How Decision-Making in Fisheries Management Contributes to Changes in the Fishery: A Case Study of North Atlantic Swordfish

By

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Abstract

Fisheries management must constantly adapt to changes in stock status, shifts in effort, and national and international policy. The North Atlantic Swordfish Fishery is an interesting case study because of the migratory range of the target species, variability of the stock status, and the variety of management actions applied at national and international scales over the past six decades. Despite the dynamic nature of this fishery, there is a lack of documentation of the management history and how behaviour of the Canadian fleet changed in response to national and international agreements, new gear types, and different quota allocation schemes. The objectives of this project are (1) produce a timeline of the management changes affecting the Canadian North Atlantic Swordfish Fishery, and (2) examine for relationships between management changes and patterns in the fleet over time. Potential connections between fleet behaviour are identified as: (1) anticipatory effects prior to the international percentage allocations in 1995, and (2) a temporal shift in the Canadian fishery after the introduction of the ITQ system in 2002. These outputs will support the creation of improved North Atlantic Swordfish population models and management measures that better account for fleet dynamics. Although focused on the Canadian fleet, this project could be applied to other fleets in the international swordfish fishery.

Keywords: swordfish; fleet behaviour; fisheries management; ICCAT; stock assessments; Canadian longline; anticipatory effects; ITQ.

List of Abbreviations

ALPAC – Atlantic Large Pelagics Advisory Council

AOI – Area of Interest

BYC – Bycatch

BIL – Billfish

CITES – Convention of International Trade in Endangered Species of Wild Fauna and Flora

CMS – Convention of Migratory Species

COSEWIC – the Committee on the Status of Endangered Wildlife in Canada

CPC – Contracting Parties, and non-Contracting Parties, Entities or Fishing Entities

CPUE – Catch-per-unit-effort

EEZ – Exclusive Economic Zone

ICCAT – International Commission for the Conservation of Atlantic Tunas

IFMP – Integrated Fisheries Management Plan

ITQ – Individual Transferable Quota

LJFL – Lower Jaw Fork Length

MPA – Marine Protected Area

MSE – Management Strategy Evaluation

MSC – Marine Stewardship Council

NAFO – Northwest Atlantic Fisheries Organization

NATL – North Atlantic

NSSA – Nova Scotia Swordfishermen's Association

RFMO – Regional Fishery Management Organizations

SARA – Species at Risk Act

SCRS – Standing Committee on Research and Statistics

SFLPAC – Scotia Fundy Large Pelagics Advisory Committee

SHA – Swordfish Harpoon Association

SHQ – Swordfish Harpoon Quota Association

SWO – Swordfish

TAC – Total Allowable Catch

TRO – Tropical Tunas

VMS – Vessel Monitoring System

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Chapter 1: Introduction

1.1 Context

Fisheries management is a dynamic field that is constantly adapting to new challenges. One challenge that is yet to be properly addressed is the influence of fleet dynamics and management measures on the perceived abundance of a fished stock. Including variables that account for fleet-dynamics (e.g., gear and technology changes, implementation of new regulations, reporting and discard changes, etc.) in stock assessment models could improve representation of stock status and trend. For highly migratory species, this process is complicated to manage due to the large amount of stakeholders, overlapping regulations, and difficulty measuring fleet behaviour (Aranda et al., 2012; Braun et al., 2019; DFO, 2015, 2016; FAO, 2012, 2017). Regulation of fisheries is an intricate relationship between CPCs and RFMOs. The creation of some regulations is organized by RFMOs such as ICCAT. ICCAT focuses on the management of tunas and tuna-like species in the Atlantic Ocean and Mediterranean Sea (DFO, 2016; Neilson et al., 2013). Swordfish (*Xiphias gladius*) are an example of a target species that requires international cooperation to facilitate management (DFO, 2000, 2016; Neilson et al., 2013). For the NATL SWO, managers are challenged with creating regulations that weigh trade-offs between economics, societal and political priorities, gear changes, and shifts in stock status (DFO, 2016). As a result, scientific assessments must contend with shifting biological, technological, and social dimensions when trying to understand the true dynamics of fished stocks. Fisheries dependent and independent data support decision making through stock assessment models which inform the creation of regulations (Branch et al., 2006; Hanke, 2017; Ortiz et al., 2017). To address the impacts of fleet dynamics, a management timeline will be created and used to explore the connection between management measures and fleet behaviour. The goal is to improve the input of information into stock assessments to better inform regulations that account for fleet behaviour. The focus of the project is the Canadian NATL SWO fishery; however, this work could serve as a template for fleets of those CPCs who participate in the ICCAT swordfish fishery.

Fleet behaviour and dynamics are a critical component influencing the status of a stock. Fleet dynamics are composed of the where, when, and how the fishermen fish, and what they use to fish (e.g., gear type) (Branch et al., 2006, 2006; FAO, 2001; Hilborn, 1985). How the fleets respond to the implementation of new regulations may vary greatly within a fishery, however, the overall response should be investigated to improve the creation and implementation of future regulations (Branch et al., 2006; FAO, 2001; Hilborn, 1985, 2007). The goal of the stock assessment model is to reflect the reality of a stock in terms of biology and abundance, as well as determine catch limits (Branch et al., 2006; FAO, 2001). To do so, assessments rely on indicators of abundance such as CPUE indices, catch length frequencies, and catch-at-age data (DFO, 2000). These indicators of abundance are derived from commercial fleet catch data and can be influenced by changes in fleet behaviour (Branch et al., 2006; Hilborn, 2007). Stock assessment models, such as those used in Atlantic swordfish stocks, rely on these inputs from the commercial fleets to model stock dynamics (Branch et al., 2006). CPUE is susceptible to changes in fleet behaviour, and if not standardized accurately, there is a risk of perceived hyperstability (when the CPUE remains constant, but the abundance is decreasing) or hyperdepletion (when the CPUE declines faster than the abundance)(Branch et al., 2006; Hilborn, 1985). Additionally, assessment models are susceptible to selectivity misspecification, as this can influence assumptions on the magnitude of unfished biomass. Therefore, there is a need for more research to measure fleet behaviour, particularly for large pelagic fisheries to investigate the impacts on stock abundances (Branch et al., 2006; FAO, 2001; Hilborn, 1985; Ward & Hindmarsh, 2007).

Tunas, sharks, or swordfish are often highly migratory species that travel long distances (Logan et al., 2021; Lynch et al., 2011). This can lead to multiple nations fishing the same stock and overlapping or conflicting regulations between the different CPCs (Aranda et al., 2012; ICCAT, 2006b). The development of RFMOs can help introduce multilateral regulations that aim to reduce this issue and improve compliance (FAO, 2020). RFMOs create a baseline of regulations that domestic CPCs can build on; however, the need to improve capacity of CPCs to implement and enforce has been identified (Aranda et al., 2012; FAO, 2020). In some nations, the capacity to enforce regulations, monitor stock status, and assess the impacts of domestic activities on the fishery are low due to limited resources and support (Aranda et al., 2012; FAO,

2020). To further complicate the situation, not all fishing fleets that direct for these species are Contracting Parties to the international RFMO responsible for the stock in question and, therefore, those fishing fleets are not governed by the RFMO's regulations (ICCAT, 2006b). For these reasons, the management of large, international fisheries with migratory target species require high levels of international collaboration to ensure long term sustainability (Aranda et al., 2012; Branch et al., 2006).

The NATL SWO fishery is an example of the unique challenges in international fisheries management (DFO, 2016; Neilson et al., 2013). ICCAT plays an important role in facilitating collaboration between nations for the management of the NATL SWO (DFO, 2016). ICCAT was established in 1969 and currently has 52 contracting parties (DFO, 2016; ICCAT, 2006b). ICCAT facilitates the collection and analysis of data to inform the creation of regulations for each species under the convention (ICCAT, 2006b, 2019d). To support this process, the SCRS, an ICCAT body made up of CPC scientists, conducts stock assessments to reassess the stock (DFO, 2000; ICCAT, 2006b). Timing of the assessments is variable, with major stocks often being assessed every 3 to 5 years. The Canadian SWO fishery has operated longlining fleets in the Atlantic since the 1960's (Caddy, 1976; Fitzgerald, 2000; Hurley & Iles, 1981; Neilson et al., 2013). The first TAC produced by ICCAT was in 1994 in response to concerns about the status of the swordfish stock (ICCAT, 1994; Neilson et al., 2013). Additionally, concerns around the swordfish stock led to the creation of a rebuilding plan in 1999. The 10-year rebuilding plan is composed of limiting TACs and a dead discard allowance with the goal of achieving biomass levels associated with MSY, with at least 50% probability (Neilson et al., 2013). Since 1995, the TAC for the NATL SWO has averaged around 13,000t, however, the average reported catch is slightly below 12,000t for 1995-2018 (DFO, 2013, 2016; ICCAT, 2021b). Proper management combined with resilient life history characteristics and strong recruitment has resulted in the successful recovery of the NATL SWO stock (DFO, 2016; Neilson et al., 2013).

Stock assessments are an important part of fisheries management for monitoring a stock's status and determining catch limits (Branch et al., 2006; DFO, 2000; FAO, 2001). There are many data inputs required for stock assessments including: biological characteristics, recruitment trends, catch data, and measures of abundance (Branch et al., 2006; DFO, 2015, 2016; FAO,

2001). Information is collected through fisheries dependent and independent data sources (Branch et al., 2006). Fisheries dependent data is collected from commercial fleets through dockside monitoring, observer coverage, and submission of log records including information on catches, bycatch, and discards (DFO, 2015; Ortiz et al., 2017). Fisheries independent information is collected through other external sources, and for pelagic species this information is often collected through tagging, aerial, and larval surveys (DFO, 2015, 2016). Together, fisheries dependent and independent data support the completion of stock assessments (DFO, 2015; Ortiz et al., 2017). Alternatively, certain factors such as new technology, adjustments in gear selectivity, implementation of new regulations, or changes to reporting and discarding may be overlooked in the assessment of the stock (FAO, 2001; Hilborn, 1985, 2007). These factors may have small individual impacts on the stock, however, their combined influence on fleet behaviour may be significant enough to change the true (or perceived) dynamics of the swordfish stock (Hilborn, 1985, 2007; Hurley & Iles, 1981). In addition to impacting the stock, a change in fleet behaviour can impact the subsequent data interpretation and the indicators developed based off this data. In this case, the models that use these indicators as input would consider the change to be a change in the population when, in reality, it could be a change in data interpretation as a result of changing fleet behaviour, or changes in management. The lack of inclusion of variables that represent fleet behaviour could potentially misguide the stock assessment, and in turn, the regulations created for the stock (Branch et al., 2006; Hilborn, 1985, 2007).

To address the impacts of fleet behaviour on stock assessments, a management timeline should be maintained to record all changes to the fishery. This timeline can then be used to investigate the impacts of fleet behaviour on measures of abundance. This could consist of the dates of enforcement of new regulations, implementation of new technology, changes in discard retention or disposal, added or removed bycatch mitigation measures, and changes in the condition of licences (Branch et al., 2006; Hilborn, 1985; Hurley & Iles, 1981). Types of changes that are included in the timeline are regulation changes, gear type changes, spatial changes, qualitative observations, and bycatch mitigation measures. Once a management timeline is created, it can be used to support population models and MSE, as well as reduce uncertainty and improve the representation of the stock status. Specifically, the timeline could help with the review of abundance indicators by highlighting the influence that a change in fleet dynamics can

have. For example, the timeline can help disentangle the true population trend versus that of the perceived population influenced by fleet behaviour.

The goal of this project is to improve the measures of abundance for assessment models by considering fleet behaviour. The first objective will be to investigate the factors contributing to the changes in a highly migratory fishery by creating a timeline of the management changes. The main question this objective aims to address is how do fishing practices change over time? The second objective will be to examine for relationships between management changes and patterns in fleet behaviour over time. The main questions this objective aims to address are (1) is there evidence of links between management and fleet dynamics; and (2) how can researching and understanding this relationship contribute to stock assessments? The NATL SWO fishery is used as the case study for this project and these objectives support the creation of assessment models that better account for management and fleet dynamics. While the focus is the Canadian component of an international fishery, this work could serve as a template for other pelagic fleets in the swordfish fishery.

1.2 Review of the Fishery

For this project, the NATL SWO fishery is used as the case study because the swordfish is an internationally managed and highly valuable species (Caddy, 1976; Fitzgerald, 2000; Hurley & Iles, 1981; Neilson et al., 2013). In this fishery, there are 5 main fleets actively fishing 94% of the ICCAT regulated TAC: Spain, United States, Canada, Portugal, and Japan (DFO, 2016; ICCAT, 1995c). Improved technology and an expansion of effort in the 1960's resulted in a higher fishing capacity and catch efficiency for swordfish (DFO, 1996; Fitzgerald, 2000; Hurley & Iles, 1981; Neilson et al., 2013; Tibbo et al., 1961). For the Canadian and American fleets, fishing capacity was limited in the 1970s due to mercury restrictions in the tissue of fish (Fitzgerald, 2000; Hurley & Iles, 1981; Neilson et al., 2013). The mercury restrictions were a limitation on the sale of swordfish with a mercury concentration higher than 0.5ppm in their tissue (Fitzgerald, 2000; Hurley & Iles, 1981). This heavily reduced swordfish landings for both fleets and decreased the fishing effort exerted on the NATL SWO stock for a period of 8 years (1972-1979) (Caddy, 1976; Fitzgerald, 2000; Hurley & Iles, 1981). In 1979, the mercury

restrictions were removed in Canada and altered in the US which allowed for the catch and sale of swordfish to continue (Fitzgerald, 2000; Hurley & Iles, 1981).

Fisheries management becomes increasingly complicated when managing international highly migratory species, such as swordfish (DFO, 2015, 2016). Tuna and tuna-like stocks have unique challenges, such as trans-boundary enforcement and the need for a high degree of international collaboration (DFO, 2016; ICCAT, 2006b). Trans-boundary enforcement presents challenges because different CPCs have varying capacities to enforce regulations, further complicating management. Moreover, collaboration between CPCs is a critical component to limit fishing effort and mitigate bycatch (FAO, 2010; Lynch et al., 2011). To facilitate management, the Atlantic Swordfish is divided into three stocks: North Atlantic, South Atlantic, and the Mediterranean Sea (DFO, 2016; Neilson et al., 2013).

This project will focus on the Canadian fleets of the NATL SWO fishery which is allocated 10% of the international SWO TAC (ICCAT, 1995c). The Canadian fleet of the NATL SWO fishery is composed of harpooners and longliners (Caddy, 1976; DFO, 2013; Fitzgerald, 2000; Hurley & Iles, 1981). The harpoon sector is allocated 10% of the overall TAC for Canada and operates from June to late August (DFO, 2000; SHQ Swordfish Harpoon Quota Society, 2018). The longline sector is allocated the other 90% of the TAC and operates between the months of April and December (DFO, 2000, 2016).

Concerns about the swordfish stock were raised in the early 1990s, when the SCRS determined that the catch of swordfish was unsustainable and overfishing was occurring (ICCAT, 1994; Neilson et al., 2013). In response to these concerns, ICCAT implemented several regulations to reduce effort, limit catch, and protect small swordfish (FAO, 2017; ICCAT, 1995b; Neilson et al., 2013). In 1999, ICCAT recommended a 10-year recovery plan for the NATL SWO for 2000-2009 (ICCAT, 1999a; Neilson et al., 2013). Proper management combined with a resilient species and a period of high recruitment has resulted in an improvement in the status of the swordfish stock (Neilson et al., 2013). More recently, both Canadian fisheries, harpoon and longline, have been awarded the MSC certification in 2010 and 2012, respectively (Acoura, 2010; Knapman et al., 2017).

1.3 Review of the Species

Swordfish are top predators and one of the fastest swimming fish in the ocean. The have a diverse diet, generally foraging for teleosts and cephalopods (Logan et al., 2021; Palko et al., 1981). Globally, one of the most common prey of adult swordfish are ommastrephid squids (Logan et al., 2021; Neilson et al., 2014). However, a higher proportion of the NATL SWO's diet is composed of fish, compared to other stocks (Logan et al., 2021). Squid and select pelagic fish (e.g., alewife, herring, and mackerel) are the two most common types of bait used in the Canadian SWO fleets (Andrushchenko et al., 2014). Diverse diets and a high tolerance to environmental change allow the species to shift their distribution as local environmental conditions change (DFO, 2000; ICCAT, 2017b; Logan et al., 2021; Neilson et al., 2014).

Swordfish have key biological features that allow the species to be resilient to fishing pressures, such as the ability to grow quickly, reach maturity at an early age, and attain a high fecundity (DFO, 2000, 2015; Hurley & Iles, 1981; Neilson et al., 2013). The ability to grow quickly and mature at an early age are important factors for defining the recovery ability of a stock (ICCAT, 2006b). Furthermore, swordfish have a high fecundity, which increases the potential to recover when the population is low (DFO, 2000). As a result of these features, the swordfish is considered a resilient species, and this has been credited as an important factor in the recovery of the NATL stock (Neilson et al., 2013).

Another factor that contributes to the swordfish's resilience is the wide distribution of the species throughout the Atlantic and their high tolerance to temperature change (Logan et al., 2021; Neilson et al., 2014; Schirripa et al., 2017). Water temperature is an important influence on the distribution of the swordfish. Typically, swordfish migrate South to the Gulf Stream in the winter months and North to the Canadian Atlantic Coast in the summer months (Hurley & Iles, 1981; Logan et al., 2021; Neilson et al., 2013, 2014). In addition to horizontal migrations across the Atlantic ocean, swordfish follow diurnal vertical migrations in pursuit of their prey (DFO, 2015; Logan et al., 2021; Schirripa et al., 2017). Swordfish are visual predators, typically foraging in deeper waters during the day when there is more available light (Logan et al., 2021).

For stock assessments, a number of biological characteristics are important as inputs, such as natural mortality, steepness, and carrying capacity (de Bruyn et al., 2013; ICCAT, 2006b, 2017b; Martell & Froese, 2013). Natural mortality is an important variable when assessing the stock because high mortality is often associated with high productivity (ICCAT et al., 2007; ICCAT, 2017b; Martell & Froese, 2013). New evidence suggests that the NATL swordfish has a lifespan up to 15 years, which could affect the stock's mortality and productivity values (ICCAT et al., 2007). Next, the steepness value is estimated based off of a fraction of the recruitment of a stock when the spawning stock's biomass is reduced to 20%, and this value is related to the stock's ability to recover when the population is low (Mangel et al., 2013). For swordfish, the steepness value used in assessments is 0.82, which is considered fairly high and associated with high recruitment even at depressed population levels (ICCAT, 2017b). Finally, carrying capacity is the highest population that the environmental resources can support, and is critical to include in stock assessments (ICCAT, 2017b; Martell & Froese, 2013). Together, these characteristics can influence the science advice from the stock assessment and, therefore, the management of the stock (Branch et al., 2006). The challenge is to determine whether or not a change in the perceived abundance is caused by biological characteristics or changes in fleet behaviour (Branch et al., 2006; Hilborn, 1985, 2007). Because of this, it is important to incorporate measures of fleet behaviour in stock assessments to better understand the factors influencing the stock status (Branch et al., 2006; Ortiz et al., 2017).

Chapter 2: Management History – The Canadian North Atlantic Swordfish Fishery

2.1 Introduction

Sustainable management of fish stocks requires data inputs on populations and the fleets that target them. For large pelagic fisheries with highly migratory target species, such as swordfish, this process involves input from a variety of nations (DFO, 2015, 2016). The goal of this process is to improve the effectiveness of regulations while maintaining a sustainable fishing practice (Hilborn, 2007; Ward & Hindmarsh, 2007). The NATL SWO has an interesting history, with a variable stock status, complications associated with mercury concentration regulations, minimum size limits, and a successful recovery of the stock (Neilson et al., 2013). This history makes the NATL SWO fishery an ideal case study to investigate the impacts of management measures on fleet dynamics (Caddy, 1976; Stone & Dixon, 2001). Fleet dynamics are changes within the behaviour of fleets or targeting within a fishery and are often poorly represented in stock assessments (Branch et al., 2006; Hilborn, 1985, 2007). The combined impacts of all the small adjustments in fishing behaviour can result in a bias in understanding of the stock patterns of abundance (Branch et al., 2006; Hilborn, 2007). Therefore, considering fleet dynamics in stock assessments is a crucial step in improving the accuracy of the estimates and management measures (Branch et al., 2006; Hilborn, 2007; Ward & Hindmarsh, 2007). Here, a record of management changes and key events impacting the Canadian SWO fishery will be compiled and used to hypothesize impacts of management measures on fleet dynamics. Although this project is focused on the Canadian SWO fleet, this process could be applied to other fleets.

The Canadian NATL SWO fishery has been active for over a century (Caddy, 1976; DFO, 2016; Fitzgerald, 2000). The harpoon fishery for swordfish in Canada began off the coast of Nova Scotia as early as 1903 (Fitzgerald, 2000). Longlining for swordfish was later introduced when foreign offshore tuna vessels reported swordfish as a bycatch species in their longline gear (Caddy, 1976; Fitzgerald, 2000). In the 1960s, longline quickly became the dominant fishing gear for catching swordfish in the NATL (Caddy, 1976; Fitzgerald, 2000; Neilson et al., 2013). During the 1970s, concerns that the amount of mercury in swordfish was too high for consumption resulted in restrictions introduced in both Canada and the US (Caddy, 1976; Fitzgerald, 2000; Neilson et al., 2013). Restrictions included a limit on the sale of

swordfish with a mercury concentration higher than 0.5ppm in the tissue (Caddy, 1976). Due to the larger-size swordfish in Canadian waters, the proportion of the catch that would be permitted for sale would be too small and the reported catches[1] for Canada during this time were virtually zero (Hurley & Iles, 1981). By 1979, the restrictions in both countries were lessened, and Canadian catches of swordfish resumed (Caddy, 1976; Fitzgerald, 2000). After the fishery reopened, Canada introduced regulations that limited the catch and effort on the swordfish stock (DFO, 1988; Neilson et al., 2013). However, the swordfish stock continued to decrease into the 1990s, therefore, ICCAT implement a ten-year recovery plan for the stock (Rec. 99-02) (ICCAT, 1999a; Neilson et al., 2013). Because of these challenges, this fishery is an example of the impacts that proper management and a resilient species can have in the successful recovery of a stock.

Domestic management of NATL SWO is overseen by the Canadian Federal Government by the Department of Fisheries and Oceans Canada (DFO), which is advised by DFO Science, the Atlantic Large Pelagics Advisory Council (ALPAC), and other advisory bodies such as the COSEWIC. The Scotia Fundy Large Pelagics Advisory Committee (SFLPAC) is composed of members from the Swordfish Harpoon Association (SHA), the Swordfish Harpoon Quota Association (SHQ) and the Nova Scotia Swordfishermen's Association (NSSA). SFLPAC reviews the issues and activity of the Canadian fleet and provides input to ALPAC. ALPAC considers the input from both international and national sources (including stakeholders) and submits' recommendations to DFO. DFO Resource Management uses these recommendations as part of their decision memo prepared for the Minister of Fisheries and Oceans Canada (DFO, 2016). The fleet is informed of regulation changes and management measures through licence conditions provided by DFO, which are updated every year (DFO, 2013). The harpoon sector is represented by SHA and SHQ, and together they govern the community quota allocation system for the Harpoon A and B licence holders (DFO, 2000, 2016; SHQ Swordfish Harpoon Quota Society, 2018). Harpoon licence A holders are defined by recently active fishermen and are allotted 90% of the harpoon sectors' TAC. Harpoon licence B holders are all other licence-

[1] Limited fishing did continue during these years by Canadian fishermen, however, swordfish were landed by US vessels and not recorded as Canadian catches.

holders and are allocated the other 10% or up to 9 tonnes of the Canadian harpoon sectors' TAC (DFO, 2000; SHQ Swordfish Harpoon Quota Society, 2018).

The management process for fisheries is a cycle that involves the input of information, synthesis of that information in assessment models, consideration of science advice by management bodies and the output of regulations and management changes (ICCAT, 2006b). Information is collected through fisheries dependent and independent data. Fisheries dependent data consist of logbooks, observer programs, port sampling, trade statistics, and collecting biological samples (DFO, 2015; ICCAT, 2006b). Fishery-independent data is classified as data collected externally from the fishery and, for tunas and other migratory species, is mainly composed of tagging, acoustic surveys, and aerial and larval surveys (Branch et al., 2006; ICCAT, 2006b). Most ICCAT assessments rely heavily (or exclusively) on fishery-dependent data because fishery-independent data are often difficult and costly to collect, particularly for the highly migratory species' that ICCAT manages (DFO, 2016; ICCAT, 2006b). Since these fishery-dependent data (catch, catch-at-size, catch-per-unit-effort, logbooks, etc.) are crucial for management it is mandatory for CPCs to submit many of them to ICCAT (Branch et al., 2006; DFO, 2016; ICCAT, 2006b). Additionally, the higher the diversity of data that is used as input into stock assessment models, the better the estimates can capture trends over large spatial scales (ICCAT, 2006b). Stock assessments are generally completed every 3 to 5 years for swordfish and are an important factor considered in the decision-making process for new regulations and management actions (DFO, 2016).

To inform regulations, population assessment models are crucial for indicating the status of the stock (ICCAT, 2006b). However, behaviour within a fleet can impact perceived abundance and are often overlooked as influential factors in stock assessments because they are difficult factors to track (Branch et al., 2006). Fleet dynamics and fleet behaviour consist of changing fishing power, temporal changes by day or year, or improved communications (Branch et al., 2006; Hilborn, 2007; Ward & Hindmarsh, 2007). Fishing power may not be limited by regulations because regulations usually target fishing effort in terms of catch rates and number of licenses, and fishing power could come in the form of increased vessel size or refrigerated fish holds (Branch et al., 2006; Ward & Hindmarsh, 2007). Temporal changes include gear or bait

changes that impact the selectivity or efficiency of the catch. These changes are typically documented in the licencing conditions, however, even a small adjustment in gear or bait can adjust the composition of the catch (Palomares & Pauly, 2019; Ward & Hindmarsh, 2007). Additionally, improved communications between vessels increase fishing efficiency by reducing the amount of search time for target species (Ward & Hindmarsh, 2007). These factors may have small individual impacts, however, their combined impact on the fishery is significant (Branch et al., 2006; Hilborn, 2007; Ward & Hindmarsh, 2007). Additionally, these factors are difficult to track in fisheries because of the volume of inputs that could be contributing to fleet dynamics and are not considered in the population assessment models (Branch et al., 2006; Ward & Hindmarsh, 2007). As a result of the lack of documentation, informative variables (e.g., gear changes, ICCAT resolutions, bycatch mitigation) are left up to assumption or simply not included in stocks assessments (Ward & Hindmarsh, 2007). With an increased amount of assumption, there is a higher level of uncertainty in stock status and trend, which could lead to bias in science advice and subsequently misguided fisheries regulations (Branch et al., 2006; de Bruyn et al., 2013).

The main objective of this chapter is to gather information on the changes in management history impacting the Canadian SWO fishery. I will do this by creating a timeline of the management changes including regulations, gear type changes, spatial and temporal closures, qualitative observations and events, and bycatch mitigation regulations. The main question I will address is how do fishing practices change over time? While the focus will be on the Canadian NATL SWO fishery, this work could serve as a template for other fleets to better inform future regulations for internationally managed fisheries.

