

**Atlantic Cod in 4Vn: Sentinel Surveys and Sustainability**

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## Abstract

Atlantic cod (*Gadus morhua*) have been a species of great historical and cultural relevance within Atlantic Canada for centuries. The fishery came to a complete collapse during the mid-1990s, and the Canadian federal government placed a full moratorium on the cod industry in Atlantic Canada which still remains today. There is an annual survey of Atlantic cod within the Northwestern Atlantic Fisheries Organization (NAFO) 4Vn (i.e., Sydney Bight) Division. This study uses the data collection from the Atlantic Cod Sentinel Survey from 1995-2019 to study the condition and abundance of Atlantic cod within 4Vn throughout the years of the survey, along with the change in abundance of recorded bycatch. Additionally, discussions with fisheries management professionals were conducted to gauge the industry's protocols and impressions on the decision-making and policy implementation approach with regards to the fisheries. This study recorded drastic declines in cod as well as the majority of bycatch species. Atlantic halibut was an outlier and showed a tremendous increase over the study period. The condition of the cod caught within 4Vn was observed using Fulton K, HSI, and GSI indices. HSI and GSI appear to correlate and both are trending upwards within the last few years. Fulton K expressed poor cod body condition consistently since 2002. Research demonstrates that Atlantic cod are sensitive to temperature and that the amalgamation of overfishing and anthropogenic climate change could have devastating consequences on the species. Discussion and policy research indicated that there is a need for more consultation between the federal government and Indigenous rightsholders and an implementation of Indigenous knowledges systems into the current decision-making process.

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## Introduction

This study will explore Atlantic cod (*Gadus morhua*) in the Northwest Atlantic Fisheries Organization (NAFO) 4Vn commercial fishing division. Atlantic cod – hereafter referred to as cod – has been a culturally significant species of fish within Atlantic Canada for centuries. However, during the mid-1990s there was a significant collapse in the cod stocks within 4Vn and other surrounding NAFO divisions. This collapse forced the Canadian federal government to place a full moratorium on the cod industry in 1993. There was immediate support for the monitoring of the cod stocks within the NAFO divisions and annual surveys were implemented to assist in this monitoring. Thus, the 4Vn Sentinel Survey was born in an effort to record to the condition of the cod stocks within the Sydney Blight NAFO division. The purpose of this report is to analyze trends within the 4Vn Sentinel Survey using data dating the years 1995-2019. Additionally, this report explores fisheries management techniques and Indigenous knowledge implementation in an effort to mitigate such fisheries collapse in the future.

### *OBJECTIVES:*

The objective of this study is to analyze DFO's Atlantic Cod Sentinel Survey in 4Vn dating from 1995-2019 to ask the following:

1. How has the condition of cod within 4Vn changed throughout the Sentinel Survey (Fulton Condition Factor (K), Hepatosomatic Index (HSI), and Gonadosomatic Index (GSI))?
2. What was the abundance of cod (kg) and bycatch species throughout the Sentinel Survey and how has it changed over time?

3. What is the science-to-policy approach and could Indigenous knowledge systems be incorporated to prevent future collapse in fisheries or help enhance recovery?

*BIOLOGY:*

Cod are benthopelagic jawed ray-finned fishes which inhabit the continental shelves of the Northwest and Northeast Atlantic Ocean (COSEWIC, 2010a; Rose, 2007a). Cod can be identified by their streamlined shape with three dorsal fins and two anal fins. Colours of cod range from near black, to brown, to red (COSEWIC, 2010a). In Canada, Atlantic cod can be found along the east coast from Georges Bank and the Bay of Fundy northward along the Scotian Shelf, through the Gulf of St. Lawrence, Newfoundland, and the eastern shores of Labrador and Baffin Island (COSEWIC, 2010a; Worester et al., 2009a).

Cod begin life as eggs which are released in batches over several weeks – 5-25% at a time – by the female and eventually hatch into larvae which live in the upper 50 metres of the ocean (COSEWIC, 2010a; Rose, 2007a). The number of eggs a female can produce in a single breeding season is approximately between 300k and 500k and can be around several million for large females that are greater than 75cm in length (COSEWIC, 2010a; Rose, 2007a). Females can be fertilized by multiple males and reproductive success rates increase with the number of males contributing (COSEWIC, 2010a). There is an apparent established hierarchy among male cod. Dominating large cod rank above smaller cod as aggressive interactions, agonistic behavior, and body size allow them to defend their temporary spawning territories (COSEWIC, 2010a; Rose, 2007a). Cod reproduce through external fertilization with no parental care. Habitat suitability for larval stages is impacted by factors including the oceanographic retention

of pelagic eggs and larvae, food availability, and temperature (Mello & Rose, 2005; Swain et al., 2019).

During their larval stage, they feed on phytoplankton and small zooplankton in the upper area of the water column (COSEWIC, 2010a). Eventually, once they have metamorphosed into juveniles, cod seek refuge on the bottom of the ocean floor in areas with protection such as an eel grass bed (COSEWIC, 2010a). Juveniles stay in this environment for the first 4 years of their life, as cod take around 3-7 years to mature (Rose, 2007a). There is variability in growth rates and maturation in cod which is impacted by their habitat or location. In warmer waters, cod matures earlier and by contrast matures later in colder waters (COSEWIC, 2010a; Swain et al., 2019). Mature adults' range in size from 35 to 85cm in length (COSEWIC, 2010a). The diversity in habitat is expanded once matured as adults. The primary factors impacting the distribution of adult cod fish are temperature and food availability (COSEWIC, 2010a; Mello & Rose, 2005; Swain et al., 2019). The diet of an adult cod includes small fish, squid, crabs, shrimp, mussels, clams, whelks, tunicates, sea stars, sand dollars, sea cucumbers, and polychaetes (COSEWIC, 2010a; Rose, 2007a).

The movements of cod can be accredited to geographical and seasonal changes in water temperature, food availability, and anticipated spawning grounds (Mello & Rose, 2005). On one end of the spectrum there are resident populations which only travel around tens of kilometres and make up about 44% of all identified cod populations (COSEWIC, 2010a; Ruzzante et al., 2000a; Swain et al., 2019). Contrasting is the other end of the spectrum, where some cod populations are known to travel hundreds of kilometres during their seasonal migrations (COSEWIC, 2010a; Ruzzante et al., 2000a; Swain et al., 2019). A good example of this is the local

cod population in 4Vn off the coast of Cape Breton. This population overwinters in the warmer water in 4Vn while migrating to feed and spawn in the southern Gulf in April (COSEWIC, 2010a; Ruzzante et al., 2000a; Swain et al., 2019). There is substantial research into the correlation between cod populations and migratory patterns (Ruzzante et al., 2000a).

It is an estimated 18% for the annual mortality probability of cod, regardless of age and size (COSEWIC, 2010a). However, recent studies have shown evidence of an annual loss in stocks of 30% to 76% depending on the region (COSEWIC, 2010a). The sources of these astoundingly high mortality rates can be traced back to incidental mortality in other fisheries, to anthropogenic climate change, and predation from seals or other predatory populations (Mohn et al., 2001).

#### *HISTORY:*

The significance of cod dates back 500 years. It was cod which brought Europeans to the waters of Newfoundland in the fifteenth century (COSEWIC, 2010a; Rose, 2007a). This cod fishery aided in the creation of the first permanent settlements in British North America in 1612 (COSEWIC, 2010a; Rose, 2007a). Cod was one of Atlantic Canada's cornerstone industry with a peak of approximately 2.5 billion spawning individuals in the early 1960's (COSEWIC, 2010a). During this peak period there was an annual landing of 200k to 400k tonnes of cod (Rose & Rowe, 2015a). There was a second peak period in the 1980s as well. In 4Vn – the zone this project focuses on – during the heydays of the industry in the 1960's, and again in the 1980's, there was a peak of 10k tonnes of cod landed (DFO, 2008). Due to large-scale commercial overfishing, cod stocks were severely depleted by the early 1990s and a full moratorium was

placed on the industry on August 31, 1993 and still stands to this day (DFO, 2008). Hutchings and Rangeley describe this as “the greatest numerical loss of a Canadian vertebrate, is one from which the species has yet to recover (Hutchings & Rangeley, R.W., 2011).” Due to this, cod is one of the most significant stock rehabilitation efforts in the entire country (Hutchings et al., 2021).

#### *SENTINEL SURVEY:*

This project will focus on the Atlantic Cod Sentinel Survey which takes place every year in the fall. In 1994, after the moratorium was put into place, there were pressures from inshore fishermen to do something about the dying industry. This inshore industry desired to complete an annual survey during the shutdown to get an accurate reading of the status of the cod stock (Lambert 2015). However, there were discrepancies between the amount of fishing wanted by the industry and the amount of science that is required to do an adequate assessment of the cod stock (Lambert 2015). Longline captains and fishermen’s associations from all over 4Vn aided in the implementation, organization, and operations in the Sentinel Survey with the guidance of Department of Fisheries and Oceans (DFO; Lambert 2015). Catch rates of cod declined by more than 50% from the inception of the sentinel survey to 2001, this decline is consistent with other research and trends (DFO 2005). The process and protocol of the sentinel survey is explained in the methods section below.

