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Research

Challenges to incorporating social and economic factors into cumulative effects assessments in Canada's marine conservation areas

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ABSTRACT. The cumulative effects of human stressors are threatening marine ecosystems. While spatial management tools such as marine conservation areas can help mitigate cumulative effects, several decision-making challenges remain. A limited availability of information and lack of knowledge, inconsistent management approaches, and ineffective consideration of social-ecological interactions hinders current cumulative effects assessment and management efforts. We examined if and how ocean managers assess cumulative effects and incorporate them into their management practices. A survey of the three Canadian federal departments responsible for marine conservation areas was conducted, and focused on the extent to which social and economic factors are considered. Managers seemed to favor ecological factors over social and economic ones when evaluating cumulative effects, such as when defining the spatial and temporal scales to use in their assessments. Managers also indicated a need for greater access to social and economic data and information to improve their assessment and management decisions. Lastly, the lack of a standardized cumulative effects assessment framework and fragmented management approaches appeared to limit managers' ability to adequately incorporate social and economic factors into assessments. The survey results indicated that a cumulative effects assessment framework that explicitly includes social and economic factors in addition to an enhanced understanding of the suite of factors that influence social-ecological interactions should be developed. This type of framework is essential to help achieve the long-term management solutions required to conserve the health and integrity of Canada's oceans and beyond.

Key Words: *Canada; cumulative effects; marine conservation areas; ocean management; social-ecological systems; socioeconomic factors*

INTRODUCTION

Globally, marine ecosystems are experiencing immense changes due to increased human use of the marine space and resources (Halpern et al. 2008b, Korpinen and Andersen 2016). Approximately half of the world's ocean is highly impacted by stressors associated with human activities, and almost no area remains untouched (Kappel et al. 2012). As human activities continue to intensify and accumulate in the marine environment, the effects of these stressors pose a significant threat to the sustained health of the world's oceans. This makes the tasks of marine managers that much more challenging because addressing these threats requires understanding not only the ecological aspects of cumulative effects and multiple stressors but also the importance of incorporating social and economic factors into integrated assessments that focus on cumulative effects (Weber et al. 2012, Foley et al. 2017, Stelzenmüller et al. 2020). Cumulative effects stem from the interplay between multiple human stressors and the receiving environment (Murray et al. 2014, Jones 2016, Foley et al. 2017). These stressors often vary across space and time, and it is difficult to predict how ecological components may respond to intense ecosystem changes (Murray et al. 2014, Hodgson et al. 2019, Murray et al. 2020). Additionally, inconsistent legislative tools and policies, insufficient data, and limited integration of social and economic factors into management decisions are recognized as challenges in effectively addressing cumulative effects in the marine environment (Canter and Ross 2010, Cormier et al. 2017, Davies et al. 2020).

Although improvements in cumulative effects assessments have been made (Hodgson et al. 2019), current cumulative effects assessment methods and management approaches in marine ecosystems appear to be inconsistent in scope and application globally. This is likely due to a lack of clear and consistent definitions of spatial and temporal scales, an inconsistent application of cumulative effects assessment tools, a focus on single-sector or single-species management, and/or a narrow understanding of social-ecological interactions in the marine environment (Duinker et al. 2013, Judd et al. 2015, Sinclair et al. 2017, Griffiths et al. 2020). Furthermore, much of the impact assessment literature and many marine conservation plans tend to focus more on the ecological components of the environment and do not adequately capture socioeconomic aspects that are inherently part of marine ecosystems (Duinker and Greig 2006, Ban et al. 2013, Murray et al. 2014, 2020). Therefore, management responses that focus on addressing and better understanding the cumulative effects of human activities on marine ecosystems, including the role of social and economic factors, are needed (Fox et al. 2006, Stelzenmüller et al. 2018).

As a social-ecological system comprised of natural and anthropogenic components, marine conservation areas (MCAs) are recognized as one of the best management tools for protecting marine ecosystems (Halpern and Warner 2002). These areas regulate human activities in order to provide protection while supporting the sustainable use of marine resources (Government of Canada 2011, Mizrahi et al. 2019). Since understanding the

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relationship between humans and the marine environment is critical when managing for cumulative effects, marine conservation areas provide a strong lens for examining the challenges of incorporating social and economic factors into cumulative effects management.

To understand some of the challenges associated with cumulative effects assessments and how marine practitioners overcame them, Foley et al. (2017) investigated the types of impacts included in their assessments and how baseline, scale, and significance were defined. We focus on the apparent gap in the use of social and economic factors in cumulative effects assessments and expand on Foley et al. (2017) by using a stepwise approach to (1) examine the extent to which cumulative effects assessments are practiced by managers in the three Canadian federal departments responsible for marine conservation areas, (2) determine the extent to which social and economic factors are considered in cumulative effects assessments, and (3) examine potential barriers to incorporating social and economic factors in cumulative effects assessments. We hypothesized that differences in how social and economic factors are considered would exist among conservation area types, oceans, and manager experience and position type. We also hypothesized that there would be differences among federal departments because of differences in geography, departmental mandates, conservation area objectives, and respondents' level of involvement in decision-making processes. Due to the threats that cumulative effects pose to the ongoing provision of marine ecosystem goods and services, our aim was to investigate current management practices, albeit at an exploratory level, and to use the findings to guide needed research and better practice when developing marine conservation plans and policies. We also suggest that our findings, while focused on marine conservation areas, may stimulate attention within federal departments regarding the need to examine the effectiveness of current marine governance in Canada and elsewhere.

