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Evaluation of the Polar Code in different environments and for different maritime activities in the two polar regions

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Abstract Because of the decrease in sea ice coverage, maritime activities in the polar regions have increased steadily over the years and several issues related to maritime activities have arisen. It is essential to understand these challenges because they could have serious political, environmental, and economic consequences. Although there are significant geographical and legal differences and differences in the types of activities between the Arctic and the Antarctic, a single International Maritime Organization Polar Code covers both regions. In this study, changes in polar regions are introduced, and the differences are discussed. Second, the differences in maritime activities are discussed, and the Polar Code is evaluated in terms of these differences.

Keywords **polar regions, sea ice, maritime activities, Polar Code**

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1 Changes and differences in polar regions

Satellite observations have shown that the Arctic sea ice extent (SIE) has diminished by about three percent per decade since 1979, and models indicate that it will continue to decrease (Cavalieri and Parkinson, 2012; Overland and Wang, 2013; Rogers et al., 2013; Notz and Stroeve, 2018). The thickness and fraction of multi-year ice have also decreased (Kwok, 2018; Onarheim et al., 2018). In the 2020 season, Arctic SIE had a maximum of 15.05×10^6 km^2 in March and a minimum of 3.74×10^6 km^2 in September, which are respectively 2.51×10^6 km^2 and 0.59×10^6 km^2 below the 1981–2010 average minimum and maximum extents (NSIDC, 2019a). September has experienced the greatest declines thus far. Because of this decreasing trend, the duration of the melt season is lengthening. September has received the most attention because it is the month with the lowest SIE.

However, Antarctic SIE trends differ. The Antarctic annual average SIE reached a record high of 12.8×10^6 km^2 in 2014 but was followed by a sharp decline to the lowest value of 10.7×10^6 km^2 in 2017 (Parkinson, 2019). In the 2019 season, the Antarctic SIE had a minimum of 2.66×10^6 km^2 in February and a maximum of 18.24×10^6 km^2 in September. These are respectively 0.40×10^6 km^2 and 0.24×10^6 km^2 below the 1981–2010 average minimum and maximum extents (NSIDC, 2019b).

The clearest difference between the Northern Hemisphere and Southern Hemisphere relates to their geographical conditions (Spindler, 1990; Maksym et al., 2012; Vaughan et al., 2013; Kern et al., 2016; Menne et al., 2018; Maksym, 2019; Parkinson, 2019). Because the Arctic Ocean is surrounded by land, the sea ice may remain trapped within it for several years, whereas the opposite condition occurs in the Antarctic. In addition, sea ice thickness varies considerably within both regions. While the

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typical sea ice thickness of the Arctic is above 2 m, Antarctic sea ice is characteristically below 2 m. A large part of the Arctic Ocean comprises multiyear ice, most of which occurs as pack ice. The Antarctic mainly comprises seasonal ice that freezes and melts within a season, and it remains in summer only in a few coastal regions.

2 Maritime activities in polar regions and Polar Code implementation

The melting sea ice presents opportunities for maritime activities, especially in the Arctic. Potential Arctic sea routes are a new phase for international maritime transportation that supply financial and time savings linked to the shorter distance between East Asia and Western Europe voyages (MARSH, 2014). In addition, the exploration and exploitation of huge oil and gas resources and the expansion of icebreaker fleets and investments on ice-class ships have released new opportunities for international operators. Although the transit numbers currently remain few, the number of operations has been increasing in the Arctic waters. The Arctic waters could see a boost in traffic with growth in natural reserve extraction. For instance, there is an increasing amount of oil and gas transport traffic in the Barents Sea, tourism traffic in Svalbard, and local fishing in Canada's northern waters (Marchenko et al., 2016; Borch, 2018). Shipping will continue to increase as ice coverage decreases (Stephenson et al., 2013). Conversely, maritime activities in the Antarctic region involve cruise, fishing, research, and re-supply ships. Antarctic tourism and fishing are the only commercial activities formally recognized by all Antarctic Treaty (AT) members. Ships are not distributed equally. The northwest part of the Antarctic Peninsula and the Ross Sea experience the most ship traffic of all types. The Antarctic and Southern Ocean Coalition (ASOC) have expressed their concerns that the increasing number of vessels raises several environmental and maritime safety issues in the region (ASOC, 2008).

The maritime activities represent a threat to the sensitivity of polar ecosystems and the vulnerability of marine wildlife and habitats (Ahyong et al., 2020). Moreover, the harshness of the polar environment presents significant risks to vessels. Thus, to take advantage of the commercial benefits, the risks and hazards of extreme circumstances of the polar regions should be understood (Ghosh and Rubly, 2015). Most casualties are related to sea ice, such as ice floe hits, and ships becoming trapped by ice, which demonstrates the real danger posed by sea ice to shipping (Marchenko, 2013).

The International Maritime Organization (IMO) was formed to legalize safety and pollution prevention measures for shipping in polar regions, and the International Code for Ships Operating in Polar Waters (the Polar Code) came into force on 1 January 2017 (IMO, 2017). It covers the full range of design, construction, equipment, operational, training, search and rescue, and environmental protection matters relevant to ships operating in the ocean surrounding the two poles. After years of debates and the implementation of a set of safety guidelines for these regions, the Polar Code has been improved with some changes in the safety guidelines (Brigham, 2014; Jensen, 2016). In the frame of maritime safety, sources of hazards are stated in the Polar Code as ice, low temperature, periods of darkness and daylight, remoteness, lack of accurate and complete hydrographic data and information, and lack of crew experience (IMO, 2017).

There is only one mandatory Polar Code for both polar regions, for which the boundaries have been set as beyond 60 degrees south and north latitudes. The boundaries of the Polar Code are therefore geographically limited. Moreover, considering the maritime traffic and SIE, the Polar Code's application boundary might be modified, especially in the Arctic (Karahalil et al., 2020). Ice information is essential for the safety of polar navigation. Detailed voyage plans should include the sea ice conditions to identify when it is unsafe to enter areas in which ice or icebergs are present and indicate safe passing distances and safe speeds in these regions. It is therefore necessary to improve the risk assessment tools, for use in each region. Moreover, obligatory sharing of cryosphere and weather observations from ships sailing in polar regions might be useful. The lack of infrastructure, the lack of accurate charting, and the harshness of the environment make emergency response and Search and Rescue (SAR) operations significantly more difficult in the Arctic and Antarctica. The Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic has been established by the member states of the Arctic Council on 12 May 2011. Therefore, there is good coverage by Arctic Countries for SAR operations in the Arctic Ocean. However, in Antarctica, the Council of Managers of National Antarctic Programs (COMNAP) are still working on improving SAR coordination and response in the Antarctic. The Polar Code also includes SAR measures, but these could be more comprehensive. In addition, the Polar Code is mandatory for certain ships under the International Convention for Safety of Life at Sea (SOLAS) and the International Convention for the Prevention of Pollution from Ships (MARPOL). Nevertheless, SOLAS does not apply to ships of war and troopships, cargo ships of less than 500 t (gross tonnage), pleasure yachts not engaged in trade, wooden ships of primitive build, and fishing vessels that are not currently covered by the safety provisions of the Polar Code. Moreover, pollution of sea ice in the Arctic can be considerable because of the higher population in the Arctic region and the more intense ship traffic. Conversely, Antarctic sea ice can still be considered pristine. There was already in place pollution prevention measures for the Antarctic, yet the second part of the Polar Code fails to introduce new mandatory ones. For instance, raw sewage discharge should have been banned.

3 Conclusion

As SIE decreases, the increasing number of ships raises the risks of maritime casualties. SIE and thickness are important factors for navigation as sea ice may damage the vessel's hull, propeller, and rudder under significant force. It is vital to evaluate maritime casualties for each polar region to better understand and assess future risks because the new routes and strategic, economic and environmental interests will motivate increased maritime activities.

Significant differences have been observed between the polar regions, which should be considered for the development of the Polar Code. Our investigation points to the need for separate revision of the mandatory Polar Code for each polar region. It could also be extended to include sea ice concentrations of 1/10 coverage or greater. Because of the differences in geographic and geopolitical conditions between the two polar regions, SAR measures should be considered separately within the Polar Code. Moreover, the inclusion of specific provisions regarding pollution in the Code could have tailored existing requirements to the individual needs of each region. In addition, the IMO is expected to develop Polar Code Phase II, which will address safety measures on ships not certified under the SOLAS Convention. However, no restrictive or voluntary arrangements have yet been issued for non-SOLAS ships. The relevant regulations should be implemented without delay. In addition, it is essential to train seafarers regarding ice formations and characteristics. Polar navigation training should include knowledge of different types of sea ice, ice navigation, vessel maneuverability in sea ice, and issues relating to ship stability. Therefore, the Polar Code should be improved, especially in terms of manning and training standards.

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Assessment of Arctic and Antarctic Sea Ice Condition Differences in the Scope of the Polar Code

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Abstract

Polar regions face increasing challenges resulting from the interactions between global climate change, human activities, and economic and political pressures. As the sea ice extent trends diminish, maritime operations have started increasing in these regions. In this respect, an international concern has arisen for the shrinking of sea ice, preserving the environment, and passengers' and seafarers' safety. The International Maritime Organization has enforced the Polar Code (PC) for the ships navigating in these challenging Arctic and Antarctic waters. Polar regions are similar in some aspects but exhibit significant differences in geographical conditions, maritime activities, and legal status. Therefore, the PC that applies to both regions should be reconsidered, accounting for the differences between the areas for further development. This study considers the Arctic and Antarctic geographical differences relevant to the PC's scope. The emphasis is placed on the changes regarding the sea ice extent and sea ice condition differences in the two regions, which are essential in maritime safety. This study also addresses the aspects of the PC that need improvement.

Keywords

Polar regions, Sea ice change, Maritime activities, Polar Code, Maritime safety

1. Introduction

The Arctic and Antarctic regions are the coldest places on the planet. Nevertheless, their environments are shaped by different forces. The Arctic region consists of a partly ice-covered ocean surrounded by the land areas of the eight Arctic countries. It is most commonly defined as the region above the 66° 33' N latitude parallel [1,2]. On the other hand, the Antarctic is a frozen land encompassed by the Southern Ocean, which is situated south of the 60°S latitude parallel [3]. There are notable variances between them. For instance, the Antarctic sea ice forms a symmetric circle around the south pole, whereas the Arctic sea ice is asymmetric through some longitudes as a result of the effects of the ocean currents and winds [4,5]. The Arctic sea ice is not as mobile as that of the Antarctic and is sometimes stationary for more than five years. On the other hand, the Antarctica sea ice does not stay on for ages or thicken as much as that in the Northern hemisphere [5,6]. Thus, the sea ice thickness and volume vary notably within both regions. The Antarctic sea ice is characteristically one to two meters thick, while a large part of the Arctic is two to three meters thick.

Although geographical and seasonal differences exist, both the Arctic and Antarctic are especially susceptible to the impacts of global climate change with the reduction of the sea ice volume and extent [7-11]. The primary cause for the decline is the increase in global mean temperatures linked to climate change. A large amount of ice loss in summer has been accelerated by warmer air temperatures that have resulted in a delay in the freezing of polar waters [12]. Some studies reveal that the Northern Hemisphere may become ice-free in summers soon [11,13,14]. On the other hand, increases in the Antarctic annual average sea ice coverage reached their highest record in 2014 according to the 1979-2018 satellite passive microwave records. However, this was followed by a sharp decline leading to the lowest value being

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measured in 2017 [15]. Notably, sea ice prediction models and studies indicate that the Arctic sea ice extent (SIE) has been decreasing at an alarming percentage since 1990, whereas the Antarctic region trends have been different.

The melting rates explained above create less sea ice, presenting maritime opportunities, particularly in the Arctic [16]. Potential Arctic sea routes between the Atlantic and Pacific oceans serve as new passages for international maritime transportation organizations that provide financial and time savings due to the shorter distance between the East Asia and Western Europe voyages [17]. Although the transit numbers are still few today, the number of operations has been rising [18]. The Northern Sea Route (NSR) will become an available course for open water ships, and the probability of transit will increase by approximately 94-98% between 2040-2059 [19]. Moreover, a research regarding the transportation in the Arctic proves that the NSR could be a good alternative route for global logistics [20]. Additionally, two types of shipping activities are expected to grow in the Arctic region: (1) transit shipping, travel, and transfer of goods from one port to another; and (2) regional shipping to exploit natural resources. Once there are more open waters, the Arctic may witness a boost in traffic with the growth in the extraction of the natural reserves. For instance, there is already an increasing amount of oil and gas transport traffic in the Barents Sea, tourism traffic in Svalbard, and local fishing in Canada's northern waters [21,22]. The exploration of vast oil and gas resources will pave new opportunities in the Arctic for international operators to expand icebreaker fleets and invest in ice-class ships. On the other hand, a significant increase has been observed in large and small passenger ships, private yachts, fishing vessels, and research vessels [23,24]. For instance, the trends in visiting these remote areas by passenger ships to seek out unique ecosystems and species have been facilitated by tourists [25]. On the other hand, Antarctic resources are protected by the Antarctic Treaty (AT) signatory countries, which recognize tourism and fishing as the only profitable activities [26,27]. Additionally, AT consultative and observing countries enter the region in their vessels to conduct scientific studies in Antarctica. As the number of vessels increases because of the situation created by lower quantities of sea ice, numerous environmental and maritime safety issues have been developed [28]. Maritime activities are dangerous and pose a threat to sensitive polar ecosystems and vulnerable marine wildlife and habitats. Moreover, the polar environment's harshness presents significant risks such as floating ice, thick fog, and polar storms that may cause ice damage or stocking in the ice, running aground, and machinery malfunctions. Thus, the risks and hazards of extreme circumstances of the polar regions should be grasped to take advantage of commercial benefits [29]. Ice navigation research also highlights challenges that involve the interpretation of sea ice conditions, weather, ship classifications, icebreaker assistance, and crew experience [30]. An investigation of maritime accidents in the polar regions revealed that the accidents have mostly been related to sea ice, which are further categorized as ice floe hit, being trapped by ice, and ice jets [31]. On the other hand, navigational challenges and the risks for the ships operating in the polar regions are pointed out by authors as route selection problem, root cause analysis of Arctic marine accidents, and navigational risk assessment of Arctic navigation [32-34].

The existence of sea ice limits maritime operations at high latitudes in both hemispheres. Thus, it is essential to know the characteristics of sea ice and its formation, and monitoring and producing sea ice forecasts is crucial to support maritime operations [35]. The Polar Code (PC)'s efforts to mitigate the hazards and reduce risks to the environment elevate "seaworthiness" to a higher standard [36]. However, there is a single mandatory PC for both polar regions. Although the preamble of the PC notes the differences between the two areas, our study argues that some significant differences regarding the sea ice have not been evaluated in the content. The questions are, what are these differences and what are their interactions with PC. This study provides an overview of the differences of the Arctic and Antarctic sea ice conditions via remote sensing data analyses in the PC's scope. This study indicates the inadequacies of PC with some evidences of the impacts of the ice conditions for ice navigation for further studies. Consequently, this study declares the research gaps for further studies on the polar regions' maritime safety.

2. Study Area

2.1. Sea Ice in Arctic and Antarctic

The most apparent difference between the Northern Hemisphere and Southern Hemisphere is their geographical conditions [6,37-40]. The changes in SIE for each hemisphere are clarified in the figures below. Figure 1 (a) and (b) demonstrate an example of the maximum (max) and minimum (min) Arctic SIE based on the data from the National Snow and Ice Data Center (NSIDC).

NSIDC states that the SIE typically covers about 14 million sq km in winter and 5 million sq km in summer. The Arctic reaches the smallest SIE every September and grows to its maximum every March. The Arctic SIE has diminished by about three percent per decade since 1979 [41]. The Arctic sea ice thickness in summer has also declined dramatically from 3.64 m in 1980 to 1.89 m in 2008, exhibiting a total decrease of 48% in thickness [37]. However, as the ice sheets are more likely to crash into each other, a thick ridge ice occurs. The ridge ice does not generally melt during summer and continues to grow the following autumn. The Arctic SIE was 14.78 million sq km on March 20th, 2020 and 4.15 million sq km on September 18, 2019, which are 650,000 sq km and 2.10 million sq km below the 1981-2010 average min. extent, respectively [42]. Recent studies indicate that by 2030, the September sea ice cover will shrink to 60%, becoming less than 40% in the 2060s and less than 10% by 2090 [11].

Most of the Antarctic is perennially coated by ice and snow. During winter, an average of 18 million sq km of sea ice exists, but only about 3 million sq km of sea ice remains in the summer. The Antarctic SIE reaches its min. every February and grows to its max. in September as shown in Figures 2 (a) and (b).

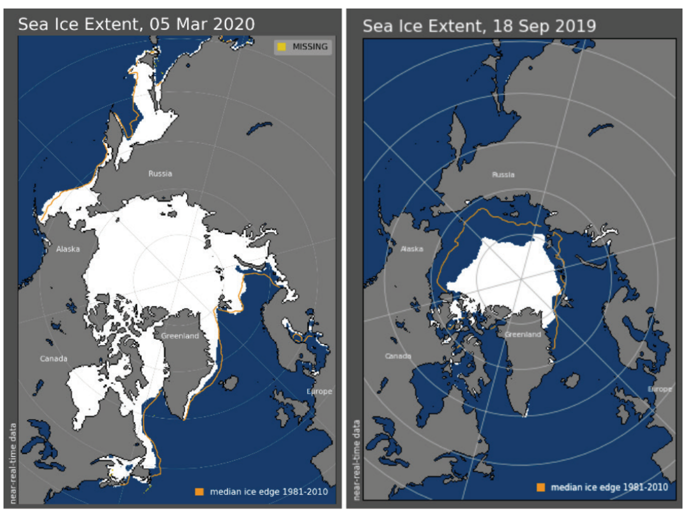

Figure 1. *The Arctic SIE in (a) March 5th, 2020 and (b) September 18th, 2019. The yellow line indicates the SIE in 1981-2010*

Source: Data from NSIDC, 2019 [42]

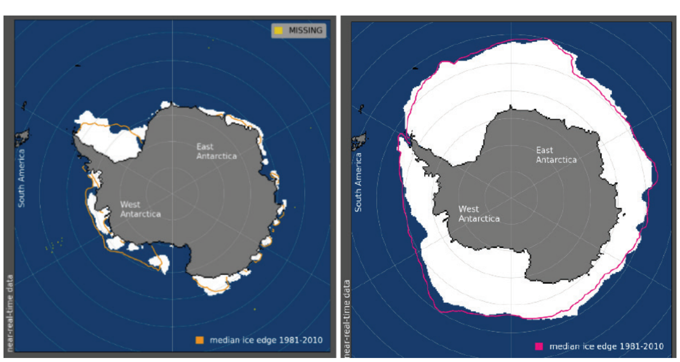

Figure 2. *The Antarctic SIE in (a) February 20th, 2020 (2.69 million sq km) and (b) September 2019 (18.244 million sq km). The yellow line indicates the SIE in 1981-2010*

Source: Data from NSIDC, 2019 [42]

A nearly complete sea ice that forms during winters disperses during summers. The Antarctic annual sea ice max. extent was the second lowest according to the NSIDC satellite record in 2019. Further, the SIE diminished by 13.2% in February 2019 compared to the averaged SIE for all the months of February from 1979 to 2009. The annual min. of the Antarctic SIE is 2.69 million sq km in February 2020 and 18.244 million sq km in September 2019, which are 0.404 million sq km and 0.234 million sq km below the 1981-2010 average min. extent, respectively [42].

Table 1 lists a variety of differences between the Southern and Northern hemisphere's sea ice parameters. Opposite geographical distributions are evident where the Arctic sea ice grows asymmetrically, whereas the Antarctic sea ice remains symmetric. Sea ice can currently exist at 38°N and 55°S in the in the Arctic and Antarctic regions, respectively. Owing to the difference in the sea ice evolution processes, the ice types differ. In the Antarctic, frazil ice is common and columnar surfaces are also found, though more rarely. In the Arctic, the topside of the ice comprises of frazil ice, while the downside is mainly congelation ice [39]. The Arctic ice melts at the air and ice interaction, whereas the Antarctic sea ice usually melts at the ocean and ice interaction. As a result, melt ponds are rarely observed in Antarctica, whereas melt ponds take a large part of the Arctic ice surface [43]. Thick and extensive ice shelves surround 75% of Antarctica's coastline; however, they are not typical for the Arctic [44]. In Antarctica, relatively large ice platelets are produced by the flowing, low salinity water underneath the ice shelves. These ice platelets can be present up to several meters in depth beneath a sea ice sheet. In contrast, platelet ice grows in pools in the Arctic region [45]. While Landfast ice is typically found at water depths in Antarctica, landfast ice in the Arctic comes in direct contact with the seafloor, because most of the shallow areas are sheltered by the ice shelves. Polynyas are divided into two types: (1) open-ocean polynyas and (2) coastal polynyas. Open-ocean polynyas

Table 1. *Polar regions' sea ice differences*

		Arctic	Antarctic
1	**Latitude**	90°N-38°N	55°S-75°S
2	**Geometric distribution**	Asymmetric	Symmetric
3	**Type of ice**	Mainly columnar	Mainly frazil
4	**Melting process**	Air/ice interaction	Ocean/ice interaction
5	**Ice shelf**	Not present	Present
6	**Platelet ice**	Not present	Present
7	**Land fast ice**	Over shallow water	Mainly over deep water
8	**Melt ponds**	Significant	Insignificant
9	**Polynyas**	Coastal	Open ocean

are estimated to occur due to the deep warm water that is mainly common in Antarctica, and Katabatic winds are believed to cause coastal polynyas that are typically found in the Arctic region [46].

2.2. PC

The International Maritime Organization (IMO) undertook work on a code for regulating the ship design, building, and operations in the early 1990s, and the guidelines for ships operating in Arctic ice-covered waters were accepted in 2002 [47]. Nevertheless, these guidelines applied only to the Arctic region and did not include the Antarctic region. Afterward, noteworthy arrangements were made by the IMO in 2009, amending them to cover the Antarctic waters [48]. Finally, the IMO changed the regulations from being mere guidelines to compulsory lawful requirements. This has been a long process for the PC, and it entered into legal force on January 1st, 2017 [49,50]. The PC is structured on the former IMO instruments and consists of two parts: Part I, introduction and safety measures and Part II, pollution prevention measures. Part II consists of five chapters that will not be evaluated in this study. Within the scope of PC, the sources of the hazards in the polar regions have been identified as ice, low temperature, periods of darkness and daylight, remoteness, and lack of accurate information and crew experience [50].

Consisting of 12 chapters, Part I of PC focuses on the safety of shipping in the polar waters and addresses a wide range of safety measures, including the need for ships to have a polar certificate and requirements according to the types of ships and ice conditions. Ships are categorized according to their design properties in different ice conditions. Every ship to which the PC applies shall have a Polar Ship Certificate (PSC) concerning the design and construction of the ships and equipment, crew and passenger clothing, ice removal, and fire safety. To support in the decision-making process, the Polar Water Operational Manual (PWOM) was developed to provide standards for vessels and crew, information about the ship's specific operational capabilities, limitations, and procedures to be followed in normal operations and in the event of incidents [50]. Other chapters of Part I include the ship structure, subdivision and stability, watertight and weathertight integrity, machinery installations, fire safety/protection, life-saving appliances and arrangements, the safety of navigation, communication, voyage planning, and manning and training. Additionally, the polar operational limit assessment risk indexing system is a significant tool for assessing the ships' operational limitations and risks of navigation in ice. It is similar with the PSC and PWOM, but it is not a mandatory requirement. Its limitations are the human factor, the frame of application, and legal status [51]. According to a PC research, shortcomings are stated that it does not exclude fishing and leisure vessels, it does not propose advanced training for all crew members, and the pollution risks are not adequately addressed. Additionally, it does not consider the crew's experience, and all Arctic aspects such as light ice conditions and ships without ice class are treated insufficiently [52].

3. Methodology

Sea ice observations have been carried out in the ships and coastal stations for more than 100 years. However, considering the remoteness of the Arctic and Antarctic regions, *in situ* measurements are not practical. For this reason, the satellite era, which gained momentum at the beginning of the 1960s, has become the most crucial observation method for the polar regions. Data from the satellites are utilized widely in research and in monitoring the SIE and other parameters [35,53].

The evolution of remote sensing systems for satellites commenced with the launch of the Russian Cosmos-243 satellite in 1968. Later, The National Aeronautics and Space Administration (NASA) launched the electrically scanning microwave radiometer (ESMR), which supplied data from 1972 to 1977. However, these satellites could not meet the technical requirements; therefore, development studies continued. With the development of new satellite systems, sea ice data has gained reliability. After the ESMR period, the scanning multichannel microwave radiometer (SMMR) was operated from 1978 to 1987. SMMR more correctly perceived the sea ice concentration extent with at least 15% sea ice. The US's Defense Meteorological Satellite Program introduced passive microwave sensors, special sensor microwave imager (SSM/I), and particular sensor microwave imager and sounder instruments. The first long-term sea ice data was provided for scientists after the introduction of SSMR [54]. In 2003, NASA launched the Ice, Cloud, and land Elevation Satellite (ICESat) to track the sea ice thickness, ice sheet heights, and land cover. Further, the ICESat-2 launched in September 2018 provides a more comprehensive and precise ice thickness valuation, marking a significant development [55]. These instruments have provided the most extended and consistent time series of sea ice data, permitting research on the tendencies of the sea ice conditions in polar regions.

In 1993, NASA contracted NSIDC to serve as the Distributed Active Archive Center (DAAC), which provides a comprehensive data on sea ice, ice sheets, and ice shelves to support research. The NSIDC DAAC archive distribute cryospheric data from NASA and help researchers utilize the data products [54].

4. Results

4.1. Arctic SIE

Figure 3 (a) displays the average monthly SIE values in 1979-2019. The average monthly values from 1979 to 2009 are indicated by the thick blue curve, and the red line represents that of 2019, which remains below the average of 1979-2009 in all months. In the last decade, all values remained below the average and each year exceeds the recorded value of the previous year. In Figure 3 (b-c), the average monthly SIE every March and September between 1979 to 2019 is indicated when the Arctic ocean begins to freeze and melt, respectively. The SIE in the Arctic region in March and September declines at a rate of 2.6% and 12.85% per decade, respectively. The linear trendline shows the steady decrease of the Arctic SIE for both months with the most significant decline experienced in September. As a result of this decreasing trend, the periods when the sea ice begins to freeze lengthen. September receives the most attention because it is the month with the least SIE.