## *RESEARCH QUESTIONS/OBJECTIVES:*

This study attempts to answer some relative questions regarding the resident cod stock of 4Vn using data that has been collected from the sentinel survey since 1995 as well as explores the science-to-policy approach and the potential for an integrated Indigenous policy framework. One focus on the quantitative research is to examine change in cod body condition (Fulton K) in 4Vn over time. Has there been a change in the condition cod within 4Vn during the data collection period? This study only presents Fulton K using carcass weight as it is more accurate than using the full cavity weight as Carcass K is not influenced by sex, stage of maturity, and stomach fullness (Dutil et al., 1995; Lambert, 2019a). This leads to a more accurate condition factor than if K was calculated using the full weight of the cod. In addition to Fulton K, this study also employs the use of the Hepatosomatic Index (HSI; liver to body ratio) for a more accurate representation of cod condition. HSI is used to determine cod condition as the liver plays a vital role in the storage of energy. Thus, the liver weight in relation to the total body weight is one of the most sensitive indices of nutritional health among cod (Dutil et al., 1995; Lambert, 2019a). Moreover, the change in reproductive development and energy allocation over time will be examined by observing precocious sexual maturity through the use of the gonadosomatic index (GSI; gonad to body weight).

Next, species abundance was observed using the same Sentinel Survey data set. The study was interested in exploring the abundance of cod in both weight (kg) and number (n) within 4Vn and the change of said abundance throughout the survey. Additionally, further analysis was conducted on bycatch species hauled up during the Sentinel Survey. Furthermore, catch rate was calculated using the industry standard for catch per unit effort (CPUE; Hurley,

2019; Lambert, 2019). The average weight of an individual species of fish cannot skew the perceived abundance of catch when all species are calculated by a standard CPUE (kg/1000 Hooks). CPUE is employed to get a more accurate representation of species abundance throughout the 4Vn survey. This study calculated CPUE for Atlantic cod and other taxonomic groups of bycatch species haul throughout the 4Vn Sentinel Survey (e.g., Gadiformes, Pleuronectiformes, and Elasmobranchii).

Subsequently, this study addresses questions and concerns regarding fisheries management, policy implementation, and Indigenous collaboration. This area of the study was conducted in an effort to understand the ambiguous nature of fisheries policy implementation and a possible make recommendations for improvements. Such queries included how does the Canadian federal government make legislative decisions surrounding fisheries such as minimum catch sizes? What factors may play a role in said decisions? What policies may be implemented to provide mitigation for the cod stock if it were to return? If there was an integration of Indigenous knowledge systems (i.e., Two-Eyed Seeing), could that possibly prevent further fisheries from collapsing in the future? All above policy inquiries have been qualitatively documented from a conversational dialogue between researchers and the corresponding fisheries professional.

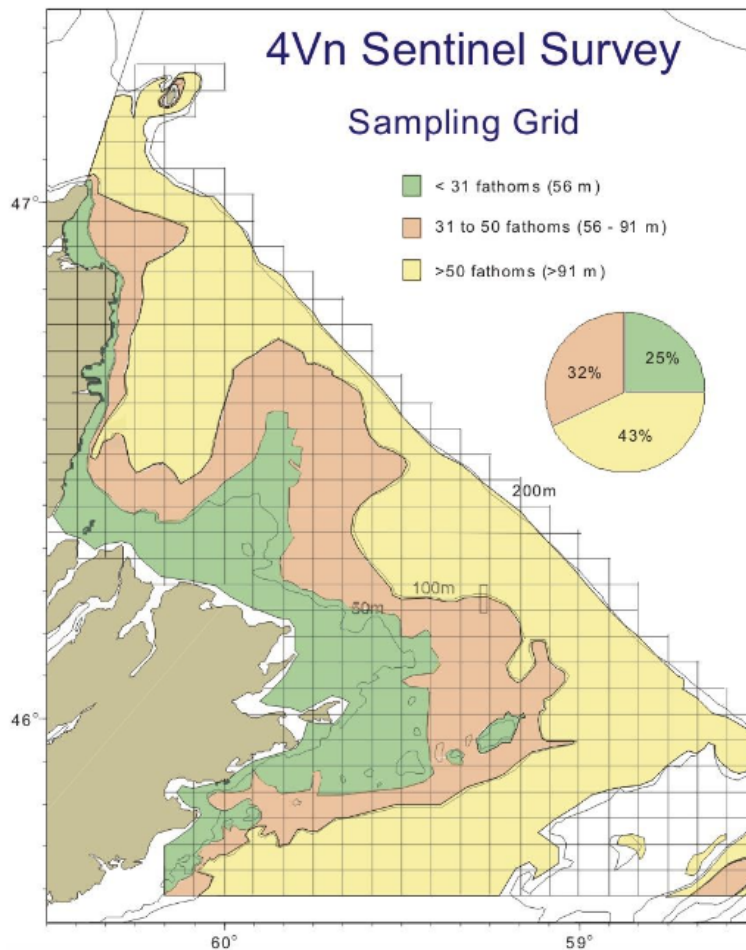
## Methods

The following will explain the methods used for collecting the sentinel data. These methods have proven to be effective at collecting data as they use a standardized protocol constructed by DFO that has been used for almost 25 years. To start, a stratified random sampling scheme is used. The sampling area (**Figure 1.**) includes the entirety of 4Vn within the 100-fathom contour which is approximately 4000 sq. nautical miles (Lambert 2019). The sampling area is divided into three strata on the basis of depth. **Table 1.** provides a representation of the different strata in the sampling area.

**Table 1.** Metrics for the commensurate strata depths of the 4Vn Sentinel Survey (Lambert, 2019).

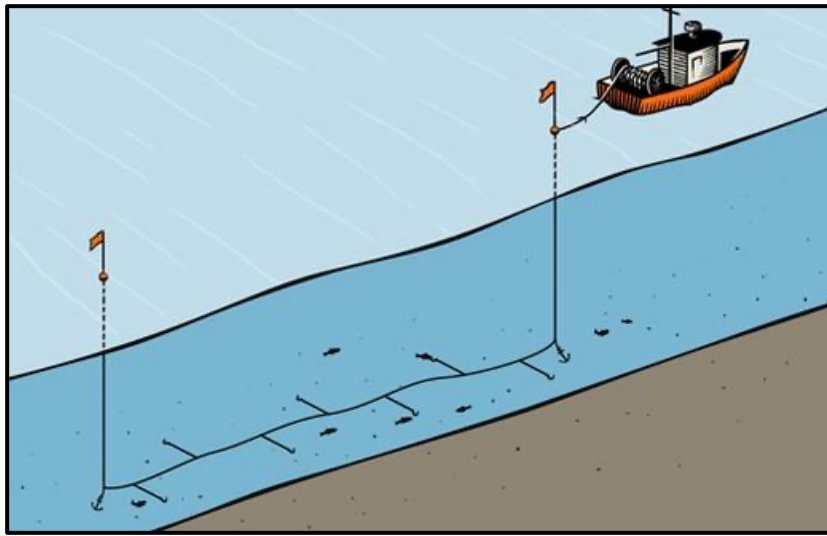
Depth (fathom)	Depth (metres)	Area (nm <sup>2</sup> )	Area (km <sup>2</sup> )	% of Total	# of Sets
<31	<56	1,070	3,674	25	14
31 – 50	56 - 91	1,320	4,532	32	18
>50	>91	1,780	6,112	43	24

The 4Vn sample grid (**Figure 1.**) consists of 463 blocks which are approximately 9 sq. nautical miles in size (Lambert, 2019). This is ideal as most longline strings fit the block by starting the string at the centre of the block. The number of sets differ depending on the stratum, this is determined by being commensurate to the area of that particular stratum (Lambert, 2019).



**Figure 1.** Map showing grid design for the 4Vn sentinel survey (Lambert 2019).

The randomized 56 sets are contracted out to captains who possess a commercial ground fishing license. These crews use standardized equipment to keep the effectiveness and consistency of the methods. One set (**Figure 2.**) consists of the following gear: 5 tubs of gear; a tub of gear contains around 500 hooks; #12 circle hooks are used; gangions are 18 inches long made of 150-200lb. test braided nylon which are set 6ft apart along the groundline (a gangion is one of the short length of moderate-weight line that bear hooks and are attached at regular intervals to the groundline of a setline) ; the groundline has floating line spliced to it at intervals to raise hooks off the bottom; the bait is always mackerel; and the soak time should be at least 3-6 hours (Lambert, 2019).



**Figure 2.** Graphic illustrating the longlining “set”.

A DFO supplied temperature recorder is attached to the trawl anchor at the end of one set of gear. This is returned to onshore technicians to upload the data at a later date. The first 50 cod that are collected from each set are kept, recorded, put on ice, and delivered to the onshore technicians. All information for each on set is recorded by an at-sea observer. It is the captain’s responsibility to retain and deliver all paperwork to the onshore technicians.

At-Sea observers follow their standard Groundfish protocol. All fish are identified down to the species. Up to 100 fish for each species (e.g., cod, hake, Atlantic halibut, American plaice, and wolffish) per set are sampled for length. It is crucial that the at-sea observer communicates with the captain to ensure that the set that is being hauled up is being recorded under the appropriate set.

Once the fish have landed, they are stored in ice and delivered to the onshore technicians the next day, along with the temperature recorder and paperwork. The next step is

to process the cod that were sampled. First, cod fish is weighed (kg) using a scale and measured (cm) using a fish board. The otoliths are removed and placed in a small marked envelope to be analyze for age by DFO. The fish is cut open and the liver, the gonads, the stomach, and the remains of the body cavity are removed. All previously mentioned organs are then weighed (g). The fish is sexed, and the sexual maturity stage (0-4; i.e., limp and unfertile gonads or gonads filled with eggs/sperm) of the gonads are identified. The stomach fullness is also recorded (0-4; i.e., no food in the stomach cavity or the stomach cavity is filled with undigested food). Supplied diet data was insufficient for this study and was not explored.

