Smith School of Enterprise and the Environment

UNIVERSITY OF OXFORD

The future of Arctic enterprise: Long-term outlook and implications

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Executive Summary

This report focuses on the outlook for the development of existing and new economic activity in the Arctic marine region.

Over the next 20 years, shipping, oil and gas, mining, tourism and aquaculture will be the key sectors of economic activity. The factors shaping the future development of each economic sector are diverse and include, political, economic, socio-cultural, technological, demographic, legal and regulatory, and ecological-environmental changes. Furthermore, there are synergies in the development of individual sectors, most notably in linkages between shipping and other sectors.

Despite the considerable uncertainties relating to existing and future economic development in the Arctic, concerns about the long term and sustainable development of the Arctic marine region are set to increase. This study draws attention to new 'hotspots' that could emerge from the synergies between different sectors and the interplay of economic activity with political and social developments in the context of climate change and cumulative environmental impacts.

The developing of more shared and systemic understanding of changes, synergies and challenges is needed if peaceful and sustainable development is to be enabled. Given the limits of forecast-based planning and the need for more systemic insights and interventions, inter-organisational scenario based initiatives are recommended.

Introduction

The Arctic region consists of a vast, ice-covered ocean surrounded by treeless permafrost. It is a unique habitat: indigenous peoples, other species, and plant life have co-evolved to form fragile, socio-ecological systems adapted to the extreme conditions of ice and cold.

The Arctic is often perceived as an outpost or frontier in a world of increasing global population and ever expanding human settlements and industrialisation. It is, however, a region undergoing significant changes, driven by a combination of economic and political developments, as well as climatic and other environmental changes.

For example, the region is subject to multiple systems and different jurisdictions of governance, and a dynamic of economic and political change is in play. Boundary disputes continue to exist among Arctic States but so far have been settled through peaceful negotiation. There is much speculation about potential new claims to resource, shipping routes and access rights by non-Arctic states. There has been increased interest in the in scientific research in the Arctic by nations who are not in the Arctic region, including China, who have launched a plan focussing on polar exploration, have established a research base in the Svalbard Archipelago. In addition there is speculation about governance rights in the Arctic, particularly in light of the European Union and China's 2008 application to gain observer status in the Arctic Council, as both display a growing interest in taking a more active role in the Arctic issues[a]. The prospect of an ice-free Arctic is expected to extend existing forms of economic activity in the region, as well as open up opportunities for new forms.

The Arctic region is also undergoing a multitude of environmental changes. These changes include the detection of persistent organic chemicals from activities in other regions and the disturbance of fragile species and ecosystems from larger scale economic activity in the region, notably, oil and gas exploration, and production and shipping. More recently, attention has focussed on the impacts of climate change on the marine environment in the region, in particular the notable reduction of sea ice and associated implications, such as water column mixing, benthic scraping and the possible shift of large marine ecosystems. Other impacts associated with climate change and the Arctic marine environment includes changes in salinity, changes to ocean acidification and pH levels, and effects on freshwater budget, surface chemistry, and ocean circulation patterns.

The co-evolution of political developments, economic activities and environmental changes in the region is characterised by complex dynamics and irreducible uncertainty. This report focuses on the outlook for the development of existing and new economic activity in the Arctic marine region, and on a range of different sectors.

The remainder of this section provides further introduction to the challenge of defining the Arctic marine environment, as well as information on governance frameworks and climate change impacts.

Section 1 identifies existing economic uses and users relevant to the Arctic marine environment.

[a] The Official Chinese News Service reported remarks by Chinese Rear Admiral Yin Zhuo stating "The Arctic belongs to all the people around the world as no nation has sovereignty over it. China must play an indispensable role in Arctic exploration as we have one-fifth of the world's population". This statement has caused some speculation about the nature of China's interest in the region.

Section 2 contains a sector-by-sector analysis of existing and prospective Arctic marine uses and users and provides an initial assessment of the wider, contextual factors that will influence future developments in each sector.

Section 3 provides a baseline of present and projected activity based on a business-as-usual extrapolation of key trends.

Section 4 draws on initial assessments of contextual factors driving the development of individual sectors to identify the system of co-evolving changes shaping Arctic marine enterprise development.

Section 5 identifies 'hotspots' – areas of concern arising from the intersection of economic, social, political and ecological changes.

Definitional challenges

The Arctic Ocean, at 14.3 million km^2, is the smallest of the world's five oceans [1]. The Arctic has permanent ice cover at the centre, with a variation in the extent of the ice pack during the year. Definitions of the Arctic region vary; so while the Arctic circle is clearly defined as the 66 degree north line, the Arctic region is subject to various definitions. One defining threshold of the Arctic environment that is often used is set by the 10°C July isotherm [2]. This isotherm marks the southern Arctic boundary where the monthly mean temperature in July is below 10°C. This limit also closely corresponds to the northern limit of the tree line. Based on the Arctic Human Development Report definition of the Arctic region it encompasses an area of over 40 million square kilometres or about 8% of the surface of the Earth. The human residents of this vast area number only about 4 million, of whom almost half are located within the Russian Federation [3], and approximately 10% of whom are classified as indigenous [1].

Existing governance frameworks

Management and governance of such a large area, particularly with disputed geographic boundaries is challenging as well as complex. To date, there are eight bilateral agreements delimiting maritime zone and continental shelf boundaries between the countries that border the Arctic Ocean, however many unresolved boundary issues remain. Six countries border the Arctic Ocean: the USA, Canada, Denmark (Greenland & the Faroe Islands), Iceland, Norway and Russia. Together with Sweden and Finland these countries form the Arctic Council[b], the only circumpolar forum for political discussions on Arctic issues, involving all the Arctic states, and with the active participation of its indigenous communities. The Arctic Council provides a means of promoting cooperation, coordination and interaction among the Arctic states, with the express involvement of Arctic indigenous communities and other Arctic inhabitants on common Arctic issues, especially issues of sustainable development and environmental protection in the Arctic [4].

The environment in the circumpolar North represents one of the areas of the world with the least human impact. Each coastal country legally has sovereignty claims to its coastal waters as

[b] Observer status in the Arctic Council is open to non-Arctic states that the Council determines can contribute to its work. Permanent Observer States include: France, Germany, Netherlands, Poland, Spain, and United Kingdom. Ad-hoc Observer States need to request permission for their presence at each individual meeting, and includes: China, European Union, Italy, Japan, and South Korea. Non-state actors are also welcome to observe; nine intergovernmental and inter-Parliamentary Organizations have been given observer status, including the United Nations Economic Commission for Europe and the United Nations Development Programme, while eleven non-government organizations are observers in the Arctic Council including the Advisory Committee on Protection of the Seas and Arctic Circumpolar Gateway.

defined by the United Nations Convention on the Law of the Sea (UNCLOS, also called the Law of the Sea Convention or the Law of the Sea treaty). These territories encompass both Shelf and High Seas components of the Arctic waters (see [5] for details). The UNCLOS defines territorial sea areas as those within the limit of the 12 nautical miles of a country's coast. Beyond this area, up to 200 nautical miles from a country's coast, Arctic coastal states have full sovereignty but foreign ships retain the right to continuous, expeditious and peaceful passage. This sea zone is known as the exclusive economic zone (EEZ) to which each coastal country has and includes rights to the seabed. This sovereign sea area may include the continental shelf beyond the 200 nautical mile limit. Outside this area are the High Seas [2].

Climate change impacts

The Arctic Climate Impact Assessment (ACIA) documented that Arctic sea ice extent has been declining for the past five decades. Research has also indicated that sea ice thickness has been decreasing during the same period, and the area of multi-year ice has also been declining in the central Arctic Ocean. Climatic conditions in the Arctic regions are expected to continue to change over the coming decades with an expectation that there will be a lengthening of the season of ice-free area in the marginal ice zone in the summer months and an increase in the area that is free of ice in the seasonal ice zone. A completely ice-free Arctic is highly unlikely within this century, however the ACIA projections indicate an increasing length of the navigation season for the Northern Sea Route (20-30 days per year in 2004, to 90-100 days by 2080) [6]. This opens a window to the region by increasing the likelihood of technically possible and safe transpolar voyages and resource extraction.

Other potential climate-induced changes in the region include; increased surface air temperatures (the IPCC reports that air temperatures have warmed at approximately twice the global rate), a reduction in albedo effects, alterations in the freshwater budget of the Arctic Ocean through increases in freshwater run-off caused by glacial retreat, increased coastal erosion, and an increase in the depth of permafrost seasonal thawing [1].

Meanwhile worldwide climate change impacts will not only affect salinity levels, but also ocean temperatures and circulation patterns with knock-on impacts in the Arctic region. Such changes will have significant effects on the uses and users of the Arctic, with increasing access to the Arctic opening the way for new uses and changing the patterns of behaviour of current users.

1. Identifying Uses and Users

Within the area defined in the previous discussion, current enterprise related uses and active users identified for this forecast study include:

- Shipping;
- Fishing;
- Oil and gas;
- Mining;
- Tourism;
- Defence.

Potential uses and users that may come online soon or within the next 20 to 30 years include:

- Bio-prospecting;
- Aquaculture;
- Deep sea mineral prospecting;
- Carbon capture and storage;
- New renewable energy production.

