The Integration of Climate Change Modeling, Monitoring and Management for Cold-Water Coral and Sponges in Eastern Canada

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Table of Contents

Abstract

Deep-sea cold-water coral and sponges are vital for maintaining ecosystem integrity. Deep-sea coral and sponge species can be found individually or in a grouping, both systems create habitat for marine species by providing an area to rest, spawn, feed and seek refuge. Deep-sea corals and sponges are both sessile species that contain long lifespans and slow-growing times; making them extremely fragile and vulnerable to surrounding threats and pressures. Canada contains multiple coral and sponges conservation laws, strategies and plans; however, their ‘effectiveness’ is being limited by climate change. Direct impacts can be restricted but indirect impacts are estimated to create inhabitable environments for deep-sea corals and sponges which may bring them to extinction. Eastern Canada has yet to fully implement climate change modeling, monitoring, and management plans for the deep-sea; and without proper instructions, these ecosystems may perish within the next 10-20 years. Nonetheless, other countries such as Australia and New Zealand are further advanced in their coral and sponge research and plans for climate change adaptation and mitigation. Many countries have produced cold-water coral and sponge modeling, monitoring and management measures themselves as they understand the vulnerability and importance of protecting such species. The purpose of this paper is to identify both the successful cases of climate change adaptation into modeling, monitoring and management, and to identify how countries are taking climate action into their own hands. Canada often reviews international nations' strategic measures when developing their own laws, strategies and plans and enforcing modeling, monitoring and management. Therefore, extensively reviewing international nations’ coral and sponge conservation measures related to climate change adaptation and mitigation, is crucial for the survival of deep-sea fauna in Eastern Canada and to understand how Canada can adopt methods and adapt their thinking into future, modeling, monitoring and management plans. This review will then allow for the determination of plausible recommendations that will aid in ecosystem success. Our findings will suggest that Canada is focused on direct impact mitigation and neglects the inclusion of climate change modeling, monitoring and management, and that Canada needs to consider developing and implementing the recommendations presented to ensure ecosystem preservation.

Keywords: Eastern Canada, Climate Change, Cold-Water Coral, Management

List of Abbreviations

ABNJ- Areas Beyond National Jurisdiction
AOI- Area Of Interest
CBD- Convention of Biological Diversity
CEO- Chief Executive Officer
CRI- Crown Research Institute
CSIRO- Commonwealth Science and Industrial Research Organisation
DFO- Department of Fisheries and Oceans Canada
EBSA- Ecologically or biologically significant areas
EEZ- Exclusive Economic Zone
ESM- Earth System Model
GHG- Greenhouse Gasses
GOCAAP- Government of Canada Adaptation Action Plan
IPCA- Indigenous Protected and Conserved Areas
IPCC- Intergovernmental Panel on Climate Change
IUCN- International Union for the Conservation of Nature
MPA- Marine Protected Area
MR- Marine Refuge
MSP- Marine Spatial Planning
NAFO- Northwest Atlantic Fisheries Organization
NGO- Non-Governmental Organization
NIWA- National Institute of Water and Atmospheric Research
NMCA- Canada National Marine Conservation Areas Act
NOAA- National Oceanic and Atmospheric Administration
OECM- Other Effective Area-Based Conservation Measure
POC- Particulate Organic Carbon
POM- Particulate Organic Matter
ROV- Remote Operated underwater Vehicle
RRAP- Reef Restoration and Adaptation Program
SDM- Species Distribution Model
UNCLOS- United Nations Convention on the Law of the Sea
UNEP- United Nations Environmental Programme
UNFCCC- United Nations Framework Convention on Climate Change
UNGA- United Nations General Assembly
US- United States
VME- Vulnerable Marine Ecosystem
WMO- World Meteorological Organization

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Introduction

The depths of the ocean are relatively unknown with less than 0.0001% of the deep ocean being explored (Danovaro, 2017). This small investigated bit makes the deep-sea the least explored biome on the planet (Danovaro, 2017). The deep-sea is home to a large variety of unique seascapes and species (Danovaro, 2017; Howell, 2016). Coral reefs are known as one of the most spectacular ecosystems within the marine environment (Freiwald, 2004). As they provide a number of organisms with resources they could not survive without such as food, shelter and nutrients (Cathalot, 2015; Finney, 2009). These cold-water reefs play a crucial role in their ecosystem for not only the marine environment but for human life as well. These vulnerable species are found globally, but are facing numerous impacts that threaten their existence. Anthropogenic impacts such as deep sea oil and gas exploration, seafloor installations, bottom contact fishing gear, oil spills, pollution and climate change are all impacting the health of these vital species (Cathalot, 2015; Consalvey, 2006; Mobilia, 2021).

Canada has put in place a number of conservation methods to protect sensitive benthic ecosystems such as cold-water corals and sponges[1]. These methods can be both binding and non-binding. Such conservation methods consist of implementing marine refuges (MRs), marine protected areas (MPAs), Vulnerable Marine Ecosystems (VMEs), Other Effective area-based Conservation Measures (OECMs), and Ecologically or Biologically Significant Areas (EBSAs) (Johnson, 2018). Many of these conservation and protection tools are in place to mitigate and restrict direct anthropogenic impacts such as deep-sea fishing, mining, oil and gas exploration and more. While these many methods are useful, they only meet short term conservation goals as

[1] The terms ‘deep-sea corals and sponges’ and ‘cold-water corals and sponges’ are often used interchangeably; within this report they will continue to be used interchangeably.

climate change is a long-term impact that will continue for decades unless proper implementation is completed. These methods are passive actions, which prohibits and limits impacts and can be effective after years of establishment, but are dependent on the levels of protection and compliance (Frys, 2020). While active action can achieve positive results at a faster pace through direct restoration and adaptation methods (Frys, 2020). Climate change is one of the largest contributors to coral and sponge depletion yet still remains relatively undefined and ignored within conservation plans. The recovery and adaptation of deep-sea coral and sponges will be highly dependent on a combination of both passive and active actions (Frys, 2020).

Nonetheless, international laws and initiatives have outlined ways in which nations can obtain conservation objectives. Such international instruments consist of the *Paris Agreement, The Convention of Biological Diversity* and the *United Nations Framework Convention on Climate Change.* These three international tools are the most effective way to ensure nations are contributing to ocean conservation while simultaneously keeping nations responsible for such conservation methods. The Paris Agreement for example, is a legally binding agreement that ensures nations are reducing their CO_2 emissions and moving towards renewable energy (Blau, 2017). This agreement holds nations accountable in times where they are not meeting the international objectives. These international agreements however, mainly focus on passive action without the addition of active action.

Additionally, other countries have established their own conservation and protection methods that have shown to be successful. New Zealand has implemented modeling methods that allow for the discovery of favorable environments for corals and sponges in the past, present and future; allowing for effective modeling, monitoring and management implementation. Australia has taken tests and research to define effective active approaches for conservation that complement their pre-existing passive actions.

While Canada contains their own conservation strategies, commitments and objectives, they continue to ignore the impacts climate change is having on the marine environment; ignorance through not including climate change in their national laws, strategies and plans, and not looking towards adaptive management for the deep-sea. The lack of climate change inclusion is impacting the effectiveness of Canada's conservation and protection methods, and further impacting deep-sea ecosystems. Until Canada or Eastern Canada introduces climate change plans into modeling, monitoring and management, deep-sea corals and sponges will be left unprotected within their ineffective conservation areas.

This graduate project will identify climate gaps within international agreements Canada has committed to, along with laws, strategies and plans that Canada has implemented. This project will attempt to fill those gaps by looking to other countries that are facing the same climate impacts on their cold-water coral and sponges and understand how they are reacting to climate change. Based on these findings recommendations will be provided for Eastern Canada on 1. What modeling, monitoring and management methods are being observed and utilized in other countries and what methods should Canada consider implementing to ensure climate change adaptation and species preservation, 2. What conservation and protection measures can Canada improve on to reduce coral and sponge depletion and 3. What methods are being considered in other countries and why Canada should consider doing the same.

Thesis Outline

Chapter 1 discusses how cold-water coral and sponge species were discovered, how they have evolved to live in such conditions. This chapter also addresses the main characteristics, such as feeding methods, reproductive methods, and information about the preferred environmental location in which they are found to most thrive. This chapter focuses on current deep-sea coral and sponge information on characteristics and traits.

Chapter 2 analyzes the impacts which are disrupting deep-sea coral and sponges the most. These impacts are negatively affecting deep-sea ecosystems as well as corals and sponges. These impacts not only impact these species externally, but internally as well. This chapter focuses on the current state of coral and sponge reactions to current levels of both direct and indirect anthropogenic impacts.

Chapter 3 discusses what international agreements Canada has signed onto and analyzes how international laws and plans have used their platform in an attempt to make nations responsible for the conservation of the ocean and its resources. This chapter also looks at the flaws in such laws and plans by analyzing how they fail to mention the severity of the impacts of climate change and how they have simultaneously ignored the importance of climate change mitigation.

Chapter 4 frames the context of Canadians laws, strategies and plans and how they have attempted to address or ignore the impacts of climate change. This chapter also analyzes what degree of Canadian laws, strategies and plans are attempting to adapt, and are these adaptation attempts modernized to fit present issues.

Chapter 5 assesses New Zealand and Australia's contain their own plans and laws surrounding deep-sea coral conservation, modeling, monitoring, and management methods. This chapter also assesses how these nations perceive climate impacts and discusses whether or not climate change is being integrated into these proposed methods. Chapter 5 will analyze both the failure and success of such nations' methods to better understand what methods are plausible for Canadian adoption.

Chapter 6 discusses the recommendations for modeling, monitoring and management that has been accumulated from the previous findings. These recommendations are based on what New Zealand and Australia are considering a priority for addressing climate change. These recommendations are plausible for Canadian integration based on their history of modeling, monitoring and management plans. These recommendations are also based upon the findings from both international agreements and Canada's national methods and ways to modernize and improve methods to better conserve deep-sea coral and sponges.

Methods

The methods of this paper primarily focus on a literature review style to get a broad understanding on how Canada's conservation laws, strategies and plans for deep-sea corals and sponges are keeping up with the unprecedented impacts of climate change. The literature review also looks at the international agreements that Canada has signed onto to better understand their responsibilities for climate change adaptations. Canada often reviews other nations' methods when developing their own. So, I looked at both New Zealand and Australia to understand how they are undergoing their responsibilities from the international treaties they signed onto, and how they are implementing conservation methods for climate change through models, monitoring and management within their jurisdiction. The purpose of this study was to identify the gaps in Canadian conservation and understand how such national parties methodology to conservation could be adopted and implemented in Canada to increase the effective and efficient modeling, monitoring and management.

Chapter 1. Corals and Sponges Occurring in Cold-Water Environments

While scientists and deep-sea fishers have known about the existence of deep-sea fauna for the past 250 years, it is only with deep-sea oceanographic expeditions on the rise that has revealed a whole new side to the ocean that had not been seen before (Reef Cause, 2021). With the evolution of technology development and research, science now has the ability to navigate, sample and measure within the deep-sea (Ramirez, 2020; Reef Cause, 2021). Although we now understand that the depths of the ocean house hundreds of thousands of species worldwide, the initial hypothesis stood that life could not exist within such extreme environmental conditions. The cruise of H.M.S *Beacon* to the Aegean from 1841-1842 is believed to be the first deep-sea expeditions conducted (Ramirez, 2020; Rehbock, 1989). On this voyage, Naturalist Edward Forbes, a professor from Edinburgh University, conducted research that consisted of 100 bottom trawling hauls at depths from 1-420m. His results showed that as he dredged deeper, there were less and less species being hauled up, leading to his 'Forbes' Azoic theory' that stated no life existed within the great depths of the sea (Ramirez, 2020; Rehbock, 1989).

Later in 1850, Michael Sars who was a theologian and biologist from Norway who conducted a similar survey, but from depths larger than 550m, he discovered the life of 19 species who thrived within such conditions. This study was later continued by Sars's son, George Ossian Sars who was able to identify an additional 73 species thriving within the great depths of the ocean (Ramirez, 2020). With the new discovery of life within the deep-sea came interest from many to explore the dark, cold depths of the ocean. From 1872-1876 came a new deep-sea expedition aboard the H.M.S *Challenger* with observations made by a larger scientific team of experts (Rehbock, 1989). This expedition was conducted by trawling and dredging more than 250 hauls at depths up to 5716m; the results showed that there were living organisms at depths this great

(Rehbock, 1989). From all these discoveries came more interest to explore the deep ocean, this cruise, aside others alike, are considered to be the first ever cold-water coral and sponges discovery (Ramirez, 2020).

These deep-sea species were discovered within the 18-19th century, while they have been estimated to have appeared more than 500 million years during the Cambrian period (Campbell, 2009; Freiwald, 2004; Ramirez, 2020; Roberts, 2006). Now since the discovery of such species, research studies are focused on how these species are able to live in such conditions, questions emerging about how do these species feed? How do they reproduce? And how have they become major sources for surrounding species? Only with the recent increase in deep-sea exploration, oil and gas mining activities and deep-sea fishing was it revealed the density and distribution of such cold-water species (Consalvey, 2006; Ramirez, 2020; Roberts, 2006; Vad, 2018). In the 1960s, technology evolved and was then developed to enter the depths of the ocean (Campbell, 2009; Vad, 2018). Now with the increased exploration for resources such as hydrocarbons within the deep-sea have since led to the discovery of deep-sea coral and sponge segregations (Consalvey, 2006; Ramirez, 2011; Vad, 2018). Cold-water corals and sponges are found in areas all over the globe, particularly they are found in areas with little to no productivity or sunlight reaching the seafloor (Cathalot, 2015; Consalvey, 2006; Howell, 2016). Within food-limiting areas, it is still unknown to why and how these areas can remain hotspots for thriving biodiversity (Cathalot, 2015). Thus, why climate change integration has been difficult to implement within Canadian waters. So, in order to understand how climate change impacts these species, we first need to identify their living habits, characteristics, and importance for both a holistic ecosystem and human resources.

1.1 Coral and Sponge Characteristics

Deep-sea corals and sponges contain similar traits and characteristics. Many species of deep-water coral and sponges are relatively consistent in terms of basic identifiers. They are both slow growing and slow recovering which makes them sensitive and vulnerable to both direct and indirect anthropogenic impacts (Roberts, 2006). Such species can also contain long-lives, some being found to live more than 4000 years (Norse, 2012). Corals and sponges living within the deep sea are most commonly found to be heterotrophic suspension filter feeders which means they primarily rely on nutrient particles that float from the surface to the seafloor (Consalvey, 2006; Hourigan, 2015; Howell, 2016; Mobilia, 2021; Ramirez, 2020). Since they are found in the depths of the ocean they have adapted to extreme conditions such as cold temperatures, high pressures, food shortage and more (Danovaro, 2017). Deep-sea corals and sponges are most commonly found between 200-2000m deep however; they have also been found to thrive in depths up to 6000m (Ramirez, 2020). Such species are also known to thrive between temperatures of 4°C and 13°C (Consalvey, 2006; Tracy, 2011; Ramirez, 2020). Corals and sponges can occur individually, in small patches over several meters, or within large reefs that can reach 300m in height and several miles in length (Roberts, 2006). However, even as both species contain similar characteristics they also contain distinctions that differentiate them from one another.

