Opportunities for the Reduction of Skate Bycatch in Atlantic Canada Trawl Fisheries: A Case Study of two Innovative Trawl Gear Designs

by

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ABSTRACT

Skates are fish under the Subclass of elasmobranchii, typically found in temperate or arctic waters. Catch of skates pose a number of issues for fishers as bycatch including increased handling effort, reduced value of target catch, and clogging of gear. Discarding of skates in Canadian trawl fisheries has led to significant declines in the abundance of a number of skate species. The Eliminator Trawl™, designed in the US has shown success in reducing the catch of skates and other groundfish. Similarly, the Radial Escape Section trawl gear has also proven useful in reducing bycatch of larger fish. The ability of either gear to reduce catch of groundfish is key to aiding in the recovery of a number of groundfish species currently under moratorium. Specifically, use of the Eliminator Trawl™ is promising given its success with reducing bycatch both in benthic and pelagic trawls. A pilot project testing these gears at-sea and benefiting from fishers' knowledge of the fishery is an ideal first step towards use of either of these trawls and the recovery of threatened skates populations.

KEYWORDS: elasmobranch; Eliminator Trawl; Radial Escape Section; skate; trawl gear; bycatch; fisheries management; Canada

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LIST OF ABBREVIATIONS USED

BRD – Bycatch Reduction Device

Bycatch – The catch of non-target species (DFO, 2013c)

COSEWIC – Committee on the Status of Endangered Wildlife in Canada

CSAS – Canadian Science Advisory Secretariat

DFO – Fisheries and Oceans Canada

DU – Designatable Unit

Elasmobranchs – A Sublclass of cartilaginous fish that includes skates, sharks, and rays

FAO – Food and Agriculture Organization of the United Nations

Frontier Area – A frontier area is a marine ecosystem area in deep water (deeper than 2000m) or in the Arctic where there is no history of fishing and little if any information available concerning the benthic features (habitat, communities and species) and the impacts of fishing on these features (DFO, 2009b)

IFMP – Integrated Fisheries Management Plan

IPOA-Sharks – International Plan of Action for the Conservation and Management of Sharks

IUCN – International Union for Conservation of Nature

NAFO – Northwest Atlantic Fisheries Organization

NOAA – National Oceanic and Atmospheric Administration

NPOA-Sharks – National Plan of Action for the Conservation and Management of Sharks in fulfillment of the **IPOA-Sharks**.

SFA – Shrimp Fishing Area

TAC – Total Allowable Catch

TRP – Target Reference Point

TED – Turtle Excluder Device

CHAPTER 1: INTROUCTION

1.1 CHARACTERISTICS OF SKATES

Skates are dorso-ventrally flattened fish grouped under the Order of Rajiformes, in the Subclass of Elasmobranchii which also includes sharks, rays, and chimeras. Of the 1100 species listed under Elasmobranchii, approximately 600 species are of the Superorder Batoidae (skates and rays). While skates and rays have similar physiology, skates inhabit temperate and arctic ecosystems, and are more demersal in nature (Ainsely et al., 2011). Skates usually remain in the benthic zone of soft bottom, seabed environments using sand as camouflage to avoid predators and prevent detection by prey (Ryer, 2008). They have an opportunistic-generalist diet, feeding on small crustaceans or teleosts depending on their abundance (Stevens et al., 2000). A study by Viana and Vianna (2014) assessed the diet of Eyespot Skates (*Atlantoraja cyclophora*) in Brazilian waters through determination of prey species composition in their stomach contents. Despite differences in diet preferences among males and females, *Achelous spinicarpus* was found to be the most important diet item based on the frequency with which it appeared in the stomach contents of Eyespot Skates. The study further classified the abundance of a given prey item as more important than the prey species itself, supporting skates as being opportunistic feeders (Viana and Vianna, 2014).

While an opportunistic diet might be perceived as a beneficial characteristic for skates, it can be indirectly detrimental to overall skate stock health. An overlap in diet, between skates and non-skate species, often leads to an overlap in habitat (DFO, 2006). When trawl fisheries target these non-skate species, skates in the same habitat can be caught as bycatch. In a study quantifying the impacts commercial fishing activities have on elasmobranchs, Stevens et al. (2000) reported that skates were one of the most threatened groups of fish species in the world. Bycatch and associated discard is noted as one of the leading causes of declines in fish stocks (Glass, 2000). The impact of skate declines on their stocks is further exacerbated by their k-selected lifestyle characteristics: slow growth, late maturity, and low fecundity (Dulvy and Reynolds, 2002).

Measuring declines of individual species of skate has been difficult, even where fisheries observer data is available. Accurate identification of skates is difficult; for example at certain life stages different species of skate can be indistinguishable, as is found between juvenile Winter

Skates (*Leucoraja oellata*) and Little Skates (*Leucoraja erinacea*) (Swain et al., 2006). As a result, caught individuals are often listed under the "Unidentified Skate" category of fishery reports (Dulvy et al., 2000). Aggregation of multispecies skate data reduces accuracy of single species abundance assessments, and limits the ability to identify changes among species populations, as well as between juveniles and adults of the same species (Stevenson and Lewis, 2010). A study by Stevenson and Lewis (2010) determined that misidentification of skates was still a concern, even with an increase in fisheries observers and skate identification training.

Aside from the additional effort required in identifying and discarding skates, they pose additional problems to fishers when caught as bycatch. As Bellman and Heery (2013) point out, where skates do not have a strong market value they are often discarded. In the Canadian demersal trawl fisheries of the west coast roughly 7% of the total discards are skates, comprised of Longnose Skates (*Raja rhina*, 5.7%) and unidentified skates (2.9%). Glass (2000) addresses negative implications of skate bycatch, with their presence as a spiny species leading to declines in the market value of target caught species. Interaction with spiny species like skates can often damage soft-bodied species, like prawns, and reduce the number of marketable individuals within a catch. The issue is further magnified when skates reach the codend of the net and cover up openings in the mesh that would have otherwise allowed for smaller non-target species to escape. This greater retention of non-target species leads to a heavier codend, inflicting more stress and damage on the fish in the trawl. Thus the retention of skates may lead indirectly to higher post-release mortality rates associated with stressors from towing, and additionally reduce the total value of the catch.

Alternatively when there is a sorting grate used in the trawl gear, skates can often reduce overall catches of target and non-target species alike. Brewer et al., (2006) reported that the Turtle Exclusion Device (TED) was attributed with large losses of catch of the target species. Their contention was that often large animals would block the TED openings, forcing fish out of the escape opening regardless of size. Skates were such an example of these "blockage" organisms, especially effective given their relatively large size and dorso-ventrally flattened shape. Studies by Courtney et al. (2006) and Brewer et al. (1998) stated that facing grates downward resulted in a reduced number of blockages as one such approach to mitigating this issue.

Skates are caught within a number of Atlantic Canada trawl fisheries that target species such as cod (*Gadus mohua)*, scallop (*Pectinidae spp.*), White Hake (*Urophycis tenuis*), American Plaice (*Hippoglossoides platessoides*), and Winter Flounder (*Pseudopleuronectes americanus*) (Swain et al., 2006). The target species of these fisheries exhibit demersal or benthic lifestyles similar to skates, which is likely one reason why skate bycatch is so common. Additionally, similarities in body form between skates and targeted flatfish makes effective selection even more difficult (Ryer, 2008). Bellman and Heery (2013) point out that of all fishing gear, trawls appear to be the most indiscriminate and are the greatest source of bycatch globally. They go on to say that increased selectivity in trawls has led to declining discards on the west coast of the US. When aiming to reduce bycatch and discards, exploring the proper gear alterations for a particular fishery can be a main point of focus.

1.2 RESEARCH SCOPE AND PURPOSE

Globally there is a wealth of knowledge on successful approaches modelled and trialed to reduce bycatch of non-target species in trawl fisheries (Dolgov et al., 1999; Halliday and Cooper, 1999; Glass, 2000; Eigaard and Holst, 2004; Beutel et al., 2008; Ryer, 2008). Fishing restrictions may include spatial or temporal limitations on fishing regions given known bycatch hotspots, reinforced measures behind the appropriate handling and discarding of non-target species, and the implementation of gear alterations promoting greater selectivity during trawling. The study presented here focuses only on trawl gear alterations; the other two approaches of bycatch limitation fall outside the scope of this paper. Trawl gear is characteristic for its indiscriminate sorting and high levels of bycatch and subsequent discard of non-target species (Bellman and Heery, 2013). Given the amount of research that has been conducted on trawl gear alterations, it is hopeful that there is a gear alteration that has not yet been trialed in Canadian trawl fisheries, which could provide significant reductions in bycatch.

The choice to focus away from spatial fisheries management arose from concerns that the process would be too data intensive (Walker and Hislop, 1998). Main and Sangster (1981) address the complications that can arise from minimal knowledge of regional bathymetry. Reduced fishing efficiency can occur in bottom trawling where variations in depth can make sustained bottom contact difficult. Additionally, data concerning non-target species hotpots should be used to inform recommendations to spatial alterations. Studies such as Macbeth et al. (2012) outline the benefit of spatial restrictions in reducing bycatch, however several other studies suggest that such data is of limited use temporally (Watson et al., 1990; Walker and Hislop, 1998; DeAlteris et al., 2000). Alterations in species' range may occur over a short period of time, meaning hotspot data quickly loses its relevance and on-going data collection is required.

Conversely, handling protocols for discarding skates is shown to vary in effectiveness, in general however proper handling can have a positive impact on their post-release mortality (Swain, 2012a). The betterment of handling practices would seemingly benefit skates, given the high magnitude of discards (Bellman and Heery, 2013). However, improving the handling of skates during discard, an activity that is already time- and energy-intensive for fishers, would prove to be a tough sell. Where skates may not be directly related to the well-being of targeted species, fishers might not perceive a direct benefit to their operations with improved handling of skates. The actual benefit derived from improved handling of skates during discard may also only improve post-release survival to a minimal degree (Cedrola et al., 2005). Though there is some variance among species and tow conditions, including duration and codend weight, skates in general are noted as being resilient to discard mortality (Benoit and CSAS, 2010). This makes presenting the case for improved handling of skates even more difficult, given the minimal benefit to be derived from doing so. Overall there is seemingly little incentive to fishers to alter bycatch handling practices, and little benefit in relation to the additional effort that would be potentially required. Additionally, there has already been work done on the most appropriate manner in which to handle and discard skates (Scotia-Fundy Groundfish Advisory Committee, 2012).

The focus on trawl gear modifications was perceived as potentially providing significant incentives given minimal impacts on fishers. Additionally, focusing on one strategy would promote exploration of one bycatch mitigation strategy to an appropriate depth and breadth. Greater trawl selectivity means retaining target species, while selecting out species with differing body forms or behaviours. If undertaken appropriately, selectivity of the targeted species should be achieved even when habitats of bycatch species shift. Selecting out bycatch species means less effort spent sorting and handling species to be discarded, and an overall reduction in mortality resulting from trawling. Effective alterations to trawl gear, when performed in the appropriate fishery, might potentially provide a number of incentives while also considering the changing ecosystem.

The aim of this study was to review two key trawl gears that have been trialed and tested outside of Canada, assessing their potential feasibility of implementation and benefit to be provided to Atlantic Canada trawl fisheries. It is the hope that one of the gear types can provide benefit to Canadian fisheries and skate stocks, in the same way they benefited the fisheries and other non-target species in the fisheries were testing occurred. If the recommended gears were tested in Canadian fisheries in the future, their effectiveness would be measured by the efficiency with which they could exclude non-target species, while still retaining an appropriate level of target catch for a given tow.

CHAPTER 2: CANADIAN OVERVIEW

2.1 STATUS OF SKATES IN CANADA

Skate landings have increased in Canada in the past few decades, as have skate discards (Benson et al., 2001). The three primary species of skate caught in Canada (Smooth, Winter, and Thorny Skates) have all experienced significant declines in population abundances where capture data has been recorded. The Department of Fisheries and Oceans (DFO) bottom trawl surveys conducted in the Gulf of St. Lawrence, since 1971, have helped develop a better understanding of the factors affecting skate populations. Data from the bottom trawl surveys have been used in research documents published by the DFO Canadian Science Advisory Secretariat (CSAS), to assess vulnerability of skates in Gulf fisheries, and by extension in Canadian waters. Similar reports consolidating information have also been published by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the International Union for Conservation of Nature (IUCN).