4.2. Antarctic SIE

Figure 4 (a) displays the average monthly Antarctic SIE in 1979-2019. The thick blue curve indicates the average monthly SIE values from 1979 to 2015. Figure 4 (b-c) shows the average monthly Arctic SIE every February and September from 1979 to 2019. The SIEs in February and September 2017 are the lowest in the last decade. The Antarctic SIE values for February over the years are even lower than those in the Arctic in September. Further, the Antarctic SIE values for September are well above the Arctic max. SIE. The Antarctic monthly and annual SIE values (for

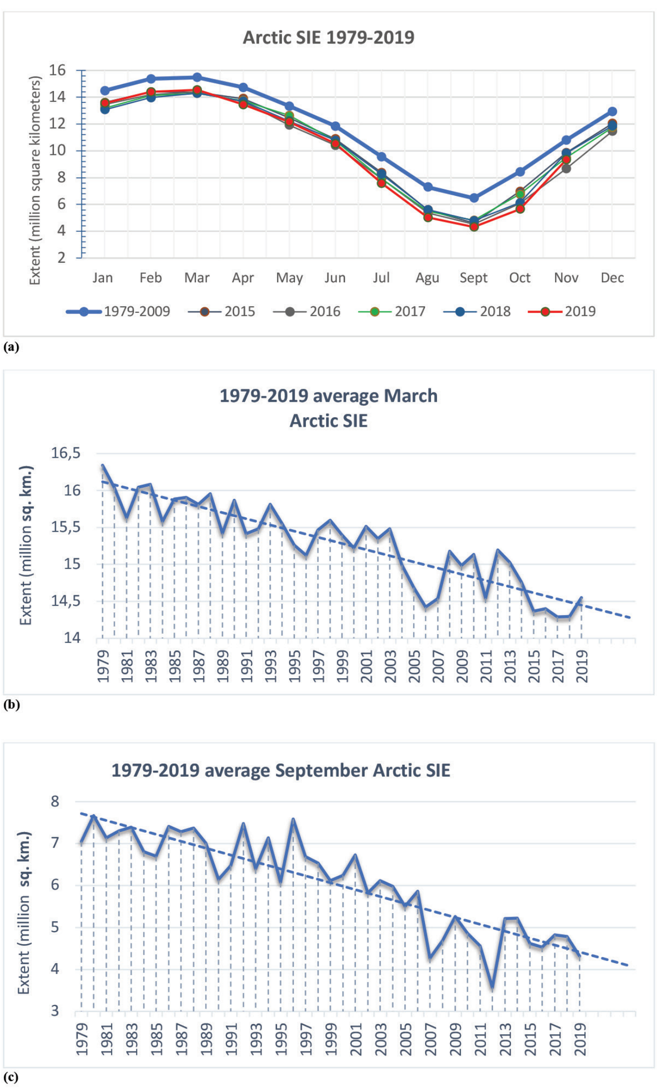

Figure 3. Arctic SIE in (a) in 1979-2019, (b) average in March 1979-2019, and (c) average in September 1979-2019

SIE: Sea ice extent

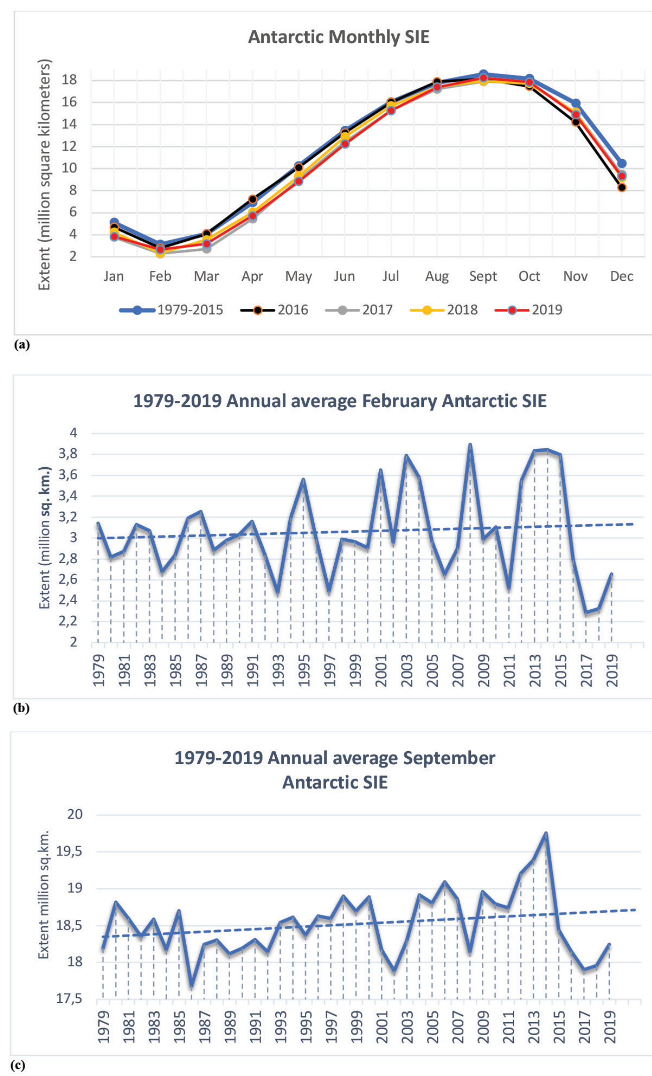

Figure 4. Antarctic SIE in (a) 1979-2019, (b) February 1979-2019, and (c) September 1979-2019

SIE: Sea ice extent

the 41 years of the dataset, 1979-2019) indicate trends until 2014. Following that, a low record in three years is reached. The Antarctic min. monthly ice extent always occurs in February and is still less than five million sq km.

As seen in Table 2, both polar regions reach their max. during winter and shrinks down to the min. during summer. The Arctic min. SIE in September 2012 and the max. SIE March 2017 extents have been the lowest recorded SIE by the satellite for 41 years. The lowest min. Arctic SIE was 3.56 million sq km in September 2012 and reached its second lowest recorded value in 2019. In 2019, the ice extent diminished by 33.23% and 6.1% compared to the average in September and March (1979-2019), respectively. The lowest monthly average Antarctic SIE was 2.288 million sq km in February 2017, and the lowest recorded yearly average for the same was 10.75 million sq km in 2017. Snow thickness creates a big difference between both poles, reaching a considerable thickness in Antarctica as compared to the Arctic snow cover. Further ice thickening may be caused by snowfalls as well as melting and refreezing of snow. Sea ice thickness varies considerably within both regions. While the typical sea ice thickness of the Arctic is above two meters, the Antarctic sea ice is characteristically below the two-meter range. Multiyear ice, which has survived more than one melting season, is three meters thick or more and firmer than the one-year ice. A large part of the Arctic Ocean is composed of multiyear ice, where most of it occurs as pack ice. Resultantly, the strength of the ice is higher in the Arctic, which is vital for navigation. The average Arctic multiyear ice has significantly reduced from 1979 to 2019. The Antarctic mainly consists of seasonal ice that freezes and melts in a season and remains in a few coastal regions.

5. Discussions

The development of the PC and its importance and shortcomings for ice navigation are introduced in section 2.2. Although the PC states that the differences were taken into consideration in its efforts to adapt the Antarctic region, the changes and differences revealed in this study should be considered for the further development of PC.

The study related to navigational risks in ice-covered waters emphasizes the importance of environmental factors such as ice thickness, ice formation, weather conditions (e.g., wind, fog, visibility, and temperature), the drift of pack ice, floating ice floes, and ice restrictions, which affect the vessel's movement and etc. [32]. Because it is being surrounded by land, the sea ice stays in the Arctic water, while the opposite condition occurs in the Antarctic. Additionally, the SIE and volume are diminishing more rapidly in the Arctic than in the Antarctic. These are essential parameters regarding the ships' operational capabilities. Some crucial questions to be considered are where the ice is and where it is drifting, what kind of ice it is, how thick and strong it is, and whether there are icebergs. Within these questions' framework, different applications should be made for both regions depending on the sea ice conditions.

The area of the PC is also geographically limited. It can be extended to sea ice concentrations with a coverage of one-tenth or higher. The PC's Arctic boundary should be changed to cover the sea ice's edge of the 1979-2010 line, rather than the 60°N line [56]. As mentioned in previous sections, maritime activities in the Antarctic region involve passengers, fishing, research, and re-supply ships, whereas those in the Arctic include various types of vessels in operation. As an outcome of the implementation of the PC, patterns of activities are expected to differ within the Arctic and Antarctic regions. Additionally, while there has been

Table 2. *Arctic and Antarctic SIE differences*

		Arctic	Antarctic
1	**Max./Min. SIE months**	March/September	September/February
2	**Max. SIE**	16.342x10^6 km^2 (March 1979)	19.756x10^6 km^2 (September 2014)
3	**Min. SIE**	3.566x10^6 km^2 (September 2012)	2.288x10^6 km^2 (February 2017)
4	**The trends in SIE; 1979-2019**	Significant decrease	Small decrease
5	**Snow thickness**	Thinner	Thicker
6	**Mean thickness**	1976: 5 m	0.5-0.6 m
7	**Typical thickness**	>2 m	<2 m
8	**Strength of ice**	High	Low
9	**The age of ice**	Largely multiyear ice	Largely one-year ice
10	**The average multiyear ice area**	1979 to 1996; 5.531×10^6 km^2, 1997 to 2016; 4.226×10^6 km^2	3.5x10^6 km^2
SIE: Sea ice extent, Max: Maximum, Min: Minimum			

an increase in the Arctic maritime activities, no significant increase in the traffic density is observed in Antarctica in recent years. The number of unique ships entering the Arctic PC area in the month of September from 2013 to 2019 has increased by 25% (1298 to 1628 ships), and the total distance sailed by all vessels increased by 75% [57]. Besides, many vessels that are currently operating in the polar regions are the non-parties to The International Convention for the Safety of Life at Sea (non-SOLAS), which means that the vessels are not compliant with PC and may present risks.

There are several definitions of sea ice for navigation. As mentioned in previous sections, 30% of Arctic sea ice is multiyear ice (3 m or thicker), while the Antarctic mainly has first-year ice (0.3 m-2 m thick). First-year ice may damage the vessel's hull and multiyear ice impact may exceed the force of the vessel's strength. On the other hand, if the vessel's machinery power is limited, drifting ice can easily collapse and the vessel might beset in the ice. Moreover, the drift ice motion takes place differently even within each region [58,59]. There should be up-to-date ice information for masters sailing in the polar regions to make tactical navigation decisions.

On the other hand, the goal of PC Part I, Chapter 11, "Voyage Planning," is to ensure sufficient information for the safety of the ships, the crew, and the passengers and to protect the environment. One of the most critical issues in this chapter is that the master shall consider a route, taking into account the areas that are remote from search and rescue (SAR) capabilities. The remoteness, lack of infrastructure and assets, lack of accurate charting, and the harshness of the environment make the emergency response and SAR operations significantly more difficult in the Antarctic. Additionally, it is highlighted in the Council of Managers of National Antarctic Programs report (SAR Workshop IV SAR Coordination and Response in the Antarctic) that although there are significant differences between the polar regions, there would be best practices to learn from Arctic SAR agencies [60]. Moreover, multiple criteria such as regulations and restrictions, traffic congestion, charges, route length, sea depth, weather, and sea conditions are the critical factors for voyage planning, which differs in two regions [61]. For instance, the ice-strengthened passenger ship M/S Explorer was the first ship that sunk in the Antarctic waters following a collision with ice in 2007. According to the incident report, the primary cause was the ship captain's misjudgment of ice where they were countering. Even though he worked in the Baltic Sea, the Antarctic ice conditions have shown to be rather different from those in the Baltic [62,63].

The human factor in the polar regions is crucial and experienced people are needed. The human element was the primary contributor to the total number of accidents (roughly 77%) due to inattention, heavy weather, age, and lack of communication [24]. Seafarers are usually inadequately trained to deal with polar conditions [30,64]. PC Part I Chapter 12, "Manning and Training," aims to ensure adequately qualified, trained, and experienced personnel. There should be a curriculum that addresses the polar regions' differences for ice navigation in polar waters in basic and advanced level training.

6. Conclusions

This study analyzed the SIE changes in the Arctic and Antarctic regions based on the NSIDC datasets. After reviewing the 41-year satellite records, SIE's variations indicated a long-term trend of reduction from 1979 to 2019. Although some studies have demonstrated these lessening outcomes, our analysis takes a precise approach regarding the differences in the PC's scope. The differences in the Arctic and Antarctic sea ice characteristics were compared within some limitations. Because the results are obtained through remote sensing data analysis, they represent changes in ice conditions observed by satellites only. The differences observed according to the formation processes and features of sea ice that concern navigation have been introduced. As explained in the methodology chapter, SIE changes measured from the data obtained from various satellite and remote sensing systems were interpreted for both regions in our results. In the discussion section, some critical issues arising from the sea ice condition differences in ice navigation were pointed out. Our study confirms that the PC should be improved. For further studies, researchers should consider the density traffic of the vessels excluded in the PC. Considering the results of this study, maritime safety tools can be generated separately for the polar regions. PC Part II, Pollution prevention measures, should also be evaluated differently, which are the research gaps to be developed for the polar regions. Regardless, this study's investigation points to the need for future improvements of the mandatory PC for each polar region separately.

Authorship Contributions

Concept Design: M. Karahalil, B. Özsoy, Data Collection or Processing: M. Karahalil, B. Özsoy, Analysis or Interpretation: M. Karahalil, B. Özsoy, Literature Review: M. Karahalil, B. Özsoy, Writing, Reviewing and Editing: M. Karahalil, B. Özsoy.

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The evaluation of the Polar Code by the survey conducted with those who have sailed in polar regions, and suggestions for further improvement

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Maritime safety

ABSTRACT

There is much evidence that ongoing global climate change has tremendous impacts on the Arctic and Antarctic environment. One of the significant effects of global climate change on polar regions is diminishing sea ice extent (SIE). Decreased SIE results in accessibility for maritime activities, which pose more threats to the fragile polar environment. For the preservation of the polar environment and the safety of the ships, International Maritime Organization (IMO) developed the International Code for Ships Operating in Polar Waters (Polar Code (PC)). The mandatory PC took a long time to develop from guidelines for Arctic waters to compulsory Code of both polar regions. Although there are similarities between the Arctic and Antarctic, such as the remoteness and harshness of the environment, the differences in physical, political, and legal conditions raise questions about the PC's adequacy. In this study, we evaluate the PC within the survey scope we conducted with the people who have sailing experience in these regions and make suggestions to develop the PC further.

1. Introduction

The Arctic and Antarctic are recognized as being geopolitically important and extremely vulnerable that ongoing impacts of the global climate change on SIE have likely to affect biodiversity and human activities [1]. Recent studies project that such changes will continue and will affect socio-economic trends. For instance, the Arctic shipping routes take a critical role in having an economic advantage for maritime transportation. Continuous decline of SIE will create new routes through Arctic waters [2–4]. According to the Northern Sea Route Administration (NSRA)'s, two types of shipping activities will grow in the Arctic region: transit shipping, traveling and transferring of goods; and regional shipping for natural resources exploitation. Although the transit numbers are still few, the number of operations has increased in the Arctic waters. Therewithal, non-environmental factors such as regional trade, global economic and social trends, tourism, shipbuilding technologies also affect Arctic shipping trends [5,6]. Moreover, maritime activities differ regarding geographies, sea ice conditions, infrastructure accessibility, geopolitics, and Arctic countries' regulations. On the other hand, although, uncertainty in changes in Antarctic sea ice conditions present challenges to shipborne activities, tourism and fishing are the only trading activities accepted by Antarctic Treaty (AT) members [7,8]. Research vessels are existing all-year-round, reach a maximum in January and February. Additionally, there are supplying vessels for the supply of fuel and consumables to the Antarctic scientific research stations and search and rescue assets of the five Rescue and Coordination Centers which are responsible for coordination and response over the Antarctic Treaty area [9].

In order to take advantage of the commercial benefits, the risks and hazards of extreme circumstances of the Arctic and Antarctic should be understood [10]. In terms of maritime safety, sources of hazards in polar regions are; sea ice, low temperature, high latitude, periods of darkness and daylight, remoteness, shortage of absolute hydrographic data, and lack of crew experience [11]. Among them, sea ice is a significant risk factor for ships' navigational performance, which may damage the vessel's hull, propeller, and rudder under substantial force or beset in

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the ice. Moreover, the melting of the ice shelves raises the risk of floating icebergs, which creates hazards resulting in a collision. On the other hand, maritime activities threaten the sensitivity of polar ecosystems and marine wildlife and habitats [12]. Although the PC is a risk-based instrument, it has limited capacity to assist risks [13]. The study on maritime accidents in Arctic waters mentions the importance of crew training and requirements due to risk mitigation [14]. Reports of most of the incidents revealed that human error was the main reason; the ice conditions and the vessel's speed were not adequately evaluated [15]. According to an information paper submitted by the Antarctic and Southern Ocean Coalition (ASOC) to the Antarctic Treaty Consultative Meeting (ATCM) XXXVI, most of the ships were involved in the accident by grounding, hitting, or beset in the ice in Antarctic waters[16]. Maritime safety depends on the skills of experienced mariners in the polar waters [17]. Such experience includes knowledge of the environment, vessel specifications and maneuvering capabilities, operations to conduct, and competence. As shipborne tourism increasing in Antarctica, self-sufficiency, people's safety on board, and search and rescue (SAR) operation issues are the main topics in forums like the Council of Managers of National Antarctic Programs (COMNAP) [18, 19].

The PC was a milestone set of regulations and guidelines for polar shipping. It adopts a holistic and risk-based approach to mitigate identified risks. The PC consists of two main parts: mandatory provisions and recommendations on safety measures and pollution prevention [20]. The safety measures chapters consist of necessary functional requirements for the ship's design and documentation, and the pollution prevention chapters consist of essential operational and structural requirements. In the PC's introduction, it is stated as the risk levels may differ depending on the location, time, ice-coverage, and sources of hazards that may vary within the Arctic and Antarctic. This study was carried out to introduce some of the differences between polar regions and evaluate the PC through the questionnaire we applied to experienced seafarers and scientists working in the region. We believe that the PC can be further improved by taking into account the issues raised in this article. It organized as follows: study area explains Arctic and Antarctic, Section 3 introduces the development of PC, Section 4 characterizes data and methodology, Section 5 describes the results, Section 6 presents the discussions and the conclusion.

2. Study area

2.1. The Arctic

The Arctic was not a significant geopolitical region as it does today. All the bordering states and even some non-Arctic countries aware of its importance look to take advantage of economic benefits [4,21–24]. The competing interests make the cold North Pole a potential hot spot. Eight countries have territories within the Arctic, and they are party to Arctic Council, which provides cooperation and coordination among them [25]. The Arctic States have intervened in binding agreements under the Arctic Council. These are "*Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic, Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic, and Agreement on Enhancing International Arctic Scientific Cooperation.*" These agreements address common concerns for preserving the Arctic environment and economic sustainability and its evidence that the Council is turning into significant international cooperation. However, the jurisdictions and the implementations of the Arctic States within their borders differ. Although the political and administrative regimes vary between countries, navigation will be key to further developing human activities.

As a result of global warming, the Arctic Ocean routes have become more navigable with decreases in SIE [2,3]. For instance, if a vessel transits between Rotterdam to Yokohama, preferably via the Northern Sea Route (NSR), then via the Suez Canal, it reduces 3.840 nautical miles (nm) and nine days [4]. Moreover, it represents fisheries' opportunities, scientific research, energy development, and tourism with great potential [26–28]. The Protection of the Arctic Marine Environment (PAME)'s 2019 Arctic Shipping Status Report 1 revealed that maritime activities have grown in previous years. The number of unique ships entering the PC area in September from 2013 to 2019 has increased from 784 to 977. Unique ships entering the Arctic PC area increased by 25% (1298–1628 ships) from 2013 to 2019. In 2019 of all vessels navigated in the PC area, 41% were fishing vessels, as seen in Fig. 1.

Additionally, the total distance sailed by all ships increased by 75% from 2013 to 2019. The complete 2013 distance sailed by all vessels was approximately 6.51 million nautical (nm) miles, which had risen to over 10,7 million nm in 2019. Another critical data is the distance sailed by bulk carriers has increased 160% between 2013 and 2019, which is evidence of increased activities in resource extraction [29]. Especially after the 2010s, maritime activities on the ice navigation routes present emerging issues. Therefore, it is essential to mitigate maritime safety risks because it has profound political, environmental, and economic consequences.

It is also necessary to understand sea ice change, which directly impacts maritime activities [24]. For the last four decades, the average Arctic SIE for all months showed melting trends. According to National Snow and Ice Data Center (NSIDC) data, in the 2020 season, Arctic SIE had a maximum of 15.05 million square kilometers (sq. km.) in March and a minimum of 3.74 million sq. km. in September, which are respectively 0,59 million sq. km. and 2.51 million sq. km. below 1981–2010 average maximum and minimum extents [30]. Fig. 2. shows sea ice extent changes in the Arctic. Unfortunately, this downward trend hints at the fact that we will be encountering the ice-free Arctic soon.

2.2. The Antarctic

Antarctica has been a point of interest of all humankind since its discovery, and it is recognized as the largest nature reserve in the world where is devoted to peace and science by the Antarctic Treaty (AT), which currently has 54 parties. Antarctica's surrounding the Southern Ocean extends from its coast to 60° south latitude determined by the AT [31]. The AT and the agreements: "*The Agreed Measures for the Conservation of Antarctic Fauna and Flora, the Convention for the Conservation of Antarctic Seals, the Convention for the Conservation of Antarctic Marine Living Resources, the Convention on the Regulation of Antarctic Mineral Resource Activities, the Protocol on Environmental Protection to the Antarctic Treaty (PEPAT)*" are named as the Antarctic Treaty System. These agreements provide for comprehensive protection of the Antarctic environment. For instance, in the PEPAT, article 7 prohibits any activity relating to mineral resources other than scientific research. Therefore, there is no diversity in maritime activities like in the Arctic.

The continent is currently subject to scientific research and activities like fishing and tourism [32–34]. In 2017/2018 austral summer, 53 tourism ships reported to the International Association of Antarctica Tour Operators (IAATO). Therewithal, 46 fishing vessels were registered the CCAMLR. Fifty-one research vessels were registered with the COMNAP [34–36]. With the growing interest in marine resources in the Southern Ocean, illegal, unreported and unregulated (IUU) fishing activities have led to the expansion of the Antarctic security agenda. The increased monitoring, control and surveillance related to fishing has deepened [37]. There has been a 10.5% increase in the number of voyages from 293 during the 2017–18 season to 324 during the 2018–19 season [33]. Ships are not distributed equally through the Antarctic. The northwest part of the Antarctic Peninsula and the Ross Sea has the highest density shipping traffic. This region is preferred because of its proximity to gateway countries, hosting many research bases and facilities, and having partially accurate charts.

The Antarctic monthly and annual SIE values (1979–2019) indicated trends upward until 2014; afterward, it reached a record low in three years. As shown in Fig. 3., in the 2020 season, the Antarctic SIE had a

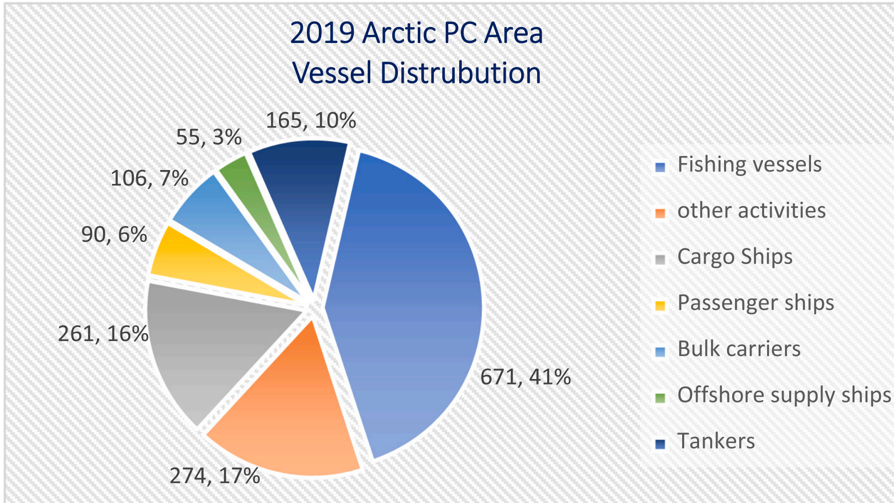

Fig. 1. Shipping activities in Arctic PC area in 2019.
Source: [29].

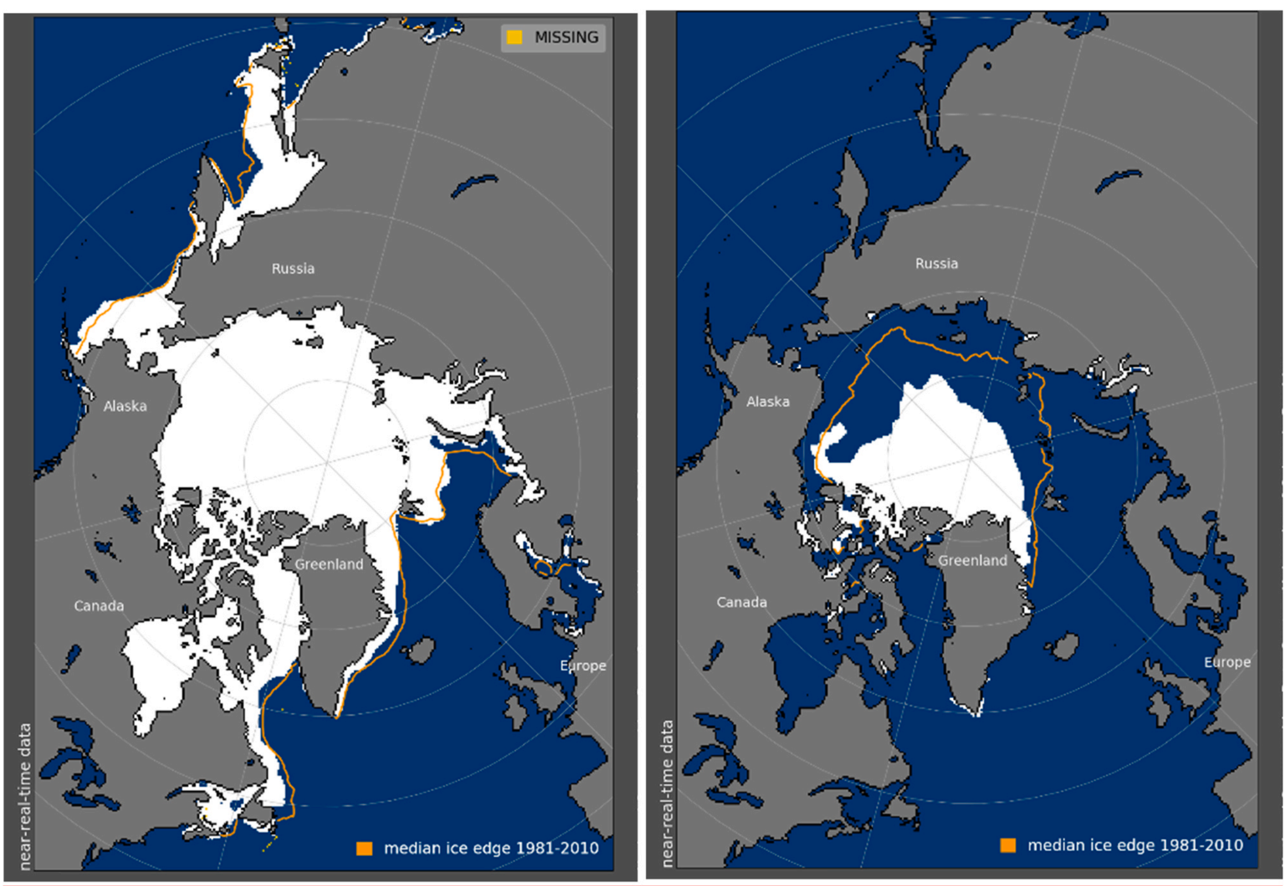

Fig. 2. The Arctic SIE in (a) March 5. 2020, (b) September 15, 2020. The line indicates the SIE in 1981–2010.
Source: Data from NSIDC, 2021.

minimum of 2.9 million sq. km. in February and a maximum of 18.77 million sq. km. in September. These are respectively 0,5 million sq. km. below and 0,3 million sq. km. above 1981–2010 average minimum and maximum extents. Antarctica sea ice does not remain ages and thicken as much as in the Arctic.

3. The Polar Code (PC)

As understood by its name, the instrument applies to ships operating in the harsh, remote, and vulnerable polar regions, both Arctic and Antarctic. When we search how the PC came into its final form, we see that its beginning dates back to the early 1990s. Many relevant requirements and recommendations have been developed over the years.

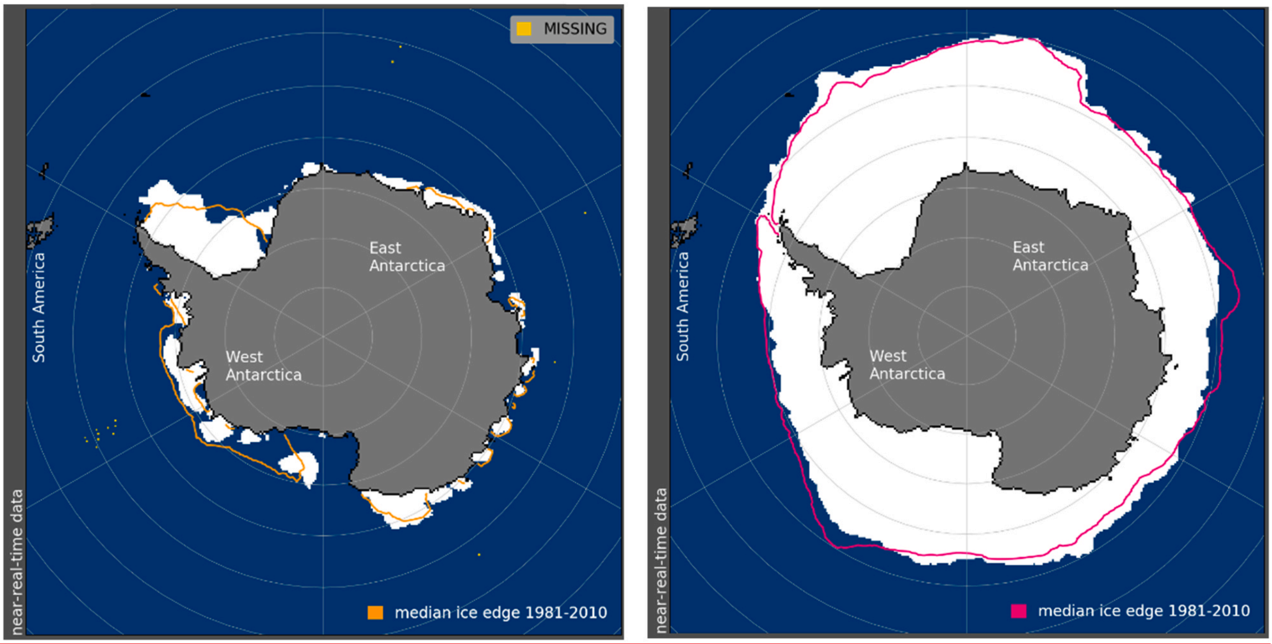

Fig. 3. The Antarctic SIE in (a) February 21. 2020 and (b) September 15, 2020. The line indicates the SIE in 1981–2010.
Source: Data from NSIDC (2021).

