Consideration of marine non-indigenous species in the planning, management, and monitoring of Canadian marine protected areas

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Table of Contents

List of Tables and Figures iv
Abstract v
List of Abbreviations Used vi
Acknowledgements vii
Chapter 1. Introduction 1
1.1 Overview and Broad Context 1
1.2 Canada's Marine Protected Areas and Marine NIS 2
1.3 The Management Problem and Project Purpose 3
1.3.1 Project Purpose and Objectives 3
Chapter 2. Global Best Practices for Managing Marine NIS in MPAs 5
2.1. Prevention 7
2.1.1 Marine NIS in Spatial Planning 7
2.1.2 Vessel Regulations 8
2.2 Early Detection and Eradication and Mitigation Strategies 9
2.2.1 Monitoring 9
2.2.2 Species-targeted removals 10
2.2.3 Citizen science initiatives 11
2.3 Strategies for All Three Stages 12
2.3.1 Risk Assessment 12
2.3.2 Suitable Habitat Modelling 13
2.3.3 Awareness and Outreach 14
2.3.4 Integrate NIS into MPA management plans 14
Chapter 3. Methods 16
3.1 Scope 16
3.2 Study Design 16
3.2.1 Review of Management Plans 16
3.2.2 Structured Interviews 16
Chapter 4. Results 19
4.1 Management Plans 19
4.2 Structured Interviews 23
4.2.1 Marine NIS Knowledge 23
4.2.2 Incorporation of Marine NIS in MPA Planning 30
4.2.3 Management Strategies for Marine NIS in MPAs 32

4.2.4 Marine NIS consideration in MPA planning, management, and monitoring 38
Chapter 5. Discussion 42
5.1 Incorporation of Marine NIS in Management Plans 42
5.2 MPA and AIS Practitioner Knowledge 44
5.3 Inclusion of Marine NIS in MPA Planning 46
5.4 Management of Marine NIS in Canadian MPAs 48
5.5 Challenges and Limitations 50
Chapter 6. Recommendations and Conclusions 51
6.1 Recommendations 51
6.2 Conclusions 52
References 54
Appendix A. List of Canada's Federally Designated MPAs 62
Appendix B. Interview Consent Form 65
Appendix C. Interview Questions 69
Questions for MPA Planners 69
Questions for MPA Managers 70
Questions for MPA Practitioners Involved with Monitoring 74
Questions for AIS Practitioners 77
References for Interview Questions: 81
Appendix D. Summary of Available Management Plans 82
Appendix E. Reference List of Available Management Plans 88

List of Tables and Figures

Table 1. Summary of management and monitoring strategies for NIS in Canada's federally designated MPAs……...…21

Figure 1. The comparative costs of prevention and management strategies for NIS…….6

Figure 2. Examples of prevention, early detection and eradication, and mitigation strategies for NIS in an MPA……7

Figure 3. The number and proportion of available management plans for each type of Canada's federal MPA……...19

Figure 4. Expert opinion of the seriousness of marine NIS A) in Canadian ecosystems and B) in Canada's MPAs according to MPA and AIS practitioners……24

Figure 5. How familiar MPA and AIS practitioners are with management, monitoring or mitigation efforts for marine NIS A) in Canada and B) within Canada's MPAs……..25

Figure 6. Marine NIS of particular concern and marine NIS that have been seen in Canada's MPAs, according to MPA and AIS practitioners……...28

Figure 7. The susceptibility of Canada's MPAs to invasion by marine NIS, according to MPA practitioners involved with MPA management or monitoring…….…29

Figure 8. The most important stressors to consider during MPA planning A) according to MPA and AIS practitioner opinions and B) based on which stressors are actually considered most during planning, according to MPA planners and managers…….……...….31

Figure 9. The relationship between marine NIS and MPA planning……...…….32

Figure 10. Strategies used to facilitate communication between MPA and AIS practitioners, according to MPA and AIS practitioners……...33

Figure 11. The information and strategies used to A) prevent marine NIS introductions, B) detect newly arrived marine NIS and C) and mitigate marine NIS in an MPA, according to MPA and AIS practitioners…….……....35

Figure 12. The best strategies to prevent marine NIS within MPAs, according to AIS practitioners……...….36

Figure 13. Marine NIS-specific monitoring in Canada's MPAs, according to MPA practitioners involved in management or monitoring…….…37

Figure 14. Opinions from MPA and AIS practitioners regarding the increased consideration of marine NIS in A) MPA planning, B) management, and C) monitoring……...….39

Figure 15. The top things MPA and AIS practitioners would like to see done with regards to marine NIS and Canada's federal MPAs……...41

Abstract

Marine protected areas (MPAs) are an important tool for protecting marine environments. They can help conserve biodiversity, protect endangered species and critical habitats, regulate human activities, and preserve social, economic, and cultural values. Despite these benefits and the increasing use of MPAs, some stressors can jeopardize the effectiveness of an MPA. One important stressor is marine non-indigenous species (NIS), which includes any marine species living outside its native range. Some of these species can cause widespread damage to ecosystems and threaten biodiversity; because MPAs lack physical boundaries between them and surrounding waters, they are not immune to NIS invasion. Marine NIS are a key management concern for many scientists worldwide. However, there is evidence suggesting marine NIS are not adequately considered during MPA planning, management, or monitoring. This research aimed to determine how marine NIS are considered in Canada's federal MPAs during MPA planning, management, and monitoring. The study included a review of all available federal MPA management plans and structured interviews with MPA practitioners and aquatic invasive species (AIS) practitioners. The results indicate that marine NIS are not given enough consideration in Canadian MPAs. Recommendations include including marine NIS into MPA management plans, increasing the inclusion of marine NIS during MPA planning, increasing collaboration between MPA and AIS practitioners, developing marine NIS awareness and outreach specific to MPAs, and increasing funding for marine NIS management, monitoring, and research.

marine protected areas; marine non-indigenous species; non-indigenous species management; aquatic invasive species; Canada

List of Abbreviations Used

AIS – Aquatic Invasive Species

AOI – Area of Interest

AS-ISK – Aquatic Species Invasiveness Screening Kit

CMIST – Canadian Marine Invasive Screening Tool

DFO – Fisheries and Oceans Canada

ECCC – Environment and Climate Change Canada

IUCN – International Union for Conservation of Nature

MBS – Migratory Bird Sanctuary

MPA – Marine Protected Area

NIS – Non-Indigenous Species

NMCA – National Marine Conservation Area

NWA – National Wildlife Area

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Chapter 1. Introduction

1.1 Overview and Broad Context

Marine protected areas (MPAs) are an increasingly important tool for protecting marine ecosystems around the world (Halpern & Warner, 2002; Picone, Buonocore, Chemello, Russo, & Franzese, 2020; Spalding et al., 2016). An MPA is defined as "any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (Kelleher, 1999). There have been numerous documented benefits of MPAs, including conserving biodiversity, protecting endangered species and critical habitats, regulating human activities, and preserving social, economic, and cultural values (Angulo-Valdés & Hatcher, 2010; Picone et al., 2020). Since the establishment of the Aichi Biodiversity Targets for 2011-2020, nations have been striving to meet Aichi Target 11: protection of 17% of their terrestrial area and 10% of their coastal and marine area (Gannon et al., 2019). As a result, there has been a recent, global increase in MPA designation to help meet this coastal and marine conservation commitment (Gill et al., 2017).

MPAs have been shown to have positive impacts on biodiversity and ecosystem health when well-managed, though there is concern that some MPAs are ineffective due to inadequate management of stressors (Gill et al., 2017; Iacarella, Saheed, Dunham, & Ban, 2019). MPA conservation objectives of protecting key features, habitats, or species (DFO, 2013) can be hindered by stressors occurring both inside and surrounding an MPA. Human activities and stressors for MPAs include aquaculture, climate change, commercial and recreational fishing, habitat alteration and loss, marine non-indigenous species (NIS), pollution, and underwater noise (Day, Laffoley, & Zischka, 2015; DFO, 2014; Mach et al., 2017). In particular, marine NIS can have impacts on native species and habitats that can be intensified by other stressors, such as climate change or habitat disturbance (Sarà, Porporato, Mangano, & Mieszkowska, 2018). The remainder of this study will focus on marine NIS in MPAs, as this is a stressor that is often overlooked in MPA planning and management (Giakoumi et al., 2016; Iacarella et al., 2019; Mačić et al., 2018).

Marine NIS, defined here as any species living outside of its native range, can be introduced by anthropogenic-mediated vectors such as ships and boats via ballast water and hull fouling, accidental or purposeful release, and aquaculture (Bax, Williamson, Aguero, Gonzalez,

& Geeves, 2003). Once introduced and established, the secondary dispersal of marine NIS is likely to occur throughout regions due to the connectedness of the marine environment (Giakoumi et al., 2019a). Many marine NIS can negatively impact marine environments by displacing native species, changing ecosystem structure and function (e.g., altering food webs), and reducing biodiversity (Mačić et al., 2018; Molnar, Gamboa, Revenga, & Spalding, 2008). MPAs are also susceptible to invaders, though well-protected native communities may have some biotic resistance (*i.e.* through competition and predation) (Gallardo et al., 2017).

Several studies have documented NIS impacts within MPAs (Coma et al., 2011; Giakoumi et al., 2019b; Kaplan et al., 2018). In addition, there are several examples of marine NIS having higher biomass inside MPAs compared to nearby unprotected areas (Byers, 2005; Giakoumi et al., 2019b; Rilov et al., 2018). This increase in biomass within an MPA can result from a lack of fishing within the reserve (which can reduce NIS as bycatch or target species) and increased NIS vectors from tourism (Burfeind, Pitt, Connolly, & Byers, 2013). Other changes due to marine NIS can have socioeconomic impacts. For example, non-indigenous cordgrasses (*Spartina* spp.) can decrease tourism by altering sandy shorelines in a way that is unattractive to MPA visitors and can cause injuries with its sharp leaves (Nehring & Hesse, 2008).

1.2 Canada's Marine Protected Areas and Marine NIS

In Canada, there are three government agencies that can establish MPAs: Environment and Climate Change Canada (ECCC), Fisheries and Oceans Canada (DFO), and Parks Canada. Under DFO, an MPA is designated with the *Oceans Act* and under Parks Canada, an MPA is designated as a National Marine Conservation Area (NMCA) with the *National Marine Conservation Areas Act* (DFO, 2005). In addition, a marine portion of a Migratory Bird Sanctuary (MBS) or National Wildlife Area (NWA) under ECCC can count as an MPA; the same is true for National Parks under Parks Canada (DFO, 2005). These five types of reserves constitute the federal MPAs in Canada.

Marine NIS may pose a threat to many MPAs in Canada (Iacarella et al., 2020a, 2020b). While not all NIS have negative impacts (*e.g.* environmental, economic, human health), those that do are considered to be invasive (Mack et al., 2000). Examples of marine NIS that are or may become invasive in Canadian ecosystems include the European green crab (*Carcinus maenas*), several species of colonial and solitary tunicates, the Pacific oyster (*Crassostrea*

gigas), and alga (*e.g. Codium fragile*, commonly known as the oyster thief) (Drolet et al., 2016; Lyons et al., 2020). DFO is the lead government department for managing marine aquatic invasive species (AIS) and other federal departments and agencies that have roles and responsibilities related to AIS include the Canadian Food Inspection Agency, ECCC, Health Canada, National Defence, Parks Canada, and Transport Canada (Leach et al., 2019).

1.3 The Management Problem and Project Purpose

Globally, MPA practitioners and scientists are concerned about marine NIS as a stressor in MPAs (Iacarella et al., 2019). However, marine NIS are often overlooked during the MPA planning process (Ardura, Juanes, Planes, & Garcia-Vazquez, 2016; Iacarella et al., 2019). In a 2016 study, only 2.5% of global marine conservation plans included marine NIS (Giakoumi et al., 2016). The same study found that when marine NIS were included or avoided in the marine spatial planning process (rather than ignored), the ideal locations for protection changed (Giakoumi et al., 2016). This indicates the importance of including marine NIS in MPA planning. Marine NIS should also be considered in MPA management, following planning and implementation of the MPA, as the conservation objectives of an MPA can be impeded by marine NIS (Iacarella et al., 2019; Mačić et al., 2018).

1.3.1 Project Purpose and Objectives

This study aims to determine the status of marine NIS consideration in Canada's federal MPAs during planning, management, and monitoring activities. First, best practices for prevention, early detection and eradication, and mitigation of marine NIS from different parts of the world were reviewed in relation to MPA planning, implementation, and management. Then two approaches were used to evaluate how well Canada currently incorporates these best practices for MPAs: (1) a review of Canada's federal MPA management plans and (2) structured interviews with MPA and AIS practitioners. Specifically, this information was used to address the following questions:

Main Research Question: To what extent are marine NIS considered during MPA planning, management, and monitoring in Canada's federally designated MPAs?

Sub-Question 1: Are marine NIS incorporated into existing MPA management plans?

***Sub-Question 2*:** Are marine NIS included in MPA spatial planning assessments and designs?

Sub-Question 3: Are marine NIS actively managed through prevention, early detection and eradication, or mitigation?

Based on the results of this study, recommendations for how Canada's MPAs can better incorporate marine NIS management strategies during MPA planning, management, and monitoring are provided.

Chapter 2. Global Best Practices for Managing Marine NIS in MPAs

Marine NIS have been shown to impact native species and ecosystems and MPAs are not exempt from these impacts. While MPAs can protect native species from multiple stressors and may slow the spread of marine invaders due to biotic resistance (Gallardo et al., 2017), some MPAs have reported higher densities of marine NIS within their boundaries compared to surrounding waters (Caselle, Davis, & Marks, 2018; Giakoumi et al., 2019b; Rilov et al., 2018). In such cases, marine NIS may reduce the ability of an MPA to achieve its conservation objectives, for example, by outcompeting a native species or by altering community dynamics (Iacarella et al., 2019). As such, they pose a challenge for MPA practitioners. Management strategies for terrestrial NIS are fairly well established, while best practices for marine NIS remain unclear (Giakoumi et al., 2016, 2019a). One reason is that many marine NIS are understudied and there is a lack of protocol for how to deal with them in general, let alone in MPAs (Otero, Cebrian, Francour, Galil, & Savini, 2013). This is in part due to the difficulty of monitoring and detecting marine invaders, as some NIS life stages may not be easily visible (*e.g.* larvae) and detection underwater is often difficult (Darling & Mahon, 2011). Further, there are few barriers to stop the spread of many NIS in marine ecosystems (Giakoumi et al., 2019a; Simberloff, 2000) and species can be dispersed via human activities such as commercial shipping, recreational boating, and aquaculture activities (Otero et al., 2013).

Three general strategies to mediate and manage effects of NIS include prevention, early detection and eradication, and mitigation. It is generally considered most cost-effective to prevent the introduction of a marine invader than it is to eradicate it, control its spread, or manage its impacts (Figure 1) (Leach et al., 2019). Eradication is highly unlikely once an NIS is established in a marine ecosystem and there are few examples of success (Giakoumi et al., 2019a; Leach et al., 2019; Thresher & Kuris, 2004). Unfortunately, marine NIS have already established in many MPAs, either prior to or since their designation, so prevention is no longer possible in these cases.

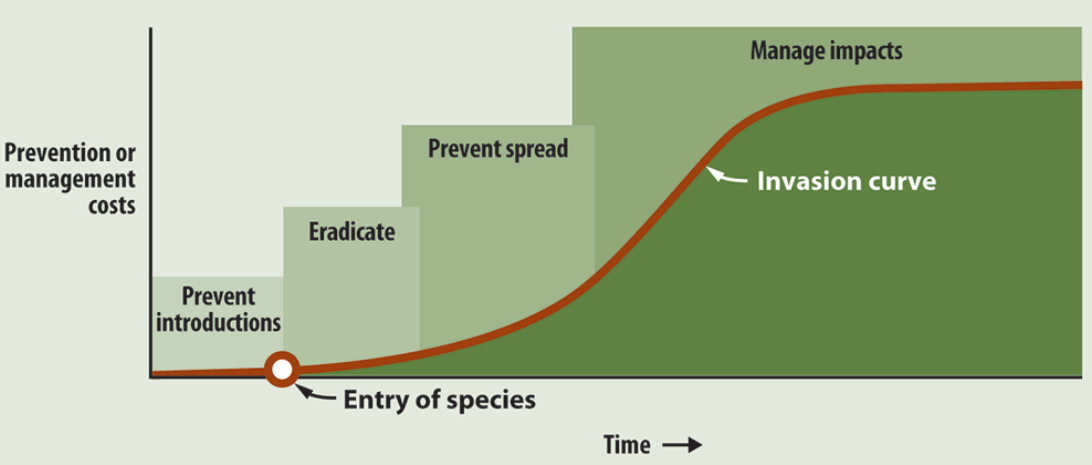

Figure 1. The comparative costs of prevention and management strategies for NIS (from Leach et al., 2019).

Different best practices can be applied during the MPA planning stage and after an MPA is designated. Before an MPA is designated, there are several strategies that can be used to identify and avoid (or target) areas with marine NIS, prevent their introduction, and plan for potential introductions. If invaded areas cannot be avoided, then it is worthwhile to consider all marine NIS currently impacting (or likely to impact) the area of interest (AOI) during MPA planning; an AOI is a precursor to an MPA and is usually selected for its ecological or biological significance or because it is in need of protection (Schram, Ladell, Mitchell, & Chute, 2019). After an MPA is designated, the best practices for managing marine NIS is somewhat dependent on the MPA itself, but some strategies can be generally applied. If a marine NIS is already present in the MPA, prevention is not an option, though there are options to help control established populations by mitigating their spread, abundance, and ultimately their impacts.

This chapter provides a review of best practices for the prevention, early detection and eradication, and mitigation of marine NIS in MPAs (Figure 2). These best practices are not exclusive to MPAs, but can and have been effectively applied to them. Literature for this chapter was compiled from peer-reviewed journal articles and practical guides and reports for marine managers. Relevant papers were selected from Google Scholar and Canada's Federal Science Library by searching for variations and combinations of keywords, including 'invasive species', 'non-indigenous species', 'non-native species', 'exotic species', 'marine protected areas', 'management', 'strategies', and 'best practices'. Strategies used for terrestrial and freshwater species were included if they could be applied to marine species. These were divided into best practices applicable during the MPA planning process, those that can be implemented after an

MPA is designated, and others that apply to multiple stages of the framework (Figure 2). Therefore, management strategies are described for prevention (section 2.1), early detection and eradication, and mitigation (section 2.2), and for all three stages of marine NIS management (section 2.3).

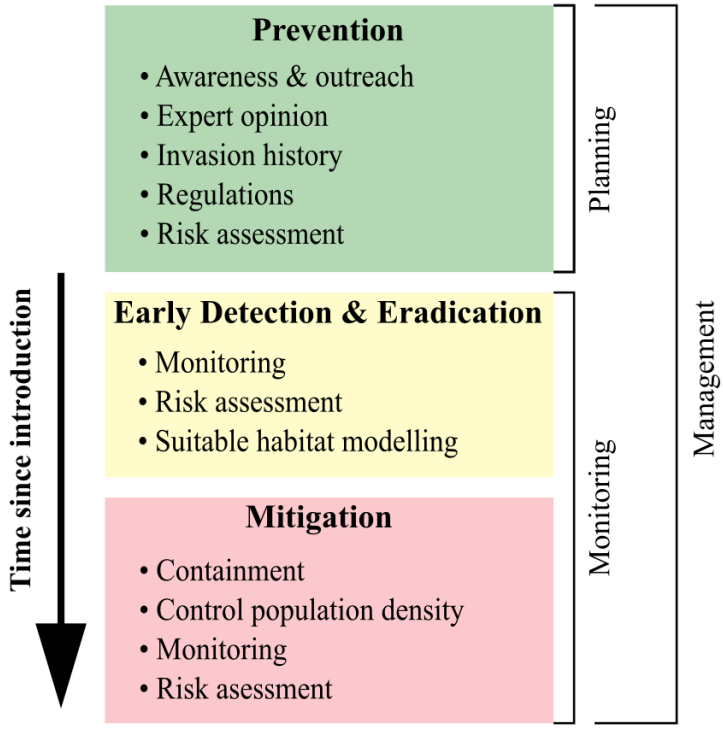

Figure 2. Examples of prevention, early detection and eradication, and mitigation strategies for NIS in an MPA. Strategies are organized by time since introduction of the NIS from top to bottom and how they fit into MPA planning, management, and monitoring is indicated (adapted from Simberloff et al., 2013).

2.1. Prevention

2.1.1 Marine NIS in Spatial Planning

Consideration of marine NIS can be incorporated during MPA spatial planning processes. In many cases worldwide, AOIs are selected using decision-support tools that help MPA planners optimize design strategies based on conservation goals that help identify where to place an MPA or MPA network in a cost-effective manner (Giakoumi et al., 2016). Decision-support tools are used in many fields of study and have become routine in environmental management (Copp et al., 2016). A frequently used decision-support tool in MPA planning is Marxan (Ball, Possingham, & Watts, 2009), a software algorithm designed to identify ecologically or biologically important locations and networks while minimizing known ecosystem stressors and

socio-economic costs (Watts et al., 2017). For example, by including the known distribution of marine NIS in Marxan-based conservation planning exercises, MPA planners can identify and help to minimize or avoid (or plan for) NIS stressors before designating an MPA. According to Giakoumi and colleagues (2016), including marine NIS data in Marxan analyses can result in different optimal locations for MPA placement and indicates the potential benefit of incorporating marine NIS into spatial planning.