2.1.1 WINTER SKATES

A number of reports focused on Winter Skates (*Leucoraja ocellata*) have indicated a continuous decline in population abundances from 1971 to present day (Benoit and CSAS, 2010). The CSAS report focusing on bycatch mortality of Winter Skates (Benoit and CSAS, 2010) put forth that within the past decade mortality of skates has been predominantly derived from non-bycatch causes. The scallop dredge fishery of focus in the study accounted for 0.07% and 0.14% of declines in population associated with juvenile and adult skates, respectively (Benoit and CSAS, 2010). From their model, Benoit and CSAS (2010) estimated post-release survival of skates at 90%. Conversely non-bycatch pressures were responsible for 75% and 34% declines in juvenile and adult populations, respectively. This and other CSAS reports (Maritime Provinces Regional Advisory Process Meeting et al., 2006) attribute high natural mortality of skates to growing Grey seal (*Halichoerus grypus*) populations (Benoit and Canada, 2012). Based on seal diet studies, it is believed that skates make up 1-2% of seals' diets (Maritime Provinces Regional Advisory Process Meeting et al., 2006). It is expected that the rising trend in natural mortality of Winter Skates will continue with increasing Grey seal populations.

Of the five Designatable Units (DUs) that were assessed by Swain et al. (2006), Winter Skate populations in the southern Gulf of St. Lawrence (Benoit and CSAS, 2010) and the eastern Scotian Shelf were listed as ‘Threatened’, or ‘Endangered’ by IUCN terminology (Kulka et al., 2009a), as of 2005. Primary reasons for these designations were that Winter Skate populations have declined by 90% since population surveying first began in 1970 (Swain et al., 2006; Kulka et al., 2009a). The recovery potential report supports the scallop fishery report, stating that the majority of Winter Skate bycatch occurs in the southern Gulf of St. Lawrence Scallop Fishery (Swain et al., 2006). The report goes on to support a high discard mortality model (Maritime Provinces Regional Advisory Process Meeting et al., 2006) as reflected in the survival rates of Winter Skates held in on-board tanks during a tagging study (Benoit et al., 2006; Swain et al., 2006). Conclusions about significant population declines were similarly presented in this study, but go one step further and suggest that these values could be an underestimation of the total vulnerability (Swain et al., 2006). The report outlines that Winter Skates prefer to come inshore during September, the same time as when the survey trawls are performed, meaning trends may not be representative over the entire habitat range (Swain et al., 2006).

An assessment of Winter Skate discards in the southern Gulf of St. Lawrence determined the trawl fisheries responsible for the highest proportion of skate discards (Benoit et al., 2006). Unlike the scallop fishery report, fisheries targeting American Plaice and Winter Flounder were outlined as predominant contributors to discard values (Benoit et al., 2006). This report considered discard of skates from a number of fisheries, including values associated with different gear types, either mobile or fixed (Benoit et al., 2006). Fixed gear is noted as causing lower post-release mortality rates than mobile gear, as a function of variations in stress on the species. When combining a number of studies the Benoit et al. (2006) report attributes a 50% post-release mortality rate to mobile gear.

The key result from this final report focusing on Winter Skates was that their population has significantly declined, from an estimated abundance of 1,972,363 individuals in 1971, to 10,216 in 2004 (Benoit et al., 2006). This would infer a 99.5% decrease in the Winter Skate southern Gulf of the St. Lawrence population, which would justify the endangered status under IUCN criteria.

2.1.2 SMOOTH SKATES

The global range for Smooth Skates (*Malacoraja senta*) predominantly encompasses four DFO organizational regions: Newfoundland and Labrador, Quebec, the Gulf, and the Maritimes (McPhie et al., 2007). This estimated Canada-centric range is supported by evidence that Smooth Skates are philopatric in nature, and rarely venture far from their native region. Substantial distances separating populations are attributed to the narrow range of temperature preference of Smooth Skates (2-7 ˚C) (McPhie et al., 2007). Temperature is also thought to limit the vertical range of Smooth Skates, with no recorded captures deeper than 600m. As an aside, this fact aids in their differentiation from Soft Skates (*Malacoraja spinacidermis*) which inhabit depths greater than 700m (McPhie et al., 2007).

One of the most recent reports focusing on Smooth Skates was the COSEWIC 2012 Assessment and Status Report on Smooth Skates (Kulka and COSEWIC, 2012). Dissimilar to an earlier COSEWIC report that split populations into regions, this report focused on four DUs for Smooth Skates: Hopedale Channel, Funk Island Deep, Nose of the Grand Bank, and Laurentian-Scotian (Fig. 1; Kulka and COSEWIC, 2012). The May 2012 report designated these four DUs as Data Deficient, Endangered, Data Deficient, and Special Concern, respectively (Kulka and COSEWIC, 2012). DUs with Data Deficient designations were listed as such because of insufficient data on both adult and juvenile skates (Kulka and COSEWIC, 2012). Attendants to a meeting following the release of this report noted that the gear efficiency should be considered, as the gear in question was thought to allow for the escape of small species (McPhie et al., 2007).

Significant declines in Smooth Skate abundance have been more prominent in other regions of Atlantic Canada. The Funk Island Deep DU was assessed as Endangered by COSEWIC in 2012 (COSEWIC, 2012; Sulikowski et al., 2009). Beginning in the 1970s, measured declines for this DU were over 80% of the estimated population. Similarly, discards of Smooth Skates in the Gulf of St. Lawrence population have declined by approximately 75% since 1991 (Swain et al., 2012b). Large contributions of discards in 1994, a year where discards spiked, were specifically noted as coming from the American Plaice and Winter Flounder fisheries.

Among the Smooth Skate declines in Atlantic Canada, there have also been fluctuations in the composition of adults and juveniles within the region. A decrease in fishing effort in the groundfish fisheries notably led to a decrease in Smooth Skate juvenile fishing mortality (Swain et al., 2012b). Despite this reduced fishing effort however, adult skate mortality increased following this reduction. Decreasing catch of adult skates has been linked to an increase in their natural mortality, similar to Winter Skates (Swain et al., 2012b). Predation by Grey seal populations is thought to be an important factor restricting the potential recovery of Smooth Skates despite reduced discard-based mortality.

2.1.3 THORNY SKATES

Though Thorny Skates (*Amblyraja radiata*) historically have the largest range of all skates caught in Atlantic Canada, they have experienced massive reductions in their abundance (Swain et al., 2012a). According to abundance indices derived from DFO bottom trawl surveys, Thorny Skate populations declined by 95% from 1971-2010 (Fig. 2). Conversely, IUCN lists the Scotian Shelf populations as having declined by 80% from the 1970s to present day, with the Grand Banks populations declining by approximately 68% during the same time frame (Kulka et al., 2009b). Declines in population are similarly reflected in reductions of habitat range, with present day Thorny Skate range only comprising 10% of their historical range (Swain, 2012).

Of the skate species caught in Atlantic Canada, the Thorny Skate is noted as one of the smallest and slowest-growing of the species (Swain et al., 2012a). This small size has historically provided benefit to their population. When Barndoor Skates (Dipturus laevis) and Common Skates (Dipturus batis) were in a period of high mortality and low fecundity, bringing them close to extirpation in the Irish Sea, Thorny Skate abundances increased (Stevens et al., 2000; Swain et al., 2012a). Stevens et al. (2000) noted this Irish Sea case and its similarity to the decline of Barndoor Skates in Atlantic Canada. Similar declines in the Canadian abundance of Barndoor Skates, the largest skate in the northwest Atlantic, occurred around the mid-1960s. Following initial population declines, there were no reports of Barndoor Skates caught between 1979-1999 (Casey and Myers, 1998). Both of these periods of decline were correlated with a period of increase in Thorny Skate abundance (Stevens et al., 2000; COSEWIC, 2011). The reduced competition for prey may be a prime explanation for the increase in smaller skates following a decrease in larger skates.

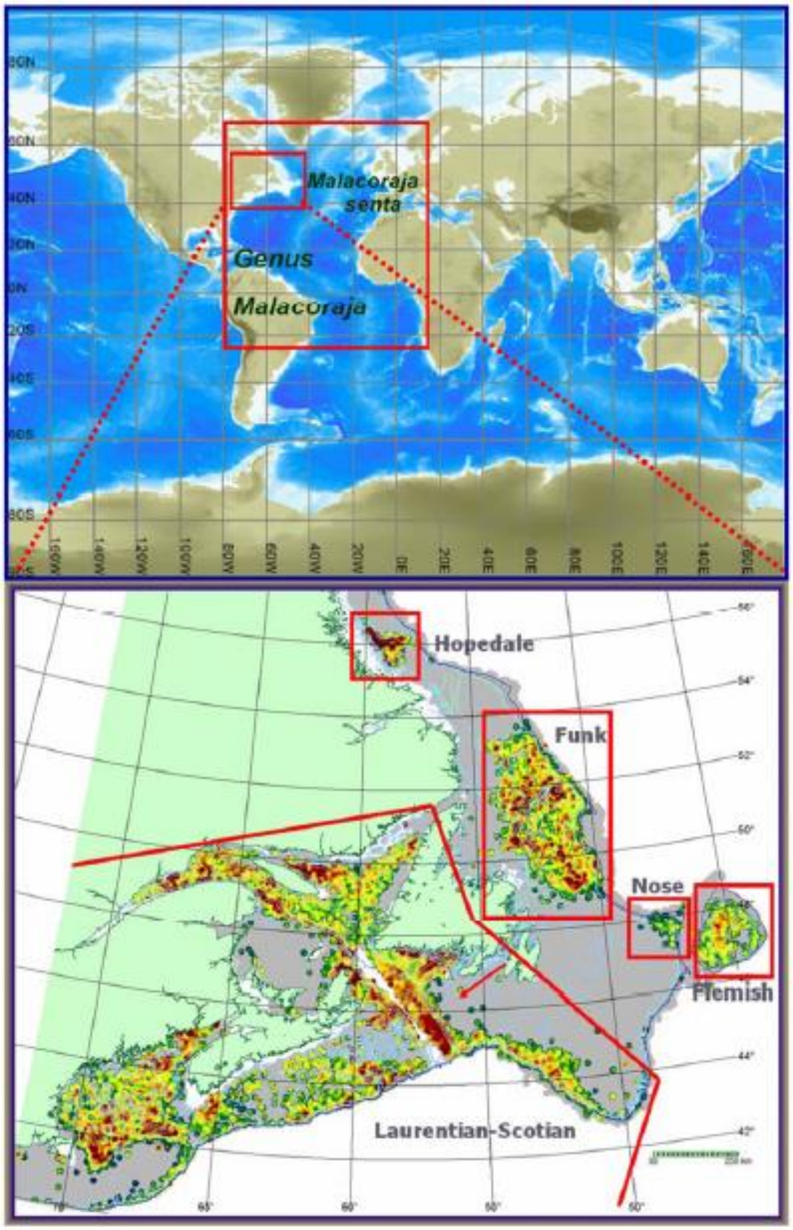

Figure 1 Upper - global distribution of the genus Malacoraja and Smooth Skate, M. senta. Within the red squares, the species is restricted to portions of the continental shelf. Lower - Distribution of Smooth Skate catches in Canadian and US trawl surveys. Colour surface denotes density level of captures. Red lines and labels delineate the proposed DUs (Kulka and COSEWIC, 2012).

Similar to caught Winter and Smooth Skates in Canada, the majority of caught Thorny Skates are discarded instead of landed (Swain et al., 2012a). Conversely, retention and discard of

Thorny Skates in the Irish Sea is governed by size-based regulations (Walker and Hislop, 1998). Where data from Canadian fisheries observers was present, significant discards of Thorny Skates have been noted. A CSAS report (Swain et al., 2012a) states that approximately 96% of reported Thorny Skate catches in the 1990s were discarded. A 90% reduction in discards occurred from 500t to 50t by 2000, attributed to a decline in fishing effort in the associated fisheries (Swain et al., 2012a). Discards during the 1990s were primarily from mobile fisheries targeting cod, American Plaice and Witch Flounder. In the late 1990s and 2000s predominant catches of Thorny Skates shifted to the fixed gear, Greenland Halibut (*Reinhardtius hippoglossoides*) gillnet fisheries (Swain et al., 2012a).

Fixed gear fisheries have a greater ability to reduce mortality of caught Thorny Skates than mobile gear. Benoit et al. (2006) noted that the immediate release of Thorny Skates from fixed gear resulted in negligible post-release mortality rates. Increased soak times within fixed gear however does result in a greater occurrence of mortality. Data from Swain et al. (2012a) calculated a within-net mortality of approximately 35% for Greenland Halibut after a soak time of 3 days. Though no similar values were recorded for Thorny Skates, their mortality rates are expected to be lower, as they are not vulnerable to occlusion of their breathing pathways like Greenland Halibut are (Swain et al., 2012a).

