WWF CANADA

REDUCING IMPACTS FROM SHIPPING IN MARINE PROTECTED AREAS: A TOOLKIT FOR CANADA

REDUCING IMPACTS FROM SHIPPING IN MPAS: EVALUATING TOOLS FOR MONITORING AND COMPLIANCE

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WEST COAST Environmental Law | ecelaw east coast environmental law

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EXECUTIVE SUMMARY

Commercial ship traffic is increasing in Canadian waters, with many vessels operating within the boundaries of federally designated marine protected areas (MPAs). These are areas that have been established to protect the marine environment, including habitats and species.[1] Vessels engaging in harmful shipping activities while within these areas may negatively impact the environmental, cultural, economic and social integrity of these sites. As there is limited literature surrounding monitoring and compliance tools of commercial vessel traffic within MPAs, this report aims to create a foundation on which future research can build.

The purpose of this report is to assess existing monitoring regimes that are used to ensure compliance by commercial vessel traffic with site-specific management measures in federally designated MPAs. This report identifies existing monitoring tools and compliance mechanisms, evaluates the perceived success rate of current protocols and explores potential barriers and areas for improvement. It also outlines best practices for ensuring compliance, identifies management gaps, discusses research limitations and highlights areas for future research. This information is based on expert opinion collected through semi-structured interviews with members of government and non-government organizations and further supplemented by a review of current literature.

Participants felt that compliance is best achieved through increasing mariners' awareness of shipping protocol while within MPAs and by placing a strong emphasis on voluntary measures, guidelines and best practices. This report explores several best practices for enhancing compliance, such as collaboration, communication, mariner education, active surveillance, incentive programs and adaptive management.

Overall, participants felt that the current monitoring regimes are successful at ensuring compliance of commercial vessel traffic within MPAs. However, there are multiple options available to further encourage compliance among mariners that could be explored to address impacts from shipping within Canadian MPAs, which are described in this report.

1 DFO, 2020b.

INTRODUCTION

We rely on shipping to transport nearly 90 per cent of traded products, making it the most heavily utilized mode of transportation in the world.[2] There were over 42,000 commercial vessels actively registered to operate in Canada in 2019, servicing over 550 ports across the country.[3] The geography of Canada contributes to a rich and diverse shipping environment as it has the most expansive coastline in the world, covering over 243,000km of Atlantic, Pacific and Arctic coasts.[4] Canada is also home to an abundance of islands and remote communities that heavily rely on shipping to import necessary supplies.[5] Shipping pressure is predicted to increase across the nation as the global population and average income grows, facilitating greater demand for Canadian bulk commodities and consumer goods.[6]

The Canadian Arctic is expected to see a rapid rise in shipping linked to development, trade and tourism as travel routes open as a result of climate change and melting sea ice.[7] For example, it is thought that the opening of the Northwest Passage – the quickest trade route from Asia to Europe – will greatly increase marine traffic in the region.[8] This is especially concerning as the Arctic is warming at a speed three times the global rate.[9] The Atlantic coast is seeing a consistent increase in commercial shipping into ports such as Halifax and Montreal, attributed to increasing trade with Asia.[10] Similarly, the Pacific coast is projecting increases in both the number and size of vessels transiting the area with the most prominent increases related to container and cruise ships.[11]

The rise in vessel traffic undoubtedly poses increased strain on the marine environment and may negatively impact marine life.[12] Importantly, Canada has committed to helping achieve the conservation target of protecting 10 per cent of coastal and marine areas by 2020 as outlined in the Convention on Biological Diversity (CBD) Aichi Target 11.[13] Moreover, Canada has committed to protecting 25 per cent of its waters by 2025, with hopes of reaching 30 per cent protection by 2030.[14] To meet these targets, Canada has been working toward growing its federal network of marine protected areas (MPAs) with many newly designated in the past decade and several more under development.[15] MPAs are generally created to protect the marine environment, their habitats and their species, with the intention of promoting environmental, cultural, social and economic prosperity.[16]

The long-term conservation of these areas is achieved through effective area-based management, including the use of regulations to minimize impacts from shipping within their boundaries.[17] However, these management measures are largely site-specific and are often difficult to effectively monitor for compliance under the current regime. Regulations can range from prohibiting high-risk shipping activities (such as dumping or anchoring) to voluntary measures (like slow down zones), although most MPAs do not explicitly regulate or prohibit shipping within their boundaries.

2 International Chamber of Shipping, 2020.
3 Transport Canada, 2019.
4 DFO, 2017.
5 Council of Canadian Academies, 2017.
6 Ibid.
7 Ibid.
8 Hauser, et al., 2018.
9 Transport Canada, 2019.
10 Port of Halifax, 2019; Port of Montreal, 2020.
11 Port of Vancouver, 2016; Port of Vancouver, 2019.
12 Council of Canadian Academies, 2017.
13 CBD, 2010.
14 ECCC 2019; DFO, 2019.
15 DFO, 2020b.
16 Ibid.
17 DFO, 2020a

This report highlights some of the environmental, cultural, social and economic impacts of commercial shipping within MPAs to better understand these impacts and highlight the need to address them. The results section leverages expert opinion obtained through semi-structured interviews to identify available monitoring tools and compliance mechanisms. It also evaluates how successful the current monitoring protocols are at ensuring compliance, identifies potential barriers and areas for improvement and explores how geographic location influences MPA management. The discussion section provides added details regarding the strengths and weaknesses of each tool, highlights best practices for achieving compliance and identifies management gaps. Finally, the report outlines limitations to this study and provides recommendations for future research.

MANAGEMENT PROBLEM

Marine protected areas are an effective tool in achieving long-term conservation of biodiversity,[18] assuming proper monitoring and enforcement measures are in place. However, there is relatively little research on how vessel traffic is being monitored to ensure compliance with specific management measures or how effective current monitoring regimes are at reducing shipping impacts within MPAs. Because there is no clear assessment of how commercial shipping is monitored to ensure compliance within federally designated MPAs in Canada, there is limited ability to compare strategies and determine best practices, making it more difficult to effectively monitor for compliance.

RESEARCH OBJECTIVES

The aim of this research was to examine existing practices for monitoring and compliance of shipping within federally designated MPAs in Canada; identify, describe and evaluate existing tools and compliance mechanisms; identify areas for improvement to enhance current protocols; outline best practices for ensuring compliance; and discuss management gaps.

Research was based on semi-structured interviews with subject experts in the field of MPAs, shipping or vessel traffic monitoring. This data was further supplemented by a review of current literature. This report provides a comprehensive overview of the current monitoring regimes in Canada for achieving compliance of commercial vessel traffic with specific MPA management measures, creating a foundation for future research. Although not the primary intent of this report, this information may help inform management decisions when supplemented with additional data.

18 DFO, 2020a.

ESTABLISHING DEFINITIONS

It is essential that terminology is clearly defined and understood in the context of this report. Several key terms are outlined below.

Marine protected areas (MPAs)

As defined by the International Union for Conservation of Nature (IUCN), a marine protected area is "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values."[19] These are areas that are designated to protect the marine environment and promote cultural, social and economic enrichment.[20]

Federally designated MPAs in Canada

There are many kinds of MPAs in Canada with varying conservation objectives and protection standards. These include provincial or territorial MPAs, federal MPAs and joint federal and provincial MPAs. For the purpose of this study, the term MPA only pertains to those which are federally designated in Canada, established by Fisheries and Oceans Canada (DFO), Environment and Climate Change Canada (ECCC) or Parks Canada (PC). These include Oceans Act MPAs, National Marine Conservation Areas (NMCAs) and marine National Wildlife Areas (mNWAs). These also include the marine portion within other federally protected areas such as National Wildlife Areas (NWAs) and Migratory Bird Sanctuaries (MBSs) as well as the Saguenay-St. Lawrence Marine Park (Figure 1).

Commercial vessel traffic

These are vessels that are owned and operated for commercial purposes such as the transportation of goods and services, travel and tourism. This includes all cargo ships, tankers, tug and barge, ferries, cruise ships and other large commercial tourism vessels. Fishing vessels have been purposefully excluded from this study as they often make routine stops within these areas and are regulated under the Fisheries Act.

19 IUCN, 2012.
20 Reuchlin-Hugenholtz and McKenzie, 2015.

Figure 1. Map of Canadian MPAs.

DFO Oceans Act MPAs (red), DFO marine refuges (blue), PC NMCAs (yellow), ECCC NWAs and MBSs (green); image modified from DFO, 2019. To view this image as an interactive map, please visit dfo-mpo.gc.ca/oceans/maps-cartes/conservation-eng.html

IMPACTS OF SHIPPING IN MPAS

Commercial vessel traffic can negatively impact the marine environment and under certain circumstances can prove detrimental to marine wildlife. This is especially true for sensitive habitats and vulnerable species that MPAs are designated to protect. This section of the report identifies key concerns regarding commercial vessel traffic in MPAs, including environmental, cultural, social and economic impacts.

ENVIRONMENTAL IMPACTS

Environmental impacts are often the direct consequence of shipping activity and can result in a range of consequences from minor interferences with wildlife behaviour to detrimental outcomes for an individual or population. These impacts can be attributed to underwater noise, chemical pollution, marine debris, invasive species, habitat disturbance, vessel strikes or other harmful practices.

Noise pollution

There are several factors contributing to the underwater noise generated by commercial shipping vessels. These range from the speed of travel to elements of the overall design and construction, such as vessel size, vessel type, engine type, hull form, propeller cavitation and the use of water bubbler systems.[21] Generally, commercial ships produce low frequency noise, which has been known to cause adverse effects on marine life.[22] These effects include decreased reproduction, hearing loss, auditory masking, disorientation, heightened stress response and shifts in habitat due to area avoidance. Underwater noise can also impede natural life functions and essential behavioural responses such as mate selection, communication, foraging and predator avoidance.[23]

Chemical pollution

Commercial ships can discharge various chemical pollutants into the water, either intentionally or unintentionally. These pollutants include greywater (i.e., untreated wastewater from shower, sink and laundry), blackwater (i.e., sewage), fuel discharge, oil and heavy metals released from scrubbers, among other sources. These pollutants are harmful to both marine life and habitat for many reasons. For example, these substances can accumulate on the seabed creating an anoxic environment, coat the gills of fish creating respiratory distress and asphyxiation or increase nutrient content in the water resulting in toxic algal blooms.[24] Additionally, as pollutants are discharged from vessels carrying passengers and cargo from around the world, they can act as vectors to transmit disease.[25] Even the release of small quantities of chemical pollutants can be enough to cause significant harm to the environment as they can disperse rapidly throughout the water column. Chemical pollution is also difficult to clean up, and its impacts are difficult to mitigate.

21 IMO, 2014; Southall et al., 2017.
22 Southall et al., 2017.
23 ASMA, 2009; Southall et al., 2017.
24 Nackle, 2016.
25 Ibid.

Marine debris

Marine debris can come from many sources and refers to materials such as plastic, paper, metal, rubber, glass or textiles that find their way into the marine environment. It is suggested that a significant portion of marine debris in the ocean is attributed to shipping activity.[26] This is a pervasive issue as the debris takes years to disintegrate while simultaneously releasing harmful chemicals into the environment. An example of this is the release of persistent organic pollutants such as DDT from degrading plastics.[27]

As plastic debris breaks down, it transforms into microplastics, which, if ingested, can bioaccumulate in the body. The accumulation of microplastics in the body often results in impacts cascading through the food web, from microscopic plankton to 170-ton blue whales. This process can lead to fatal complications such as starvation and toxicity buildup, which can result in liver failure.[28] Likewise, larger marine debris has been known to asphyxiate wildlife, either through direct consumption or entanglement, proving fatal in some instances. Lastly, as debris never completely leaves the environment, it continues to cause problems long after the ships are gone.

Invasive species

Invasive species in the marine environment are commonly introduced through commercial vessel traffic, through either the process of ballast water exchange or biofouling.[29] This is of rising concern because international trade continues to increase, facilitating greater opportunities for invasive species to be introduced. These organisms can threaten natural habitats and disturb the food web as they lack native predators to control their population. This often allows them to thrive in their new environment and damage fragile ecosystems. In Canada, invasive species have been known to reduce biodiversity, threaten existing species, limit productivity, introduce disease and degrade water quality and habitats, among other impacts.[30]

Vessel strikes

Cetaceans are at greater risk of vessel strikes than smaller marine mammals, such as pinnipeds, due to their larger body size, slower response time and limited maneuverability.[31] This is a particular threat to large baleen whales because they tend to travel alone and are less easily detected compared to those species that travel in large groups.[32] Regardless of the species, vessel collisions with any wildlife can prove lethal on impact, though they are more likely to cause trauma, hemorrhaging, broken bones and propeller wounds in cetaceans, which may result in delayed fatal complications.[33]

Habitat disturbance

Habitat disturbance has been highlighted in each of the above examples of environmental impacts; however, anchoring and vessel groundings also result in direct physical disturbance to the habitat. Anchors can be dragged across the seabed, removing biota and creating divots on the seafloor, which further alter the benthic habitat. Similarly, these impacts are illustrated on a much greater scale when vessels collide with substrate such as shallow shelves and become grounded. Often, extensive corrective effort is needed to free these vessels, promoting further disturbance to already compromised habitat. In both events, sediment is resuspended in the water column, increasing turbidity. This is harmful for multiple reasons. For example, suspended sediment limits the amount of light entering the marine environment, impeding the success of flora, and it can smoother the benthic environment as it settles, proving detrimental to sponges and seagrass beds.[34]

26 Agamuthu, et al., 2019.
27 Ibid.
28 Ibid.
29 ClearSeas, n.d.
30 Ibid.
31 ASMA, 2009.
32 Ibid.
33 Ibid.
34 Todd, et al., 2015.

CULTURAL IMPACTS

MPAs can be created to preserve areas of natural and cultural heritage in Canada, including areas that have been traditionally used by Indigenous Peoples.[35] The degradation of the marine environment may negatively influence a person's sense of place and pose challenges for both cultural and spiritual identity. In some instances, the impacts from commercial ship traffic may result in the degradation of traditional hunting grounds (e.g., Eclipse Sound within the Tallurutiup Imanga National Marine Conservation Area). This not only threatens food security for the communities that rely on these areas, but it can negatively impact their bond with the land.[36] It may also limit the development of valuable skills, such as hunting, food preparation, survival techniques and navigation, and hamper the transfer of traditional knowledge and experiences from one generation to the next.[37] For example, food insecurity can be attributed to noise pollution or other harmful shipping practices that can lead to behavioural shifts, forcing species to migrate outside of their natural habitat to avoid added stressors.[38] In cases such as this, individuals are no longer able to rely on that species for traditional services.