2.2 Methods

The main objective is investigating the factors contributing to the changes in an international fishery by creating a timeline of the management changes. Building the timeline began with collecting information on the management and fisher practices since the introduction of longlining in the early 1960's. The types of change were divided into 5 categories to aid in the delivery of the timeline: (1) Regulation Changes, (2) Gear Type, (3) Spatial Changes, (4)

Qualitative Observations, and (5) Bycatch Mitigation. The timeline would be made available in various formats, such as written in a table (Appendix A), visually through figures (Fig. 2.3, 2.4, 2.6, 2.11, 2.12), and analytically through a spreadsheet. Once the timeline was built, it would compose all key changes to the Canadian SWO fishery and be used as a reference to answer the question how do fishing practices change over time?

Regulation changes consisted of minimum size limits, changes in TAC, catch allocations, and other trip limits (DFO, 2013). Information regarding regulation changes were sourced from licencing conditions for the swordfish longline, harpoon, and other tunas, as well as ICCAT recommendations and resolutions since the first ICCAT recommendation was implemented for the swordfish fishery in 1990 (Fisheries and Oceans, 2021; ICCAT, 2021b; SHQ Swordfish Harpoon Quota Society, 2018). Next, gear type changes consisted of the shift from a harpoon to longline dominant fishery, the introduction of monofilament materials, and the switch to circle hooks instead of J-hooks (Fisheries and Oceans, 2012; Stone & Dixon, 2001). Additionally, bait changes were considered in this category, however, through conversations with Industry, the bait used in the Canadian fleet has remained consistent over the years (e.g., most commonly mackerel & squid). Gear changes were informed by licencing conditions and input from industry representatives (harpoon, longline). Spatial changes consistent of time/area closures, MPA establishments, and oil and gas exploration (DFO, 2005). Information was gathered through licencing conditions, government sites, and IFMPs (DFO, 2005, 2013). The fourth category of change was Qualitative Observations, and these consisted of important events to the overall narrative of the fishery and were informed by the literature and input from industry representatives (Caddy, 1976; Fitzgerald, 2000). The final category was bycatch mitigation, and this was informed by CITES, CMS, COSEWIC, SARA, licencing conditions and ICCAT bycatch recommendations (ICCAT, 2021b; UNEP-WCMC, 2021a, 2021b).

Table 2. 1 – Summary of the sources of information gathered for the Canadian NATL SWO fishery management timeline.

Type of Change	Source of Information
Regulation Change	1. DFO Licencing conditions (swordfish longline, harpoon, other tunas, and aboriginal fisheries) 2. ICCAT Recommendations and Resolutions (SWO, BYC, BIL, BFT, TRO, GEN)
Gear Type	1. DFO Licencing conditions 2. Input from industry representatives (Harpoon, Longline)
Spatial Change	1. DFO Licencing conditions 2. Government sites (DFO) 3. DFO integrated fisheries management plans (IFMP)
Qualitative Observation	1. Historic literature 2. Input from industry representatives (Harpoon, Longline)
Bycatch Mitigation	1. United Nation Environmental Programme (UNEP) CITES and CMS listings 2. DFO SARA 3. COSEWIC 4. ICCAT Recommendations and Resolutions (SWO, BYC, BIL)

2.3 Results

2.3.1 Context

The history of the Canadian SWO fishery is composed of approximately 145 management measures, resolutions, recommendations, and/or events impacting the fishery between 1959-2021 (Appendix. A.1). This is composed of 63 domestic measures (44%), 64 international measures (44%) and 18 measures that are classified as “Other” (12%). This can be further divided by organization; DFO – 52 (36%), Industry Led – 11 (8%), COSEWIC – 2 (1%), ICCAT – 44 (30%), and CITES/CMS – 18 (13%). Additionally, the types of change are divided into 5 categories: 61 are regulation (42%), 9 are gear type (6%), 18 are spatial change (12%), 10 are qualitative observation (7%), and 47 are bycatch mitigation (33%). See figure 2.1 for the full breakdown of the results (Fig. 2.1a, b, c).

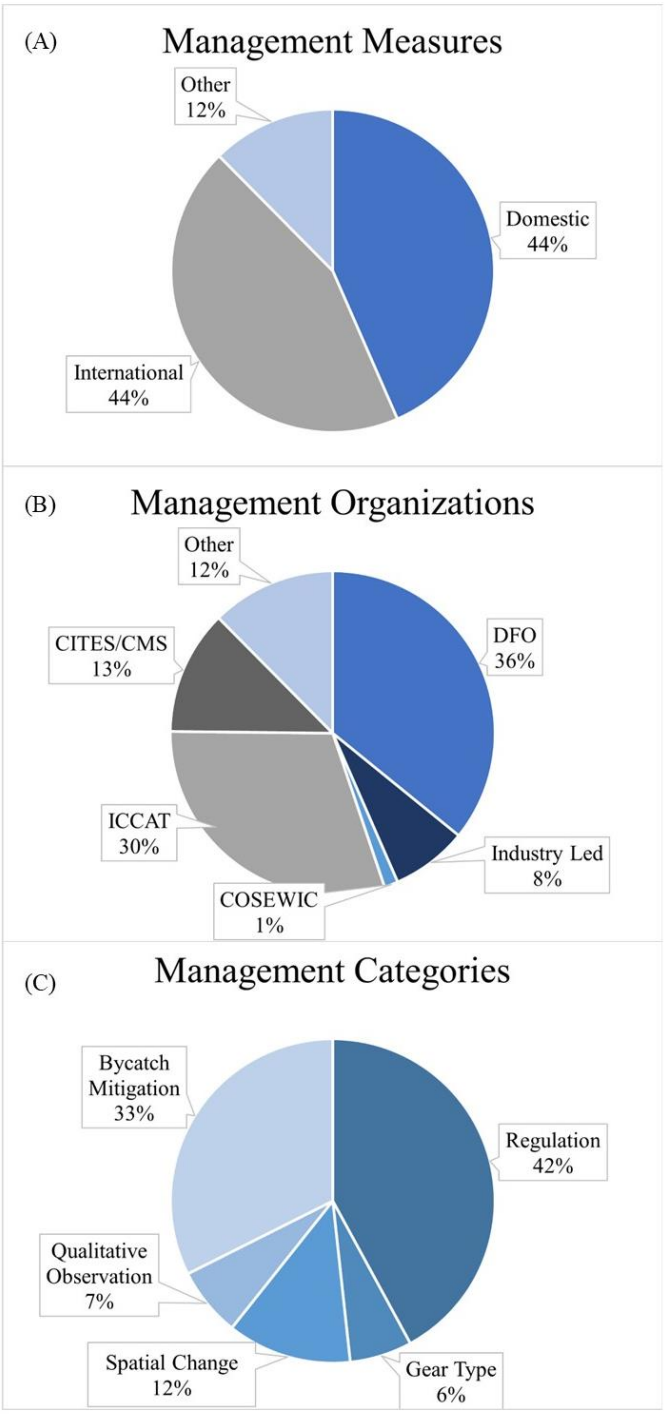

Figure 2. 1 – Breakdown of Canadian NATL SWO timeline components, including (A) scale of change (International, Domestic), (B) management organization (DFO, SHA, COSEWIC, ICCAT, UNEP), and (C) type of management change (Regulation, Gear Type, Spatial Change, Qualitative Observation, Bycatch Mitigation) between 1959-2021.

2.3.2 Regulation

Out of 145 timeline events, 61 are categorized as regulation changes (Fig. 2.3). Within this type of change, there are both domestic regulations (DFO, Industry Led, Other) and international regulations (ICCAT). Domestic organizational bodies focus on the Canadian fleet, with input from the international management organizations. International organizational bodies provide regulations for all nations impacting the NATL SWO fishery.

There are a number of domestic regulation changes over the years that could impact the behaviour of the Canadian fleet in the NATL SWO fishery. The first regulation change to impact the Canadian fleet was a reduction in the allowable mercury content in swordfish in the 1970's. In 1972, both Canada and the US prohibited the sale of swordfish with a mercury concentration higher than 0.5ppm (Caddy, 1976; Fitzgerald, 2000; Hurley & Iles, 1981). Almost all of Canadian-caught swordfish was and still is sold to US markets, so this change ceased all landings of swordfish for Canada (Fitzgerald, 2000; Hurley & Iles, 1981). This reduction in Canadian fishing activity is reflected in the catch data (Fig. 2.2); however, some Canadian fishermen did continue to fish and transferred swordfish to other CPC fishing vessels, most notably the US (Fitzgerald, 2000; ICCAT, 2017b). In 1978, the US raised the acceptable level of mercury in the tissue of swordfish and the Canadian fishery reopened (DFO, 1988; Fitzgerald, 2000). In 1979, the first Canadian TAC was established for the SWO fishery at 3500t (DFO, 1987, 1988; Hurley & Iles, 1981). In 1987, 60t of the SWO quota was granted to two exploratory tuna vessels each year until stated otherwise, the number of longline licences was limited to 70, and SWO longline licence holders were permitted to retain all tunas (excluding bluefin) (DFO, 1987, 1988). In 1991, DFO further reduced the Canadian TAC to 2000t (DFO, 1993, 2000) and in 1994, fishing logbooks became mandatory to be submitted to DFO (Andrushchenko et al., 2014; DFO, 2000). In 1995, DFO increased the number of longline licences to 77, reduced the TAC for SWO bycatch in offshore tuna fisheries from 60t to 10t, and implemented a regulation where the SWO fishery may temporarily close if 75% of the TAC is reached (DFO, 1995). In 1997, fishing a SWO longline licence concurrently with a bluefin tuna licence was prohibited, other than in NAFO subarea 3 (DFO, 1997).

In 1999, DFO implemented a trip-limit where longline trips earlier than July were required to direct for other tunas and only take swordfish if caught as incidental catch (Andrushchenko et al., 2014; DFO, 2000). The final ratio landed had to be 1 swordfish:4 tunas. After July 1st, vessels could direct for swordfish until 75% of the quota had been reached, at which point, the ratio would be reinstated (Andrushchenko et al., 2014). A key change introduced in 2000 was the introduction of gear-based allocations (DFO, 2000). The Canadian TAC was divided; 10% for the harpoon sector and 90% for the longline sector (DFO, 2000; SHQ Swordfish Harpoon Quota Society, 2018). Additionally in 2000, it was permitted to fish a SWO longline licence concurrently with a bluefin tuna licence (DFO, 2000).

In 2002, DFO ended the trip-limit regulation in longline sector and introduced an ITQ system (Andrushchenko et al., 2014). The ITQ system, regulated by DFO, allotted licence-specific quotas to mitigate the risk of exceeding the allocated quota (Andrushchenko et al., 2014). The allocation scheme followed two methods: (1) 50% of the longline quota was equally split amongst all 77 licence holders, and (2) 50% of the quota was based off of previous catch data. The previous catch data was calculated using the best 5 years of landings out of the previous 20 years for each individual licence holder (T. Atkinson & C. MacDonald, personal communication, January 24, 2022). Additionally in 2002, the harpoon fishery defined two different licence types; Harpoon licence A and B (DFO, 2000; SHQ Swordfish Harpoon Quota Society, 2018). If there is unused quota for B licences, that portion is first transferred to the harpoon licence A holders, then if still unused, the quota is transferred to the longline sector (SHQ Swordfish Harpoon Quota Society, 2018). In 2003, measures to record and account for dead discards in the swordfish fishery were implemented (DFO, 2004). Next, in 2005, a regulation was implemented that required swordfish and other tuna longline vessels to have 100% VMS coverage (DFO, 2004). In 2012, SHQ introduced an internally regulated quota system that is licence-specific and based off personal catch history for each harpooner (DFO, 2016; SHQ Swordfish Harpoon Quota Society, 2018). In 2013, it was again prohibited to fish a SWO longline licence concurrently with a bluefin tuna licence, other than in NAFO subarea 3 (DFO, 2013).

In addition to domestic regulations, there are a number of international regulations implemented between 1990-2021 that impact the NATL SWO fishery. In 1990, the first ICCAT recommendation for the NATL SWO (Rec. 90-02) was implemented with the objective to protect small swordfish by establishing a minimum size limit of 25kg or 125cm with a 15% tolerance (ICCAT, 1990). The tolerance allowed for swordfish smaller than the limit to be retained, as long as the number of fish smaller than 125cm/25kg was less than 15% of the total swordfish catch per landing (ICCAT, 1990; Neilson et al., 2013). In 1994, Rec. 94-14 established quotas for the CPCs with the highest catches of swordfish: Canada, United States, Portugal, and Spain. Canada was allocated 1500t for 1995 and 1400t for 1996 (ICCAT, 1994). In 1995, Rec. 95-10, implemented an alternative minimum size limit of 119cm with 0% tolerance (ICCAT, 1995b). Additionally, Rec. 95-11 established percentage allocations for the major CPCs fishing for swordfish based of recent catch data, allocating Canada 10% of the overall TAC from 1997 onwards (ICCAT, 1995c; Neilson et al., 2013).

Next, three recommendations were established in 1996 that impacted the NATL SWO fishery. First, Rec. 96-01 is specific to Tropical Tunas, but this recommendation required a national observer program for longliners, which set the minimum acceptable level of at-sea observers to 5% (ICCAT, 1996a). Second, Rec. 96-07 established a TAC for Canada at 1130t, 1100, 1070, for 1997, 1998, and 1999, respectively (ICCAT, 1996b). Thirdly, Rec. 96-14 was established in 1996 to promote compliance and requires CPCs exceeding their quota to report to the compliance committee and the reduction in future catches to account for the overages (ICCAT, 1996c). In 1999, Rec. 99-02 recommended each CPC establish a 10-year recovery plan for the NATL SWO. This recommendation followed the SCRS 1999 stock assessment that indicated the stock was still overfished and overfishing was ongoing (ICCAT, 1999a; Knapman et al., 2017; Neilson et al., 2013). Furthermore, this recommendation emphasized the need to protect small swordfish to achieve conservation objectives and established the lowest TAC for Canada to date: 1018t (DFO, 2000; ICCAT, 1999a). In 2002, Rec. 02-02 established the international TAC of 14 000t for 2003, 2004, and 2005, and Canada's allocation of the NATL SWO TAC increased from 10% to 10.52%. Canada received 1338t for 2003, and 1348t for 2004 and 2005, with an addition 25t each year transferred from the US (ICCAT, 2002a). Between 2006 and 2018, ICCAT recommendations (Rec.06-02, 10-02, 11-02, 13-02, 16-03, 17-02)

focused on adjusting the swordfish TAC, including transfers between CPCs (ICCAT, 2006a, 2010a, 2011a, 2013a, 2016, 2017a). Canada's TAC was established at 1348t in 2006 (Fig. 2.3); however, this total has had increases in some years through small quota transfers from other CPC members of ICCAT including Senegal, Japan, USA, and Chinese Taipei (ICCAT, 2006a). Overall, the regulation changes in the Canadian NATL SWO fishery between 1970-2021 are mainly composed of changes in TAC allocations and international minimum size limits (Fisheries and Oceans, 2021; ICCAT, 2021b).

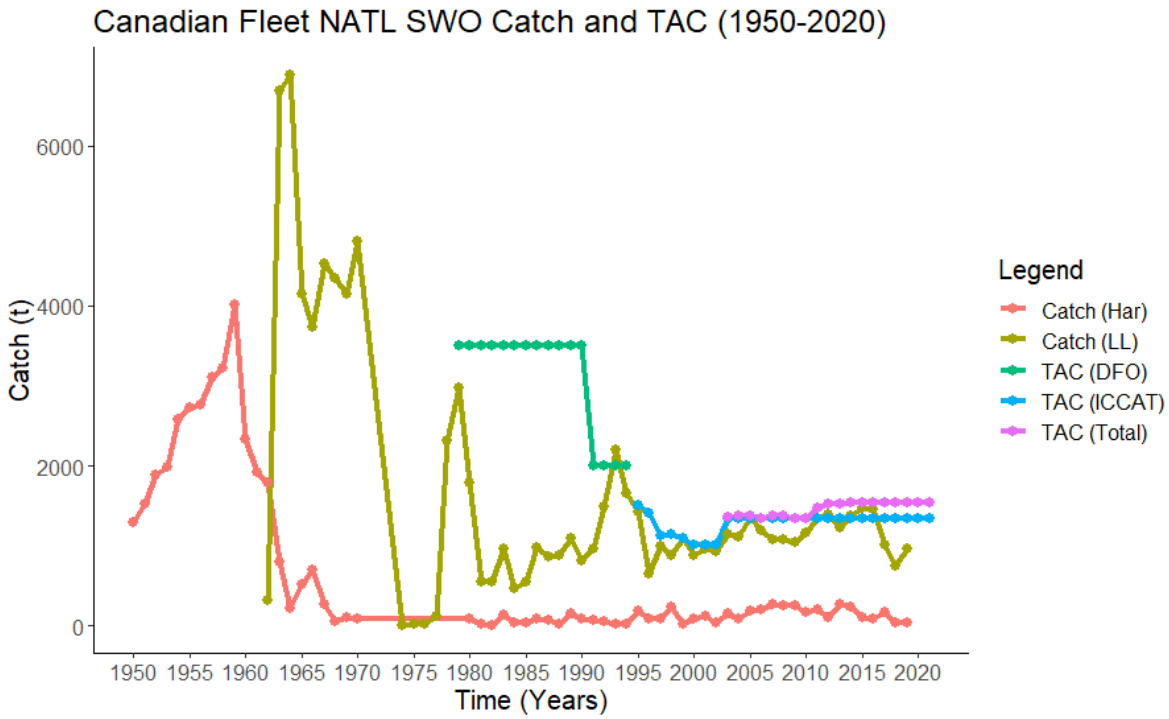

Figure 2. 2 – Catch data and TAC for the Canadian NATL SWO fishery from 1950-2020. Both harpoon (red) and longline (yellow) catch history included. Canadian TAC allocated by DFO between 1978-1994 (green) and allocated by ICCAT between 1995-2020 (blue) shown. International TAC adjusted to include transfers from other CPCs included (purple). Source: ICCAT Task I database (ICCAT, 2021a).

Figure 2. 3 – Regulation changes impacting the Canadian North Atlantic Swordfish Fishery (1972-2018). International ICCAT recommendations and resolutions shown in blue; DFO and other domestic regulations shown in black. Canadian TAC organized by DFO. Acronyms: BFT – Bluefin Tuna; CPC – Contracting Parties, and non-Contracting Parties, Entities or Fishing Entities; ITQ – Individual Transferrable Quota; LL – Longline; NAFO – Northwest Atlantic Fisheries Organization; SWO – Swordfish; TAC – Total Allowable Catch; VMS – Vessel Monitoring System. References provided in Appendix A.

2.3.3 Gear Type

Between 1962-2021, several changes in gear type and selectivity have impacted the NATL SWO fishery (Fig. 2.4). There are two main gear types fishing Canadian SWO: harpoon and longline (DFO, 2016; Fitzgerald, 2000; Hurley & Iles, 1981). Harpooning swordfish began in the North Atlantic in 1880 (Caddy, 1976; DFO, 2013; Hurley & Iles, 1981). Up until the introduction of longlining, the Canadian NATL SWO fishery was exclusively harpoon (Fitzgerald, 2000; Hurley & Iles, 1981). The harpooners typically fish between July and August, when large female swordfish bathe in the sun at the surface of the water (Fitzgerald, 2000; Hurley & Iles, 1981; Tibbo et al., 1961). Over the years, the harpoon sector has experienced relatively little change in gear specific to the harpoon equipment itself. Overall, the swordfish fishery has undergone large advancements in fishing finding and targeting technologies that have improved the ability to catch swordfish for both the harpoon and longline sectors (Fitzgerald, 2000; Palomares & Pauly, 2019; SHQ Swordfish Harpoon Quota Society, 2018; Stone & Dixon, 2001; Ward & Hindmarsh, 2007). See figure 2.5 for a diagram of the harpoon and longline gear used in the NATL SWO.

Longlining was introduced in the Canadian fleet in 1962 after swordfish were reported as incidental catch in foreign longline vessels directing for tuna (Caddy, 1976; Fitzgerald, 2000; Hurley & Iles, 1981). The next major gear change came in the early 1980's, when the majority of Canadian longline vessels started using monofilament materials for the main lines and gangions, rather than multifilament (Stone & Dixon, 2001). This change was motivated by higher catches reported by fishermen using monofilament (Fitzgerald, 2000; Stone & Dixon, 2001). Unlike multifilament, monofilament is thinner and transparent making it harder for the fish to see and, since swordfish are visual predators, this is an important characteristic to consider (Stone & Dixon, 2001). Fishing vessel technology underwent significant change beginning in the 1980s and 1990s with the introduction of geo-positioning systems, fishing finders, and access to environmental remote sensing data. Additionally, refrigerated fish holds became more common in the 1980s, which allowed for vessels to increase the length of their trips and go further than before (T. Atkinson, personal communication, August 10, 2021). In 1993, DFO restricted the NATL SWO fishery to only longline and harpoon gear types for fishing (DFO, 1993). In 1996,

there was a shift in the longline sector from J-hooks to circle hooks; however, this was not a mandatory regulation and rather influenced by the change in the US requirements for selling swordfish (DFO, 2004). Additionally, circle hooks mitigate bycatch of some species and improve survivability for some species after release (DFO, 2004). It wasn't until 2012 that circle hooks were made mandatory and added to Canadian licencing conditions (corrodible circle hooks added in 2013) (DFO, 2004; Fisheries and Oceans, 2012, 2013). In 2011, dehooking or disentanglement gear for sea turtles became required if the vessel was using longline gear (Fisheries and Oceans, 2011). Finally, the most recent gear change was made in 2021, with the introduction of angling, handline, and buoy gears as an option for longline licence holders (Fisheries and Oceans, 2021). The gear cannot be used during the same fishing trip as longline gear, but it does offer an alternative method for landing swordfish and may be beneficial to those licence holders with smaller quotas (Fisheries and Oceans, 2021).

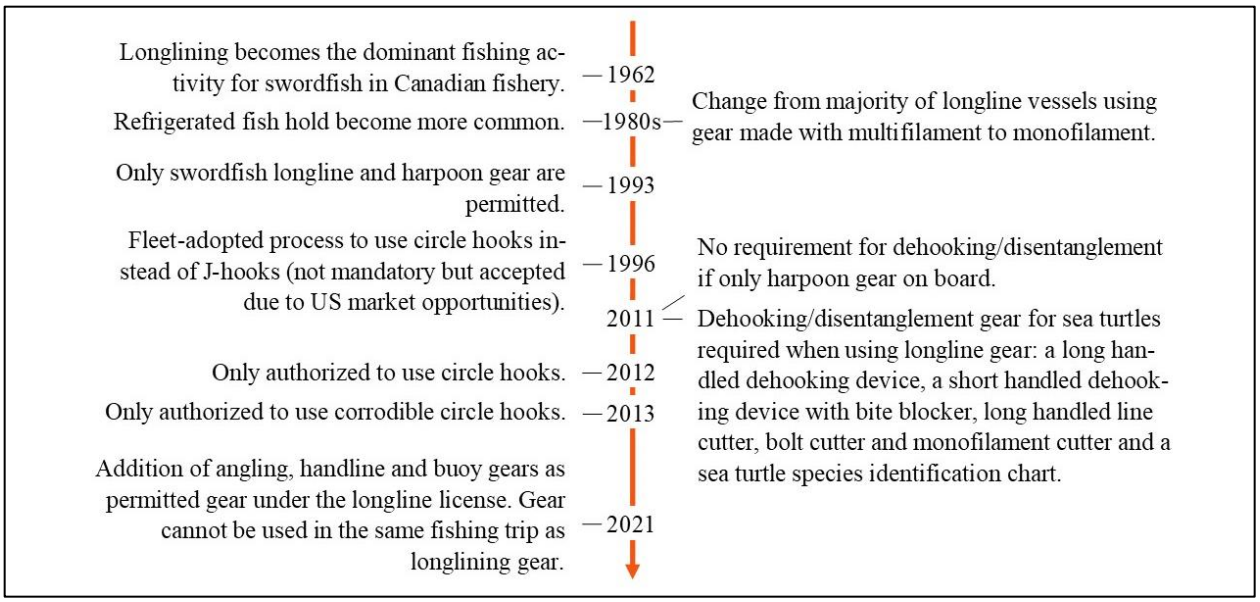

Figure 2. 4 – Gear changes impacting the Canadian North Atlantic Swordfish Fishery (1962-2021). All changes are domestic. References provided in Appendix A.

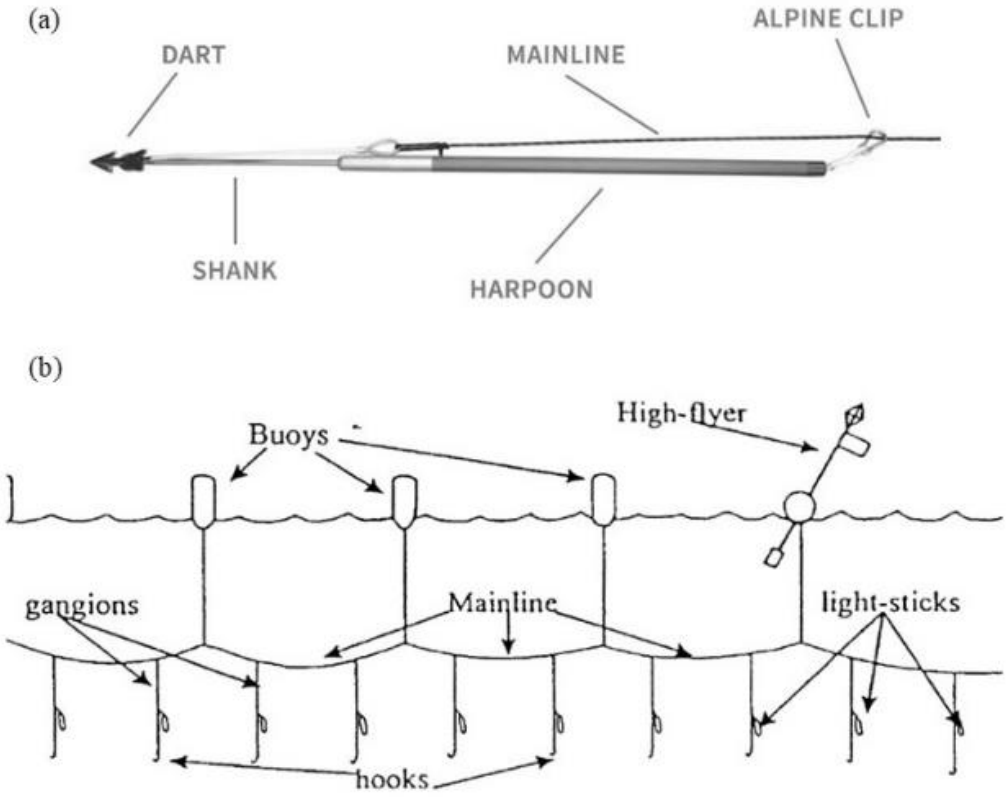

Figure 2. 5 – Diagram of Longline and Harpoon used in Canadian North Atlantic Swordfish Fishery. (a) Harpoon diagram (FishTrack, 2021), (b) Longline diagram (Sea Grant, 2011).