Conversely, post-release mortality measured in the 1990s for Thorny Skates caught in trawls was approximately 49% (+/- 9%; Swain et al., 2012a). This 49% doesn’t include variable mortality derived from gear damage, tow time, or handling procedures, all factors that could result in higher levels of post-release mortality.

2.2 CANADIAN POLICY POTECTION OVERVIEW FOR SKATES

2.2.1 NPOA-SHARKS

Though the intention of the National Plan of Action for the Conservation and Management of Sharks (NPOA-Sharks) was to provide a roadmap for addressing conservation of all elasmobranchs, the action plan fell short in its delivery. The action plan defined the term “sharks” to include groups of skates, rays, and chimeras, as well as sharks throughout the

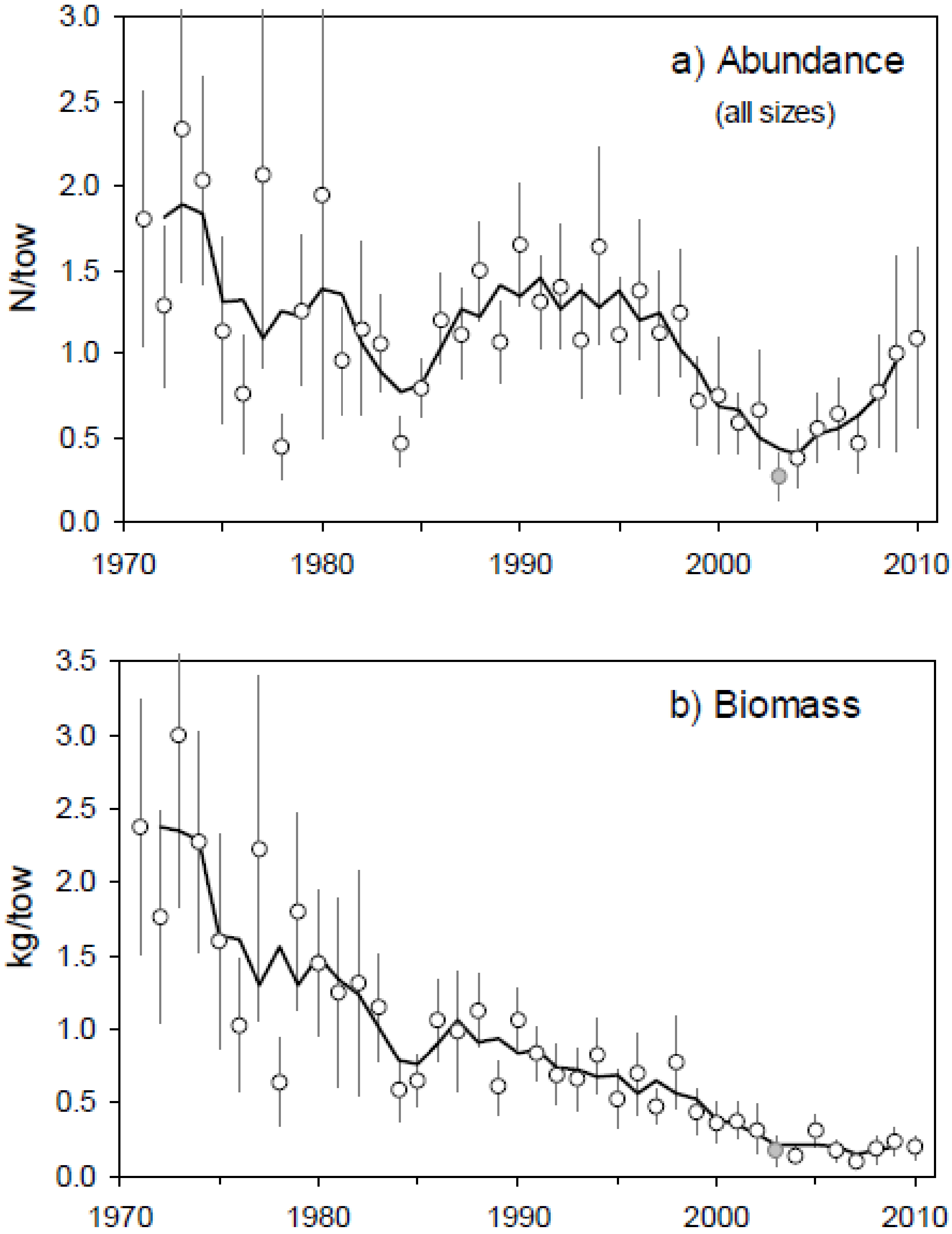

Figure 2 Stratified mean catch rates of thorny skate (all sizes) in the September survey of the southern Gulf of St. Lawrence. Vertical lines are +/-2SE. Heavy lines show 3-yr moving averages. Catch rates are adjusted to daytime catchability by the Alfred Needler. The grey circles denote the catch rates from 2003 survey, which was conducted by an uncalibrated vessel (the Wilfred Templeman). (Swain, 2012b)

document (Canada, 2007). Though there was an intention to include all elasmobranchs using "sharks," the implementation of this concept was lacking. Often specific species mentioned within the action plan were sharks, such as the Porbeagle Shark (*Lamna nasus*), further gearing the term "sharks" to specifically refer to sharks. Likely the term "sharks" was used as a common language alternative to "elasmobranchs," where the term "sharks" is more commonly used in integrated fisheries management plans (IFMP) (DFO, 2006).

To the credit of the action plan, there was specific attention given to skates caught within Atlantic Canada. NPOA-Sharks mentioned that there were 17 species of skates caught within Atlantic Canada fisheries (Canada, 2007). Specific mention was given to the IUCN statuses of the Winter and Thorny Skates, as previously mentioned in this document. Additionally, the action plan (Canada, 2007) mentioned that DFO was in the process of assessing and updating data on Smooth, Spinytailed (*Bathyraja spinicauda*), Thorny, and Winter Skates. Final mentioning specific to skates mentioned the North Atlantic Fisheries Organization's (NAFO) 2005 total allowable catch (TAC) on Thorny Skates. TAC for Thorny Skates had been reduced to 2,250t for Canada, with an overall TAC of 13,500t for the NAFO region. This is noted as the first time an Regional Fisheries Management Organization implemented management measures regarding an elasmobranch species (Canada, 2007).

Skates receive little directed protection in Canada's fisheries. As mentioned in the status report of Smooth Skates, currently there are no conservation measures specifically directed for skates in Canada (McPhie et al., 2007; Sulikowski et al., 2009). Canada's NPOA-Sharks, as an example, is simply an outline of Canada's plan for achieving long-term sustainable use of sharks. Though reference is made to forms of legislation that may aid in the protection of "sharks," the action plan itself is not legally binding. Instead, the action plan should be perceived as a framework for how marine managers should approach proper conservation and management of elasmobranchs in Canada

Unfortunately the NPOA-Sharks doesn't make any reference to any protection specific to skates in Canada (Canada, 2007). The NPOA-Sharks outlines a number of different integrated fisheries management plans (IFMPs), noting that they also provide coverage to "sharks". As with the use of "sharks" in the action plan, often the reference to elasmobranchs in the listed IFMPs is specifically to sharks and not skates. Additionally, similar to the NPOA-Sharks, IFMPs lack the enforcement authority found in fisheries regulations or Species at Risk Act designations (Canada, 2007). The mention of skates in IFMPs may be the first step towards actual protection of skates within Canada, where sufficient attention is given.

2.2.2 INTEGRATED FISHERIES MANAGEMENT PLANS

Of the IFMPs listed as relevant in the NPOA-Sharks (Canada, 2007), the Groundfish IFMP (DFO, 2002) appears to be the most relevant IFMP to skates in Canada. A brief review of the history of skates in the Maritimes is given, including the authorization of a directed skate fishery in Division 4VsW during 1994. Reference is also made to the COSEWIC designation of Winter Skates, and to skate bycatch limitations among a couple NAFO regions (DFO, 2002). NAFO regions 4VWX and 3LNO are subject to skate bycatch limits of 10-15% and 5%, respectively. No rationale is given for the use of a bycatch range in one region, and a single value in the other.

The Groundfish IFMP (DFO, 2002) makes reference to '*The Atlantic Fishery Regulations*' under the Fisheries Act (Canada, 1985) which specifically mentions skates. The regulations outline that skates, when caught alive and intended to be discarded, must be handled in an appropriate matter and returned to the water in which they were initially caught. The regulation referenced within the Groundfish IFMP (DFO, 2002) appears to constitute the major regulatory protection for skate bycatch in Canada. Additionally, mention of this regulation regarding skates was specifically focused on bycatch from trawl fisheries, as they were believed to be responsible for the majority of skate bycatch.

Other IFMPs referenced at the end of the NPOA-Sharks do not directly pinpoint regulations regarding skates. Though the use of the term "sharks" was not specifically defined in these IFMPs, some of the mentioned restrictions could potentially apply to skates as well. One key example was the Canadian Atlantic Pelagic Shark IFMP's (DFO, 2009c) mention of the finning ban in 1994. The ban extends to all Canadian vessels inside and outside the EEZ and applies to all elasmobranchs, not only sharks. According to Brendal Davis (personal communication, 2014, February 11) winging of skates is known to occur within Canadian fisheries and is considered the equivalent to finning for sharks. With the finning ban, winging of skates would also be covered under the 1994 ban.

Finally there are some additional references within other IFMPs that may have an indirect impact on skate population health. Replacement of "j" hooks with circle hooks, as outlined in the Canadian Atlantic Swordfish and Other Tunas IFMP (DFO, 2006), was implemented with the goal of reducing bycatch mortality. Though not undertaken explicitly to address skate bycatch, the reduction in stress and damage inflicted by the hooks certainly aids in promoting conservation of non-target species. Additionally, the benefits of circle hooks would facilitate the Fisheries Act (Canada, 1985) requirement to release live skates back to the waters they were caught in. Where the circle hooks are believed to increase the post-release survival of bycatch species, this may provide a positive impact on abundances for populations of caught skate species.

2.2.3 POLICIES

Though few in relevance, DFO has created a number of policies pertaining to guiding fisheries-based decisions. A DFO Policy for Managing Bycatch (DFO, 2013c) focuses not only on reducing bycatch, but also reducing fishing gear-based mortalities. The policy puts forth that only through the systematic assessment of fishing practices and gears in each of Canada's fisheries can bycatch can be reduced. In this context, bycatch includes caught non-target species that are then discarded, as well as species a harvester does not have a license for but is required to retain. Additionally, species entangled in gear or released prior to being brought aboard are also considered within the calculation of gear-based bycatch mortality (DFO, 2013c). The main point for consideration within the policy pertains to the alteration of fishing gear, ensuring that the new gear results in a reduction in mortality over the old gear.

The second policy of interest, though slightly less relevant, addresses decisions to be made regarding managing the impact of fishing on sensitive benthic areas (DFO, 2009e). Trawl gear interacting with the seafloor can damage the benthic environment by reducing the diversity of coverage types. This can negatively impact fish in the benthic environment that use coverage for camouflage from predators. Reduced benthic diversity however does not have a strong bearing on skates as they prefer soft sandy bottoms for camouflage (Ryer, 2008). However, trawling in the frontier area could have a significant impact on the health of skate stocks.

Frontier areas are defined as being sensitive areas that have never been subject to directed fishing practices before. Additionally, information pertaining to frontier areas is often lacking, making it difficult to have a strong understanding of how fishing would impact the area (DFO, 2009e). Dulvy and Reynolds (2002) have suggested that skates use deeper waters for refuge to escape fishing pressure. Where skate species are at risk of local extirpation as a result from fishing pressure, deep-water refuges may allow for greater population recovery of skates. Fishing in a frontier area could thus impact an already sensitive population of species seeking refuge. This may not always be the case as certain species of skates are traditionally found in shallower waters, and may not seek deeper waters for refuge (McPhie et al., 2007). Fortunately, the initiation of a directed fishery in a frontier area requires rigorous testing to evaluate the overall sensitivity of the area.

A final policy for consideration with reference to skates is the policy for Fishery Decision-Making Framework Incorporating the Precautionary Approach (DFO, 2009a). The policy outlines how the precautionary approach should be implemented in the absence of full certainty of data. Suggestions are also made on how to approach the remediation of a species' population depending on the severity of their condition, and their apparent population trend. Of the 17 species of skates present within the northwest Atlantic (Canada, 2007) there are only a few notable species that require immediate attention regarding the rebuilding and recovery of their populations. For the other species that are not at immediate risk of extinction, this would be an opportune time to identify baseline target reference points (TRP). TRPs are established during health population conditions, providing a point of reference for the removal of the species of focus, while maintaining healthy populations levels (DFO, 2009b). The health of future populations can be more readily assessed, given how variations in a population compare to the TRP.

