Evaluating the integration of cumulative effects in the management of Canada's marine conservation areas

By

Gillian Curren

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Abstract

One of the most prevalent threats to the persistence of coastal and marine ecosystems is the cumulative effects of human and natural stressors. Marine conservation areas can help mitigate and manage for cumulative effects; however, several challenges remain including inconsistent definitions and management approaches as well as a limited understanding of socio-ecological interactions. To examine how ocean managers in Canada assess and manage the impacts of cumulative effects on marine conservation areas, a study of the federal departments that administer these areas was conducted. Specifically, this research focused on the extent to which social-ecological factors are considered in assessing cumulative effects on marine conservation areas. It was found that managers appear to favor ecological indicators and considerations over socio-economic ones. Managers also indicated a need for additional data to improve their assessment and management approaches. Finally, the lack of a cumulative effects assessment framework limits managers in their ability to adequately address and manage these effects in marine conservation areas. Research suggests that understanding how stressors interact and accumulate in the environment as well as their impact on oceanic ecosystems will require the coordination and collaboration of multiple disciplines to elicit effective management responses. Maintaining the health and integrity of the world's oceans also requires long-term management plans guided by well-informed decision-making. Therefore, it is recommended that Canadian cumulative effects assessment and management standards for marine conservation areas be developed and a broad ecosystem-based approach is taken to increase the effectiveness of Canada's marine conservation area management.

Keywords: Cumulative effects, ocean management, marine conservation, socio-ecological systems, Canada

List of Abbreviations

CWS – Canadian Wildlife Service

DFO – Fisheries and Oceans Canada

EBM – Ecosystem-based management

ECCC – Environment and Climate Change Canada

MBS – Migratory Bird Sanctuary

MPA – Marine protected area

NMCA – National marine conservation area

NWA – National (marine) wildlife area

OECM – Other effective area-based conservation measure

SES – Social-ecological system

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Chapter 1. Introduction

Coastal and marine ecosystems worldwide are currently experiencing immense changes due to increased human use of the marine space and a greater demand for marine resources (Halpern et al., 2008; Korpinen & Andersen, 2016). As human activities continue to intensify and accumulate in the marine environment, understanding the cumulative effects of multiple stressors will be necessary. Approximately half of the world's oceans are highly influenced by stressors associated with human activities and almost no area remains untouched by human impact (Kappel et al., 2012). This is evident through activities such as aquaculture, coastal development, energy production, and agriculture, which produce a variety of stressors that can negatively impact marine species and ecosystems. For instance, coastal development has several associated stressors including habitat degradation and removal, alteration of local or regional biodiversity, increased pollution, and reduced survivorship of organisms such as juvenile sea turtles (Bulleri & Chapman, 2010; Harewood & Horrocks, 2008; Sundblad & Bergström, 2014). Moreover, the marine environment is subject to change from natural processes such as seasonal variations and extreme weather. These natural and human stressors, however, rarely operate in isolation. For example, oil and gas development, fishing, and shipping simultaneously occur in the marine environment and all have various effects on marine mammals (Duinker & Greig, 2006).

Currently, the cumulative effects of human and natural stressors are recognized as one of the largest threats to the sustained health of the world's oceans (Foley et al., 2017). Cumulative effects can be described as the combined changes in biological and/or socio-economic response of a system to one or more stressors (Clarke Murray, Mach & Martone, 2014; Foley et al., 2017; Jones, 2016). However, understanding the cumulative consequences of multiple

stressors is particularly challenging. Stressors often vary across space and time and it is difficult to predict how ecological components may respond to intense ecosystem changes (Clarke Murray et al., 2014; Hodgson, Halpern, & Essington, 2019). Additionally, the cumulative effects of multiple, overlapping stressors may lead to abrupt, unanticipated impacts or changes to the marine environment (Foley et al., 2017). To address and understand the cumulative effects of human activities on marine ecosystems as well as ensure the sustainable use of the ocean's resources, effective marine management is necessary.

One approach to minimizing the threats of multiple ocean stressors is through ecosystem-based management (EBM). This management approach aims to maintain the long-term functionality and productivity of marine ecosystems to provide ecosystem services such as food and recreational opportunities, through an ecosystem health and human welfare lens (Halpern, Lester, & McLeod, 2010; Halpern, McLeod, Rosenberg, & Crowder, 2008). To help achieve the goals of EBM and address the impacts of multiple stressors in the marine space, marine protected areas (MPAs) or marine conservation areas can be implemented. MPAs are legally designated and geographically defined spaces that are designed to manage and protect the long-term health of marine ecosystems, including associated ecosystem services and cultural values (Garcia Rodriguez & Fanning, 2017; Government of Canada, 2011). It is important to note however, that MPAs are one component of EBM and other management efforts are needed to fully realize its goals.

MPAs are recognized as one of the best management tools for protecting marine ecosystems as well as allowing for the sustainable use of marine resources since they aim to regulate human activities (Halpern & Warner, 2002; Mizrahi, Diedrich, Weeks, & Pressey, 2019). However, simply implementing MPAs does not guarantee positive environmental

impacts, nor does it assure that the cumulative effects of multiple stressors will be reduced. Factors such as the size of an MPA as well as the level of enforcement of its regulations often influence its conservation success (Agardy et al., 2003; Halpern et al., 2010). MPAs also lack physical boundaries, therefore, ecosystems within their borders could remain exposed to stressors such as temperature increases and pollution. Furthermore, many marine conservation areas remain focused on single-sector (e.g., fisheries) management practices and despite shifts in thinking, including an increased recognition that stressors do not occur in isolation, challenges in accounting for cumulative effects remain (Foley et al., 2017; Hodgson et al., 2019; Mach et al., 2017). To mitigate and manage for cumulative effects in the marine environment, managers need to understand and account for the potential impacts from both single and multiple stressors, within and outside MPA boundaries.

1.1 Context

Marine conservation areas are linked social-ecological systems (SES) that consist of anthropogenic and natural components which interact with and influence each other in a variety of ways. For example, since MPAs limit human activities within their boundaries, they often remain exposed to external stressors produced by global climate change, intense resource extraction (e.g. commercial fishing), or habitat modification (e.g. coastal development) (Mach et al., 2017; Pollnac et al., 2010). The complex nature of these social-ecological interactions is often the result of human resource needs driven by factors such as population growth, economic development, or socio-political change, which can lead to unexpected ecosystem responses (Jones, Qiu, & De Santo, 2013; Pollnac et al., 2010). When managing for cumulative effects, if the relationship between humans and the marine environment is not acknowledged, then in addition to ecological impacts, there will likely be consequences for society and human well-

being. Therefore, ecological knowledge alone is not sufficient for marine conservation or management success and the inclusion of social, economic, cultural, and political conditions when assessing and managing cumulative effects on MPAs is also needed (Fox et al., 2006; Stelzenmüller et al., 2018). Furthermore, accounting for these conditions when designing marine management plans is especially pertinent in a Canadian context.

Canada has more than 200,000 km of coastline, making it the longest in the world (Cooke et al., 2016). Many Canadians have a cultural connection to the coast, rely on it for recreation, or use it to earn a livelihood. To protect Canada's coastline and ocean ecosystems as well as ensure the sustainable use of its marine resources, Canada committed to a global target of protecting at least 10% of coastal and marine areas by 2020 (i.e., the 1992 Convention on Biological Diversity, Aichi Target 11). On August 1, 2019, Canada surpassed its marine conservation target, protecting almost 14% of Canada's marine and coastal spaces (DFO, 2019a). To uphold Canada's commitment to marine protection and sustainable use as well as ensure its marine conservation areas continue to be effectively managed over the long term, understanding how multiple stressors and cumulative effects influence Canada's marine space is essential.

Even with an increasing awareness of the impacts of cumulative effects on the marine environment, the implementation of laws and strategies to reduce these impacts, and improvements in scientific understanding, several challenges remain (Hodgson et al., 2019; Korpinen & Andersen, 2016). For example, gaps in data, variable definitions and terminology as well as inconsistency in evaluation methods are frequently cited as barriers to effectively assessing and managing cumulative effects (Duinker, Burbidge, Boardley, & Greig, 2013; Foley et al., 2017; Halpern & Fujita, 2013; Hodgson et al., 2019). In an effort to understand some of these challenges and how practitioners overcome them, Foley et al. (2017) investigated how

cumulative effects assessments are conducted, the type of scientific information included in them, and whether practitioner demography (e.g. jurisdiction and level of experience) influenced their assessments. They surveyed marine practitioners from Canada, the United States, Australia, and New Zealand and found that definitions for the components of the system being evaluated varied, and that practice and science were not closely aligned. They also found that a practitioner's role, level of experience, and jurisdiction influenced how they assess cumulative effects as well as the types of information included in their assessments. Foley et al. (2017) illustrate that the current state of evaluating cumulative effects, in the four jurisdictions studied, remains weak and highlight the need for continued research on this subject.

1.2 Management Problem

Although improvements in cumulative effects assessments have been made (Hodgson et al., 2019), it appears that ocean managers and practitioners currently struggle to fully evaluate and adequately incorporate cumulative effects of multiple stressors into marine management plans and policies (Duinker et al., 2013; Judd, Backhaus, & Goodsir, 2015; Sinclair, Doelle, & Duinker, 2017). This may be due to a lack of clear and consistent definitions, inconsistent application of cumulative effects assessment in practice, a focus on single-sector management, and/or a weak understanding of social-ecological interactions in the marine environment. Furthermore, much of the impact assessment literature and many conservation plans focus on the ecological components of the environment and fail to adequately capture the socio-economic aspects that are inherently connected to marine ecosystems (Ban et al., 2013; Clarke Murray et al., 2014; Duinker & Greig, 2006). Therefore, how cumulative environmental effects may impact socio-economic conditions as well as the potential cumulative socio-economic impacts that may

exist are not sufficiently considered in existing assessment and management frameworks (Foley et al., 2017; Rodríguez-Rodríguez, Rees, Rodwell, & Attrill, 2015; Sinclair et al., 2017).

Since cumulative effects are recognized as one of the largest threats to marine ecosystems, understanding and assessing these effects should be incorporated into all aspects of marine management, including marine conservation areas. Understanding how these stressors interact and accumulate in the environment as well as their impact on oceanic ecosystems is critical for effective ocean management and conservation. Additionally, given that marine conservation areas are linked SES, understanding the socio-economic, political, and cultural factors related to the world's oceans is an essential component to the creation and implementation of informed policy and long-term management decisions. Gaining insight into how ocean managers in Canada evaluate multiple stressors and cumulative effects as well as how they consider these factors in managing ocean spaces, such as MPAs, is also needed. This could help to advance the practice of cumulative effects assessment, identify potential areas of improvement, and ensure Canada's marine conservation areas continue to be effectively managed.

1.3 Research Objectives

To continue to improve our understanding of cumulative effects and multiple stressors and reduce their impacts on the marine environment, how managers conduct assessments and the types of information they use (e.g., ecological, social, economic, etc.) need to be identified. Potential limitations to how cumulative effects are assessed should also be identified to remove any barriers that may exist. Furthermore, understanding how ocean managers incorporate assessments of cumulative effects into marine management plans, such as for MPAs, could help improve future ocean planning and management.

This study aims to expand on the work completed by Foley et al. (2017) in a Canadian context by examining how ocean managers currently assess cumulative effects and multiple stressors and how they apply the outcomes of this into marine management plans. Specifically, how Canada's marine conservation area managers within Fisheries and Oceans Canada (DFO), Parks Canada, and Environment and Climate Change Canada (ECCC) evaluate and integrate cumulative effects and multiple stressors into their management plans were analyzed and compared. The extent to which socio-economic factors and impacts are considered in their assessments compared to ecological conditions, was also evaluated. Due to the substantial threat that the impacts of cumulative effects pose to the marine environment, this study aims to help determine how current practices may be improved to better inform the appropriateness of marine conservation plans and policies.

Addressing the following topics provides the information needed to meet the research objectives and determine a pathway to evolving current cumulative effects assessment and management practices.

Primary Research Topic

Assess the extent to which DFO, Parks Canada, and ECCC ocean managers incorporate socio-ecological indicators and conditions when assessing the impacts of cumulative effects and multiple stressors on marine conservation areas.

Secondary Research Topics

1) Determine what information (e.g., ecological, social, economic, political, legal, institutional, cultural) and tools are used by marine conservation area managers when assessing cumulative effects and multiple stressors.

2) Assess how these different types of information regarding cumulative effects are incorporated into marine conservation area management plans (e.g., distinct frameworks, laws or mandates). Determine the extent to which these different types of information are considered by marine conservation area managers.
3) Determine whether the level of the manager, region, type of the marine conservation area managed, or federal department influence how cumulative effects are assessed and the types of indicators used.

1.4 Report Outline

This report is structured using six chapters. Chapter one corresponds to the introduction, which describes the subject matter and context of the report, identifies the management problem being addressed, and outlines the research topics, objective, and scope of the study. In Chapter two, the current thinking and state of cumulative effects management in the marine environment as well as how Canada presently accounts for cumulative effects in marine conservation areas is described. Chapter three discusses how data were collected to meet the objective of this study and addresses the research questions. The results obtained from the research are presented in Chapter four. Chapter five provides an interpretation and discussion of the results to address the research topics outlined in chapter one. Lastly, Chapter six summarizes this report and provides several recommendations based on the results of the research.

Chapter 2. Literature Review

The current approaches to cumulative effects assessment and management as well as key challenges are identified and described in the following analysis of the research. Furthermore, the relationship between cumulative effects and marine conservation areas is explained. An overview of how these effects are presently assessed and managed in Canada's marine conservation areas is also discussed.

2.1 Cumulative Effects and Multiple Stressors in the marine environment

The cumulative effects of human activities and their associated stressors continue to increase, threatening the long-term health of marine habitats and species as well as human well-being (Foley et al., 2017; Hodgson et al., 2019). Stressors, also sometimes referred to as pressures, are the physical, chemical, and/or biological components of human activities that can produce an adverse response (Foley et al., 2017; Jones, 2016; Judd et al., 2015). Several different types of stressors exist in the marine environment including noise, habitat degradation, pollution, invasive species, and land-based nutrient inputs. Individually, the effects of stressors such as these may be minimal, however, when they combine and interact with one another, the effects can be detrimental. For example, the combined effects of anthropogenic pollution and rising sea temperatures has been found to increase the severity, frequency, and duration of anoxic events in the Baltic Sea (Morgan, Brown, Ciotti & Panton, 2016). Additionally, climate-related stressors such as ocean acidification and changes in sea surface temperatures can exacerbate the effects of other environmental impacts (Mach et al., 2017). For example, ocean acidification has shown to enhance the effects of increased nutrient inputs on the dominance of algae species in rocky marine ecosystems as well as amplify the effects of underwater noise on marine organisms (Brewer & Hester, 2009; Hester, Peltzer, Kirkwood, & Brewer, 2008; Russel et al., 2009, as

cited in, Mach et al., 2017). Therefore, to effectively assess and manage cumulative effects in the marine environment, understanding how stressors interact to produce cumulative effects is essential.

Cumulative effects can occur in a variety of ways, making this one of the primary challenges to understanding how they originate and operate in the marine environment. The range in which cumulative effects can be generated include: a single activity producing a repeated stressor over time; a single activity producing multiple stressors (Fig. 1a); multiple activities producing a single stressor (Fig. 1b); or multiple activities producing multiple stressors (Fig. 1c) (Clarke Murray et al., 2014; Foley et al., 2017). Furthermore, when stressors overlap, the resulting cumulative effects can interact in several ways including, linearly or non-linearly, additively, synergistically, or, antagonistically (Clarke Murray et al., 2014; Foley et al., 2017; Jones, 2016). Despite substantial recognition of these complex interactions within the cumulative effects literature, current assessment practices assume that interacting environmental stressors simply lead to additive outcomes and that stressor-effect relationships are linear (Duinker & Greig, 2006; Halpern et al., 2019; Judd et al., 2015). This is potentially due to a lack of data on marine organisms and ecosystem responses to anthropogenic stressors as well as single-sector management approaches, which limits the ability of practitioners to effectively evaluate how, where, when, and why certain responses occur (Halpern et al., 2019; Halpern, McLeod, et al., 2008; Hodgson et al., 2019; Jones, 2016; Lundquist et al., 2016). Understanding the ways in which cumulative effects are produced and interact in the marine environment will be vital to ensure the long-term sustainability of the world's oceans. Human activities do not occur in isolation of each other and continuing to manage them separately minimizes the effectiveness of current conservation efforts and puts future efforts at risk (Duinker & Greig, 2006; Halpern,

McLeod, et al., 2008). Therefore, research on the impacts of mutiple stressors produced by multiple activities which incorpoates complexity, uncertainty, and natural changes in ecosystems is needed (Clarke Murray et al., 2014; Duinker & Greig, 2006). Furthermore, understanding the relationships between multiple stressors and the impacts on ecological as well as human systems is necessary to make effective management decisions.