In 2009 an attempt to identify the causes and migration of introduced species in the Arctic produced an overview of Arctic marine activities, mapping the current shipping routes of the Arctic [2]. This highlighted the zones of current marine activities as shown in *Figure 1*. This showed an apparent connection between Arctic shipping routes and Arctic services connecting resource based activities, such as mining, fishing, and oil and gas. Currently these activities are relatively restricted to areas of ice-free coastal waters (whether year round or seasonally).

Examples of services and resources exploited today in the Arctic include:

- In the Canadian Archipelago, decreasing seasonal ice growth in the Northwest Passage is allowing access for increased destinational[c] shipping. These trans-Arctic routes are expected to become increasingly popular.

- Offshore hydrocarbon developments in the Beaufort Sea, Norwegian Sea and Chukchi Sea are leading to an increase in marine traffic in the Bering Strait and Norwegian Sea regions *(see Figure 2)*. Marine transportation of oil and gas from North West Russia to Europe is now considered technically and economically feasible due to recent successful attempts to cross this region.

- The Bering Strait region is populated with many indigenous communities and has a highly productive ecosystem with many species of marine mammals, fish and seabirds that are actively harvested for food on both small and large scales.

- Onshore mining, while well established in some regions such as Scandinavia and western Russia, is being developed in more remote locations in the Canadian Archipelago and central and eastern Russia.

[c] Destinational transport is where a ship sails to the Arctic, performs some activity in the Arctic and sails south. This category involves either shipping out resources extracted in the Arctic or shipping in goods to the many Arctic communities that depend on such deliveries for their supply of goods and fuel. *http://eyeonthearctic.rcinet.ca/en/blog/136-heather-exner-pirot/793-what-route-for-arctic-shipping.*

Arctic Communities and the marine environment are pressured by competing economic and environmental demands. Aside from the enterprise users listed previously, further pressures arise from public opinion, neighbouring communities, business corporations, NGOs, and state, local and national governments, all of whose interests must be balanced.

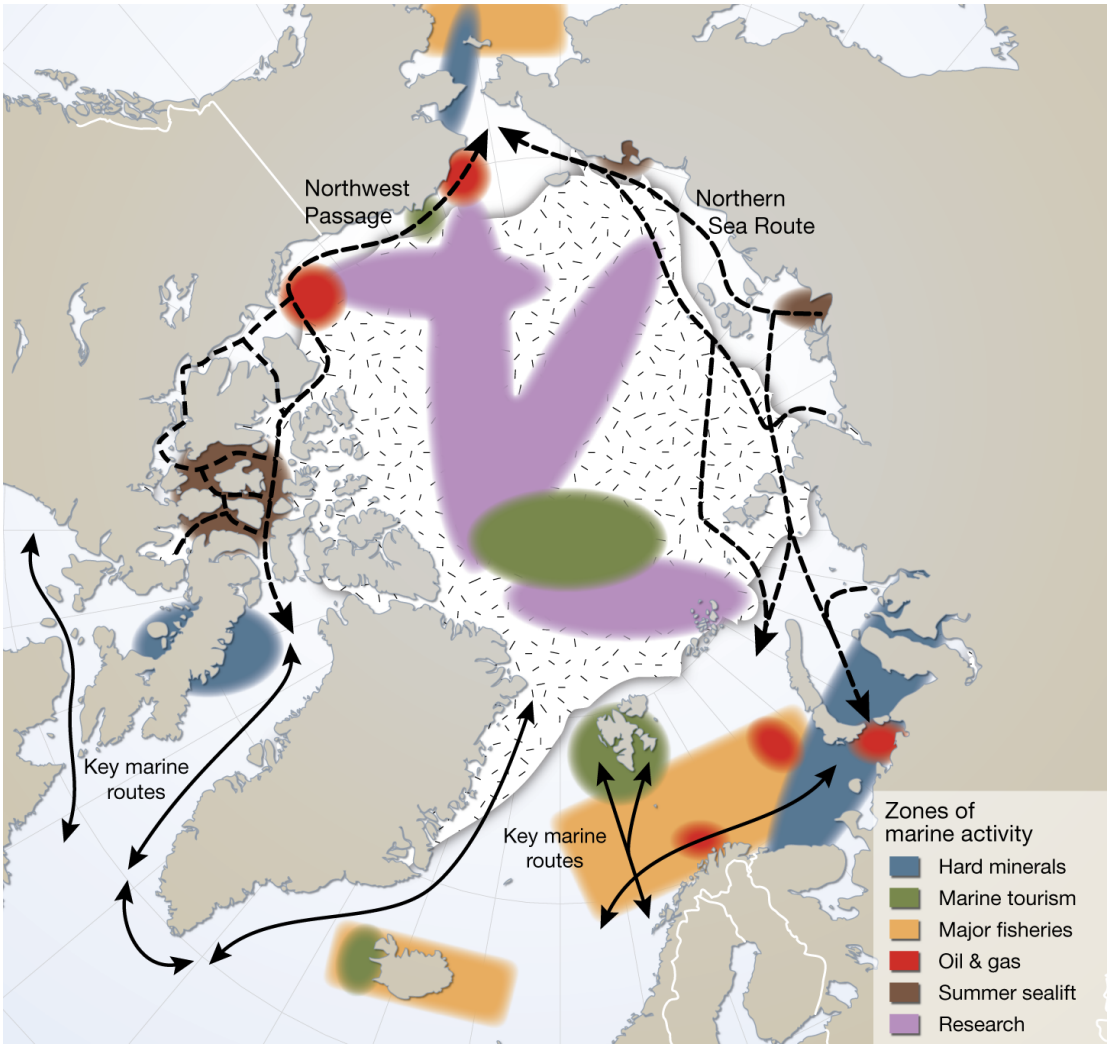


Figure 1. Zones of current marine enterprise in the Arctic [7].

2. Analysis of Arctic Marine Uses and Users

This section gives a sector-by-sector analysis of existing and prospective Arctic marine uses and users, and provides an initial assessment of the wider, contextual factors that will influence future developments in each sector. An overview is provided in the figures at the end of each sector.

Current users

Shipping

Historically, transiting northerly routes over Europe, Asia, and North America has been difficult due to seasonal ice growth and the movement of ice through these routes during the short open season. Although historically focussed on securing trans-Arctic travel routes, Arctic voyages have been overwhelmingly destinational and mainly for community re-supply, marine tourism, and the movement of natural resources out of the Arctic. There are three different shipping fleet types that navigate the Arctic Ocean: Logistics and transport ships, industry services and locational ships, and fishing fleets.

There were approximately 3,000 vessels in the Arctic in 2004. Of these, some 1,600 were fishing vessels that reported their activity and did not venture far into the Arctic Ocean [2]. The remaining 1,400 trips include short haul trips to various ports for resupply and resource extraction. Operations have been primarily in areas that are ice-free, either seasonally or year-round. In the past decade shipping has increased throughout the Arctic and in recent years icebreaking ships have frequently navigated the central Arctic Ocean in the summer. Alternative routes which link Europe and Asia through the north could be navigable for longer periods of the year *(Figure 2).* These are The Northwest Passage, a sea route through the Arctic Ocean linking Europe to Asia north of Canada, and the Northern Sea Route, a passage north of Europe and Asia.

While an extended open season and receding multi-year ice are predicted, this in the short term results in weakening blockages or ‘ice bridges’ that flush or move ice through channels and straits. Thus polar shipping, though more accessible, is becoming more complex than is commonly assumed, especially in the Northwest Passage where navigation is increasingly hazardous. It was not until very recently that reliable voyages have been possible, and even those voyages occurred in a narrow window of opportunity *(Appendix: Table 1)*. Thus while the reduction in sea ice may make the northern sea routes attractive to merchant mariners wishing to reduce voyage times, paradoxically in the short term hazards may be increased. Due to climate change the nature and extent of the hazards may be difficult to ascertain, at least in the near future.

Currently, Arctic marine traffic is predominantly based on servicing destinations with very few trans-Arctic merchant activities *(Appendix: Table 1)*. Regions of high concentration of Arctic shipping activity occur along the coasts of northwest Russia and in seasonally ice-free water offshore Norway, Greenland, Iceland and the Bering Sea. Traffic is more established and more developed off the coast of Russia where the Northern Sea Route is maintained by a fleet of nuclear-powered icebreakers to transport mining products and link coastal towns. Maritime traffic is currently minor or exploratory off the coast of Canada, but could increase with the reduction of pack ice.

