ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

LACK OF ARCTIC AND ANTARCTIC ISSUES IN INTERNATIONAL CODE FOR SHIPS OPERATING IN POLAR WATERS (POLAR CODE) AND SUGGESTING POSITIVE IMPROVEMENTS

Ph.D. THESIS

Meriç KARAHALİL

Department of Maritime Transportation Engineering

Maritime Transportation Engineering Programme

MAY 2021

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

LACK OF ARCTIC AND ANTARCTIC ISSUES IN INTERNATIONAL CODE FOR SHIPS OPERATING IN POLAR WATERS (POLAR CODE) AND SUGGESTING POSITIVE IMPROVEMENTS

Ph.D. THESIS

Meriç KARAHALİL
(512162006)

Department of Maritime Transportation Engineering

Maritime Transportation Engineering Programme

Thesis Advisor: Prof. Dr. Burcu ÖZSOY

MAY 2021

İSTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

KUTUP SULARINDA FAALİYET GÖSTEREN GEMİLERE YÖNELİK KOD, KUTUP KODU'NDA ARKTİK VE ANTARKTİKA İÇİN YER VERİLMEYEN HUSUSLAR VE KUTUP KODU’NUN GELİŞTİRİLMESİ İÇİN ÖNERİLER

DOKTORA TEZİ

Meriç KARAHALİL

(512162006)

Deniz Ulaştırma Mühendisliği Anabilim Dalı

Deniz Ulaştırma Mühendisliği Programı

Tez Danışmanı: Prof. Dr. Burcu ÖZSOY

MAYIS 2021

Meriç Karahalil, a Ph.D. student of ITU Graduate School student ID 512162006, successfully defended the thesis entitled “LACK OF ARCTIC AND ANTARCTIC ISSUES IN INTERNATIONAL CODE FOR SHIPS OPERATING IN POLAR WATERS (POLAR CODE) AND SUGGESTING POSITIVE IMPROVEMENTS”, which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor : **Prof. Dr. Burcu ÖZSOY** ....
Istanbul Technical University

Jury Members : **Prof. Dr. Ersan BAŞAR** ....
Karadeniz Techical University

Assoc. Prof. Dr. Tanzer SATIR ....
Istanbul Technical University

Assoc. Prof. Dr. Özkan UĞURLU ....
Ordu University

Dr. Tuba KEÇECİ ....
Istanbul Technical University

Date of Submission : 15 April 2021
Date of Defense : 20 May 2021

To my beloved family,

FOREWORD

I have been dreaming of this moment ever since I started my doctorate. In the end, all it takes is to thank the special people in my life who supported me in completing this challenging, life-changing process and perhaps will cause new beginnings. Before I begin, I first owe a thank to both institutions, i.e., the Istanbul Technical University and Turkish Coast Guard Command, which gave me the chance to pursue a Ph.D. degree.

Next, a big thank from the bottom of my heart goes to my supervisor, Prof. Dr. Burcu ÖZSOY. It was such an honor and fortune to work with her. She encouraged me in all the difficult times. I feel very grateful to have had an opportunity to have a supervisor like her who opened a completely different page in my life.

I also would like to thank my thesis defense committee members, Prof. Dr. Ersan BAŞAR, and Assoc. Prof. Dr. Tanzer SATIR for their peerless support. I present my gratitude to Barbaros BÜYÜKSAĞNAK for sharing his wisdom. I would also like to thank my friends Özgun OKTAR and Sinan YİRMİBEŞOĞLU. Thank you very much for your help throughout this period. I feel fortunate to have the chance to be a team member for the Turkish Arctic Science Expedition I (TASE-I).

I am thankful to those special people in my life who support me, my friends Burak Kurt and Ayşenur Şafak. You are not just friends to me you are my luck. Thank you for motivating me to go on.

Finally, I would like to special thank my dear parents Baki & Güler KARAHALİL, my lovely sister Derya Sultan ARSLAN for their endless support, love, and encouragement during all the years of my studies. I dedicate this study to my lovely niece Naz Ada and nepwhew Batuhan.

April 2021

Meriç KARAHALİL

(TUCG-93 Commanding Officer)

TABLE OF CONTENTS

Page

ABBREVIATIONS

AIS	: Automatic Identification System
AMAP	: Arctic Monitoring and Assessment Programme
AMSA	: Arctic Marine Shipping Assessment
ASOC	: Antarctic and Southern Ocean Coalition
AT	: Antarctic Treaty
ATCM	: Antarctic Treaty Consultative Meeting
ATS	: Antarctic Treaty System
CAFF	: Conservation of Arctic Flora and Fauna
CCAMLR	: Commission for the Conservation of Antarctic Marine Living Resources
COMNAP	: Council of Managers National Antarctic Programs
DAAC	: Distributed Active Archive Center
DMSP	: Defense Meteorological Satellite Program
DE	: Sub-Committee on Ship Design and Equipment
EPPR	: Emergency Prevention, Preparedness and Response
ESMR	: Electrically Scanning Microwave Radiometer
FOEI	: Friends of the Earth International
GSFC	: Goddard Space Flight Center
IAATO	: International Association of Antarctica Tour Operators
IACS	: International Association of Classification Societies
IFAW	: The International Fund for Animal Welfare
ICESAT	: Ice, Cloud, and Land Elevation Satellite
ILO	: International Labour Organization
IMO	: International Maritime Organization
IUU	: Illegal Unreported and Unregulated
MARPOL	: International Convention for the Prevention of Pollution from Ships
MEPC	: Marine Environment Protection Committee

MSC : Maritime Safety Committee

NASA : National Aeronautics and Space Administration

NSR : Northern Sea Route

NSIDC : National Snow and Ice Data Center

NWP : Northwest Passage

OW : Open Water

PAME : Protection of the Arctic Marine Environment Working Group

PC : Polar Code

PEPAT : Protocol on Environmental Protection to the Antarctic Treaty

POLARIS : Polar Operational Limitations Assessment Risk Indexing System

PSC : Polar Ship Certificate

PWOM : Polar Water Operational Manual

SAR : Search and Rescue

SIE : Sea Ice Extent

SMMR : Scanning Multichannel Microwave Radiometer

SOLAS : International Convention for the Safety of Life at Sea

SPSS : Statistical Package for the Social Sciences

SSMIS : Special Sensor Microwave Imager/Sounder

SSM/I : Special Sensor Microwave Imager

STCW : International Convention on Standards of Training, Certification and Watch keeping for Seafarers

UNCLOS : United Nations Convention on the Law of the Sea

VHF : Very High Frequency

WWF : World Wildlife Fund

SYMBOLS

N : Number

$\bar{x}$: Mean

SD : Standard deviation

F : F distribution/ Fisher snedecor distribution

p : Probability value

LIST OF TABLES

Page

LIST OF FIGURES

Page

LACK OF ARCTIC AND ANTARCTIC ISSUES IN INTERNATIONAL CODE FOR SHIPS OPERATING IN POLAR WATERS (POLAR CODE) AND SUGGESTING POSITIVE IMPROVEMENTS

SUMMARY

The effects of industrial activities have reached global dimensions in the last century. Global climate change is triggered as the result of industrialization, which has led to many global issues. The consequences of global climate change are now being observed dramatically in the polar regions. Consequently, the Arctic has become more critical in geopolitical and geoeconomic terms with melting ice and disappearance to a large extent. As the sea ice coverage decreased, maritime activities such as tourism, fishing, and maritime transportation increased in the Arctic Ocean. Conversely, the Antarctic is presently subject to scientific research and activities such as fishing and tourism, which are increasing over time. While the harsh polar environment presents significant risks to the ships, maritime activities also threaten the sensitivity of polar ecosystems and the vulnerability of marine wildlife and habitats. The lack of accurate charts and marine infrastructure, the harshness of the environment, and the limitations of radio and satellite communications to monitor and control ship movements in polar waters are the primary challenges of operations in polar regions. The International Maritime Organization (IMO) aimed to legalize polar regions' shipping measures and enforced the International Code for Ships Operating in Polar Waters (Polar Code), but it becomes a question mark whether the Polar Code provides significant protection.

This thesis consists of three articles on the issues in the Arctic and the Antarctic that are failed to be addressed in the Polar Code. The first article proposed to expand the Polar Code application areas in the Arctic. While maritime activities are increasing in the Arctic, little attention has been 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 their physical, geographical, and ecological characteristics. However, the boundaries of the Polar Code are not compatible with any of them. In the first article, the extent of sea ice change and maritime traffic in the high north and maritime safety in applying the Polar Code boundaries in the Arctic are analyzed, and extension of the Polar Code application areas in the Arctic are also suggested. In the second article, the Arctic and the Antarctic sea ice extent change, arisen maritime safety and security issues, and legal instruments relevant to the scope are evaluated. It is considered that some significant differences regarding sea ice in the content of the Polar Code are not evaluated. The primary contribution of this paper is the assessment of the sea ice condition differences between the Arctic

and the Antarctic through remote sensing data analyzes in the scope of the Polar Code. The third paper evaluates the Polar Code within the survey scope conducted with the people who have sailed in these regions and makes suggestions to develop the Polar Code further.

The original value of this study to the literature is that it draws attention to the differences between the Arctic and the Antarctic, points out the inadequacies in the Polar Code, and suggests its further development. Furthermore, it provides data regarding sea ice changes and maritime activity trends in polar regions and is supported by the opinions of the people working in those regions based on the survey evaluations.

KUTUP SULARINDA FAALİYET GÖSTEREN GEMİLERE YÖNELİK KOD, KUTUP KODU'NDA ARKTİK VE ANTARKTİKA İÇİN YER VERİLMEYEN HUSUSLAR VE KUTUP KODU'NUN GELİŞTİRİLMESİ İÇİN ÖNERİLER

ÖZET

Son yüzyılda gerçekleştirilen endüstriyel faaliyetlerin çevreye etkileri küresel boyutlara ulaşmıştır. Sanayileşmenin bir sonucu olarak, tetiklenen küresel iklim değişikliği birçok sorunu beraberinde getirmiştir. Mevcut durumda, küresel iklim değişikliğinin sonuçları kutup bölgelerinde dramatik şekilde gözlemlenmektedir.

Arktik'te buzların erime hızındaki artış ve büyük oranda yok olmaları ile birlikte, jeopolitik ve jeoekonomik açıdan daha önemli hale gelmiştir. Arktik Okyanusu olarak bilinen Arktik dairesi içerisinde yer alan bölge, mevsimsel erimeden kaynaklı bölgesel değişimler göstersede yıl genelinde deniz buzu ile örtülüdür. Çeşitli araştırmalarda yapılan modellemelere göre, 21. yüzyıl ortalarında Arktik deniz buzu yaz aylarında tamamen eriyecektir. Arktik'te yaşanan değişimlerle beraber, bölgede ve dünyada yaşanacak gelişmeleri tahmin etmesi zordur. Bu durum erimenin sürecine, ekonomik gelişmelere, doğal kaynak ve enerji ihtiyacına ve açılacak deniz yollarının tercih edilebilirliğine göre şekillenecektir. Deniz ulaştırması kapsamında, deniz buzlarının erimesi ile birlikte; Norveç, Rusya, Kanada ve Amerika'nın kıyıları yaz dönemlerinde seyredilebilir hale gelmiştir. Kuzey Avrupa ve Doğu Asya arasındaki en kısa mesafe olan Kuzeydoğu Geçidi seyir sürelerinin kısalması, az yakıt tüketimi ve maliyetlerin azalması gibi sağladığı avantajlar ile daha çekici hale gelmektedir. Buna rağmen bölgedeki deniz buzu hareketlerinin tahmin edilememesi, haritaların ve iletişim sistemlerinin yetersizliği, ağır hava şartları, yetersiz kurtarma istasyonları, mevcut gemilerin gerekli standartların altında kalması ve tecrübeli personel yetersizliği gibi sebeplerle, gemi geçişleri az miktardadır. Son yıllarda kutup bölgelerinde denizcilik faaliyetlerinin arttığı gözlemlenmektedir. Gemi trafiği artarken, gemi kaynaklı çevre kirliliği ve deniz kazası riskleri de artmaktadır. Başta Arktik'e kıyısı olan ülkeler olmak üzere, Arktik'e kıyısı olmayan birçok ülke ve uluslararası şirketlerin bölgeye olan ilgisinin arttığı ve yatırımlarını arttırdığı gözlemlenmektedir. Yürütülen bütün bu ekonomik faaliyetler sürdürülebilir kalkınma odaklı, Arktik ekosistemine zarar vermeyecek şekilde, yüksek güvenlikli, standartlara uygun olarak yapılmalı ve mevcut koruyucu düzenlemelerin geliştirilmesi gerekmektedir.

Antarktika, keşfinden sonra 1956-1958 yıllarında ilgi odağı olmuştur. Birçok ülke bölgede bilimsel programlarını bu dönemde başlatmış, çok sayıda araştırma istasyonu kurulmuştur. Kıtanın statüsü 1959 Antarktik Antlaşması'na göre düzenlenmiş ve "bilime ve barışa adanmış doğal bir rezerv" olarak kabul edilmiştir.

Kıtada çeşitli ülkelere ait 100'ü aşkın araştırma istasyonu bulunmaktadır ve kıta üzerinde sadece bilimsel çalışmalarda bulunan ve diğer işlerde çalışan insanlar bulunmaktadır. Kıtaya lojistik ihtiyaçları çoğunlukla lojistik gemileri ile sağlanmaktadır. Lojistik gemileri haricinde birçok araştırma gemisi ile araştırmacılar, yoğunluklu olarak; Ocak, Şubat ve Mart döneminde araştırma faaliyetlerini gerçekleştirmektedir. Antarktika deniz buzu, Arktik'te bulunan deniz buzları kadar kalıcı değildir ve kalınlaşmamaktadır. Güney yarım küre kış dönemi boyunca oluşan deniz buzunun neredeyse tamamı yaz aylarında erimektedir. Antarktika'nın özel hukuki statüsü ve coğrafi konumu nedeniyle daha sınırlı sayıda denizcilik faaliyetleri gerçekleştirilmektedir. Ticari kapsamda gerçekleştirilen faaliyetler; balıkçılık ve turizmdir. Antarktika turizmi son yıllarda artış göstermiştir. Yıllar içinde büyümeye devam eden turizm, zorlu ortam şartları dikkate alındığında can ve mal güvenliği açısından ve Antarktika'nın hassas doğasına, gemilerden kaynaklı verilebilecek zarar seviyesini en aza indirmek maksadıyla ek önlemler alınması gerekmektedir.

Uluslararası Denizcilik Örgütü'nün (IMO[1]), bayrak ülkesi fark etmeksizin bütün gemiler tarafından uygulanması gereken düzenlemeleri bulunmaktadır. Kutup bölgelerinde de gemiciliği ilgilendiren sorunlara çözüm için IMO en önde gelen kuruluştur. "Buzla Kaplı Arktik Okyanusunda Çalışan Gemiler İçin Rehber[2]", 2002 yılında IMO tarafından yayınlanmıştır. Daha sonra bu kılavuz geliştirilerek, kutup bölgelerinin korunması, denizcilerin ve yolcuların güvenliğine ilişkin uluslararası kaygıları gidermek üzere; "Kutup Sularında Çalışan Gemilere Yönelik Uluslararası Kutup Kodu (Polar Code[3])" 1 Ocak 2017'de yayınlamıştır. Kutup Kodu, 1974 Denizde Can Emniyeti Uluslararası Sözleşmesi (SOLAS 74[4]) ve Denizlerin Gemiler Tarafından Kirletilmesinin Önlenmesine Ait Uluslararası Sözleşme (MARPOL Convention 73/78[5])'in bağlayıcı düzenlemelerini içermekte, Arktik ve Antarktik sularında güvenli ve çevreci taşımacılığı düzenleyen maddelerden oluşmaktadır. Deniz güvenliği ve emniyeti çerçevesinde, kutup bölgelerindeki tehlike kaynakları; deniz buzu, buzlanma, düşük sıcaklık, uzun süreli karanlık ve gün ışığı, uzaklık, mürettebat deneyimi eksikliği, uygun acil müdahale ekipmanlarının bulunmaması ve ciddi şekilde değişen hava koşulları olarak belirlenmiştir. Bunlar arasında deniz buzu, gemilerin seyir performansı için önemli bir risk faktörüdür ve geminin gövdesine, pervanesine ve dümenine önemli bir kuvvet altında zarar verebilir veya buzda sıkışmasına sebep olabilir. Ayrıca, buzulların erimesi, çarpışmaya neden olabilecek tehlikeler yaratan yüzen buzdağları riskini artırır. Öte yandan, denizcilik faaliyetleri, kutup ekosistemlerinin hassasiyetini ve denizdeki vahşi yaşam ve habitatların savunmasızlığını tehdit etmektedir. Arktik ile Antarktik arasında uzaklıkları ve ortam koşullarının sertliği gibi benzerlikler olsa da, fiziksel, politik ve yasal koşullardaki farklılıklar, Kutup Kodu'nun yeterliliği hakkında soru işaretleri uyandırmaktadır. Koşullarına göre farklılıklar göstermesine rağmen her iki Kutup Bölgesi için geçerli olan bir Kutup Kodu mevcuttur.

---

[1] International Maritime Organization.
[2] IMO Guidelines for Ships Operating in Arctic Ice-covered Waters.
[3] The International Code for Ships Operating in Polar Waters.
[4] International Convention for the Safety of Life at Sea, 1974.
[5] International Convention for the Prevention of Pollution from Ships, 1973.

Bu tez çalışması, Arktik ve Antarktika arasındaki farklılıklara dikkat çekmek, Kutup Kodu'nda dikkate alınması gereken bu farklılıkları ortaya koymak ve Kutup Kodu'nun geliştirilmesi için önerilerde bulunmak maksadıyla hazırlanmış uluslararası hakemli dergilerde yayınlanan makalelerden oluşturulmuştur. Bu kapsamda hazırlanan 1'inci makalede, Arktik ikliminden etkilenen, coğrafi olarak büyük ölçüde benzerlik gösteren ve özellikle deniz buzu gözlemlenen, ancak Kutup Kodu'nda hariç tutulan bazı bölgelere dikkat çekilmiştir. Arktik'in deniz sınırları, Arktik Konseyi çalışma grupları tarafından, fiziksel, coğrafi ve ekolojik özelliklere göre farklı şekilde tanımlanmıştır. Ancak, Kutup Kodu'nun sınırları bunlardan hiçbiriyle uyumlu değildir. İlk makalede, Arktik'teki deniz buzu değişimleri ve deniz trafiği yoğunlukları, ayrıca Kutup Kodu sınırları çerçevesinde deniz güvenliği sorunları incelenmiştir. Sonuç olarak, Kutup Kodu'nun Arktik'teki uygulama sınırlarının, Pasifik'te deniz buzu genişlikleri kayıtlarına göre genişletilmesi önerilmiştir. 2'inci makalede, Arktik ve Antarktika'daki deniz buzu genişliklerindeki uzaktan algılama veri analizleri ile gösterilen değişimler ve karakteristiklerindeki farklılıklar ortaya konularak Kutup Kodu'nda ilgili bölümlerin geliştirilmesi gerektiği önerilmiştir. 3'üncü makalede ise yapılan literatür araştırmaları neticesinde, iki bölgedeki temel farklılıklar, denizcilik faaliyetleri ve Kutup Kodu değerlendirilerek bölgede çalışan denizciler ve bilim insanlarına anket uygulanmış ve yapılan analizler neticesinde, kutup bölgelerinde faaliyet gösteren gemilerin uyması gereken mevcut kuralların geliştirilmesi için önerilerde bulunulmuştur.

Bu çalışmanın özgün değeri, Arktik ile Antarktika arasındaki farklılıklara ve Kutup Kodu'ndaki eksikliklere dikkat çekmek ve geliştirilmesi için önerilerde bulunmaktır. Ayrıca, kutup bölgelerindeki deniz buzu değişimleri ve denizcilik faaliyetleri eğilimleri hakkında veri sağlamakta ve Kutup Kodu'nun geliştirilmesi gerektiği değerlendirilen kısımları, bu bölgelerde çalışan kişilere uygulanan anketlerin analizleri ile desteklenmektedir. Sonuç olarak, bu tez Kutup Kodu'nun geliştirilmesi için tavsiye niteliğindedir.

