An Impact Assessment on Shipping in the Canadian Eastern Arctic: A Baffinland Mine Case Study – Phase 2 Project Proposal

By

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Abstract

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Sea ice is melting at an unprecedented rate, improving access to the Arctic and greatly increasing development opportunities such as mining. The Baffinland Iron Mines Corporation Phase 2 project proposal aims to expand iron ore production at the Baffinland mine facility in Nunavut. If approved, this development will extend the shipping season beyond open-water season as well as increase vessel traffic from the port in Milne Inlet, through Eclipse Sound and out into Baffin Bay. This will increase the likelihood of shipping hazards such as the introduction of aquatic invasive species, underwater noise pollution, chemical pollution, habitat disturbance, and vessel strikes (with marine mammals), likely posing serious environmental and socio-cultural impacts, threatening local wildlife and neighbouring Inuit communities (e.g. the Hamlet of Pond Inlet). This study is threefold as it identifies shipping hazards and their potential impacts on valued-ecosystem components; reviews Baffinland's proposed management measures to reduce adverse impacts; and provides a high-level assignment of the likelihood and severity of impacts from shipping given Baffinland's proposed management plans. This study addresses the above research objectives through employing both a literature and policy review, while an impact matrix was developed to identify potential management gaps and areas of management priority. Recommendations were provided to further minimize adverse impacts from shipping hazards. The results suggest a need for Baffinland to strengthen their proposed management plans prior to project approval.

Keywords: Arctic shipping, shipping hazards, Baffinland Iron Ore Mine, impact assessment, impact management, Arctic wildlife, Inuit, Eclipse Sound, Pond Inlet

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List of Abbreviations

BWE	Ballast Water Exchange
CFU	Colony-forming unit
DFO	Department of Fisheries and Oceans Canada
EBSA	Ecologically and Biologically Significant Area
EMS	Environmental Management System
IIBA	Inuit Impact Benefit Agreement
IMO	International Maritime Organization
MARPOL	International Convention for the Prevention of Pollution from Ships
MHTO	Mittimatilik Hunters and Trappers Organization
MTPY	Million-Tonnes-Per-Year
MWO	Marine Wildlife Observers
NIRB	Nunavut Impact Review Board
NM	Nautical mile
NMCA	National Marine Conservation Area
OPEP	Oil Pollution Emergency Plan
TINMCA	Tallurutiup Imanga National Marine Conservation Area
UNCLOS	United Nations Convention of the Law of the Sea
UNDRIP	United Nations Declaration on the Rights of Indigenous People
VEC	Valued Ecosystem Component
WWF	World Wildlife Fund

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Chapter 1: Introduction

Climate in the Arctic has oscillated greatly throughout history, but a recent trend has emerged involving rapid decline of sea ice. Due to climate change, average global temperatures continue to soar, creating the potential for drastic environmental changes in the Arctic. Studies suggest that the Canadian Arctic may experience ice-free summers as early as 2040 (Serreze & Meier, 2019). The loss of sea ice cover opens new waterways, potentially increasing safe navigation throughout the region. This has led to an increase in vessel activity as easier commutes and access to previously inaccessible areas open up new economic opportunities, such as mining. As a result, Arctic ship traffic in Canadian waters has more than tripled since 1990 (Carter, Dawson & Weber, 2020). For example, the Baffinland Iron Ore Mine in Nunavut is seeking approval for project expansion which has sparked public interest over recent years as concern for the environment rises with climate change awareness. Likewise, the expansion project has unveiled numerous issues pertaining to Indigenous livelihood and resource use, generating important discussions surrounding inequity in the North. These challenges create a unique and pressing demand to assess project impacts prior to approval. As a result, this paper uses the Baffinland Mine as a case study to assess environmental and socio-cultural impacts from increased shipping in the Arctic.

1.1 Baffinland Iron Ore Mine

1.1.1 Development Project Description

Baffinland is located on Northern Baffin Island, Nunavut, south of the port in Milne Inlet (Figure 1). Baffinland mine sits on one of the richest iron ore deposits in the world, allowing them to export high grade iron with minimal processing, increasing profit margins (Baffinland, 2020b). Interest in the Baffinland site first began in 1962 with exploration and development commencing in 1986 (Baffinland, 2020b). It was not until 2015 that operations began, with initial production rates of 3.5 million-tonnes-per-year (MTPY) of iron ore (Baffinland, 2020b). In 2018 that number nearly doubled to 6 MTPY with plans to move 12 MTPY by 2022 (Baffinland, 2019). Although this proposal has not yet been approved by the Nunavut Impact Review Board (NIRB), Baffinland has already expressed interest to increase production to 30 MTPY by 2030 (Baffinland, 2017a; Baffinland, 2020b).

In order to export additional product, Baffinland will need to increase the size and number of vessels servicing the mine as well as extend the shipping season beyond open water season (WWF, 2016; Baffinland, 2017a). Currently servicing Baffinland are resupply ships, tugboats, fuel tankers, and ore carriers—Panamax PC4 Ore Carriers, which are medium size bulk carriers (Etkin, 2019). However, this expansion project will require Baffinland to add Capesize ore carriers which are significantly larger and have twice the oil capacity of the Panamax carriers (Etkin, 2019), greatly increasing the severity of impacts in case of an accident (e.g. oil spills). Baffinland will also require the addition of icebreaker ships to clear paths for safe navigation during ice-covered months (Etkin, 2019). Given the scope of the Phase 2 expansion proposal, this project has raised serious environmental and socio-cultural concerns among stakeholders (WWF, 2016; Baffinland, 2019) which will need to be addressed prior to project approval.

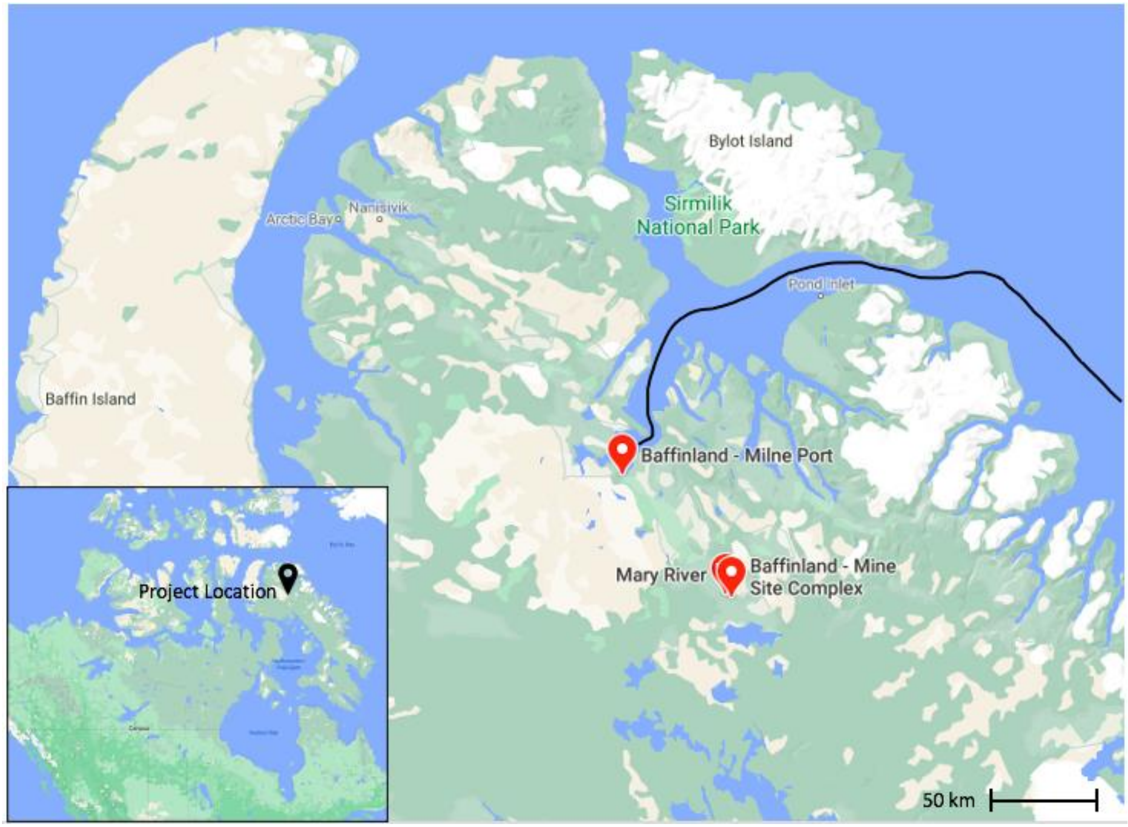

Figure 1. Regional map of the Baffinland Mine Site Complex, Milne Port and Baffinland's northern shipping route, adapted from Google Maps.

1.1.2 Geographic Scope

The Baffinland shipping route runs from the port in Milne Inlet (Bruce Head/Koluktoo Bay region) through Eclipse Sound, Pond Inlet, out to Baffin Bay (Figure 2), and finally crossing the Atlantic Ocean for use in the European market (Baffinland, 2020). The route from Milne Inlet to Baffin Bay ranges in depth from 5m to 1300m (Figure 2) and follows a narrow channel with several chokepoints identified as areas likely to result in congestion from vessel traffic (Golder Associates Ltd. 2018; Frouin-Mouy, Maxner, Austin & Martin, 2019). Defining the problem within clear spatial boundaries limits the range of shipping hazards considered within the scope of this research. The Baffinland mine and surrounding area of interest is situated in Inuit homeland (Figure 6). The study site is considered to be an ecologically and culturally sensitive area, home to a unique and diverse ecosystem which is also an important harvest location for several Inuit communities such as Pond Inlet, Arctic Bay, Clyde River, Hall Beach and Igloolik. Furthermore, Baffinland's northern shipping route is within the southern boundary of the recently established Tallurutiup Imanga National Marine Conservation Area (TINMCA), which shows the significance of this area for marine conservation (Parks Canada, 2018).

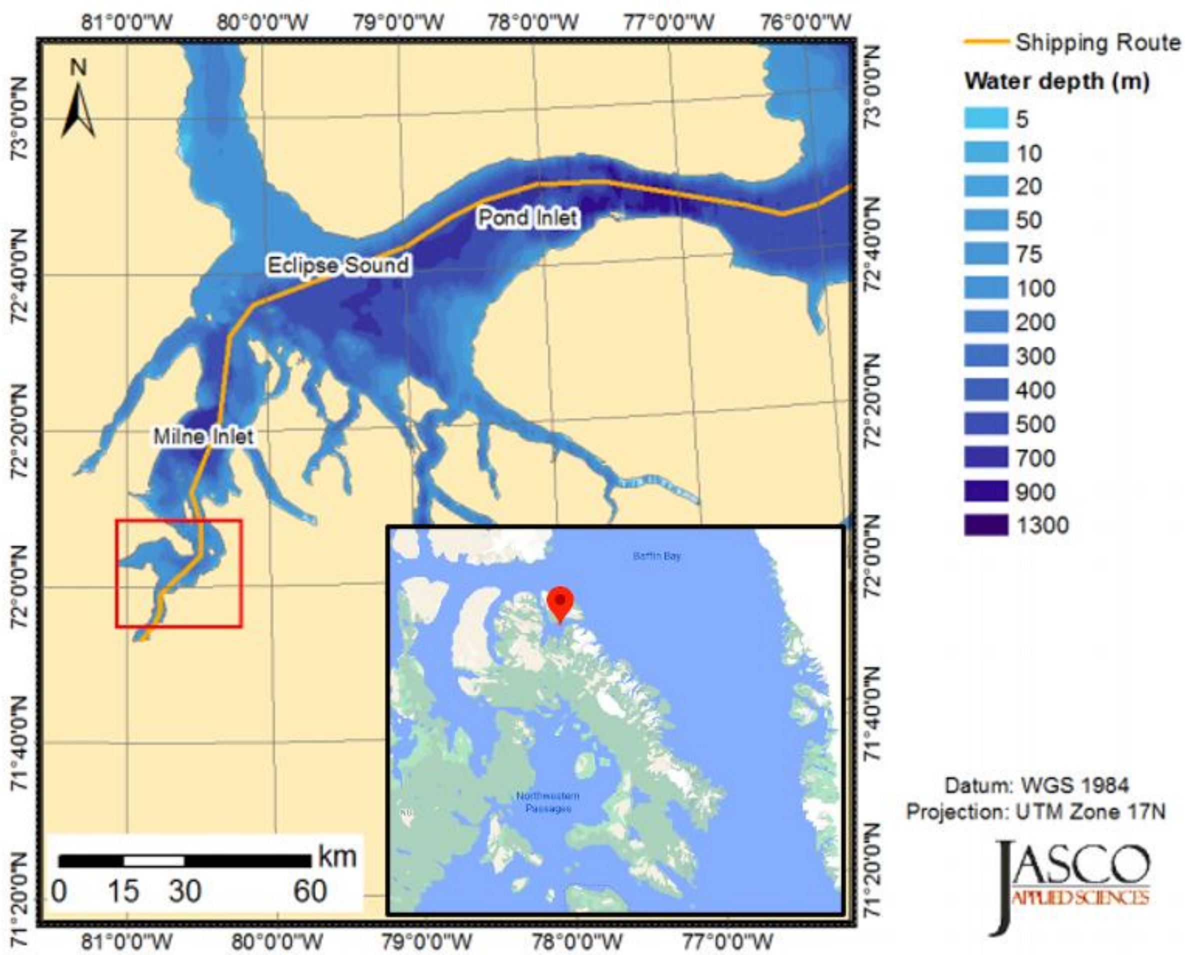

Figure 2. Map of water depths along Baffinland's northern shipping route, modified from Frouin-Mouy et al., 2019

1.1.3 Temporal Scope

Baffinland's shipping season is currently constrained within the limits of open-water season (Table 1) but varies slightly each year based on recommendations from the Pond Inlet Hunters and Trappers Organization (Baffinland, 2017a). In order to export additional product from the mine, Baffinland will need to extend their shipping season by several months (WWF, 2016). Baffinland's original plan called for shipping 10 months out of the year, which was rejected by the Nunavut Planning commission due to non-compliance with the Nunavut land use plans and its potential for adverse environmental impacts (Baffinland, 2017a). The Phase 2 project proposal aims to extend the shipping season outside of open-water season; shipping from July 1st to November 15th with the majority of export completed by the end of October (Baffinland, 2019; DFO, 2019). This would allow shipping from late spring to early winter, from the time of ice break-up, through the open water, ice freeze-up, and frozen seasons (Table 1). Extending the shipping season will result in increased shipping activity during a variety of sensitive periods for the ecosystem, potentially affecting migration and breeding patterns of marine and terrestrial mammals, as well as impacting Inuit harvesting practices that are essential for the communities' food security (Carter et al., 2018).

Table 1

List of the Six Identified Seasons in Pond Inlet, Nunavut, Adapted from Carter et al., 2018 and Itulu, 2018

Season	Timeline	Ice condition
Early spring	March - early May	Frozen
Spring	May – June	Frozen and break-up
Summer	July – August	Open water
Fall	September - October	Open water and freeze-up
Early winter	November - early December	Freeze-up and frozen
Winter	Mid-December - February	Frozen

1.2 Management Problem

If approved, this development would increase vessel traffic within the study site, increasing the level of shipping hazards such as aquatic invasive species, underwater noise pollution, chemical pollution, habitat disturbance, and vessel strikes (Baffinland, 2019). These hazards may have serious environmental and socio-cultural consequences such as negatively affecting native wildlife (e.g. pinnipeds, cetaceans, polar bears, and caribou) and posing concerns over food security for local Inuit communities (Hauser, Laidre & Stern, 2018; Teichroeb, 2019; Baffinland, 2019). As Eclipse Sound is a traditional Inuit hunting ground, both increased and prolonged vessel traffic may inhibit the harvest of country food (Qikiqtani Inuit Association, 2014). The potential impacts associated with this proposal amplifies the need for a thorough assessment prior to project approval.

Given the sensitivity and degree of uncertainty surrounding potential impacts, there are numerous interest groups to consider, including industry, government, Indigenous partners, and environmental groups (Table 2) (Baffinland, 2019). The term "Indigenous partners" refers to those who represent Indigenous interests, including Inuit communities and organizations. Baffinland has worked closely with Inuit and relevant interest groups since the Phase 2 project proposal began in 2015, promoting transparency and relationship-building early on (Baffinland, 2019). It is important to note that although other Inuit communities are in close proximity to the study site and utilize the area (e.g. Arctic Bay, Clyde River, Hall Beach, and Igoolik), Pond Inlet is the only hamlet situated within the study site and it is in direct and continuous communications with Baffinland. In order to remain consistent with the identified interest groups, Pond Inlet is the only community that will be discussed in detail throughout this study.

Table 2

Identified Interest Groups Sorted by Affiliation (Baffinland, 2019)

Affiliation	Interest group
Industry	Baffinland mine
Industry	Ship operators servicing the mine
Government	Department of Fisheries and Oceans Canada
Government	Parks Canada
Government	Environment and Climate Change Canada
Government	Transport Canada
Government	Health Canada
Government	Natural Resources Canada
Government/ Indigenous partners	Government of Nunavut
Government/ Indigenous partners	Crown-Indigenous Relations and Northern Affairs Canada
Indigenous partners	Nunavut Impact Review Board
Indigenous partners	Mittimatalik Hunters and Trappers Organization
Indigenous partners	Qikiqtani Inuit Association
Indigenous partners	Residents of Pond Inlet
Environmental groups	Oceans North
Environmental groups	World Wildlife Fund

1.3 Research Objectives

This research aims to investigate how current management plans can be adapted to further minimize impacts from increased shipping at Baffinland. This study is threefold, as it entails: 1) identifying shipping hazards and their potential impacts on valued ecosystem components (VECs); 2) reviewing Baffinland's proposed management measures to reduce adverse impacts; and 3) developing an impact matrix to assess the level of impact from shipping given Baffinland's proposed management plans. The results of this study will help identify management gaps and areas of management priority. They may also provide guidance to inform management decisions such as where to allocate resources. This study will also provide additional management recommendations to further alleviate impacts on VECs should the proposal be approved.