1.2 Corals

Two-thirds of all the discovered coral species thrive within deep, cold-waters of the ocean (Roberts, 2004; Consalvey, 2006). With the large variety of species both cold-water corals and sponges come in various shapes and sizes (Tracy, 2011). There are more than 10,000 identified species of cold-water corals globally but researchers estimate that there are approximately 800 additional species that have yet to be discovered (Tracy, 2011; Roberts, 2004).

Whether corals are living in shallow or deep-waters they can belong to either of the two classes of the phylum Cnidaria, these are Anthozoa and Hydrozoa (Roberts, 2004). Corals can then be divided into two main subclasses both stony (Hexacorallia) and soft (Octocorallia) (Roberts, 2004). Within Hexacorallia are two additional subclasses that can be derived into and they are hydrocorals (Stylasteridae), and black corals (Antipatharia) (Roberts, 2006). The subclass corals in the Stylasteridae class are species able to build a hard, calcium-based structure; this subclass is the most commonly found amongst the species (Mortensen, 2005; Robert, 2004). The subclass corals in the Antipatharia class are known to form a tree-like structure that contain prickles or lump-like structures (Robert, 2004). While the species typically found to lie within the Octocorallia class do not build fully hardened skeletons. Rather, these species are found to contain flexible skeletons that allow them to move with currents (Mortensen, 2005; Roberts, 2004).

1.2.1 Location

Deep-sea corals are normally found to thrive in deep colder waters and attach themselves to continental shelves, boulders, ridges, sedimentary slopes and seamounts (Roberts, 2004; Ramirez, 2020). Many coral species are normally found in water temperatures between 6°C and 8°C, while they can still be found in temperatures between 4°C - 13°C (Consalvey, 2006; Ramirez, 2020). Cold-water corals are mainly found in environments that contain high salinity and in regions where there is a presence of a hard bottom and hydrographical influence (Howell, 2016; Mortensen, 2005). Such coral species are also found to be in depths between 50m - 6000m (Ramirez, 2020). Some coral species are also commonly found to thrive in benthic habitats that contain consistent currents; as they require ocean movement to feed (Mortensen, 2005). Research suggests that there is a direct correlation with location and reproduction within cold-water corals.

1.2.2 Reproduction

The reproduction of deep-sea cold water corals is crucial for understanding their level of resilience or vulnerability to outside pressures, such as climate change; however, this information is relatively unknown (Howell, 2016; Mercier, 2011). Studies show that coral species can reproduce both sexually and asexually (Campbell, 2009; Combosch, 2013). Sexual reproduction is achieved through free spawning eggs and sperm, or internal incubation (Combosch, 2013). Asexual reproduction is achieved through the fission of individual polyps (Combosch, 2013). While reproduction can also occur by an existing polyp undergoing division or fragmentation where a colony undergoes a break and gives rise to new colonies (Campbell, 2009; Combosch, 2013).

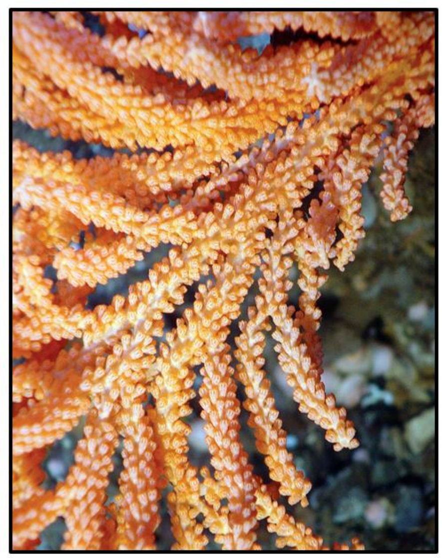

Figure 1. Coral- *Primnoa Resedaeformis*, Scotian Shelf, Atlantic Ocean, Photo by: *Fisheries and Oceans Canada* (2017).

Primnoa resedaeformis (Figure 1) is a deep-sea coral holaxonian gorgonian coral species from the *Primnoidae* family that is distributed throughout Eastern Canada (Mercier, 2011; Risk, 2002). This species is gonochoristic, meaning that they have no hermaphroditic abilities which means that they require sexual reproduction to produce off spring (Mercier, 2011). *P. resedaeformis* rely on broadcast spawning and external fertilization to reproduce sexually (Mercier, 2011). Studies confirmed that *P. resedaeformis* contains multiple reproductive contributors and the gametogenic cycle may take more than a year to complete as it undergoes four stages of spermatocytes (Waller, 2014; Fountain, 2019). Once the fertilization has been completed, gametes that are located in bundles at the base of polyps are then surrounded by individual follicle cells that thicken to create a protective shield (Waller, 2014). Once the gamete is fully matured into a larval, they detach themselves and release into the open water as planulae until they find a rocky base to stick to while they become juvenile corals (Waller, 2014).

1.2.3 Feeding Methods

Food sources in the deep-sea are sparse and difficult to find; however, microscopic organisms and particles such as zooplankton, Particulate Organic Materials (POM) and Particulate Organic Carbon (POC) are a main food source for creatures of the dark (Rooper, 2017). Feeding methods vary amongst coral species, but the one similarity is that since they are sessile species, they do not contain a symbiotic relationship, but rather they figure out a way to feed from their environment without moving (Mortensen, 2005). For example, *P. resedaeformis* are zooxanthellae coral that adapts to this environment to take advantage of the food sources that are readily available within their surroundings (Mortensen, 2005). This advantage starts during the dispersal phase of a coral planulae; when coral planulae are picked up by the current, they are then carried across the ocean looking for an ideal environment to settle in. If a planulae is able to attach themselves to a substrate they can then identify if they are within an ideal environment for survival. In the conditions that a coral species is immobile and not sessile, they will most likely contain a filter feeding method. Primnoa with the help of the gorgonian skeleton, are filter feeding animals that capture particles of food as large volumes of water pass through the colony (Mortensen, 2005). The gorgonian skeleton functions as an filtering mechanism that is structured so it can withstand strong currents while simultaneously filtering the particles around them (Mortensen, 2005). This feeding method allows the coral species to adapt to their environment, and uptake surrounding water to filter out and collect the particles of food floating within the water (Campbell, 2009; Ramirez, 2020).

1.3 Sponges

Sponges are one of the oldest organisms that still exist today, they are thought to have arrived more than 600 million years ago (Radax, 2012; Verhoeven, 2019). Sponges have a close relationship with the diverse surrounding microorganisms which have the ability to make up more than 40% of a sponges biomass (Cárdenas, 2018; Hoffmann, 2009; Radax, 2012). These microorganisms are beneficial to the sponge both directly and indirectly as many are assumed to be involved within the metabolic process of a sponge's life cycle (Cárdenas, 2018; Radax, 2012). Many sponge species are able to intake surrounding water to catch oxygen particles; however, some sponges species are unable to pump water through their body, making them anoxic (Hoffmann, 2009). In the case a sponge species is anoxic they will use a molecular diffusion method to intake oxygen, this process is done when oxygen is able to enter the sponge through a 1mm surface layer where it is then consumed (Hoffmann, 2009; Hoffmann, 2008). While in pumping sponges, they are able to intake oxygen throughout the entire tissues (Hoffmann, 2008).

1.3.1 Location

Deep-sea sponges are found within colder waters all across the globe. Sponges are typically found in intertidal zone habitats at depths more than 8000m but can also be associated with deep-sea slopes, shelfs and ridges (Campbell, 2009; Hoffmann, 2009; Kelly, 2018; Radax, 2012). Sponge species mainly thrive within regions that have both a suitable substrate and topography such as areas with firm substrate or hard bottoms and rocky floors where they can easily attach themselves (Campbell, 2009; Kutti, 2014). Deep-sea sponges can thrive in temperatures as low as 0°C, though they have been found to be living within temperatures lower than this (Kutti, 2014). They are also found to thrive in areas with a large amount of food particle availability (Kutti, 2014). Similarly, to cold-water corals, deep-sea sponges have been found to be located in rich diverse areas that directly correlate with reproduction success.

1.3.2 Reproduction

Some deep-sea sponge species can reproduce using a variety of methods and strategies (Maldonado, 2009). It is also hypothesized that reproduction in sponges can be triggered by surrounding chemistry such as a virtual flux of particulate organic carbon (Witte, 1996). Sponges have the ability to reproduce both asexually and sexually, additionally, sponge species can be either oviparous or viviparous (Maldonado, 2009; Campbell, 2009; Witte, 1996). Although it is not scientifically proven, sponge reproduction has been hypothesized. Sponges do not contain true organ systems, rather they contain several cells that are capable of giving rise to several different cell types (Kelly, 2018; Maldonado, 2009). These transitional cells have the ability to accomplish a large variety of functions (Maldonado, 2009). Therefore, it is hypothesized that some sponge species such as *Chondrocladia grandis* are a hermaphroditic and viviparous species that contain cells where embryos can be fertilized and develop internally as a larvae (Kelly, 2018; Verhoeven, 2017). After the internal formation of a larva is developed, they are then released through aquiferous canals into the open water (Maldonado, 2009). The larva then free-swim in the open ocean for days to weeks before finally settling within plankton particles to then give rise to juvenile sponges (Maldonado, 2009).

It has been discovered that some species of deep-sea sponges, unlike shallow-water sponges, do not contain nurse cells which are cells used as a food storage system (Witte, 1996). It is then hypothesized that some deep-sea sponge species contain a distinct seasonal reproductive cycle to align with influxes of particulate organic carbon concentrations (Witte, 1996). U. Witte wrote about sediment studies done by Von Bodugen, 1994 about how *Thena abyssorum* were found to accumulate yolk during the same time they received maximum amount of particle flux (Witte, 1996). This is an important discovery as it showcases how deep-sea sponges' reproductive cycle may be triggered by particulate organic carbon fluxes that coincide with the seasons (Witte, 1996). This reproductive trigger showcases how species in food-limited environments ensure they have the nutrients needed before proceeding with offspring production.

1.3.3 Feeding Methods

Sponge species have very complex and unusual feeding methods compared to other sessile species (Godefroy, 2019). One example is *C. grandis* (Figure 2) is a sponge species that is found within Eastern Canada. This sponge species is a carnivorous species that feeds by using its entire body as a filtration system (Godefroy, 2019; Verhoeven, 2017). This filtration system is called the aquiferous system which is a unique system that aids in the capture and engulfment of prey (Godefroy, 2019; Verhoeven, 2017). This system allows some sponges such as *C. grandis* the ability to feed on a range of organisms. This system also has the ability to allow such species to feed on a range of prey sizes such as small planktonic organisms to crustaceans (Howell, 2016; Verhoeven, 2017).

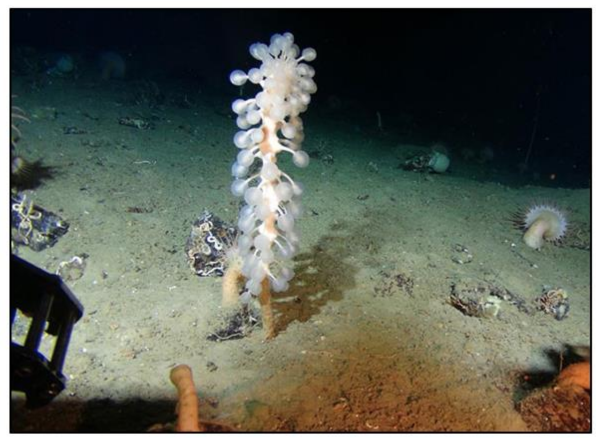

Figure 2. Sponge – *Chondrocladia grandis,* Baffin Island, Canada, Photo by: *National Oceanic and Atmospheric Administration* (2017).

Carnivorous sponges like *C. grandis* use morphological adaptations to enable the aquiferous system that allows them to feed. *C. grandis* comprises an erect body or structure that contain numerous sphere swellings that have a sticky, velcro-like surface to better help them to catch prey (Verhoeven, 2017; Godefroy, 2019). Once the prey is captured by the swellings, the cells in the sponge undergo migration to the site of capture and create a cell for the prey to be held within (Verhoeven, 2017). After this cell is created, the consumption and digestion process begins (Verhoeven, 2017). The sponge will then produce symbiotic bacteria to both consume and digest its prey and aid in the absorption process (Verhoeven, 2017).

1.4 Coral and Sponge Importance

1.4.1 Importance for the Marine Environment

Deep-sea corals and sponges play important roles within the marine environment. Both deep-sea coral and sponges aid in increasing species diversity, environmental processes and even play an important role within the lives of humankind. The habitat forming species are crucial for supporting rich benthic communities.

1.4.2 Species Diversity

The deep sea is home to ecosystems that provide rich biodiversity and play a role in transferring a number of nutrients such as primary production and carbon from the ocean surface to the seafloor (Howell, 2016; Johnson, 2018). Coral and sponges are just one of the major important ecosystems in the depths of the ocean and have been found to be associated with over 1300 marine species, more than 114 invertebrates, over 240 fish and more than 3900 specimens and other megafauna species (Campbell, 2009; Finney, 2009; Scanes, 2018). Deep-sea corals and sponges are crucial for a number of reasons; they provide complex reef structures on the seafloor that support a large amount of organisms (Campbell, 2009; Cathalot, 2015; Finney, 2009). These structures forming species can also support the marine ecosystem by providing areas for a number of organisms to spawn, feed, rest and seek refuge (Campbell, 2009; Cathalot, 2015; Finney, 2009; Ramirez, 2020). Additionally, deep-sea corals and sponges may be the only structure forming organisms on the seafloor, making them crucial for the survival of the surrounding ecosystem (Cathalot, 2015).

1.4.3 Environmental Support

In addition to supporting the marine environment, deep-sea corals and sponges also contribute to the cleaning of the ocean. Deep-sea sponges play a key role in their surrounding environment, they are not only important for creating habitat but they have the ability to clean water by filtering methods (Campbell, 2009; Verhoeven, 2019). Marine sponges are able to filter large amounts of water which results in effective removal and distribution of unwanted CO_2, nitrogen and silicon which directly influences the integrity of its surrounding environment (Mobilia, 2021; Vad, 2018; Verhoeven, 2019).

In addition to ecosystem supporters, both corals and sponges play major roles in both the nitrogen cycling and carbon fixation processes within the deep-sea (Cárdenas, 2018; Scanes, 2018; Vad 2018). The nitrogen cycle is driven by a number of complex microbial transformations of nitrogen including nitrogen fixation, nitrification, anammox and denitrification (Gruber, 2008). Gruber 2008 outlines how nitrogen cycling is crucial for thousands of marine organisms as nitrogen aids in species metabolism, energy for growth and to synthesize structural components (Gruber, 2008).

A study by Radax 2012 followed nitrate and nitrite production in sponges over where water samples were taken every 4 hours over a time-course of a 24-hour period (Radax, 2012). This study was then conducted within different simulated seasons to understand how nitrogen levels change within natural environmental changes (Radax, 2012). The experiment used 4 different cold-water sponges as test subjects; the results indicated that ¾ of the sponges selected showed that nitrification and anaerobic microbial processes of denitrification were detected within the species *Geodia barretti, Phakellia ventilabrum and Tentorium semisuberites* (Radax, 2012).