1. INTRODUCTION

Polar regions are facing increasing challenges because of global climate change, human activities, and economic and political pressures. One of the significant effects of global climate change on polar regions is the diminishing sea ice extent. As sea ice extent declines, maritime operations have started to increase in these regions. In this regard, the shrinking sea ice, environmental conservation, and safety of passengers and seafarers have raised international concerns. The International Maritime Organization (IMO) has enforced the International Code for Ships Operating in Polar Waters (Polar Code) for ships navigating these challenging Arctic and Antarctic waters. The improvement of the Polar Code has been a long process and is based on previous IMO instruments. It aims to mitigate 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. Understanding the challenges of polar circumstances and the reasons for maritime casualties is critical in mitigating future risks.

While maritime activities are increasing in the Arctic, little attention is being paid to some of the northernmost regions that are heavily 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. Conversely, although there are similarities between the Arctic and the Antarctic, such as the remoteness and harshness of the environment, they exhibit significant differences in geographical conditions, maritime activities, and legal status. Therefore, the Polar Code that applies to both regions should be reconsidered, accounting for differences between the Arctic and the Antarctic for further development.

This thesis consists of five chapters. It presents three published independent but strongly connected papers in Chapters 2, 3, and 4. Chapter 1 provides an outline of the thesis and an overview of the research articles. The three different articles are presented in the following chapters as illustrated in Table 1. The conclusion of the thesis is given in Chapter 5 where the main findings as well as suggestions for further research areas are presented. The comprehensive overview of these research papers is provided in the paragraphs below.

Table 1.1 : Publications list.

Research papers	Authors	Publication
Polar Code Application Areas in the Arctic	Meriç Karahalil, Burcu Özsoy, Özgün Oktar	WMU Journal of Maritime Affairs, 19, 219-234.
The Assessment of Arctic and Antarctic Sea ice Condition Differences in the Scope of the Polar Code	Meriç Karahalil, Burcu Özsoy	Journal of ETA Maritime Science, 2021; 9 (1): 31-40.
The Evaluation of The Polar Code by The Survey Conducted with Those Who Have Sailed in Polar Regions, And Suggestions for Further Improvement	Meriç Karahalil, Burcu Özsoy, Ersan Basar, Tanzer Satır	Marine Policy 128 (2021) 104502.

The first article, provided in Chapter 2, focuses on the increasing shipping density in the Arctic and the areas covered by sea ice that are beyond the boundaries of the Arctic region’s Polar Code. This article evaluates changes in sea ice extent and maritime traffic density beyond the Arctic Polar Code areas. The primary reason to investigate these two issues is the risk posed by sea ice to maritime safety in the polar waters. Although maritime traffic density and the sea ice exist in these regions, they are not covered by the Polar Code. The sea ice extent should have been the primary parameter to limit Polar Code boundaries. It is also revealed at the title of the regulations “guidelines for ships operating in Arctic ice-covered waters” as given in 2002 was revised to “International Code for Ships Operating in Polar Waters (Polar Code)” in 2017. The research question is: Why is the Polar Code, while enforced for ship operation in ice-covered waters (before)/polar waters (currently), not applied to some of the sea ice-covered waters? In the introduction part of the

Polar Code, ice is defined as the source of hazard in the first place. Moreover, it considers hazards that may lead to the increased probability of incidents with severe consequences. According to the definition of ice as a source of hazard, "it may affect hull structure, stability characteristics, machinery systems, navigation, the outdoor working environment, maintenance and emergency, preparedness tasks and malfunction of safety equipment and systems;" (Polar Code, 2017, p. 6). Besides, various definitions of sea ice types, such as first-year ice to old ice, are also included. Even though several research studies on Arctic shipping exist, little attention has been paid to Polar Code application areas. Some areas where sea ice is present and poses a structural risk to ships have been excluded from the Polar Code.

In this study, the 41-year monthly and daily data from the National Snow and Ice Data Center (NSIDC) database were scanned, and sea ice extent and concentration numerical data were interpreted as part of sea ice changes in the Bering Sea and the Sea of Okhotsk. To evaluate the changes in sea ice extent and concentration, based on historical measurements, satellite imagery and numerical models obtained from various remote sensing satellites were used. Furthermore, the variation in sea ice extent had been compared with previous studies, and various aspects of maritime safety had also been revealed. Moreover, the Automatic Identification System (AIS) data from marine traffic database were used to determine the areas where the shipping traffic in the Bering Sea and the Sea of Okhotsk is intensifying. Being prioritized and intensely used in commerce by countries, the Bering Sea and the Sea of Okhotsk have strategic and economic importance as they can be opened to oceans through the Arctic and the Pacific through the Bering Strait. Moreover, the density of the maritime traffic in these regions and the casualties resulted from various reasons are shown. The risky areas where the number of accidents are high are shown by processing some accidents on the map. It is also given with some examples that an analysis of ship accidents shows that most casualties were associated with sea ice. Consequently, it is stated that sea ice extent records should be the Polar Code's boundary in the Arctic. This research paper is published in the peer-reviewed journal, WMU Journal of Maritime Affairs 19, 219–234 under the title of "Polar Code Application Areas" by Meriç Karahalil, Burcu Özsoy, and Özgün Oktar (Karahalil et al., 2020). Earlier versions of the paper have been presented at the 2018 Arctic Frontiers Conference and Polar Age Symposium in Global Perspective in 2019.

The second article, presented in Chapter 3, discusses the physical and geographical differences between the Arctic and the Antarctic in the scope of the Polar Code. The focus is on sea ice extent and condition differences in two regions, which are critical to maritime safety. Chapter 3 is connected to Chapter 2 as it provides comprehensive sea ice conditions and maritime traffic densities in the Arctic. The Arctic and the Antarctic geographical differences in terms of the Polar Code's application areas are evaluated, and sea ice conditions and maritime traffic densities are compared. Data used throughout this article are several satellite-based data dating back to the 1970s. Information related to these satellites is provided in the methodology part of this article. Remote sensing data allow monitoring of the entire Arctic and Antarctic sea ice extent changes daily. Monthly and yearly averages are calculated by averaging the daily ice extents. Thus, the differences in sea ice in both regions are more clearly illustrated in the long-term trend figures. Significantly, the monthly deviation for Arctic maximum and minimum sea ice extents are March and September, respectively, and Antarctic maximum and minimum sea ice extents are September and February, respectively, from 1979 to 2019. Standard deviations of the trends in these months through the years are calculated and shown in figures. On the other hand, the relevant interpreted data come from academic articles related to sea ice research. Since most maritime activities are impacted by sea ice coverage and types, the study is limited according to physical differences of the Arctic and the Antarctic.

This research paper is published in the peer-reviewed journal, Journal of ETA Maritime Science, 2021; 9 (1): 31–40, under the title "The Assessment of Arctic and Antarctic sea ice condition differences in the scope of the Polar Code" by Meriç Karahalil and Burcu Özsoy (Karahalil & Ozsoy, 2021). Moreover, earlier versions of the paper have been presented at the National Polar Science Conference IV (December 22, 2020, The Scientific and Technological Research Council of Turkey (TUBITAK MAM KARE).

The third article, presented in Chapter 4, is strongly connected to Chapters 2 and 3. In Chapters 2 and 3, the differences between the polar regions are presented in terms of the importance of maritime safety, and the opinions of people working in the polar regions and the Polar Code are statistically interpreted in Chapter 4. In this study, the methodology is applied as follows. The hypotheses are based on the results of

Chapters 2 and 3 and relevant studies related to polar waters maritime safety issues. The questionnaire was developed based on 17 topics as shown in Appendix 1. It was prepared on Google forms and shared with the people through LinkedIn and was restricted to those who have sailing experience in polar waters. All respondents were granted anonymity. Surveying with experts is a popular method of data collection when research is relevant to future development. The part of the questionnaire referring to issues included the following questions:

- Do you think increasing maritime activities are linked to the melting of sea ice in polar regions?
- Do you think that the Polar Code is sufficient for safe ship operation and the protection of the polar environment?
- Do you think that the Polar Code needs to be separately developed for the Arctic and the Antarctic?

HP 1: Age, experience, region, and respondent's mission affect the part of the questionnaire referring to differences or the variables:
HP 2: Respondent's age affects the part of the questionnaire referring to issues.
HP 3: Respondent's years of experience affects the part of the questionnaire referring to issues.
HP 4: Respondent's region of work affects the part of the questionnaire referring to issues.
HP 5: Respondent's mission affects the part of the questionnaire referring to issues.

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 22.0. Relevant SPSS tests allowed the formulation of tables based on which different conclusions were made. Correlation analysis was used to determine the strength of the connection between factors and dependent variables.

This research paper is published in the peer-reviewed journal, Maritime Policy, 128 (2021) 104502, under the title "The Evaluation of The Polar Code by The Survey Conducted with Those Who Have Sailed in Polar Regions, And Suggestions for Further Improvement" by Meriç Karahalil, Burcu Özsoy, Ersan Başar, and Tanzer Satır (Karahalil et al., 2021).

2. POLAR CODE APPLICATION AREAS IN THE ARCTIC[6]

2.1 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 United States of America), Finland, and Sweden (Council, 2019). However, there are a variety of opinions regarding what exactly constitutes the boundaries of the Arctic.

The decreasing sea ice extent due to global climate change has been a growing concern in recent years. 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, 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 to 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 January 1, 2017, IMO adopted the Polar Code,

---

[6] This chapter is based on the paper: Karahalil, M., Ozsoy, B., & Oktar, O. (2020). Polar Code application areas in the Arctic. WMU Journal of Maritime Affairs, 19, 219-234.

aiming to supply safe and environmental-friendly ship operations in both the polar regions (Polar Code, 2017).

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 Enviroment 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.

2.2 Study Area

2.2.1 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 Working Group (EPPR), and Conservation of Arctic Flora and Fauna (CAFF) have different boundaries illustrated in Figure 2.1 (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 (Przybylak et al., 2003; Stonehouse, 2001). There is, also, a 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 & Barry, 2014).

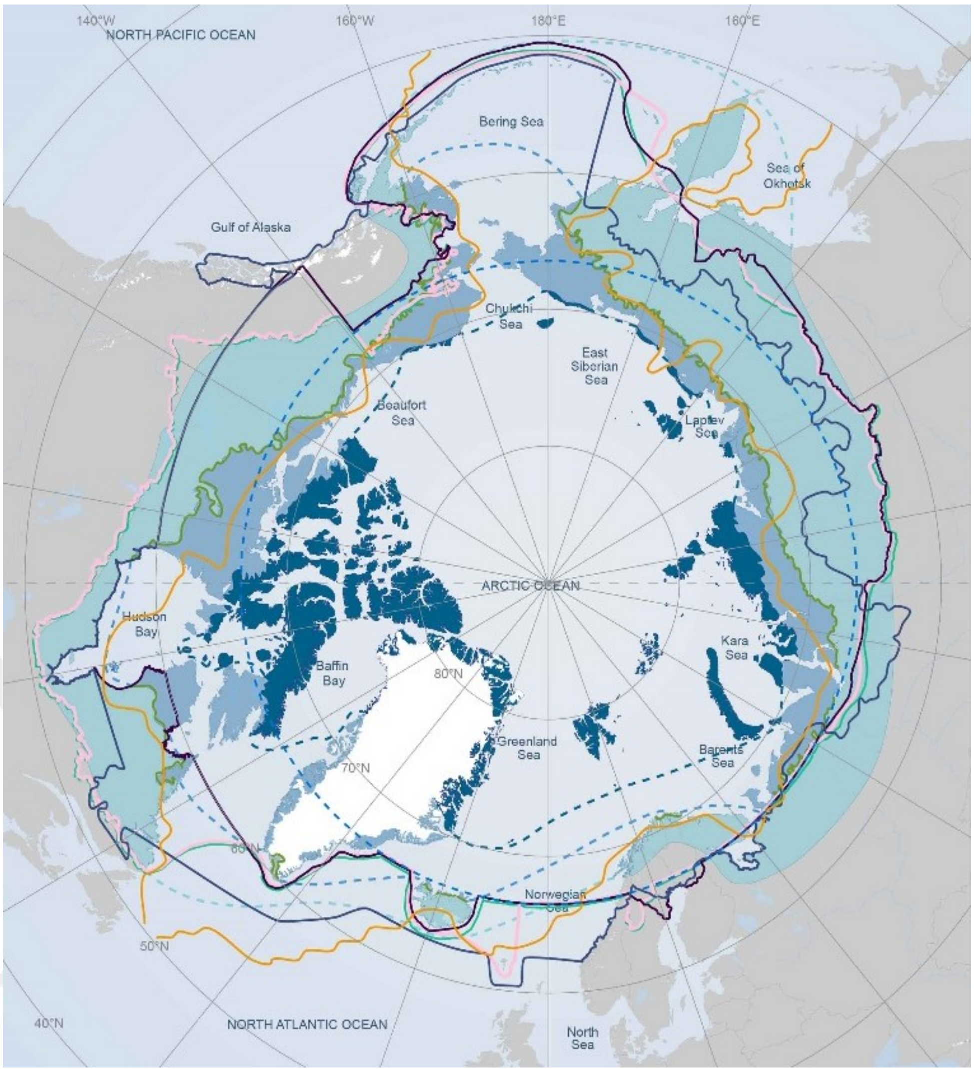

Figure 2.1 : Arctic boundaries (Grid-Arendal, ADHR, EPPR, NSIDC, AMAP, CAFF).

Table 2.1 : Arctic boundaries definitions.

High Arctic	**Low Arctic**	**Sub Arctic**

(dashed line)	the Arctic Circle (66°33'22" N) : The Arctic Circle is the southernmost latitude in the Northern Hemisphere at which the sun can remain continuously above or below the horizon for 24 hours
(orange line)	10°C July isoterm: Defined as being the area where the average temperature for the warmest month (July) is below 10° C
(dark blue line)	Arctic AHDR boundary: Arctic Human Development Report
(purple line)	Arctic EPPR boundary: The Emergency Preventio, Preparedness and Response
(pink line)	Arctic CAFF boundary: The Conservation of Arctic Flora and Fauna
(light blue line)	Arctic AMAP boundary: The Arctic Monitoring and Assessment Programme
(green line)	Arctic Treeline boundary: The northernmost latitude in the Northern Hemisphere wheretrees can grow; farther north , it is too cold all year round to sustain trees.

Boundaries of Arctic Council bodies differs regarding their assessment activities. For the AMAP assessment and recognising 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 upto 80°N, west of Spitsbergen, then to the Russian shore. (Stonehouse, 2001). Recognising 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.

2.2.2 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 regulations (Jensen, 2016). On January 1, 2017, the mandatory Polar Code was enforced. The Polar Code amends International Convention for the Safety of Life at Sea, 1974 (SOLAS 74) and International Convention for the Prevention of Pollution from Ships, 1973 (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, and training, etc. Part II addresses pollution from ships (Polar Code, 2017).

The working group on development of a mandatory Polar Code concluded that the definitions of Arctic and Antarctic waters as defined 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). Thus, sea ice extent should also be the determiner of the Polar Code' boundary in the Arctic as it is in UNCLOS Article 234. Nevertheles, 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 (SDE, 2011). As regards geographical application of Guidelines 2010, 'Arctic ice-covered waters' is defined in Section G-3.3 as:

> Arctic waters means those waters which are located north of a line extending from latitude 58º00′.0 N, longitude 042º00′.0 W to latitude 64°37′.0 N, longitude 035°27′.0 W and thence by a rhumb line to latitude 67º03′.9 N, longitude 026º33′.4 W and thence by a rhumb line to Sørkapp, Jan Mayen and by the southern shore of Jan Mayen to the Island of Bjørnøya and thence by a great circle line from the Island of Bjørnøya to Cap Kanin Nos and thence by the northern shore of the Asian continent eastward to the Bering Strait and thence from the Bering Strait westward to latitude 60º N 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 60º N and thence eastward along parallel of latitude 60º.N, to longitude 56º37′.1 W and thence to the latitude 58º00′.0 N, longitude 042º00′.0 W (see Figure 2.2) (IMO, 2010, p.7).

In Polar Code's introduction section, there is a definition and a figure which demonstrate the boundaries of the Arctic waters (Figure 2.2) (Polar Code, 2017).

Figure 2.2 : Maximum extent of Arctic waters application (Polar Code, 2017).

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 60ºN 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 (nm) 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 & Elsberry, 2019). Although shipping activity is low compared to other parts of the world, the capacity to provide aid for vessels in the strait is limited compared to elsewhere (Bering Sea Elders Advisory Group, 2011; PEW, 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, 2018).

The Bering Sea, a northern extension of the Pacific Ocean, which is over 2 million km² 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 1.000 transit large vessels carrying hydrocarbon resources within the next five 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, 2018).

The Okhotsk Sea, the northwestern extension of the Pacific Ocean, has an approximately 1.6 million km² 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).

2.3 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 60ºN. Furthermore, weather conditions beyond the 60ºN 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 is decreasing. Thus, it is imperative to analyse 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 sea state, 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 to 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 categorised 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 expenses 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 it is surrounded by many countries, the vast area of the Arctic region and its and harsh environmental conditions has rendered 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.

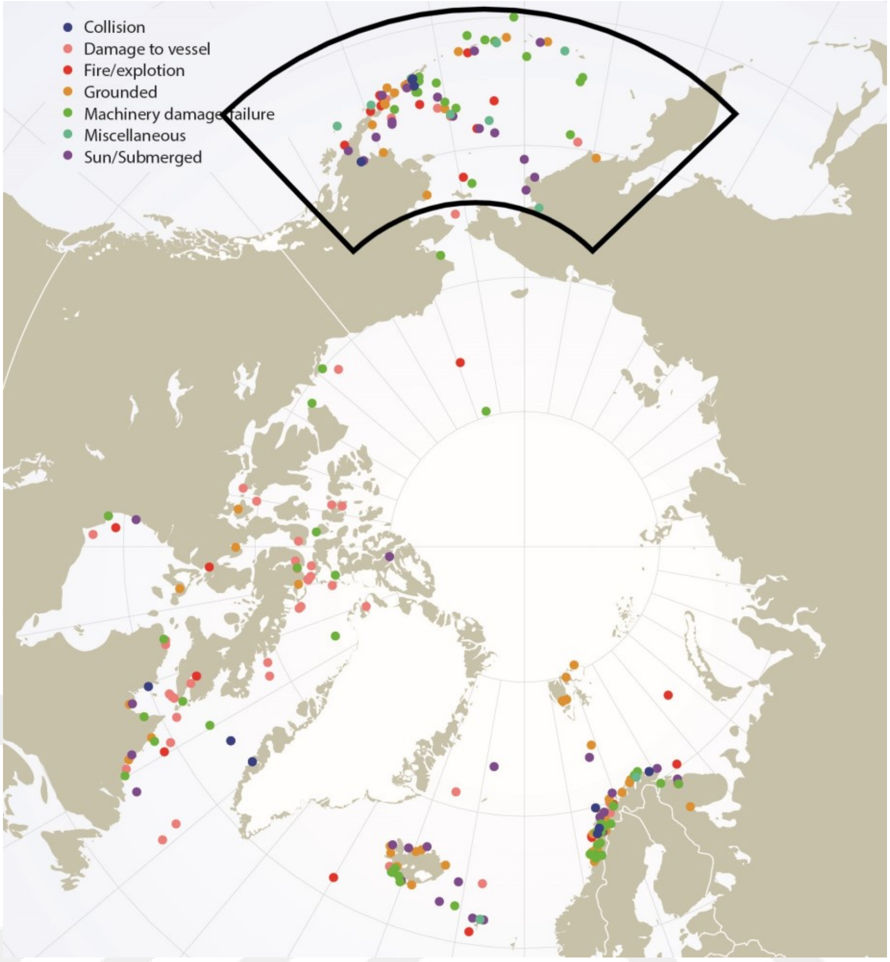

Figure 2.3 : Shipping incidents in the Arctic (Arctic Marine Shipping Assessment, 2009).

According to the Protection of the Arctic Marine Environment (PAME)' comprehensive Arctic Marine Shipping Assessment (AMSA, 2009), Figure 2.3 demonstrates the majority of shipping incidents have taken place in the coastal waters. The various coloured 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, 2013). Some examples of accidents in these regions are given below.

The fishing vessel Destination which was 33.5 meter length and 196 GT, sank in remote waters 2.6 nm northwest of St. George Island, Alaska, on February 11, 2017. None of the six crew members aboard were found in the accident. According to U.S.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 capsised and sank after an accumulation of ice on the vessel and its fishing gear after encountering forecasted heavy freezing spray conditions (NTSB, 2013).

