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IDENTIFICATION AND PROTECTION OF SPECIAL AREAS, ECAS AND PSSAS

Proposal to designate Canadian Arctic waters as an emission control area for nitrogen oxides, sulphur oxides and particulate matter

Submitted by Canada

SUMMARY

Executive summary:	This document sets forth a proposal to designate an emission control area in Arctic waters under Canadian sovereignty and jurisdiction, herein referred to as the "Canadian Arctic ECA", in accordance with regulations 13 and 14 and appendix III to MARPOL Annex VI. Given the increase in shipping in the Canadian Arctic in recent years, and expected traffic increases in the future, this proposal shows that the designation of this emission control area is supported by a demonstrated need to prevent, reduce, and control emissions of nitrogen oxides, sulphur oxides, and particulate matter from ships. Moreover, adoption of the proposed Canadian Arctic ECA will result in significant reductions in ambient levels of air pollution in Canada's Arctic, which will benefit human health and the environment. Canada invites the Committee to review this proposal at this session with a view towards adoption by the Parties to MARPOL Annex VI, at MEPC 82, of the amendments to regulations 13.5, 13.6 and 14.3 and appendix VII to MARPOL Annex VI designating the Canadian Arctic ECA as a new emission control area and to appendix VII of the Annex.
Strategic direction, if applicable:	4
Output:	4.1
Action to be taken:	Paragraph 33
Related documents:	MEPC 80/16/2; MEPC 79/3/2; PPR 7/INF.15 and MEPC 59/6/5

Introduction

1 The Government of Canada is proposing to designate an emission control area (ECA) in Arctic waters under Canadian sovereignty and jurisdiction. The prospective ECA, herein referred to as the Canadian Arctic ECA, would prohibit ships from using fuel with a sulphur

content greater than 0.1% m/m and would require all ships constructed after 1 January 2025 to comply with NO_X Tier III limits as specified in MARPOL Annex VI. This regulation would limit emissions of nitrogen oxides (NO_X), sulphur oxides (SO_X), and particulate matter (PM), including black carbon (BC). The designation of a Canadian Arctic ECA is necessary to protect public health and delicate ecosystems by reducing exposure to harmful levels of air pollution and emissions. Annex 1 to this proposal provides a complete analysis that demonstrates how the proposal satisfies each of the eight criteria for designation of an ECA established under MARPOL Annex VI, appendix III; annex 2 sets forth a detailed description of the proposed ECA boundary; and annex 3 presents a chart of the proposed area. Canada has also prepared draft amendments, presented in annex 4 of this proposal, to include the proposed ECA in the appropriate paragraphs of regulations 13 and 14 of Annex VI and to appendix VII of the Annex.

Summary of proposal

2 Designation of the proposed Canadian Arctic ECA will significantly reduce air pollutant emissions from ships, improve air quality for sensitive northern populations, deliver benefits to marine and terrestrial ecosystems, and potentially contribute to the reduction of climate forcing pollutants such as black carbon which accelerates warming, and snow melt in the Arctic. Indigenous People comprise a significant percentage of Canada's Northern population. Ship emissions can adversely affect Indigenous Peoples' food security, health, culture, traditional ways of life, and ethnoecological ties to the Arctic landscape. The health of the Arctic populations is directly connected to the health of the environment. The health of the environment is what Durkalek et al. conclude as "...a determinant of Indigenous health based on culturally-specific Indigenous epistemologies and ongoing connections to and dependence on traditional lands" (Durkalek et al., 2015; Willox et al., 2013; Inuit Circumpolar Council, 2014). Therefore, the health of the Arctic environment, which is affected by shipping emissions, is an important factor in determining Indigenous health outcomes in northern communities. The air pollutants in shipping emissions are associated with increased risk of adverse health effects, including exacerbation of respiratory symptoms, development of cardiovascular and respiratory disease, and premature death. Air pollution from ships operating in the Canadian Arctic not only affect coastal ecosystems and communities but can also travel hundreds of kilometres inland. Emissions from ships are carried over land and their derivatives (including PM) are deposited on surface waters, soils, and vegetation. This harms ecosystem health through sulphur and nitrogen loading, acidification, and eutrophication.

3 Air quality management in Canada is driven by two principles: "continuous improvement" and "keeping clean areas clean", both of which would be supported by implementation of an ECA in the Canadian Arctic. Significant gains have been made by extensive domestic regulations to control emissions from land-based sources over the last four decades across Canada. To continue to reduce harmful emissions, the focus now needs to be directed to the areas of Canada where more emission reductions measures are needed. Canada has had an ECA south of 60 degrees north since 2013, leaving the Canadian Arctic with less stringent standards for ships. This is of particular concern given the observed increased ship traffic in Canada's Arctic. To maintain and improve air quality, public health, and the environment, decisive action must be taken to realize the benefits that can be gained from additional emissions reductions in the Canadian Arctic.

4 In proposing this Canadian Arctic ECA, Canada has coordinated with Indigenous Peoples' groups and communities, territorial governments, environmental organizations, and affected stakeholders, including representatives from the shipping industry. This proposal considers the issues raised during consultations and strives to minimize impacts on affected communities and the shipping industry, while achieving crucial environmental protection. Action at the international level through designation of this Canadian Arctic ECA is necessary to reduce the impacts of shipping on air quality, human health, and ecosystems.

5 The IMO has announced prohibition on the use, and carriage for use, of heavy fuel oil (HFO) as fuels in the Arctic waters which will enter into force on 1 July 2024. The HFO Ban is a spill reduction measure for ships; however, under the HFO ban there are still options to comply with higher sulphur fuels that do not meet the standards of an ECA, resulting in higher air pollutant emissions. Furthermore, the HFO ban does not regulate any air pollutant emissions (such as NO_X); therefore, the designation of a Canadian Arctic ECA, an air pollution reduction measure, is a necessary complement to this incoming HFO ban.

Description of the proposed area of application

6 The proposed Canadian Arctic ECA includes the portion of Canada's Arctic waters (Figure 1) where the outer limit is generally setback 3 nautical miles from the 200 nautical mile limit or follows the maritime boundary between Canada and Kingdom of Denmark (Greenland) from the Lincoln Sea to the Labrador Sea. The proposed Canadian Arctic ECA is bound in the Beaufort Sea by the 137th meridian west. The southern outer limit terminates at the 60th parallel north in the Labrador Sea and is adjacent to the existing North American ECA. See annex 2 for a full description and a chart of the proposed boundary.

Figure 1: Proposed Canadian Arctic ECA Boundary. This chart is for illustrative purposes only.

7 The Canadian Arctic area subject to this proposal was excluded from the original North American ECA proposal submitted to IMO in 2009 (MEPC 59/6/5) due to a lack of data and the scarcity of shipping activity in the Arctic region at that time. Since then, rates of summer ice melt have increased and the Arctic has seen more natural resource projects – both of which have contributed to a significant increase in marine activity in the area (Hanaček et al., 2022). This growth trend is expected to continue (Hanaček et al., 2022), highlighting a need for emission controls in this region matching those further south in the North American ECA.

Populations and areas at risk

8 Home to a diversity of individuals, wildlife, natural resources, and ecologically sensitive areas, including over 36,000 islands, the Canadian Arctic is culturally, economically, and environmentally valuable both nationally and internationally. Many populations and important ecosystems along Canada's Arctic coastline are exposed to harm and damage by emissions from ships and are at risk of additional harm in the future. Further, as ship pollution travels great distances the inland populations can also be affected by ship emissions and will benefit from the cleaner air made possible by ECA fuel and engine controls. These populations are at risk of adverse health impacts from shipping emissions if the proposed Canadian Arctic ECA is not designated.

9 Annex 1 to this submission describes the populations and ecosystems at risk from increased Arctic shipping, as well as the potential impairment of ecosystems as a result of shipping emissions. With vast expanses of open tundra, glaciers and permafrost, the Canadian Arctic supports a diverse range of flora and fauna that are at risk from increased Arctic shipping. Marine mammals such as seals, walrus, belugas, and bowhead whales, as well as land mammals such as caribou, polar bear, and wood bison rely on the Arctic landscape. Many fish and wildlife species are likewise integral to the Arctic ecosystem and suffer from the impacts of shipping. Further, effects of marine emissions such as reduced sea ice volume and increasing temperatures can impact the productivity of complex Arctic ecosystems supporting animal and plant life. The melting of snow and ice in the Arctic is exacerbated by black carbon emitted from ships, which darkens the ice and snow, reducing the albedo (the ability to reflect light and heat) of the surface.

10 The Canadian Arctic has a prominent Indigenous Peoples' presence of Inuit, Métis, and First Nations. The Inuit own or have jurisdiction over half of the Arctic and are the largest Indigenous landholders in the world. The ethnoecological significance of the Arctic stems from millennia of Indigenous local management of the Northern landscape. Emissions from marine ships transiting the Canadian Arctic can adversely impact Indigenous Peoples' food security, health, culture, and traditional ways of life. Conversely, policies to control these emissions such as ECA may pose economic impacts to northern communities. Thus, consultation with affected communities is a crucial step in the process of this proposed Canadian Arctic ECA to understand the potential cultural and economic impacts of an ECA in the north.

Contribution of ships to adverse impacts on the environment and human health

11 In developing this proposal, Canada performed a comprehensive assessment of ambient air pollution in the Canadian Arctic ECA area, as well as health risks to affected communities. Estimating impacts of shipping on the environment required analyses of detailed ship traffic data, fuel use estimates, pollutant emissions estimates, detailed meteorological data, and deposition of pollutants to sensitive ecosystems.

12 Emissions of exhaust gases and particles from ocean-going ships contain carbon dioxide (CO_2), nitrogen oxides (NO_X), sulphur oxides (SO_X), carbon monoxide (CO), volatile organic compounds (VOCs), black carbon (BC), particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs), and heavy metals (Gong et al., 2018). In the Arctic, shipping contributes to a large proportion of ambient concentrations of NO_X and SO_X and their components. For instance, shipping contributes 10-50% of ambient NO_2 concentrations and 20-100% of ambient SO_2 concentrations over Arctic shipping channels (Gong et al., 2018). This proposed Canadian Arctic ECA would primarily reduce emissions of SO_X, PM, and BC. The ECA would also contribute to emission reductions of NO_X, PAHs, GHGs, and heavy metals.

13 Emissions from ships are harmful to the Arctic environment and contribute to the impairment of various ecosystems through nitrogen nutrient loading, acidification, and critical load exceedance. SO_X and NO_X emissions from ships and their derivatives travel over land and are deposited on surface waters, soils, and vegetation. This leads to the formation of nitric and sulphuric acids that harm marine organisms (Hassellöv et al., 2013). Marine emissions also lead to excess nitrogen in ecosystems and aquatic eutrophication, a process that alters biogeochemical cycles and harms animal and plant life (Camargo & Alonso, 2006). Section 5 of annex 1 contains maps showing the modelled contributions of Arctic shipping to ambient concentrations of ozone, $PM_{2.5}$, NO_2, and SO_2, sulphur and nitrogen deposition, and BC deposition flux. The adoption of the proposed Canadian Arctic ECA would reduce these contributions and lower stresses on sensitive Arctic ecosystems, including tundra, boreal forests, and coastal waters.

14 Ship emissions also affect ecosystems through their contribution to climate change. For example, particulate matter from shipping emissions contains BC. Reductions in BC will result in climate benefits comparable to those from CO_2 reductions (von Salzen, 2022). As the International Council on Clean Transportation's global shipping emissions Arctic inventory found, BC accounted for more than 20% of the global shipping industry's climate impact over a 20-year period (Comer, 2019). When BC particles settle on Arctic snow or ice they change the albedo of the surface, increasing absorption of light and heat (Pedersen et al., 2015). Should ships comply with the proposed Canadian Arctic ECA using cleaner fuels, it would help to reduce the BC emissions and resulting deposition.

15 While GHG reductions are not a focus of the proposed Canadian Arctic ECA, a switch from HFO to an ECA compliant fuel could have co-benefits for GHG emission reductions complementary to the goals of the 2023 IMO GHG Strategy.

16 In the Arctic, marine ship emissions contribute significantly to ambient air pollution (Gong et al., 2018). Exposure to the air pollutants in these emissions increases the risk of premature mortality from heart disease, stroke, and lung cancer (Health Canada, 2021). Northern populations as well as Indigenous Peoples in Canada can have higher rates of disease, which can make them more vulnerable to health risks from air pollution (National Collaborating Centre for Indigenous Youth, 2022). The proposed Canadian Arctic ECA would help reduce air pollutants and the corresponding health risks to populations who may be disproportionately impacted.

17 As established in MARPOL Annex VI, an ECA designation is intended to prevent and reduce the risks of adverse impacts on human health and the environment in areas that can demonstrate a need to prevent, reduce, and control emissions of NO_X, SO_X, and PM. Designation of the proposed Canadian Arctic ECA directly furthers this objective by reducing the emissions of NO_X, SO_X and PM from ships operating in the proposed area, thus reducing human and ecosystem exposure to these pollutants and their derivatives.

18 Designation of the proposed Canadian Arctic ECA would ensure parity in emissions controls across Canada since the Arctic was not included in the North American ECA boundary. The North American ECA has resulted in significant air quality improvements (Anastasopolos et al., 2021). Between 2009 and 2017, SO_2 concentrations decreased in a statistically significant manner in the Canadian port cities of Halifax, Vancouver, Victoria, Montreal, and Quebec City (Anastasopolos et al., 2021). Regulation-related $PM_{2.5}$ factors were also found to have decreased by 1 $\mu g/m^3$ as a result of the ECA regulations (Anastasopolos et al. 2023). The air quality improvements observed from the North American ECA emphasize the importance of implementing the proposed Canadian Artic ECA in Northern Canada, where ecosystems are highly sensitive to changes in climate variables such as air pollution.

Ship traffic and meteorological conditions

19 Ship traffic through Canada's Arctic has increased significantly – using fuel consumption as a marker for ship traffic and emissions, the fuel consumed by ships operating in the Canadian Arctic has more than doubled between 2010 and 2019 (ECCC, 2022a). The absence of Arctic Sea ice is expected to contribute to an increase in shipping activity during summer months. The Arctic sees seasonal sealift resupply services occur each year where bulky, heavy, or non-perishable items are transported to isolated communities. The annual window for Arctic shipping changes depending on ice levels, but typically occurs between June and October.

20 Meteorological conditions in Canada's Arctic ensures that a significant portion of emissions from ships at-sea and the resulting pollution formed in the atmosphere are transported to land. The strong isolation of the Arctic lower troposphere in the summer (during the shipping season) means that shipping emissions play a greater role in affecting Arctic air quality than pollutants transported from outside the polar dome. Temperature inversions are also common in the Arctic, which can lead to longer-range transport of pollutants due to them being trapped in the boundary layer.

Land-based emissions controls

21 The Government of Canada has already imposed stringent restrictions on emissions of NO_X, SO_X, PM, and other air pollutants from a wide range of land-based industrial, commercial, and transportation sources. Examples of industrial and commercial sources subject to emissions restrictions include large and small manufacturing plants, smelting and refining facilities, paper mills, chemical and pharmaceutical companies, and combustion sources at factories and power plants such as boilers, turbines, and engines. Examples of transportation sources subject to emissions restrictions and fuel quality standards include automobiles, trucks, buses, and locomotives. The costs of implementing and complying with the proposed Canadian Arctic ECA are expected to be small in absolute terms and when compared to the costs of achieving emissions reductions through land-based controls. Land-based controls have been highly successful, and Canada has seen total emissions of NO_X, SO_X, and PM decrease by 29%, 77%, and 8% respectively, over the period from 1990 to 2019 (ECCC, 2021a). The adoption of the proposed Canadian Arctic ECA would reduce emissions from the marine transport sector, which has become increasingly significant in the Arctic.

Estimated costs

22 The costs of implementing and complying with the proposed Canadian Arctic ECA are expected to be small both in absolute terms and when compared to the costs of achieving similar emissions reductions through additional controls on land-based sources. Canada estimated the total costs of the SO_X and NO_X regulations using analysis of fuel consumption, fleet composition, available NO_X abatement technologies, and historical fuel price data. The estimated cost of improving ship emissions from current performance to the proposed Canadian Arctic ECA standards is about 2.7 million USD (nominal dollars in 2023) per year between 2027-2029. After 2029, assuming ship operators choose to comply with the HFO ban by using distillate fuel, there will be no additional fuel switching costs, only costs associated with compliance to NO_X Tier III restrictions. Improving current ship emission levels to the proposed Canadian Arctic ECA standard is one of the most cost-effective measures available to obtain necessary improvements to the air quality in Canada's Arctic. This is due to the remote location, extreme weather, and relatively high contribution of shipping to ambient air pollution in this region. Due to the smaller scale of shipping in the Arctic relative to other regions, it is expected that appropriate fuel will be available in sufficient quantities to meet the demand.

23 Fuel switching costs between 2027-2029 are estimated to increase the total annual operating cost of all community resupply (sealift) voyages by up to about 1%. If these costs are then passed on through to consumers, it would result in an increase in household expenditures of 31 USD (about 41 CAD) per year for communities using sealift services between 2027 and 2029. Total annual operating costs of the other ship types (non-sealift), serving or transiting the Arctic are expected to increase by up to about 2% during the 20262029 period as a result of fuel switching.

24 The costs from NO_X Tier III compliance are expected to slowly increase over time as more ships must comply with the regulation. A new ship can comply with the NO_X Tier III standard using a variety of technologies, most commonly exhaust gas recirculation (EGR) or selective catalytic reduction (SCR). This regulation is estimated to increase household expenditures by an estimated $2.39-2.91 (USD, 2023) per household each year between 2027-2040 if sealift ships pass on all costs to consumers. When considering industry as a whole, NO_X Tier III requirements would increase the total annual operating costs of all ships by less than 0.1% annually.

25 Few modes of transportation besides marine shipping can deliver goods to the northern regions of Canada; therefore, demand for essential goods is unlikely to change in these communities regardless of price increases as individuals have few other methods of receiving certain goods. Though the costs of the proposed Canadian Arctic ECA are low, it is imperative to ensure standards of living and socio-economic capabilities do not decline in northern communities due to the introduction of the proposed Canadian Arctic ECA.

26 Specific industries are unlikely to face significant impacts from the introduction of the proposed Canadian Arctic ECA. Cruise ship ticket prices, which can range from 800 - 2200 USD or CAD per day per passenger, are estimated to increase only 2-9 USD or CAD per day. Similarly, the mining industry will experience minimal cost impacts as the proposed Canadian Arctic ECA would only increase the operating costs of all non-sealift ships by about 2% between 2027 to 2029. In addition, mines must already withstand large fluctuations in fuel and mineral prices, so are expected to be able to adjust to small increases in operational costs from the proposed ECA regulations. Section 9 of annex 1 to this proposal details the cost analysis used to derive costs and discusses impacts of the proposed Canadian Arctic ECA on northern communities and industry.

27 Implementation of an ECA in the Arctic will have benefits to human and environmental health in affected communities. As described in annex 1 to the document, exposure to ambient air pollution is associated with adverse health effects such as increased risk of respiratory symptoms, development of disease, and premature death. In Canada, approximately 15,300 premature deaths annually are associated with ambient air pollution (Health Canada, 2021). When monetized, this loss has a value of at 120 billion CAD per year (Health Canada, 2021). For the territories in Canada's Arctic, nine premature deaths were attributed to ambient air pollution (four each for NWT and Yukon; one for Nunavut), with a total economic valuation of 69 million CAD per year (Health Canada, 2021). Measures such as this proposed Canadian Arctic ECA, which aim to limit emissions of pollutants leading to health and environmental impacts can reduce (or slow down) the accrual of future costs to such communities facing negative effects associated to environmental changes.

28 Reducing emissions from ships in the Canadian Arctic can mitigate risks to human health and the environment. Controlling emissions through shipping regulations is relatively inexpensive compared to other measures due to the nature of the Arctic geography, climate, and industry.

Enforcement

29 Existing regulations in the Canadian portion of the North American ECA will inform the legislation, compliance, and enforcement of the proposed Canadian Arctic ECA. The regulations of the North American ECA are included as amendments to the Canadian domestic *Vessel Pollution and Dangerous Chemicals Regulations,* which "set out provisions to implement the North American Emission Control Area adopted under Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL)" (Transport Canada, 2016). The domestic *Canada Shipping Act, 2001*, gives legislative power to the regulations specified in the domestic *Vessel Pollution and Dangerous Chemicals Regulations* and allows Canada to enforce the regulations of the North American ECA as outlined in the *Policy on Compliance and Enforcement of the Canada Shipping Act, 2001* (Transport Canada, 2018). Canada's enforcement of the North American ECA requires ships within the portion of the boundary to keep an official logbook recording the volume of compliant fuel in each tank, as well as the date, time, and position of the ship when any fuel change-over operation is completed when it enters or leaves the North American ECA boundary. Ships must also carry bunker delivery notes stipulating the sulphur content and density of the fuel delivered to them and a certified declaration by the fuel oil supplier's representative that the fuel conforms to Annex VI to MARPOL regulations (Transport Canada, 2013). Ships using an exhaust gas clearing system (EGCS) to comply with the North American ECA's SO_X regulations must monitor and record when their EGCS are in use and demonstrate an approved ratio of SO_2 to CO_2 in their exhaust (Transport Canada, 2013). For NO_X Tier III compliance, ships are required to have a record book of engine parameters on board along with a technical file of the engine (Transport Canada, 2013). In addition, NO_X emissions should be recorded through nitrogen oxide monitoring equipment.

30 To determine compliance with ECA regulations, Canadian Marine Safety Inspectors rely on record book entries, bunker delivery notes, and certifications. However, in certain cases, a Canadian Marine Safety Inspector may conduct an inspection to determine compliance, which could involve testing a sample of fuel from a ship's engine with a fuel analyser (Transport Canada, 2016). Canada's Flag State Control program is responsible for ensuring that Canadian ships are inspected in accordance with both Canadian regulations and international protocols, and Canada's Port State Control programme is responsible for inspections of foreign ships entering Canada's waters to ensure compliance with international maritime conventions, including MARPOL (Government of Canada, 2012c). Lack of compliance with North American ECA regulations can result in enforcement action including detention of ships and fines.

31 Current domestic shipping regulations in Canada's Arctic include those under the *Arctic Waters Pollution Prevention Act, 1985* (AWPPA), which are primarily enforced by pollution prevention officers. Under the AWPPA, the pollution prevention officers can conduct inspections and may direct ships to leave shipping safety zones or to anchor in place. Pollution prevention officers can also seize ships and their cargo with the consent of the Governor in Council. Ships guilty of an offence can be fined up to 5,000 CAD for an individual and up to 100,000 CAD for a ship). For serious infractions, the *Canada Shipping Act,* 2001 provides for maximum fines upon summary conviction of 1,000,000 CAD or 18 months in prison, or both, for violations of regulations. Canadian enforcement of the AWPPA demonstrates that there is already significant regulatory capacity and experience within Canadian Arctic waters.

Conclusion

32 The Canadian Arctic waters were initially omitted from the North American ECA due to data scarcity and a lack of shipping in this region at the time. However, with improved data access, more summer ice melt, and increased shipping activity in the Arctic, the proposed

Canadian Arctic ECA is now a necessary regulation to reduce the disparity of environmental protections between the primarily Indigenous Peoples populated Arctic, and the rest of Canada. With this significant increase in ship traffic through Canada's Arctic waters, ship emissions are contributing significantly to air pollution and climate forcing emissions in the Canadian Arctic. The impact of these emissions will increase unless actions are taken. The air pollutants in ship emissions are associated with an increased risk of adverse human health outcomes and ecosystem damage in Canada's Arctic. The adoption of the proposed Canadian Arctic ECA will reduce these risks to the population and the environment. Canada has already implemented stringent emission controls on land-based sources of air pollution and marine emissions through the North American ECA. Therefore, the adoption of the proposed Canadian Arctic ECA will demonstrate the effectiveness of the regional control provisions contained in MARPOL Annex VI toward helping countries achieve their important human health and environmental goals through the application of stringent marine engine emission and fuel sulphur controls.

Action requested of the Committee

33 The Committee is invited to consider the information presented in this document and its annexes and to approve the proposed Canadian Arctic ECA, as described, for the control of NO_X, SO_X, and PM, with a view to adoption, at MEPC 82 of amendments to regulations 13.5, 13.6, and 14.3 to formally designate this Emission Control Area under MARPOL Annex VI and to appendix VII to the Annex.

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ANNEX 1

Information responding to the criteria in appendix III to MARPOL Annex VI for the Canadian Arctic Emission Control Area

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Abbreviations

Term	**Explanation**
AIS	Automatic Identification System
AMAP	Arctic Monitoring and Assessment Programme
AQMS	Air Quality Management System
BAU	Business as usual
BC	Black carbon
BCw	Base cation weathering
°C	Degrees Celsius
CAAQS	Canadian Ambient Air Quality Standards
CAC	Criteria Air Contaminant
CAD	Canadian dollars
CanAM5	Canadian Atmospheric Model version 5
CCG	Canadian Coast Guard
CCME	Canadian Council of Ministers of the Environment
Cd	cadmium
CEPA	Canadian Environmental Protection Act
CH4	Methanethiol (chemical compound)
CIRNAC	Crown-Indigenous Relations and Northern Affairs Canada
cm	Centimeter
CO	Carbon monoxide
COVID-19	Coronavirus Disease of 2019
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
cSt	The submultiple centistokes – measure of viscosity
DWT	deadweight-tonnage
ECA	Emission Control Area
ECCC	Environment and Climate Change Canada
EEDI	Energy Efficiency Design Index
EGCS	Exhaust gas cleaning system
EGR	Exhaust Gas Recirculation
eq	equivalent
g	Grams
GBD	Global Burden of Disease
GDP	Gross domestic product
GEM-MACH	Global Environmental Multi-scale - Modelling Air quality and Chemistry
GHG	Greenhouse gas
GHO	Global Health Observatory

HEI	Health Effects Institute
HFO	Heavy fuel oil
ICC	Inuit Circumpolar Council
IACCSEA	International Association for Catalytic Control of Ship Emissions to Air
IARC	International Agency for Research on Cancer
IFO	Intermediate fuel oil
IHME	Health Metrics and Evaluation
IK	Indigenous Knowledge
IMO	International Maritime Organization
km	Kilometres
kW	Kilowatt
g/kWh	Grams per kilowatt-hour
LNG	Liquefied Natural Gas
m	Metre squared
m/m	Mass by mass
MARPOL	International Convention for the Prevention of Pollution from Ships
MDO	Marine distillate oil
MEIT	Marine Emissions Inventory Tool
MEPC	Marine Environment Protection Committee
MGO	Marine gas oil
MT	Metric tonne (1,000 kg)
NA ECA	North American Emission Control Area
NAICS	North American Industry Classification System
Ni	Nickel
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NO_X	Nitrogen Oxides
NWT	Northwest Territories
O_3	Ozone
OC	Organic Carbon
OECD	Organization for Economic Co-operation and Development
PAHs	Polycyclic aromatic hydrocarbons
PAME	Protection of the Arctic Marine Environment
pH	A measure of the acidity of a solution
PM	Particulate Matter
PM_{10}	PM with a mass median diameter less than 10 µm
$PM_{2.5}$	PM with a mass median diameter less than 2.5 µm
ppm	Parts per million
Northern REACHE	Northern Responsible Energy Approach for Community Heat and Electricity
NWP	North West Passage
RFO	Residual fuel oil
SCR	Selective Catalytic Reduction
SLCP	Strategy on Short-Lived Climate Pollutants
SO_X	Sulphur Oxides

SO_2	Sulphur dioxide
μg/m^3	Micrograms per metre cubed
ULSFO	Ultra-low sulphur fuel oil
UN	United Nations
UNDA	United Nations Declaration on the Rights of Indigenous Peoples Act
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNCTAD	United Nations Conference on Trade and Development
US	United States
US EPA	United States Environmental Protection Agency
USD	US Dollars
V	Vanadium
VLSFO	Very low sulphur fuel oil
VOCs	Volatile organic compounds
W	Watt
WHO	World Health Organization
μm	Micrometre or micron

1 Introduction

1.1 Criteria for Designation of an Emission Control Area

Pursuant to Annex VI, an ECA may be considered for adoption by the Organization if supported by a demonstrated need to prevent, reduce, and control air pollution from ships. Section 3 of Appendix III to Annex VI sets out the following eight criteria for designation of an Emission Control Area (ECA):

Criterion 3.1.1 a clear delineation of the proposed area of application, along with a reference chart on which the area is marked;

Criterion 3.1.2 the type or types of emission(s) that is or are being proposed for control (i.e., NO_X or SO_X and particulate matter or all three types of emissions);

Criterion 3.1.3 a description of the human populations and environmental areas at risk from the impacts of ship emissions;

Criterion 3.1.4 an assessment that emissions from ships operating in the proposed area of application are contributing to ambient concentrations of air pollution or to adverse environmental impacts. Such assessment shall include a description of the impacts of the relevant emissions on human health and the environment, such as adverse impacts to terrestrial and aquatic ecosystems, areas of natural productivity, critical habitats, water quality, human health, and areas of cultural and scientific significance, if applicable. The sources of relevant data including methodologies used shall be identified;

Criterion 3.1.5 relevant information pertaining to the meteorological conditions in the proposed area of application to the human populations and environmental areas at risk, in particular prevailing wind patterns, or to topographical, geological, oceanographic, morphological, or other conditions that contribute to ambient concentrations of air pollution or adverse environmental impacts;

Criterion 3.1.6 the nature of the ship traffic in the proposed Emission Control Area, including the patterns and density of such traffic;

Criterion 3.1.7 a description of the control measures taken by the proposing Party or Parties addressing land-based sources of NO_X, SO_X and particulate matter emissions affecting the human populations and environmental areas at risk that are in place and operating concurrent with the consideration of measures to be adopted in relation to provisions of regulations 13 and 14 of Annex VI; and

Criterion 3.1.8 the relative costs of reducing emissions from ships when compared with land-based controls, and the economic impacts on shipping engaged in international trade. Each of the criteria is addressed individually in sections 2–9 of this annex.

1.2 Principles to be Considered when Drafting IMO Instruments

The following proposal seeking to designate an ECA is guided by the Principles to be Considered when Drafting IMO Instruments (Resolution A.1103(29) adopted on 26 November 2015). The proposal complies with the following six principles: necessity, consistency, proportionality, fit for purpose, resilience, clarity.

1.3 Existing IMO Initiatives

The Canadian Arctic ECA has connections to many existing IMO initiatives. The relationships with each of these initiatives is discussed at different points throughout the proposal.

1.3.1 Heavy Fuel Oil Ban

IMO has announced that the ban on the use, and carriage for use of heavy fuel oil (HFO) in the Arctic will enter into force on July 1st, 2024. The HFO Ban is a spill reduction measure from ships. A HFO spill in the Arctic would have grave consequences given the limited marine traffic and infrastructure, and the environment there. However, under the HFO ban, there are still options to comply with higher sulphur fuels that don't meet the standards of an ECA, resulting in higher air pollutant emissions. Further, the HFO ban does not regulate any air pollutions such as NO_X. Therefore, the designation of a Canadian Arctic ECA, which is an air pollution reduction measure, is a necessary complement to this incoming ban.

1.3.2 Polar Code

IMO's International Code for Ships Operating in Polar Waters (Polar Code) entered into force on 1 January 2017. The Polar Code covers the full range of design, construction, equipment, operational, training, search and rescue and environmental protection matters relevant to ships operating in the waters surrounding the North and South poles (IMO, n.d.-b). Canada has developed the Arctic Shipping Safety and Pollution Prevention Regulations which incorporates the Polar Code within its sovereignty and jurisdiction in the Arctic (Government of Canada, 2022d). The Polar Code did not involve amendments to MARPOL Annex VI: Prevention of air pollution by ships, making the Canadian Arctic ECA complementary to this regulation.

1.3.3 Black Carbon

In 2021, IMO adopted a resolution that encourages Member States and ship operators to voluntarily use distillate or other cleaner alternative fuels or methods of propulsion that could help reduce black carbon emissions in the Arctic (IMO, 2021b). However, this is a voluntary measure. The Canadian Arctic ECA require that vessels use fuel with a sulphur content no greater than 0.1% m/m or an alternative SO_X reduction method. The switch to ECA compliant fuels will reduce black carbon pollution. However, compliance with the use of scrubbers would not result in the same black carbon benefits. While scrubbers are currently a compliance option, Canada is aware of the concerns raised by stakeholders regarding the use of scrubbers in Canadian waters, and that some jurisdictions around the world have already chosen to impose discharge restrictions. Domestically, Canada continues to study the environmental impacts of the use of different types of scrubber systems and plans to work with the maritime industry to develop a path forward to address the issue of washwater discharge in Canadian waters on a permanent basis. Transport Canada also continues to support the ongoing work at the International Maritime Organization to evaluate and develop harmonized rules and guidance on the discharge of scrubber washwater in the aquatic environment.

1.3.4 SO_X Regulation

SO_X and associated particulate matter controls apply to the fuel oil used by marine vessels. There are SO_X controls applicable within an ECA as well as controls applicable outside such areas. When marine vessels are outside of an ECA, they are still required to meet the fuel standard of 0.50% m/m on and after 1 January 2020 (IMO, n.d.-d).

1.3.5 NO_X Regulation

The NO_X control requirements apply to installed marine diesel engines of over 130 kW output power. There are different levels (Tiers) of control applied based on the ship construction. The Tier III controls only apply in an ECA to marine diesel engines installed on a ship constructed on or after the date outlined in the ECA regulation date (IMO, n.d.-c). Therefore, the implementation of a Canadian Arctic ECA would introduce an additional region where the NO_X Tier III controls apply.

2 Description of Area Proposed for ECA Designation

2.1 Introduction

Criterion 3.1.1	*The proposal shall include a clear delineation of the proposed area of application, along with a reference chart on which the area is marked.*

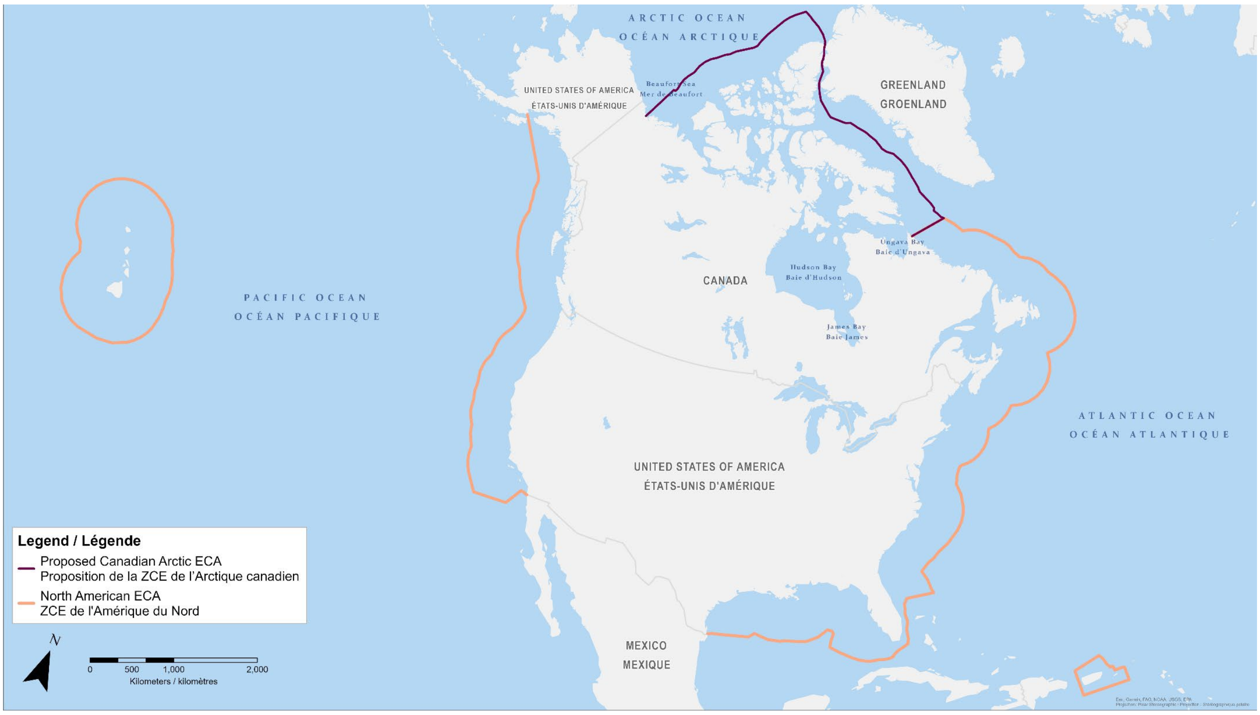
2.2 Proposed area of application for the Canadian Arctic ECA

The proposed Canadian Arctic ECA includes that portion of Arctic waters (**Figure 2.1**) where the outer limit is generally setback 3 nautical miles from the 200 nautical mile limit (to ensure no points of the boundary exceed the 200nm limit; a similar approach was taken for the North American ECA) or follows the maritime boundary between Canada and Kingdom of Denmark (Greenland) from the Lincoln Sea to the Labrador Sea. The proposed ECA is bound in the Beaufort Sea by the 137th meridian west. The southern outer limit terminates at the 60th parallel north in the Labrador Sea and is adjacent to the existing North American ECA (NA ECA) (**Figure 2.2**). Canada chose to align with the boundary of the existing NA ECA. This proposed boundary is supported by Environment and Climate Change Canada (ECCC) modelling which demonstrates that the 200nm limit will encompass the greatest amount of shipping emissions.

Annex 2 provides a full description of the proposed Canadian Arctic ECA boundary. **Annex 3** provides a chart of the proposed Canadian Arctic ECA. A list of coordinates of the proposed Canadian Arctic ECA outer boundary are provided in **Annex 2 Appendix A, Table A-1 and Table A-2**.

Figure 2.1: Proposed Canadian Arctic ECA Boundary. This chart is for illustrative purposes only.

Figure 2.2: Proposed Canadian Arctic ECA Boundary, with existing NA ECA for reference. This chart is for illustrative purposes only.



2.3 Summary

A clear delineation of the proposed area of application is presented in this section and in Annex 2 and 3, along with a chart mapping the proposed ECA area. Thus, this proposal for an ECA fulfils criterion 3.1.1 of Annex VI, Appendix III.

3 Types of Emissions Proposed for Control

3.1 Introduction

Criterion 3.1.2	*The proposal shall include the type or types of emission(s) that is or are being proposed for control (i.e. NO_X or SO_X and particulate matter or all three types of emissions).*

The Government of Canada proposes the designation of a Canadian Arctic ECA to control emissions of nitrogen oxides (NO_X), sulphur oxides (SO_X), and particulate matter (PM). As explained below, NO_X and SO_X are precursors to fine particulate matter and emissions of NO_X are also a precursor to ground-level ozone. Criterion 3.1.4 (Section 5) of this proposal provides details on the health and environmental impacts associated with the pollutants proposed for control.

The provinces and territories in Canada's North define air zones as finite geographic areas within a jurisdiction for the purpose of managing local air quality. Provinces and territories are responsible for managing air quality in these air zones. For emission sources and lands that fall under federal authority (such as transportation sources, federal lands, and national parks), the federal government collaborates with provincial and territorial governments on air quality management and the implementation of the Air Quality Management System (AQMS). The AQMS includes Canadian Ambient Air Quality Standards (CAAQS), industrial emissions requirements, provincial air zones, regional airsheds, and reporting to Canadians. Canada has developed CAAQS for $PM_{2.5}$, NO_2, ozone, and SO_2. The CAAQS are intended to drive improvements in air quality across the country to protect human health and the environment. They are supported by air quality management levels, which call for progressively more rigorous actions by jurisdictions as air quality levels within designated air zones approach or exceed the CAAQS, thereby ensuring that the CAAQS are not treated as "pollute-up-to" levels. Overall, two key principles underpin air quality management in Canada under the AQMS: "continuous improvement" of air quality; and "keeping clean areas clean" to ensure that air quality is maintained or improved to the extent practicable (CCME, n.d.). Both of these principles are of direct relevance to Canada's North.

The proposed ECA is also expected to result in the reduction of other air pollutants (in addition to NO_X, SO_X, and PM) as co-benefits through the use of cleaner fuels, including black carbon, polycyclic aromatic hydrocarbons, and heavy metals.