#### *DATA ANALYSIS*

This study used Microsoft Excel to analyze the 4Vn Sentinel Survey dataset – 1995 through 2019 – provided by DFO. However, it quickly became apparent that this method was vastly inefficient compared to other software such as *R*. It has been noted that for future use of this data, *R* is the recommended software for analyzing such an extensive dataset. Due to this issue regarding software use, the challenges of working with excel for such a large dataset made this study much more difficult. From Excel, with the use of power queries, the extensive dataset was configured into two distinct sets: (1) bycatch data; and (2) cod condition data. The bycatch data was used to determine the overall kilograms and number of individuals (*n*) in caught for Atlantic cod and all bycatch species that has been caught on hooks throughout the 4Vn Sentinel Survey. Using this information, along with set profile information, the CPUE (i.e., Catch Rate) was calculated using the industry standard of (Hurley, 2019a; Lambert, 2019a):

$$\text{CPUE} = \text{KG}/1000 \text{ HOOKS}$$

In addition, condition factors were extracted from the cod condition dataset and , GSI, Fulton's K and Fulton's Carcass K were calculated using the following (Dutil et al., 1995; Lambert, 2019a; Skjærraasen et al., 2012):

$$\text{Fulton's K: } (W/L^3)*100 \quad \text{Carcass K: } ((W-\text{organ } W)/L^3)*100$$

$$\text{HSI: } (\text{liver } W/\text{total } W)*100 \quad \text{GSI: } (\text{gonad } W/\text{total } W)*100$$

Note: weight was measured and calculated in grams and length was measured and calculated in centimetres. The results of these analyses were compiled and plotted using Excel.

#### *POLICY APPROACH*

An analysis of primary (peer-reviewed) and gray literature (e.g., technical reports and popular press articles) was carried out, as well as discussions with personnel from DFO and Unama'ki Institute of Natural Resources (UINR). Due to the COVID-19 pandemic, these discussions were held over Microsoft Teams via video chat or through email correspondence. The main contributors to these conversations were senior advisors in Fisheries Management at DFO and the Fisheries Liaison Coordinator at UINR. These individuals were selected due to the fact that they were very knowledgeable and experienced in the process science-to-policy process. Additionally, UINR is a valued confrère and stakeholder within the fisheries industry.

Due to this, informal discussion with UINR could provide insight on how indigenous voices are considered throughout the policy decision-making process and if the improvement of implementation of Indigenous knowledge systems could significantly improve management outcomes.

## Results

### *COD CONDITION:*

After analysis of the Sentinel Survey dataset the correspondence between the two indices were similar. Trends observed within HSI include a steep decline throughout 1996 to 2001 where it rebounded until it peaked in 2005. From 2005 there is a gradual decline until it started to trend upwards in 2018. GSI fluctuates throughout 1995 and 2004 where it then makes a steady decline until 2018 there is another slight trend upwards. Both indices show growth within the last two years, however this time frame is too short to make any conclusions. These condition factors should be monitored further to determine what might be occurring within the cod population (**Figure 3**).

Lastly, Fulton K (an index of condition) using carcass weight (i.e., with visceral weight removed) was plotted throughout 1995-2019. There was a typical trend observed with cod condition within 4Vn and that is persistently being under the desired K factor (<1). Spikes above 1 are only observed during 1995, 2001, and 2002. Otherwise, Fulton K using carcass weight was consistent throughout the data (**Figure 4**). Additionally, when Fulton K using carcass weight is compared with the trends of the other two condition indices (i.e., HSI and GSI) the peculiar upward trend is not observed within the last two years of carcass K (**Figure 3; Figure 4**).

### *SPECIES ABUNDANCE:*

Overall, approximately 60 different species were caught and identified during the sentinel survey for cod (Tables 1-9): 9 species of Gadiformes (cods and relatives), 8 Pleuronectiformes (flatfish and flounders), 7 Perciformes (perch-like fishes), 6 Scorpaeniformes (scorpionfishes), 6 shark species, 6 skate species, 7 species of fishes from miscellaneous orders (Table 8), and 10 species of invertebrates, and at least one species of seal. There may have been other species that were not identified since they were bycatch and ended up being lumped into unidentified categories (UID). Gadiformes comprised the largest component of the catch, with 882416kgs caught during the three-time series represented in Table 1. The next highest-ranking groups for by-catch included the Pleuronectiformes (56,638kgs), Batoidei (Skates; 23,261kgs), Selachii (Sharks; 17,041kgs), and Perciformes (11,907kgs).

Trends were identified within the abundance of cod and bycatch using total catch in weight (kg). Three-time series of 7-year increments were compared and a percentage of abundance change between the most recent time series (2012-2019) and the first time series (1995-2001) was calculated. Cod was observed to have a drastic 98% decrease in abundance throughout the survey with 500,190kgs caught within the first 7-year bracket and only 12,218kgs within the last 7-year bracket (**Table 2.**). All remaining Gadiformes – except Atlantic tomcod – also showed drastic decrease as well, including white hake with a 91% drop off of 28,159kgs to 2,564kgs (**Table 2**). Similarly, the majority of Pleuronectiformes (i.e., flatfish and flounders) showed drastic decreases between the two-time intervals. The majority of flatfish showed decreases in abundance similar to the Gadiformes. American Plaice was the most abundant flatfish species, with the majority being hauled within the first 7-year bracket at

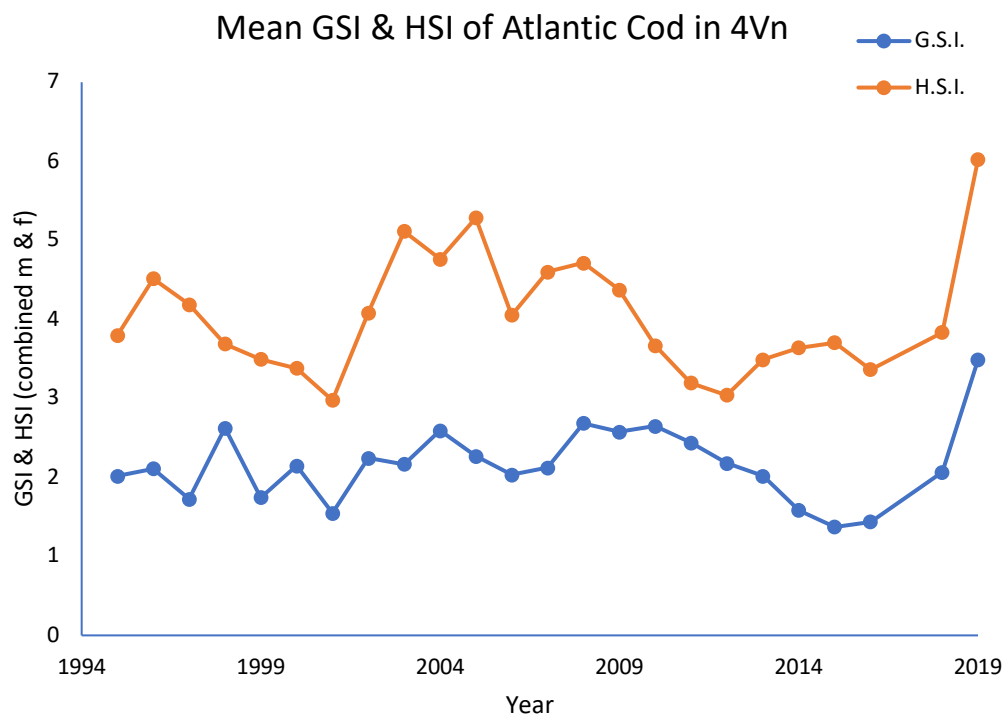
37,873kgs and only 282kgs hauled in the last time series, indicating a loss of 99% (**Table 3.**).

One of the most notable changes within the Pleuronectiformes and overall bycatch is the increase in Atlantic halibut. Throughout the years of the sentinel survey, Atlantic halibut catches were up 127% (**Table 3.**). This remarkable increase in catch for Atlantic halibut supports further inquiry as no other species had such a substantial increase.