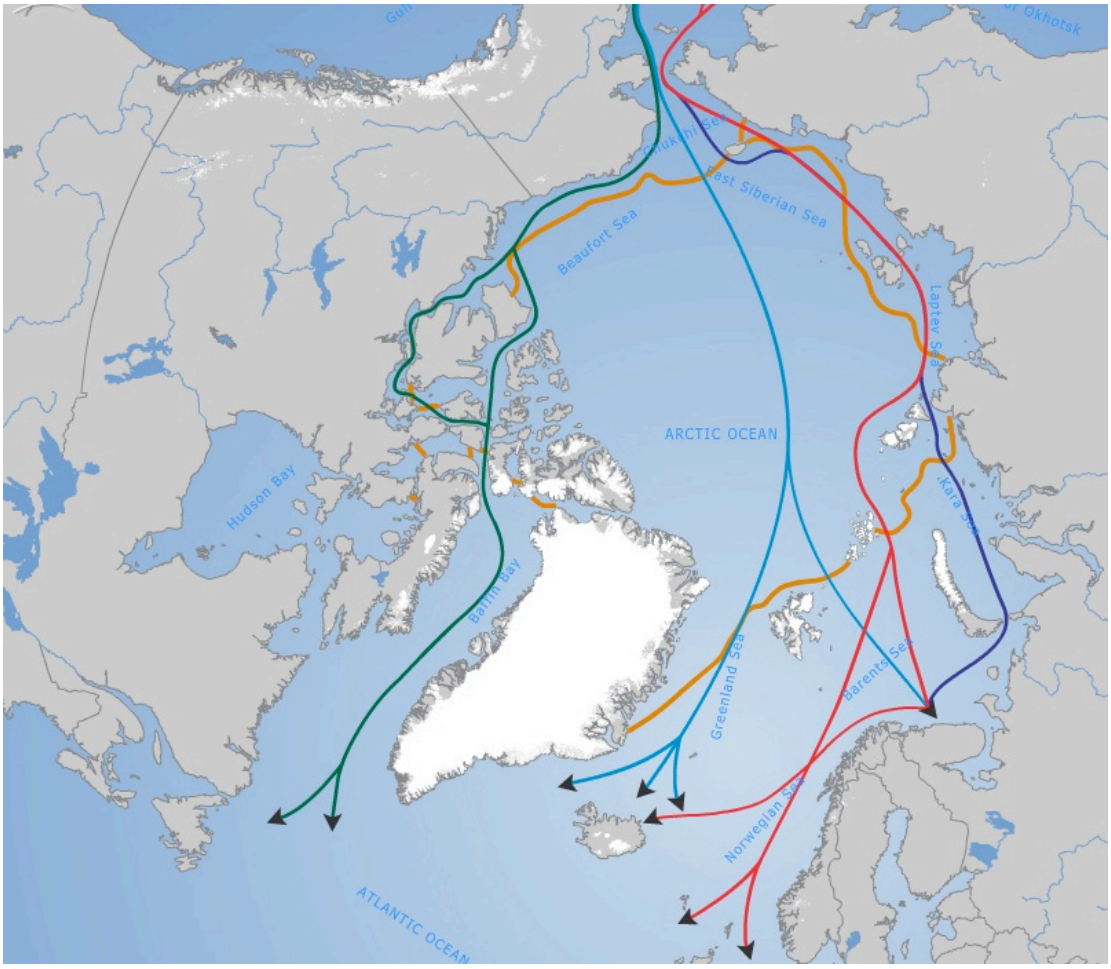


Figure 2. Current and expected major shipping routes through the Arctic region. The orange line indicates the median sea ice edge; green indicates the Northwest Passage, red indicates the Northern Sea Routes, and blue indicates the future Central Arctic route [6, 8].

A lack of major ports, apart for those in northern Norway and northwest Russia, and other critical infrastructure has caused significant limitations for Arctic marine operations. With reductions in the extent of sea ice, the long-term horizon creates the possibility of increasing usage of Arctic waters for transport shipping. New shipping routes through the Arctic could have similar effects and impacts to that of the transformation of the Middle East by the opening of the Suez Canal, where benefits would include the potential distances saved and associated economic and environmental advantages (in terms of reduced voyage time, reduced fuel consumption and reduced emissions). In addition, climate-related effects on the Panama Canal (as a rain-fed system) may drive this adaption to trans-Arctic shipping. Examples of the benefits of such voyages are detailed in *Appendix: Table 2*.

A major Arctic marine shipping interest is to cater to the transportation of equipment and material during site development and operation. From the Arctic raw material such as oil, gas, coal, minerals, and timber is removed. All of these activities are dependent on accessible ports. Traditionally, transit in the eastern Arctic and western Arctic has had different requirements for cargo. With the Northern Sea Route, servicing northern Europe and Russia is becoming easier to facilitate. Year-round operations are driven largely by natural resource development such as mining in the Canadian Arctic and northwest Russia where conditions allow. Over time, the network of Arctic ports has developed to support local mines and fossil fuel extraction, further enabling trans-Arctic shipping *(Appendix: Table 3)*.

This increased access to resources has given rise to questions over access to waterways and ownership of resources in the Arctic. It could also give rise to oil spills in areas where clean up is made considerably more difficult due to ice conditions, and where oil spills in a cold ocean could last longer than in lower latitudes. It is also likely to give rise to sovereignty, security, safety and environmental issues as access to the area increases. This will require Arctic (and even non-Arctic) States to co-operate to a much greater degree.

Fisheries

Until recent years, the sector with the dominant share of the Arctic's maritime economy was fishing. The FAO defines Arctic-fishing zones in their accounting as Major Fishing Areas 18 and portions of 27 (I, II, and XIV). The Arctic is subjected to both large and small-scale fishing. Small-scale fishing is primarily the domain of indigenous peoples who engage mostly in coastal fishing, and this activity is on the decrease *(Figure 3)*. European countries practice deep-sea fishing in the seas of Norway, Greenland, and the Barents Sea. Relatively small volumes of fish are extracted from the Davis Strait and in Baffin Bay. The main species found in the Arctic are cod, haddock, black halibut, and herring. Fish catches are used for human food, fish oil (used as an energy source in fish feeds), and fishmeal (primarily used as a protein source in animal feeds).

Cumulative fisheries' catches for the Arctic for the period 1950–2006 have been officially reported as 12,700 tonnes by Russia (former Soviet Union), while no catches have been reported by the USA or Canada. Researchers estimate that fisheries' catches in the Arctic totalled 950,000 tonnes from 1950 to 2006 (being 770,000 tonnes by Russia, 89,000 tonnes by USA, and 94,000 tonnes by Canada), almost 75 times the amount reported to the United Nations Food and Agriculture Organization (FAO) during this period [9].

It is also believed that currently, Arctic fishing activities are on the decrease, having gone from 254,000 tonnes per year to just over 10,000 tonnes in over 60 years *(Figure 3)*. With regard to individual large marine ecosystems[d] (LMEs), over 80% of total catches were taken in three exclusively Russian LMEs (Kara Sea, Laptev Sea, and East Siberian Sea LME), illustrating a marked reliance of the relatively large local population on coastal marine resources [9].

Although not reported to be affecting Arctic fisheries, global fisheries are expected to have hit a maximum in the late 1980s with what is now referred to as 'peak fish' [10]. *Figure 4* shows that while North Atlantic fish stocks were healthy 100 years ago, available harvestable biomass in the area has been close to eliminated and that fish stock depletion is encroaching on Arctic territory. This means that fisheries are forced to consider travelling the extra distance to find viable fish stocks. The trend shown in *Figure 4* indicates that a northward move is one of two options for fisheries to consider when looking for their next stock.

[d] Large marine ecosystems (LMEs) are regions of the world's oceans, encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margins of the major ocean current systems.

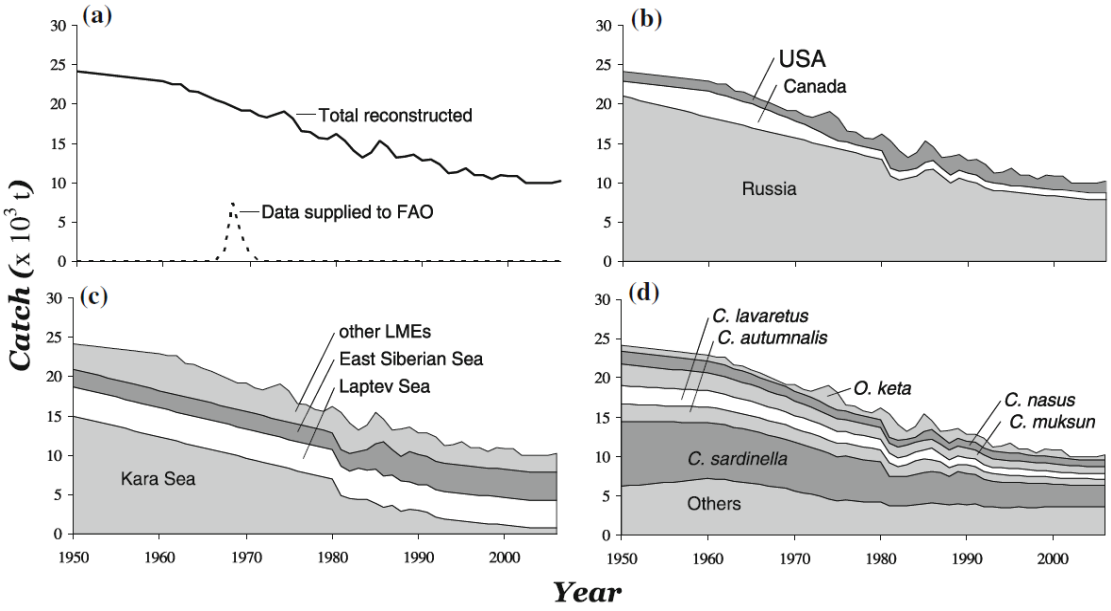
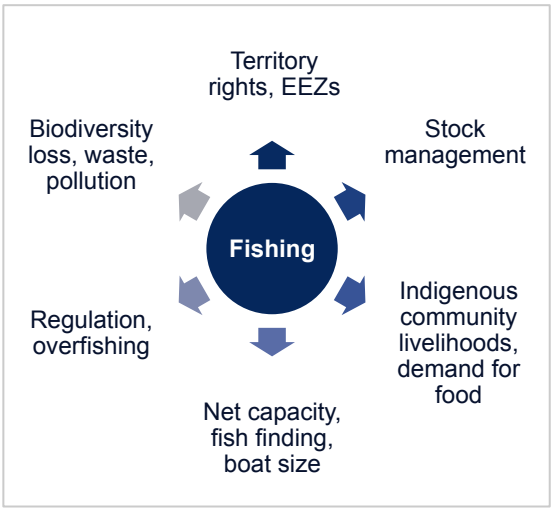


Figure 3. Fisheries' catches in the Amerasian Arctic, showing (a) reconstructed total catches versus catches reported to FAO; (b) reconstructed total catches by the three countries covered by FAO Statistical Area 18 (Russia, USA, Canada); (c) reconstructed total catches by the seven near-shore Large Marine Ecosystems comprising FAO 18; and (d) reconstructed total catches by major taxa. Zeller et al., 2011 [9].