3.2 NO_X

Nitrogen oxides (NO_X) are gases emitted predominantly from combustion sources. Most NO_X is emitted as nitric oxide (NO) (which is rapidly converted to NO_2), along with lesser quantities of NO_2 itself. NO_X also contributes to the formation of PM and ground-level ozone (O_3). Transportation contributes over half of all NO_X emissions in Canada; however, energy production and industrial processes are also significant sources of NO_X (CCME, n.d.). At high concentrations, NO_X has a strong, harsh smell and can be seen over large areas as a brownish haze (CCME, n.d.). Once NO_2 has formed, it can combine with water molecules in the air to form several different compounds (CCME, n.d.). These compounds are then returned to land through precipitation such as acid rain, snow, and fog (CCME, n.d.). When combined with volatile organic compounds (VOCs) under certain photochemical conditions, NO_X can form ground-level ozone. As discussed in Criterion 7, Canada has already imposed restrictions on NO_2 and other emissions from a wide range of land-based industrial and transportation sources as well as consumer and commercial products.

3.3 SO_X

Sulphur dioxide (SO_2) is a colourless gas with a sharp odour. It belongs to a group of sulphur-containing gases called sulphur oxides (SO_X) (CCME, n.d.). SO_2 is primarily produced from industrial processes such as metal ore smelting or electric power generation when fossil fuels or raw materials containing sulphur are burned (CCME, n.d.). Most of the emitted SO_X consist of SO_2 and to a lesser extent, sulphur trioxide (SO_3). It can also be produced in large quantities during the extraction and processing of fossil fuels. In marine shipping, SO_2 is produced from burning sulphur-containing fuels. SO_2 contributes to the formation of $PM_{2.5}$ and smog, and when combined with water molecules in the air, it can form compounds such as sulphuric acid, which eventually falls to earth as acid rain, fog, and snow (CCME, n.d.).

3.4 Particulate Matter

Particulate matter (PM) is a complex mixture of small airborne liquid and solid particles that are classified by size. (Health Canada, 2022a). PM exists in various sizes, though the particles with a diameter of less than or equal to 2.5 μm ($PM_{2.5}$ or fine PM) are of highest concern to human health (CCME, n.d.).

Ambient fine particulate matter is composed of primary $PM_{2.5}$ (directly emitted particles, such as from an exhaust pipe) and secondary $PM_{2.5}$ (particles created in the atmosphere through chemical and physical interactions of precursor pollutants). Of the precursor gases emitted by ships, SO_X and NO_X can directly lead to the formation of secondary $PM_{2.5}$ (Health Canada, 2022a. The majority of the PM associated with ship emissions, whether primary or secondary, is in the fine particle size ($PM_{2.5}$) category.

3.5 Other Pollutants

While this proposal is to limit emissions of NO_X, SO_X and PM from ships, their reduction may lead to the reduction of emissions of other pollutants as co-benefits, which are outlined in the following sections.

3.5.1 Black Carbon

Black carbon (BC) is a component of particulate matter that absorbs radiation in the atmosphere and when it lands on surfaces such as snow (Matsui et al., 2022; Clear Seas, 2021). It is formed by the incomplete combustion of fossil fuels, biofuels, and biomass, including the heavy fuel burned by ships (Pedersen et al., 2015; Climate and Clean Air Coalition, n.d.). Complete combustion turns all carbon in fuel into carbon dioxide (CO_2); however, combustion is never complete, and black carbon is formed in the process. The composition of this mixture can vary significantly, depending on the combustion conditions and fuel type. It is a short-lived climate pollutant with a lifetime of only days to weeks after release into the atmosphere (Clear Seas, 2021). During this time, black carbon can have significant impacts on the climate, including snow and ice melt (Clear Seas, 2021; Janssen et al., 2012). Black carbon is a major contributor to warming because it is very effective at absorbing light and heating its surroundings (Pedersen et al., 2015). When deposited on ice and snow, black carbon particles reduce surface albedo (the ability to reflect sunlight) and heat the surface (Matsui et al., 2022; Pedersen et al., 2015; Clear Seas, 2021). Black surfaces absorb all wavelengths of light and convert them into heat, whereas white surfaces reflect all wavelengths of light and therefore keep surrounding areas cold (Pedersen et al., 2015). When black carbon particles settle on snow and ice, they darken the surface and enhance the absorption of solar radiation, increasing the temperature and rate of melting (Pedersen et al., 2015; Clear Seas, 2021). In the Arctic, the majority of black carbon particles are emitted from sea-level sources within the region, including ships operating close to areas of snow and ice (Clear Seas, 2021). Addressing emissions of short-lived climate pollutants, in particular the black carbon component of fine particulate matter, will be highly beneficial to the Arctic climate over the next few decades. Reductions in black carbon can result in climate benefits in the Arctic comparable to those from CO_2 reductions (von Salzen et al., 2022). As the International Council on Clean Transportation's global shipping emissions Arctic inventory found, black carbon accounted for more than 20% of the global shipping industry's climate impact over a 20-year period (Comer, 2019).

3.5.2 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are a large group of organic compounds containing two or more fused aromatic (benzene) rings. The main anthropogenic sources of PAH emissions are incomplete combustion or pyrolysis of organic material such as fossil fuels and biofuels (e.g., wood or agricultural waste). Ships also emit polycyclic aromatic hydrocarbons (PAHs) – a class of polycyclic organic matter (POM) (Yu et al., 2019). Field measurements and environmental transport models have shown that PAHs are subject to long-range transport reaching remote locations such as the Arctic (Tevlin et al., 2020). Chemical transport modelling indicates that sources from Asia, Europe and North America contribute to Arctic and Sub-Arctic concentrations of PAHs (Tevlin et al., 2020). PAHs tend to accumulate in sediments and reach high enough concentrations in some coastal environments to pose an environmental threat.

3.5.3 Greenhouse Gases

Greenhouse gases (GHGs) are emitted from vessels using fossil fuels and act as climate forcers by trapping heat in the atmosphere, causing climate change (US EPA, 2023; ECCC, 2023b). GHGs comprise of CO_2, methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (US EPA, 2023). The 2023 IMO GHG Strategy aims for reducing well-to-wake GHG emissions by 20%, striving for 30% in 2030 and then 70%, striving for 80%, in 2040 compared to 2008, and reach net-zero by or around, i.e., close to, 2050 (IMO, 2023c). The Third IMO GHG Study (2014) found that international shipping accounted for about 2.4% of global GHG emissions on a CO_2 equivalent (CO_2e) basis for the period 2007-2012 (Smith et al., 2014). The Fourth IMO GHG Study (2020) found that the share of total shipping emissions in global anthropogenic emissions has increased from 2.76% in 2012 to 2.89% in 2018 (Faber et al., 2020).

While GHG reductions are not a focus of this ECA proposal, a switch from HFO to an ECA compliant fuel could have co-benefits for GHG emission reductions complementary to the goals of the 2023 IMO GHG strategy.

3.5.4 Heavy Metals

Heavy metals can be regarded as trace markers for HFO burning in ship emissions (Wen et al., 2018). This is because when HFO is used by marine engines, the particulate matter that is emitted is known to contain toxic heavy metals (Corbin et al., 2018). Due to atmospheric transport and other pathways (described further in Section 6), the Arctic region, including the Canadian Arctic, is a major receptor of some heavy metals such as mercury, cadmium and lead released from sources in other regions of the world (Government of Canada, 2017a). Human activities such as mining, metal processing, and burning fossil fuels increase the flux of metals that can be transported by wind and water. Metal contamination of food and water resources is a known public health concern in Arctic and sub-Arctic communities (Perryman et al., 2020). The release of heavy metals into the Arctic environment is further exacerbated by the effects of global warming. As permafrost thaws, it releases heavy metals sequestered in previously frozen soils, potentially contaminating food and water sources by increasing the concentration of metals in freshwater, plants, and animals (Perryman et al., 2020).

3.6 Summary

The proposal outlines that the proposed ECA would control SO_X, NO_X, PM, and contribute to the reduction of other pollutants. Thus, this proposal for an ECA fulfils criterion 3.1.2 of Annex VI, Appendix III.

4 Populations and Environmental Areas at Risk from Exposure to Ship Emissions

4.1 Introduction

Criterion 3.1.3	*The proposal shall include a description of the human populations and environmental areas at risk from the impacts of ship emissions.*

The Arctic is a significant part of the Canadian landscape, encompassing 39% of Canada's total land area at 3.5 million km^2 and over 2.1 million km^2 of maritime coverage (Statistics Canada, 2017; Ellis & Brigham, 2009). Home to a diverse range of individuals, wildlife, natural resources, and ecologically sensitive areas, including over 36,000 islands, Canada's Arctic is culturally, economically, and environmentally valuable both nationally and internationally.

Canada's Arctic is ecologically sensitive and more at-risk to climate change as it is currently warming at around three times the global rate (Natural Resources Canada, 2022c). Notably, the reduction of Arctic Sea ice has increased the possibility of Arctic transit shipping (Mudryk et al., 2021; Stephenson et al., 2013). Similar possibilities are anticipated for vessels in the Canadian Arctic that are servicing natural resource projects, provide re-supply services to communities, tourism, and other destination vessel traffic (Gong et al., 2018). As a result of this, increased emissions and air pollution pose a threat to northern communities that are disproportionately vulnerable to social and environmental change (Richmond & Ross, 2009).

Current western scientific knowledge about the Arctic is limited. This is because there is an absence of comprehensive baseline data due to environmental challenges, cost, and the remoteness of the area. Without baseline data, it is difficult to monitor and evaluate change. However, with centuries' worth of experience in the harsh climate, inhabitants' Indigenous Knowledge[1] (IMO, 2023b) of these regions can contribute to better-informed decision-making about policies, including a Canadian Arctic ECA. Using Indigenous Knowledge, Arctic communities have proven their adaptive capacity to provide solutions to the impacts of climate warming by detecting change, evaluating risks and informing adaptation (Bushman, 2022). A crucial step in discerning the impact of a potential Canadian Arctic ECA is to understand the

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[1] Indigenous Knowledge (IK) is a systematic way of thinking applied to phenomena across biological, physical, cultural, and spiritual systems. It includes insights based on evidence acquired through direct and long-term experiences and extensive and multigenerational observation, lessons, and skills. It has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation. Under this definition, IK goes beyond observations and ecological knowledge, offering a unique 'way of knowing.' Indigenous Knowledge holds multiple methodologies, evaluation, and validation processes, and ways of storing and sharing. It provides holistic contributions to an equitable, just, fair, and inclusive transition. This knowledge can identify research needs and be applied to them, ultimately informing decision-makers. There is a need to utilize both Indigenous Knowledge and scientific knowledge. Both ways of knowing will benefit the people, land, waters, air, and animals (IMO, 2023b).

communities and environmental areas that are at risk from the effects of ship emissions. Indigenous Knowledge is vital to understanding this.

4.2 Geography

For the purposes of this document, provincial and territorial boundaries are primarily used to describe the areas of focus in the Canadian Arctic. However, it is important to recognize that there are other ways northern Indigenous Peoples[2] define these areas. The majority of the Canadian Arctic is geopolitically divided into three territories that lie above 60°0'N: the Yukon, Northwest Territories, and Nunavut (**Figure 4.1**). Additionally, parts of northern Quebec and northern Labrador lie within the boundaries of the Arctic and within the proposed ECA (Government of Canada, 2019).

Figure 4.1: Canadian provinces and territories.

These provinces and territories contain traditional lands of Indigenous Peoples in Canada. The term 'Indigenous Peoples' is used here to refer collectively to the original peoples of North America and their descendants. The three groups recognised in the Canadian Constitution that are referred to under this term are First Nations, Inuit, and Métis (CIRNAC, 2022d).

Inuit[3] primarily live in Inuit Nunangat, the Inuit homeland in Canada. The regions of Inuit Nunangat and locations of Inuit communities are shown in **Figure 4.2**. The Inuit Nunangat Policy states: "Across Inuit Nunangat, there are five modern treaties (also known as land claims agreements) in place, one of which includes self-government, between Inuit and the Crown: the Inuvialuit Final Agreement, the Nunavut Agreement, the James Bay and Northern Quebec Agreement, the Nunavik Inuit Land Claims Agreement, and the Labrador Inuit Land Claims Agreement. Among other items, the Inuit Crown treaties set out specific Inuit rights related to lands and resources and also outlines various governance arrangements, including treaty obligations and objectives, that are specific to each of the four Inuit regions, including co-management, public government, and self-government arrangements. This policy affirms Canada's respect for these rights and governance arrangements and the associated Inuit

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[2] Indigenous Peoples is a collective name for the original peoples of North America and their descendants.

[3] Indigenous Peoples of the Arctic.

organizations involved, recognizing that they continue to evolve based on the inherent right of Inuit to self-determination" (CIRNAC, 2022b). Modern treaties are between Indigenous Organizations or Nations and Canada (typically with provincial/territorial governments as signatories). They also outline various governance arrangements, including treaty obligations and objectives (CIRNAC, 2022e). The rights defined in modern treaties are constitutionally protected, and work to advance a broad set of objectives that support reconciliation with Indigenous Peoples in Canada (CIRNAC, 2019). Implementation of each modern treaty is supported by an Implementation Committee or panel, where Indigenous Partners federal departments/agencies, and, where applicable, provincial, and territorial governments, meet to ensure meaningful implementation of agreements (CIRNAC, 2019). In addition to the five modern treaties in Inuit Nunangat, there are several other modern treaties supporting First Nations[4] and Métis[5] communities that would be impacted by this proposal.

Modern treaties pertain to areas of land, water, and ice across Canada. Arctic shipping routes pass through these regions of water and ice, and therefore affect treaty lands and those living within them. **Figure 4.3** shows the distribution of the 25 land claim agreements in Canada in relation to Indigenous communities. **Figure 4.4** displays 2019 ship density also in relation to Indigenous communities.

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[4] Indigenous Peoples who are ethnically neither Métis nor Inuit.

[5] Indigenous Peoples who are a collective of cultures and ethnic identities that resulted from unions between European and Indigenous Peoples.

Figure 4.2: Map of the four regions of Inuit Nunangat, Nunatsiavut (Northern coastal Labrador), Nunavik (Northern Quebec), the territory of Nunavut, and the Inuvialuit region of the Northwest Territories in relation to the 51 Inuit communities.

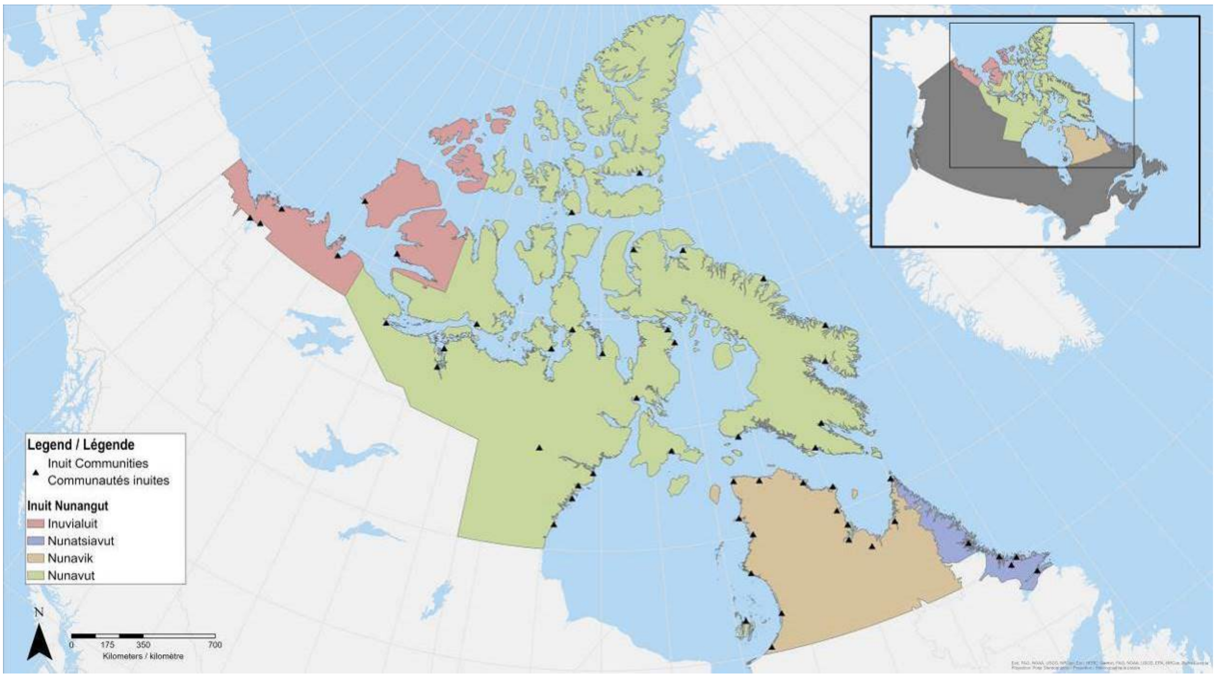
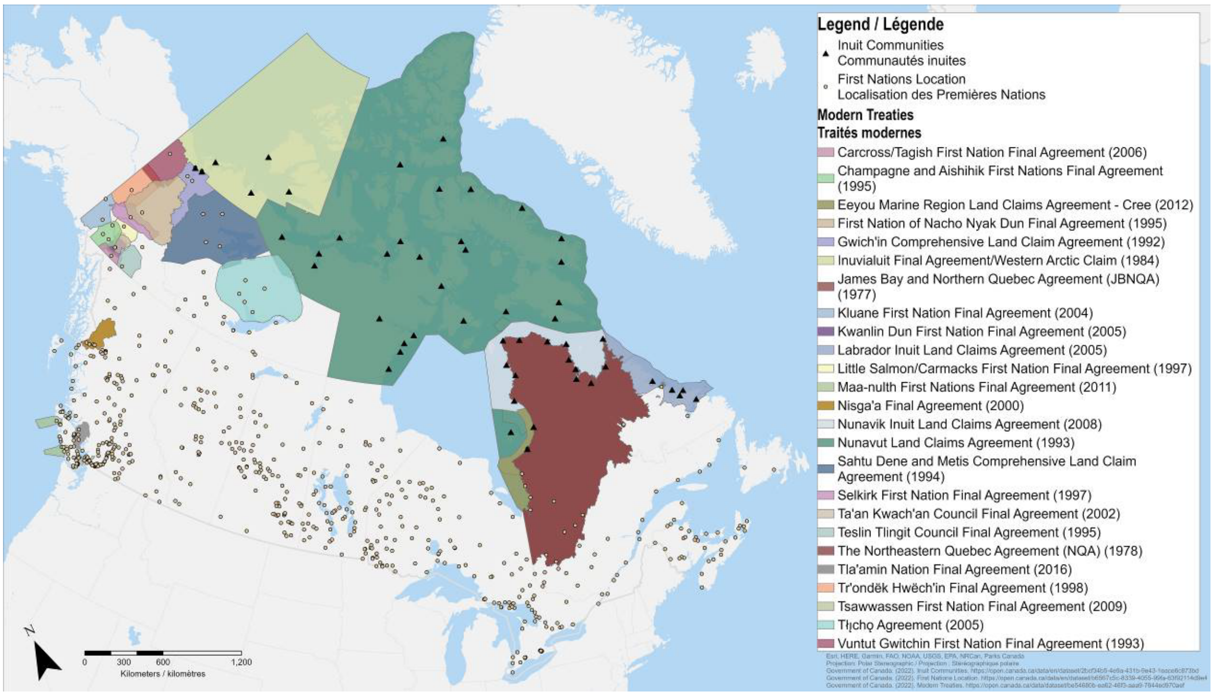
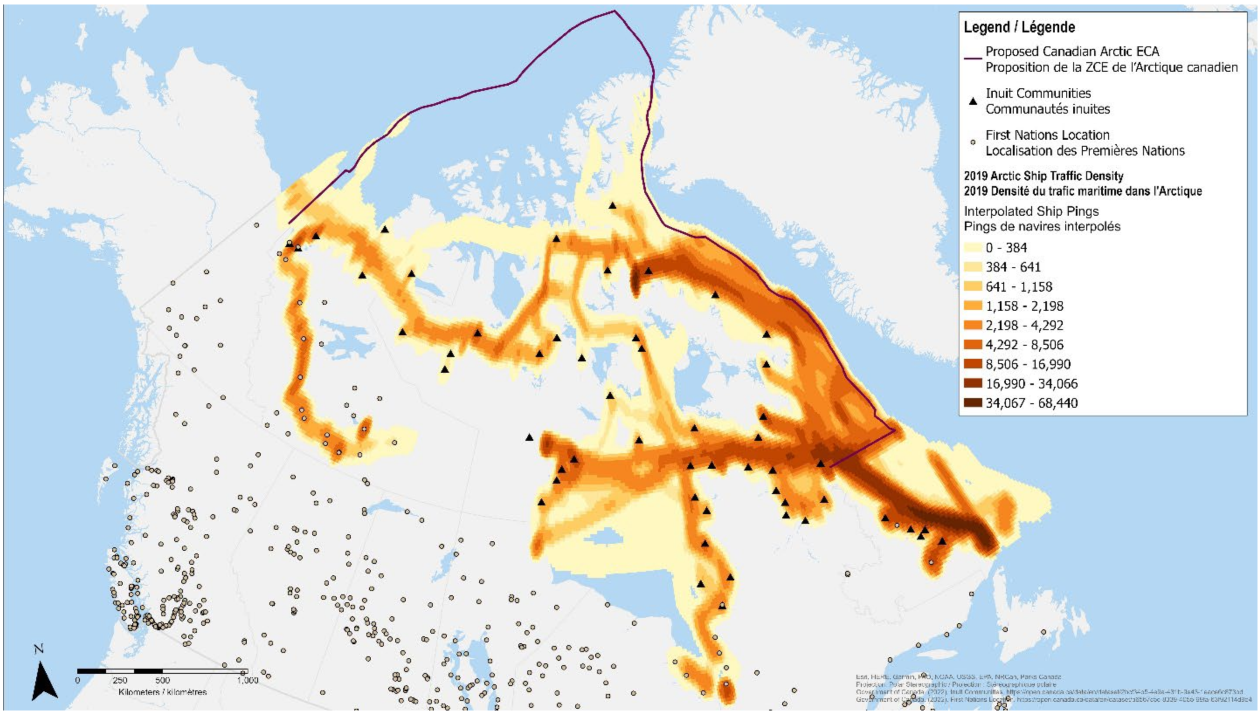


Figure 4.3: Map of Modern Treaties in relation to Inuit communities and First Nations locations.



Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
Projection: Polar Stereographic / Projection : Stéréographique polaire
Government of Canada. (2022). Inuit Communities. https://open.canada.ca/data/en/dataset/[illegible]
Government of Canada. (2022). First Nations Location. https://open.canada.ca/data/en/dataset/[illegible]
Government of Canada. (2022). Modern Treaties. https://open.canada.ca/data/dataset/[illegible]

Figure 4.4: 2019 Ship density in relation to Inuit communities and First Nations locations. Density extends beyond the Canadian Arctic ECA boundary to display ship traffic density in relation to all communities within the Inuit Nunangat boundary.



In **Figure 4.4**, 'Interpolated Ship Pings' refers to each time a vessel sends a signal to an Automatic Identification System (AIS) and the MEIT interpolated points. This density chart displays a magnitude-per-square kilometer from MEIT interpolated Ship Pings point data.

4.3 Demographics

The Northwest Territories had a total population of 41,070 in 2021 (Statistics Canada, 2022a). In Yellowknife, the capital, the population was 19,673 with a population density of 1086.3 per square kilometre (Statistics Canada, 2022a). Inuvik and Hay River, the other main inland population centres within the territory have population densities of 1871.4 and 752.8 people per square kilometre, respectively (Statistics Canada, 2022a). Remote coastal communities such as Tuktoyaktuk and Sachs Harbour have a less dense population of 74 and 0.4 people per square kilometre, respectively (Statistics Canada, 2022a).

The 2021 population of Nunavut was 36,858 (Statistics Canada, 2022a). In 2021, Iqaluit, the territory's capital, had 6,991 people with a population density of 667.0 people per square kilometre (Statistics Canada, 2022a). Most towns close to shipping lanes are small and less densely populated. For instance, Pond Inlet had a population of 1,555 and a density of 9.1 people per square kilometre in 2021 (Statistics Canada, 2022a).

The Yukon had a population of 40,232 in 2021 (Statistics Canada, 2022a). The largest city in the territories is Yukon's capital, Whitehorse, with a population of approximately 24,513 and a population density of 681.5 people per square kilometer (Statistics Canada, 2022a). Aside from several population centres in the territory, most communities have a population of less than 1,000 (Statistics Canada, 2022a).

As a result of the large land area these three territories cover, the average population density of this region is 0.031 residents per square kilometre, compared to the Canadian average population density of 4.2 residents per square kilometre (Statistics Canada, 2022a).

The population of 118,160 (Statistics Canada, 2022a) in the three northern territories make up less than 1% of Canada's total population and are distributed across the region as shown in **Table 4.1**.

Table 4.1: Population distribution across the Yukon, Northwest Territories, and Nunavut compared to Canada's population, and population growth within each territory.

Territory	Population 2011	Population 2016	Population 2021	5-year Growth 2011-2016	5-year Growth 2016-2021
Yukon	33,897	35,874	40,232	5.8%	12.1%
Northwest Territories	41,462	41,786	41,070	0.8%	-1.7%
Nunavut	31,906	35,944	36,858	12.7%	2.5%
Total	107,265	113,604	118,160	5.9%	4.0%
Canada	33,476,688	35,151,728	36,991,981	5.0%	5.2%

Adapted from: Statistics Canada, 2017; Statistics Canada, 2022a.

All territories are distinguished by a younger population when compared to Canada's median age of 41.6 (Statistics Canada, 2022a). The median ages of the Northwest Territories and Nunavut are significantly younger at 35.6 and 25.6, respectively, while the Yukon's median age of 39.2 is closer to the Canadian median (Statistics Canada, 2022a).

4.3.1 Indigenous Presence in the Territories and other Impacted Communities

Indigenous Peoples comprise a significant percentage of Canada's Northern population (as shown in **Table 4.2**). First Nations, Inuit, and Métis peoples are uniquely sensitive to the impacts of climate change because of their close relationships with and dependence on land, waters, animals, plants, and natural resources for their sustenance, livelihoods, cultures, identities, health and well-being (National Collaborating Centre for Indigenous Health, 2022). Several international Indigenous groups share similar cultural ties to the land and thus are likely to experience comparable impacts. The Arctic Circumpolar groups include Inuit Peoples in Canada, Greenland, and Russia, as well as the Inupiat, Aleut, and Yupik in Alaska (Inuit Tapiriit Kanatami, n.d.-b).

The Canadian Arctic has a prominent Indigenous presence, including in northern Quebec and northern Labrador. The vast majority of Indigenous communities in Canada's Arctic are situated on the coast or on waterways, as the marine environment provides a means of transportation, communication and subsistence (Ellis & Brigham, 2009). Beyond geographic territorial and provincial boundaries, First Nations, Inuit, and Métis make up a complex network of communities in the North, as shown in **Table 4.2.**

Table 4.2: Indigenous Population Breakdown in Northern Canada.

Territory	Total Population	Indigenous Identity		First Nations	Inuk (Inuit)	Métis
		#	% of total population			
Yukon	40,232	8,810	22	6,935	260	1,285
Northwest Territories	41,070	20,035	49	12,315	4,150	2,890
Nunavut	36,858	31,390	85	180	30,865	120

Adapted from: Statistics Canada, 2021.

In total, approximately 70,500 Inuit live in Canada, with over two-thirds living in Inuit Nunangat, making up 51 communities (Statistics Canada, 2022a; Inuit Tapiriit Kanatami, n.d.-a, n.d.-c). Inuit own or have jurisdiction over half of the Arctic and are the largest Indigenous landholders in the world (Inuit Tapiriit Kanatami, 2016). **Table 4.3** displays the number of communities and Inuit population of each Inuit Nunangat region. The territory of Nunavut is by far the largest region, with 25 communities, and a majority Inuit population. The second largest region is Nunavik, which has 15 communities along the coast of James Bay and Hudson Bay and is also mostly populated by Inuit. In Labrador, most people living in Nunatsiavut are Inuit and live in five communities within the region. Finally, Inuit in the Inuvialuit Settlement Region, although a small proportion of the Northwest Territories' population, live in six communities in the northern coastal region.

Table 4.3: The number of communities and Inuit population of each Inuit Nunangat region.

Region	# of Communities	Inuit Population
Nunavik	15	12,590
Nunatsiavut	5	2,095
Nunavut	25	30,865
Inuvialuit	6	3,145
Outside Inuit Nunangat	n/a	21,825
Total	51	70,520

Adapted From: Inuit Tapiriit Kanatami, n.d.-a; Statistics Canada, 2022a.

Although First Nations and Métis make up less of the population in Canada's Arctic than Inuit, they nonetheless make up a significant proportion of the population in the region. First Nations and Métis in the Yukon and Northwest Territories comprise a variety of different groups, predominantly the Tlingit and Dene. In Northern Canada, Métis primarily live in the urban areas of the Yukon and Northwest Territories (Royal Canadian Geographical Society, 2018). For a map of all of the Indigenous territories, languages, and treaties in Canada, refer to https://native-land.ca/.

4.4 Environmental & Ethnoecological Significance

Ethnoecological factors are the ways in which environmental components and their interrelations are interpreted and managed by local populations (Willox et al., 2013). The ethnoecological significance of the Arctic stems from millennia of Indigenous local management of the Northern landscape. Indigenous Peoples in the Arctic interact with the environment to harvest food, build shelters, make clothes, and conduct other cultural activities (Laidler et al., 2010). Many Indigenous communities throughout the Arctic maintain this strong connection to the environment through hunting, herding, fishing, and gathering (Laidler et al., 2010; Inuit Tapiriit Kanatami, n.d.-b, Inuit Circumpolar Council, 2014). The living resources of the Arctic not only sustain Indigenous Peoples in an economic and nutritional sense, but also provide a fundamental basis for social identity, spiritual life, and cultural survival (Hanaček et al., 2022, Joy, 2004; Willox et al, 2013; Inuit Circumpolar Council, 2014). Mythologies, Oral Histories, festivals, and animal ceremonies illustrate the social, economic, and spiritual relationships that Indigenous Peoples have with the Arctic environment (Joy, 2004; Hanaček et al., 2022).

With vast expanses of open tundra, glaciers and permafrost, the Arctic supports a diverse range of fauna that Indigenous communities rely on for food security, identity, and well-being (Van Oostdam et al., 2005; Kuhnlein & Receveur, 2007; Rosol et al. 2016; Willox et al., 2013; Huntington et al., 2022). The species most commonly harvested are marine mammals such as seals, walrus, belugas, and bowhead whales; land mammals such as caribou, reindeer, moose, and musk ox; fish such as salmon and Arctic char, and a variety of birds, including ducks, geese, and ptarmigan (Kuhnlein & Receveur, 2007; Willox et al., 2013; Inuit Circumpolar Council, 2014). The region is also home to many at-risk species identified in the Canadian *Species at Risk Act* such as caribou (*rangifer tarandus* [special concern]), polar bear (*ursus maritimus* [special concern]) and wood bison (*bison athabascae* [threatened]). Some of these species, such as the polar bear, are considered highly culturally and spiritually significant to Inuit.

The Arctic region encompasses several terrestrial and marine ecozones. These include the taiga plains, taiga shield, southern Arctic, northern Arctic, taiga cordillera, and Arctic cordillera ecozones (Ecological Stratification Working Group, 1996). While the Arctic cordillera, for example, is too far north to sustain much flora or fauna, it supports Arctic black spruce, cottongrass, Arctic poppy, and species of moss and lichen (Ecological Stratification Working Group, 1996). Further south, ecozones like the taiga shield support a patchwork of forests, wetlands, meadows and shrublands (Ecosystem Classification Group, 2008). These ecologically significant biomes are diverse in vegetation, moss, and lichen communities, supporting complex networks of productive systems (Elias, 2021). The productivity of these ecosystems is linked to each other; for instance, the extent, concentration, and volume of Arctic Sea ice influences tundra productivity (Macias-Fauria et al., 2017; Post et al., 2013; Bhatt et al., 2010). Each of these ecozones within the Arctic environment support larger networks of species and communities, many of which indirectly or directly support Inuit food security.

Diverse and abundant Arctic aquatic habitats (including freshwater lakes, rivers, deltas, and wetlands) support more than 14,000 species of invertebrates, fish, and marine mammals, including culturally significant Arctic char and narwhals (Meltofte, 2013). Arctic marine biodiversity is comparable to that reported off the Atlantic and Pacific coasts of Canada (Darnis et al., 2012). As with all other marine environments, Arctic marine communities are reliant on a bottom-up ecological process, in which primary productivity informs how successful communities higher up in the food web will be.

The fragile nature of the region has also been recognized by the United Nations Educational, Scientific and Cultural Organization (UNESCO) with the development of the Kluane/Wrangell-St. Elias/Glacier Bay/Tashenshini-Alsek, the Nahanni National Park Reserve and Wood Buffalo National Park World Heritage Sites (UNESCO World Heritage Centre, n.d.-a; n.d.-b; n.d.-c).

4.5 Rights of Indigenous Peoples

The Arctic is home to a large Indigenous population that often faces more economic, health, and social disparities than populations in other regions; thus, it is frequently examined as an environmental justice area (Giang et al., 2022). Emissions from marine vessels transiting the Canadian Arctic can adversely affect Indigenous food security, health, culture, traditional ways of life, and ethnoecological ties to the Arctic landscape. As a result, Indigenous communities in the Canadian Arctic have rights and interests in policies that would control marine emissions. This situation is reflected in a statement released by the Inuit Circumpolar Council which declared that "air pollutants, including black carbon, pose threats to the air quality and health of human and mammal populations" and "provisions to protect Inuit social, cultural and economic interests are required and can be achieved by engaging Inuit communities" (Koperqualuk, 2019). Historically, Inuit Peoples have not been participants in the governance of Arctic shipping, but current efforts aim to better account for Inuit rights and interests through multiple forms of collaboration (Beveridge, 2020). For example, in 2021, the Inuit Circumpolar Council became the first Indigenous Organization to receive IMO Provisional Consultative Status (Inuit Circumpolar Council, 2021a). This provides ICC the ability to represent Inuit in Canada, Alaska, Greenland, and Chukotka on matters of international importance. Inuit have also expressed concern that increasing shipping traffic in the north and corresponding increases in shipborne pollutants will fundamentally change Arctic waters and the local ecosystem, threatening public health, harming marine life, and damaging the fragile northern environment (Inuit Circumpolar Council, 2014). However, policies to control emissions from vessels in the Arctic, such as the Canadian Arctic ECA, may result in economic impacts to northern communities. The increased costs due to the Canadian Arctic ECA would likely be the result of increased price of consumer prices due to higher operating costs for sealift services[6]. Although these costs are anticipated to be minor, the Government of Canada is committed to ensuring that the Canadian Arctic ECA will not cause any adverse economic impacts on northern communities. To do so, it is critically important to consult with affected communities to gain perspective on potential cultural and economic impacts of a Canadian Arctic ECA in the North.

International and Canadian law addresses the disproportionate challenges faced by Indigenous communities. Canada is signatory to the United Nations Declaration on the Rights of Indigenous Peoples and Canada's Constitution recognizes and affirms existing rights of Aboriginal peoples[7] of Canada. Section 35 of the Constitution Act, 1982 recognizes and affirms the Aboriginal and treaty rights of Indigenous peoples, and Canada has a legal duty to meaningfully consult with Indigenous peoples in advance of government actions or decisions that may adversely affect potential or established Aboriginal or treaty rights (Government of Canada, 1982). The proposed ECA intersects with the territories covered by the five Land Claims Agreements as discussed in section 4.2 which are as recognized in Section 35.

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[6] Most people living in the Arctic depend on sealift vessel delivery services (also called community resupply) to deliver the majority of necessary goods to communities. This includes food, fuel for vehicles, and construction materials. Resource projects in the Arctic also depend on these services to deliver equipment, fuel, and supplies as well as to carry their product to market (Chamber of Marine Commerce, n.d.).

[7] Aboriginal Peoples is an alternative collective name to refer to Indigenous Peoples.

Further, the United Nations Declaration on the Rights of Indigenous Peoples Act, SC 2021, c 14 (UNDA), which came into force on June 21, 2021, sets out a framework for implementation of the United Nations Declaration on the Rights of Indigenous Peoples (UN Declaration) (Government of Canada, 2021). The UN Declaration is an international human rights instrument that describes the individual and collective rights of Indigenous Peoples, covering a range of civil, political, economic, social and cultural rights, including a right to the conservation and protection of the environment and the productive capacity of their lands or territories and resources (Article 29) (Government of Canada, 2021). Since the IMO is a UN body, this UN declaration must be considered and fully implemented into IMO work. This is stated in Article 31: "the organs and specialized agencies of the United Nations system and other intergovernmental organizations shall contribute to the full realization of the provisions of this Declaration through the mobilization, inter alia, of financial cooperation and technical assistance. Ways and means of ensuring participation of indigenous peoples on issues affecting them shall be established." (Government of Canada, 2021). The Inuit Nunangat Policy states: "The right to self-determination has been recognized as a fundamental human right in the United Nations Declaration on the Rights of Indigenous Peoples. Canada recognizes the inherent right of Inuit to self-determination including through self-government and through the exercise of their treaty and Indigenous rights, which are recognized and protected under section 35 of the Canadian Constitution" (CIRNAC, 2022b). The United Nations Declaration on the Rights of Indigenous Peoples Act includes a legal obligation for officials across government to take all measures necessary to ensure consistency of federal laws with the rights and interests set out in the UN Declaration, in consultation and cooperation with Indigenous peoples (section 5) (Government of Canada, 2021). Furthermore, Article 32 – 2 says "States shall consult and cooperate in good faith with the indigenous peoples concerned through their own representative institutions in order to obtain their free and informed consent prior to the approval of any project affecting their lands or territories and other resources, particularly in connection with the development, utilization or exploitation of mineral, water or other resources" (Government of Canada, 2021).

The *Canadian Environmental Protection Act, 1999* (CEPA), which declares that the protection of the environment is essential to the well-being of all Canadians, commits Canada to cooperate with Aboriginal peoples to achieve the highest level of environmental quality, and commits Canada to ensure that its operations and activities on federal and Aboriginal lands are carried out in a manner consistent with the principles of pollution prevention and the protection of the environment and human health (Government of Canada, 1999). CEPA was recently amended with the addition of Bill S-5, Strengthening Environmental Protection for a Healthier Canada Act, which received Royal Assent on June 13, 2023 (ECCC, 2023a). This represents the first set of comprehensive amendments since CEPA 1999 was enacted and requires that decisions made under CEPA respect the right to a healthy environment (ECCC, 2023a). This amendment requires that decisions made under CEPA avoid adverse effects that disproportionately affect vulnerable populations. This is especially important in Northern Canada as Indigenous populations are uniquely sensitive to the impacts of climate change (National Collaborating Centre for Indigenous Health, 2022).

The 94 Calls to Action of the Truth and Reconciliation Commission underpin Canada's commitment to improve relationships between Indigenous and non-Indigenous people (Truth and Reconciliation Commission of Canada, 2015).

Canada's Arctic and Northern Policy Framework aims for all individuals in Canada's North to be full participants in Canadian society, with access to the same services, opportunities, and standards of living as those enjoyed by other Canadians (CIRNAC, 2022e). The Framework recognizes that gaps and divides exist within Canada, particularly in relation to Indigenous peoples, and lists the reduction of GHG emissions and short-lived climate pollutants as a key objective (CIRNAC, 2022e).

Lastly, the Inuit Nunangat Policy applies to all federal departments and agencies. It provides guidance in the design, development, and delivery of all new or renewed federal policies, programs, services, and initiatives that apply in Inuit Nunangat and/or benefit Inuit. This includes programs of general application and those that support Inuit self-determination (CIRNAC, 2022b). This policy can be read together with the Co-development Principles, which provide guidance for collaborative work undertaken by Inuit and federal partners (Inuit-Crown Partnership Committee, 2022).

Designating an ECA in the Canadian Arctic is a tool Canada can use to work toward ensuring the same air pollution protections that currently exist in a portion of Canada are applied to all of Canada. This will help mitigate some of the environmental, health and cultural risks that Indigenous communities face in that region due to pollution. Canada's Arctic region is home to a much larger proportion of the Indigenous population in Canada compared to southern Canada. The 2021 Canadian Census counted 1.8 million Indigenous Peoples, which is about 5% of the total population in Canada (Statistics Canada, 2022c). In comparison, Indigenous Peoples make up 85% of the population in Nunavut, 49% in the Northwest Territories, and 22% in the Yukon Territory (Statistics Canada, 2021). Implementation of controls on marine emissions in the Arctic would provide similar protections to the environment and health as has been afforded to regions of southern Canada through the NA ECA since 2013. The Arctic was initially omitted from the NA ECA due to data scarcity and a lack of shipping in this region at the time. However, with improved data access, more summer ice melt, and increased shipping activity in the Arctic, an ECA is now a necessary regulation to reduce the disparity of environmental protections between the primarily Indigenous populated Arctic, and the rest of Canada.

