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# Shipping and Sea Ice in Svalbard Area. Last decade dynamics, regulations and risk

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## ABSTRACT

This study explores how sea ice variability and climate change have influenced shipping activity around Svalbard between 2013 and 2023. Using monthly sea ice concentration data from the National Snow and Ice Data Center (NSIDC) and vessel density data from the Global Maritime Traffic Density Service (GMTDS), we analyzed seasonal and spatial patterns in relation to vessel type and ice conditions. The results show a general decline in sea ice extent, especially in late summer and autumn, but with strong year-to-year variation. Unlike the broader Arctic, Svalbard's sea ice maximum often occurs later, in March or April, and the minimum sometimes shifts to August, illustrating its unique position between Arctic and Atlantic water masses.

Ship activity has increased near the ice edge, with the highest activity in marginal ice zones (15–30% concentration), particularly among fishing and passenger vessels. Many vessels classified as cargo or research are actually used for tourism, operating near or within ice-affected waters. Despite Svalbard representing only 6% of the Arctic Polar Code area, it accounts for over half of all Arctic cruise vessels and yachts, underlining its significance as a tourism hub.

While Arctic maritime regulations, such as the Polar Code (2017) and Norway's Climate Action Plan (2021), have improved safety and environmental standards, implementation varies across vessel types. The 2024 Svalbard White Paper and planned 2025 amendments aim to address this by introducing limits on cruise passengers and landing sites. These findings stress the need for adaptive, region-specific management based on actual vessel use and changing environmental conditions.

KEY WORDS: Shipping; Sea Ice; Svalbard; Accidents; Regulation.

## INTRODUCTION

Global warming is a frequently discussed topic in both the media and scientific circles. It is known that the warming is most pronounced in the Arctic and a significant reduction in sea ice has been recorded. Sea ice is often cited as the main obstacle to navigation in the Arctic. So increase in shipping traffic and accidents are expected as a result of climate change, and risk mitigation measures are being considered.

We looked at the Svalbard region (North Atlantic), where shipping is much more active than in other Arctic regions and where the most dramatic climate changes have been recorded. Longyearbyen (the main town) is warming 8 times faster than the rest of the world (ITV News, 2023) and is the northernmost permanent port in the Arctic with more than 1700 port calls yearly (Port of Longyearbyen, 2023). No wonder that this area attracts increasing attention and serves as a case for particular studies. Recently (Stocker et al., 2020) and (Müller et al., 2023) investigated shipping and sea ice variability in the Arctic regions and created relevant plots.

Stocker et al. (2020) examined mobility patterns of cruise ships and fishing vessels around Svalbard in relation to sea ice variability between August 2012 and September 2019. They observed a slight overall increase in fisheries and cruise activity, along with remarkable trends of stretching operational seasons and expanding navigational areas in these sectors. However, they found no clear trend in the total number of vessels. The highest number of fishing vessels was recorded in 2015 (223 unique vessels) and 2016 (222), with yearly counts ranging between 186 and 208 in other years. For passenger vessels, the peak was in 2013 (45 unique vessels) and 2016 (44), with annual numbers generally between 40 and 43. Their analysis combined AIS data from the Norwegian Coastal Administration and Sea Ice concentration using Python 3.7.x to generate plots of mean relative sea ice extent and vessel numbers for defined 12 zones around Svalbard.

Müller et al. (2023) calculated the number of shipping days per month across 6 Arcti c sectors between 2013 and 2022. They found a total pan-Arctic increase of 7.3% per year, in vessel activity, rising to 11.6% when excluding fisheries. Around Svalbard, fishing and cruise tourism remained the dominant activities, with a slight overall increase and a temporary decline between 2018 and 2020, including—but not limited to—the COVID-19 year (2020). However, unlike other Arctic regions, no clear long-term trend was observed for the Svalbard sector. In contrast, three other sectors showed strong growth in vessel activity, ranging from 8.6% in West Greenland to 20.2% in the Chukchi–Bering Sea, while a slight decline was recorded in the Northwest Passage (-3.0%). Interestingly, the "other" vessel category is ev en larger than the area indicating passenger and cruise.

This study builds on previous research in the Svalbard region by examining the interactions between sea ice conditions and maritime activity. The goal is to provide a more detailed understanding of recent changes and to address the following research questions:
- What are the actual sea ice dynamics around Svalbard, and to what extent is it decreasing?
- How is shipping activity changing over time, and what are the most reliable indicators for assessing this?
- Are ships entering ice-covered waters more frequently and for longer periods?
- Have ice-related incidents involving ships become more frequent?
- To what extent does sea ice remain the main factor affecting shipping and associated risks in the area?
- What are the main drivers of ship traffic dynamics: sea ice or regulatory changes?

## GEOGRAPHICAL FRAMEWORK AND DATA

To assess the dynamics of ship movements in relation to sea ice, we need to use data that are comparable in time, space and resolution. This is not easy to find, although sea ice estimates from satellite imagery and AIS (Automated Identification System) data are becoming increasingly available. Monthly averages of ice concentration data from the National Snow and Ice Data Center (NSIDC, 2025) and ship density from the Global Maritime Traffic Density Service (GMT, 2025) were defined as the most comparable and reliable and were examined.

The study area (Figure 1) covers approximately 800,000 km² around Svalbard, covering key shipping routes and navigational zones that are affected by sea ice variability. This area includes rather high vessel traffic densities (by Arctic standards), particularly around major ports, spectacular fjords and important fishing grounds. The area extends northwards to include regions of remote ice-covered waters. Understanding how vessels interact with changing ice conditions in this zone provides valuable insights into Arctic navigation risks, operational adaptations, and the impact of climate-driven sea ice retreat.

