



HAL
open science

Mapping and analysis of maritime claims in the Russian Arctic based on POLARIS System

Laurent Fedi, Olivier Faury, Laurent Etienne, Amaury de Ferriere Le Vayer

► To cite this version:

Laurent Fedi, Olivier Faury, Laurent Etienne, Amaury de Ferriere Le Vayer. Mapping and analysis of maritime claims in the Russian Arctic based on POLARIS System. 27th Annual Conference of the International Association of Maritime Economists, Jun 2019, Athens, Greece. hal-03354308

HAL Id: hal-03354308

<https://hal.science/hal-03354308>

Submitted on 24 Sep 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Mapping and analysis of maritime claims in the Russian Arctic based on POLARIS System

Laurent FEDI

KEDGE Business School, CESIT, Domaine de Luminy, 13288 Marseille, France
laurent.fedi@kedgebs.com

Olivier FAURY

Ecole de Management de Normandie, 30, rue de Richelieu 76087 Le Havre, France
ofaury@em-normandie.fr

Laurent ETIENNE

Université de Tours, BDLN, 35 Allée Ferdinand de Lesseps, 37200 Tours, France
laurent.etienne@univ-tours.fr

Amaury de FERRIERE le VAYER

Ecole de Management de Normandie, 30, rue de Richelieu 76087 Le Havre, France
amaurydf@hotmail.fr

Abstract

During the last decade, more than 500 maritime claims have been reported in the Arctic and the political will of the Russian government to develop the Northern Sea Route (NSR) for the exportation of raw materials may lead to a rise of events. However, data on maritime claims in the Russian Arctic are rather missing and not updated which hinders accurate analysis so far.

Through an evaluation of maritime claims occurred in the Russian Arctic during the period 2007-2018, this article aims to identify their primary root causes in order to determine if the new Polar Code risk mitigation measures and POLARIS system especially, would have prevented their occurrence.

Based on empirical data collection, the study gathers, classifies and maps claims occurred along the NSR till the Polar Code enforcement. The POLARIS System is used for specific case study to determine if it occurred in areas where ice conditions represented a direct risk for the integrity of the vessel. As results, the manuscript provides a categorization of maritime claims in the Russian Arctic in accordance with IMO standards and sheds a light on the type of risk occurrence a ship may face along the NSR. It brings valuable implications for maritime operators who are still expecting historical data for proper risk assessment in the Russian Arctic. Finally, it demonstrates that POLARIS is an appropriate tool for risk mitigation and how stakeholders can implement and share in their common interest best practices and data.

Keywords: *Arctic, risk analysis, risk mapping, maritime claims, Polar Code, POLARIS*

1. Introduction

Particularly visible in the Arctic, the impact of climate change causes progressive retreat of the sea ice surrounding the North Pole (Corbett et al., 2010) and offers new economic opportunities in particular for the shipping industry. Maritime traffic in the Arctic is expected to grow in the next decades (Kum and Sahin, 2015) both for the Norwest Passage (NP) and the Northern Sea Route (NSR). The new construction of a Liquid Natural Gas (LNG) plant in the Yamal peninsula (Russia), allowed the first operations in December 2017 and more than 20 passages through the Bering Strait were performed. Furthermore, the objective of the Russian Federation is to export between 133 and 153 million tons by 2030 (Ministry of Energy of the Russian Federation, 2010). The NSR gives the opportunity to reduce distances, fuel consumption and lower carbon emissions (Kitigawa, 2008). Although the relevance of the NSR is challenging notably for international transit (Lasserre, 2016), this route crystallizes both greater maritime actors' interests and high level of risk in particular as regards ice (ABS, 2014). Moreover, statistics on maritime claims in the Russian Arctic are still missing (AMSA, 2009; Goerlandt et al., 2017).

According to a recent report, ship total losses have declined by more than a third (38%) over the past decade and they were down 4% compared with 2016 figures showing a significant improvement on the 10-year loss average (ALLIANZ, 2018). This significant improvement is justified by “ship design, technology and advances in risk management and safety” (ALLIANZ, 2018). At the same time, this report recorded 71 ‘casualties-incidents’ in Arctic Circle waters in 2017, a rise of 29% compared to 2016 (ALLIANZ, 2017). Over the period 2007-2017, the number of claims doubled. Accordingly, one can assert these latest statistics on Arctic shipping are clearly opposite to the trend of global improvement of maritime events. Then, the higher number of claims in Arctic fully justifies the adoption by the International Maritime Organization (IMO) of the ‘International Code for Ships Operating in Polar Waters’, referred as the ‘Polar Code’, entered into force 1 January 2017 (IMO, 2014a). The Polar Code is indeed designed to reduce the risks of operating in Polar waters thanks to safety and environmental prevention measures (Chircop, 2013; Henriksen, 2014; Fedi and Faury, 2016).

The aim of this paper is twofold. First, it carries out an in depth analysis of the maritime claims occurred in the Russian Arctic, identifying their root causes, their level of seriousness and mapping their locations. The analysis enables a taxonomy of these claims either as merely ‘marine incident’ or ‘marine accident’ that is to say ‘casualty’ in accordance with the IMO Casualty Investigation Code (IMO, 2008). It seems that exiting literature does not provide this categorisation while it allows an accurate definition of maritime claims depending on their gravity. Secondly, a specific maritime claim linked to the ice risk is scrutinised as a case study through the lens of the “Polar Operational Limit Assessment Risk Indexing System” (POLARIS) in order to verify if its occurrence would have been prevented if it was in force at the time of the accident. Even though IMO promotes POLARIS as well as classification societies, so far few research have been carried out on this valuable system for decision-making for the Polar navigation. The contribution of this paper is to highlight the relevance of the POLARIS instrument in the shipping risk mitigation for the NSR and particularly in ice-covered areas.

After this short introduction, the remainder of the paper is organised as follows: Section 2 provides a literature review on Arctic and Russian shipping risks with a particular focus on NSR. Section 3 deals with the methodology. The analysis of maritime claims occurred in the Russian Arctic and the case study are discussed in Section 4. Finally, some concluding remarks are addressed in Section 5.

2. Literature review

As illustrated by the recent adoption of the Polar Code, the safe navigation in Polar Regions and particularly in Arctic waters, has become a pressing issue of concern. The ice presence, remoteness, low temperatures, drifting icebergs - over 1,000 icebergs drifted into North Atlantic shipping lanes in 2017 (ALLIANZ, 2018) -, rapidly changing and severe weather conditions and extended period of darkness represent considerable hazards for ships. According to the aforementioned report, “sailing in such conditions necessitates specialist training for seafarers and additional routing support”. Moreover, the maritime claims are supposed to increase in Arctic Ocean (Borgerson, 2008; Balto, 2014) and accordingly, it specifically raises the question for the NSR in light of greater likelihood traffic in the coming years.

2.1. *The Arctic shipping risks*

Numerous professional report and scholars have clearly demonstrated that physical and operational conditions in the Arctic rise the level of conventional shipping risks (Haavik, 2017) and Arctic navigation is ‘relatively novel compared to traditional navigation’ (Fu et al., 2016). Remoteness for instance is a major concern for shipping companies (Lasserre et al., 2016), as well as lack of resource, lack of search and rescue (SAR) infrastructures (SARC, 2017), aggravated by extreme natural environment that profoundly influences human and technical systems of a vessel (Montewka et al., 2015; Haavik, 2017). Insurers are still prudent (IUMI, 2018) and reluctant to insure operations in Arctic due to missing data (Kiiski, 2017; Fedi et al., 2018a). Through a general examination, there is a risk for severe accidents (Marchenko et al., 2015) and a likely worst-case scenario (Fedi et al., 2018a).

As regards risk occurrence, several studies underlined its acuity in Arctic waters. Loughnane et al. (1995) reported a 19 times higher incident rate in the Arctic compared to open-water. Concerning the main accident causes, the lack of crew experience was identified as the primary source (Tikka et al., 2008). According to the Arctic Marine Shipping Assessment Report (AMSA, 2009), human factor represented the main contributor to the total number of accidents (76.7%) due to inattention, heavy weather, age and lack of communication in particular. The second highest contributor was collisions and groundings. A survey based on 19 years’ analysis of Arctic marine accidents from 1993 to 2011 confirmed that accident to person was the most occurring accident and stressed the significance of crew training and competence requirements (Kum and Sahin, 2015). Fishing vessels, passenger or cruise ships represented a significant part of the number of injuries and marine incidents.