This discovery revealed the first proof of both anammox and denitrification processes being hosted within the same single species (Hoffmann, 2009; Vad 2018). However, the main finding showed that nitrification activity was observed both independently and with the addition of ammonia releases; meaning that the nitrogen cycling process was not limited by the available ammonium (Radax, 2012). This discovery has led scientists to believe that sponges play an important role within the nitrogen cycling process as sponges may have the ability to filter nitrogen from the water and aid in the mineralization process in certain environments and redistribute nutrients to surface species (Gruber 2008; Hoffmann, 2009; Radax, 2012).

1.4.4 Importance for Humankind

In addition to playing a crucial role within the deep-sea marine environment, deep-sea coral and sponges are also directly important for human kind and all species on land. Deep-sea coral and sponges are able to provide humans with a number of resources that they heavily depend on. Cold-water corals and sponges aid humans by providing food sources, increase the economy, and aid in medicine development. Over half a billion people depend on deep-sea coral and sponges for the sources that they provide. In addition to human important factors, cold-water coral and sponges are also culturally important to a number of Indigenous nations worldwide.

1.4.5 Culturally Important

While deep-sea coral and sponges are difficult to reach, many Indigenous nations have cultural connections to the cold-water fauna. Reid, (2022), wrote a research paper that looked to Indigenous communities for scientific knowledge and support for marine spatial projects and got their perspective on the importance of marine ecosystems (Reid, 2022). The project partnered with numerous Indigenous nations within Canada including the Haíłzaqv, Kitasoo Xai'xais, Nuxalk and Wuikinuxv Nations which are the rights holders of the unceded territory in the now known province of British Columbia (Reid, 2022). The Indigenous partners created a list of numerous species in the region and their cultural significance. Coral and sponges were just one of the many habitats and species that were mentioned to have cultural ties with. Coral and sponges have been seen and continue to be seen by Indigenous communities as the food web base as they are habitat forming and water filtering which plays a very important role within the overarching ecosystem (Reid, 2022). The importance of the coral and sponges also correlates with traditionally harvested food, meaning that without corals and sponges their traditions could be erased (Reid, 2022).

1.4.6 Economic Contribution

One main importance of cold-water corals and sponges is their economic contribution to both the local and global economy. Fishermen and women have recorded that areas that house deep-sea fauna such as corals and sponges make favorable fishing grounds (Consalvey, 2006; Foley, 2010; Muñoz, 2020). Nova Scotia fishermen have testified that they set their longline traps near areas with bubblegum tree coral to target certain fish species (Muñoz, 2020; Roberts, 2004). Furthermore, Redfish are found in high abundance in areas that contain *Lophelia* (Figure 3) reefs and grouper, snapper and amberjack fish species are normally found in areas in which *Oculins varicos*a if found (Foley, 2010). A study between 1989 and 1997 in the Gulf of Alaska, underwent a submersible dive to understand the dynamics between corals and sponges and commercially important species. The results recorded that 85% of the large rockfish were observed to seek refuge under an area that housed coral and sponge species (Roberts, 2004). This overlap causes corals and sponges to be accidentally caught into fishing lines which heavily impact their populations

(Consalvey, 2006; Muñoz, 2020). Deep-sea corals and sponges create environments and habitat for fish communities to thrive in. These habitat forming organisms provide protection to juvenile fish from currents, predators and provide sanctuary to spawn, rest, breed and more (Cathalot, 2015; Roberts, 2004). An additional study by Muñoz, 2020, surveyed various locations within the northwest Atlantic Ocean, the results from this study suggest that areas that contain high density of groundfish directly correlate with high populations of deep-sea coral and sponges (Muñoz, 2020). The bottom-trawl nets that are used to catch ground fish are also collecting a large number of coral and sponge by-catch (Muñoz, 2020).

Figure 3. Coral – *Lophelia pertusa,* Atlantic Ocean, Photo by: *Fisheries and Oceans Canada* (2021).

These sanctuary building species directly increase biodiversity and species richness. Species richness, biodiversity and thriving fish communities are the three most important aspects to the Canadian fishing industry's success (Scanes, 2018; Shester, 2005). The presence of corals and sponges directly benefit the fishing industry in Canada, which is one of the largest contributors to the Canadian economy (DFO, 2020b; Scanes, 2018; Shester, 2005). In Canada, the fishing industry alone brings in approximately $6 billion per year into the Canadian economy, exports to 140 countries worldwide and employs over 68,100 Canadians (DFO, 2020b).

Furthermore, there is evidence that coral and sponges were harvested and traded worldwide (Foley, 2010). Majority of which were harvested in shallow waters; however, with the evolution of technology, Remote Operated underwater Vehicles (ROV) aided in the collection of deep-sea corals and sponges (Foley, 2010). Cold-water coral and sponges were once sold for $239.00/kg, and harvests would collect tonnes of species to audition (Foley, 2010). The jewelry market also gained an interest in deep-sea corals, *Primnoa* was considered a valuable species because of the 'lustre of the skeleton when polished as jewelry' (Foley, 2010). The conservation of such species through preservation approaches also aid in the protection against economic loss (Clark, 2016). Climate change is not only influencing deep-sea ecosystems but will have large impacts on the economy.

1.4.7 Pharmaceutical Contributions

Aside from the economy, corals and sponges also support more than 500 million people by providing food, income, medicines and more (Cohen, 2022;). Deep-sea sponges contain strong biological effects and also have been known to carry pharmaceutical compounds that can not only help produce human medications, but this also allows them to protect themselves against unwanted bacteria and viruses (Verhoeven, 2019). Between the 18th and 19th century fishermen in Norway collected and used deep-sea corals for 'powerful medicaments', which gave indication that cold-water corals could exhibit medicinal effects (Foley, 2010). Additionally, *Sarcodictyon roseum* is a coral species currently being used in clinical trials to develop cures for various strains of cancer and a number of bamboo corals are currently being utilized for bone grafting activities (Foley, 2010).

Chapter 2. Climate Change and Multiple Stressor Impacts on Corals and Sponges

With the evolution of human activities comes evolution in technology that ultimately contributes to the increase in anthropogenic impacts that damage our planet (Ramirez, 2020). Anthropogenic impacts are human induced impacts both directly and indirectly and are the leading cause of species depletion (Ramirez, 2020). The deep-sea is no exception to these negative impacts.

2.1 Direct Anthropogenic Impacts

Anthropogenic impacts are the leading cause of coral and sponge depletion. Direct impacts are impacts that are directly impacting someone or something. Deep-sea coral and sponges can be directly impacted by anthropogenic activity such as oil and gas exploration, deep-sea mining, bottom-contact fishing gear, pollutants and more. The direct impacts deserve serious consideration, regulation and enforcement to ensure the seafloor is protected (Thiel, 2003).

2.1.1 Oil and Gas Exploration & Deep-Sea Mining

The oil and gas industry has aided in the discovery of deep-sea coral and sponges and has played a role in the gathering of information of such deep-sea species (Vad, 2018). However, the impacts oil and gas exploration is having within the deep-sea are becoming detrimental (Vad, 2018). The oil and gas industry contains many stages in which they operate; the development, operation and closure stages (Vad, 2018). Throughout the many stages, there is a range of activities that take place such as; seismic exploration of the seafloor and geological interesting features, seabed drilling and infrastructure installation (Vad, 2018). These procedures regularly take place and contain risks to the marine environment and species (Vad, 2018). Such potential impacts are the release of hydrocarbons during spills and leaks, direct damage to the seafloor and therefore benthic communities and the movement of sedimentation that can smother benthic species (Pasparakis, 2019; Vad, 2018). Impacts to deep-sea corals and sponges have been known to disturb the ocean floor, decrease the density and diversity of species and benthic communities, impacting the ability to filtrate the surrounding water, and decrease the stability of the cellular membrane in species (Vad, 2018).

In 2010 the Deepwater Horizon offshore oil drilling rig endured an explosion and sank in the Gulf of Mexico (Pasparakis, 2019; Vad, 2018). This oil spill is the largest spill the marine environment has seen to date. More than 4 million barrels of oil entered into the water and covered at least 112,110km^2 of open surface area and took more than 87 days to clean up (Pasparakis, 2019). The spill formed many subsurface oil plumes, one extended to a depth of approximately 1100m (Vad, 2018). As this incident reached a large depth in the ocean, it created a new type of oil spill where it did not just mainly impact the surface layer but the deep-sea as well (Vad, 2018). This spill exposed deep-sea species and habitats to high concentrations of crude oil that heavily impacted such species (Vad, 2018). Vad (2018) outlines how studies showed that after the spill, there was a high mortality rate of deep-sea corals and sponges such as colonial and pelagic tunicates, sea pens and glass sponges (Vad, 2018). The Canada-Nova Scotia Offshore Petroleum Board (C-NSOPB) is responsible for administrating oil and gas activities while protecting the marine environment (DFO, 2015). The risk of spills becoming more frequent with the increase in drilling activities, currently oil and gas exploration can be prohibited through management, but is often allowed and conducted within conservation areas such as marine protected areas that house sensitive benthic species (Vad, 2018).

2.1.2 Bottom Contact Fishing

An additional direct human impact is caused by bottom contact fishing gear. Bottom contact fishing activities and gear such as longline, gillnet, and bottom trawls, heavily impact the benthic ecosystem when they come in direct contact with it (Consalvey, 2006; Mobilia, 2021; Muñoz, 2020). Trawling and dredging activities such as trawl surveys and trawl fishing practices are causing extensive damage for cold-water corals and sponges (Consalvey, 2006; Finney, 2009; Muñoz, 2020; Ramirez, 2020). This damage transforms cold-water corals and sponges systems into coral rubble; which is the breakage and death of corals and sponges (Finney, 2009; Ramirez, 2020). With the preexisting recovery rate of deep-sea corals and sponges, such fishing activities are further hindering this recovery rate to the degree where recovery is unlikely (Consalvey, 2006; Finney, 2009; Muñoz, 2020; Ramirez, 2020).

2.1.3 Pollution & Ocean Litter

The increase in pollution from chemicals and marine litter poses an unprecedented challenge to the marine environment (Ramirez, 2011). The United Nations Environment Programme (UNEP) defined marine litter as 'any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment' (Ramirez, 2020). Even though the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter of 1972 has banned the dumping of litter into the ocean, reports have declared that each year approximately 6.4 million tonnes of litter and pollutants enters into the ocean (Ramirez, 2020). With deep-sea exploration pollutants and litters have been found to collect within the deep-sea's environment (Ankamah-Yeboah, 2020). The most prevalent litter has been noted to be a number of microplastics, ghost gear, nets, metal and glass (Ankamah-Yeboah, 2020; Ramirez, 2020). Ocean litter starts off by floating on the surface of the water but over time the litter will sink and end up accumulating on the ocean floor (Ramirez, 2020). This ocean litter is most commonly found on deep-sea mounts, bands, ridges, and mounds; which are active hotspots for coral and sponge segregation (Ankamah-Yeboah, 2020). Additionally, deep-sea contaminants may be invisible and eventually return to the ocean surface and add onto the pre-existing local pollution which will only further impact and disturb species and communities (Thiel, 2003).

2.2 Climate Change

In addition to the ecological impacts caused by direct anthropogenic activities, other indirect impacts will soon be impacting the deep-sea (Scanes, 2018). Discoveries have shown that despite the resiliency of the deep-sea, climate change and other pollutants and pressures will impact the ecosystem with severity and variety (Ankamah-Yeboah, 2020; Ramirez, 2011). Direct impacts as mentioned above are harming ecosystems and species all over, but climate change is one of those pressures that often gets forgotten; meanwhile it is one of the most detrimental impacts to the marine environment (Ramirez, 2011).

Climate change is impacting the waters at a remarkably fast rate. Recent studies have indicated that the properties of the water column within the deep-sea are changing in response to climate changes (Dijkstra, 2021). Global warming is primarily a cause of carbon dioxide which makes up the majority of the greenhouse gasses that get trapped in the atmosphere (Blau, 2017). Carbon dioxide (CO_2) is a chemical compound that is created when fossil fuels such as coal, oil and natural gasses are burned (Blau, 2017). After these gasses are released from the burning of fossil fuels, the odorless gas then becomes confined within the atmosphere, where it will remain for decades to centuries due to the way solar radiation is reflected and refracted from the Earth into space (Blau, 2017; Ramirez, 2011; Raval, 1989).

Majority of the reflected and refracted solar radiation gets absorbed either by the planet (23%) or within the atmosphere (48%) rather than emitting to space based on the wavelength size (Raval, 1989). Thus, approximately 71% of GHGs are absorbed by the Earth-atmosphere system which is heavily impacting the globe. So, as GHGs are confined within the atmosphere, they continue to warm the planet while they remain trapped (Raval, 1989). As there are already high numbers of GHGs already suspended in the atmosphere, cutting global emission to a net zero is crucial for conserving the plant and all of its resources (Blau, 2017; Raval, 1989).

Carbon emissions are the number one cause of planet warming, which is also the number one impact on the marine environment, both for the shallow and deep-sea. The warming of the planet impacts the melting of ice sheets in both the Arctic and Antarctic which directly impacts sea level rise which increases coastal erosion and flooding which will also result in the disappearance of small island states (Blau, 2017). Resulted impacts will also cause many species to disappear as their environment will no longer be habitable. Global warming will also impact ocean composition such as temperature, salinity, acidity and more (Blau, 2017). All these impacts have repercussions, some that heavily impact marine ecosystems such as corals and sponges.

2.2.1 Rising Ocean Temperatures

Down-welling events are increasing in frequency each year due to changes in climate. Climate change is contributing to the warming of the globe's oceans and with the addition of more frequent down-welling events, it will draw warm surface waters into the deep-sea which is estimated to increase deep-sea temperatures which will alter distribution, damage cellular tissues, and more, will cause mortality rates in numerous species (Scanes, 2018).

Corals and sponges are sensitive to outside changes, and even the smallest increase in temperature can negatively impact their life. A study in 2004, analyzed deep-sea nematodes to identify the response in species diversity and physio-chemical changes within the deep-sea of the Eastern Mediterranean (Danovaro, 2004). Similarly, to corals and sponges, nematodes are heavily impacted by small temperature changes, by analyzing nematodes, we can predict similar changes within corals and sponges, as well we can predict how other deep-sea invertebrates may react to such changes (Danovaro, 2004). The study used decadal data from 1989 to 1998, the data set showed an abrupt decrease in temperature between 1992 and 1994 (Danovaro, 2004). This decrease in temperature seemed to correlate with decrease in nematode abundance, but increased in functional diversity (Danovaro, 2004).

An additional study in 2006 and 2008 within Norway waters conducted research by simulating down-welling events similarly to those recently recorded within the natural environment, the location of the real event houses large assemblages of deep-sea corals and sponges (Scanes, 2018). The down-welling event took place for a two week period and recorded that water temperatures had risen 4-5°C and reached the highest temperature peak at 12°C (Scanes, 2018). This down-welling event and slight rise in temperature caused mass mortality rates to the sponges (*Geodia atlantica*) in the area, while the coral (*Primnoa resedaeformis*) surprisingly showed signs of stress, but given that its threshold is around 13°C, the temperature used may not show mortality (Guihen, 2012; Scanes, 2018).

There have been recordings of increased rising ocean temperatures at specific locations within the ocean, which is causing certain areas to warm faster than others (Scanes, 2018). Corals and sponges that are observed within seamounts and canyon ecosystems have been discovered to respond negatively quicker than corals and sponges within other areas; as they are exposed to warmer waters driven by climate change at a faster rate (Breeze, 2007; Dijkstra, 2021). These areas have been found to expose corals and sponges more frequently to warmer waters, decreased salinity and hypoxic conditions (Dijkstra, 2021).