CHAPTER 3: TRAWL GEAR CASE STUDIES

3.1 ELIMINATOR TRAWL^{TM}

The first case study presented will be the work of Beutel et al. (2008), assessing the effectiveness of the Eliminator Trawl^{TM}, also known as the Ruhle Trawl, in the Georges Banks Groundfish fishery.

The Eliminator Trawl^{TM} was originally designed by New England fishers, in collaboration with the net manufacturers Superior Trawl, and fishery specialists (Fig. 3; Beutel et al., 2008). Trawl designs were tested in the flume tank at Memorial University. The goal of this trawl design was to reduce cod bycatch, while retaining catch of targeted haddock (*Melanogrammus aeglefinus*). Decline of cod stocks off the U.S. east coast led to the implementation of a reduced catch quota for cod (DFO and NOAA, 2006). Exceeding the allowable bycatch for cod could initiate closure of the groundfish fishery early in the season. There were multiple examples of the groundfish fishery closing for a season before a significant portion of haddock TAC had been caught (Beutel et al., 2008). Only 39.9% of the TAC of haddock was caught between 2002 and 2006, resulting in an estimated loss of over $175 million in those years.

One of the prime challenges in the trawl design was differentiating selection between cod and haddock, due to the similarity of their body shapes. Selectivity of fish as they enter trawls is complex given the indiscriminate and passive manner in which selection occurs (Main and Sangster, 1981). Hannah and Jones (2007) note how regulations for the Pacific U.S. shrimp fisheries require the presence of BRDs (Bycatch Reduction Devices) within the trawl gear as a method of active fish selection. Additionally, their study mentions that of all components of a trawl that can be altered, the greatest range of variation permitted among gear components is with the mesh size. Considering the main challenge to the selectivity between cod and haddock was a similarity in body form, factors beyond physiology required scrutinizing where alterations to mesh composition form the foundation of a new gear type.

Central to the design of the Eliminator Trawl^{TM} were the reactionary differences between cod and haddock when these species encounter an incoming trawl. A study by Main and Sangster (1981) visually assessed the reaction of fish prompted by incoming trawl gear. They posed that the behaviour of fish could be defined by the vertical range in which they entered an incoming trawl. Levels ranged from 1 to 3, representing the top, middle, and bottom third of the net opening, respectively (Fig. 4). Reactions of the monitored species of interest in the study, including cod, haddock, and skates, were then characterised according to the level at which they entered an incoming trawl.

Results from Main and Sangster (1981) presented a significant difference in the behaviour of cod and haddock, the main species of interest for Beutel et al., (2008). Haddock were found to enter trawl nets at both levels 1 and 2, which comprise the upper portion of the net. Dissimilarly, cod were recorded as entering trawls at level 3, near the bottom of the net. This difference in reaction between cod and haddock provides a unique opportunity for selectivity, along with selectivity of body form. Additionally, skates were also recorded as entering at level 3, though they were not the main species of focus.

Beutel et al. (2008) also referenced Kennelly (2007) concerning trawl impact on the seabed environment, and the effect the relation has on the reaction of fish to an incoming trawl. Kennelly's (2007) research primarily focused on the influence differing gear types have on the benthic environment. Bottom trawls with more heavily weighted groundgear components (ex. bobbins, rollers, rockhoppers, cookies, chains) typically have greater negative impact on the benthic environment, reducing diversity of benthic coverage. Damage to the structure of the benthic environment was shown to have a significant impact on the diversity of organisms found within that environment. Heavier groundgear was thought to cause greater damage upon coming into contact with benthic organisms. Together Kennelly (2007) and Beutel et al. (2008) indicate that reduced impact on the seabed may also contribute to rejuvenating cod stocks, along with reducing their bycatch. However, these groundgear have also been shown to stimulate movement of certain organisms up from the seabed for catching, the hopes being that cod is not one of these species (Ryer and Barnett, 2006).

Additionally, Kennelly (2007) set a useful standard against which fishing gear should be trialed and tested. The gear that was trialed at sea was initially tested within a flume tank to observe its performance when mimicking real-use conditions. Beutel et al. (2008) similarly used the flume tanks at Memorial University for testing the Eliminator Trawl™. In a more recent study, Sala et al. (2009) compared the benefits derived from flume tank testing, modeling, and

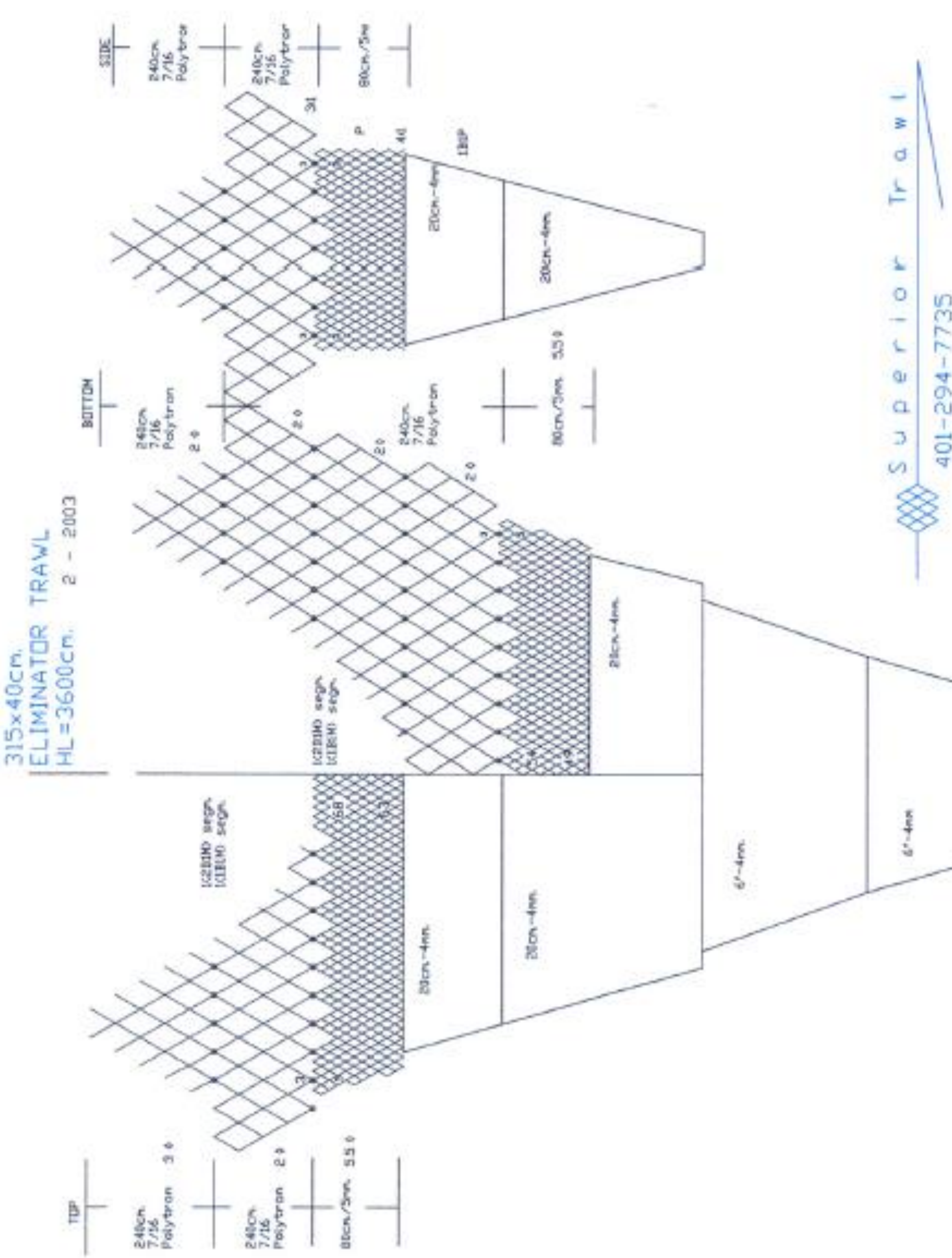

Figure 3 Net design for the Eliminator Trawl™ outlining the differences in mesh used in the top and bottom portions of the net, as well as on the wings of the trawl (Beutel et al., 2008).

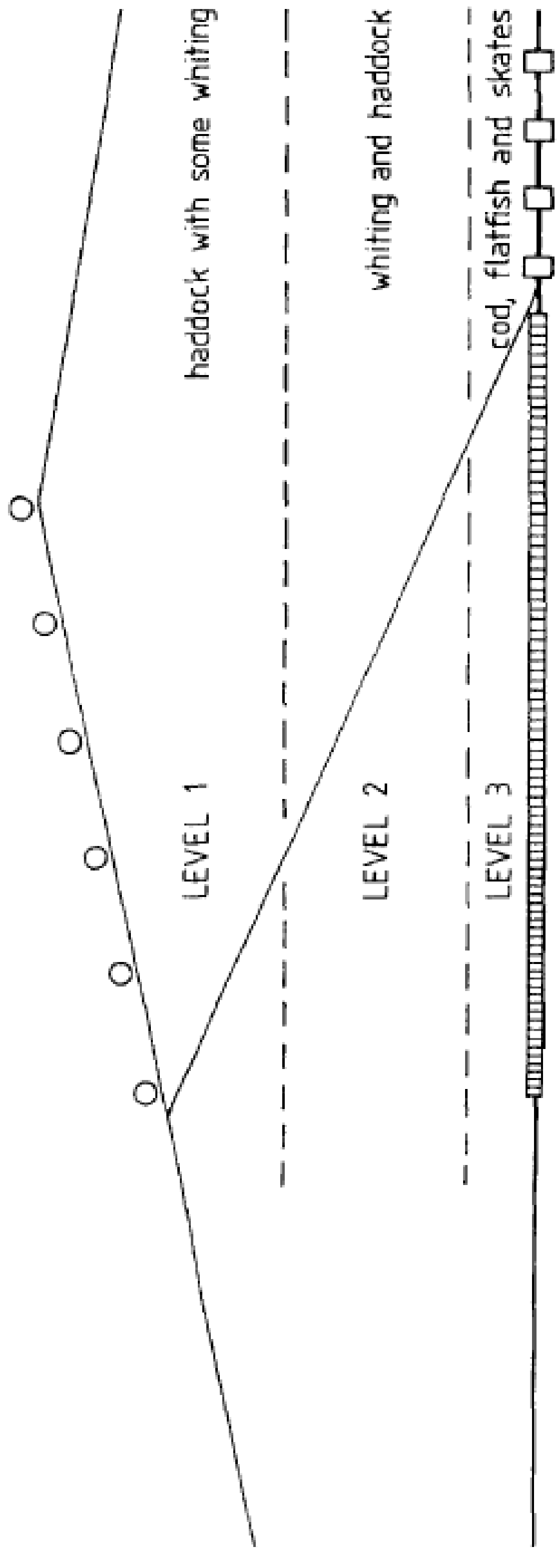

Figure 4 Displayed are the natural reactions of a number of groundfish, with regards to their location, when being overtaken by an incoming trawl (Main and Sangster, 1981).

at-sea trials. Their study concluded that results from either modeling or flume tank tests lack certainty in anticipating at-sea performance. However, Sala et al. (2009) concludes that flume tank testing is a more effective method of assessing capabilities and defect in fishing gear than computer models. In this way, Beutel et al.'s (2008) approach to the testing of the Eliminator Trawl™ is perceived as being more reliable, given the groundwork prior to the at-sea trials.

Beutel et al. (2008) were very cognisant of the potential bias that could be present within their study, and took appropriate steps to mitigate this bias. Parallel towing of both the Eliminator Trawl™ and the control trawl from the same vessel was a key method of bias reduction. Towing both gears under the same conditions ensured the least biased comparison possible. Main and Sangster (1981) however made reference to potential bias that may arise from differences in depth of the seabed under the two trawls. Differing depths in the bathymetry of the seabed between the two trawls may have altered the relative interaction either trawl had with the seabed. Beutel et al. (2008) did not outline the exact paths that were taken for testing these trawls, so variations in bathymetry cannot be assessed.

Beutel et al.'s (2008) study showed that the Eliminator Trawl™ had a significant impact on reducing skate bycatch, defined in their study as non-target catch. The control net caught primarily skates, haddock, and Winter Flounder. Skates were caught so frequently that for every kilogram of haddock caught, roughly 1.5kg of skate was caught. While catch rates of skates and haddock varied over the seasons, a total of 18,956kg of skate were caught in the control net, compared to the 12,580kg of haddock caught. Catches from the Eliminator Trawl™ presented a 98.6% reduction in the weight of skate bycatch, totaling 258kg. While not the main species of interest in Beutel et al.'s (2008) study, the Eliminator Trawl™ had the most significant impact on skate bycatch, while retaining similar catch levels for haddock. Additionally, the Eliminator Trawl™ also achieved the aim of the study by significantly reducing the catch of cod, and retaining similar catches of haddock.