CANADA'S MARINE CONSERVATION AREAS

To conserve and protect Canada's oceans while supporting the sustainable use of marine resources, several types of marine conservation areas have been and continue to be implemented and managed by three federal departments: Fisheries and Oceans Canada (DFO), Environment and Climate Change Canada (ECCC), and Parks Canada (Parks). Each has a specific mandate for establishing marine conservation areas and each type of conservation area implemented in Canada has its own intended purpose and set of regulations (Government of Canada 2011). DFO focuses on maintaining ecological integrity and protecting marine species and their habitats by using marine protected areas (MPAs) and other effective area-based conservation measures (Government of Canada 2021a). ECCC aims to preserve habitat for wildlife, including migratory birds and endangered species, by using Migratory Bird Sanctuaries and National Wildlife Areas; Parks focuses on conserving Canada's natural and cultural marine heritage by using national marine conservation areas (Government of Canada 2021a). The overarching goal of Canada's marine conservation 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: 6). However, this goal fails to acknowledge the importance of the socioeconomic components of marine conservation areas and does not provide managers with guidance on how to incorporate cumulative effects into their decision-making and management practices.

In terms of acknowledging cumulative effects, the National Framework for Canada's Network of Marine Protected Areas (DFO 2011) notes that areas subject to multiple stressors and cumulative effects require additional protection. However, it does not specifically outline management measures to mitigate these effects on these areas or what factors to consider in decision-making. Some effort in understanding and mitigating cumulative effects has been outlined in Canada's Ocean Protection Plan, but it focuses primarily on shipping (Government of Canada 2020). Canada has also recently amended several pieces of legislation, calling for an increased understanding of changes to the environment and socioeconomic conditions arising from the interaction of multiple stressors. For example, the recently amended Fisheries Act (2019) specifically calls for cumulative effects assessments of works, undertakings, or activities that affect fish and fish habitat (section 34.1(1)(d)). Furthermore, the new Impact Assessment Act (2019) requires consideration of "any cumulative effects that are likely to result from the designated project in combination with other physical activities that have been or will be carried out" (section 22(a)(1)(ii)). Though these legislative measures are important, they leave managers with a fragmented approach to addressing cumulative effects, which has been noted as a common challenge, particularly when managing marine and coastal environments (Davies et al. 2020). Recent marine conservation targets set by the Canadian government include conserving 25% of marine and coastal areas by 2025 and 30% by 2030 (Government of Canada 2021b). With millions of dollars in public funds being invested to help achieve these targets, the need for effective cumulative effects management, including the consideration and inclusion of social and economic information in these and other social-ecological systems, is critical. Additionally, although the existing guidelines and amended legislation are important steps forward, a shift to ecosystem-wide assessments that include social and economic factors is needed to fully address the impacts of cumulative effects on social-ecological systems such as marine conservation areas.

METHODS

We assessed the extent to which MCA managers from the three federal departments responsible for administering marine conservation areas (DFO, ECCC, and Parks) consider social and economic factors in their cumulative effects decision-making and management processes. The spatial boundaries of marine conservation areas and the regulation of human activities within them provided a strong basis for analyzing how managers account for cumulative effects and social and economic factors in marine conservation plans. Additionally, targeting managers across the three federal departments that administer marine conservation areas for Canada's three oceans (Arctic, Atlantic, Pacific) allowed for differences in assessment methods to be explored.

By adapting the methodology employed by Foley et al. (2017), we developed an online survey to explore how MCA managers across Canada incorporate social and economic factors into their cumulative effects decision-making processes. The survey was divided into five sections (Table 1) and consisted of 40 questions: 36 multiple-choice and four open-ended questions (Appendix 1). The options presented in the multiple-choice questions were not exhaustive; however, participants could select multiple options

and identify additional information by selecting "Other" as a response. Given that the focus of our study was on exploring the extent to which managers incorporate social and economic factors into their cumulative effects assessment and management processes, respondents who indicated that they do not consider cumulative effects were screened out of the survey.

Table 1. Division of survey questionnaire.

Section theme	Information collected
Demographics	Departmental employer
	Type of conservation area
	Level of marine conservation area experience
	Position type
	Location of marine conservation area
Defining scope	Use of cumulative effects and/or multiple stressors in decision-making
	Spatial scales used
	Temporal scales used
Information and assessment methods	Incorporation of social factors
	Incorporation of economic factors
	Activities considered
	Tools used
	Types of information used
Stressor interactions, effects, and tipping points	Consideration and incorporation of stressor interactions
	Use of stressor-effect relationships and tipping points
Adaptive management	Elements of adaptive management considered in decision-making

For the purposes of this study, a "marine conservation area manager" was defined as an individual who is involved in decision-making related to marine conservation areas, including the identification, implementation, and/or management of these areas. Potential participants were identified by applying this definition to an individual's title/position listed in the Government of Canada's employee directory[1]. The survey was e-mailed to 231 managers: 121 from DFO, 68 from ECCC, and 42 from Parks. The proportion of respondents in each department was similar to the proportion of MCA managers identified in each department. If potential participants no longer held the position indicated in the government directory, they were asked to forward the survey to the relevant individual, if known. The survey was open for 5 months (June–October 2019), and eight reminder e-mails were sent during that period to maximize the number of responses included in the analysis. The identity of respondents who participated in the survey was accessible to us, but their data were anonymized so that responses could not be traced back to any one individual.

