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Beyond military: Defining and addressing the transnational security threats in the contemporary Arctic

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Abstract

The Arctic states face a broad spectrum of specific regional security issues centred around two complementary aspects, defending humans from extremes of nature (climate) and protecting the natural environment against damage caused by human activities (pollution). The first group of challenges encompasses extreme weather patterns, melting sea ice and permafrost, and rising sea levels. The second group includes various pollutants, including persistent organic pollutants, heavy metals, plastics, a significant military and nuclear presence, industrial development, and shipping. In addition, hybrid threats, illegal activities, and the interests of non-Arctic states represent a new and emerging category of security challenges for the region. Most of these challenges are multiplying threats that do not respect borders or sectoral boundaries and require coordinated transnational action. Given the limited capacity of individual states to address security threats promptly and the trans-national nature of certain issues, regional cooperation is a prerequisite for achieving success. History shows us that during the Cold War, the most politically frozen time of all, the Arctic states, including the United States and the Soviet Union, were able to overcome their animosity and cooperate on environmental challenges. One of the outcomes of this cooperation was the establishment of the Arctic Council in 1996. Is it realistic to expect a similar development today? The Russian invasion of Ukraine has largely ended cooperation between Moscow and other Arctic countries. Can shared security challenges enhance cooperation in the region and beyond? How important are environmental issues for the states? Can Arctic science diplomacy be a useful approach to the improvement of relations? These are some of the research questions that this chapter addresses. The author also investigates mechanisms for cooperation in times of conflict and the role of international scientific cooperation in the Arctic. The chapter concludes with an exploration of possible future scenarios in the region.

Key words: Arctic security, cooperation, common security challenges, science diplomacy, hybrid threats

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Introduction

The Arctic environment is mainly characterized by cold weather, inaccessible terrain, low population density, vast distances, and sea ice. These harsh conditions have prevented a greater level of activity in the region; however, dramatic changes in climatic conditions have made the Arctic more accessible and thus more attractive for regional development and illegal activities. The region is greatly affected by climate change–perhaps more so than any other. Hence, the Arctic region can be described as the "canary in the coal mine". The impact of climate change on the region could help other vulnerable regions anticipate and prepare for such challenges.

The security of the region can be analyzed from numerous perspectives. Over recent decades, there has been a broadening of the concept of security in academic discussions. In particular, in the post-Cold War Arctic, it became clear that environmental threats were as significant as military ones (Huebert 2004). Although there is still no consensus on how the concept of security is understood, in this chapter, the author considers security in its widest possible sense except for military security which is addressed by Kříž (2025, *this volume*).

The Arctic states face a broad spectrum of regional-specific security issues recently. The majority of the new challenges are multiplying threats that do not respect borders or sectoral boundaries and require coordinated transnational action. In this chapter, the author divides the security challenges into three categories – **i) climate** (extreme weather patterns, Artic warming, melting sea ice and permafrost, and rising sea levels); **ii) pollution** (persistent organic pollutants, heavy metals, plastics, a significant military and nuclear presence, industrial development, and shipping); and **iii) new trends** (hybrid threats, illegal activities, and the interests of non-Arctic states in regional issues). The author separately elaborates each category and provides specific examples of the challenges.

Category *i*) focuses on climate change and its impact on the Arctic. New weather patterns are observed combining both more extreme and more frequent events than previously *e.g.*, heavy rain, storms, floods, snowfalls, heat waves, *etc*. Elevated temperature alters the natural environment and leads to huge changes in living conditions for humans in the Arctic and beyond. The Arctic has warmed almost ***four*** times as fast as the global average over the past four decades (Ingólfsdóttir 2014, Rantanen et al. 2022).

As a consequence of ongoing warming in the Arctic, the region is experiencing a rapid decline in sea ice and an accelerated thaw of permafrost. The extent of Arctic sea ice, for instance, has diminished by an estimated half over the past fifty years, leading to profound implications for the environment and populations throughout the Circumpolar North (Bergman Rosamond 2011). The accelerating thaw of permafrost creates significant problems for infrastructure built upon it, including roads, railway lines, oil rigs, and even entire towns. In addition, it also leads to the release of trapped methane gas, which is a notorious "climate forcer," likely to further boost the rise in Arctic temperatures (Bailes 2015).

Another layer of challenges is associated with rising sea levels, mainly caused by melting ice sheets and glaciers (further accelerated by the speed of warming). The consequences of melting ice range from the immediate threat of coastal erosion, which already endangers Indigenous villages in the Arctic (WWF Arctic 2023b[20], Tanguy et al. 2024), to a worst-case global scenario where rising sea levels could cause entire nations like Guyana, Belize, Bangladesh, or Singapore to cease to exist (Huebert 2004, Ingólfsdóttir 2014).

In category *ii*), the author takes a close look at pollution, the second biggest threat to the region. The most prevalent pollutants found in the Arctic environment are persistent organic pollutants (POPs), heavy metals, plastics, a significant military and nuclear presence, industrial development, and shipping. Over the last three decades, human-landscape interactions have accelerated, primarily through the construction of residences and infrastructure for natural resource extraction. The building of new harbours, airports, roads, pipelines, and fences has dramatically modified the pristine ecosystem. In addition, increased traffic and electricity generation has intensified the local production of pollution (Halašková 2025a). On top of that, an increased intensity in the extraction of natural resources increases the risk of environmental disasters such as oil spills or soil contamination.

Unlike the local industrial pollution, POPs do not originate in the region. Some transboundary pollutants found in the Arctic were mainly used as insecticides and fertilizers and are not native to the north. It has become apparent that the pollutants had travelled a long way before they reached the Arctic through a series of geophysical factors (Huebert 2004). Heavy metals such as mercury or lead are also seen as a threat to humans living in the Arctic. Mercury is being released into the environment as the permafrost thaws. Recent studies have also included plastics in the list of threats to the Arctic. Plastic litter is building up and can have devastating effects on wildlife. In addition, researchers have become increasingly concerned about the concentration of microplastics in the Arctic, particularly in sea ice, several bird species, and fish. For a comprehensive analysis of POPs and heavy metals in Arctic ecosystems, *see* Hájek et al. (2025, *this volume*).

The significant military and nuclear presence in the region has added another burdensome layer to the environment. The arms race between the two major nuclear superpowers, the United States and the Soviet Union, throughout the Cold War was the cause of the most extensive pollution across the Arctic. The military's use of large areas of land and sea for constant testing and training led to significant environmental damage. In addition, nuclear (submarine) accidents and leaks, experimental deployments, weapons testing, and the construction of radar stations (for example the DEW Line) have led to an enormous level of pollution in the region. Thousands of tons of rubbish, toxins, radioactive waste (solid and liquid), and pollution were left behind (Heininen and Exner-Pirot 2020).

The melting of Arctic sea ice is creating new, commercially attractive shipping routes. These routes not only offer significantly shorter transit times compared to the Panama and Suez Canals but are also becoming accessible for longer periods each year due to warming temperatures. While the increasing interest in polar sea transportation brings economic opportunities, it also brings a greater risk of accidents that may affect the Arctic marine ecosystems and coastal communities (WWF Arctic 2023a[19]).

Challenges associated with "new trends" make up category *iii*). In this section, the author looks at recent developments centred around hybrid threats, illegal activities, and the role of new non-Arctic actors in the region. Hybrid threats in the Arctic include cyberattacks and the attempted sabotage of critical infrastructure, including subsea infrastructure. If cybersecurity threats materialize in the Arctic, their impact might be even more harmful than elsewhere due to the harsh environmental conditions and remoteness. The Arctic region hosts many data hubs, and significant energy resources depend on reliable computer control. Most Arctic states are highly digitized economies, that are heavily reliant on information and communication technology (ICT), this makes them susceptible to cyber espionage, ransomware attacks, and misinformation campaigns (Gricius 2024, Heffernan and Parsons 2024).

Ice-free summers and an increase in the accessibility of Arctic waters have also attracted the interest of non-state actors involved in organized crime. The region is open to smuggling, illicit traffic, illegal fishing, and other illegal activities. In addition, the Arctic states need to deal with the increasing interest and activity in the region by non-Arctic actors, who may have economic or commercial interests. That includes shipping, fishing, or the extraction of previously unattainable resources such as oil or gas reserves (Gricius 2024).

This list of challenges and threats is not exhaustive, but the key focus here is on transnational threats that require coordinated action by the states. Even though there are differences in the way that different countries prioritize these challenges, cooperation on shared issues is key to success (Gricius 2024). Arctic states aim to promote the Arctic as a zone of cooperation and joint problem-solving while recognizing the distinct geography, demographics, and economics of the Far North (Lanteigne 2019[12]).

Nevertheless, this changed for the first time in modern history when Russia invaded Ukraine in February 2022. Russia's aggression in Ukraine (*footnote: still ongoing at the time of writing in July 2025) has largely ended cooperation at all levels between Moscow and the other Arctic countries. At the same time, Russia halted financial support for the Arctic Council (n.d.[3]). Hence, any scientific cooperation between Russia and the West has been frozen.