Although in 2006 there were only eight maritime claims reported in the Arctic, 55 ‘casualties-incidents’ occurred in 2016 including one total loss (ALLIANZ, 2017) and the number reached 71 in 2017 (ALLIANZ, 2018). It means that the number of claims doubled within only one decade. This significant rise takes the opposite stance to the stable claims frequency and long-term downward trend of total losses (IUMI, 2018). It justifies why Arctic shipping risks require accurate evaluation and mitigation measures notwithstanding the limited historical data available (Fu et al., 2016). Scholars have addressed this challenge for a long time and numerous research have provided models evaluating polar risks and proposing mitigation responses. Bergstrom, Erikstad, and Ehlers (2016) suggested a framework for holistic goal- and risk-based design of Arctic Maritime Transportation Systems (AMTS) with the aim of apprehending the whole navigation in Arctic waters instead of focusing on each vessel. Other researchers designed a probabilistic model for predicting ship besetting in ice (Fu et al., 2016). Baksh et al. (2018) contemplated a comprehensive literature review regarding accident models and consequence assessment. They demonstrated that accident models based on different types of accidents for the NSR were limited.

2.2. *The Russian Arctic risks: the NSR features*

The NSR is a common name for several navigational routes in the Russian Federation exclusive economic zone (EEZ). The NSR is defined as “a water area adjoining the northern coast of the Russian Federation, including internal sea waters, territorial sea, contiguous zone and EEZ of the Russian Federation, and limited in the East by the line delimitating the sea areas with the United States of America and by the parallel of the Dezhnev Cape in the Bering Strait; in the West, by the meridian of the Cape Zhelanie to the Novaya Zemlya archipelago, by the east coastal line of the Novaya Zemlya archipelago and the western limits of the Matochkin Shar, Kara Gates, Yugorski Shar Straits” (NSRA, 2012). The NSR is described as running through four main zones: the Kara, Laptev, Vostochno-Sibirskoye (East Siberian) and Chukchi Seas. The NSR extends for about 4,800 km (3,000 miles) representing a vast area and navigation via the route is carried out in compliance with Russian legislation. Connecting Asian and European ports, annual navigation on the NSR is feasible for two main seasons: summer season, typically from July to November, and extended season of the rest of the year (ABS, 2014). The NSR has been opened since 1991 (Zhang et al., 2016). 4091 transits were performed through the NSR from 2010 to 2017 with a significant 40% increase in 2017 (NSRA, 2018) and the main ports in the Russian Arctic saw an over 40% rise in goods handled in 2016 compared to 2015 (SARC, 2017). In 2018, roughly 93 million tons were handled by Russian Arctic seaports and almost 70 percent was oil products and LNG (Russian Transport Ministry, 2019). Thanks to the opening of production of Yamal LNG project delivering natural gas via the NSR, traffic is forecasted to grow even more rapidly over the coming years (Iudin and Petrov, 2016) while container shipping lines show a little interest for this route (Lasserre, 2016).

According to experts, the NSR conditions are harsh even when the route is open, with significant weather variability, posing ‘unique challenges to the mariner and to modern ship technology and systems’ (AMSA, 2009). Strong winds, low air temperatures, a high number of days with fog and, late in the season, long polar nights, snowstorms, polar lows, and possible blizzards characterize the NSR (ABS 2014). The main factor influencing the choice of the NSR is the distribution of ice (Liu and Kronbak, 2010) and ice may be encountered at any time including summer where concentrated ice (ice massifs) are frequent (ABS, 2014). Despite a longer seafaring season, waters are infested by floating ice, and ice conditions are still really tough for crew members and vessels (Marchenko, 2012a). Furthermore, the existence of floating or drifting ice-pack makes the seafaring conditions unpredictable (Abbassi et al., 2017). One of the seafaring keys in the NSR is that “the power and strength of ice should never be underestimated” (Vihanninjoki, 2014). The ice floes or ice drift may put a considerable pressure against the vessels’ hull. Vessels must adapt their route, trying to sail a way of “least resistance through the ice mass” to avoid the risk of being stuck or limit the occurrence of an accident (Vihanninjoki, 2014). Consequently, masters face difficulties to stick to the planned route chosen before the vessel’s departure. Furthermore, the lack of infrastructures and the remoteness of the NSR added to the environmental conditions make seafaring more challenging (Marchenko, 2014a). The NSR counts only eight major ports: Amderma, Dickson, Dudinka, Khtanga, Tiksi, Pevek, Shmidta and Sabetta (Gritsenko and Efimova, 2017). These ports are subject to hard conditions and entering or operating in their facilities is often impossible. In case of unexpected event, SAR infrastructures are limited and not equally located along the lane (Vihanninjoki, 2014). There are only two main Marine Rescue Coordination Centers (MRCCS) within the NSR: Murmansk and Dickson. Both MRCC have several Martine Rescue Sub-centers. (RSC) such as Tiksi or Pevek which are in duty only between July and November.

2.3. Maritime claims database related to the Russian Arctic

Obviously, if risks have been clearly identified, assessed, modelled and currently regulated within the Polar Code's framework (Fedi et al., 2018a), nevertheless, specific statistics on maritime claims occurred through the NSR are still limited. The 2009 AMSA report underlined this issue and recommended the development of an accurate database for ship incidents and accidents. Notwithstanding the development of different global or regional databases such as the Lloyd's Marine Intelligence Unit database, the HELCOM, the DAMA, the EMCIP and the North BAceD, numerous 'weaknesses' characterizes these databases on the Arctic region due to underreporting (Goerlandt et al., 2017), different information and different taxonomy applied to the same maritime events (Ladan and Hänninen, 2012). According to Goerlandt et al. (2017) missing and incorrect data lead to gaps in the analysis and may distort results. Furthermore, these databases are not often publicly accessible. Accordingly, providing an accurate statement on maritime claims in a given area is still a difficult task (Grabowski et al., 2009). The lasted available official report covers the 1995-2004 period with a 'complete absence' of reported claims in the Russian Arctic and NSR (AMSA, 2009). Few research have been carried out up to now in particular with a global approach including identification, categorisation and mapping of claims occurred along the NSR. Moreover, a certain ambiguity remains around the concept of 'maritime claim'. Most current reports use the notions of 'incident', 'accident' and 'casualty' alternatively and concurrently. This lack of data combined to approximate classification constitute a current gap in the existing literature.

2.4. The prophylactic response: the Polar Code and the POLARIS system

The IMO recently adopted the mandatory Polar Code with the aim to respond to increased maritime activities in Arctic and Antarctic (Chircop, 2013; Dalaklis, 2018). Following a 'risk based approach', the new code identifies the main risks in these zones, their potential consequences and provides appropriate measures to mitigate such risks in a prophylactic way (Fedi and Faury, 2016). Some authors have demonstrated that the Polar Code provisions could facilitate risk appraisal and represented a significant component of upcoming Arctic marine insurance through proceduralization of risk (Fedi et al., 2018a, 2018b). This proceduralization lies in two tools: the 'Polar Ship Certificate' (PSC) showing the ship's ice class (A, B, C) according to her ability to sail in ice-covered areas and the 'Polar Water Operational Manual' (PWOM) establishing procedures pursuant to operational limitations based on anticipated scenarios of operating, environmental conditions and hazards the vessel may face such as, ice, high latitude, low ambient air temperature, remoteness, abandon of the ship and the effect of polar conditions on crew performance. Among these tools, one observes the 'Polar Operational Limit Assessment Risk Indexing System' (POLARIS) that defines a methodology for assessing ship's operational capabilities and limitations in ice (IMO, 2016). Integrating various parameters to assess risk of navigation in ice notably risk index values and outcome, POLARIS can provide relevant managerial solutions to shipowners. POLARIS is useful for various stakeholders such as the International Association of Classification Society (IACS) and underwriters (Kujala et al., 2016; Fedi et al., 2018b). Fedi et al. (2018) showed that POLARIS constituted "a fairly complex and multipurpose tool" at the upstream and downstream of the shipowner's decision process for safer navigation in the Arctic. Accordingly, while scholars have paid little attention to POLARIS so far, authors assume this system would reduce risk occurrence along the NSR where ice is predominant and would have prevented some past claims occurred prior to the enforcement of the Polar Code's tools.

