to "Do you believe the efforts done by your organization to mitigate pelagic shark bycatch are enough?

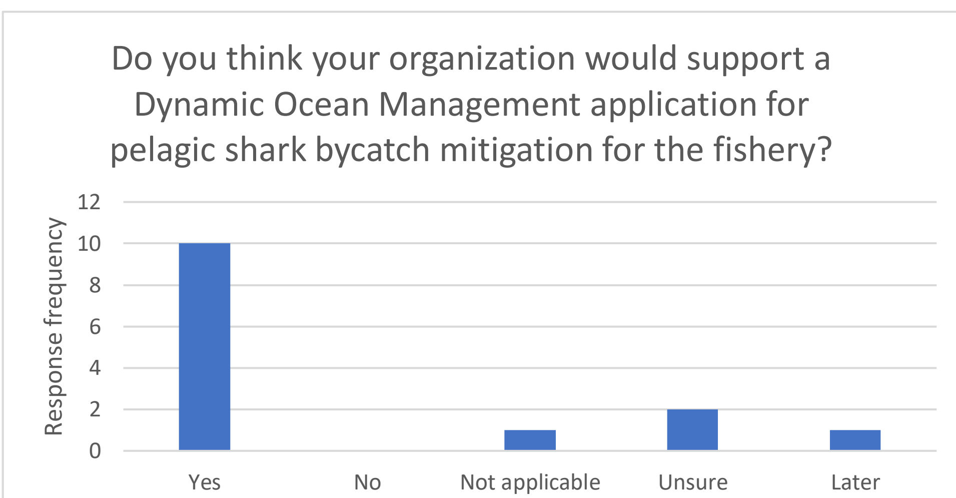

Figure 19: Participant responses to Do you think your organization would support a Dynamic Ocean Management application for pelagic shark bycatch mitigation for the fishery?"

CHAPTER 5: PRELIMINARY MANAGEMENT APPLICATION RECOMMENDATION

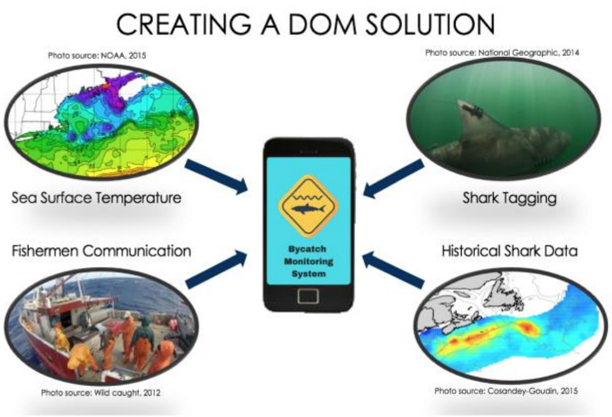

Figure 20: Proposed DOM application visualization.

The next step in addressing this management problem, is the technological development and formal creation of the proposed application. Based on the research above, a useful application should be in the form a tool used by harvesters to help them strategically plot their longlines with knowledge of predicted high shark density areas. The platform that would be the most effective, and desirable by the harvesters, is a phone app and/or website interface. For this tool, four sources of data are needed. These data sources include historical seasonal data of shark distribution, daily harvester reporting, oceanographic data, and live species tracking *(Figure 20)*. By overlapping these data streams, management and users would gain a clearer picture of real-time developments. This chapter examines the four data sources, management, and platform considerations needed for such an application's technological development.

5.1: Historical Data

Preliminary research has been done to capture seasonal patterns of the focal shark spices. This research plays an essential role in supporting the proposed application with baseline data on movement patterns and location predictability. Cosandey-Godin et al. (2015), investigated shark bycatch hotspot prediction in relation to *the fishery.* Through geo-statistical modeling, this research identified historic (2003 – 2013) hotspots for the shark species within *the fishery's* harvesting grounds. The information for these models is derived from harvester logbooks and at-sea observer data provided to the researchers from DFO. Embedding this model-based research, and further developments from it, into the app / website's algorithm processing would provide an estimation of shark interaction likelihood at a species-specific level. Aside from this project, this research, and new findings from the DOM application, could be used to develop seasonal or permanent closures for high-bycatch areas if management deemed it as needed and valuable for protecting specific shark species' populations.