1.4 Methodology

A systematic literature review was employed to achieve the intended research objectives of this study (Figure 3). The review process covered a wide range of peer-reviewed and grey literature to account for the many facets of this project. The review of literature was subdivided into categories as per the three overarching objectives (See Section 1.3). Shipping hazards and their potential to create environmental and socio-cultural impacts on VECs were identified within the study site. It is worth noting that environmental impacts refer to those directly created through shipping activity while socio-cultural impacts include those influenced by environmental degradation, attributed to the shipping activity, and are otherwise considered indirect impacts.

A review of specific management measures proposed by Baffinland was also conducted. The review analyzed Arctic shipping regulation at the international and national levels as well as any voluntary guidelines proposed by Baffinland. The results obtained through the reviews were combined to inform a high-level impact assessment which was further supplemented by literature. An impact matrix was developed comparing impacts from shipping hazards on each VEC to identify areas of management priority. Categorical values were assigned to score each interaction based on the severity and likelihood of impact. The results were then used to develop a comprehensive list of potential management recommendations ranging from avoidance to compensation mechanisms, ultimately informing the final decision on how to proceed with the proposal (e.g. proceed as intended, do not proceed, or proceed pending revision).

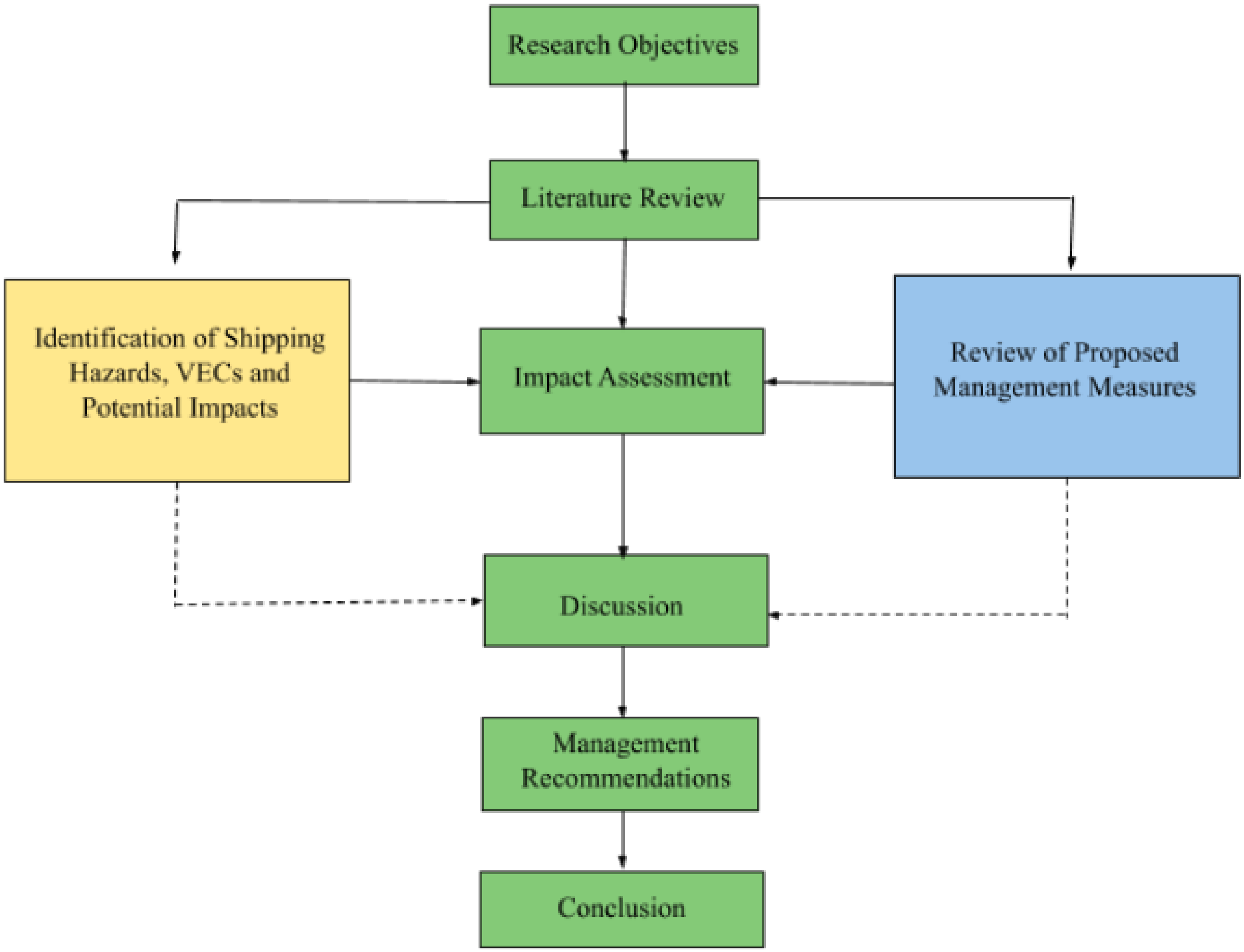

Figure 3. Flowchart of research methodology

Chapter 2: Context

This chapter provides a detailed overview of the study site, including wildlife use, traditional hunting grounds, Inuit owned territory, and aims to describe the relationship between Inuit and the land. It also provides a brief socio-political breakdown of Canada's role in protecting Indigenous rights. In doing so, it sets the context to better understand the significance of the Baffinland mine expansion and the potential severity of impacts facing the environment and surrounding communities.

2.1 Study Site

This section positions the Baffinland expansion project within a greater geographical area, noting the potential for future changes in operational requirements as the shipping route transits a National Marine Conservation Area (NMCA). It identifies native species of interest and illustrates shifts in habitat use under varying ice conditions.

2.1.1 Tallurutiup Imanga National Marine Conservation Area

Tallurutiup Imanga (also known as Lancaster Sound) is a proposed NMCA in the Canadian Eastern Arctic. It is situated at the entrance of the Northwest Passage—the shortest trade route from Asia to Europe. Eclipse Sound, within the southern boundary of TINMCA (Figure 4), is included due to its high ecological and cultural value and is also listed as an area of high importance for conservation (Parks Canada, 2018). However, for the purpose of the mining project, it is worth noting that Milne Inlet and Pond Inlet have been excluded from the NMCA (Figure 4). TINMCA was established with several goals in mind: to protect Inuit harvesting rights, to protect species at risk, to promote ecological sustainability, and to protect and conserve a representative marine area for the benefit, education, and enjoyment of all people (Parks Canada, 2017a; Parks Canada, 2017b; Parks Canada, 2020).

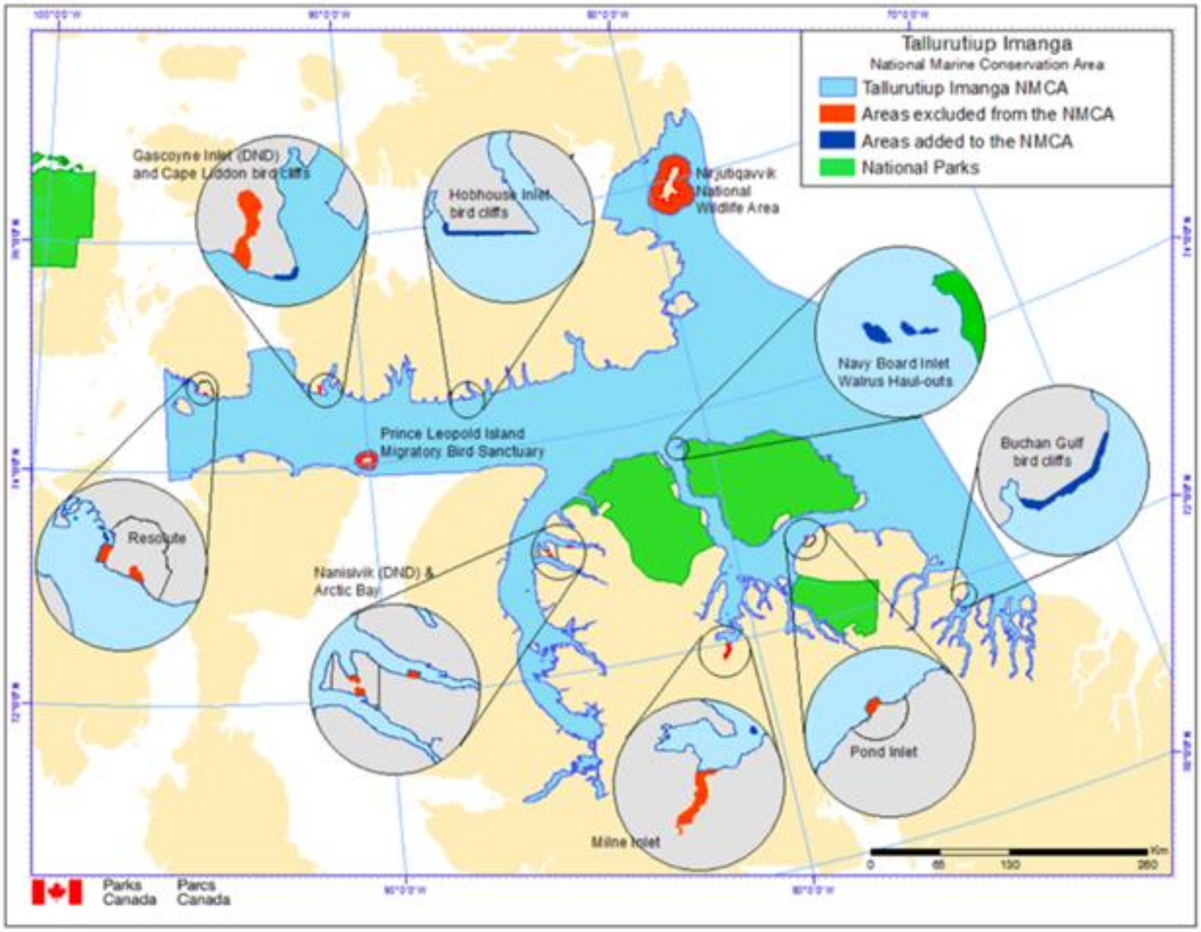

Figure 4. Proposed boundary map of Tallurutiup Imanga National Marine Conservation Area (Parks Canada, 2020)

Once established, the TINMCA will be governed in a joint effort between the federal government and the Inuit through the Aulattiqatigitt Management Board, guided by the *Canada National Marine Conservation Areas Act* and the *Nunavut Agreement* (Parks Canada, 2020). This co-governance approach recognizes that Inuit have the right to pursue their own economic, social, and cultural development through self-determination (United Nations, 2008; Nunavut Land Claims Agreement, 2013). This entitles them to participate in the decisions that affect them and to exercise autonomy over policy decisions. Shipping and marine navigation remain the primary responsibility of Transport Canada, but the Federal Government is required to seek the support of Inuit on issues that affect their territories. Once TINMCA is officially designated, it is assumed that Baffinland will need to adhere to any management requirements imposed by the Board as its shipping route transits the protected area.

2.1.2 Wildlife

The Canadian eastern Arctic is a biologically rich region, with over 20 ecologically and biologically significant areas (EBSAs), including the joint area of Eclipse Sound and Milne Inlet (Fisheries and Oceans Canada, 2015). Eclipse Sound and Milne Inlet are recognized for supporting aggregations of narwhals (*Monodon monoceros)*, including their rearing habitat and migratory corridors (Fisheries and Oceans Canada, 2015). This EBSA is also considered an area of critical ecological importance for many marine mammals such as seals (*sp. pinnipeds*), beluga whales (*Delphinapterus leucas)*, bowhead whales (*Balaena mysticetus),* walrus (*Odobenus rosmarus)*, polar bear (*Ursus maritimus),* and various seabirds (Parks Canada, 2017a). The region is home to an array of unique and vulnerable species, nearly all of which express specialized life-history strategies such as late age of maturity and few offspring (Hauser et al., 2018). Additionally, many of these species often exhibit high site fidelity and restricted habitat ranges (e.g. narwhals) making them highly vulnerable to habitat disturbance (Hauser et al., 2018). The following species have been identified as at risk from increased shipping: narwhals, walrus, beluga whales, bowhead whales, ringed seals (*Pusa hispida),* bearded seals (*Erignathus barbatus),* caribou (*Rangifer tarandus)*, polar bear, and various migratory seabirds (Jenkins et al., 2016; Hauser et al., 2018; Wong et al., 2018). It is possible that increased shipping pressures can affect access by these species to rich feeding grounds as well as affecting their migration routes.

Seasonal rotations and changes in sea ice dynamics spur an abundance of life to the area for reasons such as pupping, breeding, feeding, and migration. In some instances, the presence of certain species is highly dependent on the right environmental conditions, while other species are present year-round such as seals. Maps created using Inuit input of local wildlife and habitat use (Carter et al., 2018) suggest that animals in Eclipse Sound are most active during the open water season (Figure 5a), while ice freeze-up and frozen periods typically yield a lower diversity of species in the area (Figure 5b & 5c). Given Baffinland's proposal to ship outside of open water season, there is an increased risk of causing harm to wildlife while in vulnerable life stages.

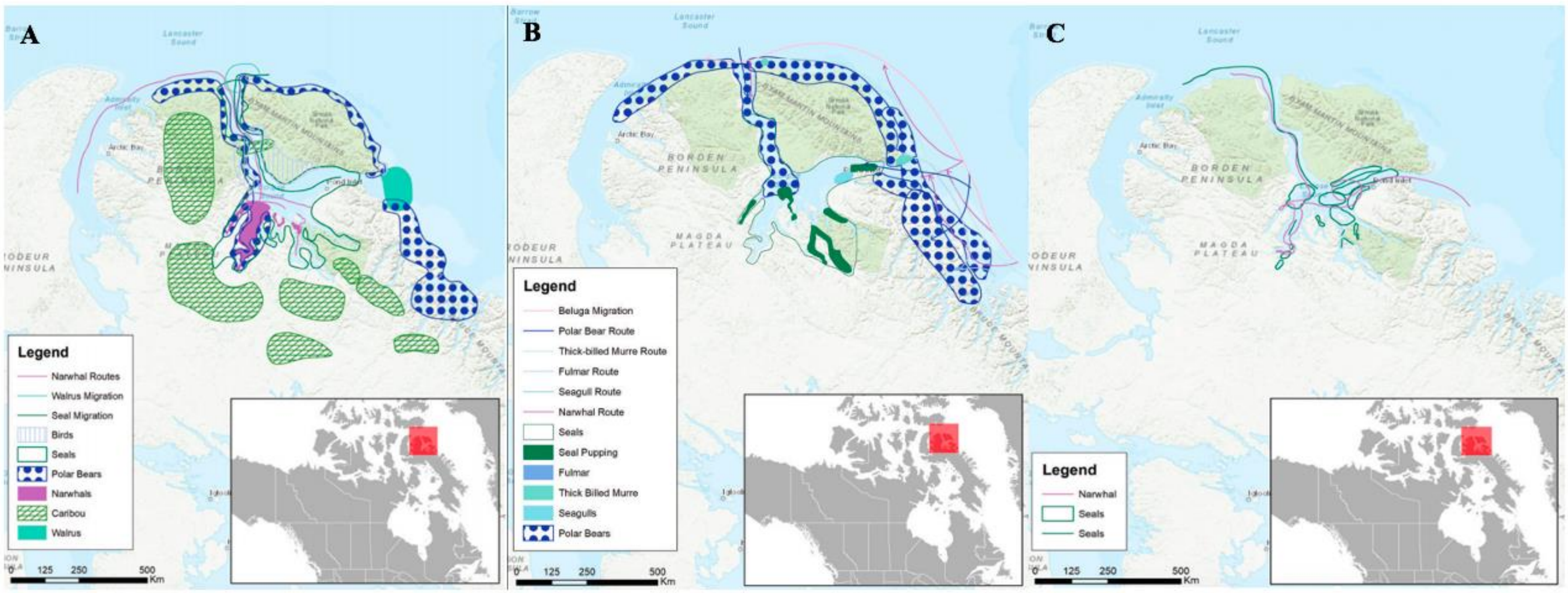

Figure 5. Map of local wildlife and habitat use during open water season (A), freeze-up season (B), and frozen season (C) within the study site (Carter et al., 2018)

2.2 Government-Indigenous Relations

Given that the land around the Milne Inlet port is Inuit owned (Figure 6), it is the obligation of Baffinland to collaborate closely with Inuit community members, co-management boards, Inuit organizations, and other interest groups. Following an inclusive and collaborative approach through every stage of project development increases transparency and can help foster partnerships and mutual respect between agencies. Although there are different international, national and territorial policy frameworks at play, this particular approach has been suggested by the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) to prevent infringement on Indigenous rights. These partnerships allow for local voices to be heard and incorporated into the decision-making process. In doing so, the hope is to lessen the impacts on the environment and the community while fostering opportunity for economic prosperity at the local level.

Canada has a conflicting history with Indigenous peoples but there is a recent movement towards achieving reconciliation. In doing so, several Treaties, Acts, and Agreements exist outlining the socio-political relationship surrounding Indigenous peoples in Canada. These outline Canada's duty to protect Indigenous rights and interests. These include UNDRIP, the Truth and Reconciliation Commission, Crown and Inuit negotiations, the Inuit Impact and Benefits Agreement (IIBA), Inuit Water Rights, Land Claims Agreement, and land settlements, among others. In Nunavut, the main objectives are to protect Inuit rights to ownership and use of lands and resources, participate in decision-making, protect wildlife harvesting rights, "provide Inuit with financial compensation and means of participating in economic opportunities, [and] to encourage self-reliance and the cultural and social well-being of Inuit" (Nunavut Land Claims Agreement, 2013, p.1).