3. Methodology

This research takes a multi-method approach and the research design is both qualitative and quantitative. The methodology used is firstly based on empirical data collection on marine claims occurred in the Russian Arctic. Considering the fragmented information and lack of specific available statistics in this field, multi-sources were used: professional reports issued from insurance companies and associations such as the International Association of Marine Insurance (IUMI), The Nordic Association of Marine Insurers (CEFOR), archive accidents especially from the Protection of the Arctic Marine Environment (PAME), marine investigation reports from CLARKSONS, literature review, internet and specialized press. The first objective was to identify and record maritime claims during the period from 2007 to 2018. This period is justified by two reasons: the 2009 AMSA report provided a global analysis till 2004 and the entry into force of the latest provisions of the Polar Code was effective in 2018.

The second key step of the data collection was to categorize the claims in accordance with their gravity that is to say: ‘incident’ or ‘accident’ / ‘casualty’ insofar as most marine reports do not provide this distinction and thus contributing to a certain confusion in the appropriate terminology and claim severity rate. Pursuant to the IMO Casualty Investigation Code adopted by the Resolution MSC 255(84) of 16 May 2008 (IMO, 2008) and effective from the 1st January 2010, the distinction between these two notions is the following:

A “*marine incident*” means an event, or sequence of events which has occurred directly in connection with the operations of a ship that endangered, or, if not corrected, would endanger the safety of the ship, its occupants or any other person or the environment. It does not include a willful misconduct that is to say a deliberate act or omission, with the intention to cause harm to the safety of a ship, an individual or the environment.

A “*marine casualty*” means an event, or a sequence of events, that has resulted in seven different cases as described in Table 1 and which has occurred directly in connection with the operations of a ship. It does not include a willful misconduct. Marine casualties are divided into two sub-notions: “*serious casualty*” which involve a fire, explosion, collision, grounding, contact, heavy weather damage, ice damage, hull cracking, or suspected hull defect, etc., resulting in: immobilisation of main engines, extensive accommodation damage, severe structural damage, such as penetration of the hull under water, etc., rendering the ship unfit to proceed, or pollution (regardless of quantity), and/or a breakdown necessitating towage or shore assistance. A “*very serious marine casualty*” involves the total loss of the ship or a death or severe damage to the environment. Accordingly, ‘marine incidents’ represent the lowest level of gravity and scale whereas ‘very serious marine casualties’ the highest.

Table 1. Taxonomy of marine incidents and casualties

Taxonomy	Marine incident	Marine casualty	Serious casualty	Very serious casualty
Definition	- Endangers the safety of the ship, its occupants or any other person or the environment.	- Death of, or serious injury to, a person, - Loss of a person - Loss, presumed loss or abandonment of a ship	- Fire - Explosion - Collision - Grounding - Contact - Heavy weather damage	- Total loss of the ship - Death - Severe damage to the environment

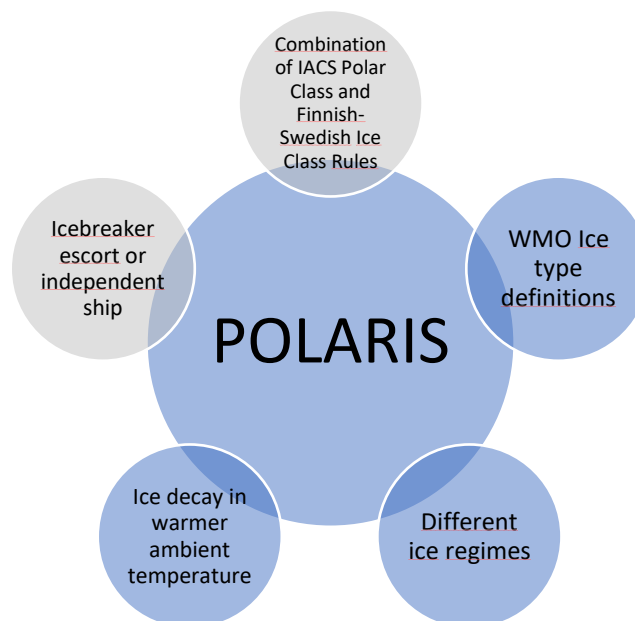
		<ul style="list-style-type: none"> - Material damage to a ship - Stranding or disabling of a ship - Material damage to marine infrastructure - Severe damage to the environment 	<ul style="list-style-type: none"> - Ice damage - Hull cracking - Suspected hull defect 	
--	--	---	--	--

Source: The authors based on IMO Resolution MSC.255(84) 16 May 2008

The third stage was to map maritime events in order to provide their location along the NSR, to verify if certain areas and periods are riskier than others and what key or aggravating factors could be identified.

Finally, we selected an actual claim as a case study and analyzed the circumstances of occurrence through the lens of the POLARIS system. POLARIS compares the existing ice typology to the ships' class with the aim to determine a safe route and the optimal class of the vessel willing to sail in polar waters. (Fedi et al., 2018b). Pursuant to the IMO *Guidance*, five elements characterize POLARIS as shown in Figure 1. Out of five elements, three directly deal with ice: the ice type definitions in accordance with the World Meteorological Organization (WMO), the different ice regimes such as partial ice concentrations or ice-free waters and ice decay in warmer temperature.

Figure 1: POLARIS key features



Source: Fedi et al. (2018b)

Furthermore, POLARIS is contemplated as a decision support tool through risk classification and proceduralization (Fedi et al., 2018b). The system defines Risk Index Values (RIVs) that are assigned to a vessel depending on its ice or polar class (IMO, 2016). RIVs provide a relative risk evaluation for corresponding ice types (heavy multi- year ice, medium first year ice, ice-free, etc.), completed by a Risk Index Outcome (RIO) value to assess limitations for operating

in ice. Pursuant to the IMO Guidance (IMO, 2016), for each ice regime met, the RIVs are used to define a RIO that represents the cornerstone of the decision to fully operate or to limit shipping operations.

Table 2. Risk Index Outcome Criteria

<i>RIO_{SHIP}</i>	<i>Ice classes PC1-PC7</i>	<i>Ice classes below PC 7 and ships not assigned an ice class</i>
RIO ≥ 0	Normal operation	Normal operation
-10 ≤ RIO < 0	Elevated operational risk*	Operation subject to special consideration**
RIO < -10	Operation subject to special consideration**	Operation subject to special consideration**

Source: IMO (2016)

As illustrated in Table 2, three scenarios are defined based on risk level, from ‘normal operation’ to ‘elevated operational risk’ and ‘operation subject to special consideration’. Considering the RIO, the master must adapt navigation in terms of limited speed, additional watchkeeping, or icebreaker support. Obviously, when the RIO is below – 10, the sailing requires ‘special consideration’ and the final decision shall rest with the master even though such navigation should be avoided (IMO, 2016, Fedi et al. 2018b). The POLARIS system is thus designed to mitigate risk with likelihood of occurrence. Our original method is to apply the POLARIS key parameters to a past maritime event involving ice factor and to analyze if the claim would have been prevented.

4. Analysis of maritime claims occurred in the Russian Arctic

4.1. Risk categories

Sailing within the Russian Arctic and the Arctic as a whole implies to deal with numerous risks as explained in Section 2. These risks can be organised in four mainly categories: climate, technical, human and geographic. Yet looking at parameters that impact directly the navigation, the climate appears as the one with the highest number of occurrences.

Table 3: Existing hazards within the Arctic

N°	Hazard nature	Definition in the convention
1.	ICE	Ice, as 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
2.	Structure	experiencing topside icing, with potential reduction of stability and equipment functionality
3.	Temperature	low temperature, as it affects the working environment and human performance, maintenance and emergency preparedness tasks, material properties and equipment efficiency, survival time and performance of safety equipment and systems
4.	Daylight time	Extended periods of darkness or daylight as it may affect navigation and human performance
5.	Location	High latitude, as it affects navigation systems, communication systems and the quality of ice imagery information
6.	Remoteness	Remoteness and possible lack of accurate and complete hydrographic data and information, reduced availability of navigational aids and seamarks with increased potential for groundings compounded by remoteness, limited readily deployable SAR facilities, delays in emergency response and limited communications capability, with the potential to affect incident response
7.	Human	Potential lack of ship crew experience in polar operations, with potential for human error
8.	Remoteness	Potential lack of suitable emergency response equipment, with the potential for limiting the effectiveness of mitigation measures
9.	Climate	Rapidly changing and severe weather conditions, with the potential for escalation of incidents
10.	Environment	The environment with respect to sensitivity to harmful substances and other environmental impacts and its need for longer restoration.