When considering marine NIS in MPA planning, areas with marine NIS can be avoided or, conversely, may be included for the purpose of using the MPA designation to manage NIS (Giakoumi et al., 2016). Choosing to avoid areas with NIS is generally done so that highly disturbed or impacted areas are eliminated or reduced by the conservation planning software (Giakoumi et al., 2016; Klein et al., 2013; Tallis, Ferdaña, & Gray, 2008). Conversely, in some cases, it may be that an MPA is planned in an area with a high density of one or more marine NIS (Giakoumi et al., 2016). There could be various reasons for protecting an area with established NIS. For example, to protect and attempt to restore important habitat for native species that has been degraded by a marine invader. Whether marine NIS are chosen to be avoided or included in areas for protection, it is useful to consider them during MPA planning as this may help determine management strategies to ensure MPAs achieve their conservation goals

2.1.2 Vessel Regulations

Vessels (both commercial and recreational) are one of the leading vectors for marine NIS and can facilitate their introduction and spread into MPAs (Iacarella et al., 2020a). In particular, marine NIS can be transported through the ballast water of commercial ships and by hull fouling on boats of all sizes (Bax et al., 2003). National and international regulations exist that help prevent the introduction and spread of marine NIS within a country or region. For example, Canada's Ballast Water Control and Management Regulations, which include management strategies such as treating ballast water or exchanging it in the mid-ocean to reduce the chance of NIS from invading (Scriven, DiBacco, Locke, & Therriault, 2015). While these types of regulations can benefit MPAs, MPA practitioners can further work with the responsible federal agencies to create regulations for vessels entering an MPA and vessel-related activities (Iacarella et al., 2020a). For example, prohibiting ballast water release when near an MPA, restricting the movement of vessel traffic through the area, and limiting or prohibiting fishing. In the Florida Keys National Marine Sanctuary, the release of NIS is prohibited and shipping traffic is

restricted (National Oceanic and Atmospheric Administration, 2007). In New South Wales, Australia, the Batemans Marine Park has applied regulatory zones to contain the spread of an invasive alga (*Caulerpa taxifolia*) by restricting commercial netting (*i.e.* fishing nets that pick up algal propagules) in infested areas within the MPA (New South Wales Department of Industry, 2009).

2.2 Early Detection and Eradication and Mitigation Strategies

2.2.1 Monitoring

Monitoring is an important strategy to help manage marine invasions once an MPA is designated. A monitoring regime can increase the chance of early detection of marine NIS (Mannino & Balistreri, 2018; Otero et al., 2013; Pomeroy, Parks, & Watson, 2004) and if paired with rapid response measures, eradication or control is much more likely (Giakoumi et al., 2019a; Ojaveer et al., 2015). The likelihood of early detection can also be increased when monitoring is paired with a screening level risk assessment tool (explained in the *Risk Assessment* section (2.3.1) below), as high-risk NIS can be determined for an area and this can help MPA practitioners to focus monitoring efforts (Drolet et al., 2016).

MPA management plans typically include monitoring priorities, however NIS are often not included (Otero et al., 2013). MPA monitoring plans can include methods specific to marine NIS or can coincide with other monitoring foci (Otero et al., 2013). For example, visual surveys or field sampling methods used to observe and monitor native species and habitats can include searching for NIS (Otero et al., 2013). Another option is to create alternate initiatives like citizen science programs, which can reduce the funding and resources needed to carry out monitoring (Larson et al., 2020; Mannino & Balistreri, 2018). Citizen science strategies are described further in the *Citizen Science Initiatives* section (2.2.3) below.

Despite best efforts, MPAs that are well-managed can still have NIS present (Caselle et al., 2018; Giakoumi et al., 2019a). In order to limit impacts of marine NIS and control their populations, consistent monitoring must continue past the detection stage (Mannino & Balistreri, 2018; Otero et al., 2013). Monitoring can indicate if management strategies are effective against marine NIS and guide adaptive management (De Poorter, Pagad, & Irfan Ullah, 2007; Pomeroy et al., 2004).

2.2.2 Species-targeted removals

One of the most frequently mentioned best practices for controlling or mitigating an NIS is by removal and culling (Hulme, 2006; Park, 2004). This strategy has been applied to MPAs, including mass culling of invasive Indo-Pacific lionfish (*Pterois* sp.) in Western Atlantic MPAs (Côté & Smith, 2018). Lionfish derbies have become a popular control method and commonly involve participation by artisanal fishers, recreational divers, and tourists (Barbour, Allen, Frazer, & Sherman, 2011; Malpica-Cruz, Chaves, & Côté, 2016). Another example includes targeted removal of the invasive alga *C. taxifolia* in the Mediterranean and southern Australia. Physical removal can be highly targeted when done by hand or diver-operated dredges (New South Wales Department of Industry, 2009). The most common way to control the European green crab (*C. maenas)* is to trap them using fyke nets or Fukui traps (Bergshoeff, McKenzie, & Favaro, 2019; Poirier, Tummon Flynn, Gehrels, & Quijón, 2020). For fouling species, such as tunicates, mechanical removal strategies are common including pressure washing, scrubbing, and hand-picking (Karney & Rhee, 2009; Paetzold & Davidson, 2010; Tamburello, Francis, & Olson, 2017). Another option for controlling fouling species is to use chemical treatments (*e.g.* acetic acid, bleach, *etc.*) (Switzer, Therriault, Dunham, & Pearce, 2011), which can be combined with enclosure techniques (*e.g.* plastic wrapping around piers or surfaces) to limit the impact on the surrounding environment (Atalah, Brook, Cahill, Fletcher, & Hopkins, 2016; Tamburello et al., 2017). Species-targeted removal of marine NIS can be applied to many of Canada's federal MPAs, particularly those that are easily accessible (*e.g.* coastal, shallow MPAs).

Unfortunately, species-targeted removal programs can be an expensive and time-consuming endeavour. Unless the invader is contained to a small area or hindered by a barrier, complete eradication is unlikely (Hulme, 2006), especially in the marine realm (Bergshoeff et al., 2019; Giakoumi et al., 2019a). For example, lionfish culling should be done at a monthly frequency over a period of years to be kept under control (Côté & Smith, 2018) In addition, there is evidence that lionfish may change their behaviour over time, resulting in less efficient culling (Côté et al., 2014). Controlling *C. taxifolia* requires repeated removal to be effective and usually results in fragmentation, which can cause the algae to spread (New South Wales Department of Industry, 2009). In the case of the *C. maenas*, trapping has proven to be non-selective, resulting in bycatch (Bergshoeff et al., 2019; Poirier et al., 2020). In addition, trapping of *C. maenas* may not be effective in the long term unless done on a more frequent timeline than annually

(Duncombe & Therriault, 2017). For fouling species, aggressive removal may cause fragmentation and spread of the species (Paetzold & Davidson, 2010). Despite these downfalls, removal is still an important method for controlling many marine NIS and in some cases is considered the best (or only) option along with consistent monitoring (Park, 2004). Removal effectiveness can be assessed periodically as a part of monitoring programs to determine if the non-indigenous population is controlled (Park, 2004).

2.2.3 Citizen science initiatives

For some designated MPAs, a formalized monitoring and control program for marine NIS may not be feasible due to limited resources (e.g., funding, staffing) or if MPA accessibility is limited (*e.g.* in offshore or remote areas). In the former case, citizen science projects and support can reduce costs and staffing (Mannino & Balistreri, 2018). Citizen science refers to a collaborative data collection and analysis process between the general public and scientists (Larson et al., 2020). Interested members of the public can be trained to recognize marine NIS, report sightings, assess abundance and help to remove invaders (Grason et al., 2018; Hulme, 2006; Malpica-Cruz et al., 2016; Mannino & Balistreri, 2018; Otero et al., 2013). In doing so, early detection and tracking the spread of NIS can be enhanced (Azzurro, Broglio, Maynou, & Bariche, 2013). Citizen scientist monitoring can also increase the spatial (conducted at more sites) and temporal (conducted more often) coverage of an MPA. Data collected by citizen scientists have been used to construct distribution maps for multiple marine NIS, including various algae, crabs, fish, molluscs, and tunicates (Carballo-Cárdenas & Tobi, 2016; Grason et al., 2018).

Citizen science projects can be applied to MPAs and can take many forms. For instance, citizens can be involved with detection and mitigation programs for an MPA through diving and snorkeling projects (López-Gómez, Aguilar-Perera, & Perera-Chan, 2014; Otero et al., 2013), coastline surveys (Otero et al., 2013), or BioBlitz events (where citizen scientists assist with surveying a region to document native and/or NIS) (Cohen, Mccann, Davis, Shaw, & Ruiz, 2011). An emerging technology for citizen science is the development of smartphone applications, which can increase public participation and organize data collection (Adriaens et al., 2015). In the Mediterranean, an application called “MedMIS” was developed for the public to report marine NIS observed in Mediterranean MPAs (Adriaens et al., 2015). Other

applications can be utilized to report potential marine invaders, such as iNaturalist, which is used to map the location of species in an area (Larson et al., 2020).

One successful implementation of citizen scientists within an MPA occurred in the Egadi Islands MPA (Italy) where interested citizens were recruited to collect data about the invasive alga *Caulerpa cylindracea* (Mannino & Balistreri, 2018). During the course of the project, citizens took photos of *C. cylindracea* and recorded the coordinates, depth, and amount of substrate covered by the alga (Mannino & Balistreri, 2018). All collected data was verified by scientists involved with the project before being entered into a database that supported further analyses and study (Mannino & Balistreri, 2018). This study highlights the value of citizen science in MPAs as a detection and monitoring strategy for marine NIS.

2.3 Strategies for All Three Stages

2.3.1 Risk Assessment

Risk assessment is a common practice that can be considered during prevention, early detection and eradication, and mitigation phases for already established and yet-to-establish marine NIS. Risk assessments can be used to estimate the likelihood of a species invasion (*i.e.*, introduction and establishment) and impacts in an area. A risk assessment for a marine NIS can be done at any point, including before and after MPA designation (see Macleod and colleagues (2016)). It can be particularly beneficial to perform risk assessments during the MPA planning stage to determine if the AOI is likely to be invaded and impacted by recognized high-risk (*i.e.* priority) marine NIS (Giakoumi et al., 2016). When funding and resources are limited, high-risk species likely to invade and impact an ecosystem should be prioritized (Byers et al., 2002; Macleod et al., 2016; Molnar et al., 2008).

In Canada, risk assessment tools have been created to assess marine non-indigenous invertebrates in marine ecoregions, including the Canadian Marine Invasive Screening Tool (CMIST) (Drolet et al., 2016). While CMIST was developed initially for marine invertebrates, it has since been adapted and applied to other taxa such as freshwater and marine fish species (DFO, 2017). This tool assesses the risk of marine NIS, including the likelihood of invasion and impact of invasion as well as the level of uncertainty in these estimates (Drolet et al., 2016). When designing CMIST, the aim was to create a quick evaluation method for a species, where databases and peer-reviewed literature could be used to evaluate a species in approximately one or two days (DFO, 2015) compared to a detailed level risk assessment process, which can take many months or even years to complete (Lodge et al., 2016). This makes CMIST a good starting

tool, specifically designed for assessing risk associated with specific marine NIS. As such, it represents a viable decision-support tool for MPA practitioners to quickly determine high-risk NIS of concern to be assessed in MPA planning.

Other rapid assessment tools, including the Aquatic Species Invasiveness Screening Kit (AS-ISK), have been used to screen NIS for potential risk in an environment (Copp et al., 2016). The AS-ISK complies with the requirements for use with the European Union's Regulation on Invasive Alien Species but can be used internationally (Copp et al., 2016). After completing a rapid assessment using a decision-support tool like CMIST or AS-ISK, any NIS predicted to become invasive should undergo a comprehensive, detailed level risk assessment (Copp et al., 2016). Therefore, these screening tools can indicate which NIS to prioritize during planning and after designation.

2.3.2 Suitable Habitat Modelling

Another useful way to assess the potential risk of marine NIS in an AOI is the use of predictive models. Suitable habitat modelling can forecast the possible range, limit, and expansion of a marine NIS in the marine environment (Campbell, Keith, Hewitt, Dawson, & Collins, 2015). For example, suitable habitat models have been used to predict where NIS can likely establish or spread based on environmental factors (Riul et al., 2013; Robinson, Nelson, Costello, Sutherland, & Lundquist, 2017). Additionally, these models can predict how the invasion potential of an NIS will be altered by climate change (Iacarella et al., 2020b; Lowen & DiBacco, 2017; Lyons et al., 2020; Robinson et al., 2017), or environmental variability (*e.g.* El Niño–Southern Oscillation events (Campbell et al., 2015)). Species distribution modelling was used to quantify suitable habitat for the non-indigenous orange cup coral (*Tubastraea coccinea*) along the coast of Brazil, where the species is considered invasive (Riul et al., 2013). It was determined that the majority of the littoral zone on Atlantic southwestern coast was suitable for the invader, including most of Brazil's MPAs (Riul et al., 2013). In British Columbia, invasion risk for eight NIS was estimated for 83 MPAs using future climate predictions and vessel routes (Iacarella et al., 2020b). In both examples, the information from suitable habitat modelling can be used by MPA practitioners to focus management and monitoring strategies towards high-risk NIS.

In the above studies, modelling was conducted in regions that included MPAs, but the same approach would be beneficial in assessing an AOI. These studies show the value of

mapping habitat suitability as proxy for predicting and mapping the potential spread of newly established or yet-to-establish NIS. Modelling present day and future distributions of marine NIS can benefit MPA practitioners during MPA planning, management, and monitoring by providing a better understanding of how an NIS may spread within an AOI or MPA. Subsequently, this information can be used to help assess the potential risk of invasion and impact during marine spatial planning exercises, including the development of management strategies focused on prevention, early detection & eradication, and mitigation (Byers et al., 2002; Ojaveer et al., 2015; Riul et al., 2013).

2.3.3 Awareness and Outreach

Increasing public awareness and outreach efforts on marine NIS and their impacts can improve their management within an MPA (Giakoumi et al., 2019a; Mannino & Balistreri, 2018; Otero et al., 2013). After an MPA is designated, marine NIS can be incorporated into the management plan by including awareness and outreach strategies, both for staff and for visitors in the MPA. The Invasive Species Specialist Group of the International Union for Conservation of Nature (IUCN) recommend that MPA field staff should be trained on how to detect and report any "unusual/probably new" species while monitoring staff and managers should seek advice from invasion specialists when needed (De Poorter et al., 2007). Awareness among MPA visitors can be increased by providing educational material about NIS and how to prevent introductions and limit their spread, as well as brochures with a 'watch list' of high-risk NIS for the MPA and their known impacts (De Poorter et al., 2007; Mannino & Balistreri, 2018; Otero et al., 2013). For instance, the "Clean Drain Dry" awareness campaign in Canada informs boaters on how to care for their boat to minimize the risk of inadvertently spreading aquatic NIS (Tamburello et al., 2017). This campaign focuses on freshwater invaders, but a marine equivalent could be implemented (Tamburello et al., 2017) and tailored to an MPA (Iacarella et al., 2020a). Lastly, awareness and knowledge of marine NIS can also increase when concerned citizens are involved with monitoring or mitigation efforts, as they may directly witness negative impacts to habitats (Adriaens et al., 2015; Mannino & Balistreri, 2018).

2.3.4 Integrate NIS into MPA management plans

A final best practice to consider after MPA designation is to incorporate a marine NIS strategy within the MPA's management plan. A management plan describes the management strategies and tasks that will be carried out to achieve the long-term conservation objectives of the MPA (Pomeroy et al., 2004). A comprehensive management plan is usually created after an

MPA is in operation and outlines the long term plan for the MPA (Pomeroy et al., 2004). For example, managers of the Mediterranean MPA network (MedPAN) advocate that an MPA management plan should include prevention, early detection and eradication, and mitigation strategies for relevant NIS (Otero et al., 2013). All of the above mentioned best practices can be included in management plans to ensure effective treatment of NIS.

Chapter 3. Methods

3.1 Scope

All of Canada's federal MPAs were considered for this study. This includes MPAs created under the *National Marine Conservation Areas Act* and the *Oceans Act*, as well as marine portions of Migratory Bird Sanctuaries, National Historic Sites, National Parks, and National Wildlife Areas (DFO, 2005). As of July 17, 2020, 92 federal MPAs were identified: three NMCAs, 14 *Oceans Act* MPAs, 49 MBS with marine portions, one National Historic Site with a marine portion, 13 National Parks with marine portions, and 12 NWAs with marine portions (Appendix A). Additionally, this study focused on marine NIS, but freshwater and terrestrial species were included in data collection when reviewing the MPA management plans (section 3.2.1), as some strategies for managing NIS are applicable in all three biomes.

3.2 Study Design

Two approaches were utilized to evaluate the management of marine NIS in MPAs: (1) all available management plans for Canada's federal MPAs were reviewed, and (2) structured interviews were conducted with MPA and AIS practitioners. Recommendations for how to better address marine NIS in Canada's MPAs were then developed by comparing global best practices (Chapter 2) to the findings of Canada's current approaches.

3.2.1 Review of Management Plans

All available MPA management plans were reviewed to collect information on the objectives of Canada's federal MPAs and to determine if and how marine NIS were included in management or monitoring strategies for the MPA. The location, approximate contribution to Canada's marine conservation target, year of MPA designation, year management plan was published, and conserved biomes included in the MPA were noted. Next, each plan was searched for NIS keywords including 'alien', 'exotic', 'introduced', 'non-indigenous', 'non-native' 'invasion', and 'invasive'. Any specific NIS referred to in a plan were recorded. Finally, details of any management or monitoring protocols for NIS were documented and each protocol was categorized as a prevention, early detection and eradication, or mitigation strategy.

3.2.2 Structured Interviews

Structured interviews were conducted to elicit information on if and how marine NIS are considered in general and for individual MPAs during planning, management, and monitoring activities. All interview participants worked for one of the Canadian federal departments in

charge of managing MPAs and were required to have at least one year of experience related to MPA planning, management, or monitoring in Canada's federal MPAs (hereafter 'MPA practitioner') or to invasion ecology in Canada ('AIS practitioner') in the last fifteen years. Interview questions focused on participants' familiarity and perspectives of marine NIS in Canadian ecosystems and in Canada's federal MPAs. Before participants were interviewed, they were required to sign a consent form that explained the objectives of the study, how their information would be protected, and that all participants would be de-identified (Appendix B). The consent form also included a section where participants could choose whether or not to consent to be recorded, quoted, and if their answers could be linked to the Canadian ocean region they work in. Interviews were conducted from July 27th to September 18th, 2020. The participants were given the interview questions one business day in advance of their interview date. Participants were free to leave the study at any point up to or during their interview and were given a deadline of August 31st, 2020 or two weeks after their interview was completed (whichever was longer) to withdraw from the study; no participants chose to do so. Structured interviews were conducted following ethics approval from the Marine Affairs Program Ethics Standing Review Committee (MAP2020-04).

Participants were grouped into one of four categories based on their occupation and associated roles: MPA planning, MPA management, MPA monitoring, or AIS practitioner (includes management, monitoring, research, and risk assessment roles). The category a participant was placed in determined which interview questions they were asked (see Appendix C for a full list of questions asked to each group). Many questions were common to each group, but some were specific to one or more groups. Most questions were close-ended, such as multiple choice, ranked response, or check-all-that-apply, and often followed by an open-ended question (*e.g.* "If yes, which species and why?"). In addition, there were a few open-ended questions to allow participants to give their opinions on Canada's current strategies for managing marine invasions and to comment on how processes could be improved.

Results from the structured interviews were analyzed in multiple ways. For close-ended questions, responses were visually depicted using graphs and pie charts. Visual representations allowed patterns to be discerned and compared between groups. Fisher's exact tests were performed using R (R Core Team, 2017) for all applicable questions to determine any differences in answers between groups (*e.g.* between MPA and AIS practitioners); only

significant results were reported ($p < 0.05$). For open-ended questions, thematic analysis was done using NVivo 12 (QSR International Pty Ltd., 2018) to determine common themes brought forth by participants. Thematic analysis follows a six step framework for identifying patterns and generating themes from the interview responses: familiarize yourself with the data, create initial codes based on interesting observations, look for themes within the initial codes, review the themes in the context of the data set, name and define the themes, and create the report (Braun & Clarke, 2006). Any common themes among participant responses for a particular question were explained in the results (section 4.2). Further, overarching themes that emerged from participants across questions in the interviews were explored in the discussion (Chapter 5).