2.2.2 Ocean Acidification

In addition to ocean warming, there are numerous other factors that are impacting ocean chemistry. Ocean acidification is resulting from large amounts of absorbed CO_2 which then dissolves into the seawater as carbonic acid (H_2CO_3) (Ilyina, 2012). Ocean acidification has already contributed to the reduction of the ocean pH by 0.1 creating more acidic environments (Ilyina, 2012). Corals and sponges are vulnerable to ocean acidification as their formation requires calcification; however, due to the reduction in available carbonate ion concentrations within the ocean it is leading to bleaching events (Breeze, 2007; Ilyina, 2012; Rooper, 2017).

Between 2012-2015, NOAAs Deep Sea Coral Research and Technology Program (DSCRTP) sponsored numerous field research projects focused on deep-sea coral and sponges within the Atlaska region. Many of the projects focused on the impacts climate change had upon such species, many of these focused on identifying and researching further into ocean acidification (Rooper, 2017). Because NOAA understands how ocean acidification is impacting high latitude systems more than others, they used bathymetry to identify areas which contained the favored topography to be impacted the most (Rooper, 2017). From these discovered areas, one study they conducted used a Stable Isotope analysis (SIA) to select specific atoms of different elements with complex food webs in remote environments to understand what is being consumed by specific species (Rooper, 2017). The study focused on the isotopes within POM and zooplankton; which are both found to be consumed by corals (Rooper, 2017). The results showed that both the POM and zooplankton collected were calcium deficient, leading to the assumption that the corals were also not receiving a sufficient amount (Rooper, 2017).

An additional study by Ilyina, (2012) was conducted where they looked at ocean acidification and future projections for the deep-sea with a focus on the Atlantic and Pacific region. The study consisted of using the Hamburg Ocean Carbon Cycle Model (HAMOCC) global biochemistry model to undergo multiple CO2 emission scenarios (Ilyina, 2012). The results of this study showed that carbonate minerals will drop significantly resulting in large amounts of dissolved calcium carbonate within the next century (Ilyina, 2012). As mentioned before corals and sponges use calcium carbonate to aid in the formation and growth, with a large decrease in available materials such species will have a difficult time surviving (Breeze, 2007; Ilyina, 2012; Rooper, 2017).

2.2.3 Particulate Organic Carbon and Matter

In addition to ocean acidification, indirect climate effects impact other aspects of oceanography. Climate change is predicted to decline the particulate organic carbon (POC) and particulate organic matter (POM) that is deposited to deep-sea benthic habitats (Dijkstra, 2021; Rooper, 2017). POC and POM both act as a food source for deep-sea species such as coral and sponges (Rooper, 2017). The decline in POC is estimated to result in an 18% reduction in the biomass of the benthic and negatively impact the formation and constitution of benthic species; such as corals and sponges (Dijkstra, 2021).

2.3 Decline in Coral and Sponges Means What for Canadians?

2.3.1 Will Impact Ecosystems

Deep-sea corals and sponges contain high biological habitat heterogeneity and thus in areas where there are high numbers of corals and sponges, there will be high numbers of species and habitat (Costello, 2017). Both coral and sponges have been known to be a vital component of deep-sea ecosystems, as mentioned before they have been found to be associated with more than 5554 marine species and invertebrates (Campbell, 2009; Finney, 2009; Scanes, 2018). As mentioned before, deep-sea coral and sponges play a role in their environment by creating habitats and cleaning the surrounding environment and keeping it in a pristine condition (Campbell, 2009; Verhoeven, 2019). With a decline in such crucial species there will be a decline in surrounding species and ecosystem integrity.

2.3.2 Will Impact the Economy

Due to the high attraction of species deep-sea coral and sponges bring, they are named as hot spots for biodiversity and species abundance (Scanes, 2018). As mentioned before, deep-sea coral and sponges play a vital role in the global and local economy by not only supporting the fishing industry but also providing necessary human resources. The Canadian fishing industry is one of the largest contributors that heavily relies on the stock and success of the fish (DFO, 2020b; Scanes, 2018; Shester, 2005). Such fish species rely on their habitat and ecosystems for prosperity (DFO, 2020b; Scanes, 2018; Shester, 2005). As mentioned before, the presence of corals and sponges directly benefit the fishing industry in Canada which brings in approximately $6 billion per year (DFO, 2020b; Scanes, 2018; Shester, 2005).

Additionally, Foley (2010) outlines how cold-water corals and sponges contain both use and non-use values, meaning the total economic value of deep-sea fauna can also be associated with an ecosystem stock, or assets as well as direct services offered by such species (Foley, 2010). As mentioned previously, coral and sponges also aid in the development of pharmaceuticals and health services, as well as jewelry (Foley, 2010). A decline in both coral and sponge species will have detrimental impacts on the local and global economy (Clark, 2016). Decline in an economy could additionally have a ripple effect across the country.

Chapter 3: International Treaties and Initiatives on Ocean Uses, Climate Change, & Conservation

Chang (2010) proposes that ocean conservation and governance may be achieved with the implementation of international agreements. Chang's argument is based on the reality that international agreements are crucial for ensuring worldwide participation in the protection of global resources (Chang, 2010). Global laws and regulations are able to outline specific objectives and targets that help guide nations worldwide to ensure marine conservation goals are being met. These marine conservation objectives become increasingly possible to achieve as international treaties create and acknowledge elements of good governance (Chang, 2010). Global leaders are then subject to the rule of law, participation, transparency, accountability, and responsibility to ensure these objectives are being met at a nation and international level (Chang, 2010). Additionally, with international treaties come frameworks for international cooperation and collaboration between nations and communities. Collaboration is one of the most effective ways to ensure nations are attempting to address environmental issues and decipher a way to resolve such issues at the local, regional and global level (Chang, 2010). However, these international treaties contain gaps and loopholes that keep nations from meeting their commitments and overall global objectives for conservation.

3.1: International Treaties: Ocean Uses

3.1.1 United Nations Convention on the Law of the Sea

The United Nations Convention on the Law of the Sea (UNCLOS), was concluded in 1982 (Convention on the Law of the Sea, 1982; VanderZwaag, 2012). The convention sets forth a comprehensive legal framework for the uses of marine resources, uses of the sea, seabed and soils

(Convention on the Law of the Sea, 1982). Additionally, the convention outlines the responsibility and obligations nations have to the conservation of their own resources and the marine environment within their jurisdiction (Convention on the Law of the Sea, 1982). UNCLOS contains numerous articles that mention more general and broad conservation obligations that nations participate in; however, acknowledges that marine resources need to be protected and the only way to ensure that is by enforcing a law that nations abide by (Convention on the Law of the Sea, 1982). In Part XII of the *Protection and Preservation of the marine environment*, article 192 outlines general obligations, article 194 outlines 'measures to prevent, reduce and control pollution of the marine environment', and article 195 outlines "Duty not to transfer damage or hazards to transform one type of pollution into another" (Convention on the Law of the Sea, 1982).

The convention does not acknowledge climate changes, nor gives rise to potential solutions, but nonetheless the convention sets up the expectations for marine conservation moving forward. Additionally, Chang (2010) acknowledges that while states can adopt and enforce activities, many international treaties such as UNCLOS, leaves room for nations to make their own decisions on what best practices will look like in their jurisdiction. Treaties nations sign onto are legally binding and require nations to administer and enforce the rule of international law (Chang, 2010). However, like many international treaties the conventions' statements and provisions are broad and this could have a positive outcome as nations could decide what that statement means to their country, but it also leaves room for incompetence, ineffective, and inadequate management practices distributed by nations.

3.2 International Treaties: Climate Change

3.2.1 United Nations Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) was signed by 150 nations in June 1992. This international treaty exhibited international recognition of climate change and how it is growing into a major threat for both the global environment but also global economic development. The UNFCCC defines 'climate change' as, "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." (Ahove, 2018). The UNFCCC's goals outline the "stabilization of GHG concentrations in the atmospheres at a level that would prevent dangerous anthropogenic interference with the climate system." (Spash, 2016).

In 1997 the *Kyoto Protocol* was developed by UNFCCC during a conference held in Kyoto, Japan, and entered force in 2005 (Brown, 2002). This protocol was ratified by 192 parties and it committed to aiding in countries' transition to limit fossil fuel usage and move towards sustainable development (UNFCCC, 1997). This transformation process was deemed crucial for combating climate changes; however, it endured its own set of challenges. One seemed to be compliance, Canada for example signed onto this protocol until resources were discovered and economic growth grew favorable over global conservation and sustainable development (Spash, 2016). Canada had then decided to take a step back from the *Kyoto Protocol* so they could withhold their responsibility to the commitments and frack on a large environmentally industrial scale (Spash, 2016). Another issue is outlined by Brown, (2002) who shows how the *Kyoto Protocol's* proposed methods such as developing sinks, allows nations to delay or avoid their adaptations to reduce fossil fuels (Brown, 2002). Nonetheless, the *Kyoto Protocol* was a regulatory instrument that gave rise to the Paris Agreement of 2015.

3.2.2 Paris Agreement

The Paris Agreement is an international treaty on climate change that was adopted in 2015 by 196 parties, and entered into force in 2016 on the 4th of November (Nations, 2016). There were over 25,000 active participants within the negotiations. Participants ranged from scientists, ministers, presidents to farmers, fishermen, Indigenous peoples, journalists, Chief Executive Officers (CEO) of organizations as well as Non-Governmental Organization (NGO) representatives (Blau, 2017). The international agreement brought global leaders together to come to consensus on a number of long-term global climate goals that would guide nations (Blau, 2017).

Such goals include to "substantially reduce global greenhouse gas emissions to limit the global temperature increase in this century to 2°C while pursuing efforts to limit the increase even further to 1.5°C", "review countries' commitments every five years", and "provide financing to developing countries to mitigate climate change, strengthen resilience and enhance abilities to adapt to climate impacts" (United Nations, 2015). These goals are legally binded by the treaty which ensures that nations make the transition from fossil fuels to renewable energy with the expectation that fossil fuel emissions will be heavily reduced. Additionally, this treaty ensures that higher income nations will aid in the transition to emission elimination in lower income countries and allow them to also reach these goals (Blau, 2017).

The main agreement goals are to hold the global average temperature to below 2°C to aid in the projected temperature increase of 1.5°C which is above pre-industrial levels (Blau, 2017; IPCC, 2018). As mentioned previously, the cause of this increase in global temperature is primarily caused by greenhouse gasses (GHGs) that hold emissions in the atmosphere mainly due to carbon dioxide emissions (CO_2) (Blau, 2017; IPCC, 2018). This gas, alongside other anthropogenic impacts, are predicted to impact a number of earth and ocean aspects. Predictions tell us that the changing climate will increase ocean temperature, increase CO_2 absorption and reduce the amount of dissolved oxygen and dissolved nutrients (Dijkstra, 2021; Howell, 2016). Deep-sea fauna are heavily impacted by environmental changes and with increased alterations from climate change, numerous species are projected to be negatively impacted (Danovaro, 2004; Ramirez, 2011). The IPCC report on the impacts of global warming estimates that warm-water coral and sponges will decline by 70%-90% even by limiting GHG to 1.5°C and is estimated to have larger losses of approximately 99% if the warming continues to 2°C (IPCC, 2018). In this document we talk about cold-water corals and sponges, but based on the current knowledge of both warm-water and cold-water corals, it is estimated that cold-water corals and sponges are equally as prone to impacts of warming as are shallow-water species (Alberts, 2022). The 2°C goal outlined in the *Paris Agreement* is to aim for the conservation of global species and resources from the impacts of climate change.

Aside from the main goals, the agreement contains articles designed to remind nations of their obligations while also providing some guidance to nations when coming up with sustainable development goals. Article 7 outlines the establishment of implementing global adaptation goals for "enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change" (United Nations, 2015). The article also outlines how "Parties recognize that the current need for adaptation is significant and that greater levels of mitigation can reduce the need for additional adaptation efforts, and that greater adaptation needs can involve greater adaptation costs" outlining the importance of developing and implementing adaptation efforts to combat climate change (United Nations, 2015).

As the *Paris Agreement* is one of the main international treaties that addresses climate change impacts, there are still potential faults at hand. One issue arose surrounding the temperature limits that the *Paris Agreement* made. The UNFCCC's party, amongst many, contained concerns regarding the state of the *Paris Agreement.* When the agreement was in development the limit was 2°C, this caused issues amongst many including the Secretariat of UNFCCC party that stated that even if the 2°C targets were met, they are only able to offer a 50:50 chance of avoiding the harsh impacts from climate change (Spash, 2016). As mentioned before, the main goal of UNFCCC is to stabilize GHG concentrations to prevent anthropogenic interference with the climate system; Spash (2016) argues that the 2°C targets are not in compliance with this requirement from the UNFCCC, and that the 50:50 chance does not align with this requirement (Spash, 2016). Spash (2016) argues that the treaty promotes risk management over disaster prevention which is altering the intentions of the agreement and seems to align more with a 3°C warming rather than their original agreement. Since the controversy the agreement is now focused on a 1.5°C effort; however, there is no mention of solutions or plans to achieve this temperature, nor is guidance offered, and there is no mention that the 50:50 chance has improved (Spash, 2016).

Another being that as elected candidates change, not all global leaders believe in climate change, nor have climate change listed as a top priority in their country; this causes issues since some countries that contain this mindset are amongst the top emitters in the world (Blau, 2017). One example is the United States (US), just 5 days after the global treaty was announced, a new elected president of the US was selected. This US president had proclaimed numerous times that 'climate change is a hoax' and withdrew their signature to the agreement; this change in government also changed the hope for the globe since members need to be compliant in order to ensure objectives are being met (Blau, 2017). However, the issue is that within article 15 of the

Paris Agreement, it mentioned that the compliance committee will be ‘non-adversarial and non-punitive’ meaning they lack enforcement and can do nothing about countries that do not want to be compliant with the carbon reduction (Spash, 2016).

3.3 International Treaties: Conservation

3.3.1 Convention of Biological Diversity

The Convention of Biological Diversity (CBD) was adopted in 1992 as the first global agreement that covered all aspects of biological diversity conservation (Nations, 1992). This agreement was established with the objective that it would be used to conserve the biological diversity and the sustainable uses of such components, and that these components be shared equally (Nations, 1992). This convention states that “States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental plans, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.” (Nations, 1992).

As Canada adopted various biodiversity conservation and protection commitments when they signed onto the convention agreement, they then took on the responsibility to meet such commitments (Finney, 2009; VanderZwaag, 2012). The biological diversity agreement is subject to species and habitats that are specific within a nation's jurisdiction, one major biological species that is important to some Canadian regions are the deep-sea coral and sponges in the region. The agreement mentions the vulnerability of the cold-water coral and sponges and the marine habitats they create, requiring them to be prioritized for conservation management and protection (Finney, 2009). Now, the agreement does not explicitly mention climate change, but there are many articles that give leeway to the idea. Within Article 8 of the agreement, it states that in-situ conservation "Develop or maintain necessary legislation and/or other regulatory provisions for the protection of threatened species and populations" which correlates with the need for a climate change adaptation strategy for deep-sea coral and sponges (Nations, 1992).