The exact boundaries of the area based on data availability, particularly the export options of the Global Maritime Traffic portal where monthly vessel density (hours per km$^2$) can be downloaded for a defined rectangular area (Figure 1, Table 1)

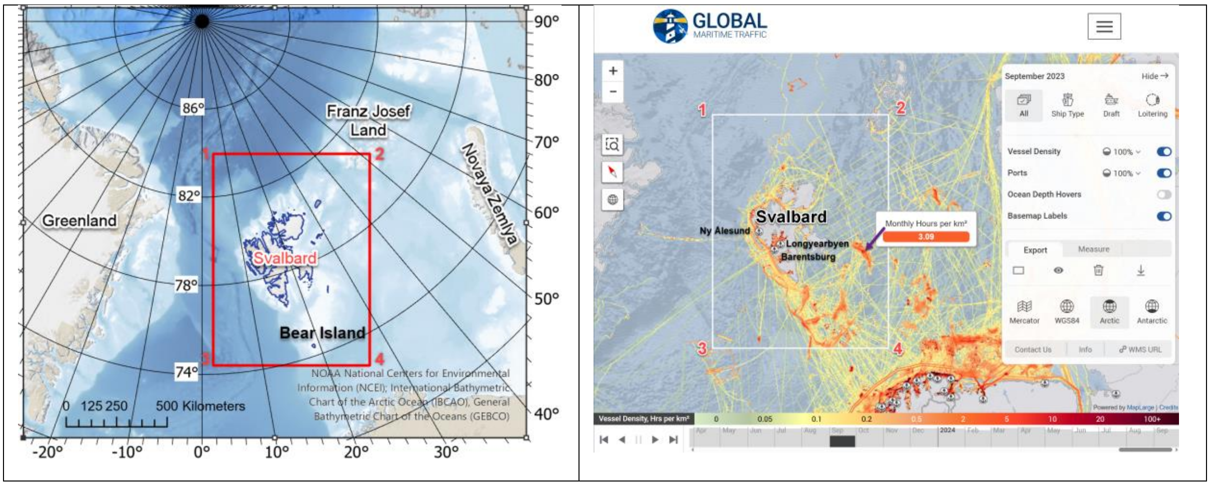


Figure 1. Study area around Svalbard shown on the Arctic map (ESRI, 2025) (left) and on the screenshot of vessel density map (GMT, 2025), illustrating layout and 3 ports on Svalbard. Corner coordinates (red numbers) are listed in the Table 1

Table 1. Corner coordinates of study (Svalbard) area.

| No. | Latitude | Longitude | No. | Latitude | Longitude |
|---|---|---|---|---|---|
| 1 | 83°56'50"N | 4°57'20"E | 3 | 74°24'4"N | 1°54'27"E |
| 2 | 80°14'48"N | 51°46'39"E | 4 | 72°40'30"N | 26°1'33"E |

AIS-derived ship density data were processed into raster grids at a 1-kilometer spatial resolution, representing vessel presence (in hours per km²) every month. Vessels were grouped into three main categories: fishing, cargo, and passenger. Research vessels were included in the cargo category if they also transported goods. The dataset excludes non-commercial, service vessels, and tankers. Passenger vessels are defined as those carrying 12 or more people, without distinguishing between expedition cruises and regular transport. Icebreakers and research vessels (unless counted under cargo) were not included.

For a more detailed analysis of vessel activity, we also used data on ship voyages in the Barents Sea from the Norwegian Coastal Administration and port call statistics from Longyearbyen. Sea ice concentration data were processed into 25-kilometer resolution raster grids, expressing ice cover as a percentage per cell, from 15% to 100%. To examine the spatial overlap between vessel activity and sea ice, ArcGIS Pro was used to generate 132 maps for the years 2013-2023. These maps combine monthly ship density (by vessel type) with sea ice concentration, helping to identify areas of frequent activity in ice, new routes, and unusual vessel behavior.

The NSIDC dataset further supported the identification of high-risk navigational zones and ice trends. Additionally, R Studio (v4.2.2) was used to analyze spatial and temporal variations in sea ice extent (Figure 2) and vessel operations near ice edges and within 15–30% sea ice concentration zones, offering deeper insight into how different vessel types respond to Arctic ice conditions.

## SVALBARD SEA ICE DYNAMICS

Svalbard, positioned between the Arctic Ocean and the North Atlantic, shows pronounced seasonal and interannual sea ice variability due to its exposure to varying oceanic influences. The West Spitsbergen Current (WSC) transports warm Atlantic Water northward along Svalbard's western coastline, limiting ice formation, while the East Greenland Current (EGC) carries cold Polar Surface Water southward, impacting local ice conditions (Johannessen et al., 2020). The influence of Atlantification, characterized by increasing inflows of warm Atlantic Water, is accelerating ice loss around Svalbard, delaying winter freezing, increasing summer melt, and contributing to higher seasonal fluctuations in ice cover (Jakobson et al., 2012).

An analysis of sea ice extent around Svalbard in defined area (Figure 1) from 2013 to 2023 reveals clear seasonal patterns. Maximum sea ice coverage occurs between February and March, while minimum coverage is observed in August and September. The lowest ice extent was recorded in September 2020, covering only 15,000 grid cells (8% of the study area), whereas the peak winter extent in March 2013 reached 115,000 grid cells (65% of the study area). Remarkable interannual variations include reduced ice coverage in September-November for the years 2018, 2020, and 2021, consistent with warming trends in the Arctic (Perovich et al., 2020).