The current estimates of the impact of climate change on fisheries is that projected climatic trends will result in no more than a 1% change in worldwide fish catch by 2050 [11]. Impacts on marine systems in general as a result of climate change may include; changes in water temperature, pH, ocean currents, and coastal upwelling, all of which will impact primary productivity, species distribution, and food-web structures. However regional impacts on the locations and distributions of fish will occur, which may have significant impacts for the Arctic. Modelling analysis by Cheung et al. suggests as ocean temperatures increase in the tropics and areas such as the Mediterranean, fish species are likely to move northward, decreasing fish catch potential at medium latitudes and increasing catch potential at higher latitude by up to 20% [12].



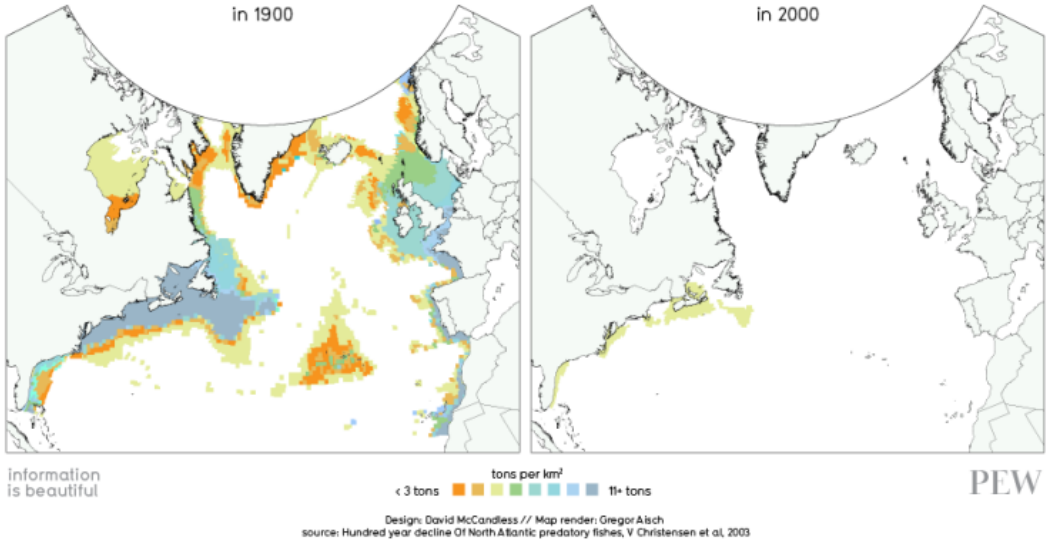


Figure 4. Available fish biomass in the North Atlantic [13].

Oil and Gas

In 2008, the US Geological Survey (USGS) produced an in-depth analysis of the anticipated oil and gas resources available for extraction. The USGS estimates that the seabed contains about 13% of the world's remaining undiscovered oil, 30% of the undiscovered natural gas, and 20% of the undiscovered natural gas liquids [14]. Of these resources about 84% of the estimated resources are expected to occur offshore. *Figure 5* indicates the likelihood of reserves to be found in the region.

The estimated volume of oil and gas in the Arctic is [14]:

Oil	2.55×10^9 cubic metres (1.6×10^{10} oil barrels)
Natural gas	4.81×10^{13} cubic metres
Natural gas liquids	1.25×10^9 cubic metres

Current estimates on the value of Arctic oil and gas have been placed at US $11.93 billion in 2011, anticipating growth over the next ten years [15].

The 2008 USGS study declares that the vast majority of the Arctic known to contain gas and oil resources is on the continental shelves and therefore already within uncontested EEZs, with a small amount in contested zones [5]. This is partly why ownership disputes exist. Countries want to 'sell' rights to areas of water for extraction.

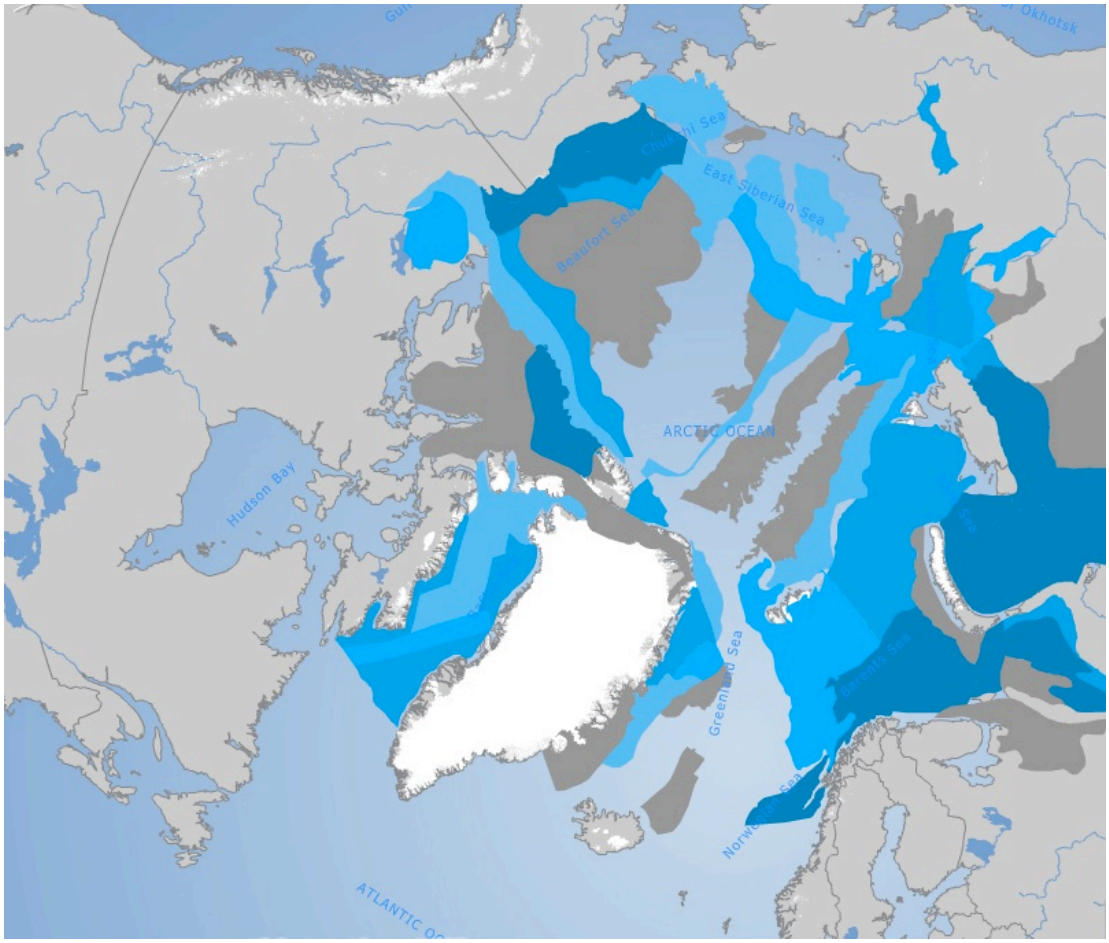
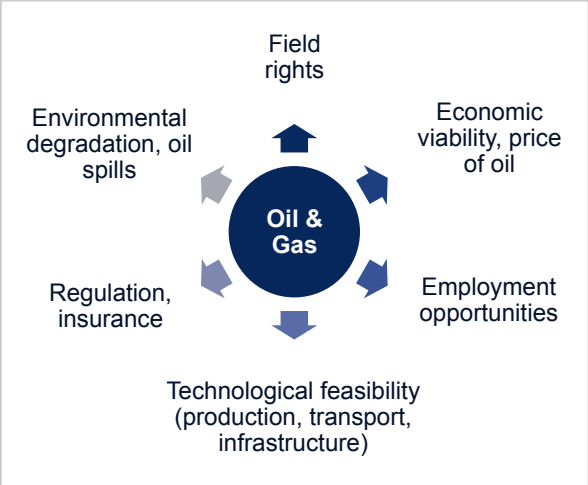


Figure 5. Potential oil and gas in the Arctic region. Dark blue indicates 100% potential, ranging down to very light blue indicating less than 10% potential [8, 14].

To date, offshore drilling in the Arctic has been limited due to the technical difficulty. The challenges are summarised below.

- The modern drill-ships needed are only starting to be built, the US hasn't built new drill-ships since the 1970s;
- Submersible drilling rigs can be used but they can only be moved in open water season and work best in water depths of less than 30 metres (most new prospects are in depths up to 1000 metres);
- Collecting 3-D seismic data in 1000 metres of water is difficult;
- Year-round transportation is needed instead of offshore platforms pumping into large and expensive storage tanks;
- There is no infrastructure or workforce in the Arctic. Marine vessels, deep-water ports, airports, road access, municipal support, and all of the conveniences of civilization do not yet exist in the Arctic;
- Activities like trenching and laying pipe are completely different in ice covered waters;
- Knowing when and how much ice to expect is another area that needs improvement;
- Evacuation and rescue operations in the Arctic must be self-sufficient as it is so remote.