SOCIAL AND ECONOMIC IMPACTS

On a larger scale, increased vessel traffic can be linked to economic development through globalization and increased trade. However, it can also be linked to a decline in social and economic prosperity when considered at the local level. This is because harmful shipping practices can degrade the marine environment, which can have cascading economic impacts, such as loss of revenue for communities.

MPAs are also known to increase fisheries' benefits, often yielding larger catch by acting as a tool to replenish stock.[39] MPAs also contribute to sustaining fisheries' livelihoods and promote a high quality of life and social well-being for the surrounding communities.

Furthermore, MPAs are often viewed as an integral part of any community as they provide a space for education, eco-tourism, employment and leisure.[40] Therefore, the degradation of the environment from increased shipping in MPAs can result in social impacts, such as reduced quality of life and loss of research and educational opportunities, and economic impacts, such as loss of livelihood.[41] It is important that these areas remain well protected to promote community growth and social prosperity.

35 DFO, 2020a.
36 Carter, et al., 2018.
37 Hoover, et al., 2016.
38 Carter, et al., 2018.
39 Reuchlin-Hugenholtz and McKenzie, 2015.
40 Reuchlin-Hugenholtz and McKenzie, 2015; MPA Network, n.d.
41 MPA Network, n.d.

METHODS

A qualitative approach was employed to achieve the research objectives of this study using semi-structured interviews supplemented by a review of current literature (see Figure 2).The interview questions were organized into four sections: management, monitoring, compliance and additional information (see ***Appendix A*** for the full set of questions). This approach proved beneficial as some interview candidates were more familiar with certain sections, allowing them to speak more directly to their experiences while leveraging new ideas. Interview candidates were selected using one of two methods: 1) an internal review in which WWF-Canada researchers were asked to recommend participants of interest; or, 2) a snowball sampling approach by which participants suggested other experts who might provide valuable insight for the study. The candidates were deemed subject-matter experts in the fields of MPAs, shipping or vessel traffic monitoring. The interview list comprised members of various government agencies, academia and private organizations across Canada (see Table 1).

A series of 11 virtual interviews were conducted using Zoom, with 17 participants over a three-week period, with the exception of one interview which was submitted in writing (see Table 1). Transcripts were generated from audio recordings of the interviews, and appropriate edits were made prior to being sent back to the participants for their review and approval, at which time participants were able to retract, revise or add any additional information to the transcript. The final copies were then anonymized to the agency level (i.e., all names were removed). Using an inductive approach, the interviews were then manually coded in NVivo – a qualitative data computer software – to identify key themes (see ***Appendix B***) prior to being incorporated into the report.

The data was then supplemented with current literature, including a review of MPA management plans, regulations, legislation and available tools for monitoring and compliance. This information was used to support the findings and provide additional clarification where needed.

Figure 2. Flowchart of research methods

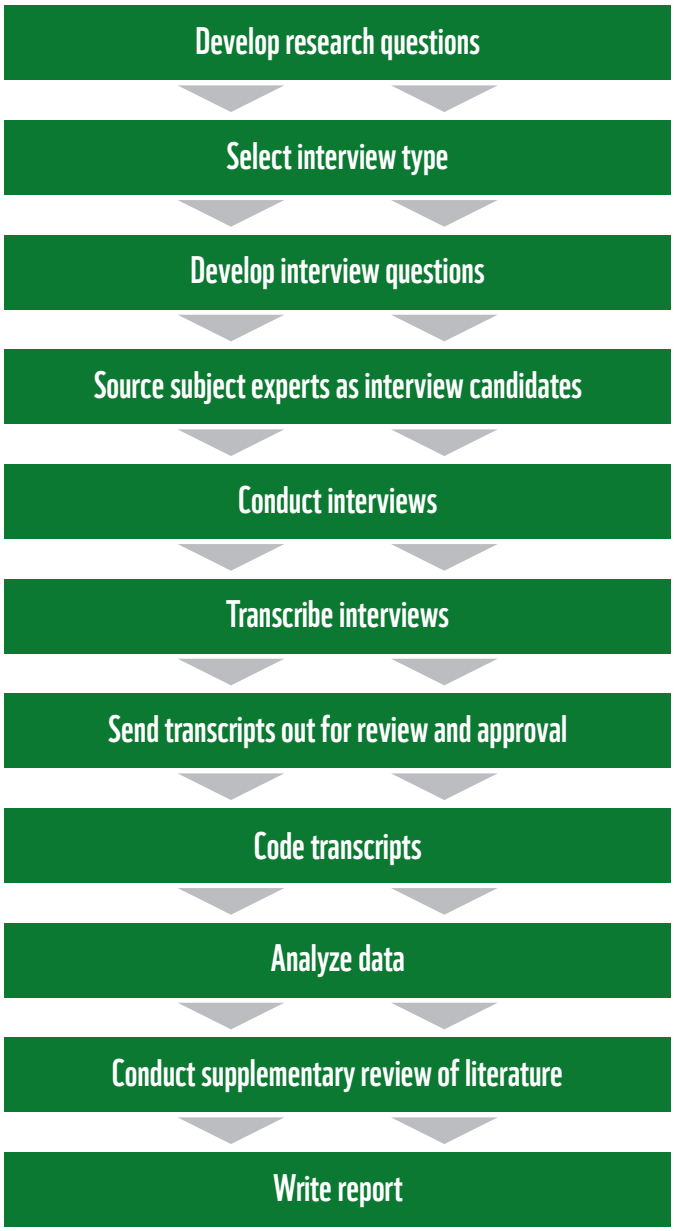


Table 1. Summary of research participants

Affiliation	Department/Organization	Number of interviews	Number of participants
Government	Fisheries and Oceans Canada (DFO)	1	1
Government	Canadian Coast Guard (CCG)	1	1
Government	Parks Canada (PC)	1	2
Government	Environment and Climate Change Canada (ECCC) – Canadian Wildlife Service	3	5
Government	Transport Canada (TC)	1	4*
Private organization	Wildlife Conservation Society (WCS)	1	1
Academic and private organization	Dalhousie University – MEOPAR	2	2
Academic and private organization	University of Victoria – NEMES	1	1

*Exact number of individuals estimated, as response was submitted in writing.

RESULTS

This section highlights various monitoring tools, mechanisms for compliance and the success rate of current monitoring protocols at ensuring compliance based on the results of 11 expert interviews with 17 participants.

This section also identifies potential barriers and areas for improvement in order to enhance the effectiveness of those monitoring regimes, as well as compares monitoring protocols for inshore, offshore and Arctic MPAs. Recognizing potential avenues to overcome these barriers is essential to understanding how to move forward to reduce impacts to wildlife and to maintain the ecological integrity of MPAs in Canada.

MONITORING TOOLS

Table 2 presents a list of available tools used to monitor vessel traffic, as identified by participants. These tools are categorized based on whether they are currently in use to monitor commercial vessel traffic within federally designated MPAs in Canada. They are marked "Yes" for in use, "No" for not in use and "Unclear" if not easily discerned. If a tool has only been used for pilot studies or is still in a developmental or trial period for use in MPAs, they are labelled "unclear." The discussion section of this report describes and evaluates these tools in further detail.

Table 2. Monitoring tools identified by participants

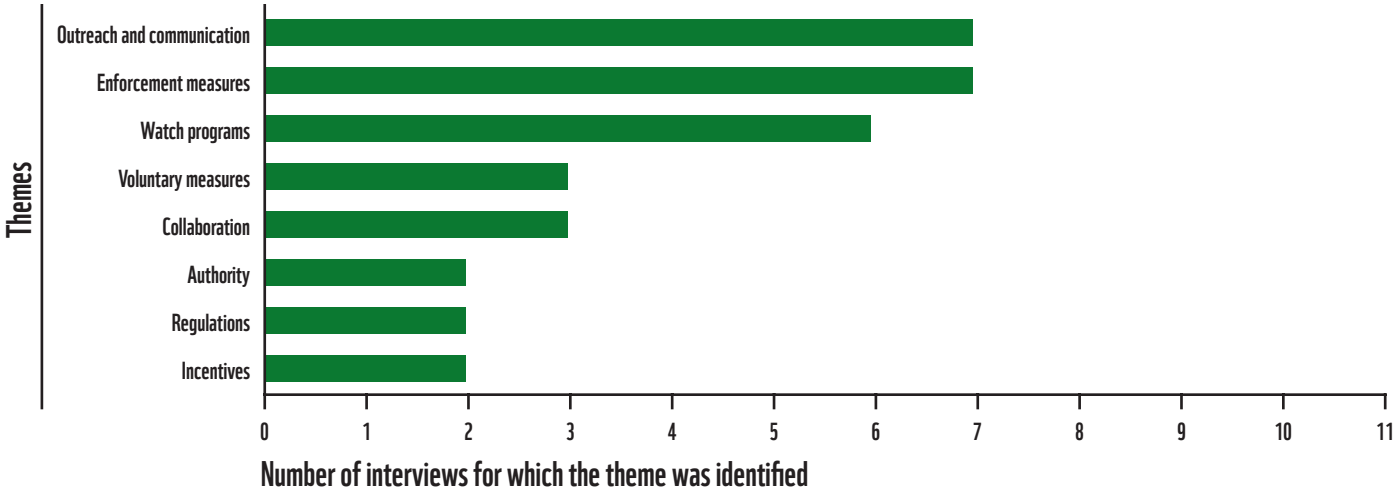
Monitoring tools	In use
Automatic Identification System (AIS)	Yes
Satellite-AIS (S-AIS)	Yes
Long-Range Identificaion and Tracking (LRIT)	Yes
Aerial surveillance	Yes
Radar	Yes
Satellite imagery	Yes
Cameras	Yes
Acoustic recording	Unclear
Marine guardianship program	Unclear
Infrared cameras	No
Smart buoys	No
Designated patrol officers	No

COMPLIANCE MECHANISMS

This section identifies mechanisms to promote compliance for commercial vessel traffic within MPAs, as identified by participants. The mechanisms are further categorized into key themes based on the number of interviews during which they were identified (see Figure 3). Their order is not representative of which mechanisms ensure the greatest success rate. Mechanisms vary from mariner education programs to strict sanctions for non-compliance, and each theme of mechanisms is further described. The general opinion of how best to achieve compliance is captured by one participant below:

"In Canada, the most socially accepted way of achieving compliance is through voluntary mechanisms, collaboration and communication; that seems to be the Canadian approach. Governments, local communities and provinces are reluctant to impose regulations because it often requires enforcement and often results in people being unhappy with the outcomes, so it is not a desired approach; but, in some cases, it is required." – ECCC

Figure 3. Mechanisms to promote compliance of commercial vessel traffic within federally designated MPAs in Canada



Outreach and communication

Outreach includes measures to increase awareness and education among mariners such as the "Notice to Mariners," "Mariner's Guides" and electronic charting. Communication includes geofencing technologies and automated alert systems. Participants also identified transponding buoys and two-way communication via AIS as possible tools to improve communication; however, these technologies are not currently used in Canada. With these technologies, automated alerts directly enter the instrument panel in the bridge of ships informing mariners that they have entered an MPA and to follow appropriate protocols. Alternative solutions that are used in Canada include the ability to directly contact ships by radio or email. This allows officers to inform a ship of its whereabouts in relation to the MPA and provide additional information, as needed, regarding appropriate protocols. Effective outreach and communication are considered by participants as proven mechanisms to ensure compliance in Canada, as expressed below:

> *"Our ability to affect these MPAs is just our ability to monitor them to find out what the vessels are doing – their intentions – and then providing a direction or recommendation if needed. For example, if you have an area with a voluntary slowdown zone, we can't direct a vessel to do anything in there, but we can still ask them if they know about this slowdown and if* they are intending to participate. Very often they just don't know and will leave right away." – CCG

In this instance, CCG noticed a vessel within a slowdown zone, actively reached out to the captain making them aware that the vessel had just entered a slowdown zone where voluntary measures were in place and was able to successfully ensure compliance through raising awareness.

Enforcement measures

Enforcement measures such as courtesy checks, routine inspections and sanctions are also thought to ensure compliance.

Courtesy checks can be performed by government vessels or aircraft, where, if time permits, government officials may be able to check on vessels that appear to be stopped or engaged in unusual behaviour while within an MPA if those checks are authorized by law (which can be dependent on where the ship is located). This is considered a common practice and requires the collaboration of multiple departments.

> *"We've also tapped into some of the enforcement tools. For example, if there was some kind of suspicious activity or something that we wanted to have a closer look at based on some of these positional reports, there is the potential for us to work with [other departments] and ask if they are in this vicinity to please take a look at this vessel … that's pretty standard." – DFO*

Routine inspections may be used to ensure vessels are in compliance with various requirements such as proper AIS maintenance and reporting. The other frequently discussed mechanisms for ensuring compliance involve issuing sanctions to those vessels that do not comply. Some participants expressed the view that larger, more severe punishments could be a viable method of holding mariners responsible for their actions. This could be in the form of formal warnings, monetary fines, barring captains from entering Canadian waters or other effective bans based on the severity of their actions. For example, participants suggested that first-time offenders receive a warning while repeat offenders receive a fine. Participants thought that using sanctions to ensure compliance would deter poor behaviour, promoting a punitive approach. Others suggested that follow-up does not necessarily lead to punishment; it can simply be used to inform mariners that regulators are aware of their behaviour in hopes that they correct it without further interference.

Watch programs

Dedicated watch programs and other forms of direct observation are identified as effective mechanisms to ensure compliance. The idea is that mariners who are aware of being continuously monitored, or believe that they are being continuously monitored, will behave appropriately because they perceive there to be a greater chance of being caught. This mechanism has resulted in measurable slowdowns:

> *"I'm not sure if it was the AIS that ensured compliance as much as [it was] the follow-up. So, it was clear to the operators that they were being observed, and then there was a commensurate slowdown in their speed." – MEOPAR*

For this mechanism to be effective, it is important that the industry is aware that they are being monitored by various mediums. Participants have offered several examples of where this approach has proven effective in their experience. Firstly, the National Aerial Surveillance Program (NASP) monitors vessels through their pollution patrols, which are equipped with remote sensors that allow them to easily detect as little as one litre of oil on the surface of the water, making them an effective deterrent against polluters. Secondly, observers are required to monitor whale-watching operators to ensure compliance in the Saguenay-St. Lawrence Marine Park. Lastly, Canada's Pacific coast has 24/7 monitoring of 100 per cent of the coastline out to 50 nautical miles (NM) by the CCG, who are tasked with observing incoming radar and AIS signals. It has been expressed that under these conditions, monitoring to ensure compliance has had great success and should be used in areas where this approach is possible.