3.2 RADIAL ESCAPE SECTION

The second case study focuses on the study by Courtney et al. (2006) assessing the effectiveness of BRD and TEDs used in Queenland, Australia's eastern King Prawn fishery. In the King Prawn fishery both BRDs and TEDs are required for all vessels. The aim of their use is to reduce bycatch of non-target species, which are annually is around 25,000t compared to the 10,000t of target prawn caught. This trend is similar among all shrimp and prawn fisheries, accounting for over a third of the world's bycatch (Alverson et al., 1997). Grey et al. (1990) noted that the small nets required in retaining target prawn are the main reason for the substantial levels of bycatch these fisheries experience. Smaller mesh sizes ensure that both small prawns, and larger fish species, are not able to escape through the netting in the codend. Grey et al. (1990) conducted their study in a freshwater shrimp fishery, where 93 species of bycatch were caught. Similarly, a study by Harris and Poiner (1990) noted the majority of their catch weight was from bycatch species. It is evident that the issue of bycatch in prawn fisheries requires an assessment of bycatch reduction mechanisms.

TEDs have been the primary method for separating non-target fish and larger organisms from trawl catches. Initially TEDs were sorting grates geared towards reducing catches of turtles. Brewer et al.'s (1998) work with TEDs found they were especially effective at the exclusion of "Monsters," defined as organisms over 5kg. Sorting grates, either up- or down-facing, aim towards an exit opening through which these larger organisms can pass through to exit the trawl. At the time of Brewer et al.'s (1998) study, little research had been performed on the effectiveness of BRDs and TEDs.

Spacing of the bars in a sorting grate is just large enough such that shrimp, along with smaller fish, are able to pass through the TED into the codend. This proves to be effective at retaining shrimp while excluding larger marine organisms (Grey et al., 1990). Use of the TED becomes complicated however when larger organisms block, or get stuck on the sorting grate. In Watson and Taylor's (1986) research, blockages of vertical sorting grates were common, especially during longer tows. Trash was also noted as a potential source of blockage for TEDs. Halliday and Cooper's (1999) study found that blockages were most commonly created by skates and dogfish. This study is especially significant as it was conducted in Nova Scotia's Silver Hake fishery. The concern regarding blockages, as outlined by Brewer et al. (2006), is that it may result in reduced target catch. Courtney et al.'s (2006) concern with TEDs is that blocked sorting grates could force prawns out of the escape exit, reducing their target catch.

Effectiveness of the Radial Escape Section BRD was tested in Courtney et al.'s (2006) study alongside TEDs (Fig. 5). This BRD was originally invented by Watson et al. (1986) and was called the Finfish Separator Device. They invented the device in response to high bycatch levels in the U.S. penaid shrimp fishery. It is also referred to as the Extended Mesh Funnel, placing greater emphasis on the main webbing funnel that characterises the BRD.

The Radial Escape Section is comprised of three large rings holding together a webbing funnel, a sorting grate, and a portion of webbing between the middle and posterior rings (Fig. 5). The webbing funnel contracts to accelerate flow of water towards the sorting grate. According to Watson et al. (1986), this accelerated flow of water would force prawns and smaller fish through the sorting grate, their swimming abilities being too weak to combat the force. Congested conditions within the mesh funnel were also thought to elicit an escape response from larger finfish. In some instances larger fish can get stuck and clog this funnel (Brewer et al., 2006). Though the flow of water would be too strong to combat, it was believed a region of low water flow occurred at the end of the BRD. Watson et al. (1986) believed this reduction in water flow, in tandem with the escape response of finfish, was enough to allow larger fish to escape through the mesh opening between the anterior and middle rings. At the time of their study however, there was little research supporting this low-flow area.

Broadhurst et al. (2002) has since reviewed other studies that reflected on the presence of this low turbulence region. Their study found that a region of low turbulence was created anterior to the codend. Specific focus was given to the relative effectiveness of bycatch separation, with an escape opening at varying distances from the codend. Of the three distances tested, the escape opening in the most anterior location was found to be the most effective at reducing bycatch. For their study, this “forward panel” was approximately 1.6m from the codend. Broadhurst et al. (2002) commented that significant losses of prawn occurred when the escape opening was closer to the codend. Courtney et al. (2006) utilized these conclusions from Broadhurst et al. (2002) by placing an escape opening in a “forward panel” location. Indirectly their opening placement also relies on the study of Watson et al. (1986) with regards to propulsion of shrimp and smaller fish through the sorting grate.

Courtney et al.’s (2006) study was successful in identifying the relative benefits provided from the TED and BRD, both individually and when used in tandem. As expected, both the TED and BRD reduced bycatch of nontarget species within their tows. Greatest reductions to bycatch occurred when using both the TED and BRD, followed by only the BRD, and only the TED.

Bycatch reduction rates by weight were 24%, 19%, and 10% respectively. Courtney et al. (2006) found that similar to the conclusions of Grey et al.'s (1990), small fish were the primary contributor to bycatch. Often smaller fish caught were the juvenile equivalents of the species that were excluded by the TED. Additionally, prawn retention was 20% lower than that of the control net. Other studies similarly experienced success with the BRDs, as well as the retention of small fish in their tows (Brewer et al., 1998; Garcia-Caudillo et al., 2000; Steele et al., 2002). Overall they met their objective of clearly outlining the benefits derived from each gear type.

There were some additional considerations Courtney et al. (2006) did not address in their study. Dissimilar to the traditional method of TED design, Courtney et al. (2006) used a down-facing sorting grate. Throughout their study there was also no mention of blockages of the TED. Potentially this could infer that a down-facing grate may allow larger organisms to escape the trawl net more readily. Specifically this may allow skates to escape more readily, noted as inhabiting level 3 of trawls upon entry (Main and Sangster, 1981). Their behaviour to stay near the seabed could lead to the bottom escape opening providing specific benefit to skates and other groundfish. There is also some other more complicated considerations regarding skate behaviour.

Ryer's (2008) review of fish behaviour under varying conditions can elicit different flight responses from flatfish. Greater light levels for example tend to initiate herding responses from flatfish. In these scenarios flatfish attempt to avoid the incoming trawl, interpreted as a predator, by swimming in the opposite direction the trawl is approaching from. This escape response is typically referred to as herding, and is one of a few reactions flatfish have to incoming trawls (Ryer, 2008). Where most flatfish are weak swimmers, this usually results in them being overtaken by the trawl. Exhausted flatfish coming into contact with sorting grates is a prime way in which blockages occur.

Herding can provide additional complications for flatfish, and the fishing gear. Main and Sangster (1981) assessed that when flatfish come into contact with netting that their response is to swim perpendicular to the point of contact (Fig. 6). In a confined area like in the webbing funnel, herding behaviour of flatfish could promote clogging of the funnel. Clogging and herding could lead to additional stress for flatfish and skates, and might increase impact gear-based mortality. As with any gear alteration, it is important to assess that new gears lead to a decrease in mortality and bycatch. In this case, though outside the scope of this study, research would additionally focus of varying bycatch during varying light levels.

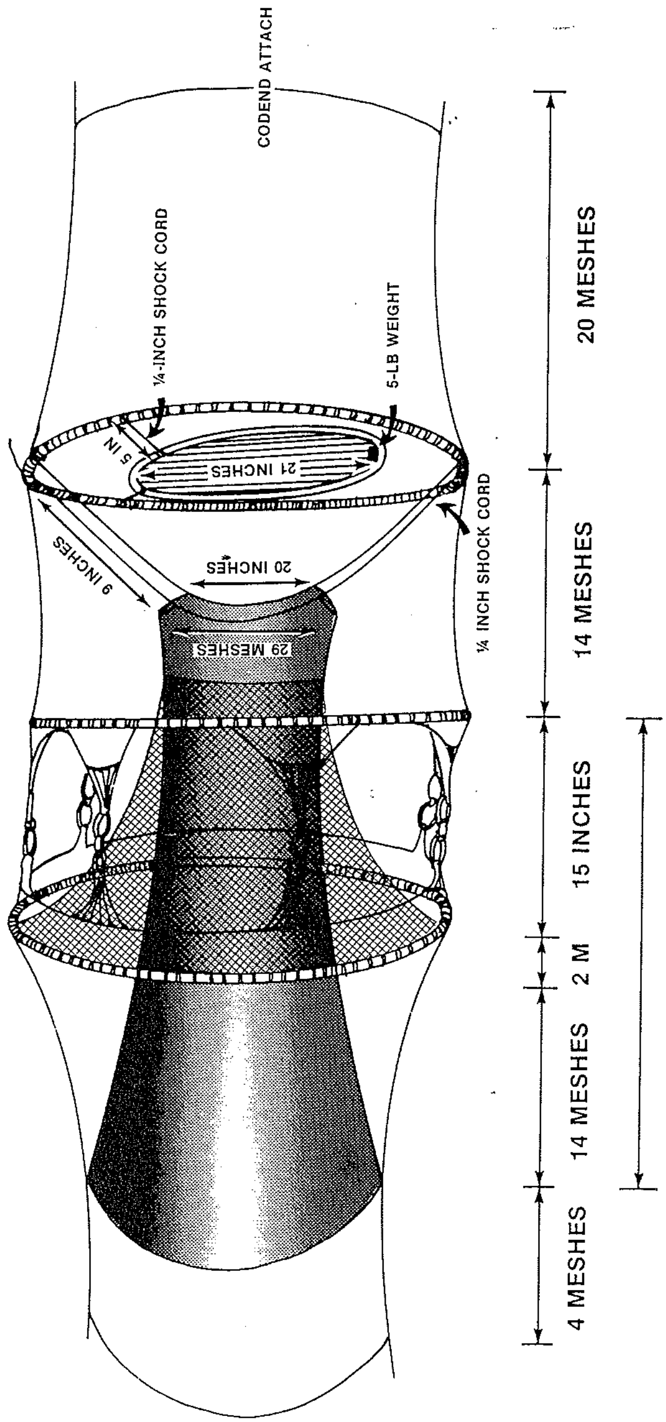

Figure 5 The Finfish separator device, later called the Radial Escape Section. Webbing is removed from the from and middle rings to create an escape opening for larger finfish (Watson et al., 1986)

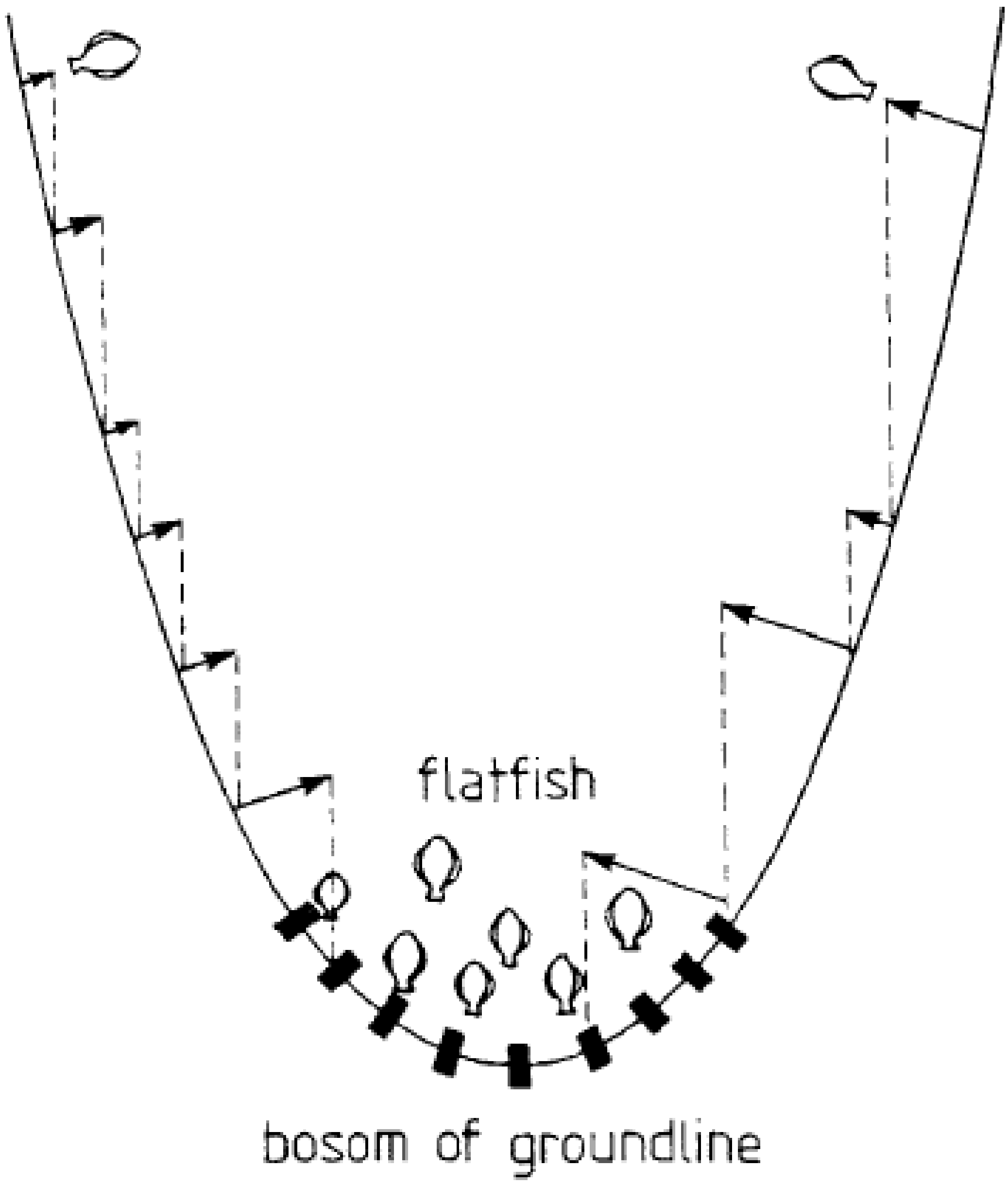

Figure 6 Behaviour of herding flatfish when interacting with groundgear of the trawl (Main and Sangster, 1981).