The variability in sea ice extent and concentration between the broader Arctic region and Svalbard shows similarities and distinct differences. While the Arctic generally experiences its sea ice minimum in September and maximum in March, Svalbard's patterns show more variability. In Svalbard, the maximum often occurs in April (2013-2018, 2022) or March, while the minimum is typically observed in August (2015, 2016, 2018, 2022) or September.

Svalbard's unique geographical position at the intersection of Arctic and Atlantic water masses contributes to its greater sea ice variability compared to the broader Arctic. This variability is particularly pronounced during the months September, October, and November, as revealed by the boxplot analysis. These months display larger interquartile ranges and outliers, indicating heightened sensitivity to seasonal temperature fluctuations.

Years of high sea ice extent in Svalbard tend to correlate with denser ice coverage (2015, 2017, 2019, 2021), while 2016 and 2018 experienced lower ice extent. The year 2019 stands out for its significant ice variability throughout the year, including August with sea ice extent dropping significantly below expected levels. In contrast to the variable autumn months, February and March generally show more stable ice coverage in Svalbard, although some years have experienced slightly lower-than-average ice cover, possibly due to early melting events. Extreme deviations from the mean were observed in April 2013 and December 2023, with unexpectedly high ice coverage.

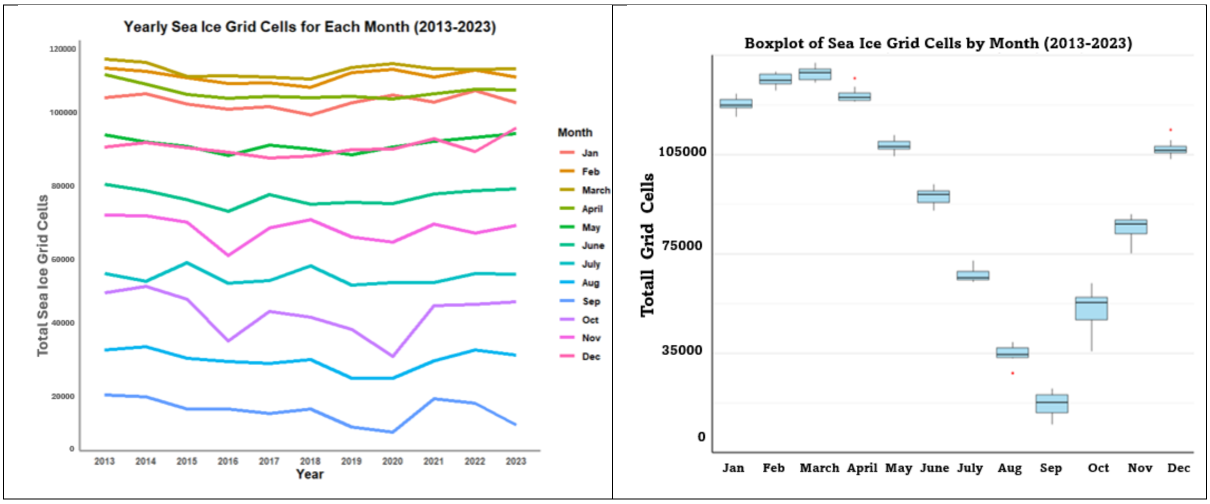


Figure 2. Sea ice extent dynamics in Svalbard area (2013-2023)

The appearance of ice in the area of the port of Longyearbyen has been quite rare in recent years, however, it does happen and even creates difficulties for navigation. Icebergs, ice floes and rubbles were observed in 2015, 2020 and 2022. Significant presence of ice in the Adventfjorden (where the main port of Svalbard Longyearbyen is located) was observed from the beginning of January to 14 April 2020. Large ice rubble near the fjord had dimensions of 250x500 m with a sail height of ice blocks up to 6 m above the water level. The thickness of the ice floes forming the rubble reached 0.9 m (Marchenko, 2023).

Figure 3. Adventfjorden covered by ice in March-April 2024 for the first time after 2009. **Left:** View on city pier with *MS Polarsyssel* docked, Photo: Line Nagell Ylvisåker from (Markussen Hansen, 2024 ) **Right:** *MS Polarsyssel* makes the channel for oil/chemical tanker *MT Isfjord*, Photo: Martin Hansen from (Markussen Hansen, 2024).

The unusually "icy" spring of 2024 is a very good example of sea ice variability and non-linear trends. This has not yet been covered by scientific analysis/publication, but has been seen first-hand and commented on by local media. In April 2024, Adventfjorden was covered in ice and the governor's ship *MS Polarsyssel* had to carry out ice treatment to open a channel for a cargo ship to the pier (unloading point) and free a tourist sailboat trapped in ice (Figure 3). Several tourist ships arriving early in the season in Longyearbyen encountered drifting ice, causing problems in the harbor (Markussen Hansen, 2024 ).

In 2024, sea ice in the Barents Sea was particularly notable, with the ice edge extending further south than in the extreme years of 1866 and 1966, especially south of Bear Island (Solheim, 2024). In 2020 and 2025 sea ice was registered on the Bear Island meteorological station (https://x.com/Meteorologene).

## NAVIGATION IN ICE COVERED WATERS

Superimposing ship density on an ice concentration map (Figure 4 as example) showed that while most vessel operations occur in ice-free waters, some extend into ice-covered regions during specific months.