2.3.4 Spatial Change

Between 1967-2019, there have been changes impacting the spatial footprint of the NATL SWO fishery such as seismic activity, oil and gas exploration, time/area closures, and marine protected area (MPA) establishment (DFO, 2005) (Fig. 2.6). Oil and gas exploration is regulated by the Federal Department of Energy, Mines and Resources (DFO, 2005). The time/area closures and MPAs are implemented by DFO, and the fishery is informed of these changes through licence conditions (DFO, 2013; Fisheries and Oceans, 2021).

There are a number of oil and gas activities on the Scotian Shelf that impact the Canadian NATL SWO fishery (Fig. 2.7) (DFO, 2005, 2017a). The main impact discussed with industry on the longline fishery is reduced fishing success in the vicinity of exploratory seismic activity (T. Atkinson, personal communication, August 10, 2021). Fishing areas would be closed temporarily to allow for exploratory seismic activity, which would impede the ability for the longline fleet to fish in that area (T. Atkinson, personal communication, August 10, 2021). In 1967, the first exploratory well was drilled on Sable Island for oil and gas exploration (DFO, 2005, 2017a). This was the beginning of several discoveries in the area and led to the development of some offshore energy projects (DFO, 2005). In 1988, a moratorium on petroleum exploration of Georges Bank was established (DFO, 2005). Next, in 1992, the Cohasset-Panuke Project (COPAN) started production as the first offshore energy project on the Scotian Shelf (DFO, 2005). 7 years later, in 1999, the Sable Offshore Energy Project (SOEP) began production (DFO, 2005).

Since the beginning of the longlining sector, there have been spatial management changes that impact the activity of the Canadian NATL SWO fishery (Fig. 2.8). The first significant change was in 1977 when Canada extended its exclusive economic zone (EEZ) from 12nm to 200nm (Applebaum, 2001; Fleury, 2013). Within this border, there are very productive fishing grounds and this change reserved the area for Canadian fisheries, reducing competition with other nations (Applebaum, 2001; DFO, 2005, 2016). In 1987, SWO licences were valid in NAFO Convention Subareas 3, 4, and 5, excluding the Gulf of the St. Lawrence and the Bay of Fundy (subareas 1 and 2) (DFO, 1987). Another important change was the establishment of Saint-Pierre and Miquelon's EEZ in 1992 with an unusual spatial footprint (Fleury, 2013). The

reasoning behind the unique shape of this EEZ was to allow for French vessels to travel to the islands without traversing the Canadian EEZ. However, only 4 years later, Canada adjusted the boundary of it's EEZ in 1996 using Sable Island as a base, which extended the EEZ to surround the Saint-Pierre and Miquelon's EEZ (Fleury, 2013). Next, in 1995, the area West of the 65˚30' longitude line was closed to longlining activities earlier than August 1st, in an effort to reduce bluefin tuna bycatch (DFO, 1995). Additionally in 1995, the Broodstock closure area was established to address concerns of bluefin tuna bycatch (DFO, 1995). The longlining restrictions in place in the Broodstock closure were removed in 2001 and the Bluefin Exclusion Zone was established and closed to longlining gear (DFO, 2004). In 2003, the exclusion zone referred to as "the Hell Hole" was established and closed to longlining gear, also in an effort to reduce bycatch of bluefin tuna (DFO, 2004). In 2005, the restriction in the area West of the 65˚30' longitude line were removed (DFO, 2004). In 2018, DFO authorized a test fishery to start in the Hell Hole for 30 longline sets, with 100% observer coverage. It was determined that bycatch levels are too high, therefore, restrictions in the exclusion zone remain (C. MacDonald, personal communication, September 21, 2021). In 2019, the Bluefin Exclusion Zone was extended to fill a gap in protection at Sherbrook, NS (Fisheries and Oceans, 2019).

Since 2004, there have been 3 MPAs proposed and implemented in the Canadian Atlantic (Fig. 2.10), starting with the Gully Marine Protected Area (MPA) (DFO, 2004). In 2004, the Gully MPA was established and is located East of Sable Island, on the edge of the Scotian Shelf (DFO, 2004, 2017b). Zone 1 of the Gully MPA is completely closed to fishing activities and composes an area of 475 km^2 (DFO, 2017b). Longlining and harpooning swordfish is permitted in Zones 2 and 3 of the MPA but fishing activity must comply with the conditions of the licence and not damage the habitat (DFO, 2017b). Next, in 2018, the St. Ann's Bank MPA was established off the coast of Cape Breton and Zone 1 (total area of 3310 km^2) is closed for fishing activities (DFO, 2019b; Fisheries and Oceans, 2018). Zones 2, 3, and 4 of the St. Anne's Bank MPA are open to bottom longlining and harpooning (DFO, 2019b). Finally, in 2019, the Laurentian Channel MPA was established and both Zone 1 and 2 are closed to all fishing activity (DFO, 2019a; Fisheries and Oceans, 2019). This MPA is a total of 11,619 km^2 and is located between Cape Breton and Newfoundland and Labrador (DFO, 2019a).

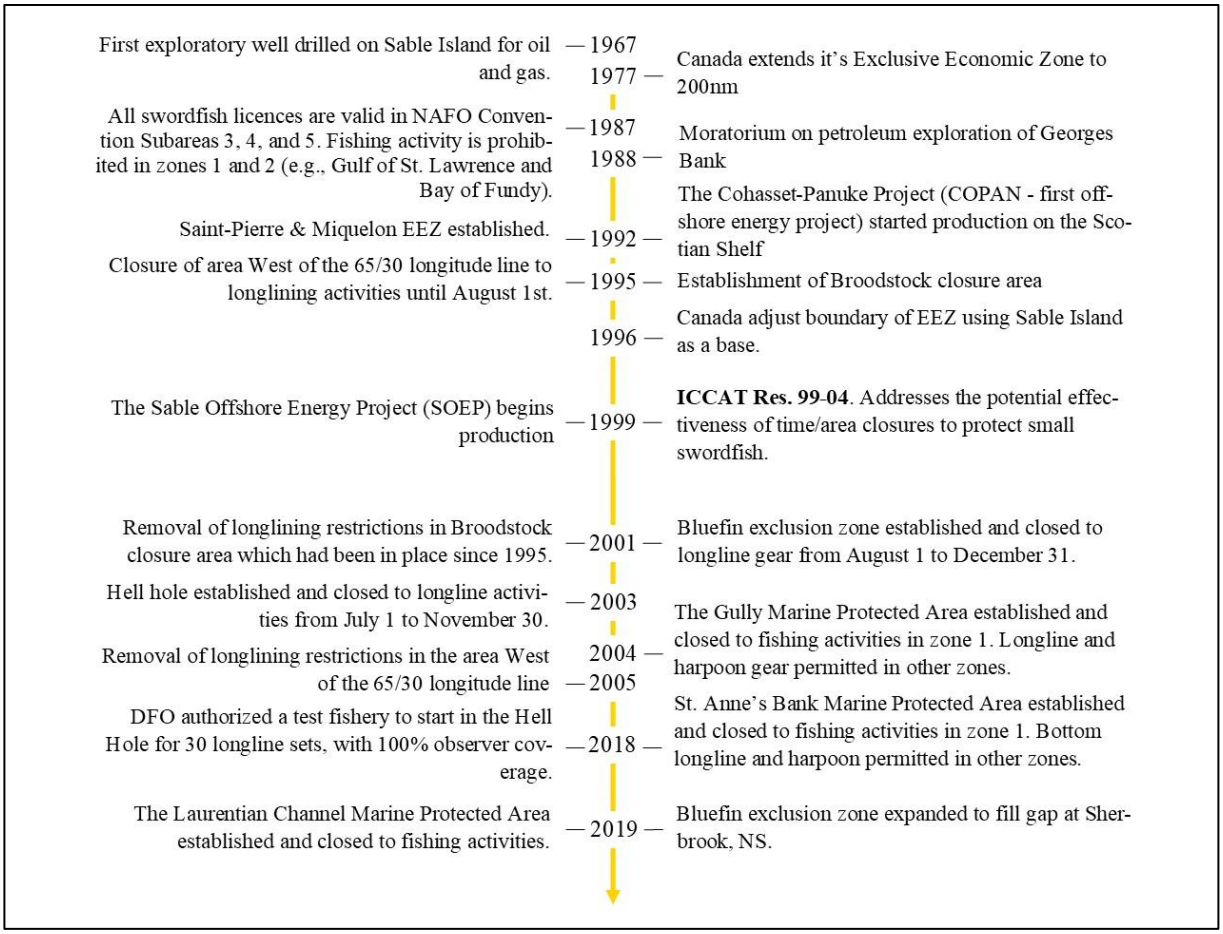

Figure 2. 6 – Spatial changes impacting the Canadian North Atlantic Swordfish Fishery (1967-2019). Changes composed of both international and domestic changes. International (ICCAT) are bolded. Acronyms: EEZ – Exclusive Economic Zone; NAFO – Northwest Atlantic Fisheries Organization. References provided in Appendix A.

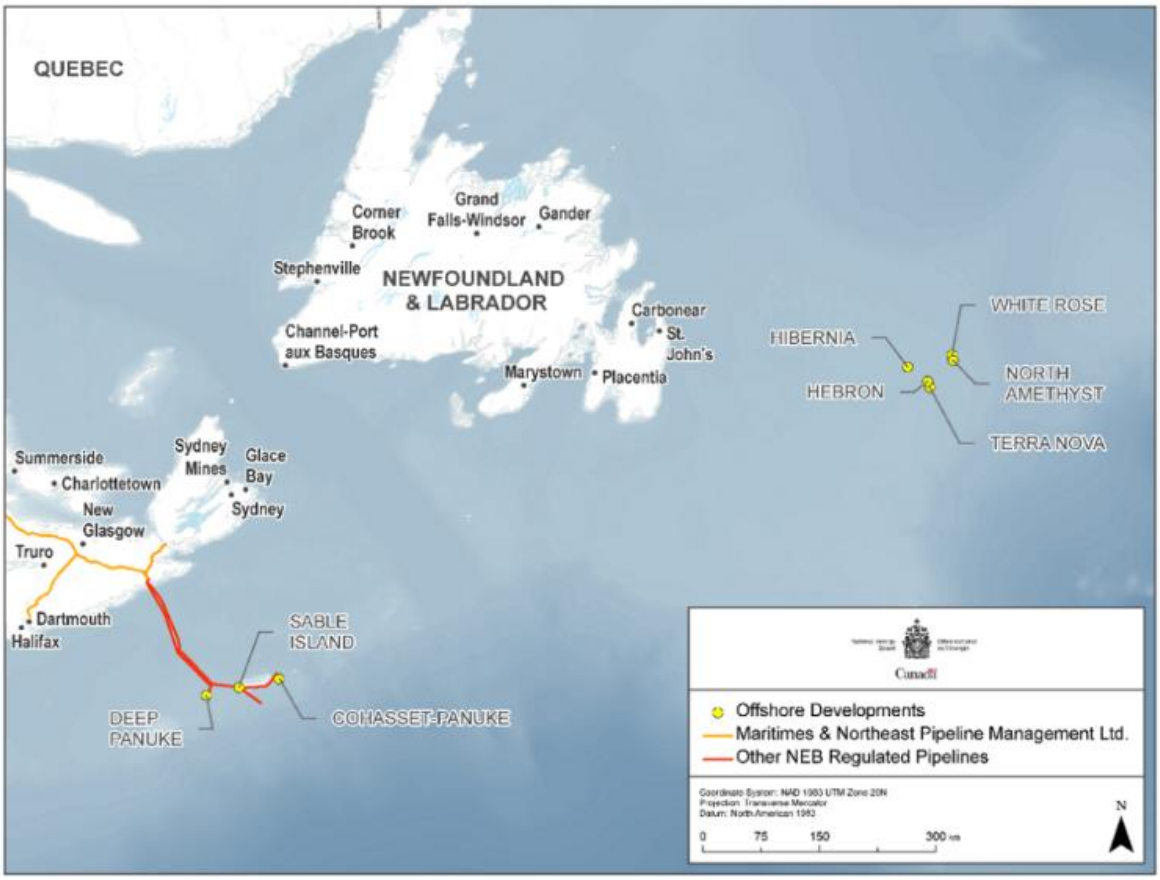

Figure 2. 7 – Map of offshore oil and gas sites in the Canadian Atlantic (DFO, 2017a). Offshore developments are represented by yellow circles (Deep Panuke, Sable Island, Cohasset Panuke), pipelines represented by orange or red lines.

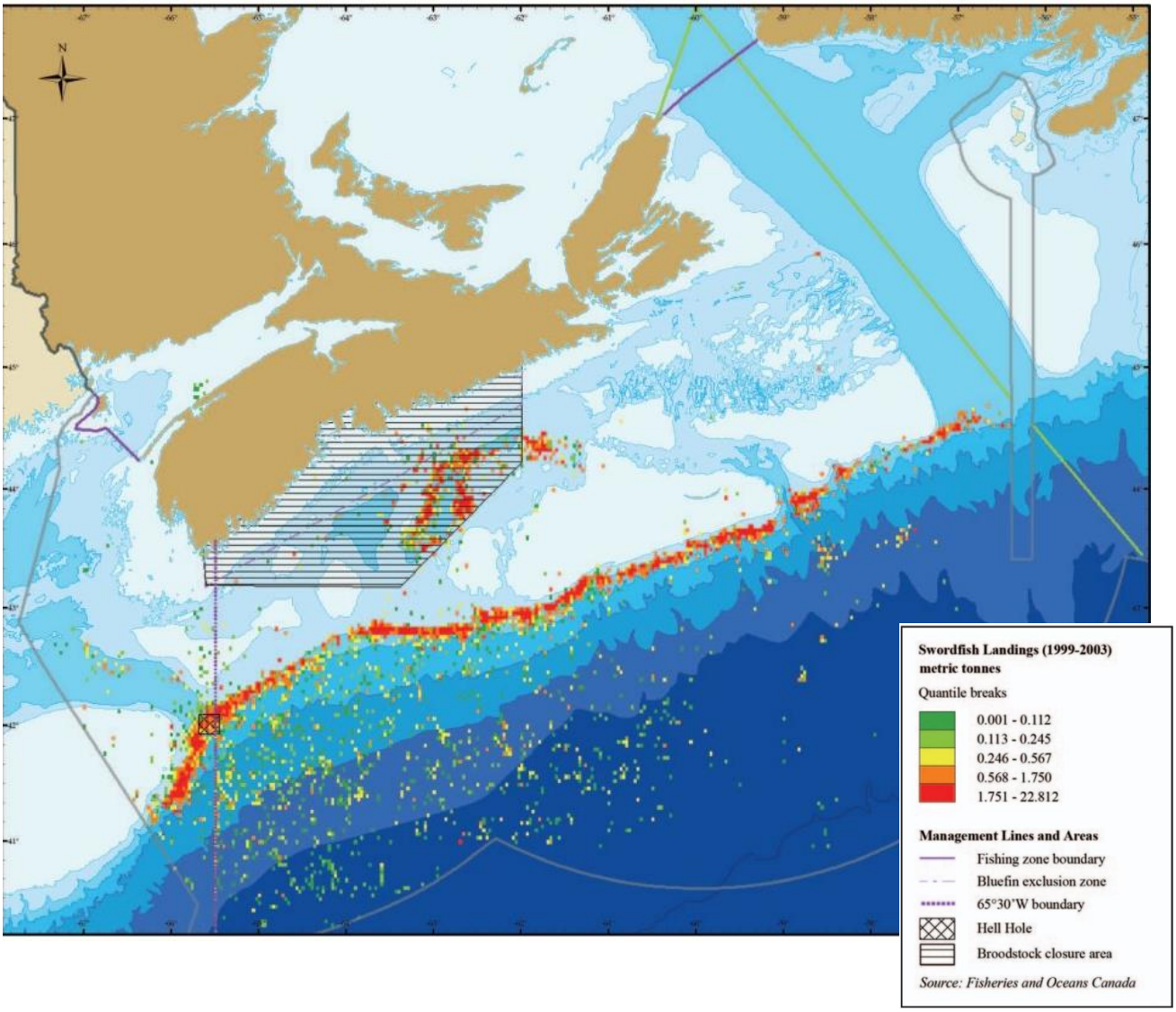

Figure 2. 8 – Map of time/area closures in the Canadian Atlantic (DFO, 2005). The swordfish landings for the Canadian North Atlantic Swordfish Fishery (1999-2003) shown in green, yellow, orange, and red. Green dots represent lower and red dots represent higher catch in metric tonnes. Fishing zone boundary shown as solid line, the Bluefin Exclusion zone is shown by large, dashed line, Broodstock closure area represented by diagonal line box on NS shoreline, the 65˚30˚W boundary shown as small, dashed line, and the closure area referred to as the "Hell Hole" is shown as a small box with crossing diagonal lines.

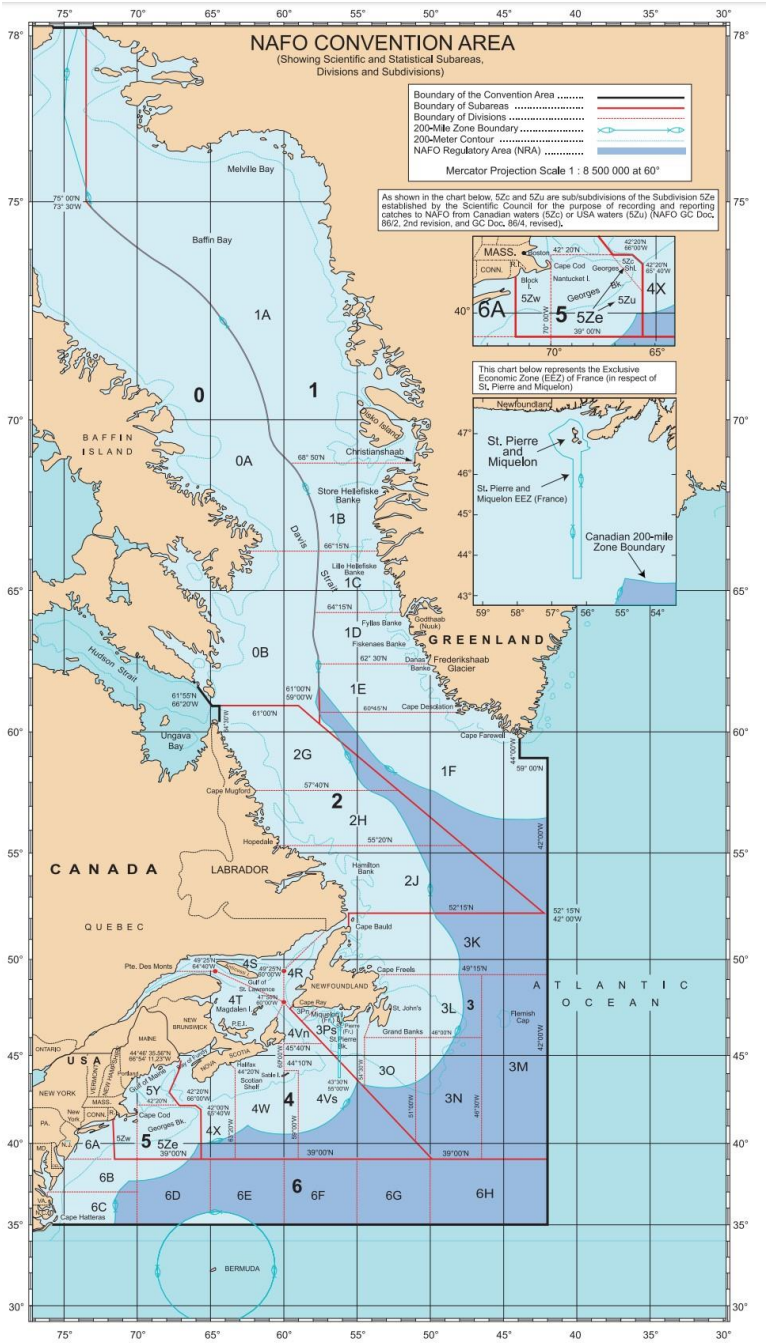

Figure 2. 9 – A map of NAFO convention zones 0-6 (NAFO, 2015). Note that the Gulf of the St. Lawrence and the Bay of Fundy are not official NAFO zones, but are considered smaller "fishing zones" and the use of the swordfish licence to fish within those areas is prohibited (DFO, 1987).

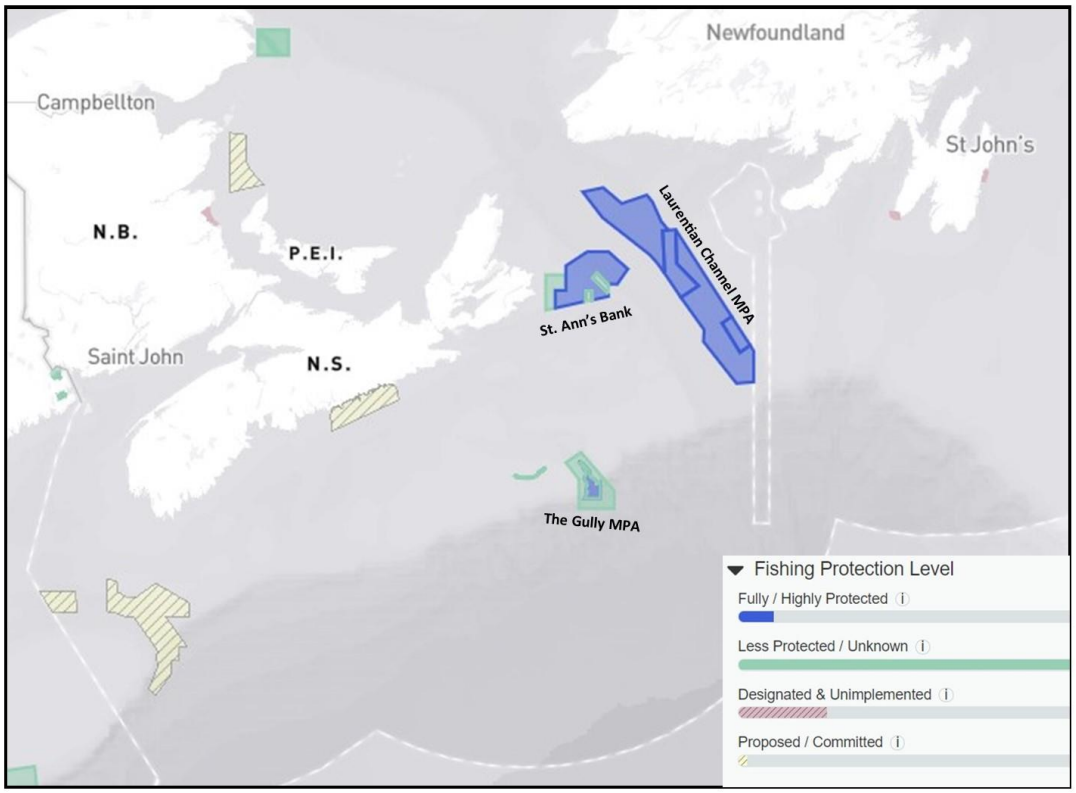

Figure 2. 10 – Marine Protected Areas (MPAs) in the Canadian Atlantic (Marine Conservation Institute, 2021). Three MPAs are highlighted; the Laurentian Channel, St. Anns Bank, and the Gully. Fully protected zones of MPAs shown in dark blue, less protected zones of MPAs shown in green. Areas of Interests (AOIs) or proposed protected areas shown in yellow.

2.3.5 Qualitative Observation

Throughout the history of the Canadian SWO fishery there have been events important to it's growth and development (Fig. 2.11) (Caddy, 1976; Fitzgerald, 2000; Hurley & Iles, 1981). Beginning in 1959, the first offshore exploration permit was issued to Mobil Oil Canada, which led to additional discoveries of oil and gas and later, offshore projects (DFO, 2005, 2017a). At this time, there were disputes between Nova Scotia and Canada over rights to oil and gas exploration (DFO, 2005). By 1966, the Federal Department of Energy, Mines and Resources assumed administrative authority (DFO, 2005). After the first exploratory well was drilled on Sable Island in 1967, a significant discovery of natural gas by Shell Canada was made on the Scotian Shelf (just south of Sable Island) in 1972 (DFO, 2005). The development of the oil and gas industry on the Scotian Shelf between 1950s-80s was associated with large advancements in technology to locate areas of potential petroleum reserves (CAPP, 2021; DFO, 2005). The process of locating reserves involves seismic surveys of potential petroleum reserves. The occurrence of seismic activity in an area would require temporary closure of the area to fishing which would displace the swordfish fleet (T. Atkinson, personal communication, August 10, 2021).

Additionally, the opening and closing of both lobster and deer hunting seasons could impact the swordfish fishery. There is an overlap between the fishermen who target swordfish or lobster, as well as the hunters for terrestrial mammals or birds in the fall. Depending on which activity is more profitable, the participants have the option to switch activities as a result of the variable timing of each of these seasons throughout the year (T. Atkinson, personal communication, August 10, 2021). In 1997, observer data reported discards of blue shark exceeding the catch of swordfish (in both numbers and weight) (Fitzgerald, 2000). In 2011-2014, blue shark still composed approximately 40-50% of the overall observed catch in the swordfish longline fleet (Knapman et al., 2017). With the help of regulations and quota allocations, both the harpoon and longline fishery received the MSC certification in 2010 and 2012, respectively (Knapman et al., 2017). In 2019, an amendment to the ICCAT convention, known as the Palma de Mallorca Protocol, was announced that would allow ICCAT to oversee protection of highly migratory shark species in the NATL. This amendment was ratified in 2019 in the US and in

2021 in Canada. Once 50% of CPCs ratify it at the national level, the amended ICCAT Convention will come into effect (ICCAT, 2021b).

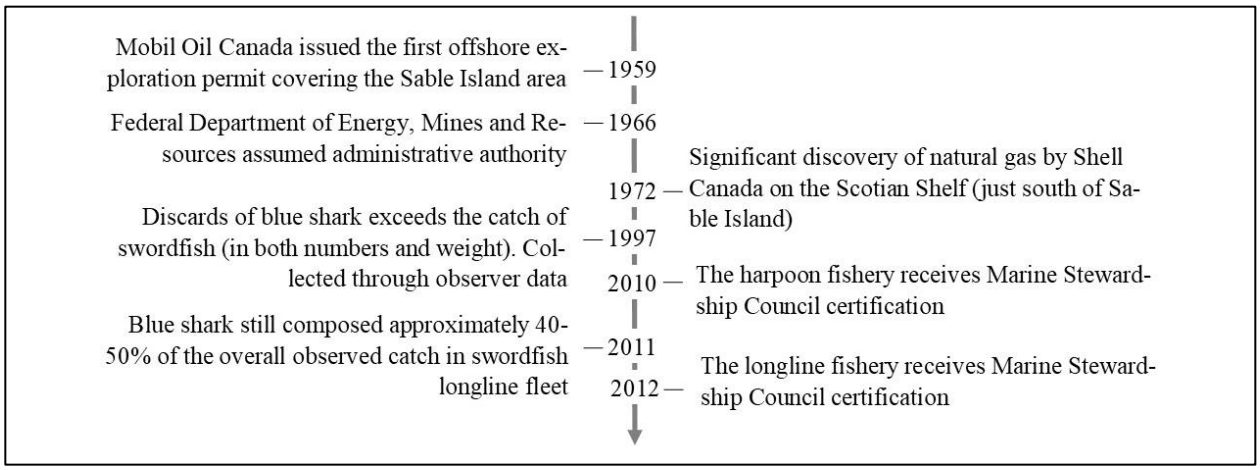

Figure 2. 11 – Qualitative observations impacting the Canadian North Atlantic Swordfish Fishery (1959-2012). All qualitative changes are domestic. References provided in Appendix A.