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 the temperature was -22°C. The ships needed icebreaking assistance to be rescued. More than six hours later, nobody was injured, and all the fishermen were rescued (BBCnews, 2010; Leon, 2012). As Far East Shipping Company reported, the rescue operation took a month and cost approximately 5 million 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, 6.030 gross tonnage (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).

2.4. 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 & 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 & 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 & 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. NSIDC's data are derived from satellite imagery collected and processed by the National Aeronautics and Space Administration Goddard Space Flight Center (NASA GSFC). However, some of the instruments past its lifetime and some of these intruments failed that significantly increased the risk of a gap in coverage in the next years (Gerland et al. 2019). On the other hand, NASA GSFC 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 very high frequency (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 (Tsou, 2010; Willems et al., 2009). 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.

2.5 Results

2.5.1 The Arctic: The Bering Sea and Sea of Okhotsk Sea sea ice extent

The Arctic sea ice extent reaches its annual minimum (min.) 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 & Köberle, 2007; Screen & Williamson, 2017). According to NSIDC, this year's min. Arctic sea ice extent averaged 4.32 million km² (Figure 2.4a). This extent is 2.09 million km² below the 1981 to 2010 average. Arctic sea ice extent reached its maximum (max.) for 2019 at 14.78 million km². Furthermore, it is 860.000 km² below 1981 to 2010 average max. (Figure 2.4b) (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 & 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 evaluated, which is provided via satellite passive microwave records from 2018 to 2019 by the NSIDC. In Figure 2.4b, median sea ice edge 1981-2010, March 2019 sea ice extent, and Polar Code boundary are showed.

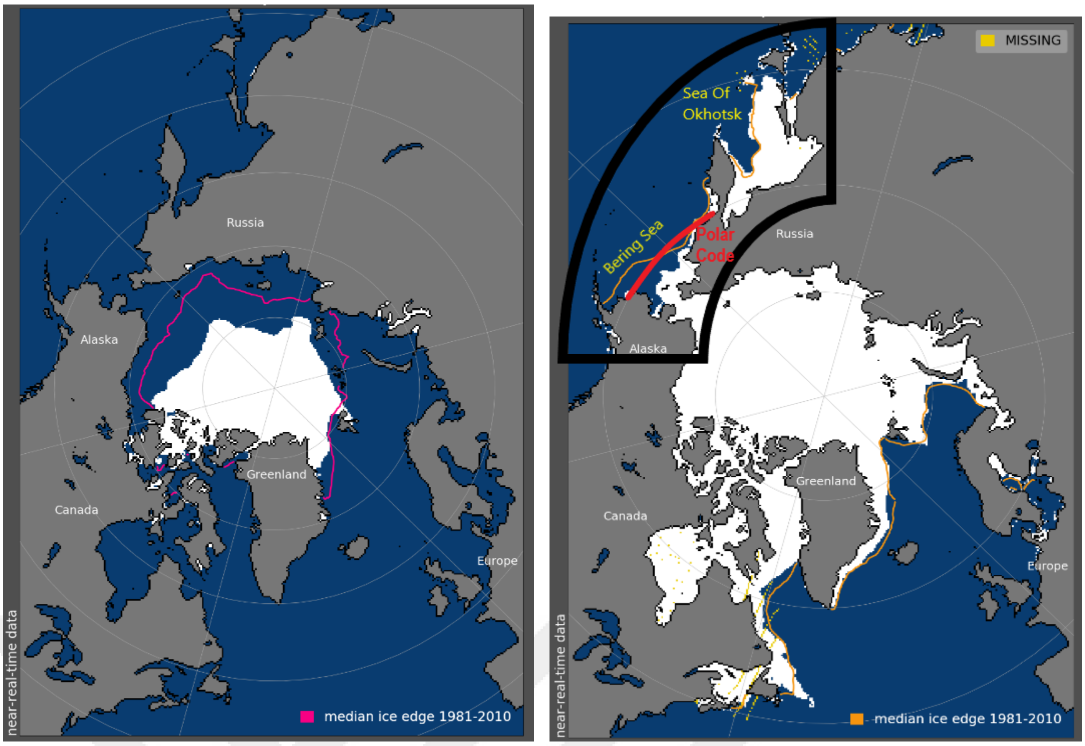

Figure 2.4 : a) Arctic sea ice extent at min. for 2019, b) Arctic sea ice extent at max. for 2019 (NSIDC, 2019).

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 (Figure 2.4b). Given are some figures (Figure 2.5 (a-f)) to illustrate the sea ice extent in the Bering Sea, Sea of Okhotsk, and the Sea of Japan over the last two years, spanning the months December to May.

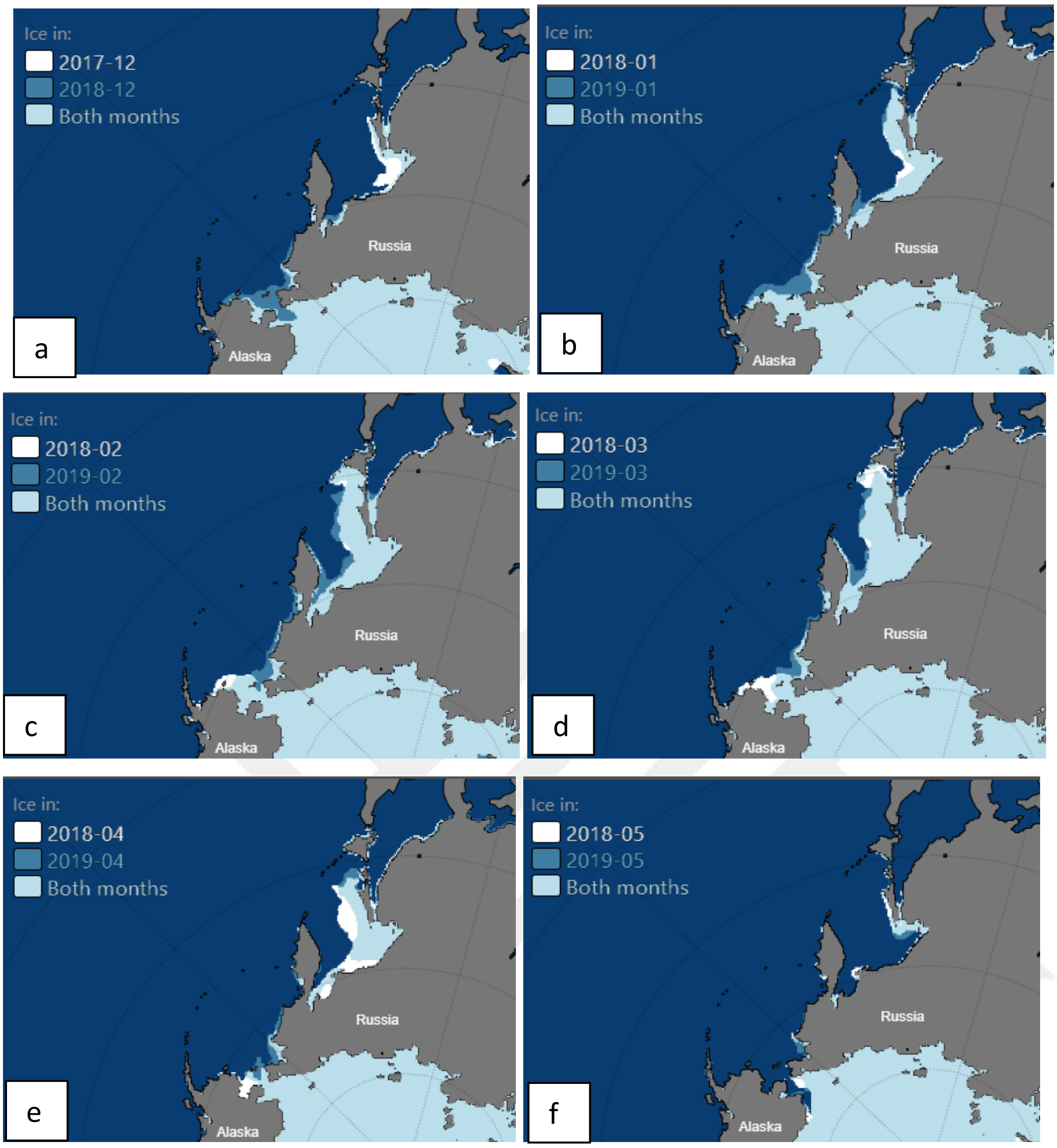

Figure 2.5 : a) Bering Sea and Sea of Okhotsk sea ice extents December 2017-2018, b) Bering Sea and Sea of Okhotsk sea ice extents January 2018-2019, c) Bering Sea and Sea of Okhotsk sea ice extents February 2018-2019, d) Bering Sea and Sea of Okhotsk sea ice extents March 2018-2019, e) Bering Sea and Sea of Okhotsk sea ice extents April 2018-2019, f) Bering Sea and Sea of Okhotsk sea ice extents May 2018-2019.

In Figure 2.6 (a and b), the graphs show Bering Sea and Sea of Okhotsk sea ice extent data for previous years. Although the max. 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 max. sea ice extent in these regions follow a long-term trend of reduction from 1979 to 2019 (Figure 2.7). 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).

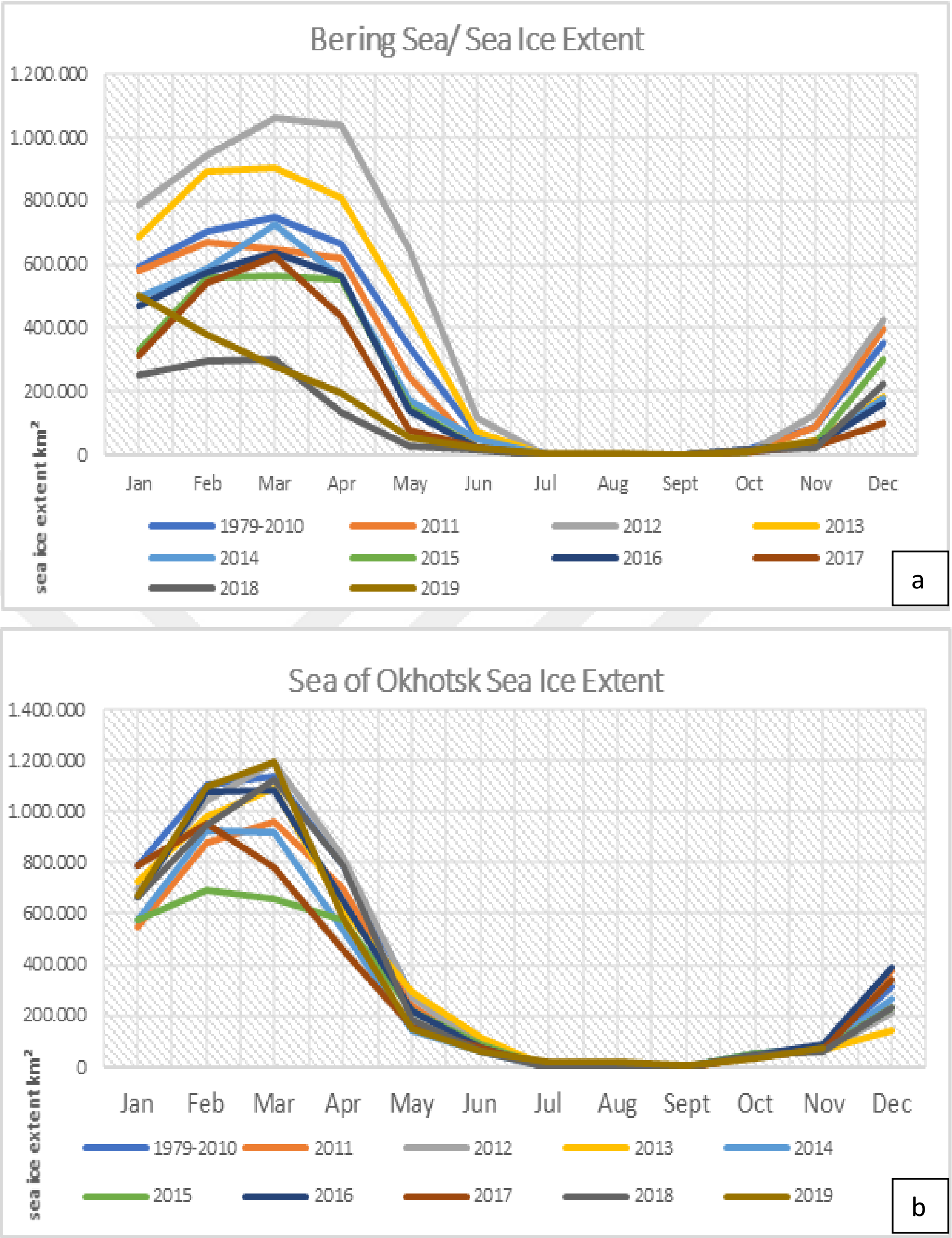

Figure 2.6 : a) Bering Sea monthly average sea ice extents from 1979 to 2019, b) Sea of Okhotsk monthly average sea ice extents from 1979 to 2019.

The northern part of the Okhotsk Sea is greatly influenced by the Arctic climate, and its average January temperature ranges between 8°C 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°C to -1.8°C in February and March that sea ice extent can cover upto 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 to 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 showed in Figure 2.7 (a, b).

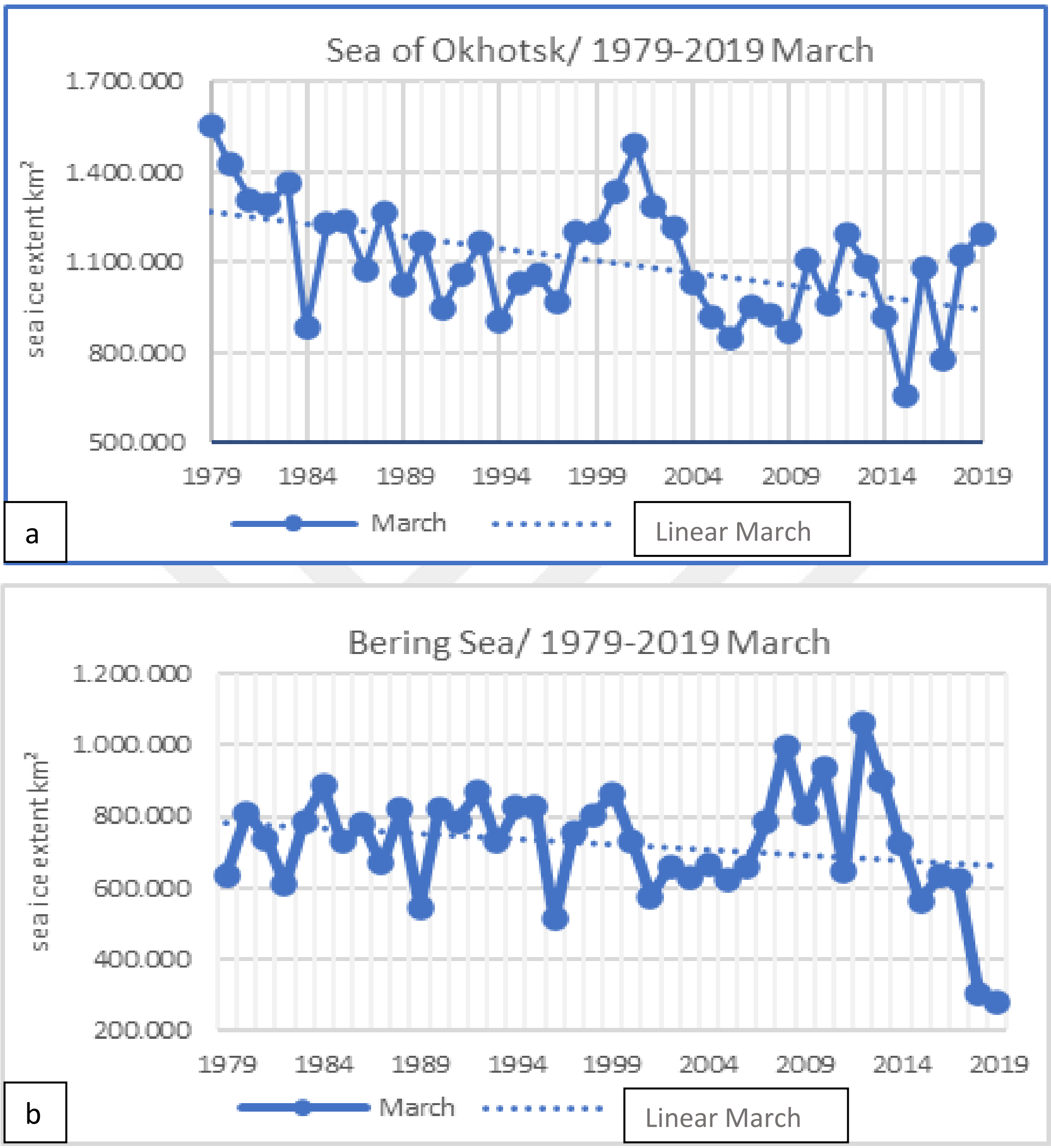

Figure 2.7 : a) Time series representation of March sea ice extents in the Sea of Okhotsk from 1979 to 2019, b) Time series representation of March sea ice extents in the Bering Sea from 1979 to 2019.

2.5.1 The density of ship traffic in the region

The availability of instant information from ships is provided by the AIS. Following the SOLAS rules set by IMO, AIS systems are compulsory in any cargo ship bigger than 500 GT transiting within national waters, all passenger ships, and all vessels bigger than 300 GT transiting international routes (Marinetraffic, 2019).

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 & Stephenson, 2013; Stephenson et al., 2013). Density maps of the regions illustrated in Figure 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 (Marinetraffic, 2019). The colours of lines show routes according to vessel type as in Figure 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 & special craft.

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 km^2. The "colder" colours show less dense routes. Moreover, the "hotter" the colours are, the higher the number of routes. These ship density maps are created based on the 2017 AIS datasets (Marinetraffic, 2019).

As seen in Figure 2.8 (a-h), according to vessel types cargo vessels, tankers, and fishing vessels density for the total year rate are 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.

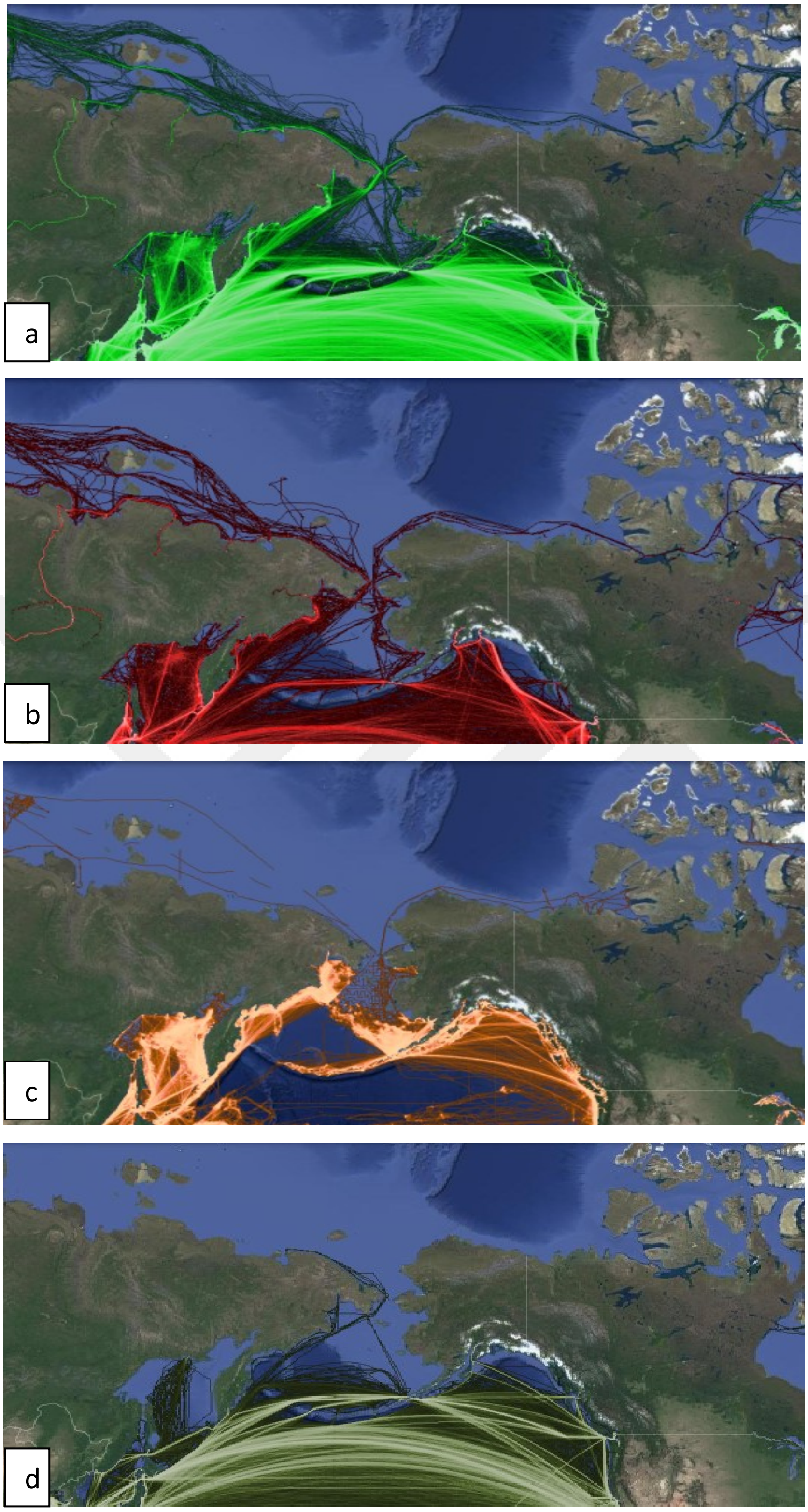

Figure 2.8 : a) Cargo vessels density map, b) Tankers density map, c) Fishing vessels density map, d) Container ships density map.