5.2: Daily Reporting

Harvesters reporting their daily levels of shark bycatch is essential for the application's ability to keep up with the dynamic nature of *the fishery*. Without this stream of data, the other sources would not be reliable or accurate enough to establish a precise depiction on such a short timescale. As mentioned by multiple participants in the stakeholder interview sessions, the harvesters already communicate on their radios to inform each other if their lines have caught a lot of sharks and the locations of those lines. This shows industry-lead effort to help mitigate shark bycatch. This current participation and interest to avoid sharks means that a DOM application would not be a significant change in their mindset or communication levels on the water. This application is a means to streamline their on-the-water observational data with other valuable data sources. Additionally, participation could be expanded via *fishery* observers submitting data to the application as well. When combined, it can aid in making the decision-making process of setting lines more strategic regarding bycatch avoidance.

With this type of direct participant data gathering, there are challenges in ensuring data accuracy and avoiding falsified information. The participant from the industry stated that the harvesters are open and truthful in their inter-communication on the radios, even more so when it comes to bycatch communication. Furthermore, the harvesters benefit from telling the truth and all working together, as it has the potential of more success at catching target species. Therefore, while it is important to state that falsified data is a risk, current communication patterns indicate that this threat would most likely be negligible within the confines of the application.

5.3: Ocean Conditions

Sea surface temperature (SST) guides the harvesters in their decision-making on where to set their lines. The harvesters look at SST contour lines, seeking out frontal areas that tend to have a higher chance of swordfish catch. Additionally, as mentioned in the literature review, each of the three shark species have their own SST preferences. Having a SST map that is updated daily as the underlying base layer in the application will help harvesters keep up with SST changes while simultaneously providing a better understanding of which areas are preferable for which shark species; and where there are higher potentials of an encounter. For example, while this temperature data is valuable for all three species, it is especially so for the porbeagle shark's higher risk population levels. Since they have tendencies to be in colder water, the app could advise harvesters to avoid setting lines in colder temperature areas that overlap with notable points from the other data streams.

5.4: Live Species Tracking

Another valuable source of data is the live species tracking that occurs through tagging initiatives. While there are many types of tags that can be used on sharks, the ones that would be most able to keep up with the dynamic needs to *the fishery* are acoustic tags. The acoustic tags work by placing an implant in individual sharks; this produces an ultrasonic signal that can be heard with a hydrophone or a receiver. These transmitters are then detected by receivers that are stationed at various locations either on the ocean floor and/or attached to subsurface moorings, which continuously listen for transmissions (HIMC, n.d.). When a tagged shark enters a detection zone, up to 1km away, their unique identification code is recorded with the date and time of the occurrence. The combination of this with records from other receivers at different locations, it can help triangulate the accuracy of the site and create an overview of the shark's movement patterns (HIMC, n.d.). Additionally, the tags consistent monitoring, without the need of the individual going to the surface, provides near-real-time data.

Furthermore, there are a variety of organizations and institutions developing and using shark tagging in order to gain a better understanding of sharks. One group which is relevant to this project given their capability, location, and current initiatives is the Ocean Tracking Network (OTN). OTN is a research program developed by academics, government, and industry partners in 2010. The goal of OTN is to conduct research related to the question "*what are the movements of continental shelf marine animals, how do these movements affect species interactions, and what are the consequences of environmental variability/change and human activities on these species' distributions and abundance?*" (Cooke, p. 583, 2011). OTN uses tools including biotelemetry, biologging, and oceanographic technology to gain a better understanding of changing ocean dynamics and impacts on ecosystems, species movements and populations, and ecology (Cooke, 2011). One area OTN researches, in relation to this project, is developing a better understanding of the spatial distribution of sharks via electronic tracking technologies. Some examples of OTN's work with shark tagging include a partnership with DFO in the summer of 2017 to acoustically tag porbeagle sharks; developing a comprehensive evaluation (Voutour, 2017). Additionally, in 2014, OTN initiated a marine tagging initiative which involved tagging blue sharks off the shores of Nova Scotia (Davis & Whoriskey, 2014). Moreover, in partnership with OTN, DFO, and the Apex Predator Program, Blue Shark fishing charters, tags sharks before releasing them back into the ocean (BlueSharkFishingCharters, n.d). OTN produces valuable scientific data that can inform resource management, shape policies, and foster governance practice improvements (Cooke et al., 2011). Given the fact that OTN and DFO are already involved in shark tagging in the region, both institutions could play a valuable role in supporting the development of a rigorous shark bycatch mitigation application through tracking data support.

On its own, the data currently available through these tags are not enough to give an accurate depiction to the harvesters as to where the sharks are and create recommended areas for them to avoid. However, as a supportive data stream, this information can help solidify the indications given by the other data streams to increase the phone app / website's validity.