2.3.6 Bycatch Mitigation

Over the years there have been a number of species listings to improve protection of vulnerable species (Fig. 2.12). These listings are produced from conventions, committees, and Acts such as Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES), Convention of Migratory Species (CMS), the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and Species at Risk Act (SARA). First, CITES is focused on the trade of protected species with two Appendices' listings: Appendix I refers to species at risk and commercial trade is generally not permitted, and Appendix II refers to species that need controls to protect them and commercial trade is possible with permits (UNEP-WCMC, 2021a). Second, CMS focuses on the protection of migratory species with two Appendices' listings: Appendix I is specific to species that are in danger of extinction throughout most or all of their migratory range and any Parties within this range must take strict measures to protect the species, and Appendix II is specific to species identified with unfavorable status in terms of conservation and may require international cooperation to establish protection measures (UNEP-WCMC, 2021b). Third, COSEWIC is an advisory panel to Environment and Climate Change Canada to

assess the status of wildlife species, and species listed are in danger of extinction (COSEWIC, 2021). Last, SARA listings are a part of Canada's strategy to protect vulnerable wildlife (DFO, 2016). It is unlikely that these listings have significant impacts on the domestic catch rates or fleet behaviour because many of the species are not retained for trade, and measures to mitigate bycatch were already in place prior to the listing. All species listings can be found in Figure 2.12.

In addition to these listings, DFO implements bycatch mitigation regulations for the Canadian NATL SWO fishery. In 1995, it became prohibited to remove only fins from a retained shark (DFO, 1995). Fins can be removed, as long as the number of shark fins removed from a shark carcass do not exceed 5% of the total landed sharks (DFO, 1995). In 2012, it became prohibited to retain white shark (*Carcharodon carcharias*), all other species of shark were still permitted at the time (Fisheries and Oceans, 2012). In 2014, bigeye thresher (*Alopias superciliosus*), hammerhead (*Sphyrna mokarran*), oceanic whitetip (*Carcharhinus longimanus*), and silky sharks (*Carcharhinus falciformis*) were added to the list of sharks that cannot be retained (Fisheries and Oceans, 2014). In 2015, the act of "tail-cutting" to determine fat content of a fish was prohibited until the fish was offloaded and weighed by a dockside monitoring company (Fisheries and Oceans, 2015). In 2016, it became mandatory to release and record all live porbeagle sharks (*Lamna nasus*) (Fisheries and Oceans, 2016). In 2017, it became permitted to retain bluefin tuna only if they would be discarded dead otherwise and bycatch logs became mandatory (Fisheries and Oceans, 2017). In 2018, all tuna species were required to be retained if the tuna were dead when caught, and basking sharks (*Cetorhinus maximus*) were added to the list of sharks that cannot be retained (Fisheries and Oceans, 2018). Moreover, it was prohibited to use harpoon gear to catch porbeagle (*Lamna nasus*) and shortfin mako sharks (*Isurus oxyrinchus*) (Fisheries and Oceans, 2018). In 2020, shortfin mako sharks (*Isurus oxyrinchus*) were added to the list of sharks that cannot be retained, and in 2021, harpooners were prohibited from retaining any shark species (Fisheries and Oceans, 2020, 2021).

Additionally, ICCAT produces international recommendations specifically addressing bycatch. In 2000, Rec. 00-03 addresses SWO bycatch in tuna fisheries, and recommends CPCs allocate a small quota specific to this issue (ICCAT, 2000a). In 2004, the first recommendation (Rec. 04-10) was put in place to improve compliance and reporting of the incidental catch of

sharks (ICCAT, 2004b). Furthermore, CPCs are directed to fully utilize any shark catch and limit the number of fins retained without the full shark attached (ICCAT, 2004b). In 2007, Rec. 07-06 addresses the mortality of porbeagle and shortfin makos and directs CPCs to research nursery areas to avoid (ICCAT, 2007). In 2009, Rec. 09-07 prohibits the retention, transportation, landing, or storing of bigeye thresher sharks (ICCAT, 2009b).

In 2010, four ICCAT recommendations were produced to address shark and sea turtle bycatch concerns. The first, Rec. 10-06, prohibits CPCs that do no report Task I data for shortfin mako sharks from retaining the species (ICCAT, 2010b). The next two prohibit the retention, transportation, landing, or storing of oceanic whitetip and hammerhead sharks (Rec.10-07, Rec.10-08, respectively) (ICCAT, 2010c, 2010d). The fourth, Rec. 10-09, requires CPCs to carry on board vessels safe handling equipment, disentanglement and release equipment to protect sea turtles from harm. Additionally, all sea turtle interactions are to be reported to ICCAT (ICCAT, 2010e). In 2011, Rec. 11-08, prohibited the retention, transportation, landing, or storing of silky sharks; however, this resulted in limited data collection (ICCAT, 2011b). Therefore, in 2013, Rec. 13-10 was implemented so that certain prohibited shark species could be retained in the interest of collecting biological samples with an at-sea observer (ICCAT, 2013b). In 2015, Rec. 15-06 required the release of live porbeagle sharks and this data is required to be recorded (ICCAT, 2015). Finally, in 2019, Rec. 19-06 prohibited the retention of shortfin mako in some situations (ICCAT, 2019b). The major trend seen in the bycatch regulations implemented between 2004-2021 was a focus on sea turtle and shark species (Fisheries and Oceans, 2021; ICCAT, 2021b; UNEP-WCMC, 2021a, 2021b).

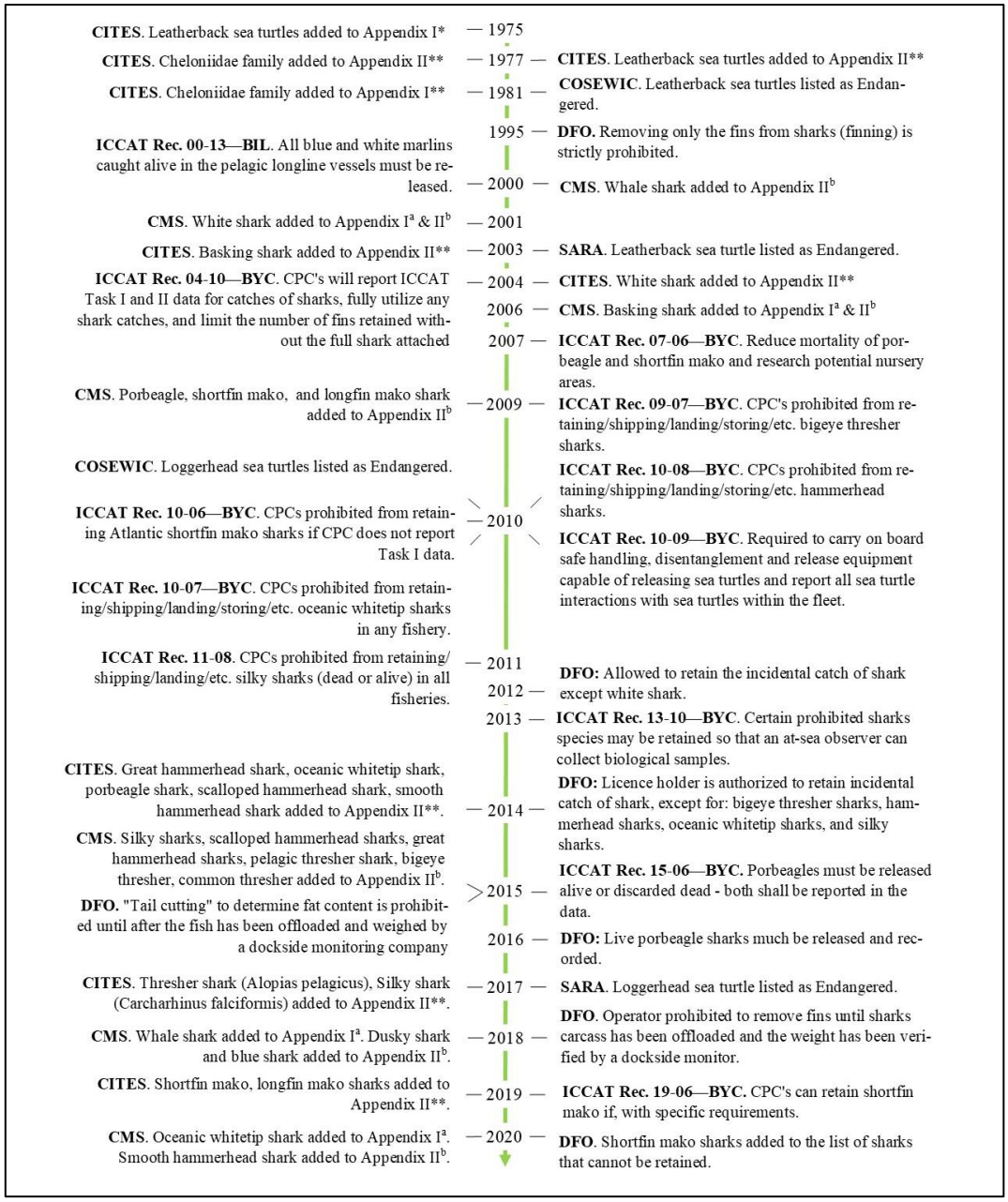

Figure 2. 12 – Bycatch mitigation impacting the Canadian North Atlantic Swordfish Fishery (1975-2021). References provided in Appendix A.

Table 2. 2 – ICCAT Recommendations and Resolutions impacting the Canadian NATL SWO Fishery between 1990-2021.

Key	Title	Year Enforced	Reference
	Regulation Category		
Rec. 90-02 (SWO)	Recommendation by ICCAT for the Conservation of Atlantic Swordfish Stocks	1991	(ICCAT, 1990)
Rec. 94-14 (SWO)	Recommendation by ICCAT for the Management of Atlantic Swordfish	1995	(ICCAT, 1994)
Rec. 95-10 (SWO)	Recommendation by ICCAT Regarding the Implementation of an Alternative Option for the Conservation of Undersized Atlantic Swordfish and the Reduction of Fishing Mortality	1996	(ICCAT, 1995b)
Rec. 95-11 (SWO)	Recommendation by ICCAT to Establish Percentage Shares of Total Allowable Catch (TAC) and Overage & Underage Provisions for Nations Fishing for North Atlantic Swordfish	1996	(ICCAT, 1995c)
Rec. 96-01 (TRO)	Recommendation on Bigeye Tuna & Yellowfin Tunas	1997	(ICCAT, 1996a)
Rec. 96-07 (SWO)	Recommendation by ICCAT Regarding North Atlantic Swordfish Catch Quotas for 1997, 1998, and 1999	1997	(ICCAT, 1996b)
Rec. 96-14 (COM)	Recommendation by ICCAT Regarding Compliance in the Bluefin Tuna and North Atlantic Swordfish Fisheries	1997	(ICCAT, 1996c)
Rec. 99-02 (SWO)	Recommendation by ICCAT to Establish a Rebuilding Program for North Atlantic Swordfish	2000	(ICCAT, 1999a)
Rec. 02-02 (SWO)	Recommendation by ICCAT Relating to the Rebuilding Program for North Atlantic Swordfish	2003	(ICCAT, 2002a)
Rec. 06-02 (SWO)	Supplemental Recommendation by ICCAT to Amend the Rebuilding Program for North Atlantic Swordfish	2007	(ICCAT, 2006a)
Rec. 10-02 (SWO)	Recommendation by ICCAT for the Conservation of North Atlantic Swordfish	2011	(ICCAT, 2010a)
Rec. 11-02 (SWO)	Recommendation by ICCAT for the Conservation of North Atlantic Swordfish	2012	(ICCAT, 2011a)
Rec. 13-02 (SWO)	Recommendation by ICCAT for the Conservation of North Atlantic Swordfish	2014	(ICCAT, 2013a)
Rec. 16-03 (SWO)	Recommendation by ICCAT for the Conservation of North Atlantic Swordfish	2017	(ICCAT, 2016)
Rec. 17-02 (SWO)	Recommendation by ICCAT Amending the Recommendation for the Conservation of North Atlantic Swordfish, Rec. 16-03	2018	(ICCAT, 2017a)

Key	Title	Year Enforced	Reference
	Spatial Category		
Res. 99-04 (SWO)	Resolution by ICCAT for the Development of Possible Time/Area Closures for North and South Atlantic Swordfish and Gear Modifications to Reduce Undersized Swordfish Catch and Fishing Mortality	1999	(ICCAT, 1999b)
	Bycatch Mitigation & Species Protection Category		
Rec. 00-03 (SWO)	Recommendation by ICCAT Concerning Swordfish Catches by the Tuna Longline Fishery	2001	(ICCAT, 2000a)
Rec. 00-13 (BIL)	Recommendation by ICCAT to Establish a Plan to Rebuild Blue Marlin and White Marlin Populations	2001	(ICCAT, 2000b)
Rec. 04-10 (BYC)	Recommendation by ICCAT Concerning the Conservation of Sharks Caught in Association with Fisheries Managed by ICCAT	2004	(ICCAT, 2004b)
Rec. 07-06 (BYC)	Supplemental Recommendation by ICCAT Concerning Sharks	2007	(ICCAT, 2007)
Rec. 09-07 (BYC)	Recommendation by ICCAT on the Conservation of Thresher Sharks Caught in Association with Fisheries in the ICCAT Convention Area	2009	(ICCAT, 2009b)
Rec. 10-06 (BYC)	Recommendation by ICCAT on Atlantic Shortfin Mako Sharks Caught in Association with ICCAT Fisheries	2010	(ICCAT, 2010b)
Rec. 10-07 (BYC)	Recommendation by ICCAT on the Conservation of Oceanic Whitetip Shark Caught in Association with Fisheries in the ICCAT Convention Area	2010	(ICCAT, 2010c)
Rec. 10-08 (BYC)	Recommendation by ICCAT on Hammerhead Sharks (Family Sphyrnidae) Caught in Association with Fisheries Managed by ICCAT	2011	(ICCAT, 2010d)
Rec. 10-09 (BYC)	Recommendation by ICCAT on the By-Catch of Sea Turtles in ICCAT Fisheries	2010	(ICCAT, 2010e)
Rec. 11-08 (BYC)	Recommendation by ICCAT on the Conservation of Silky Sharks Caught in Association with ICCAT Fisheries	2011	(ICCAT, 2011b)
Rec. 13-10 (BYC)	Recommendation on Biological Sampling of Prohibited Shark Species by Scientific Observers	2013	(ICCAT, 2013b)
Rec. 15-06 (BYC)	Recommendation by ICCAT on Porbeagle Caught in Association with ICCAT Fisheries	2015	(ICCAT, 2015)
Rec. 19-06 (BYC)	Recommendation by ICCAT on the Conservation of North Atlantic Stock of Shortfin Mako Caught in Association with ICCAT Fisheries	2019	(ICCAT, 2019b)

2.4 Discussion

2.4.1 Overview

The timeline of management changes impacting the Canadian SWO fishery indicated approximately 145 changes that have occurred between 1959-2021. Of the 145 management and fleet changes impacting the fishery, 34% are related to bycatch mitigation. Additionally, the bycatch mitigation category has the second highest number of management changes out of the five categories. The category with the most changes was regulation changes, which is mainly composed of TAC changes and domestic management measures. There are a number of notable changes which could impact fleet behaviour. In the regulation category, these are the international quota allocations, Canadian gear-based allocations, and introduction of the Individual Transferrable Quota (ITQ) system in the early 2000s. In the gear type category, the introduction of longlining and the shift from J-hooks to circle hooks are of note. In the spatial category, establishment of the exclusive zone called the "Hell Hole" and the first Atlantic MPA called "the Gully" are likely of greatest importance to fleet fishing footprint and potentially to bycatch patterns. In the qualitative category, timing of deer and lobster seasons, and the MSC certification for both the harpoon and longline sectors are likely the most important. In the bycatch mitigation category, the shark listings and regulations implemented between 2009-2019 are the most influential changes because of their potential influence on the temporal pattern and gear choices of the fleet. Overall, this timeline of management measures highlights the number and scale of impacts that management can have on the dynamics within a fishery.

2.4.2 Regulation

Regulation changes composed 39% of the 145 management changes in the Canadian SWO fishery between 1959-2021. Regulation changes are important for improving our understanding of the relationship between fleet behaviour and management because regulations are the most common type of change impacting the fishery. There are three key regulation changes that impacted the Canadian NATL SWO fishery between 1972 and 2018. First, in 1996, ICCAT recommended percentage allocations to the 5 main CPCs targeting swordfish in the North Atlantic; Spain, USA, Canada, Portugal, and Japan (Rec. 95-11) (ICCAT, 1995c). Next, in

2000, DFO regulated the division of the Canadian fleets' TAC into two; 10% for the harpoon sector and 90% for the longline sector (DFO, 2000). Finally, in 2002, the trial and later permanent implementation of the ITQ system in the Canadian longline sector (DFO, 2004). These changes all impacted the dynamics with the Canadian NATL SWO fishery.

In 1996, ICCAT allocated Canada 10% (Rec. 95-11) of the SWO TAC (ICCAT, 1995c). This change followed the SCRS evaluation stating the swordfish stock was less than the biomass needed to produce MSY, and the percentage allocations were created based off recent catch history for each nation (ICCAT, 1995c; Neilson et al., 2013). The objective of this change was to rebuild the swordfish stock to 50% probability of reaching B_{MSY} within 10 years (ICCAT, 1995c; Neilson et al., 2013). The reported swordfish catch for the Canadian fleet for 1995 and 1996 was 1421t and 646t, with Canadian TACs of 1500t in 1995 and 1400t in 1996 (Rec. 94-14) (DFO, 2000; ICCAT, 1994). The allocation was followed with further reductions in the swordfish quota in 1997-2000, in parallel with reduced North Atlantic catch (DFO, 2000).

Implemented in 2000, the division of the Canadian TAC between the two gear types in the fishery is notable because it changed the structure of the Canadian fishery. This domestic regulation was requested by longline sector during the creation of the 1997-1999 management plan which initiated the process (DFO, 2000). The percentages chosen for this division was 10% for the harpoon sector and 90% for the longline sector, based of historical catches in each sector (DFO, 2000, 2004; Knapman et al., 2017). The objective of this change was to eliminate competition for swordfish catch between the longline and harpoon sector in reaching the quota (DFO, 2000). For overages, the international regulation is to address them within two years; however, for this domestic regulation splitting the quota, overages are required to be adjusted for in the following year (DFO, 2000). Additionally, unused harpoon sector quota can be transferred to the longline sector (SHQ Swordfish Harpoon Quota Society, 2018). The fishing activity of both sectors was strictly monitored before and after this change; however, this quota split was an important first step in reaching conservation objectives within the ICCAT allocation (DFO, 2000).

The introduction of the ITQ system in the longline sector of the Canadian NATL SWO fishery was first implemented on a trial basis, from 2002-2003 (DFO, 2004; Knapman et al.,

2017). The cause of this change was a complex set of issues in the early 2000's, including a further reduction in the Canadian quota, a low profitability in the swordfish fishery, and concerns of overfishing (DFO, 2004, 2016; Knapman et al., 2017). The permanent implementation of the ITQ system came in 2003, with the objective of improving fleet rationalization (Andrushchenko et al., 2014; DFO, 2004, 2016). Fleet rationalization is the adjustment of management measures to allow for higher profitability in the fishery, and the ITQ system allows for this by reducing operating costs (DFO, 2004). The ITQ system was successful in reducing competition between licence holders and shifting the temporal footprint of the fishery later in the year (Andrushchenko et al., 2014; Knapman et al., 2017).

Out of the 61 management measures classified as regulation changes, these three years (1996, 2000, and 2002) stood out because they were implemented during a challenging time for the fishery. In 1994, the SCRS identified that the swordfish stock was overfished, and overfishing was currently ongoing (Neilson et al., 2013). Additionally, 2000 was the beginning of a 10-year recovery plan (Rec. 99-02) agreed to by ICCAT CPCs and implemented in Canada by DFO to rebuild the swordfish stock (ICCAT, 1999a). The time period of 1995-2002 was a time of revaluating and change for the swordfish fishery, and this is reflected in these three regulation changes.

2.4.3 Gear Type

There are minimal gear changes in the history of the Canadian NATL SWO fishery, with only 9 changes included in the timeline (Appendix A.1). The two key changes impacting the fishery are the introduction of longline gear in 1962, and the shift to circle hooks (from 1996 to 2012). Prior to the introduction of longline gear in 1962, the Canadian fleet targeting swordfish was completely a harpoon fishery (Fitzgerald, 2000; Hurley & Iles, 1981). The change to longlining was caused by the reported bycatch of swordfish in foreign offshore tuna vessels (Caddy, 1976; Fitzgerald, 2000). It was a rapid change for the Canadian fleet to convert to longline vessels when the news of higher catches spread (Caddy, 1976; Fitzgerald, 2000). The speed in which longline fishing gear was used can be seen in the increase of swordfish catches from 2092t in 1962 to 7482t in 1963 (Fitzgerald, 2000; Hurley & Iles, 1981). Despite the

increased effort, swordfish landings decreased and remained between 4000-5000t from 1965 until 1972 (Fitzgerald, 2000; Hurley & Iles, 1981).

Next, the gear change from J-hooks to circle hooks first took place in 1996 as an internal decision within the longline sector (DFO, 2004). There is some evidence that circle hooks reduce bycatch of certain species and could reduce post-release mortality (DFO, 2004). This evidence is the reasoning behind the requirement for mandated circle hooks to be considered for the MSC certification (DFO, 2004; Knapman et al., 2017). DFO mandated this change in 2012, which aided the longline sector to achieve it's MSC certification (DFO, 2004; Fisheries and Oceans, 2012, 2013). Corrodible circle hooks were mandated by DFO in 2013, to specifically address concerns with sea turtle bycatch and post release mortality (Fisheries and Oceans, 2013; Knapman et al., 2017). This change in fleet behaviour in 1996 is reflective of initiatives rather than regulations. Swordfish longliners switched hook type, not because they were required to, but because there was motivation from the US market, rumoured higher catches, and the hooks facilitate an easier live release of unwanted bycatch species (DFO, 2004).

It is important to note that there have been minimal changes to gear since the beginning of the Canadian NATL SWO fishery, particularly in the harpoon sector (Fitzgerald, 2000; SHQ Swordfish Harpoon Quota Society, 2018). The shift to longline stands out because of the rapidness of this change and the impacts it had on the efficiency of the catch (Caddy, 1976; Fitzgerald, 2000; Hurley & Iles, 1981). The shift to circle hooks stands out because it occurred internally in the fleet over 15 years before it was mandated by DFO (Caddy, 1976; DFO, 2004; Hurley & Iles, 1981). Although gear changes were few, there may have been increases in effort (e.g., boat size, spatial range, vessel capacity) that likely impacted the fishery.

2.4.4 Spatial Change

There are two key spatial changes that impacted the Canadian NATL SWO fishery between 1967 and 2019. The first is the closure of the exclusion zone referred to as the "Hell Hole" in 2003 (DFO, 2004). The following year, the first of three MPAs was established in the Canadian Atlantic; the Gully MPA (DFO, 2004, 2017b). These back-to-back spatial changes

were not the first exclusion zones to impact the Canadian SWO fishery; however, they were influential in their placement and timing of the fishery (DFO, 2004, 2013, 2017b). Additionally, both closures had conservation motives and objectives to reduce bycatch (DFO, 2004, 2017b).

In 2003, DFO implemented a time/area closure in the exclusion zone called the Hell Hole, prohibiting longline activities between July 1st and November 30th every year (DFO, 2004, 2005). The area is approximately 750km^2 (Fig. 2.8), and earned it's nickname "Hell Hole", because of it's challenging environmental fishing conditions that fishermen would brave (Dybas, 2002). The motivation for this closure is to address the bluefin tuna dead discards in the pelagic longline fleets (DFO, 2004, 2005). The closure of this area is based off scientific evidence that reduced longline activity within it's boundary would reduce dead discards of bluefin tuna (DFO, 2004). This was tested again in 2018, when DFO allowed 30 longline sets within the exclusion zone to assess the bycatch and discard levels. The levels of both bycatch and discards were determined to be too high to remove restrictions in this area (C. MacDonald, personal communication, September 21, 2021). Prior to the closure of the Hell Hole, this area was frequently fished by the swordfish fleet and reported catches were worth the long trip offshore (Dybas, 2002). After the closure, a portion of the swordfish fleets were displaced to other areas and this could have impacted the catch rates (DFO, 2004, 2005).

In 2004, the Gully MPA (Fig. 2.10) became the first MPA in Canada's Atlantic (DFO, 2017b; WWF, 2017). The Gully was identified for protection because it is a deep underwater canyon, composed of the highest diversity of corals in Atlantic Canada (DFO, 2004; WWF, 2017). It covers around 2300km^2 and is located approximately 200km off of the coast of Nova Scotia, near Sable Island, NS. Additionally, it's location is one of the areas with the highest reported swordfish landings (Fig. 2.8) (DFO, 2005). The MPA is divided into three zones, with Zone 1 (an area of 475 km^2) having the highest protection and all fishing activities are completely prohibited within its boundary. Zones 2 and 3 (an area of 1,888 km2) compose a buffer zone around Zone 1, where pelagic longline directing for swordfish is permitted (DFO, 2017b). The impacts of this closure on the swordfish fishery were influential. Typically, longline vessels set up there sets along the edge of the continental shelf, extending from Georges Bank then East towards Newfoundland (Fig. 2.8) (DFO, 2000, 2005). Due to the placement of the

MPA, the closure zone divides the line that vessels would normally follow (Fig. 2.8 & 2.10). Additionally, the high diversity of prey species in the canyon attracts large predators (e.g., swordfish); therefore, prior to the closure, swordfish catches were high in the area (DFO, 2000, 2005, 2017b).

2.4.5 Qualitative Observation

There are three key qualitative events that impacted the Canadian NATL SWO fishery between 1959 and 2012. The first, did not occur in one particular year, but could influence the yearly temporal pattern of the fishery. This is the opening and closing of lobster harvesting and deer hunting seasons (T. Atkinson, personal communication, August 10, 2021). Since swordfish fishing is a seasonal activity, it is common that swordfish fishermen involve themselves in other activities to generate income throughout the year (T. Atkinson, personal communication, August 10, 2021). This external factor could influence the timing of the swordfish fishery because both the lobster and deer harvesting have variable start and end-dates (DFO, 2021; Government of Nova Scotia, 2013). The timing of the Canadian lobster season in zones 27-28 is variable, occasionally open from November to January, and then March to July (DFO, 2021). Depending on the year and the timing of the lobster season, this may influence the participation in the swordfish fishery. Deer hunting season in Nova Scotia (where the majority of Canadian swordfish fishermen reside) is open from late October to early December (Government of Nova Scotia, 2013). The swordfish fishing season runs to the end of December; however, if the swordfish landings are low, or fishing conditions are not ideal, the fishermen may opt in October to hunt for deer, or harvest lobster in November. Additionally, if the lobster season at the beginning of the year is particularly lucrative and lobster prices increase, fishermen may not participate in the swordfish fishery until after the lobster season has closed.