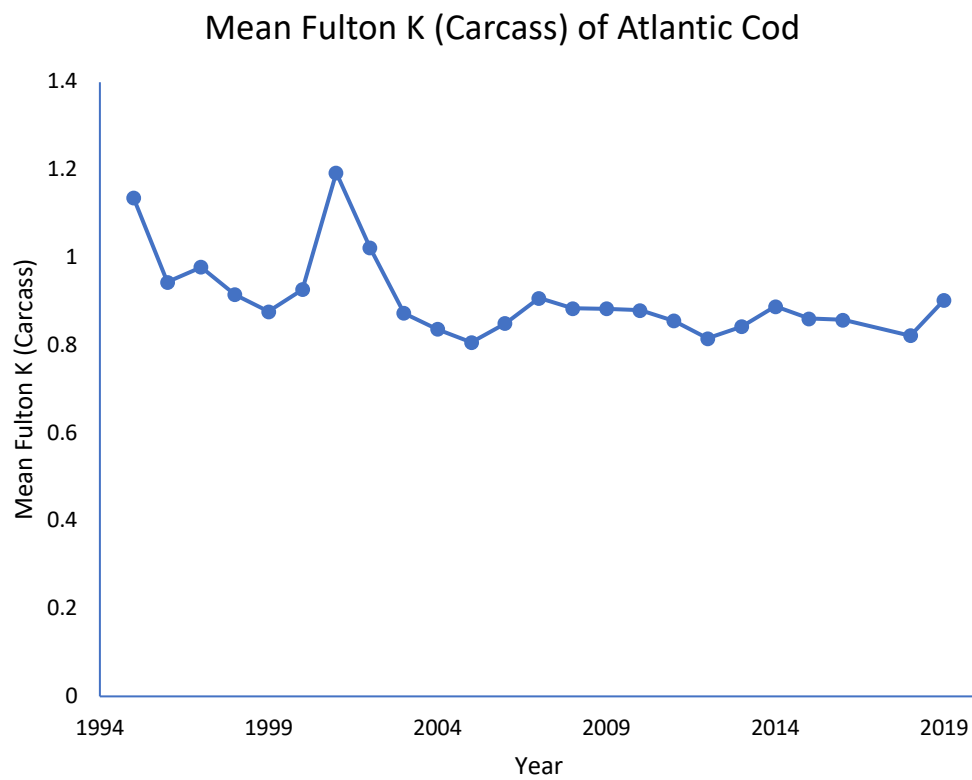
For other osteichthyans (i.e., bony fishes), Perciformes were examined, with the largest contributor being Striped Atlantic wolffish at a total catch of 8,223kgs and a decrease in abundance by 93% (**Table 4.**). Followed by the Spotted wolffish at a 98% decrease in abundance with a total of 18,55kgs (**Table 4.**). Scorpaeniformes were recorded throughout the study, however most sculpin species were not identified to the species. Due to this, most abundant Scorpaeniform are unidentified sculpins at a total of 12,26kgs over the three-time series of 7-year increments with a decrease in 24% throughout the years (**Table 5.**). Elasmobranchs were categorized between sharks, and skates and rays. For the sharks, the spiny dogfish was one of the most abundant species during the beginning years of the survey but saw a dramatic drop from the first 7-year bracket at 9,483kgs to the last 7-year increment at 2kgs for a 100% decrease in species abundance (**Table 6.**). This was followed by the blue shark with a surprising total of 3,844kgs caught and a decrease of 88% throughout the three 7-year increments (**Table 6.**). For Elasmobranchii, only skates were significant, with a total catch of 21,007kgs of thorny skate throughout the survey, despite a 95% decrease throughout the years (**Figure 7.**). Miscellaneous fish species were grouped together within **Table 8.** with Anguilliformes making up the majority of the catch at a total of 133kgs. Lastly, non-fish species such as invertebrates

and mammals were group within **Table 9.** with crustaceans and pinnipeds making up the majority of the catch in kilograms.

Catch rate was calculated using the industry standard for CPUE (kg/1000 Hooks). This provided results similar to the species abundance tables described above. The CPUE plots provide an excellent visual of the standardized catch rate between species caught during the 4Vn Sentinel Survey. Using CPUE, there is an observed drastic drop off in the species abundance of cod during 2005 which is similar to the decline shown in cod body condition within the mid-2000s (**Figure 5.; Table 2.**). All remaining trends observed within the species abundance tables are witnessed within the CPUE plots. The drastic declines of White Hake, American Plaice, Thorny Skate and Spiny Dogfish are clear (**Figure 6; Figure 7; Figure 9**). The extreme success of Atlantic halibut throughout the survey is evident in the Pleuronectiformes plot (**Figure 7.**). CPUE was plotted for other groups of species as well for more visualization (**Figure 8; Figure 10; Figure 11**). Overall, the trend of the decline in species abundance and biodiversity within 4Vn is indicative in the CPUE plots.



**Figure 3.** Mean comparison of condition indices HSI and GSI throughout the years of the Sentinel Survey (1995-2019). Sex was not calculated for separate and were calculated jointly.



**Figure 4.** Mean Fulton K using Carcass Weight throughout the years of the Sentinel Survey (1995-2019).

**Table 2.** Total catch (kg) of Gadiformes in brackets of 7-year increments throughout the Survey. For congruency, three years were removed to make brackets uniform. Time series 2 had years 2008 and 2009 removed after quality control flagged some issues with the reported data which will be investigated further in future research. However, the % Change is calculated between Time Series 3 vs. Time Series 1. For bycatch that was abundant enough to assess changes, either a -% is provided for a loss, a + for increase, and no value if not enough data. This has been repeated in the remaining tables.

Gadiformes

Common name	Species	Time 1: Sum of 1995- 2001	Time 2: Sum of 2003- 2011	Time 3: Sum of 2012- 2019	Total (kg)	%Change from Time 1 to 3
Atlantic cod	<i>Gadus morhua</i>	500190	304876	12218	817284	-98
White Hake	<i>Urophycis tenuis</i>	28159	11666	2564	42388	-91
UID Hake species	UID Gadiformes spp.	719	13716	0	14435	-100
Greenland cod	<i>Gadus ogac</i>	2275	1047	464	3786	-80
Haddock	<i>Melanogrammus aeglefinus</i>	973	1829	91	2893	-91
Red Hake	<i>Urophycis chuss</i>	1056	165	0	1221	-100
Atlantic tomcod	<i>Microgadus tomcod</i>	160	0	181	341	+
Pollock	<i>Pollachius virens</i>	39	24	3	66	-92
Silver hake	<i>Merluccius bilinearis</i>	1	0	0	1	-100
Arctic cod	<i>Boreogadus saida</i>	0	0	1	1	
OVERALL TOTAL					882416	

**Table 3.** Total catch (kg) of Pluronectiformes in brackets of 7-year increments throughout the survey. For congruency, three years were removed to make brackets uniform.

Pleuronectiformes

Common name	Species	Time 1: Sum of 1995- 2001	Time 2: Sum of 2003- 2011	Time 3: Sum of 2012- 2019	Total (kg)	% Loss from Time 1 to 3
American plaice	<i>Hippoglossoides platessoides</i>	37873	1282	282	39438	-99
Atlantic halibut	<i>Hippoglossus hippoglossus</i>	2906	4681	6597	14184	+
Winter flounder	<i>Pseudopleuronectes americanus</i>	1059	0	5	1064	-100
Yellowtail flounder	<i>Limanda ferruginea</i>	113	0	0	113	-100
Turbot	<i>Reinhardtius hippoglossoides</i>	379	328	35	742	-91
UID Flounders	Suborder Pleuronectoidei spp.	526	63	28	616	-95
Summer flounder	<i>Paralichthys dentatus</i>	286	0	0	286	-100
Smooth flounder	<i>Pleuronectes putnami</i>	163	0	0	163	-100
Witch flounder	<i>Glyptocephalus cynoglossus</i>	0	0	33	33	
OVERALL TOTAL					56638	

**Table 4.** Total catch (kg) of Perciformes in brackets of 7-year increments throughout the Survey. For congruency, three years were removed to make brackets uniform.

Perciformes

Common name	Species	Time 1: Sum of 1995- 2001	Time 2: Sum of 2003- 2011	Time 3: Sum of 2012- 2019	Total (kg)	% Loss from Time 1 to 3
Striped Atlantic wolffish	<i>Anarhichas lupus</i>	7218	482	524	8223	-93
Spotted wolffish	<i>Anarhichas minor</i>	1775	49	31	1855	-98
Unidentified Wolffish	<i>Anarhichas</i> spp.	1109	418	52	1578	-95
Ocean pout	<i>Zoarces americanus</i>	81	5	76	162	-5
North Atlantic Wolffish	<i>Anarhichas denticulatus</i>	49	15	0	64	-100
Wrymouth	<i>Cryptacanthodes maculatus</i>	0	0	12	12	
Eelpout	Zoarcid species	0	1	11	12	
Cunner	<i>Tautoglabrus adspersus</i>	0	1	0	1	
OVERALL TOTAL					11907	

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Eelpout	Zoarcid species	0	1	11	12	
Cunner	<i>Tautogolabrus adspersus</i>	0	1	0	1	
					OVERALL TOTAL	11907

**Table 5.** Total catch (kg) of Scorpaeniformes in brackets of 7-year increments throughout the survey. For congruency, three years were removed to make brackets uniform.

Scorpaeniformes

Common name	Species	Time 1: Sum of 1995- 2001	Time 2: Sum of 2003- 2011	Time 3: Sum of 2012- 2019	Total (kg)	% Loss from Time 1 to 3
UID Sculpins	Superfamily Cottoidea spp.	375	565	286	1226	-24
Redfish species unseparated	<i>Sebastes</i> spp.	484	288	84	856	-83
Fourhorn sculpin	<i>Myoxocephalus quadricornis</i>	687	74	93	853	-87
Longhorn sculpin	<i>Myoxocephalus octodecemspinosus</i>	16	45	202	263	+
Shorthorn sculpin	<i>Myoxocephalis scorpius</i>	0	0	59	59	+
Twohorn sculpin	<i>Icelus bicornis</i>	20	0	0	20	-100
Grubby fish	<i>Myoxocephalus aeneus</i>	0	0	6	6	
				OVERALL TOTAL	3283	

**Table 6.** Total catch (kg) of sharks in brackets of 7-year increments throughout the survey. For congruency, three years were removed to make brackets uniform.

Elasmobranchs: Sharks						
Common name	Species	Time 1: Sum of 1995- 2001	Time 2: Sum of 2003- 2011	Time 3: Sum of 2012- 2019	Total (kg)	%Change from Time 1 to 3
Spiny dogfish	<i>Squalus acanthias</i>	9483	20	2	9506	-100
Blue shark	<i>Prionace glauca</i>	3177	279	388	3844	-88
Shortfin mako	<i>Isurus oxyrinchus</i>	772	351	107	1230	-86
Smooth dogfish	<i>Mustelus canis</i>	906	0	0	906	-100
UID Shark	UID Selachii	110	680	0	790	-100
Porbeagle shark	<i>Lamna nasus</i>	216	216	158	590	-27
Black dogfish	<i>Centroscyllium fabricii</i>	52	0	113	165	+
UID dogfish shark	Squalid species	10	0	1	11	-90
OVERALL TOTAL					17041	

**Table 7.** Total catch (kg) of skates and rays in brackets of 7-year increments throughout the survey. For congruency, three years were removed to make brackets uniform.