Chapter 4. Results

4.1 Management Plans

Of the 92 federally designated MPAs in Canada, thirty-four had management plans available online, for a total of thirty plans (one plan covered five MPAs) (see Appendix D for a summary of the plans and Appendix E for the reference list). National parks had the most available plans, followed by *Oceans Act* MPAs, and NWAs (Figure 1). Twenty-eight of the thirty plans were published in 2010 or later (93.3%). Most of these MPAs include freshwater (83.3%) and terrestrial (70.0%) components, thus these plans do not focus solely on marine conservation.

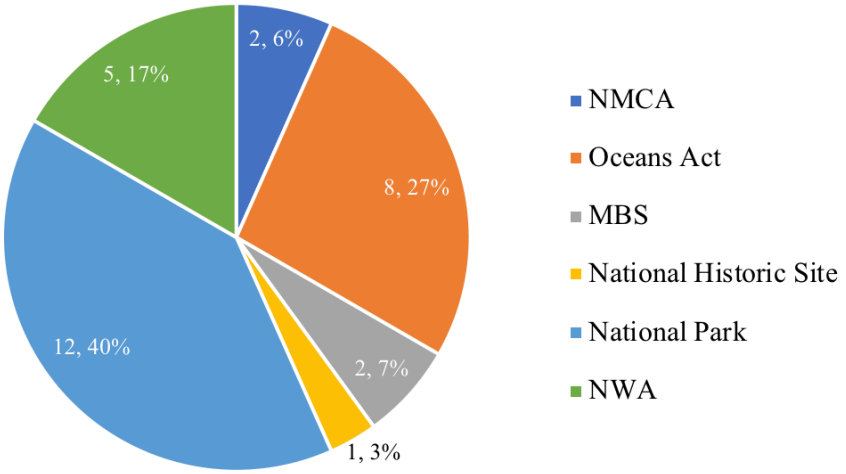

Figure 3. The number and proportion of available management plans for each type of Canada's federal MPA. In total, there was 30 management plans. NMCA= National Marine Conservation Area, MBS= Migratory Bird Sanctuary, NWA= National Wildlife Area.

In total, fifteen management plans (50.0%) mentioned NIS. Nine plans (30.0%) mentioned marine NIS without referring to specific species. In comparison, eight management plans (26.7%) mentioned a total of sixteen specific NIS, but the European green crab (*C. maenas*) was the only marine species identified. The European green crab was included in the management plans of the Basin Head MPA (Prince Edward Island), Kejimkujik National Park (Nova Scotia), and Wallace Bay NWA (Nova Scotia). Management plans for Cape Jourimain NWA (New Brunswick) and John Lusby Marsh NWA (Nova Scotia) mentioned *Phragmites* spp., which is not strictly marine, but found in tidal wetlands throughout North America (Chambers, Meyerson, & Saltonstall, 1999). Other NIS mentioned include seven terrestrial plants, two freshwater fish, four terrestrial mammals, and one terrestrial insect.

Fourteen plans (46.7%) included general management strategies for NIS within MPAs. These strategies have been classified as (i) prevention, (ii) early detection and eradication, and (iii) mitigation (Figure 2). There was a total of twelve strategies for prevention, fifteen for early detection & eradication, and thirteen mitigation strategies across taxonomic groups (Table 1). Only fifteen of the thirty-two strategies (46.9%) were specifically aimed at managing marine NIS. Of the nine plans that mentioned marine NIS in general (Appendix D), six included strategies for NIS prevention, early detection and eradication, or mitigation. The remaining three (John Lusby Marsh NWA (Nova Scotia), Saguenay-St. Lawrence NMCA (Quebec), and Sand Pond NWA (Nova Scotia)) simply mentioned the potential threat of marine invaders or listed that none were present at the time the plan was published. All three plans that mentioned the European green crab included strategies for NIS, though the strategies listed for the Wallace Bay NWA (Nova Scotia) were not specific to NIS.

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Table 1. Summary of management and monitoring strategies for non-indigenous species in Canada's federally designated MPAs.

MPA Name	Management/Monitoring Proposals for Non-Indigenous Species	Type(s) of Strategies
Basin Head MPA	- Reduce aquatic invasive species spread in Basin Head ecosystem with public awareness and stewardship initiatives	**Mitigation**
	- Continue the annual Community Aquatic Monitoring Program (monitor trends in abundance and diversity of fish and benthic invertebrates in the Basin Head lagoon)*	**Early detection & eradication**
Boot Island NWA	- Current monitoring is "sufficient" to detect presence of non-indigenous plants	**Early detection & eradication**
Cape Jourimain NWA	- Control or eradicate (species dependent) new invasive and non-indigenous plants within two years of detection	**Early detection & eradication**
	- Monitoring of existing nodes of invasive plants to determine possible expansion	**Mitigation**
	- Promote biological controls that have been deemed safe	**Mitigation**
Endeavour Hydrothermal Vents MPA	These apply to "exotic microbes" that may be introduced:	
	- Report amount of debris left after research cruise or experiment, remove structures where safe/possible*	**Prevention**
	- Discourage dumping of non-biodegradable material*	**Prevention**
	- When possible, release ballast weights off-axis	**Prevention**
	- Consider sterilizing submersible ballast tanks before dives	**Prevention**
Forillon National Park	- Monitor the aquatic region focusing on the brook trout, non-indigenous fish species, the community structure of benthic invertebrates, water temperature and quality, and the beaver situation	**Early detection & eradication**
Gulf Islands National Park Reserve	- Restore ecosystems on the islands, focus on reducing fallow deer population	**Mitigation**
	-Improve ecological integrity through prescribed burning*	**Mitigation**
Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site	- By 2019, create an invasive species biosecurity plan (prevention, detection, and adaptive response measures)	**Prevention, early detection & eradication, mitigation**
	- No new invasive species in offshore islands, eradication sites, and other important identified areas	**Prevention, early detection & eradication**
	- Eradicate invasive rats to help increase seabird abundance	**Early detection & eradication**

Kejimkujik National Park and National Historic Site	- Active management and removal of European green crab, purple loosestrife, and glossy buckthorn to control their spread -Restore damaged eelgrass beds and young-age classes of soft-shell clams -Monitor for presence of non-indigenous insects and diseases	**Mitigation** **Mitigation** **Early detection & eradication**
Kouchibouguac National Park	- Implement Invasive Plant Index (IPI) monitoring program in forest ecosystem - Detect and quickly respond to new non-indigenous plants that pose a threat to the forest ecosystem - Use freshwater and coastal monitoring protocols to monitor AIS - Build awareness of commercial fishing best practices, including an emphasis on AIS (work collaboratively with fishers, DFO, and Harbour Authorities) - Contain or eradicate invasive species that threaten terrestrial or aquatic ecosystems	**Early detection & eradication** **Early detection & eradication** **Early detection & eradication and mitigation** **Prevention** **Early detection & eradication and mitigation**
Pacific Rim National Park Reserve	- Plan to remove and hopefully eradicate invasive plants	**Early detection & eradication and mitigation**
Queen Maud Gulf (Ahiak) MBS	- Biological invasions predicted to increase with climate change, monitoring should occur	**Early detection & eradication**
Quttinirpaaq National Park	- Manage park use so that sensitive species are not disturbed and ban domestic animals* - Close sport fishing until it is determined that the park can sustain this*	**Prevention** **Prevention**
Sgaan Kinghlas-Bowie Seamount MPA	- Manage fishing gear according to best practices to prevent the introduction and spread of AIS - Exchange ballast water ≥ 50nm from seamount pinnacle to avoid the introduction of invasive species - Manage research and monitoring equipment according to best practices to prevent the introduction and spread of AIS	**Prevention and mitigation** **Prevention** **Prevention and mitigation**
Wallace Bay NWA	- Monitor macro habitat changes using annual aerial photos, support this with annual ground inspections and botanical surveys every five years*	**Early detection & eradication**

** Strategy is not specific to non-indigenous species*

4.2 Structured Interviews

Twenty-nine MPA and AIS practitioners were interviewed to understand if and how marine NIS are considered in MPAs during planning, management, and monitoring. Participants worked in British Columbia, Quebec, Ottawa, New Brunswick, Prince Edward Island, Nova Scotia, and Newfoundland and Labrador; no participants from the Arctic region were available. Eighteen participants were MPA practitioners, including five MPA planners, seven MPA managers, and six responsible for MPA monitoring. Eleven participants were categorized as AIS practitioners and self-identified a role in AIS management (n = 4), monitoring (n = 6), research (n = 9), or risk assessment (n = 4; more than one could be selected). The interviews investigated four general themes: marine NIS knowledge (section 4.2.1), involvement of marine NIS in MPA planning (section 4.2.2), marine NIS management in MPAs (section 4.2.3), and marine NIS consideration in MPA planning, management, and monitoring (section 4.2.4).

4.2.1 Marine NIS Knowledge

When asked to rank ***how serious an issue are marine NIS in Canadian ecosystems***, all participants ranked NIS between a "somewhat serious" and "very serious" issue (Figure 4a). The majority of MPA practitioners (88.8%) felt that marine NIS represented a moderate (44.4%) or very serious (44.4%) threat, while AIS practitioners ranked the threat as either moderate (54.5%) or very serious (45.5%). No participants believed that the threat of marine NIS was "not serious" or were unsure. One of two MPA practitioners who ranked marine NIS in Canadian waters as "somewhat serious" explained that they believed it was important, but that there were more pressing issues. Participants who chose "moderately serious" and "very serious" generally conveyed their understanding that marine NIS can greatly damage ecosystems, with three participants basing their answers on past experiences or knowledge on marine NIS invasions. Finally, there is one notable reason why some participants said marine NIS were a "moderately serious" issue rather than a "very serious" one. Four participants mentioned that the seriousness was variable in Canadian waters and it depends on the area considered, as the risk could be very serious for one area but not for another.

When ranking the ***seriousness of marine NIS in Canada's MPAs***, MPA practitioners selected "somewhat serious" to "very serious", with the majority (66.6%) saying the threat was moderately (44.4%) or very serious (22.2%) (Figure 4b). AIS practitioners' responses ranged from "not serious" to "very serious", with the most common response being marine NIS are a moderate threat (36.4%). For the two AIS practitioners who chose "not serious", their responses

related only to the MPAs for which they were familiar within their regions (Quebec and Newfoundland and Labrador). For the participants who chose "somewhat serious", the responses fit into two key explanations: marine NIS are not a problem in MPAs they are familiar with or NIS impacts in coastal MPAs are more of a concern than in offshore and remote ones. For those who chose "moderately serious" and "very serious", the explanations fit mainly into the concept that MPAs protect important areas and marine NIS can threaten that level of protection. Much like when asked about marine NIS in Canadian waters, some participants chose "moderately serious" instead of "very serious" because they said that the seriousness was variable and in some MPAs marine NIS may pose more of a risk. Lastly, those who said "not sure" said so because they were only familiar with certain MPAs and regions or they did not know enough about marine NIS in Canada's MPAs.

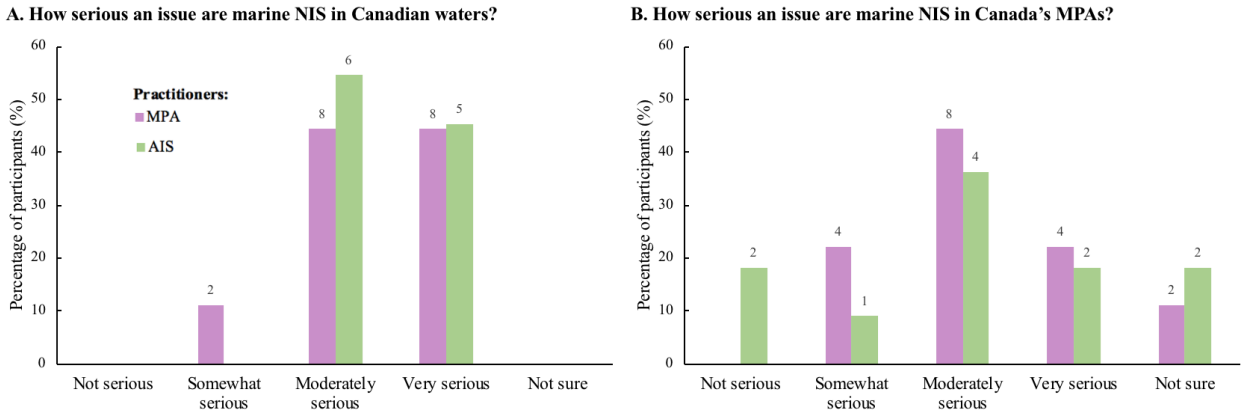

Figure 4. Expert opinion of the seriousness of marine NIS **A)** in *Canadian ecosystems* and **B)** in *Canada's MPAs* according to MPA and AIS practitioners (n = 29). The practitioners were asked this question on a scale of 1 to 4, where 1 = "Not serious", 2 = "Somewhat serious", 3 = "Moderately serious", and 4 = "Very serious". Numbers above each bar represent the number of respondents that chose that ranking.

When asked how ***familiar they were with ongoing management, monitoring, or mitigation efforts for marine NIS in Canada***, most MPA practitioners (83.3%) said they were somewhat (33.3%) or moderately (50%) familiar (on a scale from "not familiar" to "very familiar") (Figure 5a). In contrast, most AIS practitioners were moderately (72.7%) or very (27.3%) familiar. No AIS practitioners chose "not familiar" or "somewhat familiar".

In the final ranking question, participants were asked ***how familiar they were with ongoing management, monitoring, or mitigation efforts for marine NIS in Canada's MPAs*** (Figure 5b). The majority of MPA and AIS practitioners were somewhat familiar (MPA = 50%;

AIS = 36.4%) or moderately familiar (MPA = 33.3%; AIS = 36.4%). Some of these MPA and AIS practitioners explained that they were only familiar with *Oceans Act* MPAs and did not know what efforts were occurring in other types of Canada's federal MPAs. Others noted having knowledge about only a few sites and in a particular regions only, but not across Canada.

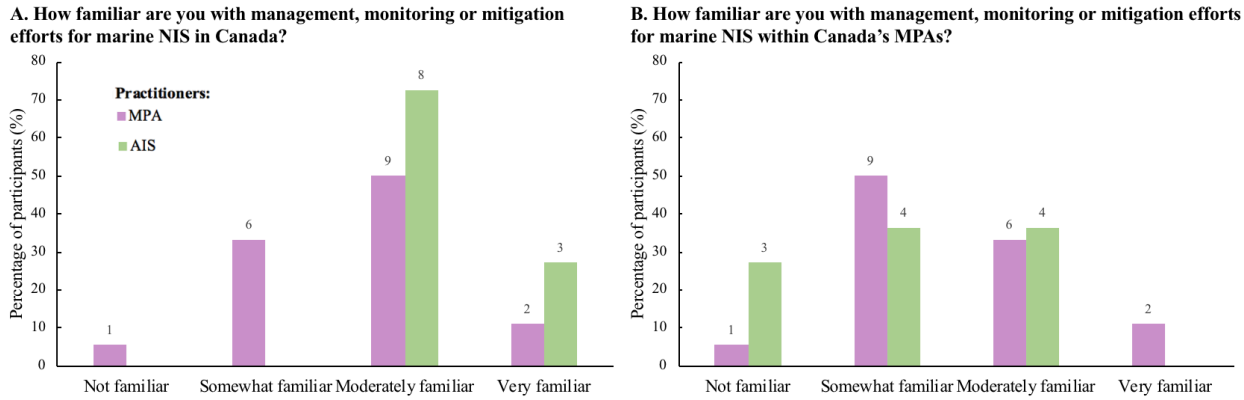

Figure 5. How familiar MPA and AIS practitioners are with management, monitoring or mitigation efforts for marine NIS **A)** in *Canada* and **B)** within *Canada's MPAs* (n = 29). The practitioners were asked this question on a scale of 1 to 4, where 1 = "Not familiar", 2 = "Somewhat familiar", 3 = "Moderately familiar", and 4 = "Very familiar". Numbers above each bar represent the number of respondents that chose that ranking.

When asked if there were any ***NIS of particular concern in Canadian ecosystems***, the majority of MPA practitioners (88.9%) and AIS practitioners (90.9%) said "yes" (Figure 6a). Three participants who said there were no NIS of particular concern to them explained this was specifically for their area of focus. All participants who confirmed there were NIS of particular concern mentioned the European green crab (*C. maenas*) (Figure 6b). The European green crab was said to have a destructive impact on habitats and an ability to outcompete native species. The second most common taxa was tunicates (69.2%), which were identified to smother native sessile species and have impacts on shellfish and finfish aquaculture by attaching to equipment. The third most common response was the Asian shore crab (*Hemigrapsus sanguineus*) (11.5%), which has just recently been found in the southwestern portion of Nova Scotia and can be highly aggressive, sometimes even outcompeting the European green crab, according to an AIS practitioner. The next most common response was the alga oyster thief (*C. fragile*) (7.7%) whose presence was said to be of concern in the Atlantic because of their impacts on kelp, combined with the already poor status of kelp in the Maritimes.

All other species or taxa were mentioned by one participant only. Similar to oyster thief, non-indigenous bryozoans were said to be of concern in the Atlantic because of their impacts on kelp. A non-indigenous cordgrass (*Spartina* sp.) was of concern to an MPA practitioner on the Pacific coast because it can disrupt habitats used as nursery grounds for many fish species and stopover sites by migratory birds. The striped bass (*Morone saxatilis*) concerned one MPA practitioner due to their range moving further north into Labrador. The AIS practitioner who mentioned the Rapa whelk (*Rapana venosa*) and the seaweed wakame (*Undaria pinnatifida*) referred to these as "pending species" that could be a future threat. In addition to the marine NIS mentioned, two MPA practitioners raised concerns regarding terrestrial non-indigenous mammals and their impacts on seabirds, such as minks and rats which were said to forage on the eggs of these birds and decimate colonies.

When asked if they were aware of any ***marine NIS species in Canada's MPAs***, over half of the MPA practitioners (61.5%) and AIS practitioners (63.6%) said "yes" (Figure 6c). There was a total of eleven marine NIS and taxa mentioned by participants (Figure 6d). Tunicates were the most frequently mentioned by nine participants (60.0%). The club tunicate (*Styela clava*), golden star tunicate (*Botryllus schlosseri*), vase tunicate (*Ciona intestinalis*), and violet tunicate (*Botrylloides violaceus*) have been observed in the Basin Head MPA (Prince Edward Island). One AIS practitioner explained that tunicates have been found growing on a unique strain of Irish moss (*Chondrus crispus*) in the Basin Head MPA and have the potential to reduce its productivity. According to an AIS practitioner, tunicates were also found within Gwaii Haanas NMCA (British Columbia). The next most mentioned species was the European green crab, mentioned eight times (53.3%). The crab was reported in the Basin Head MPA (Prince Edward Island), Kejimkujik National Park (Nova Scotia), Kouchibouguac National Park (New Brunswick), and Pacific Rim National Park Reserve (British Columbia). Cited impacts of the species included the destruction of eelgrass habitats and the indirect displacement of Irish moss as a consequence of their predation of mussels which the latter are needed to anchor the Irish moss in the Basin Head MPA. Four participants were aware of bryozoans (26.7%) in Gwaii Haanas NMCA (British Columbia) and the Eastport MPA (Labrador), but no impacts were identified. The striped bass was documented within the Gilbert Bay MPA (Labrador) by three participants (20.0%) and, according to an MPA practitioner, may eat golden cod (a genetically distinct population of *Gadus morhua*), capelin (*Mallotus villosus*), and Atlantic salmon (*Salmo*

salar) smolts. The varnish clam (*Nuttallia obscurata*) and Pacific oyster (*Crassostrea gigas*) (grouped as bivalves) were said to be present in the Pacific Rim National Park Reserve and were naturalized in the Pacific (*i.e.* established but not disruptive to ecosystems) by two participants (13.3%). All other species said to be present in MPAs were mentioned by one participant. Three marine NIS were listed for the SGaan Kinghlas-Bowie Seamount MPA (British Columbia): the bottlenose dolphin (*Tursiops* sp.), the great white shark (*Carcharodon carcharias*), and a colonial, free-floating tunicate (*Pyrosoma* sp.), but the participant claimed there were no documented impacts in the MPA. The oyster thief seaweed (*C. fragile*) was mentioned as a concern for MPAs, but locations and impacts were not given. The seaweed *Sargassum muticum* was noted to be growing on rocks and between eelgrass beds along the Pacific coast, including in MPAs, but the MPA practitioner who mentioned this was unsure if impacts of the seaweed were being studied. The eelgrass *Zostera japonica* was also noted to be in the Pacific Rim National Park Reserve, but with no known impacts.