Three key limitations to the study are worth noting. First, the timing of the data collection spanned the summer months when many managers are either on vacation and/or out in the field. We believe this accounted for the low response rate and suggest that an alternative period may have enhanced the response rate. Second, because this was an exploratory study, it involved multiple variables (department, conservation area type, experience, position type, and location) and various response options within each variable; therefore, the sample size of responses to our survey was not large enough to statistically test for differences based on our hypotheses. Nonetheless, by using only descriptive statistics such as frequency, several themes and patterns emerged. These provided valuable insight on marine conservation, management, and governance communities in Canada and beyond, as well as guidance for more in-depth, targeted research on each of the variables. Third, we recognize that because science-based departments were contacted, and given the focus on ecological components in MCA management, the number of natural science-trained respondents likely exceeded those trained in the social sciences, which potentially skewed the survey results. However, since the proportion of respondents in each department was similar to the proportion of MCA managers identified in each department, we believe this concern has been mitigated.

RESULTS

In total, 72 responses were received. Incomplete responses with fewer than 10 answers were not included in the analysis since they focused primarily on demographic information. We analyzed 39 complete and eight partially completed surveys. Because respondents did not always answer every question, we report the proportion of responses to particular questions, as well as the number of total responses for individual questions.

Demographics

Of the 47 survey responses analyzed, more than half the respondents indicated that they worked for DFO (53%); the remainder worked for ECCC (30%) or Parks (17%). Thirty-six percent of managers indicated that they managed marine protected areas; 40% managed marine national wildlife areas, national marine conservation areas, other effective area-based conservation measures, or migratory bird sanctuaries; and 23% selected "Other", indicating that they managed more than one type of conservation area (e.g., national wildlife areas and migratory bird sanctuaries), collaborated with other departments on various marine protection tools, or regulated disposal at sea, which may occur near conservation areas.

Most respondents had 1–5 years (38%) or more than 10 years (40%) of experience in decision-making that affected the design, implementation, and/or management of marine conservation areas (Fig. 1). The most common position type reported was junior-level biologist (or scientist) (23%), which was most often selected by participants from DFO. The remaining respondents identified as senior-level manager (21%), senior-level biologist (or scientist) (17%), junior-level manager (13%), senior-level policy advisor (9%), or "Other" (17%). No respondents identified as a junior-level policy advisor. Additionally, several managers described their position as a mix of science- and policy-related responsibilities. The ocean area managed by respondents is illustrated in Fig. 2. Not shown in the figure are the percentages of respondents who were responsible for marine conservation areas in three oceans (17%) and in two oceans (11%).

Defining scope

Regardless of department, experience, ocean, or type of conservation area, most respondents (79%) indicated that they consider cumulative effects in their decision-making related to the identification, implementation, and management of marine conservation areas. Respondents who indicated they do not consider cumulative effects at all (21%) cited a lack of data as the primary reason. Some respondents also noted that a cumulative effects framework to help guide decision-making is lacking and that cumulative effects are generally not considered in the

identification and establishment processes for marine conservation areas.

Fig. 1. Experience of respondents involved in decisions affecting the design, implementation, and/or management of marine conservation areas (n = 47).

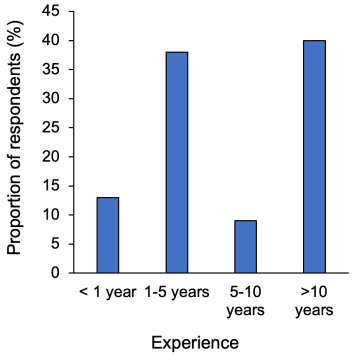
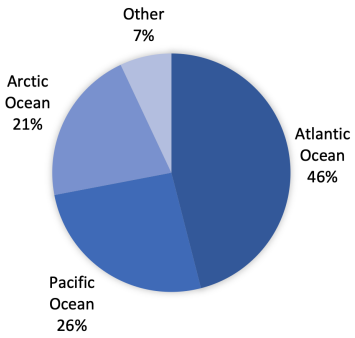


Fig. 2. Location of conservation area managed by respondents.



The spatial and temporal scales that managers used to assess cumulative effects in marine conservation areas were varied, although some scales were used more often than others. Of the 37 responses received, the most common spatial scales used were the spatial scale of the conservation area (89%), the spatial distribution of key species/habitats (86%), and the spatial distribution of marine resource use and activities (73%). Furthermore, managers reported having to deal with multiple spatial scale issues, with 45% using a combination of five or more of the 10 categories listed in the survey. "Other" spatial scales identified by respondents included bioregion or ecoregion, planning region, watershed, and legal precedence. Managers from DFO (84%) indicated that they more often use the spatial distribution of social and economic factors such as marine resource use and activities (e.g., fishing areas, marine transportation corridors, tourism, and recreation) to account for cumulative effects in their decision-making than do managers from ECCC (64%) and Parks (40%).