However, in 2010, the Strategic Plan for Biodiversity was adopted which outlined 20 targets called the Aichi Biodiversity Targets that aid in global, regional and national achievements (VanderZwaag, 2012). Four targets focus directly on marine stressors and marine areas (VanderZwaag, 2012). Target 10 outlines that "By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning" (Nations, 1992; VanderZwaag, 2012). This was one of the first instruments that Canada signed onto that holds them accountable for climate change impacts on corals and sponges; however, this does not mean that this target has been addressed within Canada to date.

Target 11, outlines that "By 2020, at least 17% of terrestrial and inland water areas, and 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative, and well-connected systems of protected areas and other effective area-based conservation measures, and are integrated into the wider landscapes and seascapes" (Nations, 1992; VanderZwaag, 2012). Target 11 has been achieved by Canada through the implementation of Marine Protected Areas, Marine Refuges, OECMs, etc.

One target that could be used to hold Canada responsible for climate change impacts on coral and sponge species is Target 12, which outlines that "By 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained" (Nations, 1992; VanderZwaag, 2012). Target 12 has not been completed by Canada for corals and sponges, as mentioned before the IPCC has released reports on how corals and sponges may react to climate changes, their results showed that 70-99% of coral and sponge populations will decline in future years (IPCC, 2018). Additionally, DFOs coral and sponge science department has undergone numerous studies using modeling techniques for corals and sponges to understand how they may react to indirect impacts. Wang (2022) published a paper that used modeling to determine future habitat suitability for the vulnerability *Paragorgia arborea*. The results showed an estimated projection of 99% loss of suitable habitat for this coral species, leading to a potential large loss in this coral and thus creating a potential ecosystem collapse (Wang, 2022).

The CBD has produced a number of guidelines that are important for the sustainability of marine ecosystems (VanderZwaag, 2012). During the 2016 Conference of the Parties to the Convention on Biological Diversity a number of decisions were adopted (CBD, 2016). Decisions were recalling paragraph 7 of the annex to decision XII/23 urging parties to "advocate and contribute to effective carbon dioxide emission reductions by reducing anthropogenic emissions from sources and through increasing removals of greenhouse gasses by sinks under the United Nations Framework Convention on Climate Change, *noting* also the relevance of the Convention on Biological Diversity and other instruments" (CBD, 2016). The document quotes "cold-water areas sustain ecologically important and vulnerable habitats, such as cold-water corals and sponge fields, which play important functional biological and ecological roles, including supporting rich communities of fish as well as suspension-feeding organisms such as sponges, bryozoans and hydroids, some of which may be undergoing change due to the combined and cumulative effects of multiple stressors, including both global stressors, in particular ocean acidification, and local stressors" (CBD, 2016). The CBD outlines the importance of conserving cold-water coral and sponges from climate impacts and urges nations to take action. The convention's guidelines outlines how nations should further develop predictive models to identify refugia and conserve them to aid in species adaptation, while also improving species and habitat occurrence (CBD, 2016).

Aside from Canada's commitment to the CBD, and the CBDs great understanding of the protection of cold-water coral and sponges from climate change, the CBD does contain some weaknesses throughout. One large issue is that the CBD is unable to enforce compliance amongst nations, leading to targets getting neglected and countries unable to fulfill their commitments. Meaning that while the CBD contains great guidance and advice, they are having a difficult time ensuring nations are following up with their responsibilities, leaving coral and sponges to defend for themselves.

3.4 International Initiatives

3.4.1 Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) was developed in 1988 by both the United Nations Environment Programme (UN Environment) and the World Meteorological Organization (WMO) (IPCC, 2022). The IPCC is supported by 195 member states involved and comprises three main working groups that look at different aspects of scientific information and climate change (IPCC, 2022). These three groups are, 1. The Physical Science Basis, 2. Impacts, Adaptation and Vulnerability, and 3. Mitigation of Climate Change (IPCC, 2022). Through these three main groups and the addition of their task force, IPCC is able to identify the current state of climate change, what further research is necessary, and provide information regarding future predictions (IPCC, 2022). The main goal of the IPCC is to provide decision makers with the most recent and reliable scientific, technical and social information relevant to climate change impacts. The reports that IPCC produces are all readily available online to allow for transparency and guidance (IPCC, 2022).

The IPCC has expressed its understanding of the causes and impacts that arise from climate change and has presented options for management by proposing mitigation and adaptation strategies (IPCC, 2018). One understanding is that global warming is directly linked to greenhouse gas emissions and the warming level is above the pre-industrial levels of 1.5°C (IPCC, 2018). It is estimated that pre-human activities, the global warming level was likely between 0.8°C and 1.2°C , now with the increase in anthropogenic activities it is hypothesized that the global temperature will reach 1.5°C between the years 2030 and 2052 if activities persist without change (IPCC, 2018). But other projections suggest we may be moving at a rate that will exceed this limit. IPCC is used more as a tool for information to aid in decisions and to inform negotiations, rather than an enforceable instrument meaning that nations do not have to rely on the IPCC when developing their conservation measures.

International treaties and initiatives have their uses and allow for global collaboration and conservation measures. However most of the time they are vague and leave room for interpretation and noncompliance, leading to no real changes. Nonetheless, numerous nations, including Canada have taken their commitments seriously to some degree and have developed some of their own laws, strategies and plans to better align with their responsibilities.

Chapter 4. Canadian National & Regional Tools: Laws, Strategies, Plans & Organizations

In addition to international laws, strategies and plans, countries such as Canada contain their own ideas on how conservation will be achieved within their country (VanderZwaag, 2012). In the start of 1945 came the increase for asserting power through governance and jurisdiction over the ocean resources in a nation's borders (Mageau, 2015). This power assertion grew globally, soon nations from all over started to develop and understand the ownership of their resources; creating restrictions and management plans in their spaces (Mageau, 2015). The management of the ocean carries some difficulties as the ocean is forever moving which creates boundaries that are not always clear and impacts can be hard to detect with the numerous ocean users (Mageau, 2015). Despite these challenges, Canada has come up with substantial modes of conservation and management and thus, has been deemed a global leader for ocean management by global countries (Mageau, 2015). The international treaties in chapter 3 have gained Canada’s commitment to meeting specific goals. Additionally, Canada is just one of the many nations that contain a number of internal laws, strategies and plans that guide and standardize their decision making, while simultaneously committing and supporting the conservation of the marine environment (Breeze, 2007; VanderZwaag, 2012).

Within the Atlantic and Pacific waters of Canada there have been approximately 23-30 species of deep-sea coral and about 34 species of deep-sea sponge that have been confirmed to reside in the area (Breeze, 2007; Campbell, 2009; Finney, 2009). The habitation of deep-sea coral and sponges makes the region’s ocean resources far more valuable than originally expected (Breeze, 2007; Campbell, 2009; Finney, 2009). Despite the fact that Canada has been considered a global leader; the country is far behind in the integration of a climate change modeling, monitoring, and management plan for ocean conservation. Mageau et al. (2015) points out how plans, acts, strategies and management practices that Canada has thus far implemented are becoming outdated; these governance tools were created during a time where resources were plentiful, the ocean was healthy and there were little to no conflicting arguments amongst users. While now the ocean is being heavily impacted by anthropogenic impacts such as climate change and pollutants which are resulting in a depletion of ocean resources, killing the ocean and its biodiversity which is creating more conflict and is disregarding the bigger picture (Mageau, 2015). While Canada contains numerous conservation plans, targets and objectives, they are failing to understand the need for a climate change management plan for both the ocean and deep-sea ecosystems. Below we discuss the numerous conservation methods that are being utilized in Canada, and where they fail to meet larger objectives.

4.1 Canadian National Tools: Laws

4.1.1 Oceans Act

The *Oceans Act* was developed to implement a fundamental approach for ocean management to address the issues within the ocean (Jessen, 2011). The *Oceans Act* came into force in 1997 after 10 years of development (Jessen, 2011). The *Oceans Act* (1996) outlines Canada's legal authority over its ocean spaces, offers instruments for spatial marine area protection, and establishes a framework for integrated ocean management through cooperation between different governmental levels and agencies (Bent, 2022). Additionally, the *Oceans Act* describes the duties and responsibilities Canada has within its territory and outlines Canada’s ocean lines and zones, such as fishing zones, continental shelf, territorial sea, exclusive economic zone, etc. (DFO, 2015). This Act gives Canada both authority and accountability to ensure they are promoting sustainable development and sustainable management approaches within waters under their jurisdiction (DFO, 2015). The *Oceans Act* is Canada's flagship marine protection law, giving them the responsibility to lead a national system of conservation plans such as Marine Protected Areas (DFO, 2015; Jessen, 2011).

Section 17 and 18 of the *Oceans Act* outlines information regarding the continental shelf and Canada's sovereign rights. The Act defines the continental shelf as extending beyond Canada's territorial sea and EEZ; however, outlining that Canada still contains jurisdiction over exploring and exploiting the sedentary species and mineral resources of that continental shelf (Oceans Act, 1996). While in section 35 of the act, it outlines that the designation of MPAs may only be established within internal waters, the territorial sea or the exclusive economic zone of Canada, meaning even though Canada contains jurisdiction outside of its EEZ it may not establish MPAs for the protection of species, such as deep-sea coral and sponges (Oceans Act, 1996). This is a legislative barrier that is impacting Canada's ability to conserve vulnerable species in the high seas, such as deep-sea coral and sponges.

After the act was developed and instated, Canada was then considered a global leader for modern oceans management as they were the first country to adopt a comprehensive ocean management plan (DFO, 2005; Jessen, 2011). However, even after nearly two decades of the act being enforced many promising features have not been fully implemented are in need of renewal and further amendments. The Act itself contains many faults that weaken the legal authority it has been given. One issue is that the Act lacks adequate governance instruments to ensure all federal governments and departments are compliant with the rules of the Act (Jessen, 2011). In addition to Jessen (2011), Bent (2022) also acknowledges and outlines how the Act contains many weaknesses. Bent (2022) mentions that the Act lacks a baseline of protection as well as protection standards, and contains no requirements to create and implement management plans. Bent (2022) also acknowledges that although regulations under the Act do contain a standard prohibition of activities that "damage, disturb, destroy, or remove any living marine organism or habitat", there is no information on how the Act defines such activities, leaving the Act too broad and difficult to enforce (Bent, 2022). Furthermore, the *Oceans Act* does not mention climate change within its legislation which is creating a further deviation from achieving conservation targets (Jessen, 2011). Nonetheless, this act is one of the few that has been used to promote the protection of cold-water corals and sponges (Breeze, 2007). The *Oceans Act* also contains numerous key provisions that have the ability to restrict many different types of activities through the implementation of Marine Protected Areas (MPAs), Marine Spatial Planning (MSP) and Integrated Planning; however this paper will only cover MPAs (Breeze, 2007).

4.1.1.1 Oceans Act: Marine Protected Areas

Marine protected areas (MPA) are conservation areas that aid in the protection of marine habitats, species and ecosystems (World Wildlife fund, 2022). MPAs are legally protected and managed areas that aim to achieve long-term protection of the natural environment and have the ability to benefit Canadians through environmental, social, cultural and economic benefits (DFO, 2019). MPAs are normally designated through regulations under the *Oceans Act*, but they can be created by federal, territorial or provincial governments and can also be created using other Canadian legislation such as the *Canada National Marine Conservation Act* and the *Canada Wildlife Act;* but for this paper, we will be focusing on *Oceans Act* designations (World Wildlife fund, 2022; Breeze, 2007).

To designate an area as an MPA under the *Oceans Act*, there are five main steps that need to be completed:

- “Step 1: Selection of Area of Interest (AOI) through one of the 13 bioregional MPA Network Process”
- “Step 2: Ecological/biophysical, social, cultural and economic overview & assessment of the AOI”
- “Step 3: Development of the regulatory intent and consultation with interested/affected parties”
- “Step 4: Regulatory process & designation of the MPA”
- Step 5: MPA management” (DFO, 2019).

The Department of Fisheries and Oceans Canada has six regions which designate, manage and administrate MPAs (Breeze, 2007). These six regions are responsible for the protection of marine species, habitats and ecosystems within their own district (Breeze, 2007). In Canada, there are currently 14 MPAs designated under the *Oceans Act* (Bent, 2022; DFO, 2019). The designation can also contain zones within an MPA where specific activities may either be restricted or allowed (Bent, 2022). The restriction of activities aids in the conservation and protection for marine ecosystems and ensures no activities are allowed that disturbs, damages or destroys the marine environment (Bent, 2022).

Although MPAs are used as a conservation tool, they contain their own set of weaknesses. MPAs lack the requirement to develop and enforce a management plan in an efficient timeline (Bent, 2022; Jessen, 2011). Additionally, MPAs are unable to be designated outside of Canada’s EEZ as per the *Oceans Act* (Oceans Act, 1996). EEZ refers to the sea beyond Canada’s territorial sea, but not beyond 200 nm from the baseline of Canada’s coast (Oceans Act, 1996). However coral and sponges do not segregate to accommodate Canada’s jurisdictions, rather they extend this invisible line and are found to house within ABNJ. Furthermore, MPAs do not guarantee that deep-sea corals and sponges will not be damaged by activities such as fishing, even with such restrictions in place (Foley, 2010). Between 1970 and 2001, Koenig (2001) reported that there was strong evidence to show that illegal trawling activities were still taking place within a conservation area off the central east coast of Florida. The area had been closed to fishing activities in 1984 and was designated a Habitat Areas of Particular Concern (HAPC) area (Koenig, 2001). After monitoring observations were conducted, there was substantial evidence that showed more than 90% of the Oculina habitat was destroyed due to illegal fishing activities in the conservation area. Furthermore, MPAs are typically designed for one conservation effort, and have issues addressing numerous threats to the marine ecosystem (Bent, 2022). Bent (2022) outlines the importance of looking to MPAs as one part of a solution to conservation and ecosystem adaptation, and should not be used as the sole tool (Bent, 2022).

4.1.2 Fisheries Act

Fishing activities are the most valuable economic contributors, but are also one of the most invasive activities that are impacting deep-sea corals and sponges off the coast of the Maritimes region in Canada fishing (Breeze, 2007). The *Fisheries Act* allows the government, specifically the Department of Fisheries and Oceans Canada to manage, support, restrict and close commercial, recreational and Indigenous fisheries (DFO, 2015). This authority ensures fisheries across Canada are sustainable and productive for both fishermen and fellow Canadians (DFO, 2015). This authority also ensures that fishing activities are not causing harm such as “death of fish or permanent alteration to, or destruction of, fish habitat” (DFO, 2015).

In 2002, DFO implemented the first *Fisheries Act* closure for the conservation and protection of cold-water corals and sponges (Breeze, 2007). It became known to DFO that direct anthropogenic activities such as fishing activities were heavily impacting deep-sea habitats and species such as corals and sponges and that restrictions needed to be implemented. Soon fishery closures through designation by the *Fisheries Act* became one of the most common conservation methods for deep-sea benthic fauna (Breeze, 2007). But similarly to MPAs, the restriction of fishing does not always guarantee that illegal fishing activities will not take place. Nonetheless, the implementation of the fisheries closure by the *Fisheries Act* gave a new direction into the conservation of such species, this method gave rise to a new method called Marine Refuges.