Voluntary measures and collaboration

> *"I think in general that this approach in all areas across the country is a really solid approach. It demonstrates community engagement and community buy-in, which … is the best way to achieve long-term environmental outcomes." – ECCC*

Participants felt that voluntary measures and collaboration help build partnerships and community support at the local level. Part of this approach is realized through co-management committees and agreements that involve others in the monitoring and regulatory process. This is thought to help foster positive relationships and build stewardship to encourage mariners to voluntarily slow down and respect suggested guidelines. One interview revealed that this approach was successfully demonstrated in an MBS in Nunavut where the regulations are not strong enough to ensure compliance on their own; however, when the regulatory mechanisms were used in conjunction with this collaborative process, the community was able to effectively control activities within that area.

Authority and regulations

Government participants noted that many mariners seek official sources of information and are presumably more likely to comply with guidelines when they are brought to their attention by an authoritative body such as government, as opposed to an environmental group. It was also noted that ensuring compliance through regulations should be considered a last resort, after other means have been exhausted.

> *"There is obviously a role for regulation, and […], in my opinion and in my experience working in the protected areas program, regulations are a necessity when you can't achieve compliance or conservation outcomes from other means" – ECCC*

Incentives

Non-government participants felt that incentives may be a more effective solution when given to reward good behaviour, rather than strengthening regulations and sanctions. The rationale for this suggestion is that disincentives may lead to reduced usage of tools as expressed below:

> *"If [monitoring tools] are viewed as tools that are used for enforcement, then [they] could lead to reduced usage or there would be a sentiment toward reduced usage – if it was only used as a negative tool as opposed to a positive one. That said, using [monitoring tools] in combination with incentives would probably be more productive then negative disincentives." – MEOPAR*

SUCCESS RATE OF MONITORING AND COMPLIANCE PROTOCOLS

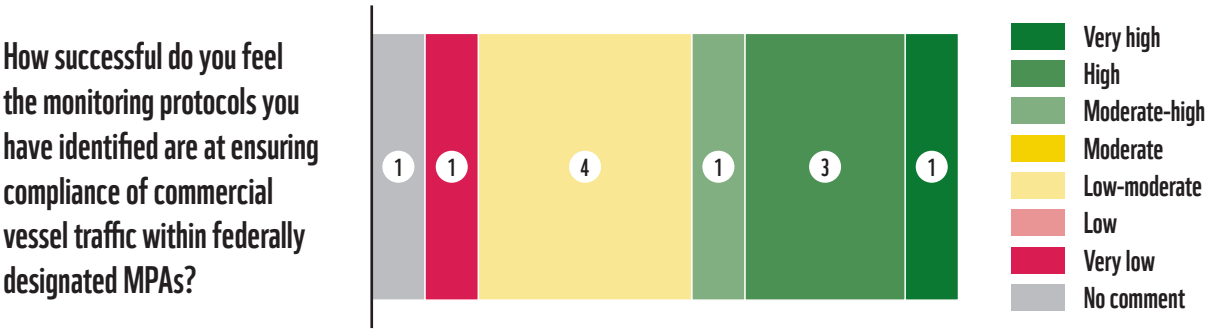
Participants were asked to rate the success of the monitoring and compliance protocols that they previously identified. They were provided a table (see Table 3) to use as a guide to promote consistency in responses across all interviews and were asked to provide a rationale to support their rating.

Table 3. A guide to assessing the success rate of monitoring protocols to ensure compliance within MPAs

Success rate	Definition
Low	Unsatisfactory, does not meet performance requirements, often linked to low levels of compliance
Moderate	Improvement needed, results are not consistent across MPAs or vessel type, often linked to moderate levels of compliance
High	Meets or exceeds expectations, often linked to high levels of compliance

Based on the suggested guide (Table 3), participants were asked to subdivide each category to include a greater spectrum of possibilities. Most participants felt that the protocols in place rated between moderate to high in their success at ensuring compliance, while one felt compliance was low and another chose not to comment (see Figure 4). Generally, participants felt that improvements are needed in order to ensure higher levels of compliance.

Figure 4. Success rate of monitoring protocols for ensuring compliance of commercial vessel traffic within federally designated MPAs in Canada, as perceived by participants (N=11)



High success rate

Half of the interviewees that provided a comment felt that the protocols in place are highly successful at ensuring compliance. All five of these interviewees made direct reference to remote sensing tools such as AIS and radar as being the primary tools used for monitoring commercial vessel traffic. For example, one participant affiliated with the Marine communication and traffic services program (MCTS) at CCG provided a "very high" success rate, as the monitoring and compliance protocols exceed expectations for nearby MPAs. This particular protocol provides 100 per cent coverage for all vessels >20m in length within 50NM from the coast. Although this does not capture vessels <20m in length, the participant felt that this is not a significant issue, as many commercial vessels are above this size and would therefore be flagged using this protocol. This participant's rational for a "very high" success rating is captured in the excerpt below:

> *"[Vessels] are being monitored 24 hours a day, somebody is sitting there staring at them and looking at their movements and is being paid to make judgement against the rules and what is best for the protection of the coastal environment; so in that aspect, compliance would be very high, because there's somebody looking at every action and every interaction." – CCG*

For this example, it should be noted that while MPAs within 50NM of the Pacific coast are viewed as achieving high compliance, this compliance is a secondary result of the monitoring protocols in place to prevent vessel collisions (not to monitor vessel activity in MPAs). Thus, the "very high" success rating attributed to this particular protocol is only true for MPAs within this finite area and is not mirrored in other parts of Canada.

Moderate success rate

In comparison, the four interviews that expressed a moderate rating discussed tools such as overflights, cameras and permitting as methods to ensure compliance. The following excerpts represent their rationale for selecting a moderate rating:

> *"If you look at all the marine pollution prevention work, Canada's got a pretty active presence. We see weekly overflights in most of the MPAs. It's starting to feel like we've got a pretty good handle on it. So, I would probably say moderate because I think we're doing okay given the amount of resources that have been put into it. I think we still have a lot more we could do to improve." – DFO*

> *"The compliance promotion efforts we have undertaken have resulted in less illegal entry into the ECCC protected areas in Nunavut. The cruise ship compliance especially has definitely improved through permit applications. However, some of the current tracking tools, like AIS and the remote cameras, are not able to track all vessels." – ECCC*

Looking beyond what is required of the MCTS sector of CCG, it was noted that remote sensing technology such as AIS and radar are more likely to have a "moderate to high" success rate. This information was provided as a general opinion, not specific to any one MPA or management plan. The rationale behind this rating is that there are still improvements to be made where remote sensing technology does not currently capture all commercial vessels or all vessel activity, or does not provide the same data latency for all MPAs. Additionally, this participant felt that in order to be awarded a "high" or "very high" rating there should be few to no infractions, which is not currently the case.

> *"I'd say at least medium to high. Not sure I want to say high because I don't know how many people slip through the cracks … High would be virtually never any infractions, and I don't think we're at that stage." – MEOPAR*

Low success rate

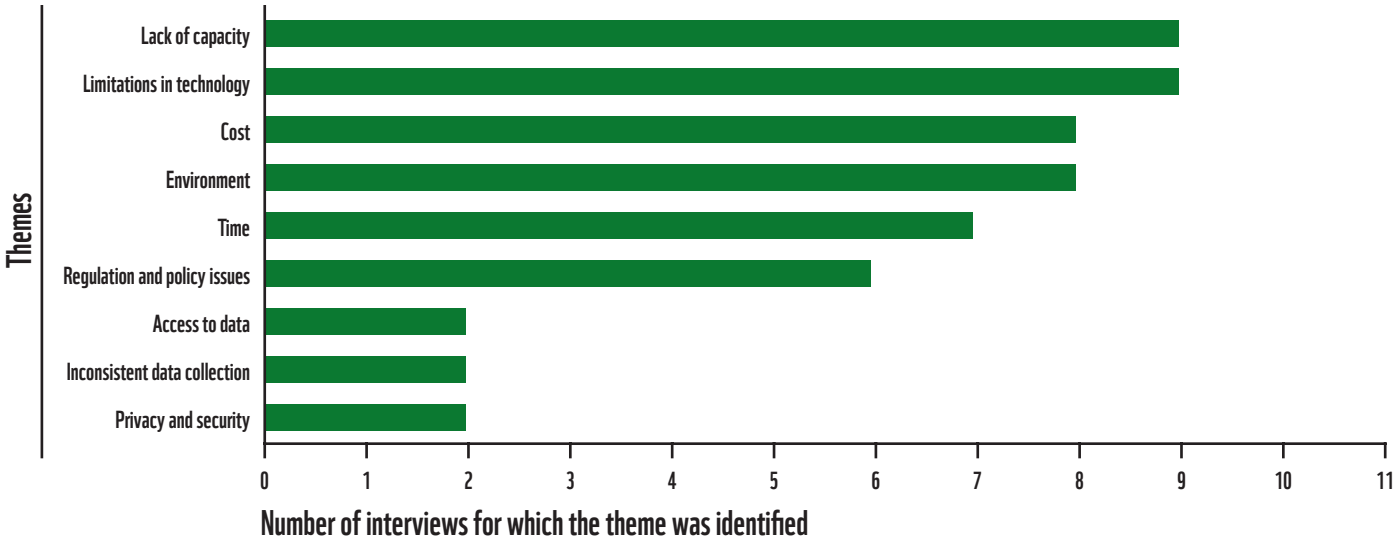
One participant expressed a "very low" success rating and felt that the barriers were too cumbersome at this time to provide a higher rating. They noted that within a specific MPA, compliance of recently imposed voluntary measures were not achieved and may be largely attributed to a lack of general awareness of the rules by mariners and a lack of time to adequately incorporate them into travel plans. The participant also noted that the MPA was only recently designated and added that there is hope for higher compliance in coming years under the same protocol as mariners become more aware of the area.

> *"For more recent rules [such as] going certain speeds [and] avoiding the MPA, that compliance has so far been very low, but I think that's partly to do with uptake. It's a very new rule that was put in place late in the season last year. So, people are already out on the water when the rules are put in place. So, I'm hopeful that this year and next year could show a lot higher compliance, simply because people have had longer for the uptake." – WCS*

BARRIERS TO SUCCESS

Participants were then asked to describe potential barriers or challenges that they felt may inhibit the success of the monitoring protocols at ensuring compliance of commercial vessel traffic within federally designated MPAs. The responses ranged from specific limitations in the monitoring tools to systematic barriers in the structure and organization of the protocols themselves. The concerns noted during the interviews are categorized into key themes to better represent the data (see Figure 5). The themes are ordered based on the number of interviews that identified them as an issue. No correlation should be assumed between importance and the number of times these themes were identified. For example, "privacy and security" does not pose less of a barrier than "limitations in technology"; rather, it was simply identified in fewer interviews.

Figure 5. Barriers to successful monitoring and compliance of commercial vessel traffic within federally designated MPAs in Canada



Lack of capacity

Participants mentioned lack of capacity as a barrier, as it is thought that not enough people are currently employed to effectively monitor for compliance and or make compliance a priority. They noted that in many cases, the notifications from AIS and S-AIS are sent to an email account where they remain in an archival database unless there is specific reason to access the data, like notifying regional colleagues or enforcement officers. Additionally, government offices are not available in some remote regions, meaning that in certain cases offices in Ontario may be monitoring activity in the Arctic rather than those regions monitoring their own areas.

Non-government participants noted that a common challenge for them is having enough staff with the appropriate expertise to carry out and coordinate the activity as the data in its raw form is not easy to work with and requires a special set of skills to undergo proper analysis.

For areas where staff actively monitor for compliance, such as in the MCTS centres, it was noted that there are issues with being able to monitor all vessels simultaneously while an event is occurring. For instance, the CCG noted that if an officer is called to deal with an impending infraction, there is a period of time where other vessels could slip through undetected. This is why CCG has requested more officers and supervisors be hired and that the four current vessel traffic service sectors be split into five zones, to allow for greater support when monitoring vessel traffic, which they expect to be brought into effect in 2021.

Limitations in technology

This theme refers to issues with the monitoring tools themselves, mainly addressing limitations with AIS and S-AIS, such as the potential for these systems to relay incorrect information or be tampered with. Other issues with reporting in both AIS and S-AIS have been identified as limited fields for data entry (e.g., vessel name), coarsely defined vessel types (e.g., not being able to differentiation between container ships and bulk carriers) and the reuse of Maritime Mobile Service Identities. The latter is thought to make it difficult to trace repeat offenders or take corrective action as the vessel identified for non-compliance may no longer be operating under its previous identity or multiple vessels could be using or sharing the same identity. Other technological limitations include the inability to properly identify ships detected using radar or optical satellite, meaning these tools must be used in unison with other available technologies.

Range was often identified as a barrier; for example, terrestrial AIS has a maximum range of 50NM in which it can successfully detect signals from ships. Similarly, radar is also limited in range but is largely dependent on the altitude at which the device is installed. On the Pacific coast of Canada, the radar is positioned to detect roughly the same distance as terrestrial AIS, approximately 50NM. As range can be a limiting factor, it was expressed that remote areas such as the Arctic, which are more sparsely populated with receivers, do not benefit from the same amount of coverage, resulting in potentially large blind spots or data gaps. Participants noted that these blind spots also occur on the Atlantic coast, where there are several large MPAs. For example, it was stated that officers are not actively monitoring vessel movements between Halifax, NS, and St. Johns, NL, and other areas along the Atlantic shoreline. Therefore, this data would need to be recovered using satellite technology.

Issues with signal processing, positional alerts and data latency were also noted by participants to have resulted in data discrepancies with respect to S-AIS. This is in part dependent on which constellation the satellite is operating under, as it may be expected to be overhead at extended intervals, resulting in fewer pings. Given the possibility for many issues with S-AIS, LRIT has been proposed as a more reliable option, though data latency remains a key concern as signals are broadcasted every 6 hours. Additionally, LRIT data belongs to the ship's flag state and access to this data must be requested and, if approved, is provided via archives that include their own set of limitations. Participants also reported issues with using camera and video for monitoring. These tools offer a narrow scope of capabilities, in the sense that they can only monitor specific areas within a site, such as nearshore passages or choke points. They also require large amounts of data processing time and need routine maintenance.

Beyond issues with the tools themselves, participants have expressed doubt in having the appropriate tools available for use to effectively monitor for compliance of all vessel activities and commercial vessels. Some participants felt that this is largely a research field as opposed to an operational field and that technologies need to be improved before they can effectively monitor all activities of concern such as ballast water exchange and greywater discharge.