During the Cold War era, scientific cooperation offered a path towards warming of US-Russia relations. Is a similar development also realistic today? Can shared security challenges enhance cooperation in the region and beyond? Can Arctic science diplomacy be a useful approach to improving relations and mending strategic fences? These are some of the research questions to which this chapter provides answers. The key variables that influence cooperative/competitive relationships between states and relevant regional stakeholders are mentioned and discussed.

Different approaches to security

The concept of regional security can be analyzed from multiple perspectives, a shift exemplified by the robust academic debate over the last few decades concerning the link between climate change and security. The discussion has been characterized by a deep division between those that argue that the requirements for security are fixed and others that suggest climate change necessitates a transformation in the approach to security towards a more precautionary, global, and integrated approach. This division has its roots in the debate within the field of Security Studies over the normative and analytical appropriateness of broadening and deepening the security agenda to include non-state actors and non-military issues, such as the environment (Kalliojärvi 2020).

Particularly in the Arctic, with the end of the Cold War, it became clear that environmental threats were of equal importance to military threats (Huebert 2004). The so-called Copenhagen School was one of the first pioneers that broadened the security concept. Barry Buzan, an international relations theorist, and his colleagues at the Copenhagen Peace Research Institute emphasized the non-military aspects of security, representing a shift away from traditional security studies. Besides the military sector, the school distinguishes between political, economic, environmental, and societal sectors. In addition, the state is no longer seen as the only actor. Non-state actors such as environmental organizations, businesses, industry, *etc*., have started to play an important role (Padrtová 2017).

The notion that security has (many) more dimensions than just "hard" military defence has become commonplace in the twenty-first-century. In 1994, the Human Development Report from the UN Development Programme (UNDP) identified that the economy, environment, food, and health are crucial for human survival and welfare. The focus shifted from warlike threats to a wider security spectrum, to softer issues such as cybersecurity, energy security, and climate change (Bailes 2015). There are two complementary aspects to environmental security; protecting and preserving the natural environment from damage by humans and defending people from violence and the extremes of nature. As a threat multiplier, climate change is today's single largest challenge under both headings (Bailes 2015).

While the direct threats of climate change, such as sea-level rise and extreme weather events, have found their way into the national security strategies of many states, the security discussion is mainly focused on indirect threats (Kalliojärvi 2020). In this chapter, the author applies an understanding of security that is as broad as possible, including all sectors, except for military security which is covered in Kříž (2025, *this volume*).

Common security challenges and threats in the Arctic

This analysis categorizes the region's common security challenges and threats into three main areas: *i*) climate and its environmental impacts, *ii*) pollution from various sources, and *iii*) challenges posed by emerging geopolitical and economic trends.

Category i) challenges – the climate

In this section, the author details the threats stemming from several key environmental shifts: new weather patterns, diminishing ice cover, permafrost thaw, and sea-level rise.

New weather patterns

The impacts of climate change are more dramatic and visible in the Arctic than in any other region on Earth. Over the past four decades, the frequency and intensity of extreme weather events have markedly increased, altering the environment and challenging local populations. This includes more frequent heavy rains, powerful storms, unseasonal floods, and unprecedented heat waves. This instability is driven by the fact that the region has warmed almost four times faster than the global average since 1979 (Rantanen et al. 2022).

The latest studies illustrate that these ecosystems have never witnessed the pace of warming we are currently experiencing. Although there are attempts to limit warming to 1.5°C, it is unlikely to be enough to reverse the retreat of Arctic sea ice. Nevertheless, every fraction of a degree helps and cooperation between states to prevent the complete decimation of Arctic ecosystems is inevitable (WWF Arctic 2022a[17]).

Melting of ice cover and permafrost

The Arctic is experiencing a rapid decline in sea ice cover, and with permafrost thawing at an extremely high rate, it is estimated that the extent of Arctic sea ice has been reduced by half over the past fifty years, which has important implications for the environment and those living in the Circumpolar North (Bergman Rosamond 2011). In addition, scientists suggest that the thinning ice cover will make it easier for volcanoes to erupt, an issue that affects Alaska and Iceland and the transport regions around them. There is also an increased risk of transportation accidents or infrastructure breakdown, including pipelines, cables, and supply chains (Bailes 2015).

Climate models consistently project that the Arctic will experience its first ice-free summer within the next few decades. Projections based on the latest generation of models (CMIP6) indicate a high likelihood of this occurring before 2050, even under low-emission pathways (IPCC 2021[22], Notz and SIMIP Community 2020, Kim et al. 2023). Since an ice-free ocean surface absorbs more solar heat rather than reflecting it, the Arctic Ocean will warm. This, in turn, will cause more melting and further amplify climate warming (WWF Arctic 2023a[19]).

The accelerating pace at which the ground thaws brings obvious problems for structures built on permafrost, *e.g.*, roads, railway lines, oil rigs, and in some cases whole towns, but it also releases trapped methane gas, which is a notorious "climate forcer," likely to further boost the rise in Arctic temperatures (Bailes 2015). Thawing permafrost also leads to snow accumulation, water damming, and flooding. At the same time, these effects permanently change terrain and drainage patterns and have a dramatic effect on vegetation (Halašková 2025b).

In addition, thawing permafrost releases some toxic chemicals. As organic matter decays carbon dioxide and/or methane is liberated into the atmosphere, adding as much greenhouse gas as a large country. Also, scientists have found new evidence that melting permafrost could unleash large amounts of mercury, a dangerous toxin buried in the frozen ground (Schuster et al. 2018). Studies using environmental archives have estimated that atmospheric mercury deposition has increased by five- to ten-fold compared to pre-industrial levels, primarily due to anthropogenic activities such as burning coal. Scientists believe the Arctic permafrost may hold more mercury than the atmosphere, the oceans, and every living organism combined (Engstrom and Swain 1997, Streets et al. 2011).

Another tranche of problems connected to melting sea ice is the impact on marine ecosystems and biodiversity (WWF Arctic 2022a[17]). The loss of sea ice, among others, endangers polar bear populations that rely on the ice to capture prey, such as seals. In turn the decline of many Arctic species is negatively impacting the Indigenous communities that depend on these animals to support their way of life; they rely on them for everything: from the food they eat to the clothes they wear (WWF Arctic 2023a[19]).

On the other hand, the northward migration of species may create opportunities for subsistence, fishing, and hunting. For instance, the appearance of fish species previously found only in lower latitudes could open avenues for local fisheries or aquaculture. However, this potential benefit in the north could create an ecological imbalance in the southern regions from which these species are migrating (Halašková 2025a).

Sea level rise

Perhaps the most visible demonstration of climate change and the need for co-operation is the rise in sea level. It is an integrated effect due to processes associated with global warming, which have changed the intensity and direction of atmospheric circulation, ice distribution, rates of sea ice melting and freezing, and temperature and salinity fields (Proshutinsky et al. 2001). The rising sea level is mainly caused by melting ice sheets and glaciers (44%) and the thermal expansion of water that takes up more volume as it warms (42%). The remainder is caused by melting land ice, which adds mass to the ocean and increases its volume (Scott 2023[14]).

Together, the Antarctic and Greenland Ice Sheets hold enough water to raise sea levels by roughly 65 meters if they entirely melt, but this will not happen in the foreseeable future (Scott 2023[14]). However, it hardly takes the loss of an entire ice sheet to affect population centres worldwide. So far, the increase in temperature has caused the average sea level to rise by 15-25 cm (between 1901 and 2018) (WCRP Global Sea Level Budget Group 2018[25]). Projections indicate that even if global warming is stabilized at 1.5°C, sea levels are still expected to rise by approximately 2-3 meters over the next 2000 years. The IPCC (2021[22]) indicates that not only does the peak temperature determine the total long-term sea-level rise–projected at 19-22 meters for a 5°C peak–but the speed of warming also dictates how quickly this rise occurs (IPCC 2021[22]).

A primary challenge of rising sea levels is the heightened risk of shoreline erosion and frequent flooding in low-lying coastal areas (WWF Arctic 2023b[20]). Furthermore, this rise is projected to disrupt a wide range of systems and activities, including sediment transport, navigation conditions, oil and gas operations, and traditional hunting. Storms will also be stronger and more frequent, and coastal communities that are already struggling with erosion will experience accelerated shoreline retreat (Proshutinsky et al. 2001). The worst-case scenario predicts the total disappearance of entire low-lying islands or coastal states located far from the Arctic, such as Guyana, Belize, Bangladesh, or Singapore (Huebert 2004, Ingólfsdóttir 2014).

Category ii) challenges – pollution

This section focuses on key regional pollutants, including persistent organic pollutants (POPs), heavy metals, and plastics. It also examines the primary sources of this pollution, such as the significant military and nuclear presence, urban and industrial development, and shipping activities.

Persistent organic pollutants (POPs), heavy metals and plastics

Since the 1980s, numerous studies have focused on the investigation of pollutants in the Arctic. As early as the 1980s, research produced evidence that the types of pollutants found in the Arctic were not indigenous to the region. The pollutants came from all over the globe and could threaten the very existence of entire states (Huebert 2004).