CHAPTER 4: FISHERIES OF CONCERN

4.1 WINTER FLOUNDER

Winter Flounder is found in the western Atlantic, spanning from southern Labrador to the coasts of Georgia (DFO, 2006). They reside in the Gulf region year-round, preferring to inhabit more inshore areas (DFO, 2012). Directed fishing for Winter Flounder was initially implement in the Bay of Fundy in 1948 (Hendrickson et al., 2006). More recently directed fishing for Winter Flounder occurs in NAFO Division 4T, as well in the US Gulf of Maine fishery (DFO, 2006; Hendrickson et al., 2006). The Winter Flounder fishery involved no quota management until 1996, following the moratorium on cod (DFO, 2006). Quota management was additionally prompted by the first status report on Winter Flounder completed in 1994 (DFO, 2006). Most recently, there were closures of the groundfish fisheries in 2003 and 2004 from April to mid-June (DFO, 2006). Cod spawning is thought to occur during this time, when a closure might reduce gear-based mortalities (DFO, 2006).

The fishery was mainly operated by mobile gear smaller than 45’, even where TAC is split 50:50 between mobile and fixed gear (DFO, 2006). Mesh sizes within mobile gear increased considerably during the 1960s from 130mm to 140mm (DFO, 2006). Along with other regulations to the fishery, including an average TAC of 1,000t starting in 1996, 145mm became the minimum required mesh size in 2003 (DFO, 2006). It was also noted that fishers often utilized mesh size larger than that of the minimum. This was partially a reflection on the declining status of Winter Flounder in the region.

Winter Flounder stocks have been declining since the 1990s, which was especially notable given the decrease in fishing effort within the fishery at the same time (DFO, 2006). Winter Flounder biomass was at its peak in the mid-1980s (DFO and CSAS, 2012). Though there has been some variation, the abundance, size, and biomass of the population have all been noted as being below average in the past decade (DFO, 2006; Hendrickson et al., 2006). Landings dropped from being roughly 1,671t in the 1960s, to 600t in the late 1990s, and finally 381t in 2004 (DFO, 2006). Most recently catch of Winter Flounder was less than 200t in 2007 and 2008, due largely to a reduction in fishing effort (DFO and CSAS, 2012). A survey of flounder fishers indicated that they felt flounder abundance had been similar to previous periods

(DFO, 2006). Additionally, the report mentions that Winter Flounder populations leveled off in 1995 and have since maintained similar abundances.

The 1990s also saw an increase in the capacity to identify Winter Flounder from other flounder species. Even with greater certainty of landings on a species level, survey trawl landings were not 100% representative of flounder abundances (DFO, 2006). Survey trawls were not able to reach the inshore areas where Winter Flounder are also known to occur (DFO, 2006). This issue was further exacerbated by the fact that the vessel used for surveying has been changed multiple times, meaning results from these trawls of varying efficiencies were not comparable (DFO, 2006).

Winter Flounder have a number of characteristics in common with skates that increase the difficulty in reducing skate bycatch in the Winter Flounder fishery. Similar to skates, Winter Flounder prefer soft bottoms and are opportunistic feeders (DFO, 2006). Winter Flounder from Canadian populations are also fairly endemic, remaining within similar regions through their entire life (DFO, 2006). One tagging study recaptured Winter Flounder a number of years later less than 5km from their release location (DFO, 2006). Dissimilar to skates, Winter Flounder prefer hard bottoms, and usually reside in depths less than 40m, often residing in estuaries during the winter (DFO, 2006). Finally, they are known to be dormant at night and more active during the day (Hendrickson et al., 2006). There is no similar information on the diurnal variance in activity for skates.

Within the Winter Flounder fishery, Winter Skates are the most frequently caught species of skate. However, in recent years bycatch of skates has declined to approximately 6t yearly (Swain et al., 2012a). Likely this is as a result of reduced fishing effort within the fishery. Current catch values are certainly much lower than before, with the Winter Flounder fishery previously being among the top three fisheries responsible for skate discards, following cod, Greenland Halibut, and American Plaice fisheries (Fig. 7; Swain et al., 2012a).

4.2 AMERICAN PLAICE

The northwest Atlantic is the primary location of American Plaice, with a range similar to Winter Flounder that only extends as far south as Rhode Island (O'Brien, 2006). The commercial

American Plaice fishery began in 1947 with the introduction of the otter trawl in the southern Gulf of St. Lawrence (Morin, 2012), as well as the development of a market for American Plaice (Rideout and Morgan, 2009). The first quota set for American Plaice was 10,000t in 1977 in NAFO Subdivision 4T. This quota persisted until the closure of the cod fishery in 1993 (Morin, 2012). Restrictions on American Plaice included a reduced quota to 5,000 t, mandatory landing of all American Plaice caught, and bycatch limitations on groundfish (Morin, 2012).

At one time the American Plaice fishery on the Grand Banks of Newfoundland and Labrador was the largest groundfish fishery in the world (Rideout et al., 2009). American Plaice landings accounted for 10% of the weight of all groundfish fisheries in Canada (Rideout et al., 2009). In 2009 TACs among NAFO regions varied from 750t to 2000t each (Rideout et al., 2009). Currently there is a moratorium on American Plaice, as well as a bycatch quota of 5% or 1,250kg, whichever is greater (DFO, 2009b). This moratorium extends from NAFO Areas 1 to 4, limiting catch by Canada, the EU, and the Russian Federation. Separately the U.S. also has a moratorium on American Plaice, and has additionally set goals for rebuilding stocks (O'Brien, 2006).

Prior to the moratorium, the groundfish fisheries underwent a number of alterations to the allowable mesh size (Morin, 2012). The original mesh size used was 75mm in 1947, which is comparatively small by today's standards (Morin, 2012). Minimum mesh size requirements for otter trawls continually increased up to 152mm in 1996 (Morin, 2012). It is thought that a number of fishers actually used mesh sizes larger than the required minimum, as with the fishers in the Winter Flounder fishery. These continual increases in minimum mesh size were an attempt to reduce capture and discard of American Plaice (Morin, 2012). Significant discards were noted in the 1950s, with later spikes in discards rates in the 1970s and 1980s, with U.S. discards mostly from the shrimp fisheries (O'Brien, 2006). Alterations to mesh size were key considering 90% of landed American Plaice were caught in purse seine and otter trawl gear (Morin, 2012). Roughly 85% of the TAC for American Plaice is given to the mobile fleet operators.

Moratoriums were placed on NAFO regions 3M in 1994, and 3LNO in 1995 for American Plaice (DFO, 2009b). Declining stocks of American Plaice, persisting for over two decades, were the main driver behind the moratoriums (DFO, 2009b). Canadian and U.S. tagging studies have recorded population declines in the Gulf and Scotian Shelf regions of approximately

86% and 67%, respectively (Fowler, 2013). However, a recent status report of American Plaice in 3LNO in 2009 reported a recent increase in their population since a 1995 status report (DFO, 2009b). Unfortunately abundance was still quite low, and so it was recommended that a recovery plan should be created and that the moratorium should continue (DFO, 2009b).

Prior to the moratorium, American Plaice were one of the most abundant species of flatfish in the Northwest Atlantic (Rideout et al., 2009). Average catch around the mid-1980s was around 12,700t (O'Brien, 2006). Catch of American Plaice has since declined, with the 2004 catch at 1,711t as a significant low point (O'Brien, 2006). A proportion of these reductions are potentially associated with increasing natural mortality of American Plaice (Rideout et al., 2009). Unusually cold conditions since the 1990s may have led to increased mortality (Rideout et al., 2009), and a reduced ability to withstand the effects of fishing mortality (Fowler, 2013). Current population levels have been noted as being 1% of the historical levels previously noted (Rideout et al., 2009). Declines are so substantial that the Maritime, Newfound and Labrador populations were all listed as Threatened according to a COSEWIC status report (Rideout et al., 2009).

Similar to Winter Flounder, American Plaice are common flatfish to the northwest Atlantic, and also exhibit behaviour similar to skates (DFO, 2009b). They are laterally flattened (Rideout et al., 2009), and around the age of 2-3 years the left eye migrates to the right side of their body (O'Brien, 2006). This adaptation promotes their ability to burrow in seabed sediment, being visually aware of predators or prey in the area (O'Brien, 2006). Similar to skates, American Plaice prefer soft muddy bottom environments for burrowing and camouflaging. They typically reside at depths between 90-250m (DFO, 2009b), with the greatest abundances occurring above 182m (O'Brien, 2006).

American Plaice often remain within a given region, with no evidence of long-distance migrations (Fowler, 2013). In tagging studies most tagged individuals were recaptured in subsequent years close to their release location (Fowler, 2013). This small range is thought to be related to their temperature preference for waters between -0.5 and 4°C (Rideout et al., 2009). In rare cases they have been known to occupy areas with non-ideal environmental conditions in favour of a greater abundance of prey (Rideout et al., 2009).

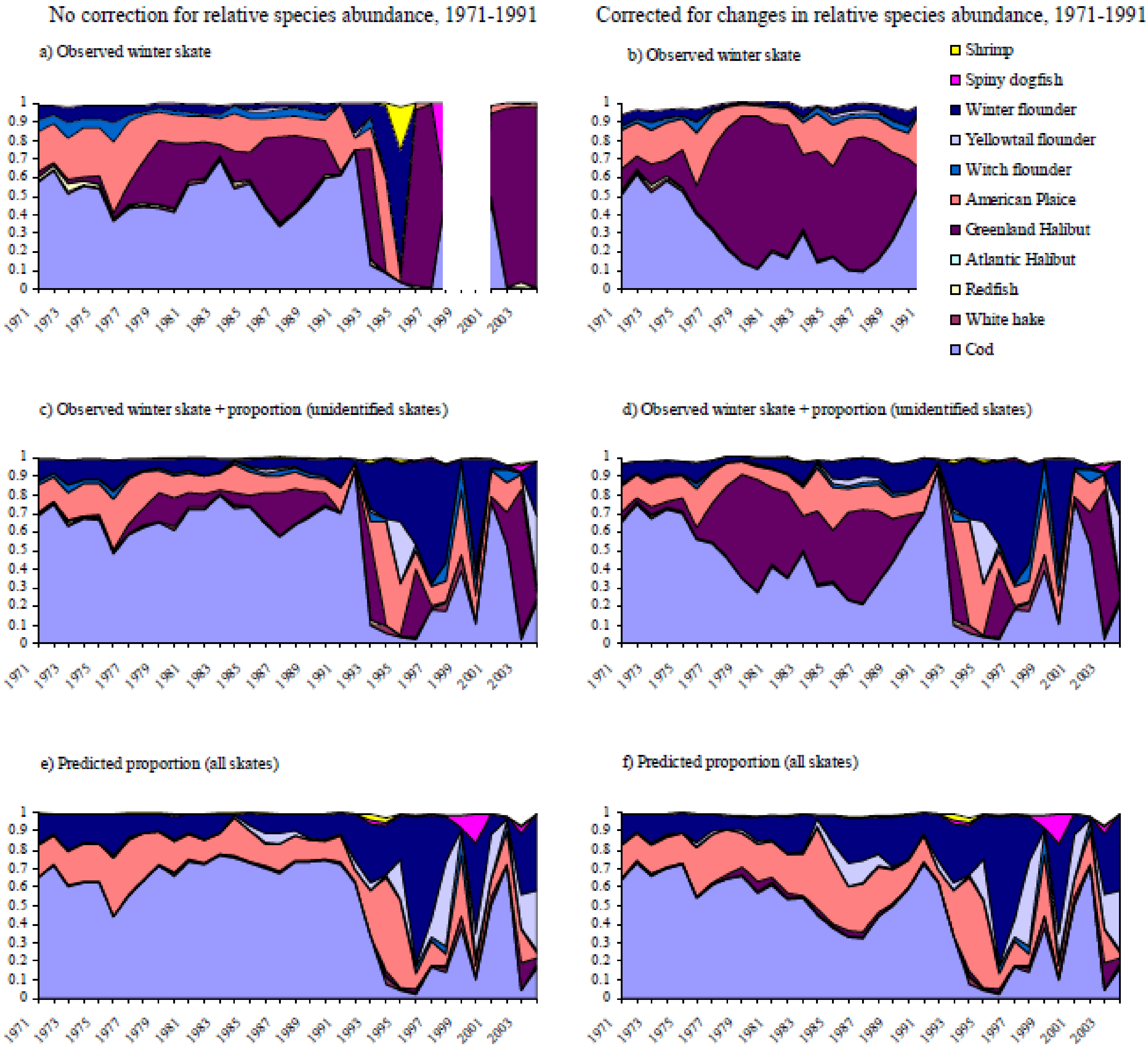

Figure 7 Proportion of total Winter Skate bycatch associated with each of the commercially- important species, 1971-2004, with (left column) and without (right) corrections for changes in the relative abundance of species over the period 1971-1991 (Benoit et al., 2006).