The next two qualitative events that occurred in the Canadian NATL SWO fishery are the two MSC certifications for the harpoon and longline sectors (Acoura, 2010; Knapman et al., 2017). In 2010, the Canadian harpoon SWO fishery became the first swordfish fishery to achieve the MSC certification (Acoura, 2010). This sector of the Canadian fishery has experienced minimal changes in regulations and gear type over the years (Fitzgerald, 2000; SHQ Swordfish

Harpoon Quota Society, 2018). Two years later, the longline sector became officially MSC certified (Knapman et al., 2017). Becoming MSC certified opens market opportunities and could increase profitability of the fishery (Marine Stewardship Council, n.d.). Additionally, the certification of both sectors could impact the swordfish fleet's behaviour by increasing stewardship which could result in increasing the stability (spatially and temporally) of the fishery (Knapman et al., 2017).

2.4.6 Bycatch Mitigation

Between the years 1975-2020, there have been over 50 regulations focused on the mitigation of bycatch in the Canadian NATL SWO fishery. This is composed of species protection listings, domestic regulations, and ICCAT recommendations and resolutions (DFO, 2016; ICCAT, 2021b; UNEP-WCMC, 2021a, 2021b). For the Canadian NATL SWO fishery, the harpoon sector was not affected by most bycatch regulations because the fishing practice is very selective (SHQ Swordfish Harpoon Quota Society, 2018). Generally, the species protection listings produced by CITES and CMS are focused on the trade of vulnerable species, therefore, it is unlikely individual listings had significant impacts of the fleet behaviour within the fishery. Harpoon licence holders were permitted to retain select shark species if the opportunity arose, however, beginning in 2021, this is no longer permitted (Fisheries and Oceans, 2020, 2021).

Many of the management measures in the other categories of change (regulation, gear type, spatial, and qualitative), have a bycatch mitigation element. However, there are regulations created by both DFO and ICCAT that specifically address concerns around bycatch. The general trend in bycatch regulations was limiting the types of bycatch that could be retained, and this is mirrored in both international and domestic regulations. For example, between 2009-2019, it became prohibited to retain the following shark species; bigeye thresher *Alopias superciliosus* (internationally in 2009 and domestically in 2014), hammerhead *Sphyrna mokarran* (internationally in 2010 and domestically in 2014), oceanic whitetip *Carcharhinus longimanus* (internationally in 2010 and domestically in 2014), and silky *Carcharhinus falciformis* (internationally in 2011 and domestically in 2014). Additionally, white shark (*Carcharodon carcharias*) and basking shark (*Cetorhinus maximus*) were protected through domestic

regulations created by DFO in 2012 and 2018, respectively (Fisheries and Oceans, 2012, 2018). These regulations prohibit the retention, transportation, landing, or storing of the shark species, and generally improve the avoidance of the shark species because there is no economic gain from retaining them (Fisheries and Oceans, 2021; ICCAT, 2021b). Porbeagle *Lamna nasus* and shortfin mako *Isurus oxyrinchus* are only prohibited to be retained in the case that they are alive when brought to the boat (ICCAT, 2015, 2019b).

2.4.7 Conclusion

Information gathering identified over 145 management regulations, recommendations, resolutions, and events that impact the Canadian SWO fishery between 1959-2021. This information contributes to a management timeline of this fishery, that can be used to explore connections between management and fleet dynamics. Any of these 145 changes could influence the fleet; however, within each of the five categories, a number of changes are highlighted in this chapter for their impact of the fishery.

Chapter 3: Exploratory Analysis of Fleet Dynamics and Management Measures

3.1 Introduction

Fleet dynamics describe the when, where, and how a fleet behaves (Hilborn, 1985, 2007). These dynamics can change in response to management measures, regulations, environmental conditions, and significant events (Hilborn, 1985, 2007). The response in behaviour can have significant impacts on both the abundance and perceived abundance of the fished stock (Branch et al., 2006; Hilborn, 1985, 2007). Although influential, these dynamics are difficult to measure, and the cause of the change is challenging to determine. Measuring these dynamics is further complicated in international fisheries with highly migratory target species, such as swordfish, because of the large number of potential factors influencing the stock (FAO, 2001; Hilborn, 2007). An example of an international fishery where fleet behaviour has played an important role in the recovery of its stock is the NATL SWO fishery (Andrushchenko et al., 2014; ICCAT, 2021b; Neilson et al., 2013). This fishery is used as a case study to explore the relationship between fleet behaviour and management measures. Two potential impacts to fleet behaviour from management are explored: anticipatory effects, and changes in the allocation of catch within the fleet. These impacts are investigated using the Canadian SWO fishery, focusing on two regulations: the implementation of an international quota allocation table in 1996 (ICCAT, 1995c); and the domestic introduction of an ITQ system in 2002 (Andrushchenko et al., 2014; DFO, 2004).

Stock assessments are an important method for evaluating the status of fished species and informing the creation of regulations (Branch et al., 2006; DFO, 2016). Fisheries dependent and independent data support this process by supplying data on abundance, recruitment trends, catch, and biological characteristics of the stock (Branch et al., 2006; DFO, 2015; Ortiz et al., 2017). The goal of the stock assessment is to accurately reflect the conditions and the true dynamics of the stock (Branch et al., 2006; FAO, 2001). However, abundance variables can be influence by changes in fleet behaviour, such as the announcement of new regulations, alternative regulations with discard reporting, or the implementation of new quota systems (Branch et al., 2006; Hilborn, 1985, 2007). These impacts are difficult to measure in a fishery, and therefore, the causal relationship between these changes and perceived stock abundance is often overlooked

when assessing a stock (Branch et al., 2006; FAO, 2001; Hilborn, 1985, 2007; Ward & Hindmarsh, 2007).

One impact that has yet to be examined is the anticipatory impacts of new regulations, and how this changes fleet dynamics. The anticipatory effect of a regulation is the reaction of a fleet prior to implementation of the regulation (McDermott et al., 2019). There are a diversity of potential anticipatory effects, such as a higher fishing effort exerted in an area of interest (AOI), the implementation of quotas, or increased effort prior to a regulation (McDermott et al., 2019). One potential anticipatory effect that could be observed in the Canadian fleet is an increase in effort before the 1996 international quotas are allocated (ICCAT, 1995c). Since the allocations were created based off previous catch history, the predicted results would be an increase in effort directly before this regulation is implemented. The issue with anticipatory effects in the fishery is that they risk impacting the stock assessment estimates, which could misinform regulations (Branch et al., 2006; Hilborn, 1985, 2007; McDermott et al., 2019). Additionally, the impact of anticipatory effects (in increased effort or catch) could cancel out the conservation effort that the regulation is trying to address (McDermott et al., 2019).

A second impact of management on fleet behaviour explored is the change in the temporal pattern of the fishery in response to regulations. ITQs are licence-specific quotas that can be transferred between licence holders (Essington et al., 2012; Melnychuk et al., 2012). The impacts of ITQs are debated, as fisheries have reported various benefits and drawbacks (Gibbs, 2010; Melnychuk et al., 2012). One main benefit is the elimination of competition for fish between licence-holders, due to their pre-set quota (DFO, 2004; Essington et al., 2012; Knapman et al., 2017). One main drawback is the concentration of wealth that is caused by the implementation of this quota system. Since longlining requires a high number of resources (e.g., number of people, large vessels, equipment), some licence holders with small allocations of the quota will sell their portion to other licence holders with a larger allocation (Melnychuk et al., 2012). The impact of this change is explored through the introduction of the ITQ system in 2002 within the Canadian SWO longline fishery (DFO, 2000, 2004). The predicted result would be a shift in the temporal pattern of the fishery, showing effort evenly distributed within the peak months to catch swordfish (May-November). This change would suggest a reduction in the race-

to-fish situation in the fishery, therefore effort in the later months of the year may be higher (September-November). Exploring the impact of this management measure and the impact it has on the behaviour of the Canadian fleet could better inform stock assessments of the influence of fleet behaviour on the abundance of the swordfish stock (Essington et al., 2012; Hilborn, 2007).

The objective of this chapter is to examine for relationships between fleet dynamics and management in the Canadian SWO fishery. The main questions addressed are (1) is there evidence of links between management and fleet dynamics; and (2) how could these results contribute to current stock assessments? This is explored using two key management changes; however, any of the over 145 management changes could have an influence on fleet behaviour. These two are chosen because they represent defining shifts in the history of the fishery which developed the fishery into its current state. These regulations are created and implemented on both international and national scales; however, the focus will be on the impacts within Canadian fleet.

3.2 Methods

The main objective of this chapter is examining for relationships between fleet dynamics and management measures in the Canadian SWO fishery. The first step is using the management timeline created for the Canadian fleet (Chapter 2) to identify key changes that could impact fleet dynamics. The two changes identified are: the international percentage allocations in 1996 (ICCAT, 1995c), and the introduction of an ITQ system in 2002 (Andrushchenko et al., 2014; DFO, 2004). The second step was using measures of effort (e.g., number of hooks or trips), catch, and CPUE to explore the impacts that the regulation changes had on the fishery. Data is sourced from the ICCAT Task I & II databases.

The international percentage allocations recommended by ICCAT in 1995 entered into force in 1996 (Rec. 95-11)(ICCAT, 1995c). To explore the impact that this change had on the Canadian fleet, measures of effort (number of hooks or trips) and catch (tonnes) are compared. The average estimated number of hooks (Fig. 3.1) is plotted against catch data from the Canadian SWO fishery. Additionally, number of fishing trips for the Canadian SWO fishery is

plotted on a separate plot (Fig. 3.2). Both these plots are then visually compared for any notable trends or outliers.

Next, the ITQ system in the Canadian SWO longline fishery was introduced as a trial in 2002 and then permanently in 2004 (DFO, 2000, 2004). To explore the impact that this change had on the Canadian fleet, the change in effort data (number of hooks) for the Canadian fleet is compared between months and years. The priority was comparing temporal trends in effort within a year, so the effort data was scaled to 1 within a year to account for long term variation in the fleet. Scaling the data facilitates the comparison of relative effort exerted each month throughout the year and highlights temporal trends of the fishery. First, the scaled estimated effort data is plotted by month, between the years of 1997-2008 (Fig. 3.3). The purpose of this figure is to demonstrate the scaled effort in each month through the years 1997-2008 to compare trends between the years. For example, the month of August is always represented by a 1 (meaning it is the month with the highest estimated effort) every year except 2006 (Fig 3.3). Months included from May-November; effort in all other months was not included because it was negligible.

Then the effort data is grouped into three time periods: (1) 1997-2001 represents 5-years before to the trial ITQ system, (2) 2002-2003 is the two-year trial, and (3) 2004-2008 represents 5-years after the trial ITQ system. These time periods represent the average scaled effort by month for the years included and are plotted by month in a bar graph (Fig. 3.4). The purpose of this figure is to compare the average scaled effort by month between the three time periods.

Finally, the percentage difference between the before (1997-2001) and after (2004-2008) time periods is calculated by month using the following formula:

$$\%change = \frac{(Catch_{post} - Catch_{pre})}{Catch_{pre}} \times 100$$

The results from this equation are plotted to compare the differences within a year (Fig. 3.5). The purpose of this figure was to compare the change in the temporal pattern of the fishery before and after the ITQ trial period.

3.3 Results

3.3.1 Overview

The exploratory analysis shows potential connections between fleet behaviour and management measures. Specifically, there are potential anticipatory effects, and changes in the temporal pattern of the fleet in response to management. The two changes highlighted are the international percentage allocations in 1996 (ICCAT, 1995c), and the introduction of an ITQ system in 2002 (Andrushchenko et al., 2014; DFO, 2004).

3.3.2 Percentage Allocations

Earlier in the management of the Canadian SWO fishery, in 1995, international percentage allocations were implemented that divided the quota between the main nations targeting swordfish. In 1995 (Rec. 95-11) percentages of the NATL SWO TAC were allocated to the five main CPCs: Canada 10.00%, Japan 6.25%, Portugal 7.50%, Spain 41.25%, United States 29.00%, and Others (total) 6.00% (ICCAT, 1995c). These allocations were based off of each individual CPC's catch history of NATL SWO. Data explored in this section include reported catch and two measures of efforts (number of hooks and number of trips). The comparison between catch and effort (number of hooks) in the Canadian NATL SWO longline fleet shows in the late 1980s, Canada's swordfish catches were averaging around 850t (ICCAT, 2021a). Next, variable effort is observed between 1990-1995, followed by a dramatic decrease and then a stabilization in estimated effort in 1996 (Fig. 3.1). This corresponds with the year that Canada was allocated 10% of the NATL SWO TAC (Rec. 95-11) and the Canadian TAC of 1400t (Rec. 94-14) (ICCAT, 1994). Reported catch peaked in 1993 at 2206t and in 1994 at 1654t. After 1995, catch decreased before slightly increasing and stabilizing between 2005-2015.

A second measure of effort explored in this section is the number of fishing trips (Fig. 3.2). The number of fishing trips in the 1960s prior to the closure of the Canadian fishery is between 200-300 trips. The fishery closed in 1972 and the number of reported fishing trips was 0 until 1979 when the fishery reopened. After the fishery reopened, the number of fishing trips stabilized around 40 trips. A steep increase is observed in the early 1990s, with the two peaks of

number of fishing trips at 427 and 405 occurring in 1994 and 1995, respectively. After the year 2000 the number of trips remained between 150-250 trips.

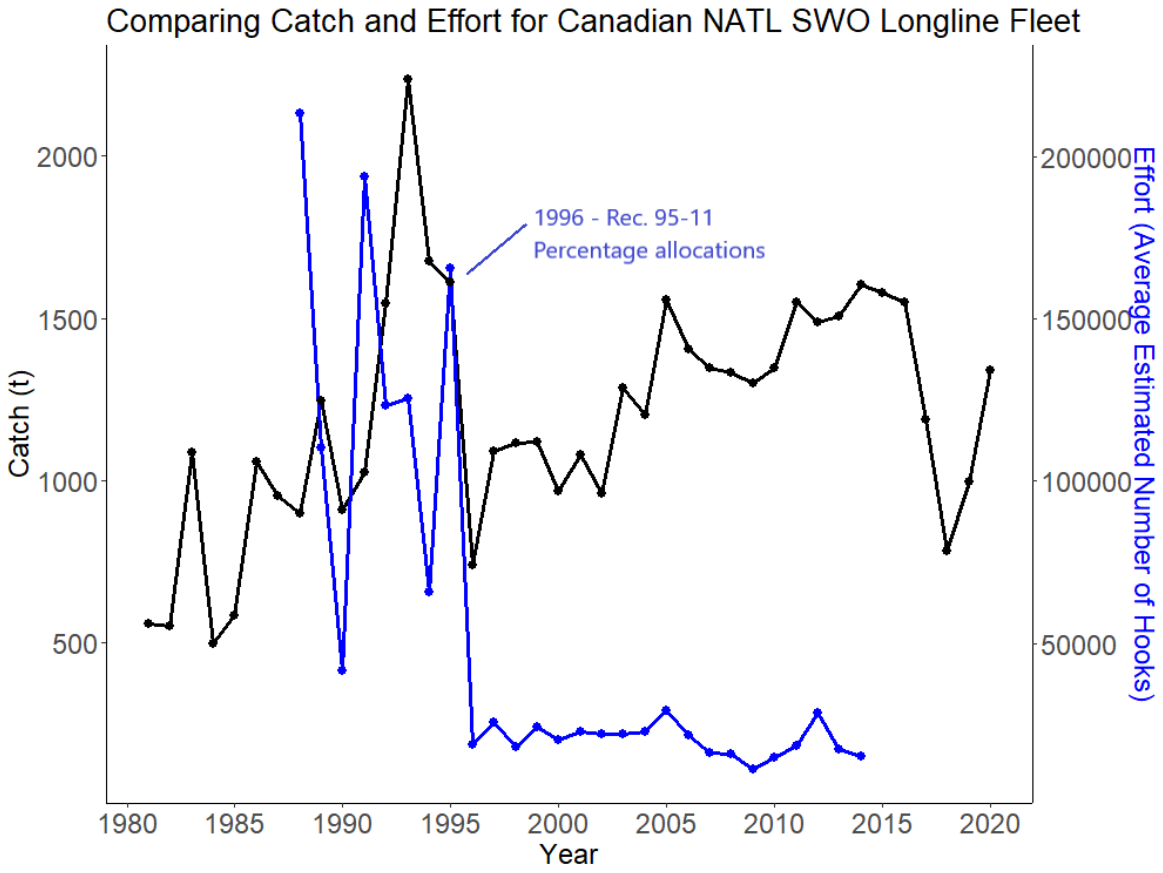

Figure 3. 1 – A comparison of catch data and estimated effort data for the Canadian North Atlantic Swordfish Fishery between 1980-2020. Catch (tonnes) is represented in black on the left y-axis. Average effort is represented in blue on the right y-axis. Sources: ICCAT Task I & II Data.

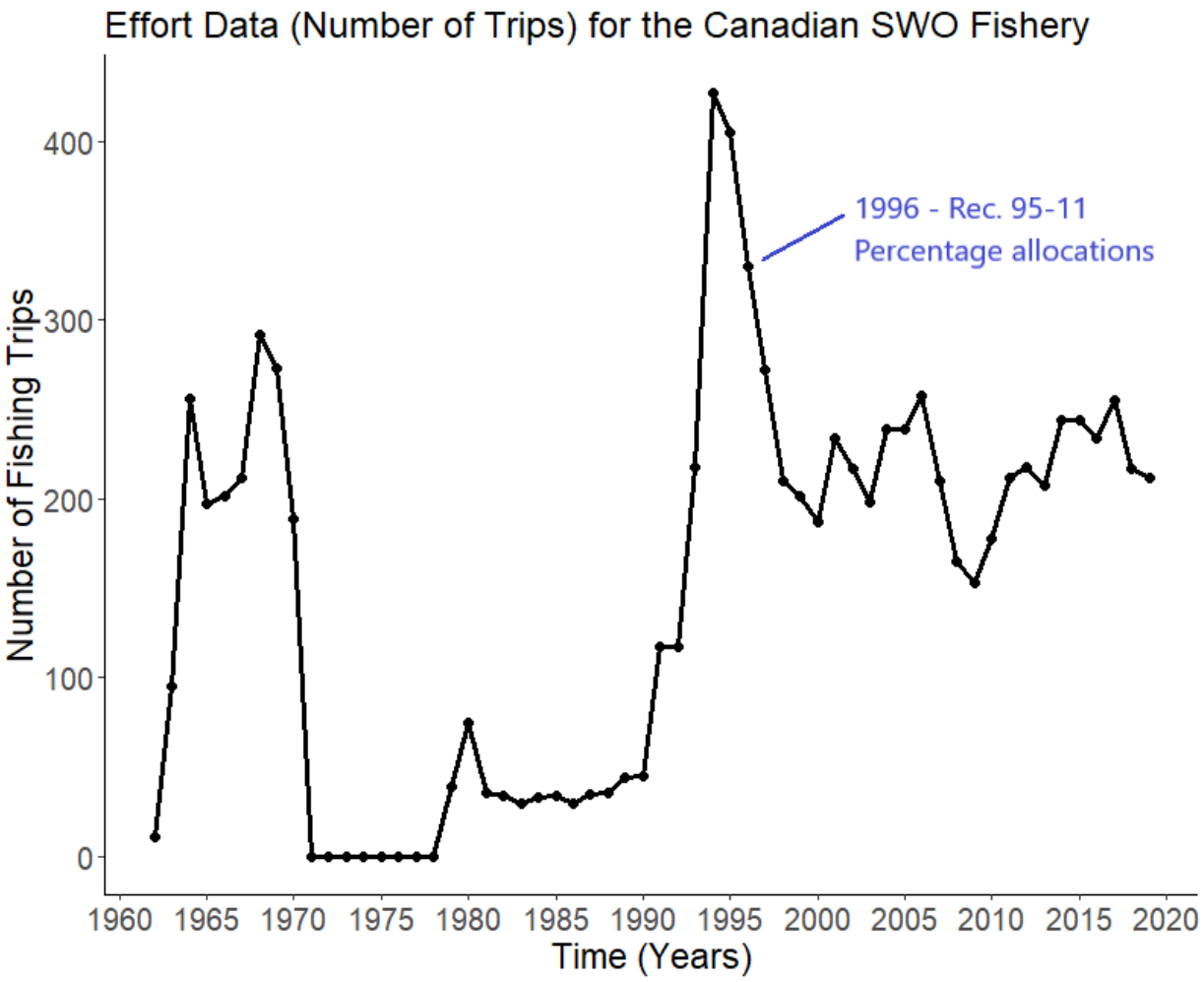

Figure 3. 2 – A line plot of effort (represented by number of fishing trips) in the Canadian North Atlantic Swordfish Fishery between 1962-2012. Maximum number of fishing trips is 427 in 1994. Source: (Andrushchenko et al., 2014).

3.3.3 Individual Transferrable Quotas

Later in the management of the Canadian NATL SWO fishery, in 2002, an internal quota system was introduced as the international TAC was further reduced (ICCAT, 2002a). Before this changed, there were no internally regulated quotas for the Canadian fleet, other than the total allocated TAC from ICCAT. Fishermen would compete for swordfish until this total quota is reached, then the fishery would temporarily close until the start of the next season. Data explored in this section includes average estimated effort data (number of hooks) for the Canadian NATL SWO fishery between 1997-2008 (Fig. 3.3). It is observed that August is almost always the month with the peak effort within a year, excluding 2006. Estimated effort in many of the months is stable throughout the years, excluding September and July, which both show slight increases in later years. Next, the effort representing the "before" time period (1997-2001) shows a higher effort exerted in the earlier months of the year (Fig. 3.4). Alternatively, the effort representing the "after" time period (2004-2008) is more evenly distributed throughout the year, with even amounts of effort exerted in July and September. Finally, the percentage change between the 5-years before and after the ITQ system is compared by month (Fig. 3.5). May is the only month with a decrease in percentage change, and August is the only month with no observed change in effort. A percentage increase in effort is observed in all other months, with the majority of the increase observed in the later months of the year (September, October, November). October has the highest change of a 35% increase in effort, with an additional 12% in September and 10% in November. This suggests that after ITQ implementation, there was a temporal shift in effort to later in the year.

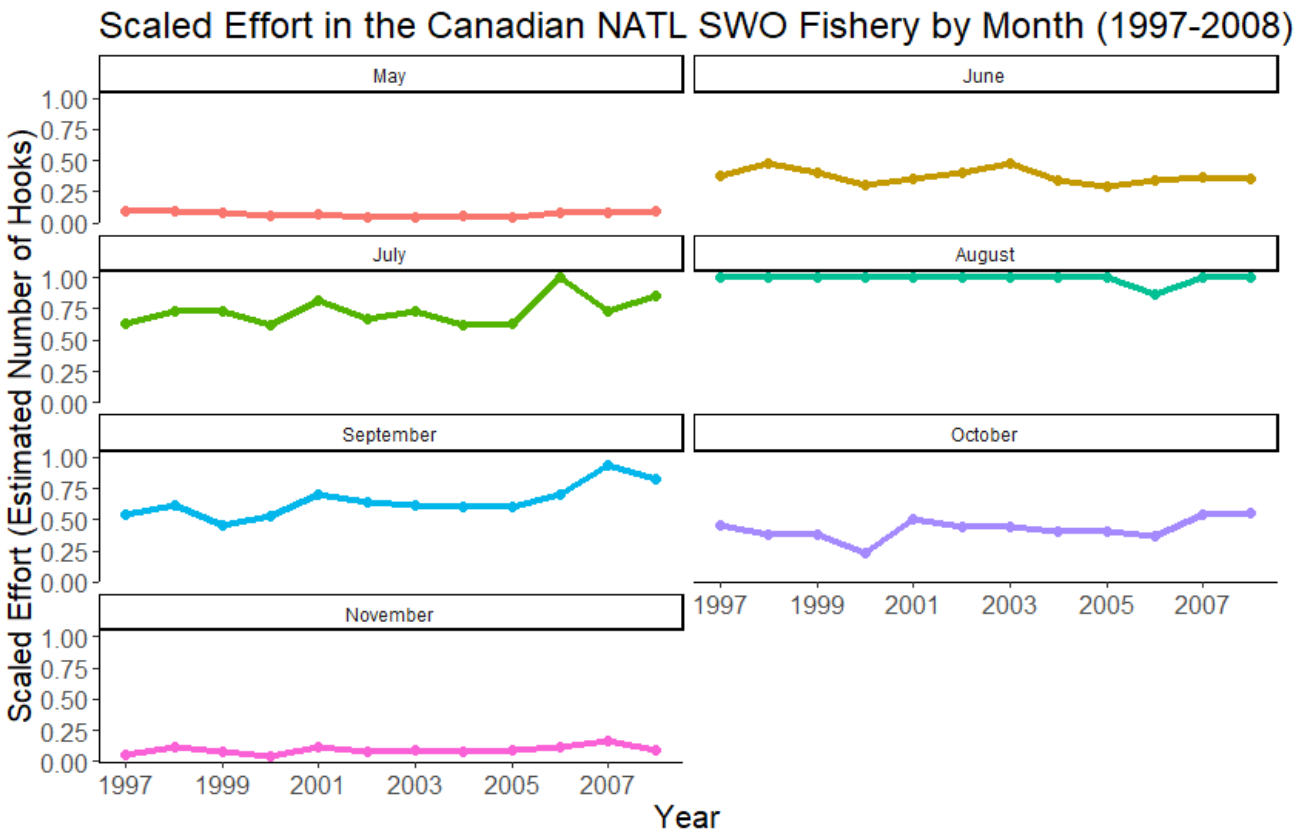

Figure 3. 3 – Comparing monthly effort between years 1997-2008 for the Canadian North Atlantic Swordfish Fishery. Effort scaled to 1 within a year. Months included: May, June, July, August, September, October, November. Effort in all other months was not included because it was negligible. Source: ICCAT Task II Data.