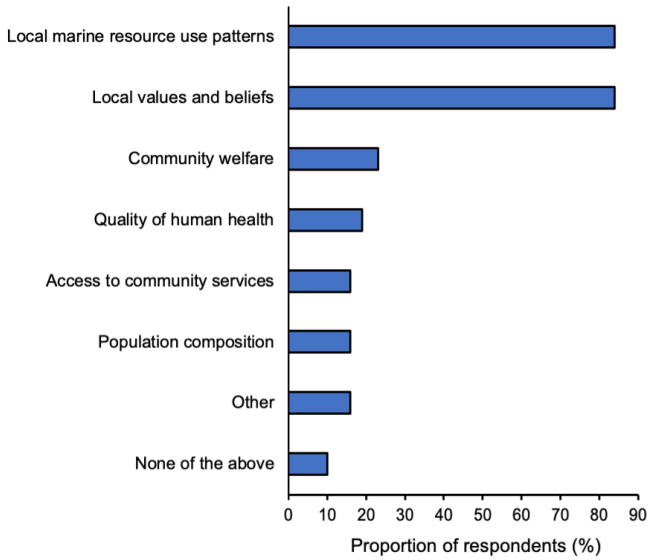
The primary temporal scales identified by respondents to account for cumulative effects in their decision-making included present activities and effects (89%), past activities and effects (84%), and present baseline conditions (70%). A time frame that includes future activities and effects (up to 1 year, 1–5 years, or more than 5 years) was selected less frequently (32%) than past and present temporal scales, in general. However, 67% of respondents with 5–10 years of experience and those in senior biologist positions more often considered future activities and effects when conducting assessments than respondents with less experience or in junior-level positions.

The three most frequently selected socioeconomic activities considered by respondents when assessing cumulative effects were fish harvesting (91%), marine transportation (88%), and recreation (79%). However, managers in DFO (n = 17) selected offshore oil and gas development (82%) more often than recreation (63%), while managers from Parks (n = 6) selected tourism and coastal development (100%) more often than fish harvesting (80%). Some respondents indicated that they also consider acoustic impacts, invasive species, pollutants, and mooring or anchoring in their assessments and decision-making.

Social and economic factors and types of information

Local marine resource use patterns, and local values and beliefs regarding marine resources were the two social factors most frequently selected by respondents (84%, n = 31) (Fig. 3). Thirty-four percent of responses were similarly distributed among community welfare, quality of human health, access to community services, population composition, and "Other". Respondents who selected "Other" indicated that they also consider Indigenous rights and consult with Indigenous partners when considering social factors.

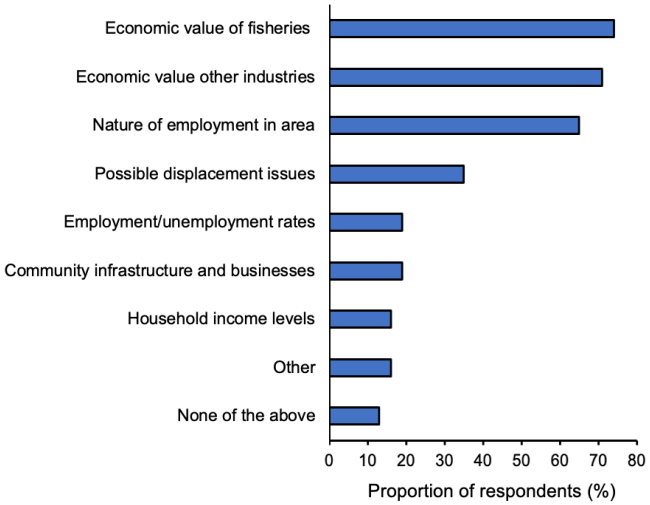
Fig. 3. Social factors considered by Canadian ocean managers in their cumulative effects assessments and decision-making pertaining to marine conservation areas (n = 31).



Economic factors considered by managers related primarily to the value of an industry and job type. The most commonly selected factors were 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); most respondents (64%) selected all three (Fig. 4). Factors such as employment rates, possible displacement issues, and household income levels were less commonly selected. Respondents who selected "Other" specified that they consider Indigenous rights and considerations (e.g., subsistence harvesting) when selecting economic factors.

Fig. 4. Economic factors considered by Canadian ocean managers in their cumulative effects assessments and decision-making pertaining to marine conservation areas (n = 31).