In the 1990s, the diverse challenges in polar waters came forward on the international agenda, in addition to the mandatory and recommendatory provisions in existing IMO instruments, and "Guidelines for Ships Operating in Arctic Ice-covered Waters" were first established in 2002. Afterward, the Maritime Safety Committee (MSC) considered the Antarctic Treaty Consultative Meeting (ATCM) [38] for expanding the geographical scope to include ice-covered waters in Antarctic Treaty Area as well. An effort to include waters off Antarctica, in turn, lead to the Guidelines for Ships Operating in Polar Waters (2008), and the move to develop a mandatory Code followed the adoption by the 86th session of the IMO's Maritime Safety Committee (MSC) a legally binding regime for navigation in polar waters was formally proposed (2009). Those additional provisions are considered necessary to existing requirements of the International Convention for the Safety of Life at Sea (SOLAS) and the International Convention for the Prevention of Pollution from Ships (MARPOL). The PC and SOLAS amendments were adopted during the 94th session of MSC in 2014; the environmental provisions and MARPOL amendments were adopted during the 68th session of the Marine Environment Protection Committee (MEPC) in 2015.

Finally, the mandatory PC entered into force on January 1, 2017. The PC aims to address risks in polar waters, and it covers the full range of design, construction, equipment, operational, training, search and rescue, and environmental protection matters. The PC is mandatory for individual ships under the SOLAS and MARPOL Conventions. However, SOLAS does not apply to some particular types of ships, including cargo ships of less than 500 gross tonnages, pleasure yachts not engaged in trade, warships, and fishing vessels. These types of vessels which are not fit within the definition of a SOLAS ship are also called non-SOLAS

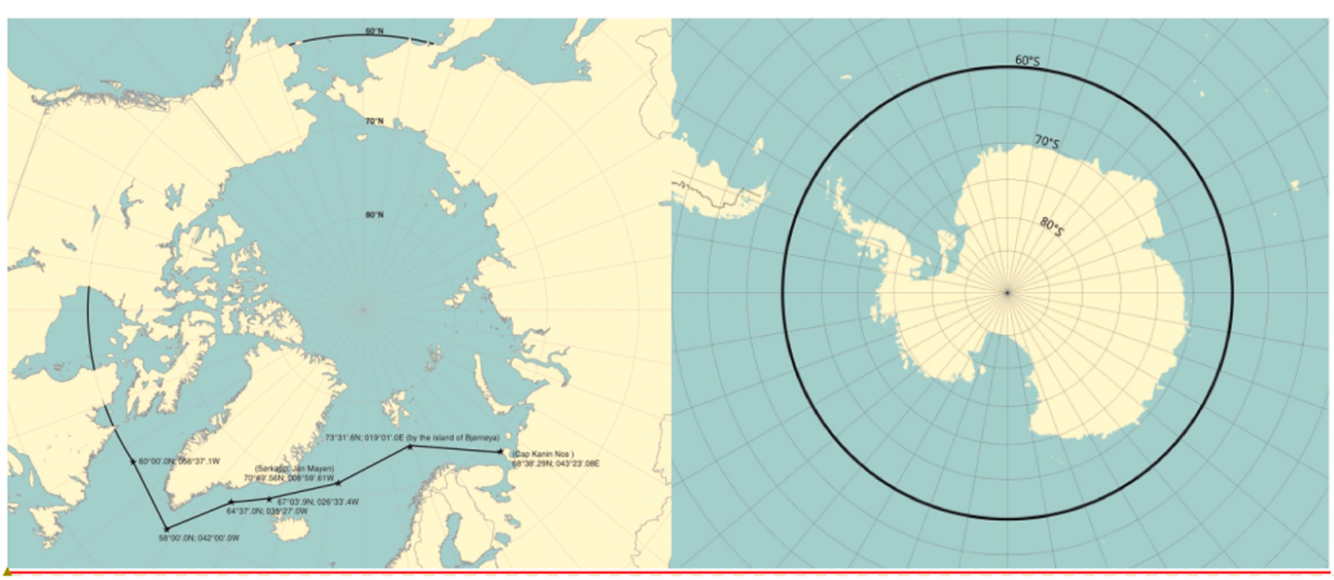

Fig. 4. Polar Code boundaries.
Source: Polar Code (2017).

vessels. IMO's MSC and sub-committees are working on the application of the PC to non-SOLAS ships. Voluntarily, the IMO Assembly adopted a resolution, safety measures of the PC on non-SOLAS ships [39]. IMO's MSC has also approved guidelines for navigation and communication equipment and life-saving appliances and arrangements for ships operating in polar waters in 2019.

The PC defines Arctic and Antarctic application boundaries as in Fig. 4. Figures illustrate the Arctic and Antarctic waters, as defined in SOLAS and MARPOL regulations [11].

The PC aims for safe operations and the prevention and control of maritime pollution from ships. It is structured into three parts: introduction, Part I (Ship Safety), and Part II (Pollution). Polar Code Part I consist of 12 chapters, and it focuses on the safety of ships and addresses a wide range of measures, including polar ship certificate and requirements according to types of ships and ice conditions. Ships are categorized according to their design properties in different ice conditions. Every ship to which PC applies shall have a Polar Ship Certificate. The Certificate will only be issued to those vessels with a Polar Water Operations Manual (PWOM) based on assessment. The PWOM was developed to provide information about the ship-specific operational capabilities, limitations, and procedures to be followed in normal operations and incidents to support the decision-making process. In order to comply with the functional requirements, the PWOM should include specific procedures, such as search and rescue (SAR), to be followed in the event of accidents. During emergencies, PC requires sufficient SAR coordination communication capability in ships. Additionally, for the safety of the ships and persons on board, the master is required to take into account operation in an area remote from SAR capabilities for the voyage planning [11].

The PC acknowledges that *"While Arctic and Antarctic waters have similarities, there are also significant differences. Hence, although the Code is intended to apply as a whole to both Arctic and Antarctic, the legal and geographical differences between the two areas have been taken into account."* [11]. However, the differences in physical, political, and legal conditions raise questions about the adequacy, scope, and application of the Code. In this study, the differences and problems were presented to evaluate those who work and have experience in polar regions within the PC framework.

4. Data and methods

This study uses a survey consisting of two parts as the data collection method. The first part was including demographic profile status. The second part dealt with the shipping in polar regions and PC. This scale consisted of 17 questions. Each question was assessed separately. Likert scale used for scaling responses in survey to indicate level of agreement of participants (5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree). The data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 22.0. Quantitative data were given as mean ± S.D. For normal distribution assumptions, the Shapiro−Wilk test was used. Skewness and Kurtosis coefficients and distribution in q-q plot graphs were checked. As the data show a normal distribution, an independent sample *t*-test was used for work subject status, One Way Anova test, an LSD's post hoc multiple comparisons, was applied to determine statistical significance when the groups consist of more than two variables. Pearson's correlation analysis was conducted to observe the relationship between the questions. Based on the p-value of <0.05, results were accepted as statistically significant.

5. Results

The respondents that participated in this research were selected from among the senior seafarers and scientists. The questionnaire website's link was shared with the online platform to the who had worked in polar regions and mostly have PC certificate. A total of 52 questionnaires were eligible; 2 of them were excluded because of missing data. Participants were blinded to the questionnaire results. According to Table 1., 58% of the participant in the survey are Captain, 10% are Dr., and 32% of Mr./Mrs. It is seen that 6% of the respondents are in the 20–30 age range, 32% are in the 31–40 age range, and 62% are more than 40 age. When the people's experiences in the polar regions are observed, it is indicated that 22% of people have between 0 and 5 years, 38% between 5 and 10 years, and 40% have more than ten years of experience. It is seen that 34% of the employees work in the Arctic region, 16% in the Antarctic region, and 50% in both regions. 48% of the respondents are Master / Chief Mate, 12% are sea ice scientists, 14% are from Officer in Charge of a navigational watch, 18% from Maritime Authority / Adviser / Expert, and 8% are consists of the crew. The majority of respondents (90%) have the experience to work subject to SOLAS and MARPOL. On the other hand, the rest of the 10% did not work on ships subject to SOLAS and MARPOL.

The relation between participants' sea service (experience) and each question was examined at the first stage of the analysis. According to ANOVA analysis results, there was no statistically significant difference between participants' sea service and questions in the survey. ($F = 1547$; $p > 0,05$) Even though there was no statistically significant difference as stated above, each 16 questions were examined one by one to get precise results. In this context, it's found that the experience of each participant made a statistically significant difference inside the group considering the following two questions; "The PC phase II would be required to identify measures that should be made applicable to those vessels not covered by the PC, including fishing vessels, small cargo ships (<500GT), and pleasure yachts. Do you think that should it be mandatory provisions?" and "Do you think that the PC needs to be separately developed for the Arctic and Antarctic?".

When the reason for the difference between groups was examined according to the first question, it is noticed that the participants who have sea service experiences of 5–10 years answered as 4,58 on average. And the participants who have sea service above ten years answered as 4,05 on average. Given that, the foregoing facts show that the question is mostly supported by the participants who have sea service of 5–10 years. The other significant difference considering above stated second question is the participants who have sea service 0–5 years supported the question more (4,36 average) than the participants who have sea service above ten years (3,20 average). In light of the foregoing information, it is seen that as the sea service experience increases, the idea of developing

Table 1
The descriptive statistics of respondents.

Variables	n	%
Title		
Captain	29	58
Dr	5	10
Mr./Mrs.	16	32
Age		
20–30 age	3	6
31–40 age	16	32
More than 40	31	62
Experience		
0–5 years	11	22
5–10 years	19	38
More than 10 years	20	40
Region		
Arctic	17	34
Antarctic	8	16
Arctic and Antarctic	25	50
Mission on the ship		
Master/Chief Mate	24	48
Sea ice Scientist	6	12
Officer in Charge of a navigational watch	7	14
Maritime Authority Adviser/Expert	9	18
Crew	4	8
Solas & Marpol Vessel		
Yes	45	90
No	5	10

the PC between sections becomes weak by the participants.

In the other phase of the study, the participants' answers to the questions working in different regions are examined. In this context, The ANOVA analysis was carried out, and it is seen that there was not any statistically significant difference between regions in term of answers. ($F = 0134$; $p > 0.05$), Even though there wasn't any significant difference between regions as stated above, given responses from participants who are working in different regions were examined one by one to get precise results. Consequently, it's noticed that the participants who were working in the Arctic region answered the following question as 4,00 on average, and the participants who were working in both the Arctic and Antarctic regions answered as 4,68 on average. "Do you think there is a difference in search and rescue capacities in the two regions?" Given that, it has been observed that the participants who have the experience of working in both regions noticed the need for SAR capacities more clearly ($F = 4722$; $p < 0.05$).

In another analysis of the study, working onboard vessels status which subjects to SOLAS and MARPOL was examined according to each question in the survey by independent sample *t*-test, and it is observed that there was not a statistically significant difference between groups and the given answers ($F = 1501$; $p > 0.05$). The answers by age were examined with the ANOVA test, and it is seen that there was no significant difference between groups in terms of ages ($F = 0532$; $p > 0.05$). Whether or not the occupational status creates a statistically significant difference in the questions was tested by ANOVA analysis. It is observed that there was not any significant difference among the groups ($F = 0178$; $p > 0.05$). Besides, answers given based on the questions were very close to each other. Thus, the occupational status of the participants was not considered to be a significant criterion.

According to correlation results, the relation between each question was examined. In this context, the relation between the following two questions was found to be significant in a positive mid-level affecting way. "Do you think there is a difference in maritime accident risks in the two regions?" and "Do you think that the PC needs to be separately developed for the Arctic and Antarctic?" ($r = 0.577$, $p < 0.01$). Based on this result, the participants who agree with the idea of "there is a difference between accident risks for different regions" were observed to support the concept of developing the PC separately for both regions.

Also, another significant relation was found in a positive mid-level affecting way between the following two questions. "Considering the protection of marine life and cultural heritage in the two regions, do you think there should be regional/sectoral restrictions in the PC? (please consider marine mammal avoidance during voyage planning: speed limits, extra watchman, etc.) and "Considering the protection of marine resources, do you think there should be underwater noise restrictions in the PC?" ($r = 0.542$, $p < 0.01$). Based on this result, the participants who agree with the idea of "regional/sectoral restrictions were to be applied to protect marine life, and cultural heritage" were observed to support the concept of developing the PC in a way that includes restrictions to prevent underwater noises.

Another significant relation is also found between the following two questions. "Do you think the difference in sea ice characteristics affects the navigational and maneuverability of the ships?" and "Do you think there are differences in terms of maritime safety in the two regions?" ($r = 0.478$, $p < 0.01$). And again, the effect of the relation is in a mid-level positive way. Based on this result, it's observed that the participants who agree with the idea of "sea ice characteristics affect the navigational and maneuverability of the ship", are also agreed with the idea of "there are differences in terms of maritime safety in two regions".

Finally, the last significant statistical relation was found between the following two questions. "Do you think that the types and characteristics of sea ice in the two regions are different?" and "Do you think there is a difference in search and rescue capacities in the two regions?" ($r = 0.441$, $p < 0.01$). It is observed that the effect of the relation is in a mid-level positive way. Based on this result, it's observed that the participants who agree with the idea of " types and characteristics of sea ice are different in the two regions" are also agreed with the idea of "there is a difference in search and rescue capacities in two regions.".

Before the analyzing phase, reliability analysis was carried out to check the questions' internal consistency and randomness. And it is observed that the question about "prevention of pollution by sewage" affects the reliability in a bad manner. Thus, the mentioned question is excluded from the study, and the resulting Cronbach's alpha coefficient is calculated as 0705 for the PCs scale, as seen in Table 2. As this value satisfies the study's reliability criteria, all analyses were made over remained 16 questions, and nomenclature is given in Table 3.

The results regarding the PC were found out in the level of "agree" in general. The highest score was determined in the idea of "There is a difference in search and rescue capacities in the two regions" (4,40), while the lowest score with the idea of disagreeing was "Legal and geographical differences between the two areas have been taken into account in the PC" (2,64) (Tables 4 and 5).

6. Discussion and conclusion

Within this study's scope, 17 questions were asked to 50 persons who participated in the questionnaire. These questions have been analyzed in terms of age, experience, the region of work, rank, and working status in ships subject to SOLAS and MARPOL of participants. Participants remained neutral (3,02) on the PC's sufficiency while agreeing (3,54) that decreasing SIE might have increased the maritime activities.

The content of the PC is briefly evaluated below regarding our survey results:

1. The Arctic is an ocean surrounded by five coastal states and governed by the United Nations Convention on the Law of the Sea (UNCLOS) and associated instruments. When assessing Article 234 UNCLOS and the PC, it is crucial to keep in mind that Article 234 is a part of UNCLOS and the PC is an IMO instrument. For instance, it would allow Arctic States to use Article 234 as a justification for applying stricter discharge rules than those laid down in the PC, and regarding safety measures, it's the same as well, since UNCLOS is a part of international law [40,41]. On the other hand, the Antarctic is governed by the specific regime, the Antarctic Treaty, and related documents known as the Antarctic Treaty System (ATS). The ATS has protected the untouched Antarctic environment from resource extraction, sustainably managed fisheries, devoted peace, and science, and is widely regarded as a model in international environmental law [38,42]. Even though 50% of participants are operating in both regions, responses close to neutral-disagree (2,64) have been received in the survey that the PC considers the differences in the two areas. Thus jurisdictional conflicts and geographical differences might be reevaluated in the PC.
2. The participants agree/strongly agree (4,32) that there are differences in terms of maritime safety in the two regions considering the lack of accurate charting and complete hydrographic data and information and the types and characteristics of sea ice in the two regions are different, which affects the navigational and maneuverability capabilities of the ships (4,28). Thus, It is essential to train seafarers regarding ice formations and characteristics. Polar navigation training/courses should include sea ice types knowledge, ice navigation, vessel maneuverability in ice, and stability issues [15]. However, participants neutral/disagree (2,86) with the adequacy of PC manning and training requirements.
3. The participants agree/strongly agree that there is a difference in maritime accident risks (4,08) and SAR capacities (4,40) in the two

Table 2
Reliability Statistics.

Cronbach's alpha	Cronbach's alpha based on standardized items	N of items
,705	,719	16

Table 3
Nomenclature.

N	Number
x¯	Mean
SD	Standard Deviation
F	F distribution/ Fisher Snedecor distribution
p	Probability Value

Table 4
Descriptive statistics of the PC expressions.

Expressions	x¯	SD
1. Increasing maritime activities are linked to the melting of sea ice in polar regions	3,54	1,15
2. The PC is sufficient for safe ship operation and the protection of the polar environment	3,02	0,98
3. Legal and geographical differences between the two areas have been taken into account in the PC	2,64	0,98
4. The types and characteristics of sea ice in the two regions are different	4,20	0,86
5. The difference in sea ice characteristics affects the navigational and maneuverability of the ships	4,28	0,81
6. There are differences in terms of maritime safety in the two regions	4,32	0,82
7. The PC requirements in terms of "manning and training or ice navigation courses are adequate	2,86	1,21
8. There are a difference in search and rescue (SAR) capacities in the two regions	4,40	0,76
9. There is a difference in maritime accident risks in the two regions	4,08	1,00
10. The PC boundaries are sufficient considering the SIEs	2,76	1,02
11. There should be regional/sectoral restrictions in the PC	4,16	0,71
12. There should be underwater noise restrictions in the PC	4,02	0,89
13. The prevention of pollution by sewage from ships requirements are adequate in the PC	3,10	1,13
14. It should be mandatory provisions for PC Phase II.	4,32	0,62
15. Port State Control is eligible for identifying deficiencies in ships	3,38	1,10
16. The PC needs to be improved	4,22	0,71
17. The PC needs to be separately developed for the Arctic and Antarctic	3,68	1,17

Table 5
ANOVA test results according to the PC.

Scale	Groups	N	x¯	SD.	F	p
	Experience					
PC	0–5 Years	11	3,86	0,30		
	5–10 Years	19	3,80	0,38	1547	0224
	More than 10 Years	20	3,63	0,45		
	Region					
PC	Arctic	17	3,70	0,41		
	Antarctic	8	3,76	0,42	0134	0875
	Arctic and Antarctic	25	3,77	0,40		
	Age					
PC	20–30 age	3	3,96	0,37		
	31–40 age	16	3,70	0,35	0532	0591
	More than 40	31	3,75	0,43		
	Mission on the ship					
PC	Master/Chief Mate	24	3,73	0,41		
	Maritime Authority Advise/ Expert	9	3,80	0,43		
	Officer in Charge of a navigational watch	7	3,71	0,57	0188	0943
	Sea ice scientist	6	3,83	0,30		
	Crew	4	3,64	0,11		
	Solas and Marpol Work	7	3,71	0,57		
PC	Yes	45	3,72	0,41	1501	0294
	No	5	3,93	0,27		

regions. Safety and emergency preparedness are highly crucial that not only small casualties but also large-scale emergencies such as the evacuation of a large cruise ship should be taken into account for the SAR operations. Due to lack of infrastructure, the time of rescue is long in terms of range and capacity to carry survivors under unlikely weather conditions. Although SAR organizations cannot guarantee the expected time of rescue, the PC safety requirement and lifesaving appliances capability shall never be less than five days. In 2016, the SAR exercise North of Spitzbergen report indicated that the related technology must be developed for the equipment to be functional [43]. The Arctic countries have adopted regional agreements and international rules for Arctic shipping and SAR. However, the COMNAP holding workshops on SAR stated that SAR regions of the Antarctic have different characteristics in terms of distances to the mainland of responsible countries [19]. For instance, the shortest distances are approximately 500 nautical miles from the Antarctic Peninsula to South America, which means the arrival time is long to conduct SAR operations. Moreover, the availability of assets varies throughout the summer and winter seasons. Additionally, It is highlighted in the COMNAP's SAR Workshop Report that although there are significant differences between the Polar regions, there would be best practices to learn from Arctic SAR agencies [19]. For instance, according to the analyses of the three SAR exercises held in Arctic, it is proved that SOLAS-certified rescue equipment is not compliant with the PC requirements for survival. And re-assessment of the PC's requirements for survival and maximum expected time of rescue should be addressed [44].

4. The participants neutral/disagree (2,76) that the PC boundaries sufficiency considering the SIEs. The marine boundaries of the Arctic region have been defined differently by the Arctic Council Working Groups based on physical, geographical, and ecological characteristics. However, the boundaries of the PC are not compatible with any of them. It does not cover all the ice-covered areas, primarily through the Pacific ocean where the sea ice generally exists, as in Fig. 5 [45]. On the other hand, in the Antarctic, for latitudes higher than 60 degrees south, some regions have not been any sea ice appearance for decades. The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) area boundaries are different from the identified Southern Ocean's 60°S latitude. The application boundaries might be modified.
5. The participants agree (4,16) that there should be regional/sectoral restrictions in PC considering the protection of marine life and cultural heritage regarding marine mammal avoidance during voyage planning: speed limits, extra watchman, etc., the two regions. For instance, cetaceans are particularly sensitive to vessel disturbance, acoustic effects, and in the case of bowhead whales, ship strikes in the Arctic [46]. Moreover, there should be underwater noise restrictions considering protecting marine resources (4,02) [47–49]. Detecting key habitats to avoiding routes and minimizing noise pollution could be effective ship-based measures, all of which can be further enhanced by restricting speed.
6. The PC is mandatory for specific categories of ships under the SOLAS and MARPOL Conventions. The IMO adopted an assembly resolution urging member states to implement, voluntarily, safety measures of the PC on ships not certified under the SOLAS Convention [50]. However, when it is considered that there are a lot of non-SOLAS vessels operating, voluntary practice will raise question marks. The participants agree/strongly (4,32) agree that PC Phase II should be consist of mandatory provisions.
7. Another criticism of the PC is the lack of a joint enforcement mechanism to control measures adopted and ensure compliance. As such, the PC does not include a specific instrument to ensure compliance; instead, flag states, port states, and coastal states are relied upon to provide enforcement and control of the new regime [8]. The participants neutral/agree (3,38) that the Port State Control (PSC) is eligible for identifying deficiencies in ships regarding PC implementations. Unfortunately, not all Flag States comply with their international commitments. The Port States also have the authority to inspect the fulfillment of the IMO requirements; however, there is no coastal state sovereignty recognized in Antarctica. Thus, the development of an Antarctic Memorandum of Understanding

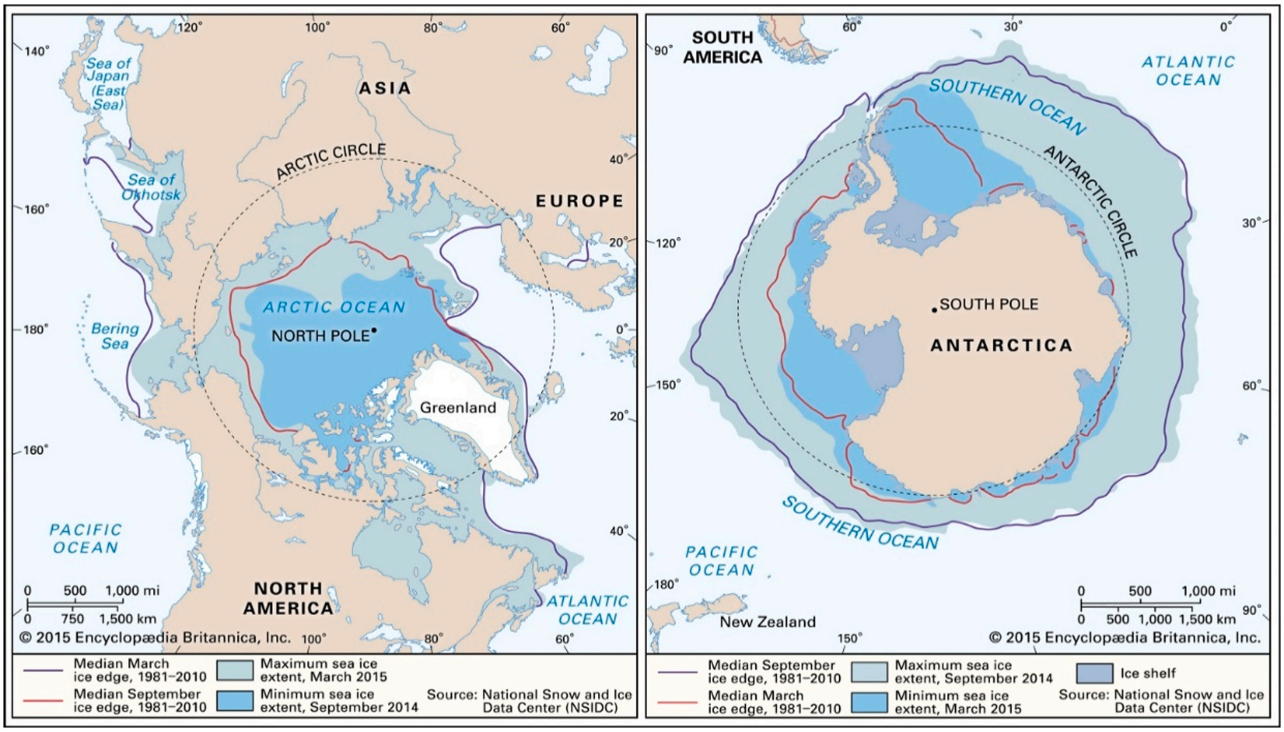

Fig. 5. The Arctic and Antarctic SIE.
Source: NSIDC (2015).

(MOU) would be effective on the ships going to the Antarctic to minimize risks.

As maritime activities are growing, it has several impacts and threats on the Arctic and Antarctic environment and life safety at sea. We compared the maritime activities and SIE changes in the two regions, and the PC development is briefly explained. The purpose of this study is to reveal the shortcomings of the PC that need improvement. For this reason, we statistically interpret how the differences between the two regions and some issues in the PC were evaluated by the people working in this region. These issues highlight the need and the challenges of further developing the PC. IMO is a recognized competent body that has a vital role in strengthening regulations concerning safety and environmental issues. At present, several problems remain unsatisfactory addressed or are simply not adequately regulated. When we examine the questionnaires' results, the answers given to each question point out that PC should be improved. A further study to identify deficiencies of the ships planning to operate in polar waters by the authorities who carry out their controls, would be enlightening. We believe that by building a bridge between the main parties involved in the regulation of polar waters operation and those working in polar waters, the PC's requirements can be re-evaluated.

CRediT authorship contribution statement

Meric Karahalil: Conceptualization, Methodology, Writing - original draft preparation, Visualization. **Burcu Ozsoy**: Supervision, Writing - review & editing. **Ersan Basar**: Writing - review & editing. **Tanzer Satır**: Writing - review & editing.

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ARTICLE

Polar Code application areas in the Arctic

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Abstract
The improvement of the International Code for Ships Operating in Polar Waters (Polar Code) has been a long process and is based on the previous International Maritime Organization (IMO) instruments. It aims at mitigating the risks of harsh environments and weather conditions for safe operations and the prevention and control of maritime pollution from ships in the polar regions. It is essential to understand the challenges pertaining to polar circumstances and reasons for maritime casualties in order to mitigate future risks. While maritime activities are increasing in the Arctic, little attention is being paid to some of the northernmost regions that are greatly influenced by the Arctic climate and are excluded from the Polar Code. The marine boundaries of the Arctic region have been defined differently by the Arctic Council Working Groups based on physical, geographical, and ecological characteristics. However, the boundaries of the Polar Code are not compatible with any of them. In this study, we analyze the extent of sea ice changes and the maritime traffic in the high north and also evaluate maritime safety in the frame of the application of the Polar Code boundaries in the Arctic.

Keywords Polar Code · Arctic sea ice extent · Arctic shipping · Polar Code application boundaries · Maritime safety

1 Introduction

The Arctic region consists of the Arctic Ocean and its contiguous seas. It is surrounded by landmasses including Canada, Greenland (Denmark), Iceland, Norway, Russia, Alaska (the USA), Finland, and Sweden (Council 2019). However, there are a variety of opinions regarding what exactly constitutes the boundaries of the Arctic.

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The decreasing sea ice extent due to global climate change has been a growing concern in recent years. The National Snow and Ice Data Center (NSIDC) has recorded record lows. For instance, the Arctic sea ice extent for September 2019 is the third lowest in the last 41 years (Serreze et al. 2019). However, owing to this event, some potential opportunities have emerged regarding maritime activities such as tourism, fishing, and trans-polar passages in the Arctic waters. Nevertheless, while maritime activities have increased, so have the risks in the region. The existence of sea ice and its thickness are important factors affecting navigational performance, and a vessel's hull, propeller, and/or rudder may incur damages under significant forces from them.

On the other hand, the melting of ice shelves has increased the risk of floating sea ice, which presents a significant danger for navigation. Compared with the open-water incident rate, the probability of a maritime accident is 19 times higher in the Arctic (Loughnane et al. 1995). Unfortunately, several accidents have occurred in this region in recent years. In this manner, IMO brought to its agenda guidelines for ships that operate in Arctic ice-covered waters in 2002. Afterward, in 2010, the agenda was changed to include Antarctic waters as well. Finally, the development of the regulations from guidelines to binding legal obligations re-emerged on the IMO agenda (Jensen 2016). On 1 January 2017, IMO adopted the Polar Code, aiming to supply safe and environmentally friendly ship operations in both the polar regions (Marine Environment Protection Committee n.d.).