4.1.2.1 Fisheries Act: OECM's

Other Effective area-based Conservation Measures (OECM) were introduced in 2010 at the 10th annual meeting of the Conference of the Parties to the United Nations Convention on Biological Diversity (Bent, 2022; DFO, 2020a). This conservation tool was introduced when Aichi Target 11 was agreed upon by all included parties that agreed to conserve at least 17% of terrestrial and inland waters, and 10% of coastal and marine areas by 2020 (DFO, 2020a). This tool was adopted and implemented to protect both coastal and ocean areas in a form unlike MPAs (Bent, 2022). OECMs have the ability to offer a simple conservation implementation to quickly and efficiently protect an area (DFO, 2020a).

Other Effective area-based Conservation Measures or 'Other Measures' are conservation tools that conserve an area by means other than that of a protected area (DFO, 2020a). An OECM is governed and managed differently than a typical MPA in that they will achieve positive and sustainable long-term goals for the conservation of biodiversity and ecosystems (DFO, 2020a; Lemieux, 2019; Tan, 2021). The main difference between an OECM and an MPA is the primary purpose of the designated area (Tan, 2021). An MPA may outline a number of conservation objectives, but OECMs may exhibit conservation in the process of attempting to meet other main objectives. However, OCEMs must contribute towards biodiversity which is one objective that is not required by an MPA (Tan, 2021). Such OECMs such as fishery closure measures have created new conservation areas called marine refuges that have been used in places for the conservation of deep-sea corals and sponges.

4.1.2.2 Fisheries Act: Marine Refuges

Marine refuges were created by DFO in 2017 as a designation under the *Fisheries Act*, they are declared as a form of OECM (Bent, 2022). Marine refuges are long-term fisheries closures under ministerial regulations, license conditions and variation orders put in place to conserve marine ecosystems, species and biodiversity (Bent, 2022; World Wildlife fund, 2022). Marine refuges can be designed and implemented at a faster pace than marine protected areas, this allows the Aichi conservation targets to be met quickly and efficiently by Canada (Bent, 2022; World Wildlife fund, 2022). Marine refuges were mainly used to meet their committed targets faster, but are now used to implement fast conservation measures (Bent, 2022).

Currently there are 34 established marine refuges and they make up a majority of the conservation areas within Canada (Bent, 2022). The Jordan Basin Conservation Area is just one of the many established marine refuges within Canada’s waters. This marine refuge is located on the Scotian Shelf Bioregion of Nova Scotia and is approximately 49km² (DFO, 2022a). This conservation area contains only one protection objective and that is to conserve the cold-water corals in the area which are *Primnoa resedaeformis* (DFO, 2022a). The protection is derived through prohibiting all bottom-contact fishing gear to relieve some of the pressures such species are enduring (DFO, 2022a).

Fishery closures are the best way to prevent interactions between bottom contact fishing gear and benthic habitats and species (Muñoz, 2020). Such benthic habitats are home to deep-sea corals and sponges and the implementation of marine refuges allow these species to thrive (World

Wildlife fund, 2022). However, this is also the main weakness for marine refuges, is that they are only able to restrict fishing activities. Because of this one ability, it is difficult to mitigate other threats that may be adding an additional pressure to such deep-sea species (Bent, 2022). Additionally, unlike MPAs, marine refugees lack permanence; meaning that there is always a chance they can be removed (Bent, 2022).

4.1.3 National Marine Conservation Areas Act

The Canada National Marine Conservation Areas Act (NMCA) (2002) was enacted to identify and establish marine protected areas to aid in the conservation of marine environment across the 29 Canadian regions (Bent, 2022). The Act outlines the importance of protecting the natural, self-regulating marine ecosystems in order to maintain biodiversity (CNMCAA, 2002). The Act acknowledges the use of adopting the precautionary approach in instances where scientific information is uncertain to ensure the conservation of the marine environment (CNMCAA, 2002). The NMCA allows designations in one of three areas; internal, territorial and within a nation's Exclusive Economic Zone EEZ (Bent, 2022).

Additionally, this Act was designed for the conservation of seabed and benthic species and contains baseline conservation measures that restricts bottom-contact fishing gear, mining, dumping and oil and gas (Bent, 2022). However, this Act contains some issues, one being the establishment of an NMCA and the implementation and enforcement of restrictions are both a lengthy process (Bent, 2022). An additional issue is that the Act does not mention or acknowledge climate change, nor does it contain any mitigation or management plans for the impacts climate change will post. However, the most recent amendment was in 2019 and is to be re-amended in 2022 which will be current until January 25th, 2023, meaning there is still hope that climate change be mentioned (CFLC, 2023).

4.2 Canadian National Tools: Strategies

4.2.1 Canada's Ocean Strategy 2002

Canada's Ocean Strategy of 2002 provides a strategic framework for ocean-related programs and policies that are based on the sustainable development guiding principles (DFO, 2002). Such guiding principles are applied by a central governance mechanism within the strategy through development and implementation of integrated management plans (DFO, 2002).
An integrated management plan for Canada's ocean systems would require a large consideration around the impacts and pressures that marine ecosystems endure (DFO, 2002).

The strategy acknowledges the economic contribution that estuaries, coasts and oceans provide (DFO, 2002). The strategy outlines how any management plan that were to be introduced would consider both the conservation of marine ecosystems as well as understanding the importance of providing job opportunities and building economic growth (DFO, 2002). Aside from the numerous mentions of direct impacts and economic growth, the topic of climate change only appears twice within the entire document; leading readers to believe that climate change is not a topic of concern at this point in time.

4.2.2 Coral and Sponge Conservation Strategy for Eastern Canada, 2015

The *Coral and Sponge Conservation Strategy for Eastern Canada* was released in 2015 (DFO, 2015). This strategy has been used as a tool that can be integrated into the larger regional management plans (Finney, 2009). The strategy acknowledges the importance to protect and conserve deep-sea sponges and corals within Eastern Canadian waters, and with the guidance of this strategy the goal is that it can be achieved through integrated ocean management and collaboration (DFO, 2015). The strategy also acknowledges that deep-sea coral and sponges are ‘integral components of a health ecosystem’ (DFO, 2015). The goal of the strategy is to facilitate conservation and protection plans for cold-water coral and sponges, the habitats they provide and the communities they create within Eastern Canada (DFO, 2015). The strategy identifies a number of targets and actions that are meant to guide provinces to meet their objectives and the objectives of the strategy. These targets and actions are to aid in conservation, management and research interests of the provinces of Eastern Canada (DFO, 2015). The targets are broad overarching titles, while the actions are meant to facilitate the objectives of the targets. For example Target 1 is “Define and identify important coral and sponge areas”. Which contains four actions to meet this target being 1. “Refine and focus on ‘significant’ coral and sponge species” 2. “Compile and map existing data on the distribution and relative abundance of coral and sponge species, and update as new data becomes available” 3. “Identify and delineate significant coral and sponge concentrations using advice from Canadian Science Advisory Secretariat (CSAS), predictive models and other appropriate sources” and 4. “Identify and delineate coastal sponge aggregations and study their distribution and ecological function” (DFO, 2015).

The *Coral and Sponge Conservation Strategy* briefly mentions and acknowledges climate change. The document mentions how climate change is impacting the ocean and marine environments within it (DFO, 2015). The strategy acknowledges impacts such as sea level rise, upwelling changes, changes to ocean circulation patterns, ocean acidification and increases in ocean temperature. All of these are briefly mentioned and are then related back to how these changes will impact deep-sea coral and sponge species. While this information is important to have when creating ocean conservation plans, the strategy does not suggest any solutions to how to combat, adapt, or mitigate climate change within such management plans. Nonetheless, the strategy does mention and outline their lack of information and available research which creates gaps in the scientific information (DFO, 2015).

Although this strategy is not meant to act as a management plan, it is a strategy that provinces could look to when developing conservation priorities (DFO, 2015). The management options within the document also are vague and only consider the management of direct impacts and not the indirect impacts. The strategy is also meant to be updated every 5 years, yet it has been nearly 8 years and the strategy has remained the same. The hope is that the strategy can benefit decision makers, clients and the marine environment by fostering information, creating accountability and ensuring provinces are being transparent with their communities (DFO, 2015). However, with very little mention of climate change, indifference behavior from provinces, no guidance on climate change management and year delayed strategy updates, this strategy is failing to help protect deep-sea coral and sponges in Canada.

4.2.3 Canada's National Adaptation Strategy

From the Paris Agreement came requirements that parties put an adaptation mechanism in place to adapt to changes in climate. Canada developed the National Adaptation Strategy as part of their commitments to the Paris Agreement. The strategy focuses on pre-planning and acting on the predetermined impacts of climate change, and attempting to make appropriate changes before impacts happen (ECCC, 2022a). The National Adaptation Strategy was released in November 2022; however, it has a focus on the human aspect rather than the impacts that our marine ecosystems will endure (ECCC, 2022a). The strategy outlines ways in which climate change will impact Canada and Canadian coastlines. The document focuses on land-related impacts from climate change such as; forest fires, sea-level rise impacting coastal communities, infrastructure damage, drought, etc. (ECCC, 2022a). While this strategy is not meant to be a management plan, it does outline the importance of adaptive management to combat climate changes, and could be utilized to address climate changes for the marine environment, including coral and sponges.

4.3 Canadian National Tools: Plans

4.3.1 Government of Canada Adaptation Action Plan

During the same time as Canada's National Adaptation Strategy was released, another document called the Government of Canada Adaptation Action Plan (GOCAAP) was also published (ECCC, 2022b). The Adaptation Action Plan was released in 2022 which uses the strategy as a blueprint for the action plan that aids in raising awareness on Canada's priorities. The Adaptation Action Plan acknowledges the impacts of climate change and understands that action is required to ensure Canadians across the country are able to adapt to the changes around them (ECCC, 2022b).

The action plan outlines similar things to that of the strategy; focusing on human factors, economic loss, and building resilient communities (ECCC, 2022b). The plan emphasizes the importance of being better prepared to respond and recover to changes around them, and that the adaptation actions implemented now will aid in the future for Canadians (ECCC, 2022b). But one thing that the action plan mentions, that the strategy does not; is that the Government of Canada is responsible for the protection and sustainability of Canada's ocean and marine spaces. This document outlines their responsibilities and some ways they wish to perform those responsibilities. One large one being the modernization of the *Oceans Act* to specifically mention climate change and consider its impacts on both the marine ecosystem and its species (ECCC, 2022b). The document outlines that impacts on the marine environment and ecosystems need to be considered, alongside developing a national working group with an interdisciplinary background to focus on climate-resilient conservation planning (ECCC, 2022b).

While this action plan has only been recently enforced, it shows that the Canadian Government understands the importance of adapting and creating resolutions before impacts happen. Additionally, the plan outlines how changes need to be made to older legislation to ensure adaptation is applicable.

4.3.2 Canada's Oceans Action Plan

Following the passage of the *Oceans Act* (1996) came Canada's Oceans Strategy (2002) which led to the establishment of a new policy framework to modernize oceans management called Canada's Oceans Action Plan (DFO, 2005). Within Canada's Oceans Action Plan of 2005, the government of Canada committed to conserving and protecting important, productive and biologically diverse areas and species with high vulnerability (DFO, 2005; Breeze, 2007). This action plan outlines a nation-wide government approach for sustainable development within Canada (DFO, 2005).

The Oceans Action Plan (2005) is based on four main associated themes:

- "International Leadership, Sovereignty and Security"
- "Health of the Oceans"
- "Ocean Science and Technology"
- "Integrated Oceans Management for Sustainable Development"

These four main themes are meant to drive the policy into a positive, effective and efficient direction into modern ocean management. The government of Canada is committed to using the policy to maximize the use and development of ocean technology, conserve the ocean resources through the establishment of a network of MPAs, update and enforce rules in the ocean and fisheries, and implement a number of cohesive management plans (DFO, 2005). The policy framework outlines the importance of modernizing management plans for the ocean to ensure the longevity of resources for Canadians both in the present and future (DFO, 2005). The Action Plan outlines the challenges ocean management is currently facing as management measures lose relevance (DFO, 2005). The Canada's Ocean Action Plan (2005) outlines how Canada's current approach to ocean management has resulted in:

- "Failing oceans health, including some declining fish stocks and increasing fluctuations of stocks, increasing numbers of marine species at risk and invasive species, marine habitat loss, and declining biodiversity"
- "Growing oceans user conflicts and administrative, jurisdictional and regulatory complexities, and lost or delayed investments"
- "An ocean industry sector that is significantly weaker than its potential"

The three results listed above allow us to understand the importance of modernizing management and also gives us the information needed to identify that the government of Canada acknowledges their faults and knows where they can improve and that they need to adapt to changes around them.

The action plan outlines the importance of the health and productivity of the oceans and ocean ecosystems (DFO, 2005). While the plan outlines a number of direct impacts, the plan briefly mentions the impacts of climate change. Such mention consists of how climate change impacts are creating major shifts within oceanography cycles and how certain locations may be impacted by climate change in the future (DFO, 2005). While the policy mentions climate change on three different occasions, it is clear the document contains either little information or little care for climate change impacts. It is understandable that the document contains very little mention of climate change as it was written within the early 2000s which was a time where global warming impacts were misunderstood in the perception of the public.

4.4 Canadian Regional Tools: Organizations

4.4.1 Northwest Atlantic Fisheries Organizations

The Northwest Atlantic Fisheries Organization (NAFO) was founded in 1979 and is an intergovernmental fisheries science and management body (DFO, 2021; NAFO, 2022b). NAFO currently consists of 13 contracting parties that contain their own representatives, experts and advisors (NAFO, 2022b). The objective of NAFO is to aid in the collaboration of party members, ensure knowledge and information is shared amongst members and, to use this shared information to manage and conserve the high seas or Areas Beyond National Jurisdiction (ABNJ) resources within the Northwest Atlantic Ocean (DFO, 2021). The ABNJ consists of more than 40% of the global ocean, these waters are not owned or governed by one single nation, rather all nations share a responsibility in the management and conservation of such resources (FAO, 2020). The organization’s long term goal is to “ensure long term conservation and sustainable use of the fishery resources in the Convention Area and, in so doing, to safeguard the marine ecosystems in which these resources are found” (NAFO, 2022b). As NAFOs objectives are to conserve fishery resources, they are then by association interested in conserving fish habitats and ecosystems; including deep-sea corals and sponges. Within ABNJ bottom-contact fishing gear is deployed on continental shelves, slopes, seamounts, ridges, etc. which are all topographic areas that deep-sea fauna favor (NAFO, 2022a). In 2014 it was estimated that more than 150,000 tonnes of catch was caught by bottom-contact fishing (NAFO, 2022a). This catch has been reported to capture more than 50 species, both intentionally and accidentally (NAFO, 2022a).

As mentioned previously the *Oceans Act* limits the amount of protection Canada can implement within ABNJ; however, NAFO acts as a partial solution. NAFO has implemented Vulnerable Marine Ecosystems (VME) into their conservation and protection methods after the United Nations General Assembly resolutions that called for the conservation of such vulnerable ecosystems (Kenchington, 2019). VMEs are a conservation tool that mainly restricts bottom contact activities in areas where there has been a sensitive benthic area identified (NAFO, 2022b). Since the adoption of VME, NAFO has implemented 14 fishery closures for the conservation of deep-sea coral and sponges (Kenchington, 2019).