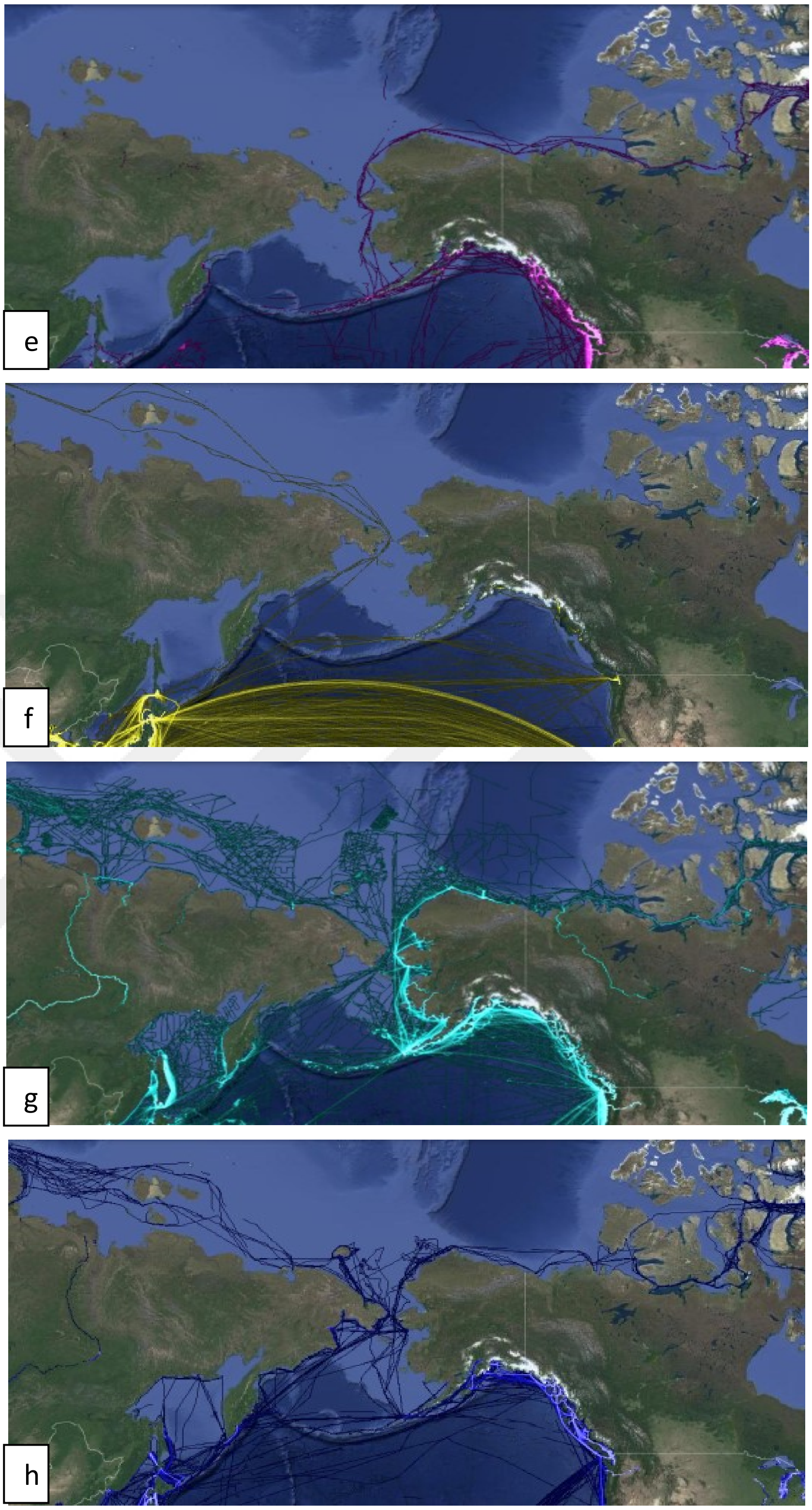

Figure 2.8 (continued) : e) Pleasure crafts density map, f) Gas carriers density map, g) Tugs/special crafts density map, h) Passenger ships density map.

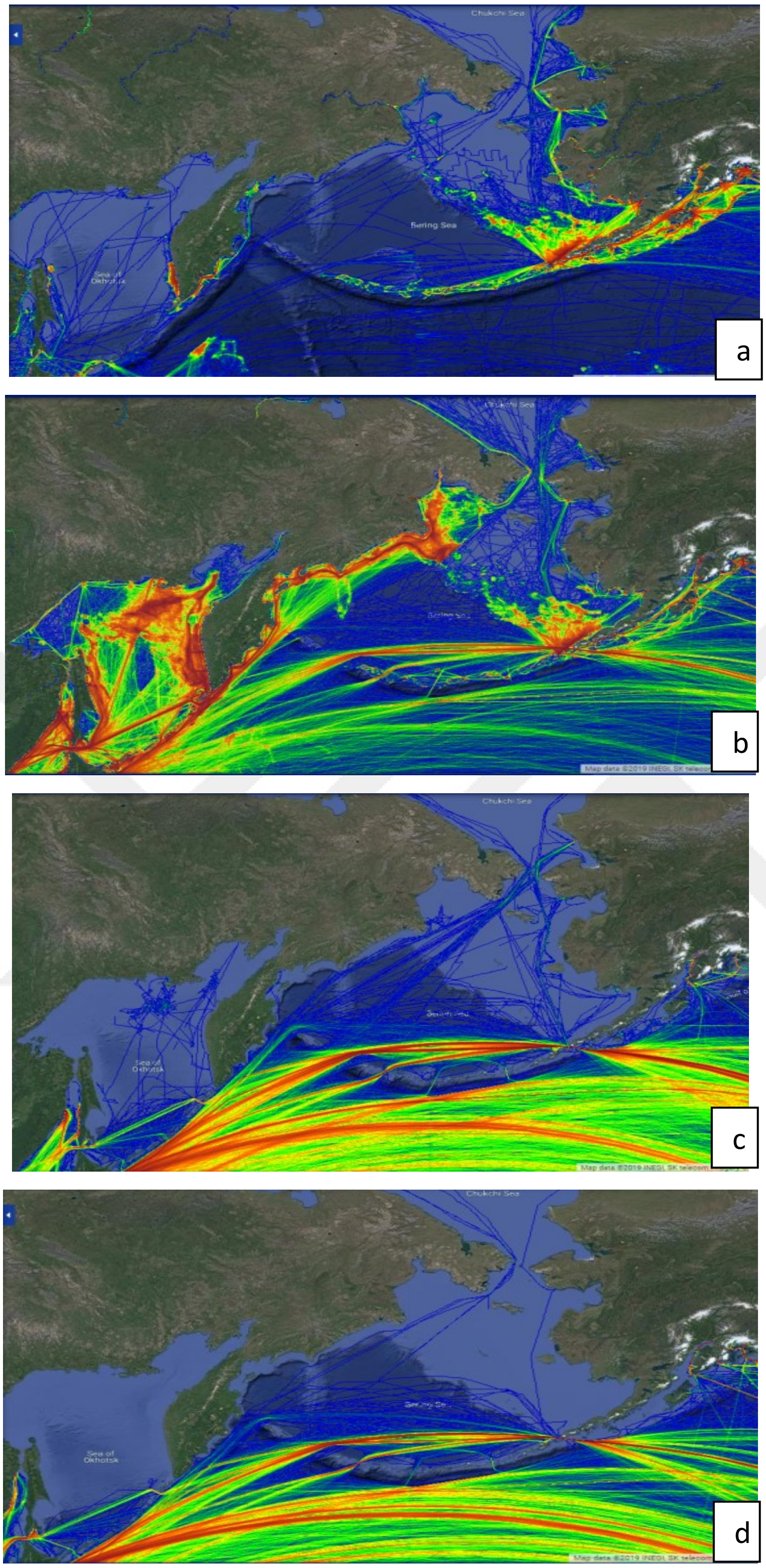

Figure 2.9 : a) Small size of vessels (GT< 500), b) Medium size of vessels (GT 500 - 25K), c) Large size of vessels (25K - 60K), d) Very Large size of vessels (GT> 60K).

On the other hand, the ship sizes also matter. Figure 2.9 (a-d) demonstrates the density of ships according to their size that are categorised into four different types.

Figure 2.9a show small size of vessels which are below 500 GT and the other figures are medium size (500 GT - 25K), large size (GT 25K - 60K), and very large size (GT 60K >) 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, Figure 2.9b is vital to analyze the Polar Code application areas and the size of ships.

2.6. 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, the boundaries of Arctic Council Bodies regarding their assessment activities to the Polar Code implementation areas are compared. Therefore, we investigated the maritime safety issues and ship accidents caused by sea ice in the 60ºN and beyond the 60ºN. Furthermore, the sea ice extent changes in the Northern Hemisphere based on NSIDC datasets are examined. 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 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, and type of ice, etc. The measures to address specific hazards in polar waters 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, a long period of sea ice extent in specific areas, if ship traffic density and recent maritime incidents taking 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 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.

3. THE ASSESSMENT OF ARCTIC AND ANTARCTIC SEA ICE CONDITION DIFFERENCES IN THE SCOPE OF THE POLAR CODE[7]

3.1 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 the partly ice-covered ocean surrounded by land areas of the eight Arctic countries. It is most commonly defined as the region above the 66° 33' N latitude parallel (Sun and Beckman, 2018; Zieliński et al., 2018). On the other hand, the Antarctic is a frozen land encompassed by the Southern Ocean, situated south of the 60° S latitude parallel (The Antarctic Treaty, 1959). There are noteworthy variances between them. For instance, the Antarctic sea ice forms a symmetric circle around the south pole, while the Arctic sea ice is asymmetric through some longitudes as a result of ocean currents and winds (Anisimov et al., 2007; Simmonds, 2015). The Arctic sea ice is not as mobile as that of the Antarctic and sometimes stays for more than five years. On the other hand, Antarctica sea ice does not stay on for ages or thicken as much as that in the northern hemisphere (Anisimov et al., 2007; Maksym et al., 2012). Thus, sea ice thickness and volume vary notably within both regions; Antarctic sea ice is characteristically one to two meters thick, while a large part of the Arctic is two to three meters thick.

It has been proved that 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 sea ice volume and extent (Gerdes and Köberle, 2007; Masson-Delmotte et al., 2019; Overland and Wang, 2013; Pachauri et al., 2014). It

[7] This chapter is based on the paper: 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

should be mentioned that 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 up of polar waters (Stroeve et al., 2014). Some studies reveal that the Northern Hemisphere may become ice-free in summers soon (Notz and Stroeve, 2018; Overland and Wang, 2013; Rogers et al., 2013). On the other hand, according to the 1979–2018 satellite passive microwave records, increases in Antarctic annual average sea ice coverage reached their highest record in 2014. However, this was followed by a sharp decline leading to the lowest value being measured in 2017 (Parkinson, 2019). Notably, sea ice prediction models and studies indicate that 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 present maritime opportunities, particularly in the Arctic (Humpert and Raspotnik, 2012). Potential Arctic sea routes between the Atlantic and Pacific oceans serve as a new passage for international maritime transportation organizations that provide financial and time savings due to the shorter distance between East Asia and Western Europe voyages (Arctic Shipping: Navigating The Risks And Opportunities, 2014). Although the transit numbers are still few today, the number of operations has been rising (Smith & Stephenson, 2013). The Northern Sea Route (NSR) will become an available course for open water (OW) ships, and the probability of transit will increase by approximately 94–98% between 2040–2059 (Issue 328, 2013). Moreover, the research regarding transportation in the Arctic proves that NSR could be a good alternative route for global logistics (Şahin et al., 2014). Additionally, two types of shipping activities are expected to grow in the Arctic region, namely, transit shipping, travel and transfer of goods from one port to another, and regional shipping, to exploit natural resources. Once there is more open water, the Arctic may see a boost in traffic with growth in natural reserves extraction. 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 (Borch, 2018; Marchenko et al., 2016). 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 (Council, 2009; Erazo, 2009). For instance, the trends to visit these remote areas by passenger ships to seek out unique ecosystems and species have been facilitated by tourists (Palma et al., 2019). On the other hand, the case is different for Antarctica. Antarctic resources are protected by the Antarctic Treaty (AT) signatory countries, and tourism and fishing are the only profitable activities adequately recognized by all AT members (Erbe et al., 2019). Additionally, AT consultative and observer 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 (ASOC, 2008). The 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 (Ghosh and Rubly, 2015). It also highlighted ice navigation research that ice navigation challenges involve interpreting sea ice conditions, weather, ship classifications, icebreaker assistance, and crew experience (Kum and Sahin, 2016). An investigation of maritime accidents in the polar regions revealed that accidents have mostly been related to sea ice, further categorized as ice floe hit, being trapped by ice, and ice jets (Marchenko, 2013). On the other hand, navigational challenges and the risks for the sips 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 (Kum and Sahin, 2015; Şahin, 2015).

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. Therefore, it is crucial to monitor and produce sea ice forecasts to support maritime operations (Sandven et al., 2006). The Polar Code's (PC) efforts to mitigate the hazards and reduce risks to the environment elevate "seaworthiness" to a higher standard (Cullen, 2016). However, there is a single mandatory PC for both polar regions. Although the preamble of the PC notes the differences between the two areas, we argue that some significant differences regarding sea ice have not been evaluated in the content. The question is, what are these differences and what is their interaction with PC? In this study, an overview of the Arctic and Antarctic sea ice condition differences via remote sensing data analyses in the PC's scope is provided. It is pointed out that the PC's inadequacies with some evidence of the impacts of ice conditions for ice navigation for further studies. Consequently, the research gaps for the further polar regions' maritime safety studies are declared.

3.2 Study Area

3.2.1 Sea ice in Arctic and Antarctic

The most apparent difference between the Northern Hemisphere and Southern Hemisphere is their geographical conditions (Kwok and Rothrock, 2009; Maksym, 2019; Maksym et al., 2012; Spindler, 1990). The changes in SIE for each hemisphere are clarified in the figures below. Figure 3.1 (a and b) demonstrate an example of max. and min. Arctic SIE. The yellow line indicates 1981–2010.

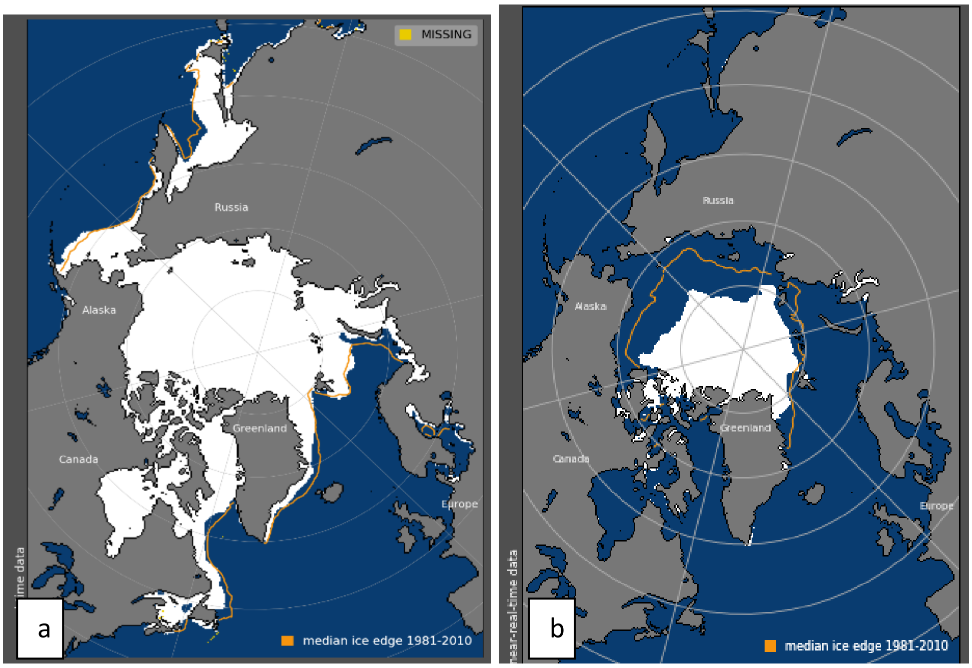

Figure 3.1 : a) The Arctic SIE, March 5. 2020, b) The Arctic SIE, September 18, 2019 (NSIDC, 2019).

NSIDC states that SIE typically covers about 14 million sq km in winter and 5 million sq km in summer. Arctic reaches the smallest SIE each September and grows to its max. each March. The Arctic SIE has diminished by about three percent per decade since 1979 (Cavalieri and Parkinson, 2012). The summer means Arctic sea ice thickness also has declined dramatically, leading to a decrease from 3.64 m in 1980 to 1.89 m in 2008, a total of 48% in thickness (Kwok and Rothrock, 2009). However, as ice sheets are more likely to crash into each other, thick ridge ice occurs. The ridge ice generally does not melt during the summer season and continues to grow the following autumn. The Arctic SIE was recorded at 14.78 million sq km on March 20, 2020, and 4.15 million sq km on September 18, 2019, 650.000 sq km and 2.10 million sq km below the 1981–2010 average min. extent, respectively (NSIDC, 2019). 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 (Overland and Wang, 2013).

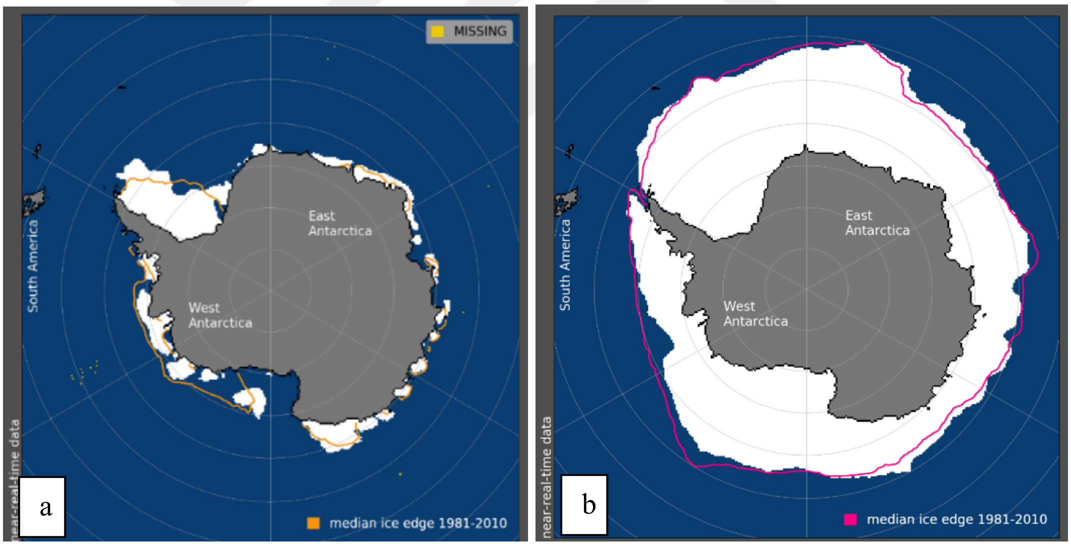

Figure 3.2 : a) The Antarctic SIE, February 20, 2020 (2.69 million sq km), b) The Antarctic SIE, September 2019 (18.244 million sq km) **(**NSIDC, 2019).