Source: The authors based on IMO Polar Code (IMO, 2014a)

As stressed by Table 3, hazards related to climate represent five issues out of ten (ice, temperature, daylight time, climate and environment). Yet the presence of ice has a strong impact on the navigation within polar waters (Faury and Cariou, 2016; Lasserre, 2014) and floating ice has been identified as the key factor of most maritime casualties (Marchenko 2012b, 2014b). According to ice thickness and concentration, a vessel may not be able to sail (Löptien and Axell, 2014). However, numerous tools exist to prevent these risks. Among them, the use of vessels designed to polar navigation with hull reinforced and more powerful main engine. The use of icebreaker to assist vessel and provide a channel through the ice is in some cases made compulsory by underwriters (Fedi et al., 2018a) and national legislations such as the Russian NSR requirements (NSRA).

The additional cost an ice-class vessel, compared to a non-ice class one, the fees for the assistance of an icebreaker and the additional fuel consumption and related cost, may hinder the use of the Arctic and more precisely of the NSR (Lasserre, 2014; Gritsenko and Kiiski, 2015; Faury and Cariou, 2016). This “under-exploitation” of the NSR can be also explained by

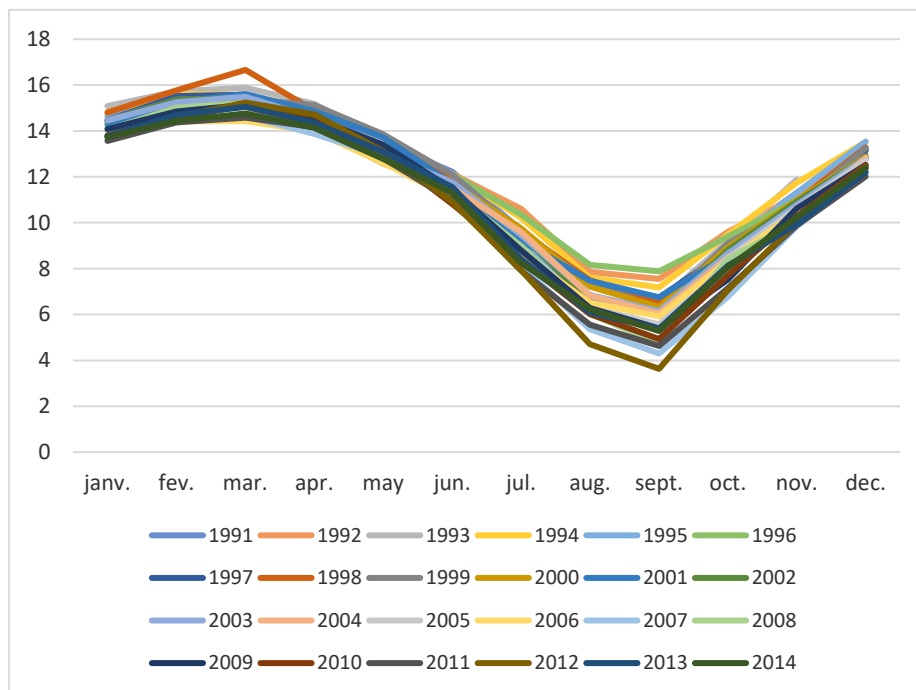
the low number of ports (Ragner, 2000) and at the opposite, the low number of vessels can be a reason for this low density of ports.

The direct consequence of the low number of vessels using the NSR is a lack of historical data. This information is the corner stone of underwriter’s risk management who act as Arctic gate keepers and adopt a case-by-case approach (Fedi et al., 2018a).

Looking at the current literature, the ice appears as the main risk weighing upon vessels. Even if the ice melts, the fast-changing conditions due to the freezing and thawing of the ice blanket can posit the vessel in a non-forecasted situation.

As stressed by the Figure 2, the ice extent of change on year basis. The months with the lowest and the highest surface of ice are respectively September and March. If one focuses on months presenting an important variability in the ice superificies, they are between May and August and between October till December. The ice extent amplitude is less important during the rest of the year.

Figure 2: Arctic ice extent 1991-2014



Source: NSIDC (2014).

Fedi et al. (2018a) highlighted that if the melting ice provides a larger period of navigation, it also generates an increase of ice drifting which can be a source of incident or casualties. If the drifting ice represents a danger for the vessel integrity, as stressed by Faury (2015) and Dalaklis et al. (2019), so it is the case for an unsuitable speed with the ice conditions (Marchenko, 2014b).

Hence the drifting ice, the fast-changing climate conditions can block a vessel within the ice making the use of an icebreaker mandatory in some cases.

4.2. Data collection on maritime claims through the NSR and mapping

We identified thirty events occurred along the NSR from 2007 to 2018. The ship’s name, its type, its ice-class, year of event, and factor, that is to say the root cause of these events are provided in the Table 3 below. We classified these events either as marine incident (MI), marine

casualty (MC), serious casualty (SC) or very serious casualty (VSC), depending on their respective consequences and in accordance with the IMO taxonomy defined in the Casualty Investigation Code (IMO, 2018).

Table 4. Marine incidents and casualties from 2007 to 2018

	Vessel	Type	Date	Location	Factor	Consequences	Taxonomy
1	Viktor Koryakin	Dry Cargo	2007	Barents Sea	Climate	Grounding	SC
2	Alexei Kulakovsky	Tow-boat	2010	Laptev Sea	Climate	Sinking / death	VSC
3	Alushta	General cargo	2010	Barents Sea	Human	Fire	SC
4	M/T Indiga	Tanker	2010	Laptev Sea	Ice	Collision	SC
5	Varnek	Pontoon	2010	Barents Sea	Climate	Sinking / Death	VSC
6	M/T Varzuga	Tanker	2010	Laptev Sea	Ice	Collision	SC
7	Asteropa	Fishing	2011	Barents Sea	Ice	Ship stuck	MI
8	M/T Perseverance	Tanker	2011	East Siberian Sea	Human	Collision	SC
9	Salsa	General cargo	2011	NA	Human	Collision	SC
10	Sinegorsk	Bulk carrier	2011	East Siberian Sea	Ice	Ship stuck	MI
11	Soyana	Bulk carrier	2011	Barents Sea	Human	Collision	SC
12	Vaygach	Nuclear ice-breaker	2011	Barents Sea	Human	Fire	SC
13	M/T Palva	Tanker	2012	Chukchi Sea	Ice	Collision	SC
14	M/T Stena Poseidon	Tanker	2012	Chukchi Sea	Ice	Collision	SC
15	Noble Discoverer	Drilling ship	2012	Chukchi Sea	Climate	Collision	SC
16	M/T Nordvik	Tanker	2013	Kara Sea	Ice	Collision	SC
17	Polargirl	Exploration ship	2013	Barents Sea	Ice	Grounding	SC
18	Barents-1100	Small boat	2014	Barents Sea	Climate	Abandonment	SC
19	GSP Saturn	Jack-up rig	2014	Pechora Sea	Climate	Hull damage	SC
20	LNG/C	LNG carrier	2015	Kara Sea	Ice	Ship stuck	MI
21	Motor Tanker	Tanker	2015	Kara Sea	Ice	Ship stuck	MI
22	Plutonas	Fishing trawler	2015	Barents Sea	Human	Injury	MC

Mapping and analysis of maritime claims in the Russian Arctic
based on POLARIS System
PREPRINT Paper ID 109