During its development, several concerns from a variety of foundations (International Fund for Animal Welfare (IFAW), Friends of the Earth International (FOEI), World Wildlife Fund (WWF), and Pacific Environment were addressed to include in the Polar Code. However, when the Polar Code was evaluated according to maritime casualties and seasonal sea ice extent, it was found to be insufficient and left much to be desired. Even though the number of maritime activities is predicted to increase in the Arctic, little attention has been paid to the rest of the sea-ice-covered waters that lie beyond the Polar Code Arctic boundary and how this lack of attention affects maritime safety. In this article, we will assess the sea-ice-covered northern waters that are excluded from the Polar Code. Additionally, maritime traffic density in these regions will be evaluated, and suggestions will be made about the actions that can be taken to improve maritime safety.

2 Study area

2.1 Arctic region: differing boundaries

Some definitions of the Arctic region boundaries have emerged in terms of physical, geographical, and ecological characteristics. In this frame, some Arctic Council bodies such as the Arctic Monitoring and Assessment Program (AMAP), Emergency Prevention, Preparedness and Response (EPPR) Working Group, and Conservation of Arctic Flora and Fauna (CAFF) have different boundaries illustrated in Fig. 1 (Arctic Council 2019).

The most intimate definition of the Arctic region is north of 66° 33′N latitude where the polar night and the midnight sun are observed. Another approach at definition involves the region where the average temperature of the warmest month of July temperature is 10 °C (Stonehouse 2001; Przybylak et al. 2003). There is, also, a

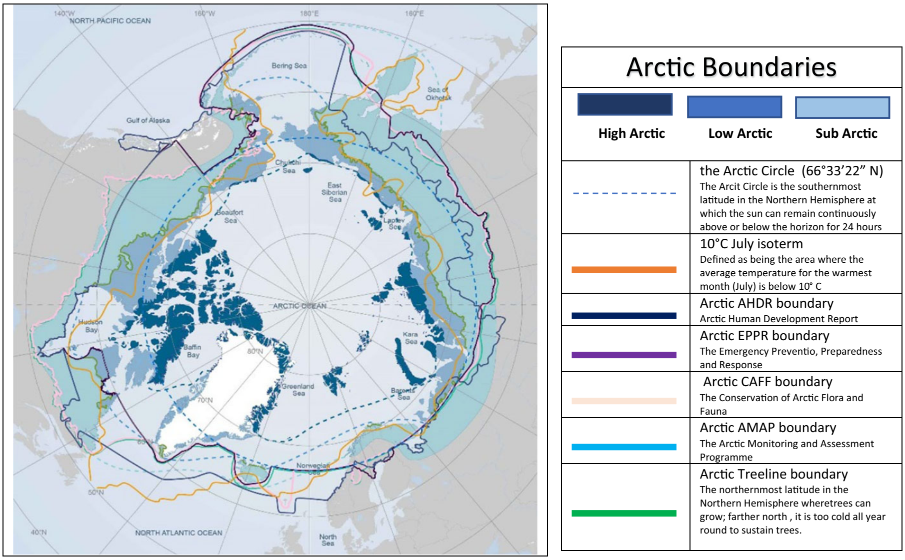


Fig. 1 Arctic boundaries. Source: Grid-Arendal, ADHR, EPPR, NSIDC, AMAP, CAFF

boundary determined by the vegetation, according to which the Arctic is the region where trees do not grow (Walker et al. 2005). Yet another definition pertains to the presence of permafrost (Serreze and Barry 2014).

Boundaries of Arctic Council bodies differ regarding their assessment activities. For the AMAP assessment and recognizing other factors which may be used to define the Arctic marine area, such as Arctic marine biology and sea ice cover, the AMAP marine area to the south of the region also includes the Labrador Sea and Hudson Bay; the Greenland, Iceland, Norwegian, Barents, Kara Sea; and Bering Sea (AMAP 1998).

The marine boundary of the Arctic is based on oceanographic characteristics whereby the warm and less dense waters from the south meet the Arctic Ocean. This region starts approximately at about 63°N in the Canadian shore or 65°N near the coast of Greenland. The warm waters of the Atlantic Current may alter this boundary up to 80°N, west of Spitsbergen, then to the Russian shore (Stonehouse 2001). Recognizing the difficulty of assigning a distinct boundary separating the Pacific water from the Arctic water, the boundary has been arbitrarily drawn across the Bering Strait as the point at which modification is likely to commence (Stonehouse 1989). Defining the Arctic marine boundary by a direct line across the Bering Sea may give rise to a debate as it excludes fundamental areas with comparable environmental characteristics to higher latitudes. For instance, sea ice extends well below 60°N in the Pacific Ocean, while the waters may be ice free in many parts of the Arctic Ocean.

2.2 Polar Code application areas in the Arctic

In the 1980s, different national implementations regarding the structure of vessels operating in polar waters started to be developed. Nevertheless, this created confusion because there was a variety of national regulation (Jensen 2016). On 1 January 2017, the mandatory Polar Code was enforced. The Polar Code amends SOLAS 74 and MARPOL 73/78 with binding regulations. It has been structured into three parts: Introduction, Part I-A (Ship Safety), Part II-A (Pollution), Additional Guidances: Part I-B, and Part II-B. Part I addresses a wide range of safety measures such as operational manual, ship structure, the safety of navigation, life-saving appliances and arrangements, communication, voyage planning, manning, training, etc. Part II addresses pollution from ships (Marine Environment Protection Committee n.d.).

The Working Group on the Development of a Mandatory Polar Code defined the Arctic and Antarctic waters as in the Guidelines for Ships Operating in Polar Waters. However, there are potential conflicts between the Polar Code and Article 234 of the United Nations Convention for the Law of the Sea (UNCLOS). According to Article 234 of UNCLOS, sea ice must be present "most of the year" (Thorén 2014). We think that sea ice extent should also be the determiner of the Polar Code boundary in the Arctic as it is in UNCLOS Article 234. Nevertheless, there is nothing changed in terms of marine boundaries during the development of Polar Code. It has already been defined in existing IMO mandatory instruments, e.g., Antarctic in MARPOL (51). As regards geographical application of Guidelines 2010, "Arctic ice-covered waters" is defined in Section G-3.3 as "[waters] … and thence by the northern shore of the Asian Continent eastward to the Bering Strait and thence from the Bering Strait westward to latitude 60° North as far as Il'pyrskiy and following the 60th North parallel eastward as far as and including Etolin Strait and thence by the northern shore of the North American continent as far south as latitude 60° North…" (Jensen 2007). In Polar Code's Introduction section, there is a definition and a figure which demonstrate the boundaries of the Arctic waters (Fig. 2) (Marine Environment Protection Committee n.d.).

However, some areas which sea ice present and which pose a structural risk to ships have been excluded in Polar Code. For instance, these areas are North Atlantic Ocean to part of the Norwegian Sea along the shore of Norway and the adjacent part of the Barents Sea to the Kola Peninsula in Russia. The exclusion of these areas is partially acceptable because sea ice concentration is not a big deal in these areas. However, sea ice temporarily exists beyond the 60°N part of the Bering Sea, Sea of Okhotsk, Strait of Tartary, and the Sea of Japan. It is important to describe some of these regions to understand the situation briefly.

The Bering Strait is 44 nautical miles wide at the narrowest point, which is between the Bering Sea and the Arctic Ocean. Vessel traffic through the Bering Strait has been increasing steadily and sharing with Arctic wildlife. The growth in shipping operations is expected to continue due to resource development as decreasing sea ice. Bering Strait transit ship number in total was 220 in 2008 and increased to 540 in 2015 (Boylan and Elsberry n.d.). Although shipping activity is low compared with other parts of the world, the capacity to provide aid for vessels in the strait is limited compared with elsewhere (Bering Sea Elders Advisory Group 2011; Communities 2014; McFarland et al. 2018). IMO approved to designate to six two-way shipping lanes to protect the marine environment and the people of the region (Rosen n.d.).

The Bering Sea, a northern extension of the Pacific Ocean, which is over 2 million km^2 is surrounded by Russia, Kamchatka Peninsula, Aleutian Islands, Alaska, and ends in the Bering Strait. Ship traffic through the Bering Sea with the opening of Yamal LNG and the future Arctic LNG 2 facility will see more than 1000

Fig. 2 Maximum extent of Arctic water application. Source: Polar Code, Introduction, Fig. 2

transit large vessels carrying hydrocarbon resources within the next 5 years. In addition to that, there is a large number of smaller non-fishing and fishing vessels. Together with these vessels, there were more than 110,000 individual voyages in the waters between Russia and Alaska in 2014 and 2015 (Humpert n.d.).

The Okhotsk Sea, the northwestern extension of the Pacific Ocean, has an approximately 1.6 million km^2 area and 10,460 km coastline (Alekseev et al. 2006). The Sea of Okhotsk is an economically important region that includes oil and gas fields (Tkachenko 2008). While oil and gas exploration and exploitation are increasing, the possibility of oil spills as well (Miller et al. 2004). Due to the presence of one of the wealthiest fisheries of the world, the fishing industry plays a significant role in the local economy and results in the distribution of fishing fleets from not only Russia and Japan but also other parts of the world (Elferink 1995).

3 Maritime safety and ship accidents caused by sea ice in the high north

According to the Polar Code Introduction section, sources of hazards, especially ice, create a structural risk to ships. Severe weather conditions and low temperatures also affect the working environment and human performance, both of which are crucial. Remoteness, lack of correct hydrographic data, and crew experience are other sources of hazards observed in these areas. Determining the particular level of ice extent is not easy, but it is evident that sea ice temporarily exists beyond the 60°N. Furthermore, weather conditions beyond the 60°N are quite like in the Arctic region (Alekseev et al. 2006).

In challenging the fragile Arctic region, maritime activities are growing as sea ice extent and volume are decreasing. Thus, it is imperative to analyze the maritime incidents caused by sea ice. There are a variety of factors, ranging from humans to the environment, that cause ship accidents, such as the state of the sea, wind, current, weather, and sea ice along the polar waters. Moreover, the melting of ice shelves raises the risks of drifting pack ice. This, together with the factor of the wind can create dangerous icing conditions (Şahin 2015). Sea ice existence and thickness are important factors for navigational performance that the vessel's hull, propeller, and rudder may be damaged under significant forces. On the other hand, the lack of marine infrastructure and accurate charting and the limitations of radio and satellite communications present significant risks of ice damage or getting stuck in the ice, groundings, machinery failures, etc. Compared with the open-water incident rate, the probability of a maritime accident is 19 times higher in the Arctic region (Loughnane et al. 1995).

An analysis of ship accidents in the Arctic over the previous century shows that a majority of casualties were related to sea ice. The cases categorized such as ice floe hit, trapping by ice, and ice jet show the real danger posed by sea ice to shipping (Marchenko 2013). Generally, it is possible to rescue a vessel trapped in ice using modern equipment and technique. However, the problem is time and money involved in conducting that kind of rescue operations. On the other hand, if any oil spills occur, there are serious concerns about how to clean oil-polluted icy waters. Most pollution prevention methods are based on open-water conditions in coastline environments. Emergency Prevention, Preparedness and Response (EPPR) released oil spill response guidance which is specific to the unique climatic and geographic conditions of the polar environment (Owens et al. 1998). Unfortunately, even though many countries surround it, the vast area of the Arctic region is insufficient for emergency preparedness for maritime accidents in the Arctic insufficient (Sakhuja 2014). Thus, while making significant investments to protect the environment, binding rules concerning maritime safety standards must also be developed.

The Protection of the Arctic Marine Environment (PAME)'s comprehensive Arctic Marine Shipping Assessment 2009 (Council 2009) (Fig. 3) demonstrates that the majority of shipping incidents have taken place in the coastal waters. The various colored dots demonstrate the nature of these incidents in the Arctic. On the other hand, when recent marine incidents were studied to identify the cases caused by sea ice beyond the Polar Code application areas, there were too many cases that occurred between the Gulf of Alaska and Northern China coasts/Yellow Sea and between the Labrador Sea and Baltic Sea (LMAlloyds). Some examples of accidents in these regions are given below.

The fishing vessel *Destination* which was 33.5-mt length and 196-gross ton, sank in remote waters 2.6 mi northwest of St. George Island, Alaska, on February 11, 2017. None of the six crew members aboard were found in the accident. According to the US National Transportation Safety Board investigation report, while the exact nature of the accident is unknown because there were no survivors, no witnesses, and no mayday call from the *Destination*, evidence indicates it capsized and sank after an accumulation of ice on the vessel and its fishing gear after encountering forecasted heavy freezing spray conditions (NTSB 2013).

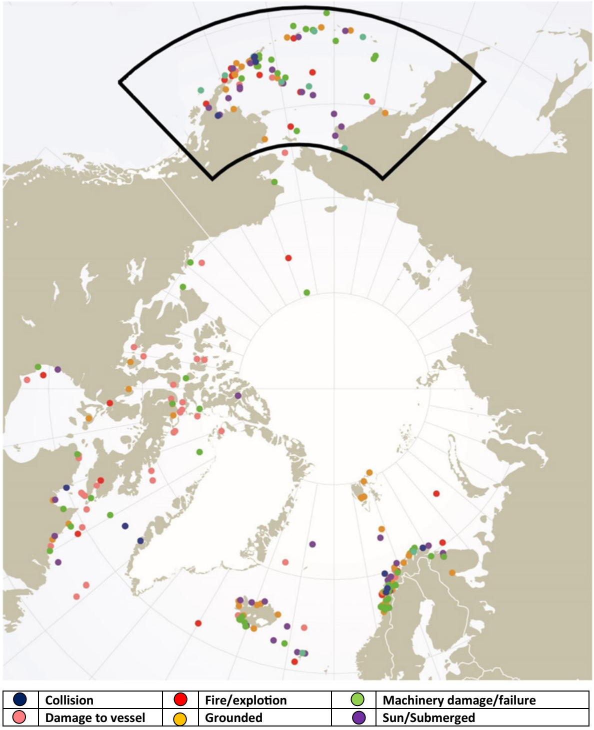


Fig. 3 Shipping incidents in the Arctic. Source: Arctic Marine Shipping Assessment 2009

In December 2010, 10 fishing vessels (675 crew) had been trapped by a vast sheet of drifting sea ice while fishing in Sea of Okhotsk, Sakhalin Gulf. The sea ice was up to 30-cm thick, and its temperature was −22C. The ships needed icebreaking assistance to be rescued. More than 6 h later, nobody was injured, and all the fishermen were rescued (BBC News 2010; Leon 2012). As Far East Shipping Company reported, the rescue operation took a month and cost approximately 5 ml USD. Fortunately, none of the vessels had been damaged. The first vessel had been escorted 23.6 nm, second 62 nm, and third 150 nm. Towing ropes were broken several times due to severe ice conditions (Marchenko 2014).

In December 2013, 6030 GT general cargo ship, *Diomid*, while navigating from Magadan to Vladivostok, drifted to the shore due to adverse weather conditions. The vessel sheltered in Sakhalin Bay and waited for the excellent weather conditions (LMAlloyds 2013).

4 Methodology

The maps of sea ice extent and concentrations in the Arctic and surrounding waters were developed using brightness temperature imagery in the passive microwave wavelengths collected by satellites (Emery and Camps 2017). Satellite remote sensing provides sea ice data to estimate the total extent where sea ice concentration is more than 15%. Data from 1978 to 1987 were collected using the Scanning Multichannel

Microwave Radiometer on board the Nimbus-7 Pathfinder (Nimbus-7 SMMR) satellite and afterward series of Special Sensor Microwave/Imager (SSM/I) instruments used which have been carried onboard Defense Meteorological Satellite Program (DMSP) satellites (Foster et al. 2009). In 2008, the Special Sensor Microwave Imager/Sounder (SSMIS) replaced the SSM/I as the source for sea ice products (Epa and Change Division n.d.). Remote Sensing Systems generates SSM/I and SSMIS data products using a unified, physically based algorithm to simultaneously retrieve the products' season (Kern and Ozsoy-cicek 2018). These instruments also provide data regarding surface temperature and surface water which helps to determine the start and end dates of the melt. The National Snow and Ice Data Center (NSIDC)'s data are derived from satellite imagery collected and processed by the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC). However, some of the instruments past its lifetime, and some of these instruments failed that significantly increased the risk of a gap in coverage in the next years (Gerland et al. 2019). On the other hand, NASA Goddard produces sea ice thickness estimates based on data from the European Space Agency CryoSat-2 radar altimeter. While direct estimates of sea ice thickness can be obtained from airborne and satellite systems using laser and radar altimeters, as well as from submarines using sonar, these data sources cannot provide sufficiently long and consistent time series to be used as an indicator (Gerland et al. 2019).

Traffic Density Maps are a simple and effective way of displaying vessel movement patterns, which contribute to a better understanding of maritime traffic. The Automatic Identification System (AIS) produces massive amounts of maritime data daily. It transmits vessel information, such as location, speed, and heading via VHF to other vessels and terrestrial or satellite receivers. Terrestrial receivers are land-based stations that receive messages from vessels within their line of sight, while Satellite receivers do not require line of sight. The working principle of both receivers is similar, by transmitting the received AIS message to a computer for data storage, processing, and visualization. Several studies attempt to understand maritime behavior by generating density maps for supporting decision-making (Willems et al. 2009; Tsou 2010). The main shipping lanes and what type of vessels navigating on which routes can be seen via the created density maps. Most of the existing methodologies are based on the same approach to generate density maps where the area to be monitored is divided into cells to create a spatial grid. This method rebuilds the track of each type of vessel from the recorded positions and counts how many routes are crossing each cell of the grid during the selected time period (Zissis et al. 2020).

The archived monthly and daily concentration and extent data are available on the NSIDC website, and Traffic Density Maps are available on the Marine Traffic website. We analyze, in particular, the Bering Sea and Sea of Okhotsk sea ice extent data provided via satellite records from 1978 to 2019, based on the NSIDC datasets, and the density of maritime traffic provided by the Marine Traffic.

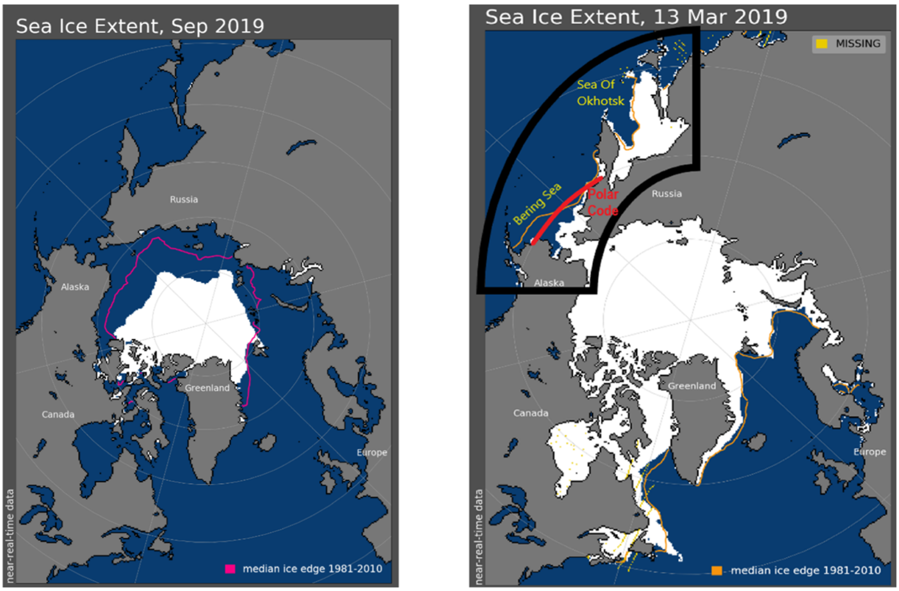
5 Results

The Arctic sea ice extent reaches its annual minimum in September that has decreased approximately 33% since 1979, and it is estimated that it will be ice free during the summer months of 2050 (Gerdes and Köberle 2007; Screen and Williamson 2017).

According to NSIDC, this year's minimum Arctic sea ice extent averaged 4.32 million km^2 (Fig. 4a. This extent is 2.09 million km^2 below the 1981 to 2010 average. Arctic sea ice extent reached its maximum for 2019 at 14.78 million km^2. Furthermore, it is 860,000 km^2 below 1981 to 2010 average maximum (Fig. 4b) (Serreze et al. 2019). In the northernmost part of the world, the seawater freezes during the winter months (min. extent in September to max. extent in March) and melts during the summer, but in some areas, sea ice cover is retained throughout the year. Moreover, sea ice can exist as far south as 38 °N, Bohai Bay, China (Liu and Horton 2016). In this study, we focus on beyond the Polar Code boundary of the Arctic, the Bering Sea, and the Sea of Okhotsk. Thus, the sea ice extent data is evaluated, which is provided via satellite passive microwave records from 2018 to 2019 by the NSIDC. In Fig. 4b, median sea ice edge 1981–2010, March 2019 sea ice extent, and Polar Code boundary are showed.

In March 2019, sea ice coverage was far below average in the Bering Sea, but it was slightly above average in the Sea of Okhotsk (Fig. 5b). Given are some figures (Fig. 5 a–f) to illustrate the sea ice extent in the Bering Sea, Sea of Okhotsk, and the Sea of Japan over the last 2 years, spanning the months December to May.

In Fig. 6 a–b, the graphs show Bering Sea and Sea of Okhotsk sea ice extent data for previous years. Although the maximum sea ice extent in the Bering Sea and the Sea of Okhotsk shows significant interannual variations because of changes in regional air temperature, wind, and sea surface temperature, the maximum sea ice extent in these regions follows a long-term trend of reduction from 1979 to 2019 (Fig. 7). The annual ice period lasts for an average of 260 days in the northwest and for 190–200 days in the north and the Sakhalin coasts (Alekseev et al. 2006).



a Arctic sea ice extent at minimum for 2019 **b** Arctic sea ice extent at maximum for 2019

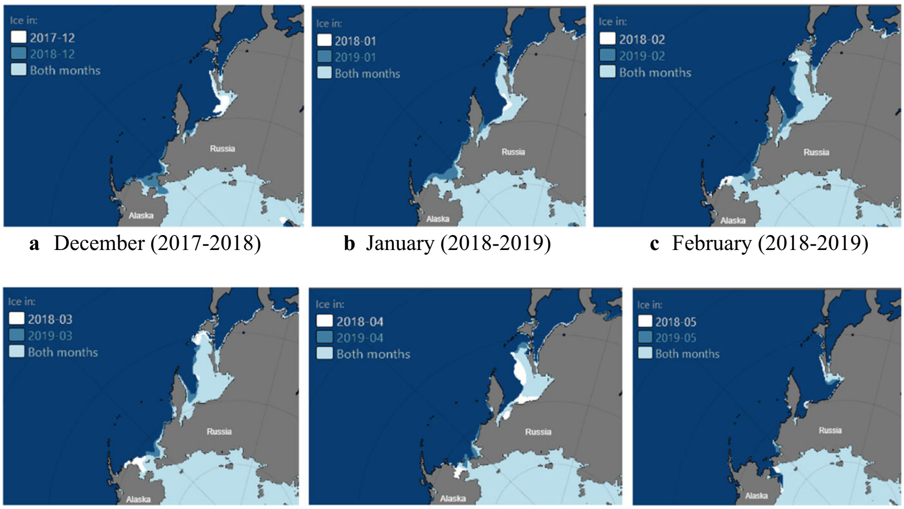
Fig. 4 **a** Arctic sea ice extent at minimum for 2019. **b** Arctic sea ice extent at maximum for 2019. Source: NSIDC at the University of Colorado Boulder

The northern part of the Okhotsk Sea is greatly influenced by the Arctic climate, and its average January temperature ranges between 8 and −32 °C. The cold period lasts 210–220 days in the north of the region. In general, the surface water temperatures of −1.0 to −1.8 °C in February and March sea ice extent can cover up to 99% of the water area during severe winters and, in milder winters, about 65%. The sea ice form is both stagnant and drifting, which is comparable with the Arctic ocean (Alekseev et al. 2006). Time series of sea ice extents in the Sea of Okhotsk and the Bering Sea from March 1979 to 2019 are showed in Fig. 7.

5.1 The density of ship traffic in the region

The availability of instant information from ships is provided by the Automatic Identification System (AIS). Following the SOLAS rules set by IMO, AIS systems are compulsory in any cargo ship > 500 GT transiting within national waters, all passenger ships, and all vessels > 300 GT transiting international routes (Marine Traffic n.d.).

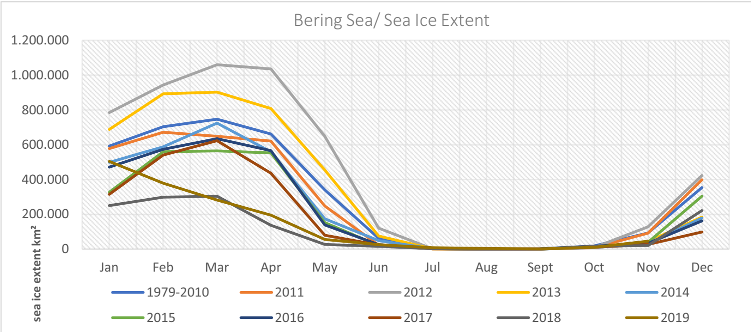
In 2014, Arctic shipping was found to occupy between 57 and 80% of ice-free waters (Eguíluz et al. 2016). In the Arctic, shipping will continue to increase as the ice coverage decreases (Smith and Stephenson 2013; Stephenson et al. 2013). Density maps of the regions are illustrated in Fig. 8, taken from marine traffic application, which is widely used by mariners, and supply a variety of data related to shipping activities. It is based on the AIS track of vessels (Marine Traffic n.d.). The colors of lines show routes according to vessel type as in Fig. 8 a–h, the red for tankers, light green for cargo vessels, blue for passenger ships, orange for fishing vessels, purple for pleasure crafts, dark green for container ships, yellow for gas carriers, and light blue for tugs and special craft.



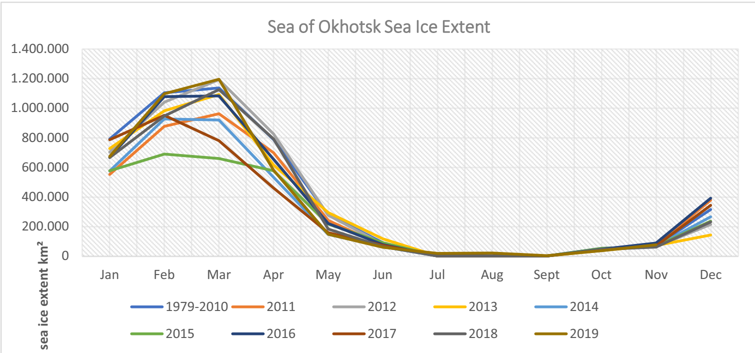
a December (2017-2018) **b** January (2018-2019) **c** February (2018-2019)

d March (2018-2019) **e** April (2018-2019) **f** May (2018-2019)

Fig. 5 **a-f** Sea ice extent in the Bering Sea, Sea of Okhotsk, and the Sea of Japan over the last 2 years



a Bering Sea monthly average sea ice extents from 1979 to 2019.



b Sea of Okhotsk monthly average sea ice extents from 1979 to 2019.

Fig. 6 **a** Bering Sea monthly average sea ice extents from 1979 to 2019. **b** Sea of Okhotsk monthly average sea ice extents from 1979 to 2019

There is a metric bar that the numbers refer to distinct vessels daily and count positions per square km. The numbers on the bottom right indicate the number of routes within every 382 km2. The "colder" colors show less dense routes. Moreover, the "hotter" the colors are, the higher the number of routes. These ship density maps are created based on the 2017 AIS datasets (Marine Traffic n.d.).

As seen in Fig. 8 a–h, according to vessel types cargo vessels, tankers, and fishing vessels, density for the total year rate is quite high. There are a large number of routes preferred in the areas focused on in this study. No significant accidents have occurred in these regions, but it is obvious that there is a high risk depending on a large number of ships. On the other hand, the ship sizes also matter. Figure 9 a–d demonstrate the density of ships according to their size that are categorized into four different types. Figure 9a shows small size of vessels which are below 500 GT, and the other figures are medium size (500 GT–25 K), large size (GT 25–60 K), and very large size (GT 60 K>) of vessels, respectively.

These figures provide essential tips. As it is seen, while small and mainly medium size of ships operate more often in these areas, a large and extensive size of ships slightly operate beyond the Aleutians Islands. When we take ship sizes into account, which must comply with SOLAS, Fig. 9b is vital to analyze the Polar Code application areas and the size of ships.