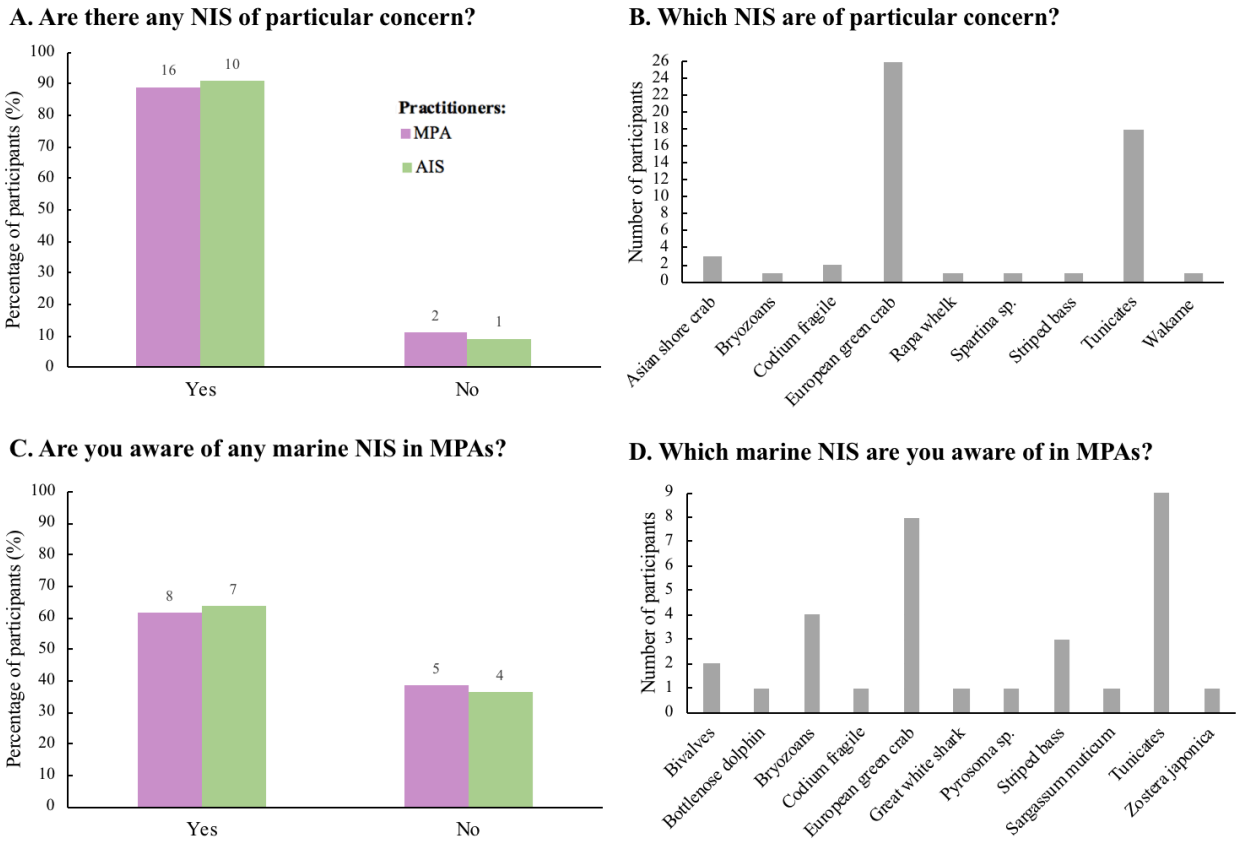

Figure 6. Marine NIS of particular concern and marine NIS that have been seen in Canada's MPAs, according to MPA and AIS practitioners. **A)** *Are there any marine NIS that MPA and AIS practitioners* (n = 29) *are particularly concerned about in Canadian waters?* **B)** *The list of marine NIS of concern* (n = 26). **C)** *Are MPA practitioners (involved with management or monitoring) and AIS practitioners* (n = 24) *aware of any marine NIS in Canada's MPAs?* **D)** *The list of marine NIS in MPAs provided by MPA and AIS practitioners* (n = 15). Numbers above bars represent the number of respondents that picked that response.

Next, MPA practitioners were asked if they were familiar with any MPAs that were ***particularly susceptible to invasion by marine NIS*** and to explain why or why not (Figure 7). Responses were categorized by the type of MPAs mentioned by participants—accessible or remote—based on the information given by practitioners during interviews. Accessible refers to MPAs publicly accessible or nearshore. Remote refers to MPAs that are far offshore, not frequently visited, or in areas not accessible to the public. The majority of MPA practitioners (66.7%) referenced accessible MPAs, and 100% said these MPAs were particularly susceptible to invasion (Figure 7a). Comparatively, most practitioners who mentioned remote MPAs (75.0%) said they were not particularly susceptible to invasion by marine NIS (Accessible vs. remote MPAs, Fisher's exact test, $p = 0.018$). Of those who said "yes" an MPA was particularly

susceptible, the most common reasons were “anthropogenic-mediated spread” (62.5%) and “suitable environmental conditions” (62.5%) (Figure 7b). For those who said “no” for remote MPAs, the most common response to why an MPA was not particularly susceptible was “low chance of anthropogenic-mediated spread” (100%) (Figure 7c). Examples of accessible MPAs included Eastport MPA (Labrador), Gilbert Bay MPA (Labrador), Gulf Islands National Park Reserve (British Columbia), Musquash Estuary MPA (New Brunswick), Pacific Rim National Park Reserve (British Columbia). Examples of remote MPAs included Endeavour Hydrothermal Vents MPA (British Columbia), Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs MPA (British Columbia), Scott Islands Marine NWA (British Columbia), SGaan Kinghlas-Bowie Seamount MPA (British Columbia), and MBS in general in Newfoundland.

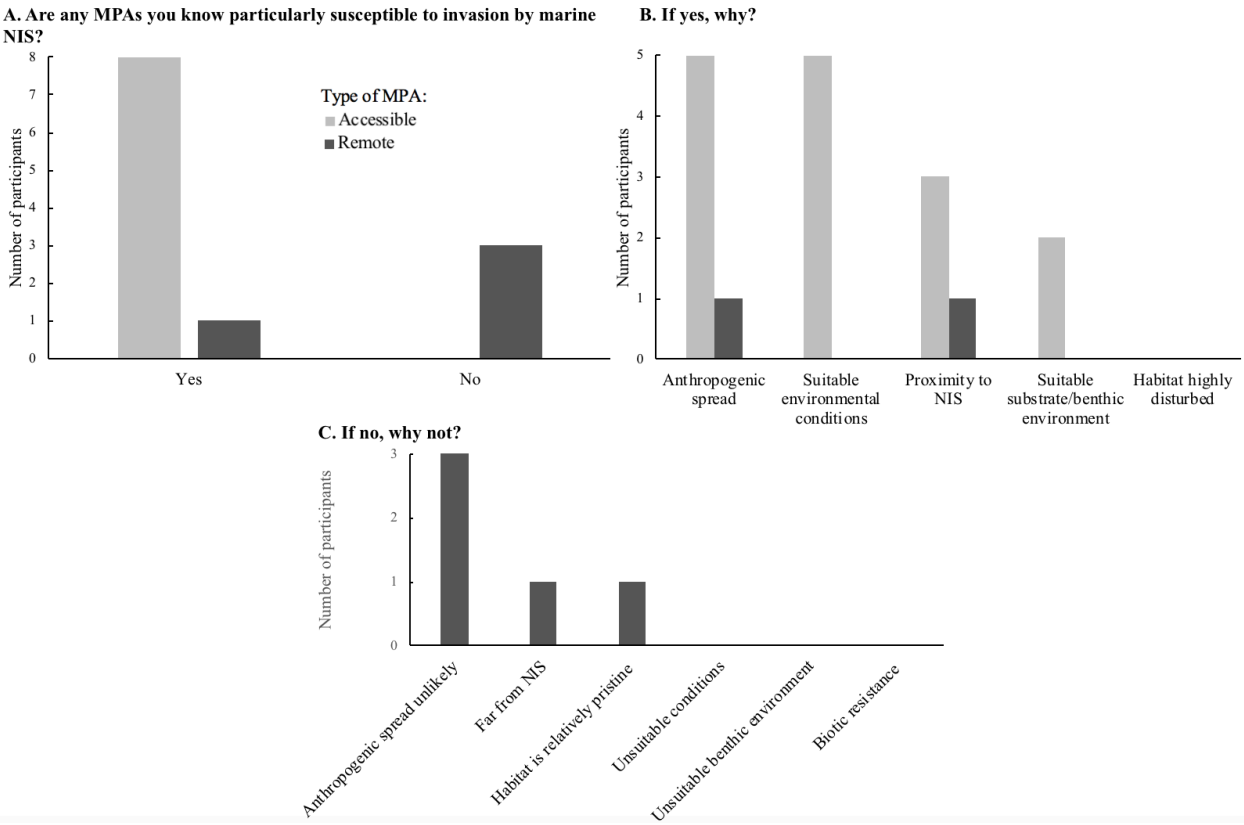

Figure 7. The susceptibility of Canada’s MPAs to invasion by marine NIS, according to MPA practitioners involved with MPA management or monitoring (n = 12) and their identification of whether an MPA was accessible or remote. Practitioners were asked **A)** *if they were aware of any MPAs particularly susceptible to invasion by marine NIS* and to **B)** *explain why* or **C)** *why not*. MPAs were identified as being accessible or remote in terms of nearshore or offshore location, respectively, and ease of access and public amenities, based on the recurring information given by 41.2% of practitioners during the interviews.

4.2.2 Incorporation of Marine NIS in MPA Planning

When MPA practitioners were asked to prioritize the ***three most important marine stressors with respect to MPA planning in their opinion***, they predominantly identified "climate change" (82.4%), "fishing" (64.7%), and "habitat alteration and loss" (64.7%) (Figure 8a). AIS practitioners identified "habitat alteration and loss" (81.8%) and "NIS" (54.5%) followed by a three-way tie between "climate change", "fishing", and "pollution" (45.5%). Six MPA and three AIS practitioners mentioned that the top stressors may change depending on the species and habitats that the MPA conservation objectives aim to conserve. However, all participants chose their top stressors without consideration of particular species or conservation objectives. Fishing was mentioned to be a top stressor because it can influence where an MPA is put due to its economic importance. Habitat alteration and loss was a top stressor because it can impact all species in a habitat and therefore which species can live there. Climate change and pollution were considered important because they can induce other problems (*e.g.* habitat alteration and loss). Lastly, those who chose NIS did not elaborate on their reasoning.

Then MPA planners and managers were asked ***which three marine stressors were considered most in practice when identifying or designating areas to protect*** (Figure 8b). The top three were "fishing" (100%), "aquaculture" (50.0%), and a tie between "habitat alteration and loss" and "vessel traffic" (40.0%). The main rationale was that fishing is often the most dominant stressor considered for economic and environmental reasons. One MPA practitioner spoke about the Eastern Shore AOI (Nova Scotia), where fishing is considered the backbone of the local economy. Another practitioner from British Columbia mentioned that MPAs are focused on benthic fish habitat conservation objectives, making fishing a key stressor in planning. A second critical theme was that stressors with readily accessible data are used more frequently. Two MPA practitioners mentioned that fishing data was readily accessible. Other stressors with accessible data included aquaculture (lease location and size), habitat alteration and loss, distribution and abundance of NIS, and vessel traffic, which were all named top three stressors except NIS (chosen by only 20.0%).

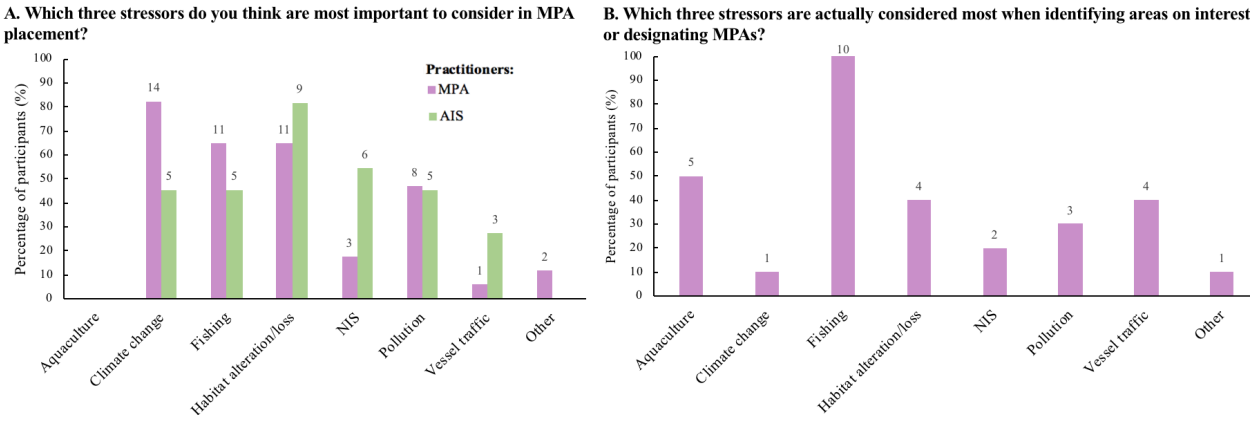

Figure 8. The most important stressors to consider during MPA planning **A)** *according to MPA (n =17, purple bars) and AIS practitioner (n = 11, green bars) opinions* and **B)** *based on which stressors are actually considered most during planning*, according to MPA planners and managers (n = 10). Numbers above each bar represent the number of respondents that picked that response.

When MPA planners and AIS practitioners were asked ***if marine NIS were adequately considered during MPA planning***, just over half of MPA planners said "yes" (60.0%) and a comparable amount of AIS practitioners said "don't know" (63.6%) (MPA vs. AIS practitioners, Fisher's exact test, $p = 0.038$) (Figure 9a). The seven AIS practitioners who responded "don't know" said they were not familiar enough with MPA planning to know whether NIS were adequately considered. For the three MPA planners that said marine NIS were adequately considered, all mentioned they are considered during the planning process, usually after some potential sites have been proposed. However, two MPA practitioners made the point that while adequate, this process is currently quite simple and could be improved. One suggested the process could be enhanced by engaging more with AIS practitioners at DFO. Finally, the one MPA planner and four AIS practitioners who said that NIS are not adequately considered in the MPA planning process identified that not enough of the available information was being used. An MPA planner suggested that one of the impediments to having NIS considered more explicitly was the lack of spatial information, including current ranges and distributions. Three AIS practitioners explained that more should be done during MPA planning for marine NIS. For example, while NIS are identified as threats, not enough analysis is done to quantify or help prioritize these threats. When ***AIS practitioners were asked if they had a role in MPA planning***, 18.2% said "yes" and 81.8% said "no" (Figure 9b). For the two practitioners who said "yes", both of their roles involved providing AIS advice during MPA planning.

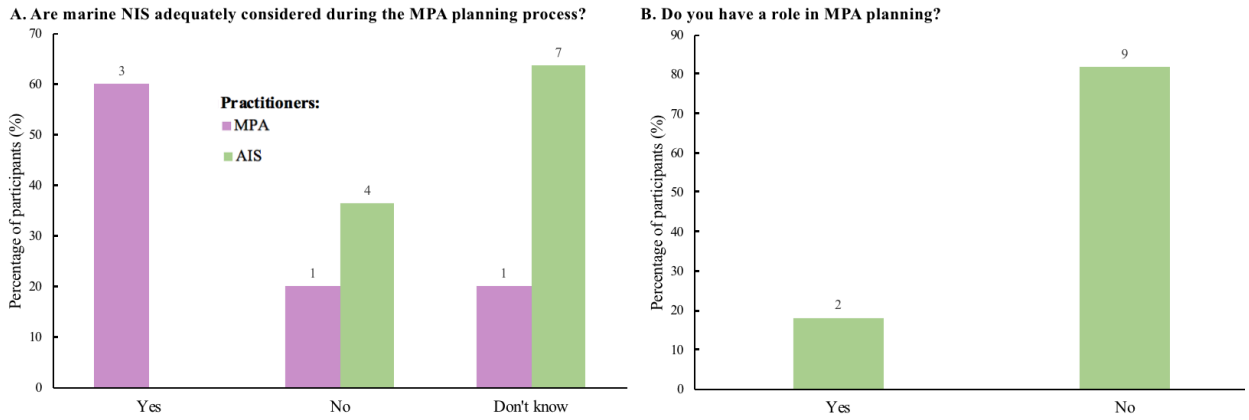

Figure 9. The relationship between Marine NIS and MPA Planning. **A)** *Do MPA planners and AIS practitioners think marine NIS are adequately considered during MPA planning processes?* (n = 16). **B)** *Do AIS practitioners have a role in MPA planning?* (n = 11). Numbers above each bar represent the number of respondents that picked that response

4.2.3 Management Strategies for Marine NIS in MPAs

To determine ***how MPA and AIS practitioners communicate***, all participants were asked to choose strategies that applied from a prescribed list (Figure 10). The most common strategy was "informal conversations" (85.2%), followed by "formal meetings" and "review of published reports on NIS" (both 63.0%), and "data sharing platforms" (59.3%). There were four participants who mentioned "other" strategies, which included doing collaborative risk assessments and NIS modeling, joint information sessions for students, and public awareness campaigns. Of the strategies mentioned by practitioners, 57.0% were types of direct communication and 43.0% were types of independent inquiry. In addition, one MPA practitioner said they did not communicate with AIS practitioners and one AIS practitioner said they were not familiar with any forms of communication, but said meetings would probably be useful.

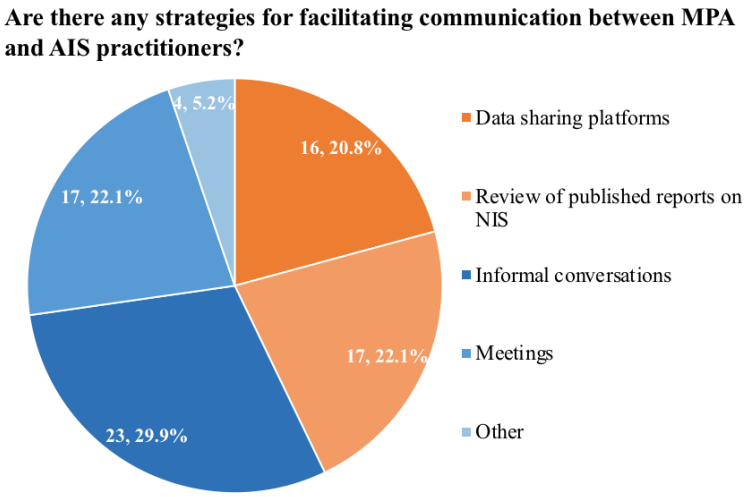

Figure 10. Strategies used to facilitate communication between MPA and AIS practitioners, according to MPA and AIS practitioners (n = 27). Here orange sections represent types of independent inquiry (where a practitioner must seek the information on their own) and blue sections represent types of direct communication (where both parties are involved).

When given a list of ***information and potential strategies for preventing introductions of marine NIS***, "risk assessment" was the most common response among MPA practitioners (75%), followed by "awareness and outreach" (66.7%) (Figure 11a). For AIS practitioners, "awareness and outreach" was the most common response (72.7 %), followed by "invasion history" (45.5%) and "risk assessment" (45.5%). For those who chose "awareness & outreach", a common explanation by both MPA and AIS practitioners was that this strategy is frequently used, but is not often specific to an MPA. One exception was the Basin Head MPA, which according to an MPA practitioner, has marine NIS educational materials and signage to inform visitors of NIS impacts and how to prevent introductions (*e.g* cleaning your boat before launching). A pattern was found among those who chose "risk assessment", where the risk assessments being done are not specific to an MPA, but a broader region. For the participants who chose "expert opinion", AIS practitioners from DFO and academic researchers were named as the experts. Two participants explained that "expert opinion" and "risk assessment" are related, as risk assessments often involve expert opinion and interpretation. Another said "expert opinion" is also utilized during MPA planning "to identify potential locations where [non-indigenous] species would be an issue" (MPA practitioner). One MPA practitioner mentioned that "invasion history" can be a part of a risk assessment and may be looked at during the MPA design stage. Of those who chose "other", four participants mentioned regulations in some form, such as activity plan regulations (where those who want to do work in an MPA must apply and

get approval), ballast water exchange zones, and studying previous publications on marine NIS in the Maritimes. An activity plan is something those who want to do work in an MPA, such as "scientific or research activities [must] apply for" (MPA practitioner).

The ***best two strategies for preventing marine NIS within MPAs*** according to AIS practitioners were "vector awareness and outreach" (90.9%) and "regulations" (54.5%) (Figure 12). One participant explained that education should be paired with regulations to be successful, and another said that "risk assessment" is also important but currently not specific enough to MPAs.

When given a list of ***information and potential strategies for detecting newly arrived marine NIS***, "monitoring" was the most common response by 92.3% of MPA practitioners and 81.8% of AIS practitioners; "risk assessment" and "suitable habitat modeling" were chosen by less than 25.0% of practitioners in both groups (Figure 11b). In addition, one MPA practitioner provided an option for "other": outreach to local fishers. All participants chose monitoring except the one MPA and two AIS practitioners that chose "don't know". One MPA and two AIS practitioners mentioned that while monitoring occurs in MPAs, it is often not NIS-focused and detection of an NIS would occur by chance. In contrast, MPA practitioners mentioned NIS-specific monitoring does occur in the Basin Head (Prince Edward Island), Gwaii Haanas (British Columbia), and Pacific Rim (British Columbia) MPAs. For those who chose "risk assessment" and "suitable habitat modeling", the recurring theme was that these strategies can complement the detection process, but monitoring is needed to actually detect a marine NIS. Finally, the MPA practitioner who mentioned outreach to local fishers explained that fishers in Labrador can make qualitative observations about marine NIS while fishing.