23	Svyatov Petr		2015	Laptev Sea	Human	Collision	SC
24	Arctic Pioneer	Fishing	2015	Barents Sea	Human	Injury	MC
25	Johann Mahmastal	Bulk carrier	2016	East Siberian Sea	Ice	Ship stuck	MI
26	M/T Chukotka	Tanker	2016	Laptev Sea	Climate	Collision	SC
27	M/T Nordic Barents	Bulk carrier	2017	Kara Sea	Human	Collision	SC
28	Arctica-1	General cargo	2017	Kara Sea	Engine failure	Drift	MI
29	Sinegorsk	Bulk carrier	2017	East Siberian Sea	Ice	Ship stuck	MI
30	LNG/C Boris Vilkitsky	LNG carrier	2018	Kara Sea	Ice	Drift	MI

Source: The Authors, 2019

MI: Marine Incident - SC: Serious Casualty - MC: Marine Casualty - VSC: Very Serious Casualty

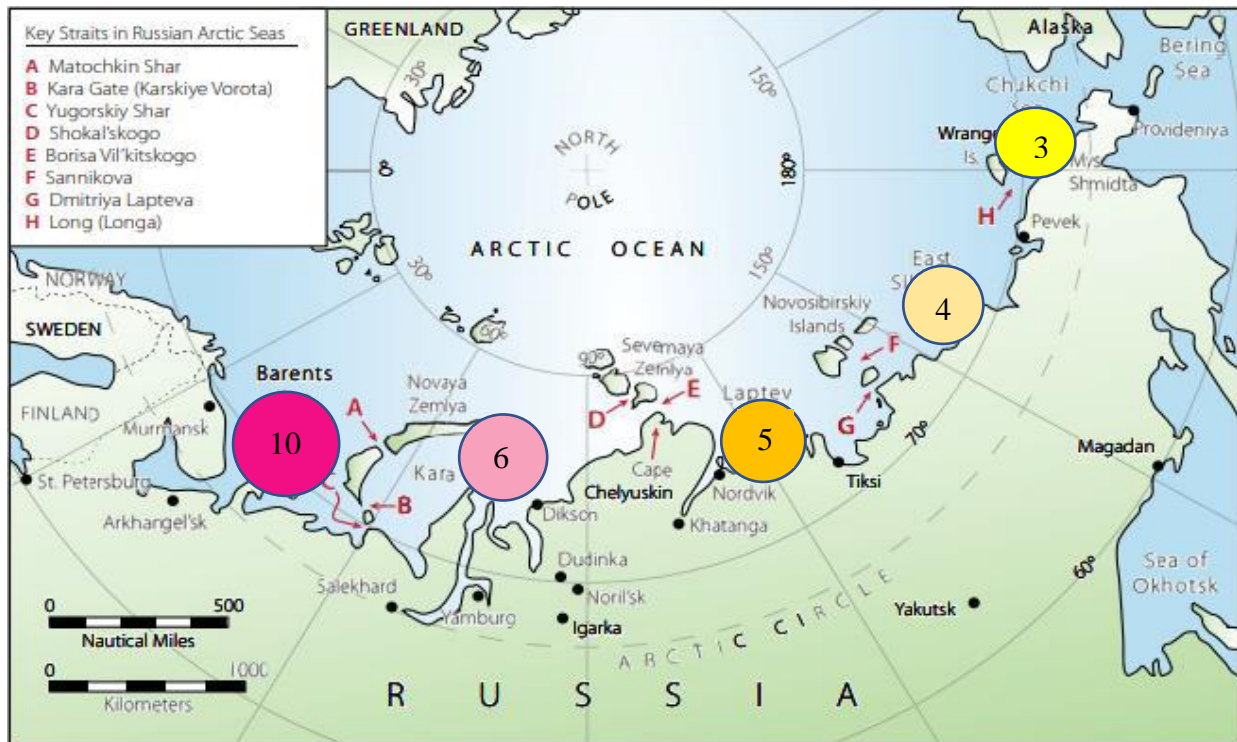
As shown in Table 4, ‘marine casualties’ are the most frequent events representing 22 events out of 30, that is to say more than 73%. Two are categorized as simple ‘marine casualties’, 18 as ‘serious casualties’ and two as ‘very serious’. Eight events are considered as simple ‘marine incidents’. Concerning marine incidents, ship stuck represents 75% of the most common events whereas drift represents 25%. As regards serious casualties, the collisions are dominated with more roughly 67% while grounding, fire, hull damage and abandonment of ship constitute the other events but they are really fewer. Very serious marine casualties involving mainly sinking and death represent around 9% of total casualties. As a consequence, ‘casualties’ that is to say events with a certain gravity, are more widespread than mere ‘incidents’ in the Russian Arctic.

With regard to determining factors, ice is identified as being the dominant factor with 13 events out of 30 then 43% of the total. It means that roughly the half of the maritime claims are caused by ice. Ice impacts are not homogeneous leading either to marine incident without detrimental consequences for ship and crew such as drift, ship stuck or to serious casualty: grounding and collision. Human factor is the second key root cause with nine events with 30% and responsible of different types of consequences such as collision, fire and injury. Although climate factor represents seven events (23%), it can cause very serious casualty notably sinking and death. Finally, only one event was attributed to engine failure with minor consequences (4%).

As regard the typology of vessels, with ten claims out of a total of thirty, tankers are primarily involved representing around 33% of maritime events. They are followed by bulk carriers with five claims and worth 17% of the total. General cargoes and fishing vessels account for three claims respectively and worth 10% each. The other types of vessel involved in claims are miscellaneous (tow-boat, ice-breaker, drilling-ship, etc.) and account for 30% of the total maritime events.

One observes that the year 2011 accounted the greater number of recorded claims (six) while 2010 and 2015 were in second position with five claims. The other years show a lower rate between one claim at the minimum (2007, 2018) or three claims maximum annually (2012, 2013, 2014, 2017).

Figure 3. Accidents representation along the Northern Sea Route



Source: The authors based on ABS (2014)

As illustrated in Figure 3, during the period 2007-2018 the Barents Sea has concentrated the highest number of claims with a total of 10 out of 30 representing 33% of events and it can be considered as the most significant accidental area along the NSR. The first source of claims is the human factor with around 56%. Paradoxically, while the Barents Sea is located at the extreme south of the NSR, it accounts more claims than the extreme north with the Chukchi Sea. The claims are indeed progressively fewer in the north of the NSR. Different taxonomies of claims are recorded in this area from merely ‘minimum incident’ to ‘very serious casualty’. The Kara Sea can be considered as the second most dangerous area with six claims accounting for 20% of the total. The Kara Sea is made up of several straits through isles and archipelagoes involving difficult sailing conditions especially when ice is present. Consequently, it is not surprising to note that around 67% of claims are associated with ice factor, collisions represent 33% of ‘serious casualties’ whereas drifts and ships stuck as ‘marine incidents’ account for the rest. The Laptev Sea is the third most risky area with five claims (16%). It is worth noting that the Laptev Sea only faced ‘very serious’ and ‘serious casualties’ with mostly collisions and one total loss. The determining factors are ice with 40% of identified claims, climate factor 40% and human factor 20%. The East Siberian Sea is in fourth position with four recorded claims (13%). In the East Siberian Sea, 75% of claims concern ship stuck while they are classified as ‘marine incident’. Finally, as regards the Chukchi Sea, only three claims are recorded and worth 10% of the total. Nevertheless, ‘serious casualties’ systematically occurred in this area, mainly collisions, ice factor contributed to the two thirds of events and climate one third.

This situation can be explained by the fact that most of sealift within the Arctic Russian EEZ are made of cargo coming from the oil and gas fields located between the Yamal and Kola

Peninsula. Besides, if navigation in convoy with an icebreaker avoids the risk represented by ice, it may be at the origin of collision¹.