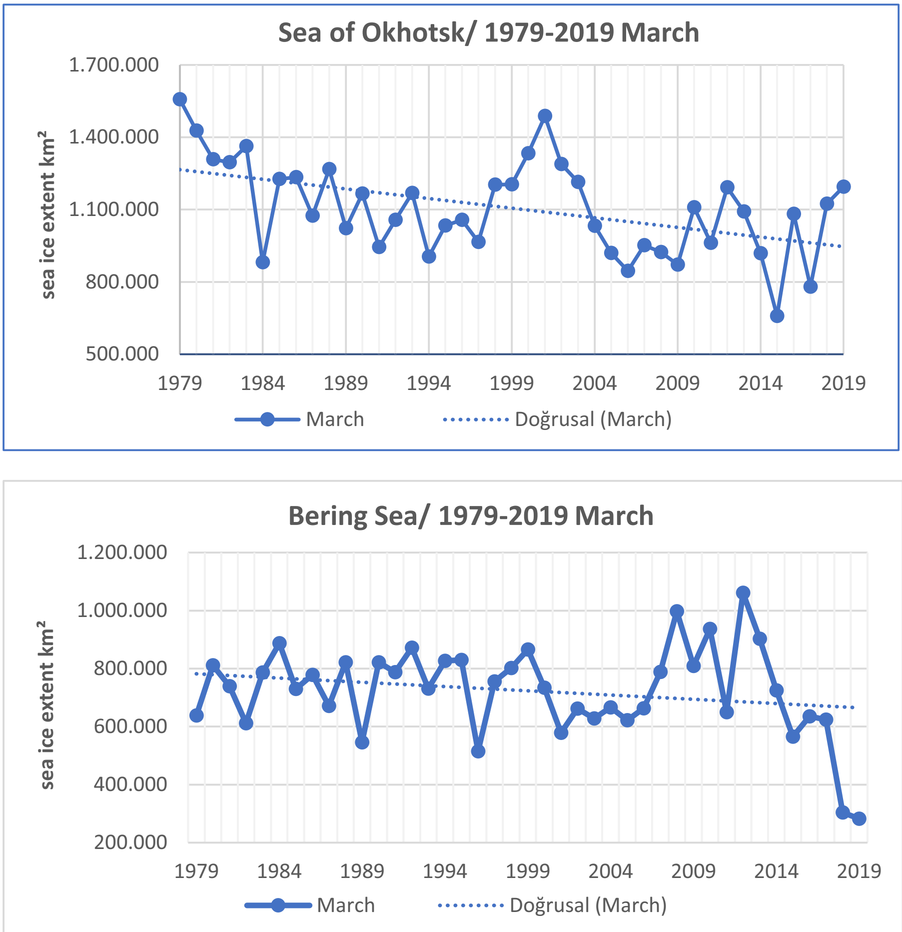


Fig. 7 Time series representation of March sea ice extents in the Sea of Okhotsk and the Bering Sea from 1979 to 2019

6 Discussion and conclusion

The decreasing sea ice extent in Arctic waters due to global climate change offers opportunities by opening Arctic waters as shipping lanes, fishing ground, and potential cruise tourism destination with the potential risks for more incidents. In this study, we compared the boundaries of Arctic Council bodies regarding their assessment activities to the Polar Code implementation areas. Therefore, we investigated the maritime safety issues and ship accidents caused by sea ice in the 60°N and beyond the 60°N. Furthermore, we examined the sea ice extent changes in the Northern Hemisphere based on NSIDC datasets. After examining the 41-year satellite records of sea ice extent in the Arctic area, including the Bering Sea and the Sea of Okhotsk, our analysis concluded that the interannual variations of sea ice extent resulted in outcomes that were a long-term trend of reduction 1979 to 2019. Although previous findings indicated that trend of reduction outcomes, our study followed a specific approach concerning

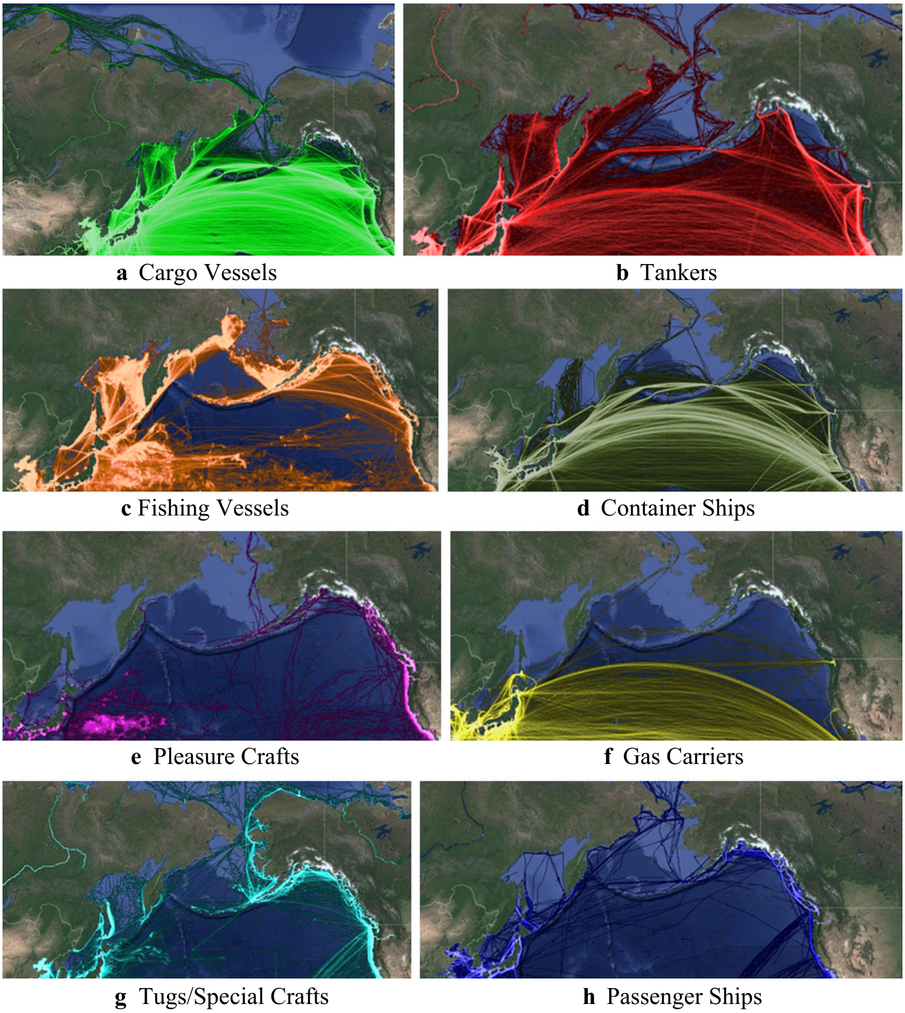
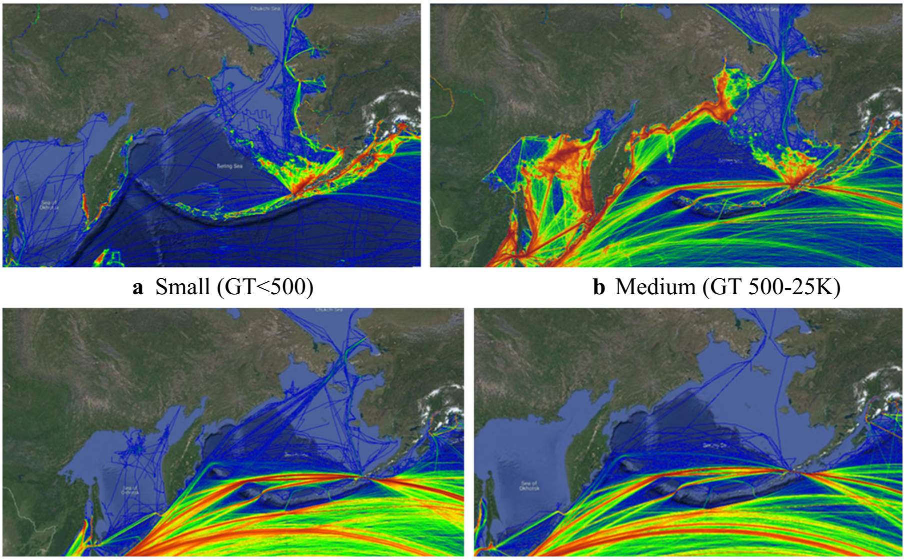


Fig. 8 Traffic density maps by vessel types

maritime traffic density and maritime safety than those in major studies conducted previously. The risk level regarding maritime activities within polar waters differs according to location, season, temperature, weather, sea conditions, remoteness, ice coverage, type of ice, etc. The measures to address specific hazards in polar waters are included in the Polar Code, which is imposed in 2017. However, this is an important finding in the understanding of the Polar Code that it does not cover all sea ice–covered areas as specifying hazards in the Introduction section. Thus, the present findings confirm that Polar Code's application boundary might be modified in the Pacific according to the sea ice period and the sea ice extent records of the last decades. Additionally, in a long period of sea ice extent in specific areas, if ship traffic density and recent maritime incidents are taken into account, the development of the Polar Code would be beneficial. Although there have been few incidents that there is a considerable risk of oil spills in these regions due to rising oil extraction operations, the potential consequences of an accident are considerable when the ecological and



a Small (GT<500) **b** Medium (GT 500-25K)

c Large (25K-60K) **d** Very Large (GT>60K)

Fig. 9 Traffic density maps by vessel sizes beyond the Polar Code region

economic importance of the Arctic region is taken into account. This assumption might be addressed in future studies. Future researchers also should consider investigating the impact of decreasing sea ice extent and increasing maritime activities in these regions. Regardless, our research points to the need for revision of the boundaries of the Polar Code to cover the part of the Bering Sea and the Sea of Okhotsk to sea ice edge 1981–2010 line instead of an arbitrary line in order to prevent terrible consequences.

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Timeline

13 July 2019 - 26 July 2019

Areas of project general coverage

Sea ice edge (Remote Sensing), Sea ice observations, Arctic Maritime Meteorology, Meteorological/Atmospheric Measurements (installation of (50cm by 50cm size) instrument established by high school students), Sea Water Sampling for microplastic, Sedimantology, Maritime Law, Arctic Shipping Safety (Polar Code), Education & Outreach

Summary

Turkey is almost a mid latitude country and has far distance from polar regions. But, the effects of climate change are also visible in Turkey. The Turkish Polar Scientific Strategies between 2018-2022 consist of scientific researches in Arctic and Antarctica. The Turkish Antarctic Expeditions had been completed successfully since 2017 with the coordination of Istanbul Technical University (ITU) Polar Research Center (PolReC). The very first Turkish Arctic Scientific Expedition (TASE) planned with the coordination of PolReC. The Turkish Polar Scientific Strategy also conducts education activities and raises awareness among students and society. The TASE project includes seven individual educational institutions / universities, additonally PhD candidates on the field and an installation of Meteorological/Atmospheric equipment project which made by high school students. TASE team consist of Istanbul Technical University, Karadeniz Technical University, Piri Reis University, Istanbul University, Ankara University Research Center of the Sea and Maritime Law, Bilfen High School and Polar Research Center.

This project will contribute various scientific researches such as sea water, underwater sediment and plankton sampling, atmospheric measurements, sea ice observations, etc. which directly related to climate change issues. Additionally, there will be installation of scientific equipment which created by high school students to install at the University Center of Svalbard. The news and results of the expedition will take place in the country to raise awareness for polar regions. TASE will conduct onboard “Anikina” which will be use as a gateway to understand Arctic Shipping challenges and evaluate implementations of Polar Code and examination of Arctic law. On the other hand, various social polar science studies such as scientist photography, middile school students painting contest will be conducted for education and outreach activities through the homeland. Also, international collaborations are going to make possible such as planning meeting at Svalbard University, visiting scientific stations in Svalbard.

Description

The objective of this project is to conduct first Turkish Arctic Scientific Expedition with the team of multidisciplinary scientists. The topics of the including projects are:

·Installation of Meteorological/Atmospheric instrument
·Sea ice observations
·Maritime Meteorology recordings
·Sea water sampling for microplastic
· Bioprospecting
·Plankton sampling
·Sedimentology studies
·Underwater sampling
·Studying Arctic - Maritime Law
·Sky quality measurements
·Arctic Shipping Safety (Polar Code)
·Education & Outreach

Microplastics Classification and Identification of Svalbard Island and Surroundings: Microplactics are ubiquitous and bioavaliable particles. Therefore their adverse effects have been increased on environment and health in recent years. In aquatic environments, waterfowl, sea turtles and marine organisms can intake microplastics from water column and microplasics may go down to the sea bottom as feces and sea snow. Microplastics, which are also found in sediment, are at least as dangerous to benthic organisms as they are to aquatic organisms. There have been identified some negative effects such as decreased nutrient uptake and growth rate, weight loss, energy depletion on subsequent generations in living organisms which are exposed to microplastic pollution. In this study, classification and identification of microplastics will be performed in water samples collected from surrouindings of the Island. For this purpose, water samples will be collected by using phytoplankton net. They will be stored in deep freezer until the analysis in laboratory.

Determination of Presence and Quantity of Selected Pharmaceutical Recidues and Hormones: Pharmaceutical recidues and hormones are not purified completely in wastewater traetment system. For this reason, these chemicals can be reach to marine system directly and/or/ indirectly. So, research studies about adverse effects of pharmaceutical recidues and hormones on aquatic life have become mandatory in recent years. In this study, determination of presence and quantity of selected pharmaceutical ecidues and hormones will be performed in water samples collected from surrouindings of the Island. For this purpose, 1 L water samples will be collected by niskin sampler. They will be stored in freezer until the analysis in laboratory after addition 1 ml HNO3.

Determination of Persistent Organic Pollutant Levels in the Arctic Ecosystem: Application of Passive Samplers: The sampling locations will be chosen according to the route of the expedition. 2 stainless steel cages containing 5 layers of spiders with 3 different type of passive samplers of persistent organic pollutants will be deployed in 2 different stations depending on the route of the expedition. The GPS coordinates of the deployment sites will be recorded and the salinity and temperature of the seawater will be measured. Sediment samples will be tried to be collected from the bottom of the deployment point, if exists.

Determine the levels of PAH and POP: Researches about the level and behavior of polycyclic aromatic hydrocarbons (PAH) and persistent organic pollutants (POP) with their adverse effects on organisms are conducted routinely within the scope of pollution monitoring studies in the whole world. Beginning from the mid of 1970s, active usage of many POPs has been banned in many countries. However, POPs are still seen commonly in sediment and organisms due to their properties like low solubility in water, persistence to physical and chemical degradation. Present studies show that PAHs, especially POPs can travel long distances through the conventional airflow of the world, water cycle and accumulation paths due to their physicochemical properties, and accumulate in different matrices (water, sediment, organisms) in polar areas. POPs, which evaporate at high temperatures, can arrive at high latitudes due to their semi-volatile nature, and can accumulate by condensing at low temperatures, especially at poles, where no POPs have been produced or used. Thus, POPs are considered as globally important pollutants. Sediment samples will be collected from the field by grab samplers to determine the levels of PAH and POP. Also results will be compared with the samples collected throughout Turkish Antarctic Expeditions I, II and III.

Installation of Meteorological/Atmospheric instrument to The University Centre in Svalbard: One of the components of the project will be the installation of a measurement equipment, to measure temperature, pressure and humidity, to measure the amount of ultraviolet and infrared rays, the total amount of illumination, and, in 3D, the amount and intensity of the magnetic field. The epuipment total size is approximately 50 cm * 50 cm. The measurements will be available freely on official website: (http://bilfenarastirmaistasyonu.com/en/). This station planning to be established in The University Centre in Svalbard.

The measurements of sky quality in Arctic: The night-sky brightness can be used as an environmental assessment indicator to characterize the relative intensity of light pollution. The night-sky brightness will measure and monitor using a portable light-sensing device called "The Sky Quality Meter" during the expedition. The Sky Quality Meter (SQM) is a device that can instantaneously measure the brightness of the night sky in units of magnitude per arc second square (mag arcsec^2), the international unit for measuring sky brightness. We'll calculated the positions of moonrise/moonset, sunrise/sunset, civil/nautical and astronomical twilight which cause poor sky quality when observing the sky. Besides of these, we'll observe cloudiness and temperature in order to study on astronomical and meteorological parameters. It is crucial to monitor those measurements for observing the sky and measure atmospheric parameters.

Mikro and Meso Plankton Distribution Along Svalbard Island In Arctic Summer: Micro and mesoplankton are composed of organisms between 2- 200 µm and 0.2 mm -20 mm in size respectively. They are a mixture of phytoplankton and zooplankton. It is import -ant component of marine pelagic ecosystem not only for primary production but also as consumer at the food web. They transfer the energy from sun to top predators all aquatic habitats. So the plankton community studies are the basic way for understanding the marine habitats. The primary goals in this proposal are to determination of microplankton and mesoplankton in the planktonic food web of Svalbard Island and to provide basic information vicinity of the island in North pole. Our objectives for achieving these goals are to examine the distribution, abundance, taxonomic composition of planktonic community. Planktonic community structure and species composition will be compared between bays, coastal and off-shore along the Svalbard Island, as well as across a spatial gradient throughout coast. For this purpose eleven station placed in bay, coast and off-shore of the Svalbard Island were determined. Plankton samples will be collected from 1 m depth by means of plankton net applied horizontal tow for qualitative analysis and 500 ml polycarbonate bottles for qualitative analysis. Samples will be fixed with acidic lugol solution immediately. The sample will be kept in cold and dark place till the analysis. After settlement of organism and over the concentrations procedures of the sample, microscopic examination will be done under Nikon E 600 light microscope which has bright field, dark field and epifluorescence specification for microplankton and Zeiss Stemi 508 and Zeiss Discovery V20 binocular microscope for mesoplankton. The results will be analyzed using various statistical models and ecological indices. This project will provide the information for understanding the planktonic structure along Svalbard Island during the 2019 Arctic summer

Evaluation Fieldwork in Arctic Fjord System in Svalbard by Bioprospecting Outlook: On recent studies, extreme life forms have been discovered both on Arctic and Antarctic regions. Marine sediment samples have an abundance of microbiota. Identifying and characterizing these life forms could lead us to provide new perspective to understand our biosphere and has a trending outlook in pharmaceutics industry. By the help of the transgenic studies and direct cultivating the isolated microbiota from the sampling sites, help us to produce industrially important bioproducts for humanity. The pharmaceutical industry continues to be interested in natural products, natural product drug discovery is slow and costly in comparison to drug development based on synthetic compounds, and may therefore lead to a decrease in the pharmaceutical industry's reliance on natural compounds. As the environment can retain the molecular imprint of inhabiting species, our approach allows the reliable detection of secretive organisms in wetlands without direct observation. Environmental DNA (eDNA) describes the DNA that can be extracted from an environmental sample, such as soil, sediments, water or snow. The DNA samples extracted from sediment and eDNA marine filtered samples, both, would be analysed by Oxford Nanopore MinION Next Generation Sequencing System and some bioinformatics work will be done according to results. Then, industrially important gene structures could be grabbed from stack of DNA consensus sequences.

Determination Of The Origin Of Petroleum Pollution In The Svalbard Island: Understanding and investigating of the pressure coming from human activities such as fishing and oil drilling/exploration in the Arctic region will be investigated by means of petroleum pollution. One of the aims of the project is to investigate whether the origin of the petroleum pollution is petrogenic or pyrolytic and which petroleum compound is more dominant in arctic waters. The distribution of crude oil and its derivatives will be examined under the arctic sea physicochemical characteristics (temperature, salinity, DO, bacteria content, etc.) from the coast through the offshore at 11 selected stations. In addition to that, it is planned to determine the source of the pollutants in the selected stations whether coming from human activities in the coastal areas/harbors or by currents. These data will be compared with a reference station which is selected from offshore. 1-15 L seawater is taken from the surface in the plastic bags. The bag should be filled with seawater (no air) and closed tightly. Pollution coming from plastic bags will be minimized by blank studies. This sample transfer method is preferred in order to carry the samples in the most accurate and undamaged conditions in which the preliminary analyzes (extraction and concentration) are not possible. The samples are stored and transport in the dark to minimize bacterial activities.

Samples to Collect

- Sea Water 1 lt from each field
- Plankton 5mml x 10 from each field
- Sedimen 500 gr from each field
- 7 samples of surface marine water (up to 50 ml)
- 7 samples of injector filters obtained from filtration of 3 litres of marine water (2 filters each)
- 7 samples of sediment (up to 50 ml)

Sampling Coordinates

Sea Water & Plankton & Sedimen

TYPE	PERIOD	FROM / TO	COORDINATES
Fieldwork	1	2019-07-13 - 2019-07-26	78°16'07,55"N 15°21'29,17"E
Fieldwork	2	2019-07-13 - 2019-07-26	78°11'13,29"N 14°14'42,04"E
Fieldwork	3	2019-07-13 - 2019-07-26	77°57'20,13"N 12°22'13,37"E
Fieldwork	4	2019-07-13 - 2019-07-26	77°38'47,25"N 14°15'46,62"E
Fieldwork	5	2019-07-13 - 2019-07-26	76°58'12,78"N 15°40'59,95"E
Fieldwork	6	2019-07-13 - 2019-07-26	78°35’10,78”N 12°02’29,55” E
Fieldwork	7	2019-07-13 - 2019-07-26	79°01' 25,36"N 11°37'20,43"E

Meteorological – Atmospheric instrument

The epuipment total size is approximately 50 cm * 50 cm (I also included the picture of the station).

In our instrument we can currently measure temperature, pressure and humidity. In addition, we can also measure the intensity of ultraviolet and infrared rays, the total intensity of illumination, and, in 3D, the amount and intensity of the magnetic field. These measurements are recorded on an SD card at the station and are also sent to our website (http://bilfenarastirmaistasyonu.com/en/). We used Arduino microcontroller and compatible sensors at our station. The names of the sensors we use;

- Inside humidity-temperature sensor DHT22
- External tempruture sensor DS18B20
- Elektronic compass GY_271
- Triple axis compass magnetometer sensor module hmc5883l
- UV sensor ML8511_3-8-13
- Lux sensor TSL25911
- Also the sensors datasheets are in the attached file.
- For the instrument, it need 9V max 0.3A. Total data transferred by last similar station in Longyearbyen over 3 years 485 MB.

Main researches are:

From 1970s, active usage of many POPs has been banned in many countries. However, POPs are still seen commonly in sediment and organisms due to their properties like low solubility in water, persistence to physical and chemical degradation. POPs, which evaporate at high temperatures, can arrive at high latitudes due to their semi-volatile nature, and can accumulate by condensing at low temperatures, especially at poles, where no POPs have been produced or used. Sediment samples will be collected to determine the levels of PAH and POP.

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INTER⇄ACT

Images of Arctic Science

AARHUS
UNIVERSITY
DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

INTERACT

Images of Arctic Science

Morten Rasch, Carsten Egevang and Elmer Topp-Jørgensen

Photo: Carsten Egevang.

Content

About this book

Photo: Morten Rasch.

The idea behind this book is to provide a visual impression of arctic science in pictures.

As scientists, we normally tell stories in words, figures and tables in scientific papers, in textbooks, at lectures and in popular science articles. However, many of us – if not all of us – have also experienced the Arctic through our cameras; both for more technical, research related pictures and for pictures simply catching the beauty of our workplace and what surrounds it.

For this book we have chosen 107 pictures to tell 107 different stories – every picture in the book is a story of its own – about arctic science, arctic landscapes, arctic nature and the people living there.

INTERACT is a network of research stations in the Cold North. The pictures in this book were submitted by INTERACT community members through an 'INTERACT Photo Competition' that took place in March – April 2020. For the competition, we received almost 800 pictures from almost 100 photographers.

The photo competition included the following themes for which the photographers could submit pictures:

Arctic Fieldwork
Climate Change
Glaciers
Landscapes
Local Communities
People
Remote Field Camps
Research Stations
Wildlife and Plants

For each category a winner, a 2nd and a 3rd place were chosen by an evaluation committee consisting of scientists from the INTERACT community in cooperation with internationally recognized photographers.

The pictures presented in the book have all been chosen by award winning photographer and biologist Carsten Egevang from among the pictures submitted for the INTERACT Photo Competition. Carsten Egevang was a member of the photo competition evaluation committee, but for the selection of pictures for this book he has had freedom to choose 10-15 pictures for each theme/chapter. His job was to find pictures in which the high photographic quality, the photographic aesthetics and the motive itself combined to tell a story of its own.

The photographers contributing to the book are Andreas Alexander, Andreas Palmen, Beatriz Fernandez, Birgitte Danielsen, Blair Fyffe, Carsten Egevang, Catherine Moody, Christelle Guesnon, Dan Cogalniceanu, Dorthe Dahl-Jensen, Elena Kavvatha, Fieke Rader, Grant Francis, Gregory Tran, Hanne Hendrickx, Helge Markussen, Jakub Pelka, James Bradley, Jennifer Kissinger, Jiri Lehejcek, Jon Leithe, Jonathan von Oppen, Kamilla Oliver, Kari Fannar Larusson, Kari Saikkonen, Katarzyna Wasak-Sek, Klemens Weisleitner, Lars Holst Hansen, Laura Halbach, Lorenzo Ragazzi, Maaike Weerdesteijn, Marek Ewertowski, Martin Lulak, Martin Nielsen, Michael Gardner, Mikkel Tamstorf, Morten Rasch, Nicholas Hasson, Ole Zeising, Oliver Bechberger, Paulina Wietrzyk-Pelka, Pierre Rasmont, Santiago Giralt, Sergey Kirpotin, Sinan Yirmibesoglu, Susan Christianen, Tom Versluijs, Tommi Nyman, Vasileios Gkinis and Yael Teff Seker.

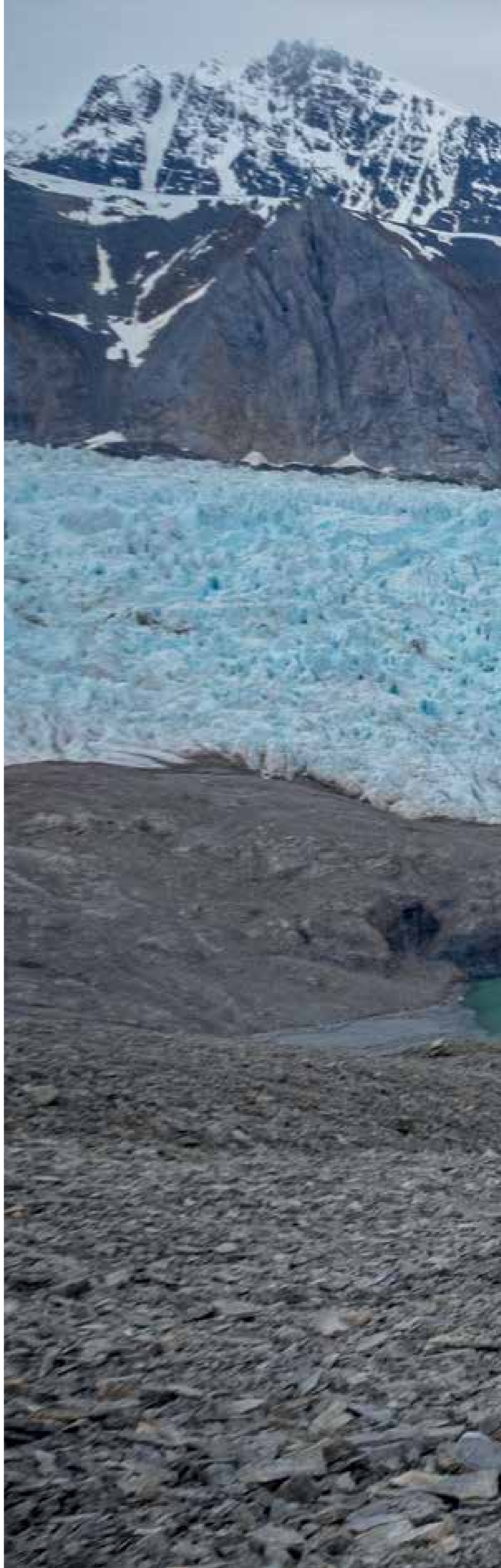
In the preparation of the book we have been eager to reduce the number of words to an absolute minimum. Each chapter/theme is introduced by a very short introduction, and each picture is accompanied by a very short descriptive text, mainly telling 'what', 'where' and 'who'. It is the pictures themselves that tell the full stories.

We hope that you will enjoy the book and take the time to explore each individual story. They are all worth it!

Carsten Egevang, Morten Rasch and Elmer Topp-Jørgensen

Iceberg calving among birds looking for food off the west coast of Svalbard, Norway.
Photo: Sinan Yirmibesoglu.

Expedition Leader Burcu Ozsoy is posing with a handmade picture created by a student from Turkey during a scientific research expedition in Svalbard, Norway, to raise awareness about Climate Change.
Photo: Sinan Yirmibesoglu.



Leader of the Ny Ålesund Research Station – Sverdrup, Helge Markussen, admiring the Blomstrandbreen glacier and the fjord Kongsfjorden during a mid-summer hike in Ny-Ålesund, Svalbard, Norway.
Photo: Helge Markussen.

Photographer Burcu Camcioglu taking close up pictures of seagulls from the window at the Polish Polar Station Hornsund, Svalbard, Norway.
Photo: Sinan Yirmibesoglu.

Images of Arctic Science

The Arctic, one of the Earths extremes, is the scene for magnificent land- and seascapes, snow and ice, cold climate adapted species and expanding science endeavors. Despite the often harsh conditions, people have been living there for thousands of years and in closer contact with nature than we are used to further to the South. Capturing the essence of the Arctic, Climate Change, life in the Arctic and the science conducted there in a single image is challenging. In this book members of the INTERACT community provide an insight into arctic wonders as experienced through the lens by scientists and other stakeholders working in the fascinating and breath taking Cold North.