When given a list of ***information and potential strategies for mitigating established marine NIS***, "monitoring" was the top response among MPA practitioners (53.8%), followed by "control population density" (38.5%) and "don't know" (38.5%) (Figure 11c). For AIS practitioners, "control population density" was most common (54.5%), followed by "don't know" (45.5%). One MPA practitioner who chose "monitoring" and "no information is used", explained that if anything is done it is usually just monitoring. Population control followed by monitoring was said to be carried out for the European green crab in the Basin Head (Prince Edward Island), Kejimkujik (Nova Scotia), and Kouchibouguac (New Brunswick) MPAs and for tunicates along wharves in Quebec.

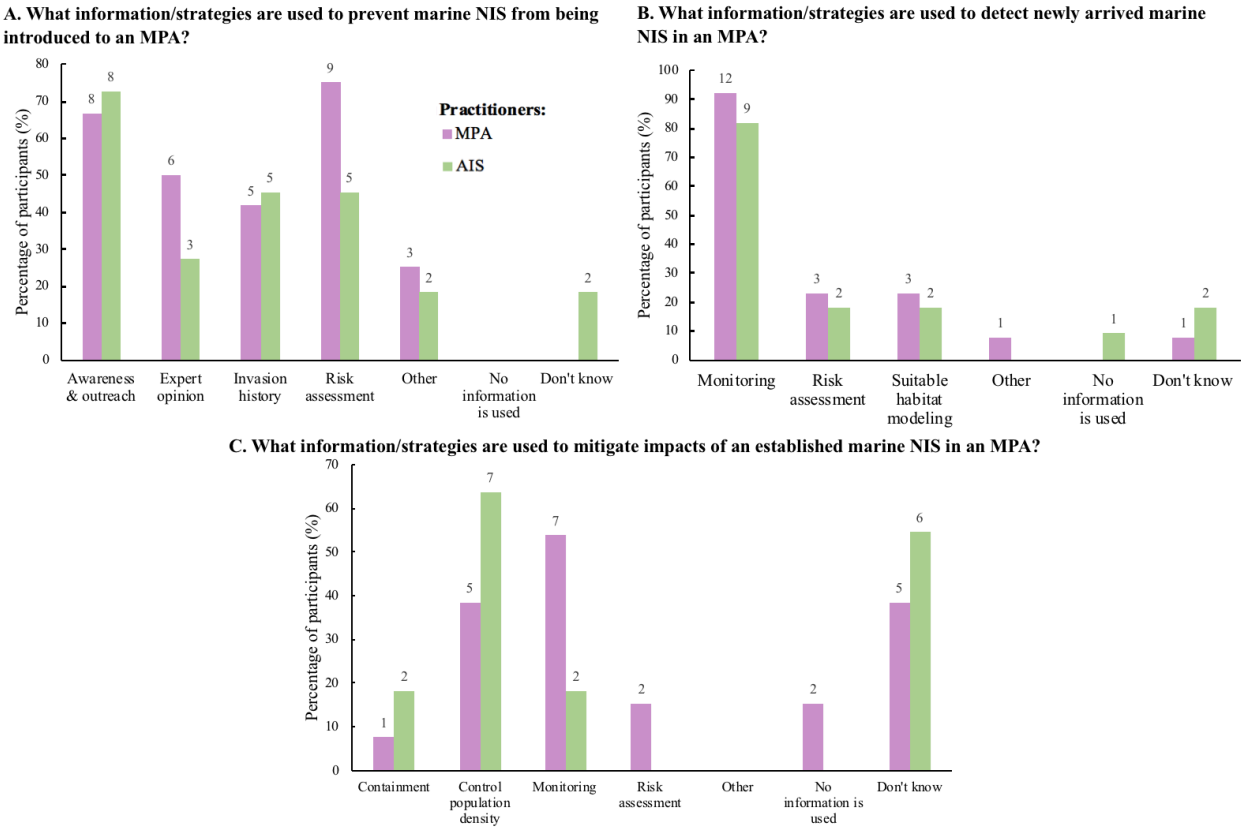

Figure 11. The information and strategies used to **A)** *prevent marine NIS introductions* (n = 23), **B)** *detect newly arrived marine NIS* (n = 24) and **C)** and *mitigate marine NIS* (n = 24) in an MPA, according to MPA and AIS practitioners. In (A), MPA practitioners included those involved with planning and management. In (B) and (C), MPA practitioners included those involved with management and monitoring. Numbers above each bar represent the number of respondents that picked that response.

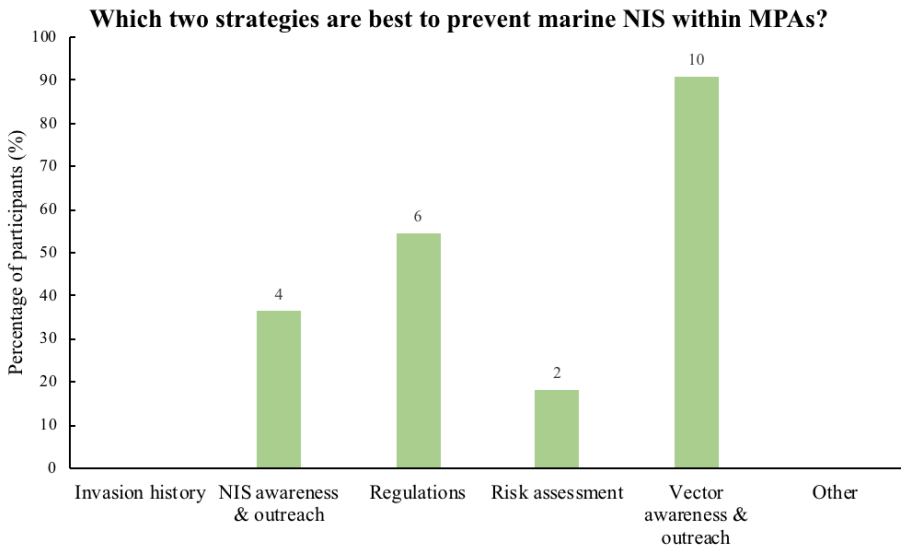

Figure 12. The best strategies to prevent marine NIS within MPAs, according to AIS practitioners (n = 11). Each practitioner was asked to pick two options. Numbers above each bar represent the number of respondents that picked that response.

When MPA practitioners were asked ***if they are familiar with any specific NIS monitoring in any MPAs***, all of those speaking for Atlantic MPAs said "yes", whereas 42.9% of those talking about Pacific MPAs said "yes" (Figure 13a). In the Atlantic category, specific MPAs mentioned to have NIS-specific monitoring were: Basin Head MPA (Prince Edward Island), Gilbert Bay MPA (Labrador), and Musquash Estuary MPA (New Brunswick). In the Pacific category, the Gulf Islands National Park Reserve (British Columbia) and Pacific Rim National Park Reserve (British Columbia) were mentioned. The Scott Islands NWA (British Columbia) and the offshore MPAs in general were mentioned to have no NIS-specific monitoring.

When asked which ***strategies were used to monitor NIS in MPAs,*** in the Atlantic, "settlement plates" were the most common strategy mentioned (100%), followed by "trapping surveys" (75.0%) (Figure 13b). In the Basin Head MPA (Prince Edward Island) trapping surveys were said to be done to monitor European green crab abundance and settlement plates to monitor presence/absence of tunicates. In the Gilbert Bay MPA (Labrador), genetic analysis, trapping surveys, and visual surveys were said to be done for the striped bass and settlement plates were listed as a strategy used in general to detect any sessile NIS, though this was not specific to the MPA. Finally, under "other", one practitioner explained that they communicate with members of the community to help with detection. In Musquash Estuary MPA, one practitioner mentioned

that there has been a NIS tunicate monitoring program for approximately eight years, using settlement plates. In the Pacific, the most common strategies mentioned were "trapping surveys" (100%) and "visual surveys" (100%), followed by "timed/random walk or transect surveys" (66.7%) and "settlement plates" (66.7%). In the Gulf Islands National Park Reserve (British Columbia), NIS-specific monitoring is done generally using visual surveys and settlement plates to detect presence/absence and walk and transect surveys to detect and measure abundance. According to one practitioner, eDNA monitoring and genetic analysis have been used to detect presence/absence. In the Pacific Rim National Park Reserve, transect surveys are used to monitor abundance and impact of bivalve species, trapping surveys are used to monitor European green crab abundance and impact, and visual surveys are used to monitor for NIS in general.

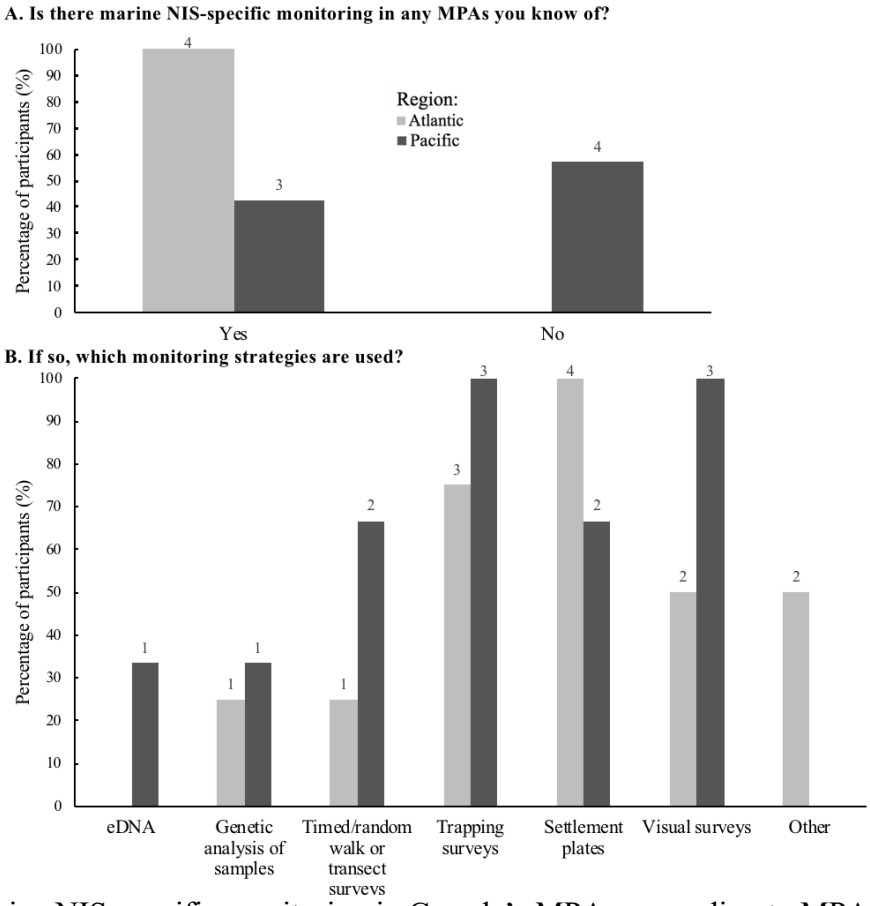

Figure 13. Marine NIS-specific monitoring in Canada's MPAs, according to MPA practitioners involved in management or monitoring (n = 10), where **A)** shows *how many participants knew about NIS-specific monitoring in MPAs* and **B)** shows *which monitoring strategies are used*. Participant responses were categorized as either Atlantic or Pacific, based on where the MPA(s) or regions mentioned were. Numbers above each bar represent the number of respondents that picked that response.

4.2.4 Marine NIS consideration in MPA planning, management, and monitoring

When asked ***if marine NIS should be given more consideration in MPA planning***, 40.0% of planners said "yes" and 60.0% said "it depends" (Figure 14a). In comparison, 80.0% of AIS practitioners said "yes" and 20.0% said "don't know" (MPA vs. AIS practitioners, Fisher's exact test, $p = 0.032$). Among those who said "yes", there were three common explanations. First, that marine NIS may compromise the conservation objectives of an MPA so it is important to consider potential impacts of marine NIS. The second explanation was that marine NIS should be given more consideration when choosing potential sites for MPAs and sites heavily impacted by NIS (or where NIS are likely to invade) should be avoided. The third common explanation was that more consideration is needed in the context of climate change. For the MPA planners who said "it depends", they mostly said it depends on the MPA, its conservation goals, and its susceptibility to marine NIS. For the AIS practitioners who said they didn't know if marine NIS should be considered more, their reasoning was because they were not familiar enough with the MPA planning process or how much consideration marine NIS are currently given.

When asked ***if marine NIS should be given more consideration during MPA management***, most MPA managers (71.4%) and AIS practitioners (70.0%) said "yes" (Figure 14b). For the participants who said "yes" the most mentioned reason was related to marine NIS hindering the achievement of MPA conservation goals. The second was that MPA managers need to prepare for any future threats. For instance, two practitioners said that while marine NIS may not have been present during MPA designation, species could arrive after and will need to be managed, therefore marine NIS consideration should be increased during MPA management. The one MPA manager who said "no" based their answer only on their experiences with the Gilbert Bay MPA (Labrador). They explained that in the MPA, they assess threats regularly and if new threats arise (including potential NIS), they are assessed. The one MPA manager who said "it depends" explained that more consideration should be given to MPAs where many anthropogenic activities occur, but for remote offshore MPAs the threat is fairly low. Finally, of the two AIS practitioners who said "don't know", one said they were not familiar enough with what MPA management involves and the other said in comparison to increasing consideration during planning and monitoring, it may be less of a priority.

Lastly, when asked ***if marine NIS should be given more consideration during MPA monitoring***, most MPA practitioners (83.3%) and AIS practitioners (90.0%) said "yes" (Figure

14c). For those who answered "yes", conservation objectives were referred to by most, with participants explaining that without monitoring for marine NIS, an MPA may not meet its conservation objectives to protect an important native species or habitat. Beyond this, two participants explained that consistent monitoring can provide early detection of marine NIS, which can lead to rapid response and a greater likelihood that the species can be controlled. The one MPA practitioner who said "it depends" explained that if marine NIS could put the conservation objectives of the MPA at risk, they should be part of the MPA's monitoring plan. Lastly, for the AIS practitioner who said "don't know", they were not sure what level of consideration was currently given during MPA monitoring but said that marine NIS should maybe be considered more if they could threaten the conservation objectives.

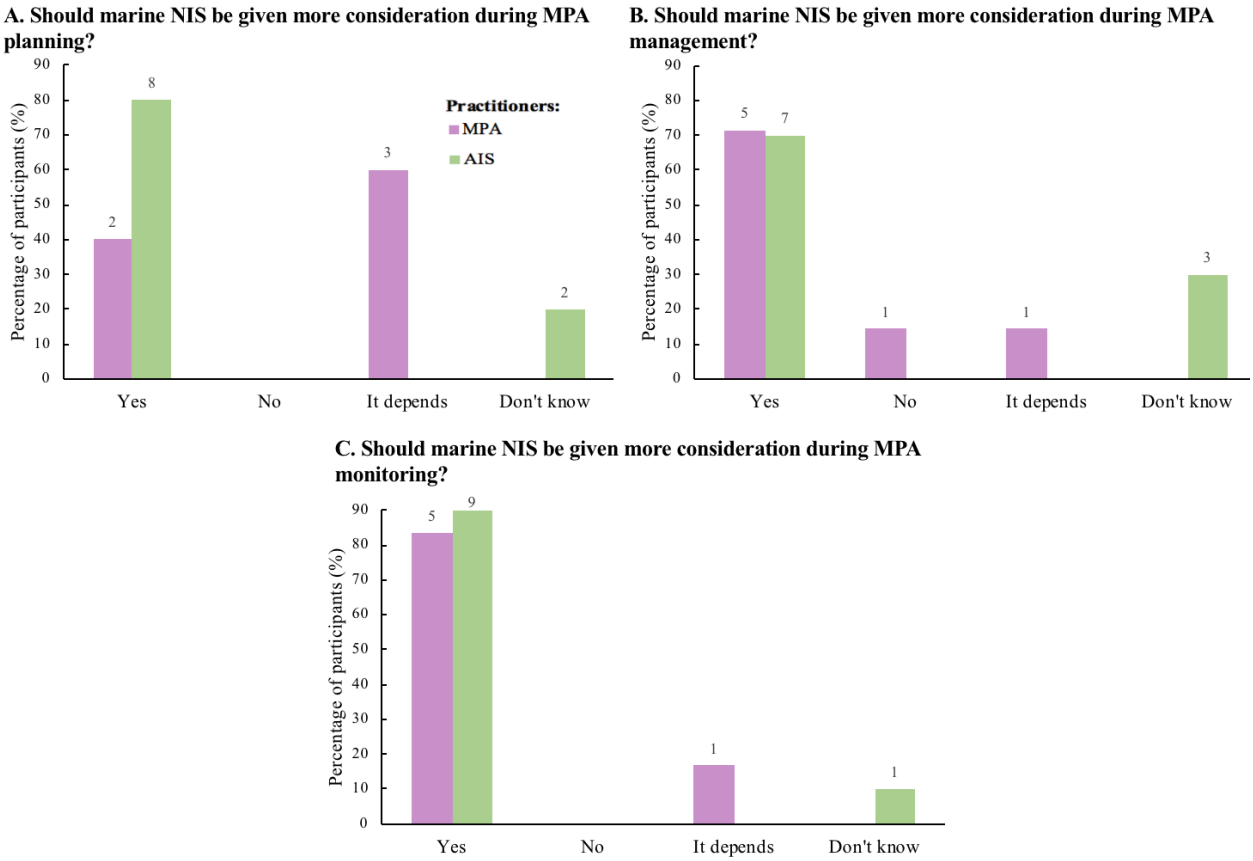

Figure 14. Opinions from MPA and AIS practitioners regarding the increased consideration of marine NIS in **A)** *MPA planning* (n = 15), **B)** *management* (n = 17), and **C)** *monitoring* (n = 16). In (A), MPA practitioners refers to those involved with planning. In (B), MPA practitioners refers to those involved with management. In (C), MPA practitioners refers to those involved with monitoring. Numbers above each bar represent the number of respondents that picked that response.

For the final interview question, all participants were asked to choose three actions from a list that ***they would most like to see done with regard to marine NIS and Canada's federal MPAs*** (Figure 15). For MPA practitioners the top three responses were: "More involvement of AIS practitioners to help prevention, early detection, and mitigation of NIS in MPAs" (72.2%), "Increased funding for management, monitoring, and research"(61.1%), and "Increased awareness and outreach" (38.9%). For AIS practitioners the top three responses were: "Increased application of NIS risk assessments and research outputs for MPA planning, management, and monitoring" (72.3%), "More involvement of AIS practitioners to help prevention, early detection, and mitigation of NIS in MPAs" (72.3%), and "Increased awareness and outreach" (36.4%). In addition, one MPA practitioner provided a choice for "other": that there should be more involvement of First Nations in preventing and managing marine NIS within MPAs, both to build capacity and to provide a more collaborative approach. Of the participants from both groups who chose "Increased awareness and outreach", many said it can help reduce the chance of introduction and spread of marine NIS in MPAs. Of the practitioners who chose "Increased application of NIS risk assessments and research outputs for MPA planning, management, and monitoring", one participant said they chose this because NIS risk assessments and research outputs are often not applied well in MPA planning and there should be more emphasis on pressures that can impact the ecosystem components of an MPA. Of the participants who chose "Increased funding for management, monitoring, and research", most participants said there is not enough funding available currently for these activities. Additionally, two MPA practitioners added that increased funding needs to be combined with increased capacity (*e.g.* vessel time, training, scientist time). Lastly, there was the agreement from both groups of practitioners that "More involvement of AIS practitioners to help prevention, early detection, and mitigation of NIS in MPAs" would be helpful. Some MPA practitioners further explained that AIS practitioners can provide the needed expertise on marine NIS during MPA planning, management, and monitoring stages.