Figure 6. Inuit owned land in the community area of Pond Inlet (Qikiqtani Inuit Association, 2014)

2.3 Pond Inlet (Mittimatalik)

The hamlet of Pond Inlet has a population of approximately 1,500 people and has been home to Inuit who have lived in the region for centuries (Qikiqtani Inuit Association, 2014). The region is known for its many fjords and shallow bays sheltered from the open ocean. Its coastal topography greatly influences land-use as the area supports a biologically rich hunting ground for the Inuit (Qikiqtani Inuit Association, 2014). The Inuit rely heavily on subsistence hunting of country food to maintain their diet, harvesting a variety of wildlife depending on the season (Qikiqtani Inuit Association, 2014). Figure 7 depicts the Inuit harvest cycle for the Hamlet of Pond Inlet, illustrating the harvest period for Arctic wildlife, adding that certain species are hunted year-round (e.g. seals). Like many remote Arctic communities, Pond Inlet relies on annual shipments of supplies (e.g. food, lumber, fuel) which are often expensive as stock is limited in the North (Carter et al., 2020). Not only do traditional hunting grounds provide nutritious meals for the community, but they provide a variety of goods and services. Typically, Inuit use as much of the animal as possible, transforming their catch into a variety of items such as textiles, tools, oil and medicines which can be used to support them in other aspects of their life and generate revenue for their community (Laidler, Elee, Ikummaq, Joamie & Aporta, 2010; Hoover et al., 2016). Thus, traditional hunting grounds are used to maintain food security and hold cultural, social and economic significance which further highlights the importance of preserving the ecological integrity of this site.

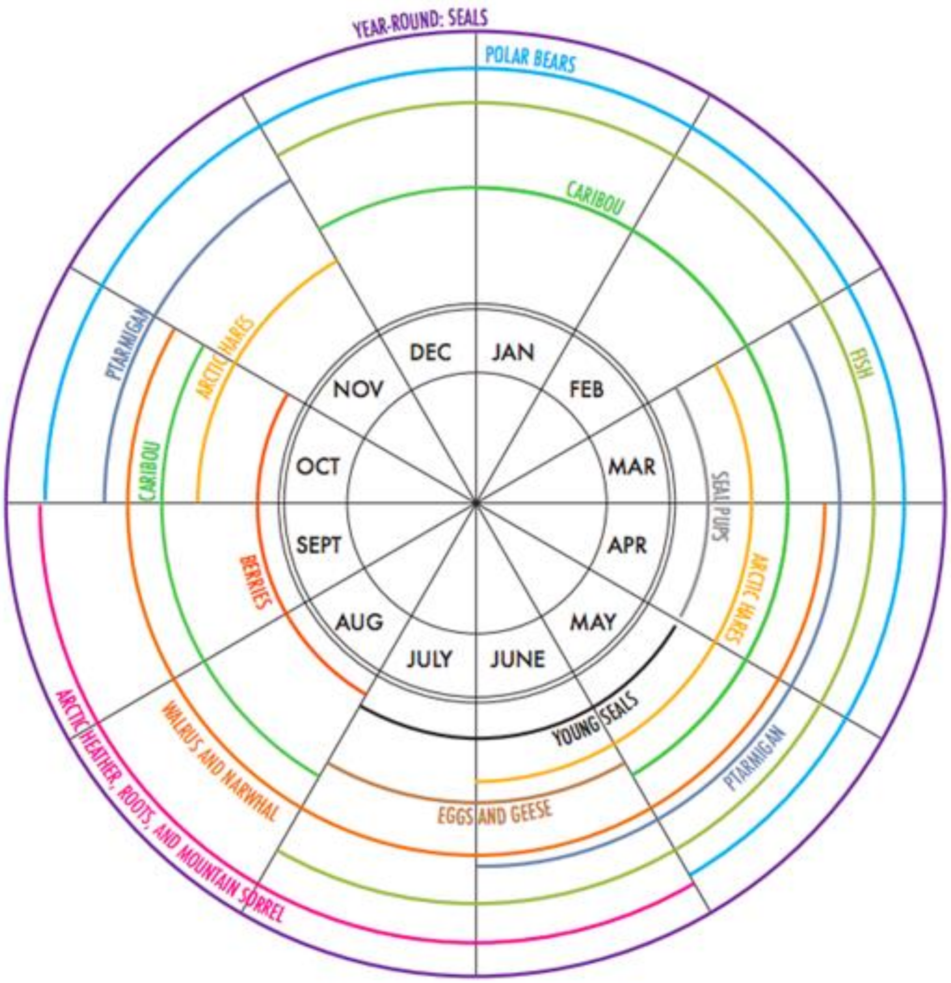

Figure 7. Seasonal harvest cycle, Pond Inlet (Carter et al., 2018)

Additionally, subsistence hunting is an opportunity to transfer generational knowledge and build valuable skills such as survival and navigation. Inuit knowledge is a crucial element of Inuit culture, and is also known as Inuit Qaujimajatuqangit (IQ). IQ has been defined as the seamless integration of "traditional Inuit culture including values, world-view, language, social organization, knowledge, life skills, perceptions and expectations" (Tester & Irniq, 2008, p.1). IQ combines spiritual and factual knowledge that is gained through centuries of experience and passed down from generations through storytelling and lived experiences (Tester & Irniq, 2008; Laidler et al., 2010). This knowledge informs their awareness of their surroundings and their understanding of animal behaviour, including habitat use and species range as they change with the environment. This knowledge also allows Inuit to undertake safe navigation practices, as experienced travelers are able to identify unstable sea-ice conditions using various indicators such as floe edge position (Laidler et al., 2010; Qikiqtani Inuit Association, 2014). This is important as Inuit are highly dependent on the ice and increased ship traffic (e.g. the Baffinland expansion project) can disturb natural sea-ice formation. Inuit rely on sea-ice for access to wildlife, hunting and leisure (Laidler et al., 2010)—contributing to their mental and physical well-being. However, it also plays a vital role in connecting communities who inhabit this remote and isolated region (Laidler et al., 2010). During frozen periods the sea becomes nearly indistinguishable from the land and the presence of sea-ice supports an abundance of seasonal trails, increasing access to communities, camps and hunting grounds (Laidler et al., 2010). Hunting and traveling are part of Inuit history and culture, and they strengthen bonds with the land (Hoover et al., 2016). As the Inuit are deeply connected to their environment, they are able to adapt their hunting patterns to align with the migratory patterns of wildlife. They hunt only where the season allows and harvest what is needed for their community. For these reasons, hunting takes place year-round (Figure 7). This practice minimizes harm to the environment and ensures local wildlife remains a sustainable resource for future generations.

As species move with changing seasons so do the most fertile hunting grounds, as illustrated in the following example. During open water season, Eclipse Sound is home to many species and travel is made easy by boat, giving the communities full access to the region (Figure 8a). As the sea-ice freezes the species shift and travel conditions restrict viable routes, reducing access to hunting sites (Figure 8b). Then, as sea ice thickens, travel routes become safer, and areas that were previously inaccessible during freeze-up can be reopened for hunting (Figure 8c). This cycle is disrupted by commercial shipping/icebreaking activity as it disturbs natural sea-ice formation, causing unsafe travel conditions for hunters, hindering successful hunts, personal safety, and the overall well-being and traditional livelihood of the Inuit (Carter et al., 2020). For example, for Baffinland to extend shipping season into ice-covered periods, icebreakers will be required to guide vessels safely through the channel, delaying the formation of solid sea-ice. The impacts from shipping activity on Inuit will be discussed in further detail in chapter 3.

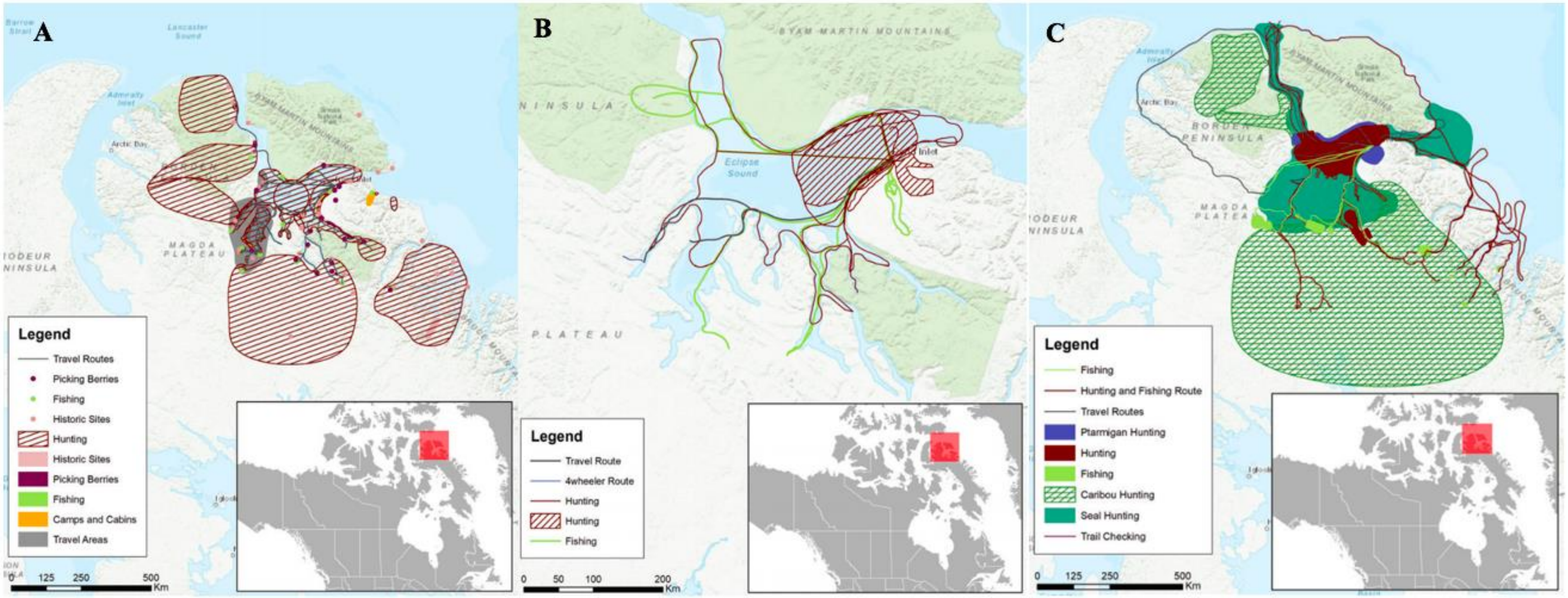

Figure 8. Map of local community activity during open water season (A), freeze-up season (B), and frozen season (C) within the study site, modified from Carter et al., 2018

Chapter 3: Impacts from Arctic Shipping Hazards

If the expansion project is approved, it will increase vessel traffic throughout the region (i.e. Milne Inlet, Eclipse Sound, Pond Inlet, and Baffin Bay) increasing the risk of shipping hazards. These hazards can result in potentially devastating impacts that may seriously harm local wildlife, food security, traditional livelihood, and the health and safety of the surrounding Inuit communities. This chapter identifies and describes impacts on valued ecosystem services (VECs) and serves to build a solid understanding of the impacts from shipping hazards in the Arctic that will later inform the assigned impact scores in Chapter 5.

A systematic literature review was conducted using Novanet and Google Scholar as the primary search engines to consolidate relevant peer-reviewed sources on potential shipping hazards in the Arctic. Articles were selected based on a keyword search and then vetted for English peer-reviewed journals. The selected articles were used to identify potential VECs and describe impacts from Arctic shipping, with particular focus on research in Canada's eastern Arctic. The selection of relevant literature was then limited to impacts from shipping hazards attributed to vessels that are likely to service Baffinland (e.g. cargo vessels, tug/line boats, supply vessels, and icebreakers), purposefully excluding articles which were directly linked to fishing vessels, cruise ships, recreational boating, and research vessels. Reports published by government agencies, industry or those in collaboration with Baffinland (e.g. NIRB, JASCO Applied Sciences) were also included to supplement the literature review. Due to the scope of this study, hazards and impacts that did not directly pertain to the marine environment and their users (i.e. Inuit) were omitted, including impacts from atmospheric pollution. Thus, it is important to recognize that other hazards may exist as a result of the Baffinland expansion, potentially impacting non-identified VECs. No surveys, interviews, or questionaries were included due to resource constraints for this study.

3.1 Results

Five main shipping hazards were identified in the literature for having the ability to severely impact the marine environment: aquatic invasive species, underwater noise pollution, chemical pollution, habitat disturbance, and vessel strikes. This section identifies potential impacts threatening marine environmental and socio-cultural VECs given the likelihood of increased shipping hazards occurring under Baffinland's Phase 2 expansion. VECs are defined as aspects of the natural environment that people value or that hold environmental, social, cultural, or spiritual importance (Noble, 2015). For example, VECs may include species that have conservation value (Treweek, 1999) and those which have medicinal properties (e.g. seals). VECs may also include components that hold recreation or traditional value, and those which can be used for scientific, educational, or economic purposes, among other merits of importance (Noble, 2015). In the case of this study, the environmental VECs were largely chosen based on their conservation status while socio-cultural VECs were influenced by UNDRIP (United Nations, 2008).

Based on the literature review, 15 VECs were identified as most likely to be affected by the Baffinland proposal, eight of which are species-specific. Many of these species exhibit high site fidelity, restricted habitat ranges, and specialized life-history strategies making them more susceptible to impacts from increased shipping pressure (Gross, 2018; Hauser et al., 2018). Other vulnerable species are those which depend on the waters and sea ice for hunting, breeding, or migration. The following species are identified as being at risk and are listed as marine environmental VECs: narwhals, walruses, beluga whales, bowhead whales, ringed seals, bearded seals, polar bears, caribou and seabirds (Jenkins et al., 2016; Hauser et al., 2018; Wong et al., 2018). Other marine environmental VECs include fish, benthic habitat quality, and water quality. Additionally, three socio-cultural VECs have been identified and include food security, traditional livelihood, and public health and safety. In the context of this research, the term "traditional livelihood" refers to one's ability to preserve and share traditional knowledge, access traditional medicines, hunt, and encompasses aspects of one's mental and emotional well-being, whereas "public health and safety" refers only to one's physical well-being.

3.1.1 Aquatic Invasive Species

Aquatic invasive species are defined as non-native species that threaten the ecosystem (Government of Nunavut, 2010). These species lack native predators to control their population—allowing them to thrive in their new environment if the conditions are hospitable. In Canada, invasive species have been known to reduce biodiversity, threaten existing species, limit productivity, introduce disease, and degrade water quality and alter natural habitat, among other environmental impacts (Clear Seas, n.d). The introduction of invasive species can lead to trophic cascades as they can deplete the primary energy source for native species and destabilize predator-prey relationships (David et al., 2017). These species are commonly introduced to the marine environment through ballast water exchange (BWE) and biofouling. For clarity, BWE is a necessary process used to stabilize ships and improve their maneuverability for safe navigation, whereas biofouling is the process by which marine organisms attach themselves to the hull of vessels and are transported to new locations.

Ballast water discharge has the potential to transport pathogens, invasive species, and pollutants into new areas, impacting the environment (Jing, Chen, Zhang & Peng, 2012). It is thought that most invasive species found in northern coastal environments have been introduced through BWE (Jing et al., 2012). Baffinland is at increased risk as it relies on international transport from Canada to Europe, Taiwan, and Japan (Goldsmit et al., 2019). Due to the increase in shipping, it is predicted that vessels servicing this mine will exchange ballast water 176 times a year. This converts to just over three million tonnes of ballast water being discharged into Milne Port each shipping season (DFO, 2019). This exchange will result in a temperature increase and a decrease in nutrient concentration near the point of exchange which can impede the success of native marine fish and invertebrates (DFO, 2019). Once invasive species have established themselves in a new area, they are likely to impact the natural environment such as degrading water quality and affecting wildlife habitats (Canadian Council on Invasive Species, 2020). For example, a study by Dias et al. (2019) indicated that seabirds are likely to be impacted by invasive fish species although the severity of the impact is predicted to be low.

The introduction of invasive species is much more concerning in Milne Inlet as the water is shallower (Figure 2) and sheltered within the Bay, promoting the settlement of marine organisms and pathogens (Golder Associates Ltd., 2018a). A report by DFO suggests that Baffinland will perform BWE while the vessels are anchored or at port rather than in transit, resulting in more concentrated impacts affecting local water quality and causing added environmental stress (DFO, 2019). For example, Ragged Island has been identified as one of the main anchoring sites, ranging from 14-21m depth which could promote the settlement of invasive species (Golder Associates Ltd., 2018a). A map of all six designated anchoring sites servicing the Baffinland Mine can be found in section 3.1.4 (Figure 12).

To date, there are several known cases where temperate species have survived and settled in the Arctic after being transported via biofouling (e.g. *Harpacticus obscurus* and *Amphibalanus improvises*) (Chan, MacIsaac & Bailey, 2016). There have also been new species of zooplankton and benthic epifauna recorded within the study site, illustrating that the survival and settlement of invasive species is possible, and likely to affect benthic habitat (Golder Associates Ltd., 2018a). Additionally, several potential invasive marine species have been identified in Nunavut (e.g. *Eriocheir sinensis)*, ranging from parasites to invertebrates, some of which are considered high risk to the region (Government of Nunavut, 2010). Although many were introduced from southern Canada, it is not unreasonable to expect a rise in marine invasive species from foreign waters as international travel to Baffinland intensifies—increasing the potential for disease transfer (Goldsmit et al., 2019). In general, algae are found to be more tolerant of the Arctic environment and are more successful at establishing themselves compared to invertebrates (Chan et al., 2016).