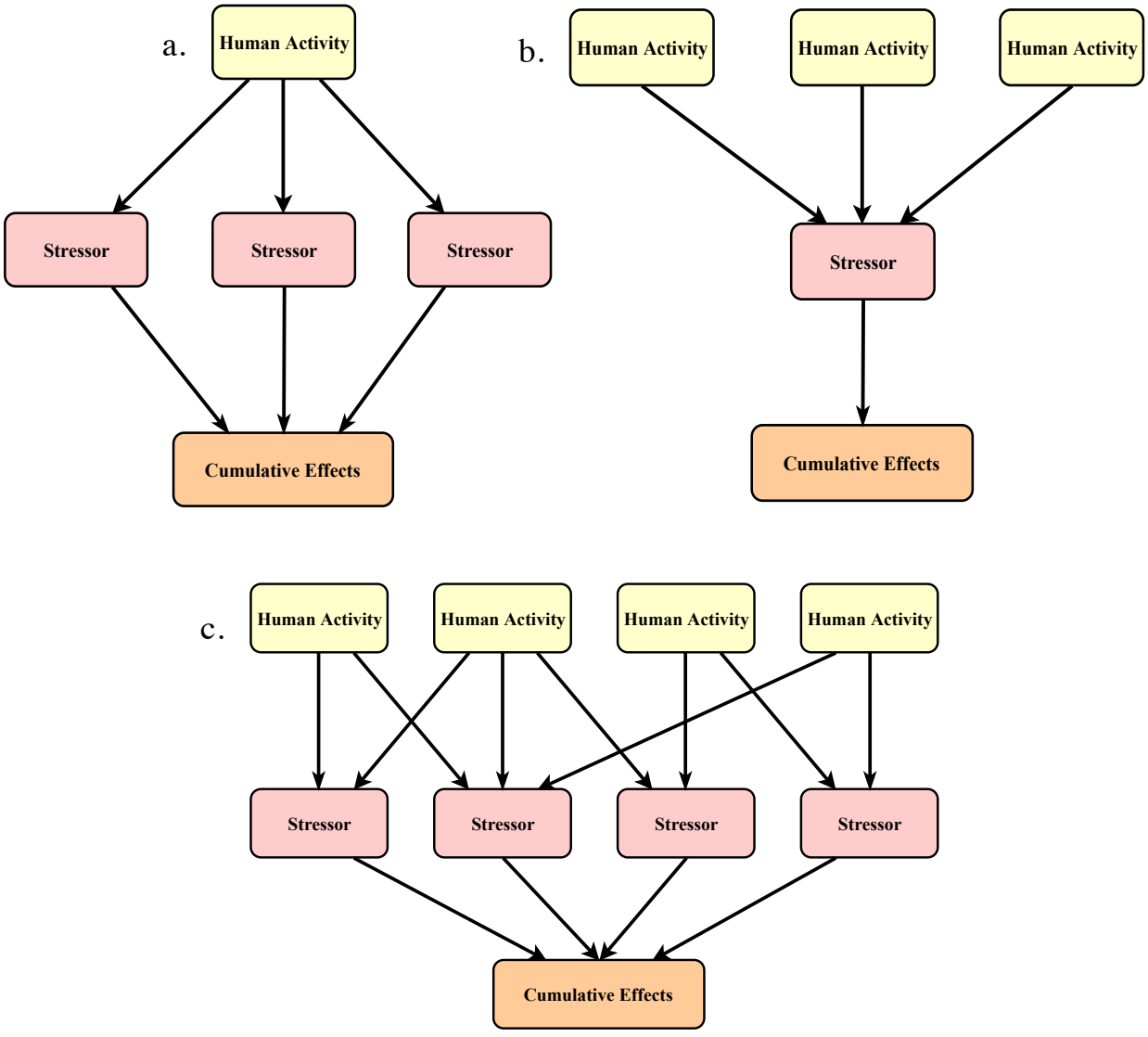

Figure 1. Overview of how cumulative effects can be produced: **(a)** A single activity produces multiple stressors; **(b)** Multiple activities produce a single stressor; **(c)** Multiple activities producing multiple stressors. (Adapted from Foley et al., 2017 & Clarke Murray et al., 2014).

2.1.1 Challenges in cumulative effects assessment

A strong understanding of cumulative effects and multiple stressors exist in the scientific literature; however, several barriers and challenges that inhibit the effectiveness of cumulative effects assessments and management plans persist in practice (Foley et al., 2017; Judd et al., 2015). The primary challenges associated with assessing and managing cumulative effects in the marine environment include: inconsistent definitions and assessment methods, single-sector management approaches, data deficiencies, a disconnect between science and management, and a limited understanding of social-ecological interactions. These challenges are commonly cited throughout the literature and do not appear unique to any one geographic location or management process (Duinker et al., 2013; Foley et al., 2017; Halpern & Fujita, 2013; Hodgson et al., 2019; Jones, 2016; Judd et al., 2015; Lundquist et al., 2016; Mach et al., 2017; Sinclair. et al., 2017). Identifying and understanding the challenges of cumulative effects assessment and management is critical to improving current practices as well as enhancing the effectiveness of marine conservation areas. Therefore, the aforementioned challenges are discussed in further detail in this section.

Inconsistent definitions and assessment methods

One of the most frequently cited challenges to cumulative effects assessment is a lack of clear, consistent definitions (Duinker et al., 2013; Foley et al., 2017; Hodgson et al., 2019; Judd et al., 2015). Presently, there is not a collectively agreed upon definition of cumulative effect, which has led to confusion among practitioners and weakened assessment approaches (Duinker et al., 2013; Judd et al., 2015). Clear and consistent definitions of cumulative effects are important since they often determine the direction or approach that an assessment will take. This includes identifying how impacts, baselines, and temporal and spatial scales will be defined as

well as the tools or methods that will be used to complete an assessment. Defining what constitutes an impact is a crucial first step in cumulative effects assessments as it can help managers determine the scope of their analysis. Yet, how impacts are defined and applied in practice can vary greatly between practitioners as well as jurisdiction. For example, a survey of cumulative effects practitioners from four countries around the Pacific Rim demonstrated that despite similar legal definitions and interpretations of impacts, practitioners did not consistently apply these in practice and their jurisdiction influenced the types of effects included in their assessments (Foley et al., 2017). How cumulative effects and impacts are defined may also influence how managers assess baseline conditions of an ecosystem as well as how spatial and temporal scales are determined (Duinker et al., 2013). If the definition of a cumulative effect includes historical, current, and future changes, then managers may be more likely to account for these when defining the baseline and scale of their assessment. However, determining baseline conditions is a major challenge for practitioners due to limits on the availability of data on past, present, and future human activities and impacts (Clarke Murray et al., 2014; Foley et al., 2017). This can cause managers to simply use current ecosystem conditions as the baseline, limiting the effectiveness of their assessments (Foley et al., 2017). In addition to defining baselines, setting spatial and temporal bounds is essential to effective and successful cumulative effects assessment and management. Spatial boundaries determine what activities, stressors, and impacts should be included in an assessment while temporal boundaries define the length of time in which stressors will be analyzed (Foley et al., 2017; Judd et al., 2015). However, setting appropriate spatial and temporal scales is extremely challenging since the spatial extent of human activities is not well documented and stressors and effects can significantly vary over space and time (Jones, 2016; Judd et al., 2015; Mach et al., 2017). It is evident that explicit, agreed upon definitions are

needed for effective cumulative effects assessments to occur and developing a set of standard definitions could improve both assessment and management practices.

Single-sector management approaches

Human activities and stressors overlap both spatially and temporally in the marine space, requiring a suite of disciplines, perspectives, and methods to accurately assess and manage the cumulative effects that are produced. However, despite recognition of the need for more integrated knowledge and management of cumulative effects, single-sector approaches remain common in practice (Hodgson et al., 2019; Lundquist et al., 2016; Mach et al., 2017). For example, many marine protected areas remain focused on reducing the impacts of single stressors such as fishing mortality or habitat degradation and do not adequately account for stressor interactions or external pressures, such as noise pollution and sedimentation (Agardy, di Sciara, & Christie, 2011; Halpern & Fujita, 2013; Mach et al., 2017). Research on cumulative effects in the marine environment is often focused on how stressors impact an individual organism or species and is typically conducted within academic disciplines or "silos", leading to fragmented assessment and management approaches (Clarke Murray et al., 2014; Hodgson et al., 2019). For example, research on the effects of climate change on marine and coastal systems has concentrated on how changes in temperature will impact individual organisms (Harley et al., 2006). However, temperature is one of several potentially interacting climate stressors and impacts on populations and communities also exist. Additionally, cumulative effects assessments are frequently limited in their scope by focusing on stressors and impacts at a local instead of regional scale (Agardy et al., 2011; Halpern, McLeod, et al., 2008). Marine protected areas are important and often address specific needs, however, a shift towards an integrated, collaborative,

and transdisciplinary approach to assessing and managing cumulative effects could enhance conservation area design, implementation, and management.

Data Deficiencies

Another major challenge to successfully assessing and managing cumulative effects in the marine environment is gaps in information and data. When, where, and how single and multiple stressors are expected to occur and impact species or ecosystems are difficult to predict and poorly understood (Clarke Murray et al., 2014; Hodgson et al., 2019). Although some progress has been made in increasing data availability through open-data sources, several species and ecosystem responses remain understudied and a considerable amount of data remains inaccessible (Halpern & Fujita, 2013; Hodgson et al., 2019). This includes limited public access to private, government, and academic research as well as unpublished or unshared data. Additionally, much of the data that presently exists regarding cumulative effects does not incorporate historical data, adequately represent the nature of stressors in the marine environment (e.g., how noise travels through the ocean), or acknowledge the rate of change in cumulative effects on the world's oceans (Halpern et al., 2019; Halpern & Fujita, 2013). Another challenge regarding data gaps and accessibility relates to the gap between the natural and social sciences. This gap is well-recognized and attempts to close it have been made, however, truly collaborative and integrated approaches to cumulative effects management have not been realized (Fox et al., 2006; Lundquist et al., 2016). Understanding both ecological and socio-economic components of the marine environment and incorporating this information into assessments is essential to develop holistic management of cumulative effects. With limited availability and access to information, duplication of research efforts is a potential risk and the

ability to implement effective and strategic cumulative effects management plans is substantially weakened.

Disconnect between science and management

Presently, research conducted on cumulative effects and the information generated from this is not sufficiently translated into concrete guidance that managers can use to make decisions or develop management strategies (Clarke Murray et al., 2014; Foley et al., 2017). This has created a disconnect between disciplines as well as between science and management, hindering the ability for robust cumulative effects assessments to occur (Hodgson et al., 2019; Lundquist et al., 2016). Scientists and managers must communicate with each other to identify the pertinent research issues as well as prioritize research needs. However, the priorities of academic research, which includes government scientists as well as independent researchers, and management needs often do not align. Additionally, science does not always adequately consider the social, economic, or political nuances that are also incorporated into decision-making (Lundquist et al., 2016). To enhance the current understanding of cumulative effects and improve assessment and management practices, stronger communication and collaboration between disciplines and decision-makers is needed. Furthermore, public engagement in cumulative effects assessment is also an important consideration as it can help shape decision-making processes (Duinker et al., 2013). To minimize the disconnect between science and management, exploring new methods of engagement is essential. For example, encouraging communication beyond science and management to include the general public as well as indigenous and local knowledge holders could help to bridge gaps, improve research priorities, and generate new approaches to cumulative effects management. Understanding where key disconnects exist and improving collaboration among science, government, and civil society will be critical for mitigating and

managing cumulative effects since cumulative problems will require collective solutions (Canter & Ross, 2010).

Limited understanding of socio-ecological interactions

The marine environment supports ecological, social, cultural, and economic systems, making each of these important considerations when developing and implementing marine management plans. When assessing and managing for cumulative effects in the marine space, understanding and incorporating information about each of these systems is especially relevant since cumulative effects impact both natural and human systems. However, many researchers and managers tend to focus their attention on the ecological or environmental impacts of cumulative effects and do not sufficiently consider the potential socio-economic impacts (Weber, Krogman, & Antoniuk, 2012). Focusing only on one component of marine systems limits the robustness of assessments and the success of management actions. Furthermore, social, economic, and cultural indicators and information are inadequately incorporated into cumulative effects assessments. For example, practitioners may rely on basic social and economic indicators with available information such as unemployment rates or income levels, however, issues of human or community well-being often cannot be addressed by these (Mitchell & Parkins, 2011; Weber et al., 2012). The issue of assessing impacts on social-ecological systems and incorporating socio-economic indicators in assessments appears to be largely due to communication barriers between natural and social science disciplines as well as siloed research approaches (Fox et al., 2006). These disciplines do not share a common language, have different publishing expectations, and often hold misconceptions about one another (Fox et al., 2006; Jones, 2016; Mitchell & Parkins, 2011). Therefore, it is critical for managers to take a broader

approach to evaluating cumulative effects on marine conservation areas to help ensure that future protected areas are developed using more holistic assessment and management methods.

2.1.2 Cumulative effects and marine conservation areas

Marine conservation areas are an important tool to help protect and conserve marine ecosystems as well as support the sustainable use of marine resources. Several prominent examples of MPAs around the globe include the Gully MPA, located off the coast of Nova Scotia, Canada; California's Channel Islands National Marine Sanctuary; and the Great Barrier Reef Marine Park. The Gully MPA, for example, has helped to prevent the further decline of a population of northern bottlenose whales by reducing anthropogenic stressors such as underwater noise and entanglements in fishing gear (O'Brien & Whitehead, 2013). The Channel Islands National Marine Sanctuary is an example of an MPA that has been successful in balancing protection with sustainable use by limiting activities such as oil and gas development, while permitting some low-impact fishing to occur (Agardy et al., 2011; Osmond, Airame, Caldwell, & Day, 2010). Although MPAs can be effective at regulating human activities and stressors in a defined area, they do not have physical boundaries to protect against external threats. As natural and human stressors such as ocean acidification, noise pollution, eutrophication, and warming ocean temperatures continue to accumulate, managing for the cumulative effects of these stressors both inside and outside MPAs remains a substantial challenge (Agardy et al., 2011; Mach et al., 2017). Therefore, managers must strive to reduce and mitigate cumulative effects of multiple stressors both on MPAs themselves and the surrounding environment. This could be achieved by implementing regular monitoring and evaluation of conservation actions and management plans to ensure that objectives continue to be met. As such, it is incumbent on marine conservation managers of all types of areas to familiarise themselves with a broader

understanding of potential stressors and build interdisciplinary relationships to achieve the best possible outcomes. This is particularly relevant in a Canadian context to ensure that Canada's commitment to marine protection is upheld and conservation targets[1] continue to be met.

2.2 Canada's Marine Conservation Areas

Canada is a maritime nation with many individuals reliant on the marine environment for economic, cultural, recreational, or social purposes, therefore, maintaining healthy oceans is of critical importance (Government of Canada, 2016). To conserve and protect Canada's oceans while allowing for the sustainable use of marine resources, several types of marine conservation areas have been and continue to be implemented under federal jurisdiction. These include MPAs, Other Effective Area-Based Conservation Measures (OECMs), National Marine Conservation Areas (NMCAs), Migratory Bird Sanctuaries (MBSs), and National Wildlife Areas (NWAs). Three federal departments are responsible for identifying, implementing, and managing these areas including DFO, ECCC, and Parks Canada. Each department has a specific mandate for establishing marine conservation areas; however, these mandates also promote communication and collaboration between departments (Government of Canada, 2011). Additionally, each type of conservation area implemented in Canada has its own set of regulations and intended purpose, although, the overarching goal of these areas is to achieve "an ecologically comprehensive, resilient, and representative national network of marine protected areas that protects the biological diversity and health of the marine environment for present and future generations" (Government of Canada, 2011, p. 6). While Canada has several methods for achieving effective marine conservation and sustainable resource use, adequately accounting for and mitigating cumulative effects on these areas remains weak.

[1] See website: https://www.dfo-mpo.gc.ca/oceans/conservation/plan/index-eng.html

Key legislation for protecting Canada's oceans including the *Oceans Act* (1996), the *Fisheries Act* (1985), the *Canada National Marine Conservation Areas Act* (2002), do not explicitly require the management of cumulative effects. The *National Framework for Canada's Network of Marine Protected Areas* (2011) acknowledges that areas subject to multiple stressors and cumulative effects require sufficient protection; however, it fails to specifically outline management measures to mitigate the impacts of cumulative effects on these areas (Government of Canada, 2011). Furthermore, current efforts to understand and mitigate cumulative effects through Canada's *Ocean Protection Plan* are focused on the shipping industry (Government of Canada, 2016). Although this is important, shifting away from single-sector management focuses is needed to fully address the impacts of cumulative effects. Current legislation, regulations, and policies should adapt to changing ocean conditions to better account for cumulative effects and maintain the effectiveness of current conservation areas as well as ensure the success of future ones. Therefore, deliberation and collaboration between all levels of government, industry, non-governmental organizations, Indigenous communities, and the general public is needed to create a set of a balanced and effective management plans and help ensure conservation areas achieve desired outcomes.

2.2.1 Marine Protected Areas

DFO's mandate requires that Canada's oceans and aquatic ecosystems are protected from harmful activities and negative impacts (DFO, 2019e). To achieve this, DFO is responsible for establishing and managing MPAs in Canada under the direction of the *Oceans Act* (1996). They define an MPA as "a part of the ocean that is legally protected and managed to achieve the long-term conservation of nature" (DFO, 2018, para. 1). This includes prohibiting or permitting certain human activities, depending on their impacts to the ecological components being

protected. When implemented, MPAs can help protect biodiversity or endangered species, enhance ecological resilience of marine spaces, promote and protect cultural heritage as well as help sustain fisheries (Government of Canada, 2011). Recently, Canada implemented new standards to enhance the protection of the marine environment by prohibiting oil and gas activities, mining, dumping, and bottom trawling in MPAs (DFO, 2019b). Protections such as these are important; however, these standards do not specifically account for the accumulation of external pressures such as noise or sedimentation that may cross MPA boundaries. Furthermore, current legislation (e.g. the *Oceans Act* (1996)), does not explicitly require the management of cumulative effects when designing, implementing, or managing MPAs. However, the *Oceans Act* (1996) does require the implementation of integrated management plans, which encourages collaboration with other federal departments and recognizes the need to consider the impacts of human activities in the marine environment as well as those affecting marine and coastal spaces (e.g., land-based pollution).