> *"I just don't know if we're there with technology … in terms of ballast water and discharge of greywater … I'm not quite sure the technology is there [to track it effectively]. Again, just not yet having the tools to manage all aspects of shipping that we would want to look at." – PC*

Cost

Another limiting factor is cost, which participants identified as creating a barrier to being able to provide equitable access of resources in remote areas such as the Arctic (as in, there is a very limited quantity of terrestrial AIS receivers in the north). Remote locations like the Arctic require more extensive planning to get access to these tools and to have them set up in their desired location, as well as to hire and train staff to monitor and analyze the data, all of which increase costs.

Tools themselves, like AIS and satellite tracking technology, are expensive to purchase, both for the agency requiring the data, because they must purchase satellites or subscriptions, and for the vessel operators who must purchase and maintain the AIS units aboard their ships. It was reported that less expensive tools such as cameras can also become costly when the time and energy required to process the data are considered. This also applies to data where human analysis or processing is required – if there are staff involved, the operation costs are high, especially for larger operations such as MCTS centres.

Environment

Environmental barriers include both the physical location (e.g., remoteness) of the MPA and the weather conditions present in the area. Participants noted that environmental challenges are more prevalent in the Arctic because the region regularly experiences harsh weather conditions. These conditions are thought to make it more difficult to report and monitor instances of non-compliance because weather interferes with the performance of the tools. For example, harsh weather may result in tools being more likely to require regular maintenance and may cause greater issues with receiving signals. It is also thought that the electromagnetic field or atmospheric channels in the Arctic may interfere with some technologies being able to work at full capacity. It has been suggested that similar challenges face the southern region of Canada as cloud coverage and extreme weather conditions such as hailstorms may also temporarily impede the usefulness of the tools.

> *"In terms of successfully monitoring, a huge barrier [for Arctic MPAs] is the remoteness." – WCS*

Time

Time has been identified as a barrier by several participants for a number of reasons. Firstly, the processing time required to analyze the data is a barrier as it increases operational costs. Secondly, the time at which the data is made available (e.g., real-time data versus archival data) is a barrier as archived data encourages post hoc analysis which impedes compliance by facilitating late detection of incidents. Thirdly, the time between detection and follow-up is a barrier as longer lag times between the incident and the time needed to provide corrective action reduce the success of ensuring compliance because an offending vessel may already have left the MPA or Canadian waters.

Additionally, not allowing enough time for mariners to understand new guidelines or regulations and incorporate them into travel plans is also thought to greatly impede compliance. One participant highlighted that they felt the current timeline for sending out information is not conducive to ensuring compliance, especially when the measures are

voluntary. They provided an example where mariners in the Arctic received the "Notice to Mariners" too late in the season. The mariners had already decided their travel routes and did not have enough time to adjust their plans to meet the new recommended guidelines, resulting in an observed lack of compliance. In this case, it is clear that the time provided to mariners to properly respond and incorporate the new information was inadequate to promote their ability to comply.

Regulations and policy issues

Participants noted that regulation and policy concerns pose significant challenges when monitoring to ensure compliance. Challenges related to AIS include that not all vessels are required to carry AIS, leaving gaps in the data collection, and that AIS is mandated for use for safe navigation rather than for ensuring compliance with MPAs. Furthermore, there are no requirements on the quality of information that is entered into the system by mariners, and very few of the available data fields even require data entry. There are numerous fields in AIS that are often unused but could contribute to monitoring and compliance, such as navigational status (e.g., moored, underway, etc.) were they required. The lack of regulatory support behind using AIS to ensure compliance is thought to be negatively impeding its success rate.

> *"MPA enforcement is not explicitly in [the AIS] mandate for why they have to be carried. So, that's something that could be considered, that they also be maintained and operated in a way that supports that functionality." – MEOPAR*

Beyond the regulations surrounding the use of AIS, participants identified other barriers within regulation and policy. They noted that offshore MPAs are generally assumed to be more difficult to monitor successfully as there is less regulatory power outside of the territorial sea. Government participants added that this area is still actively monitored but suggested that Canada has less influence over shipping activity. Participants also expressed that there are certain gaps in MPA management plans that could be addressed for issues such as ballast water exchange and greywater discharge to help limit their occurrence from a policy standpoint. Lastly, they noted that fines may be too low to deter harmful practices. For instance, participants suggested that paying such small fines may be more acceptable to mariners than missing a deadline or engaging in the activity in the first place.

Access to data and inconsistent data collection

The main issues expressed under this theme are challenges with accessing other data sources, making datasets interchangeable and facilitating data sharing. Participants noted that there are technical challenges with making datasets interchangeable. These include the added time and processing power to run data quality checks and perform the necessary steps to ensure that the data can be merged appropriately without compromising the accuracy or integrity of the files.

Privacy and security

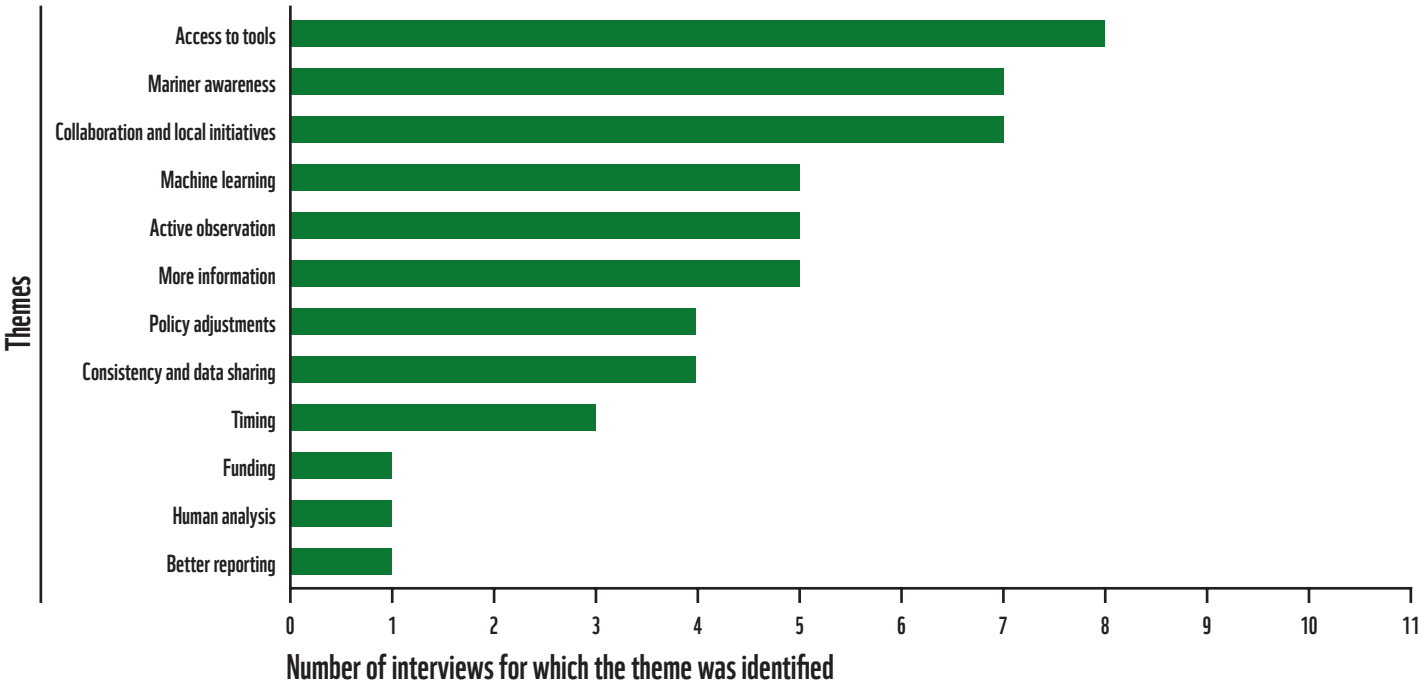
Participants noted one issue is the potential to breach privacy agreements when sharing data. For example, data could be confidential, containing personal or sensitive information, or could have been collected for a specific purpose. Thus, providing others access to that data for a different purpose, such as to ensure compliance within MPAs, may breach government protocol.

> *"There are things like Marine Traffic and Global Fishing Watch which are available to the public, but what about the sources of information that aren't public, and how do we even within the MPA community tap into some of those more confidential or classified types of information sources [without breaching protocol]?" – DFO*

AREAS FOR IMPROVEMENT

Similarly, participants were asked to describe areas that need improvement to overcome the previously listed barriers to success. Participants offered numerous strategies to enhance the current protocols in place. Their suggestions are categorized into key themes to better illustrate the results (see Figure 6). Once more, the themes are not ordered based on importance but rather based on the number of interviews that referred to them as an area that could be improved.

Figure 6. Areas for improvement to promote successful monitoring and compliance of commercial vessel traffic within federally designated MPAs in Canada



Access to tools

The most commonly suggested area for improvement is increased accessibility of tools, especially for the Arctic. For example, installing AIS receivers near Arctic MPAs would improve coverage and help alleviate some of the equity imbalance. The lack of access to tools is not only an issue for the Arctic, but remote MPAs in general, as one participant suggested installing an AIS receiver on Sable Island to improve monitoring for the Gully MPA. Others suggested that cameras could be installed to monitor areas of interest in inshore MPAs to reconcile data gaps for vessels without mandatory AIS carriage.

Moreover, participants expressed a need to develop new tools, such as ways to effectively monitor for ballast water exchange and greywater discharge. The Coast Guard provided an interesting example, as they requested a "whale desk" be developed on the Pacific coast of Canada to ensure a dedicated observer monitor for whale sightings and alert nearby vessels to respond accordingly. CCG noted that a whale desk would allow them to better monitor vessel traffic within interim sanctuary zones and slowdown zones, which consequently improves the active monitoring of inshore MPAs in the area.

Other participants suggested that promoting access to certain tools for purposes beyond MPA management could be an option when trying to improve the cost-effectiveness of new tools. For example, if the same tool to monitor vessel activity in MPAs could also reliably monitor vessel activity in ports or other areas of interest, then forming these kinds of resource-sharing partnerships may prove beneficial in increasing access to tools.

Participants also felt strongly about increasing access to tools that would alerts mariners upon entering an MPA and inform them of the appropriate protocols when transiting the area. Some participants suggested using transponding buoys and improving electronic charts, while others encouraged the use of geo-fencing with built-in plotter alarms to send real-time notifications to mariners.

Mariner awareness

Numerous participants stated that increasing mariner awareness is a leading factor in ensuring compliance. Participants noted that mariners are simply unaware of the guidelines and best practices in place, and thus their non-compliance is largely a product of a lack of information rather than disregard.

> *"With any infraction, by any human, in any situation, the question is: how much is deliberate and how much is inadvertent? So, you want to get the inadvertent stuff out right away to minimize the problem." – MEOPAR*

As awareness is gained through education, participants identified several pieces of information that should be clearly articulated to mariners to improve their general understanding of the importance of following regulations and recommended guidelines. They expressed the need to distinctly define Canadian environmental concerns and conservation objectives and how those objectives would be achieved. Participants noted the need for greater acknowledgement of voluntary measures, increased compliance promotion efforts, stronger outreach initiatives, real-time communication with captains, stronger advertising for guidelines and a greater focus on mariner education programs. Participants also mentioned that increasing access to tools that can effectively disseminate information to mariners, such as those outlined previously, would improve mariner awareness.

Collaboration and local initiatives

Collaboration and use of local initiatives are dually recognized for their important role in ensuring compliance. These suggestions are influenced by greater collaboration between federal departments and agencies, industry, external partners, researchers, knowledge holders, Indigenous Peoples and other relevant groups. For example, there is a push for closer involvement of Indigenous communities by leveraging marine guardianships and community watch programs. Participants felt that these initiatives promote stronger compliance because they allow groups to be more involved, participate in discussions and take ownership for environmental protection. Additionally, participants felt that through collaboration, there is an opportunity to leverage external strengths, such as human effort, expertise and networking, to overcome other barriers simultaneously, such as the lack of available resources. Some government participants suggested that industry could play a more active role in the monitoring program by collecting data through added sensors or onboard equipment. Industry would then be expected to report back that data to enhance the understanding on environmental conditions within more remote MPAs. This information could be used to detect high concentrations of discharge and help draw conclusions on what activities are occurring within those areas.

Based on participant responses, it appears that active collaboration has led to multiple success stories with monitoring to ensure compliance and should continue to be viewed as a useful tool. DFO highlighted one example, with respect to resource sharing, where it had funding and was able to join efforts with TC to help support NASP on the condition that they include boundary points for MPAs on their flight path. In doing this, NASP was able to capture information about vessel activity within those MPAs and report their findings back to DFO. This effective use of inter-agency collaboration is just one example of how partnerships can be used to accomplish conservation objectives.

Machine learning

In response to issues such as lack of capacity, time, cost and resources (which in part encourage the use of passive monitoring), participants proposed that machine learning and artificial intelligence (AI) technology can help mitigate these concerns. One participant commented that it is not unreasonable to think that algorithms could be easily developed to scan incoming alerts and flag anomalies in the data such as unusual or inaccurate data entry, not following speed restrictions or veering off course. They went on to explain that these algorithms could be used to recognize repeat offenders and could help limit the number of people needed to monitor the incoming data. Furthermore, they suggested that machine learning could promote near-real-time analysis, encouraging faster follow-up as it is assumed that any anomalies in the data would be detected automatically as they appear.

Building on that concept, participants suggested that AI could be used to develop criteria for follow-up and to inform officers. Although this technology is not thought to be readily available for that specific purpose currently, participants suggested that it could be retrofitted to meet these needs. Alternatively, they suggested that computational techniques or statistical assessments are more readily available, which can, with high accuracy, identify when incoming reports appear unlikely to be true. These notifications could be used to inform patrol officers who can then decide how to proceed, whether through conducting courtesy checks or radioing the captains.

Some participants also expressed an interest in developing a way to nest information within automated alert systems that relay information directly into the bridge of ships to notify mariners that their ship has been flagged for unusual behaviour, remind them of the appropriate protocols and notify officers if not corrected. This is thought to help reduce unintentional infractions as mariners would be informed of proper protocol upon entering an MPA. They also suggested developing a user-friendly interface for two-way communication through AIS to further increase mariners' awareness. These are only a few examples of how machine learning could be incorporated to improve the monitoring regime for MPAs. Regardless of the method chosen, it is clear that participants feel that

AI is a new frontier that could greatly improve the successful monitoring and compliance of vessels within MPAs.