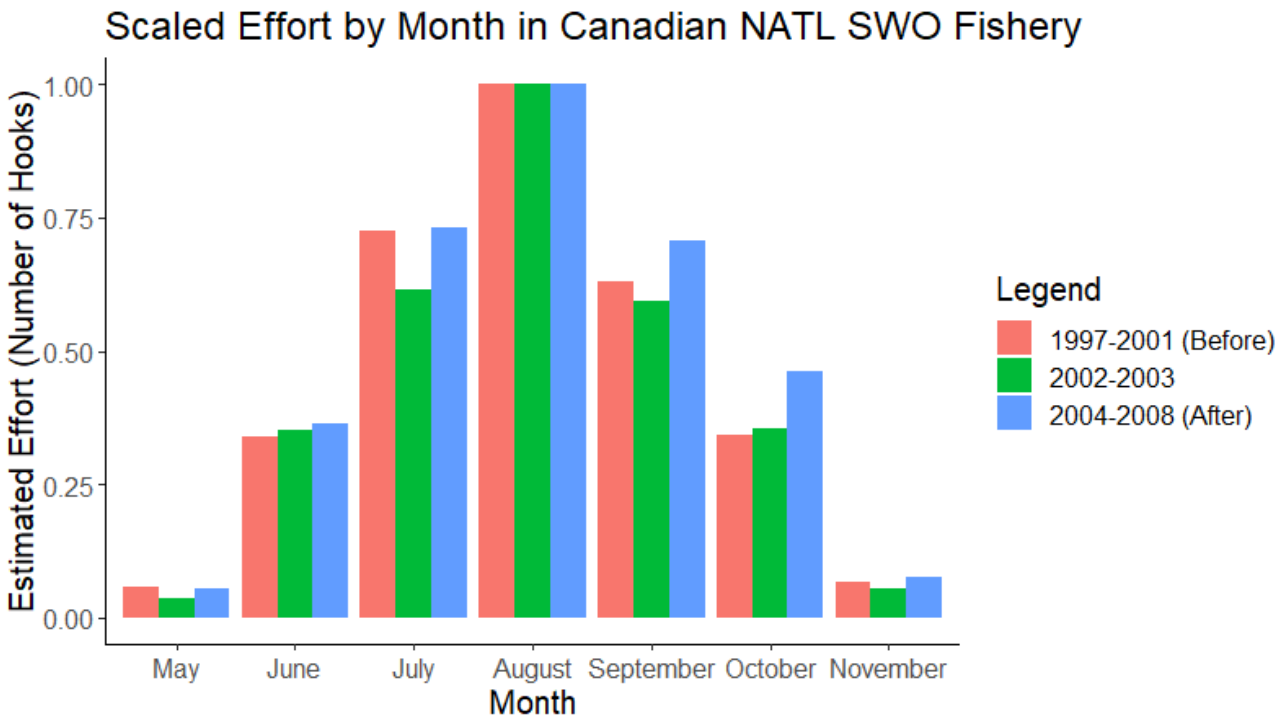

Figure 3. 4 – Comparing monthly effort between years 1997-2008 for the Canadian North Atlantic Swordfish Fishery. Effort scaled to 1 within the year. Effort average by grouped years: 1997-2001 before the ITQ system, 2002-2003 during the trial stage, and 2004-2008 after the permanent implementation of the ITQ system. Months included: May, June, July, August, September, October, November. Effort in all other months was not included because it was negligible. Source: ICCAT Task II Data.

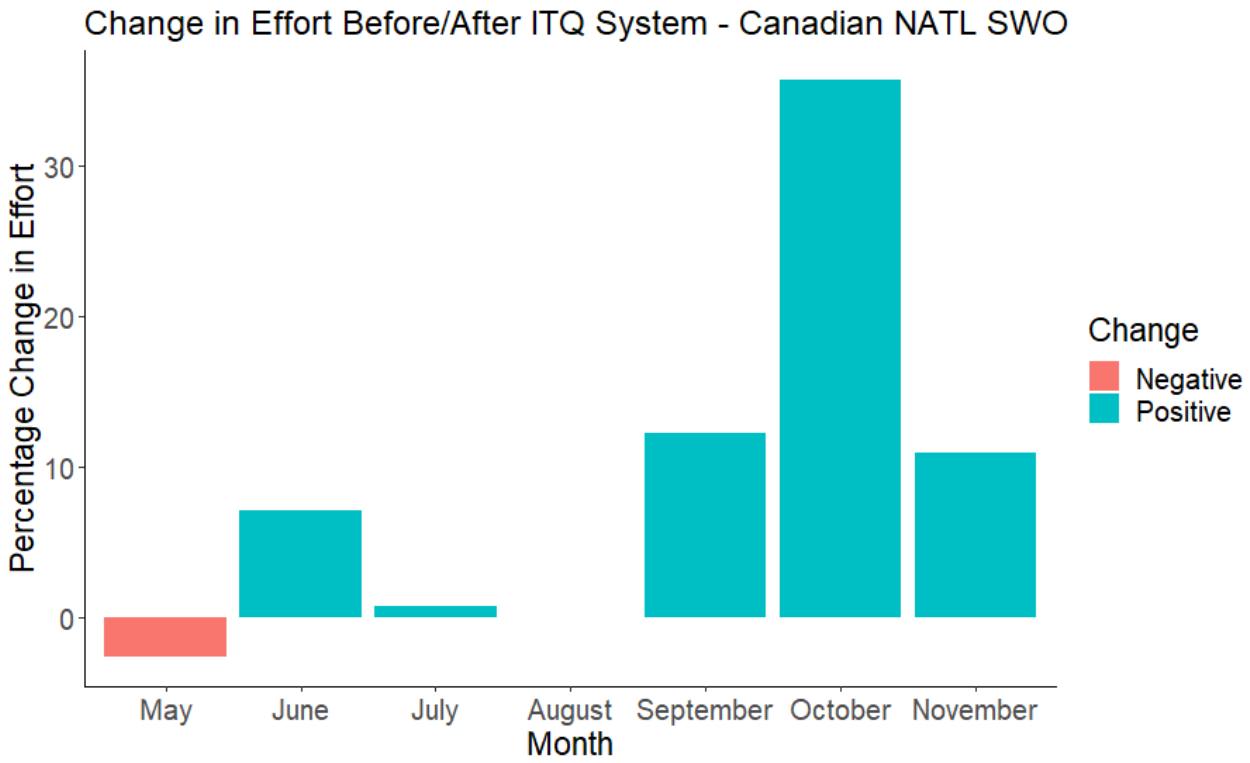

Figure 3. 5 – Comparing percentage change in estimated effort before (1997-2001) and after (2004-2008) the implementation of the permanent ITQ system for the Canadian North Atlantic Swordfish Longline Fishery. Effort scaled to 1 within the year. Months included: May, June, July, August, September, October, November. Effort in all other months was not included because it was negligible. Source: ICCAT Task II Data.

3.4 Discussion

3.4.1 Overview

This exploratory analysis suggests evidence of links between management changes and fleet behaviour. Any of the 145 management measures, events, and changes impacting the Canadian SWO fishery between 1959-2021 could present potential connections with fleet dynamics. However, in this project, two notable changes are explored further for potential connections. The first connection is observed earlier in the management of this fishery with ICCAT Rec. 95-11, implemented in 1996, when Canada was allocated 10% of the NATL SWO TAC (ICCAT, 1995c). The results of this analysis suggest this change could have caused potential anticipatory effects within the Canadian fleet in terms of increased effort (Fig. 3.1 & 3.2). The next connection is observed later in the management of this fishery through the introduction of the ITQ system in 2002 within the Canadian SWO longline fishery (DFO, 2004). The results suggest this change may have shifted the temporal pattern of the fishery and allowed fishermen to fish later in the year (Fig. 3.3 & 3.4 & 3.5). It is important to note that there may be issues with the accuracy of the data. Log submissions and data reporting were mandated in 1994 and are still improving to this day. Earlier data is difficult to obtain and confidence in this earlier data is variable (e.g., incorrect data entry; poor reporting from some vessels; etc.); therefore, these results are very exploratory. The priority of this project is exploring potential impacts of management on fleet dynamics to generate interesting discussion, noting that there are many other factors that can influence fleet dynamics (environmental, economic, social, political, etc.). The goal is to highlight areas to be researched further and identify potential data gaps that limit current research.

3.4.2 Percentage Allocations

Earlier in the management of the Canadian SWO fishery, in 1995, percentage allocations were introduced at an international scale (ICCAT, 1995c). These percentage allocations are based off previous catch history, and the impact this regulation had on fleet behaviour should be investigated. The announcement of regulations, prior to implementation of restrictions, may influence fleet behaviour and cause anticipatory effects. Anticipatory effects are the measurable

changes in effort, where/when fishing occurs, gear changes, and other adjustments to a fleet's decisions in response to a potential regulation change (Hilborn, 2007; McDermott et al., 2019). The issue with anticipatory effects is the potential increase in pressure on a fish stock or habitat. Regardless of the objective that is to be achieved, these effects may cancel-out the original intentions of the regulation (McDermott et al., 2019). As a result, the increased pressure on the vulnerable area and species causes more stress on the area than if there were no potential regulations announced (Hilborn, 2007; McDermott et al., 2019). It is important to research the influence of regulations on the behaviour of the fleet to predict and prepare for the potential impact of anticipatory effects.

These results are interesting because it could be speculated that in anticipation of the international allocations based off catch history, the Canadian fleet increased effort in the early 1990's. The allocations are based off of previous catch history, therefore, higher catches would result in a larger percentage allocation for future years. This may be a reason why the Canadian fleet attempted to increase their reported catches by increasing their effort in both number of hooks and number of fishing trips directly before this calculation was made (Fig. 3.1 & 3.2). Alternatively, the status of the NATL SWO stock in the mid 1990's was overfished (Neilson et al., 2013). Therefore, another explanation for the increase in effort at that time could be an increased difficulty in catching swordfish. This increase in effort could have been an attempt to maintain stable swordfish landings. Additionally, environmental factors, such as increasing ocean temperatures, could cause the spatial distribution of the swordfish population to change. The differences observed between the trend in CPUE, number of hooks, and number of trips suggest some inconsistency in the cause of these changes. This emphasizes the difficulty in assessing causality between relationships in a fishery, due to the large number of factors that could influence the activity.

3.4.3 Individual Transferrable Quotas

Later in the management of the Canadian SWO fishery, in 2002, an internal quota system was introduced in the longline sector that allocated licence-specific quotas (DFO, 2004). The ITQ system was trialed in 2002 and 2003, then permanently implemented in 2004 (DFO, 2004,

2016; Knapman et al., 2017). It is important to explore the connections between this type of management measure and fleet behaviour because the results may be influential on the perceived abundance of the fished stock (Branch et al., 2006; Essington et al., 2012; Melnychuk et al., 2012). Based off the biology of the swordfish and the environmental conditions of the North Atlantic, the earliest swordfish to migrate north during the season could be larger individuals (DFO, 2015, 2016). If the fleet is racing to reach the quota earlier in the year, the biological size data collected through commercial fleets would report a larger average size of swordfish than that of the true population (Fig. 3.4). This could misguide stock assessments and, therefore, misguide regulations based of these estimates. Considering the influence of the fleets' response to an ITQ system on the perceived abundance is a difficult factor to measure, and therefore, requires further investigation (Essington et al., 2012; Melnychuk et al., 2012). In the Canadian fleet, the motivation to implement an ITQ system was to maintain swordfish catches within the international TAC and increase profitability in the fishery (Andrushchenko et al., 2014; DFO, 2004, 2016; Knapman et al., 2017). The ITQ system allocates specific quotas to each licence-holder, so that they can plan for the most opportune time and area to fish and use their quota (Essington et al., 2012; Knapman et al., 2017; Melnychuk et al., 2012). Additionally, this system can increase profitability for licence-holders because they can choose to catch and sell swordfish in coordination with higher market demands (Knapman et al., 2017; Melnychuk et al., 2012).

The results of the exploratory analysis suggest the implementation of the ITQ system may have changed the temporal pattern of the Canadian SWO longline fleet. An increase in effort exerted later in the year is observed for the 5-year period (2004-2008) after this change is implemented (Fig. 3.5). These results are aligned with the predicted results that the ITQ system influences the timing of the fishery, giving fishermen the ability to fish at the optimum time (in terms of weather, catch efficiency, market demands, etc.). August remains the peak month regardless of this management change because August is the most opportune time to catch swordfish via longline (DFO, 2016; Knapman et al., 2017). However, the distribution of the effort per month prior to the change is earlier in the year (Fig. 3.4). Then, after the trial for the ITQ system is introduced in 2002, an increase in estimated effort occurs in September, October, and November (Fig. 3.5). These results support the theory that the ITQ system allows fishermen

to choose the most optimum time to fish, rather than competing with other licence-holders (Essington et al., 2012; Knapman et al., 2017; Melnychuk et al., 2012).

3.4.4 Conclusion

The exploratory analysis identified several potential connections between fleet behaviour and management between 1959-2021 within the Canadian SWO fishery. The two potential connections identified are: the anticipatory effects before an international regulation, and a shift in the effort distribution within a year after a domestic quota system. These changes are important to explore because of their impact on perceived stock abundance (Branch et al., 2006; Hilborn, 2007). Fleet behaviour is still difficult to measure and is, therefore, still overlooked as a factor in stock assessments (Branch et al., 2006; Hilborn, 1985, 2007). To improve the assessment process, further investigation is required into the causal relationship between fleet dynamics, management, and true population dynamics. A limitation to this investigation is the reliability of the effort data, particularly before logbook submissions were mandated in 1994 (DFO, 1994). The results are exploratory, with the intention of generating discussion around this topic and highlighting areas where more research is needed. Although interesting, this is the first step to identify factors that should be investigated in a larger analysis to determine stronger relationships between these factors and stock abundance.

Chapter 4: Conclusion

4.1 Introduction

This project explores changes in fleet behaviour in connection with management measures that will contribute to swordfish stock assessments by: (i) investigating factors contributing to management in the Canadian SWO fishery, and (ii) examining for relationships between management changes and patterns in the fleet over time. In Chapter 2, I documented the history of the Canadian SWO fishery, detailing over 145 management measures, regulations, recommendations, and/or events that may influence fleet dynamics. This timeline is important for documenting key changes and further investigating the impacts of management on this fishery. In Chapter 3, I highlighted two key changes that indicate potential connections between fleet behaviour and management. These connections included potential anticipatory effects and temporal changes in response to regulations within the Canadian SWO fishery. These findings are important to improve our understanding of the impact of management on fleet behaviour.

This project identified potential connections between management measures and fleet dynamics; however, this is simply the first step in a much larger analysis of this topic. Ideally, this concept should be explored using statistical approaches in Canadian fleets and in other international fleets to investigate whether or not this is a common trend observed throughout the fishery. Further, the influence of fleet dynamics should be investigated to improve our understanding of how this can impact the status of the fish stock.

4.2 Research Findings and Broader Context

4.2.1 How do management regulations change over time?

In Chapter 2, over 145 management measures and events are identified impacting the Canadian SWO fishery between 1959-2021. The composition of this timeline is evenly split between international and national changes. Additionally, regulation and bycatch mitigation were the two most common types of change observed. Any of these changes could have potential influence on the dynamics of the fleet, however, two in particular are highlighted in Chapter 3 for further exploration. In Chapter 3, the two changes are: (1) the international percentage

allocations introduced by ICCAT in 1996, and (2) the introduction of ITQs within the Canadian swordfish longline fleet in 2002.

4.2.2 Is there evidence of links between management and fleet dynamics?

In Chapter 3, I identified two potential links between management and fleet dynamics. First, there are potential anticipatory effects observed in the Canadian SWO fishery. A spike in effort within the Canadian fleet is observed in 1994 and 1995, which could be in anticipation of the introduction of international percentage allocations in 1996. Next, a shift in the distribution of effort within the Canadian longline fleet is observed after the introduction of the ITQ system in 2002. Both these changes are preliminary observations that require further analysis to determine whether a causal relationship exists.

4.2.3 How can these results contribute to stock assessments?

One of the main purposes of investigating the influence of management on fleet dynamics, is to better incorporate these factors in calculation of stock status and trend. For example, in Chapter 2, introduction of circle hooks likely resulted in altered catch rate profiles among species—an effect important to account for in abundance indices. In Chapter 3, I took a focused look at two factors. The first was a sharp spike effort in the 1-2 years before the introduction of a regulation. In many cases, the most up to date effort and catch data is not available for use in an assessment (e.g., a 1-2-year lag in available data). My finding indicates that assessment teams should be conscious of complex fleet dynamics and associated uncertainties when making assumptions about recent and as-yet undocumented fleet behaviours.

The second impact was a shift in the temporal pattern of the fishery, so that fishing effort was more evenly spread out throughout the fishing season, rather than the majority of the effort exerted earlier in the season. Based off the biology of the swordfish and the environmental conditions of the Canadian Atlantic, I can speculate that the first swordfish to migrate north to these colder waters may be larger individuals. If the Canadian fleet is racing to fish early in the

season, this would influence the catch-at-size data, skewing it to represent a larger average-sized swordfish than that of the true population. Therefore, this shift in effort observed after the introduction of the ITQ system could alter the biological data and is a bias that should be accounted for in the abundance indices.

4.3 Limitations

Improving the understanding of fleet behaviour as a factor in stock assessments is an evolving process that is limited by a number of confounding factors.

In a perfect world, the following elements would not limit the objectives of this project:

- Poor record keeping for management changes. As time moves forward, we are having to rely more on the memories of people, rather than written reports. Ideally, this wealth of knowledge would be available and organized in a database or library to be referred to in the future.
- Variable reliability of early effort data. The earlier effort data for the fishery can be difficult to obtain and unreliable when analyzed. For example, there seems to be some differences between the trends in effort data between the types of effort examine, such as number of hooks versus number of trips. The reasoning why these two measures of effort do not align in patterns is unknown, and this could influence the results of the project. The exploratory analysis is limited based off of the availability of the data, therefore, different relationships could have been identified with access to different data.

4.4 Recommendations

1. **Better record keeping**. One of the biggest challenges to overcome in this project was locating and collecting the information surrounding the fishery. Clear gaps in the records (e.g., licencing conditions, integrated fisheries management plans, etc.) complicated the data gathering phase. Additionally, there is a wealth of knowledge in the people involved in the fishery (e.g., fishermen, industry representatives, etc.) that could be lost with time.

This critical knowledge needs to be documented and organized for future reference. Currently, there is regular interactions between science, industry, and management; however, due to poor record keeping, it is unclear whether this has always been the case. It is important to keep records to fill in knowledge gaps and improve this our understanding of the fishery for generations to come.

2. **Historical data recovery**. There are databases to collect catch and effort data; however, reliability diminishes when working with the older data. There is a process that reviews historical data with the objective of improving historical effort data and filling in gaps. This project could have benefitted from historical data recovery because different relationships could have been identified in the fleet dynamics.
3. **Incorporate fleet behaviour in stock assessments**. This is an important recommendation because stock assessments aim to represent the true dynamics of the fished population to inform fishing regulations. However, if the assessments don't consider fleet dynamics as a factor influencing the stock, there may be changes in the population that are misinterpreted, thus, misguiding the creation of regulations and the activity of the fishery.

4.5 Future Work

This project identified potential relationships between management and fleet dynamics, however, to truly investigate these connections, a model-based approach is necessary. Fisheries management is a very complex reality to understand and with so many factors at play, it is very difficult to identify causality in these relationships. Interesting patterns are identified in this project; however, this project did not identify correlations and is only a first step in a much larger analysis. The benefit of a model-based approach is the ability to incorporate the many dynamic factors that impact fisheries, and to create estimates based off these models.

4.6 Conclusion

This project contributes to the understanding of the influence of management measures on fleet dynamics and indicates the importance to investigate this topic further. Fisheries management is a dynamic field that is constantly adapting to new information and new challenges. This work highlights the magnitude of change within the fishery and the large number of factors that are in a constant state of flux. Evaluating the dynamics of the fishery and the stock is an incredibly difficult task; however, the more knowledge we collect, the better management we can provide. Additionally, this project identifies the importance to continue to investigate the impact of current management frameworks and identify areas of improvement.

References

Acoura. (2010). *Northwest Atlantic Canada harpoon swordfish*. Marine Stewardship Council. https://fisheries.msc.org/en/fisheries/north-west-atlantic-canada-harpoon-swordfish/about/

Andrushchenko, I., Hanke, A., Whelan, C. L., Neilson, J. D., & Atkinson, T. (2014). A description of the Canadian swordfish fisheries from 1988 to 2012, and candidate abundance indices for use in the 2013 stock assessment. *Collect. Vol. Sci. Pap. ICCAT*, *70*(4), 1679–1710.

Applebaum, B. (2001, January). *Law of the Sea—The Exclusive Economic Zone. An Overview of the Development of the 200 Mile Exclusive Economic Zone and the Related Canadian Fisheries and Other Interests*. Canadian Museum of History. https://www.historymuseum.ca/cmc/exhibitions/hist/lifelines/apple1e.html#contents

Aranda, M., Murua, H., & de Bruyn, P. (2012). Managing fishing capacity in tuna regional fisheries management organisations (RFMOs): Development and state of the art. *Marine Policy*, *36*(5), 985–992. https://doi.org/10.1016/j.marpol.2012.01.006

Atlantic Leatherback Turtle Recovery Team (Canada), C. & Department of Fisheries and Oceans. (2006). *Recovery strategy for the leatherback turtle (Dermochelys coriacea) in Atlantic Canada.* Fisheries and Oceans Canada. https://central.bac-lac.gc.ca/.item?id=En3-4-14-2006E&op=pdf&app=Library

Branch, T. A., Hilborn, R., Haynie, A. C., Fay, G., Flynn, L., Griffiths, J., Marshall, K. N., Randall, J. K., Scheuerell, J. M., Ward, E. J., & Young, M. (2006). Fleet dynamics and fishermen behavior: Lessons for fisheries managers. *Canadian Journal of Fisheries and Aquatic Sciences*, *63*(7), 1647–1668. https://doi.org/10.1139/f06-072

Braun, C. D., Gaube, P., Afonso, P., Fontes, J., Skomal, G. B., & Thorrold, S. R. (2019). Assimilating electronic tagging, oceanographic modelling, and fisheries data to estimate movements and connectivity of swordfish in the North Atlantic. *ICES Journal of Marine Science*, *76*(7), 2305–2317. https://doi.org/10.1093/icesjms/fsz106

Caddy, J. F. (1976). A review of some factors relevant to management of swordfish fisheries in the northwest Atlantic. *Environment Canada Fisheries and Marine Service*, 1–44.

CAPP. (2021). *Atlantic Canada's Offshore Oil and Gas Industry*. Canada's Oil & Natural Gas Producers. https://atlanticcanadaoffshore.ca/working-with-the-fishing-industry/

Committee on the Status of Endangered Wildlife in Canada. (2012). *COSEWIC assessment and status report on the leatherback sea turtle, Dermochelys coriacea in Canada.* COSEWIC. https://central.bac-lac.gc.ca/.item?id=CW69-14-116-2012-eng&op=pdf&app=Library

COSEWIC. (2021). *COSEWIC Committee on the Status of Endangered Wildlife in Canada*. https://www.cosewic.ca/index.php/en-ca/

de Bruyn, P., Murua, H., & Aranda, M. (2013). The precautionary approach to fisheries management: How this is taken into account by tuna regional fisheries management organisations (RFMOs). *Marine Policy*, *38*, 397–406. https://doi.org/10.1016/j.marpol.2012.06.019

DFO. (1987). *Fisheries management plan: 1987 swordfish*.

DFO. (1988). *Fisheries management plan: 1988*. 1–19.

DFO. (1993). *1993 management plan Atlantic swordfish fishery*. 1–5.

DFO. (1994). *1994 Atlantic swordfish management plan*. 1–4.

DFO. (1995). *1995 management plan Atlantic swordfish fishery*. 1–33.

DFO. (1996). *1996 management plan Atlantic swordfish fishery*. 1–38.

DFO. (1997). *1997-1999 management plan Atlantic swordfish fishery*. 1–58.

DFO. (2000). *The Canadian Atlantic swordfish Xiphias gladius fishery 2000-2002 integrated management plan*. 1–58.

DFO. (2004). *Canadian Atlantic swordfish and other tunas—Integrated fisheries management plan 2004-2006*. 1–41.

DFO. (2005). The Scotian shelf: An atlas of human activities. *Government of Canada*. https://www.dfo-mpo.gc.ca/oceans/publications/scotian-atlas-ecossais/page01-eng.html

DFO. (2013). *Canadian Atlantic swordfish and other tunas—Integrated fisheries management plan 2013*. 1–118.

DFO. (2015). *Swordfish*. Government of Canada. https://www.dfo-mpo.gc.ca/fisheries-peches/sustainable-durable/fisheries-peches/swordfish-espadon-eng.html

DFO. (2016). *Canadian Atlantic Swordfish and Other Tunas*. Government of Canada. https://www.dfo-mpo.gc.ca/fisheries-peches/ifmp-gmp/swordfish-espadon/NEW-swordfish-2013-espado-eng.html

DFO. (2017a). *Market snapshot: 25 years of Atlantic Canada offshore oil & natural gas production*. https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2017/market-snapshot-25-years-atlantic-canada-offshore-oil-natural-gas-production.html

DFO. (2017b). The Gully Marine Protected Area Management Plan. *Oceans and Coastal Management Division Second Edition*. https://waves-vagues.dfo-mpo.gc.ca/Library/4083556x.pdf

DFO. (2019a). *Laurentian Channel Marine Protected Area (MPA)*. Government of Canada. https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/laurentian-laurentien/index-eng.html

DFO. (2019b). *St. Anns Bank Marine Protected Area (MPA)*. Government of Canada. https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/stanns-sainteanne/index-eng.html

DFO. (2021). *2021 inshore lobster (Maritimes region)*. Government of Canada. https://www.dfo-mpo.gc.ca/fisheries-peches/decisions/fm-2021-gp/atl-29-eng.html

Dybas, C. L. (2002, November 11). *Survival of fish, deep-sea corals may be linked*. The Washington Post. https://www.washingtonpost.com/archive/politics/2002/11/11/survival-of-fish-deep-sea-corals-may-be-linked/39923d5c-f9cd-4cab-a07d-bba08f125e24/

Essington, T. E., Melnychuk, M. C., Branch, T. A., Heppell, S. S., Jensen, O. P., Link, J. S., Martell, S. J. D., Parma, A. M., Pope, J. G., & Smith, A. D. M. (2012). Catch shares, fisheries, and ecological stewardship: A comparative analysis of resource responses to a rights-based policy instrument: Catch shares and ecological stewardship. *Conservation Letters*, *5*(3), 186–195. https://doi.org/10.1111/j.1755-263X.2012.00226.x

FAO. (2001). *Research implications of adopting the precautionary approach to management of tuna fisheries*. FAO Fisheries Circular. https://www.fao.org/3/y0490e/y0490e05.htm#bm05

FAO. (2010). *The role of international fishery organizations and other bodies in the conservation and management of living aquatic resources*.

FAO. (2012). *The state of world fisheries and aquaculture 2012*. http://books.google.com/books?id=DpKqcJzkN3YC

FAO. (2017). *Stock status report 2017—Swordfish—North Atlantic*. ICCAT - SCRS.

FAO. (2020). *The state of world fisheries and aquaculture 2020*. FAO. https://doi.org/10.4060/ca9229en

Fisheries and Oceans. (2011). *Canadian Atlantic swordfish longline licence condition*.

Fisheries and Oceans. (2012). *Canadian Atlantic swordfish longline licence condition*.

Fisheries and Oceans. (2013). *Canadian Atlantic swordfish longline licence condition*.

Fisheries and Oceans. (2014). *Canadian Atlantic swordfish longline licence condition*.

Fisheries and Oceans. (2015). *Canadian Atlantic swordfish longline licence condition*.

Fisheries and Oceans. (2016). *Canadian Atlantic swordfish longline licence condition*.

Fisheries and Oceans. (2017). *Canadian Atlantic swordfish longline licence condition*.

Fisheries and Oceans. (2018). *Canadian Atlantic swordfish longline licence condition*.

Fisheries and Oceans. (2019). *Canadian Atlantic swordfish longline licence condition*.

Fisheries and Oceans. (2020). *Canadian Atlantic swordfish longline licence condition*.

Fisheries and Oceans. (2021). *Canadian Atlantic swordfish longline licence condition*.