Many chemicals classified as POPs are used globally in commercial products, particularly fertilizers, pesticides, and insecticides (Friedrich 2016[9]). Well-known pollutants include polychlorinated biphenyls (PCBs), widely used in plastic products, and dichlorodiphenyltrichloroethane (DDT), which in some countries is still used to protect against malaria, typhus, and other diseases spread by insects. Even where its use is restricted, DDT remains a potential threat due to its capacity for long-range transport and its tendency to bioaccumulate in the food chain. Furthermore, glacial meltwater is now considered a secondary source of this pollution, releasing historical deposits and confirming the persistence of DDT in remote polar regions. Despite international efforts like the 2001 Stockholm Convention to regulate such pollutants, their continued use in some parts of the globe and their environmental persistence mean they remain a significant concern (Friedrich 2016[9]).

These pollutants, which did not originate in the Arctic, were transported north through a series of geophysical factors. They are transported over long distances by air and water, and, to a lesser extent, by migratory species that travel from regions further south (Huebert 2004, Friedrich 2016[9]). The distance travelled by these pollutants led to the term transboundary pollutants (Huebert 2004).

POPs can be produced and released by mines, military sites, smelters, power stations, and various other industrial sources. By definition, these pollutants are environmentally persistent, because they are slow to degrade. This persistence is significantly amplified in the Arctic due to a combination of environmental factors. The region's low temperatures dramatically slow down the chemical and microbial breakdown of these compounds. Additionally, the long polar night limits or completely halts degradation by sunlight (phototransformation), while the presence of snow and ice can trap and preserve POPs for extended periods (AMAP 2004[1]). Consequently, the environmental half-life of some POPs can be prolonged from years in temperate climates to many decades or even centuries in the Arctic. It is important to note, however, that this persistence is not uniform; it is "species-specific," meaning it varies greatly among different types of POPs, some of which may degrade more rapidly under specific conditions (AMAP 2004[1], Friedrich 2016[9]).

A review of scientific studies brought striking findings; POPS are found concentrated in the tissues of several arctic species, including polar bears, whales, seals, and several species of seabirds and fish. In spring the melting ice and snow releases the accumulated POPs into the environment, where in turn they are ingested by wildlife. In the winter, through the metabolism of fat reserves, where they have accumulated, the POPs are released and impact the organism (Friedrich 2016[9]). In addition to contributing to a decline, diseases, and various abnormalities in wildlife species, POPs also represent a serious threat to human health and well-being. Like many animal species, their effects on humans include the promotion of certain types of cancer, congenital disabilities, dysfunctional immune and reproductive systems, damage to the nervous system, and a generally higher susceptibility to diseases through a weakened immune system. Human exposure to POPs mainly comes from contaminated food or transmission to the placenta and breast milk (Friedrich 2016[9]).

High levels of POPs are especially dangerous in the traditional subsistence foods consumed in the Arctic, many of which are high up in the food chain, rich in fat, and therefore rich in POPs. Marine and other mammals at the top of a food chain that contains high levels of POPs are the traditional northern foods and central to the diets of Indigenous Artic peoples. Furthermore, the price of food is high in the north and consequently the local population relies more on subsistence foods. As a result, they are more exposed to the harmful effects of persistent pollutants (Friedrich 2016[9]).

Besides POPs, heavy metals, such as mercury and lead, are the main contaminants found in the Arctic. When the ice melts in the summer, toxins are washed into rivers and the sea (Discovering the Arctic, n.d.[7]). Mercury pollution, much of which is a result of air and ocean transport represents a threat to Arctic wildlife and human populations. Mercury is bioaccumulated and biomagnified in Arctic food chains. This can result in high levels of mercury in the apex predators such as polar bears and toothed whales. Humans, especially some Indigenous populations, that rely on marine mammals as part of their traditional diet, can experience high dietary exposure, raising concerns about the possible effects on human health (Arctic Council, n.d.[3]).

In recent years, plastic debris and microplastics have been identified as a critical and fast-growing contaminant within the fragile Arctic ecosystem. A comprehensive review by Bergmann et al. (2022) identifies two primary origins for the plastic pollution: distant regions and local activities. A substantial amount of plastic is transported long-range into the Arctic from lower latitudes via ocean currents and atmospheric deposition. In addition, local sources are significant contributors, with waste stemming from regional fisheries, aquaculture, shipping, and community landfills. Regardless of its origin, this plastic litter can be devastating for wildlife. Researchers are increasingly concerned about the high concentration of microplastics accumulating in sea ice and the food chain, threatening various species, including seabirds, fish, and ultimately humans (Bergmann et al. 2022).

The interconnected threats of pollution and climate change pose a significant risk to freshwater access, an issue highlighted by the Intergovernmental Panel on Climate Change (IPCC) as early as 2007. These predictions are now materializing in the Arctic, where many small, remote Indigenous villages face growing water insecurity (Ingólfsdóttir 2014, Lawson 2019[13]). Historically, these communities relied on natural sources like ice melt and local lakes. However, recent studies show these traditional water sources are becoming contaminated, giving rise to health concerns (Evengard et al. 2011). This has led to a greater dependence on costly purchased tap or bottled water, creating new economic burdens (Lawson 2019[13]).

A significant military and nuclear presence

Prior to climate change being considered as a security threat, the focus of the Arctic states was on the heavy military and nuclear presence stemming from the Cold War. This era was marked by the construction of vast military infrastructure projects across the North, leaving a complex legacy that endures today. The arms race between the two major nuclear superpowers, the United States and the Soviet Union, caused extensive environmental damage and pollution across the Arctic. The use of large areas of land and sea for constant military testing and training, nuclear (submarine) accidents and leaks, and the experimental deployment and testing of weapons resulted in thousands of tons of rubbish, toxins, and radioactive waste (solid and liquid) being left behind. For decades, neither of the superpowers had the incentive (nor the expertise) to clean up the polluted areas. It was only due to the growing environmental awakening of the 1980s and 1990s that the severe ecological consequences of this military buildup began to be seriously addressed (Heininen and Exner-Pirot 2020).

One of the most relevant military projects is the US installation in northwestern Greenland. Built secretly in the early 1950s, the Pituffik Space Base (formerly Thule Air

Base) was established as a strategically vital U.S. installation for Cold War defenses against the Soviet Union. Today, under the U.S. Space Force, it remains a vital installation focused on missile warning and space surveillance. While the Cold War-era nuclear bombers are gone, the base's nuclear legacy continues to be a factor, particularly concerning the environmental fallout from a B-52 crash in 1968 and waste from abandoned research sites.

Another monumental project was the Distant Early Warning Line (DEW Line), a system of radar stations built in 1957 across the northern parts of Canada, Alaska, the Faroe Islands, Greenland, and Iceland to detect incoming Soviet bombers. Technology quickly made parts of the DEW Line obsolete, and many sites were abandoned within years, with the rest closing by 1993 (Contenta 2012[6]). This massive construction project resulted in a huge degree of contamination of the land and caused unimaginable environmental pollution. Around 10,000 personnel lived on site and operated the infrastructure. The soil was directly contaminated by diesel fuel and other chemicals, but the construction of warehouses, garages, living quarters, giant antennas, and water tanks irreversibly changed the pristine environment (Contenta 2012[6]). In the 1980s, the US and Canada started to cooperate on the clean-up, which continued till the 2010's. Without cooperative efforts and a common goal, removing toxic waste would not be financially or technically possible. Chemical pollution from the DEW Line caused serious diseases among the Inuit people thus the remediation project has given hope to Inuit communities (Contenta 2012[6]).

In the early 1990s, the full scale of the Soviet Union's nuclear legacy in the Arctic began to be understood. A central element of Moscow's Cold War activity was the Novaya Zemlya test site, established in 1955 as the primary testing polygon for new, high-yield nuclear weapons due to its remote location. To fulfill this role, between 1955 and 1990, the site hosted 130 nuclear tests, including the largest man-made explosion in history, the 50+ megaton "Tsar Bomba." In total, these tests released an explosive energy equivalent to 265 megatons of TNT (Khalturin et al. 2007).

In addition to the direct impacts of this testing, new reports in the 1990s revealed decades of deliberate radioactive dumping in the region, which served as a hub for the Soviet nuclear fleet (Sawhill 2000, US Government 1995[24]). For three decades, the former Soviet Union had disposed of radioactive waste in the Arctic Ocean and adjacent seas. Between 1960 and 1991, Russia sank 16 nuclear reactors–many of which had suffered accidents and still contained nuclear fuel–from its submarines and an icebreaker, in the Kara Sea. The former USSR also discharged vast quantities of low-level liquid and intermediate-level solid radioactive waste into these waters (Sawhill 2000).

Growing concerns over nuclear safety and the effects on human health galvanized public attention, which in turn forced nations to seek solutions. Several international mechanisms were implemented to enhance Russia's capacity to manage spent nuclear fuel and radioactive waste from its Northern Fleet (Sawhill 2000). The US-Soviet relationship took a decisive turn as a process was set in motion to address the nuclear legacy of the Cold War. This spirit of environmental cooperation between the Arctic states eventually led to the foundation of the Arctic Council in 1996 (Halašková 2025b).