Most of the Antarctic is perennially coated by ice and snow, and during the winter season, an average of 18 million sq km of sea ice exists, but only about 3 million sq km of sea ice remains in summer. Each February, Antarctic SIE reaches its min. and grows to its max. in September that Figure 3.2 (a and b) show an example of the Antarctic SIE. As seen, 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 average month of February between 1979–2009. The annual min. of the Antarctic SIE 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 (NSIDC, 2019). The differences considering Southern and Northern hemisphere sea ice parameters are given in Table 3.1.

Table 3.1 : Polar regions sea ice differences.

	Arctic	Antarctic
Latitude	90 °N–38°N	55°S–75°S
Geo. Distribution	Asymmetric	Symmetric
Type of ice	Mainly columnar	Mainly frazil
Melting Process	Air/ice interaction	Ocean/ice interaction
Ice shelf	Not present	Present
Platelet ice	Not present	Present
Land fast ice	Over shallow water	Mainly over deep water
Melt ponds	Significant	Insignificant
Polynyas	Coastal	Open ocean

As seen in Table 3.1, there are a variety of differences. Geographical distribution is quite the opposite when the Arctic sea ice grows asymmetric, whereas the Antarctic sea ice remains symmetric. Sea ice can currently exist at 38° N in the Arctic and 55° S in the Antarctic regions. Owing to the difference in sea ice evolution processes, ice types differ. In the Antarctic, frazil ice is common and columnar surface is also found, though more rarely. In the Arctic, the topside of ice comprises frazil ice, while the downside is mainly congelation ice (Spindler, 1990). Many Arctic ice melts at the air and ice interaction, while the Antarctic sea ice usually melts at the ocean and ice interaction. As a result, melt ponds are rarely observed in Antarctica, whereas they take a large part of the Arctic ice surface (Zhang et al., 2018). Thick and extensive ice-shelves surround 75% of Antarctica's coastline; however, they are not typical for the Arctic (Ice shelf collapse, 2020). 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 (Dieckmann et al., 1986). Landfast ice in the Arctic comes in direct contact with the seafloor, while in Antarctica, it is typically found at water depths since most of the shallow areas are sheltered by the ice-shelves shelter. Polynyas are divided into two types. Open-ocean polynyas are estimated to occur due to deep warm water that is mainly common in Antarctica. Katabatic winds are believed to cause coastal polynyas typically found in the Arctic region (Leppäranta, 2019).

3.2.2 Polar Code (PC)

The IMO undertook work on a code for regulating ship design and building, and operations in the early 1990s, and the Guidelines for Ships Operating in Arctic Ice-covered waters were accepted in 2002 (Jensen, 2007). Nevertheless, these guidelines were to apply only to the Arctic and did not include the Antarctic region. Afterward, noteworthy arrangements were made by IMO in 2009, amending them to cover the Antarctic waters (IMO, 2009; Arctic Yearbook, 2014). Finally, the IMO changed the regulations from guidelines to compulsory lawful requirements. It has been a long process for the PC, and it entered into legal force on January 1, 2017 (Jensen, 2016; Polar Code, 2017). The PC is structured on the former IMO instruments, and it consists of three parts. These are the introduction, safety measures (Part I), and pollution prevention measures (Part II). The PC Part II consists of 5 chapters that will not be evaluated in this study. Within the scope of PC, the sources of hazards in polar regions have been identified as ice, low temperature, periods of darkness and daylight, remoteness, and lack of accurate information and crew experience (Polar Code, 2017).

The PC Part I consist of 12 chapters, and it focuses on the safety of shipping in polar waters and addresses a wide range of safety measures, including the need for ships to have a polar 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 the PC applies shall have a Polar Ship Certificate

(PSC) concerning the design and construction of ships and equipment, crew and passenger clothing, ice removal, and fire safety. To support the decision-making process, the Polar Water Operational Manual (PWOM) was developed to provide standards for vessels and crew, information about the ship-specific operational capabilities, limitations, procedures to be followed in normal operations, and the event of incidents (Polar Code, 2017). The other chapters of Part I are: 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 (POLARIS) is a significant tool for assessing the ships' operational limitations and risk of navigation in ice as the PSC and PWOM, but it is not a mandatory requirement. Its limitations are the human factor, the frame of application, and legal status (Fedi, 2018). 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 light ice conditions and ships without ice class are treated insufficiently (Fedi et al., 2018).

3.3 Methodology

The sea ice observations have been carried out from 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 satellites are utilized widely in research and to monitor the SIE and other parameters (Ozsoy-Cicek et al., 2011; Sandven et al., 2006).

The evolution of remote sensing systems for satellites overtime commenced with the launch of the Russian Cosmos-243 satellite in 1968. Later, 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 sea ice concentration extent with at least 15% sea ice. The US's Defense Meteorological Satellite Program (DMSP) introduced passive microwave sensors, special sensor microwave imager (SSM/I), and particular sensor microwave imager and sounder (SSMIS) instruments. The first long-term sea ice data was provided for scientists after the introduction of SSMR (NSIDC, n.d.). In 2003, NASA launched the Ice, Cloud, and land Elevation Satellite (ICESat) to track 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 (NSIDC, n.d.). 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 Centre (DAAC). The NSIDC DAAC provides comprehensive data on sea ice, ice sheets, and ice shelves to support research. The NSIDC DAAC archive and distribute cryospheric data from NASA and help researchers utilize the data products (NSIDC, 2020).

3.4 Results

3.4.1 Arctic sea ice extent (SIE)

Figure 3.3a displays the average monthly SIE values for 1979–2019. From the years 1979 to 2009, the average monthly values are indicated by the thick blue curve. The red line represents 2019 and remains below the average of 1979–2009 in all months. In the last decade, all values have remained below average and each year exceeds the recorded value of the previous year. In Figure 3.3 (b and c), the average monthly SIE each March and September between 1979 to 2019 is indicated, when the Arctic ocean begins to freeze and melt, respectively.

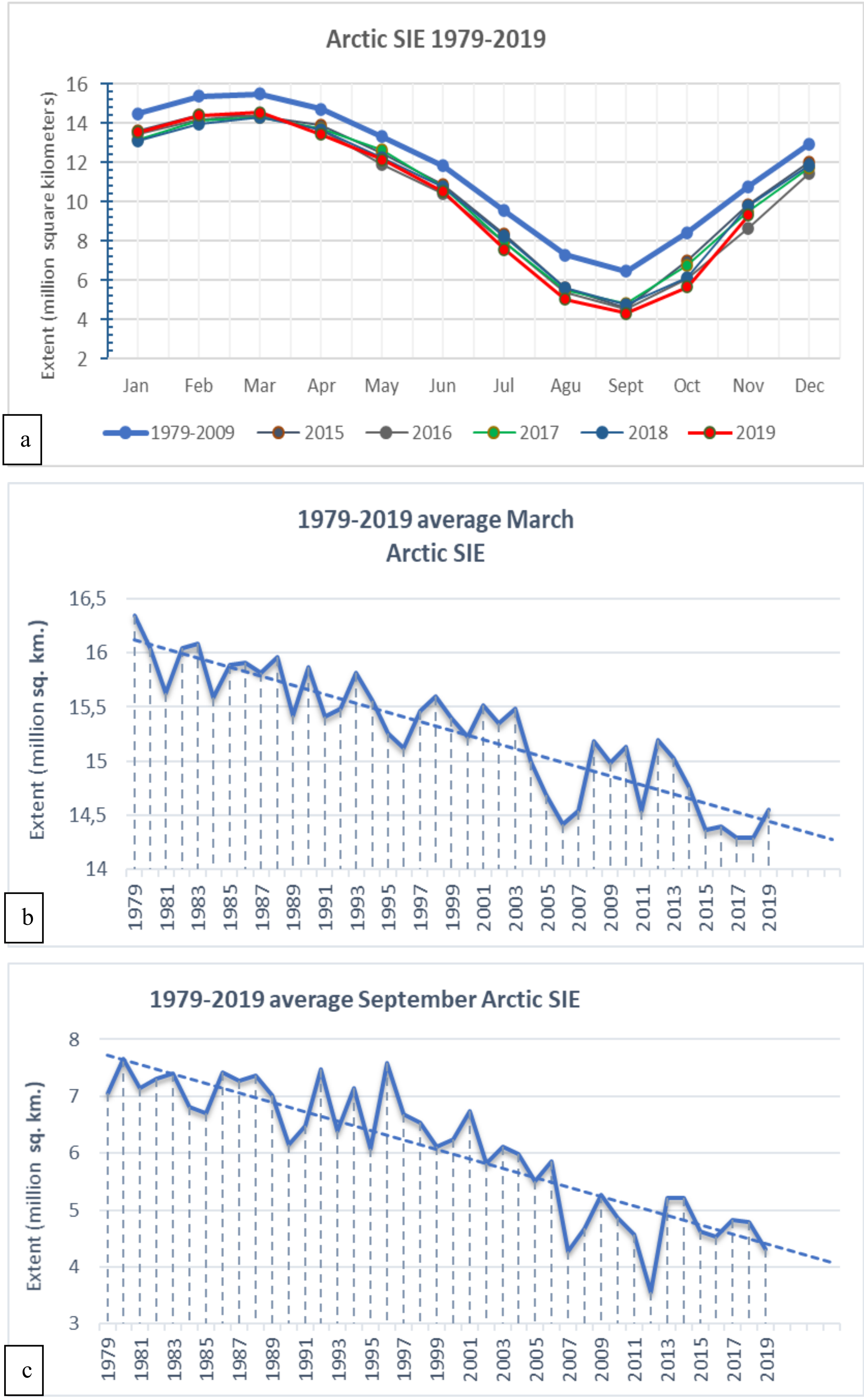

Figure 3.3 : a) The Arctic SIE 1979–2019, b) The Arctic SIE, average March 1979–2019, c) The Arctic SIE, average September 1979–2019.

In March, the SIE in the Arctic region is declining at a rate of 2.6% per decade, while in September is declining at a rate of 12.85%. As the linear trendline shows, the Arctic SIE for both months is decreasing at a steady pace. September has experienced the most significant declines thus far. As a result of this decreasing trend, the periods when sea ice begins to freeze are lengthening. September receives the most attention because it is the month with the least SIE.

3.4.2 Antarctic SIE

Figure 3.4a displays the average monthly Antarctic SIE for 1979–2019. The thick blue curve indicates the average monthly SIE values between 1979 to 2015. Figure 3.4 (b and c) shows the average monthly Arctic SIE each February and September between 1979 to 2019. The February and September 2017 SIEs 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 the 41 years of the dataset, 1979–2019) indicate trends until 2014. Following that, they reach a record low in three years. The Antarctic min. monthly ice extent always occurs in February and is still well under 5 million sq km.

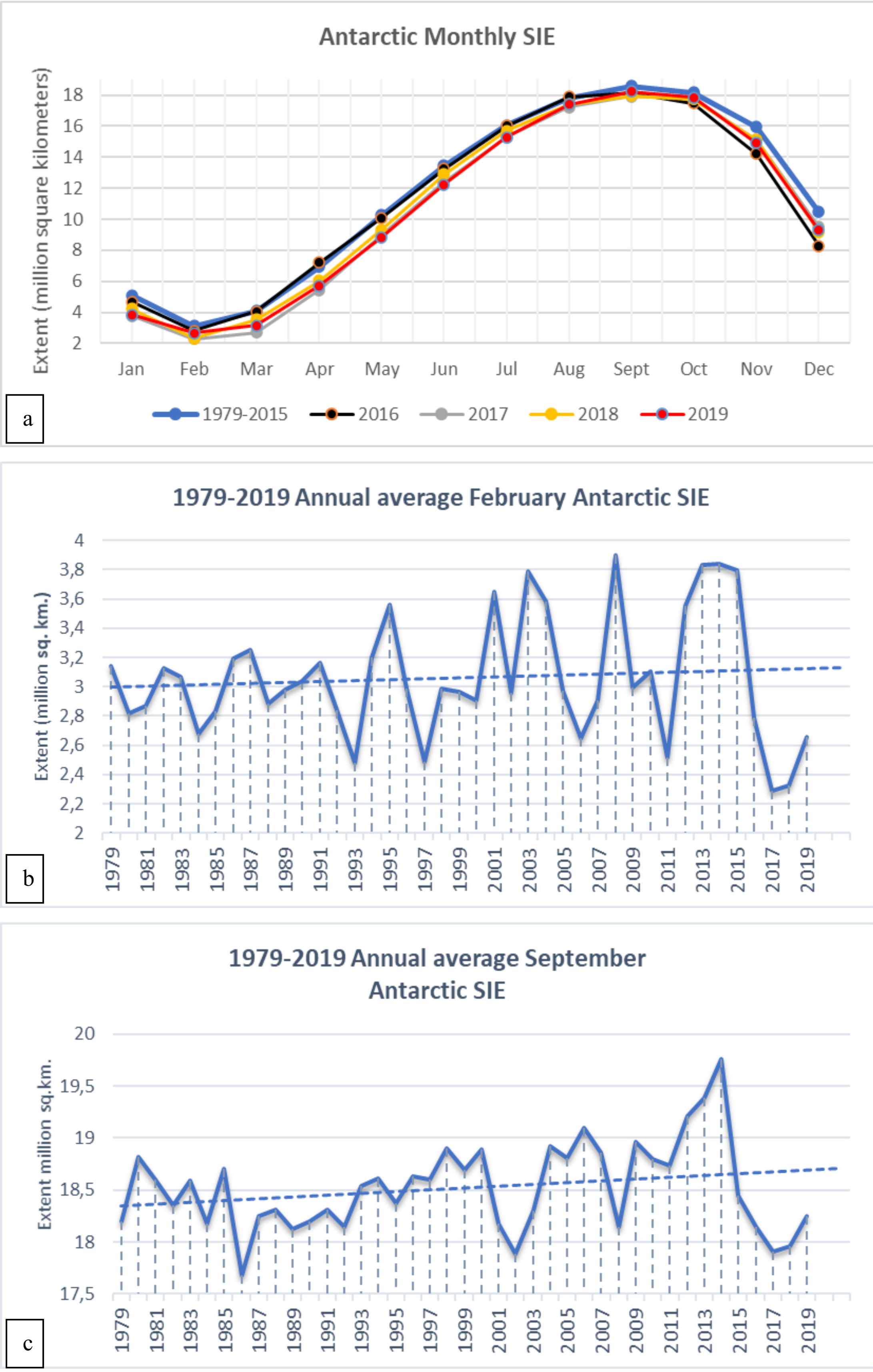

Figure 3. 4 : a) The Antarctic SIE 1979–2019, b) The Antarctic SIE February 1979–2019, c) The Antarctic SIE September 1979–2019.

Table 3.2 : Arctic and Antarctic SIE differences.

	Arctic	Antarctic
Max./Min. SIE Months	Mar./Sept.	Sept./Feb.
Max. SIE	16.342 x 10^6 km² (Mar. 1979)	19.756 x 10^6 km² (Sept. 2014)
Min. SIE	3.566 x 10^6 km² (Sept 2012)	2.288 x 10^6 km² (Feb. 2017)
The trends in SIE; 1979–2019	Significant decrease	Small decrease
Snow Thickness	Thinner	Thicker
Mean Thickness	1976: 5 m	0.5–0.6 m
Typical Thickness	> 2 m	< 2 m
Strength of ice	High	Low
The age of ice	Largely multiyear ice	Largely one-year ice
The Average Multi-year ice area	1979 to 1996; 5.531 × 10^6 km^2, 1997 to 2016; 4.226 × 10^6 km^2	3.5 x 10^6 km²

As seen in Table 3.2, they both reach their max. during winter and shrinks down to the min. during summer. The Arctic min. SIE September 2012 and max. SIE March 2017 extents have been the lowest recorded in the satellite's 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% compared to the average in the month of September between 1979–2019 and 6.1% in March. The lowest monthly average Antarctic SIE was 2.288 million sq km in February 2017, and the record low yearly average for the same was 10.75 million sq km in 2017. Snow thickness creates a big difference between both poles. Snow reaches 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, Antarctic sea ice characteristically is below the two meters range. Multiyear ice, which has survived more than one melting season, is three meters thick or more and firmer than 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 it remains in a few coastal regions.

3.5 Discussions

The development of the PC and its importance and shortcomings for ice navigation are introduced in section 2.2. Although it is stated in the PC that the differences were taken into consideration during the efforts for adaptation to the Antarctic, 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 the environmental factors such as ice thickness, ice formation, weather conditions (wind, fog, visibility, temperature), the drift of pack ice, floating ice floes, and ice restrictions, which affect the vessel's movement, etc. (Şahin, 2015). Due to its characteristic of 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 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 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 of one-tenth coverage or higher. The PC's Arctic boundary should be changed to cover the sea ice edge of the 1979–2010 line rather than the 60° N line (Karahalil et al., 2020). As mentioned in the previous sections, maritime activities in the Antarctic region involve passengers, fishing, research, and re-supply ships, while those in the Arctic include various types of vessels in operation. It is an actual outcome considering the PC that patterns of activities differ within the Arctic and Antarctic regions. Additionally, while there has been an increase in the Arctic maritime activities, no significant traffic density increasing 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% (PAME, 2020). Besides, many vessels currently operating in the polar regions are non-SOLAS, which means not compliant with PC that 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 (3m or thicker) while the Antarctic mainly has first-year ice (0.3m - 2m thick). Even first-year ice might damage the vessel hull, and multiyear ice impact might 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. And, drift ice motion takes place differently even within each region (Ice shelf collapse, 2020; Talley et al., 2011). There should be up-to-date ice information for masters sailing in the polar regions to make tactical navigation decisions.

On the other hand, PC Part I, Chapter 11, "Voyage Planning," goal is to ensure sufficient information for the safety of ships and the crew and passengers and environmental protection. One of the most critical issues in this chapter is that the master shall consider a route, taking into account areas 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 (COMNAP 2019) that although there are significant differences between the polar regions, there would be best practices to learn from Arctic SAR agencies. Moreover, multiple criteria such as regulations and restrictions, traffic congestion, charges, route length, sea depth, weather, sea conditions, etc., are the critical factors for voyage planning, which differs in two regions (Şahin, 2015). For instance, the ice-strengthened passenger ship M/S Explorer was the first ship that sunk in Antarctic waters following a collision with ice in 2007. According to the incident report, the primary cause was the ship masters's misjudgment of ice where they were countering. Even master worked in the Baltic Sea; Antarctic ice conditions have shown to be rather different from the Baltic (R.L., 2009; Stewart and Draper, 2008).

The human factor in the polar regions is crucial that 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 (AMSA, 2009). Seafarers are usually inadequately trained to deal with polar conditions (Karahalil and Ozsoy, 2018; Kum and Sahin, 2016). PC Part I Chapter 12, "Manning and Training" aims to ensure adequately qualified, trained, and experienced personnel. There should be a curriculum that addresses both polar regions' differences for the ice navigation in polar waters in basic and advanced level training.

3.6 Conclusions

In this study, we analyzed the SIE changes in the Arctic and Antarctic regions based on 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 Arctic and Antarctic sea ice characteristics were compared within some limitations. Since 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. And in the discussion section, some critical issues arising from sea ice condition differences in ice navigation were pointed out. This 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. The 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 research points to the need for future improvements of the mandatory PC for each polar region separately.

4. THE EVALUATION OF THE POLAR CODE BY THE SURVEY CONDUCTED WITH THOSE WHO HAVE SAILED IN POLAR REGIONS, AND SUGGESTIONS FOR FURTHER IMPROVEMENT[8]

4.1 Introduction

The Arctic and Antarctic are recognized as being geopolitically important and extremely vulnerable that ongoing impacts of the global climate change on sea ice extent (SIE) have likely to affect biodiversity and human activities (Anisimov et al., 2008). 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 (Humpert and Raspotnik, 2012; Lee and Song, 2014; Smith and Stephenson, 2013). 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 (Dawson et al., 2018; Meredith, 2019). 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 (Chown and Brooks, 2019; Erazo, 2009). Research vessels are existing all-year-round, reach a maximum in January and February. Additionally, there are supplying vessels for the supply of

[8] This chapter is based on the paper: 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,(2021),104502 https://doi.org/10.1016/j.marpol.2021.104502.