> *"The development of these [AI] approaches and techniques that can detect suspicious activity and/or errors in AIS [is something that] I think would be valuable because it will build the confidence in being able to reliably use this data." – MEOPAR*

Active observation

The participants expressed a growing interest in improving the ability to actively observe vessels and conduct continuous surveillance of vessels when they are transiting within MPAs. It has been proposed that using real-time AIS capabilities, automated alerts to ships, overflights or patrol officers conducting courtesy checks could achieve these intended results. Regardless of the method, participants agree that the ability to maintain an active presence is thought to play a big role in deterring non-compliance. This is described in greater detail in later sections.

More information

Some participants felt that more information is needed to properly identify thresholds for non-compliance and inform decisions on shipping-related stressors and impacts of shipping within MPAs. One area identified as needing immediate improvement is widening the scope of data that is collected to focus on all vessel activity rather than vessel characteristics such as location, distribution and abundance. The purpose of this recommendation is to better understand the potential impacts from shipping activity within MPAs, based on the relative occurrence of vessels caught engaging in harmful practices. Similarly, it was proposed that attention should be given to evaluating the current level of compliance associated with shipping in MPAs. Participants felt that without a baseline assessment it is difficult to determine how much improvement is needed, and that more information is required to complete a comprehensive assessment.

Policy adjustments

Interestingly, both government and non-government participants identified the need to improve policy to better support monitoring for compliance. They suggested a variety of potential solutions including: 1) installing AIS devices in all commercial vessels; 2) mandating the use of AIS for compliance and enforcement purposes within MPAs; 3) requiring high-quality data reporting by all users; and, 4) requiring the use of additional fields for core-data entry. Certain government participants felt that using policy to support better practices could help build compliance through the prosecution of offenders in court, if necessary. Conversely, non-government participants felt that policy should be explored as a means to incentivize compliance rather than a means to enforce punishment. They noted that positive reinforcement is perhaps more effective than negative reinforcement.

Consistency and data sharing

Participants suggested that using a more consistent approach to monitoring could provide better insight into effective means of ensuring compliance by commercial vessels while inside MPAs, with the rationale being that MPAs do not exist in singularity but exist as a network and should be held to the same high-quality standards. Many participants recommended that terrestrial or satellite AIS be used as the minimum requirement to monitor vessel activity in all federally designated MPAs in Canada, while also suggesting that more site-specific tools should be used in conjunction with AIS technology when specific management measures are in place, such as prohibitions on dumping. Participants felt that a more uniform and streamlined approach to monitoring would improve mariners' understanding of what is expected of them within Canadian waters. This approach is thought to facilitate transparency and ensure compliance.

As mentioned above, consistency in tools and how they are used promotes data sharing across departments and with external agencies, as appropriate. A standardized approach facilitates data sharing as the datasets are more compatible with multiple interfaces, simplifying the analysis process. Participants mentioned that improving consistency can be a chance to invest additional resources into

common tools, making them less expensive and more easily accessible and thus available to a wider audience. They also identified a need for more effective sharing of information between data sources to bridge knowledge gaps by piecing together separate reports to extract more detailed information.

Timing

Three participants identified a need for more effort in strategic timing when disseminating information to mariners and conducting effective follow-up. They felt very strongly that early intervention allows for greater compliance, meaning the information is delivered with enough time to be properly understood and incorporated into mariners' travel plans. This is thought to significantly influence success because it provides an opportunity for mariners to ask for clarity and access additional resources as needed.

> *"Having things brought in early into the process makes them more easily accepted rather than being imposed last minute ... and thus, compliance can be fairly high." – PC*

Participants also felt that following up faster could help ensure compliance as vessels would be notified immediately or soon after they have failed to comply with management measures. Participant experience suggests that this would position officers to provide corrective action while the vessel is still transiting the MPA and within Canadian waters.

Funding

Funding was identified as an area of conflicting interest when it comes to improvements, considering cost was commonly listed as a barrier to improving compliance. However, increasing funding was not commonly suggested as an effective solution to the problem. This is because participants felt that the potential benefits are not significant enough to justify the cost of investment. Participants felt that there is not enough evidence to suggest significant improvements from increased funding; and since funds are largely collected through taxation, they felt that there are alternatives in which to invest funds that see greater social gain.

Human analysis and better reporting

Lastly, the need for greater human analysis (i.e., analysis conducted by humans) and better reporting practices were rarely noted as areas for improvement. One interview determined that human analysis is needed in order to validate the data as there can be missing data or duplicates based on how the data is recognized. They noted that human analysis can provide added clarity and help users understand the data in the context of the environment. Another participant noted that better reporting and monitoring practices internal to government are needed to provide more detailed results for analysis in order to better understand vessel activity within MPAs. This recommendation was provided as a general observation across government departments.

COMPARING MONITORING PROTOCOLS ACROSS MPAS

The management of MPAs is largely site-specific, and location can greatly influence the ability to effectively monitor an area. As such, monitoring to ensure compliance requires different strategies depending on the MPA's environment. This section explores the differences and similarities when monitoring to ensure compliance between inshore, offshore and Arctic MPAs, as identified throughout the interview process, including disparities in available monitoring tools. Table 4 provides a summary of what tools can be used based on the location of the MPA, noting that inshore MPAs have the most options while offshore and Arctic MPAs have access to just over half of the available tools. The following sections will provide further insight into Table 4.

Table 4. Available monitoring tools based on MPA location

Monitoring tools	Inshore MPA	Offshore MPA	Arctic MPA
AIS	✓		✓
S-AIS	✓	✓	✓
LRIT	✓	✓	✓
Aerial surveys	✓	✓	✓
Radar	✓		
Satellite imagery	✓	✓	✓
Cameras	✓		✓
Acoustic recording	✓	✓	
Marine guardianship program	✓		✓
Infrared cameras	✓		
Smart buoys	✓	✓	
Designated patrol officers	✓	✓	

Inshore MPAs

Shipping in MPAs that are located in Canada's internal waters and territorial sea is more easily regulated because Canada has full sovereignty and greater regulatory authority in this space under international law.[42] In general, these areas are often well monitored given that each of the monitoring tools presented in this report is available for use in inshore MPAs (see Table 4). However, participants noted that the following tools are more commonly used to monitor these areas: radar, terrestrial AIS, cameras, acoustic recording and marine guardianship programs. Due to their proximity to coastal receivers, inshore MPAs can experience high data latency and enhanced sampling rates (e.g., pings can be received every couple of seconds through AIS). This allows for near-real-time observation and can facilitate immediate follow-up. Participants have noted that high data latency increases the reliability of the data and creates a clear image of vessel movement in the area.

Participants noted that since vessels transiting inshore MPAs are relatively close to shore, officers have more options for effective follow-up, including contacting the captains, meeting them at port or sending out a patrol vessel if needed. It was suggested that these MPAs are more likely to be situated within the boundaries of other areas of interest, enabling them to be more easily monitored For example, the Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs are monitored continuously by the CCG, not because they are mandated to monitor the MPA but because it falls within their zone of coverage.

Additionally, participants noted that shipping in coastal sites enables greater compliance as the environment creates natural deterrents. For example, there are mandatory speed restrictions in some zones of the Musquash Estuary MPA;[43] however, DFO stated in their interview that the area is too shallow for most commercial vessels, making it difficult to speed or even transit the area, consequently ensuring high compliance. Another example is found in the management plan for the Tarium Niryutait MPA, which suggests that a supply route marked by CCG buoys should be followed by vessels whenever possible while transiting through.[44] However, Canadian Wildlife Service stated in their interview that compliance is, again, largely ensured by the environment itself, as it is a shallow estuary and vessels are unable to stray far from the recommended routes.

Conversely, participants recognized that there is greater risk of accidents occurring inshore due to an increase in navigational hazards, such as shallow shelves, and greater vessel density, which may warrant stronger monitoring efforts. This was deemed especially true when transiting through narrow channels and near busy ports, as is the case for the Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs. Participants also noted that it is more difficult to distinguish between vessels in highly congested areas such as inshore MPAs, prompting the need for mandatory high-quality data reporting in AIS.

Offshore MPAs

Although Canada has jurisdiction in the EEZ to regulate shipping, including for the purposes of exploration, extraction, conservation and management of its resources, and for the purposes of environmental protection, the ability to regulate is more restricted by international law and convention.[45] That is why participants felt that the best approach to governing offshore MPAs is largely through voluntary measures, guidelines, collaboration and agreement.

Offshore MPAs utilize LRIT, S-AIS, aerial surveys and other satellite-based technologies, in addition to acoustic monitoring, which it shares exclusively with inshore MPAs (see Table 4). Participants have noted that these tools tend to be more costly and resource intensive, making it more challenging to improve monitoring practices in offshore areas without leveraging partnerships and AI technologies. It was mentioned by government participants that due to the remoteness of these sites; they are less often patrolled and are less likely to benefit from the same data latency as their inshore counterparts. Another identified limitation to effectively monitoring offshore MPAs is the inability to provide direct observation through marine guardianships or MCTS centres.

42 UNCLOS, 1982.
43 Government of Canada, 2015.
44 DFO, 2013.
45 UNCLOS, 1982.

This can result in spatial and temporal "blind spots," especially if the data is archived and not automatically filtered for anomalies.

Participants noted two useful advantages that offshore MPAs have over inshore and Arctic MPAs. The first is that vessels are less congested in the offshore MPAs, making it easier to distinguish between ships and layer multiple data sources together to gather additional information (e.g., confirm vessel ID) compared to inshore MPAs. The second is that offshore MPAs south of 60 degrees benefit from being within the temperate zone and have access to additional resources in comparison to their northern counterparts. This includes greater accessibility to a wider range of monitoring tools, faster response times and increased aerial coverage through NASP, among other benefits.

Arctic MPAs

ECCC participants stated that their Arctic MPAs are managed using a highly collaborative approach between the Inuit and federal government through co-management boards and agreements. They added that since nearly all of these protected areas are remote, they are more difficult to effectively monitor for compliance. ECCC also explained that their monitoring strategy in the north is largely based on permitting, promoting compliance, raising awareness (for guidelines and voluntary measures) and facilitating continuous communication with mariners to encourage their participation.

While many Arctic MPAs are inshore, it is interesting to note that MPAs in this region share more similarities with offshore MPAs. It was identified that both share similar challenges associated with remote areas, such as limited availability of tools and increased resources needed to successfully monitor for compliance. Participants noted that Arctic MPAs are particularly disadvantaged as they face a larger equity imbalance regarding access to resources. Participants singled out the Arctic for having the lowest rate of coverage in Canada in terms of monitoring and for having very few terrestrial AIS receivers along its coastline. This means terrestrial AIS is not a viable monitoring option in most Arctic MPAs. Instead, participants stated that tools such as LRIT, S-AIS and other satellite-based technologies are more commonly used.

Participants highlighted that marine guardianship and other community watch programs have been more recently developed for the purpose of monitoring shipping to ensure compliance with management measures. Although these programs have not yet been used for monitoring MPAs specifically, they are thought to be a useful tool for MPAs in close proximity to Inuit communities. Established in 2017, the Inuit Marine Monitoring Program in Nunavut is one of many examples where a guardianship program has been effective. This program combines Inuit observation and local knowledge with real-time AIS data to fill in gaps about vessel activity and shipping impacts that are not readily being collected by the federal government.[46] This includes information on suspicious vessels, vessel speeds, concerns for wildlife, ship characteristics, vessel behaviour, activities, timing and other pertinent information.[47] The use of these programs for monitoring ships in Arctic MPAs is shared with their inshore counterparts, particularly inshore MPAs on the Pacific coast that neighbour many First Nations communities. For example, there are similar guardianship programs in development on Haida Gwaii, which incorporate Indigenous knowledge to effectively monitor inshore MPAs.[48]

Another effective monitoring strategy for Arctic MPAs is aerial surveys. These surveys are conducted by TC through NASP, which contributes 15 per cent of its budgeted flight hours (approximately 500 hours per year) to pollution patrols in the Arctic.[49] Although monitoring vessel traffic in MPAs is not the primary purpose of NASP, they do collect information on their activity and report back to the appropriate agencies (e.g., DFO, PC, ECCC) for follow-up.[50] Thus, it is through effective collaboration that government is able to monitor vessel activity for compliance with specific management measures in Arctic MPAs.

46 Indigenous Guardians Toolkit, 2016; Dawson, et al., 2019.
47 Dawson, et al., 2019.
48 Parks Canada, 2017.
49 TC, personal communication, July 3, 2020.
50 Ibid.

DISCUSSION

This section provides further detail on the monitoring tools and highlights best practices for achieving compliance of commercial vessel traffic within federally designated MPAs in Canada. It also identifies management gaps and offers suggestions to improve monitoring and compliance protocols.

EFFECTIVE MONITORING

As illustrated above in Table 2, many different monitoring tools are available. This section offers a brief description of each tool, outlines their uses in monitoring vessel traffic in MPAs and identifies their strengths and weakness (see Table 5).