2.2.2 Other Effective Area-Based Conservation Measures

Another type of marine conservation area managed by DFO are OECMs. These areas include existing marine management measures such as marine refuges and fisheries closures that contribute to achieving Canada's marine conservation targets (DFO, 2017b). To be considered an OECM, five criteria must be met including: a clearly defined geographic location; a conservation focus; the presence of ecologically important species or habitats; long-term duration of implementation; and the ecological components of interest must be effectively conserved (DFO, 2017a). Presently, around 5% of Canada's oceans are protected by OECMs, which contributes to approximately one quarter of the total area of ocean protected in Canada (DFO, 2019d). OECMs are an important conservation tool since they help mitigate and regulate harmful human activities

such as bottom-trawling and enhance overall Canadian marine conservation efforts. Although OECMs are important contributions to Canada's marine conservation areas, they strictly manage fishing activities and cannot account for potential stressors such as pollution, noise, or invasive species. Therefore, additional protections implemented through new or existing legislation may be needed to sufficiently consider cumulative effects in these areas.

2.2.3 National Marine Conservation Areas

NMCAs are implemented and managed by Parks Canada "to protect and conserve representative marine ecosystems and key features, while ensuring the ecologically sustainable use of marine resources" (Parks Canada, 2017a, para. 3). These conservation areas encompass the seabed and water column above it as well as wetlands, estuaries, islands, or other coastal areas across Canada's three oceans and the Great Lakes. Activities that are prohibited in NMCAs include ocean dumping, mining, oil and gas exploration, and development (Parks Canada, 2017a). Traditional or Indigenous resource uses such as traditional fishing practices are permitted, but managed with a conservation focus (Parks Canada, 2017a). NMCAs aim to balance the sustainable use of ocean resources and preserving ecologically sensitive areas for future and present generations (Canada National Marine Conservation Areas Act, 2002). To achieve this, Parks Canada builds partnerships with stakeholders, reduces conflict with resource users, identifies threats to the sustainability of marine ecosystems, protects important habitats and species as well as provides educational and recreational opportunities (Parks Canada, 2017a). Furthermore, Parks Canada acknowledges the need for integrated management plans to assist in the successful administration of NMCAs by managing marine and terrestrial areas outside conservation area boundaries (Parks Canada, 2017b). Although managing for cumulative

effects is not explicitly stated, considering activities and their impacts beyond conservation area borders is an important component to including cumulative effects in all management plans.

2.2.4 Migratory Bird Sanctuaries

ECCC establishes and manages MBSs through the Canadian Wildlife Service (CWS), which is guided by the *Migratory Birds Convention Act* (1994) and *Migratory Bird Sanctuary Regulations* (ECCC, 2017c). Sanctuaries can be implemented in the terrestrial or marine environment, including coastal areas and islands. These areas are primarily implemented strictly for conservation purposes and help protect migratory birds from human-caused harm, harassment, and death during important stages of their life cycle, such as breeding (ECCC, 2017a). For example, the Sable Island MBS, located about 175 kilometers southeast of Nova Scotia helps protect a large population of Arctic Tern breeding pairs as well as sandpipers and other birds that utilize the island (ECCC, 2018a). To ensure protection of migratory birds, MBSs prohibit hunting, disturbance of nests, the possession of birds or eggs, among other activities that are deemed to be harmful to migratory birds (ECCC, 2017c). MBSs have a specific purpose to protect migratory birds and their nests as well as their habitat and therefore do not appear to explicitly account for cumulative human disturbances such as habitat loss and pollution beyond MBS boundaries (ECCC, 2017a; Migratory Birds Convention Act, 1994).

2.2.5 National Wildlife Areas

NWAs are also implemented and managed by ECCC which aim to "protect and maintain habitat vital for wildlife and to improve habitat when necessary for wildlife use" (ECCC, 2017b, para. 2). Similar to MBSs, NWAs may be terrestrial or marine and their primary purpose is to conserve wildlife and their habitat. Therefore multiple human activities are prohibited in these areas including hunting, fishing, dumping, any commercial or industrial activities, recreational

activities such as camping or boating, and habitat destruction or removal (ECCC, 2017b). Presently, only one marine NWA exists in Canada – the Scott Islands marine NWA – and was implemented in June 2018. This NWA supports and protects the largest concentration of breeding seabirds on Canada's west coast and is recognized for its biological diversity which supports several fish species and habitat for marine mammals at risk (ECCC, 2018b). Prohibited activities in this conservation area include: disturbing, damaging or removing wildlife and their habitat, low-level flights, and dumping waste; however, fishing and navigation activities are allowed to occur (Scott Island Protected Marine Area Regulations, 2018). Similar to other conservation areas described in this section, NWAs do not explicitly manage for cumulative effects on these areas, nevertheless, through existing regulations and coordination with other federal departments, managing for cumulative effects could still occur.

2.3 Chapter Summary

Assessing and managing for cumulative effects in the marine environment is a challenging and complex process, with many barriers to overcome. This is particularly difficult with regards to marine conservation areas since they have no physical boundaries to prevent external stressors from entering their zones. Additionally, most marine conservation areas are managed within specific legal boundaries, which can prevent the adequate inclusion of changing ocean conditions outside conservation area borders. In Canada, several methods for conserving and protecting its marine environment as well as permitting the sustainable use of ocean resources exist. However, there does not appear to be specific legislation, regulations, or policies that call for the explicit management of cumulative effects on marine conservation areas. The various approaches taken by Canadian ocean managers to assess and address the impacts of cumulative effects on marine conservation areas is explored further in the following sections.

Chapter 3. Methodology

This project investigated how ocean managers across Canada currently assess cumulative effects and multiple stressors in relation to marine conservation area management and also evaluated the extent to which socio-economic factors are considered in their assessments and decision-making processes. The foundation for the methodology used in this study is based on research conducted by Foley et al. (2017) which examined the types of information, methods, and tools used by ocean managers to assess cumulative effects from four locations around the Pacific Rim. To determine and evaluate what information, tools, and methods were being used by managers, Foley et al. (2017) first conducted a review of completed cumulative effects assessments. However, due to a lack of detail in most of the assessments, they designed and administered a survey as well as conducted follow-up interviews to gain greater insight into how ocean managers around the Pacific Rim conducted cumulative effects assessments.

A literature review to assess the current practices of assessing cumulative effects and multiple stressors in marine conservation areas as well as identify the social, economic, and ecological indicators that are already and/or should be included in these assessments was initially conducted. The databases used to complete the literature review included: Google Scholar, ProQuest, Web of Science, and the Canadian Federal Science Library. Key search terms used to identify relevant literature included *cumulative effects* or *impacts; cumulative effects* or *impacts assessment; multiple stressors; marine protected areas; marine conservation; marine* or *ocean ecosystems; socio-economic indicators;* and *socio-ecological systems.* Following the completion of the literature review, an online survey based on the one administered by Foley et al. (2017), was developed. The purpose of the survey was to evaluate and compare how ocean managers

across Canada assess cumulative effects and multiple stressors in terms of the ecological as well as socio-economic dimensions of marine conservation areas.

3.1 Sample Population

An initial sample of 231Canadian ocean managers including 121 from DFO, 42 from Parks Canada, and 68 from ECCC that are involved in marine conservation area management were selected for this study. However, this sample size may be smaller depending on the managers' level of involvement with marine conservation areas and individuals potentially changing their roles. For the purposes of this study, an 'ocean manager' was defined as *an individual that is involved in the decision-making related to marine conservation areas, including the identification, implementation and management of these zones.* Marine conservation areas included in this study were MPAs, OECMs, NMCAs, MBSs, and NWAs.

To identify ocean managers according to the definition above, the Government of Canada's employee directory (https://geds-sage.gc.ca/en/GEDS?pgid=012) was used. The list of potential participants from each federal department was then developed based on the individual's title/position indicated by the directory. Individuals from DFO were identified through the Ecosystem Management Branch of each region across Canada as well as through the Office of the Assistant Deputy Minister, Aquatic Ecosystems Branch. Potential participants from Parks Canada were identified through the Protected Areas Establishment and Conservation Directorate. Individuals from ECCC were identified through the Environmental Protection Branch and the CWS.

This sample population was chosen because marine conservation areas are spatially-defined social-ecological systems that aim to protect and maintain the ecological integrity of the marine environment while balancing the needs and interests of the social, cultural, and economic

activities that occur there. The spatial bounds and the regulation of human activities in marine conservation areas provide a strong basis for analyzing how managers account for cumulative effects in marine management plans and the extent to which socio-economic dimensions are considered. Targeting managers within the federal departments that administer marine conservation areas also allowed for differences in assessment methods between departments and regions of the country to be investigated.

3.2 Survey Design

The survey consisted of 40 questions, including 36 multiple-choice and four open-ended questions (Appendix A). These questions were divided into five sections: demographic questions (questions 1 through 5); defining scope (questions 6 through 11); information and assessment methods (questions 12 through 30); stressor interactions and tipping points (questions 31 through 38); and adaptive management (question 39). The final question (question 40) asked participants if they had any additional comments about how they assess and manage cumulative effects and/or multiple stressors in relation to marine conservation areas. Additionally, several questions also contained text-boxes to allow respondents to elaborate on their answers. All survey questions were optional, which allowed participants to skip questions they did not want to answer without preventing them from proceeding to subsequent questions. To accurately capture the state of cumulative effects management in Canada's marine conservation areas, participants that indicated they did not consider cumulative effects (question 6) or multiple stressors (question 7) in their decision-making were screened out of the survey. However, these responses were valuable in determining how many managers do not consider cumulative effects and multiple stressors at all in relation to marine conservation area management. Participants that answered "No" to question 6, but "Yes" to question 7 were directed to the sections on stressor

interactions and tipping points as well as adaptive management. The survey continued as normal for respondents that answered "Yes" to both question 6 and 7 or "Yes" to question 6 and "No" to question 7 since all survey questions were relevant to these participants.

The questions and response options used in the survey were adapted from Foley et al. (2017) as well as determined by the literature review (Dehens & Fanning, 2018; Hodgson & Halpern, 2018; Murray, Marmorek, & Greig, 2015; Pullin, Knight, Stone & Charman, 2004; Garcia Rodriguez, & Fanning, 2017). The survey administered by Foley et al. (2017) focused on the types of information ocean managers use for cumulative effects assessments as well as how they conduct their assessments in terms of spatial and temporal scales, baselines, and determining significance of effects. Questions about the types of information and the methods used to complete assessments, provided a strong basis upon which to design the questions and meet the objectives of this study. Survey questions were also collaboratively developed with Melissa Orobko, a PhD candidate at Simon Fraser University. This was done to ensure that the survey would support this graduate research and Melissa's PhD thesis as well as the Canadian Healthy Oceans Network (CHONe) project 2.2.4 – *Ecosystem resilience, multiple stressors and scale: Developing a framework to inform management.*

Survey participants were not anonymous to the researchers; however, their data was anonymized and their responses cannot be traced back to them. To determine if the level of manager, type of marine conservation area managed, and/or federal department influenced how cumulative effects are assessed, respondents were asked to answer questions in these categories. Additionally, to compare differences and similarities in assessment methods and the types of information used between regions, respondents were asked to identify which of Canada's three oceans the conservation area they work with is located.

3.2.1 Survey Distribution

An online survey was developed using the survey platform Opinio. This method was chosen to disseminate the survey due to its ability to reach a wide audience across a variety of platforms (i.e., computers, tablets, and cell phones). Using Opinio's built in invitation feature, the survey was distributed to potential participants via e-mail. The e-mail included an invitation to take part in the survey, a description of the research, and a link to the survey. If potential participants no longer held the position indicated on the government directory, they were asked to forward the survey to the relevant individual to maximize the number of responses. The survey was initially open for a period of four weeks from June 28, 2019 to July 26, 2019. Two reminder e-mails were also sent to individuals who had not yet completed the survey at the end of weeks one and three. Individuals who indicated they did not work with marine conservation areas were removed from the invitation list so that they did not receive reminder e-mails. Due to a low survey response rate as of July 22, the survey deadline was extended until August 12 to help maximize the number of responses included in the analysis. Following this extension, survey response rates remained low, which prompted another survey extension until September 30 to capture as many responses as possible.

3.3 Data Analysis

Survey results were analyzed using descriptive statistics through Microsoft Excel due to the small sample size and open-ended responses were analyzed by determining commonalities and differences amongst responses. Open-ended questions (10, 11, 14, and 40) focused on identifying the legislation, regulations, policies, and/or standards of practice that may require managers' to consider cumulative effects and multiple stressors; the ecological indicators used in assessments; and any additional information managers wanted to share. Questions that allowed

participants to elaborate on their answers, such as those containing an “Other” option, were analyzed using the same methods as the open-ended response questions. Due to the collaborative development of the survey with PhD candidate Melissa Orobko, who focused on the ecological components of cumulative effects assessments and multiple stressor interactions, some questions were not directly relevant to include in the analysis. Therefore, questions 32 through 38 were not included as these focused on how managers incorporate stressors interactions, stressor-effect relationships, and tipping points into their assessments and decision-making related to marine conservation area management.

Chapter 4. Results

A total of 231 invitations were sent to marine conservation area managers and decision-makers. When the survey closed on September 30, a total of 62 people had opened the survey, which resulted in a response rate of 27%. Of the 62 respondents who opened the survey, 36 complete responses and 7 partially complete responses for a total of 43 were included in the analysis. Incomplete responses with less than 10 answers were not included because these questions primarily focused on demographic information. However, it should be noted that survey participants that responded "No" to considering both cumulative effects and multiple stressors (questions 6 & 7) were included in the analysis to determine how many managers do or do not consider these factors in marine conservation area management. Due to a relatively small sample size, it was difficult to make comparisons and determine if the level of manager, region, type of marine conservation area, or federal department influenced how cumulative effects are assessed and managed. However, some broad generalizations can be made and are worth reporting because it may help identify similarities and differences in assessment and management methods, presenting potential learning opportunities.

4.1 Demographics

To identify the population of respondents, participants were asked to indicate which department they work for, the type of marine conservation area they manage, their position and level of experience as well as which of Canada's three oceans they conduct their work. Of the responses analyzed (n=43), about half (53%) said that they work for DFO, followed by those that work for ECCC (33%), and 14% of respondents indicated that they work for Parks Canada. In terms of the types of areas being managed, the largest percentage of respondents (40%) identified MPAs as the type of marine conservation area that they currently manage and/or work

with, which likely correlates with the higher number of responses received from DFO. As shown in Figure 2, this is followed by those indicating "Other," those who manage and/or work with marine NWAs, NMCAs, or OECMs, and finally those managing MBSs. Those that selected "Other" indicated that they manage more than one type of conservation area (e.g., NWAs and MBSs), collaborate with other departments on various marine protection tools, or regulate disposal at sea, which may occur near protected areas. Additionally, two respondents said that they manage and/or work with bioregional planning areas, which are large ocean management areas contributing to Canada's network of MPAs and can require cross-jurisdictional management with provinces or the United States (Government of Canada, 2011).

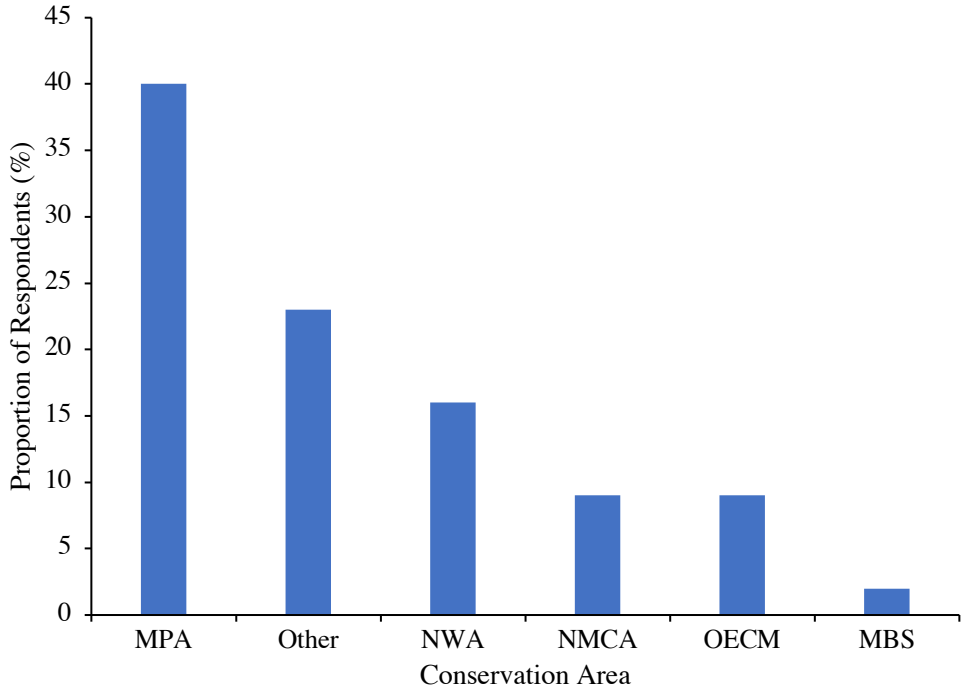

Figure 2. Type of marine conservation area managed by respondents.