Elasmobranchs: Skates and Rays						
Common name	Species	Time 1: Sum of 1995- 2001	Time 2: Sum of 2003- 2011	Time 3: Sum of 2012- 2019	Total (kg)	%Change from Time 1 to 3
Thorny skate	<i>Amblyraja radiata</i>	18590	1573	844	21007	-95
UID Skate	UID Rajiformes	209	796	290	1295	+
Spinytail skate	<i>Bathyrāja spinicauda</i>	412	0	1	413	-100
UID Skates and Rays	Batoidea spp.	235	100	0	336	-100
Winter Skate	<i>Leucoraja ocellata</i>	92	41	0	133	-100
Barndoor skate	<i>Dipturus laevis</i>	0	0	51	51	+
Smooth skate	<i>Melacoraja senta</i>	15	0	0	15	
Little skate	<i>Leucoraja erinacea</i>	0	0	12	12	
OVERALL TOTAL					23261	

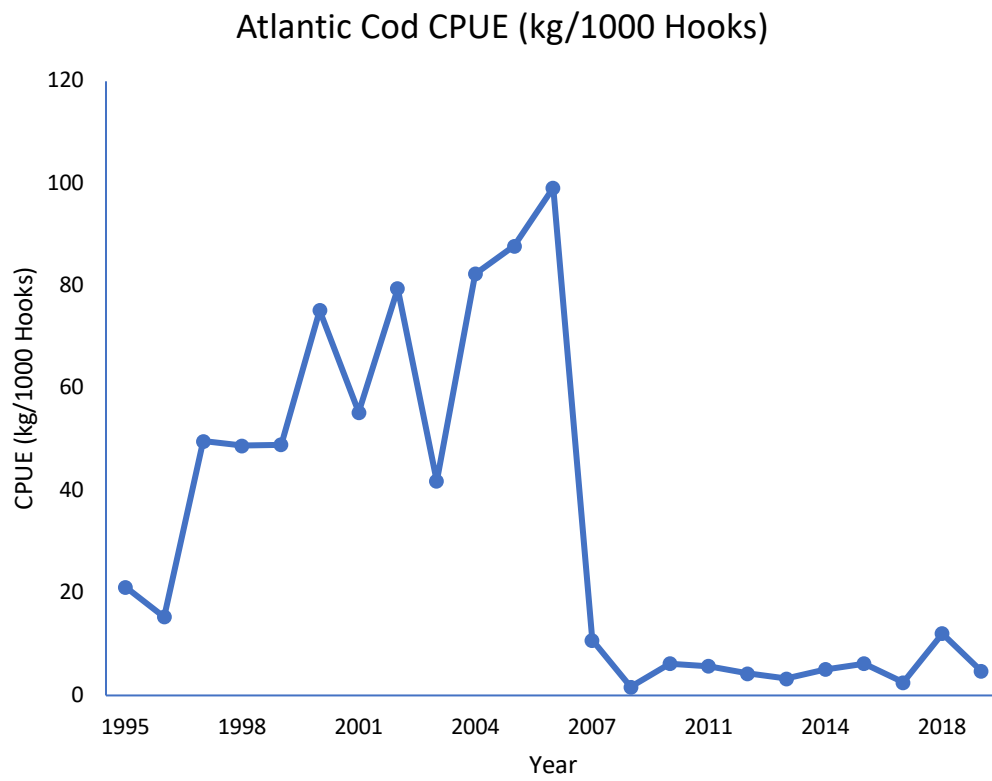
**Table 8.** Total catch (kg) of miscellaneous fishes in brackets of 7-year increments throughout the survey. For congruency, three years were removed to make brackets uniform.

Miscellaneous Fishes							
GROUP	Common name	Species	Time 1: Sum of 1995-2001	Time 2: Sum of 2003-2011	Time 3: Sum of 2012-2019	Total (kg)	%Change from Time 1 to 3
Agnatha	Arctic lamprey	<i>Lethenteron camtschaticum</i>	0	2	8	10	
	Atlantic hagfish	<i>Myxine glutinosa</i>	1	0	1	2	
Anguilliformes	Conger eel	<i>Conger oceanicus</i>	114	0	0	114	-100
	American eel	<i>Anguilla rostrata</i>	0	9	10	19	
Ophidiiformes	Cusk	<i>Brosme brosme</i>	0	17	0	17	
Lophiiformes	Monkfish	<i>Lophias americanus</i>	1	3	5	10	
Scombrini	UID Mackerel	Scombrid species	0	3	5	8	
	King Mackerel	<i>Scomberomorus cavalla</i>	1	0	0	1	
						OVERALL TOTAL	181

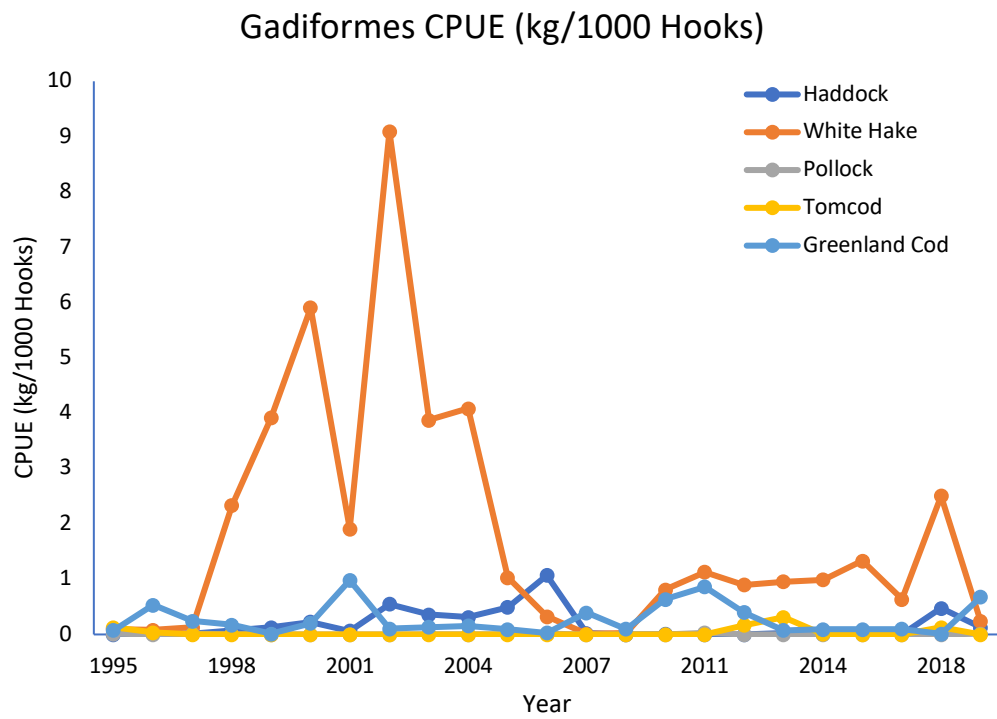
**Table 9.** Total catch (kg) of invertebrates and mammals in brackets of 7-year increments throughout the survey. For congruency, three years were removed to make brackets uniform.

Others – Invertebrates and Mammals

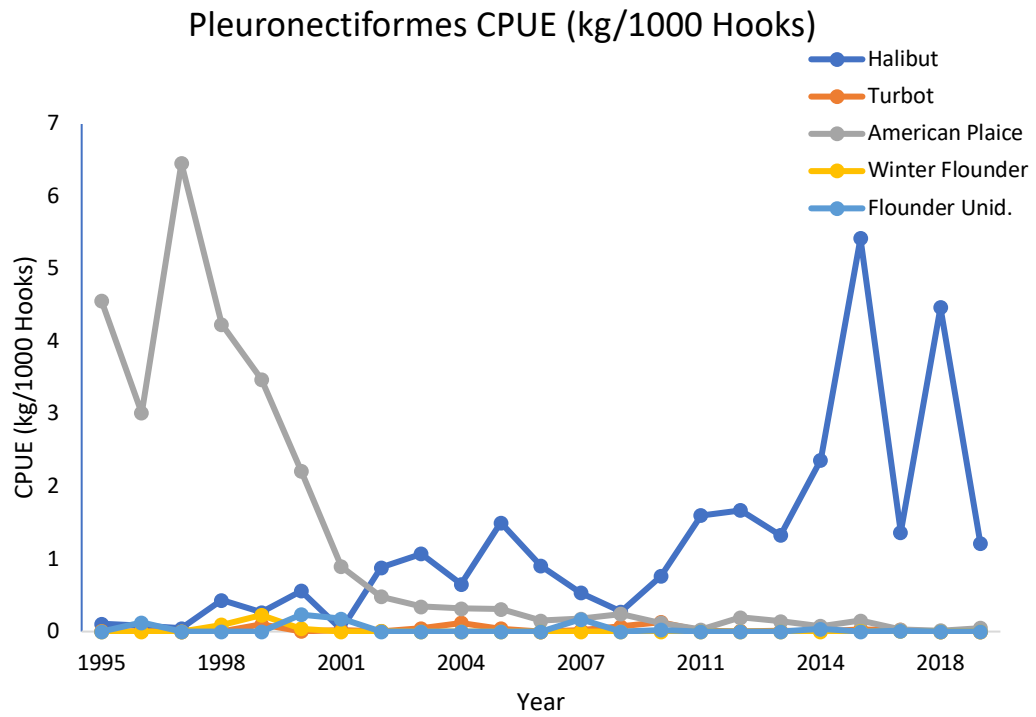
GROUP	Common name	Species	Time 1: Sum of 1995-2001	Time 2: Sum of 2003-2011	Time 3: Sum of 2012-2019	Total (kg)	%Change from Time 1 to 3
Ascidians	UID tunicates	Asciacea spp.	0	0	1	1	
Crustacea	Snow Crab (Queen)	<i>Chionoecetes opilio</i>	83	120	131	334	+
	UID Brachyuran crabs	Brachyuran spp.	169	0	0	169	-100
	UID Toad crab	<i>Hyas</i> spp.	16	11	18	45	
	American lobster	<i>Homarus americanus</i>	2	0	16	18	
	Atlantic rock crab	<i>Cancer irroratus</i>	0	5	2	7	
	Northern stone crab	<i>Lithodes maja</i>	0	0	2	2	
	Spiny crab	<i>Neolithoides grimaldii</i>	1	0	0	1	
Echinodermata	UID Seastars	<i>Asteroidea</i> species	17	0	19	36	
	UID Basket stars	<i>Gorgonocephalus</i> species	0	0	2	2	
Pinnipeds - Marine Mammals	UID Seals	Phocid species	590	0	453	1043	-23
OVERALL TABLE						1658	