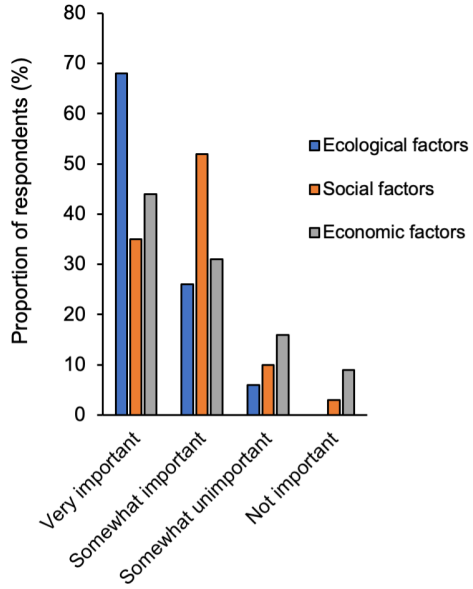


It did not appear that the department, level of manager, type of conservation area, or ocean influenced the types of social or economic factors that managers used to assess cumulative effects. For example, all responding managers with less than 1 year or more than 10 years of experience identified local values and beliefs regarding marine resources as a social factor they considered in their assessment and decision-making processes. Similarly, both groups selected the economic value of fisheries as a factor for inclusion.

Sixty-eight percent of respondents (n = 31) agreed that ecological factors were "very important" when considering cumulative effects in their decision-making related to the identification, implementation, and management of marine conservation areas, regardless of the ocean or their position type, department, or experience (Fig. 5). However, only 35% and 44% agreed that the same was true for social factors and economic factors, respectively. Three percent of respondents indicated that social factors were "not important"; 9% said the same for economic factors. Half (50%) of the DFO respondents indicated that social factors were "very important", whereas only 20% from ECCC and none from Parks said the same.

Most managers (78%) selected local or community knowledge as the main source of social and economic information used in their decision-making, followed by traditional knowledge (72%), expert opinion (72%), and other managers or practitioners (69%, n = 32) (Fig. 6). Cultural and economic information, published peer-reviewed social science literature, published books, and demographic data were selected less often. Additionally, two respondents from DFO stated that a separate socioeconomic team, led by the department's Policy Branch, analyzes socioeconomic information and provides it to conservation area practitioners to be considered in their work.

Fig. 5. Importance of ecological factors (n = 31), social factors (n = 31), and economic factors (n = 32) to Canadian ocean managers when assessing cumulative effects in their decision-making related to marine conservation areas.



The most commonly selected barrier to incorporating social and economic information into MCA managers' assessments and decision-making was the availability of data (81%, n = 32) (Fig. 7). The quality of data (63%), quantity of data (60%), and the relevance of data (57%) were also noted as barriers. Furthermore, respondents who selected "Other" indicated that quantifying some social information (e.g., social values) can be challenging, which makes it difficult to include in their assessments. Some respondents further indicated that a lack of expertise and/or frameworks, heavy workloads, tight time frames for decision-making, and the cost of collecting and monitoring all relevant data were also limitations to managing cumulative effects holistically and effectively.

Assessment methods

Respondents from each federal department identified a variety of legislation, regulations, and standards of practice that guide the inclusion of social and economic factors in MCA decision-making (Table 2). Respondents appeared to use standards of best practice most often. However, several respondents stated that currently there is no explicit legislation, regulations, or standards of practice for considering social and economic factors in the assessment and management of cumulative effects. Several respondents also highlighted the need to consult Indigenous peoples and local communities when designing, implementing, and managing marine conservation areas. Additionally, even if

Table 2. Acts, regulations, policies, and standards of practice used by managers in Fisheries and Oceans Canada, Environment and Climate Change Canada, and Parks Canada to consider socioeconomic effects in their decision-making related to the design, implementation, and management of marine conservation areas (n = 36).

Department	Legislation	Regulations	Policy	Best practices	Other
Fisheries and Oceans Canada	Oceans Act Fisheries Act Species at Risk Act	Site-specific Marine Protected Area regulations	None identified	Co-governance agreements with Indigenous partners	Frameworks for Marine Protected Area establishment and management
Environment and Climate Change Canada	Canadian Environmental Protection Act Canadian Wildlife Act Impact Assessment Act Oceans Act Fisheries Act	Treasury Board regulatory processes 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	Environment and Climate Change Canada guidance document for the creation of management plans
Parks Canada	Canada National Marine Conservation Areas Act Impact Assessment Act	Zoning provisions of National Marine Conservation Areas Act	None identified	Traditional Indigenous Knowledge considerations	Site-specific legislation and agreements

Fig. 6. Sources of social and economic information considered by Canadian ocean managers when assessing cumulative effects in their decision-making related to marine conservation areas (n = 32).