4.6 Economy

Amongst the territories, the real Gross Domestic Product (GDP) is highest in the Northwest Territories at $4.3 billion in 2021 (Statistics Canada, 2022b). Although the impact of COVID-19 on the territories' economy was significant, territorial economies have rebounded since 2020, as shown in **Table 4.4**.

Table 4.4: GDP of all industries by territory. Values are normalized to 2012 Canadian Dollars.

Territory	2019 GDP (in billions)	2020 GDP (in billions)	2021 GDP (in billions)	Growth rate from 2020-2021
Yukon	2,555	2,687	2,931	9.1%
Northwest Territories	4,509	4,036	4,291	6.3%
Nunavut	3,084	3,164	3,376	6.7%

Adapted From: Statistics Canada, 2022b

Table 4.5 shows the top two industries that make up the highest share of GDP for each territory. Industries are broken down into categories specified by the North American Industry Classification System (NAICS). NAICS is the classification standard used by federal statistical agencies in North America to ensure standardization and comparability. Mining, quarrying, and oil and gas extraction contributes to 15%, 18%, and 41% of the GDP in the Yukon, Northwest Territories, and Nunavut, respectively (Statistics Canada, 2023).

Table 4.5: Top GDP contributor(s) by industry in 2021

Territory	Industry	% of Total GDP in Territory
Yukon	Public Administration	23%
	Mining, quarrying, and oil and gas extraction	15%
Northwest Territories	Public Administration	21%
	Mining, quarrying, and oil and gas extraction	18%
Nunavut	Mining, Quarrying, and oil and gas extraction	41%
	Public Administration	18%

Adapted From: Statistics Canada, 2023

Natural resource development contributes significantly to GDP in all three territories and is expected to continue to play a role in the territories' economic development. In the Yukon and Nunavut, recent growth has been largely due to the expanding metals market in gold, silver and iron ore, supporting the mining and oil and gas extraction industry (Statistics Canada, 2022b). Growth in the mining sector of the Northwest Territories in 2020-2021 is largely attributed to diamond mining operations (Statistics Canada, 2022b).

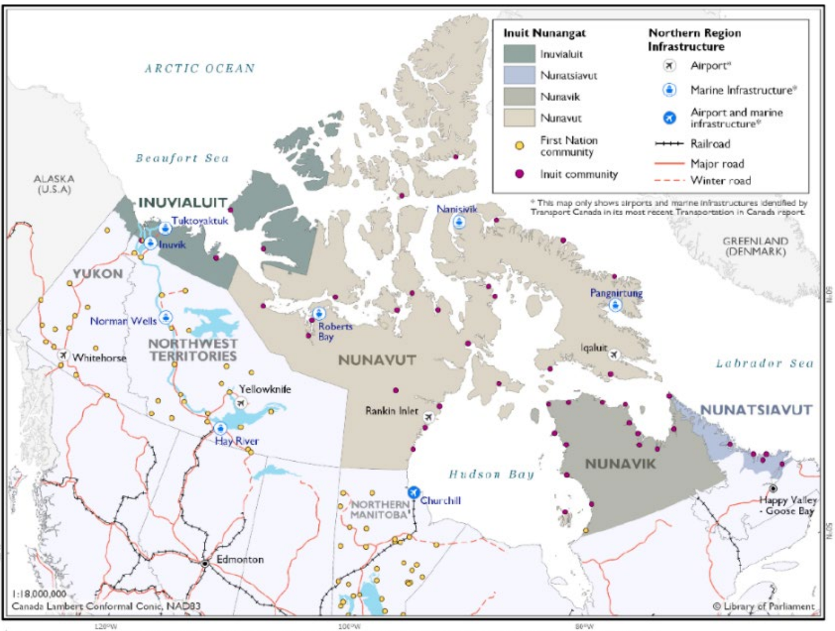
The mining, quarrying, and oil and gas industries in the Arctic use shipping to deliver equipment and supplies to sustain operations. Though most mines fly out their products, some use shipping to export their goods to end markets around the world (Têtu et al., 2015). With an increase in these industries, the demand for Arctic shipping will likely increase, further justifying the need for establishing a Canadian Arctic ECA.

4.7 Transportation

Many of the communities in the Canadian Arctic are very remote and only accessible year-round by one mode of transportation. **Figure 4.5** shows the Inuit and First Nation communities that are inaccessible by road, or only accessible by winter roads for a portion of the year. The harsh environment, short construction season, lack of resources, and shifting environmental conditions due to climate change make it challenging to build and maintain transportation infrastructure. Nunavut mostly relies on air and marine transportation, as there are no highways in the territory and only a few small roads connecting some communities. The Northwest Territories (NWT) have a strong reliance on seasonal roads, which are being greatly impacted by climate change.

There is a network of around 10,000 km of ice roads that link Arctic communities (Dong et al., 2022). These roads are usually only accessible for a few months of the year, typically from December until April. However, due to warming of the Arctic surface, the period that ice roads are suitable for transport is shortening (Dong et al., 2022). Thus, there is a significant dependence on Arctic shipping for resupply of bulk goods and necessities to these communities and for many Inuit this service is critical for community wellness (Inuit Circumpolar Council, 2021b).

Figure 4.5: Transportation Infrastructure in the Arctic (Parliament of Canada, House of Commons, 2019).



¹Crown-Indigenous Relations and Northern Affairs Canada does not use a standardized definition to determine the boundaries of "Northern Manitoba". As such, on this map, there are no clear boundaries for this region, but the location of First Nations communities was nonetheless included.

Since air transportation is costly and most communities in the Arctic have no road or rail access, sealift is a safe and economically feasible means of transporting goods to and from Canada's Arctic (Ellis & Brigham, 2009). Seasonal sealift resupply services occur each year during periods over the summer when shipping routes are not blocked by ice, and are used to transport bulky, heavy or non-perishable items. These items include necessities such as food, household items, and fuel for power generation.

4.8 Summary

While Northern Canada is not densely populated, it contains sensitive, unique ecosystems that are important to the lives and culture of the area's Indigenous population. It is crucial that Canadian Arctic coasts have equal protections as those applied by the NA ECA to Canada's southern coasts. The section above describes the human populations and environmental areas at risk from the impacts of ship emissions. Thus, this proposal for an ECA fulfils criterion 3.1.3 of Annex VI, Appendix III.

5 Impact of Emissions from Ships on Ecosystems and Human Health

5.1 Introduction

Criterion 3.1.4	*The proposal shall include an assessment that emissions from ships operating in the proposed area of application are contributing to ambient concentrations of air pollution or to adverse environmental impacts. Such assessment shall include a description of the impacts of the relevant emissions on human health and the environment, such as adverse impacts to terrestrial and aquatic ecosystems, areas of natural productivity, critical habitats, water quality, human health, and areas of cultural and scientific significance, if applicable. The sources of relevant data including methodologies used shall be identified.*

Emissions from ships adversely affect air pollution levels and sensitive ecosystems across Northern Canada (Gong et al., 2018; Law et al., 2017). These impacts are expected to grow in the coming decades, widely affecting terrestrial and aquatic ecosystems, including areas of natural productivity, critical habitats, and regions of cultural and scientific significance.

This section will provide an overview of current and projected emission rates from ships operating in the proposed Canadian Arctic ECA and their contribution to ambient concentrations of air pollution. It will also cover the impact of vessel emissions on terrestrial and aquatic ecosystems, critical habitats, water quality, human health, and areas of cultural significance in Canada's Arctic. The sources of relevant data, including methodologies used, are identified.

5.2 Current & Projected Emission Rates from Shipping and Contribution to Ambient Concentration of Pollutants in the Canadian Arctic

Many sources contribute to ambient concentrations of air pollution in the Arctic, including ships, oil rigs, mining activities, and local combustion sources (Law et al., 2017; Gong et al., 2018; Marelle et al., 2016; Dalsøren et al., 2013; Hassellöv et al., 2013). Depending on several factors such as the nature of the emission sources, geography, and the season, some pollutants can remain airborne for short amounts of time. Therefore, the concentrations can be highest closest to their source (e.g., shipping lanes), and in the Arctic, such pollutants like black carbon have a greater impact on local warming (AMAP, 2015a). However, emissions from sources at lower latitudes can also travel long distances and contribute significantly to Arctic air pollution and warming (Browse et al, 2013).

5.2.1 Research Paper on the Impact of Shipping Emissions in Canada's Arctic (Gong et al., 2018)

The Government of Canada conducted a study, published as a peer reviewed paper, to assess the impact of shipping emissions in the Canadian Arctic, investigating their contribution to ambient concentrations of criteria pollutants (O_3, $PM_{2.5}$, NO_2, SO_2), atmospheric deposition of sulphur and nitrogen, and atmospheric loading and deposition of black carbon (Gong et al., 2018). The study carried out model simulations over a domain with a grid projection at a 15-km horizontal resolution centered over the Canadian Arctic using GEM-MACH (Global Environmental Multi-scale – Modelling Air quality and Chemistry), an air quality forecast model developed by ECCC. For this study, the model was upgraded with improved dry deposition parameterization for sea ice, improved chemical lateral boundary conditions, and the inclusion of North American boreal wildfire emissions. A detailed baseline emissions inventory for ships sailing in Arctic waters under Canadian sovereignty and jurisdiction was developed using the

ECCC's Marine Emissions Inventory Tool (MEIT), which includes vessel movement data tracked by the Canadian Coast Guard (CCG). Vessel movements, also called trips in the MEIT, occur between anchorage and berthing points. One vessel's 'voyage' through the Arctic may be composed of more than one trip if a vessel makes several stops. Data were collected on the transit of commercial marine vessels as well as small commercial craft such as ferries, tugboats, and fishing vessels. The Arctic waters considered in the study included Canadian coastal waters excluded from the NA ECA as well as inland lakes and rivers. Emissions from ships were estimated based on calculated vessel speed and corresponding load on engines for each segment of a voyage. In the 2010 baseline year, the study found that the majority of trips were made by merchant vessels. In this analysis, merchant vessels include merchant bulk and merchant other[8], followed by tugboats engaged in community resupply and tankers. The majority of emissions were released from large commercial and merchant vessels.

The analysis also projected 2030 vessel activity in the Canadian Arctic. Gong et al. (2018) performed an extensive review of ship traffic to build a projection of the types and number of sailings of vessels in 2030. Forecasts considered several growth activities, future anticipated use of navigable channels, as well as planned resource development projects, and increases in Arctic ecotourism. The expected emissions from these vessels were then estimated, also taking into account future technological changes to vessels, such as fuel standards and fleet turnover. The study notes that sea-ice variability, navigability issues, and dangerous weather are major challenges in the Arctic that present an inherent degree of uncertainty in predicting future shipping levels.

The study presents ship emissions in the Canadian Arctic in three cases, 2010 baseline emissions as well as projected emissions in 2030 under two scenarios:

1. Baseline data: The 2010 data from MEIT provided a detailed baseline inventory for ships sailing in Arctic waters under Canadian sovereignty and jurisdiction. Neither the 0.5% global sulphur cap nor the NA ECA were in place in 2010. The 2010 emissions levels therefore do not reflect any transboundary emissions improvements associated with the NA ECA that could be present in later years.

2. 2030 BAU scenario 1 (BAU 1): The business-as-usual (BAU) scenario is based on projected marine shipping activities in the Canadian Arctic waters accounting for all existing and planned regulations at the time. This includes the global 0.5% sulphur cap, which applies to all international waters including the Canadian Arctic waters and the North America ECA, which applies to the Canadian west coast, east coast, the Great Lakes and St. Lawrence seaway. Vessels in Canadian Arctic waters in this BAU scenario are assumed to be using fuels compliant with the sulphur cap, such as very low sulphur fuel oil (VLSFO). Marine fuels with a sulphur content between 0.1% and 0.5% are VLSFO. The analysis does not consider the HFO ban specifically since at the time of the study the ban had not been adopted. See section 5.2.4 for further details on how these original study emission projections were updated, including the consideration of the HFO ban.

3. 2030 ECA scenario 1 (ECA 1): The ECA scenario is a forecasted scenario that applies the same North America ECA regulations over the Canadian

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[8] The merchant other classification is all merchant vessels that are not classified as merchant bulk, container, or tanker. Examples of merchant other classifications include merchant auto, general, ro/ro, lash, dry, ore, reefer, and coastal.

Arctic waters as well. In this scenario, all regulated vessels are subject to compliance with ECA regulations and would use distillate fuels.

For black carbon column loading and deposition, the Gong et al. (2018) study represented black carbon by the elemental carbon component of internally mixed aerosols in the model. By its sources and chemical and physical properties represented in the model, the modelled elemental carbon was determined equivalent to black carbon. This means that the approach to black carbon was more intrinsic in the model, rather than calculating the direct emission rates of black carbon from vessels.

5.2.2 Results of the Research Paper on the Impact of Shipping Emissions in Canada's Arctic (Gong et al., 2018)

Figures 5.1, 5.2, and 5.3 show the percentage contributions from shipping emissions in the Canadian Arctic waters to ambient concentrations of O_3, $PM_{2.5}$, NO_2, and SO_2 and deposition of S, N, and black carbon from Gong et al. They were derived from model simulations carried out with and without the Canadian Arctic marine shipping emissions in the 2010 baseline and the projected 2030 scenarios (2030 BAU 1 and 2030 ECA 1), based on the previous estimates and projections.

Gong et al. (2018) found that 2010 ship traffic contributed 10%–50% and 20%–100% of ambient NO_2 and SO_2 concentrations, respectively, over Arctic shipping channels (Gong et al., 2018). In their 2030 BAU 1 scenario, the projected marine shipping emissions over Arctic waters under Canadian sovereignty and jurisdiction are expected to contribute to 5% and 5-20% of ambient concentrations of O_3 and $PM_{2.5}$, respectively, which is a significant increase compared to 2010 levels. The 2030 ECA 1 scenario would considerably limit this increase (as seen in **Figure 5.1**).

The same study found that Canadian Arctic shipping contributed to < 5% of the atmospheric deposition of sulphur and nitrogen to the Arctic ecosystem at the 2010 baseline, but projections indicate an increase in the Arctic shipping contribution to atmospheric deposition of up to 20% for sulphur and 50% for nitrogen under the 2030 BAU 1 scenario (Gong et al., 2018). The 2030 ECA 1 scenario lowers shipping's contribution to sulphur deposition generally below the 2010 level (as indicated in **Figure 5.2**). In contrast, the shipping contribution to nitrogen deposition is not significantly reduced in their 2030 ECA 1 scenario (see **Figure 5.2**). The contribution to black carbon deposition from marine shipping in the Canadian Arctic is predicted to increase significantly from below 5% at the 2010-baseline level to up to 30% under their 2030 BAU 1 scenario. Their 2030 ECA 1 scenario reduces shipping's contribution to black carbon deposition (shown in **Figure 5.3**).

Figure 5.1: Contribution to ambient concentrations of O_3, $PM_{2.5}$, NO_2, and SO_2 from Canadian Arctic shipping emissions over the July–August–September period (accumulated) for the 2010 base year (b), 2030 BAU scenario (c), and 2030 ECA scenario (d). Figures and data are sourced from Gong et al. (2018).

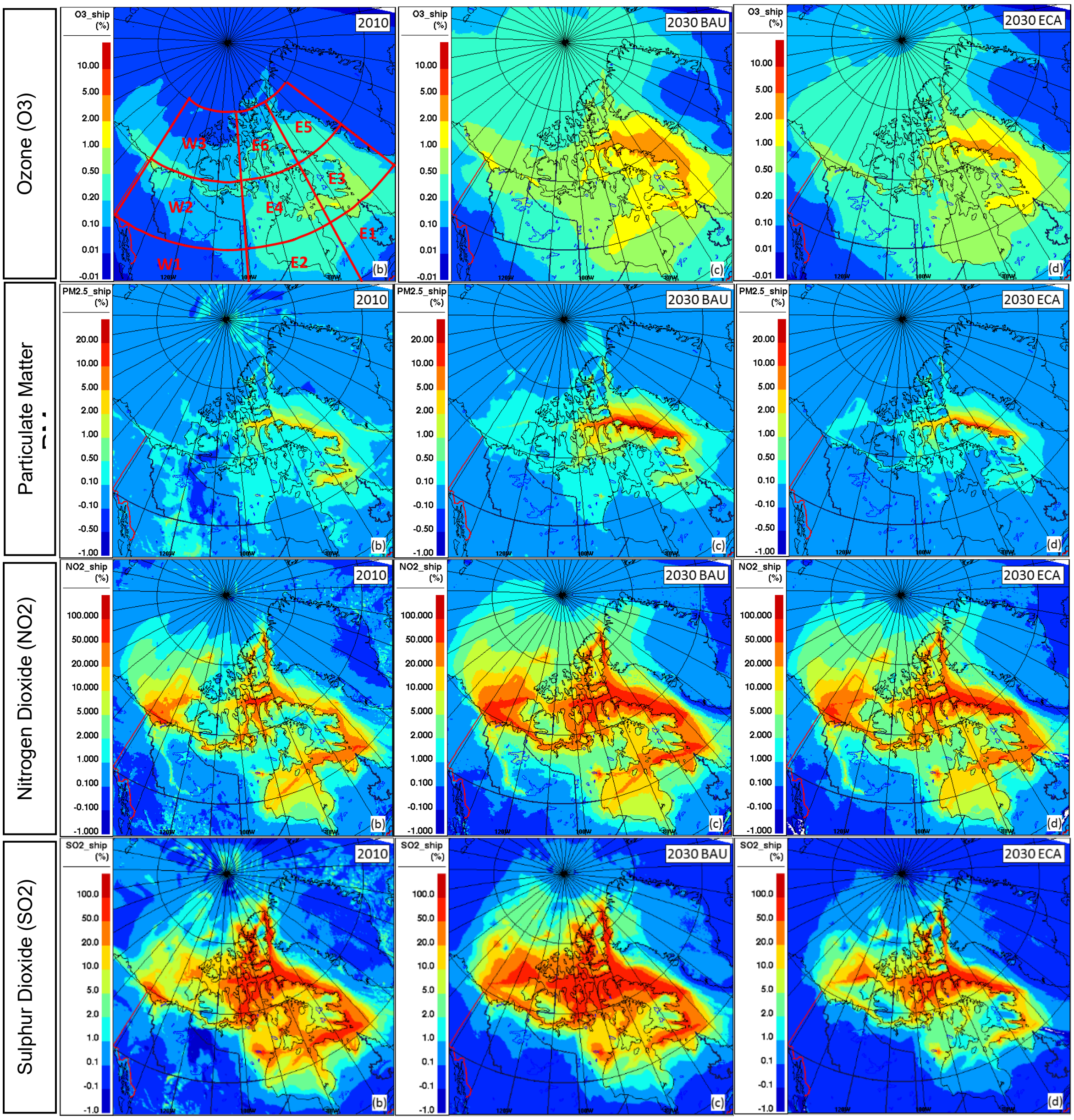


Figure 5.2: Arctic Shipping Contribution to total sulphur and nitrogen deposition over the July–August–September period (accumulated) for the 2010 base year (b), 2030 BAU scenario (c), and 2030 ECA scenario (d). Figures and data are sourced from Gong et al. (2018).

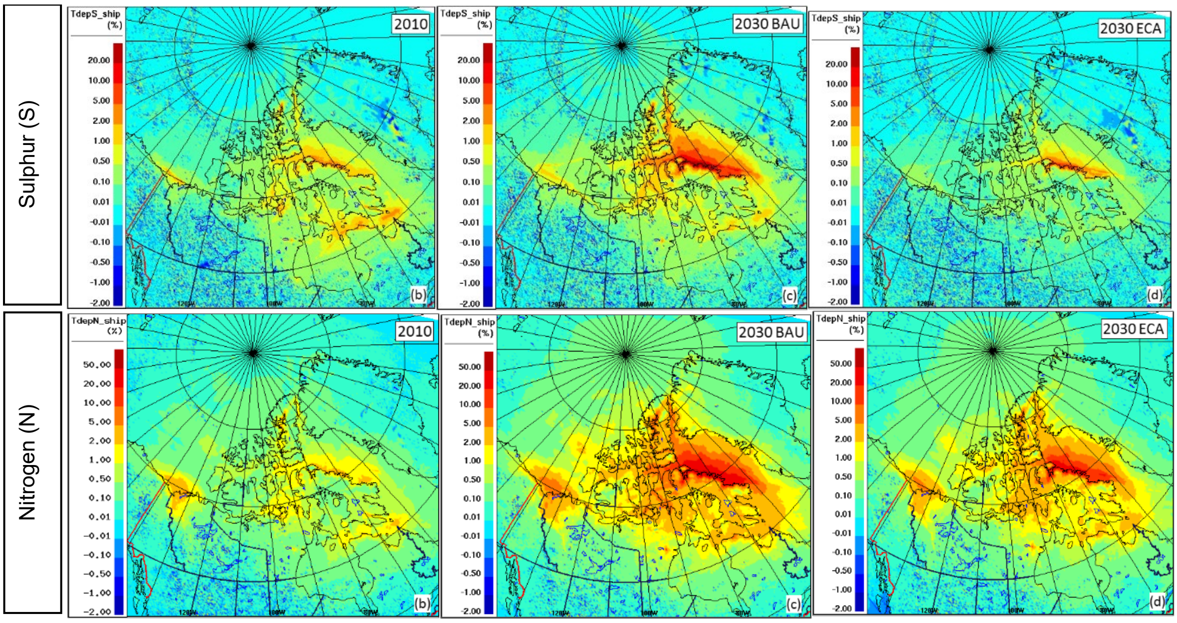
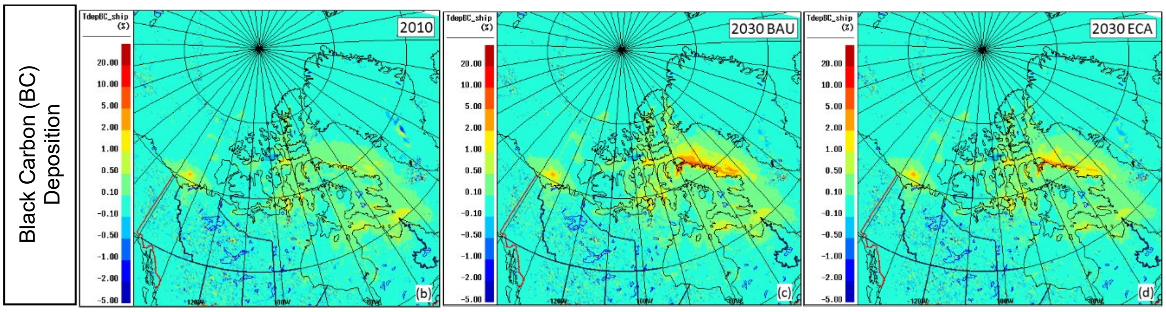


Figure 5.3: Canadian Arctic Shipping emissions contribution (%) to modelled total black carbon deposition flux accumulated over the 2010 July–August–September period (b), 2030 BAU scenario (c), and 2030 ECA scenario (d). Figures and data are sourced from Gong et al. (2018).

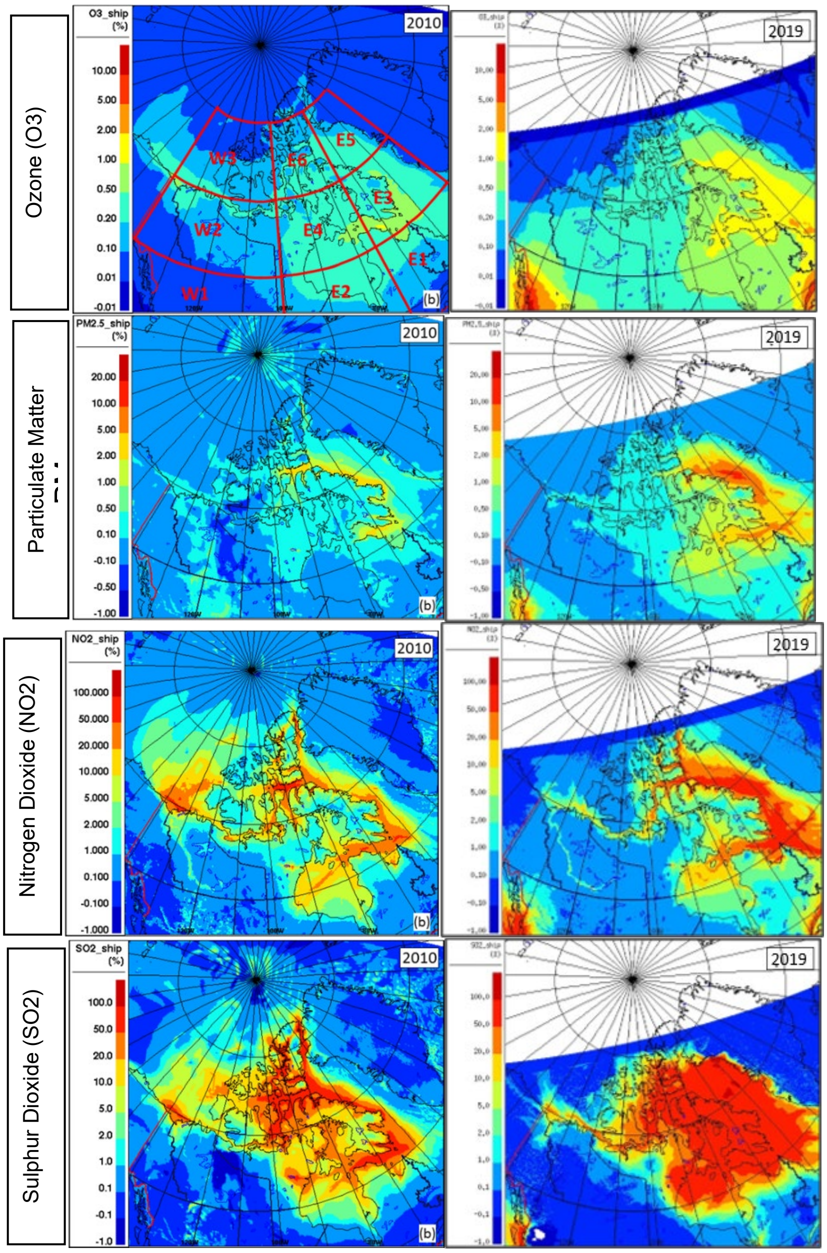


5.2.3 Supplemental Modelling to the Gong et al. (2018) Paper on the Impact of Shipping Emissions in Canada's Arctic

In assessing the impact of Canadian Arctic shipping emissions, Gong et al. used 2010 as a baseline representative for "current" level due to data availability at the time. With the new data released from MEIT for 2019 Canadian marine shipping emissions, model simulations using the GEM-MACH model on a North American continental domain were conducted for 2019 in a separate study, where the Canadian marine shipping emissions were switched on and off. **Figure 5.4** shows the marine shipping emissions contribution to ambient concentrations in the Arctic in 2019 compared to the results of the 2010 base case in the Gong et al. study (note that the North American continental domain for the 2019 simulations does not cover all of the Canadian Arctic). The visual representations demonstrate that the impact at the 2019 level is greater than the 2010 level, reflecting the increased marine shipping emissions in the Canadian Arctic waters from the 2010 level. However, there are some caveats in this comparison. The 2010 study looked at vessels within Canadian Arctic waters only, while the 2019 analysis looks at the impact of marine shipping emissions from vessels in all Canadian waters including the Canadian Arctic. In addition, the 2010 simulations included forest fire emissions while the 2019 simulations did not. The relative contribution (or impact) from marine shipping can appear larger when forest fire emissions are not included (depending on how much the fire emissions impact the Arctic and northern regions).

Although the two analyses have their slight differences in approaches, they both demonstrate an increase in ambient concentrations from marine shipping emissions from 2010 to 2019 consistent with the projections in the original Gong et al. (2018) study. This indicates that the projected ambient concentrations and deposition in the Gong et al. (2018) scenarios are still representative of future scenarios. As a result, new modelling with a different baseline year will not show any new significant relationships or trends for future shipping impacts. Further to this baseline modelling scenario comparison, a further emissions analysis was also conducted to supplement the emissions portion of the Gong et al. (2018) study. This is discussed in sections 5.2.4 and 5.2.5.

Figure 5.4: Comparison of the contribution to ambient concentrations of O_3, $PM_{2.5}$, NO_2, and SO_2 from Canadian Arctic shipping emissions in 2010 and 2019.



5.2.4 Supplemental Emissions Analysis to the Gong et al. (2018) Paper on the Impact of Shipping Emissions in Canada's Arctic

As mentioned, the primary source of emissions data for the Gong et al. (2018) study, the MEIT, only had 2010 data available when the initial analysis was conducted. Since 2018 when the initial analysis was published, data from the MEIT have been released for 2015-2022 for fuel consumption and vessel emissions in the Canadian Arctic. In addition to new years of data, the emissions were updated to use the Fourth IMO GHG Study emission factors. The increased availability of reliable data and new fuel consumption estimates allowed ECCC to update emissions projections for SO_X, NO_X, particulate matter, and black carbon, and account for the effects of the HFO ban on emissions. HFO encompasses fuels with a sulphur content above 0.5% (and includes most fuels referred to as 'intermediate fuel oil' [IFO]). Ships using HFO typically operate an Exhaust Gas Clearing System (EGCS), or scrubber, where they are required to do so to comply with SO_X related regulations. Updated MEIT data from 2015-2022 were used to project the expected fuel consumption in 2027-2040, by fuel type and vessel type, with and without the ECA in place. The updated emissions calculations also use fuel consumption as a metric of ship traffic, which inherently captures the length and intensity of vessel trips more accurately than a measure of the number of vessel trips. In addition, to account for the HFO ban, two additional business-as-usual scenarios were considered:

1. 2030 BAU 2: includes all existing regulations and where all vessels subject to the HFO ban comply with ECA compliant Marine Diesel Oil (MDO)

2. 2030 BAU 3: includes all existing regulations and where all vessels subject to the HFO ban comply using Very Low Sulphur Fuel Oil (VLSFO).

In addition to the updated 2030 BAU scenarios, a new 2030 ECA scenario was created:

3. 2030 ECA 2: similar to Gong et al. (2018), this case is a forecasted scenario that applies the same North America ECA regulations over the Canadian Arctic waters as well. In this scenario, all regulated vessels are subject to comply with ECA regulations and would use distillate. It was then updated to reflect changes to assumed NO_X Tier III compliance dates and updated fuel consumption projections.

The Gong et al. (2018) study assumed NO_X Tier III regulations would apply to new vessels with a keel-laid date later than January 1, 2021. The updated projections for 2030 ECA 2 reflect the new potential timelines and assume that only vessels with a keel-laid date in 2025 or later must comply with NO_X Tier III regulations.

The 2030 BAU 1 and 2030 ECA 1 scenarios assumed that shipping of iron ore from the Baffinland Iron Mine's expansion at Mary River Mine would be fully in place by 2030. However, in November 2022, the Nunavut Impact Review Board (NIRB) reviewed the project environmental assessment and rejected the proposed expansion. This decision was made due to the potential significant adverse effects which the NIRB deemed could not be adequately prevented, mitigated, or managed under the proposed mitigation (NIRB, 2022; Vandal, 2022). Since that verdict, Baffinland has submitted a "Sustaining Operations Proposal" to continue current operations at the levels put in place in 2018 (Baffinland, n.d.). Though Baffinland may appeal the project expansion verdict, the updated analysis (2030 BAU 2 and 3, and 2030 ECA 2) assume that the Baffinland phase II expansion project will not be underway by 2030.

Table 5.1 summarizes the various scenarios. Emissions reductions from updated calculations are shown in **Figure 5.5** and **Table 5.1.** The 2030 BAU 3 scenario is represented in the table and figure as it is the most comparable to the 2030 BAU 1 scenario in Gong et al. (2018). Since some VLSFO formulations are HFO ban-compliant, and are the least expensive compliant fuels, it was assumed that VLSFO will be the most likely fuel choice in the Arctic in 2030. Therefore, the 2030 BAU 3 scenario is the most likely scenario as it assumes compliance with VLSFO. However, in reality, emissions reductions will likely fall somewhere in this range between the two scenarios since it is uncertain how vessels will comply with the HFO ban.

Figure 5.5: Air pollutant emissions from shipping in the Canadian Arctic: 2030 forecast scenarios and 2022, 2019, and 2010 emissions. The updated 2030 BAU 3 scenario forecasts emissions within Arctic waters under Canadian sovereignty and jurisdiction with the global sulphur cap (0.5%) and HFO ban in place; the 2030 ECA 2 scenario forecasts emissions with an ECA in place. SO_X (sulphur oxides), NO_X (nitrogen oxides), PM (particulate matter) and BC (black carbon) are presented in metric tonnes. Note that there is no BC data available for 2010.

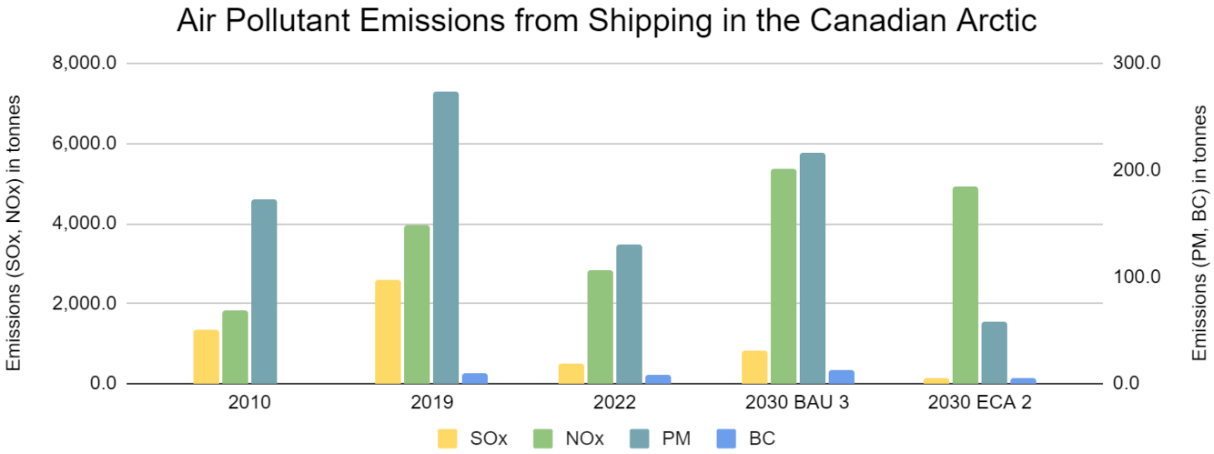


Table 5.1: Air pollutant emissions forecast scenarios, including baseline year, in tonnes. Includes emissions from all merchant and tanker vessels (excludes coast guard, tugs, and special purpose vessels).

Pollutant	2010	2019	2022	2030 BAU 3	2030 ECA 2	Change
SO_X	1,351.0	2,602.3	487.7	809.8	159.2	-80.3%
NO_X	1,818.0	3,951.3	2,850.1	5,349.0	4,922.3	-8.0%
PM	173.0	273.5	129.8	216.7	57.4	-73.5%
$PM_{2.5}$	152.0	241.6	114.6	192.3	50.7	-73.6%
BC	No data	10.1	8.8	13.5	5.6	-58.9%

5.2.5 Analysis Comparison

As described throughout Section 5.2, there are various scenarios considered when estimating the possible emission reductions of an ECA. **Table 5.2** provides a summary of all scenarios discussed in Section 5.2.

Table 5.2: Summary of the analysis scenarios.
Blue rows indicate scenarios that from Gong et al. (2018), green rows indicate scenarios that were included in the updated supplemental analysis.

Scenario	Description
2010 Baseline	• Baseline MEIT data used in Gong et al. (2018) to determine shipping projections for BAU 1 and ECA 1
2030 BAU 1	• Projected marine shipping activities in the Canadian Arctic waters accounting for all existing and planned regulations at the time of Gong et al. (2018) (compliance with 0.5% sulphur cap using VLSFO) • Baseline 2010 used
2030 ECA 1	• Projected marine shipping activities in the Canadian Arctic waters under ECA regulations (compliance with MDO and NOx tier III keel laid date of 2021) • Gong et al. (2018)
Updated baseline (2015-2022)	• Updated baseline emissions from MEIT for 2015-2022. 2019 was primarily used as the baseline year.
2030 BAU 2:	• Updated fuel consumption projections using 2015-2022 MEIT data • Accounts for all existing and planned regulations • All vessels subject to the HFO ban comply with ECA compliant MDO • 2019 baseline data used • Case considered
2030 BAU 3	• Updated fuel consumption projections using 2015-2022 MEIT data • Accounts for all existing and planned regulations • All vessels subject to the HFO ban comply using Very Low Sulphur Fuel Oil (VLSFO). • 2019 baseline data used • Case used in the emissions analysis
2030 ECA 2	• Updated fuel consumption projections using 2015-2022 MEIT data • Assumes ECA compliance using MDO • Reflects changes to assumed NO_X Tier III compliance dates (2025) • 2019 baseline data used

As described in section 5.2.4, there are six new considerations that were taken into account for the updated emissions analysis (green rows of **Table 5.2**):

1. Updated emission factors from the Forth IMO GHG study;
2. Calculation of black carbon emissions from fuel consumption rather than modelled from elemental carbon;
3. New years of real baseline data for 2015 – 2022 to create new fuel consumption projections to 2030;
4. The rate of introduction of NO_X Tier III vessels into ECAs and compliance timeline assumptions;
5. HFO ban compliance options; and

6. Baffinland Iron Mines Phase II expansion inclusion.

These six considerations have resulted in the absolute values of the emissions projections differing between the Gong et al. (2018) analysis and the new projections. However, these differences are not large enough to have an impact on the overall results in the ECA's potential for reducing emissions from vessels. Comparing the emission reductions between the 2030 BAU 1 and 2030 ECA 1 scenarios from the Gong et al. (2018) analysis and the supplemental analyses (2030 BAU 1 and 2, and 2030 ECA 2) indicates that the latter resulted in greater emission reduction for all pollutants other than NO_X. Specifically,

- The 2030 ECA 1 emissions reductions as a result of the ECA presented in the Gong et al. (2018) paper were an 80% reduction in SO_X, 44% reduction in NO_X and 39% reduction in particulate matter.

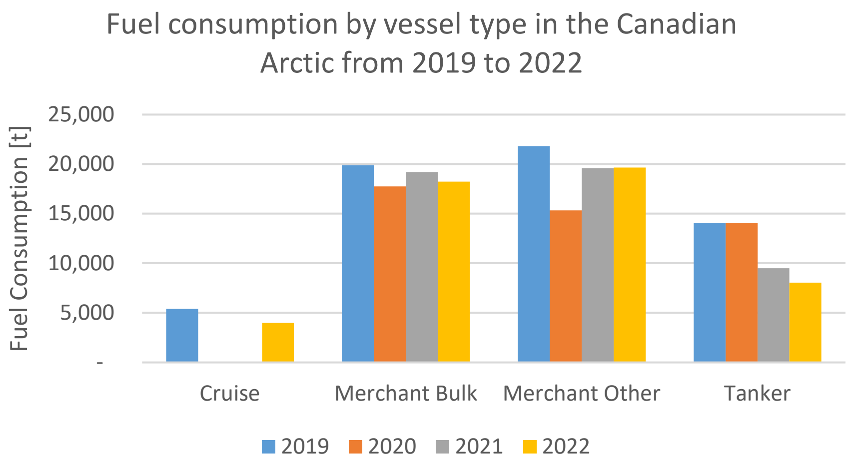
- The 2030 ECA 2 emissions reductions as a result of the ECA as calculated in the supplemental analysis are projected to be 80% for SO_X, 8.4% for NO_X, 74% for particulate matter, and 59% for black carbon.

Careful consideration was taken in the decision to not remodel concentrations and depositions and when conducting the analysis a few key observations were made: The relative changes from 2010 to 2030 BAU with regard to NO_2 and N deposition are minor. This is because the relative changes in NO_X emissions from the 2010 levels are similar between the previous and the new projections, despite the higher absolute values from the previous analysis. The impact of the ECA with respect to NO_2 would be reduced from the previous assessment due to revised emission projections. The impact of the ECA on PM and black carbon would be increased from the previous assessment as the PM and BC reductions due to ECA were underestimated in the previous projections (as shown by the supplemental analysis). However, these changes in the emission projections are not expected to result in material differences in the conclusions of the impacts of shipping to air pollution and deposition.