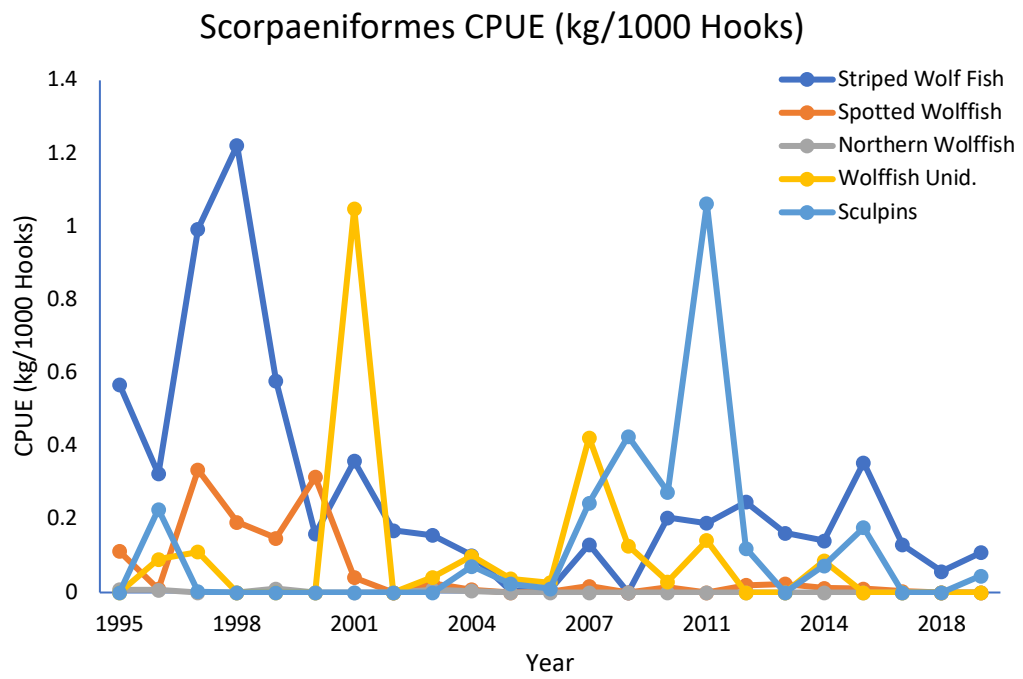
**Figure 5.** Catch rate of Atlantic cod throughout the years of the 4Vn Sentinel Survey excluding 2008.



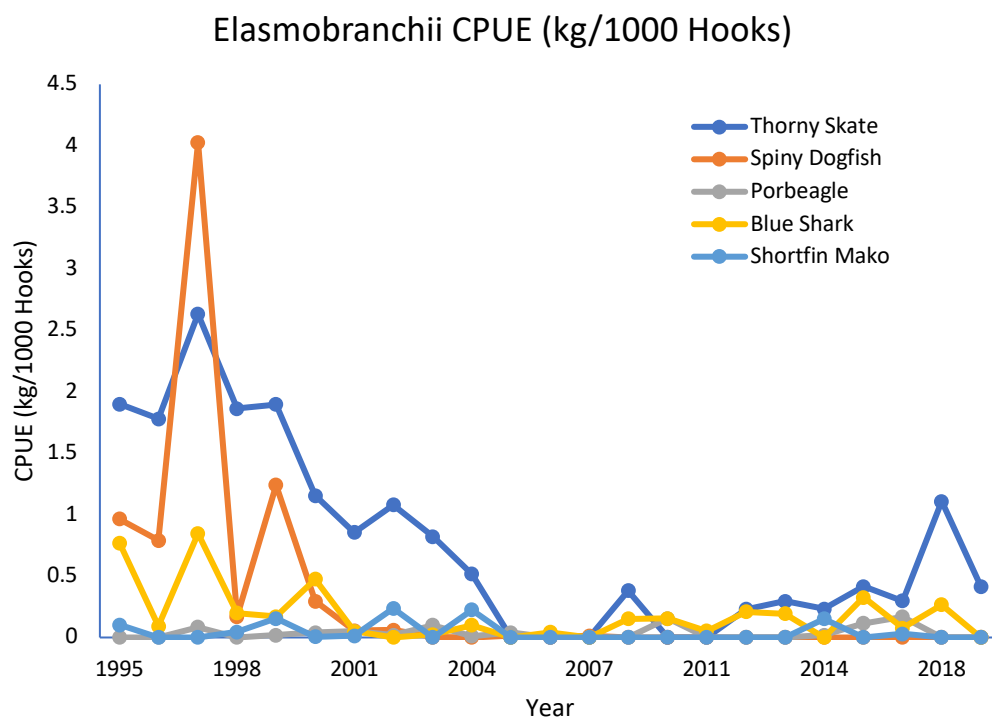
**Figure 6.** Catch rate of Gadiformes caught as bycatch throughout the years of the 4Vn Sentinel Survey excluding 2008.



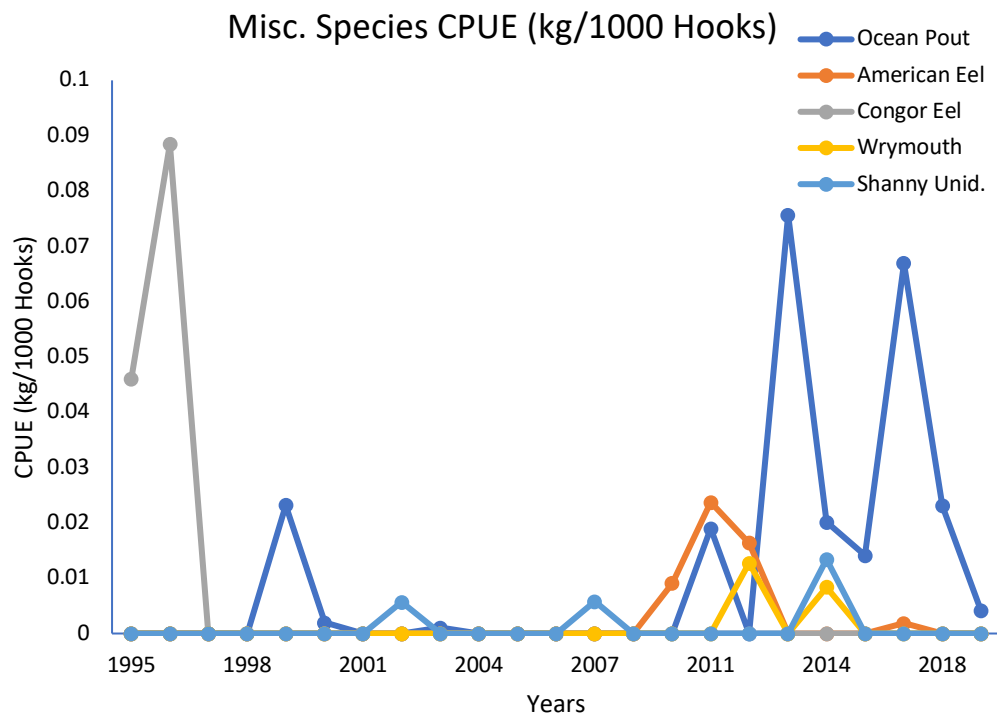
**Figure 7.** Catch rate of Pleuronectiformes caught as bycatch throughout the years of the 4Vn Sentinel Survey excluding 2008.



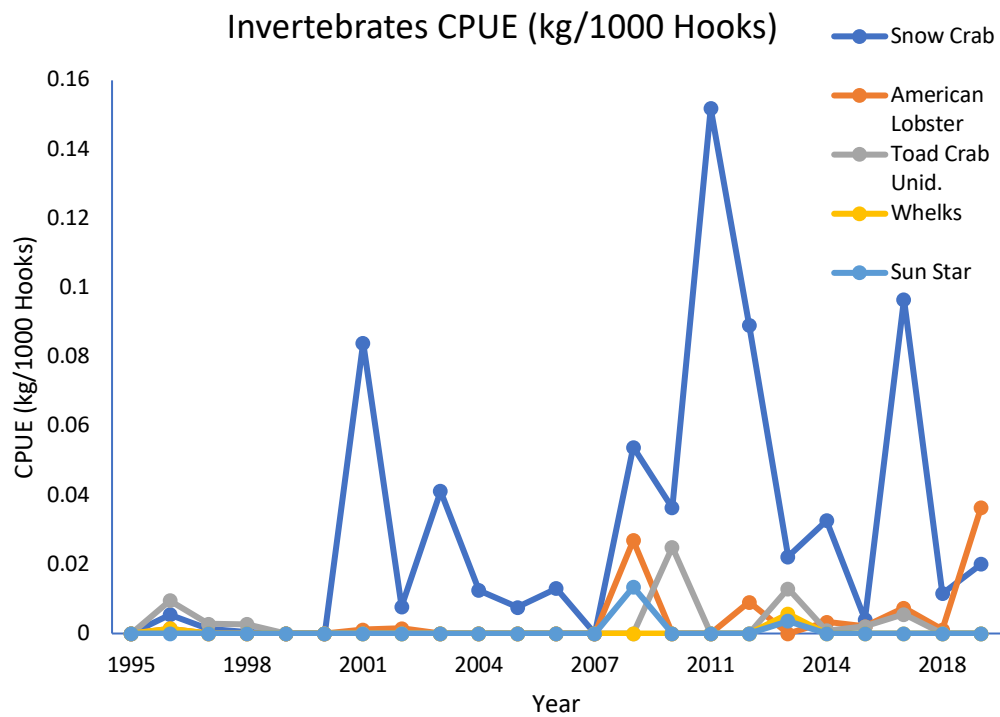
**Figure 8.** Catch rate of Scorpaeniformes caught as bycatch throughout the years of the 4Vn Sentinel Survey excluding 2008.