Due to the similarity in behaviour and habitat, it is not surprising that the American Plaice fisheries were responsible for significant discards of skates. Swain et al. (2012b) address the fact that the majority of recorded Thorny Skate discards were in the Winter Flounder and American Plaice mobile fisheries. The moratorium on American Plaice came in to effect in 1995, and so ceased to contribute to the discard of skates following that year. Likely, this means that the Winter Flounder fishery played a more significant role in the discarding of skates caught as bycatch.

4.3 GREENLAND HALIBUT

Greenland Halibut is a deepwater flatfish found throughout much of the northern Atlantic Ocean (Dyck et al., 2007). Though Greenland Halibut are caught in a number of NAFO Divisions (3KLMNO and 4RST) (Healey and NAFO, 2012; DFO, 2013b), they are also caught by England and Norway in the eastern Atlantic, and by Greenland and Iceland in the central Atlantic (Dyck et al., 2007). Depths of peak Greenland Halibut catches are noted as varying among NAFO Divisions (Junquera et al., 2013). Catches in 3M peak between at depths of 1000-1400m, with the 3N range being concentrated to 1200-1300m (Junquera et al., 2013). There is further differentiation of peak catches between adults and juvenile Greenland Halibut (DFO, 2013b).

Since the early 2000s fluctuating catch compositions in the Greenland Halibut fishery have revealed a level of susceptibility within their populations. Greenland Halibut catches increased in 1990 as a result of developing fisheries within NAFO regions (Gonzalez et al., 2004). In the late 1990s and early 2000s, Greenland Halibut fisheries became dominated by catches of juveniles. This prompted the development of a 15-year stock rebuilding program that started in 2004 (Healey and NAFO, 2012). There are concerns as to how successful this program will be, where the shift in composition of Greenland Halibut is thought to have been prompted by the TAC being exceeded for multiple years (Healey and NAFO, 2012). This may partially explain why catches in 2011 and 2012 fishing seasons, with a TAC of 3,751t, were lower than the quota at 3,716t and 3,554t, respectively (DFO, 2013b). For reference, catches of Greenland Halibut in the early 2000s were significantly reduced from 10,600t in 2000, to slightly above 4,800t in 2002 (Gonzalez et al., 2004).

TAC for the Greenland Halibut fishery has experienced significant fluctuations since the initiation of the fishery. Directed fishing for Greenland Halibut using gillnets and bottom trawls began at the end of the 1970s (DFO, 2013b). Up to 1995, TAC for the Greenland Halibut fishery was set by the Government of Canada (Gonzalez et al., 2004). Up until that point, the major notable change in TAC had been the prohibition of mobile gear for a period of time following the moratorium on cod (DFO, 2013b). TAC for mobile gear is still restricted at 4,500t (DFO, 2013a). Since 1995, the TAC for Greenland Halibut fisheries has been set by NAFO (Gonzalez et al., 2004). TAC for mobile gear may tentatively increase to 6,000t with future healthier Greenland Halibut stocks (DFO, 2013a). However, catches from mobile gear have consistently remained between 1,800-2,500t (Gonzalez et al., 2004). TAC for mobile gear is also the first gear type that would experience the most significant reductions in quota following an overall reduction in TAC for the Greenland Halibut fishery (DFO, 2013a). Likely this is a result of gillnets contributing the greatest magnitude of Greenland Halibut catch (61.5%), with catches from mobile gear and longlines being lower by comparison (1.8%) (DFO, 2013a).

Among the Greenland Halibut fishery NAFO Divisions, predominant catch of skates have been noted in the divisions associated with the Spanish mobile fishery. The Spanish Greenland Halibut fishery is comprised of NAFO Divisions 3LMNO (Junquera et al., 2013). Within Divisions 3LM, bottom trawling for Greenland Halibut has being on-going since 1990 (Gonzalez et al., 2004). In a study by Duran et al. (1994), annual yield (kg/h) values for skates during 1993 and 1994, by large and small vessels, were in the range of 40-50kg/h (Duran et al., 1997). Skate bycatch values were among greatest values for the fishery in those years, with values for Roughhead Grenadier (*Macrourus berglax*) and Roundhead Grenadier (*Odontomacrurus marrayi*) having similarly high values (Duran et al., 1997).

Though bycatch of skates and other flatfish species occur throughout all of the Spanish fishery divisions, the range of Greenland Halibut is not thought to significantly overlap with the ranges of these bycatch species. Specifically, a NAFO report (Junquera et al., 2013) noted that the Greenland Halibut fishery does not have a significant range overlap with American Plaice, yellowtail flounder, skate or cod such that there should be any concern (Junquera et al., 2013). Part of the rationale for this statement is due to the large variance in catch composition among the different NAFO Divisions for the fishery. Skates typically comprise 4% of catch by weight in

3M, though conversely over 24% of the catch weight in 3N is attributed to skate (Junquera et al., 2013). Catch fluctuations are even more disparate for American Plaice, where catches in Divisions 3M and 3N comprise 0.04% and 34% of catch by weight, respectively (Junquera et al., 2013). Contrary to Duran et al. (1994) whose notes that skates and these other bycatch species are primarily caught in the range of 800-1500m depth, the majority of bycatch in the NAFO report (Junquera et al., 2013) occur in waters less than 200m.

4.4 NORTHERN SHRIMP

Northern Shrimp (*Pandalus borealis*) are found in the northern waters of the Atlantic and Pacific oceans (DFO, 2014c). In the 1970s the Canadian shrimp fishery began as an exploratory fishing program, with offshore licenses and quotas established between 1978 and 1991 (DFO, 2010). The Northern Shrimp fishery significantly grew in abundance following the cod moratorium in 1992 (DFO, 2010). Currently they are the most common species of shrimp caught in Canada, comprising 97% of shrimp catches (DFO, 2014c). Catches of Northern Shrimp occur within the 15 Shrimp Fishing Areas (SFAs) of Atlantic Canada (DFO, 2014c). Inshore fisheries are highly seasonal, lasting 16-18 weeks in July and August when 50-60% of the catch for the year is made (Gardner Pinfold Consulting Economists Ltd., 2006). Offshore fisheries run all-year, with vessels spending 270-320 days at sea over 8 trips made throughout the year (Barrow et al., 2001). Total catches of Northern Shrimp from inshore and offshore fisheries are noted as comprising 14.9% of Atlantic Canada's commercial fisheries economic value, as of 2005 (Atlantic Canada Opportunities Agency, 2006).

TAC in Canadian shrimp fisheries have notably increased over the past couple of decades. In the mid-1980s a number of the shrimp licenses went unused because of the poor market conditions at the time (Barrow et al., 2001). Major markets for Northern Shrimp have since developed globally. In 2004 Canada was responsible for 39% of the global coldwater shrimp supply, with Greenland at a close second supplying 31% (Gardner Pinfold Consulting Economists Ltd., 2006). Naturally, quota for Northern Shrimp has increased almost 20-fold to meet this increase in demand, from a TAC of 8,200t in 1978, to 160,000t in 2007 (DFO, 2010). In that same time period, catch of the shrimp fishery has increased 50-fold, from 2,500t to a peak of 137,500t (DFO, 2010). Increase in the catch of shrimp have resulted from a healthy production of shrimp, and potentially more importantly, the implementation of the Nordmore Grate as a requirement in Northern Shrimp fisheries (DFO, 2010).

A number of gear restrictions made within Canadian Northern Shrimp fisheries have promoted greater fishing efficiency, resulting in the reduction of bycatch of groundfish. To-date the Nordmore Grate is potentially the single-most beneficial contributor to the reduction in bycatch in Canadian shrimp fisheries. Use of the grate on Otter Trawls was initially introduced in 1993 (DFO, 2010). Following its success in reducing bycatch of groundfish (Barrow et al., 2001), use of sorting grates in Canadian shrimp fisheries became mandatory in 1997 (DFO, 2010). Between inshore and offshore fleets minimum sizing of grates differ from 22mm to 28mm, respectively (DFO, 2010). Additionally, mesh size minimums for all shrimp trawls were limited to 40mm, so as to reduce the catch of young Northern Shrimp (DFO, 2014c). Where the use of Otter Trawls and their gear requirements are consistent among all SFAs, TACs are therefore solely differentiated by region.

Although shrimp fisheries account for over a third of global bycatch (Hall et al., 2000), the Canadian Northern Shrimp fishery seemingly contributes little to the bycatch of skates. Efficiency of tows, aided by the Nordmore Grate, has resulted in bycatch species comprising roughly 2% of overall catch rates in Northern Shrimp fisheries (DFO, 2010). Sorting grate effectiveness is especially impressive given the number of identified predators Northern Shrimp have (Gardner Pinfold Consulting Economists Ltd., 2006). Species of skates, cod, and Greenland Halibut are all reliant on Northern Shrimp as an important prey item (Gardner Pinfold Consulting Economists Ltd., 2006). Similar to a number of groundfish species, shrimp also prefer to inhabit soft bottom regions during the adult stage of their life (Gardner Pinfold Consulting Economists Ltd., 2006). Without appropriate BRDs in place, catch of these non-target species could be prevalent within shrimp fisheries. Despite this speculation, Canada’s shrimp fisheries are MSC certified. The Northern Shrimp fishery has been noted as being one of the world’s most respected fish inspection and control systems, utilizing on-board observers and dockside monitoring for all inshore fishery fleets (DFO, 2010).

CHAPTER 5: DISCUSSION

There is no question that the main skates covered in this study are at risk, though potentially not as threatened as the other groundfish species covered. While DUs of skates are afforded the designation of Vulnerable, Threatened, or Endangered under IUCN, a number of groundfish fisheries with declining populations are not designated as such. Among the groundfish species still available to catch, only two of ten species were allocated quota for catch by mobile gear (Table 1). Additionally six of the species are currently under moratorium, with another two species have no TAC allocated for their divisions. It is unsure whether a lack of TAC means a lack of management, or that there is currently no quota for those fisheries. The poor conditions of the groundfish fisheries in general reinforces the need for a trawl gear that can effectively select for target species, reducing catch of groundfish bycatch, while also providing additional benefits to the fishers who utilize these gears.

Though in the groundfish fisheries skates may not be the species of most concern, the benefits of not catch them may still outweigh the benefit from reduction in catch of other groundfish species at risk. Firstly, in some studies skates were mentioned as being resilient to the negative effects of discarding and post-release mortality. Where fishers adopt models of low post-release mortality for skates, such as in Cedrola et al.'s (2005) study, then there is seemingly little benefit to put more effort into effectively handling skates for the sake of increasing their post-release survival. Ideally skates would not be caught at all, not only reducing handling effort of skates, but also gear-based mortality. Elimination of skates additionally reduces damage inflicted on target species that come into contact with spikes on the skates. While other studies have mentioned this reduction in value, as of yet there have been no Canadian studies on the impact that skate damage has to tow value.