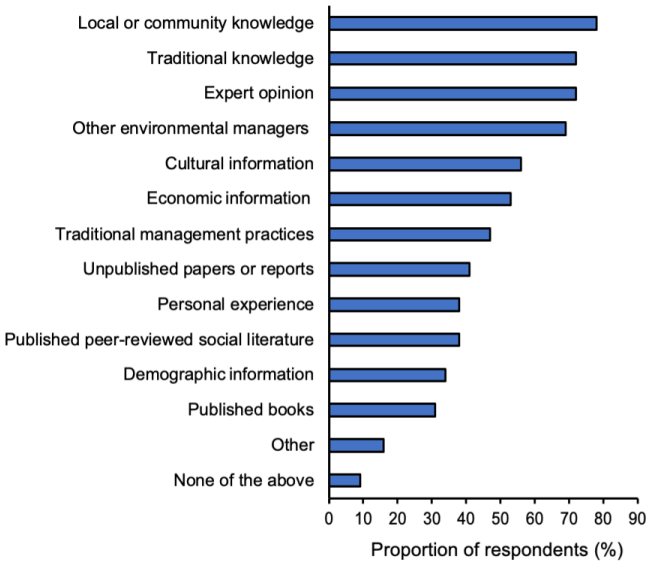
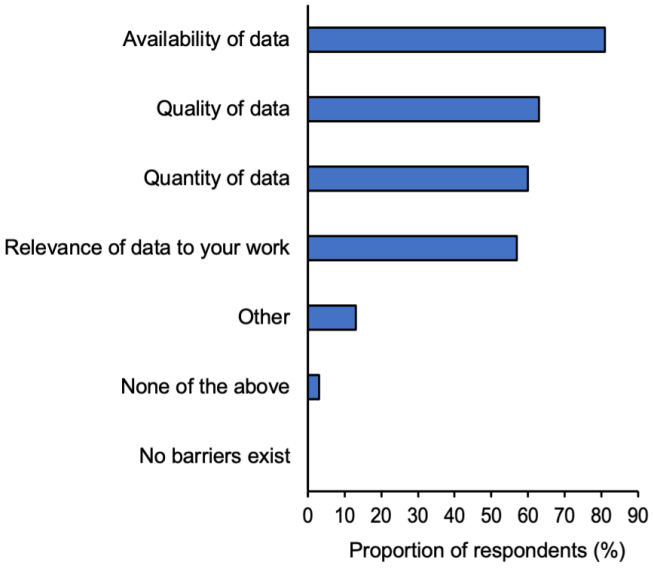


Fig. 7. Barriers to the inclusion of social and economic information for Canadian ocean managers when assessing cumulative effects in their decision-making related to marine conservation areas (n = 32).



the above-mentioned assessment methods existed across the federal departments surveyed, respondents seemed unaware of any formal and/or legal frameworks that require cumulative effects to be considered in decision-making processes related to marine conservation areas.

DISCUSSION

Among the MCA managers who responded to our survey, there appeared to be broad recognition about the importance of understanding and accounting for cumulative effects in management decisions, as well as some recognition of the importance of incorporating social and economic factors and

information. Our analysis suggests that the issue of incorporating cumulative effects assessment into MCA management is therefore not one of a lack of appreciation of its value but rather is due to limited information about cumulative effects and an incomplete understanding of social, economic, and ecological interactions necessary to achieve a holistic approach to management and decision-making.

Contrary to our working hypothesis, the manager position type and level of experience, the ocean, and the type of marine conservation area managed did not seem to substantially influence how cumulative effects are assessed or how social and economic factors are considered by managers. However, the federal department that respondents worked for seemed to exert some influence on certain aspects of how they assess cumulative effects. For example, each department uses different pieces of legislation to guide its decision-making (Table 2), which has been identified as a key challenge in cumulative effects management in other jurisdictions (Foley et al. 2017, Davies et al. 2020). In addition, managers from DFO generally gave more consideration to social factors than did those from ECCC and Parks. This is somewhat unexpected, especially for Parks Canada, whose mandate is stated as follows:

> *On behalf of the people of Canada, we protect and present nationally significant examples of Canada's natural and cultural heritage, and foster public understanding, appreciation and enjoyment in ways that ensure the ecological and commemorative integrity of these places for present and future generations* (Parks Canada 2002).

In the following sections, we discuss the activities, information, assessment methods, and social and economic factors used by MCA managers to assess and manage cumulative effects.

Defining scale and activities

Defining the appropriate spatial scale to accurately understand and manage cumulative effects has been cited as a substantial challenge, especially in relation to marine conservation areas (Mach et al. 2017). While previous studies have noted that broader, ecosystem, or eco-regional scales better account for the breadth of interactions generated by socioeconomic activities at multiple scales (Murray et al. 2014, Foley et al. 2017), our study indicated that Canadian MCA managers consider local or site-specific scales more often than regional ones, and less than half said they deal with multiple spatial scales in their work. While practicality and a focus on the MCA for which the managers are being held accountable may drive the spatial scales being used, this potentially undermines the managers' ability to fully understand the interactions taking place within the MCA. Complementing the broader spatial scale with ecosystem-based management tools could also ensure that social and economic factors are adequately captured in cumulative effects assessments and decision-making processes (Halpern et al. 2008a).

In terms of the temporal scales used by managers to account for cumulative effects, only limited consideration was given to future activities and potential effects, which suggests that managers may consider cumulative effects only on a temporal scale that is relevant to the duration of immediate impacts that a project or human activity is likely to have on the environment. Attention has been raised about the limitation this poses in adequately accounting for effects on ecological components (Judd et al. 2015, Foley et al. 2017) and the subsequent downstream impacts of ecological changes on the social system that relies on ecosystem services provided by the marine environment (Bograd et al. 2019). Although future activities and effects were given limited consideration overall, managers with 5-10 years of experience or those in senior positions considered them more often than did other managers. Whether this can be mitigated through training of less experienced managers or by being prescriptive in how cumulative effects assessments are conducted, regardless of experience, or a combination of the two, our findings suggest experience likely plays an important role in determining appropriate temporal scales that better capture social and economic factors when assessing and managing cumulative effects.