Regional developments (urban and industrial)

In the distant past, Indigenous people mainly lived off the region's resources, typically seals and fish. Skins were made into clothing. Later, in the 19th and early 20th centuries, the commercial exploitation of resources, walrus hunting, whaling, and large-scale fishing, inevitably led to the decline of some species, and people searched for alternative opportunities to support themselves. Nowadays, the local population supports itself through a mixture of traditional and cash economies. Indigenous people still largely depend on subsistence hunting, trapping, and fishing. In contrast, others are employed full-time as wage earners (mining, oil and gas development, construction, services, and government activities). They only occasionally turn to hunting to supplement their diet with their preferred meat (Halašková 2025a).

Development in the Arctic is multifaceted, presenting both significant benefits and considerable drawbacks depending on one's perspective. For instance, while new infrastructure is crucial for the well-being of Arctic peoples, its construction irreversibly alters the landscape and impacts the ecosystem. Despite these development pressures, many communities still lack connections to basic road, electrical, water, and sewerage systems (Halašková 2025b).

Much of the Arctic's infrastructure construction is a direct result of industrial development, which is driven by external political and economic interests. These industrial activities–primarily oil and gas exploration, power generation, and extensive mining for coal, gold, and diamonds–require facilities whose construction and operation inevitably alter the natural habitat through pollution, noise, road dust, and hydrological changes (Halašková 2025b).

Expanding industries in the Arctic exert significant pressure on its ecosystems and biodiversity while also adversely impacting local communities. This is particularly critical for Indigenous peoples, whose cultural identity is deeply intertwined with their traditional livelihoods. A primary issue is the disruption of animal migration routes, which directly threatens these subsistence practices. For example, roads and windmills can impede the migration of caribou and reindeer, while underwater noise from drilling and the threat of oil spills endanger marine life, from whales to entire ecosystems (WWF Arctic 2022a[17]).

Warming of the Arctic provides access to previously unattainable resources, such as oil and gas reserves, which brings an increased risk of environmental disaster. Oil spills at sea impact Arctic security in more than one way due to the damage to commercial fisheries, coastal environments, and wildlife (Bailes 2015). This development is happening even though new Arctic oil and gas exploration and production goes against the goal of the Paris Agreement to stay within the 1.5°C limit for global warming (WWF Arctic 2022a, 2022b[17,18]).

New and easily accessible areas are attracting a rapidly growing number of tourists, creating two significant pressures on the Arctic environment. First, the expansion of tourism necessitates the construction of new infrastructure and logistical facilities on land. Second, it facilitates the introduction of non-native species, as tourists can inadvertently carry plant seeds and microorganisms on their clothes and shoes. When introduced via cruise ships and other boats, these invasive species negatively impact the region's unique habitat and biodiversity (Halašková 2025a, 2025b).

Although this section's primary focus is on the negative impacts of pollution, it is important to acknowledge that anthropogenic changes can have complex and sometimes paradoxical effects. On one hand, these changes can create economic opportunities, such as new shipping routes and longer seasons for sailing, fishing, and hunting (Halašková 2025a). On the other hand, new infrastructure can lead to unforeseen ecological shifts. For instance, recent studies have documented how some opportunistic species adapt to industrial development; predatory birds like ravens and gulls, for example, leverage oil field structures for perching and forage at associated rubbish dumps.

Fig. 1. A young Polar Bear foraging near the Czech polar station in Svalbard. His presence interrupted the fieldwork of a group of geology and climatology students, compelling them to shelter within the cabin for several days (2014, author Ondřej Bárta).

Fig. 2. Black-legged Kittiwake utilizing abandoned human infrastructure for nesting in the former Soviet mining settlement of Pyramiden, Svalbard (2014, author Jana Elsterová).

This anthropogenic support has been shown to increase their local populations, leading to higher predation pressure on vulnerable ground-nesting birds (Liebezeit et al. 2009). Another study observed that some animals, such as caribou and bears in Alaska, lie down close to oil and gas pipelines, using the radiant heat for warmth to protect their infant offspring or as shelter from harsh weather, while other wildlife has been observed seeking shelter in abandoned buildings or sites (Cameron and Whitten 1979[5], Wolfe et al. 2000[16], Halašková 2025b).

Shipping

The opening of Arctic waters presents significant economic opportunities, primarily through new shipping routes that are shorter than those via the Panama and Suez Canals and more viable than difficult overland transport (Halašková 2025a). This potential has already driven a 25 percent increase in Arctic shipping traffic between 2013 and 2019 as more oil tankers and bulk carriers passed through the region's waters. A prime example of this strategic development is Russia's recent focus on modernizing the port of Tiksi, a key hub on the Northern Sea Route. Plans to dredge the harbor and construct a new deepwater facility are designed to support year-round shipping of resources like oil, gas, and coal. Such large-scale industrial development in a fragile environment brings considerable risks, including the potential for devastating oil spills in ice-covered waters, disruption of marine ecosystems from underwater noise, and increased pollution from ship traffic (Gricius 2024, WWF Arctic 2023a[19]). Despite the ambitious plans, as Povoroznyuk (2024, cited in Ellekrog 2024[8]) notes, there is a major discrepancy between the Russian government promises for the Tiksi port and the current reality. The planed modernization has yet to materialize, leaving the port with deteriorating infrastructure and an economy in continuous decline (Ellekrog 2024[8]).

Heavy fuel oil (HFO) accounts for approximately three-quarters of the marine fuel currently used by ships in the Arctic. HFO is problematic for the Arctic ecosystems in several ways. When this dirty, viscous, and polluting fossil fuel is spilled in cold polar waters, it breaks down even more slowly than other fossil fuels and there is currently no viable method to remove the oil from ice (Eguíluz et al. 2016, WWF Arctic 2023a[19]).

There is also no infrastructure in place in the Arctic where a cleanup operation could be based. Thus, any HFO spill will have long-term, devastating effects on Arctic communities and the marine ecosystems and species they depend upon. It could also hinder Arctic communities' subsistence harvesting of fish and marine mammals through coastline contamination. This could lead to food shortages and jeopardize livelihoods, cultures, and human health in the Arctic, especially Indigenous communities. When HFO is burned, it produces high levels of black carbon particles that enter the environment through exhaust fumes. Not only is black carbon a dangerous pollutant linked to heart and lung disease, but it also reduces the reflectivity of Arctic snow and ice. This accelerates snow and ice melt, as more heat from the sun is absorbed rather than reflected (WWF Arctic 2023a[19]).

More ships in Arctic waters have also led to an increase in underwater noise, which is harmful to marine life. All marine mammals rely on sound to locate food, find mates, navigate, avoid predators, and care for their young. The cold temperature and other oceanographic conditions of the Arctic Ocean enable sounds from ships to travel long distances in shallow water.

This means that underwater noise is concentrated within the swimming and diving ranges of whales, walruses, and seals. Even a small increase in ship traffic can significantly impact the acoustic environment of the Arctic Ocean when compared to other oceans around the world (WWF Arctic 2023a[19]).

While shipping provides an essential supply service for the Arctic communities, the harsh environment demands robust safety and environmental rules. A significant improvement to the previously inconsistent and often voluntary guidelines was needed. This led to the creation of the first legally binding document covering the full range of shipping-related matters: the International Code for Ships Operating in Polar Waters (Polar Code). The Polar Code, which entered into force in January 2017, defines all the conditions that any ship willing to sail in the Arctic Ocean needs to fulfil. It includes all relevant information for navigation in waters surrounding the two poles; ship design, construction, equipment; operational and training concerns; search and rescue; and, equally importantly, protection of the unique environment and ecosystems of the polar regions (IMO 2023[10]).

In addition to the Polar Code, there is still a need for a transition to lower-emission fuels and methods of propulsion to ensure it is sustainable. Switching to distillate fuels would reduce black carbon emissions by some 40 percent, and installing particulate filters on ship engines would reduce emissions by more than 90 percent (WWF Arctic 2023a[19]). Besides that, adopting responsible routing measures, such as the development of shipping lanes, traffic separation schemes, precautionary areas, and areas to avoid throughout the year, could reduce the effect of shipping on the environment. Developing and implementing tighter regulation on ship speeds in sensitive areas for biodiversity and technological solutions for ship and propeller design would also help to reduce the underwater noise that is putting Arctic marine life at risk (WWF Arctic 2023a[19]).

Category iii) challenges – new trends

This final section considers new trends such as hybrid threats, illegal activities, and the interests of non-Arctic states in the region.

Hybrid threats

Cyberattacks and the attempted sabotage of critical infrastructure have recently increased across the region. Since Russia's full-fledged invasion of Ukraine in February 2022, tensions in the Baltic Sea have heightened and the number of incidents involving damage to undersea infrastructure has increased. Russia's undersea hybrid warfare aims to disrupt the European economy through attacks on cables, internet cables, and pipelines. Consequently, all critical economic infrastructure on the seabed–such as pipelines and communication cables–is considered vulnerable. Specifically, in the Arctic, hybrid tactics aim to have a large impact across the region, targeting democratic electoral systems, healthcare organizations and they seek to conduct operations that would influence the area (Gricius 2024).