5.5: Management

The management route that would best suit the needs of this project is challenging to address. Indicated through the interview process, there are multiple considerations as to who would be the most appropriate for the manager position. The ideas presented by the participants included DFO, DFO-industry management, industry alone, or a collaboration between third-party leadership with DFO and industry support. Additionally, there are a variety of positives and negatives for both compulsory and voluntary systems.

For a compulsory system, the logical manager for the application would be DFO. Given that they are the overarching manager of *the fishery*, this would be the most streamlined process. Having a compulsory system helps maintain levels of participation, data integrity, and enforcement. However, while many participants stated they thought DFO would be responsible, there were concerns that DFO would not have the resources required, or that it might work better as a voluntary system. Furthermore, the industry perspective needs to be taken into consideration as the application's success is strongly correlated to the harvester's interest and participation. The industry perspective during the interviews, was strongly against DFO as the manager and against a compulsory system.

To have a system based on voluntary practices by *the fishery* and a manager outside of DFO has many benefits, but raises concerns. A voluntary system does not guarantee full and continued participation from harvesters and provides no ability to enforce avoiding areas that have been reported to have shark bycatch. However, if the pilot project was successful, the harvester's own incentives to avoid these species may be sufficient to ensure necessary participation. If they see success in the process and personal benefit, harvesters would want the application to succeed. When it comes to the position of the manager, there are multiple options to consider if DFO were to be ruled out as the overarching manager. One consideration that was brought up by numerous participants was a co-management system between *the fishery* and DFO. This approach could help ensure that the harvester's interests are accounted for within the regime while still having some power to influence DFO. However, there are challenges in establishing a real and balanced co-management system. If the efforts are not equal and DFO holds the executive decision, this leads to the challenges similar to DFO being the sole manager. In contrast with this, having harvesters as the manager of the system could be beneficial as they know the interactions on the water. However, multiple participants, including the industry perspective stated that harvesters would most likely not want to participate in the application development and management. The harvesters already have a variety of responsibilities and tasks to complete when they are out at sea, and off duty time is a brief period for rest. Therefore, there is a significant challenge in establishing a management regime that incorporates the needs and capabilities of all critical stakeholders without concern or conflict.

One way that this could be addressed is through a third-party organization or institution that holds the highest level of responsibility for the application's development and management. This body would be capable of initiating data sourcing from multiple sourcing and ensure that *the fishery* and DFO could contribute their knowledge and support to management. A third-party organization, either specifically created for the purposes of management, or an organization such as, or similar to OTN or Javitech, would be beneficial as they would be an unbiased actor in the relationship between harvesters and DFO. This would reduce concerns and fears from harvesters regarding the final decision-making being done by DFO. But at the same time, the management system remains in the hands of a governing body that has the time, capability, and resources to develop, maintain, and improve upon the application. Therefore, what seems to be the most effective way to establish this management application is a three-way collaboration between *the fishery*, DFO, and the third-party operational body having the title as the formal manager. However, in the future, if the application is deemed successful, this does not mean that DOM approaches for this *fishery* could not be adopted under the DFO regime.

Concerning approaching management through compulsory or voluntary measures, both present their benefits and short-comings. To address this, a hybrid measure could aim to capture the benefits of both approaches. Since a third-party organization would be running the management operations, they would not have the jurisdiction over mandatory enforcement of area avoidance; this would place harvester's mindset at ease and promote further participation. However, dismissing the benefits associated with a DFO-lead compulsory system would be a mistake. To address this, the system could benefit from DFO playing the role of an auditor of this system. The audits being completed by DFO could take shape in two ways, technological auditing and fisheries auditing. For the former, DFO would ensure that the information system maintains integrity, ensures that the data is appropriately safeguarded and that the goals and objectives of the application are being fulfilled. The fisheries auditing process would focus on monitoring bycatch levels. The analysis could observe if the application is successful over time in decreasing shark bycatch encounters. Additionally, if VMS tracking capabilities continue to develop, a potential way to monitor could be overlaying the area avoidance recommendations with the fisheries movements to see how well the harvesters response to the application is. Having governmental support ensures that management is done fairly and correctly, facilitates innovation, and allows DFO to assess if DOM is competent in this setting. This evaluation could then potentially foster development for future DOM applications in the department.