Given that the goals and objectives of Canada's marine conservation areas are to balance protection and sustainable use (Government of Canada 2011), it was not surprising that fish harvesting, marine transportation, and recreational activities, such as angling or public beach use, were the most common socioeconomic activities that MCA managers considered for cumulative effects assessments. Additionally, departmental policies could play a key role in identifying activities to include in cumulative effects assessments, as we found DFO respondents, more so than ECCC and Parks respondents, gave attention to offshore oil and gas development, which likely reflects new provisions that prohibit oil and gas activities in marine protected areas (DFO 2019a). Similarly, the previously stated mandate of Parks to ensure that examples of natural and cultural heritage are adequately protected accounts for the department's focus on activities such as marine transportation, recreation, tourism, and coastal development. Parks likely gives these activities more consideration due to the type of conservation areas it manages (national marine conservation areas), which often include coastal areas. Additionally, Parks has no authority to deal with commercial fisheries.

Respondents also identified climate change, acoustic impacts, invasive species, and pollutants as other socioeconomic "activities" that they consider in their assessments and decision-making, but the literature usually defines these as stressors (Crain et al. 2008, Murray et al. 2014, Foley et al. 2017). This suggests an apparent confusion in terminology, which indicates a need for better clarity and consistency in how these terms are defined and used. Previous studies have shown that variable definitions and terminology are common in cumulative effects assessment practices and can be a significant barrier to effectively managing cumulative effects (Duinker et al. 2013, Foley et al. 2017, Hodgson et al. 2019). Therefore, a set of clear definitions regarding cumulative effects assessment in marine conservation areas that applies across departments should be developed and implemented.

Social and economic factors and types of information

Marine managers often struggle to effectively incorporate social and economic factors when assessing cumulative effects and developing MCA design, implementation, and management plans (Canter and Ross 2010, Weber et al. 2012, Lundquist et al. 2016, Dehens and Fanning 2018, Davies et al. 2020). Our results confirm that while DFO, ECCC, and Parks managers often

consider ecological factors, they only infrequently incorporate both social and economic factors into their assessment and decision-making. The two most frequently considered social factors were local marine resource use patterns and local values and beliefs regarding marine resources. This suggests that the social factors considered in assessments are selected based on their relationship to ecological components of marine conservation areas and their potential to impact them. Though it is important to consider social factors in this context, it does not sufficiently account for issues of community and regional well-being, which are often given minimal attention in current cumulative effects assessment practices (Weber et al. 2012). This can generate feedback loops, and thus negatively affect the achievement of MCA objectives. It is worth noting that among the managers in our study who considered social factors, those from DFO were more likely to do so. This may reflect roles and mandates of fisheries departments (Halpern 2003, Hilborn et al. 2004). For example, "managing Canada's fisheries and safeguarding its waters" is part of DFO's primary role (DFO 2019b), which includes working with fishers as well as coastal and Indigenous communities to ensure continued access to and benefits from Canada's ocean resources. However, it may also reflect departmental efforts to address growing antagonism with coastal communities over marine protected area establishment (DFO 2018) and increasing attention being paid to respecting constitutionally protected rights of Indigenous peoples' access to such resources (Ban and Frid 2018, UNDRIP Act 2021).

Based on our survey results, the three most frequently considered economic factors managers used in cumulative effects assessments were the economic value of fisheries in an area, the economic value of other industries present, and the nature of employment in an area. Respondents from DFO suggested that these factors are likely derived directly from its commercial landings databases or its socioeconomic team, which provides the information to MCA managers. This highlights an inconsistent and fragmented approach to data used for cumulative effects assessments and management, and indicates the need for a more transparent process for determining which factors should be incorporated into cumulative effects assessments for effective MCA management (Canter and Ross 2010). Rodriguez and Fanning (2017) noted household income levels, possible displacement issues, and employment rates are also important considerations in marine conservation areas; however, few managers we surveyed indicated using these in their assessments and decision-making.

Our study suggests that most MCA managers who responded to our survey may lack expertise or experience in incorporating necessary social and economic factors into cumulative effects assessment, or they mistakenly consider them outside the scope of their decision-making. The limited consideration of social and economic factors is consistent with existing research, which suggests that these factors are often poorly incorporated into cumulative effects assessments (Fox et al. 2006, Canter and Ross 2010, Weber et al. 2012, Davies et al. 2020). To address this significant gap, and given the impact of legislation on activities and communities to be considered in marine protected area management, Canada's goal to "achieve an ecologically comprehensive, resilient, and representative national network of MPAs" (DFO 2011) may need to be expanded to explicitly include social and economic considerations. Enhancing managers' familiarity with and understanding of social and economic factors, information, data gathering, and analyses through training and guidelines could lead to better incorporation of cumulative effects into spatial management approaches such as marine conservation areas and protected area networks. However, our results suggest that Canada currently lacks comprehensive models and assessment frameworks that are broad enough to achieve this.