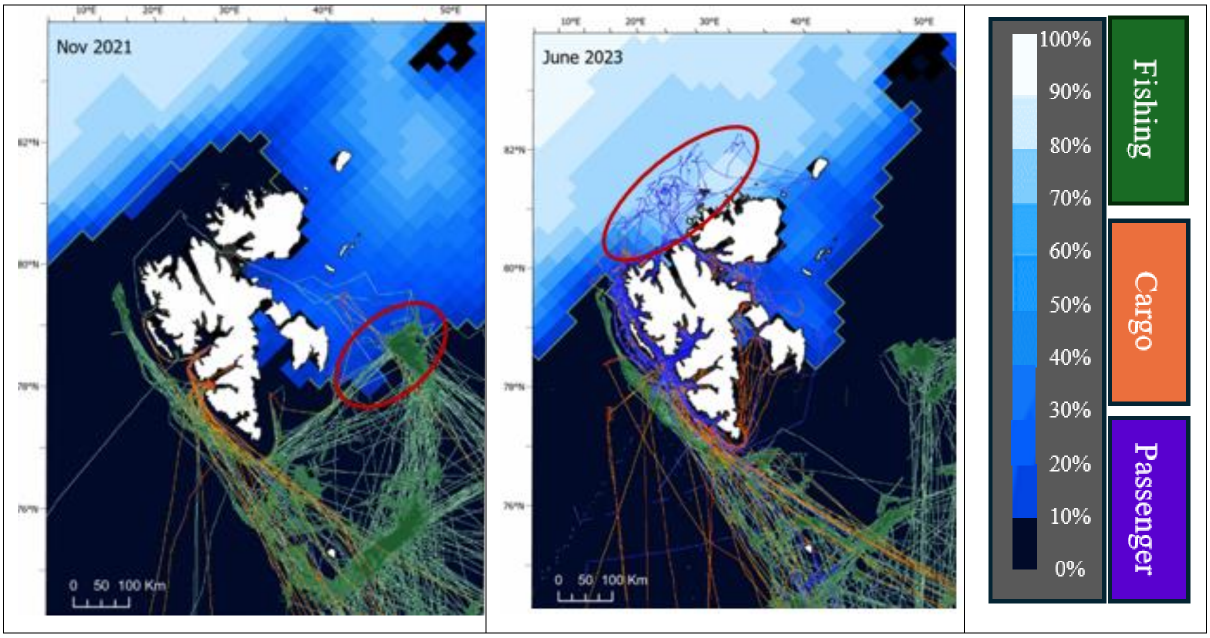


Figure 4. Vessel density overlaid on sea ice concentration. Created in ArcGIS PRO on the base of data from (GMT, 2025) and (NSIDC, 2025). The legend on the right shows the sea ice concentration scale and vessel type symbology. Red circles indicate the areas with highest vessel density in sea ice in the east and north of Svalbard.

Fishing vessels primarily operate near the ice edge, adjusting their routes based on seasonal fish migrations, and to the east, north, and south of Svalbard, where they track fish stocks. The western waters remain mostly ice-free year-round, allowing uninterrupted fishing. In the south and east, vessels continue operations despite ice presence, whereas in the north, activity is limited to periods of minimal ice cover. These patterns highlight how fishing operations adapt to shifting ice conditions and seasonal ice retreat.

Passenger vessels primarily travel northward toward the sea ice edge for wildlife viewing and Arctic tourism. Their routes are dictated by seasonal ice variability, adjusting yearly based on navigability. Cargo vessels, on the other hand, follow stable shipping lanes but must occasionally adjust routes to avoid sea ice, which can lead to longer transit times and increased logistical challenges.

Figure 5 shows grid cell activity which indicates where vessel operations occurred (in bins), while vessel hours quantify the duration of activity within each cell (in lines). A vessel passing briefly through multiple grid cells increases activity but contributes minimal vessel hours. Comparing these metrics helps assess whether maritime traffic is becoming more dispersed or concentrated, with implications for navigational risks, environmental impacts, and SAR preparedness.

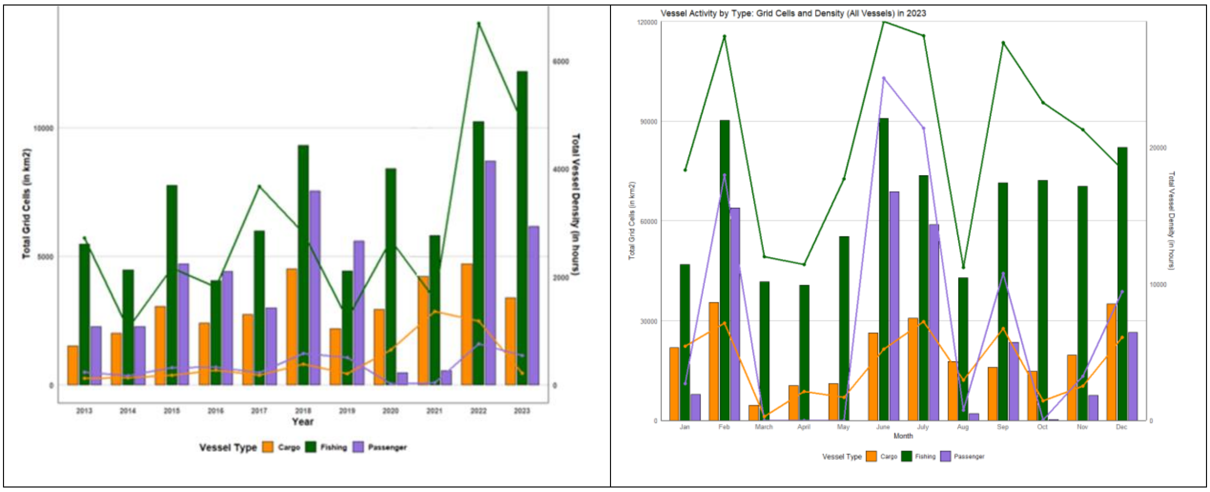


Figure 5. Total vessel density in 15-30% sea ice concentration (for passenger, cargo and fishing vessels) around Svalbard in 2013-2023. **Left:** 2013-2023 variation, **Right:** Interyear variation 2023 example. Created in R Studio on the base of data from (GMT, 2025) and (NSIDC, 2025).