To gauge respondents' involvement in decision-making regarding marine conservation areas, they were asked to indicate their level of work experience. An almost equal number of respondents either had one to five years or more than 10 years of experience related to decisions affecting the design, implementation, and management of marine conservation areas (Fig. 3).

Managers were also asked to self-identify their role or position within their department. Most (23%) identified as a junior level biologist (or scientist) or senior level manager (21%), followed by senior level biologists (or scientists) (19%). Sixteen percent of respondents identified as "Other," 12% as junior level managers, and 9% as senior policy advisors, with no participants identifying as junior level policy advisors. Managers that selected "Other" indicated that their position is a mix between science- and policy-related responsibilities or provided a different position from the options listed in the question.

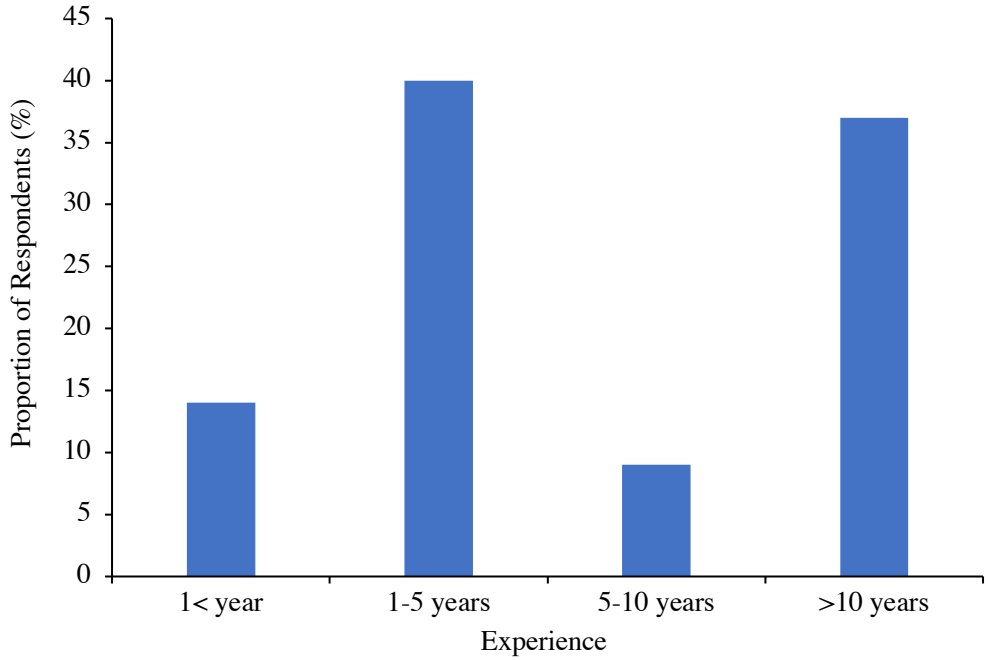

Figure 3. Experience of respondents related to decisions affecting the design, implementation, and management of marine conservation areas.

Identifying which region of Canada (Pacific, Arctic, or Atlantic) that participants conduct their work was important for understanding how cumulative effects and multiple stressors are considered in marine conservation area management across the country as well as to make comparisons between areas. Of the responses evaluated (n=42), 47% indicated that the conservation area(s) they manage and/or work with are located in Canada's Atlantic Ocean, 25% said Canada's Pacific Ocean, 21% of respondents said Canada's Arctic Ocean, and 7% selected

"Other." Those that selected "Other" identified Canada's Great Lakes and Gulf of St. Lawrence as additional areas of management and one respondent indicated that they "also contribute to national policies spanning all of Canada's marine areas" (Respondent #14). Furthermore, 10% of respondents said that they manage and/or work with marine conservation areas in all three of Canada's oceans.

4.2 Defining Scope

Prior to identifying the types of information, tools, and assessment methods used by managers, participants were asked about how they consider cumulative effects and/or multiple stressors as well as how they define the scope of their assessments. This was done to determine how many managers account for cumulative effects and/or multiple stressors in their decision-making and to identify the spatial and temporal scales in which these stressors and effects are considered. Of the responses analyzed (n=43), regardless of department, experience, region, or type of conservation area, most (79%) indicated that they do consider cumulative effects, while 21% said that they do not (Fig. 4). A majority of participants (84%) also said that they consider multiple stressors (Fig. 4). Of the 21% of respondents that indicated they do not consider cumulative effects in their decision-making, 16% said that they also do not consider multiple stressors and 5% said they consider multiple stressors, but not cumulative effects. Furthermore, respondents that indicated they do not consider cumulative effects and/or multiple stressors were asked to elaborate on their response. Of those who provided an explanation (n=6), half of the respondents (n=3) cited a lack of data as the primary reason they do not consider cumulative effects in their decision-making. Some respondents noted that a cumulative effects framework to help guide decision-making is lacking or that cumulative effects are generally not considered in the identification and establishment processes for marine conservation areas.

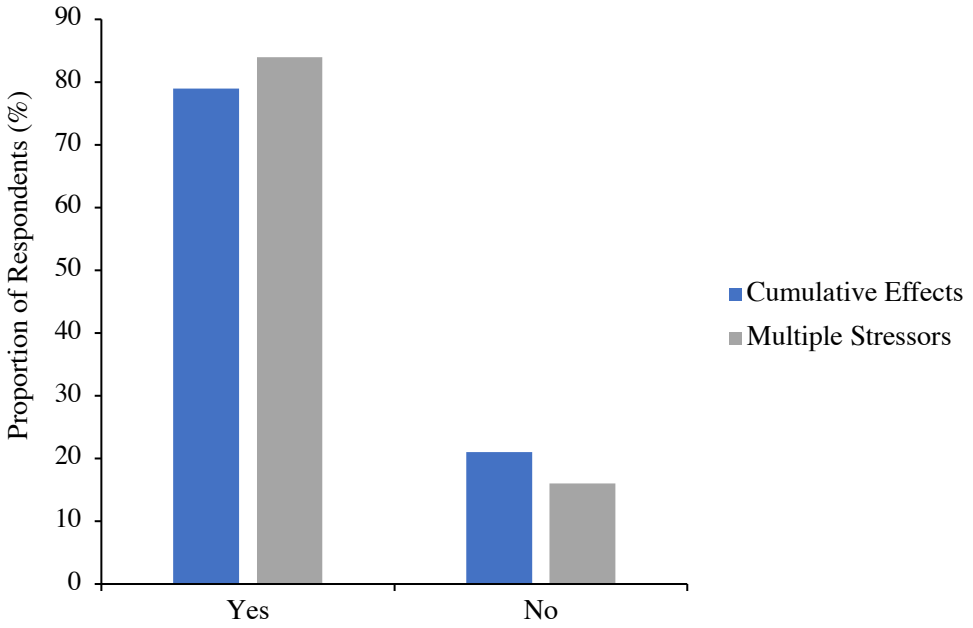

Figure 4. Proportion of respondents that consider cumulative effects and/or multiple stressors in their decision-making related to the design, implementation, and management of marine conservation areas.

Next, managers were asked to identify how they define the spatial and temporal bounds they use to consider cumulative effects in their decision-making, with the option to select multiple answers. Four different spatial scales made up the majority of responses (70%). The two most common spatial scales used by respondents (n=34) included, the spatial scale of the conservation area and the spatial distribution of important species or habitats (Fig. 5). These were followed by the spatial distribution of marine resource use and activities and the spatial scale of the anticipated effects of stressors. The remaining 30% of responses were similarly distributed among other spatial scales, which included watershed, bioregion or ecoregion, planning region, legal precedence, and "Other." One respondent that selected "Other" identified "depth within the water column" (Respondent #9) as an additional spatial consideration, suggesting recognition of the need to consider the three-dimensional nature of the marine environment when assessing and managing cumulative effects.

The temporal scales that managers use to account for cumulative effects in their decision making was similarly distributed across the response options (Fig. 6). However, three temporal scales in particular made up roughly half (53%) of the responses. These included past activities and effects, present activities and effects, and present baseline conditions. Respondents that selected "Other" indicated that past, present, and future temporal scales are considered when and where possible and that both spatial and temporal scale considerations can be case-specific.

While a statistical test for correlation is needed to confirm this, the department that managers work for appeared to influence the spatial and temporal scales managers use to assess for cumulative effects. The majority of managers in DFO (83%) and ECCC (73%) use the spatial scale of anticipated effects/stressors to account for cumulative effects in their decision-making. However, respondents from Parks Canada indicated that they do not use this spatial scale at all to assess cumulative effects. Instead, managers from Parks Canada seem to use the watershed of an area more often than the other two federal departments with 40% of Parks Canada respondents selecting this option. In terms of the temporal scales used by managers to consider cumulative effects in their decision-making, 40% of respondents from DFO indicated that they use past baseline conditions while 73% of respondents from ECCC and 60% from Parks Canada said that they use this scale.

Using only descriptive statistics, the position of participants also seemed to influence the type of temporal scale considered by managers to assess cumulative effects on marine conservation areas. Twenty-five percent of respondents that identified as "senior level manager" indicated that they consider future activities and effects up to one year and more than five years, while 13% said they consider future activities and effects between one and five years. More than half of participants that identified as "senior level biologist" or "senior level policy advisor"

indicated that they consider future activities and effects at various scales including up to one year, between one and five years, and more than five years.

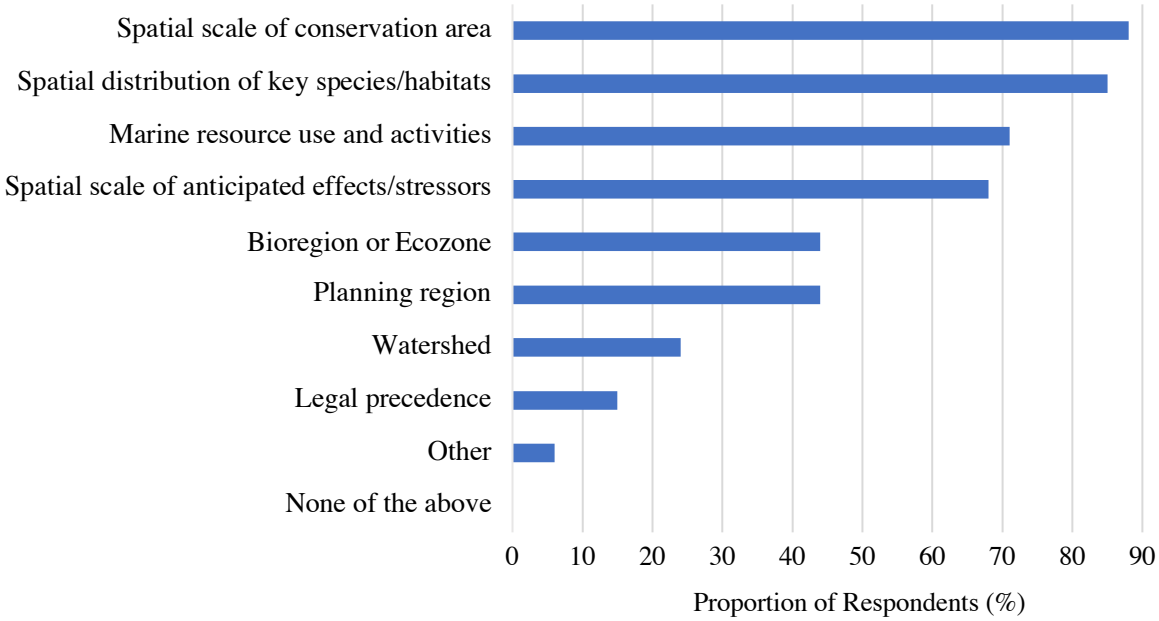

Figure 5. Spatial scales considered in cumulative effects assessment and decision-making.

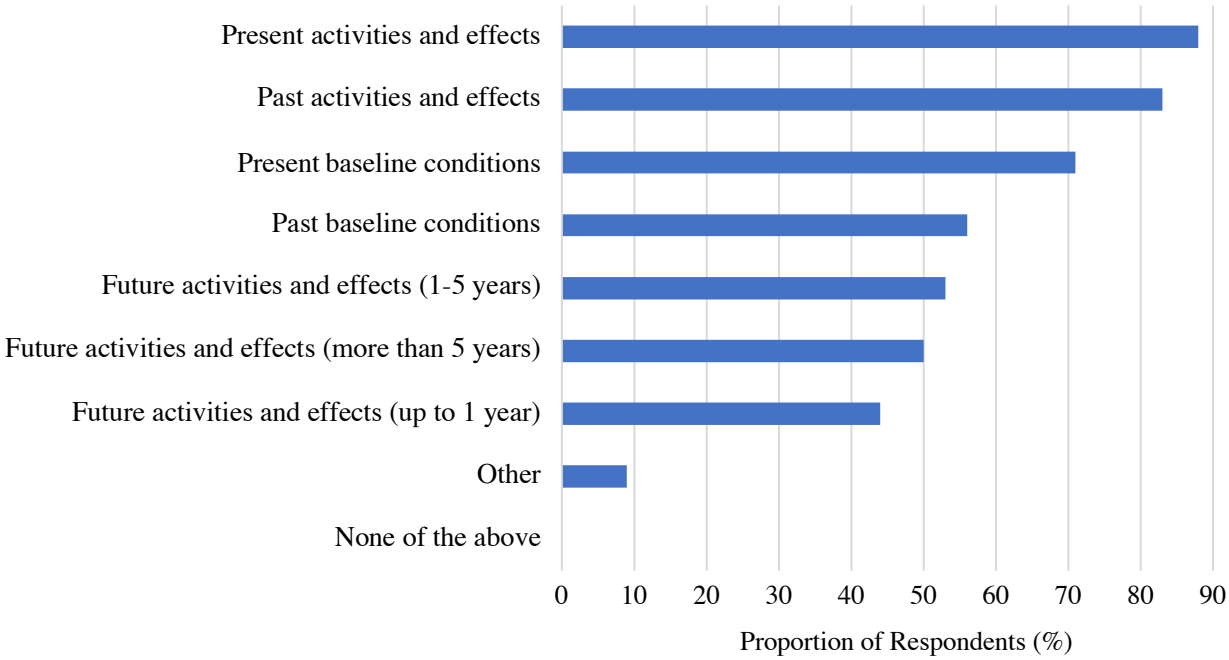

Figure 6. Temporal scales considered in cumulative effects assessment and decision-making.

4.3 Indicators and Information

To understand how marine conservation area managers consider cumulative effects and assess the extent to which they incorporate socio-ecological indicators and conditions, managers were asked about the activities, indicators, and stressors as well as the tools and type of information that they include in their assessments and decision-making. Of the respondents that answered this question (n=31), the top three activities considered when assessing cumulative effects included fish harvesting, marine transportation (e.g., shipping), and recreation (Fig. 7). However, these were not the three most common activities considered by managers in DFO or Parks Canada, suggesting that department affiliation and mandate may influence which activities are considered when assessing and managing cumulative effects. However, a statistical test is needed to confirm this result. Respondents from DFO (n= 16) indicated that they give more consideration (81%) to offshore oil and gas development than recreation (63%) and participants from Parks Canada (n=5) appear to give more consideration to tourism and coastal development (100%) over fish harvesting (80%).

Additional activities considered by managers in their assessments of cumulative effects on conservation areas included waste discharges, marine spills, and aquaculture. In general, offshore oil and gas development was among the bottom three activities considered along with mining and agriculture. In-text responses (n=10) identified other activities considered when assessing cumulative effects, which primarily included traditional/subsistence hunting and harvesting, cultural uses, and research activities. Some respondents identified acoustic impacts, invasive species, pollutants, mooring or anchoring, and climate change as “activities”, suggesting that there may be a lack of clarity on what is considered an activity or stressor. It was also noted that the activities considered in assessments and decision-making are often site-specific and any

potential cumulative effects from activities permitted within a conservation area are monitored and regulated as needed.

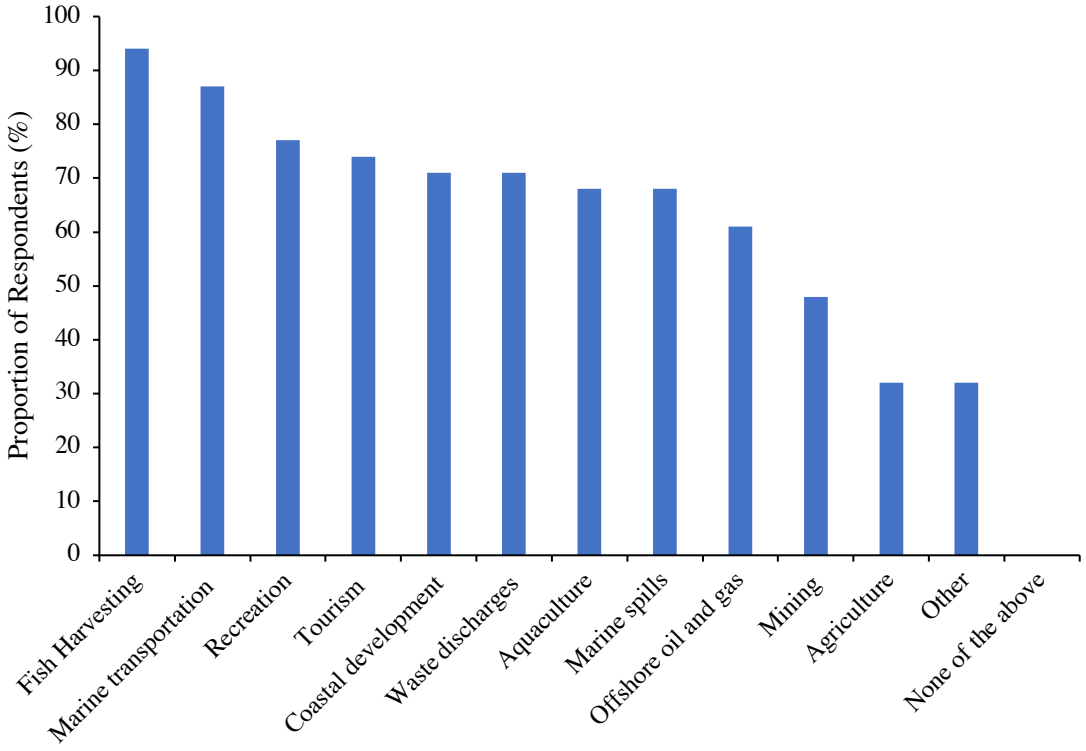

Figure 7. Human activities considered in cumulative effects assessment and decision-making.