Invasive species not only affect the environment but results in socio-cultural impacts such as a loss of ecosystem services and elevated health concerns. Biofouling and BWE also introduce the potential to transfer pathogens (e.g. parasites and viruses) which act as vectors for disease (Bonesteel, 2006). These pathogens can be transported up the food web to larger wildlife and ultimately spread disease to the Inuit who rely on subsistence hunting, causing health issues they may have little to no defensive tolerance for (Bonesteel, 2006). Once invasive species are established in an area, they are difficult, if not impossible to eradicate, which may cause irreversible damage to the environment and impede the success of native wildlife (Canadian Council on Invasive Species, 2020), affecting food security.

3.1.2 Underwater Noise Pollution

Baffinland will require frequent use of cargo vessels, tug/line boats, supply vessels, and icebreaker ships throughout their shipping season, which will overlap with particularly sensitive life history phases (e.g. breeding, pupping, migration) for vulnerable Arctic wildlife (DFO, 2019). Baffinland has determined its worst-case shipping scenario to include nine vessel transits per day, contributing to approximately 16 hours of disturbance from ship-related noise exposure (Baffinland, 2019). This means that under Baffinland's worst-case scenario, wildlife would experience eight hours of quiet time per day, where noise is below disturbance thresholds.

Cargo vessels tend to create underwater noise at low frequencies (typically below 1 kHz), thus mysticetes (baleen whales) are among the most vulnerable to noise pollution from increased cargo traffic (WWF, 2017a; Hauser et al., 2018). In contrast, icebreakers used to clear shipping routes to and from Milne port produce high-frequency noise attributed to propeller cavitation and surface water bubbler systems. Propeller cavitation noise results from the propeller turning at high speeds generating bubbles which then burst underwater. Although a common product of shipping, it can produce sharp pulses of noise reaching a maximum of 20kHz when vessels are trapped or pushing against ice as the system is under greater pressure (Erbe & Farmer, 2000). Water bubbler systems are used to push broken ice away from the ship by forcing air into the water at high pressure, resulting in a consistent stream of sound reaching a maximum of 5kHz (Erbe & Farmer, 2000). Thus, greater ice concentrations can be linked to increased noise pollution from icebreaking activities. In general, high-frequency noise affects a broader range of Arctic wildlife (Figure 9). Belugas and narwhals appear most sensitive, responding to noise from icebreakers well before other species (Finley, Miller, Davis & Greene, 1990; Cosens & Dueck, 1993). For example, belugas have been known to respond to icebreakers while nearly 50km away, sometimes forcing them to flee the area for several days (Finley et al., 1990).

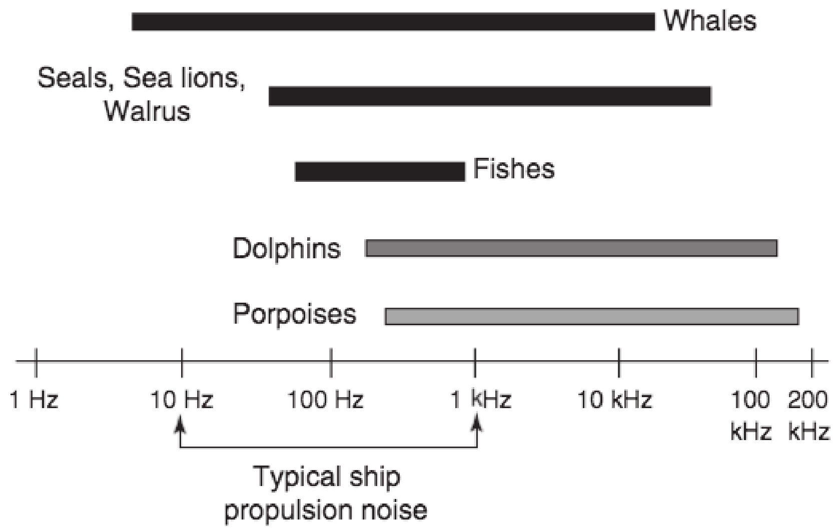

Figure 9. Average hearing range for marine mammals relative to commercial shipping noise (Southall et al., 2017)

In addition to the above sources, several factors further contribute to shipping noise including vessel speed, vessel size, vessel type, engine type, hull form, and vessel condition (Southall et al., 2017). Noise pollution from ships is further amplified by the environment as sound propagation is dependent on multiple factors including the bathymetry of the ocean, type of the sediment, properties of the water column, and characteristics of the sea surface (Farcas, Thompson & Merchant, 2016; DFO, 2019). For instance, shallow bodies of cold water have been shown to propagate sound much further, causing a greater impact on marine life (Farcas et al., 2016). This suggests that similar results may occur in Milne Inlet. For reference, Figure 10 illustrates how far sound travels within the channel based on four locations along the shipping route: Koluktoo Bay, Milne Inlet, Eclipse Sound, and Pond Inlet. Sound modeling was performed by JASCO Applied Sciences using Baffinland's original panamax-size ore carriers; however, the Phase 2 expansion requires capesize vessels which are significantly larger and are assumed to cause more widespread effects, increasing the risk of impact.

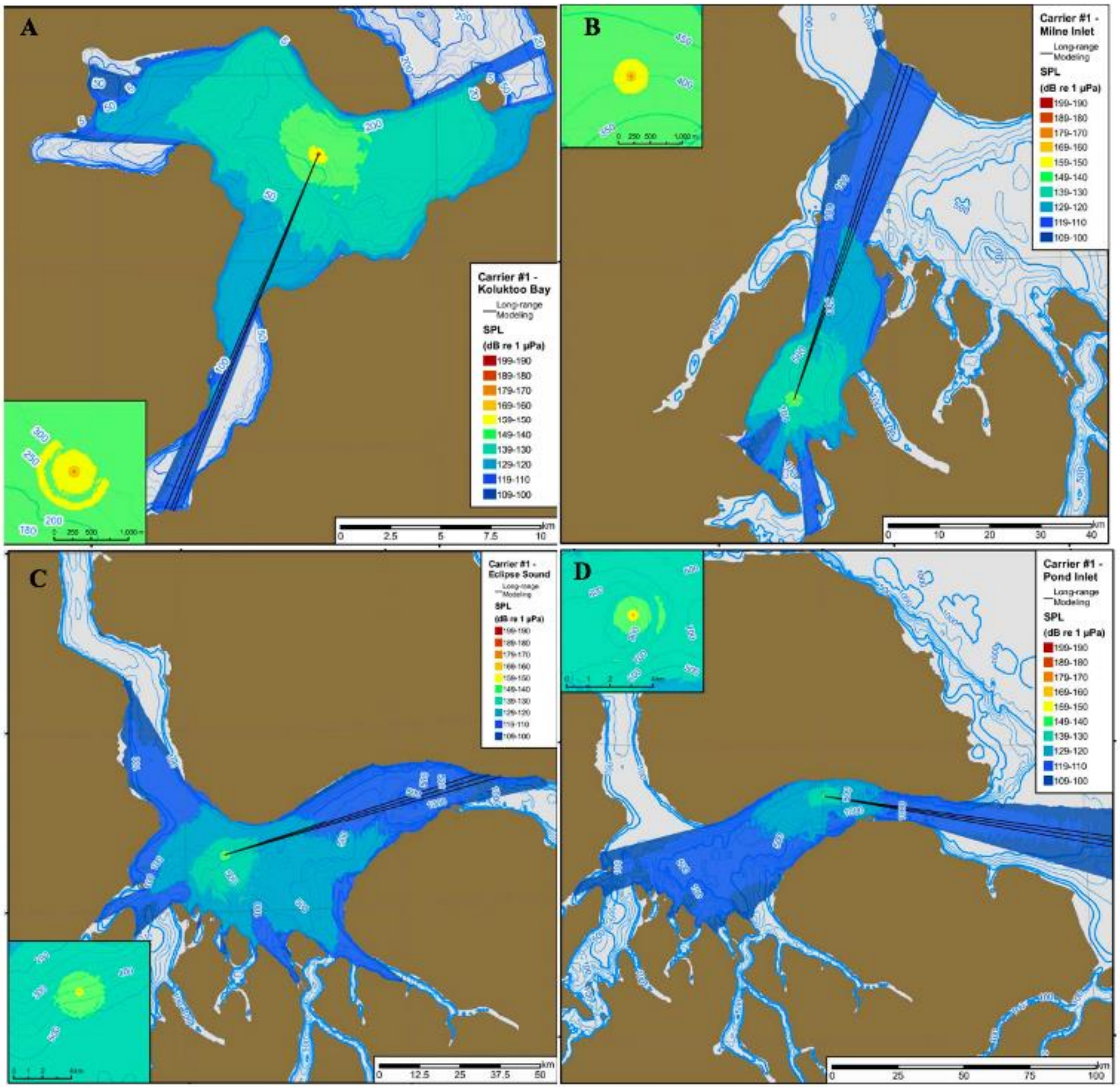

Figure 10. Sound propagation map of a panamax-size ore carrier (10-2000 Hz) transiting Koluktoo Bay (A), Milne Inlet (B), Eclipse Sound (C), and Pond Inlet (D) in open water season, modified from Zykov & Mathews, 2010

Possible impacts on wildlife include heightened stress response, decreased reproduction, hearing loss, auditory masking, and disorientation. If wildlife is exposed to high levels of noise pollution for a prolonged period (as is expected with the Baffinland proposal) it may inhibit natural life functions and essential behavioural responses such as mate selection, communication, foraging, and predator avoidance, as well as cause wildlife to shifts habitat due to area avoidance mechanisms (Weilgart, 2007; ASMA, 2009; Southall et al., 2017). It has been modeled that belugas can experience auditory masking and disturbance while over 40km from an icebreaker, while hearing damage can occur when near the source for as little as 30 minutes (Erbe & Farmer, 2000). Typically, belugas are known to flee the area before permanent damage is endured; however, in important life stages (e.g. mating, nursing, or feeding) they may remain in the area, increasing the risk of impact from noise (Erbe & Farmer, 2000). Similarly, narwhals and walruses have been reported eliciting a freeze response in some cases when in the presence of intense noise, rendering them more vulnerable to permanent damage (Finley et al., 1990; WWF, 2017a). However, narwhals often fled the area for upwards of 48hrs once vessels were detected within close range (Finley et al., 1990).

There is concern over narwhals experiencing either temporary or permanent hearing impairments due to increased noise, especially in Milne Inlet as the environment is thought to encourage sound propagation more than other areas within the study site (DFO, 2019). Narwhals may experience the masking effect (DFO, 2019) and avoidance behaviour has been recorded within 3km from a vessel, coupled with changes in dive cycles such as increased dive rates, and reduced surface time, suggesting a flight response (Finley et al., 1990; Baffinland, 2019). In heavy ice conditions, it is predicted that narwhals will be "exposed to noise levels above the disturbance threshold [120dB] for up to 9.5 hours per day …. [and] would be exposed to noise levels above the avoidance threshold (135 dB) for up to 2 hours per day" (Baffinland, 2019. p. 72). It has also been calculated that nearly half of the summer aggregation of narwhals will be impacted by noise disturbance from ships servicing Baffinland while similar results were concluded for the bowhead whale population (DFO, 2019). Another study suggests that bowhead whales may avoid areas with high noise levels, pushing them outside of their preferred habitat

(Richardson et al., 1985). It is also reported that certain teleost fish (i.e. boney fish with their swim bladder connected to their ear such as herring) are more strongly impacted by anthropogenic noise, resulting in inference in communication, hearing damage, or barotrauma, impeding their survival (Normandeau Assocaites, 2012). A study by Ivanova et al., (2018) showed that shorthorn sculpin (*Myoxocephalus scorpius*) altered their behaviour in the presence of vessels (anchored or in transit). It is thought that sculpin perceive vessel presence as a threat, thus limiting their movement which may negatively impact foraging success among other aspects of their fitness (Ivanova et al., 2018). A later study by Inanova et al., 2019 showed similar results; that shipping alters the movement and behaviour of Arctic cod (*Borgeogadus saida*) by restricting their spatial range, avoiding vessels in favor of areas with less anthropogenic noise and decreasing exploratory activities. Irrespective of species, the impact of noise pollution largely depends on the individual, as characteristics such as age, health, and tolerance influence their response (Weilgart, 2007; Gomez et al., 2016).

Additionally, it is thought that narwhals may actively choose to avoid Eclipse Sound on their northern migration if noise pollution is too high and instead travel to Admiralty Inlet (DFO, 2019). Thus, ship noise has been linked to unfavourable habitat leading to area avoidance behaviours for Arctic wildlife. This can critically impact Inuit communities which rely on Eclipse Sound as their primary hunting ground by diminishing stock abundance and influencing animal distribution. These factors can impact food security, hinder the development of valuable skills (e.g. hunting, food preparation, etc.), and impede the transfer of traditional knowledge by limiting opportunities for experiential learning (Hoover et al., 2016; Carter er al., 2018).

3.1.3 Chemical Pollution

Shipping is a major source of marine-based chemical pollution and is commonly associated with oil spills, operational discharges, and the use of scrubber systems in vessels. Oil spills can be the result of mechanical issues (e.g. leaks in the hull), human error induced accidents as the environment can pose navigational barriers (e.g. icebergs or chokepoints), or from accidental or illegal discharge (Tornero & Hanke, 2016). A report by Reich, Etkin, Rowe and Zamorski uses deterministic modeling to map possible oil spill distribution patterns from bulk carriers in Eclipse Sound in open water and ice-covered seasons (2016). A model was run over 30 days using 1,000m^3 of oil with no spill response. Note that iron ore carriers typically carry 5,500 m^3 of IFO bunker fuel and 750 m^3 of diesel fuel (Reich et al., 2016), meaning the modeled spill is rather small in comparison. The worst-case scenario is highlighted below (Figure 11), although the dispersal pattern changes given the amount of ice present at the time of the spill and the environmental conditions (e.g. wind, tides). The spread of oil is greatest during open water season (Reich et al., 2016); however, it is thought that the impacts from an oil spill would be greatest during freeze-up and ice-covered periods when clean-up is challenging given the mixture of oil, water, and ice (DFO, 2019). Furthermore, oil is known to degrade much slower in cold temperatures compared to temperate waters, leaving the effects of a spill to linger much longer in the Arctic environment (Huntington et al., 2015).

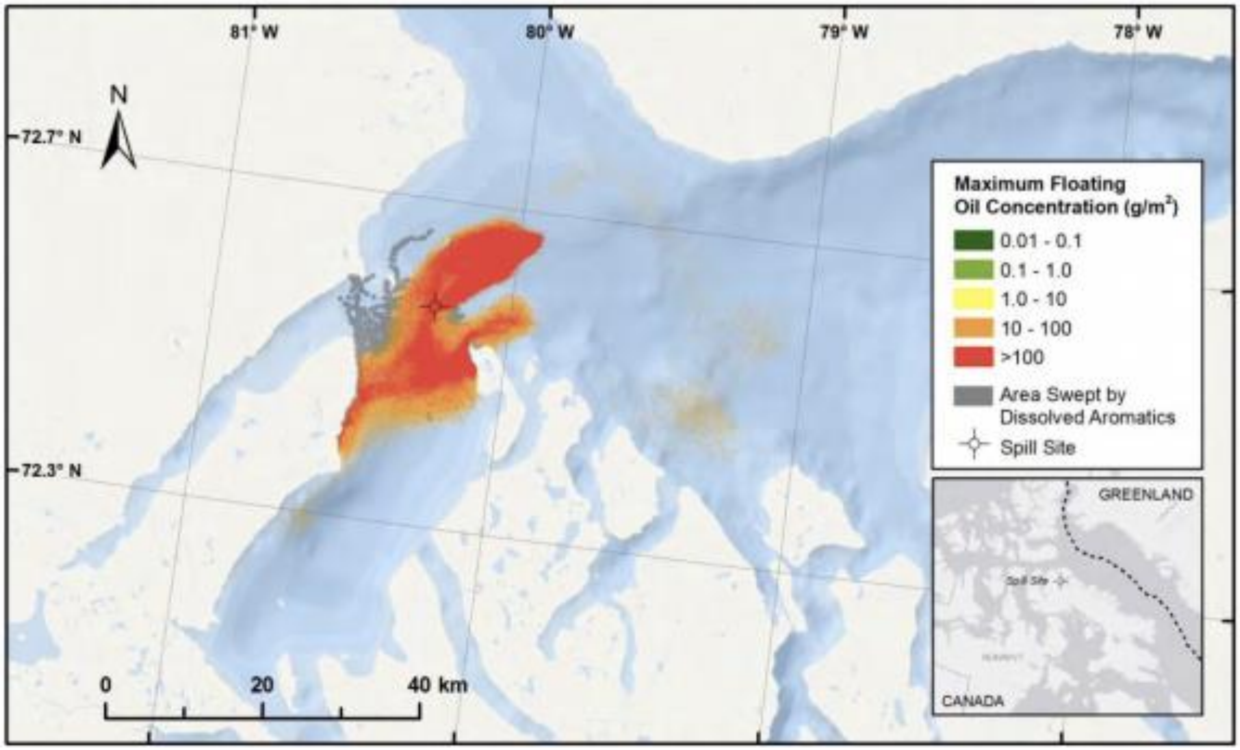

Figure 11. Worst-case trajectory of maximum floating oil concentration (g/m3) in Eclipse Sound during ice-covered period (Reich et al., 2016)

Under the worst-case scenario (Figure 11), over 40km of shoreline is oiled above the ecological threshold of 100g/m^3 and the water column is saturated with aromatics (Reich et al., 2016). Thus, oil spills can cause serious impacts to wildlife by contaminating the environment and destroying sensitive habitat (Gross, 2018). Additionally, the oil can be ingested by wildlife leading to serious health complications, and interfere with ocular and olfactory cues (DFO, 2019). For example, oil can clog the gills of fish leading to asphyxiation or contaminants can bioaccumulate in the body proving lethal to both the individual and its predators as contaminants are then transferred up the food web (Teal & Howarth, 1984). A study by Langangen et al. (2017) suggests that low concentrations of oil or chemical contaminants can be fatal to fish eggs and larvae as it causes issues in developmental such as morphological deformities and reduced growth rates, making them vulnerable to predation. The same study further suggests that oil spills can negatively affect fish stocks if they occur during mass spawning events as it may impact recruitment.