Analysis of vessel density trends in sea ice concentrations of 15-30% reveals distinct operational patterns among different vessel types. Fishing vessels exhibit the highest degree of adaptability, regularly navigating ice-covered waters in pursuit of fish stocks. Their activity fluctuates from 2,000 vessel hours in low-sea-ice years (2016) to peaks of 6,000 vessel hours in years with favorable ice conditions (2023). Cargo vessels generally avoid high ice concentrations, except in cases of post-COVID trade peaks, such as in 2021, when their vessel hours spiked significantly. Passenger vessels demonstrate variable activity, with significant reductions during high-ice years (2020-2021) and increased navigation in ice-covered waters in 2022, as tour operators sought ice-covered regions for expedition cruises.

While the long-term decline in sea ice has facilitated increased maritime activity, the persistence of interannual variability continues to impose operational constraints. The risks associated with Arctic navigation vary depending on ice concentration levels. Areas with 80-100% ice concentration are particularly hazardous, with dense pack ice creating high risks of ship entrapment, while regions with 15-30% ice concentration present more dynamic challenges, including increased collision risks from drifting ice floes (Johannessen et al., 2020).

## VESSELS AND SHIPPING PATTERN

In (Marchenko, 2015) the main patterns of shipping in Svalbard at the beginning of XXI century were described and analyzed in the context of safety. The main features (seasonality, domination of passenger and fishing vessels) remain the same. But changes, such as the closure of large coal mine in Svea, restriction in regulation provoke the modifications (reduction of small expedition ships as a response on the reduction for landing sites).

To assess the dynamics of shipping patterns, especially during the implementation of the Polar

Code we used data provided by the Norwegian Coastal administration (NCA). This dataset includes the first recorded voyage, vessel characteristics (MMSI, IMO, name, type, parameters) as well as departure and destination port. Based on this information we counted the number of unique ships operating in the Svalbard from 2015-2023. The results (Table 2) allowed us to identify trends and changes by vessel type, illustrating periods of peak activity and changes in fleet composition.

Table 2. Number of vessels operating in the Svalbard region by type, based on IMO codes and NCA records. Vessel types are grouped and colour-coded; red numbers indicate the maximum count within each category across 2015-2023.

| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|---|
| Bulk Carrier (0-21) | 9 | 21 | 3 | 6 | 4 | 2 | 1 | 0 | 2 |
| General Cargo (7-19) | 7 | 12 | 15 | 17 | 19 | 15 | 13 | 10 | 9 |
| Refrigerater (7-14) | 13 | 11 | 13 | 14 | 7 | 7 | 8 | 8 | 7 |
| Chemical Tanker (1-3) | 3 | 2 | 3 | 1 | 1 | 3 | 1 | 2 | 1 |
| Products Tanker (1-3) | 1 | 1 | 2 | 3 | 2 | 2 | 2 | 2 | 2 |
| Fish Carrier (1-4) | 3 | 1 | 3 | 3 | 2 | 4 | 3 | 3 | 3 |
| Fish Factory (1-4) | 1 | 1 | 2 | 4 | 1 | 1 | 1 | 2 | 1 |
| Fishery Research (1) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Fishing Vessel (9-24) | 9 | 13 | 9 | 24 | 13 | 14 | 17 | 17 | 20 |
| Cargo/Passenger (0-2) | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 1 | 1 |
| Passenger Ship (2-5) | 3 | 5 | 2 | 4 | 4 | 2 | 2 | 5 | 4 |
| Passenger/Cruise (3-47) | 26 | 35 | 33 | 35 | 42 | 3 | 3 | 40 | 47 |
| Yacht+Sail (1-12) | 1 | 8 | 2 | 5 | 9 | 2 | 2 | 12 | 12 |
| Research (3-13) | 7 | 3 | 8 | 9 | 13 | 7 | 5 | 9 | 9 |
| Icebreaker (0-2) | 3 | 2 | 1 | 2 | 0 | 1 | 0 | 0 | 2 |
| Patrol Vessel (1-3) | 1 | 2 | 1 | 3 | 2 | 1 | 2 | 3 | 3 |
| Platform Supply (1) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Unknown (0-1) | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 |
| Tug (0-4) | 2 | 2 | 1 | 0 | 3 | 4 | 1 | 0 | 2 |
| Buoy Tender (0-4) | 1 | 1 | 1 | 1 | 1 | 0 | 2 | 4 | 3 |
| Summa | 94 | 123 | 104 | 136 | 127 | 71 | 66 | 120 | 131 |

According to the report (PAME, 2024) compiled by Arctic Council working group “Protection on the Arctic Marine Environment” on the base Arctic Ship Traffic Data (ASTD), there were the 1661 ships operated in the Arctic Polar Code area in 2022. The Svalbard waters make up approximately 6% the Polar Code Area. However, vessels associated with the tourism industry presented more than half of “Arctic fleet” (Table 3). The 12 yachts that visited Svalbard counted as 57% of the total number of Arctic yachts, 40 cruise vessels made up 52%, and 6 passenger vessels - 43%.