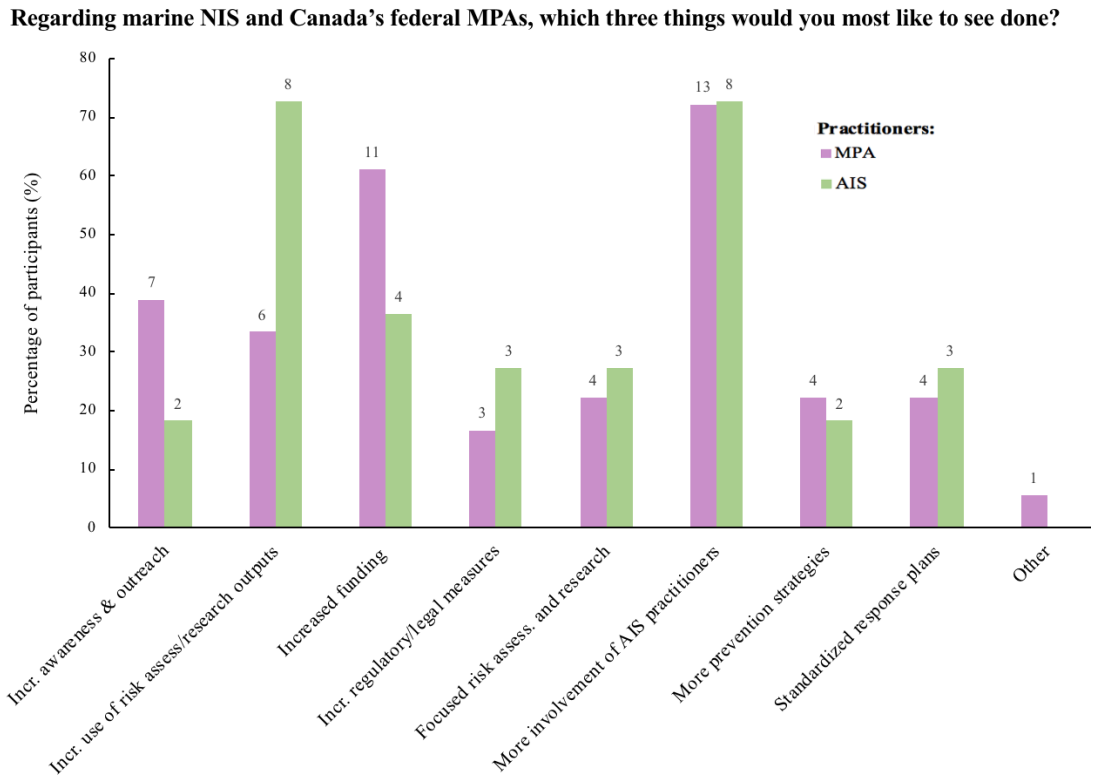

Figure 15. The top actions MPA and AIS practitioners would like to see done with regards to marine NIS and Canada's federal MPAs (n = 29). Each practitioner was asked to pick three options, however, one MPA practitioner only picked two. Numbers above each bar represent the number of respondents that picked that response.

Chapter 5. Discussion

This study reviewed and assessed the extent to which marine NIS were considered during planning, management, and monitoring of Canada's federally designated MPAs. Based on results from both the review of MPA management plans and the interviews with MPA and AIS practitioners, marine NIS should be given more consideration in Canadian MPAs.

Only thirty of the 92 MPAs (32.6%) had management plans available and only nine plans mentioned marine NIS in general. Further, only eight plans mentioned specific NIS species and of that only three mentioned the European green crab (which was the only marine NIS specifically mentioned). Lastly, only fourteen plans listed prevention, early detection and eradication, or mitigation strategies for NIS; many strategies were aimed at terrestrial species or were not specific.

MPA and AIS practitioners were familiar with marine NIS issues in Canada's ecosystems and MPAs and generally believed they were an important consideration for MPA planning, management, and monitoring. However, marine NIS are rarely adequately considered in these three aspects and other stressors, particularly fishing, are given priority during MPA planning. Practitioners identified eleven NIS and taxa that are already present in Canada's MPAs, five of which may have notable impacts on protected communities. MPA practitioners recognized that marine NIS can be a serious threat to MPAs, yet there are relatively few efforts in place to minimize the threat. Some management efforts are underway, yet most MPA and AIS practitioners agreed that increased consideration of marine NIS is needed during MPA planning, management, and monitoring. Finally, there were three overarching themes uncovered in the interviews: (i) recognition by practitioners that marine NIS can limit MPAs from achieving their conservation objectives, (ii) the risk of marine NIS may be higher in coastal or other readily accessible MPAs and lower in offshore and remote MPAs, and (iii) marine NIS should be considered more with respect to climate change.

5.1 Incorporation of Marine NIS in Management Plans

While all available management plans considered marine ecosystems, often the focus was terrestrial or freshwater ecosystems. This helps explain why identified NIS were either terrestrial or freshwater species except the European green crab (*C. maenas*). In general, only National Parks and NWAs listed specific species, except for the Basin Head MPA (Prince Edward Island)

and Gwaii Haanas NMCA (British Columbia). Gwaii Haanas focused on non-indigenous mammals, likely because of its status as a National Park Reserve and Haida Heritage Site.

Six of the nine plans that mentioned marine NIS in general and the three plans that mentioned the European green crab included prevention, early detection and eradication, and mitigation strategies. The remaining three plans that mentioned marine NIS did not include any management strategies. Specific prevention strategies in management plans included cleaning research equipment before sampling in a new area, ballast water guidelines, and educating commercial and recreational fishers how to avoid the transfer and introduction of NIS with fishing gear. All early detection and eradication strategies focused on monitoring, though specific monitoring strategies were not explained. The only exception was the Wallace Bay NWA (Nova Scotia) management plan, where habitat changes were monitored with aerial photographs and verified with ground surveys (though this was not specific to NIS). Specific mitigation strategies included monitoring, species-targeted removal of invaders, containment, and awareness and outreach to the public and commercial fishers on ways to stop the spread of NIS. These strategies from the management plans are consistent with best practices identified from the literature (see Chapter 2) for application to designated MPAs. Best practices that were absent from reviewed management plans were strategies that included modelling and risk assessment tools. Finally, over half of available management plans lacked any NIS management strategies, while fewer still had marine NIS strategies. This is concerning because best practices for managing invasions and their negative impacts requires explicit description and inclusion of marine NIS management strategy in the MPA management plans (Mačić et al., 2018; Otero et al., 2013).

In interviews, five particularly concerning (or high-risk) marine NIS were recognized in MPAs, including tunicates and bryozoans in general as well as the European green crab, the oyster thief, and the striped bass. While tunicates were the most mentioned taxa, no management plans identified any tunicate species or strategies to manage them. They were reported specifically by practitioners to be present in the Basin Head MPA (Prince Edward Island) and Gwaii Haanas NMCA (British Columbia). Tunicates have been documented in both provinces prior to the publication of the MPA management plans. The clubbed, golden star, violet, and vase tunicates were all found in the waters of Prince Edward Island by 2004 (Ramsay, Davidson, Landry, & Arsenault, 2008), twelve years prior to the release of the Basin Head MPA

management plan. The golden star and violet tunicates were first documented in the waters of Haida Gwaii, British Columbia in 2007 (Gartner et al., 2016) including in sampling sites within the Gwaii Haanas NMCA, eleven years before the management plan was released. These examples suggest that tunicates were either not considered or not considered a threat to these MPAs when their management plans were published. However, this contradicts concerns raised by practitioners that tunicates can have environmental impacts by smothering native species. Several MPA practitioners mentioned that the unique strain of Irish moss that the Basin Head MPA was designated to conserve can have non-indigenous tunicates growing on their fronds. They mentioned that on occasion, tunicate species were found on Irish moss fronds cultivated in suspended mesh bags in the MPA but very rarely on Irish moss growing on the sea floor.

Another important note is the lack of any management plan for the vast majority (58) of Canada's federal MPAs. One explanation for the missing plans could be that many of Canada's MPAs were only designated within the last ten years. In 2011, only 0.9% of Canada's marine area was protected under MPAs and other effective area-based conservation measures (*i.e.* fishery closures) (ECCC, 2015), compared to 13.8% as of 2019 (DFO, 2020a). This rapid increase in coverage is due to Canada working to achieve Aichi Target 11 (Lemieux et al., 2019). An MPA management plan is not usually developed until after designation (Pomeroy et al., 2004) and in Canada developing a plan can take many years. Of the available management plans, 80% were published more than ten years after the MPA was designated (Appendix D). This makes it challenging to determine how many (if any) marine NIS are being considered during active management of these MPAs.

5.2 MPA and AIS Practitioner Knowledge

The perceived risk of marine NIS in Canadian ecosystems and in Canada's MPAs were ranked similarly, with most participants describing the threat to be moderately serious due to the variable risk across ecosystems or an MPA and its characteristics. An overarching theme among participants throughout the interviews (mentioned by 62.1%) was that marine NIS may hinder some MPAs from achieving their conservation objectives. Many practitioners said that the threat of marine NIS ultimately depends on what the MPA aims to protect. However, there are many instances where marine NIS could compromise these objectives. For instance, as one MPA practitioner explained:

> *...the conservation objectives for MPAs, not always, but generally, are focused on maintaining or improving biodiversity, or improving or maintaining habitat quality or [the] conservation of native at risk species, and we know that marine non-indigenous species are threats to all of those factors.*

Another MPA practitioner explained that marine NIS "…have the ability to really change the structure of an ecosystem…" and that the goal of an MPA is to maintain naturalness and biodiversity. They gave an example applicable to Nova Scotia: "…if kelp is completely wiped out due to *Codium*, [that is] not a situation that we're looking to have in a marine protected area". The idea that conservation objectives can be compromised by marine NIS coincides with a framework proposed by Mačić and colleagues (2018) that aims to better incorporate NIS in MPA planning. The authors suggest that marine NIS should be considered when conservation objectives are being determined so that any potential impacts on these objectives are identified *a priori* and integrated accordingly into NIS management strategies (Mačić et al., 2018).

Another overarching theme among participants (mentioned by 41.2%) was that the seriousness of marine NIS may be lower for remote MPAs. Coastal and accessible MPAs were said to be more at risk than remote or offshore MPAs, which is consistent with the literature (Krug et al., 2012; Sheppard et al., 2012; Voight, Leee, Reft, & Bates, 2012). When MPA practitioners were asked if any of the MPAs they were familiar with were particularly susceptible to invasion by marine NIS, there was a significant difference between accessible and remote MPAs. The top two reasons they considered coastal and accessible MPAs to be more susceptible were anthropogenic-mediated spread and suitable environmental conditions. Typically there are higher levels of human activities in or around accessible MPAs like recreational boating, fishing, shipping, and aquaculture, which are all considered significant vectors for marine NIS spread (Gestoso, Ramalhosa, Oliveira, & Canning-Clode, 2017; Otero et al., 2013). That said, marine NIS should not be disregarded in remote and offshore MPAs, as they can establish and may have impacts in these types of ecosystems as well. Several sea slug species in the *Philine* genus have invaded soft benthic habitats more than 300 metres deep along the west coast of the United States and negatively impacted native bivalve species (Krug et al., 2012). In deep-sea hydrothermal vents, like those present in the Endeavour Hydrothermal Vents MPA (British Columbia), research equipment can be a vector for marine NIS (Voight et al., 2012).

MPA practitioners who thought marine NIS were a very serious threat in Canadian MPAs and associated ecosystems often related their responses to their past experiences or knowledge of marine invasions. One MPA practitioner stated that "…when I think about different areas across Canada that are facing different issues that [marine NIS represent] a major problem…Everything from zebra mussels, to green crab, to *Codium*, there's just issues right across the country". Further, one MPA practitioner explained that MPAs with marine invaders should serve as an example:

> *I guess my tendency is to say we better learn from a few sites where we've had a major problem and make sure that the rest of the country is paying attention, whether or not it's a serious problem in any given MPA.* (MPA practitioner).

This concept follows the precautionary principle, that in uncertainty preventative measures should be taken to avoid environmental harm (Kriebel et al., 2001).

The familiarity of participants regarding ongoing marine NIS management, monitoring, and mitigation efforts varied between MPA and AIS practitioners. Most MPA practitioners were only somewhat or moderately familiar with ongoing efforts to manage NIS in Canada and in Canada's MPAs. Comparatively, most AIS practitioners were moderately or very familiar with NIS management for Canada in general, but only somewhat or moderately familiar with management in Canada's MPAs.

5.3 Inclusion of Marine NIS in MPA Planning

The top stressors to consider during MPA planning in the opinion of MPA practitioners were climate change, fishing, and habitat alteration and loss. Similarly, AIS practitioners chose those stressors along with NIS and pollution. Although NIS was not selected in the top three stressors by MPA practitioners, they identified the importance of interactions between climate change and NIS. This links to the third overarching theme from the interviews (mentioned by 20.7%), that <u>marine NIS need to be considered more with respect to climate change</u>. Practitioners mentioned they expect to see shifts in species distributions with climate change and marine NIS need to be considered more in MPA planning in the context of climate change. In particular, warmer water temperatures creates optimal conditions for some NIS (*e.g.* earlier and longer period where spawning can occur), allowing them to increase their reproductive rate and

subsequently expand their range and impacts (Keller et al., 2009). However, two MPA practitioners mentioned that despite the huge importance of climate change, it is difficult to include in MPA planning, with one practitioner saying: “that [climate change is] so inconceivably huge as to be almost insurmountable in terms of making effective decisions around placement”. Further, there is high uncertainty surrounding climate change and how it may impact an MPA, as it can interact with other stressors such as NIS and pollution (Keller et al., 2009). With a lack of information on how best to adapt an MPA to impacts of climate change and other stressors more immediately pressing to consider, MPA planners may choose not to focus on climate change issues (Wilson, Tittensor, Worm, & Lotze, 2020). This may help to explain why climate change was not named as a top stressor considered during MPA planning. However, climate change can be indirectly included in planning by incorporating marine NIS predictions. For example, changes in the distribution of a marine NIS can be predicted under future climate change scenarios using the best practice of suitable habitat modelling (Iacarella et al., 2020b; Lowen & DiBacco, 2017; Robinson et al., 2017).

Regarding the current consideration of marine NIS during MPA planning, there was a discrepancy between MPA planners and AIS practitioners, where 60% of MPA planners said marine NIS were adequately considered during planning and 63.6% of AIS practitioners said they did not know. This perhaps could be due to limited communication between the two groups or the fact that most of the AIS practitioners interviewed had no role in MPA planning. For the MPA planners who said marine NIS were given adequate consideration during planning, all said this was usually done after AOIs were proposed. This indicates that marine NIS are not considered *a priori*. According to the framework proposed by Mačić and colleagues (2018), marine NIS should be considered at the very start of MPA planning. However, one MPA planner explained that all potential stressors are considered at the same time after AOIs are picked. They then said:

> *Do we really want to proceed with an area if we know that it's under significant pressure [from marine NIS] and the ecosystem is going to be, you know, significantly altered? Probably not. In the same way that we wouldn't want to put an MPA in a highly polluted harbour.* (MPA practitioner).

Two of the three MPA planners who said the consideration of marine NIS was adequate conceded that the process was rather simple and could be improved, with one planner indicating

engagement with AIS practitioners could be beneficial. Mačić and colleagues (2018) suggested including AIS experts as stakeholders prior to the conservation objectives being defined and consistently throughout the planning process. The one MPA planner who said NIS were not considered enough identified a lack of spatial information about NIS ranges and distributions. This further suggests there is insufficient communication between MPA and AIS practitioners, as these data can be provided by AIS practitioners at DFO (*e.g.* DFO, n.d.; Sephton et al., 2017).

Later in the interviews, MPA and AIS practitioners were asked about the ways they communicate with each other and the most common answer was informal conversations. These types of interactions mainly involved sending emails or communicating in person when a practitioner needed expert opinion on a subject (*e.g.* an MPA practitioner asking an AIS practitioner about a particular NIS). As many interactions are occurring on an *ad hoc* basis, this may indicate a need for more regular communication between the two groups.

5.4 Management of Marine NIS in Canadian MPAs

Only thirteen specific MPAs were brought up in detail during interviews and of those eight (61.5%) had management plans with NIS strategies (section 4.1). The remaining five MPAs included the Eastport MPA, Gilbert Bay MPA, Musquash Estuary MPA, Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs MPA, and Scott Islands marine NWA. Of these, the first three are coastal and readily accessible MPAs (Eastport MPA, Gilbert Bay MPA, Musquash Estuary MPA) with marine NIS management strategies detailed by practitioners, even though these were not mentioned in their management plans. This indicates that management strategies for NIS can be employed in an MPA regardless if they were included in the management plan. Since only 14.1% of Canada's 92 MPAs were referred to by practitioners, it is difficult to determine what level of consideration marine NIS are given during the management of the majority of MPAs compared to what is described in management plans.

According to MPA and AIS practitioners, current marine NIS prevention strategies used in MPAs include all strategies listed in the prevention section of the NIS management framework (Figure 2). This included awareness and outreach, expert opinion, invasion history, regulations, and risk assessment. The most common strategies employed were awareness and outreach, risk assessment, and invasion history. However, a recurring theme among respondents was that both awareness and outreach and risk assessments were more effective towards prevention, and that

these strategies were never specific to an MPA. In comparison, AIS practitioners identified vector awareness, outreach, and regulations as the best strategies for preventing marine NIS within MPAs. In both questions awareness and outreach were considered a best practice by practitioners, which concurs with the best practices found in the literature.

According to MPA and AIS practitioners, the top strategy currently used for detecting newly arrived marine NIS in MPAs is monitoring. All participants said monitoring was used, except those who did not know what strategies were used. However, three participants said MPA monitoring is often not focused on detecting marine NIS. One AIS practitioner who chose both "monitoring" and "no information is used" said: "It's a little bit contradicting, first I would say no information is used and second probably monitoring. But it's not a dedicated monitoring." and further explained that detection of an NIS would be by chance. This was echoed by an MPA practitioner who said monitoring occurs in the MPAs in Newfoundland and Labrador following the conservation objectives (*e.g.* lobster monitoring). In contrast to these statements, NIS-specific monitoring was mentioned for five specific MPAs in the Atlantic and Pacific, all of which were coastal MPAs.

The most common mitigation strategies used for marine NIS in MPAs were less clear. A total of five MPA and six AIS practitioners said they did not know which strategies were used. Population control followed by monitoring (to assess if population control was successful) was mentioned in select MPAs in New Brunswick, Nova Scotia, and Quebec for the European green crab and tunicates. Some MPA practitioners stated that sometimes mitigation strategies are not attempted due to limited management options. For example, one MPA practitioner said containment was not possible for European green crab mitigation in the Basin Head MPA (Prince Edward Island) because "…larvae come in and out and it's just not an option. And being an MPA, we wouldn't be trying to eradicate with using products that kill them, for example, killing everything else". In this example, eradication of the European green crab was said to be unlikely, which coincides with the idea that complete eradication is improbable in a marine environment (Hulme, 2006). Another MPA practitioner explained that if anything, just monitoring is done and "There's not a lot of active mitigation". They further said that once marine NIS have established, it can take years of continuous effort to mitigate and "…it's often not even attempted". This relates to the principle that it is most cost effective to prevent a marine NIS and least cost effective to mitigate an established invader's impacts (Leach et al., 2019).

5.5 Challenges and Limitations

While reviewing the MPA management plans provided some baseline information, this approach had limitations. Namely, not all the federal MPAs have a published management plan (and many MPAs are newly designated) and some plans focused more on terrestrial aspects (*i.e.* MBS, National Historic Sites, and NWAs with marine portions). Another consideration is that the lack of information about marine NIS in a management plan does not indicate that they are not considered in that MPA. This was demonstrated during the interviews when participants mentioned marine NIS management strategies taking place in MPAs whose management plans lacked this information.

Interviews responses pertained to those MPAs and marine NIS the practitioners were familiar with. Mostly participants spoke about *Oceans Act* MPAs or National Parks and only 14.1% of Canada's federal MPAs were discussed in detail. Further, there was no Arctic representation; no MPA or AIS practitioners contacted from this region were able to participate. Therefore, this study is limited to Pacific and Atlantic perspectives. Lastly, there may have been a bias within those who agreed to be interviewed for this study. There is potential that those who were willing to participate were more knowledgeable about marine NIS and/or MPAs than those who did not choose to be interviewed.

Chapter 6. Recommendations and Conclusions

6.1 Recommendations

Canada's current strategies for managing marine NIS in MPAs were compared to global best practices (Chapter 2). A total of six recommendations are provided that may improve the level of consideration given to marine NIS in Canada's federal MPAs.

First, MPA management plans should include a mandate to evaluate relevant high-risk marine NIS. Best practices can be employed to determine which species are high-risk. To quickly evaluate the risk of a marine NIS, a risk assessment tool like CMIST can be used; in a matter of days any high-risk species can be determined. Suitable habitat modelling can also be utilized to predict how a marine NIS may spread, including under future climate scenarios. Any relevant marine NIS that are identified can be prioritized by MPA managers in the management plan through the inclusion of applicable prevention, early detection and eradication, and mitigation strategies.

Second, marine NIS should be incorporated into MPA planning earlier and more frequently. During MPA planning, the focus is usually on native species or biodiversity and the distribution and impacts of NIS may be overlooked (Giakoumi et al., 2016; Mačić et al., 2018). However, as marine NIS can hinder the conservation objectives of an MPA, any high-risk species should be included early in the planning process. Following the framework proposed by Mačić and colleagues (2018), MPA planners can include marine NIS in MPA planning at different stages of the process such as during the scoping of potential AOIs, by considering their cost (*i.e.* potential costs related to prevention, eradication, or management), studying their ecological role within an AOI, and considering their impacts and how they may hinder conservation objectives.

Third, marine NIS should be considered more with regard to climate change. Both MPA and AIS practitioners indicated that shifts in species distributions are likely under future climate scenarios. By considering how climate change will influence marine NIS ranges, MPA practitioners can plan for potential future impacts of marine NIS and adapt MPA management strategies as needed.