**Figure 9.** Catch rate of Elasmobranchs caught as bycatch throughout the years of the 4Vn Sentinel Survey excluding 2008.



**Figure 10.** Catch rate of Miscellaneous species caught as bycatch throughout the years of the 4Vn Sentinel Survey excluding 2008.



**Figure 11.** Catch rate of Invertebrates caught as bycatch throughout the years of the 4Vn Sentinel Survey excluding 2008.

## Discussion

### *DATA TRENDS:*

The condition of cod within 4Vn was examined using Carcass K, HSI, and GSI. The results indicated parallel changes in GSI and HSI condition factors as both showed an increase in 2001 followed by a decrease in 2005 through 2018 where there has been a slight upwards trend since **(Figure 3.)** This indicates that the cod stock within 4Vn has not been consistent throughout the survey with some extreme dips and peaks in their condition. The last year of data for this study – 2019 – has the highest recorded condition factors which demonstrates a growth in reproductive allocation and energy allocation with the cod stock (i.e., higher HSI and GSI indicate a greater allocation to liver and gonadal tissue, respectively, relative to cod body weight). However, additional years of data collection will be required to observe if the upward trend is to continue.

Fulton K using carcass weight expressed a bleaker representation of the 4Vn stock. The desired K factor ( $\geq 1$ ) was only achieved during 1995, 2001, and 2002 **(Figure 4)**. The Carcass K condition of cod never reached above 1 in approximately 17 years **(Figure 4)**. While HSI and GSI may provide a glimmer of hope for a rebound of the 4Vn cod stock, Carcass K coupled with the sheer decline in cod abundance – may suggest otherwise. There has been an almost constant decline in Fulton K using carcass weight since 2002. This fosters more questions than answers as to why the condition of cod has declined so steadily over the last 25 years? Additionally, why does it appear that cod in 4Vn are allocating more energy to sexual output and liver development over size and condition?

In addition to the assessment of cod body condition, I also examined the species abundance within 4Vn, and the data indicated a very tragic reality below the water. A total of 38 species out of the 60 recorded species were observed to have a significant loss in species abundance throughout the 7-year increments during the survey (**Table 2.**). Declines in species abundance ranged from a 24% decrease in abundance to over 100% between 1995 and 2019. All decreasing bycatch species – with the exception of Atlantic cod – were observed to have a significant drop off in abundance throughout the 2000s with 2004 being a year of commonality for the steepest drop off. However, for the case of cod, the steep decline in abundance is observed a couple years later during 2005-2007 (**Table 2.**). As mentioned in the results, Atlantic halibut was an extreme outlier within the species abundance data as populations have appeared to have drastically increased 127% (**Table 3.**). This provides researchers with more questions as to why Atlantic halibut is seemingly doing well while in general, the biodiversity within 4Vn seems to be critically in decline. Although the answer for the increase of Atlantic halibut is unclear, the halibut fishery can aid in the reassessment and recovery strategies for species of concern such as cod (Hurley, 2019b). This can be done by implementing bycatch assessments onboard commercial halibut boats to determine the spatial overlap of species of conservational concern (e.g., Atlantic cod) across all NAFO divisions. This information may be used to assist in the application of new bycatch quotas, identifying areas of concern, and promoting more selective gear and release practices (Hurley, 2019b).

#### *GENETIC DIFFERENCES & CLIMATE CHANGE:*

As stated previously, genetics in certain populations of cod varies. It can be noted that one of the greatest environmental influences on Atlantic cod physiology is water temperature. When cod are in cold waters – as low as -0.5C – ice crystals form in their blood (COSEWIC, 2010b). To prevent this from happening cod produce plasma antifreeze proteins or glycoproteins (AFGPs). Evidence for the adaptation to the local environment by Atlantic cod can be seen by the presence of these AFGPs. It was observed that Atlantic cod which reside in colder waters produce 50% more AFGPs than those to the south in warmer waters (COSEWIC, 2010b; Ruzzante et al., 1996). These findings were supported by additional evidence using genome scans of cod from different temperature ranges. This observation revealed that the spatial variation in genes indicates adaptive changes in populations approximately 500km apart (COSEWIC, 2010b; Ruzzante et al., 2000b). This discovery opens up a discussion on the detrimental impacts of climate change on Atlantic cod populations.

Although cod are cold water fish, studies have indicated cods' sensitivity to temperature including cold water itself. (Lambert, 2019b; Sguotti et al., 2019). 4Vn Sentinel Survey data indicated that cod sought out shallow inshore water when it was warm and avoiding deep water when it was cold (Lambert, 2019b). However, cod were also observed to move deeper into the stratum when the temperature warmed up (Lambert, 2019b). This perplexing conclusion leads to questions regarding cod and their temperature tolerance. It has been observed that stocks that overwinter inshore have less AFGPs than stocks that overwinter offshore (Ruzzante et al., 1996). It could be speculated that due to 4Vn having a resident

overwinter population, the resident cod are not gifted with high AFGPs and thus more sensitive to temperature and climate change (Ruzzante et al., 2000b; Worester et al., 2009b).

The main consensus to the collapse of Atlantic cod is usually targeted at the substantial overfishing that has taken place within the region over the past few centuries (Rose, 2007b). Although, that is an obvious significant components of the collapse, many studies have started making the connection between climate change and cod dynamics (Hutchings & Rangeley, 2011; Morgen et al., 2010). Studies have even extrapolated this into an understanding of a congregation of anthropogenic and environmental impacts (Sguotti et al., 2019). It is with this recognized Snicket-esque series of unfortunate events for the Atlantic cod that may be leading to their ongoing demise. The overfishing of cod to the point of collapse followed by anthropogenic climate change has led to hysteresis in cods' response to the reduction in fishing pressure of the moratorium (Sguotti et al., 2019). This leads into the discourse concerning the possibility of the return of cod stocks within 4Vn and other NAFO divisions.

## *DISCOURSE:*

The dominating discourse that surrounds cod is if or when cod stocks will recover and if the Canadian government will ever lift the moratorium on the fishery. As it stands, the research mostly points to the stocks to be not in a state of recovery, thus no reopening of the industry (Hutchings & Rangeley, 2011; Lambert, 2019b; Worester et al., 2009b). However, some publications point to the opposite. According to Rose and Rowe, in spring of 2015, there was an observed increase in cod abundance and size composition for the first time since the moratorium (Rose & Rowe, 2015b). They note a rebound correlating with the rebound of caplin (*Mallotus villosus*), one of cods' favourite meal of choice. During the 1990s caplin declined along with the cod stocks and have since started to recover due to warmer ocean water from anthropogenic climate change (Rose, 2007b; Rose & Rowe, 2015b). Perhaps warmer water from climate change will aid in cod's rejuvenation. However, others are less optimistic (Sguotti et al., 2019). While diet analysis was an original objective of my thesis, the diet data was not sufficient to analyze. Perhaps future collection of diet data may render enough to analyze and the presence of caplin could be a targeted species.

Predominately all stakeholders would prefer that the industry stays under a moratorium until there is a full recovery of the cod stocks. Such stakeholders include the Canadian government and associated departments, groundfish license holders, groundfish operators, fishermen's association, and Indigenous populations. If the industry were to be opened up prematurely then there is a risk of a total depletion of stocks which would leave them at a point of no return. To this day, cod holds the crown for the greatest numerical loss of a Canadian vertebrate and it still has yet to recover (Hutchings & Rangeley, 2011).

### *SCIENCE-TO-POLICY APPROACH:*

Throughout this study I conducted discussions with fisheries management professionals who are stakeholders and rightsholders within the cod industry. The goal of this segment was to understand how the federal government (DFO) makes decisions concerning fisheries management. The understanding of their approach to decision-making may uncover how such a fishery collapse transpired. To start, I had an insightful conversation with Senior Fisheries Management Advisor at DFO, Penny Doherty. Doherty's lighthearted personality enlivened an otherwise gloomy conversation about cod mortality and the surrounding decision-making process. She pleasantly described a decision-making process which involves science advice, socio-economic considerations, fishery policies, stakeholder consultations, and Indigenous considerations (DFO, 2020; P. Doherty, personal communication, November 18, 2020). She explained that decision-making must incorporate the principles of conservation, legally-binding agreements, indigenous and treaty rights, and orderly management (DFO, 2020; P. Doherty, personal communication, November 18, 2020).