Table 3. Number of vessels in Svalbard area vs. the whole Arctic Polar code area.

| | Arctic | Svalbard | % |
|---|---|---|---|
| Yacht | 21 | 12 | 57 |
| Cruise | 78 | 40 | 52 |
| Passenger | 14 | 6 | 43 |
| Buoy Tender | 14 | 4 | 29 |
| Patrol | 16 | 3 | 19 |
| Research | 51 | 9 | 18 |

Based on local knowledge and operator websites, it is clear that many vessels perform functions that differ from their official classification. Several vessels involved in the tourism industry in Svalbard are formally registered under other categories, such as research vessels (*Kinfish, Polar)*, cargo ships (*Malmo, Perseverence*) or buoy tenders (*Virgo, Villa, Vestland Explorer).* Some fishing vessels, such as *Helmer Hanssen,* also perform research surveys. Refrigerated cargo ships are used to transport of fish products and are functionally part of the fishing fleet. Most yachts in the region are small sailboats, but others resemble cargo vessels (*Isbjornen II*) or luxury cruisers (e.g. the 79 m long *Rocinante*, 74 m long *Legend).* In April 2025, the world's largest yacht, *Launchpad*, with a length of 118 meters, also sailed in Svalbard waters and docked several days in Longyearbyen Port. Checking vessels performing voyages for tourists at the Association of Arctic Expedition Cruise Operators web-page (AECO, 2025) we regroup vessels according to their current functions (Figure 10).

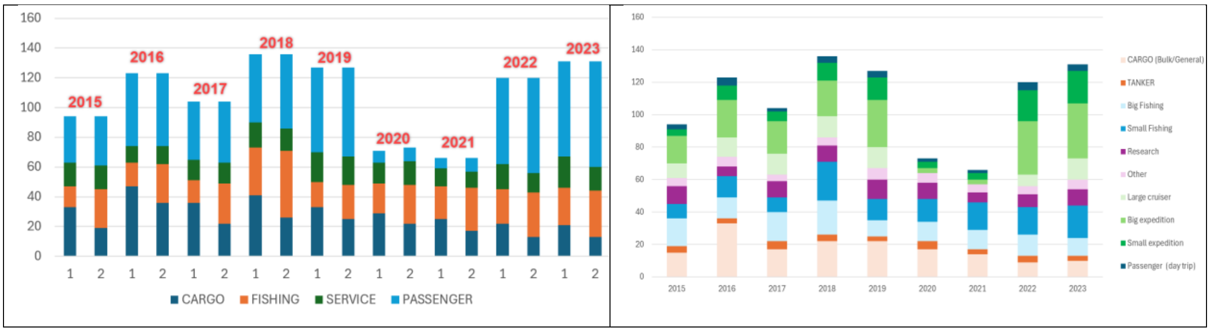


Figure 6. Number of unique ships in Svalbard Area. 2015-2023
**Left:** Four general groups according to IMO list; **Right:** Ten detailed vessel categories after reclassification according to observed operational roles.

## SHIPPING REGULATION

Basic information on the rules and regulations for Svalbard is presented in the guidelines of Norwegian authority (Norwegian Coastal Administration, 2024). In addition to common maritime conventions, local environmental acts and rules are very important and influence ship traffic significantly. The key moments are shown in Figure 6. Since the early 20th century, several key milestones have shaped maritime safety and environmental protection in Svalbard.

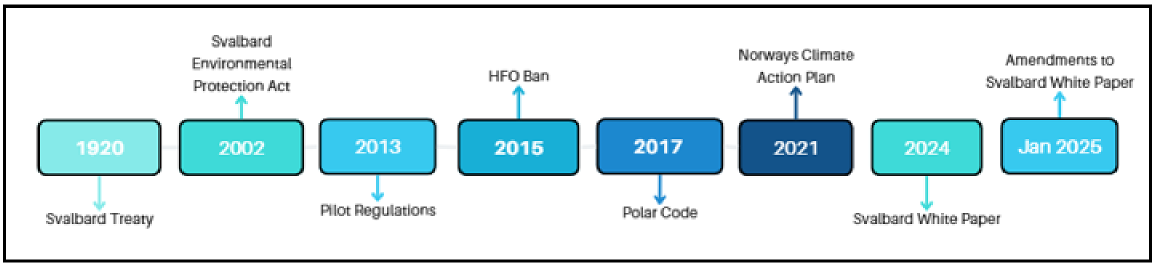


Figure 6. Turning points for Shipping regulation in Svalbard waters

The Svalbard Treaty (1920) established Norwegian sovereignty while ensuring international access and environmental protection. The opening of Svalbard Airport in 1975 improved regional accessibility, facilitating tourism, research, and logistical operations. In 2002, the Svalbard Environmental Protection Act introduced strict regulations on Arctic ecosystems to minimize the impact of human activities, including maritime traffic. Recognizing the growing risks of vessel navigation, pilot regulations were implemented in 2013, requiring licensed pilots for vessels entering Svalbard's fjords to enhance safety. In 2015, the Heavy Fuel Oil (HFO) Ban was enforced, prohibiting the use of heavy fuel oil to reduce pollution and the risk of oil spills. The 2017 adoption of the Polar Code by the International Maritime Organization (IMO) set mandatory safety and environmental standards for ships operating in polar waters, improving vessel design, crew training, and pollution control. As part of its broader climate commitments, Norway's Climate Action Plan in 2021 introduced stricter emissions regulations, further impacting maritime operations in Arctic waters. Most recently, the 2024 Svalbard White

Paper (Norwegian Ministry of Justice and Public Security, 2024) outlines future policies aimed at balancing economic development, environmental sustainability, and safety measures in the region. Additionally, the gradual closure of coal mining operations in Svalbard, including the planned closure of Mine 7, reflects a shift away from coal-dependent industries, leading to a decline in coal-related cargo vessel traffic while tourism and fisheries continue to grow as dominant maritime sectors. The amendments to the White Paper in 2025 aim to protect tourism influence by limiting the number of landing sites and passengers on board a cruise ship.