Identifying which ecological stressors managers consider in their assessments and decision-making is important for understanding how marine ecosystems may be affected by human activities both inside and outside of protected area boundaries. Of the respondents that answered this question (n=30), roughly half (49%) indicated that they consider physical disturbance, anthropogenic noise, the introduction of pollutants, and/or the introduction of non-native species as the primary ecological stressors of concern (Fig. 8). These were followed closely by changes in climate condition and anthropogenic litter or debris. The most common response identified by those that selected "Other" was that the ecological stressors included in assessments and decision-making are usually specific to each conservation area and its location. In general, the ecological stressors considered by managers when assessing cumulative effects do

not appear to be influenced by their department, level of experience, type of conservation area, or region. However, this result needs to be confirmed by statistically testing for correlation.

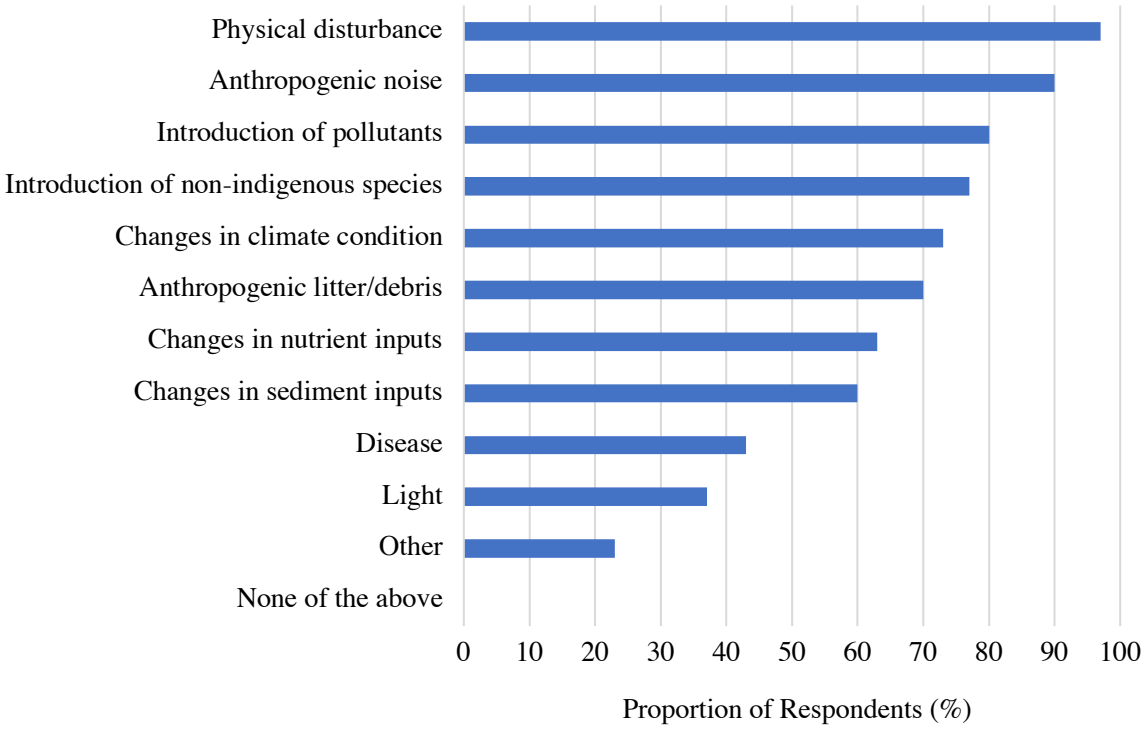

Figure 8. Ecological stressors considered in cumulative effects assessment and management.

How managers consider and incorporate stressor interactions is also important to understanding how they account for cumulative effects in marine conservation areas. Of those who responded to this question (n=25), most (76%) indicated that they primarily consider additive stressor interactions (i.e., cumulative effect = sum of individual stressor effects), followed by synergistic stressor interactions (56%) (i.e., cumulative effect > sum of individual stressor effects). Antagonistic stressor interactions (i.e., cumulative effect < sum of individual stressor effects) were only considered by 28% while 16% of respondents did not consider stressor interactions at all. While a statistical test with a larger sample size is needed to confirm this, overall, position and level of experience did not appear to influence the type of stressor interactions considered by respondents. However, the department respondents work for seemed

to influence responses. Managers that identified that they work for DFO indicated that they give less consideration to antagonistic and synergistic interactions compared to ECCC and Parks Canada. The region in which managers work, in relation to synergistic interactions also appeared to have some influence. Those that work with conservation areas in the Arctic indicated that they give more consideration to these interactions than those who work in the Pacific or Atlantic. However, given the relatively small sample size and lack of statistical analysis, these findings are cautionary since they are based simply on descriptive statistics.

When assessing cumulative effects, managers often use several indicators to detect changes in the condition of the marine environment. These can include ecological, social, and/or economic indicators. In general, the most common ecological indicators identified by participants included habitat-related (e.g., quality, sensitivity), species-related (e.g., abundance, diversity), and ecosystem-related indicators (e.g., structure, function). The two most common social indicators identified by respondents (n=30) were local marine resource use patterns and local values and beliefs regarding marine resources (Fig. 9). Thirty-one percent of responses were similarly distributed between quality of human health, access to community services, community welfare, population composition, and "None of the above." Seven percent of respondents selected "Other" and most indicated that they also consider Indigenous rights and consult with their Indigenous partners when selecting social indicators. Economic indicators related primarily to the value of an industry and job type. Most respondents (65%) identified the economic value of fisheries in an area, the economic value of other industries in an area, and the nature of employment in an area (e.g., fish harvester versus tour boat operator) as the most common economic indicators (Fig. 10). Other indicators such as employment rates, possible displacement issues, and household income levels were less common. Similar to social

indicators, respondents that selected "Other" indicated that they consider Indigenous rights and considerations (e.g., subsistence harvesting) when selecting economic indicators. One respondent also identified the economic value of ecosystem services as another type of economic indicator. In general, the level of manager, type of conservation area, department, and region did not seem to influence the types of social or economic indicators used by managers to assess cumulative effects. However, this finding is based solely on an assessment of the descriptive statistics.

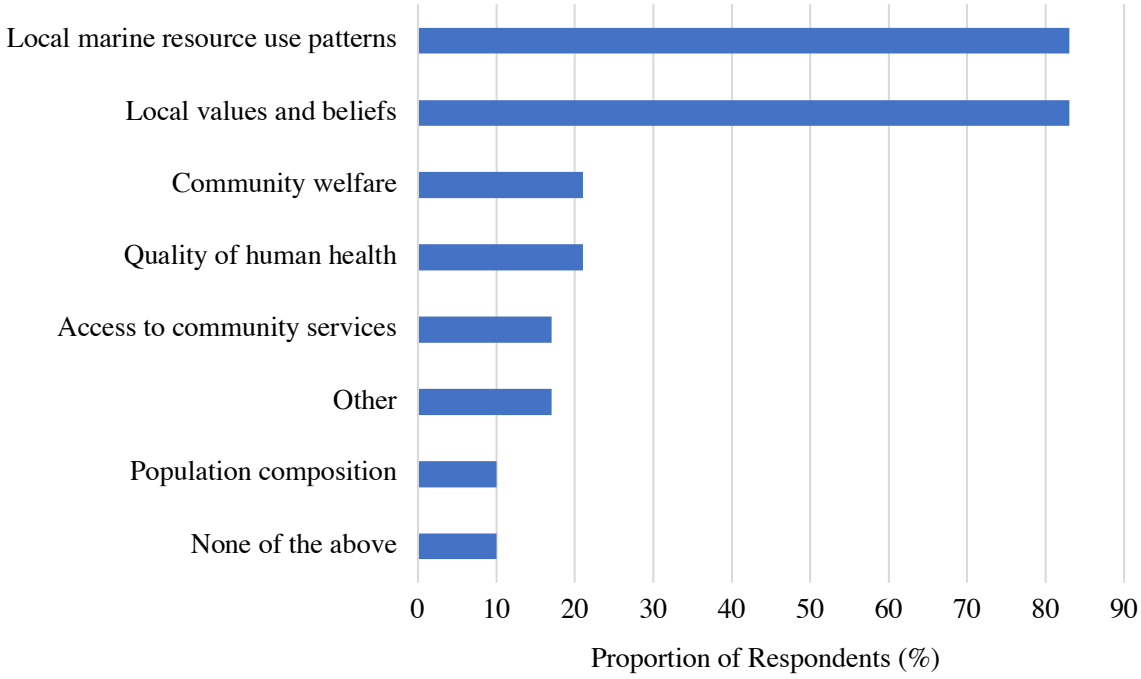

Figure 9. Social indicators considered in cumulative effects assessment and decision-making.

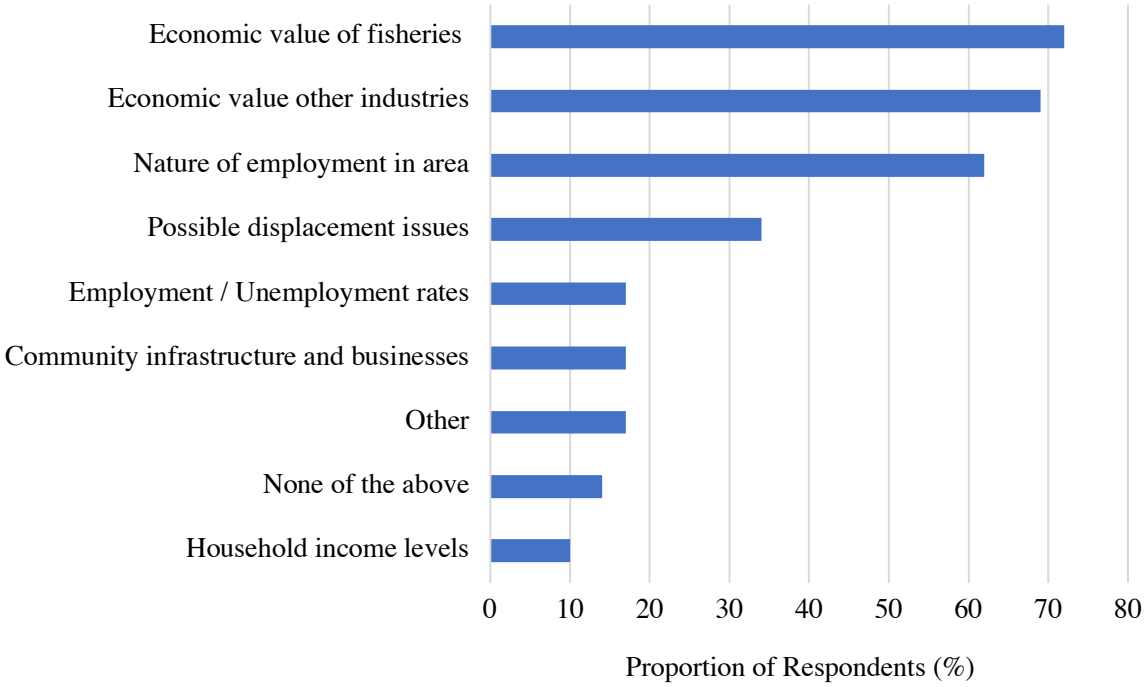

Figure 10. Economic indicators considered in cumulative effects assessment and decision-making.

To help determine the extent to which ecological, social, and economic indicators are considered when assessing the impacts of cumulative effects on marine conservation areas, participants were asked to indicate the level of importance they assign to the various indicators as it relates to their decision-making. Sixty-nine percent of respondents (n=29) agreed that ecological indicators are "Very important" to cumulative effects assessments, regardless of region, role, department, or experience. However, only 31% agreed the same is true for social indicators (Fig. 11). Furthermore, 43% of participants (n=30) indicated that economic indicators are also "Very important." Four percent of respondents indicated that social indicators are "Not important," while 10% said the same for economic indicators. Interestingly, no respondents said that ecological indicators are "Not important," suggesting that managers may have a better understanding of ecological indicators compared with social and economic ones. In contrast to the overall trend, almost half (46%) of respondents working for DFO indicated that social

indicators are “Very important” while only 20% from ECCC and none from Parks Canada said the same. Similarly, half (50%) of respondents working for ECCC and Parks Canada indicated that economic indicators were “Somewhat important.”

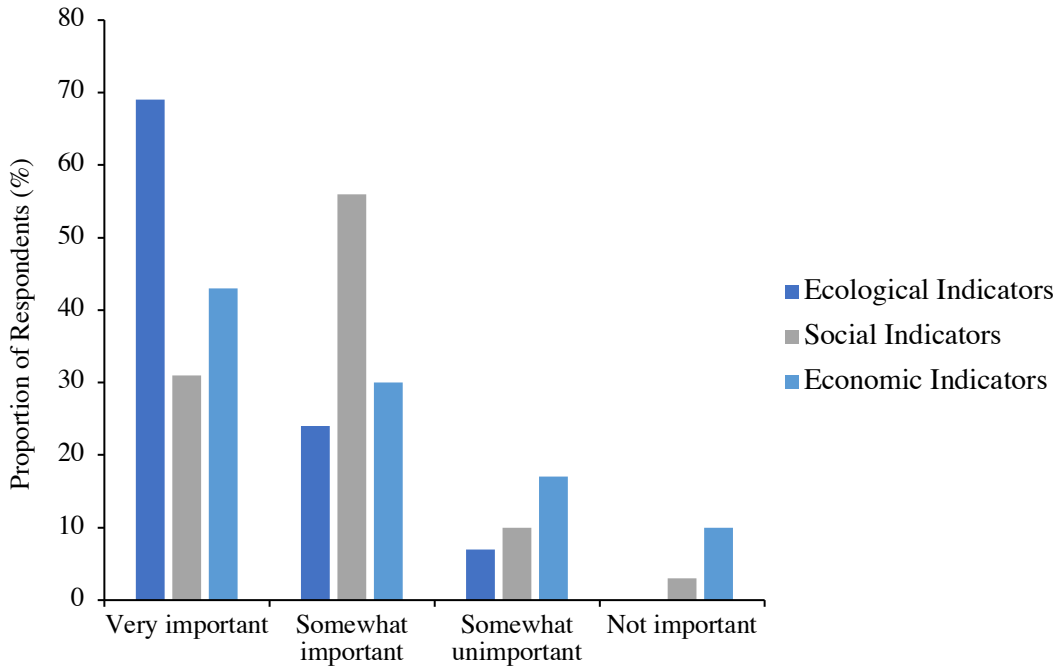

Figure 11. Importance of ecological, social, and economic indicators to Canadian ocean managers when assessing cumulative effects in their decision-making related to marine conservation areas.

Participants were also asked about whether or not they consider the potential negative ecological cumulative effects as well as the potential positive and negative cumulative socio-economic effects of conservation areas. These effects may include decreases in fish populations outside of conservation areas due to displacement of fishing effort, improved human health and well-being, and/or loss of employment or traditional use of an area. Overall, most participants (n=30) indicated that they do consider the potential negative ecological cumulative effects or socio-economic effects of conservation areas (87%) while slightly less consider the potential positive cumulative socio-economic effects (80%). Respondents that do not consider these potential effects generally indicated that they “would not move in a direction that would [result in] negative [ecological] or socio-economic effects” (Respondent #12). However, it was also

noted that socio-economic effects are not usually a key consideration in marine conservation area planning and management, and several respondents said this was outside their scope of research and/or work.

Next, participants (n=30) were asked to identify the sources of ecological, social, and economic information they use to assess cumulative effects. The sources of ecological information that conservation area managers use in their assessments and management of cumulative effects was varied in distribution (Fig. 12). Regardless of department, level of experience, region, or type of conservation area managed, monitoring data was identified as the primary source (100%) of ecological information, followed closely by spatial data (97%) and published peer-reviewed literature (97%). Other important sources of information identified by respondents included expert opinion (90%), other environmental managers / practitioners (87%) and, traditional ecological knowledge (87%). Respondents that selected "Other" identified private industry as another source of information and one respondent stated that "Traditional [Indigenous] knowledge [is] considered in the same way as peer-reviewed literature" (Respondent #1). However, this does not appear to be reflected in the multiple-choice responses. Managers also indicated that the sources of ecological information used in their assessments and decision-making is a mix between sources of information specific to their conservation area and other ecosystems or conservation areas.