As demonstrated in **Figure 5.2**, the shipping contribution to nitrogen deposition is not significantly reduced in the 2030 ECA 1 scenario. However, in the 2030 ECA 2 scenario, the expected impact from the ECA on nitrogen deposition would be even smaller due to insignificant reduction in NO_x emissions from shipping in the new projection. NO_X reductions are also less in the 2030 ECA 2 scenario due to the change in date of compliance from 2021 to 2025 and the observed effects of the slow rate of introduction of NO_X Tier III complaint vessels in the NA ECA. Since the implementation of the NA ECA the rate of Tier III compliant vessels calling at Canadian ports has increased much slower than anticipated at the time of this ECA proposal: about 1.4% in 2020 compared to 30% predicted in the 2009 ECA proposal (ECCC, 2022a). One potential explanation is the high production of keels laid in 2015 given that any new vessel with a keel-laid date prior to 2016 would not have to comply with the NA ECA NO_X Tier III regulation (Mercator International LLC, 2019). Research is now showing more NO_X Tier III vessels are entering the NA ECA; however, the rate of introduction is still much slower than anticipated. This trend was considered as part of the update to the emission calculations for the Canadian Arctic ECA analysis. In both the Gong et al. analysis and the new projections, NO_X emissions reductions are low in 2030 as estimations assumed few vessels in 2030 would be NO_X Tier III compliant. This assumption was made so that the analysis did not overestimate the NO_X effects of the ECA.

Figure 5.5 and **Table 5.1** show lower emissions in 2022 compared to 2010 and 2019. This can be partly attributed to the 0.5% sulphur cap, which was introduced in 2020. Since this cap reduces the upper limit of the sulphur content of ships' fuel oil to 0.5% from the previous 3.5% limit (IMO, 2021a), emissions after 2020 are expected to reflect these reductions. However, the overall lower emissions in 2022 can also be explained by the slow recovery in Arctic ship traffic since the COVID-19 pandemic. This is demonstrated in **Figure 5.6,** which shows that fuel consumption in 2020-2022 did not reach 2019 levels in the Canadian Arctic. Cruise vessels were the most affected ship types. From March 2020 until the end of February 2022, cruise vessels were restricted in Canadian waters (Transport Canada, 2022a), slowing recovery of the sector. **Figure 5.6** shows that tankers also experienced a decline in fuel consumption. This decline can likely be attributed to the fact that one vessel which was a significant contributor to the tanker fuel consumption retired in 2021. This vessel was replaced by a newer vessel, but the ship characteristics have it classified as a merchant bulk despite it performing a similar role. Since communities relied on sealift services to deliver essential goods, cargo transportation continued throughout COVID-19. However, the resource sector in the North experienced disruptions and downsizing which resulted in a decline in demand for marine transportation (Arctic Council, 2020). Due to this, 2019 data was chosen to be used throughout the majority of the proposal.

Figure 5.6: Fuel consumption (in tonnes) by vessel type in the Canadian Arctic from 2019 to 2022. Fuel consumption aggregates the total of all fuel types (HFO, VLSFO, MDO, etc.) used by each vessel class for a given year.



5.2.6 *Summary*

In summary, the impacts of ship emissions determined by Gong et al. (2018) as presented in Section 5.2.1 and 5.2.2 and the supplemental emissions analysis provided in Section 5.2.4 make up the key conclusions for the current and projected emission rates from shipping and contribution to ambient concentration of pollutants in the Canadian Arctic.

5.3 Impact of Ship Emissions on Ecosystems

SO_X, NO_X, and black carbon emissions from ships are carried over land and their derivatives (including PM) are deposited on surface waters, soils and vegetation. This harms ecosystem health through sulphur and nitrogen loading, acidification, and eutrophication.

5.3.1 Impacts of Nitrogen and Sulphur Deposition on the Environment & Critical Load Analysis and Ecosystem Impacts due to Ship Emissions

Nitrogen and sulphur deposition affect Arctic ecosystems through two primary pathways: acidification and eutrophication (Stevens et al., 2009; Zhao et al., 2017; Camargo & Alonso, 2006; Bergström & Jansson, 2006; Chen et al., 2020). Acidification occurs through surface water diffusion and seawater mixing, which reduces the pH of ocean and freshwater bodies. The shock from reduced pH levels kills organisms low in the food web, diminishing ecosystem biodiversity (Moiseenko, 2018). Eutrophication occurs through increased nitrogen deposition into water and terrestrial ecosystems. Certain species such as algae can take up the excess nitrogen which increases their productivity, leading to an algal bloom. When the algae die and are decomposed by oxygen-consuming bacteria, the water can become temporarily hypoxic. This limits the survival of organisms and can reduce overall biodiversity in the Arctic Ocean as most Arctic aquatic species depend directly or indirectly on primary production. Along with deposition, nitrogen can also interact with volatile organic compounds (VOCs) to produce ozone, which in turn increases radiative forcing and warming. These effects contribute to sea ice melt and global and regional climate change. This directly affects aquatic and terrestrial ecosystems, harming the plants and animals that inhabit them (Smith et al., 2011).

A critical load is a quantitative estimate of a level of exposure to at least one given pollutant, below which significant harmful effects on specified sensitive elements of the environment do not occur (de Vries et al., 2015). Critical loads can be determined empirically or modeled with supporting empirical evidence (de Vries et al., 2015). Obtaining empirical data requires analysis of biotic or abiotic indicators, which are used to measure nitrogen deposition and determine critical load exceedance. Such indicators form the basis for critical load assessments and are the metrics by which future impacts of critical load exceedances can be evaluated using dynamic models (de Vries et al., 2015). Measuring critical load exceedance for acidification can include analysis of surface water pH or the state of calcifying species (Liang & Aherne, 2019; Repka et al., 2021; Azevedo et al., 2015). For eutrophication, lichen or mosses are a useful indicator of biodiversity impacts (Linder et al., 2013). The process of characterizing the relationships between nitrogen deposition and indicators can be measured using controlled experiments or long-term observational studies (e.g., Åström et al., 2018; Linder et al., 2013; Holmberg et al., 2013; Bobbink et al., 2015). Critical load analysis also depends on interactions and compounding effects with other pollutants, regionalism, seasonality, and climate change. Seasonal changes in climate change impacts, such as sea ice melt and warming, contribute to changes in diffusiveness and surface mixing which in turn influence impacts of N deposition (Popova et al., 2014).

To determine the effects of sulphur and nitrogen deposition associated with shipping emissions in the Canadian Arctic, ECCC conducted a study with researchers from Trent University in Peterborough, Canada. The study assessed soil base cation[9] weathering, ecosystem sensitivity from acid deposition, and critical load exceedance in the Canadian Arctic.

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[9] Base cations are defined as the most prevalent, exchangeable and weak acid cations in the soil (Lövblad et. al, 2004).

To conduct the assessment of ecosystem sensitivity to acidic deposition, a thorough review and collation of existing mapped data (i.e., on soils, geology, climate, land cover) and point survey data (including water chemistry, soil and till geochemistry) was conducted. Data on soil physicochemical properties by soil horizon from the International Soil Reference and Information Centre (ISRIC) were used to estimate soil base cation weathering, a measure of the long-term capacity of ecosystems to buffer acidic deposition. Published data on the lake water chemistry of about 1000 lakes in the Canadian Arctic were used to assess the acid sensitivity of aquatic ecosystems in the region. Data on soil pH, organic carbon soil content, and lake pH are presented in **Figures 5.7** and **5.8**.

Figure 5.7: The pH (left) and Organic Carbon (OC) content (right) of soils (0-15 cm depth) in Arctic Canada. The data window (20 by 30 degrees) is centered on Baffin Island. Arctic ship tracks during the 2010 shipping seasons are also shown in dark grey lines.

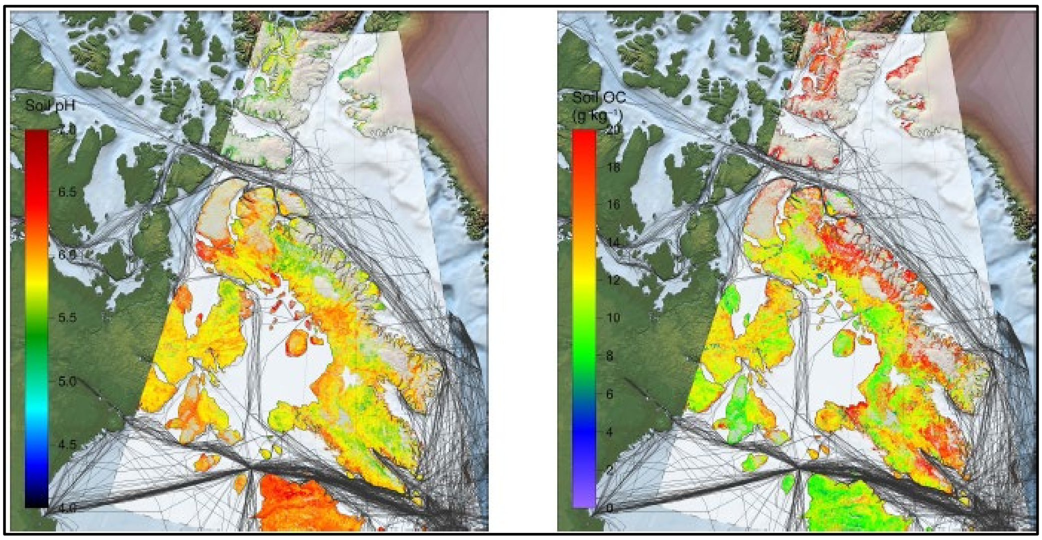
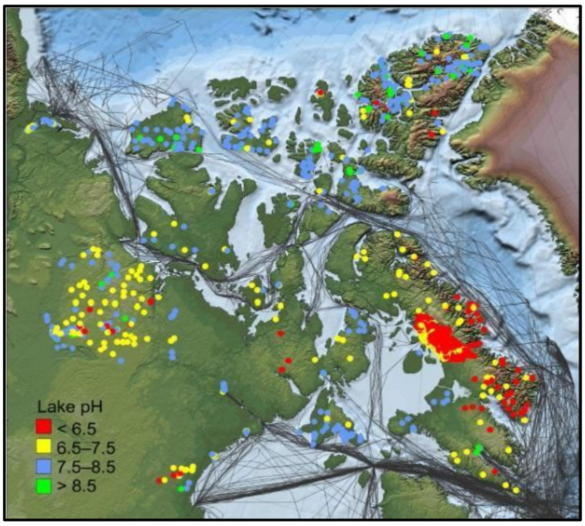
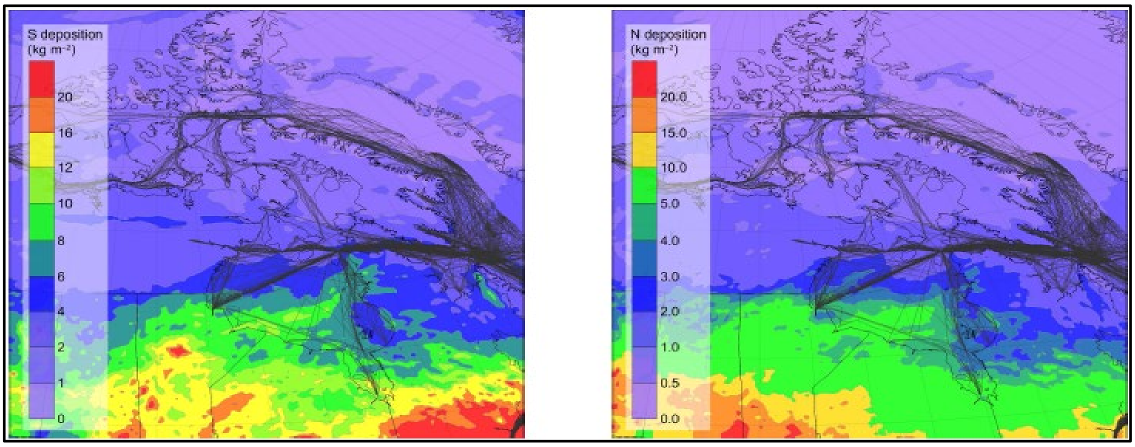


Figure 5.8: Acidity of Lakes in the Canadian Arctic. Arctic ship tracks during the 2010 shipping seasons are shown in dark grey lines.



The analysis also made use of the modelled monthly total sulphur and nitrogen deposition with shipping emissions during the period from March to October 2010. These results were collated to provide an estimate of annual (7-month) deposition (**Figure 5.9**). To complete the assessment, soil base cation weathering rates (0-15 cm) were overlaid with modelled sulphur deposition to delineate regions receiving acidic deposition greater than the long-term soil buffering capacity. Due to high ship traffic near Baffin Island and the island's many lower pH lakes, the analysis focused on Baffin Island.

Figure 5.9: Modeled total sulphur deposition (left) and nitrogen deposition (right) from March to October of 2010. Arctic ship tracks during the 2010 shipping seasons are also shown in dark grey lines.



Estimated soil base cation weathering for the upper 0-15 cm of soil was inferred from soil indicators (clay, bulk density, organic carbon, course fragment) and were predicted to be low for Baffin Island (<100 eq ha^{-1}a^{-1}). It should be noted that in many places soil depth was much less than 15cm. Given that a Level 0 empirical or semi-quantitative critical load approach was used in this analysis, the ecosystem critical load was set equal to the base cation weathering rate. Overlaid onto the soil weathering map shown in **Figure 5.11** is a contour delineating total sulphur deposition (based on model simulation) > 25 eq ha^{-1}a^{-1}. Areas that receive acidic deposition equal to or in excess of the base cation-weathering rate indicate potential critical load exceedance. Thus, **Figure 5.11** illustrates the regions receiving levels of acidic deposition potentially in excess of the terrestrial ecosystem critical load. **Figure 5.10** shows the modelled relative contribution from Arctic shipping emissions to total sulphur deposition over the 2010 July-September period (peak Arctic shipping season). The area mostly impacted by ship emissions (in terms of sulphur deposition) coincides with the area of low soil base cation weathering rate (or low ecosystem critical load) over Baffin Island.

Figure 5.10: Contribution of Arctic shipping emissions to modeled total sulphur deposition as relative differences in accumulated fluxes for July to September 2010 (Gong et al., 2018).

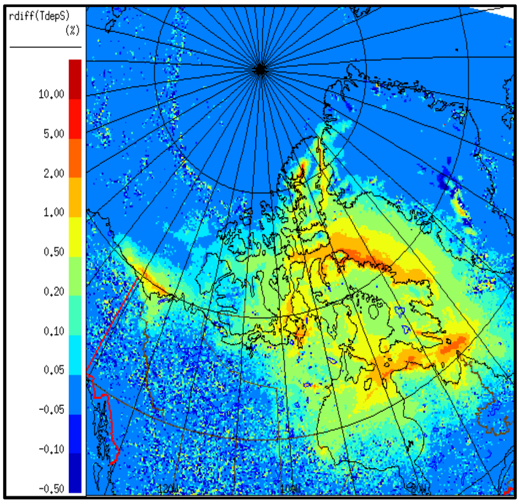
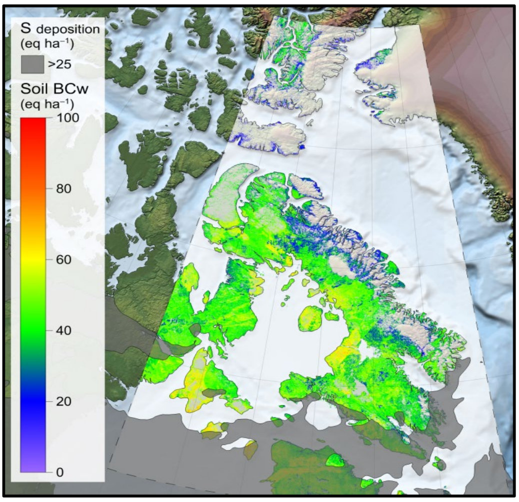


Figure 5.11: Estimated soil base cation weathering (BCw) rate (0-15cm depth). The data window (20 by 30 degrees) is centered on Baffin Island. The modeled total sulphur deposition > 25 eq ha-1a-1 (April to October 2010) is shown in a grey shaded polygon, indicating potential critical load exceedance.



The results of this ecosystem sensitivity analysis suggest that the soil in the eastern Canadian Arctic is more acid sensitive compared with northern and western Canadian Arctic regions. Although deposition of sulphur and nitrogen in the 2010 shipping season was relatively low in the Arctic compared with southern Canada, soil buffering in the upper 0-15 cm was also found to be quite low in the Arctic. The Precambrian Shield underlying the eastern Arctic contributes to the thin, base-poor soil in this area. Lake water pH data showed a similar regional pattern from east to west. This suggests that these aquatic ecosystems may be sensitive to shipping emissions, owing to the high concentration of shipping routes and traffic in the eastern Arctic around Baffin Island (as shown previously in **Figure 4.4**). The lake pH in north-central Baffin Island ranged from acidic (pH=3.8) to neutral (pH=7.8), with 40% of the lakes being less than or equal to a pH=6 (**Figure 5.8**). The Level 0 critical load assessment in this study also showed that ship emissions in south-western Baffin Island may contribute to an exceedance of critical loads in the region. The potential impacts of such an exceedance include damage to the fine roots of Arctic plant species, as well as altered soil processes and habitat structure. Moreover, reduced alkalinity also negatively affects aquatic ecosystems, influencing fish reproduction and survival (Portz et al., 2006). Though this is a screening level risk assessment, results provide a rationale for introducing regulations that limit deposition of sulphur and nitrogen in sensitive Arctic ecosystems. The Canadian Arctic ECA, as described in section 5.2, would result in large reductions in SO_X and NO_X emissions from ships, which contribute to deposition of nitric and sulphuric acids and subsequent critical load exceedance, acidification, and eutrophication.

This result is reflected by other studies analyzing critical load exceedance in the Arctic. In general, the Arctic is found to be more sensitive to climate impacts and Criteria Air Contaminant (CAC) deposition than other regions (Popova et al., 2014; Liang & Aherne, 2019). A systematic review of critical loads across ecoregions in the U.S. found critical loads in the tundra ecoregion in coastal Alaska, near the western boundary of the proposed Canadian Arctic ECA. This ecoregion was found to have a low critical load for N deposition of 1-3 kg N ha^{-1} yr^{-1}. Exceedance of this level was found to affect shrub cover, CO_2 exchange, composition of vascular plants, and changes in lichen pigment production and ultrastructure (Arens et al., 2008; Hyvärien et al., 2003; Makkonen et al., 2007). Further studies have analyzed acidification and critical load exceedance in freshwater lakes in the Canadian Arctic with respect to marine shipping. Liang and Aherne (2019) quantified critical loads of acidity for freshwater lakes and ponds in the Canadian Arctic using a steady-state water chemistry model. They found that currently about 12% of freshwater lakes and ponds in the Canadian Arctic included in their study experience critical load exceedances under modelled sulphur deposition for 2010. They also showed that elevated critical load exceedances are linked to shipping emissions. Popova (2014) found that the central Arctic, Canadian Arctic Archipelago, and Baffin Bay show greatest rates of acidification and carbonate saturation decline due to melting sea ice across the Arctic regions. These findings regarding air pollutant emissions, critical loads, and S and N deposition in the Arctic support the analysis conducted by ECCC and legitimize the findings of the ecosystem sensitivity analysis presented in this section.

5.3.2 Impacts of Particulate Matter Deposition on the Environment

Ecological responses to $PM_{2.5}$ are determined by the atmospheric concentration of particles and the mix of compounds that make up the particles (such as sulphate, nitrate, metals, and organic compounds). $PM_{2.5}$ deposition can alter attributes of vegetation such as leaf area, leaf number, stomata structure, flowering, growth, and reproduction (Rai, 2016). It can also inhibit photosynthesis and increase plant susceptibility to injuries caused by microorganisms and insects (Rai, 2016).

Furthermore, vessel emissions of $PM_{2.5}$ can contain small amounts of heavy metals including nickel, vanadium, cadmium, iron, lead, copper, zinc, and aluminum. These heavy metals can accumulate on plant matter and undergo chemical changes that increase their toxicity (Briffa et al., 2020). After heavy metals accumulate in plant tissue, they can be passed to the soil or to animals consuming the plant matter. In the Arctic, vegetation such as Arctic cotton grasses, sedges, shrubs, mosses, and lichens could be impacted by particulate matter deposition. Other components of $PM_{2.5}$ include polycyclic aromatic hydrocarbons (PAHs) (Lakhmanov et al., 2022). PAHs tend to accumulate in sediments and can reach high concentrations in the Arctic, where the transfer of PAHs by living organisms has resulted in a 30-fold increase of PAH concentration in Arctic fish and mussels over the last 30 years (Lakhmanov et al., 2022). Despite an overall global decline in PAH emissions since the 1990s, there has been a persistence of pollution, especially in the Arctic, where the main sources of PAH pollution involve coal/biomass and liquid fuel combustion (Lakhmanov et al., 2022).

Reduction in PM emissions from ships in the Arctic would reduce the long-range transport of air toxicants and reduce impacts to Arctic vegetation and marine ecosystems.

5.3.3 Impacts of Black Carbon on the Environment

Black carbon emissions contribute significantly to climate change (Pedersen et al., 2015). When deposited on ice and snow, black carbon particles darken the surface and reduce surface albedo (the ability to reflect sunlight), enhancing the absorption of solar radiation and increasing the temperature and rate of melting (Matsui et al., 2022; Bond et al., 2013; Pedersen et al., 2015). Black surfaces absorb all wavelengths of light and convert them into heat, while white surfaces reflect all wavelengths of light and keep surrounding areas cold (Pedersen et al., 2015). Thus, when black carbon particles settle on ice and snow, they darken the surface and increase warming capability (Pedersen et al., 2015). In addition, even when suspended in the atmosphere, black carbon contributes to warming by enhancing atmospheric absorption of solar radiation and through impacts on clouds. The majority of black carbon particles emitted in the Arctic are from sea-level sources within the region, including ships operating close to areas of snow and ice (Clear Seas, 2021).

Although Arctic marine shipping currently accounts for a small percentage of global shipping emissions, it makes a proportionally larger impact on the Arctic environment than shipping at lower latitudes, as the Arctic has a higher sensitivity to carbonaceous emissions due to snow albedo effects (Bond et al., 2013; Gong et al., 2018). The Arctic Council, under its Arctic Monitoring and Assessment Programme (AMAP), concluded that a mass of black carbon emitted within the Arctic is likely to warm the Arctic several times more than the same mass of black carbon emitted outside the Arctic (Quinn & Stohl, 2015). It has been found that black carbon emitted within the Arctic hashas an almost five times larger Arctic surface temperature response (per unit of emitted mass) compared to emissions at midlatitudes (Sand et al., 2013). Ice environments in Canada's Arctic remain a critical habitat to a number of species, including polar bears, walruses, reindeer, narwhals, and many others (Oceans North Conservation Society et al., 2018). Therefore, increased loss of ice in these regions results in increased vulnerability of the populations and species that directly depend on Arctic environments.

Furthermore, deposition of black carbon can modify rain patterns, creating a more uncertain environment for terrestrial ecosystems. When deposited on plant leaves, black carbon can also increase the overall temperature of vegetation (Climate & Clean Air Coalition, n.d.). These combined impacts have the potential to change the structural integrity of the terrestrial system.

Since Gong et al (2018) discussed above, more recent research to determine black carbon impacts from shipping has determined that emission rates of black carbon could be even higher under the study's BAU scenario (von Salzen et al., personal communication, August 12, 2019). A modified version of the Canadian Atmospheric Global Climate Model (CanAM5) was used to estimate the potential response of Arctic climate to black carbon emissions from Canadian shipping (von Salzen et al., personal communication, August 12, 2019), following the AMAP analysis strategy (AMAP, 2015a). Specifically, CanAM5 was used to simulate the impact of emissions from Canadian shipping in the Arctic (60ºN latitude and higher). The simulations were conducted using baseline emissions for the year 2015 and an emission scenario generated by the MEIT for the year 2030, and assuming that the Arctic climate is in equilibrium with the radiative forcing impact of the black carbon shipping emissions. The latter is a necessary approximation for the model analysis of the climate impacts of shipping emissions (AMAP, 2015a).

In the CanAM5 simulations, each tonne of black carbon that was emitted by the ships in 2015 increased the total mean black carbon loading in the Arctic by 7.7 g/m^2/tonne. This enhanced the Arctic radiative forcing by 0.56×10^{-6} W/m^2/tonne, thereby warming the Arctic by up to 0.6×10^{-6} °C/tonne. These findings are largely consistent with the estimated Arctic temperature impact of black carbon emissions from other Arctic sources, including transport and domestic sources. For instance, according to Sand et al. (2016), the temperature responses to emissions from other Arctic black carbon sources ranges from 0.7 to 3.6 °C for each W/m^2 of radiative forcing. In comparison, the simulated temperature response to Canadian shipping emissions in the Arctic in CanAM5 is 1.1 °C for each W/m^2 of radiative forcing.

According to the MEIT scenario, the Canadian Arctic shipping black carbon emissions are projected to increase by 73% from 2015 to 2030 (from 26.6 to 46 tonnes/year), which could cause an increase in the Arctic black carbon loading by 71%. Consequently, the radiative forcing could increase by 48% and the Arctic could thereby warm by up to 8×10^{-6} °C.

5.4 Impact of Ship Emissions on Human Health

Canadian data show that marine transport contributed to 57% of SO_X emissions from the entire mobile sector in 2019 (ECCC 2021a). In addition to SO_X emissions, large marine vessels including category 3 vessels directly release $PM_{2.5}$, NO_X, carbon monoxide (CO), and VOCs into the atmosphere. These primary pollutants can undergo photochemical reactions and contribute to the formation of secondary pollutants, including ground-level ozone as well as secondary sulphate and nitrate, which contribute to ambient $PM_{2.5}$ pollution (Anastasopolos et al. 2021). $PM_{2.5}$ is emitted from ships using high-sulphur content fuels, such as residual fuel oil

(RFO), and has been shown to be enriched in species and compounds with potential health effects including heavy metals (e.g., nickel (Ni), vanadium (V), and cadmium (Cd), polycyclic aromatic hydrocarbons, dioxins/furans, and black carbon) (Anastasopolos et al. 2021). As a result, the marine transportation sector may contribute significantly to ambient air pollution and its associated health risks in areas near commercial ports and seaways, including inland locations due to the potential for long-range pollutant transport (Anastasopolos et al. 2021; Kotchenruther 2015, 2017). Health risks from heavy metals emitted from ships include the increased risk of cancer in humans (Wen et al., 2018). Canadian analyses have investigated the effects of implementing the North American Emissions Control Area (NA ECA) on air quality. The first study conducted in 2021 concluded that in five Canadian port cities (Halifax, Vancouver, Victoria, Montreal, and Quebec City) the NA ECA has resulted in improved air quality by decreasing ambient concentrations of SO_2 and $PM_{2.5}$ components (Anastasopolos et al. 2021). The reduction in markers of RFO combustion in $PM_{2.5}$ samples, notably as V and Ni, coincided with the transition from the use of RFO to low-sulphur distillate fuel by marine vessels in Canadian waters, in compliance with the ECA regulations. Similarly, a second study concluded that in two Canadian port cities (Halifax and Burnaby) the NA ECA regulations have been effective at reducing regulation-related $PM_{2.5}$ factors by 1 $\mu g/m^3$ and thereby improving local air quality (Anastasopolos et al. 2023).

As shipping in the Arctic is expected to increase with longer shipping seasons, additional emissions from marine transport are anticipated near Arctic communities (Mudryk et al., 2021; Smith & Stephenson, 2013). The current and increased emissions would contribute to ambient concentrations of air pollutants such as NO_2, SO_2, $PM_{2.5}$, and other air pollutants to which northern populations may be exposed, with associated risks to health. The health risks associated with ship emissions are especially important to consider in the Canadian Arctic considering the lack of an exposure threshold for the adverse effects of air pollutants including $PM_{2.5}$. Therefore, even at low concentrations, air pollutants can present a human health risk.

5.4.1 Air Pollutant Effects on Human Health

Air pollution is recognized globally as a major contributor to the development of disease and premature death and represents one of the largest environmental risk factors to human health (WHO, 2016). Exposure to air pollution increases the risk of premature mortality from heart disease, stroke and lung cancer. The health and atmospheric sciences have advanced significantly in recent years, making it possible to estimate the number of deaths and illnesses associated with air pollution. Estimates of air pollution-attributable deaths and other adverse health outcomes have been developed globally and for many individual countries, including by the Institute for Health Metrics and Evaluation (IHME), the Health Effects Institute (HEI) and the World Health Organization (WHO) (2016). According to the Global Burden of Disease (GBD) project, air pollution was the fourth leading mortality risk factor in the world, with outdoor air pollution responsible for 8% of deaths globally in 2019 (or 4.5 million premature deaths worldwide) (Global Burden of Disease Collaborative Network, 2020). According to the GBD analyses, air pollution ranks as a leading environmental risk factor overall for premature death and disability in Canada.

The health effects of $PM_{2.5}$, O_3 and NO_2 are well documented in the scientific literature. It is recognized that exposure to these air pollutants increases the risk of a wide variety of adverse health effects in the population, which range from respiratory symptoms to disease development and premature death. Overall, it is estimated that ambient $PM_{2.5}$, NO_2 and ozone pollution is associated with approximately 15,300 premature deaths in Canada annually, as well as nonfatal health outcomes that include 2.7 million asthma symptom days and 35 million acute respiratory symptom days per year (Health Canada, 2021). The total socioeconomic cost of all health impacts attributable to air pollution reaches $120 billion per year in Canada (Health Canada, 2021).

Importantly, the scientific evidence indicates that there are no safe levels for many of these pollutants. Moreover, research on air pollution and population health has indicated that populations that may be disproportionately impacted, such as people with pre-existing health conditions, children, older adults, and people with lower socioeconomic status, can be more sensitive to the adverse health effects of air pollution. These disproportionately impacted groups, due to either greater susceptibility or greater exposure, may be at higher risk of experiencing adverse health effects from exposure to air pollution than the general Canadian population.

The human health effects of individual air pollutants associated with marine emissions are summarized below.

5.4.1.1 SO_X Health Effects

The majority of ambient sulphur oxides (SO_X) comes from anthropogenic sources including high temperature burning of fossil fuels containing sulphur such as coal, oil and natural gas. Most of the emitted SO_X consists of SO_2 and to a lesser extent, sulphur trioxide (SO_3). SO_2 is an irritant and very short-term exposures (e.g., 10 minutes) can result in respiratory tract and ocular irritation as well as adverse effects to lung function (Health Canada, 2016b). SO_X also contributes to the formation of PM, which can also cause adverse health effects (US EPA, 2022a).

Assessments by Health Canada and the US EPA concluded that exposure to SO_2 causes adverse respiratory effects, particularly in individuals with asthma, as seen by increases of asthma exacerbation related hospital admissions and emergency room visits with increased exposure to SO_2 (Health Canada, 2016b; US EPA, 2017). Studies indicate that a proportion of people with asthma experience changes in pulmonary function and respiratory symptoms after exposure to SO_2 (Health Canada, 2016b; US EPA 2017). Moreover, hospital admissions for respiratory disease and mortality increase on days with higher SO_2 levels (WHO, 2021a). For SO_2, Health Canada established a 10-min human health reference concentration of 67 parts per billion (ppb) (175 $\mu g/m^3$ at 25ºC) (Health Canada, 2016b).

5.4.1.2 NO_X Health Effects

Nitrogen oxides (NO_X) are gases emitted predominantly from combustion sources. Most emissions of NO_X are as nitric oxide (which is rapidly converted to NO_2), along with lesser quantities of NO_2 itself. NO_X also contributes to the formation of PM and ground-level ozone which can occur at distances far away from emission sources; exposure to these ambient air contaminants also causes adverse health effects.

Short-term exposure to NO_2 causes adverse respiratory outcomes (Health Canada, 2016a; US EPA 2016). The effects are often related to respiratory diseases, such as asthma and chronic obstructive pulmonary disease, leading to the worsening of respiratory symptoms (such as coughing, wheezing or difficulty breathing) and hospitalizations (Health Canada, 2016a; US EPA, 2016). Short-term exposure to NO_2 has also been linked with cardiovascular effects and mortality; however, uncertainties remain (Health Canada, 2016a; US EPA, 2016). Long-term exposure to NO_2 has been linked to adverse respiratory (e.g., increased susceptibility to respiratory infections and response to allergens), cardiovascular, reproductive, and developmental effects, and an increased risk of lung cancer and mortality (Health Canada, 2016a; US EPA, 2016). People with asthma, as well as children and the elderly, are generally at greater risk for the health effects of NO_2 (Health Canada, 2016a; US EPA, 2016; WHO, 2021a). No exposure threshold has been identified for NO_2 below which there is no risk to population health.

5.4.1.3 Particulate Matter Health Effects

Particulate matter (PM) is a mixture of small particles and droplets that vary in size and chemical composition. $PM_{2.5}$ and PM10 refer to particles with a diameter less than 2.5 and 10 µm in size, respectively. The scientific literature on the health effects of PM, particularly $PM_{2.5}$, is extensive.

$PM_{2.5}$ constitutes approximately 50-80% of PM by weight, and it is for this size fraction that the majority of adverse health effects have been observed. This is because $PM_{2.5}$ is smaller in size and more likely to travel into and deposit in the lungs, while PM_{10} is more likely to deposit in the larger airways of the upper respiratory tract. Particles deposited deeper in the lungs can induce tissue damage and lung inflammation and pass into the bloodstream.

Health Canada (2022) and the US Environmental Protection Agency (2019) have concluded that exposure to $PM_{2.5}$ can cause premature mortality, respiratory effects, and cardiovascular disease. Associations have also been reported with additional adverse health effects including lung cancer, and to a lesser extent neurological effects and adverse reproductive and developmental outcomes (Health Canada, 2022a; US EPA, 2019). Children with asthma, older adults, and people with underlying respiratory and/or cardiovascular conditions are at greater risk of adverse health effects following exposure to PM (Health Canada, 2022a; US EPA 2019). Moreover, the International Agency for Research on Cancer (IARC) has classified PM from outdoor air pollution as carcinogenic to humans or Group 1 (WHO, 2013). No known safe exposure level has been identified for $PM_{2.5}$, and risks can occur at very low ambient air concentrations, including those observed in Canada (Health Canada, 2022a).

5.4.1.4 Black Carbon Health Effects

Black carbon is a component of particulate matter, formed by the incomplete combustion of fossil fuels, biofuels, and biomass. Due to its small size, it is most strongly associated with the $PM_{2.5}$ size fraction (Janssen et al., 2012). The composition of this mixture can vary significantly, depending on combustion conditions and fuel type.

Black carbon can adversely affect human health. As black carbon constitutes a significant portion of $PM_{2.5}$, the health effects are generally consistent with those of $PM_{2.5}$. These health effects include increased risk of respiratory and cardiovascular effects, as well as premature death (Janssen et al., 2012).

Although health effects from black carbon may be influenced by other constituents in the aerosol mix, insufficient data exists to determine specific mechanisms of action. Existing data suggested that black carbon may not be a directly toxic component of $PM_{2.5}$ and instead operate as a universal carrier of a wide variety of chemical constituents of varying toxicity, to sensitive pulmonary and cardiovascular targets (Janssen et al., 2012).

5.4.1.5 Ozone Health Effects

Ground-level ozone is a naturally occurring gas and one of the two primary components of smog. It is produced by the reaction of NO_X with volatile organic compounds within the atmosphere in the presence of sunlight (US EPA, 2022b). Short-term and long-term exposure to ground-level ozone is highly reactive in the respiratory tract, damages lung tissue, and is associated with premature mortality and increased hospitalizations and medical visits (US EPA, 2020; Health Canada, 2013). Persons considered especially sensitive to ground-level ozone are those with existing respiratory problems, the elderly, and children. No exposure threshold has been identified for ground-level ozone below which there is no risk to population health.

5.4.1.6 Polycyclic Aromatic Hydrocarbons Health Effects

Polycyclic aromatic hydrocarbons (PAHs) are a large group of organic compounds containing two or more fused aromatic (benzene) rings. The main anthropogenic sources of PAH emissions are incomplete combustion or pyrolysis of organic material such as fossil fuels and biofuels (e.g., wood or agricultural waste). PAHs containing five or more aromatic rings are poorly water soluble and lipophilic; thus, they are mainly found adsorbed on PM_{10} particles as well as on black carbon associated with fine PM ($PM_{2.5}$), whereas PAHs containing four or less aromatic rings predominately exist as gases (WHO, 2021b). Although hundreds of PAHs exist, the congeners most commonly measured in air include acenaphthene, acenaphthylene, anthracene, B[a]P, benzo[a]anthracene, benzo[b] fluoranthene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenzo[ah]anthracene, fluoranthene, fluorene, indeno[1,2,3-cd]pyrene, naphthalene, phenanthrene and pyrene (WHO, 2021b).

Several PAHs have been classified by the International Agency for Research on Cancer (IARC) as probable or known carcinogens (WHO, 2021b). B[a]P is the most well-studied congener and is currently the only PAH classified as Group 1 (carcinogenic to humans) (WHO, 2021b). PAHs are on the Government of Canada's toxic substances list under the Canadian Environmental Protection Act (CEPA) based on the carcinogenicity of five PAHs and effects on the environment (Government of Canada, 1994). The major mechanism of PAH-induced mutagenesis and carcinogenesis involves binding to DNA, leading to the formation of stable PAH-DNA adducts. Non-carcinogenic effects of PAHs include adverse effects to the respiratory and cardiovascular systems as well as neurotoxicity in children. It should be noted that PAH toxicity has historically been based on data derived from using B[a]P as a surrogate marker of PAHs and/or an index compound together with component-based potency factors (WHO, 2021b).

5.4.2 Health Characteristics of Northern Populations

Canada's territories have a combined population of about 118,160 people (Statistics Canada 2022a). At the time of the 2021 national population census, Indigenous people made up a large portion of the population in the territories: 85.8% in Nunavut, 49.6% in the Northwest Territories and 22.3% in Yukon, with Inuit representing about 85% of the population of Nunavut. (Statistics Canada, 2022c). The following health characteristics are for northern populations as a whole not solely indigenous populations. Rates of disease and mortality in northern populations can differ from rates for Canada as a whole (**Table 5.2**), indicating potential vulnerabilities to risks such as air pollution. For example, adult populations in Yukon, Northwest Territories and Nunavut have elevated rates of chronic obstructive pulmonary disease compared to national levels (Public Health Agency of Canada, 2018). Additionally, rates of mortality (all-cause mortality, cerebrovascular disease mortality and ischemic heart disease mortality) are elevated above national rates in one to three of the territories (Public Health Agency of Canada, 2017). Overall, life expectancy in the three territories is reduced by approximately 3 to 11 years compared to the national average of 81.8 years (Public Health Agency of Canada, 2017).

Table 5.2: Age-standardized morbidity prevalence and mortality rates of health conditions reported in Canadian territories and nationally.

Health Condition	Yukon	Northwest Territories	Nunavut	Canada
Chronic obstructive pulmonary disease in adults 35 years or older (age-standardized prevalence (%)[a]	16.1	12.4	23.3	9.4
Asthma in adults (age-standardized prevalence (%))[b]	8.8	6.4	8.7	8.0
Obesity in adults (self-reported, age-standardized prevalence (%))[c]	34.1	41.1	36.3	26.6
All-cause mortality (age-standardized rate per 100,000 population)[b]	905.2	875.3	1423.6	692.9
Ischemic heart disease mortality (age-standardized rate per 100,000 population) [b]	87.1	139.6	55.4	100.0
Cerebrovascular disease mortality (age-standardized rate per 100,000 population) [b]	54.4	56.2	40.3	39.4
Lung Cancer incidence (age-standardized rate per 100,000 people) [d,e]	68	96	168	63.4
Life Expectancy from birth (ecological level, years) [b]	78.4	77.5	71.0	81.8

a: Source: Public Health Agency of Canada (2018): data for 2011-2012
b: Source: Public Health Agency of Canada (2017): asthma data for 2010-2013; mortality data for 2009-2011
c: Source: Public Health Agency of Canada (2020): data for 2015-2018
d: Source for territorial statistics: Canadian Cancer Statistics Advisory Committee (2020): data for 2012-2016.
e: Source for national statistics (excludes data for Quebec): Public Health Agency of Canada (2021): data for 2016

Indigenous populations experience a disproportionate burden of ill health compared to non-Indigenous people in Canada, due, in part, to important social determinants of health such as income, education, access to health services, and historical trauma. In addition, because of their close relationship with and dependence on the environment, First Nations, Inuit, and Métis are uniquely sensitive to adverse effects from climate change, and northern populations live in an environment that is experiencing rapid change. Overall, Indigenous Peoples in Canada experience health and socio-economic inequities that will be exacerbated by direct and indirect impacts of climate change (National Collaborating Centre for Indigenous Health, 2022).