Some recent examples include: the cutting of a cable from mainland Norway to Svalbard, the circling of Russian ships above a key transatlantic cable close to Ireland, and the sabotage of the Nord Stream 2 pipeline (Gricius 2024). The latest incident was in November 2024, when two undersea fibre-optic communication cables in the Baltic Sea were damaged. After investigation, Germany confirmed that the damage to two internet cables, one running between Finland and Germany and the other between Sweden and Lithuania, were acts of sabotage (Bryant 2024[4]). Hence, Sweden took steps to protect additional undersea infrastructure such as windfarms, which have "system vulnerabilities" (Bryant 2024[4]).

When cybersecurity threats materialize in the Arctic, their impact can be even more harmful than elsewhere due to the harsh environmental and climatic conditions, the remoteness, vast distances, and vulnerability of Arctic communities. Hence, the critical infrastructure in Arctic countries becomes "extra critical," and any economic development opportunities in the High North are accompanied by the dangers of cyber threats. Amongst critical infrastructure, the energy sector is especially relevant in the north. This sector is in a large part dependent on digitalization, the Internet, and the demands of computers (Cassotta et al. 2019).

The Arctic regions host many data hubs, and significant energy resources depend on reliable computer control. Weather conditions and potential natural disasters require new methodologies for risk and resilience assessment, as well as effective legal and governance frameworks to protect critical infrastructure and sustain both civilian and military activities (Arctic Centre 2019[2]). Each of the Arctic states is trying to fight against these hybrid threats on their own. However, their efforts are rather limited, and international cooperation is vital here. Sharing lessons learned and best practices could strengthen ties. For this purpose, the European Centre of Excellence for Countering Hybrid Threats was established in 2017 and today it also covers issues that threaten the Arctic, including threats to critical infrastructure, information, cybersecurity, and societal resilience. The Centre conducts training courses and exercises for policymakers and practitioners (Gricius 2024).

Illegal activities

In the aftermath of the 2001 terrorist attacks, the US and Canada grew concerned that the under-monitored Arctic could become an entry point for terrorists into North America, prompting efforts to improve surveillance and interception capabilities (Huebert 2004). However, as scholars like Elgaas (2017) note, the region's security challenges have become significantly more complex. The focus has expanded to include a mix of illegal activities, increased commercial traffic, and international resource competition, all of which demand robust monitoring. In response to this multifaceted threat environment, various states have bolstered their presence; for example, Denmark has enhanced its air and sea surveillance to prevent international organized crime (Bergman Rosamond 2011), underscoring the critical need for comprehensive regional monitoring (Kirk 2023[11]).

Although terrorist activities in the Arctic are rather limited at this moment, the overall decrease in sea ice could lead northern borders to become increasingly accessible for different types of illegal activity and maritime crimes, for example, smuggling, irregular migration, piracy, or illegal fishing (Gricius 2024). All five Arctic coastal states acknowledge there are threats to maritime security stemming from non-state organized criminal actors. Nevertheless, they lack any system-based understanding of these threats, a differentiated approach to assess specific types of potential maritime criminal activities, or developed practical measures aimed at their prevention and suppression. Also, they lack the necessary capability and resources to efficiently address these threats on their own; hence, enhanced regional interstate cooperation in this field, for example, through the Arctic Coast Guard Forum, should be a priority (Todorov 2019).

Currently, the most significant maritime security threats in the region include terrorist attacks on cruise ships, the trafficking of drugs and weapons, and illegal migration. Regarding piracy, the Arctic has not historically been a hotspot compared to busier shipping lanes in warmer climates, such as the Gulf of Aden or the Malacca Strait. Still, increased economic opportunities and resource exploration, together with a lack of oversight, allow pirates to operate without much fear of getting caught (Todorov 2019). To mitigate these threats, the Arctic states rely on international laws, such as those outlined in the United Nations Convention on the Law of the Sea (UNCLOS), which plays a crucial role in addressing piracy. The UNCLOS provides provisions for the prosecution of pirates and emphasizes the freedom of navigation for all states, regardless of their coastal or landlocked status. However, the implementation of these laws requires international cooperation and a unified approach to ensure the security and safety of Arctic waters (Todorov 2019).

Illegal fishing is one of the threats spreading across the Arctic region. The World Wildlife Fund (WWF) differentiates between illegal fishing, unreported fishing, and unregulated fishing. Illegal fishing is "conducted by vessels of countries that are party to a fisheries organization, but which operate in violation of its rules, operate in a country's waters without permission, or on the high seas without showing a flag or other markings". The second category, unreported fishing, "catches are not reported to the relevant authorities by the fishing vessels or flag state, whether they are parties or not of the relevant fisheries organization, this includes misreported and underreported catches". The last category is unregulated fishing, which is "conducted by vessels flying the flag of countries that are not parties of or participants in relevant fisheries organizations and therefore consider themselves not bound by their rules" (WWF 2024[21]). Arctic coastal states report all these types of criminal maritime activity.

In recent years, the Arctic states have made significant progress in reducing, but by no means eliminating, IUU (illegal, unreported, unregulated) fishing in the Barents Sea. However, the new WWF report states that it is still a concern in the western Bering Sea and the Sea of Okhotsk in the Russian Far East. One of the valuable instruments in this field is the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean, which came into force in June 2021. In addition, to reduce IUU fishing in the Arctic, some regional fishery management organizations (RFMOs) have established Port State Control that measures and blacklists vessels that are known to not observe national and international law (WWF 2024[21]).

Interests of non-Arctic states

The last and most complicated area to tackle is the relationship between Arctic states and rising interest and activities of non-Arctic actors, who may have economic or commercial interests in the region (Gricius 2024). The agenda of the Arctic Council covers some areas of the involvement of non-Arctic states in the region. The Council (through the governments of Arctic states) recognizes the need to provide an opportunity for the governmental and non-governmental organizations of non-Arctic countries with Arctic interests to actively participate in the work of the

Council. Following this, the Declaration of the First Ministerial Meeting of the Arctic Council in 1998 (The Iqaluit Declaration[15]) approved the provision of observer status for several committed intergovernmental and international non-governmental organizations and non-Arctic states. Although there are certain criteria for the admission of observers, as well as restrictions on their rights, the granting of (permanent) observer status at the Arctic Council is attractive to many non-Arctic states, particularly those with scientific interests in the polar regions or global economic interests. By the 11th Ministerial of the Arctic Council in May 2019, a total of 39 states and organizations, 13 non-Arctic states, 14 intergovernmental and inter-parliamentary organizations, and 12 international non-governmental organizations, had been approved as observers at the Arctic Council (Heininen et al. 2019).

Besides joint decisions made at the Council, each Arctic state has a different approach to cooperation and business relations with non-Arctic actors at a bilateral level. Some of their strategies comment on scientific cooperation with non-Arctic states. This is important as science is often the only connection and gateway a non-Artic state has into the Arctic (Heininen and Exner-Pirot 2020, Everett and Halašková 2022). Many non-Arctic states have research stations based in the Arctic, which provides them with further opportunities to cooperate with other regional actors.

Among all non-Arctic states involved in the region, China's Arctic interests and policies have been subject to the most intense international scrutiny and speculation (Heininen et al. 2019). Despite not sharing a border with the region, China's interest in the Arctic is manifested through bilateral cooperation with Russia. In September 2022, reports that the US Coast Guard had spotted Chinese and Russian naval vessels engaged in some form of military operation off the coast of the Alaskan Aleutian Islands offered another signal of increased Sino-Russian Arctic cooperation in the aftermath of Russia's 2022 invasion of Ukraine. In April 2023, a Memorandum of Understanding between the Chinese and Russian coast guards was signed in the Arctic town of Murmansk. Increased cooperation between the two countries on Arctic and ocean affairs, including fisheries, is likely to play out in the Bering Sea (Evans and Østhagen 2023).

Cooperation in 2025 and onwards

This final section analyzes how cooperation can be maintained in the region, exploring mechanisms like international scientific partnerships and science diplomacy, especially during times of conflict. These topics are explored alongside potential future developments, with a focus on the inherent tension between shared threats and divergent national priorities.

Mechanisms for cooperation in times of conflict

Although sovereign Arctic states continue to be the most important actors in shaping the future of the region, the border-crossing nature of contemporary challenges demands deep regional cooperation. This is not without precedent; a foundational shift towards collaboration occurred in the latter years of the Cold War, when leaders began to envision the Arctic as a zone of scientific partnership rather than military confrontation. Given the need to develop an international response to the devastating pollution, it was decided that a focus on these problems would be the best way to promote cooperation. The overall impact of this decision was to elevate the issue of environmental security to become the primary issue for international cooperation in the circumpolar north. This was institutionalized by the creation of the Arctic Environmental Protection Strategy (AEPS), which then evolved into the Arctic Council. While the agenda of the Council later developed to include other issues in its mandate, environmental protection remained its core mandate (Huebert 2004).

The Council continues to be a venue for scientific collaboration through working groups and their studies and initiatives, along with binding agreements such as the 2017 Agreement on Enhancing International Arctic Scientific Cooperation. Other organizations, such as the International Arctic Science Committee (IASC) and the University of the Arctic (UArctic), also support cooperation in international research. Cooperation between states also takes place through formal large-scale research programs, such as the International Geophysical Year and International Polar Year initiatives (IPY) (Everett and Halašková 2022). The IPY has a long-term legacy, it started as early as 1882/83 as a wide international research program, with the participation of scientists from 12 states that collaborated on the expedition and research. It is worth emphasizing that there were subsequent editions of the initiative in 1932/33, 1957/58, and 2007/8 (Łuszczuk et al. 2020). Currently, planning for a fifth IPY-5 program in 2032/33 has begun following an agreement between the IASC and the Scientific Committee on Antarctic Research (SCAR).