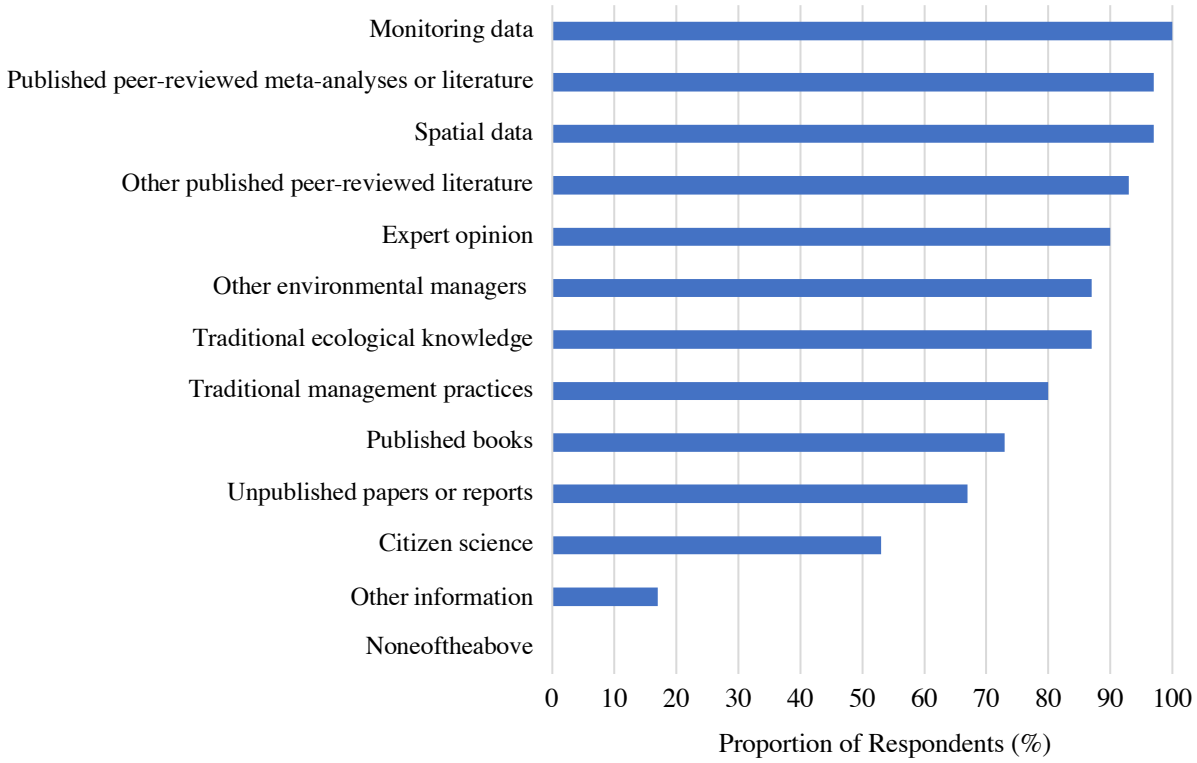

Figure 12. Sources of ecological information considered by Canadian ocean managers when assessing cumulative effects in their decision-making related to marine conservation areas.

Of the responses analyzed (n=30), most managers (77%) identified local or community knowledge as the primary source of socio-economic information used in their decision-making, followed by expert opinion (70%), traditional knowledge (70%), and other managers or practitioners (67%) (Fig. 13). About half of participants use cultural and/or economic information while roughly one-third use published peer-reviewed social science literature (37%), published books (30%), or demographic data (30%). Ten percent of respondents also indicated that they do not consider any of these sources of information, but did not identify additional sources of information used. Using only descriptive statistics, it appeared that socio-economic sources of information were not influenced by department, region, level of experience or type of conservation area. However, in general, it seemed that MPA managers rely more heavily on economic information and information from other managers/practitioners than traditional

knowledge, compared to the overall trend. Those that selected "Other" indicated that the sources of socio-economic (and ecological) information used often depend on its availability and can be limited in some locations. Additionally, respondents from DFO noted that a separate socio-economic team, led out of the Policy Branch, analyzes this information and passes it on to conservation area practitioners to be considered in their work. Lastly, compared to the sources of ecological information, socio-economic sources of information are primarily derived from the conservation area or ecosystem in which managers work with.

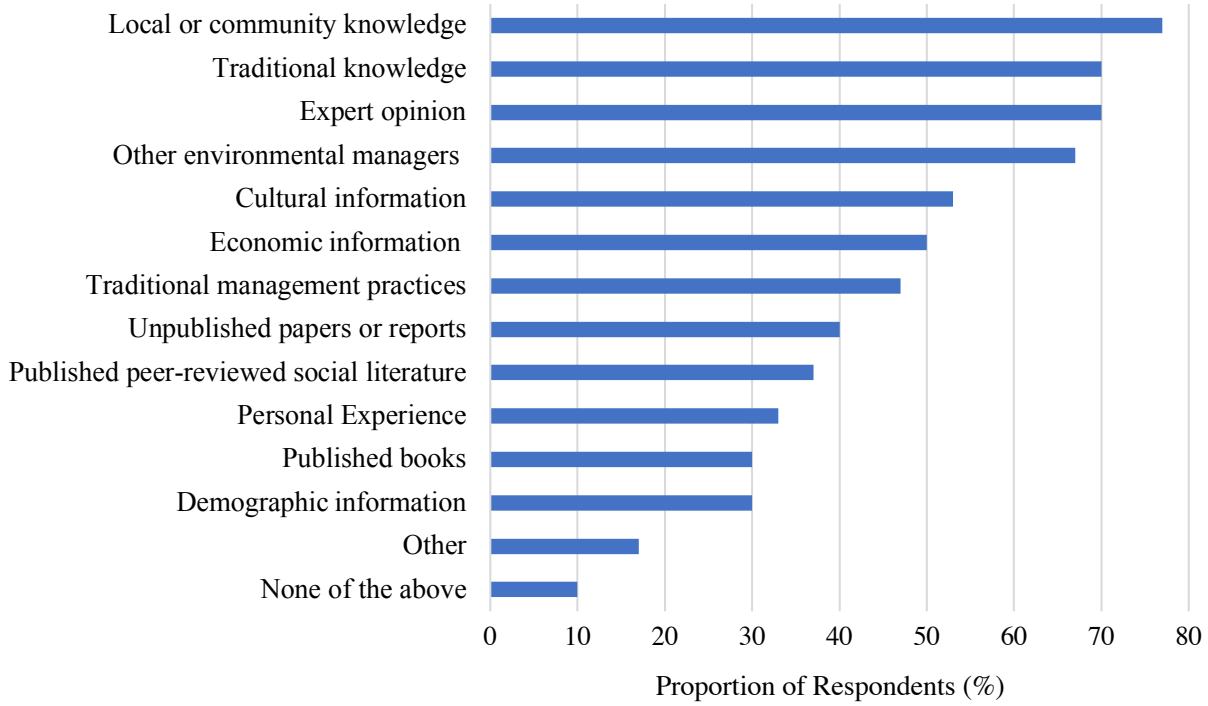

Figure 13. Sources of socio-economic information considered by Canadian ocean managers when assessing cumulative effects in their decision-making related to marine conservation areas.

The availability of information was identified as the largest barrier that may limit or prevent marine conservation area managers (n=30) from incorporating both ecological and socio-economic information into their decision-making (Fig. 14). This barrier was followed by the quality of data and quantity of data with the quality of data presenting as a slightly larger barrier

than quantity. The relevance of data to managers' work was less of a barrier to incorporating ecological information than it was for socio-economic information, suggesting managers may have more experience or knowledge related to ecological information. Additionally, it appeared that across all types of marine conservation areas, the quality of ecological information is a larger barrier than availability while the availability of socio-economic information is a larger barrier than quality (Fig. 14). Explanations provided by respondents that selected “Other” indicated that some ecological information may not be available to them to protect the confidentiality of fishing grounds and that quantifying some socio-economic information (e.g. social values) can be challenging.

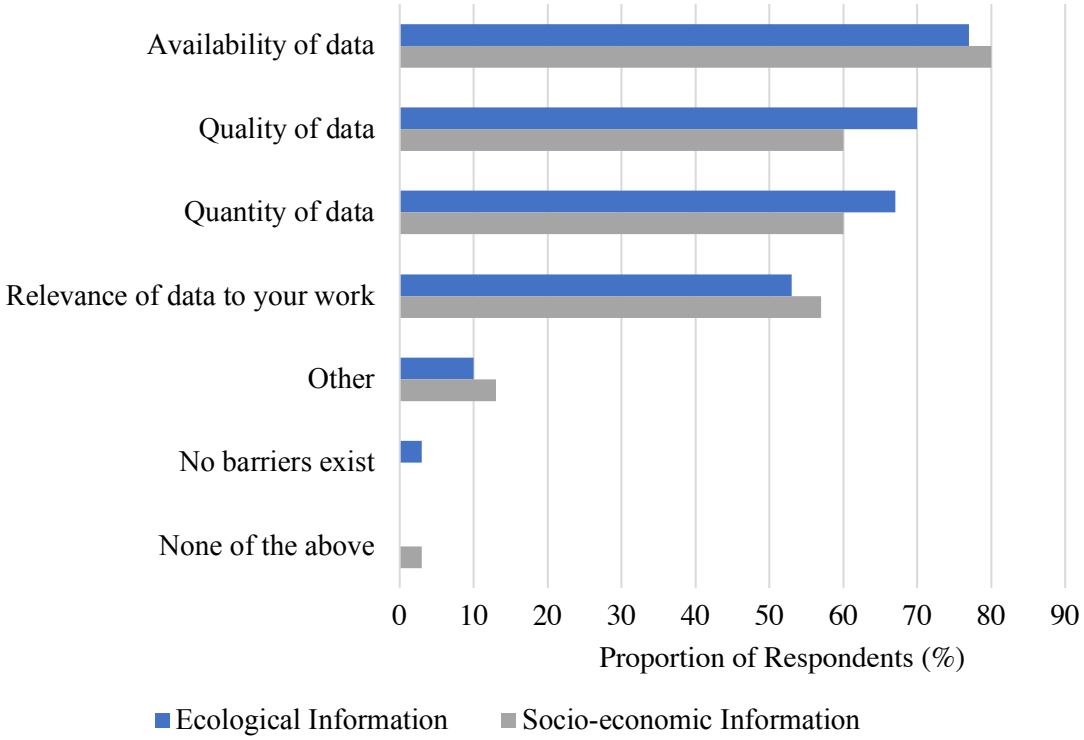

Figure 14. Barriers to the inclusion of ecological and socio-economic information in cumulative effects assessment and decision-making.

4.4 Assessment Methods

To evaluate how different types of information and indicators regarding cumulative effects are incorporated into marine conservation area management plans, respondents were asked about the legislation, regulations, policies, and/or standards of practice as well as any frameworks or tools that they may use. Each federal department (DFO, ECCC, and Parks Canada) uses a variety of legislation, regulations, policies, and standards of practice to consider cumulative ecological effects on marine conservation areas (Table 1). Of the responses assessed (n=36), some elaborated on these regulations and guidelines and indicated that under new provisions, the Fisheries Act explicitly calls for the consideration of cumulative effects on fish and fish habitat. Some participants also noted that the Oceans Act requires the development of integrated management plans, which "helps [them] to identify all human activities, current or planned, that may contribute to pressures in the region or specific habitat under analysis" (Respondent #23). This piece of legislation also necessitates that each MPA have its own set of regulations, which "require an evaluation of [the impact of] cumulative effects pertaining to the approval of activity plan requests" (Respondent #9), suggesting a project- or activity-based approach is used.

Table 1. Acts, regulations, policies, and standards of practice used by managers in DFO, ECCC, and Parks Canada to consider cumulative ecological effects in their decision-making related to the design, implementation, and management of marine conservation areas.

Department	Legislation	Regulations	Policy	Best Practices	Other
DFO	Oceans Act Fisheries Act Species at Risk Act	Site-specific MPA regulations	Canada's Ocean Strategy	Government priorities and mandates	Canada's Ocean Protection Plan
ECCC	Canadian Environmental Protection Act Migratory Birds Convention Act Canadian Wildlife Act Impact Assessment Act Species at Risk Act Oceans Act Fisheries Act	Disposal at sea regulations Site-specific conservation area regulations	ECCC protected areas establishment policy & guidance	Open Standards for the Practice of Conservation Ecosystem-based approaches	Site-specific agreements
Parks Canada	Canada National Marine Conservation Area Act Species at Risk Act National Parks Act Impact Assessment Act	Site-specific conservation area regulations	None identified	Cabinet Directive on Strategic Environmental Assessment of plans, programs and policies Parks Canada Directive on Impact Assessment	N/A

The legislation, regulations, policies, and standards of practice that managers use to consider socio-economic effects in their decision-making relating to marine conservation areas was similar to those used for ecological effects (Table 2). However, more respondents cited that

no explicit legislation, regulations, or policies presently exist to consider socio-economic factors in the assessment and management of cumulative effects. Respondents also appeared to rely more heavily on standards of best practice when considering socio-economic effects in their decision-making. Participants also alluded to the need to consult Indigenous peoples and local communities when designing, implementing, and managing marine conservation areas. Although a range of legislation, regulations, policies, and best practices exist across the federal departments surveyed, it appears that no explicit framework or standards exist that require the consideration of cumulative effects in decision-making related to marine conservation areas.

Table 2. Acts, regulations, policies, and standards of practice used by managers in DFO, ECCC, and Parks Canada to consider socio-economic effects in their decision-making related to the design, implementation, and management of marine conservation areas.

Department	Legislation	Regulations	Policy	Best Practices	Other
DFO	Oceans Act Fisheries Act Species at Risk Act	Site-specific MPA regulations Treasury board regulatory processes	None identified	Co-governance agreements with Indigenous Partners	Frameworks for MPA establishment and management
ECCC	Canadian Environmental Protection Act Canadian Wildlife Act Impact Assessment Act Oceans Act Fisheries Act	London Protocol: consideration of 'other users of the sea' when granting permits for disposal at sea	None identified	Indigenous, industry, and community consultations Open Standards for the Practice of Conservation	ECCC guidance document for the creation of management plans
Parks Canada	Canada National Marine Conservation Area Act Impact Assessment Act	Zoning provisions of NMCA Act	None identified	Traditional Indigenous Knowledge considerations	Site-specific legislation and agreements

Several frameworks are used to assess and manage cumulative effects in marine conservation areas. Of the responses evaluated (n=27), 52% indicated that they do not use a specific framework to assess cumulative effects in their decision-making. However, the remaining 48% of respondents identified a variety of frameworks, which appeared to differ across and within federal departments. Examples of frameworks identified by managers include ecological risk assessment frameworks, strategic environmental assessment methods, and decision support frameworks. Some managers also noted that specific guidance on how to assess cumulative effects on marine conservation areas does not presently exist and is an "area of ongoing work within [their] department" (Respondent #43). A variety of tools are also used by managers to assess cumulative effects in marine conservation areas. Of respondents (n=26), most (92%) indicated that they use mapping, followed by risk assessment models (73%). Pathways of effects models and decision support tools (e.g., Marxan) were the third most common tools used (58%) and very few respondents (12%) said that they use Driver-Pressure-State-Impacts-Response (DPSIR) models or variants (e.g., DAPSI(W)R(M)). Additionally, some participants (23%) indicated that they use agency-specific tools (Table 3). Overall, based simply on descriptive statistics, it did not appear that the type of conservation area, department, region, or level of manager influenced what tools are most commonly used. However, respondents working for Parks Canada, seem to rely less on risk assessment models than ECCC and DFO.

Table 3. Agency-specific tools used by managers when assessing cumulative effects in their decision-making related the identification, implementation, and management of conservation areas.

Department	Tool(s)
DFO	GIS toolbox for cumulative effects assessment; GIS database of the spatial distribution of ecosystem components and human activities
ECCC	Risk analysis frameworks; expert opinion; mapping; and GPS data
Parks Canada	Recreational use assessment tool

Finally, managers were asked if they incorporated any elements of adaptive management into their decision-making related to the assessment and management of cumulative effects on marine conservation areas. Responses (n=27) were relatively varied, however, the majority (>90%) of participants indicated that defining problems by setting clear goals and objectives as well as involving stakeholders and scientists are important. Monitoring and assessing baseline conditions also appeared to be an important consideration among managers. Elements of adaptive management pertaining to the evaluation of results and adjusting management actions appeared to be less important, suggesting that managers may not completely apply the full extent of adaptive management practices in their decision-making.

4.5 Anecdotal Responses

The final survey question asked participants to provide any additional comments they had on how they assess cumulative effects and/or multiple stressors in their decision-making related to marine conservation areas. Of these responses analyzed (n=19), two general themes emerged and are elaborated on in this section. The first broad theme to emerge among participants was that there is an overall lack of and access to information needed to adequately assess and manage cumulative effects in marine conservation areas. Roughly one-third (32%) of respondents

described this or a variant of this theme as a major challenge, especially in regards to their ability to "feed models and [make predictions]" (Respondent #19). Other factors limiting managers' ability to assess and manage cumulative effects included a lack of expertise and/or frameworks; heavy workloads; tight timeframes for decisions; and the cost to collect and monitor all relevant data. Despite these barriers, respondents appear to be aware of the importance of considering cumulative effects and multiple stressors and expressed that improvements are currently in progress. As one respondent stated: "there is a gap in how DFO assesses cumulative effects - this is a known gap that we are working to fix" (Respondent 30). This suggests that although several barriers presently exist, practitioners are aware of them and are actively working to make improvements and ensure Canada's protected area receive the best possible management.