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 (COMNAP, 2019).

In order to take advantage of the commercial benefits, the risks and hazards of extreme circumstances of the Arctic and Antarctic should be understood (Ghosh and Rubly, 2015). 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 (Polar Code, 2017). 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 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 (Erbe et al., 2019). Although the PC is a risk-based instrument, it has limited capacity to assist risks (Fedi et al., 2018). The study on maritime accidents in Arctic waters mentions the importance of crew training and requirements due to risk mitigation (Kum and Sahin, 2015). 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 (Schmied et al., 2017). 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 (ASOC, 2013). Maritime safety depends on the skills of experienced mariners in the polar waters (AMSA, 2009). 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 SAR operation issues are the main topics in forums like the Council of Managers of National Antarctic Programs (COMNAP, 2016; COMNAP, 2019).

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 (Polar Code, 2017). 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 that applied to experienced seafarers and scientists working in the region. In this article, the PC further improvement suggested by taking into account the issues raised. 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.

4.2 Study Area

4.2.1 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 (Bertelsen and Gallucci, 2016; Hansen et al., 2016; Lee and Song, 2014; Ma, 2019; The Security Council of the Russian Federation, 2015). 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 (Ottawa, 1996). 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 (Humpert and Raspotnik, 2012; Smith and Stephenson, 2013). 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 nm and nine days (Lee and Song, 2014). Moreover, it represents fisheries' opportunities, scientific research, energy development, and tourism with great potential (Boylan and Elsberry, 2019; Palma et al., 2019; Silber and Adams, 2019). 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 to 1628 ships) from 2013 to 2019. In 2019 of all vessels navigated in the PC area, 41% were fishing vessels, as seen in Figure 4.1.

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 nm, 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 (PAME, 2020). 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.

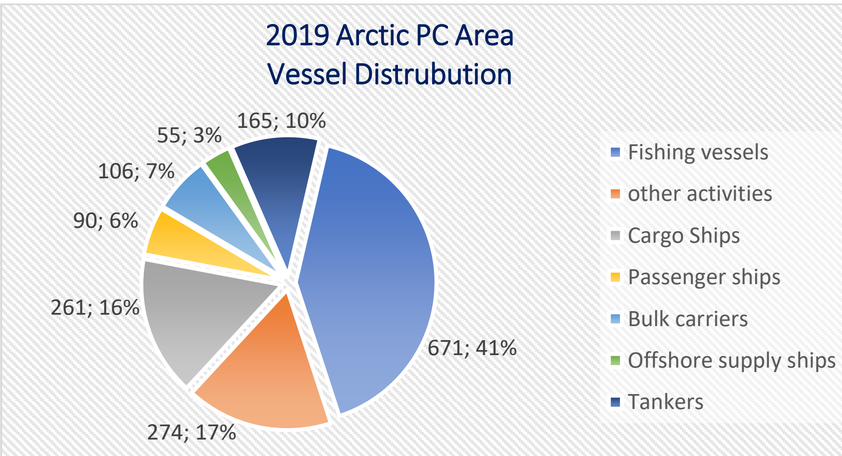

Figure 4.1 : Shiping Activities in Arctic PC Area in 2019 (PAME 2020).

It is also necessary to understand sea ice change, which directly impacts maritime activities. For the last four decades, the average Arctic SIE for all months showed melting trends. According to NSIDC data, in the 2020 season, Arctic SIE had a max. of 15.05 million square kilometers (sq. km.) in March and a min. of 3.74 million sq. km. in September, which are respectively 0.59 million sq. km. and 2.51 million sq. km. below 1981 to 2010 average max. and min. extents (NSIDC, 2020). Figure 4.2 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.

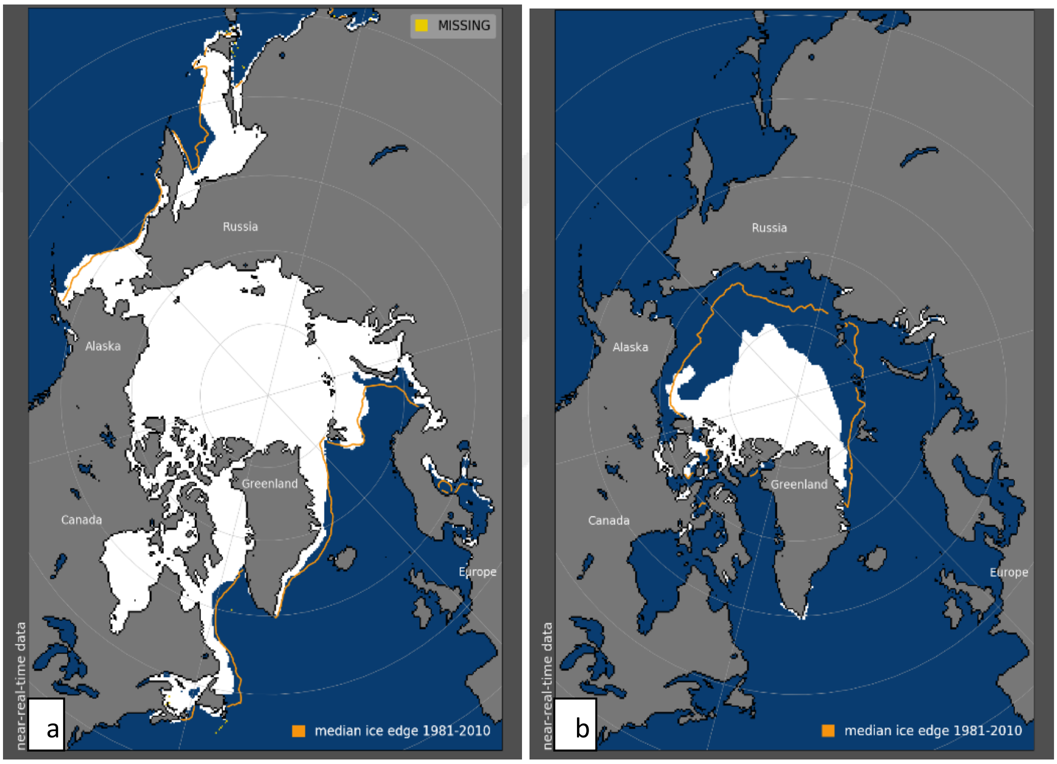

Figure 4.2 : a) The Arctic SIE in March 5, 2020, b) The Arctic SIE in September 15, 2020 (NSIDC, 2021).

4.2.2 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 60ºS latitude determined by the AT (The Antarctic Treaty, 1959). 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 (CCAMLR, 2020; IAATO, 2019; ASOC, 2008). 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 (CCAMLR, 2020; IAATO, 2019; Overland and Wang, 2013). 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 (Haward, 2012). 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 (IAATO, 2019). 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 Figure 3., in the 2020 season, the Antarctic SIE had a min. of 2.9 million sq. km. in February and a max. 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 to 2010 average min. and max. extents. Antarctica sea ice does not remain ages and thicken as much as in the Arctic.

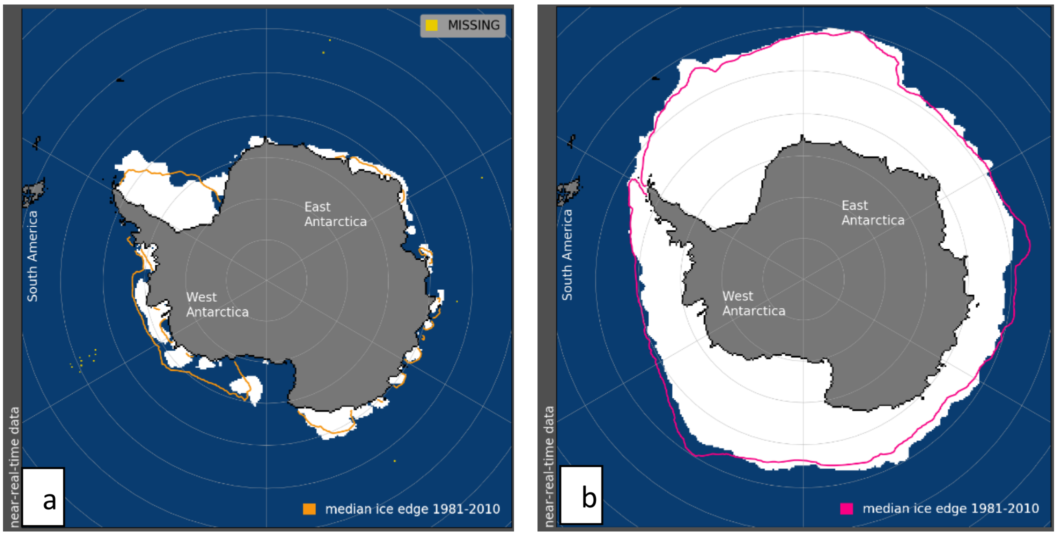

Figure 4.3 : a) The Antarctic SIE in February 21, 2020, b) The Antarctic SIE in September 15, 2020 (NSIDC, 2021).

4.3 The Polar Code

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. 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) (Weber, 2012) 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 (IMO, 2009), and the move to develop a mandatory Code followed the adoption by the 86th session of the IMO’s MSC a legally binding regime for navigation in polar waters was formally proposed. Those additional provisions are considered necessary to existing requirements of the SOLAS and the 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 (Polar Code, 2017). 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 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 (IMO, 2020). 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 Figure 4.4. Figures illustrate the Arctic and Antarctic waters, as defined in SOLAS and MARPOL regulations (Polar Code, 2017).

Figure 4.4 : Polar Code Arctic boundaries.

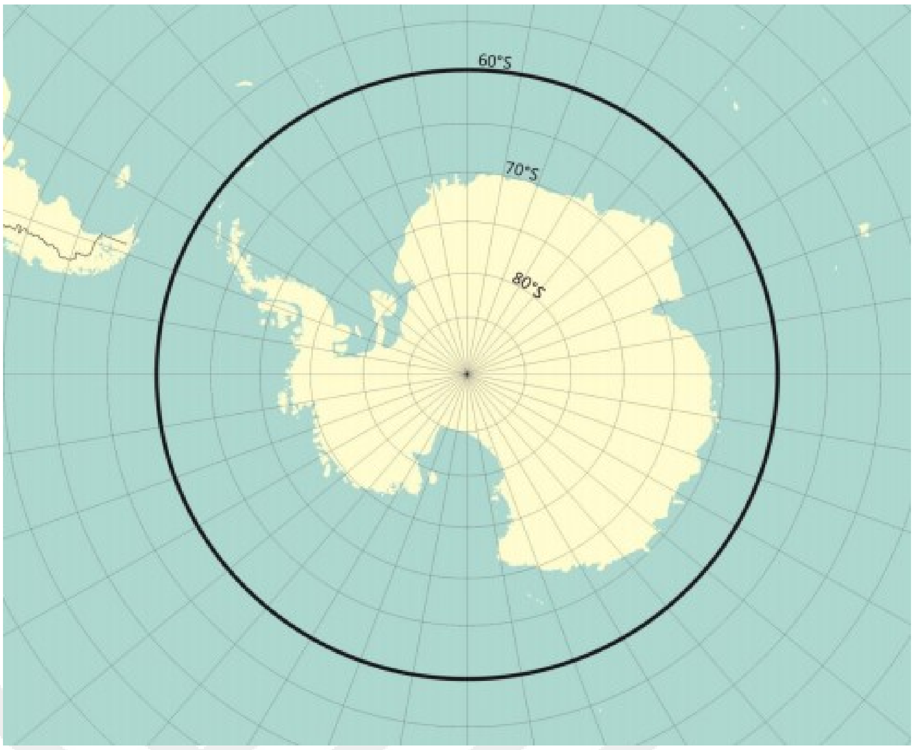

Figure 4.5 : Polar Code Antarctic boundaries (Polar Code, 2017).

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 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 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 (Polar Code, 2017).

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." (Polar Code, 2017, p.5). 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.

4.4 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.

4.5 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 0-5 years, 38% between 5-10 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.

Table 4.1: 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 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=1,547; p>0,05) Even though there was no statistically significant difference as stated above, each 17 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 (<500 GT), 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 to 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 to 10 years. The other significant difference considering above stated second question is the participants who have sea service 0 to 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 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=0,134; 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 ($F=4,722$; $p<0,05$).

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 ($F=1,501$; $p>0,05$). 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 ($F=0,532$; $p>0,05$). 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. ($F=0,178$; $p>0,05$) 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?” ($r=.577$, $p<.01$). 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?” ($r=.542$, $p<.01$). 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?” ($r = .478$, $p < .01$). 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?” ($r = .441$, $p < .01$). 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 0,705 for the PCs scale, as seen in Table 4.2. As this value satisfies the study's reliability criteria, all analyses were made over remained 16 questions, and nomenclature is given in Table 4.3.

Table 4.2 : Reliability statistics.

Cronbach's Alpha	Based on standardized items	N of items
,705	,719	16

Table 4.3 : Nomenclature.

N	Number
x̄	Mean
SD	Standard deviation
F	F distribution/ Fisher snedecor distribution
p	Probability value

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) (Table 4.4).

Table 4.4 : Descriptive statistics of the PC expressions.

Expressions	**x̄**	**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 4.5 : ANOVA test results according to the PC.

Scale	Groups	N	x̄	SD.	F	p
	Experience					
PC	0-5 Years	11	3,86	0,30		
	5-10 Years	19	3,80	0,38	1,547	0,224
	More than 10 Years	20	3,63	0,45		
	Region					
PC	Arctic	17	3,70	0,41		
	Antarctic	8	3,76	0,42	0,134	0,875
	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	0,532	0,591
	More than 40	31	3,75	0,43		
	Mission on the ship					
PC	Master/Chief Mate	24	3,73	0,41		
	Maritime Expert	9	3,80	0,43		
	Officer in Charge	7	3,71	0,57	0,188	0,943
	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	1,501	0,294
	No	5	3,93	0,27		

4.6 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 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 (Bartenstein, 2019; Gavrilov et al., 2019). 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 (Weber, 2012; Wing, 2017). 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 Arctic and Antarctic 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 (Schmied et al., 2017). 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 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

(SARex, 2016). 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 (COMNAP, 2019). For instance, the shortest distances are approximately 500 nm 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 (COMNAP, 2019). 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 requirments for survival and maximum expected time of rescue should be addressed (Engtrø et al., 2020).

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 Figure 5 (Karahalil et al., 2020). On the other hand, in the Antarctic, for latitudes higher than 60°S, some regions have not been any sea ice appearance for decades. The Convention on the CCAMLR area boundaries are different from the identified Southern Ocean's 60°S latitude. The application boundaries might be modified.

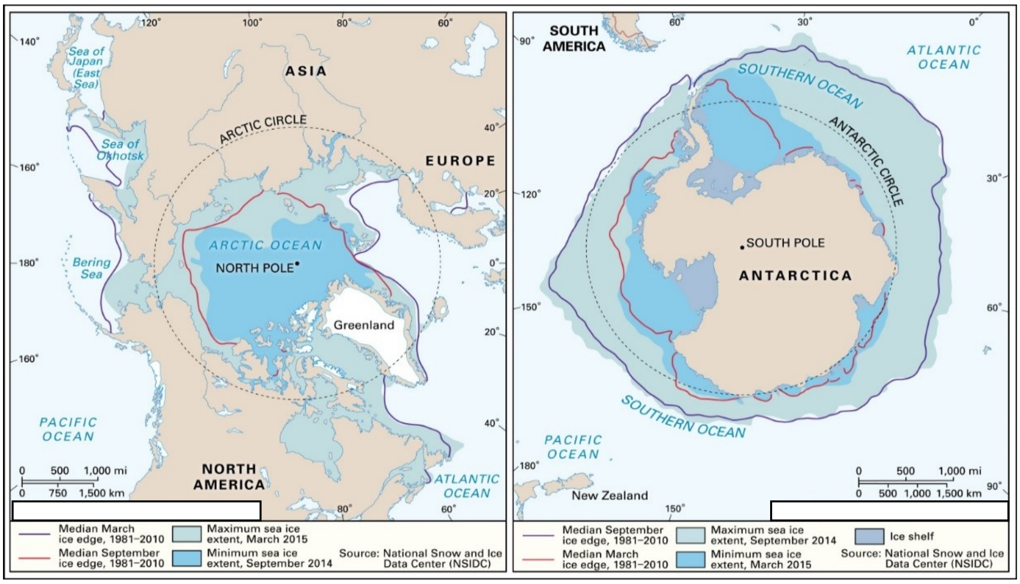

Figure 4.6 : The Arctic and Antarctic SIE (NSIDC 2015).

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 (Hauser et al., 2018). Moreover, there should be underwater noise restrictions considering protecting marine resources (4,02) (Ahmasuk et al., 2018; PAME, 2019; Riley and Hollich, 2017). 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 (IMO, 2020). 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 (Erazo, 2009). 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 (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.

5. CONCLUSIONS AND RECOMMENDATIONS

With the changes in the polar regions due to global climate change, countries' interest in the these regions has increased. Furthermore, as maritime activities are increasing, so are the several impacts and threats on the Arctic and the Antarctic environment and the safety of life at sea. Although the Arctic and the Antarctic regions have similarities, there are significant differences between them in terms of their political, legal, geographical, and physical conditions. Considering the polar regions' geographical and physical conditions, maritime activities and examples of marine accidents have increased the importance of safety and environmental issues. Therefore, the measures to address specific hazards in polar waters included in the Polar Code were imposed in 2017. This thesis focuses on the recent changes and developments in the two polar regions and the associated Polar Code deficiencies. IMO is a recognized competent body vital to strengthening regulations concerning safety and environmental issues. However, at present, several problems remain unsatisfactorily addressed or inadequately regulated.

This thesis comprises three independent but connected papers on some Polar Code deficiencies developed for ships operating in the polar regions. The first article focuses on sea ice changes and maritime safety issues in the Arctic. In this respect, the boundaries of Arctic Polar Code areas and ship accidents caused by sea ice beyond these areas were investigated. Furthermore, the sea ice extent change was evaluated in the Northern Hemisphere based on NSIDC data sets. The analyses revealed that the interannual variations of sea ice extent have undergone a long-term reduction from 1979 to 2019. Therefore, this is an essential finding indicating that Polar Code does not consider all areas covered with sea ice as specifying hazards in the introduction section. Thus, the present findings confirm that the Polar Code's application boundary needs to be modified in the Pacific according to the sea ice period and the sea ice extent records of the previous decades. This research highlights the need to revise the Polar Code's boundaries 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 (Karahalil et al., 2020).

The second article compares the changes and differences in both regions and points to the Polar Code's shortcomings. The Arctic and the Antarctic regions' sea ice extent changes were analyzed based on 41-year satellite records, which indicated a long-term reduction from 1979 to 2019. Although some other studies have also demonstrated these outcomes, our analysis takes a precise approach regarding the differences in the scope of the Polar Code. The differences were observed according to the formation processes and sea ice features that concern navigation. In conclusion, maritime safety tools can be generated separately for the polar regions (Karahalil & Ozsoy, 2021).

In the third article, the opinions of seafarers and scientists working in the polar regions are presented with the survey study created from the findings made in the first two articles and literature. According to the results of the questionnaires, the answers to each question highlight that the Polar Code should be improved. Accordingly, this study points to the need to improve the mandatory Polar Code for each polar region separately. Additionally, if ship traffic density and recent maritime incidents are considered, the Polar Code's further development would be beneficial (Karahalil et al., 2021).

For further studies, researchers should consider investigating the vessels excluded in the Polar Code. Additionally, the authorities who carry out controls should identify; deficiencies in the ships planning to operate in polar waters this would be enlightening. Finally, by building a bridge between the primary parties involved in regulating polar waters operation and those working in polar waters, the Polar Code's requirements can be reevaluated.