One of the biggest advantages of the Arctic is that the region is deeply embedded within multiple governance systems, lacks large geopolitical fault lines, and anticipates no resource wars. Although there are some tendencies among the Arctic coastal states to try and expand their national territories in the High North, to date all disagreements have been solved through the application of international rules and laws (Lathrop et al. 2018, Bergman Rosamond 2011). Nevertheless, the cooperative setup has changed since the Russian invasion of Ukraine. Since then, all partnerships and areas of cooperation between Moscow and Europe/North America have fallen apart.

This major conflict in Europe, after decades of relative peace, sparked a profound debate within the global scientific community. The central dilemma was whether to isolate Russian researchers as a punitive measure against their government or to uphold the principle of open scientific collaboration. In response, a broad coalition of Western nations, including most Arctic states and other key scientific players like Germany, the UK, and the United States, suspended formal cooperation with Russian state-funded institutions. However, the approach toward individual scientists and publications was more nuanced. Most major international scientific journals, including publishers like Elsevier and Springer Nature, explicitly stated they would not boycott manuscripts based on their authors' nationality, continuing to judge research on scientific merit alone. This led to a complex landscape of responses: some universities halted all collaboration with Russian entities, others excluded Russian scientists only from new projects, while many sought ways to support individual researchers, distinguishing them from their government's actions.

The Arctic Council remains the key platform for the enhancement of inter-state cooperation and setting regional governance structures. Although Russia stopped all financial support to the Council, there are still instruments, through working groups, that allow the involvement of Russian scientists in research focused on global challenges such as climate change and pollution. Avoiding the complete isolation of Russian scientists from international cooperation brings at least one additional benefit that Western countries should consider, the prevention of scientific protectionism. Even in times of conflict, states must engage in scientific collaboration to prevent scientific protectionism, which includes risks like a dependence on foreign countries and dual-use technology. Indeed, scientific protectionism can slow the pace of innovation, weaken international problem-solving capabilities, and deprive researchers of the opportunity to work across borders on global challenges (Van Langenhove and Piaget 2024).

At an international level, science is recognized as a strategic tool to foster international cooperation and an important channel for peace and building of trust. The rationale is that scientists speak the same "language," which can weave cultures together and build trust, irrespective of the political animosities between governments. Over time, science has demonstrated its utility in peacekeeping and conflict mitigation. Considering that one day, this conflict will be over, it is important not to lose sight of the post-conflict picture and think about the future of science (Van Langenhove et al. 2022, Van Langenhove and Piaget 2024). Hence, in the long term, maintaining open scientific collaboration with Russia seems to be advantageous.

International scientific cooperation and science diplomacy

According to The Royal Society, science diplomacy (SD) "seeks to strengthen the symbiosis between the interests and motivations of the scientific and foreign policy communities". This concept is typically actualized in three distinct forms: *Science in diplomacy*, which uses scientific evidence to inform foreign policy decisions; *Diplomacy for science*, which uses diplomatic action to facilitate international scientific collaboration; and *Science for diplomacy*, which uses scientific cooperation as a tool to "improve international relations between countries" (The Royal Society 2010[23], Everett and Halašková 2022).

Indeed, scientific collaboration (the essence of science diplomacy), even between states in conflict, can keep lines of dialogue open and contribute to the development of mutual trust (Van Langenhove et al. 2022). Certainly, "through scientific research, states are able to overcome their disagreements and create strong international science cooperation" (Kavan and Halašková 2022). States realize that the increasing threats are often of a transborder character and could threaten their existence. Therefore, engaging in international cooperation is crucial to their survival. What is more, scientific cooperation also stimulates cooperation in other areas, which is particularly important for the Arctic (Łuszczuk et al. 2020). The current challenge for SD is to ensure that even warring countries keep working together on common threats (Van Langenhove et al. 2022).

Although some experts argue that strictly speaking SD can only be performed by state governments, given the interdisciplinary character of polar science, it is important that non-state actors are also included, for example, scientists (assuming that they are unbiased and apolitical) to invigorate the diplomatic interchange. NGOs, the private sector, and academic institutions must increase their engagement in diplomacy. These actors can bring innovation, resources, and the diverse perspectives essential to allow global challenges to be tackled (Van Langenhove and Piaget 2024). Scientific cooperation also exists outside of formal structures and initiatives. For instance, infrastructure such as research stations can be shared, thus minimizing the potential for conflict in the Arctic. For example, despite the larger geopolitical discourse of distrust, China actively participates in multiple facets of the international Arctic science community (Everett and Halašková 2022, Bertelsen 2020).

A clear illustration of 'science for diplomacy' emerged following the 2022 Russian invasion of Ukraine in a statement by the Association of Polar Early Career Scientists (APECS). The statement performed a delicate diplomatic function: it strongly condemned the invasion while simultaneously working to preserve the scientific community. Recognizing the research contributions of both countries, APECS committed to mitigating the isolation of its Russian members, vowing to "encourage the continued participation of our Russian members, who may feel trapped in a situation imposed upon them" (Van Langenhove et al. 2022).

During the Cold War, SD was a useful mechanism for maintaining peace in the Arctic. Even though SD then and now (in times of a hot conflict) are totally different, some of these practices still carry on today through different organizations (Bertelsen 2020, Van Langenhove et al. 2022). Most notable are the previously mentioned Arctic Council and international organizations. SD can be a very effective "tool of soft power, given its neutral and nonpolitical character." Therefore, when SD is used alongside other foreign policy mechanisms, it can help to maintain existing relationships and foster new ones while keeping lines of communication open, such as those that have been developed through scientific and intergovernmental networks (Everett and Halašková 2022).

Possible future developments: shared threats – different priorities

The concept of environmental security has been central to understanding the post-Cold War Arctic, a field significantly shaped by prominent Finnish political scientist and Arctic security scholar Lassi Heininen. In his edited volume, *Climate Change and Arctic Security: Searching for a Paradigm Shift* (2020), he poses a fundamental question: Do individuals and states share common security interests related to the environment, and if so, does climate change represent such an interest? The argument of this publication is that it does. Given that no single Arctic state can resolve the region's environmental threats independently, cooperation becomes a necessity. The Arctic states face new challenges and multiplying threats that require coordinated action. Even though there are differences in the level of priority they give these challenges, cooperation on shared issues is key to success (Gricius 2024).

Most of the Arctic states share similar views on common security challenges. At the same time, some of the threats might conflict with their economic or foreign policy goals. For example, regarding environmental protection, we observe conflicting views, ranging from support for unlimited oil and gas development by state-owned and private oil companies to the proposal by international environmental organizations for an offshore oil drilling ban (Heininen et al. 2019). There are also various views regarding the extent to which stakeholders: governments, companies, communities, and Indigenous peoples are responsible for the mitigation of climate change and reduction of the related uncertainty at a time when some are stressing economic growth and others are highlighting the environmental risks of exploitation. The new ethical questions regarding Arctic oil and gas development have a fundamental global dimension, highlighted by an 'Arctic Paradox,' namely, that global warming will open up access to resources whose utilization will further speed up changes and the melting of sea ice (Heininen et al. 2019).

In addition to pre-existing differences in state priorities, Russia's 2022 invasion of Ukraine served as a profound geopolitical shock. As noted earlier, the conflict effectively ended cooperation between Moscow and Western Arctic nations. This rift extended to academia, with numerous universities abandoning relationships developed over 30 years. Consequently, vital research projects on climate science and industrial development were halted, setting back environmental protection efforts at a time when climate impacts and geopolitical tensions in the Arctic are intensifying. The most realistic future scenario includes an issue-oriented change 'from theory to action' that could be facilitated via a co-design interdisciplinarity approach involving all relevant stakeholders based on open dialogue. Through 'ethics' and 'political ability', strict environmental regulations (even to stop offshore drilling in Arctic seas) should be adopted to protect the Arctic. However, all this calls for a holistic understanding of the state of the Arctic and its governance and geopolitics, along with the policies stakeholders have adopted and are designing for the region and its future development (Heininen et al. 2019).

Concluding remarks

The last three decades established a new paradigm for Arctic security. The notion that security has many dimensions has become commonplace. Especially in the Arctic, it has become clear that threats to the environment are of equal importance to military threats. The Arctic states have also come to an understanding that multiplier threats necessitate deep regional cooperation. The success of joint initiatives like the Arctic Council demonstrated that this cooperative model was not just aspirational, but realistic.

The central, unanswered question today is whether this cooperative paradigm can survive open military conflict. Russia's 2022 invasion of Ukraine has created an unprecedented rupture, forcing a dilemma upon the international community. On one hand, isolating Russia through sanctions is a primary tool to pressure an end to the war, holding the state accountable for violating international norms. On the other hand, this strategy comes at a steep environmental price. Halting collaboration with Russia, a critical Arctic actor, severely compromises the ability to mitigate shared, intensifying climatic threats.