The second major theme to emerge from the additional comments was that the assessment and management of cumulative effects in marine conservation areas is often site- and case-specific. Due to this, there exists "a fair amount of variation in how cumulative effects/multiple stressors are assessed and used in decision-making across the various conservation sites in the country […]" (Respondent #29). This suggests that current assessment and management practices may be fragmented, potentially contributing to some of the challenges identified above, warranting the need for a more streamlined approach to evaluating and managing cumulative effects in marine conservation areas.

Chapter 5. Discussion

Overall, there appears to be broad recognition among the Canadian marine conservation area managers surveyed in this study about the importance of understanding and accounting for cumulative effects and multiple stressors in management decisions. Furthermore, a variety of information, indicators, tools, and approaches to assess and manage these stressors and effects appear to exist. However, data deficiencies and an apparent disconnect between social and ecological interactions seem to prevent managers from adequately incorporating the most relevant information and indicators into their assessments and decision-making.

Drawing only on descriptive statistical analysis of the responses received, level of experience, region, and type of marine conservation area did not appear to substantially influence how cumulative effects are assessed or the types of indicators used. However, the federal department that participants work for seemed to exert some influence on some aspects of how they assess cumulative effects. This suggests that inconsistencies in indicators, frameworks, and management approaches may exist between each of the federal departments responsible for Canada's marine conservation areas. Below, the activities, information, tools, assessment methods, and indicators used by marine conservation area managers to assess and manage cumulative effects are discussed in more detail.

5.1 Activities, Stressors and Scope

Defining the appropriate spatial and temporal scales in which to assess cumulative effects is cited as a substantial challenge to adequately account for these in management plans, especially in relation to marine conservation areas (Clarke Murray et al., 2014; Mach et al., 2017). The results of this study suggest that this holds true for Canadian marine conservation area managers. Most participants identified the spatial scale of the conservation area, the spatial

distribution of important species or habitats, marine resource use patterns, and the spatial scale of the anticipated effects of stressors as the primary spatial scales they use to consider cumulative effects. This suggests that managers tend to focus their assessments more on local or site-specific scales and is likely due to the fact that marine conservation areas are defined zones of protection that aim to regulate human activities and conserve specific habitats or species. However, it has been suggested that broader, ecosystem or eco-region scales that account for the interactions between local and regional stressors are needed to adequately address and manage cumulative effects (Clarke Murray et al., 2014; Foley et al., 2017). This is especially pertinent for marine conservation areas since they often remain exposed to external stressors (e.g., increasing ocean temperatures), which cannot be directly controlled simply through the implementation of protected areas (Mach et al., 2017). Despite a general focus on local or site-specific spatial scales, Parks Canada managers seem to consider cumulative effects on a slightly broader scale. Managers from this department indicated that they do not use the spatial scale of anticipated effects/stressors to consider cumulative effects and instead more often tend to use watershed as a spatial scale when considering cumulative effects. This may be due to the type of conservation areas managed by Parks Canada (i.e., NMCAs), which often include coastal lands (Parks Canada, 2017a), necessitating a broader approach to considering cumulative effects.

An additional challenge to defining appropriate spatial scales is the three-dimensional nature of the marine environment. It is often difficult to identify processes connecting food webs and ecosystems at different depths as well as incorporate the movement of stressors (e.g., stressors impacting surface waters may also affect deeper waters) (Halpern & Fujita, 2013). Considering depth within the water column was only identified by one participant as an additional spatial consideration that they use and suggests that the three-dimensionality of the

marine environment may be overlooked in many assessments. To improve the effectiveness of existing marine conservation areas in Canada as well as ensure the success of future ones, managers should consider the potential effects of activities and stressors both inside and surrounding protected area boundaries. Additionally, the interactions between stressors in the water column should also be accounted for. This will help ensure that the appropriate activities, stressors and impacts are included in cumulative effects assessments as well as help guide the temporal boundaries needed for effective management.

The temporal scales that managers use to account for cumulative effects in their decision making primarily include: past activities and effects, present activities and effects, and present baseline conditions. The lesser consideration of future activities and effects suggests that managers may only consider cumulative effects on a time scale that is relevant to the duration of impacts that a project or activity is likely to have on the environment. This is consistent with practices of other cumulative effects practitioners in Canada at the provincial level as well as practitioners from California, Australia and New Zealand (Foley et al., 2017). However, it is recommended that temporal scales should be informed by the duration in which stressors effect ecological components, which may extend beyond the operating time of a project or activity, particularly when a system has a slow recovery potential (Foley et al., 2017; Judd et al., 2015).

Although marine conservation area managers generally appear to use temporal scales which include historical considerations, managers from DFO indicated that they give less consideration to past baseline conditions compared to ECCC and Parks Canada. This suggests that DFO may rely on current baselines for their assessments which is concerning as these can exclude critical historical information, thereby diminishing the severity of a proposed project or activity in or near conservation areas (Clarke Murray et al., 2014). Furthermore, the lack of clear

and consistent definitions regarding cumulative effects across the departments could help explain this difference since they often determine the direction or approach that an assessment will take (Duinker et al., 2013; Judd et al., 2015). Interestingly, the position or role of managers also seemed to influence the temporal scales managers use to consider cumulative effects. Individuals that identified as "senior level manager" appear to give less consideration to future activities and effects in their assessments. However, statistical tests for correlation are needed to confirm these interpretations. This result suggests that because of their experience, senior level managers may prioritize past and/or current activities and effects possibly due to limited data, financial constraints or time restrictions.

The limited consideration of future activities and effects may also suggest that there is currently a lack of data or information needed to predict future outcomes. For example, several managers indicated that the idea of considering cumulative effects in conservation area decision-making is "well known to be a good one" (Respondent #24), however, managers rarely have "all the information or data needed to feed a model" (Respondent #19). This is consistent with much of the cumulative effects literature which cites deficiencies in information and data as one of the primary challenges to conducting effective assessments (Halpern et al., 2019; Halpern & Fujita, 2013; Hodgson & Halpern, 2019). Both spatial and temporal bounds are essential to effectively conducting cumulative effects assessments. If adequate scales are not defined by managers at the outset of their assessment, they risk missing key activities and stressors needed to eliminate, reduce, or mitigate the threats to successful marine conservation and protection.

The top three human activities considered by managers when assessing cumulative effects include fish harvesting, marine transportation, and recreational activities (e.g., public beach use, angling). These were likely selected due to the goals and objectives of Canada's

marine conservation areas to balance protection and sustainable use as well as to maintain biologically and ecologically important marine areas for current and future generations (Government of Canada, 2011). Furthermore, although fish harvesting, marine transportation, and recreational activities were identified as the primary activities considered by managers overall, DFO and Parks Canada prioritize slightly different activities. Managers from DFO indicated that they consider fish harvesting and marine transportation as important activities, however, offshore oil and gas development was identified as their third most considered human activity when assessing cumulative effects. This is potentially due to new provisions recently implemented by DFO to enhance the protection of the marine environment by prohibiting harmful activities, including oil and gas activities in MPAs (DFO, 2019b). Parks Canada indicated that they consider marine transportation and recreation, however, tourism and coastal development activities are given more consideration than fish harvesting. These activities are likely given more consideration due to the type of conservation areas managed by Parks Canada, which often include coastal areas (e.g., Tallurutiup Imanga NMCA). Additionally, the mandate of Parks Canada is to "protect and present nationally significant examples of Canada's natural and cultural heritage" (Parks Canada, 2018, para. 1), which likely contributes to an increased concentration on supporting activities related to tourism.

Managers also consider climate change, acoustic impacts, invasive species, and pollutants as "activities" in their assessments, however, these should more accurately be considered stressors, suggesting that there may be a lack of clarity on what is considered an activity or stressor. The potential confusion between activities and stressors demonstrates that there is a need for better transparency on how these are defined. Therefore, a set of clear definitions regarding cumulative effects assessments in marine conservation areas that applies across

departments should be developed and implemented. Furthermore, frameworks such as the Drivers-Activities-Pressures-State Change-Impacts (on human Welfare)-Responses (as Measures) (DAPSI(W)R(M)) framework developed by Elliot et al. (2017) could help define the differences between activities and stressors. This framework expands on the Drivers-Pressures-State-Change-Impact-Response (DPSIR) framework and provides explicit definitions of activities and pressures (or stressors) that could be adopted by DFO, ECCC, and Parks Canada in their assessment of cumulative effects. Additionally, while this study did not concentrate on the ecological stressors that managers include in their assessments, it is important to acknowledge their relationship and ability to impact social systems. Humans can have negative impacts on the environment, which can lead to degradation of ecological systems and in turn it can ultimately create impacts on human livelihoods and well-being. Consideration of ecological stressors and their relationship to human systems is also important to help determine how to best evaluate changes in socio-economic and ecological conditions in cumulative effects assessments.

5.2 Indicators and Information

A variety of indicators are used by marine conservation area managers to detect changes in ocean conditions including ecological, social, and economic. However, marine managers often struggle to effectively incorporate social and economic considerations into both cumulative effects assessments and conservation area design, implementation, and management (Dehens & Fanning, 2018; Weber, et al., 2012). This study focused on the social and economic indicators that Canadian marine managers use since these are often given limited consideration when assessing cumulative effects (Lundquist et al., 2016; Weber et al., 2012). Results suggest that managers from DFO, ECCC, and Parks Canada all struggle to adequately incorporate both social and economic indicators into their assessment and decision-making. Managers identified local

marine resource use patterns and local values and beliefs regarding marine resources as the two most common types of social indicators used in their assessments and decision-making. Supplemental comments from participants suggest that these indicators are likely derived from information provided by "Indigenous governance partners that tell [managers] what to consider on behalf of their nation" (Respondent #7) as well as "multi-stakeholder advisory committees" (Respondent #7). Other indicators including, quality of human health, access to community services, community welfare, and population composition are considered much less. This is consistent with the cumulative effects literature, which indicates that in practice, cumulative effects assessments fail to sufficiently consider issues of community and regional well-being (Weber et al., 2012).

Economic indicators used by managers when assessing and managing cumulative effects include the economic value of fisheries in an area, economic value of other industries present, and the nature of employment in an area. Survey respondents suggest that these indicators are likely derived from the commercial landings data base as well as DFOs socio-economic team that analyzes this type of information before passing it on to conservation area managers. Other economic indicators such as household income levels, possible displacement issues, and employment rates are also important considerations in marine conservation area management (Rodriguez & Fanning, 2017), however fewer managers appear to consider these.

When asked about the importance of ecological, social, and economic indicators when assessing cumulative effects, managers indicated that ecological indicators were the most important followed by economic indicators, with social indicators considered the least important of the three (Fig. 11). This data suggests that managers may have a lack of expertise or experience working with social and economic indicators as well as a narrow understanding of the

relationship between social and ecological systems. Furthermore, the limited consideration of socio-economic factors is consistent with the literature, which suggests these indicators are typically poorly incorporated into cumulative effects assessments (Fox et al., 2006; Weber et al., 2012). Therefore, enhanced integration within and across departments as well as a broader, transdisciplinary approach to cumulative effects assessment should be implemented. In contrast to the overall trend, respondents from DFO appear to give more weight to social indicators than respondents from ECCC and Parks Canada. This may be due to differences in departmental roles and mandates. For example, "managing Canada's fisheries and safeguarding its waters" (para. 1) is part of DFOs primary role, which includes working with fishers as well as coastal and Indigenous communities to ensure their continued access to and benefits from Canada's ocean resources (DFO, 2019e). Therefore, DFO may give more consideration to social indicators when assessing cumulative effects on marine conservation areas since they can help protect fish populations and fish habitat (Halpern, 2003; Hilborn et al., 2004).

The sources of information used by marine conservation area managers to inform their assessments and decision-making are diverse and vary depending on the type of information being sought. Managers identified several sources of information that they use to collect ecological information while the sources of socio-economic information were mainly limited to four different sources. Spatial data, monitoring data, and published peer-reviewed literature were identified as the primary sources of ecological information that managers use to assess cumulative effects. However, expert opinion, information from other environmental managers, and traditional ecological knowledge are also used. The main sources of socio-economic information used by managers include local or community knowledge, traditional knowledge, expert opinion, and other managers or practitioners. This data suggests that managers may have

more experience with or access to ecological sources of information rather than socio-economic. Additionally, sources of peer-reviewed social science literature are considered much less than sources of ecological peer-reviewed literature. Despite this, managers' apparent reliance on local community knowledge and traditional knowledge indicates that stakeholders are likely consulted and involved in the cumulative effects and marine conservation area management process. Stakeholder involvement is critical to marine conservation success and can help inform the social and economic dimensions needed to adequately design and manage these areas (Mangubhai, Wilson, Rumetna, Maturbongs, & Purwanto, 2015). Therefore, collaboration between conservation area managers and stakeholders should continue.

Although managers indicated that they use multiple sources of information to account for cumulative effects in their decision-making, several barriers exist that limit or prevent the incorporation of both ecological and socio-economic information. The largest barrier that prevents practitioners from incorporating these types of information is the availability of data. This may be due to the relevance of information to managers' work, the timeliness of data, and the accessibility to applicable sources. The literature supports this and indicates that despite some improvements in increasing data availability, some ecological and socio-economic information remains understudied and inaccessible (Cvitanovic et al., 2014; Halpern & Fujita, 2013; Hodgson & Halpern, 2019). Additional barriers that may prevent or limit managers from incorporating ecological and socio-economic information into their decision-making include the quality and quantity of information as well as a lack of guidelines, expertise, funding, and time. Interestingly, across all conservation areas, it appears that the quality of ecological data is a larger barrier than availability and the availability of socio-economic information is a larger barrier than the quality. This suggests that ecological information is relatively more available

than socio-economic data and may help explain the limited inclusion of socio-economic indicators and information in assessments. To reduce these barriers and improve assessment methods, enhancing integration within and between departments could improve collaboration and communication among practitioners of varying expertise. Furthermore, promoting a transdisciplinary approach to cumulative effects assessment may help to reveal information that was thought to be unavailable.

5.3 Tools and Assessment Methods

The tools and assessment methods used by managers to incorporate cumulative effects in their decision-making appear to be fragmented and take a project- or activity-based approach. Anecdotal survey responses received from managers indicate that a cumulative effects assessment framework is currently lacking and no explicit legislation, regulations, or policies exist. Therefore, managers utilize a suite of department- and site-specific laws, regulations, policies, and standards of practice to account for cumulative effects in their decision-making (Tables 1 and 2). Anecdotal responses indicated that overall, there is a lack of a broader scope taken when considering cumulative effects in marine conservation areas with one respondent reporting “it's a 'take it as it comes' approach more often than not with no rigorous framework to follow” (Respondent #27). Furthermore, approximately half of the managers surveyed indicated that they do not use a specific framework to assess cumulative effects in their decision-making. This suggests there is a need to streamline the cumulative effects assessment process by developing a framework or guidelines which can be used by managers across departments, regions, and conservation areas.

Although a lack of a cumulative effects assessment framework currently exists, managers employ a range of tools as a part of their assessment and decision-making regarding cumulative

effects and marine conservation areas. These include mapping, risk assessment models, and pathways of effects models, among others. Of these tools, mapping can help to understand the spatial distribution of cumulative effects as well as establish spatial and temporal baselines (Atkinson & Canter, 2011). Furthermore, mapping cumulative effects can also help visually identify which ecosystems are vulnerable to human stressors as well as identify areas where stressors interact and overlap (Kappel et al. 2012). This suggests that mapping may be used to help prioritize conservation measures for marine protected areas as well as influence their design, implementation and management.

Finally, managers indicated that they use all elements of adaptive management to some extent. The elements that are employed by marine managers are primarily used in the preliminary stage of defining the problem and designing management plans. The research also suggests that a small number of managers appear to document improved knowledge from management outcomes and adjust management actions accordingly. Literature suggests that adaptive management is a necessary component in addressing uncertainty in decision-making processes (Murray et al., 2015). This is especially pertinent to assessing the impacts of cumulative effects on marine conservation areas as predicating future stressors and their impacts is difficult. Adaptive management introduces a component of flexibility that would contribute to the long-term viability of marine conservation areas.

Chapter 6. Conclusion

The extent to which Canadian marine conservation area managers incorporate socio-ecological indicators and conditions when assessing the impacts of cumulative effects on marine conservation areas appears to be limited in scope and application. Despite a broad recognition about the importance of understanding and accounting for cumulative effects in management decisions, managers seem to favour ecological indicators and conditions. This appears to have led to limited considerations of the social and economic indicators and conditions that are inherently linked to the marine environment. The results of this study suggest that this is likely due to a variety of factors including, a lack of clear definitions, guidelines, and frameworks, the unavailability of information as well as narrow and fragmented management approaches.

To effectively mitigate and manage for cumulative effects in conservation areas, managers need to understand and account for complex socio-ecological interactions. This is particularly relevant to marine conservation areas since they consist of interacting human and natural systems. To improve the inclusion of socio-economic considerations in assessment practices, improving the utilization of data that currently exists through data sharing and better communication is a critical first step. The current lack of and unavailability of data that exists necessitates that existing socio-ecological information is better utilized. This includes increasing information and data sharing within and between federal departments as well as consulting experts in areas where marine managers may lack familiarity with data and information. Moving forward, generating relevant data and accounting more equally for ecological and socio-economic factors will be essential to the effective and efficient management of marine conservation areas.