5.6: Platform

After the data components have been amalgamated, run through processing, and the management system has delineated distribution, a key factor is continuing the cycle of the user's application interaction. For bycatch management to be improved, harvesters need a service that is easy for them to use and something they will want to engage in. As the interviews revealed, the harvesters have access to the internet while at sea and use computers and smartphones. Therefore, it is technologically feasible to develop a website-based service or phone app, that the harvesters can access to both report their data and view the current readings when deciding where to set their lines. This technology may serve better through a log-in system, ensuring that data is protected and information on who submitted can be seen by management. The harvesters would be able to submit their reporting to the application by geo-tagging their location and informing whether the bycatch levels were low, medium, or high, and having the reporting be species specific. These submissions could also potentially be done with *fishery* observers as well. In turn, the amalgamation of all the datasets would be processed at the end of the day to create an updated view of the latest harvesters reports, updated SST patterns, any updates from shark tagging initiatives, and underlying baseline data of historical mapping.

CHAPTER 6: DISCUSSION

The proposed application configuration shows that a DOM approach has the potential to be successful. However, if that next stage of this project were to occur, there are concerns and shortcomings that also need to be addressed. To start, while the data sources are all reputable and valid, they have weaknesses concerning sourcing and quality. Considerations for potential data-gaps and accuracy pose a potential risk to the application's precision. Additionally, in data collection, the management regime needs to ensure that they do not impose on any intellectual property right infringements and would need to provide confidentiality for the harvester's submissions (Hobday et al., 2014). A challenge in monitoring success comes from the fact that these species do not remain in Canadian waters year-round. Additionally, even within Canada, the longline fishery is not the only industry to interact with them. These sharks interact with other Canadian fleets, fleets in other domestic waters, and fleets of the high seas. Therefore, success monitoring needs to strongly rely on patterns in the submissions by the harvesters.

This approach provides economic benefit to the harvesters by avoiding issues such as lower target catch, lost time, bait loss, and gear damage. For the species, it helps depleted populations rebuild to healthy levels, it helps maintain overall ecosystem health by ensuring that the apex predators continue to support the food web, and in turn, ensures that the ocean's ability to provide ecosystem services is resilient. So, while the main catch of blue shark might not be on the same level of sustainability concern as the other two species, from a precautionary approach, if the sharks can be avoided, all stakeholders will benefit. For stakeholder relationships, it fosters increased communication among governance, management, and *the fishery*. It builds on existing relationships, as it requires data from multiple sources and ensures that those involved remain engaged. Furthermore, increased communication can develop improvements to management as the platform for further discussion and collaboration has been established (Hobday et al., 2014). Together, increased communication and improved management practices could enhance the relationship between *the fishery* and DFO.

Moving beyond the direct benefits, this application and its data amalgamation can support other research areas including climate change impacts on species movements and patterns. Climate change is disrupting ecosystems and altering habitats in the marine environment (Hoegh-Guldberg, 2010). The ability to understand responses to this, changes in movements, and future hotspots may play a crucial role in future environmental management. The data provided in this application would show the species movements over time, and with enough data, it will show if their movement patterns and hotspots are changing. From this, researchers gain a better understanding of climate change impacts on shark species and potential implications. Finally, the development of this application could provide support for the growing desire to incorporate ecosystem-based management into management structures. DOM applied to this situation means that the interactions among humans and the ecosystem are acknowledged within the management structure. This interaction awareness becomes the guiding tool on how users will continue to interact in both the immediate and long-term.

CHAPTER 7: CONCLUSION

Canada has a variety of tools that are designed to improve marine ecosystem and species conservation and protection as well as fisheries management. However, given the dynamic nature of *the fishery* and the species, static spatial approaches are limited. Spatial management tools address some concerns of species and fisheries management. However, their inability for quick adaptation in a changing environment and frequently moving users fails to work cohesively with the specific challenge of shark bycatch mitigation within *the fishery*. In contrast, DOM applications are designed to address highly dynamic issues through the amalgamation of data sources in near real-time (Dunn et al., 2016). A variety of measures need to be used to control bycatch. Therefore, DOM is highly recommended to be incorporated into this toolbox to address this challenge and others like it.

There are a variety of stakeholders and associated governance tools that need to be considered in developing a DOM approach for this case study. RFMOs, DFO, *the fishery*, and third-party organizations all provide valuable perspective and present useful considerations concerning what needs to be included for an application to be successful. The development of an application that involves data from daily bycatch reporting, historical patterns, SST readings, and species tracking has the capabilities to keep up with the highly dynamic scenario and can address user-species interactions. This management regime could be successfully run by a third-party organization in collaboration with *the fishery* and DFO, capturing the benefits of a voluntary system and having quality assurance through a DFO auditing system. Given *the fishery's* high technological capacities, the harvesters would be able to access and participate in the application through either a phone app and or website interface.