Table 5. Summary of the strengths and weaknesses for each of the identified monitoring tools

Monitoring tools	Pros	Cons
AIS	• Real-time data • High data latency and sampling rate • Continuous data collection • Effectively detects presence of vessels within MPAs	• Expensive for vessel owners to install and maintain • Not mandatory for all commercial vessels • Can be tampered with, resulting in data gaps and misinformation • Data is largely archived and being used for passive monitoring at this time • Communication is largely one-way, limiting shore-to-ship communication • No mandate on use for compliance purposes, no quality control and not all available fields are required to be reported • Not used to its full potential; limited information available on vessel activity and compliance • Maximum range of 50NM from receiver • Few receivers are available in remote regions, reducing coverage
S-AIS	• Real-time data • Relatively high data latency and sampling rate • Continuous data collection • Effectively detects presence of vessels within MPAs	• Expensive for vessel owners to install and maintain • Not mandatory for all commercial vessels • Can be tampered with, resulting in data gaps and misinformation • Data is largely archived and being used for passive monitoring at this time • Communication is largely one-way, limiting shore-to-ship communication • No mandate on use for compliance purposes, no quality control and not all available fields are required to be reported • Not used to its full potential; limited information available on vessel activity and compliance • Expensive for data users to purchase satellite time • Issues with data masking and resolution
LRIT	• Global tracking system • Required of all vessels engaging on international voyage: cargo vessels and passenger vessels • Continuous data collection	• Low sampling rate (typically every 6hrs but can be increased to every 15min) • Limited data fields mean it must be used in conjunction with other methods • The data is transmitted to the ship's flag state and must be requested for use by other countries • Archival data used for post hoc analysis
Aerial surveillance	• Direct observation of vessels engaging in harmful activities • Aircraft are equipped with MPA boundary markers to clearly observe vessels within protected areas • Collaborative effort across government departments to share relevant information • Discourages harmful activity	• Harsh weather conditions and increased cloud coverage can impede successful overflights • Data gaps due to inconsistent data collection • Used in conjunction with other monitoring methods

Table 5. Summary of the strengths and weaknesses for each of the identified monitoring tools (continued)

Monitoring tools	Pros	Cons
Radar	• Real-time monitoring • 24/7 surveillance	• Detects vessels >20m length, thus not all commercial vessels are included • Restricted range (~50NM radius) • Range is further restricted by low visibility (e.g., rain, snow, fog) • Limited data (e.g., location, direction, speed) is obtained • Few towers available in Canada • Inaccurate detection due to shadows and sea-clutter
Satellite imagery	• Fine resolution allows vessels as small as 5m to be detected • Can detect discharge from vessels and other harmful practices	• Must be used in conjunction with other methods to identify vessels • Post hoc analysis
Cameras	• Capture images of vessels engaging in harmful activity • Ideal to gather information in nearshore areas where compliance is presumed to be low	• Narrow range, can only monitor small areas of interest not the entire MPA • Data is archived and data processing is time-consuming • Weather conditions impede success • Only captures clear images during daylight • Require frequent maintenance • Must be used in conjunction with other methods
Acoustic recordings	• Option of real-time data collection • Useful for monitoring vessel speeds and anthropogenic noise	• Must be used in conjunction with other methods to identify vessels • Only useful to monitor select vessel activities
Marine guardianship program	• Direct observation of vessel activities • Leverages local knowledge, capacity building, resource sharing, collaboration and partnerships	• Only useful for select inshore MPAs
Infrared cameras	• Capture images of vessels engaging in harmful activity • Ideal to gather additional information in nearshore areas where compliance is presumed to be low • Can be used in low visibility (e.g., light snow, light fog, light rain and complete darkness)	• Narrow range, can only monitor small areas of interest not the entire MPA • Data is archived and data processing is time-consuming • Post hoc analysis • Require frequent maintenance • Must be used in conjunction with other methods
Smart buoys	• Real-time data collection • Information disseminated directly to ships • Can be equipped with sensors to collect additional information (e.g., traces of discharge)	• Create additional navigational hazards in the water column • Not readily available in Canada
Designated patrol officers	• Direct observation • Effective follow-up	• Resource intensive (e.g., cost, time, capacity)

Automatic Identification System (AIS)

Vessels meeting the following criteria are required by the Navigational Safety Regulations to carry an AIS transponder within Canada's jurisdiction, including in the EEZ and the Arctic:

- ≥150 gross tonnage, carrying 12 or more passengers and engaged on an international voyage
- >300 gross tonnage engaged on an international voyage
- >500 gross tonnage and not engaged on an international voyage
- Any vessel not captured above engaged on a voyage that is not a sheltered waters voyage (which are voyages on internal waters like lakes and rivers, as set out in the *Vessel Certificates Regulations*)

Although this is a comprehensive list, it does not necessarily encompass all commercial vessel traffic transiting in MPAs.[51]

Terrestrial-based AIS and Satellite-AIS are widely used in Canada to promote safe navigation and collision avoidance, though there are several issues with using these technologies as previously alluded to. These systems are expensive, often requiring annual satellite subscriptions, and although data is made available in near-real-time there is still the potential for data gaps (e.g., receivers going offline) limiting their overall effectiveness.[52] Other weaknesses include that inaccurate data can be transmitted either intentionally or unintentionally (e.g., AIS "spoofing" or "tampering").[53] Participants also noted that in its current state, the data is largely archived by the user and passively monitored, further impeding it reaching its full potential. There is currently no mandate for AIS to be used beyond the purpose of safe navigation, no requirements for quality control over data that is being reported and limited requirements for information to be provided in data fields.[54] Thus, an entire range of useful data such as navigational status, speed or rate of turn is omitted.[55]

Other limitations include a maximum detection range of 50NM for terrestrial AIS with few receivers set up in remote locations, leading to areas of low coverage – especially in the Arctic region.[56] While S-AIS is not restricted in range, data masking and issues with the resolution are possible, making it difficult to distinguish between vessels.[57] AIS and S-AIS in their current state are useful tools when making initial observations such as the presence and absence of a vessel in an area. This is through effectively creating polygons or geofencing areas of interest, such as MPAs.[58] AIS technology is currently not being used to its full potential in Canada but shows promise in becoming the primary mode of vessel monitoring to ensure compliance.

51 Bereta, et al., 2019.
52 Brooke, et al., 2010; Lacarella, et al., 2020.
53 Golaya and Yogeswaran, 2019.
54 Navigation Safety Regulations, 2005.
55 Lacarella, et al., 2020.
56 Bereta, et al., 2019.
57 Lacarell,a et al., 2020.
58 Bereta, et al., 2019.

Long-Range Identification and Tracking (LRIT)

LRIT is used to track ships globally, made mandatory for Canadian vessels under the Canada Shipping Act and internationally by the IMO.[59] In Canada under the Canada Shipping Act, this system is required for any Canadian vessel, other than government vessels and pleasure crafts, if they are engaged on international voyages and are cargo vessels (>300gt) or passenger vessels (>12 passengers).[60] Communication signals are broadcasted at a minimum of every 6 hours to the ship's flag state; however, signals can be increased to a maximum rate of one every 15 minutes if requested.[61] As a vessel is only required to transmit information on its vessel ID, its coordinates and the date and time of transmission, LRIT cannot effectively be used to monitor for compliance on its own.[62] Because there is no information collected on the activities the vessel is engaging in or speed of travel, this tool is best used in combination with other monitoring tools to help fill data gaps for vessel traffic in offshore and remote areas.[63] This is supported through a study using LRIT tracks to infer speed between 6-hour interval position reports in the Gully MPA, in which it was noted that this method should be used with caution if attempting compliance monitoring.[64] Furthermore, as the information is only transmitted to the ship's flag state, authorities would need to contact their government and request this data, meaning it is often released as archived data.[65]

Aerial surveillance

Aerial surveys are conducted using the National Aerial Surveillance Program (NASP) through Transport Canada (TC). This program surveys areas along all three coasts, including Canada's EEZ, for over 3,000 hours each year.[66] The main objective of the surveys is to monitor shipping activity, ice conditions, marine security and pollution.[67] They use remote sensing equipment to conduct pollution prevention patrols, detecting and documenting oil spills and other pollutants such as chemical discharge and debris. The success of these flights is based largely on weather conditions as cloud cover can impair visibility.[68]

Additionally, aircraft are equipped with MPA boundary markers to highlight areas of interest. If a vessel is assumed to be non-compliant while inside an MPA during an overflight, the necessary information is recorded (e.g., vessel ID and observed activity, etc.) and shared with DFO and PC for appropriate follow-up.[69] Monitoring plans are often made in conjunction with DFO to patrol MPAs and in some cases include service level agreements for added monitoring of specific sites. For example, Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs were subject to one to two weekly patrols of up to 16 hours of flight time annually between 2014 and 2019.[70] Overflights collect data on vessel activity within the MPAs that is stored with AIS information in a database for later use, which makes it a useful tool for additional monitoring of areas of interest.[71] Aerial surveillance is considered a useful monitoring tool for ensuring compliance because it provides accurate visual reporting of vessel activity. The biggest challenge is temporal data gaps because monitoring is not continuous; therefore, aerial surveys are encouraged to be used in conjunction with other monitoring tools. Participants also felt that aerial surveillance greatly improves compliance because it is thought that the idea of being under a watchful eye discourages vessels from engaging in harmful activities. This is discussed in further detail in subsequent sections.

59 See regulation V/19-1 of the 1974 SOLAS Convention.
60 Long-Range Identification and Tracking of Vessels Regulations, 2010.
61 Long-Range Identification and Tracking of Vessels Regulations, 2010; Koropatnick, et al., 2012.
62 Long-Range Identification and Tracking of Vessels Regulations, 2010.
63 Koropatnick, et al., 2012.
64 Ibid.
65 Brooke, et al., 2010.
66 TC, personal communication, July 15, 2020.
67 Transport Canada, 2020.
68 Lacarella, et al., 2020.
69 TC, personal communication, July 15, 2020.
70 Lacarella, et al., 2020.
71 Ibid.

Radar

Radar is a commonly used tool to monitor vessels >20m in length, though it omits certain commercial vessels that fall below this size requirement.[72] The range of detection is often limited to within 50NM of the central tower, though the range can vary based on altitude because radar requires an unobstructed line of sight. Other limitations include erroneous detection of vessels attributed to shadows from waves, sea-clutter and other sources.[73] Fog and other low-visibility conditions like rain and snow can reduce the detection range.[74]

Radar is used to capture information about the location, direction and speed a vessel is travelling and should be used in conjunction with other monitoring tools. For example, CCG uses radar information collated with AIS data and relies on staff to actively and continuously monitor incoming vessels while communicating with vessels through VHF radio to provide navigational assistance. CCG believes that the protocols in place for the use of radar on the Pacific coast of Canada make radar a very successful tool when observing inshore MPAs in the area (Hecate Strait MPA, for example). Radar is not thought to be useful for monitoring MPAs outside of these regions and thus is a site-based solution. It should be noted that as part of the ocean protection plan, Canada will be adding ten or more new radar towers to expand coverage along both the Pacific and Atlantic coasts.[75]

Satellite imagery

There are several forms of satellite imagery available. For example, RadarSat was identified during the interviews and is used for multiple purposes including maritime surveillance, vessel traffic monitoring, environmental monitoring and disaster management.[76] It can detect a wide range of vessels, depending on the resolution used, with the extra-fine resolution being able to detect vessels of 5m in length,[77] well below the average size of commercial vessels.

A specific example where satellite imagery has been used to monitor MPAs is through the Integrated Satellite Targeting of Polluters (I-STOP) program. This uses space-borne synthetic aperture radar imagery to capture satellite images of the water to monitor and improve response to pollution.[78] It can detect oil spills and pollutant discharges in the water and gather information to report illegal and accidental activity, making it a useful tool to encourage compliance.[79] Because these images are captured using satellites, harmful activities can be observed discreetly, and vessels remain unaware that they are being monitored. This is especially useful in remote or offshore areas.

An interview with ECCC revealed that I-STOP has also been used to monitor for discharge and vessel groundings within the Scott Islands mNWA. Additionally, RadarSat is commonly used to monitor vessel presence within Oceans Act MPAs on the Pacific coast but has not yet been documented being used for compliance purposes.[80] The main challenges with satellite imagery are that the data must be compared to another data source, such as AIS, to extract information for specific vessel IDs and that analysis is often performed post hoc.[81]

72 Canadian Coast Guard, 2020a.
73 Ocean Navigation, 2009.
74 Ibid.
75 Government of Canada, 2020a.
76 Canadian Space Agency, 2019.
77 Lacarella, et al., 2020.
78 Government of Canada, 2020c.
79 Ibid.
80 Lacarella, et al., 2020.
81 Ibid.

Cameras

Participants revealed that cameras have been used to monitor vessel activity in coastal MPAs on the Pacific coast and in the Arctic. They noted one challenge is their limited scope: cameras do not have a wide enough angle to capture large portions of an MPA and have limited capabilities in adverse weather conditions and at night. Cameras are often used in narrow channels, "choke points" or in areas where there is an identified concern or interest within a specific portion of the MPA. For example, they could be used to target a specific area where compliance is presumed to be low. This data is captured, fed into a database and archived within the system making it time-consuming to analyze. Participants noted that the information collected can provide greater details into specific vessel activities; however, it must be paired with other tools to properly identify the vessels. Despite their challenges, cameras have been used for years to monitor human impacts within MPAs both in Canada and abroad and are proven to be an effective tool when used in conjunction with other methods.[82]

Acoustic recordings

Acoustic monitoring uses hydrophones to capture sound recordings of vessels transiting the area to deduce the speed of transit and monitor ship noise attributed to various activities. There are several programs geared toward monitoring vessel speed and noise frequency using acoustic recordings in the Pacific, one of which has led to the implementation of a noise reduction incentive at the port of Vancouver.[83] While there seems to be less acoustic work in Atlantic MPAs, a pilot study was performed in the Gully between 2005 and 2007; however, it has not been reintroduced.[84] It is apparent that acoustic monitoring is underway in Canada and is a possible approach to monitoring vessel traffic within MPAs but is not yet recognized as an appropriate monitoring tool for this purpose.

Acoustic recordings are being used more commonly in the United States, which indicates they would be an effective tool in Canada. For example, autonomous acoustic buoys are used in Stellwagon Bank National Marine Sanctuary, located in the centre of Boston's shipping lanes, to detect North Atlantic right whale calls and transmit their location to mariners to reduce impacts from shipping.[85] These buoys use real-time data, providing reliable and current information directly to the ships' captain in the form of polygons. In response, the vessels must reduce their speeds below 10 knots when transiting within these virtual polygons, effectively creating dynamic slowdown zones that move with the animals.[86]

Marine guardianship programs

Marine guardianships and community watch programs are an area of new development in terms of monitoring vessel traffic within MPAs. They are commonly led by Indigenous Peoples, and participants have noted that there is a growing interest in using these programs to monitor shipping activity in the Arctic and Pacific coast, especially in Haida Gwaii. Investments have increased to develop a strong network of Indigenous guardians across Canada. More than 40 programs have already launched.[87] These programs allow for direct observation of shipping activity and are geared toward coastal MPAs near communities. The Inuit Marine Monitoring Program is one example in Nunavut where local Inuit watchmen and AIS technology are working in unison to create a more detailed picture of shipping activity in the area.[88] These programs leverage Inuit knowledge and local capacity to improve shipping management and MPA planning.[89] They are also opportunities to build partnerships, share resources and collaborate outside of government departments. The aim of Indigenous guardianships is to "monitor ecological health, maintain cultural sites and protect sensitive areas and species,"[90] which aligns with the general purpose of many federally designated MPAs.

82 Bicknell, et al., 2016.
83 Port of Vancouver, 2018.
84 DFO, 2010.
85 Spaulding, et al., 2009.
86 Ibid.
87 Indigenous Leadership Initiative, n.d.
88 Indigenous Guardians Toolkit, 2020.
89 Ibid.
90 Indigenous Leadership Initiative, n.d.

Infrared cameras

Infrared cameras display all the same characteristics as regular cameras as noted above. The main difference is that they can detect activity in low visibility, rending them slightly more useful in comparison. Incidents of low visibility include complete darkness, light fog, light rain and light snow; however, adverse weather limits their range of detection.[91] They are currently not being used to monitor vessel traffic in Canadian MPAs but show promise when used in conjunction with alternative methods.