The lack of data available to marine conservation managers limits the type of information included in assessments and hinders management actions. For example, the unavailability of socio-economic indicators and data appears to restrict the use of this type of information in the assessment and management of cumulative effects in Canada's marine conservation areas. However, to best achieve sustainable conservation and ocean management, greater inclusion of socio-economic indicators and conditions is needed. As highlighted by Weinstein et al. (2007), a sustainable future will rely on the ability of humans to implement an ecologically, socially, and economically robust approach to ocean and environmental management.

Ambiguous definitions and guidelines seem to have led to confusion among managers about how to best define the spatial and temporal scales of their assessments as well as which activities and stressors to include. A lack of definitions and guidelines also appear to have created confusion about the differences between activities and stressors. Therefore, clear definitions and guidelines are needed to shape the direction of assessments and ensure the most relevant information and evaluation methods are used.

The current scope and effectiveness of cumulative effects management approaches in marine conservation areas does not appear to be holistic enough to account for the potentially detrimental impacts of these effects. In particular, the selective use of adaptive management principles and techniques hinders the ability of conservation areas to be flexible to changing ocean and societal conditions. Therefore, improving assessment and management techniques such as these are important to ensuring the success and sustainability of existing and future conservation areas.

6.1 Recommendations

Social and economic systems are dependent on a healthy marine environment; however these same systems produce many of the activities and impacts that occur there. Therefore, the cumulative effects of anthropogenic stressors on ecological components must be linked back to socio-economic systems to ensure holistic, robust, and equitable management is conducted. Based on the results and supporting literature, the following recommendations are made to potentially enhance the effectiveness of assessing and managing for cumulative effects in marine conservation areas.

First, it is recommended that Canadian cumulative effects assessment and management standards for marine conservation areas be developed. These should include clear and consistent definitions of 'cumulative effects,' 'activities,' and 'stressors' to limit confusion and streamline assessment approaches. Furthermore, the inclusion of standardized adaptive management measures to increase the flexibility of management actions would help to enhance the effectiveness and sustainability of marine conservation areas. For example, the implementation of dynamic rather than static protected area boundaries could allow these areas to adapt to changing human and ocean conditions. This could be achieved by enhancing existing legislation or regulations, similar to what was done with the Fisheries Act (1985) through amendments made in 2019 (DFO, 2019c).

Next, a shift in thinking away from project- and activity-based management approaches to conservation areas is encouraged. However, targeted assessments of activities and projects as well as site-specific conservation area regulations cannot be completely abandoned and remain important to the effective assessment and management of cumulative effects in these areas. The ocean is a dynamic environment, therefore the need for broad, ecosystem-based protection is

needed to ensure healthy oceans and societies persist into the future. This involves better incorporating all sectors that may potentially impact a conservation area when assessing cumulative effects, designing management plans, and implementing mitigation strategies. This could be achieved through improved cross-departmental collaboration as well as consultation with all necessary stakeholders. Additionally, enhanced integration between federal departments and all levels of government could help ensure holistic and robust assessments are conducted.

Third, the inclusion of socio-economic indicators, information, data gathering, and analyses requires an increased focus in cumulative effects assessment and management in marine conservation areas. Marine protected areas are a type of social-ecological system; therefore the consideration and inclusion of social and economic information is just as important as ecological information. Enhancing managers' familiarity with and understanding of socio-economic indicators, information, data gathering, and analyses through training or guidelines could potentially increase the use of these in cumulative effects assessments. Furthermore, providing managers with guidance on the available sources and experts on this information could also improve the inclusion and use of socio-economic indicators This could result in a more balanced and holistic approach to cumulative effects assessment and conservation area management.

Finally, it is suggested that this research be repeated with other ocean users and managers such as fishermen, private industry, fisheries managers, Indigenous communities, and non-governmental organizations, among others. This could help determine if cumulative effects evaluation methods differ between ocean user and management groups to improve and streamline assessment and management practices. Additionally, based on the relatively small sample size received through an outside academic survey-based approach, the federal departments could repeat and administer the survey (Appendix A) themselves. This may help

generate a larger sample size, allow for more robust statistical analyses, and provide departments with the critical information needed to plan for the ongoing training of new and existing managers as well as the future development of marine conservation area management strategies.

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Appendix A. Survey Questionnaire

Evaluating the integration of cumulative effects and multiple stressors in the management of Canada's marine conservation areas

First, you will be asked some basic information about where you work, the type of conservation area you currently work with and your level of experience working with marine conservation areas.

1) Which federal department do you work for?
    - Fisheries and Oceans Canada
    - Environment and Climate Change Canada
    - Parks Canada

2) What type of conservation area do you currently manage and/or work with?
    - National Marine Conservation Area
    - Marine Protected Area
    - National Wildlife Area
    - Migratory Bird Sanctuary
    - Other effective area-based conservation measures (please describe)
    - Other (please explain)

3) How long have you been involved in decisions affecting the design, implementation or management of marine conservation areas?
    - Less than 1 year
    - 1 to 5 years
    - 5 to 10 years
    - More than 10 years

4) In terms of your departmental hierarchy, please indicate which of the following best matches your position?
    - Junior level biologist (or scientist)
    - Senior level biologist (or scientist)
    - Junior level manager
    - Senior level manager
    - Junior level policy advisor
    - Senior level policy advisor
    - Other (please explain)

5) In which of Canada's three oceans is the conservation area(s) that you manage and/or work with? (select all that apply)
    - Pacific Ocean
    - Arctic Ocean
    - Atlantic Ocean
    - Other (please explain)

Next, you will be asked some questions about how you consider cumulative effects and/or multiple stressors in your work as well as how you define the scope of your assessments. For the rest of this survey, "stressor" is akin to "driver" and is defined as "any natural or anthropogenic pressure that causes a quantifiable change, whether positive or negative, in biological or socio-economic response". "Cumulative effects" are akin to "cumulative impacts" and are defined as "combined or accumulated quantifiable changes in biological or socio-economic response from one or more stressor(s)".

6) Do you take into account or assess **cumulative effects** in your decision-making related to conservation areas, including their identification, implementation and management?
    - Yes
    - No (please explain)

7) Do you take into account or assess **multiple stressors** in your decision-making related to conservation areas, including their identification, implementation and management?
    - Yes
    - No (please explain)

8) At what **spatial scale(s)** do you consider cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management? (select all that apply)
    - Spatial scale of the conservation area
    - Spatial scale of the anticipated effects of stressors
    - Spatial distribution of important species or habitats (e.g. Valued Ecological Components, threatened or endangered species, key species, foundation habitats)
    - Spatial distribution of marine resource use and activities (e.g. Fishing areas, marine transportation corridors, tourism and recreation)
    - Watershed
    - Bioregion or Ecozone (i.e. geographical units with characteristic flora, fauna, and ecosystems)
    - Planning region
    - Legal Precedence
    - None of the above
    - Other (please explain)

9) At what temporal **scale(s)** do you consider cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management? (select all that apply)
    - Past activities and effects
    - Present activities and effects
    - Future activities and effects (up to 1 year)
    - Future activities and effects (1-5 years)
    - Future activities and effects (more than 5 years)
    - Past baseline conditions
    - Present baseline conditions

- None of the above
- Other (please explain)

10) What Acts, Regulations, Policies and/or Standards of practice require you to consider **cumulative ecological effects** in your decision-making related to conservation areas, including their identification, implementation and management? (please describe)

11) What Acts, Regulations, Policies and/or Standards of practice require you to consider **socio-economic effects** in your decision-making related to conservation areas, including their identification, implementation and management? (please describe)

The next set of questions will ask you about the indicators, activities, and stressors as well as the tools and the type of information you include in your assessments and decision-making related to the identification, implementation and management of marine conservation areas.

12) Which **human activities** do you consider when assessing cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management? (select all that apply)
    - Fish Harvesting
    - Aquaculture
    - Waste discharges or marine spills
    - Recreation
    - Tourism
    - Marine transportation
    - Coastal development
    - Mining (e.g. deep-sea mining)
    - Offshore oil and gas development
    - Agriculture (e.g. land-based nutrient pollution)
    - None of the above
    - Other (please explain)

13) Which **ecological** stressors do you consider when assessing cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management? (select all that apply)
    - Changes in climate conditions (e.g. temperature, precipitation, acidification, UV radiation)
    - Changes in sediment inputs
    - Changes in nutrient inputs
    - Physical disturbance
    - Disease
    - Introduction of pollutants
    - Introduction of non-indigenous species
    - Anthropogenic litter/debris
    - Anthropogenic Noise
    - Light

- None of the above
- Other (please explain)

14) What are three key ecological indicators that you use when assessing cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management. (Please describe)

15) Please indicate any **social** indicators (e.g. cultural use, human health & community well-being) you consider when assessing cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management. (select all that apply)
    - Quality of human health (e.g. stress levels)
    - Access to community services (e.g. education)
    - Community welfare (e.g. standard of living)
    - Population composition (e.g. demographics)
    - Local marine resource use patterns (e.g. fishing areas, marine transportation corridors, tourism and recreation)
    - Local values and beliefs regarding marine resources
    - Other (please explain)

16) Please indicate any **economic** indicators (e.g. employment & economic value of industries) you consider when assessing cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management. (select all that apply)
    - Economic value of fisheries in the area
    - Economic value other industries in the area (e.g. tourism)
    - Nature of employment in the area (e.g. fish harvester versus tour boat operator)
    - Employment / Unemployment rates
    - Household income levels
    - Community infrastructure and business
    - Possible displacement issues (i.e. availability of alternative income or livelihood sources)
    - None of the above
    - Other (please explain)

17) How important are **ecological** indicators (e.g. spawning stock biomass, fishery recruitment, species diversity) when assessing cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management?
    - Very important
    - Somewhat important
    - Somewhat unimportant
    - Not important

18) How important are **social** indicators (e.g., community well-being, cultural use) when assessing cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management?
    - Very important
    - Somewhat important
    - Somewhat unimportant
    - Not important

19) How important are **economic** indicators (e.g. employment) when assessing cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management?
    - Very important
    - Somewhat important
    - Somewhat unimportant
    - Not important

20) Do you consider the potential *negative* cumulative **ecological** effects (e.g. decreases in fish populations outside of the conservation area) of a conservation area in your decision-making related to conservation areas, including their identification, implementation and management?
    - Yes
    - No (please explain)

21) Do you consider the potential *positive* **socio-economic** cumulative effects (e.g. improved quality of human health or increased value of industries in the area) of a conservation area on human communities in your decision-making related to conservation areas, including their identification, implementation and management?
    - Yes
    - No (please explain)

22) Do you consider the potential *negative* **socio-economic** cumulative effects (e.g. loss of employment or loss of cultural/traditional use of the area) of a conservation area on human communities in your decision-making related to conservation areas, including their identification, implementation and management?
    - Yes
    - No (please explain)

23) What sources of **ecological** information do you use to assess cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management? (select all that apply)
    - Published peer-reviewed meta-analyses or literature reviews
    - Other published peer-reviewed papers
    - Published books
    - Unpublished papers or reports
    - Spatial data

- Monitoring data
- Traditional management practices
- Other environmental managers / practitioners
- Personal Experience
- Expert opinion
- Traditional ecological knowledge
- Citizen science
- None of the above
- Other information (please describe)

24) Referring to the previous question, are these information sources specific to the ecosystem or conservation area that you manage and/or work with?
    - All or mostly from your ecosystem or conservation area
    - About evenly mixed
    - All or mostly from other ecosystems or conservation areas

25) What sources of **socio-economic** information do you use when assessing cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management? (select all that apply)
    - Published peer-reviewed social science literature
    - Published books
    - Unpublished papers or reports
    - Economic information (e.g., employment data)
    - Demographic information
    - Cultural information
    - Traditional management practices
    - Other managers or practitioners
    - Personal experience
    - Expert opinion
    - Traditional knowledge
    - Local or community knowledge (e.g., local fishermen)
    - None of the above
    - Other (please explain)

26) Referring to the previous question, are these information sources specific to the ecosystem or conservation area that you manage and/or work with?
    - All or mostly from your ecosystem or conservation area
    - About evenly mixed
    - All or mostly from other ecosystems or conservation areas

27) What barriers, if any, exist that may limit or prevent you from incorporating **ecological** information in your decision-making related to conservation areas, including their identification, implementation and management? (select all that apply)
    - Quality of data
    - Quantity of data

- Availability of data
- Relevance of data to your work
- No barriers exist
- None of the above
- Other (please explain)

28) What barriers, if any, exist that may limit or prevent you from incorporating **socio-economic** information in your decision-making related to conservation areas, including their identification, implementation and management? (select all that apply)
    - Quality of data
    - Quantity of data
    - Availability of data
    - Relevance of data to your work
    - No barriers exist
    - None of the above
    - Other (please explain)

29) For this question, a framework is defined as "a description of steps and components necessary to achieve desired goals". Do you use any specific frameworks when assessing cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management?
    - Yes (please name or specify)
    - No

30) Which tools do you use when assessing cumulative effects in your decision-making related to conservation areas, including their identification, implementation and management? (select all that apply)
    - Mapping
    - Experiments
    - Single-species models
    - Multi-species models
    - Ecosystem models (e.g. Atlantis, EcoSim)
    - Risk assessment models
    - Qualitative models (e.g. loop analysis, fuzzy logic, cognitive maps, signed digraphs)
    - Driver-Pressure-State-Impact-Response (DPSIR) models or variants (e.g. DAPS(W)I(R)M)
    - Pathways of Effects models
    - Decision support tools (e.g. InVEST, MarineMap, Marxan)
    - Agency-specific tools (please specify)
    - None of the above
    - Other (please specify)

The next set of questions will ask you about how you consider and incorporate stressor interactions, stressor-effect relationships, and tipping points in your assessments and decision-

making related to the identification, implementation and management of marine conservation areas.

31) Which stressor interaction types do you consider in your in decision-making related to the identification, implementation and management of marine conservation areas? (select all that apply)
    - Additive (i.e. cumulative effect = sum of individual stressor effects)
    - Antagonistic (i.e. cumulative effect < sum of individual stressor effects)
    - Synergistic (i.e. cumulative effect > sum of individual stressor effects)
    - None
    - Other (please describe)

32) How do you incorporate interactions among multiple stressors into your decision-making related to the identification, implementation and management of marine conservation areas? (select all that apply)
    - Quantitatively (e.g. using numeric estimates of interaction strength)
    - Qualitatively (e.g. categorizing an interaction as synergistic, additive, or antagonistic without estimates of interaction strengths)
    - Do not incorporate (please explain)
    - Other (please describe)

33) Regardless of implementation, how important do you think it is to consider different potential stressor interaction types in your decision-making related to the identification, implementation and management of marine conservation areas?
    - Very important
    - Somewhat important
    - Somewhat unimportant
    - Not important

34) Which types of stressor-effect relationships (e.g. the relationship between temperature and species mortality) do you consider in your decision-making related to the identification, implementation and management of marine conservation areas? (select all that apply)
    - Categorical (i.e. a change in stressor magnitude causes a positive or negative change in effect)
    - Linear (i.e. a change in stressor magnitude causes a linear change in effect)
    - Smooth nonlinear (i.e. a change in stressor causes a continuous nonlinear change in effect)
    - Discontinuous nonlinear, or hysteresis (i.e. a change in stressor magnitude causes a discontinuous change in effect that is hard to reverse)
    - None
    - Other (please describe)

35) Regardless of implementation, how important do you think it is to consider *nonlinear* stressor-effect relationships in your decision-making related to the identification, implementation and management of marine conservation areas?

- Very important
- Somewhat important
- Somewhat unimportant
- Not important

36) We define a tipping point as a drastic change in the ecosystem that are hard to reverse. Do you consider potential ecosystem tipping points in your decision-making related to the identification, implementation and management of marine conservation areas?
    - Yes (please describe)
    - No

37) If yes, do you consider how *multiple* stressors may affect the existence of tipping points in your decision-making related to the identification, implementation and management of marine conservation areas?
    - Yes (please describe)
    - No

38) Regardless of implementation, how important do you think it is to consider potential ecosystem tipping points or thresholds in your decision-making related to conservation areas, including their identification, implementation and management?
    - Very important
    - Somewhat important
    - Somewhat unimportant
    - Not important

This question will ask you about adaptive management.

39) Do you incorporate any of the following elements of adaptive management in your decision-making related to conservation areas, including their identification, implementation and management? (select all that apply)
    - Defining the problem:
        - Clearly stating management goals and objectives
        - Regarding management actions as experimental treatments that will increase knowledge of the system being managed
        - Exploring alternative management actions
        - Developing conceptual models that predict the results of management actions
        - Explicitly stating assumptions
        - Involving stakeholders and scientists when defining the management problem
    - Designing management plans:
        - Involving stakeholders and scientists when designing management plans
        - Peer-reviewing designs of management plans
    - Monitoring:
        - Monitoring or assessing baseline conditions
        - Monitoring the implementation and effectiveness of management actions
    - Evaluating results and adjusting actions:
        - Comparing monitoring results against goals and objectives

    - Comparing monitoring results against model predictions
    - Monitoring the impacts of management actions
    - Comparing results against model predictions
    - Documenting improved knowledge from management action impacts
    - Adjusting hypotheses, conceptual models, and management actions with improved knowledge from previous management actions
- Other (please describe)

40) Finally, is there anything else you would like to tell us about how you assess cumulative effects and/or multiple stressors in your decision-making related to conservation areas, including their identification, implementation and management? (please explain)