Fourth, more collaboration should occur between MPA and AIS practitioners and AIS practitioners should be more involved with prevention, early detection and eradication, and mitigation of marine NIS in Canada's MPAs. As AIS practitioners have expertise on the

management of high-risk invaders in Canada, it is logical for them to share their expertise, data, and any best practices for specific invaders. Regular meetings were suggested by interview participants as something that would be helpful to both groups. Communication between MPA and AIS practitioners appears to be lacking and meetings or other collaborative processes (*e.g.* working groups) would likely allow for key issues to be addressed regarding marine NIS in MPAs.

Fifth, interview participants indicated that more marine NIS awareness and outreach would be beneficial. Awareness and outreach strategies are occurring, however, interview participants indicated these strategies are not often specific to MPAs. Educating MPA staff and visitors about high-risk marine NIS present in or likely to invade an MPA can reduce the chance of accidental introduction or spread. Educational materials should provide information on regulating vectors (*e.g.* cleaning your boat before entering the MPA) and any high-risk species to look for (can be provided to MPA monitoring team and MPA visitors).

Finally, more funding should be provided for marine NIS management, monitoring, and research within MPAs. Interview participants mentioned that currently there is not enough funding or capacity to carry out these tasks. However, costs can actually be reduced in the long-term by investing in research and prevention. For example, determining high-risk NIS for an MPA can help MPA managers prioritize their monitoring efforts and resources, increasing the likelihood of early detection and reducing the chance costly long-term control is needed (Otero et al., 2013).

6.2 Conclusions

Overall, this study suggests marine NIS should be given more consideration in Canada's MPAs during MPA planning, management, and monitoring. Global best practices for managing marine invasions in MPAs provided key strategies that could be compared to Canada's current approach. Despite the acknowledgement from MPA and AIS practitioners that marine NIS are important to consider in Canada's MPAs, so far piecemeal efforts have been made to reduce these threats. While some MPAs had management plans that mentioned NIS and provided management strategies, the vast majority of MPAs had no plan at all or did not consider NIS of any kind. During MPA planning, marine NIS seem to be minimally considered as other stressors take priority. Management and monitoring strategies specific to marine NIS were mentioned for

only a few MPAs. Yet, marine NIS and taxa were mentioned to be present in several MPAs and practitioners reported some negative impacts on native habitats and species. MPA and AIS practitioners agreed that increased consideration of marine NIS is needed during MPA planning, management, and monitoring. To improve the consideration of marine NIS in Canada's MPAs, global best practices for managing marine NIS in MPAs should be applied.

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Appendix A. List of Canada's Federally Designated MPAs

Oceans Act MPAs:

1. Anguniaqvia niqiqyuam MPA
2. Banc-des-Américains MPA
3. Basin Head MPA
4. Eastport MPA
5. Endeavour Hydrothermal Vents MPA
6. Gilbert Bay MPA
7. Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs MPA
8. Laurentian Channel MPA
9. Musquash Estuary MPA
10. SGaan Kinghlas-Bowie Seamount MPA
11. St. Anns Bank MPA
12. Tarium Niryutait MPA
13. The Gully MPA
14. Tuvaijuittuq MPA

Migratory Bird Sanctuaries with a Marine Portion:

15. Akimiski Island Migratory Bird Sanctuary
16. Anderson River Delta Migratory Bird Sanctuary
17. Baie De Brador Migratory Bird Sanctuary
18. Baie Des Loups Migratory Bird Sanctuary
19. Banks Island Migratory Bird Sanctuary No. 1
20. Banks Island Migratory Bird Sanctuary No. 2
21. Betchouane Migratory Bird Sanctuary
22. Big Glace Bay Lake Migratory Bird Sanctuary
23. Boatswain Bay Migratory Bird Sanctuary
24. Bonaventure Island And Percé Rock Migratory Bird Sanctuary
25. Bylot Island Migratory Bird Sanctuary
26. Cap-Saint-Ignace Migratory Bird Sanctuary
27. Cape Parry Migratory Bird Sanctuary
28. Dewey Soper (Isulijarnik) Migratory Bird Sanctuary
29. East Bay (Qaqsauqtuuq) Migratory Bird Sanctuary
30. Esquimalt Lagoon Migratory Bird Sanctuary
31. George C. Reifel Migratory Bird Sanctuary
32. Grand Manan Migratory Bird Sanctuary
33. Gros-Mécatina Migratory Bird Sanctuary
34. Hannah Bay Migratory Bird Sanctuary
35. Harry Gibbons (Ikkattuaq) Migratory Bird Sanctuary
36. Île à la Brume Migratory Bird Sanctuary
37. Île aux Basques Migratory Bird Sanctuary
38. Île Aux Canes Migratory Bird Sanctuary
39. Île du Corossol Migratory Bird Sanctuary

40. Kendall Island Migratory Bird Sanctuary
41. L'Isle-Verte Migratory Bird Sanctuary
42. L'Islet Migratory Bird Sanctuary
43. Machias Seal Island Migratory Bird Sanctuary
44. McConnell River (Kuugaarjuk) Migratory Bird Sanctuary
45. Montmagny Migratory Bird Sanctuary
46. Moose River Migratory Bird Sanctuary
47. Port Hebert Migratory Bird Sanctuary
48. Port Joli Migratory Bird Sanctuary
49. Prince Leopold Island Migratory Bird Sanctuary
50. Queen Maud Gulf (Ahiak) Migratory Bird Sanctuary
51. Rochers aux Oiseaux Migratory Bird Sanctuary
52. Sable River Migratory Bird Sanctuary
53. Saint-Augustin Migratory Bird Sanctuary
54. Saint-Omer Migratory Bird Sanctuary
55. Saint-Vallier Migratory Bird Sanctuary
56. Sainte-Marie Islands Migratory Bird Sanctuary
57. Seymour Island (Nauyavaat) Migratory Bird Sanctuary
58. Shepherd Island Migratory Bird Sanctuary
59. Shoal Harbour Migratory Bird Sanctuary
60. Terra Nova Migratory Bird Sanctuary
61. Trois-Saumons Migratory Bird Sanctuary
62. Victoria Harbour Migratory Bird Sanctuary
63. Watshishou Migratory Bird Sanctuary

National Marine Conservation Areas:

64. Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site
65. Saguenay–St. Lawrence Marine Park
66. Tallurutiup Imanga National Marine Conservation Area

National Wildlife Areas with a Marine Portion:

67. Akpait National Wildlife Area
68. Alaksen National Wildlife Area
69. Boot Island National Wildlife Area
70. Cape Jourimain National Wildlife Area
71. John Lusby Marsh National Wildlife Area
72. Ninginganiq National Wildlife Area
73. Nirjutikarvik National Wildlife Area
74. Polar Bear Pass National Wildlife Area
75. Qaqulluit National Wildlife Area
76. Sand Pond National Wildlife Area
77. Scott Islands marine National Wildlife Area
78. Wallace Bay National Wildlife Area

National Parks and National Historic Sites with a Marine Portion:

79. Aulavik National Park
80. Auyuittuq National Park
81. Forillon National Park
82. Gulf Islands National Park Reserve
83. Ivvavik National Park
84. Kejimkujik National Park and National Historic Site
85. Kouchibouguac National Park
86. Pacific Rim National Park Reserve
87. Pingo Canadian Landmark
88. Qausuittuq National Park
89. Quttinirpaaq National Park
90. Sirmilik National Park
91. Ukkusiksalik National Park
92. Wapusk National Park

Appendix B. Interview Consent Form

CONSENT FORM

Project title: Consideration of marine non-indigenous species in marine protected area planning, management, and monitoring in Canada

Lead Researcher: Rachel Rickaby, Dalhousie University, Marine Affairs, Rachel.Rickaby@dal.ca

Supervisors:

Dr. Claudio DiBacco, DFO Research Scientist at the Bedford Institute of Oceanography, Claudio.DiBacco@dfo-mpo.gc.ca

Dr. Josephine Iacarella, DFO Research Scientist at the Institute of Ocean Sciences, Josephine.Iacarella@dfo-mpo.gc.ca

Introduction

We invite you to take part in a research study being conducted by Rachel Rickaby, a Master's student at Dalhousie University. Choosing to take part in this research is entirely your choice. The following information explains the purpose of the interviews and describes any potential benefits and risks you might experience.

Purpose and Outline of the Research Study

The objective of this study is to determine how marine non-indigenous species are considered during marine protected area (MPA) planning, management, and monitoring in Canada's federally designated MPAs. For this study, **marine non-indigenous species** refers to any marine fish, invertebrate or plant species that is living outside its native range. **Canada's federal MPAs** include those under the Oceans Act, the National Marine Conservation Areas Act, the National Wildlife Act, and the Migratory Birds Act. There are three parts of this study: (i) interviews, (ii) the review of all available Canadian MPA management plans, and (iii) a literature review on global best practices for managing MPAs and marine invasions. In the final section of the report, a proposed framework for managing marine invasions in Canada's MPAs will be developed. For the interviews, we want to hear opinions from invasive species practitioners and MPA planners, managers, and scientists. If you choose to participate in this research, you will complete one interview where the lead researcher (Rachel Rickaby) will ask questions related to MPAs and marine non-indigenous species as pertains to your capacity as an invasive species practitioner or MPA planner, manager, and/or scientist.

Who Can Take Part in the Research Study

You may participate in this study if you are an invasive species practitioner or an MPA planner, manager, or scientist who has at least one year of experience in your relevant field within the last 15 years. You have been identified as a potential candidate for this study because of your experience with Canada's federal MPAs and/or invasion ecology.

What You Will Be Asked to Do

You will be asked to complete a 30-45 minute *Skype* or phone interview at a time convenient to you. During the interview, you will be asked questions about how marine non-indigenous species are considered during MPA planning, monitoring, and/or management as pertains to your occupation. All participant answers and quotes will be de-identified. You can decide if you would like your interview to be recorded and if direct quotes may be used. If there is a part of the interview that cannot be de-identified it will not be quoted. Additionally, you can choose whether you would like your answers to be linked to the region where you work. The signature page has an option to agree to this or not.

Possible Benefits, Risks and Discomforts

Benefits:

Participating in this study will contribute to a national overview of marine non-indigenous species management in MPAs. Additionally, a short description of group results will be provided to interested participants after the study is complete. No individual results will be provided. You can obtain these results by including your contact information at the end of the signature page.

Risks and Discomforts:

There is a low risk that some interview questions may cause psychological or emotional discomfort. If there is a question you do not want to answer, you can choose not to.

How Your Information Will Be Protected

Your participation in this research will be known only to the members of the research team. The information that you provide to us will be kept confidential. Only the lead researcher, Rachel Rickaby, will have access to this information. All your identifying information (such as your name and contact information) will be securely stored separately from your research information. We will use a participant number in our written and computer records so that the research information we have about you does not contain your name. During the study, all electronic records will be kept secure in an encrypted file on the lead researcher's password-protected computer. A backup of the encrypted file will be kept on an encrypted USB. All paper records will be kept secure by the lead researcher in a locked cabinet.

It is anticipated that the results of this study will be shared in several ways. However, only group results will be reported and not individual results. You will not be identified in any way in our reports. The study results will be published as part of a Graduate Project for the Marine Affairs Program at Dalhousie University. All Graduate Projects are publicly available on the DalSpace website (https://dalspace.library.dal.ca/). Additionally, study results will be presented at a Dalhousie academic conference and an end-of-year academic presentation. Finally, results may be used in a peer-reviewed journal article.

Your data will be retained for three years following the receipt of final grades of the Graduate Project in January 2021. After this date, all participant data will be permanently deleted from the encrypted files and encrypted USB. All paper records will be shredded.

If You Decide to Stop Participating

You have the option to leave the study at any time up to or during the interview. If you decide to stop participating during the interview, you can choose whether you want any of the information that you have provided up to that point to be removed or if you will allow us to use that information. After participating in the study, you will have a minimum of two weeks following the interview or until August 31st, 2020, whichever is longer, to withdraw from the study.

Questions

For any questions or concerns you may have about your participation in this research study please contact Rachel Rickaby (at Rachel.Rickaby@dal.ca).

If you have any ethical concerns about your participation in this research, you may also contact Research Ethics, Dalhousie University at (902) 494-3423, or email: ethics@dal.ca (**MAPERSC #:** MAP2020-04).

Signature Page

Project Title: Consideration of marine non-indigenous species in marine protected area planning, management, and monitoring in Canada

Lead Researcher: Rachel Rickaby, Dalhousie University, Marine Affairs, Rachel.Rickaby@dal.ca

I have read the explanation about this study. I have been given the opportunity to discuss it and my questions have been answered to my satisfaction. I understand that I have been asked to take part in one *Skype* or phone interview that will occur at a time acceptable to me. I agree to take part in this study. My participation is voluntary and I understand that I am free to withdraw from the study at any time, until August 31st, 2020 or two weeks following the interview, whichever is longer.

I agree that my interview can be recorded ☐Yes ☐No

I agree that direct quotes from my interview may be used, without identifying me ☐Yes ☐No

I agree that my answers can be linked to the region I work, without identifying me ☐Yes ☐No

_____	_____	_____
Name	Signature	Date

Please provide an email address below if you would like to be sent a summary of the study results.

Email address: _____

Appendix C. Interview Questions

Questions for MPA Planners

1. What is your role in MPA planning?
2. How many years have you worked in this role?
3. Have you worked in a different role related to Canada's federal MPAs prior to your current role?
   a. Yes / No
   b. If yes, what was the role?
   c. How long did you work in that role?
4. In your opinion, how serious of an issue (ecological, commercial, cultural) are marine non-indigenous species **in general in Canadian waters** on a scale of 1 to 4? (1= not serious, 2= somewhat serious, 3= moderately serious, 4= very serious, not sure)
5. In your opinion, how serious of an issue (ecological, commercial, cultural) are marine non-indigenous species **in Canada's MPAs** on a scale of 1 to 4? (1= not serious, 2= somewhat serious, 3= moderately serious, 4= very serious, not sure)
   a. Are there any non-indigenous species you are particularly concerned about in Canadian waters?
      i. Yes / No
      ii. If yes, which species and why?
6. On a scale of 1 to 4, how familiar are you with ongoing management, monitoring or mitigation efforts for marine non-indigenous species **in Canada**? (1= not familiar, 2= somewhat familiar, 3= moderately familiar, 4= very familiar)
7. On a scale of 1 to 4, how familiar are you with ongoing management, monitoring or mitigation efforts for marine non-indigenous species **within Canada's MPAs**? (1= not familiar, 2= somewhat familiar, 3= moderately familiar, 4= very familiar)
8. The following factors have been identified as important stressors for consideration in MPA planning (*e.g.* Day et al., 2015; DFO, 2014; Mach et al., 2017).
   - Aquaculture
   - Climate change
   - Fishing
   - Habitat alteration and loss
   - Non-indigenous species
   - Pollution (*e.g.* chemical spills, nutrient loading, plastic)
   - Vessel traffic (*e.g.* noise, physical disturbance)
   - Other: ____

   a. In your opinion, which **three** stressors do you think are most important for considering in MPA placement?
   b. In your experience, which **three** stressors are considered most when identifying areas of interest (AOIs) or designating MPAs?

9. To your knowledge, are there any strategies for facilitating communication between MPA practitioners and aquatic invasive species (AIS) practitioners?
    a. Data sharing platforms
    b. Informal conversations
    c. Meetings
    d. Review of published reports on non-indigenous species
    e. Other: ____
10. Are marine non-indigenous species **adequately** considered during the MPA planning process?
    a. Yes / No / Don't know
    b. If yes, why?
    c. If no, why?
11. In your experience, what information is used to prevent non-indigenous species in MPA planning?
    a. Awareness & outreach
    b. Expert opinion (from whom?)
    c. Invasion history
    d. Risk assessment
    e. No information is used
    f. Don't know
    g. Other: ____
12. From a planning perspective, do you think marine non-indigenous species should be given more consideration in MPA planning?
    a. If yes, why?
13. Regarding marine non-indigenous species and Canada's federal MPAs, what **three things** would you most like to see done?
    a. Increased awareness & outreach
    b. Increased application of non-indigenous species risk assessments and research outputs for MPA planning, management, and monitoring
    c. Increased funding for management, monitoring, and research
    d. Increased regulatory/legal measures
    e. More focused risk assessments and research on non-indigenous species in MPAs
    f. More involvement of Aquatic Invasive Species practitioners to help prevention, early detection, and mitigation of non-indigenous species in MPAs
    g. More prevention strategies
    h. Standardized response plans
    i. Other: ____
14. Is there anything else you would like to add or any questions you would like to go back to?
15. Is there anything that could have improved your interview experience?

Questions for MPA Managers

1. What is your role in MPA management?
2. How many years have you worked in this role?

3. Have you worked in a different role related to Canada's federal MPAs prior to your current role?
    a. Yes / No
    b. If yes, what was the role?
    c. How long did you work in that role?
4. In your opinion, how serious of an issue (ecological, commercial, cultural) are marine non-indigenous species **in general in Canadian waters** on a scale of 1 to 4? (1= not serious, 2= somewhat serious, 3= moderately serious, 4= very serious, not sure)
5. In your opinion, how serious of an issue (ecological, commercial, cultural) are marine non-indigenous species **in Canada's MPAs** on a scale of 1 to 4? (1= not serious, 2= somewhat serious, 3= moderately serious, 4= very serious, not sure)
    a. Are there any non-indigenous species you are particularly concerned about in Canadian waters?
        iii. Yes / No
        iv. If yes, which species and why?
6. On a scale of 1 to 4, how familiar are you with ongoing management, monitoring or mitigation efforts for marine non-indigenous species **in Canada**? (1= not familiar, 2= somewhat familiar, 3= moderately familiar, 4= very familiar)
7. On a scale of 1 to 4, how familiar are you with ongoing management, monitoring or mitigation efforts for marine non-indigenous species **within Canada's MPAs**? (1= not familiar, 2= somewhat familiar, 3= moderately familiar, 4= very familiar)
8. Do you have a role in MPA planning?
    a. If so, what is your role?
9. The following factors have been identified as important stressors for consideration in MPA planning (*e.g.* Day et al., 2015; DFO, 2014; Mach et al., 2017).
    - Aquaculture
    - Climate change
    - Fishing
    - Habitat alteration and loss
    - Non-indigenous species
    - Pollution (*e.g.* chemical spills, nutrient loading, plastic)
    - Vessel traffic (*e.g.* noise, physical disturbance)
    - Other: ____

    a. considering in MPA placement?
    b. In your experience, which **three** stressors are considered most when identifying areas of interest (AOIs) or designating MPAs?
10. To your knowledge, are there any strategies for facilitating communication between MPA practitioners and aquatic invasive species (AIS) practitioners?
    a. Data sharing platforms
    b. Informal conversations
    c. Meetings
    d. Review of published reports on non-indigenous species
    e. Other: ____

11. Are you aware of any marine non-indigenous species in the MPA(s) you are involved with or know about?
    a. If yes, please list them.
    b. Are you aware of any impacts or potential impacts associated with these non-indigenous species?
    c. Have any of these impacts been assessed or documented?
12. Of the MPAs you are aware of or have worked on, are any **particularly susceptible to invasion** by marine non-indigenous species?
    a. Yes / No (indicate which MPA(s) and species/groups you are referring to)
    b. If yes, why?
        i. Anthropogenic mediated spread (*e.g.* aquaculture, ballast water, vessel traffic)
        ii. Suitable environmental conditions (*e.g.* depth, temperature)
        iii. Suitable substrate or benthic environment
        iv. Proximity to sources of non-indigenous species (*i.e.* high potential for spread)
        v. Habitat is highly disturbed or degraded (*i.e.* higher chance of invasion)
        vi. Other: ____
    c. If no, why not?
        i. Low chance of anthropogenic mediated spread
        ii. Unsuitable environmental conditions
        iii. Unsuitable substrate or benthic environment
        iv. Far from sources of non-indigenous species
        v. Habitat is relatively pristine with rich native community
        vi. Biotic resistance from native species (*i.e.* competition or predation by native species)
13. Of the MPAs you mentioned in the previous question, are any **particularly susceptible to impacts** of marine non-indigenous species?
    a. Yes / No (indicate which MPA(s) and species you are referring to)
    b. If yes, why?
        i. Optimal conditions for high invader abundances
        ii. Vulnerable native species
        iii. Vulnerable habitat
        iv. Other: ____

14. In your experience, what **<u>information or strategies</u>** are used to:
    a. Prevent marine non-indigenous species from being introduced in an MPA?
        i. Awareness & outreach
        ii. Expert opinion (from whom?)
        iii. Invasion history
        iv. Risk assessment
        v. No information is used
        vi. Don't know
        vii. Other: ____
    b. Detect newly arrived marine non-indigenous species in an MPA?
        i. Monitoring
        ii. Risk assessment
        iii. Suitable habitat modeling
        iv. No information is used
        v. Don't know
        vi. Other: ____
    c. Mitigate impacts of established marine non-indigenous species in an MPA?
        i. Containment
        ii. Control population density
        iii. Monitoring
        iv. Risk assessment
        v. No information is used
        vi. Don't know
        vii. Other: ____
15. Is there any monitoring being done in MPAs you work on or are aware of that specifically targets marine non-indigenous species?