## RISK AND ACCIDENTS

In (Marchenko, 2015) significant ship accidents in the Svalbard area were listed and briefly described. The rock matrix presented in (Marchenko et al., 2015) showed that in the Svalbard waters, the risk to the environment is mainly middle and partly low. For people, the most dangerous events are fires on tourist and cargo vessels as well as grounding and collisions occurring with tourist vessels. Groundings with cargo and other accidents, including collisions with fishing vessels, represent a low risk.

Figure 7. Map of Accidents. Compiled on the base of (Hamrock and Marchenko, 2024 )

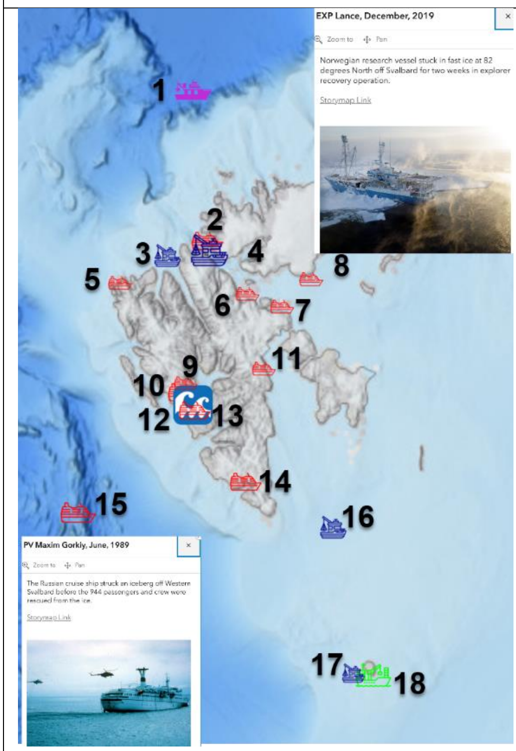


Table 4. Overview of main ship accidents in Svalbard presented in Figure 7. Large scale events are marked in orange.

| | Name | Date | Accident Type |
|---|---|---|---|
| 1 | RV Lance | 2019-12 | Ice Accident |
| 2 | PV Hanseatic | 1997-07 | Grounding |
| 3 | FV Remøy | 2009-01 | Ice Accident |
| 4 | FV Northguider | 2018-12 | Grounding |
| 5 | PV Virgo | 2022-06 | Grounding |
| 6 | PV Ortelius | 2016-06 | Engine Issues |
| 7 | PV Malmo | 2019-09 | Ice Accident |
| 8 | PV Ocean Atlantic | 2022-07 | Grounding |
| 9 | PV Isbjørn II | 2022-07 2023-05 | 2 Groundings |
| 10 | PV Polaris I | 2012-08 | Ice Accident |
| 11 | PV Sjøveien | 2019-09 | Engine Issues |
| 12 | Helicopter Mi-8 | 2017-10 | Crash |
| 13 | PV Aurora Explorer | 2018-07 | Collision |
| 14 | PV Aleksey Maryshev | 2007-08 | Ice Accident |
| 15 | PV Maxim Gorkiy | 1989-06 | Ice Accident |
| 16 | FV Frøyanes Senior | 2008-11 | Fire |
| 17 | FV Kamaro | 2012-10 | Engine Issues |
| 18 | CV Petrozavodsk | 2009-05 | Grounding |

Although ship accidents are still not frequent events in the waters of Svalbard, the number of medical evacuations, due to health problems of crew members or passengers, makes up the majority of recorded incidents. But even "less serious ship accidents" are discussed, as the consequences can be significant. Ships generally follow the rules and are well prepared for difficulties. Nonetheless, even seemingly minor accidents can have significant consequences in remote Arctic conditions. Most vessels operating in Svalbard are well-equipped and compliant with regulations. However, efforts to deliver exceptional experiences to tourists have occasionally led to risky navigational decisions, including groundings. The lack of detailed and outdated nautical charts cannot justify these incidents. In recent years, there has been a concerning increase in groundings and engine failures involving tourist ships, which now occur multiple times per year. In 2024 there were 5 cases when tourist ships requiring assistance (2 groundings, 2 engine problems and one fire on board). As example, *MS Polarfront* was towed from Moffen Island to Longyearbyen by *MS Polarsyssel* in August 2024. It was the 380 km long voyage, that took 2 days.

In assessments of events with low frequency and limited amount (as shipping accidents in Svalbard waters), case study and qualitative approach are more relevant than statistical analyses (Marchenko, 2020). A fairly comprehensive overview of instructive ship accidents in Svalbard area in provided by the developed Geographic Information System (GIS) where main accidents were presented as cases with full explanations and references (Hamrock and Marchenko, 2023). The cases can be explored in the developed online version of the GIS (Hamrock and Marchenko, 2024 ). Figure 7 illustrates the content of the GIS, all 18 included accidents are listed in Table 4.

## CONCLUSION

This study examined how sea ice variability and sampling methodology influence maritime activity in the Svalbard region, offering insights into vessel behavior under changing environmental conditions. Although the overall sea ice extent is declining, Svalbard shows stronger seasonal and year-to-year variability than the broader Arctic. These patterns affect when and where ships can safely operate. Vessel activity has increased near the ice edge, with the highest presence in marginal ice zones (15–30% concentration), especially from fishing and passenger vessels.