REFERENCES

Ahmasuk, A., Hubbell, D., & Nacke, M. (2018). *Marine mammal avoidance in polar waters.* July, (pp. 22–23). Retrieved from, https://www.nautinst.org/uploads/assets/uploaded/803fd21f-15de-460a-8efd597a67dfe509.pdf

Alekseev, A., Baklanov, P., Arzamastsev, I., Blinov, Y., Fedorovskii, A., Kachur, A., Krapchenkov, F.,… Ishitobi, H. (2006). *Sea of Okhotsk: Global International Waters Assessment (GIWA) 30.* 71. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/8814/GIWA_regional_assessment_31_Oyashio_current.pdf?sequence=3&isAllowed=y

AMAP (1998). *Arctic pollution issues. Arctic Monitoring and Assessment Programme (AMAP) assessment report,* Oslo, Norway, 12, 859. Retrieved from https://www.amap.no/documents/doc/amap-assessment-report-arctic-pollution-issues/68

AMAP (2007). *Arctic Monitoring and Assessment Programme, Arctic boundaries (physical) | (2007)*. November 6, 2019, Retrieved from https://www.amap.no/documents/doc/arctic-boundaries-physical/380

AMSA (2009). *Arctic marine shipping assessment 2009 report.* Retrieved from https://oaarchive.arctic-council.org/handle/11374/54

Anisimov, O.A., D.G. Vaughan, T.V. Callaghan, C. Furgal, H. Marchant, T.D. Prowse, H. Vilhjálmsson and J.E. Walsh. (2007). Polar regions (Arctic and Antarctic). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., *Cambridge University Press*, Cambridge, 653-685ASOC. 2008. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg2-chapter15-1.pdf

Arctic shipping: navigating the risks and opportunities (2014), Retrieved from https://www.marsh.com/us/insights/research/arctic-shipping-navigating-risks-opportunities.html

Arctic Council (2019). Working Groups - Arctic Council Homepage. Retrieved from https://arctic-council.org/index.php/en/about-us/working-groups

Arctic Yearbook (2014). *The Developing International Maritime Organization Polar Code.* Retrieved March 25, 2020, from https://arcticyearbook.com/arctic-yearbook/2014/2014-commentaries/108-the-developing-international-maritime-organization-polar-code

ASOC (2008). *The Antarctic Southern Ocean Coalition, Antarctic Shipping.* 1–13. http://www.asoc.org/storage/documents/Meetings/ATCM/XXXI/ASOC_IP_on_shipping_050108_final.pdf

ASOC (2013). *The Antarctic Southern Ocean Coalition, Update to Vessel Incidents in Antarctic Waters,* (pp.1–7). Retrieved from https://www.asoc.org/storage/documents/Meetings/ATCM/XXXVI/Update_to_Vessel_Incidents_in_Antarctic_Waters.pdf

Bartenstein, K. (2019). Between the Polar Code and Article 234: The Balance in Canada's Arctic Shipping Safety and Pollution Prevention Regulations. *Ocean Development & International Law, 50*(4), 335–362. Retrieved from https://doi.org/10.1080/00908320.2019.1617932

BBCnews (2010). Ten ships, 600 crew trapped in frozen Sea of Okhotsk - *BBC News.* Retrieved from https://www.bbc.com/news/world-europe-12099928

Bering Sea Elders Advisory Group. (2011). The Northern Bering Sea: our way of life. A Project of the Bering Sea Elders Advisory Group, with Support from Alaska Marine Conservation Council, 54. Retrieved from http://eloka-arctic.org/communities/media/files/AMCC_BeringSeaElders-northern-bering-sea-report-04-01-12.pdf

Bertelsen, R. G., & Gallucci, V. (2016). The return of China, post-Cold War Russia, and the Arctic: Changes on land and at sea. *Marine Policy, 72,* 240–245. https://doi.org/10.1016/j.marpol.2016.04.034

Boylan, B. M., & Elsberry, D. T. (2019). *Increased Maritime Traffic in the Arctic: Implications for International Cooperation and Security.* Retrieved from https://www.uaf.edu/caps/our-work/arctic-ocean-transit-project-files/increased-maritime-traffic-in-the-arctic-paper-final-9Dec2019.pdf

Borch, O. J. (2018) *Offshore service vessels in high arctic oil and gas field logistics operations fleet configuration and the functional demands of cargo supply and emergency response vessels*, Project. Nord University.

Cavalieri, D. J., & Parkinson, C. L. (2012). Arctic sea ice variability and trends, 1979-2010. *In Cryosphere, Vol. 6,* Issue 4, 881–889. Retrieved from https://doi.org/10.5194/tc-6-881-2012

CCAMLR (2020). *Key challenges and achievements.* Retrieved March 24, 2020, Retrieved from https://www.ccamlr.org/en/organisation/key-challenges-and-achievements

Chown, S. L., & Brooks, C. M. (2019). The State and Future of Antarctic Environments in a Global Context. *Annual Review of Environment and Resources, 44,* 1–30. https://doi.org/10.1146/annurev-environ-101718-033236

COMNAP (2016). *Search and Rescue (SAR) Workshop III - Improving SAR Coordination and Response in the Antarctic Final Report.* 15. Retrieved from https://documents.ats.aq/ATCM40/att/ATCM40_att003_e.pdf

COMNAP (2019). *Search and Rescue (SAR) Workshop IV SAR Coordination and Response in the Antarctic Final Report.* 5. Retrieved from https://www.comnap.aq/documents/COMNAP-Antarctic-SAR-Workshop-IV-Final-Report-31-May-2019.pdf

Council (2019). *A Quick Guide to the Arctic Council.* Retrieved from https://oaarchive.arctic-council.org/bitstream/handle/11374/2424/2019-09-30-A_quick_guide_to_the_AC_online.pdf?sequence=1&isAllowed=y

Cullen, P. J. (2016). *Polarworthiness: A new standard of seaworthiness in the polar context ?* Retrieved from https://mlaus.org/wp-content/uploads/bp-attachments/5056/Polarworthiness-A-new-standard-of-seaworthiness-in-the-polar-context.pdf

Dawson, J., Pizzolato, L., Howell, S. E. L., Copland, L., & Johnston, M. E. (2018). Temporal and spatial patterns of ship traffic in the Canadian Arctic from 1990 to 2015. *Arctic, 71*(1)*,* 15–26 DOI: 10.14430/arctic4698

Dieckmann, G., Rohardt, G., Hellmer, H., & Kipfstuhl, J. (1986). The occurrence of ice platelets at 250 m depth near the Filchner Ice Shelf and its significance for sea ice biology. Deep Sea Research Part A. *Oceanographic Research Papers, 33*(2)*,* 141–148. https://doi.org/10.1016/0198-0149(86)90114-7

Eguíluz, V. M., Fernández-Gracia, J., Irigoien, X., & Duarte, C. M. (2016). A quantitative assessment of Arctic shipping in 2010–2014. *Scientific Reports, 6,* 30682. https://repository.kaust.edu.sa/bitstream/10754/618215/1/srep30682.pdf

Elferink, A. G. O. (1995). Fisheries in the Sea of Okhotsk High Seas Enclave-The Russian Federation’s Attempts at Coastal State Control. *Int’l J. Marine & Coastal L., 10,* 1. https://core.ac.uk/download/pdf/267981061.pdf

Emery, W., & Camps, A. (2017). *Introduction to satellite remote sensing: atmosphere, ocean, land and cryosphere applications.* https://www.elsevier.com/books/introduction-to-satellite-remote-sensing/emery/978-0-12-809254-5

Engtrø, E., Gudmestad, O. T., & Njå, O. (2020). Implementation of the polar code: Functional requirements regulating ship operations in polar waters. *Arctic Review on Law and Politics, 11,* 47–69. https://doi.org/10.23865/arctic.v11.2240

Epa, U., & Change Division, C. (n.d.). Technical Documentation: Arctic Sea Ice. Retrieved April 2, 2020 from http://nsidc.org/data/amsre.

Erazo, J. C. (2009). *The Maritime Commons: Digital Repository of the World Maritime University Shipping in Antarctica : can safety and environmental protection be addressed considering the existing legal regimes?* (Master Thesis). World Maritime University, Maritime Affairs , Malmö http://commons.wmu.se/all_dissertationshttp://commons.wmu.se/all_dissertations/347

Erbe, C., Dähne, M., Gordon, J., Herata, H., Houser, D. S., Koschinski, S., Leaper, R.,… Janik, V. M. (2019). Managing the Effects of Noise From Ship Traffic, Seismic Surveying and Construction on Marine Mammals in Antarctica. *Frontiers in Marine Science, 6,* 647. https://doi.org/10.3389/fmars.2019.00647

R.L. (2009) *Decision of the Commisioner of Maritime Affairs, R.L. and the Report of Investigation in the Matter of Sinking of Passenger Vessle Explorer (O.N.8495)* 23 November 2007 in the Bransfield Strait near the South Shetland Islands. The Bureau of Maritime Affairs, 26 March 2009, Monrovia, Liberia. Retrieved from http://www.photobits.com/dl/Explorer%20-%20Final%20Report.PDF

Fedi, L. & Etienne, L. (2018). POLARIS in the Arctic. 58–71. *The Journal of Ocean Technology, Vol. 13,* No. 4, 2018

Fedi, L., Faury, O., & Gritsenko, D. (2018). The impact of the Polar Code on risk mitigation in Arctic waters: a "toolbox" for underwriters? *Maritime Policy and Management, 45(4),* 478–494. https://doi.org/10.1080/03088839.2018.1443227

Foster, J. L., Hall, D. K., Kelly, R. E. J., & Chiu, L. (2009). Seasonal snow extent and snow mass in South America using SMMR and SSM/I passive microwave data (1979–2006). *Remote Sensing of Environment, 113*(2), 291–305. https://doi.org/10.1016/j.rse.2008.09.010

Gavrilov, V., Dremliuga, R., & Nurimbetov, R. (2019). Article 234 of the 1982 United Nations Convention on the law of the sea and reduction of ice cover in the Arctic Ocean. *Marine Policy, 106,* 103518. https://doi.org/10.1016/j.marpol.2019.103518

Gerdes, R., & Köberle, C. (2007). Comparison of Arctic sea ice thickness variability in IPCC Climate of the 20th Century experiments and in ocean–sea ice hindcasts. *Journal of Geophysical Research: Oceans, 112*(C4). https://doi.org/10.1029/2006JC003616

Gerland S., Barber D., Meier W., Mundy C., Holland M., … Perovich D. (2019). Essential gaps and uncertainties in the understanding of the roles and functions of Arctic sea ice. *Environmental Research Letters, 14*(4).

Ghosh, S., & Rubly, C. (2015). The emergence of Arctic shipping: issues, threats, costs, and risk-mitigating strategies of the Polar Code. *Australian Journal of Maritime & Ocean Affairs, 7*(3), 171–182. https://doi.org/10.1080/18366503.2015.1093695

Hansen, C. Ø., Grønsedt, P., Graversen, C. L., & Hendriksen, C. (2016). *Arctic Shipping – Commercial Opportunities and Challenges Cbs Maritime Cross Disciplinary Problem-Focused Research and Education in the Maritime Industry Context.* In Copenhagen Business School. https://services-webdav.cbs.dk/doc/CBS.dk/Arctic Shipping - Commercial Opportunities and Challenges.pdf

Hauser, D. D. W., Laidre, K. L., & Stern, H. L. (2018). Vulnerability of arctic marine mammals to vessel traffic in the increasingly ice-free northwest passage and Northern Sea Route. *Proceedings of the National Academy of Sciences of the United States of America, 115*(29), 7617–7622. Retrieved from https://doi.org/10.1073/pnas.1803543115

Haward, M. (2012). Marine resources management, security and the Antarctic Treaty System: An ongoing agenda? *Antarctic Security in the Twenty-First Century: Legal and Policy Perspectives,* 215–237. Retrieved from https://doi.org/10.4324/9780203121009

Humpert, M. (2018). IMO Approves New Shipping Corridors in Bering Sea to Improve Safety. *Highnorthnews.* Retrieved November 7, 2019. Retrieved from https://www.highnorthnews.com/en/imo-approves-new-shipping-corridors-bering-sea-improve-safety

Humpert, M., & Raspotnik, A. (2012). The Future of Arctic Shipping Along the Transpolar Sea Route. *Arctic Year Book 2012.* Retrieved from https://arcticyearbook.com/arctic-yearbook/2012/2012-scholarly-papers/20-the-future-of-arctic-shipping-along-the-transpolar-sea-route

IAATO (2019). *The International Association of Antarctica Tour Operators*, *Tourism Statistics Report.* Retrieved May 3, 2020 from https://iaato.org/tourism-statistics-327mnsyd

IAATO (2019) *Report on IAATO Operator Use of Antarctic Peninsula Landing Sites and ATCM Visitor Site Guidelines, 2018-19 Season IP 142 3*. Retrieved March 10, 2020, from www.iaato.org

***Ice shelf collapse** (2020). May 21, 2020. Retrieved from http://www.antarcticglaciers.org/glaciers-and-climate/shrinking-ice-shelves/ice-shelves/*

IMO (2020). *International Maritime Organization Shipping in polar waters.* Retrieved November 20, 2020, from https://www.imo.org/en/MediaCentre/HotTopics/Pages/polar-default.aspx

Issue 328. (2013). Probability of Rapid Increase in trans Arctic shipping routes is confirmed, *Science for Enviroment Policy European Commision.* https://ec.europa.eu/environment/integration/research/newsalert/pdf/328na2rss_en.pdf

Jarl Borch, O. (2018). N*ord universitet FoU-rapport nr Offshore service vessels in high arctic oil and gas field logistics operations Fleet configuration and the functional demands of cargo supply and emergency response vessels.* https://core.ac.uk/download/pdf/225907014.pdf

Jensen, Ø. (2007). *The IMO Guidelines for Ships Operating in Arctic Ice-covered Waters: From Voluntary to Mandatory Tool for Navigation Safety and Environmental Protection. In FNI-Report* 2/2007. Retrieved from https://www.fni.no/getfile.php/131675-1469868943/Filer/Publikasjoner/FNI-R0207.pdf

Jensen, Ø. (2016). The International Code for Ships Operating in Polar Waters: Finalization, Adoption and Law of the Sea Implications. *Arctic Review on Law and Politics, 7*(0), 60–82. https://doi.org/10.17585/arctic.v7.236

Karahalil, M., & Özsoy, B. (2018). Arctic shipping and human risk factors. *The Journal of Ocean Technology, 13*(4).

Karahalil, Meric, & OZSOY, B. (2021). The Assessment of Arctic and Antarctic sea ice condition differences in the scope of the Polar Code. *Journal of ETA Maritime Science, 9*(1), 0. https://dx.doi.org/

Karahalil, Meric, Ozsoy, 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,* 104502. https://doi.org/https://doi.org/10.1016/j.marpol.2021.104502

Karahalil, Meric, Ozsoy, B., & Oktar, O. (2020). Polar Code application areas in the Arctic. *WMU Journal of Maritime Affairs,* 1–16. https://doi.org/10.1007/s13437-020-00200-4

Kern, S., & Ozsoy-cicek, B. (2018). Satellite remote sensing of snow depth on antarctic sea ice: an inter-comparison of two empirical approaches. *Remote Sensing 8*(6), 450. October. Retrieved from https://www.mdpi.com/2072-4292/8/6/450/htm

Kum, S., & Sahin, B. (2015). A root cause analysis for Arctic Marine accidents from 1993 to 2011. *Safety Science, 74,* 206–220. https://doi.org/10.1016/j.ssci.2014.12.010

Kum, S., & Sahin, B. (2016). *A Survey On Ice Navigation Research. Transactions of Navigation, 1*(1), 23–28. https://doi.org/10.18949/jintransnavi.1.1_23

Kwok, R., & Rothrock, D. A. (2009). Decline in Arctic sea ice thickness from submarine and ICESat records: 1958-2008. *Geophysical Research Letters, 36*(15), n/a-n/a. https://doi.org/10.1029/2009GL039035

IMO (2010) Guidelines for Ships Operating in Arctic Ice-Covered Waters (*IMO doc. MSC/Circ.1056 and MEPC/Circ.399*, 22 December 2002).

IMO International Code of Safety for Ships in Polar Waters (*IMO doc. DE 41/10*).

IMO (2020). Interim safety measures for ships not certified under the solas convention operating in polar waters. *Resolution A.1137*(31).

Lee, S. W., & Song, J. M. (2014). Economic possibilities of shipping though Northern Sea Route. *Asian Journal of Shipping and Logistics, 30*(3), 415–430. https://doi.org/10.1016/j.ajsl.2014.12.009

Leon, W. (2012). Russian emergency services rescue 675 fishermen stranded on a sheet of ice drifting out to sea | *Daily Mail Online. Dailymailnews.* Retrieved from https://www.dailymail.co.uk/news/article-2123696/Russian-emergency-services-rescue-675-fishermen-stranded-sheet-ice-drifting-sea.html

Leppäranta, M. (2019) Encyclopedia of Ocean Sciences (Third Edition), *Academic Press,* 187-199. https://doi.org/10.1016/B978-0-12-409548-9.04346-3.

Liu, J., & Horton, R. M. (2016). Arctic Sea Ice and Its Role in Global Change. *In Our Warming Planet: Vol.1* (pp. 295–307). *World Scientific.* https://doi.org/doi:10.1142/9789813148796_0014

LMAlloyds. (n.d.). *Recent Incidents Archive. Lmalloyds.* November 7, 2019 from http://www.lmalloyds.com/lma/underwriting/marine/JHC_Nav_Limits/Recent_Incidents_Archive.aspx

Loughnane, D., Judson, B., & Reid, J. (1995). Arctic tanker risk analysis project. *Maritime Policy and Management, 22*(1), 3–12.

Ma, C. (2019). *The United States And China In The Arctic a Roadmap for Sino-US Cooperation on Energy, Climate Change, and Global Governance* (One Terms Senior Essay). Yale University, Department of Political Science, Connecticut.

Maksym, T. (2019). Arctic and Antarctic Sea Ice Change: Contrasts, Commonalities, and Causes. *Annual Review of Marine Science, 11*(1), 187–213. https://doi.org/10.1146/annurev-marine-010816-060610

Maksym, T., Stammerjohn, S. E., Ackley, S., & Massom, R. (2012). Antarctic Sea Ice- A Polar Opposite? *Oceanography, 25*(3), 140–151. https://doi.org/10.5670/oceanog.2012.88

Marchenko, N. (2013). Navigation in the Russian Arctic: Sea ice caused difficulties and accidents. *ASME 2013 32nd International Conference on Ocean, Offshore and Arctic Engineering.*

Marchenko, N. (2014). *22 nd IAHR International Symposium on Ice.*

Marchenko, N. A., Borch, O. J., Markov, S. V, & Andreassen, N. (2016). Maritime safety in the high north-risk and preparedness. *ISOPE - International Offshore and Polar Engineering Conference.* Proceedings, 1, 1233-1240. Retrieved from http://hdl.handle.net/11250/2424682

MEPC (2015). Annex: International Code for Ships Operating in Polar Waters (Polar Code). 1, 3–56. *Marine Environment Protection Committee. MEPC 68/21/Add.1.* Retrieved from http://www.imo.org/en/MediaCentre/HotTopics/polar/Documents/POLAR CODE TEXT AS ADOPTED.pdf

Marinetraffic *(2019). MarineTraffic: Global Ship Tracking Intelligence | AIS Marine Traffic. Retrieved November 5, 2019, from https://www.marinetraffic.com/en/ais/home/centerx:176.7/centery:61.8/*

Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P. R., Pirani, A.,…Waterfield, T. (2019). *Global warming of 1.5°C An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty Summary for Policymakers Edited by Science Officer Science Assistant Graphics Officer Working Group Technical Support.* https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Citation.pdf

McFarland, H. R., Eicken, H., Thoman, R., Labe, Z., Druckenmiller, M., & Sheffield, G. (2018). *Bering Strait: An overview of winter 2018 sea ice conditions. 4.* https://www.arcus.org/witness-the-arctic/2019/1/article/29394

Meredith, M., Sommerkorn, M., Cassotta, S., Derksen, C., Ekaykin, A., Hollowed A.,…E.A.G. Schuur, (2019). *Polar Regions. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.* https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/07_SROCC_Ch03_FINAL.pdf

Miller, A. J., Chai, F., Chiba, S., Moisan, J. R., & Neilson, D. J. (2004). Decadal-scale climate and ecosystem interactions in the North Pacific Ocean. *Journal of Oceanography, 60*(1), 163–188. Retrieved from http://horizon.ucsd.edu/miller/download/jgofs/JO_60-1-11.pdf

NSIDC (2019). Arctic Sea Ice News and Analysis | Sea ice data updated daily with one-day lag. Retrieved November 5, 2019, from http://nsidc.org/arcticseaicenews/

NSIDC (2020). Arctic Sea Ice News and Analysis. March | 2020 | . Retrieved August 29, 2020, from http://nsidc.org/arcticseaicenews/2020/03/

NSIDC (2020). Retrieved May 3, 2020, from https://nsidc.org/nsidc-monthly-highlights/2018/08/25-years-servicing-nasa's-earth-observing-system-data

NSIDC (2020). ICESat-2, Retrieved May 3, 2020, https://nsidc.org/data/ICESat-2

Notz, D., & Stroeve, J. (2018). The Trajectory Towards a Seasonally Ice-Free Arctic Ocean. *In Current Climate Change Reports Vol. 4,* Issue 4, 407–416. Springer. https://doi.org/10.1007/s40641-018-0113-2

NTSB (2013). *National Transportation Safety Board Marine Accident Brief Capsizing and Sinking of Fishing Vessel Destination.* Retrieved from https://www.ntsb.gov/investigations/AccidentReports/Reports/MAB1814.pdf.