    ***Answer this question for each species/group that is relevant**
    a. If so, which methods are used (i – vii)?
    b. Explain which of these methods are used for monitoring presence/absence, abundance, or impact.
    c. Explain which of these methods are used to monitor species that have already established in the MPA, and which are methods are used to detect species that have newly arrived.
        i. eDNA
        ii. Genetic analysis of samples
        iii. Timed / Random walk or transect surveys
        iv. Trapping surveys (*e.g.* traps, seines, phytoplankton nets)
        v. Settlement plates
        vi. Visual surveys
        vii. Other: ____

16. Are there measures and resources available to prevent marine non-indigenous species from being introduced in the MPA(s)?
    a. Awareness/outreach campaigns
    b. Guidelines or rules
    c. Physical barriers
    d. Risk assessment
    e. Other: ____
17. From a management perspective, do you think marine non-indigenous species should be given more consideration during MPA management?
    a. If yes, why?
18. Regarding marine non-indigenous species and Canada's federal MPAs, what **three things** would you most like to see done?
    a. Increased awareness & outreach
    b. Increased application of non-indigenous species risk assessments and research outputs for MPA planning, management, and monitoring
    c. Increased funding for management, monitoring, and research
    d. Increased regulatory/legal measures
    e. More focused risk assessments and research on non-indigenous species in MPAs
    f. More involvement of Aquatic Invasive Species practitioners to help prevention, early detection, and mitigation of non-indigenous species in MPAs
    g. More prevention strategies
    h. Standardized response plans
    i. Other: ____
19. Is there anything else you would like to add or any questions you would like to go back to?
20. Is there anything that could have improved your interview experience?

Questions for MPA Practitioners Involved with Monitoring

1. What is your role in MPA monitoring?
2. How many years have you worked in this role?
3. Have you worked in a different role related to Canada's federal MPAs prior to your current role?
    a. Yes / No
    b. If yes, what was the role?
    c. How long did you work in that role?
4. In your opinion, how serious of an issue (ecological, commercial, cultural) are marine non-indigenous species **in general in Canadian waters** on a scale of 1 to 4? (1= not serious, 2= somewhat serious, 3= moderately serious, 4= very serious, not sure)
5. In your opinion, how serious of an issue (ecological, commercial, cultural) are marine non-indigenous species **in Canada's MPAs** on a scale of 1 to 4?
   (1= not serious, 2= somewhat serious, 3= moderately serious, 4= very serious, not sure)
    a. Are there any non-indigenous species you are particularly concerned about in Canadian waters?
        i. Yes / No
        ii. If yes, which species and why?

6. On a scale of 1 to 4, how familiar are you with ongoing management, monitoring or mitigation efforts for marine non-indigenous species **in Canada**? (1= not familiar, 2= somewhat familiar, 3= moderately familiar, 4= very familiar)
7. On a scale of 1 to 4, how familiar are you with ongoing management, monitoring or mitigation efforts for marine non-indigenous species **within Canada's MPAs**? (1= not familiar, 2= somewhat familiar, 3= moderately familiar, 4= very familiar)
8. Do you have a role in MPA planning?
   b. If so, what is your role?
9. The following factors have been identified as important stressors for consideration in MPA planning (e.g. Day et al., 2015; DFO, 2014; Mach et al., 2017)
   - Aquaculture
   - Climate change
   - Fishing
   - Habitat alteration and loss
   - Non-indigenous species
   - Pollution (*e.g.* chemical spills, nutrient loading, plastic)
   - Vessel traffic (*e.g.* noise, physical disturbance)
   - Other: ____

   a. In your opinion, which **three** stressors do you think are most important for considering in MPA placement?
10. Of the MPAs you are aware of or have worked on, are any **particularly susceptible to invasion** by marine non-indigenous species?
    a. Yes / No **(indicate which MPA(s) and species/groups you are referring to)**
    b. If yes, why?
       i. Anthropogenic mediated spread (*e.g.* aquaculture, ballast water, vessel traffic)
       ii. Suitable environmental conditions (*e.g.* depth, temperature)
       iii. Suitable substrate or benthic environment
       iv. Proximity to sources of non-indigenous species (*i.e.* high potential for spread)
       v. Habitat is highly disturbed or degraded (*i.e.* higher chance of invasion)
       vi. Other: ____
    c. If no, why not?
       i. Low chance of anthropogenic mediated spread
       ii. Unsuitable environmental conditions
       iii. Unsuitable substrate or benthic environment
       iv. Far from sources of non-indigenous species
       v. Habitat is relatively pristine with rich native community
       vi. Biotic resistance from native species (*i.e.* competition or predation by native species)
11. Of the MPAs you mentioned in the previous question, are any **particularly susceptible to impacts** of marine non-indigenous species?
    a. Yes / No **(indicate which MPA(s) and species you are referring to)**
    b. If yes, why?
       i. Optimal conditions for high invader abundances
       ii. Vulnerable native species
       iii. Vulnerable habitat
       iv. Other: ____

12. Are you aware of any marine non-indigenous species in the MPA(s) you are involved with or know about?
    a. If yes, please list them.
    b. Are you aware of any impacts or potential impacts associated with these non-indigenous species?
    c. Have any of these impacts been assessed or documented?
13. In your experience, what **information or strategies** are used to:
    a. Detect newly arrived marine non-indigenous species in an MPA?
        i. Monitoring
        ii. Risk assessment
        iii. Suitable habitat modeling
        iv. No information is used
        v. Don't know
        vi. Other: ____
    b. Mitigate impacts of established marine non-indigenous species in an MPA?
        i. Containment
        ii. Control population density
        iii. Monitoring
        iv. Risk assessment
        v. No information is used
        vi. Don't know
        vii. Other: ____
14. Is there any monitoring being done in MPAs you work on or are aware of that specifically targets marine non-indigenous species?

    ***Answer this question for each species/group that is relevant**
    a. If so, which methods are used (i – vii)?
    b. Explain which of these methods are used for monitoring presence/absence, abundance, or impact.
    c. Explain which of these methods are used to monitor species that have already established in the MPA, and which are methods are used to detect species that have newly arrived.
        i. eDNA
        ii. Genetic analysis of samples
        iii. Timed / Random walk or transect surveys
        iv. Trapping surveys (*e.g.* traps, seines, phytoplankton nets)
        v. Settlement plates
        vi. Visual surveys
        vii. Other: ____

15. To your knowledge, is there any training, information, or other resources available to those who do on the ground monitoring that can help them identify or assess marine non-indigenous species? (*e.g.* a guidebook or training session).
    a. If so, explain what is available.
    b. Do you communicate with aquatic invasive species (AIS) practitioners in your region? If so, how?
        i. Data sharing platforms
        ii. Informal conversations
        iii. Meetings
        iv. Review of published reports on non-indigenous species
        v. Other: ____
16. If a new marine non-indigenous species is discovered within an MPA you monitor are you responsible for the response?
    a. If yes, please explain the process.
        i. Is the process different depending on the species?
    b. If not, who is responsible for this process?
        i. Is there a person/organization you can report sightings to (for non-indigenous species in general or specifically marine non-indigenous species)?
17. From a monitoring perspective, do you think marine non-indigenous species should be given more consideration during MPA monitoring?
    a. If yes, why?
18. Regarding marine non-indigenous species and Canada's federal MPAs, what **three things** would you most like to see done?
    a. Increased awareness & outreach
    b. Increased application of non-indigenous species risk assessments and research outputs for MPA planning, management, and monitoring
    c. Increased funding for management, monitoring, and research
    d. Increased regulatory/legal measures
    e. More focused risk assessments and research on non-indigenous species in MPAs
    f. More involvement of Aquatic Invasive Species practitioners to help prevention, early detection, and mitigation of non-indigenous species in MPAs
    g. More prevention strategies
    h. Standardized response plans
    i. Other: ____
19. Is there anything else you would like to add or any questions you would like to go back to?
20. Is there anything that could have improved your interview experience?

Questions for AIS Practitioners

1. Which category best describes your role as an AIS practitioner?
    a. Management
    b. Monitoring
    c. Research
    d. Risk assessment
    e. Other: ____
2. What is your role regarding AIS?

3. How many years have you worked in this role?
4. Have you ever worked in a role related to Canada's federal MPAs?
    a. Yes / No
    b. If yes, what was the role?
    c. How long did you work in that role?
5. In your opinion, how serious of an issue (ecological, commercial, cultural) are marine non-indigenous species **in general in Canadian waters** on a scale of 1 to 4? (1= not serious, 2= somewhat serious, 3= moderately serious, 4= very serious, not sure)
6. In your opinion, how serious of an issue (ecological, commercial, cultural) are marine non-indigenous species **in Canada's MPAs** on a scale of 1 to 4? (1= not serious, 2= somewhat serious, 3= moderately serious, 4= very serious, not sure)
    a. Are there any non-indigenous species you are particularly concerned about in Canadian waters?
        i. Yes / No
        ii. If yes, which species and why?
7. On a scale of 1 to 4, how familiar are you with ongoing management, monitoring or mitigation efforts for marine non-indigenous species **in Canada**? (1= not familiar, 2= somewhat familiar, 3= moderately familiar, 4= very familiar)
8. On a scale of 1 to 4, how familiar are you with ongoing management, monitoring or mitigation efforts for marine non-indigenous species **within Canada's MPAs**? (1= not familiar, 2= somewhat familiar, 3= moderately familiar, 4= very familiar)
9. Do you have a role in MPA planning?
    a. If so, what is your role?
10. The following factors have been identified as important stressors for consideration in MPA planning (e.g. Day et al., 2015; DFO, 2014; Mach et al., 2017).
    - Aquaculture
    - Climate change
    - Fishing
    - Habitat alteration and loss
    - Non-indigenous species
    - Pollution (*e.g.* chemical spills, nutrient loading, plastic)
    - Vessel traffic (*e.g.* noise, physical disturbance)
    - Other: ____

    a. In your opinion, which **three** stressors do you think are most important for considering in MPA placement?
11. To your knowledge, are there any strategies for facilitating communication between MPA practitioners and AIS practitioners?
    a. Data sharing platforms
    b. Informal conversations
    c. Meetings
    d. Review of published reports on non-indigenous species
    e. Other: ____

12. Are you aware of any marine non-indigenous species in the MPA(s) you are involved with or know about?
    a. If yes, please list them.
    b. Are you aware of any impacts or potential impacts associated with these non-indigenous species?
    c. Have any of these impacts been assessed or documented?
13. Are there measures and resources available to prevent marine non-indigenous species from being introduced in the MPA(s)?
    a. Awareness/outreach campaigns
    b. Guidelines or regulations
    c. Physical barriers
    d. Risk assessment
    e. Other: ____
14. In your experience, what **information or strategies** are used to:
    a. Prevent marine non-indigenous species from being introduced in an MPA?
        i. Awareness & outreach
        ii. Expert opinion (from whom?)
        iii. Invasion history
        iv. Risk assessment
        v. No information is used
        vi. Don't know
        vii. Other: ____
    b. Detect newly arrived marine non-indigenous species in an MPA?
        i. Monitoring
        ii. Risk assessment
        iii. Suitable habitat modeling
        iv. No information is used
        v. Don't know
        vi. Other: ____
    c. Mitigate impacts of established marine non-indigenous species in an MPA?
        i. Containment
        ii. Control population density
        iii. Monitoring
        iv. Risk assessment
        v. No information is used
        vi. Don't know
        vii. Other: ____
15. Are marine non-indigenous species **adequately** considered during the MPA planning process?
    a. Yes / No / Don't know
    b. If yes, why?
    c. If no, why not?

16. If a new marine non-indigenous species is discovered within an MPA are AIS practitioners responsible for the response?
    a. If yes, please explain the process.
        i. Is the process different depending on the species?
    b. If not, who is responsible for this process?
        i. Is there a person/organization MPA monitoring teams can report sightings to (for non-indigenous species in general or specifically marine non-indigenous species)?
17. Which **three** areas are most important to focus **AIS monitoring**:
    a. Areas susceptible to high risk invaders
    b. Areas with a high impact invaders
    c. Areas with high non-indigenous species richness
    d. Important natural areas that are not protected (*e.g.* biologically and ecologically significant areas)
    e. MPAs
    f. Vector hubs – aquaculture facilities
    g. Vector hubs – ports and marinas
    h. Other: ____
18. Which **three** areas are most important areas to focus **AIS management**:
    a. Areas susceptible to high risk invaders
    b. Areas with a high impact invaders
    c. Areas with high non-indigenous species richness
    d. Important natural areas that are not protected (*e.g.* biologically and ecologically significant areas)
    e. MPAs
    f. Vector hubs – aquaculture facilities
    g. Vector hubs – ports and marinas
    h. Other: ____
19. In your opinion, which **two** strategies are the best to prevent marine non-indigenous species within MPAs?
    a. Invasion history
    b. Non-indigenous species awareness & outreach (*e.g.* Watchlist)
    c. Regulations
    d. Risk assessment
    e. Vector awareness & outreach (*e.g.* hull cleaning)
    f. Other: ____
20. From an AIS perspective, do you think marine non-indigenous species should be given more consideration during:
    a. MPA planning?
        i. If yes, why?
    b. MPA management?
        i. If yes, why?
    c. MPA monitoring?
        i. If yes, why?

21. Regarding marine non-indigenous species and Canada's federal MPAs, what **three things** would you most like to see done?
    a. Increased awareness & outreach
    b. Increased application of non-indigenous species risk assessments and research outputs for MPA planning, management, and monitoring
    c. Increased funding for management, monitoring, and research
    d. Increased regulatory/legal measures
    e. More focused risk assessments and research on non-indigenous species in MPAs
    f. More involvement of Aquatic Invasive Species practitioners to help prevention, early detection, and mitigation of non-indigenous species in MPAs
    g. More prevention strategies
    h. Standardized response plans
    i. Other: ____
22. Is there anything else you would like to add or any questions you would like to go back to?
23. Is there anything that could have improved your interview experience?

References for Interview Questions:

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Appendix D. Summary of Available Management Plans

Summary of available management plans for Canada's federal MPAs, including their location, approximate contribution to Canada's marine conservation target (to conserve 10% of the coastal and marine areas), year of MPA designation, year management plan was published, conserved biomes included in the MPA, if marine NIS were mentioned in general, and any specific NIS included in a plan. The type of MPA and approximate contribution to marine conservation targets (as of July 17, 2020) for each MPA came from (DFO, 2020b).

MPA Name and Location	MPA Type	Approximate contribution to marine conservation targets (%)	Year MPA was Designated	Year Management Plan Published	Conserved Biomes	Mentions Marine NIS in General	Specific NIS mentioned
Northwest Territories: **Anderson River Delta, Banks Island MBS No. 1 & 2, Cape Parry, Kendall Island**	MBS	Each <0.01	All designated in 1961	1992	Terrestrial, freshwater, and marine	No	None
Aulavik, Banks Island, Northwest Territories	National Park	<0.01	1992	2002	Terrestrial, freshwater, and marine	No	None
Auyuittuq, Cumberland Peninsula, Nunavut	National Park	0.02	1976 as National Park Reserve, Established in 2001 as a National Park	2010	Terrestrial, freshwater, and marine	No	None

Basin Head MPA, Basin Head, Prince Edward Island	*Oceans Act*	<0.01	2005	2016	Marine and freshwater	**Yes**	European green crab (*Carcinus maenas*) is invasive.
Boot Island, Boot Island, Nova Scotia	NWA	<0.01	1979	2014 (proposed)	Terrestrial, freshwater, and marine	No	None
Cape Jourimain, Cape Jourimain, New Brunswick	NWA	<0.01	1980	2018	Terrestrial, freshwater, and marine	No	Glossy Buckthorn (*Rhamnus frangula*) and Purple Loosestrife (*Lythrum salicaria*) are invasive. Phragmites (*Phragmites* communis) and Reed Canary Grass (*Phalaris arundinacea*) said to be potentially invasive.
Eastport MPA, Bonavista Bay, Newfoundland	*Oceans Act*	<0.01	2005	2013	Marine	No	None
Endeavour Hydrothermal Vents MPA, Juan de Fuca Ridge, British Columbia	*Oceans Act*	<0.01	2003	2010	Marine	**Yes**	None
Forillon, Gaspé Peninsula, Quebec	National Park	<0.01	1970	2010	Terrestrial, freshwater, and marine	**Yes**	None

Gilbert Bay MPA, Gilbert Bay, Labrador	*Oceans Act*	<0.01	2005	2013	Marine	No	None
Gulf Islands, Gulf Islands, British Columbia	National Park	<0.01	2003	2013 (draft)	Terrestrial, freshwater, and marine	No	Fallow deer (*Dama dama*) is listed as the most invasive species, impacting the ecological integrity and vegetation of Sidney Island.
Gwaii Haanas, southern Haida Gwaii, British Columbia	NMCA	0.06	2010, but the Haida Heritage Site designated in 1985 and the National Park Reserve in 1988	2018	Terrestrial, freshwater, and marine	**Yes**	Sitka black-tailed deer (*Odocoileus hemionus sitkensis*), black rat (*Rattus rattus*), and raccoon (*Procyon lotor*) are invasive.
Ivvavik, 200 km east of Inuvik, Northwest Territories	National Park	<0.01	1984	2018	Terrestrial, freshwater, and marine	No	None
John Lusby Marsh, Cumberland County, Nova Scotia	NWA	<0.01	1978	2016	Terrestrial, freshwater, and marine	**Yes**	*Phragmites* sp. are present but have not impacted salt marshes in the NWA

Kejimkujik, Maitland Bridge and Port Joli, Nova Scotia	National Park	<0.01	1974, but National Historic Site designated in 1995	2010	Terrestrial, freshwater, and marine	**Yes**	European green crab (*Carcinus maenas*), glossy buckthorn (*Rhamnus frangula*), purple loosestrife (*Lythrum salicaria*), smallmouth bass (*Micropterus dolomieu*), and chain pickerel (*Esox niger*) are invasive. Non-indigenous insects (*e.g.* gypsy moth (*Lymantria dispar dispar*) have had negative effects on tree species.
Kouchibouguac, Kouchibouguac, New Brunswick	National Park	<0.01	1979	2010	Terrestrial, freshwater, and marine	**Yes**	None
Musquash Estuary MPA, Musquash Estuary, New Brunswick	*Oceans Act*	<0.01	2006	2017	Marine and freshwater	No	None
Pacific Rim, from Tofino to Port Renfrew, British Columbia	National Park	<0.01	1970	2010	Terrestrial, freshwater, and marine	No	English ivy (*Hedera helix*), Scotch broom (*Cytisus scoparius*) and American/European dune grass (*Ammophila arenaria*) are invasive.

Pingo Canadian Landmark, south of Tuktoyaktuk, Northwest Territories	National Historic Site	<0.01	1984	2018	Terrestrial, freshwater, and marine	No	None
Queen Maud Gulf (Ahiak), south-west of Victoria Island, Nunavut	MBS	0.11	1961	2020	Terrestrial, freshwater, and marine	No	None
Quttinirpaaq, Ellesmere Island, Nunavut	National Park	0.04	1988	2009	Terrestrial, freshwater, and marine	**Yes**	None
Saguenay-St. Lawrence, Baie-Sainte-Catherine / Sacré-Coeur, and Tadoussac, Quebec	NMCA	0.02	1998	2010	Marine and freshwater	**Yes**	None
Sand Pond, 2 km inland of intertidal zone of Argyle River, Nova Scotia	NWA	<0.01	1978	2014	Terrestrial, freshwater, and marine	**Yes**	None
Sgaan Kinghlas-Bowie Seamount, 180 km west of Haida Gwaii, British Columbia	*Oceans Act*	0.11	2008	2019	Marine	**Yes**	None
Sirmilik, Bylot Island, Nunavut	National Park	<0.01	2001	2016	Terrestrial, freshwater, and marine	No	None
Tarium Niryutait, Mackenzie River Delta and estuary, Yukon and Northwest Territories	*Oceans Act*	0.03	2010	2013	Marine and freshwater	No	None

The Gully, Scotian Shelf, Nova Scotia	*Oceans Act*	0.04	2004	2017	Marine	No	None
Ukkusiksalik, 300 km north of Chesterfield Inlet, Nunavut	National Park	0.05	2014, but the park has been "operating in the spirit" of the Canada National Parks Act since 2003	2018	Terrestrial, freshwater, and marine	No	None
Wallace Bay, Wallace Bay, Nova Scotia	NWA	<0.01	1980	2018	Terrestrial, freshwater, and marine	**Yes**	Localized Norway maple (*Acer platanoides*) is present. The European green crab (*Carcinus maenas*) is recorded as not present but is considered a major threat.
Wapusk, 45 km south of Churchill, Manitoba	National Park	0.01	1996	2017	Terrestrial, freshwater, and marine	No	None

Appendix E. Reference List of Available Management Plans

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