New and legislative regimes that govern individual areas for explorations are undergoing development. The new legislation needs to consider the fragile environment in the case of a major oil spill accident. As was seen in past northern oil spills, such as the Exxon Valdez in Alaska, an oil spill would have devastating effects on Arctic shorelines habitats, seabirds, fish stocks, and marine mammals. An Arctic oil spill would severely damage not only the environment but also the livelihoods of local communities and public trust in the oil companies present. Therefore expansion into this region is under close scrutiny. The key sectors will have to strive for safe and environmentally responsible operations to meet the challenges of the changing Arctic in connection with future economic developments.

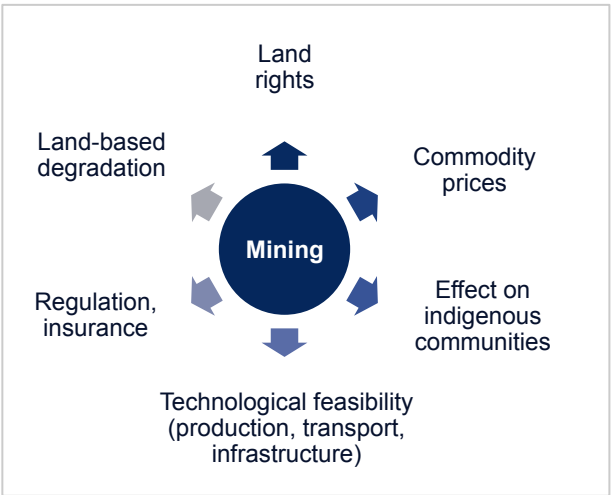


Mining

The mining industry is a primary driver of growth in the shipping industry. Maritime activity will be stimulated by a mining boom in the Arctic via needs for shipping supplies and removing mined products. According to Burakova [16], the estimated value of Arctic minerals was US $1.5-2 trillion. In addition there were 25 mines operating in Arctic Russia in 2006 [17]. The majority of Russian mines extract nickel and copper but lead, uranium and phosphate are also mined.

Northern mining is expensive and access is difficult. It is driven by the global commodity prices of the metals and minerals, and changing access to coastal regions. As an example, estimates of Alaska's gold resources have grown from just a few million ounces in 1980 to nearly 140 million ounces in 2011 [18]. This increase in prospecting is driven by the price of gold in addition to technological and climatic developments that allow mining in this area.

Arctic mines are land-based and mainly depend on permafrost land and ice roads that are at risk due to the warming climate. As the shipping season lengthens, mines and coastal mines are likely to begin exploring marine shipping for exporting their material. Nearly all bulk traffic in the Arctic is outbound, shipping extracted natural resources out of the region to the world's markets. In 2004, there were no Arctic transits of bulk goods east, west or through the central Arctic Ocean. See *appendix: table 5* for details of current Arctic mining activities by country.



Tourism

Tourism comprises a small proportion of total Arctic activity, and will most likely remain so as the region opens up to new activities. Arctic tourism began in the 1970s and this interest has developed considerably in past years; around 2.5 million tourists visited the region as part of cruises in 2007 [2, 19].

Arctic marine tourism is mostly confined to coastal trips, particularly along the Norwegian, Svalbard, and west Greenland coasts. Other popular routes are direct to the North Pole from Norway and Russia, and through Canada's Northwest Passage *(figure 6)*. In the years from 2003 to 2007 the number of cruise ship arrivals at Greenland ports rose from 164 to 375 [20].

The level of interest in tourism is deeply embedded in local cultures as part of processes of change that are occurring in the world's Polar Regions [19]. The majority of cruise ships observed recently in Arctic waters are not purpose-built for Arctic operations. Many are built for voyaging in open water, lower latitudes, and warmer climates. However in 2006 at least one scheduled cruise liner (the MS Bremen) successfully navigated the Northwest Passage.

Figure 6. The main tourist ship routes used in the past decade [8].

Defence

There are numerous military bases in Russia, Alaska, Greenland and Canada. The largest bases are the Russian naval base of Murmansk, and the American air bases of Thule in Greenland and Fairbanks in Alaska. Historically, Arctic military activity was a result of the Cold War. The surveillance networks installed on the shores (in particular in Norway, Scotland, Iceland, the Faroe Islands, and Greenland) are still active. As activities in the Arctic grow and resources begin to materialise, military activities will evolve to include other government needs such as border patrol, shipping monitoring, and search and rescue.

New users

The combination of a search for more sustainable human development and changing environmental conditions in the Arctic may result in new uses and users. As new users are appearing in the temperate oceans the expectation is that these will move northwards as conditions allow and the need arises. Here we briefly introduce some of these users. New sectors in development outside the Arctic region include bioprospecting, aquaculture, deep sea mineral prospecting, carbon capture and storage, and new renewable energy production.

Bioprospecting

The United Nations University Institute of Advanced Studies (UNU-IAS) published a report in 2008 indicating that bioprospecting is a new and exciting sector for the Arctic [21]. Biotechnology based on Arctic genetic resources covers several key areas including: 'nutraceuticals', which are dietary supplements and other health products; medicines and pharmaceuticals; food technology; anti-freeze proteins and enzymes; cosmetics and skin care products; products with life science research applications; and research-based service companies. Activities in bioprospecting in the Arctic are conducted by at least forty-three companies who are involved in R&D and/or the sale of products derived from the genetic resources of the Arctic. An example of this R&D is in Norway, where MabCent, one of 14 research centres established in Norway, plans to 'bring marine bioactives from the deep waters of the Arctic to the pharmaceutical and other high value markets'. A total of US $32,560,000 has been committed to the MabCent initiative by the Norwegian Research Council, the University of Tromsø and associated biotechnology companies, 25% of which is private funding [21].

Aquaculture

Aquaculture in the Arctic is based primarily on the farming of Arctic char, a relatively recent addition to the industry with serious farming efforts beginning in the mid-1980s. Arctic char are farmed mainly in the Nordic countries and Canada. Reliable statistics on Arctic char production are difficult to find. Recent estimates suggest that total world production of Arctic char in 2007 was in the range of 6000 tonnes. To put this into perspective, in 2007 total world production of salmonidae was 2.3 million tonnes, of which Atlantic salmon and rainbow trout represented 1.4 million and 600,000 tonnes respectively (estimated from FAO statistics).

Deep-sea mineral prospecting, carbon capture and storage, and renewable energy

Across the world's oceans new enterprise activities such as deep-sea mineral prospecting, carbon capture and storage, and renewable energy have emerged as having potential for growth in the decades to come. At present there is no clear indication that these activities will migrate to the Arctic Ocean in the short term, but are worth recognition that they may one day operate in the region. This will have knock-on implications for the marine environment and the other current users of the region.

3. Baseline of Present and Projected Activity

Following the previous discussion of uses and users of the Arctic region, we have generated a baseline from key indicators for both industry sectors and the physical environment. From these indicators we have made projections of the estimated rates of change up to the year 2050 under a business as usual (BAU) trajectory. This assumes the execution of standard functional operations within organisations, sectors, and governments, without taking into account factors that would introduce major change.

Current indicators

	Indicator	Year	Value
Sea ice extent	Minimum ice extent [1]	2011	4.33m km^2
Tourism	Cruise ship arrivals at Greenland ports [2]	2008	375
Shipping	Number of ships per day through Hudson strait [22]	2008	1,440
Fish stocks	Total catches per year in USA, Canada, Russia [9]	2000	11,500 tonnes
Oil	Total oil production [23]	2005	415 Mtoe
Gas	Total gas production [23]	2005	500 Mtoe
Mining	Number of large mines in Fennoscandia [24]	2009	48

The following sources and methods have been used to make trend-based forecasts for each sector. This gives an approximate rate of change that we expect each sector to increase or decrease by up to the year 2050.

- Sea ice extent: estimated projection provided by the IPCC [1];
- Tourism: forecast based upon 10-year average of number of cruise ship arrivals at Greenland ports [2];
- Shipping: forecast based upon 10-year average of shipping traffic volume [22];
- Fishing: estimated projection of the change in catch potential in Alaska, Russia, Greenland, Norway and Iceland provided by Cheung et al. [12];
- Oil production: estimated projection of oil production provided by Peters et al. [23];
- Mining: forecast based upon the 30-year average number of large mines in Fennoscandia (Finland, Norway, Russia and Sweden) [24].

Analysis of projections

Tourism will see the highest increase in activity to 2050. This is due to the relatively small number of tourist ships already active in the Arctic region, combined with the forcing factor of the vast increase over the past 10 years the sector has already seen. It is reasonable to assume that as trans-Arctic shipping routes open up, the Arctic tourism region will experience the same boom that the Antarctic has seen over the past few decades. The growth will primarily fall in the marine-based tourism segment dominated by small expedition style vessels and large luxury cruise liners, with Arctic voyages becoming a vital part of international cruises [2]. According to the Arctic Marine Shipping Assessment (AMSA) the number of passengers travelling to the Arctic more than doubled between 2004 and 2007 demonstrating the scale of growth in this sector.