INTERACT

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A Review on Geological View of Svalbard with its Infrastructure and Strategies

Sevval YALCINKAYA., Sinan YIRMIBESOGLU., Nurgul BALCI, Burcu OZSOY

Abstracting and Indexing: TR DIZIN, DOAJ, Index Copernicus, OAJI, Scientific Indexing Services, International Scientific Indexing, Journal Factor, Google Scholar, Ulrich's Periodicals Directory, WorldCat, DRJI, ResearchBib, SOBIAD

International Journal of Environment and Geoinformatics 9(4):024-034 (2022)

Review Article

A Review on Geological View of Svalbard with its Infrastructure and Strategies

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Abstract

Arctic Region (AR); Its role in global climate change, recently opened commercial sea routes, unexploited industrial resources, unique polar ecosystem, and international geopolitical balance making it a strategic area that attracts the attention of many countries. In this aspect, the Arctic Council carries out various studies and international cooperation, especially interdisciplinary scientific research in AR. Apart from the Council, many institutions, organizations and societies come to the AR to conduct scientific studies. When these studies are examined from a geological point of view, it is been seen that they are classified as glacial science, marine geology, geomorphology, microbial ecology, permafrost, biogeochemistry and geochemistry. Svalbard is geologically salient as well as being the place where most scientific studies are being conducted in the AR. In line with the geological significance of Svalbard, many institutions are engaged in educational research, science strategies, international projects, etc. In this study, the geological structure, geological infrastructure and scientific strategy for geological research of the Svalbard Region are examined. Moreover, projects that can be done within the scope of scientific research of Turkey in AR, are evaluated as a recommendation.

Keywords: Arctic, Svalbard, Geology, Infrastructure, Strategy

Introduction

Svalbard archipelago, which is a part of Norway, was formed as a collection of islands in the Arctic Region (AR). Figure 1, adapted and reproduced from Petrov et al., 2019 shows the location of the archipelago with a general view of tectonic plate boundaries over AR. Svalbard region, located between the Arctic Ocean and the Barents Sea, is one of the focal points of scientific research due to its unique environment. The region has a significant and crucial place in the wildlife care of Svalbard, which is among the protected areas by the Government and the National Assembly of Whom Norway. Researchers in the region are required to be in limited contact with wildlife and not to cause any harm within the area (Cetin and Buyuksagnak, 2021; Larssen, et al., 2008; Korkmaz, et al., 2022).

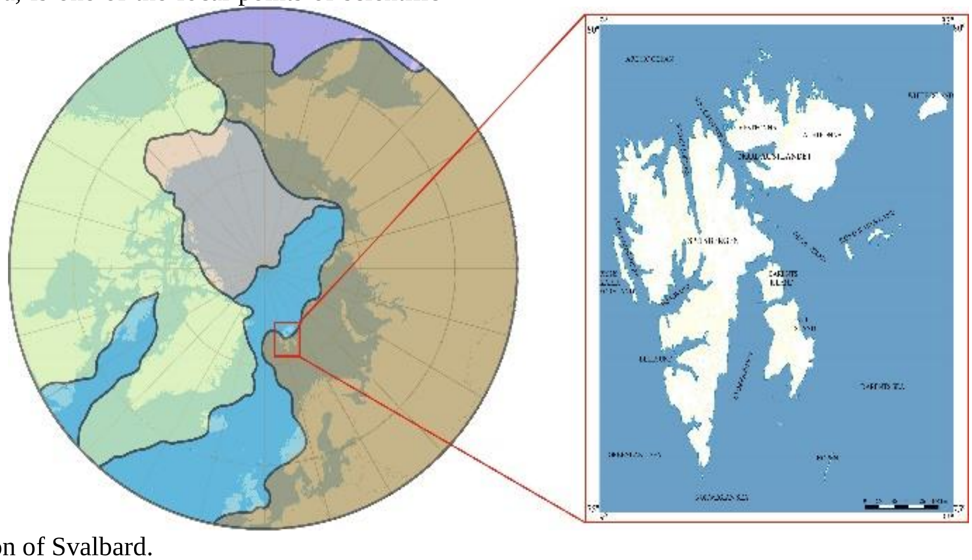

Fig. 1. Location of Svalbard.

Spitsbergen, the largest island of the archipelago, covers 37,673 km^2 area. The center town of the island where the settlements are located is Longyearbyen. There are museum, hospital, primary and secondary schools, university and other places where various social activities are held. Coal mining activities have diminished over the years in the region where coal mining used to be significant economic sector for the archipelago. The Longyear Power Station in the region is currently being operated with the extracted coal (Midttomme, 2017; Norwegian Ministry of Justice and Police, 2009).

During the first decade of the 20^{th} century, glaciers were increased significantly in and around Svalbard due to the Little Ice Age (Dallmann, et al., 2007). In the region, ice floes formed by tidal water cover more than 1.000 km (Dowdeswell, 1989). Nuth et al. (2013) reported that 57 % of the Svalbard archipelago consists of glaciers. A total of 20 % of the coastline of the major islands in the region is covered with ice. Ice cover lies 92% of the coast of the White Island (Kvitoya) in eastern Svalbard and 41% of the coast of the Big Island (Storoya) (Dowdeswell, 1989). Ice covers are more common in Nordaustlandet, Edge and Barents regions (Ingólfsson, 2004; Harland, et al., 1997). Nordaustlandet has two glaciers known as Vestfonna (2500 m^2) and Austfonna (7800 km^2) and it is the second largest island of Svalbard with 14,443 km^2 area (Moholdt and Kaab, 2012).

Large braided river systems that occur in glacial valleys are very common in the region as they form fjords during material transport (Harland, et al., 1997; Choudhary, et al., 2020). Wijdefjorden in northern Svalbard is about 110 km long which makes it the longest fjord in the region (Allaart, 2020).

Svalbard and its surroundings generally have an Arctic climate with long and cold winters along with intense snow falls. The annual average temperature in the region is calculated as -6.9°C which could create suitable conditions to host human population to live (Denstadli, et al., 2014; Hanssen-Bauer, et al., 2019). According to 2021 census data, 2459 people live in the region (Statistics Norway, 2021).

General Geology

Svalbard spreads between 74° - 81° North latitudes and 10° - 35° East longitudes. The region has a tremendously diverse geological history dating back to a very long time. Figure 2 shows the geological map of Svalbard that adapted from the map produced by the Norwegian Polar Institute (NPI).

The Barent shelf is located in the northwest of Svalbard. The rise of the shelf, after Devonian, has led to the formation of archipelagos (Johnsen, 2001). In addition, the 400-million-year-old Caledonian mountain range caused the formation of different rock complexes (Dallmann, et al., 2007; Holtedahl, 1926).

The Svalbard region consists of five important geological sequences. The first is the Hecla Hoek Complex, which consists of Precambrian to Early Silurian metamorphic rocks. These rocks crop out in the northeastern part of Spitsbergen along the west coast and at Nordaustlandet and are the basement (Old Red base). Second, the Devonian Grabens in Northern Spitsbergen are cover rocks. The third is the central basin in the central part of Spitsbergen. This basin covers the center with a distinctive syncline feature and is bounded by the West Spitsbergen fold and thrust belt. The fourth event is the platform areas in the eastern parts of Spitsbergen and in Barents Island and Edge Island. Tertiary fold belt which outcrop on the west coast of Spitsbergen can be considered as the last stage of geological processes in the region (Johnsen, 2001).

The Caledonian Orogeny, which includes faulting, folding, thrusting and metamorphism of Precambrian to Middle Ordovician deposits and magmatic complexes, is very intense and formed the basis of Hecla Hoek. The Hecla Hoek succession consists of Proterozoic and older Paleozoic deposits and was strongly faulted and metamorphosed during the during Caledonian orogeny. The succession is composed of partially garnet, quartzite and less frequently marble schists intercalated. It is followed by quartzite and dolomites, followed by a thick conglomerate or dolomite-limestone series containing tillite, oolite and collenia. Fossils of brachiopods, gastropods and cephalopods identified in the Hornsund region and Paleozoic sequence of the Hecla Hoek series indicate that the sequence is approximately 4500 m thick (Winsnes, 1962; Johnsen, 2001).
The region is mainly composed of igneous and metamorphic rocks of Devonian age formed by the Caledonian Orogeny. Rb-Sr and K-Ar dating also revealed Precambrian aged rocks (Ohta, 1992; Jørgensen, 2021; Burzynski, et al., 2018). Additionally, metamorphic rocks consisted of eclogites and blue schists are described in the region (Labrousse, 2008; Burzynski, et al., 2018).

The sedimentary rocks in the region consists of large-sized sand, gravel and mudstones dating from the Devonian period. The Old Red Sandstones, consisting of conglomerates, sandstones and shales, form the Devonian beds. They contain Caledonian folding and metamorphism, as well as fish and plant fossils. Because of these primitive fish fossils, the period is called 'The Age of Fishes' (Gjelsvik, 1986).

Due to the influence of the Ellesmerian Orogeny, outcrops consisting of quartzites with carbonate-rich laminae and garnet metapelites containing kyanite are observed in the Prince Karls Fornland region. Age determination from garnet metapilites, revealed Late Devonian-Turnesian time period (Majka and Kośmińska, 2017; Burzynski, et al., 2018). In addition, the Old-Red Sandstones after the Caledonian, which were faulted and folded in the Late Devonian, also support the Ellesmerian Orogeny (Majka and Kośmińska, 2017). During the Middle Carboniferous period, evaporites and carbonates were deposited with tectonic movements on land and in shallow marine environments. In the same period, new river systems formed.

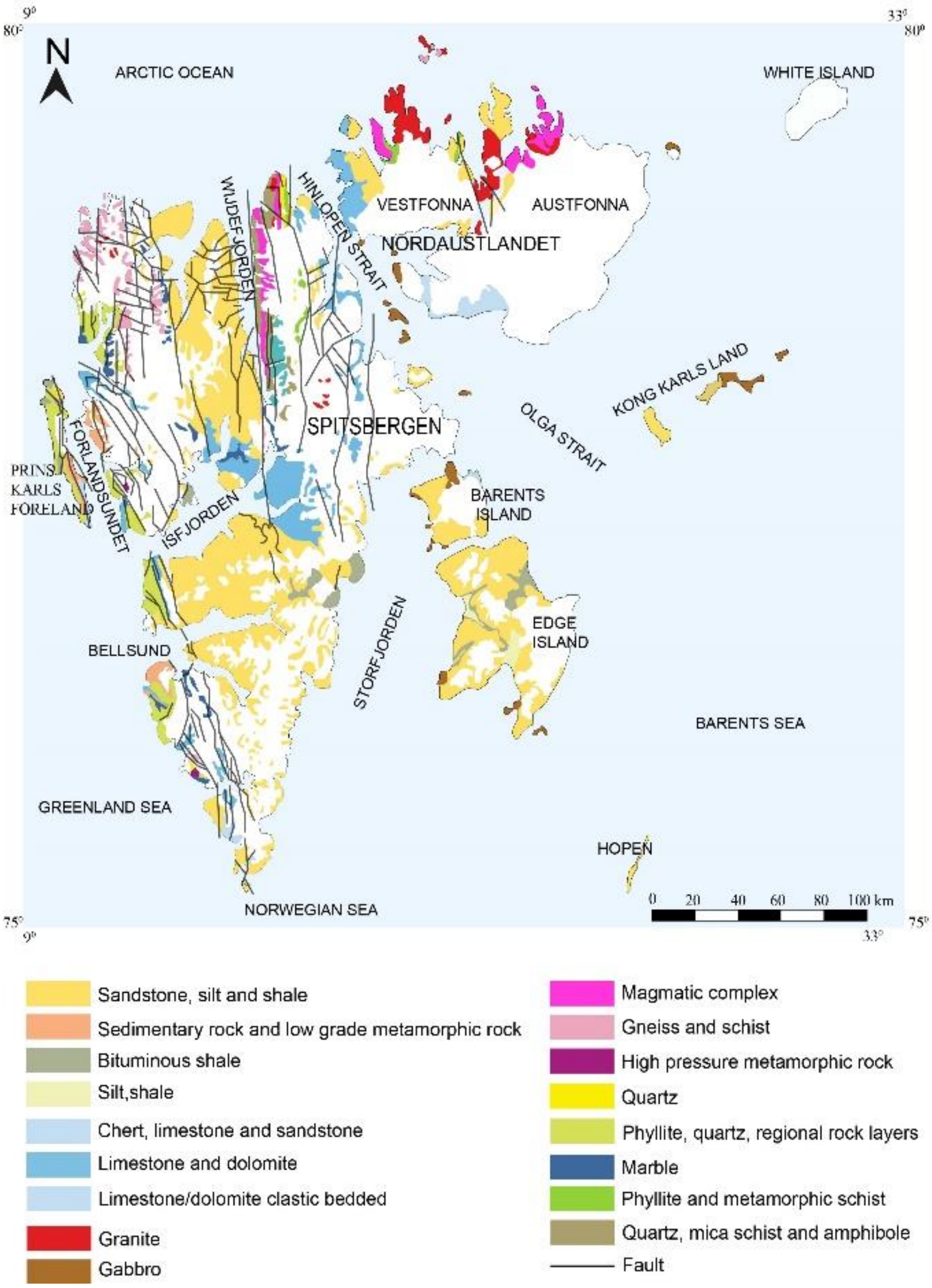

Fig. 2. Svalbard geological map.

Accordingly, accumulation and deposition occurred in delta deposits, evaporites, carbonates, and red alluvial fan deltas. As a result of the periodic flooding of the region, it became rich in organic matter and coal seams from the Tertiary period were identified (Friend, 1961; Piepjohn and Dallmann, 2014; Dallmann, et al., 2007; Gjelsvik, 1986).

Between the Cretaceous and Tertiary, Svalbard collided with Greenland, causing folds in the western part of Svalbard and a depression basin in the eastern part where sedimentation took place. As plate pressure began to decrease in the second part of the Tertiary, Svalbard was exposed to intense faulting and volcanism. The Eurekan deformation represents the formation of different systems of regional fold and thrust belts, different thrust zones and strike-slip fault zones (Piepjohn, et al., 2015). The structures in the Svalbard region are Cenozoic in age and Eurekan deformation is observed in the Northern Greenland and Queen Elizabeth Islands region (Piepjohn, et al., 2015; 2016).

Unconsolidated deposits of Quarternary age are observed, generally as moraines, fluvial deposits and coastal deposits. Active volcanism is still observed in the northwest of the region where these sediments are located. During the first decade of the 20th century, glaciation increased significantly by through the Little Ice Age (Goncharov, et al., 2015; Cianfarra and Salvini, 2013; Dallmann, et al., 2007).

Geological Research Infrastructure

Scientists conduct their research at scientific research stations, science camps, scientific research ships, universities etc. at temporary infrastructures of various countries in the Svalbard Region (Svalbard Science Forum, 2021; Norwegian Polar Institute, 2021). Research stations where scientific studies are carried out are located in Ny-Ålesund, Pyramiden and Longyearbyen regions on Spitsbergen Island. Infrastructure services such as electricity, water, food facilities, accommodation, air and sea transportation to Ny-Alesund stations are provided by the Kings Bay company (Bryhn, 2016). Researchers from twenty different countries can carry out their studies at the scientific research stations of 12 countries in the region. Figure 3 shows these stations' locations with the names of operating countries. While there are 150-180 scientist in the region in June and August, this number drops down to 40-60 people in the spring and winter months (INTER-ACT, 2017).

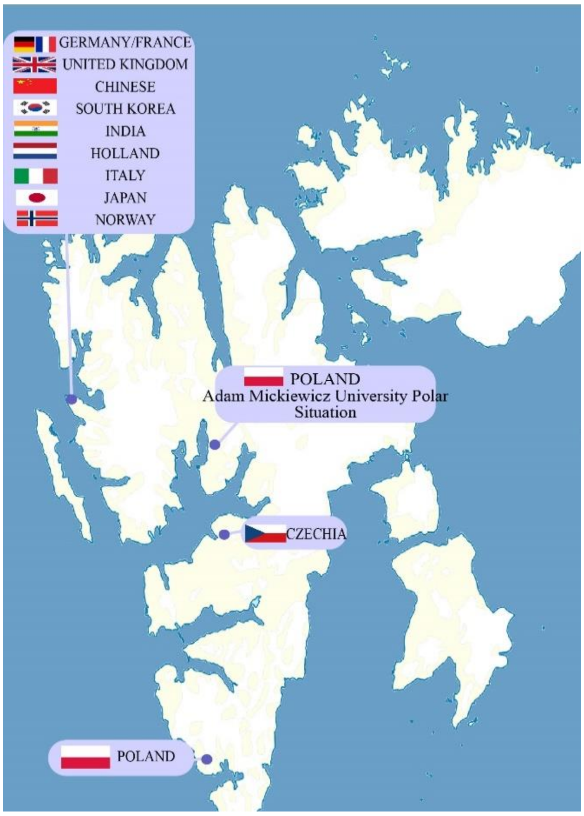

Fig. 3. Research Stations in Svalbard Archipelago.

Scientific Research Stations

List of scientific research stations belonging to 12 different countries in the Svalbard Region are listed below and Figure 4 shows the chronological list of the scientific research stations that established in Spitsbergen.

- AWIPEV Arctic Research Station,
- CNR Arctic Station "Dirigibile Italia",
- Ny-Alesund Research Station- NPI Sverdrup,
- UK Arctic Research Station,
- Netherland's Arctic Station,
- AMUPS Perunabukta,
- Czech Arctic Research Station,
- Hornsund Poland Station,
- South Korea Dasan,
- Japan National Institute of Polar Studies,
- India Himadri
- China Yellow River Station

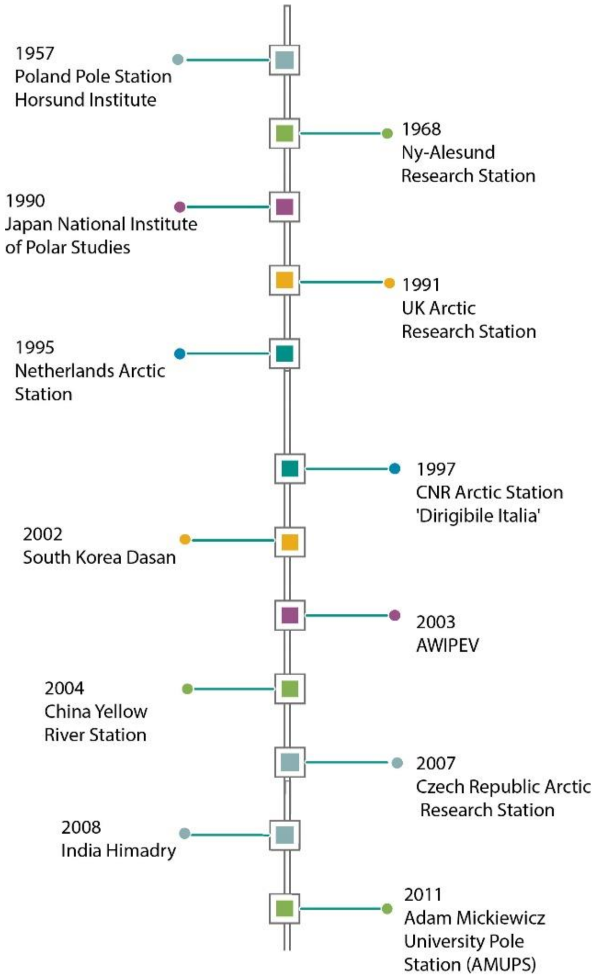

Fig. 3. Time sequence of stations.

The AWIPEV scientific research station in the partnership of Germany / France has been operating in Ny-Ålesun since 2003. Marine, land and glacial science and permafrost are studying in terms of geology at the station. There is no permanent activity at the station (Stolpmann, et al., 2021; Wunder, et al., 2021; Schlager, et al., 2021).

CNR Arctic Station named 'Dirigibile Italia', which belongs to Italy, has been carrying out various studies in the Ny-Ålesund region since 1997. In terms of geology, permafrost, biogeochemistry, remote sensing and climate issues are focused at the station in terms of geology. (Doveri et al.; Cianfarra, Salvini, 2016).
Norwegian station, "Ny-Ålesund Research Station – NPI Sverdrup" since 1968, marine, land and glacial science and environmental observation of the region have been carried out as geological studies in Ny-Ålesund (INTERACT, 2020).

The UK-owned Arctic Research Station has been located in the Ny-Ålesund region since 1991. The geological topics at the station are geomorphology, hydrology and glacial/periglacial studies (Arctic Office, 2021).

The Netherlands' Arctic Station has been located in Ny-Ålesund since 1995. They mostly work on the food chain, the harm of herbivores-predators to the environment, social and humanity sciences (INTERACT, 2020).

Polar Station of Adam Mickiewicz University (AMUPS) "Petuniabukta", which belongs to Poland, has been operating in the Pyramiden region since 2011. In terms of geology, it deals with permafrost, ice science, hydrology, geomorphology and geochemistry (Bednorz and Kolendowicz, 2010; Dragon and Marciniak, 2010; Gibas, et al., 2005).
Another Polish Polar Station has been operated by the Hornsund Institute since 1957 and is located in the Hornsund region to the southern side of the island of Spitsbergen. As geology; glacial science, geophysical monitoring, permofrost, geomorphology, geomagnetism, marine and land geophysics are studied (Hornsund Polska Stacja Polaarna, 2014).

Czech Republic's Arctic Research Station has been located in the Longyearbyen region since 2007. Geology study topics include geomorphology, hydrology, interdisciplinary bioclimatology and ecology (Centre for Polar Ecology, 2013).

Consisting of archipelagos, Svalbard has made a great contribution to the literature in numerous geological studies carried out so far. In general, glacial science, marine geology, geomorphology, microbial ecology, permafrost, biogeochemistry and geochemistry are the main scientific areas (INTERACT, 2020; Ny-Alesund Science Managers Committee).

Science Town: Ny-Ålesund

Ny-Ålesund, considered to be the northernmost science town in the world, is a settlement built entirely for scientific purposes. Ny-Ålesund was primarily a coal mining town from 1916 to 1962. After 1962, coal-mining activities almost ended and the region turned into a research center. Infrastructure in the region is provided by Kings Bay Company and active scientific studies continue. 25% of research activities in the Svalbard archipelago are conducted here (Ny-Ålesund Research Station, 2019).

Ny-Ålesund is a radio silent area with a long-term goal to further reduce emissions of electromagnetic pollution. Some important sensing devices, such as the VLBI radio telescopes at Norway's geodetic laboratory, need radio silence to function optimally. For this reason, an application must be made to the National Communications Authority for the technology used between 2 GHz-32 GHz frequencies within a radius of 20 km from Ny-Ålesund (Ny-Ålesund Research Station, 2019).

Furthermore, there are laboratories open to common sharing in the region. These are: marine laboratory, Airship observatory, climate change tower, Vaskeri laboratory, MS Teisten (scientific research vessel), terrestrial laboratory (Veksthuset) and photosensitive cabin. Geology, marine geology and biogeochemistry are also studied in the laboratories.

UNIS: The University

Svalbard University Center (UNIS), located in Longyearbyen, opened in 2006. Next to the 12,000 m^2 center there is also the Svalbard Museum, the Norwegian Polar Institute's Svalbard office, the SIOS (Svalbard Integrated Arctic Earth Observation System) and the Svalbard Science Forum. Svalbard University Center provides undergraduate and postgraduate education. According to UNIS 2021, the center conducts studies in the fields of Arctic Biology, Arctic Geology, Arctic Geophysics and Arctic Technology with additional various course opportunities.

According to UNIS 2021 data 50% Norwegian and 50% international staff work at the university center. Currently, 48 professors, 15 associate professors and nearly 160 guest lecturers are actively working on Arctic subjects. In addition, according to 2019 data, nearly 750 students from 43 countries participated in the courses at the center.

Geological research at the center is divided into three main branches: Arctic Basins, Quaternary and Cryosphere. The rich geological history of the Svalbard region makes it possible to study many diverse subjects. For instance, geology, structural geology, geomorphology, sedimentology, geochemistry and geobiochemistry to name a few. In addition, the location of the center provides unique opportunities to monitor to global climate change. Researches on marine and terrestrial current sediments also provide opportunities for issues such as sea level, glaciation and climate. There is also the opportunity to work in oil exploration fields in the region (Kalinowska, et al., 2020; Hodson, et al., 2020; Marchenko, 2014).

Geological Science Strategies

Svalbard, the northernmost piece of land in the Arctic Ocean, where the most scientific studies are carried out, even the science town is located, is an important region in terms of geology. Consisting of archipelagos, Svalbard came under the sovereignty of Norway with the Treaty of Svalbard signed on February 9, 1920, and opened the door to scientific research to other countries. The region is open to studies in almost all fields, especially mining in terms of geology.
Strategy is the policies determined in line with the main objectives (Sağbansua and Biskek, 2006). As Sun Tzu states in his book The Art of War, mentioned that a person could achieve success with good strategy and different policies. These policies include geopolitical, tourism, industrial, environmental, technological and scientific studies (Pedersen, 2021). The Polar Regions are important for the strategic ambitions of many

different countries. In this direction, various studies and collaborations, especially scientific research, are carried out by the member states of the Arctic Council in the North Pole region and the Antarctic Treaty in the South Pole Region (Arctic Council; Antarctic Treaty). States such as the USA and Russia, which are important powers, recently have been making strategic plans in this region (Shubin, 2020; Calik, 2021). Ostreng, in his 2010 study, summarized the six most important geopolitical features of the AR as the location of the AR, its role in global climate change, sea routes, industrial resources, ecosystem and compliance with international conventions. In addition, new sea routes opened as a result of melting sea ice under the effects of global climate change increase the geopolitical importance of the AR (Squire and Dodds, 2020; Canturk and Atvur, 2021). Apart from military and political strategies, scientific studies also have an important place for the Arctic (IASC, 2018).

There are many institutions, organizations and communities in the AR that are interested in scientific polar research and planning long-term strategies. According to data retrieved from Arctic Portal, some of these were the Arctic Council, APECS (Society of polar early career scientists), the Arctic Energy Summit, Edu-Arctic (Arctic research of STEM education to include students through), IASC (International Arctic Science Council) inter-act (International Arctic Terrestrial research and monitoring network), ARTICLE (Svalbard Integrated Arctic Earth Observing System), UNIS (University Centre in Svalbard) and the UArctic (University of the Arctic).

The European Union (EU) operates research especially in the AR in terms of studying global climate change. Considering the geological plans of the EU, it has a detailed investigation of the permafrost event and its environmental degradation. Geospatial analyzes are carried out with the EU Satellite Center (SatCen). In line with these analyzes, data on subjects such as environment, weather, ice, biology and maritime can be obtained. In addition to these issues, thanks to the Copernicus Emergency Management Service of the EU, it provides early warning and mapping opportunities by detecting disasters in the region beforehand. The EU is currently engaged in mining activities in the AR. In addition, it supports policies for the safe use, recycling, disposal and recovery of raw materials from mining and operational wastes and other secondary sources (European Commission, 2021).

Turkey, on the other hand, carried out the first National Arctic Scientific Expedition (TASE-I), which started in the Svalbard Region in 2019 and extended to 81° North latitude in the Arctic Ocean, under the coordination of Istanbul Technical University Polar Research Center. During the expedition, 15 different projects were completed, from marine sciences, atmospheric studies to social sciences and environmental sciences. As part of the expedition, scientific research stations of countries such as Norway, South Korea, Poland, and India were visited, and it was also aimed to develop bilateral cooperation in scientific terms for the future field operations (Bilim Teknik, 2019).

Fig. 4. Arctic Council member states and observers.

Arctic Council

The Arctic Council consists of Arctic states, permanent participants, observers and working groups (Arctic Portal, 2021). Eight states bordering the Arctic Ocean: Canada, the Kingdom of Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden and the United States. In addition to these states, there are 13 countries in observer status: Germany, United Kingdom, Netherlands, Poland, France, Spain, China, South Korea, India, Italy, Japan, Singapore, Switzerland (Arctic Council, 2021). Both Arctic States and observers showed in Figure 5. According to the

2021-2030 Arctic Council Strategic plan, it is aimed to be united as a global power for the Arctic climate, to reduce greenhouse gases and pollutants (Arctic Council Strategic Plan 2021-2030, 2021). In this direction, they planned to prevent global climate change by reducing the amount of emissions. In addition, it maintains the current status of Arctic ecosystems and promotes the conservation of biodiversity in a sustainable way. It enables cooperation to prevent marine pollution by protecting the Arctic Ocean and its environment (Arctic Council, 2021).

Its six permanent members are: Arctic Athabaskan Council, Aleutian International Union, Greenwich International Council, Inuit Environmental Council, North Russian Arctic Indigenous Peoples and Saami Council. There are also observers: non-Arctic states, intergovernmental and inter-parliamentary organizations. Working groups of the Arctic Council: Arctic Pollutants Action Programme, Arctic Monitoring and Evaluation Program, Conservation of Arctic Flora and Fauna, Emergency Prevention – Preparedness – Combat, Arctic Marine Environment Protection and Sustainable Development Working Group. These working groups also study topics such as interdisciplinary geobiology, pollution sources and climate change (Arctic Council, 2021).