Oil spills may severely impact marine mammals, particularly polar bears as it coats their fur and reduces their ability to self-insulate, often leading to hypothermia, fur loss, increased stress, fever, and inflammation (Helm et al., 2015). Polar bears have been reported grooming their fur to try to remove the oil, causing them to ingest toxins which can lead to respiratory issues, liver and kidney failure, gastrointestinal problems, and other fatal complications (Helm et al., 2015). Pinnipeds, which rely on blubber for insulation, are less likely to be directly impacted by oil spills; however, they are considered vulnerable during important life stages (e.g. breeding, moulting) as they haul out on the ice and are at greater risk of exposure (Helm et al., 2015; Nevalainen, Helle & Vanhatalo, 2018). In severe cases, seals were reported covered in oil to the point where they were unable to swim and drowned (Helm et al., 2015). The presence of oil is also thought to impact walruses' wintering areas (DFO, 2019). Conversely, bowhead whales and other cetaceans are considered less vulnerable to the effects of oil spills as oil does not accumulate on their skin, although if ingested while surfacing for air it may cause respiratory issues (Helm et al., 2015).

Oil spills and chemical pollutants have been known to threaten seabirds and their habitat. Direct impacts include hypothermia, as oil can be absorbed into their feathers reducing insulation and organ failure, and trace amounts of oil can prove toxic if ingested (Wiese & Ryan, 2003). Indirect effects on seabirds include a loss of important food sources as fish (e.g. Arctic cod) would be negatively impacted (Humphries & Huettmann, 2012). It is thought that the slow, persistent release of oil and other contaminants is more detrimental than occasional large spill events as impacts are felt long-term with the potential to reach a larger number of individuals over time and are more difficult to detect and clean up in the environment (Wiese & Ryan, 2003). Although it is not just wildlife that is impacted by chemical pollutants, it can seriously degrade the marine habitat from reducing water quality to contaminating the seabed (Teal & Howarth, 1984). As oil residue sinks, it may continue to impact wildlife that forage or utilize the seabed as well as decrease the abundance and diversity of the benthic community and cause anoxic conditions (Helm et al., 2015; Teal & Howarth, 1984).

Operational discharge refers to other contaminants not linked to oil or scrubbers (e.g. cleaners, lubricants, antifouling paint, sewage, bilge water, etc.), which are released into the water. These contaminants can include elements such as copper, arsenic, iron, lead, and others which are toxic to wildlife and further degrade the health of the environment (Tornero & Hanke, 2016). Lastly, the use of scrubbers to treat sulphur emissions from entering the atmosphere releases harmful contaminants into the water column such as heavy metals, thereby reducing pH value, increasing turbidity and temporarily increasing temperature (Lange et al., 2015). These pollutants can accumulate in the environment, degrading the natural habitat, and impacting lower trophic levels causing bottom-up cascades in the food web (Lange et al., 2015). If these pollutants are ingested by wildlife, they can cause acute to chronic toxic symptoms and other health complications (Lange et al., 2015). This is concerning for Inuit communities which rely on these animals as their primary food source as contaminated wildlife may cause illness (Bonesteel, 2006; Humphries & Huettmann, 2012; Huntington et al., 2015). For example, Arctic char that were caught within the study site were determined to have heavy metals and chemicals such as arsenic, cadmium, chromium, copper, iron, mercury, and zinc present in their tissue samples, some of which are extremely poisonous (Golder Associates Ltd. 2018a). It has been noted that Inuit hunters are having to discard more of their catch as it is deemed not suitable for consumption which inadvertently impacts local food security in the area (Bonesteel, 2006). Furthermore, the introduction of chemical pollution from scrubbers is assumed to increase as the IMO has recently implemented a sulphur cap as of January 2020, restricting the use of fuel with > 0.5% sulphur concentration for all vessels unless fitted with an exhaust gas cleaning system or scrubber (International Chamber of Shipping, 2019). This means that more vessels are seeking to be fitted with scrubbers to avoid the added cost of switching fuels to comply with the IMO regulations—essentially converting atmospheric pollution into marine pollution.

3.1.4 Habitat Disturbance

Habitat disturbance can be attributed to various shipping activities such as icebreaking, anchoring, and grounding. As noted earlier, icebreakers are used to clear paths for other vessels which ultimately disturbs the natural formation of sea ice. This impacts wildlife which rely on the sea ice as part of their critical habitat. The use of icebreakers has been known to hamper the migration of caribou in the fall as there is a loss of connectivity between landmasses (Jenkins et al., 2016). There have also been reports of narwhal being entrapped in new ice floats during their migration. For instance, in 2015 over 250 narwhals were entrapped due to shipping activity in Eclipse Sound. This is thought to affect their migration pattern in the future as they learn to avoid unsafe areas (Laidre, Markus, Helfst & Mayer, 2012; DFO, 2019). Similarly, disturbing natural sea ice formation has stranded polar bears trapped on broken ice sheets (Stover, 2019). This inhibits their safe return to land as the newly forming ice (after an icebreaker has passed) is too thin to support their weight, leaving them stranded for days or weeks until the ice thickens.

The use of icebreakers during important life stages can impede foraging, moulting, and breeding behaviours in pinnipeds (Hauser et al., 2018). For example, the use of icebreakers during pupping season can displace seal pups from their mothers and destroy resting and birthing areas, increasing their stress response (Wilson et al., 2017; Yurkowski, Young, Dunn & Ferguson, 2019). Studies suggest that icebreaking puts pinnipeds at an increased risk of predation, impedes their ability to access haul-out sites, and destroys critical habitat that is necessary for their survival (Yurkowski et al., 2019). Walruses have been recorded responding to icebreakers up to 2km away, forcing them to enter the water, disturbing their activity, and making them susceptible to predation (Fay, Kelly, Gehnrich, Sease & Hoover, 1984). A study by Huntington suggests that the icebreakers can disturb the denning habitat for seals and polar bears, impeding their overall fitness (2009). Thus, it is evident that habitat disturbance attributed to shipping activity can have numerous adverse impacts on Arctic wildlife. Other concerns include the impact on seabirds from increased shipping traffic as transit routes overlap foraging sites, disturbing foraging behaviour (Humphries & Huettmann, 2012). This is especially concerning as Baffinland's shipping route passes south of Bylot Island, a migratory bird sanctuary home to 71 diverse species—where seabirds make up 37% of the island population (Government of Canada, 2019). Moreover, the surrounding waters of Bylot Island (specifically Navy Board Inlet and Eclipse Sound) provide key foraging grounds and important post-breeding and migratory habitat increasing risks of disturbance from vessel traffic (Wong et al., 2018; Government of Canada, 2019).

There is also concern with impacts from vessels anchoring at the six designated anchoring locations planned in Milne Inlet and Eclipse Sound (Figure 12) as collisions with the seabed can alter the environment, remove biota and disturb sediment (increasing the turbidity in the water). This is problematic as it reduces visibility and can smother benthic communities which then indirectly impacts prey availability and causes changes further up the food web

(Todd et al., 2015). However, anchoring is not thought to pose a significant impact on Arctic wildlife as the effects are usually localized and short-term (Todd et al., 2015). Likewise, groundings can cause similar impacts but on a much greater scale and with the added risk of an oil or bunker fuel spill (Reich et al., 2016). Moreover, propeller-generated currents can cause seabed erosion and disturb fine sediment, contributing to the degradation of both water quality and benthic habitat (Golder Associates Ltd., 2018b). More specifically, propeller rotation is thought to increase the concentrations of nutrients, metals, and other substances in the water column, and is assumed to cause a greater impact in shallow, narrow channels such as Milne Inlet (Golder Associates Ltd., 2018b).

Figure 12. Map of the six designated anchoring locations (depicted as stars) within the study site, adapted from DFO, 2019 and Google Maps

Furthermore, heavy ship traffic has been linked to severe structural and temporal alterations in sea ice cover (Lawson & Lesage, 2013). This can influence how Inuit use the marine space and interact with the environment given that they rely heavily on their relationship with the sea, ice, and land (Aporta, Kane & Chircop, 2018). For example, heightened wave action attributed to increased shipping in the channel (e.g. wave wake) delays sea ice formation. Consequently, Inuit are unable to use the landfast ice until later in the season, delaying their hunting season and reducing safe travel conditions (DFO, 2019). Additionally, Inuit also suffer from habitat fragmentation attributed to shipping activity as many of their travel routes extend across the ice and sea (Aporta et al., 2018) and they may be forced to travel further to reach their intended destinations or risk unsafe travel conditions. Residents transiting the area by boat or sled may be at greater risk of being struck, capsized, or displaced in the presence of larger commercial vessels (Huntington et al., 2015). The restricted use of their territory coupled with reduced habitat suitability for wildlife may increase the risk of food insecurity throughout the region. This finding is supported as many species are known to migrate seasonally; thus, if conditions are unfavourable, they may choose to avoid the area the following year, further limiting food availability (DFO, 2019).

3.1.5 Vessel Strikes

An increase in ship traffic intuitively raises the likelihood of ship strikes occurring. This is mainly a concern with larger marine mammals such as cetaceans, while bowhead whales are considered especially vulnerable (Hauser et al., 2018). Odontocetes (toothed whales) and pinnipeds are less likely to be struck by a vessel as they have better maneuverability and tend to travel in groups that are more easily detected in comparison to the bowhead whale and other large cetaceans (ASMA, 2009). Both narwhal and walruses have been documented eliciting a freeze response in the presence of icebreakers, making them more vulnerable to vessel strikes at that time (Finley et al., 1990; WWF, 2017a). However, it should be noted that narwhals generally fled the area once the vessel was closer, often not returning for 48hrs (Finlet et al., 1990). In general, odontocetes are considered at an advantage compared to mysticetes (baleen whales) as they rely on echolocation to navigate their environment and are therefore more likely to avoid incoming vessels (Baffinland, 2019).

The risk of vessel strikes increases with migration and important life-history phases when wildlife is more abundant in the area. For example, pinnipeds are exposed to a greater risk of vessel strikes during breeding which requires them to haul out onto the ice (DFO, 2019). In the case of Baffinland, this is especially true for ringed or bearded seals in birthing lairs or basking on ice (Lawson & Lesage, 2013). Collision risk also increases in the presence of multiple vessels as there is less space to avoid oncoming traffic (DFO, 2019). Additionally, as vessels may be transiting outside of daylight hours, there is an increased risk of striking wildlife due to low visibility conditions (DFO 2019). It is also reported that cargo carriers and larger vessels are less likely to avoid collisions with wildlife as they are difficult to maneuver, especially in shallow and ice-covered waters (DFO, 2019). Regardless of the species, vessel collisions with any wildlife can prove lethal on impact, although it is more likely to cause trauma, hemorrhaging, broken bones, and propeller wounds which may later result in fatal complications (ASMA, 2009). As impacts are permanent and likely lethal, vessel strikes are considered a significant shipping hazard in the Arctic (DFO, 2019).

Chapter 4: Baffinland's Proposed Management Plans

This chapter outlines Baffinland's intent to comply with appropriate legislation and implement additional management measures to minimize impacts from shipping (see Chapter 3). Baffinland recognizes its potential to negatively impact native wildlife, the environment, and local communities and claims that they are dedicated to improving operating practices to limit disturbance. By implementing additional measures beyond what is legally required, Baffinland plans to exceed industry standards to achieve their goal of "minimiz[ing] any negative effects on the environment and traditional land use activities" (Baffinland, 2019, p. 85) in hopes of gaining project approval.

A review of current and proposed management measures was conducted to determine how Baffinland plans to manage impacts from shipping hazards. The results of this chapter are largely drawn from a 2019 report detailing Baffinland's response to concerns raised by various interest groups. A review of international and national legislation was also conducted to identify mandatory management measures with which Baffinland must comply. This multilateral approach ensures a more comprehensive list of proposed management efforts for each of the five identified shipping hazards.

The research methods are encumbered by two underlying assumptions. Firstly, this research does not directly assess whether these measures are effective at achieving their targets, rather it assumes that they are. This assumption is based on the results from a series of studies conducted for the Baffinland Mine Cooperation as well as studies that compared empirical evidence from previous years of operation—supporting Baffinland's decision to implement the proposed management measures. Thus, this research assumes that their findings were conclusive and will reduce impacts from shipping hazards. Secondly, this research assumes Baffinland will honour its plans to implement, enforce, and comply with each of the discussed management measures.

4.1 Results

Baffinland has expressed written intent to follow all mandatory regulations to minimize impacts from shipping, including those at the international and national levels. In addition, Baffinland plans to implement a series of voluntary best practices and guidelines. This section defines each of these measures and their role in managing adverse impacts from the identified shipping hazards. It also outlines some of the overarching legislation that contributes to the complex governance structure for shipping in the Canadian Arctic.

Internationally, the United Nations Convention of the Law of the Sea (UNCLOS) provides the legal framework that dictates which activities can be carried out at sea, including safe navigation (UNCLOS, 1982). Under UNCLOS, the International Maritime Organization (IMO) has a mandate to further regulate maritime issues including the International Convention for the Prevention of Pollution from Ships (MARPOL) (IMO, 2020). These regulatory bodies set the international requirements and standards for marine shipping and take precedence over national regulation. At the national level, the *Canadian Shipping Act* (2001) is the primary shipping legislation, accompanied by the *Arctic Waters Pollution Prevent Act* (1985) and numerous supporting regulations.

All relevant management measures that Baffinland intends to implement have been summarized (Table 3) and are discussed in more detail throughout this chapter. In addition, Baffinland plans to continue monitoring for impacts from shipping hazards, particularly acoustic disturbance, entrapment of narwhals, and ballast water monitoring for invasive species (including temperature and salinity sampling) throughout their project lifecycle to maintain environmental awareness and improve management plans as needed (Baffinland, 2019). In an effort to manage social impacts, Baffinland plans to increase Inuit employment with a focus on gender equality in the workplace (Baffinland, 2019). This is thought to benefit the communities by improving their socio-economic status. It is anticipated that the expansion project will require 1075 entry-level workers by 2025, providing an opportunity for many locals to join the workforce if they choose.

Table 3

List of Management Measures that Baffinland Corporation Plans to Implement to Minimize Impacts from Shipping Hazards

Management measures	Brief Description	Mandatory/ Voluntary	Shipping Hazard
International Convention for the Control and Management of Ship's Ballast Water and Sediment	-Conduct mid-ocean exchange unless fitted with an onboard treatment system -Achieve at least 95% volumetric exchange -Follow strict maximum concentrations for organisms and pathogens in treated ballast water -Exchange of sediment at reception facilities only	Mandatory (International)	Aquatic Invasive Species
Ballast Water Control and Management Regulations	-BWE must be performed in an area in Lancaster Sound that is east of 80° west longitude where the water depth is at least 300 m and achieve at least 95% volumetric exchange -Abide by strict maximum concentrations for organisms and pathogens in treated ballast water -Prohibit disposal of sediment from ballast water into Canada waters	Mandatory (National)	Aquatic Invasive Species
Treatment of Ballast water	-All vessels must perform a BWE prior to treatment -Undergo regular inspections and onboard ballast water testing	Voluntary	Aquatic Invasive Species
Speed restrictions	-Maximum 9 knot limit for all Baffinland vessels transiting within Eclipse Sound and Milne Inlet	Voluntary	Underwater noise pollution, Vessel strikes
Avoid shipping during sensitive periods	-Shipping and icebreaking activities will be restricted to outside of sensitive life history periods for marine life	Voluntary	Underwater noise pollution, Habitat disturbance, Vessel strikes
Limit transits during moderate-heavy ice conditions	-One transit per 24hr period in >6/10 ice concentration -Two transits per 24hr period in 4-6/10 ice concentrations -Regular operations in ≤ 3/10 ice concentrations	Voluntary	Underwater noise pollution, Vessel strikes
Quiet periods	-A minimum eight hour quite period per 24hr cycle	Voluntary	Underwater noise pollution
MARPOL construction standards	-Abide by oil fuel tank protection standards	Mandatory (International)	Chemical pollution

Oil Pollution Emergency Plan (OPEP)	-Develop a detailed emergency response plan to remediate oil spills	Mandatory (National)	Chemical pollution
Arctic Waters Pollution Prevention Act	-Enforce “no person or ship shall deposit or permit the deposit of waste of any type in the Arctic waters” (p. 4)	Mandatory (National)	Chemical pollution
No passing zones	-Areas along the northern shipping route where vessels are not permitted to pass other vessels	Voluntary	Chemical pollution (accident)
Clearance from the Mittimatilik Hunters and Trappers Organization (MHTO)	-Shipping will not commence until Baffinland receives clearance from the MHTO that the floe edge is no longer being used by Inuit	Voluntary	Habitat disturbance
No breaking of landfast ice	-Shipping will not occur where landfast ice is present	Voluntary	Habitat disturbance
Marine Mammal Regulations	-A minimum distance that vessels must maintain from marine mammals	Mandatory (National)	Vessel strikes
Marine Wildlife Observers (MWOs)	-MWOs are required on all icebreaker ships to alert the vessel Master of marine mammal sightings	Voluntary	Vessel strikes
Stoppage of movement in the presence of disturbed wildlife	-Vessels will cease operations or implement appropriate protocols to minimize disturbance in the presence of disturbed or entrapped wildlife	Voluntary	Vessel strikes
Buffer zones	-Vessels must wait 40km east of the floe edge at the entrance to Eclipse Sound until no marine mammals are present and they have been cleared to enter -Maintain a 300 m buffer zone from polar bear and walrus when present on sea ice	Voluntary	Vessel strikes

4.1.1 Aquatic Invasive Species

There are three main management measures that Baffinland plans to implement in order to reduce the introduction of aquatic invasive species into the study area. Baffinland will comply with the IMO, under the International Convention for the Control and Management of Ship's Ballast Water and Sediment (2017), which states that all vessels must conduct BWE in mid-ocean until fitted with an onboard ballast water treatment system. For vessels using a ballast water treatment system, the convention states that ballast water must meet the following requirements: under 10 viable organisms per m^3 for organisms ≥ 50 µ or per ml for organisms ≥10 µ but < 50 µ; no more than one colony-forming unit (cfu) of toxicogenic Vibrio cholerae (O1 and O139) per 100 mL or one cfu of that microbe per gram (wet weight) of zooplankton samples; no more than 250 cfu of Escherichia coli per 100 mL; and no more than 100 cfu of intestinal enterococci per 100 mL before being discharged. For vessels not using a treatment system, they much achieve at least 95% volumetric exchange in mid-ocean. Regardless of the BWE option, sediment from the ballast is to be exchanged only at reception facilities, not disposed of at sea. It is also mandatory for each vessel to carry a ballast water record book and hold an international ballast water management certificate to ensure that proper protocol is maintained and logged for reference.