5.4.3 Air Pollution from Shipping and the Health of Northern Populations

The incremental health risks to northern populations associated with current and increased marine traffic in the Arctic could be partly addressed by implementation of control measures such as an ECA in Canada's Arctic. This would reduce the risks of adverse outcomes such as respiratory symptoms, cardiovascular disease and premature death of individuals living in areas impacted by marine emissions. Previous national analyses have estimated the health benefits of reducing marine emissions. For example, it was estimated that implementation of the Canadian region of the NA ECA would prevent an average of $1.2 billion in adverse health impacts annually in Canada (2020-2032), due to the lowering of air pollution emissions (Government of Canada, 2012c). Although the population of the Arctic is small compared to the national population, reducing air pollution in the Arctic would reduce the associated health risks for each individual in the exposed population.

The health of the people living in the Arctic is directly connected to the health of the environment. The health of the environment is what Durkalec et al. conclude as "...a determinant of Indigenous health based on culturally-specific Indigenous epistemologies and ongoing connections to and dependence on traditional lands" (Durkalek et al., 2015; Willox et al., 2013; Inuit Circumpolar Council, 2014). Therefore, the health of the Arctic environment, which is affected by shipping emissions, is an important factor in determining Indigenous health outcomes in northern communities.

Adverse environmental effects resulting from shipping air pollution are of utmost importance to consider in the Canadian Arctic due to the sensitivity of Arctic ecosystems. These ecosystems are interconnected with the health of the populations that inhabit the area and support many species that are at risk or crucial to Inuit diet and well-being. An ECA in the Canadian Arctic would provide similar environmental protections throughout the north and south of Canada, ensuring all populations experience the health benefits associated with reduced shipping emissions.

Contaminants in wildlife species traditionally harvested for food are a concern in several northern communities (Van Oostdam et al., 2005; Donaldson et al., 2010). Air pollution can contribute to higher concentrations of some contaminants, such as persistent organic pollutants and some metals, in wildlife (Government of Canada, 2012a). This occurs through bioaccumulation and biomagnification in the Arctic food web, where pollutants enter the food chain and collect and increase in concentration as animals are consumed by other animals at higher trophic levels of the food web. These contaminants can accumulate in the tissues of animals (such as in the muscle or fatty tissue depending on the properties of the contaminant), which are then a source of dietary exposure for humans (Government of Canada, 2012a; Donaldson et al., 2010). Air pollutants can also disrupt endocrine function, cause organ injury, increase vulnerability to stresses and diseases, and lower reproductive success in wildlife, which effectively damages the supply and quantity of food available (Government of Canada, 2012a). The consumption of Arctic wildlife species, including terrestrial and marine mammals, represent an important part of the Inuit traditional diet. These traditional foods, known as country foods, are intrinsically linked to Inuit well-being and identity and provide other cultural, nutritional, and economic benefits to Indigenous communities (Rosol et al., 2016; Donaldson et al., 2010). Therefore, an increase in air pollution in the Arctic may increase the presence of contaminants in country foods, which can impact Indigenous health and well-being as alternative food sources fail to maintain the nutritional and cultural integrity of the Inuit diet (Rosol et al., 2016; Van Oostdam et al., 2005; Donaldson et al., 2010).

As established in this section, Indigenous communities and their health are intrinsically linked to the health of the environment which illustrates a need to not only focus on direct impacts to health but also the impacts to the environment when considering health outcomes of the Canadian Arctic population.

5.5 Impacts of Ship Emissions to Areas of Cultural Significance

Marine vessel emissions directly impact the Arctic landscape and those who rely on it for food, identity, and cultural practices (Hauser et al., 2018; Bennett et al., 2015; Inuit Circumpolar Council, 2014). Arctic populations that consume traditional foods "are among the most exposed in the world to certain toxic chemicals" (AMAP, 2015b). Higher rates of sea ice melt, partially driven by black carbon emissions, spur increases in marine activity in new locations, which poses a risk to northern Indigenous Peoples and the marine environment on which they depend on for sustenance (Durkalec et al., 2015; MacDonald et al., 2015; Inuit Circumpolar

Council, 2014). Thus, vessel emissions may have a significant impact on Inuit Language, Knowledge (Inuit Qaujimajatuqangit), experiential learning, Tradition; physical, mental and social health, spirituality, and more (Willox et al., 2013; Koperqualuk, 2019; Inuit Circumpolar Council, 2014). Inuit traditional harvesting practices will be deeply impacted by the melting of ice, snow, and thawing of permafrost in Canada's Arctic, associated with a warming climate. For instance, sea ice is an important platform both for hunting and for connecting communities. Enhanced sea ice melt can limit communities' ability to safely make use of traditional over-ice routes when the ice freezes late, the ice thaws early, or the thickness/stability of the ice is uncertain at various times throughout the ice season. This introduces new risks when undertaking traditional practices, limits access to important dietary staples during the ice-covered season, and inhibits travel and important social interactions between communities.

As Article 29 - 1 in the United Nations Declaration on the Rights of Indigenous Peoples Act states "Indigenous peoples have the right to the conservation and protection of the environment and the productive capacity of their lands or territories and resources" (Government of Canada, 2021). Therefore, a Canadian Arctic ECA would help contribute to protecting Inuit food security and harvesting rights (Stevenson, 2017; Nunavut Tunngavik, 2018).

5.6 Summary

As described above, shipping contributes to the ambient concentrations of air pollutants in the Arctic and emissions from vessels can contribute to adverse effects on ecosystem health and human health. The information presented in this section suggests that an ECA established under both regulations 13 and 14 is warranted. Designation of the proposed ECA would reduce NO_X emissions under regulation 13, and SO_X and PM emissions under regulation 14. This would reduce deterioration of ambient air quality, reduce black carbon emissions causing warming, and limit effects of nitrogen deposition such as acidification and eutrophication. The ECA would also contribute to reductions in risks of adverse health effects associated with air pollution. Thus, this proposal for an ECA fulfils criterion 3.1.4 of MARPOL Annex VI, Appendix III.

6 Role of Meteorological Conditions Influencing Air Pollution

6.1 Introduction

Criterion 3.1.5	*The proposal shall include relevant information pertaining to the meteorological conditions in the proposed area of application to the human populations and environmental areas at risk, in particular prevailing wind patterns, or to topographical, geological, oceanographic, morphological, or other conditions that contribute to ambient concentrations of air pollution or adverse environmental impacts*.

Meteorological conditions significantly influence the processes that determine pollutant concentrations. In the Canadian Arctic, large-scale meteorological patterns dictate the distance and dispersion of pollutants emitted by ships. These pollutants can have adverse impacts on ecosystems and human health, as described in Sections 4 and 5. This section describes key meteorological features influencing Arctic air pollution and how these processes relate to shipping emissions.

Key meteorological features influencing air pollution in the Arctic include surface based and low-level temperature inversions, sloping isentropic surfaces, the Arctic front, the polar dome, low-level clouds and precipitation, mid-latitude cyclones, and North Atlantic Oscillation (Klonecki et al., 2003; Stohl, 2006; Law & Stohl, 2007; Fuelberg et al., 2010; Tjernström et al., 2014; Schmale et al., 2018).

6.2 Surface based and low-level temperature inversions

The Arctic lower atmosphere is characterized with a surface-based inversion and low-level temperature inversions. The surface-based inversion is particularly strong in the winter due to extremely cold surfaces and lack of solar heating. However, the surface-based temperature inversion is common even in summertime. For example, surface-based inversion frequencies remain between 30 – 40% frequency over Siberia, Canada, and Greenland (Zhang, Y., et al., 2011). Low-level temperature inversions are also prevalent over the Arctic Ocean throughout the year (Devasthale et al., 2010; Zhang L., et al., 2021). These inversions (or stable stratifications) inhibit vertical turbulence mixing and ventilation of pollutants out of the boundary layer. Thus, pollutants within the boundary layer become trapped, resulting in longer transport. Shipping emissions are injected directly into the stable marine boundary layer which can result in longer range horizontal transport of the pollutants.

6.3 Sloping isentropic surfaces, the Arctic front, and the polar dome

The cold Arctic air mass results in an upward inclination of isentropic surfaces (i.e., constant potential temperature surfaces) in the lower troposphere towards the pole (Klonecki et al., 2003; Fuelberg et al., 2010). This creates a transport barrier, or polar dome, which influences the transport of air masses from mid-latitudes by increasing the transport of air in the winter and decreasing it during the summer (Bozem et al., 2019). In the absence of diabatic heating/cooling, transport of tracers tends to follow the isentropic surfaces. This means that the transport of pollutants from lower latitudes (usually starting at relatively higher potential temperature) towards the polar region would rise to higher altitudes following the upward sloping isentropic surfaces. The upward motion can be further enhanced by latent heat release following condensation and precipitation during the transport. The Arctic front, which separates the cold Arctic air mass from the warm mid-latitude air mass, forms a barrier to cross-isentropic transport (due to the sharp gradients of potential temperature across the Arctic front). The polar dome, often defined by the Arctic front, is not zonally symmetric and can extend as far south as 40°N over Eurasia during winter (Law & Stohl, 2007; Stohl, 2006). The southerly location of the Arctic front, as well as the strong diabatic cooling from snow-covered surfaces in northern Eurasia in cold seasons, makes the transport of pollutants at low levels from the Eurasian source regions to the Arctic particularly efficient; this is a main contributor to the winter and springtime Arctic haze (Stohl, 2006). Another important contributing factor to the Arctic haze is the lack of precipitation in the Arctic during winter (Garrett et al., 2010). During summer, however, the polar dome retreats and the Arctic front is located much farther north (> 70°N). Thus, the lower atmosphere in the Arctic during summer is strongly isolated from the influence of southern latitudes. Stohl (2006) defined an Arctic age of air, the time that air resides continuously north of 70°N, as a measure of the degree of isolation of the Arctic troposphere. He found that the mean Arctic age of air near the surface is about 1 week in winter and 2 weeks in summer. The strong isolation of the Arctic lower troposphere in the summer means that local sources, such as emissions from marine shipping, play a greater role in affecting Arctic air quality and ecosystems than pollutants transported from lower latitudes (outside the polar dome). Pollutants emitted locally from marine shipping remain the Arctic for a longer period and are therefore more likely to deposit in the Arctic.

6.4 Low-level clouds and precipitation

Low-level clouds are frequently present in the Arctic (Shupe & Intrieri, 2004; Shupe et al., 2011), particularly during summer when low-level stratus decks are often formed by warm air advection over cold ice packs (Barrie, 1986). During Arctic winter, strong surface inversions create favourable conditions for the formation of radiation fog and ice fog (Przybylak, 2016; Serreze & Barry, 2014; Ye, 2009). Low-level clouds play an important role in surface energy balance in the Arctic. In contrast to similar clouds at lower latitudes, Arctic low-level clouds can have a warming effect due to highly reflective underlying surfaces and long wave radiation process (Tjernström et al., 2014). In addition, fog and low-level clouds can interact with air pollution. For example, the formation of fog and clouds leads to the scavenging of activated aerosol particles, which can have a cleansing effect through precipitation formation and/or sedimentation. The same wet scavenging processes contribute to the deposition of air pollutants to the Arctic ecosystem. Entrainments at the top of low-level stratus clouds, as well as buoyancy-driven overturning in these clouds can also lead to the entrainment of air pollutants transported in free troposphere into the Arctic boundary layer (Shupe et al., 2013; Tjernström et al., 2014). Precipitation plays an important role in both atmospheric cleansing and wet deposition of air pollutants into the ecosystem. Precipitation is generally low in the Arctic during winter and early spring. The lack of precipitation and consequently the lack of wet scavenging is recognized as a key factor for the winter-spring Arctic haze (Garrett et al., 2010). Precipitation is more frequent during summer in the Arctic; the prevalent low-level stratus clouds are frequently associated with drizzles (Tjernström et al., 2014). More frequent precipitation causes more efficient wet scavenging, which is believed to be partially responsible for a cleaner lower atmosphere in the Arctic during summer. However, under clean conditions, the amount of aerosols capable of serving as cloud condensation nuclei (or ice nuclei) is limited, promoting frequent light precipitation in the Arctic low-level clouds (Tjernström et al., 2014). In a modelling study, Ghahreman et al. (2021) showed that an enhancement in aerosol loading in an otherwise pristine summer Arctic boundary layer led to increased cloud droplet number concentration and decreased cloud droplet size in the low-level clouds, which further led to decreased precipitation and increased cloud amount over the Canadian Arctic Archipelago. The increase in air pollution from marine shipping contributes to deposition of sulphur and nitrogen through wet scavenging processes, negatively affecting Arctic ecosystems.

6.5 Mid-latitude cyclones and North Atlantic Oscillation

Cyclones and oscillation play an important role in large-scale transport in the Arctic. Mid-latitude cyclones influence Arctic meteorology. The warm 'conveyor belts' often associated with mid-latitude cyclones can lift low-level air into the upper troposphere where it can be transported northward to the high Arctic (Eckhardt et al., 2004, Stohl, 2006). Studies have also shown that, during the positive phase of the North Atlantic Oscillation (NAO), transport from all three continents in northern hemisphere (Europe, North America, and Asia) into the Arctic is enhanced; this results in higher Arctic pollution levels (Eckhardt et al., 2003; Duncan & Bey, 2004; Stohl, 2006).

6.6 Summary

In conclusion, meteorological conditions in the Canadian Arctic ensure that a significant portion of at-sea emissions are transported to land, where they have negative impacts on human health and ecosystems. Thus, this proposal for an ECA fulfils Criterion 3.1.5 of MARPOL Annex VI, Appendix III.

7 Ship Traffic in the Proposed Area

7.1 Introduction

Criterion 3.1.6	*The proposal shall include the nature of the ship traffic in the proposed Emission Control Area, including the patterns and density of such traffic.*

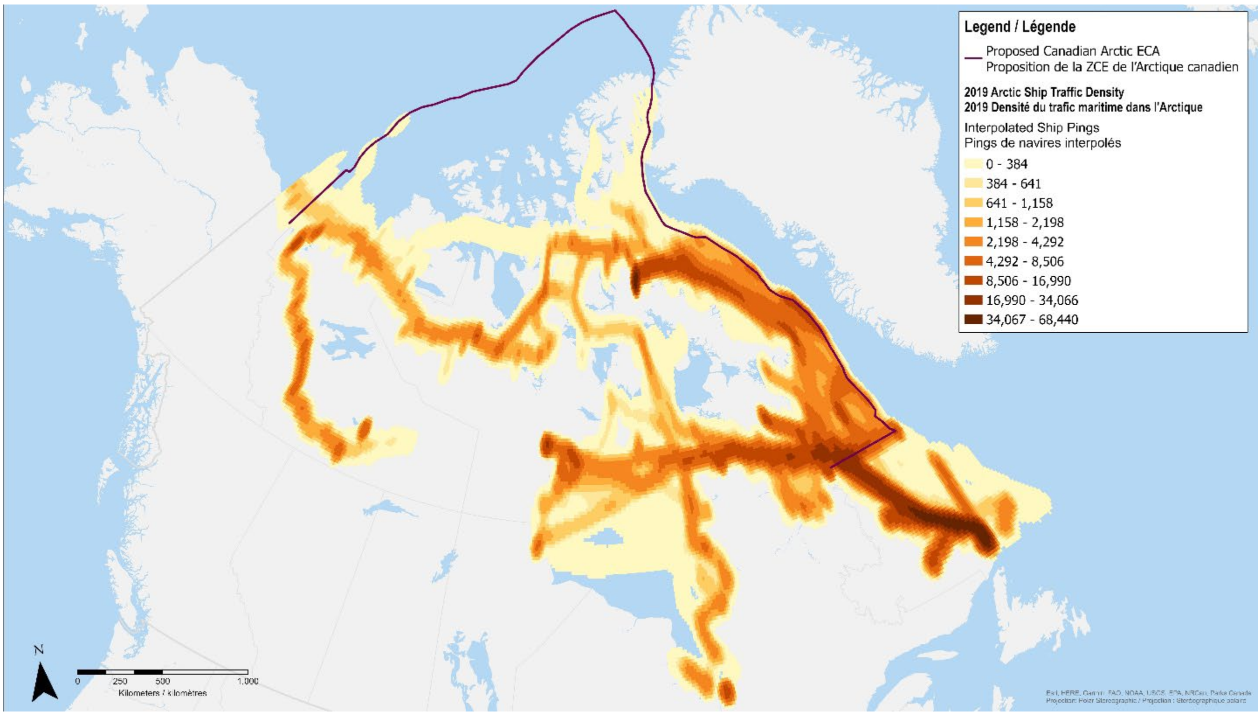
Model projections show that much of the Arctic Ocean could be almost ice-free in the summer by the middle of this century (Docquier & Koenigk, 2021). This means some of the Canadian Arctic may be increasingly navigable from July to October for ice-strengthened ships (Mudryk et al., 2021; Smith and Stephenson, 2013).

7.2 Current Shipping Traffic Patterns and Densities

Current marine traffic in Canada's Arctic is primarily comprised of vessels heading to specific Northern destinations in Canada. These vessels function as a vital link between remote Northern communities and the essential supplies they need from Southern Canada. In addition to these vital community resupply sealifts, ships transiting Canada's Arctic are also engaged in resource exploration and extraction, tourism, and activities of the Canadian Coast Guard, including ship-escorts and research missions. Vessel transits within the Canadian Arctic have been observed by the Canadian Coast Guard (CCG) since 1990.

The CCG tracks and records vessel movements in Canadian waters. Tracking ships movements in the Arctic region is pertinent to ensure safe transiting, compliance with regulations, and for the CCG to provide aid to vessels when necessary. ECCC's MEIT analyzes vessel data using data from the CCG and the AIS tracking system and was used to conduct analysis of ship traffic density and patterns. The raw AIS data gives information on the vessel, position, time, speed, bearing, and other vessel information. However, sometimes there can be gaps in the AIS data based on the frequency vessels report (called a vessel "ping"). To ensure MEIT has continues vessel movement information, it adjusts for points that may be going over land if lines are drawn between two raw data points. Since the AIS data provides time and position between two pings, the speed and direction are used to determine time and position for all intermediary points between the raw AIS data points. The output of this process produces continuous vessel movement data that can be used to illustrate traffic density. **Figure 7.1** uses data from ECCC's MEIT and shows the ship track density in the Canadian Arctic.

Figure 7.1: 2019 Ship Traffic Density in the approximate area of the proposed Canadian Arctic ECA. 'Interpolated Ship Pings' refers to each time a vessel sends a signal to an Automatic Identification System (AIS) and the MEIT interpolated points. This density chart displays a magnitude-per-square kilometre from MEIT interpolated ship ping point data.



Statistically significant increases in traffic have been already observed by the CCG on both monthly and annual timescales, coincident with declines in sea ice area (for First Year Ice (FYI), Multi Year Ice (MYI), and total ice) (Pizzolato, 2015). **Figure 7.2** illustrates the annual increase in shipping travel distances in the Canadian Arctic between 1990 and 2015. In addition to the increase in distance travelled, the number of ship trips has also increased. ECCC has found that the Canadian Arctic saw 29% more vessel trips in 2019 compared to 2015, and approximately 70% more vessel trips than 2010 (**Figure 7.3.1**; ECCC, 2022a). Ship 'trips', as defined by ECCC's MEIT, are vessel movements between anchorage and berthing points. One vessel's 'voyage' through the Arctic may be composed of more than one trip if a vessel makes several stops. This upward trend is expected to continue, driven by resource extraction projects and foreign shipping lines capitalizing on longer ice-free seasons.

Figure 7.2: Total kilometers travelled annually by all vessel types in the Canadian Arctic between 1990 and 2015 (Dawson et al., 2018).

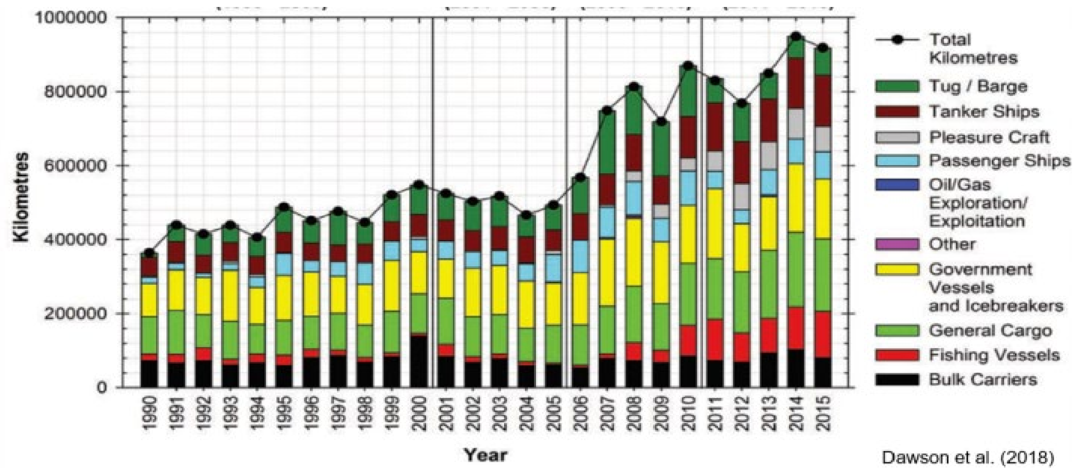
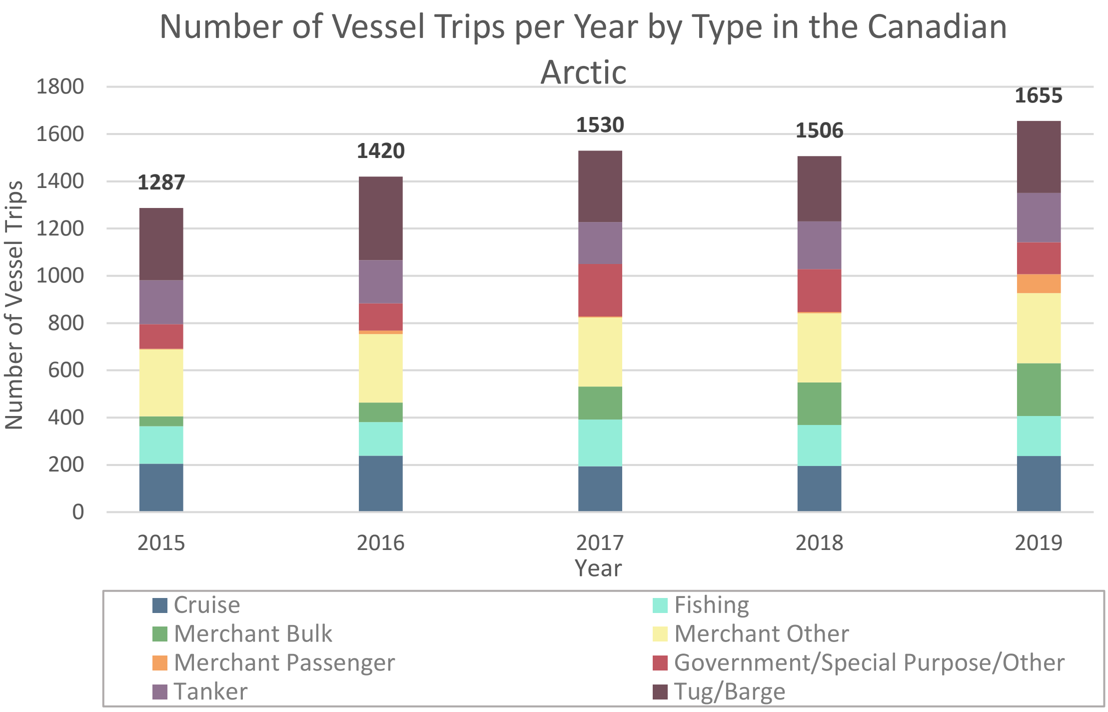
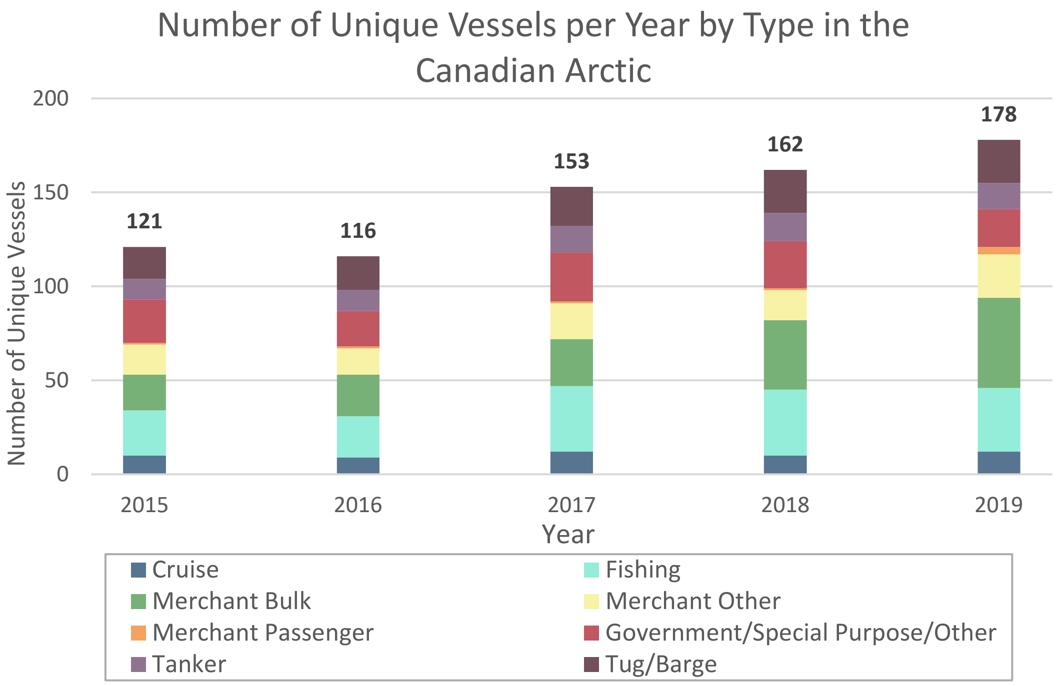


Figure 7.3.1: The number of vessel trips per year by type in the Canadian Arctic. Vessel trips are defined by vessel movements between each time a vessel stops (at berth or at anchor).



ECCC also recorded the number of unique vessels that visited the Canadian Arctic documenting a 47% increase in unique vessels from 2015 to 2019. In 2015, the Canadian Arctic was visited by 121 unique vessels, 153 unique vessels in 2017, and 178 unique vessels in 2019. (**Figure 7.3.2**; ECCC, 2022a).

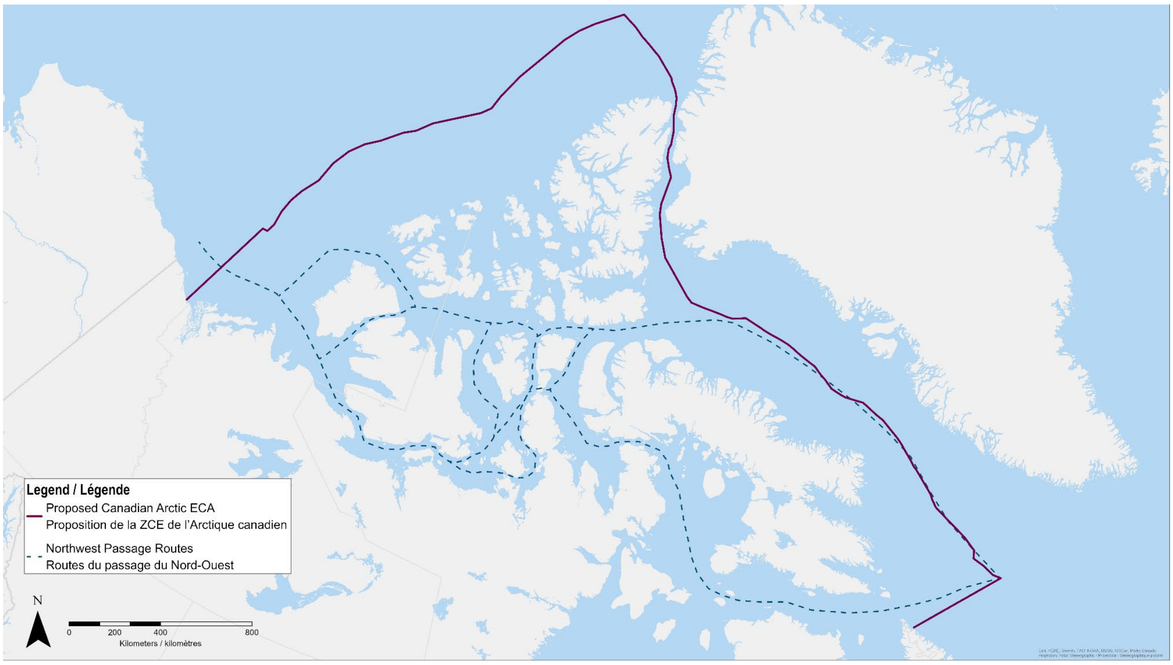
Figure 7.3.2: The number of unique vessels per year by type in the Canadian Arctic.



7.2.1 *Arctic Shipping Routes*

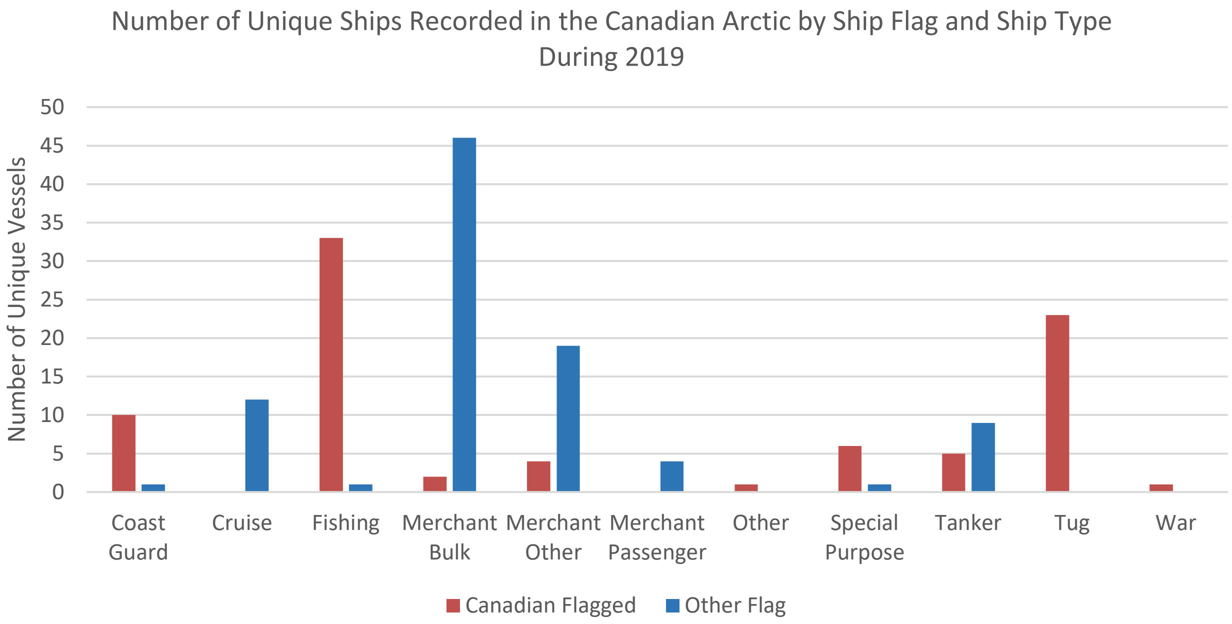
Protection of the Arctic Marine Environment (PAME) is one of the six working groups of the Arctic Council. PAME has studied shipping in the Arctic by comparing 2013 to 2019 vessel activity (PAME, 2021). PAME's study area includes six potential routes through the Arctic, as identified in **Figure 7.4**. PAME found that between 2013 and 2019, there was a 44% increase in the use of these routes by unique vessels (PAME, 2021). This increase was mostly apparent during the months of June, July, August, and September as these months made up 73% of the total hours spent by ships in the region in 2019 (ECCC, 2022a). Of all vessels that enter the Canadian Arctic, the vast majority of them are destinational vessels coming to the region to perform an economic activity (Lasserre, 2022). However, a small portion of vessels do transit through the Northwest Passage (NWP) without making any stops. In 2019, 23 vessels transitted the NWP without making stops (Lasserre, 2022).

Figure 7.4: Chart combining all six Northwest Passage (NWP) routes identified by PAME.



Of the total unique vessels in 2013 and 2019, around half of them are Canadian-flagged (PAME, 2021). **Figure 7.5** breaks down these unique ships by their ship class and illustrates the proportion of these ships that are Canadian flagged compared to other international flags (ECCC, 2022a).

Figure 7.5: Count of unique vessels in the Canadian Arctic during 2019 by ship flag and ship type (ECCC, 2022a).



7.3 Future Ship Traffic Projections

One of the factors contributing to increasing marine traffic in the Canadian Arctic is resource development. Currently, there are several operating resource development projects in Canada's North that require regular servicing by ships, including product transport and resupply vessels. In addition, it is believed that transits through the Canadian Arctic and Arctic tourism will increase. This is partly due to destinations and routes becoming easier to reach because of thinning ice as a result of a changing climate. The expectation of a projected increase in vessel traffic is generally in line with the conclusions of several other studies on Arctic shipping, notably by the Arctic Council in 2009 (Ellis & Brigham, 2009).

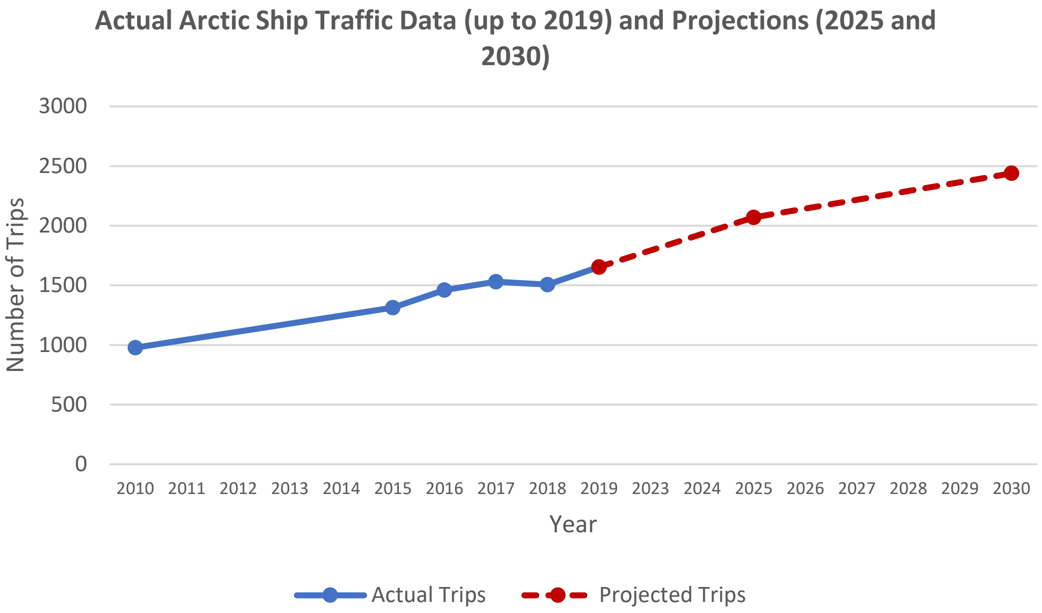
Gong et al. (2018) conducted an extensive review of ship traffic and potential projects with shipping in the Canadian Arctic. Expected increases in other sectors were also taken into account. Based on this information, a projection of the types and number of sailings of vessels in the year 2030 was developed (**Table 7.1**). To validate the forecast, the growth rates were compared with published data from companies and published studies related to shipping forecasts in the Arctic.

Table 7.1: Number of trips of marine shipping activity over Arctic waters under Canadian sovereignty and jurisdiction for the year 2010 base case and for the projected 2030 scenario (Gong et al., 2018).

	Number of Vessel Trips per Year	
Vessel Class	**2010**	**2030**
Coast Guard	20	25
Fishing	134	156
Merchant Bulk	39	191
Merchant Other	246	453
Merchant Passenger	63	271
Special Purpose	7	6
Tanker	169	247
Tug Boat	300	367
Total	**978**	**1,716**

Ship 'trips' are defined as vessel movements between anchorage and berthing points. One vessel's 'voyage' through the Arctic may be composed of more than one trip if a vessel makes several stops. The ship traffic projections presented above were conducted based on data that has since been updated. Projections based on more recent data from the MEIT (ECCC, 2022a) show even greater increases in future ship traffic (see **Figure 7.6**).

Figure 7.6: Actual and projected Arctic ship traffic data (ECCC, 2021).

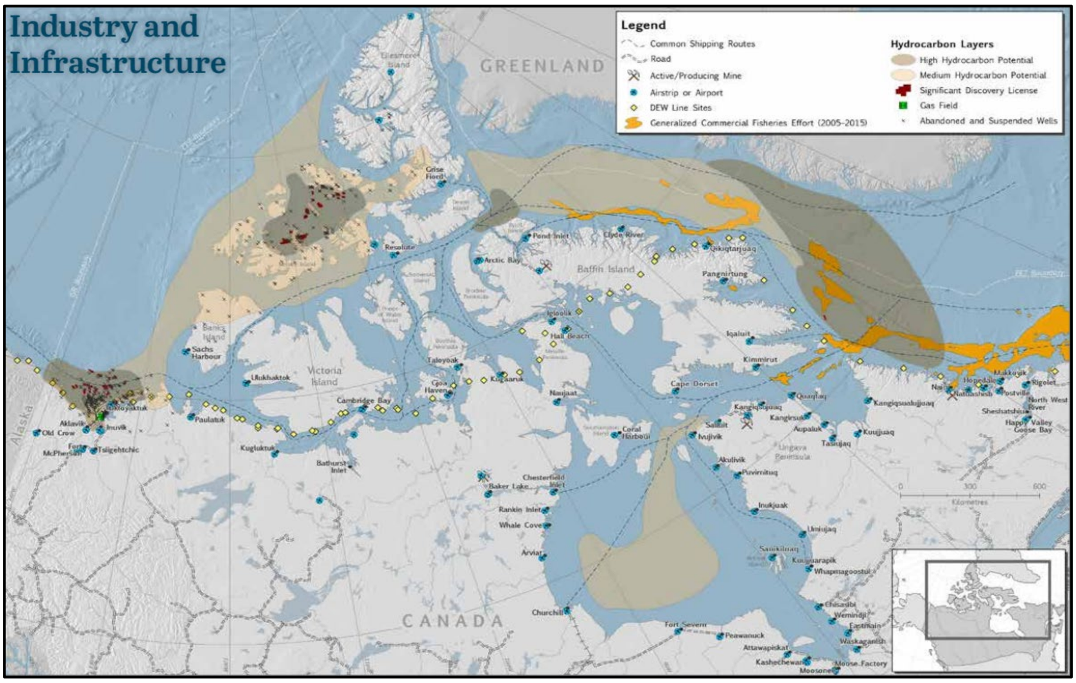


There are uncertainties when predicting the future of Arctic shipping. Using the best data available, it is expected that increased navigability of the Arctic will result in increased marine traffic. Furthermore, despite predictions of an ice-free Arctic, sea-ice variability and dangerous weather are still anticipated (Mudryk et al., 2021; Chen et al., 2021; Gascard et al., 2017). These conditions will result in difficulties for navigation and present constant challenges to Arctic shipping (Mudryk et al., 2021; Chen et al., 2021; Gascard et al., 2017). Combined, these factors present an inherent degree of uncertainty in predicting future shipping levels in the Canadian Arctic (Gascard et al., 2017; Mudryk et al., 2021). Despite the uncertainty, there is still strong justification for a Canadian Arctic ECA as the trend in increased shipping in the Canadian Arctic is already apparent. Already from 2010 to now there is a longer navigation season and there has been a demonstrated increase in shipping activity as ice sheets melt, opening passageways for ships to use (OHCHR, 2022).