Shipping sees an average 6% increase per year in line with the expected sea ice reduction (direct), and increase in industry activity (indirect) as described in Section 2.

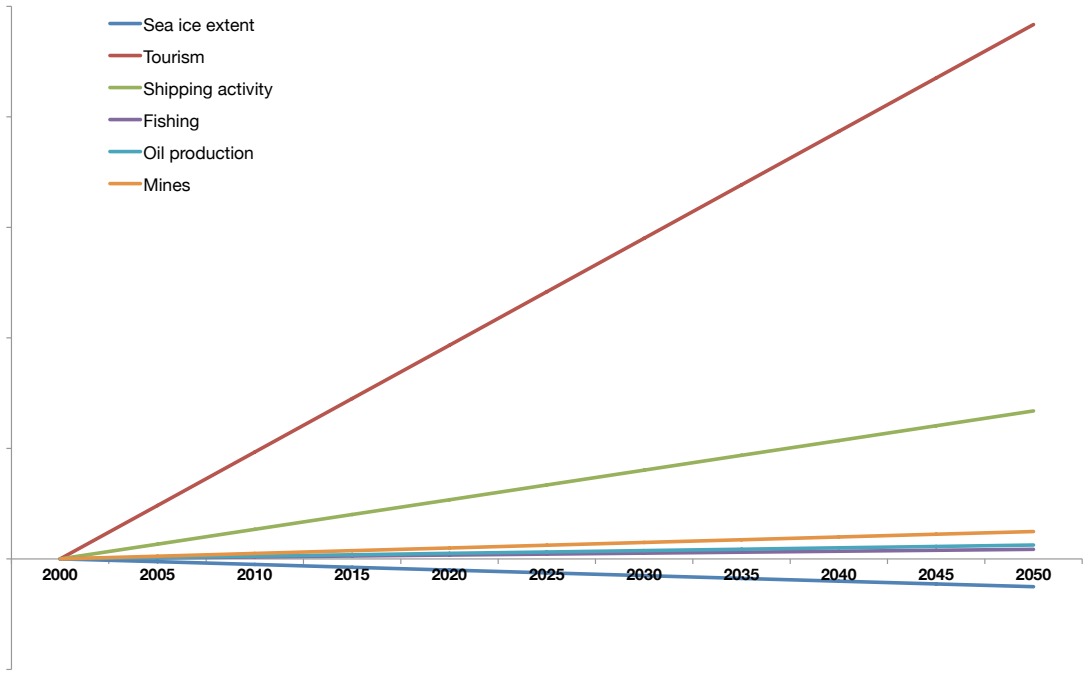


Figure 7. Projected rate of change per year of industry activities and the physical environment up to 2050: Sea ice (-1.2%), Tourism (24.9%), Shipping (6.4%), Fishing (0.4%), Oil production (0.6%), and Mining (1.1%).

As discussed in section 2, analysis suggests fish species are likely to move northward as ocean temperatures increase in the tropics, thereby increasing the catch potential in high latitude Arctic regions. Since fishing in the Arctic takes place up to the ice edge and not in close ice pack conditions, operations are in completely or seasonally ice-free areas and are opportunistic in nature. The increase in seasonally ice-free areas and catch potential may lead to an increase in enterprise opportunities for fishing, such as shrimp fisheries off the coast of Greenland [2]. Consequently we expect the fishing industry to grow in line with the catch potential, especially in areas that already see high catch levels.

The Arctic oil and gas industry has seen a boom and bust in production over the past few decades, primarily driven by the rise and fall of the Soviet Union. Growth is expected again in this sector, especially as access to new unexploited offshore fields increases and the search for new sources of hydrocarbons widens. However due to economic viability and technological feasibility factors, the rate is not expected to be much more than a 0.5% per year increase in production. Natural gas production is expected to follow a similar increase.

The number of large mineral mines in coastal areas has steadily increased over the past 30 years. This increase will continue at perhaps a slightly higher than historical rate, as demand for mineral resources grows globally in coming decades. Volume of extraction and mining activity are difficult to predict, but for the reasons given previously these are also expect to increase.

The key drivers underlying these industry sectors and projections are discussed in the next section.

4. Drivers of Change

There are a number of underlying drivers that will affect the shape and scope of enterprise opportunities and governance processes of an Arctic system undergoing economic and environmental change. These drivers, which can be either positive or negative, vary in magnitude and scale, and are often heavily interlinked and interdependent.

A PESTLE analysis of the six main industry sectors identified in Sections 1 and 2 has enabled a number of drivers of change to be identified. These can be categorised as primary (driven by wider impacts of climate change, and economic globalisation) and secondary (implications of the primary drivers that give rise to wider exogenous factors on each sector). These drivers are discussed in more detail below *(see Figure 8)*.

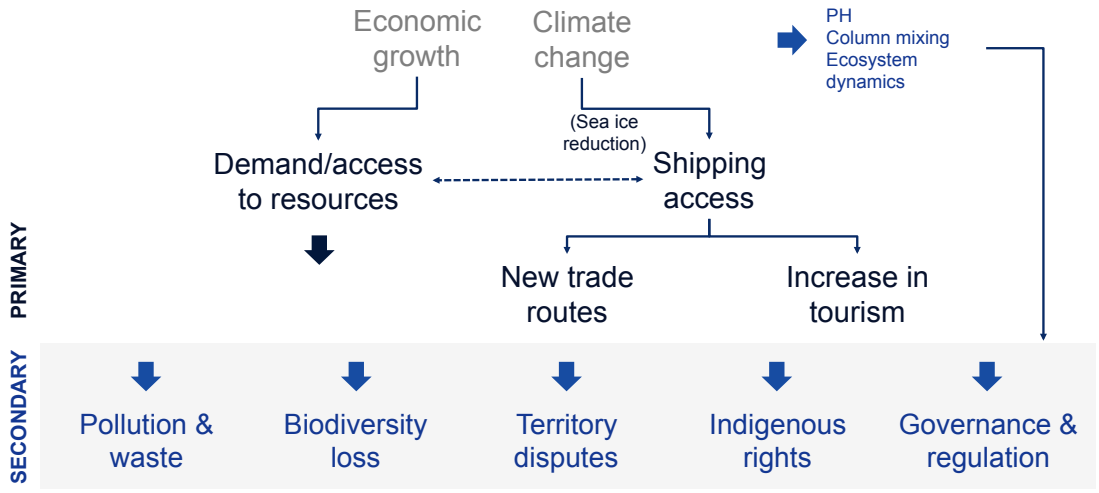


Figure 8. Primary and secondary drivers.

The primary drivers can be summarised quite simply: the increase in enterprise activity is being driven by the global demand for resources and logistical efficiency. In addition, the reduction in sea ice is opening new shipping routes that are also driving and enabling enterprise activity. This is either directly through trade, or indirectly by accelerating resource exploitation. The implications of this produce a set of secondary issues that are the key issues governments will need to address in order to keep stability in the region.

Primary drivers

Global

Wider global issues such as climate change, economic growth, population increase, and an increase in food and energy demand will have a notable effect on resource rich corners of the planet such as the Arctic. In particular, the effects of climate change will be a key driver for the opportunities and challenges already mentioned in this study. Without reduced sea ice, the enterprise opportunities would remain difficult to exploit.

Demand for resources

Vast oil and gas reserves have already been identified along with substantial mineral deposits, which with retreating sea ice, will be increasingly available for exploitation. It is these resources that are driving the various political disputes and as further resources (both real and false) are

reported this pressure will only grow. The increasing value of commodities will also amplify the importance of the Arctic region, the desire of agents to exploit it, and the challenge of Arctic governance.

Shipping access

Arguably the central driver of change faced by the Arctic region as outlined in this study is shipping. The reduction in sea ice in the Arctic Ocean will open access to a variety of marine vessels, ranging from scientific icebreakers to container ships travelling from Asia to Europe. As discussed in Section 2, the open season is becoming longer year-on-year, allowing more ships to navigate albeit in increasingly hazardous conditions. It is unlikely in the short term that Arctic ice cover will decrease to the extent that new trade routes become a reality, however long-term climatic changes may result in a maritime trading system which could reduce journey times between Pacific and Atlantic ports significantly, reducing shipping costs through fuel and time savings, changing ship size restrictions, and by-passing maritime choke points at the Malacca's straights and Panama Canal. Through to 2020, it is expected that shipping in the region will remain mainly destinational, and not trans-Arctic, although it is likely that there will be increased traffic in existing areas of use; particularly in the Barents Sea due to increased tourism and cruise ships, and increased oil and gas related traffic.

Increase in tourism

As has been previously discussed, the tourism industry will grow at a phenomenal rate over the coming decades. A longer open season will only help this. One of the more worrying issues facing Arctic management will be the rise in unsuitable vessels, particularly cruise ships, attempting to make the voyage into previously inaccessible waters. This has implications for Search and Rescue, environmental conservation, and biodiversity loss, as many of these tourism voyages will venture beyond traditional shipping routes.

Secondary drivers

Sovereignty and territory issues

While the UNCLOS process may be confusing in some aspects, it is likely to yield concrete and mutually acceptable results in most conflicts. Whilst current diplomatic trends indicate peaceful negotiations over disputed Arctic borders[e] and claims are likely to be the norm *(Appendix: Table 5)*, there is some speculation that conflicts over access to resources might increase in the future.