Under the Ballast Water Control and Management Regulations (2011), vessels which navigate more than 200 NM from shore in waters ≥2,000 m (e.g. vessels returning to Baffinland from international travel) must exchange ballast water in “an area in Lancaster Sound east of 80° west longitude where the water depth is at least 300 m” (p. 7) in addition to the above requirements implemented by the IMO. These regulations further support that vessels do not release settled sediment from ballast water under Canadian jurisdiction unless at a recognized reception facility. These processes reduce the chance of harmful non-native organisms and pathogens from entering the study site and limit survival if introduction does occur, as it is more difficult to settle in deeper waters and colonize in low concentrations (Goldsmit et al., 2019).

Beyond the above requirements, Baffinland plans to ensure that all vessels calling into Milne Port conduct a ballast water exchange prior to treatment and have their ballast water sampled for salinity and temperature prior to discharge (Baffinland, 2019). Baffinland also plans to implement regular ship inspections and onboard ballast water testing to monitor for and prevent the transfer of aquatic invasive species (Golder Associates Ltd., 2018a; Baffinland, 2019).

4.1.2 Underwater Noise Pollution

Baffinland noted several voluntary measures to reduce anthropogenic noise pollution. Firstly, Baffinland plans to implement a voluntary speed reduction whereby all project vessels transiting within the study site will be restricted to a maximum speed of 9 knots compared to their previous 14 knot requirement (Baffinland, 2019). This is a more conservative measure than the 10 knot guideline suggested by the federal government. Speed reductions have been linked to considerable declines in noise production as it reduces vessel cavitation, the primary source of vessel noise (McWhinnie, Halliday, Insley, Hilliard & Canessa, 2018). JASCO Applied Sciences has conducted numerous studies within the region and mapped the reduction in noise pollution in Eclipse Sound from vessels traveling at 14 knots compared to 9 knots (M. Austin, personal communication, October 21, 2020); the results show a significant decrease in exposure (Figure 13) (Zykov & Mathews, 2010; Quijano, O’Neill & Austin, 2018).

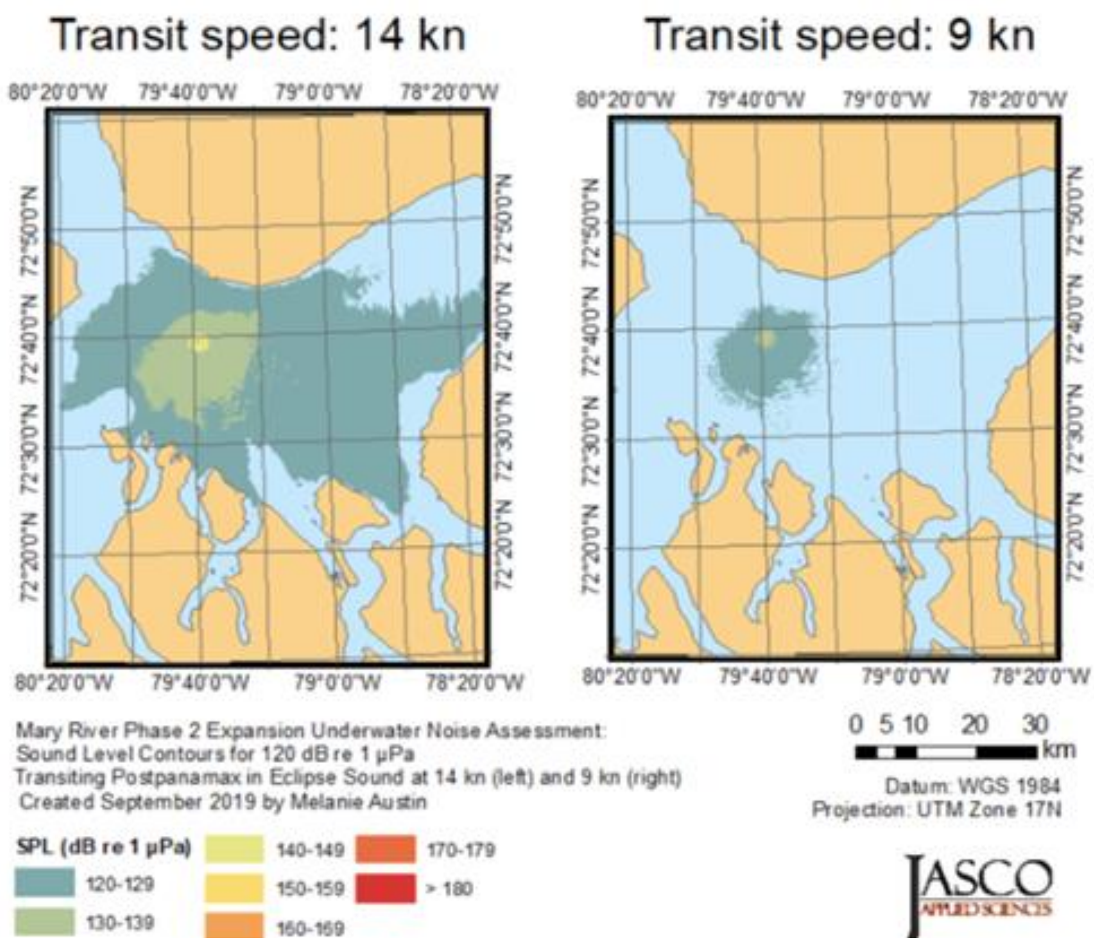

Figure 13. Reduction in sound propagation from vessels traveling at 14 knots verses 9 knots in Eclipse Sound, image adapted from Zykov & Mathews, 2010 and Quijano et al., 2018 by M. Austin (personal communication, October 21, 2020)

Secondly, Baffinland aims to implement areas of avoidance during sensitive life history periods for marine life where all shipping will occur outside of these periods (Baffinland, 2019). For example, shipping will not occur during pupping, nursing, and mating periods for ringed seals (Baffinland, 2019). This will minimize disturbance and added stress during critical periods where marine life is considered most vulnerable. Thirdly, Baffinland will voluntarily reduce allowable transits during moderate to heavy ice conditions. This measure largely targets shipping in the early shoulder season and restricts vessel transits per 24hr period based on ice concentration. For clarity, the term "transit" can include up to five vessels traveling in convoy at one time (e.g. one icebreaker and up to four ore carriers) and is categorized as one event. When ice concentrations are > 6/10 only one transit is allowed per 24hr period. When ice concentrations are between 4/10 and 6/10 two transits are allowed; and when ice concentrations are ≤ 3/10 vessel transits are unrestricted and regular operations can continue (Baffinland, 2019). Regular operations are described as 6-9 transits per day. Fewer transits coupled with slower speeds (typically less than 9 knots) per 24 hr period in moderate to high ice concentrations will reduce daily noise exposure for vulnerable marine life (e.g. pinnipeds and cetaceans).

Fourthly, in addition to limiting transits, Baffinland has committed to ensuring quiet periods to reduce the impact on marine life. Under the above conditions, the average quiet time is: 14 hrs in > 6/10 ice concentrations; 15 hrs in 4/10 to 6/10 ice concentrations; and 12 hrs in ≤ 3/10 ice concentrations (Baffinland, 2019). The worst-case scenario has been calculated using a conservative model and provides only 8 hrs of quiet time per 24 hr period. For clarity, the term "quiet time" pertains to the period where vessel noise is not thought to disturb marine life—this threshold was calculated at < 120 dB (Baffinland, 2019).

4.1.3 Chemical Pollution

Baffinland plans to implement both mandatory and voluntary measures to reduce impacts from chemical pollution. In accordance with MARPOL construction standards including the amendment to Annex I (regulation 12a), all vessels with an aggregate oil fuel capacity of ≥ 600 m^3 (such as those used by Baffinland) must ensure that their oil tanks are protected inside a double hull and follow performance standards to reduce potential oil spills (MARPOL,1973). In compliance with the *Arctic Waters Pollution Prevention Act* (1985) “no person or ship shall deposit or permit the deposit of waste of any type in the Arctic waters" (p. 4) including sewage, food waste, garbage, oil discharge, etc. (*Arctic Waters Pollution Prevention Act, 1*985; Baffinland, 2019). Additionally, Baffinland has developed an OPEP in accordance with national regulations to contain and clean up oil spills, should they occur (Pope, 2019; DeCola, Fletcher & Hughes, 2017). In terms of voluntary measures, Baffinland plans to implement no passing zones within the study site to reduce collisions along narrow passages and areas where navigation is difficult (Baffinland, 2019). This reduces the potential for oil spills and chemical pollution as a result of ship-on-ship collisions.

4.1.4 Habitat Disturbance

Baffinland plans to implement three voluntary measures specific to reducing habitat disturbance. Firstly, Baffinland Iron Mines Corporation must seek written confirmation from the MHTO that the Inuit are no longer using the floe edge before shipping can commence in the early shoulder season (Baffinland, 2019). This is beneficial as Inuit rely on the floe edge to hunt seal and narwhal during haul out, and shipping often makes these areas inaccessible by reducing safe travel, hindering harvests, and impeding their use of traditional knowledge as ice conditions in the presence of shipping are unpredictable (Carter et al., 2018). Secondly, Baffinland agreed to not break landfast ice (Baffinland, 2019). Once again, this is an important area for Inuit and wildlife use and is a fertile hunting ground for seal—a key food source for both Inuit and polar bears (Mahoney, 2018).

Thirdly, Baffinland plans to avoid shipping during sensitive periods for marine life with a specific focus on the pupping, nursing, and mating of ringed seal when densities are highest (Baffinland, 2019). This reduces the risk of impacts from habitat disturbance such as prematurely forcing wildlife into the water which can cause separation and inhibit mother-pup bonding (Wilson et al., 2017; Yurkowski et al., 2019).

4.1.5 Vessel Strikes

In compliance with the recently amended Marine Mammal Regulations (2018), all vessels must keep a minimum distance of 100 m from whales, dolphins, and porpoises or 200 m if they are resting or with their calf, 100 m from walrus in water, 200 m from walrus on ice, and 300 m from walrus onshore (Government of Canada, 2018). To further minimize risk, Baffinland has committed to ensuring local Inuit MWOs are required on all icebreakers to detect marine life and alert the vessel Master of any sightings (Baffinland, 2019). Their role minimizes collision risk as it allows vessels to respond accordingly; for example, vessels may proceed with caution or cease movement until the animal has left the area or they present no imminent risk (Baffinland, 2019). Baffinland has also agreed to implement a 40km buffer zone east of the floe edge at the entrance of Eclipse Sound, where vessels must receive clearance from the Port Captain prior to entering to ensure that no marine mammals are present (Baffinland, 2019). This is particularly useful to prevent collisions with narwhals and other species during their seasonal migration. In addition to the minimum distances from wildlife stated in the Marine Mammal Regulations, Baffinland plans to implement a 300 m buffer between vessels and polar bears (Baffinland, 2019).

As previously mentioned in section 4.1.2, Baffinland plans to implement a speed limit of 9 knots while within Eclipse Sound and Milne Inlet, noting that icebreakers will travel slower in heavy ice conditions to further reduce collision risk (Baffinland, 2019). Likewise, Baffinland plans to avoid shipping during sensitive periods and will limit transits during moderate to heavy ice conditions to reduce the number of vessels in the area (Baffinland, 2019). This is especially useful during sensitive life history periods when wildlife is most vulnerable and often in large aggregates, limiting their ability to safely avoid oncoming vessels. These proposed management initiatives will help limit vessel collisions within the study site, reducing impact to wildlife.

Chapter 5: Impact Assessment

This chapter combines the results from Chapters 3 and 4 to develop an impact matrix. The matrix provides a high-level assessment of the potential impacts from shipping hazards on the 15 identified environmental and socio-cultural VECs. The assessment takes into consideration the proposed management measures that Baffinland Mine Corporation plans to implement in order to mitigate impacts from shipping hazards (Table 3). Thus, the impact scores are reflective of the intended management plans and can help identify areas of concern that have not yet received adequate attention. The impact assessment, therefore, provides a general overview of which impacts may require additional management measures, otherwise identified as areas of management priorities that should be addressed prior to project approval.

5.1 Methods

5.1.1 Impact Matrix

The methodology used for the impact assessment was adapted from Lawson and Lesage (2013), Wood, Southall and Tollit (2012), and Nobel (2015). Impact ratings were assigned for both the severity and likelihood of impacts affecting the identified VECs as a result of shipping hazards. The severity rating was assigned based on the temporal and spatial extent of each impact. The impacts were then categorized from negligible to high (Table 4). Similarly, the likelihood of those impacts occurring as a result of each shipping hazard was assigned from very low to high (Table 5). For clarity, this is not a measure of how frequently each hazard will occur—that value is assumed proportional to the number of vessels transiting the area and further assumes that each transit will negatively impact each VEC. The likelihood estimate for each impact was influenced by the proposed management measures outlined by Baffinland—as described in Chapter 4. It is important to note that the assigned impact ratings are judgment-based and are intended to provide a reasonable estimate for each impact. These estimates are guided by the literature review, not rooted in empirical evidence or direct expert opinion.

Table 4

Severity of Impact

Impact rating	Description
Negligible	No noticeable impact
Low	Temporary, localized, few individuals effected
Moderate	Temporary or permanent, widespread, many individuals affected
High	Permanent or lethal

Table 5

Likelihood of Impact (Lawson & Lesage, 2013)

Impact rating	Description
Very low	Effects are very unlikely
Low	Effects are unlikely
Moderate	Effects are possible or probable
High	Effects are very likely to occur

Relative impact rating was determined based on a combination of the severity of impact and the likelihood of that impact occurring, resulting in four categories of impact rating from negligible to high (Table 6). The impact ratings were converted into categorical values (from zero to three) to easily compare and calculate overall impact scores. The categorical values were used to provide the reader with a general sense of the overall level of threat associated with increasing shipping with the Baffinland proposal. Additionally, each of the categorical values was assigned a colour for clear visual representation in the matrix. See Appendix A for a full list of severity, likelihood, and impact ratings.

Table 6

Impact Rating Adapted from Lawson and Lesage (2013)

Severity Rating	Likelihood Rating	Impact Rating	Categorical Value
High	High or Moderate	High	3
High	Low	Moderate	2
Moderate	High or Moderate	Moderate	2
Low	High	Moderate	2
High	Very Low	Low	1
Low	Moderate	Low	1
Low	Low	Low	1
Moderate	Low or Very Low	Low	1
Low	Very Low	Negligible	0
Negligible	Any	Negligible	0

An impact matrix was adapted from a template retrieved from Nobel (2015) to include both the 15 identified marine environmental and socio-cultural VECs and the five identified shipping hazards, resulting in 75 individual impact scores (Table 7). Separate rows were created to calculate the environmental impact score, socio-cultural impact score, and overall impact score to assess the level of impact attributed to each shipping hazard. Similarly, a separate column was created to assess the overall impact score awarded to each VEC when considering the potential impact of all shipping hazards simultaneously. Overall impact scores were calculated using averages and were rounded to the first decimal place, while impact colours were set relative to the nearest whole number (Table 7). For example, an overall score between 1.5 - 2.4 was determined to be a moderate impact score and coloured orange.

5.1.2 Limitations

Limitations to the study include that the impact matrix does not operate on a weighted scale, thus it assumes that each VEC is valued the same. Without direct expert opinion, it would be difficult to provide an estimate that would properly differentiate between VECs, which is beyond the scope of this study. Similarly, this study does not use empirical evidence to provide quantitative measures of impact; instead, this study uses categorical values to provide a high-level assessment. In this case, the results alone cannot be used to generate action, rather they provide a reasonable estimate of potential impacts from shipping hazards under Baffinland's proposed management measures which can help inform decision-making. The impact matrix may be used to identify potential management gaps; however, further research is needed to support the need for additional management measures. Thus, the matrix is judgment-based (informed by literature) and should be used as a guide for future research. These limitations do not undermine the value of this study as it does provide an appreciation for some of the key potential impacts that may arise due to increasing shipping at the Baffinland facility, supporting the recommendation for further investigation before project approval.