FishTrack. (2021). *How to rig and use a harpoon for monster fish*. http://www.fishtrack.com/how-to/how-to-harpoon-fish_132530

Fitzgerald, G. (2000). The decline of the Cape Breton swordfish fishery: An exploration of the past and recommendations for the future of the Nova Scotia fishery. *Marine Issues Committee Special Publication - Ecology Action Centre*, *6*.

Fleury, C. (2013). *The island/sea/territory relationship: Towards a broader and three dimensional view of the Aquapelagic Assemblage*. *7*(1), 1–13.

Gibbs, M. T. (2010). Why ITQs on target species are inefficient at achieving ecosystem based fisheries management outcomes. *Marine Policy*, *34*, 708–709. https://doi.org/doi:10.1016/j.marpol.2009.09.005

Government of Nova Scotia. (2013). *Hunting*. Nova Scotia Canada. https://novascotia.ca/natr/hunt/

Hanke, A. (2017). A relative index of Atlantic swordfish abundance based on Canadian pelagic longline data (2002 to 2016). *Collect. Vol. Sci. Pap. ICCAT*, *74*(3), 1009–1035.

Hilborn, R. (1985). Fleet dynamics and individual variation: Why some people catch more fish than others. *Canadian Journal of Fisheries and Aquatic Sciences*, *42*(1), 2–13. https://doi.org/10.1139/f85-001

Hilborn, R. (2007). Managing fisheries is managing people: What has been learned? *Fish and Fisheries*, *8*(4), 285–296. https://doi.org/10.1111/j.1467-2979.2007.00263_2.x

Hurley, P. C. F., & Iles, T. D. (1981). A review of the Canadian swordfish fishery. *Collect. Vol. Sci. Pap. ICCAT*, *15*(2), 348–360.

ICCAT. (1990). *1990-02-Recommendation by ICCAT for the Conservation of Atlantic Swordfish Stocks*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1990-02-e.pdf

ICCAT. (1994). *1994-14-Recommendation by ICCAT for the Management of Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1994-14-e.pdf

ICCAT. (1995a). *1995-09-Resolution by ICCAT for North Atlantic Swordfish Recovery Program*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1995-09-e.pdf

ICCAT. (1995b). *1995-10-Recommendation by ICCAT Regarding the Implementation of an Alternative Option for the Conservation of Undersized Atlantic Swordfish and the Reduction of Fishing Mortality*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1995-10-e.pdf

ICCAT. (1995c). *1995-11-Recommendation by ICCAT to Establish Percentage Shares of Total Allowable Catch (TAC) and Overage & Underage Provisions for Nations Fishing for North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1995-11-e.pdf

ICCAT. (1995d). *1995-13-Resolution by ICCAT Concerning an Action Plan to Ensure the Effectiveness of the Conservation Program for Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1995-13-e.pdf

ICCAT. (1996a). *1996-01-Recommendation by ICCAT on Bigeye & Yellowfin Tunas*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1996-01-e.pdf

ICCAT. (1996b). *1996-07-Recommendation by ICCAT Regarding North Atlantic Swordfish Catch Quotas for 1997, 1998, and 1999*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1996-07-e.pdf

ICCAT. (1996c). *1996-14-Recommendation by ICCAT Regarding Compliance in the Bluefin Tuna and North Atlantic Swordfish Fisheries*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1996-14-e.pdf

ICCAT. (1997). *1997-06-Recommendation by ICCAT Regarding Catches of North Atlantic Swordfish for 1998 and 1999*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1997-06-e.pdf

ICCAT. (1998). *1998-17-Resolution by ICCAT for the Development of Recovery Scenarios for North and South Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1998-17-e.pdf

ICCAT. (1999a). *1999-02-Recommendation by ICCAT TO Establish a Rebuilding Program for North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1999-02-e.pdf

ICCAT. (1999b). *1999-04-Resolution by ICCAT for the Development of Possible Time/Area Closures for North and South Atlantic Swordfish and Gear Modifications to Reduce Undersized Swordfish Catch and Fishing Mortality*. https://www.iccat.int/Documents/Recs/compendiopdf-e/1999-04-e.pdf

ICCAT. (2000a). *2000-03-Recommendation by ICCAT Concerning Swordfish Catches by the Tuna Longline Fishery*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2000-03-e.pdf

ICCAT. (2000b). *2000-13-Recommendation by ICCAT to Establish a Plan to Rebuild Blue Marlin and White Marlin Populations*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2000-13-e.pdf

ICCAT. (2000c). *2000-14-Recommendation by ICCAT Regarding Compliance with Management Measures Which Define Quotas and/or Catch Limits*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2000-14-e.pdf

ICCAT. (2001). *2001-04-Resolution by ICCAT for Evaluating Alternatives to Reduce Catches of Juveniles or Dead Discards of Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2001-04-e.pdf

ICCAT. (2002a). *2002-02-Recommendation by ICCAT Relating to the Rebuilding Program for North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2002-02-e.pdf

ICCAT. (2002b). *2002-04-Resolution by ICCAT for the Evaluation of Small Swordfish Mortality*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2002-04-e.pdf

ICCAT. (2003). *2003-03-Recommendation by ICCAT to Amend the Rebuilding Program for North Atlantic Swordfish and South Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2003-03-e.pdf

ICCAT. (2004a). *2004-02-Supplemental Recommendation by ICCAT to Amend the Rebuilding Program for North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2004-02-e.pdf

ICCAT. (2004b). *2004-10-Recommendation by ICCAT Concerning the Conservation of Sharks Caught in Association with Fisheries Managed by ICCAT*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2004-10-e.pdf

ICCAT. (2006a). *2006-02-Supplemental Recommendation by ICCAT to Amend the Rebuilding Program for North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2006-02-e.pdf

ICCAT. (2006b). *ICCAT Manual. International Commission for the Conservation of Atlantic Tuna. In: ICCAT Publications [online]. Updated 2016.*

ICCAT. (2007). *2007-06-Supplemental Recommendation by ICCAT Concerning Sharks*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2007-06-e.pdf

ICCAT. (2008). *2008-02-Supplemental Recommendation by ICCAT to Amend the Rebuilding Program for North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2008-02-e.pdf

ICCAT. (2009a). *2009-02-Suuplemental Recommendation by ICCAT to Amend the Rebuilding Program for North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2009-02-e.pdf

ICCAT. (2009b). *2009-07-Recommendation by ICCAT on the Conservation of Thresher Sharks Caught in Association with Fisheries in the ICCAT Convention Area*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2009-07-e.pdf

ICCAT. (2009c). *2009-12-Resolution by ICCAT for the Pilot Application of the Kobe 2 Decision Matrix*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2009-12-e.pdf

ICCAT. (2010a). *2010-02-Recommendation by ICCAT for the Conservation of North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2010-02-e.pdf

ICCAT. (2010b). *2010-06-Recommendation by ICCAT on Atlantic Shortfin Mako Sharks Caught in Association with ICCAT Fisheries*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2010-06-e.pdf

ICCAT. (2010c). *2010-07-Recommendation by ICCAT on the Conservation of Oceanic Whitetip Shark Caught in Association with Fisheries in the ICCAT Convention Area*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2010-07-e.pdf

ICCAT. (2010d). *2010-08-Recommendation by ICCAT on Hammerhead Sharks (Family Sphyrnidae) Caught in Association with Fisheries Managed by ICCAT*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2010-08-e.pdf

ICCAT. (2010e). *2010-09-Recommendation by ICCAT on the By-Catch of Sea Turtles in ICCAT Fisheries*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2010-09-e.pdf

ICCAT. (2011a). *2011-02-Recommendation by ICCAT for the Conservation of North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2011-02-e.pdf

ICCAT. (2011b). *2011-08-Recommendation by ICCAT on the Conservation of Silky Sharks Caught in Association with ICCAT Fisheries*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2011-08-e.pdf

ICCAT. (2013a). *2013-02-Recommendation by ICCAT for the Conservation of North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2013-02-e.pdf

ICCAT. (2013b). *2013-10-Recommendation on Biological Sampling of Prohibited Shark Species by Scientific Observers*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2013-10-e.pdf

ICCAT. (2015). *2015-06-Recommendation by ICCAT on Porbeagle Caught in Association with ICCAT Fisheries*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2015-06-e.pdf

ICCAT. (2016). *2016-03-Recommendation by ICCAT for the Conservation of North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2016-03-e.pdf

ICCAT. (2017a). *2017-02-Recommendation by ICCAT Amending the Recommendation for the Conservation of North Atlantic Swordfish, Rec. 16-03*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2017-02-e.pdf

ICCAT. (2017b). Report of the 2017 ICCAT Atlantic swordfish stock assessment session. *Atlantic SWO Stock Assessment Meeting - Madrid 2017*.

ICCAT. (2019a). *2019-03-Recommendation by ICCAT Amending the Recommendation 17-02 by ICCAT for the Conservation of North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2019-03-e.pdf

ICCAT. (2019b). *2019-06-Recommendation by ICCAT on the Conservation of North Atlantic Stock of Shortfin Mako Caught in Association with ICCAT Fisheries*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2019-06-e.pdf

ICCAT. (2019c). *2019-14-Resolution by ICCAT on Development of Initial Management Objectives for North Atlantic Swordfish*. https://www.iccat.int/Documents/Recs/compendiopdf-e/2019-14-e.pdf

ICCAT. (2019d). ICCAT Basic Texts. *Madrid, 7th Revision*.

ICCAT. (2021a). *Access to ICCAT statistical databases*. ICCAT - SCRS. https://www.iccat.int/en/accesingdb.html

ICCAT. (2021b). Compendium management recommendations and resolutions adopted by ICCAT for the Conservation of Atlantic Tunas and Tuna-Like Species. *ICCAT Corazón de María*, *8*(28002).

ICCAT, Abid, N., & Indrissi, M. (2007). ICCAT Manual. Chapter 2.1.9: Swordfish. *International Commission for the Conservation of Atlantic Tunas*.

Knapman, P., Stokes, K., & Blyth-Skyrme, R. (2017). MSC sustainable fisheries certification north west Atlantic Canada longline swordfish. *Acoura Marine Ltd*, 1–288.

Logan, J. M., Golet, W., Smith, S. C., Neilson, J., & Van Guelpen, L. (2021). Broadbill swordfish (Xiphias gladius) foraging and vertical movements in the north-west Atlantic. *Journal of Fish Biology*, *99*(2), 557–568. https://doi.org/10.1111/jfb.14744

Lynch, P. D., Graves, J. E., & Latour, R. J. (2011). Challenges in the assessment and management of highly migratory bycatch species: A case study of the Atlantic marlins. *Sustainable Fisheries: Multi-Level Approaches to a Global Problem*, 197–225.

Mangel, M., MacCall, A. D., Brodziak, J., Dick, E. J., Forrest, R. E., Pourzand, R., & Ralston, S. (2013). A perspective on steepness, reference points, and stock assessment. *Canadian*

Journal of Fisheries and Aquatic Sciences, *70*(6), 930–940. https://doi.org/10.1139/cjfas-2012-0372

Marine Conservation Institute. (2021). *Marine Protection Atlas*. Marine Conservation Institute. https://mpatlas.org/zones

Marine Stewardship Council. (n.d.). *Why get your fishery MSC certified*. Marine Stewardship Council. https://www.msc.org/for-business/fisheries/why-get-certified

Martell, S., & Froese, R. (2013). A simple method for estimating MSY from catch and resilience. *Fish and Fisheries*, *14*(4), 504–514. https://doi.org/10.1111/j.1467-2979.2012.00485.x

Martin, K. A. & Committee on the Status of Endangered Wildlife in Canada. (2010). *COSEWIC assessment and status report on the loggerhead sea turtle, Caretta caretta, in Canada.* COSEWIC Secretariat, Canadian Wildlife Service. http://epe.lac-bac.gc.ca/100/200/301/environment_can/cws-scf/cosewic-cosepac/loggerhead_sea_turtle-ef/CW69-14-485-2010-eng.pdf

McDermott, G. R., Meng, K. C., McDonald, G. G., & Costello, C. J. (2019). The blue paradox: Preemptive overfishing in marine reserves. *Proceedings of the National Academy of Sciences*, *116*(12), 5319–5325. https://doi.org/10.1073/pnas.1802862115

Melnychuk, M. C., Essington, T. E., Branch, T. A., Heppell, S. S., Jensen, O. P., Link, J. S., Martell, S. J. D., Parma, A. M., Pope, J. G., & Smith, A. D. M. (2012). Can catch share fisheries better track management targets?: Catch shares to meet management targets? *Fish and Fisheries*, *13*(3), 267–290. https://doi.org/10.1111/j.1467-2979.2011.00429.x

NAFO. (2015). *NAFO Convention Area (map)*. NAFO - Northwest Atlantic Fisheries Organization. https://www.nafo.int/About-us/Maps

Neilson, J., Arocha, F., Cass-Calay, S., Mejuto, J., Ortiz, M., Scott, G., Smith, C., Travassos, P., Tserpes, G., & Andrushchenko, I. (2013). The recovery of Atlantic swordfish: The comparative roles of the regional fisheries management organization and species biology. *Reviews in Fisheries Science*, *21*(2), 59–97. https://doi.org/10.1080/10641262.2012.754842

Neilson, J., Loefer, J., Prince, E. D., Royer, F., Calmettes, B., Gaspar, P., Lopez, R., & Andrushchenko, I. (2014). Seasonal distributions and migrations of northwest Atlantic swordfish: Inferences from integration of pop-up satellite archival tagging studies. *PLoS ONE*, *9*(11), e112736. https://doi.org/10.1371/journal.pone.0112736

Ortiz, M., Mejuto, J., Hanke, A., Ijima, H., Walter, J., Coelho, R., & Ikkiss, A. illah. (2017). Updated combined biomass index of abundance of north Atlantic swordfish stock 1963-2015. *Collect. Vol. Sci. Pap. ICCAT*, *74*(3), 1275–1294.

Palomares, M. L. D., & Pauly, D. (2019). On the creeping increase of vessels' fishing power. *Ecology and Society*, *24*(3), art31. https://doi.org/10.5751/ES-11136-240331

Schirripa, M. J., Abascal, F., Andrushchenko, I., Diaz, G., Mejuto, J., Ortiz, M., Santos, M. N., & Walter, J. (2017). A hypothesis of a redistribution of north Atlantic swordfish based on changing ocean conditions. *Deep Sea Research Part II: Topical Studies in Oceanography*, *140*, 139–150. https://doi.org/10.1016/j.dsr2.2016.08.002

Sea Grant. (2011). *Louisiana Fisheries*. LSU. https://www.seagrantfish.lsu.edu/management/longlines.htm

SHQ Swordfish Harpoon Quota Society. (2018). Harpoon gear sector conservation harvesting plan. *Swordfish Harpoon Association*.

Stone, H. H., & Dixon, L. K. (2001). A comparison of catches of swordfish, Xiphias gladius, and other pelagic species from Canadian longline gear configured with alternating monofilament and multifilament nylon gangions. *Fishery Bulletin*, *99*, 210–216.

Tibbo, N., Day, L. R., & Doucet, W. F. (1961). The swordfish (Xiphias gladius its life-history and economic importance in the northwest Atlantic. *Fisheries and Oceans Canada*, 60.

UNEP-WCMC. (2021a). *Checklist of CITES species*. CITES Secretariat, Geneva, Switzerland and UNEP-WCMC, Cambridge, United Kingdom.

UNEP-WCMC. (2021b). *Convention on the conservation of migratory species of wild animals.* https://www.cms.int/en/species

Ward, P., & Hindmarsh, S. (2007). An overview of historical changes in the fishing gear and practices of pelagic longliners, with particular reference to Japan's Pacific fleet. *Reviews in Fish Biology and Fisheries*, *17*(4), 501–516. https://doi.org/10.1007/s11160-007-9051-0

WWF. (2017, December 1). *Lessons from Atlantic Canada's oldest marine protected area*. WWF. https://wwf.ca/stories/lessons-atlantic-canadas-oldest-marine-protected-area/

Appendix A Supporting Material for Chapter 2

A.1 Management timeline of the changes impacting the Canadian North Atlantic Swordfish Fishery (1959-2021). Types of change as follows; (R) Regulation; (G) Gear Type; (S) Spatial; (Q) Qualitative Observation; (B) Bycatch Mitigation.