Governance and regulation

The issue of governance is a key driver of change within the Arctic region. Currently the eight Arctic governments address the issue of Arctic governance through the Arctic Council, which also has permanent representatives of indigenous groups and observers from other interested groups and nations. It is yet to be seen if this arrangement will continue to be sufficient, particularly considering the possible areas of high seas and the increasing level of usage. As the area becomes more open there will be an increasing need for government presence to either protect economic zones, project force or provide Search and Rescue services.

The laws currently governing the Arctic region and ocean were not designed specifically with resource and enterprise challenges in mind, and as these change in the coming years with new uses and new users entering the area, there will be greater pressure on the UNCLOS process

[e] Such as Norway and Russia's peaceful negotiations on disputed areas of the Barents Sea in 2011.

and other governance measures to anticipate and adapt to these changes, and specify more detailed regulation relevant to sustainable enterprise development.

Marine insurance will also play a major role in the sustainability of Arctic shipping. The Arctic is still viewed as an unknown by insurers, and until the risks associated with polar navigation are better understood, insurance will remain expensive and issued on a case-by-case basis.

Indigenous communities

The indigenous communities of the Arctic are important stakeholders in the area and have the ability and the right to influence exploitation opportunities in the Arctic region. Their claim to valuable resources will bring economic benefits to their communities, giving them the opportunity for growth and new access to goods and services provided by their Arctic neighbours. There will reach a point where these communities will want more control over the region, this will add more complexity to issue of governance in the area.

Pollution and biodiversity loss

Increasing activity will also promote the risk of environmental damage through both accidental incidents and pollution. A warming climate will also drive change in biodiversity and enterprise opportunities in biological systems, as well as effect sea chemistry and other environmental issues.

The implications of these drivers are discussed in Section 5.

5. Hotspots

This section draws attention to new 'hotspots' that could emerge from the synergies between different sectors and the interplay of economic activity with political and social developments in the context of climate change and cumulative environmental impacts. Hotspots and potential conflicts are influenced by factors identified via the drivers discussed in Section 4 and additional literature reviews [1-3, 25-28].

Environmental issues

Change	Effect
Increasing periods of ice-free sea in coastal Arctic regions	Greater coastal erosion with potential impacts on support infrastructure for Arctic development and marine transportation
Arctic sea ice will be more mobile	Increased ridging of seasonal sea ice, potentially creating more difficult operating conditions for marine navigation
Sea ice changes, arctic water changes	Change the migration routes and migration times for species including bowhead, beluga, narwhal and walrus
Changes in ice cover	Keystone predators within a given region may move into the region, move away from the region, or become extinct; Impacts on one type of ice-associated organism may have far-reaching consequences as species in the Arctic have short food webs. I.e. if multi-year ice disappears, long-lived amphipods and the larger ice algae will decline drastically with knock-on effects; Migration of species from other regions to the Arctic; Orca Whales have been observed crossing into the Arctic since 1997, Humboldt squid usually found off Chile have been observed in Alaska
Reduction in ice thickness and extent in the Arctic Ocean	Southward transport of ice-associated organisms on drifting ice, reducing prey availability and carbon input to subarctic seas
Earlier ice break-up (earlier Springs) and an earlier onset of the annual bloom in plankton	May lead to a temporary mismatch between primary production (algae) and secondary production (the animal life that feeds on the algae) in some areas
Changes to sea ice, Arctic waters and human impacts in previously ice-covered areas	Changes to polar marine mammals; these include changes to their forage base (such as shifts in the species, density and distribution of prey species); increased competition from temperate species expanding northward; increased predation rates from killer whales (Orcas); increased risks from disease and parasites; greater potential for exposure to increased pollution via increased human presence
Ecological changes; decreasing pH levels (increasing acidity), diminishing of water column mixing	Variations in ecosystems; difficulty producing shells and calcium carbonate skeletons; potential changes in arctic fish populations due to changes in chemical composition of habitat; and, impacts on nutrient circulation and plankton (with further impacts on food webs)

Social and societal issues

Change	Effect
Migration due to mining and exploration	Seasonal workers would create a very large demographic change that could have social implications, and will swell population size. Currently indigenous communities make up only 10% of the 4 million strong Arctic population; Creation of new settlements and the associated impacts of large scale development and tundra damage
Social impacts of mining and exploration	Long-term social, economic and cultural impacts on towns where large in-migration occurs, particularly if migrants leave when the finite resources are extinguished
Risk of increased accidents as more ships travel in the Arctic for destination shipping, particularly tourist ships that are not designed for Arctic conditions	Intense pressure is likely to emerge on Search and Rescue services, with reports saying local populations are already struggling to provide sufficient services; There are currently no established vessel routing measures in the Bering Strait region, a Traffic Separation Scheme (TSS) may need to be established in the region as vessel traffic increases
Impacts on local communities in terms of mixing of cultures; cultural threats	The emergence of cultural communication barriers, and the potential weakening of cultural customs, language and tradition by the native population. E.g. in Norway, development of onshore mineral resources and offshore oil and gas are seen as major threats to the Saami way of life; Indigenous communities have in most regions been encouraged to become permanent residents in fixed locations, which has had a predominantly negative effect on subsistence activities and some aspects of community health
Impacts of ship noise	Scaring away animals necessary for hunting: E.g. in Resolute, Nunavut, a period of increased shipping in the 1990s pushed walrus away from the community, too far for hunters to reach them; More than 95% of total subsistence harvests are marine-based resources in the St Lawrence Islands, and such impacts would have devastating consequences
Physical and noise related disturbances of seismic activity during oil & gas exploration	The noise associated with seismic surveys can affect the ability of these animals to detect natural underwater sounds, thereby disrupting these critical activities. Whales avoid areas where seismic is in use, changing their behaviour patterns.
Increased shipping	Potential for collision between coastal and offshore large ship traffic and traditional small open boats using marine resources
Sea ice breakup by icebreakers	Cutting off hunters travelling over sea ice

Economic issues

Change	Effect
In areas of high shipping	Several areas in the Arctic of special ecological significance (such as Bering Strait, Hudson Strait, Lancaster Sound, Pechora Sea) occur, putting species at high risk if oil spills take place
Black carbon emitted from shipping	Significant regional impacts occur from black carbon by accelerating ice melt and effecting ice albedo
Conflict between shipping lanes and migration routes	The migration corridors used by marine mammals and birds correspond broadly with the main shipping routes into and out of the Arctic; with changes to the shipping season running earlier in Spring and later in Autumn there could be conflict
Oil spills	There is a short feeding season for many Arctic species, an oil spill could cause animals to not get enough food to provide the energy needed for the long migrations; Many of the species found in the arctic have short simple food chains, relying primarily on one or two types of food e.g. lichen, polar cod. An impact on one species due to an oil spill could have large implications
Sea ice melt	Increased carving of icebergs may affect navigation and shipping lanes; Changing ice conditions may make it challenging to maintain tight transportation schedules and ensure the punctuality of certain cargoes
Ship conflict with large marine mammals	Ship strikes of whales and other marine mammals are of concern in areas where shipping routes coincide with seasonal migration and areas of aggregation
Introduction of invasive species from shipping; main sources include ballast water discharge, hull fouling, cargo operations and casualties or shipwrecks	Potential devastating impact on native biota populations and food chains
Behaviour of fishing boats	Fishing vessels typically meander in search of catch rather than follow a specific itinerary, increasing dangers of crashing with other larger ships
Economic drivers encouraging year-round operations	Year-round mining and transport operations may occur given economic incentive, for mines with high-value perishable cargoes such as nickel from Deception Bay. Impacts will include; year-round pollution, increased ice-breaking etc.
On-shores mines	Tundra damaged by tundra travel, leading to habitat disturbances
Mining externalities from the exploration, construction, production and decommissioning phases	Potential soil contamination, permafrost instability, vegetation, fauna and animal behaviour patterns, impacts on habitat diversity, water contamination from waste water

Governance issues

Change	Effect
Management of old dumping grounds now with potential for shipping lanes running through them	The Russian Tsivolka Inlet on Novaya Zemyla has been used as a burial ground for nuclear reactors such as the one from the first atomic-powered icebreaker, the *Lenin*, and authorities are still undecided about how to manage and regulate this
Territory claims	Numerous territorial claims over Arctic boundaries exist, such as a dispute in Canada over whether the famous North West Passage is international water or sovereign territory. Territorial claims create governance issues between the eight Arctic states and indigenous communities
Trans-Arctic shipping	A coastal state's authority to regulate foreign shipping does not extend to the high seas, transiting ships would only be subject to global shipping safety, environmental and security rules, and standards adopted through the IMO and as may be applied by the flag states
Management of cruise ships operating in the Arctic	The International Maritime Organisation has a set of "guidelines" for cruise ship operators and others about how to proceed in the area but it is only advice. A wider polar code is now being developed by the UN organisation but it must be formulated, agreed and then ratified

There are clearly significant potential 'hotspots' or conflict areas emerging in the Arctic. While these can be defined in sectors, such as those used above (environmental, social, economic, and governance), it is clear that such conflicts are cross-sectoral in nature. A key area for further research would comprise a stakeholder analysis of hotspots, to further analyse the inter-relationships and ownership of conflicts, with a view to recommending approaches to handling and mitigating future conflict.

Conclusion

Over the next 20 years, shipping, oil and gas, mining, tourism, and aquaculture are expected to remain the key economic sectors in the Arctic marine region. Whilst new marine enterprise activities are emerging in other world ocean regions, e.g. bioprospecting, offshore renewable energy, and carbon capture and storage, there is no clear indication that these activities will migrate to the Arctic Ocean in the near term.