5.2 Results

Table 7

Impact Matrix Comparing the Estimated Level of Impact for Each VEC Assuming the Respective Shipping Hazards Have Occurred (Red/3 = High, Orange/2 = Moderate, Yellow/1 = Low, Grey/0 = Negligible)

Valued Ecosystem Components (VECs) \ Shipping hazards		Aquatic invasive species	Underwater noise pollution	Chemical pollution	Habitat disturbance	Vessel strikes	Overall impact score
Marine environmental	Narwhals	0	3	1	1	2	1.4
	Walrus	0	3	2	2	1	1.6
	Belugas	0	3	1	1	2	1.4
	Bowhead whales	0	2	1	1	3	1.4
	Ringed seals	0	2	2	2	1	1.4
	Bearded seals	0	2	2	2	1	1.4
	Caribou	0	0	0	2	0	0.4
	Polar bear	0	0	3	2	0	1
	Seabirds	0	0	3	1	0	0.8
	Fish	1	2	3	0	0	1.2
	Benthic habitat	2	0	2	2	0	1.2
	Water quality	1	0	2	2	0	1
Socio-cultural	Food security	1	2	2	2	0	1.4
	Traditional livelihood	1	2	2	2	0	1.4
	Public health & safety	1	0	2	3	0	1.2
Environmental impact score		0.3	1.4	1.8	1.5	0.8	
Socio-cultural impact score		1	1.3	2	2.3	0	
Overall impact score		0.5	1.4	1.9	1.7	0.7	

5.2.1 Comparing Shipping Hazards

Chemical pollution and habitat disturbance pose the greatest threat among all identified shipping hazards, receiving a "moderate" impact score, although chemical pollution poses a slightly greater threat by a differential of +0.2. Chemical pollution has the greatest potential to impact environmental VECs while habitat disturbance is more likely to cause a greater impact on socio-cultural VECs. Conversely, aquatic invasive species, underwater noise pollution, and vessel strikes were each awarded an overall "low" impact score under Baffinland's proposed management measures. Impacts from aquatic invasive species pose the least threat overall by a differential of –0.2 and pose a "negligible" impact to environmental VECs, while vessel strikes pose the least threat to socio-cultural VECs with an estimated zero impact score (negligible impact).

5.2.2 Comparing VECs

When comparing impacts across all hazards the most common overall impact score was “low” with 13/15 of the identified VECs ranging from 0.8 - 1.4. Walruses were awarded the greatest overall impact score of 1.6, yielding a moderate impact, making them the most likely to be affected by a wide range of hazards from increased shipping. The impact on caribou received an estimated 0.4 impact score, translating to a “negligible” impact overall, while none of the identified VECs were awarded a “high” overall impact score.

5.2.3 Comparing Individual Impacts

Under Baffinland's proposed management measures narwhals, walruses and belugas are estimated to be at greatest threat from underwater noise pollution, achieving a "high" impact score. Similarly, polar bears, seabirds, and fish are estimated to be impacted the greatest from chemical pollution. Public health and safety is most threatened by habitat disturbance, and bowhead whales are most impacted from vessel strikes; each achieving a "high" impact score. A general breakdown revealed that 8/75 impacts were estimated as "high", 26/75 as "moderate", 15/75 as "low" and 26/75 as "negligible".

Chapter 6: Discussion

This chapter identified gaps in Baffinland's proposed management plans which should be addressed prior to project approval. It also provides the rationale behind the assigned impact scores, demonstrating how the implementation of effective management measures can reduce both the likelihood and severity of impact. Using this rationale, it identifies several areas of management priority to guide resource allocation to further minimize adverse impacts. Additionally, this chapter explores the relationship between environmental and socio-cultural impacts and discloses related issues not otherwise discussed throughout this study.

6.1 Management Gaps

Baffinland's proposed management measures (Table 3) suggest that impacts from chemical pollution, habitat disturbance, and vessel strikes are less well managed compared to impacts from aquatic invasive species and underwater noise pollution. Additionally, impacts from habitat disturbance appear to be more difficult to manage overall. This section explores these management gaps in greater detail while management recommendations are offered in Chapter 7.

6.1.1 Chemical Pollution

In accordance with Transport Canada, Baffinland is required to develop an OPEP; however, its most recent plan (2019 version) fails to provide adequate spill response measures outside of open water season. This is concerning as their proposal calls for shipping in both the spring and fall shoulder seasons which includes ice breakup, ice formation, and ice-covered periods. Baffinland's OPEP relies heavily on booms and skimmers to remove oil from the ocean's surface, although this equipment is easily compromised in icy conditions and is not a reliable solution for shoulder seasons (DeCola et al., 2017; Pope, 2019). Their OPEP also fails to state how much equipment is available at Baffinland, although noting that spills larger than $5m^3$ will require 3rd party assistance (Pope, 2019). This leads me to believe that Baffinland is better prepared to respond to smaller spills. Similarly, neighboring communities such as Pond Inlet and Arctic Bay have equipment to clean near-shore spills less than one tonne, providing little relief as Baffinland tankers can carry 4,000 tonnes of oil, while resupply vessels carry up to 18,000 tonnes (DeCola et al., 2017). For larger spills, Baffinland has partnered with Oil Spill Response Limited located in Southampton, UK to airlift additional equipment; meanwhile the Canadian Coast Guard would be called in from the nearest oil response services in Hay River or Yellowknife (DeCola et al., 2017; Pope, 2019). The inaccessibility of the region coupled with adverse weather and limited human capacity greatly increases response time, impeding successful cleanup, and elevating the risk of devastating environmental and socio-cultural impacts. It is estimated that a spill of 1,000 tonnes in the Arctic may take up to a week to clean, while larger spills require longer (DeCola et al., 2017). Baffinland’s new OPEP should be revised to include appropriate response measures for shipping outside of open water season while accounting for larger spill volumes.

6.1.2 Habitat Disturbance

Baffinland's shipping season spans the traditional harvest of seal, beluga, walrus, narwhal, caribou, Arctic char, and polar bear (Carter et al., 2018; Itulu, 2018). However, these species are not all equally protected from shipping hazards. This is particularly true of impacts from habitat disturbance on caribou, polar bear, and Inuit hunters who rely on thick ice formation for safe travel, hunting, and migration. Baffinland's proposed management measures do not manage impacts from habitat fragmentation beyond their agreement to not break landfast ice (Table 3). There are currently no plans to protect wildlife from becoming stranded on broken ice sheets or to protect hunters from being stranded far from home as they must make longer voyages further from home to avoid unsafe ice conditions. The loss of connectivity between landmasses is not only a barrier to successful harvests—affecting food security—but it can influence one's connection to the land and disrupt knowledge transfer as local knowledge on safe travel routes and harvest access points is no longer reliable under unpredictable ice conditions from increased shipping. Baffinland has not adequately considered the environmental and socio-cultural impacts of habitat disturbance and should work with community members to develop appropriate management plans prior to project approval. The lack of effective management strategies can be partially attributed to habitat disturbance being more difficult to manage than other shipping hazards. This is not possible without restricting the shipping season to open water, impacting the feasibility of the Phase 2 project proposal.

6.1.3 Vessel Strikes

The low overall impact score from vessel strikes (Table 7) can be attributed to the limited number of VECs which are impacted rather than the lack of impact in general, as those which are impacted may endure permanent or fatal damage. Most of Baffinland's management measures help mitigate impacts from vessel strikes during the day when visibility is good. However, most of their measures fail to consider impact management in low visibility (e.g. MWOs). This is especially concerning as the Arctic frequently experiences low visibility conditions such as intense fog, heavy snowfall or "white-out periods" and limited daylight hours (Pope, 2019). This is particularly true during the fall shoulder season. During this period Baffinland is seeking approval to ship up to 16 hours per day (Baffinland, 2019). It is reasonable to assume much of the shipping will occur in the dark or low visibility conditions, rendering many of their proposed management measures ineffective. Thus, management measures should be improved to account for low visibility to reduce impacts on marine mammals.

6.2 Rationale for Assigning Impact Scores

This section explains the rationale behind how impact scores were assigned, increasing the transparency of this research. As mentioned in Chapter 5, scores were awarded in consideration of Baffinland's proposed management measures to limit adverse impacts. In many cases, the proposed management measures were deemed effective at lowering the likelihood of impact. For example, the severity of impact from vessel strikes on cetaceans and pinnipeds was considered "high" as it can cause permanent or lethal damage while the likelihood of impact was also "high" as collisions are very likely to occur with increased shipping activity. However, Baffinland proposed several management measures such as speed restrictions, MWOs, and buffer zones (Table 3) which significantly reduce the risk of collisions. Under the assumption that these measures are implemented and enforced, the likelihood of impact on pinnipeds was reduced to "very low" as they frequent the ice, making them easier to be observed by the MWOs and avoided. Alternatively, the likelihood of impact on cetaceans was only reduced to "low" given that they spend more time underwater—making it more difficult for MWOs to identify them—and are slow moving with limited maneuverability, making them less likely to avoid oncoming vessels. (ASMA, 2009).

6.3 Management Priorities

Despite Baffinland’s effort, there were several instances where their proposed management measures were not capable of addressing all identified shipping impacts. These cases are highlighted in red in the impact matrix (Table 7) and have been listed as areas of management priority, which should be addressed prior to project approval. The matrix highlighted seven interactions resulting in "high" impact ratings, including the impact of noise pollution on narwhals, walruses, and belugas, the impacts of chemical pollution on polar bear, seabirds, and fish, as well as the impacts from habitat disturbance on public health and safety.

As discussed in chapter 3, narwhals and belugas are highly sensitive to the noise from icebreakers, resulting in temporary or permanent hearing loss, altering their natural behaviour, and potentially forcing them to flee their preferred habitat. Meanwhile, walruses are at risk of permanent auditory damage as they are more likely to elicit a freeze response in the presence of intense noise (WWF, 2017a). Baffinland has voluntarily agreed to speed reductions, limiting vessel transits during heavy ice conditions and avoiding shipping during sensitive life history periods which helps limit the likelihood of impact, but these measures do not significantly limit the severity of impact. Thus, narwhals, walruses, and belugas were each awarded "high" severity of impact, while walruses were awarded "moderate" likelihood of impact compared to narwhals and belugas which were awarded a "high" likelihood of impact, each resulting in overall "high" impact scores (see Appendix).

The impact of chemical pollution, specifically oil spills can be detrimental and often unavoidable for polar bears, seabirds and fish for numerous reasons (see chapter 3). It is reasonable to assume that these animals will be particularly vulnerable to spills, yet Baffinland has not offered an effective solution to manage these impacts beyond complying with the minimum vessel design standards (Table 3). Conversely, Baffinland has increased the likelihood of impact by increasing vessel traffic and acquiring larger vessels which are more difficult to maneuver and carry larger volumes of oil, increasing the risk and intensity of spills. In this case, polar bears, seabirds and fish have each been awarded "high" severity and "high" likelihood of impact, receiving "high" impact scores (see Appendix A). Similarly, an effective solution has not been proposed to manage impacts on public health and safety from habitat disturbance given traditional travel routes are compromised by unpredictable ice conditions. In response, Baffinland has agreed to not break landfast ice and to receive clearance from the MHTO prior to entering the channel to reduce the risk of impacting Inuit (Table 3). However, these measures only minimize the likelihood, not the severity of impact, and are confined by strict spatial-temporal boundaries, resulting in a "high" impact score (see Appendix A).

6.4 Managing Environmental vs Socio-cultural Impacts

Often the impacts on socio-cultural VECs are more challenging to manage than environmental VECs. This is largely the result of two factors: 1) introducing a human component typically adds another dimension of complexity to a problem; and 2) environmental impacts are likely the direct result of shipping hazards, whereas socio-cultural impacts are likely indirect results. This means that environmental impacts usually have a clear link between cause and effect, while the connection is more convoluted for socio-cultural impacts and their resolution usually depends on the management of environmental impacts as part of their management strategies. For example, the impact on wildlife from vessel strikes can be fairly well managed by reducing vessel speeds to 9 knots and implementing MWOs. However, when managing socio-cultural impacts such as food security the solution is impeded by a combination of factors such as access to fertile hunting grounds, available and healthy wildlife stocks, and the knowledge to hunt, prepare and preserve one's catch. In this case, it is easy to see why environmental impacts would first need to be managed to ensure that there are healthy wildlife stocks available and that access to hunting grounds is not compromised in order to effectively address indirect impacts such as food security.

6.5 Related Issues

It is important to remember that this study does not cover all impacts from all shipping hazards on all VECs and that there are numerous other issues affecting the environment and surrounding communities as a result of the Baffinland proposal that have not been addressed. This study merely covers a fraction of these issues and focuses on some of the most salient aspects which were commonly identified throughout the literature review. It is also imperative to note that not all impacts are negative, as some may have neutral or even positive effects. Nor do all individuals view the proposal in a negative light since the Baffinland expansion encourages job creation, builds infrastructure, and generates revenue for the area. Furthermore, individuals within the same interest group may hold diverging interests. For example, not all community members are Inuit, nor do all Inuit actively practice or rely on subsistence hunting or other aspects of their traditional heritage. This is further illustrated in a response report from stakeholders regarding the Baffinland expansion wherein each interest group expressed their priorities, objectives, and concerns to support a more throughout review. For example, the government (e.g. DFO, PC, and ECCC) focused on environmental issues whereas Indigenous partners (e.g. Pond Inlet and QIA) focused on social issues, and each group may further diverge on specific interests (Baffinland, 2019). The purpose of this research is not to demonize the development of Baffinland Mine but to ensure the proposal is given thorough consideration and to provide the necessary guidance to manage as many adverse impacts as possible, promoting more sustainable development.

Chapter 7: Managing Adverse Impacts

The chapter explores potential management recommendations that could be implemented to reduce adverse impacts from shipping hazards on the identified VECs as a result of the Baffinland development. Impact management requires a "hierarchy approach" from impact avoidance, mitigation, remediation, and lastly, compensation (Noble, 2015, p. 149). These recommendations are in addition to those previously proposed by Baffinland (Table 3). For measures that are already proven effective (e.g. speed reductions), the aim is to further enhance their benefits by coupling additional measures to limit or eliminate potential impacts. Impact management is typically considered the most salient aspect of an impact assessment (Noble, 2015); however, there are limits to the overall effectiveness of these recommendations which require further investigation prior to implementation. For instance, a cost-benefit analysis should be performed to determine the best approach to managing each impact. Based on the wide range of potential impacts from shipping hazards, the results suggest a need for Baffinland to employ the precautionary approach to safeguard valued ecosystem components. The following sections discuss the importance of each management approach from avoidance to compensation and provide specific recommendations to manage adverse impacts. It also identifies several additional management measures with emphasis on agreements, management systems, and adaptive management.

7.1 Avoidance

Avoidance is the first and most desirable approach to effectively managing adverse impacts (Noble, 2015). These measures are largely in the form of policy and regulatory standards which prevent the activity from occurring in the first place. For example, prohibiting shipping during particularly sensitive periods such as seal pupping (March-April) or prohibiting dumping of any discharge within the study site. This section identifies several additional measures that Baffinland could impose to help avoid adverse impacts.

At the international level, the IMO is in the process of banning the use of Heavy Fuel Oil (HFO) in the Arctic. This will reduce the impacts of oil spills, should they occur, as HFO is highly viscous, slow to evaporate, and stays in the environment longer than lighter fuels (Chircop, Goerlandt, Aporta & Pelot, 2020). Canada supports the ban of HFO (Government of Canada, 2020), as should Baffinland in their commitment to comply with all regulatory outcomes (Baffinland, 2019). Likewise, the IMO has implemented a global sulphur cap as of January 1st, 2020 banning the use of fuel with sulphur content over 0.5% for all vessels not fitted with scrubbers (International Chamber of Shipping, 2019). However, as mentioned in chapter 3, the use of scrubbers transfers atmospheric pollution into marine pollution. Thus, the IMO could consider a ban on all scrubbers, preventing the installation of new scrubbers, particularly open-loop scrubbers to limit the amount of chemical pollution entering the marine environment. Moreover, vessels that have been previously fitted with open-loop scrubbers should convert to closed-loop scrubbers to reduce chemical discharge and agree to gradually phasing out existing scrubbers on ships.

It is recommended that Baffinland explore further restrictions surrounding anchoring, including prohibiting anchoring along migratory routes while marine mammals are in migration as these are sensitive, high traffic areas (Dawson et al., 2020). Baffinland could also avoid anchoring during periods of high wildlife aggregations, particularly for seals and belugas as residents of Pond Inlet have reported that the disturbance causes them to move further away from the area, impacting hunting (Dawson et al., 2020). Additionally, Baffinland could prohibit the dumping of any discharge including bilge water while in anchoring sites as the pollutants are more concentrated upon release, causing greater impacts. This is particularly true for the anchor site near Ragged Island and Milne Inlet as the shallow depths promote the settling of invasive species and may easily disturb water quality and benthic habitat (Golder Associates Ltd., 2018b). One can also recommend Baffinland vessels be fitted with high efficiency ballast water treatment systems to further minimize harmful discharge.

Baffinland could explore additional areas of avoidance, including complying with the existing legislation for a 3.2km buffer zone around the Bylot Island migratory bird sanctuary to limit impacts to seabirds and other wildlife (Dawson et al., 2020). Spatial-temporal areas of avoidance are effective tools to manage impacts by eliminating the risk of hazards in the area. Regulations could be developed to avoid shipping during important harvest and travel periods, ensuring opportunities to preserve food security and traditional livelihood for the Inuit. As these periods may shift annually, Baffinland should communicate with Inuit communities each year to develop appropriate timelines.

Members of Pond Inlet have already expressed concern over commercial shipping within Eclipse Sound and have proposed low impact corridors. These include areas to be avoided and limited entry areas which overlap a significant portion of Baffinland's shipping route (Figure 14); however, Baffinland has a rite of passage from the IIBA, exempting them from these guidelines (Dawson et al., 2020). This being said, Baffinland is knowingly operating in an ecologically and culturally sensitive area with opposition from community members and should therefore make a noticeable effort to manage as many of the identified impacts as possible, paying special attention when transiting through these corridors.