The presented DOM application could help *the fishery* mitigate pelagic shark bycatch by providing them with the capability to strategically setting their longlines in areas that potentially have less shark density. This provides the harvesters with economic benefit, and for the species and the ecosystem, it fosters protection, an increased understanding of the species, and strategic management and planning in an era of climate change. With a structure of organized management, data-sourcing, and harvester participation, this application could help marine managers in the Maritime region of Canada consider new adaptive ways when approaching challenging dynamic circumstances. Moving forward, a DOM application specific to this management challenge starts with the direct communication between the harvesters, interested third-parties, and DFO. Having collaboration from these three groups can allow a process of development to occur with the greatest amount of resources, avoiding duplicated work, and setting out responsibilities. Furthermore, to support the development of this project. and similar DOM developments in Canada, DFO support through new or revised legislation helps ensure ocean and fisheries management can reach its full potential. Avenues such as new fisheries legislation, bycatch policy revisions, and further incorporation of the ecosystem approach would all contribute value to management. The ocean holds a variety of species and users that may require and benefit from management approaches that go beyond the capabilities of static spatial tools. As such in this case of sharks and longline harvesters, DOM can fill the gaps and aid both sides of the challenge, addressing economic and ecological needs.

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APPENDICES:

Appendix I: *Research Interview Questions*

Stakeholder Interview Questions
Project Title: Protection on the Move: Applying Dynamic Ocean Management to Pelagic Shark Bycatch in the Canadian Atlantic Fisheries Industry.

Participant ID #: ____

Please state your name, the organization you represent, and your role.

Section 1: Shark Bycatch

1. Are you aware of pelagic shark bycatch being an issue in the Canadian North Atlantic pelagic longline fishery targeting swordfish and tuna?

2. How well do you think shark bycatch in the fishery is currently being addressed?

3. Do you think current efforts for shark bycatch mitigation in the fishery are enough?

4. What does effective shark bycatch management look like to you?

5. What management tools do you think would be effective in improving pelagic shark bycatch mitigation for the fishery? (I.e. specific measures or policy?)

- DOM presentation-

Section 2: Dynamic Ocean Management

1. Before this discussion were you aware of the concept Dynamic Ocean Management?

2. Do you think some type of Dynamic Ocean Management application could help the issue of pelagic shark bycatch for the fishery?

3. Do you think Dynamic Ocean Management measures are feasible for this issue?

4. Out of the four examples provided for Dynamic Ocean Management applications, which measure would you envision for this issue? *multiple

responses allowed*

a: type 1 / ratio map indicating where bycatch is currently high vs. low;
b: type 2 / move on rules: temporary / small area closures;
c: type 3 / tag & bycatch monitoring
d: type 4 / spatial habitat modelling
e: other idea - explain

5. Who do you think should be the overarching manager of the Dynamic Ocean Management application?

6. Who do you think would be involved in collecting data samples? *multiple responses allowed*

7. Do you think the Dynamic Ocean Management application would work better as a compulsory or voluntary measure?

Section 3: Organization Specific:

1. What is your organization currently doing to mitigate pelagic shark bycatch?

2. Do you believe the efforts done by your organization to mitigate pelagic shark bycatch are enough?

3. Do you think your organization would support a Dynamic Ocean Management application for pelagic shark bycatch mitigation for the fishery?

NAFO:

1. Do you think the ecosystem-based and precautionary approaches within NAFO have influenced shark bycatch management?

2. Do you think these approaches could support Dynamic Ocean Management in the future?

ICCAT:

1. Why do you think there is such reluctance from member parties to enforce the science-based advice of setting Blue Shark catch limits?

DFO:

1. Do you think DFOs policies (Fisheries Act / Oceans Act) are sufficient to support Dynamic Ocean Management Development?

2. Do you think the National Plan of Action for the Conservation and Management of Sharks sufficiently addresses the bycatch issue?

NSSA:

1. Would it be valuable to have an overarching management structure assist the longline industry with shark bycatch? Or do you think this would be better managed between the users themselves?

2. Are there any potential concerns of harvesters that you know of related to shark bycatch management? Explain.

3. Has there been any vocalized interest within the longline community to mitigate this problem?

4. Do you think harvesters would be interested in participating in a management plan to reduce shark bycatch?

NGOs:

1. What communication/education efforts have been followed to inform the public and stakeholders regarding shark bycatch?

2. What future research and/or communication initiatives on shark bycatch are envisioned, if any?