Since the region is rich in energy resources, geological activities are also carried out in the council countries under the name of the energy sector. Among these activities, mining activities are at the forefront. With the extraction of various metals, oil exploration studies are carried out in the ocean and on land (Kurt, 2021; Stauffer, 2009). The amount of oil is 1732,4 thousand barrels in the world in 2020 (Bp, 2021). According to studies, 41% of the oil resources in the AR belong to Russia, 28% to Alaska, 18% to Greenland, 9% to Canada and 4% to Norway (Lindholt and Glomsrød, 2011). The potential of the region is also high in terms of renewable energy sources. Moreover, hydroelectric and geothermal energy enables geological studies (Energy Portlet).

International Arctic Science Council (IASC)

The International Arctic Science Council (IASC) was established in 1990 by representatives of eight Arctic countries. It has regularly taken its place as an international science organization in the AR. Today, it conducts research in the AR with at least 23 countries (The International Arctic Science Committee, 2015). It includes research in many different branches of science that has the potential to be done in the AR. The main themes of these researches in scientific studies were brought together under five headings: Atmosphere, cryosphere, marine, terrestrial and social-humanity. It has been observed that many geological surveys have been carried out in the study groups under these five headings. From a geological perspective, the marine studies focus on the understanding of geochemical processes in the Arctic Ocean and Sub-arctic Seas, and the development and improvement of access to the paleo record of the Arctic Ocean through scientific drilling technique. When looking at terrestrial studies, those following are studied; examining the current state of Arctic terrestrial geosystems and ecosystems at multiple spatial scales, investigating past changes in Arctic geobiological diversity, measuring current change and predicting future changes, using high spatial resolution models of terrestrial geosystem and ecosystem change and adaptation strategies and naturalization strategies by Arctic stakeholders. The development of other tools that can be used for the sustainable management of resources and ecosystem services, and the study of the functioning of Arctic terrestrial systems, including the connections within the Arctic-global system, are discussed in geological perspective. In addition, interdisciplinary studies are being conducted on how the decreasing ice cover will affect the carbon cycle in the Arctic and what are the consequences it might cause, and how changes in the hydrological cycle will affect various components of the Arctic system (IASC, 2021). Also, the IASC is dedicated to scientists, young career researchers, technicians, etc. for the Arctic climate system. It provides a communication network among science stakeholders. A MOSAiC (Multidisciplinary Observatory for the Study of Arctic Climate) training program established for young researchers, providing extensive environmental research opportunities in many branches of science and especially in geology (IASC, 2021).

Norway

The NPI, founded on March 7, 1928, is now an institution under the Ministry of Climate and Environment. Its main research area is both Arctic and Antarctic Regions. The institute conducts research on biodiversity, geological mapping, climate, pollutants, etc. especially for Arctic. With the Svalbard Treaty, especially geological and topographical researches in and around Svalbard gained importance (Norwegian Polar Institute, 2021). At its stations located in Svalbard in the North, geological mapping, glacial science, atmospheric science, marine geology and bedrock geology were studied in particular. The institute continuous its geological research projects (NPI, 2021).

The Treaty of Svalbard was signed in Paris on February 9, 1920, between the countries; Norway, the United States, Denmark, France, Italy, Japan, the Netherlands, Great Britain, Ireland, and the British Overseas Dominions and Sweden. According to Article 1 of the Treaty, Bear Island and North Spitsbergen Island, Northeast Land Island, Barents Island, Edge Island, Wiche Islands, Hope Island and Prince Charles Foreland Island along with other smaller islands in the Spitsbergen Archipelago are under the sovereignty of Norway. In line with the framework of the treaty, scientific studies are carried out on these islands within the rules determined by various institutions of Norway.

The Norwegian Research Council is the funding agency for scientific research, was established in 1993 (The Research Council of Norway, 2021). The Svalbard Integrated Arctic Earth Observation System

(SIOS) was launched in 2008 to establish the SIOS Information Center funded by the Norwegian Research Council. The SIOS Remote Sensing Service (RSS) provides researchers with satellite data for Svalbard. This opportunity provides a great contribution to geology. It provides the opportunity to work remotely on topics such as geological mapping, oil exploration, geochemical factors (Svalbard Integrated Arctic Earth Observing System, 2021).

The Svalbard Science Forum (SSF), coordinated by the Norwegian Research Council, organizes research activities in the Svalbard region, providing cooperation between both institutions and researchers (Svalbard Science Forum, 2021). The Svalbard Strategic Grant (SSG) program runs workshop funded by the Norwegian Research Council (RCN) and affiliated with the SSF. Scientific studies are actively supported by these platforms at stations located in Ny-Ålesund, Hornsund, Longyearbyen and Barentsburg. In terms of geology, glaciology, seismology, environment etc. topics are main working themes. It has also been being operating in Barentsburg since 1962 with the Polar Marine Geological Survey Expedition (PMGRE) (Svalbard Science Forum, 2021).

The Svalbard Research Database (RIS) is an international platform by Norway for building research infrastructures in Svalbard. It allows researchers to work interdisciplinary and encourages the study of geology subjects with other disciplines (Research in Svalbard Database, 2021).

Suggestions and Outcomes

The aim of the presented study here is to review geological studies, scientific infrastructures and the interest of various international organizations, which have been studied in Svalbard since the 1900s. It is important that Turkey should take a leading role, particularly in scientific research including and prioritizing earth sciences in the Svalbard archipelago by developing bilateral cooperation with Norway within the scope of polar research studies. Some suggestions within the context are presented below:

- To develop and applicate the National Polar Science Program in AR, especially the geological research in Svalbard should be added.
- Focusing on underrepresented research areas of Svalbard that Turkey will carry out in the AR,
- Encouraging the participation of Turkish scientists and university students to educational programs in the Svalbard Region.
- Establishing bilateral cooperation with the countries of the region in order to take part in new studies that can be completed in the AR, since the increasing glacier meltdowns provide opportunities to access to unexplored regions.
- Facilitating scientific research and access to the region for Turkish researchers by ensuring that Turkey becomes a party to the Svalbard Treaty.
- Creating a scientific memory about the region by conducting scientific studies at points of geopolitical importance, as countries are eyeing the polar regions due to the increasing energy needs and decreasing natural resources in the world.
- Polar Research Institute in Turkey should develop close relations with other institute such as NPI to work bilateral projects on the island.

Conclusion

AR; Its role in global climate change, newly opened maritime sea routes, unexploited industrial resources, unique polar ecosystem and international geopolitical balance is a strategic area that attracts the attention of many countries. Especially countries such as America, Russia and England are making significant investments to this region. In this direction, especially in the AR, the Arctic Council carries out various studies and international cooperation, particularly interdisciplinary scientific research. Apart from the council, many institutions, organizations and societies also come to the AR to conduct scientific studies. When these studies are examined from a geological point of view, it is seen that they are classified as glacial science, marine geology, geomorphology, microbial ecology, permafrost, biogeochemistry and geochemistry.

As sum up from the geological view of Svalbard showed that the archipelago was formed by the combination of different rock complexes under the influence of the 400-million-year-old Caledonian mountain range. The main rock of the region was formed by the alteration of the mountains formed by the Caledonian Orogeny and Devonian aged magmatic and metamorphic rocks. Its sedimentary structure consists of coarse sand, pebbles and mudstones from the Devonian period. Quaternary aged unconsolidated sediments, moraines, fluvial deposits and coastal deposits are also observed. Active volcanism are still monitored in the northwestern part of Svalbard, where glaciers are located.

In line with the geological importance of Svalbard, many institutions present scientific infrastructures such as educational studies, science strategies, international projects. Svalbard University Center (UNIS), educational institutions like many universities of northern countries, accepts students and researchers from different countries and makes a great contribution to the geological research of Svalbard. Educational institutions accept students and researchers from different countries and contribute greatly to the geological research of Svalbard. In addition, important organizations such as the Arctic Council also provide many different funds for these scientific studies.

The geological structure, geological infrastructure and science strategy of geological researches of the Svalbard Region are presented here. It is vital that

Turkey should join geological studies for the future researches in the archipelago with bilateral collaborations.

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Research Article

Presence of some commonly used pharmaceutical residues in seawater and net plankton: A case study of Spitsbergen, Svalbard Archipelago

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Abstract

The occurrence of eleven pharmaceutical compounds in the surface seawater and plankton samples from Spitsbergen, Svalbard Archipelago, were investigated. The target compounds included diclofenac, fenoprofen, ketoprofen, ibuprofen, naproxen, carbamazepine, clofibric acid, gemfibrozil, estrone, 17β-estradiol, and 17α-ethynylestradiol, which are among the most widely used pharmaceuticals in the world. The water samples were extracted by liquid-liquid extractions, which were followed by solid-phase extractions (SPE). Ultrasonic extractions were used for the plankton samples, and a clean-up process was then carried out using the SPE method. The quantifications of the pharmaceutical compounds were obtained by using high-performance liquid chromatography (HPLC–DAD). The highest concentrations (2.17 µg L^{-1}) that were measured in seawater were for gemfibrozil. 17α-ethynylestradiol and fenoprofen were the most abundant pharmaceuticals that were detected in the seawater samples. All of the studied compounds were detected in the plankton samples. The concentrations of ibuprofen (4543 ng g^{-1}), 17β-estradiol (3338 ng g^{-1}), 17α-ethynylestradiol (3262 ng g^{-1}), and gemfibrozil (6940 ng g^{-1}) were high in the plankton samples. Pharmaceutical compounds have been identified in the Arctic region due to the inadequate or incomplete wastewater treatment facilities in this region, which exhibit reduced biodegradation levels at low temperatures and prolonged half-life for the compounds in the receiving environments at low temperatures.

Keywords: Pharmaceutical residues, seawater, plankton, Arctic

Introduction

The presence of pharmaceutical compounds and their residues in water bodies have received much attention in recent years, as these compounds can produce adverse effects on aquatic organisms and ecosystems (Brausch and Rand, 2011; Claessens, et al., 2013; Fent et al., 2006; Kümmerer, 2009; Lonappan, et al., 2016). Pharmaceuticals are emerging contaminants that enter aquatic environments from many different sources. The main source of this type of pollution is attributed to the effluents from wastewater treatment plants (WWTPs), in which pharmaceuticals cannot be completely treated et al., 2014). For example, the maximum removal rates of diclofenac and ibuprofen from WWTPs were reported to be 75% and >70%, respectively (Almeida, et al., 2020; Bueno et al., 2012). Additionally, the removal rate of carbamazepine (<45%) on WWTPs is very low (Clara, et al., 004). Other pollution sources also include domestic wastes, industrial effluents, landfills, livestock and agricultural activities (Archer, et al., 2017; Gaw, et al., 2014). The pharmaceutical compounds that reach aquatic environments can undergo various processes, such as photodegradation, biodegradation, diffusion, dilution, evaporation and adsorption in sediments (Anekwe, et al., 2017; Baena-Nogueras, et al., 2017; Liu and Wong, 2013). These processes are mostly dependent on the pH, temperature, solar radiation intensity, eutrophic conditions in water and the organic matter structure in sediments (Anekwe et al., 2017; Baena-Nogueras et al., 2017; Emídio, Calisto, et al., 2017; Jin et al., 2017; Koumaki et al., 2015).

Pharmaceutical compounds are present in surface water, freshwater, groundwater, drinking water, wastewater, and marine water bodies with concentrations that range from ng L^{-1} to mg L^{-1} (Brausch, et al., 2018; Runnalls, et al., 2010). Although pharmaceutical compounds have been detected in seawater (marine and coastal areas) with a broad range of concentrations that is similar to that detected in freshwater systems, there are fewer studies on the presence of pharmaceutical compounds in marine ecosystems (Álvarez-Muñoz et al., 2015; Alygizakis et al., 2016; Arpin-Pont, et al., 2016; Ebele, Abou-Elwafa Abdallah, and Harrad, 2017; Gaw et al., 2014; Mezzelani et al., 2018). The detection of pharmaceuticals in water bodies has great importance for determining the effects of these compounds on both aquatic organisms and ecosystems.

Table 1. Therapeutic groups, compound names, log K_{ow} values and solubilities for all studied pharmaceutical compounds (Aydin and Talinli, 2013; Kim and Tanaka, 2009; NCBI, 2020; Patel et al., 2013; Scheytt et al., 2005; Westerhoff et al., 2005)

Therapeutic groups	Compounds	Molecular formula	Log K_{ow}	Solubility (mg/L)
Nonsteroidal anti-inflammatory drugs (NSAIDs)	Diclofenac	$C_{14}H_{11}Cl_2NO_2$	4.51	2.37
	Fenoprofen	$C_{15}H_{14}O_3$	3.1	slightly
	Ibuprofen	$C_{13}H_{18}O_2$	4	21
	Ketoprofen	$C_{16}H_{14}O_3$	3.12	51
	Naproxen	$C_{14}H_{14}O_3$	3.18	15.9
Hormones (natural and synthetic)	Estrone	$C_{16}H_{22}O_2$	3.13	12.42
	17β-estradiol	$C_{18}H_{24}O_2$	4.01	3.9
	17α-ethynylestradiol	$C_{20}H_{24}O_2$	3.67	11.3
Antilipidemic agent	Clofibric acid	$C_{10}H_{11}ClO_3$	2.84	582.5
	Gemfibrozil	$C_{15}H_{22}O_3$	4.77	11
Antiepileptic	Carbamazepine	$C_{15}H_{12}N_2O$	2.77	17.66

The Arctic is considering to be a pollution-free zone, as it is located in the northernmost region of the world. However, several studies have verified the presence of anthropogenic pollutants (e.g., polyaromatic hydrocarbons and pharmaceuticals) in this remote environment (Butt, et al., 2010; Wang et al., 2015; Zhu et al., 2015). Several recent studies have shown that the occurrence of these organic pollutants in this region occurs especially due to sea currents or due to pollutant transport via the atmosphere (Choi, et al., 2020). However, the source of the pharmaceutical contaminants that are detected in Arctic environments has been shown to be directly related to human activities in this area. Little is known about the presence of pharmaceutical compounds in the Arctic region (Kallenborn, et al., 2018). Therefore, this study will provide data on the levels of pharmaceutical compounds in the seawater of Spitsbergen, Svalbard.

The aims of this study were:

i. to determine the levels of different types of pharmaceuticals, including antiepileptic drugs, nonsteroidal anti-inflammatory drugs, hormones, and antilipidemic agents, in surface seawater at several stations in the Spitsbergen, Svalbard,
ii. to identify the presence of the selected pharmaceuticals in plankton samples (net plankton suspended solids). Eleven types of pharmaceuticals (e.g., carbamazepine, naproxen, fenoprofen, ibuprofen, ketoprofen, diclofenac, 17α-ethynylestradiol, estrone, 17β-estradiol, gemfibrozil, and clofibric acid) were analyzed in this study. These compounds were selected based on their common use worldwide, their frequent detection in water bodies (wastewater, freshwater, groundwater, and seawater), and their toxicological effects on marine organisms. Furthermore, the hormones were chosen according to their existence on the European Union's watch list (EC, 2018). The physicochemical characteristics of the target compounds are presented in Table 1.

Materials and Methods

Chemicals

HPLC-grade acetonitrile (≥99.9%), methanol (99.5%), dichloromethane (99.8%), chloroform (99.4%) and sulfuric acid (98%) were purchased from Merck (Darmstadt, Germany). Potassium dihydrogen phosphate was purchased from Fluka (Steinheim, Germany). The SPE cartridges [Cleanert PEP (500 mg/6 mL)] were supplied by Agela Technologies (Torrance, USA). The standards for diclofenac, fenoprofen, ibuprofen, naproxen, ketoprofen, clofibric acid, gemfibrozil, carbamazepine, estrone, 17β-estradiol and 17α-ethynylestradiol were purchased from Sigma-Aldrich (purity >95% or higher) (Athens, Greece).

Study Area and sampling

The Arctic Ocean is undergoing rapid change because of the effects of oceanic and atmospheric warming, sea ice losses, and rises in freshwater inputs (Wassmann, and Reigstad, 2011; Onarheim et al., 2014, Polyakov et al., 2017). Svalbard archipelago is located in the Atlantic Arctic that the Arctic Ocean connects to the North Atlantic Ocean via the Barents Sea and the Fram Strait Jones et al., 2021). The Svalbard archipelago has become a very important center for polar scientific research in recent years (Çetin and Büyüksağnak, 2021). Spitsbergen Island is the only permanently populated island in the Svalbard archipelago and is also the largest. Many fjords surround this island, such as Isfjorden, Hornsund and Bellsund. Arctic fjords can be considered to be critical aquatic areas, as they host terrestrial, oceanic, atmospheric, and cryospheric interactions that are especially susceptible to human-induced factors and climate change (Bianchi et al., 2020; Zaborska, et al., 2020). Isfjorden is Svalbard's second longest fjord and is located in the western part of Spitsbergen. The three largest settlements on Svalbard are located around the Isfjorden fjord: Longyearbyen, Barentsburg, and Pyramiden. Another fjord is Hornsund, which is located on the southern side of Spitsbergen Island. Hornsund is affected by warm waters of Atlantic origin that are carried along the shelf by the western Spitsbergen Current (Walczowski and Piechura, 2006). Additionally, cold Arctic water enters the fjord along with the eastern Spitsbergen current. The melting of glaciers, inputs from rivers, and precipitation are the sources of Hornsund's freshwater (Błaszczyk et al., 2019). Additionally, although it is categorized as a fjord, Bellsund is actually a sound, which is wider than a fjord, and is located on the west coast of Spitsbergen.

Svalbard's climate is mainly a conclusion of its latitude (74° and 81° north). The North Atlantic Current causes the temperatures of Spitsbergen to be moderate, especially during the winter months (Jónsdóttir, 2005). Average temperatures in Svalbard in 2019 were -9.1 ºC in winter and 6.5 ºC in summer (MOSJ, 2022). Generally, precipitation is low on the west coast of Spitsbergen (200-400 mm/year). However, the precipitation rates have increased by 20-30% in this region in recent years (Johansen, et al., 2021). In general, the area around Svalbard is covered with glaciers and has sparse vegetation. Therefore, seasonal erosion occurs in the area, and large amounts of sediment are transported to the receiving coastal zones from June to September (Bogen and Bønsnes, 2003; Forwick et al., 2010).

The seawater and plankton samples were collected from different parts of Spitsbergen in July 2019. Sampling stations are shown on the map in Fig. 1. The sampling stations, sample types, locations, sampling dates, and water temperatures are shown in Table 2. Station 1 was located close to Isfjorden fjord, and station 2 was located in Hornsund fjord. Station 3, which was the sea ice boundary, and also station 4 were located offshore to the north of the Nordvest-Spitsbergen National park. Station 5 was located at Bellsund sound, and station 6 was located offshore to the west of Spitsbergen. Surface water samples were collected from stations 1, 2, 3, and 4 using amber glass bottles. Plankton samples were collected from stations 1, 3, 4, 5 and 6 by using a conical plankton net (mouth opening: 55 cm, mesh size: 60 μm). Each net plankton sampled an area that extended for approximately 2 km during superficial horizontal hauls that lasted for approximately 30 minutes. The plankton sampling process was unaffected by ship oscillations. After the sample collection, 10M HCl was added as a preservative. The water and plankton samples were brought to the laboratory and were filtered through glass fiber filter papers (GF/F, 0.7 μm). After filtration, the suspended solids of the net plankton samples (Pss) were used to analyze the studied pharmaceutical compounds.

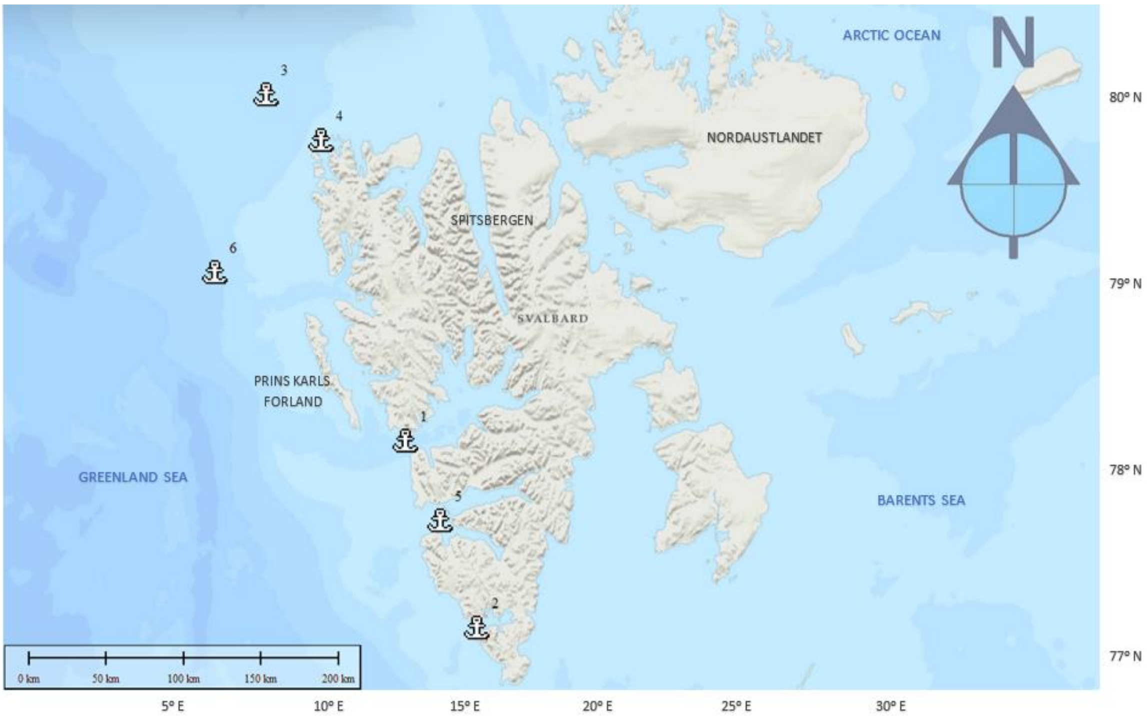

Fig. 1. Locations of sample collection from Svalbard, the Arctic Ocean.

Extraction and purification methods

The seawater samples were extracted using liquid-liquid extractions (100 mL $CH_2Cl_2/CHCl_3$ (1/1, v/v)). Aliquots of the extracts were evaporated to dryness. Before the solid-phase extractions (SPE), the samples were dissolved by adding 2 mL of ultrapure water. SPE was conducted with Cleanert-PEP (500 mg, 6 mL) cartridges that were conditioned with 4 mL of methanol and 4 mL of distilled water. Next, the samples (2 mL) were loaded into the cartridges. The cartridges were washed with 10 mL of deionized water and eluted with 10 mL of methanol and 10 mL of acidic methanol. The final samples were evaporated to dryness, and the volumes were then adjusted to 5 mL with acetonitrile: water (1/1, v/v). The samples were filtered using syringe filters (0.22 μm). The enrichment factor that was obtained for the water samples was 1000.

The Pss samples were lyophilized and homogenized. The ultrasonic extraction method proposed by Xie et al. was modified and used (Xie et al., 2019). Acetonitrile (10 mL) was added to the samples (average weights were 2.27 g), and ultrasonic extraction was applied for 30 min. The samples were then kept in the dark for 24 hours and then decanted. Then, 10 mL of acetonitrile: water (8/2, v/v) was added to the solid part of the decanted samples, and ultrasonic extraction was applied for 30 min. Next, the samples were kept in the dark for 24 hours, decanted and mixed with the first decanted solution. The final volumes were adjusted to 10 mL with acetonitrile: water (8/2, v/v) after the solutions were evaporated using a rotary evaporator. SPE was applied for clean-up, and the applied SPE method was the same as that applied for the water samples.

Table 2. Sampling stations, sample types, locations, sampling dates, and water temperatures.

Station	Sample Type	Latitude (N)	Longitude (E)	Date	Water temperature (°C)
1	Surface water (S1) Net plankton suspended solids (Pss1)	78.108392°	13.71174°	14/07/2019	6
2	Surface water (S2)	76.998966°	15.571538°	15/07/2019	6
3	Surface water (S3) Net plankton suspended solids (Pss3)	80.173637°	9.701489°	20/07/2019	2
4	Surface water (S4) Net plankton suspended solids (Pss4)	79.849206°	10.954807°	20/07/2019	8
5	Net plankton suspended solids (Pss5)	77.632017°	14.48217°	15/07/2019	6
6	Net plankton suspended solids (Pss6)	79.091125°	7.752208°	23/07/2019	2

Instrumental analysis of the target compounds

Ten microliters of each sample were analyzed using HPLC (DAD detector). The separations were performed with a C18 column (250 × 4.6 mm, 5 µm). Acetonitrile and 25 mM potassium dihydrogen phosphate were used as the mobile phases. The flow rate was set to 1.2 mL min^{-1}. The gradient elution that was used by Camacho-Muñoz et al. was also used in this study (Camacho-Muñoz, et al., 2009). The wavelengths ranged from 220 to 300 nm (Camacho-Muñoz et al., 2009; Debska, et al., 2005). Pharmaceutical compounds analyzes were performed within 65 min. The recoveries of the pharmaceutical compounds in the seawater and Pss samples varied between 65.7 – 100% and 67.8 – 93.2%, respectively. The detection limits of these compounds in seawater and Pss were 0.009 – 0.156 µg L^{-1} and 20.7 – 235 ng g^{-1}, respectively. Average recoveries, MDL, and MQL of pharmaceutical compounds are shown in Table 3.

Table 3. Average recoveries (R, n=3), MDL, and MQL of the target compounds in water and net plankton samples in the Spitsbergen, Svalbard.

Pharmaceutical compounds	Seawater			Net plankton		
	R±RSD (%)	MDL (µg L^{-1})	MQL (µg L^{-1})	R±RSD (%)	MDL (ng g^{-1})	MQL (ng g^{-1})
Diclofenac	82.2 ± 5.7	0.023	0.077	82.3 ± 3.9	29.2	97.2
Ketoprofen	66.5 ± 5.1	0.031	0.103	70.5 ± 8.7	39.8	133
Fenoprofen	91.3 ± 4.2	0.015	0.050	89.7 ± 7.2	59.1	197
Ibuprofen	97.4 ± 7.1	0.012	0.040	81.2 ± 4.4	20.7	69
Naproxen	66.1 ± 5.9	0.019	0.063	67.8 ± 2.9	21.1	71
17α-ethynylestradiol	100 ± 6.7	0.009	0.030	91.3 ± 4.2	70.5	235
17β-estradiol	98.7 ± 8.6	0.029	0.096	85.1 ± 6.7	40.7	136
Estrone	95.2 ± 8.8	0.043	0.140	93.2 ± 3.7	69.2	230
Clofibric acid	65.7 ± 3.4	0.047	0.156	69.8 ± 3.7	45.5	152
Gemfibrozil	69.5 ± 8.3	0.013	0.043	71.2 ± 8.7	30.1	101
Carbamazepine	90.3 ± 6.8	0.035	0.117	91.4 ± 5.9	25.5	84.9

Results and Discussion

The presence of the selected pharmaceutical compounds in the surface seawater and Pss samples of the Spitsbergen, Svalbard archipelago were investigated in July 2019.

Presence of the target pharmaceutical compounds in seawater

The spatial distributions of the target pharmaceuticals in the seawater of Spitsbergen are shown in Fig. 2.

The concentrations of diclofenac, ketoprofen, naproxen, fenoprofen and ibuprofen in the seawater of Spitsbergen ranged between (<0.023 - 0.44 µg L^{-1}), (<0.031 µg L^{-1}),

(<0.019 - 0.23 μg L^{-1}), (0.23 - 0.60 μg L^{-1}) and (<0.012 - 1.24 μg L^{-1}), respectively. Diclofenac was detected at two of the four stations in the study area. Diclofenac is quickly degraded by photodegradation and biodegradation (Andreozzi, et al., 2003; Baena-Nogueras et al., 2017; Benotti and Brownawell, 2009; Koumaki et al., 2015; Yamamoto et al., 2009). However, this compound was detected at two stations because the low-temperature environmental conditions in the Arctic environment caused reduced microbiological degradation (Green et al., 2008; Gunnarsdóttir, et al., 2013; Huber et al., 2013; Kallenborn et al., 2008; Vasskog, et al., 2008; Vasskog, et al., 2006; S. Weigel et al., 2004; Weigel, et al., 2004). Among the NSAIDs, fenoprofen was detected at all stations in the seawater of Spitsbergen. Fenoprofen can be removed in only low amounts after traditional treatments and is therefore one of the highest persistence pharmaceutical compounds found in wastewater and sediments (Kramer, et al., 2018). As a result, given that wastewater treatments are insufficient or incomplete in most Arctic regions (Gunnarsdóttir et al., 2013), it was a predictable result that fenoprofen was commonly detected in the seawater of the study area. Ibuprofen was detected at high concentrations (1.04 - 1.24 μg L^{-1}) at some stations when compared to other NSAID pharmaceuticals. The half-life of ibuprofen in aquatic environments is 50 days (Buser, et al., 1999). However, due to the low temperatures in the northern environments, the half-life of the compounds in the receiving seawaters were found to be longer than those in middle-latitude regions. In addition, high ibuprofen levels in the receiving environments are expected to result as the biodegradation rate of ibuprofen is decreased due to the low temperatures in northern environments (Kallenborn et al., 2008). The ketoprofen concentrations were below the method detection limit (MDL) at all stations (Fig. 2).