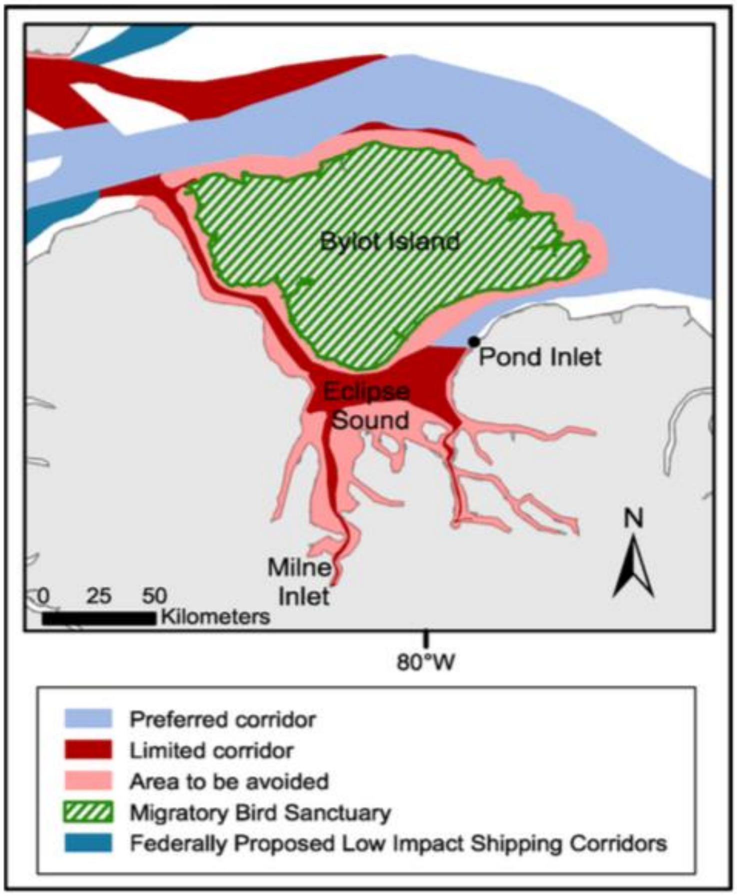

Figure 14. Low impact shipping corridors proposed by members of Pond Inlet (Dawson et al., 2020)

7.2 Mitigation

Mitigation applies to impacts that are unavoidable and aims to minimize disturbance, rather than eliminate it. In the case of Baffinland, many of the impacts will fall under this category of management. There are multiple design aspects that can be improved on vessels to mitigate the impact, such as reinforcing the bulkhead between holds and at the bottom of the vessel to protect against flooding (IMO, n.d.). This would limit the chance of oil and chemical pollutants from entering the environment. Baffinland could require that all vessels install an oil tray below the engine and that vessels undergo regular maintenance to prevent leaks and fix worn-out materials before spills occur. To minimize noise pollution, vessels could be modified with slower propeller rotations (Normandeau Associates Inc., 2012), fitted with non-cavitating propellors and noise dampening devices (e.g. acoustic filters and isolation mounts), and undergo frequent maintenance (Southall, 2005). A report by Hemmera Envirochem Inc. (2016) identified 30 noise dampening solutions from machine maintenance to a complete overhaul in design. Some of these include the use of quieted engines such as electric and diesel-electric alternatives, other methods of propulsion, hull coating, and change of hull form. The most effective solution was identified as regular propeller cleaning and repair. Baffinland could also ensure that vessel speeds are lower than the cavitation inception speed as this prevents the vibration while simultaneously releasing pressure on the propeller as to not damage the equipment (WWF, 2017a). Lastly, noise budgets or maximum noise thresholds can be enforced for Baffinland cargo vessels to prevent cumulative impacts of noise if multiple ships are present at the same time.

To mitigate impacts from habitat disturbance, Baffinland could enforce no wake zones and limited wake areas within the study site to protect sensitive habitat and key travel routes (Dawson et al., 2020). It is also recommended that Baffinland implement permanent moorings at all anchoring sites to reduce damage to the benthic habitat, limit vessel idling, and impede drifting within the study site to reduce the risk of collisions and minimize noise (DFO, 2019). Local Inuit have recommended limiting shipping activity during caribou migration and increasing buffer zones for all marine mammals to 1500 m to minimize disturbance (Dawson et al., 2020). As the Arctic can present many obstacles from weather to physical barriers, from the glare from the snow to icebergs, it may be better to use thermal or infrared imagery to detect wildlife (Wilson et al., 2017). Other visual aids can include the use of drones and aerial surveys, weather permitting. Baffinland could also encourage the use of hydrophones within the study site to detect wildlife during low visibility (e.g. fog, snow, dark) as other measures such as the use of marine wildlife observers is compromised in such conditions. Furthermore, Baffinland should continuously review, improve, and disseminate information regarding their contingency and emergency response plans to ensure all staff and community members are prepared and aware of the appropriate actions if needed.

7.3 Remediation

Remediation is the third option for managing adverse impacts and is largely used to restore environmental components (e.g. water quality) when mitigation and avoidance are not options. Although remediation does not necessarily return the environment to its pre-disturbed state, it aims to "return it to a more desirable condition than what was created by the project actions" (Noble, 2015, p. 152). As such, some of these measures may only be implemented post-operation, once the project is decommissioned. Baffinland has not currently proposed any remediation measures (Table 3), although certain measures do exist. For example, Baffinland should develop an effective remediation strategy in the event of chemical spills. This may include strengthening their oil spill response plan to account for large spills given that resupply vessels can transport up to 18,000 tonnes of oil and many Arctic communities only have enough equipment available to address spills under 1 tonne (WWF, 2017b). More effort could be placed in ensuring northern communities are well prepared to respond to spills including the appropriate tools and training to facilitate quick recovery. Baffinland should play an active role in facilitating the response without causing added harm to the community.

Additionally, Baffinland could explore engineered solutions to manage the disturbance to landfast ice from shipping activity as it impedes safe travel and harvest for many Inuit. Among potential solutions could include floating bridges or platforms to facilitate travel over unsafe conditions, effectively acting as a sea-bridge or ice-bridge. These temporary structures would be anchored to the land to prevent dislodging—creating however additional navigational barriers—and removed from the environment when conditions are favorable.

7.4 Compensation

Compensation is the last resort and is often used to manage irreversible impacts. Depending on the VEC, compensation can be in the form of monetary reimbursement, employment opportunity, education, the creation or restoration of new habitat, or other effective measures. Regardless, the main goal of compensation is to ensure there is "no net loss" (Noble, 2015, p. 152). The following are examples of how Baffinland can compensate for adverse impacts; however, it is imperative that community members have an active role in the decision making surrounding appropriate compensation.

Baffinland may compensate for food insecurity by providing monetary reimbursement to community members to purchase store-bought food, provide food stamps, or organize additional supply trips to restock groceries and other necessary items. For example, Baffinland plans to develop a “Regional Harvesters Enabling Program” which guarantees $750,000 be shared between HTOs of impacted communities for each year that the project is operational (Baffinland, 2020c). Additionally, Baffinland may expand local employment opportunities over a range of skills including laborers, translators, administrators, and environmental technicians. To ensure equitable opportunities, Baffinland could consider a diverse range of employment opportunities to benefit marginalized groups (e.g. women and seniors). To facilitate this transition, Baffinland could provide workshops and educational opportunities to acquire new skills. Furthermore, Baffinland has committed to building childcare centers in Pond Inlet, Arctic Bay, Clyde River, Igloolik and Sanirajak to enable women and caretakers to join the Mary River mine workforce (Baffinland, 2020a). Alternatively, it may not always be possible to compensate for cultural or traditional loss and other arrangements may need to be made external to the above management measures in collaboration with the proponent and relevant interest groups.

7.5 Additional Measures

There are several additional measures that could be explored which further support impact management, including impact benefit agreements such as the IIBA. The IIBA is a legally binding agreement between the proponent (Baffinland) and the community to "ensure that communities have the capacity and resources required to maximize the potential positive benefits stemming from project development" (Noble, 2015, p. 157). These types of agreements emphasize Indigenous engagement in environmental monitoring and impact management for development projects and address concerns such as community-industry relationships and benefits-sharing (Noble, 2015). Fortunately, these agreements are common practice for mining industries seeking development opportunities in Canada and Baffinland has already agreed to the IIBA.

In addition to the IIBA, Baffinland could develop an Environmental Management System (EMS). EMS is an industry-based management system that identifies environmental impacts and sets explicit targets and objectives to manage adverse impacts (Noble, 2015). This system goes beyond industry standards and is a voluntary commitment to enhance environmental performance (Noble, 2015). EMS is a cyclical process (including policy, planning, implementation, monitoring, corrective action, and program review) by which industry is continuously improving and revising its management plans (Noble, 2015). It can be assumed that additional effort to manage adverse impacts beyond industry standards may help improve social acceptance of the project.

Finally, Baffinland could adopt adaptive management strategies, allowing them to continuously reevaluate their management measures throughout the project life cycle. This will allow them to incorporate new information and ensure all impacts are properly managed long-term. This is beneficial for a highly dynamic environment as impacts may change over time. For example, changing temperatures and ocean currents may affect feeding grounds and migration pathways shifting populations from one location to another. In this case, static measures such as anchoring sites or spatial-temporal closures may need to adapt to better accommodate these changes.

Chapter 8: Conclusion

Baffinland's expansion proposal will increase ship traffic through Milne Inlet, Pond Inlet, and Eclipse Sound—an ecologically and culturally significant area. This will increase the likelihood of shipping hazards, including the introduction of aquatic invasive species, underwater noise pollution, chemical pollution, habitat disturbance, and vessel strikes. These hazards may cause a wide range of adverse environmental and socio-cultural impacts including degrading key habitat, disturbing native wildlife, and threatening Inuit food security. Baffinland has proposed several management measures to reduce impacts, many of which exceed industry standards. However, Baffinland has failed to effectively manage all impacts, neglecting key aspects that have been identified as management gaps. Overall, more effort is needed to properly manage impacts from chemical pollution, habitat disturbance, and vessel strikes. Additionally, management priorities have been identified based on "high" impact scores (chapter 5). Special attention should be given to reduce impacts from underwater noise on narwhals, walruses, and belugas, vessel strikes on bowhead whales, impacts from chemical pollution on polar bear, seabirds, and fish as well as impacts from habitat disturbance on public health and safety. Furthermore, it has been noted that environmental impacts need to be managed before socio-cultural impacts can be fully addressed.

As this study provides a high-level assessment based on reasonable estimates, there is room for uncertainty. The impact assessment provides guidance on areas that may require further research prior to project approval. Additionally, this study offers numerous management recommendations to alleviate adverse impacts including measures of avoidance, mitigation, remediation, and compensation. A cost-benefit analysis is required to better determine which measures should be implemented, if any. The results of this research demonstrate a need for both the precautionary approach and adaptive management. This holistic approach will help safeguard the environment and the community by reducing the risk of damage and improving the decision-making process to promote sustainable development now, and in the future.

Baffinland has worked closely with interest groups to address environmental and socio-cultural concerns, revising their proposal numerous times to incorporate these concerns. This study demonstrates a need for further revisions to account for both management priorities and management gaps. As Baffinland plans to begin operating at 12MTPY capacity by 2022 there is sufficient time to request that Baffinland develop a comprehensive plan in collaboration with stakeholders detailing how they intend to manage the remaining impacts before their proposal should be approved. To date, Baffinland’s proposed management measures are presumed effective at reducing impacts from shipping hazards. Thus, it is reasonable to assume that Baffinland could gain project approval once they address these remaining concerns.

8.1 Project Limitations

This section addresses the three most salient limitations to this research, although other limitations are discussed in chapters 3-5. These limitations are largely a result of time and resource constraints, pushing them beyond the project scope. As previously mentioned, the lack of empirical data or direct expert opinion (beyond what was available in the literature) limits the accuracy of the impact scores assigned in the matrix (Table 7). Likewise, not using a weighted scale for the impact matrix skews the results as it assumes all VECs are valued the same, whereas public health and safety may be considered more important than impacts to seabirds, for example. In this sense, using a weighted scale would better depict management priorities. Lastly, this research does not consider cumulative impacts from other shipping activities occurring with the study site such as cruise ships, supply ships, research vessels, or pleasure crafts. This is critical when considering true impact scores as multiple activities occurring simultaneously may pose a greater threat than activities occurring individually, potentially pushing impacts above threshold. This is important as Baffinland's vessels will not be the only vessels transiting the area throughout the project lifecycle and other known environmental stressors should be included. Thus, in order to facilitate a more comprehensive management plan, a cumulative impact assessment would be needed.

8.2 Areas of Future Research

In response to project limitations, Baffinland would benefit from replicating this research using empirical data to construct a full cumulative impact assessment using a weighted scale to properly differentiate between VECs. This would provide more accurate results which can then affect decision-making and generate action. Additionally, it would be interesting to run the model three times: once in absence of management measures, once with Baffinland's proposed measures, and once with additional measures to see how effective the changes were at reducing adverse impacts. Moreover, a risk analysis is an important step for any impact assessment and should be included to better account for uncertainties. These results should then be compared against various risk control options to determine which strategies yield the greatest benefit in order to better allocate resources.

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Appendix A

Impact assessment

Table A1

Impact Rating (N = Negligible, VL = Very Low, L = Low, M = Moderate, H = High)

Shipping Hazard	VECs	Severity Rating	Likelihood Rating	Impact Rating	Categorical Value
Aquatic invasive species	Narwhals	N	N/A	N	0
Aquatic invasive species	Walrus	N	N/A	N	0
Aquatic invasive species	Belugas	N	N/A	N	0
Aquatic invasive species	Bowheads	N	N/A	N	0
Aquatic invasive species	Ringed seals	N	N/A	N	0
Aquatic invasive species	Bearded seals	N	N/A	N	0
Aquatic invasive species	Caribou	N	N/A	N	0
Aquatic invasive species	Polar bear	N	N/A	N	0
Aquatic invasive species	Seabirds	L	VL	N	0
Aquatic invasive species	Fish	L or M	L	L	1
Aquatic invasive species	Benthic habitat	H	L	M	2
Aquatic invasive species	Water quality	L	L	L	1
Aquatic invasive species	Food security	M	L	L	1
Aquatic invasive species	Traditional livelihood	L	L	L	1
Aquatic invasive species	Public health & safety	M	L	L	1
Underwater noise pollution	Narwhals	H	H	H	3
Underwater noise pollution	Walrus	H	M	H	3
Underwater noise pollution	Belugas	H	H	H	3
Underwater noise pollution	Bowheads	M	H	M	2
Underwater noise pollution	Ringed seals	M	M	M	2
Underwater noise pollution	Bearded seals	M	M	M	2

Underwater noise pollution	Caribou	N	N/A	N	0
Underwater noise pollution	Polar bear	N	N/A	N	0
Underwater noise pollution	Seabirds	L	VL	N	0
Underwater noise pollution	Fish	M	M	M	2
Underwater noise pollution	Benthic habitat	N	N/A	N	0
Underwater noise pollution	Water quality	N	N/A	N	0
Underwater noise pollution	Food security	M	H	M	2
Underwater noise pollution	Traditional livelihood	M	H	M	2
Underwater noise pollution	Public health & safety	N	N/A	N	0
Chemical pollution	Narwhals	M	L	L	1
Chemical pollution	Walrus	M	M	M	2
Chemical pollution	Belugas	M	L	L	1
Chemical pollution	Bowheads	M	L	L	1
Chemical pollution	Ringed seals	M	M	M	2
Chemical pollution	Bearded seals	M	M	M	2
Chemical pollution	Caribou	N	N/A	N	0
Chemical pollution	Polar bear	H	H	H	3
Chemical pollution	Seabirds	H	H	H	3
Chemical pollution	Fish	H	H	H	3
Chemical pollution	Benthic habitat	M	H	M	2
Chemical pollution	Water quality	M	H	M	2
Chemical pollution	Food security	M	M	M	2
Chemical pollution	Traditional livelihood	M	M	M	2
Chemical pollution	Public health & safety	M	M	M	2
Habitat disturbance	Narwhals	L OR M	L	L	1
Habitat disturbance	Walrus	M	H	M	2
Habitat disturbance	Belugas	L	L	L	1
Habitat disturbance	Bowheads	L	L	L	1
Habitat disturbance	Ringed seals	M	H	M	2

Habitat disturbance	Bearded seals	M	H	M	2
Habitat disturbance	Caribou	M	H	M	2
Habitat disturbance	Polar bear	M	H	M	2
Habitat disturbance	Seabirds	L	M	L	1
Habitat disturbance	Fish	N	N/A	N	0
Habitat disturbance	Benthic habitat	L	H	M	2
Habitat disturbance	Water quality	L	H	M	2
Habitat disturbance	Food security	M	M	M	2
Habitat disturbance	Traditional livelihood	M	M	M	2
Habitat disturbance	Public health & safety	H	M	H	3
Vessel strikes	Narwhals	H	L	M	2
Vessel strikes	Walrus	H	VL	L	1
Vessel strikes	Belugas	H	L	M	2
Vessel strikes	Bowheads	H	M	H	3
Vessel strikes	Ringed seals	H	VL	L	1
Vessel strikes	Bearded seals	H	VL	L	1
Vessel strikes	Caribou	N	N/A	N	0
Vessel strikes	Polar bear	N	N/A	N	0
Vessel strikes	Seabirds	N	N/A	N	0
Vessel strikes	Fish	N	N/A	N	0
Vessel strikes	Benthic habitat	N	N/A	N	0
Vessel strikes	Water quality	N	N/A	N	0
Vessel strikes	Food security	N	N/A	N	0
Vessel strikes	Traditional livelihood	N	N/A	N	0
Vessel strikes	Public health & safety	N	N/A	N	0

Note. N/A was awarded automatically as the likelihood rating if the severity rating was listed as “(N) negligible”