While expected scientific sources and types of ecological information (e.g., published peer-reviewed sources and quantitative data) were identified by respondents to our survey, social and economic sources of information were primarily non-quantitative and relied on local or community knowledge, traditional knowledge, expert opinion, and information from other managers or practitioners. We speculate that reliance on local and traditional knowledge may indicate a lack of availability and/or access to quantitative social and economic data. However, it also suggests that managers use these sources to mitigate gaps in social and economic information by involving some stakeholders in the cumulative effects and MCA management processes. Such stakeholder involvement has been shown to be a critical factor in influencing marine conservation success because it helps inform the social and economic dimensions needed to adequately design and manage marine conservation areas, and thus enhances their legitimacy (Mangubhai et al. 2015, Dehens and Fanning 2018).

Survey respondents confirmed that the main challenge practitioners face in incorporating social and economic information into cumulative effects is the unavailability of data. Other barriers included the relevance of existing information to managers' work, the timeliness of data, and accessibility to applicable data sources. Additionally, the quality and quantity of information, and a lack of guidelines, expertise, funding, and time, all of which have been identified in previous studies as key challenges to cumulative effects assessment and management, account for socioeconomic information remaining understudied, inaccessible, and limited in use in cumulative effects assessments (Canter and Ross 2010, Halpern and Fujita 2013, Cvitanovic et al. 2014, Hodgson and Halpern 2019, Davies et al. 2020). To help reduce these barriers and improve assessment methods, enhancing the exchange of available socioeconomic information within and between departments and collaborating on acquiring new information could improve the practice of cumulative effects assessment and communication among practitioners with varying expertise.

Assessment methods

Our study highlights the failure of current approaches being used by MCA managers in Canada to adequately account for the interaction of human activities and the resulting cumulative consequences. Managers indicated that a holistic cumulative effects assessment framework is currently lacking, and no explicit legislation, regulations, policies, or even best practices exist to guide the overall scope and use of social and economic factors and information in their assessments; therefore, they use a patchwork of department- and site-specific laws, regulations, and standards of practice to account for cumulative effects in their decision-making. As noted by one respondent, "it's a 'take it as it comes' approach more often than not with no rigorous framework to follow". This suggests there is a need to streamline how cumulative effects are assessed by developing a framework

or specific guidelines that can be used by managers across departments, oceans, and conservation areas. The recent review by Murray et al. (2020), which focuses on cumulative effects research and assessment within DFO, echoes this suggestion.

Overall, our study revealed considerable differences within and across federal departments in the use of social and economic factors, frameworks, and approaches for cumulative effects assessment. While the explanation for these inconsistencies was not specifically part of our survey, we speculate that some of these inconsistencies may be due to differences in departmental mandates, authority, organizational structure, and functioning, as well as varying levels of resources and interdisciplinary capability. How policies are set, who is involved in such policy setting, and the type and source of information used are all areas in need of better understanding in order to improve decision-making. While we used marine conservation areas as the vehicle for exploring the practice of cumulative effects assessments in Canada, our findings suggest the need for a broader examination of the root causes affecting how social-ecological systems are currently being governed, including how, to what extent, and for what effects certain types of knowledge are being used. Our study also highlighted the need for a more proactive approach to managing these systems by anticipating and incorporating the effects of social and economic factors on both the natural and social system, using cumulative effects assessments. As such, we strongly suggest additional research is needed on these factors we uncovered and which are known to affect the effectiveness of marine governance, and highlight the need for a government-wide strategic approach to addressing these gaps.

CONCLUSION

Based on our study, Canadian MCA managers appear to incorporate some aspects of cumulative effects into their decision-making processes. However, consistent with other studies, the use of social and economic factors and information appears to be limited. While our study did not indicate that manager position type or experience, type of marine conservation area, or oceanic location influenced the use of cumulative effects assessment or the incorporation of social and economic factors into cumulative effects assessment, the department that employed MCA managers seemed to play a role, as did the level of experience when considering the temporal scale. Our findings highlight the need to study the role of these dependent variables in cumulative effects assessment in greater depth because such knowledge can maximize effective MCA management and planning in Canada and beyond. In the meantime, our findings suggest that the limited use of cumulative effects assessment in MCA planning and management by Canadian managers is likely due to a lack of clear definitions, guidelines, and frameworks, the unavailability of information, and fragmented management approaches. To effectively achieve conservation objectives, managers need to mitigate and manage for cumulative effects by using a well-designed framework, supported by an enhanced understanding of the spatial, temporal, and marine governance factors that influence the complex suite of social-ecological interactions taking place within the marine conservation area.

[1] https://geds-sage.gc.ca/en/GEDS?pgid=012

Responses to this article can be read online at:
https://www.ecologyandsociety.org/issues/responses.php/13342

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Data Availability:

The data that support the findings of this study are available upon request from the corresponding author [GC]. The data are not publicly available because the they contain information that could compromise the privacy of research participants. Ethical approval for this research study was granted by Dalhousie University"s Marine Affairs Program Ethics Review Standing Committee (MAPERSC), file number MAP2019-03, and the Simon Fraser University Office of Research Ethics, file number 2019s0221.

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Appendix 1. 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. DAPSI(W)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)