Secondly, effective exclusion of skates aids in the cleaner separation of species, whether in the presence of a sorting grate or not. With the use of down-facing sorting grates, blockages by skates has been shown to reduce. In the absence of skates blocking a grate, smaller targeted species like prawn can flow through the grate with larger species being forced through an escape opening. Where sorting grates are not used, the exclusion of skates reduces overall bycatch by not covering up openings in the codend mesh, intended for smaller fish to escape through. As previously mentioned, this also aids in reducing damage from skates as they interact with other bycatch species. In this way, reducing catch of skates not only benefits the fishers, but also the other groundfish caught within the fisheries, aiding in the recovery of their stocks.

Lastly, though skates still have a TAC and may not be as commercially important as other groundfish species, reducing bycatch of skates is still key to the recovery of their populations. Even with potential reductions in the discard-based mortality of skates, resulting from reductions in fishing effort within the groundfish fisheries, skates populations are still in decline. A number of sources have listed the increase in their natural mortality to be one of the factors limiting their recovery, along with bycatch. Increasing populations of Grey seals, whose diets consists of skates, is continually referenced as a key variable restricting recovery of skates, along with a number of other species. Solutions suggesting the culling of Grey seals is outside the scope of this study, but at a minimum any further reductions in the bycatch of skate species will aid in promoting their recovery within the northeast Atlantic. Though the benefits of reducing catch of skates is apparent, the appropriate gear to use to achieve these results is less obvious.

Table 1 A list of the 2013 allocations for groundfish (DFO, 2014b).

Species	Vessels Over 100'	Communal	Fixed Gear					Mobile Gear	
			fg < 35'	fg 35-64'	fg < 65'	fg > 65'	fg 65'-100'	mg < 65'	mg 65'-100'
2GH and 2J3KL Cod	Moratorium								
3LNO Haddock	Moratorium								
2+3K Redfish	Moratorium								
2+3K and 3NLO American Plaice	Moratorium								
3NLO Yellowtail	100%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2J3KL Witch	Moratorium								
2+3K Greenland Halibut (Turbot)	37.04%	3.38%	N/A	N/A	51.12%	N/A	6.48%	1.81%	0.17%
3LMNO Greenland Halibut (Turbot)	32.84%	3.38%	N/A	N/A	59.42%	N/A	2.61%	1.55%	0.19%
2J3KL Grenadier	Moratorium								
3LNO Skates	N/A	N/A	11.69%	32.49%	N/A	10.00%	N/A	45.82%	
2J3KL Winter Flounder	No Total Allowable Catch								
2GHL & 3KL Lumpfish	No Total Allowable Catch								

The Radial Escape Section trawl gear is innovative in its approach to reducing bycatch, however there are a number of different theories and assumptions that are required for the gear to work effectively. Use of the Radial Escape Section has the potential to reduce catch of skates and flatfish characterized by their Level 3 reaction to trawl entry (Fig. 4). One issue presented by the gear however is the accelerator funnel (Fig. 5). While the benefits from the funnel in catching smaller fish species is apparent, this may result in greater gear-based mortality of skates and flatfish. Their inclination to herd away from points of contact with the mesh (Fig. 6) could lead to congestion and clogging of the funnel.

For the Radial Escape Section to prove useful, a fine balance would have to be struck among the individual components of the gear. The openings in the grates would need to allow for target fish to enter, such that they are above the minimum size allowable for catch. However, the grate openings would also have to be small enough to exclude bycatch of groundfish, skates, and other non-target catch. Though there are no apparent articles comparing the baseline successes of sorting grate orientations, either up- or down-facing, this may also be a variable for consideration depending on the nature of the fishery the gear is used in, whether pelagic or demersal. Although, with the mesh openings in the anterior section of the Radial Escape Section, this may be effective enough at releasing species with a reaction to swim up when being caught. Were that the case, a down-facing sorting grate would be recommended considering the success it has seen with reducing blockages of the grate by larger fish (Brewer et al., 1998; Courtney et al., 2006). Additionally in the codend, the size of the mesh would have to be large enough to allow for the escape of target fish that are below the allowable size of catch. This would include juveniles of the target species, as well as other small fish and juveniles of non-target species.

The Radial Escape Section does have the potential to provide cleaner catches in trawl fisheries. However, effectively using this BRD would require a strong knowledge of the morphology and behaviour of the targeted species, common bycatch species, and size restrictions on all fish in the region. In this respect, creating an effective Radial Escape Section for a particular fishery may require thorough flume tank testing, modeling, and at-sea trials, the doing of which all hinging on the availability of funding to do so.

As for what fisheries the Radial Escape Section could be beneficial, it is safe to say that the four fisheries covered in with high general bycatch, or where bycatch of skates has previously been high, would not be suitable. Winter Flounder and American Plaice have both experienced significant declines in their abundance, currently having no assigned TAC and being under moratorium, respectively (DFO, 2014b). Use in the Greenland Halibut fisheries may have limited benefit where only approximately 2% of the total TAC is allocated to mobile gear (DFO, 2014b). It was also previously mentioned that there is limited overlap between the ranges of Greenland Halibut and other groundfish bycatch species, additionally limiting the benefit that could be provided from the Radial Escape Section. Lastly in the Northern Shrimp fishery, there is the potential that bycatch could be reduced further. The use of the sorting grate coincides with the requirement of TEDs in the shrimp fisheries, and would also benefit from the accelerator funnel because of the poor swimming capabilities of shrimp. However, where bycatch is the shrimp fisheries is only 2% of the entire weight of the catch, there is again a limit to the overall benefit that could be provided from the Radial Escape Section.

Conversely, the Eliminator Trawl™ may provide benefit to Canadian fisheries, but not as it was used by Beutel et al. (2008) in their study. Within the study the Eliminator Trawl™ was tested for how effectively it reduced catch of cod while retaining catches of haddock. As successful as the trials were, and as applicable as these results may be to a Canadian haddock fishery, haddock are currently under moratorium (Table 1). While it may be worth performing at-sea trials to determine the magnitude of haddock caught with the Eliminator Trawl™, until haddock stocks are healthier the gear could not be used for directed fishing of haddock. The Eliminator Trawl™ does have application outside of bottom trawl fisheries however, that could select for pelagic species while still reducing bycatch of groundfish.

The Eliminator Trawl™ additionally has application in pelagic trawls, and has been proven equally effective at reducing bycatch of groundfish, including skates. Originally the Eliminator Trawl™ was conceived as an alternate trawl design in the US squid fishery by John Knight (personal communication, 2014, November 6), owner of Superior Trawl. A solution was needed to reduce the bycatch of flatfish, as well as hake and whiting. Following its success in the squid fishery, Beutel et al. (2008) tested the benefit of the trawl in the New England haddock fishery. Currently, Mr. Knight (personal communication, 2014, November 6) noted that more Eliminator Trawls™ are used in the directed pelagic fisheries for Atlantic mackerel (*Scomber scombrus*) and Atlantic herring (*Clupea harengus*) than another other US fishery on the east coast. Their popularity in these fisheries is a result of the "Clean Tows," catching predominantly the target species, with negligible bycatch.

Where US fisheries have found success with the Eliminator Trawl™, there is potential for Canada to also experience those same benefits. According to Mr. Knight (personal communication, 2014, November 6), the Eliminator Trawl™ at a minimum requires the removal of the trawl doors for pelagic use. This allows for greater lift of the trawl within the water column, appropriate for use in pelagic fisheries. Similar to the US, Canada has pelagic fisheries for both Atlantic mackerel and Atlantic herring (DFO, 2009d, 2014a). When considering use of the Eliminator Trawl™ in either fishery, the mackerel fishery would appear to be the poorer of the choices. Canadian populations of Atlantic mackerel declined between 1995 and 2007 (DFO, 2009d). While the Eliminator Trawl™ may provide reductions in bycatch, there is the concern that mackerel populations could also be at risk in the near future. Conversely, the Atlantic herring populations appear to be in a better position to find benefit from the Eliminator Trawl™. While herring stocks 4VWX off of the coast of Nova Scotia are experiencing declines in abundance, this is not consistent among all herring stocks (DFO, 2009d). Commercial catch data has inferred that herring stocks in NAFO Divisions 4TRS and 3KLPs are all increasingly healthy. Measured variables included increases in recruitment, biomass, and number of spawning individuals. Were these population trends to continue (DFO, 2009d), and the success of the US herring replicated in Canada's herring fishery (John Knight, personal communication, 2014, November 6), conditions would be ideal for effectively implementing and using the Eliminator Trawl™ in Canada.

Before the Eliminator Trawl™ is adopted into the Atlantic herring fishery, there are a few additional variables that should be taken into consideration to assess the feasibility of its use. Firstly, the effectiveness of the Eliminator Trawl™ in the herring fishery should be tested. Ideally a pilot test would be conducted with the assistance of a fisher who is active in the herring fishery. Their assistance would aid in reducing bias by ensuring that the conditions under which the trawl was tested were identical to those of an actual tow. This includes using an appropriately sized vessel, maintaining a representative towing speed, depth, and duration, and towing in traditional herring stock areas. Knowledge of these variables are required before the ordering of the Eliminator Trawl™, as the construction of the trawl is geared towards the size and specifications of the trawl, including depth of tow (John Knight, personal communication, 2014, November 6). Secondly, where bycatch is significantly reduced with the use of the Eliminator Trawl™, ideally there would be a program to aid in the transition from previous trawl gear. The cost to manufacture an Eliminator Trawl™ for a vessel of 145ft, larger than any vessel used in herring fisheries, would cost approximately $30,000 (John Knight, personal communication, 2014, November 6). This represents the high-end of the cost range for trawling manufacturing. It is unlikely that fishers would be able to sell their current gear for that price, and so would benefit from a government subsidy to aid in making the transition. Though outside of the scope of this study, an evaluation extrapolating the value gained in the fisheries of recovering groundfish in the future may aid with promoting the benefits of such a government program. Finally, greater focus on skates in policies and IFMPs would reinforce the initiatives put in place to aid in their population recovery, as well as the recovery of other groundfish species populations. Boris Worm (personal communication, 2014, September 14) mentioned that there is currently a skate IFMP in developed for Atlantic Canada. A management plan specifically focused on skates and not "sharks" would bring more attention to the condition of skates in Canada. This in-turn would hopefully prompt additional regulations and conservation efforts for the species, initiatives that will hopefully aid in the recovery of their threatened populations.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

Skates are a vulnerable group of elasmobranchs that are in a pivotal position for requiring special fisheries management attention. Given no focused effort at population recovery, declining populations may proceed to a condition of endangerment, for species that are not there already. Where a majority of groundfish species are under moratorium, threatened, or are trending towards being a future species at risk, substantial effort needs to be made towards the recovery of Canada's groundfish fisheries.

Where the implementation of IFMPs, policies, and actions plans all contribute to the theory of skate protection, groundfish fisheries in Atlantic Canada require measures that have more teeth to them. Regulations or immediate TAC alterations however may be a less practical approach in the long-run, where survey data lags behind the true condition of the fisheries, and the implementation of effective regulations come after a point of no return. However, the direct reduction of bycatch through a transition to more selective trawl gears may provide direct benefits to the recovering skate and groundfish stocks. This is not to say that sufficient trialing and at-sea testing should be skipped, but the alteration of gear is a movement that can be instigated by non-government stakeholders.

6.1 RECOMMENDATIONS

1. For skate and groundfish species currently in a healthy condition, take active steps to create baseline assessments against which future trends can be compared.
2. Creation of a recovery strategy for threatened skates: Winter, Thorny, and Smooth Skates. This strategy should also incorporate the Barndoor and other threatened skates, even where little recent data may be available.
3. Stock assessment review of all groundfish species under moratorium or threatened, specifically by COSEWIC.
4. Completion of the Atlantic Skate IFMP, incorporating the input from a number of different stakeholders. Stakeholders would include fishers, indigenous communities, government, industry, and the public when necessary.
5. Trialing of the Eliminator Trawl™ in Atlantic herring and Atlantic mackerel fisheries to test the efficiency with which bycatch species can be selected out from the targeted fish.

6. Modeling and Flume Tank testing of the Radial Escape Section for use in Atlantic herring and Atlantic mackerel fisheries. Testing and modeling should involve the inclusion of fishers knowledge with regards to the use of a proper vessel, tow depth, speed, and duration, and trawl configuration.
7. DFO and governments of maritime provinces should invest in subsidizing a gear transition program where A) one or both of the gears tested is found to be particularly effective at reducing bycatch, and B) where the benefits of the gear to current and future stocks of the affected non-target fish outweigh the cost of transitioning to a new set of gear.
8. Implementation of skate awareness initiatives aimed at providing the public with information on the status and vulnerability of skates in Atlantic Canada.

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