In 2004 NAFO adopted the United Nations General Assembly (UNGA) resolution to protect VMEs from fishing impacts in ABNJ (NAFO, 2021). The UNGA has passed several resolutions for conserving cold-water corals and sponges, and urges nations to do the same, including Canada (Finney, 2009). The scientific council of NAFO has since implemented their own conservation measures for deep-sea fauna through seamount closures; which are areas closed to bottom-contact fishing gear; however, regular fishing activities are still permitted (NAFO, 2021).

In 2022, the United Nations held their fifth session at the Intergovernmental Conference on implementing the first-ever treaty on conserving ocean's biological diversity in ABNJ (Nations, 2022; Robin, 2022). This meeting was following the 2018 conference that discussed a number of matters including ABNJ (Nations, 2022). The conference was meant to be in 2019 but due to COVID-19 the session was postponed until 2022 (Nations, 2022). The expectation is to implement an internationally legally binding agreement under UNCLOS (1982) to ensure the conservation of marine biodiversity and ecosystems within the high seas or ABNJ (Nations, 2022; Robin, 2022). The discussion did not come to a finalized agreement, but rather will be further discussed in the resumed fifth session of the Intergovernmental Conference which is expected to take place early 2023 (Nations, 2022).

High-seas conservation areas for the deep-sea are going to be crucial for global conservation efforts to be achieved (Gjerde, 2007). Gjerde (2007) outlines how coral and sponge protection within the high seas will require both passive and active conservation measures to prevent overlap between fishing gear and coral and sponges, while also looking into gear modification to reduce contact (Gjerde, 2007). Gjerde (2007) also expressed that there are several legal issues that will need to be altered in order to have success in high seas conservation.

4.5 Climate Change is Challenging Canada's Ocean Conservation Approaches

Even with the numerous developed management plans, monitoring strategies and modeling projects, Canadian enforced legislation is not only insufficient for the needs of conservation, but is becoming increasingly challenging to commit to (VanderZwaag, 2012). Although Canada has committed to fulfilling a number of both international and national agreements (VanderZwaag, 2012). However, as Canada has the world's largest coastline and a large marine environment to cover, much of the country's obligations have gone either incomplete or poorly executed (VanderZwaag, 2012). With the addition of indirect impacts such as climate change, it is now impacting the way in which Canada implements conversation methods.

Climate change is now testing the effectiveness of conservation methods such as MPAs, Marine Refuges, Indigenous Protected and Conserved Areas (IPCA) and more. While Canada has developed and implemented conservation methods to decrease a number of stressors to the deep-sea, there are outside factors that such conservation measures are unable to help protect species against. As climate change impacts the conditions of the deep-sea there is a risk of loss in population expansion, and disruption to hitherto established populations (Dijkstra, 2021).

Canada has committed to meeting Aichi targets by conserving 25% of ocean habitats by 2025 and 30% by 2030 (DFO, 2022b). The conservation targets are to be reached by using both MPAs and OCEMs to conserve ocean species and habitats (DFO, 2022b). However, in this case direct impacts are no longer the threat and indirect impacts are. How is Canada going to adapt in order to conserve ocean habitats, species and ecosystems from indirect impacts? There are also many concerns that conservation areas and management plans are being implemented for the sake of meeting the global Aichi targets and not for the actual protection or conservation of habitats and species. Many Canadians believe that Canadian jurisdictions are more focused on the quantity of marine conservation than the quality (Lemieux, 2019). An additional argument by Lemieux (2019) mentioned how OECM: marine refuges may also be a redesigned version of fishery closures and bring questions regarding the real intent of Canada's commitments to both CBD and its own conservation laws and plans (Lemieux, 2019).

Chapter 5: National and Local Plans for Conservation of Coral and Sponges

Other countries have also committed to conservation and protection of deep-sea coral and sponges (Breeze, 2007). Other countries have agreed and ratified international treaties as well as developed and implemented their own set of conservation measures and methods to protect such vulnerable species (Breeze, 2007). As climate change impacts on the deep-sea are becoming more known, numerous countries have started to implement methods to increase resilience and mitigate climate impacts. Some countries are focused mainly on decreasing emissions from sources to decrease the impacts, while others such as New Zealand and Australia are implementing monitoring, modeling and testing hands-on methods to understand the impacts and how to mitigate them (Consalvey, 2006; CSIRO, 2022).

5.1 New Zealand

5.1.1 New Zealand Coral and Sponges

New Zealand is a maritime region that contains the fourth largest EZZ on the globe (DOC, 2021). Within the region of New Zealand live numerous deep-sea corals and sponge species that support a variety of astonishing biodiversity within numerous ecosystems (Mobilia, 2021; Tracey, 2019). It is estimated that New Zealand's waters contain between 55-110 coral species and include the deepest reef-forming coral species globally and contain more than 700 sponge species (Kelly, 2018; Tracey, 2019). New Zealand's deep-sea corals are mainly comprised of black corals, stony corals, octocorals and red corals (Consalvey, 2006).

As New Zealand understands the importance of conserving and restoring such vulnerable species, they have also signed onto numerous international agreements and initiatives that commit the country to a number of responsibilities. Such international agreements and initiatives are similar to those that Canada has signed onto such as UNCLOS, the paris agreement, UNFCCC, and CBD that play a role in coral and sponge conservation (Tracey, 2019). In addition to international tools, the country has also come up with a number of policies, acts and methods to aid in the protection of such species (Tracey, 2019). In 1953 New Zealand developed the *The Wildlife Act* which outlines the corals that require protection as well the country contains a Department of Conservation Services Plan that outlines a number of methods that can be utilized to protect deep-sea species (Consalvey, 2006; The Wildlife Act, 1953). However, the main authority over the conservation of such species is the The National Institute of Water and Atmospheric research (NIWA) which oversees a number of management initiatives and scientific research and more (Tracey, 2019).

5.1.2 New Zealand's Coral and Sponge Conservation Plans, Objectives & Targets

New Zealand's parliament adopted *The Wildlife Act* of 1953 that outlined the protection for all 'black corals' and 'red corals' (Consalvey, 2006; The Wildlife Act, 1953). The *Wildlife Act* applies to the lands and waters of New Zealand, including their EEZ and Territorial Sea (Tracey, 2019). This Act is administered by the Department of Conservation which is the public service department that is charged with conserving New Zealand's natural and historical heritage and species (DOC, 2021). This Act focuses on protection and control of wildlife which include corals and sponges through the amendment of the Act in 2010 (Tracey, 2019). But with the increased recognition of anthropogenic impacts on corals and sponges, this protection act is being reviewed and revised by the parliament to better define what 'black corals' and 'red corals' are to ensure appropriate conservation is enforced (Consalvey, 2006).

Currently, much of New Zealand's coral and sponge conservation initiatives are focused on addressing core required research on deep-sea corals and sponges (Consalvey, 2006). The conservation of cold-water corals and sponges is dependent on the available research, and New Zealand's numerous science departments understands that without adequate research on species ecology and how long term impacts will affect deep-sea benthic communities, it is difficult to come up with an effective management plan (Consalvey, 2006). Climate change modeling and monitoring projects and studies are under development to assess the current, and future status of such vulnerable species (Consalvey, 2006; Tracey, 2019).

5.1.2.1 National Institute of Water and Atmospheric Research

The National Institute of Water and Atmospheric research (NIWA) was established by the Crown Research Institute (CRI) in 1992 (NIWA, 2022). NIWA contains more than 610 employees working in different sectors at different levels to conduct leading environmental science to inform and enforce sustainable management within New Zealand as well as the globe (NIWA, 2022). The institute's purpose is to enhance the economy and incorporate sustainable management for the marine and aquatic resources of the region while simultaneously undergoing research that provides an understanding to the impacts of climate change and how resilience of species can be improved (NIWA, 2022).

In 2022, NIWA's scientists published a research paper that outlines the need for conservation and protection for deep-sea coral and sponges from climate change impacts (Anderson, 2022). Anderson (2022) outlines the importance of understanding the current distribution of coral and sponges and what environmental conditions are favorable for such species. From this information Anderson (2022) outlines how we can then understand and identify areas of potential coral and sponge refugia in the future based on changes in ocean conditions. Ocean conditions are subject to be altered by climate change, while others may remain relatively suitable for deep-sea corals and sponges.

To understand the future distribution of deep-sea species, we first need to understand the past and present state of the distribution. Many models have failed in the past due to the limitations of model predictability, but with rapidly developing modeling technology they are more reliable (Anderson, 2022). Currently in New Zealand a regional model has been developed that incorporates highly complex aspects of biology, chemistry and ocean biogeochemistry to understand and model the climate system (Anderson, 2022). Earth System Modeling (ESM) provides a way to estimate the past, present and future conditions of the marine environment, Habitat Suitability Models (HSM) can produce useful projections of species preferred habitat and predict the probability of species occurrence based on the known distribution of species and Species Distribution Models (SDM) have the ability to provide a way to project potential distribution changes amongst species (Anderson, 2022; Gormley, 2015; Morato, 2020).

The study used the latest predictions from New Zealand's ESM in combination with several complex data sets and fixed variables to build a model that would present the climate impacts on the distribution of deep-sea species (Anderson, 2022). Anderson (2022) used 12 taxa of deep-sea corals in the New Zealand region for the predictive models and used both two HSM; Random Forests and Boosted Regression Trees, and an ESM to predict the seafloor environmental conditions both in the present and in the future (Anderson, 2022). Both models predicted that most species will undergo substantial shifts in their locations most suitable (Anderson, 2022). Anderson (2022) also suggests the consideration for connectivity pathways to colonize corals into potential predicted future refugia. By using habitat suitability models, we can understand what marine ecosystems will be destroyed and what areas will become new refugia for such deep-sea benthic species and habitats. This understanding will enable adequate future protection against changing climate conditions (Anderson, 2022).

5.1.2.2 Department of Conservation

5.1.2.2.1 Services Programme Strategic Plan

The Department of Conservation contains a Services Programme Strategic Plan which provides guidance and plans to protect and conserve deep-sea coral species (Consalvey, 2006). The Strategic Plan's purpose is to provide guidance to the Department of Conservation to aid in decision making (DOC, 2021). The country has expressed their growing concerns about the long term impacts that deep-sea coral and sponges are enduring (Consalvey, 2006). The Strategic plan's statement outlines that they will:

- "Identify the vision and objectives for the Conservation Services Programme"
- "Establish criteria and a framework to assist in the determination of priority projects for the annual plan cycle"
- "Provide guidance for cost recovery and administration of levied projects"
- "Provide guidance on process and relationship issues"
- "Establish monitoring and review provision" (DOC, 2021).

The Conservation Services Programme mainly focuses on using the *Fisheries Act* to ensure commercial fishing efforts do not overlap or compromise the conservation and protection of species within New Zealand waters (DOC, 2021). But the Department of Conservation has also turned to focus on other management approaches to better protect the species in the region.

5.1.2.2.2 Adaptive Management

A recent publication from the Department of Conservation reviewed the impacts climate change is having on the marine environment within New Zealand. This publication looked at a range of species and potential results that will arise due to the impacts of a changing climate and marine environment (Roberts, 2022). A recommendation from the Department of Conservation publication looked at adaptive management. Adaptive management is a management tool used for decision-making during a time of uncertainty, it is an iterative process that allows for constant improvement of management practices through continuous learning and gaining new information (Steeves, 2017). Adaptive management also has the ability to reduce uncertainty and aid in the development of a resilient ecosystem (Steeves, 2017). This management tool is appropriate and applicable when working with climate change impacts on natural marine systems as it is able to address both short-term and long-term impacts (Steeves, 2017).

While this publication and recommendation is recent, adaptive management has yet to be introduced; however it is being addressed and considered within New Zealand's marine conservation management plans. Roberts (2022) stressed the importance of developing and including climate change adaptation strategies into future conservation management plans. This means that during the development process of a management plan will also have to identify and attempt to remove legislative barriers to ensure adaptation measures are met (Roberts, 2022). This integration of adaptive management will also need to include and consider species distribution models and habitat suitability models to predict changes due to climate change (Roberts, 2022). A key approach outlined within the publication mentions how key variabilities will need to be identified and observed within the models to predict how species will be influenced by the future projected ocean conditions (Roberts, 2022).

5.2 Australia

5.2.1 Australia's Corals and Sponges

Within the continental shelf of southwestern Australia lies a number of submarine canyons that are home to numerous deep-sea coral and sponge species (Trotter, 2022). Between 16-21% of the world's coral and sponges are located within the waters of Australia. These cold-water coral and sponge species act as important substrates for numerous other species and have exhibited rich ecosystems (Trotter, 2022). Much of Australia's coral and sponge species live closer to the surface; however, the region also contains deep-sea species that still remain relatively unexplored (Trotter, 2022). Approximately 2 million people benefit and are highly dependent on the corals and sponges in the country. Additionally, shallow water coral and sponges are used as a tourist attraction and on average contributed $2 billion annually. However, with the use of ROV technology, the region was able to identify the deep-sea living communities within their waters (Trotter, 2022). The region supports more than 400 species of coral and about 1500 species of sponges. The importance of such species has given rise to Australia numerous conservation plans in place to protect such vulnerable species.

5.2.2 Australia's Coral and Sponge Conservation Plans, Objectives & Targets

Although more than 85% of Australia's corals and sponges are currently protected by means of MPAs, where 25.5% of MPAs are listed as fully or highly protected areas; however, modeling projections suggest that more than half of the coral and sponges in Australia will experience the impacts of climate change, and by 2030 more than 90% of species will experience such impacts (Trotter, 2022). The impacts are predicted to create habitats that will no longer be viable for species within the next 50 years (Thresher, 2015). Because of such projections, and past experience with bleaching events, Australia has implemented both indirect and direct conservation and restoration methods.

5.2.2.1 Australian Government's Commonwealth Scientific and Industrial Research Organization

The Australian government's Commonwealth Scientific and Industrial Research Organization (CSIRO) is a multidisciplinary research organization whose main goal is to solve challenges through innovative science and technology (CSIRO, 2022). CSIRO is the national science agency and innovation catalyst for Australia who aims to increase innovation through collaboration and science (CSIRO, 2022). CSIRO has taken numerous studies and workshops to understand the climate issue and how coral and sponges in the region can adapt, restore, or resist the results of climate changes (CSIRO, 2022).

In 2015, there was a CSIRO workshop held in Australia to address the potential fate of cold-water coral and sponge communities due to climate change. The workshop consisted of numerous deep-sea ecologists, oceanographers and marine managers (Thresher, 2015). The participants discussed pressures, and jointly developed a list of potential solutions that could be implemented to reduce, mitigate or adapt to climate change impacts on deep-sea coral and sponges (Thresher, 2015). The list of ideas were developed with risk and cost attributes, as well as time and benefits in mind. For example, on time considerations, engineering options were judged to be ones that could be implemented quickly, regulatory frameworks were seen as intermediate and would take an equal amount to develop and implement, and biological options were judged to be ones that may require more time to develop and implement (Thresher, 2015).

In the end a total of 17 options or solutions were presented; 6 options were surrounding exposure reduction, 7 opinions were surrounding approaches to reduce coral and sponge sensitivity, and 4 options were surrounding the increase of adaptation to stressors (Thresher, 2015). Out of all the options, 6 contained engineering solutions, 5 contained biological solutions, 3 contained translocating solutions and the other 3 contained solutions that involve changes to regulatory frameworks (Thresher, 2015).