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
1959	Qualitative Observation	Mobil Oil Canada issued the first offshore exploration permit in Sable Island area. The later led to the discovery of oil and gas observations on Sable Island and the Scotian Shelf.			x	x		(DFO, 2005)
1962	Gear Type	Canadian swordfish fishery shifts from a harpoon-dominant fishery to a longline-dominant fishery.		x				(Fitzgerald, 2000); ICCAT Task I data
1966	Qualitative Observation	Federal Department of Energy, Mines and Resources assumed administrative authority. Prior to this change, oil and gas exploration activities were disputed between Nova Scotia and Canada.			x	x		(DFO, 2005)
1967	Qualitative Observation	First exploratory well drilled on Sable Island for oil and gas. This was the beginning of a number of natural gas discoveries in this area.			x	x		(DFO, 2005)
1972	Qualitative Observation	Significant discovery of natural gas by Shell Canada on the Scotian Shelf (south of Sable Island).			x	x		(DFO, 2005)
	Regulation Change	USA and Canada prohibit the sale of swordfish with mercury concentration higher than 0.5ppm. This essentially shut down the Canadian fishery, as the main market for selling swordfish is US markets.	x					(Caddy, 1976; Fitzgerald, 2000)
1975	Bycatch Mitigation: CITES	Leatherback sea turtles (*Dermochelys coriacea*) added to Appendix I*.	x				x	(UNEP-WCMC, 2021a)
1977	Bycatch Mitigation: CITES	Leatherback sea turtles (*Dermochelys coriacea*) added to Appendix II**.	x				x	(UNEP-WCMC, 2021a)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
1977	Bycatch Mitigation: CITES	Sea turtle family *Cheloniidae* added to the CITES Appendix II**. This family is occasionally captured in Canadian surface longline gear.	x				x	(UNEP-WCMC, 2021a)
	Spatial Change	Canada extends its EEZ from 12nm to 200nm.	x		x			(Fleury, 2013)
1978	Regulation Change	USA raises acceptable levels of mercury concentration in Swordfish to 1.0ppm and Canada removes restrictions. The Canadian Fishery reopens, and catches increase to ~2500t.	x					(Caddy, 1976; Fitzgerald, 2000)
1979	Regulation Change	Canadian TAC set to 3500t by DFO.	x					(DFO, 1988)
1980	Gear Type	Refrigerated fish holds become more common allowing longer trips and different target species.		x		x		Longline Industry Representative
	Gear Type	Shift from multifilament material in gangions and mainline to monofilament material for the majority of the longline vessels. This shift was gradual over 2-3 years in the early 1980s.		x		x		(Stone & Dixon, 2001)
1981	Bycatch Mitigation: COSEWIC	Leatherback sea turtles (*Dermochelys coriacea*) listed as Endangered. COSEWIC is an advisory panel to Environment and Climate Change Canada to assess the status of wildlife species, and species listed are in danger of extinction. Leatherbacks are occasionally captured in Canadian surface longline gear.					x	(Committee on the Status of Endangered Wildlife in Canada, 2012)
	Bycatch Mitigation: CITES	Sea turtle family *Cheloniidae* added to the CITES Appendix I*. This family is occasionally captured in Canadian surface longline gear.	x				x	(UNEP-WCMC, 2021a)
1987	Spatial	All swordfish licences are valid in NAFO Convention Subareas 3, 4, and 5. Fishing activity is prohibited in zones 1 and 2 (e.g., Gulf of St. Lawrence and Bay of Fundy). *This is the earliest mention of this regulation in the literature; however, it may not be the earliest that this regulation was enforced.*	x		x			(DFO, 1987)
	Regulation Change	60t quota granted to each of two exploratory offshore tuna vessels.	x					(DFO, 1987)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
1987	Regulation Change	Swordfish longline licence holders permitted to catch all tunas (except bluefin tuna).	x					(DFO, 1987)
	Regulation Change	Number of swordfish longline licences limited to 70.	x					(DFO, 1987)
1988	Spatial Change	Moratorium on petroleum exploration on Georges Bank.			x	x		(DFO, 2005)
1990	Regulation: ICCAT Rec. 90-02 (SWO)	CPCs actively fishing swordfish in North Atlantic reduce fishing mortality by 15%. Prohibit the retention of swordfish smaller than 25 kg or 125cm (LJFL), with a tolerance of 15%. CPCs should consider time and area closures to further protect small swordfish. CPCs with small catches may remain the same. CPC's not directing for SWO will take measures to reduce SWO bycatch. This recommendation was created due to the SCRS report that the current catch of swordfish was unsustainable. Stock is overfished and overfishing is ongoing.	x					(ICCAT, 1990)
1991	Regulation Change	Canadian TAC reduced to 2000t by DFO.	x					(DFO, 2000)
1992	Spatial Change	Saint-Pierre and Miquelon EEZ boundary established.	x		x			(Fleury, 2013)
	Qualitative Observation	The Cohasset-Panuke Project (COPAN - first offshore energy project) started production on the Scotian Shelf.			x	x		(DFO, 2005)
1993	Gear Type	Only swordfish longline and harpoon gear are permitted.	x	x				(DFO, 1993)
	Regulation Change	60t of Canadian TAC allocated for swordfish bycatch in Canadian offshore tuna fishery.	x					(DFO, 1993)
1994	Regulation Change	Mandatory log submissions. This improved reporting, compliance, and data collection in the fishery.	x					(Andrushchenko et al., 2014)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
1994	Regulation: ICCAT Rec. 94-14 (SWO)	Quotas assigned to the following CPCs: Canada, United States, Portugal, and Spain. The first TAC allocated by ICCAT for Canada is 1500t for 1995 and 1400 for 1996. Japan will reduce SWO bycatch so that it does not compose more than 8% of the total weight of total catch. Other CPCs shall not increase their catches beyond their 1993-1994 levels. Size limits remain in effect. CPCs encourage to determine measures that will protect small swordfish (e.g., time area closures, test fisheries).	x					(ICCAT, 1994)
1995	Spatial Change	Closure of area West of the 65°/30° longitude line to longlining activities until August 1st. This closure was put in place to reduce the amount of bycatch (i.e., Bluefin tuna and shark species).	x	x	x			(DFO, 1995)
	Spatial Change	Establishment of Broodstock closure area (September 1st to December 31st); Longlining prohibited within this area to reduce Bluefin tuna bycatch. Point Latitude (N) Longitude (W) 1. 43˚23'18" 65˚37'10" (Cape Sable N.S.) 2. 43˚12' 65˚36' 3. 43˚11' 63˚24' 4. 44˚13' 62˚00' 5. 45˚00' 62˚00' (Liscomb Point N.S.)	x	x	x			(DFO, 1995)
	Bycatch Mitigation	Removing only the fins from sharks (finning) is strictly prohibited. Fins may be sold, but the proportion of fins to shark carcasses cannot exceed 5%.	x				x	(DFO, 1995)
	Regulation Change	Once 75% of the swordfish quota has been reached, DFO may temporarily close the fishery.	x					(DFO, 1995)
	Regulation Change	10t of Canadian TAC allocated for swordfish bycatch in Canadian offshore tuna fishery. 150t is allocated for bycatch in swordfish fleet.	x					(DFO, 1995)
	Regulation Change	Number of swordfish longline licences increased to 77.	x					(DFO, 1995)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
1995	Regulation: ICCAT Res. 95-09 (SWO)	This resolution is based off the 1995 SCRS report that showed swordfish biomass was at 68% of what it should be. It resolves that the SCRS will proposed recovery options and an annual TAC series to support MSY levels within 5, 10, and 15 years. Stock is overfished (B=68% of B_{MSY}).				x		(ICCAT, 1995a)
	Regulation: ICCAT Rec. 95-10 (SWO)	Establishes an alternative lower minimum size regulation of 119cm with 0% tolerance, CPCs can choose this to use this as an alternative to the 125cm with 15% tolerance. The purpose is to aid CPC's develop protection of smaller swordfish. CPCs that choose this alternative will need to provide proper records of discards.	x					(ICCAT, 1995b)
	Regulation: ICCAT Rec. 95-11 (SWO)	Establishes quota allocations for each country based on previous catch history. Canada 10.00%, Japan 6.25%, Portugal 7.50%, Spain 41.25%, United States 29.00%, Others (total) 6.00%. If a country exceeds their allotted quota, the overage will be deducted in subsequent adjustment years.	x					(ICCAT, 1995c)
	Regulation: ICCAT Res. 95-13 (SWO)	Resolution to promote compliance by non-CPCs. Potential annual review of implementation of conservation efforts by all CPCs and non-CPCs.	x			x		(ICCAT, 1995d)
1996	Spatial Change	Canada adjusts boundary of EEZ using Sable Island as a base. This expanded the fishing grounds that are reserved for the Canadian fleet and displaced other CPCs further. Completely surrounded the EEZ of Saint Pierre and Miquelon.	x		x	x		(Fleury, 2013)
	Regulation: ICCAT Rec. 96-01 (TRO)	Establishes a national observer program for longliners, purse seiners and bait boats on 25% of vessels using fish aggregating devices (FADs) and 5% of vessels using other methods to obtain data on the composition of the catches. Survey implemented of the vessels using FADs in an effort to maintain the stock of tropical tunas.	x					(ICCAT, 1996a)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
1996	Regulation: ICCAT Rec. 96-07 (SWO)	This recommendation establishes the TAC at 11,300 MT in 1997, 11,000 MT in 1998, and 10,700 MT in 1999. The TAC is divided according to TAC allocation previously determined. Canada received 1130t for 1997, 1140 for 1998, and 1095 for 1999.The over-harvesting provisions previously determined, and size limits will apply. Stock is overfished (B=58% of B_{MSY}) and overfishing is ongoing (F=204% of F_{MSY}).	x					(ICCAT, 1996b)
	Regulation: ICCAT Rec. 96-14 (GEN)	CPCs exceeding quota must report to compliance committee. Future catches to be reduced by 100% of the amount of overages. If CPCs exceed catch limits in two consecutive years, the catch limit in the following year will be reduced by 125% of the excess catch amount. Other consequences possible at the discretion of the Commission.	x					(ICCAT, 1996c)
	Gear Type	Fleet-adopted shift from J-hooks to circle hooks to reduce bycatch and improve US market opportunities.		x		x		(DFO, 2004)
1997	Qualitative Observation	Discards of blue shark exceeds the catch of swordfish (in both numbers and weight) - collected through observer data.				x	x	(Fitzgerald, 2000)
	Regulation Change	Swordfish longline licence holders that possess bluefin tuna licences are NOT authorized to used them concurrently, other than in NAFO subarea 3.	x					(DFO, 1997)
	Regulation: ICCAT Rec. 97-06 (SWO)	CPCs that catch swordfish without specific quota reduce their catches for 1998 and 1999 to 45% of their 1996 levels. If no catches in 1996, refrain from developing swordfish directed fisheries in 1998 or 1999.	x					(ICCAT, 1997)
1998	Regulation: ICCAT Res. 98-17 (SWO)	If the stock assessment indicates that stocks levels are still below MSY, SCRS will develop rebuilding options. SCRS will evaluate the effectiveness of current regulations for achieving conservation objectives. CPCs will provide the best available data to support stock assessments.	x			x		(ICCAT, 1998)
1999	Spatial Change	The Sable Offshore Energy Project (SOEP) begins production.			x	x		(DFO, 2005)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
1999	Regulation: ICCAT Rec. 99-02 (SWO)	All CPC's will create their own rebuilding program for 2000-2009. Establishes a dead discard allowance for the years 2000, 2001, and 2002. Allocation of TAC will follow 96-07. Canada receives 1018t for 2000-2002. CPC's must attempt to provide the best data to SCRS (catch, catch at size, location, and month of capture on the smallest scale possible). Previous management measures (size limits) still in place. Stock is overfished (B=65% of B_{MSY}) and overfishing is ongoing (F=134% of F_{MSY}).	x					(ICCAT, 1999a)
	Regulation: ICCAT Res. 99-04 (SWO)	This resolution addresses the potential effectiveness of time/area closures to protect small swordfish. SCRS to determine regulations using data provided by the CPC's, specifically the impact of changing longlining gear to protect small swordfish.		x	x		x	(ICCAT, 1999b)
	Regulation Change	Trip-limit established for 2000 and 2001. Earlier than July, required to direct for other tuna, and only take swordfish as bycatch with a 1 swordfish: 4 tuna ratio. After July 1st, permitted to target swordfish until 75% of quota reached, then back to 1:4 tuna ratio.	x					(Andrushchenko et al., 2014)
2000	Regulation Change	Gear-based allocations introduced, so that the harpoon and the longline fisheries have separate quotas. This eliminated the competitive allocations between fisheries. The divide was originally set at 90% for longliners and 10% for harpooners, with 5t set aside for offshore tuna licences.	x	x				(DFO, 2000)
	Regulation Change	Swordfish longline licence holders that possess bluefin tuna licences are authorized to used them concurrently.	x					(DFO, 2000)
	Regulation Change	Minimum of 5% at-sea observer coverage for longline vessels directing for swordfish required.	x					(DFO, 2000)
	Bycatch Mitigation: ICCAT Rec. 00-03 (SWO)	Addressing the impacts of swordfish bycatch in tuna longline fishing (e.g., Japan) and the reallocation of some TAC from countries with underages (e.g., USA) to account for these differences.	x				x	(ICCAT, 2000a)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2000	Regulation: ICCAT Rec. 00-14 (GEN)	Recommendation regarding compliance with management measures which define quotas and/or catch limits. For any species under quota/catch limit management, underages/overages from one year may be added to/must be subtracted from the quota/catch limit of the management period immediately after or one year after that year.	x					(ICCAT, 2000c)
	Bycatch Mitigation: ICCAT Rec. 00-13 (BIL)	All blue and white marlins caught alive in the pelagic longline vessels must be released. Marlins can only be retained if dead went brought to the boat. CPCs must maintain records of all dead and live releases.	x				x	(ICCAT, 2000b)
2001	Spatial Change	Removal of longlining restrictions in Broodstock closure area which had been in place beginning in 1995.	x	x	x			(DFO, 2004)
	Spatial Change	Bluefin exclusion zone established and closed to longline gear from August 1 to December 31. POINT LATITUDE(N) LONGITUDE(W) 1. 43°23'18" 65°37'10" (CAPE SABLE NS) 2. 43°10'48" 65°37'10" 3. 44°42'00" 62°00'00" 4. 45°00'00" 62°00'00" (LISCOMB POINT)	x	x	x			(DFO, 2004)
	Regulation: ICCAT Res. 01-04 (SWO)	This resolution further addresses the potential effectiveness of time/area closures to protect small swordfish. SCRS to determine regulations using data provided by the CPC's.	x		x			(ICCAT, 2001)
	Bycatch Mitigation: CMS	White shark (*Carcharodon carcharias*) added to Appendix I[a].	x				x	(UNEP-WCMC, 2021b)
	Bycatch Mitigation: CMS	White shark (*Carcharodon carcharias*) added to Appendix II[b].	x				x	(UNEP-WCMC, 2021b)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2002	Regulation Change	End of trip-limit for the longline sector. Switch to an ITQ system for longline sector so each licence has an associated quota. This change eliminated the derby-style fishery and mitigated the risk of exceed swordfish quota allocations.	x					(Andrushchenko et al., 2014)
	Regulation: ICCAT Rec. 02-02 (SWO)	CPCs who have been actively fishing SWO shall implement a 10-year recovery rebuilding program, continuing through 2009. Establishing the TAC of 14 000t for 2003, 2004, and 2005. Canada receives 1338t for 2003, and 1348t for 2004 and 2005, with an addition 25t each year transferred from USA. Establishing the allocation of catch that can be retained and total dead discard allowance. After 2003, TAC will include a dead discard allowance. Japan's arrangement to count 400mt of SWO caught in the North Atlantic against its uncaught South Atlantic quota continued, however, observer coverage required increased from 5% to 8%. Starting in 2005, SCRS will conduct a stock assessment every 3 years. Stock is overfished (B=95% of B_{MSY}) and overfishing is no longer on going (F=75% of F_{MSY}).	x					(ICCAT, 2002a)
	Regulation: ICCAT Res. 02-04 (SWO)	This resolution addresses the mortality of undersized swordfish and requires the SCRS to continue to monitor the effects that this mortality has on the stock and prepare any necessary additional measures for the 2005 meeting of the Commission.	x			x		(ICCAT, 2002b)
2003	Regulation Change	Measures introduced to account for dead discards (allocation, records).	x					(DFO, 2004)
	Regulation Change	The use of airplanes or other aerial devices to assist in the catch of swordfish is prohibited. *This is the earliest mention of this regulation in the literature; however, it may not be the earliest that this regulation was enforced.*	x					(SHQ Swordfish Harpoon Quota Society, 2018)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2003	Regulation Change	Harpoon A[1] licence quota will be 123.4 t and B licence quota will be 9 t for 2004. If Harpoon A[1] TAC caught early, Harpoon A[1] licence holders permitted to retain up to 30% of 2005 quota. Unused quota in 2003 will rollover to 2004, likewise for unused quota in 2004. Any unused quota in 2005 will be granted to the longline sector.	x					(SHQ Swordfish Harpoon Quota Society, 2018)
	Spatial change	Established the area between Browns and Georges Bank known as the "Hell Hole" to be closed to longlining activities from July 1 to November 30. POINT LATITUDE(N) LONGITUDE(W) 1. 42°06'00" 65°41'24" 2. 42°06'00" 65°27'30" 3. 41°55'48" 65°27'30" 4. 41°55'48" 65°41'24" 5. 42°06'00" 65°41'24"	x		x			(DFO, 2004)
	Bycatch Mitigation: SARA	Leatherback sea turtle (*Dermochelys coriacea*) listed as Endangered.					x	(Atlantic Leatherback Turtle Recovery Team (Canada) & Department of Fisheries and Oceans, 2006)
	Regulation: ICCAT Rec. 03-03 (SWO)	This recommendation amends 02-02 to start the SCRS stock assessment in 2006, instead of 2005.	x					(ICCAT, 2003)
	Bycatch Mitigation: CITES	Basking shark (*Cetorhinus maximus*) added to Appendix II**.	x				x	(UNEP-WCMC, 2021a)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2004	Spatial Change	The Gully Marine Protected Area established and closed to fishing activities. Zone 1 of this MPA is completely closed to longlining and harpooning activities and composes an area of 475 km^2. Longlining and harpooning swordfish are permitted in Zones 2 and 3, activity is highly regulated.	x		x			(DFO, 2004)
	Regulation: ICCAT Rec. 04-02 (SWO)	This recommendation extends the management measures established in 02-02 until 2006. Additionally, adjustment years re-established for 2003-2006.	x					(ICCAT, 2004a)
	Bycatch Mitigation: ICCAT Rec. 04-10 (BYC)	Recommendation by ICCAT concerning the conservation of sharks caught in association with fisheries managed by ICCAT. CPC's will report ICCAT Task I and II data for catches of sharks, fully utilize any shark catches, and limit the number of fins retained without the full shark attached. Fishing vessels are prohibited from retaining or handling fins in contravention with this recommendation. All non-shark directed fisheries should release sharks in a way that reduces potential harm, research nursery areas to avoid, use gear that reduces bycatch	x				x	(ICCAT, 2004b)
	Bycatch Mitigation: CITES	White shark (*Carcharodon carcharias*) added to Appendix II**.	x				x	(UNEP-WCMC, 2021a)
2005	Regulation Change	Swordfish/other tuna longline vessels require 100% VMS coverage.	x					(DFO, 2004)
	Spatial Change	Removal of longlining restrictions in the area West of the 65/30 longitude line.	x	x	x			(DFO, 2004)
2006	Bycatch Mitigation: CMS	Basking shark (*Cetorhinus maximus*) added to Appendix I[a].	x				x	(UNEP-WCMC, 2021b)
	Bycatch Mitigation: CMS	Basking shark (*Cetorhinus maximus*) added to Appendix II[b].	x				x	(UNEP-WCMC, 2021b)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2006	Regulation Change	TAC of 134 t for Harpoon sector, with 125 t for Harpoon licence A^1 holders and 9 t for Harpoon licence B^2 holders. If Harpoon A^1 licence caught early, Harpoon A^1 licence holders permitted to retain up to 40% of 2007 quota.	x					(SHQ Swordfish Harpoon Quota Society, 2018)
	Regulation: ICCAT Rec. 06-02 (SWO)	TAC of 14 000 t extended through 2008. 2690 t from the US unused portion during 2003-2006 added to the TAC available, raising the TAC above scientific recommendations. Canada receives 1348 t for 2007 and 2008, with an addition 25 t each year transferred from USA. Starting in 2009, SCRS will conduct a stock assessment and every 3 years thereafter. Percentage allocations are the following: European Community 52.42%, United States 30.49%, Canada 10.52%, and Japan 6.57%. Stock nearly recovered (B near B_{MSY}) and no longer overfished (F< F_{MSY} since 2001).	x					(ICCAT, 2006a)
2007	Regulation Change	TAC of 65.07 t for Harpoon sector, with 56.07 t for Harpoon licence A^1 holders and 9 t for Harpoon licence B^2 holders. If Harpoon A^1 licence caught early, Harpoon A^1 licence holders permitted to retain up to 40% of 2008 quota.	x					(SHQ Swordfish Harpoon Quota Society, 2018)
	Bycatch Mitigation: ICCAT Rec. 07-06 (BYC)	Supplemental recommendation by ICCAT concerning sharks. Reduce mortality of porbeagle and shortfin mako and research potential nursery areas. By 2009, SCRS will conduct a stock assessment and provide measures and recommendations for porbeagle shark.	x				x	(ICCAT, 2007)
2008	Regulation Change	TAC of 88 t for Harpoon sector, with 79 t for Harpoon licence A^1 holders and 9 t for Harpoon licence B^2 holders. If Harpoon A^1 licence caught early, Harpoon A^1 licence holders permitted to retain up to 40% of 2009 quota.	x					(SHQ Swordfish Harpoon Quota Society, 2018)
	Regulation: ICCAT Rec. 08-02 (SWO)	This recommendation extends 06-02 through 2009.	x					(ICCAT, 2008)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2009	Bycatch Mitigation: CMS	Porbeagle (*Lamna nasus*), shortfin mako (*Isurus oxyrinchus*), and longfin mako shark (*Isurus paucus*) added to Appendix II[b].	x				x	(UNEP-WCMC, 2021b)
	Regulation: ICCAT Rec. 09-02 (SWO)	This recommendation extends the terms of 06-02 through 2010, except the TAC will be 13700 t, overages will be deducted from quotas for each CPC in 2011, and transfers between north and south Atlantic quotas for some CPCs are permitted. SCRS will develop a Limit Reference Point (LRP) for North Atlantic swordfish in advance of the nest assessment. ($B > B_{MSY}$; $F < F_{MSY}$)	x					(ICCAT, 2009a)
	Bycatch Mitigation: ICCAT Rec. 09-07 (BYC)	CPCs prohibited from retaining/shipping/landing/storing/etc. bigeye thresher sharks. Shark must be released in a manner that reduces harm and CPCs must implement research into this species.	x				x	(ICCAT, 2009b)
	Resolution: ICCAT Res. 09-12 (GEN)	The pilot application of the Kobe 2 Decision Matrix for use by SCRS to provide management advice (BFT and BET)	x					(ICCAT, 2009c)
2010	Regulation Change	TAC of 131.007 t for Harpoon sector, with 122.007 t for Harpoon licence A[1] holders and 9 t for Harpoon licence B[2] holders. If Harpoon A[1] licence caught early, Harpoon A[1] licence holders permitted to retain up to 40% of 2011 quota. Harpoon B[2] licence holders limited to 3 fish per trip.	x					(SHQ Swordfish Harpoon Quota Society, 2018)
	Qualitative Observation	The Canadian Atlantic harpoon fishery receives Marine Stewardship Council certification.				x		(Knapman et al., 2017)
	Bycatch Mitigation: COSEWIC	Loggerhead sea turtle (*Caretta caretta*) designated as Endangered. Loggerheads are occasionally captured in Canadian surface longline gear.					x	(Martin & Committee on the Status of Endangered Wildlife in Canada, 2010)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2010	Regulation: ICCAT Rec. 10-02 (SWO)	TAC of 13700 t extended through 2011, overages will be deducted from quotas for each CPC in 2013. Canada receives 1348 t for 2011, with an addition 25 t transferred from USA and 100t from Senegal. Previous non-conflicting regulations still in place. This recommendation replaces Recs 06-02, 08-02, 09-02.	x					(ICCAT, 2010a)
	Bycatch Mitigation: ICCAT Rec. 10-06 (BYC)	CPCs to take action to improve Task I and II data collection for shark catches. CPCs prohibited from retaining Atlantic shortfin mako sharks if CPC does not report Task I data.	x				x	(ICCAT, 2010b)
	Bycatch Mitigation: ICCAT Rec. 10-07 (BYC)	CPCs prohibited from retaining/shipping/landing/storing/etc. oceanic whitetip sharks in any fishery.	x				x	(ICCAT, 2010c)
	Bycatch Mitigation: ICCAT Rec.10-08 (BYC)	CPCs prohibited from retaining/shipping/landing/storing/etc. hammerhead sharks, with some exception (e.g., developing coastal CPCs). The number of discards is required to be reported to ICCAT.	x				x	(ICCAT, 2010d)
	Bycatch Mitigation: ICCAT Rec.10-09 (BYC)	Requiring pelagic longline vessels operating in the Convention area to carry on board safe handling, disentanglement, and release equipment capable of releasing sea turtles and to report all sea turtle interactions within the fleet. SCRS shall use the data collected to provide advice to further mitigate sea turtle bycatch.	x				x	(ICCAT, 2010e)
2011	Qualitative Observation	Blue shark still composed approximately 40-50% of the overall observed catch in swordfish longline fleet				x		(Knapman et al., 2017)
	Regulation Change	TAC of 146.773 t for Harpoon sector, with 137.773 t for Harpoon licence A[1] holders and 9 t for Harpoon licence B[2] holders. Fishery will close once 70% of the quota is reached, then fishery will reopen July 1. If Harpoon A[1] licence caught early, Harpoon A[1] licence holders permitted to retain up to 40% of 2012 quota. Harpoon B[2] licence holders limited to 2 fish per trip.	x					(SHQ Swordfish Harpoon Quota Society, 2018)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2011	Regulation: ICCAT Rec.11-02 (SWO)	This recommendation replaces 10-02 and extends the TAC of 13 700 t to 2012 and 2013. Canada receives 1348 t for 2012 and 2013, with an addition 35 t each year transferred from Japan, 100t from Senegal, and 35 t from Chinese Taipei. Management plans should be developed for developing/coastal CPCs and other CPCs for 2012 and 2013. CPCs will submit management plans by Sept 15th each year. Previous non-conflicting regulations still in place.	x					(ICCAT, 2011a)
	Bycatch Mitigation: ICCAT Rec.11-08 (BYC)	CPCs prohibited from retaining/shipping/landing/etc. silky sharks (dead or alive) in all fisheries, with some exceptions. Sharks must be released in a manner that reduces harm and CPCs must implement research into this species. CPCs to take action to improve Task I and II data collection for shark catches. SCRS shall use data collected to provide advice on silky shark management options.	x				x	(ICCAT, 2011b)
	Licence Condition Change (SWO, Other Tuna)	No requirement for dehooking/disentanglement if only harpoon gear on board. Dehooking/disentanglement gear required when using longline gear: a long handled dehooking device, a short handled dehooking device with bite blocker, long handled line cutter, bolt cutter and monofilament cutter and a sea turtle species identification chart.	x	x			x	(Fisheries and Oceans, 2011)
2012	Qualitative Observation	The Canadian Atlantic longline fishery receives Marine Stewardship Council certification.				x		(Knapman et al., 2017)
	Regulation Change	Internal quota system established in harpoon sector for individual licences based off catch history (1998-2009) and using the formula of 90% catch history and 10% equal share. Overruns by licence holders will have to be covered within 30 days. Unused quota will be carried forward to the next year, with a limit of 25% for individual licence holders to carry forward.	x					(SHQ Swordfish Harpoon Quota Society, 2018)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2012	Licence Condition Change (SWO, Other Tuna)	- Allowed to retain the incidental catch of shark except white shark (*Carcharodon carcharias*). - Only authorized to use circle hooks.	x	x			x	(Fisheries and Oceans, 2012)
2013	Regulation Change	Swordfish longline licence holders that possess bluefin tuna licences are NOT authorized to used them concurrently, other than in NAFO subarea 3.	x					(DFO, 2013)
	Regulation Change	Shift from a single year management plan to a multiyear plan (3-year to align with the stock assessments). The period will start again in 2014, so any unused Harpoon quota in 2013 will be transferred to the Longline Sector. Other management measures for quotas and transfers still in place.	x					(SHQ Swordfish Harpoon Quota Society, 2018)
	Regulation: ICCAT Rec. 13-02 (SWO)	This recommendation replaces 11-02. Stock is no longer overfished. Canada receives 1348t for 2014-2016, with an addition 35t each year transferred from Japan, 125t from Senegal, and 35t from Chinese Taipei. This recommendation is valid through 2016. SCRS shall consider the LRP in stock assessments. Previous non-conflicting regulations still in place.	x					(ICCAT, 2013a)
	Bycatch Mitigation: ICCAT Rec. 13-10 (BYC)	Recommendation on biological sampling of prohibited shark species by scientific observers. Certain prohibited sharks' species may be retained so that an at-sea observer can collect biological samples.	x				x	(ICCAT, 2013b)
	Licence Condition Change (SWO, Other Tuna)	Corrodible circle hooks required.	x	x				(Fisheries and Oceans, 2013)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2014	Bycatch Mitigation: CITES	Great hammerhead shark (*Sphyrna mokarran*), oceanic whitetip shark (*Carcharhinus longimanus*), porbeagle shark (*Lamna nasus*), scalloped hammerhead shark (*Sphyrna lewini*), smooth hammerhead shark (*Sphyrna zygaena*) added to Appendix II**.	x				x	(UNEP-WCMC, 2021a)
	Licence Condition Change (SWO, Other Tuna)	Licence holder is authorized to retain incidental catch of shark, except for bigeye thresher sharks, hammerhead sharks, oceanic whitetip sharks, and silky sharks.	x				x	(Fisheries and Oceans, 2014)
2015	Bycatch Mitigation: CMS	Silky sharks (*Carcharhinus falciformis*), scalloped hammerhead sharks (*Sphyrna lewini*), great hammerhead sharks (*Sphyrna mokarran*), pelagic thresher shark (*Alopias pelagicus*), bigeye thresher (*Alopias superciliosus*), common thresher (*Alopias vulpinus*) added to Appendix II[b].	x				x	(UNEP-WCMC, 2021b)
	Bycatch Mitigation: ICCAT Rec. 15-06 (BYC)	Porbeagles must be released alive, and this information shall be reported in the data. Additional measures will be considered if discard levels exceed those of 2014.	x				x	(ICCAT, 2015)
	Licence Condition Change (Other Tuna)	"Tail cutting" to determine fat content is prohibited until after the fish has been offloaded and weighed by a dockside monitoring company The tail and adjoining fin are not permitted to be removed until after the fish is offloaded and weighed.	x				x	(Fisheries and Oceans, 2015)
2016	Regulation Change	Any unused Harpoon quota will be carried forward to the next year, with a limit of 15% (reduced from 25%) for individual licence holders to carry forward.	x					(SHQ Swordfish Harpoon Quota Society, 2018)
	Regulation: ICCAT Rec. 16-03 (SWO)	This recommendation replaces 13-02 for the management of North Atlantic Swordfish. TAC of 13700t extended through 2017. Canada receives 1348t for 2017, with an addition 35t transferred from Japan, 125t from Senegal, and 35t from Chinese Taipei. Previous non-conflicting regulations still in place.	x					(ICCAT, 2016)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2016	Licence Condition Change (SWO, Other Tuna)	Live porbeagle sharks much be released and recorded.	x				x	(Fisheries and Oceans, 2016)
2017	Regulation: ICCAT Rec. 17-02 (SWO)	This recommendation replaces 16-03 for the management of North Atlantic Swordfish. Establishes a TAC of 13 200 for 2018-2021. Canada receives 1348t for 2018-2021, with an addition 35t each year transferred from Japan, 125t from Senegal, and 35t from Chinese Taipei. Previous non-conflicting regulations still in place.	x					(ICCAT, 2017a)
	Bycatch Mitigation: SARA	Loggerhead sea turtle (*Caretta caretta*) designated as Endangered.					x	(Fisheries and Oceans, 2020)
	Bycatch Mitigation: CITES	Thresher shark (*Alopias pelagicus)*, silky shark (*Carcharhinus falciformis*) added to Appendix II**.	x				x	(UNEP-WCMC, 2021a)
	Licence Condition Change (Other Tuna)	Only bluefin tuna that would otherwise be discarded dead may be retained.	x				x	(Fisheries and Oceans, 2017)
	Licence Condition Change (SWO)	Addition of mandatory bycatch logs. All species caught as bycatch must be recorded in the logbook.	x				x	(Fisheries and Oceans, 2017)
2018	Regulation Change	The Harpoon fleets may be authorized to borrow 20.2t from future allocations if the Harpoon catch reaches 150t.	x					(SHQ Swordfish Harpoon Quota Society, 2018)
	Bycatch Mitigation: CMS	Dusky shark (*Carcharhinus obscurus*) and blue shark (*Prionace glauca*) added to Appendix II[b].	x				x	(UNEP-WCMC, 2021b)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2018	Spatial Change	DFO authorized a test fishery to start in the Hell Hole for 30 longline sets, with 100% observer coverage. It was determined that bycatch levels are too high, therefore, restrictions in the exclusion zone remain.	x		x			(C. MacDonald, personal communication, September 21, 2021)
	Licence Condition Change (SWO, Other Tuna)	Addition of no take zone in St. Ann's Marine Protected Area. Zone 1 (total area of 3310 km^2) is closed for longlining activities. Zones 2, 3, and 4 are open to bottom longlining and harpooning.	x		x			(Fisheries and Oceans, 2018)
	Licence Condition Change (SWO, Other Tuna)	Must retain all species of tuna that would be dead regardless. If tuna is alive, they must be released in a manner that causes the least harm. Basking sharks added to the list of sharks that cannot be retained.	x				x	(Fisheries and Oceans, 2018)
	Licence Condition Change (SWO)	Operator prohibited from removing fins until shark's carcass has been offloaded and the weight and species has been verified by a dockside monitor.	x				x	(Fisheries and Oceans, 2018)
	Licence Condition Change (SWO)	Operator prohibited to take porbeagle and shortfin mako using harpoon gear.	x	x			x	(Fisheries and Oceans, 2018)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2019	Licence Condition Change (SWO)	Bluefin Exclusion Zone extended to fill gap at Sherbrook, NS. Point LATITUDE(N) LONGITUDE(W) 1. 43°23'18" 65°37'10" (Cape Sable Island, NS) 2. 43°10'48" 65°37'10" 3. 44°42'00" 62°00'00" 4. 44°50'00" 61°30'00" 5. 45°00'00" 61°30'00" 6. 45°09'37" 61°39'37" (Isaacs Harbour, NS)	x	x	x			(Fisheries and Oceans, 2019)
	Bycatch Mitigation: CITES	Shortfin mako (*Isurus oxyrinchus*), longfin mako (*Isurus paucus*) sharks added to Appendix II**.	x				x	(UNEP-WCMC, 2021a)
	Regulation: ICCAT Rec. 19-03 (SWO)	This recommendation amends 17-02 for North Atlantic Swordfish and adjusts the footnotes.	x					(ICCAT, 2019a)
	Bycatch Mitigation: ICCAT Rec. 19-06 (BYC)	Recommendation by ICCAT on the conservation of North Atlantic Stock of Shortfin mako caught in association with ICCAT fisheries. CPC's can retain shortfin mako if, for vessels longer than 12m, the vessel has an observer or an electronic monitoring system, the shark is dead when brought up to the boat, the observer collects biological data, and the retention does not exceed the average shortfin mako landings. Domestic laws may permit the retention of shortfin mako. All data must be collected and reported to ICCAT.	x				x	(ICCAT, 2019b)
	Regulation: ICCAT Res. 19-14 (SWO)	This resolution requests decisions be made by Panel 4 during the 2021 Panel 4 Intersession meeting concerning MSE management objectives for North Atlantic Swordfish (e.g., stock status, safety, yield, stability).	x					(ICCAT, 2019c)

Year	Category	Management Description	R	G	S	Q	B	Reference(s)
2019	Qualitative Observation: ICCAT press release	Amendment to the ICCAT convention, known as the Palma Mallorca Protocol. This allows ICCAT to oversee protected of highly migratory shark species in the NATL. US passed this amendment in 2019 and Canada passed the amendment in 2021. Waiting for 50% of CPCs to pass before it is accepted.				x		(ICCAT, 2021b)
	Licence Condition Change (SWO, Other Tuna)	Addition of Laurentian channel Marine Protected Area. No fishing activity permitted in Zone 1 and 2.	x		x			(Fisheries and Oceans, 2019)
2020	Bycatch Mitigation: CMS	Oceanic whitetip shark (*Carcharhinus longimanus*) added to Appendix I[a].	x				x	(UNEP-WCMC, 2021b)
	Bycatch Mitigation: CMS	Smooth hammerhead shark (*Sphyrna zygaena*) added to Appendix II[b].	x				x	(UNEP-WCMC, 2021b)
	Licence Condition Change (Other Tuna)	Shortfin mako sharks added to the list of sharks that cannot be retained.	x				x	(Fisheries and Oceans, 2020)
2021	Licence Condition Change	Addition of angling, handline, and buoy gears as permitted gear under the longline license. Gear cannot be used in the same fishing trip as longlining gear.	x	x				(Fisheries and Oceans, 2021)

*CITES is focused on the trade of protected species. Appendix I refers to species at risk and commercial trade is generally not permitted.

**CITES is focused on the trade of protected species. Appendix II refers to species that need controls to protect them and commercial trade is possible with permits.

[a] CMS focuses on the protection of migratory species. Appendix I is specific to species that are in danger of extinction throughout most or all of their migratory range and any Parties with this range must take strict measures to protect the species.

[b] CMS focuses on the protection of migratory species. Appendix II is specific to species identified with unfavorable status in terms of conservation and may require international cooperation to establish protection measures.

[1]Hapoon Licence Group A is composed of recently active licences, defined by at least one landed swordfish or hail out during the 1996-1999 fishing period.

[2]Hapoon Licence Group B is composed of all other harpoon-only licences that do not qualify for Group A.