The carbamazepine concentrations in the Spitsbergen seawater ranged between <0.035 and 1.57 μg L^{-1}. Carbamazepine was detected at station 1 (1.57 μg L^{-1}) and station 3 (1.19 μg L^{-1}) (Fig. 2). The detection of high carbamazepine concentrations suggested that this pharmaceutical compound was used by the people living in the area. Carbamazepine is a persistent ($t_{1/2}$ 82 days) pharmaceutical compound in aquatic environments (Lam et al., 2004). Additionally, its detection in offshore areas, such as station 3, proved the persistence of this compound. The clofibric acid and gemfibrozil concentrations in the seawater were in the ranges of <0.047 and 0.94 - 2.17 μg L^{-1}, respectively. The clofibric acid levels were below the method detection limit (MDL) at all stations. Accordingly, clofibric acid was not consumed by humans in this region. Gemfibrozil was detected at all stations, and the highest concentration of this compound was 2.17 μg L^{-1} at station 4 (Fig. 2). Gemfibrozil is a permanent contaminant in aquatic environments due to its long half-life (200 days) in surface water (Araujo et al., 2011; Fang, et al., 2019). In addition, gemfibrozil undergoes less photodegradation at low temperatures (Daneshvar, et al., 2010; Loraine and Pettigrove, 2006). In addition, the large amounts of fresh water input in the summer months (July-September) (Zaborska et al., 2020) caused increases in the amounts of organic pollutants (e.g., pharmaceutical) in the receiving environment. For this reason, gemfibrozil was detected at all stations in the study area.

The concentrations of estrone, 17β-estradiol and 17α-ethynylestradiol in seawater ranged from (<0.043 - 0.42 μg L^{-1}), (<0.029 - 0.14 μg L^{-1}) and (0.34 - 0.85 μg L^{-1}), respectively. The highest estrone and 17β-estradiol concentrations were observed at station 1. 17α-ethynylestradiol was detected at all stations (Fig. 2). The half-life of 17β-estradiol and 17α-ethynylestradiol in water systems are 2 and 81 days, respectively. Therefore, the synthetic hormone, 17α-ethynylestradiol, is more persistent in aquatic environments than the natural hormone 17β-estradiol (Adeel, et al., 2017). As a result, it was an expected result that synthetic hormones were detected at higher concentrations than natural hormones. Many studies have shown that 17β-estradiol easily degrades to estrone (Adeel et al., 2017; Xuan, et al., 2008). The fact that the estrone concentrations were higher than the 17β-estradiol concentrations at the three stations in this study suggests that estrone may be the main degradation product of 17β-estradiol.

There are very few studies on the presence of these selected pharmaceuticals in Arctic sea waters. The diclofenac, ibuprofen, and naproxen concentrations that were determined in this study were higher than those found in other studies of the Arctic region (Choi et al., 2020; Kallenborn et al., 2018; S. Weigel et al., 2004). Diclofenac and naproxen were not detected in the seawater of Kongsfjorden in Spitsbergen in the study by Choi et al. (2020). Weigel et al. detected ibuprofen with maximum concentration of 0.7 ng L^{-1} in the seawater of Tromsø/Norway (S. Weigel et al., 2004). In a different study, Kallenborn et al. indicated that the maximum concentrations of diclofenac and ibuprofen in the seawater of Oslo were 48 ng L^{-1} and 52 ng L^{-1}, respectively. Additionally, the maximum diclofenac and ibuprofen concentrations in the Longyearbyen, Svalbard seawater, were determined to be 4 ng L^{-1} and 1 ng L^{-1}, respectively (Kallenborn et al., 2018).

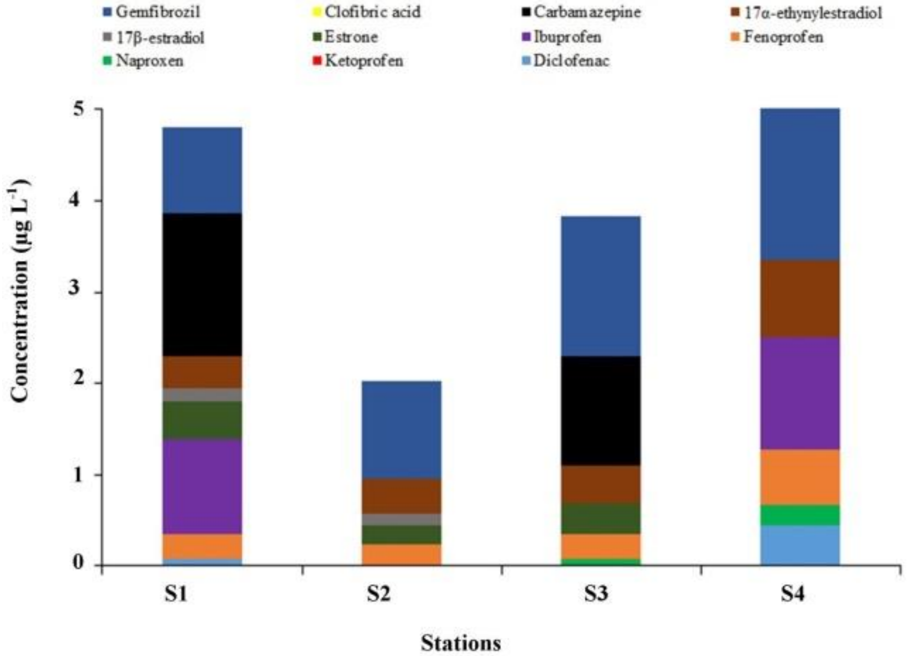

Fig. 2. Cumulative levels of pharmaceutical compounds in the seawater of Spitsbergen, Svalbard.

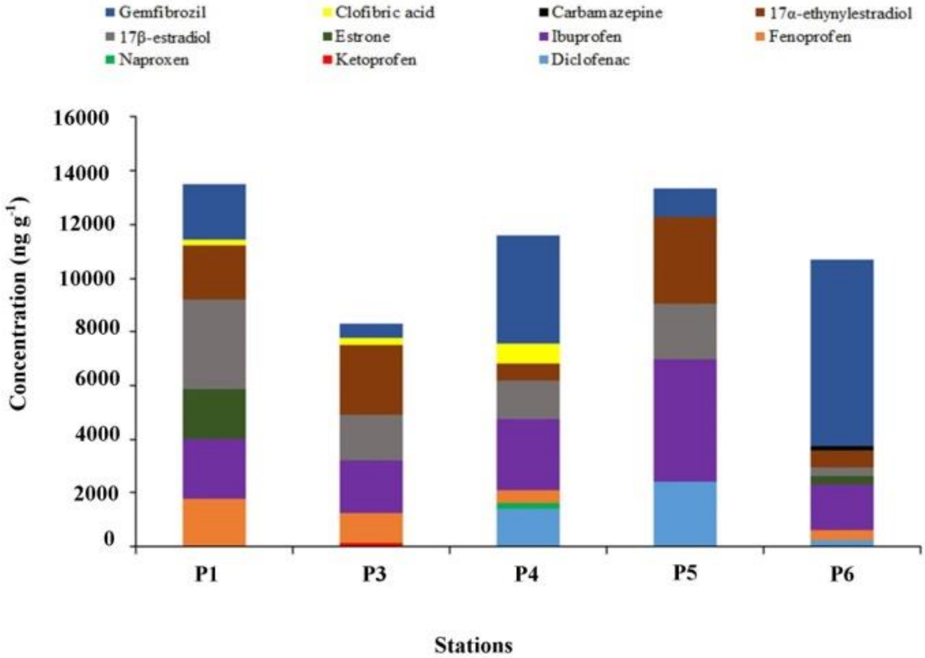

Fig. 3. Cumulative levels of pharmaceutical compounds in the net plankton of Spitsbergen, Svalbard.

Presence of the target pharmaceutical compounds in the net plankton suspended solids (Pss)

The concentrations of the selected compounds in the Pss samples from Spitsbergen are shown in Fig. 3. The compounds that had the highest concentrations in the Pss samples were ibuprofen (4543 ng g^{-1}), 17β-estradiol (3338 ng g^{-1}), 17α-ethynylestradiol (3262 ng g^{-1}) and gemfibrozil (6940 ng g^{-1}). Complexation, ion exchange, hydrogen bonding and hydrophobic partitioning processes are sorption processes of organic pollutants into solids (e.g., suspended solids and sediment). The sorption of polar and ionic pharmaceutical compounds to solids cannot be evaluated from their log K_{ow} values (Kwon and Armbrust, 2008). Since the log K_{ow} values of the studied pharmaceuticals are in the range of 3 - 4.8, they can be found in both water and solids. Another factor that affects the sorption of organic pollutants into solids is the pK_a values of these compounds. Compounds with pK_a>7 have higher sorption to solids (Silva et al., 2011). In this work, it was determined that 17β-estradiol (pK_a 10.6) and 17α-ethynylestradiol (pKa 10.4), with their basic properties, had strong tendencies to bind to suspended solids. However, acidic pharmaceuticals (pKa 4.1-4.9) (Fent et al., 2006) such as diclofenac, naproxen, ketoprofen, ibuprofen, fenoprofen, clofibric acid and gemfibrozil, for which the sorption of these compounds into solids is very weak, were thought to be absorbed in suspended solids by forming ternary surface complexation (Fein, 2002). In addition, ibuprofen and gemfibrozil were detected at high levels in both water and suspended solids, which confirms their high consumption levels by humans near the study area. As a result, it was determined that the amounts of the pharmaceutical compounds in the Pss samples were too high to be neglected. To our knowledge, there is no study on the concentrations in the plankton of these selected pharmaceutical compounds around Svalbard. Therefore, this work will provide valuable information for the literature.

Conclusion

Eleven selected pharmaceutical compounds that were analyzed using HPLC-DAD were investigated in the surface seawater and plankton samples of Spitsbergen, Svalbard. The results showed that the highest concentration of these compounds (2.17 µg L^{-1}) in the seawater occurred for gemfibrozil. Additionally, 17α-ethynylestradiol and fenoprofen were detected in the seawater at all sampling stations. Also, gemfibrozil, ibuprofen, 17β-estradiol, and 17α-ethynylestradiol were detected at high concentrations in the plankton samples. Gemfibrozil was a dominant component of the investigated seawater and plankton samples. There are several reasons why pharmaceutical compounds are detected in the Arctic environment. The main reasons were thought to be that these compounds could not be treated in the Arctic region due to the lack of wastewater treatment facilities and because of their prolonged half-life in the receiving environment due to the low temperatures. One of the reasons was thought to be that in the summer melting season, during which our sampling was conducted, freshwater, which transported micropollutants from the terrestrial to marine waters, extensively entered the Arctic Ocean. Another reason was the increased tourism activities in Spitsbergen during the summer season, which was when we conducted sampling. In addition, the detection of these micropollutants in offshore areas can be explained by the fact that they are transported over long distances in marine areas by binding to suspended solids.

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Project Period: 13 Jul 2019 - 26 Jul 2019

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Cruise Information "MY Anakena" 190620 on Directorate of Fisheries

Description of Project:

The objective of this project is to conduct first Turkish Arctic Scientific Expedition with the team of multidisciplinary scientists. The topics of the including projects are:

Installation of Meteorological/Atmospheric instrument

- Sea ice observations
- Maritime Meteorology recordings
- Sea water sampling for microplastic
- Bioprospecting
- Plankton sampling
- Sedimentology studies
- Underwater sampling
- Studying Arctic - Maritime Law
- Sky quality measurements
- Arctic Shipping Safety (Polar Code)
- Education & Outreach

PUBLICATIONS

Articles

- Karahalil, M., Özsoy, B., & Oktar, Ö. (2020). Polar Code application areas in the Arctic. WMU Journal of Maritime Affairs, 1–16. https://doi.org/10.1007/s13437-020-00200-4.
- Karahalil, M., & Özsoy, B. (2020). Evaluation of the Polar Code in different environments and for different maritime activities in the two polar regions. Advances in Polar Science, 31(4), 237-24. https://doi.org/10.13679/j.advps.2020.0028.
- Karahalil, M., & Özsoy, B. (2021). Assessment of Arctic and Antarctic Sea Ice Condition Differences in the Scope of the Polar Code. Journal of ETA Maritime Science, 9, (1), 31-40. https://doi.org/10.4274/jems.2021.32448
- Karahalil, M., Özsoy, B., Basar, E. & Satır T. (2021). The evaluation of the Polar Code by the survey conducted with those who have sailed in polar regions, and suggestions for further improvement. Marine Policy, 128.
- Flow cytometric investigation of picoplankton in Arctic and Antarctic Polar Regions During Summer Period of 2019 (on publication process)
- Ersoy-Korkmaz, N., Aksu, A., Karacık, B., Bayırhan, İ., Çağlar-Balkıs, N., Gazioğlu, C., & Özsoy, B. (2022) Presence of some commonly used pharmaceutical residues in seawater and net plankton: A case study of Spitsbergen, Svalbard Archipelago. (on publication process)
- Yalçınkaya, Ş., Yirmibeşoğlu, S., Balcı, N., & Özsoy, B. (2022) A Review on Geological View of Svalbard with its Infrastructure and Strategies. International Journal of Environment and Geoinformatics, V (9)-4, 2022. (on publication process).

NCBI GenBank (Species Discovery)

- Kırkıncı, F.S., Edbeib, M.F., Sevgi, M., Aksoy, H.M., & Kaya,Y. (18-Ocak-2020). Isolation, characterisation and identification of Psychrophile bacteria, (Psychrobacter sp. TaseBurcu001) from Svalbard Islands, MN923049, NCBI Genbank.
- Özçimen, D., Aksoy, H.M., Çelik, A., Koçer, A.T. & İnan, B. (26-Ekim-2020). Isolation, characterization and identification of Pseudochlorella pringsheimii strain TASE-Ozcimen.001 isolated from Arctica, MW147154.1, NCBI GenBank.
- Özçimen, D., Kaya, Y., İnan, B., Koçer, A.T. & Çelik, A. (16- Ocak -2021). Isolation of Chlorella sorokiniana strain Egemen.002 from Arctica, MW454367.1, NCBI GenBank,

Books

- Sinan Yirmibesoglu (2020). Turkish Scientists at North Pole. Kultur Publications", Children's book, 19 June 2020.
  Link: https://indd.adobe.com/view/5a42f528-0d8e-4230-b5c7-37ec971428e0
- Name: "Warm Islands of the Cold North Svalbard" TÜBİTAK MAM PRI Publisher 2021.
- Published photographs from TASE accepted and published on "INTERACT Images of Arctic Science" 2020. ISBN: 978-87-93129-16-0.
- Chapter: Sinan Yirmibesoglu, Ozgun Oktar, Burcu Ozsoy. (2021). "Sea Ice Problems in the Arctic Ocean and Southern Ocean Regions" Regional Problems in the 21st Century. Novel Publisher, ISBN 978-625-417-178-9. pg 803 - 817.

Abstracts

- Benjamin Berke Cicek, Sinan Yirmibesoglu, Ozgun Oktar, Burcu Ozsoy; Importance of Arctic and Antarctic Sea Ice, The AGU Fall Meeting, San Francisco, 9-13/12/2019.
- Deniz Vural, Burcu Ozsoy; The Polar Regions of Climate Change and Its Sensitive Role in Raising Awareness; 4. National Polar Science Workshop, 22 October 2020, Turkey.
- Deniz Vural, Sinan Yirmibesoglu, Ozgun Oktar, Meric Karahalil, Burcu Ozsoy, "The Contribution of Turkish Arctic Scientific Expedition to Education Activities in Turkey" Poster, 3. National Polar Science Workshop, ODTU 5-6.09.2019.
- Feyzioğlu, A., M., Başar, E., Yıldız, İ., Ağırbaş, E., Altınok, İ., Öztürk, R., Ç., (2019). Plankton Studies During the Turkish Arctic and Antarctic Scientific Expeditions (Tae-I, Tae-II, Tae-II and Tase-2019). 3. National Polar Science Workshop, ODTU 5-6.09.2019.
- Feyzioğlu, A., M., Başar, E., Yıldız, İ., Ağırbaş, E., Altınok, İ., Öztürk, R., Ç., (2020). istribution of Synechococcus Spp in the Arctic and Antarctic Polar Regions in the Summer of 2019. 4. National Polar Science Workshop, 22 October 2020, Turkey.
- Furkan Ali Kucuk, Osman Sıklar, Ceyhan Kahya, Ozgun Oktar, Sinan Yirmibesoglu, Burcu Ozsoy; Atmospheric Particle Measurements within the First Turkish Arctic Scientific Expedition; 4. National Polar Science Workshop, 22 October 2020, Turkey.
- Kırkıncı, S., F., Edbeib, M., F., Kaya, S., Aksoy, H., M., Marakli, S., Kaya, Y., (2020). Dehalogenase Producing Psychrophil Bacteria Isolate Taseburcu001 and Its Potential Role in Bioremediation. 4. National Polar Science Workshop, 22 October 2020, Turkey.

- Meric Karahalil, Burcu Ozsoy; Evaluation of the Polar Code in Terms of Differences in Polar Regions and Maritime Activities; 4. National Polar Science Workshop, 22 October 2020, Turkey.
- Nasıh Sarp Erguven, Burcu Ozsoy, Ozgun Oktar, Sinan Yirmibesoglu, “Application of the IMO's Polar Code: A Critical View with a Multidisciplinary Approach”, Polar Law, 2020 Symposium, Kobe / Japonya, 23-25 November 2020.
- Ozgun OKTAR, Meric KARAHALIL, Sinan YİRMİBESOGLU, Burcu OZSOY, "Implementations Of Polar Code For Ships Operating In Polar Waters" 3. National Polar Science Workshop, ODTU 5-6.09.2019.
- Sinan Yirmibesoglu, Ozgun Oktar, Burcu Ozsoy, "Comparision Between Satellite Datas With Sea Ice Observations During TASE – I" 3. National Polar Science Workshop, ODTU 5-6.09.2019.
- Sinan Yirmibesoglu, Ozgun Oktar, Burcu Ozsoy; First National Arctic Science Expedition Studies; 4. National Polar Science Workshop, 22 October 2020, Turkey.
- Y. Barbaros Buyuksagnak, Burcu Ozsoy, Ozgun Oktar; 100th Anniversary of the Treaty of Svalbard and the Arctic Region; 4. National Polar Science Workshop, 22 October 2020, Turkey.
- Yalçınkaya, Ş., Yirmibeşoğlu, S., & Özsoy, B. Investıgatıon Of Svalbard's Geology, Scıentıfıc Infrastructure And Its Strategıes. 5. National Polar Science Workshop, 30 November 2021, Turkey.

Documentary

- Name: “Kuzeyde 15 Gün” 2019, Link: https://youtu.be/aC3yBr_YOUE

Awards

- Turkish Academy of Sciences, TUBA-GEBIP Polar Sciences Award, 2020
- Photography from Arctic TASE; 2nd Prize, TUBITAK 2022 Environment and Climate Change Photography Competition, 14/4/2022.

Education and Outreach Activities

Popular Science Maganizes

- Sinan Yirmibesoglu, Ozgun Oktar, Burcu Ozsoy; "First Turkish Arctic Scientific Expedition", TUBİTAK Science and Technology Journal, No 624, December 2019.

TV Shows

- Haberturk TV, Arctic Scientific Expedition, https://youtu.be/Kr9OKNYrJtw 01 February 2020.
- Kumbara Journal, Interview with Arctic Scientists, www.kumbaradergisi.com/icerik/kutuplari-arastiran-turk-bilim-insanlari-ile-soylesi 01 April 2020
- Polar and Climate Program, Bunyamin Surmeli, TUBITAK MAM Polar Research Institute, 17 May 2021. https://www.youtube.com/watch?v=Q9YoS39tKXY
- Polar and Climate Program, Prof. Dr. Mikdat Kadıoglu, TUBITAK MAM Polar Research Institute, 24 May 2021. https://www.youtube.com/watch?v=lgNaHygF8uU

Keynote Speakers (Prof. Dr. Burcu Özsoy)

- Arctic and Antarctica Remote Sensing Studies, ISAG 2019, 7-9.11.2019.
- Climate at World, Climate at Polar Regions; Climate Change Conference, 13 January 2022.
- Challenges and opportunities of interdisciplinary studies in Polar environment, 'Yeditepe Dental Congress, 20.11.2019
- Challenges and opportunities in Polar environment, 28. Quality Congress, 26.11.2019
- Polar Research and Climate Presentation, UNDP "Human Development Report 2020 Turkey Habitat Follow-up Meeting" 20 January 2021.

High School Competition

- 2204-C High School Student's Polar Research Project competition had been arranged annually since 2020 to improve E&O on students for Arctic and Antarctic Science. Thousands of projects had been evaluated by polar scientists.

Seminars, etc.

- Thousands of Polar Research and Climate Change seminars, exhibitions, and other activities had been completed since 2019 by experts of TÜBİTAK MAM PRI. Details could be found at National Polar Research Program Reports: https://kare.mam.tubitak.gov.tr/tr/yan-menu/ulusal-kutup-bilim-programi-2018-2022

TURKISH ARCTIC SCIENCE EXPEDITION (TASE) REPORT

Project Date: 2019-07-13- 2019-07-26, RIS-ID 11301

Istanbul Technical University, Polar Research Center (ITU-PolReC) closely follows the changes in the Arctic. Thus, the first Turkish Arctic Scientific Expedition (TASE-I) was conducted by ITU-PolReC in July 2019 with a total of 8 participants, including 7 scientists and one cinematographer. The project included a total of 41 researchers, including expedition researchers. These researches represent universities with different scientific purposes. All projects mainly aimed to see the climate change effects. Seven scientists made field studies and cinematographer recorded the expedition.

TASE projects consisted of several universities/institutions from Turkey as follow:

1. Istanbul Technical University Polar Research Center (PolReC)
   Polar Research Center, Responsible Institution inTurkey
2. Amasya University (AU), Medical Services and Techniques Participating Institution,Turkey
3. Ankara University Research Center of the Sea and Maritime Law (DEHUKAM), Department of International Law Participating Institution,Turkey
4. Istanbul Technical University (ITU), Science, Engineering and Technology Participating Institution,Turkey
5. Istanbul University (IU), Institute of Marine Sciences and Management Participating Institution,Turkey
6. Istanbul Yeni Yuzyil University (IYYU),Participating Institution,Turkey
7. Karadeniz Technical University (KTU), Faculty of Marine Sciences Participating Institution,Turkey
8. Ondokuz Mayıs University (OMU), Agricultural Biotechnology Participating Institution,Turkey
9. Pîr'i Reis University (PRU), Maritime Higher Vocational School Participating Institution,Turkey
10. The Scientific and Technological Research Council of Turkey (TUBITAK), Participating Institution, Turkey

Main studies were related with oceanography, maritime, sediment sampling, atmospheric studies, device installation and social sciences. The main purpose was the conduct multiple scientific researches with a team onboard a ship. TASE-I was carried out in total 14 projects. These were:

1. Classification of micro-plastics in Svalbard Island and surrounding waters,
2. Determination of the presence and quantity of selected pharmaceutical residues and hormones,
3. Determination of levels of persistent organic pollutants in the Arctic ecosystem; passive sampler applications,
4. Determination of PAH and POP levels and their sources,
5. Meteorological-Atmospheric BILFEN Station feasibility studies,
6. Distribution of micro and meso plankton along the west coast of Svalbard Islands during the Arctic summer period,
7. Svalbard Arctic fyord system biological mining (bioprocessing / bioprospecting) field study,
8. Determination of the origin of oil pollution around Svalbard Islands,
9. Arctic Maritime Safety (Polar Code),
10. Evaluating the outputs of the TASE in line with international maritime law,
11. Observations of maritime meteorology,
12. Verification of sea ice observations and satellite data,

13. Education and awareness activities,
14. Air Quality Measurement.

The seawater, microplankton and mesoplankton samples have been collected at stations as permissions given.

Table 1: TASE-I Sampling Stations

Station	Cooardinates	Samples
1	77°57'20,13"N 12°22'13,37"E	50ml seawater /// 1lt seawater /// 250ml fitoplankton /// 250ml zooplankton /// 2ml seawater /// Microplastic sample collected
2	78°16'07,55"N 15°21'29,17"E	50ml seawater /// 1lt seawater /// 250ml fitoplankton /// 250ml zooplankton /// 2ml seawater /// Microplastic sample collected
3	78°20'42,24"N 16°04'57,33"E	50ml seawater /// 1lt seawater /// 250ml fitoplankton /// 250ml zooplankton /// 2ml seawater /// Microplastic sample collected
4	78°27'59,37"N 42°48'33,72"E	50ml seawater /// 1lt seawater /// 250ml fitoplankton /// 250ml zooplankton /// 2ml seawater /// Microplastic sample collected
5	78°11'13,29"N 14°14'42,04"E	50ml seawater /// 1lt seawater /// 250ml fitoplankton /// 250ml zooplankton /// 2ml seawater /// Microplastic sample collected
6	79°01' 25,36"N 11°37'20,43"E	50ml seawater /// 1lt seawater /// 250ml fitoplankton /// 250ml zooplankton /// 2ml seawater /// Microplastic sample collected
7	78°32'55,93"N 11°44'21,36"E	50ml seawater /// 1lt seawater /// 250ml fitoplankton /// 250ml zooplankton /// 2ml seawater /// Microplastic sample collected
8	76°58'12,78"N 15°40'59,95"E	50ml seawater /// 1lt seawater /// 250ml fitoplankton /// 250ml zooplankton /// 2ml seawater /// Microplastic sample collected
9	77°38'47,25"N 14°15'46,62"E	50ml seawater /// 1lt seawater /// 250ml fitoplankton /// 250ml zooplankton /// 2ml seawater /// Microplastic sample collected

The whole team members stayed onboard during the expedition. Samples collected by glass vials. There were no pollution created and no waste produced during the sampling. Also no chemicals used to create pollution and/or waste. There are no research equipment left behind.

The projects description of TASE team members conducted;

Plankton Distribution Along Svalbard Islands: Micro and mesoplankton are composed of organisms between 2- 200 µm and 0.2 mm -20 mm. They’re mixture of phytoplankton and zooplankton. The primary goals were to determine of microplankton and mesoplankton in the planktonic food web of Svalbard Islands and to provide basic information vicinity of the islands. Our objectives were to examine the distribution, abundance, taxonomic composition of planktonic community. Planktonic community structure and species composition will be compared between bays, coastal and off-shore along the Svalbard Island, as well as across a spatial gradient throughout coast. The analyze process of collected samples still continue.

Bioprospecting: On recent studies, extreme life forms have been discovered both on Arctic and Antarctic regions. Environmental DNA (eDNA) describes the DNA that can be extracted from an environmental sample, such as soil, sediments, water or snow. The DNA samples extracted from sediment and eDNA marine filtered samples, both, would be analysed by Oxford Nanopore MinION Next Generation Sequencing System and some bioinformatics work will be done according to results. Then, industrially important gene structures could be grabbed from stack of DNA consensus sequences. The analyze process of collected samples still continue.

Determination Of The Origin Of Petroleum Pollution: The pressure coming from human activities (fishing and oil drilling/exploration etc) in the Arctic region investigated by means of petroleum pollution. One of the aims of the project was to investigate whether the origin of the petroleum pollution is petrogenic or pyrolytic and which petroleum compound was more dominant in arctic waters. The distribution of crude oil and its derivatives examined under the arctic sea physicochemical characteristics (temperature, salinity, DO, bacteria content, etc.) from the coast through the offshore. Also, it is planned to determine the source of the pollutants in the selected stations whether coming from human activities in the coastal areas/harbors or by currents. 1-15 L seawater taken from the surface for analyse. The analyze process of collected samples still continue.

Air quality measurement carried out with small device. Many parameters had been recorded to study air pollution. Also, we observed cloudiness and temperature in order to study on astronomical and meteorological parameters. The analyze process of collected data still continue. After analyzing the datas, the results will be published and shared.

Sea ice observations have been done once reached to 80 degrees North. In addition, data were collected to assess sea ice forecasting skills, errors and improve forecasting systems. It was useful for observing sea ice concentration and thickness for risk assessments in the maritime field.

On the other hand, education and outreach activities organized such as painting competition, and handcrafted works related to Arctic before the expedition and the products of the students were taken to the region during the expedition. After the the expedition, in order to raise awareness about Arctic, the media has been widely featured throughout the country.

The projects have been successfully operated from 13 July 2019 to 25 July 2019 onboard Anakena from Longyearbyen to Hornsund and then to Ny-Ålesund, and from Ny-Ålesundto sea ice edge North of 80 degrees and back to longyearbyen. The ship's crew had rifle for polar bear security reasons. We did not encounter polar bear risk.

As a result, to follow-up the developments that concern the whole world and to contribute scientifically to the solution of Arctic issues, the TASE project supported the objectives of ITU - PolReC.