4.3. The M/V *Sinegorsk* case: evaluation analysis and discussion

4.3.1. Evaluation analysis

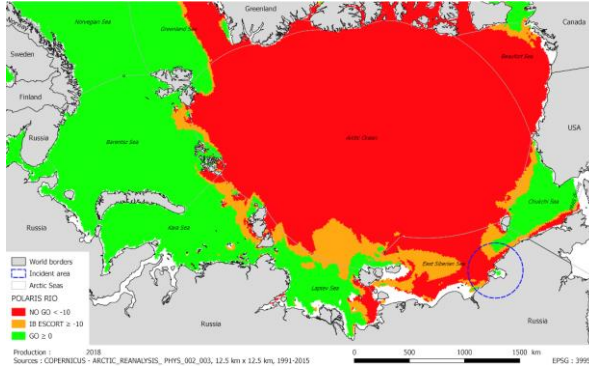


Figure 4a: 1AS vessel – Chaunskaya Bay (Ship stuck) December 28th – bad case scenario

Source: Authors based on Copernicus-Arctic Reanalysis-phys-002-003, 12.5kmx12.5km, 1991-2015

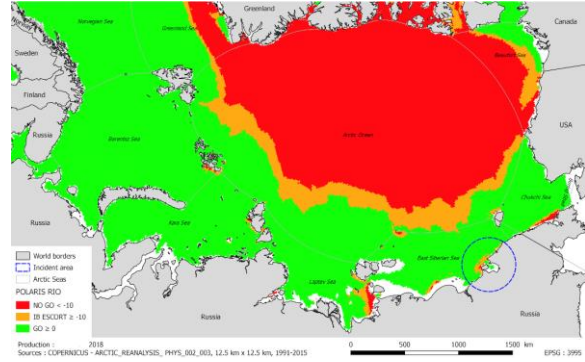


Figure 4b: 1AS vessel – Chaunskaya Bay (Ship stuck) December 28th – median case scenario

Source: Authors based on Copernicus-Arctic Reanalysis-phys-002-003, 12.5kmx12.5km, 1991-2015

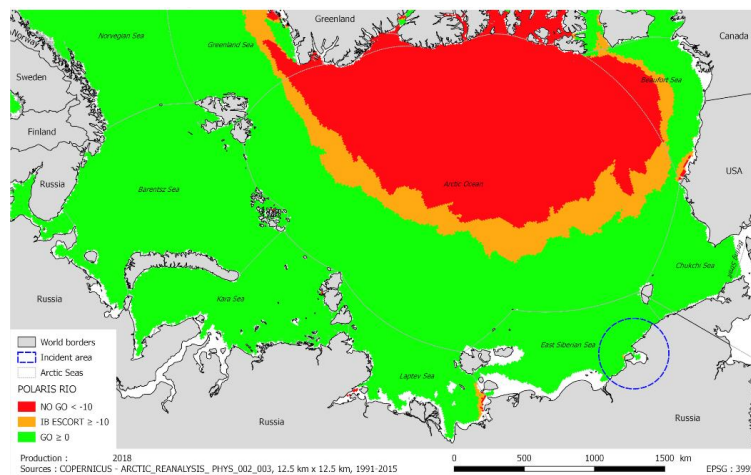


Figure 4c: 1AS vessel – Chaunskaya Bay (Ship stuck) December 28th – best case scenario.

Source: Authors based on Copernicus-Arctic Reanalysis-phys-002-003, 12.5kmx12.5km, 1991-2015

Fedi et al. (2018b) shed a light on the use of POLARIS as a decision tool intended to shipowners and crew officers. In order to stress the positive impact of this tool upon the Russian Arctic navigation, we applied POLARIS index to the case of an incident that occurred in 2017 involving an ice-class 1AS assisted by an icebreaker in harsh sailing conditions.

¹ http://arctic-lia.com/wp-content/uploads/2018/05/news_2017-04-25_Helsinki.pdf
IAME 2019 Conference, June 25th – 28th, Athens, Greece

The general cargo vessel M/V *Sinegorsk* (IMO – 8711291) was sailing from Arkhangelsk in the White Sea to Pevek in convoy with the M/V *Johann Mahmastal* assisted by the diesel icebreaker *Admiral Makarov* in order to supply cargo. While they were supposed to deliver their goods on the 30th December, they arrived on the 7th of January.

The M/V *Sinegorsk* is an ice-class 1AS vessel meaning that according to Konygin et al. (2015), it shall not be able to sail in ice with a thickness above 0.8 meters. Yet, ice conditions changed and the ice thickness reached 1m with ridged at 2.5 meters, blocking the convoy at the entrance of the Chaunskaya Bay, 24 miles for Pevek².

If this incident did not have any impact on the hull structure and on the crew integrity as it was divulged, we could imagine that the eight days delay had some economic consequences. Thus, it raises the following question: would the use of POLARIS and the ice historical data have allowed an anticipation of this claim?

Our analysis leans on the ice thickness and concentration extracted from Copernicus database (2018) over 25 years. Based on this data, pursuant to IMO Guidance (2016), we considered the level of navigability of the 1AS according to three scenarios: a best, median and worst-case scenario (Figure 4a, 4b, 4c).

As explained previously, the ice blanket tends to increase between September till March and December is the month with the higher ice variations. Connected to this fact, the ice conditions along the NSR are not homogenous and the eastern part is worse than the Western one (Marchenko, 2014a).

Our results show that the risk of being stuck in ice could have been forecasted thanks to POLARIS system. The only scenario that does not present any risk for the navigation is the best case. The two others scenarios point out that the vessel needs at least an icebreaker, potentially a nuclear powered one, instead of a diesel one as it was the case. Defining operational limitations of the vessel's capabilities, the PWOV would have also been useful as it anticipates different scenarios of operating and environmental conditions the ship may face.

4.3.2. Discussion and managerial implications

Whereas the recorded marine claims presented in Table 4 do not pretend to constitute an exhaustive data base, their analysis provides a global overview of the NSR accidentology pursuant to the IMO taxonomy during the 2007-2018 period. Obviously, most of events are 'casualties' illustrating their seriousness. With regard to accident factors, our analysis highlights that ice remains a key determining cause of marine claims (43%) and confirms the significant risks resulting from (AMSA, 2009; Marchenko, 2012a; Abassi et al., 2017). Collisions represent the most frequent 'serious casualties' while ships stuck and drifts constitute the common 'marine incidents' showing that ice conditions along NSR are still tough for ships (Vihanninjoki, 2014; Marchenko, 2014a). Moreover, human factor is identified as the second cause of marine claims in the Russian Arctic (30%) and emphasizes the importance of training and experience in polar areas (Tikka et al, 2008; Kum and Sahin, 2015) as required by the new Polar Code (Fedi and Faury, 2016; Fedi et al., 2018). Finally, climate represents the third factor in line with the findings of previous consistent reports (AMSA, 2009; ABS, 2014).

With regard to the typology of vessels, the analysis shows that numerous claims involve tankers and bulk carriers. Insofar as raw materials are mainly carried along the NSR (Faury and Cariou,

² <https://gcaptain.com/russian-vessel-convoy-beset-ice-northeast-passage/>

2016), this statement is not surprising. Nevertheless, tankers face most ‘serious casualties’ in particular collisions. It raises the topical issue of oil spills and their impact in fragile Arctic ecosystems (AMSA, 2009; 2017). Taking into consideration the strategic role of the NSR in the exportation of Russian oil products, this traffic is expected to grow especially with the Yamal plant while related risks shall proportionally increase. A worst-case scenario can not be excluded and the low density of SAR infrastructure along the NSR heightens the threat of oil spills (Vihanninjoki, 2014). Regarding fishing vessels, one observes the low rate of claims, only 10% of the total, compared to the statistics provided in AMSA report (2009) that identified 108 accidents/incidents and accounted around 37% of claims. These preliminary results would allow maritime stakeholders such as shipowners, classification societies and underwriters who need statistics in particular (Kiiski, 2017; Fedi et al., 2018a), to have a better operational knowledge on past claims (Schmied et al., 2016) and to adopt a proper risk assessment for undertaking a journey via the NSR.

Through the M/V *Sinegorsk* case, we underlined the valuable contribution of POLARIS as a risk mitigation tool for ice-covered areas. Its implementation prior to 2018 would have certainly prevented other claims occurred along the NSR where ice still represents a huge risk as illustrated by a high number of identified casualties during the last decade. Nevertheless, POLARIS implies complementary measures for an appropriate decision-making. POLARIS is not self-sufficient since it only covers ice conditions which constitutes a sole parameter of ship’s operational limitations (Fedi et al., 2018b). Even though the shipowner and the master must take into consideration the vessel’s capabilities to sail through or in ice-covered areas thanks to the PSC, a wide range of operating and environmental conditions beyond ice must be also evaluated: low air temperature, high latitude, remoteness or weather conditions that is to say the main hazards identified by the Polar Code as detailed in Table 3. In addition, an appropriate voyage planning shall be defined and the master shall respect the PWOM and related procedures on operational limitations. Whereas the human factor is particularly important (AMSA, 2009), it is not included in POLARIS. The Polar Code’s requirements on specific polar crew’s certification compensates the POLARIS shortage on human element. Accordingly, POLARIS system cannot be ‘disconnected’ from the key Polar Code’s provisions such as PSC, PWOM, voyage planning, experienced and trained crew members. Then, the implementation of POLARIS combined to the Polar Code’s compliance enable operators to adopt appropriate decision in a prophylactic way and prevent risk occurrence in the Russian Arctic.