Decisions are made within an annual cycle which in chronological order is as follows: planning, consultative process, pre-season preparations, fishing season monitoring, and a post-season review (DFO, 2020). The consultation period is when policy makers actually glean knowledgeable advice from scientists and the counsel of Indigenous rightsholders. This is usually held in a forum environment in which interested stakeholders are able to express their views on the proposed policy changes (P. Doherty, personal communication, November 18, 2020). Although, the final decisionmakers are those who put the pen to the paper in regard to fishery policy implementation. There is a monumental onus on scientists and Indigenous

knowledge holders to guide policy holders towards the right direction of conservation over profits.

Subsequently, this study was in need of a dialogue with Indigenous rightsholders as they are a crucial component within the decision-making processes of fisheries management. I reached out to Fisheries Liaison Coordinator, John Couture, of Unama'ki Institute of Natural Resources (UNIR). John Couture provided informative, candid opinions concerning Indigenous inclusion within fisheries management decision-making. Couture made it clear that their status as rightsholders needs to be emphasized more as up until the discussion with him, Indigenous rightsholders were always referred to as stakeholders. Couture's despairing responses are a sign of the state of affairs within the decision-making between the two philosophies. The belief that is held is that Indigenous voices are not being heard as consultation with Indigenous peoples and their communities is not done properly (J. Couture, February 10, 2021). Consultation is intended to be meaningful, however according to Couture, Indigenous perspectives and knowledge systems are largely excluded from the discourse until it is in the government's best interest (J. Couture, personal communication, February 10, 2021). Although the current system of Indigenous incorporation within cod fisheries decision-making has been abysmal, Couture provides examples in which this system has worked (i.e., surf clam partnership with Clearwater Seafoods). Over the years, the Canadian federal government and DFO have made efforts to incorporate Indigenous knowledge systems and an Indigenous policy framework into Canadian science and legislation. DFO has had a vested interest in Indigenous communities since the 1990s and the *R v. Marshall Case* (Davis et al., 2004). DFO's five-year Strategic Plan "Our Waters, Our Future" 2005-2010 uncovered the need to strengthen and

promote relationships between DFO and Indigenous communities. Thus, the Integrated Aboriginal Policy Framework (IAPF) was born (DFO, 2019). DFO states the objective of the IAPF is to “serve as a guide for DFO employees for the renewal of DFO's Aboriginal policies and programs, to provide strategic policy direction for the development of operational guidelines and programs, and to guide DFO in discussions and collaboration with other federal agencies, provinces, territories, stakeholders and Aboriginal groups” while the purpose is to achieve in success in building on DFO’s relationship with Indigenous groups (DFO, 2019). In addition to the IAPF, the Canadian federal government has proposed the implementation of an Indigenous Knowledge Policy Framework (IKPF; Government of Canada, 2019). The main focus of the IKPF at the moment is the introduction and implementation of indigenous knowledge within the newly proposed (February 2018) Bills C-68 and C-69. The hope is that the IKPF will help guide such implementation of Indigenous knowledge within the two new Bills. However, just by reading some of the language used throughout the IKPF’s preliminary document it becomes apparent that this implementation of Indigenous Knowledge systems within decision-making and science is disingenuous. To quote the document: “The Bills use “Indigenous knowledge” in broad terms, to be inclusive of the evolving knowledge of Indigenous peoples (Government of Canada, 2019).” Now, to dismantle such a statement, the fact the Canadian federal government felt the need to put Indigenous knowledge within quotation marks is an accurate representation of their hesitancy to actually provide a platform and legitimization for Indigenous knowledge. Secondly, the admit to using the term in a broad sense in an effort to just be inclusive. If that doesn’t scream disingenuous, I do not know what does. To use some vocabulary from the discussion with Couture, it is clear that the Canadian federal government is

“window-dressing” Indigenous consultation as they appear to be focusing on rights recognition over rights reconciliation (J. Couture, personal communication, February 10, 2021).

#### *INDIGENOUS KNOWLEDGE SYSTEMS:*

This study has recognized that the historical system of decision-making was Eurocentric and myopic, and discussions with Indigenous rightsholders has made it apparent that work still needs to be done to achieve holistic management of the cod industry and most other fisheries as well. There have been recent efforts made to incorporate Indigenous knowledge systems within the Eurocentric canon of academia. Such methods include insurgent education, comparative political theory, and Two-Eyed Seeing (Broadhead & Howard, 2021; Morgensen, 2012; Omar, 2016; Reid et al., 2021). Insurgent education exposes “normative knowledge production as being not only non-Indigenous but colonial, they denaturalize power within settler societies and ground knowledge production in decolonization (Morgensen, 2012)” In addition, comparative political theory has the ability to “reform at our university spaces from a provincial and parochial environment [and] move to a more open and critical cosmopolitan pluriversalism’ which envisages ‘knowledge production that is open to epistemic diversity (Omar, 2016)” Furthermore, Two-Eyed Seeing and other “indigenous methodologies envision the termination of colonial rule, by fomenting the knowledges of sovereign and decolonizing peoples: that is, knowledges that subvert the ontology of a perpetually colonial society toward radical transformations of land, life, and governance (Morgensen, 2012)” This section with focus on Two-Eyed Seeing which has Cape Breton origins as Mi’kmaw elders Albert and Murdena Marshall coined the term with their colleague Cheryl Bartlett (Broadhead & Howard,

2021).” Albert Marshall distinguishes aspects between settler and Mi’kmaw worldviews as the Mi’kmaw does not prescribe to the notion of fragments and division (Broadhead & Howard, 2021). Wildcat reiterates this point, “modernist Western epistemology seems deeply rooted in the Aristotelian job of developing categories into which the “things” of the world can be placed ... In contrast ... North American Indigenous knowledges seem to focus on the way the borders/boundaries of such alleged categories are permeable (Wildcat, 2004). Two-Eyed Seeing can be defined as the ability to use one eye to view the world through the lens of traditional indigenous knowledge systems and the other eye to view the world through the perspective of Western knowledge systems (Broadhead & Howard, 2021; Mantyka-Pringle, 2017; Reid et al., 2021). In theory, if implemented properly, the interplay of knowledge systems may allow the user to gain the advantages that are provided by both distinct conceptualizations. However, as noted previously, there are many conflicting views between the two knowledge systems, and we must be cautious in assuming that an amalgamation of these two complex systems will be effective.

The exploitation of natural resources for the gain of humans is a distinct characteristic of the Eurocentric hegemony. Indigenous knowledge is widely regarded as the complete opposite of that as the belief is that humans are components of the ecosystem and not the gatekeepers of it (Barsh, 1986). It is with this holistic understanding of the world that Indigenous knowledge systems are regarded as being the new pathway to conservation. The agenda of the federal government and the Eurocentric academy needs to disregard these systems as a dichotomy. This is a fallacy of a false dichotomy made by the hegemony. It does not need to be one knowledge system or the other. Power and dialogue must be equal within cotemporary political

realities before the effects of actual authentic and practical discourse can begin. The Eurocentric hegemony of the academy is insecure about letting other pedagogies contribute to the canon as they view themselves as the gatekeeper of knowledge and truth (Broadhead & Howard, 2021). Power and dialogue must be equal within cotemporary political realities before the effects of actual authentic and practical discourse can begin. The contradictions between the Indigenous holistic system and the Eurocentric reductionist system are often suppressed or denied regarding Two-Eyed Seeing (Broadhead & Howard, 2021). There are dangers in this oversight as these contradictions make the integration of the two knowledge systems difficult. On the other hand, there are apparent advantages between both systems and if policymakers, scientists, academics, and knowledge holders would be able to integrate the two valued systems together such mismanagement and collapses may be prevented in the future. However, as noted, this feat will be easier said than done due to the extreme discrepancies between the two knowledge systems.

## Conclusion

To conclude, this study indicates that Atlantic cod within 4Vn has yet to express a true sign of rehabilitation. Correlating trends between HSI and GSI showed fluctuation between the two indices. K using carcass weight indicated a consistent underachievement since 2002. Species abundance in cod and the vast majority of bycatch species showed a significant loss in abundance throughout the years of the 4Vn Sentinel Survey. Atlantic halibut continues to be an outlier species as it has increased in abundance 127% within 4Vn between 1995 and 2019. There is a clear need for the continuation of the 4Vn Sentinel Survey as the data provides a comprehensive view of cod and other bycatch species within 4Vn over a long period of time. Additional analyses should include diet data which was intended but the data was insufficient at the time of the study. Furthermore, a contemporary cod age analysis should be conducted (otoliths were available, but aging methodologies could not have been fit in to the timeframe of my research). The HSI and GSI data shows a slight upwards trend the last three years and with a continuation of the 4Vn Sentinel Survey it would become more apparent whether the trend is significant. In addition, further research should be conducted on the unexpected success of Atlantic halibut in 4Vn. The results have presented this study with many more questions than answers and will provide great material for future investigations into the status of Atlantic cod in the Sydney Bight.

Lastly, this study proposes a future implementation of Indigenous knowledge systems such as Two-Eyed Seeing within fisheries management to prevent such a collapse from happening again. It is possible that Two-Eyed Seeing could prevent future overexploitation, or improved management of the 4Vn stock. Perhaps a holistic approach to fisheries can be

implemented and the targeting of species in fisheries can be exchanged for targeting all sustenance within fishing areas while limiting catch quotas and not retaining endangered species. However, Two-Eyed Seeing must be used cautiously and must not be addressed as a disingenuous guiding principle, but to be approached as an actual Traditional Indigenous Science. Furthermore, through dialogue between fisheries management, stakeholders, and rightsholders, it is clear that additional consultation is required between all involved groups. While the fisheries decision-making process may improve, the Atlantic cod population does not appear to have the same fate. Although there has been reduced exploitation pressures due to the long withstanding moratorium, anthropogenic climate change may have grave implications for the remainder of Atlantic cod within 4Vn.

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