7.4 Industries Utilizing Shipping in the Canadian Arctic

Ship traffic in the Canadian Arctic fulfils the requirements for local community resupply and supports domestic fishing, mining, and tourism activities. **Figure 7.7** displays commercial fisheries, hydrocarbon layers, active mines, and routes of common transportation servicing these industries.

Figure 7.7: Chart of industry and infrastructure in the Canadian Arctic, along with common transportation routes utilized by industry (Oceans North Conservation Society et al., 2018).



7.4.1 *Mining*

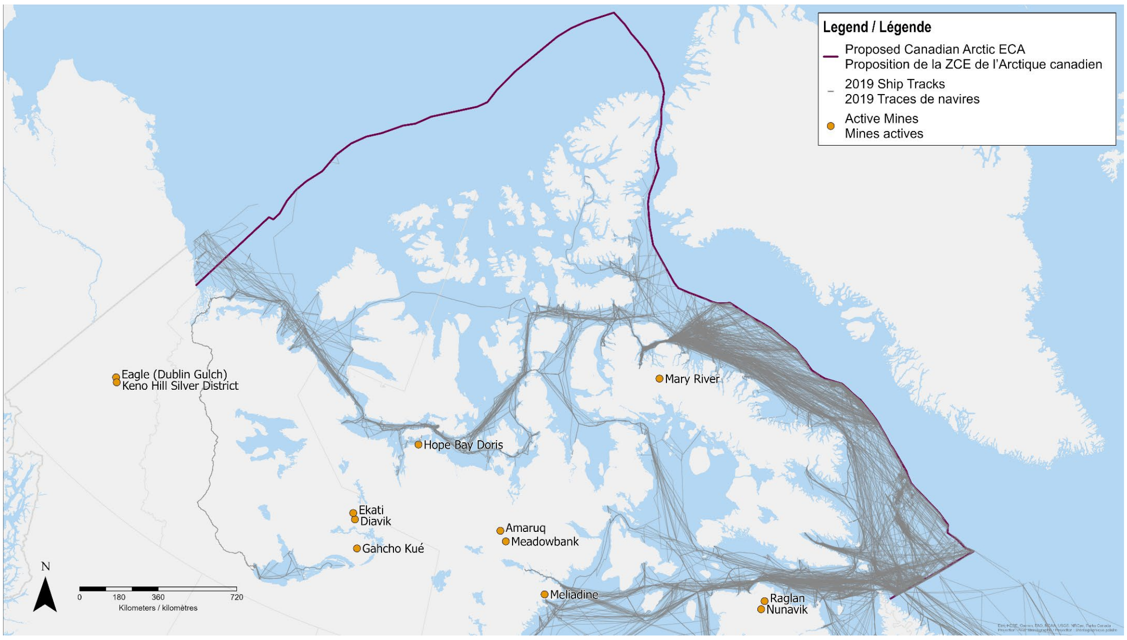
There are six mines currently in production in the Canadian Arctic that are serviced by ships:

- Meadowbank and Amaruq Gold Mine near Baker Lake in the Kivalliq region of Nunavut
- Mary River (Baffinland) Iron Mine near Pond Inlet on northern Baffin Island region of Nunavut
- Hope Bay Doris Gold Mine near Cambridge Bay in the Kitikmeot region of Nunavut. However, in 2022 and 2023, production activities have remained suspended and the primary focus at Hope Bay is on exploration
- Meliadine Gold Mine near Rakin Inlet in the Kivalliq region of Nunavut
- Nunavik Nickel Mine in Nunavik (northern Quebec)
- Raglan Nickel Mine on the Ungava Peninsula in Nunavik (northern Quebec)

There are also five other mines currently in production in the Canadian Arctic that are not serviced by ships. These mines are Ekati Diamond Mine, Diavik Diamond Mine, Gahcho Kué Mine, Keno Hill Silver District Mine, and Eagle Gold Mine.

Merchant vessels (merchant bulk and merchant other), tugs, and tankers are used to support the mining sector (ECCC, 2022a). Many Arctic mines require sealift support to bring in equipment and supplies (Oceans North Conservation Society et al., 2018). A map of active mines and ship tracks in 2019 can be viewed in **Figure 7.8.** The proximity of these mines to high ship traffic routes suggests the reliance on marine shipping by the mining sector. Most mines export their product by air, while others export by vessel (such as Mary River). The number of vessels required for mines reliant on marine shipping is directly correlated to the productivity of the mine.

Figure 7.8: Active mines in Canada's Arctic and 2019 ship tracks.

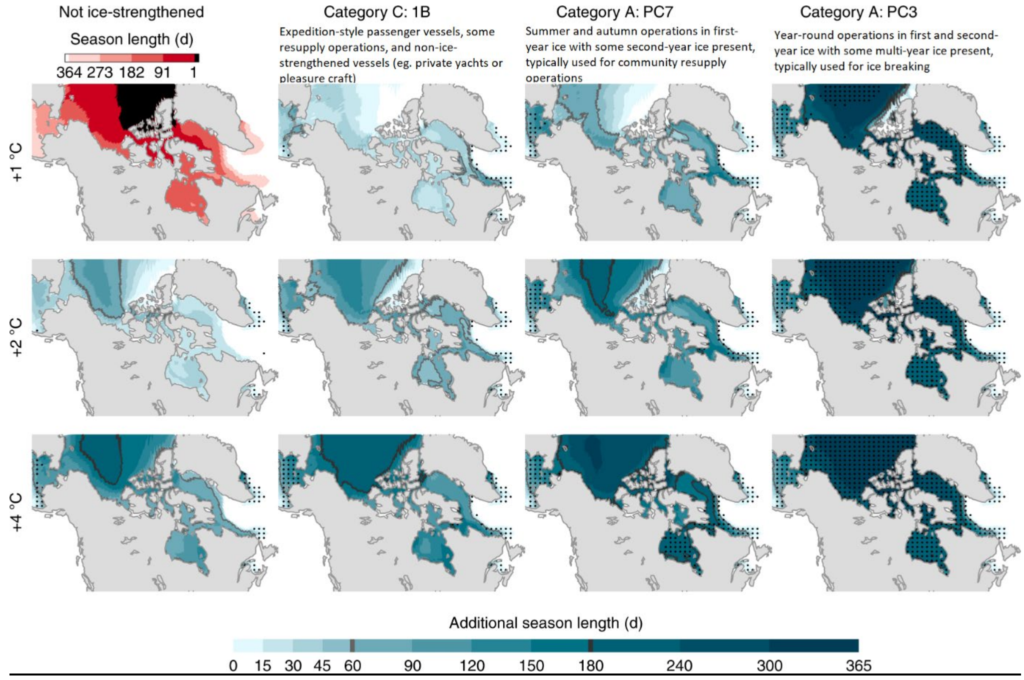


7.4.2 Community Resupply

Seasonal community resupply services (called sealift) occur each year during ice-free periods over the summer, and are used to transport bulky, heavy, or non-perishable items. These items include necessities such as food, household items, and fuel for power generation. Up to 95% of nontraditional food and other goods delivered to these communities are shipped via sealift resupply services (Government of Canada, 2017b). The number of vessel trips required to ship goods to communities is correlated with population growth. Community growth has the potential to impact shipping significantly as statistics Canada predicts that by 2041, the population of Inuit Nunangat could increase by 39% to 53% compared to the population in 2016 (Statistics Canada, 2021). Currently, an estimated 55,537 people (or 16,115 households) are reliant on sealift services in the Canadian Arctic (Statistics Canada, 2022a; Government of Northwest Territories, 2022; Groupe Desgagnés, 2022; Nunavut Eastern Arctic Shipping, 2020).

As climate change causes longer navigable summers with potentially ice-free shipping routes, resupply services may increase as marine shipping is less expensive compared to freight delivery by air. This is evident in **Figure 7.9** which shows the present-day and projected changes in shipping season length for various vessel classes in the Canadian Arctic. In **Figure 7.9**, the first graphic with season length in red shows the present-day season length. The remainder of the figure shows the increased number of days each month that will be navigable relative to the present day for different warming scenarios (+1°C, +2°C, +4°C) (Mudryk et al., 2021). Note that it does not show the total monthly days that are navigable.

Figure 7.9: Present-day and projected changes in shipping season length for various vessel classes (Mudryk et al., 2021).



7.4.3 *Tourism*

Arctic tourism is growing rapidly, primarily through visitors visiting on cruises. The global cruise market is the fastest growing sector in the travel industry. It is estimated that there was a 7% annual growth rate of cruise passengers over the last decade indicating a demand for this service (Brida & Zapata, 2009). In the Canadian Arctic, trips by cruise ships increased by 16% from 2015 to 2019 (ECCC, 2022a). The increase in popularity of Arctic cruises is expected to continue into the future as the sector becomes more popular in the Arctic region. Though cruise traffic is increasing, some operations are taking steps to reduce their environment impact. For instance, the Arctic Expedition Cruise Operators, an international association for expedition cruise operators operating in the Arctic, is aiming to strengthen responsible industry practices by implementing a self-imposed ban on the use and carriage of HFO by Arctic Expedition Cruise Operators members (AECO, 2019).

7.4.4 *Fishing*

Historically, fishing in the Arctic has been restricted by short fishing seasons, sea ice cover, and dangerous navigation. Despite this, subsistence fishing has been practiced in Inuit Nunangat for over 4,000 years and continues to this day (Hurtubise, 2016). In addition to subsistence fishing, commercial fishing began in the Canadian Arctic in the early 2000s. Commercial fisheries in the Canadian Arctic are primarily located in Baffin Bay, Davis Strait, and Hudson Bay and Strait (Tai et al., 2019). There are also Arctic Char fisheries that operate in Cumberland Sound and Cambridge Bay, which are smaller-scale and community-based (Hurtubise, 2016). Long-term fishing trends in the Canadian Arctic are difficult to anticipate due to fishing traffic being dependent on fish stocks and licenses. The International Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean came into force in June 2021 and prevents commercial fishing by the signatory states (including Canada) in the high seas of the Arctic Ocean for 16 years (at which point parties can decide to renew). Though not directly applicable to Canadian waters, this agreement may be reflective of future fishing trends in the Arctic. However, as climate change decreases sea ice extent, more vessels will be able to navigate Arctic waters under Canadian sovereignty and jurisdiction, which could increase fishing vessel activity (Tai et al., 2019). In the Canadian Arctic, there was an estimated 26% increase in fishing vessel activity from 2010 to 2019 (ECCC, 2022a).

7.4.5 Oil and Gas

Offshore oil and gas activities in the Arctic typically use vessels to supply and support exploration and production. However, on December 20, 2016, the Government of Canada announced that Arctic waters under Canadian sovereignty and jurisdiction would be indefinitely off limits to new offshore oil and gas licensing (CIRNAC, 2022a). In 2019, the federal government issued an order prohibiting all offshore oil and gas activities in the Canadian Arctic, including activities associated with existing licenses (Government of Canada, 2022c). This ban was set to be reviewed every five years through a science-based review, and as of January 2023, the ban has been extended until December 2023 (Pressman, 2023). Furthermore, in 2019, a prohibition order was issued that disallowed any marine seismic programs in the Canadian Arctic until the end of 2021, further limiting new offshore oil and gas development (Canada Energy Regulator, 2022a). The last marine seismic program was conducted in 2012 in the Beaufort Sea (Canada Energy Regulator, 2022a). Since then, no further marine seismic programs have been conducted despite continued interest in the Mackenzie Delta region and in exploring Baffin Bay (Oceans North Conservation Society et al., 2018).

While land-based oil and gas projects are still allowed in the Arctic, they currently have a minimal shipping component. As of 2023, Nunavut is the only Northern territory that produces crude oil and natural gas (Canada Energy Regulator, 2022b).

7.5 Summary

Vessel traffic in the Arctic is increasing over time, and this will be exacerbated as the Arctic becomes more navigable due to increased ice melt. This proposal has described the ship traffic patterns expected in the proposed ECA, and as such, this proposal for an ECA fulfils criterion 3.1.6 of Annex VI, Appendix III.

8 Control of Land-Based Sources

8.1 Introduction

Criterion 3.1.7	*The proposal shall include a description of the control measures taken by the proposing Party or Parties addressing land-based sources of NO_X, SO_X and particulate matter emissions affecting the human populations and environmental areas at risk that are in place and operating concurrent with the consideration of measures to be adopted in relation to provisions of regulations 13 and 14 of Annex VI.*

Existing restrictions imposed by Canada limit emissions of NO_x, SO_x, PM, and other air pollutants, as well as GHGs from a wide range of land-based and mobile sources, but not all. Regulations and control measures highlighted in this section focus on relevant CACs, which are pollutants for which ambient air quality standards have been established by ECCC.

Across Canada overall, between 1990 and 2019, emissions of NO_x, SO_x, and PM decreased by 29%, 77%, and 8%, respectively (ECCC, 2021a). The transportation sector (road, rail, air, and marine) accounts for 37% of all NO_X emissions, <3% of all SO_X emissions, and 1% of PM emissions across Canada (ECCC, 2021a). The 29% decline in NO_x emissions between 1990 and 2019 is largely attributable to a reduction in emissions from transportation, off-road vehicles, and mobile equipment after the year 2000 (ECCC, 2021a). Currently in Canada, off-road and on-road equipment have more stringent NO_x and PM regulations than marine vessels. Other reductions in air pollutants have resulted from regulations in the oil and gas sector and programs supporting a clean energy transition away from diesel and coal-fired electricity. See Table 8.1 for a list of control measures implemented by Canada and its provinces and territories that work to restrict or eliminate certain pollutants.

Reductions specific to on-road and off-road vehicles contributed to a 34% decrease in NO_x emissions from 1990 to 2019 in the transportation sector alone (ECCC, 2021a; **Figure 8.1**). The progressive introduction of cleaner technology and fuels for vehicles is directly linked to this decrease (ECCC, 2021a). Recently, however, NO_x emissions have started to trend upwards mainly due to increases in emissions in the transportation and oil and gas sectors (ECCC, 2021a). **Figure 8.1** illustrates this trend in NO_X emissions.

Emissions of SO_x from marine vessels alone decreased by 87% between 2014 and 2019 due to the introduction of the North American Emission Control Area (NA ECA) which was a large contributor to the overall SO_X emission reductions across Canada (ECCC, 2021a). Marine vessels remain the largest source of SO_x emissions in the transportation sector despite the influence of the NA ECA (ECCC, 2021a). Further, in order to control SO_X emissions, Canada implemented the Sulphur in Diesel Fuel Regulations, which require diesel fuel used by on-road, off-road, rail (locomotive), domestic marine vessels, and stationary diesel engines to contain a maximum of 15 mg/kg S (ECCC, 2021b). The current standard applicable in Canada's Arctic for international marine vessels is 5000 mg/kg (0.5%), which is over 300 times higher. **Figure 8.2** illustrates this trend in SO_X emissions.

While there was a significant decrease (48%) in PM emissions observed in the transportation sector alone between 2014 and 2019, there are many other large PM sources across Canada. The reductions in transportation PM emissions are also partly due to the implemented NA ECA (ECCC, 2021a). **Figure 8.3** illustrates this trend in PM emissions.

Figure 8.1: Annual NO_X emissions by the road and marine components of the transportation sector in Canada from 1990 to 2019.

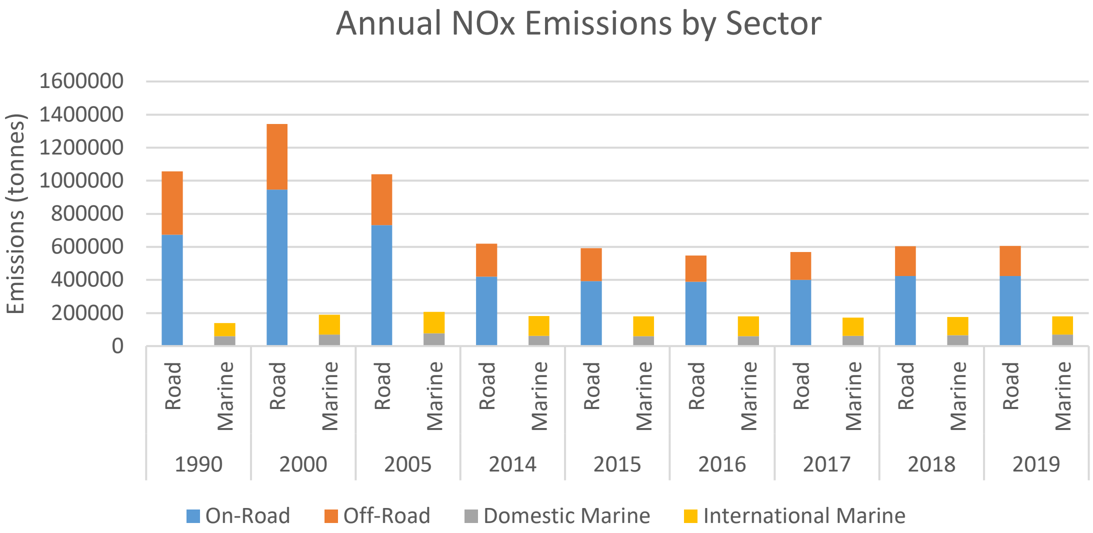


Figure 8.2: Annual SO_X emissions by the road and marine components of the transportation sector in Canada from 1990 to 2019.

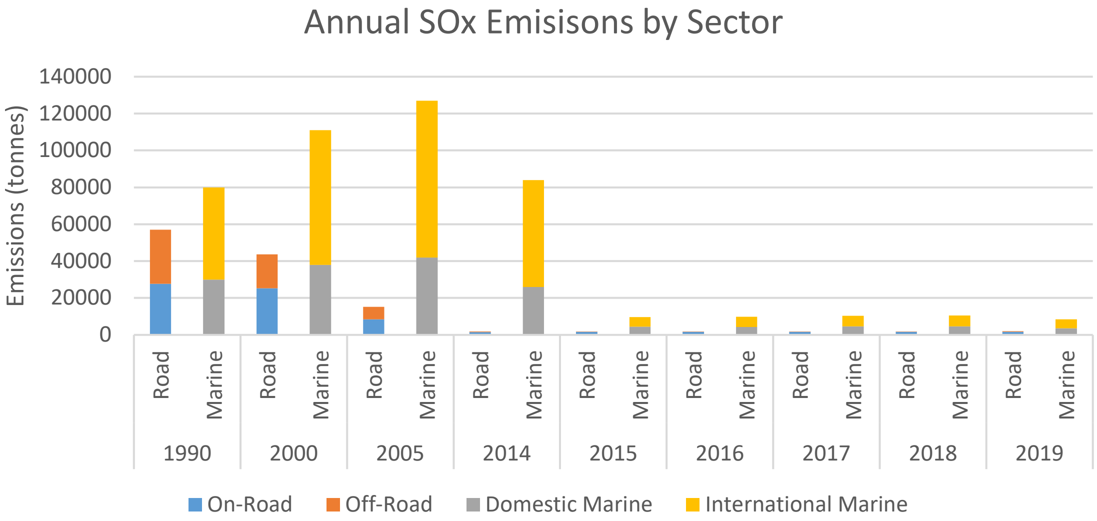
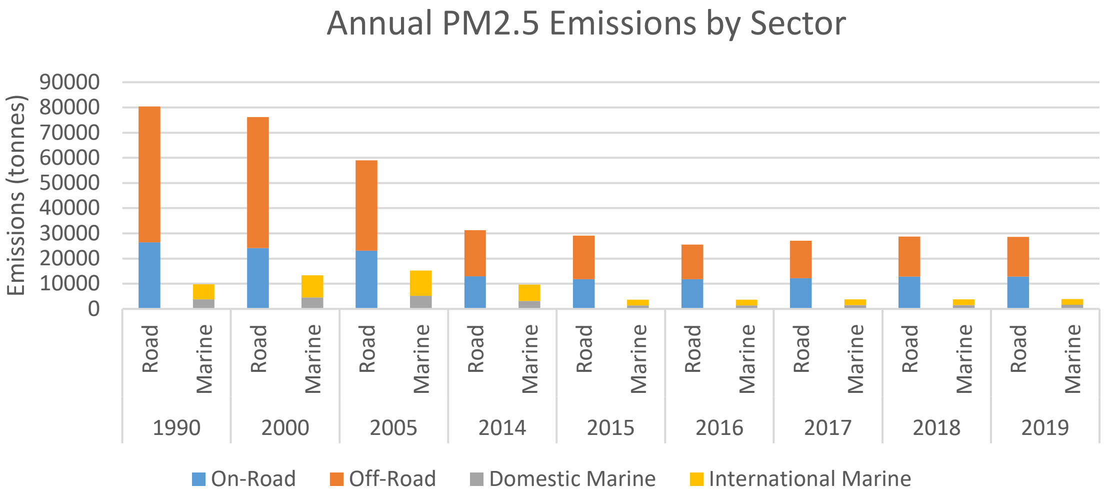


Figure 8.3: Annual $PM_{2.5}$ emissions by the road and marine components of the transportation sector in Canada from 1990 to 2019.



The NA ECA has been successful in reducing marine-source SO_X and PM, improving air quality for SO_X and $PM_{2.5}$ components (including vanadium and nickel) and reducing health risks for port cities in North America (Anastasopolos et al., 2021). As marine vessel emissions continue to increase in the Canadian Arctic, they will increasingly undermine emission reduction benefits from other sectors unless specifically addressed by a new control measure.

The following two figures (**Figure 8.4 and 8.5**) compare the SO_X and NO_X emission regulations for vessels outside of an ECA, in an ECA, and for on-road vehicles in Canada. These figures demonstrate that on-road regulations are much more stringent than current regulations for marine vessels in the Canadian Arctic.

Figure 8.4: Current SO_X Regulations.

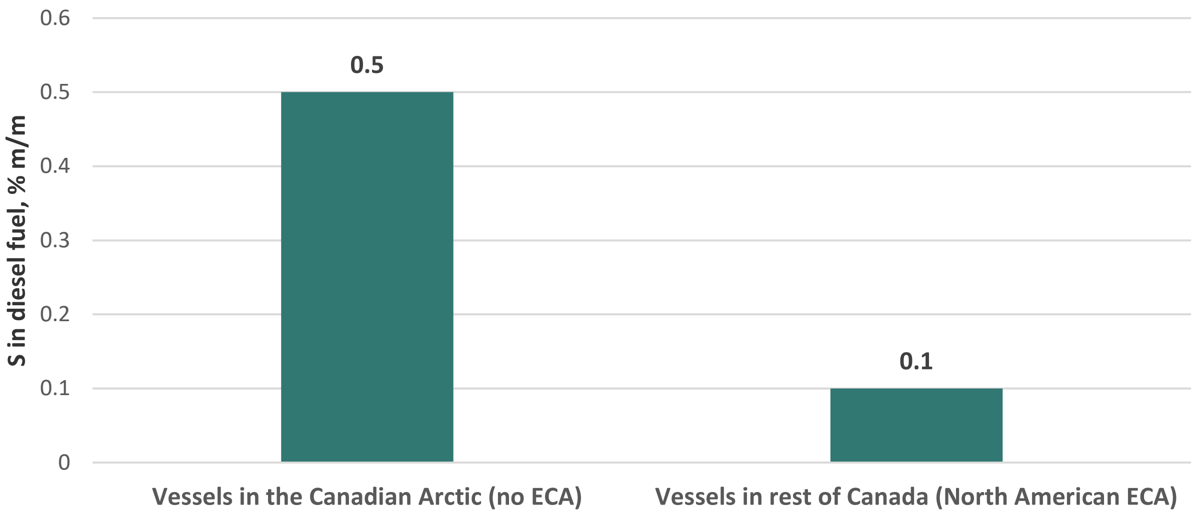
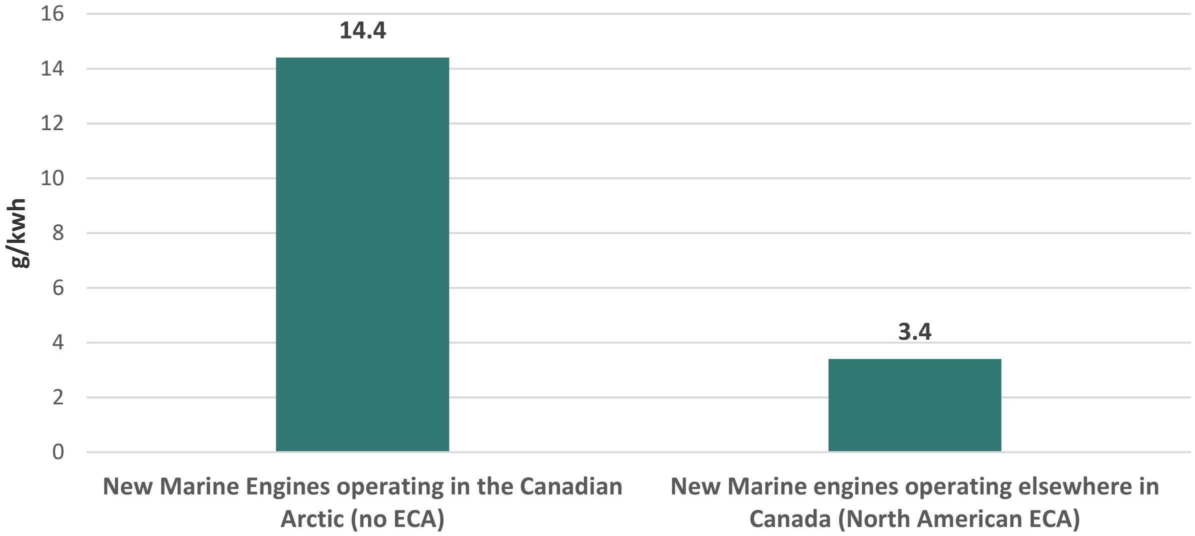


Figure 8.5: Current NO_X Regulations.



8.2 Control Measures in Place

Canada has implemented progressively more stringent emission standards for various land-based sources, including on-road vehicles and engines, off-road vehicles and engines, and locomotives. These regulations restrict or eliminate certain pollutants to improve air quality in Canada. **Table 8.1** outlines existing regulations specific to land-based sources in Canada.

Table 8.1: Descriptions, targeted pollutants, and geographic scope of control measures implemented by Canada that work to restrict or eliminate certain pollutants.

Control Measure	Description	Targeted Pollutants	Geographic Scope
Arctic and Northern Policy Framework	Presents a clear set of priorities and actions, through 2030, for the federal government to ensure that "Canadian Arctic and northern ecosystems are healthy and resilient". Specifically, objective 1 of this goal is to "accelerate and intensify national and international reductions of greenhouse gas emissions and short-lived climate pollutants". This includes a commitment to "support and enhance international efforts through the Arctic Council, UN bodies and other forums to reduce emissions of short-lived climate pollutants, especially black carbon" (CIRNAC, 2022e).	NO_x, SO_x, Black Carbon	Northern Canada
Arctic Energy Fund	Helps address energy security in the territories, especially if it is designed on a "Renewable Energy First" principle. In other words, when replacing old diesel generators or adding power generation capacity, the fund ensures that renewable	GHGs, NO_x, PM	Northern Canada

Control Measure	Description	Targeted Pollutants	Geographic Scope
	energy opportunities are considered first, new generators are compatible with future renewable energy development, community ownership and capacity development is encouraged, and additional investment in renewable energy from the private sector is leveraged (Green Budget Coalition, 2018).		
Clean Energy for Rural and Remote Communities Program	Aims to reduce the reliance of rural and remote communities on diesel fuel for heat and power. The program awards funds to successful applicants for demonstration projects that reduce reliance on diesel in Canada's remote communities and at remote industrial sites (Natural Resources Canada, 2022a).	GHGs, NO_x, PM	Canada
i-ZEV Program	Offers point-of-sale incentives for consumers who buy or lease a zero emissions vehicle (Transport Canada, 2022b).	GHGs	Canada
Indigenous Off-Diesel Initiative Challenge	Supports Indigenous clean energy champions and their communities with training, access to expertise, and resources to develop and start implementing ambitious diesel reduction plans (Natural Resources Canada, 2022b).	GHGs, NO_x, PM	Canada
Marine Spark-Ignition Engine and Off-Road Recreational Vehicle Emission Regulations	Sets emission standards for marine spark-ignition outboard engines, personal watercraft, inboard engines, vessels, off-road motorcycles, snowmobiles, all-terrain vehicles, and utility vehicles of the 2012 and later model years. These regulations came into force on April 5, 2011, and were last amended in 2021 (Government of Canada, 2022a).	NO_x	Canada
Multi-Sector Air Pollutants Regulations	Regulates NO_X emissions from boilers, heaters, and stationary spark-ignition engines using gaseous fuels in certain industrial facilities. Regulates NO_X and SO_2 from cement manufacturing facilities (Government of Canada, 2023b).	NO_X, SO_X	Canada
Northern Responsible Energy Approach for Community Heat and Electricity Program	Funds renewable energy and efficiency projects in Canada's three territories as well as the Inuit regions of Nunavik (Northern Quebec) and Nunatsiavut (Northern	GHGs, NO_x, PM	Northern Canada

Control Measure	Description	Targeted Pollutants	Geographic Scope
	Labrador). The program's primary objective is to support off-grid Indigenous and northern communities to reduce their reliance on diesel fuel for heat and electricity by promoting the use of local renewable energy sources (CIRNAC, 2022c).		
Off-road Compression-Ignition and Large Spark-Ignition Engine Emission Regulations	Sets performance-based emissions standards for air pollutants from new off-road diesel engines and large spark engines (Government of Canada, 2020a).	PM, NO_x, Black Carbon (controlled but not regulated)	Canada
Off-Road Small Spark-Ignition Engine Emission Regulations	Regulates engines that develop less than 19 kW of power and use spark plugs, such as lawnmowers, garden tractors, and hedge trimmers; has been in place since January 1, 2005 (Government of Canada, 2023c).	NO_X	Canada
On-Road Vehicle and Engine Emission Regulations	Sets air pollutant emission standards for new passenger cars, light-duty trucks, motorcycles, heavy-duty vehicles (such as highway tractors, buses and dump trucks) and their engines beginning with the 2004 model year. The regulations came into effect on January 1, 2004, and were last amended in 2018 (Government of Canada, 2022b).	NO_x, PM	Canada
Pan-Canadian Framework on Clean Growth and Climate Change	Outlines Canada's plan to meet emission reduction targets under the Paris Agreement while growing the economy; includes the Low Carbon Economy Fund and the Clean Fuel Standard (ECCC, 2016b).	CO_2, PM	Canada
Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations	Establishes progressively more stringent emission standards, while providing flexibility for compliance in a cost-effective manner (ECCC, 2018).	GHGs,	Canada
Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds	Includes requirements for implementing a program to detect and repair leaks of fugitive emissions, measurement of emissions from compressors and zero venting and conservation of natural gas from wells used for hydraulic fracturing	CH4 and VOCs	Canada

Control Measure	Description	Targeted Pollutants	Geographic Scope
(Upstream Oil and Gas Sector)	(Government of Canada, 2023d).		
Regulations to Phase-out Coal-Fired Electricity by 2030	Introduced to help make a transition to cleaner energy and cut carbon and air pollution from coal plants (Government of Canada, 2012b).	SO_x, NO_x, PM, CO_2	Canada
Strategy on Short-Lived Climate Pollutants (SLCPs)	Takes a holistic approach to addressing SLCPs through 48 commitments. The objective of the strategy is to generate reductions from all key SLCP emission sources while ensuring a coordinated approach across the Government of Canada for addressing SLCPs (ECCC, 2017).	SLCPs	Canada
Sulphur in Gasoline Regulations	Limits the sulphur content of gasoline to 12 mg/kg for gasoline produced and imported into Canada (Government of Canada, 2020b).	SO_x	Canada
Sulphur in Diesel Fuel Regulations	Limits the sulphur concentration in diesel fuel to 15mg/kg for on-road vehicles and off-road engines and 1000mg/kg for vessel engines and large stationary engines (Government of Canada, 2017c).	SO_x, PM (indirectly)	Canada

8.3 Summary

As outlined above, multiple control measures targeting different sectors have been adopted in Canada to reduce criteria air contaminants from land-based sources. Most of these measures apply throughout Canada, including the Arctic. As land-based and other transportation sources are increasingly controlled, the contribution of ship emissions to total emissions becomes greater. Implementing an Arctic ECA in Canadian waters would greatly contribute to reaching goal 5 in Canada's Arctic and Northern Policy Framework, which commits to ensuring environmentally responsible shipping (CIRNAC, 2022e). It would also contribute to the success of the "2030 Emissions Reduction Plan" goals that are focused on improving efficiency and supporting fuel switching in the marine sector (ECCC, 2022b). The emissions reductions from a Canadian Arctic ECA would improve air quality for communities in the Arctic. This section has outlined control measures in Canada that address sources of NO_X, SO_X, and PM emissions from non-marine sectors. Thus, this proposal for an ECA fulfils criterion 3.1.7 of Annex VI, Appendix III.

9 Costs of Reducing Emissions from Ships

9.1 Introduction

Criterion 3.1.8	*The proposal shall include the relative costs of reducing emissions from ships when compared with land-based controls, and the economic impacts on shipping engaged in international trade.*

The benefits to human health and ecosystems from the Canadian Arctic ECA would coincide with some increased costs to industry and northern communities. However, economic impacts are determined to be modest, especially when considered in conjunction with pre-existing regulations.

9.2 Costs of ECA relative to costs of pre-existing regulations

Preliminary analysis ahead of the implementation of the HFO ban in Canada assumed that vessels would respond to the HFO ban by switching to distillate fuels such as MDO from VLSFO. Many vessels will likely opt to comply with the HFO ban by using <0.1% sulphur distillate fuel and thus will face no incremental cost associated with the SO_X regulation of the Canadian Arctic ECA. However, the ban does not specifically require a switch to distillate. It instead prohibits fuels with a density at 15°C higher than 900 kg/m^3 or a kinematic viscosity at 50°C higher than 180 mm^2/s. Fuels below this threshold that are not considered distillate could still be used under the HFO ban. Vessels could opt to use these low-density, low-viscosity fuels since they are cheaper than true distillates. Furthermore, the availability of such fuels could increase to meet rising demand after the HFO ban is instated. The ECA therefore provides certainty that vessels will switch to using 0.1% sulphur content distillate fuels. A ship can reduce its black carbon emissions by 50 to 80% when using distillate instead of VLSFO (Osipova & Comer, 2022). All analysis considers distillate fuels to be marine fuels with a sulphur content less than 0.1%, often referred to as marine gas oil (MGO), marine diesel oil (MDO), or ultra-low sulphur fuel oil (ULSFO). Marine fuels with a sulphur content between 0.1% and 0.5% are considered to be very low sulphur fuel oil (VLSFO). The term heavy fuel oil (HFO) encompasses fuels with a sulphur content above 0.5% (and includes most fuels referred to as 'intermediate fuel oil' [IFO]). Ships using HFO typically operate an Exhaust Gas Clearing System (EGCS) to comply with the regulations of the 0.5% global sulphur cap.

Both the HFO ban, and the Canadian Arctic ECA are important as they work together to address different environmental risks or outcomes associated with HFO usage in the Arctic. The ECA regulations (under MARPOL Annex 6) assure reductions of SO_X, PM, and NO_X emissions, whereas the HFO ban (under MARPOL Annex 1) aims to limit effects of oil spills by regulating the usage of high-density HFO in addition to its carriage for use as fuel (in contrast to the ECA which only regulates emissions).

Based on preliminary analysis, the costs of the Canadian Arctic ECA would be significantly less than the costs of the HFO ban. The minimal incremental costs of the ECA would arise from 1) fuel switching and 2) vessels needing to comply with the NO_X Tier III regulations of the ECA. It is expected that these costs will have manageable impacts on the shipping industry calling or transiting through the Canadian Arctic. these costs will be passed to consumers, affecting the cost of sealift and the prices of goods in northern communities. The impacts of the ECA on communities and industry in the Arctic are explored in Section 9.6.1 and 9.6.2. If this proposal is approved, the preliminary analysis explained in this section will be updated during regulation development, especially in consideration of impacts to affected communities in the North.

9.3 Methodology

All economic analysis projecting future costs involve inherent uncertainties. The assumptions made in calculations are defined below and some are elaborated on in section 9.4. To reduce uncertainties associated with this analysis, a sensitivity analysis was conducted to carry out all calculations using a range of inputs. This is further discussed in *Section 9.3.3. Cost Summary*. All values presented in the following sections are in nominal (2023) US dollars, unless stated otherwise.

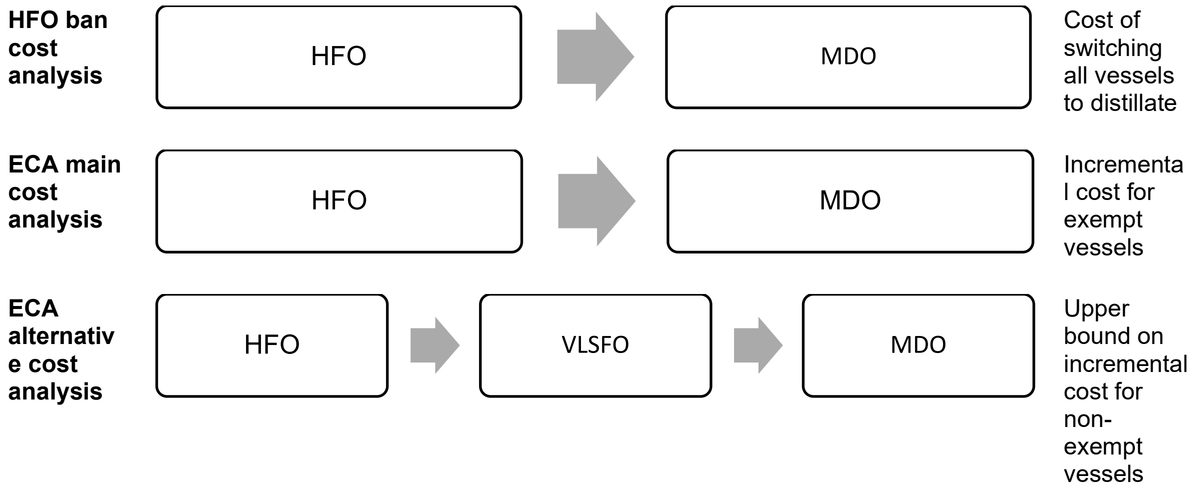
9.3.1 Determining costs from Fuel Switching (Regulation 14)

Impacts of the HFO ban were previously analyzed (see PPR 7/INF.16) under the assumption that all vessels would respond to the HFO ban by switching to distillate (Canada, 2019). The Canadian Arctic ECA would still result in modest incremental costs above the *assumed* costs of the HFO ban. This incremental cost is a result of the exemptions included in the HFO ban, which allows certain vessels to continue using residual fuels until July 1, 2029. If approved, the Canadian Arctic ECA is expected to come into force about two years earlier in the spring of 2027. The ECA may not allow for these types of exemptions and would therefore require ships exempt from the HFO ban to adopt ECA-compliant fuel (or an equivalent compliance method) 2 years earlier than originally expected. This earlier transition would result in costs to these vessels transiting through the Canadian Arctic.

In addition, vessels that had switched to low density/viscosity residuals to comply with the HFO ban in 2024 may also experience increased costs from the Canadian Arctic ECA if they were then required to switch to distillate in 2027. However, these costs are not included in the main cost analysis to avoid double counting the assumed costs of the HFO ban. It is also difficult to determine how many and which ships, if any, would use low-density/viscosity VLSFO instead of distillate to comply with the HFO ban. Thus, the scope of the main analysis considers the fuel-switching costs in 2027-2029 of vessels which would be required to switch to distillate earlier than expected due to the ECA.

To supplement the main cost analysis, an additional hypothetical scenario was considered. The findings from this scenario are not considered central to the analysis, they provide supplemental information useful in discussing cost ranges associated with the Canadian Arctic ECA. These costs are highlighted later in this section. The purpose of this scenario is to estimate the upper-bound potential cost to vessels switching from low density/viscosity VLSFO to MDO as a result of ECA regulations. This scenario assumes *all* vessels complied with the HFO ban by using low density/viscosity VLSFO and would then switch to MDO after ECA implementation. It is important to note that the costs under this scenario would not be in addition to the estimated cost of compliance of the HFO ban in Canada's impact analysis, which already assumed a switch to ECA-compliant distillate fuel. Rather, this cost analysis scenario represents the upper bound on the incremental cost that would result from implementation of the ECA. These added costs would accrue on top of the other fuel switching costs from the HFO ban, realized by non-exempt vessels from 2027 onwards and exempt vessels from July 1, 2029, onwards. This type of compliance would depend on fuel availability of HFO ban compliant VLSFOs (one analysis found that 93-95% of VLSFOs meet the definition of HFO and would therefore be subject to the HFO ban regulations [IBIA, 2020]). **Figure 9.1** is an illustration of the cost analysis scenarios.