Smart buoys

An interesting example that has not yet been used in Canada, but which was proposed during the interviews, is the use of smart buoys. These are autonomous buoys that can be moored in the ocean to outline the perimeter of an area of interest, essentially creating a geofence. These buoys would ideally detect vessels within the area, transmit signals via satellite or towers and send alerts directly to the captains with information – such as both mandatory and voluntary measures – specific to the area. Participants have proposed that they also be equipped with sensors to collect data on the environment, such as traces of discharge, and potentially link those results to specific ships in the area.

This technology is already available in some capacity as highlighted by the Boston shipping example above. Similarly, mounting AIS transceivers on moored buoys has also been explored as an option. It is thought that the AIS technology could be adapted to outline detailed MPA boundaries and transmit that information to ships to alert them of the area. This would reduce the risk of vessels relying on navigational charts that may be outdated or that fail to include smaller MPAs.[92] This technology is also thought to be more cost-effective in comparison to radar beacons or other technologies offering similar navigational awareness at sea.[93] If smart buoys became more viable, participants felt that they have the potential to drastically improve monitoring to ensure compliance of all vessel traffic within MPAs in all waters.

Designated patrol officers

Currently, there are no designated patrol officers actively monitoring federally designated MPAs by water or by air in Canada. This has been proposed by participants as a possible monitoring tool for areas of high concern (e.g., an MPA with strict prohibitions on activities and low compliance). These officers would be responsible for conducting in-person surveillance as well as conducting appropriate follow-up and enforcement as needed. Although this type of monitoring is not officially being done in Canada, CCG noted that the Royal Canadian Navy and certain government vessels and aircrafts are known to conduct passive patrols within MPAs if prohibited activity is suspected, provided that they are in the area and that they have the capacity. Under this scenario, information would be documented and reported to the necessary agencies for appropriate follow-up. Another option not formally used in Canada but that is used in the United States is the use of courtesy checks. These occur when vessels that are suspected of misusing their AIS system or transmitting inaccurate information are flagged. Once these vessels have been identified, officers follow up and the vessel is not released from the courtesy check until they can demonstrate that they have corrected the situation.

91 Beier and Gemperlein, 2004.
92 Brooke, et al., 2010.
93 Ibid.

BEST PRACTICES FOR ACHIEVING COMPLIANCE

Compliance has traditionally been achieved through a regulatory regime that uses a top-down approach.[94] While a strong regulatory regime is necessary, there are other best practices that can aid in improving compliance, many of which were discussed by the participants of this study. This section provides additional detail about best practices for enhancing compliance for shipping activity in Canada's MPAs.

Enhanced collaboration

Generally, mariners are more willing to comply with management measures when they are developed in collaboration with industry.[95] This bottom-up approach helps them develop a sense of ownership over the creation of these measures and typically results in mutually beneficial solutions. This approach has proven effective at increasing compliance with voluntary speed restrictions in the St. Lawrence Estuary.[96] It is reasonable to assume that similar results can be achieved within MPAs using the same collaborative approach.

Participants noted that government departments already closely collaborate but that the perspectives of private organizations, industry, academia and Indigenous Peoples could be better incorporated. That has the potential to create monitoring partnerships that can harness the strengths of various groups such as human capacity, funding, access to tools and local knowledge and lead to more cost-effective and innovative solutions. Furthermore, a highly collaborative approach can remove unnecessary redundancy in the system by joining efforts and encouraging information and resource sharing. For example, if multiple parties are working on similar initiatives, they can pool their resources and focus on solving management gaps that they may not otherwise be able to solve as effectively through independent work.

Pairing multiple data sources can help reconstruct specific scenarios to better understand what activities occurred and who engaged in them. For instance, AIS data can display a ship's path while remote sensing data can detect oil spills and those data can then be overlapped to determine which ship is responsible for the spill. However, participants stated that this is not common practice and should be incorporated through future protocol. A similar approach that is gaining traction for Canadian MPAs is the Inuit Marine Monitoring Program, which pairs Indigenous guardians with AIS data. This combined approach provides greater detail on vessels' behaviour in inshore areas than either approach could provide if used alone. One government participant suggested that this strategy could help build corroborating evidence to prosecute repeat offenders, if needed. These are both examples where effective collaboration within government and local communities contribute to the collection of valuable data that cannot be captured through any one approach used on its own.

Participants also suggested that collaboration could improve how information is being disseminated to mariners. For example, government and environmental groups could work together to produce a comprehensive document, where mariners can access all information in one place. Overall, increasing collaboration in a constructive way that addresses specific concerns can provide many benefits for improving the current approach to monitoring for compliance of commercial vessel traffic within MPAs.

Continued communication and educational awareness

As mentioned previously, it is necessary that mariners are aware of the regulations and guidelines in place as well as the potential risks associated with non-compliance, such as impacts to the environmental, cultural and social integrity of an MPA. Making mariners aware of their actions and how they can reduce their impacts equips them with the knowledge to behave responsibly. This technique helps build compliance from the bottom up and is thought to be a more sustainable and long-term solution. Furthermore, mariners are more likely to comply when the known benefits of compliance

94 Sampson, et al., 2014.
95 Guzman, et al., 2020.
96 Ibid.

outweigh the consequences,[97] promoting the need to clearly articulate conservation objectives and how compliance with management measures can provide considerable benefits to the environment and society. In order for this to be more effective, investments are needed in outreach and educational support.

> *"Conversation is the first step to conservation." – PC*

There are multiple ways to increase mariner awareness, including existing ones like educational guides, such as the "Mariner's Guide" and "Notice to Mariners," and developing new ways to communicate information to mariners, like live alerts to wheelhouses. A study suggested that transmitting information directly to the vessel's wheelhouse is the preferred method of communication for mariners because it is less disruptive and yields real-time broadcasting of important information, facilitating faster response times.[98] The top communication channels identified by a 2015 survey were Navigational Tellex (NavTax) and AIS broadcasting, followed by VHF radio and MCTS, with strong opposition toward using web- and mobile-based technologies.[99] Based on this study, it is reasonable to assume that similar results could be achieved through using smart buoys, improving two-way communication through AIS or investing in new alert systems that feed into the instrument panel and send instant messages to mariners. Other strategies include providing educational support to industry to discuss changes in protocols and providing mariners the chance to seek necessary clarification. This aims to reduce unintentional infractions by furthering mariners' understanding and clearly articulating what is expected of them when transiting protected areas.

Regardless of the approach used to disseminate information to mariners, increased effort is needed to ensure adequate timing to facilitate uptake of new rules and guidelines. Participants felt that information is often released too late in the season for mariners to effectively incorporate it into their travel plans, with limited time to make the necessary adjustments or seek clarification. This is especially concerning for ensuring compliance with voluntary measures because mariners are not required to accommodate for these changes. In this event, mariners would presumably opt to follow their original plans without considering new guidelines. Thus, it is not enough that the information is released, it needs to be made available in a timely manner that promotes compliance and user uptake. This is further supported by a study that identified a strong correlation between the rate of compliance and the time before and after new management measures have been implemented.[100]

Promoting continuous surveillance

Participants felt that promoting an environment in which mariners feel they are under regular surveillance can be an effective mechanism to ensure compliance. This psychological phenomenon has been explored since the 1970s, with studies consistently showing that the mere notion of being watched (rather than physically being under active surveillance) is enough to stimulate behavioural changes and self-censorship.[101] This is thought to be because the area of the brain responsible for recognizing whether you are being observed is activated automatically.[102] These findings suggest that both physical observation and automated alerts can elicit the same type of response.

Human observation is not needed for this strategy to be effective. The studies noted above seem to indicate that sending alerts and various notifications to marines through AI technology may be enough to promote compliance. There are numerous tools available that could better facilitate this, including smart buoys, geofence alerts, real-time notifications through AIS and algorithms that automatically alert mariners when unusual activity is detected. Alternatively, tools like marine guardianship programs, overflights and frequent radio communication leverage direct human observation and can encourage the same response.

This method is regularly used in the United States through the Aleutian Islands monitoring program (see ***Appendix C***). There are certain elements

97 Guzman, Hinojosa and Kaiser, 2020.
98 Hovey, 2015.
99 Ibid.
100 Guzman, et al., 2020.
101 Emest-Jones, et al., 2011.
102 Emest-Jones, et al., 2011; Van der Linden, 2011.

of this program that should be considered when working on monitoring and compliance of vessel traffic in Canadian MPAs because both regions have commonalities. This is particularly true for remote or inaccessible areas where compliance is not yet commonly achieved.

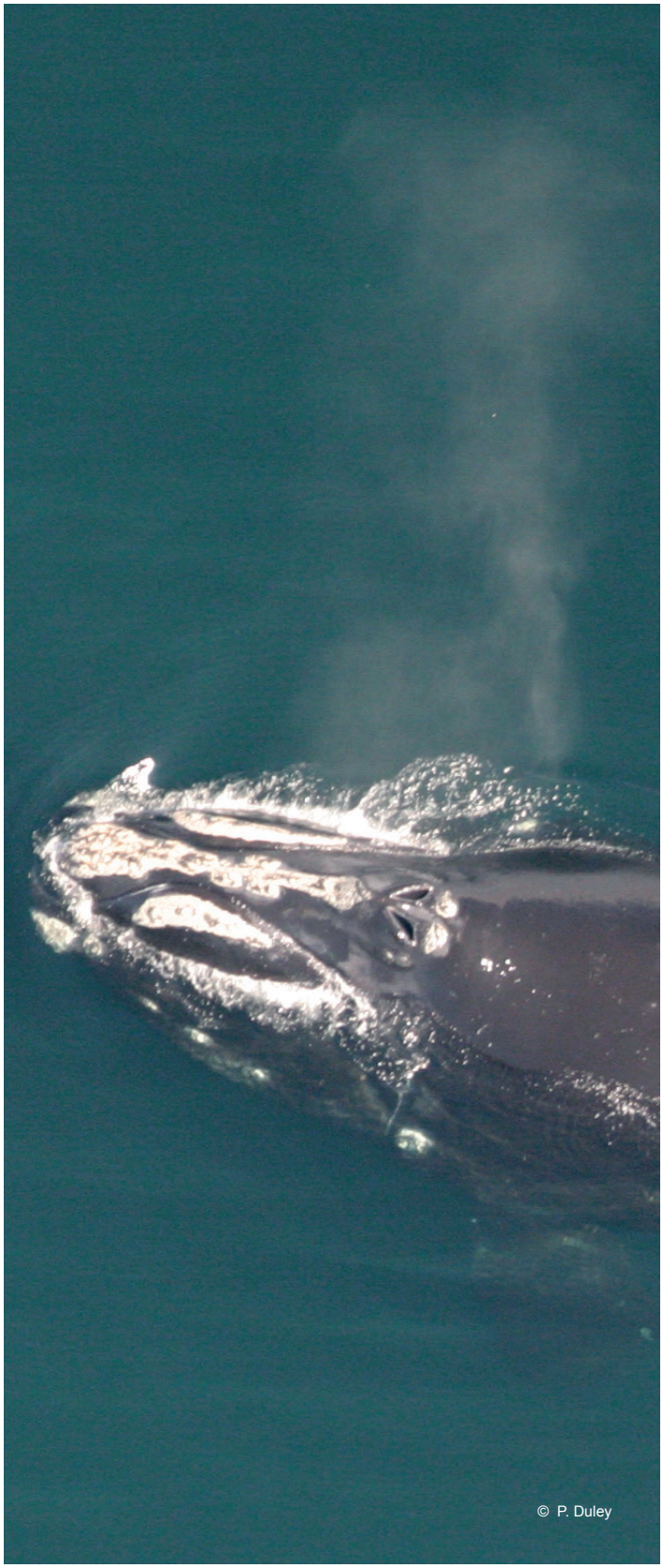
Encouraging the use of incentives

Incentive programs are considered an effective approach to achieve compliance compared to negative reinforcement and have proven beneficial in the Port of Vancouver where port fees are reduced for vessels that show a reduction in underwater noise.[103] Similar incentives could be provided to vessels that regularly comply with the best practices outlined for transiting MPAs, either in the form of monetary awards or national recognition of their commitment to high environmental standards. This strategy could provide certain vessels or companies a competitive advantage on the market by building a good rapport and increasing social acceptance.

Moreover, vessels that are consistently reported for non-compliance can be flagged for poor behaviour. Although more aligned with the notion of negative reinforcement, this strategy is also thought to promote compliance through inflicting fear of reputational damage and loss of business interest.[104]

Adaptive management

It is important to acknowledge that imposing a static management approach on a dynamic system like the marine environment may not work for a prolonged period. The management regime for addressing shipping in MPAs needs to be adapted to accommodate for new tools, new technologies, increased vessel traffic and new risks. This is why reliance on regulations is not always considered the best option; they can become outdated and can take a long time to amend – a time-consuming and expensive process to undertake as new information becomes available. Voluntary measures and guidelines can be adapted more easily to stay current and effective. Thus, adaptative management can help to ensure that new information is incorporated and that management measures continue to support the conservation objectives for which they were created.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103 Port of Vancouver, 2018.
104 Sampson, et al., 2014.

MANAGEMENT GAPS

This section identifies two prominent management gaps that are inhibiting the ability to effectively monitor commercial vessel traffic for compliance with specific management measures of federally designated MPAs in Canada.

Not effectively monitoring for all vessel activity

The expert interviews highlighted that most monitoring efforts only monitor for the presence of vessels within federally designated MPAs, rather than monitor specific vessel activities. This limits the ability to monitor for compliance with specific management measures because data is not continuously collected for all activities (e.g., discharge of harmful substances) unless an incident is reported or noncompliance is directly observed during an overflight. The inability to effectively monitor for all activity makes it difficult to determine if vessels are following protocols. Participants noted that in addition to monitoring the presence of vessels, other regularly documented activities include speeding violations and anchoring; however, this information is interpreted based on the location and time between AIS pings and is subject to error. For example, if a vessel has not moved for a prolonged period, it is reasonable to assume that it is anchored.

The fact that all vessel activity is not effectively monitored within MPAs makes it difficult to ensure compliance. The lack of data for vessel activity can be attributed to numerous factors but is likely due to the fact that many of the available monitoring tools that are regularly used – AIS, S-AIS, Radar, LRIT – are not capable of providing accurate information on vessel activity. However, numerous available methods can reliably provide this information, such as aerial surveillance, cameras, satellite imagery, marine guardianship programs or retrofitting alert systems such as smart buoys. Thus, it is important to use multiple tools and compare datasets to capture enough information to reasonably assume all vessel activity.