The factors shaping the future development of each sector are diverse and include, political-, economic-, socio-cultural, technological-, demographic-, legal and regulatory-, and ecological-environmental changes. There are significant uncertainties associated with the scale, nature, and environmental impacts of different sectors of economic activity and stemming from the interplay between different sectors.

For example, there are significant technological and operational challenges involved in existing economic activities in oil and gas and mining. Uncertainties persist about the nature of oil and gas reserves, as well as considerable operational and technical challenges in producing and transporting oil and gas under extreme conditions of pressure, temperature and weather. There is also uncertainty about the impact of oil and gas operations on the marine ecosystems that unique to the Arctic, and how both might be affected by climate change related impacts.

Shipping activities will be driven by a combination of factors, including servicing the logistical needs of other economic activities, such as mining, oil, and gas, and the growth of tourism in the region. The extent to which an ice-free Arctic facilitates the relocation of global shipping lanes and traffic routes from the Suez and Panamanian Canals is unclear. In sectors such as fishing and aquaculture, the impacts of climate change on Arctic marine biophysical- and eco-systems will also determine the scale and location of activity. It is unclear, whether and how fast new forms of enterprise, such as bio-prospecting, deep ocean mining or renewable energy, might enter into the region. There is a lack of shared and systemic understanding of the complex interplay of changes unfolding in the region.

Despite the considerable uncertainties relating to existing and future economic development in the Arctic, concerns about the outlook for indigenous communities and marine Arctic ecosystems are set to increase. The dynamic interplay of an increasing number of users and uses, in a context of political and regulatory uncertainty and global environmental changes, has catalysed stories of hope, hype and horror about the future of the Arctic. Economic activities in the region are governed by a variety of international and national agreements and laws, and the management of different uses and users is evident in the shift towards more integrated marine management planning approaches by member states of the Arctic Council.

However, the nature of the Arctic marine environment economy is unique in terms of the numbers of jurisdictions, interests and dimensions of challenge involved. The scales of enterprise range from community fishing to global mining, shipping, oil, and gas. The communities that depend on the Arctic include coastal towns, indigenous peoples, and nation states, within and beyond the Arctic region.

Developing more shared and systemic understanding of changes, synergies, and challenges is needed if peaceful and sustainable development is to be possible. Given the limits of forecast-based planning in situations of social and political ambiguity, and the complex interplay of uncertain dynamics, scenario based initiatives are needed to enable more proactive, collaborative approaches. For example, scenarios focussed on the interplay of economic developments in the Arctic and associated cumulative environment, developed in a process that involves a range of different sectors and wider stakeholders, would provide a basis for the redevelopment of more detailed regulations and/or cross-industry guidelines.

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Appendix: Supporting Information

Table 1. Timeline of sailings through the Arctic (various sources).

Year	Ship, description	Route
1903–1906	Roald Amundsen's first successful trip.	Northwest Passage (over North America)
1944	Henry Larsen was the second to sail the passage, crossing west to east, from Vancouver to Halifax. St. Roch a RCMP "ice-fortified" schooner.	Northwest Passage
1957	USCG Cutter Storis, USCGC Bramble and USCGC Spar transitted together.	Northwest Passage
1969	The oil tanker SS Manhattan made the passage, accompanied by CCGS John A. Macdonald and CCGS Louis S. St-Laurent. Accompanied by USCG icebreakers Northwind and Staten Island.	Northwest Passage
1977	Willy de Roos sailed from Belgium through the Northwest Passage in his 13.8 m (45 ft) steel yacht Williwaw.	Northwest Passage
1984	Commercial passenger vessel MS Explorer became the first cruise ship to navigate the Northwest Passage.	Northwest Passage
1991	The 1st foreign vessel to make a transit voyage through NSR was a French AntArctic research vessel "L'Astrolabe" in 1991 (ice class 1 A Super). This was a test voyage with no cargo shipped.	Northern Sea Route (over Europe/Asia)
1997	First cargo shipping with foreign vessel through NSR. Neste Shipping, Uikku.	Northern Sea Route
2008	The first commercial ship, the MV Camilla Desgagnés, owned by Desgagnés Transarctik Inc. and, along with the Arctic Cooperative, as part of Nunavut Sealift and Supply Incorporated (NSSI), transported cargo from Montreal to the hamlets of Cambridge Bay, Kugluktuk, Gjoa Haven and Taloyoak.	Northwest Passage
2009	First foreign flag ships to transport goods: Two German vessels (Beluga shipping), South Korea to Rotterdam, each with 45,000 tonnes.	Northern Sea Route
2010	Multiple shipping interests and countries present in multiple routes.	Both
2010	MV Nordic Barents sails from the Northern Norwegian harbour of Kirkenes loaded with iron-ore concentrate, heading for China and was the first ever foreign flag vessel to sail the entire Northern Sea Route in transit without entering any Russian harbour.	Northern Sea Route
2011	Rosatomflot planned to escort 6 to 8 tankers. 15 bookings made.	Both

Table 2. Shipping times between Asia and Kirkenes, Norway.

Destination	Via Suez Canal			Through Northern Sea Route			Days saved
	Distance (NM)	Speed Knots	Days	Distance (NM)	Speed Knots	Days	
Shanghai, China*	12050	14	37	6500	12.9	21	16

Busan, Korea	12400	14	38	6050	12.9	19.5	18.5
Yokohama, Japan	12730	14	39	5750	12.9	18.5	20.5

* Based on actual voyage performed by MV Nordic Barents from Kirkenes, Sør-Varanger, Finnmark, Norway, to China (Sept 2010).
- Source: Tschudi Shipping.
- 1 nautical mile = 1.85 kilometres

Table 3. Principle Arctic ports with general activity estimates in tonnes of commodities that pass per year. Data is collected from the Port authority's website (where available).

Country	Port/City	General traffic (million tonnes pa)[5]	Operation window	Major component
Iceland	Akureyri	2.3	1.1	Wood products; freight handling; fish processing; and tourism
	Reykjavik[3]	230,000 TEU		Containers
	Grundartangi[3]	Very small		
Russia	Murmansk[2]	0.22[1995] 15[2009]	Year round	Coal; apatite concentrate; containers
	Dudinka[4]	4.5	11 months	Metals (Nickel + copper and cobalt)
	Arkhangelsk[4]	1.5	Year round	Metals, coal, timber, and containers
	Belomorsk	9	Year round	
	Dikson		< 12 months	
	Vitino[4]	8		Oil and oil products
United States	Barrow, Alaska			
	Prudhoe Bay, Alaska			
Canada	Churchill, Manitoba[4]	0.424		Grain;
	Inuvik, NT			
	Nanisivik, Nunavut			
	Tuktoyaktuk, NT			
Norway[1]	Rana	16.5		All freight
	Bronoy	3.7		
	Trondheim	1.9		
	Tromsø	1.9		
	Hammerfest[4]	1		Port of call;
	Honningsvåg			
	Kirkenes			
	Longyearbyen			
	Narvik			
	Vardø			

1. 2007 – Source: Statistik Sentralbyra (Statistics Norway)
2. ISEMAR - Institut Supérieur d'Economie Maritime (Applied Research Centre in Maritime Economics)
3. 2006 – Source: Statistics Iceland.
4. Port website.
5. Most recent available data.
6. TEU: twenty-foot equivalent unit (often TEU or teu) represents the cargo capacity of a standard intermodal container, 20 feet (6.1 m) long and 8 feet (2.44 m) wide.

Table 4. Primary activities of Arctic based mines by country.

Country	Primary activity
Canada	Diamonds, nickel-copper-cobalt, iron, nickel, zinc, copper, gold, lead, molybdenum, and uranium reserves
Denmark	prospective for gold, nickel, platinum group elements (PGE), copper, lead, zinc, molybdenum, diamonds and specialty metals including rare earth elements
Iceland	
Fennoscandia (Norway, Finland, Sweden)	51 large unexploited deposits and 57 potentially large deposits[1] 1300 known deposits, 56% have not yet been tapped (FODD website[2], 2011)
Russia	$1.5-2 trillion (USD)
Svalbard	Coal: Store Norske Spitsbergen Kulkompani produced 2.4 million tons in 2009; Gold: Store Norske found gold-bearing deposits with a few g/t up to 1000 g/t, with an average of 300 g/t.
United States (Alaska)	Precious metals (zinc, lead, gold, silver); coal; construction minerals (sand, gravel, crushed-rock). Minerals account for 30% of state's export, second after Active mining claims currently cover 3.6 million acres of land in Alaska

[1] Smelror, 2011.
[2] http://en.gtk.fi/ExplorationFinland/fodd/

Table 5. Some key legally disputed waters in the Arctic.

Countries	Disputed territory
US – Canada	Dispute based on extending land borders. The Canadian position is that the maritime boundary should follow the land boundary; the American position is that it should extend along a path equidistant from the coasts of the two nations.
Denmark and Canada	Hans Island in the Nares Straight between Ellesmere Island and Greenland.
Russia, Denmark, and Canada	Russia is claiming a large extended continental shelf as far as the North Pole based on the Lomonosov Ridge within their Arctic sector.
Northwest Passage	Its legal status is disputed with Canada considering it to be part of its internal waters according to UNCLOS; whereas most maritime nations consider it an international straight.


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