Figure 9.1: Illustration of cost analysis scenarios.



The analysis used a list of all the vessels that passed through Arctic waters under Canadian sovereignty and jurisdiction in 2019 sourced from ECCC's MEIT as a baseline. The MEIT tracks vessel movements using AIS information and estimates fuel consumption and emission rates based on data from the Fourth IMO GHG Study (Faber et al., 2020). All vessels in the fleet were classified by whether the vessel was affected by HFO ban and ECA regulations, as exempt or not exempt from HFO ban regulations until 2029, and as sealift (resupply) or non-sealift (non-resupply) vessels. Only cruise, merchant, and tanker vessels were considered to be impacted by the ECA. Coast guard vessels, tugboats, and other special purpose vessels would be largely unaffected by new regulations and already primarily use distillate fuels; thus, they were not considered in the analysis. Data from MEIT and Clarkson's World Fleet register were used to find the year of delivery, keel-laid date, fuel tank capacity, and ice class of all included vessels to determine which vessels would have been exempt from the HFO ban if it had been in place in the baseline year (2019). Where fuel tank capacity data were not available, fuel tank capacity was estimated via a trendline calculating the relationship between deadweight-tonnage (DWT) and fuel tank capacity based on real data from similar ships. Vessels exempt from the HFO ban (until July 1, 2029) are those subject to Regulation 12A of MARPOL Annex I or Regulation 1.2.1 of Polar Code Part II-A, chapter 1. This includes 1) ships delivered on or after August 1, 2010, that have a combined oil fuel tank capacity greater than 600 m^3 and 2) ships constructed (keel-laid) on or after January 1, 2017 that also have a combined oil fuel tank capacity of less than 600 m^3 and have a category A or B ice classification. Though many vessels travelling through Canadian Arctic would be subject to the first regulation (12A of MARPOL Annex I), few are expected to be affected by the second (Regulation 1.2.1 of Polar Code Part II-A, chapter 1). Other analysis has considered the impacts of the Regulation 1.2.1 exemption to be negligible because most ice-class vessels in the Arctic are not category A and B, the 2017 keel-laid date limits the number of vessels to which the exemption could apply, and many of these vessels are already using distillate fuels (Comer, Osipova, & Mao, 2019). Thus, this analysis does not consider impacts from this second exemption associated with the HFO ban. The vessels transiting the Canadian Arctic in 2019 were further categorized as sealift (resupply) or non-sealift (non-resupply) vessels based on the ship's owner. Vessels were determined to be involved with resupply services if they belonged to one of the major companies offering sealift services in the Arctic (such as Desgagnés, Nunavut Sealink and Supply Inc., Nunavut Eastern Arctic Shipping, or Coastal Shipping).

The fuel consumption of vessels was projected based on historical fuel consumption data from the MEIT for cruise, merchant, and tanker ships. The MEIT data estimates the fuel consumption of each vessel during its time in Arctic waters under Canadian sovereignty and jurisdiction over the course of a year based on the ship's capacity, engine power, and speed variation throughout a voyage (measured through AIS data). The analysis considered fuel consumption data between 2010-2019 and 2021-2022. Data from 2020 were not used in fuel consumption projections due to the influence of the COVID-19 pandemic on shipping. 2021-2022 data were only used for merchant vessels since fuel consumption of these vessels had nearly returned to pre-pandemic levels by 2021-2022. Cruise ships were still operating at reduced levels in 2021-2022 as the cruise industry was significantly impacted by the COVID-19 pandemic. Cruise vessels were restricted in Canadian waters from March 2020 until the end of February 2022 (Transport Canada, 2022a). This meant that the 2020 and 2021 cruise seasons in the Canadian Arctic were non-existent, and the 2022 cruise season was reduced as cruise companies recovered after a significant break from regular operations. Traffic of tanker vessels was also reduced in 2021-2022. This decline can likely be attributed to the fact that one vessel which was a significant contributor to the tanker fuel consumption retired in 2021. This vessel was replaced by a newer vessel, but the ship characteristics have it classified as a merchant bulk despite it performing a similar role. Tanker traffic was also affected by widespread effects of COVID-19, such as declining demand for transportation, mines reducing operations or shutting down entirely, restricted flights, reduced household consumption, and strained Arctic tourism (Arctic Council, 2020; Duhaime et al., 2020). The Russian invasion of Ukraine may have also affected ship traffic in this region, as the Government of Canada amended the Special Economic Measures regulations in March 2022, prohibiting Russian vessels from docking in Canada or passing through Canadian waters (Government of Canada, 2023e). The combination of factors above meant that tanker traffic was lower over 2021-2022 than in pre-pandemic years. To account for the outliers in the data from 2021-2022, the analysis omits these years in the calculation of projected future fuel consumption of cruise and tanker ships. This ensures that slow recovery from COVID-19 does not cause an underestimation of future ship traffic. It also provides the most conservative estimate of future costs.

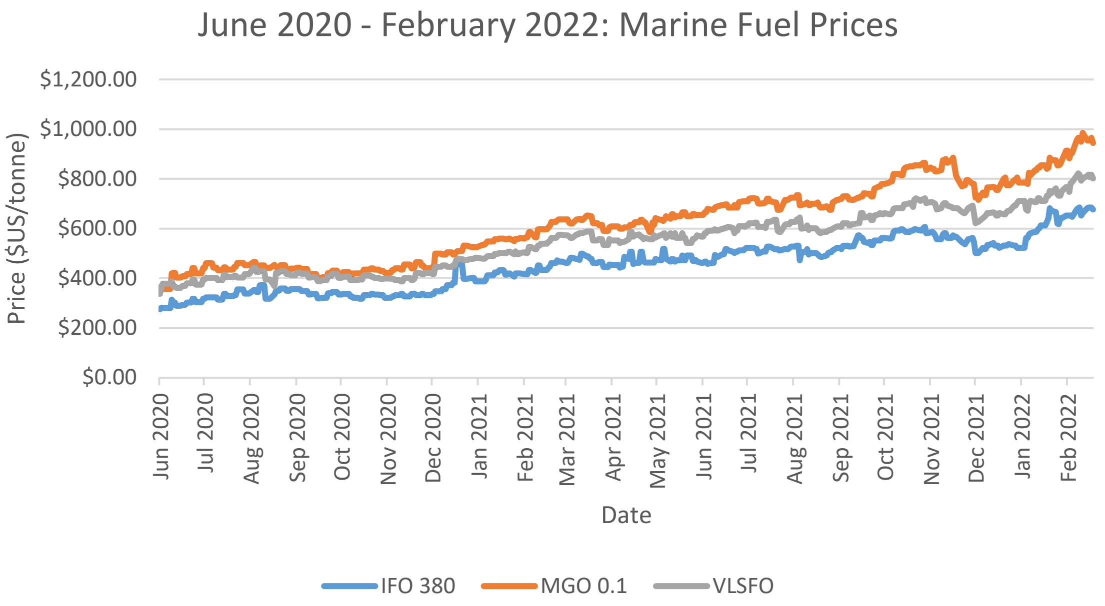
Fuel consumption projections were estimated for each ship class until 2040 based on linear trends derived from the historical data as described above. Sensitivity analysis varied the increases in projected fuel consumption by +/-5%. All projections were initially made in equivalent tonnes of HFO, then converted to the proper fuel types used by vessels after the 0.5% Global sulphur cap was instated. Clarksons World Fleet Register was used to find the current fuel type used by each vessel as of 2023, and this type of fuel was assumed to represent the type of fuel the vessel would be using in 2027-2029 if further regulations were not imposed (Clarksons Research, 2023). Of the vessels impacted by marine fuel regulations, most (90%) were using VLSFO as of 2023, 9% were using IFO 180 or IFO 380, and 1% were using MDO (Clarksons Research, 2023). It should be noted that all vessels using IFO 180 and 380 were fitted with Exhaust Gas Cleaning Systems (EGCS) to comply with the 0.5% sulphur cap. Conversion from HFO assumed that VLSFO is 3% more fuel efficient than HFO (Integr8 Fuels, 2020). MDO equivalents to HFO fuel consumption were also found for all vessels, sourced from the MEIT, where the g/kwh for HFO and MDO are calculated for each vessel based on engine type and year built. On average, MDO was found to be about 5% more fuel-efficient than HFO. Using the above data, fuel consumption projections for 2027-2029 could be separated by different ship classes (cruise, merchant bulk, merchant other, and tanker), fuel types (IFO 380, 180, VLSFO, and MDO 0.1), and regulatory categories (sealift, non-sealift, HFO ban exempt, non-HFO ban exempt).

Fuel prices of HFO, VLSFO, and MDO were estimated using historic data from the Port of Quebec (Bunker Index, 2022). This data included historical prices of IFO 380 and MGO 0.1 from October 2015 to November 2022 and historical prices of VLSFO from December 2019 to

November 2022. MGO 0.1 fuel price was used as a metric for MDO fuel price, as both fuels are interchangeable at the 0.1% sulphur content level. IFO 380 prices were used as a metric for IFO 180 prices since the prices of both fuels are similar and show parallel trends over time. IFO 180 can tend to be more expensive than IFO 380, however assuming lower prices of HFO increases price differentials and thus overestimates fuel-switching costs, providing a conservative analysis.

Forecasting fuel price projections of marine fuels is difficult and imprecise. Demand shocks from economic crises (such as the 2008 financial crisis), health crises (such as COVID-19), or conflicts (such as Russia's invasion of Ukraine) can have an unpredictable impact on fuel price levels. Supply shocks, market speculations, and supply strategies can further add uncertainty and volatility to fuel prices. While fuel prices are in constant flux, the price differential between the different types of fuels is comparatively stable. Analysis therefore used the average price differentials between IFO 380, VLSFO, and MGO as a more reliable metric in cost calculations. Price differentials were averaged from a 'business as usual' period between June 2020 and February 2022. Though this period involved large-scale economic recovery from the Covid-19 pandemic and increasing fuel prices, the differences in fuel prices were relatively stable. This business-as-usual period begins in 2020, since earlier data were not available for VLSFO, and ends in February 2022 due to international affairs that have affected the price and volatility of certain fuels. The recent Russian invasion of Ukraine began on February 20, 2022, and has had significant impacts on the price and volatility of marine fuels. As European countries shift away from Russian oil products, less supply is available in the Americas, and has dramatically increased prices and accelerated momentum behind the deployment of a range of clean energy technologies. Though the prices of all fuels have been volatile, some fuels have been affected more than others. Thus, looking at the period before this invasion and after the initial shock from COVID-19 provides a better estimate of price differences in a 'business as usual' scenario (IEA, 2023). Fuel price data for the BAU period are shown in **Figure 9.2.**

Figure 9.2: Marine Fuel Prices used in differential calculation.



Historical price data sourced from Bunker Index, 2022.

Over this period (June 2020 – February 2022), the average price differential was found to be $166.26 $US/tonne between IFO 380 and MGO and 92.73US/tonne between IFO 380 and VLSFO. To derive prices from the price differentials, a conservative estimate for average IFO 380 fuel prices in 2027-2040 was derived from past data, predicted from trends in 2015-2022. IFO 380 was used in projections since there were more data available over a longer time period and IFO 380 has been less volatile in price. The price differentials were then used to calculate prices of VLSFO and MGO. Sensitivity analysis determined a range of prices using price differentials that were 10% higher and 10% lower than the projected price differentials. Nominal, per-tonne prices of HFO, VLSFO, and MDO are projected to be $900, $980, and $1044 (USD, 2023), respectively in 2030 (Canadian dollar equivalents are estimated at $1170, $1274, and $1357, respectively, assuming an exchange rate of 1.3).

The costs of switching from IFO 380, IFO 180, or VLSFO to ECA compliant MDO fuels were calculated by ship class and categorized by whether vessels provided sealift services. Vessels were also sorted by whether they were exempt from the HFO ban. Only costs to vessels exempt from the HFO ban until 2029 were considered in the main analysis, as non-exempt vessels already face fuel switching costs from the HFO ban in 2024 onwards, and all vessels must comply with the HFO ban from July 1, 2029, onwards. Though full costs were calculated for 2027 and 2028, costs in 2029 were reduced since the vast majority of seasonal shipping activity in the Canadian Arctic occurs after July 1 when the HFO ban takes effect. It was assumed that 10% of total fuel consumption by cruise, merchant, and tanker vessels in 2029 would occur prior to July 1 and 90% would occur after. This may be an overestimation, but it accounts for year-to-year variability and provides a conservative estimate of 2029 costs. It is important to also note that all vessels using IFO 380 and IFO 180 before switching to ECA-compliant fuel would also be operating a scrubber. The minor operating costs of scrubbers were not taken into account, so the true cost of switching from HFO to MDO is smaller than the costs estimated in the analysis.

The total cost of fuel switching to sealift and non-sealift vessels is projected to be about $2.42 million in 2027 and 2028, and $247,000 in 2029 (USD 2023). After this point, the main analysis assumes that no additional fuel switching costs would incur since all vessels would be subject to the HFO ban after July 1, 2029 and would be using distillate fuels regardless of the ECA. A secondary analysis exploring alternative HFO ban compliance is discussed in the next paragraph. Findings in the main analysis showed that fuel switching costs of the ECA could increase the operating costs of sealift vessels by about 1% annually in 2027 and 2028. To determine how these switching costs would impact communities serviced by sealift, the analysis assumed that all costs incurred by sealift vessels would pass through to consumers via price increases. The number of impacted communities and households were found through data from Canada's major sealift companies and the 2021 Census (Statistics Canada, 2022a; Government of Northwest Territories, 2022; Groupe Desgagnés, 2022; Nunavut Eastern Arctic Shipping, 2020). This showed that the number of locations serviced by sealift in Canada's north is about 90, with approximately 16,115 households relying on resupply services for essential delivery of goods each year. For the purposes of this analysis, it is assumed that this number would not change over time but it is expected that the population in the Arctic will grow in the future adding more households that would be reliant on sealift vessels (see Section 4). Assuming that all costs to sealift vessels pass through to consumers, annual household expenditures are estimated to be $31 USD (about $41 CAD) higher in 2027-2028 and $3.22 USD ($4.18 CAD) higher in 2029 as a result of fuel switching costs from the ECA. Costs to non-sealift vessels from fuel switching were found to increase operating costs by about 2% annually in 2027-2028. This analysis calculated total operating costs assuming that fuel expenditures comprise 55% of total operating costs, varied to 50-60% in sensitivity analysis (UNCTAD, 2009; Stratiotis, 2018). Findings based on the methodology presented in this section are further discussed in Section 9.6.

In the scenario in which vessels would comply with the HFO ban using VLSFO rather than distillate, the incremental cost of fuel switching is 2.1 million higher in 2027-2028 (since all vessels that are subject to the HFO ban from 2024 onwards would need to switch to MDO from VLSFO), 4.11M higher in 2029, and about 4.64M higher in 2030 onwards relative to a scenario in which all vessels comply with the HFO ban using distillate (costs in 2023 USD). These values represent the upper bound of incremental costs since it can be expected that only some fraction of vessels would have actually switched to VLSFO for compliance with the HFO ban.

9.3.2 Determining costs from NO_X Tier III (Regulation 13)

NO_X Tier III regulations apply to vessels constructed (defined in MARPOL Annex VI as ships the keels of which are laid or that are at a similar stage of construction) after the date of the ECA's adoption (currently assumed to be January 1, 2025). Costs of NO_X Tier III will be low in 2027, when the ECA is expected to come into force, and increase over time as the proportion of vessels with a keel-laid-date in 2025 or later increases. This number of vessels with a keel laid date post-2025 will rise as more new vessels are deployed to the Arctic and as old vessels are replaced.

The MEIT records data on the number of unique vessels, categorized by vessel class and build year, transiting the Arctic each year. This historical data from MEIT, as well as information on past increases in Arctic ship traffic (PAME, 2021) were used to estimate the annual growth in the number of vessels joining the Arctic fleet each year. The number of new Tier III-compliant vessels will be low in 2027, as many vessels are likely to have a keel-laid date before 2025. Over time, the number of new Tier-III compliant ships will increase as traffic grows and older vessels are replaced (see **Table 9.1** for a reference of the current age distribution of the Arctic Fleet). **Figure 9.3 shows** future Arctic fleet composition assuming an annual growth rate of 2% in the number of vessels transiting Canadian Arctic waters and an annual replacement rate of 1.5% (consistent with about 1-2 vessels in the Arctic fleet being replaced each year). This graph may overestimate the number of vessels that would have to comply with NO_X Tier III, especially in earlier years since companies may choose to lay keels in years before the NO_X Tier III regulation applies, as occurred with the NA ECA (see Mercator International LLC, 2019).

Figure 9.3. Arctic Fleet Composition, 2022-2040.

This graph shows the number of vessels that would need to comply with NO_X Tier III restrictions (in blue) over time. The 'Arctic Fleet' refers to only the vessels that could be subject to NO_X Tier III restrictions, including cruise, merchant, and tanker vessels that transit Canadian Arctic waters each year. It does not include other vessels such as Coast Guard vessels, tugboats, and other special purpose ships. 'Constructed' is defined in MARPOL Annex VI as ships the keels of which are laid or that are at a similar stage of construction.

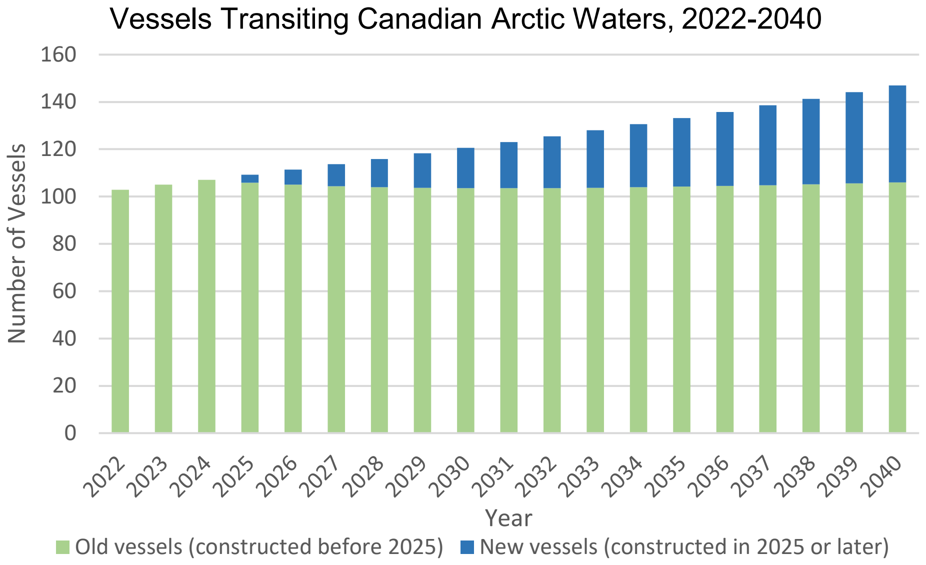


Table 9.1 Age distribution of the 2019 Arctic Fleet.

Vessel Class	0-4 years	5-9 Years	10-14 years	15-19 years	20+ years
Cruise	0	3	0	2	7
Merchant Bulk	16	26	5	1	0
Merchant Other	2	8	8	0	5
Tanker	2	3	4	1	4
Total	**20**	**40**	**17**	**4**	**16**
Total (%)	**20.6%**	**41.2%**	**17.5%**	**4.1%**	**16.5%**

Analysis of NO_X Tier III costs assumed that Selective Catalytic Reduction (SCR) is the most likely technology to be used by ships constructed after January 1, 2025, for compliance with the Tier III standard. SCR is an exhaust gas after-treatment technology with a NO_X abatement capability of up to 95% (IACCSEA, n.d). Alternative compliance methods such as alternative energy propulsion systems or Exhaust Gas Recirculation (EGR) could also be used. However, SCR is considered the most viable and available compliance method and provides more conservative cost calculations since it is typically more expensive to operate than other methods (EGCSA, 2014). Though there is an associated cost with equipping vessels with SCR, this analysis assumed that there would be no capital costs of SCR as a result of the proposed ECA. This is because most ships subject to the Canadian Arctic ECA transiting through the Arctic from 2027 onwards will also transit through other NO_X-regulated areas such as the NA ECA (which already includes NO_X Tier III limitations). In 2019, 98% of cruise, merchant, and tanker ships operating in the Arctic passed through other ECAs. Thus, the Canadian Arctic ECA is unlikely to be the driving force behind a company's decision to install a NO_X-compliant engine system, and the number of vessels that would incur installation fees as a result of the Canadian Arctic ECA would be negligible. In addition, manufacturers estimate that the lifetime of a basic SCR construction can be as long as the lifetime of the ship, so no system replacement costs were included in estimations. Therefore, the Canadian Arctic ECA's NO_X regulation is unlikely to increase *capital* costs for ships transiting the Arctic. As a result, this analysis considers only the increased *operating* costs from vessels using SCR the Canadian Arctic ECA.

The main cost of operating an SCR system is the cost of the reducing agent, assumed to be a urea solution of 40 wt% (weight percent). Urea costs are assumed to account for 80% of total operating costs of an SCR system, though sensitivity analysis considers a range from 85% to 75%. Analysis for the Baltic Sea ECA likewise assumed that urea costs account for 80% of total operating costs of NO_X Tier III (IMO, 2016). To find the amount of urea used by new vessels with a keel laid date in 2025 or later, analysis first measured the projected annual distillate fuel consumption (with ECA sulphur content restrictions in place) between 2027-2040 for sealift and non-sealift vessels, categorized by ship class. This was based on projections discussed in Section 9.3.1. Fuel consumption growth is a better measure for vessel traffic increase than the increase in the number of vessels transiting the Arctic since it inherently captures differences in the number of trips, vessel size, speed, and routes taken.

The growth in fuel consumption each year is partially attributed to new vessels that must comply with NO_X Tier III requirements. Fuel consumption growth over time inherently captures increases in the number of vessels (recently built or older vessels) transiting the Arctic as well as increased trips. Thus, all traffic growth is not attributed to growth in new, NO_X Tier III compliant vessels in this analysis. Instead, analysis assumes that 40% of increased fuel consumption from traffic growth can be attributed to new NO_X Tier III compliant vessels, with sensitivity analysis ranging from 30-50%. In addition, the analysis assumes a replacement rate of 1.5%, meaning 1.5% of fuel consumption each year is used by new vessels replacing old vessels (sensitivity analysis varies the replacement rate from 1-2%. The sum of annual fuel consumption of new vessels (from traffic growth) and replaced vessels represents the total fuel consumption each year of NO_X compliant vessels (during their time in Canadian Arctic waters). This total was calculated for each year between 2027 and 2040.

Urea consumption is estimated at 9% (7% and 11% in sensitivity analysis) of MDO fuel consumption to achieve the Tier III level (Wärtsilä, n.d). Urea prices are highly volatile over time and differ across the globe. Usually created as a by-product of LNG and ammonia, urea is highly dependent on these commodities and their costs. To account for the volatility associated with urea prices, a range of costs was assumed in a sensitivity analysis. The main price used in the medium scenario was $500 USD/tonne in 2023 real dollars but ranged from $300-700 in the sensitivity analysis. Real prices of urea were not assumed to change over time. Prices were estimated based on projected trends, past analysis, and current urea prices (Statista research department, 2023b; IMO, 2016; Bedick et al., 2011; Zhang, G. et al., 2021; US EPA, 2009). Using estimated urea consumption and price, total expenditures on urea for sealift and non-sealift vessels were approximated. Under the assumption that urea costs account for 80% of total operating costs of an SCR system (75% and 85% in sensitivity analysis), the total operating costs of SCR for sealift and non-sealift vessels were estimated. It should be noted that the operating costs of SCR are likely overestimated since there are usually fuel savings as a result of operating an SCR system that were not accounted for in this analysis (Zhang, G. et al., 2021, IACCSEA, 2013).

Costs were estimated both as a cumulative total over time and as an incremental cost each year on top of the previous year's cost. Though costs are measured over an entire calendar year, essentially all costs would be incurred over the Arctic shipping season (typically June-October). Incremental costs increase slightly over time as more vessels transit the Arctic each year, more vessels are replaced, and the proportion of new vessels that are built in 2025 or later increases. Between 2027 and 2040, costs of the NO_X Tier III regulation are projected to increase by $39,000-47,000 each year for sealift vessels and $82,000 - 102,000 each year for non-sealift vessels (all values in real USD 2023). This represents an increase each year to operating costs of <0.1% for sealift vessels and non-sealift vessels.

The total operating costs of SCR increase over time as more and more vessels must comply with NO_X Tier III. The cumulative totals of NO_X Tier III costs are pictured in **Figure 9.4** and **Figure 9.5.** Though costs appear to be increasing exponentially, at some point after 2040, annual increases in costs will level off when all vessels built prior to 2025 have been replaced by NO_X-compliant vessels. Increases in NO_X costs each year will then be due only to traffic increases, rather than traffic increases and replacement.

Figure 9.4: Cumulative Cost of NO_X Tier III to sealift vessels, 2027-2040. Costs are displayed over a range (low, medium, high) to account for urea price volatility and other factors associated with the inherent uncertainty of projecting these future costs. Monetary values are presented in 2023 real USD.

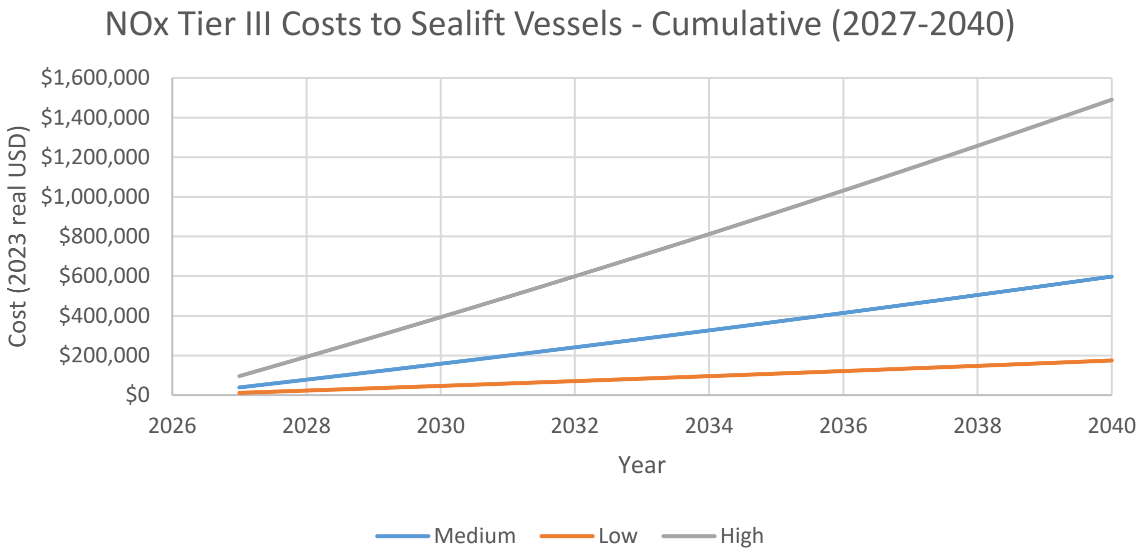
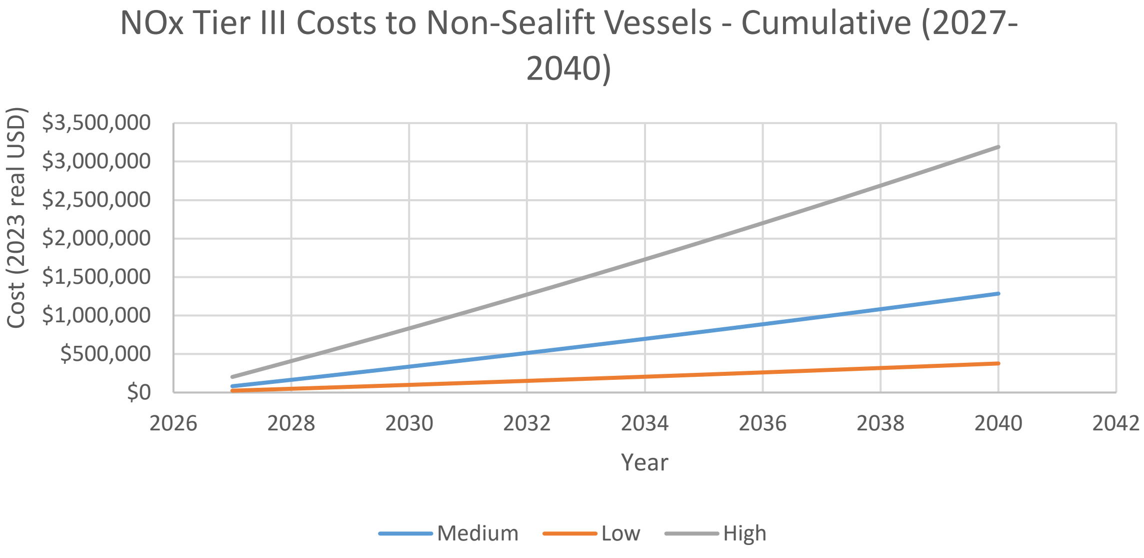


Figure 9.5: Cumulative Cost of NO_X Tier III to non-sealift vessels, 2027-2040. Costs are displayed over a range (low, medium, high) to account for urea price volatility and other factors associated with the inherent uncertainty of projecting these future costs. Monetary values are presented in 2023 real USD.



The hourly urea cost for different vessels over a range of 'typical' engine sizes and engine characteristics, categorized in the proposal for the NA ECA (IMO, 2009), was also calculated, assuming a urea price of $500 per tonne (USD 2023). (See **Table 9.2). ** Calculations used per-hour urea consumption as defined in the analysis of the NA ECA (US EPA, 2009). **Table 9.2** demonstrates how operational costs of SCR can change depending on vessel's engine type. The average engine characteristics of ships in the Arctic at baseline (2019) are presented in **Table 9.3**.

Table 9.2: Urea Costs per Hour for "Typical Engine Types". Monetary values presented in 2023 US dollars.

SPEED	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	LOW
Engine Power (kW)	4,500	9,500	18,000	8,500	15,000	48,000
Cylinders	9	12	16	6	8	12
Litres/cylinder	35	65	95	380	650	1400
Engine Speed (rpm)	650	550	500	130	110	100
Aqueous Urea Cost per hour	**$26**	**$55**	**$104**	**$46**	**$80**	**$256**

Table 9.3: Average characteristics of vessels transiting the Arctic (2019). Note that Coast Guard and tug vessels are not subject to ECA regulations.

Ship Class	Gross Tonnage	DWT	Engine Power (kW)	Cylinders	Engine Speed (rpm)
Coast Guard	5,892	2,716	12,340	14	1,061
Cruise	20,157	2,593	7,617	9	751
Merchant Bulk	38,293	68,858	11,428	6	115
Merchant Other	11,544	15,139	6,520	6	427
Tanker	19,336	31,708	7,481	7	239
Tug	848	663	4,233	12	1,042

Assuming sealift vessels pass on costs to communities through increased sealift prices, NO_X Tier III compliance is estimated to increase household expenditures by $2.39-2.91 (USD, 2023) each year between 2027-2040. This calculation required the number of households impacted by sealift, which was determined using Census population data and sealift port data as described in Section 9.3.1. The proposed impacts of NO_X Tier III regulations to communities and industry are assessed further in Section 9.6.

9.3.3 Summary of Cost Findings

This section provides summary tables of the projected costs of Canadian Arctic ECA.

The analysis used to determine the costs of the Canadian Arctic ECA employed a sensitivity analysis to help account for the intrinsic uncertainty of projecting future costs. In this way, costs could be determined over a large range to assess outcomes based on changes to the inputs to the cost analysis. **Table 9.4** demonstrates the different inputs used in calculations of costs in the low, medium, and high scenarios. The medium scenario is considered the most likely, or average scenario. All costs presented in Sections 9.3.1, 9.3.2, and 9.6 are derived from calculations made using 'medium scenario' inputs. Medium, low and high scenario outcomes are presented in **Tables 9.5, 9.6, and 9.7**.

Table 9.4: Description of inputs used in different scenarios. The Medium scenario provides the most likely or average expected outcomes, while the low and high scenarios are used in sensitivity analysis to provide a range of costs since future projections are inherently uncertain.

	Low	Medium	High
Fuel consumption projections[1]	-5% from medium scenario	Fuel consumption projections derived from historical data	+5% from medium scenario
Prices of MDO, VLSFO, HFO[2]	10% smaller price differentials between fuel types	Price projections derived from historical data	10% larger price differentials between fuel types
Fuel costs as a percentage of operating costs[3]	50%	55%	60%
Replacement rate of vessels[4]	1.0%	1.5%	2.0%
Urea consumption as a percentage of fuel consumption[5]	7%	9%	11%
Urea Costs as a percentage of SCR operating costs[6]	85%	80%	75%
Discount rate[7]	10%	7%	3%
Real price of Urea (USD 2023)[8]	$300	$500	$700
Percentage of increased fuel consumption from traffic growth attributed to new vessels	30%	40%	50%

Sources: 1: ECCC, 2022a; Clarkson's Research, 2023. 2: Bunker Index, 2022. 3: Stratiotis, 2018; Elgohary et al., 2015. 4: ECCC, 2022a. 5: US EPA, 2009; IMO, 2016; Wärtsilä, n.d. 6: IMO, 2009; IMO, 2016; Zhang G. et al., 2021. 7: Government of Canada, 2023a. 8: Statista research department, 2023b; IMO, 2016; Bedick et al., 2011; Zhang, G. et al., 2021; US EPA, 2009.

Table 9.5: The projected total annual costs of the Canadian Arctic ECA for 2028, 2030, and 2040. All values are listed in nominal (2023) US dollars.

	2028			2030			2040		
	Low	Med	High	Low	Med	High	Low	Med	High
Fuel switching costs for sealift vessels (USD)	$424,464	$511,088	$604,139	$0	$0	$0	$0	$0	$0
Fuel switching costs for non-sealift vessels (USD)	$1,577,352	$1,913,480	$2,274,920	$0	$0	$0	$0	$0	$0
Cumulative NO_X Tier III costs to sealift vessels	$22,802	$77,722	$292,202	$46,312	$157,993	$392,859	$174,500	$597,579	$1,488,979
Cumulative NO_X Tier III costs to non-sealift vessels	$48,757	$165,002	$408,494	$99,230	$336,171	$832,744	$377,320	$1,284,501	$3,190,325
Total	**$2,073,375**	**$2,667,292**	**$3,579,755**	**$145,542**	**$494,164**	**$1,225,602**	**$551,820**	**$1,882,080**	**$4,679,303**

Table 9.6: The annual costs of the Canadian Arctic ECA to households using sealift services in Canada. All values are listed in nominal (2023) US dollars

	2028			2030			2040		
	Low	Med	High	Low	Med	High	Low	Med	High
Cost of fuel switching to each household using sealift	$26.34	$31.72	$37.49	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Cost of NO_X Tier III to each household using sealift	$1.41	$4.82	$11.99	$2.87	$9.80	$24.38	$10.83	$37.08	$92.40
Total Cost of ECA to each household using sealift	$27.75	$36.54	$49.48	$2.87	$9.80	$24.38	$10.83	$37.08	$92.40

The number of households was found through data from Canada's major sealift companies and the 2021 Census (Statistics Canada, 2022a; Government of Northwest Territories, 2022; Groupe Desgagnés, 2022; Nunavut Eastern Arctic Shipping, 2020). This showed that the number of locations serviced by sealift in Canada's north is about 90, with approximately 16,115 households relying on resupply services for essential delivery of goods each year.

Table 9.7: Percentage increases in operating costs as a result of the proposed Canadian Arctic ECA

	2028			2030			2040		
	Low	Med	High	Low	Med	High	Low	Med	High
Increase to sealift total operating costs from fuel switching	0.79%	0.98%	1.19%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Increase to sealift total operating costs from NO_X Tier III	0.04%	0.15%	0.38%	0.07%	0.26%	0.66%	0.15%	0.53%	1.37%
Total increase to sealift operating costs from ECA	0.83%	1.13%	1.76%	0.07%	0.26%	0.66%	0.15%	0.53%	1.37%
Increase to non-sealift total operating costs from fuel switching	1.55%	1.93%	2.35%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Increase to non-sealift total operating costs from NO_X Tier III	0.05%	0.17%	0.42%	0.08%	0.29%	0.73%	0.16%	0.57%	1.44%
Total increase to non-sealift operating costs from ECA	1.59%	2.10%	2.77%	0.08%	0.29%	0.73%	0.16%	0.57%	1.44%
Total increase to operating costs of all vessels from ECA	1.33%	1.76%	2.42%	0.08%	0.28%	0.71%	0.16%	0.56%	1.42%

Overall, the costs of the ECA will be low in relative terms, as illustrated by the small increases to overall operating costs in **Table 9.7**. Values presented in **Tables 9.5-9.7** are calculated under the assumption that vessels will switch to distillate when they are subject to the HFO ban. Cost calculations for a scenario in which vessels switch to VLSFO as a result of the HFO ban are higher since there are more fuel switching costs involved. If all non-exempt vessels had responded to the HFO ban by switching to VLSFO, and then to the ECA by switching to distillate, overall fuel-switching costs would be 1.8x higher in 2028, 9.9x higher in 2030, and 3.5x higher in 2040, compared to a scenario in which vessels responded to the HFO ban by switching to distillate. Despite these seemingly large differences, assuming the VLSFO scenario the total spent on operating costs by sealift and non-sealift vessels transiting the Canadian Arctic would be 2-3.2% higher annually than a business-as-usual scenario without the ECA in place (note that all values in this paragraph assumed medium sensitivity scenario inputs).

9.4 Assumptions made when calculating costs

9.4.1 Negligible hardware costs associated with fuel switching

For a given vessel, complying with ECA standards may require upfront capital expenditures. However, this is not expected to be a significant cost in the Canadian Arctic as 98% of cruise, merchant, and tanker ships operating within Arctic waters under Canadian sovereignty and jurisdiction pass through other ECAs at some point in the year. This indicates that they already have the capacity and ability to comply with ECA standards through using 0.1% fuel or alternative compliance measures. Unlike HFO, distillate fuels and low sulphur fuel oil do not normally require heating in temperate climates. However, in cold Arctic temperatures, distillate fuel may cool and form wax that plugs fuel filters and injectors (Vermeire, 2021). To prevent this, vessels may use winter grade diesel or heated tanks (Vermeire, 2021). Since additional measures in cold weather are already required for heavier fuels, Arctic temperatures do not significantly impact fuel switching and are therefore considered negligible in cost calculations. For these reasons, only the difference in fuel costs is considered when calculating the impacts of fuel switching from ECA regulations.

9.4.2 No Route Alterations

There is a possibility that ships will avoid Canadian waters in favour of other shipping routes if the Canadian Arctic ECA comes into force. This would be an especially attractive option for vessels exempt from the HFO ban that could continue to use residual fuel until 2029 if they avoided Arctic waters under Canadian sovereignty and jurisdiction. In our analysis, we assume that this is not the case, which provides for the most conservative cost estimate to industry. It is also a reasonable assumption since many vessels that pass through Canadian waters deliver resupply goods to Canadian communities or to use ice free shipping routes through the Canadian Arctic. Furthermore, the mines are in remote areas of the Arctic requiring them to rely on marine vessels to deliver fuel and supplies as well as transport their final product to the market (Jones, 2023).

9.4.3 Fuel availability

This analysis assumes that sufficient refinery capacity and production exist to meet the Arctic fleet's demand for 0.1% sulphur content fuels. This is a fair assumption because Arctic-transiting vessels comprise such a small segment of the marine fuel market demand. Due to limited bunkering operations in the Arctic, these vessels typically bunker outside the Canadian Arctic ECA region at their port of departure. The introduction of an Arctic ECA should have a negligible effect on global fuel prices or production. Though the main analysis of projected Canadian Arctic ECA cost impacts assumed that vessels would respond to the HFO ban and ECA by switching to distillate fuels, calculations were also done for a secondary scenario where vessels instead respond to the HFO ban by switching to low-density, low-viscosity VLSFO then respond to the Canadian Arctic ECA by switching to distillate. The HFO ban applies to fuel with a density at 15°C above 900 kg/m^3 and/or a kinematic viscosity at 50°C above 180 cSt. The availability of low-density, low-viscosity VLSFOs that fall outside these restrictions and therefore are compliant with the HFO ban restrictions is unknown. However, the International Bunker Industry Association found in fuel testing that approximately 93-95% of VLSFOs would be subject to HFO ban restrictions (IBIA, 2020). Thus, about 5-7% of VLSFOs currently on the market could be used by vessels with the HFO ban in place. Though it is likely that some vessels could use these fuels to comply with HFO ban restrictions, availability for all vessels operating in Canadian Arctic waters is uncertain. The secondary analysis makes the assumption that all vessels are able to acquire and use these VLSFOs to account for highest possible costs.