Furthermore, the beneficial and tangible impacts of POLARIS system shall be evaluated in the medium and long-run and especially in light of greater maritime activities in the Russian Arctic. As a modern methodology for assessing ship’s operational capabilities, the benefits of POLARIS must be promoted by Arctic stakeholders, classification societies, shipowners and underwriters in particular. This promotion seems necessary insofar as POLARIS is not mandatory. As stated in the Recommendations Part-I-B of the Polar Code (IMO, 2014), other methodologies can be used such as AIRSS from Canada or the Russian Ice Passport. The Arctic Shipping Best Practice Information Forum (‘the Forum’) that aims to raise awareness of the Polar Code and to exchange best practices for Arctic marine operations (AMSA 2017; Fedi et al. 2018a) provides a relevant setting for this promotion.

Finally, pursuant to the PAME 2017-2019 Work Plan (PAME, 2017), the Compendium of Arctic Shipping Accidents (CASA) should be launched prior to end 2019. This project is designed to provide updated data on maritime events occurred in Arctic Ocean and should constitute a valuable source of information for more exhaustive analysis on the nature of claims,

their location, their impacts and contemplating measures that might be pursued to reduce their occurrence. If Russia participated in this data base, it would allow an accurate identification and mapping of maritime claims along the NSR.

5. Concluding remarks

The aim of this paper was to identify, categorize and map marine claims occurred in the different seas belonging to NSR that is facing greater shipping activities. The categorisation was based on the IMO Casualty Investigation Code. So far few research have been carried out following the IMO standards and providing a global approach as regards identification, taxonomy and mapping of marine claims in the Russian Arctic. The analysed claims provided an overhaul picture of the situation and underlined that serious casualties represented the largest number of events. Our results confirmed the role of ice as determining factor in marine casualties during the 2007-2018 period. In light of growing traffic through the NSR, these preliminary results would allow stakeholders such as underwriters, classification societies and shipowners, to have a better knowledge on past claims and to adopt a proper risk assessment for undertaking a journey via the NSR. This evaluation of risk must not be neglected considering that the NSRA has recently observed numerous violations of rules (NSRA, 2017).

The second contribution of the research was to highlight the relevance of the POLARIS instrument combined to the Polar Code in the shipping risk mitigation for the NSR ice-covered areas. Through the *M/V Sinegorsk* case study, we have shown that POLARIS constituted a valuable decision support tool and an appropriate mitigation response to ice risk which remains one of the greater hazards in the Russian Arctic.

With regard to the limitations of the study, the provided data on maritime claims along the NSR are not exhaustive and do not constitute a data base while we have combined different sources in order to optimise the statistics. Moreover, our analysis is mainly based on a single case study. Consequently, future research should examine if the same findings and theoretical implications are duplicated in other case studies with similar context. In addition, regarding the recent entry into force of the Polar Code, operators are in a transition phase and a certain time is necessary to assess the long-term impacts on NSR and Arctic as a whole. Nevertheless, the new prophylactic Polar Code's provisions associated with POLARIS should contribute to a reduction of the number of claims in the long-run. This analysis is a part of our research agenda and shall be facilitated by the access to a global data base that is currently missing. The promising CASA should enable us to deepen this research.

References

- ABS. 2014. “Navigating the Northern Sea Route – Status and Guidance.” American Bureau of Shipping Advisory, 28 pages.
- ABBASSI, R., KHAN F., VEITCH B. and EHLERS S. 2017. “Risk analysis of offshore transportation accident in Arctic waters.” *International Journal of Maritime Engineering*, Vol 159, Part A3, Jul-Sep 2017, A213-A224.
- ALLIANZ. 2018. Safety and shipping review: an annual review of trends and developments in shipping losses and safety. www.agcs.allianz.com/assets/PDFs/Reports/AGCS_Safety_Shipping_Review_2018.pdf.
- ALLIANZ. 2017. Safety and shipping review: an annual review of trends and developments in shipping losses and safety. www.agcs.allianz.com/assets/PDFs/Reports/AGCS_Safety_Shipping_Review_2017.pdf.
- AMSA. 2009. Arctic Marine Shipping Assessment 2009 Report. Arctic Council, April 2009, second printing. <http://www.arctic-council.org/index.php/en/documentarchive/category/20-main-documents-from-nuuk>.
- AMSA. 2017. Status on Implementation of the AMSA 2009 Report Recommendations. May 2017. Accessed 1 March 2019. https://oaarchive.arctic-council.org/bitstream/handle/11374/1957/PAME_4th-AMSA_Implementation_Progress_Report_for_the_period_2015-2017.pdf
- BALTO, J.B.H. 2014. “Risk of Ship Collision in the Barents Sea in 2030.” Department of Engineering and Safety. UiT The Arctic University of Norway, Norway, p. 60.
- BAKSH, A.-A., ABBASSI, R., GARANIYA, V. and KHAN, F. 2018. “Marine transportation risk assessment using Bayesian Network: application to Arctic waters.” *Ocean Engineering* 159, 422-436.
- BORGERSON, S.G. 2008. “Arctic meltdown: the economic and security implications of global warming.” *Foreign Aff.* 87, 63–77.
- CHIRCOP, A. 2013. “Regulatory challenges for international Arctic navigation and shipping in an evolving governance environment.” *CMI Yearbook*, pp. 408-427. Published by CMI Headquarter, Antwerp, Belgium.
- COPERNICUS DATA BASE, 2018, <http://www.copernicus.eu/main/marine-monitoring>.
- DALAKLIS, D., BAXEVANI, E., and SIOUSIOURAS, P. 2018. “The future of Arctic shipping business and the positive influence of the international code for ships operating in polar waters.” *The Journal of Ocean Technology*, Vol 13 (4) pp 76-94.
- De FERRIERE LE VAYER, A. 2018. The Northern Sea Route: A try in assessing the maritime risk in the Arctic waters. Master Thesis. EM Normandie.
- FAURY, O., and CARIOU, P. 2016. “The Northern Sea Route competitiveness for oil tankers.” *Transportation Research Part A: Policy and Practice*, 94, 461-469.
- FAURY, O. 2015. “Risk management in the Arctic from an underwriter’s perspective. IAME Conference, Kuala-Lumpur, 24-26 August 2015.