Late detection of non-compliance

The second management gap is rooted in the data analysis process, where participants noted that AIS information is largely archived for post hoc analysis. Thus, it is possible that incidences of non-compliance within an MPA are only recognized once a vessel has already exited the MPA or perhaps even exited Canadian waters. At this point, the damage is already done to the environment. Furthermore, participants reported that in cases like this, it is often difficult to follow up with the vessel or attain official resolution.

This highlights the need for more efficient detection and a follow-up process that allows officers to catch vessels in the act and enforce corrective action. Once more, machine learning has been suggested by participants as a possible solution to bridge this gap, as it facilitates early detection. This is done by analyzing data the moment it enters a system, immediately flagging unusual activity and alerting the necessary officials for follow-up. Participants noted that because there are such large quantities of data being collected through AIS and other means, performing human analysis requires enormous capacity.

CONCLUSION

Expert interviews provided a general overview of how commercial vessel traffic is monitored to ensure compliance in Canada's federally designated MPAs. Based on their experiences, participants noted that current monitoring protocols exhibit moderate to high success at ensuring compliance. It is evident that numerous strategies are available to enable more effective monitoring and compliance of commercial vessel traffic within MPAs to help reduce impacts on the environment. These include investing in machine learning, mariner education, active surveillance and incentive programs. Moving forward, current management systems need to be augmented to address gaps. For example, this might mean ensuring effective monitoring of all vessel activity and early detection of harmful practices. By achieving high-level compliance, Canada can ensure the protection of its federally designated MPAs and help enhance the environmental, cultural, social and economic integrity of these areas.

The following subsections outline limitations to this study and recommendations for future research.

LIMITATIONS

One limitation of this study was the lack of Indigenous voices in the sample group. Due to a strict research timeline, Indigenous representatives were unable to schedule a meeting during the three-week interview period. Because this is a national study spanning all three coasts of Canada and Indigenous Peoples play an integral role in monitoring vessel traffic – particularly in the Arctic and along the Pacific coast – it is essential that we engage in further conversations with Indigenous Peoples.

Another limitation, due to the strict timeline, is that only 11 interviews were conducted. This does not support statistical significance; therefore, this study is purely qualitative.

FUTURE RESEARCH

There are several knowledge gaps remaining that could benefit from future research. These include:

1. A quantitative assessment of compliance rating for commercial vessel traffic within federally designated MPAs to determine the level of compliance at each site for different measures. An in-depth analysis would help identify sites that may require additional resources and identify which measures are working and which could benefit from further management measures.
2. A policy analysis to identify how Canadian policy could be better adapted to account for vessel traffic in MPAs, beyond improving AIS regulations.
3. An international study on the monitoring and compliance of commercial vessel traffic to provide further insight into available tools and best practices on the global scale, which could then be assessed for use in Canada.
4. Expanding the research scope to include all vessel traffic within MPAs, including recreation and pleasure crafts. This is an area of study that most participants felt would be useful as there is relatively little monitoring being conducted for these vessels within Canadian MPAs.
5. Finally, more research on how machine learning can encourage compliance would provide additional direction when considering potential investments in resources. It should be noted that there is ongoing effort using AI technology to try to estimate the level of risk associated with vessel activity in MPAs based on certain environmental factors,[105] which may help focus current monitoring efforts.

105 Bereta, et al., 2019.

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APPENDIX A: INTERVIEW QUESTIONS

Note: *For simplicity the term "MPA" refers only to those which are federally designated in Canada and the term "vessel traffic" refers only to commercial vessels.*

Only MPA managers will be asked to answer questions 1 through 3 and will be omitted from answering question 5.

MANAGEMENT

1. What is your role in relation to MPA management?
2. How is vessel traffic managed within the MPAs that you work with?
    a. Are any shipping activities prohibited in the MPAs that you work with?
    b. Are any management measures voluntary?
3. Is there any way to improve **management** of vessel traffic within these MPAs?

MONITORING

4. Can you describe your experience with vessel traffic **monitoring** in MPAs?
5. Are their certain rules in place for vessel traffic within MPAs that would warrant the need for monitoring? Please explain.
6. How is vessel traffic being **monitored** within these MPAs?
7. Do you think there is any way current monitoring practices could be improved?

COMPLIANCE

8. Is there any additional monitoring to **ensure compliance** with management measures for shipping in these MPAs?
    a. If possible, can you provide a site-specific example?
    b. Do these methods differ when monitoring inshore vs offshore MPAs?
        i. Can you provide an example? Please explain.
    c. Do these methods differ when monitoring arctic vs. temperate MPAs?
        i. Can you provide an example? Please explain.
9. Can you rate how successful you feel the monitoring protocols previously listed are at **ensuring compliance** of vessel traffic within these MPAs? (See Table 3, repeated below.)
    a. If possible, can you provide any additional insight behind why you have chosen that answer?

Table 3. A guide to assessing the success rate of monitoring measures to ensure compliance of commercial vessel traffic within federally designated MPAs in Canada.

Success rate	Definition
Low	Unsatisfactory, does not meet performance requirements, often linked to low levels of compliance
Moderate	Improvement needed, results are not consistent across MPAs or vessel type, often linked to moderate levels of compliance
High	Meets or exceeds expectations, often linked to high levels of compliance

10. What, if anything, do you feel are some of the **challenges or potential barriers** of successfully monitoring vessel traffic to **ensure compliance** within MPAs?
    a. Is anything needed in order to improve the current situation?

ADDITIONAL INFORMATION

11. Thinking now of monitoring practices within other marine spatial management areas, are you aware of any other tools or methods that could be applied to MPAs?
12. Is there anything else that you would like to share with me today?
13. Is there anyone else that you think I should talk to?

APPENDIX B: NVIVO CODING SCRIPT

Table 6. List of nodes used to code interviews in NVivo

Nodes	Files	References
Arctic MPA	10	31
Offshore MPA	5	9
Inshore MPA	7	10
Barriers		
Cost	8	17
Environmental	8	15
Inconsistent data or tools	2	3
Lack of access to data	2	4
Lack of capacity	9	20
Mandate or policy issues	6	13
Privacy and security concerns	2	4
Limitation to technology	9	27
Time	7	13
Areas for improvement		
Access to tools	8	16
Direct observation	5	5
Awareness for mariners	7	18
Better reporting	1	1
Better use of policy	4	6
Collaboration and local initiatives	7	27
Consistency and data sharing	4	7
Faster follow-up	1	1
Funding	1	1
Human analysis	1	1
Machine learning	5	11
More information	5	10
Strategic timing	3	3
Management	7	18
Prohibited	7	11
Voluntary	7	11

Nodes	Files	References
Mechanisms for compliance	11	45
Outreach (awareness and education)	7	20
Authoritative presence	2	2
Collaboration	3	5
Community support	2	2
Follow-up or enforcement	7	9
Courtesy checks	3	3
Inspections	1	1
Sanctions	2	5
Incentives	2	2
Rules and regulations	2	2
Voluntary measures and guidelines	3	3
Watch programs and notion of being under continuous surveillance	6	7
Monitoring tools		
Currently in use	11	44
Currently not in use	7	13
Unclear	4	11
Success rating	3	5
High	4	6
Moderate	5	5
Low	1	1
Examples of best practices		
Collaboration	4	9
Education	2	3
Information sharing	5	6
Combining tools	3	4

APPENDIX C: INTERNATIONAL CASE STUDY: ALEUTIAN ISLANDS MONITORING PROGRAM

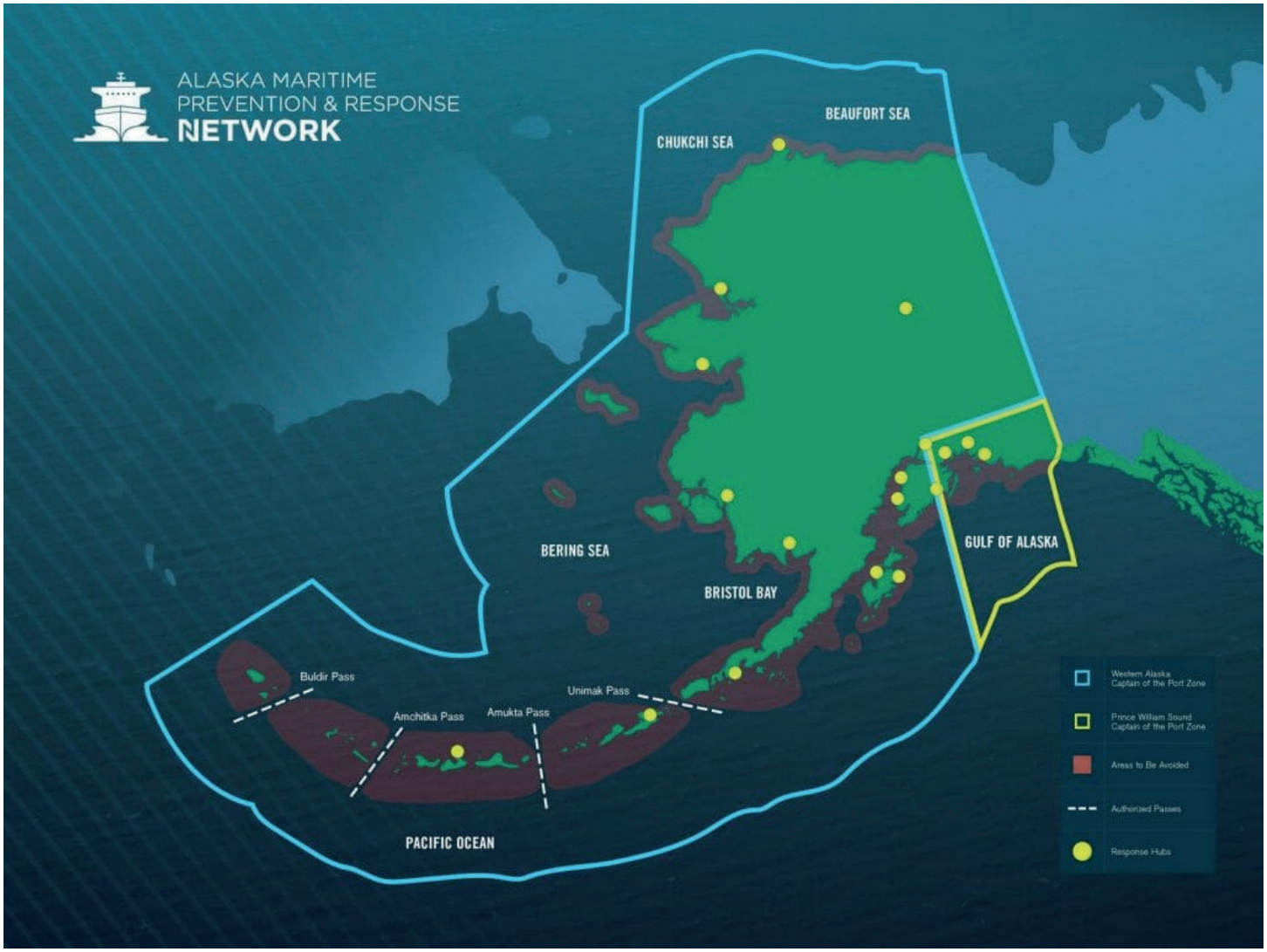
The Aleutian Islands monitoring program, otherwise known as the Alaska Maritime Prevention and Response Network or the Marine Exchange of Alaska (MXAK) is a prime example of how to achieve high compliance through vessel traffic monitoring. Their monitoring centre is led by local Alaskans who are professionally trained and familiar with the area and the nuances of the environment, leveraging local knowledge and first-hand experience on the land. MXAK uses a preventative approach based on continuous monitoring, communication and action to get ahead of potential incidents and prevent them from occurring in order to fully minimize impacts.[106] MXAK prides itself on always using the best available tracking technologies and continues to adapt with industry to ensure high precision monitoring. The centre uses geofencing to set boundaries around areas of interest (e.g., areas to be avoided) and gathers information from transiting vessels through both terrestrial and satellite AIS. When possible, data is incorporated from other satellite transponders to fill in gaps where vessels do not use AIS.[107]

The centre is staffed 24 hours a day, 7 days a week, providing real-time data visualization and human analysis to over 1.5 million square miles of Alaskan coastline, including area out until the EEZ. This makes it the largest non-government AIS vessel tracking and monitoring system in the world.[108] This method ensures information is relayed quickly and effectively to the appropriate officials, as needed, to promote safe navigation in one of the world's harshest marine environments. Vessels are flagged when considered special concern, which are typically those which have inexplicably reduced speeds for an extended duration or those displaying otherwise unusual behaviours. If identified, these vessels are contacted to request additional information, and email notifications are sent out to the appropriate parties, including the US Coast Guard. A follow-up email is then sent out once the issue has been resolved.[109]

The centre's primary objectives are to provide navigational assistance, emergency response and recovery services and to protect the environment through aiding in environmental compliance and response.[110] This area is home to an abundance of vulnerable and sensitive species that need protection – much like Canadian waters. MXAK goes beyond monitoring vessels as it also provides numerous services such as pollution clean-up and wildlife response teams to safely capture and rehabilitate wildlife injured by shipping activity.[111] This centre is a global leader in ensuring vessel compliance and is the result of a collaborative effort across industry, government and local experts.[112] A potential drawback is that vessels must pay to be enrolled in the program as it is a non-profit organization. Therefore, not all vessels are included under its coverage.

106 Alaska Maritime Prevention and Response Network, 2019.
107 Marine Exchange of Alaska, 2020.
108 Alaska Maritime Prevention and Response Network, n.d.
109 Ibid.
110 Ibid.
111 Ibid.
112 Ibid.

Figure 7. Map of the area covered by 24/7 in-person monitoring through the Alaska Maritime Prevention & Response Network (n.d.)



GLOSSARY OF TERMS

AI	Artificial intelligence
AIS	Automatic Identification System
CCG	Canadian Coast Guard
DFO	Fisheries and Oceans Canada
ECCC	Environment and Climate Change Canada
EEZ	Exclusive Economic Zone
IMO	International Maritime Organization
I-STOP	Integrated Satellite Targeting of Polluters
LRIT	Long-Range Identification and Tracking
MBS	Migratory Bird Sanctuaries
MCTS	Marine communications and traffic services program
MEOPAR	Marine Environmental Observation, Prediction and Response Network
mNWA	Marine National Wildlife Areas
MPA	Marine protected areas
MXAK	Marine Exchange of Alaska
NASP	National Aerial Surveillance Program
NEMES	Noise Exposure to the Marine Environment from Ships
NMCA	National Marine Conservation Areas
PC	Parks Canada
S-AIS	Satellite Automatic Identification System
TC	Transport Canada
UNCLOS	United Nations Convention on the Law of the Sea
WCS	Wildlife Conservation Society

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