Currently, the principles of Realpolitik are prevailing, where the immediate security interests of states supersede the collective need for environmental action. While environmental security is undeniably crucial–affecting everything from biodiversity to human access to clean water–it has proven insufficient to compel a renewal of scientific cooperation with Russia. Instead, Western Arctic states are reallocating environmental budgets toward military defense against a perceived Russian threat. The ultimate consequence of this geopolitical realignment is that the Arctic's fragile environment and its peoples bear the highest cost.

References

BAILES, A. J. K. (2015): Wilder security angles. *In:* J. Jokela (eds.): *Arctic security matters*. EU Institute for Security Studies, pp. 69–74. https://www.iss.europa.eu/sites/default/files/EUISSFiles/Report%2024.pdf

BERGMANN, M., COLLARD, F., FABRES, J., GABRIELSEN, G. W., PROVENCHER, J. F., ROCHMAN, C. M., VAN SEBILLE, E. and TEKMAN, M. B. (2022): Plastic pollution in the Arctic. *Nature Reviews Earth & Environment*, 3: 323-337. doi: 10.1038/s43017-022-00279-8

BERGMAN ROSAMOND, A. (2011): Perspectives on security in the Arctic area. DIIS Report. *Danish Institute for International Studies*, 2011(09). https://www.files.ethz.ch/isn/133473/RP2011-09-Arctic-security_web.pdf

BERTELSEN, R. G. (2020): Science diplomacy and the Arctic. *In:* G. H. Gjørv, M. Lanteigne, & H. Sam-Aggrey (eds.): *Routledge Handbook of Arctic Security*. Routledge, pp. 233–244.

CASSOTTA, S., SIDORTSOV, R., PURSIAINEN, C. and GOODSITE, M. (2019): Cyber threats, harsh environment and the European High North (EHN) in a human security and multi-level regulatory global dimension: Which framework applicable to critical infrastructures under "Exceptionally Critical Infrastructure Conditions" (ECIC)?. *Beijing Law Review*, 10(2): 317-360. doi: 10.4236/blr.2019.102020

EGUÍLUZ, V. M., FERNÁNDEZ-GRACIA, J., IRIGOIEN, X. and DUARTE, C. M. (2016): A quantitative assessment of Arctic shipping in 2010–2014. *Scientific Reports*, 6: 30682. doi: 10.1038/srep30682

ELGSAAS, I. M. (2019): Arctic counterterrorism: Can Arctic cooperation overcome its most divisive challenge yet? *The Polar Journal*, 9(1): 27-44. doi: 10.1080/2154896X.2019.1618550

ENGSTROM, D. R., SWAIN, E. B. (1997): Recent declines in atmospheric mercury deposition in the upper Midwest. *Environmental Science & Technology*, 31(4): 960-967. doi: 10.1021/es9600892

EVANS, G., ØSTHAGEN, A. (2023): In hot water: Arctic fisheries as a proxy for geopolitical tensions. *The Royal United Services Institute*. https://rusi.org/explore-our-research/publications/commentary/hot-water-arctic-fisheries-proxy-geopolitical-tensions

EVENGARD, B., BERNER, J., BRUBAKER, M., MULVAD, G. and REVICH, B. (2011): Climate change and water security with a focus on the Arctic. *Global Health Action*, 4(1). doi: 10.3402/gha.v4i0.8449

EVERETT, K., HALAŠKOVÁ, B. (2022): Is it real? Science diplomacy in the Arctic states' strategies. *Polar Record*, 58(27): 1-14. doi: 10.1017/S0032247422000183

GRICIUS, G. (2024): A transatlantic perspective on Arctic security how can Europe and North America address common security concerns in the Arctic while trying to overcome distinct challenges in the High North? *The Transatlantic Policy Center*. https://www.american.edu/sis/centers/transatlantic-policy/policy-briefs/20240226-a-transatlantic-perspective-on-arctic-security.cfm

HALAŠKOVÁ, B. (2025a): How do human activities impact the Arctic environment? *In*: S. Dotta, M. Bassoi, L. Campos, H. Griffiths (eds.): *101 Questions about the Arctic*. Biodiverdade nas Regioes Polares. 1st ed. Santo André: InterAntar, 2025, pp. 197–198. Coleçao Perguntas sobre regioes polares - vol. 2. ISBN 978-65-01-69615-7.

HALAŠKOVÁ, B. (2025b): Does infrastructure hurt or help the Arctic nature? *In:* S. Dotta, M. Bassoi, L. Campos, H. Griffiths (eds.): *101 Questions about the Arctic*. Biodiverdade nas Regioes Polares. 1st ed. Santo André: InterAntar, 2025, pp. 148–149. Coleçao Perguntas sobre regioes polares - vol. 2. ISBN 978-65-01-69615-7.

HEFFERNAN, A., PARSONS, C. (2024): The increased relevance of Arctic and cyber politics. *The Arctic Online*, 9(9). https://www.queensu.ca/cidp/arctic-online-cybersecurity-quintessential-canadas-arctic-security

HEININEN, L., EVERETT, K., PADRTOVÁ, B. and REISSELL, A. (2019): Arctic policies and strategies – analysis, synthesis, and trends. *IIASA*. ISBN 978-3-7045-0156-1. doi: 10.22022/AFI/11-2019.16175

HEININEN, L., EXNER-PIROT, H. (2020): Introduction: Theorizing and broadening Arctic security– Towards the environment and climate. *In*: L. Heininen, H. Exner-Pirot (eds.): *Climate change and Arctic security*. Palgrave Pivot, Cham. doi: 10.1007/978-3-030-20230-9_1 https://link.springer.com/book/10.1007/978-3-030-20230-9

HUEBERT, R. (2004): Arctic security: Different threats and different responses. A Discussion Paper. *University of Akureyri research centre*. https://www.rha.is/static/files/NRF/OpenAssemblies/Yellowknife2004/3rd-nrf_plenary-4_pp_huebert.pdf

INGÓLFSDÓTTIR, A. H. (2014): Environmental security and small states, *In*: C. Archer, A. Bailes, A. Wivel (eds.): *Small states and international security*. Routlege, pp. 80–92.

KALLIOJÄRVI, S. (2020): Age of changes: Threat of climate change and its meaning for security. *In*: L. Heininen, H. Exner-Pirot (eds.): *Climate change and Arctic security*. Palgrave Pivot Cham, pp. 9–32. https://link.springer.com/book/10.1007/978-3-030-20230-9#toc

KAVAN, J., HALAŠKOVÁ, B. (2022): The rise and fall of Pyramiden: The story of a town in a wider geopolitical and environmental context. *Polar Record,* 58. doi: 10.1017/S0032247422000018

KHALTURIN, V. I., RAUTIAN, T. G., RICHARDS, P. G. and LEITH, W. S. (2005): A review of nuclear testing by the Soviet Union at Novaya Zemlya, 1955–1990. *Science and Global Security*, 13: 1-42. doi: 10.1080/08929880590961862

KIM, Y. H., MIN, S. K., GILLETT, N. P., NOTZ, D. and MALININA, E. (2023): Observationally-constrained projections of an ice-free Arctic even under a low emission scenario. *Nature Communications*, 14: 3139. doi: 10.1038/s41467-023-38511-8

LATHROP, C. G., ROACH, J. A. and ROTHWELL, D. R. (2018): Baselines under the international law of the sea: Reports of the International Law Association Committee on baselines under the international law of the sea. *The Law of the Sea*, 2.1–2: 1-177. doi: 10.1163/24519359-12340005

LIEBEZEIT, J. R., KENDALL, S. J., BROWN, S., JOHNSON, C. B., MARTIN, P., MCDONALD, T. L., PAYER, D. C., REA, C. L., STREEVER, B., WILDMAN, A. M., and ZACK, S. (2009): Influence of human development and predators on nest survival of tundra birds, Arctic Coastal Plain, Alaska, USA. *Ecological Applications*, 19(6): 1594-1605. doi: 10.1890/08-1661.1

ŁUSZCZUK, M., PADRTOVÁ, B. and SZCZERBOWICZ, W. (2020): Political dimension of Arctic research. *Oceanologia,* 62(4): 608-621. doi: 10.1016/j.oceano.2020.03.008.