One focused option looked at 'liming' which is a hands-on solution which includes the dumping of lime (CaO) chemicals that increase carbonate saturation levels in reefs (Thresher, 2015). Lime is a product of limestone after it has gone through a dissolving process to dilute the calcium carbonate contained inside (Renforth, 2013). Lime dissolution in the ocean results in an increase in pH and has the ability to shift the equilibrium to reduce the CO_2 concentrations (Renforth, 2013). This method also reduced the migration of CO_2 from the atmosphere as CO_2 is then stored as a calcium bicarbonate, working as a carbon trapping mechanism (Renforth, 2013). This is because for every 1mol of lime there is 1.7mol of CO_2 stored (Renforth, 2013). Such chemical dumping methods to increase the local carbonate levels could be undertaken at a relatively low cost and could have local benefits (Thresher, 2015). The achievement idea that is proposed would be derived from the scattering bags of lime in reef areas, bags could be sourced by local cement companies and delivered by fishing boats. The uncertainty of this idea looked at the surrounding benefits, as the outcome is that the benefits would be very localized and most likely temporary. The uncertainty additionally rests with the tonnage and frequency of delivery being unknown and would need further development and studies to be determined and successfully implemented (Thresher, 2015).

Another focused discussion surrounded the conservation or 'savior' of coral and sponges in the deep-sea from the impacts of climate change. This option focused on the use of tools to identify and protect future refugia sites (Thresher, 2015). The use of modeling can aid in the discovery of past, present and future suitable habitats for corals and sponges.

An additional option was to focus on the high seas region and aid in the conservation of deep-sea coral and sponges globally, rather than just within a nation's EEZ. Outside of Australia’s EEZ are numerous coral and sponge species; however the protection of such species outside a nation's jurisdiction is difficult to enforce. This option also had relation to the previous option where future refugia would be identified, the identification of global refugia rather than only focused within an EEZ gives rise to new conservation opportunities and efforts (Thresher, 2015).

5.2.2.2 Reef Restoration and Adaptation Program: Hands-on Solutions

Australia is also currently in the developmental stages of some hands-on projects that would aid in the recovery of deep-sea sponges and corals directly. Scientists from CSIRO have accepted that indirect solutions are not always going to be plausible and to ensure climate change impacts are mitigated, direct solutions need to be considered. In 2020 Australia had its second hottest summer on record and caused more than ¼ of deep-sea corals and sponges to turn white as a result of bleaching (Conroy, 2021). This was the third mass coral bleaching event over the course of five years (Conroy, 2021). These continuing mortality events have led scientists in Australia to undergo bold actions and to consider direct options to conserve deep-sea coral and sponges.

In 2020, the Australian government announced its $116 million investment to develop and test hands-on climate change initiatives and solutions for reef restoration, resilience and adaptation (Conroy, 2021). Many techniques are investigated under the Reef Restoration and Adaptation Program (RRAP) which is a consortium of researchers working together to aid in the restoration of deep-sea coral and sponges from the impacts of climate change through coral and sponge management and methods to reduce carbon emissions (Conroy, 2021; RRAP, 2021a). The goal of RRAP is to provide managers and decision-makers with innovative, cost-effective, plausible and safe options to aid in the protection of coral and sponge against climate change (RRAP, 2021a).

RRAP is currently examining over one hundred possible methods to aid in reef resistance, adaptation and recovery from climate change impacts (RRAP, 2021b). Below are three methods RRAP is testing:

5.2.2.2.1 Cold-Water Baths

One project is the implementation of cold-water baths in the deep-sea to combat the warming temperatures and keep vulnerable species in cooler conditions (Conroy, 2021). This project involves the transportation of cooled seawater to such reefs and to guard them against high temperatures (Conroy, 2021). The cooling of reefs by water injection has been attempted on a small scale and is said to be quite successful. An aquatic scientist from CSIRO, Mark Baird said "It's appealing because it directly addresses the problem of warm water at the seabed, which causes bleaching." (Conroy, 2021). Mark Baird and his team used modeling methods to simulate 19 sites on the Great Barrier Reef during a bleaching event from 2016-2017 (Conroy, 2021). The study took studies that consisted of tidal patterns and current cycles to understand the best suitable technique to cool the water at such a large depth. The research identified that in order to cool the water enough to conserve deep-sea coral and sponges they would have to use four pumps that would pump the cooled water at 5^3m/s, and ensure the water was cooled to 27°C, which is one degree below the average temperature of the Great Barrier Reef (Conroy, 2021). This project would then have the ability to cool more than 97 hectares of coral and sponge segregations by 0.15°C which is a survivable temperature and would prevent bleaching (Conroy, 2021). The issues at hand revolve around the energy cost involved as out of the 3,100 reefs on the Great Barrier Reef, it would cost $3.9 million to cool just one over the course of the summer months (Conroy, 2021). Additionally, as 79% of Australia's energy is generated from fossil fuels, the production would be counterintuitive and further contribute to the climate change impacts that are heavily damaging such species (Conroy, 2021). This project would need further studies and results that outline the risks and benefits before applying such a project to a real world environment (Conroy, 2021).

5.2.2.2.2 Stabilization or Removal of Coral Rubble

A second example is stabilization by utilizing pre-existing coral rubble. When reefs or individual corals are damaged by a number of factors, they can have breakage or moralities which result in loose pieces of coral or coral rubble. During weather events coral rubble has the ability to cause secondary damage to other corals and sponges through resuspension and redistribution (Zimmer, 2006). Additionally, an additional layer of unstable substrate or coral rubble can slow down the pre-existing slow recovery times of coral and sponge within the deep-sea (Zimmer, 2006). The removal or stabilization of coral rubble can reduce this chance of secondary damage and aid in coral restoration, habitat complexity and species enhancement (RRAP, 2021a; Zimmer, 2006). Currently Australia is testing both removal and stabilization methods for coral rubble in the region (RRAP, 2021a). They have been implementing this to aid in reef recovery; the stabilization process would consist of putting rubble into mesh baskets to strengthen and stabilize the rubble while simultaneously providing a new structure for corals to settle and grow upon (RRAP, 2021a). While the removal approach outlines the removal of coral rubble by utilizing a suction machine; however, RRAP outlines this method is most effective where reefs have been impacted by ships or boats (RRAP, 2021a).

5.2.2.2.3 Liming

A third hands-on example would be the ‘liming’ process, which was mentioned at the 2015 CSIRO workshop held in Australia. This workshop outlined a number of options that could mitigate climate change in coral and sponge communities. Liming was an option presented in which the previous section outlines this process, risks and benefits in more details.

As climate change persists and species continue to deplete, managers and decision-makers need to assist the possibility of implementing direct methods. Hands-on conservation methods may be the gateway to conserving our deep-sea species against the impacts of climate change. Such methods contain a number of risks and uncertainty associated with these hands-on projects, they may be necessary to consider to ensure such species are conserved.

Chapter 6: Discussion & Recommendations

6.1 Discussion

As climate change impacts are inevitable, modeling, monitoring, and management need to adapt to climate changes and need to adopt new methods to help make informed decisions for conservation and protection. Other countries have identified and enforced numerous initiatives that allow coral and sponges to adapt to the changing environmental conditions.

Some countries, including Canada have implemented passive actions to combat climate change. Prime Minister Justin Trudeau announced the release of a 2030 emission reduction plan in March of 2022 (GOC, 2022). This plan is a sector-by-sector approach to ensure Canada achieves net-zero emissions by 2050 (GOC, 2022). This plan includes the cutting of emissions by 40% below the 2005 levels by 2030 (GOC, 2022).. This emission reduction plan just shows how Canada's climate action remains to focus on passive actions, rather than active actions. Nonetheless, other countries are turning towards active actions; however, both should be considered within modeling, monitoring, and management enforcement when developing integrating climate change plans.

Many of the current initiatives other countries have been developing and enforcing are ones that Canada has previously or currently developed and implemented themselves; however, some initiatives are new to Canada and should be considered moving forward. Additionally, while some of the examples within the case studies are focused on shallow water coral and sponges, the idea could be replicated to better suit a Canadian environment while also presenting suggestions and recommendations that the region could consider when developing and enforcing new regulations.

Based on the results from this study, recommendations have been provided for how Eastern Canada can incorporate climate change into the modeling, monitoring and management within coral and sponge conservation plans. Recommendations are drawn from Canadian laws, strategies and plan issues and potential changes and both New Zealand and Australia's priorities and the plausibility of Canadian adoption and enforcement.

6.2 Recommendations

6.2.1 Modeling

6.2.1.1 Habitat Suitability & Species Distribution Models to Identify Refugia

Scientific research should focus on building habitat suitability models, to understand the favorable habitat in the present day and in the future as environmental conditions are predicted to change due to climate impacts. This scientific research should be focused on Species Distribution Models (SDM) and Habitat Suitability Models (HSM) as they can help identify predicting areas of high habitat suitability for species of concern (Ramierz, 2020). By implementing such models, we can understand what marine ecosystems will be destroyed and what areas will become new refugia for such deep-sea benthic species and habitats. Eastern Canada has undergone numerous models within the past and will most likely continue to do so. The numerous nations using this tool only solidifies Canada’s accomplishment to implement the same, while nations such as New Zealand have been altering their models to ensure accuracy, Canada could consider improving their methods. It is important that nations continue to evolve their technology and methods as new information becomes available.

With the implementation of models we can better understand potential changes based on factors we have already identified. However, models are just predictions and are not reality and could potentially change with future conditions, but based on available science it can give us a better understanding of what we may encounter in the future. Nonetheless, if both Canada and specifically Eastern Canadian provinces were to improve their modeling techniques they need to consider the limitations to modeling and understand that modeling is not a way to replace the gathering of primary scientific data, but to be used in co-occurrence with data gathering.

6.2.2 Monitoring

6.2.2.1 Annual Long-term Monitoring within Predicted Areas of Refugia to Understand the Level at which Coral and Sponges Become Present

Once predicted current and future marine refugia for deep-sea coral and sponges are identified, annual monitoring needs to be conducted. The monitoring will aid in the understanding of if and when such species may become present. Modeling is not always certain, but it is an accurate prediction that aids in proactive monitoring and management efforts. So by implementing annual monitoring we can then identify if such predictions were correct and in the case corals and/or sponges start to appear, proactive management plans can be determined. Coral and sponges are slow growing so annual monitoring would not be required to occur immediately or frequently, rather monitoring plans can be determined and enforced at a slower pace and can be implemented over longer increments of ~5-10 years.

6.2.2.2 Scientific Research should focus on Monitoring Deep-sea Coral and Sponge to Understand their Biology and Ecology

Scientific research should focus on deep-sea coral and sponge biology to better understand how they will react to climate change. One major gap in the development of a climate change plan for modeling, monitoring and the management of deep-sea corals and sponges in Eastern Canada is due to the lack of scientific information. Despite the available information on deep-sea coral and sponges' ability to enhance biodiversity in benthic ecosystems, the biology of such species remains limited (Vad, 2018). Deep-sea corals and sponges are a relatively new discovery and thus contain sparse studies. With little information available, it is creating uncertainty in decision making. With a better understanding on the biology and ecology of coral and sponge species' traits such as life cycle and history, reproduction, feeding methods, heat tolerance, and more; it will aid in the reduction of uncertainty and allow decision-makers to produce informed, science-based decisions for climate change adaptation and mitigation for deep-sea coral and sponges.

6.2.3 Management

6.2.3.1 Adaptive Management

Adaptive management is being considered and enforced within other countries for the conservation and protection of cold-water corals. Canada has adopted a National Adaptation Strategy for building resilient communities and economy across the country; however, this strategy is not focused on the marine environment or coral and sponges, but rather focused on the human aspect (ECCC, 2022a). The document focuses on land-related impacts from climate change such as; forest fires, sea-level rise impacting coastal communities, infrastructure damage, drought, etc. (ECCC, 2022a). However, this strategy does outline the importance of adaptive management to combat climate change, and ways to introduce it; meaning that Canada already has an understanding of this management tool and it could be easily replicated and applied to the management of deep-sea coral and sponges. Additionally, the strategy undergoes a formal review every 5 years, and could potentially include ocean conservation as concerns continue to rise.

6.2.3.2 Remove Legislative Barriers to ensure Climate Change Adaptation is Achieved to Achieve conservation beyond Canada's EEZ

As mentioned previously, legal tools at both the national and regional level will need to be amended to ensure there are no legislative barriers to implementing conservation within the high seas. Management and conservation tools need to extend to ABNJ that contain deep-sea coral and sponges to aid in the conservation of cold-water fauna globally. The *Ocean's Act* could be amended to allow conservation beyond Canada's EEZand aid in the protection within international waters. Outlined in the *Oceans Act* is Canada's sovereign rights over the continental shelf and its resources within the seabed; including the deep-sea coral and sponges species; however the establishment of a protected area is restricted based on the *Oceans Act* provisions for MPAs. The amendment of the Act could allow Canada to implement conservation areas within ABNJ for the protection of vulnerable deep-sea species. While Canada contains a tool box of ocean protection through laws, strategies and plans; they need to be improved, amended and adapted to fit the modern impacts the marine environment is facing. This amendment could also aid in Canada being a global leader for the establishment of high seas MPAs.

6.2.3.3 Hands-on Adaptation needs to be Considered

Human interactions and influence have shown to have negative impacts upon the ocean and the deep-sea. However, with the current climate projections and the ineffective conservation plans, human direct solutions have to be considered. Restrictions and indirect conservation can protect corals and sponges in the short-term and result in limited protection, currently indirect methods have not been studied enough to understand whether or not they are conserving what they were established to protect. Hands-on methods need to be considered as a gateway to ensuring conservation goals are met, and species are preserved.

6.2.3.4 Include Guidance to Adaptive Management within the Coral and Sponge Conservation Strategy

The Coral and Sponge Conservation Strategy needs to include guidance for adaptive management within Eastern Canada. Amendments concerning climate change will be one of the most vital steps for Canada's laws, strategies and plans to ensure conservation and adaptation is achieved. The Coral and Sponge Conservation Strategy should be reviewed and updated every five years, but with the current update being 8 years without an update, the amended version should include adaptive management as a guidance tool within the action items and targets for coral and sponge management. This guidance tool will aid in shaping regional behavior and provide the information necessary to achieve their conservation goals, make informed decisions and sustain local resources.

6.3 Conclusion

Deep-sea coral and sponges are crucial for ecosystem integrity, species abundance, the Canadian Economy, human health and more, yet humans are failing to ensure they remain. Cold-water coral and sponges in Eastern Canada are facing detrimental impacts, and as climate change persists the hope for their survival is starting to diminish. Canada has committed to reducing climate change impacts on numerous occasions and has implemented their own conservation plans to do just that. But in pressing times, climate change is challenging these conservation plans and people are starting to doubt if Canada is working against climate impacts or just working towards a check mark. Countries such as New Zealand and Australia are taking matters into their own hands and testing extreme methods to ensure these species are able to adapt to the changing environment. Eastern Canada also needs to adapt their conservation methods to accommodate climate change, this can be done through numerous types of monitoring, modeling, and management that include and acknowledge climate changes. Additionally, legislative barriers need to be removed or altered to accommodate adaptation and ensure these species remain. Without the proper methods in place, these species will perish and cause a massive shift within marine ecosystems.

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