Shipping trends are commonly analyzed using two methods: AIS tracking and port call records. AIS data reveals where and when ships travel, while port call data provides official logs of arrivals. Both are useful but limited, particularly in areas like Svalbard with fewer vessels. Misclassification is common, for example, ships registered as research or cargo vessels often operate as tourist cruises. This overlap makes it difficult to accurately track tourism-related activity.

Port call records also fail to capture operations like fishing or day tours within Isfjorden that don't formally dock at ports such as Longyearbyen. Yet these vessels account for a large share of local incidents, showing a clear gap between monitoring systems and real activity at sea.

To address this, future Arctic maritime policy should better connect environmental data with actual vessel use. This means improving classification systems, especially for ships not using formal ports, and adapting regulations to local risks and vessel patterns. Sustainable Arctic navigation depends not just on tracking sea ice and weather but also on understanding human activity in this dynamic environment.

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## REFERENCES

AECO. 2025. *Association of Arctic Expedition Cruise Operators* [Online]. Available: https://aeco.no/ [Accessed 03.04.2025].

ESRI. 2025. *ArcGIS Living Atlas of the World* [Online]. Available: https://livingatlas.arcgis.com/en/home/ [Accessed 03.04.2025].

GMT. 2025. *GMTDS Map* [Online]. Available: https://globalmaritimetraffic.org/gmtds.html [Accessed 03.04.2025].

HAMROCK, P. & MARCHENKO, N. 2023. ArcGIS Online Arctic Marine Accident/Exercise Collection. *Proceedings of the 27th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC-23).* . Glasgow, United Kingdom.

HAMROCK, P. & MARCHENKO, N. 2024 *Arctic Marine Accidents & Exercises. ArcGIS Dashboard with StoryMaps* [Online]. ESRI. Available: https://www.arcgis.com/apps/dashboards/716c03b195ef48dd857fd9c9516c78cd [Accessed 03.04.2025].

ITV NEWS 2023. Svalbard: The remote Arctic island warming seven times faster than the global average.

JAKOBSON, E., VIHMA, T., PALO, T., JAKOBSON, L., KEERNIK, H. & JAAGUS, J. 2012. Validation of atmospheric reanalyses over the central Arctic Ocean. *Geophysical Research Letters,* 39.

JOHANNESSEN, O. M., BOBYLEV, L. P., SHALINA, E. V. & SANDVEN, S. 2020. *Sea Ice in the Arctic*, Springer.

MARCHENKO, N. 2020. Maritime Activity and Risk in the Arctic. *In:* ANDREASSEN, N. & BORCH, O. J. (eds.) *Crisis and Emergency Management in the Arctic: Navigating Complex Environments.* Routledge.

MARCHENKO, N. 2023. Coastal Ice Rubbles in Isfjorden (Spitsbergen). *Proceedings of the 27th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC-23).* . Glasgow, United Kingdom.

MARCHENKO, N. A. 2015. Ship traffic in the Svalbard area and safety issues. *The 23rd Int. Conf. on Port and Ocean Eng. under Arctic Conditions (POAC 2015).* Trondheim.

MARCHENKO, N. A., BORCH, O. J., MARKOV, S. V. & ANDREASSEN, N. 2015. Maritime activity in the High North – the range of unwanted incidents and risk patterns. *The 23rd Int. Conf. on Port and Ocean Eng. under Arctic Conditions (POAC 2015).* Trondheim.

MARKUSSEN HANSEN, A. C. 2024. Vil ikke anbefale folk å gå ut på isen nå. *Svalbardposten*, 22.03.2024.

MARKUSSEN HANSEN, A. C. 2024 Bistod tankbåt med å bryte is. *Svalbardposten*, 18.03.2024.

MÜLLER, M., KNOL-KAUFFMAN, M., JEURING, J. & PALERME, C. 2023. Arctic shipping trends during hazardous weather and sea-ice conditions and the Polar Code's effectiveness. *npj Ocean Sustainability,* 2**,** 12.

NORWEGIAN COASTAL ADMINISTRATION 2024. *Approaching Svalbard - Regulations and Information Services*.

NORWEGIAN MINISTRY OF JUSTICE AND PUBLIC SECURITY 2024. Meld. St. 26 (2023–2024) Report to the Storting (white paper).

NSIDC. 2025. *National Snow and Ice Data Center. Sea Ice Data* [Online]. Available: https://nsidc.org/sea-ice-today [Accessed 03.04.2025].

PAME 2024. Types of ships in the Arctic. *In:* ENVIRONMENT, P. O. T. A. M. (ed.) *ARCTIC SHIPPING STATUS REPORT (ASSR).* Arctic Council.

PEROVICH, D., MEIER, W., TSCHUDI, M., HENDRICKS, S., PETTY, A. A., DIVINE, D., FARRELL, S., GERLAND, S., HAAS, C., KALESCHKE, L., PAVLOVA, O., RICKER, R., TIAN-KUNZE, X., WEBSTER, M. & WOOD, K. 2020. Arctic Report Card 2020: Sea Ice.

PORT OF LONGYEARBYEN 2023. Båttrafikk. Longyearbyen Havn.

SOLHEIM, J.-E. 2024. Mer is i Barentshavet i april i år. *Svalbardposten*, 29.05.2024.

STOCKER, A. N., RENNER, A. H. H. & KNOL-KAUFFMAN, M. 2020. Sea ice variability and maritime activity around Svalbard in the period 2012–2019. *Scientific Reports,* 10**,** 17043.