NOTZ, D. and SIMIP COMMUNITY (2020): Arctic sea ice in CMIP6. *Geophysical Research Letters*, 47: e2019GL086749. doi: 10.1029/2019GL086749

PADRTOVÁ, B. (2017): Securitization of the Arctic: US Securitizing Actors and Their Strategies. *PhD thesis*, Masaryk University. https://is.muni.cz/auth/th/o6uon/Padrtova_PhD_thesis_FINAL.pdf

PROSHUTINSKY A., PAVLOV, V. and BOURKE, R. H. (2001): Sea level rise in the Arctic Ocean. *Geophysical Research Letters*, 28(11): 2237-2240. https://www.whoi.edu/science/po/arcticsealevel/pdfs/Prosh-sea-level-rise.pdf

RANTANEN, M., KARPECHKO, A. Y., LIPPONEN, A., NORDLING, K., HYVÄRINEN, O., RUOSTEENOJA, K., VIHMA, T. and LAAKSONEN, A. (2022): The Arctic has warmed nearly four times faster than the globe since 1979. *Commun Earth Environ* 3(1): 168. doi: 10.1038/s43247-022-00498-3

SAWHILL, S. G. (2000): Cleaning-up the Arctic's cold war legacy: Nuclear waste and Arctic military environmental cooperation. *Cooperation and Conflict*, 35(1): 5-36. https://www.jstor.org/stable/45083162

SCHUSTER, P. F., SCHAEFER, K. M., AIKEN, G. R., ANTWEILER, R. C., DEWILD, J. F., GRYZIEC, J. D., GUSMEROLI, A., HUGELIUS, G., JAFAROV, E., KRABBENHOFT, D. P., LIU, L., HERMAN-MERCER, N., MU, C., ROTH, D. A., SCHAEFER, T., STRIEGL, R. G., WICKLAND, K. P. and ZHANG, T. (2018): Permafrost stores a globally significant amount of mercury. *Geophysical Research Letters*, 45(3): 1463-1471. doi: 10.1002/2017GL075571

STREETS, D. G., DEVANE, M. K., LU, Z., BOND, T. C., SUNDERLAND, E. M. and JACOB, D. J. (2011): All-time releases of mercury to the atmosphere from human activities. *Environmental Science & Technology*, 45(24): 10485-10491. doi: 10.1021/es202765m

TANGUY, R., BARTSCH, A., NITZE, I., IRRGANG, A., PETZOLD, P., WIDHALM, B., VON BAECKMANN, C., BOIKE, J., MARTIN, J., EFIMOVA, A., VIEIRA, G., WHALEN, D., HEIM, B., WIECZOREK, M. and GROSSE, G. (2024): Pan-Arctic assessment of coastal settlements and infrastructure vulnerable to coastal erosion, sea-level rise, and permafrost thaw. *Earth's Future*, 12(12). doi: 10.1029/2024ef005013

TODOROV, A. (2019): Assessment of threats related to maritime crimes in the Arctic. *World Economy and International Relations*, 63(9): 104-111. doi: 10.20542/0131-2227-2019-63-9-104-111

VAN LANGENHOVE, L., PIAGET, E. (2024): Leveraging science diplomacy in times of conflict. *Georgetown Journal of International Affairs*. https://gjia.georgetown.edu/2024/07/19/leveraging-science-diplomacy-in-times-of-conflict/

VAN LANGENHOVE, L., SOETE, L. and PIAGET, E. (2022): Science diplomacy in the age of war Commentaries. *Frontiers Policy Labs*. https://policylabs.frontiersin.org/content/science-diplomacy-in-the-age-of-war

Web sources / Other sources

[1] AMAP (2004): AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic. Oslo, Norway. https://www.amap.no/documents/doc/amap-assessment-2002-persistent-organic-pollutants-in-the-arctic/75

[2] Arctic Centre (2019): Workshop: Governance for Cyber Security and Resilience in the Arctic. https://www.arcticcentre.org/events/Workshop-Governance-for-Cyber-Security-and-Resilience-in-the-Arctic/tx3hyamc/42bb614c-8e49-4a5c-b735-28c61cc2b9b1 (Accessed on 12-Dec-2024).

[3] Arctic Council (n.d.): Contaminant Issues: Pops and Mercury, Assessing the effects of contaminants in the Arctic. (Accessed on 12-Dec-2024). https://arctic-council.org/projects/contaminant-issues-pops-and-mercury/

[4] Bryant, M. (2024): We assume damage to Baltic Sea cables was sabotage, German minister says. https://www.theguardian.com/world/2024/nov/19/baltic-sea-cables-damage-sabotage-german-minister (Accessed on 12-Dec-2024).

[5] Cameron, R. D., Whitten, K. R. (1979): Effects of the Trans-Alaska pipeline on caribou movements. Alaska Department of Fish and Game, Division of Game, Federal Aid Project Progress Report 1 January 1978 – 30 June 1979, Federal Aid in Wildlife Restoration Job 3.18R, Juneau.

[6] Contenta, S. (2012): DEW Line: Canada is cleaning up pollution caused by Cold War radar stations in the Arctic. https://www.thestar.com/news/insight/dew-line-canada-is-cleaning-up-pollution-caused-by-cold-war-radar-stations-in-the/article_3b7cc76e-ddb9-5cfb-99fd-36928bd966bc.html (Accessed on 12-Dec-2024).

[7] Discovering the Arctic. (n.d.): Arctic Pollution. (Accessed on 12-Dec-2024). https://discoveringthearctic.org.uk/science/arctic-science/arctic-pollution/

[8] Ellekrog, O. (2024): In shrinking Soviet towns, Northern Sea Route promise is keeping hope alive. 8. October 2024. *Polar Journal*. https://polarjournal.net/in-shrinking-soviet-towns-northern-sea-route-promise-is-keeping-hope-alive/

[9] Friedrich, D. (2016): The problems won't go away: Persistent Organic Pollutants (POPs) in the Arctic. *The Arctic Institute*. https://www.thearcticinstitute.org/persistent-organic-pollutants-pops-in-the-arctic/

[10] International Maritime Organization (2023): Shipping in polar waters. International Code for Ships Operating in Polar Waters (Polar Code). (Accessed on 12-Dec-2024). https://www.imo.org/en/MediaCentre/HotTopics/Pages/polar-default.aspx

[11] Kirk, A. (2023): Arctic security is increasingly under threat. Drones can help. https://www.atlanticcouncil.org/blogs/new-atlanticist/arctic-security-is-increasingly-under-threat-drones-can-help (Accessed on 12-Dec-2024).

[12] Lanteigne, M. (2019): The changing shape of Arctic security. *NATO Review*. https://www.nato.int/docu/review/articles/2019/06/28/the-changing-shape-of-arctic-security/index.html (Accessed on 12-Dec-2024).

[13] Lawson, D. (2019): Increasing the availability of clean drinking water in small Arctic villages and communities. https://jsis.washington.edu/news/increasing-the-availability-of-clean-drinking-water-in-small-arctic-villages-and-communities/ (Accessed on 12-Dec-2024).

[14] Scott, M. (2023): Where will sea level rise most from ice sheet melt? https://nsidc.org/learn/ask-scientist/where-will-sea-level-rise-most-ice-sheet-melt (Accessed on 12-Dec-2024).

[15] Arctic Council (1998): The Iqaluit Declaration. The First Ministerial Meeting of the Arctic Council. Iqaluit, Canada, September 17–18, 1998. Available at: http://hdl.handle.net/11374/86

[16] Wolfe, S. A., Griffith, B. and Wolfe, C. A. G. (2000): Response of reindeer and caribou to human activities. *Polar Research*, 19: 63-73. doi: 10.1111/j.1751-8369.2000.tb00329.x

[17] WWF Global Arctic Programme (2022a): Arctic Connected. Arctic biodiversity under threat. (Accessed on 12-Dec-2024). https://www.arcticwwf.org/newsroom/features/arctic-connected-arctic-biodiversity-under-threat/

[18] WWF Global Arctic Programme (2022b): Arctic Connected. The Arctic's Indigenous communities under threat. (Accessed on 12-Dec-2024). https://www.arcticwwf.org/newsroom/features/arctic-connected-the-arctics-indigenous-communities-under-threat/

[19] WWF Global Arctic Programme (2023a): Arctic connected. More ships in the Arctic bring serious risks. (Accessed on 12-Dec-2024). https://www.arcticwwf.org/newsroom/features/arctic-connected-more-ships-in-the-arctic-bring-serious-risks/

[20] WWF Global Arctic Programme (2023b): Arctic connected: Shining a light on Arctic warming. (Accessed on 12-Dec-2024). https://www.arcticwwf.org/newsroom/features/arctic-connected-shining-a-light-on-arctic-warming/

[21] WWF Global Arctic Programme (2024): Illegal fishing in arctic waters: Catch of today – gone tomorrow? (Accessed on 12-Dec-2024). https://media.wwf.no/assets/attachments/45b-iuu_report_summary.pdf

[22] IPCC (2021): Intergovernmental Panel on Climate Change (IPCC). Summary for Policymakers. *In:* Climate Change 2021 – The Physical Science Basis: Working Group. Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press 2023, pp. 3–32. https://www.cambridge.org/core/books/climate-change-2021-the-physical-science-basis/summary-for-policymakers/8E7A4E3AE6C364220F3B76A189CC4D4C

[23] The Royal Society (2010): New frontiers in science diplomacy: Navigating the changing balance of power. *American Association for the Advancement of Science (AAAS) and The Royal Society*. https://www.aaas.org/sites/default/files/New_Frontiers.pdf

[24] US Government (1995): Nuclear wastes in the Arctic: An analysis of Arctic and other regional impacts from soviet nuclear contamination, OTA-ENV-623. US Government Printing Office, Washington DC. https://ota.fas.org/reports/9504.pdf

[25] WCRP Global Sea Level Budged Group (2018): Global sea-level budget 1993–present, *Earth System Science Data*, 10(3): 1551-1590. doi: 10.5194/essd-10-1551-2018