- FEDI, L. and FAURY, O. 2016. “Les Principaux Enjeux et Impacts du Code Polaire OMI.” [“The main stakes and impacts of the IMO Polar Code”], *Le Droit Maritime Français* 779 : 323-337.
- FEDI, L., FAURY, O., and GRITENSKO, D. 2018a. “The impact of the Polar Code on risk mitigation in Arctic waters: a ‘toolbox’ for underwriters?” *Maritime Policy and Management*, Vol. 45, No. 4, pp. 478-49. doi.10.1080/03088839.2018.1443227.
- FEDI, L., ETIENNE L., FAURY, O., RIGOT-MÜLLER, P. STEPHENSON, S. and CHEAITOU, A. 2018b. “Arctic Navigation; Stakes, Benefits, Limits of the Polaris System.” *The Journal of Ocean Technology*, Vol. 13, No. 4, 2018, 54-67.
- FU, S., ZHANG, D., MONTEWKA, J., YAN, X., and ZIO, E. 2016. “Towards a Probabilistic Model for Predicting Ship Besetting ice in Arctic Waters.” *Reliability Engineering & System Safety* 155: 124-136.
- GOERLANDT, F., GOITE, H., VALDEZ BANDA, O., HÖGLUND, A., AHONEN-RAINIO, P., LENSU, M. 2017. “An analysis of wintertime navigational accidents in the Northern Baltic Sea,” *Safety Science* 92, 66–84.
- GRABOWSKI, M., YOU, Z., ZHOU, Z., SONG, H., STEWARD, M., STEWARD, B. 2009. Human and organizational error data challenges in complex, large-scale systems. *Safety Science*. 47, 1185–1194.
- GRITSENKO, D. and EFIMOVA, E. 2017. “Policy environment analysis for Arctic seaport development: the case of Sabetta (Russia).” *Polar Geography* Vol. 40, p. 186-207, <http://doi.org/10.1080/1088937X.2017.1328466>
- GRITSENKO, D. and KIISKI, T. 2015. “A review of Russian ice-breaking tariff policy on the northern sea route 1991–2014.” *Polar Record / First View Article* Copyright © Cambridge University Press 2015 DOI: <http://dx.doi.org/10.1017/S0032247415000479>, 15 pages.
- HAAVIK, T.K. 2017. “Remoteness and Sensework in Harsh Environment.” *Safety science* 95: 150-158. doi:10.1016/j.ssci.2016.03.020.
- HENRIKSEN, T. 2014. “The Polar Code: ships in cold water – Arctic issues examined.” *CMI Yearbook*, pp. 332-344. Published by CMI Headquarter, Antwerp, Belgium.
- IMO 2008. Resolution MSC.255(84) adopted on 16 May 2008 adoption of the Code of the international standards and recommended practices for a safety investigation into a marine casualty or marine incident (Casualty investigation code).
- IMO 2014a. Resolution MSC 385 (94) of November 21, 2014 and Resolution MEPC 264 (68) of May 15, 2015. International Code for Ships Operating in Polar Waters (Polar Code).
- IMO 2014b. Maritime Safety Committee POLARIS – proposed system for determining operational limitations in ice. Submitted by the International Association of Classification Societies, MSC 94/3/7, 9th Session, Agenda 3, September 12, 2014.
- IMO 2014c. Maritime Safety Committee – technical background to POLARIS. Submitted by Canada, Finland, Sweden, and the International Association of Classification Societies, MSC 94/INF13, 9th Session, Agenda 3, September 12, 2014.
- IMO, 2016. “MSC. 1/Circ 1519, 6 June 2016, Guidance on Methodologies for Assessing Operational Capabilities and Limitations in Ice.” [https://docs.imo.org/Final Documents/English/MSC.1-CIRC.1519\(E\).docx](https://docs.imo.org/Final Documents/English/MSC.1-CIRC.1519(E).docx)

- IUDIN, I. and PETROV, S. 2016. "The Russian Sea Areas and Activity Level Up to 2025." From the report: Maritime activity in the High North - current and estimated level up to 2025, MARPART Project Report 1. Nord Universitet, No 7. Bodø 2016.
- IUMI, 2018. Global marine insurance report 2018. Cape-Town, 16-19 September 2018. https://cefor.no/globalassets/documents/statistics/iumi-statistics/2018/monday-1155-seltmann_final.pdf
- KIISKI, T. 2017. "Feasibility of Commercial Cargo Shipping along the Northern Sea Route." *Annales Universitatis Turkuensis*, University of Turku.
- KITAGAWA, H. 2008. "Arctic routing: challenges and opportunities." *WMU Journal of Maritime Affairs* 7, 485–503.
- KONYGIN, A., NEKHAEV, S., DMITRUK, D., SEVASTYANOVA, K., KOVALEK, D., CHERENKO, V., 2015. "Oil Tanker Transportation." In: The Russian Arctic. *International Journal of scientific & technology. Research volume 4(03): 27-33.*
- KUJALA P., KÄMÄRÄINEN J., and SUOMINEN, M. 2016. "Challenges for Application of Risk Based Design Approaches for Arctic and Antarctic Operations." 6th International Maritime Conference on Design for Safety, Hamburg, Germany, 28-30.11.2016.
- KUM, S. and SAHIN, B. 2015. "A root cause analysis for Arctic marine accidents from 1993 to 2011." *Safety Science*, Vol. 74, pp. 206-220. doi:10.1016/j.ssci.2014.12.010
- LADAN, M., HÄNNINEN, M., 2012. "Data Sources for Quantitative Marine Traffic Accident Modeling." *Science + Technology* No. 11/2012. Aalto University publication series Science + Technology. Aalto University, Department of Applied Mechanics, Helsinki, Finland.
- LASSERRE, F. 2016. "Polar seaways? Maritime transport in the Arctic: an analysis of shipowners' intentions II." *Journal of Transport Geography*, 57
- LASSERRE, F. 2014. "Case studies of shipping along Arctic routes. Analysis and profitability perspectives for the container sector." *Transp. Res. Part A* 66, 144– 161.
- LOPTIEN, U., and AXELL, L. 2014. "Ice and AIS : Ship speed data and sea ice forecast in the Baltic Sea." *The Cryosphere*, 8, 2409-2418, 2014 <www.the-cryosphere.net/8/2409/2014/> doi:10.5194/tc-8, 2409-2014.
- LIU, M. and KRONBAK, J. 2010. "The potential economic viability of using the Northern Sea Route as an alternative route between Asia and Europe." *Journal of Transport Geography*, Vol. 18, Issue 3, p 434-444.
- LOUGHNANE, D., JUDSON, B., and REID J. 1995. "Arctic Tanker Risk Analysis Project." *Maritime Policy & Management* 22 (1): 3–12. doi:10.1080/03088839500000028.
- MARCHENKO, N. 2012a. "Ice Conditions and Human Factors in Marine Accidents at the Arctic." The University Centre in Svalbard, Longyearbyen, Norway.
- MARCHENKO, N. 2012b. "Russian Arctic Seas: navigational conditions and accidents." Heidelberg: Springer.
- MARCHENKO, N., 2014a. "Northern Sea Route: Modern state and challenges." Proceedings of the 33rd International conference on ocean, offshore and arctic engineering. OMAE2014. June 8-13, San Francisco, CA.
- MARCHENKO, N., 2014b. "Floating Ice Induced Ship Casualties." In *22nd IAHR International Symposium on Ice, Singapore.*

MARCHENKO, N., BORCH, O., MARKOV, S., ANDREASSEN, N. 2015. "Maritime activity in the high North – the range of unwanted incidents and risk patterns." Proceedings of the 23rd International conference on port and ocean engineering under Arctic conditions (June 14–18, 2016)

MINISTRY OF ENERGY OF THE RUSSIAN FEDERATION. 2010. "Energy Strategy of Russia for the period up to 2030." Decree N°1715-r of the Government of the Russian Federation dated 13 November 2009, 174 pages.

MONTEWKA, J., GOERLANDT, F., KUJALA, P., and LENSU, M. 2015. "Towards a Probabilistic Model of a Ship Performance in Dynamic Ice." *Cold Regions Science Technology* 112: 14-28.

NATIONAL SNOW & ICE DATA CENTER (NSIDC). 2014. http://nsidc.org/data/docs/noaa/g02135_seaice_index/index.html#processingstep

NSRA (Northern Sea Route Administration), 2012. The Federal Law of Shipping on the Water Area of the Northern Sea Route July 28, 2012, N 132-FZ. http://www.nsra.ru/en/ofitsialnaya_informatsiya/zakon_o_smp.html

NSRA 2017. Violation of the Navigation Rules on the NSR. Accessed 5 January 2019. <http://www.arctic-lio.com/node/277>

NSRA 2018. Northern Sea Route Administration. http://www.nsra.ru/en/glavnaya/ceci_funktsii.html

RAGNER, C.L., 2000. "Northern Sea Route Cargo Flows and Infrastructure – Present state and Future potential." The Fridtjof Nansen Institute. FBI Report 13/2000.

SARC, 2017. "Arctic Search and Rescue Capabilities Survey. Enhancing International Cooperation." 56 Pp.

TIKKA, K., RISKKA, K., and LIU, S. 2008. "Tanker Design Considerations for Safety and Environmental Protection of Arctic Waters: Learning from Past Experience." *WMU Journal of Maritime Affairs* Vol. 7 (1): 189–204. doi:10.1007/BF03195131.

VIHANNINJOKI, V. 2014. "Arctic Shipping Emission in the Changing Climate." Finnish Environment Institute 41.

ZHANG, Y., MENG Q., and ZHANG L. 2016. "Is the Northern Sea Route attractive to shipping companies? Some insights from recent ship traffic data." *Marine Policy*, Volume 73, 53-60.