9.4.4 *Capital costs of NO_X Tier III regulation*

The Canadian Arctic ECA requires all vessels with a keel laid date after the adoption date of the ECA to comply with NO_X Tier III regulations. This date is expected to be January 1, 2025. New ships will have to invest in NO_X Tier III compliance mechanisms such as Exhaust Gas Recirculation (EGR), Selective Catalytic Reduction (SCR) and other technological, operational measures and alternative energy systems. and Liquefied Natural Gas (LNG) usage. Though there is an associated cost with equipping vessels with NO_X compliant systems, as described in 9.3.2, the Canadian Arctic ECA is unlikely to be the driving force behind a company's decision to implement a NO_X-compliant engine system. This is because most ships transiting through the Arctic from 2027 onwards will also transit through other NO_X-regulated areas such as the NA ECA (which already includes NO_X Tier III limitations). In 2019, 98% of cruise, merchant, and tanker ships operating in the Canadian Arctic passed through ECAs. Therefore, the Canadian Arctic ECA's NO_X regulation is unlikely to significantly change capital costs for ships transiting the Arctic. However, there will be increased operating costs for vessels with a keel-laid-date in 2025 or later when they use NO_X Tier III systems in the Canadian Arctic ECA. These costs are estimated in Section 9.3.2.

9.4.5 *Alternative methods of SO_X regulation compliance*

While the SO_X regulation requirements of the ECA can be met by using low sulphur distillate fuel, alternative compliance strategies may be employed such as use of alternative fuels, as well as the desulphurisation of exhaust gasses. However, the use of distillates such as MDO is considered the most likely approach, and therefore our analysis assumes this method of compliance when calculating costs.

Vessels are less likely to switch to alternative fuels because they incur large upfront costs. In addition, there is currently little infrastructure to support the availability of alternative fuels in the Arctic (such as onshore facilities and local distribution channels) (Clear Seas, 2022). These factors make alternative fuels a less attractive compliance method within the Canadian Arctic ECA. Vessels are also less likely to use Exhaust Gas Cleaning Systems (EGCS), or scrubbers, than switch to distillates. Currently, only 11% of the fleet subject to potential Canadian Arctic ECA regulations are fitted with EGCS, even though 98% of all vessels travel through other ECAs at some point during the year. Thus, the majority of vessels are unlikely to comply with ECA restrictions using EGCS. In addition, the regulations of the HFO ban will restrict HFO fuels that require corresponding scrubber usage in the Arctic. Even though a few vessels currently use EGCS, considering a switch to MDO provides a more costly, conservative estimate. It also provides an analysis that will not change if further regulations on EGCS are introduced before or during the Canadian Arctic ECA's implementation. While scrubbers are currently a compliance option, Canada is aware of the concerns raised by stakeholders regarding the use of scrubbers in Canadian waters, and that some jurisdictions around the world have already chosen to impose discharge restrictions. Domestically, Canada continues to study the environmental impacts of the use of different types of scrubber systems and plans to work with the maritime industry to develop a path forward to address the issue of washwater discharge in Canadian waters on a permanent basis. Transport Canada also continues to support the ongoing work at the International Maritime Organization to evaluate and develop harmonized rules and guidance on the discharge of scrubber washwater in the aquatic environment.

9.4.6 Savings from energy efficiency improvements

Costs calculated in the analysis may also be overestimated due to the increased energy efficiency of vessels over time, which will result in cost savings. This increase will likely be driven by the IMO's regulation on Energy Efficiency Design Index (EEDI). The EEDI requires a minimum energy efficiency level per capacity mile (e.g., tonne mile) for different ship type and size segments and provides a specific figure for an individual ship design, expressed in grams of carbon dioxide CO_2 per ship's capacity-mile. It requires new vessels to improve their energy efficiency over time and is calculated by a formula based on the technical design parameters for a given ship (IMO, n.d.-a).

9.4.7 NO_X reductions are in accordance with NO_X Tier III restrictions

Canada submitted a paper to MEPC 80 (IMO, 2023a) assessing low-load performance of IMO NO_X Tier III Technologies. This submission was conducted in response to concerns that actual NO_X emission levels may exceed Tier III standards when ships are operating at low engine loads, such as when they are in port, coastal regions, inland areas, and ship speed reduction zones (IMO, 2023a). Even if vessels have engines compliant with NO_X Tier III standards, the actual emissions from these engines at low loads could exceed the levels articulated in the Tier III standard. This could occur during usage of SCR systems, one of the common compliance methods to NO_X Tier III restrictions, since these systems are not designed to function at low exhaust temperatures that occur at low loads. Preliminary research indicates that NO_X emissions in Tier III-compliant marine vessels may increase to 13 g/kWh operating at low load areas (IMO, 2023a). At this time, more studies are being conducted that include real world measurements of NO_X exceedance over Tier III levels as the regulation certification testing by IMO do not include NO_X levels that were below 25% Maximum Continuous Rating (MCR) (IMO, 2023a). As more data become available, Canada will take such exceedances into further consideration. The analysis presented in this proposal assumes that SCR systems reduce emissions to levels below the Tier III restrictions, in line with analyses conducted for past ECA submissions.

9.5 Economic Health Benefits of Emissions Reductions in the Arctic

Implementation of an ECA in the Arctic could have benefits to human health in affected communities and environmental health. As described in Section 5, exposure to ambient air pollution is associated with adverse health effects such as increased risk of respiratory symptoms, development of disease, and premature death. In Canada, approximately 15,300 premature deaths annually are associated with ambient air pollution (Health Canada, 2021). When monetized, this loss has a value of at $120 billion CAD per year (Health Canada, 2021). For the territories, nine premature deaths were attributed to ambient air pollution (four each for NWT and Yukon; one for Nunavut), with a total economic valuation of $69M CAD per year (Health Canada, 2021). Benefits of reducing pollution can also come from reduced emergency room visits, hospitalizations, asthma exacerbation events, and other adverse health effects (Health Canada, 2021).

Populations in the Canadian Territories have higher baseline rates of certain diseases and mortality, which can make them more vulnerable to health risks from air pollution (see table 5.2). In addition, Indigenous Peoples, who comprise a significant proportion of the Northern population in Canada, experience a disproportionate burden of ill health compared to non-Indigenous people in Canada, due, in part, to important social determinants of health, and can be more susceptible to adverse effects from air pollution (National Collaborating Centre for Indigenous Health, 2022).

The projected economic benefits of ambient air quality policies in Arctic Council Countries were modelled by the Organisation for Economic Co-operation and Development (OECD, 2021). In a scenario where Canada adopts the best available technologies to achieve the maximum technically feasible reduction in air pollutant emissions across the country, the OECD estimated a 60% decrease in pollution-related deaths for the country as a whole, estimated as 7930 avoided deaths yearly in Canada by 2050 (OECD, 2021). The analysis also estimated that the costs to achieve these health outcomes would be outweighed by the monetized benefit of the emission-reduction technologies.

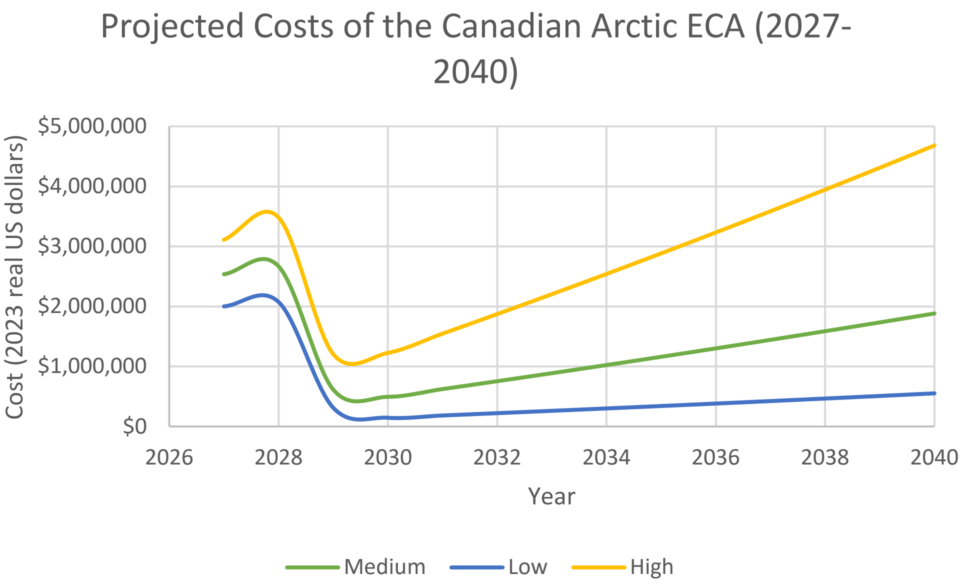
As discussed at length in this proposal, emissions such as black carbon can increase the rate of sea ice melt in the Arctic, as well as ocean acidification. Sea ice melt in the Arctic is a major contributor to rising ocean levels, which has and will continue to have larger and larger negative impacts on shoreline erosion, flooding, storm hazards, ocean recreation, and harm to marshes, wetlands, and estuaries (Neumann et al., 2000). Furthermore, increasing ocean acidification could alter marine food chains and corresponding food supply to humans over time (NOAA Fisheries, n.d.). These impacts are likely to pose high monetary and social costs to coastal communities in future years. Measures such as this ECA, which aim to limit emissions of pollutants leading to such impacts can reduce (or slow down) the accrual of future costs to such communities facing negative effects associated with these environmental changes.

Reducing emissions from ships in the Canadian Arctic can mitigate risks to human health and the environment. Controlling emissions through shipping regulations is relatively inexpensive compared to other measures due to the nature of Arctic geography, climate, and industry. This is explored further in Section 9.7.

9.6 Impacts of ECA Costs

The estimated cost of improving ship emissions from current performance to ECA standards is estimated to be 2.67 million in 2028, $494,000 in 2030, and 1.88 million in 2040. Costs of the ECA fall in 2029 due the full implementation of the HFO ban on July 1, 2029, and then increase over time as more vessels comply with NO_X tier III restrictions. This can be seen in **Figure 9.6.** The costs of the ECA, while small in relative terms, will accrue to communities, Arctic tourists, industry stakeholders, and the mining sector. This section provides a cost breakdown for each of these sectors and discusses how costs will affect operations.

Figure 9.6: Projected Cumulative Costs of the Canadian Arctic ECA, 2027-2040. Costs are displayed over a range (low, medium, high) to account for the inherent uncertainty of projecting future costs. Monetary values are presented in 2023 nominal US dollars.



9.6.1 *Communities*

The annual cost of fuel switching to the sealift industry operating in the Canadian Arctic is projected to be $504,000-511,000 in 2027 and 2028. This translates to a 1% increase in total operating costs for sealift in 2027 and 2028. These costs are incurred by the portion of resupply vessels that are exempt from the HFO ban, and thus must switch to ECA-compliant fuels in 2027, about 2 years earlier than HFO ban exemptions permit. Note that vessels, including sealift vessels, are exempt from the HFO ban if they are subject to Regulation 12A of MARPOL Annex I or Regulation 1.2.1 of Polar Code Part II-A, chapter 1. Shipping companies incurring increased costs to deliver goods to northern communities could pass on these costs to the consumers of their sealift products. This could occur through increased prices of resupply products, which are already high relative to prices elsewhere in Canada. Note that resupply products in this analysis included fuel transported by tankers to sealift communities. Assuming all costs of these companies pass through to consumers, the average cost of fuel switching as a result of the Canadian Arctic ECA to a household using sealift services is $31 USD (about $41 in Canadian dollars) per year in 2027 and 2028. Tier III costs to communities are projected to increase household expenditures by a further $2.39-2.91 per household each year, continuing after 2029 since NO_X Tier III regulations are indefinite.

Preliminary analysis of the HFO ban estimated product price increases for community resupply products in the range of 0.7% to 1.9%. This translates to an increase in annual household expenditures of $248-$679 (2019 CAD). Though the Canadian Arctic ECA's cost to communities is 6-18 times lower than the estimated costs of the HFO ban in real terms, it is still important to ensure standards of living and socio-economic capabilities do not decline in northern communities due to the introduction of a Canadian Arctic ECA.

Few modes of transportation can deliver goods to the northern regions of Canada besides marine shipping. Approximately 53 communities in the Arctic have no road access (Parliament of Canada, House of Commons, 2019). Thus, demand for essential goods is unlikely to change in these communities regardless of price increases as individuals have few other methods of receiving goods that cannot be delivered by air. The demand for non-essential goods, however, could decline if delivering such goods become less affordable.

The Green Budget Coalition proposed that a $12 million investment over three years during the fuel transition away from HFO in the Arctic would support communities that rely on sealift and prevent prohibitive price increases on essential goods (Green Budget Coalition, 2018). The Government of Canada understands that sealift is a crucial service for Arctic communities and that consumer prices in Canada's Arctic are already much higher than in southern Canada. The Government of Canada is committed to developing a cost mitigation plan for the Canadian Arctic ECA. The cost mitigation plan will apply to Arctic community sealift vessels so that the implementation of the ECA is cost-neutral for communities in the Canadian Arctic. Canada is seeking input on how best to deliver the environmental benefits of the Canadian Arctic ECA proposal without adversely impacting food security and the cost of living in the North.

9.6.2 Industry

When considering industry as a whole, fuel switching costs of the ECA would increase the total annual operating costs of non-sealift vessels by about 2% in 2027 and 2028 (see Table 9.7). Costs to the industry from NO_X Tier III requirements are estimated to increase total operating costs of non-sealift vessels by <0.1% ($82,000 – 102,000 USD, 2023) annually between 2027-2040. These changes will have a small impact on vessel voyage costs and freight rates. However, the costs associated with the ECA are low relative to the approximate $50 million (USD) total spent on operating costs by all non-sealift merchant bulk, cruise, and tanker ships in the Canadian Arctic in the baseline year of 2019 and the relative time ships spend in the Arctic. These costs are also minimal when considered next to costs introduced by fluctuating fuel prices, crew wage changes, maintenance costs, vessel repairs, overhead, and insurance. Whether shipping companies will bear the costs of the ECA depends on whether they can pass on costs to businesses requesting their services, such as retailers receiving products shipped through the Arctic. If it is difficult for shipping companies to raise prices or shipping companies have signed contracts specifying their shipping costs, shipping companies themselves may bear the costs of the ECA.

Specific industries could face small costs from a Canadian Arctic ECA. The tourism industry would see minor increases in costs for cruise ships regulated by ECA restrictions. However, these costs would be minimal since most cruise ships in the Arctic already use MDO or VLSFO. Cruise ships transiting to remote Arctic regions are usually luxury vessels that require advanced icebreaking technologies. Ticket prices can cost anywhere from $800 - $2200 per day (2022 CAD) per passenger (Quark expeditions, 2022; Adventure Canada, 2022). Assuming costs pass entirely to consumers, and that cruise vessels are using VLSFO before the ECA comes into force, the ECA could increase ticket prices by about $9, $2, and $9 per day on top of initial prices in 2027, 2030, and 2040, respectively. These costs, though small, are likely overestimations since many cruise ships may be already using ECA compliant fuels when the ECA comes into force. Thus, costs of the ECA are unlikely to negatively impact Arctic tourism. Decreases in mining revenue from the ECA are also expected to be minimal. As described in Section 7.4.1, six of the major mines in Canada's Arctic are serviced by ships. Most rely on airplanes for cargo transportation and only use marine shipping for sealift services of equipment and materials (Larouche et al., 2015; Lawson et al., 2020). Baffinland's Mary River Mine in Nunavut relies heavily on marine transportation for shipment of its iron ore. The mine has withstood large fluctuations in iron ore and fuel prices since it began operations in 2015, indicating its resilience despite increased costs (Comer et al., 2019). Between January 2017 and January 2022, the price of iron ore ranged from $57 to $215 (US dollars / metric tonne) (Market Index, n.d.). Fuel prices of MDO, VLSFO, and HFO have also fluctuated dramatically (Comer et al., 2019). This indicates that the mining industry in Canada's Arctic is well positioned to adjust to small increases in operational costs.

9.7 Cost to Shipping Industry in Comparison with Land-based Measures

The costs of the ECA outlined in the previous section compare favourably to other Canadian land-based control programs that have been implemented to reduce air pollution emissions.

Land-based methods to reduce emissions vary greatly in cost depending on the type of pollutant, the source, and the method of reduction. **Table 8.1 in Section 8.1** summarizes control measures implemented by Canada that work to restrict or eliminate certain pollutants. The costs of three specific measures are examined below. All values are normalized to 2023 Canadian dollars (USD 2023 values in parenthesis).

The Base-level Industrial Emissions Requirements (BLIERs) are a key element of the Air Quality Management System. BLIERs are intended to apply to major industrial sectors or equipment types to ensure that significant industrial sources achieve a good base-level of performance. Since 2016, several federal regulatory and non-regulatory instruments have been put in place to establish BLIERs for many sectors, pollutants and classes of equipment targeted under the AQMS. The Multi-Sector Air Pollutants Regulations (MSAPR) establish the BLIERs for addressing boilers and heaters, stationary spark-ignition engines, and cement manufacturing (ECCC, 2016a). In total, the MSAPR is estimated to reduce NO_X emissions by 2,037 kt over the 2016-2035 period (ECCC, 2016a). The estimated cost of industry compliance with these regulations is over $600 million (445 million USD), meaning an approximate cost of $300 ($225 USD) per tonne of NO_X emissions reductions (ECCC, 2016a).

The Off-Road Compression Ignition and Large Spark Ignition Engine Emission Regulations are set to reduce 179,500 tonnes of CO, 26,900 tonnes of NO_X, and 133,000 tonnes of CO_2e between 2021 and 2035 (Government of Canada, 2020a). The regulations will result in an estimated incremental cost of $92 million (70 million USD), yielding a cost of $3,475 ($2600 USD) per tonne of NO_X reduced and $695 ($515 USD) per tonne of CO_2e reduced (Government of Canada, 2020a).

The Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations, which set a stringent performance standard for coal-fired electricity generation units, will result in a net reduction of approximately 214 Mt of CO_2e over 2015-2035 (Government of Canada, 2012b). Cost estimates for this reduction come to about $100 ($75 USD) per tonne of CO_2e reduction (Government of Canada, 2012b).

Based on the above regulations, the cost to reduce emissions from land-based controls in Canada ranges from $200-3,000 per tonne of NO_X reduced and $75-600/tonne per tonne of CO_2e reduced (USD 2023). While estimates for SO_X and PM abatement from land-based sources in Canada and it's Arctic are more uncertain, abatement costs projected in other ECA analyses ranged from $4,500-8,900 per tonne of SO_X abated, $43,000-94,000 per tonne of $PM_{2.5}$ abated, and $1,400-$2,100 per tonne of NO_X abated (IMO, 2022; IMO 2009; IMO, 2016). The costs of the Canadian Arctic ECA are not expected to exceed these ranges; the average abatement costs for NO_X, PM, and SO_X were found to be $1,286 per tonne of NO_X abated, $32,934 per tonne of $PM_{2.5}$ abated, and $7,289 per tonne of SO_X abated (USD 2023). ECA regulations on vessels are anticipated to be a competitive method to reduce emissions in the Arctic.

The above regulations were implemented Canada-wide. The ECA outlined in this proposal is specific to the Arctic region of Canada given that the NA ECA already covers the rest of Canada. Due to extreme weather conditions, limited accessibility, and lack of industry infrastructure, implementing land-based controls in the Arctic can be more costly and difficult than implementation in other Canadian regions. Several Arctic-specific governments-run programs exist, including the Northern Responsible Energy Approach for Community Heat and

Electricity (REACHE) Program, which has funded 139 projects with $29 million since 2016 (CIRNAC, 2022c). Similarly, the Arctic Energy Fund is a federal government-run land-based initiative, which has pledged to invest $400 million into supporting infrastructure projects that improve energy consumption (Infrastructure Canada, 2017). These programs are important in reducing air pollution and investing in Indigenous communities; however, they require voluntary interest and participation by municipal governments, Indigenous Governments, ENGOs, and/or businesses to reduce emissions. The Canadian Arctic ECA, in contrast, would require participation in emission reductions from the shipping industry, a pollution-intensive sector that may require incentives to reduce emissions.

9.8 Economic Impacts on Shipping Engaged in International Trade

If implemented, the Canadian Arctic ECA would have negligible effects on international trade. The costs associated with the proposed ECA are small and would result in minimal increases in the prices of goods transported by ship through this region. There are also few alternatives for large-scale shipping through the Arctic, and ships often provide the most efficient method of transport on a tonne-kilometre basis. Thus, the demand for shipping services in the Arctic is unlikely to change as a result of the proposed ECA. The demand for different marine fuels is also unlikely to change on a large scale since Arctic-transiting vessels comprise such a small segment of buyers in the marine fuel market. This indicates that the ECA will have a negligible effect on global fuel prices or production.

The costs associated with the proposed Canadian Arctic ECA are described earlier in this section. The total cost of fuel switching in the Canadian Arctic is estimated to raise annual operating costs of sealift vessels by about 1% and non-sealift vessels by about 2% in 2027 and 2028. NO_X costs are estimated to increase total operating costs of vessels by <0.1% annually. These costs are low relative to other costs introduced by fluctuating fuel prices, crew wage changes, maintenance costs, vessel repairs, etc., and can be largely passed on to consumers through increased shipping fees. These estimated costs therefore would not pose a significant burden to the shipping industry and would have negligible effects on international trade.

9.9 Summary

In conclusion, the proposed ECA is estimated to have manageable costs given the potential emissions it will reduce of NO_X, SO_X, PM, and black carbon. Further, the relative costs of reducing emissions from ships and the economic impacts on the international shipping industry will be minimal, particularly when compared to the benefits of human health. Thus, this proposal for an ECA fulfils criterion 3.1.8 of Annex VI, Appendix III.

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ANNEX 2

DESCRIPTION OF THE PROPOSED CANADIAN ARCTIC EMISSION CONTOL AREA

1 The proposed Canadian Arctic ECA includes that portion of Canada's Arctic waters (**Annex 3**) where the outer limit is generally setback 3 nautical miles from the 200 nautical mile limit or follows the maritime boundary between Canada and Kingdom of Denmark (Greenland) from the Lincoln Sea to the Labrador Sea. The proposed Canadian Arctic ECA is bound in the Beaufort Sea by the 137th meridian west. The southern outer limit terminates at the 60th parallel north in the Labrador Sea and is adjacent to the existing North American ECA.

2 This proposed Canadian Arctic ECA does not extend into waters subject to the sovereignty, sovereign rights, or jurisdiction of any State other than Canada as is consistent with international law. The proposed Canadian Arctic ECA is without prejudice to any unresolved maritime boundaries.

3 The proposed Canadian Arctic ECA, using the outer limits described above, are defined by two segments starting at the:

.1 Yukon mainland at 68.900° North 137.000° West; following the coordinates listed in Appendix A Table A-1 and ending at the north coast of Hans Island at 80.83183° North 66.45667° West; and

.2 continuing from the south coast of Hans Island at 80.82144° North 66.45067° West, following the coordinates listed in Appendix A Table A-2, and ending at the coast of Newfoundland and Labrador at 60.000° North, 64.160° West.

4 The coordinates are based on the World Geodetic System 1984 (WGS84) datum and are connected by geodesic lines. A list of coordinates of the proposed Canadian Arctic ECA outer boundary are provided in **appendix A, table A-1 and table A-2**.

5 The proposed Canadian Arctic ECA falls within the IMO Arctic Boundary and excludes those waters of the Kingdom of Denmark (Greenland), the Russian Federation, the United States and Norway.

APPENDIX A

LIST OF COORDINATES OF THE PROPOSED CANADIAN ARCTIC ECA OUTER BOUNDARY

Table A-1: List of coordinates of the proposed Canadian Arctic ECA outer boundary starting at the Yukon mainland and ending at the north coast of Hans Island.

POINT	LONGITUDE	LATITUDE
1	-137.000	68.900
2	-137.000	72.943
3	-136.362	73.007
4	-136.341	73.362
5	-136.960	73.939
6	-137.218	74.503
7	-137.120	75.057
8	-136.534	75.821
9	-136.951	76.703
10	-136.579	77.471
11	-135.475	78.121
12	-133.748	78.662
13	-131.416	79.493
14	-129.537	79.886
15	-127.558	80.524
16	-118.604	81.906
17	-116.483	82.272
18	-115.491	82.881
19	-112.120	83.909
20	-97.281	85.769
21	-89.241	86.163
22	-78.993	86.376
23	-60.16942	86.31967
24	-58.17633	85.64869
25	-57.98697	85.37153
26	-57.91136	85.20072
27	-57.22136	84.82608
28	-56.71819	84.36919
29	-56.59628	84.28864
30	-56.49214	84.18414
31	-57.00347	83.17978
32	-57.46303	83.07150
33	-57.54528	83.01583
34	-58.00633	82.74514
35	-58.11303	82.70944
36	-58.19564	82.67814
37	-58.42167	82.58250
38	-58.64267	82.52075
39	-58.83528	82.45864
40	-59.03325	82.38111
41	-59.35633	82.33767
42	-59.53758	82.30906
43	-59.68842	82.28703
44	-59.93431	82.24014
45	-59.93431	82.24014
46	-60.03722	82.20097
47	-62.15997	81.86119
48	-64.14547	81.29817
49	-66.25556	80.84139
50	-66.44942	80.83497
51	-66.45667	80.83183

Table A-2: List of coordinates of the proposed Canadian Arctic ECA outer boundary continuing from the south coast of Hans Island and ending at the coast of Newfoundland and Labrador.

POINT	**LONGITUDE**	**LATITUDE**
52	-66.45067	80.82144
53	-66.44286	80.81986
54	-67.06658	80.75714
55	-68.23981	80.43600
56	-68.78322	80.02983
57	-69.07806	79.67292
58	-72.87267	78.80150
59	-73.76092	78.41744
60	-74.63731	77.51378
61	-74.94142	76.72442
62	-73.26789	75.00000
63	-73.04525	74.84447
64	-72.88108	74.73667
65	-71.76197	74.47775
66	-71.76197	74.47775
67	-71.42789	74.40036
68	-70.55094	74.20700
69	-70.38531	74.16725
70	-70.20267	74.12506
71	-70.11144	74.10258
72	-69.85717	74.04219
73	-69.83886	74.03756
74	-69.51692	73.95903
75	-69.18136	73.87117
76	-68.85239	73.77886
77	-68.81353	73.76958
78	-68.49425	73.69614
79	-68.20567	73.63189
80	-68.09031	73.60847
81	-67.25872	73.51894
82	-66.41653	73.43167
83	-66.13178	73.30800
84	-65.12536	72.84819
85	-65.01044	72.79497
86	-64.97039	72.76267
87	-64.90447	72.72975
88	-64.64567	72.60667
89	-64.43408	72.50972
90	-64.21858	72.41478
91	-63.67581	72.18269
92	-63.50692	72.10556
93	-63.34544	72.02753
94	-63.06433	71.88306
95	-62.87783	71.78683
96	-62.82347	71.74517
97	-62.55583	71.54831
98	-62.52761	71.52886
99	-62.48317	71.48975
100	-62.42289	71.43219
101	-62.29078	71.31633
102	-62.14975	71.20169
103	-61.70889	70.86408
104	-61.62708	70.80283
105	-61.33797	70.59244
106	-61.28503	70.55114
107	-61.17478	70.22469
108	-61.14442	70.14711
109	-61.13197	70.12581
110	-61.06800	70.02797
111	-60.99756	69.93036
112	-60.99022	69.92111
113	-60.96656	69.83025
114	-60.85606	69.49019
115	-60.45664	69.21367
116	-60.39119	69.17064
117	-60.30553	69.11314
118	-60.14981	69.01467
119	-60.03683	68.94719
120	-59.24058	68.63367
121	-59.23347	68.63094
122	-59.07439	68.56700
123	-59.02486	68.54792
124	-58.70094	68.42083
125	-58.64392	68.36111
126	-58.56253	68.26781
127	-58.44878	68.12333

POINT	**LONGITUDE**	**LATITUDE**
128	-58.44297	68.11450
129	-58.41156	68.07097
130	-58.38589	68.03150
131	-58.32697	67.94908
132	-58.16325	67.73758
133	-58.10089	67.66278
134	-58.03450	67.58889
135	-57.96097	67.51269
136	-57.93336	67.48603
137	-57.91681	67.47011
138	-57.90956	67.45458
139	-57.87253	67.35867
140	-57.71394	66.82456
141	-57.67247	66.69522
142	-57.65753	66.63128
143	-57.64978	66.60028
144	-57.63392	66.50453
145	-57.62600	66.40833
146	-57.62589	66.31136
147	-57.63347	66.21400
148	-57.65758	66.05828
149	-57.66544	65.96028
150	-57.66544	65.95833
151	-57.67400	65.86247
152	-57.67428	65.84683
153	-57.69575	65.62647
154	-57.70294	65.57908
155	-57.74719	65.38875
156	-57.76161	65.30139
157	-57.74986	65.24203
158	-57.73700	65.19158
159	-57.72811	65.14650
160	-57.73253	65.10069
161	-57.80144	64.20106
162	-57.81686	64.07003
163	-57.88994	63.95608
164	-57.94108	63.87614
165	-57.95025	63.83411
166	-57.97664	63.73311
167	-58.01672	63.61936
168	-58.03100	63.58367
169	-57.99372	63.47706
170	-57.95486	63.38092
171	-57.68042	62.78567
172	-57.41872	62.18911
173	-57.36922	62.05786
174	-57.36028	62.03714
175	-57.34861	62.00650
176	-57.26928	61.41225
177	-57.645	61.169
178	-57.294	60.726
179	-57.076	60.256
180	-56.717	60.000
181	-64.160	60.000

ANNEX 3

CHART OF THE PROPOSED CANADIAN ARCTIC EMISSION CONTROL AREA

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ANNEX 4

PROPOSED AMENDMENT TO REGULATIONS 13 AND 14 AND APPENDIX VII IMPLEMENTING THE PROPOSED EMISSION CONTROL AREA

Regulation 13
Nitrogen Oxides (NO_X)
…
Tier III

Amend paragraph 5 as follows indicated in underlined text:

5.1 Subject to regulation 3 of this Annex, in an emission control area designated for Tier III NOx control under paragraph 6 of this regulation (NO_X Tier III emission control area), the operation of a marine diesel engine that is installed on a ship is prohibited:

.1 except when the emission of nitrogen oxides (calculated as the total weighted emission of NO_2) from the engine is within the following limits, where *n* = rated engine speed (crankshaft revolutions per minute):

.1 3.4 g/kWh when *n* is less than 130 rpm;

.2 $9\ n^{(-0.2)}$ g/kWh when *n* is 130 or more but less than 2,000 rpm;

.3 2.0 g/kWh when *n* is 2,000 rpm or more;

When

.2 that ship is constructed on or after:

.1 1 January 2016 and is operating in the North American Emission Control Area or the United States Caribbean Sea Emission Control Area;

.2 1 January 2021 and is operating in the Baltic Sea Emission Control Area or the North Sea Emission Control Area;

.3 that ship is operating in a NO_X Tier III emission control area other than an emission control area described in paragraph 5.1.2 of this regulation, and is constructed on or after the date of adoption of such an emission control area, or a later date as may be specified in the amendment designating the NO_X Tier III emission control area, whichever is later; and

.4 1 January 2025 and is operating in the Canadian Arctic Emission Control Area.

Amend paragraph 6 as follows:

Emission control area

6 For the purposes of this regulation, a NO_X Tier III emission control area shall be any sea area, including any port area, designated by the Organization in accordance with the criteria and procedures set forth in appendix III to this Annex. The NO_X Tier III emission control areas are:

.1 the North American Emission Control Area, which means the area described by the coordinates provided in appendix VII to this Annex;

.2 the United States Caribbean Sea Emission Control Area, which means the area described by the coordinates provided in appendix VII to this Annex;

.3 the Baltic Sea area as defined in regulation 1.11.2 of Annex I of the present Convention; and

.4 the North Sea area as defined in regulation 1.14.6 of Annex V of the present Convention; and

.5 the Canadian Arctic Emission Control Area, which means the area described by the coordinates provided in appendix VII to this Annex.

Regulation 14
Sulphur oxides (SO_X) and particulate matter

Amend paragraph 3 as follows:

Requirements within emission control areas

3. For the purpose of this regulation, an emission control area shall be any sea area, including any port area, designated by the Organization in accordance with the criteria and procedures set forth in appendix III to this Annex. The emission control areas under this regulation are:

.1 the Baltic Sea area as defined in regulation 1.11.2 of Annex I of the present Convention;

.2 the North Sea area as defined in regulation 1.14.6 of Annex V of the present Convention;

.3 the North American Emission Control Area, which means the area described by the coordinates provided in appendix VII to this Annex; ~~and~~

.4 the United States Caribbean Sea Emission Control Area, which means the area described by the coordinates provided in appendix VII to this Annex; and

.5 the Canadian Arctic Emission Control area, which means the area described by the coordinates provided in appendix VII to this Annex.

Emission control areas (regulations 13.6 and 14.3)

Amend Appendix VII Emission control areas (regulations 13.6 and 14.3) as follows:

1 The boundaries of emission control areas designated under regulations 13.6 and 14.3, other than the Baltic Sea and the North Sea areas, are set forth in this appendix.

2 The North American area comprises:

.1 the sea area located off the Pacific coasts of the United States and Canada, enclosed by geodesic lines connecting the following coordinates:

3 The United States Caribbean Sea area includes:

.1 the sea area located off the Atlantic and Caribbean coasts of the Commonwealth of Puerto Rico and the United States Virgin Islands, enclosed by geodesic lines connecting the following coordinates:

4 The Canadian Arctic area comprises of two segments starting at the:

.1 Yukon mainland at 68.900° North 137.000° West; following the coordinates listed below and ending at the north coast of Hans Island at 80.83183° North 66.45667° West; and

.2 continuing from the south coast of Hans Island at 80.82144° North 66.45067° West, following the coordinates listed below, and ending at the coast of Newfoundland and Labrador at 60.000° North, 64.160° West, enclosed by geodesic lines connecting the following coordinates:

POINT	LONGITUDE	LATITUDE
1	-137.000	68.900
2	-137.000	72.943
3	-136.362	73.007
4	-136.341	73.362
5	-136.960	73.939
6	-137.218	74.503
7	-137.120	75.057
8	-136.534	75.821
9	-136.951	76.703
10	-136.579	77.471
11	-135.475	78.121
12	-133.748	78.662
13	-131.416	79.493
14	-129.537	79.886
15	-127.558	80.524
16	-118.604	81.906
17	-116.483	82.272
18	-115.491	82.881
19	-112.120	83.909
20	-97.281	85.769
21	-89.241	86.163
22	-78.993	86.376
23	-60.16942	86.31967
24	-58.17633	85.64869
25	-57.98697	85.37153
26	-57.91136	85.20072
27	-57.22136	84.82608
28	-56.71819	84.36919
29	-56.59628	84.28864
30	-56.49214	84.18414
31	-57.00347	83.17978
32	-57.46303	83.07150
33	-57.54528	83.01583
34	-58.00633	82.74514
35	-58.11303	82.70944
36	-58.19564	82.67814
37	-58.42167	82.58250
38	-58.64267	82.52075
39	-58.83528	82.45864
40	-59.03325	82.38111
41	-59.35633	82.33767
42	-59.53758	82.30906
43	-59.68842	82.28703
44	-59.93431	82.24014

POINT	LONGITUDE	LATITUDE
45	-59.93431	82.24014
46	-60.03722	82.20097
47	-62.15997	81.86119
48	-64.14547	81.29817
49	-66.25556	80.84139
50	-66.44942	80.83497
51	-66.45667	80.83183
52	-66.45067	80.82144
53	-66.44286	80.81986
54	-67.06658	80.75714
55	-68.23981	80.43600
56	-68.78322	80.02983
57	-69.07806	79.67292
58	-72.87267	78.80150
59	-73.76092	78.41744
60	-74.63731	77.51378
61	-74.94142	76.72442
62	-73.26789	75.00000
63	-73.04525	74.84447
64	-72.88108	74.73667
65	-71.76197	74.47775
66	-71.76197	74.47775
67	-71.42789	74.40036
68	-70.55094	74.20700
69	-70.38531	74.16725
70	-70.20267	74.12506
71	-70.11144	74.10258
72	-69.85717	74.04219
73	-69.83886	74.03756
74	-69.51692	73.95903
75	-69.18136	73.87117
76	-68.85239	73.77886
77	-68.81353	73.76958
78	-68.49425	73.69614
79	-68.20567	73.63189
80	-68.09031	73.60847
81	-67.25872	73.51894
82	-66.41653	73.43167
83	-66.13178	73.30800
84	-65.12536	72.84819
85	-65.01044	72.79497
86	-64.97039	72.76267
87	-64.90447	72.72975
88	-64.64567	72.60667

POINT	**LONGITUDE**	**LATITUDE**
89	-64.43408	72.50972
90	-64.21858	72.41478
91	-63.67581	72.18269
92	-63.50692	72.10556
93	-63.34544	72.02753
94	-63.06433	71.88306
95	-62.87783	71.78683
96	-62.82347	71.74517
97	-62.55583	71.54831
98	-62.52761	71.52886
99	-62.48317	71.48975
100	-62.42289	71.43219
101	-62.29078	71.31633
102	-62.14975	71.20169
103	-61.70889	70.86408
104	-61.62708	70.80283
105	-61.33797	70.59244
106	-61.28503	70.55114
107	-61.17478	70.22469
108	-61.14442	70.14711
109	-61.13197	70.12581
110	-61.06800	70.02797
111	-60.99756	69.93036
112	-60.99022	69.92111
113	-60.96656	69.83025
114	-60.85606	69.49019
115	-60.45664	69.21367
116	-60.39119	69.17064
117	-60.30553	69.11314
118	-60.14981	69.01467
119	-60.03683	68.94719
120	-59.24058	68.63367
121	-59.23347	68.63094
122	-59.07439	68.56700
123	-59.02486	68.54792
124	-58.70094	68.42083
125	-58.64392	68.36111
126	-58.56253	68.26781
127	-58.44878	68.12333
128	-58.44297	68.11450
129	-58.41156	68.07097
130	-58.38589	68.03150
131	-58.32697	67.94908
132	-58.16325	67.73758
133	-58.10089	67.66278
134	-58.03450	67.58889
135	-57.96097	67.51269
136	-57.93336	67.48603
137	-57.91681	67.47011
138	-57.90956	67.45458
139	-57.87253	67.35867
140	-57.71394	66.82456
141	-57.67247	66.69522
142	-57.65753	66.63128
143	-57.64978	66.60028
144	-57.63392	66.50453
145	-57.62600	66.40833
146	-57.62589	66.31136
147	-57.63347	66.21400
148	-57.65758	66.05828
149	-57.66544	65.96028
150	-57.66544	65.95833
151	-57.67400	65.86247
152	-57.67428	65.84683
153	-57.69575	65.62647
154	-57.70294	65.57908
155	-57.74719	65.38875
156	-57.76161	65.30139
157	-57.74986	65.24203
158	-57.73700	65.19158
159	-57.72811	65.14650
160	-57.73253	65.10069
161	-57.80144	64.20106
162	-57.81686	64.07003
163	-57.88994	63.95608
164	-57.94108	63.87614
165	-57.95025	63.83411
166	-57.97664	63.73311
167	-58.01672	63.61936
168	-58.03100	63.58367
169	-57.99372	63.47706
170	-57.95486	63.38092
171	-57.68042	62.78567
172	-57.41872	62.18911
173	-57.36922	62.05786
174	-57.36028	62.03714
175	-57.34861	62.00650
176	-57.26928	61.41225

POINT	**LONGITUDE**	**LATITUDE**
177	-57.645	61.169
178	-57.294	60.726
179	-57.076	60.256

POINT	**LONGITUDE**	**LATITUDE**
180	-56.717	60.000
181	-64.160	60.000