Ottawa Declaration (1996). Declaration On The Establishment Of The Arctic Council. Derieved from http://hdl.handle.net/11374/85

Overland, J. E., & Wang, M. (2013). When will the summer Arctic be nearly sea ice free? *Geophysical Research Letters, 40*(10), 2097–2101. https://doi.org/10.1002/grl.50316

Owens, E. H., Solsberg, L. B., West, M. R., & McGrath, M. (1998). *Field guide for oil spill response in Arctic waters. Emergency Prevention, Preparedness and Response Working Group (EPPR).* Retrieved from http://environmentalunit.com/Documentation/05%20Response%20Techniques/EPPR%20Field%20Guide%20for%20Oil%20Arctic.pdf

Ozsoy-Cicek, B., Ackley, S. F., Worby, A., Xie, H., & Lieser, J. (2011). Antarctic sea-ice extents and concentrations: comparison of satellite and ship measurements from International Polar Year cruises. *Annals of Glaciology, 52*(57)*,* 318–326. https://doi.org/10.3189/172756411795931877

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., Church, J. A… & Dasgupta, P. (2014). *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. Ipcc.*

Palma, D., Varnajot, A., Dalen, K., Basaran, I. K., Brunette, C., Bystrowska, M., Korablina, A. D., Nowicki, R. C., & Ronge, T. A. (2019). Cruising the marginal ice zone: climate change and Arctic tourism. https://doi.org/10.1080/1088937X.2019.1648585

PAME (2020). *Protection of the Arctic Marine Environment, The increase in arctic shipping.* Retrieved from https://storymaps.arcgis.com/stories/592bfe70251741b48b0a9786b75ff5d0/print

PAME (2019). *Protection of the Arctic Marine Environment, Underwater Noise in the Arctic: A State of Knowledge Report.* Retrieved from https://pame.is/index.php/document-library/pame-reports-new/pame-ministerial-deliverables/2019-11th-arctic-council-ministerial-meeting-rovaniemi-finland/421-underwater-noise-report/file

Parkinson, C. L. (2019). A 40-y record reveals gradual Antarctic sea ice increases followed by decreases at rates far exceeding the rates seen in the Arctic. *PNAS 116* (29) 14414-14423. https://doi.org/10.1073/pnas.1906556116

PEW (2014). Arctic Vessel Traffic in the Bering Strait Key Measures for Developing Regulatory Standards. *The PEW Charitable Trusts.* Retrieved from, https://www.pewtrusts.org/-/media/legacy/oceans_north_legacy/arctic_vessel_for_print_200copies may20141.pdf

Polar Code (2017). International Code for Ships Operating in Polar Waters. *MEPC 68/21/Add.1 Annex 10,* Retrieved May 3, 2020, from https://wwwcdn.imo.org/localresources/en/MediaCentre/HotTopics/Documents/POLAR%20CODE%20TEXT%20AS%20ADOPTED.pdf

Przybylak, R., Sadourny, R., & Mysak, L. A. (2003). *The climate of the Arctic.* Springer. https://www.springer.com/gp/book/9789048162260

Riley, T., & Hollich, S. (2017). The Arctic : Anthropogenic Noise , Shipping , Impact on Marine Mammals , & Future Management. *NCRL subject guide 2018 - 01.* https://doi.org/10.7289/V5/SG-NCRL-18-01

Rogers, T. S., Walsh, J. E., Rupp, T. S., Brigham, L. W., & Sfraga, M. (2013). Future Arctic marine access: Analysis and evaluation of observations, models, and projections of sea ice. *Cryosphere, 7*(1), 321–332. https://doi.org/10.5194/tc-7-321-2013

Rosen, Y. (2018). With marine traffic growing, international shipping agency approves US-Russia plan for Bering Strait shipping lanes - *ArcticToday.* Retrieved November 7, 2019, from https://www.arctictoday.com/marine-traffic-growing-international-shipping-agency-approves-us-russia-plan-bering-strait-shipping-lanes/

Sahin B, Serdar Kum (2015). Route Selection Approach for Vessels in Ice Covered Waters, *Marine Science and Technology Bulletin***.** Retrieved from https://asosindex.com.tr/index.jsp?modul=articles-page&journal-id=470&article-id=23506

SARex Spitzbergen *April 2016 Search and rescue exercise report conducted off North Spitzbergen.* Retrieved December 24, 2019, from http://hdl.handle.net/11250/2414815.

Sakhuja, V. (2014). The Polar Code and Arctic Navigation. *Strategic Analysis, 38*(6)*,* 803–811. https://doi.org/10.1080/09700161.2014.952943

Sandven, S., Johannessen, O. M., & Kloster, K. (2006). Sea ice monitoring by remote sensing. *Encyclopedia of Analytical Chemistry: Applications, Theory and Instrumentation.* https://doi.org/10.1002/9780470027318.a2320

Schmied, J., Borch, O. J., Roud, E. K. P., Berg, T. E., Fjørtoft, K., Selvik, Ø., & Parsons, J. R. (2017). Maritime Operations and Emergency Preparedness in the Arctic–Competence Standards for Search and Rescue Operations Contingencies in Polar Waters *The Interconnected Arctic — UArctic Congress 2016,* pp. 245–255. https://doi.org/10.1007/978-3-319-57532-2_25

Screen, J. A., & Williamson, D. (2017). Ice-free Arctic at 1.5° C? *Nature Climate Change, 7*(4), 230. https://doi.org/10.1038/s41558-018-0137-6

Serreze, M. C., Barrett, A. P., Crawford, A. D., & Woodgate, R. A. (2019). Monthly Variability in Bering Strait Oceanic Volume and Heat Transports, Links to Atmospheric Circulation and Ocean Temperature, and Implications for Sea Ice Conditions. *Journal of Geophysical Research: Oceans,* 2019JC015422. https://doi.org/10.1029/2019JC015422

Serreze, M. C., & Barry, R. G. (2014). The Arctic climate system. *Cambridge University Press.* Retrieved from http://assets.cambridge.org/97805218/14188/frontmatter/9780521814188_frontmatter.pdf

Silber, G. K., & Adams, J. D. (2019). Vessel Operations in the Arctic, 2015–2017. *Frontiers in Marine Science, 2,* 573. Retrieved from https://doi.org/10.3389/fmars.2019.00573

Simmonds, I. (2015). Comparing and contrasting the behaviour of Arctic and Antarctic sea ice over the 35 year period 1979-2013. *Annals of Glaciology, 56*(69), 18–28. https://doi.org/10.3189/2015AoG69A909

Smith, L. C., & Stephenson, S. R. (2013). New Trans-Arctic shipping routes navigable by midcentury. *Proceedings of the National Academy of Sciences of the United States of America, 110*(13). https://doi.org/10.1073/pnas.1214212110

Spindler, M. (1990). A comparison of Arctic and Antarctic sea ice and the effects of different properties on sea ice biota. *Geological history of the polar oceans: Arctic versus Antarctic* (pp. 173–186). Springer. https://doi.org/10.1007/978-94-009-2029-3_10

Stephenson, S. R., Smith, L. C., Brigham, L. W., & Agnew, J. A. (2013). Projected 21st-century changes to Arctic marine access. *Climatic Change, 118*(3), 885–899. https://doi.org/10.1007/s10584-012-0685-0

Stewart, E. J., & Draper, D. (2008). The sinking of the MS Explorer: Implications for cruise tourism in Arctic Canada. *Arctic, 61*(2), 224–228. https://doi.org/10.14430/arctic68

Stonehouse, B. (1989). Polar Bears in Canada-Polar bears. I. Stirling 1988. Ann Arbor, University of Michigan Press. 220. *Polar Record*, *25*(153).

Stonehouse, B. (2001). Polar environments. *The Encyclopedia of Ecotourism,* 219.

Stroeve, J. C., Markus, T., Boisvert, L., Miller, J., & Barrett, A. (2014). Changes in Arctic melt season and implications for sea ice loss. *Geophysical Research Letters, 41*(4), 1216–1225. https://doi.org/10.1002/2013GL058951

SDE (2011) *Sub-committee on ship design & equipment 55.* Retrieved from https://documents.ats.aq/ATCM34/att/ATCM34_att066_e.pdf

Sun, Z., & Beckman, R. (2018). The Development of the Polar Code and Challenges to Its Implementation. In Global Commons and the Law of the Sea (pp. 303–325). *Brill Nijhoff.* https://doi.org/10.1163/9789004373334_021

Şahin, B. (2015). Route Prioritization by Using Fuzzy Analytic Hierarchy Process Extended Dijkstra Algorithm. *Journal of ETA Maritime Science.* https://doi.org/10.5505/jems.2019.39306

Şahin, B. (2015). *Risk assessment and marine accident analysis in ice-covered waters* (Doktora Tezi). İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul. http://hdl.handle.net/11527/16142

Şahin, B., Şenol, Y. E., & Kartal, Ş. E. (2014). Swot analysis of transportation in the arctic region. October, 669–683.

Talley, L. D., Pickard, G. L., Emery, W. J., & Swift, J. H. (2011). Arctic Ocean and Nordic Seas. *In Descriptive Physical Oceanography* (pp. 401–436). Elsevier. https://doi.org/10.1016/b978-0-7506-4552-2.10012-5

The Antarctic Treaty (1959). Retrieved https://www.ats.aq/e/antarctictreaty.html

The Security Council of the Russian Federation (2015). *Maritime Doctrine of the Russian Federation.* Retrieved from http://static.kremlin.ru/media/events/files/41d527556bec8deb3530.pdf

Thorén, A. M. (2014). *Article 234 UNCLOS and the Polar Code-The interaction between regulations on different levels in the Arctic region.* (Master Thesis), University of Oslo, Oslo. http://urn.nb.no/URN:NBN:no-46488

Tkachenko, G. (2008). Estimation and development of oil-gas resources in the Okhotsk Sea Basin and sustainable development in Northeast Asia. *Energy and Environment in Slavic Eurasia: Toward the Establishment of the Network of Environmental Studies in the Pan-Okhotsk Region*, 19, 67. Retrieved from https://www.files.ethz.ch/isn/58462/Full%20Text%20issue%2019.pdf

Tsou, M.-C. (2010). Discovering Knowledge from AIS Database for Application in VTS. *Journal of Navigation, 63*(3), 449–469. https://doi.org/10.1017/S0373463310000135

Walker, D. A., Raynolds, M. K., Daniëls, F. J. A., Einarsson, E., Elvebakk, A., Gould, W. A., Katenin, A. E., Kholod, S. S., Markon, C. J., & Melnikov, E. S. (2005). The circumpolar Arctic vegetation map. *Journal of Vegetation Science, 16*(3), 267–282. https://doi.org/10.1111/j.1654-1103.2005.tb02365.x

Weber, M. (2012). Cooperation of the Antarctic Treaty System with the International Maritime Organization and the International Association of Antarctica Tour Operators. *The Polar Journal, 2*(2), 372–390. https://doi.org/10.1080/2154896x.2012.735045

Willems, N., Van De Wetering, H., & Van Wijk, J. J. (2009). Visualization of vessel movements. *Computer Graphics Forum, 28*(3), 959–966. https://doi.org/10.1111/j.1467-8659.2009.01440.x

Wing, T. (2017). Poles Apart? The Antarctic Treaty System as a Model for Arctic Governance. *Climate Institute*. http://climate.org/poles-apart-the-antarctic-treaty-system-as-a-model-for-arctic-governance/%0Ainternal-pdf://0.0.2.79/poles-apart-the-antarctic-treaty-system-as-a-model-for-arctic-governance.html

Zhang, J., Schweiger, A., Webster, M., Light, B., Steele, M., Ashjian, C., Campbell, R., & Spitz, Y. (2018). Melt Pond Conditions on Declining Arctic Sea Ice Over 1979–2016: Model Development, Validation, and Results. *Journal of Geophysical Research: Oceans, 123*(11), 7983–8003. https://doi.org/10.1029/2018JC014298

Zieliński, T., Darecki, M., & Węsławski, J. M. (2018). Climate-Related Changes In The Arctic Environment. *EduCO2cean Magazine Vol. 1*, No. 9, 116 –130. http://magazine.educo2cean.org/wp-content/uploads/sites/2/2018/03/9.-CLIMATE-RELATED-CHANGES-IN-THE-ARCTIC-ENVIRONMENT.pdf

Zissis, D., Chatzikokolakis, K., Spiliopoulos, G., & Vodas, M. (2020). A Distributed Spatial Method for Modeling Maritime Routes. *IEEE Access, 8,* 47556–47568. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9028151

APPENDICES

APPENDIX A : Polar Code Questionnaire

APPENDIX A: Polar Code Questionnaire

Title/ How old are you? / How long have you been working in polar regions?
In which polar region do you have sailing experience? / What is/was your mission on the ship?
Is/was the ship you work subject to SOLAS and MARPOL?
1. Do you think increasing maritime activities are linked to the melting of sea ice in polar regions?
2. Do you think that the PC is sufficient for safe ship operation and the protection of the polar environment?
3. The PC is intended to apply as a whole to both Arctic and Antarctic. Do you think that the legal and geographical differences between the two areas have been taken into account in the PC? (in terms of legal differences, please consider the Arctic countries' implementations during the voyages in their territorial waters/ exclusive economic zones and the Antarctic Treaty System implementations.)
4. Do you think that the types and characteristics of sea ice in the two regions are different?
5. Do you think the difference in sea ice characteristics affects the navigational and maneuverability of the ships?
6. Do you think there are differences in terms of maritime safety in the two regions? (Please consider the lack of accurate charting and complete hydrographic data and information, navigational aids and seamarks, etc.)
7. "Potential lack of ship crew experience in polar operations, with potential for human error" considered as a source of hazards in the PC. Do you think that PC requirements in terms of "manning and training (Part I-A Chapter 12)" or ice navigation training/courses are adequate?
8. Do you think there is a difference in search and rescue capacities in the two regions?
9. Do you think there is a difference in maritime accident risks in the two regions? (Please consider the geographical location, ice-coverage, etc.)
10. Do you think the PC boundaries are sufficient considering the sea ice extents?
11. Considering the protection of marine life and cultural heritage in the two regions, do you think there should be regional/sectoral restrictions in PC? (Please consider marine mammal avoidance during voyage planning: speed limits, extra watchman, etc.)
12. Considering the protection of marine resources, do you think there should be underwater noise restrictions in PC?
13. Considering the protection of the marine environment, do you think the prevention of pollution by sewage from ships' requirements are adequate in PC? (Part II-A / Chapter 4.2.1. discharging sewage that at a distance of more than 12nm from any ice-shelf or fast ice...allowed)
14. 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 (<500 GT), and pleasure yachts. Do you think that should it be mandatory provisions? (The safety provisions of the PC, as implemented through the SOLAS, primarily apply to cargo ships of 500 GT or larger and to all passenger ships.)
15. If a vessel will undertake a voyage into polar waters, then the inspection would include PC requirements. Do you think that Port State Control (PSC), under a Memorandum of Understanding (MOU) scoring system, is eligible for identifying deficiencies in ships?
16. Do you think that the PC needs to be improved?
17. Do you think that the PC needs to be separately developed for the Arctic and Antarctic?

CURRICULUM VITAE

Name Surname : Meriç KARAHALİL

EDUCATION :

- **B.Sc.** : 2012, Turkish Naval Academy, Department of Naval Architecture and Marine Engineering
- **M.Sc.** : 2016, Istanbul Technical University, Department of Maritime Transportation Engineering

PROFESSIONAL EXPERIENCE AND REWARDS:

- Turkish Coast Guard Command, Coast Guard Officer since 2012
- 2019-2021 Commanding Officer of Coast Guard Vessel, TCSG-93

PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

- **Karahalil M**, Ozsoy B, "Arctic Shipping and Human Risk Factors" The Journal of Ocean Technology, Vol. 13, No. 4, 2018.
- **Karahalil M**., Ozsoy B., and Oktar O., 2020. "Polar Code Application Areas in the Arctic." WMU Journal of Maritime Affairs19(2):219-34, DOI:10.1007/s13437-020-00200-4
- **Karahalil M,** Ozsoy B, "Evaluation of the Polar Code in different environments and for different maritime activities in the two polar regions" Advances in Polar Science, December 2020 Vol. 31 No. 4: 237-240, doi: 10.13679/j.advps.2020.0028
- **Karahalil M.,** & Ozsoy, 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.,** Ozsoy, 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.* https://doi.org/10.1016/j.marpol.2021.104502

- **Karahalil M.,** Ozsoy B, "Evaluation of the Polar Code in different environments and for different maritime activities in the two polar regions" (Presentation), National Polar Science Conference IV (22 Dec 2020, The Scientific and Technological Research Council of Turkey (TUBITAK MAM KARE)
- **Karahalil M.,** Ozsoy B, "Arctic Shipping Safety Issues (Presentation)" and "Polar Research platforms: Navies of Countries that Support Polar Research (Presentation)" 3rd National Polar Science Conference (Sept 2019, Middle East Technical University, Turkey)
- **Karahalil M.,** Ozsoy B, "Maritime Safety and Polar Code Implementations in the Arctic (Presentation)", Polar Age Symposium in Global Perspective (Aug 2019, Antalya Science University, Turkey)
- **Karahalil M.,** Ozsoy B, "Maritime Security Issues in the Arctic (Presentation)" Maritime Security from Underwater to Space (Dec.2018, National Defence University, Turkey)
- **Karahalil M.,** Ozsoy B, " Assessment of Polar Code", Polar Route Conference (Dec. 2018, Turkish Naval Academy), (Convenor of the conference)
- **Karahalil M.,** Ozsoy B, "Educating And Capacity Building About Polar Regions Through Science.", APECS Turkey Workshop on Education and Outreach (Oct.2018, Istanbul Technical University, Turkey)
- **Karahalil M.,** Ozsoy B, " The Evaluation of International Code for Ships Operating in Polar Waters Implementation" and "Studies for Raising Awareness Regarding Polar Regions in Turkey (Presentation)" 2nd National Polar Science Conference (Sept. 2018, Istanbul Technical University, Turkey)
- **Karahalil M.,** Ozsoy B, "What Does Mid-Latitudinal Countries People Know about Polar Regions Issues? What Should We Do to Raise Awareness? (Convenor of one of the Education Session)", UARCTIC Conference (Sept. 2018, Finland)
- **Karahalil M.,** Ozsoy B, "Polar Code for the Polar Regions. (Presentation)", 7th Global Conference on Global Warming (2018, Turkey)
- **Karahalil M.,** Ozsoy B, "Educating And Capacity Building About Polar Regions Through Science. (Poster Presentation)" and "A Comparative Study: Polar Regions. (Poster Presentation)" Polar 2018 SCAR Conference (Davos/ Switzerland)
- **Karahalil M.,** Ozsoy B, "One Polar Code for both Polar Regions. (Poster Presentation)" 3th National Maritime Science Conference (2018, 9 Eylul University, Turkey)
- **Karahalil M.,** Ozsoy B, "Does Polar Code Adequate for Both Polar Regions? (Poster Presentation)", Arctic Frontiers Conference (2018, Tromso/ Norway)
- **Project:** Turkish Arctic Science Expedition-I (TASE-I / July 2019), (Participant scientist), Focus: Polar Research which was carried under auspices of Presidency of the Republic of Turkey, supported by the Ministry of Industry and Technology and coordinated by TUBITAK MRC Polar Research Institute., (Research project on board for three weeks in Svalbard/ Norway), Supervisor: Assoc.Prof.Dr. Burcu Ozsoy
- **Project:** Combined Ground-Based and Satellite Measurements for Atmosphere Vertical Profiles and Aerosols (COMAPA), The Scientific and Technological Research Council of Turkey 2020/2021 (Scholarship).